A. Assessment of the Northern Stock of Black Sea Bass

Consensus Assessment Report

SARC 39

SAW Coastal/Pelagic Working Group

National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole Laboratory
Woods Hole, MA

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A meeting of the Coastal/Pelagic working group was held April 27-29th in Woods Hole, MA. The objective was to produce a stock assessment for the northern stock of black sea bass for consideration at the 39th SARC. Participants in the meeting were:

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Terms of reference were:

1) Characterize the commercial and recreational catch data (including length distributions).
2) Update NEFSC survey indices and evaluate appropriate state survey indices.
3) Summarize tagging program results.
4) Develop tag-based estimate(s) of exploitation.
5) Evaluate use of index-based methods for estimating relative Fs.
6) Evaluate biological reference points.

INTRODUCTION

Black sea bass (*Centropristis striatus*) range from the Gulf of Maine to southern Florida, with the majority of landings from Massachusetts to North Carolina. The population is partitioned into two stocks north and south of Cape Hatteras, NC (Musick and Mercer 1977, Shepherd 1991). The northern stock of black sea bass is jointly managed by the Atlantic States Marine Fisheries Commission (ASMFC) and the Mid-Atlantic Fishery Management Council (MAFMC) under Amendment 9 to the Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan (FMP). The most recent stock assessment, completed in June 1998, indicated that black sea bass were over-exploited and at a low biomass level (NEFSC 1998). The status of the stock was determined using a time series of relative abundance indices from the National Marine Fisheries Service (NMFS) Northeast Fisheries Science Center (NEFSC) spring offshore bottom-trawl survey, beginning in 1968. Amendment 12 to the Summer Flounder, Scup and Black Sea Bass FMP established a biomass threshold based on the maximum value of a three-year moving average of the NEFSC spring offshore survey mean biomass-per-tow. The overfishing definition in the FMP is based on Fmax as a proxy for Fmsy. Since there is not a currently accepted value of fishing mortality for black sea bass, the status of the stock relative to the overfishing definition cannot be established. However, a relative measure of exploitation (total landings / exploitable biomass index) can be used to evaluate stock status.

The conclusion of the 27th SARC was that black sea bass were overfished and overfishing was likely occurring. It was recommended that regulatory measures should continue with the objective of increasing total biomass and spawning stock biomass as well as expanding the age distribution within the population. The rebuilding schedule developed in the FMP calls for a reduction in the target exploitation rate for 2001-2002 to 37% with a further reduction in 2003 to the exploitation rate associated with F_{max} (25.6% for F_{max} = 0.33).

FISHERIES

Commercial sea bass landings have varied without trend since 1981, ranging from a low of 2.0 million pounds in 1994 to a high of 4.3 million pounds in 1984 (Table 1, Figure 1). The 2003 quota restricted landings of 3.1 million pounds was average for 1981-2000 but slightly lower than 2002 landings of 3.5 million pounds. Recent landings are all substantially below the peak landings of 21.8 million pounds estimated for 1952 (NEFSC 1998).

Commercial black sea bass landings in 2002-2003 were primarily from sea bass pots (42%), otter trawl (40%) and hook and line (12%). Massachusetts, New Jersey, Virginia and Maryland account for the majority (69%) of landings. Minimum size is 11” (28 cm) and landings are restricted by quota. The pot and hook fisheries begin in coastal waters in May and continue until late October in MA to December in southern areas (Shepherd and Terceiro 1994). Otter trawl landings are generally offshore during the winter months in the summer flounder, scup and squid fisheries (Shepherd and Terceiro 1994).

Biological samples collected by NMFS were used to expand length frequencies of commercial landings. Samples from 2002 and 2003 landings were partitioned by quarter, market category (small, medium, large and jumbo) and gear type (pots, trawls, hand lines and float traps). Large accounted for 33% and 31% of landings in 2002 and 2003, respectively although mediums (28% and 29%) and jumbos (23% and 27%) were a significant part of landings in both years. Expansion of lengths were made from 17 samples in 2002 and 25 in 2003. Length to weight conversions were based on length-weight equations in Wigley et al (2002).

Ln Wt (kg) = ln a + b ln Len (cm)

	ln a	b
spring	-11.2205	3.0225
autumn	-11.5992	3.122

Expanded length distributions are shown in Figures 2 and 3. Total estimated landings were 5.7 million fish in 2002 and 4.9 million in 2003. Commercial discards were not estimated.

Recreational fisheries account for roughly half of black sea bass landings. The recreational fishery takes place in coastal areas from May until November and is subject to a 12" (30 cm) minimum size, a 25 fish bag limit and a 2 week closed season. Landings ranged from a low of 1.2 million pounds in 1998 to a high of 12.4 million pounds in 1986 (Table 1, Figure 1). MRFSS estimates of black sea bass recreational landings (A + B1) in 2002 were 2,024 mt (3.38 million fish) and 1,933 mt (3.33 million fish) in 2003. The average for 1981-2001 was 1,772 mt. In 2000-2002, an average of 55% of the recreational landings were from the state of New Jersey. The next highest percentages per state were 9.7% from Delaware and 8.7% from Maryland. Length distributions from the recreational landings are shown in figures 4 and 5. Recreational discards (B2) amounted to 11.7 million and 9.1 million fish in 2002 and 2003, respectively. The previous assessment assumed a 25% discard mortality rate which would result in losses of 2.9 million and 1.8 million sea bass. A published estimate (Bugley and Shepherd 1991) of 5% results in 585,000 and 455,000 sea bass lost due to discarding.

FISHERY INDEPENDENT SURVEY INDICES

NEFSC

The highest abundance index (Log re-transformed mean number per tow) occurred in 1974 and was followed by a period of decline until the mid-1980s (Table 2, Figure 6). A slight rise in abundance was evident in the late 1980s but was followed by a decade of fluctuations around low levels of abundance. Since 1999 there has been a noticeable increase and the index in 2002 (2.175 / tow) was the highest in the time series and three times greater than the series average (0.7 / tow). The preliminary point estimate of the 2004 index (0.86 / tow) remains slightly above average. The NEFSC winter survey, begun in 1992, followed a similar pattern with a large index for 2002 (8.2/tow) followed by a higher index in 2003 (10.4 / tow) (Table 3, Figure 7). The preliminary 2004 index dropped to 2.0 /tow, below the time series average of 3.2 / tow. The autumn survey has also had relatively large indices in recent years (Table 4) but has not been considered reliable as an index of adult abundance due to potential catchability issues during sea bass residency in coastal waters.

Total biomass indices from the spring and winter trawl surveys indicate a significant increase over the past six years. Spring survey log re-transformed mean weight per tow peaked in 2003 at 0.85 kg/tow, well above the long term average of 0.25 kg/tow (Table 5, Figure 8). The preliminary 2004 index declined to 0.39 kg/tow. The winter survey also peaked in 2003 at 1.83 kg/tow, three times greater than the time series average of 0.63 kg/tow (Table 6, Figure 9). The 2004 index decreased to 0.67 kg/tow. A 3-point moving average of an exploitable biomass index provides the basis for biomass determination in the current FMP. During development of the FMP, exploitable biomass from survey results was defined as fish greater or equal to 22 cm. The working group decided to maintain this definition for evaluation of trends over the time series. Exploitable biomass increased substantially beginning in 1998 and reached a peak in 2002 of 0.799 kg/tow that exceeded the 1974 threshold value of 0.509 kg/tow (Table 7, Figure 10). The index has declined in successive years since 2002, reaching 0.320 kg / tow in 2004 (preliminary estimate). The 3-point moving average of the non-transformed biomass indices, as used in the FMP, peaked in 2003 at 1.403 kg/tow compared to the 1978 standard of 0.976 kg/tow (Table 7). The preliminary 2004 index declined to 0.937 kg / tow. Relative exploitation rate (total landings/biomass index) reached its lowest point in 2002 and 2003 (Table 7).

The difference in the pattern between total biomass indices and exploitable biomass appears to be due to the influence of a strong 2002 year class (Table 8, Figure 11). A black sea bass juvenile index has been defined in previous assessments as the log re-transformed stratified mean #/tow for fish $\leq$14 cm. The recruitment index has shown several recent strong year classes with 4 of the past 6 years above the time series average. The 2000 (0.661) and 2002 (0.554) recruitment indices were well above average (0.144) for the period 1968-2003. The 2003 index (0.154) suggests an average year class while the preliminary 2004 juvenile index was below the long term mean.

Massachusetts Division of Marine Fisheries

The Massachusetts spring bottom trawl survey, initiated in 1978, showed a recent increase in sea bass abundance with a peak index of 4.0/tow in 2000 (Table 9, Figure 12). However the indices have declined since and were below the time series average (1.21/tow) in 2003 (0.83/tow). The comparable biomass indices also peaked in 2000 at 1.93 kg/tow and have declined in 2003 to 0.72 kg/tow. The time series of number per tow and weight per tow were not strongly correlated with the NMFS, Connecticut or New Jersey surveys. The MA juvenile sea bass index from the autumn survey indicates strong cohorts in 2000 and 2003.

Connecticut Long Island Sound Trawl survey

The time series of geometric mean number per tow from the CT trawl survey begins in 1984 (Table 9, Figure 12). The survey shows a similar trend as the NMFS surveys with a sharp increase in abundance over the past several years, beginning in 1998. The index peaked in 2002 at 0.67/tow and decreased in 2003 to 0.21/tow, which remains above the series average of 0.14/tow.

New Jersey Coastal Ocean Survey

The New Jersey trawl survey is conducted during January, April, June, August, and October. The survey data from April was used as the index of abundance because it had the closet relationship with all other survey indices of abundance. Mean number per tow peaked in 2002 (2.7/tow) and remained above average (0.73/tow) in 2003 (1.66/tow). Biomass indices were similar, peaking in 2002 and remaining above average in 2003. Indices of juvenile abundance (<= 14 cm) varied considerably among bi-monthly surveys (Table 10, Figure 11). However, the 2002 year class was dominant in both June and August surveys.

The state survey indices were well correlated with the NEFSC spring and winter surveys (Table 11), however the NEFSC fall survey did not match either state or federal surveys well. MA indices also were not highly correlated with either NMFS or NJ but were closest to CT with an r value of 0.52.

Maryland Coastal Bays Survey

Maryland Department of Natural Resources has conducted trawl surveys at twenty fixed stations in Maryland coastal bays since 1972. Sampling is done from April to October using a 16 ft. otter trawl and captures primarily juvenile fish. A time series of geometric mean numbers per tow is provided in Table 10.

TAGGING PROGRAM

A tagging program for black sea bass was suggested in the research recommendations of the 27th SARC as a method to determine exploitation rate and examine migration patterns. The project was initiated in 2002 with funding from NOAAs MARFIN program. Estimation of survival, and subsequently exploitation rates, for fish populations using mark-recapture data depends on several assumptions. Among those assumptions are that distribution of tagged fish is equivalent to untagged fish, survival of tagged fish is not influenced by the tags, tag shedding during the recovery period is minimal, fish survive the tagging procedure, the tag recoveries are reported accurately, the rate of tag reporting is known and the tags recoveries represent dead fish. Most of these assumptions can be tested through experimentation and appropriate adjustments made in the estimation of survival rates.

Tag mortality and retention

Three experiments were conducted to determine tag retention and tag induced mortality. In the Woods Hole aquarium, 9 fish (29 to 38 cm) were collected in August 2002 by hook and line and placed in a 250 gallon aquarium tank. After a day of acclimation, the fish were tagged with Floy internal anchor tags with a 3 ½” tube and a ¼”x ¾” anchor tab. A small incision was made with a hook scalpel through the lower left abdominal wall and the tag inserted. Four fish survived until May with no tag losses. The remaining five fish retained the tags but died from diseases related to captivity 4 - 8 months after tagging.

A second experiment was conducted in the NEFSC J.J. Howard Laboratory in Sandy Hook, NJ under the direction of Dr. Mary Fabrizio. Thirty-one sea bass were tagged with internal anchor tags and held for 10 – 12 months. Sizes ranged from 22.5 to 36 cm TL. Within the first week, the tag loss rate was 3.2% (1 loss from 31 fish). Over the remainder of the experiment, the loss rate was 6.9% (2 losses from the remaining 29 fish (1 jumper at day 9 not included)). Overall, 3 tags were lost among 31 fish for a loss rate of 9.7% and no deaths were attributed to the tagging.

A third experiment was conducted by Brian Murphy of the Rhode Island Division of Fish and Wildlife. The duration of the study was 27 days and involved 30 tagged fish ranging in size from 26 to 41 cm. Tag loss was 13.3% with no tag induced mortalities. Among all three experiments, tag loss was 10.1% (7 of 70) and tag induced mortality was 0% (Figure 13).

Tag Releases

Locations and sample size of tag releases were chosen to disperse the tags throughout the range of the fishery, proportional to annual landings. In addition, the design was to release all the tags coastwide within a two week period, beginning in September 2002. Releases were repeated in May 2003 and September 2003. Appropriate sample size for tag release was estimated by examining the variance of a population estimate from a Petersen model. Using catch estimates from 2000 (N_c) a series of tag release values (M), and recovered tags (M_c) under three recovery rate assumptions (10, 20 and 30%), population size (N) was calculated as:

$$N = M\ (N_c / M_c)$$

Variance was estimated as (Sullivan et al. 1993, Seber 1970):

$$V(N) = ((M+1)\ (N_c+1)(M-M_c)(N_c-M_c))\ /\ ((M_c+1)^2\ (M_c+2))$$

Under all three recovery rates, approximately 3,000 fish or greater produced relatively little reduction in variance (Figure 14). Therefore, the total number of releases per period was targeted as a minimum of 3,000. The number of high reward tags targeted for release was 10%, and were regularly distributed among regular tags. For budgetary reasons the number of high reward tags in spring releases were reduced because of an anticipated high recapture rate.

Tags were released in September 2002 during 3 trips on sea bass pot boats in Nantucket Sound, MA, 1 trip in Cape Cod Bay, MA, 3 pot trips in Narragansett Bay, RI, 2 trips with recreational hook and line gear in Long Island, NY, 1 trip using lobster pot gear in LI, NY, 1 trip with sea bass pot gear in south/central NJ, 1 trip with recreational hook and line gear from Cape May, NJ, 1 trip with recreational hook and line gear in Ocean City, MD and 2 trips with commercial hook and line gear off Norfolk, VA. In May 2003, tags were released in MA, NJ, DE, MD, and VA all with commercial and recreational hook and line gear, and in September 2003, tags were released in MA, RI, CT, NY, NJ, MD and VA from hook and line and pot gear. A group of tags (n= 249) were also released in mid-April 2003 off VA. Tag release locations are summarized in figure 15.

Fish brought onboard a vessel for tagging were examined for evidence of external injuries and measured (total length to nearest ½ cm). A small incision was made in the lower abdominal wall and an anchor tag was inserted into the incision. In cases where there was an inflated air bladder, the bladder was punctured as the tag was inserted. If the bladder remained inflated, the fish was vented with a syringe needle while being held in a holding tank. Fish were returned to the water as soon as possible, generally in less than 1 minute. If there was some question about the condition, the fish was returned to a tank until it showed signs of recovery, usually within several minutes. If the fish did not recover, the tag was removed and the fish discarded. Occasionally (perhaps 2-3 per trip) a released fish would be unable to return to the bottom. In that event, attempts were made to recover the fish and remove the tag. If unsuccessful, the tag number was noted and excluded from the results. Equipment was sterilized with Betadine during each tagging cruise as time allowed. At each station, depth, surface water temperature, location (lat/lon or loran C) and tagger were recorded. Depths ranged from 6 m to 36.5 m. Locations were also categorized as places well known to the general fishing public or those known only to the captain. Regular tags (orange) were imprinted with tag # and a telephone number on both sides of the tag. Special high reward tags (red) also specified $100 reward. In total, 8,909 regular tags and 659 high reward tags were released (Table 12). Tagged fish ranged in length from 19 to 61 cm; 3% of tagged fish were below 26 cm. Length frequencies of tagged fish are shown in figure 16 by geographic region and regions combined for each release season. The tagged fish appeared to be comparable to the fishery length frequencies for each release period (Figure 17).

Dispersal

An assumption in tagging models is that tagged fish are homogeneously dispersed among non-tagged fish. The rate of movement of tagged fish among NEFSC statistical areas served as one measure of dispersal rate. For each release season, tagged fish were caught in an adjacent statistical area within 1 to 2 weeks of tagging, suggesting that dispersal was occurring in a relatively short time (Table 13a-13c).

Date and location information from release and recapture data allowed the calculation of linear distance and angle of movement (Sullivan et al. 1993) (Appendix I). Tag release locations were initially grouped into 4 regions: MA-RI, NY-northern NJ, southern NJ- DE, MD-VA. Vectors were created with the mean linear angle and mean distance of all tags released in a given region among five groups of days at liberty: 1-60 days, 61-120 days, 121-225 days, 226-365 days and >365 days. The results suggest that fish dispersed from the original tagging location and were likely to mix in the offshore areas during the winter. The general trend was for fish in the northern end of the range to move south-southwest along the 50 fathom line during winter. Sea bass in the NJ-DE area tended to move east-southeast to the shelf edge during winter. Black sea bass further south had a general tendency of seasonal movement towards the east. The extent of seasonal movement was significantly reduced from New Jersey south, particularly in the Virginia area. Most fish in all areas returned the following spring to the area of release although site fidelity was not 100%.

Based on the distribution of tag recaptures relative to release area, the study area was sub-divided into 3 regions: Massachusetts to New York, New Jersey to Delaware, and Maryland to North Carolina (Figure 15). These regions were used for subsequent analyses of reporting and recapture rates. Analysis of recapture matrices by region for fall 2002 and spring 2003 releases indicate 4% - 5% movement among regions within a year at large (4.6% and 4.1%, respectively).

Recaptures

Tags recovered by fishermen, dealers or others were reported to NEFSC via telephone. We asked for information on tag number, date and location of recapture, size of fish, type of fishery (recreational, party/charter, commercial) and gear, port and condition of tagged area on the fish. Tags were not required to be returned unless they were high reward tags or a questionable tag number.

Among the fall 2002 releases were a series in Rhode Island using a local pot fisherman. The fish were tagged and released along the same transect as the pots were set. Within the next several weeks, that same fisherman recaptured and reported over 70 tagged bass. It was evident that the tagged fish did not disperse properly but returned to the pots for shelter (these were unbaited pots typical in New England). Therefore in subsequent analyses we eliminated fish tagged and recaptured by that fisherman within the first two weeks at large.

A total of 1,154 regular tags and 107 high reward tags had been reported as of April 30, 2004 (Figure 18).

The black sea bass commercial and recreational fisheries have different minimum size limits; commercial is 11" (28 cm) and recreational is 12" (30 cm). Estimation of reporting rates and exploitation rates required a definition of the size at which sea bass are to fully vulnerable to exploitation. The working group decision was to use the 28 cm limit because of comparability between size of released fish and fisheries data, the inherent measurement error in the fisheries, the contribution of discards to total catch (unknown sizes and amounts) and the potential growth of fish from 28 to 30 cm during the course of the year.

Reporting Rates

Recapture rates of the high reward tags, relative to regular tags, was used to calculate tag reporting rates. The underlying assumption was that \$100 rewards would elicit 100% compliance from fishermen. Incremental rewards have been used in both bird banding and fish tagging studies and \$100 is generally accepted as a reasonable tag value that would provide full compliance (see Working Group comments).

Reporting rates were calculated as:

$$R_s = (R / M) / (R_h / M_h)$$

where:

R_s = reporting rate for tag recoveries
R = number of regular tags reported
M = number of regular tags released
R_h = number of high reward tags reported

M_h = number of high reward tags released

The Working Group recommended comparison of reporting rate between cells using a log-linear model for categorical data. Stratification into season of release and a smaller geographic cell than region (as previously defined) reduced the sample sizes such that many cells had no reported high reward tags and consequently no reporting rate. Data from fall 2002 and spring 2003 releases were combined to increase sample sizes (fall 2003 releases were not included since time at large was not long enough to include in subsequent exploitation estimates). Tag fate was categorized as either fish killed by the recreational fishery, the commercial fishery or not killed. The working group decided that legal size fish which were caught and re-released, with the tag removed, would constitute a killed fish. The reasoning was that under a quota or bag limited fishery with fish readily available, fishermen would likely replace a tagged fish with a non-tagged fish. Therefore to account for the substituted fish and the fact that the released fish was effectively removed from the population of tagged fish, released fish with tags removed (10.6% of recaptures) were included as kills. Additional restrictions on the data set were: fish greater or equal to 28 cm, fish caught in the same region of release (to avoid migration effects in the recapture rates), same season of release, fish at large greater than 7 days and removal of the first two weeks of recoveries by the RI fisherman as previously noted. Restricted input data are provided in table 14. Expected frequencies of tag type (regular or high reward tags), region (north, middle or south) and tag fate (recreational killed, commercial killed or not removed) were compared in a full log-linear model using SAS CATMOD (2004) (Appendix II). The main effects were significant (Pr > 0.01), as well as a significant region*fate interaction term (PR > 0.001) (the 3-way interaction could not be estimated). A simplified model was run using only the significant terms with similar results. The significant interaction term is likely the result of different recapture rates between the recreational fishery in the middle region and the commercial fishery in the north. Based on the significance of the main effects in the model, expected recapture rates were calculated using separate reporting rates by region and fishery.

Results of the reporting rate calculations by region and fishery are presented in table 15. There were no reported high reward tags in the NJ-DE commercial fishery, so reporting rate had to be estimated from other fisheries or regions. Reporting rates varied from 49% to100%. Overall, the recreational fishery had a 68.9% reporting rate and the commercial fishery was 57.1%. Anecdotal reports from commercial fishermen suggest that the assumption of 100% reporting for high reward tags may be incorrect. To evaluate the implications of an incorrect assumption, reporting rates were also calculated assuming only 80% reporting rate of the $100 tags from commercial fishermen (cells with 0 reported were increased to 1 reported). The change resulted in an overall commercial reporting rate decrease to 44.4 % (Table 16).

Exploitation Rate Estimation

The northern stock of black sea bass is managed as a single unit stock from Massachusetts to Cape Hatteras, NC. Therefore, estimates of exploitation and fishing mortality were provided as a single stock-wide value.

Exploitation rates were calculated using a modification of the Petersen estimate. The number of fish recaptured (R) was adjusted for the reporting rate from the area/fishery cell. The number of tags released was reduced by a tag loss rate of 10%. Therefore, exploitation rate estimate was calculated as:

$$\mu = \sum (R_{rf} / \gamma_{rf}) / \sum (M_{rf} - (M_{rf} * \theta))$$

where:

μ = exploitation rate

R_{rf} = tags recaptured by region and fishery

γ_{rf} = tag reporting rate by region and fishery

M_{rf} = tags released by region and fishery

θ = percent of tag loss

Fishing mortality was calculated from the exploitation rate by iteration of F values that would produce the equivalent μ, assuming a natural mortality of 0.2.

The recommendation of the working group was to estimate exploitation rates by region and fishery and weight the final estimate by annual landings or survey abundance indices within each cell. The purpose was to reduce the affect of heterogeneity of tag release and recoveries due to unequal sample sizes. However, there was a difficulty in producing region specific estimates with R/M models when inter-region mixing occurs, due to the confounding of recovery rate, migration and local abundance (Dorazio 1993). For example, suppose an equal number of fish are marked in area A and B. The recaptures in area A would be the sum of fish originating in A plus those originating in B but migrating to A. However, there would be no information available to determine what percent of the unseen marked population also moved into A. Therefore, any exploitation estimate would have an unknown number of marked fish available for recapture. If the assumption can be made that recaptures in different regions is limited (4-5% in this study), local F can be calculated and an overall weighted F produced. Weighting by proportion of tags released in each cell (region, fishery) approximates the estimate based on the sum of all releases. Choice of the weighting factor then presents a problem. Weighting by catch assumes that catch reflects abundance when in fact it also represents exploitation rate which is the objective in solving R/M. Consequently it becomes a circular argument. Survey indices which overlap the inshore fishery are unreliable due to the problems with using trawl gear in sea bass habitat. In each of the options, the effects of migration, abundance and exploitation rate are confounded. With a simple r/m model, it is not possible to find a unique solution for exploitation rate among regions without independent estimates of the other factors. However, a series of weighting schemes and F estimates were produced to examine the sensitivity of different assumptions. The recommended approach remained use of recapture rates, adjusted for regional/fishery specific reporting rates, divided by the total number of tags released.

Estimates were made separately for fall 2002 and spring 2003 releases (using the same reporting rates). Input data were limited to fish $\geq$ 28 cm that were caught and killed (including caught, tag removed and released) after 7 days following tagging but within 365 days at large

(Tables 17 and 18). High reward tags were included in the estimate assuming 100% reporting. A second estimate was made assuming 80% reporting of commercial high reward tags (Tables 19 and 20).

The overall exploitation rate for October 2002-September 2003 recoveries from September 2002 releases was estimated at 0.148 or F = 0.18; May 2003 releases recovered from June 2003-May 2004 had an exploitation rate of 0.197 or F =0.24 (Tables 17 and 18). Alternative exploitation rate estimates, assuming 80% commercial reporting of high reward tags were 0.170 (F=0.21) in fall 2002 and 0.207 (F=0.258) in spring 2003 (Tables 19 and 20).

Sensitivity of fishing mortality estimates to alternative weighting schemes are provided in table 21. Options included region/fishery specific and region specific estimate assuming no inter-region movement, weighting schemes assuming equal proportions among regions, and proportions skewed to one region (50%, 25%, 25%).

Other Tagging Models

An alternative model was evaluated for calculation of fishing mortality (Rago and Goodyear 1985) Fishing mortality was estimated as the value that produced the expected number of tag recaptures equivalent to the observed number using the equation:

$$E_{(i,j)} = N_{(i)} * S_t * (1-(\exp(-(F+M))*(t_j - t_i)))*(F/(F+M))$$

where:

$E_{(i,j)}$ = expected number of tags returns at time t_j from releases at t_i
$N_{(i)}$ = number of marked fish released at time t_i modified for tag loss and reporting rate.
S_t = fraction of marked fish that survive tagging (100%)
F = instantaneous rate of fishing mortality
M = instantaneous rate of natural mortality (0.2)
t_j = time period of recapture
t_i = time period of release

Solving for F such that $E_{(i,j)} = R_{(ij)} * \gamma$

where:

$R_{(ij)}$ = observed tag recaptures
γ = overall reporting rate of 63.6% (combined regions, fisheries for fall 2002-spring 2003 releases).

Estimates were also made assuming a 10% lower reporting rate.

The estimate of F for the period October 2002 – September 2003 was 0.15, and for June 2003 – May 2004 equaled 0.27 (Table 22). Alternative estimates using an 80% commercial reporting of high reward tags (overall = 56.4%) produced estimates of 0.18 and 0.31 for the fall and spring, respectively. Assuming an overall reporting rate 10% lower (57.2%) produced estimates of 0.17 and 0.30 for fall 2002 and spring 2003 releases.

REPLACEMENT F

Spring survey biomass indices and landings data were further examined using the program AIM (An Index Method from NOAA Fisheries Toolbox, version 1.4). The model uses a statistical fitting procedure to examine the relationship between indices and landings to calculate a relative F and estimate a replacement ratio necessary to maintain the population. Two models runs were used; one with the longer time series of data involving only commercial landings (1968-2003) and a second with a shorter time series which included recreational landings. The NEFSC spring survey log re-transformed biomass indices provided the relative abundance information.

The analysis using total landings since 1981 produced a significant relationship in the simple regression between relative F and replacement ratio (Table 23). The bootstrap mean relative F value for a ln replacement ratio of 0 was equal to 17.319 with an 80% interval between 14.92 and 21.12 (Figure 19). The relative F in 2003 was 3.91, with a replacement ratio of 2.18. A comparable analysis using the longer time series with only commercial landings produced similar results (Table 24). The relative F value with ln replacement ratio of 0 was equal to 7164.47, with an 80% bootstrap interval of 6472.82 to 7860.93 (Figure 19). The 2003 relative F from this data set was 1638.50 with a replacement ratio of 2.186. In both cases relative F in 2003 suggest the biomass should continue to increase at the current levels of removal (Figures 20 and 21).

BIOLOGICAL REFERENCE POINTS

The present BRP for black sea bass is Fmax as a proxy for Fmsy. Fmax as currently defined is equal to 0.33 based on Thompson-Bell yield per recruit model (Table 25, Figure 22). The working group did not recommend any changes to the estimate. The group also concluded that the use of F from the tagging results as a fully recruited F for comparison to Fmax was acceptable.

Biomass reference points have been based on exploitable biomass indices from the NEFSC spring survey. No alternative biomass estimates are available and no recommendations were made to change the current biomass threshold reference point.

SUMMARY

Results of the assessment for the northern stock of black sea bass show a level of exploitation at or below the management target and biomass levels comparable to the 1970s. Exploitation rate estimates from fall 2002 releases ranged from 0.14 to 0.17; spring 2003 releases were 0.20 to 0.24. Associated fishing mortality estimates ranged from 0.17 to 0.21 in October 2002 – September 2003 while June 2003 to May 2004 preliminary estimates were 0.24 to 0.30.

Relative exploitation values based on the NEFSC spring survey were the lowest in the time series. Relative F estimates from the AIM model indicate low values and well below the F needed to maintain replacement. Relative biomass indices from state and federal surveys show a stock biomass that increased substantially since 1998, reached highest values between 2000 and 2002 and have begun to decline in 2003. Juvenile recruitment over the past five years, based on survey indices, has included possibly two strong cohorts.

Tag reporting rates varied by geographic region and type of fishery. Coastwide the recreational reporting rate was higher at 69% compared to the commercial rate of 57%. Regional differences occurred in reporting rates and tended to be highest in the MD-NC region (90-100%) but may have been influenced by low sample sizes and the assumption of 100% reporting of high reward tags. A relaxation of that assumption to 80% commercial reporting decreased the southern reporting rate from 90 to 68%.

The conclusion of the working group was that the stock appeared to be below the target exploitation rate and target F. Although biomass has been high over the past several years, recent decreases in biomass indices suggests that caution should be exercised in setting quotas. The current tagging models provided an acceptable measure of exploitation but there remains an unknown degree of uncertainty in the estimates.

WORKING GROUP COMMENTS

The comments could be divided into several general topics:

1. Tag retention: The group felt that further studies should be conducted to examine tag retention. Some issues to consider would be effect of vessel movement while tagging compared to tagging under laboratory conditions, effect of handling fish in the laboratory after tagging; pectoral fin erosion by tags over long term; and possible temperature effects (i.e. temperature contrast in water column when fish are caught or released and differences in tagging mortality rate between areas due to temperature differences). Also include a control group to examine possible affects of gear used to collect fish. The use of double tagging to estimate tag loss should be considered in future releases.

2. Experimental design: the group stressed the importance of continuing releases in the same geographic areas as the past releases. Shifts in locations can create difficulty in comparisons between release cohorts. Effort should continue to be made to distribute tag releases in proportion to expected population abundance.

3. Tag reporting: Tag reporting may be increased with additional outreach efforts and perhaps a 1-800 phone number for reporting tags. Consideration should be given to include sociologists in the project to identify the reasons behind non-reporting. Further efforts should be made to compare reporting rates among specific groups by area, gear types etc.

4. Modeling: The group strongly endorsed the continuation of the tagging program through at least another round of releases. The difficulties involved with use of the simple Peterson estimates may be overcome with more sophisticated models. However, implementation of models such as MARK or SURVIV, require development of recapture matrices involving several release-recapture periods. Although it was suggested that such models should be explored using the current data, the modeling efforts will be strengthened with additional data.

5. General comments: Beyond the sea bass program, the group discussed the future of tagging programs within the states and the NEFSC. It was agreed that a proper experimental design was critical prior to any release of tags. The number of tags released should be estimated based on expected reporting rate and exploitation rate. Tag releases should be made over several years in a consistent fashion and should be done each time over a short release time period (several weeks not months). Degree of tag loss should be examined, tag induced mortality and efforts made to quantify reporting rates. Prior to release, the proper infrastructure should be in place to data collection, outreach to increase likelihood of reporting and funding to pay rewards returned over several years. Although it was noted that compared to many techniques, tagging projects were relatively inexpensive, efforts should be made to coordinate tagging among species to reduce costs (i.e. tag scup and fluke while tagging sea bass).

RESEARCH RECOMMENDATIONS

1. Continue tagging project over another season at the minimum.
2. Conduct double tagging experiment to estimate tag loss over time.
3. Develop non-parametric bootstrap method to estimate variance in R/M model.
4. Develop survival estimates using tagging models such as MARK.
5. Develop age information for possible re-examination of age based analytical models.
6. Evaluate use of a short time series of tag based mortality estimates for conversion of relative index based estimates to absolute values.
7. Increase outreach efforts, possibly with the assistance of sociologists.

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BLACK SEA BASS TABLES

Table 1. Landings of the northern stock of black sea bass, 1968-2003.

Year	commercial landings 000s lbs	commercial landings (mt)	recreational landings (mt)	total landings (mt)
1963				
1964				
1965				
1966				
1967				
1968	2,648	1201		
1969	2,643	1199		
1970	2,425	1100		
1971	1,354	614		
1972	1,676	760		
1973	2,560	1161		
1974	2,357	1069		
1975	4,156	1885		
1976	3,726	1690		
1977	5,344	2424		
1978	4,663	2115		
1979	4,134	1875		
1980	2,760	1252		
1981	2,489	1129	559	1688
1982	2,595	1177	4483	5660
1983	3,336	1513	1850	3363
1984	4,332	1965	656	2621
1985	3,419	1551	951	2502
1986	4,191	1901	5621	7522
1987	4,167	1890	873	2763
1988	4,142	1879	1301	3180
1989	2,919	1324	1492	2816
1990	3,501	1588	1252	2840
1991	2,804	1272	1899	3171
1992	3,007	1364	1227	2591
1993	3,113	1412	2196	3608
1994	1,975	896	1337	2233
1995	2,039	925	2815	3740
1996	3,245	1472	1811	3283
1997	2,615	1186	1936	3122
1998	2,564	1163	522	1685
1999	2,974	1349	755	2104
2000	2,714	1231	1798	3029
2001	2,934	1331	1630	2961
2002	3,532	1602	2024	3626
2003	3,077	1396	1933	3329

Table 2. NEFSC spring offshore survey ln re-transformed stratified mean number per tow.

		95% CI	
Year	MEAN	LOW	HIGH
1968	0.159	0.109	0.212
1969	0.113	0.084	0.142
1970	0.111	0.073	0.150
1971	0.135	0.084	0.188
1972	0.555	0.393	0.735
1973	0.377	0.242	0.526
1974	1.277	0.851	1.803
1975	0.648	0.506	0.803
1976	1.587	1.286	1.929
1977	1.014	0.817	1.233
1978	0.854	0.650	1.082
1979	0.483	0.369	0.607
1980	1.328	0.981	1.735
1981	0.465	0.373	0.562
1982	0.120	0.085	0.156
1983	0.387	0.261	0.526
1984	0.219	0.149	0.292
1985	0.388	0.277	0.508
1986	1.136	0.811	1.519
1987	0.680	0.525	0.849
1988	0.982	0.731	1.269
1989	0.428	0.329	0.533
1990	0.553	0.372	0.757
1991	0.838	0.598	1.114
1992	0.962	0.735	1.218
1993	0.290	0.210	0.375
1994	0.198	0.131	0.269
1995	0.521	0.409	0.642
1996	0.306	0.228	0.389
1997	0.704	0.524	0.904
1998	0.210	0.154	0.268
1999	0.801	0.541	1.103
2000	1.066	0.788	1.388
2001	1.126	0.866	1.423
2002	2.175	1.769	2.641
2003	2.136	1.598	2.787
2004	0.864	0.700	1.043

Table 3. NEFSC winter survey ln re-transformed stratified mean number per tow.

		95% CI	
Year	MEAN	LOW	HIGH
1992	2.452	2.015	2.952
1993	1.365	1.091	1.676
1994	0.761	0.554	0.996
1995	1.537	1.203	1.921
1996	3.319	2.640	4.126
1997	0.700	0.564	0.847
1998	0.771	0.637	0.915
1999	1.176	0.947	1.431
2000	4.481	3.523	5.641
2001	3.829	3.196	4.558
2002	8.188	6.718	9.937
2003	10.400	7.752	13.850
2004	2.023	1.704	2.379

Table 4. NEFSC fall survey ln re-transformed stratified mean number per tow.

		95% CI	
Year	MEAN	LOW	HIGH
1972	0.454	0.330	0.590
1973	2.069	1.554	2.689
1974	1.871	1.423	2.402
1975	3.952	2.786	5.477
1976	4.547	3.021	6.653
1977	3.824	2.960	4.877
1978	0.521	0.330	0.739
1979	0.675	0.520	0.845
1980	1.844	1.270	2.562
1981	1.004	0.598	1.514
1982	1.230	0.924	1.585
1983	1.778	1.379	2.244
1984	0.905	0.598	1.270
1985	1.882	1.468	2.366
1986	3.685	2.572	5.146
1987	1.357	0.932	1.875
1988	3.695	2.834	4.749
1989	1.553	1.079	2.135
1990	2.069	1.483	2.792
1991	2.292	1.692	3.026
1992	1.880	1.277	2.643
1993	0.740	0.577	0.921
1994	1.642	1.251	2.101
1995	3.457	2.391	4.858
1996	0.838	0.586	1.130
1997	1.927	1.489	2.443
1998	3.299	2.324	4.559
1999	2.609	1.615	3.979
2000	6.102	4.278	8.557
2001	2.050	1.573	2.616
2002	3.138	2.306	4.178
2003	2.741	2.085	3.536

Table 5. NEFSC spring offshore survey ln re-transformed stratified mean weight (kg) per tow.

Year	MEAN	95% CI LOW	95% CI HIGH
1968	0.054	0.035	0.074
1969	0.058	0.040	0.075
1970	0.073	0.048	0.100
1971	0.051	0.020	0.083
1972	0.156	0.098	0.216
1973	0.203	0.112	0.303
1974	0.621	0.378	0.907
1975	0.315	0.247	0.386
1976	0.591	0.439	0.760
1977	0.379	0.277	0.490
1978	0.336	0.251	0.426
1979	0.290	0.215	0.369
1980	0.277	0.187	0.374
1981	0.232	0.174	0.294
1982	0.041	0.026	0.056
1983	0.125	0.067	0.186
1984	0.108	0.064	0.154
1985	0.147	0.098	0.197
1986	0.355	0.225	0.499
1987	0.254	0.178	0.335
1988	0.328	0.238	0.424
1989	0.146	0.093	0.202
1990	0.131	0.079	0.186
1991	0.077	0.034	0.121
1992	0.306	0.220	0.399
1993	0.094	0.059	0.130
1994	0.080	0.043	0.118
1995	0.153	0.103	0.206
1996	0.105	0.073	0.137
1997	0.250	0.168	0.339
1998	0.091	0.057	0.126
1999	0.292	0.164	0.434
2000	0.161	0.104	0.222
2001	0.383	0.275	0.502
2002	0.723	0.582	0.875
2003	0.852	0.601	1.141
2004	0.390	0.300	0.485

Table 6. NEFSC winter survey ln re-transformed stratified mean weight (kg) per tow.

		95% CI	
Year	MEAN	LOW	HIGH
1992	0.464	0.374	0.560
1993	0.506	0.390	0.632
1994	0.170	0.112	0.231
1995	0.365	0.262	0.477
1996	0.501	0.380	0.633
1997	0.198	0.142	0.257
1998	0.195	0.166	0.224
1999	0.266	0.212	0.323
2000	0.478	0.366	0.599
2001	0.949	0.747	1.175
2002	1.573	1.293	1.888
2003	1.832	1.360	2.398
2004	0.671	0.551	0.801

Table 7. NEFSC Spring offshore survey indices of exploitable biomass (>= 22 cm) and relative exploitation rate.

Year	Mean kg/tow	3 pt avg mov. Avg.	ln re-transformed Mean kg/tow	3 pt avg mov. Avg.	Rel Expl. index/1000	3 pt avg mov. Avg.
1968	0.152		0.040			
1969	0.217	0.145	0.024	0.042		
1970	0.066	0.115	0.062	0.041		
1971	0.063	0.095	0.036	0.069		
1972	0.155	0.163	0.108	0.092		
1973	0.272	0.464	0.131	0.249		
1974	0.964	0.694	0.509	0.292		
1975	0.846	0.814	0.237	0.367		
1976	0.631	0.866	0.355	0.247		
1977	1.120	0.827	0.149	0.232		
1978	0.730	**0.976**	0.193	0.149		
1979	1.078	0.700	0.104	0.144		
1980	0.292	0.560	0.134	0.134		
1981	0.311	0.210	0.164	0.106	10.32	
1982	0.027	0.161	0.019	0.088	294.25	115.39
1983	0.145	0.098	0.081	0.066	41.60	120.94
1984	0.122	0.144	0.097	0.098	26.98	30.05
1985	0.164	0.281	0.116	0.142	21.56	27.97
1986	0.559	0.367	0.213	0.177	35.36	23.50
1987	0.380	0.448	0.204	0.205	13.56	21.63
1988	0.407	0.308	0.199	0.162	15.97	20.95
1989	0.138	0.230	0.085	0.123	33.31	27.62
1990	0.144	0.113	0.085	0.072	33.58	44.25
1991	0.057	0.188	0.048	0.114	65.84	37.30
1992	0.362	0.187	0.208	0.099	12.47	55.73
1993	0.141	0.196	0.041	0.102	88.89	46.47
1994	0.086	0.125	0.059	0.069	38.04	53.96
1995	0.148	0.126	0.107	0.086	34.95	36.34
1996	0.143	0.197	0.091	0.111	36.04	31.35
1997	0.300	0.185	0.135	0.093	23.06	30.53
1998	0.111	0.278	0.052	0.136	32.50	21.68
1999	0.424	0.230	0.222	0.137	9.49	21.37
2000	0.156	0.350	0.137	0.198	22.11	14.73
2001	0.470	0.582	0.235	0.390	12.59	13.08
2002	1.121	1.247	0.799	0.509	4.54	7.96
2003	2.151	1.403	0.493	0.537	6.75	
2004	0.937		0.320			

Table 8. NEFSC black sea bass juvenile indices
(<= 14 cm) from spring survey.

Year	ln re-transformed stratified mean #/tow
1968	0.085
1969	0.000
1970	0.000
1971	0.000
1972	0.143
1973	0.000
1974	0.000
1975	0.061
1976	0.557
1977	0.163
1978	0.148
1979	0.017
1980	0.482
1981	0.045
1982	0.003
1983	0.009
1984	0.007
1985	0.085
1986	0.149
1987	0.030
1988	0.232
1989	0.070
1990	0.171
1991	0.499
1992	0.164
1993	0.007
1994	0.011
1995	0.162
1996	0.063
1997	0.024
1998	0.000
1999	0.347
2000	0.661
2001	0.078
2002	0.554
2003	0.154
2004	0.080

Table 9. Black sea bass mean number per tow from state spring surveys.

	MA #/tow	CT #/tow	NJ #/tow
1968			
1969			
1970			
1971			
1972			
1973			
1974			
1975			
1976			
1977			
1978	1.958		
1979	0.988		
1980	0.997		
1981	2.233		
1982	2.158		
1983	4.529		
1984	1.597	0.164	
1985	1.208	0.274	
1986	1.583	0.123	
1987	0.705	0.053	
1988	0.420	0.045	
1989	0.547	0.079	0.166
1990	0.698	0.103	0.044
1991	0.381	0.072	0.327
1992	0.087	0.026	0.392
1993	0.112	0.072	0.123
1994	0.219	0.121	0.202
1995	0.465	0.066	1.673
1996	0.154	0.107	0.295
1997	0.452	0.095	0.763
1998	0.224	0.042	0.317
1999	1.255	0.077	1.094
2000	4.003	0.219	0.246
2001	1.752	0.253	0.912
2002	1.880	0.673	2.699
2003	0.830	0.213	1.657

Table 10. Juvenile black sea bass indices, mean number per tow. NJ indices are $\log_e$ transformed, MD indices are geometric mean

	MA	NJ	MD
1972			8.34
1973			1.40
1974			1.94
1975			1.48
1976			1.28
1977			0.78
1978	79.3		0.75
1979	73.2		0.07
1980	93.1		1.08
1981	62.9		0.78
1982	397.2		0.53
1983	185.7		0.00
1984	201.3		0.99
1985	198.5		1.70
1986	80.4		4.94
1987	35.3		1.35
1988	60.4	0.536	1.41
1989	6.5	0.380	0.16
1990	4.3	0.043	1.24
1991	9.5	0.851	1.12
1992	10.8	0.872	0.92
1993	1.1	0.449	0.18
1994	45	0.178	0.84
1995	32.6	0.512	1.71
1996	23.6	1.032	0.06
1997	5.3	5.136	0.93
1998	9.9	2.880	0.33
1999	22.1	0.577	1.74
2000	195.5	0.974	1.95
2001	87.9	0.628	1.12
2002	118.9	0.815	1.95
2003	178.2	0.516	0.82

Table 11. Correlation among spring surveys.

	NMFS spring	MA	CT	NJ	NMFS winter	NMFS fall
NMFS -spr	1.00					
MA	0.10	1.00				
CT	0.62	0.52	1.00			
NJ	0.76	0.23	0.73	1.00		
NMFS -winter	0.90	0.39	0.69	0.63	1.00	
NMFS -fall	0.45	0.25	0.19	0.26	0.25	1.00

Table 12. Summary of black sea bass releases by state, season, tag type.

	MA	RI	CT	NY	NJ	DE	MD	VA
Fall 2002								
regular	1168	234		206	517		1014	332
$	93	24		20	33		98	44
Spring 2003								
regular	131				445	283	557	955
$	7				25	16	35	
Fall 2003								
regular	369	535	24	216	686		550	652
$	30	30	2	18	55		46	83

Table 13a. Tagged black sea bass dispersal among statistical areas for Fall 2002 releases.

Recapture Area

Release Area

week 1

	538	539	612	613	614	621	631
538	2						
539		33					
612			1				
613				9			
614					1		
621						1	
631							1

week 2

	514	537	538	539	612	613	614	621	625	631
514	2									
537										
538		1	4							
539				32						
612					4	1				
613						3				
614							1			
621								3		
625										2
631										

week 3

	514	537	538	539	612	613	614	621	625	631
514										
537										
538		1	13							
539				14						
612					4					
613										
614										
621								1		
625										4
631										

week 4

	514	537	538	539	612	613	614	621
514	7							
537								
538		3	14					
539								
612					4			
613						2		
614								
621							1	2

Table 13b. Tagged black sea bass dispersal among statistical areas for spring 2003 releases.

Recapture area

Release area

week 1	538	612	614	621	625	631	635
538	3						
612		5	1				
614							
621				14			
625					1		
631						4	1
635							

week 2	538	612	614	615	621	631
538	2					
612		4		1		
614						
615						
621			1		17	
631						6

week 3	538	612	621	626	631
538	1				
612		15			
621			12		
626				2	
631					1

week 4	538	612	613	621	631
538	1				
612		5	1		
613					
621				15	1
631					2

Table 13c. Tagged black sea bass dispersal among statistical areas for fall 2003 releases.

Recapture area

week 1

Release Area	538	539	612	613	614	621	625	631
538	2	1						
539		11						
612			8		1			
613				5				
614					2			
615					4			
621						11		
625							2	5
631								

week 2

	538	539	611	612	613	614	615	621	625	631
538	1									
539		3								
611			1							
612				2						
613					5					
614						42	4			
615							1			
621								13		
625									5	
631										11

week 3

	539	612	613	614	615	621	631
539	6						
612		1					
613			3				
614				4			
615				1			
621						3	
631							8

week 4

	539	611	612	613	614	615	621	631
539	1							
611		1						
612			2					
613				2				
614					14	1		
615					2			
621							2	
631								6

Table 14. Black sea bass tag recapture rates by region, fishery and combined for fall 2002 and spring 2003 releases. Assumed reporting rate for $100 tags of 100%.

Regular Tags

Area	Number Released	Recreational Recaptures	Commercial Recaptures	total
MA-NY	1652	43	131	174
NJ-DE	1050	179	8	187
MD-VA	2623	53	45	98
total	**5325**	275	184	**459**

Recapture rate

Rec.	Com.
2.6%	7.9%
17.0%	0.8%
2.0%	1.7%

Area only	
MA-NY	3.3%
NJ-DE	3.5%
MD-VA	1.8%

Fishery only	
Rec	Com
5.2%	3.5%

Overall
8.6%

High Reward Tags

Area	Number Released	Recreational Recaptures	Commercial Recaptures	
MA-NY	132	7	18	25
NJ-DE	57	17	0	17
MD-VA	158	2	3	5
total	**347**	26	21	**47**

Recapture rate

Rec.	Com.
5.3%	13.6%
29.8%	0.0%
1.3%	1.9%

Area only	
MA-NY	7.2%
NJ-DE	4.9%
MD-VA	1.4%

Fishery only	
Rec	Com
7.5%	6.1%

Overall
13.5%

Table 15 . Black sea bass tag reporting rates by region, fishery and combined for fall 2002 and spring 2003 releases. Assuming 100% reporting of high reward tags.

Area	**Fishery** Rec.	Com.
MA-NY	49.1%	58.2%
NJ-DE	57.2%	0.0%
MD-VA	100.0%	90.4%

Area	
MA-NY	45.4%
NJ-DE	71.7%
MD-VA	127.7%

Fishery	
Rec	Com
68.9%	57.1%

Overall
63.6%

Table 16. Black sea bass tag reporting rates by region, fishery and combined for fall 2002 and spring 2003 releases with the assumption of 80% reporting of high reward tags in the commercial fishery.

Area	**Fishery** Rec.	Com.
MA-NY	49.1%	47.6%
NJ-DE	57.2%	43.4%
MD-VA	100.0%	67.8%

Area	
MA-NY	39.1%
NJ-DE	67.7%
MD-VA	106.4%

Fishery	
Rec	Com
68.9%	44.4%

Overall
56.4%

Table 17. Black sea bass Fall 2002 tag release/recaptures for fish ≥ 28 cm, at large > 7 and ≤ 365 days and without RI recaptures within 2 weeks of releases. Killed fish only, assuming 100% high reward reporting and 10% tag loss rate.

region	Releases: Regular Tags	Releases: High Reward Tags	fishery	Regular Tag Recaptures	Reporting Rates	expected regular Recaptures	High Reward Recaptures	sum
MA-NY	1524	125	Com	120	58.2%	206	15	221
			Rec	33	49.1%	67	7	74
NJ-DE	416	24	Com	7	**57.2%**	12	0	12
			Rec	47	57.2%	82	6	88
MD-VA	1192	130	Com	28	90.4%	31	4	35
			Rec	22	100.0%	22	2	24
sum	3132	279				**421**	**34**	**455**

* region 2 com reporting rate set = rec

tag loss adj.

	R	M
Regular	421	2819
$	34	251
Overall	455	3070

Overall

u	F
14.8%	**0.177**

Table 18 . Black sea bass Spring 2003 tag release/recaptures for fish ≥ 28 cm, at large > 7 and ≤ 365 days and without RI recaptures within 2 weeks of releases. Killed fish only, assuming 100% high reward reporting and 10% tag loss rate.

region	Releases Regular Tags	Releases High Reward Tags	fishery	Regular Tag Recaptures	Reporting Rates	expected regular Recaptures	High Reward Recaptures	sum
MA-NY	128	7	**Com**	10	58.2%	17	0	17
			Rec	8	49.1%	16	0	16
NJ-DE	634	33	**Com**	3	**57.2%**	5	0	5
			Rec	130	57.2%	227	10	237
MD-VA	1431	28	**Com**	20	90.4%	22	0	22
			Rec	97	100.0%	97	2	99
sum	2193	68		268		385	12	397

tag loss adj.

	R	**M**
Regular	385	1974
$	12	61
Overall	397	2035

Overall

u	**F**
19.5%	**0.241**

Table 19. Black sea bass Fall 2002 tag release/recaptures for fish $\geq$ 28 cm, at large > 7 and $\leq$ 365 days and without RI recaptures within 2 weeks of releases. Killed fish only, assuming 80% high reward reporting and 10% tag loss rate.

region	Releases: Regular Tags	Releases: High Reward Tags	fishery	Regular Tag Recaptures	Reporting Rates	expected regular Recaptures	High Reward Recaptures	sum
MA-NY	1524	125	Com	120	47.6%	252	19	271
			Rec	33	49.1%	67	7	74
NJ-DE	416	24	Com	7	43.4%	16	1	17
			Rec	47	57.2%	82	6	88
MD-VA	1192	130	Com	28	67.8%	41	5	46
			Rec	22	100.0%	22	2	24
sum	3132	279				481	40	**521**

tag loss adj.

	R	M
Regular	481	2819
$	40	251
Overall	521	3070

Overall

u	F
17.0%	**0.207**

Table 20. Black sea bass Spring 2003 tag release/recaptures for fish ≥ 28 cm, at large > 7 and ≤ 365 days and without RI recaptures within 2 weeks of releases. Killed fish only, assuming 80% high reward reporting and 10% tag loss rate.

region	Releases: Regular Tags	Releases: High Reward Tags	fishery	Regular Tag Recaptures	Reporting Rates	expected regular Recaptures	High Reward Recaptures	sum
MA-NY	128	7	**Com**	10	47.6%	21	2	23
			Rec	8	49.1%	16	2	18
NJ-DE	634	33	**Com**	3	43.4%	7	2	9
			Rec	130	57.2%	227	**12**	239
MD-VA	1431	28	**Com**	20	67.8%	30	2	32
			Rec	97	100.0%	97	**2**	99
sum	2193	68		268		398	22	421

tag loss adj.

	R	**M**
Regular	398	1974
$	22	61
Overall	420	2035

Overall

u	**F**
20.6%	**0.258**

* region 2 com reporting rate set = region 1

Table 21. Sensitivity analyses of alternative weighting schemes in the calculation of from R/M model. M per region assumed independent and 100% reporting of high reward

Region	Fishery	Fall 2002 F	Spring 2003 F
MA-NY	Com	0.179	0.170
	Rec	0.056	0.160
NJ-DE	Com	0.035	0.010
	Rec	0.280	0.568
MD-VA	Com	0.032	0.019
	Rec	0.022	0.086
Weighted by proportion M per	overal	**0.176**	**0.258**

Alternative weighting

		Fall 2002 F	Spring 2003 F
by % marked per regio		0.183	0.258
Hypothetica	33:33:33	0.168	0.348
Regiona	25:50:25	0.189	0.405
Proportion of	50:25:25	0.175	0.352
	25:25:50	0.138	0.287

Table 22 . Alternative estimation method for black sea bass tag release/recaptures.
Limited to fish at large >7 days, <=365 days; excludes RI recaptures <=14 days;
Released fish >= 28 cm, releases adjusted for 10% tag loss; includes regular and high reward tags;
high reward tags assume 100% reporting; regular tags adjusted for overall reporting rate.

expected recaptures: $E(i,j) = N(i) * St * (1-(\exp(-(F+M))*(tj - ti)))*(F/(F+M))$

solve F such that E(I,j) = R(I,j)

time = Sept. 2002 to Sept. 2003

Fall 2002

10/01/2002 - 9/30/2003

					if commercial high reward reporting rate 80%				if overall reporting rate 10% lower			
Ni	3411			Ni	3411			Ni	3411		
St	1			St	1			St	1		
F	**0.152**	E(I,j)	R(I,j)	F	**0.174**	E(I,j)	R(I,j)	F	**0.169**	E(I,j)	R(I,j)
M	0.2	438.0	438	M	0.2	496.0	495.7	M	0.2	483.0	483
tj	1			tj	1			tj	1		
ti	0	$ rcaps=	34	ti	0	red rcaps=	40	ti	0	red rcaps=	34
Rs	0.636	rcaps=	257	Rs	0.564	or rcaps=	257	Rs	0.572	or rcaps=	257

Spring 2003

6/1/2003 - 5/1/2004

Ni	2261			Ni	2261			Ni	2261		
St	1			St	1			St	1		
F	**0.236**	E(I,j)	R(I,j)	F	**0.276**	E(I,j)	R(I,j)	F	**0.266**	E(I,j)	R(I,j)
M	0.2	433.0	433	M	0.2	497.0	497.2	M	0.2	481.0	481
tj	1			tj	1			tj	1		
ti	0	$ rcaps=	12	ti	0	red rcaps=	22	ti	0	red rcaps=	12
Rs	0.636	rcaps=	268	Rs	0.564	or rcaps=	268	Rs	0.572	or rcaps=	268

Ni # tags released
St tag induced mortality
F fishing mortality
M natural mortality
tj end of time period
ti beginning of time period
Rs reporting rate

Table 23 . AIM results using shortened catch time series.

```
First Year:      1981
Last Year:       2003
Number of Years: 23

Number of Years for Smoothing Abundance Indices: 4
Number of Years for Smoothing Relative F:        1
Number of Realizations for Randomization Test:   1000
Number of Bootstrap Iterations:                  1000
Number of Lags for Auto & Cross-correlation:     7

Relative F Smoothing Method is Lagged
          Catch          SPR WT
1981     1.6900E+00     2.3200E-01
1982     5.6600E+00     4.1000E-02
1983     3.3600E+00     1.2500E-01
1984     2.6200E+00     1.0800E-01
1985     2.5000E+00     1.4700E-01
1986     7.5200E+00     3.5500E-01
1987     2.7600E+00     2.5400E-01
1988     3.1800E+00     3.2800E-01
1989     2.8200E+00     1.4600E-01
1990     2.8400E+00     1.3100E-01
1991     3.1700E+00     7.7000E-02
1992     2.5900E+00     3.0600E-01
1993     3.6100E+00     9.4000E-02
1994     2.2300E+00     8.0000E-02
1995     3.7400E+00     1.5300E-01
1996     3.2800E+00     1.0500E-01
1997     3.1200E+00     2.5000E-01
1998     1.6900E+00     9.1000E-02
1999     2.1000E+00     2.9200E-01
2000     3.0300E+00     1.6100E-01
2001     2.9600E+00     3.8300E-01
2002     3.6300E+00     7.2300E-01
2003     3.3300E+00     8.5200E-01

Base Case Results

       Replacement     Relative
          Ratio          F
1981     N/A          7.2844828
1982     N/A          138.0487805
1983     N/A          26.8800000
1984     N/A          24.2592593
1985     1.1620553    17.0068027
1986     3.3729216    21.1830986
1987     1.3823129    10.8661417
1988     1.5185185    9.6951220
1989     0.5387454    19.3150685
1990     0.4838412    21.6793893
1991     0.3585565    41.1688312
1992     1.7947214    8.4640523
1993     0.5696970    38.4042553
1994     0.5263158    27.8750000
1995     1.0987433    24.4444444
1996     0.6635071    31.2380952
1997     2.3148148    12.4800000
1998     0.6190476    18.5714286
```

```
1999     1.9499165     7.1917808
2000     0.8726287     18.8198758
2001     1.9294710     7.7284595
2002     3.1197411     5.0207469
2003     2.1860167     3.9084507


Simple Regression Results
LN(Replacement Ratio) = A + B * LN(Relative F)

SPR WT
Coefficient                        A               B

Estimated Value                    2.2254E+00    -7.7808E-01
Std Error Coeff                    4.4470E-01     1.5970E-01
t Statistic                        5.0042E+00    -4.8720E+00
p-Value (2 Sided)                  1.0862E-04     1.4335E-04
Variance Inflation Factor          1.8103E+01     1.0000E+00

Relative F (for ln(Replacement Ratio = 0) = 1.746357E+01

Analysis of Variance

Degrees of Freedom for Regression                          1.0000E+00
Degrees of Freedom for Error                               1.7000E+01

Total Degrees of Freedom                                   1.8000E+01
Sum of Squares for Regression                              4.9267E+00
Sum of Squares for Error                                   3.5285E+00
Total Sum of Squares                                       8.4552E+00
Regression Mean Square                                     4.9267E+00
Error Mean Square                                          2.0756E-01
F-Statistic                                                2.3737E+01
p-Value                                                    1.4335E-04
R Squared (percent)                                        5.8268E+01
Adjusted R Squared (percent)                               5.5814E+01
Estimated Standard deviation of model error                4.5559E-01
Mean of response (dependent) variable                      1.1947E-01
Coefficient of Variation (percent)                         3.8134E+02


Least Absolute Value Regression Results

LN(Replacement Ratio) = A + B * LN(Relative F)

SPR WT
Coefficient                        A               B

Estimated Value                    2.3217E+00    -8.3749E-01
Sum of Absolute Value of Error  = 5.4203E+00
Relative F (for ln(Replacement Ratio = 0) = 1.599398E+01
```

Table 24. AIM results when using commercial catch series only.

```
First Year:       1968
Last Year:        2003
Number of Years: 36

Number of Years for Smoothing Abundance Indices: 4
Number of Years for Smoothing Relative F:        1
Number of Realizations for Randomization Test:   1000
Number of Bootstrap Iterations:                  1000
Random Number Generation Seed:                   123456
Number of Lags for Auto & Cross-correlation:     7

Relative F Smoothing Method is Lagged
          Catch          SPR WT
1968     1.2010E+03     5.4000E-02
1969     1.1990E+03     5.8000E-02
1970     1.1000E+03     7.3000E-02
1971     6.1400E+02     5.1000E-02
1972     7.6000E+02     1.5600E-01
1973     1.1610E+03     2.0300E-01
1974     1.0690E+03     6.2100E-01
1975     1.8850E+03     3.1500E-01
1976     1.6900E+03     5.9100E-01
1977     2.4240E+03     3.7900E-01
1978     2.1150E+03     3.3600E-01
1979     1.8750E+03     2.9000E-01
1980     1.2520E+03     2.7700E-01
1981     1.1290E+03     2.3200E-01
1982     1.1770E+03     4.1000E-02
1983     1.5130E+03     1.2500E-01
1984     1.9650E+03     1.0800E-01
1985     1.5510E+03     1.4700E-01
1986     1.9010E+03     3.5500E-01
1987     1.8900E+03     2.5400E-01
1988     1.8790E+03     3.2800E-01
1989     1.3240E+03     1.4600E-01
1990     1.5880E+03     1.3100E-01
1991     1.2720E+03     7.7000E-02
1992     1.3640E+03     3.0600E-01
1993     1.4120E+03     9.4000E-02
1994     8.9600E+02     8.0000E-02
1995     9.2500E+02     1.5300E-01
1996     1.4720E+03     1.0500E-01
1997     1.1860E+03     2.5000E-01
1998     1.1630E+03     9.1000E-02
1999     1.3490E+03     2.9200E-01
2000     1.2310E+03     1.6100E-01
2001     1.3310E+03     3.8300E-01
2002     1.6020E+03     7.2300E-01
2003     1.3960E+03     8.5200E-01
```

Base Case Results

	Replacement Ratio	Relative F
1968	N/A	22240.7407407
1969	N/A	20672.4137931
1970	N/A	15068.4931507
1971	N/A	12039.2156863
1972	2.6440678	4871.7948718
1973	2.4023669	5719.2118227
1974	5.1428571	1721.4170692
1975	1.2221145	5984.1269841
1976	1.8254826	2859.5600677
1977	0.8763006	6395.7783641
1978	0.7051417	6294.6428571
1979	0.7156076	6465.5172414
1980	0.6942356	4519.8555957
1981	0.7238690	4866.3793103
1982	0.1444934	28707.3170732
1983	0.5952381	12104.0000000
1984	0.6400000	18194.4444444
1985	1.1620553	10551.0204082
1986	3.3729216	5354.9295775
1987	1.3823129	7440.9448819
1988	1.5185185	5728.6585366
1989	0.5387454	9068.4931507
1990	0.4838412	12122.1374046
1991	0.3585565	16519.4805195
1992	1.7947214	4457.5163399
1993	0.5696970	15021.2765957
1994	0.5263158	11200.0000000
1995	1.0987433	6045.7516340
1996	0.6635071	14019.0476190
1997	2.3148148	4744.0000000
1998	0.6190476	12780.2197802
1999	1.9499165	4619.8630137
2000	0.8726287	7645.9627329
2001	1.9294710	3475.1958225
2002	3.1197411	2215.7676349
2003	2.1860167	1638.4976526

Simple Regression Results

LN(Replacement Ratio) = A + B * LN(Relative F)

Coefficient	A	B
Estimated Value	8.4237E+00	-9.4919E-01
Std Error Coeff	1.0122E+00	1.1465E-01
t Statistic	8.3222E+00	-8.2788E+00
p-Value (2 Sided)	2.7384E-09	3.0586E-09
Variance Inflation Factor	1.7870E+02	1.0000E+00

Relative F (for ln(Replacement Ratio = 0) = 7.148225E+03

Analysis of Variance

Degrees of Freedom for Regression	1.0000E+00
Degrees of Freedom for Error	3.0000E+01
Total Degrees of Freedom	3.1000E+01
Sum of Squares for Regression	1.2575E+01
Sum of Squares for Error	5.5041E+00
Total Sum of Squares	1.8079E+01
Regression Mean Square	1.2575E+01
Error Mean Square	1.8347E-01
F-Statistic	6.8539E+01
p-Value	3.0586E-09
R Squared (percent)	6.9555E+01
Adjusted R Squared (percent)	6.8540E+01
Estimated Standard deviation of model error	4.2833E-01
Mean of response (dependent) variable	6.7345E-02
Coefficient of Variation (percent)	6.3603E+02

Least Absolute Value Regression Results

LN(Replacement Ratio) = A + B * LN(Relative F)

Coefficient	A	B
Estimated Value	8.6533E+00	-9.7562E-01

Sum of Absolute Value of Error = 1.0706E+01

Relative F (for ln(Replacement Ratio = 0) = 7.112004

Table 25. Yield per recruit of black sea bass, assuming M=0.2.

Proportion Fishing Mortality Before Spawning = 0.53
Proportion Natural Mortality Before Spawning = 0.30

Age	Selectivity F	Selectivity M	Stock Weight	Catch Weight	Maturity
1	0.0000	1.00	0.0590	0.0640	0.10
2	0.1020	1.00	0.1620	0.1770	0.65
3	0.6780	1.00	0.3700	0.3210	0.90
4	0.9550	1.00	0.6540	0.5240	1.00
5	1.0000	1.00	0.8030	0.7980	1.00
6	1.0000	1.00	1.1960	1.2540	1.00
7	1.0000	1.00	1.0310	1.1320	1.00
8	1.0000	1.00	1.6560	1.4370	1.00
9	1.0000	1.00	1.8360	1.9310	1.00
10	1.0000	1.00	1.9970	1.9970	1.00
11	1.0000	1.00	2.1630	2.1630	1.00
12	1.0000	1.00	2.3800	2.3800	1.00
13	1.0000	1.00	2.5750	2.5750	1.00
14	1.0000	1.00	2.7470	2.7470	1.00
15	1.0000	1.00	2.8980	2.8980	1.00

Reference Point	F	YPR	SSBR	Mean Age	Mean Gen T	Exp Spawn
F Zero	0.000	0.000	3.828	4.731	8.297	3.265
F-01	0.187	0.261	1.628	3.405	6.339	1.937
F-Max	**0.329**	0.280	1.048	2.915	5.340	1.502
F at 20 %MSP	0.465	0.274	0.766	2.638	4.706	1.255

BLACK SEA BASS FIGURES

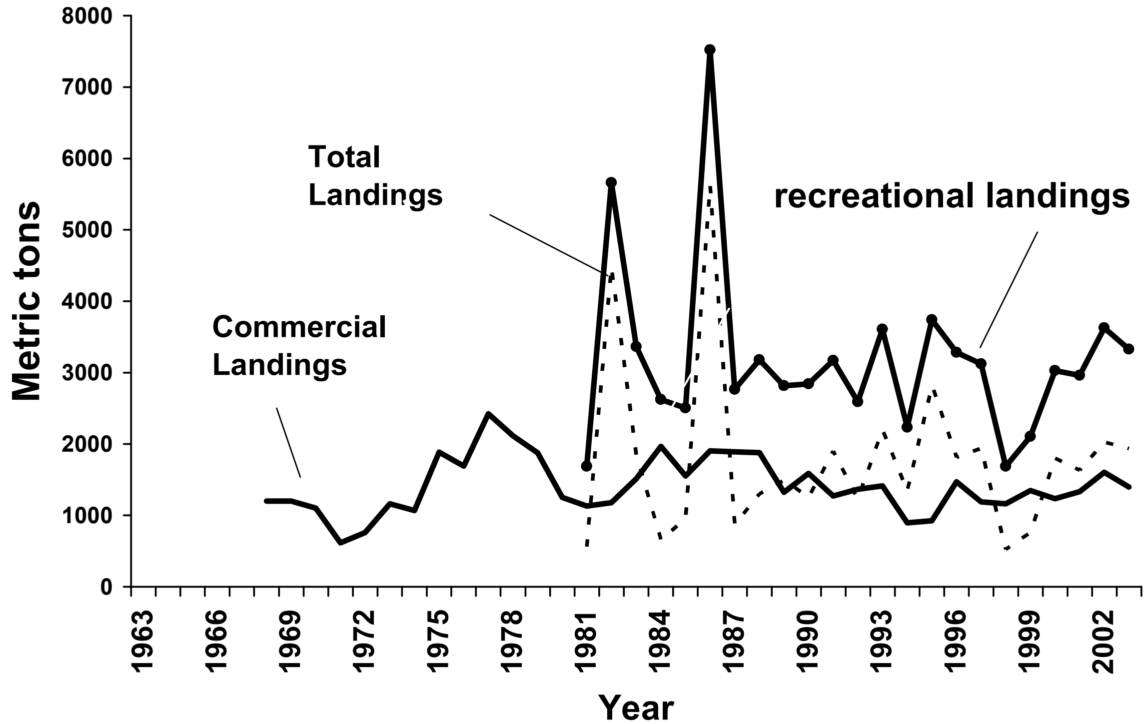


Figure 1. Landings of the northern stock of black sea bass in mt.

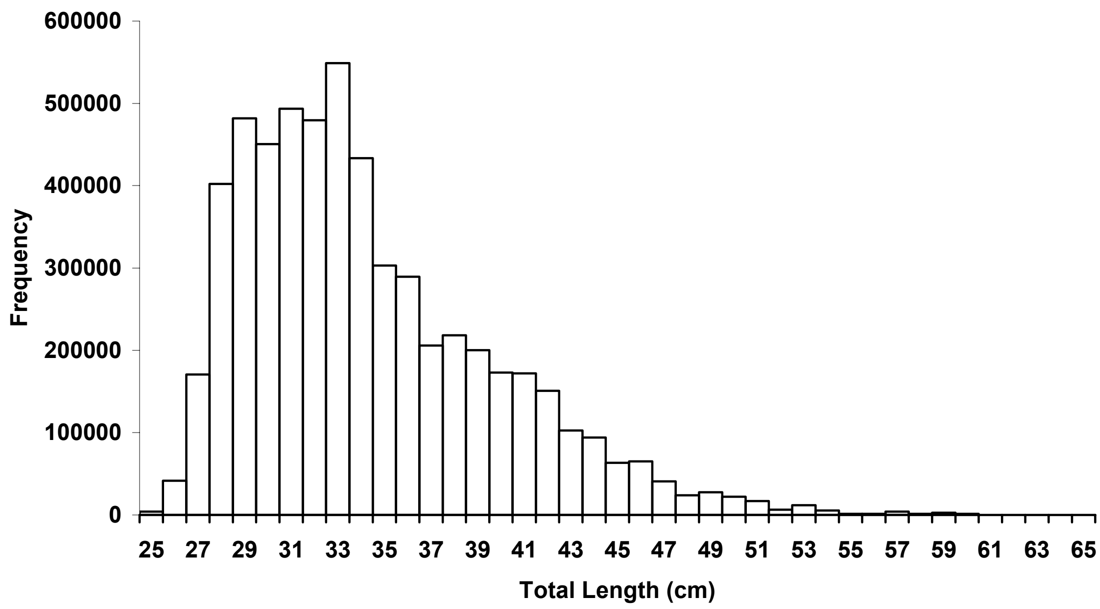


Figure 2 . 2002 commercial black sea bass landings length distribution.

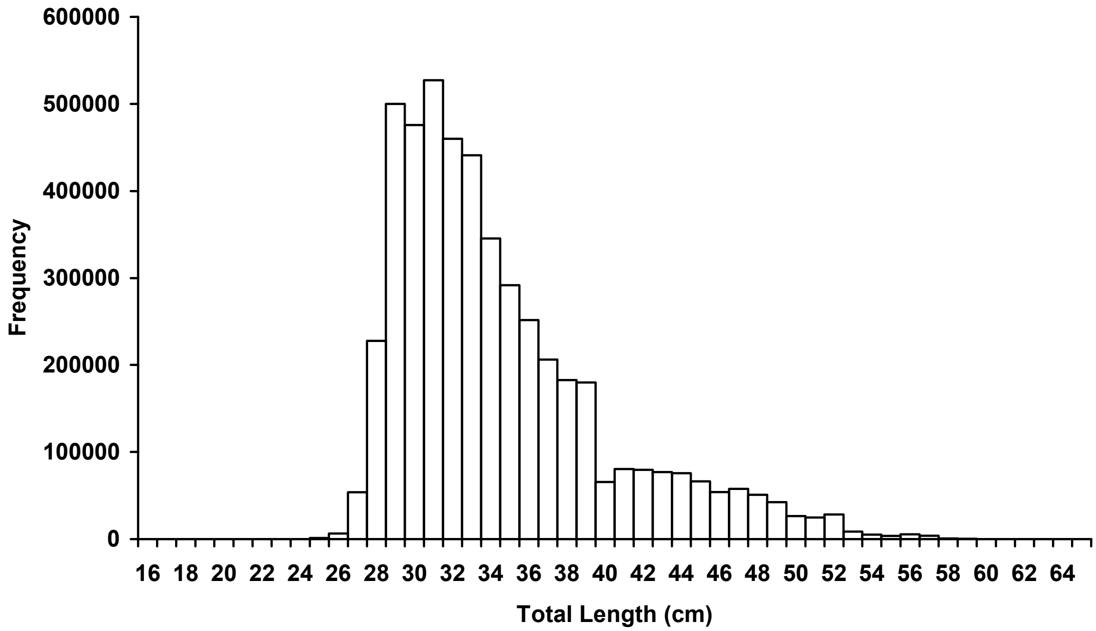


Figure 3. 2003 commercial black sea bass landings length distribution.

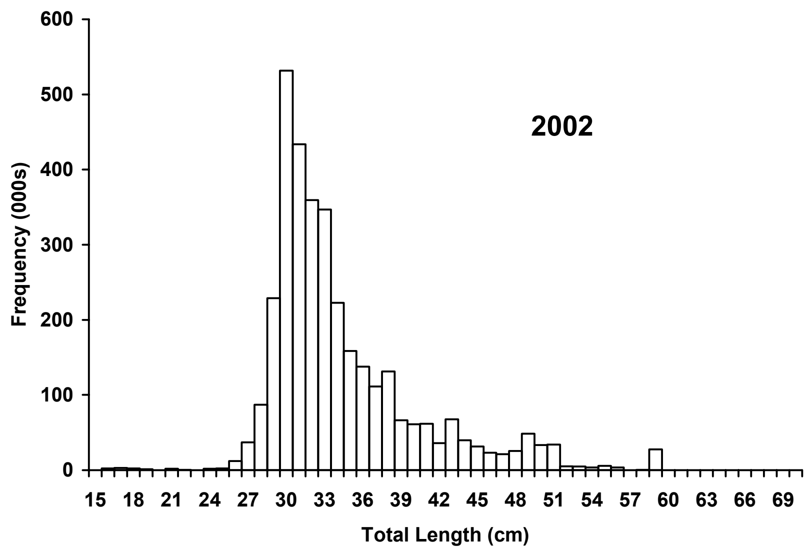


Figure 4. 2002 length frequency of black sea bass recreational landings.

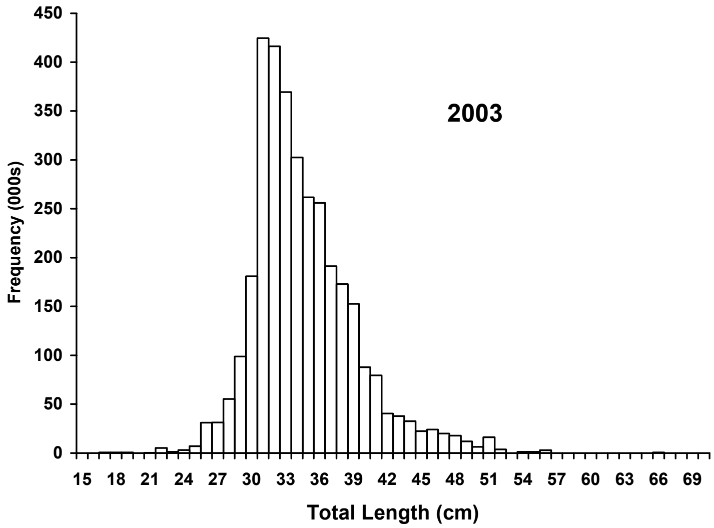


Figure 5. 2003 length frequency of black sea bass recreational landings.

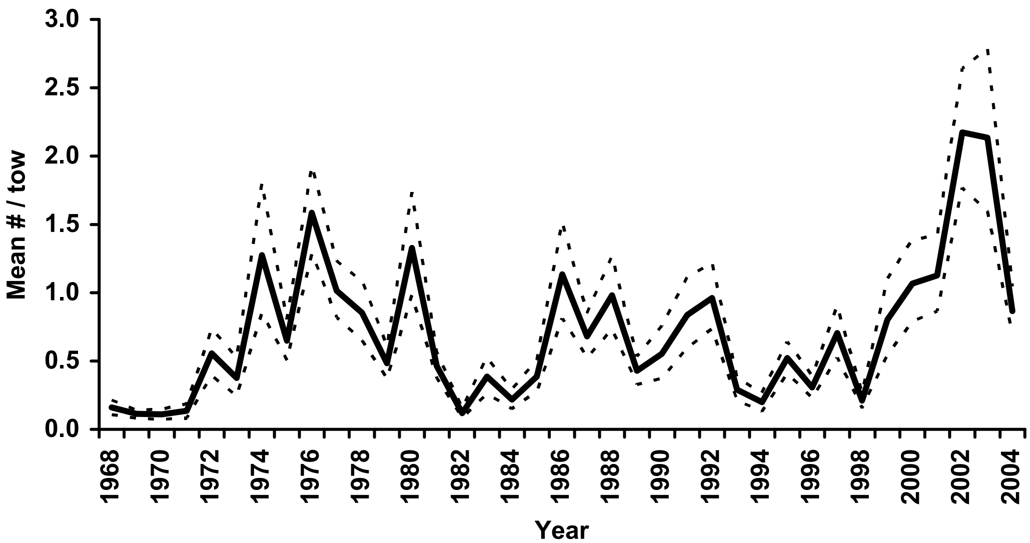


Figure 6. NEFSC spring offshore ln re-transformed mean number per tow of black sea bass, ± 95% confidence intervals.

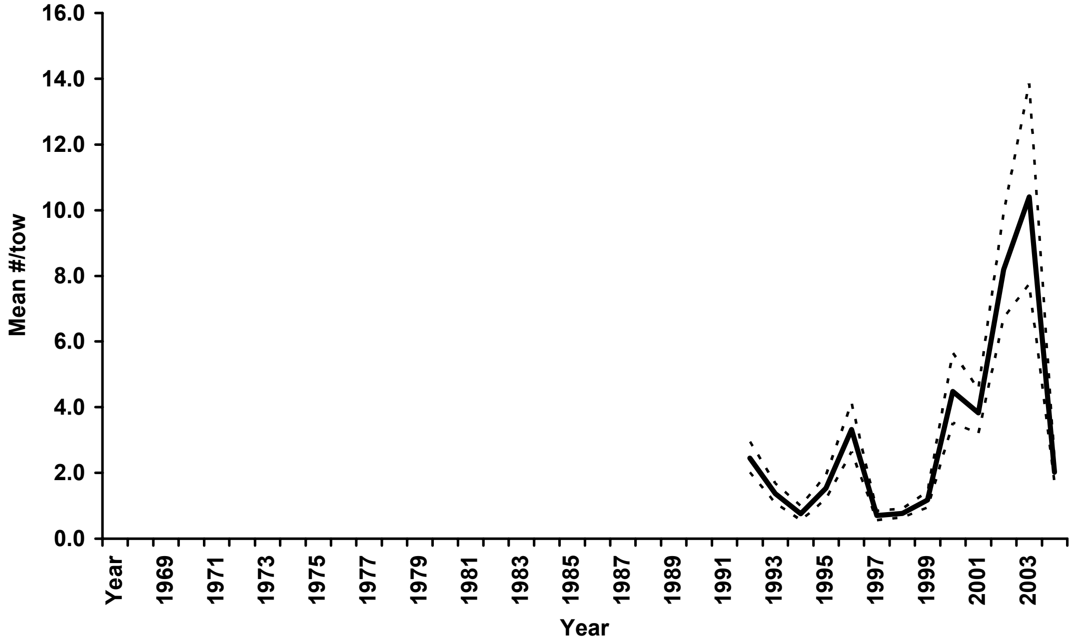


Figure 7. NEFSC winter survey ln re-transformed mean number per tow of black sea bass, $\pm$ 95% confidence intervals.

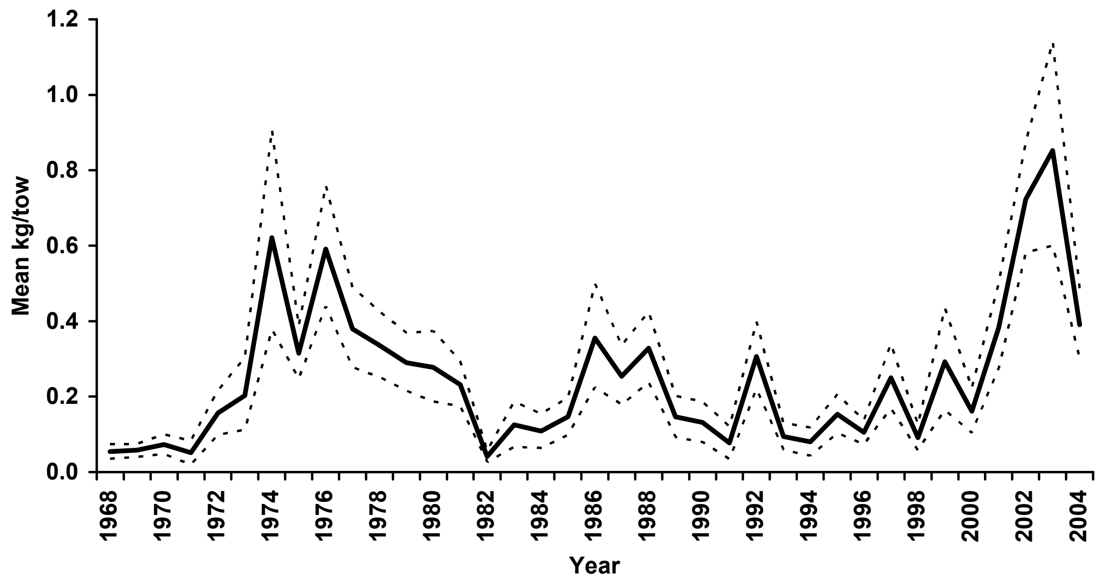


Figure 8. NEFSC spring offshore ln re-transformed mean weight (kg) per tow of black sea bass, $\pm$ 95% confidence intervals.

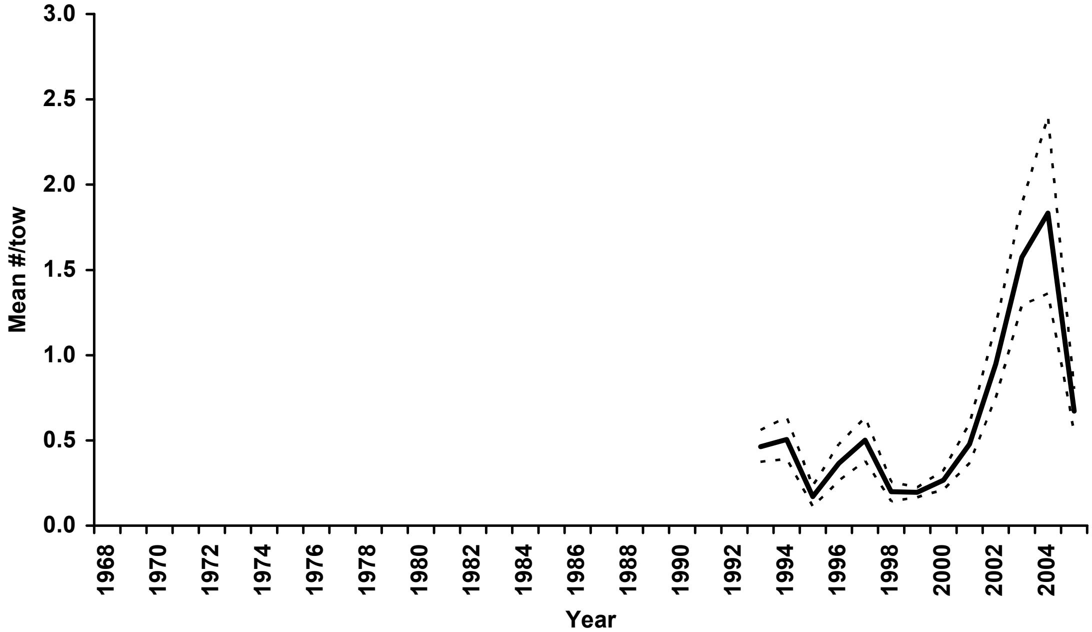


Figure 9. NEFSC winter survey ln re-transformed mean weight (kg) per tow of black sea bass, + 95% confidence intervals.

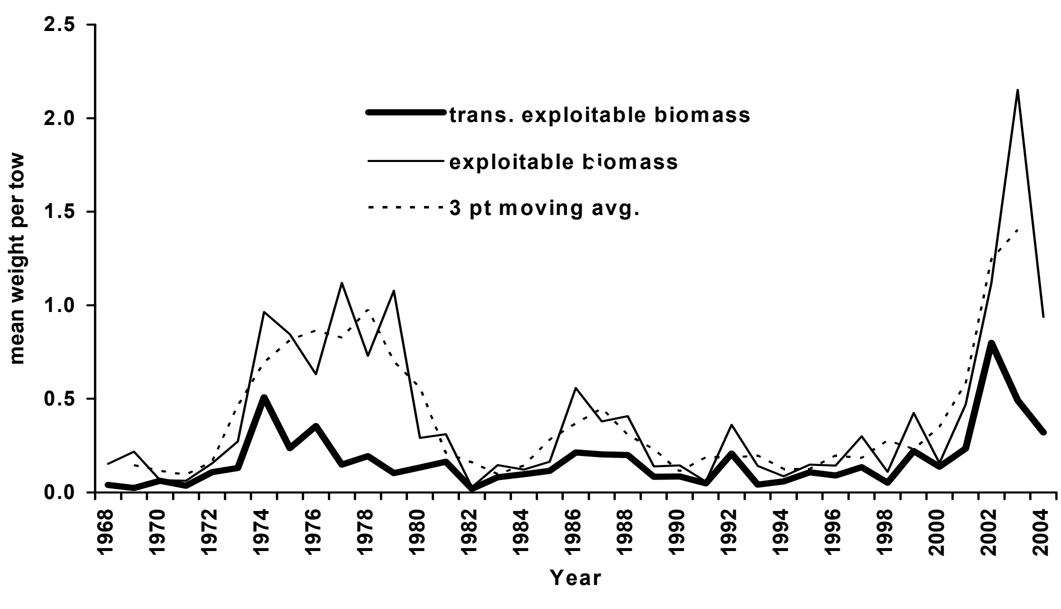
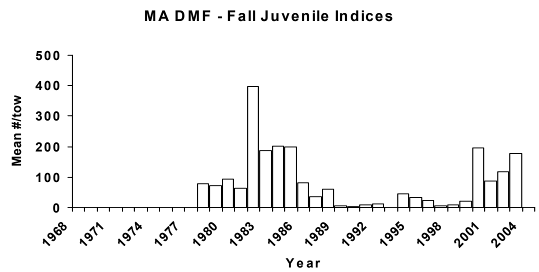
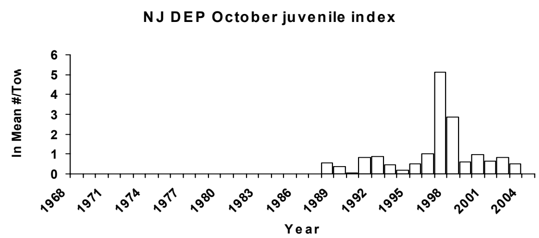
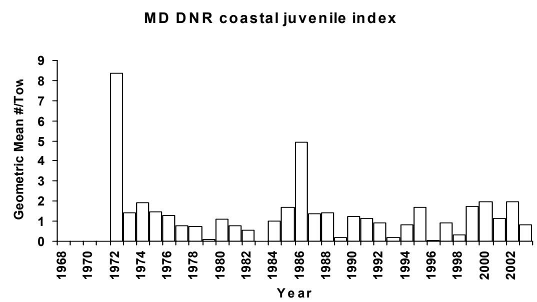
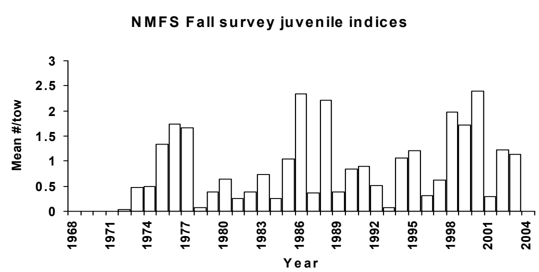


Figure 10. NEFSC spring offshore survey black sea bass index of exploitable biomass, (≥22 cm), 3 point moving average and ln re-transformed exploitable biomass.


MA DMF - Fall Juvenile Indices
Mean #/tow
Year


NJ DEP October juvenile index
ln Mean #/Tow
Year


MD DNR coastal juvenile index
Geometric Mean #/Tow
Year


NMFS Fall survey juvenile indices
Mean #/tow
Year

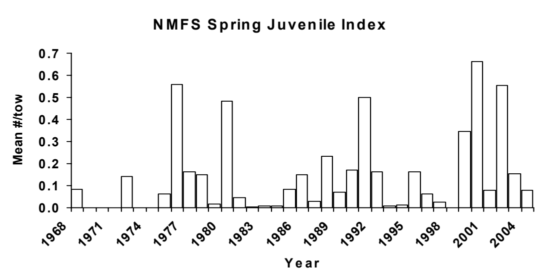
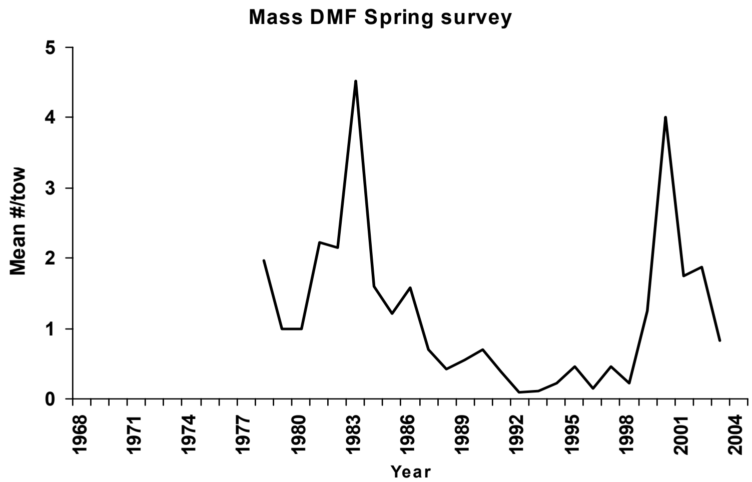
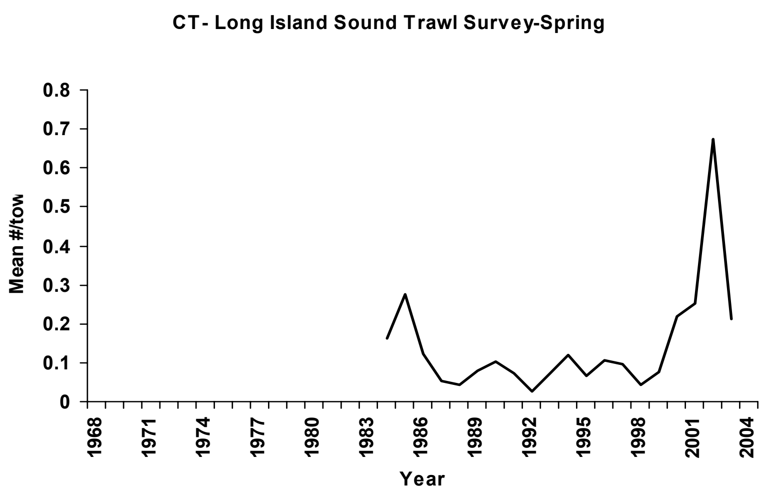

NMFS Spring Juvenile Index
Mean #/tow
Year

Figure 11. Juvenile abundance indices from state and federal surveys.





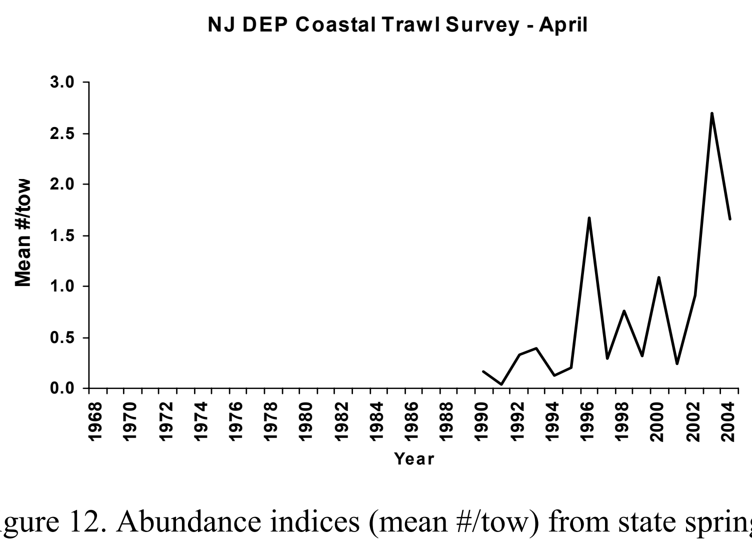


Figure 12. Abundance indices (mean #/tow) from state spring surveys.

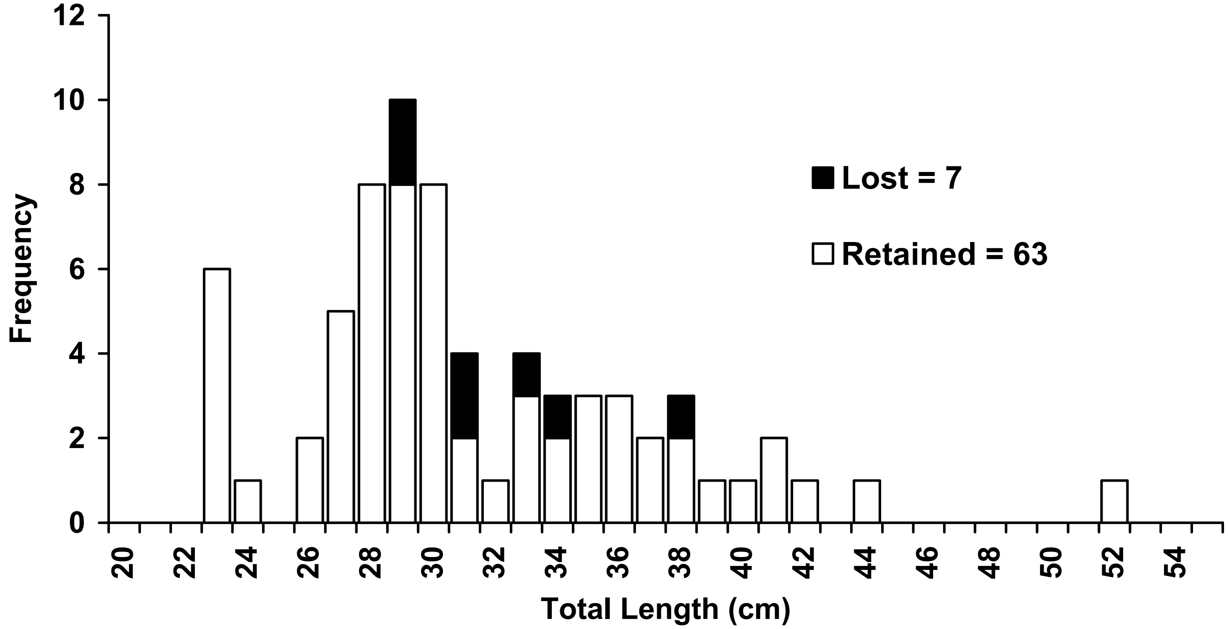
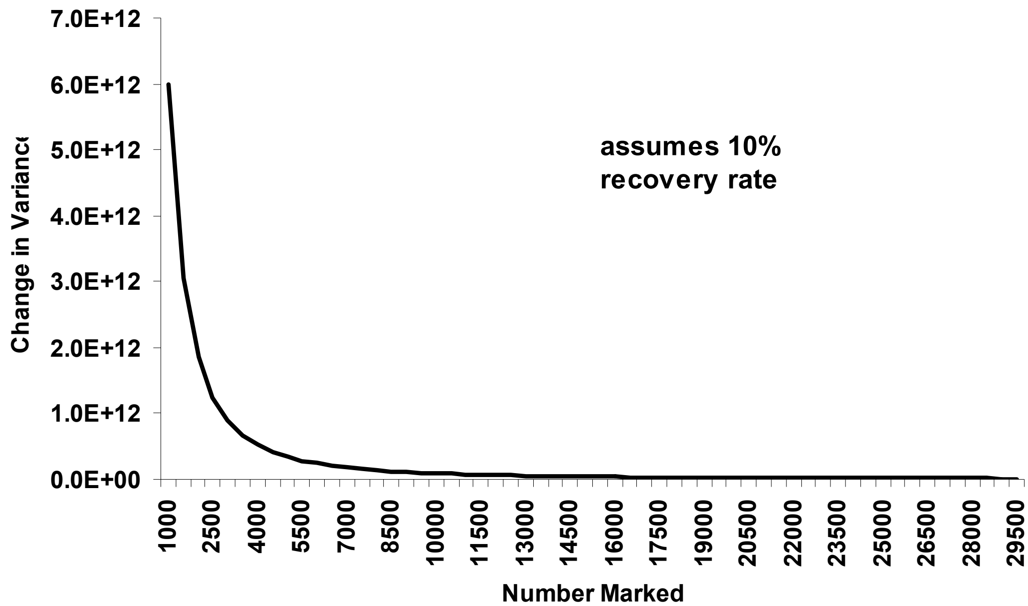


Figure 13. Sum of length distribution of black sea bass used in tag retention experiments. Fate of tags as indicated.



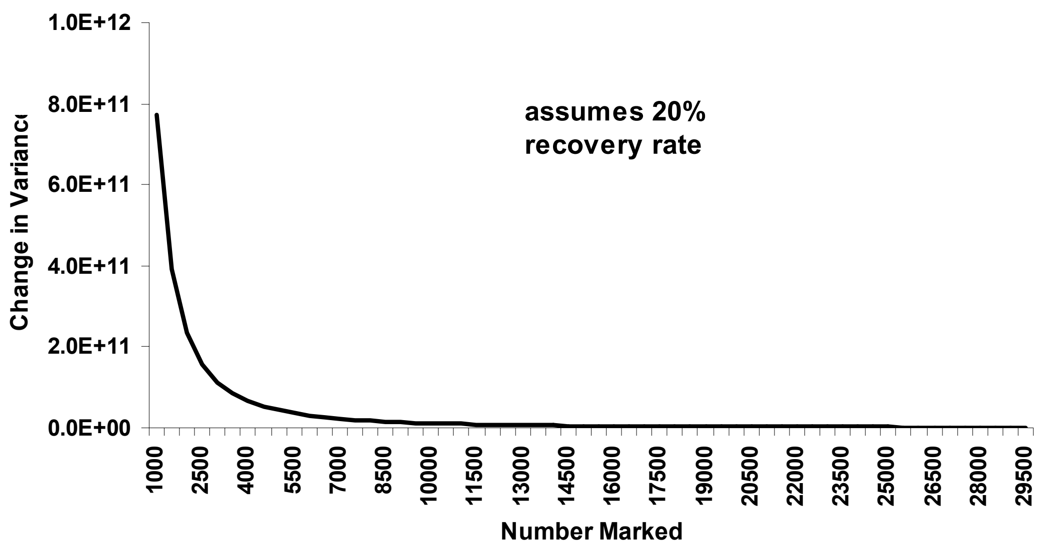


Figure 14. Effect on variance of N with changes in sample size under 2 recovery rate assumptions.

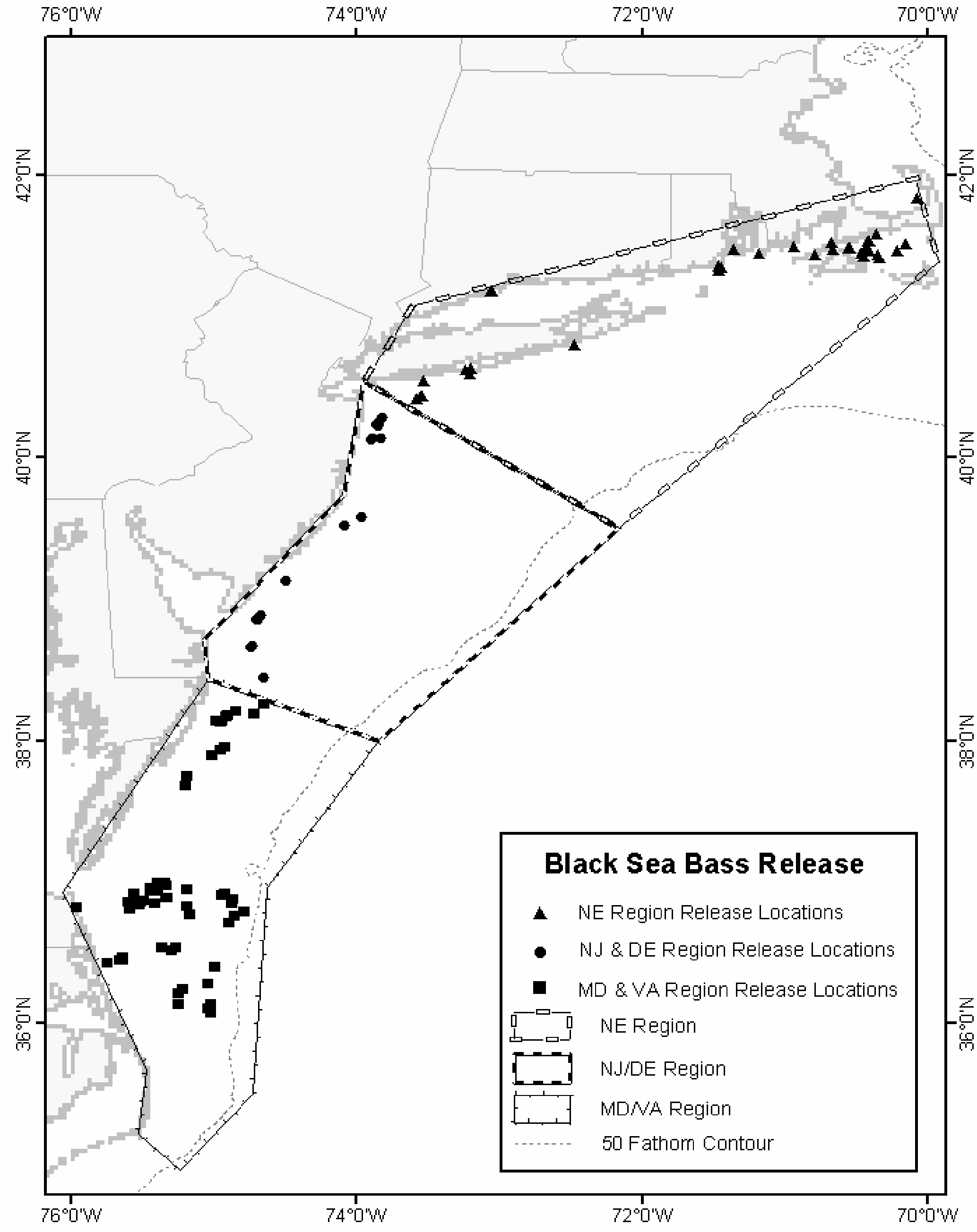


Figure 15. Geographic distribution of black sea bass tag releases. Three regions indicated.

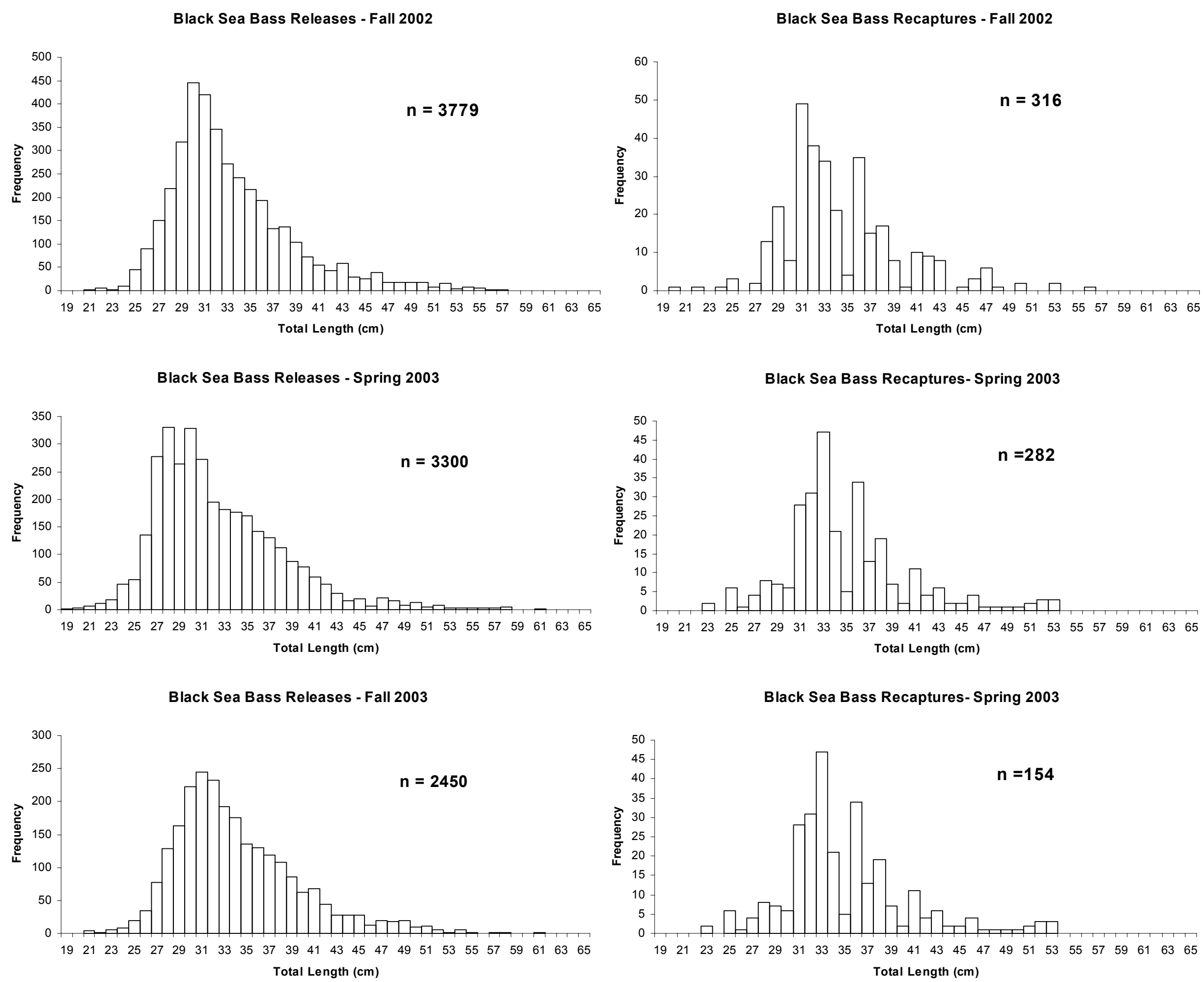


Figure 16. Length distributions of tagged and released black sea bass and subsequent recapture sizes.

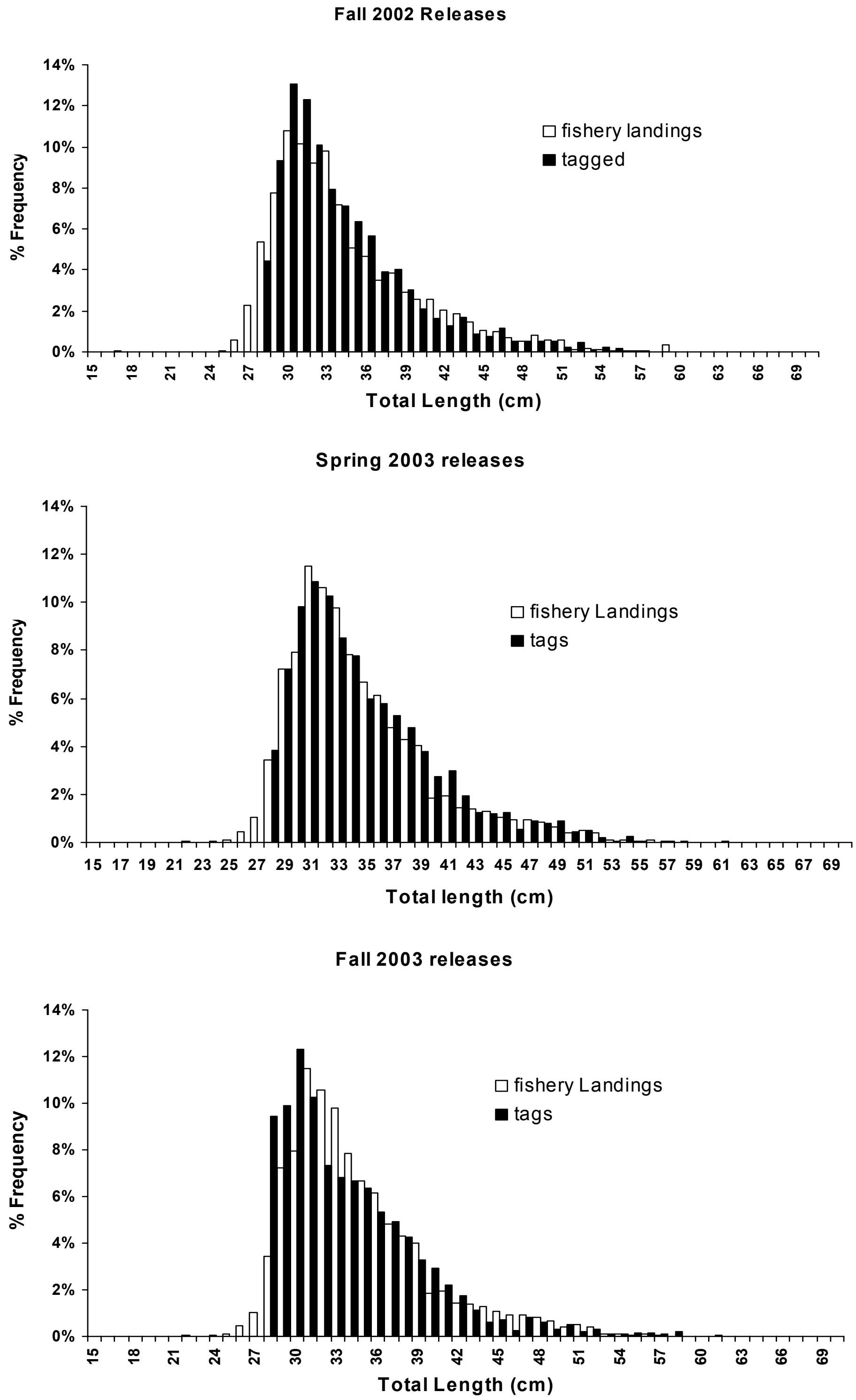


Figure17. Comparison between length distributions of tagged black sea bass and fishery landings.

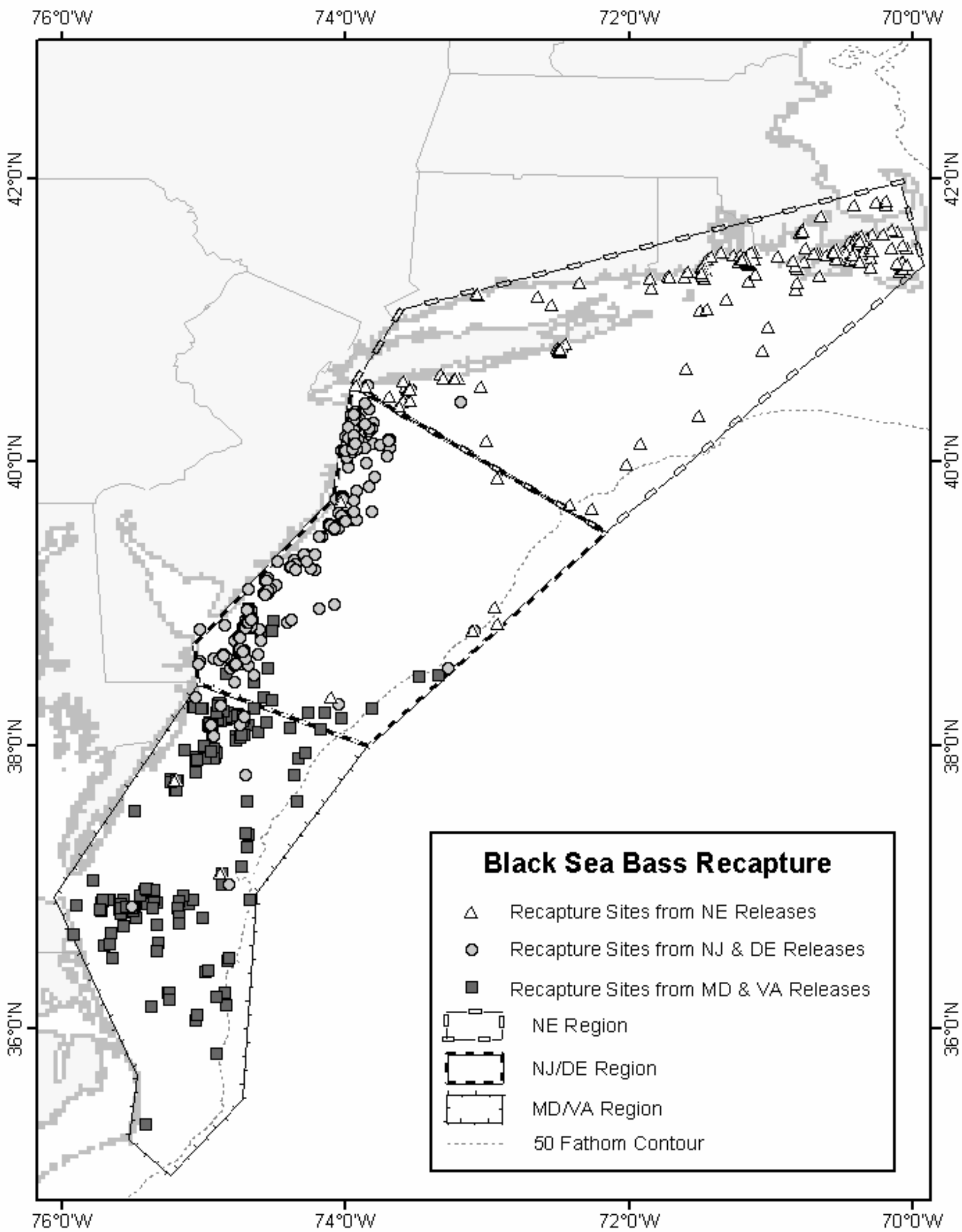
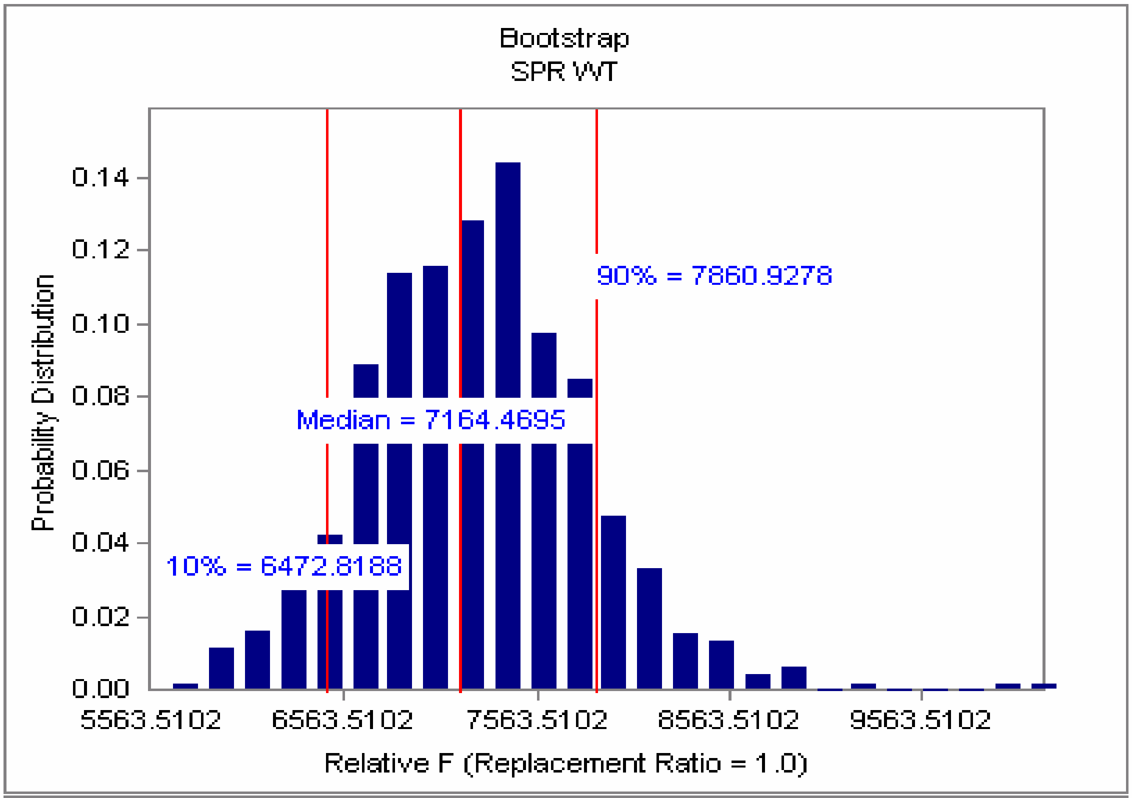


Figure18. Geographic distributions of recaptured black sea bass for all releases combined.



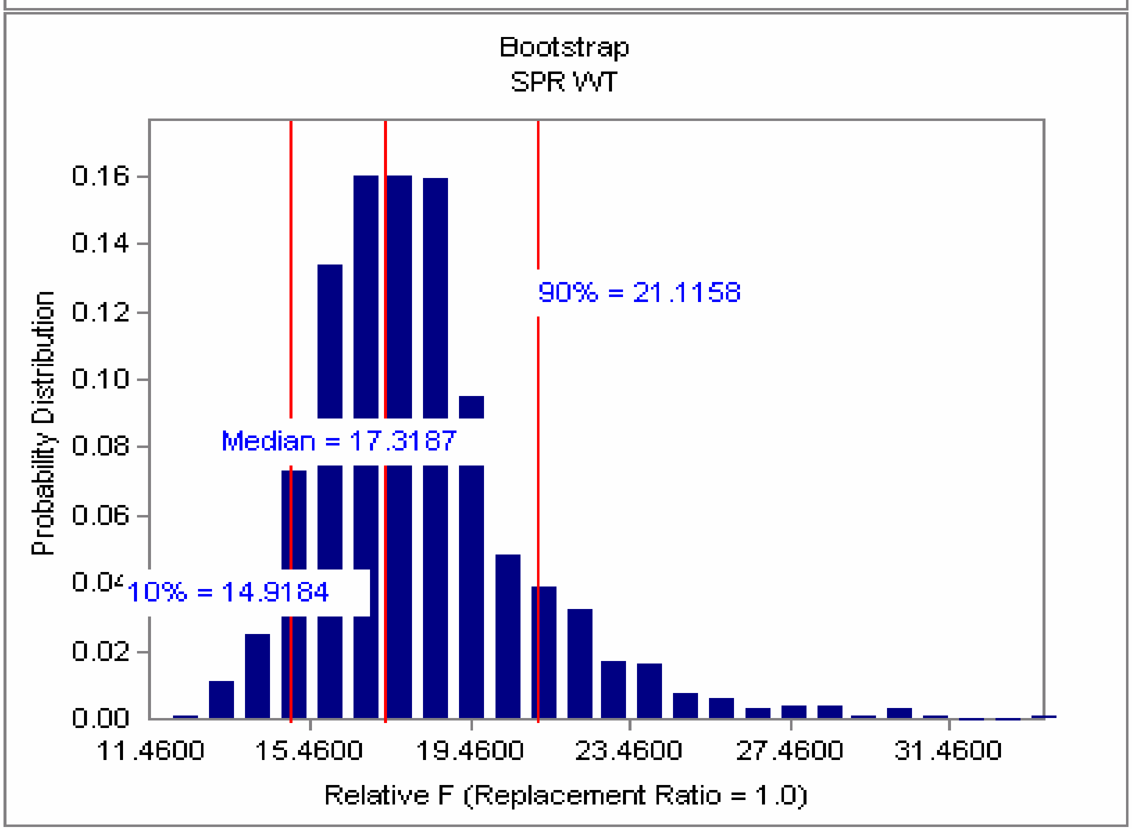


Figure19. Bootstrap distributions of relative Fs using AIM model. Top graph for commercial landings series, bottom for shorter total landings.

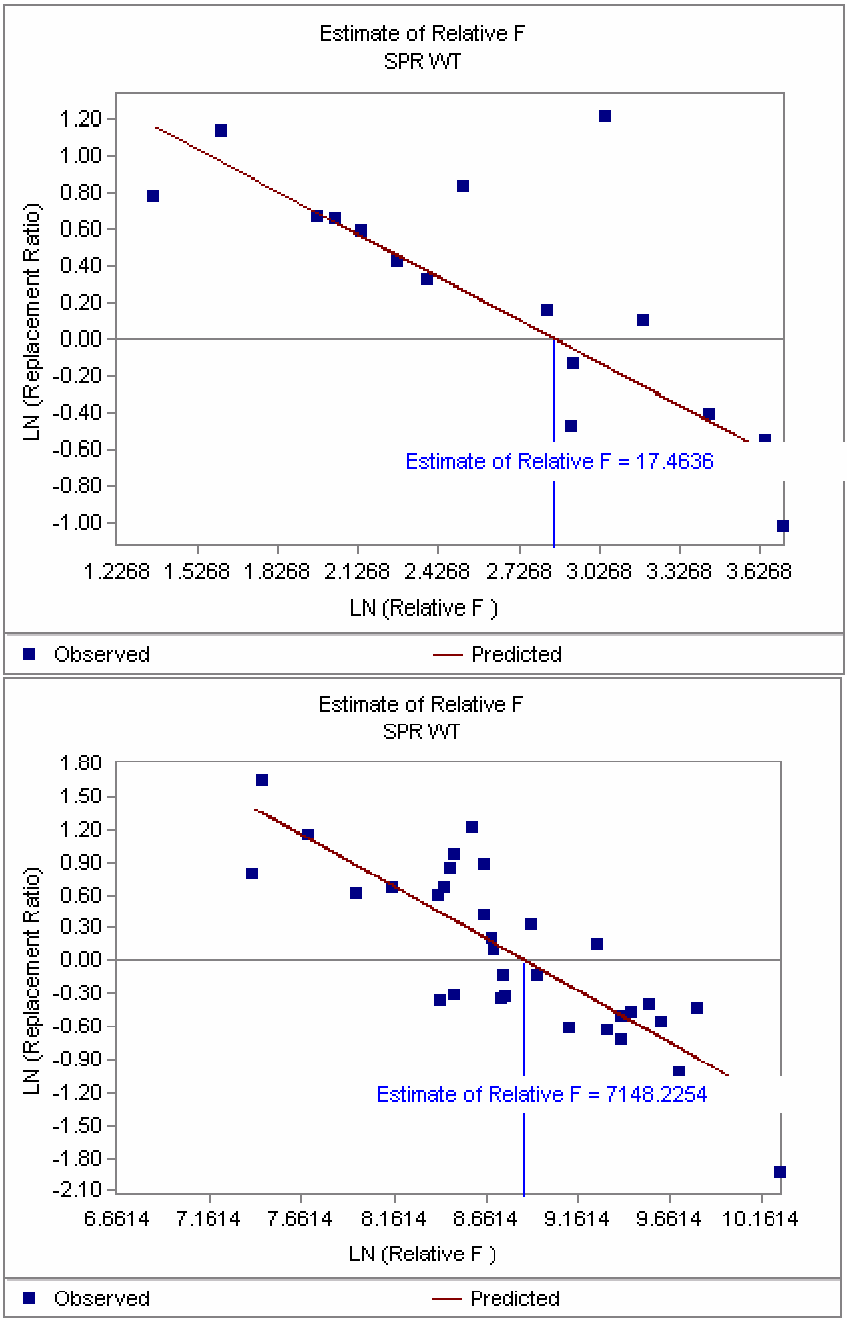
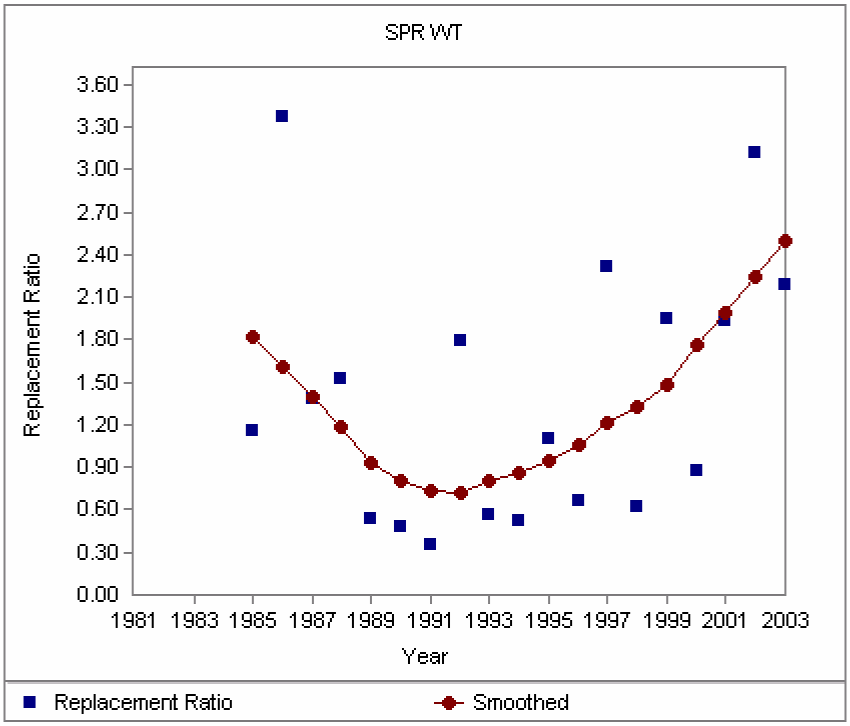


Figure 20. Relationship between relative F and associated replacement ratio. Top graph uses total landings series and bottom commercial landings only.



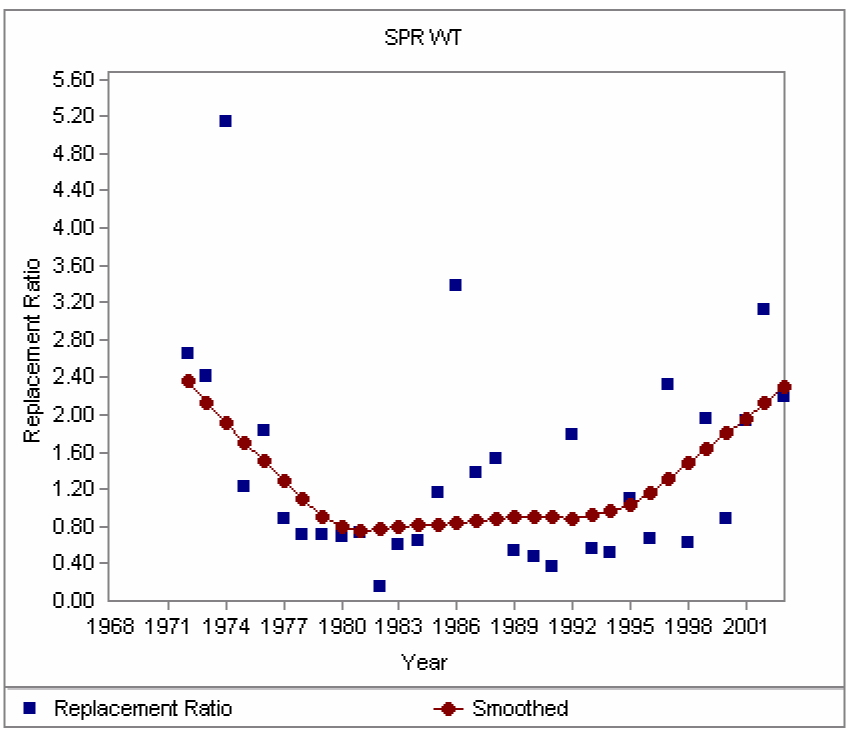


Figure 21. Time series of replacement ratios from AIM model and Lowess smoothed average. Top figure for total landings and bottom for commercial landings series.

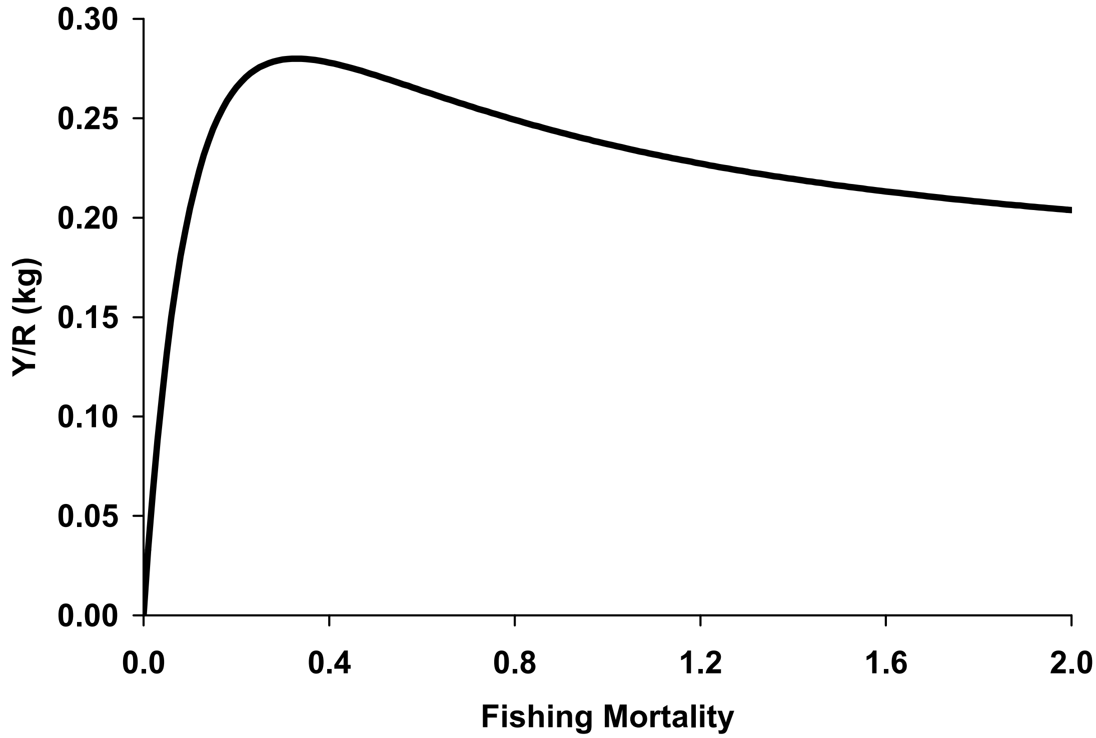
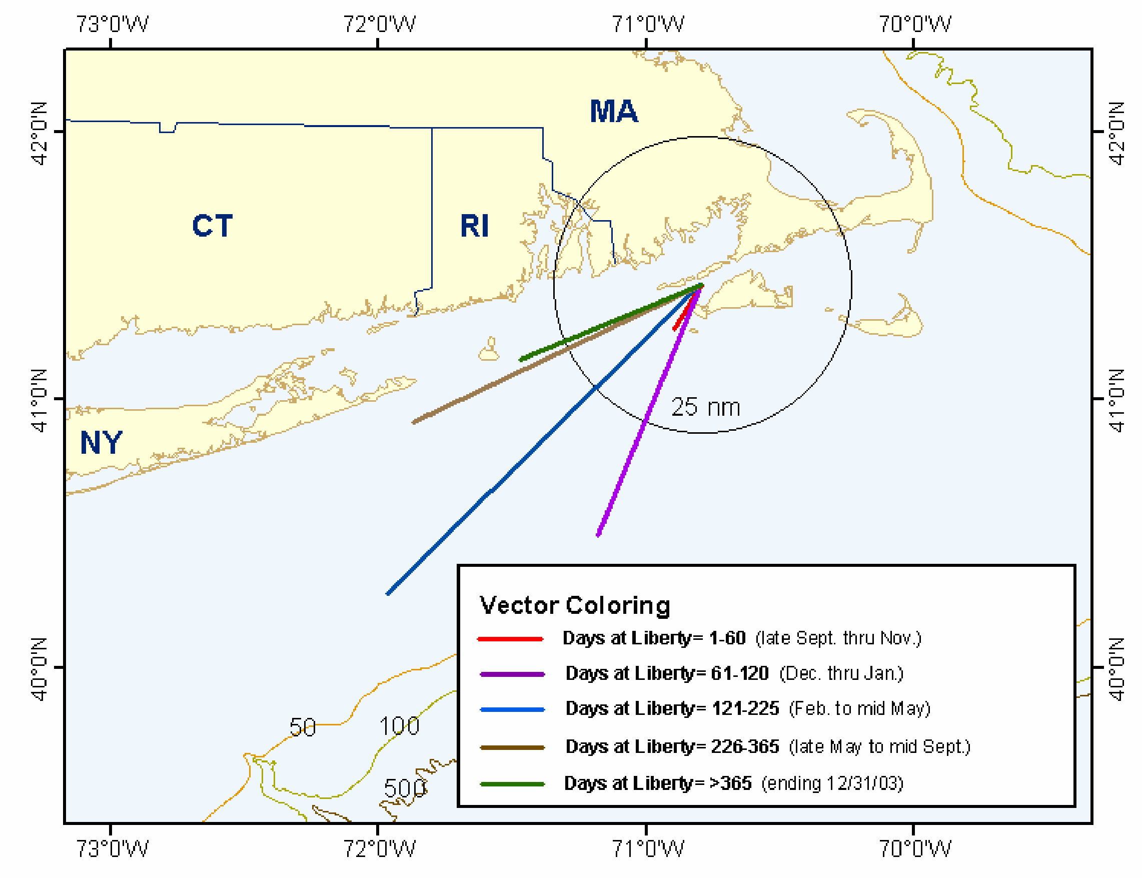


Figure 22. Yield per recruit (kg) for black sea bass. Age at full recruitment equals 5 (96% at age 4). Fmax = 0.33.

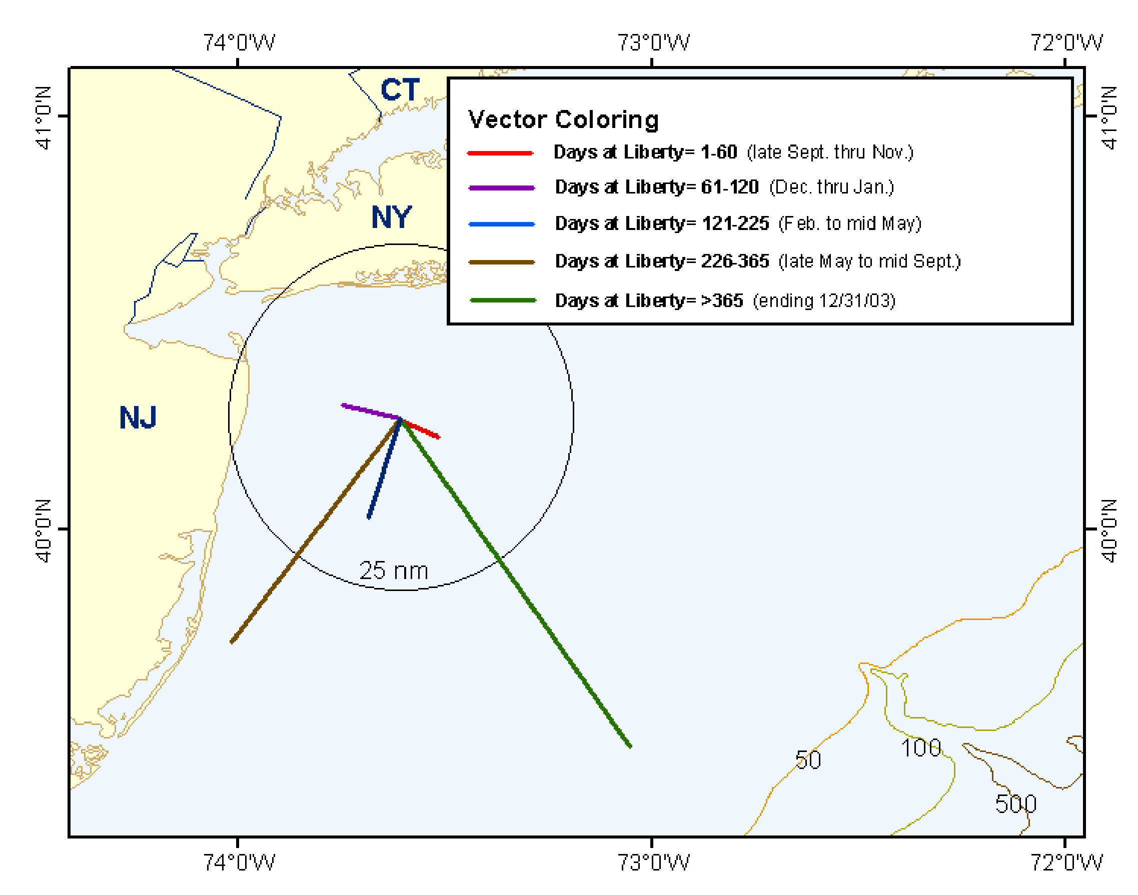
Appendix I. Black Sea Bass Region Vector Summary

Figure A1.
New England Region (MA, RI, CT releases):



Total releases: 2511		
Total recaptures: 289		
Recapture rate: 11.5%		
Distance Traveled	Max: 234 nm	Mean: 19.6 nm
Days at Liberty	Max: 402	Mean: 73
Dist./Day	Max: 9.9 nm/day	Mean: 0.7 nm/day

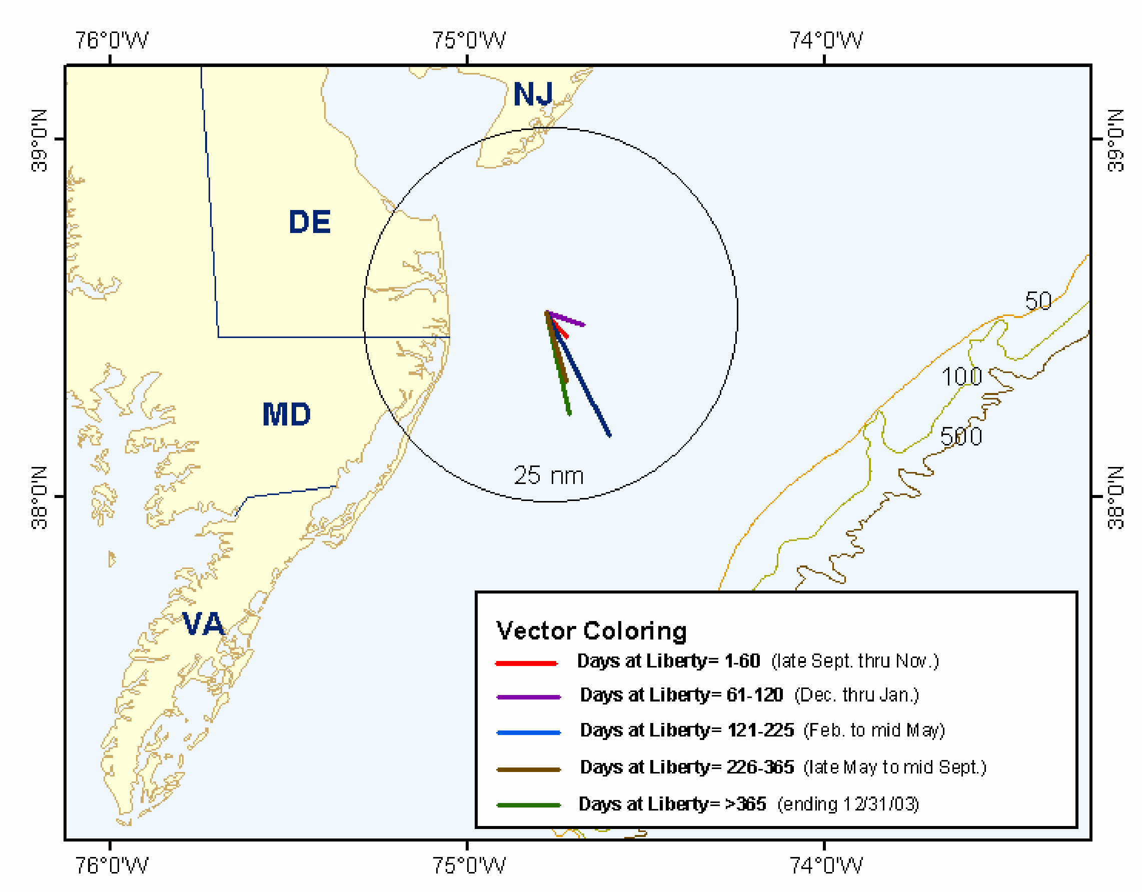
Figure A2.
Long Island-N. NJ Region:



Total releases: 953
Total recaptures: 125
Recapture rate: 13.1%

Distance Traveled	Max: 171 nm	Mean: 8.3 nm
Days at Liberty	Max: 421	Mean: 44
Dist./Day	Max: 7.8 nm/day	Mean: 0.4 nm/day

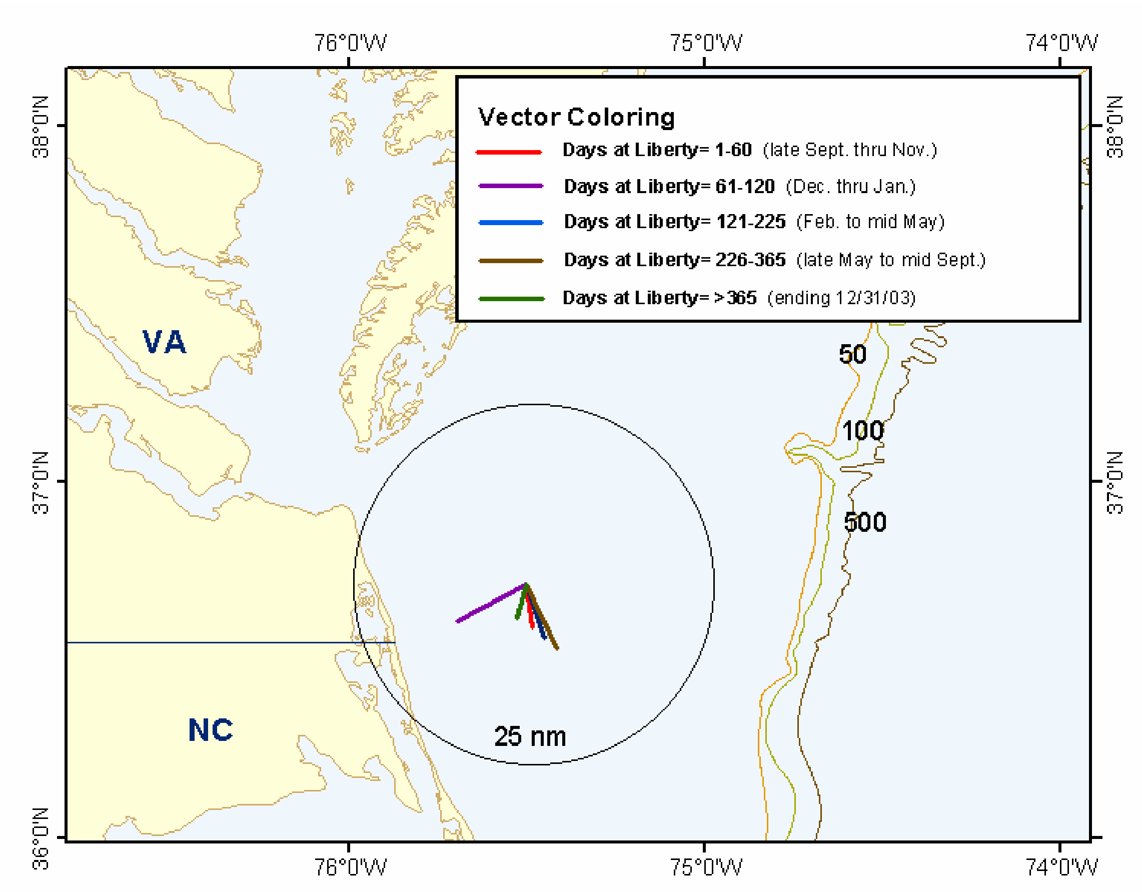
Figure A3.
Cape May-Delmarva Peninsula Region:



Total releases: 2812
Total recaptures: 339
Recapture rate: 12.1%

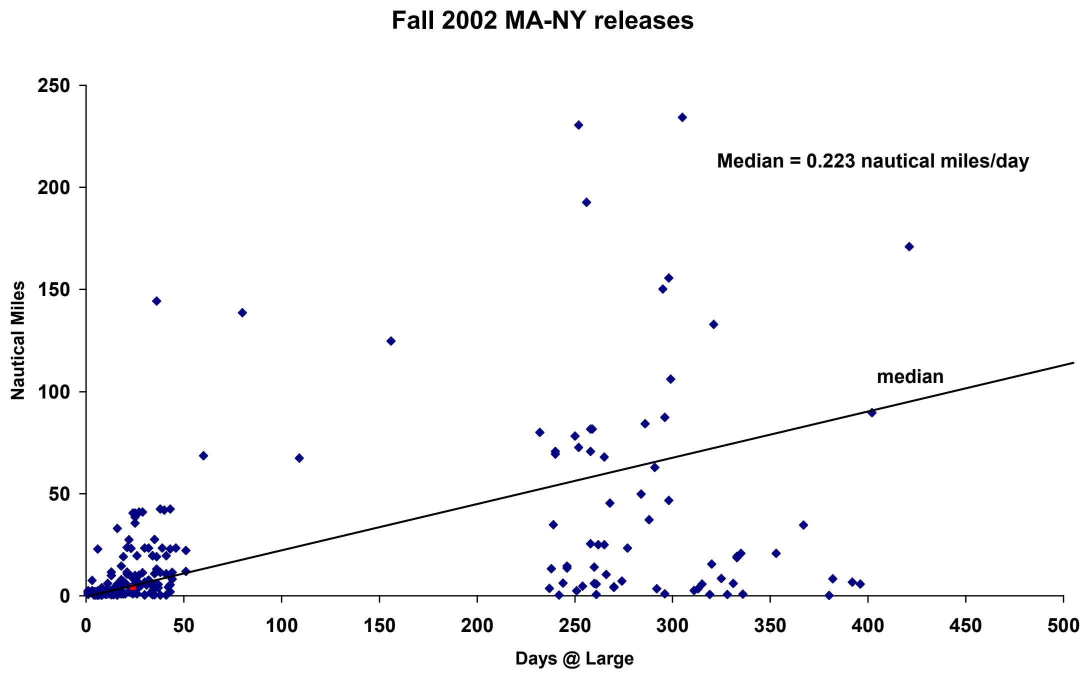
Distance Traveled	Max: 182 nm	Mean: 8.9 nm
Days at Liberty	Max: 470	Mean: 117
Dist./Day	Max: 10.1 nm/day	Mean: 0.2 nm/day

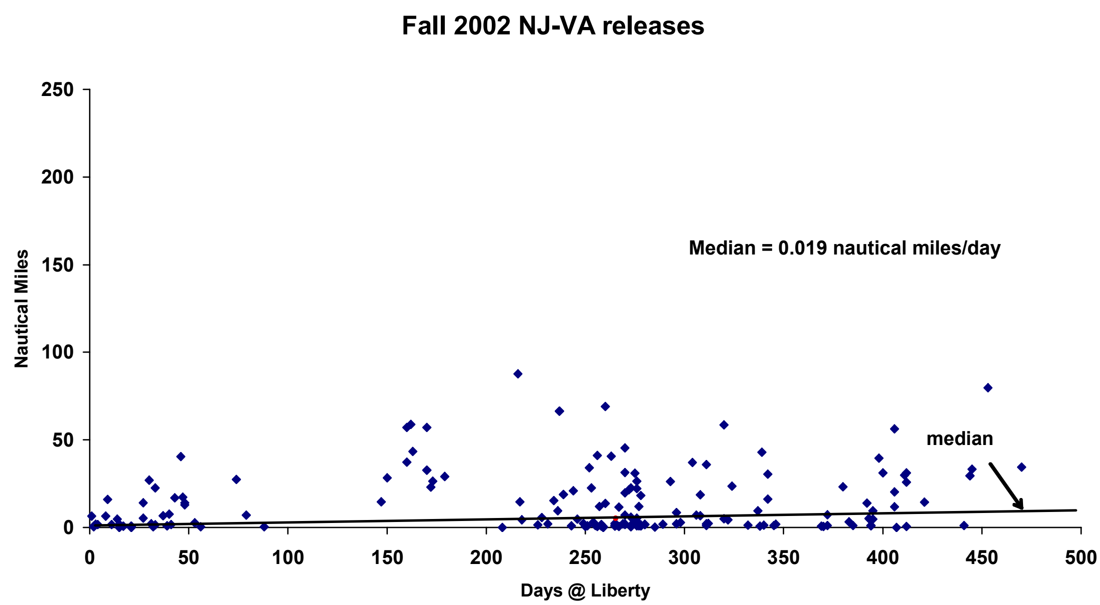
Figure A4.
Virginia Beach Region:



Total releases: 819
Total recaptures: 103
Recapture rate: 12.6%

Distance Traveled	Max: 62 nm	Mean: 7.1 nm
Days at Liberty	Max: 406	Mean: 89
Dist./Day	Max: 1.8 nm/day	Mean: 0.2 nm/day


Fall 2002 MA-NY releases
Median = 0.223 nautical miles/day
median
Nautical Miles
Days @ Large
0
50
100
150
200
250
300
350
400
450
500


Fall 2002 NJ-VA releases
Median = 0.019 nautical miles/day
median
Nautical Miles
Days @ Liberty
0
50
100
150
200
250
300
350
400
450
500

Appendix II. Log-linear model results of black sea bass reporting rates using SAS CATMOD.

Response	type*region*fate	Response Levels	17
Weight Variable	count	Populations	1
Data Set	NEWFATE	Total Frequency	5672
Frequency Missing	0	Observations	30

Type 1= regular tags
2= High reward tags

Region 1= MA - NY
2= NJ - DE
3= MD - NC

Fate 1= not removed
2= Recreational killed
3= Commercial killed

Sample	Sample Size
1	5672

Response Profiles

Response	type	region	fate
1	1	1	1
2	1	1	2
3	1	1	3
4	1	2	1
5	1	2	2
6	1	2	3
7	1	3	1
8	1	3	2
9	1	3	3
10	2	1	1
11	2	1	2
12	2	1	3
13	2	2	1
14	2	2	2
15	2	3	1
16	2	3	2
17	2	3	3

Response Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	1	0	1	0	1	0	1	0	1	0	0	0	1	0	0	0
2	1	1	0	1	0	0	1	0	1	0	1	0	0	0	1	0	0
3	1	1	0	1	0	-1	-1	-1	-1	-1	-1	0	0	-1	-1	0	0
4	1	0	1	0	1	1	0	1	0	0	0	1	0	0	0	1	0
5	1	0	1	0	1	0	1	0	1	0	0	0	1	0	0	0	1
6	1	0	1	0	1	-1	-1	-1	-1	0	0	-1	-1	0	0	-1	-1
7	1	-1	-1	-1	-1	1	0	1	0	-1	0	-1	0	-1	0	-1	0
8	1	-1	-1	-1	-1	0	1	0	1	0	-1	0	-1	0	-1	0	-1
9	1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1
10	-1	1	0	-1	0	1	0	-1	0	1	0	0	0	-1	0	0	0
11	-1	1	0	-1	0	0	1	0	-1	0	1	0	0	0	-1	0	0
12	-1	1	0	-1	0	-1	-1	1	1	-1	-1	0	0	1	1	0	0
13	-1	0	1	0	-1	1	0	-1	0	0	0	1	0	0	0	-1	0
14	-1	0	1	0	-1	0	1	0	-1	0	0	0	1	0	0	0	-1
15	-1	-1	-1	1	1	1	0	-1	0	-1	0	-1	0	1	0	1	0
16	-1	-1	-1	1	1	0	1	0	-1	0	-1	0	-1	0	1	0	1
17	-1	-1	-1	1	1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1

The CATMOD Procedure

Maximum Likelihood Analysis

Iteration	Sub Iteration	-2 Log Likelihood	Convergence Criterion	Parameter Estimates 1	2	3	4	5	6	7
0	0	32139.972	1.0000	0	0	0	0	0	0	0
1	0	28815.127	0.1034	1.0383	0.1561	-0.8102	-0.2790	0.0859	1.9389	-0.6516
2	3	20076.527	0.3033	1.3433	0.5228	-1.0404	-0.4736	1.0372	3.0646	-0.9324
3	1	17004.075	0.1530	1.2685	0.4945	-0.5834	-0.1467	0.0624	2.6155	-0.9882
4	0	16836.472	0.009857	1.2551	0.4798	-0.3948	-0.2055	0.0595	2.5373	-1.0366
5	0	16831.238	0.000311	1.2677	0.4950	-0.4155	-0.2055	0.0496	2.5308	-1.0236
6	0	16831.235	1.9593E-7	1.2680	0.4953	-0.4159	-0.2055	0.0493	2.5306	-1.0232
7	0	16831.235	3.009E-13	1.2680	0.4953	-0.4159	-0.2055	0.0493	2.5306	-1.0232

Maximum Likelihood Analysis

Parameter Estimates

Iteration	8	9	10	11	12	13	14	15	16	17
0	0	0	0	0	0	0	0	0	0	0
1	1.3170	-0.9698	-0.3634	-0.2051	-0.3951	0.9111	0.0397	0.2330	-1.1135	0
2	-0.2602	-0.3856	-0.7323	-1.1457	-0.1741	2.3430	-0.2280	-0.0979	-0.3736	0
3	0.0339	-0.0404	-0.3696	-0.8414	-0.3318	1.6768	0.1070	-0.1112	0.0871	0
4	0.1272	-0.1088	-0.4156	-0.6869	-0.1882	1.5067	0.1077	-0.1987	0.0679	0
5	0.1264	-0.1048	-0.3951	-0.7218	-0.1868	1.5375	0.0964	-0.1791	0.0510	0
6	0.1266	-0.1049	-0.3946	-0.7227	-0.1864	1.5381	0.0961	-0.1785	0.0503	0
7	0.1266	-0.1049	-0.3946	-0.7227	-0.1864	1.5381	0.0961	-0.1785	0.0503	0

Maximum likelihood computations converged.

Maximum Likelihood Analysis of Variance

Source	DF	Chi-Square	Pr > ChiSq
type	1	213.55	<.0001
region	2	13.86	0.0010
type*region	2	3.17	0.2054
fate	2	681.20	<.0001
type*fate	2	2.70	0.2588
region*fate	4	178.46	<.0001
type*region*fate	3*	1.22	0.7480
Likelihood Ratio	0	.	.

NOTE: Effects marked with '*' contain one or more redundant or restricted parameters.

Analysis of Maximum Likelihood Estimates

Effect	Parameter	Estimate	Standard Error	Chi-Square	Pr > ChiSq
type	1	1.2680	0.0868	213.55	<.0001
region	2	0.4953	0.1344	13.59	0.0002

Analysis of Maximum Likelihood Estimates

Effect	Parameter	Estimate	Standard Error	Chi-Square	Pr > ChiSq
region	3	-0.4159	0.2433	2.92	0.0874
type*region	4	-0.2055	0.1262	2.65	0.1035
	5	0.0493	0.2229	0.05	0.8250
fate	6	2.5306	0.1096	533.07	<.0001
	7	-1.0232	0.2069	24.45	<.0001
type*fate	8	0.1266	0.0903	1.97	0.1609
	9	-0.1049	0.2051	0.26	0.6091
region*fate	10	-0.3946	0.1383	8.14	0.0043
	11	-0.7227	0.2166	11.14	0.0008
	12	-0.1864	0.2488	0.56	0.4539
	13	1.5381	0.1405	119.82	<.0001
type*region*fate	14	0.0961	0.1306	0.54	0.4622
	15	-0.1785	0.2051	0.76	0.3842
	16	0.0503	0.2293	0.05	0.8265
	17	.	.	.	.

Maximum Likelihood Predicted Values for Response Functions

Sample	Function Number	Observed Function	Observed Standard Error	Predicted Function	Predicted Standard Error	Residual
1	1	6.63922203	0.707569	6.63922203	0.707569	0
	2	2.2512918	0.743392	2.2512918	0.743392	0
	3	3.95124372	0.713874	3.95124372	0.713874	0
	4	6.14525802	0.707864	6.14525802	0.707864	0
	5	4.03424064	0.713337	4.03424064	0.713337	0
	6	0.69314718	0.866025	0.69314718	0.866025	0
	7	7.1592919	0.707382	7.1592919	0.707382	0
	8	2.30258509	0.74162	2.30258509	0.74162	0
	9	2.74084002	0.72956	2.74084002	0.72956	0
	10	4.06902675	0.713125	4.06902675	0.713125	0
	11	0.69314718	0.866025	0.69314718	0.866025	0
	12	1.70474809	0.768706	1.70474809	0.768706	0
	13	3.15700042	0.721995	3.15700042	0.721995	0
	14	1.60943791	0.774597	1.60943791	0.774597	0
	15	4.35027794	0.711654	4.35027794	0.711654	0
	16	-0.6931472	1.224745	-0.6931472	1.224745	0

Maximum Likelihood Predicted Values for Frequencies

Sample	type	region	fate	Function Number	Observed Frequency	Observed Standard Error	Predicted Frequency	Predicted Standard Error	Residual
1	1	1	1	F1	1529	33.41897	1529	33.41898	6.3665E-10
	1	1	2	F2	19	4.351592	19	4.351593	0
	1	1	3	F3	104	10.10411	104	10.10411	0
	1	2	1	F4	933	27.92004	933	27.92004	3.8904E-10
	1	2	2	F5	113	10.52372	113	10.52373	0
	1	2	3	F6	4	1.999295	4	1.999294	0
	1	3	1	F7	2572	37.49283	2572	37.49283	1.07775E-9
	1	3	2	F8	20	4.464244	20	4.464245	0
	1	3	3	F9	31	5.552528	31	5.552529	0
	2	1	1	F10	117	10.70451	117	10.70451	0
	2	1	2	F11	4	1.999295	4	1.999294	0
	2	1	3	F12	11	3.313407	11	3.313408	0
	2	2	1	F13	47	6.827191	47	6.827192	0
	2	2	2	F14	10	3.159489	10	3.159489	0
	2	3	1	F15	155	12.27861	155	12.27858	-2.3067E-9
	2	3	2	F16	1	0.999912	1	0.999912	0
	2	3	3	F17	2	1.413964	2	1.413964	0

Reduced Model

Sample	Sample Size
1	5672

Response Profiles

Response	type	region	fate
1	1	1	1
2	1	1	2
3	1	1	3
4	1	2	1
5	1	2	2
6	1	2	3
7	1	3	1
8	1	3	2
9	1	3	3
10	2	1	1
11	2	1	2
12	2	1	3
13	2	2	1
14	2	2	2
15	2	3	1
16	2	3	2
17	2	3	3

Response Matrix

	1	2	3	4	5	6	7	8	9
1	1	1	0	1	0	1	0	0	0
2	1	1	0	0	1	0	1	0	0
3	1	1	0	-1	-1	-1	-1	0	0
4	1	0	1	1	0	0	0	1	0
5	1	0	1	0	1	0	0	0	1
6	1	0	1	-1	-1	0	0	-1	-1
7	1	-1	-1	1	0	-1	0	-1	0
8	1	-1	-1	0	1	0	-1	0	-1
9	1	-1	-1	-1	-1	1	1	1	1
10	-1	1	0	1	0	1	0	0	0
11	-1	1	0	0	1	0	1	0	0
12	-1	1	0	-1	-1	-1	-1	0	0
13	-1	0	1	1	0	0	0	1	0
14	-1	0	1	0	1	0	0	0	1
15	-1	-1	-1	1	0	-1	0	-1	0
16	-1	-1	-1	0	1	0	-1	0	-1
17	-1	-1	-1	-1	-1	1	1	1	1

Maximum Likelihood Analysis

Iteration	Sub Iteration	-2 Log Likelihood	Convergence Criterion
0	0	32139.972	1.0000
1	0	19481.248	0.3939
2	0	17709.493	0.0909
3	0	16865.254	0.0477
4	0	16844.48	0.001232
5	0	16844.447	1.9744E-6
6	0	16844.447	6.5E-12

Maximum Likelihood Analysis

Iteration	Parameter Estimates 1	2	3	4	5	6	7	8	9
0	0	0	0	0	0	0	0	0	0
1	0.9317	0.0496	-0.5972	1.8324	-0.7582	-0.2569	-0.0985	-0.6082	0.6981
2	1.2471	0.1873	-0.1005	2.7003	-1.1659	-0.3565	-0.6109	0.1685	0.9777
3	1.3539	0.2969	-0.3181	2.6611	-1.1362	-0.3696	-0.8444	-0.0942	1.4985
4	1.3649	0.3298	-0.3811	2.6374	-1.1017	-0.3262	-0.8576	-0.1290	1.5281
5	1.3650	0.3302	-0.3822	2.6362	-1.1012	-0.3256	-0.8588	-0.1317	1.5303
6	1.3650	0.3302	-0.3822	2.6362	-1.1012	-0.3256	-0.8588	-0.1318	1.5304

Maximum likelihood computations converged.

Maximum Likelihood Analysis of Variance

Source	DF	Chi-Square	Pr > ChiSq
type	1	2427.99	<.0001
region	2	16.48	0.0003
fate	2	1761.35	<.0001
region*fate	4	296.29	<.0001
Likelihood Ratio	7	13.21	0.0671

Analysis of Maximum Likelihood Estimates

Effect	Parameter	Estimate	Standard Error	Chi-Square	Pr > ChiSq
type	1	1.3650	0.0277	2427.99	<.0001
region	2	0.3302	0.0823	16.10	<.0001
	3	-0.3822	0.1201	10.13	0.0015
fate	4	2.6362	0.0699	1420.76	<.0001
	5	-1.1012	0.0922	142.79	<.0001
region*fate	6	-0.3256	0.0832	15.34	<.0001
	7	-0.8588	0.1236	48.27	<.0001
	8	-0.1318	0.1208	1.19	0.2756
	9	1.5304	0.1378	123.30	<.0001

Maximum Likelihood Predicted Values for Response Functions

Sample	Function Number	Observed Function	Observed Standard Error	Predicted Function	Predicted Standard Error	Residual
1	1	6.63922203	0.707569	6.63968757	0.184338	-0.0004655
	2	2.2512918	0.743392	2.36907841	0.277221	-0.1177866
	3	3.95124372	0.713874	3.97851632	0.205106	-0.0272726
	4	6.14525802	0.707864	6.12113676	0.185454	0.02412126
	5	4.03424064	0.713337	4.04576855	0.203723	-0.0115279
	6	0.69314718	0.866025	0.68305362	0.531986	0.01009356
	7	7.1592919	0.707382	7.14454158	0.183683	0.01475033
	8	2.30258509	0.74162	2.27810663	0.284591	0.02447846
	9	2.74084002	0.72956	2.73009175	0.055406	0.01074827
	10	4.06902675	0.713125	3.90959582	0.175814	0.15943093
	11	0.69314718	0.866025	-0.3610133	0.271628	1.05416053
	12	1.70474809	0.768706	1.24842457	0.197481	0.45632353
	13	3.15700042	0.721995	3.39104501	0.176985	-0.2340446
	14	1.60943791	0.774597	1.31567679	0.196044	0.29376112
	15	4.35027794	0.711654	4.41444982	0.175128	-0.0641719
	16	-0.6931472	1.224745	-0.4519851	0.279146	-0.2411621

Maximum Likelihood Predicted Values for Frequencies

Sample	type	region	fate	Function Number	Observed Frequency	Observed Standard Error	Predicted Frequency	Predicted Standard Error	Residual
1	1	1	1	F1	1529	33.41897	1545.23042	32.51361	-16.230416
	1	1	2	F2	19	4.351592	21.5919195	4.493692	-2.5919195
	1	1	3	F3	104	10.10411	107.959598	9.971438	-3.9595977
	1	2	1	F4	933	27.92004	920.003529	26.91074	12.9964714
	1	2	2	F5	113	10.52372	115.469831	10.30551	-2.4698306
	1	2	3	F6	4	1.999295	4	1.999298	0
	1	3	1	F7	2572	37.49283	2560.05064	36.37653	11.9493649
	1	3	2	F8	20	4.464244	19.7143613	4.294582	0.28563867
	1	3	3	F9	31	5.552528	30.9797107	5.378199	0.02028934
	2	1	1	F10	117	10.70451	100.769584	5.643677	16.2304164
	2	1	2	F11	4	1.999295	1.40808045	0.302024	2.59191955
	2	1	3	F12	11	3.313407	7.04040226	0.74591	3.95959774
	2	2	1	F13	47	6.827191	59.9964714	3.574457	-12.996471
	2	2	2	F14	10	3.159489	7.53016937	0.77744	2.46983063
	2	3	1	F15	155	12.27861	166.949365	8.984007	-11.949365
	2	3	2	F16	1	0.999912	1.28563867	0.287904	-0.2856387
	2	3	3	F17	2	1.413964	2.02028934	0.36607	-0.0202893