Assessment of Atlantic Coast Weakfish in 1994

By

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Report to the Atlantic States Marine Fisheries Commission
Weakfish Technical Committee and Management Board.

Executive Summary

Weakfish were assessed through 1994 using updated fishery landings data and survey indices. Revised estimates of shrimp discards and new life history findings on maturation and longevity were also incorporated. Loss rates of recreational discards was reduced from 35% to 20%. A new VPA model which does not require an assumption of constant selection pattern and which can utilize more fishery independent indices was used for the first time.

Commercial landings in 1994 were 2767 MT while recreational landings were 810 MT. Commercial landings have declined by 83% since 1980 while recreational landings have declined by over 90%. Mean weight of fish caught in the recreational catch has also declined. Landings at age data indicate that most of the declines have occurred in weakfish age 4 and older. Shrimp discards have ranged from 24 million to 51 million age 0 weakfish. Recent estimates are the lowest reflecting reduced abundance of age 0 weakfish and usage of BRD devices in North Carolina. Recreational discards (B2) have increased from less than 10% of the recreational catch to over 40% but still make up a small amount of total fishery losses. CPUE in the commercial and recreational fisheries has declined significantly over time. Reductions of 50% and 80% respectively are evident. Age specific CPUE indices indicate a loss of older, larger fish from the stock. These declines are matched by sportfish citation data which show a complete collapse of trophy size weakfish from Delaware through North Carolina.

The primary fishery dependent abundance index is the NMFS/NEFSC fall inshore trawl survey. Abundance of age 2+ weakfish has declined sharply since 1985 to only about 15% of historical levels. Abundance of age 0 and 1 weakfish has not declined as much although 7 of the last 9 years were below average. A number of other surveys conducted by state agencies, universities, and power companies are also available. Comparisons are difficult due to differences in length of time series. Collectively, they indicate low or average recruitment in recent years with greater reductions in the northern portion of the range. Limited indices available for 1995 indicate average recruitment in North Carolina and Virginia, above average in Delaware, below average in New York, and a record low in Rhode Island.

Virtual population analyses (VPA) indicate that spawning stock biomass declined over 90% from 1979 to 1991. A modest increase is evident through 1994. The 1994 estimate of 9608 MT is only 15% of the estimated unfished level and about one half of that needed to produce stable recruitment. The decline in SSB occurred while fishing rates on age 2-7+ weakfish rose from 0.42 in 1979 to over 2.0 in 1989. The 1994 estimate of F=1.88 (CV=18%) is well over the FMP

reference point of 0.35. Recruitment peaked at 161 million age 0 in 1986 but was below average from 1990-1994. Recruitment estimates were sensitive to inclusion of shrimp discards in the VPA but SSB and F rates were not. Stock and recruitment analyses indicated that an SSB of 20,000 MT is needed to produce stable recruitment with the possibility of strong year classes. Spawner per recruit ratios have increased over time and appear to have reached maximum compensation in the form of high maturation at age 1+. Diagnostic evaluations of the VPA indicate the possibility of overestimation of SSB and recruitment and underestimation of fishing mortality. This may result from increasing catchability in the fishery, landings underreporting, and age-key methods changes.

Biological reference points were estimated including the effect of shrimp discard losses. The FMP reference rate corresponding to 20% of maximum SSB/R was estimated at 0.35. The current fishing rate of 1.89 allows for only 2.7% of maximum SSB/R. Fmsy was estimated at 0.70 which is associated with a long term sustainable yield of 16210 MT (including discards). Short term projections indicated that continued high F rates would result in declines in SSB from the 1994 level. To reach the FMP target of F=0.35, landings in 1995 would need to fall 70% to 2705 MT (includes discards). Longer term recovery projections indicate that the stock can be rebuilt to 20,000 MT SSB in 5 years if F is reduced to 0.50. Yield to the fishery is maximized over 5 years at F=0.6 but lower F resulted in less than a 10% difference. The projections also indicate that F rates of 0.5 or less are needed to rebuild weakfish age structure to historical levels. Removal of shrimp discard loss had little effect on conservative reference points such as F0 1 and F30 but a moderate effect on Fmsy and F20. Long term maximum sustainable yield (with discard) was reduced by 8% under discard losses. This reflects the high natural loss rates assumed for age 0 weakfish.

Future research needs include correcting older scale based aging to be consistent with otolith based aging, study of the north-south gradient in growth, and improved estimates of shrimp discard losses. Stock reconstruction type analyses back to 1945 would help to better understand the reasons for fluctuations in the weakfish stock. Further evaluation of assessment models best suited for weakfish should continue.

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Introduction-

This report updates the status of the Atlantic coast weakfish stock using new information developed by the stock assessment subcommittee. Past assessments have indicated a deterioration in the stock with increasing fishing rates and declining catches (Vaughan et al. 1991, Seagraves 1992). Gibson (1993) estimated fishing mortality in 1992 to be F=1.1, below the peak value of 1.6 reached in 1988 but still well above the F20 reference point of 0.34. A consensus was reached by the coastal states and ASMFC that the original management plan (Mercer 1985) had not been fully implemented and was ineffective. These findings resulted in the development and approval of additional regulatory measures. Amendment 1 to the FMP required states to reduce fishing mortality by 25% by the year 1993. The measures included minimum size limits and mesh restrictions for the commercial fisheries, bag and size limits for the recreational fishery, and use of by catch reduction devices in non-directed fisheries. Difficulty in complying with Amendment 1 objectives on the part of the states and passage of the Atlantic Coastal Act prompted ASMFC to develop Amendment 2. This amendment maintained requirements for F reduction and mesh size increases but postponed them until a later date. Amendment 2 was intended to be an interim measure while a more comprehensive Amendment 3 was developed. This report is intended as a supporting document for Amendment 3 to the weakfish FMP.

This assessment incorporates several changes since the last including data updates through 1994 and a revision of the catch at age matrix to reflect "new" MRFSS methodology. Recreational discard (B2) loss rate was reduced from 0.35 to 0.20 based on new information. Shrimp bycatch losses of juvenile weakfish have also been reestimated and linked to shrimp fishery effort. A number of new survey and fishery dependent abundance indices are added which were unavailable in past assessments. Modifications to the maturation ogive and longevity based on new research are included. Finally, a different assessment model is used which is more robust to variability in selection pattern arising from changing regulations. Short and long term projections were made under various F rate scenarios to assess recovery likelihoods.

Fishery Data-

Catch Data- Commercial landings data were taken from the NMFS general canvas and weighout system (ME-FL) and state (NC) sources (Vaughan 1995). Estimates of commercial scrap, or fish used for industrial purposes, were obtained from state data sources (VA, NC). Recreational catch estimates were taken from the MRFSS coastwide survey. They are the "new" estimates, reflecting weighting changes in the telephone portion of the survey. For the assessment period 1979 to 1994, commercial landings peaked in 1980 at 16312 MT and declined to only 2767 MT by 1994 (Figure 1). Recreational landings (A+B1) have followed a similar pattern. They peaked in 1980 at 19355 MT and then dropped to only 810 MT by 1994. The percentage decline in recreational landings is more severe than in the commercial fishery (96% vs 83%). Mean weight of weakfish landed in the recreational fishery has also declined from 1.28 kg in 1979-1982 to only 0.38 kg by 1994. Commercial mean weight did not change significantly over time but was lower overall, ranging from 0.26 to 0.60 kg. Commercial scrap landings ranged from 10 to 750 MT from 1965 to 1973 (Mercer 1985). More recent scrap estimates increased from 354 MT in 1982 to 1076 MT in 1988. They have declined to only 68 MT in 1994 with size limit regulation. Recreational discards were estimated as 20% of the B2 type catch. B2 catch, as a percentage of recreational total, has increased from 4% in 1979 to over 40% by 1994 but still remains a small component of total fishery related losses. Revised estimates of weakfish discarded in shrimp trawls were made using the methods in Gibson (1994). Briefly, shrimp bycatch loss was estimated as a function of shrimp fishing effort, weakfish relative abundance, and catchability of weakfish in shrimp trawls. Shrimp effort in the south Atlantic region came from the NMFS data base. Relative weakfish abundance was the combined YOY index for the same area (NC, SEAMAP, NMFS indices). Weakfish catchability was estimated for selected years where observer data on weakfish/shrimp catch ratios existed. The geometric mean catchability was then used with year specific shrimp effort and weakfish abundance to estimate total bycatch. New results of seasampling in 1993 on S. Atlantic shrimp trawlers (SC-FL) were incorporated as an additional observation on weakfish/shrimp ratios (SABWG 1995).

A new catch at age (CAA) matrix was developed for years 1982-1994 that accounts for fish taken as scrap and bait in addition to directed recreational and commercial losses. Separate CAA matrices were generated for recreational, directed commercial, and scrap commercial fisheries using semi-annual age-length keys applied to length samples. Additional details on biological sampling, the age-length keys used and generation of the CAA may be found in Vaughan et al. (1991) and Vaughan (1995). Several enhancements have occurred to the CAA over time. Otololith based age keys have been replacing scale based keys since 1987 although not exclusively so. In addition, more comprehensive sampling has allowed for regional keys beginning in 1991. For this study, the CAA in Vaughan (1995) was extended back to 1979 using the MRFSS length frequencies and some limited commercial sampling. Aging for years 1979 to 1981 was accomplished with a pooled 1982-1983 age-length key. Proportion at age for the MRFSS data in 1979-1981 was assumed to be representative of the commercial fishery. ANOVA testing of the 1982-1985 MRFSS and commercial proportions at age indicated a marginally significant difference (P=0.08) in the fishery-age interaction terms. The difference occurred over ages 0 to 3 where the commercial data indicated more age 0 and 1 fish while the recreational data had more age 2 and 3 fish. Both components had extended age structure at this time (4-7+). Although there may be bias in early years due to reliance on only recreational length sampling and pooled keys, the data contrast provided by large catches and extended length structure was considered more important in catch at age analysis. Overestimation of age structure from 1979 to 1981 is offset to some degree by the scale aging bias. Scales are known to produce younger ages than otoliths in a number of fish species including weakfish (Casselman 1987, Lowerre-Barbieri et al. (1994). A limited comparison of the otolith and scale method for paired samples of weakfish age 1 to 6 indicated that most of the discrepancies occurred at ages 2 and 3 (L. Daniel-NCDMF, D. Vaughan-NMFS, pers. comm.). Otolith aging produced about 25% more age 3 fish whereas scales produced 25% more age 2. The discrepancies were most likely to occur for fish sampled in June.

The catch at age matrix (CAA) comprising directed fisheries, recreational discards, and scrap landings is found in Table 1. Ages 0 to 7+ are included with the last group representing all fish age 7 and older. Estimated shrimp discards of age 0 and age 1 weakfish are found in Table 2. Total catch at age including discards is found in Table 3. While there has been some reduction in the catch of younger weakfish, the most noticeable declines are in ages 4 through 7+. Weight at age for years 1978 to 1994 was computed from the age-length key data and a standard weight-length equation (Table 4). Mean values for age 0 were substituted in years when sample size was less than 10. Overall, there is a tendency for a parabolic function of mean weight over time. The heaviest fish occurred during the 1982 to 1990 period. A total CAA in weight computed from a sums of products calculation is compared to reported landings and discard estimates in Table 5. Notable departures from a 1.0 occurred in 1979, 1985, 1990, and 1994. Directed commercial and recreational fisheries accounted for 26.3% and 24.8% of the removals by weight from the stock from 1982-1994. Scrap and B2 losses were only 5.1% and 0.4% respectively. By contrast, shrimp bycatch at the estimated levels has accounted for 43.5% of the removals.

Fishery Dependent Abundance Indices- Fishery CPUE indices were developed from data on recreational and commercial fishing effort. Total recreational catch of weakfish from the MRFSS data base (A+B1+B2) was divided by the number of fishing trips directed at weakfish to produce the recreational CPUE index (Table 6). Directed trips were calculated as total trips multiplied by the fraction of anglers indicating that weakfish was a targeted species. The CPUE index was then disaggregated by age using the MRFSS proportion at age estimates (Table 7). Trends in weakfish commercial CPUE were estimated using data from the NCDMF commercial sampling program since NC accounts for most of the commercial landings. Mean CPUE of weakfish sampled from the North Carolina flynet, haul seine, poundnet, and sink gillnet fisheries were averaged, with weighting by proportion of landings, to give a combined commercial CPUE index (Table 8). This index was then disaggregated using the commercial proportion at age estimates (Table 9). Gear specific effort indices were computed by dividing landings by gear by mean CPUE by gear.

Following Lowerre-Barbieri et al. (1995), abundance of large weakfish was indexed using citation data from state award programs. Several states have offered awards to anglers catching trophy size weakfish. Data from the states of Delaware, Virginia, Maryland, and North Carolina were available for this assessment. In Virginia, data for weakfish 12 pounds and over was used. Delaware changed minimum sizes from 10 to 11 pounds in 1987. Maryland applies a 10 pound standard. In North Carolina, the minimum award size has been 6 pounds. To standardize for possible changes in participation rates, citation numbers were divided by total MRFSS trips in each state. The VA, MD and DE data were considered to be an index of abundance for the age 7+ group based on weakfish growth rates (Vaughan 1995). The NC data were considered an index of age 5 abundance. Sportfishery citation data is summarized in Table 10.

Effort indices for the weakfish recreational and commercial fishery are graphed in Figure 2. Effort in both fisheries has exhibited significant declines from 1979 to 1988. Directed trips in the weakfish recreational fishery declined at the rate of 62,170 trips per year ($P<0.01$). The commercial effort index declined at the rate of 14.3 trips per year ($P<0.05$). For both series, the decline is not smooth but occurs mainly after 1988. Significant declines ($P<0.01$) in CPUE were also evident in both the commercial and recreational series (Figure 3). Recreational CPUE declined at the rate of 0.48 kg/trip while the commercial decline was 261 kg/trip. Although the commercial slope is of greater magnitude, the extent of the recreational decline is greater. The overall reduction is about 50% for the commercial fishery but near 80% for the recreational fishery. Declines in age specific CPUE were most apparent in weakfish age 4 and older for both indices. The sportfish citation data show a drastic reduction to trace levels in 1990 (Figure 4). Citation levels had fluctuated between 900 and 3600 awards from 1976 to 1989 but then dropped to 20 or less from 1990 on. Data for 1995 from MDDNR and DEDFW had zero and 1 trophy weakfish, respectively . Overall, the fishery dependent data indicate a general decline in abundance from 1979 to 1995 which is very pronounced in the older fish.

Fishery Independent Survey Data-

NMFS/NEFSC Trawl Survey- The primary fishery independent abundance index is the fall inshore trawl survey conducted by the National Marine Fisheries Service. Data were available from 1975 to 1994. The survey sampling strata cover the inshore area from Cape Cod to Cape Hatteras. The survey catches primarily age 0 and age 1 weakfish but fish out to age 7+ were taken in early years. A stratified mean CPUE index was developed and age disaggregated using a von Bertalanffy growth curve and the cohort splitting method (V. Crecco, CTDEP- pers. comm.). This method rearranges the von Bertalanffy model to solve for age given length. Although this method is less satisfactory than annual age-length keys, the marked reduction in larger fish through time likely overwhelm any bias introduced. Weight per tow at age indices were also computed using mean weight at age data as noted above. Abundance of adult weakfish, that is fish age 2 and older, has declined sharply since 1985 (Figure 5). The smoothed data indicate that the abundance of older weakfish is currently only about 15% of that which existed from 1975 to 1985. Abundance of weakfish in the recruiting ages (0 and 1) has declined in recent years as well although the magnitude of the decrease is not as great (Figure 6). Good year classes were produced in the late 1970's and mid 1980's. The 1994 year class is average in strength. Collectively the data suggest that despite good year class production as late as 1988-1989, biomass of older weakfish declined sharply in the 1990's.

New England State Surveys- The Massachusetts Division of Marine Fisheries (MADMF) conducts a trawl survey in state waters. Weakfish catches are variable and restricted to survey strata south of Cape Cod. Most of the fish caught are age 0. An index of YOY weakfish since 1978 was obtained from MADMF. It was considered to be a measure of recruitment strength at the species northern limit. Several agencies including the Rhode Island Division of Fish and

Wildlife (RIDFW), the University of Rhode Island Graduate School of Oceanography, and New England Power (NEP) conduct trawl surveys in portions of Narragansett Bay. The RIDFW survey dates from 1979 while the utilities index began in 1972. The URIGSO survey is the oldest dating back to 1959. These surveys catch primarily age 0 weakfish in the fall. A combined Narragansett Bay index was computed by reducing the surveys to standard normal deviates and averaging. The retransformed index in RIDFW trawl units was used as a measure of recruitment strength in Narragansett Bay. The Connecticut Department of Environmental Protection has conducted a trawl survey in Long Island Sound since 1984. The random stratified survey in the fall catches primarily age 0 weakfish. A mean CPUE index was computed and used to index 0 group abundance in this area. A second survey in the state is conducted by Northeast Utilities Service Company in the vicinity of Millstone Nuclear Power station. This index dates back to 1977. Survey data for YOY weakfish are summarized in Table 11. Trawl survey results for full age structure surveys are given in Tables 12 to 15. Recruitment data for New England are graphed in Figure 7. The data have been plotted as Z-transforms to reduce scale differences. There is not much coherency in the indices although most suggest below average recruitment since 1992. There is also a common signal that the 1978 and 1982 year classes were above average. The only 1995 available was the RIDFW survey which had the lowest index since 1979.

There are no survey data to directly index adult weakfish abundance in the New England region. However, NEP has a time series of larval weakfish abundance in upper Narragansett Bay from ichthyoplankton monitoring. This survey clearly documents past spawning by weakfish in Rhode Island waters. If survival of weakfish eggs varies without trend, larval abundance may be a proxy for weakfish SSB. From 1972 to 1984, larval abundance of weakfish declined steadily. From 1985 to present, it dropped to zero suggesting that SSB has declined to very low levels in this area.

Mid-Atlantic State Surveys- The New York Department of Environmental Conservation began a trawl survey in Peconic Bay on Long Island to monitor weakfish recruitment in 1985. Geometric mean catch per tow of juvenile weakfish was used as an index of 0 group abundance. Data were available from 1985, and 1987-1994. The 1986 value was estimated from a significant ($P<0.01$) regression of this index on the NYDEC haul seine index one year later. The ocean haul seine survey on Long Island is directed primarily at striped bass but also catches adult weakfish. Mean CPUE was available from 1987 to 1994. Aging work is incomplete so the index was used in aggregated form as an index of age 2 weakfish. The New Jersey Department of Environmental Protection has conducted a random stratified trawl survey since 1988 in marine waters off New Jersey. Weakfish catches in the bimonthly survey are most numerous in the fall. A CPUE index of weakfish was available since 1988 for this assessment. Age disaggregation was accomplished using a von Bertalanffy growth curve and the cohort splitting method. The Delaware Division of Fish and Wildlife (DEDFW) conducts a trawl survey in Delaware Bay using a 30 foot otter trawl. The survey has been intermittent and was active from 1966 to 1971, 1979-1984, and most recently from 1990 to 1994. A catch per nautical mile towed index of weakfish was computed. Age dissagregation for all years was accomplished using an age-length key from 1993 collections. Again, the drastic changes in length composition observed in the stock through time likely overwhelm any bias from limited age key availability. A YOY index from a second survey using a smaller trawl is available since 1980 and has a similar year class pattern. The Maryland Department of Natural Resources conducts annual trawling in bays along the Maryland Atlantic coast. The survey began in 1972. Mean catch per tow of YOY weakfish was computed from this survey. The Virginia Institute of Marine Science has conducted a trawl survey since 1955 in several VA rivers of the Chesapeake Bay. Several methodological changes have occurred and a standardized index of age 0 weakfish is available since 1979. Pending gear efficiency studies, additional years of early data may become available. Recruitment indices for the Mid Atlantic are found in Figure 8. Like New England, above average year classes are indicated in 1978 and 1982. Trend coherency is better, particularly since 1985. A period of low recruitment from 1987 to 1990 was followed by above average recruitment from 1991 to 1994. Historical data from the VIMS survey, which is not yet standardized for methodological differences, suggests that weakfish recruitment was very low from 1955 to 1967 (Mercer 1985). This is confirmed by the age structure in the early segment of the DEDFW large trawl survey. Significant year classes did not return to Delaware Bay until 1966 (Table 13). Relative abundance of older weakfish was high from 1979 to 1984 following the improved recruitment. Current age structure indicates no fish older than age 5. The NJDEP trawl survey currently has few fish older than age 3. The 1995 data available for this area is from the DEDFW small trawl, the VIMS trawl surveys, and the NYDEP Peconic Bay survey. Weakfish recruitment was below average in Virginia, above average in Delaware, and below average in New York.

S. Atlantic State Surveys- The North Carolina Division of Marine Fisheries conducts two trawl surveys in coastal waters which catch age 0 and age 1 weakfish. The first, conducted since 1979, is a statewide juvenile finfish survey. The second, conducted since 1987, is restricted to Pamlico Sound. The NCDMF regards the Pamlico Sound survey as the better index of weakfish recruitment. Mean catch per tow of juvenile weakfish was computed for both surveys. The area from Cape Hatteras, NC to Cape Canaveral, FL has been surveyed since 1989 by the SEAMAP shallow water trawl survey. This survey, conducted by the South Carolina Wildlife and Marine Resources Commission, samples 48 strata in the south Atlantic Bight. A stratified mean CPUE of weakfish was developed and disaggregated by age using age keys provided by C. Wenner- SCWMRC. This survey catches primarily age 1 and 2 weakfish. To give a longer perspective of recruitment in this area, S. Atlantic commercial landings of weakfish were used as a proxy for recruitment because of the positive correlation (P<0.05) between the NMFS/NEFC age 0 index and SA landings two years later first noted by Boreman and Seagraves (1984). In the South Atlantic region, recruitment trends are not clear (Figure 9). Good recruitment generally occurred from 1984 to 1986 but was lower in 1990 and 1991. From 1992 to 1994, the surveys have had mixed results. The 1995 NCDMF survey in Pamlico Sound produced an average YOY index while the coastwide juvenile survey had above average abundance of YOY. Additional recruitment indices for weakfish in this region exist from electric utilities monitoring in the Cape Fear River estuary. Although the complete data set is not yet available, a qualitative account in Mercer (1985) indicates that weakfish recruitment was at a high point from 1978 to 1980 and lower in 1973-1977 in 1981-1982. This pattern is in general agreement with the long term pattern inferred from lagged commercial landings. No long term index of adult weakfish exists in this region. The SEAMAP trawl currently indicates few fish older than age 2.

Estimates of Fishing Mortality and Stock Size-

Extended Survivors Virtual Population Analysis- Estimates of current fishing mortality rate and stock size of Atlantic coast weakfish were made using Extended Survivors (ESA) tuning of VPA (Darby and Flatman 1994). In general, this procedure uses relative abundance data at age from various surveys to produce terminal estimates of population abundance at age to initiate a VPA run. Past assessments of weakfish have used conventional VPA (Vaughan et al. 1991) or separable VPA with auxiliary data (Gibson 1993). Conventional VPA cannot estimate terminal stock size and mortality rate and as such is not useful for real time management. The CAGEAN separable VPA model used auxiliary abundance and effort information, but made strong assumptions about selection pattern and catchability which can no longer be supported. CAGEAN assumes that the fishery selection pattern and catchability coefficient are constant, at least for several time blocks (Deriso et al. 1985). Since weakfish regulations will be tightened under Amendment 2 and 3, changes to the fishery selection pattern are expected. The assumption of constant catchability may be tenous for schooling pelagic species (MacCall 1976, Crecco and Savoy 1985). Iterated VPA methods such as ESA do not assume separability so that the selection pattern is emergent from the analysis. Also, the current CAGEAN model has software limitations on the number of indices and years which can be analyzed.

The ESA procedure begins by assuming starting values for the terminal stock size at age vector. A VPA run is conducted, and back calculated VPA populations at age are related to survey counterparts through a catchability parameter estimated by regression. New starting populations are estimated from the fitted relationships and the process repeated. Iterations continue until the terminal F at age vector converges to a solution, that is values don't change much. Various catchability relationships between indices and VPA populations can be specified so that the important possibility of catchability inversely related to stock size can be evaluated. A number of options which further constrain the model such as shrinkage to the mean, time series weighting, and downweighting of noisy indices are available. Extensive residual diagnostics are available to judge model fit. As noted by Darby and Flatman (1994), a coefficient of variation on the terminal F at age estimates is approximately the standard error of the weighted mean terminal stock sizes estimated from the tuning procedure. Individual estimates are combined with inverse variance weighting so that poorly estimated values have less weight. A bootstrap option to assess uncertainty is not currently available in the ESA software.

A total of 20 survey indices were used in the ESA runs. These included the NMFS/NEFC survey, recreational and commercial CPUE, four citation indices, the SEAMAP trawl survey, and 12 state agency indexes. Seven indices had multiple age structure available while 13 indexed a single age. A priori weighting was also used so that surveys with greater geographic coverage such as the NMFS/NEFC and SEAMAP were given greater weight (2X) than state surveys. The recreational and commercial indices also had double weighting. The final ESA configuration required catchability related to stock size for ages 0 to 4. This was evident in early diagnostics where key indices had slopes significantly less than 1.0 in regressions of log VPA populations on log index. Catchability was independent of age and constant with respect to time for ages 5 and 6. No time weighting was used. Prediction regression of survivors with a minimum of 5 data points without shrinkage to the mean was used. Although calibration regression with shrinkage is the recommended procedure (Rosenberg et al. 1992), it caused out of range errors and great variance in the predicted terminal populations. Shrinkage to the mean F for older ages was expanded to 5 years and 3 ages. A CV on the shrinkage term of 0.50 was specified. This allowed a moderate influence by past F's on the terminal estimate. Trial runs with less shrinkage had notable retrospective patterns of F underestimation. No sums of products correction factor (SOPCF) was used to adjust biomass estimates. This ESA run is referred to as the reference run in later diagnostic evaluations.

Spawning stock biomass (SSB) declined from 34463 MT in 1979 to only 3035 MT by 1991. It then increased to 9608 MT by 1994 (Figure 10). Under status quo F, SSB in 1995 will be about 8140 MT. Removal of shrimp bycatch loss from the CAA had little impact on the SSB estimates. Recruitment (with shrimp bycatch) rose from 109 million age 0 in 1979 to a peak of 161 million in 1986 (Figure 11). Recruitment declined to a low of 72.8 million in 1990 and was below average since. Recruitment in 1994 was estimated at 102.9 million. Based on partial 1995 YOY surveys, recruitment in 1995 will be about 115 million. Recruitment estimates made without shrimp bycatch in the CAA were considerably lower but followed a similar pattern. Fishing mortality rate on weakfish age 2 and older rose from F=0.42 in 1979 to a high of F=2.40 in 1990 (Figure 12). It then declined to F=1.54 in 1992. The 1994 estimate has risen somewhat to 1.88. Precision on the 1994 estimate was good with a CV of 18%. Inclusion of shrimp bycatch loss did not effect F on older fish but had a large effect on F for age 0 weakfish (Figure 13). Age 0 F averaged about 0.70 including shrimp bycatch losses but was generally less than 0.20 without discard losses. The 1994 F of 0.56 on age zero reflects the operation of fish exclusion devices in the North Carolina shrimp fishery which was assumed to produce a 25% reduction in weakfish catchability across the region. A summary of the ESA VPA results is found in Table 16.

<u>Stock and Recruitment</u>- The stock and recruitment data from the VPA covered years 1979 to 1994. To increase contrast in the data, additional estimates of stock-recruit data pairs were made back to 1975 by indirect methods. The period 1975-1978 were years of high stock size and good recruitment strength as indicated by the NMFS/NEFSC survey and commercial landings data. Significant regression relationships between the 1979-1994 VPA estimates and survey indices or lagged landings data were used to estimate recruitment and SSB from 1975 to 1978. For stock-recruit analyses and reference point estimation, recruitment from VPA runs without shrimp discard was used since it was more conservative.

Atlantic weakfish stock-recruit data are plotted in Figure 14. SSB has varied by an order of magnitude whereas recruitment has only varied by a factor of 3. There is clear evidence of strong compensation. Recruitment was stable over a range of SSB from 10000 to 35000 MT. Recruitment was reduced when SSB fell below 10000 MT although not greatly so. A Ricker curve was fit to the data by nonlinear regression. The alpha parameter, or slope at the origin, was estimated at 10.83 age 0 per kg SSB (SE=1.50). The compensatory parameter was estimated at 0.00006 per MT (SE=.00001). Recruit per spawner ratios have increased through time and appear to have reached a maximum

(Figure 15). It is clear that the ability to compensate for high F must have a physiological limit. The range in SSB values, proximity to the origin of recent observations, and a high degree of maturity at age 1 suggests that this stock is very close to that limit.

Diagnostic and Retrospective Analysis- Examination of the catchability residuals in the ESA reference run showed that a number of indices produced patterns across time of negatives values changing to positives. This was most evident in the older ages where catchability was constant rather than related to abundance (Figure 16). The pattern indicates that the fitted tuning relationships between VPA populations and survey indices overestimated catchability in early years and underestimated it in later years. Additional model flexibility beyond age 4 could not be specified and still achieve convergence. Alternate time series weights or more shrinkage were also ineffective in rectifying the pattern. Underestimated catchability could cause overestimated stock sizes and biased low F in terminal years.

A trend in the SOPCF term was also noticed. SOPCF tended to decrease over time from values greater than 1.0 to values less than 1.0. This indicates some inconsistency between aggregate landings in weight by year and the summation of crossproducts of catch at age and mean weight at age within a year. It was most noticeable in model runs without shrimp bycatch loss in the CAA. This is probably due to the evolution of the CAA methods over time which have mixed otolith and scale based aging and only recently incorporated north-south keys. These methodological changes are superimposed on stock biology which seems to have a north-south distribution gradient based on size or growth. Although the SOPCF correction terms were not applied to biomass estimates in the final run it is worth noting the effect. Trial runs incorporating the correction had greater declines in SSB levels from 1979 to 1991 and smaller increases from 1991 to 1994. This would be consistent with more extended age structure in early years if otolith aging and north-south keys were available.

Retrospective VPA was used to further examine the stability and reliability of terminal estimates. A tendency to underestimate fishing mortality in the final year has been reported for some VPA type assessments using ADAPT tuning in Canada (Sinclair et al. 1990) and in the USA (NEFSC 1994). Retrospective analysis involves repeated estimations of F in a given year with progressively longer data series. Estimates of F in the converged portion of the VPA are generally accepted as the best estimates. When an estimation from a terminal run for that year departs widely from the "best" estimate, the assessment is said to exhibit retrospective bias. Although there is no guarantee that the converged estimates are correct, it is recommended such biases be removed so that management advice is consistent from year to year (Darby and Flatman 1994). Retrospective VPA was run over the range of years 1987 to 1994. The same model configuration was used as described above for the reference run. Since retrospective VPA involves analysis of progressively shorter data sets, incomplete time series are a problem for the tuning algorithms which require a minimum of 5 data points. Therefore, only a subset of 13 indices with complete time series (1979-1994) were used. The retrospective F pattern for the ESA run is found in Figure 17. There was a tendency to underestimate F in the terminal year from 1988 to 1991. Use of a moderate level of shrinkage reduced the retrospective F bias in 1992 and 1993 suggesting that the 1994 value is unbiased as well. The SSB pattern was reversed with a tendency to overestimate SSB from 1988 to 1992. There was little change in the 1993 estimate when 1994 data was added suggesting that the bias was reduced in 1994. These patterns are consistent with diagnostics for the reference run which showed some serial correlation in residuals. Several possible causes of such patterns have been identified (Sinclair et al. 1990). They include; misspecification of M concurrent to a rise in fishing mortality, misspecification of terminal selection pattern, increasing catchability in the fishery, and underreporting of landings. To evaluate the effect of M, retrospective runs were made with constant M rates ranging from 0.10 to 0.30 as apposed to the age specific values which have been adopted by the ASMFC technical committee. There was no improvement in residual or retrospective pattern suggesting that the age specific M rates in concert with rising F were not responsible. To better estimate terminal selection pattern, separable VPA runs without auxiliary data were performed. Model sums of squares was lowest and residual pattern best with unit selection at age 4, full selection at age 7, and a terminal F of 2.0. This was somewhat at odds with the reference ESA run which estimated slightly lower terminal F, full selection at age 3, and a slight dome (1992-1994). These differences were to small and the sums of squares surface to flat to warrant more adjustments to the VPA. The reference ESA run used a tuning configuration with catchability related to abundance for as many ages as possible. To further evaluate the effect of catchability on retrospective bias, a second configuration known as "Hybrid Tuning" was used which allows catchability for key indices to rise as an exponential function of time rather than abundance (Darby and Flatman 1994). Four indices with complete age structure, NMFS/NEFC, MRFSS and commercial CPUE, and the DEDFW Delaware Bay trawl were specified to have serial trends in catchability. In these runs, retrospective bias in early years was reduced further but not completely eliminated. Serial residual pattern was also improved. Terminal F estimates were similar at 1.9. No further model structure in the form of more indices with time varying catchability could be introduced without triggering convergence problems. This run was not ultimately accepted since the phenomenon of exponential catchability with time was not as explainable as an inverse relationship to abundance. These analyses suggest that the retrospective bias in the reference ESA run is related to increasing catchability of weakfish in the fishery and some surveys. Independent analyses have suggested the same (Crecco 1995). Underreporting of catch could also be a problem along with the methodological changes noted in the SOPCF discussion above. Increasing catchability could occur if the weakfish stock is shrinking in spatial distribution with declining abundance. In that case, a unit of effort fished in the core range would remove a greater fraction of the stock at low abundance than at high abundance. This would help to explain why fishing mortality rate has not dropped as much as has fishing effort. An important implication is that the recent moderation of fishing rates and increase in SSB indicated by the reference ESA run could be overstated.

Biological Reference Points-

Life History Parameters- Life history parameters were updated by Vaughan (1995) using the combined 1982-1994 age-length key data set. Length at age and weight at age from von Bertalanffy growth curves and weight-length regressions are found in Table 17a. Natural mortality rates are age specific and estimated using the Boudreau and Dickie (1989) power function which relates vital rates to body mass. Use of natural mortality rates which are an inverse function of body mass have important implications to the assessment. High age 0 natural mortality rates minimize the consequence of discards in this age group. New research on maturation in weakfish indicates that maturation at age 1 is 90% as apposed to 50% used in prior assessments. Also, otolith aging has suggested a maximum age of 17 years so reference point models were carried out to a 15+ group instead of 12+.

Thompson-Bell Yield per Recruit Model- The NMFS/NEFSC version of the Thompson-Bell yield per recruit (YPR) and spawning biomass per recruit (SSB/R) model was used to estimate traditional fishery reference points such as F0.1, Fmax, and F30%. The weakfish FMP calls for a fishing rate which generates 20% of maximum spawning potential on a per recruit basis (F20%). Model runs were made using selection patterns (mean 1992-1994) from both VPA runs, with and without shrimp discard. Using the fishing pattern from the VPA run including shrimp bycatch, F0.1 and Fmax were estimated at 0.17 and 0.27 respectively. Fishing rates associated with 20% and 30% of maximum SSB/R were 0.35 and 0.24. YPR and SSB/R over a range of F rates are graphed in Figure 18. The current F=1.88 allows for only 2.7% of maximum SSB/R to exist. F0.1 and Fmax increased to 0.18 and 0.30 respectively when the selection pattern without shrimp discard was used. Fishing rates associated with 20% and 30% of maximum SSB/R were 0.40 and 0.25. A summary of reference points is found in Table 17b.

Shepherd Equilibrium Yield Model- Estimates of maximum sustainable yield (MSY), the fishing rate generating MSY (Fmsy), and unfished SSB level were made using the stock-recruit data and the GENMOD implementation of the Shepherd equilibrium yield approach (Hightower and Lenarz 1989). The fishing rate resulting in stock collapse (Fcoll) was also estimated. This approach differs from the traditional in that yield and SSB based reference points are not reduced to a per recruit basis but remain linked to the S-R curve. For the shrimp discard selection pattern, MSY was estimated at 16210 MT (includes discards) at an F of 0.70. The Fmsy reference point is considerable higher than the FMP F20% point and reflects the large stock-recruit slope and high compensatory reserve in the stock. It is however well below the current fishing mortality rate of F=1.88. Fcoll in the Shepherd model was 2.00. Equilibrium yield over a range of prevailing F is found as Figure 19. Unfished SSB was estimated at 68,500 MT. The 1994 estimate of SSB is only 14% of the unfished level and is outside of the range where recruitment was stable. Under a selection pattern without shrimp discard, Fmsy rose to 0.80 and MSY to 17540 MT. The collapse fishing rate was F=2.85.

Projections-

Short Term Projections- The VPA results, estimates of life history parameters, and the stock-recruit curve were used to make step ahead forecasts of catches and consequences to SSB under several fishing mortality rate levels. Forecasts were made through 1997 using the fishing pattern including shrimp bycatch loss (Table 18). If fishing mortality remains at the 1994 F=1.88, landings including shrimp discards are projected at 9347 MT in 1995 and 8885 MT in 1996 (1994 equals 8480 MT). SSB would decline from 9954 MT in 1994 to 6291 MT by 1997 (Figure 20). If F were reduced to the Fmsy=0.70 level, landings in 1995 would fall to 4820 MT and increase to 7996 in 1996. SSB would rise to 20988 MT by 1997. If F were reduced to the F20%=0.35 level, landings in 1995 would fall to 2705 MT and increase to 5476 in 1996. SSB would rise to 31370 MT by 1997.

Long Term Projections- Longer term rebuilding trials evaluating the likelihood of SSB recovery to former levels were performed using the GENMOD simulator. GENMOD is a generalized age-structured population model used to explore different harvest policies. All input is user specified, no estimations are done. Input consists of age specific data on weight, mortality, maturation, and partial recruitment along with the S-R model. Also required is information on the length of fishing season and the timing of spawning relative to fishing. In the deterministic form, the model estimates equilibrium yield, total biomass, spawning biomass, and recruitment for various levels of fishing rate. The likelihood of recovery from a low stock condition was evaluated using a stochastic version of the GENMOD simulator. Input data is as before with the addition of a log-normal error variance for the Ricker recruitment function. This was set equal to 0.37, the observed variance in weakfish recruitment data. The log-normal error variance acts as a random factor which modifies recruitment success. An initial, depressed stock condition was specified as the 1995 starting population age vector from the VPA run. The selection pattern employed included shrimp discards. Stock recovery probabilities were estimated by running 500 replications for 5 and 10 year stock projections and noting how many times SSB reached the recovery criteria. Recovery criteria was defined as attainment of 30% of unfished SSB (20000 MT) at the end of the projection. This level of SSB was selected based on the stock-recruit data which indicates that a moderate SSB level allows for occasional large year classes and is safely away from the ascending limb of the curve. Simulations were run for a range of fishing rates from 0 to 2.0 to simulate a range of conditions corresponding to continuation of high fishing rates and complete closure of the fishery. Simulations were run for the current fishing pattern as estimated by VPA. Recovery probabilities are graphed in Figure 21. The target SSB level can be reached with good certainty (P>0.75) in 5 years at an F=0.5 and in 10 years at F=0.6. Continued fishing at rates in excess of 1.0 allowed for no chance of SSB recovery.

The GENMOD model was also configured to output fishery yield statistics and population age structure under the same scenarios. Mean yield over 5 and 10 year projections was maximized at an F=0.6 (Figure 22). Fishing at F=0.4 resulted in mean yield dropping only about 6% from the maximum possible. Continued fishing at high F rates resulted in a loss of 30-60% of the maximum possible over the projection periods. Variation in yield was lowest at low F rates (Figure 23). Since larger weakfish are more common in the northern portion of the range, rebuilding of the age structure to include older fish will be necessary. Recently, MDDNR biologists have suggested using a relative stock index (RSD) to assess weakfish age-size structure as is commonly done in freshwater fisheries (Gablehouse 1984). This involves calculating the fraction of large, or quality fish in the exploitable stock. The age structure at the end of 5 and 10 year projections was examined for the different F rates. An RSD index for weakfish was defined as the ratio of age 6+ to 2+ weakfish. Age 2 was considered the minimum since younger fish will primarily be involved in discards. Age 6 was selected for the large category subset since the combined age-length data indicate a fish of about 25 inches which has largely disappeared from recent MRFSS length frequencies. RSD was calculated for the projection results and compared to RSD values calculated from the VPA results for the period when large weakfish were present. From 1979 to 1986, the RSD for weakfish from VPA ranged from 0.01 to 0.07 with a mean of 0.04 (Figure 24). After 1986, RSD dropped essentially to zero. The projection results indicate that RSD in weakfish cannot be restored to historic levels (0.04) unless F is dropped to 0.5 or less (Figure 25).

Stock Summary and Recommendations-

1. Total landings, effort, and catch per unit effort in the weakfish fishery have declined in the past decade. The decline in catch and CPUE is most notable in age 4 and older weakfish.

2. The primary fishery independent abundance indicator, the NMFS/NEFSC fall inshore trawl survey shows a strong decline in age 2+ weakfish with a more moderate decline in age 0 and 1 weakfish since 1975.

3. State juvenile abundance surveys are available from Massachusetts to South Carolina and show mixed recruitment results. Generally, surveys in New England show below average abundance in recent years while those from the mid and south Atlantic show average abundance. Because of the disparities in time series lengths, comparison of trends between state surveys is difficult.

4. VPA analyses indicate that fishing rates on weakfish rose to very high levels from 1979 to 1991. Although there has been some moderation in recent years, F remains well above any reasonable reference points. SSB fell to very low levels in 1991 but increased somewhat in 1994. Recruitment has been more stable than SSB but has been below average since 1989.

5. Several VPA diagnostics suggest underestimation of F and overestimation of SSB and recruitment.

6. Biological reference points under the current fishing pattern including shrimp discards are low. F0.1, Fmax, and F20 were estimated at 0.17, 0.27, and 0.35 respectively compared to the 1994 F estimate of 1.88. SSB/R at the 1994 F of 1.88 is only 2.7% of maximum per recruit spawning potential. Removal of shrimp discards from the selection pattern had little effect on conservative reference points such as F0.1 and F30 but increased more liberal reference points such as F20 and Fmsy by about 15%. Maximum sustainable yield from the stock (with discards) was 8% lower in the presence of shrimp discarding. The 1994 SSB estimate of 9608 MT is only 14% of the unfished maximum and

48% of the 20,000 MT needed to stabilize recruitment. Average stock RSD from 1979 to 1986 when large weakfish were more abundant was 0.04. That is, 4% of the stock age 2+ was age 6 or greater. RSD in 1994, following years of high fishing mortality, was essentially zero.

7. Short term projections indicate that continued fishing at high F rates will lead to declines in SSB whereas reductions in F to the F20 reference point would yield immediate increases in SSB. Longer term projections indicate that an SSB target of 20,000 MT can be reached with good certainty in 5 years if F is dropped to 0.50 or less. Mean yield to the fishery over 5 years is maximized at an F=0.60 indicating that the short term losses are rapidly made good by stock growth. Continued fishing at high rates resulted in loss to the fishery. The projections indicated that weakfish RSD could not be restored to former levels unless F was dropped to 0.50 or less. Mean yield to the fishery was reduced less than 10% of maximum at the lower F rates. Collectively, the projections indicate that the FMP reference point of F20=0.35 is a suitable rate to rebuild the weakfish stock throughout the range without great loss to the fishery in the short term. Rapid growth potential results in quick payoff of yields foregone.

8. Methods should be evaluated to correct the existing scale based age-length keys to be consistent with otolith based keys. Application of the EM algorithm approach of Hoenig and Heisey (1987) is suggested. Study should also be made of the north-south growth differences as it relates to age-length key application to fishery biological samples. Research in these areas may eliminate some of the diagnostic problems in the current VPA.

9. All survey length frequencies currently aged with a von Bertalanffy cohort splitting method should be re-aged using updated age-length keys.

10. There are more abundance indices available in the form of utilities monitoring in the vicinity of power plants. Icthyoplankton abundance monitoring may be valuable as additional indices of spawner abundance and geographic distribution. Further, the NMFS/NEFSC fall inshore trawl survey and the SEAMAP surveys should be examined on a finer geographic basis to estimate range contractions.

11. If possible, retrospective estimates of stock size and fishing rates should be made back to 1945 to better understand the reasons for fluctuations in the weakfish stock.

12. Because of the evidence of changing catchability in the weakfish fishery, other emerging assessment methods such as ICA (Patterson and Melvin 1995) should be investigated.

13. Estimates of discard losses of weakfish, particularly in the south Atlantic shrimp fishery, need to be improved. At least three comprehensive direct estimates based on sea sampling need to be made to validate the indirect methods used to date. Current sea sampling lacks coverage and sample intensity to make reliable direct estimates.

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ɩle 1- Atlantic Weakfish Catch at Age 1979-1994. Includes Recreational (A+B1+.20*B2), mercial Market Class, and Commercial Bait Landings (1000's fish).

	Age								
ear	0	1	2	3	4	5	6	7	Total
1979	1372.1	8024.7	7809.8	2513.8	1300.2	523.1	139.8	121.0	21804.5
1980	2501.0	9523.1	9241.2	5121.4	4012.4	2085.6	629.4	1086.8	34200.9
1981	2850.3	9546.3	6165.0	2934.1	1992.9	1137.6	290.1	301.3	25217.6
1982	5058.3	12556.3	3932.1	1547.1	669.4	374.6	294.9	297.5	24730.2
1983	4289.9	9137.7	7116.0	1783.1	397.5	236.7	181.9	243.8	23386.6
1984	6972.3	10813.9	7584.9	1136.7	291.2	133.1	91.9	101.7	27125.7
1985	7526.8	10295.1	8426.0	721.7	238.5	106.6	65.1	64.6	27444.4
1986	15006.6	17700.8	3815.2	1191.4	162.4	75.0	35.0	40.5	38026.9
1987	10614.3	13268.2	7892.7	2221.5	194.1	35.2	12.2	11.3	34249.5
1988	12454.7	10907.6	11722.5	3447.8	341.6	76.4	16.2	25.9	38992.7
1989	1721.7	4800.6	5293.1	3046.3	340.1	22.0	22.2	24.0	15270.0
1990	2809.2	8159.7	5657.3	852.6	103.7	25.1	7.2	7.5	17622.3
1991	6473.9	6416.2	4606.8	1369.7	98.8	10.1	0.4	0.1	18976.0
1992	3385.5	5696.0	4249.7	739.4	68.8	2.9	0.9	0.5	14143.7
1993	2499.3	5113.0	4716.2	697.2	106.8	8.0	1.1	0.3	13141.9
1994	700.9	3016.2	5030.9	2935.7	144.3	4.5	0.9	0.1	11833.5

ɩle 2- Estimates of Weakfish Discard in South Atlantic Shrimp Trawl Fishery. imates (1000's fish) are Based on Shrimp Fishery Effort, Relative Weakfish ndance, and the Ratio of Weakfish to Shrimp in Observer Data.

	Age	
'ear	0	1
1979	38019.7	4365.7
1980	45771.7	5255.8
1981	39700.2	4558.7
1982	50659.8	5715.1
1983	46113.4	5107.2
1984	35061.0	4319.5
1985	36770.9	4730.2
1986	46712.3	5177.3
1987	30443.5	3229.9
1988	43604.0	5232.2
1989	45517.1	5205.5
1990	24048.7	2773.7
1991	37009.3	4351.8
1992	25879.4	2803.5
1993	29399.4	3266.6
1994	33742.2	6405.5

ıle 3- Atlantic Weakfish Catch at Age 1979-1994. Includes Recreational (A+B1+.20*B2), mercial Market Class, Commercial Bait Landings (1000's fish), and Shrimp Bycatch.

				Age					
ear	0	1	2	3	4	5	6	7	Total
1979	39391.8	12390.4	7809.8	2513.8	1300.2	523.1	139.8	121.0	64189.9
1980	48272.7	14778.9	9241.2	5121.4	4012.4	2085.6	629.4	1086.8	85228.4
1981	42550.5	14105.0	6165.0	2934.1	1992.9	1137.6	290.1	301.3	69476.5
1982	55718.1	18271.4	3932.1	1547.1	669.4	374.6	294.9	297.5	81105.1
1983	50403.3	14244.9	7116.0	1783.1	397.5	236.7	181.9	243.8	74607.2
1984	42033.3	15133.4	7584.9	1136.7	291.2	133.1	91.9	101.7	66506.1
1985	44297.7	15025.3	8426.0	721.7	238.5	106.6	65.1	64.6	68945.5
1986	61718.9	22878.1	3815.2	1191.4	162.4	75.0	35.0	40.5	89916.6
1987	41057.8	16498.1	7892.7	2221.5	194.1	35.2	12.2	11.3	67922.9
1988	56058.7	16139.8	11722.5	3447.8	341.6	76.4	16.2	25.9	87828.9
1989	47238.8	10086.1	5293.1	3046.3	340.1	22.0	22.2	24.0	66072.6
1990	26857.9	10933.4	5657.3	852.6	103.7	25.1	7.2	7.5	44444.7
1991	43483.2	10768.0	4606.8	1369.7	98.8	10.1	0.4	0.1	60337.1
1992	29264.9	8499.5	4249.7	739.4	68.8	2.9	0.9	0.5	42826.5
1993	31898.7	8379.6	4716.2	697.2	106.8	8.0	1.1	0.3	45807.9
1994	34443.1	9421.7	5030.9	2935.7	144.3	4.5	0.9	0.1	51981.2

ıle 4- Atlantic Weakfish Mean Weight at Age (kgs) Used in the
ˌessment. Mean Weights were Derived from the Age-Length Keys and
ˌtandard Length-Weight Equation. Mean Values Used for Age 0 in
ˀ81, 1982, 1989, 1990, and 1994.

'ear	Age 0	1	2	3	4	5	6	7	Mean
1978	0.074	0.192	0.486	1.537	2.317	2.749	2.620	3.981	1.744
1979	0.055	0.221	0.473	1.048	1.840	2.579	3.005	3.786	1.626
1980	0.074	0.213	0.445	1.251	2.128	2.921	3.215	3.744	1.749
1981	0.067	0.239	0.436	1.075	2.162	2.480	3.359	3.822	1.705
1982	0.067	0.320	0.684	1.035	1.423	3.201	4.134	5.020	1.986
1983	0.163	0.295	0.635	1.091	3.170	3.670	4.012	4.613	2.206
1984	0.098	0.240	0.556	1.119	2.115	3.020	3.684	4.805	1.955
1985	0.032	0.256	0.741	1.677	3.405	3.678	3.875	4.768	2.304
1986	0.013	0.311	0.782	2.008	3.493	4.234	4.024	4.693	2.445
1987	0.073	0.239	0.541	1.140	2.073	2.951	3.561	4.589	1.896
1988	0.047	0.143	0.563	0.775	1.762	3.622	4.129	5.140	2.023
1989	0.067	0.250	0.471	1.099	1.863	2.930	4.536	4.917	2.017
1990	0.067	0.362	0.483	0.959	1.789	2.265	4.230	5.777	1.992
1991	0.100	0.150	0.381	0.634	1.321	1.802	2.350	4.805	1.443
1992	0.101	0.236	0.442	1.327	1.604	2.420	3.965	4.649	1.843
1993	0.075	0.173	0.541	0.745	1.258	2.547	2.413	4.805	1.570
1994	0.067	0.225	0.523	0.877	1.484	3.034	3.304	3.883	1.675
lean	0.073	0.239	0.540	1.141	2.071	2.947	3.554	4.576	

ıle 5- Atlantic Weakfish Landings at Age 1979-94. Includes Recreational (A+B1+.20*B2),
mercial Market Class, Commercial Bait Landings, and Shrimp Bycatch (MT). SOP Totals
ː From Sums of Products Calculation Using Tables 3 and 4. Reported Landings are Total
mercial plus Recreational plus Shrimp and B2 Discards.

'ear	Age 0	1	2	3	4	5	6	7	SOP Tot	Reported	Ratio
1979	2148.6	2742.8	3695.5	2633.8	2391.8	1349.1	420.0	458.2	15839.7	22886.2	1.44
1980	3554.6	3150.6	4116.5	6408.7	8537.3	6091.8	2023.2	4069.1	37951.9	40157.9	1.06
1981	2850.9	3372.7	2687.4	3152.8	4308.3	2821.8	974.5	1151.5	21319.8	23021.0	1.08
1982	3733.1	5846.9	2689.9	1602.0	952.4	1199.1	1219.0	1493.6	18735.9	17818.1	0.95
1983	8202.0	4202.2	4521.9	1945.2	1260.1	868.7	729.8	1124.7	22854.6	22259.5	0.97
1984	4132.6	3631.3	4218.2	1272.2	615.8	402.0	338.5	488.7	15099.4	16634.6	1.10
1985	1429.6	3845.1	6242.9	1210.5	812.0	392.1	252.2	308.0	14492.4	12370.2	0.85
1986	785.5	7123.4	2982.8	2392.0	567.2	317.6	140.8	190.1	14499.4	16418.6	1.13
1987	2979.1	3944.9	4270.5	2532.0	402.4	103.9	43.4	51.9	14328.1	13957.3	0.97
1988	[illegible]	2310.9	4596.6	2670.5	602.0	276.7	66.9	133.1	15306.7	14994.4	0.98
1989	3165.0	2516.9	2492.6	3348.2	633.7	64.5	100.7	118.0	12459.5	[illegible]	[illegible]
1990	1799.5	3955.9	2730.9	817.7	185.5	56.9	30.5	43.3	9620.2	7490.8	0.78
1991	4348.3	1610.3	1754.8	867.9	130.5	18.2	0.9	0.5	8731.4	9263.7	1.06
1992	2966.4	2005.1	1877.6	981.4	110.4	7.0	3.6	2.3	7953.7	7309.6	0.92
1993	2392.4	1447.4	2553.2	519.4	134.3	20.4	2.7	1.4	7071.2	6404.2	0.91
1994	2307.7	2115.6	2629.8	2575.4	214.2	13.7	3.0	0.4	9859.7	5800.5	0.59

ɔle 6- Recreational Catch per Unit Effort Index of Atlantic
ıst Weakfish from the MRFSS Survey. Catch in 1000's Includes all
:ch Types. Effort in 1000's of Directed Weakfish Trips.

'ear	A+B1+B2 Catch	MRFSS Dir trip	All CPUE	A+B1 Catch	B2 Catch	Frac B2	A+B1+.20B2 Catch	Catch Wt MT	Mean Wgt Kg	Weight CPUE	B2 Mean Wgt Kg	Rec B2 Kill MT
1979	5518.8	1751.5	3.2	5287.0	231.8	0.04	5333.4	5898.00	1.12	3.37	0.14	6.4
1980	15059.2	1558.1	9.7	13538.0	1521.2	0.10	13842.2	19355.00	1.43	12.42	0.14	43.6
1981	9800.0	793.2	12.4	9295.0	505.0	0.05	9396.0	7313.00	0.79	9.22	0.15	15.5
1982	2200.0	742.5	3.0	2111.0	89.0	0.04	2128.8	3760.00	1.78	5.06	0.19	3.4
1983	6200.0	1412.3	4.4	6165.0	35.0	0.01	6172.0	5323.00	0.86	3.77	0.23	1.6
1984	4500.0	1417.2	3.2	4092.0	408.0	0.09	4173.6	3182.00	0.78	2.25	0.17	13.8
1985	4700.0	1191.9	3.9	3057.0	1643.0	0.35	3385.6	2283.00	0.75	1.92	0.14	47.3
1986	12200.0	1297.1	9.4	9927.0	2273.0	0.19	10381.6	4601.00	0.46	3.55	0.16	73.7
1987	7700.0	1455.2	5.3	5828.0	1872.0	0.24	6202.4	3063.00	0.53	2.10	0.16	58.3
1988	8500.0	1020.0	8.3	5218.0	3282.0	0.39	5874.4	2873.00	0.55	2.82	0.10	62.5
1989	2000.0	850.0	2.4	1495.0	505.0	0.25	1596.0	987.00	0.66	1.16	0.16	16.0
1990	2438.3	700.0	3.5	1232.0	1206.3	0.49	1473.3	611.00	0.50	0.87	0.21	51.7
1991	3256.1	850.0	3.8	1813.0	1443.1	0.44	2101.6	967.00	0.53	1.14	0.12	36.0
1992	2230.8	475.0	4.7	960.0	1270.8	0.57	1214.2	635.00	0.66	1.34	0.17	42.9
1993	2349.9	450.0	5.2	945.0	1404.9	0.60	1226.0	445.00	0.47	0.99	0.12	34.8
1994	4191.2	607.5	6.9	2150.0	1831.0	0.44	2516.2	810.00	0.38	1.33	0.15	53.4

: B2 mean wt is average of age 0 and 1 weights

ɔle 7- Proportion at Age and Catch per Unit Effort at Age in the
:antic Coast Weakfish Recreational Fishery. Ages Determined from
:SS A Type Length Frequencies. A Pooled Age-Length Key was Used
· 1979-1981 and Annual Keys from 1982-1994.

MRFSS PAA

Age	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
0	0.005	0.011	0.019	0.019	0.012	0.168	0.067	0.155	0.075	0.037	0.037	0.018	0.017	0.085	0.027	0.015
1	0.244	0.170	0.223	0.143	0.147	0.229	0.213	0.696	0.428	0.230	0.265	0.336	0.258	0.320	0.110	0.136
2	0.382	0.295	0.262	0.186	0.590	0.463	0.516	0.102	0.290	0.497	0.334	0.518	0.460	0.306	0.669	0.370
3	0.196	0.216	0.230	0.225	0.206	0.122	0.146	0.040	0.186	0.216	0.308	0.104	0.240	0.264	0.163	0.462
4	0.121	0.168	0.154	0.158	0.025	0.010	0.031	0.003	0.017	0.018	0.047	0.018	0.022	0.023	0.029	0.015
5	0.037	0.076	0.075	0.102	0.010	0.003	0.013	0.002	0.002	0.002	0.003	0.003	0.002	0.001	0.001	0.001
6	0.007	0.021	0.017	0.079	0.006	0.002	0.006	0.001	0.001	0.001	0.002	0.001	0.000	0.001	0.000	0.000
7	0.008	0.042	0.021	0.087	0.006	0.003	0.009	0.002	0.001	0.001	0.003	0.001	0.000	0.000	0.000	0.000

Fish per 1000 Trips

Age	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
0	0.017	0.105	0.237	0.055	[illegible]	[illegible]	[illegible]	1.458	0.396	0.305	0.087	0.063	0.064	0.401	0.140	0.105
1	0.768	1.644	2.757	0.425	0.644	0.726	0.839	6.544	2.266	1.913	0.624	1.172	0.990	[illegible]	[illegible]	[illegible]
2	1.203	2.856	3.236	0.551	2.590	1.470	2.033	0.961	1.533	4.139	0.786	1.804	1.762	1.436	3.496	2.555
3	0.616	2.092	2.839	0.667	0.904	0.389	0.575	0.375	0.984	1.797	0.726	0.363	0.921	1.239	0.849	3.190
4	0.381	1.627	1.897	0.469	0.108	0.033	0.123	0.025	0.091	0.149	0.111	0.064	0.084	0.109	0.152	0.107
5	0.115	0.737	0.929	0.302	0.042	0.010	0.052	0.017	0.013	0.020	0.008	0.011	0.009	0.007	0.006	0.005
6	0.023	0.200	0.206	0.235	0.027	0.006	0.025	0.011	0.004	0.005	0.006	0.004	0.001	0.003	0.001	0.001
7	0.027	0.403	0.254	0.259	0.024	0.009	0.035	0.015	0.004	0.005	0.006	0.003	0.000	0.001	0.000	0.000

le 8- Estimates of Catch per Unit Effort in the North Carolina
nercial Weakfish Fishery from the NCDMF Sampling Program

/1 ear	NCDMF kg/trip	Mean wt	No./trip
1979	8903.0	0.46	19239.4
1980	7464.0	0.50	14932.6
1981	9178.0	0.43	21561.3
1982	8112.6	0.58	13943.8
1983	6423.0	0.48	13248.9
1984	6654.3	0.32	21001.8
1985	5349.0	0.38	14068.9
1986	6407.7	0.44	14700.7
1987	8532.4	0.42	20270.3
1988	4522.4	0.56	8138.0
1989	5287.3	0.60	8872.8
1990	4659.0	0.43	10868.4
1991	6438.0	0.26	25173.0
1992	8003.2	0.28	28853.2
1993	3287.1	0.28	11752.0
1994	3863.6	0.41	9374.4

stimates for 1979-1981 made by lagged regression with NMFS/NEFSC index

le 9- Commercial Catch per Unit Effort at Age for Atlantic Coast Weakfish
ng Estimates of North Carolina CPUE and Commercial Proportions at Age.

	1000's Fish per Trip								
ear	0	1	2	3	4	5	6	7	Total
1979	1572.0	7861.0	6742.6	1713.3	763.1	382.1	116.9	88.5	19239.5
1980	1741.4	5288.5	3771.1	1539.6	1219.2	751.2	250.9	370.8	14932.7
1981	3653.8	10178.2	5044.4	1037.3	737.6	582.5	181.0	146.4	21561.2
1982	330.2	8778.1	3110.4	993.6	327.4	159.9	127.8	116.3	13943.8
1983	2457.0	6179.6	3332.2	553.2	234.5	165.2	134.2	193.0	13248.9
1984	4653.6	8995.7	6049.2	727.7	264.6	126.8	88.9	95.5	21001.8
1985	2691.8	5957.4	4939.1	251.6	112.7	52.0	34.6	29.8	14068.9
1986	5770.2	6390.2	1850.8	531.1	88.5	37.4	15.6	16.9	14700.7
1987	4303.6	8711.4	5894.6	1220.4	102.5	22.1	8.2	7.4	20270.3
1988	1352.4	2837.5	3052.5	777.0	84.2	22.2	4.5	7.8	8138.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.6	13.8	14.9	8872.8
1990	515.4	5318.5	4295.2	638.6	71.0	18.9	5.1	5.7	10868.4
1991	6643.9	10069.0	6674.9	1671.7	103.4	9.9	0.2	0.0	25173.0
1992	6087.3	12054.4	9427.6	1166.2	112.7	3.4	1.0	0.5	28853.2
1993	1917.6	4865.7	4316.9	562.9	79.9	7.7	0.9	0.2	11752.0
1994	392.9	2635.3	4288.7	1939.6	114.4	2.9	0.4	0.1	9374.4

Table 10- Weakfish Sportfishery Citation Data for Delaware, Maryland, Virginia, and North Carolina

Number Citations Issued

Year	/1 DEDFW	/2 NCDMF	/3 VAMRC	/4 MDDNR	Total
1973			9	275	284
1974		3	15	459	477
1975		197	46	470	713
1976	315	182	75	610	1182
1977	329	324	167	927	1747
1978	561	128	279	1275	2243
1979	533	67	416	928	1944
1980	1299	104	636	1536	3575
1981	539	64	249	1180	2032
1982	316	28	360	488	1192
1983	642	2	202	79	925
1984	568	5	168	103	844
1985	1039	1	85	86	1211
1986	1842	19	168	234	2263
1987	1349	19	55	NA	1423
1988	959	6	24	13	1002
1989	981	1	5	NA	987
1990	11	1	4	1	17
1991	3	1	0	0	4
1992	15	2	3	0	20
1993	3	10	1	0	14
1994	4	2	0	0	6
1995	1	NA	NA	0	NA

/1
Award minimum changed from 10 to 11 pounds in 1987

/2
Award minimum of 6 pounds

/3
Award minimum of 12 pounds

/4
Award minimum of 10 pounds

le 14- Catch per Tow at Age of Atlantic Weakfish in the SEAMAP South antic Trawl Survey. Ages Determined Using Annual Age-Length Keys.

	Age				
ear	0	1	2	3	Total
1989	0.17	32.60	2.62	0.01	35.39
1990	0.01	16.58	1.48	0.00	18.07
1991	0.07	14.57	1.44	0.01	16.09
1992	0.01	19.32	2.01	0.00	21.34
1993	0.08	29.88	1.86	0.00	31.82
1994	0.03	29.80	1.97	0.00	31.80

le 15- Catch per Tow at Age of Atlantic Weakfish in the NJDEP wl Survey. Ages Determined Using the von Bertalanffy Growth el and the Cohort Splitting Method.

	Age								
ear	0	1	2	3	4	5	6	7	Total
1988	18.57	0.16	0.10	0.08	0.00	0.00	0.00	0.00	18.91
1989	44.85	1.02	0.00	0.25	0.00	0.25	0.00	0.00	46.38
1990	8.50	4.44	0.72	0.10	0.05	0.01	0.00	0.00	13.82
1991	51.07	6.02	0.45	0.18	0.12	0.01	0.01	0.00	57.84
1992	6.33	6.89	1.40	0.08	0.02	0.01	0.00	0.00	14.72
1993	62.57	12.22	0.90	0.23	0.01	0.01	0.00	0.00	75.93
1994	42.00	33.54	0.55	0.08	0.01	0.00	0.00	0.00	76.19

Table 16- Summary of Extended Survivors VPA Analysis for the Atlantic Coast Weakfish Population, 1979-1995.

Year	Recruits 1000's Age1	Biomass MT	SSB MT	F Rate Age 0-7+	F Rate Age 2-7+
1979	109039	54383	34463	0.45	0.42
1980	112291	67498	30315	1.08	1.20
1981	119681	40217	16278	1.03	1.15
1982	127450	38469	16095	0.89	0.91
1983	127321	47628	13373	1.03	1.15
1984	107013	30806	9742	1.05	1.19
1985	143066	26877	10094	1.09	1.25
1986	160914	30755	15012	1.09	1.24
1987	105512	32816	13572	0.98	1.13
1988	115449	25552	8515	1.56	1.79
1989	100343	22150	6148	1.74	2.12
1990	72831	19414	6727	1.92	2.40
1991	100638	17405	3035	1.92	2.36
1992	86072	19461	5490	1.25	1.54
1993	95187	19040	7006	1.45	1.82
1994	102856	24365	9608	1.49	1.88
1995	114954		8143		
Mean	111801	32302	12566	1.25	1.47

Recruitment in 1995 estimated with partial survey data,
SSB in 1995 projected from Jan 1 1995 stock size and status quo F.

Table 18b – Shows decline

Table 17a- Life History Parameters for Atlantic Weakfish from the 1982-1994 Age-Length Data Base which Were Used to Estimate Fishery Reference Points and SSB in the VPA.

Age	Length cm /1	Weight Kg	% Mature	M Rate
0	17.0	0.03	0.00	0.67
1	27.7	0.11	0.90	0.43
2	36.6	0.25	1.00	0.33
3	45.0	0.45	1.00	0.27
4	55.9	0.84	1.00	0.22
5	68.3	1.41	1.00	0.19
6	75.7	1.83	1.00	0.17
7	79.2	2.09	1.00	0.16
8	81.0	2.24	1.00	0.16
9	81.5	2.27	1.00	0.16
10	82.3	2.33	1.00	0.16
11	84.6	2.54	1.00	0.15
12	85.6	2.63	1.00	0.15
13	86.9	2.80	1.00	0.15
14	87.9	2.88	1.00	0.15
15	88.6	2.96	1.00	0.15

/1 Length is mean observed at age not backcalculated

.11 kg · 10968 1000 / .454

Table 17b- Biological Reference Points for Atlantic Coast Weakfish Estimates are from the Thompson-Bell Yield per Recruit and Shepherd Equilibrium Yield Models Using the Mean 1992-1994 Fishing Pattern Incorporating Estimates of Shrimp Discards.

Reference Point	F Rate
F0.1	0.17
F30%	0.24
Fmax	0.27
F20%	0.35
Fmsy	0.70 /1
Fcoll	2.00
SSBmax	0.00 /2

/1 MSY equals 16210 MT including discards

/2 Unfished SSB equals 68,500 MT ≈ 3.6×10^8 lbs

le 18a- Quota Projections for the Atlantic Coast Weakfish
:k for the 1995 and 1996 Fishing Years. Quota is the Total
logical Catch (TBC) for F=0.70 and Includes Discards.

rate	0.18
ll F	0.92
ac Z	0.50
an 2+F	0.70

	1995	1996	1997
TBC MT	4819.8	7996.2	
TBC Kgs	4819772	7996192	
TBC lbs	10603499	17591623	
SSB MT	11296.2	16564.5	20988.4

Age	Jan 95 1000's Fish	1995 SSB MT	Mean wgt Kgs	Catch Wgt Kgs	PR	Full F	Effec F	M	exp rate	1995 TBC MT	% mat	Jan 96 1000's Fish	1996 SSB MT	1996 TBC MT	Jan 97 1000's Fish	1997 SSB MT
0	62070.9	0.00	0.01	0.01	0.207	0.92	0.19	0.50	0.14	85.37	0.000	66351.9	0.0	91.3	64473.0	0.0
1	27252.0	3306.56	0.18	0.18	0.161	0.92	0.15	0.43	0.11	551.80	0.900	31119.6	3775.82	630.1	33265.9	4036.24
2	11082.0	4927.08	0.63	0.63	0.399	0.92	0.37	0.33	0.26	1845.47	1.000	15287.1	6796.66	2545.7	17456.6	7761.23
3	3377.0	2653.89	1.28	1.28	0.767	0.92	0.71	0.27	0.45	1947.86	1.000	5519.3	4337.43	3183.5	7613.5	5983.27
4	337.0	383.07	2.01	2.01	1.000	0.92	0.92	0.22	0.55	371.82	1.000	1273.0	1446.99	1404.5	2080.5	2364.90
5	13.0	23.42	2.75	2.75	0.713	0.92	0.66	0.19	0.44	15.82	1.000	107.8	194.16	131.2	407.1	733.42
6	1.0	2.22	3.45	3.45	0.772	0.92	0.71	0.17	0.47	1.63	1.000	5.6	12.39	9.1	46.3	102.76
7	0.0	0.00	4.07	4.07	0.772	0.92	0.71	0.16	0.47	0.00	1.000	0.4	1.09	0.8	2.3	6.09
8	0.0	0.00	4.61	4.61	0.772	0.92	0.71	0.16	0.47	0.00	1.000	0.0	0.00	0.0	0.2	0.52
9	0.0	0.00	5.07	5.07	0.772	0.92	0.71	0.16	0.47	0.00	1.000	0.0	0.00	0.0	0.0	0.00
10	0.0	0.00	5.46	5.46	0.772	0.92	0.71	0.16	0.47	0.00	1.000	0.0	0.00	0.0	0.0	0.00
11	0.0	0.00	5.77	5.77	0.772	0.92	0.71	0.15	0.48	0.00	1.000	0.0	0.00	0.0	0.0	0.00
12	0.0	0.00	6.03	6.03	0.772	0.92	0.71	0.15	0.48	0.00	1.000	0.0	0.00	0.0	0.0	0.00
13	0.0	0.00	6.23	6.23	0.772	0.92	0.71	0.15	0.48	0.00	1.000	0.0	0.00	0.0	0.0	0.00
14	0.0	0.00	6.33	6.33	0.772	0.92	0.71	0.15	0.48	0.00	1.000	0.0	0.00	0.0	0.0	0.00
15	0.0	0.00	6.40	6.40	0.772	0.92	0.71	0.15	0.48	0.00	1.00	0.00	0.00	0.00	0.00	0.00
ums MT	104133	11296					0.70	0.18		4820		119665	16565	7996	125345	20988

es: Jan 1 1995 stock size and PR pattern from ESA run
Age 1 in 1995-1997 from estimated Ricker Curve

le 18b- Quota Projections for the Atlantic Coast Weakfish
ck for the 1995 and 1996 Fishing Years. Quota is the Total
logical Catch (TBC) for F=1.89 and Includes Discards.

				1995	1996	1997
rate	0.18		TBC MT	9346.9	8885.3	
ll F	2.50		TBC Kgs	9346885	8885264	
ac Z	0.50		TBC lbs	20563147	19547582	
			SSB MT	8142.9	7413.7	6291.0
an 2+F	1.89					

Age	Jan 95 1000's Fish	1995 SSB MT	Mean wgt Kgs	Catch Wgt Kgs	PR	Full F	Effec F	M	exp rate	1995 TBC MT	% mat	Jan 96 1000's Fish	1996 SSB MT	1996 TBC MT	Jan 97 1000's Fish	1997 SSB MT
0	54063.2	0.00	0.01	0.01	0.207	2.50	0.52	0.50	0.32	175.57	0.000	51423.2	0.0	167.0	46676.3	0.0
1	27252.0	2911.64	0.18	0.18	0.161	2.50	0.40	0.43	0.27	1340.08	0.900	19543.7	2088.08	961.0	18589.4	1986.11
2	11082.0	3594.97	0.63	0.63	0.399	2.50	1.00	0.33	0.55	3855.16	1.000	11853.5	3845.26	4123.6	8500.7	2757.62
3	3377.0	1447.88	1.28	1.28	0.767	2.50	1.92	0.27	0.78	3363.91	1.000	2938.3	1259.77	2926.9	3142.8	1347.48
4	337.0	173.85	2.01	2.01	1.000	2.50	2.50	0.22	0.86	581.57	1.000	378.9	195.46	653.9	329.7	170.07
5	13.0	13.33	2.75	2.75	0.713	2.50	1.78	0.19	0.78	27.81	1.000	22.2	22.77	47.5	25.0	25.60
6	1.0	1.21	3.45	3.45	0.772	2.50	1.93	0.17	0.81	2.78	1.000	1.8	2.18	5.0	3.1	3.73
7	0.0	0.00	4.07	4.07	0.772	2.50	1.93	0.16	0.81	0.00	1.000	0.1	0.18	0.4	0.2	0.32
8	0.0	0.00	4.61	4.61	0.772	2.50	1.93	0.16	0.81	0.00	1.000	0.0	0.00	0.0	0.0	0.02
9	0.0	0.00	5.07	5.07	0.772	2.50	1.93	0.16	0.81	0.00	1.000	0.0	0.00	0.0	0.0	0.00
10	0.0	0.00	5.46	5.46	0.772	2.50	1.93	0.16	0.81	0.00	1.000	0.0	0.00	0.0	0.0	0.00
11	0.0	0.00	5.77	5.77	0.772	2.50	1.93	0.15	0.81	0.00	1.000	0.0	0.00	0.0	0.0	0.00
12	0.0	0.00	6.03	6.03	0.772	2.50	1.93	0.15	0.81	0.00	1.000	0.0	0.00	0.0	0.0	0.00
13	0.0	0.00	6.23	6.23	0.772	2.50	1.93	0.15	0.81	0.00	1.000	0.0	0.00	0.0	0.0	0.00
14	0.0	0.00	6.33	6.33	0.772	2.50	1.93	0.15	0.81	0.00	1.000	0.0	0.00	0.0	0.0	0.00
15	0.0	0.00	6.40	6.40	0.772	2.50	1.93	0.15	0.81	0.00	1.00	0.00	0.00	0.00	0.00	0.00
ums MT	96125	8143					1.89	0.18		9347		86162	7414	8885	77267	6291

es: Jan 1 1995 stock size and PR pattern from ESA run
Age 1 in 1995-1997 from estimated Ricker Curve

.e 18c- Quota Projections for the Atlantic Coast Weakfish
:k for the 1995 and 1996 Fishing Years. Quota is the Total
.ogical Catch (TBC) for F=0.35 and Includes Discards.

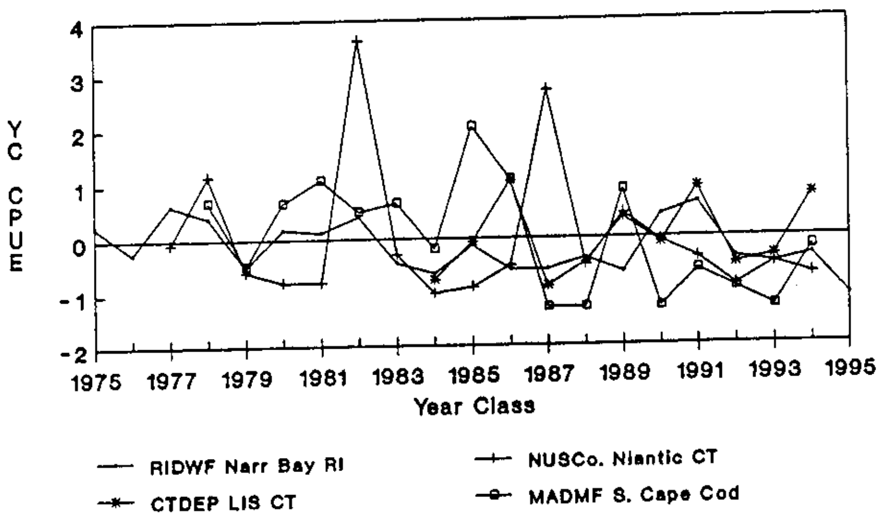
'ate	0.18					
ll F	0.46					
ac Z	0.50					
an 2+F	0.35					

	1995	1996	1997
TBC MT	2704.7	5476.1	
TBC Kgs	2704697	5476094	
TBC lbs	5950333	12047406	
SSB MT	12510.2	21653.3	31370.3

Age	Jan 95 1000's Fish	1995 SSB MT	Mean wgt Kgs	Catch Wgt Kgs	PR	Full F	Effec F	M	exp rate	1995 TBC MT	% mat	Jan 96 1000's Fish	1996 SSB MT	1996 TBC MT	Jan 97 1000's Fish	1997 SSB MT
0	63912.4	0.00	0.01	0.01	0.207	0.46	0.10	0.50	0.07	45.86	0.000	63914.2	0.0	45.9	51687.9	0.0
1	27252.0	3431.30	0.18	0.18	0.161	0.46	0.07	0.43	0.06	285.36	0.900	35243.9	4437.56	369.0	35244.9	4437.68
2	11082.0	5400.64	0.63	0.63	0.399	0.46	0.18	0.33	0.14	1002.16	1.000	16462.2	8022.59	1488.7	21289.9	10375.30
3	3377.0	3165.90	1.28	1.28	0.767	0.46	0.35	0.27	0.26	1135.13	1.000	6631.2	6216.66	2229.0	9850.5	9234.78
4	337.0	482.13	2.01	2.01	1.000	0.46	0.46	0.22	0.33	226.08	1.000	1811.5	2591.67	1215.3	3557.2	5089.08
5	13.0	27.59	2.75	2.75	0.713	0.46	0.33	0.19	0.26	9.15	1.000	170.7	362.38	120.2	917.7	1947.95
6	1.0	2.65	3.45	3.45	0.772	0.46	0.36	0.17	0.28	0.95	1.000	7.7	20.55	7.4	101.7	269.86
7	0.0	0.00	4.07	4.07	0.772	0.46	0.36	0.16	0.28	0.00	1.000	0.6	1.86	0.7	4.6	14.41
8	0.0	0.00	4.61	4.61	0.772	0.46	0.36	0.16	0.28	0.00	1.000	0.0	0.00	0.0	0.4	1.26
9	0.0	0.00	5.07	5.07	0.772	0.46	0.36	0.16	0.28	0.00	1.000	0.0	0.00	0.0	0.0	0.00
10	0.0	0.00	5.46	5.46	0.772	0.46	0.36	0.16	0.28	0.00	1.000	0.0	0.00	0.0	0.0	0.00
11	0.0	0.00	5.77	5.77	0.772	0.46	0.36	0.15	0.28	0.00	1.000	0.0	0.00	0.0	0.0	0.00
12	0.0	0.00	6.03	6.03	0.772	0.46	0.36	0.15	0.28	0.00	1.000	0.0	0.00	0.0	0.0	0.00
13	0.0	0.00	6.23	6.23	0.772	0.46	0.36	0.15	0.28	0.00	1.000	0.0	0.00	0.0	0.0	0.00
14	0.0	0.00	6.33	6.33	0.772	0.46	0.36	0.15	0.28	0.00	1.000	0.0	0.00	0.0	0.0	0.00
15	0.0	0.00	6.40	6.40	0.772	0.46	0.36	0.15	0.28	0.00	1.00	0.00	0.00	0.00	0.00	0.00
ums MT	105974	12510					0.35	0.18		2705		124242	21653	5476	122655	31370

es: Jan 1 1995 stock size and PR pattern from ESA run
Age 1 in 1995-1997 from estimated Ricker Curve

Fig.7- Weakfish Recruitment in New England from State Surveys



Indices are Z-scores

Fig.8- Weakfish Recruitment in the Mid-Atlantic Region from State Surveys

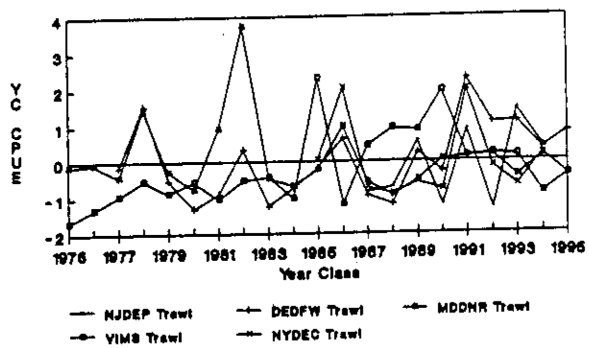


Fig.9- Weakfish Recruitment in the S. Atlantic Region from State Surveys

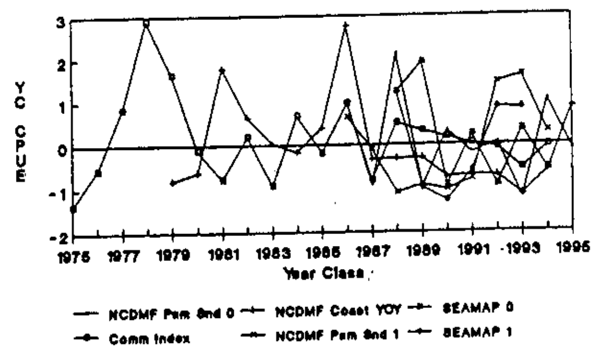
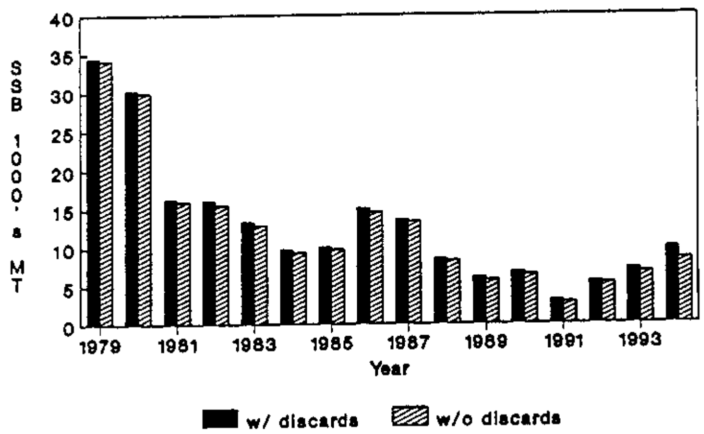
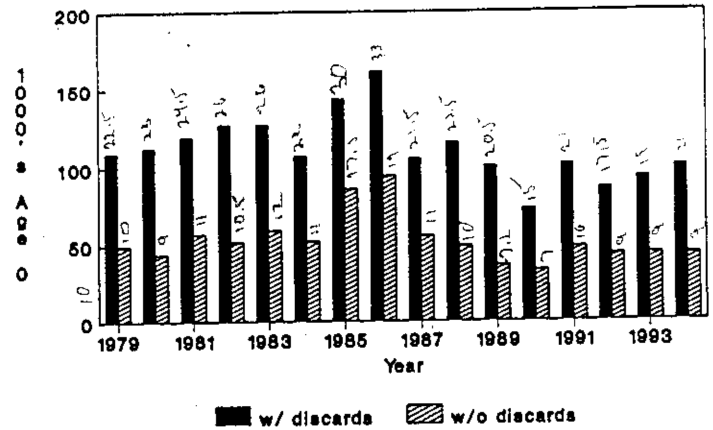


Fig.10-Atlantic Coast Weakfish Spawning Stock Biomass 1979-1994 from VPA



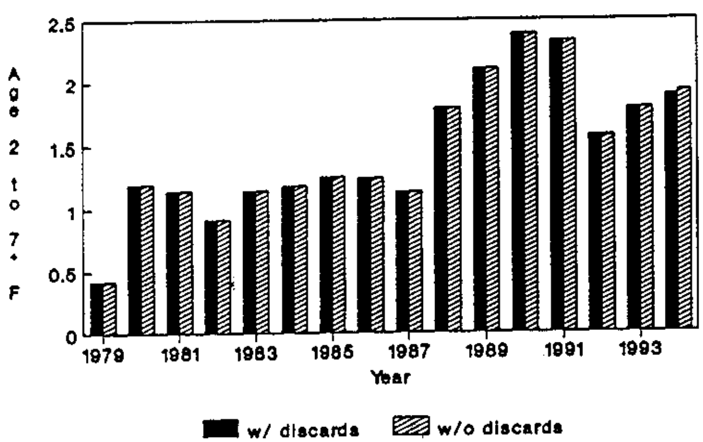
Extended Survivors VPA

Fig.11-Atlantic Coast Weakfish Recruitment 1979-1994 from VPA



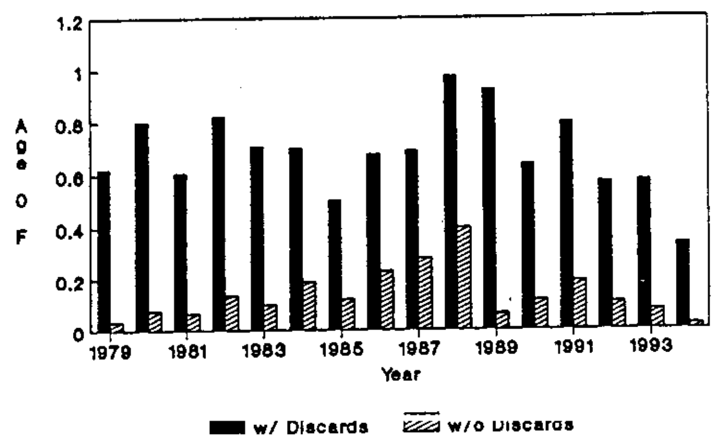
Extended Survivors VPA

Fig.12-Atlantic Coast Weakfish Fishing Mortality 1979-1994 from VPA



Extended Survivors VPA

Fig.13-Atlantic Coast Weakfish Age 0 Fishing Mortality 1979-1994 from VPA



Extended Survivors VPA

Fig.14-Atlantic Coast Weakfish Stock and Recruitment Data 1975-1994

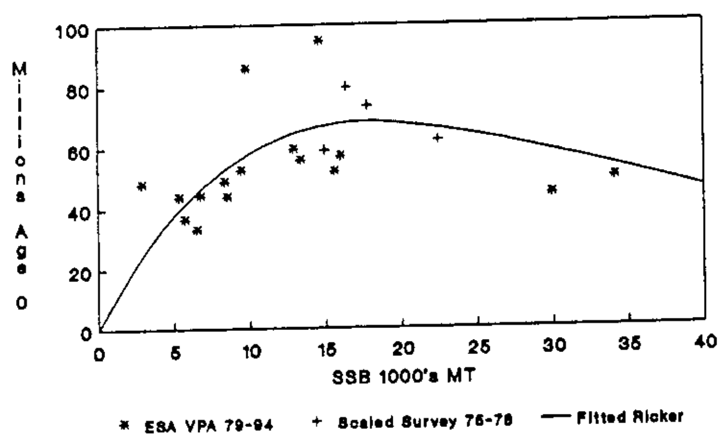


Fig.15-Weakfish Recruit per Spawner Ratios from S-R Data, 1975-1994

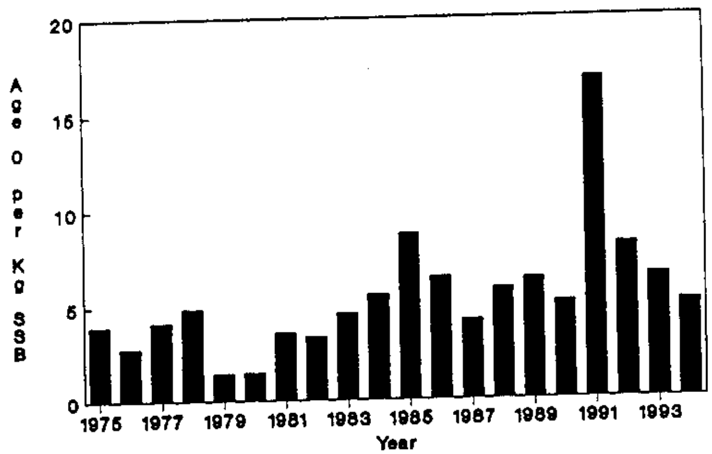


Fig.16- Catchability Residuals at Age for the NMFS/NEFC Trawl Survey Used in Tuning the Weakfish ESA VPA

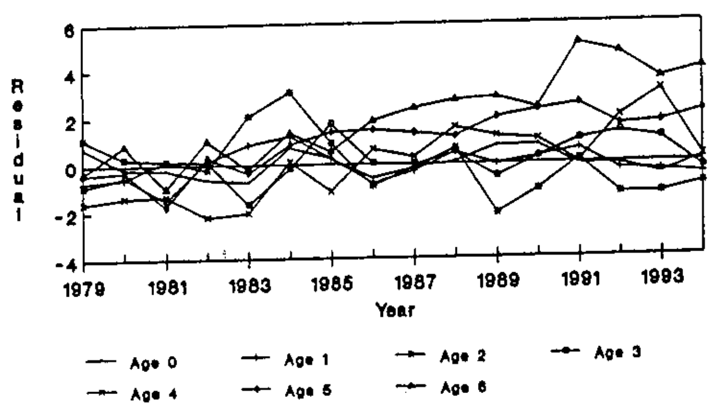


Fig.17- Retrospective Fishing Rates for Atlantic Weakfish from ESA VPA

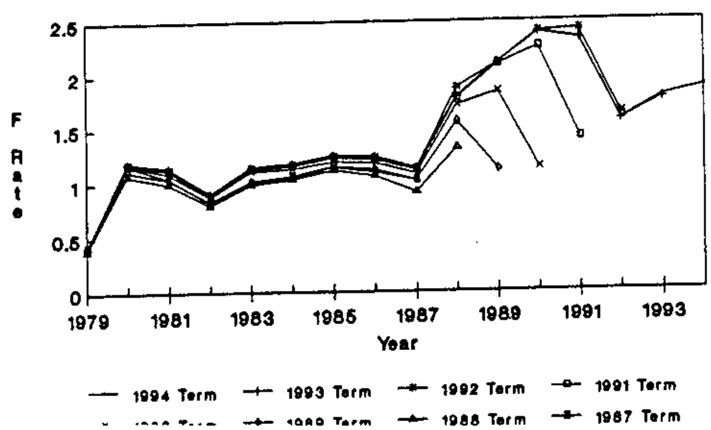
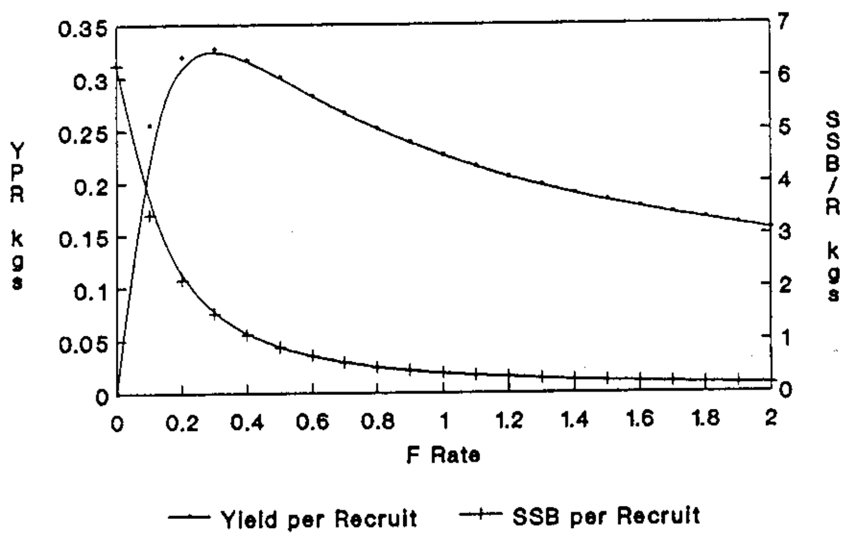
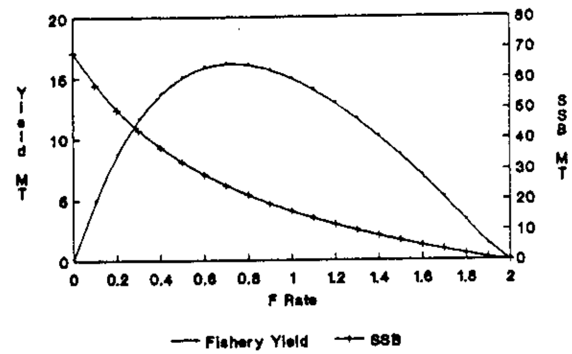


Fig.18- Atlantic Weakfish Yield per Recruit and SSB/R vs. Fishing Rate



Thompson-Bell w/shrimp bycatch

Fig.19- Atlantic Weakfish Fishery Yield and SSB vs. Fishing Rate



Shepherd Model w/shrimp bycatch

Fig.20- Trends in Atlantic Weakfish SSB and Recruitment with Projections of SSB

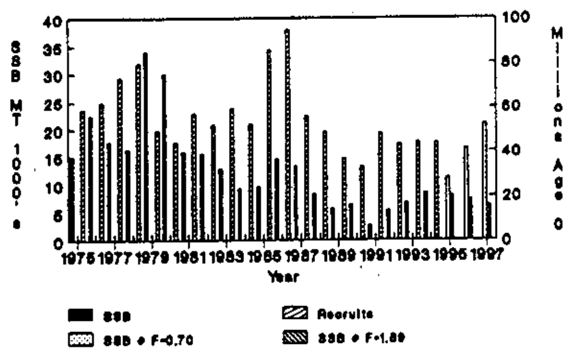


Fig.21- Probability of Reaching 30% of Unfished SSB at Various Levels of F

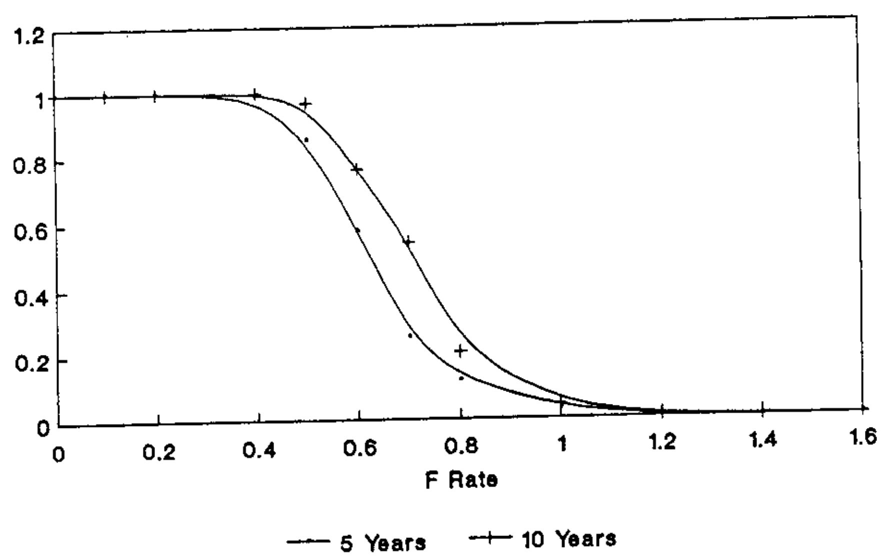


Fig.22- Mean Fishery Yield at Various Levels of F

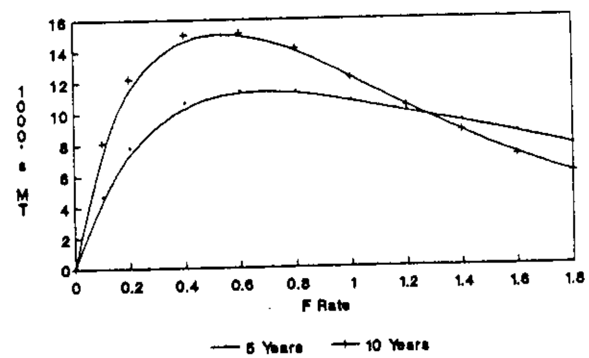


Fig.23- Variation in Fishery Yield at Various Levels of F

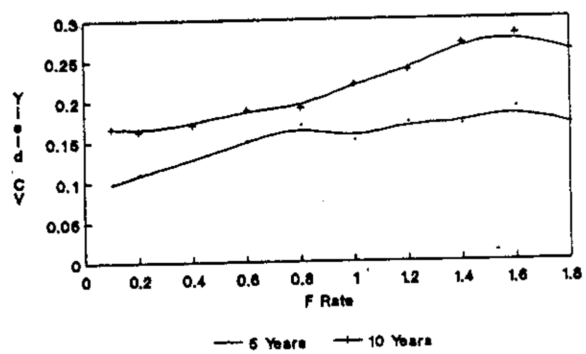
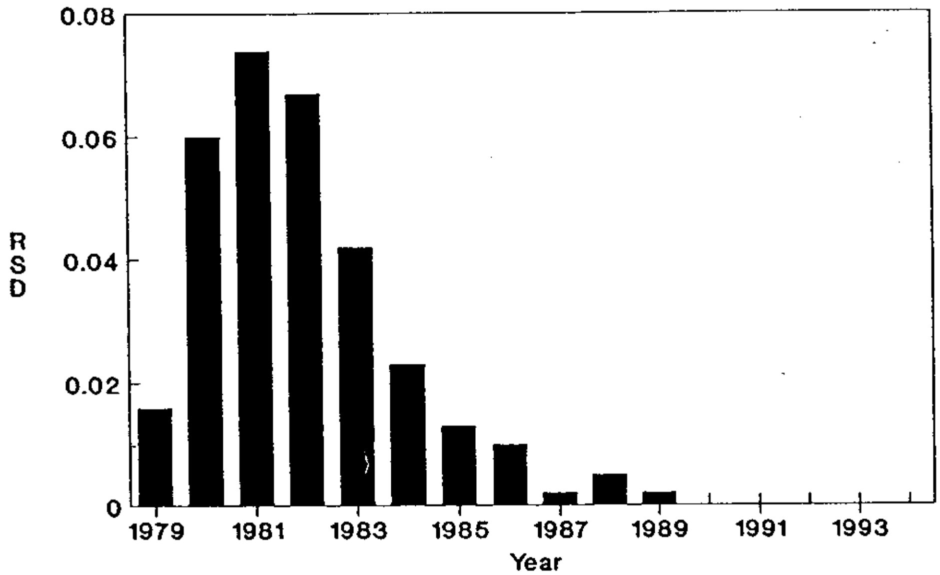
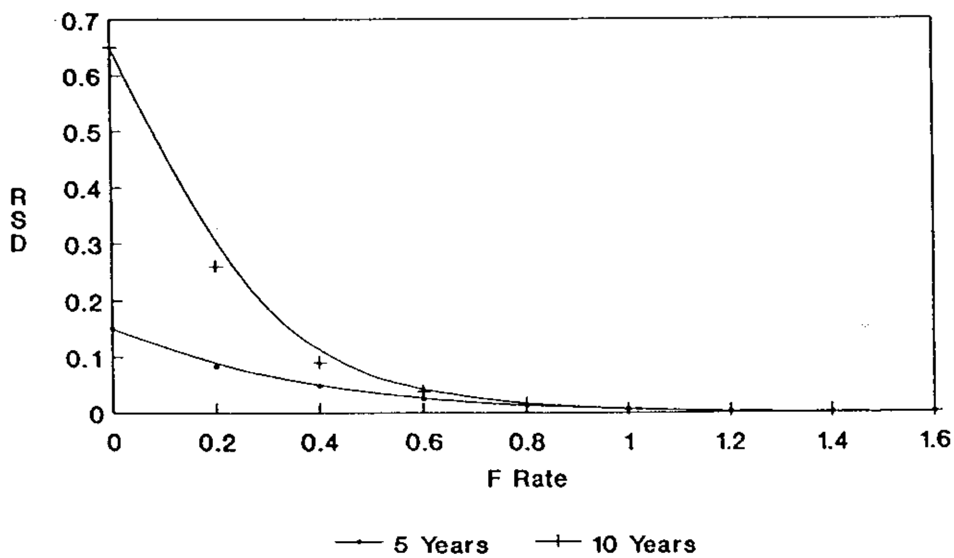


Fig.24- Weakfish Relative Stock Density from VPA, 1979-1994



Ratio of age 6+ to 2+

Fig.25- Weakfish Stock RSD at Various Levels of F Rate



Ratio of age 6+ to age 2+