A Population Study of Atlantic Striped Bass

Submitted to the:

Committee on Resources of the United States House of Representatives

and

Committee on Commerce, Science, and Transportation of the United States Senate

by

Donald L. Evans	Gale A. Norton
Secretary of Commerce	**Secretary of the Interior**

Executive Summary

In accord with the December 2000 reauthorization of the Atlantic Striped Bass Conservation Act, a study of striped bass was conducted to examine the population demographics appropriate for maintaining adequate long-term recruitment and sustainable fishing opportunities. Of particular concern was the age structure of the population and the implications of a balanced age structure in promoting reproductive success.

The study examined historical changes in the population and possible reasons for the stock collapse that occurred in the 1970s. The current status of the stock was evaluated, and projections were made of future stock conditions under a variety of management scenarios. Information from the most recent stock assessment was used to determine (1) a "biological reference point" that would generate maximum sustainable yield; and (2) a target fishing mortality rate that would foster the goal of maintaining an abundance of older trophy-size striped bass.

The most recent striped bass stock assessment (August 2000) completed by the Atlantic States Marine Fisheries Commission (ASMFC) Striped Bass Technical Committee provides estimates of abundance, biomass, and fishing mortality rates through January 1, 2000. During 1999, the average fishing mortality rate (F) on fully exploited striped bass was 0.32, which is not significantly different from the current target mortality rate of F=0.31. Since 1995, total population abundance (age 1 fish and older) has been relatively stable at approximately 35 million fish while total stock biomass has decreased slightly to 66,000 mt from a 1997 peak of 72,000 mt.

Abundance and recruitment estimates during the 1982-1999 period reveal a strong relationship between striped bass spawning stock biomass and subsequent recruitment. A stock-recruitment relationship was used to evaluate future recruitment under different fishing mortality levels and to determine the fishing mortality rate that would produce maximum sustainable yield (*i.e.,* F_{msy}). F_{msy} was estimated to be between 0.25 and 0.30, depending on the fishery exploitation pattern (*e.g.,* which age groups in the stock are vulnerable to harvest). Analyses of historic tagging data suggest that the fishing mortality during the 1970s exceeded the level where the stock was able to sustain itself.

Population projections for the next decade indicate that striped bass stock abundance and biomass could be maintained near present levels (*i.e.,* those in 2000) if fishing mortality rates do not exceed F=0.4. However, fishing mortality rates higher than 0.25 will result in a reduced proportion of older fish (age 10 and older) in the population and a decline in spawning stock biomass. As fishing mortality is increased, the age structure of the spawning stock is progressively shifted towards younger spawning fish. Research on striped bass and other species indicate that spawning of smaller and younger fish is significantly less successful than older, more mature individuals. At fishing mortality rates greater than F=0.25, there is a heightened risk of reduced recruitment in the stock due to greater reliance on younger spawners.

Resource allocation of striped bass represents a significant management challenge due to seasonal availability changes resulting from migration patterns. Striped bass seasonally segregate by size between coastal areas and estuaries, such as the Chesapeake Bay. The current ASMFC Fishery Management Plan for striped bass permits different minimum landing sizes between fisheries in large estuaries (i.e., those where spawning occurs) and fisheries in coastal waters. To achieve and maintain a healthy and balanced population age structure, an overall target fishing mortality on the striped bass stock of F=0.25 or less is recommended. The two stage size limit system currently in place would be enhanced if overlap was minimized between the maximum size regulations in the estuaries and the lower size limits in the coastal fisheries. Ultimately, the regulatory regimen should reflect the mix of objectives and priorities established by fishery managers and the public.

Introduction

This study of the Atlantic striped bass is in response to the December 2000 reauthorization of the Striped Bass Conservation Act, which requested the following:

Sec 102. Population Study of Striped Bass

(a) Study - The Secretaries (as that term is defined in the Atlantic Striped Bass Conservation Act), in consultation with the Atlantic States Marine Fisheries Commission, shall conduct a study to determine if the distribution of year classes in the Atlantic striped bass population is appropriate for maintaining adequate recruitment and sustainable fishing opportunities. In conducting the study, the Secretaries shall consider:

(1) long-term stock assessment data and other fishery-dependent and independent data for Atlantic striped bass; and

(2) the results of peer-reviewed research funded under the Atlantic Striped Bass Conservation Act.

(b) Report - Not later than 180 days after the date of the enactment of this Act, the Secretaries, in consultation with the Atlantic States Marine Fisheries Commission shall submit to the Committee on Resources of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate the results of the study and a long-term plan to ensure a balanced and healthy population structure of Atlantic striped bass, including older fish. The report shall include information regarding:

(1) the structure of the Atlantic striped bass population required to maintain adequate recruitment and sustainable fishing opportunities; and

(2) recommendations for measures necessary to achieve and maintain the population structure described in paragraph (1).

Management of Atlantic striped bass (*Morone saxatilis*) began in earnest with the passage of the Atlantic Striped Bass Conservation Act in 1984. At that time the populations of striped bass, particularly in the Chesapeake Bay and Delaware River, were at extremely low levels. The passage of the Act allowed the ASMFC to implement a Fishery Management Plan (FMP) for striped bass that would ensure that comprehensive management regulations were enacted by all Atlantic States. As a result of state and federal regulations, Atlantic coast striped bass populations (composed of striped bass from stocks originating in the Hudson River, Delaware River, and tributaries of the Chesapeake Bay) have rebounded to abundance levels previously seen in the 1960s, a time when the stocks were considered healthy. The challenge now for fishery managers is to develop long-term management strategies and approaches that will maintain the population at a high level while providing significant opportunities for recreational and commercial fishermen. In the 2000 reauthorization of the Atlantic Striped Bass Conservation Act, a population study was requested to determine the appropriate distribution of year classes in the striped bass population necessary for maintaining adequate recruitment and sustainable fishing opportunities. The study was to include recommendations for a long-term plan to ensure a balanced and healthy age structure. The study results, presented herein, provide evidence of historical changes in striped bass populations, current conditions, and potential direction for future management.

Current Population Status

Assessment of Atlantic coast striped bass is performed annually by the ASMFC Striped Bass Technical Committee. The Committee evaluates indices of abundance from a variety of sources, incorporates results from ongoing tag-recovery studies, and completes a virtual population analysis (VPA) to estimate current abundance and rate of removal. Results of the assessment are provided to the ASMFC Striped Bass Management Board to serve as a scientific basis for management decisions. The analytical procedures used in the assessment were reviewed by a panel of scientific experts at the fall 1996 Northeast Regional Stock Assessment Workshop (NEFSC 1998; ASMFC 1998). The assessment provides annual information on total abundance, total biomass, total spawning stock biomass (SSB), abundance at age and the rate of removal from fishing (F). The time series of such information from the VPA begins in 1982.

The most recent assessment completed in August 2000 includes estimates of fishing mortality[1] through 1999 and population abundance estimates through January 1, 2000 (ASMFC 2000). The 1999 exploitation rate on fully exploited ages (4 and older) was 26 percent (F=0.32). The exploitation rate estimated from tag-return data was 21 percent, assuming a tag reporting rate of 52 percent. The harvest of striped bass has steadily increased since 1987, but the exploitation rate has not exceeded 26 percent (F=0.32) (Figure 1). Abundance and biomass of striped bass increased six fold between 1982 and 1994 and have remained relatively steady since 1995. Current abundance is approximately 35 million fish and a total biomass of 66,000 mt (Figures 2 and 3).

Amendment 5 to the ASMFC Striped Bass Fishery Management Plan enacted in 1995 defines maximum sustainable yield (F_{msy}) as occurring at an exploitation rate of 29 percent (F=0.38). This biological reference point was developed prior to the current analytical assessment and was based on the information available through 1990. Managers recognized that uncertainty exists with any reference point and adopted a target mortality rate that was lower than the F_{msy} to provide a buffer so that chances of inadvertently exceeding F_{msy} would be reduced. The F_{target} value has been 0.31 since the implementation of Amendment 5 to the Striped Bass FMP. Although F in 1999 (F=0.32) exceeded F_{target}, the Striped Bass Technical Committee determined that the difference was not statistically significant.

Historical Changes in Striped Bass Populations

Since 1995, when estimates of F_{msy} and F_{target} were developed, changes in the fisheries and improved data have prompted reevaluation of the biological reference points. A key component in this reevaluation is understanding the processes that led to the collapse of striped bass during the 1970s, particularly in Chesapeake Bay. Although environmental problems contributed to the decline, most evidence indicates that the primary cause was overfishing (Richards and Rago 1999). Once spawning biomass dropped below a critical level, the remaining fish could not successfully reproduce at a rate to offset removals and the population declined.

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[1] Fishing mortality rate (F) is the instantaneous rate of population decrease, whereas exploitation rate is the percent of the population removed annually by fishing.

The levels of fishing mortality associated with the 1970s decline are important because they provide the benchmark for comparison with current exploitation levels. Information is available that documents exploitation rates of striped bass determined from coastal tagging studies back to 1934 (ASMFC 1990). These estimates indicate that fishing mortality increased in the 1970s and ranged between 0.5 and 0.6 for most of the decade (Figure 4). These rates of mortality, beginning with age 2 fish, contributed to the marked stock decline during this period. Abundance began increasing in the 1980s when the fishing mortality was reduced to below 0.25 and the size at which fish were captured increased.

Although fishing mortality increased in the 1960s, there was little evidence of declines in spawning success. The population continued to produce average to strong year-classes while catches increased. By the early 1970s, however, fishing had reduced spawning biomass below the level adequate to maintain recruitment. Once this happened, recruitment fell far below the long-term average. The high level of fishing mortality on the remaining population only served to deplete the stock further. When management restrictions were imposed and fish were allowed to reach maturity under conditions of minimal exploitation, the striped bass populations began to recover.

Analysis to Determine Stable and Sustainable Population Abundance

Levels of fishing mortality that produce stable and high levels of stock biomass and recruitment can be evaluated using the results of the current assessment as information is provided on the number of age 1 fish in the population (recruits) as well as the biomass of mature fish (spawning stock biomass). The relationship between spawning stock biomass and recruits is referred to as a stock-recruitment relationship and assumes that spawning stock biomass is a measure of the stock's reproductive potential. Increases in egg production generally result in increased numbers of recruits, eventually reaching a maximum level of recruits. Beyond that point, increases in recruitment are limited and decreased recruitment may even result with increasing spawning biomass. Growth information and patterns of exploitation can also be evaluated to determine the fishing mortality rate that provides the best per capita yield and spawning stock biomass. These results can then be combined with a stock-recruitment relationship to estimate the fishing mortality that will generate maximum long-term yield (F_{msy}).

From 1982 onwards, there has been a clear relationship between the abundance of spawners and subsequent recruitment in the striped bass population (Figure 5). When the stock-recruitment data are combined with yield and SSB per recruit information, F_{msy} is estimated to be between 0.25 and 0.3 (Figure 6), depending on the age at which fish are assumed to be vulnerable to capture in the fishery. The level of fishing mortality that maintains 30 percent of a population's spawning potential (F30 percent) is often used as a target for management (Mace and Sissenwine 1993). In striped bass, F30 percent is equal to fishing mortality of 0.3, assuming the 1999 fishing pattern. If higher levels of spawning stock are desired, the fishing mortality must be lower, or age at entry into the fishery increased.

Striped bass population dynamic models were used to explore the impacts of different fishing mortality rates on future recruitment. At fishing mortality rates up to 0.4, only relatively small reductions in recruitment would be expected (Figure 7). However, at higher fishing mortality levels there is a greater likelihood that a small increase in fishing mortality may reduce recruitment from moderate levels to recruitment failure (e.g., a steep decline on the left-hand side of the curve plot). This is illustrated by the abrupt and steep slope of the spawner-recruitment relationship at lower SSB values, which would result from higher levels of F (Figure 7).

Future Populations of Striped Bass

Projections of striped bass populations and associated variability were made using a range of possible starting stock sizes. Statistical uncertainty of the population estimates was assessed using a statistical method known as "bootstrapping," which produces a range of possible outcomes by resampling the data used in the model. Using these outcomes, a range of possible current stock size values was projected into the future under a variety of fishing mortality rates and recruitment estimates. The projections results indicate that current levels of striped bass abundance and biomass are relatively robust to moderate changes in fishing mortality (Figures 8 and 9). An increase in F to 0.4 during the next decade would not significantly reduce abundance (Figure 8) or biomass (Figure 9) below current (2000) levels.

However, at fishing mortalities higher than 0.2 , the proportion of large fish in the population would decline well below the 2000 level (Figure 10). In this model, large fish are considered all fish greater than age 10 (about equal or greater than 36 inches in total length). Since female striped bass are estimated to reach full maturity at age eight, the decline in older fish results in a decreased spawning stock biomass. As seen in the previous examples relating SSB and recruitment, a reduction in SSB would not necessarily equate to a steep reduction in recruitment but would increase the likelihood of recruitment declines.

Significance of Age Distribution

Following the large 1970 year class produced in Chesapeake Bay, striped bass recruitment remained well below average until 1989 (Richards and Rago 1999). As striped bass recovered during the 1990s, the poor year classes of the previous decades resulted in relatively few older fish in the population. Good recruitment in the 1990s, particularly the 1993, 1997, and 1998 year classes (Figure 2), skewed the age demographics of the population toward younger age groups. However, as these year classes grow older (e.g., striped bass can attain ages in excess of 25 years) and fishing mortality rates on them are controlled, older fish will comprise an increasing proportion of the population. The abundance of older fish (considered in this analysis as ages 10 and older) is expected to sharply increase in 2003 when the large 1993 year class become 10 years old.

The distribution of age classes in a population has important implications for stock productivity and stability. Studies on striped bass have shown that larger fish produce larger eggs and larvae, and larger individuals of these life stages have a greater chance of survival (Zastrow et al. 1989; Monteleone and Houde 1990). Studies on other species such as cod (Marteinsdottir and Steinarsson 1998; Trippel 1998) have demonstrated that first-time spawners are generally less successful in producing offspring than fish that have spawned multiple times. As such, populations that rely heavily on first-time spawners to maintain recruitment levels face a greater risk of recruitment failure than those composed of a number of spawning classes.

The implications of increased fishing mortality on striped bass abundance is well illustrated in Figure 11. A hypothetical cohort of one million striped bass was exposed to four different fishing levels assuming that fish were vulnerable to capture beginning at age five. The hypothetical egg production at age of this cohort under these same fishing levels is depicted in Figure 12. The results indicate that even modest levels of fishing mortality reduce the proportion of older fish in the stock and shift the bulk of egg production towards younger fish. Shifting the age at which fish are first vulnerable to capture or altering the age groups subject to full exploitation also have major implications on the stock. For example, reducing fishing mortality on ages 8 to 12 (e.g., fish approximately 32 to 40 inches) to one half the full exploitation level results in much greater egg production in the stock and an age distribution in which older fish are much more dominant (Figure 13). Maintaining a diverse number of ages in the population has the biological advantages of increased spawning potential through inclusion of older more fecund fish, and a reduced risk of poor recruitment associated with dependence on younger fish for egg production. In addition, such a strategy provides the opportunity for fishermen to catch trophy-size striped bass.

The migratory nature of striped bass is a complicating factor in fishery management. Striped bass spend their first several years in coastal nursery areas (designated 'producer areas' in the Fishery Management Plan) before undertaking long-distance migrations. Once the fish enter the coastal migratory component of the population, their migration route brings them back to the producer areas for a limited time during each spawning season. The challenge to managers is to promote equity among fishermen, recognizing that the availability of different size fish varies by location and season. Historically, fishermen in producer areas have targeted smaller fish while coastal fishermen generally targeted the larger coastal migrants. Regulatory changes in the 1980s amplified these differences as size limits increased in the coastal states (up to 36 inches in some locations) and, together with sharp reductions in fishing mortality, contributed to the restoration of the stocks. Since 1995, when striped bass were declared restored by the ASMFC, fishery regulations have become less restrictive and size limits have been reduced in many states. If one of the objectives of management is to produce a high quality coastal trophy fishery while maintaining the traditional "small fish" fishery in producer areas, one possible approach might be to implement an upper size limit in producer areas and a minimum size limit in the coastal fishery. Such a "slot limit" would potentially afford a sizable portion of the striped bass stock a "length window"of lowered exploitation rates.

Conclusion

To produce maximum yield and generate recruitment levels necessary to sustain striped bass stock abundance over the long-term, fully-recruited fishing mortality should be limited to F= 0.25 or less. Reducing fishing mortality to a lower level will increase the population of older, trophy size striped bass for recreational fishermen. Ultimately, the regulatory regimen should reflect the mix of objectives and priorities established by fishery managers and the public.

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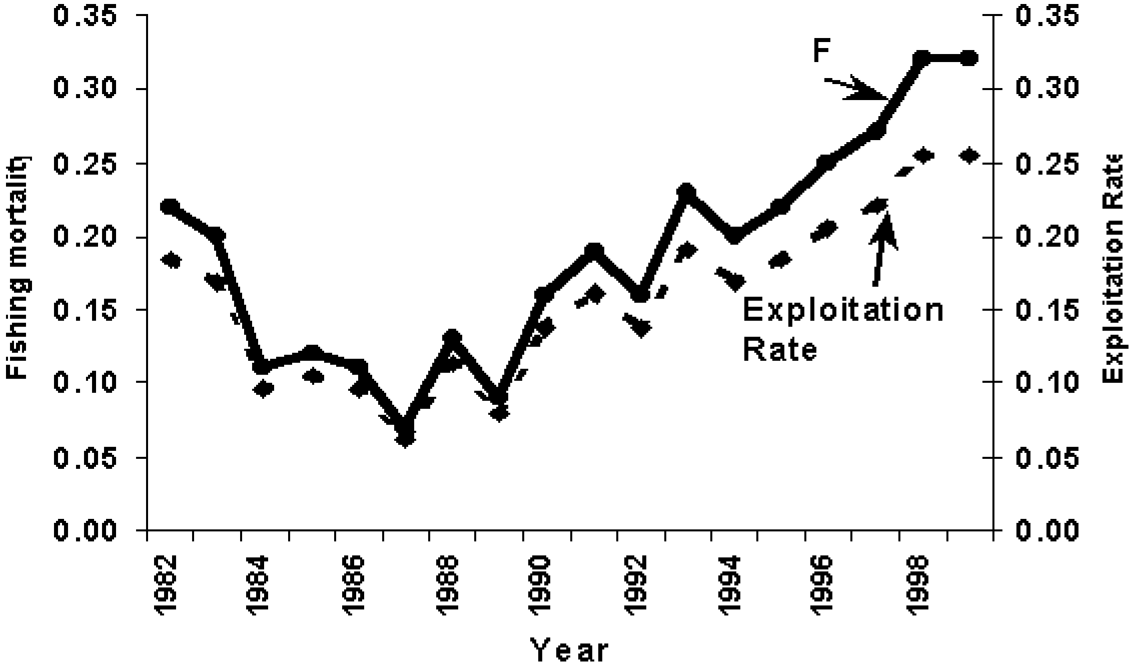

Figure 1. Striped bass fishing mortality rate and associated exploitation rate, age 4-13 average, as estimated from virtual population analysis (VPA), 1982-1999.

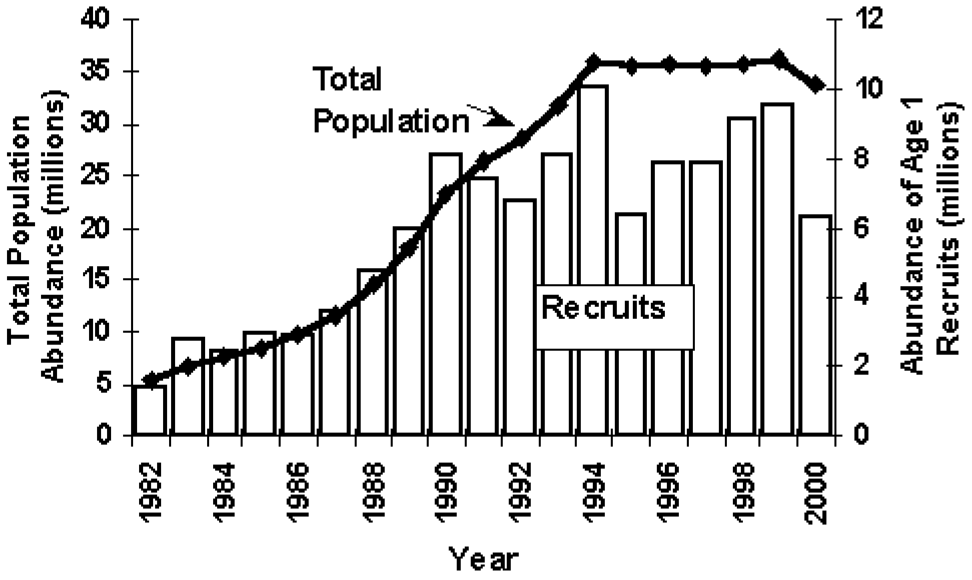

Figure 2. Abundance of striped bass recruits (at age 1) and total population abundance (fish age 1 and older) as estimated from VPA , 1982-1999.

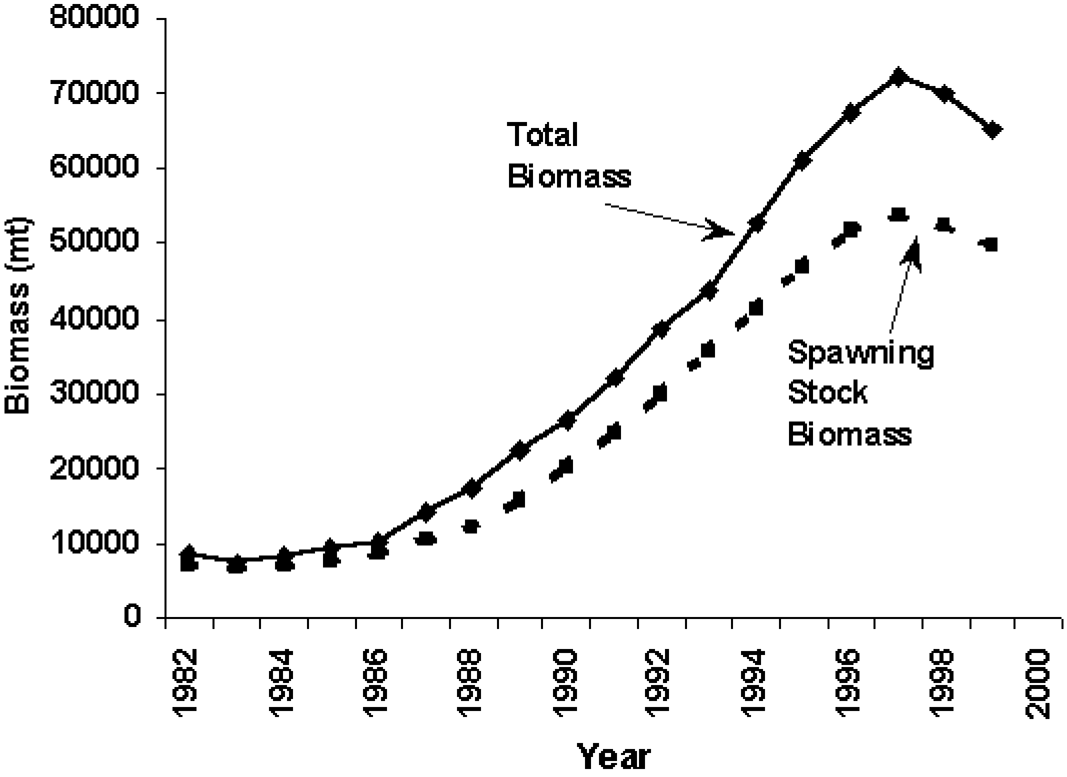

Figure 3. Striped bass total stock biomass (January 1 estimate for fish age 1 and older) and spawning stock biomass, 1982-1999.

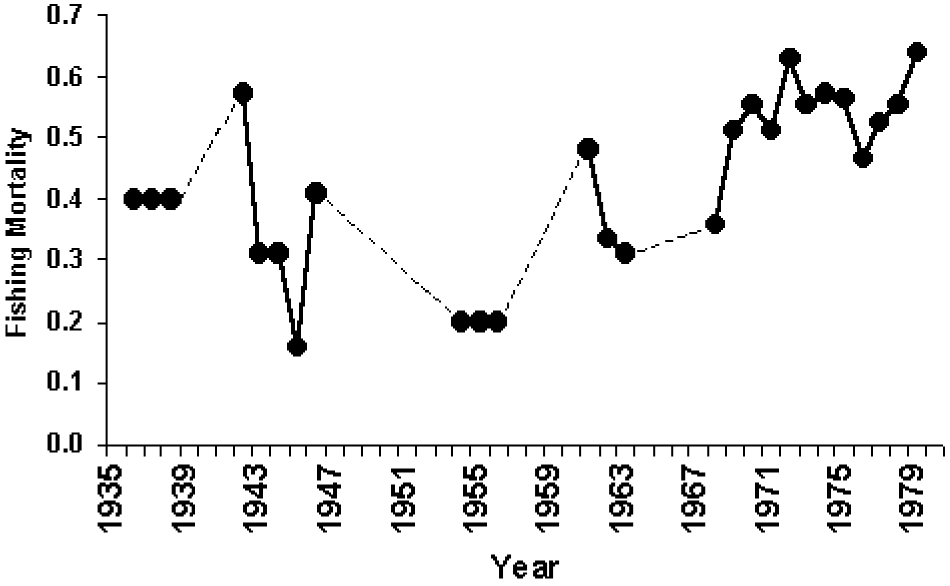

Figure 4. Estimates of striped bass fishing mortality in coastal fisheries from various tagging studies conducted since 1934.

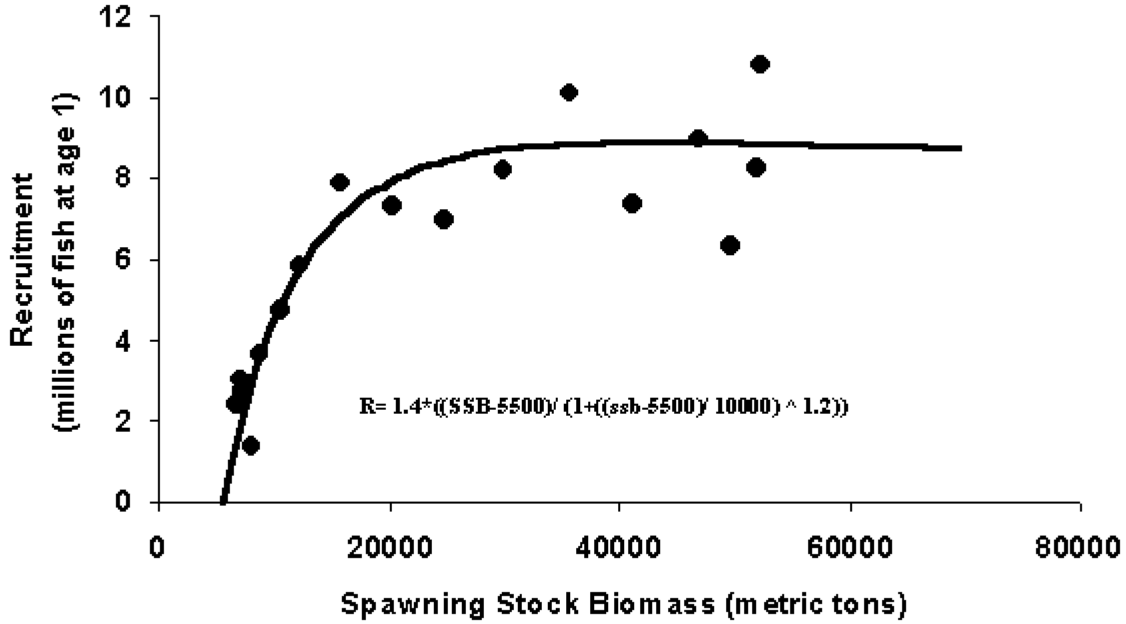

Figure 5. Striped bass stock-recruitment relationship, 1982-1999.

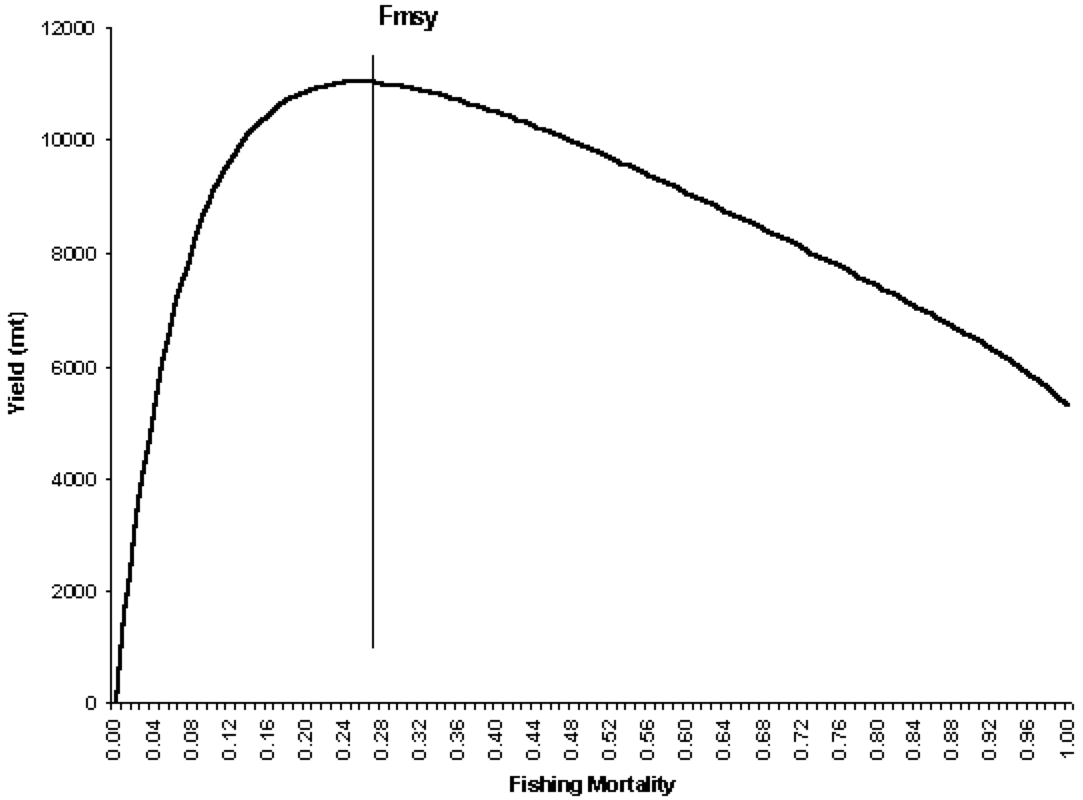

Figure 6. Striped bass yield (mt) under various fishing mortalities and associated F_{msy}.

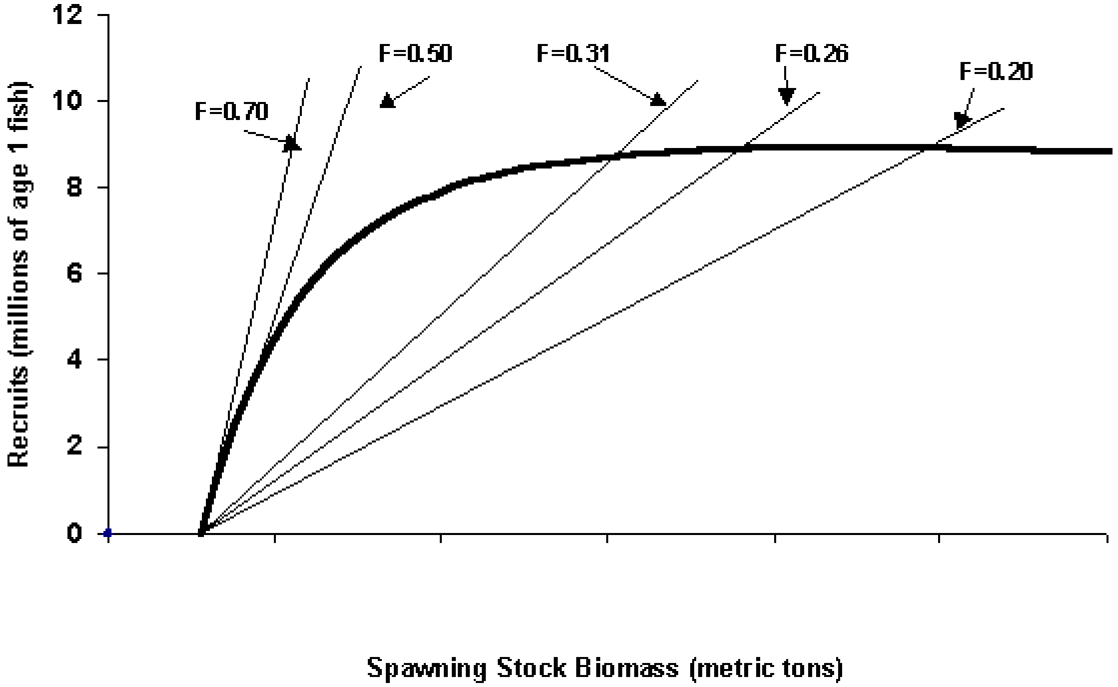

Figure 7. Striped bass recruitment curve and replacement lines corresponding to various levels of recruitment at five different levels of fishing mortality (F). The point where F line intersects the curve is the equilibrium level of recruitment for a given F. (Note: at F=0.7 and greater, there is no intersection of the replacement line and s/r curve; the population cannot be maintained at any level.)

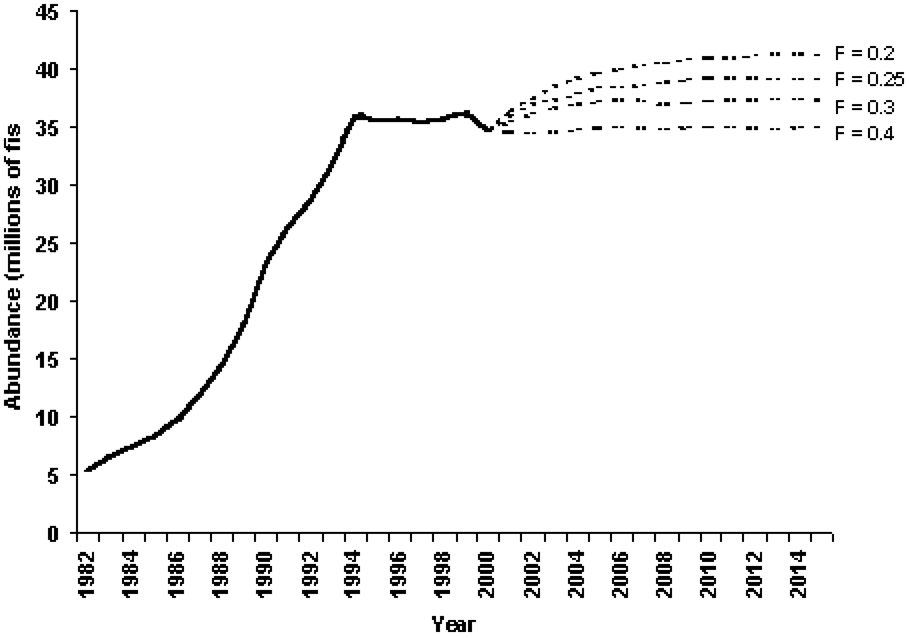

Figure 8. Stochastic projections of striped bass abundance under four different fishing mortality rates.

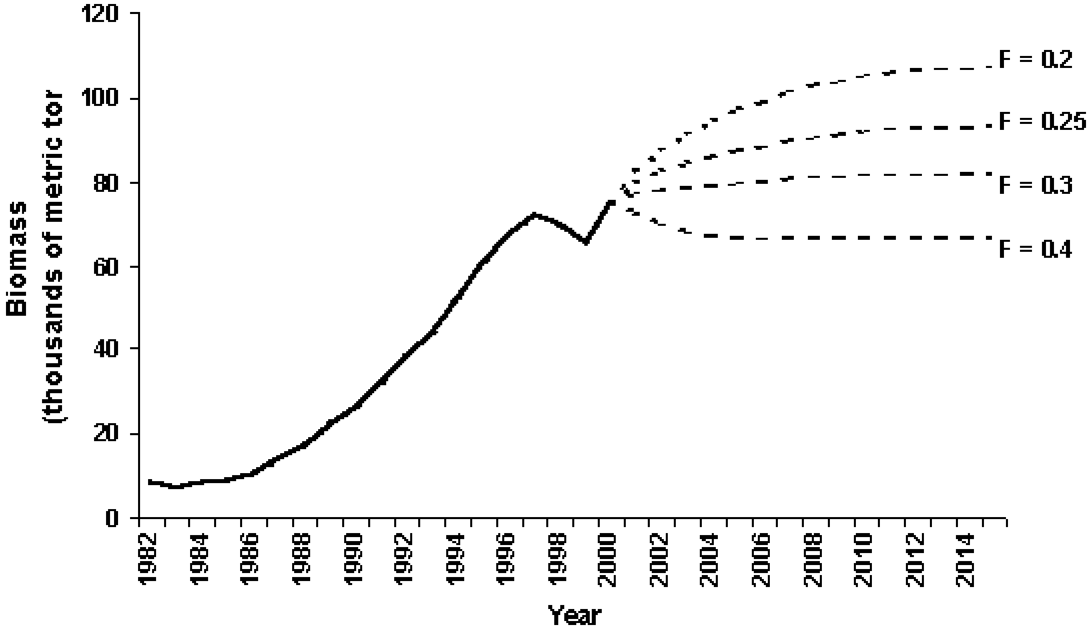

Figure 9. Stochastic projections of striped bass biomass under four different fishing mortality rates.

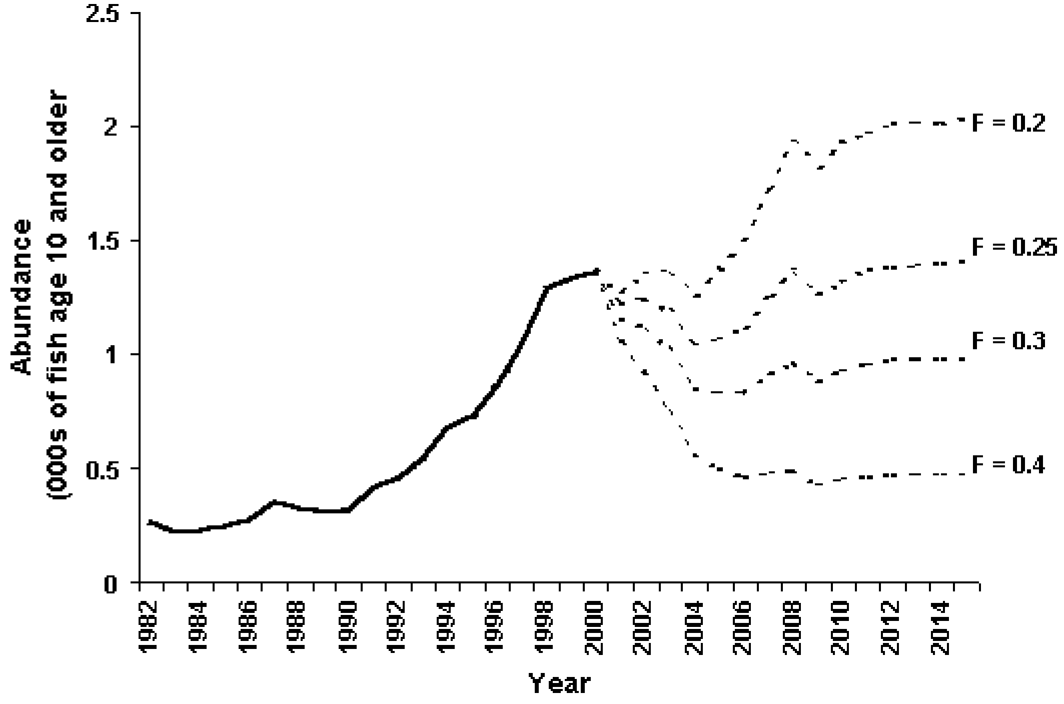

Figure 10. Stochastic projections of abundance of striped bass age 10 and older under four different fishing mortality rates.

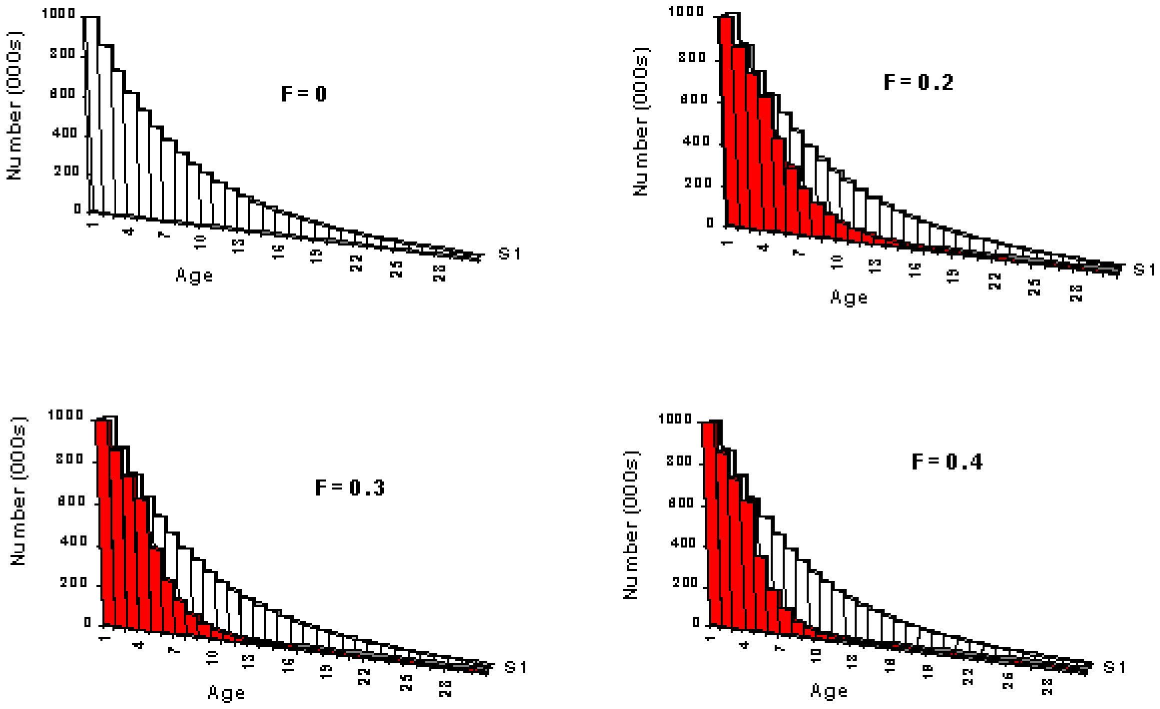

Figure 11. Striped bass cohort abundance at age 1-30 (number of fish from a hypothetical cohort of 1 million at age 1) simulated for four different fishing mortality rates (F). Dark bars represent abundance at age 1-30. Entry to fishery is at age 5.

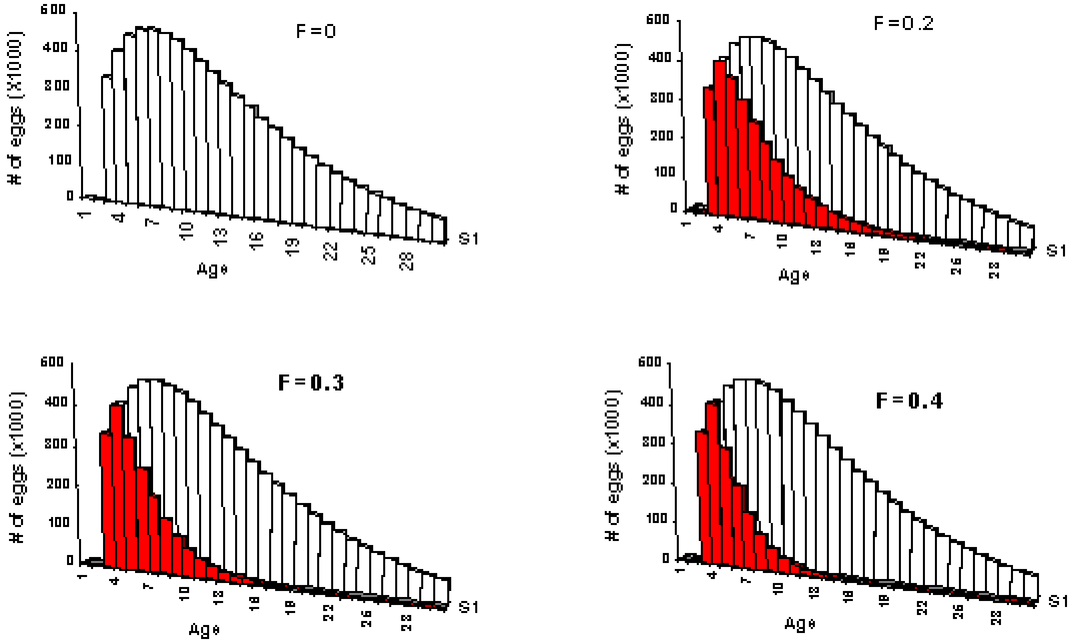

Figure 12. Striped bass cohort egg production at age 1-30 (from a hypothetical cohort of 1 million fish at age 1) simulated for four different fishing mortality rates (F). Dark bars represent egg production at age 1-30. Entry to fishery is at age 5.

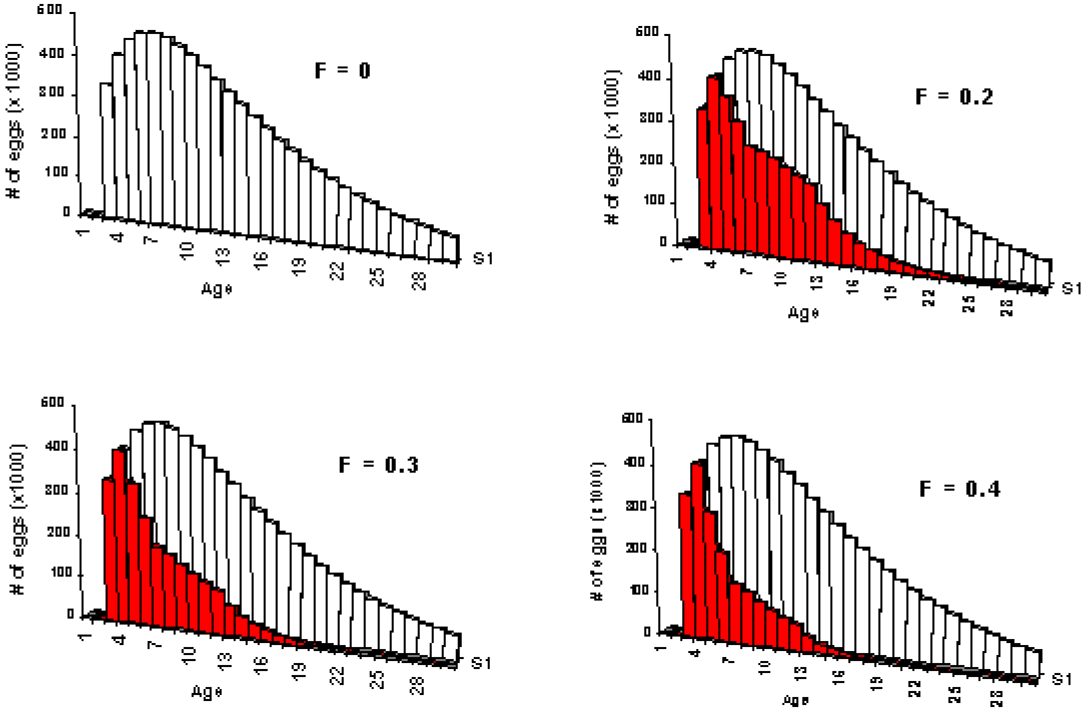

Figure 13. Striped bass cohort egg production at age 1-30 (from a hypothetical cohort of 1 million fish at age 1) simulated for four different fishing mortality rates (F) with a 50 percent reduction in fishing mortality between age 8 and 12. Dark bar represent egg production at age 1-30. Entry to fishery is at age 5.