B. STOCK ASSESSMENT OF BLACK SEA BASS FOR 2011

[SAW-53 Editor's Note: The SARC-53 review panel accepted the work done on TORs 1-4, but rejected the results of all new work done on TOR 5, on stock status and on stock projections. The SARC concluded that the results from the new black sea bass ASAP model developed in Fall 2011 for SAW/SARC-53 should NOT be used at this time to determine stock status or for management advice. The ASAP model and results are included in the body of this report just to show the work that was done by the SAW Working Group for the December 2011 peer review.]

Executive Summary

The principal gears used in commercial fishing for black sea bass are fish pots, otter trawl and hand-line. Commercial landings peaked in 1952 at 9,900 mt then declined markedly during the 1960s until commercial landings during the late 1980s and 1990s averaged 1,300 mt. Commercial fishery quotas were implemented in 1998 but landings remained stable between 1,300 mt and 1,600 mt until 2007. Recent quota restrictions resulted in declining commercial landings of 523 and 751 mt in 2009 and 2010, respectively. The recreational rod-and-reel fishery for black sea bass harvests a significant proportion of the total catch. After peaking in 1986, recreational landings averaged 1,700 mt annually until 1997. Recreational fishery harvest limits were implemented in 1998 and landings have since ranged between 500 mt and 2,000 mt. Landings in 2010 were 1,350 mt. Commercial fishery discard losses, although poorly estimated, appear to be a minor part of the total fishery removals from the stock, generally less than 200 mt per year. Recreational discard losses assuming 15% hook and release mortality are similar, ranging from 30 to 390 mt per year.

The 2008 Northeast Data Poor Stocks Working Group (NEDPSWG) Review Panel (NEFSC 2009a) recommended $F_{40\%}$ be used as a proxy for F_{MSY} and spawning stock biomass at $F_{40\%}$ ($SSB_{40\%}$) be used as the proxy for the stock biomass target reference point. The SCALE model, which was accepted (NEFSC 2009a,b), was most recently used in June and July 2011 (MAFMC 2011; NEFSC 2011) to estimate the status of the stock compared to previously accepted reference points. Based on that analysis, a comparison of 2010 estimates of the spawning stock biomass and fishing mortality rate to existing biological reference points (SSB_{MSY} proxy estimate = 12,537 mt and F_{MSY} proxy estimate = 0.42) indicated that black sea bass was not overfished and overfishing was not occurring. SSB in 2010 was estimated to be 13,926 mt (30.7 million lbs) and the fully selected F was estimated to be 0.41. The 2010 stock was at 111% of the SSB_{MSY} proxy. Based on deterministic projections for 2012 at the F_{MSY} proxy (0.42), the resulting catch would be 3,551 mt (7.8 million lbs) with landings equal to 2,841 mt (6.3 million lbs) (assuming the release mortality rate that was used in June 2011).

SDWG-data meeting participants:

BSB WG Data meeting September 19-September 20, 2011

BSB WG Model meeting October 18-October 20, 2011

Name	Affiliation	Data Mtg.	Model Mtg.
Mark Terceiro (chair)	NEFSC	x	x
Gary Shepherd	NEFSC	x	x
Chris Batsavage	NC DMF	x	
Toni Kerns	ASMFC	x	x
Jason McNamee	RI DFW	x	x
Jeff Brust	NJ DFW	x	x
Allison Watts	VA MRC	x	
Steve Doctor	MD DNR	x	x
Tony Wood	NEFSC	x	
Paul Caruso	MA DMF	x	x
Julie Nieland	NEFSC	x	x
Paul Nitschke	NEFSC	x	x
Jessica Coakley	MAFMC	x	x
Rich McBride	NEFSC	x	
Mark Wuenschel	NEFSC	x	
Jason Morsen	Rutgers	x	
Greg Wojcik	CT DEP	x	x
Eric Powell	Rutgers	x	x
Jon Deroba	NEFSC	x	
David McElroy	NEFSC		x
Chad Keith	NEFSC		x
Rob O'Reilly	VA MRC		x
Rich Wong	DE DEP		x
Kiersten Curti	NEFSC		x
Jim Weinberg	NEFSC		x
Ray Kane	Fisherman		x
Dorwine Allen	Fisherman		x
Al Keller	Fisherman		x
Rick Rozen	Fisherman		x
Joe Huckemeyer	Fisherman		x

Introduction

Life History

Black sea bass (*Centropristis striata*) are distributed from the Gulf of Maine to the Gulf of Mexico, however, fish north of Cape Hatteras, NC are considered part of a single fishery management unit. Sea bass are generally considered structure oriented, preferring live-bottom and reef habitats. Within the stock area, distribution changes on a seasonal basis and the extent of the seasonal change varies by location. In the northern end of the range (New York to Massachusetts), sea bass move offshore crossing the continental shelf, then south along the edge of the shelf (Moser and Shepherd 2009). By late winter, northern fish may travel as far south as Virginia, however most return to the northern inshore areas by May. Sea bass originating inshore along the Mid-Atlantic coast (New Jersey to Maryland) head offshore to the shelf edge during late autumn, travelling in a southeasterly direction. They return inshore in spring to the general area from which they originated. Black sea bass in the southern end of the stock (Virginia and North Carolina) move offshore in late autumn/early winter. Given the proximity of the shelf edge, they transit a relatively short distance, due east, to reach over-wintering areas (Figure B1).

Fisheries also change seasonally with changes in distribution. Inshore commercial fisheries are prosecuted primarily with fish pots (baited and unbaited) and handlines. Recreational fisheries generally occur during the period that sea bass are inshore. Once fish move offshore in the winter, they are caught in a trawl fishery targeting summer flounder, scup and *Loligo* squid (Shepherd and Terceiro, 1994). Handline and pot fisheries in the southern areas may still operate during this offshore period. Additionally a small sector of the NJ charter fleet target sea bass offshore during the winter.

Black sea bass are protogynous hermaphrodites and can be categorized as temperate reef fishes (Steimle et al. 1999, Drohan et al. 2007). Transition from female to male generally occurs between the ages of two and five (Lavenda 1949, Mercer 1978). Based on sex ratio at length from NMFS surveys, males constitute approximately 35% of the population by 15 cm, with increasing proportions of males with size (Figure B2). Following transition from female to male, sea bass can follow one of two behavioral pathways; either becoming a dominant male, characterized by a larger size and a bright blue nuccal hump during spawning season, or subordinate males which have few distinguishing features. The initiation of sexual transition appears to be based on visual rather than chemical cues (Dr. David Berlinsky, UNH, Personal communication). In studies of protogny, among several coral reef fish species, transition of the largest female to male may occur quickly if the dominate male is removed from the reef, however, similar studies have not been published for black sea bass.

Spawning in the Middle Atlantic peaks during spring (May and June) when the fish reside in coastal waters (Drohan et al. 2007). The social structure of the spawning aggregations is poorly known although some observations suggest that large dominant males gather a harem of females and aggressively defend territory during spawning season (Nelson et al. 2003). The bright coloration of males during spawning season suggests that visual cues may be important in structuring of the social hierarchy.

Black sea bass attain a maximum size around 60 cm and 4 kg. Growth curves are available from only one published study as well as several unpublished studies. Lavenda (1949) suggested a maximum age for females of 8 and age 12 for males. However he noted the presence of large males (>45 cm) in deeper water that may have been older. A working paper considering recent maturity and sex ratio data by Wuenschel et al. is provided in Appendix 1.

Fisheries

In the Northwest Atlantic, black sea bass support commercial and recreational fisheries. Prior to WWII in 1939 and 1940, 46-48% of the commercial landings were in New England, primarily in Massachusetts. After 1940, the center of the fishery shifted south to New York, New Jersey and Virginia. Landings increased to a peak in 1952 at 9,883 MT with the bulk of the commercial landings from otter trawls, then declined steadily reaching a low point in 1971 of 566 MT. Historically, trawl fisheries for sea bass have focused on the over-wintering areas near the shelf edge. Inshore pot fisheries, which were primarily in New Jersey, showed a similar downward trend in landings between the peak in 1952 and the late 1960s. The large increase in landings during the 1950's appears to be the result of increased landings from otter trawlers, particularly from New York, New Jersey and Virginia. During the same period, a large increase in fish pot effort, and subsequent landings, occurred in New Jersey. In recent years, fish pots and otter trawls account for the majority of commercial landings with increasing contributions from hand-line fisheries. The species affinity for bottom structure and reefs during its seasonal period of inshore residency increases the availability to hook and line or trap fisheries while decreasing susceptibility to bottom trawl gear.

Stock assessment history summary

Black sea bass stock assessments have been reviewed in the SARC/SAW process (SAWs 1, 9, 11, 20, 25, 27, 39 and 43) beginning with an index based assessment in 1991. In 1995 a VPA model was approved and the results generally showed fishing mortalities exceeding 1.0 (estimated using an M=0.2). The VPA was reviewed again in 1997 and at this time was considered too uncertain to determine stock status but indicative of general trends. In 1998, another review was conducted and both VPA and production models were rejected as either too uncertain or inappropriate for use with an hermaphroditic species. A suggestion was made to use an alternative method such as a tag/recapture approach. The NEFSC survey remained the main source of information regarding relative abundance and stock status. A tagging program was initiated in 2002 and the first year results were presented for peer review in 2004. The review panel concluded that a simple tag model using the proportion recovered in the first year at large, as well as an analysis of survey indices, produced acceptable results to determine exploitation rate and stock status. The release of tags continued through 2004 and results of tag models as well as indices were presented for SARC review in 2006. Their findings were that the tag model did not meet the necessary assumptions and the variability in the survey indices created uncertainty which prevented determination of stock status. The panel did not recommend any alternative reference points, however they did recommend continued work on length based analytical models. Black sea bass were once again considered at the NDPSWG in December 2008. The review panel considered a statistical catch-at-length model (SCALE) and a variety of natural mortality options. That panel concluded that the length-based model was suitable for evaluating stock status and recommended a constant natural mortality option of 0.4. Although the stock was considered not overfished or experiencing overfishing, the uncertainty in the results prompted the reviewers to recommend caution in applying the results for management.

<u>SAW/SARC 53 Terms of Reference</u>

B. Black sea bass

1. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data. Evaluate available information on discard mortality and, if appropriate, update mortality rates applied to discard components of the catch. Describe the spatial and temporal distribution of fishing effort.

2. Present the survey data being used in the assessment (e.g., indices of abundance, recruitment, state surveys, age-length data, etc.). Investigate the utility of commercial or recreational LPUE as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data.

3. Consider known aspects of seasonal migration and availability of black sea bass, and investigate ways to incorporate these into the stock assessment. Based on the known aspects, evaluate whether more than one management unit should be used for black sea bass from Cape Hatteras north and, if so, propose unit delineations that could be considered by the Mid-Atlantic Fishery Management Council and for use in future stock assessments.

4. Investigate estimates of natural mortality rate, M, and if possible incorporate the results into TOR-5. Consider including sex- and age-specific rate estimates, if they can be supported by the data.

5. Estimate annual fishing mortality, recruitment and appropriate measures of stock biomass (both total and spawning stock) for the time series (integrating results from TOR-4), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with most recent

assessment results.

6. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY}, and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the appropriateness of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

7. Evaluate stock status with respect to the existing model (from the most recent accepted peer reviewed assessment) and with respect to a new model developed for this peer review.
   a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.
   b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs (from black sea bass TOR 6).
8. Develop and apply analytical approaches to conduct single and multi-year stock projections to compute the PDF (probability density function) of the OFL (overfishing level) and candidate ABCs (Acceptable Biological Catch; see Appendix to the SAW TORs).
   a. Provide numerical annual projections (3-5 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment, and definition of BRPs for black sea bass).
   b. Comment on which projections seem most realistic. Consider major uncertainties in the assessment as well as the sensitivity of the projections to various assumptions.
   c. Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.
9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

TOR 1. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data. Evaluate available information on discard mortality and, if appropriate, update mortality rates applied to discard components of the catch. Describe the spatial and temporal distribution of fishing effort.

Commercial fishery

The commercial fishery on the northern black sea bass stock (Maine to Cape Hatteras, NC) is prosecuted primarily with fish pots, otter trawls and hand lines (Figure B3). Fish pots and hand lines are generally fished in inshore waters and target black sea bass (with the exception of some lobster and sea bass targets in NY). Trawls are generally offshore in the winter months in conjunction with summer flounder and scup fisheries (Shepherd and Terceiro 1994). Fish pots have accounted for 46% of landings since 1998, followed by otter trawls at 38% and hand lines at 10%. Other gears account for 6%. The majority of the landings occur in January through June (Figure B4). Total landings by NMFS statistical areas are presented for 2008-2010 in Figures B5-B7.

Trends in landings were relatively stable at around 1,300 MT until 2007 (Table B1, Figures B8, B9). State and Federal management plans were implemented in 1998 which included minimum size restrictions and commercial quotas. In 2008, additional quota regulations were enacted which decreased landings to an average of 720 MT between 2008 and 2010. The commercial sea bass fishery is prosecuted in all states between Massachusetts and North Carolina however Massachusetts, New Jersey and Virginia account for 50-60% of total commercial landings (Figure B10)

Length measurements (cm) of sea bass in the commercial landings are sampled by NMFS in ports from Maine to North Carolina. Samples are collected from boxes of fish available from dealers and sorted by market category. Market categories are extra small, small, medium, large and jumbo. Length frequencies by market category and half year were expanded to total catch beginning with 1984, the first year associated age data were available. NMFS samples were supplemented with similar information collected by the state of North Carolina between 1984 and 1998. The NC lengths measurements were combined with NMFS data by market category and half year. Sample sizes and total number of fish measured from NMFS and NC data are provided in Tables B2-B6. Expansion requires weight at length information which was available from NMFS spring and autumn survey data since 1992. The equations applied to all length samples by season were:

Spring: 1.0428e-5 *len^3.072
Autumn: 1.2924e-5*len^3.027

In the expansion process, missing cells were replaced with lengths from the same market category and the closest year or years containing measurements. The extra small category in years 2000 to 2010 were minimal and the few lengths available matched the smalls. Therefore in those years, extra smalls were combined with smalls. Changes in the length distributions resulting from changes in regulations are shown in Figure B11. Recent length distributions (2005-2010) are displayed in Figure B12.

The total number of black sea bass landed has declined since 1996 (5.1 million) to a low of 926,000 in 2009. Landings in 2010 increased slightly to 1.3 million. Mean length in the landings were relatively stable between 1984 and 1996 around 26 cm (Table B7, Figure B13). Mean length rose steadily from 28 cm in 1997 to 34 cm in 2004 where it has remained on average until 2010 (Figure B14). The small market category averaged 59% of landings between 1984 and 1996 before steadily declining and by 2010 the small category comprised only 9% of landings (Figure B15). Mediums were replaced as the dominant market category with 45% of landings in 2010. The large category also showed a proportional increase from 9% between 1984 and 1996 to 25% by 2010.

Commercial discards

Estimated discards were calculated for the three primary gear types. Otter trawl discards were calculated using the Standard By-catch Reporting Methodology (SBRM) (Wigley et al 2008). SBRM relies on information collected by NMFS observers on a sub-sample of commercial trips as part of a program begun in 1989. Discards per year and quarter are estimated as the ratio of recorded discards for the species in question to recorded kept of all species landed, multiplied by the total reported landings of all species in that time strata. The associated CV for the estimate is also calculated (Table B8). The observer program does not regularly monitor hand-line or pot trips, therefore the SBRM estimates were only made for otter trawls trips. Prior to observer coverage in 1989, discards were estimated using landings of sea bass, scup and summer flounder which are the principle targeted species in the sea bass winter trawl fishery. For the period 1989 to 1992, a ratio was calculated between sea bass discards and total sea bass, summer flounder and scup landings targeted by the trawl fleet. This ratio was then applied to sea bass, flounder and scup landings between 1984 and 1988 as an estimate of sea bass discards.

Pot and hand-line discards from 1994-2010 were estimated from self-reported vessel trip logs (VTR), adjusted to total landings by gear. VTR logs were not required prior to 1994, therefore the 1984 to 1993 discard estimates were based on the discard to landing ratio for 1994-1996, by half year. This ratio was applied to sea bass landings by gear type.

Discards from the trawl fishery were assumed to suffer 100% mortality because of depths fished and length of tow time. Discard mortalities of 15% were applied to pot and hand-line discards. The rational was that depths fished generally resulted in minimal barotrauma and the volume of fish in a pot catch would result in minimal damage to released fish. Hand-line discard mortality was assumed equivalent to recreational discard mortalities.

Discards prior to 1984 were not estimated by fishery. A ratio of 0.06 (std. dev among annual ratios = 0.011) was developed from the median discard to landings ratio from 1984 to 1996. This ratio was applied to total landings (commercial plus recreational) for the period 1968 to 1983 to produce estimates of total discards. Discards by fishery reported in Table B1 were calculated from the proportion of commercial to recreational discards in 1984-1996 and applied to total discards for that period. The stock assessment model does not incorporate the landings and discards by fishery but instead uses total catch as a single fleet.

The time series of commercial discard length frequencies available for age expansion was limited (Table B9). Length samples from observer trawl trips were available from 1989 and 1995-2010 in the spring and 1994-1997 and 2000-2010 in the fall. There were few observations from fish pot trips (none from hand-line) vessels (Table B9), therefore the samples were combined with otter trawl discards lengths. Annual commercial discard length distributions show a shift in the size composition over time (Figure B16). Prior to the FMP, discards were composed primarily of sizes below 30 cm. As minimum sizes and quotas went into effect the size distribution increased (likely due to gear changes) and included larger individuals of legal size.

Recreational Landings and Discards

Information from the NMFS Marine Recreational Fishery Statistical Survey (MRFSS) was downloaded from the website (http://www.st.nmfs.noaa.gov/st1/recreational/queries/index.html) for Mid-Atlantic and North Atlantic AB1 fish (fish kept or fish filleted, released dead, disposed in some other way) (Table B1, B10) and B2 fish (released alive) (Table B11). Estimates are provided for waves (two month period) 2 to 6. Wave 1 (Jan/Feb) is not sampled in the Northeast/ however since 2004, wave 1 estimates have been produced for North Carolina. Catch estimates by wave and year include a value for proportional standard error (PSE).

Since North Carolina catch may occur from either stock (partitioned at Cape Hatteras, NC) annual MRFSS catches are split north and south of Hatteras based on intercept sites. MRFSS estimates are provided as number of fish for AB1, B2 and weight (kg) of AB1 catches. Total weight of discards was derived by applying a length-weight equation to the expanded discard length frequencies. In the time series of catch in numbers, 1982 and 1986 appear as anomalies. The 1982 increase can be attributed to outliers in MD and VA estimates since it is unreasonable to assume that landings increased by a factor of 3 or 4 in a single year. For purposes of the analysis, the MRFSS value in 1982 (which was not expanded by age in the model) was replaced with an average of 1981 and 1983. The high 1986 MRFSS estimate was influenced by an unusually large estimate in NJ wave 5. The NJ wave 5 value was replaced with the average AB1 of waves 4 and 6, then re-summed.

Stockwide recreational landings averaged 1700 MT between 2000 and 2003 then declined to an average of 950 MT thereafter (Table B1, Figure B17). Some of the decline could be attributed to changes in the regulations, particularly minimum size and bag limits beginning in 2008. The majority of sea bass landings (53%) since 2000 are taken in New Jersey (Figure B18). The next closest states, by percentage, are New York (13.4%), Massachusetts (7.8%) and Delaware (7.3%). Since 2000, from MA to VA, 77% of landings have occurred in waves 4 and 5 (July to October), although in 2009 and 2010 this proportion was influenced by seasonal closures. Mean length in the recreational landings averaged 27 cm between 1984 and 1996, then steadily increased to 35 cm by 2003 and has remained at that average length through 2010 (Figure B19).

Previous sea bass assessments assumed a 25% discard mortality in the recreational fishery. That rate was re-evaluated and the WG determined that a15% mortality was more appropriate. This conclusion was based on information from published studies showing mortalities of 5% (Bugley and Shepherd 1991) and 12% (Rudershausen and Buckel 2007), potential barotraumas in the range of depths fished (generally less than 40 m), and published studies for other species (summer flounder, striped bass, snapper, etc.).

Recreational landings for years between 1968 and 1980, prior to the implementation of the MRFSS program, were based on the ratio of commercial to recreational landings between 1981 and 1997 (1982, 1986 and 1995 excluded). The ratio of 1.03 (std. dev among annual ratios=0.441) was applied to commercial landings for that time period to estimate recreational landings. Discard (B2) values for the pre-1981 period were estimated similarly to commercial discards (total discards estimated then divided into commercial and recreational) (Table B11, Figure B20).

Length frequencies of the recreational catch were sampled by MRFSS personnel during dockside interviews. Sample sizes in Table B10 are based on number of annual intercepts. Lengths were expanded to total landings by half year then summed to annual totals (Figure B21). Discard lengths were compiled from a variety of sources. Since the majority of the recreational fishery occurs from July to October, the limited discard data were assumed equivalent to the annual discard totals. The American Littoral Society is a conservation group that promotes fish tagging of recreationally caught fish to follow their movement. Therefore they are by definition B2s (caught and released alive). The lengths of the fish tagged between 1984 and 2010 were available, but measured in inches. Consequently, the length frequencies of all discard measurements were converted to inches. Additional information came from a tagging program conducted by NJDEP from 1995 to 2003 involving hook and line gear. Released fish below the minimum size were classified as discards. NJ also operates a Volunteer Angler Survey program to collect information, including lengths of discarded fish. This information was available for 2008 to 2010. New York DEP provided discard length information collected from party/charter boats between 1995 and 1999. Finally, the MRFSS program began at-sea sampling of party/charter boats in 2005. The total number of discard lengths expanded to total discards, and subsequently discards at age, are shown in Table B12.

Since the last benchmark assessment, age-length data is available from the spring and fall NMFS surveys between 1984 and 2010. No data were available for 1997, so we created an average age key from surrounding years. In 2008-2010 the survey age key was supplemented with commercial age samples. Overall, 8,262 ages were used to develop age-length keys, with an average of 107 and 124 ages in spring and fall, respectively, prior to 2008. The addition of the commercial samples in 2008-2010, increased the average to 668 and 315 ages for spring and fall, respectively. These age keys were applied to all indices and fishery lengths. Missing ages were interpolated with information from surrounding years.

The maximum age in the time series was 12, but that was represented by only 1 fish among the 8,262 ages; a total of 21 fish of the 8,262 were age 10 or greater. We truncated the catch at age to a plus group of 7+. In the final CAA, the plus group represented 1% or less with the exception of 2007 at 4% (from spring 2007 recreational catch) (Tables B13-B16; Figures B22-B26). Catch weight at age was developed from the expanded length frequencies at age by half year period, then combined into an overall mean, weighted by half-year catch (Table B18). A CV around the mean weight was developed for the last five years for input to a stochastic yield per recruit model (Table B19).

TOR 2. Present the survey data being used in the assessment (e.g., indices of abundance, recruitment, state surveys, age-length data, etc.). Investigate the utility of commercial or recreational LPUE as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data.

Survey data available included NMFS winter, spring and fall surveys and state survey data from MA, RI, CT, NY, NJ, MD, VA and the CHESMAP program in Chesapeake Bay.

<u>State Surveys:</u>

The Virginia Institute of Marine Science (VIMS) conducts a monthly trawl survey targeting juvenile fish within Virginia tributaries of the Chesapeake Bay and provided a random stratified index of black sea bass abundance (Figure B27). The index is for black sea bass sampled in May, June, and July since 1989 and contains fish that are less than 110, 150, and 175 mm total length, respectively. All are age-1 fish, assuming a Jan 1 birthdate. Thus, the mean number per tow index for 2010 represents the 2009 year class (spawned in 2009). The results show a declining trend in abundance with above average year classes in 1989, 2001 and 2007. The 2010 index (0.32 fish/tow) was below the series average (0.71 fish/tow).

The CHESMAP program is a trawl survey also conducted by VIMS which targets fish in the Chesapeake Bay (Figure B28). About 80 stations are sampled in March, May, July, September and November beginning in 2002. The age classes sampled include ages 0 to age 2. The results (delta-lognormal mean number per tow) show an increasing abundance of age 1 fish since 2006, with above average indices in 2007 and 2009 (Figure B29).

The Maryland Dept. of Natural Resources conducts surveys from April through October in coastal bays using a 16ft trawl. Twenty sites have been sampled monthly since 1989. Black sea bass collected in the survey are all less than 21 cm and age 1 or less. The index (geometric mean) has not shown any trends and the 2010 index (1.70 fish per tow) was close to the series average of 1.14 fish per tow (Figure B30).

The Northeast Monitoring Program (NEMAP) is a trawl survey conducted between New York and Virginia within the NMFS inshore strata. The series began in 2008 when the Bigelow dropped sampling of those strata. The time series (4 years) is not yet indicative of trends in abundance (Figures B31, B32). No calibration factor is available to convert the NEMAP indices to ALB IV indices.

The New Jersey Department of Environmental Protection conducts a stratified random trawl survey in state waters during January, April, June (Figure B33), August, and October (Figure B34). The index in June shows a large degree of inter-annual variability, likely due to the difficulty sampling inshore near structured habitat. The index in 2010 (1.17 fish/tow) was below the series average (3.3 fish/tow), however the std. deviation of the series average was 4.69. The October survey was primarily age 0 sea bass (Figure B35). The mean number per tow shows high age 0 abundance in 1998 with above average indices in 1999 and 2007.

New York Department of Environmental Conservation has conducted a small mesh trawl survey in Peconic Bay (eastern Long Island) from August to November since 1987 (excluding 2006). Mean CPUE has shown a variable but increasing trend in age 0 black sea bass with the highest index in 2002 followed by 2009. However the 2010 index was among the lowest in the series (Figure B36).

Connecticut Department of Energy and Environmental Protection conducts monthly trawl surveys in Long Island Sound between April and November since 1984 (Figure B37). The sampling intensity is generally 40 stations per month. The survey results were partitioned into spring and fall with the fall index being primarily age 0 and 1 fish (Figures B38 and B39). Both seasonal indices show a variable but increasing trend, with a large age 0 index in 2002 and age 1 in 2008. The state also conducts a seine survey within coastal CT during the fall (Figure B40). The mean number per tow in this survey shows an increasing trend in age 0 sea bass, with peaks occurring in 2001 and 2009. The 2010 value (0.40 fish/tow) exceeded the series average (0.25 fish/tow, std. dev =0.310).

Rhode Island Department of Environmental Management conducts several surveys which catch black sea bass. A seasonal trawl survey in Narragansett Bay and along the coast since 1979 employs a stratified random design as well as several fixed stations (Figure B41). The indices have been highly variable over time, although the spring index includes several above average years since 1999 (Figure B42). The fall index, dominated by age 0 and 1, includes several high values in the mid-1980s and a large age 0 index in 2005 (Figures B43- B44). The 2010 overall index (1.429 fish/tow) was below the series average (4.14 fish/tow, std dev = 6.721). The Department also conducts a coastal pond seine survey

(Figure B45). Although the mean catches per tow are small, it does show an increasing trend, peaking in 2009 at 2.04 fish per tow. The 2010 value (0.06 fish/tow) is well below the series average (0.40 fish/tow, std dev =0.575).

Massachusetts Division of Marine Fisheries has conducted a spring and fall bottom trawl survey in coastal waters of Massachusetts since 1978 (Figures B46-B49). The spring index declined during the 1990s, peaked briefly in 2000, then again in 2008 and 2010. The spring 2011 mean number per tow (0.51) was below the series average (1.40 fish/tow, std dev. 1.226). The fall survey is primarily age 0 sea bass. The trends are similar to spring, with peaks in the early 1980s, a low period in the 1990s with an increasing index through 2005, followed a several years of average indices. The fall 2010 age 0 index was 113.7 which remains above the series average (103.9 fish/tow, std dev = 108.3).

NMFS surveys

The NEFSC winter bottom trawl survey was conducted with stratified random tows in offshore strata between Georges Bank and Virginia between 1992 and 2007. The trawl gear was modified with a chain sweep rather than roller gear used on the spring and autumn surveys. The stratified mean number per tow increased to a peak in 2003 of 3.86 fish/tow before declining to average values by 2007 of 0.5 fish per tow (Figures B50-B52).

The NEFSC spring bottom trawl survey is conducted between Nova Scotia and North Carolina, beginning in 1968. The indices (stratified mean number per tow) for black sea bass were developed using offshore strata containing at least one positive tow in the time series. In addition, the NEFSC autumn bottom trawl survey, which included inshore strata prior to 2009, is dominated by age 0 sea bass. Consequently that survey was included as a young of year index of abundance. Previous assessments using the NMFS data considered a log transformation of catch per tow to reduce the influence of high catches. The WG reconsidered the use of the transformation and concluded that it was unnecessary. The survey is designed to account for variation and the transformation can violate the underlying assumption of the designed survey (T. Miller, NEFSC, pers. comm.). Therefore the indices in the NMFS surveys were the arithmetic mean number or mean weight per tow. In 2008 the NMFS acquired a new ship, the FSV *Henry B. Bigelow*, to conduct the survey. Field work was done to develop calibration factors to convert *Bigelow* indices into equivalent FRV *Albatross IV* units. Previous assessments used a constant value of 3.41 across all sizes, however new model results allow calibration by length categories (Figure B53). The length calibration factors in sea bass produced a bi-modal sequence of values described by a polynomial equation. The working group considered the calibration results and concluded that the tails of the distribution with few samples (Figure B54) was not appropriate for calibration (small calibration values had large influence on small indices). Therefore the calibration factor was held constant for lengths beyond 40 cm. The factor for the smallest fish sizes, less than 5 cm, was also held constant at 1.0, which implies no difference in catchability between the ships. The calibration at length was applied to the NEFSC spring and fall survey data series.

The NEFSC spring mean number per tow followed a pattern of an increasing index during the late 1970s, followed by a decline during the 1980s and 1990s (Figure B55-B57). An increase in the index occurred beginning in 1998, peaking in 2003, followed by a decline. The calibrated 2010 index (1.687 fish/tow) was near the series average of 1.707 fish/tow (std dev = 1.691).

An additional abundance index was developed using the recreational catch per angler trip. The MRFSS program has collected information since 1981 (Figure B58). CPUE was developed following the procedure outlined in Terceiro (2003), using a GLM with a negative binomial error structure. The index shows an increasing trend through 2000, followed by a decline until 2005. With the exception of a spike in 2006, the index has remained stable through 2010. On a regional basis, the catch per angler index shows an increase in the northern states and a stable or decreasing trend in the south.

The only surveys that integrate across all areas are the NEFSC winter, spring and fall surveys and the REC CPA. Past reviews have expressed concern that the NEFSC fall inshore survey does not tow in areas of sea bass habitat (structure), thus cannot be representative of abundance. In addition, the 2 most inshore strata are no longer sampled by the Bigelow. However, the age 0 fish (lt 14 cm) do not require the same structure (a clam shell is enough), so that age group was included as an index (Figure B59). The spring and winter surveys use the offshore strata set. Those surveys were conducted during the period sea bass are resident on the over-wintering ground of the continental shelf or are moving across the shelf. Therefore the habitat requirements during that time should be minimal. To examine potential biases in the offshore spring survey, an analysis was done to examine the frequency of tear ups in the tows, the idea being that tear ups would represent tows in structured habitat. Results are detailed in Appendix II. The analysis concluded that there is no evidence to imply a bias in sea bass catches in the offshore strata resulting from structured habitat. In addition, the presence of a commercial otter trawl fishery in the offshore area implies some degree of towable bottom.

NEFSC survey data was also used to develop maturity at age information. On-going work to verify black sea bass maturity stages and the characteristics of transforming gonads is described in Appendix I. Information collected on surveys was used to develop a maturity ogives. Male and female maturities were divided into mature or immature categories. Logistic maturity at length ogives were first developed for each sex (Figure B60). The resulting parameters were:

Male: alpha = -6.638, beta=0.359; Female: alpha = -5.720, beta=0.282

A maturity at age ogive was also developed, using the SAS Proc Logistic function. A model was developed for females as well as both sexes combined. The resulting model showed an A50 for females at age 1.15 and for both sexes of 1.57. In both scenarios, the fish were fully mature by age 5. Results are shown in Figure B61 and Table B20.

TOR 3. Consider known aspects of seasonal migration and availability of black sea bass, and investigate ways to incorporate these into the stock assessment. Based on the known aspects, evaluate whether more than one management unit should be used for black sea bass from Cape Hatteras north and, if so, propose unit delineations that could be considered by the Mid-Atlantic Fishery Management Council and for use in future stock assessments.

Black sea bass undergo seasonal migrations between coastal and shelf waters (Moser and Shepherd 2009). The general over-wintering areas are on the continental shelf south of the Hudson Canyon. The distance of the migration varies depending on the starting point in the fall, with fish from the northern end of the stock (Massachusetts) travelling the furthest distance. The tagging study documented the movement and showed that the further the distance travelled, the higher the chance of returning to an area other than the point of origin (Figure B62). Consequently there is a higher likelihood of mixing among adjacent areas at the northern end of the stock (e.g. greater chance of fish leaving MA and returning to RI than fish leaving VA and returning to MD or NC).

A preliminary genetics study to examine mixing around Cape Hatteras, NC (the demarcation between the northern and southern stocks) also examined the genetic characteristics within the Middle Atlantic (McCartney and Burton, 2011). The study concluded that there were no distinct sub-stocks with the northern group with the possible exception of fish from Massachusetts. The MA fish had some unique genetic characteristics however further work is required to determine if these differences are robust. A published study examining meristics and morphometrics in black sea bass also concluded that there was likely a clinal gradient rather than distinct sub-units (Shepherd 1991).

Local variations in black sea bass abundances became an issue following the 2010 fishing season when states in the northern end of the stock (NY-MA) exceeded their recreational quota. Examination of the relationship in CPA among states shows a clinal gradient in black sea bass CPUE. States are most similar to adjacent states and more dissimilar the further the distance (Figure B63).

The recent NMFS age data were fit to growth curves north and south of the Hudson Canyon, a possible geographic boundary seen in tag results. The fitted von Bertalanffy curves show slower growth north of the Canyon but not significantly different between the areas based on the overlap in the confidence intervals (Figure B64). The growth curve parameters are presented in Table B21.

After examining tagging data, growth curves, meristic and morphometric analyses, and genetic studies, the Working Group concluded that the northern stock of black sea bass (north of Cape Hatteras, NC) shows a clinal gradient north to south but there is not enough evidence to further divide the northern stock into sub-units. Preliminary genetic studies show some unique characteristics between MA fish and the rest of the stock which should be explored with additional analysis.

In addition, the current data is inadequate to conduct an assessment accounting for spatial differences. The stock mixes in the offshore winter areas such that offshore catch cannot be accurately assigned to area of origin. In addition, mixing between areas may vary by year which creates problems in a spatial assessment model. While acknowledging differences among states, it may be possible to consider these differences in the context of management rather than within an analytical assessment.

TOR 4. Investigate estimates of natural mortality rate, M, and if possible incorporate the results into TOR-5. Consider including sex- and age-specific rate estimates, if they can be supported by the data.

The issue of natural mortality in sea bass was examined at the Northeast Data Poor Stocks Working Group meeting (NDPSWG 2008). Preliminary results (Shepherd and Moser 2008) from an analysis of tag returns using the Instantaneous Rates Model (Hoenig et al. 1998) had shown that M was likely much greater than the 0.2 used in earlier assessment. However, the tag model estimates greater than 1.0 were considered unrealistic (note that the M in the tagging model is a function of unseen tags which includes the effect of unaccounted for non-reporting, tag loss, etc.). The NDPSWG considered estimates of M using the rule of thumb approach ($3/t_{max}$) and the Hewitt and Hoenig (2005) approach ($4.22/t_{max}$), both with a maximum age of 9. The review group adopted the average of the two models (0.4) as an appropriate value of M.

Estimates of M were reconsidered using several different approaches (Table B22), including the Lorenzen (1996) model for age-specific estimates of natural mortality and two constant M models with an alternative maximum age of 12 (Appendix III). The WG concluded that sex specific rate estimates were not appropriate at this time since complimentary catch by sex was unavailable. The WG adopted an age-specific, time invariant estimate of M based on the Lorenzen curve re-scaled to an average M equal to 0.4 (Table B22). Since the model includes age 0, the Lorenzen model was fitted to a power curve:

$$M = 0.694\ \text{age}^{-0.417}$$

and extrapolated to age 0.5. The fitted values were used in the model and the plus category set at M=0.29. Sensitivities to the assessment model results were conducted using the alternative of a constant 0.4 at all ages.

TOR 5. Estimate annual fishing mortality, recruitment and appropriate measures of stock biomass (both total and spawning stock) for the time series (integrating results from TOR-4), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with most recent assessment results.

Updated age information has not been available for recent black sea bass assessments, consequently the working model has been SCALE, a statistical catch at length model (NDPSWG 2008). An update to the assessment was completed in June 2011 and provided to managers for quota setting in 2012 (Figure B65). That update followed the previous approach which incorporated NEFSC $\log_e$ transformed indices from the winter and spring surveys and assumed a recreational discard mortality of 25%. The resulting estimate of F_{2010} equaled 0.41, an increase from 2009 of 0.32 and the 2010 SSB equaled 13,926 MT (Figure B66).

[SAW53 Editor's Note: The SARC-53 review panel did not accept new models or results (described below) that were done for TOR 5. Text about TOR 5 that describes those new models is included below to demonstrate the work that was done by the SAW Working Group for the December 2011 peer review. Those results are not intended to be used for management at this time.]

The availability of age data beginning with 1984 allowed for development of an age based assessment as recommended in the NDPSWG review (2008). A statistical catch at age model (ASAP) served as the basis for the new analytical assessment (which was then rejected by the SARC53 peer review panel in December 2011). A catch at age matrix was developed for 1984 to 2010, while NEFSC spring survey indices were available since 1968. Total commercial landings recorded since 1939 provided a basis for estimating historic total catch using ratios. Initial model configurations began with 1939 catch partitioned into four separate fleets; commercial landings, commercial discards, recreational landings and recreational discards. Models starting in 1939 or 1950 (prior to the peak catch in 1952) did not properly converge despite numerous variations in model configuration.

The ASAP model was simplified and ultimately configured with catch beginning in 1968 and one fleet. Natural mortality was based on a Lorenzen curve for M at age, scaled to a constant of 0.4. Maturity was constant within the time series and equaled the average maturity at age from the survey results. Catch weights at age were estimated from 1984 to 2010 using expanded length frequencies of the catch. In several years, the weights at age for ages 6 or 7+ decreased due to limited sample sizes. This was not considered biologically feasible, therefore those values were replaced with calculated weights at age using the relation between weight and age from earlier ages within the same year. Weights at age prior to 1984 were based on the average of the last three years (1984-1986) (Table B18). Black sea bass spawning stock weights (Table B23) for ages 1 to 4 were set equal to NEFSC spring survey weights at age, as recommended by SARC53 reviewers, while ages 5 to 7+ remained equal to catch weights. Age 0 weights were fixed at 0.001 kg but have no bearing on SSB calculation since percent mature is 0. Rivard weights were calculated for use as January 1 stock weights.

Selectivity at age was divided into two periods, with a split between 1997 and 1998. A fishery management plan was implemented in 1998 which set minimum sizes in both the commercial and recreational fisheries. Prior to the plan few size restrictions were in place. Since both the recreational and commercial fleets target large fish using a variety of gear types, selectivity was assumed flat-topped and fixed at 1.0 beginning with age 4. Selectivity at younger ages was freely estimated, using a lambda value of 1.0 and CV of 0.5. Fishing mortality was fixed at 0.3 for the initial year (1968) in the final model although a variety of options for the initial F were explored.

Prior to 1981 recreational landings and total discards were estimated based on a ratio to commercial landings. Therefore in the modeling process the predicted catch was allowed to vary to a greater degree pre-1981 by increasing the CV settings.

In a protogynous hermaphrodite such as black sea bass, defining spawning stock biomass has been the subject of debate. We followed the recommendation of Brooks et al. (2008) and defined SSB as combined male and female, although the SSB is not used in a stock-recruitment model. In the ASAP model we have limited the influence of the stock recruit curve in defining recruitment. The model software assumes recruits are age 1 and consequently adjusts the time series to correspond to the correct SSB. Since our input includes age 0 as the first age, the recruits using the S/R curve would be incorrectly estimated. Consequently, we have fixed the steepness in the curve to 1.0 to essentially disregard the stock-recruitment relationship. The CV in years with age information (1984-2010) was set to 0.6 with a lambda of 1.0, which keeps the recruitment near the mean in years prior to 1984 when there is limited information about cohort strength.

Abundance indices used in the model included the recreational catch per angler trip, Virginia spring trawl survey age 1 index, New Jersey autumn trawl survey age 0 index, Massachusetts autumn trawl survey age 0 index, NMFS autumn bottom trawl survey age 0 index, NMFS spring bottom trawl survey number per tow and age composition for ages 1 to 7+, and NMFS winter bottom trawl survey number per tow and age composition for ages 1 to 7+ indices. NMFS winter and spring indices incorporated empirical CVs estimated from survey data whereas the CVs for the other surveys were set equal to 0.6. Survey selectivity for surveys other than the spring and winter were set equal to 1.0. Following numerous models runs and the ratio of qs of indices at age, the winter and spring index selectivities were fixed at 1.0 for age 2 and at 0.5 for age 7+. The remaining ages were freely estimated using a lambda value of 1.0 and a CV equal to 0.3.

<u>Base model results</u>

The index fit total was the largest component of the objective function, followed by recruitment deviations and the catch at age comps (Table B24, Figure B67). The catch age composition (Figures B68a-68f) and associated residuals (Figures B69-B70) showed the largest residuals in ages 2 and 3 in the 1980s and also the late 1990s, implying an underestimate of the predicted values. The effective sample size of the fleet was set equal to 50, which corresponded to the mean age trends (Figures B70-B71). Catch selectivities pre- and post-1998 (Figure B72) reflect a greater A_{50} post-1998, indicative of the shift in the selectivity patterns in the fishery due to regulations. Quantile plots of the model results are shown in figure B73.

The standardized residuals in the indices were generally centered near 0 as shown in the distribution of the probability density (Figures B74-B89). The exception was the Massachusetts age 0 index which tended to be under-estimated in recent years (Figure B77). The residual patterns in the age composition for the NMFS winter and spring indices did not display any large positive or negative residuals (Figures B79-B80). The selectivity at age for the NMFS winter and spring survey indices showed a declining selectivity beyond age four. The spring selectivity declined to 78% at age 5 and 74% at age 6 (age 7+ fixed at 0.5). Similarly, the winter survey was dome shaped with selectivity at 65% for age 5 (Figure B90).

Average spawning stock biomass increased between 1997 (2,701 MT) and 2005 (9,654 MT), remained stable until 2008 (9,587 MT) then increased to the 2010 estimate of 10,843 MT (± 1 std. dev of 1,226 MT) (Figure B91). Total January 1 biomass followed a similar trend, peaking in 2006 at 10,353 MT, declining briefly in 2007 to 9,877 MT before increasing through 2010, reaching 11,616 MT (Figure B91). Trends in exploitable biomass were similar to SSB with 2010 biomass being one of the largest in the series at 11,022 MT (Figure B91). Posterior distributions of SSB were developed from an MCMC simulation. The MCMC process was completed with 1000 iterations and a thinning factor of 200. The range of values in the 2010 SSB distribution ranged from 8,100 MT to 15,600 MT, with a median value of 11,456 MT (Figure B92). The 80% confidence interval was between 10,012 MT and 13,082 MT (Figure B93).

With the exception of the 2007 year class, recruitment since 2001 has been below the time series average (72 million (1984-2010)) (Figure B94). The 2010 cohort was estimated at 40.7 million (with ±1 std. dev of 7.8 million) and the 2009 cohort at only 35.3 million (± 1 std dev of 11.6 million). Total stock numbers follows the same decline since 1999 owing to the dominance of the age 0 fish in the total number. Biomass has increased in recent years (Figure B91) with the growth of the 2007 year class contributing to the biomass already accumulated since a large 1999 cohort.

Fishing mortality, estimated as F on fully recruited ages, has decreased since reaching the time series maximum of 0.97 in 1996. The trend continued downward until reaching an F of 0.16 in 2008

(Figure B95). The most recent value in 2010 equaled 0.18. Posterior distributions of fishing mortality were developed from an MCMC simulation. The MCMC process was completed with 1000 iterations and a thinning factor of 200. The range of values in the distribution ranged from 0.12 to 0.23, with a median value of 0.17. The 80% confidence interval ranged from 0.149 to 0.195 (Figure B96). The model selectivity also showed a change in the age at 50% selectivity between the two periods, with an increase from 1.6 in 1968-1987 to 2.1 in 1998 to 2010 (Figure B74).

Retrospective patterns were explored for F and SSB beginning with 2003. Fishing mortality had a retrospective pattern showing consistent under-estimation (Figure B97-B98). The pattern for fishing mortality was considered reasonable a maximum range in 2006 of 0.15 to 0.22 and a relative difference of 33%. However, the relative difference between 2009 and 2010 was only 1.4%. The retrospective pattern for SSB was a consistent over-estimation (Figure B99-B100). The maximum in 2006 ranged from 14,070 MT decreasing to 9,368 MT and a maximum relative difference of 50%. The last three years in the SSB varied considerably less, ranging from 10,302 MT in the 2008 terminal year to 10,843 MT in 2010. The relative difference in 2009 was 0.2%. The WG concluded that the large index pulse around 2002 produced the retrospective pattern and as the influence of that index group passed, the retrospective problems subsided.

The WG explored a variety of model configurations before choosing the base model (Figure B101-B105). The examination of the models showed that retrospective effects could be reduced by increasing the influence of the catch in the model while reducing the weight on the indices. However, the resulting estimates of fishing mortality were thought to be unrealistically low throughout the time series. In addition, the WG felt that the indices provided information on abundance and should not be completely down-weighted. The chosen model provided a compromise between the retrospective pattern, fishing mortalities that were not comparable to a previous tag based estimates of F and convergence properties that would allow execution of the MCMC function.

Comparison of the base model run to previous F estimates is presented in Table B25, Figure B106. The previous estimates of F using length based models were all higher, particularly during the 1984 to 2004 period. However, the differences are a matter of scale and the trends among all models are very similar.

(NOTE: The SARC53 panel concluded that the ASAP and revised SCALE results shown here should not be used at this time as a basis for developing management advice or for determining stock status. The methods and results are included here to show the work that was done by the SAW Working Group and reviewed for SARC53.)

TOR 6. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY}, and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the appropriateness of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

The most recent biological reference points (BRP) were developed and approved at the NDPSWG review (2008). Since no age data were available for BRP development, results from a length based yield per recruit model were adopted. An $F_{40\%}$ equal to 0.42 was chosen as a proxy for F_{MSY} and the associated SSB_{MSY} was estimated using the average recruitment derived from the SCALE model applied to the SSB/R ratio at $F_{40\%}$. The SCALE model and the YPR model both used constant M equal to 0.4.

[SAW53 Editor's Note: Because the SARC-53 review panel rejected the ASAP model, no new reference points were considered. The text below about TOR 6 is included to show the work that was done by the SAW Working Group for the December 2011 peer review, and should not be used for management.]

A new stochastic yield per recruit model was developed to derive new age-based biological reference points. The model was developed with an age 7 plus group but a maximum age of 12. In order to develop the probability distribution around the reference points the model required CVs for stock weights, catch weights, SSB weights, fishery selectivity, natural mortality and maturity at age (Table B26). Mean weights at age developed from both fishery and survey data suggest CVs in the order of 30%. The age specific values from the fishery mean weights were input for all three weight input data. Fishery selectivity CVs were fixed at 20%, M CVs at 30% and the maturity CVs were resulting from the variance around the fitted survey values at age. The model was run with 1000 realizations and the results summarized in Table B27. Similarly, an optional stochastic model was run with a constant M=0.4 and also in deterministic mode for both cases. The proxy for F_{MSY} remained at $F_{40\%.}$ SSB_{MSY} was determined as the median estimate of SSB following a stochastic projection of 100 years under F_{MSY}, with recruitment based on the 1984 to 2010 empirical recruitment estimates.

The preferred model was the stochastic YPR with age varying M. Median fishing mortality at F_{MSY} equaled 0.275 (80% CI between 0.230 and 0.337). The corresponding deterministic estimate at F_{MSY} equaled 0.252. SSB_{MSY} generated from 100 year projections with age variable M resulted in a median SSB of 9,467 MT with an 80% CI between 8,004 and 11,184 MT. The comparable BRP estimate using a constant M=0.4 produced a median F_{MSY} equaled 0.316 and the associated SSBMSY of 8,128 MT with an 80% CI between 6,734 and 9,870 MT (Table B27). Maximum sustainable yield (MSY) was calculated for both the variable and constant M model. With an age varying M, median MSY equaled 3,087 MT (80%

CI between 2,593 MT and 3,675 MT), whereas the MSY under a constant M at age assumption equaled 3,197 MT (80% CI between 2,628 MT and 3,905 MT).

The appropriateness of $F_{40\%}$ as a proxy for F_{MSY} and the associated SSB_{MSY} is dependent on the assumption that black sea bass populations respond to changes in F in a similar fashion as gonochoristic species. Without empirical evidence that sustainability differs, the WG felt that the recommended BRPs were appropriate.

TOR 7. Evaluate stock status with respect to the existing model (from the most recent accepted peer reviewed assessment) and with respect to a new model developed for this peer review.

a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.

b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs (from black sea bass TOR 6).

The existing model (SCALE) estimates of F_{2010} equaled 0.41 and SSB_{2010} of 13,926 MT. The corresponding BRPs were F_{MSY} =0.42 and SSB_{MSY}=12,537 MT. The results of the SCALE model indicates that the stock is 98% of F_{MSY} and 111% of SSB_{MSY}. Therefore, based on previous work presented in the summer of 2011 (MAFMC 2011; NEFSC 2011), the stock is not overfished or experiencing overfishing.

[SAW53 Editor's Note: Because the SARC-53 review panel rejected the ASAP model, the default was to fall back on using the previously accepted BRPs and SCALE model fit from the summer of 2011, which indicated that the stock was not overfished and overfishing was not occurring. The TOR 7 text below is included to show the work that was done by the SAW53 Working Group for the December 2011 peer review and is not intended for use by managers at this time.]

The 2010 estimate of average F from the ASAP model equaled 0.18 with corresponding SSB of 10,843 MT. Comparison of the 2010 ASAP results to the BRPs generated from the stochastic YPR show that the stock is not overfished or experiencing overfishing (Figure B107, Table B28). The 90% confidence bound of the median F_{2010} (0.171) remains below the 10% confidence bound of F_{MSY} (0.230). The 2010 F is 62% of F_{MSY}. The same conclusion is reached in comparison with the deterministic BRP estimate. Alternative stochastic and deterministic BRPs were calculated using a constant M=0.4. The deterministic $F_{40\%}$ = 0.292, while the median value in the stochastic model equaled 0.316. In either case the comparison with average F_{2010} (0.17 with M=0.4) shows that the stock is not experiencing overfishing.

Similarly, the median SSB_{2010} (11,456 MT) with age variable M shows the stock is not overfished when compared to the stochastic estimate of SSB_{MSY} (9,467 MT) (Figure B108). The lower bound of the 80% CI of median SSB_{2010} (10,012 MT) is below the upper bound of the SSB_{MSY} 80% CI (11,184 MT). The median SSB_{2010} estimated with constant M=0.4 equal to 11,863 MT is greater than the associated SSB_{MSY} of 8,128 MT, consequently the stock would not be considered overfished.

TOR 8. Develop and apply analytical approaches to conduct single and multi-year stock projections to compute the pdf (probability density function) of the OFL (overfishing level) and candidate ABCs (Acceptable Biological Catch; see Appendix to the SAW TORs).

Provide numerical annual projections (3-5 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment, and definition of BRPs for black sea bass).

[SAW53 Editor's Note: Because the SARC-53 review panel rejected the ASAP model, no projections were considered. The text below is included to show the work that was done by the SAW Working Group for the December 2011 peer review.]

Short term (5 year) projections of catch were computed using the stochastic methods available in AGEPRO software (Table B29-B32). For the harvest scenario, the projection assumed the 2011quota of 2,041 MT would be taken and thereafter fished at a target F. Recruitment estimates for 2011 were developed under two scenarios; using the last 5 years of the ASAP model (2006-2010) or the full series since 1984 (27 years). Recruitment for the years 2012 to 2015 were randomly chosen in the bootstrap process from the 27 year time series (Figure B107).

Four scenarios were evaluated; 2006-2010 recruits w/variable M, 2006-2010 recruits with constant M, 1984-2010 recruits w/variable M and 1984-2010 recruits w/constant M. The median SSB projections using the 1984-2010 series declined over the five years from 11,160 MT to 8,550 MT (variable M) or 11,177 MT to 7,651 MT (constant M), and in both case declined below the median of SSB_{MSY}. In projections using the shorter recruitment time series, SSB also declined below the median SSB_{MSY} by 2015 using either variable M or constant M. In all cases, the projected 2012 catch would exceed the current 2011 quota of 2,041 MT (Table B33). The 2012 OFL using the recent recruitment scenario and variable M would equal 3,093 MT. Comparable values for constant M equaled 3,444 MT; with long-term recruitment estimate and variable M, OFL in 2012 = 3,103 MT and similarly with constant M = 3,451 MT.

The SARC53 panel concluded that the ASAP and revised SCALE results shown here should not be used at this time as a basis for developing management advice or for determining stock status. The methods and results are included here to show the work that was done by the SAW Working Group and reviewed for SARC53.

Comment on which projections seem most realistic. Consider major uncertainties in the assessment as well as the sensitivity of the projections to various assumptions.

Depending on the amount of risk that is acceptable to managers, each scenario could be considered realistic. The trend in recent recruitment and the preferred model incorporating variable M would imply that the scenario with 2006-2010 recruitment and variable M is most realistic.

The major uncertainties in the assessment were considered to be the choice of natural mortality, the impact of fishing on the life history and behavior as well as the local variability in population dynamics. The choice of M has been examined under two scenarios and the conclusion on stock status remains the same. The uncertainties associated with the other issues were not examined in this assessment. It should be noted that the recreational catch estimates were generated from the MRFSS program. Beginning in 2011 changes to the estimation procedures may result in new recreational catch estimates. The sensitivity to potential changes was not examined at this time since there is no available information on the potential magnitude of those changes.

Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.

Explanation of "Vulnerability" (DOC Natl. Standard Guidelines, Fed. Reg., vol. 74, no. 11, 1/16/2009): *"Vulnerability.* A stock's vulnerability is a combination of its productivity, which depends upon its life history characteristics, and its susceptibility to the fishery. Productivity refers to the capacity of the stock to produce MSY and to recover if the population is depleted, and susceptibility is the potential for the stock to be impacted by the fishery, which includes direct captures, as well as indirect impacts to the fishery (e.g., loss of habitat quality)." (p. 3205)

Like most members of the family Serranidae, black sea bass are protogynous hermaphrodites. Generally speaking, black sea bass are relatively short-lived, highly fecund, and mature relatively early. These life history characteristics could make black sea bass inherently resilient to fishing pressure. However, the vulnerability of the stock to fishing pressure while aggregated on structured habitat in coastal areas and the potential impacts on productivity from being fished while spawning (May-July), make this stock more susceptible to impacts from the fishery when compared to species with other reproductive strategies (i.e., gonochoritic species). In many species with territorial spawning behavior controlled by a dominant male, the smaller precocious males may play some role in spawning. During spawning season, the large dominant males are targeted by fisheries. It is unknown if this has a severe negative impact on spawning success or if the precocious males fill the void left by removal of the larger male. Given the uncertainties in the influence of fishing on spawning behavior and subsequent recruitment success, black sea bass is moderately vulnerable to becoming overfished. On this basis, an ABC should be selected that considers these sources of uncertainty relative to life history/reproductive characteristics for this stock.

TOR 9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

<u>NDPSWG Panel Recommendations:</u>

a) On-going ageing studies should be continued to provide a foundation for an age-based assessment.

- Aging has been completed for 1984-2010 survey data and 2008-2010 commercial.

b) A pot survey for black sea bass should be considered.

- A pilot project is ongoing and proposals are being considered for funding to expand the program throughout the range of the management unit (MA-NC).

c) At-sea samples need to be taken to improve understanding of the timing of sex change over years in order to study the potential influence of population size on sex switching. This may have implications of overfishing BRPs.

- Work is being conducted at NEFSC and UMass-Dartmouth on the northern stock and UNC-Wilmington on the South Atlantic stock.

d) Ageing validation studies should be undertaken to examine the implications of sex change as well as temperature and salinity changes associated with movement onshore and offshore on ageing reliability.

- The issue will be discussed at a future workshop. Also see literature from SEDAR 2011 BSB assessment. (http://www.sefsc.noaa.gov/sedar/Sedar_Workshops.jsp?WorkshopNum=25).

e) Meta-analysis of patterns of natural mortality in protogynous fishes should be undertaken.

- This recommendation is not yet addressed. It is to be discussed at a future workshop on modeling hermaphroditic species.

f) Exploration of management approaches used on species with protogynous life histories would be helpful.

- This is addressed in Brooks et al. (2008) as well as Heppel et al. (2006).

g) Research is needed to understand the implication of the removal of large males on population dynamics. These could be field studies or large scale mesocosm experiments. This could involve collaboration with industry and recreational sectors.

- This has not been addressed.

h) Efforts to quantify discard mortality are needed.

- This work is still needed and has not been addressed.

i) Exploration of model behavior, including retrospective analysis, is required.

- This exploratory work was conducted in this assessment.

j) Non-compliance may be an alternate explanation for high assumed rates of natural mortality. It would be useful to estimate whether or not there are sufficient amounts of non-reported catch to account of the assumed high rates of M.

- This has not been addressed.

k) The sensitivity of the SCALE model results to alternative data weightings should be explored.

- The assessment model advanced to a statistical catch at age model and alternative model settings were explored.

New WG research recommendations.

- In addition to recommendation "e" above: more simulation work should be done to better understand the implications of alternative natural mortality schemes.
- Research the source of the retrospective pattern, especially when survey data and fisheries catch data are weighted equally in the model (i.e., why is the survey data unreliable).
- Comparison of scale vs. otolith ages.
- Encourage the continuation of genetics work for stock identification (i.e., do multiple BSB stocks exist from Cape Cod to Cape Hatteras).

Acknowledgments

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Tables

[SAW53 Editor's Note:
The SARC-53 review panel did accept the work presented on TORs 1-4 (which primarily gives an update on fishing patterns, landings and survey data. Tables B1-B23 and Figures B1-B66 are associated with TORs 1-4.

The SARC-53 review panel did not accept new assessment models (or results from those new models) that were prepared by the SAW53 Working Group. Tables B24-B33 and Figures B67-B110 are associated with the new models and results. They are included in this report to demonstrate the work that was done by the SAW Working Group for the December 2011 peer review. However, those Tables and Figures are not intended to be used for management at this time.]

List of Tables –

Table B21. Black sea bass von Bertalanffy growth curves for all areas, north and south of Hudson Canyon.

Table B22. Models and associated values for natural mortality evaluated for black sea bass. Lorenzen M scaled to constant used in model. M in assessment model extrapolated to age 0.5 = 0.87.

Table B23. Black sea bass mean stock weights at age (kg), 1968-2010. 1968-1983 weights at age the average of 1984-1986.

Table B24. Components, number of residuals and residual mean square errors of ASAP model objective function.

Table B25. Historic retrospective estimates of black sea bass fishing mortality.

Table B26. Black sea bass CVs used in stochastic biological reference points.

Table B27. Black sea bass biological reference points and 2010 catch.

Table B28. Black sea bass stock status (2010) compared to biological reference points.

Table B29. Black sea bass projected catch (000s MT) for 2012-2015, under age varying M and 2011 recruitment from 2006-2010 average, at F40%.

Table B30. Black sea bass projected catch (000s MT) for 2012-2015, under constant M=0.4 and 2011 recruitment from 2006-2010 average, at F40% .

Table B31. Black sea bass projected catch (000s MT) for 2012-2015, under age varying M and 2011 recruitment from 1984-2010 average, at F40%.

Table B32. Black sea bass projected catch (000s MT) for 2012-2015, under constant M and 2011 recruitment from 1984-2010 average, at F40%.

Table B33. 2012 OFL (median and 80% CI) under two M options and two recruit series. 2011 catch assumed equal to ABC (2,041 MT).

Table B1. Black sea bass northern stock commercial and recreational landings (MT) and commercial and recreational discard losses, 1968-2010. (*1982 and 1986 rec landings adjusted*)

	Landings		Discard losses		
Year	Com	Rec	Com	Rec	Total MT
1968	1,079.0	1,108.5	64.3	66.0	2,317.8
1969	1,097.0	1,127.0	65.3	67.1	2,356.5
1970	970.0	996.5	57.8	59.4	2,083.6
1971	566.0	581.5	33.7	34.6	1,215.8
1972	727.0	746.9	43.3	44.5	1,561.7
1973	1,115.0	1,145.5	66.4	68.2	2,395.1
1974	1,023.0	1,051.0	60.9	62.6	2,197.5
1975	1,680.0	1,725.9	100.1	102.8	3,608.8
1976	1,557.0	1,599.5	92.7	95.3	3,344.5
1977	1,985.0	2,039.2	118.2	121.5	4,263.9
1978	1,662.0	1,707.4	99.0	101.7	3,570.1
1979	1,241.0	1,274.9	73.9	75.9	2,665.8
1980	977.0	1,003.7	58.2	59.8	2,098.7
1981	1,129.0	558.2	67.2	33.3	1,787.7
1982	1,177.1	*1,213.4*	70.1	268.0	2,728.6
1983	1,513.2	1,868.6	90.1	111.3	3,583.2
1984	1,519.4	601.5	104.5	33.0	2,258.4
1985	1,074.8	957.6	88.9	43.9	2,165.1
1986	1,508.5	*1,829.5*	100.7	98.6	3,537.3
1987	1,635.3	880.4	97.7	34.3	2,647.7
1988	1,424.0	1,299.2	101.8	92.3	2,917.4
1989	1,104.5	1,487.8	82.1	37.6	2,712.1
1990	1,401.6	1,255.9	52.8	94.4	2,804.6
1991	1,189.6	1,885.1	19.1	94.2	3,188.0
1992	1,264.3	1,187.9	91.2	83.4	2,626.9
1993	1,352.6	2,193.8	179.2	63.2	3,788.9
1994	848.4	1,332.7	33.8	80.7	2,295.5
1995	889.1	2,815.4	35.7	129.2	3,869.3
1996	1,448.4	1,809.0	482.7	92.0	3,832.0
1997	1,197.9	1,931.8	31.2	115.2	3,276.1
1998	1,171.2	519.0	135.8	86.6	1,912.6
1999	1,305.1	745.5	36.2	115.2	2,202.0
2000	1,205.5	1,804.3	41.7	277.4	3,328.8
2001	1,298.5	1,545.3	187.3	309.0	3,340.1
2002	1,587.4	1,982.9	24.3	390.7	3,985.2
2003	1,359.2	1,498.5	58.3	313.9	3,229.9
2004	1,405.5	761.6	369.9	142.3	2,679.3
2005	1,298.0	852.2	29.4	149.9	2,329.5
2006	1,285.4	897.7	16.1	173.2	2,372.4
2007	1,036.9	1,011.2	57.3	220.3	2,325.7
2008	875.1	712.7	36.7	252.0	1,876.6
2009	523.2	1,049.2	164.8	228.2	1,965.4
2010	751.4	1,351.1	110.1	231.4	2,444.0

Table B2. Black sea bass length measurements from Jan-June (spring) and July to December (fall) commercial sampling.

Lengths measured

Spring

	Unclass.	Jumbo	Large	Medium	Small	Ex-small
1984	669	592	3326	2777	2209	0
1985	157	710	3143	1471	1921	1062
1986	113	672	3551	2509	2507	231
1987	310	170	3211	1168	898	389
1988	799	341	2389	1449	1293	0
1989	202	132	2066	1341	1604	161
1990	181	260	2798	2537	3075	194
1991	226	0	2106	452	568	0
1992	33	89	786	827	894	99
1993	75	74	1534	1816	1927	0
1994	188	0	1307	1150	1471	0
1995	482	98	938	906	562	0
1996	24	107	1175	984	905	163
1997	384	0	1454	1432	1485	0
1998	0	152	1491	1559	1217	0
1999	221	103	949	1268	1157	0
2000	0	198	628	610	632	0
2001	169	0	1037	1278	956	0
2002	101	365	1384	648	285	0
2003	231	603	1153	537	200	0
2004	56	240	942	845	0	0

Fall

	Unclass.	Jumbo	Large	Medium	Small	Ex-small
1984	329		182	0	200	
1985	164		0	156	567	
1986	108	95	175	131	300	100
1987	216	43	200	53	41	51
1988	106	0	20	13	52	
1989	38	13	48	39	84	
1990	168	0	10	0	328	
1991	117	67	105	12	130	4
1992	37	0	31	142	280	
1993	0	0	37	0	56	
1994	0	3	42	38	67	
1995	0	0	151	215	476	
1996	495	10	491	408	1099	
1997	0	17	183	325	355	
1998	69	15	18	362	668	
1999	0	35	275	612	752	
2000	0	0	0	185	621	
2001	0	0	127	309	500	
2002	0	243	281	401	300	
2003	50	350	544	613	99	
2004	209	207	184	409	104	

Table B3. Number of black sea bass commercial samples from otter trawls and by half-year from NMFS samples.

Otter Trawl Jan-June	ex-small	small	medium	large	ex-large	unclass	total
1984		4	10	5	2	4	25
1985	2	3	4	5	3	1	18
1986		5	5	4	1	2	17
1987		2	2	4		2	10
1988		1	2	2		5	10
1989		2	2	2		2	8
1990		4	3	2			9
1991							
1992	1	1	2	1			5
1993			2	1			3
1994			2	1			3
1995			2	1			3
1996		3	5	1			9
1997		7	6	4		3	20
1998		7	8	6	2		23
1999		9	11	3	1		24
2000		3	4	4	1		12
2001		8	14	6		2	30
2002		1	7	6	4	1	19
2003		1	4	3	2	5	15
2004			7	4	1	2	14
2005		2	9	9	8	2	30
2006		1	3	8	8	3	23
2007		4	14	12	5	1	36
2008		5	13	12	8	2	40
2009	2	3	8	10	5	3	31
2010	2	2	9	6	5	2	26
							463

Otter Trawl July-Dec	ex-small	small	medium	large	ex-large	unclass	total
1984				2		1	3
1985		1					1
1986	1		1	2	1	1	6
1987				1		1	2
1988						1	1
1989							
1990		1	1				2
1991							
1992							
1993							
1994							
1995		1	1	1			3
1996		2		1		5	8
1997			1	1			2
1998							
1999				3	2		5
2000							
2001			1				1
2002							
2003			1	3	5	1	10
2004				1	4	3	8
2005			2	5	8	1	16
2006			4	1	8		13
2007		1	1	1	4	1	8
2008				2	6	3	11
2009			3	3	4	2	12
2010			1	2	7		10
							122

Table B4. Number of black sea bass commercial samples from fish pots and by half-year from NMFS samples.

Fish Pot Jan-June	ex-small	small	medium	large	ex-large	unclass	total
1984		4	2				6
1985							
1986		3					3
1987			1			1	2
1988						2	2
1989							
1990							
1991		2	2	2			6
1992				1			1
1993							
1994							
1995						3	3
1996		3	3	3	1		10
1997		6	7	5	1		19
1998		5	5	3	2		15
1999		3	2				5
2000		3	4	1	1		9
2001		2		1			3
2002		1					1
2003		1	2				3
2004				1	1		2
2005		1	2				3
2006		1	6	5	3	2	17
2007		1	9	7	4		21
2008		4	12	8	2	2	28
2009		1	8	1	2	1	13
2010		1	8	2			11
							183

Fish Pot July-Dec	ex-small	small	medium	large	ex-large	unclass	total
1984		2					2
1985		5	1			1	7
1986		3					3
1987						1	1
1988							
1989							
1990							
1991		1					1
1992							
1993							
1994							
1995		2	2	2			6
1996		7	5	5	1		18
1997		3	3	1	1		8
1998		7	5	1			13
1999		8	10	3			21
2000		6	2				8
2001		5	2	2			9
2002		3	3	2	2		10
2003		1	5	2	1	1	10
2004		1	4		1	3	9
2005			6	4		1	11
2006		2	15	7	2	1	27
2007		1	15	11	6	1	34
2008		9	9	4	4	3	29
2009		4	4	2	1	1	12
2010		3	2	1	1		7
							246

Table B5. Number of black sea bass commercial samples for other gears and by half-year from NMFS samples.

Other gear Jan-June	ex-small	small	medium	large	ex-large	unclass	total
1984							
1985							
1986			1	1			2
1987							
1988							
1989							
1990							
1991							
1992							
1993							
1994							
1995							
1996							
1997							
1998							
1999						2	2
2000		1			1		2
2001				1			1
2002		1		1			2
2003				2	5		7
2004			1		1		2
2005					1		1
2006					4	1	5
2007			2	1	2	4	9
2008							
2009			2	2	1		5
2010			1		1		2
							40

Other Gear Jul-Dec	ex-small	small	medium	large	ex-large	unclass	total
1984							
1985							
1986							
1987							
1988							
1989							
1990							
1991							
1992							
1993							
1994							
1995							
1996		1					1
1997							
1998							
1999							
2000			1				1
2001							
2002			1	1	1		3
2003				1			1
2004				1			1
2005			1	2		1	4
2006		2	1	4	4	1	12
2007		3	3	3	3	4	16
2008			2	1	1		4
2009		1	2	3	3	2	11
2010			1				1
							55

Table B6. Number of black sea bass commercial samples from otter trawl by half-year from NCDMF samples.

NC Otter trawl
1st half

	3356	3355	3353	3351	3352	3350	
1984	3	14	1			3	21
1985	11	10		1		8	30
1986	9	16		1		4	30
1987	10	7				1	18
1988	4	21	3			4	32
1989	5	29				2	36
1990	1	33	2	2		5	43
1991	2	14	5	1		8	30
1992	2	10		1		2	15
1993	2	29	2			2	35
1994	3	30	2	1		5	41
1995		18	3	1		4	26
1996	2	16	5	1		2	26
1997		3	1				4
1998		6	4	1		1	12
1999		2	3	2	1	7	15
							414

NC Otter trawl
2nd half

	3356	3355	3353	3351	3352	3350	
1984	1	4	2			7	14
1985	2	5	3			10	20
1986	2	14	1	1		7	25
1987	9	8	1	1		3	22
1988	1	12	3			2	18
1989	4	7	2	1		4	18
1990	1	11	2	2		11	27
1991	1	19	4			7	31
1992	1	6	7	1		2	17
1993		11	5	2			18
1994	1	11	4	2		1	19
1995	2	2	2	1			7
1996						1	1
1997	1	2					3
1998		1	1	1		8	11
1999		2	2	2	1		7
							258

Table B7. Black sea bass commercial landings mean length (cm), 1984-2010.

	Mean Length	CV
1984	27.05	0.20
1985	27.56	0.22
1986	25.47	0.24
1987	26.24	0.21
1988	25.57	0.22
1989	26.99	0.22
1990	26.40	0.19
1991	25.18	0.20
1992	25.39	0.18
1993	25.69	0.18
1994	25.59	0.18
1995	27.20	0.17
1996	26.59	0.19
1997	27.84	0.17
1998	29.74	0.16
1999	31.43	0.17
2000	32.47	0.18
2001	32.79	0.15
2002	33.92	0.15
2003	33.33	0.22
2004	34.15	0.16
2005	35.24	0.19
2006	34.99	0.19
2007	34.24	0.18
2008	32.98	0.16
2009	33.65	0.16
2010	34.04	0.17

Table B8. Black sea bass commercial discard estimates (MT) (prior to discard mortality). Trawl data based on SBRM method (1989-2010) includes CV.

	Otter trawl	CV	Fish Pot	Hand line	Total
1984	103.9		4.3	0.3	108.4
1985	88.1		3.3	1.5	92.9
1986	99.5		6.9	0.9	107.3
1987	96.5		7.4	0.6	104.5
1988	100.4		7.8	1.2	109.5
1989	80.9	0.37	6.9	1.1	88.9
1990	51.0	0.38	10.3	1.5	62.7
1991	17.1	0.28	11.8	1.8	30.7
1992	89.4	0.40	10.5	1.5	101.5
1993	177.9	0.94	7.9	1.1	186.9
1994	33.1	0.52	4.3	0.5	37.8
1995	34.2	0.44	8.2	1.3	43.7
1996	480.8	0.87	8.3	4.3	493.4
1997	27.2	1.93	25.2	1.7	54.1
1998	124.2	0.39	74.8	2.5	201.6
1999	22.6	0.30	83.6	7.5	113.6
2000	24.9	0.29	104.3	7.2	136.5
2001	170.1	0.30	108.7	5.9	284.6
2002	10.0	0.51	89.9	5.5	105.4
2003	46.6	0.49	70.0	8.1	124.7
2004	359.5	0.26	65.1	4.4	429.0
2005	22.3	0.28	43.8	3.5	69.6
2006	10.5	0.39	32.2	5.2	47.8
2007	51.7	0.36	31.6	5.8	89.1
2008	32.2	0.31	25.8	4.2	62.3
2009	160.7	0.36	23.0	4.2	187.9
2010	105.4	0.17	27.7	3.6	136.7

Table B9. Sample size (number of black sea bass measured) from otter trawl trips and fish pot trips.

	Otter Trawls	Fish Pots
1989	477	
1990		
1991		
1992		
1993		46
1994	26	158
1995	89	
1996	514	
1997	304	
1998	509	
1999	13	
2000	116	
2001	297	
2002	156	
2003	1200	64
2004	2349	254
2005	1051	14
2006	605	
2007	903	172
2008	982	320
2009	2154	
2010	2092	1084

Table B10. Black sea bass recreational landings (AB1), proportional standard error and sample sizes. Note that the 1982 and 1986 landings are unadjusted values.

	Total Num (000s)	PSE	Number fish Inspected
1981	1886.7	15.7	744
1982	*10045.9*	35.5	1153
1983	4968.4	17.5	1330
1984	1700.1	12.9	1354
1985	3377.1	11.8	1863
1986	*21732.6*	21.6	2913
1987	2875.6	13.9	1759
1988	3058.8	15.3	2033
1989	4221.1	6.6	4202
1990	3879.8	8.4	3109
1991	5226.3	8.0	3569
1992	3535.3	7.6	4011
1993	5994.4	19.5	2470
1994	3422.2	11.8	2989
1995	6742.8	14.5	2535
1996	3619.4	10.9	2734
1997	4736.2	9.4	2690
1998	1147.0	12.5	2353
1999	1361.6	15.3	2102
2000	3631.5	10.7	3022
2001	2845.8	7.2	3651
2002	3372.1	7.0	3456
2003	3258.7	5.5	4137
2004	1750.7	9.2	3609
2005	1255.1	11.6	4057
2006	1484.9	11.5	3244
2007	1738.0	13.7	3691
2008	1107.8	10.9	3566
2009	1603.2	11.2	3223
2010	1897.3	13.0	4113

Table B11. Black sea bass recreational discards (B2) totals, ME to northern NC, 1981-2010.

	Total Num(000s)	PSE
1981	1,760	29.08
1982	1,338	17.85
1983	2,653	20.69
1984	1,610	20.69
1985	2,651	11.59
1986	7,175	12.88
1987	2,117	13.61
1988	5,014	10.64
1989	2,129	7.31
1990	5,246	7.77
1991	5,610	6.21
1992	4,304	8.74
1993	3,223	11.16
1994	3,970	7.16
1995	7,565	7.28
1996	4,549	8.28
1997	6,010	7.74
1998	3,900	8.68
1999	5,751	7.90
2000	13,208	6.09
2001	10,886	4.27
2002	11,304	5.63
2003	8,877	4.72
2004	5,853	6.78
2005	5,667	7.51
2006	6,895	7.50
2007	8,576	6.41
2008	9,730	7.27
2009	7,753	7.32
2010	7,327	9.08

Table B12. Lengths measurements of discarded black sea bass.

	ALS tags	NJ Tags	NJ Volunteers	MRFSS Party/Charter	New York Party/Charter	Total
1984	9					9
1985	59					59
1986	41					41
1987	23					23
1988	45					45
1989	20					20
1990	22					22
1991	98					98
1992	43					43
1993	45					45
1994	39					39
1995	35	253			232	520
1996	14	8			175	197
1997	40	528			325	893
1998	52	492			63	607
1999	125	17			224	366
2000	194					194
2001	392	1265				1657
2002	337	482				819
2003	248	184				432
2004	308					308
2005	263			4348		4611
2006	230			5255		5485
2007	202			7799		8001
2008	988		413	7614		9015
2009	967		315	8332		9614
2010	680		242	8963		9885

Table B13. Black sea bass commercial landings at age, 1984-2010.

000s

	0	1	2	3	4	5	6	7	8	9
1984	0.0	84.5	1327.0	2255.8	1249.8	87.9	36.0	5.1	7.9	0.0
1985	0.0	17.2	862.5	1386.4	863.3	94.4	39.3	16.5	10.2	0.3
1986	0.0	185.8	3896.5	1098.7	258.9	50.6	78.5	5.4	19.6	15.3
1987	0.0	26.3	3194.0	2131.5	345.3	74.3	56.6	4.4	9.0	0.0
1988	0.0	108.9	2363.7	2228.5	563.1	166.9	39.2	0.0	10.3	1.7
1989	0.0	9.7	1892.1	1146.6	424.5	44.1	56.8	3.3	9.8	1.6
1990	0.0	67.4	2297.3	2252.7	261.3	59.4	27.6	23.5	1.9	0.7
1991	0.0	56.7	3273.4	922.1	403.0	123.1	15.8	3.2	0.0	0.0
1992	0.0	28.6	2749.6	1958.4	281.9	48.5	13.1	2.2	1.3	0.0
1993	0.0	57.4	1814.7	2957.6	399.2	48.7	21.8	5.8	1.0	0.0
1994	0.0	44.5	1149.7	1425.1	655.4	80.4	17.5	4.2	0.4	0.2
1995	0.0	203.3	1794.0	770.1	128.9	39.0	11.3	1.4	0.0	0.0
1996	0.0	296.7	2470.1	1717.2	347.5	189.1	49.6	11.9	1.3	0.3
1997	0.0	65.8	1508.2	1561.0	458.1	64.9	24.2	7.3	1.2	0.3
1998	0.0	63.3	1080.8	1173.3	596.2	41.9	32.9	6.7	6.3	0.7
1999	0.0	27.1	664.4	1215.6	614.7	187.9	71.5	20.6	3.5	1.2
2000	0.0	140.3	466.1	796.2	610.5	264.3	42.9	6.7	2.7	2.8
2001	0.0	3.8	411.8	1522.9	443.4	85.1	36.9	2.4	9.9	2.7
2002	0.0	14.2	239.1	1512.9	895.3	51.4	21.1	7.9	1.2	12.0
2003	0.0	5.1	218.4	805.3	654.0	366.5	91.6	13.1	0.0	0.0
2004	0.0	0.0	207.7	969.6	501.1	573.7	49.5	5.2	7.9	0.0
2005	0.0	0.0	316.4	375.2	760.3	196.5	232.7	18.1	3.3	0.0
2006	0.0	1.3	349.3	373.6	591.3	419.3	139.9	13.8	3.6	1.8
2007	0.0	27.3	239.0	613.2	446.2	125.5	113.5	86.2	7.0	1.3
2008	0.0	0.3	183.2	1028.9	260.3	93.0	38.8	10.8	5.5	1.0
2009	0.0	0.3	101.7	408.7	305.3	56.2	38.4	8.1	6.1	1.4
2010	0.0	0.0	41.8	529.3	444.6	209.8	60.6	10.9	3.8	2.0

Table B14. Black sea bass commercial discards at age, 1989, 1994-2010.

000s	0	1	2	3	4	5	6	7	8	9
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	0.0	422.2	737.8	74.0	1.5	0.0	0.0	0.0	0.0	0.0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1994	31.5	243.8	134.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	43.1	115.0	100.9	22.8	0.0	0.0	0.0	0.0	0.0	0.0
1996	207.1	2217.5	1817.5	55.8	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.0	25.3	149.1	11.8	0.3	0.0	0.0	0.0	0.0	0.0
1998	0.0	0.1	698.5	27.0	20.3	1.7	0.0	1.5	0.0	1.5
1999	0.0	0.0	69.1	83.1	34.2	0.0	0.0	0.0	0.0	0.0
2000	0.0	50.0	117.4	32.7	8.3	0.4	0.0	0.0	0.0	0.0
2001	1.9	170.7	625.2	161.1	40.3	4.8	3.8	0.0	0.8	0.0
2002	86.8	28.3	101.8	9.3	5.7	0.0	0.6	0.6	0.0	0.0
2003	1.9	34.9	43.1	21.1	19.7	6.7	6.6	1.3	0.0	0.0
2004	4.2	127.3	181.5	218.8	103.4	91.9	27.6	3.4	1.1	0.0
2005	3.1	0.8	22.2	9.1	21.2	4.3	4.8	0.3	0.0	0.0
2006	0.0	3.4	7.5	3.3	5.1	3.7	2.3	0.2	0.0	0.0
2007	0.0	33.4	113.4	31.2	10.7	5.0	6.7	0.5	0.0	0.0
2008	2.2	30.2	54.0	21.8	4.4	1.0	1.4	2.3	0.2	0.0
2009	3.8	81.9	230.5	118.7	56.3	12.4	15.5	3.5	1.3	0.6
2010	0.3	8.9	55.5	90.7	51.2	24.0	12.7	1.3	1.8	0.0

Table B15. Black sea bass recreational landings at age, 1984-2010.

000s

	0	1	2	3	4	5	6	7	8	9
1984	0.0	269.7	588.0	552.3	126.8	30.4	23.6	0.5	0.9	0.0
1985	10.4	515.3	1623.7	735.3	340.0	67.1	36.9	5.9	1.3	0.0
1986	0.0	790.4	4437.6	1235.6	259.2	56.6	86.9	8.9	11.3	16.9
1987	0.0	158.4	1489.6	946.0	96.0	33.9	91.1	11.2	15.0	0.0
1988	0.0	237.5	1097.7	1064.6	417.6	110.7	36.6	0.0	12.8	0.0
1989	2.8	139.9	2499.9	1254.0	259.1	15.4	44.8	2.0	3.2	0.0
1990	0.0	535.4	1499.5	1474.3	259.3	57.0	17.7	10.0	0.0	0.0
1991	2.5	208.1	3152.7	1196.4	474.2	109.5	32.1	17.7	2.4	4.9
1992	0.0	124.7	1699.8	1168.4	379.6	86.9	37.7	7.9	1.8	0.0
1993	1.3	359.4	3502.0	1447.2	536.7	61.7	59.2	12.2	7.6	0.0
1994	10.7	418.6	1494.9	859.4	430.4	147.1	37.5	10.2	0.0	0.0
1995	90.1	2100.8	2895.2	1067.2	231.2	179.4	31.3	8.0	0.0	0.0
1996	8.5	562.4	1841.0	509.4	481.5	152.3	47.2	5.3	0.0	2.1
1997	0.4	168.1	2117.6	1486.4	670.3	182.7	68.1	27.8	0.0	0.0
1998	0.0	29.3	339.5	399.2	279.9	32.3	28.6	11.2	6.0	0.0
1999	0.0	37.8	303.0	525.2	306.9	115.6	33.8	1.1	0.0	0.0
2000	0.4	464.4	786.1	1161.6	795.3	309.6	60.3	14.3	9.9	5.9
2001	0.0	5.9	740.4	1617.1	331.3	63.8	58.5	7.8	4.7	0.9
2002	0.0	29.4	287.0	1989.0	924.0	50.4	38.1	14.9	0.8	3.4
2003	0.0	10.7	311.5	1359.1	962.7	490.1	79.4	11.9	0.6	0.0
2004	0.0	1.2	139.9	878.5	245.9	346.5	18.8	3.4	2.7	0.0
2005	0.0	0.3	289.6	327.3	423.3	125.4	68.2	6.3	1.2	0.0
2006	0.0	3.6	106.1	401.9	483.5	393.5	63.5	3.7	3.2	0.3
2007	0.0	4.6	58.9	733.4	565.9	126.2	128.3	105.0	6.5	1.5
2008	0.0	11.6	138.5	561.0	223.5	88.7	43.7	14.1	6.2	0.5
2009	0.0	4.5	165.6	733.4	489.5	138.3	37.7	10.4	8.7	1.9
2010	0.6	10.9	172.6	873.1	555.4	213.0	38.6	6.8	0.0	0.2

Table B16. Black sea bass recreational discards at age, 1984-2010.

000s

	0	1	2	3	4	5	6
1984	24.8	142.4	33.4	40.9	0.0	0.0	0.0
1985	4.7	221.0	156.5	6.1	0.0	0.0	0.0
1986	40.6	731.0	284.3	0.0	0.0	0.0	0.0
1987	21.2	160.3	131.6	4.4	0.0	0.0	0.0
1988	12.5	494.4	234.3	0.0	0.0	0.0	0.0
1989	0.0	158.2	154.7	6.3	0.0	0.0	0.0
1990	67.3	446.6	220.5	52.5	0.0	0.0	0.0
1991	46.7	325.9	441.3	21.1	0.0	0.0	0.0
1992	9.0	268.1	356.1	12.6	0.0	0.0	0.0
1993	28.0	246.5	208.1	0.9	0.0	0.0	0.0
1994	3.6	376.0	68.8	147.2	0.0	0.0	0.0
1995	2.2	1,085.9	46.7	0.0	0.0	0.0	0.0
1996	7.0	405.7	269.7	0.0	0.0	0.0	0.0
1997	0.0	328.8	572.1	0.7	0.0	0.0	0.0
1998	0.5	323.2	261.2	0.0	0.0	0.0	0.0
1999	0.7	803.5	58.4	0.0	0.0	0.0	0.0
2000	21.5	1,636.3	303.5	20.0	0.0	0.0	0.0
2001	1.2	776.5	768.6	86.6	0.0	0.0	0.0
2002	0.8	562.6	916.4	215.8	3.7	0.0	0.0
2003	0.5	439.4	655.8	229.7	6.0	0.0	0.0
2004	8.3	612.5	203.9	50.2	2.8	0.4	0.0
2005	35.2	477.0	258.9	77.4	1.1	0.0	0.0
2006	29.7	632.3	291.7	60.9	18.5	1.1	0.0
2007	44.9	594.3	613.5	31.7	1.3	0.7	0.0
2008	144.0	871.0	417.0	27.4	0.0	0.0	0.0
2009	50.2	517.0	514.0	76.2	4.8	0.8	0.0
2010	69.9	450.1	378.5	183.9	16.2	0.5	0.0

Table B17. Black sea bass total catch at age, 1984-2010.

000s

	0	1	2	3	4	5	6	7	8	9
1984	24.8	496.7	1948.4	2849.0	1376.7	118.3	59.6	5.7	8.7	0.0
1985	15.1	753.5	2642.7	2127.8	1203.4	161.5	76.2	22.4	11.5	0.3
1986	40.6	1707.2	8618.4	2334.2	518.0	107.3	165.4	14.3	30.9	32.2
1987	21.2	345.0	4815.2	3081.9	441.3	108.1	147.7	15.6	24.0	0.0
1988	12.5	840.8	3695.7	3293.0	980.6	277.6	75.8	0.0	23.0	1.7
1989	2.8	730.0	5284.5	2481.0	685.1	59.5	101.6	5.3	13.0	1.6
1990	67.3	1049.5	4017.3	3779.4	520.6	116.4	45.3	33.5	1.9	0.7
1991	49.2	590.8	6867.4	2139.7	877.2	232.6	47.9	20.8	2.4	4.9
1992	9.0	421.3	4805.5	3139.3	661.4	135.3	50.8	10.1	3.1	0.0
1993	29.3	663.3	5524.8	4405.7	935.9	110.4	81.0	17.9	8.6	0.0
1994	45.8	1082.9	2847.8	2431.6	1085.8	227.5	55.0	14.4	0.4	0.2
1995	135.4	3505.2	4836.8	1860.1	360.1	218.4	42.6	9.3	0.0	0.0
1996	222.5	3482.2	6398.3	2282.4	829.0	341.4	96.7	17.1	1.3	2.4
1997	0.4	588.0	4346.9	3059.9	1128.7	247.6	92.3	35.1	1.2	0.3
1998	0.5	416.0	2380.0	1599.6	896.4	76.0	61.4	19.4	12.3	2.1
1999	0.7	868.3	1094.9	1823.9	955.8	303.5	105.2	21.7	3.5	1.2
2000	21.8	2291.1	1673.1	2010.5	1414.1	574.3	103.2	21.0	12.6	8.7
2001	3.0	956.9	2545.9	3387.7	815.1	153.7	99.2	10.3	15.4	3.6
2002	87.7	634.6	1544.3	3727.1	1828.8	101.8	59.7	23.4	2.1	15.4
2003	2.4	490.0	1228.8	2415.3	1642.4	863.2	177.6	26.3	0.6	0.0
2004	12.4	741.0	732.9	2117.2	853.2	1012.5	95.9	11.9	11.8	0.0
2005	38.2	478.2	887.0	789.0	1205.9	326.1	305.7	24.7	4.5	0.0
2006	29.7	640.7	754.6	839.7	1098.4	817.6	205.7	17.7	6.8	2.1
2007	44.9	659.7	1024.7	1409.5	1024.0	257.5	248.4	191.7	13.5	2.8
2008	146.3	913.0	792.7	1639.1	488.3	182.7	83.9	27.2	11.9	1.6
2009	54.0	603.8	1011.8	1337.1	855.9	207.6	91.6	22.0	16.1	3.9
2010	70.8	470.0	648.4	1677.0	1067.4	447.4	111.9	19.0	5.6	2.3

Table B18. Black sea bass mean catch weights at age (kg), 1968-2010. 1968-1983 weights at age the average of 1984-1986.

year	0	1	2	3	4	5	6	7+
1968	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1969	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1970	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1971	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1972	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1973	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1974	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1975	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1976	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1977	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1978	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1979	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1980	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1981	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1982	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1983	0.01	0.08	0.17	0.32	0.54	0.89	1.34	2.43
1984	0.01	0.10	0.17	0.30	0.45	0.82	1.33	2.29
1985	0.01	0.07	0.16	0.27	0.51	0.84	1.37	2.10
1986	0.01	0.08	0.18	0.40	0.66	1.00	1.34	2.89
1987	0.03	0.08	0.17	0.34	0.57	0.92	1.58	2.02
1988	0.01	0.10	0.18	0.32	0.49	0.62	1.38	1.93
1989	0.01	0.03	0.18	0.35	0.58	0.86	1.37	2.54
1990	0.02	0.09	0.17	0.33	0.60	0.81	1.20	2.22
1991	0.03	0.08	0.17	0.36	0.54	0.66	1.16	1.84
1992	0.01	0.08	0.18	0.31	0.58	0.90	1.05	2.02
1993	0.02	0.11	0.21	0.29	0.59	0.88	1.15	1.94
1994	0.02	0.08	0.20	0.28	0.40	0.86	0.99	1.77
1995	0.05	0.12	0.24	0.45	0.76	1.01	1.21	1.69
1996	0.05	0.11	0.19	0.34	0.66	0.70	1.08	1.61
1997	0.06	0.15	0.23	0.37	0.61	0.84	0.94	1.37
1998	0.03	0.18	0.21	0.40	0.54	1.09	1.13	1.94
1999	0.03	0.14	0.28	0.41	0.59	0.85	0.92	1.78
2000	0.05	0.18	0.30	0.47	0.68	0.82	1.60	2.08
2001	0.02	0.08	0.26	0.48	0.67	1.12	1.47	1.94
2002	0.01	0.16	0.31	0.44	0.75	1.25	1.44	2.40
2003	0.03	0.14	0.36	0.49	0.63	0.84	1.40	2.13
2004	0.03	0.11	0.32	0.47	0.67	0.73	1.72	2.18
2005	0.02	0.12	0.35	0.47	0.60	0.85	1.29	2.17
2006	0.04	0.12	0.32	0.49	0.61	0.70	1.38	1.92
2007	0.04	0.15	0.27	0.48	0.64	0.88	1.06	1.79
2008	0.04	0.14	0.32	0.45	0.70	0.82	1.11	1.78
2009	0.04	0.11	0.27	0.47	0.66	0.83	1.20	1.83
2010	0.05	0.14	0.35	0.46	0.60	0.79	1.33	1.83

Table B19. Black sea bass mean catch weights at age (kg) 2006-2010, variance and CV

	Age								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
2006									
mean wt		0.15	0.34	0.57	0.65	0.66	1.61	1.89	
var		0.006	0.002	0.028	0.096	0.108	0.178	0.477	
CV		0.52	0.13	0.29	0.48	0.50	0.26	0.37	
2007									
mean wt		0.28	0.33	0.50	0.78	0.90	1.66	2.16	
var		0.00	0.01	0.02	0.11	0.07	0.24	0.41	
CV		0.19	0.30	0.29	0.44	0.30	0.29	0.30	
2008									
mean wt		0.14	0.39	0.49	1.00	1.54	1.99	1.96	2.98
var		0.001	0.008	0.025	0.016	0.036	0.068	0.184	0.008
CV		0.18	0.23	0.32	0.12	0.12	0.13	0.22	0.03
2009									
mean wt		0.15	0.37	0.52	0.60	0.73	1.19	1.40	
var		0.001	0.010	0.020	0.038	0.093	0.082	0.344	
CV		0.25	0.26	0.27	0.33	0.42	0.24	0.42	
2010									
mean wt	0.02	0.09	0.25	0.46	0.58	0.79	1.26	1.45	1.88
var	0.000	0.001	0.002	0.011	0.034	0.121	0.121	0.270	0.036
CV	0.00	0.36	0.18	0.23	0.32	0.44	0.28	0.36	0.10

Table B20. Model results for black sea bass maturity at age, female and sexes combined.

Female at age

	estimate	SE	L95	U95
intercept	-1.372	0.121	-1.614	-1.130
age	1.150	0.054	1.042	1.258

All at age

	estimate	SE	L95	U95
intercept	-2.578	0.101	-2.780	-2.376
age	1.572	0.048	1.476	1.668

Table B21. Black sea bass von Bertalanffy growth curves for all areas, north and south of Hudson Canyon.

All areas	n=5484	SE	lower 95%CI	upper 95%CI
Linf	65.12	1.44	62.30	67.93
K	0.181	0.006	0.168	0.193
to	0.146	0.017	0.112	0.180

North	n=4215	SE	lower 95%CI	upper 95%CI
Linf	63.64	1.71	60.29	66.98
K	0.183	0.008	0.167	0.199
to	0.150	0.026	0.099	0.201

South	n=1269	SE	lower 95%CI	upper 95%CI
Linf	65.19	2.30	60.69	69.70
K	0.202	0.011	0.180	0.224
to	0.190	0.019	0.154	0.227

Table B22. Models and associated values for natural mortality evaluated for black sea bass. Lorenzen M scaled to constant used in model. M in assessment model extrapolated to age 0.5 = 0.87.

Age	Constant	Rule of Thumb[1]	Rule of Thumb[2]	Hewitt & Hoenig[1]	Hewitt & Hoenig[2]	Lorenzen	Lorenzen Scaled to Constant	Lorenzen Scaled to Rule of Thumb[1]	Lorenzen Scaled to Hewitt & Hoenig[1]	Lorenzen Scaled to Rule of Thumb[2]	Lorenzen Scaled to Hewitt & Hoenig[2]
1	0.40	0.33	0.25	0.47	0.35	0.87	0.65	0.56	0.78	0.50	0.62
2	0.40	0.33	0.25	0.47	0.35	0.69	0.49	0.44	0.62	0.36	0.46
3	0.40	0.33	0.25	0.47	0.35	0.60	0.41	0.38	0.53	0.29	0.38
4	0.40	0.33	0.25	0.47	0.35	0.52	0.36	0.33	0.47	0.24	0.33
5	0.40	0.33	0.25	0.47	0.35	0.47	0.33	0.30	0.42	0.21	0.29
6	0.40	0.33	0.25	0.47	0.35	0.42	0.31	0.27	0.37	0.18	0.25
7	0.40	0.33	0.25	0.47	0.35	0.39	0.29	0.25	0.35	0.16	0.23
8	0.40	0.33	0.25	0.47	0.35	0.37	0.27	0.24	0.34	0.15	0.21
9	0.40	0.33	0.25	0.47	0.35	0.36	0.26	0.23	0.33	0.15	0.21
10	0.40		0.25		0.35	0.33	0.25			0.13	0.19
11	0.40		0.25		0.35	0.32	0.24			0.12	0.17
12	0.40		0.25		0.35	0.30	0.23			0.11	0.16

[1]Maximum age = 9

[2]Maximum age = 12

Table B23. Black sea bass mean stock weights at age (kg), 1968-2010. 1968-1983 weights at age the average of 1984-1986.

year	0	1	2	3	4	5	6	7+
1968	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1969	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1970	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1971	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1972	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1973	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1974	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1975	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1976	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1977	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1978	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1979	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1980	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1981	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1982	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1983	0.001	0.01	0.13	0.29	0.51	0.89	1.34	2.43
1984	0.001	0.01	0.13	0.29	0.51	0.82	1.33	2.29
1985	0.001	0.01	0.14	0.28	0.46	0.84	1.37	2.10
1986	0.001	0.01	0.14	0.32	0.54	1.00	1.34	2.89
1987	0.001	0.01	0.15	0.32	0.54	0.92	1.58	2.02
1988	0.001	0.01	0.13	0.27	0.53	0.62	1.38	1.93
1989	0.001	0.01	0.13	0.25	0.46	0.86	1.37	2.54
1990	0.001	0.01	0.12	0.25	0.46	0.81	1.20	2.22
1991	0.001	0.01	0.12	0.27	0.46	0.66	1.16	1.84
1992	0.001	0.01	0.11	0.23	0.44	0.90	1.05	2.02
1993	0.001	0.01	0.12	0.23	0.39	0.88	1.15	1.94
1994	0.001	0.01	0.15	0.26	0.58	0.86	0.99	1.77
1995	0.001	0.01	0.17	0.32	0.64	1.01	1.21	1.69
1996	0.001	0.02	0.16	0.31	0.67	0.70	1.08	1.61
1997	0.001	0.02	0.15	0.32	0.50	0.84	0.94	1.37
1998	0.001	0.01	0.16	0.34	0.47	1.09	1.13	1.94
1999	0.001	0.01	0.18	0.37	0.55	0.85	0.92	1.78
2000	0.001	0.01	0.17	0.37	0.60	0.82	1.60	2.08
2001	0.001	0.01	0.18	0.36	0.68	1.12	1.47	1.94
2002	0.001	0.01	0.16	0.35	0.61	1.25	1.44	2.40
2003	0.001	0.01	0.17	0.33	0.58	0.84	1.40	2.13
2004	0.001	0.01	0.16	0.32	0.47	0.73	1.72	2.18
2005	0.001	0.01	0.17	0.35	0.52	0.85	1.29	2.17
2006	0.001	0.01	0.17	0.33	0.52	0.70	1.38	1.92
2007	0.001	0.01	0.17	0.34	0.60	0.88	1.06	1.79
2008	0.001	0.01	0.16	0.33	0.58	0.82	1.11	1.78
2009	0.001	0.01	0.15	0.33	0.55	0.83	1.20	1.83
2010	0.001	0.01	0.14	0.31	0.49	0.79	1.33	1.83

Table B24. Components, number of residuals and residual mean square errors of ASAP model objective function.

Component	Num.resids	RMSE
_Catch_Fleet_1	43	0.364
Catch_Fleet_Total	43	0.364
_Discard_Fleet_1	0	0
Discard_Fleet_Total	0	0
_Index_1	30	0.428
_Index_2	22	1.27
_Index_3	22	2.94
_Index_4	27	2.67
_Index_5	27	2.63
_Index_6	43	2.34
_Index_7	16	2.3
Index_Total	187	2.23
Nyear1	7	0.341
Fmult_Year1	0	0
_Fmult_devs_Fleet_1	0	0
Fmult_devs_Total	0	0
Recruit_devs	43	0.542
Fleet_Sel_params	16	1.66
Index_Sel_params	16	0.383
q_year1	2	5.62
q_devs	0	0
SRR_steepness	0	0
SRR_unexpl_S	0	0

Table B25. Historic retrospective estimates of black sea bass fishing mortality.

	SCALE M=0.4 DPWG (model avg)	SCALE M=0.4 2008 (model avg)	SCALE M=0.4 2009 (model avg)	SCALE M=0.4 June update	M=0.4 Revised SCALE	M=0.4 ASAP	Lorenzen M ASAP
1968	0.62	0.59	0.58	0.57	0.46	0.30	0.30
1969	0.48	0.46	0.45	0.45	0.38	0.29	0.30
1970	0.46	0.44	0.43	0.43	0.37	0.25	0.25
1971	0.21	0.20	0.20	0.20	0.18	0.13	0.13
1972	0.24	0.23	0.23	0.23	0.21	0.15	0.15
1973	0.29	0.29	0.29	0.28	0.27	0.21	0.21
1974	0.28	0.28	0.28	0.28	0.24	0.19	0.19
1975	0.43	0.43	0.43	0.42	0.35	0.33	0.32
1976	0.50	0.50	0.51	0.48	0.34	0.34	0.34
1977	0.72	0.72	0.74	0.70	0.44	0.54	0.52
1978	0.66	0.64	0.65	0.62	0.31	0.57	0.55
1979	0.35	0.33	0.34	0.34	0.16	0.49	0.48
1980	0.36	0.33	0.34	0.34	0.17	0.39	0.38
1981	0.28	0.26	0.26	0.26	0.15	0.29	0.28
1982	0.83	0.79	0.79	0.79	0.54	0.41	0.41
1983	0.65	0.63	0.62	0.63	0.44	0.58	0.58
1984	0.49	0.48	0.48	0.48	0.37	0.41	0.41
1985	0.42	0.41	0.40	0.41	0.36	0.39	0.40
1986	1.21	1.27	1.26	1.25	1.34	0.49	0.50
1987	0.66	0.68	0.67	0.67	0.71	0.40	0.41
1988	0.91	0.92	0.90	0.90	0.93	0.49	0.50
1989	0.95	0.88	0.89	0.89	0.93	0.43	0.43
1990	1.02	0.94	0.96	0.95	1.03	0.47	0.47
1991	1.01	1.00	1.00	1.01	1.15	0.55	0.55
1992	0.78	0.73	0.75	0.75	0.75	0.40	0.40
1993	0.95	0.87	0.90	0.88	0.91	0.60	0.60
1994	0.52	0.51	0.52	0.51	0.53	0.52	0.52
1995	0.86	0.90	0.89	0.88	0.90	0.76	0.76
1996	1.19	1.07	1.15	1.14	1.10	0.96	0.97
1997	1.01	0.99	1.02	1.02	0.92	0.76	0.80
1998	0.62	0.58	0.62	0.61	0.56	0.52	0.57
1999	0.60	0.59	0.62	0.62	0.59	0.49	0.56
2000	0.93	0.93	0.97	0.98	1.01	0.56	0.65
2001	1.16	1.09	1.17	1.21	1.24	0.43	0.51
2002	1.02	0.98	1.03	1.03	0.72	0.34	0.41
2003	0.86	0.81	0.87	0.84	0.48	0.25	0.31
2004	0.80	0.56	0.68	0.65	0.35	0.19	0.24
2005	0.54	0.40	0.46	0.46	0.26	0.17	0.21
2006	0.50	0.39	0.45	0.46	0.26	0.19	0.22
2007	0.48	0.37	0.43	0.46	0.27	0.20	0.22
2008		0.28	0.35	0.39	0.24	0.15	0.17
2009			0.29	0.32	0.22	0.15	0.16
2010				0.41	0.30	0.17	0.18

Table B26. Black sea bass CVs used in stochastic biological reference points.

Catch, SSB, Jan 1 Mean Weights

	True Age							
	0	1	2	3	4	5	6	7+
Input CV	0.301	0.301	0.222	0.281	0.336	0.356	0.214	0.332

Fishery Selectivity

	True Age							
	0	1	2	3	4	5	6	7+
Input CV	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200

Maturity at age

	True Age							
	0	1	2	3	4	5	6	7+
Input CV	0.190	0.220	0.150	0.050	0.020	0.010	0.010	0.010

Natural Mortality

	True Age							
	0	1	2	3	4	5	6	7+
Input CV	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300

Table B27. Black sea bass biological reference points and 2010 catch.

Biological Reference Points	F40%	SSB40%	MSY	F2010	SSB2010	Catch2011
Existing BRPs and July 2011 Scale update	0.42	12,537 MT	3,903 MT	0.41	13,926 MT	2,960 MT
LOR M=0.40 from final base run (median SSB 2010)	DET: **0.252** AVG: **0.279** SD: 0.041 CV: 0.147 **50%: 0.275** 10%: 0.230 90%: 0.337	50%: 9,467 MT 10%: 8,004 MT 90%: 11,184 MT	50%: 3,087MT 10%: 2,593 MT 90%: 3,675 MT	avg 0.18 50%: 0.171 10%: 0.134 90%: 0.216	avg 10,843 MT 50%: 11,456MT 10%: 10,012 MT 90%: 13,082 MT	2,444 MT
Const M = 0.4. from alternate run	DET: **0.292** AVG: **0.323** SD: 0.050 CV: 0.155 **50%: 0.316** 10%: 0.262 90%: 0.390	50%: 8,128 MT 10%: 6,734 MT 90%: 9,870 MT	50%: 3,197 MT 10%: 2,628 MT 90%: 3,905 MT	avg 0.17 50%: 0.161 10%: 0.143 90%: 0.182	avg. 11,412 MT 50%: 11,863 MT 10%: 10,521 MT 90%: 13,369 MT	2,444 MT

Table B28. Black sea bass stock status (2010) compared to biological reference points.

Biological Reference Points	Status 2010	2010 % BRP
Existing BRPs and July 2011 Scale update	Not overfished No overfishing	111% of SSB40% 98% of F40%
LOR M=0.40 from final base run	Not overfished No overfishing	121% of SSB40% 62% of F40%
Const M = 0.4. from alternate run	Not overfished No overfishing	146% of SSB40% 59% of F40%

Table B29. Black sea bass projected catch (000s MT) for 2012-2015, under age varying M and 2011 recruitment from 2006-2010 average, at $F_{40\%}$.

Variable M
recruitment 2006-2010

SSB

	10% CI	Median	90% CI
2011	9.849	11.160	12.596
2012	8.883	9.905	10.960
2013	8.150	9.029	9.909
2014	7.843	8.712	9.663
2015	7.527	8.550	9.741

Catch	10% CI	Median	90% CI
2011	3.204	3.628	4.076
2012	2.783	3.093	3.401
2013	2.535	2.799	3.087
2014	2.509	2.779	3.075
2015	2.434	2.806	3.229

Total biomass	10% CI	Median	90% CI
2011	11.219	12.802	14.554
2012	10.170	11.363	12.653
2013	9.207	10.202	11.181
2014	8.851	9.766	10.722
2015	8.451	9.519	10.732

Mean biomass	10% CI	Median	90% CI
2011	10.796	12.162	13.643
2012	9.744	10.847	11.92
2013	9.086	10.028	11.009
2014	8.823	9.863	11.038
2015	8.529	9.767	11.246

Table B30. Black sea bass projected catch (000s MT) for 2012-2015, under constant M=0.4 and 2011 recruitment from 2006-2010 average at $F_{40\%}$.

Constant M
recruitment 2006-2010

SSB

	10% CI	Median	90% CI
2011	9.950	11.177	12.499
2012	8.402	9.325	10.357
2013	7.409	8.184	9.070
2014	6.953	7.762	8.707
2015	6.574	7.588	8.831

Catch

	10% CI	Median	90% CI
2011	3.839	4.292	4.800
2012	3.109	3.444	3.827
2013	2.743	3.032	3.371
2014	2.701	3.003	3.351
2015	2.562	3.007	3.534

Total Biomass

	10% CI	Median	90% CI
2011	11.747	13.318	14.982
2012	9.981	11.101	12.369
2013	8.560	9.462	10.501
2014	8.049	8.881	9.818
2015	7.499	8.564	9.808

Mean Biomass

	10% CI	Median	90% CI
2011	10.961	12.266	13.719
2012	9.300	10.282	11.423
2013	8.402	9.253	10.251
2014	7.931	8.943	10.114
2015	7.553	8.798	10.370

Table B31. Black sea bass projected catch (000s MT) for 2012-2015, under age varying M and 2011 recruitment from 1984-2010 average at $F_{40\%}$.

Variable M
recruitment 1984-2010

SSB

	10% CI	Median	90% CI
2011	9.849	11.160	12.596
2012	8.893	9.910	10.960
2013	8.355	9.171	9.991
2014	8.141	8.931	9.804
2015	7.784	8.754	9.899

Catch	10% CI	Median	90% CI
2011	3.205	3.628	4.076
2012	2.797	3.103	3.409
2013	2.591	2.840	3.109
2014	2.638	2.873	3.133
2015	2.520	2.878	3.286

Total biomass	10% CI	Median	90% CI
2011	11.220	12.802	14.555
2012	10.184	11.372	12.659
2013	9.312	10.281	11.223
2014	9.196	10.011	10.865
2015	8.743	9.749	10.890

Mean Biomass	10% CI	Median	90% CI
2011	10.802	12.165	13.646
2012	9.778	10.868	11.942
2013	9.397	10.256	11.134
2014	9.150	10.116	11.208
2015	8.792	9.982	11.422

Table B32. Black sea bass projected catch (000s MT) for 2012-2015, under constant M and 2011 recruitment from 1984-2010 average at $F_{40\%}$.

Constant M
recruitment 1984-2010

SSB

	10% CI	Median	90% CI
2011	9.950	11.177	12.499
2012	8.407	9.328	10.356
2013	7.523	8.228	9.057
2014	7.105	7.841	8.702
2015	6.678	7.651	8.854

Catch

	10% CI	Median	90% CI
2011	3.839	4.292	4.800
2012	3.119	3.451	3.824
2013	2.775	3.048	3.365
2014	2.777	3.040	3.351
2015	2.600	3.033	3.547

Total Biomass

	10% CI	Median	90% CI
2011	11.748	13.318	14.982
2012	9.988	11.102	12.364
2013	8.620	9.488	10.485
2014	8.241	8.966	9.787
2015	7.630	8.638	9.820

Mean Biomass

	10% CI	Median	90% CI
2011	10.962	12.270	13.718
2012	9.316	10.288	11.419
2013	8.564	9.327	10.223
2014	8.091	9.026	10.112
2015	7.659	8.865	10.409

Table B33. 2012 OFL (median and 80% CI) under two M options and two recruit series. 2011 catch assumed equal to ABC (2,041 MT).

	2012 OFL R=2006-2010	2012 OFL R=1984-2010
LOR M = 0.40 from final base run	50%: 3,093 MT 10%: 2,783 MT 90%: 3,401 MT	50%: 3,103 MT 10%: 2,797 MT 90%: 3,409 MT
Const M = 0.4. from alternate run	50%: 3,444 MT 10%: 3,109 MT 90%: 3,827 MT	50%: 3,451 MT 10%: 3,119MT 90%: 3,824 MT

Figures

[SAW53 Editor's Note:
The SARC-53 review panel did accept the work presented on TORs 1-4 (which primarily gives an update on fishing patterns, landings and survey data. Tables B1-B23 and Figures B1-B66 are associated with TORs 1-4.

The SARC-53 review panel <u>did not accept</u> new assessment models (or results from those new models) that were prepared by the SAW53 Working Group. Tables B24-B33 and Figures B67-B110 are associated with the new models and results. They are included in this report to demonstrate the work that was done by the SAW Working Group for the December 2011 peer review. However, those Tables and Figures are not intended to be used for management at this time.]

List of Figures –

Figure B107. Fishing mortality time series and associated biological reference point (median from stochastic yield per recruit).

Figure B108. Spawning stock biomass time series and associated biological reference point (median from stochastic yield per recruit).

Figure B109. Estimated recruitment from final ASAP model used in projections.

Figure B110. Relationship between time series spawning stock biomass and fishing mortality for black sea bass. Lines represent biological reference points and the red diamond is the 2010 value.

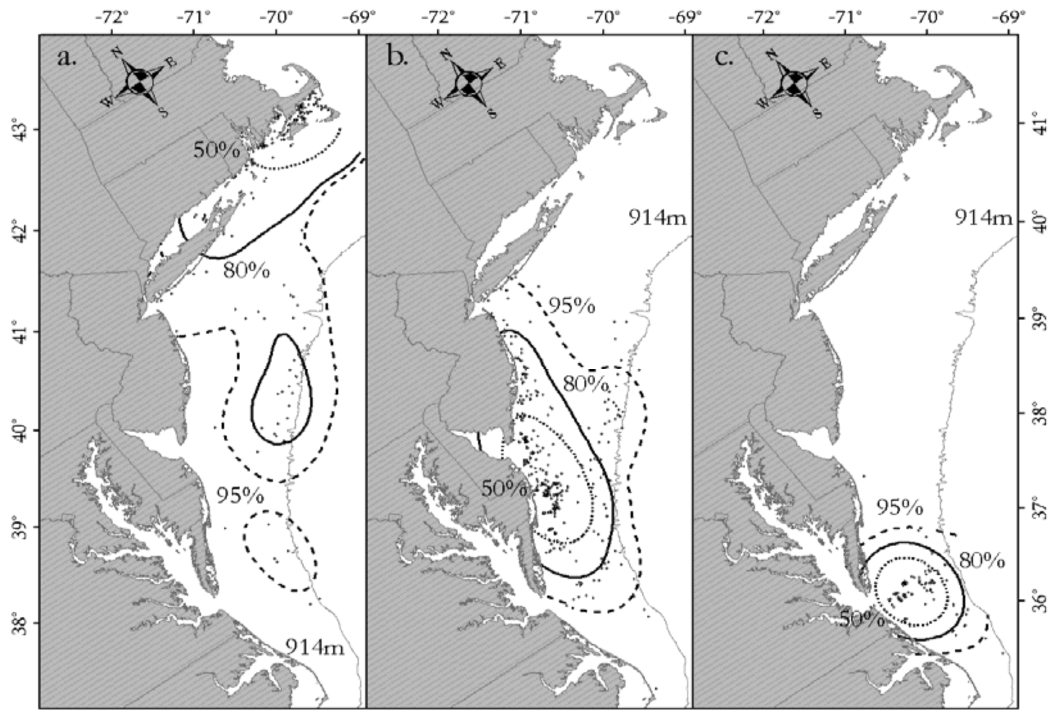


Figure B1. Percent volume contours of black sea bass tag recaptures released from a) the Northern area, b) the Central area, and c) the Southern area. The area within the dashed line contains 95% of tag recaptures, the solid line contains 80% of tag recaptures and the dotted line contains 50% of the recaptured tags from the respective area. Small circles indicate the respective tag recapture locations for tags released in that area. (*from* Moser and Shepherd 2009)

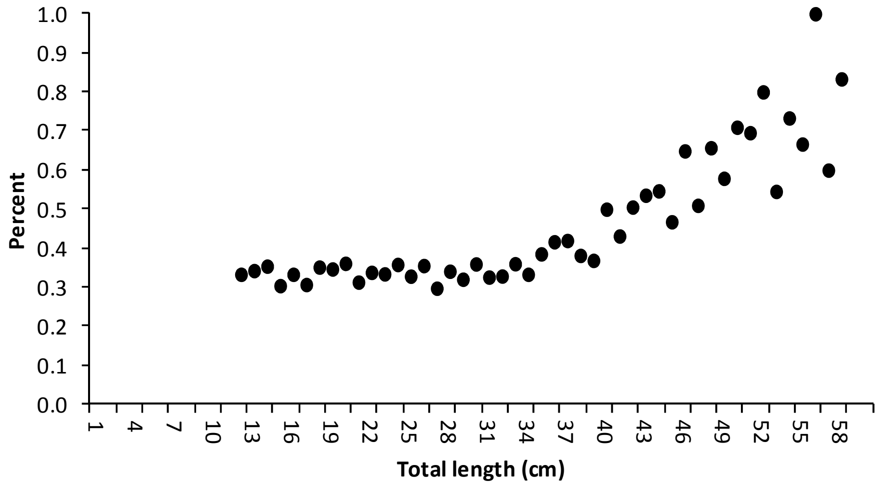


Figure B2. Percent male black sea bass from NMFS surveys, 1981-2010 (n=6,238)

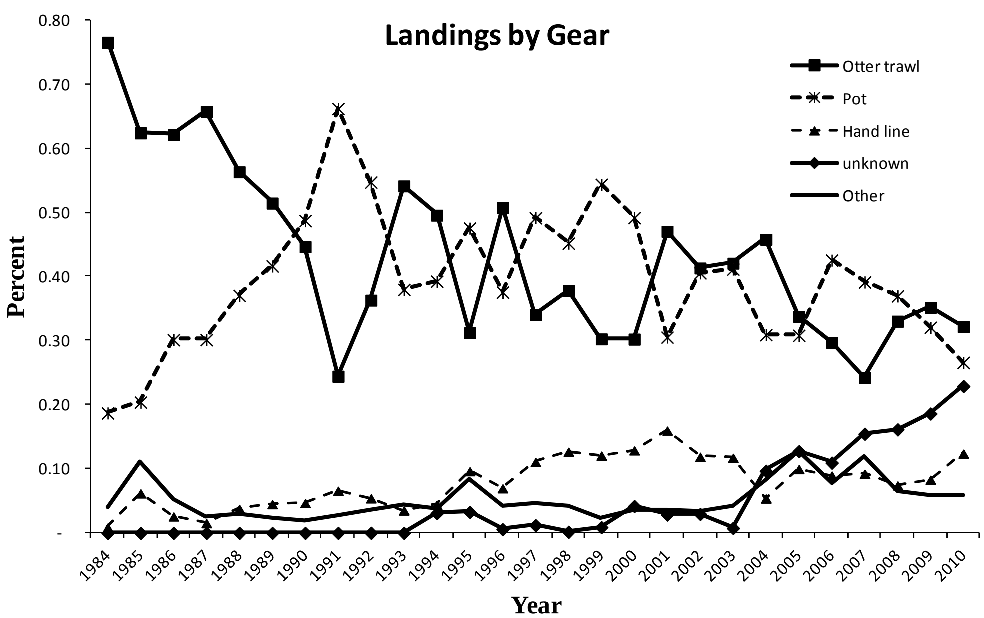


Figure B3. Black sea bass commercial landings by gear type, 1984-2010.

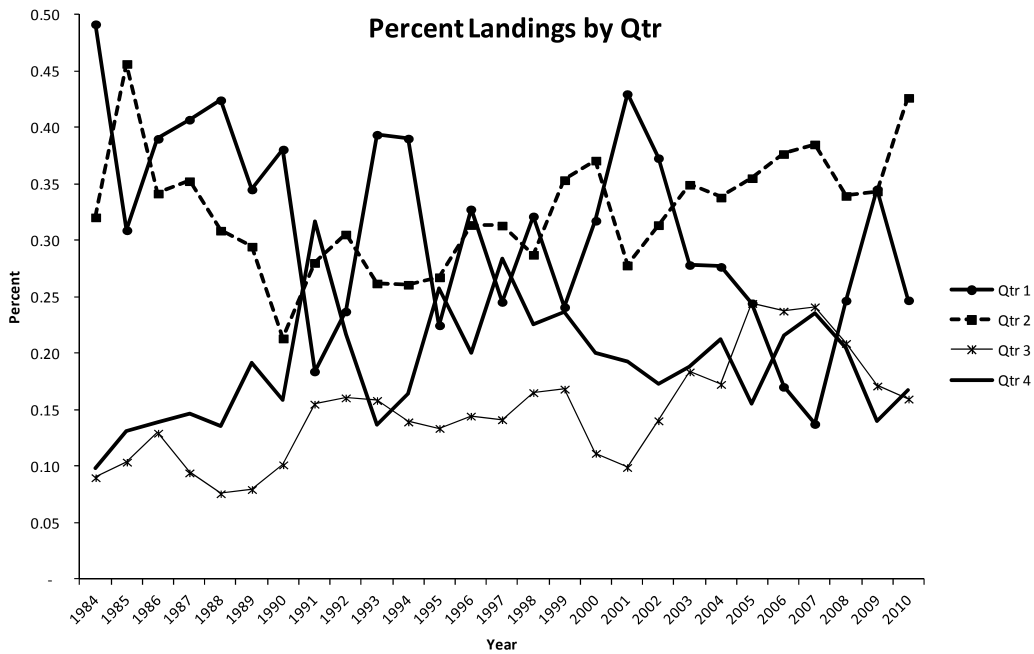


Figure B4. Black sea bass commercial landings by qtr, 1984-2010

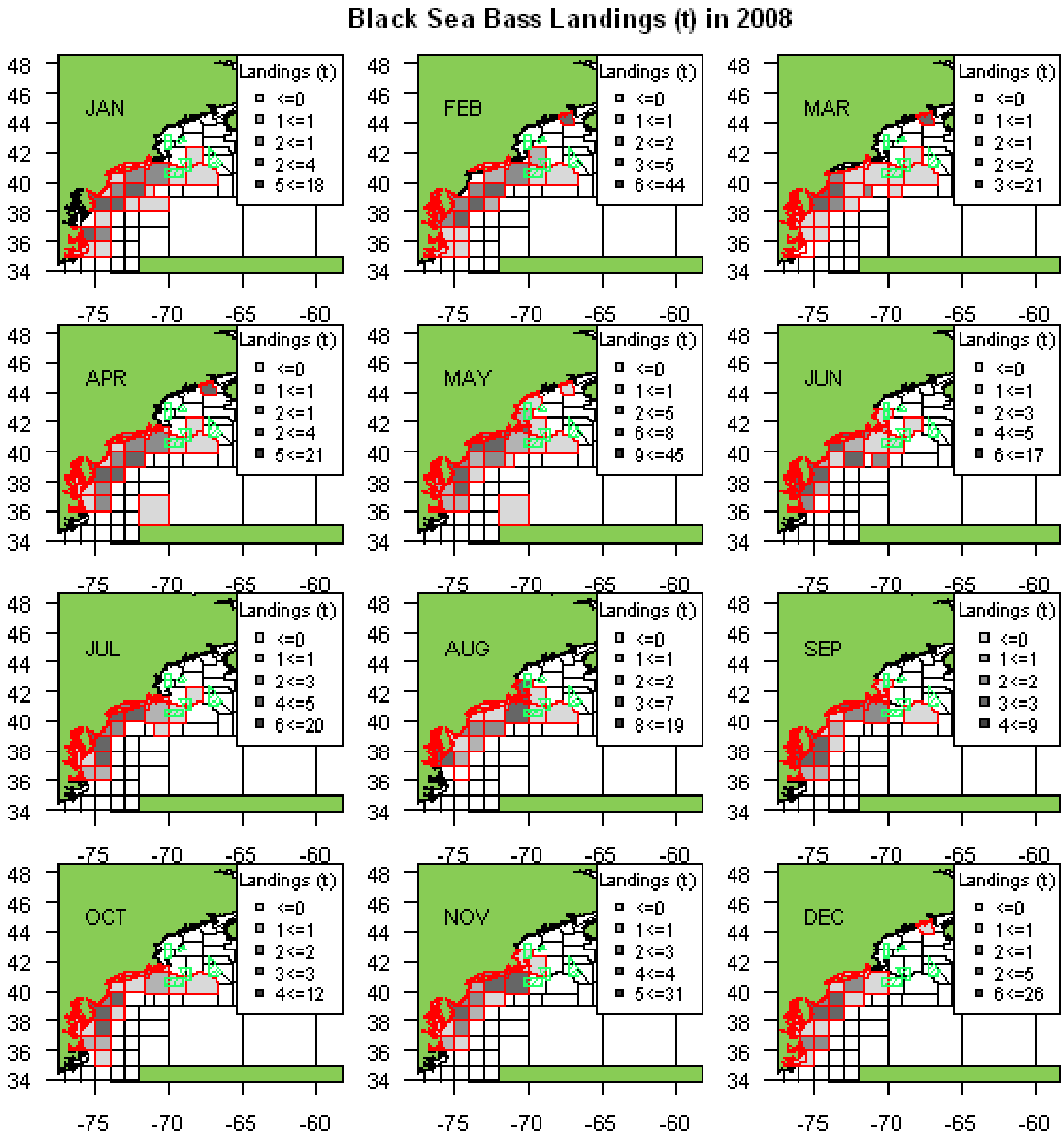


Figure B5. Commercial black sea bass landings, 2008, by statistical area.

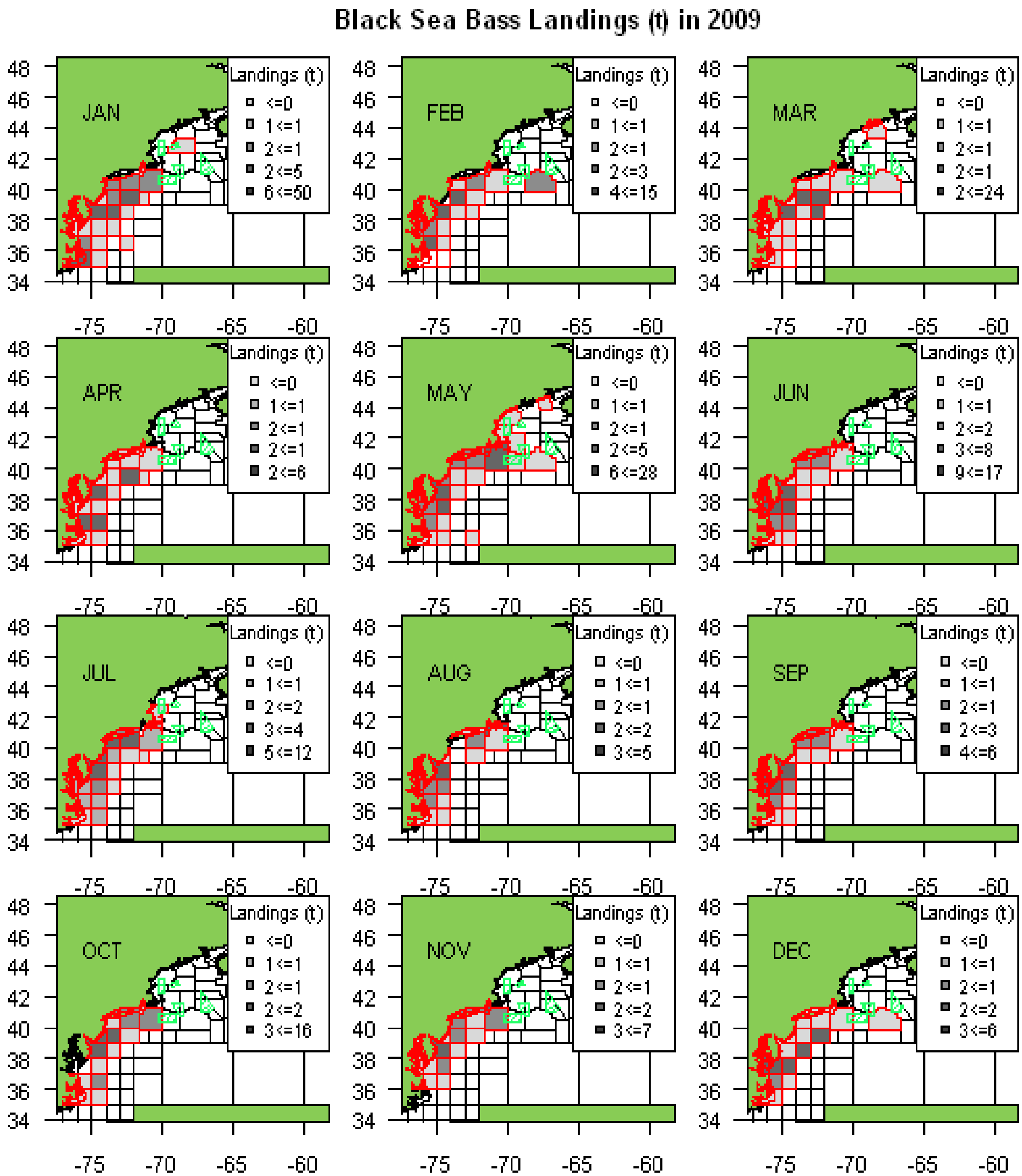


Figure B6. Commercial black sea bass landings, 2009, by statistical area.

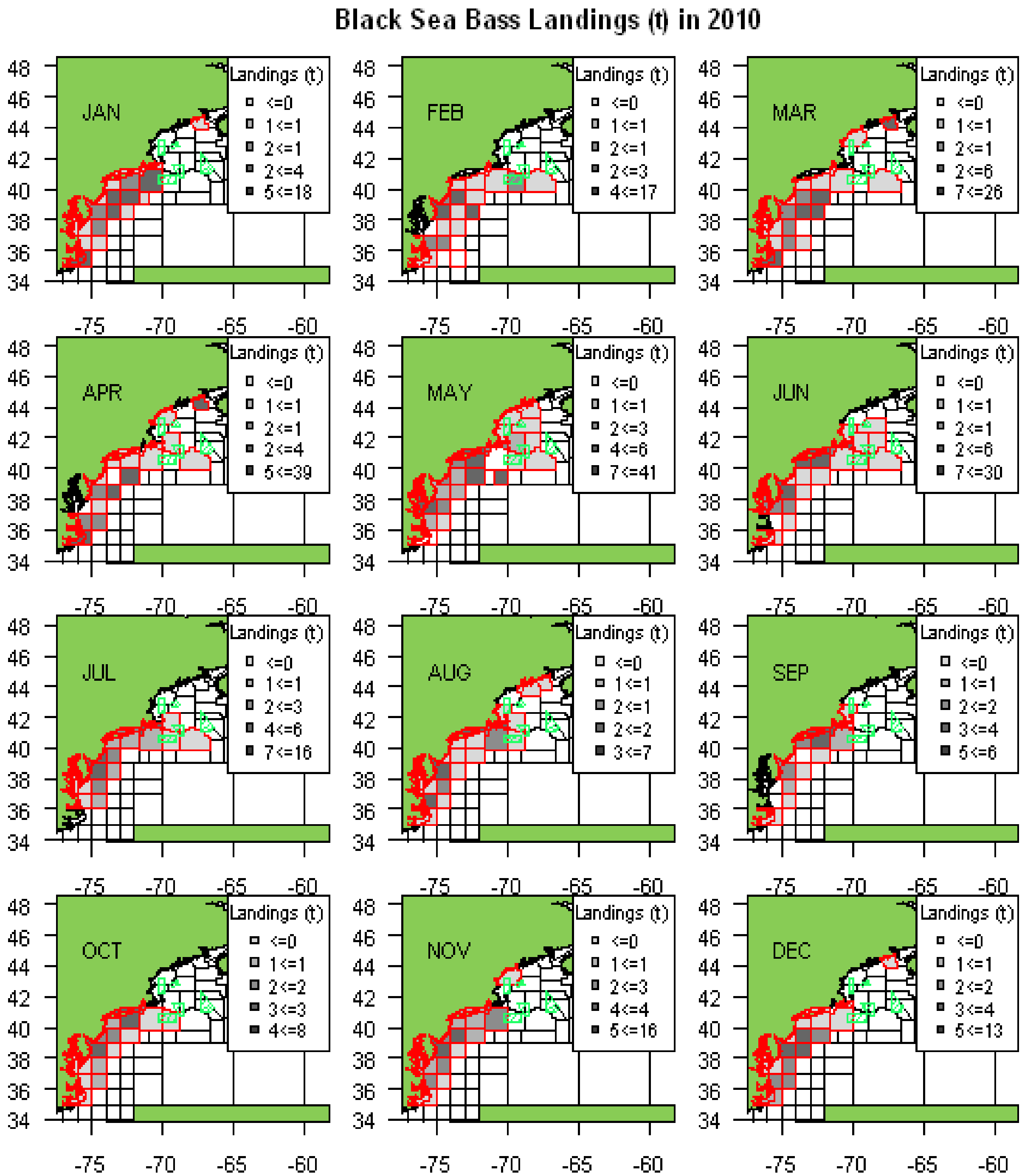


Figure B7. Commercial black sea bass landings, 2010, by statistical area.

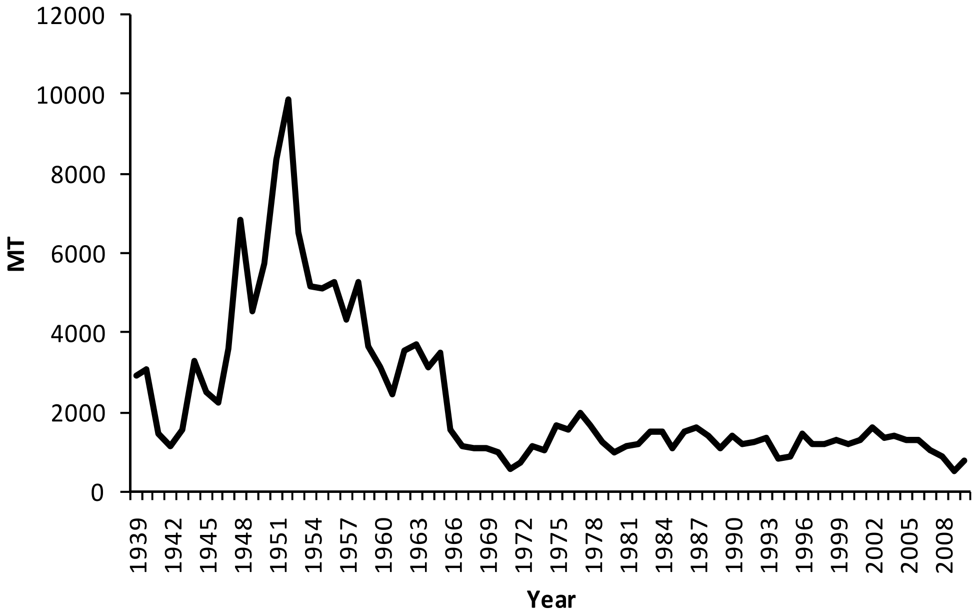


Figure B8. Commercial black sea bass landings from the northern stock since 1939.

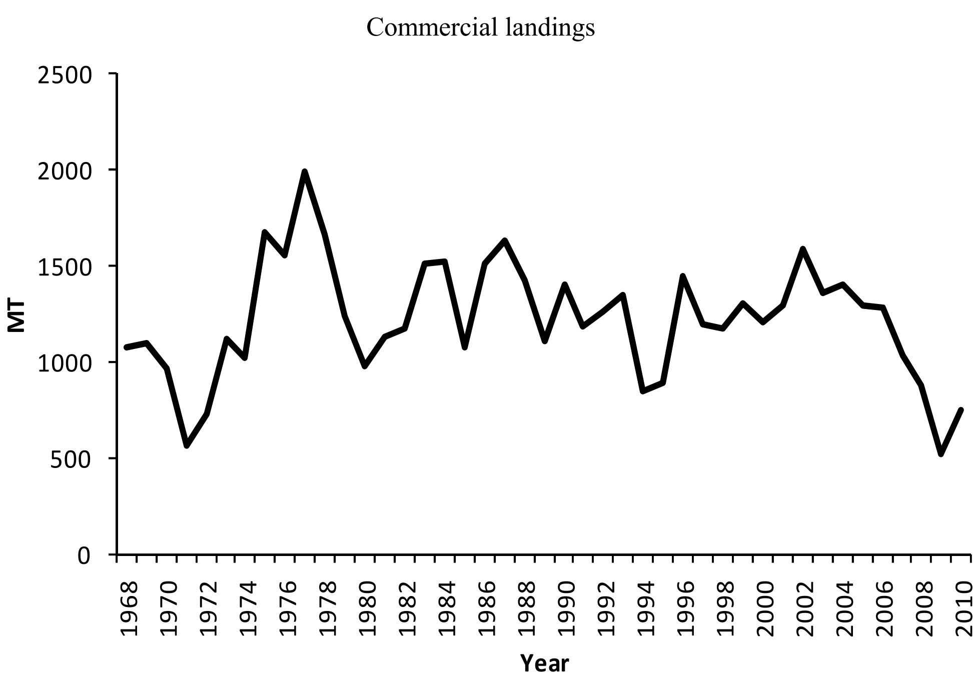


Figure B9. Commercial black sea bass landings from the northern stock since 1968.

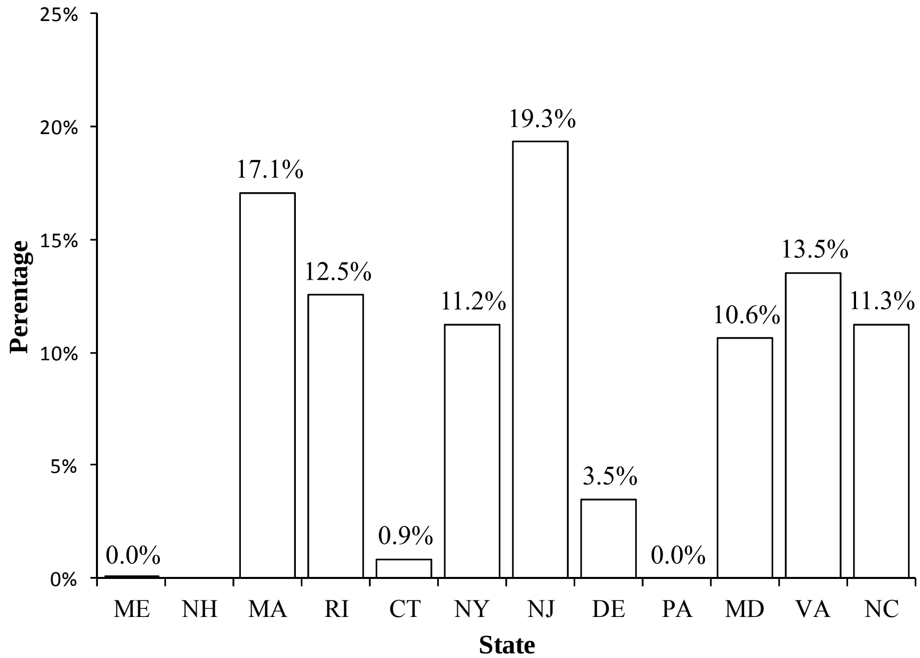


Figure B10. Commercial black sea bass landings by state 2006-2010.

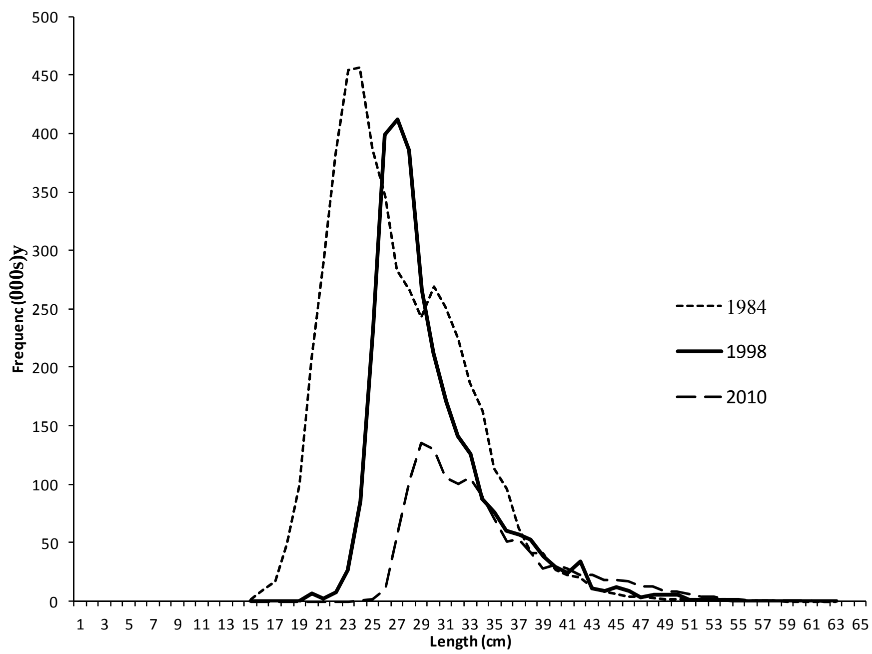


Figure B11. Length frequency comparison of black sea bass commercial landings; 1984,1998 and 2010.

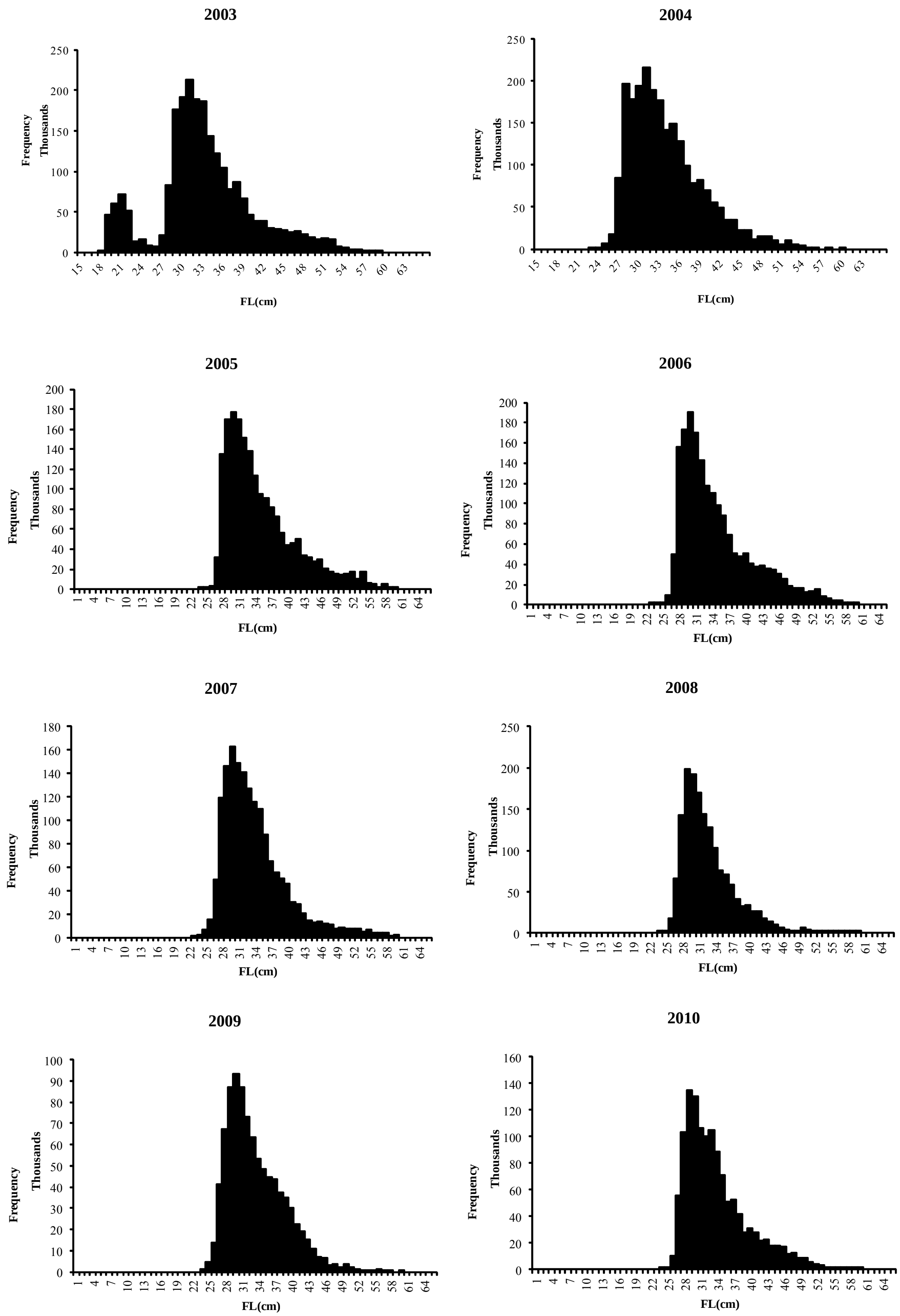


Figure B12. Length distributions of commercial black sea bass landings, 2003-2010.

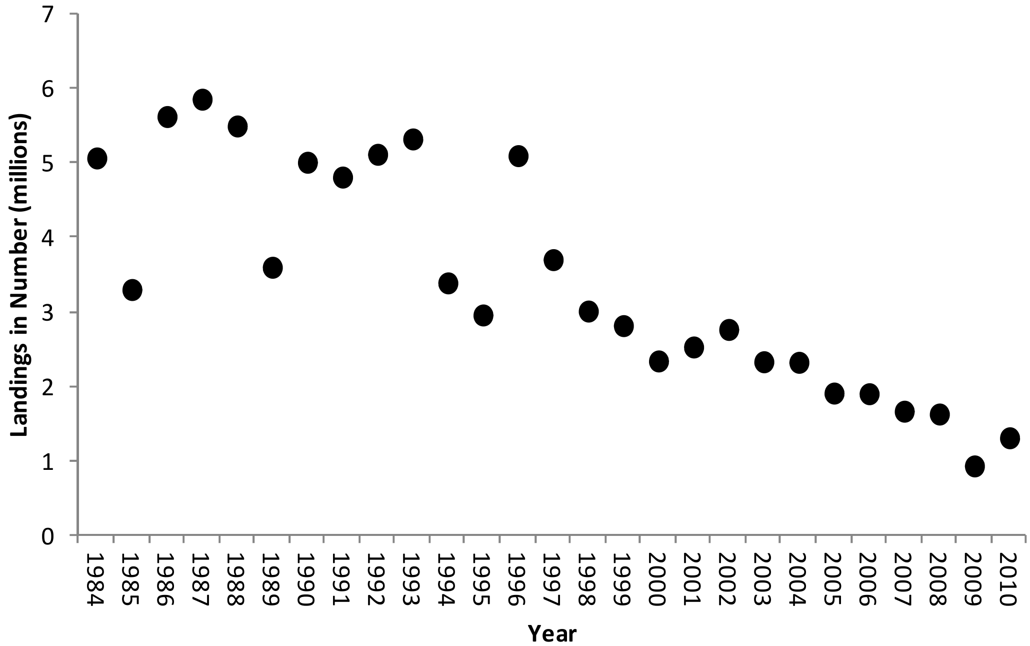


Figure B13.Total number of black sea bass landings in commercial fishery.

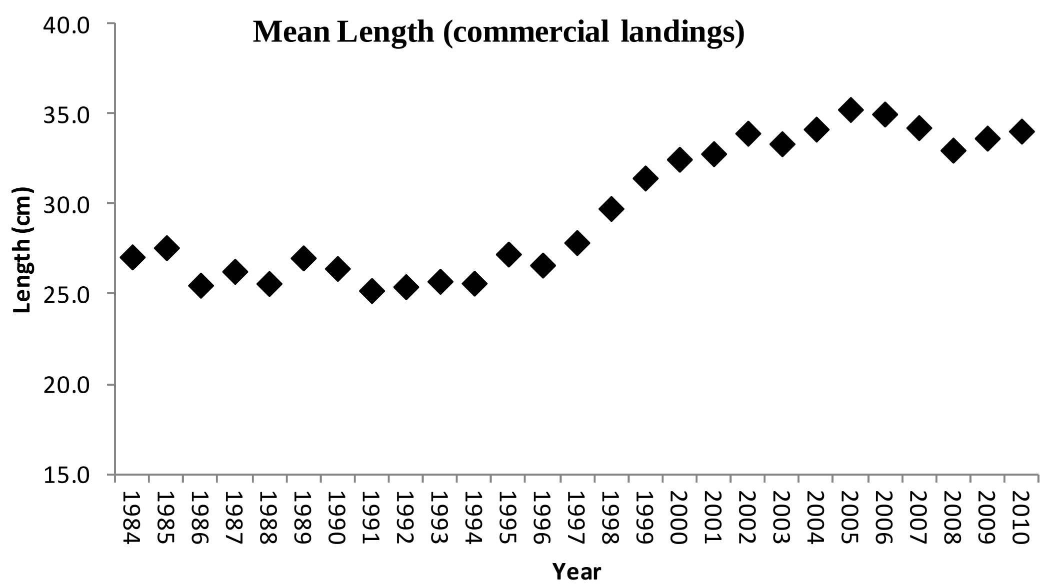


Figure B14. Mean length from commercial landings, 1984-2010.

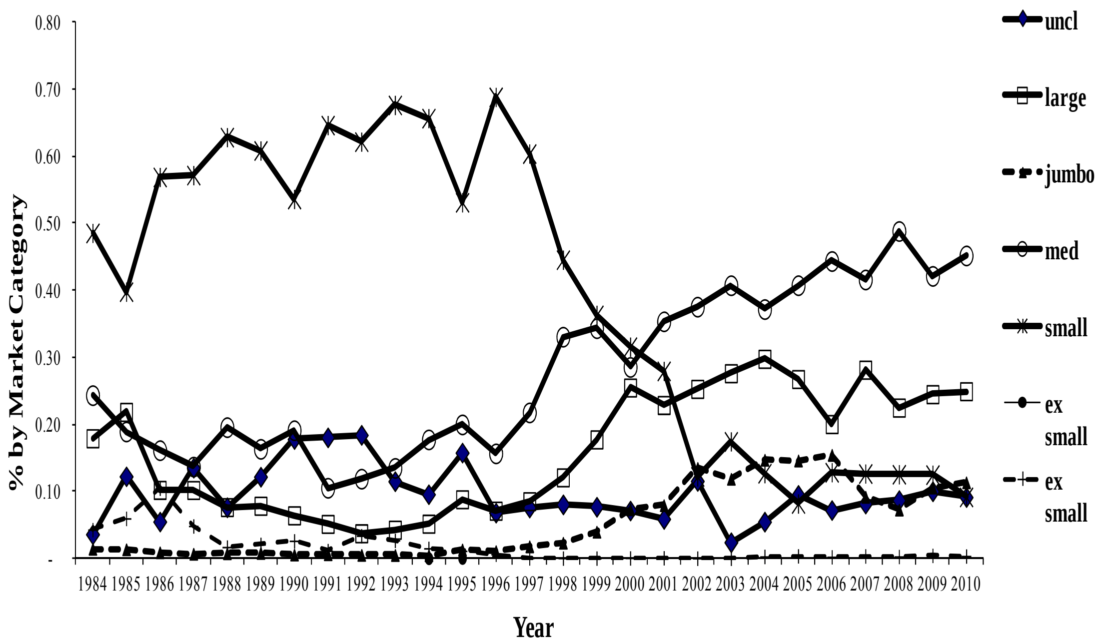


Figure B15. Percent commercial black sea bass landings by market category.

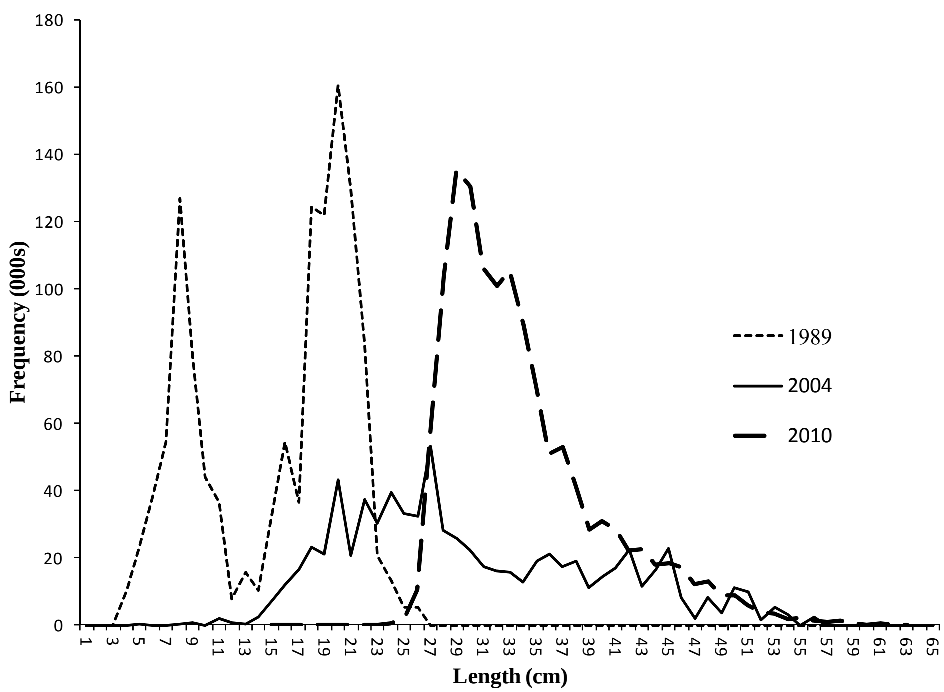


Figure B16. Black sea bass length frequencies of commercial discards from 3 regulatory periods, 1989, 2004 and 2010.

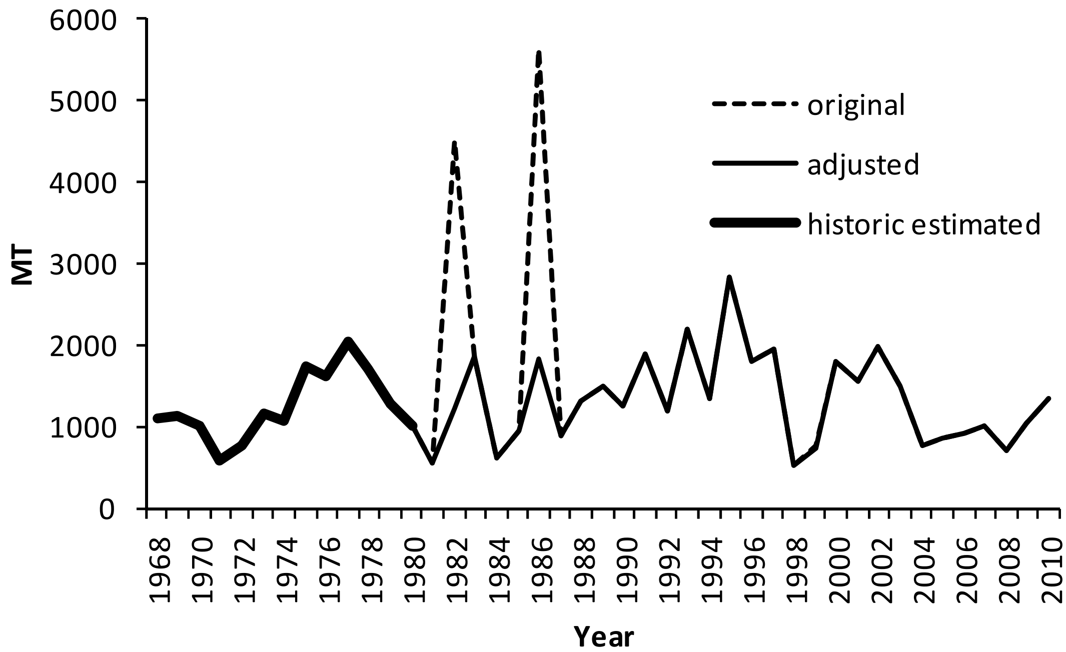


Figure B17. Black sea bass northern stock recreational landings.

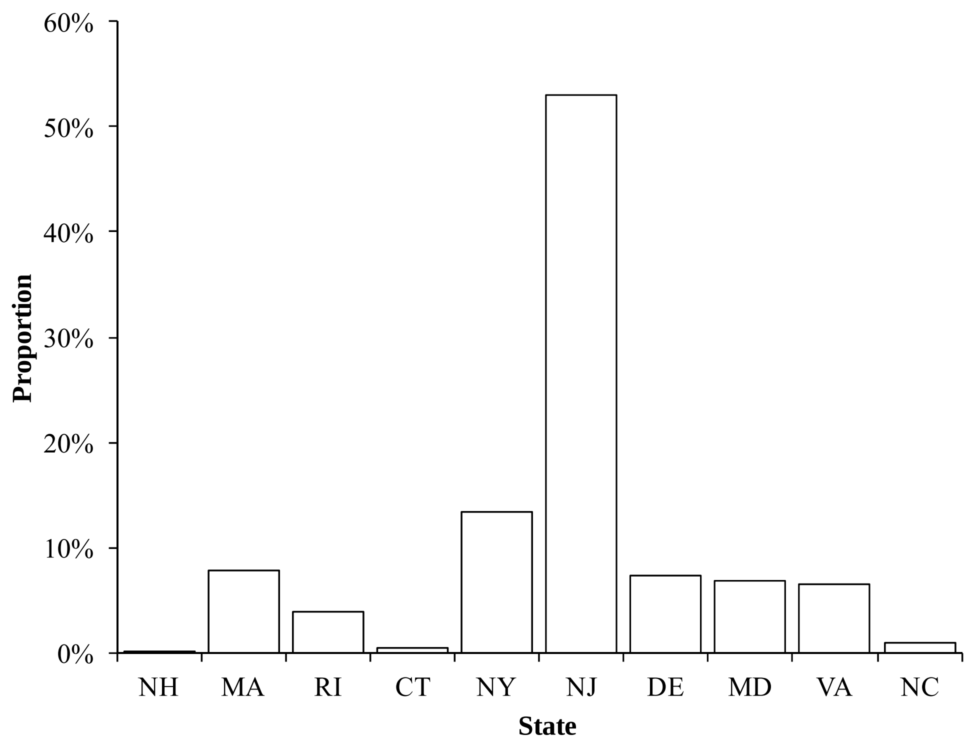


Figure B18. Recreational landings by state, 2000-2010

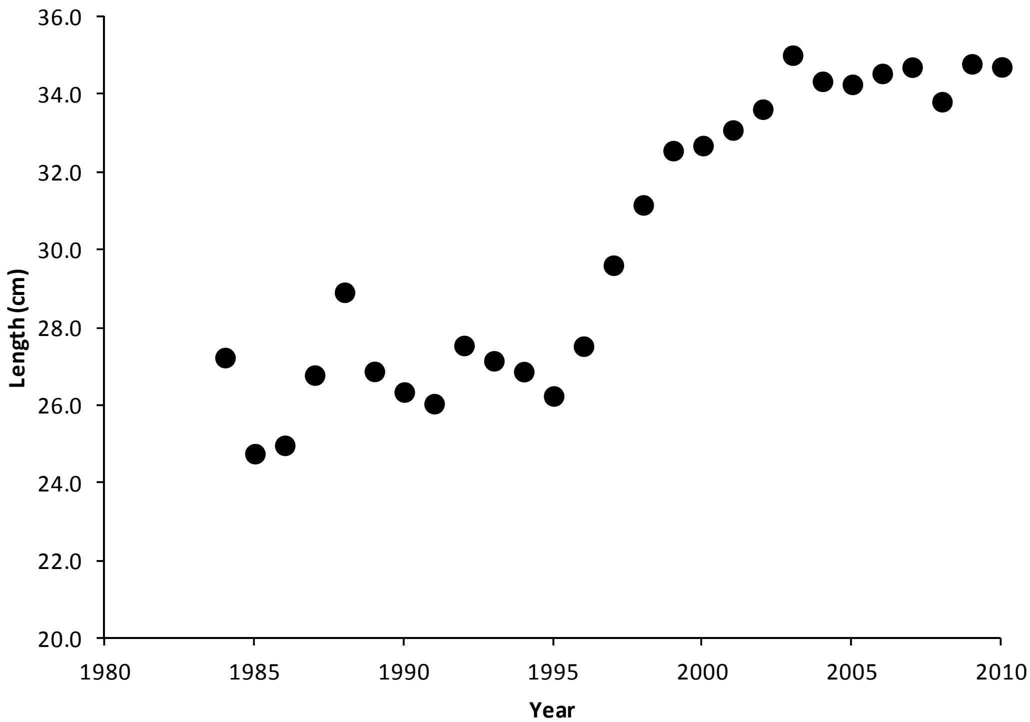


Figure B19. Mean length (cm) of black sea bass recreational landings, 1984-2010.

Figure B20. Black sea bass northern stock recreational discard total.

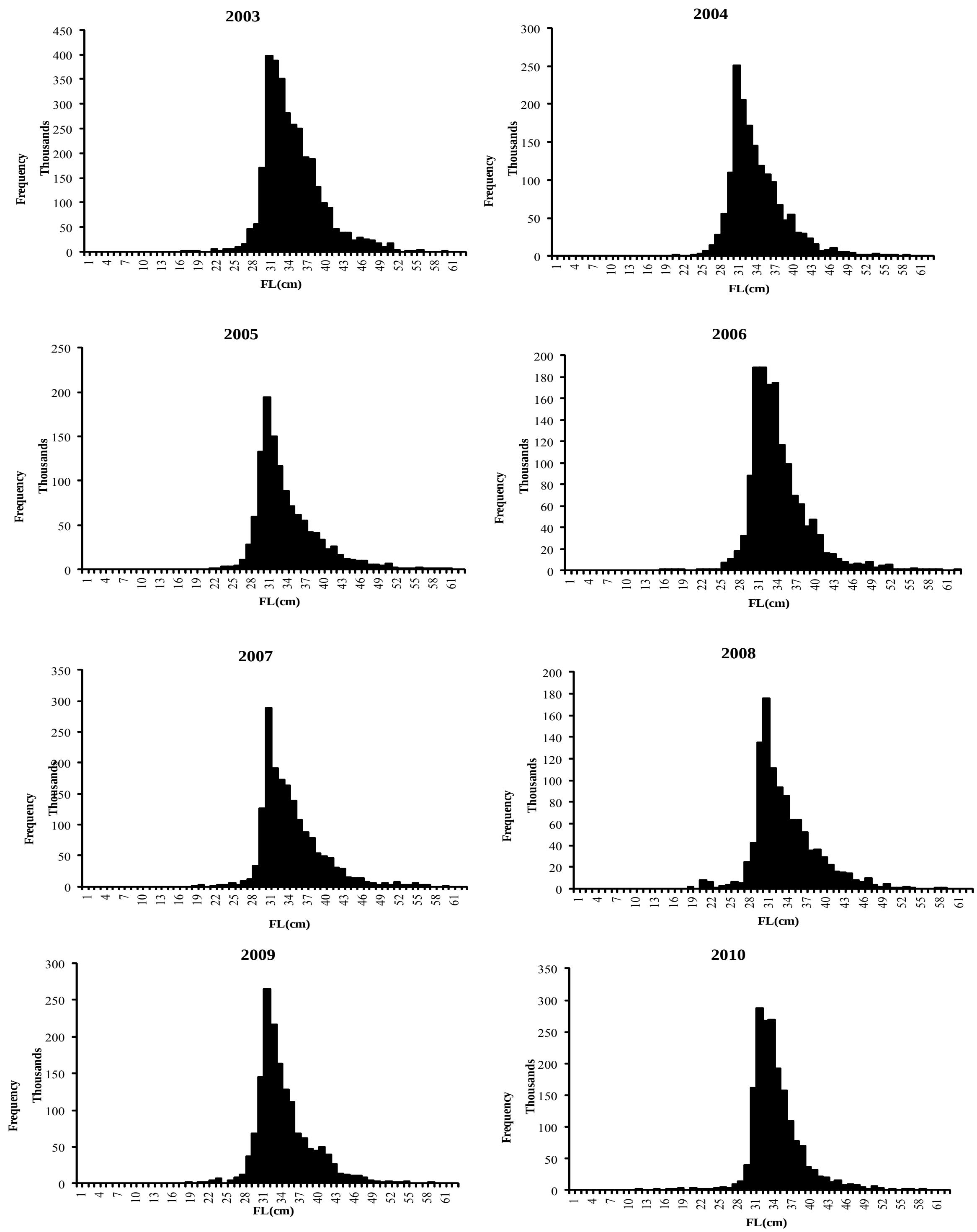


Figure B21. Black sea bass recreational landings length frequencies, 2003-2010.

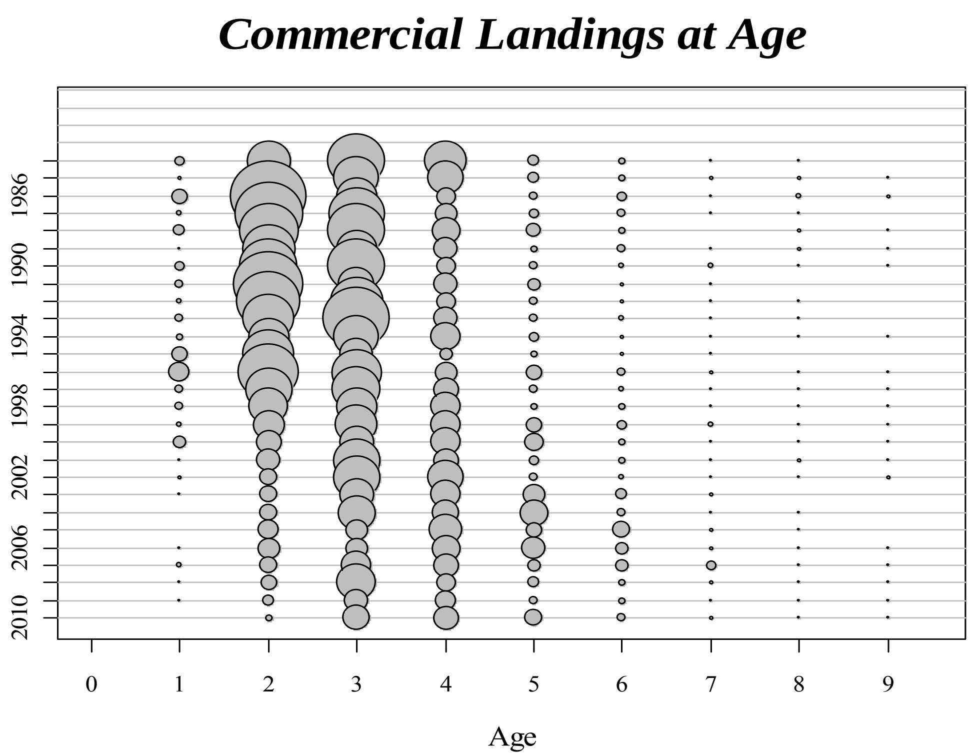


Figure B22. Commercial black sea bass landing numbers at age, 1984-2010.

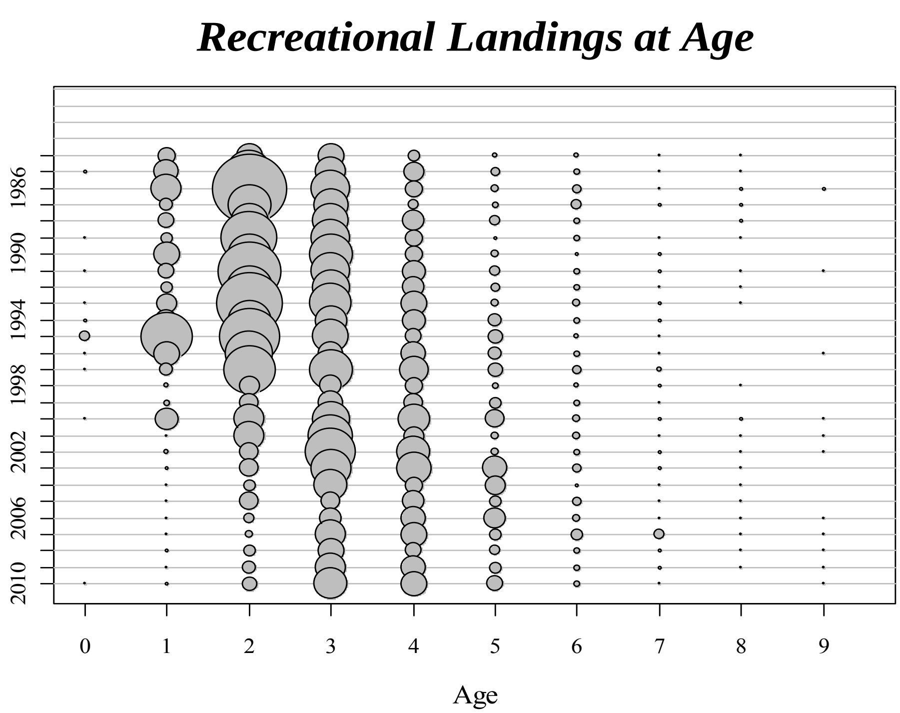


Figure B23. Recreational black sea bass landing numbers at age, 1984-2010.

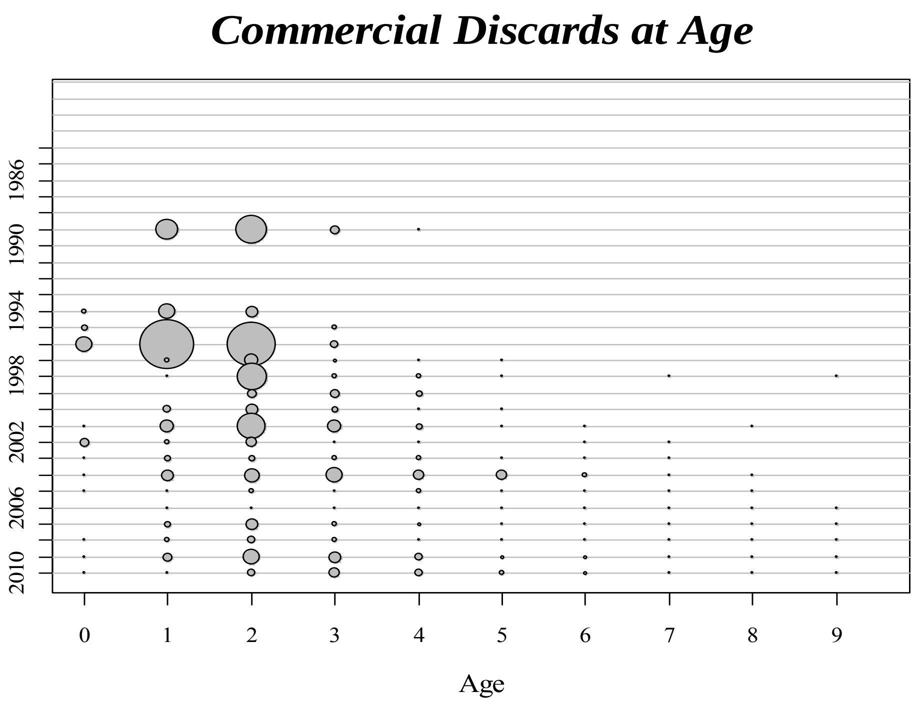


Figure B24. Commercial black sea bass discard numbers at age.

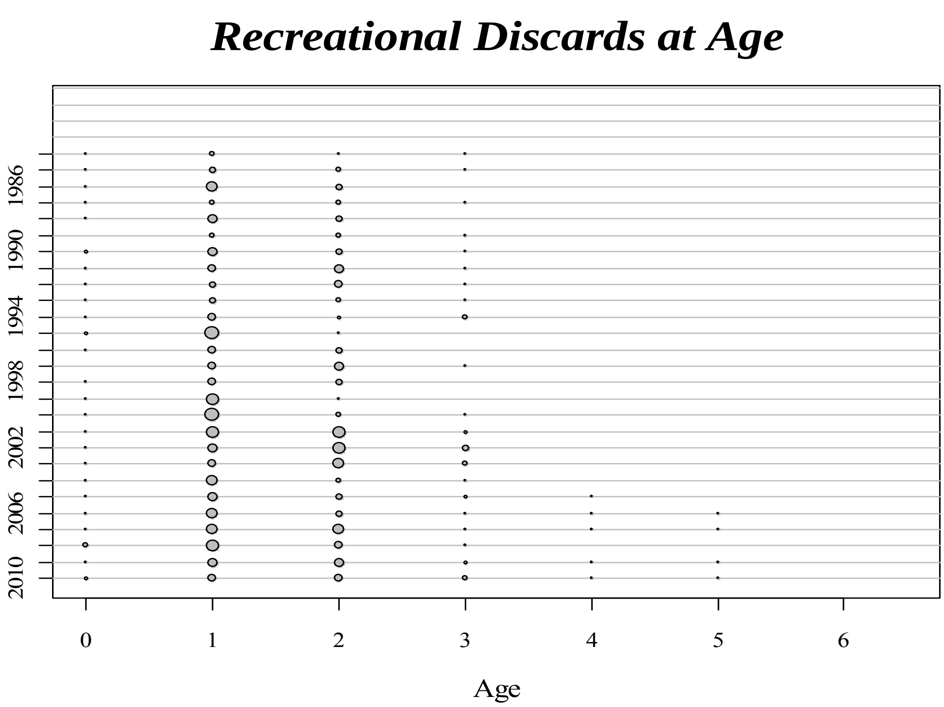


Figure B25. Recreational black sea bass discard numbers at age.

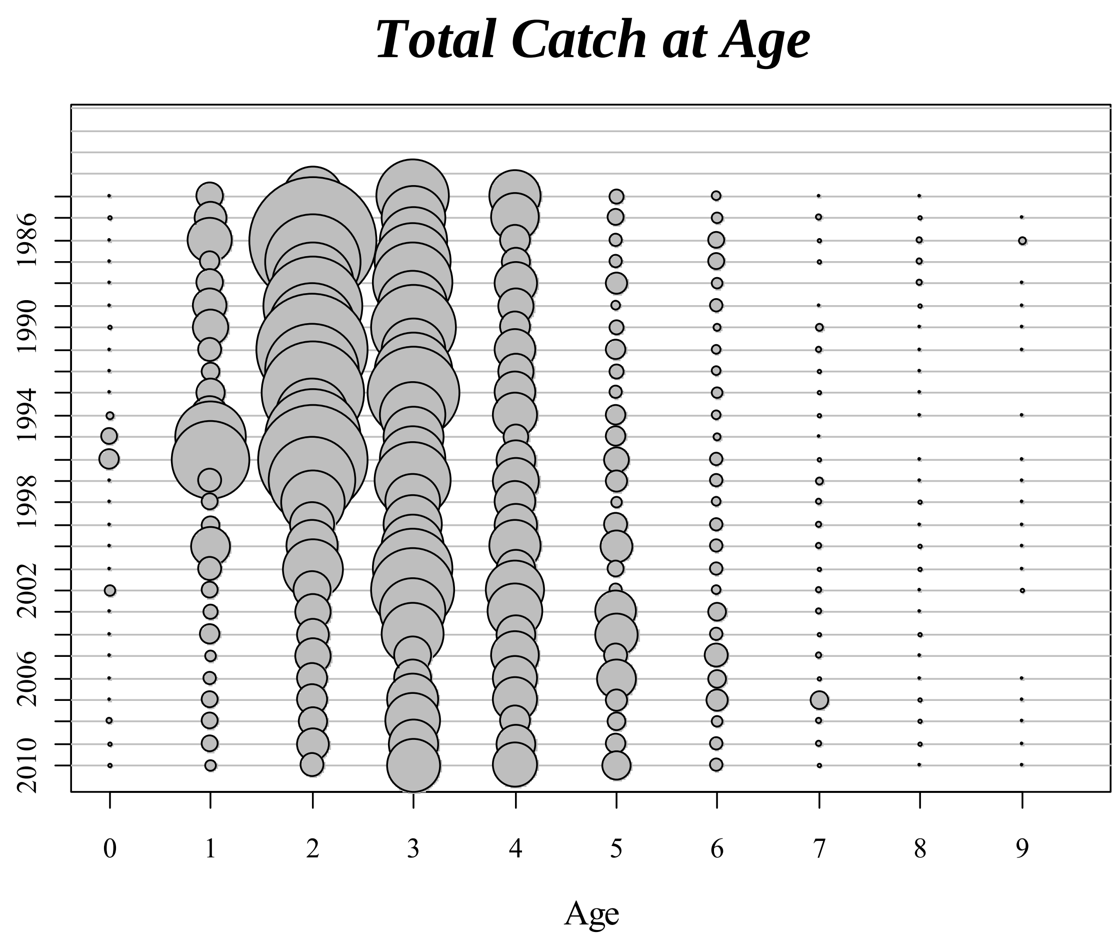


Figure B26. Black sea bass total catch numbers at age. Age 9 in plot represents ages 9-12.

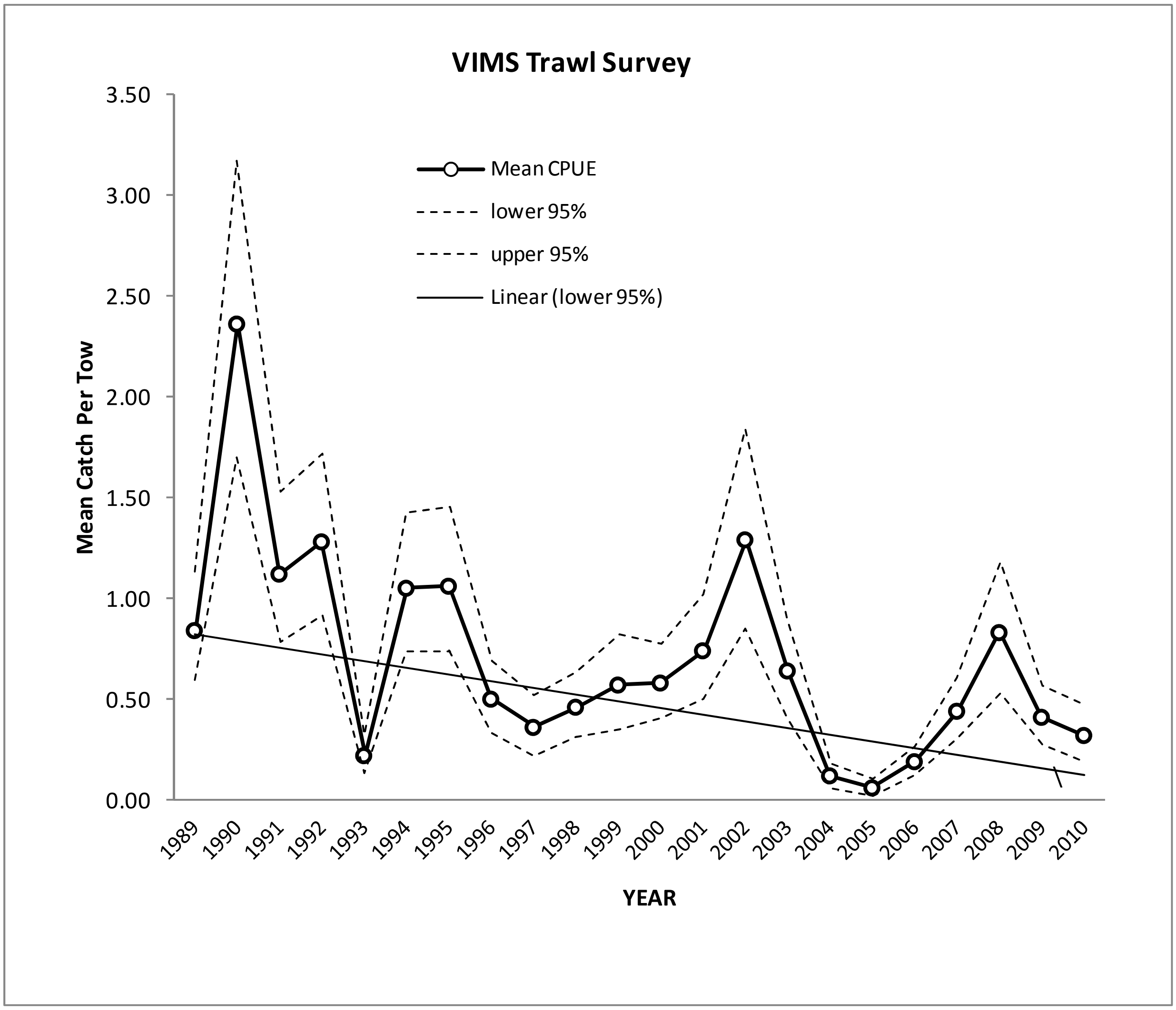


Figure B27. Virginia Institute of Marine Science trawl survey results for age 1 black sea bass.

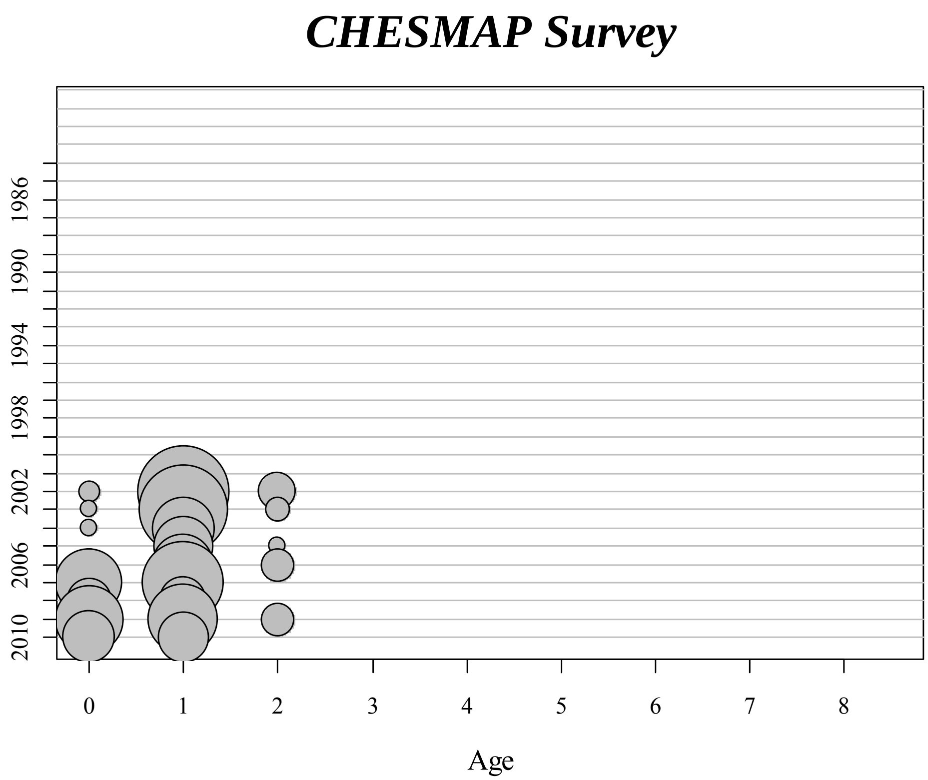


Figure B28. Age distribution of Chesapeake Bay CHESMAP survey.

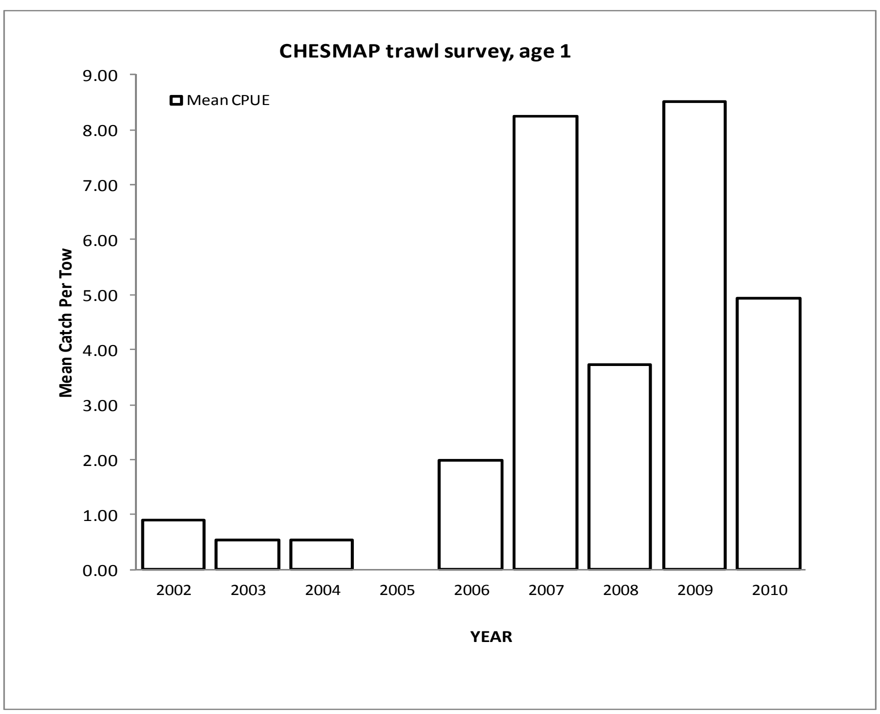


Figure B29. CHESMAP indices of black sea bass age 1 abundance.

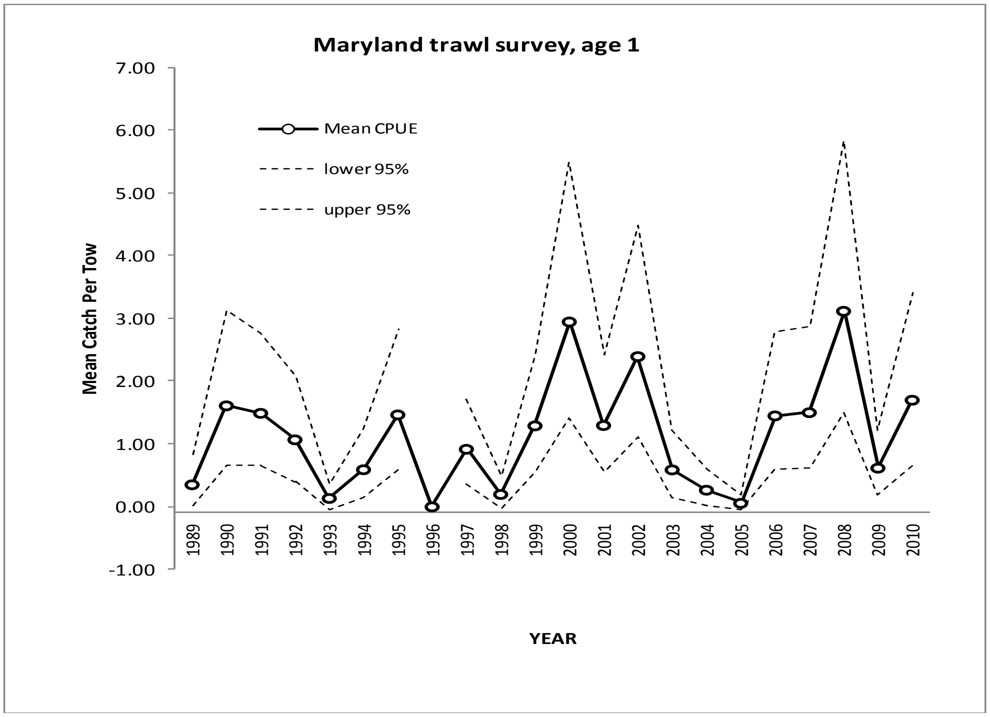


Figure B30. Mean catch per tow of black sea bass from MD coastal bay survey.

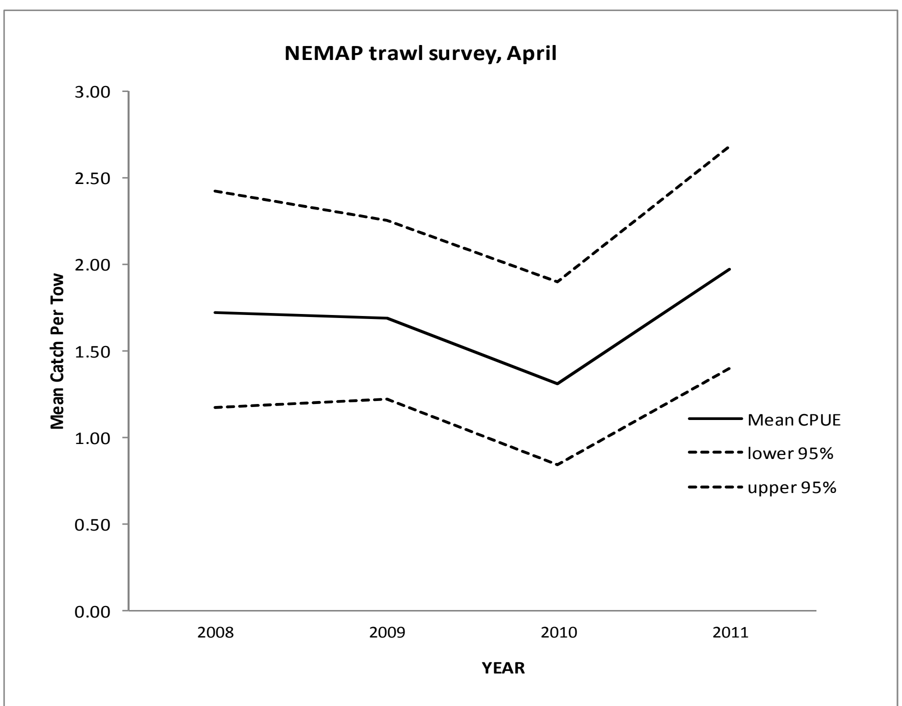


Figure B31. Black sea bass indices of abundance from April NEMAP survey.

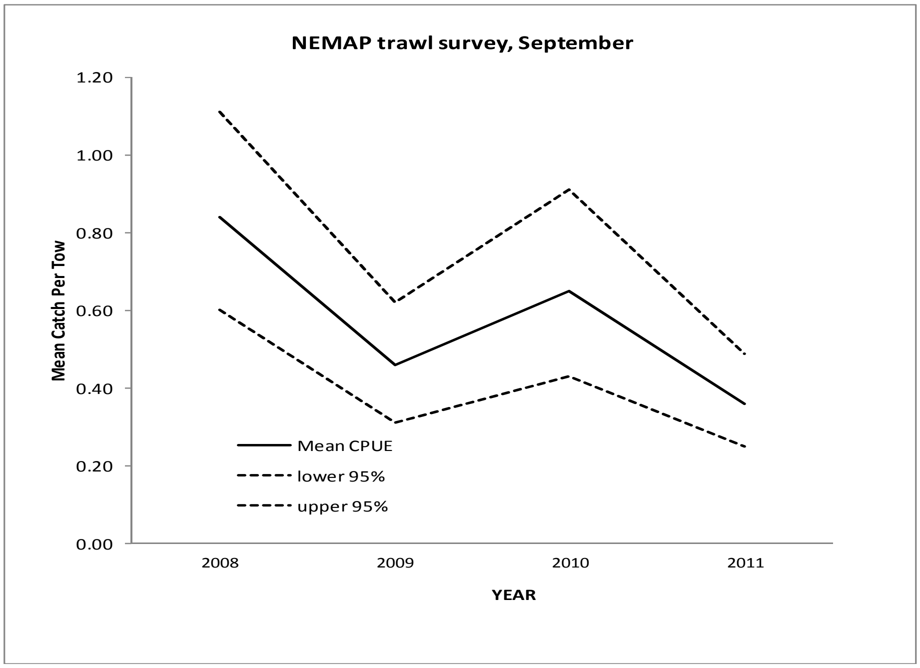


Figure B32. Black sea bass indices of abundance from September NEMAP survey.

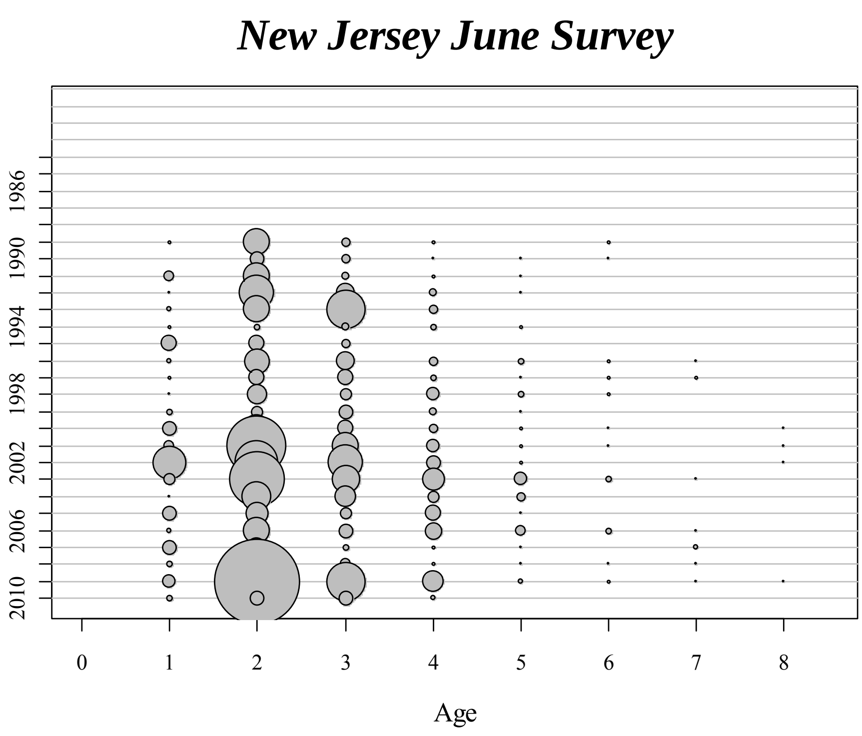


Figure B33. Age distribution of New Jersey June ocean trawl survey.

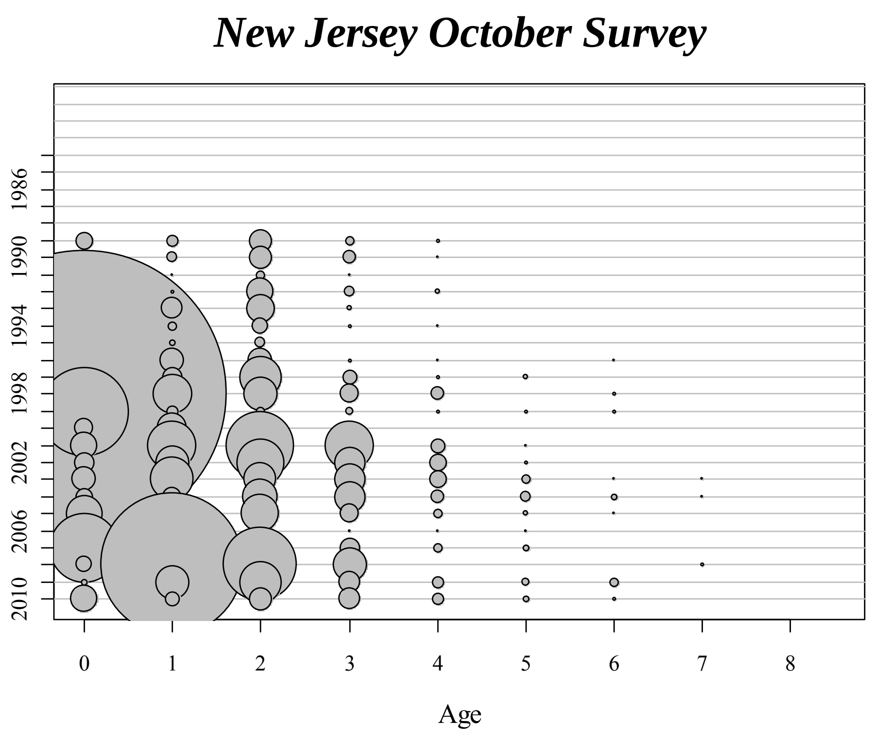


Figure B34. Age distribution of New Jersey October ocean trawl survey.

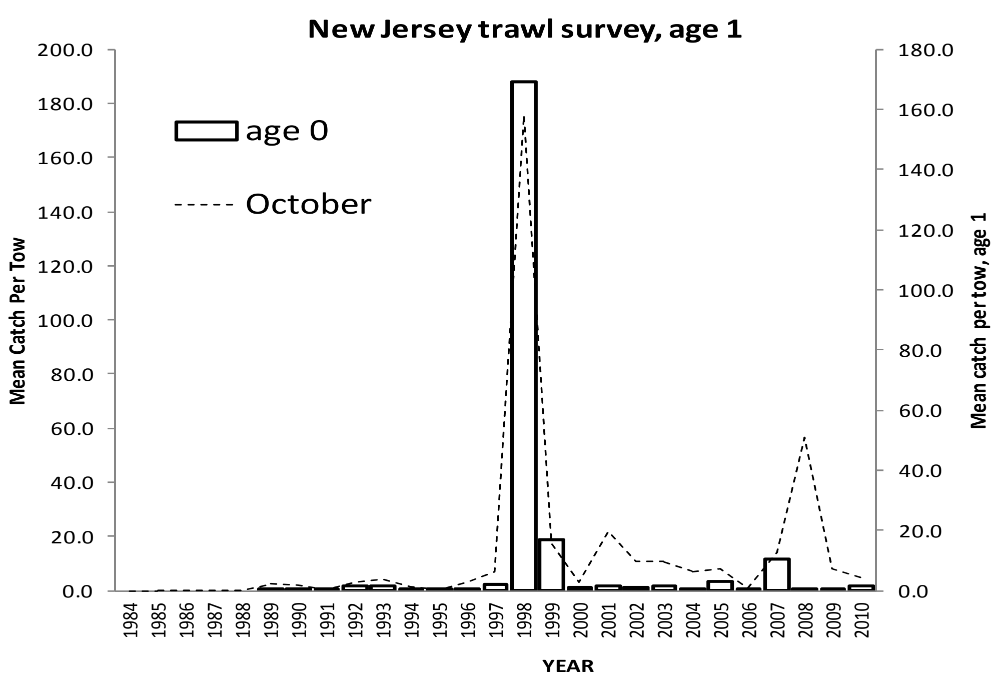


Figure B35. Age 0 indices of abundance from New Jersey October ocean trawl survey.

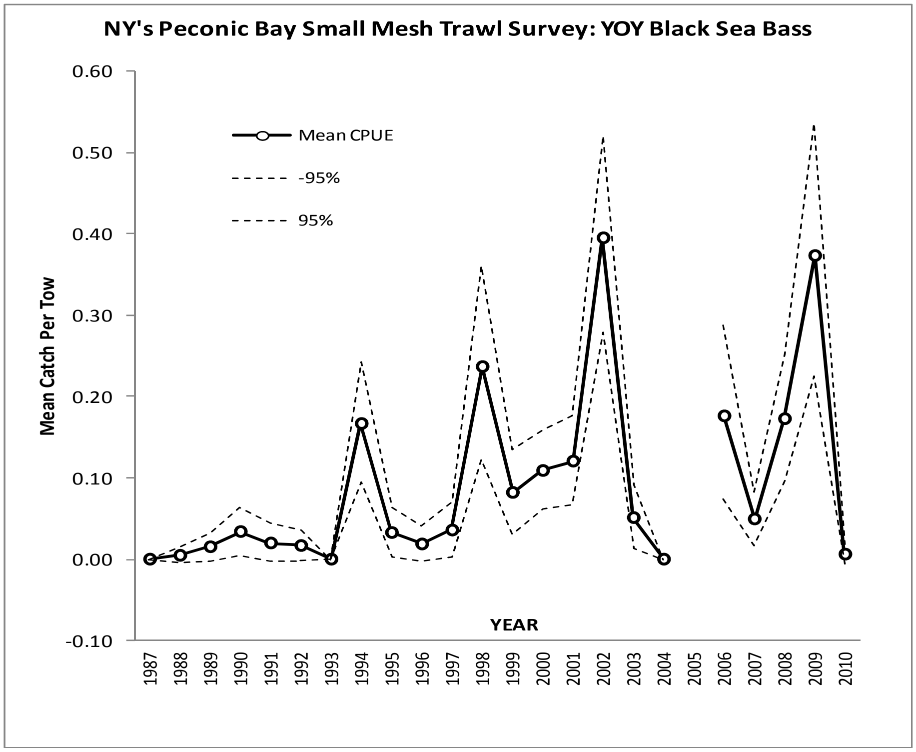


Figure B36. Black sea bass indices of age 0 abundance from Peconic Bay New York trawl survey.

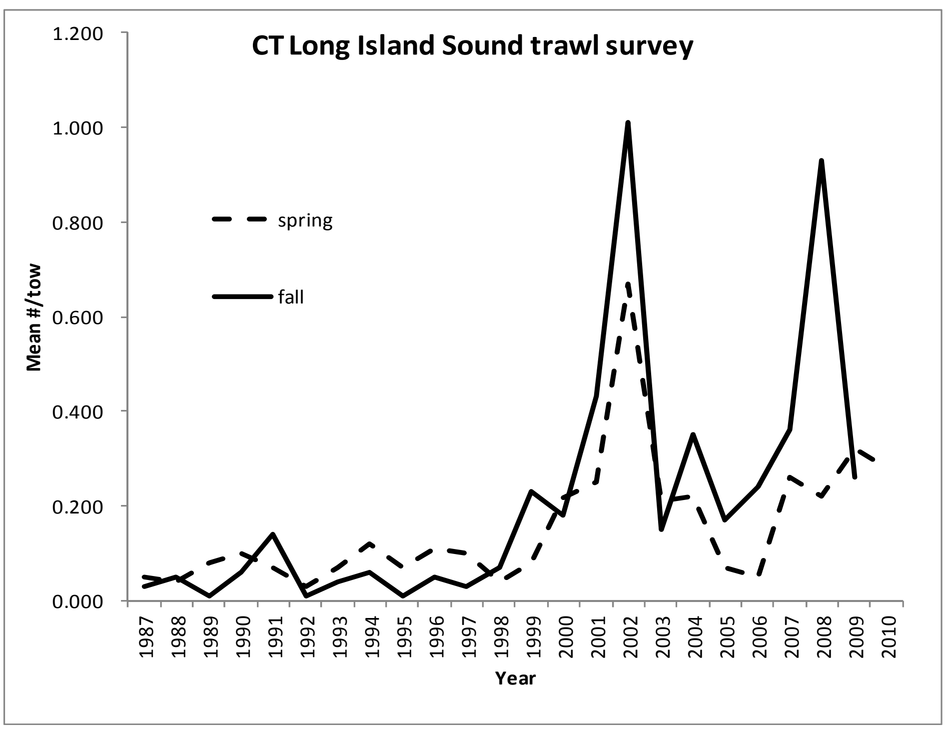


Figure B37. Black sea bass indices of abundance from CT Long Island trawl surveys.

Connecticut Spring Survey

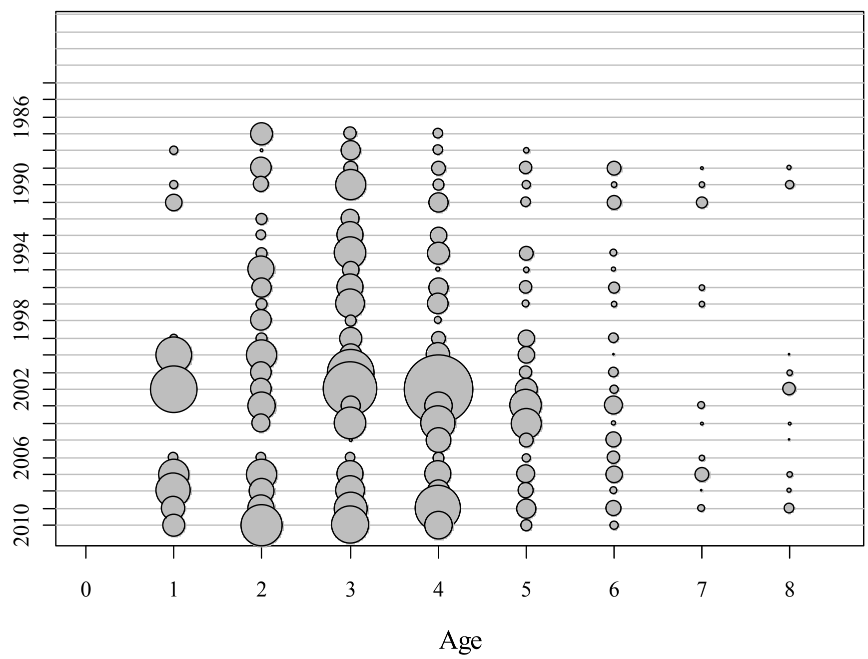


Figure B38. Black sea bass age distribution from CT Long Island Sound spring survey.

Connecticut Fall Survey

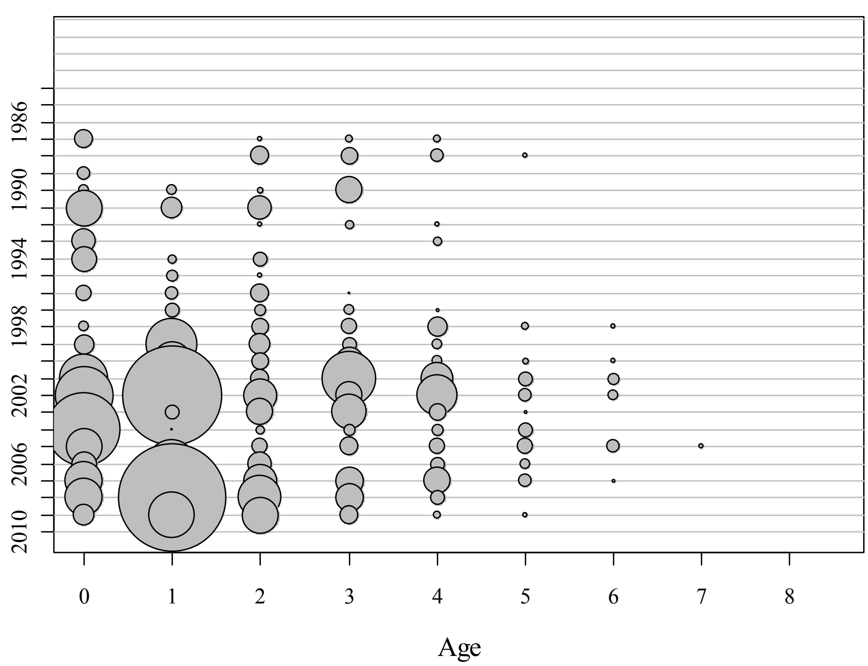


Figure B39. Black sea bass age distribution from CT Long Island Sound fall survey.

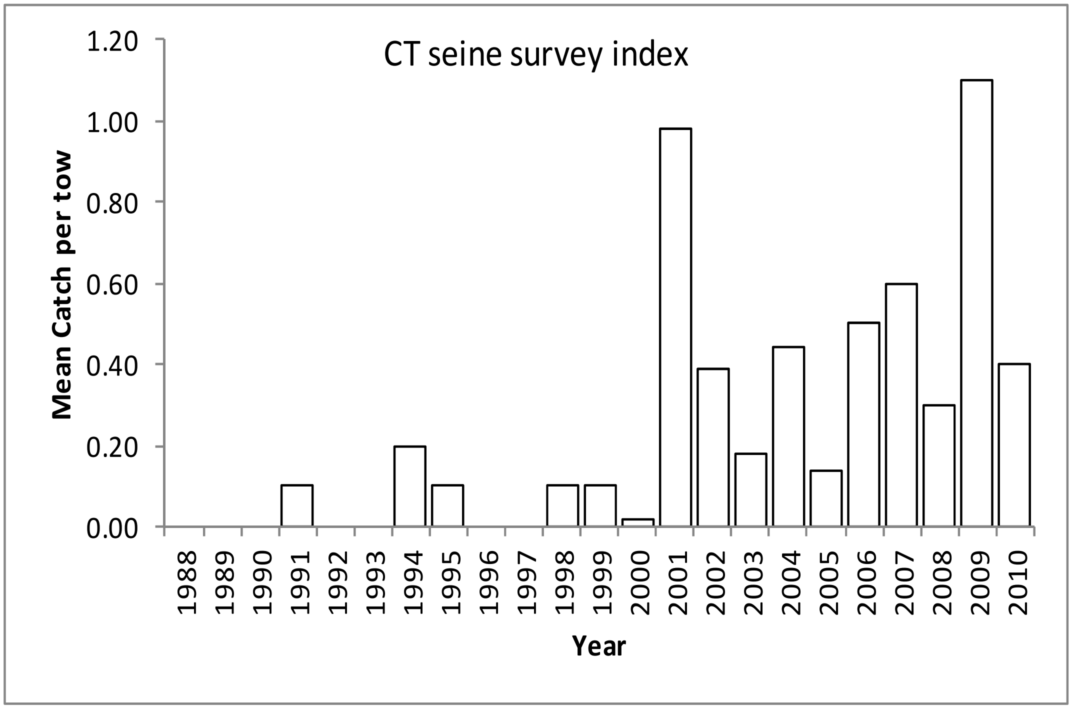


Figure B40. Black sea bass indices of abundance from CT seine survey of coastal ponds.

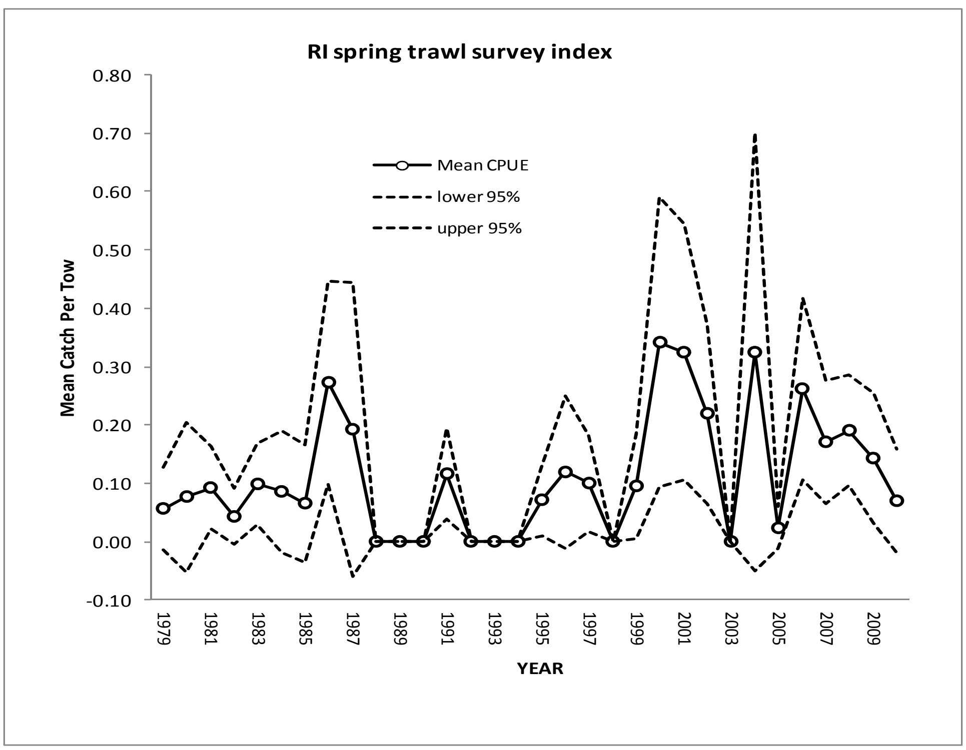


Figure B41. Black sea bass indices of abundance from RI spring trawl survey.

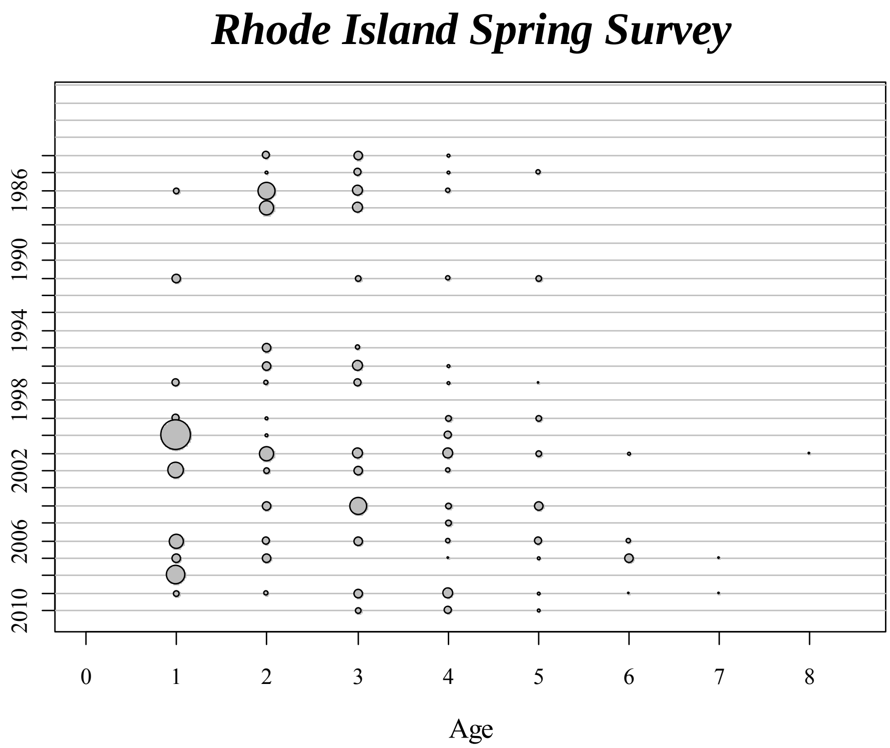


Figure B42. Black sea bass age distribution of RI spring trawl survey.

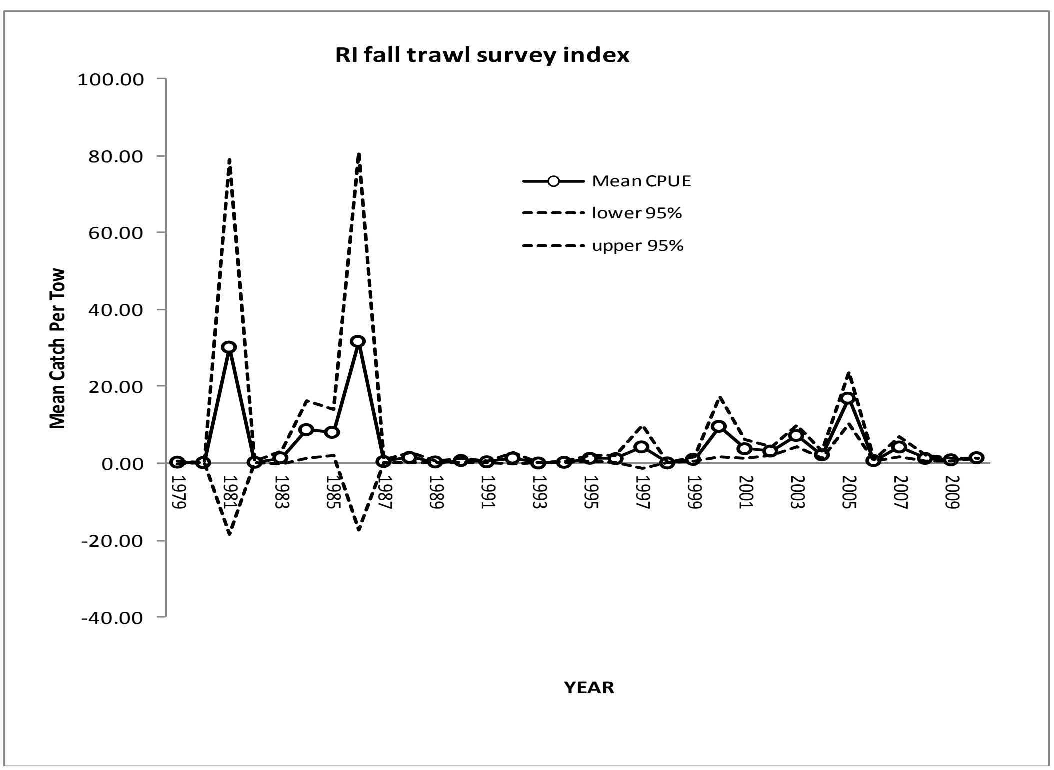


Figure B43. Black sea bass indices of abundance from RI fall trawl survey.

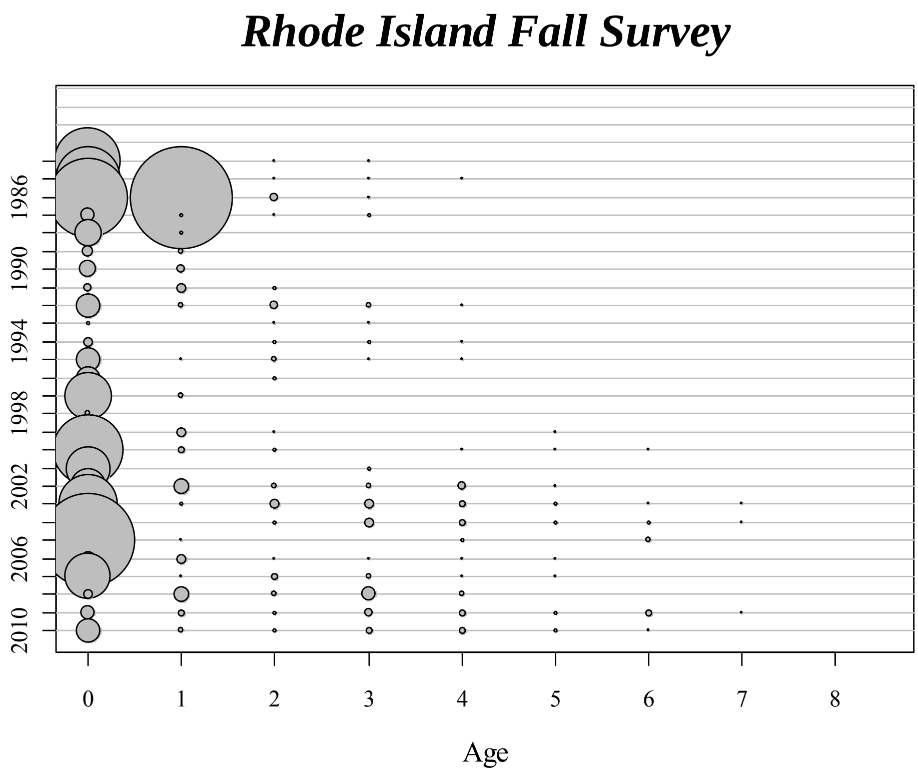


Figure B44. Black sea bass age distribution of RI fall trawl survey.

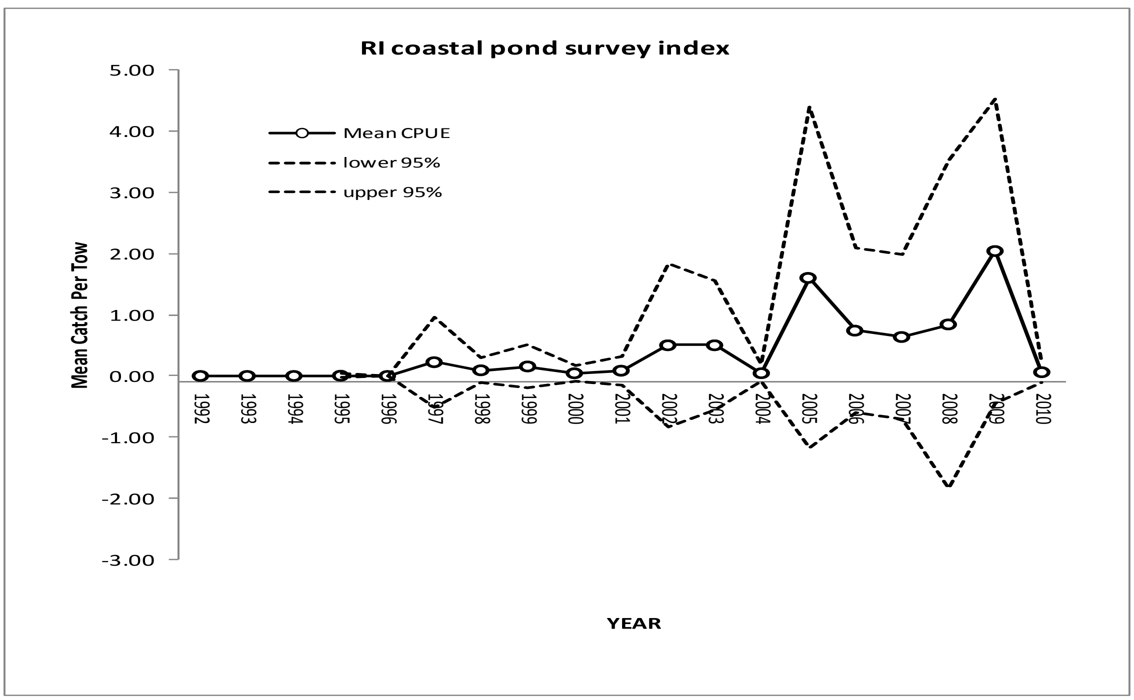


Figure B45. Black sea bass indices of abundance from RI coastal pond survey.

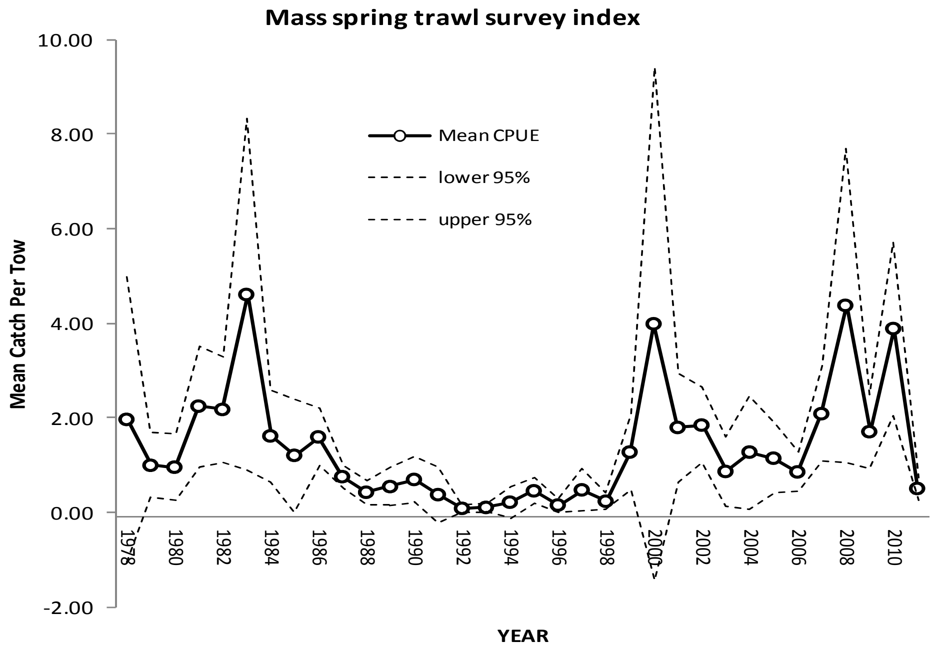


Figure B46. Black sea bass indices of abundance from MA spring trawl survey.

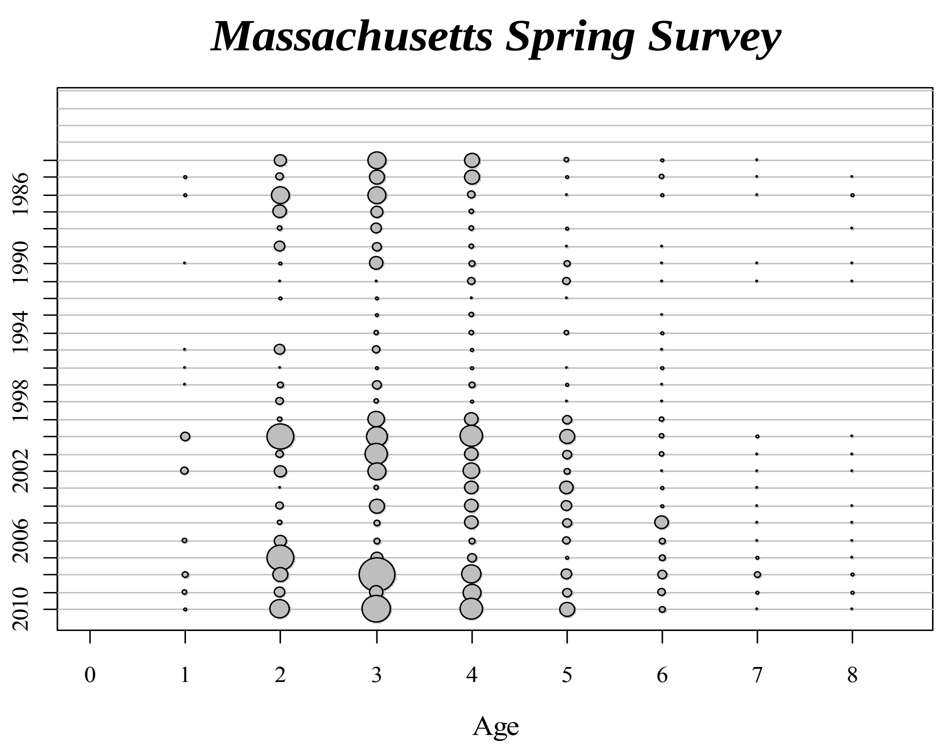


Figure B47. Black sea bass age distribution of MA spring trawl survey.

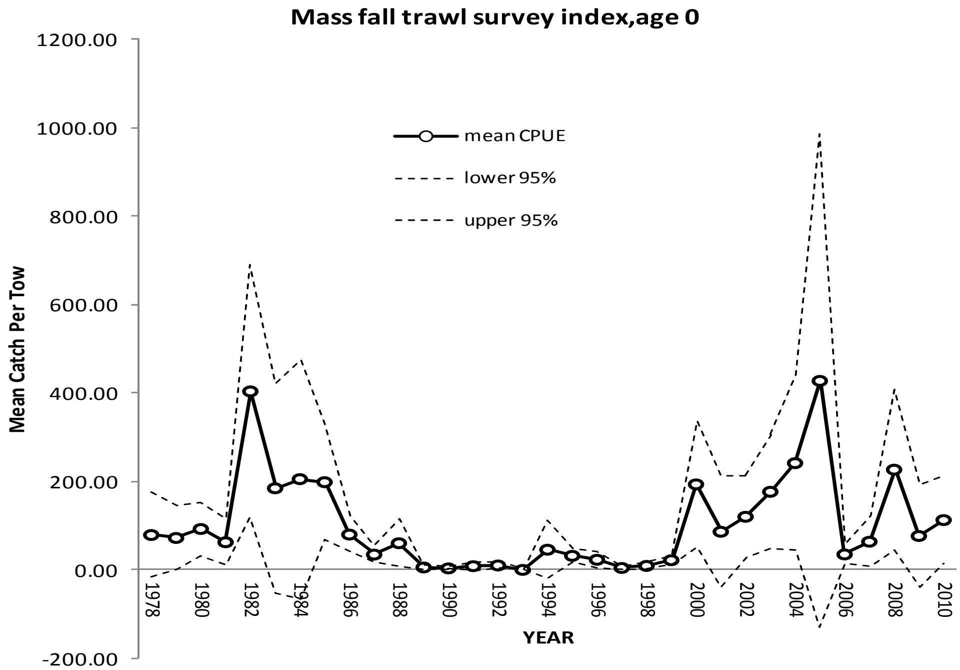


Figure B48. Black sea bass indices of age 0 abundance from MA fall trawl survey.

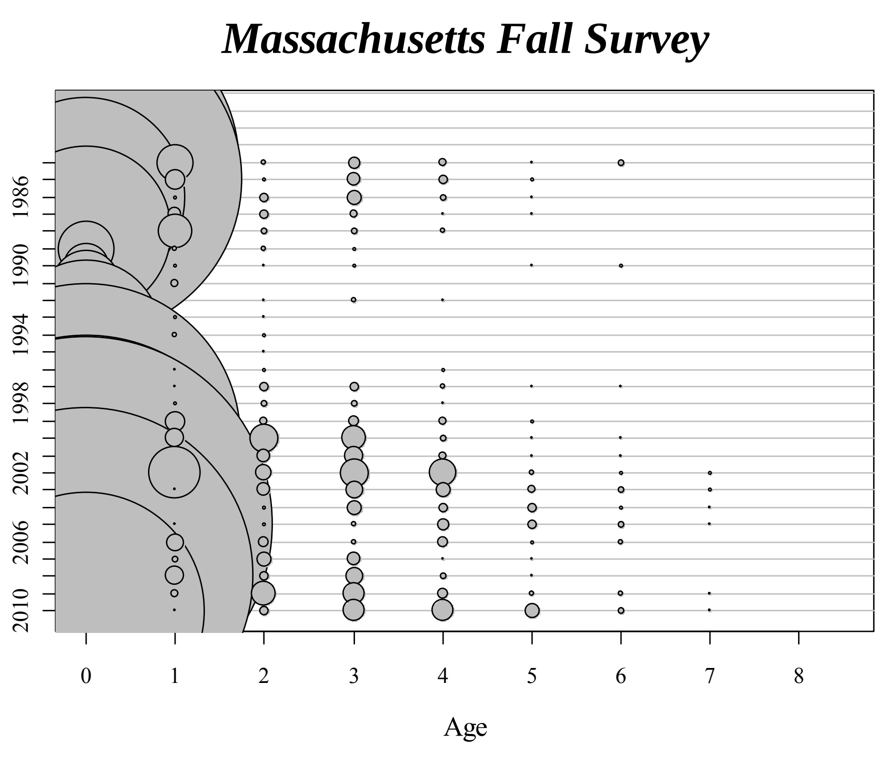


Figure B49. Black sea bass age distribution of MA fall trawl survey.

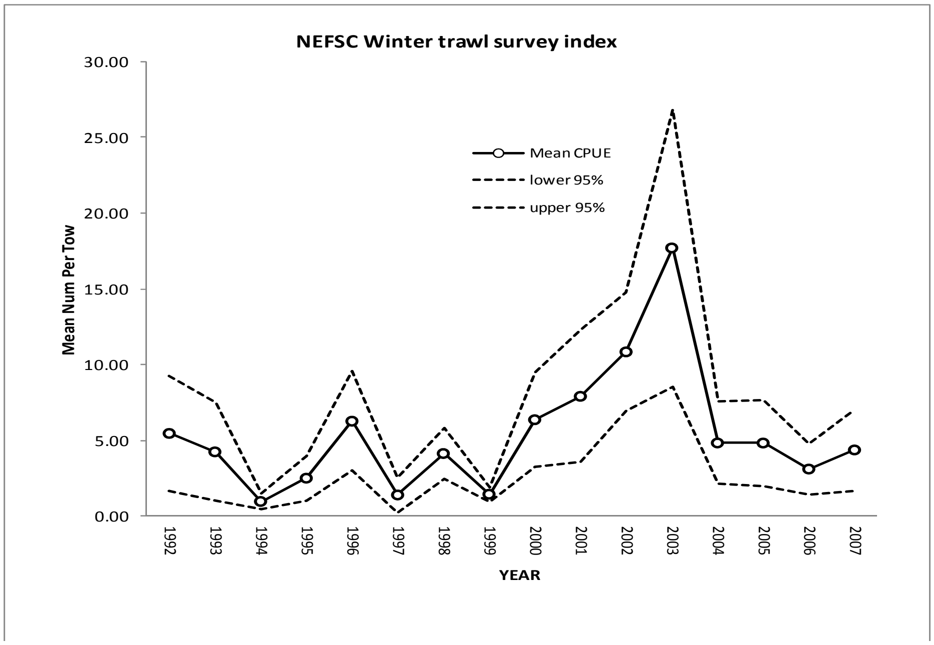


Figure B50. Black sea bass mean number per tow from NEFSC winter trawl survey.

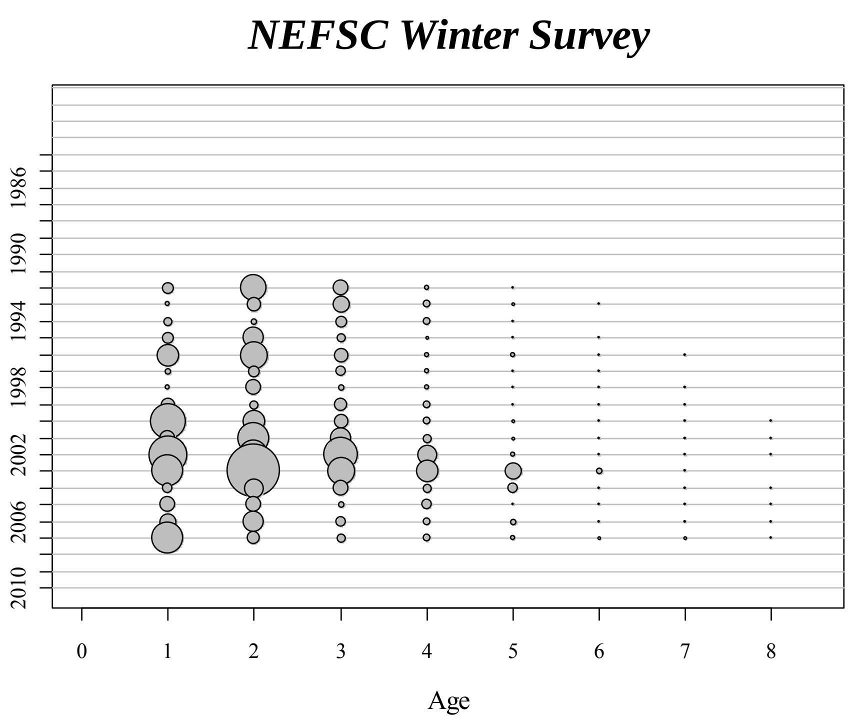


Figure B51. Black sea bass age composition of NMFS winter trawl survey.

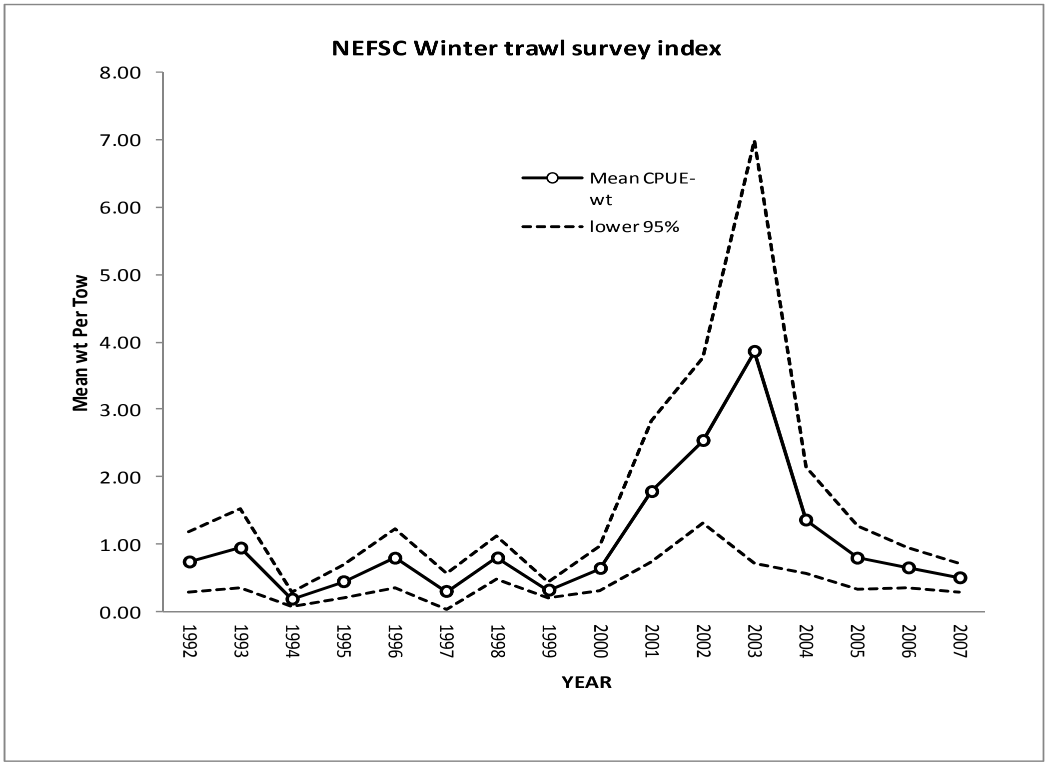


Figure B52. Black sea bass mean weight per tow from NEFSC winter trawl survey.

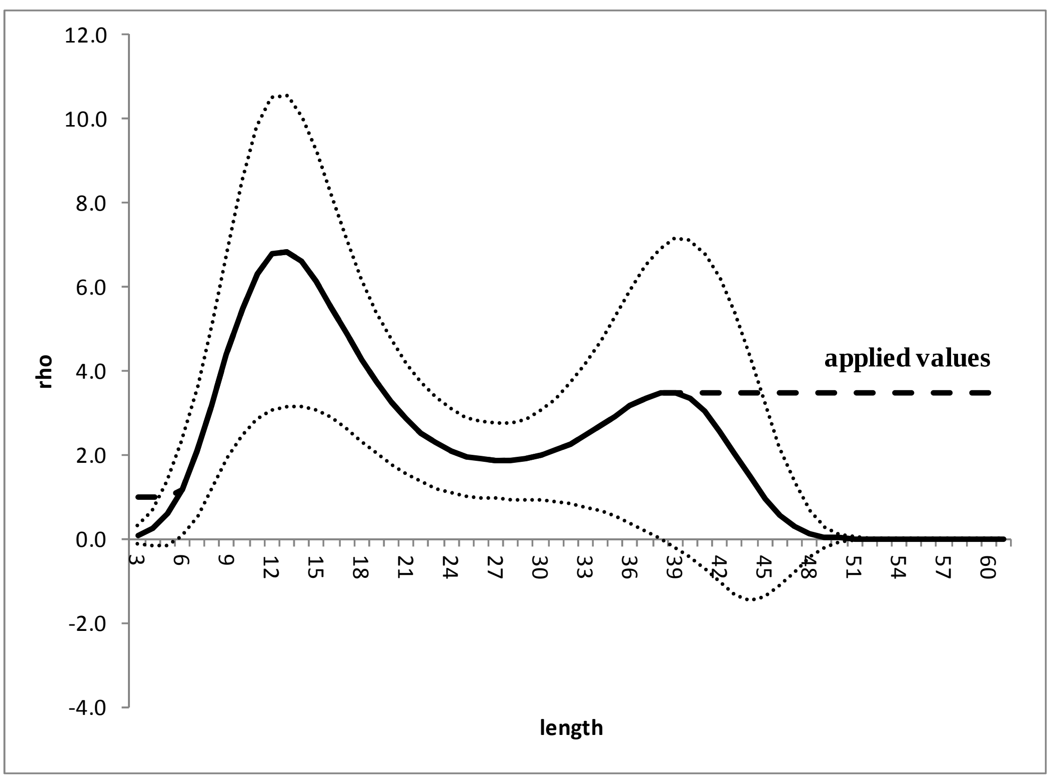


Figure B53. FRV Bigelow to Albatross calibration coefficients for black sea bass.

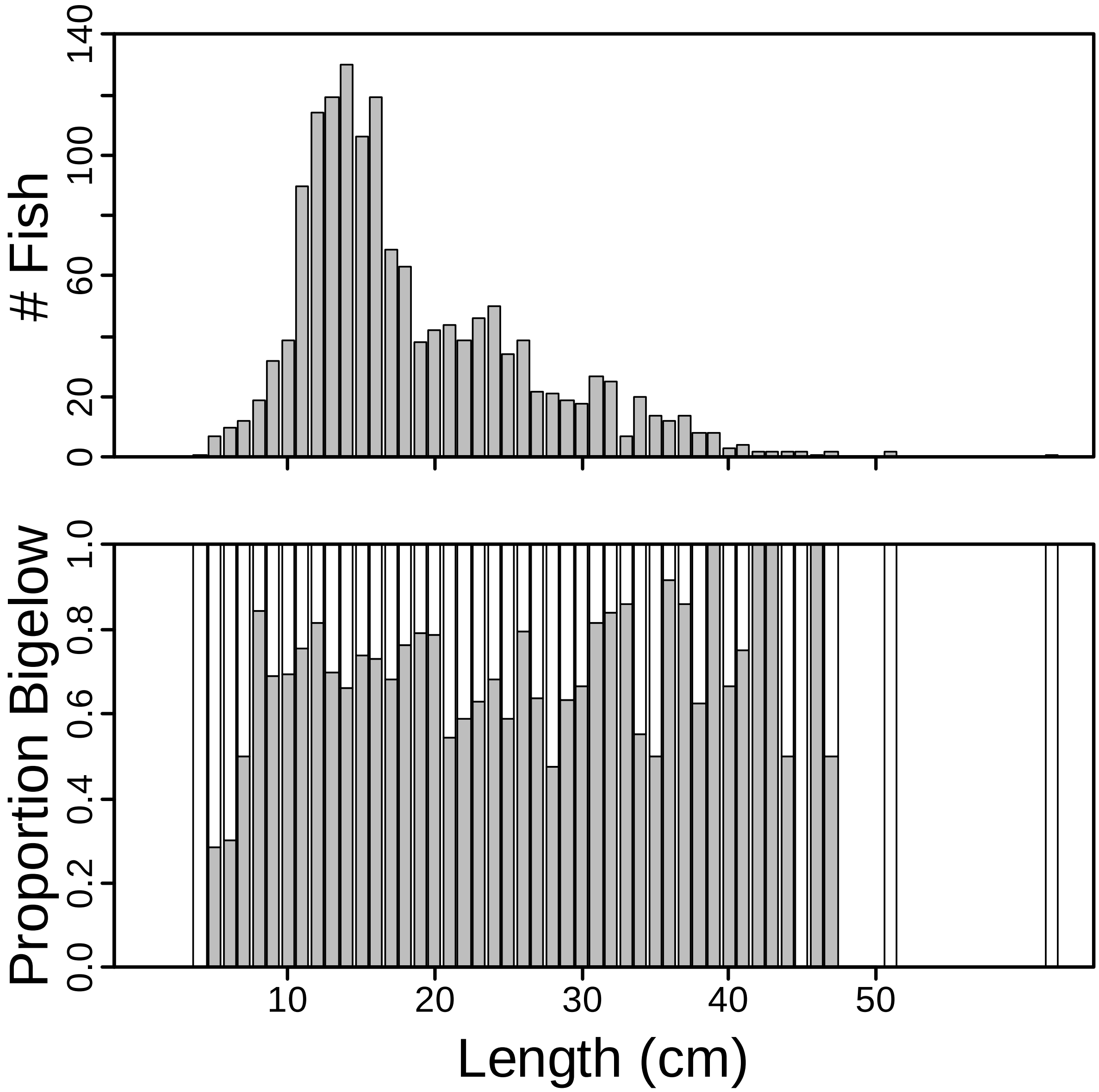


Figure B54. Total number of fish captured at each station in offshore strata (both vessels combined) at length (top) and proportions captured by the *Albatross IV* (white) and *Henry B. Bigelow* (gray) (bottom) from data collected at all stations in 2008 (T. Miller, pers. comm.)

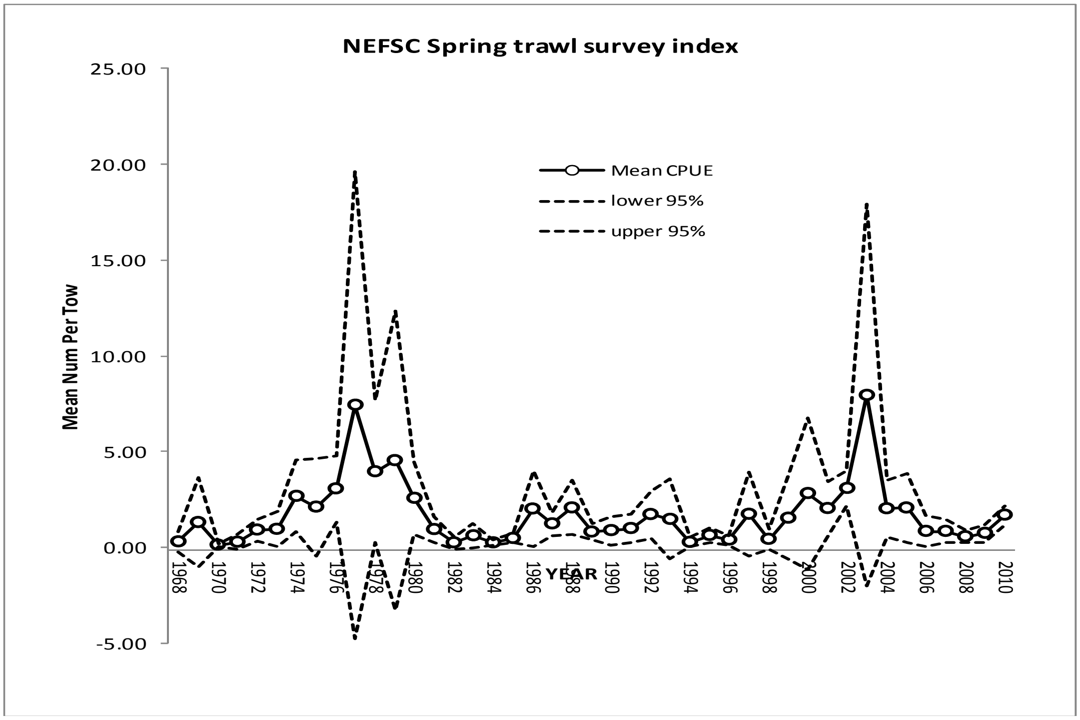


Figure B55. Black sea bass mean number per tow from NEFSC spring trawl survey.

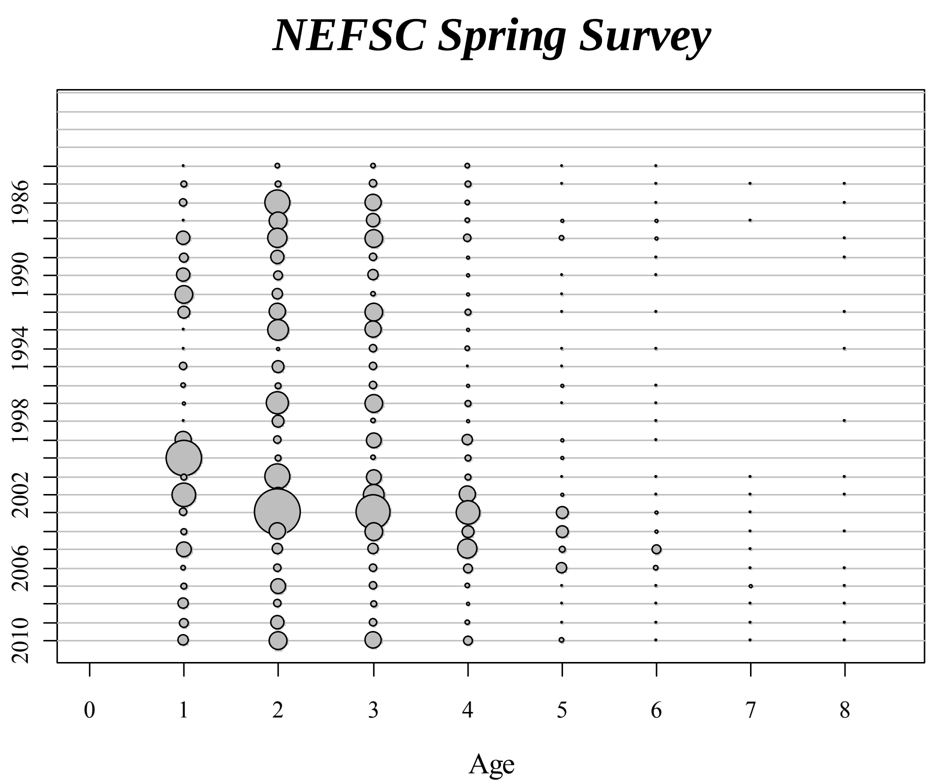


Figure B56. Black sea bass age composition of NMFS spring trawl survey.

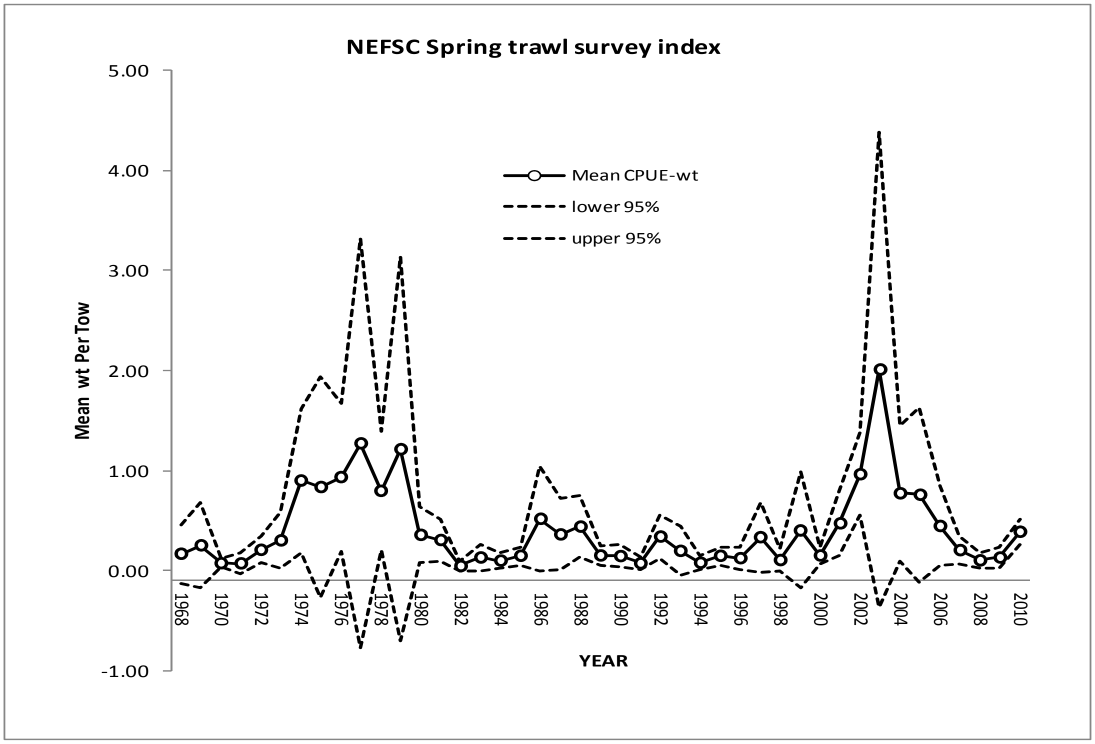


Figure B57. Black sea bass mean weight per tow from NMFS spring trawl survey.

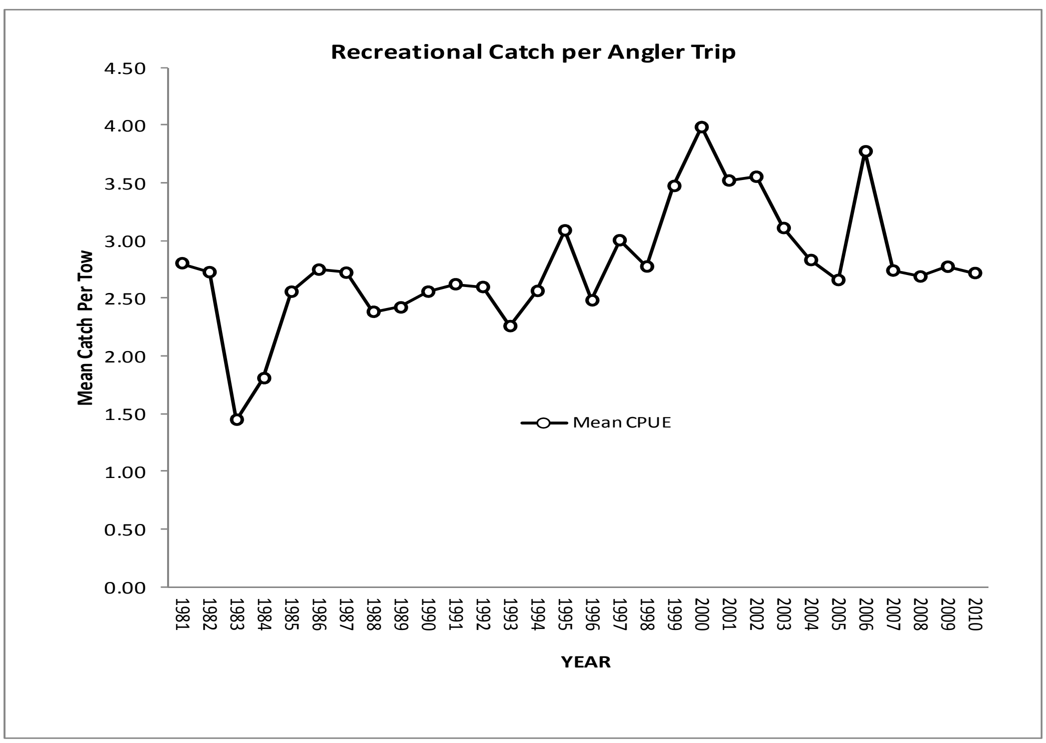


Figure B58. Recreational catch per angler trip for northern stock of black sea bass, 1981-2010.

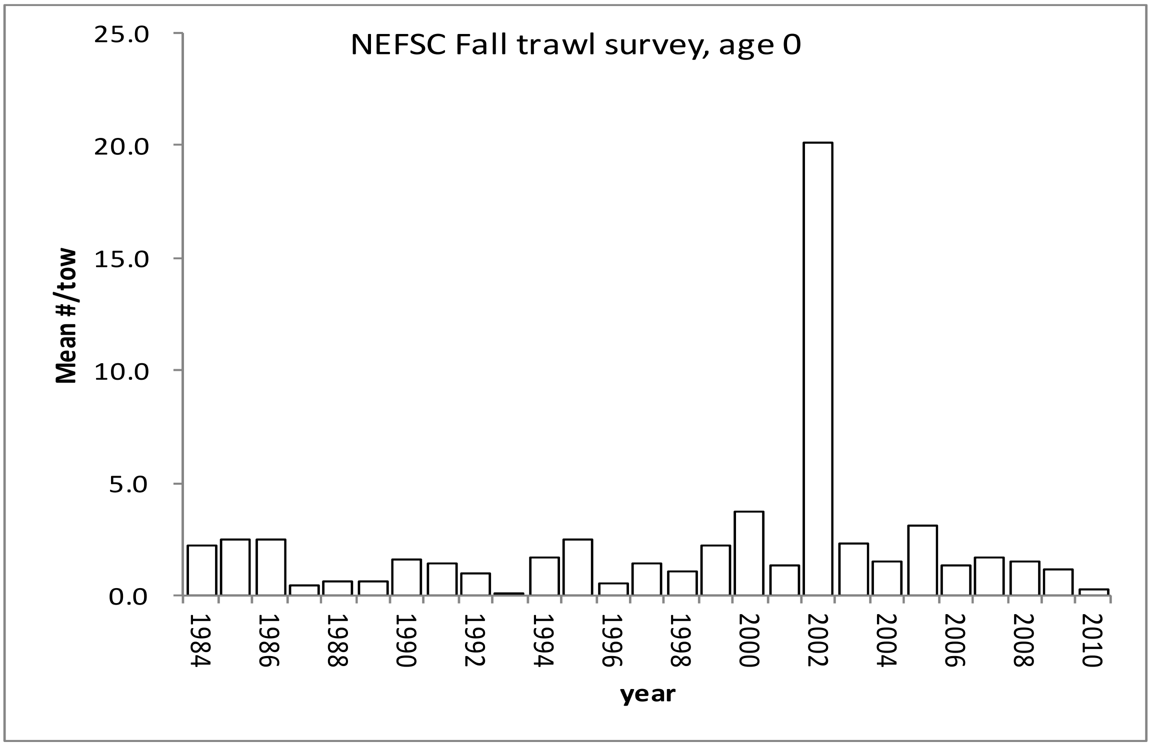


Figure B59. Black sea bass indices of age 0 abundance from NMFS fall trawl survey.

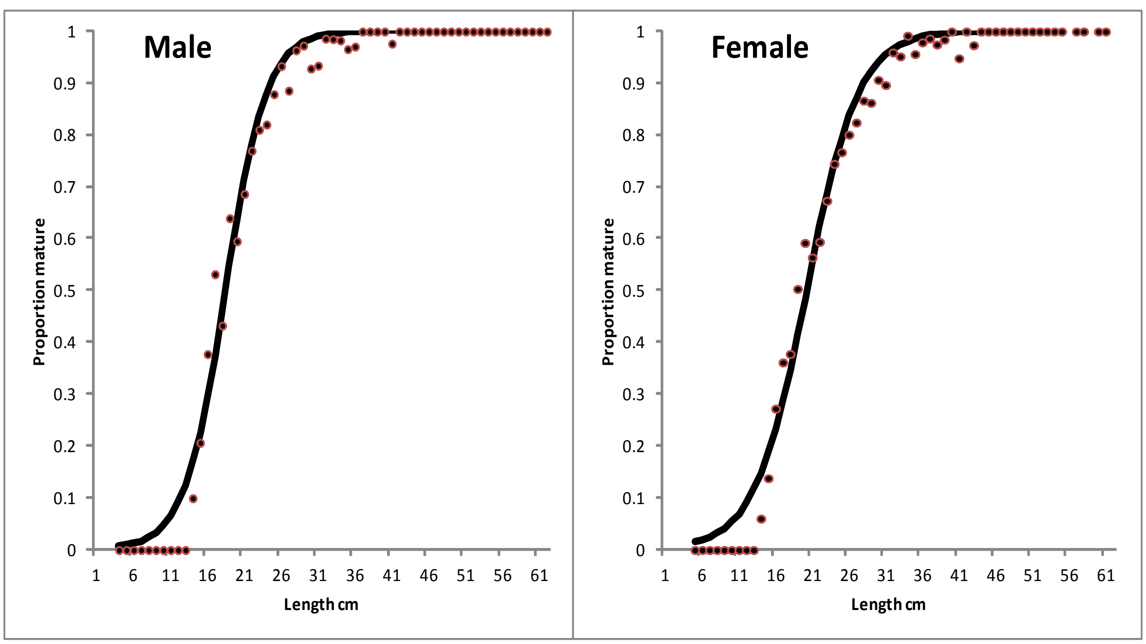


Figure B60. Black sea bass observed and predicted maturity at length for male and female from NMFS survey data.

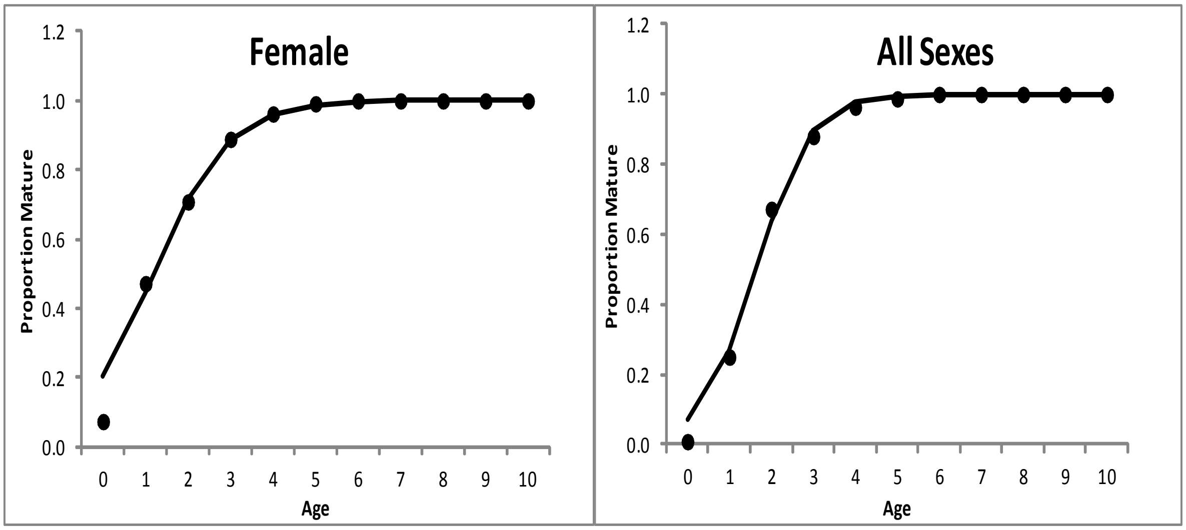


Figure B61. Black sea bass observed and predicted maturity at age for female and male/female combined from NMFS survey data.

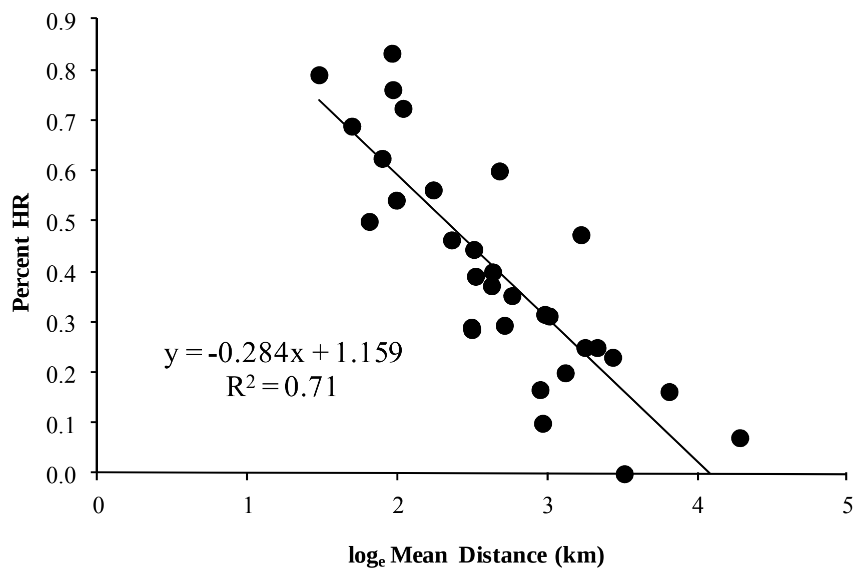


Figure B62. Relationship between distance tagged black sea bass traveled and percent return to within 10 km of release site the following season.

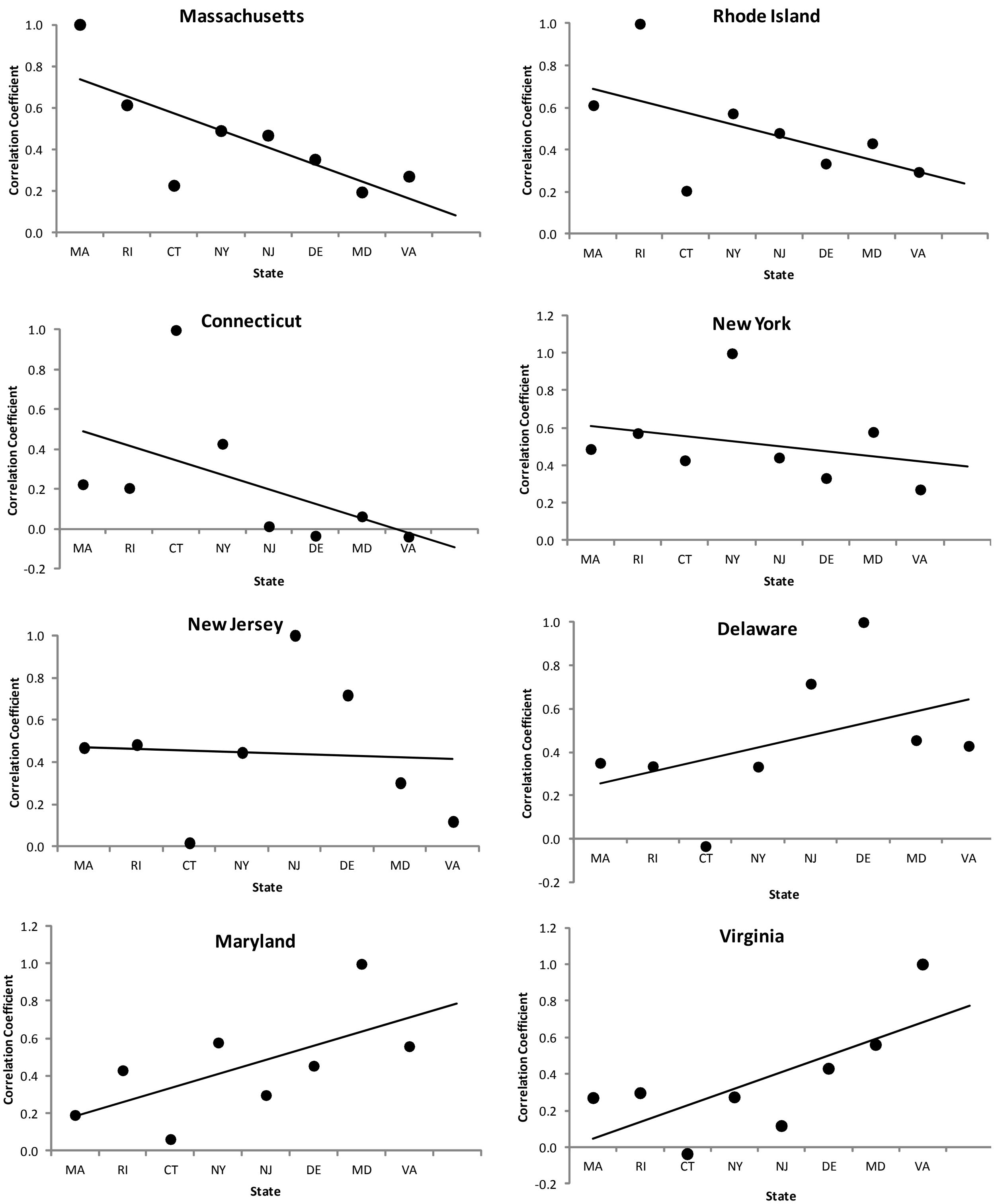


Figure B63. Correlation coefficients and trendline of black sea bass catch per angler trip (1984-2010) among states, MA to VA

.

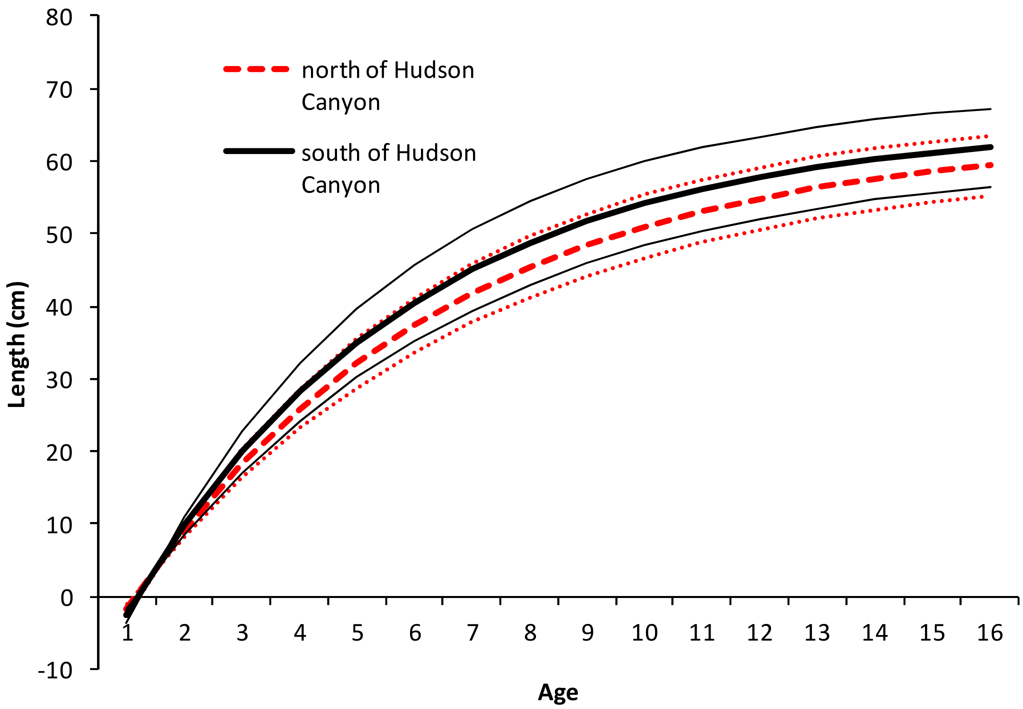


Figure B64. Black sea bass von Bertalanffy growth curves north and south of Hudson Canyon.

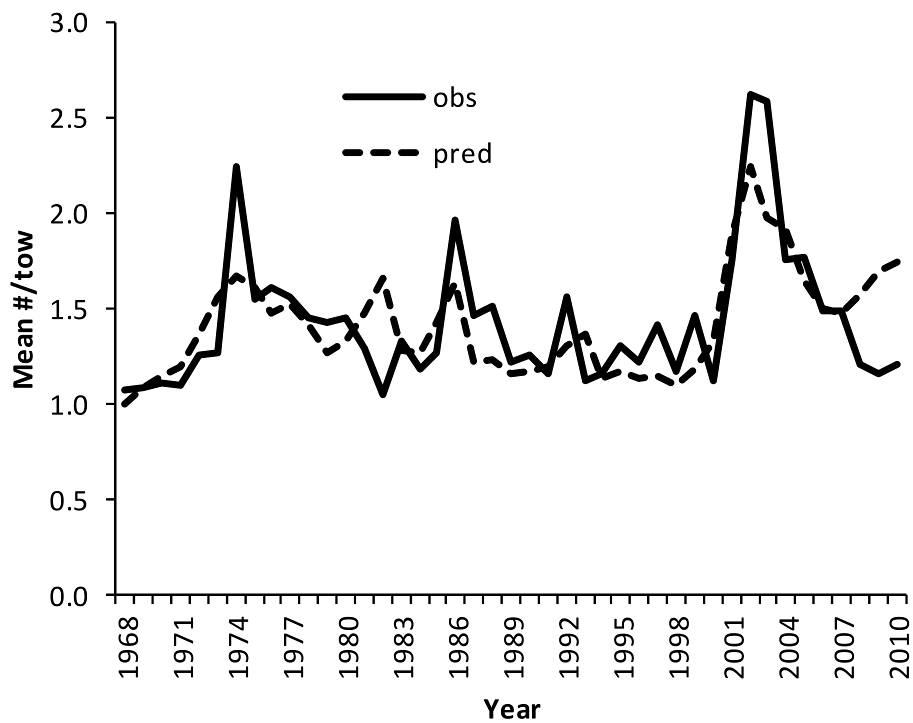


Figure B65. Observed and predicted adult (≥22 cm) black sea bass NMFS spring indices from June SCALE model.

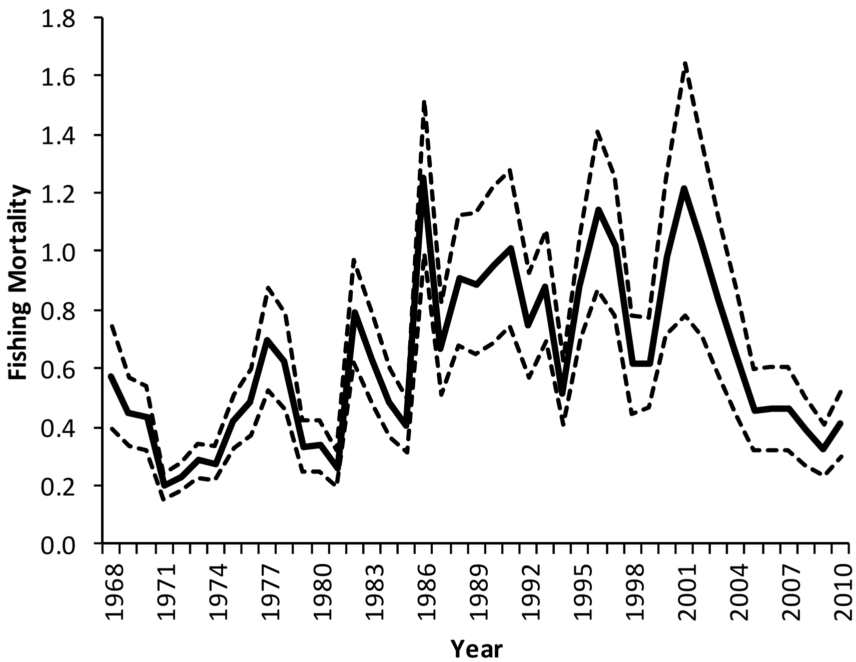


Figure B66. Estimates of black sea bass fishing mortality (+ 1 std dev) from June 2011 SCALE model.

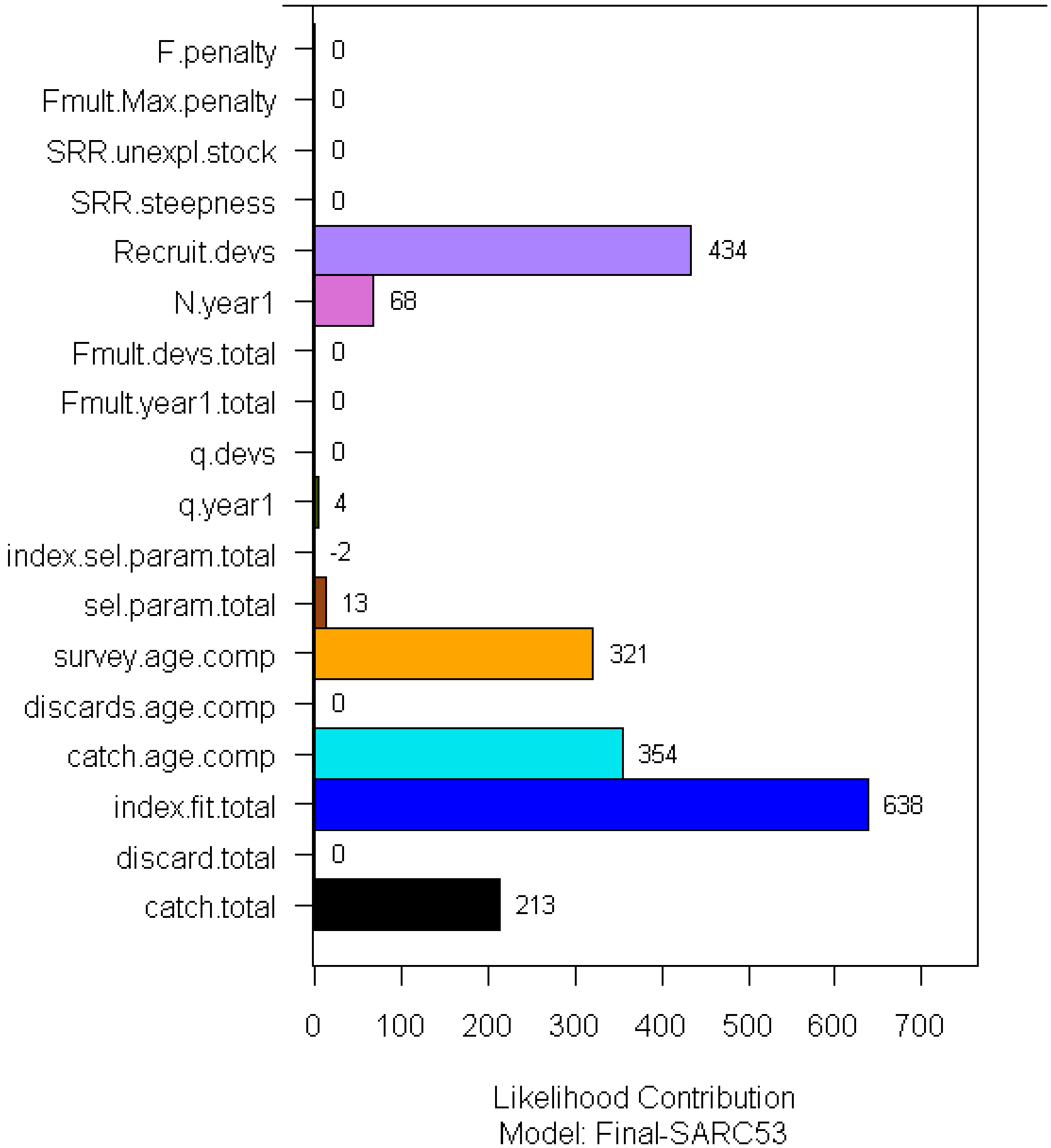


Figure B67. Components of ASAP model objective function.

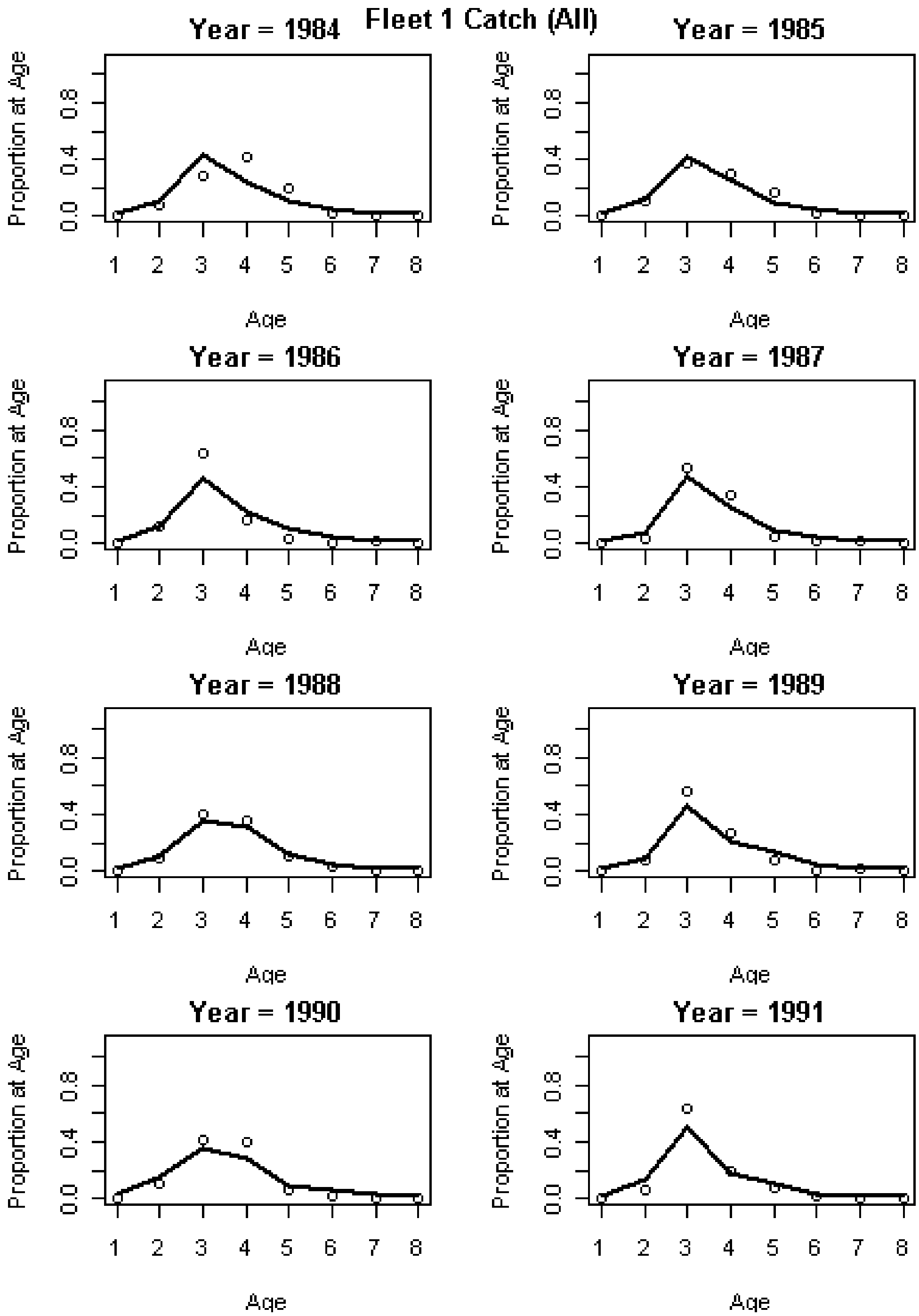


Figure B68a. Observed and predicted age comps of fleet, 1984-2010. (note: ages are shown are a+1).

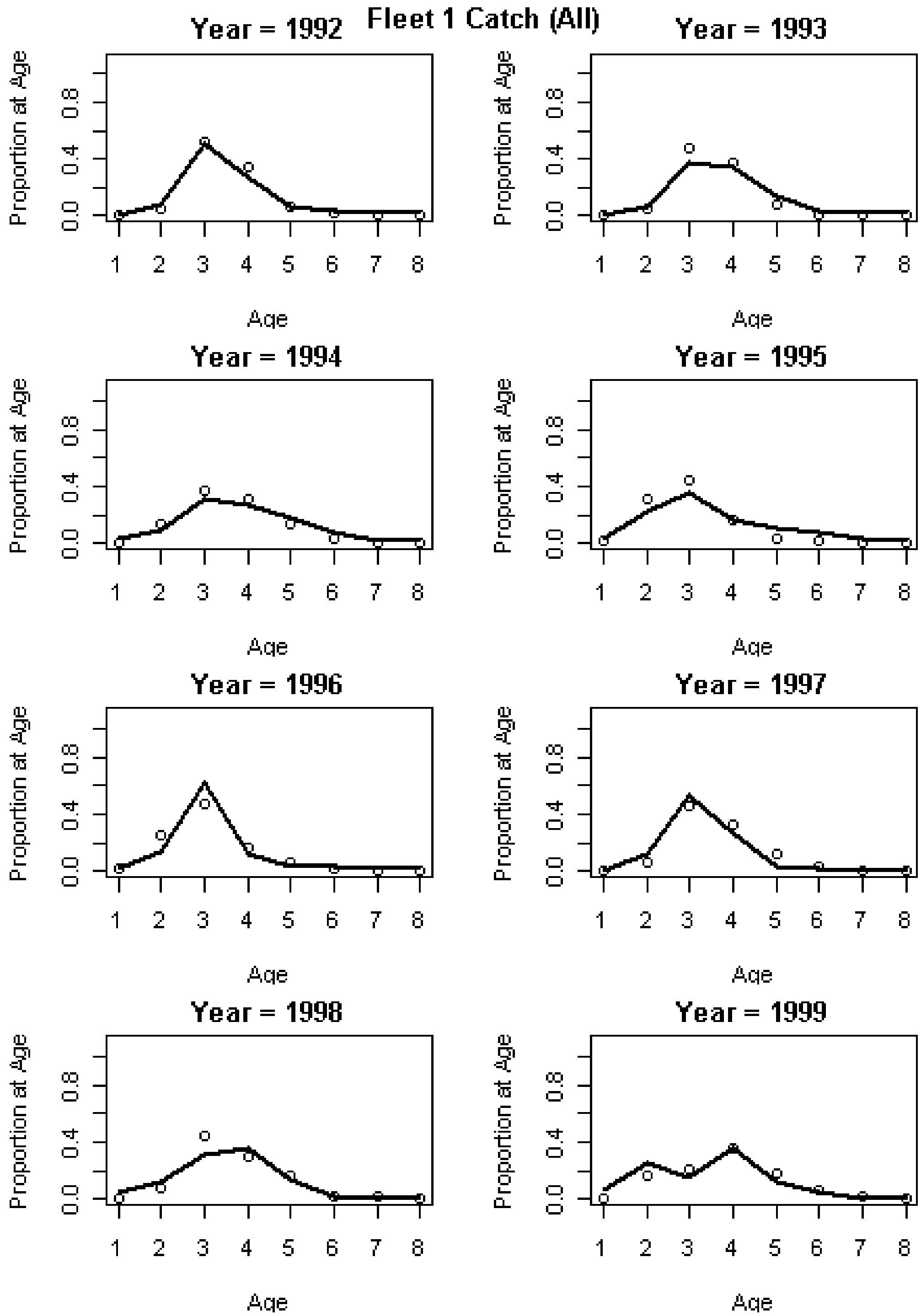


Figure B68b. Observed and predicted age comps of fleet, 1984-2010. (note: ages are shown are a+1).

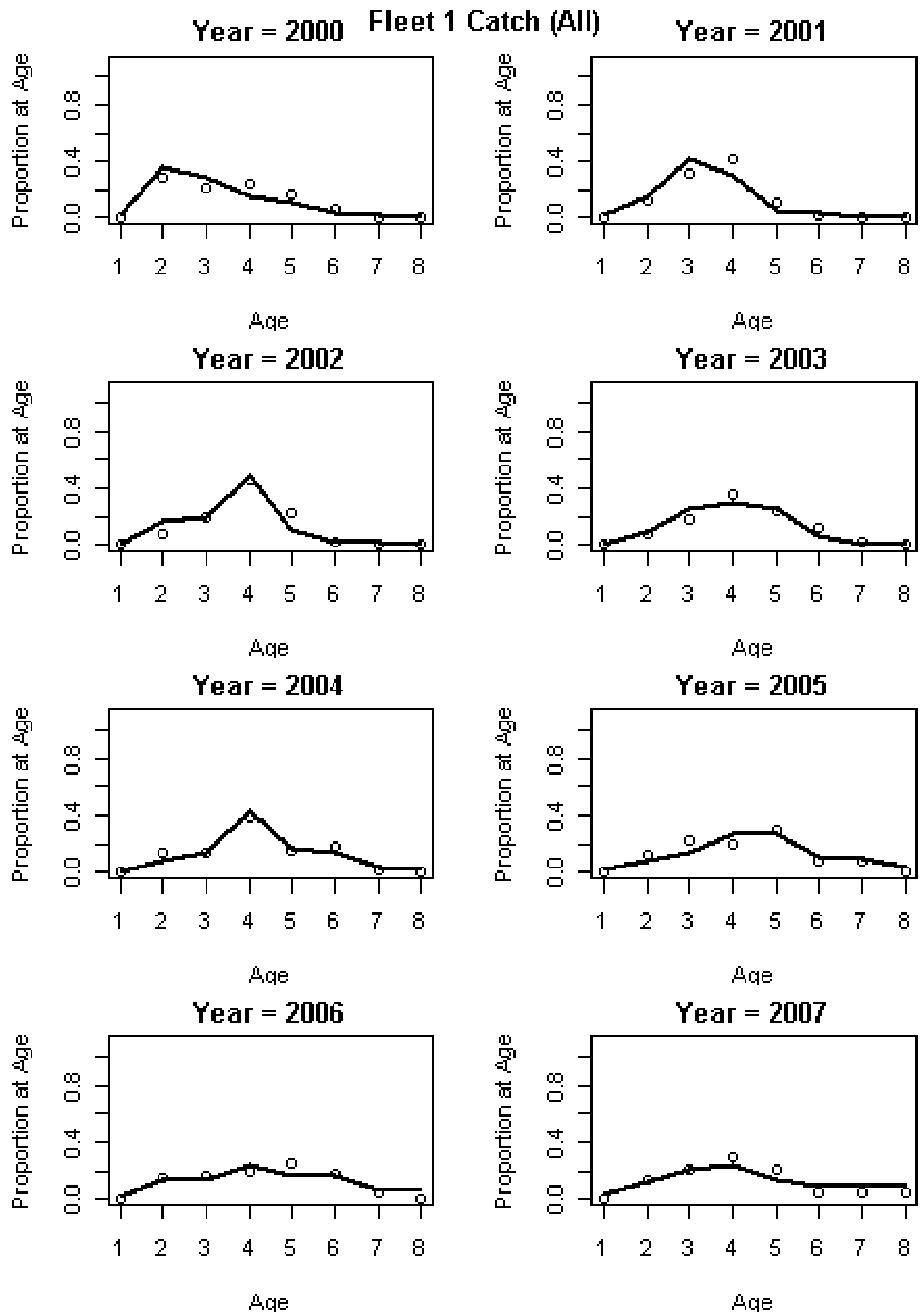


Figure B68c. Observed and predicted age comps of fleet, 1984-2010. (note: ages are shown are a+1).

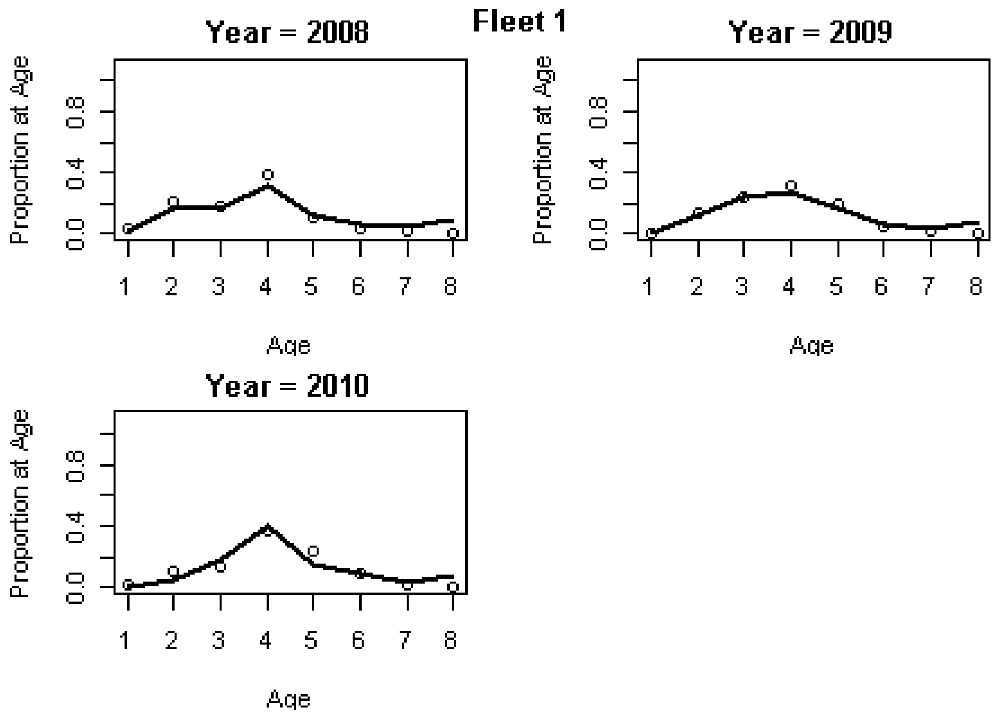


Figure B68d. Observed and predicted age comps of fleet, 1984-2010. (note: ages are shown are a+1).

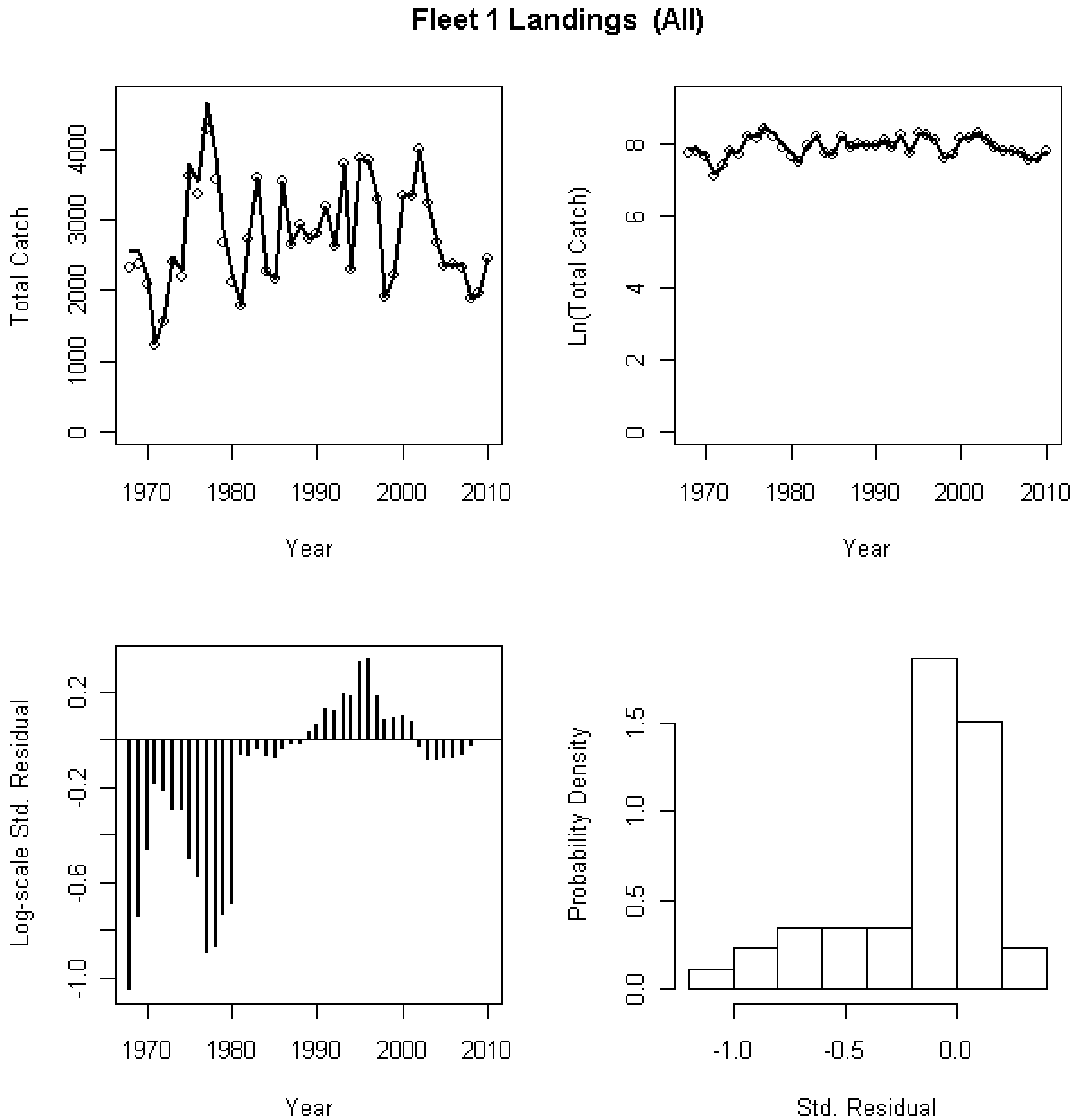


Figure B69. Observed and predicted catch and residual patterns from ASAP model.

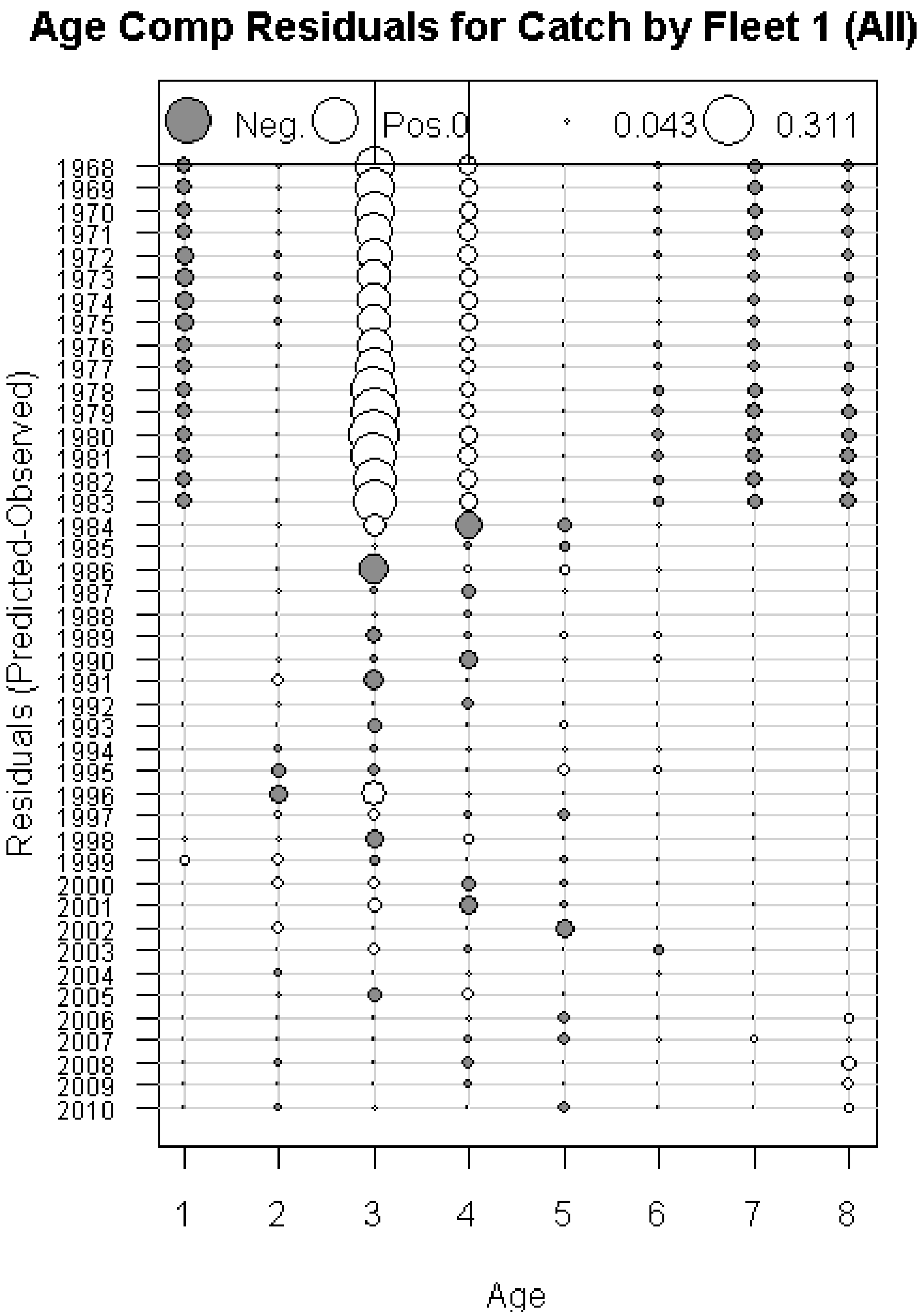


Figure B70. Age composition residuals of catch from ASAP model. (note: ages are shown are a+1).

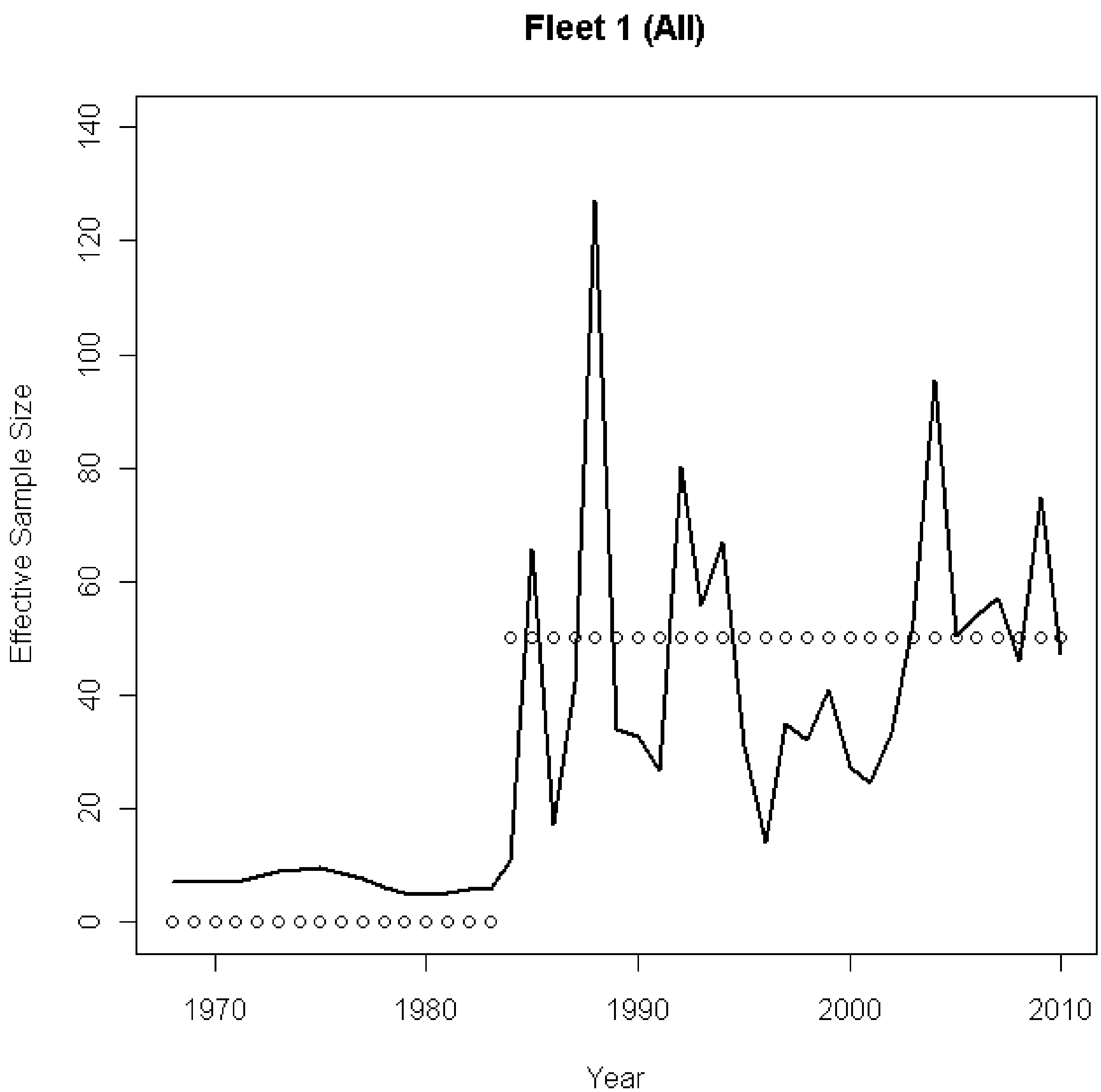
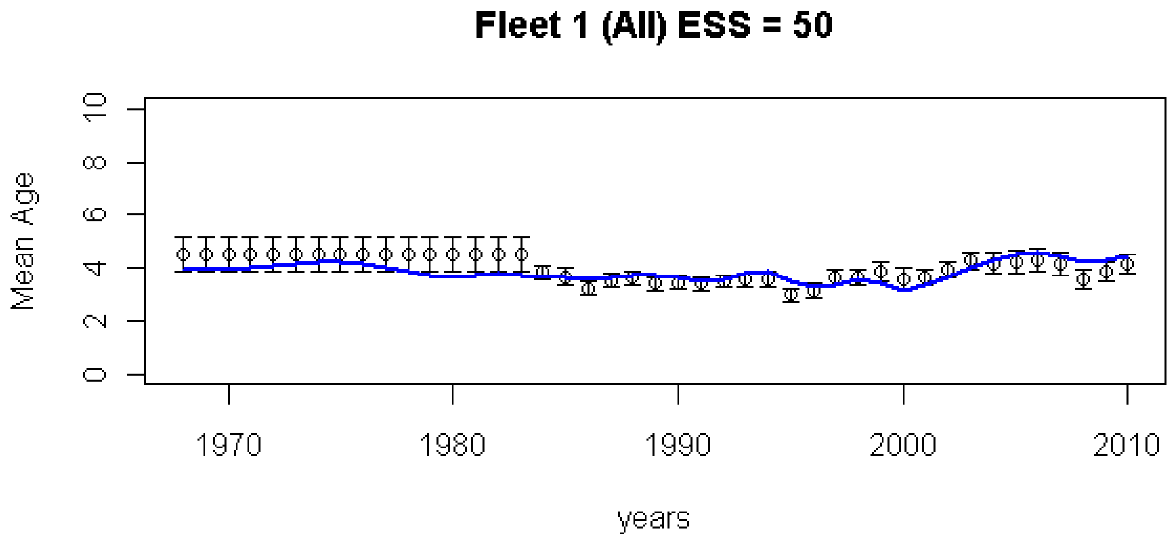


Figure B71. Observed and predicted effective sample size for fleet in ASAP model.



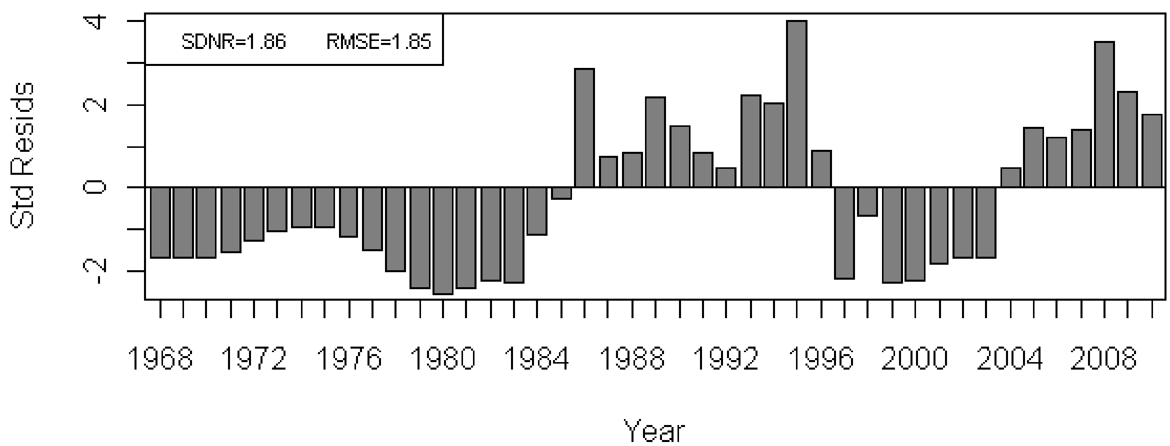


Figure B72. Fleet mean age and effective sample size plus residuals from ASAP model.

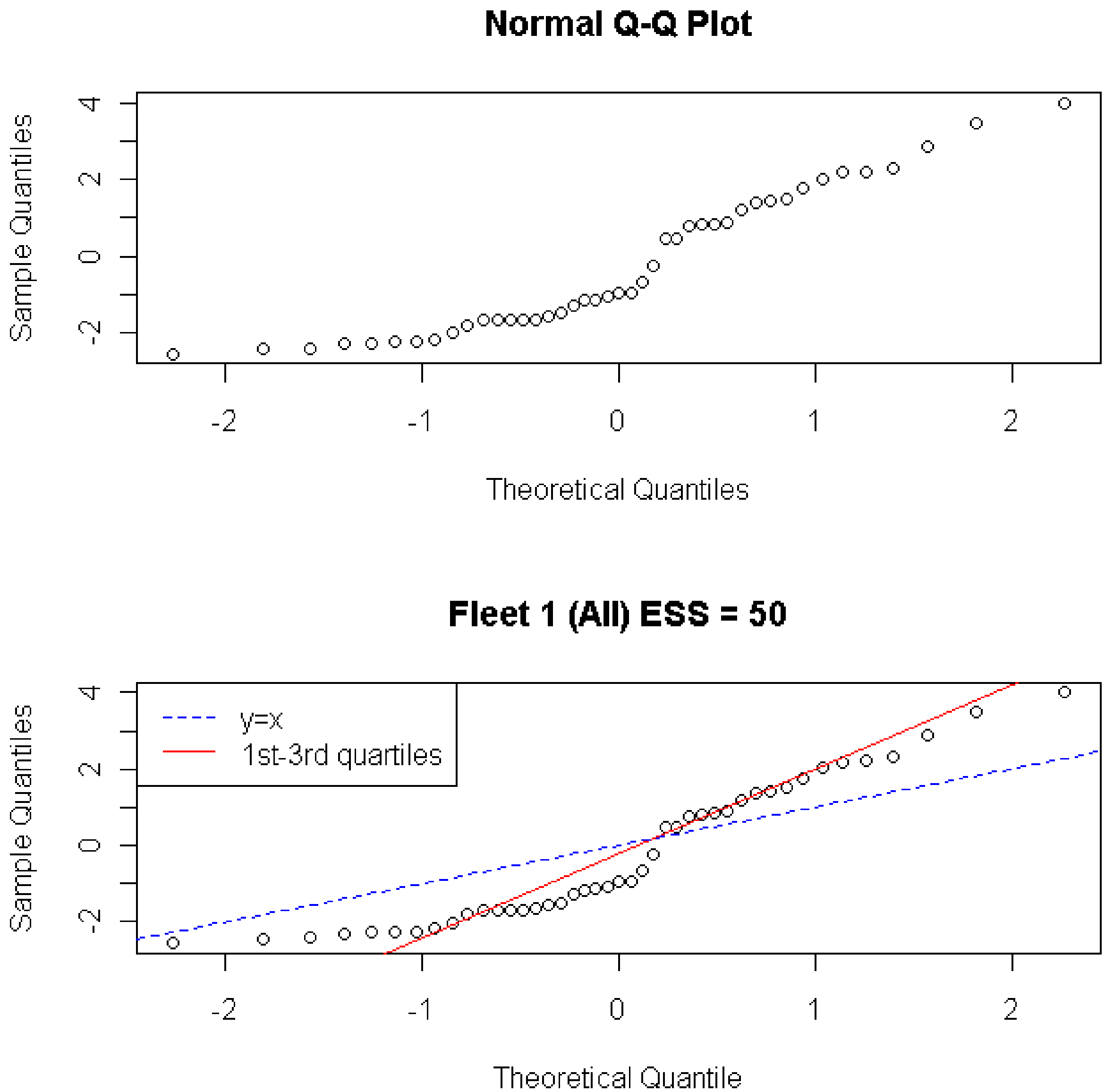


Figure B73. Quantile plots of ASAP model results.

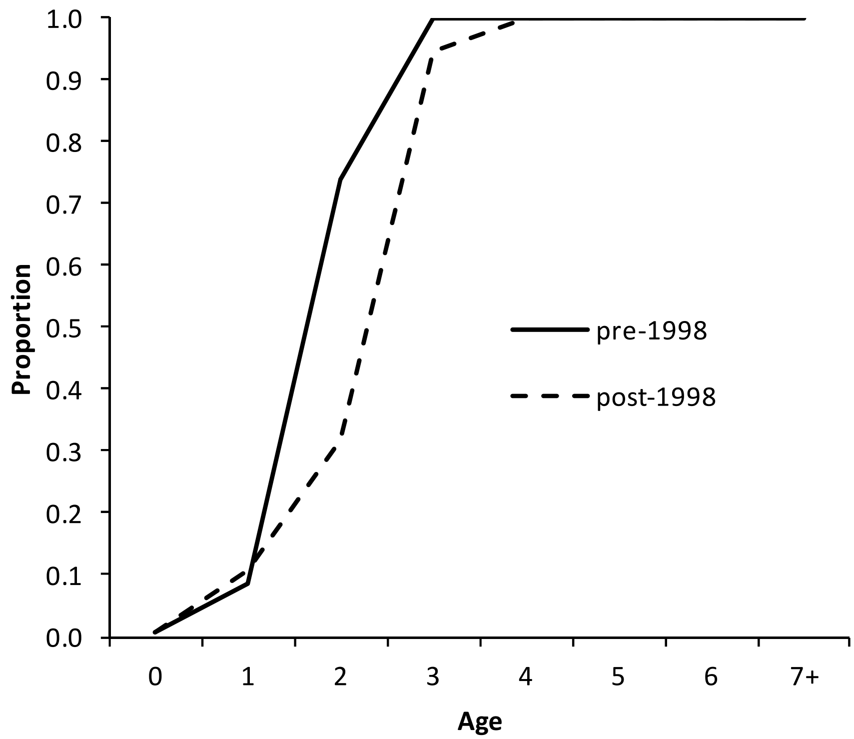


Figure B74. Catch selectivity at age pre- and post 1998 for fleet in ASAP model.

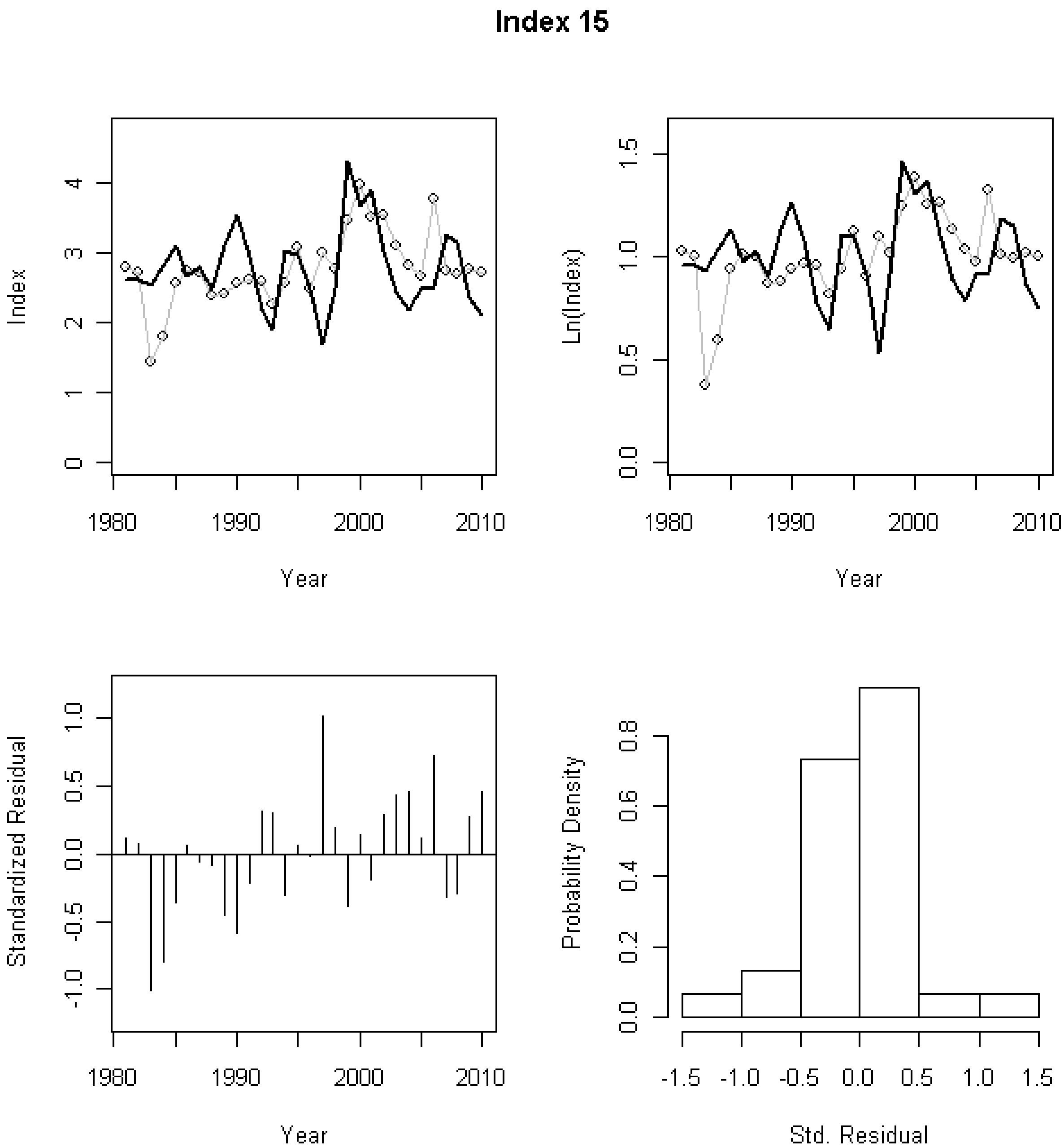


Figure B75. Observed and predicted indices and residual patterns for REC catch per angler index in ASAP model.

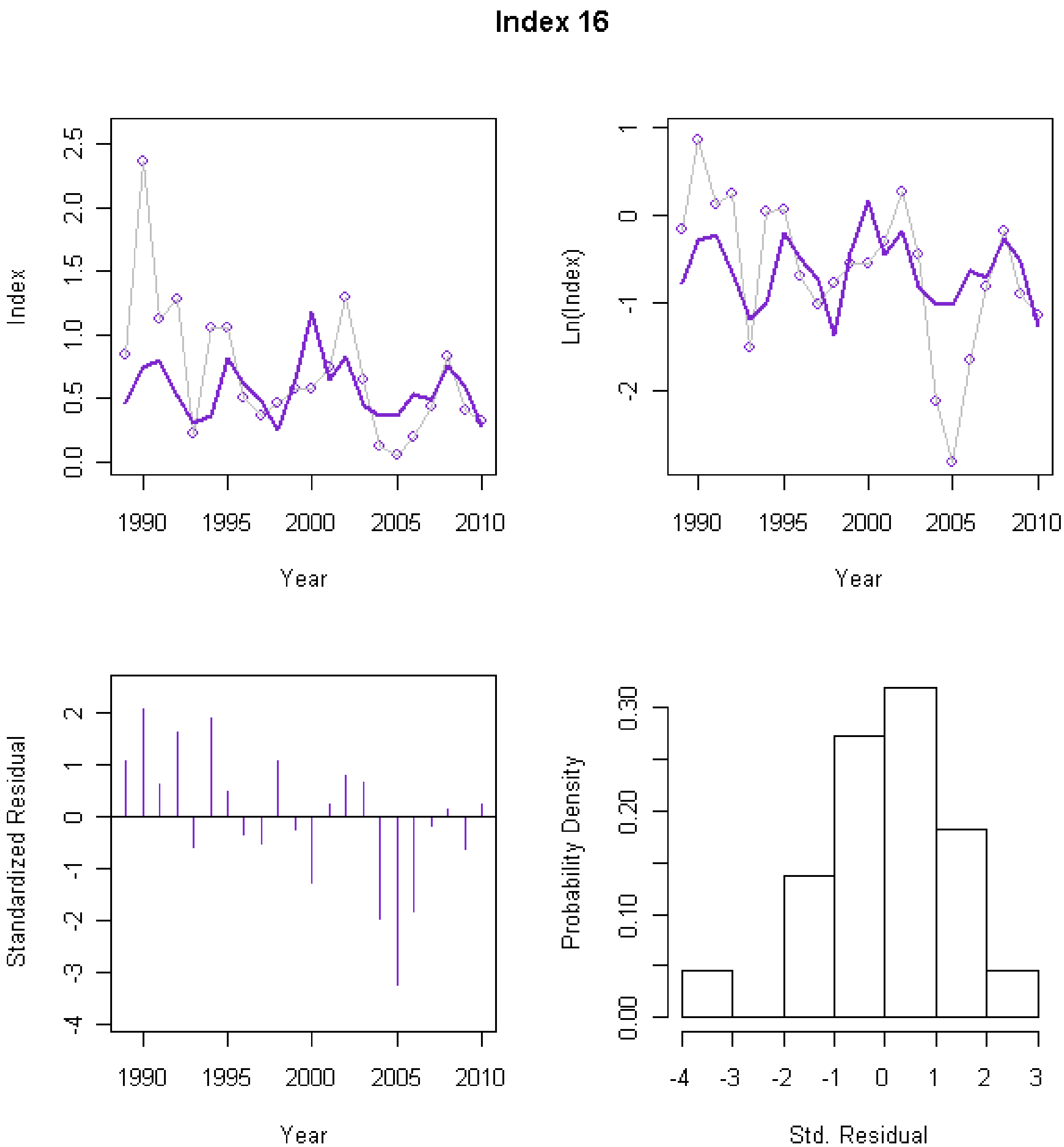


Figure B76. Observed and predicted indices and residual patterns for VA age 1 index (mean number per tow) in ASAP model.

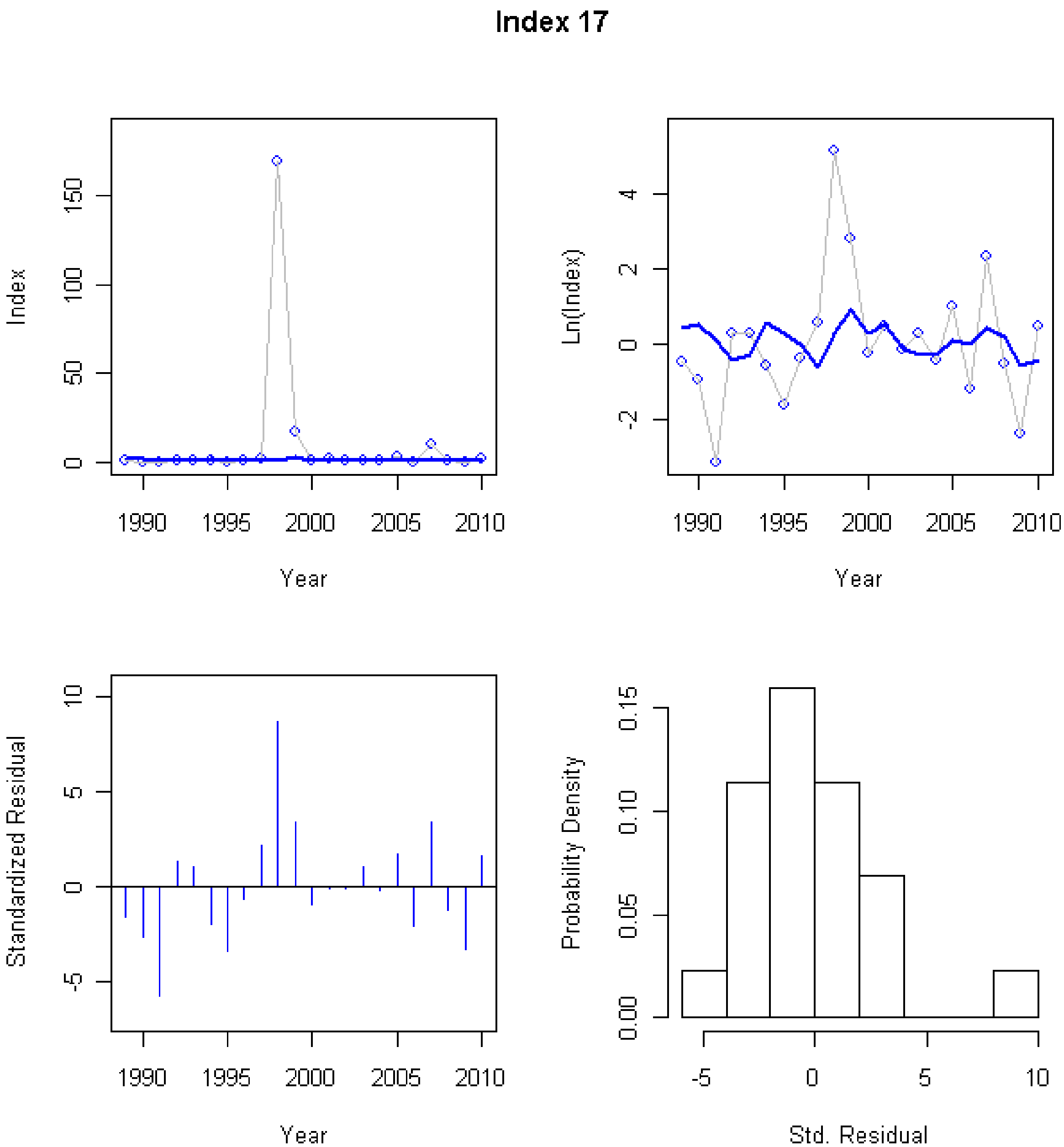


Figure B77. Observed and predicted indices and residual patterns for NJ age 0 index (mean number per tow) in ASAP model.

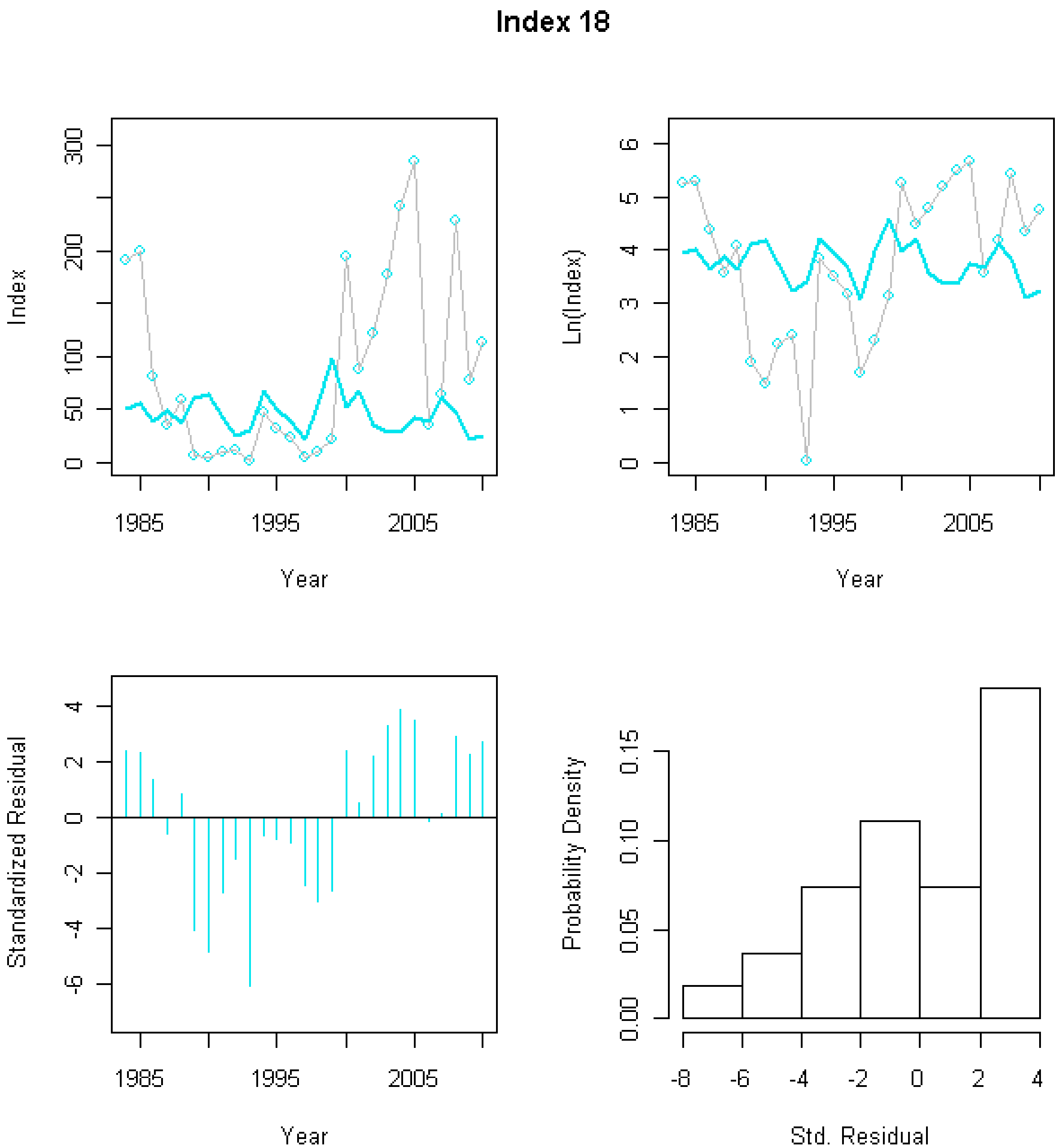


Figure B78. Observed and predicted indices and residual patterns for MA age 0 index (mean number per tow) in ASAP model.

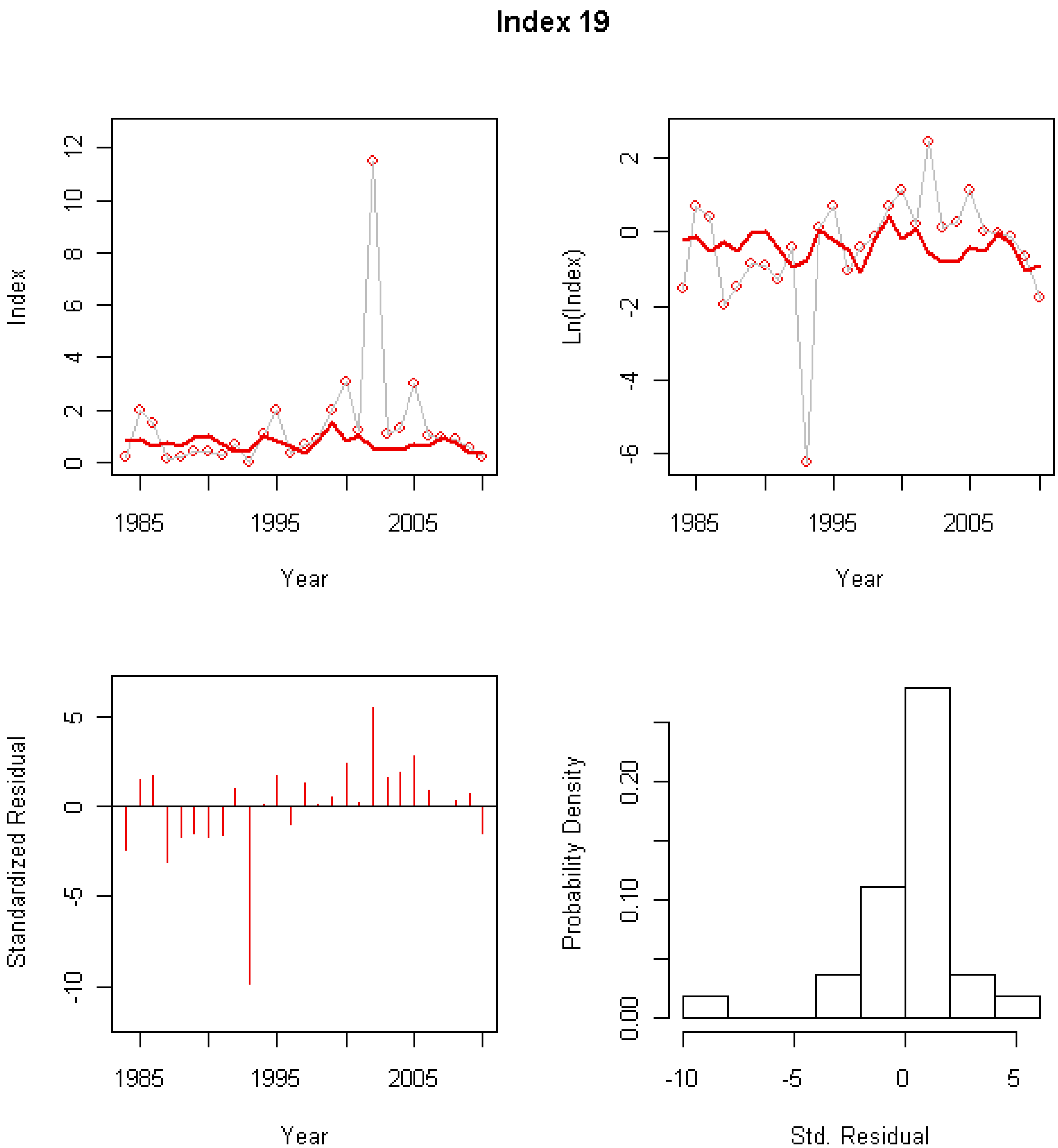


Figure B79. Observed and predicted indices and residual patterns for NEFSC Fall trawl survey age 0 index (mean number per tow) in ASAP model.

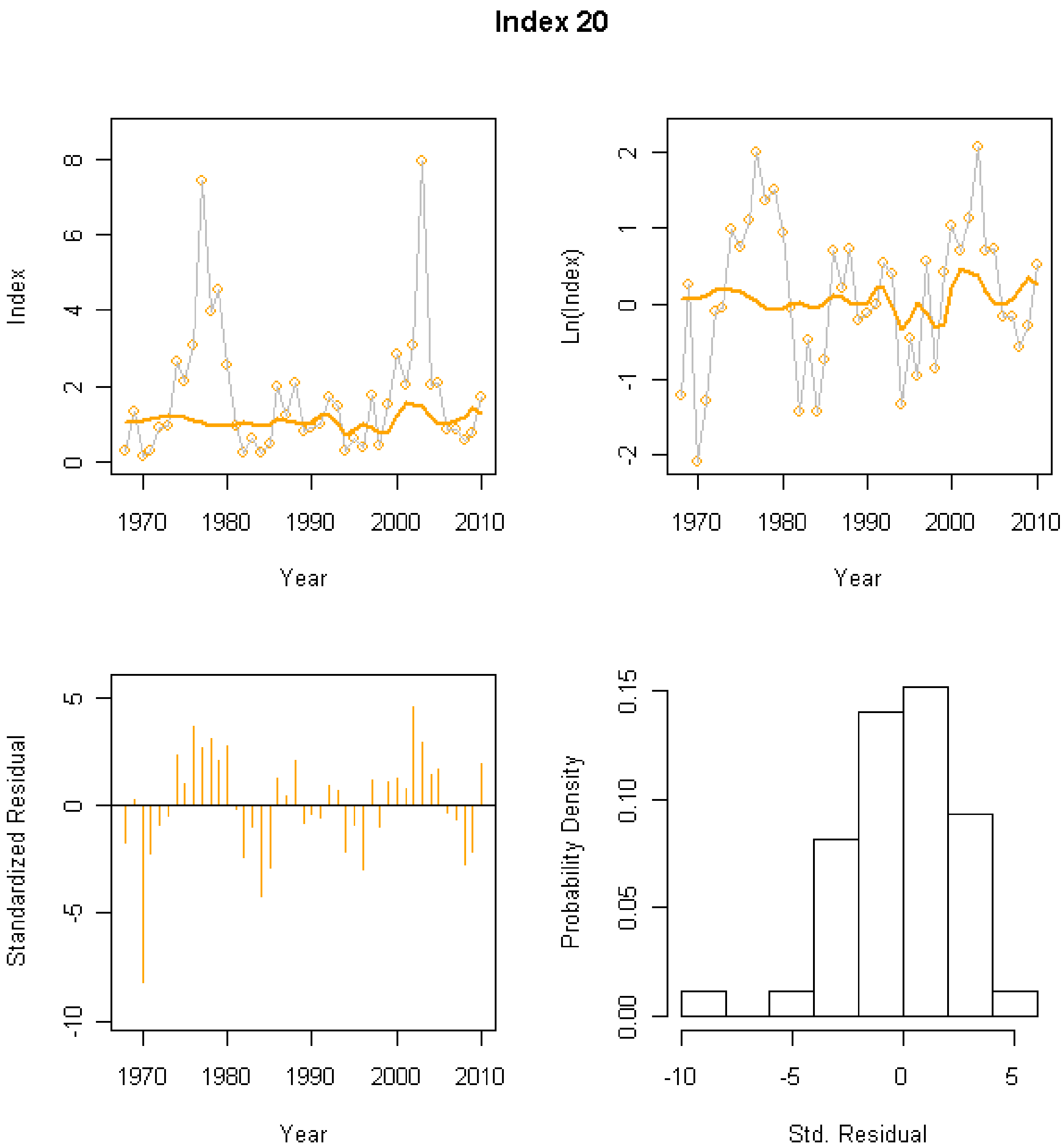


Figure B80. Observed and predicted indices and residual patterns for NEFSC spring trawl survey index (mean number per tow) in ASAP model.

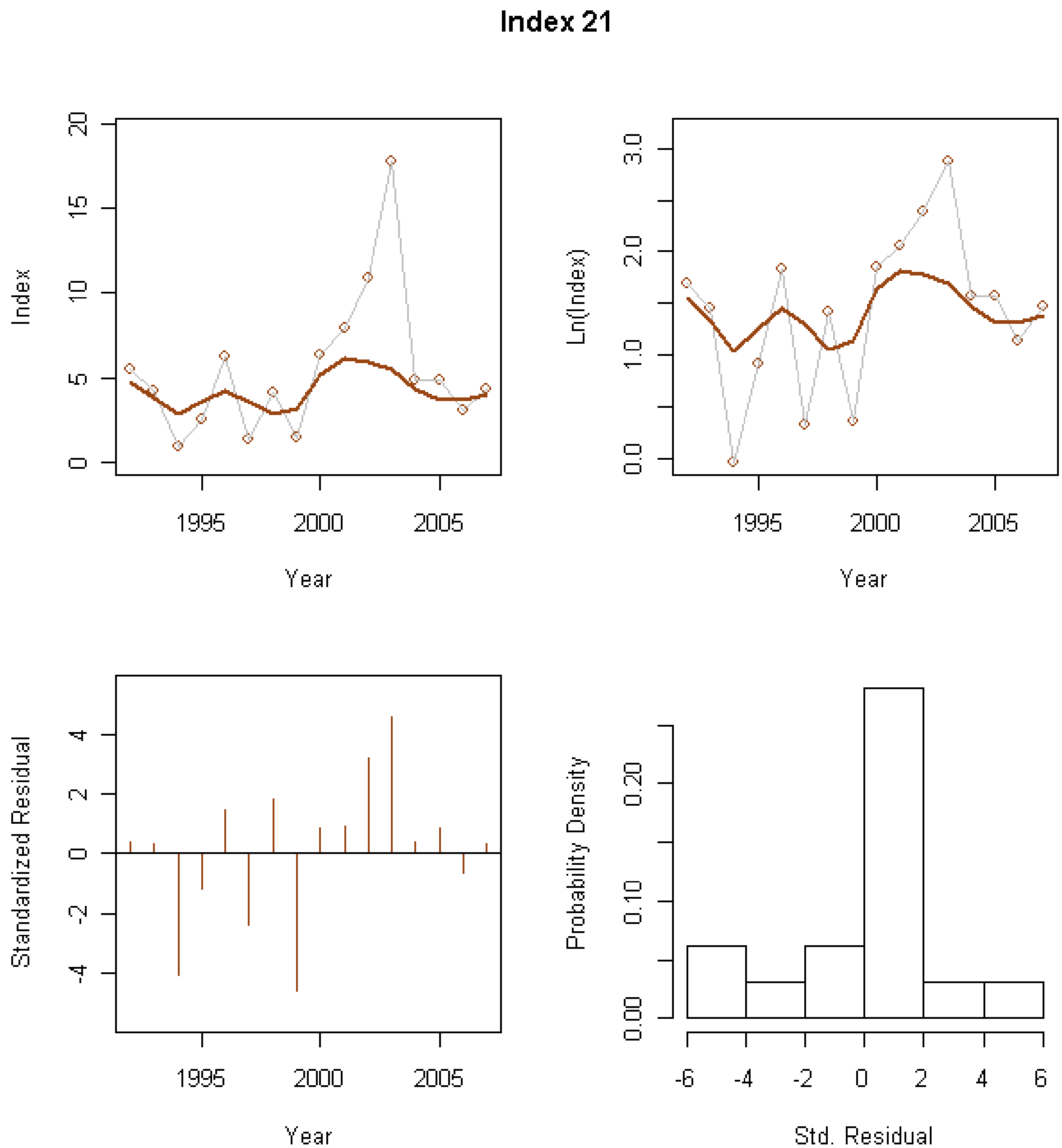


Figure B81. Observed and predicted indices and residual patterns for NEFSC winter trawl survey index (mean biomass per tow) in ASAP model.

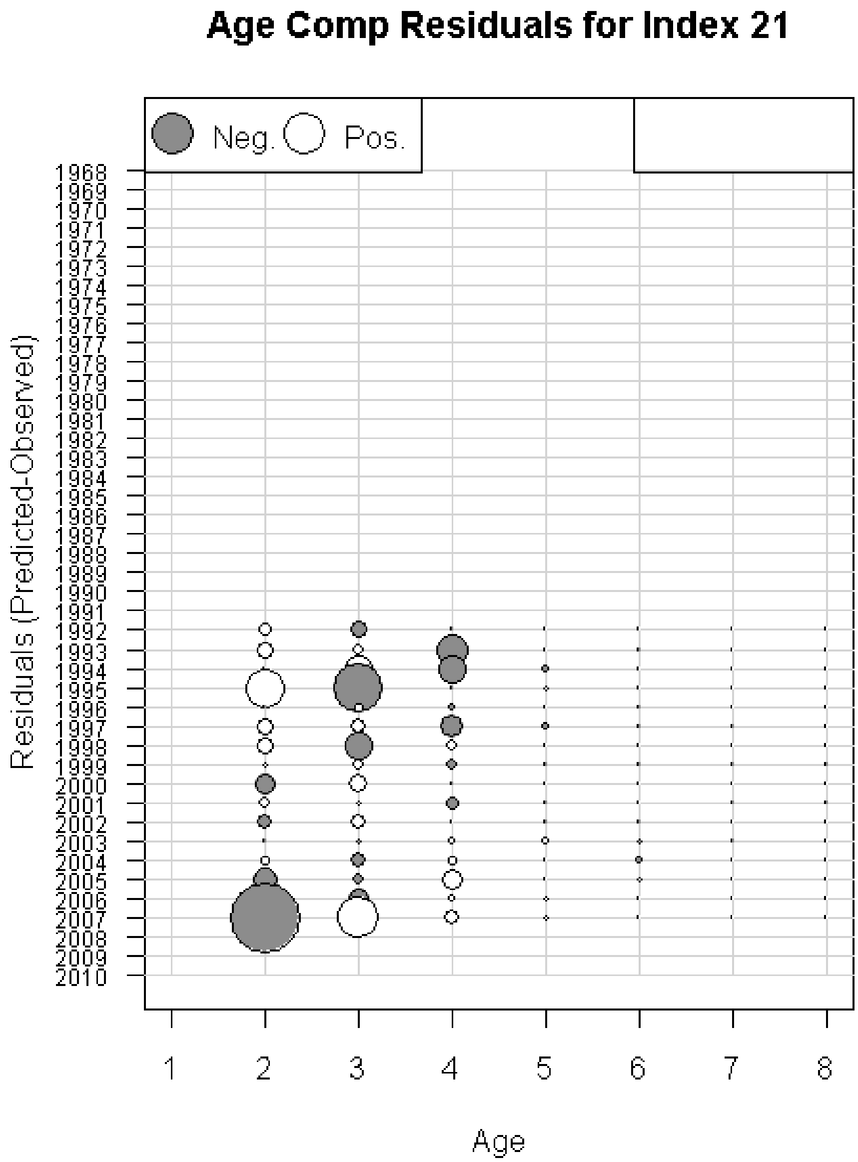


Figure B82. Age composition of NMFS winter trawl survey in ASAP model. (note: ages are shown are a+1).

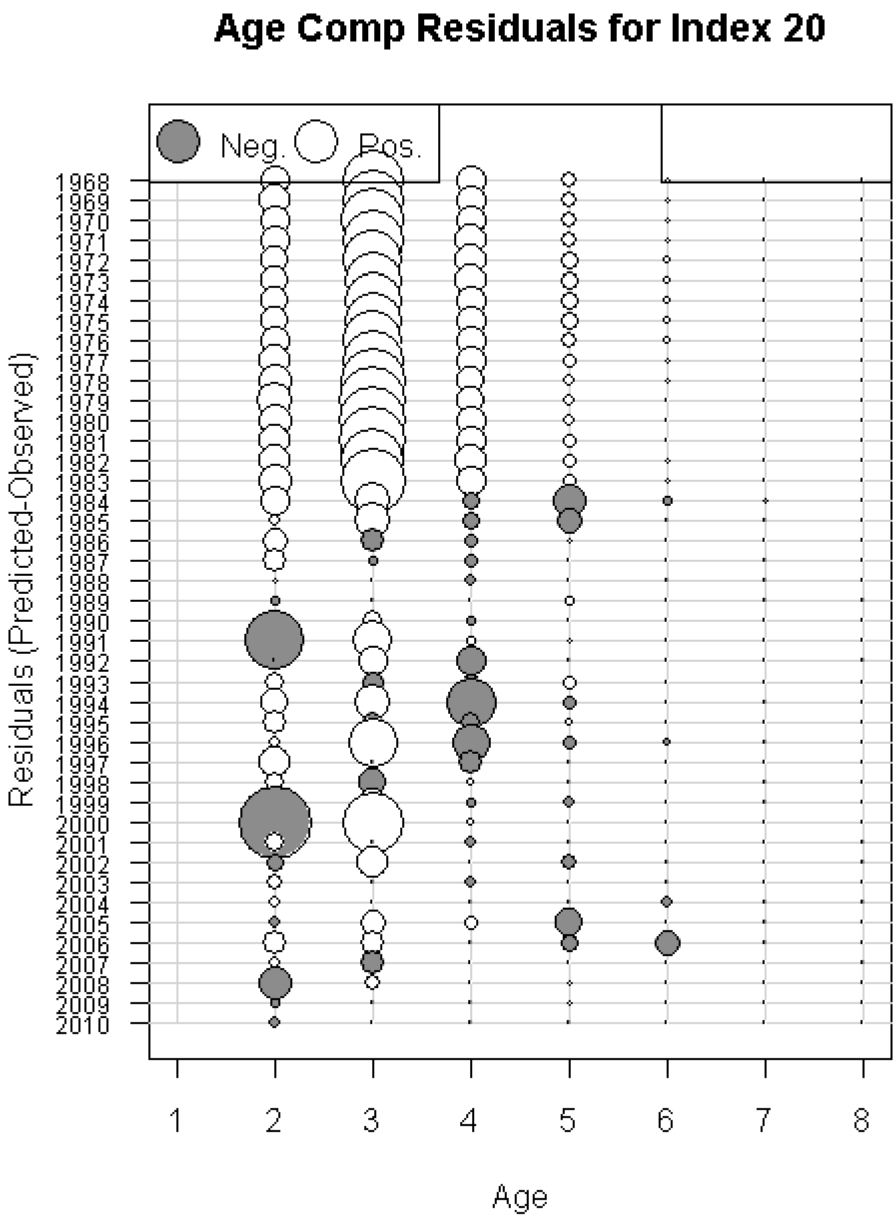


Figure B83. Age composition of NMFS spring trawl survey in ASAP model. (note: ages are shown are a+1).

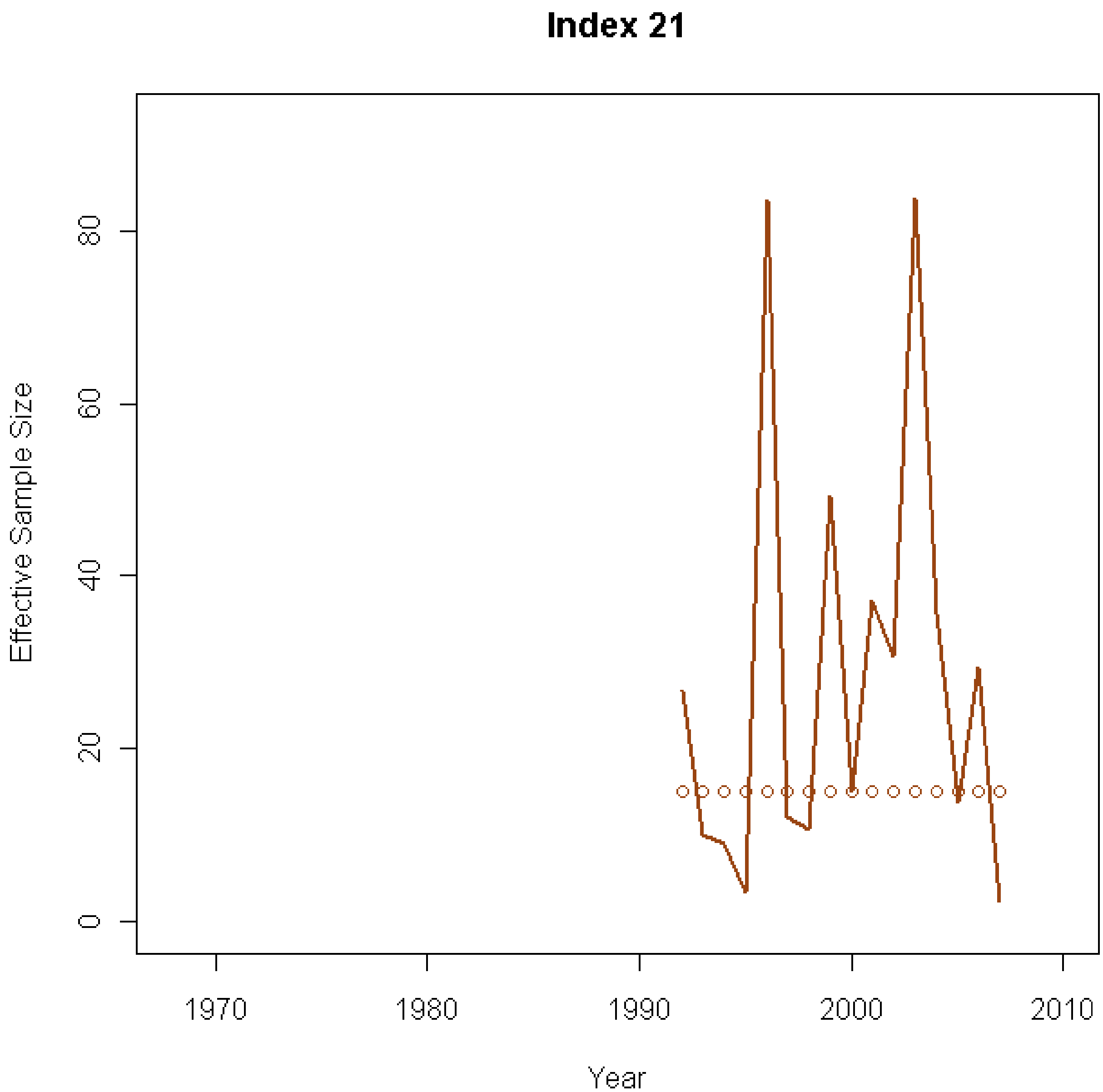


Figure B84. Observed and predicted effective sample size for NEFSC winter trawl survey index.

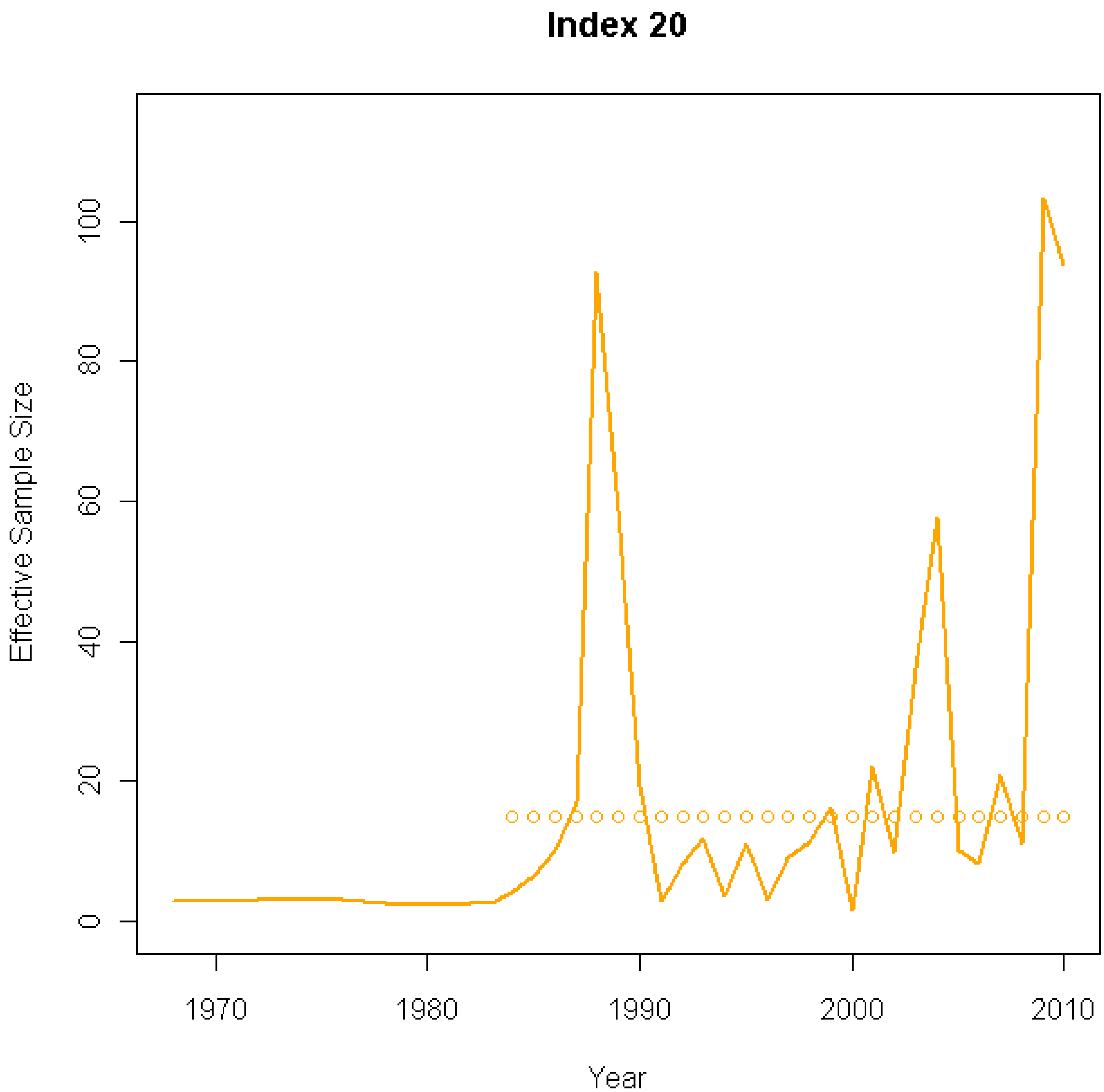


Figure B85. Observed and predicted effective sample size for NEFSC spring trawl survey index.

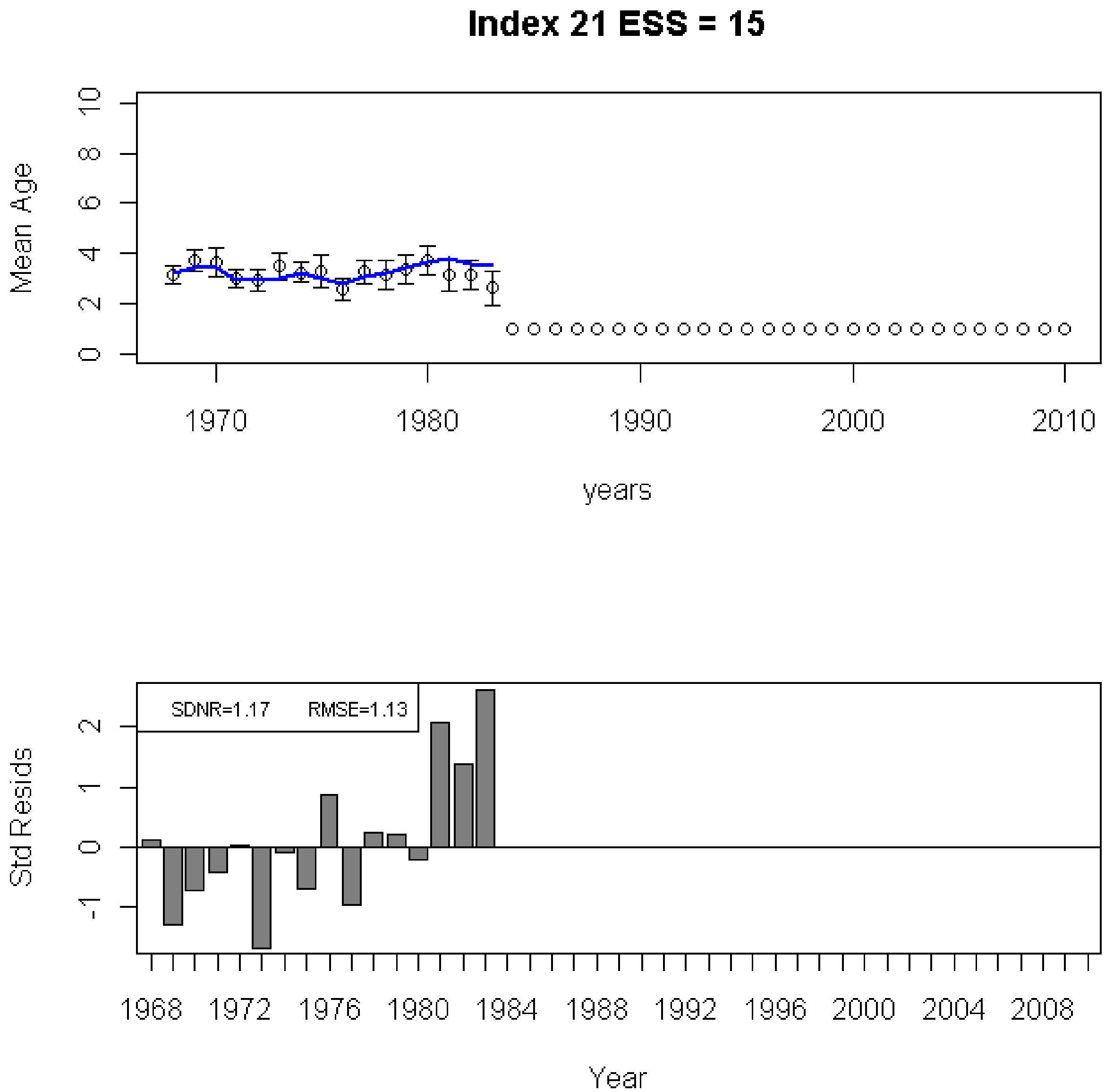
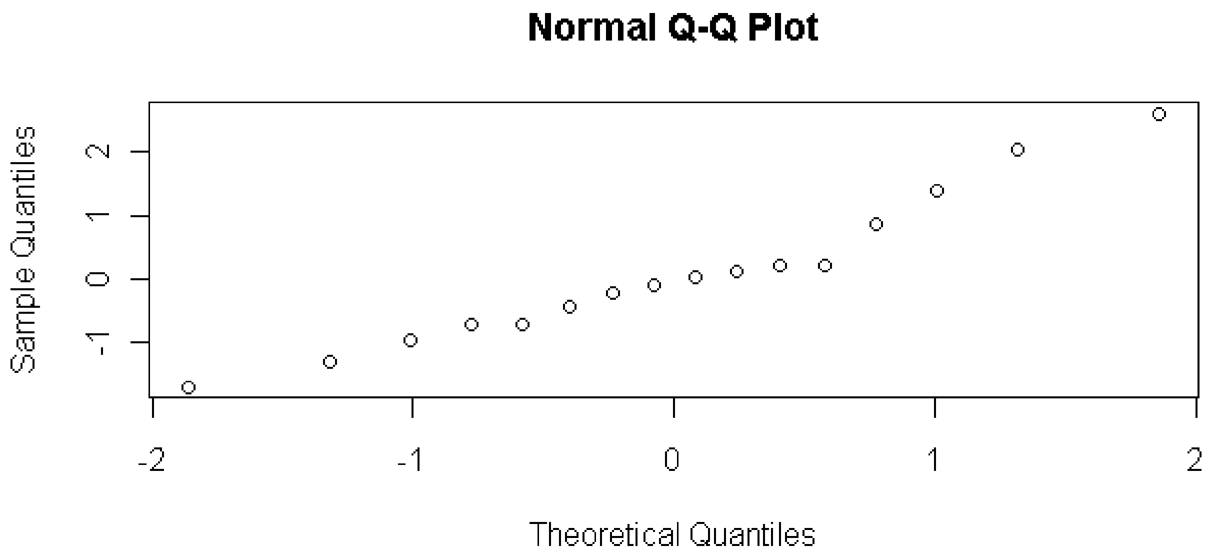


Figure B86. Mean age and effective sample size for NEFSC winter trawl survey in ASAP model.



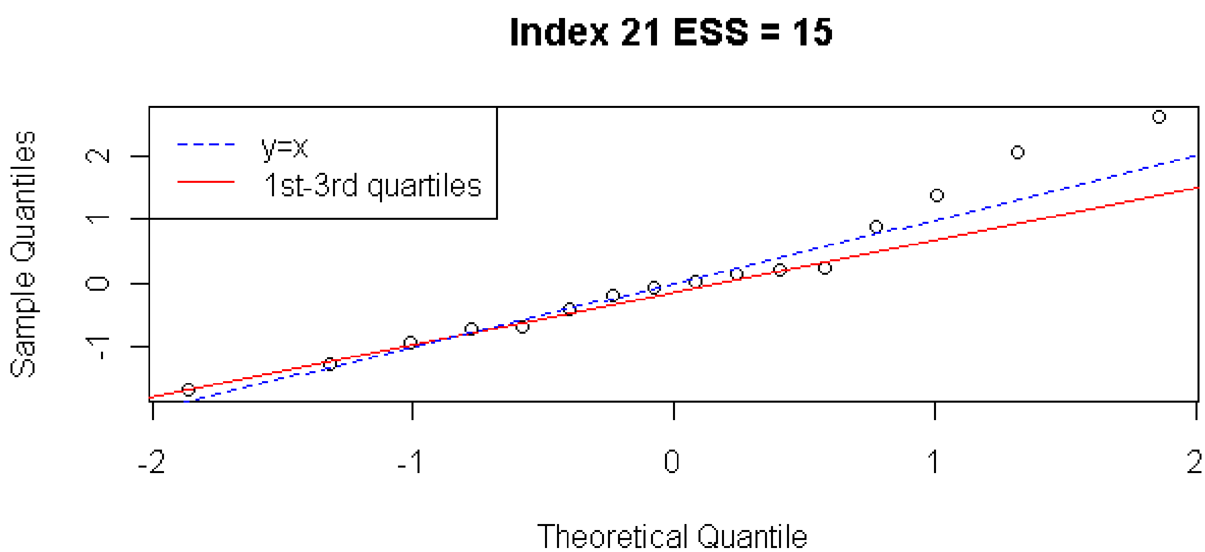


Figure B87. Quantiles from NEFSC winter trawl survey indices.

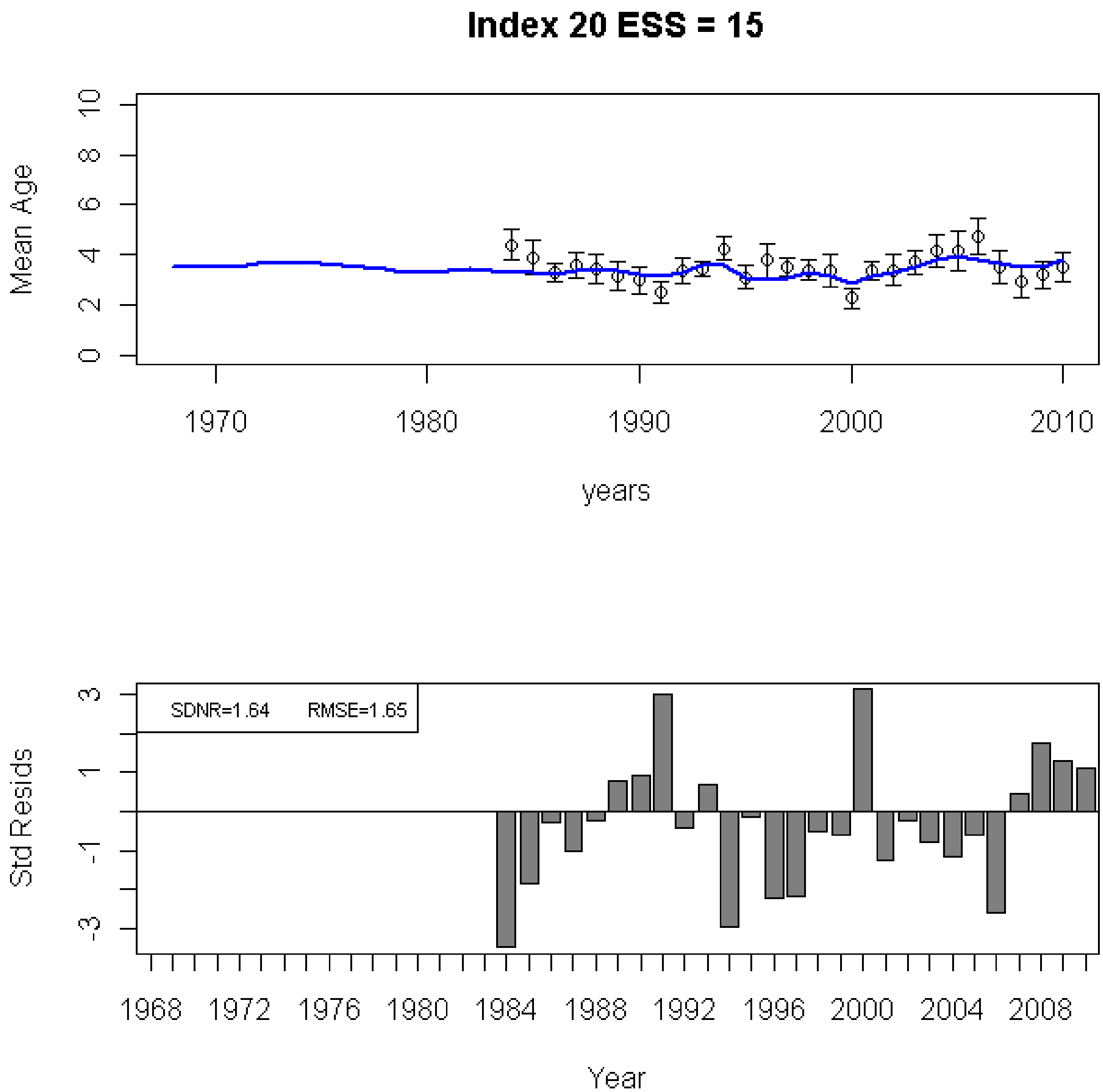


Figure B88. Mean age and effective sample size for NEFSC spring trawl survey in ASAP model.

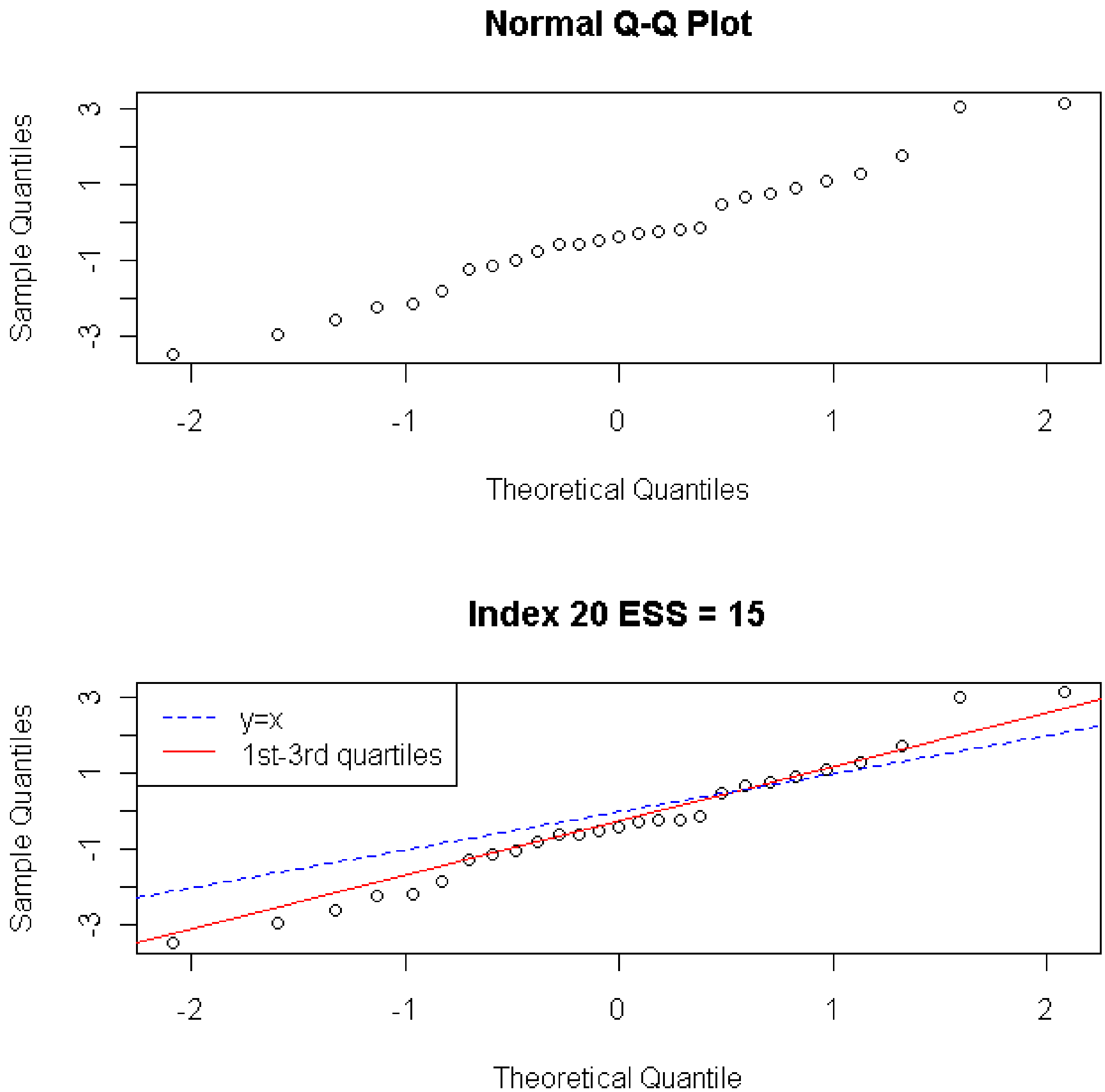


Figure B89. Quantiles from NEFSC spring trawl survey indices

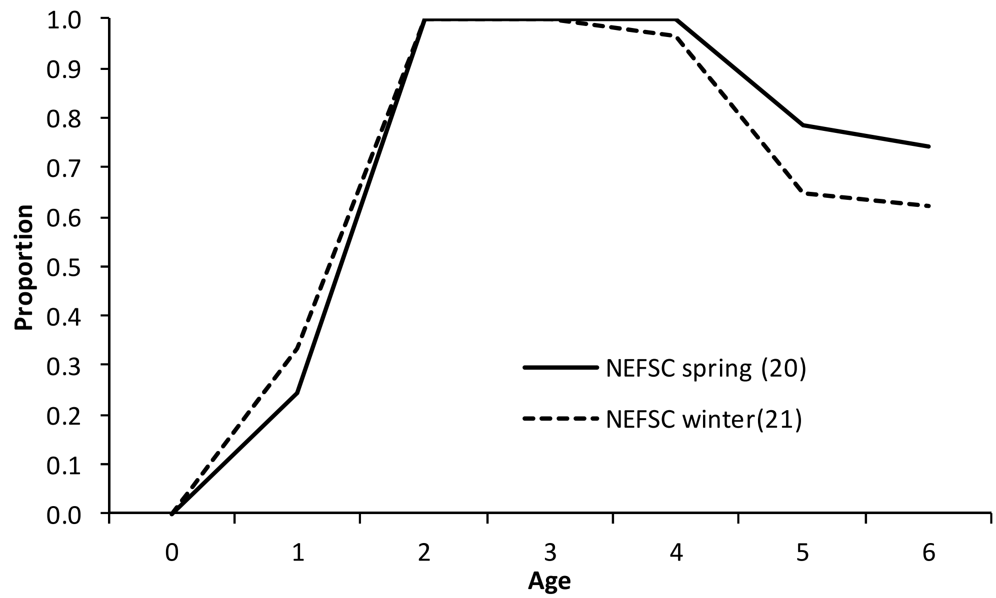


Figure B90. Selectivity at age from ASAP model for NEFSC winter and spring survey indices.

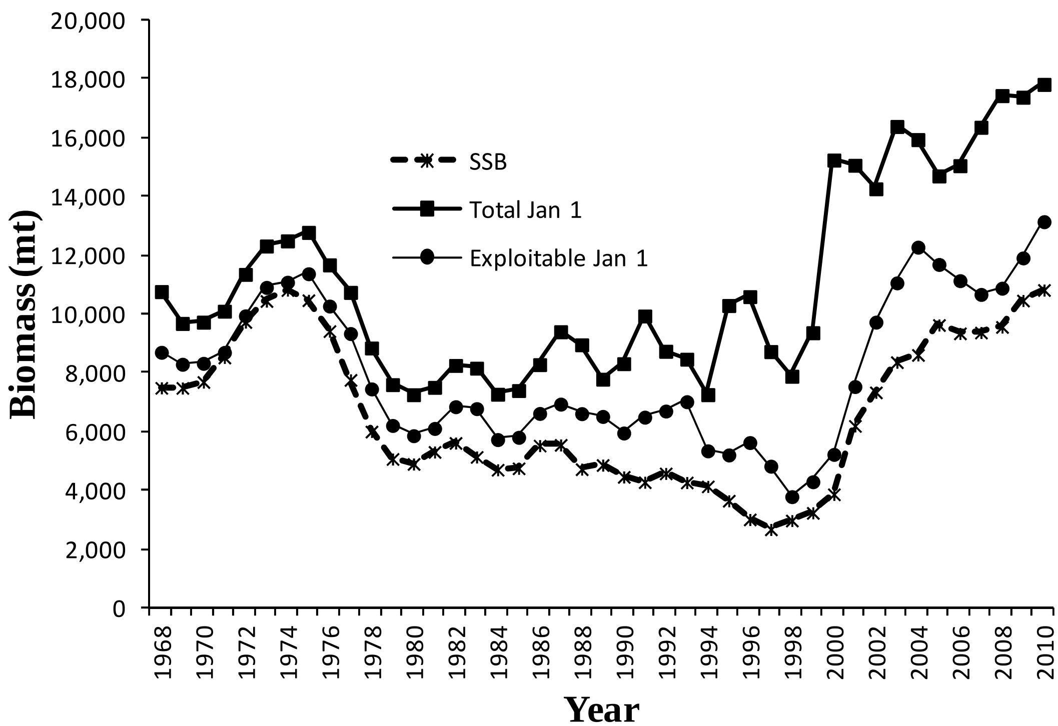


Figure B91. Predicted black sea bass spawning stock biomass, exploitable biomass and January 1 biomass from ASAP model results.

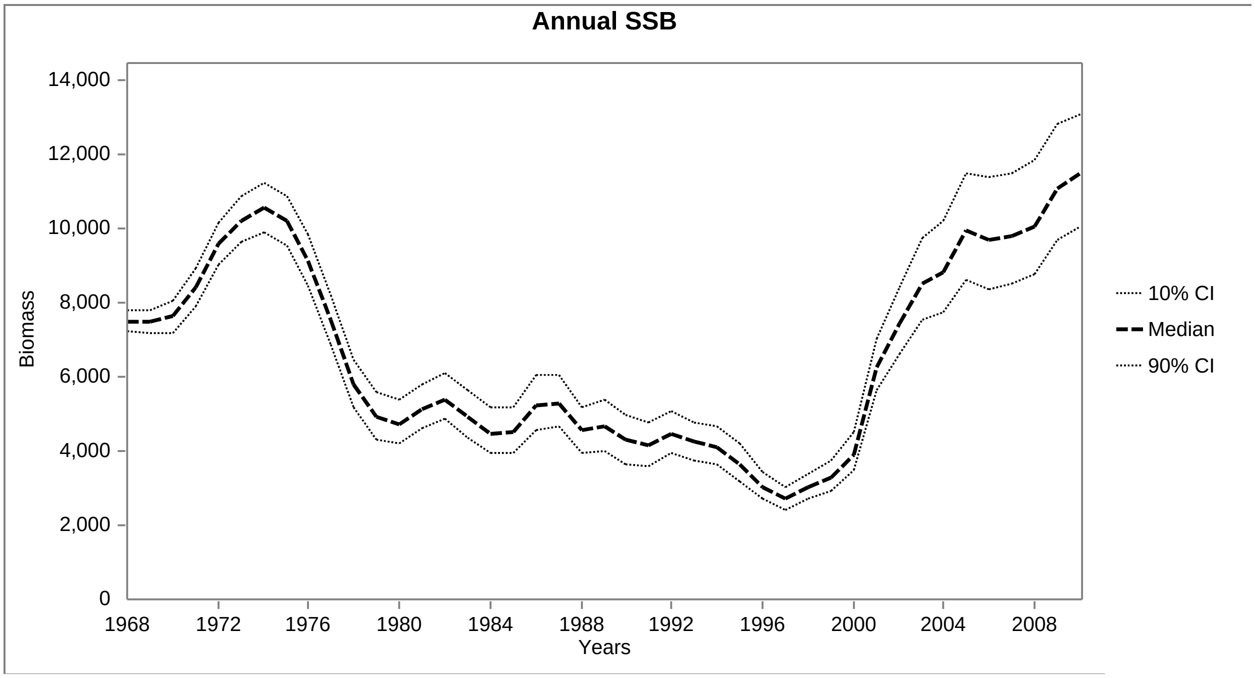


Figure B92. Results of MCMC run for black sea bass spawning stock biomass.

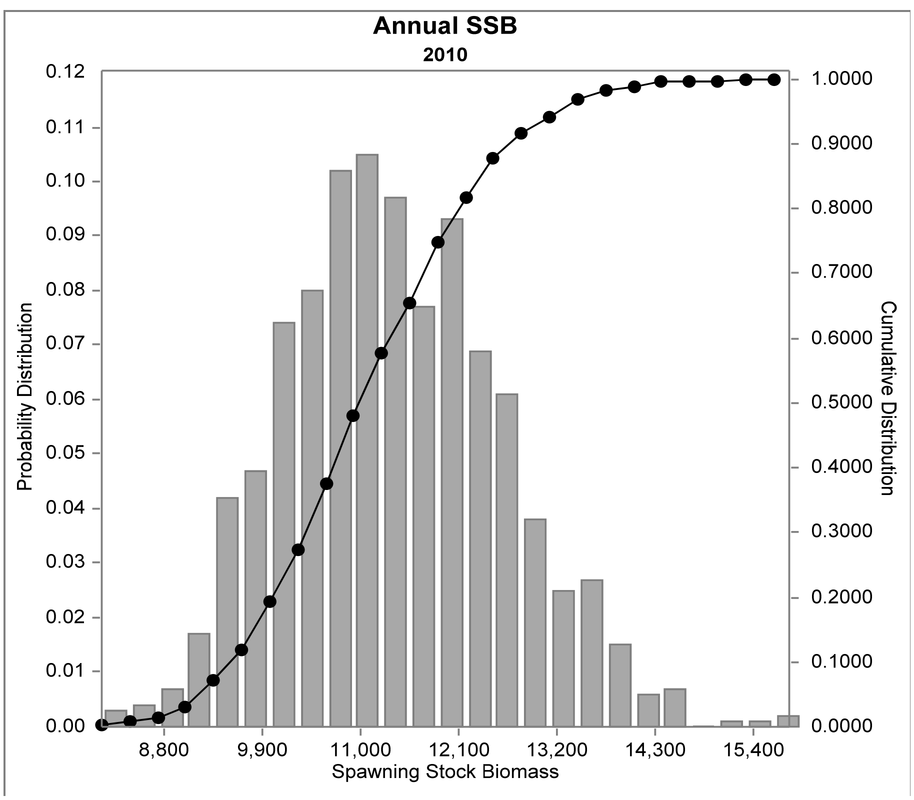


Figure B93. Distribution of 2010 black sea bass SSB from MCMC run.

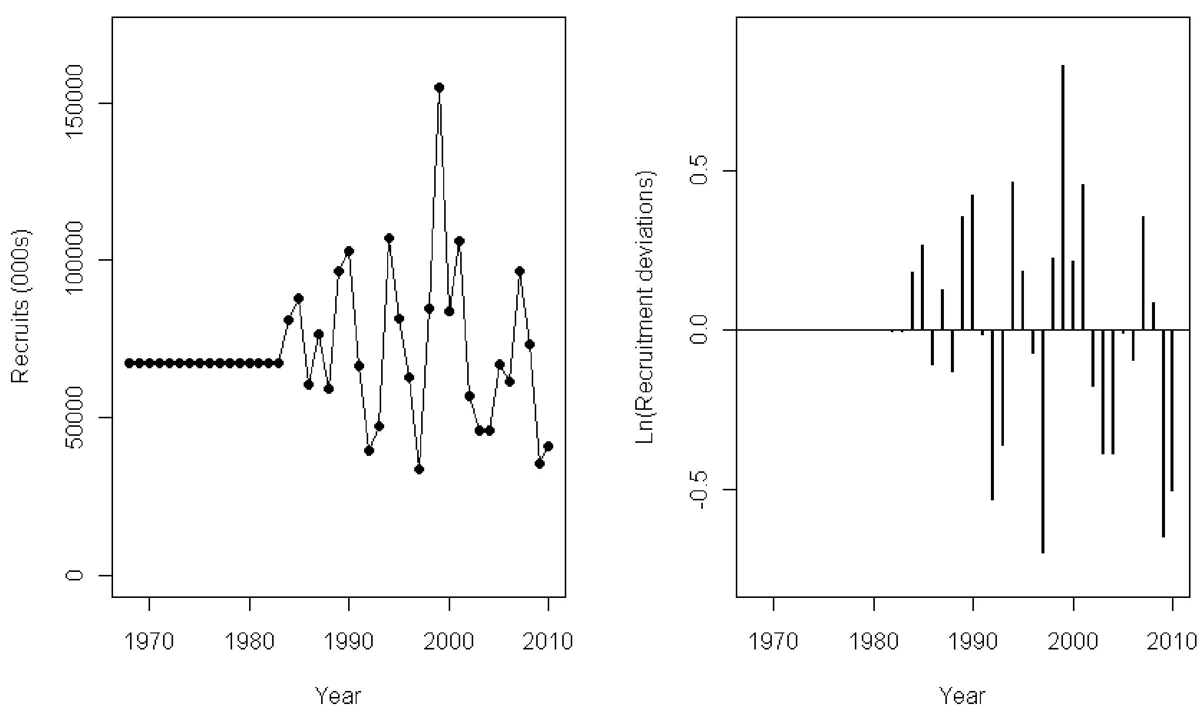


Figure B94. Predicted black sea bass age 0 recruits and associated residuals from ASAP model.

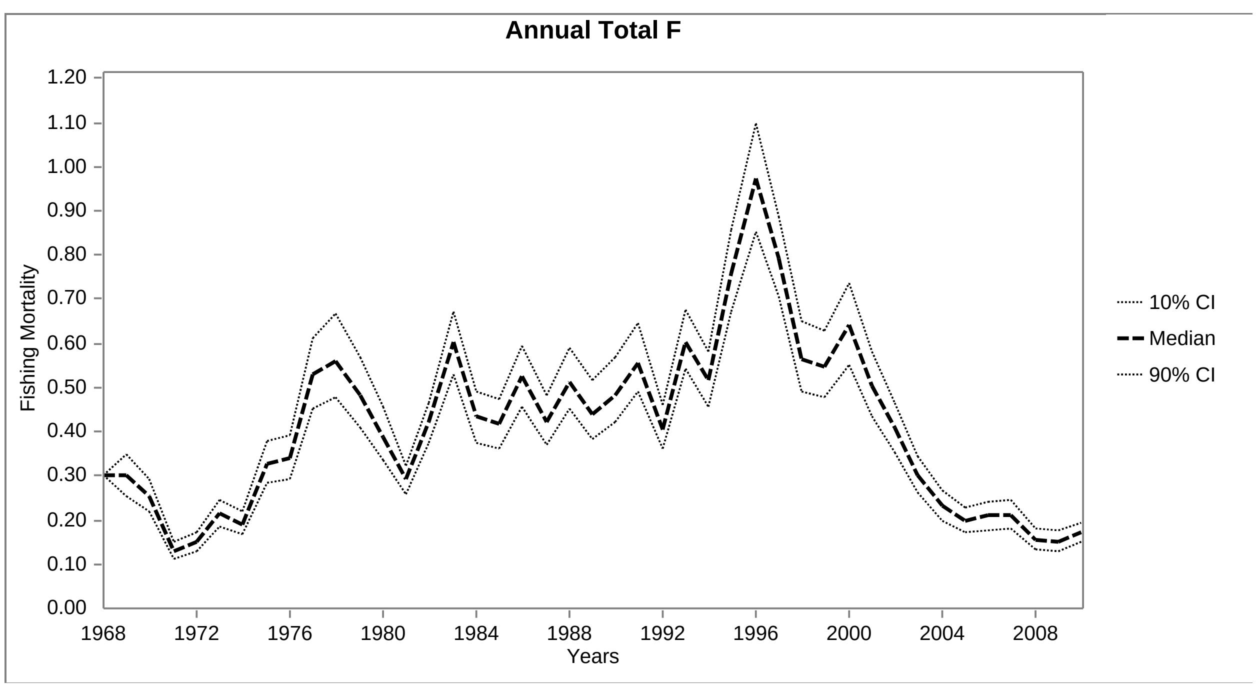


Figure B95. Results of MCMC run for black sea bass fishing mortality.

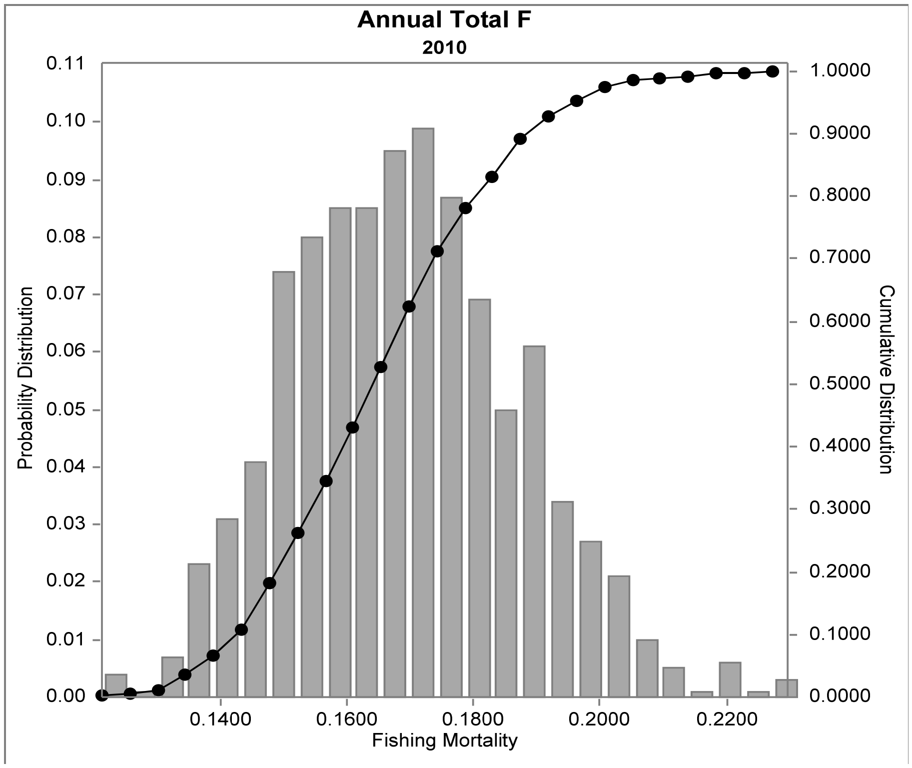


Figure B96. Distribution of 2010 black sea bass fishing mortality from MCMC run.

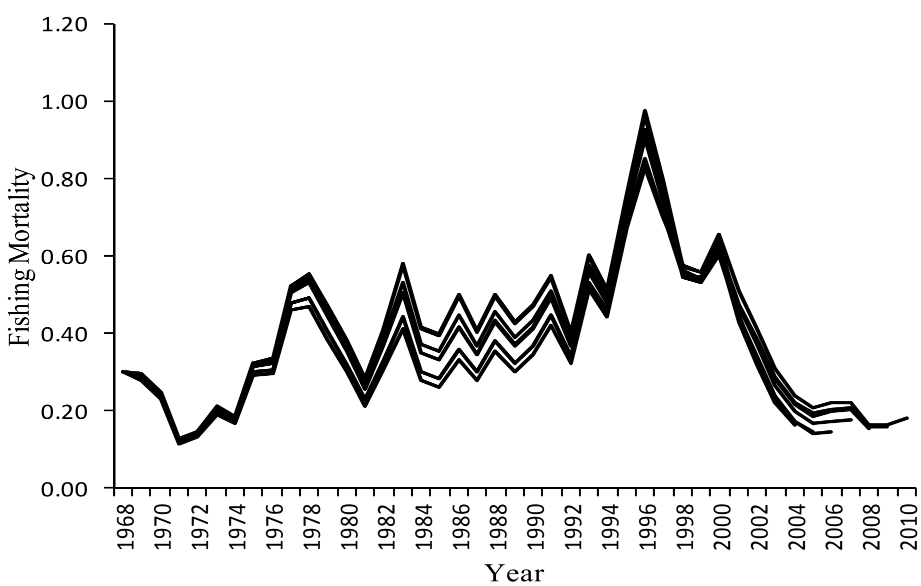


Figure B97. Retrospective pattern of fishing mortality, 2003-2010, from ASAP model results.

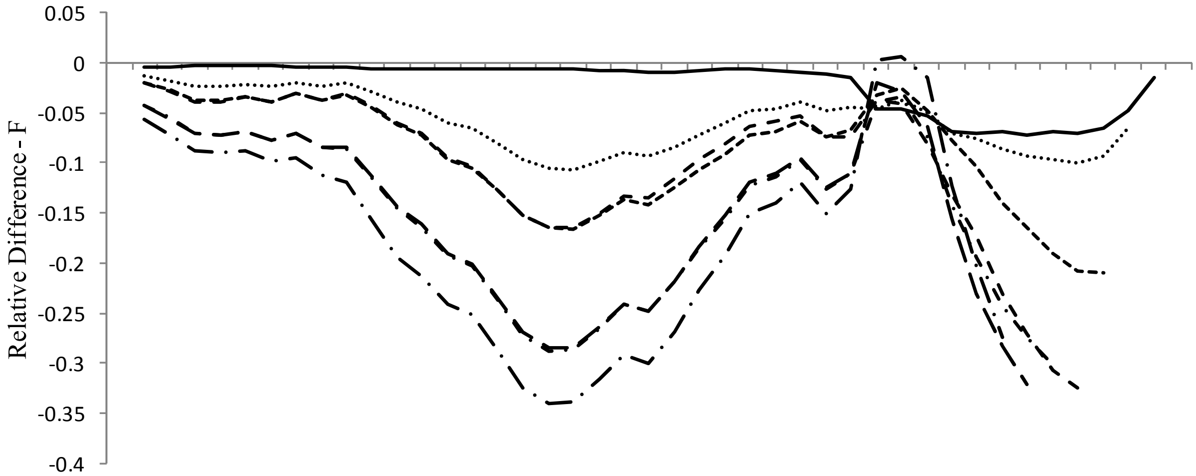


Figure B98 . Relative difference of fishing mortality, 2003-2010, from ASAP model results.

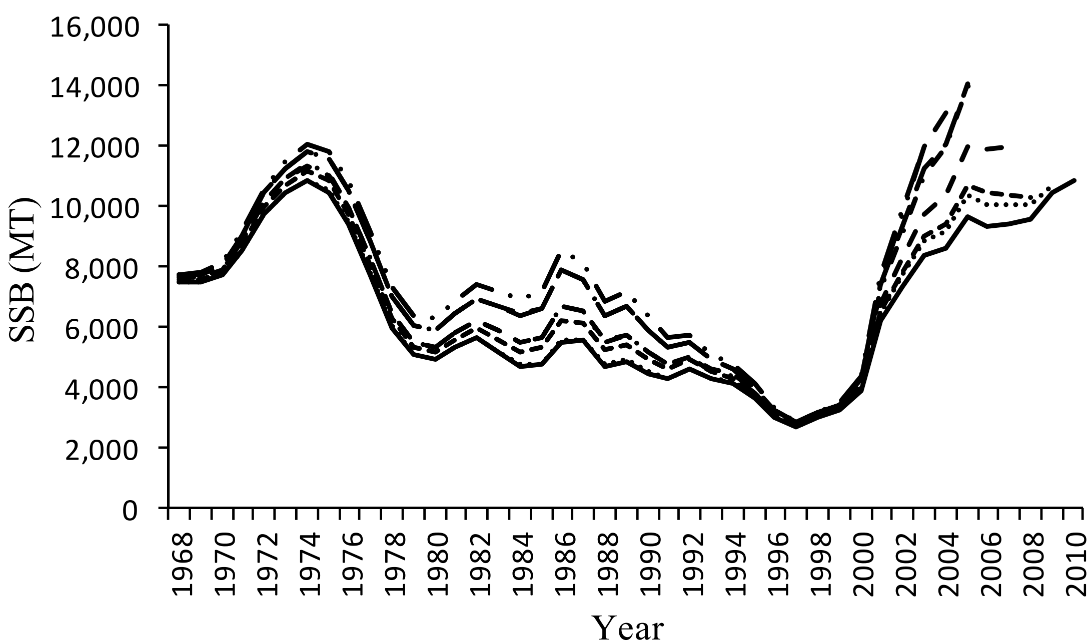


Figure B99. Retrospective pattern of spawning biomass, 2003-2010, from ASAP model results.

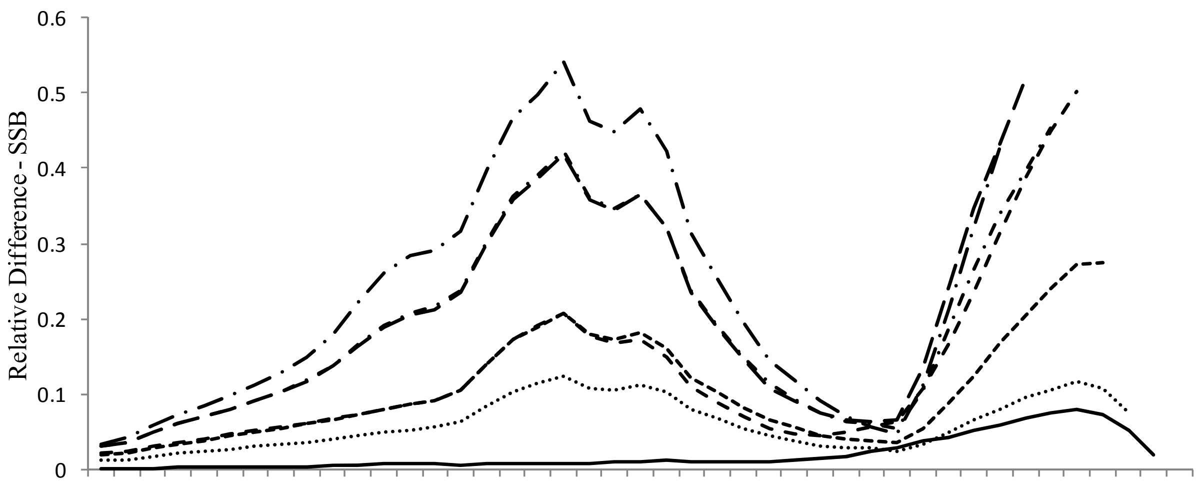


Figure B100. Relative difference of spawning biomass, 2003-2010, from ASAP model results.

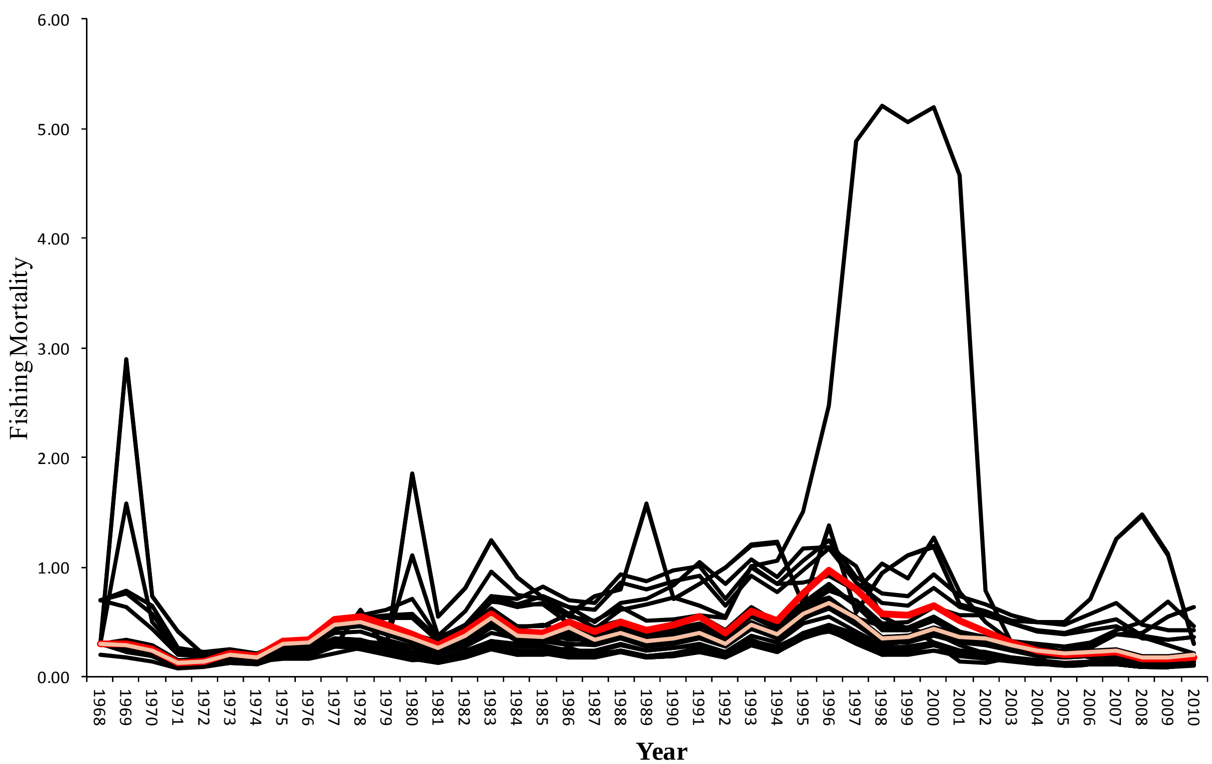


Figure B101. Fishing mortality estimates from the various ASAP and SCALE models considered by the WG. Red line represents final model.

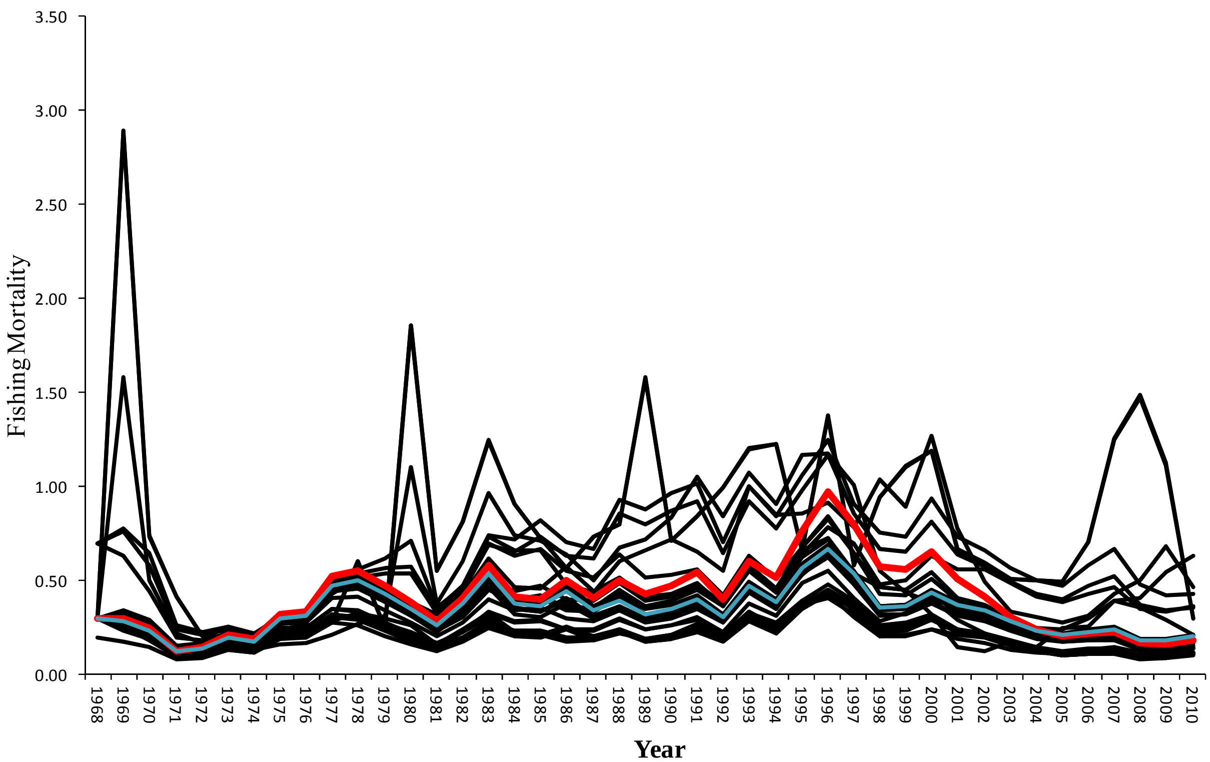


Figure B102. Fishing mortality estimates from the various ASAP and SCALE models considered by the WG, with the maximum value not included. Red line represents final model.

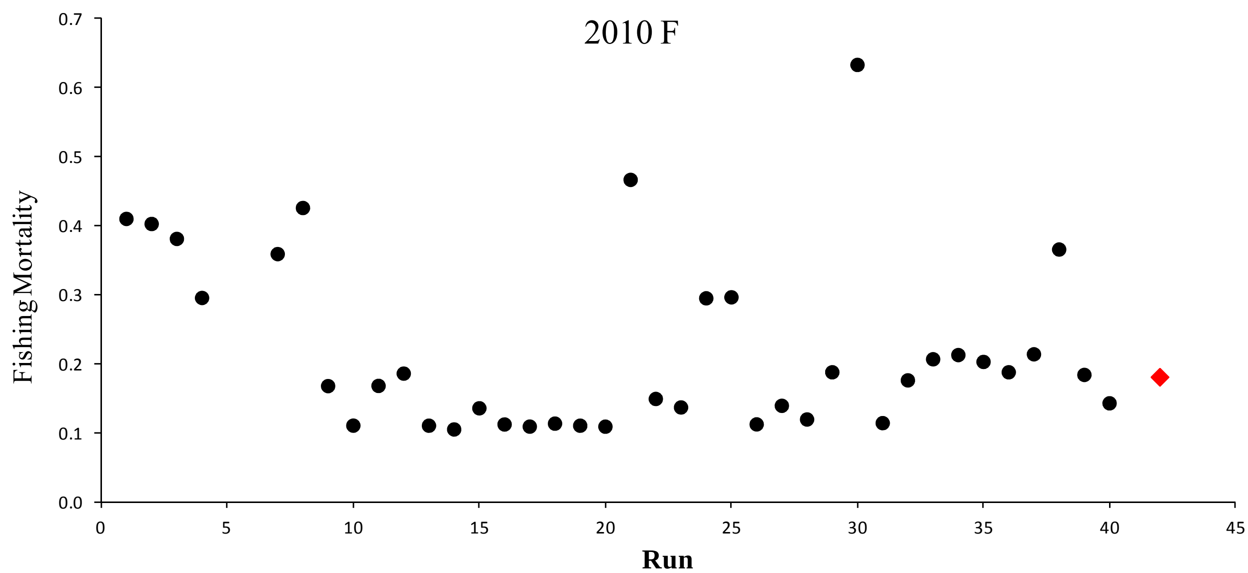


Figure B103. 2010 estimates of fishing mortality from among the models considered by the WG. Red diamond represents the final model results.

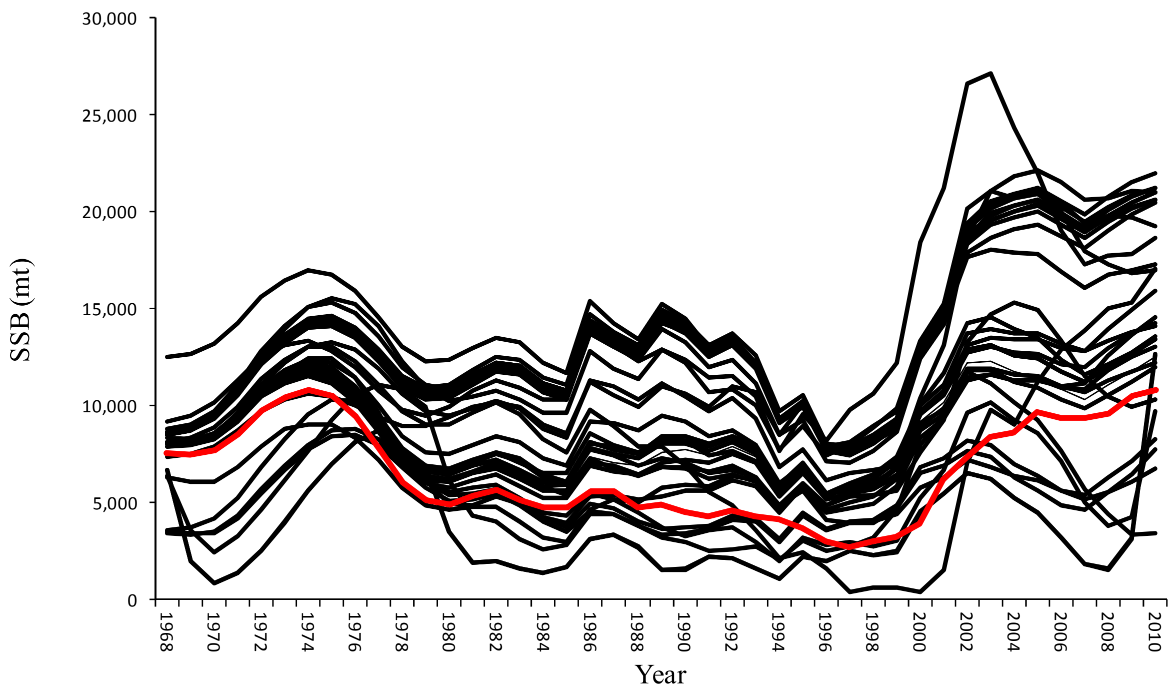


Figure B104. Spawning stock biomass estimates from the various ASAP and SCALE models considered by the WG. Red line represents final model.

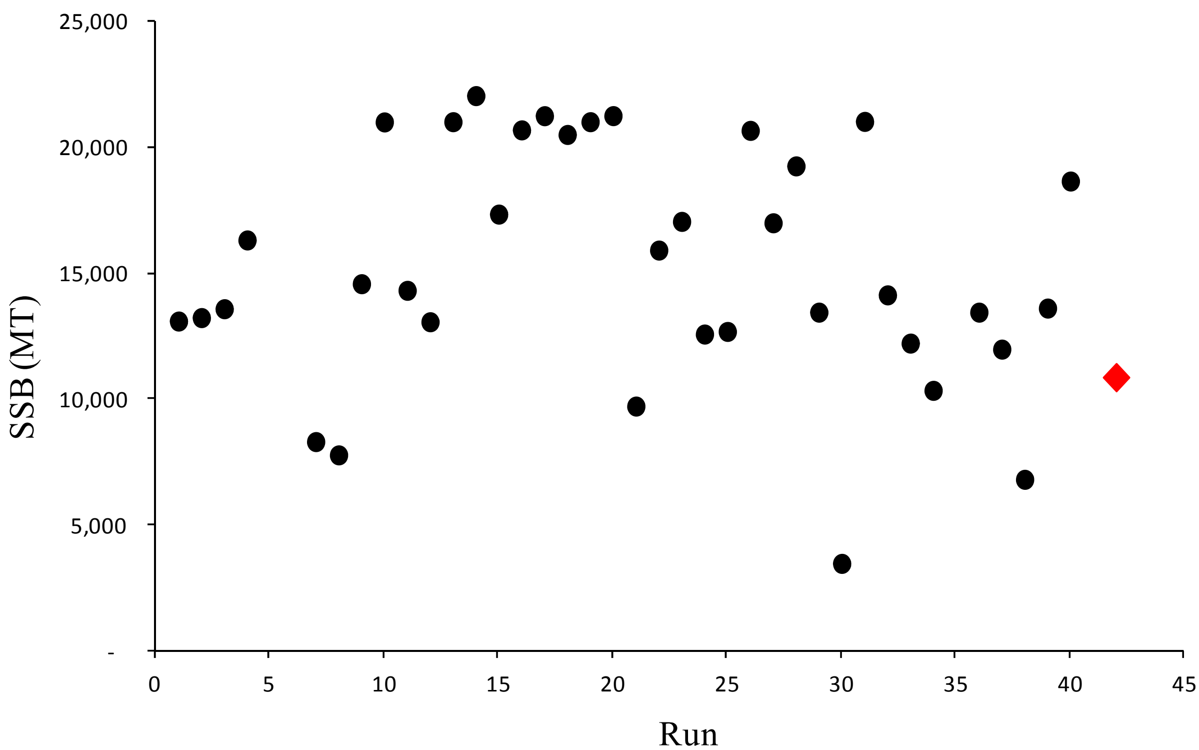
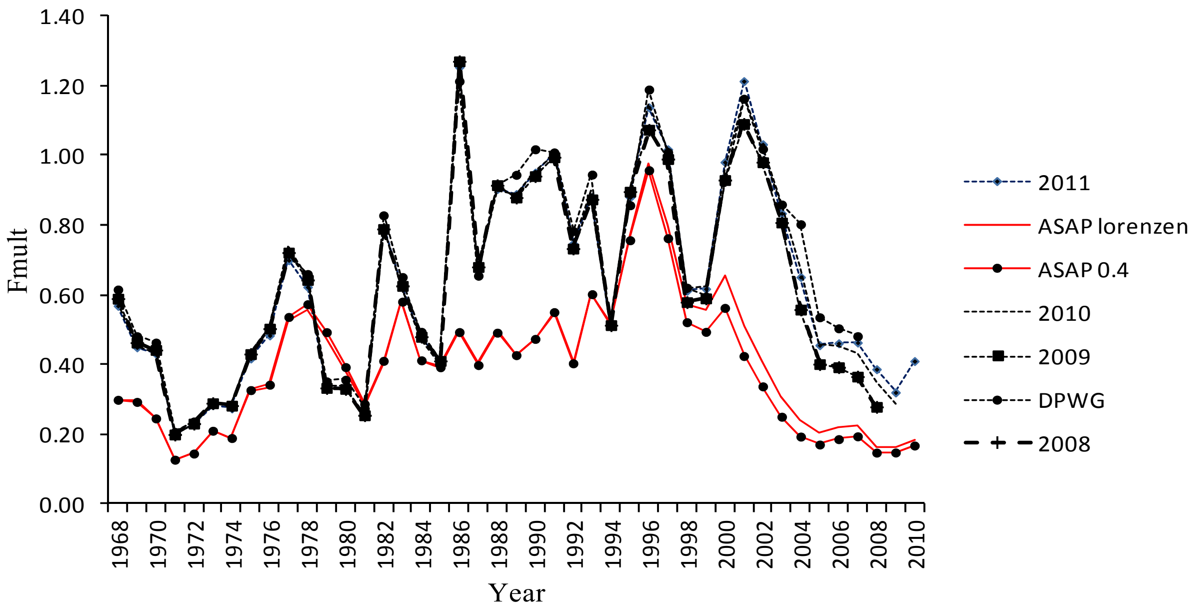


Figure B105. 2010 estimates of spawning stock biomass from among the models considered by the WG. Red diamond represents the final model results.



Fishing

Figure B106. Historical retrospective of black sea bass fishing mortality estimates. ASAP models are the recommendation of the WG.

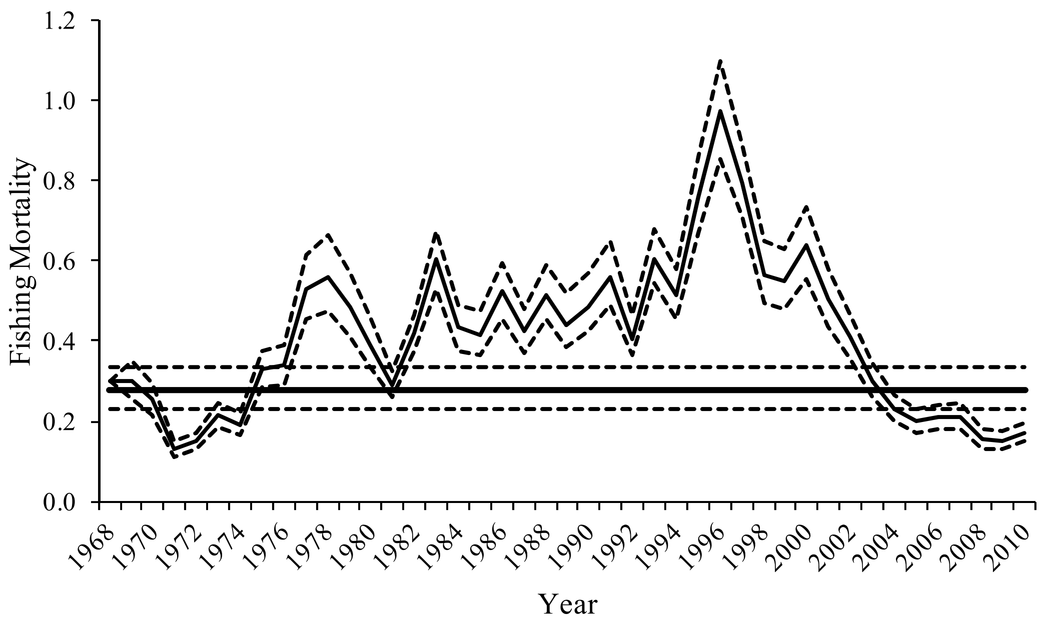


Figure B107. Fishing mortality time series and associated biological reference point (median from stochastic yield per recruit).

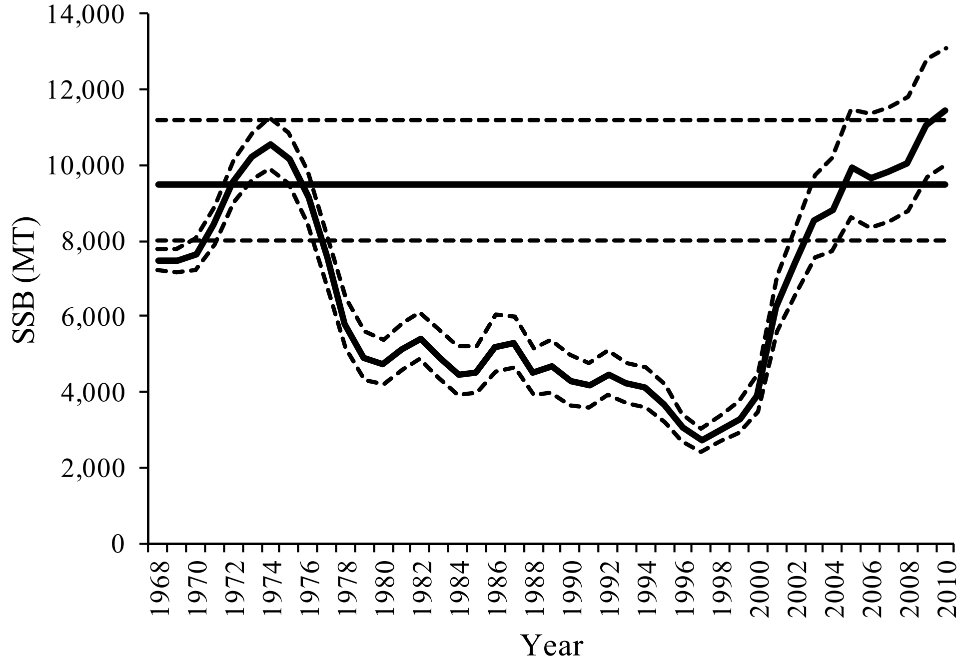


Figure B108. Spawning stock biomass time series and associated biological reference point (median from stochastic yield per recruit).

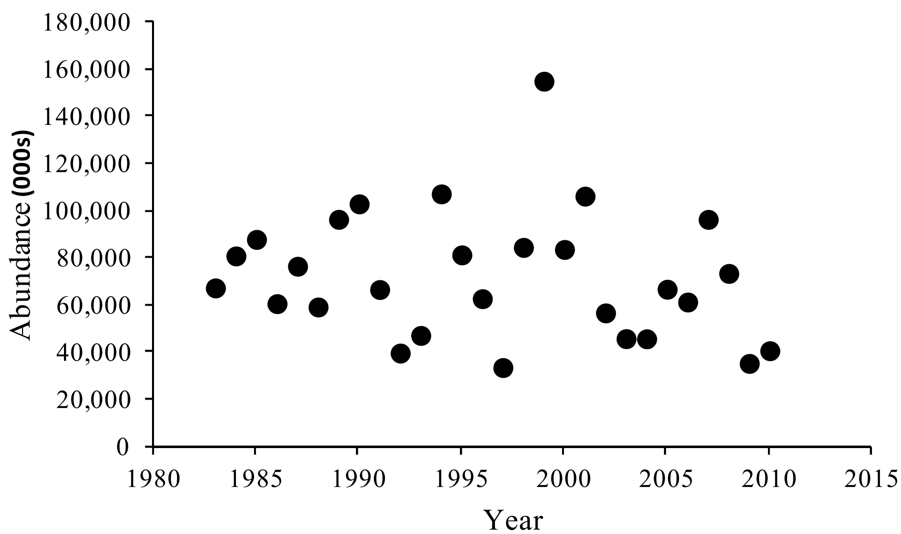


Figure B109. Estimated recruitment from final ASAP model used in projections.

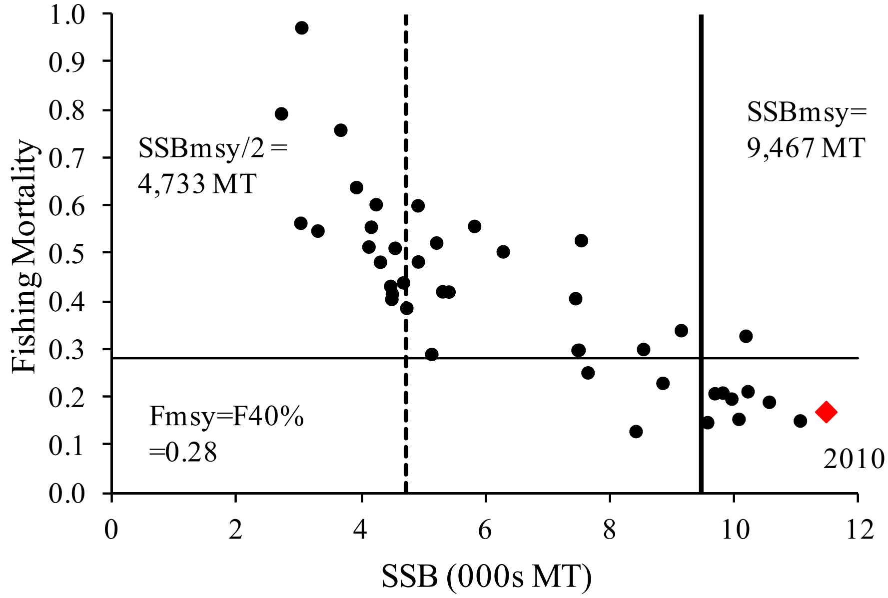


Figure B110. Relationship between time series spawning stock biomass and fishing mortality for black sea bass. Lines represent biological reference points and the red diamond is the 2010 value.

Sex and maturity of black sea bass collected in Massachusetts and Rhode Island waters; preliminary results based on macroscopic staging of gonads with a comparison to survey data

A working paper for SARC 53- Black Sea Bass Data Meeting

September 2011

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Introduction

Black sea bass (*Centropristis striata*) are protogynous hermaphrodites, with most individuals maturing first as a female before changing sex to male later in life (Wenner et al 1986). This life history characteristic poses unique challenges for management of the species (Shepherd and Nieland 2010), and requires accurate information/understanding of the sex ratios and the size at which sex changes. Several studies have described salient aspects of black sea bass life history, however these have largely been limited to populations in the South Atlantic Bight (SAB) and Gulf of Mexico (Mercer 1978, Wenner et al. 1986, Hood et al. 1994, McGovern et al 2002). Although black sea bass north of Cape Hatteras, NC are considered part of a single fishery management unit, focused life history studies on more northern portions of the population are lacking. Given greater migration distances and larger sizes attained by the northern stock component 'borrowing' of data from southern populations may be inappropriate. To reduce uncertainties in management of this population requires accurate estimate of sex ratios and size at sexual transition for this population. The need for more current and detailed (histology based) life history information for the northern component of the stock is currently being addressed in a cooperative research funded project ('A histology- and otolith-based study of black sea bass (Serranidae: *Centropristis striata*) life history in southern New England', Dr. K. Oliveira, R. Jorgensen UMASS Dartmouth). However, the scheduling of SARC53 necessitates reporting preliminary data to address questions about sex ratios of black sea bass in the northern management unit. Specifically, there is an apparent conflict of this species characterized as a protogynous hermaphrodite but that small and young males are evident in the NEFSC groundfish survey database. Namely, how likely are these small males misspecified by macroscopic methods used in routine survey operations? This working paper documents in detail the macroscopic method of identifying sex and maturity class of black sea bass, and although it does note that criteria for identifying active sex change needs further clarification, it also confirms that small males in survey data are real and should be accounted for in modeling of sex ratios.

Methods

Fish were obtained from two sources; the Massachusetts Division of Marine Fisheries (MA-DMF) inshore trawl survey (spring, May; and fall, September) and Research Set Aside (RSA) funded fishery independent scup survey of hard bottom areas in southern New England waters (MA and RI; June, August and October). Subsamples of fish from both sources were selected to cover the size range encountered, kept on ice, transported to the Woods Hole laboratory and processed the same or following day. A total of 217 black sea bass were processed from May to October, 2010 (Table 1). Fish were measured (total length in mm, total weight in grams, gonad and liver weight) photographed, and the gonads were dissected and photographed on a copy stand. A gonadosomatic index (GSI) was calculated as 100*(gonad weight/gonad free body weight). Gonadal tissue samples were preserved for histological analysis but these aspects of the research are ongoing and not presented here. Scales and otoliths were removed from fish for age determination following procedures outlined in Penttila and Dery (1988).

This working paper describes only the macroscopic maturity staging of these samples. Although the macroscopic staging may be less accurate and/or precise than histology-based determinations, individuals experienced in macroscopic assignment of fish maturity processed these samples in the laboratory. In addition, the authors convened to review the high-resolution photographs taken of each fish. Images were projected on a large screen, examined at higher magnification if necessary, discussed and consensus sex and maturity classifications were assigned. This approach may be considered intermediate to at-sea staging on resource surveys (that cannot be reviewed or revisited) and the more definitive gonad histology based approach currently underway. To accommodate sex change in this protogynous hermaphrodite, we included transitional and unknown classifications for individuals whose sex was ambiguous (Table 2). In the present analysis, transitional and unknown fish are combined into a single sex category, as there are no clear macroscopic criteria for the transitional stage yet. The histological analysis may help resolve the classification of transitional fish; however, this preliminary analysis of macroscopic criteria is applicable during and immediately following the late spring to summer spawning season when sex is more apparent and less likely to be in transition.

The sex ratio (percent male) was modeled as a function of length (or age) using a four parameter logistic regression model.

$$f(Length) = c + \frac{d - c}{\left(1 + \exp\left(b(Length - e)\right)\right)}$$

Where *Length* is fish total length (or age) and the parameter *e* is the length (or age) halfway between the upper (*d*) and lower (*c*) asymptotes, and *b* denotes the slope around *e*. In this model both the upper and lower asymptotes are fitted (not fixed) allowing for estimation of non zero lower asymptote as well as upper asymptote different than 100 percent. All models were fitted using the 'drm' function in the 'drc' add-on package for the language and environment R (R Development Core Team 2004). To evaluate the potential influence of data density and variability, models were fitted to sex ratios binned by 1, 2, 3, and 5 cm length categories. Age classes were not binned beyond annual age.

Sex at length data were summarized for the period 1984-2010 from NEFSC and MADMF trawl surveys. Results of the monthly sampling (below) indicated some uncertainty in determining sex in the fall, therefore we limited our analysis to spring surveys. This survey data was modeled using the same approach as above (four parameter logistic model). Macroscopic determination of sex in small fish is difficult, therefore we limited our analysis to fish > 15 cm. Two models were fit; with percent male binned by either 1 or 2 cm length categories.

Results

A wide range of fish sizes (19-59 cm total length) and maturity stages (developing, ripe, running ripe, spent and resting) were sampled over the six month period (Figs. 1-3). Four individuals analyzed were considered to be immature (19.4, 20.0, 20.6, 27.5 cm TL), and these were all classified as females. Mature male and female black sea bass were easily distinguished macroscopically during the spawning season, when ovaries and testes were developing or ripe and GSI was high (Figs. 1 and 4). Review of the high resolution photographs resulted in changing the sex classification for 10 of the 217 fish examined (4.6%), all associated with changing to or from the transitional class. Nine were initially classified as transitional/unknown but during the review and discussion process we were able to assign an agreed upon sex (4 female, 5 male). One individual was classified as a female during the initial workup, but upon review was changed to transitional/unknown. During the consensus review process, no fish sex classifications were changed from the May and June samples, three individuals collected in August were changed, two in September, and 5 were changed in October. Individuals classified as transitional/unknown had low GSI and occurred from August- October, well after the peak spawning season (Fig. 2).

Across all months, the size distribution of males was greater than that for females, with a large region of overlap (Fig. 3). Small males (<40cm) occurred in all months sampled. Fits of the four parameter logistic model indicated a significant non-zero (c = 19.7-22.9; Appendix 1) percentage male at smaller size classes. The different binning approaches resulted in similar fits, however only the 1 cm bin model had a significant slope parameter (b), possibly due to the abrupt change predicted in the other models. All models had similar estimates for the inflection point (e = 43.4-44.0) and upper limit (d = 100.1-101.2).

Female ages ranged from 1 to 7 years while male ages ranged from 2 to 12 years (Fig. 6). Thus, age classes 2 to 7 were comprised of both sexes, with an increasing percentage male after age 6 or 7. Fits of the four parameter logistic model indicated a significant non-zero (c = 19.9; Appendix 2) percentage male at younger age classes. This model indicated a significant inflection at about age 7 (e = 6.96) and an upper asymptote near 100 percent (d = 104.6).

The spring survey data (NEFSC and MADMF; 1984-2010) showed similar patterns in percentage male vs. length (Fig 7). Although sample size was large for this dataset (1061 males and 2386 females) sample sizes were generally small at for length bins greater than 50 cm. Two models were fit with length data binned at 1 and 2 cm intervals. Fits of the four parameter logistic models indicated a significant non-zero (c = 24.6, 22.8; Appendix 3) percentage male at smaller size classes. The different binning approaches resulted in similar fits, however only the 2 cm bin model had a significant slope parameter (b). Both models had similar estimates for the inflection point (e = 42.8, 45.6). The estimates for the upper limit were variable (d = 81.0, 95.1), influenced by the low data density at larger sizes.

Discussion

Despite being regarded as sequential hermaphrodites, in most cases the sex of black sea bass was readily identifiable macroscopically, and few individuals were reclassified (10 of 217) after reviewing images and consulting others experienced with this and other hermaphroditic species. Of these 'reclassified' fish, most (9 of 10) were initially identified as transitional/unknown, therefore they should not be considered misclassifications. Difficulty in determining sex increased after the spawning season (August – October), when fish had low GSI and sexual transition is thought to occur (Mercer 1978, Wenner 1986).

As in other studies on black sea bass elsewhere, we observed males across the full length range of mature fish analyzed. In the Gulf of Mexico, Hood et al. (1994) estimated close to 20% percent males at smallest mature sizes. Similarly, Wenner et al. (1986) reported the presence of ~3% mature males at small sizes. Both of these populations (GOMEX and SAB) mature at smaller sizes than the northern population studied here that attains greater sizes (Gulf of Mexico, Hood et al. 1994; South Atlantic Bight, Wenner et al. 1986, McGovern et al. 2002). Only four individuals analyzed were considered to be immature (19.4, 20.0, 20.6, 27.5 cm TL), and these were among the smallest individuals analyzed in the present study. The low number of small and immature fish precluded more detailed analysis of size at maturity.

The approach we used to confirm macroscopic classification of sex, reviewing high resolution images, is intermediate to the more definitive classification possible via gonad histology and the macroscopic classifications made at sea by scientists of varying experience levels whose classifications cannot be reviewed (the fish go overboard and no images are taken). While pictures are less ideal than evaluating the fresh specimen, they provide the opportunity to consult others who may not have been present during the initial processing of samples. Thus, data resulting from a consensus review may be considered to be more precise and accurate than routine macroscopic classifications. The images were of high enough quality to allow us to zoom in on specific regions of the gonad and when reviewed by the entire group we agreed with nearly all of the initial classifications. In addition, we were able to classify difficult samples that were initially classified as unknown. The images also provide a permanent record that can be revisited in the future as needed (if new macroscopic classification schemes are developed). More detailed histological analyses of gonad samples from these and other collections is needed to verify the preliminary conclusions presented here.

Analysis of spring survey data from both NEFSC and MADMF surveys for the period 1984-2010, collected over a broad geographical region showed similar patterns of percentage males at length we estimated from a more localized region in 2010. Models fit to these datasets both indicated about 20 percent male at smaller sizes, and an inflection near 42-45 cm. The slope of the survey time series is more gradual, possibly influenced by differences in size at transition occurring over time. Additionally, this more gradual pattern may be the result of averaging of data over a large region, where transition points differ regionally. Similarly, the estimate of the upper asymptote is likely influenced by averaging across broad geographic scales, since the presence of larger sized females in some portion of the range will pull down the percentage male at large sizes across the entire range.

The results from these datasets of macroscopic sex classifications, one determined by a ‘panel’ of experienced biologists and the other larger dataset determined by many individuals with varying experience levels (novice-expert) both indicate approximately 20 percent males throughout most of the mature size and age distribution. Similar estimates have been determined from the NEFSC and MADMF spring surveys (Shepherd and Nieland 2010) however, the accuracy of the sex classifications on the surveys was not evaluated. We did not observe any indication of sexual transition in individuals collected during the spawning season. Several caveats should be considered with respect to the estimates of the size at transition (and the estimated inflection point *e*). First, samples were pooled over a six month period, during which time significant growth occurs. Secondly, the parameter *e*, represents the halfway point between the two modeled asymptotes and not 50% (i.e. for the 1 cm bin model, the length 43.8 has a percent male halfway between 22.9 and 101.2). The present study provides supporting evidence for the presence of significant numbers of males at small sizes, and demonstrates that sex determination of mature black sea bass by macroscopic examination during the spring is reliable.

Research recommendations

1. Very few immature and age 1 fish were collected in the sampling done in 2010, precluding detailed evaluation of first maturity. A detailed characterization of these sizes and ages, both macroscopically and microscopically (histological) is needed to determine developmental pathways and functionality (or viability) of small males.

2. Although the percentage male appears relatively constant at small sizes and young ages, it is not known whether the rates of transitioning fish and sex-specific mortality rates are constant. A better understanding of the criteria to identify transitioning fish, and an evaluation of when and which individuals change sex is needed to evaluate the proportions transitioning at length and age.

3. Given the latitudinal differences in maximum size attained by black sea bass, the size and age at transition is likely to also differ with latitude. More regional evaluation of sex ratios and the inflection in percent male is warranted.

4. Similarly, given the potential effect of selective fishing on size and age structure, the percentage of small males and the size at transition should be evaluated through time in conjunction with fishing mortality and size regulations.

Acknowledgements

We are grateful for the cooperation by MADMF (especially Jeremy King), and the fishery independent scup survey (especially Dave Borden) who both provided fresh samples in 2010 for this analysis. We thank the many individuals who participated in NEFSC and MADMF surveys over the years and collected some of the data analyzed here. We also thank the Northeast Cooperative Research Program for funding continuing work on life history of black sea bass (Grant # NFFM7230-11-06444).

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Table 1. Summary of black sea bass biological samples collected processed from various sources May-Oct 2010. Sources are; Massachusetts Division of Marine Fisheries (MA-DMF) inshore trawl surveys, Research Set Aside funded fishery independent scup survey (RSA-scup survey).

Date	**Source**	***n***	**Length range (cm)**
5/16/2010	MA-DMF	55	20-42
6/29/2010	RSA-Scup survey	65	30-56
8/2/2010	RSA-Scup survey	50	22-51
9/19/2010	MA-DMF	16	27-38
10/15/2010	RSA-Scup survey	31	19-59

Table 2. Macroscopic maturity staging criteria applied to images of black sea bass gonads; modified from Burnett et al. (1989), and Lyon et al. (2008). TR* not previously used on NEFSC bottom trawl surveys.

Sex/Class	Code	Description
Female		
Immature	I	Ovary paired, tube-like organ, small relative to body cavity; thin, transparent outer membrane; contains colorless to pink jell-like tissue with no visible eggs
Developing	D	Ovaries enlarge; if blood vessels present, they become prominent; ovary has granular appearance as yellow to orange yolked eggs develop
Ripe	R	Enlarged ovary; mixture of yellow to orange yolked eggs and hydrated or "clear" eggs present
Ripe & Running	U	Ripe female with eggs flowing from vent with little or no pressure to abdomen
Spent	S	Ovaries flaccid, sac-like, similar in size to ripe ovary; color red to purple; ovary wall thickening, becoming cloudy and translucent vs. transparent as in ripe ovary; some eggs, either clear or yolked, may still be present, however most adhere to ovary wall; therefore, CUT OPEN OVARY to make sure there is no mass of eggs in center of ovary (as in stages D and R)
Resting	T	Gonad reduced in size relative to ripe ovary, but larger than an immature; interior jell-like with no visible eggs
Transitional	TR*	Gonad contains both female and male tissue; inactive or regressing ovarian tissue with concurrent testicular proliferation
Unknown	UNK	Sex is uncertain
Male		
Immature	I	Testes paired, tube-like organ, small relative to body cavity; thin, translucent, colorless to gray or pinkish
Developing	D	Testes enlarge; color is gray to off-white, outer texture appears smooth; firm with little or no milt
Ripe	R	Enlarged testes; color chalk white, milt (spermatozoa) flows easily when testes is cut
Ripe & Running	U	Before cutting open fish, milt flows easily from vent with little or no pressure on abdomen; once cut open milt flows easily and color is chalk white
Spent	S	Testes flaccid, not as full of milt and robust as in Ripe stage; may contain residual milt; edges or parts of testes starting to turn gray and milt recedes
Resting	T	Testes shrunken in size relative to Ripe stage; color off-white-gray with little or no milt

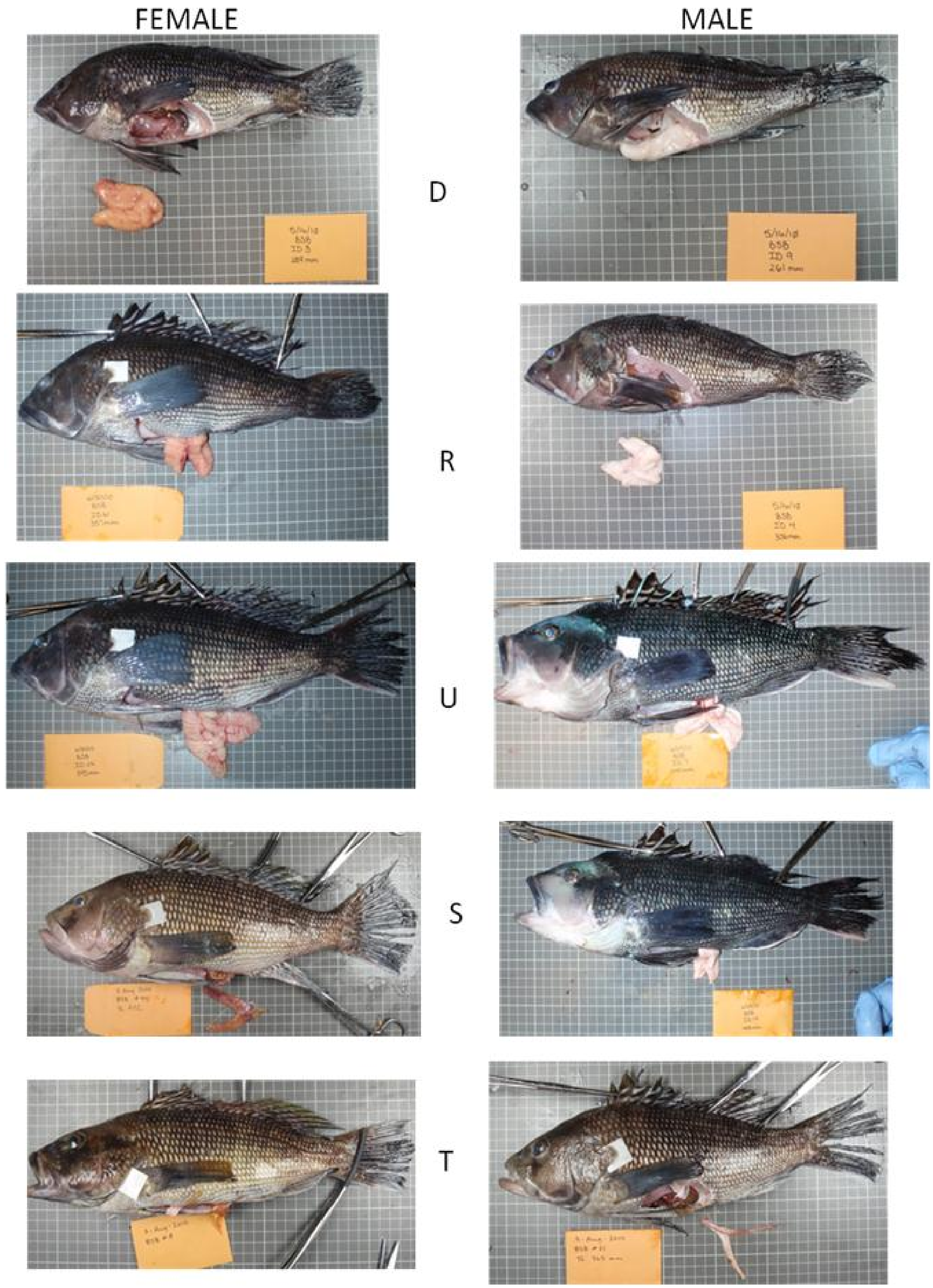

Figure 1. Representative images of black sea bass maturity stages observed in collections over the six month study. D-Developing, R-Ripe, U-Running ripe, S-Spent, T-Resting.

TRANS/UNK – Aug

TRANS/UNK – Aug

TRANS/UNK – Sept

Figure 2. Three individual black sea bass collected in August and September that were classified as transitional/unknown.

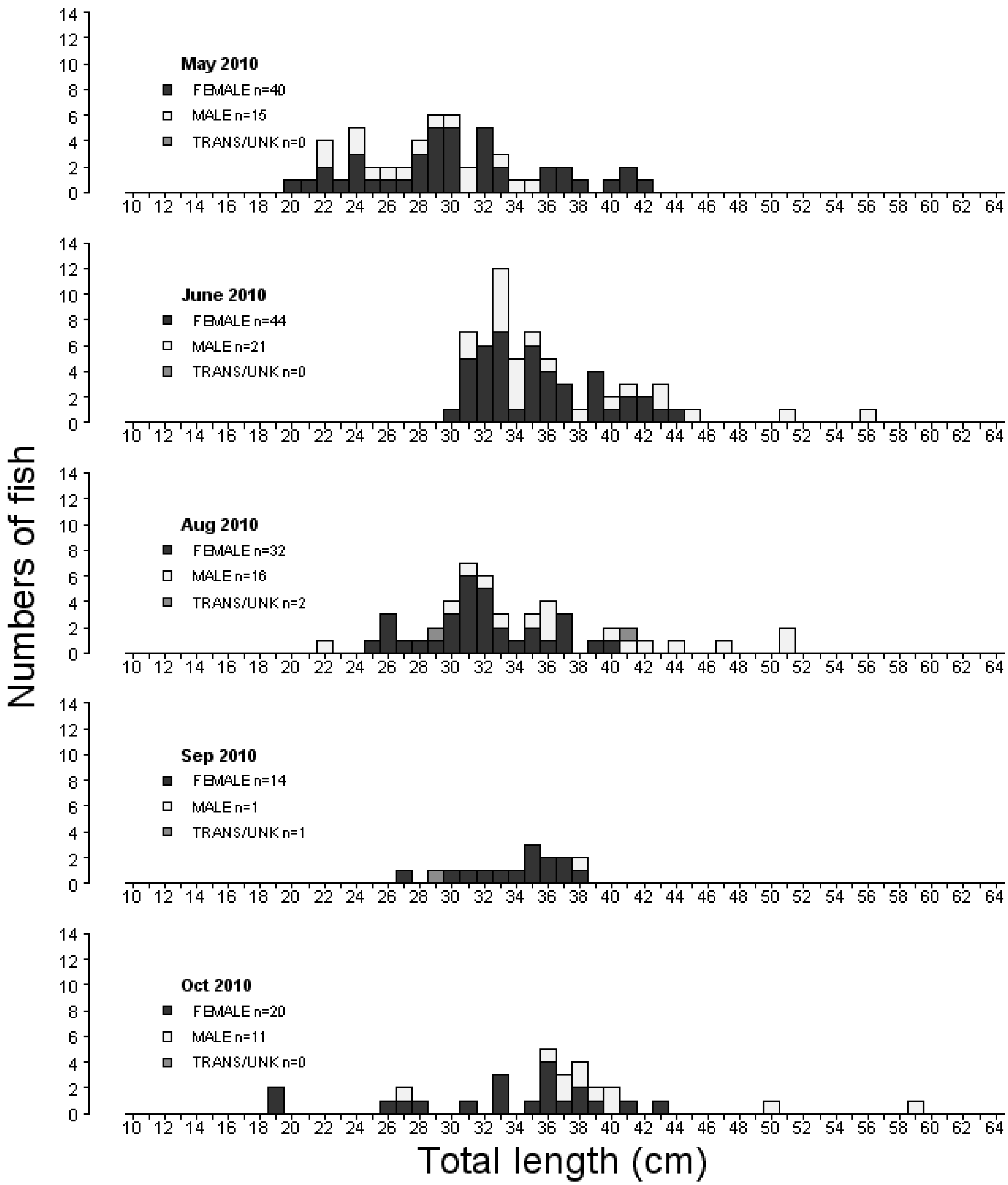

Fig. 3. Size distribution (length frequency) of male, female and transitional black sea bass collected in each month sampled in 2010.

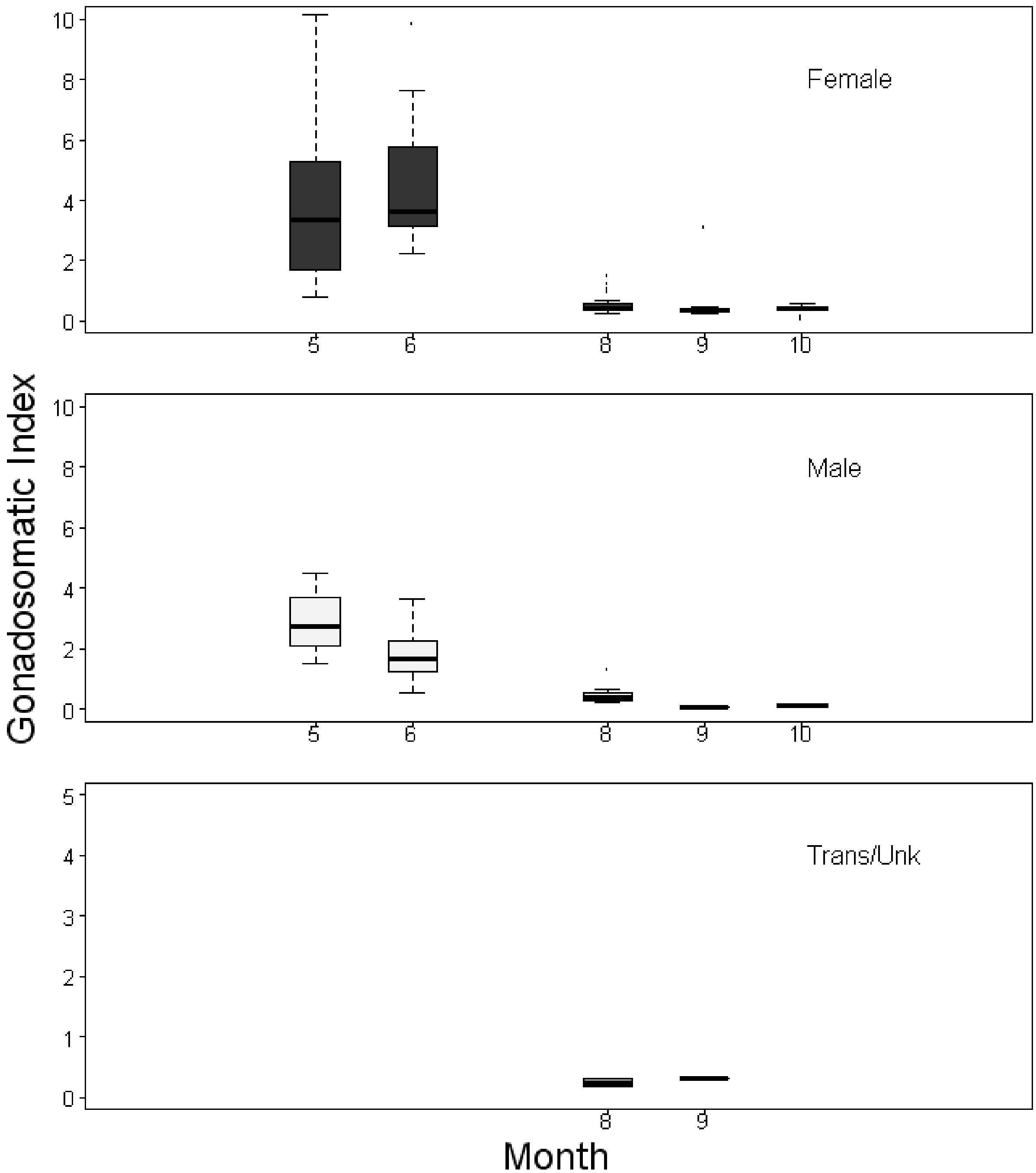

Fig. 4. Gonadosomatic index by month to indicate spawning seasonality. Note different y-axis scales.

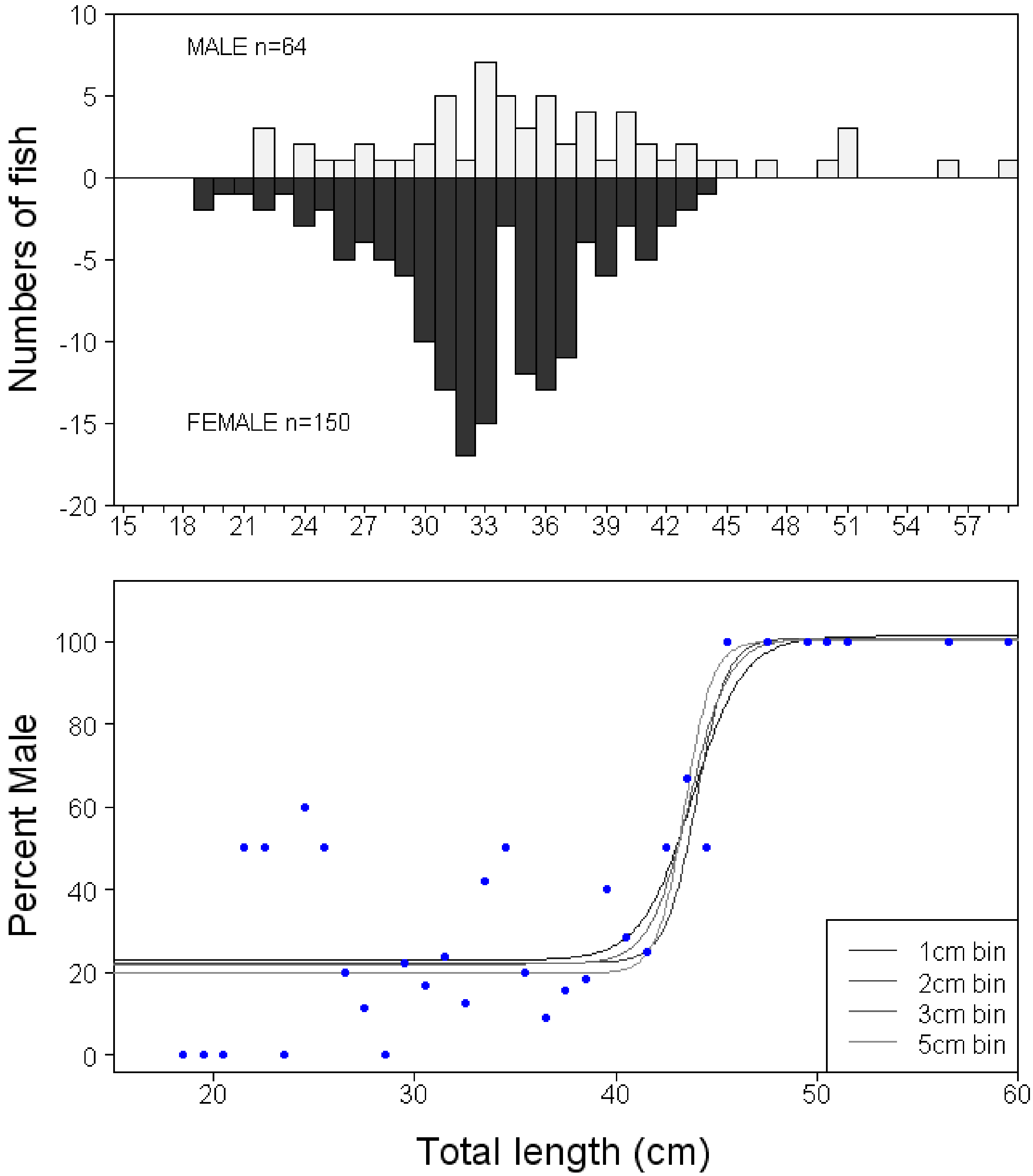

Figure 5. Percent male for black sea bass sampled in 2010 as a function of length. Points represent percentages in each 1 cm length bin. Lines represent the fits of the four parameter logistic model with data binned by 1, 2, 3, and 5cm.

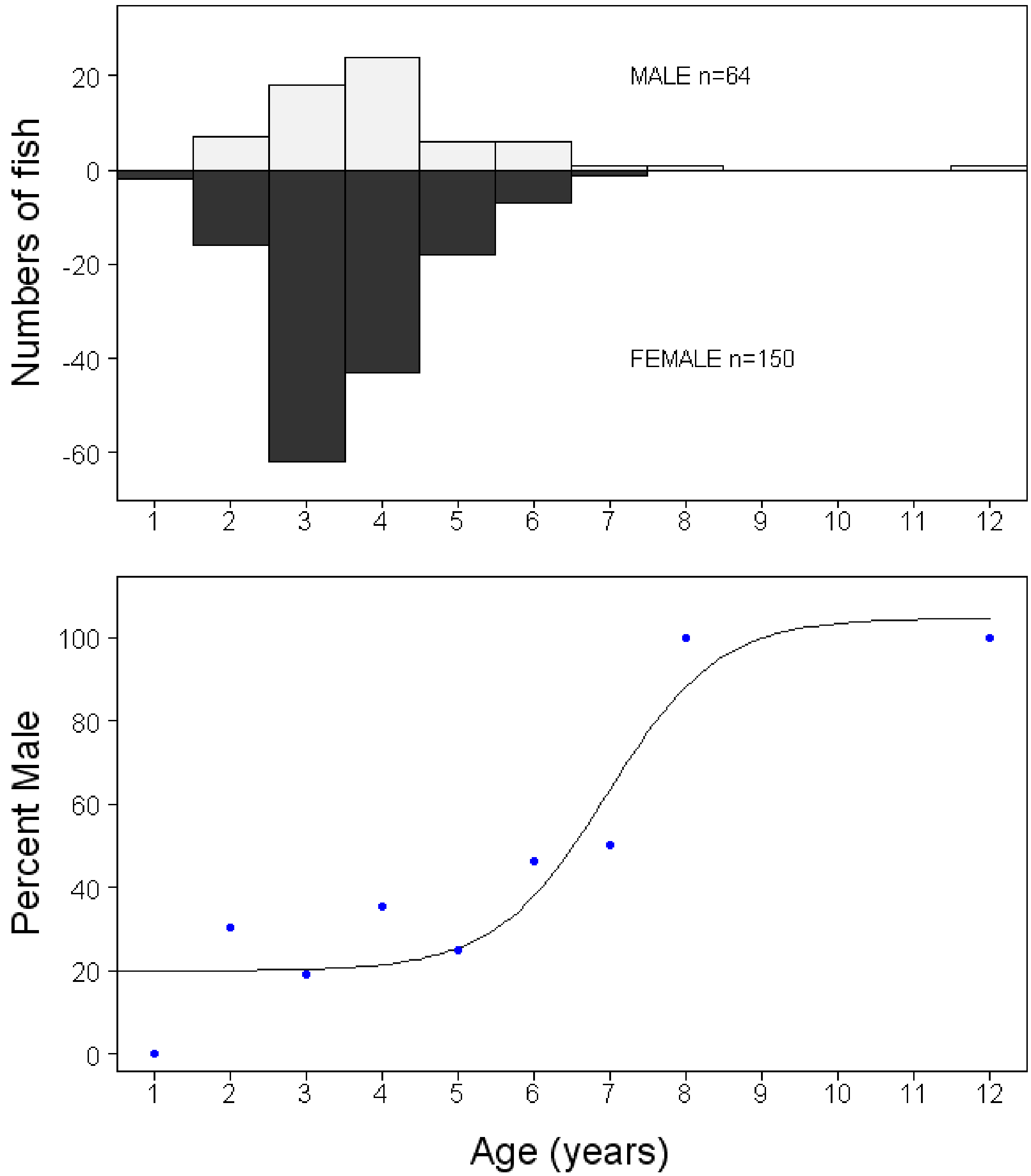

Figure 6. Percent male for black sea bass sampled in 2010 as a function of age. Points represent percentages in each 1 year age bin. Lines represent the fit of the four parameter logistic model.

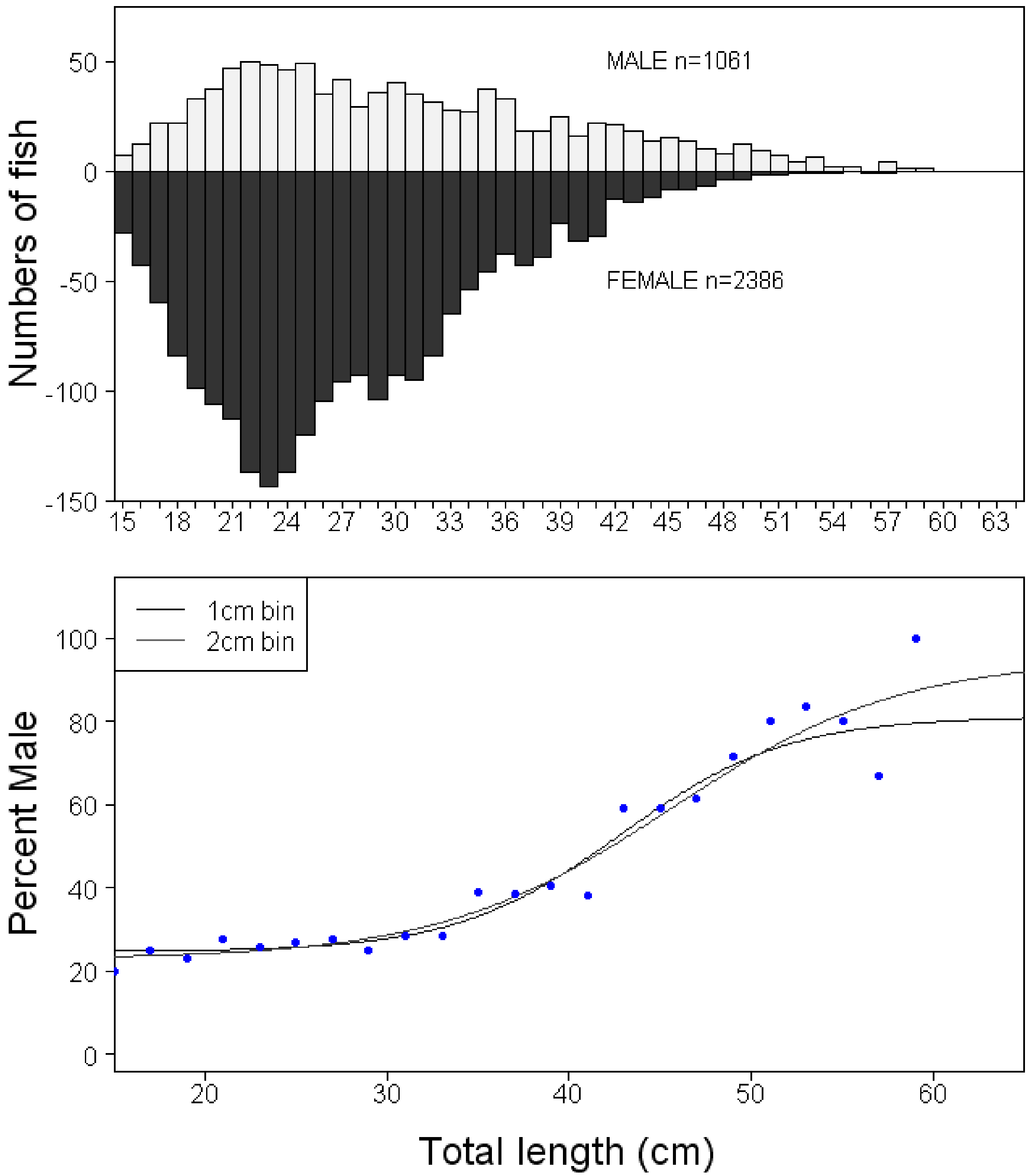

Figure 7. Percent male for black sea bass sampled on NEFSC SBTS and MADMF SBTS (1984-2010) as a function of length. Points represent percentages in each 2 cm length bin. Lines represent the fits of the four parameter logistic model with data binned by 1 and 2 cm.

Appendix 1. Summary of four parameter logistic model fits to the percentage male at length for black sea bass collected in 2010 from various sources (Table 1). See text for model formula and explanation. Four models were fit, with variable size length bins.

Model 1- 1cm binned Length data

Model fitted: Logistic (ED50 as parameter) (4 parms)

Parameter estimates:

	Estimate	Std. Error	t-value	p-value
b:(Intercept)	-0.78981	0.37082	-2.12993	0.0415
c:(Intercept)	22.87569	3.80002	6.01989	1.319e-06
d:(Intercept)	101.23089	7.55191	13.40467	3.349e-14
e:(Intercept)	43.79021	0.73120	59.88786	4.394e-33

Residual standard error:

17.38728 (30 degrees of freedom)

Model 2- 2cm binned Length data

Model fitted: Logistic (ED50 as parameter) (4 parms)

Parameter estimates:

	Estimate	Std. Error	t-value	p-value
b:(Intercept)	-1.3346	1.2352	-1.0805	0.296
c:(Intercept)	22.3124	3.9912	5.5904	4.062e-05
d:(Intercept)	100.7394	5.9271	16.9964	1.157e-11
e:(Intercept)	43.9883	0.5388	81.6416	1.063e-22

Residual standard error:

13.50645 (16 degrees of freedom)

Model 3- 3cm binned Length data

Model fitted: Logistic (ED50 as parameter) (4 parms)

Parameter estimates:

	Estimate	Std. Error	t-value	p-value
b:(Intercept)	-1.01834	0.86342	-1.17943	0.2655
c:(Intercept)	21.95482	4.30140	5.10411	0.0005
d:(Intercept)	100.73393	5.52513	18.23196	5.294e-09
e:(Intercept)	43.64280	0.59727	73.07078	5.587e-15

Residual standard error:

11.41578 (10 degrees of freedom)

Model 4- 5cm binned Length data

Model fitted: Logistic (ED50 as parameter) (4 parms)

Parameter estimates:

	Estimate	Std. Error	t-value	p-value
b:(Intercept)	-1.47008	9.16190	-0.16046	0.8788
c:(Intercept)	19.71305	5.62585	3.50401	0.0172
d:(Intercept)	100.06556	7.86294	12.72623	0.0001
e:(Intercept)	43.41306	5.74844	7.55215	0.0006

Residual standard error:

12.57344 (5 degrees of freedom)

Appendix 2. Summary of four parameter logistic model fits to the percentage male at age for black sea bass collected in 2010 from various sources (Table 1). See text for model formula and explanation. A single model was fit, no age groups were binned.

Model 1- 1 year binned Age data
Model fitted: Logistic (ED50 as parameter) (4 parms)

Parameter estimates:

	Estimate	Std. Error	t-value	p-value
b:(Intercept)	-1.36333	1.03397	-1.31853	0.2445
c:(Intercept)	19.87582	9.30625	2.13575	0.0858
d:(Intercept)	104.61013	13.40348	7.80470	0.0006
e:(Intercept)	6.95768	0.56333	12.35091	0.0001

Residual standard error:
14.62701 (5 degrees of freedom)

Appendix 3. Summary of four parameter logistic model fits to the percentage male at length for black sea bass collected on NEFSC SBTS and MADMF SBTS (1984-2010). See text for model formula and explanation. Two models were fit with different size length bins (1 and 2 cm).

Model 1- 1cm binned Length data
Model fitted: Logistic (ED50 as parameter) (4 parms)

Parameter estimates:

	Estimate	Std. Error	t-value	p-value
b:(Intercept)	-0.22023	0.11726	-1.87813	0.0675
c:(Intercept)	24.58665	4.86670	5.05202	9.486e-06
d:(Intercept)	81.04034	9.06859	8.93638	3.574e-11
e:(Intercept)	42.84653	2.32888	18.39792	1.009e-21

Residual standard error:
14.64586 (41 degrees of freedom)

Model 2- 2cm binned Length data
Model fitted: Logistic (ED50 as parameter) (4 parms)

Parameter estimates:

	Estimate	Std. Error	t-value	p-value
b:(Intercept)	-0.157158	0.054259	-2.896457	0.0093
c:(Intercept)	22.842641	3.720414	6.139811	6.682e-06
d:(Intercept)	95.094550	12.142503	7.831544	2.296e-07
e:(Intercept)	45.576677	2.541987	17.929550	2.299e-13

Residual standard error:
6.162665 (19 degrees of freedom)

Comparing Black Sea Bass Catch and Presence Between Smooth and Structured Habitat in Northeast Fisheries Science Center Spring Bottom Trawl Surveys

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September 2011

Introduction
The northern stock of black sea bass (*Centropristis striata*) ranges from the southern Gulf of Maine to Cape Hatteras, North Carolina. Black sea bass in this stock are generally located in inshore areas from late spring to autumn and move to offshore areas for overwintering (Kendall 1977; Musick and Mercer 1977; Able et al. 1995; Collette and Klein-MacPhee 2002; Drohan et al. 2007).

The National Marine Fisheries Service (NMFS) Northeast Fisheries Science Center (NEFSC) spring bottom trawl survey (hereafter called the spring bottom trawl survey) is used to assess black sea bass abundance. Black sea bass may congregate in structured bottom (e.g., near rocks or other substrate), which may not be adequately sampled by the bottom trawls. Consequently, the accuracy of black sea bass abundance estimates from bottom trawl surveys is in question.

The objective of this research is to determine if black sea bass catches or presence in spring bottom trawl surveys is greater in areas with structured bottom than with smooth bottom. To address this objective, we will compare characteristics of black sea bass catches in the spring bottom trawl survey between tows conducted over structured bottom and smooth bottom. We used tows with problems due to hangups, tears, or obstructions as a proxy for having occurred over structured bottom (hereafter called structured tows) and tows without any damage or entanglement as a proxy for having occurred over smooth bottom (hereafter called smooth tows).

Methods
The National Oceanic and Atmospheric Administration (NOAA) Fisheries Toolbox (NFT) program SAGA was used to compile black sea bass catch data from the spring bottom trawl survey during 1968 – 2010. Only data from strata 1 – 12, 25, and 61 – 76 were used, as these are strata where black sea bass are typically located (Figure 1). Strata 8, 9, 12, and 25 were later removed because no black sea bass were caught in these areas. Only data from the following station, haul, and gear (SHG) codes were used: 111, 121, 122, 123, 135, and 136. Other SHG codes were not used because the tow was not from survey trips, the tow was not considered representative, the problem with the tow was caused by a malfunction in the gear instead of structured bottom, or no black sea bass were caught. SHG codes 111 and 121 represent tows without any damage or entanglement and were used as proxies for smooth tows and the other codes were used as proxies for structured tows (Table 1).

The Mann-Whitney test, a special case of the Wilcoxon rank test, was used to compare the catches of black sea bass (in number and weight) between smooth and structured tows ($\alpha = 0.05$). This non-parametric test was used because the data were distributed in a manner that violated the assumptions of alternative parametric tests (i.e., unequal sample sizes, unequal variances, and non-normal distribution), such as a two-sample t-test. A Mann-Whitney test was also used to compare the proportion of the total catch (of all species) comprised of black sea bass (in number and weight) between smooth and structured tows ($\alpha = 0.05$). If black sea bass congregate near structured bottom, the catches of black sea bass and the proportion of the total catch comprised of black sea bass may be larger in structured tows than smooth tows.

Furthermore, the proportion of smooth tows that caught black sea bass was calculated as the number of smooth tows that caught black sea bass divided by the total number of smooth tows. The proportion of structured tows that caught black sea bass was calculated as the number of structured tows that caught black sea bass divided by the total number of structured tows. If black sea bass congregate near structured bottom, the proportion of structured tows that caught black sea bass may be greater than the proportion of smooth tows that caught black sea bass.

Results

The number of black sea bass caught in smooth tows was significantly greater than the number of black sea bass caught in structured tows (mean smooth = 4.2872; mean structured = 1.4448; W = 575576, P = 0.0243). Similarly, the weight of black sea bass caught in smooth tows was significantly greater than the weight of black sea bass caught in structured tows (mean smooth = 0.9881; mean structured = 0.4635; W = 576742.5, P = 0.0232).

The proportion of the total catch in numbers comprised of black sea bass in smooth tows was significantly greater than the proportion of the total catch in numbers comprised of black sea bass in structured tows (smooth = 0.0046; structured = 0.0022; W = 576465.5, P = 0.0409). Likewise, the proportion of the total catch in weight comprised of black sea bass in smooth tows was significantly greater than the proportion of the total catch in weight comprised of black sea bass in structured tows (smooth = 0.0080; structured = 0.0058; W = 572181, P = 0.0292).

The proportion of smooth tows that caught black sea bass was 0.1922 (Figure 2), and the proportion of structured tows that caught black sea bass was 0.1420 (Figure 3).

Conclusions

More black sea bass (in number and weight) were caught in survey areas with smooth bottom than with structured bottom, which contradicts the assumption that black sea bass congregate in structure while on the continental shelf. This result, however, could be due to our use of entangled or damaged tows as having occurred over structured habitat. If the gear was entangled or damaged, then we would expect fewer black sea bass to have been caught over structure, which would obscure any effect of congregating behavior.

None the less, assuming that any entanglement or damage to the gear affects the catchability of all species equally, if black sea bass do congregate around structured habitat then the proportion of black sea bass caught in structured bottom areas should still be greater than the proportion of black sea bass caught in smooth bottom areas. We found, however, that a greater proportion of the total catch comprised of black sea bass (in number and weight) were caught in survey areas with smooth bottom than with structured bottom. Hence, we found no evidence for black sea bass congregating in structured habitat in a way that would invalidate the use of the spring bottom trawl survey as a method to assess black sea bass abundance.

Acknowledgements

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Figure 1. NMFS NEFSC spring bottom trawl survey strata. (Figure courtesy of Elizabeth Holmes.)

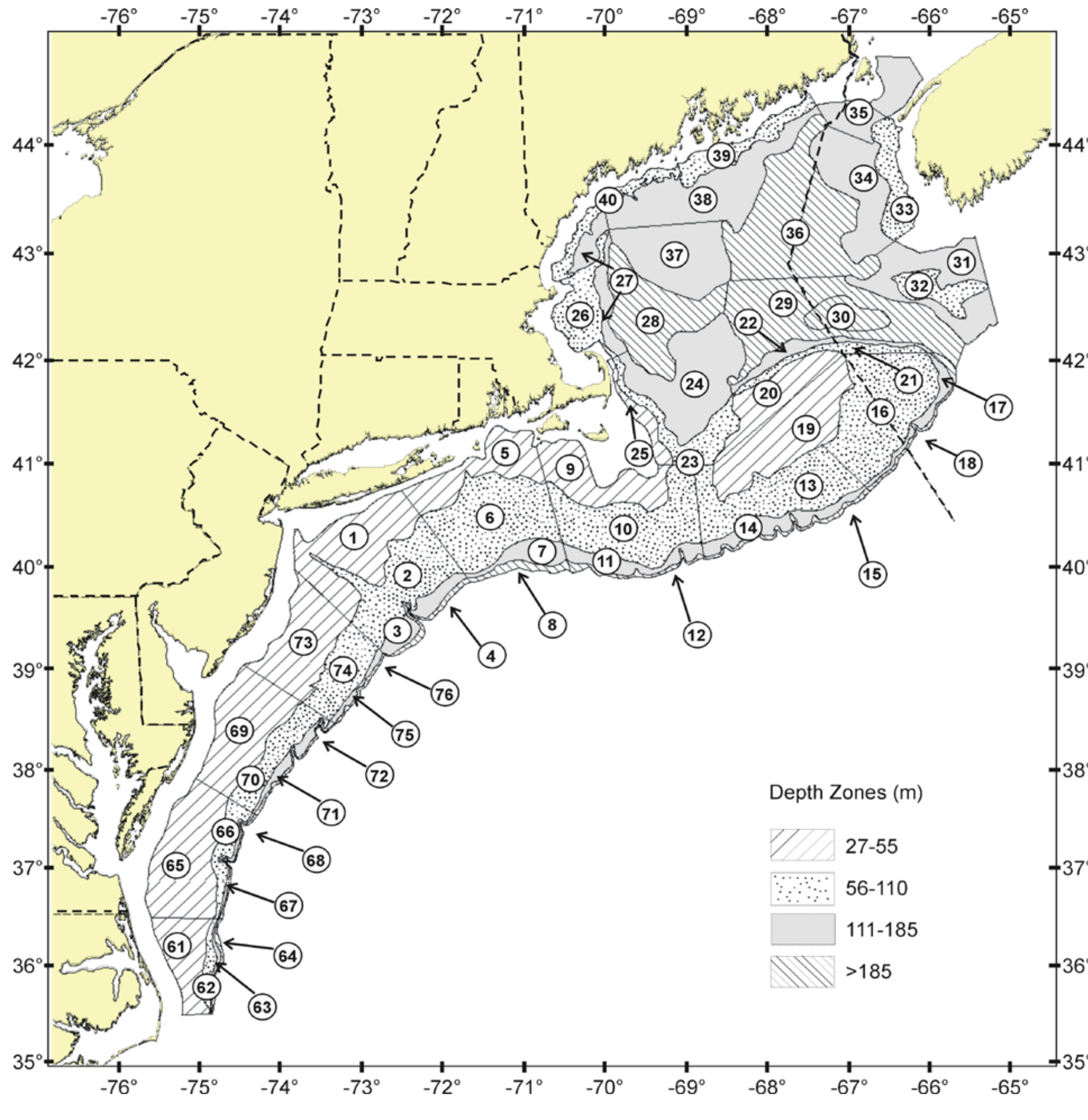

Figure 2. Locations of smooth tows where black sea bass were caught (black circles) and not caught (red circles).

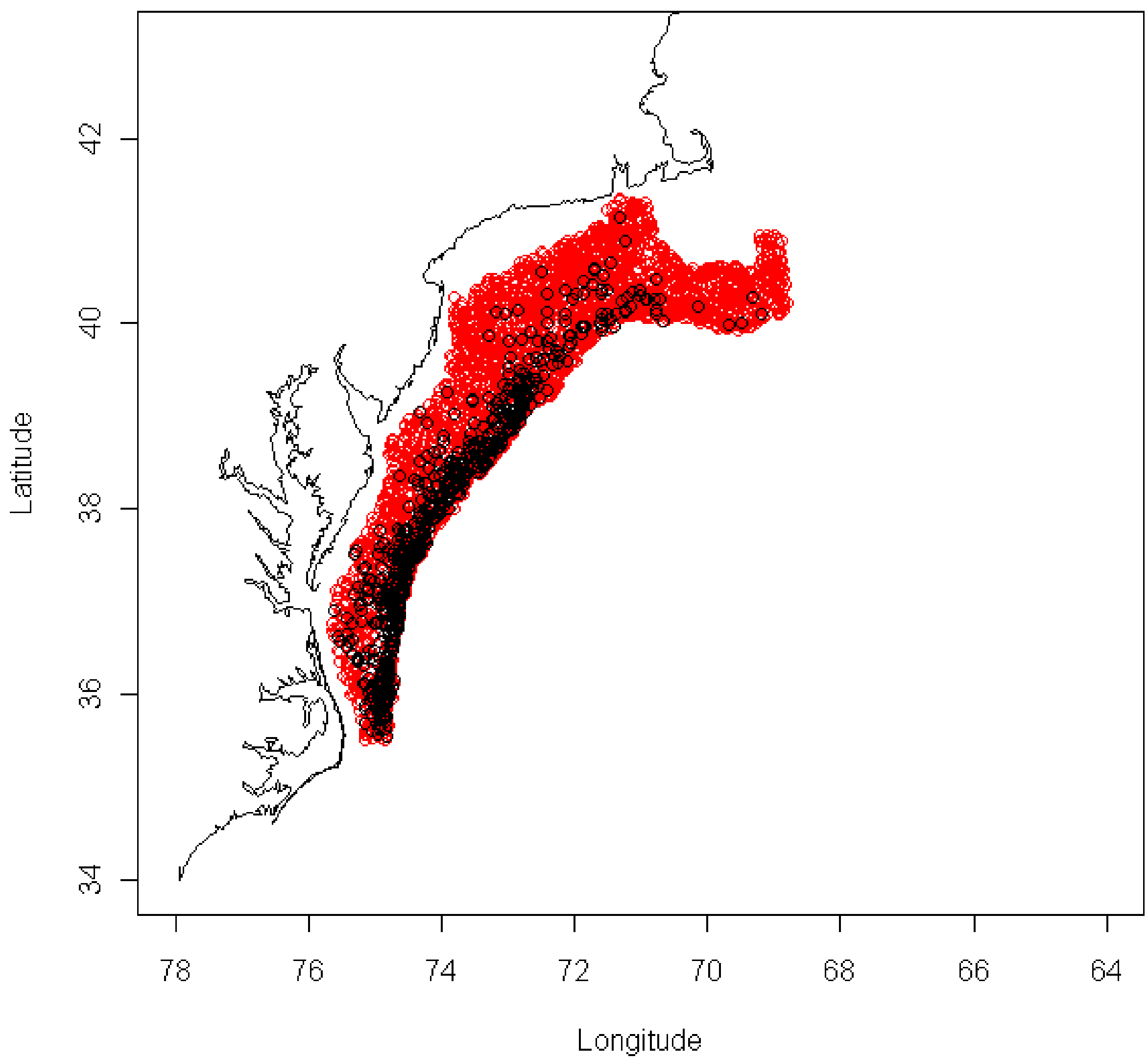

Figure 3. Locations of structured tows where black sea bass were caught (black circles) and not caught (red circles).

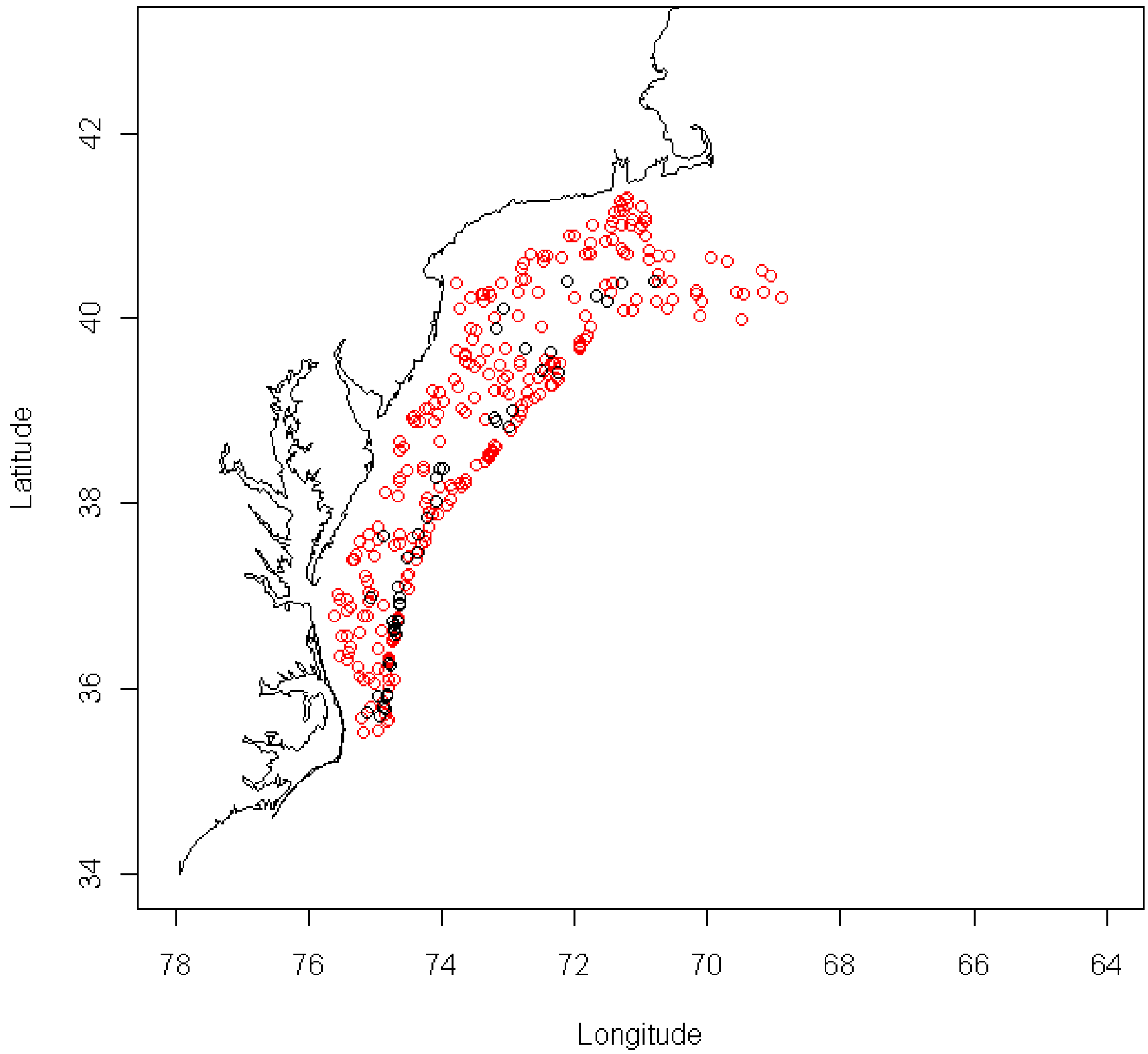

Table 1. Relevant station, haul, and gear (SHG) codes.

Station, Haul, or Gear Code	Description
Station Type	
1	Survey tows.
Haul Type	
1	Good tow. No gear or tow duration problem.
2	Representative, but some problem encountered due to gear or tow duration.
3	Problem tow. May or may not be representative due to gear or tow duration.
Gear Condition	
1	No damage to insignificant damage.
2	Wing twisted or tears in upper or lower wings not exceeding 10 feet; tear in square not exceeding 5 feet; tears not exceeding 3 feet in upper belly, or 6 feet in lower belly; codend or liner with tears not exceeding 2 feet; parted idler; liner hanging out of codend.
3	Hung up with minor damage.
5	Tearup exceeding limits for code 2, but not total.
6	Significant obstruction in trawl, such as fixed gear, rocks, old anchors, timbers, etc. Problem with third wire; unmatched doors; strong current.

Estimating Black Sea Bass Natural Mortality Using Several Methods

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The natural mortality rate, M , of black sea bass was estimated using several methods. The rule-of thumb approach, M_R , was estimated by dividing a constant by the maximum age observed in the stock, $t_{\max}$:

$$M_R = \frac{3}{t_{\max}}.$$

The 3 in this equation implied that 5% of the stock remains alive at $t_{\max}$, and this value was selected arbitrarily (Hewitt and Hoenig 2005). If $t_{\max}$ was selected based on data from an exploited stock, M could also be biased. The Hewitt and Hoenig (2005) approach, M_H , was based on a regression equation rearranged for consistency with the rule-of thumb approach:

$$M_H = \frac{4.22}{t_{\max}}.$$

The 4.22 in this equation implied that 1.5% of the stock remains alive at $t_{\max}$, and this value was estimated based on a meta-analysis of fish stocks. Maximum age, $t_{\max}$, equaled 9 or 12 in both the rule-of-thumb and Hewitt and Hoenig approaches. The Lorenzen (1996) approach modeled natural mortality as a power function of weight (in grams), or in our application, mean weight at age, W_a , to produce natural mortality at age, $M_{L,a}$:

$$M_{L,a} = \alpha W_a^{\beta},$$

where α was the natural mortality rate at unit weight and β was the allometric scaling factor. The values of α and β were set to the estimates for marine species in Lorenzen (1996) and were 3.69 and -0.305, respectively. Mean weight at age was calculated as the average weight during 1984–2010 for ages 1–9 (Table 1). Mean weight for ages 10-12 were predicted from the fitted wt for ages 1 to 9 (wt=4.7155*age^0.2233). A constant value, M_c , was used in the last assessment and was carried forward as an option for the natural mortality rate in this assessment:

$$M_c = 0.4$$

(Figure 1). This value was based on estimates from tagging studies and meta-analyses of mortality rates in other fishes (Miller et al. 2009).

The $M_{L,a}$ values from the Lorenzen approach were also scaled, $\widetilde{M}_{L,a}$, so that the average among ages equaled each of the other methods (i.e., M_R , M_H , and M_c) for calculating natural mortality, M_i :

$$\widetilde{M}_{L,a} = M_{L,a} \frac{M_i}{\overline{M}_{L,a}},$$

where $\overline{M}_{L,a}$ was the average of $M_{L,a}$ over all ages considered (Table 2; Figure 2).

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Table 1. Black sea bass mean weight at age (in grams).

Age	WAA (g)
1	112.92
2	243.19
3	395.48
4	604.69
5	861.95
6	1279.68
7	1542.01
8	1821.36
9	1974.56
10	2658.4
11	3149.8
12	3689.1
Average	

Table 2. Black sea bass natural mortality estimates at age using a constant, the rule-of-thumb approach, the Hewitt and Hoenig approach, the Lorenzen approach, and the Lorenzen approach scaled to each of the other three methods.

Natural Mortality											
Age	Constant	Rule of Thumb[1]	Rule of Thumb[2]	Hewitt & Hoenig[1]	Hewitt & Hoenig[2]	Lorenzen	Lorenzen Scaled to Constant	Lorenzen Scaled to Rule of Thumb[1]	Lorenzen Scaled to Hewitt & Hoenig[1]	Lorenzen Scaled to Rule of Thumb[2]	Lorenzen Scaled to Hewitt & Hoenig[2]
1	0.40	0.33	0.25	0.47	0.35	0.87	0.67	0.56	0.78	0.50	0.62
2	0.40	0.33	0.25	0.47	0.35	0.69	0.53	0.44	0.62	0.36	0.46
3	0.40	0.33	0.25	0.47	0.35	0.60	0.46	0.38	0.53	0.29	0.38
4	0.40	0.33	0.25	0.47	0.35	0.52	0.40	0.33	0.47	0.24	0.33
5	0.40	0.33	0.25	0.47	0.35	0.47	0.36	0.30	0.42	0.21	0.29
6	0.40	0.33	0.25	0.47	0.35	0.42	0.32	0.27	0.37	0.18	0.25
7	0.40	0.33	0.25	0.47	0.35	0.39	0.30	0.25	0.35	0.16	0.23
8	0.40	0.33	0.25	0.47	0.35	0.37	0.29	0.24	0.34	0.15	0.21
9	0.40	0.33	0.25	0.47	0.35	0.36	0.28	0.23	0.33	0.15	0.21
10	0.40		0.25		0.35	0.33	0.24			0.13	0.19
11	0.40		0.25		0.35	0.32	0.22			0.12	0.17
12	0.40		0.25		0.35	0.30	0.21			0.11	0.16

[1]Maximum age = 9

[2]Maximum age = 12

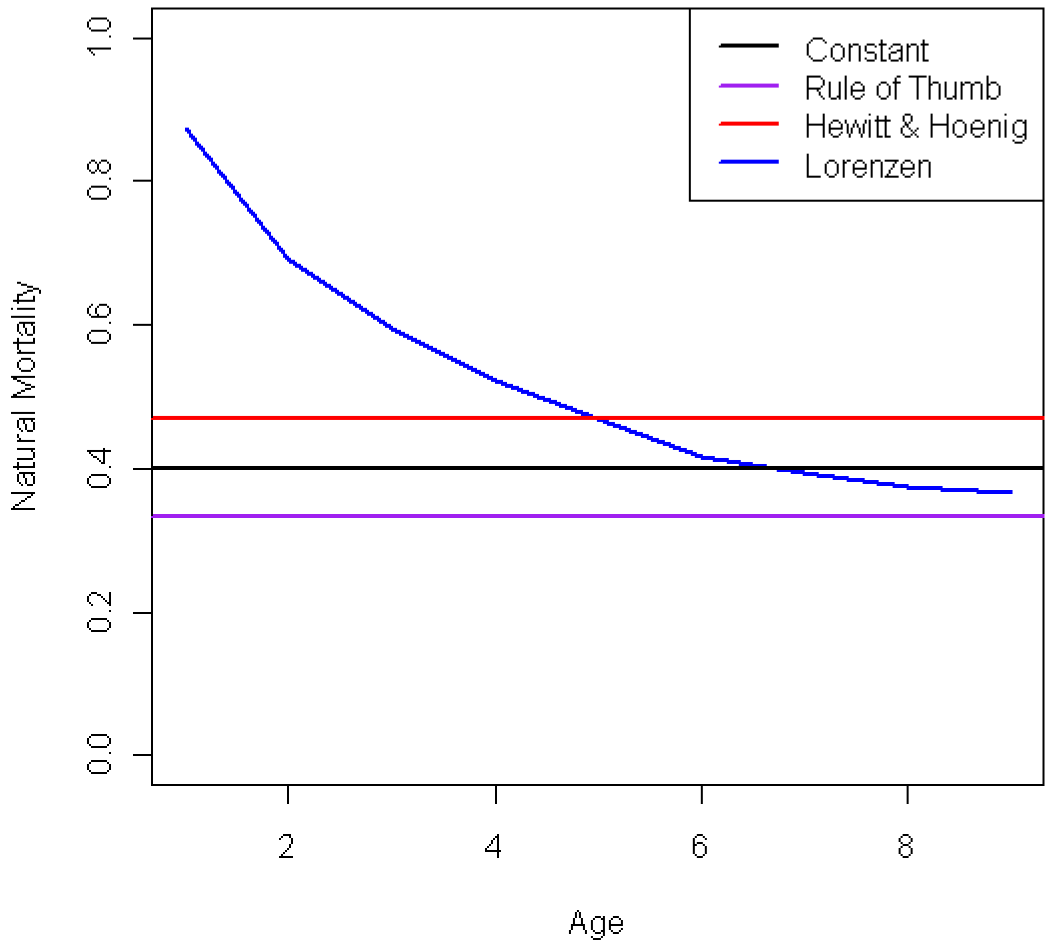

Figure 1. Black sea bass natural mortality estimates at age using a constant, the rule-of thumb approach, the Hewitt and Hoenig approach, and the Lorenzen approach.

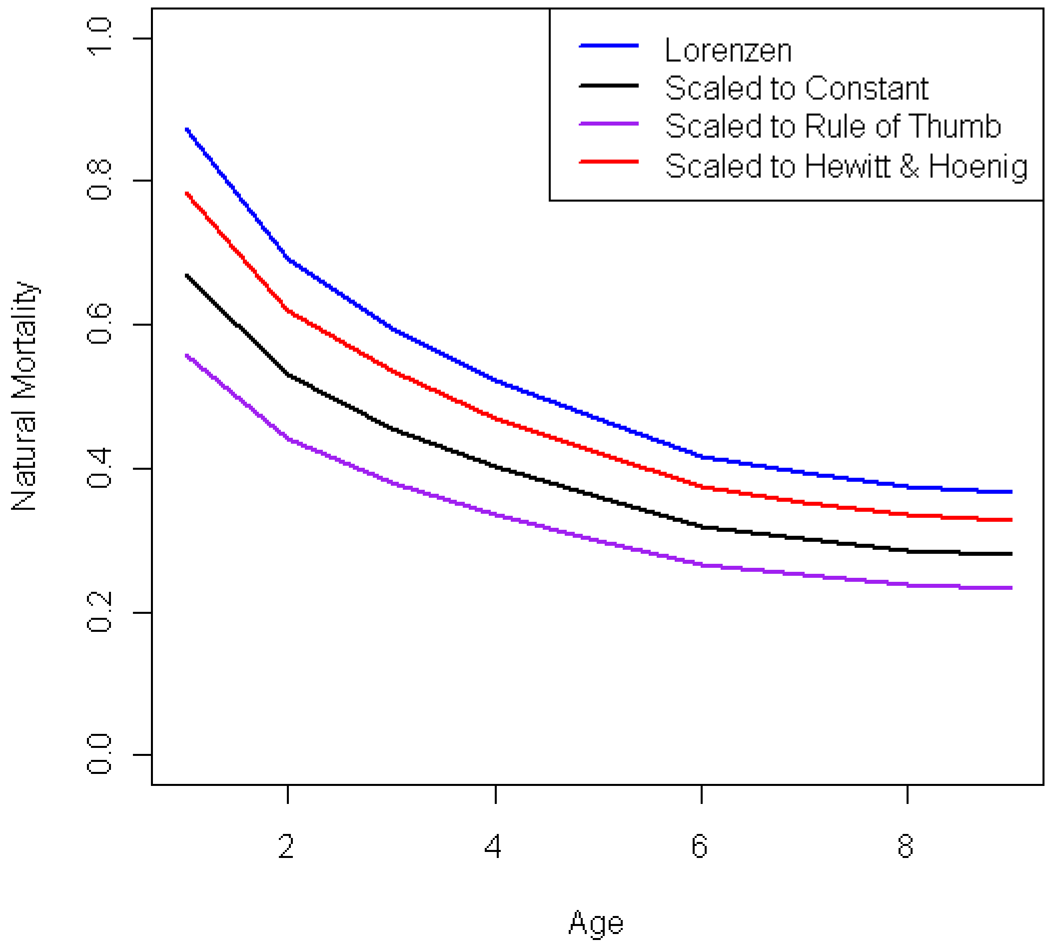

Figure 2. Black sea bass natural mortality estimates at age using the Lorenzen approach, and the Lorenzen approach scaled to the constant, rule-of thumb, and Hewitt and Hoenig approaches.