D. ATLANTIC STRIPED BASS

The Atlantic Coast striped bass stock is assessed with two separate methods: 1) catch-age based virtual population analysis, and 2) tag release-recovery based survival estimation. Each program is presented in this report as separate segments. The VPA analysis, prepared by the Stock Assessment Subcommittee, is used to evaluate fishing mortality for the mixed coastal stock and provide estimates of abundance and biomass. The tagging analysis, prepared by the Tagging Workgroup, is used to evaluate fishing mortality for specific stocks and averaged results are used to develop a mixed stock mortality estimate. Fishing mortality rates from both programs are compared. A summary of the Chesapeake Bay tag-based direct enumeration study, used to evaluate compliance of the Chesapeake Bay management program with FMP mortality targets, is also presented. The ASMFC Striped Bass stock assessment sub-committee and Technical Committee met in September 2002 to evaluate the status of the striped bass resource.

I. CATCH-AGE BASED VPA ANALYSIS

The first analytical assessment using virtual population analysis (VPA) was conducted in 1997 (for years 1982-1996) and reviewed by the 26th Stock Assessment Review Committee at the Northeast Fisheries Science Center. The results of the review were reported in the proceedings of the 26th Northeast Regional Stock Assessment Workshop (26th SAW): SARC Consensus Summary of Assessments (NEFSC Ref. Document 98-03). This report represents the latest in the series of annual assessments with the inclusion of the 2001 catch and survey data.

<u>Commercial Fishery</u>

Commercial landings in 2001 totaled 941.7 thousand fish and 6.2 million pounds (2,826 mt) (Table D1, Table D2). The landings represent a decline of 109.5 thousand fish (10.4%) and of 395.7 thousand pounds (6%) compared to 2000 (Table D8). The Chesapeake Region (Maryland, PRFC, and Virginia) accounts for most of the commercial harvest, 65% by weight and 82% by number (Table D3). Overall, commercial harvest represented 22% by number and 24% by weight of total harvest in 2001, and 29 % of total catch in number (harvest + discard) (Figure D1, Table D2). Commercial harvest was comprised primarily of fish ages 4 to 6 (60% of commercial harvest). Ages 3 through 8 comprised 88.5% of the harvest.

Direct measurements of commercial discards of striped bass were not available. For past assessments that incorporated 1982-97, the estimates were based on the ratio of commercial to recreational released fish tag recovery data, scaled by total recreational discards:

$$CD = RD*(CT/RT)$$

where:

CD is an estimate of the number of fish discarded by commercial fishery,
RD - number of fish discarded by recreational fishery,
CT- number of tags returned from discarded fish by commercial fishermen,
RT- number of tags returned from discarded fish by recreational fishermen.

Total discards were allocated to gears based on the overall distribution of recovered tags by gear. Discards by fishing gear were multiplied by gear specific release mortalities and summed to estimate total number of fish killed. The technical committee attempted to improve the estimate of commercial discards for the 1998-2001 period by accounting for spatial distribution of different fishing gear and effort. The ratio of tags recovered in commercial and recreational fisheries and corresponding discards were calculated separately for Chesapeake Bay and the coast. Commercial discards for the Hudson and Delaware Rivers were estimated separately. Total commercial discards losses for 2001 were estimated as 310,900 fish, representing 7.2% of total removals in number (Figure D1, Table 2, Table 4, Table 9).

Commercial discard proportions at age were obtained using age distributions from fishery dependent and independent surveys done using comparable gear. These proportions at age were applied to discard estimates by gear and expanded estimates summed across all gears. Total commercial discards were dominated by fish of ages 3 to 6.

Recreational Fishery

Recreational statistics were collected as part of the MRFSS (Marine Recreational Fishery Statistics Survey) program. Landings (A+B1) in 2001 were 2.0 million fish totaling 19.58 million pounds (8,889 mt) (Table D1, Table D2). The landings represent an increase of 88.3 thousand fish (4.6%) and 2.48 million pounds (14.5%) compared to 2000 (Table D1). The states landing the largest proportion of the recreational landings were New Jersey, Maryland, Virginia, New York, and Massachusetts (Table D6, Figure D2). Overall, recreational landings represented 71% by number and 76% by weight of the reported total landings (Figure D1). Striped bass of age 4 to 8 comprised 75% of landings.

Recreational discards (B2's) declined in 2001 to 13.5 million fish (Table D2) compared to 2000 estimates. Application of an 8% hooking mortality rate resulted in estimated losses of 1.1 million fish (Table D2). The states with the largest proportion of the overall discards were Massachusetts and Maryland (Table D7). Recreational discards represented 25% by number of the total catch (Figure D1, Table D2). Discards of the 1996 year class were greatest among all cohorts both in 2000 and 20001. Total recreational striped bass catch in 2001 was 3.1 million fish. The catch was dominated by ages 4 to 8 (76.5% of total). Total recreational discard and landings losses have been growing steadily between 1982 and 2001, with some intermittent decline in 1998-1999 (Table D10, Figure D3).

Total Catch at Age

The above components are totaled by year to produce the overall catch at age matrix for VPA input (Table D11). The total catch of striped bass in 2001 was 4.3 million fish, a decline from 5.04 million fish in 2000. The decline in harvest occurred primarily in ages 2-7 and especially ages 4 and 5 (Figure D4). At the same time there was in increase in the number of harvested fish of age 8 and older with the exception of age 10.

Indices of Abundance

Fishery Independent Indices

The Maryland gillnet survey of spawning biomass has generally declined since 1993, although there was a strong peak in 1996. The 2002 value was very similar to 2001 about one-half the series average (Figure D5). Values for age-2 were dropped as tuning indices due to frequency of zero catches over time. The New York ocean haul seine index increased considerably for 1996-1998, while the 2001 value decreased from 2000 and was near the 1999 value (Figure D6). The NEFSC spring inshore survey was incorporated as an age-aggregated index in the 1999 assessment, and was used in the 2000 and current assessment as age-specific indices. The aggregated index increased during the early to mid-1990s before declining in 1998 and 1999. The 2002 value increased to one of the highest in the series (Figure D7). The Rappahannock River, Virginia pound net CPUE was included for the first time in 2001, in an attempt to provide more information on the overall spawning stock. This survey, begun in 1991, showed high abundance in 1999 and 2000, while the 2001 value was just below average (Figure D8). Three age-aggregated trawl indices from Connecticut, New Jersey and Delaware were added in the 2000 VPA (Figure D9). All surveys showed a decline from 1999 to 2001 to near or below average although Connecticut and New Jersey indices increased in 2002.

Juvenile indices from the Chesapeake Bay (Maryland and Virginia) show another very strong recruitment in 2001 (Figure D10). Previous strong cohorts in 1993 and 1996 have been clearly detectable in coast-wide landings during recent years. The juvenile index for the Hudson River was very high in 2001, while the Delaware index was below average (Figure D11). The NY and NJ young-of-year surveys showed overall increasing trends since 1991.

The Maryland age-1 index was slightly above average in 2001, and reflected only a slight upward trend over the last few years (Figure D12). The Long Island age 1 index in 2001 was the highest for the time series (Figure D12).

Fishery Dependent Indices

The Massachusetts commercial catch per trip reached the highest level in 2001 (Figure D13). The Connecticut volunteer angler catch per trip was well above average in 2000 and reached the highest level in 2001 (Figure D14). The index for age 1 (lagged ahead as age 2) was not included in the VPA analysis.

The Hudson River shad fishery by-catch of spawning striped bass (age 8+) was reconfigured by the NYDEC for use as an age-aggregate index in the VPA. This survey increased steadily through 1996, then dropped to the average for 1997-1998. The survey index was well below average in 2000 and 2001 (Figure D15).

Weight at Age

Weight at age information was updated for the period 1997-2001. Mean weights at age for the 2001 striped bass catch were determined from available state data. The available data were from Maine and New Hampshire recreational harvest and discards; Massachusetts recreational and commercial catch; New York recreational catch and commercial landings; New Jersey recreational catch; Delaware commercial catch and Virginia recreational and commercial catch. Weighted mean weights at age were calculated as the sum of weight at age multiplied by the catch at age in numbers, divided by the sum of catch in numbers. In the VPA model, the estimated weights at age for 2001 were applied to 1997 to 2000 where weight data were unavailable. Details of developing weights at age for 1982 to 1996 can be found in NEFSC Lab Ref. 98-03. Weight at age for the 1982-2001 period is presented in Table D12.

Virtual Population Analysis

Catch at Age

A catch at age matrix was developed using standard methods described in the previous assessment documents (Anon 2001). Commercial landings at age were estimated by applying corresponding length frequency distributions and age length keys to the reported number of fish landed by the commercial fishery in each state. Length frequencies of recreational landings were based on a combination of MRFSS length samples and volunteer angler logbooks. State specific age-length keys were applied to length frequencies to estimate number of fish at age landed by recreational fishery. Age composition of the recreational discards was estimated using lengths available from volunteer angler logbooks and American Littoral Society data.

All states agencies used striped bass scales to estimate age. However, the Technical Committee was concerned about a problem ageing striped bass. Several recent studies (Secor et al. 1995, Bobko 2002, King 2002) have indicated that scales may not provide a reliable age estimate for older fish, beginning with ages 10 to 12. In previous assessments of striped bass, fish of age 15 and older were combined into a 15+ group. The committee adopted the 12+ configuration as the preferred option because 1) estimation of fewer ages reduced the uncertainty associated with ageing error in older fish 2) the change resulted in a more stable exploitation pattern and 3) the estimates of fishing mortality were more closely aligned with estimates from tag models which do not rely on age data. The ADAPT program, a part of the NEFSC stock assessment software FACT, was used to analyze striped bass populations.

ADAPT model inputs

Fishing mortality estimation for age 11, the oldest true age, was based on ages 5 through 10. Abundance of age classes 1 through 11 in the terminal year was estimated using a Marquardt algorithm. Fishing mortality on the plus group was set equal to the fishing mortality for the last true age and was estimated using a backward method. Natural mortality was assumed constant and equal to 0.15 $year^{-1}$. The model was run using the iterative re-weighting option in FACT.

Model fit.

All estimates of abundance at age (N) and catchability coefficients (q) were significant at the 0.05 level (T statistic > 1.96, Table D13). CVs of the N and q estimates were relatively low (most in the range of 20-30%), indicating a good fit. Estimate of ages 1and 2 abundance had greater CVs (50 and 38%), which were expected due to generally higher variation of indices of abundances of younger ages. Among the catchability coefficient estimates, poor performers were the following indices: NEFSC trawl survey indices for ages 1 and 2 with CVs of 0.5 and 0.38 respectively and Virginia pound net survey indices for ages 1 and 12+ with CVs of 0.49 and 0.33. High variances for these indices were likely caused by the scarcity of either very young (ages 1 and 2) or old fish (ages 10-12+) in the sampling gear. Mean square residuals were 0.95 prior to re-weighting and 0.008 following iterative re-weighting, indicating a good fit of the model. The correlation between parameters was small, which indicated parameters independence, a desired property.

Each survey used to tune the VPA contributes to the overall variance in the model, and the amount of the total variance attributable to an index is indicated by its partial variance (PV). Surveys or particular ages of surveys with high PV's are often deleted from assessment runs because they contribute relatively little additional information, and such an approach has been used in the past to trim down the number of surveys. This assessment was a compilation of several stocks and the relative importance of each component's contribution to the total harvest and population abundance was unknown. Iterative re-weighting was used to reduce the influence of surveys with high partial variance while retaining the information of each survey concerning the abundance of particular stock components. Iterative re-weighting resulted in very small changes in estimates of abundance and fishing mortality, indicating that none of the indices had performed very poorly.

Fishing Mortality

The 2001 average fishing mortality rate (F) for fully recruited ages, 7 through 10 (plus group age minus two), equaled 0.29 and was below current target (0.31) and overfishing values (0.38) (Table D14, Figure D16). Average fishing mortality for ages 4 through 10, which has been reported as average F in previous assessments, was 0.23 (Table D14, Figure D16). Fishing mortality on ages 3-8, which are generally targeted in producer areas, was 0.19. An F weighted by N was calculated for comparison to tagging results since the tag releases and recaptures also weighted by abundance as part of the experimental design. The VPA F weighted by N for ages 5-10 (age 5 to compare with tagged fish > 28") was 0.21.

A bootstrap procedure was used to estimate variation in fully-recruited fishing mortality (ages 7-10). Results of 500 bootstrap iterations show Fs ranging from 0.21 to 0.36 with an 80% probability that F was between 0.26 and 0.32 in 2001 (Figure D22).
The VPA indicates that fishing mortality has been steadily increasing since 1989 (Table D14). The modification of the VPA model to limit the ages to 12 plus changed the estimate of F in the early years of the time series. New estimate in 1982 for fully recruited F was 0.54 (Figure D15) with maximum Fs at age of 0.78.

Partial Recruitment

Full recruitment estimated as the back-calculated partial recruitment was at age 7 in 2001, up from age 6 in 2000. Prior to 2000, age at full F varied between ages 7 and 10 (Table D16). Changes in regulations in 2000 and 2001 to shift exploitation patterns may account for the changes from the 1990s.

Population Abundance

Population abundance (stock size as of January 1, 2002) was at the highest level in time series (Table D17, Figure D19) and was estimated at 59.6 million fish. Bootstrap estimates of population abundance are shown in Figure D23. VPA results suggested that the increase was due to very strong 2000 and 2001 year classes. Recruitment of age 1 fish in 2002 (2001 cohort) was estimated as 17.9 million fish, which makes it the biggest cohort ever, exceeding both 1993 and 1996 year classes (Figure D20). This follows the 2000 cohort estimated as 15.5 million fish which also exceeded 1993 and 1996. Abundance estimates for striped bass age 3 and older have declined slightly since 1999 as the previously strong cohorts move through the fishery. However, both the 1993 and 1996 year classes remain the most abundant at age in the time series.

Spawning Stock Biomass

All VPA runs indicated that spawning stock biomass (SSB) has been growing steadily since 1982 and reached the highest level in 2001 (Figure D21). However, SSB growth was slowed after 1998. Female SSB estimates are of 25.8 mt in 2001.

Retrospective Patterns

A retrospective analysis was conducted on the VPA results with successive terminal years extending back to 1995, in order to determine trends in estimation of F or total abundance in the terminal year. The analysis revealed that there was little evidence of retrospective bias in the assessment. However, there was a tendency of overestimation of age 1 abundance by the model.

Sensitivity Analysis

Due to the uncertainty in age determination, sensitivity runs were made for the VPA using a 13+ group. Changing the plus group ages had a significant change in the estimates. The average F for ages 4 to 11 was 0.32, ages 8 to 10 equaled 0.4 and average F for ages 3 to 8 was 0.22.

Stock size estimates were also influenced, as 1+ abundance with 13+ decreased to 52.6 million fish compared to 59.6 million with 12+. Recruitment estimates at age 1 also declined by 1.8 million fish to 16.1 million.

The overall trend appears to be a decrease in fishing mortality and increase in stock size estimates as the plus group is reduced in age.

II. TAGGING PROGRAM ANALYSIS

Introduction

This report summarizes results from analyses of tagging data from the U.S.F.W.S. Cooperative Striped Bass Tagging Program. The results include estimates of instantaneous fishing mortality (F) and survival (S) rates. Estimates of F and S are provided with and without correction for live release bias. Also, included are QAICc estimates and weights used for model selection and model averaging, length frequency of tag releases, age frequency of recaptures, geographic distributions of recaptures by month, and estimates of catch and exploitation rates by program.

Description of Tagging Programs:

Eight tagging programs provided information for this report, and have been in progress for at least nine years. Producer area tagging programs operate mainly during spring spawning, and use many capture gears, such as pound nets, gill nets, seines and electroshocking. Coastal programs tag striped bass from mixed stocks during fall and use several gears including hook & line, seine, gill net, and otter trawl. Most producer area and coastal programs tag striped bass during routine state monitoring programs. The Western Long Island Survey seines striped bass from May through October in bays along the western end of Long Island, New York; data from May through August are most consistent and were used for tag analysis.

Tag release and recapture data are exchanged between the U.S. Fish and Wildlife Service (USFWS) office in Annapolis, MD, and the cooperating tagging agencies. The USFWS maintains the tag release/recovery database and provides rewards to fishermen who report the recapture of tagged fish. Through July of 2002, a total of 385,891 striped bass have been tagged and released, with 70,118 recaptures reported and recorded in the USFWS database (Tina McCrobie, personal comm.).

Analysis Methods:

The Striped Bass Tagging Committee analysis protocol is based on assumptions described in Brownie et. al. (1985). The tag recovery data is analyzed in program MARK (White, 1999). Important assumptions of the tagging programs (as reported in Brownie 1985) are as follows:

1. The sample is representative of the target population.
2. There is no tag loss.
3. Survival rates are not affected by the tagging itself.
4. The year of tag recoveries is correctly tabulated.

Other assumptions related to the modeling component of the analyses include:

5. The fate of each tagged fish is independent of the fate of other tagged fish.
6. The fate of a given tagged fish is a multinomial random variable.
7. All tagged individuals of an identifiable class (age, sex) in the sample have the same annual survival and recovery rates.

The tagging committee calculates maximum likelihood estimates of the multinomial parameters of survival and recovery based on an observed matrix of recaptures (using Program MARK). The analysis protocol follows an information-theoretic approach based on Kullback-Leibler information theory and Akaike's information criterion (Burnham and Anderson 1988), and involves the following steps. First, a full set of biologically-reasonable candidate models are identified prior to analysis. Various patterns of survival and recovery are used to parameterize the candidate models. These include models, which allow parameters to be constant, time specific, or allow time to be modeled as a continuous variable. Other models allow time periods to coincide with changes in regulatory regimes established coastwide. Candidate models used in the analyses of striped bass tag recoveries are listed and described below.

S(.) r(.)	Constant survival and reporting
S(t) r(t)	Time specific survival and reporting
S(.) r(t)	Constant survival and time specific reporting
S(p) r(t)	*Regulatory period based survival and time specific reporting
S(p) r(p)	*Regulatory period based survival and reporting

S(.) r(p)	*Constant survival and regulatory period based reporting
S(t) r(p)	*Time specific survival and regulatory period reporting
S(d) r(p)	*Regulatory period based survival with unique terminal year and regulatory period based reporting
S(v) r(p)	*Regulatory period based survival with 2 terminal years unique and regulatory period based reporting
S(Tp) r(Tp)	*Linear trend within regulatory period for both survival and reporting
S(Tp) r(p)	*Linear trend within regulatory period survival and regulatory period based reporting (no trend)
S(Tp) r(t)	*Linear trend within regulatory period survival and time specific reporting (no trend)
* Periods	1 = { 87- 89}, 2 = { 90- 94}, 3 = { 95- 2001}

Candidate models are fit to the tag recovery data and arranged in order of fit by the second order adjustment to Akaike's information criterion (AICc) (Akaike, 1973; Burnham and Anderson, 1992). If overdispersion is detected, then an estimate of the variance inflation factor (i.e., c-hat) is used to adjust AICc (after adjustment, AICc is called QAICc; Anderson et al 1994). Annual survival is calculated as a weighted average across all models, where weight is a function of model fit (Burnham and Anderson 1998; Smith et al. 2001). Model averaging eliminates the need to select the single 'best' model, allowing the uncertainty of model selection to be incorporated into the variance of parameter estimates (Burnham and Anderson 1998; Smith et al. 2001). Also, the committee uses a goodness-of-fit bootstrap procedure (included in program MARK) to estimate the probability that the fully time saturated model fits the data. At the Striped Bass Technical/Stock Assessment meeting (10-12 September 2002), it was suggested that a probability under 0.2 represents lack of fit; this is an arbitrary cutoff point but we use it herein to indicate model fit.

Since survival cannot be uniquely estimated for the terminal year in the fully time saturated {S(t)r(t)} model, the time saturated model is excluded from the model averaged survival estimate for the terminal year only. The final steps involve adjusting the estimates of survival for reporting rate (Kahn, 2001) and bias due to live release (Smith et al. 2001). Instantaneous fishing mortality (F), not directly estimated by these analysis procedures, is determined by converting survival (S) to total mortality (Z) and subtracting a constant value for natural mortality (M) of 0.15. Using this technique, natural mortality is held fixed, and any change in total mortality (Z) results in an equal change in fishing mortality (F).

Results

The 2001 weighted-mean instantaneous fishing mortality (F) was **0.53** for >= 18 inch fish from producer area (Delaware and Maryland) tagging programs (Table D20). This weighted mean excluded Hudson River (data were unavailable for 2001) and Virginia (because of lack of fit for the full parameterized model). For the subset of >= 28 inch striped bass, the weighted mean fishing mortality (F) in 2001 was **0.16** (Table D21). The weights used in the calculations were as follows: Delaware (0.10) and Maryland (0.90). These were modified from the previous weight scheme [Hudson (0.13); Delaware (0.09); and Chesapeake Bay (0.78), with MD (0.67) and VA (0.33)] as provided from G. Shepherd (pers. comm.). The weight scheme was modified because of the lack of Hudson River data and the lack of fit of the full parameterized model with Virginia data.

A 2001 unweighted-mean instantaneous fishing mortality (F) was not calculated for >= 18 inch fish from the coastal mixed stock tagging programs (Table D20). Survival estimates from three of the four coastal tagging programs were not representative; MADFW primarily tags fish larger than 28 inches, and GOF bootstrap analyses indicated a lack of model fit of data from NYOHS and NCCOOP. For striped bass tagged at twenty-eight inches and greater in total length (believed to represent those fish fully recruited to the coastal fisheries) the 2001 unweighted-mean fishing mortality was **0.09** (Table D21). This unweighted mean was calculated with data from MADFW, NYOHS, and NJDEL, but excluded NCCOOP because of lack of model fit.

In general, fishing mortality estimated by tag-based survival analyses has increased in recent years for the >= 18 inch group, and decreased for the >= 28 inch group. This relationship is consistent with recent changes to regulations that have shifted harvest to smaller fish.

Tables D22 and D23 provide the raw estimates of survival from MARK, and components of the live release bias adjustment. For most tagging programs, the proportion of >= 28 inch fish released alive was lowest within the years of 1996 to 1999; these estimates in recent years have increased slightly (Table D23). If the entire time series is considered, then live release bias has decreased since the late 1980's and early 1990's and may result from lowered size limits. The overall decreasing trend in the number of fish released alive (based on tag data) differs from recent MRFSS reports.

For bias adjustment calculations, the committee applies an 8% mortality to live releases, because most live releases are captured with hook and line. Also, a reporting rate of 0.433 is used to adjust survival and fishing mortality rates (based on a high reward tag study of striped bass released in Delaware; D.Kahn, pers. comm.).

A GOF bootstrap test indicated that most time saturated models fit the data (exceptions included the >= 18 inch group of NYOHS, and both size groups of VARAP and NCCOOP; Tables D22 and D23).

Tables D24 and D25 provide the Akaike weights used to calculate the model averaged survival estimates for each program. Those highlighted were the highest weighted models for that program. These are provided so that the reader may evaluate the model (or models) that influence the overall results. In nearly each case, the best fitting models inferred time or regulatory period specific survival or reporting. For several programs, a model of trend within regulatory period received highest weight. The only case where a model of constant survival and reporting received highest weight was for fish greater than twenty-eight inches total length in the Virginia/Rappahannock producer area program.

Tables D26 and D27 provide the total length frequencies of fish tagged and released by program for 2001 and the age frequencies of 2001 (year) recaptures. The length frequency data show the relative differences within and between fish tagged on the coast and in producer area programs. The bimodal length frequencies of producer area programs are probably related to differences between sexes. The coast programs exhibit single modes, likely related to differences in program design and gear type. In general, the Massachusetts program (which captures fish with hook and line) releases proportionally more large fish than other coastal programs, whereas the North Carolina trawl survey releases proportionally more small fish than other tag programs.

Age distributions of 2001 recaptures are problematic since few programs assign ages to all tagged fish. Hence, fish not aged at release cannot be assigned an age at recapture. The greatest proportions of recaptures were among ages four through eight, which included 13.3, 25.4, 16.5, 12.4, and 10.1% of the total. In general, these cohorts accounted for 84% of recaptures from fish tagged on the coast, and 64% of those from producer areas.

Table D28 provides geographic distributions of recaptures by state and month during 2001. Northward spring movements followed by southward returns during fall are consistent across programs and reflect migration patterns and fishing effort.

Tables D29 through 12 provide results from the Western Long Island Survey of juvenile striped bass (ages 1, 2, and 3+). These results indicate a decrease in total mortality as age increases from 1 to 3+.

Trends in encounter and exploitation rates:

Annual catch rates and annual exploitation rates were estimated with tag recoveries of striped bass released by seven agencies (1987 - 2001) of the Cooperative Striped Bass Tagging Program (Tables D32 to D35). Previous estimates of VA-York (1991 - 1999) and NYHUD (1988 - 2000) are included for comparison. Each time series of annual catch rates and annual exploitation rates reflects trends in fishing effort and exploitation, respectively.

Catch and exploitation rates are estimated from recaptures of two size groups (>= 18 inch and >= 28 inch) during the first year after release. Adjusted R/M ratios were used as described below (Reporting rate = 0.43, hooking mortality rate = 0.08, R_k = killed recaptures, R_L = recaptures released alive):

(1) Annual catch rate = (R / 0.43) / M

(2) Annual exploitation rate = $((R_k + R_L * 0.08) / 0.43) / M$

Herein, we report trends across the entire time series by program. Overall increases in annual catch rates and annual exploitation rates from 1987 - 1997 or 1987 - 1998 suggest an increase in fishing pressure over that part of the time series, but recent estimates (i.e., the previous two years) of annual catch rates and annual exploitation rates have decreased for most tagging programs.

In general, estimates of exploitation rates are consistent with estimates of F (from survival analyses) as reported above for >= 28 inch fish, but not with those reported for >= 18 inch fish.

III. STATUS OF INDIVIDUAL STOCKS

A coast-wide stock of striped bass is comprised of several populations, primarily Hudson River, Delaware Bay and Chesapeake Bay. It is equally important to maintain individual stock at healthy level so that over-fishing does not occur at the local level. For that purpose we report estimates of fishing mortality and population characteristics for each individual stock.

Chesapeake Bay

Fishing mortality

Tag-based estimates of fishing mortality in 2001 for the Chesapeake Bay stock were available only from the Maryland spring tagging program and the direct enumeration study conducted through the calendar year of June 2001-June 2002. For fish $\geq$28 inches, the spring estimate of F = 0.13 was lower than the N-weighted VPA F estimates of 0.27 and 0.37 on ages 8-10 (12+) and 8-11 (13+), respectively. It should be noted that the tag-based F and N-weighted VPA F are not directly comparable to the reference point because of the methods used to calculate that measure.

A direct enumeration study to estimate the bay-wide fishing mortality based on the tag release and recovery data is conducted by Maryland and Virginia since 1993. The multiple release design and analysis used in this study was reported in Hebert et. al. 1997; Goshorn et al. 1998; Goshorn et al. 1999; Goshorn et al. 2000; Hornick et al. 2000; Hornick et al. 2001. Striped bass were tagged and released throughout the Chesapeake Bay prior to and during the recreational fishing seasons for each respective jurisdiction during four release rounds in Maryland, and three in Virginia. Jurisdictional regions within the Chesapeake Bay were open for recreational striped bass fisheries for a combined total of approximately 31 weeks (6/1/01 - 12/31/01) during the 2001 fall season. All tagging was done cooperatively with commercial watermen. Tag recoveries were handled and recorded by each management jurisdiction and by the U. S. Fish and Wildlife Service (USFWS). USFWS internal anchor tags were applied to 6,663 striped bass. A logistic model was applied to tag recovery and release data. The proportion of the number of recovered tags to the number of tags released was the response variable and the explanatory variables consisted of one categorical variable (interval number, which accounted for unequal interval lengths) and two binary variables, disposition and angler type Estimates of exploitation for the recreational/charter season were converted to instantaneous rates for each round and summed across intervals to determine F for the recreational/charter fishery (F_R). This estimate was then adjusted to include the Chesapeake Bay resident portion of the commercial and recreational fisheries that occurred during summer 2001, winter 2001-2002 and during spring of 2002, respectively. The expanded estimates of total F were calculated based on weighting of recreational/charter estimates of F_R by proportional additions of spring recreational or commercial harvest in numbers. The estimate of the Chesapeake Bay-wide F (F_{Bay}) for 2001 is F_{Bay}= 0.23. Non-harvest mortality (0.10) was added to the point estimate of F = 0.13 to obtain the final estimate of bay-wide fishing mortality of F_{Bay} = 0.23 for 2001. The final estimate of bay-wide F (F_{Bay} = 0.23) is below the Atlantic States Marine Fisheries Commission's (ASMFC) determined 2001 target fishing rate of F = 0.28 for the Chesapeake Bay. A time series of fishing mortality estimates derived by this method is presented in Table D38.

Spawning stock
Spawning stock relative abundance (ages 8+) has been increasing since 1999. The index increased to 79.81 in 2001, but dropped slightly in 2002 to 72.7. Although the spawning stock index dropped in 2002, this value is well above the 1985-2001 average of 46.6 and is equivalent to the 1993-1998 levels.

Recruitment
Both Maryland and Virginia index of YOY striped bass abundance (geometric mean) in 2001 was well above the 1957-2000 average. These observations indicated that 2001 was an excellent recruitment year. At the same time the 2002 index was well below the 1957-2001 average.

<u>Hudson River</u>

Fishing mortality
Data from 2001 have not been processed due to lack of staff at NYDEC; therefore; no tag-based estimates were available for the Hudson River.

Spawning stock
Spawning stock relative abundance (gillnet CPUE; ages 8+) increased slightly in 2001 to 633.2; however, the index is still below the 1985-2000 average of 746.9.

Recruitment
The Hudson River index of YOY striped bass abundance (geometric mean) increased to 22.98 in 2001. The 2001 value is well above the 1979-2000 average of 13.32, indicating that 2001 was a relatively good year of recruitment for striped bass.

<u>Delaware Bay</u>

Fishing mortality
Tag-recapture data is employed in two analyses, a Petersen exploitation estimate and an estimate of F based on survival modeling with MARK program software. The two sets of estimates have been the highest on the coast for the last several years. Both estimates, when translated into F, are F weighted by N. The exploitation estimate for 2001 was 28%, which translates into F_{2001} = 0.36. The 2001 F estimate from the MARK program with trend models included was F_{2001} = 0.42. If trend models are eliminated, the MARK estimate was F_{2001} = 0.35. The Delaware River stock suffers high levels of entrainment mortality from the Salem Nuclear Generating Station. This mortality on YOY larvae and juveniles has been estimated as averaging 32% per year, in the worst case of no compensatory increase in survival of those YOY fish escaping entrainment and impingement.

Spawning stock
The spawning stock survey occurs in April and May on the spawning grounds in the tidal freshwater Delaware River from Wilmington through Philadelphia. Two agencies co-operate in this survey, which tags fish and develops Catch Per Unit Effort estimates of abundance in standardized surveys. The Delaware Division of Fish and Wildlife (DDFW) employs electrofishing gear in a formal systematic sampling design (this type of design is randomized), while the Pennsylvania Fish and Boat Commission (PFBC) also employs electrofishing gear, but in a fixed design. Trends in overall abundance are flat from 1995-2001 for the PFBC and

indicate a slow decline in the DDFW estimates for the period 1996-2001. Further analysis will be conducted. The more extensive DDFW data shows an increase in larger, older fish in recent years, but a decline in recruitment of younger age groups into the spawning stock.

Recruitment
A YOY survey is conducted annually by the New Jersey Division of Fish, Game and Wildlife employing a beach seine. The index was extremely low at the beginning of the time series in 1980, then gradually climbed to a value of 1.03 in 1989. Since then, it has fluctuated without trend between about 1.00 and 2.00. The 2001 index was 1.07.

IV. DISCUSSION

<u>VPA Analysis</u>
The results of the VPA analysis indicate that the coastal stocks of striped bass remain at or below the target F and are not in an overfished condition. Recruitment continues to increase to record levels while spawning stock biomass estimates are at the highest level in the time series. Catches in the recreational fishery also continue to increase.

The sensitivity of the VPA model to changes in the plus grouping was of concern to the Technical Committee. The primary purpose of reducing the plus group was to reduce problems associated with age error. This change also illustrated the problems associated with defining plus groups and oldest age F estimates in an age-structured model. A change in the plus group influenced the calculated exploitation pattern and consequently the average F at fully recruited ages. With more ages in the model, the average F tended to be higher. However, due to the direction of the potential age bias in the inputs, it is expected that the model would be over-estimating F by incorporating older and possibly incorrect ages. Consequently there is more uncertainty in the VPA estimates than are indicated by the bootstrap results.

<u>Tag Analysis</u>
There are several sources of uncertainty associated with the estimation of survival and recovery parameters in the tagging analysis for striped bass. The primary source involves the violation of assumptions basic to all tag recovery modeling, as mentioned earlier in this text. Others involve ad-hoc methods employed to correct for live release bias, as well as the use of a contemporary reporting rate to adjust retrospective recaptures. In addition, the best fitting model for several programs in the >= 18 inch total length group was the time saturated model, which is omitted from the suite of models during model averaging due to constraints on the terminal year survival estimate. The application of a constant value for natural mortality across all groups and time does not allow for potential changes in natural mortality, and dictates that changes in survival result only in changes in fishing mortality.

Also, GOF bootstrap analyses indicated a lack of fit for time saturated models from some tagging programs. The c-hat adjustment corrects for lack of fit associated with overdispersion, but will not correct lack of fit when data do not support the full parameterized model. In the latter case, additional thought toward selection of candidate models may be necessary. In general, lack of fit occurred in program results with highest weight on the full parameterized (time saturated) model and large year to year variation in survival estimates. The tagging committee plans to examine the use of covariate models in future analyses; preliminary covariate analyses with the NCCOOP data reduced problems with the full parameterized model and extreme year to year variation in survival estimates.

Additionally, the tagging committee will examine the use of trend models, which have been used to fit increasing or decreasing trends in survival estimates. In all cases for the 2001 analysis, when trend models were given highest weight (such as DE and MD for the >= 18 inch group, and DE and NJ for the >= 28 inch group), F estimates of the terminal year were high. This effect also occurred for the terminal year estimates of NYOHS, NJ, and VA for the >= 18 inch group, because the trend models received highest weight after omission of the time saturated model. Resolution of many of these issues will take time, and may require a change in the analysis protocol adopted by the tagging committee. It is likely that additional research is required to investigate the differences in release mortality associated with different capture gears, or that the committee may need to investigate other methods to directly determine instantaneous fishing mortality (F). Some solutions may take longer, as the state of the theoretical science is generally in advance of any practical application. Perhaps, as in the model averaging approach, we should not focus on individual tagging program results, but instead consider the aggregate, and examine trends applicable to the whole stock over time.

TAG-VPA F Comparison

Results from the VPA average F and the tagging estimates of F are not directly comparable. Since the tag releases are made proportional to abundance, the appropriate comparison between tag and VPA F's are the tag F with the VPA F weighted by N. Tag results are for striped bass 28 inches and greater. Therefore, comparison was between VPA F's weighted by N for ages 5 to 10 and average tag F's from coastal programs (only positive F values were included in the average).

The results from the two independent estimates of fishing mortality show the same increasing trend over time. The VPA Fs tend to be slightly higher than the average coastal tag Fs (Figure D24, D26), although the VPA estimate is not statistically different based on 95% confidence intervals. The NC offshore winter tag program provided the closest comparison with the VPA results as shown in Figure D25. Part of the variation between the two is the result of the different models used for the estimation.

V. CONCERNS

The uncertainty associated with ageing striped bass with scales remains a problem. A thorough analysis of the scale and otolith database is required to develop a reliable procedure for correction of ages estimated with scales. In response to this problem, the ASMFC will convene an ageing workshop during the winter of 2003 to evaluate the problem and develop some possible solutions.

The Technical Committee remained concerned about the high levels of fishing mortality on the Delaware River stock as determined by tagging estimates of survival.

Some members of the Technical Committee were concerned that the distribution of larger striped bass has shifted to offshore waters as the population has increased in abundance. Since the EEZ is closed to harvest and there is limited fishery independent survey data for older striped bass beyond state waters, these fish may not be represented in the assessment. Low tag recovery of fish tagged in MA may be an indication of shifting distribution.

Some members of the Technical Committee were concerned that the VPA is not adequately robust when dealing with a mixed stock such as coastal striped bass. Other methods that are capable of directly accounting for mixed stock management units should be explored in the future. Some members were also concerned that the tag based estimates of survival among coastal programs were so variable. It is possible that the assumption of mixing and dispersal is not being adequately met to provide a comprehensive estimate of mortality.

Developing consensus management recommendations remains difficult when faced with two separate assessment techniques. Methods that combine catch, survey, and tag data into a single analytical framework should be explored.

VI. SARC COMMENTS

VPA Analysis

Selection of ages 5-10 to estimate the F on age 11 will produce strong dome shaped PR. A flat top PR is not appropriate. When fishing offshore is prohibited, it provides a refuge for large fish and may result in a dome shape PR. Availability may be declining not because of the decline of fish numbers but because they are moving out of the area. Partial recruitment calculation is shifting around with age class dominance.

Including ages 5 and 6 may be helpful early on in the time series when there were not many age 7 and older fish, but that is not helpful now. Need to be careful how you calculate the F on the oldest true age. Use the previous age to estimate the F on the first age in the plus group (ie use age 10 to estimate the F on age 11). That allows for a greater potential for allowing a dome to occur. There would be an even stronger dome if the age range were 4-10 rather than 5-10. Catch on age 4, 5 and 6, tagging information, fish moviement into an area where fishing is not occurring- all of these are evidence for a domed shaped curve.

Plots of residual time series are needed to judge the quality of fit.

Estimates of F are sensitive to the plus group. For example, in the 13+ run, the F in 2001 is 0.4 (Table D14).

There are 4 years were the plus group is greater than the sum of the previous plus group.age 11.

There is no description in the document that describes how the target and threshold Fs were derived in Amendment 5. Need some background on the derivation of the target and threshold Fs.

The document should include table of F by age and year in addition to average Fs.

It appears that there is a problem with age precision beyond age 8 in MA scale reading study. The mean weight at age in some cohorts is going down. This is because of the bias and imprecision in ageing.

The SARC recommends developing a calibration matrix that creates conversion between scales and otoliths. This is a very important outcome from the intended ageing workshop.

The issue of an appropriate VPA configuration should also address allowing for a dome shaped selectivity pattern and an objective discrimination of which tuning indices were included or withheld from the model.

Indices should be tested through the randomization tests, PCA.

Range of the stock distribution by season and fraction of the stock that would be present in a certain area should be considered in parallel with the indices selection. All of the indices that are north of the spawning areas may be capturing the stock as a whole and maybe those indices should be provided with greater weight in the VPA.

Error bars should be included around the estimators if it is based on ratios or bootstrap should be done if ratios are not used.

Use the MRFSS estimate for recapture rate (1 in 13 fish is actually retained?) as an independent estimate of recaptures.

<u>Tag Analysis</u>
Tagging in Delaware is done in the Delaware River, this may be a reason for the increase in DE estimates.

Assume the tagging reporting is constant because there aren't better estimates. Reporting rates may vary.

Including the constant survival models is inappropriate if one wants to be able to compare the tagging estimates and the VPA results.

28" or greater (at tag and release) are assumed to be about age 7. Have not run age based models. Analysis uses 28" or greater as a group and that is compared to the 5-10 ages. Probably should be examined a bit further.

Diminishing the quality of the parameter estimates when including models that are not given much weight, although it may not significantly influence the output, it is going to influence the uncertainty. This may be a reason to throw out these models.

Tag analysis implies a very high dome because the F is greater on the 18" and greater (tag analysis) compared to the F estimate from the tag analysis for 28" or greater.
Fish captured more than once are only included the first time around in the analysis.

<u>Research recommendations.</u>

Conduct a workshop to evaluate an appropriateness of scales in ageing old fish.

Explore applicability of Bayesian framework to striped bass assessment.

Develop the model that will combine VPA and tagging data.

V. References

Anonymous 2001. 2001 Stock Assessment Report for Atlantic Striped Bass. Atlantic States Marine Fisheries Commission. Striped Bass Technical Committee.

Akaike, H. 1973. Information theory as an extension of the maximum likelihood principle. *In* Second International Symposium on Information Theory. *Edited by* B.N. Petrov and F. Csaki. Budapest: Akademiai Kiado.

Anderson, D.R., K.P. Burnham, and G.C. White. 1994. AIC model selection in overdispersed capture-recapture data. Ecology 75:1780-1793.

Bobko S. 2002. A Comparison of Otolith and Scale Age Determination for Striped Bass harvested in Virginia. VMRC/ODU Age and Growth Laboratory Center for Quantitative Fisheries Ecology Old Dominion University. Draft Manuscript.

Brownie, C., D.R. Anderson, K.P. Burnham, and D.R. Robson. 1985. Statistical Inference from Band Recovery - a handbook. 2nd ed. U.S. Fish and Wildlife Service Resource. Publication. No 156.

Burnham, K.P., and D.R. Anderson. 1992. Data-based selection of an appropriate biological model: The key to modern data analysis. *In.* Wildlife 2001: Populations. *Edited by* D.R. McCullogh and R.H. Barrett. London:Elsevier Science Publications.

Burnham, K.P., and D.R. Anderson. 1998. Model selection and inference: a practical information theoretical approach. Springer-Verlag, New York.

Goshorn, C.J., B.A. Rodgers, and R.E. Harris. 2000. Revised estimate of the 1998 striped bass rate of fishing mortality in Chesapeake Bay. Maryland Department of Natural Resources. Annapolis, Maryland, and the Virginia Institute of Marine Science, Gloucester Point, Virginia. 29 pp.

Goshorn , C.J., D.R. Smith, B.A. Rodgers, L.D. Warner and H.T. Hornick. 1999. Revised estimate of the 1997 striped bass rate of fishing mortality in Chesapeake Bay. Maryland Department of Natural Resources. Annapolis, Maryland, and the U.S. Geological Survey, Leetown Science Center, Kearneysville, West Virginia. 29 pp.

Goshorn , C.J., D.R. Smith, B.A. Rodgers and L.D. Warner and H.T. Hornick. 1998. Estimates of the 1996 striped bass rate of fishing mortality in Chesapeake Bay. Maryland Department of Natural Resources. Annapolis, Maryland, and the U.S. Geological Survey, Leetown Science Center, Kearneysville, West Virginia. 31 pp.

Hebert, K.P, D.R. Smith, P.W. Jones. 1997. Estimates of the 1995 Striped Bass Rate of Fishing Mortality in Chesapeake Bay. Maryland Department of Natural Resources, Annapolis, Maryland, and the U.S. Geological Survey, Leetown Science Center, Kearneysville, West Virginia. 33 pp.

Hornick, H.T., B.A. Rodgers, R.E. Harris and J. Zhou. 2000. Estimate of the 1999 striped bass rate of fishing mortality in Chesapeake Bay. Maryland Department of Natural Resources. Annapolis, Maryland, and the Virginia Institute of Marine Science, Gloucester Point, Virginia. 10 pp.

Hornick, H.T., B.A. Rodgers, and R.E. Harris. 2000. Estimate of the 2000 striped bass rate of fishing mortality in Chesapeake Bay. Maryland Department of Natural Resources. Annapolis, Maryland, and the Virginia Institute of Marine Science, Gloucester Point, Virginia. 11 pp.

Kahn, D.M., and C.A. Shirey. 2000. Estimation of Reporting Rate for the U.S.F.W.S. Cooperative Striped Bass Tagging Program for 1999. Report to the ASMFC Technical Committee. Mimeo 5 pp.

Northeast Fisheries Science Center. 1998. 26th Northeast Regional Stock Assessment Workshop: stock assessment review committee (SARC) consensus summary of assessments. NEFSC Reference Document 98-03.

Secor D.H., Trice T.M., Hornick H.T. 1995. Validation of otolith based ageing and a comparison of otolith and scale based ageing in mark recaptured Chesapeake Bay Striped Bass, Morone saxatilis. Fish. Bull 93:186-190.

Smith, D.R., K.P. Burnham, D.M. Kahn, X. He, C.J. Goshorn, K.A. Hattala, and A.W. Kahnle. 2000. Bias in survival estimates from tag recovery models where catch-and-release is common, with an example from Atlantic striped bass (*Morone saxatilis*). Canadian Journal of Fisheries and Aquatic Science 57:886-897.

White, G.C., and K.P. Burnham. 1999. Program MARK - survival estimation from populations of marked animals. Bird Study 46: 120-138