Appendix B1. Commercial Landings Data Sources

State Commercial Landings Monitoring Programs

Massachusetts

Fish dealers are required to obtain special authorization from the Division of Marine Fisheries (DMF) in addition to standard seafood dealer permits to purchase striped bass directly from fishermen. Dealer reporting requirements include weekly reporting to the DMF or Standard Atlantic Fisheries Information System (SAFIS) of all striped bass purchases. If sent to DMF, all harvest information is entered into SAFIS by DMF personnel. Harvest is tallied weekly to determine proximity of harvest to the quota cap. Following the close of the season, dealers are also required to provide a written transcript consisting of purchase dates, number of fish, pounds of fish, and names and permit numbers of fishermen from whom they purchased. Fishermen must have a DMF commercial fishing permit (of any type) and a special striped bass fishing endorsement to sell their catch. They are required to file catch reports at the end of the season, which include the name of the dealer(s) that they sell to and extensive information describing their catch composition and catch rates. If an angler does not file a report, he/she can not obtain a permit in the next year.

Rhode Island

Commercial harvest is reported through Interactive Voice Recording (IVR) and SAFIS. The IVR is a phone-in system designed to monitor quota-managed species, including striped bass. The reported data are aggregated by dealer and include gear, pounds landed, and date landed. SAFIS collects trip level data over the web in accordance with data standards developed by the Atlantic Coastal Cooperative Statistics Survey (ACCSP). Specific data fields include: vessel name, vessel identification (state registration or US Coast Guard Documentation Number), RI commercial license number, port landed, species, reported quantity, unit of measure, date landed, and price. The commercial harvest reported for RI is considered a complete census. The RI Division of Fish and Wildlife (DFW) has a harvester logbook for the commercial finfish and crustacean fishery sectors that collects catch and effort statistics and the associated gear types, gear sets, and areas fished as well as validates data reported by dealers and commercial fishermen.

New York

New York's annual quota (in pounds) is converted into a total number of fish, based on the mean weight of striped bass sampled during state monitoring efforts in the prior year. Each participant in the fishery is issued a fixed number of tags and a set of trip report forms. The regulations governing the fishery require that a commercial harvester tag each legal fish taken within the slot limit for sale, and that report forms are completed whenever any fishing trips are taken. Forms include all the data fields as described in the Rhode Island and Virginia sections of this appendix, as well as fields for area and depth fished, amount of fish harvested in both pounds and count, and specific serial numbers of tags used for each trip. If no trips were taken for an entire month, harvesters must submit a monthly "did not fish" report. All reports are due within 15 days from the end of each month. At the conclusion of the commercial season, any unused tags must be returned to the department. Each participant's harvest records are examined to account for all tags issued. A complete census of the commercial harvest is reported to NMFS each year, and information is also sent to the ACCSP for inclusion to the Data Warehouse.

Delaware

Each fisherman has an Individual Transferable Quota (ITQ), for which they are issued tags by the Division of Fish and Wildlife (DFW). Tags are tamper-proof and serial numbered in accordance with the recommendations of the ASMFC's Law Enforcement Committee. Each harvested fish must be tagged by the fisher and then tagged by a certified weigh station, which must report daily to a real-time quota monitoring system. Fishers must also submit a seasonal catch log.

Potomac River Fisheries Commission (DC)
Mandatory reports of daily activity are submitted on a weekly basis. Failure to report can, and has, resulted in the loss of licenses. Harvest numbers are considered a complete census since all fishermen must report. Each fisherman is given a report book with one sheet for each fishing week at the beginning of the year. He/she records daily harvest (in pounds by market size category and the number of striped bass ID tags used, i.e. the number of fish harvested), amount of gear used (effort), the area of the river where the fish were caught and the port or creek of landing. The buyer records the average selling price and the estimated discards are reported for the week. The reports are mailed to the PRFC weekly and entered into the system and reported to NMFS via the Virginia Marine Resources Commission (VMRC).

Maryland
All commercially harvested striped bass are required to be tagged by the fishermen prior to landing with serial numbered, tamper evident tags inserted in the mouth and out through the operculum. These tags verify the harvester and easily identify legally harvested fish to the public and law enforcement. Each harvest day and prior to sale, all tagged striped bass are required to pass through a commercial fishery check station. Check station employees, acting as representatives of MD Department of Natural Resources (DNR), count, weigh, and verify that all fish are tagged. The check stations are required to call daily and report the total pounds of striped bass checked the previous day, as well as keep daily written logs detailing the activity of each fisherman, which are returned weekly by mail. Individual fishermen are required to report their striped bass harvest on monthly fishing reports and to return their striped bass permit to DNR at the end of the season.

Virginia
All permitted commercial harvesters of striped bass must report the previous month's harvesting activities to VMRC no later than the 5th day of the following month, in accordance with the VMRC regulation that governs the mandatory harvester reporting program. This regulation requires that the monthly catch report and daily catch records shall include the name and signature of the registered commercial fisherman and his license registration number, buyer or private sale information, date of harvest, city or county of landing, water body fished, gear type and amount used, number of hours gear fished, number of hours watermen fished, number of crew on board including captain, species harvested, market category, and live weight or processed weight of species harvested, and vessel identification (Coast Guard documentation number, VA license number or Hull/VIN number). Any information on the price paid for the catch may be provided voluntarily. In addition, all permitted commercial harvesters of striped bass must record and report daily striped bass tag use and specify the number of tags used on striped bass harvested in either the Chesapeake Area or Coastal Area. Daily striped bass tag use on striped bass harvested from either the Chesapeake area or Coastal area, within any month, must be recorded on forms provided by the Commission and must accompany the monthly catch

report submitted no later than the 5th day of the following month. Any buyer permitted to purchase striped bass harvested from Virginia tidal waters must provide written reports to VMRC of daily purchases and harvest information on forms provided by VMRC. Such information shall include the date of the purchase; buyer and harvester striped bass permit numbers, and harvester Commercial Fisherman Registration License number. In addition, for each different purchase of striped bass harvested from Virginia waters, the buyer shall record the gear type, water area fished, city or county of landing, weight of whole fish, and number and type of tags (Chesapeake area or Coastal area) that applies to that harvest. These reports shall be completed in full and submitted monthly to VMRC no later than the 5th day of the following month. In addition, during the month of December, each permitted buyer shall call the VMRC interactive Voice Recording System, on a daily basis, to report his name and permit number, date, pounds of Chesapeake area striped bass purchased, and pounds of Coastal area striped bass purchased.

North Carolina
Commercial harvest is monitored real time through dealer reporting on a daily basis. Dealers report total numbers of fish and total pounds each day. Each fish must have a Division of Marine Fisheries (DMF) tag affixed through mouth and gills upon processing at the fish house. However, the final numbers and pounds used in reports come from the NC DMF trip ticket program. The trip ticket program collects gear data, species data, and total pounds per species each time a commercial fisherman makes a sale at a fish house.

Commercial Harvest Length-Frequencies

Data on length and weight of commercially harvested striped bass are collected through various state-specific sampling programs described below.

Massachusetts
Commercial port samplers visit fish houses throughout the state during the commercial season and measure striped bass being sold. All fish present on a given day are sampled or if there are too many, a sub-sample of totes containing fish are randomly selected. The number measured (TL and FL) and weighted (pounds) is based on the discretion of the port sampler. Approximately, 500-700 fish are measured each season. The length information collected is used the generate length distributions of harvested fish.

Rhode Island
Dockside samples are collected from commercial floating fish trap and rod and reel fisheries. Every individual striped bass observed is measured for fork length (inches) and weighed (pounds). Sampling begins in May or June and continues through October, when the majority of commercial fishing for striped bass in Rhode Island takes place. The low possession limit, especially in the rod and reel fishery, limits the number of striped bass available for sampling on any given day. The proportion of striped bass at length caught in the commercial fisheries is assumed equal to the proportion of striped bass at length sampled from the commercial harvest. The length frequency distributions are estimated separately for the trap and rod and reel fisheries and generally about 185-492 fish are measured per year per gear type. The total number of striped bass commercial harvest is estimated for each fishery by using the sample numbers and

weights to extrapolate to the total weight landed. The estimated total number and the proportions at length are multiplied to compute the estimated number at length for each gear.

New York

Each week during the open season, staff from the Bureau of Marine Resources visit wholesale markets (packing houses), retail markets, or intercept commercial harvesters at marinas or gas docks to sample striped bass caught for commercial purposes. The open geographic area is limited in size, therefore only a few large wholesale markets/packing houses are worth visiting. The information recorded from each fish includes the tag number, fork length, total length, and weight. A sample of scales is collected from each fish. Each year, approximately 1,000 samples are collected.

Delaware

Commercial harvest is sampled at certified, permitted weigh stations. Real-time quotas are monitored to determine sampling frequency, both temporally and spatially. Random sub-sampling includes fork and total length, weight, sex, and scale sample for age determination. Additionally, striped bass are purchased throughout the commercial season for stomach content analysis and otolith age determination.

Potomac River Fisheries Commission (DC)

A random sample (weekly or monthly) is purchased from local fish buyers. The samples are transported to Virginia Institute of marine Sciences (VIMS), where length, weight, sex and age (scales) are recorded. The recent average monthly harvest is used to establish a target sampling frequency and sample sizes. Samples are processed by professionally trained people at VIMS.

Maryland

Pound net sampling occurs during five rounds from May through October. Each round is 10 to 11 days long. Maryland waters of the Chesapeake Bay are subdivided into three regions; the Upper Bay (Susquehanna Flats south to the Bay Bridge), the Middle Bay (Bay Bridge south to a line stretching between Cove Point and Swan Harbor), and the Lower Bay (Cove Point/Swan Harbor south to the Virginia line. For each round, an optimum number of fish to be sampled is determined for each Bay region. At each net sampled, data recorded includes latitude and longitude, date the net was last fished, depth, surface salinity, surface water temperature, air temperature, secchi depth (m), and whether the net was fully or partially sampled. If the net is fully sampled, all striped bass (including sub-legal fish) are measured for total length (mm TL) and, healthy, legal-size fish (≥457 mm total length) are tagged with USFWS internal anchor streamer tags. If the pound net is partially sampled, legal-size striped bass are targeted for tagging. Check stations across Maryland are randomly sampled for pound net and hook-and-line harvested fish each month from June through November. For pound nets, sample targets of fish per month are established for June through August and for September through November. For hook-and-line, a sample target of fish per month is established over the six-month season.

Virginia

VMRC has been collecting striped bass biological data since 1988. The field sampling program is designed to sample striped bass harvests, in general proportion to the extent and timing of these harvests within specific water areas. Since 2003, VMRC has managed its Coastal Area and Chesapeake Area harvests by two different ITQ systems, and data collections procedures are intended to ensure adequate representation of both harvest areas. Samples of biological data are collected from seafood buyers' place of business or dockside from offloaded striped bass caught by pound nets or haul seines. Infrequently, some gill net or commercial hook-and-line fishermen's harvests may be sampled directly. At a majority of the sites, striped bass are sampled from a 50-pound box that was previously boxed and iced. At other sites, recently landed fish are randomly sampled directly from the culling table. For each specimen, length is measured using an electronic fish measuring board (FMB), with the accuracy of +/- 2.5 millimeters, and weight is recorded directly to the FMB, from an Ohaus scale, accurate to the nearest 0.01 pound. A sub-sample of fork lengths are taken, but all striped bass are measured for total length (natural) from the tip of the fish snout to the end of its caudal fin. Sub-samples of sex information and fish hard parts (scales and otoliths) are also collected, on a 1-inch interval basis. Generally, only 40-50% of striped bass sampled for scales are also sampled for otoliths. Supplementary data is collected for each biological sample, such as date of collection, harvest location, market grade, harvest area, and gear type.

North Carolina
Samples are collected by DMF personnel at the fish houses or on the beach for the beach seine fishery. DMF sets a target to collect length, weight, sex (Sykes method), and scale samples from 300 fish per gear type, which is usually about 6% of the total harvest.

Commercial Age Samples

The primary ageing structures for striped bass are scales. All states with commercial striped bass fisheries collected samples on a routine basis. Descriptions of the sampling programs are below.

Massachusetts
Commercial port samplers visit fish houses throughout the commercial season and collect scale samples from striped bass being sold. Generally, scale samples from 500-800 fish are collected each season. The proportion that each age comprised the total samples is estimated from a sub-sample of 250-350 fish which guarantees a precision of $\pm$7-10% at α= 0.05. Weighted proportions at age are generated by weighting the age proportions sampled in each county by county harvest. Scales are impressed in plastic using a heated press and aged by projecting impressions on a microfiche machine.

Rhode Island
Scales are removed from the first 25 striped bass that are weighed and measured in a given sample in the commercial dockside sampling program. A sample of scales (typically seven or more) is removed from the area behind the pectoral fin and then cataloged for ageing. The number of age samples taken range from 185 to 492 per year per gear type.

New York
A sample of scales is collected from each fish sampled by staff from the Bureau of Marine Resources (as described in the previous New York section). Each year, approximately 1,000 age samples are collected. Scales are pressed into clear acetate and age assignment is completed by a minimum of two readers. Age assignments are compared for agreement. Disagreements are settled by a group reading or repress of the sample. Samples for which no agreement can be reached are discarded from the set.

Delaware
Commercial harvest is sampled at certified, permitted weigh stations. Real-time quotas are monitored to determine sampling frequency, both temporally and spatially. Random sub-sampling includes fork and total length, weight, sex, and scale sample for age determination. Additionally, striped bass are purchased throughout the commercial season for stomach content analysis and otolith age determination.

Potomac River Fisheries Commission (DC)
A random sample (weekly or monthly) is purchased from local fish buyers. The samples are transported to VIMS, where length, weight, sex and age (scales) are recorded. The recent average monthly harvest are used to establish a target sampling frequency and sample sizes. The sample is 'worked-up' by professionally trained people at VIMS.

Maryland
Age composition of the pound net and hook-and-line fisheries is estimated via two-stage sampling (Kimura 1977, Quinn and Deriso 1999). The first stage refers to total length samples taken during the surveys, which was assumed to be a random sample of the commercial harvest. In this case, the length frequencies from hook-and-line and pound net check stations were combined with the pound net tagging length frequency. In stage 2, a random sub-sample of scales was aged which were selected in proportion to the length frequency of the initial sample. The total number of scales to be aged was determined using a Vartot analysis which is a derived index measuring the precision of an age-length key (Kimura 1977, Lai 1987). Regardless of the sample size indicated by the Vartot analysis, 10 fish in each length category over 700 mm TL were aged. Year-class was determined by reading acetate impressions of the scales placed in microfiche readers, and age was calculated by subtracting year-class from collection year. The resulting ages were used to construct an age-length key.

Virginia
VMRC has been collecting striped bass biological data since 1988. The field sampling program is designed to sample striped bass harvests, in general proportion to the extent and timing of these harvests within specific water areas. Since 2003, Virginia has managed its Coastal Area and Chesapeake Area harvests by two different ITQ systems, and data collections procedures are intended to ensure adequate representation of both harvest areas. Samples of biological data are collected from seafood buyers' place of business or dockside from offloaded striped bass caught by pound nets or haul seines. Infrequently, some gill net or commercial hook-and-line fisherman's harvests may be sampled directly. At a majority of the sites, striped bass are sampled from a 50-pound box that was previously boxed and iced. At other sites, recently landed fish are randomly sampled directly from the culling table. For each specimen, length is measured using an electronic fish measuring board (FMB), with the accuracy of +/- 2.5 millimeters, and weight is recorded directly to the FMB, from an Ohaus scale, accurate to the nearest 0.01 pound. A sub-sample of fork lengths are taken, but all striped bass are measured for total length (natural) from the tip of the fish snout to the end of its caudal fin. Sub-samples of sex information and fish hard parts (scales and otoliths) are also collected, on a 1-inch interval basis. Generally, only 40-50% of striped bass sampled for scales are also sampled for otoliths. Supplementary data is collected for each biological sample, such as date of collection, harvest location, market grade, harvest area, and gear type.

North Carolina
Scales are obtained from striped bass above the lateral line and below the dorsal fin, pressed on acetate sheets using a Carver heated hydraulic press and read by DMF personnel on a microfiche reader. Age is assigned using ASMFC striped bass ageing guidelines. A sub-sample of 15 fish per sex per 25 mm size group are aged. Year class is then assigned to the remainder of the sample.

Commercial Harvest-At-Age

Commercial harvest at age are usually estimated by applying corresponding length-frequency distributions and age-length keys to the reported number of fish landed by the commercial fisheries in each state. State-specific descriptions of the estimation procedures are below.

Massachusetts
The proportion that each age comprises the total samples of harvested fish is estimated from a sub-sample of 250-350 fish which guarantees a precision of $\pm$10% at α= 0.05. Weighted proportions at age are generated by weighting the age proportions sampled in each county by county harvest. The number of fish harvested is then multiplied by the proportions-at-age to get numbers harvested-at-age.

Rhode Island
Gear-specific age-length keys are computed based on the length and age samples collected from the commercial dockside sampling program. In years when no RI age data is available, a combined Ma and NY age-length key is used. The keys are applied to the commercial length frequencies to estimate the catch-at-age for each gear. The numbers at age are summed over gear types to provide an estimate of the total commercial catch-at-age for the year.

New York
Since sampling is conducted weekly throughout the open season and open geographic area, it is assumed that the annual sample is representative of the harvest. The number of fish harvested is disaggregated by the length and age frequency of the monitoring samples. No effort has been made to apportion the release data to length or age classes because no physical samples are collected.

Delaware
The DFW develops age-length keys by commercial gear type. Landings in the commercial hook and line commercial fishery comprise a very low proportion of the total commercial landings. Therefore, age samples from this fishery are supplemented with age samples from recreational hook and line striped bass to formulate an age-length key specific to harvest from this gear type.

Potomac River Fisheries Commission (DC)
Harvest is apportioned via ageing of the commercial samples. No age data (except fish < 18”) are collected for released fish. Also included is information on the For-Hire fisheries, as the PRFC considers party, charter, guide and other such boats as commercial operations that carry recreational fishermen. PRFC requires a commercial license for the captain and requires him to

have a sport fishing decal (license) for his boat that exempts his passengers from needing to be individually licensed. Captains use a logbook system to report their boats' catch and estimates of the released fish. PRFC also cooperates with the NMFS "For-Hire" Survey by providing a monthly list of boats and captains licensed to carry fee-paying passengers in the Potomac. This allows NMFS to include the PRFC boats in their database and to survey them. At present, NMFS is unable to produce a separate catch and release estimate for the Potomac, but the information on the total harvest is included in the MD and VA estimate. Since, the PRFC, MD and VA all share in one overall Chesapeake Bay F-base management system, there is no immediate need for a Potomac River sub-total for the "For-Hire" fishery.

Maryland
The harvest-at-age for each fishery is calculated by applying the age-length key developed from the hook-and-line and pound net data to the length frequencies observed in each fisheries and expanding the resulting age distribution to the harvest.

Virginia
Harvest data are apportioned to age classes by using an area-specific (Chesapeake Area or Coastal Area), seasonal age-length key (if possible) or annual key. Collected lengths and the age-length key are inputs, along with the harvest weight, into the template that has been used for 3 years to determine catch at age.

North Carolina
Total pounds landed is obtained from trip ticket program. Then year classes are apportioned to harvest based on the percentage of pounds per year class as observed in the sample taken from fish houses. Numbers of fish per year class are then assigned using the average weight per fish per year class as observed in the sample.

Appendix B2. Estimation of Virginia and North Carolina Wave-1 Harvest, 1996-2004

DT: 7/11/2005

TO: ASMFC Striped Bass Technical Committee

FR: Joseph Grist, ASMFC

RE: MRFSS North Carolina Wave-1 2004 harvest

Introduction

During the March 2005 Striped Bass Technical Committee (STB TC) meeting, the results for the 2004 wave-1 North Carolina (NC) harvest were reported. This was the first time wave-1 was directly sampled by the Marine Recreational Fisheries Statistics Survey (MRFSS), and the results were both predictable and a cause for concern. A total of 177,288 striped bass (equivalent to 3,615,670 lb) were harvested during wave-1 in North Carolina.

Anecdotal knowledge has suggested that North Carolina, Virginia, and possibly other states had a sizeable wave-1 fishery. The 2004 wave-1 harvest values for North Carolina and the wave-1 tag return data (Figure 1) for North Carolina and Virginia support this suggestion. However, information is still lacking on what the previous annual harvest rates were, as well as the level of exploitation in Virginia and elsewhere during wave-1. The STB TC requested an examination of the data that included suggestions for how to incorporate these data efficiently into the coastwide STB assessment.

The goal of this analysis is to determine if tag return data during wave-6 and wave-2 are correlated with the reported total harvest and, if so, if a proxy ratio may be utilized to back-calculate wave-1 data for North Carolina and Virginia.

Data

Striped bass tag return data from North Carolina and Virginia were provided by the U.S. Fish and Wildlife Service (USFWS). Data were queried from the MRFSS website (http://www.st.nmfs.gov/st1/recreational/queries/effort/effort_time_series.html) on July 11, 2005 for North Carolina and Virginia, having selected variables by harvest (A+B1), all oceans combined, and all modes combined.

Methods

Tag return and MRFSS data were merged by wave and by year and were analyzed for each state. SAS 9.1 was utilized to calculate Pearson's correlation coefficient (PROC CORR), generate linear regressions, and conduct ANOVA or analysis of variance (PROC REG) to test for similarities between tag return and total harvest data by wave. Only wave-6 (November and December) and Wave-2 (March and April) data were analyzed.

Results

North Carolina

Tag returns were positively correlated with total harvest (0.5828) during wave-6 (Figure 2). ANOVA indicated significant evidence (*p*-value = 0.0366) that total harvest could explain the proportion of tag returns during wave-6.

Tag returns were positively correlated with total harvest (0.9518) during wave-2 (Figure 3). ANOVA indicated significant evidence (*p*-value < 0.0001) that total harvest could explain the proportion of tag returns during wave-2.

Virginia

Tag returns were positively correlated with total harvest (0.5827) during wave-6 (Figure 4). Although ANOVA did not indicate statistically significant evidence (*p*-value = 0.0599) that total harvest could explain the proportion of tag returns during wave 6, the given p-value indicates suggestive, but inconclusive, evidence that the null hypothesis is false, possibly representing biological significance.

Tag returns were slightly negatively correlated with total harvest (-0.4007) during wave-2 (Figure 5). ANOVA did not indicate significant evidence (*p*-value = 0.4311) that total harvest could explain the proportion of tag returns during wave-2. However, the tag return data were not consistent from year to year and a negative correlation was expected.

Estimates of Wave-1 Harvest 1996-2004

Based on the above analyses and suggestion from the Striped Bass TC, Table 1 contains estimates for total harvest for each state.

North Carolina: Wave-1 total harvest for 1996-2003 is based on the NC specific 2004 wave-1 ratio of tag returns to MRFSS total harvest numbers. There were 47 tags returned during the wave-1 fishery period for the ocean fishery. The MRFSS reported harvest (A+B1) was 177,288 striped bass during the same period. This resulted in a 2004 ratio tags to harvest of 0.000265. This ratio was applied to the wave-1 tag returns for the NC ocean fishery to provide a back-calculated total harvest for wave-1 in NC.

Virginia: Unlike NC, a 2004 wave-1 total harvest was not reported. However, analysis of the tag returns suggested that a winter fishery similar to that of North Carolina occurred off VA during 2004. The July 11th report to the TC did indicate that VA wave-6 tag returns were positively correlated to harvest and implied biological significance, though wave-2 analysis did not. Personal communication with Sara Winslow (NCDMF) confirmed that the winter fishery begins in the latter half of wave-6 and continues into wave-1 in northeastern NC, and similar trends would be expected for southeastern VA. Anecdotally, this suggested that wave-6 and wave-1 harvest would show some level of correlation in fishing activity. Using known wave-1 tag returns, a mean ratio (0.000167) of tag returns to harvest for VA wave-6, 1996-2004, was utilized to back-calculate the total wave-1 harvest.

Summary

The 2004 wave-1 total harvest for North Carolina corresponds with observed recreational effort that begins during wave-6 and continues into wave-1 throughout the coastal waters of northeastern North Carolina and southeastern Virginia (Sara Winslow, NCDMF, personal communication).

Analysis indicates that tag return data can be used to explain total harvest in wave-6 and wave-2 in North Carolina. If the assumption that wave-1 follows a similar trend is acceptable by the STB TC, then wave-1 data before 2004 could be back-calculated for North Carolina striped bass harvest. There are two possible methods for back-calculation (Figure 6). One would be using the direct 2004 ratio of tag returns to reported total harvest. The other would be to use the combined ratio of tag returns to total harvest for both wave-6 and wave-2.

Correlation analysis for Virginia did indicate total harvest could be explained by tag returns, although ANOVA did not provide strong evidence for or against the reported correlation. However, tag return evidence does show a wave-1 striped bass fishery is occurring in Virginia (Figure 1), and using the wave-6 mean ratio of tag returns to reported total harvest for 1996-2004 could be utilized to back-calculate the wave-1 striped bass recreational fishery (Figure 7).

Table 1. Estimates of wave-1 harvest by the winter striped bass recreational fisheries off Virginia and North Carolina.

Year	**Total harvest values (projected)**	
	NC	VA
1996	18,860	5,985
1997	49,037	83,793
1998	15,088	89,778
1999	18,860	107,734
2000	7,544	53,867
2001	18,860	53,867
2002	75,442	89,778
2003	79,214	53,867
2004	177,288*	155,616

*actual harvest

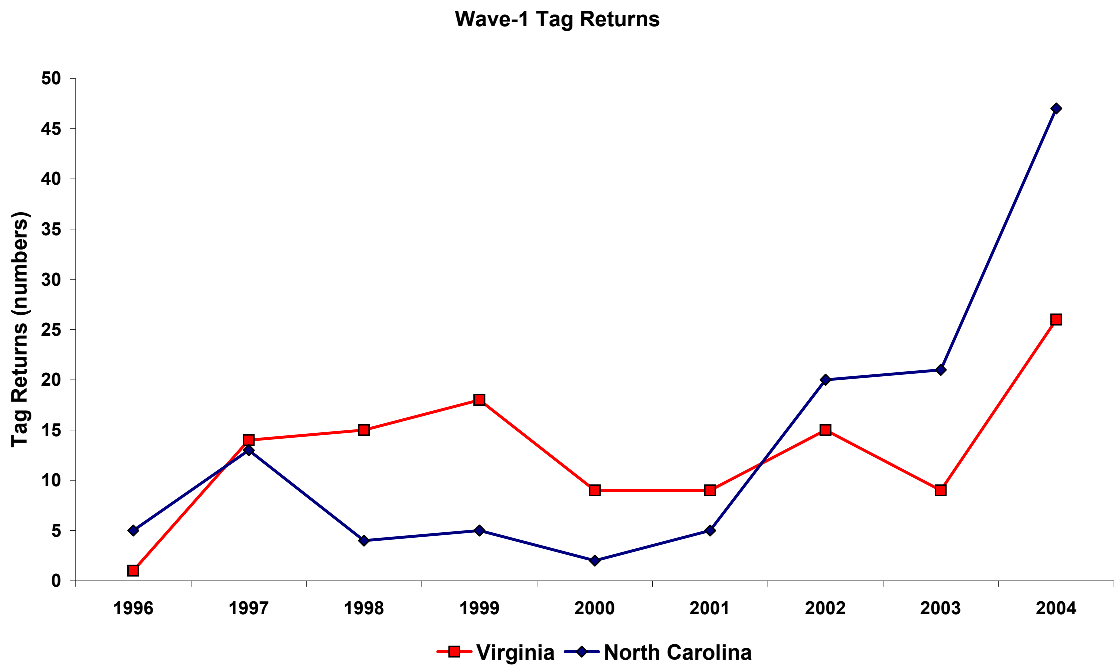


Figure 1. Wave-1 tag returns for Virginia and North Carolina.

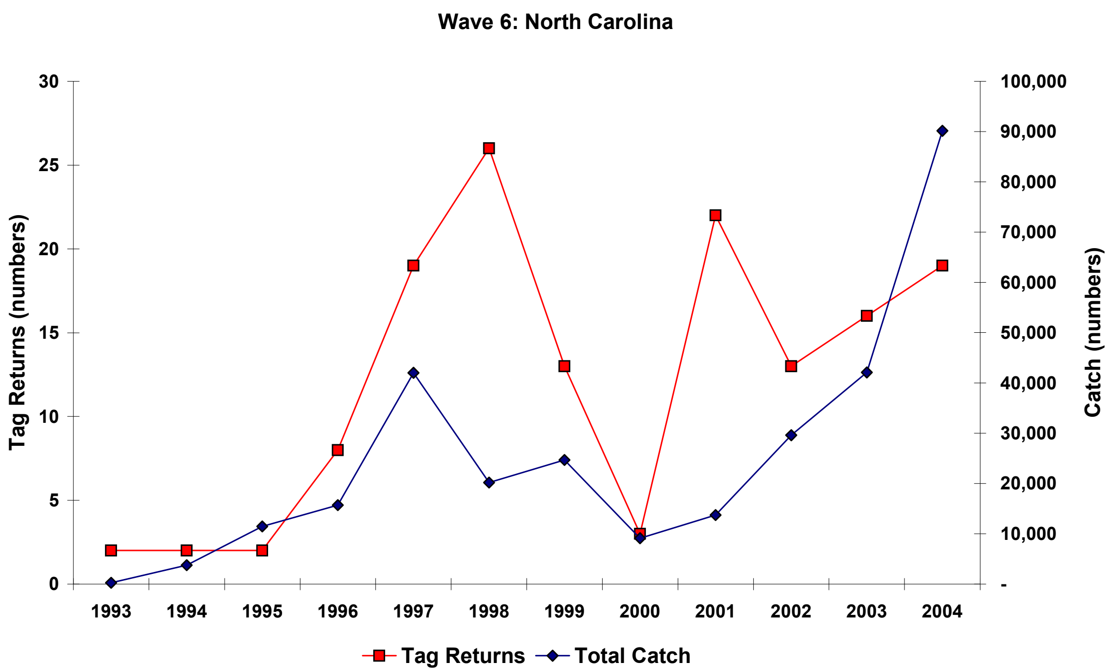


Figure 2. Wave-6 tag returns versus total harvest for North Carolina.

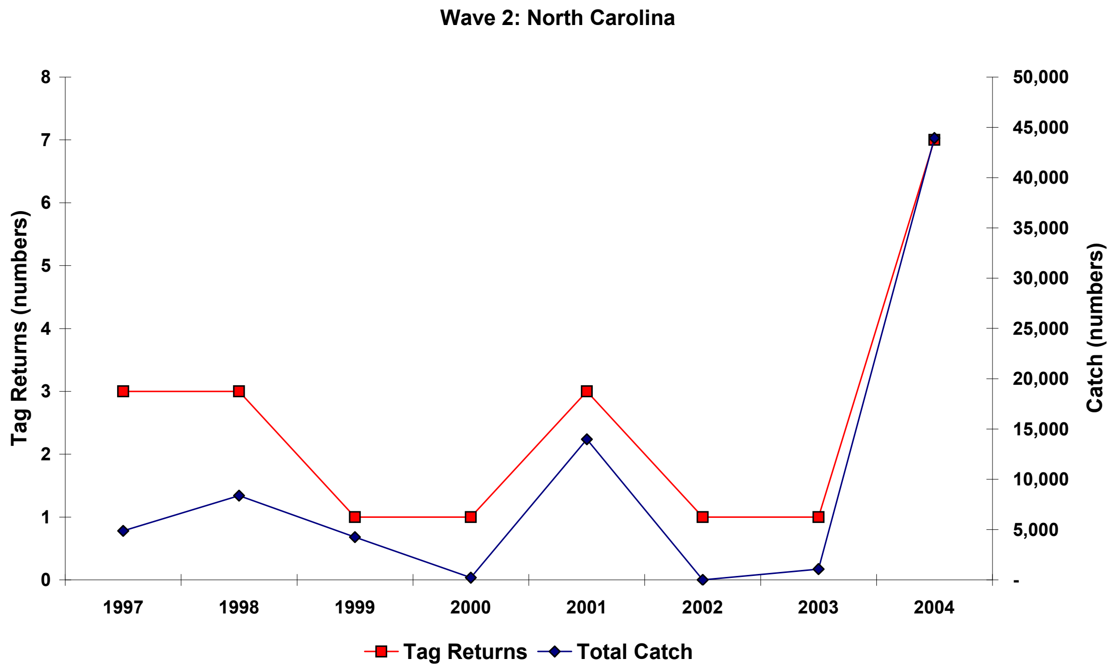


Figure 3. Wave-2 tag returns versus total harvest for North Carolina.

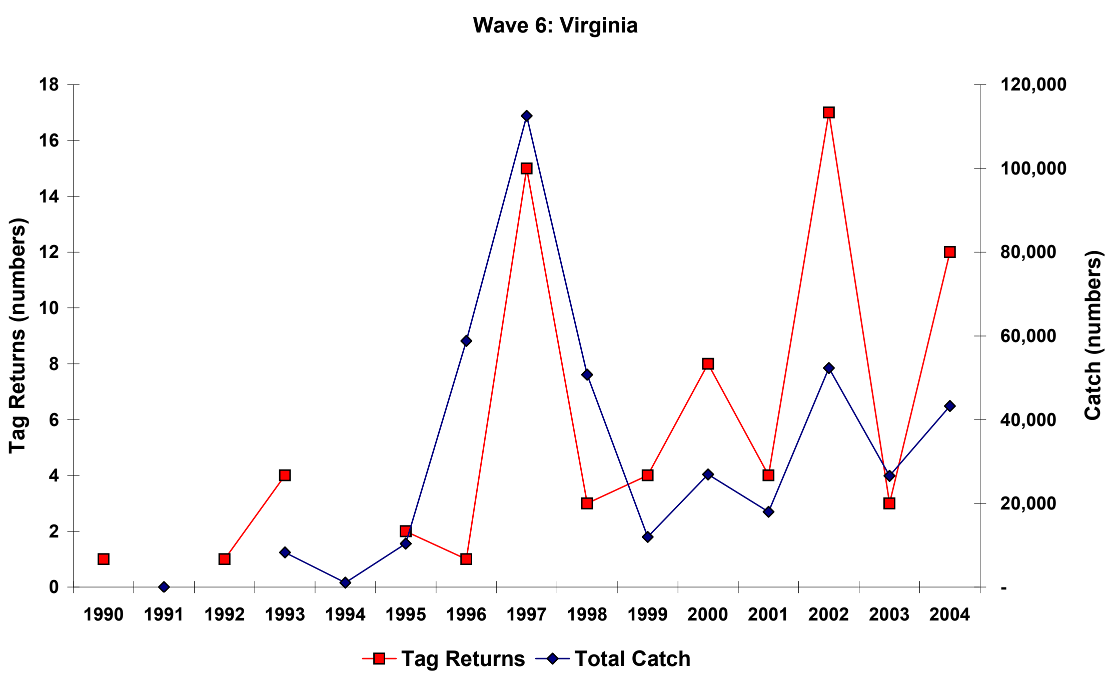


Figure 4. Wave-6 tag returns versus total harvest for Virginia.

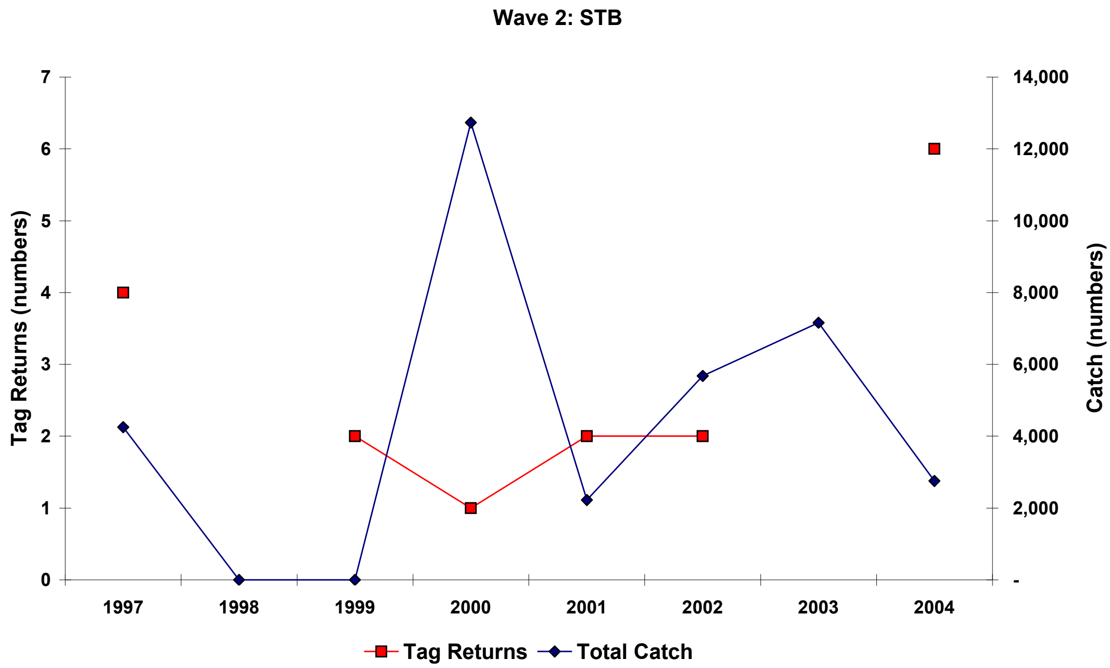


Figure 5. Wave-2 tag returns versus total harvest for Virginia.

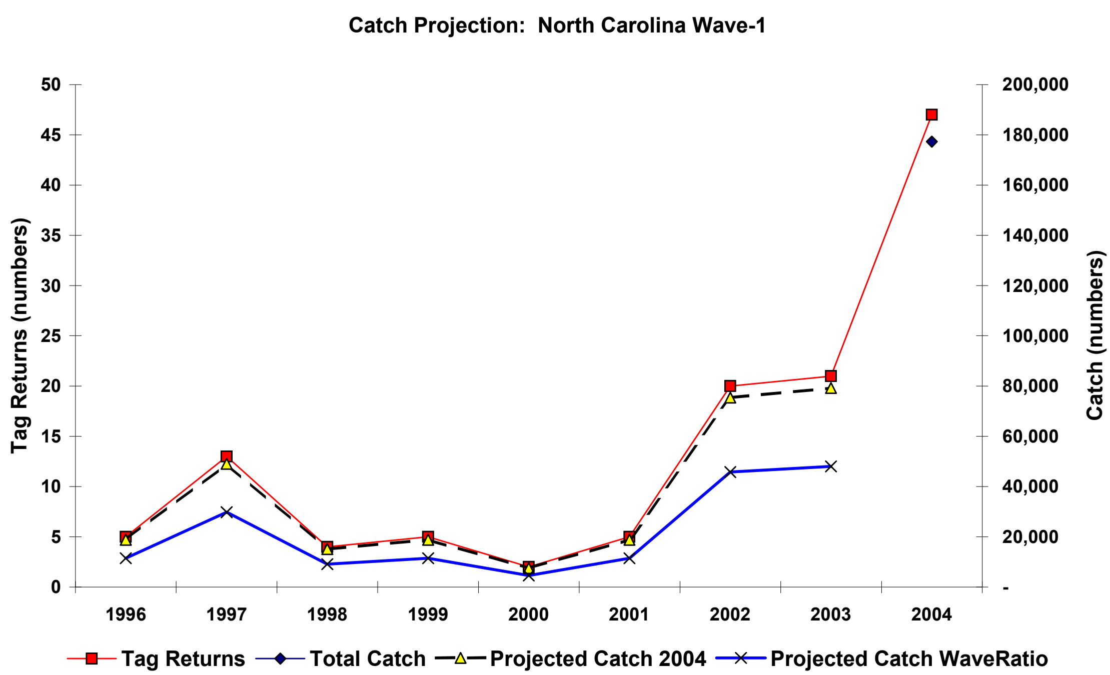


Figure 6. Comparison of harvest projections for North Carolina wave-1.

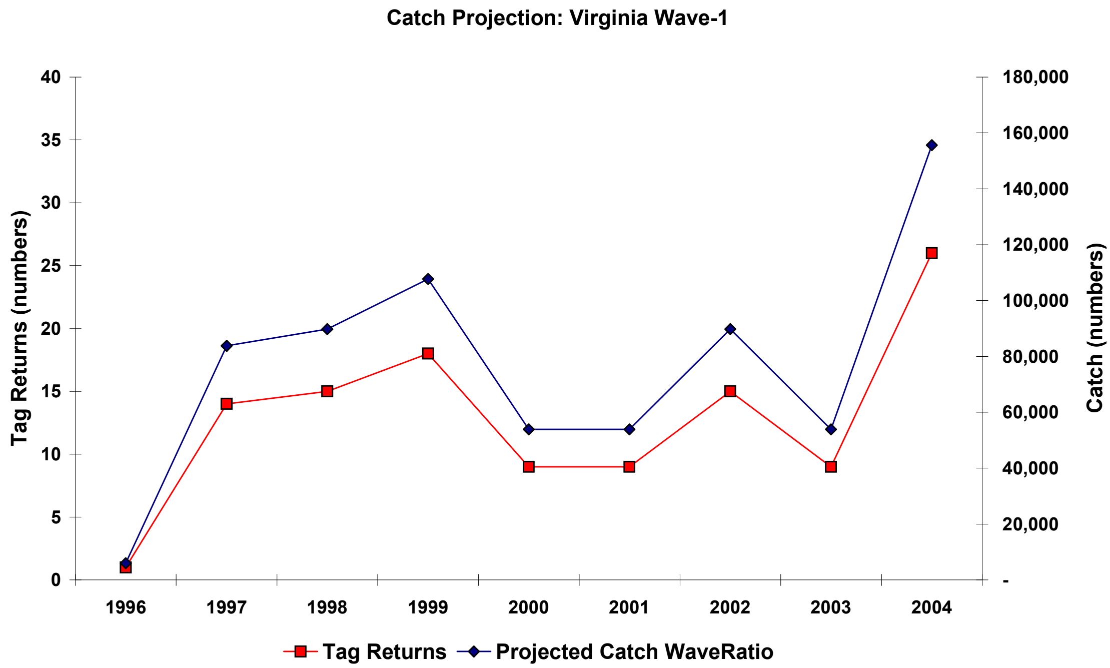


Figure 7. Harvest projection for Virginia wave-1.

Estimation of Virginia Wave 1 Harvest in 2005 and 2006

In Appendix C of the 2005 stock assessment, a memo from Joe Grist states "Personal communication with Sara Winslow (NCDMF) confirmed that the winter fishery begins in the latter half of wave-6 and continues into wave-1 in northeastern NC, and similar trends would be expected for southeastern VA." If the fisheries are similar because of their close proximity, it follows that complete information on harvest from NC in 2005 and 2006 could be used to provide more realistic estimates of harvest in Virginia during wave 1.

If it is assumed that the number of tags returned from killed fish is proportional to the numbers of fish harvested regardless of location, the ratio of the NC harvest in wave 1 to tag returns from NC harvested fish will provide a means by which harvest in Virginia can be estimated in the same wave using Virginia wave 1 tag returns:

VA harvest = NC harvest/NC tag returns*VA tag returns

"Killed" tag numbers from only recreational anglers fishing were extracted from the USFWS tag database using the following codes:

Region = "COAST",
disposition="K"
recapturertype="H" or "S",
event=1
capmonth =1 or 2
capyear=2005 or 2006
State = "NC" (or "VA")

To match the tag data, estimates of wave 1 NC harvest from charter/private boats in the state territorial seas for 2005 and 2006 were extracted from the MRFSS website.

Estimates of harvest are given below

	Wave 1				Wave 1	
	NC	NC	Ratio		VA	Est.
Year	Harvest	Tag Returns	(har/tags)		Tag Returns	Harvest
2005	71981	14	5141.50		7	35991
2006	84144	23	3658.43		23	84144

Estimation of Virginia Wave 1 Harvest in 2007 and 2008

TASK 4 (Comments from Laura Lee)

In Task 4, the Board asked how the winter wave 1 fishery off NC and VA affects the age structure of the population. Gary Nelson computed the percentage of harvest that this fishery comprised of the total harvest for the stock using data from 2006. The estimated percentages at age were presented in the TC report to the board under task 4 (report attached, see page 8).

The Board did not specifically request updated harvest estimates for wave 1 from VA. Gary suggested that if we do calculate an estimate, that we include it in the annual compliance report and spreadsheet due in June. The VA wave 1 estimates for 1996 through 2004 were derived based on a correlation of tag returns to harvest. The calculation of estimates for 2005 and 2006 was tasked to Gary. Since the original correlation fell apart, he simply used the ratio of NC wave 1 harvest to NC wave 1 tag returns multiplied by VA wave 1 tag returns to estimate the wave 1 harvest for Virginia. Joe Grist provided the USFWS data to me, and, using Gary's approach, I computed the following estimates for VA's wave 1 harvest (number of fish) in 2007 and 2008:

2007 369,090
2008 879,225

However, the number of tag returns in NC during wave 1 in these years was low relative to other years (2005/06) and the method (Harvest $_{NC}$ / Tag Returns$_{NC}$ * Tag Returns$_{VA}$ is questionable

Year	NC Harvest (N)	NC Tag Returns	VA Tag Returns	Estimated VA Harvest (N)
2005	71,962	14	8	41,121
2006	85,884	23	22	82,150
2007	36,382	**3**	30	363,820
2008	41,741	**2**	41	855,690

We looked at average harvests (2005/06) / average tag returns for the same years, and 19 was the average tag returns, for the 2 years. We used that avg. harvest:average tag return (2005/06) proportion, and determined that the average (2007/08) harvest of 39,061 fish would correspond to an average of 9 tags in NC for 2007/08. That average tag return (9) was used to estimate the 2007 and 2008 Virginia harvests (numbers of striped bass).

Year	NC Harvest (N)	NC Tag Returns	VA Tag Returns	Estimated VA Harvest (N)
Avg. 2005/06	78,923	19		
2007	36,382	**9**	30	121,273
2008	41,741	**9**	41	190,153

Comparison of Wave 6 harvest (numbers), of striped bass, by recreational fisheries, in Virginia and North Carolina. Included are North Carolina ocean recreational harvests of striped bass, for Wave 1, 2005-08.

Year : From: 2004 To: 2008				Year : From: 2004 To: 2008				Year : From: 2005 To: 2008			
Wave : 6				Wave : 6				Wave : 1			
Species : STRIPED BASS				Species : STRIPED BASS				Species : STRIPED BASS			
Geographic Area: VIRGINIA				Geographic Area: NORTH CAROLINA				Geographic Area: NORTH CAROLINA			
Fishing Mode : ALL MODES COMBINED				Fishing Mode : ALL MODES COMBINED				Fishing Mode : ALL MODES COMBINED			
Fishing Area : ALL OCEAN COMBINED				Fishing Area : ALL OCEAN COMBINED				Fishing Area : ALL OCEAN COMBINED			
Type of Catch : HARVEST (TYPE A + B1)				Type of Catch : HARVEST (TYPE A + B1)				Type of Catch : HARVEST (TYPE A + B1)			
Information:				Information:				Information:			
NUMBERS OF FISH				NUMBERS OF FISH				NUMBERS OF FISH			
Year	HARVEST	NumPSE		Year	HARVEST	NumPSE		Year	HARVEST	NumPSE	
2004	44,948	19		2004	92,276	18		2005	71,982	26	
2005	53,922	23		2005	31,139	28		2006	85,884	23	
2006	114,336	15		2006	4,869	30		2007	36,382	27	
2007	18,139	20		2007	4,878	25		2008	41,741	26	
2008	39,752	18		2008	2265	36					

VA Wave 1 Harvest Estimates in 2009-2010

Three methods were used to calculate the 2009 and 2010 wave 1 harvest estimates.
Method 1 (Old Nelson): VA $harvest_i$ = NC $harvest_i$/NC tag $returns_i$*VA tag $returns_i$
"Killed" tag numbers from only recreational anglers fishing are extracted from the USFWS tag database using the following codes:

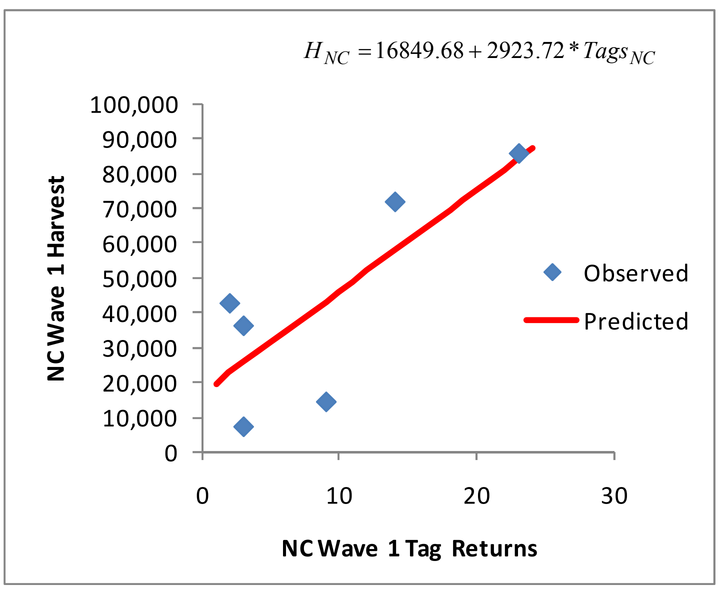
Region = "COAST", disposition="K"
recapturertype="H" or "S",
event=1
capmonth =1 or 2
capyear=2009 or 2010
State = "NC" (or "VA")

Method 2 (Lee):
Adj. NC tags (2009/10) = NC avg. harvests (2005/06) / NC avg. tag returns (2005/06) * NC avg. harvest (2009/10)

VA $harvest_i$ = NC $harvest_i$/Adj. NC tag (2009/10)*VA tag $returns_i$

This method was developed because the Old Nelson method produced unrealistic estimates for 2007 and 2008. The Adj. NC tags returns for 2009/10 is 3.

Method 3 (New Nelson):
A linear equation was fitted to the NC harvest and NC tag returns to develop an relationship between harvest and tag returns (see below). The equation was then used to calculate the VA harvest by using the values of the VA wave 1 tag returns.



The historical and current data are:

Year	NC Wave 1 Harvest	PSE	NC Tag Retuns	VA Tag Returns
2005	71,982	25.5	14	8
2006	85,884	22.9	23	22
2007	36,382	26.6	3	30
2008	42,833	27.6	2	41
2009	7,375	32.4	3	26
2010	14,523	35.2	9	6

The estimates of VA wave 1 harvest are:

Year	New Nelson	Old Nelson	Lee
2005	40,239	41,121	
2006	81,172	82,150	
2007	104,561	363,820	121,273
2008	136,722	878,077	195,128
2009	92,866	63,917	63,917
2010	34,392	9,682	29,046

The New Nelson Method was used in 2009-2010.

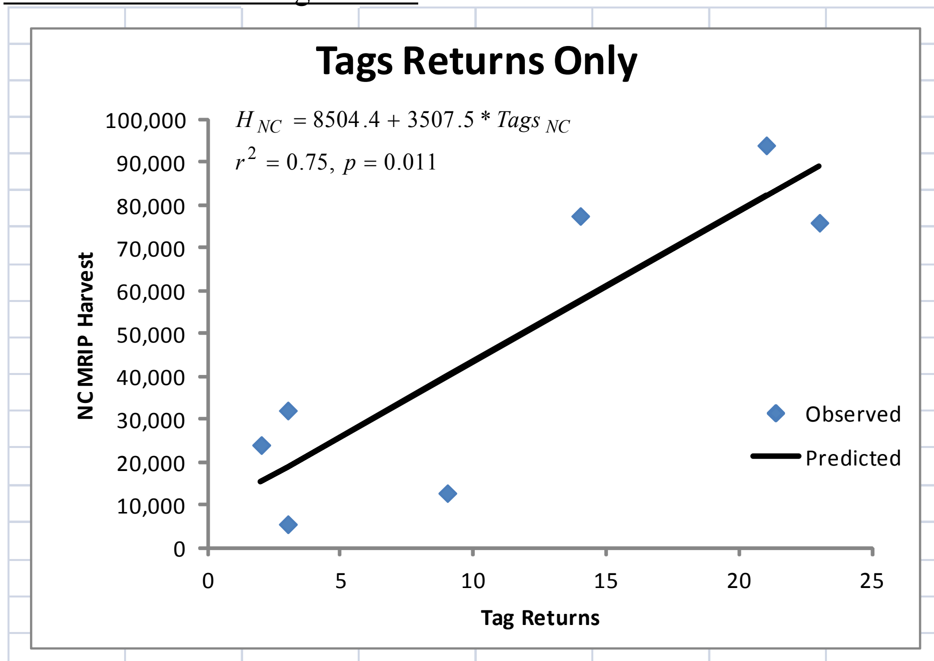
New VA Wave 1 Estimates for 2005-2011 MRIP Updated

The regression method of Nelson was updated to include the new MRIP NC wave 1 estimates of harvest and 2011 MRIP and tag data. A linear equation was fitted to the NC harvest and NC tag returns to develop a relationship between harvest and tag returns (see below). The equation was then used to calculate the VA harvest by using the values of the VA wave 1 tag returns.

Year	NC Wave 1 Harvest	PSE	Tag Releases	Tag Releases (w/o NY)	NC Tag Retuns	VA Tag Returns
2005	77,594	28	12564	9655	14	8
2006	76,031	50	12365	9142	23	22
2007	32,198	42.2	8759	5981	3	30
2008	24,129	40.5	7225	5044	2	41
2009	5,650	47.5	6369	5333	3	26
2010	12,901	46.8	7023	5550	9	6
2011	94,093	31.2	5241	4014	21	5

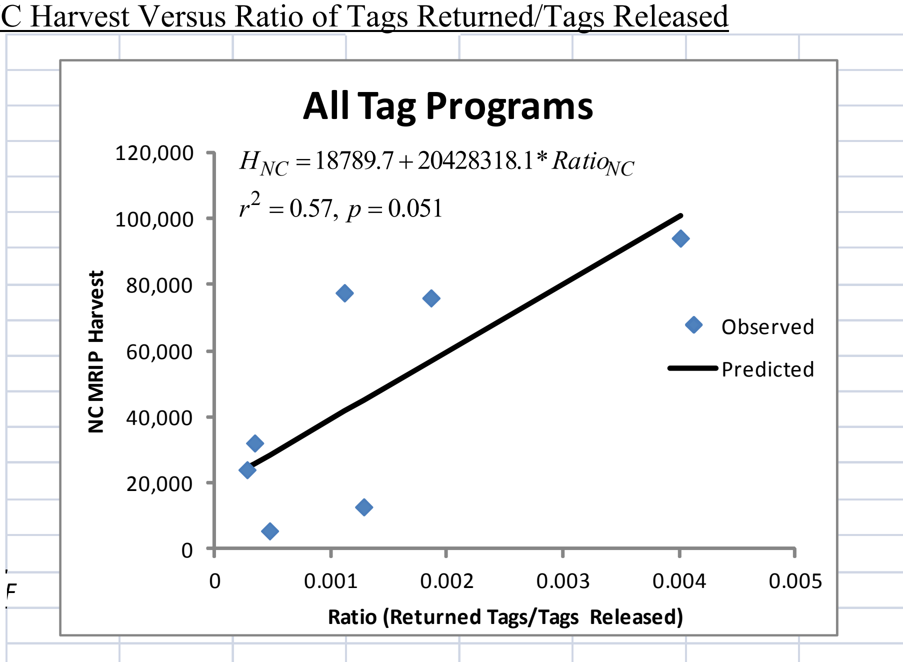
Additional analyses were conducted to determine if a better covariate might be the ratio of tags returned to the total number of fish released with tags by all tagging programs since tag returns are likely to be dependent on the total number released.

<u>NC Harvest Versus Tag Returns</u>



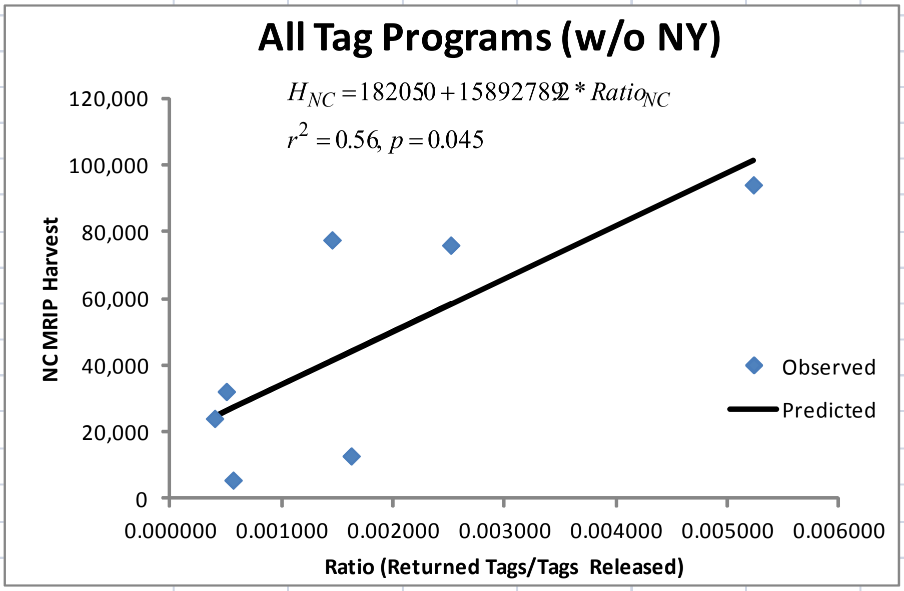
There was a strong linear relationship between MRIP harvest and tag returns for NC. The r^2 for the regression was fairly high (0.75).

<u>NC Harvest Versus Ratio of Tags Returned/Tags Released</u>



There was a moderate linear relationship between MRIP harvest and ratios for NC. The r^2 for the regression was lower (0.57) than the r^2 for the harvest-tag return regression (0.75).

Because few fish tagged in NY migrate south of New Jersey, the regression analysis was repeated with the total number of releases for NY deleted .



There was a moderate linear relationship between MRIP harvest and ratios for NC. The r^2 was lower (0.56) than the r^2 for the harvest-tag return regression (0.75). Using the number of releases did not produce better predictive relationships with harvest.

Comparison of New Updated Estimates for VA wave 1 with Previous Methods

	MRIP	MRFSS		
Year	New Nelson	New Nelson ('05-'10)	Old Nelson	Lee
2005	36,565	40,239	41,121	
2006	85,670	81,172	82,150	
2007	113,730	104,561	363,820	121,273
2008	152,313	136,722	878,077	195,128
2009	99,700	92,866	63,917	63,917
2010	29,550	34,392	9,682	29,046
2011	26,042	31,468		
		MRFSS 2011 data for wv 1 unavailable		

The New Nelson method is used for 2005-2011.

New VA Wave 1 Estimates for 2005-2012 MRIP Updated

The “New Nelson” regression method was updated to include the new MRIP NC wave 1 estimates of harvest and 2012 MRIP and tag data. A linear equation was fitted to the NC harvest and NC tag returns to develop a relationship between harvest and tag returns (see below). The equation was then used to calculate the VA harvest by using the values of the VA wave 1 tag returns.

Year	VA Wave 1 Estimates (no. fish)
2005	35,308
2006	86,386
2007	115,573
2008	155,706
2009	100,980
2010	28,011
2011	24,363
2012	64,495

Appendix B3. Recreational Fishery Monitoring Programs

Recreational Harvest and Releases

Information on harvest and release numbers, harvest weights, and sizes of harvested bass from 1982-2003 come from the National Marine Fisheries Service's Marine Recreational Fisheries Statistics Survey (MRFSS/MRIP). The MRFSS/MRIP data collection consisted of a stratified intercept survey of anglers at fishing access sites that obtains numbers of fish harvested and released per angler trip, and a telephone survey that derives numbers of angler trips. Estimation of harvest and catch per trip from intercept data considered intercepts at a location as independent samples. Estimates of harvest and release numbers are derived on a bi-monthly basis . With the establishment of the Marine Recreational Information Program (MRIP), estimates are now made assuming intercepts at a site represent a cluster of samples. Re-estimation of catch and harvest from 2004-2010 using the new methodology occurred in 2011 and is the standard used presently. The timeline of MRIP changes can be found at http://www.st.nmfs.noaa.gov/recreational-fisheries/in-depth/making-improvements-mrip-initiative/history-timeline/index.

Recreational Length-Frequencies of Harvested Fish

Most states use the length frequency distributions of harvested striped bass measured by the MRFSS/MRIP. The MRFSS/MRIP measurements are converted from fork length (inches) to total length (inches) using conversion equations. Proportions-at-length are calculated and multiplied by the MRFSS/MRIP harvest numbers to obtain total number harvest-at-length. The sample sizes of harvested bass measured by MRFSS/MRIP may be inadequate for estimation of length frequencies; therefore, some states use length data from other sources (e.g., volunteer angler programs) to increase sample sizes. Descriptions of these programs are below.

Maine
A volunteer angler program targets avid striped bass fishermen as a means of collecting additional length data. Though this has increased the sample size of the MRFSS, it still overlooks lengths and weights on sub-legal or released stripers. Because many anglers opt for catch and release, field interviewers actually see limited numbers of fish. An angler using the Volunteer Angler Logbook (VAL) records information about fish harvested or released during each trip for themselves and any fishing companions. Information about each trip is also recorded, including time spent fishing, area fished, number of anglers, and target species. At the end of the season each angler mails his/her logbook to the Department of Marine Resources (DMR), which is then copied and sent back to the angler.

Massachusetts
For released and harvested fish, volunteer recreational anglers are solicited to collect length and scale samples from striped bass that they captured each month (May-October). Each person is asked to collect a minimum of 5 scales from at least 10 fish per month, place the scales in marked coin envelopes, and record the disposition of each fish (released or harvested), fishing mode (boat or shore-based fishing), and location. Over 1,200 samples are received each year from over 30 anglers. Starting in 2005, DMF began using the MRFSS/MRIP length data and the volunteer angler harvest length data to estimate the length structure of harvested fish. This is

done by first generating the percentages-at–length from MRFSS/MRIP and volunteer program by fishing mode and then averaging the proportions-at-length across programs. DMF then estimates the harvest by fishing mode and applies the numbers to the correct proportions-at-length to get harvest numbers at length and fishing mode, and then sums across modes to get total numbers harvested-at-length. The volunteer angler data adds about 200-400 extra measurements to estimate harvest length distributions.

Connecticut
The Volunteer Angler Survey (VAS) is designed to collect fishing trip and catch information from marine recreational (hook and line) anglers who volunteer to record their angling activities via a logbook. VAS anglers contribute valuable fisheries-specific information concerning striped bass, fluke, bluefish, scup, tautog, and other important finfish species used in monitoring and assessing fish populations inhabiting Connecticut marine waters. The survey logbook is easy to fill out. Each participating angler is assigned a personal code number for confidentiality. Recording instructions are provided on the inside cover of the logbook. Upon completion, anglers tape the pre-postage paid logbook shut and drop it off in the mail. Anglers that send in logbooks are rewarded with a VAS cooler and updated results of the program. After all the logbooks are computer entered and error checked, the logbooks are returned to each participant for their own records. The CT Fisheries Division has annually supplemented the MRFSS/MRIP survey with about 2,000-3,000 length measurements from the angler survey.

New York
Prior to 2011, the MRFSS/MRIP length data were not used in any fashion. Instead, the American Littoral Society's (ALS) release data were used to estimate length distribution of both harvested fish (>28") and released fish (B2 sub-legal <28"). The sample sizes are about 5,000 fish each year.

New Jersey
New Jersey collects information on harvested fish through the Striped Bass Bonus Program (SBBP). NJ's historical commercial quota forms the basis of this program where a recreational angler can apply online for a non-transferrable permit to harvest one additional striped bass per day measuring not less than 28 inches. Upon harvest and prior to transportation, the angler is required to immediately fill out a non-transferable permit with the following information: date, location, caught, and length. This harvest information is submitted online (mandatory harvest reporting) to the NJ Bureau of Marine Fisheries for monitoring and analysis.

Maryland
There are two additional sources for size frequency data: a volunteer angler survey and the DNR creel survey during the spring trophy season. Neither of the additional surveys employ statistical design. The volunteer angler survey is described in the next MD section. The DNR creel survey was initiated in 2002. The survey samples access sites (docks and marinas) with the largest volume of recreational angler traffic during the spring trophy season (mid-April to mid-May). The number of intercepted boats has varied from 137 to 181, number of anglers from 180 to 461, and the number of examined fish from 460 to 510. Biological data collected during the survey includes total length, weight, sex, spawning condition, and age (both scales and otoliths are collected). Other fishing statistics are collected, such as number of hours fished, number of lines fished, boat type, number of anglers per boat, number of fish kept, and number of fish released.

Recreational Length-Frequencies of Released Fish

Data on sizes of released striped bass come mostly from state-specific sampling programs. Proportions-at-length are calculated and multiplied by the MRFSS/MRIP dead discard numbers to obtain total number released dead-at-length. Descriptions of these programs are below.

Maine
Release data are collected through the Volunteer Angler Survey, as described in the previous Maine section. DMR has annually supplemented the MRFSS survey with about 1200 - 9200 length measurements from the Volunteer Angler Survey.

New Hampshire
The Fish and Game Department (FGD) uses a striped bass volunteer angler survey for anglers fishing in New Hampshire. Roughly 30-50 volunteer anglers per year report information about each striped bass fishing trip they take that originates in NH. They are asked to measure every striped bass they catch (both harvested and released fish) to the nearest inch. Volunteers report on roughly 500-1700 trips each year and provide usable measurements on 1000-7000 fish each year. About 95% of the measured fish are released.

Massachusetts
For released and harvested fish, volunteer recreational anglers are solicited to collect length and scale samples from striped bass that they captured each month (May-October). Each person is asked to collect a minimum of 5 scales from at least 10 fish per month, place the scales in marked coin envelopes, and record the disposition of the each fish (released or harvested), and fishing mode. Over 2,200 samples are received each year from over 100 anglers. Approximately 1,000-1,500 lengths of released striped bass are reported each year.

Rhode Island
The size structure of striped bass released from Rhode Island's recreational fishery is based on the American Littoral Society's (ALS) release data for Rhode Island by year.

Connecticut
Release data come from the Volunteer Angler Survey, as described in the previous Connecticut section. About 2000-3000 length measurements of released fishes are obtained each year.

New York
The ALS release data are used to estimate length distribution. The ALS tags are released all around the marine district of New York all year long. Because fish can be tagged at any size, the Bureau of Marine Resources gets both legal and sub-legal length distributions, both within and outside NY's open recreational season. Thus, the length distribution for harvested fish is from the fish >28 in, and the length distribution for the released fish is from the sub-legal (i.e., <28).

New Jersey
Lengths of released striped bass are collected through a volunteer angler survey (VAS), as described in the previous New Jersey section. It is important to note that, although the VAS is primarily administered through the SBBP, the VAS and the SBBP are independent data sources. Someone does not need to harvest a Bonus fish or have a Bonus Permit in order to participate in,

fill out, and submit their logbooks. There is a broad range of participant avidity and apparent skill level – from someone that fishes once or twice a year and does not catch/harvest a single bass to someone that fishes 100 days of the year. The only ‘screening/removal’ of logbooks for analysis the Bureau of Marine Fisheries conducts is to ensure the logbooks are filled out correctly and contain the proper information. Information on the size composition of harvested and released fish as well as effort (by trip and even hours), CPUE and fishing mode are available by region. (The state is broken down into 26 different regions and each location provided by the fisherman is assigned to one of those areas.) The VAS survey was initiated in 1990 when the NJ Fish and Wildlife initiated the SBBP. VAS provides about 500-1500 length measurements on released fish per year.

In addition to the VAS, length information is also collected through Party/Charter Boat Logbooks, administered through the SBBBP. Each boat that signs up to participate in the SBBP is mailed a logbook as well as the instructions on how to fill it out properly. A Private/Charter boat does not need to use or harvest any SBBP fish to fill out or participate in the logbook survey but they do need to be a participant in the SBBP. Boat owners are asked to fill out a daily trip logbook for each trip they take when targeting striped bass, even if no striped bass are caught; they are not asked to record striped bass information when they are making trips targeting other species. They are asked to record the date, location fished, number of patrons, number of hours fished, lengths of released fish (longest length to the nearest inch), number of released fish, lengths of harvested fish, and number of harvested fish. Logbooks must be completed even if no Bonus Cards are used or all bonus cards have been used for the year. All logbooks are returned by the end of the season. Private/Charter Boat Logbooks were first collected in 1997 and have continued ever since. Much of this data has never been looked at closely or analyzed but all of the information has been entered, checked, and screened for incorrect information.

Delaware

Number at length of recreational discards are acquired annually from the American Littoral Society’s tag release database for Delaware River, Delaware Bay, and the near shore waters of the Atlantic Ocean adjacent to Delaware Bay.

Maryland

There are two additional sources for size frequency data: a volunteer angler survey and the DNR creel survey during the spring trophy season. Neither of the additional surveys employs statistical design. The DNR creel survey is described in the previous MD section. Maryland DNR has conducted a volunteer angler survey to obtain information on size structure of kept and released striped bass in the recreational fishery since 2000. The areas and time periods covered are defined by the number of responses received from anglers. Anglers are asked to provide information on the date of fishing, number of hours fished, number of anglers in the party, and method of fishing. Anglers also record the total number of striped bass kept and the total number of striped bass released and measure and record the length for the first twenty striped bass caught. A separate form is filled for each trip even if no fish are caught. If more than one survey participant is fishing on the same boat, only one designated individual is asked to fill out the survey form for the group for that day to avoid duplication. The data are submitted to MD DNR either on paper forms or via internet entry. Participation varies from year to year, which is reflected in the total number of entries. The number of reported trips varies between 200 and 300 and the total number of measured fish varies approximately from 600 to 2000 per year.

Volunteer angler survey data are combined with the MRFSS/MRIP information and MD DNR Spring Trophy Survey to characterize size frequency distribution of recreational harvest by wave. Volunteer survey data are the only source for the characterization of the discards. The volunteer survey does not provide age information.

Virginia
Data on releases are derived from the MD DNR Volunteer Logbook Survey described above.

North Carolina
North Carolina does not collect information on size of releases. Usually, release length frequency data that reflect the release sizes in NC are borrowed from other states.

Recreational Age Data

Many states collect scale samples during state sampling programs designed to collect information on harvest and released striped bass from the recreational fishery (described above). For those states that do not collect scale samples, age-length keys are usually borrowed from neighboring states. Detailed descriptions of how age samples are collected are given below.

Massachusetts
For released and harvested fish, volunteer recreational anglers are solicited to collect length and scale samples from striped bass that they capture each month (May-October). Each person is asked to collect a minimum of 5 scales from at least 10 fish per month and record the disposition of the each fish (released or harvested) and fishing mode. Over 2,200 samples are received each year from over 100 anglers. The size frequency of released fishes by mode are used to allocate MRFSS/MRIP release numbers by mode among size classes. A sub-sample of all scale samples collected (about 450-520 fish/yr) are aged and combined with commercial samples (250 fish/yr) and tagging samples (about 150-300 fish/yr) to produce an age-length key used to convert the MRFSS/MRIP size distribution into age classes. Recreational scale samples are selected using a weighted random design based on the total number of striped bass caught in each wave and mode stratum (as determined by MRFSS/MRIP).

New York
An age-length key is created using data from NY's combined projects: the cooperative angler survey, western Long Island beach seine survey, and a fall Ocean Haul Seine/Ocean Trawl survey. The cooperative angler (fishery-dependent) data is from both kept and released fish, but the geographical distribution of the samples are biased towards the Western Long Island Sound. Samples are at the pleasure of the cooperating fishers, collected - nearly all year long. Each year, anglers contribute anywhere from 500 to 5,000 samples, over a fairly wide range of sizes. The Western Long Island beach seine survey is a multi-species, fishery-independent survey conducted at fixed sampling sites in bays around the north and south shores of Long Island. Most of the samples are of small juvenile fish, but some larger adult fish are caught. Each year the beach seine survey contributes approximately 1,000 length/age samples collected over the months of April through November. The fall Ocean Haul seine survey is a fishery-independent survey conducted at fixed survey sites. The geographic distribution of sampling is biased towards the eastern South Shore of Long Island, during the months of September through December. The Ocean Trawl Survey replaced the Ocean Haul Seine Survey in 2007. It covers the geographic

area of the entire south shore of Long Island, during the month of November. Each year, about 1,000 samples are collected. The survey samples the adult coastal migratory mixed striped bass stocks. The age-length key created is applied to both legal and sub-legal fish (assumed harvest and discards), broken down into two six-month seasonal keys.

New Jersey
New Jersey collects age (scale) samples from harvested and released fish through a biological sampling program. In 2010, New Jersey instituted new protocols for targeting fishing tournaments and party/charter boats in the spring and fall in order to streamline the collection process and eliminate duplicate data or data not being used for the coastal assessment. A recent decrease in sample sizes necessitated a change in the methods used to collect samples resulting in the development of a new long-term plan. This information is collected, monitored, entered and analyzed by the NJ Bureau of Marine Fisheries.

Delaware
Recreational age data is compiled from directed fishery sampling in the summer slot season (July 1 – Aug 31) and the fall recreational fishery. Length, sex, scales, and otoliths are acquired from each fish, and when available, weight.

Maryland
Direct age data are available from the creel survey of the trophy fishery only. Both scales and otoliths are collected from the fish examined in creel survey. For periods not covered by the creel survey, an age-length key developed from the samples of commercially harvested fish is applied to recreational length frequency to characterize age structure of the recreational harvest.

Virginia
Most age data are collected from the commercial fishery. The sampling group will sometimes sample from one or more recreational tournaments, but not in every year. In 2004, there were two length and age samples; no sampling of tournaments occurred in 2005.

5.1.2.5 Recreational Harvest-At-Age

Recreational harvest-at-age is usually estimated by applying corresponding length-frequency distributions expanded to total numbers of harvest-at-length and age-length keys to the MRFSS/MRIP number of fish harvested by the recreational anglers in each state. State-specific descriptions of the estimation procedures are below.

Maine
DMR uses age-length data collected by MA DMF. The age-length key is applied to the Volunteer Angler Survey lengths, which is then applied to MRFSS/MRIP estimates of harvested fish.

New Hampshire
FGD uses age-length data collected by MA DMF. The age-length key is applied to the Volunteer Angler Survey lengths, which is then applied to MRFSS/MRIP estimates of harvested fish.

Massachusetts
Harvest numbers-at-age are generated by applying total numbers of harvested fish by length to the age-length key as described above.

Rhode Island
Age-length data collected by NY DEC and MA DMF are combined to create annual age-length keys. The combined NY-MA age-length key is applied to the expanded length frequencies from RI's recreational fishery to estimate recreational harvest-at-age on an annual basis.

Connecticut
The Fisheries Division uses age-length keys from Long Island Sound provided by NY DEC and applies the numbers-at-length obtained from the volunteer angler survey.

New York
The MRFSS/MRIP numbers of harvest and releases by wave are disaggregated by the ALS length frequency distribution (calculated by wave). The numbers at length are added by wave together into two seasonal length distributions. The seasonal length distributions are multiplied by the seasonal length/age keys created (see above) for legal (i.e., >28 inches, harvest) and sub-legal (i.e., <28 inches, releases) fish. The length distributions are adjusted, due to the conversion of ALS data from fork length to total length and the "gaps" which result, by averaging the values before and after the interval with no observed frequency. Next, the numbers are added for each season. Occasionally there is a need to re-adjust for the actual numbers of harvest or releases from MRFSS/MRIP due to the adjustments and rounding.

New Jersey
New Jersey uses the length frequency information gained from the Striped Bass Volunteer Angler Survey to characterize the length structure of NJ's recreational harvest of striped bass and the MRFSS harvest data by season (fall and spring) to expand the length frequency data. A variety of age sources are then used to develop NJ's age-length key by season. For the spring key, age data from NJ's Delaware Bay Striped Bass Tagging Survey (occurs in March – May), NJ's January, April and June cruises of the Ocean Trawl Survey, and spring harvested and released striped bass from tournament and party/charter boat biological sampling are used. To develop NJ's fall age-length key, age data from the August and October cruises of the Ocean Trawl Survey and fall harvested and released fish from the tournament and party/charter boat biological sampling are utilized. The appropriate seasonal age-length key is then expanded to the length frequency information to develop NJ's striped bass harvest by age and season.

Delaware
Delaware's recreational harvest at age data is developed from the known harvest of 3 distinct sectors of the fishery. Spring landings numbers, lengths, and weights are acquired from MRIP Wave 2 and 3 reports. Age at length is derived from the DFW's spawning stock survey in April and May. Delaware's summer slot (20" - 26") landings numbers, lengths, and weights are acquired from MRIP Wave 4 reports. Age at length is derived from DFW's sampling of harvested slot fish during July and August. Recreational harvest (landings, weight, and lengths) for the remainder of the calendar year is acquired from MRIP Wave 5 and 6 reports. Age at length data is derived from DFW sampling of recreationally caught fish during October through December.

Potomac River Fisheries Commission (DC)
Length and age data collected from the commercial fisheries are used to generate recreational numbers-at-age.

Maryland
Length frequency of recreational harvest is characterized using MRFSS/MRIP, VAS, and creel survey length data. The age-length key derived from the spring spawning survey is applied to length frequency for waves 2 and 3. For waves 4–6, an age length key derived from samples of commercial harvest is used.

Virginia
A catch-at-age matrix is developed, starting with an age-length key from the commercial samples of length and weight and proportions of harvested striped bass at length from MRFSS/MRIP.

North Carolina
The NY age-length key is used along with length frequencies to apportion harvest numbers into age classes.

<u>Recreational Dead Discards-at-Age</u>
The number of dead discards-at-age is usually estimated by applying corresponding total numbers of dead discards-at-length to age-length keys. State-specific descriptions of the estimation procedures are below.

Maine
DMR uses age-length data collected by MA DMF. These data are applied to the Volunteer Angler Survey lengths, which is then applied to the dead discard estimates.

New Hampshire
FGD uses age-length data collected by MA DMF. These data are applied to the Volunteer Angler Survey lengths, which is then applied to the dead discard estimates.

Massachusetts
Dead discards-at-age are generated by applying total numbers of discards-at-length to the age-length key described above.

Rhode Island
Age-length data collected by NY DEC and MA DMF are combined to create annual age-length keys. The combined NY-MA age-length key is applied to the expanded length frequencies from Rhode Island's recreational fishery to estimate recreational releases-at-age on an annual basis.

Connecticut
The Fisheries Division uses age-length keys from Long Island Sound provided by NY DEC and applies the dead discards numbers-at-length.

New York
The MRFSS/MRIP numbers of harvest and releases by wave are disaggregate by the ALS length frequency distribution (calculated by wave). The numbers at length are added by wave together into two seasonal length distributions. The seasonal length distributions are multiplied by the seasonal age-length keys created (see previous NY section) for legal (i.e., >28 inches, harvest) and sub-legal (i.e., <28 inches, releases) fish. The length distributions are adjusted, due to the conversion of ALS data from fork length to total length and the "gaps" which result, by averaging the values before and after the interval with no observed frequency. Once complete, the numbers are added for each season. Occasionally there is a need to re-adjust for the actual numbers of harvest or releases from MRFSS/MRIP due to the adjustments and rounding.

New Jersey
New Jersey uses the length frequency information gained from the Striped Bass Volunteer Angler Survey to characterize the length structure of NJ's recreational harvest of striped bass and the MRFSS harvest data by season (fall and spring) to expand the length frequency data. A variety of age sources are then used to develop NJ's age-length key by season. For the spring key, age data from NJ's Delaware Bay Striped Bass Tagging Survey (occurs in March – May), NJ's January, April and June cruises of the Ocean Trawl Survey, and spring harvested and released striped bass from tournament and party/charter boat biological sampling are used. To develop NJ's fall age-length key, age data from the August and October cruises of the Ocean Trawl Survey and fall harvested and released fish from the tournament and party/charter boat biological sampling are utilized. The appropriate seasonal age-length key is then expanded to the length frequency information to develop NJ's striped bass harvest by age and season.

Delaware
Dead discards at age for Delaware are calculated as 8 percent (assumed mortality) of the total discard numbers from MRIP wave reports by season (spring and fall). For the spring, age at length is derived from DFW's spawning stock survey in April and May. For the fall, age at length is derived from DFW's recreational sampling conducted during the months of October through December. Age at length of sub-legal discards caught during the fall is derived from the DFW's trawl survey and the spring spawning stock survey.

Potomac River Fisheries Commission (DC)
Length and age data collected from the commercial fisheries are used to generate recreational numbers-at-age.

Maryland
Length frequency of recreational releases is characterized using MRFSS/MRIP, VAS, and creel survey length data. The age-length key derived from the spring spawning survey is applied to length frequency for waves 2 and 3. For waves 4–6, an age-length key derived from samples of commercial harvest is used.

Virginia
Release numbers (discards from the recreational fishery by spring (Waves 2,3) and summer-fall (Waves 4,5,6)) are apportioned to age classes, using the MD DNR Volunteer Angler Survey

proportion of discards-at-age and proportion of discards-at-length, expanded according to seasonal harvest in numbers.

North Carolina
The NY age-length key is used, along with length frequencies, to apportion release numbers into age classes.

Appendix B4. Report of the Striped Bass VPA Indices Workshop

Baltimore, MD
July 28 & 29, 2004

List of Participants

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Workshop Purpose

Impetus: "An objective discrimination of which tuning indices to include or withhold from the model should be integrated in the next assessment." 36th SAW Advisory

Goal: Develop criteria for the inclusion/exclusion of current and future indices for aggregate or age-specific (≥age 2+) used in the striped bass virtual population model.

Objectives: Critically evaluate the survey design and precision of the index, and validate each index by comparing it to other area indices. If applicable, determine how the survey design should be modified to be more valuable.

Background: The Role of Indices in the VPA

Indices are used in the tuning process as a relative index of abundance (abundance at age). Some surveys provide an aggregrate index and others provide an age specific index. Some may be appropriate for aggregation due to precision; others are more precise as an age-specific index.

ADAPT uses the entire time series to determine relative abundance of the cohort in the terminal year. The longer the time series the more information the model has to produce an estimate. After the model produces the estimate, the stock assessment subcommittee evaluates the correlation of the index to the known abundance as the VPA has estimated it.

Evaluation Criteria

The Workshop participants began the discussion with the some suggested guidelines provided by Gary Nelson prior to the meeting. The guidelines are as follows:

a. Have a sampling design
b. Have an acceptable level of precision (if applicable)
c. Has it been validated? (i.e., is it correlated with indices of abundance of other life stages, etc.)

The sampling design should be appropriate to achieve the objectives of the survey. Additionally, the sampling design should produce a precise estimate. Further indication of a good index is the validation of the survey, comparing it to another index that shows similar trends. There should be a correlation between indices sampling similar portions of the coastwide stock. If an age class can be followed through time, it is also indicative of a good survey.

Taking Gary's suggestions a step further, John Hoenig developed a set of discussion points regarding the index. The following list includes the John points plus additional comments from other participants.

1) Correlation of an index with the VPA is not an appropriate evaluation criterion unless the index pertains to the whole stock. (If substocks in the North go up, as reflected in three indices, and substocks in the South go down, as reflected in one index, you'd get a biased

picture if you eliminated the southern index just because it disagreed with the average (which is dominated by the North)).

2) Validity of sampling design can be used to determine inclusion. An index should not be evaluated based on an inappropriate variance. The appropriate variance can be determined based on the survey's sampling design. For example, if one site is sampled repeatedly (e.g., a pound net) the sample size is one (i.e., one site).
3) The number of sites and the number of days sampled may be useful criteria; a minimum number of fish sampled might be appropriate *in combination* with other factors (number of sites, etc.)
4) All indices should be treated "equally" to be "fair".
    a. If you evaluate one index you should evaluate all of them.
    b. You can kick out indices but there must be a way to reinstate them and there must be a way to introduce new indices that is "fair" in the sense of holding the index to the same standards as other indices.
5) If you want to make a change to the set of indices, it is important to do two assessments in parallel – one the old way and one the new way for several (e.g., 3) years. Otherwise, you can't distinguish between changes in stock perception due to methodology and changes due to stock dynamics.
6) If an index represents only a portion of the stock complex then it should receive a weight less than one. The stock assessment subcommittee has typically weighted the indices according to how well they fit the VPA, e.g., using iteratively reweighted least squares.
7) If an index is unique in representing a particular portion of the stock complex, then it may be desirable to retain the index even if it is not perfect.
8) The primary criterion thus would appear to be whether an index tracks weak and strong year classes well. An index can be considered poor if year-to-year changes in catchability obscure abundance trends.
    a. In looking for year effects, it is not appropriate to look at the residuals from the VPA unless the index being evaluated pertains to the whole stock.
    b. If one plots age-specific indices versus time, then synchronous peaks and valleys (all indices going up and down together) is problematic.
9) If age-specific indices are problematic, the program might still provide an aggregate index
10) Validation of one index against another index from the area provides support for the two indices.

Some of the indices used in the VPA assessment are age-specific and some are age-aggregated indices. It might be necessary to develop different criteria for the two kinds of indices. Before eliminating an age-specific index, the survey should be considered as an aggregated index. The problem with the index may be the ageing. It could still track the stock appropriately as an aggregate.

The Stock Assessment Subcommittee currently uses iterative reweighting for the surveys, meaning the survey weighting is based on how well the index fits the estimate produced by the VPA. The VPA is currently used to derive a single estimate of the fishing mortality on the coastal migratory stock. Ideally, there would be stock specific VPAs that are combined into one coastwide assessment.

If you believe that the particular index gives you reliable representation of the dynamics and abundance of the species in the particular area, then an estimate of variability of the index is needed. Also, you need to know if the same index is representative of the stock coastwide because we are looking for an ideal index of relative abundance that would be truly representative of the stock coastwide. An alternative to the VPA's iterative reweighting would be to assign weights to each index based on an assumed contribution to the overall coastwide migratory stock.

There is some concern about apriori weighting because an index may represent the local stock accurately. Also, as the stocks have rebuilt over time the contribution to the coastal stock has increased. There is uncertainty as to how this can be accounted for in the apriori weighting.

Review of Sampling Program and Indices

The participant agreed to many of the points in John Hoenig's list, but not all. The group decided to continue with a review of the sampling programs. The evaluation criteria would be further refined as the surveys are reviewed.

Massachusetts – Commercial CPUE Index (Gary Nelson)

The Massachusetts Commercial catch per unit effort index has been used in the VPA assessment since the Striped Bass Stock Assessment Subcommittee has used the VPA. The unit of effort has changed over the course of the time series. The method for calculating the CPUE has changed over time with different MA DMF personnel. The time series has been recalculated using a consistent methodology.

The index is really a measure of commercial harvest per effort or an estimate of the number of fish sold per trip. It uses the weight of the fish reported by the dealer and the average weight of the fish measured in the fish house. The average is then weighted by the total fish (whole fish) landed in each county. The total weight reported is an absolute (no variance), but the average weight is estimated so the variance is included. The number of trips comes from the required catch reports. Fishermen must submit catch reports to receive a license for the following year. Catch reports include information such as hours fished, number of fish sold and released by month, and dealer transactions. This survey is used as an age aggregated index and age-specific index.

The sampling design is not ideal for this index because the sampling is dependent on which fish house lands striped bass. Three counties in Massachusetts make up about 80% of the total landings. The information gathered in the fish house does not provide information about the trip, whether it was landed as a direct or indirect take. Most of the Massachusetts striped bass fishermen are weekend warriors.

There are a few problems with the survey design. Permits are issued to the boat, not individuals. Therefore, an average trip per boat is estimated not per fishermen. The number of fishermen is not collected. In Massachusetts, this fishery is hook and line only and has a trip limit of 40 fish per day. There could be five guys on a boat for one hour catching 40 fish or one guy out there all day catching 40 fish.

The catch per effort per trip is not well defined because the information is not collected. There are over 4,300 people permitted but Massachusetts only receives 100-200 voluntary logs with trip dates, numbers caught, hours fished per trip. The average hours fished is estimate from the logbooks. Average hours fished contributes to variability in the survey. There can be hours fished with zero catch. Even though commercial fishermen are required to submit catch reports, not all submit the report despite the penalty of losing the permit in the next year. So Gary has to impute the fish caught using the information he does have. Additional information may be available through the VTR data for commercial fishermen holding a federal permit.

This survey has a multiple stage sampling design, meaning it needs a randomly sample a fish house and then randomly sample the fish. The variance estimate is conditional on assumption of random sample, but sample may not be representative. The fish that end up in the fish houses are random, but the selection of which fish house is sampled is not random. Therefore, we do not know if the sample is representative of all the catch because it is not random. Bootstrapping does not confer validity on an index.

The group discussed the difficulty of setting one standard for all the surveys – the protocol for variation estimation will depend on the survey design, therefore will not be consistent across all surveys. The index should not be thrown out because it's not perfect, especially if there is not another index to replace it and its representative of the area.

The number of trips is declining because the quota is filling more quickly. There is a jump in the CPUE from 1994-1995 because there was a change in the minimum size and the commercial quota also increased. The group is not confident that the CPUE represents the population, particularly the fishery has capped out the quota since 2000. Also, in a representative catch, the cohorts can be followed through the samples. The 1993 yearclass was strong and it cannot be followed through the MA CPUE. One suggestion was to apply a length frequency to the ageing samples for a more representative sample.

For an age-specific index, Massachusetts could randomly pick a fish box to collect samples. The proportion of ages in a sample could be applied to the aggregate index. Massachusetts had to cut down on the sizes of age samples from the fish house due to personnel cut backs.

Connecticut Recreational CPUE and Trawl Survey

Connecticut submitted information regarding the trawl survey, but did not provide information on the recreational catch per unit effort. Additionally, there was no representative from Connecticut in attendance at the Workshop. The Connecticut surveys were not reviewed at this time.

New York Long Island Ocean Haul Seine Survey (Vic Vecchio)

Originally, the survey had 10 sampling locations that consisted of inshore sandy sites. The locations were randomly sampled from October to November. After the commercial striped bass fishery reopened, commercial trawls were prohibited from state waters. Some localities prohibit NY DEC from accessing traditional sampling sites. In New York, fishermen are not allowed to use ocean haul seine survey to commercially catch striped bass, but can use to fish for other species. The estimates derived from 10 sampling locations were compared to the results with fewer sampling locations. There was no difference in the ages in the catch. Additionally, funding has been reduced impacting the sampling dates and actual survey catch. The dates of the older survey have been standardized.

In reviewing the time series, it is interesting to note that the catch jumped in 1996-1998 due to the 1993 and 1996 yearclasses. Also, in some cases the coefficient of variance exceeded the catch. Bootstrapping would be appropriate for the New York data.

Age samples are taken from every fish measured in the survey. New York is able to produce an estimate of geometric mean catch at age for each survey year. The CV is then calculated for the catch at age and an averaged from 1997-2003 is produced. The survey is not very good at catching the larger fish, so the sample sizes for the older fish are pretty small.

The survey samples a mixed stock. To evaluate the survey, the ocean haul seine survey was correlated to the YOY index. Out of 13 age groups, 11 had positive correlation, but only 6 had a significant correlation.

New Jersey Trawl Survey (Tom Baum)

The New Jersey trawl survey has a stratified random sampling design. The survey occurs in April and October. Decreases in funding have led to reductions in annual sampling effort, from 60 to 45 seine hauls. New Jersey's survey was not designed to sample striped bass survey; it was originally for sampling groundfish. Striped bass are tagged when feasible.

In a typical year, there are 30-40 tows in 18 strata, which comes out to about 2 tows per site. The CVs are pretty low in the later half of the time series. The high CVs in the latter half of the time series could be attributed to low sample sizes at each stratum. The standard error should be checked to determine if it was calculated for a stratified random design.

The survey is used as an age aggregated index, aggregating ages from 2-13. April and October are used as separate age aggregated indices because the length frequencies differ significantly, representing different stock composition. April survey is more consistent and therefore probably the better candidate for an age-specific index. New Jersey has an age-length key for every year, so most of the information is available for switching over to an age-specific index. If the survey measures all of the fish caught, then it could be used as an age-aggregated index. It is possible to get age specific data, but New Jersey is not likely to produce the data.

To reduce the variance, some of the strata should be thrown out because no striped bass were caught in that location. The strata should only be removed from the index if there were no striped bass throughout the time series. The variance can be a problem with fixed station trawl surveys because there is no random element to the survey.

Delaware Trawl Survey (Des Kahn)

The Delaware trawl survey began during the 1960's, but the exact start date is not well documented. The survey collects weight rather than numbers of fish (kilograms per tow of striped bass). The time series is disjointed because a different vessel was used in the first two segments of the time series. In 2002, the survey began using a new custom-built stern rig trawler. Comparative tows were conducted to get a handle on the catchability of the two vessels.

The trawl survey uses a fixed sampling scheme. It was selected due to the lack of towable bottom in Delaware Bay. The index was conducted the whole year. Due to the number of zero tows, the data was jackknifed – used for situations were the distribution assumptions may not be true. Jackknife does not deal with the lack of distribution of the data; it does assume that the sample is representative of the population from which it is drawn.

The sample size is the number of months that were sampled. In some years, the trawl survey did not operate in March. In each month, the fixed sites were sample nine times.

The trawl survey is used as an aggregate index in the VPA (age 2-7). There is age data available from 1998 forward. To validate the index, it should be compared to another mixed stock index. The lagged juvenile index is often used to confirm trends.

Delaware Spawning Stock Survey (Greg Murphy)

The Delaware River spawning stock survey collects age, size, sex, and abundance estimates for striped bass. The survey began in 1991 experimenting with three different collection methods and has continued using electrofishing since 1994. The survey divided the Delaware River into two zones based on river access. There are twelve Delaware stations and fourteen Pennsylvania stations. Over time, some of the stations have been lost due to development.

The stations cannot be considered random, but the observations at each station are random. The survey has a multistage lattice design. The strata are sampled independently of another (i.e. sampling does not affect other sites). The lattice survey design imposes a structure to control the number of times each area sampled.

Another challenge that confronts the survey has been the moving salt line, which can restrict the sample areas upstream where electrofishing is effective. Reviewing its correlation to other life stages, such as a juvenile survey, could validate this survey.

Maryland Spawning Stock Survey (Linda Barker)

The objective of the Maryland's spring gillnet survey is to characterize the Chesapeake Bay portion of the spawning stock biomass and provide a relative abundance at age. The survey area at one time covered the Chesapeake Bay, Choptank River and Potomac River, but the Choptank River has since been dropped from the survey. A stratified random design is used to sample the spawning areas.

The group discussed the survey's sampling design to determine if it was truly randomly stratified. Because Maryland DNR samples the same site twice in some days, the design can be referred to as two-stage cluster sampling. It is important to correctly identify the sampling design to properly calculate the variance.

For each sample, all of the striped bass are measured, all females are aged, but only males greater than 700 mm are aged and smaller males are subsampled. Since 2000, approximately 500 fish are aged per year. The group recommended developing area and sex specific age length keys. MD DNR should also look into applying selectivity coefficients.

The survey has revealed that it does not accurately capture the spawning stock biomass as it collects samples of fish ages 2-8. There is a very low variance for ages less than 8 years old and higher variable estimates for ages greater than 8 years old. The number of age 8+ appearing in the survey has increased since the moratorium. The fish caught in the survey are mostly males (age 2-8) and the ages 10 and greater are mostly females. The data is representative of the behavior of the fish, capturing mostly males. The CPUE provides a decent relative abundance at age, but it is not doing a good job of characterizing the spawning stock survey.

Virginia Pound Net Survey (Phil Sadler)

Since 1991, Virginia Marine Institute of Science has conducted the Viginia pound net survey. The pound net survey takes place on the striped bass spawning grounds in the Rappahannock River between river miles 44-47. VIMS has the option of sampling up to four commercial nets. The upper and lower nets are used for this survey and the middle nets are used for tagging. VIMS alternates sampling between the upper and lower nets. The sampling occurs from March 30 to May 3, when the females are on the spawning ground. The pound nets are checked twice a week, but are fishing constantly. When the samples are collected, the fish are sexed and measured, scales are taken from every fish, and a subsample of otoliths.

The sex ratio in the catch tends to be two males to every female. The females captured in the survey are generally ages 4 and older and males are age 3 and older. There appears to be no bias in net catchability.

There are several periods where no fish were caught. By averaging the CPUE data, the estimate is low. To eliminate the zero effect, VIMS could graph CPUE by date and determine the area under the curve.

The Workshop participants had a lengthy discussion on the Virginia pound net survey because it is an example of a survey that was removed in recent stock assessment due to poor performance in the VPA. The Virginia pound net survey provides an estimate of catch in the commercial fishery. If a variance is estimated, it is not an estimate of the striped bass abundance rather it is the variance for the commercial catch. The workshop participants suggested several ways to evaluate the survey. Local juvenile surveys can be used for validation. A longitudinal catch curve can also be applied to investigate year effects, specifically to detect downward trends. The catch curves explain how often the striped bass are seen and if the patterns are explainable.

VIMS should also examine the temporal window and the spatial window to evaluate the survey design.

NEFSC Trawl Survey (Gary Shepherd)

The NEFSC trawl survey uses a stratified random design and assumes that time is irrelevant. The index samples fish from Nova Scotia to North Carolina. It is an eight-week cruise, completed in four two-week legs. Fishing occurs 24 hours per day. The survey did not really start to encounter striped bass until 1991. The survey has shown a general upward trend since 1990. The catch distribution tends to very from year to year and the sizes encountered are also variable.

The NEFSC trawl survey data would be a good candidate for an age-specific index. An age-length key from the New Jersey March-April gillnet survey could be applied to the NEFSC samples. The NEFSC survey is important because it is the only survey to cover the range of the coastal migratory stock. For a good index, the NEFSC would need 400 ageing samples. The fish are encountered in different locations in different years. So the appropriate key needs to applied to the samples. For the fish encountered in the southern range, an age-length key could be derived from the North Carolina Cooperative Cruise.

VPA Output Compared to the Indices

The group reviewed the ADAPT VPA output from last year's assessment to each of the indices reviewed during the workshop. The VPA predicted the indices very well when there weren't many striped bass. As the stock increased, the variance went up with the mean. If one of the criteria for inclusion was the index must follow the same trend as the VPA, then none of the indices would be used. The coastal indices should carry the same signal as the VPA output because they characterize the coastal migratory stock. Some of the indices may not align with the VPA because they were down weighted.

Several of the indices show spikes. The spikes should be compared to other indices to determine if there is correlation. The coastal indices should be reviewed to determine if there are spikes that correlate with one another or the VPA output. To determine the validation of the indices, it would be helpful to know how the VPA weighs the indices.

The stock assessment subcommittee has typically used the bootstrap estimates to determine the variation in the surveys. All of the surveys are entered into the VPA and the bootstrap estimates determine if it is appropriate to include each index.

On the other hand, the VPA produces an estimate of the overall stock complex abundance. To use the VPA to evaluate the indices may mean eliminating an index that does not track the overall stock complex, but tracks local trends accurately. An index should not be removed without a legitimate reason for removing the index. The effect of each index on the VPA should be analyzed.

General Overview of Survey Issues

The sampling design of each survey was a common theme for discussion during the review of the indices. There tends to be two separate types of programs. The first group includes the NEFSC trawl survey and the Maryland Spawning Stock Survey. These two surveys are randomized over space. The second group includes other programs such as MA CPUE, which is a census of commercial catch rates, but fishermen are not fishing over random fish. The New York ocean haul seine survey is not randomized over space. The Virginia pound net survey uses two nets over fixed locations. Delaware is randomized, but only 30% can be sampled.

There is confidence that the Maryland spawning stock survey and the NEFSC trawl survey are catching a representative sample of the population because both surveys are randomized over space. Both surveys can get a valid variance. The sampling design of the other surveys may not be randomized; therefore it cannot be assumed that the surveys are a good representation of the stock. Without randomization, the estimate of variance for each survey may not be appropriate.

The Virginia pound provides a good estimate of the fishermen's catch rate, but the variance is not very useful. The NEFSC survey is not designed to catch striped bass and does catch a lot of striped bass. The variance is only useful for qualitative purposes. Variance estimates are for the survey index.

In addition to variance, age information is collected through the indices, despite some of the ageing error issues. Another important measure for the indices is the ability to track cohorts over time. There needs to be confidence that the survey is tracking cohort abundance in a logical trend. Catchability can influence the ability of a survey to track a cohort over time. If the design of the survey changes, the catchability can change.

A survey could reflect logical trends for 8 of the 10 years, straying from the trend in the remaining two years. Those two years could be eliminated if there was adequate evidence that is was due to abnormal climatic conditions influencing fish abundance.

To verify a cohort trend, the survey can be compared to a local young of the year index. States would need to be careful about using the index to validate the juvenile survey and vice versa. In some areas, a young of the year index may not be available for comparison. In these situations, a catch curve could be applied to the cohort. Longitudinal catch curves could be used, not to estimate mortality rates, but to see if there is trend that is useful.

Ideally, the stock assessment will include the same indices as in previous years and then a separate run is made to remove more questionable indices. There should be some guidelines for removing an index from the model run or at the very least an explanation provided in the assessment report. To evaluate an index for inclusion, one could plot the indices by year for each cohort. If one of the indices has a dramatically different trend, the index is not tracking things well. It is important to remember that an index can be valid for a local area, but not for the stock complex. It may track a different trend or a local stock. For example, Chesapeake Bay recruitment correlates well with the Delaware River recruitment, but not the Hudson River.

Striped bass is a stock complex measured by local indices, but the stock complex abundance is supposed to be annually evaluated.

Recommendations for criteria to evaluate the VPA indices

The Workshop participants developed a list of evaluation steps that should be applied to each index. The state agencies should use the evaluation list for each state survey. Each program should be analyzed to determine if the survey is conducted at the appropriate time of year, i.e. bracketing the correct spawning period. Similarly, the survey design should be reviewed by the state to determine if the sampling area is correct. If the state determines there is a lot of noise in the data, the state should attempt to refine the data. For instance, if some of the stations catch striped bass consistently and others do not, can something be done to refine these data? The states should identify if the indices are sex-specific indices or age-specific due to survey design. Because a self-evaluation by each state could be subjective, the Technical Committee should evaluate the state's program evaluation and make a recommendation to the Striped Bass Stock Assessment Subcommittee.

1. Evaluate design and best method to evaluate uncertainty of index.
2. Assess the index and/or improve the index to get the best signal.
3. Validate the index before use in the VPA.
    a. Sensitivity of the VPA results to the influence each index.
    b. Validate an index to a JAI, where possible.
    c. Longitudinal catch curves, to determine the cohort trends.
    d. Plots of age specific index v. year to see if cohorts are moving in a specific direction.
4. Evaluation by the agency conducting the survey
    a. Rank (weight) index
    b. Criticisms/Supporting Evidence
5. Evaluate by the Striped Bass Technical Committee
    a. Evaluate index based on survey design, precision, and ability to track cohorts or portion of the stock targeted.
    b. Provide recommendations to the Striped Bass Stock Assessment Subcommittee on which indices should be used in the assessment.

The Workshop participants developed a matrix in Excel that includes the important components for evaluating each index (sampling design, time of year, tracking stock or catch, etc.). Also included in the matrix are recommendations to improve and evaluate the survey.

PURPOSE: TO ESTIMATE FINAL YEAR ABUNDANCE							
SURVEY	**SINCE**	**SAMPLING DESIGN**	**TIME OF YEAR**	**STOCK OR CATCH**	**WHAT STOCK?**	**AGES**	**VARIANCE?**
NMFS (TOTAL, REC HARVEST)		SURVEY	ALL	CATCH	MIXED		YES??
NEFSC CRUISE		STRAT RANDOM	SPRING/FALL	STOCK	MIXED		YES
MASS COMM CATCH		NONE	ALL	CATCH/HARVEST	MIXED		
RI - FLOATING TRAPS?							
CONN TRAWL SURVEY				STOCK	MIXED		
CONN REC CATCH				CATCH	MIXED		
NY HAUL SEINE		FIXED STATION	FALL	STOCK	MIXED		
NY HUDSON SPAWN SURVEY		STRAT RANDOM		STOCK	HUDSON	5-10	YES
PA RIVER SURVEY							
NJ TRAWL SURVEY		STRAT RANDOM	SPRING	STOCK	MIXED		YES?
NJ REC CATCH		NONE	ALL	CATCH	MIXED		NO
DEL RIVER SURVEY		CLUSTER??	SPRING	STOCK	DEL		
DEL TRAWL SURVEY		FIXED STATION	ALL	STOCK	MIXED		
MD JI		FIXED STATIONS	SUMMER	STOCK	CBAY		
MD SPRING GILLNET SURVEY	1985	STRAT RANDOM	SPRING	STOCK	CBAY		
VA POUND NETS	1991	FIXED STATIONS		CATCH	RAPP	3+	YES/NO

SURVEY	EVALUATION/CRITERIA	RECOMMENDATIONS
NMFS (TOTAL, REC HARVEST)		Define what an index would be using total catch and effort
NEFSC CRUISE		Age fish samples from trawls; review strata choices
MASS COMM CATCH		Standardize minimum length numbers; compare lengths of subsamples to length of all; examine applying age-length keys;develop index with total catch; adjust index for covariates; examine whether change in week-end warrior composition
RI - FLOATING TRAPS?		see if data is available for development of an index
CONN TRAWL SURVEY		segregate into age-specific indices; use age-length key instead of VB equation
CONN REC CATCH		Describe and evaluate
NY HAUL SEINE	AGAINST TOTAL JI? NY JI?	resestimate precision using bootstrap; compare index at age to Jis individually
NY HUDSON SPAWN SURVEY		Describe and evaluate; generate age-specific indices with appropriate variance
PA RIVER SURVEY		Describe and evaluate
NJ TRAWL SURVEY		Examine strata choices; generate age-specific indices using April data
NJ REC CATCH		determine if development of an index is possible
DEL RIVER SURVEY		investigate area under curve method for possible spatial distribution issues; examine temporal disitribution within strata; compare upper river index to PA survey
DEL TRAWL SURVEY		change biomass index to numbers; generate age-specific indices; compare indices to VPA for age 1
MD JI	AGAINST LAGGED CATCH	
MD SPRING GILLNET SURVEY		examine first vs second set;review impact of sex-specific catchabilities
VA POUND NETS	AGAINST JI, LONG CATCH CURVES, YEAR EFFECTS, CATCH VS. TEMPORAL WINDOW	AGAINST JI, LONG CATCH CURVES, YEAR EFFECTS, CATCH VS. TEMPORAL WINDOW; examine flow regimes; compare index to MDs

Summary of Responses To Workshop Recommendation

Survey	Index Type	In VPA?	Workshop Recommendations	Recommendations Addressed?	PSE Range	Attempted Validation?
NEFSC	Age-specific: ages 3-11	Yes	Age fish samples in trawl;review strata choices	No	No PSEs provided for age-specific indices. Untransformed, aggregate index PSEs (91-04): range= 0.13-0.58, mean=0.29	No
MA Comm Catch	Aggregate and age-specific commercial Index	Yes	Standardize min. length numbers; compare lengths of subsamples to length of all; examine applying age-length keys; develop index with total catch; adjust covariate; examine week-end warrior composition	Yes A total catch index was developed using covariates, making most recommend ations moot.	Old index age 7-12 average PSE: 7-0.51,8-0.23,9-0.13, 10-0.13,11-0.18,12-0.23. New Index age7-12 PSE (for 2000): 7- 0.05, 8-0.08, 9-0.10,10-0.11,11-0.15,12-0.22	Yes, correlation of aggregate indices to other aggregate indices (MRFSS, NYOHS, NJ, CT) but no significant correlations of new age indices to other programs; only 1996 YC could be tracked over only three years; influence of age-specific and aggregate index on VPA results increased.
RI – Floating Traps	?	No	See if data is available for development of an index	No	None	No
CT Trawl Survey	Aggregate Index (spring)	Yes	Segregate into age-specific indices using age-length keys instead of VB equation	No	Ln transformed, aggregate index PSEs: range=0.1-0.5, mean=0.20	No

Survey	Index Type	In VPA?	Workshop Recommendations	Recommendations Addressed?	PSE Range	Attempted Validation?
CT Rec Catch	Age-specific: ages 2-11	Yes	Describe and evaluate	No	None	No
NY Ocean Haul Seine	Age-specific Index: ages: 3-13+	Yes	Re-estimate precision using bootstrap; compare index at age to juvenile indices individually	Yes	Aggregate PSEs:mean=0.08; Age-specific PSEs: 2-0.17,3-0.11,4-0.13,5-0.16,6-0.22,7-0.23,8-0.39,9-0.51	Yes, strong correlations between CB juvenile index and indices for ages 2-5; not so for older ages.
NY Hudson Spawn Survey	?	No	Describe and evaluate; generate age-specific indices	No, but survey would be inappropriate	None	No
PA River Survey	Electrofishing survey	No	Describe and evaluate	No	None	No
NJ Trawl Survey	Aggregate Index	Yes	Examine strata choices; generate age-specific indices using April data	No	Aggregate index PSEs (91-03): range 0.18-0.69, average 0.38	No
NJ Rec Catch	RecCatch/Effort	No	Determine if development of an index is possible	No	None	No

Survey	Index Type	In VPA?	Workshop Recommendations	Recommendations Addressed?	PSE Range	Attempted Validation?
DE Spawning stock River Survey	Electrofishing aggregate and age-specific: ages 2-15	No	Investigate area under the curve method for possible spatial distribution issues; examine temporal distribution within strata; compare upper river index to PA survey	Yes – claims multistage lattice design addresses spatial and temporal distribution issues.	Aggregate PSEs (96-03): mean=0.20. Age-specific mean PSEs: 2-0.52,3-0.3,4-0.31,5-0.29,6-0.27,7-0.27,8-0.26,9-0.27,10-0.36,11-0.34,12-0.47, 13-0.46	Yes, compared age-specific indices to NJ juvenile fish index and found 6 out of 14 were significantly correlated. However, only 3 of nine comparisons between DE and PA surveys were significantly correlated.
DE Trawl Survey	Aggregate Index	No	Change biomass index to number; generate age-specific indices; compare indices to VPA for age 1	Some – developed numbers index using GLM	Aggregate mean PSE (91-04): 0.29 (I calculated from Table 3)	No
MD Spring Gillnet Survey	Age-specific 2-13+	Yes	Examine first vs second set;review impact of sex-specific catchabilities	In progress, showed differences in catchability and visibility	Age-specific mean PSEs (91-04):2-0.11, 3-0.02, 4-0.02,5-0.03,6-0.03,7-0.03,8-0.04,9-0.06,10-0.14,11-0.10,12-0.10,13-0.71	No

Survey	Index Type	In VPA?	Workshop Recommendations	Recommendations Addressed?	PSE Range	Attempted Validation?
VA Pound Net Survey	Fixed Pounds Net	No	Validate Index against MD and VA juveniles indices; examine year effects,; use longitudinal catch curves; examine catch versus temporal window, flow regimes.	Yes – no relationship between river flow and index; Mar 30-3May window better for inter-annual assessment of stock	Can't be calculated due to fixed sites	Yes, compared age-specific indices for age 3 8 to VA JI index but found poor correlation; weak correlation for age 9-10; high correlation between age 11-12 index and JI; there were no correlations between index and MD juvenile indices.

Appendix B5. Development of Age-specific Natural Mortality Rates for Striped Bass

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Massachusetts Division of Marine Fisheries

Lorenzen (1996)

The Lorenzen (1996) M-weight equation was used to generate Ms-at-age. Weights-at-age were estimated by fitting a curvilinear model (W=a*Age^b) to coast-wide mean weights-at-age available from the stock assessment (Figure 1). Since we are interested in obtaining baseline estimates of M, I used only weights-at age from 1991-1996 in the model fitting. The weights were used in the Lorenzen equation (3.0*weight^-0.288) but scaled to grams before use. The resulting unscaled M estimates were then re-scaled to 1.4% survival at the maximum age of 31 using a spreadsheet formulation provided by Doug Vaughan.

Empirical Estimates

I also derived an M-age equation by fitting another curvilinear model to empirical estimates of M for ages 1-6. The New York Western Long Island tagging program provides annual estimates of instantaneous total mortality rates (Z) for ages 1, 2, and 3-4 by using MARK and the bias-correction method for live releases (Table 1). Since fishing mortality is unlikely a large component of Z, I assumed that M=Z. Based on the proportions of fish released alive by anglers (age 1: avg. 0.83; age 2: avg. 0.94; age 3-4: 0.88; max for all ages =1.0), this assumption is not unrealistic. I averaged estimates from 1991-1996 over each age. I also obtained estimates of M for ages 3, 4, 5 and 6 from 1991-1996 using the Jiang et al. (2007) data and age-dependent model. I re-estimated M for each age (Jiang originally estimated M for ages 3-5 combined and age 6 separately) using program IRATE (Table 2). To aid in model fitting, I assumed a constant M at age 7 using either the assumed SASC M=0.15 or the average M prior to 1997 derived by tagging programs for bass >= 28 inches (Table 3). For ages greater than 7, the estimate of M was assumed the predicted M at age 7 since the equations predicted steep drops in M after age 7. The model (M=a+b/age+c/age^2) was fitted assuming log-normal errors and using least-squares.

Results

The Lorenzen unscaled and scaled estimates of natural mortality are shown in Table 4 and are plotted in Figure 2. The unscaled Lorenzen estimates were much lower than the estimates of M from WLI striped bass at ages 1 and 2, were close to the estimates of M for ages 3-6 for WLI and Jiang, and were generally higher than the assumed SASC constant M of 0.15 through age 22. Scaling the Lorenzen estimates lower the estimates of M for ages 1-6 considerably (Table 4; Figure 2). M estimates for ages >10 were lower than the assumed SASC constant of M=0.15.

The equations estimated using the WLI and Jiang data were:

Assuming M=0.15 at age 7,

$$M = -0.108 + \frac{1.919}{Age} + \frac{-0.683}{Age^2}$$

Assuming M=Avg. Tag M at age 7,

$$M = -0.179 + \frac{2.229}{Age} + \frac{-1.005}{Age^2}$$

The equation estimates of M were much higher at ages 1-4 than either Lorenzen method (Figure 2).

The stock assessment committee chose to use the curve fit/M=0.15 estimates in the SCA model because they thought the estimates were more realistic than the Lorenzen estimates and M for ages <7 were based on tag model estimates prior to the suspected increase in Mycobacterium related mortality in Chesapeake Bay.

Table 1. NY West Long Island Z estimates for 1991-1996 using MARK and bias-correction methods.

		Age	
Year	1	2	3-4
1991	1.17	0.62	0.31
1992	1.20	0.68	0.21
1993	1.15	0.63	0.30
1994	1.19	0.76	0.39
1995	1.16	0.72	0.30
1996	1.16	0.84	0.30
Average	1.17	0.71	0.30

Table 2. Re-estimated age-specific M estimates from Jiang et al. (2007) data and model.

Age	M
3	0.44
4	0.43
5	0.36
6	0.152

Table 3. Estimated M of 28 inch bass and greater (age 7+) for period prior to 1997 by state programs.

State	M
MA	0.10
NYOHS/Trawl	0.10
NJ	0.07
NC	0.16
HUD	0.09
DE/PA	0.10
MD	0.14

Table 4. Resulting M estimates from the Lorenzen and curve fitting methods.

	Lorenzen (1996)		Curve Fit	
Age	Unscaled	Scaled	M=0.15	Avg. Tag M
1	0.64	0.40	1.13	1.11
2	0.47	0.29	0.68	0.71
3	0.39	0.24	0.45	0.47
4	0.34	0.21	0.33	0.33
5	0.31	0.19	0.25	0.24
6	0.28	0.18	0.19	0.17
7	0.26	0.16	0.15	0.13
8	0.25	0.15	0.15	0.13
9	0.23	0.15	0.15	0.13
10	0.22	0.14	0.15	0.13
11	0.21	0.13	0.15	0.13
12	0.20	0.13	0.15	0.13
13	0.20	0.12	0.15	0.13
14	0.19	0.12	0.15	0.13
15	0.18	0.12	0.15	0.13
16	0.18	0.11	0.15	0.13
17	0.17	0.11	0.15	0.13
18	0.17	0.11	0.15	0.13
19	0.17	0.10	0.15	0.13
20	0.16	0.10	0.15	0.13
21	0.16	0.10	0.15	0.13
22	0.15	0.10	0.15	0.13
23	0.15	0.09	0.15	0.13
24	0.15	0.09	0.15	0.13
25	0.15	0.09	0.15	0.13
26	0.14	0.09	0.15	0.13
27	0.14	0.09	0.15	0.13
28	0.14	0.09	0.15	0.13
29	0.14	0.09	0.15	0.13
30	0.13	0.08	0.15	0.13
31	0.13	0.08	0.15	0.13

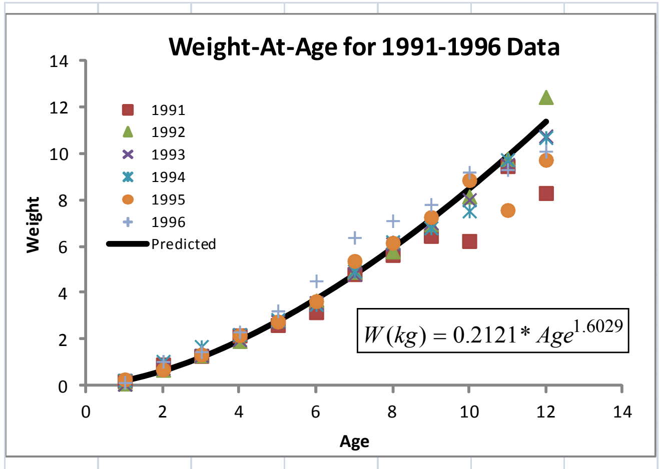


Figure 1. Observed versus predicted weights-at-age.

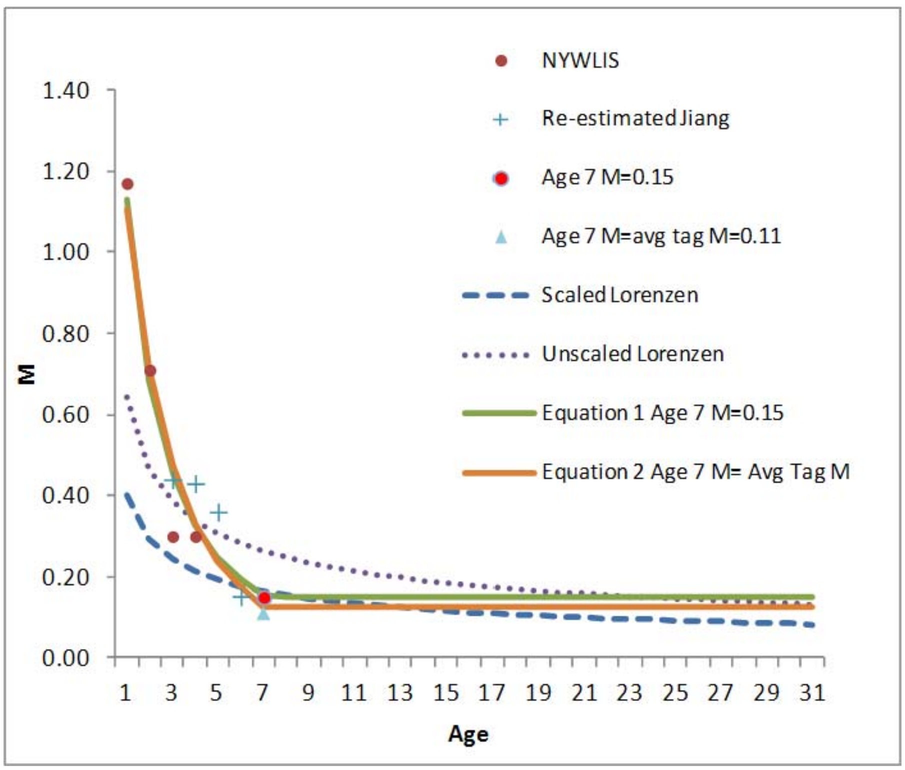


Figure 2. Comparison of estimates of age-specific Ms.

Appendix B6. AD Model Builder code for the striped bass statistical catch-at-age model.

```
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//
//        Striped bass Statistical Catch-At-Age Model
//        Gary Nelson
//        Massachusetts Division of Marine Fisheries
//        Gloucester, MA 01930
//
//        ADMB code for the calculation of effective sample size using the Francis (2011) method
//                              copied from ASAP written by Chris Legault, NMFS.
//
//       ADMB code for fitting S-R curves was adapted from code written by Erik Williams, NMFS in his
//        Atlantic Menhaden model
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
TOP_OF_MAIN_SECTION
 arrmblsize=1000000;
 gradient_structure::set_NUM_DEPENDENT_VARIABLES(300);
GLOBALS_SECTION
 #include <string.h>
 char hh[2];
DATA_SECTION
 init_int styrR;
// STARTING AND ENDING YEAR OF MODEL
 init_int styr;
 init_int endyr;
// NUMBER OF AGES
 init_int nages;
 int y;
 ivector agebins(1,nages);
 LOCAL_CALCS
   for(y=1;y<=nages;y++) agebins(y)=y;
 END_CALCS
 init_matrix M(styr,endyr,1,nages);
 init_vector fsex(1,nages);
 init_matrix fmat(styr,endyr,1,nages);
 init_matrix cwgt(styr,endyr,1,nages);
 init_matrix swgt(styr,endyr,1,nages);
 init_matrix ssbwgt(styr,endyr,1,nages);
 //TOTAL CATCH CVs
 init_number nfleets;
 init_3darray obs_age_comp(1,nfleets,styr,endyr,1,nages);
 init_matrix obs_total_catch(styr,endyr,1,nfleets);
 init_matrix total_catch_CV(styr,endyr,1,nfleets);
 init_matrix ss_age_comp(styr,endyr,1,nfleets);
 init_number nselperiods;
 init_matrix fleetsel(1,nselperiods,1,4);
 init_matrix fleetllw(1,nfleets,1,3);
// AGGREGATE SURVEYS
 init_int agg_surv_num;
 init_vector use_agg(1,agg_surv_num);
 init_vector agg_surv_flag(1,agg_surv_num);
 init_vector agg_surv_ages(1,agg_surv_num);
 init_vector agg_wgt(1,agg_surv_num);
 init_vector agg_index_CV_wgt(1,agg_surv_num);
 init_matrix agg_obs_surv_indices(styrR,endyr,1,agg_surv_num);
 init_matrix agg_surv_CV(styrR,endyr,1,agg_surv_num);
//SURVEYS WITH AGE COMPOSITION
 init_int ac_surv_num;
 init_vector use_ac(1,ac_surv_num);
 init_matrix acsel(1,ac_surv_num,1,6);
 init_matrix acuser(1,ac_surv_num,1,nages);
 init_3darray surv_comps(1,ac_surv_num,styrR,endyr,1,nages);
 init_matrix ac_obs_surv_indices(styrR,endyr,1,ac_surv_num);
 init_matrix ac_surv_CV(styrR,endyr,1,ac_surv_num);
 init_matrix ac_ss(styrR,endyr,1,ac_surv_num);
  init_number pF;
 init_number pM;
```

```
init_int rivard;
//Recruitment Model
init_int srmodel;
int srcnt;
LOCAL_CALCS
 if(srmodel==1) srcnt=1;
 if(srmodel==2||srmodel==3) srcnt=3;
 if(srmodel==4) srcnt=4;
END_CALCS
init_number log_R_con1;init_number log_R_con2;init_number log_R_con3;init_number log_R_con4;
init_number log_R_dev_con1; init_number log_R_dev_con2; init_number log_R_dev_con3; init_number log_R_dev_con4;
init_number log_F_con1; init_number log_F_con2; init_number log_F_con3; init_number log_F_con4;
init_number aggqs_con1;init_number aggqs_con2;init_number aggqs_con3;init_number aggqs_con4;
init_number acqs_con1;init_number acqs_con2; init_number acqs_con3; init_number acqs_con4;
init_number flgom_a_con1;init_number flgom_a_con2;init_number flgom_a_con3;init_number flgom_a_con4;
init_number flgom_b_con1;init_number flgom_b_con2;init_number flgom_b_con3;init_number flgom_b_con4;
init_number fllog_a_con1;init_number fllog_a_con2; init_number fllog_a_con3; init_number fllog_a_con4;
init_number fllog_b_con1;init_number fllog_b_con2; init_number fllog_b_con3; init_number fllog_b_con4;
init_number flgam_a_con1;init_number flgam_a_con2; init_number flgam_a_con3; init_number flgam_a_con4;
init_number flgam_b_con1;init_number flgam_b_con2;init_number flgam_b_con3;init_number flgam_b_con4;
init_number flthom_a_con1;init_number flthom_a_con2;init_number flthom_a_con3;init_number flthom_a_con4;
init_number flthom_b_con1;init_number flthom_b_con2; init_number flthom_b_con3; init_number flthom_b_con4;
init_number flthom_c_con1;init_number flthom_c_con2; init_number flthom_c_con3; init_number flthom_c_con4;
init_number fldlog_a_con1;init_number fldlog_a_con2;init_number fldlog_a_con3;init_number fldlog_a_con4;
init_number fldlog_b_con1;init_number fldlog_b_con2; init_number fldlog_b_con3; init_number fldlog_b_con4;
init_number fldlog_c_con1;init_number fldlog_c_con2; init_number fldlog_c_con3; init_number fldlog_c_con4;
init_number fldlog_d_con1;init_number fldlog_d_con2; init_number fldlog_d_con3; init_number fldlog_d_con4;
// If GOmpertz Plus
init_number flgomp_a_con1;init_number flgomp_a_con2;init_number flgomp_a_con3;init_number flgomp_a_con4;
init_number flgomp_b_con1;init_number flgomp_b_con2;init_number flgomp_b_con3;init_number flgomp_b_con4;
init_number flgomp_c_con1;init_number flgomp_c_con2;init_number flgomp_c_con3;init_number flgomp_c_con4;
// If Thompson  Plus
init_number flthomp_a_con1;init_number flthomp_a_con2;init_number flthomp_a_con3;init_number flthomp_a_con4;
init_number flthomp_b_con1;init_number flthomp_b_con2; init_number flthomp_b_con3; init_number flthomp_b_con4;
init_number flthomp_c_con1;init_number flthomp_c_con2; init_number flthomp_c_con3; init_number flthomp_c_con4;
init_number flthomp_d_con1;init_number flthomp_d_con2; init_number flthomp_d_con3; init_number flthomp_d_con4;
 // If Exponential
init_number flexp_a_con1;init_number flexp_a_con2;init_number flexp_a_con3;init_number flexp_a_con4;
init_number flexp_b_con1;init_number flexp_b_con2; init_number flexp_b_con3; init_number flexp_b_con4;
init_number acgom_a_con1;init_number acgom_a_con2;init_number acgom_a_con3;init_number acgom_a_con4;
init_number acgom_b_con1; init_number acgom_b_con2; init_number acgom_b_con3; init_number acgom_b_con4;
init_number aclog_a_con1;init_number aclog_a_con2;init_number aclog_a_con3;init_number aclog_a_con4;
init_number aclog_b_con1; init_number aclog_b_con2; init_number aclog_b_con3; init_number aclog_b_con4;
init_number acgam_a_con1; init_number acgam_a_con2; init_number acgam_a_con3; init_number acgam_a_con4;
init_number acgam_b_con1; init_number acgam_b_con2; init_number acgam_b_con3; init_number acgam_b_con4;
init_number acthom_a_con1;init_number acthom_a_con2;init_number acthom_a_con3;init_number acthom_a_con4;
init_number acthom_b_con1; init_number acthom_b_con2; init_number acthom_b_con3; init_number acthom_b_con4;
init_number acthom_c_con1;init_number acthom_c_con2;init_number acthom_c_con3;init_number acthom_c_con4;
init_number user_con1;init_number user_con2;init_number user_con3;init_number user_con4;
init_number BH_a_con1;init_number BH_a_con2;init_number BH_a_con3;init_number BH_a_con4;
init_number BH_b_con1;init_number BH_b_con2;init_number BH_b_con3;init_number BH_b_con4;
init_number r_a_con1; init_number r_a_con2; init_number r_a_con3; init_number r_a_con4;
init_number r_b_con1; init_number r_b_con2; init_number r_b_con3; init_number r_b_con4;
init_number shep_a_con1; init_number shep_a_con2; init_number shep_a_con3; init_number shep_a_con4;
init_number shep_b_con1; init_number shep_b_con2;init_number shep_b_con3;init_number shep_b_con4;
init_number shep_c_con1; init_number shep_c_con2; init_number shep_c_con3; init_number shep_c_con4;
init_number log_R_lam;
init_number R_dev_lam;
init_int navgf;
init_matrix avgftable(1,navgf,1,3);
init_int pspr;
init_int Myear;
init_int Selyear;
init_int Wgtyear;
init_int Matyear;
init_int oldest;
init_number maxF;
```

```
init_number calcincr;
init_number repincr;
init_number nconver;
init_number convflag;
init_3darray convmatrix(1,nconver,1,nages,1,nages);
init_int cilike;
init_int alike;
init_int biascor;
int cnt;
int p;
int a;
int t;
int realage;
int d;
int total;
int n_parms;
int ncsel;
int nsurvsel;
int df;
int parmFlag;
int devFlag;
int nflparms;
int nacparms;
int nacuserparms;
int nFparms;
int nRparms;
int ndeltaR;
int ndeltaF;
int ndeltaq;
int ndeltaSSB;
int ndeltaFullF;
int fltwogom;
int fltwolog;
int fltwogam;
int flthree;
int flfour;
int flgomp;
int fltp;
int flnexp;
int actwogom;
int actwolog;
int actwogam;
int acthree;
int acfour;
int user;
int cnter;
int cnter2;
int cnter3;
int cnter4;
int cnter5;
int cnter6;
int cnter7;
int iyear;
int nfs;
int ok;
int looper;
int aggdiff;
int acdiff;
int acparms;
int aggparms;

LOCAL_CALCS
 aggdiff=0;
 acdiff=0;
 for(t=1;t<=agg_surv_num;t++){
   if(use_agg(t)==0) aggdiff+=1;
 }
```

```
 for(t=1;t<=ac_surv_num;t++){
   if(use_ac(t)==0) acdiff+=1;
 }
 acparms=ac_surv_num-acdiff;
 aggparms=agg_surv_num-aggdiff;
// Calculate the number of fleet selectivity parameters
  nfs=ceil(maxF/calcincr);
  nflparms=0;
  for(t=1;t<=nselperiods;t++){
  if(fleetsel(t,4)==1) nflparms+=2;
  if(fleetsel(t,4)==2) nflparms+=2;
  if(fleetsel(t,4)==3) nflparms+=2;
  if(fleetsel(t,4)==4) nflparms+=3;
  if(fleetsel(t,4)==5) nflparms+=4;
  if(fleetsel(t,4)==6) nflparms+=3;
  if(fleetsel(t,4)==7) nflparms+=4;
  if(fleetsel(t,4)==8) nflparms+=2;
 }
 nFparms=nfleets*(endyr-styr+1);
 //Count number of each selectivity curve
 fltwogom=0;
 fltwolog=0;
 fltwogam=0;
 flthree=0;
 flfour=0;
 flgomp=0;
 fltp=0;
 flnexp=0;
 for(t=1;t<=nselperiods;t++){
   if(fleetsel(t,4)==1){
     fltwogom+=1;
   }
  if(fleetsel(t,4)==2){
      fltwolog+=1;
   }
  if(fleetsel(t,4)==3){
      fltwogam+=1;
   }
   if(fleetsel(t,4)==4){
      flthree+=1;
    }
   if(fleetsel(t,4)==5){
     flfour+=1;
   }
   if(fleetsel(t,4)==6){
     flgomp+=1;
   }
   if(fleetsel(t,4)==7){
     fltp+=1;
   }
   if(fleetsel(t,4)==8){
     flnexp+=1;
   }
 }
if(fltwogom==0) {
   flgom_a_con1=-1;
   flgom_b_con1=-1;
 }
if(fltwolog==0){
   fllog_a_con1=-1;
   fllog_b_con1=-1;
 }
if(fltwogam==0){
   flgam_a_con1=-1;
   flgam_b_con1=-1;
 }
 if(flthree==0){
```

```
   flthom_a_con1=-1;
   flthom_b_con1=-1;
   flthom_c_con1=-1;
  }
  if(flfour==0){
    fldlog_a_con1=-1;
    fldlog_b_con1=-1;
    fldlog_c_con1=-1;
    fldlog_d_con1=-1;
  }
  if(flgomp==0){
   flgomp_a_con1=-1;
   flgomp_b_con1=-1;
   flgomp_c_con1=-1;
  }
  if(fltp==0){
   flthomp_a_con1=-1;
   flthomp_b_con1=-1;
   flthomp_c_con1=-1;
   flthomp_d_con1=-1;
  }
   if(flnexp==0){
   flexp_a_con1=-1;
   flexp_b_con1=-1;
  }
 //Age Conp Surveys
  nacparms=0;
  nacuserparms=0;
 if(ac_surv_num>0){
   for(t=1;t<=ac_surv_num;t++){
    if(use_ac(t)==1){
      if(acsel(t,6)==1) nacparms+=2;
      if(acsel(t,6)==2) nacparms+=2;
      if(acsel(t,6)==3) nacparms+=2;
      if(acsel(t,6)==4) nacparms+=3;
      if(acsel(t,6)==5){
        for(a=1;a<=nages;a++){
         if(acuser(t,a)>1) nacuserparms+=1;
        }
      }
    }
   }
   actwogom=0;
   actwolog=0;
   actwogam=0;
   acthree=0;
   user=0;
  //Age Comp Surveys
  for(t=1;t<=ac_surv_num;t++){
    if(use_ac(t)==1){
      if(acsel(t,6)==1){
         actwogom+=1;
      }
      if(acsel(t,6)==2){
        actwolog+=1;
      }
      if(acsel(t,6)==3){
        actwogam+=1;
      }
      if(acsel(t,6)==4){
        acthree+=1;
      }
     if(acsel(t,6)==5){
       for(a=1;a<=nages;a++){
         if(acuser(t,a)>1) user+=1;
       }
     }
```

```
   }
  }
 }
 if(actwogom==0){
  acgom_a_con1=-1;
  acgom_b_con1=-1;
 }
 if(actwolog==0){
  aclog_a_con1=-1;
  aclog_b_con1=-1;
 }
 if(actwogam==0){
  acgam_a_con1=-1;
  acgam_b_con1=-1;
 }
 if(acthree==0){
  acthom_a_con1=-1;
  acthom_b_con1=-1;
  acthom_c_con1=-1;
 }
 if(user==0) user_con1=-1;
 if(ac_surv_num<=0){
   actwogom=1;
   actwolog=1;
    actwogam=1;
   acthree=1;
   user=1;
 }
 //Recruitment model parameters
  if(srmodel==1){
    iyear=styrR;
    nRparms=1+endyr-styrR+1;
    BH_a_con1=-1;
    BH_b_con1=-1;
    r_a_con1=-1;
    r_b_con1=-1;
    shep_a_con1=-1;
    shep_b_con1=-1;
    shep_c_con1=-1;
  }
 if(srmodel==2){
    nRparms=1+(endyr-(styrR+1)+1)+2;
    iyear=styrR+1;
     r_a_con1=-1;
    r_b_con1=-1;
    shep_a_con1=-1;
    shep_b_con1=-1;
    shep_c_con1=-1;
  }
 if(srmodel==3){
      iyear=styrR+1;
     nRparms=1+(endyr-(styrR+1)+1)+2;
    BH_a_con1=-1;
    BH_b_con1=-1;
    shep_a_con1=-1;
    shep_b_con1=-1;
    shep_c_con1=-1;
  }
 if(srmodel==4){
    BH_a_con1=-1;
    BH_b_con1=-1;
    r_a_con1=-1;
    r_b_con1=-1;
   iyear=styrR+1;
   nRparms=1+(endyr-(styrR+1)+1)+3;
  }
   //SEs for log-Recruitment, log-qs, log Fs and SSB
```

```
  ndeltaR=endyr-styrR+1;
  ndeltaq=aggparms+acparms;
  ndeltaF=nfleets*(endyr-styr+1);
  ndeltaSSB=endyr-styrR+1;
  ndeltaFullF=endyr-styr+1;

  // fl selectivty, Fs,qs for agg, qs for ac, ac selecticity parms, recruitment
  df=nflparms+nFparms+acparms+aggparms+nacparms+nacuserparms+nRparms+ndeltaR+ndeltaF+ndeltaq+ndeltaSSB+ndeltaFullF;
  n_parms=nflparms+nFparms+aggparms+acparms+nacparms+nacuserparms+nRparms;
 END_CALCS
 matrix sigma(1,df,1,df+1);
 !! set_covariance_matrix(sigma);
PARAMETER_SECTION
//TEMPORARY VARIABLES
 number adds;
 number pgroup;
 number diff;
 number diff2;
 number sel;
 number sumage;
 number maxs;
 number dodo;
 number dodo1;
 number sumdo;
 number sumdo1;
 number fpen;
 number cl;
 number maxer;
 number dd1;
 number dd2;
 number slope;
 number origslope;
 number sigma1;
 number pgroup1;
 number cl1;
 number maxer1;
 number msy;
 number fmsy;
 number ssbmsy;
 number concll;
//---------------------INITIATE SCAM ARRAYS--------------------------//
//AVERAGE RECRUITMENT
 init_bounded_number log_R(log_R_con3,log_R_con4,log_R_con1);
 number log_R_constraint;
//RECRUITMENT DEVIATIONS
 init_bounded_dev_vector log_R_dev(iyear,endyr,log_R_dev_con3,log_R_dev_con4,log_R_dev_con1);
//FISHING MORTALITY
 init_bounded_matrix log_F(styr,endyr,1,nfleets,log_F_con3,log_F_con4,log_F_con1);
//CATCH SELECTIVITY
 init_bounded_vector flgom_a(1,fltwogom,flgom_a_con3,flgom_a_con4,flgom_a_con1);
 init_bounded_vector flgom_b(1,fltwogom,flgom_b_con3,flgom_b_con4,flgom_b_con1);
 init_bounded_vector fllog_a(1,fltwolog,fllog_a_con3,fllog_a_con4,fllog_a_con1);
 init_bounded_vector fllog_b(1,fltwolog,fllog_b_con3,fllog_b_con4,fllog_b_con1);
 init_bounded_vector flgam_a(1,fltwogam,flgam_a_con3,flgam_a_con4,flgam_a_con1);
 init_bounded_vector flgam_b(1,fltwogam,flgam_b_con3,flgam_b_con4,flgam_b_con1);
 init_bounded_vector flthom_a(1,flthree,flthom_a_con3,flthom_a_con4,flthom_a_con1);
 init_bounded_vector flthom_b(1,flthree,flthom_b_con3,flthom_b_con4,flthom_b_con1);
 init_bounded_vector flthom_c(1,flthree,flthom_c_con3,flthom_c_con4,flthom_c_con1);
 init_bounded_vector fldlog_a(1,flfour,fldlog_a_con3,flthom_a_con4,fldlog_a_con1);
 init_bounded_vector fldlog_b(1,flfour,fldlog_b_con3,fldlog_b_con4,fldlog_b_con1);
 init_bounded_vector fldlog_c(1,flfour,fldlog_c_con3,fldlog_c_con4,fldlog_c_con1);
 init_bounded_vector fldlog_d(1,flfour,fldlog_d_con3,fldlog_d_con4,fldlog_d_con1);
 // GOmpertz Plus
 init_bounded_vector flgomp_a(1,flgomp,flgomp_a_con3,flgomp_a_con4,flgomp_a_con1);
 init_bounded_vector flgomp_b(1,flgomp,flgomp_b_con3,flgomp_b_con4,flgomp_b_con1);
 init_bounded_vector flgomp_c(1,flgomp,flgomp_c_con3,flgomp_c_con4,flgomp_c_con1);
//Thompson Plus
```

```
init_bounded_vector flthomp_a(1,fltp,flthomp_a_con3,flthomp_a_con4,flthomp_a_con1);
init_bounded_vector flthomp_b(1,fltp,flthomp_b_con3,flthomp_b_con4,flthomp_b_con1);
init_bounded_vector flthomp_c(1,fltp,flthomp_c_con3,flthomp_c_con4,flthomp_c_con1);
init_bounded_vector flthomp_d(1,fltp,flthomp_d_con3,flthomp_d_con4,flthomp_d_con1);
//Exponentia;

init_bounded_vector flexp_a(1,flnexp,flexp_a_con3,flexp_a_con4,flexp_a_con1);
init_bounded_vector flexp_b(1,flnexp,flexp_b_con3,flexp_b_con4,flexp_b_con1);

//SURVEY SELECTIVITIES
init_bounded_vector acgom_a(1,actwogom,acgom_a_con3,acgom_a_con4,acgom_a_con1);
init_bounded_vector acgom_b(1,actwogom,acgom_b_con3,acgom_b_con4,acgom_b_con1);
init_bounded_vector aclog_a(1,actwolog,aclog_a_con3,aclog_a_con4,aclog_a_con1);
init_bounded_vector aclog_b(1,actwolog,aclog_b_con3,aclog_b_con4,aclog_b_con1);
init_bounded_vector acgam_a(1,actwogam,acgam_a_con3,acgam_a_con4,acgam_a_con1);
init_bounded_vector acgam_b(1,actwogam,flgam_b_con3,acgam_b_con4,acgam_b_con1);
init_bounded_vector acthom_a(1,acthree,acthom_a_con3,acthom_a_con4,acthom_a_con1);
init_bounded_vector acthom_b(1,acthree,acthom_b_con3,acthom_b_con4,acthom_b_con1);
init_bounded_vector acthom_c(1,acthree,acthom_c_con3,acthom_c_con4,acthom_c_con1);
init_bounded_vector userparms(1,user,user_con3,user_con4,user_con1);
//SURVEY CATCHABILITY COEEFFICIENTS AND PREDICTED INDICESindices
init_bounded_vector agg_qs(1,aggparms,aggqs_con3,aggqs_con4,aggqs_con1);
matrix agg_pred_surv_indices(styrR,endyr,1,agg_surv_num);
matrix resid_agg(styrR,endyr,1,agg_surv_num);
matrix std_resid_agg(styrR,endyr,1,agg_surv_num);
vector RMSE_agg(1,agg_surv_num);
init_bounded_vector ac_qs(1,acparms,acqs_con3,acqs_con4,acqs_con1);
matrix ac_pred_surv_indices(styrR,endyr,1,ac_surv_num);
matrix resid_ac(styrR,endyr,1,ac_surv_num);
matrix std_resid_ac(styrR,endyr,1,ac_surv_num);
vector RMSE_ac(1,ac_surv_num);
matrix p_sel(1,nselperiods,1,nages);
matrix surv_sel(1,ac_surv_num,1,nages);
// If S_RRecruit relationship
init_bounded_number BH_a(BH_a_con3,BH_a_con4,BH_a_con1);
init_bounded_number BH_b(BH_b_con3,BH_b_con4,BH_b_con1);
init_bounded_number r_a(r_a_con3,r_a_con4,r_a_con1);
init_bounded_number r_b(r_b_con3,r_b_con4,r_b_con1);
init_bounded_number shep_a(shep_a_con3,shep_a_con4,shep_a_con1);
init_bounded_number shep_b(shep_b_con3,shep_b_con4,shep_b_con1);
init_bounded_number shep_c(shep_c_con3,shep_c_con4,shep_c_con1);
//PREDICTED SURVE AGE COMPOSITIONS
3darray calc_comps(1,ac_surv_num,styrR,endyr,1,nages);
3darray surv_pred_comps(1,ac_surv_num,styrR,endyr,1,nages);
3darray std_resid_surv_comps(1,ac_surv_num,styrR,endyr,1,nages);
// INDIVIDUAL LIKELIHOOD SAVE VECTORS
vector like_agg(1,agg_surv_num);
vector like_ac_surv(1,ac_surv_num);
vector like_ac_age(1,ac_surv_num);
//CATCH-AT-AGE,PREDICTED TOTAL CATCH, PREDICTED CATCH AGE COMPOSITION, AND SSB
//NUMBERS,F,Z MATRICES
matrix N(styrR,endyr,1,nages);//Population numbers by year and age
3darray Ffleet(1,nfleets,styr,endyr,1,nages);
matrix Z(styrR,endyr,1,nages);
3darray C(1,nfleets,styr,endyr,1,nages);
matrix pred_total_catch(styr,endyr,1,nfleets);
3darray pred_age_comp(1,nfleets,styr,endyr,1,nages);
3darray selbyfleet(1,nfleets,styr,endyr,1,nages);
vector fleet_total_catch_like(1,nfleets);
vector fleet_age_comp_like(1,nfleets);
matrix rwgts(styr,endyr,1,nages);
matrix W2(styr,endyr,1,nages);
matrix jan1bio(styr,endyr,1,nages);
3darray catchbio(1,nfleets,styr,endyr,1,nages);
matrix aceffssyr(styrR,endyr,1,ac_surv_num);
matrix resid_C(styr,endyr,1,nfleets);
matrix std_resid_C(styr,endyr,1,nfleets);
```

```
 3darray std_resid_CAA(1,nfleets,styr,endyr,1,nages);
 matrix Fcomb(styr,endyr,1,nages);
 matrix avgF(styr,endyr,1,navgf);
 number FF;
 vector partialF(1,nages);
 vector Zypr(1,nages);
 vector psb(1,oldest);
 number maxSPR;
 number recvar;
 number recsigma;
 number recpen;
 matrix SSBatage(styr,endyr,1,nages);

 vector Neff_stage2_mult_catch(1,nfleets);
 vector Neff_stage2_mult_index(1,ac_surv_num);
 vector mean_age_obs(styr,endyr);
 vector mean_age_pred(styr,endyr);
 vector mean_age_pred2(styr,endyr);
 vector mean_age_resid(styr,endyr);
 vector mean_age_sigma(styr,endyr);
 number mean_age_x;
 number mean_age_n;
 number mean_age_delta;
 number mean_age_mean;
 number mean_age_m2;

//REPORT STANDARD DEVIATIONS FOR ANNUAL FS,RS, AND CATCHABILITY COEFFICIENTS
 //sdreport_vector F_ann(styr,endyr);
 sdreport_vector R(styrR,endyr);
 sdreport_matrix F(styr,endyr,1,nfleets);
 sdreport_vector q_AC(1,acparms);
 sdreport_vector q_Agg(1,aggparms);
 sdreport_vector SSB(styrR,endyr);
 sdreport_vector FullF(styr,endyr);
 //likeprof_number AvgF;
 objective_function_value f;
INITIALIZATION_SECTION
 log_F log_F_con2;
 agg_qs aggqs_con2;
 ac_qs acqs_con2;
 userparms user_con2;
RUNTIME_SECTION
 maximum_function_evaluations 10000, 10000, 10000;
 convergence_criteria 1e-5, 1e-7, 1e-16;
PRELIMINARY_CALCS_SECTION
 Ffleet.initialize();
 C.initialize();
 calc_comps.initialize();
 like_agg.initialize();
 like_ac_surv.initialize();
 like_ac_age.initialize();
 surv_sel.initialize();
 agg_pred_surv_indices.initialize();
 ac_pred_surv_indices.initialize();
 surv_pred_comps.initialize();
 resid_agg.initialize();
 std_resid_agg.initialize();
 RMSE_agg.initialize();
 resid_ac.initialize();
 std_resid_ac.initialize();
 std_resid_surv_comps.initialize();
 //Starting values
 log_R=log_R_con2;
 if(srmodel>1){
   BH_a=BH_a_con2;
   BH_b=BH_b_con2;
   r_a=r_a_con2;
```

```
  r_b=r_b_con2;
  shep_a=shep_a_con2;
  shep_b=shep_b_con2;
  shep_c=shep_c_con2;
}
for(t=1;t<=nselperiods;t++){
   if(fleetsel(t,4)==1){
     flgom_a=flgom_a_con2;
     flgom_b=flgom_b_con2;
   }
   if(fleetsel(t,4)==2){
     fllog_a=fllog_a_con2;
     fllog_b=fllog_b_con2;
   }
   if(fleetsel(t,4)==3){
     flgam_a=flgam_a_con2;
     flgam_b=flgam_b_con2;
   }
   if(fleetsel(t,4)==4){
    flthom_a=flthom_a_con2;
    flthom_b=flthom_b_con2;
    flthom_c=flthom_c_con2;
   }
   if(fleetsel(t,4)==5){
    fldlog_a=fldlog_a_con2;
    fldlog_b=fldlog_b_con2;
    fldlog_c=fldlog_c_con2;
    fldlog_d=fldlog_d_con2;
   }
   if(fleetsel(t,4)==6){
     flgomp_a=flgomp_a_con2;
     flgomp_b=flgomp_b_con2;
     flgomp_c=flgomp_c_con2;
   }
    if(fleetsel(t,4)==7){
    flthomp_a=flthomp_a_con2;
    flthomp_b=flthomp_b_con2;
    flthomp_c=flthomp_c_con2;
    flthomp_d=flthomp_d_con2;

   }
   if(fleetsel(t,4)==8){
    flexp_a=flexp_a_con2;
    flexp_b=flexp_b_con2;
   }
 }
 for(t=1;t<=ac_surv_num;t++){
  if(use_ac(t)==1){
   if(acsel(t,6)==1){
     acgom_a=acgom_a_con2;
     acgom_b=acgom_b_con2;
   }
   if(acsel(t,6)==2){
     aclog_a=aclog_a_con2;
     aclog_b=aclog_b_con2;
   }
   if(acsel(t,6)==3){
     acgam_a=acgam_a_con2;
     acgam_b=acgam_b_con2;
   }
   if(acsel(t,6)==4){
    acthom_a=acthom_a_con2;
    acthom_b=acthom_b_con2;
    acthom_c=acthom_c_con2;
   }
 }
}
```

```
  userparms=user_con2;
 //Rivard weights
  for(a=2;a<=nages-1;a++){
   for(y=styr+1;y<=endyr;y++){
     W2(y,a)=(log(cwgt(y,a))+log(cwgt(y-1,a-1)))/2;
    }
   }
 for(y=styr;y<=endyr-1;y++){
     W2(y,1)=2*log(cwgt(y,1))-W2(y+1,2);
    }
 for(a=1;a<=nages-2;a++){
     W2(styr,a)=2*log(cwgt(styr,a))-W2(styr+1,a+1);
   }
 W2(styr,nages-1)=(W2(styr,nages-1)+W2(styr,nages-2))/2;
 W2(endyr,1)=2*log(cwgt(endyr,1))-W2(endyr,2);
 for(y=styr;y<=endyr;y++){
     W2(y,nages)=log(cwgt(y,nages));
    }
 for(y=styr;y<=endyr;y++){
   for(a=1;a<=nages;a++){
     rwgts(y,a)=exp((W2(y,a)+log(cwgt(y,a)))/2); // Added 4-3-2013
   }
  }
PROCEDURE_SECTION
  calc_selectivity();
  calc_mortality();
  calc_biascorrect();
  calc_numbers_at_age();
  calc_catch_at_age();
  calc_predict_indices_agg();
  calc_predict_indices_ac();
  //exit(0);
  scam_likelihood();

  evaluate_the_objective_function();
FUNCTION print
//CALCULATE CATCH SELECTIVITIES VALUES FOR CURRENT PARAMETER ESTIMATES
 cout<<agg_index_CV_wgt<<endl;
FUNCTION calc_selectivity
 cnt=0;
 cnter=0;
 cnter2=0;
 cnter3=0;
 cnter4=0;
 cnter5=0.;
 cnter6=0;
 cnter7=0;
 for(p=1;p<=nselperiods;p++){
   maxs=0.;
    for(a=1;a<=nages;a++){
     if(fleetsel(p,4)==1){
       if(a==1) cnt+=1;
       p_sel(p,a)=mfexp(-1.*mfexp(-1.*flgom_b(cnt)*(double(agebins(a))-flgom_a(cnt))));
       if(p_sel(p,a)<0) p_sel(p,a)=0;
       if(p_sel(p,a)>maxs) maxs=p_sel(p,a);
      }
    if(fleetsel(p,4)==2){
       if(a==1) cnter+=1;
       p_sel(p,a)=1./(1.+mfexp(-1.*fllog_b(cnt)*(double(agebins(a))-fllog_a(cnt))));
       if(p_sel(p,a)<0) p_sel(p,a)=0;
       if(p_sel(p,a)>maxs) maxs=p_sel(p,a);
      }
    if(fleetsel(p,4)==3){
       if(a==1) cnter2+=1;
       p_sel(p,a)=pow(double(a),flgam_a(cnt))*exp(-1.*flgam_b(cnt)*double(a));
       if(p_sel(p,a)<0) p_sel(p,a)=0;
       if(p_sel(p,a)>maxs) maxs=p_sel(p,a);
```

```
    }
   if(fleetsel(p,4)==4){
    if(a==1) cnter3+=1;
    p_sel(p,a)=(1./(1.-flthom_c(cnter3)))*pow((1-flthom_c(cnter3))/flthom_c(cnter3),flthom_c(cnter3))*
       (mfexp(flthom_a(cnter3)*flthom_c(cnter3)*(flthom_b(cnter3)-double(a)))/
       (1+mfexp(flthom_a(cnter3)*(flthom_b(cnter3)-double(a)))));
    if(p_sel(p,a)<0) p_sel(p,a)=0;
    if(p_sel(p,a)>maxs) maxs=p_sel(p,a);
    }
   if(fleetsel(p,4)==5){
     if(a==1) cnter4+=1;
     p_sel(p,a)=(1./(1.+mfexp(-1.*fldlog_b(cnter4)*(double(agebins(a))-fldlog_a(cnter4)))))*
        (1-(1./(1.+mfexp(-1.*fldlog_d(cnter4)*(double(agebins(a))-fldlog_c(cnter4))))));
     if(p_sel(p,a)<0) p_sel(p,a)=0;
     if(p_sel(p,a)>maxs) maxs=p_sel(p,a);
    }
   if(fleetsel(p,4)==6){
     if(a==1) cnter5+=1;
     if(a<nages) p_sel(p,a)=mfexp(-1.*mfexp(-1.*flgomp_b(cnter5)*(double(agebins(a))-flgomp_a(cnter5))));
     if(a==nages) p_sel(p,a)=flgomp_c(cnter5);
     if(p_sel(p,a)<0) p_sel(p,a)=0;
     if(p_sel(p,a)>maxs) maxs=p_sel(p,a);
    }
    if(fleetsel(p,4)==7){
    if(a==1) cnter6+=1;
    if(a<nages){ p_sel(p,a)=(1./(1.-flthomp_c(cnter6)))*pow((1-flthomp_c(cnter6))/flthomp_c(cnter6),flthomp_c(cnter6))*
       (mfexp(flthomp_a(cnter6)*flthomp_c(cnter6)*(flthomp_b(cnter6)-double(a)))/
       (1+mfexp(flthomp_a(cnter6)*(flthomp_b(cnter6)-double(a)))));}
    if(a==nages) p_sel(p,a)=flthomp_d(cnter6);
    if(p_sel(p,a)<0) p_sel(p,a)=0;
    if(p_sel(p,a)>maxs) maxs=p_sel(p,a);
    }
     if(fleetsel(p,4)==8){
      if(a==1) cnter7+=1;
      if(a<4) p_sel(p,a)=flexp_a(cnter7)*mfexp(flexp_b(cnter7)*double(a));
      if(a>=4) p_sel(p,a)=1;
      if(p_sel(p,a)<0) p_sel(p,a)=0;
      if(p_sel(p,a)>maxs) maxs=p_sel(p,a);
    }
   }//age
   p_sel(p)=p_sel(p)/maxs;
 }
//MATCH PERIOD SELECTVITIES TO YEARS AND CALCULATE ANNUAL F AND F-AT-AGE
FUNCTION calc_mortality
 for(t=1;t<=nfleets;t++){
  for(p=1;p<=nselperiods;p++){
    for(y=styr;y<=endyr;y++){
      for(a=1;a<=nages;a++){
       if(fleetsel(p,1)==t){
         if (y>=fleetsel(p,2) && y<=fleetsel(p,3)){
           Ffleet(t,y,a)=p_sel(p,a)*mfexp(log_F(y,t));
           selbyfleet(t,y,a)=p_sel(p,a);
        }
       }
      }
   }
  }
 }
  // Combined Fleet Fs at age
  for(y=styr;y<=endyr;y++){
     for(a=1;a<=nages;a++){
     Fcomb(y,a)=0;
      for(t=1;t<=nfleets;t++) Fcomb(y,a)+=Ffleet(t,y,a);
     }
   }

  for(y=styrR;y<=endyr;y++){
```

```
  for(a=1;a<=nages;a++){
   if(y<styr)Z(y,a)=Fcomb(styr,a)+M(styr,a);
   if(y>=styr)Z(y,a)=Fcomb(y,a)+M(y,a);
  }
 }

 for(t=1;t<=nfleets;t++){
  for(y=styr;y<=endyr;y++){
   F(y,t)=mfexp(log_F(y,t));
  }
 }

  for(y=styr;y<=endyr;y++){
    FullF(y)=0;
    for(t=1;t<=nfleets;t++){
      FullF(y)+=mfexp(log_F(y,t));
    }
 }
FUNCTION calc_biascorrect
 if(biascor==1) recvar=norm2(log_R_dev(styr,endyr)-(sum(log_R_dev(styr,endyr))/(endyr-styr+1)))/(endyr-styr+1-1.0);
 if(biascor==0) recvar=0;
//CALCULATE AND FILL NUMBERS-AT-AGE MATRIX
FUNCTION calc_numbers_at_age
  // First row of pre-data year
 if(srmodel==1){
   N(styrR,1)=mfexp(log_R+log_R_dev(styrR)-0.5*recvar);//Fill in Recruits in first year and age
  }
 if(srmodel>1){
   N(styrR,1)=mfexp(log_R);//Fill in Recruits in first year and age
  }

  for(a=2;a<=nages;a++){
   N(styrR,a)=N(styrR,a-1)*mfexp(-1.*Z(styrR,a-1));//Fills in top row of matrix
   }
  N(styrR,nages)=N(styrR,nages-1)*mfexp(-1.*Z(styrR,nages-1))/(1.-mfexp(-1.*Z(styrR,nages)));
     sumdo1=0;
     for(a=1;a<=nages;a++){
       if (rivard==1) sumdo1+=N(styrR,a)*mfexp(-1.*(pF*Fcomb(styr,a)+pM*M(styr,a)))*fsex(a)*fmat(styr,a)*rwgts(styr,a);
       if (rivard==0) sumdo1+=N(styrR,a)*mfexp(-1.*(pF*Fcomb(styr,a)+pM*M(styr,a)))*fsex(a)*fmat(styr,a)*ssbwgt(styr,a);
     }
    SSB(styrR)=sumdo1/1000;
    // Constraints on first recruitment to follow S-R curve
    if(srmodel>1){
      if(srmodel==2) log_R_constraint=log(BH_a)+log(SSB(styrR))-log(1+SSB(styrR)/BH_b)-0.5*recvar;
      if(srmodel==3) log_R_constraint=log(r_a)+log(SSB(styrR))-SSB(styrR)/r_b-0.5*recvar;
      if(srmodel==4) log_R_constraint=log(shep_a)+log(SSB(styrR))-log(1+pow(SSB(styrR)/shep_b,shep_c)-0.5*recvar);
     }
  //Rest of data
   for(y=styrR+1;y<=endyr;y++){
    if(srmodel==1) N(y,1)=mfexp(log_R+log_R_dev(y)-0.5*recvar);
    if(srmodel>1){
      if(srmodel==2) N(y,1)=mfexp(log(BH_a)+log(SSB(y-1))-log(1+SSB(y-1)/BH_b)+log_R_dev(y)-0.5*recvar);
      if(srmodel==3) N(y,1)=mfexp(log(r_a)+log(SSB(y-1))-SSB(y-1)/r_b+log_R_dev(y)-0.5*recvar);
      if(srmodel==4) N(y,1)=mfexp(log(shep_a)+log(SSB(y-1))-log(1+pow(SSB(y-1)/shep_b,shep_c))+log_R_dev(y)-0.5*recvar);
     }
    N(y)(2,nages)=++elem_prod(N(y-1)(1,nages-1),(mfexp(-1.*Z(y-1)(1,nages-1))));
    N(y,nages)+=N(y-1,nages)*mfexp(-1.*Z(y-1,nages));//plus  group
     if(y<styr){
        sumdo1=0;
         for(a=1;a<=nages;a++){
           if (rivard==1) sumdo1+=N(y,a)*mfexp(-1.*(pF*Fcomb(styr,a)+pM*M(styr,a)))*fsex(a)*fmat(styr,a)*rwgts(styr,a);
           if (rivard==0) sumdo1+=N(y,a)*mfexp(-1.*(pF*Fcomb(styr,a)+pM*M(styr,a)))*fsex(a)*fmat(styr,a)*ssbwgt(styr,a);
          }
          SSB(y)=sumdo1/1000;
      }
      if(y>=styr){
        sumdo1=0;
```

```
        for(a=1;a<=nages;a++){
          if (rivard==1) sumdo1+=N(y,a)*mfexp(-1.*(pF*Fcomb(y,a)+pM*M(y,a)))*fsex(a)*fmat(y,a)*rwgts(y,a);
          if (rivard==0) sumdo1+=N(y,a)*mfexp(-1.*(pF*Fcomb(y,a)+pM*M(y,a)))*fsex(a)*fmat(y,a)*ssbwgt(y,a);
         }
         SSB(y)=sumdo1/1000;
      }

    }
  R=column(N,1);
 //CALCULATE CATCH-AT-AGE MATRIX
FUNCTION calc_catch_at_age
 for(t=1;t<=nfleets;t++){
  for(y=styr;y<=endyr;y++){
   for(a=1;a<=nages;a++){
     C(t,y,a)=N(y,a)*Ffleet(t,y,a)*(1.-mfexp(-1.*Z(y,a)))/Z(y,a);
   }
  }
 }
 for(t=1;t<=nfleets;t++){
   for(y=styr;y<=endyr;y++){
     sumage=0;
     for(a=1;a<=nages;a++){
       sumage+=C(t,y,a);
     }
     pred_total_catch(y,t)=sumage;
      for(a=1;a<=nages;a++){
        pred_age_comp(t,y,a)=C(t,y,a)/(sumage+0.001);
     }
    if(convflag==1) pred_age_comp(t,y)=convmatrix(t)*pred_age_comp(t,y);
  }
 }
// Calculate Predicted Aggregate Indices
FUNCTION calc_predict_indices_agg
 if(agg_surv_num>0){
  cnt=0;
  for(t=1;t<=agg_surv_num;t++){
   if(use_agg(t)==1){
     cnt+=1;
     adds=0;
     realage=0;
     diff2=0;
     for(y=styrR;y<=endyr;y++){
       if (agg_obs_surv_indices(y,t)>=0.) //Skip missing values (-1)
        {
               realage=(int)floor(agg_surv_ages(t));
               diff2=int(ceil(agg_surv_ages(t)*100)-(floor(agg_surv_ages(t))*100));
               pgroup=0;
               for (a=realage;a<=diff2;a++)
                 {
                  pgroup+=N(y,a)*mfexp(-1.*agg_surv_flag(t)*Z(y,a));
         }
                 agg_pred_surv_indices(y,t)=mfexp(agg_qs(cnt))*pgroup;
        }//agg_surv_indices>=0
        if (agg_obs_surv_indices(y,t)==-1) agg_pred_surv_indices(y,t)=-1;
     }//y loop
     q_Agg(cnt)=mfexp(agg_qs(cnt));
   }
  }//t loop
 }
FUNCTION calc_predict_indices_ac
  //calc survey selectivities
 if(ac_surv_num>0){
   cnt=0;
   cnter=0;
   cnter2=0;
   cnter3=0;
   cnter4=0;
```

```
for(t=1;t<=ac_surv_num;t++){
 if(use_ac(t)==1){
   maxs=0;
  for(a=1;a<nages;a++){
   if(acsel(t,6)==1){
        if(a==1) cnt+=1;
        surv_sel(t,a)=exp(-1.*exp(-1.*acgom_b(cnt)*(double(agebins(a))-acgom_a(cnt))));
        if(surv_sel(t,a)>=maxs) maxs=surv_sel(t,a);
    }
    if(acsel(t,6)==2){
        if(a==1) cnter+=1;
        surv_sel(t,a)=1./(1.+mfexp(-1.*aclog_b(cnter)*(double(agebins(a))-aclog_a(cnter))));
        if(surv_sel(t,a)>=maxs) maxs=surv_sel(t,a);
    }
     if(acsel(t,6)==3){
        if(a==1) cnter2+=1;
        surv_sel(t,a)=pow(double(a),acgam_a(cnter2))*exp(-1.*acgam_b(cnter2)*double(a));
      if(surv_sel(t,a)>=maxs) maxs=surv_sel(t,a);
    }
    if(acsel(t,6)==4){
        if(a==1)  cnter3+=1;
        surv_sel(t,a)=(1./(1.-acthom_c(cnter3)))*pow((1-acthom_c(cnter3))/
             acthom_c(cnter3),acthom_c(cnter3))*(mfexp(acthom_a(cnter3)*acthom_c(cnter3)*(acthom_b(cnter3)-double(a)))/
             (1+mfexp(acthom_a(cnter3)*(acthom_b(cnter3)-double(a)))));
        if(surv_sel(t,a)>=maxs) maxs=surv_sel(t,a);
    }
    if(acsel(t,6)==5){
       if(acuser(t,a)>=0 && acuser(t,a)<=1) surv_sel(t,a)=acuser(t,a);
       if(acuser(t,a)==99){
         cnter4+=1;
         surv_sel(t,a)=userparms(cnter4);
       }
       if(surv_sel(t,a)>=maxs) maxs=surv_sel(t,a);
    }
 }
  surv_sel(t,nages)=surv_sel(t,nages-1);
  surv_sel(t)=surv_sel(t)/maxs;
 }
}
cnt=0;
for(t=1;t<=ac_surv_num;t++){
  if(use_ac(t)==1){
     cnt+=1;
     for(y=styrR;y<=endyr;y++){
        for(a=1;a<=nages;a++){
           calc_comps(t,y,a)=-1;
           if (surv_comps(t,y,a)>=0.){
              calc_comps(t,y,a)=surv_sel(t,a)*mfexp(ac_qs(cnt))*N(y,a)*mfexp(-1.*acsel(t,2)*Z(y,a));
            }
          }//a loop
       }//y loop
    q_AC(cnt)=mfexp(ac_qs(cnt));
  }
}//t loop
for(t=1;t<=ac_surv_num;t++){
  if(use_ac(t)==1){
   for(y=styrR;y<=endyr;y++){
       sumage=0;
       for (a=1;a<=nages;a++){
          if(surv_comps(t,y,a)>=0.) sumage+=calc_comps(t,y,a);
        }
          if(sumage>0.) ac_pred_surv_indices(y,t)=sumage;
          if(sumage<=0.) ac_pred_surv_indices(y,t)=-1;
        for (a=1;a<=nages;a++){
          surv_pred_comps(t,y,a)=-1;
          if(sumage>0.){
            if(surv_comps(t,y,a)>=0.)surv_pred_comps(t,y,a)=calc_comps(t,y,a)/sumage;
```

```
            }
            if(sumage<=0.){surv_pred_comps(t,y,a)=-1;}
          }
     }
     if(convflag==1){
       for(y=styrR;y<=endyr;y++){
         if(ac_pred_surv_indices(y,t)>=0.) surv_pred_comps(t,y)=convmatrix(t+nfleets)*surv_pred_comps(t,y);
       }
     }
    }
   }
 }//if surveys>0
FUNCTION scam_likelihood
 cnt=0;
 //CALCULATE TOTAL CATCH Likelihoods
   for(t=1;t<=nfleets;t++){
     fleet_total_catch_like(t)=0.;
   for(y=styr;y<=endyr;y++){
    if(obs_total_catch(y,t)>=0.){
         fleet_total_catch_like(t)+=square(log((obs_total_catch(y,t)+0.00001)/(pred_total_catch(y,t)+0.00001))/total_catch_CV(y,t));
         cnt+=1;
    }
   }
  }
//CALCULATE CATCH AGE COMP LIKELIHOOD
   for(t=1;t<=nfleets;t++){
     fleet_age_comp_like(t)=0.;
    for(y=styr;y<=endyr;y++){
      for(a=1;a<=nages;a++){
        if(obs_age_comp(t,y,a)>=0.){
          fleet_age_comp_like(t)-=ss_age_comp(y,t)*obs_age_comp(t,y,a)*log(pred_age_comp(t,y,a)+1e-7);
        }
      }
    }
   }
//CALCULATE AGGREGATE SURVEY WEIGHTED RESIDUAL SUM OF SQUARES
  if(agg_surv_num>0){
   for(t=1;t<=agg_surv_num;t++){
     like_agg(t)=0;
     if(use_agg(t)==1){
       for(y=styrR;y<=endyr;y++){
                   if(agg_obs_surv_indices(y,t)>=0.){

like_agg(t)+=square(log((agg_obs_surv_indices(y,t)+0.00001)/(agg_pred_surv_indices(y,t)+0.00001))/(agg_surv_CV(y,t)*agg_index_CV_wgt(t)))
;
             cnt+=1;
                   }
     }
    }
   }
  }
// CALCULATE SURVEY WITH AGE COMPOSITIONS
 if(ac_surv_num>0){
  for(t=1;t<=ac_surv_num;t++){
    like_ac_surv(t)=0;
    if(use_ac(t)==1){
     for(y=styrR;y<=endyr;y++){
       if(ac_obs_surv_indices(y,t)>=0.){
             like_ac_surv(t)+=square(log((ac_obs_surv_indices(y,t)+0.00001)/(ac_pred_surv_indices(y,t)+0.00001))/(ac_surv_CV(y,t)*acsel(t,5)));
             cnt+=1;
      }
     }
    }
  }
  for(t=1;t<=ac_surv_num;t++){
     like_ac_age(t)=0;
     if(use_ac(t)==1){
```

```
    for(y=styrR;y<=endyr;y++){
      for(a=1;a<=nages;a++){
        if(surv_comps(t,y,a)>=0.){
            like_ac_age(t)-=ac_ss(y,t)*surv_comps(t,y,a)*log(surv_pred_comps(t,y,a)+1e-7);
        }
       }
     }
    }
   }
 }
FUNCTION evaluate_the_objective_function
 f=0;
 sumdo1=0;
 recpen=0;
 sumdo=0;
 dodo=0;
 dodo1=0;
  for(t=1;t<=nfleets;t++){
    sumdo+=fleet_total_catch_like(t)*fleetllw(t,2);
    f+=fleet_age_comp_like(t)*fleetllw(t,3);
  }
 for(t=1;t<=agg_surv_num;t++){
    if(use_agg(t)==1){
      dodo+=like_agg(t)*agg_wgt(t);
    }
 }
  for(t=1;t<=ac_surv_num;t++){
    if(use_ac(t)==1){
      dodo1+=like_ac_surv(t)*acsel(t,3);
      f+=like_ac_age(t)*acsel(t,4);
   }
 }
 //CONCENTRATED LIKELIHOOD
  concll=0.5*cnt*log((sumdo+dodo+dodo1)/cnt);
   f+=concll;
   if(biascor==0) f+=R_dev_lam*norm2(log_R_dev);
   if(biascor==1){
     if(current_phase()==log_R_dev_con1) f+=norm2(log_R_dev);
     if(current_phase()>log_R_dev_con1){
       for(y=styr;y<=endyr;y++){
         recpen+=log(sqrt(recvar))+square(log_R_dev(y))/2*recvar;
       }
      f+=R_dev_lam*recpen;
     }
  }
  if(srmodel>1) f+=log_R_lam*square(log_R-log_R_constraint);
 //CALCULATE PENALTY CONSTRAINT FOR F
   if(current_phase()<3){
    fpen=10.*norm2(mfexp(log_F)-0.15);
   }
   else{
    fpen=0.000001*norm2(mfexp(log_F)-0.15);
   }
 f+=fpen;

REPORT_SECTION
 report <<"Likelihood Components" << endl;
 report <<" "<<endl;
 report <<"                    "<<"\t"<<"Weight"<<"   "<<"RSS"<<endl;
  for(t=1;t<=nfleets;t++){
    report <<" Fleet "<<t<<" Total Catch: "<<"\t"<<fleetllw(t,2)<<"\t"<<setw(10)<<fleetllw(t,2)*fleet_total_catch_like(t)<<endl;
  }
 report <<" Aggregate Abundance Index    " << endl;
  for(t=1;t<=agg_surv_num;t++){
   if(use_agg(t)==1){
    report <<"   Survey "<<t<<"        : "<<"\t"<<agg_wgt(t)<<"\t"<<setw(10)<<agg_wgt(t)*like_agg(t)<<endl;
   }
```

```
  }
 report <<" Age Comp Abundance Indexs   " << endl;
 for(t=1;t<=ac_surv_num;t++){
    if(use_ac(t)==1){
     report <<"   Survey "<<t<<"        : "<<"\t"<<acsel(t,3)<<"\t"<<setw(10)<<acsel(t,3)*like_ac_surv(t)<<endl;
    }
  }
 report<<" "<<endl;
 report <<" Total RSS          "<<"\t"<<" "<<"\t"<<setw(10)<<sum(elem_prod(column(fleetllw,2),fleet_total_catch_like))+
       sum(elem_prod(agg_wgt,like_agg))+sum(elem_prod(column(acsel,3),like_ac_surv))<<endl;
 report <<" No. of Obs          "<<"\t"<<" "<<"\t"<<setw(10)<<cnt<<endl;
 report <<" Conc. Likelihood    "<<"\t"<<  "<<"\t"<<setw(10)<<concll<<endl;
 report<<"Age Composition Data "<<endl;
 for(t=1;t<=nfleets;t++){
    report <<" Fleet "<<t<<" Age Comp: "<<"\t"<<fleetllw(t,3)<<"\t"<<setw(10)<<fleetllw(t,3)*fleet_age_comp_like(t)<<endl;
 }
 for(t=1;t<=ac_surv_num;t++){
    if(use_ac(t)==1){
     report <<"   Survey "<<t<<"        : "<<"\t"<<acsel(t,4)<<"\t"<<setw(10)<<acsel(t,4)*like_ac_age(t)<<endl;
    }
   }
report <<" "<<endl;
if(srmodel>1) report <<"log_R constraint "<<"        : "<<"\t"<<log_R_lam<<"\t"<<setw(10)<<log_R_lam*square(log_R-log_R_constraint)<<endl;
if(biascor==0) report <<"Recr Devs "<<"        : "<<"\t"<<R_dev_lam<<"\t"<<setw(10)<<R_dev_lam*norm2(log_R_dev)<<endl;
if(biascor==1) report <<"Recr Devs "<<"        : "<<"\t"<<R_dev_lam<<"\t"<<setw(10)<<R_dev_lam*recpen<<endl;
report <<" "<<endl;
report <<"Total Likelihood    : "<<"\t"<<  "<<"\t"<<setw(10)<<f<<endl;
if(biascor==0) report <<"AIC    : "<<"\t"<<  "<<"\t"<<setw(10)<<2*f+2*n_parms<<endl;
if(biascor==1) report <<"AIC    : "<<"\t"<<  "<<"\t"<<setw(10)<<2*f+2*(n_parms+1)<<endl; // for calculated recvar
report << " " << endl;

ofstream ofs36("LLtable.out");
   ofs36 <<"Likelihood Components" << endl;
 ofs36 <<" "<<endl;
 ofs36 <<"                    "<<"\t"<<"Weight"<<"\t"<<   "<<"RSS"<<endl;
  for(t=1;t<=nfleets;t++){
    ofs36 <<"Fleet "<<t<<" Total Catch: "<<"\t"<<fleetllw(t,2)<<"\t"<<setw(10)<<fleetllw(t,2)*fleet_total_catch_like(t)<<endl;
 }
ofs36 <<" Aggregate Abundance Indices  " << endl;
  for(t=1;t<=agg_surv_num;t++){
    if(use_agg(t)==1){
    ofs36 <<"   Survey "<<t<<"        : "<<"\t"<<agg_wgt(t)<<"\t"<<setw(10)<<agg_wgt(t)*like_agg(t)<<endl;
   }
  }
 ofs36 <<" Age Comp Abundance Indices  " << endl;
 for(t=1;t<=ac_surv_num;t++){
     if(use_ac(t)==1){
      ofs36 <<"   Survey "<<t<<"        : "<<"\t"<<acsel(t,3)<<"\t"<<setw(10)<<acsel(t,3)*like_ac_surv(t)<<endl;
     }
  }
 ofs36<<" "<<endl;
ofs36 <<" Total RSS          "<<"\t"<<" "<<"\t"<<setw(10)<<sum(elem_prod(column(fleetllw,2),fleet_total_catch_like))+
       sum(elem_prod(agg_wgt,like_agg))+sum(elem_prod(column(acsel,3),like_ac_surv))<<endl;

ofs36 <<" No. of Obs          "<<"\t"<<" "<<"\t"<<setw(10)<<cnt<<endl;
ofs36 <<" Conc. Likel.        "<<"\t"<<  "<<"\t"<<setw(10)<<
         0.5*cnt*log((sum(elem_prod(column(fleetllw,2),fleet_total_catch_like))+
       sum(elem_prod(agg_wgt,like_agg))+sum(elem_prod(column(acsel,3),like_ac_surv)))/cnt)<<endl;
 ofs36<<" "<<endl;
 ofs36<<"Age Composition Data "<<"\t"<<"Likelihood"<<endl;
 for(t=1;t<=nfleets;t++){
    ofs36 <<" Fleet "<<t<<" Age Comp: "<<"\t"<<fleetllw(t,3)<<"\t"<<setw(10)<<fleetllw(t,3)*fleet_age_comp_like(t)<<endl;
 }
 for(t=1;t<=ac_surv_num;t++){
   if(use_ac(t)==1){
     ofs36 <<"   Survey "<<t<<"        : "<<"\t"<<acsel(t,4)<<"\t"<<setw(10)<<acsel(t,4)*like_ac_age(t)<<endl;
   }
```

```
   }
ofs36 <<" "<<endl;
if(srmodel>1) ofs36 <<"log_R constraint"<<": "<<"\t"<<log_R_lam<<"\t"<<setw(10)<<log_R_lam*square(log_R-log_R_constraint)<<endl;
ofs36 <<"Recr Devs "<<"          : "<<"\t"<<R_dev_lam<<"\t"<<setw(10)<<R_dev_lam*norm2(log_R_dev)<<endl;
ofs36 <<" "<<endl;
ofs36 <<"Total Likelihood    : "<<"\t"<<"  "<<"\t"<<setw(10)<<f<<endl;
ofs36 <<"AIC                : "<<"\t"<<"  "<<"\t"<<setw(10)<<2*f+2*n_parms<<endl;
ofs36.close();
report <<"***********************************************************************************************************"<<endl;
report<<"Mortality Rates "<<endl;
report << "Natural" << endl;
report << M << endl;
report<<" "<<endl;
report << "Fishing" << endl;
report << mfexp(log_F)<< endl;
report<<" "<<endl;
report <<"*********************************************SCAM Output***********************"<<endl;
 report << "Total Catch" << endl;
report << "Observed" <<endl;
report << obs_total_catch << endl;
report << "Predicted" << endl;
report << pred_total_catch <<endl;
report <<" "<<endl;
report << "Obs Catch Age Comp "<< endl;
report<<obs_age_comp<<endl;
report <<" "<<endl;
report <<"Pred Catch Age comp"<<endl;
report<<pred_age_comp<<endl;
report <<" "<<endl;
report << "Number-At-Age "<< endl;
report << N<<endl;
 report<<"Observed Aggregate Indices"<<endl;
report<<agg_obs_surv_indices<<endl;
report <<" "<<endl;
report<<"Predicted Aggregate Indices"<<endl;
report<<agg_pred_surv_indices<<endl;
report <<" "<<endl;
report<<"Aggregate Survey qs"<<endl;
report<<mfexp(agg_qs)<<endl;
report <<" "<<endl;
report<<"Aggregate Indices CVs"<<endl;
report<<agg_surv_CV<<endl;
report <<" "<<endl;
report<<"Observed Age Comp Indices"<<endl;
report<<ac_obs_surv_indices<<endl;
report <<" "<<endl;
report<<"Predicted Age Comps Indices"<<endl;
report<<ac_pred_surv_indices<<endl;
report <<" "<<endl;
report<<"Age Comps Survey qs"<<endl;
report<<mfexp(ac_qs)<<endl;
report <<" "<<endl;
report<<"Age Comps Indices CVs"<<endl;
report<<ac_surv_CV<<endl;
report <<" "<<endl;
report<<"Observed Survey Age Comps "<<endl;
report<<surv_comps<<endl;
report <<" "<<endl;
report<<"Predicted Survey Age Comps "<<endl;
report<<surv_pred_comps<<endl;
report <<" "<<endl;
report<<"Predicted Survey Age Comps Selectivities"<<endl;
report<<surv_sel<<endl;
report <<" "<<endl;

report<<"Fishing Mortality at age"<<endl;
//report<<F<<endl;
```

```
 report <<" "<<endl;
 report<<"Female SSB"<<endl;
 report<<SSB<<endl;
 report <<" "<<endl;

 report<<"Rivards Weights(kg)"<<endl;
 report<<rwgts<<endl; report <<" "<<endl;
 report<<"Catch Weights (kg)"<<endl;
 report<<cwgt<<endl; report <<" "<<endl;
 report<<"January-1 stock biomass (mt)"<<endl;
 report<<jan1bio/1000<<endl; report <<" "<<endl;
 report<<"Catch biomass (mt)"<<endl;
 report<<catchbio/1000<<endl; report <<" "<<endl;

FINAL_SECTION
 // Number of Parameters
 ofstream ofs51("nparms.out");
 ofs51<<n_parms<<endl;
 ofs51.close();
 //Final calculations
 ofstream ofs1("jan1bio.out");
 ofstream ofs2("catchbio.out");
    for(y=styr;y<=endyr;y++){
      for(a=1;a<=nages;a++){
       jan1bio(y,a)=rwgts(y,a)*N(y,a);
       if(a<nages) ofs1<<jan1bio(y,a)/1000<<" ";
       if(a==nages) ofs1<<jan1bio(y,a)/1000<<endl;
        for(t=1;t<=nfleets;t++){
         catchbio(t,y,a)=cwgt(y,a)*obs_total_catch(y,t)*obs_age_comp(t,y,a)/1000;
       }
      }
    }
   for(t=1;t<=nfleets;t++){
    for(y=styr;y<=endyr;y++){
      for(a=1;a<=nages;a++){
       if(a<nages) ofs2<<catchbio(t,y,a)<<" ";
       if(a==nages) ofs2<<catchbio(t,y,a)<<endl;
     }
   }
  }
  ofs1.close();
  ofs2.close();

// Output Average F
  cnter=0;
  cnter2=0;
  for(t=1;t<=navgf;t++){
    cnter=avgftable(t,1);
    cnter2=avgftable(t,2);
    for(y=styr;y<=endyr;y++){
       sumdo=0;
       cnt=0;
       sumdo1=0;

   if(avgftable(t,3)==1){ //Unweighted
      for(a=cnter;a<=cnter2;a++){
       sumdo+=Fcomb(y,a);
       cnt+=1;
      }
      avgF(y,t)=sumdo/cnt;
    }
   if(avgftable(t,3)==3){ //N-weighted Jan-1
       for(a=cnter;a<=cnter2;a++){
       sumdo+=Fcomb(y,a)*N(y,a);
       sumdo1+=N(y,a);
      }
      avgF(y,t)=sumdo/sumdo1;
```

```
 }
 if(avgftable(t,3)==2){ //B-weighted Jan-1
   for(a=cnter;a<=cnter2;a++){
     sumdo+=Fcomb(y,a)*jan1bio(y,a);
     sumdo1+=jan1bio(y,a);
    }
    avgF(y,t)=sumdo/sumdo1;
 }
}
}
ofstream ofs3("avgF.out");
   for(y=styr;y<=endyr;y++){
     for(t=1;t<=navgf;t++){
   if(t<navgf) ofs3<<avgF(y,t)<<" ";
   if(t==navgf) ofs3<<avgF(y,t)<<endl;
 }
}
ofs3.close();


//Ouput R and Rsd
ofstream ofs4("R.out");
  d=n_parms+1;
 for(t=styrR;t<=endyr;t++){
     ofs4<<R(t)<<" "<<sigma(d,1)<<endl;
     d+=1;
 }
 ofs4.close();
// Output Fleet Fully-recruited F and Fsd
 for(t=1;t<=nfleets;t++){
   sprintf(hh,"%i",t);
   adstring u=adstring("Fleet")+hh+adstring("FullF.out");
   ofstream ofs5(u);
   for(y=styr;y<=endyr;y++){
    ofs5<<F(y,t)<<" "<<sigma(d,1)<<endl;
     d+=1;
   }
    ofs5.close();
 }

//Output F-at-age
ofstream ofs82("Fatage.out");
  for(y=styr;y<=endyr;y++){
    for(a=1;a<=nages;a++){
    if(a<nages) ofs82<<Fcomb(y,a)<<" ";
    if(a==nages) ofs82<<Fcomb(y,a)<<endl;
   }
 }
ofs82.close();
//Output Catchability Coefficients of Age-specific and Aggregate Indices
ofstream ofs6("acqs.out");
 cnt=0;
  for(t=1;t<=ac_surv_num;t++){
   if(use_ac(t)==1){
     cnt+=1;
     ofs6<<mfexp(ac_qs(cnt))<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/mfexp(ac_qs(cnt)))<<endl;
     d+=1;
   }
   if(use_ac(t)==0){
     ofs6<<"0"<<" "<<"0"<<" "<<"0"<<endl;
   }
 }
 cnt=0;
 ofstream ofs7("aggqs.out");
  for(t=1;t<=agg_surv_num;t++){
    if(use_agg(t)==1){
      cnt+=1;
```

```
      ofs7<<mfexp(agg_qs(cnt))<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/mfexp(agg_qs(cnt)))<<endl;
      d+=1;
    }
    if(use_agg(t)==0){
      ofs7<<"0"<<" "<<"0"<<" "<<"0"<<endl;
    }
  }
//Output Female Spawning Stock Biomass
 ofstream ofs8("SSBfem.out");
  for(y=styrR;y<=endyr;y++) {
    if(y>=styr) ofs8<<SSB(y)<<" "<<sigma(d,1)<<endl;
     d+=1;
  }
 ofs8.close();
 //
 //
 // Output Total Fully-Recruited F and Fsd
 ofstream ofs81("FullF.out");
   for(y=styr;y<=endyr;y++){
     ofs81<<FullF(y)<<" "<<sigma(d,1)<<endl;
     d+=1;
   }
 ofs81.close();
 //Output N-at-age
 ofstream ofs9("N.out");
 for(y=styrR;y<=endyr;y++){
   for(a=1;a<=nages;a++){
    if(a<nages) ofs9<<N(y,a)<<" ";
    if(a==nages) ofs9<<N(y,a)<<endl;
   }
 }
// Output Predicted Survey Selectivities-at-Age
  ofstream ofs("survsel.out");
    for(a=1;a<=nages;a++){
      for(t=1;t<=ac_surv_num;t++){
       if(t<ac_surv_num) ofs<<surv_sel(t,a)<<" ";
       if(t==ac_surv_num) ofs<<surv_sel(t,a)<<endl;
    }
  }
  ofs.close();
//Output Fleet Catch Age Comp
 for(t=1;t<=nfleets;t++){
   sprintf(hh,"%i",t);
   adstring u=adstring("Fleet")+hh+adstring("CAApred.out");
   ofstream ofs(u);
  for(y=styr;y<=endyr;y++){
   for(a=1;a<=nages;a++){
     if(a<nages) ofs<<pred_age_comp(t,y,a)<<" ";
     if(a==nages) ofs<<pred_age_comp(t,y,a)<<endl;
   }
  }
 ofs.close();
 }
//Output Catch Age Comp
  for(t=1;t<=nfleets;t++){
   sprintf(hh,"%i",t);
   adstring u=adstring("Fleet")+hh+adstring("CAAobs.out");
   ofstream ofs(u);
  for(y=styr;y<=endyr;y++){
   for(a=1;a<=nages;a++){
     if(a<nages) ofs<<obs_age_comp(t,y,a)<<" ";
     if(a==nages) ofs<<obs_age_comp(t,y,a)<<endl;
   }
  }
  ofs.close();
 }
//Output Predicted Total Catch
```

```
  for(t=1;t<=nfleets;t++){
   sprintf(hh,"%i",t);
   adstring u=adstring("Fleet")+hh+adstring("Catpred.out");
   ofstream ofs(u);
   for(y=styr;y<=endyr;y++){
      ofs<<pred_total_catch(y,t)<<endl;
   }
  ofs.close();
  }
//Output Observed Total Catch
  for(t=1;t<=nfleets;t++){
    sprintf(hh,"%i",t);
    adstring u=adstring("Fleet")+hh+adstring("Catobs.out");
    ofstream ofs(u);
    for(y=styr;y<=endyr;y++){
     ofs<<obs_total_catch(y,t)<<endl;
    }
   ofs.close();
  }
 // Output Fleet F at age
 for(t=1;t<=nfleets;t++){
   sprintf(hh,"%i",t);
   adstring u=adstring("Fleet")+hh+adstring("Fatage.out");
   ofstream ofs(u);
  for(y=styr;y<=endyr;y++){
   for(a=1;a<=nages;a++){
    if(a<nages) ofs<<Ffleet(t,y,a)<<" ";
    if(a==nages)  ofs<<Ffleet(t,y,a)<<endl;
   }
  }
 ofs.close();
}
//Output Predicited and Observed Indices
  ofstream ofs15("AggPred.out");
   for(y=styrR;y<=endyr;y++){
     for(t=1;t<=agg_surv_num;t++){
     if(t<agg_surv_num) ofs15<<agg_pred_surv_indices(y,t)<<" ";
     if(t==agg_surv_num) ofs15<<agg_pred_surv_indices(y,t)<<endl;
     }
   }
  ofstream ofs16("AggObs.out");
    for(y=styrR;y<=endyr;y++){
     for(t=1;t<=agg_surv_num;t++){
     if(t<agg_surv_num) ofs16<<agg_obs_surv_indices(y,t)<<" ";
     if(t==agg_surv_num) ofs16<<agg_obs_surv_indices(y,t)<<endl;
     }
   }
//Output Predicited and Observed Age Comp surveys
 ofstream ofs17("ACPred.out");
     for(y=styrR;y<=endyr;y++){
     for(t=1;t<=ac_surv_num;t++){
     if(t<ac_surv_num) ofs17<<ac_pred_surv_indices(y,t)<<" ";
     if(t==ac_surv_num) ofs17<<ac_pred_surv_indices(y,t)<<endl;
     }
   }
 ofstream ofs18("ACObs.out");
   for(y=styrR;y<=endyr;y++){
     for(t=1;t<=ac_surv_num;t++){
     if(t<ac_surv_num) ofs18<<ac_obs_surv_indices(y,t)<<" ";
     if(t==ac_surv_num) ofs18<<ac_obs_surv_indices(y,t)<<endl;
     }
   }
 ofstream ofs19("survacpred.out");
    for(t=1;t<=ac_surv_num;t++){
      for(y=styrR;y<=endyr;y++){
        for(a=1;a<=nages;a++){
         if(a<nages) ofs19<<surv_pred_comps(t,y,a)<<" ";
```

```
        if(a==nages) ofs19<<surv_pred_comps(t,y,a)<<endl;
   }
  }
 }
 ofstream ofs20("survacobs.out");
   for(t=1;t<=ac_surv_num;t++){
      for(y=styrR;y<=endyr;y++){
        for(a=1;a<=nages;a++){
         if(a<nages) ofs20<<surv_comps(t,y,a)<<" ";
          if(a==nages) ofs20<<surv_comps(t,y,a)<<endl;
   }
  }
 }
 ofstream ofs21("calccomps.out");
  for(t=1;t<=ac_surv_num;t++){
      for(y=styrR;y<=endyr;y++){
        for(a=1;a<=nages;a++){
         if(a<nages) ofs21<<calc_comps(t,y,a)<<" ";
          if(a==nages) ofs21<<calc_comps(t,y,a)<<endl;
   }
  }
 }
 //*****************************************************************************************************
 // Effective Sample Sizes - McAllister and Ianelli Method
 //*****************************************************************************************************
  // Output Average Effective Sample Size for Catch Age Comps
     sumdo1=0;
    dodo1=0;
   for(t=1;t<=nfleets;t++){
     sprintf(hh,"%i",t);
     adstring u=adstring("Fleet")+hh+adstring("ess.out");
     ofstream ofs(u);
    for(y=styr;y<=endyr;y++){
        sumdo=0;
        dodo=0;
        for(a=1;a<=nages;a++){
             if(obs_age_comp(t,y,a)>=0){
              sumdo+=pred_age_comp(t,y,a)*(1-pred_age_comp(t,y,a));
              dodo+=square(obs_age_comp(t,y,a)-pred_age_comp(t,y,a));
             }
             if(obs_age_comp(t,y,a)<0){
              sumdo=0;
              dodo=0;
             }
          }
                  if(sumdo>0 && dodo>0) sumdo1+=sumdo/dodo;
      }
   for(y=styr;y<=endyr;y++){
      if (obs_total_catch(y,t)>=0) dodo1+=1;
     }
   ofs<<sumdo1/dodo1<<endl;
   ofs.close();
  }
//Output Input Fleet Effective Sample
    for(t=1;t<=nfleets;t++){
      sprintf(hh,"%i",t);
      adstring u=adstring("Fleet")+hh+adstring("obseffss.out");
      ofstream ofs(u);
       for(y=styr;y<=endyr;y++){
         ofs<<ss_age_comp(y,t)<<endl;
       }
    ofs.close();
     }
//Output Survey Age Comps Average Efficitive Sample Size
  ofstream ofs23("acavgeffss.out");
  for(t=1;t<=ac_surv_num;t++){
    if(use_ac(t)==1){
```

```
    sumdo1=0;
    dodo1=0;
    for(y=styrR;y<=endyr;y++){
       sumdo=0;
       dodo=0;
       for(a=1;a<=nages;a++){
           if(surv_comps(t,y,a)>=0){
            sumdo+=surv_pred_comps(t,y,a)*(1-surv_pred_comps(t,y,a));
            dodo+=square(surv_comps(t,y,a)-surv_pred_comps(t,y,a));
           }
           if(surv_comps(t,y,a)<0){
            sumdo=0;
            dodo=0;
           }
         }
                 if(sumdo>0 && dodo>0) sumdo1+=sumdo/dodo;
     }
   for(y=styrR;y<=endyr;y++){
      if (ac_obs_surv_indices(y,t)>=0) dodo1+=1;
     }
   ofs23<<sumdo1/dodo1<<endl;
  }
  if(use_ac(t)==0) ofs23<<"0"<<endl;
  }
 //Observed ac effective sample size
 ofstream ofs231("acobseffss.out");
  for(y=styrR;y<=endyr;y++){
    for(t=1;t<=ac_surv_num;t++){
     if(t<ac_surv_num) ofs231<<ac_ss(y,t)<<" ";
     if(t==ac_surv_num) ofs231<<ac_ss(y,t)<<endl;
    }
  }
// Catch yearly effective sample size
  for(t=1;t<=nfleets;t++){
    sprintf(hh,"%i",t);
    adstring u=adstring("Fleet")+hh+adstring("yreffss.out");
    ofstream ofs(u);
    for(y=styr;y<=endyr;y++){
       sumdo=0;
       dodo=0;
       for(a=1;a<=nages;a++){
           if(obs_age_comp(t,y,a)>=0){
            sumdo+=pred_age_comp(t,y,a)*(1-pred_age_comp(t,y,a));
            dodo+=square(obs_age_comp(t,y,a)-pred_age_comp(t,y,a));
           }
           if(obs_age_comp(t,y,a)<0){
            sumdo=0;
            dodo=0;
           }
         }
         if(sumdo==0 && dodo==0) ofs<<"-1"<<endl;
                   if(sumdo>0 && dodo>0) ofs<<sumdo/dodo<<endl;
       }
   ofs.close();
   }

 //Survey Age Comps Yearly Effective Sample Size
  ofstream ofs25("acyreffss.out");
  for(t=1;t<=ac_surv_num;t++){
   if(use_ac(t)==1){
    for(y=styrR;y<=endyr;y++){
       sumdo=0;
       dodo=0;
       for(a=1;a<=nages;a++){
           if(surv_comps(t,y,a)>=0){
            sumdo+=surv_pred_comps(t,y,a)*(1.-surv_pred_comps(t,y,a));
            dodo+=square(surv_comps(t,y,a)-surv_pred_comps(t,y,a));
```

```
            }
            if(surv_comps(t,y,a)<0){
             sumdo+=0;
             dodo+=0;
            }
         }
        if(sumdo==0 && dodo==0) aceffssyr(y,t)=-1;
                if(sumdo>0 && dodo>0) aceffssyr(y,t)=sumdo/dodo;
      }
    }
    if(use_ac(t)==0) aceffssyr(y,t)=0;

  }
      for(y=styrR;y<=endyr;y++){
         for(t=1;t<=ac_surv_num;t++){
         if(t<ac_surv_num) ofs25<<aceffssyr(y,t)<<" ";
         if(t==ac_surv_num) ofs25<<aceffssyr(y,t)<<endl;
      }

  }
//*****************************************************************************************************
 // Effective Sample Sizes - Francis (2011) method equation 1.8
 //*****************************************************************************************************
// Compute Francis (2011) stage 2 multiplier for multinomial to adjust input Neff
// Francis, R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. CJFAS 68: 1124-1138
// Code from ASAP3
// Catch
 Neff_stage2_mult_catch=1;
for (t=1;t<=nfleets;t++){
  mean_age_obs=0.0;
  mean_age_pred=0.0;
  mean_age_pred2=0.0;
  mean_age_resid=0.0;
  for(y=styr;y<=endyr;y++){
   for(a=1;a<=nages;a++){
     if(obs_age_comp(t,y,a)>=0.){
      mean_age_obs(y)+=obs_age_comp(t,y,a)*a;
      mean_age_pred(y)+=pred_age_comp(t,y,a)*a;
      mean_age_pred2(y)+=pred_age_comp(t,y,a)*a*a;
     }
   }
  }
  mean_age_resid=mean_age_obs-mean_age_pred;
  mean_age_sigma=sqrt(mean_age_pred2-elem_prod(mean_age_pred,mean_age_pred));
  mean_age_n=0.0;
  mean_age_mean=0.0;
  mean_age_m2=0.0;
  for(y=styr;y<=endyr;y++){
     if (obs_total_catch(y,t)>=0.){
        mean_age_x=mean_age_resid(y)*sqrt(ss_age_comp(y,t))/mean_age_sigma(y);
        mean_age_n+= 1.0;
        mean_age_delta=mean_age_x-mean_age_mean;
        mean_age_mean+= mean_age_delta/mean_age_n;
        mean_age_m2+= mean_age_delta*(mean_age_x-mean_age_mean);
     }
  }
  if ((mean_age_n > 0) && (mean_age_m2 > 0)) Neff_stage2_mult_catch(t)=1.0/(mean_age_m2/(mean_age_n-1.0));
}

//Indices
  Neff_stage2_mult_index=1;
for (t=1;t<=ac_surv_num;t++){
 if (use_ac(t)<=0.) Neff_stage2_mult_index(t)=0;
 if (use_ac(t)>=1.) {
    mean_age_obs=0.0;
    mean_age_pred=0.0;
    mean_age_pred2=0.0;
```

```
    mean_age_resid=0.0;
   for(y=styrR;y<=endyr;y++){
    for(a=1;a<=nages;a++){
      if(surv_comps(t,y,a)>=0.){
        mean_age_obs(y)+=surv_comps(t,y,a)*a;
        mean_age_pred(y)+=surv_pred_comps(t,y,a)*a;
        mean_age_pred2(y)+=surv_pred_comps(t,y,a)*a*a;
      }
     }
   }
   mean_age_resid=mean_age_obs-mean_age_pred;
   mean_age_sigma=sqrt(mean_age_pred2-elem_prod(mean_age_pred,mean_age_pred));
   mean_age_n=0.0;
   mean_age_mean=0.0;
   mean_age_m2=0.0;
   for(y=styrR;y<=endyr;y++){
     if (ac_obs_surv_indices(y,t)>=0.){
        mean_age_x=mean_age_resid(y)*sqrt(ac_ss(y,t))/mean_age_sigma(y);
        mean_age_n+=1.0;
        mean_age_delta=mean_age_x-mean_age_mean;
        mean_age_mean+=mean_age_delta/mean_age_n;
        mean_age_m2+=mean_age_delta*(mean_age_x-mean_age_mean);
     }
   }
   if ((mean_age_n > 0) && (mean_age_m2 > 0)) Neff_stage2_mult_index(t)=1.0/(mean_age_m2/(mean_age_n-1.0));
  }
  }

  ofstream ofs50("Francis.out");
  for(t=1;t<=nfleets;t++) ofs50<<Neff_stage2_mult_catch(t)<<endl;
  for(t=1;t<=ac_surv_num;t++) ofs50<<Neff_stage2_mult_index(t)<<endl;
  ofs50.close();

   //****************************************************************************
   // Compute Standardized Residuals for Total Catch
   //****************************************************************************
   //Residuals
   for(t=1;t<=nfleets;t++){
       sprintf(hh,"%i",t);
      adstring u=adstring("Fleet")+hh+adstring("std_res_C.out");
      ofstream ofs(u);
      sumdo=0;
    for(y=styr;y<=endyr;y++){
       if(obs_total_catch(y,t)<0.) resid_C(y,t)=0;
       if(obs_total_catch(y,t)>=0.){
        resid_C(y,t)=log(obs_total_catch(y,t)+1e-5)-log(pred_total_catch(y,t)+1e-5);
        sumdo+=1;
       }
    }
 //Calculate standardized residuals
   for(y=styr;y<=endyr;y++){
      if(obs_total_catch(y,t)>=0.){
         std_resid_C(y,t)=resid_C(y,t)/sqrt(log(square(total_catch_CV(y,t))+1));
       }
      if(obs_total_catch(y,t)<0.) std_resid_C(y,t)=-99999.0;
    }
   for(y=styr;y<=endyr;y++){
    ofs<<std_resid_C(y,t)<<endl;
    }
   ofs.close();
   }
   //Output RMSE for Fleet Catch
   for(t=1;t<=nfleets;t++){
       sprintf(hh,"%i",t);
      adstring u=adstring("Fleet")+hh+adstring("RMSE.out");
      ofstream ofs(u);
    sumdo=0;
```

```
  for(y=styr;y<=endyr;y++){
     if(obs_total_catch(y,t)<0.) resid_C(y,t)=0;
     if(obs_total_catch(y,t)>=0.){
      resid_C(y,t)=log(obs_total_catch(y,t)+1e-5)-log(pred_total_catch(y,t)+1e-5);
      sumdo+=1;
      }
    }
//Calculate standardized residuals
  for(y=styr;y<=endyr;y++){
     if(obs_total_catch(y,t)>=0.){
        std_resid_C(y,t)=resid_C(y,t)/sqrt(log(square(total_catch_CV(y,t))+1));
      }
     if(obs_total_catch(y,t)<0.) std_resid_C(y,t)=0;
    }
// Calculate RMSE
    adds=0;
    for(y=styr;y<=endyr;y++){
      if(obs_total_catch(y,t)>=0.) adds+=square(std_resid_C(y,t));
    }
    ofs<<sqrt(adds/sumdo)<<endl;
   ofs.close();
   }
 //***************************************************************************************************
 // Compute Standardized Residuals for Aggregate indices
 //***************************************************************************************************
  sumdo=0;
 for(t=1;t<=agg_surv_num;t++){
   if(use_agg(t)==1){
    sumdo=0;
    for(y=styrR;y<=endyr;y++){
          if(agg_obs_surv_indices(y,t)<0.) resid_agg(y,t)=0;
          if(agg_obs_surv_indices(y,t)>=0.){
             resid_agg(y,t)=log(agg_obs_surv_indices(y,t)+1e-5)-log(agg_pred_surv_indices(y,t)+1e-5);
             sumdo+=1;
           }
      }
//Calculate standardized residuals
  for(y=styrR;y<=endyr;y++){
          if(agg_obs_surv_indices(y,t)>=0.){
             std_resid_agg(y,t)=resid_agg(y,t)/sqrt(log(square(agg_surv_CV(y,t)*agg_index_CV_wgt(t))+1));
            }
           if(agg_obs_surv_indices(y,t)<0.) std_resid_agg(y,t)=-99999.0;
    }
// Calculate RMSE
    adds=0;
    for(y=styrR;y<=endyr;y++){
      if(agg_obs_surv_indices(y,t)>=0.) adds+=square(std_resid_agg(y,t));
      }
    RMSE_agg(t)=sqrt(adds/sumdo);
   }
  }
  ofstream ofs28("RMSE_agg.out");
  for(t=1;t<=agg_surv_num;t++){
   ofs28<<RMSE_agg(t)<<endl;
  }

  ofstream ofs29("std_res_agg.out");
   for(y=styrR;y<=endyr;y++){
    for(t=1;t<=agg_surv_num;t++){
     if(t<agg_surv_num) ofs29<<std_resid_agg(y,t)<<" ";
     if(t==agg_surv_num) ofs29<<std_resid_agg(y,t)<<endl;
    }
  }
//***************************************************************************************************
// Compute Standardized Residuals for AC Surveys indices
//***************************************************************************************************
  sumdo=0;
```

```
 for(t=1;t<=ac_surv_num;t++){
   if(use_ac(t)==1){
   sumdo=0;
   for(y=styrR;y<=endyr;y++){
        if(ac_obs_surv_indices(y,t)<0.) resid_ac(y,t)=0;
        if(ac_obs_surv_indices(y,t)>=0.){
           resid_ac(y,t)=log(ac_obs_surv_indices(y,t)+1e-5)-log(ac_pred_surv_indices(y,t)+1e-5);
           sumdo+=1;
          }
     }
 //Calculate standardized residuals
    for(y=styrR;y<=endyr;y++){
        if(ac_obs_surv_indices(y,t)>=0.){
          std_resid_ac(y,t)=resid_ac(y,t)/sqrt(log(square(ac_surv_CV(y,t)*acsel(t,5))+1));
          }
         if(ac_obs_surv_indices(y,t)<0.) std_resid_ac(y,t)=-99999.0;
    }
// Calculate RMSE
    adds=0;
   for(y=styrR;y<=endyr;y++){
     if(ac_obs_surv_indices(y,t)>=0.) adds+=square(std_resid_ac(y,t));
     }
   RMSE_ac(t)=sqrt(adds/sumdo);
 }
 }
   ofstream ofs30("RMSE_ac.out");
   for(t=1;t<=ac_surv_num;t++){
   ofs30<<RMSE_ac(t)<<endl;
   }
 ofstream ofs31("std_res_ac.out");
  for(y=styrR;y<=endyr;y++){
   for(t=1;t<=ac_surv_num;t++){
    if(t<ac_surv_num) ofs31<<std_resid_ac(y,t)<<" ";
    if(t==ac_surv_num) ofs31<<std_resid_ac(y,t)<<endl;
   }
 }
//*************************************************************************************************
//   Standardized Residuals for Catch Age Comp
//*************************************************************************************************
   for(t=1;t<=nfleets;t++){
     sprintf(hh,"%i",t);
     adstring u=adstring("Fleet")+hh+adstring("std_res_CAA.out");
     ofstream ofs(u);
    for(y=styr;y<=endyr;y++){
      for(a=1;a<=nages;a++){
        if(obs_age_comp(t,y,a)>=0.){
          std_resid_CAA(t,y,a)=((obs_age_comp(t,y,a)+1e-5)-(pred_age_comp(t,y,a)+1e-5))/sqrt(((pred_age_comp(t,y,a)+1e-5)*(1-
(pred_age_comp(t,y,a)+1e-5)))/ss_age_comp(y,t));
        }
       if(obs_age_comp(t,y,a)<0.) std_resid_CAA(t,y,a)=0.;
       if(a<nages) ofs<<std_resid_CAA(t,y,a)<<" ";
       if(a==nages) ofs<<std_resid_CAA(t,y,a)<<endl;
      }
    }
 ofs.close();
  }
//***********************************************************************************************
//   Standardized residuals for Surveys Age Comp
//***********************************************************************************************
 ofstream ofs33("std_res_survey_agecomp.out");
  for(t=1;t<=ac_surv_num;t++){
    if(use_ac(t)==1){
    for(y=styrR;y<=endyr;y++){
      for(a=1;a<=nages;a++){
        if(surv_comps(t,y,a)>=0.){
          std_resid_surv_comps(t,y,a)=((surv_comps(t,y,a)+1e-5)-(surv_pred_comps(t,y,a)+1e-5))/sqrt(((surv_pred_comps(t,y,a)+1e-5)*(1-
(surv_pred_comps(t,y,a)+1e-5)))/ac_ss(y,t));
```

```
      }
     if(surv_comps(t,y,a)<0.) std_resid_surv_comps(t,y,a)=0.;
     if(a<nages) ofs33<<std_resid_surv_comps(t,y,a)<<" ";
     if(a==nages) ofs33<<std_resid_surv_comps(t,y,a)<<endl;
    }
   }
  }
 }

//*********************************************************************************************
// Output Catch Selectivity Parameters
//*********************************************************************************************
 ofstream ofs34("catsel.out");
  d=nRparms+nFparms+1;
   for(t=1;t<=fltwogom;t++){
    if(flgom_a_con1>0){
     ofs34<<flgom_a(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/flgom_a(t))<<endl;
     d+=1;
     ofs34<<flgom_b(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/flgom_b(t))<<endl;
     d+=1;
    }
  }
  for(t=1;t<=fltwolog;t++){
   if(fllog_a_con1>0){
     ofs34<<fllog_a(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/fllog_a(t))<<endl;
     d+=1;
     ofs34<<fllog_b(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/fllog_b(t))<<endl;
     d+=1;
    }
  }
   for(t=1;t<=fltwogam;t++){
    if(flgam_a_con1>0){
     ofs34<<flgam_a(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/flgam_a(t))<<endl;
     d+=1;
     ofs34<<flgam_b(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/flgam_b(t))<<endl;
     d+=1;
    }
  }
   if(flthom_a_con1>0){
     for(t=1;t<=flthree;t++){
     ofs34<<flthom_a(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/flthom_a(t))<<endl;
     d+=1;
     ofs34<<flthom_b(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/flthom_b(t))<<endl;
     d+=1;
     ofs34<<flthom_c(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/flthom_c(t))<<endl;
     d+=1;
     }
   }
  if(fldlog_a_con1>0){
   for(t=1;t<=flfour;t++){
     ofs34<<fldlog_a(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/fldlog_a(t))<<endl;
     d+=1;
     ofs34<<fldlog_b(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/fldlog_b(t))<<endl;
     d+=1;
     ofs34<<fldlog_c(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/fldlog_c(t))<<endl;
     d+=1;
     ofs34<<fldlog_d(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/fldlog_d(t))<<endl;
     d+=1;
   }
  }
  ofstream ofs35("surveysel.out");
   for(t=1;t<=actwogom;t++){
    if(acgom_a_con1>0){
     ofs35<<acgom_a(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/acgom_a(t))<<endl;
     d+=1;
     ofs35<<acgom_b(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/acgom_b(t))<<endl;
     d+=1;
```

```
    }
   }
   for(t=1;t<=actwolog;t++){
    if(aclog_a_con1>0){
      ofs35<<aclog_a(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/aclog_a(t))<<endl;
      d+=1;
      ofs35<<aclog_b(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/aclog_b(t))<<endl;
      d+=1;
    }
   }
   for(t=1;t<=actwogam;t++){
   if(acgam_a_con1>0){
      ofs35<<acgam_a(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/acgam_a(t))<<endl;
      d+=1;
      ofs35<<acgam_b(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/acgam_b(t))<<endl;
      d+=1;
    }
  }
  if(acthom_a_con1>0){
     for(t=1;t<=acthree;t++){
      ofs35<<acthom_a(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/acthom_a(t))<<endl;
      d+=1;
      ofs35<<acthom_b(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/acthom_b(t))<<endl;
      d+=1;
      ofs35<<acthom_c(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/acthom_c(t))<<endl;
      d+=1;
     }
   }

  if(user>0){
   for(t=1;t<=user;t++){
    ofs35<<userparms(t)<<" "<<sigma(d,1)<<" "<<fabs(sigma(d,1)/userparms(t))<<endl;
    d+=1;
   }
  }
 // Output Fleet Catch Selecitivites
 for(t=1;t<=nfleets;t++){
    sprintf(hh,"%i",t);
    adstring u=adstring("Fleet")+hh+adstring("Select.out");
    ofstream ofs(u);
   for(y=styr;y<=endyr;y++){
    for(a=1;a<=nages;a++){
     if(a<nages) ofs<<selbyfleet(t,y,a)<<" ";
     if(a==nages) ofs<<selbyfleet(t,y,a)<<endl;
    }
  }
  ofs.close();
 }
//*****************************************************************************************************
// Output Female Spawning Stock Biomass-At-Age
//*****************************************************************************************************
 ofstream ofs361("SSBatage.out");
  for(y=styr;y<=endyr;y++){
   for(a=1;a<=nages;a++){
     sumdo1=0;
     if (rivard==1) sumdo1=N(y,a)*mfexp(-1.*(pF*Fcomb(y,a)+pM*M(y,a)))*fsex(a)*fmat(y,a)*rwgts(y,a);
     if (rivard==0) sumdo1+=N(y,a)*mfexp(-1.*(pF*Fcomb(y,a)+pM*M(y,a)))*fsex(a)*fmat(y,a)*ssbwgt(y,a);
    if (a<nages) ofs361<<sumdo1/1000<<" "; //Metric tons
    if (a==nages) ofs361<<sumdo1/1000<<endl;
  }
 }
//******************************************************************************************************
// Output Stock-Recruit Values
//******************************************************************************************************
   ofstream ofs362("predSR.out");
   sumdo=(max(SSB)*1.05)/100;
   sumdo1=0;
```

```
  for(y=1;y<=100;y++){
     if(y==1) sumdo1=1;
     if(y>1) sumdo1=sumdo1+sumdo;
     if(srmodel==1) ofs362<<"1"<<" "<<"0"<<endl;
     if(srmodel==2) ofs362<<mfexp(log(BH_a)+log(sumdo1)-log(1+sumdo1/BH_b))<<" "<<sumdo1<<endl;
     if(srmodel==3) ofs362<<mfexp(log(r_a)+log(sumdo1)-sumdo1/r_b)<<" "<<sumdo1<<endl;
     if(srmodel==4) ofs362<<mfexp(log(shep_a)+log(sumdo1)-log(1+pow(sumdo1/shep_b,shep_c)))<<" "<<sumdo1<<endl;
 }
 ofstream ofs363("res_SR.out");
  for(y=styr;y<endyr;y++){
     if(srmodel==1) ofs363<<"0"<<endl;
     if(srmodel==2) ofs363<<log(R(y+1))-(log(BH_a)+log(SSB(y))-log(1+SSB(y)/BH_b))<<endl;
     if(srmodel==3) ofs363<<log(R(y+1))-(log(r_a)+log(SSB(y))-SSB(y)/r_b)<<endl;
     if(srmodel==4) ofs363<<log(R(y+1))-(log(shep_a)+log(SSB(y))-log(1+pow(SSB(y)/shep_b,shep_c)))<<endl;
 }
 ofstream ofs364("SRparms.out");
     if(srmodel==1){
        ofs364<<"1"<<" "<<"0"<<endl;
        ofs364<<"1"<<" "<<"0"<<endl;
      }
     if(srmodel==2){
        ofs364<<BH_a<<" "<<sigma(n_parms-1,1)<<endl;
        ofs364<<BH_b<<" "<<sigma(n_parms,1)<<endl;
     }
      if(srmodel==3){
         ofs364<<r_a<<" "<<sigma(n_parms-1,1)<<endl;
         ofs364<<r_b<<" "<<sigma(n_parms,1)<<endl;
     }
     if(srmodel==4){
        ofs364<<shep_a<<" "<<sigma(n_parms-2,1)<<endl;
        ofs364<<shep_b<<" "<<sigma(n_parms-1,1)<<endl;
        ofs364<<shep_c<<" "<<sigma(n_parms,1)<<endl;
     }
ofstream ofs365("recvar.out");
   if(biascor==0)  ofs365<<"0"<<endl;
   if(biascor==1)  ofs365<<recvar<<endl;
 ofs365.close();

//*******************************************************************************************************
// Reference Points
//*******************************************************************************************************
 //!!!!!!!!!!!!!!!!!!!    Yield Per Recruit
   ofstream ofs37("ypr.out");
   FF=calcincr;
   maxs=0;
   maxer=0;
   sumdo=0;
   sumdo1=0;
   dodo1=0;
   cnter=nfs/int(ceil(maxF/calcincr));
   cnter2=0;
    for(a=1;a<=nages;a++){
      if(Fcomb(Selyear,a)>=dodo1) dodo1=Fcomb(Selyear,a);
     }
   for(looper=1;looper<=nfs;looper++){
     for(a=1;a<=nages;a++){
       partialF(a)=FF*Fcomb(Selyear,a)/dodo1;
     }
  for(a=1;a<=nages;a++){
    Zypr(a)=partialF(a)+M(Myear,a);
  }
    for(a=1;a<=oldest;a++){
      if(a==1) psb(a)=1;
      if(a>1){
       if(a<=nages) psb(a)=mfexp(-1.*Zypr(a-1));
       if(a>nages) psb(a)=mfexp(-1.*Zypr(nages));
      }
```

```
  }
 //Cumulative product
  for(a=1;a<=oldest;a++){
     if(a==1) psb(a)=psb(a);
     if(a>1) psb(a)=psb(a)*psb(a-1);
  }
  sumdo1=0;
  for(a=1;a<=oldest;a++){
     if(a<=nages) sumdo1+=partialF(a)/Zypr(a)*(1-mfexp(-Zypr(a)))*psb(a)*cwgt(Wgtyear,a)/1000;
     if(a>nages)  sumdo1+=partialF(nages)/Zypr(nages)*(1-mfexp(-Zypr(nages)))*psb(a)*cwgt(Wgtyear,nages)/1000; //change to metric tons
   }
  //get Ymax and Fmax
   if(sumdo1>=maxs){
       maxs=sumdo1;
       maxer=FF;
   }
  if(looper==2) origslope=sumdo1/FF*0.10;
  cnter2+=1;
  if(looper==1) ofs37<<0<<" "<<0<<endl;
  if(cnter2==cnter){
    ofs37<<value(FF)<<" "<<sumdo1<<endl;
    cnter2=0;
  }
  FF+=calcincr;
}
//YPR Reference Points
 ofstream ofs38("yprref.out");
 ofs38<<maxer<<" "<<maxs<<endl;
//F0.1
  sumdo=0;
  sumdo1=0;
  FF=maxer;
  diff=FF/2;
  ok=0;
  dodo=0.000000001;
  dodo1=0;
   for(a=1;a<=nages;a++){
     if(Fcomb(Selyear,a)>=dodo1) dodo1=Fcomb(Selyear,a);
    }
  while(ok==0){
    //Calculate average F ratio for each fleet
     for(a=1;a<=nages;a++){
       partialF(a)=FF*Fcomb(Selyear,a)/dodo1;
     }

    for(a=1;a<=nages;a++){
     sumdo=0;
      Zypr(a)=partialF(a)+M(Myear,a);
    }

   for(a=1;a<=oldest;a++){
     if(a==1) psb(a)=1;
     if(a>1){
       if(a<=nages) psb(a)=mfexp(-1.*Zypr(a-1));
       if(a>nages) psb(a)=mfexp(-1.*Zypr(nages));
      }
   }
  for(a=1;a<=oldest;a++){
    if(a==1) psb(a)=psb(a);
     if(a>1) psb(a)=psb(a)*psb(a-1);
   }
  sumdo1=0;
  for(a=1;a<=oldest;a++){
    sumdo=0;
     if(a<=nages) sumdo1+=partialF(a)/Zypr(a)*(1-mfexp(-Zypr(a)))*psb(a)*cwgt(Wgtyear,a)/1000;
     if(a>nages)  sumdo1+=partialF(nages)/Zypr(nages)*(1-mfexp(-Zypr(nages)))*psb(a)*cwgt(Wgtyear,nages)/1000;//metric tons
   }
```

```
 dd1=sumdo1;
  //Calculate average F ratio for each fleet
  for(a=1;a<=nages;a++){
   partialF(a)=(FF+calcincr)*Fcomb(Selyear,a)/dodo1;
   }

  for(a=1;a<=nages;a++){
    Zypr(a)=partialF(a)+M(Myear,a);
  }
 for(a=1;a<=oldest;a++){
    if(a==1) psb(a)=1;
    if(a>1){
     if(a<=nages) psb(a)=mfexp(-1.*Zypr(a-1));
     if(a>nages) psb(a)=mfexp(-1.*Zypr(nages));
    }
 }
for(a=1;a<=oldest;a++){
   if(a==1) psb(a)=psb(a);
    if(a>1) psb(a)=psb(a)*psb(a-1);
 }
sumdo1=0;
for(a=1;a<=oldest;a++){
   sumdo=0;
    if(a<=nages) sumdo1+=partialF(a)/Zypr(a)*(1-mfexp(-Zypr(a)))*psb(a)*cwgt(Wgtyear,a)/1000;
    if(a>nages)  sumdo1+=partialF(nages)/Zypr(nages)*(1-mfexp(-Zypr(nages)))*psb(a)*cwgt(Wgtyear,nages)/1000;
  }
 dd2=sumdo1;
 slope=(dd2-dd1)/((FF+calcincr)-FF);
 if(fabs(origslope-slope)<=dodo) ok=1;
  if(ok==0){
    if(slope>origslope) FF=FF+diff;
              if(slope<origslope) FF=FF-diff;
                diff=diff/2;
   }
}
ofs38<<FF<<" "<<sumdo1<<endl;
ofs38.close();

//!!!!!!!!!!!!!!!!!!  Spawning Stock Biomass Per Recruit !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
  ofstream ofs39("spr.out");
  //Calculate SPR at F=zero
   sumdo=0;
   sumdo1=0;
    for(a=1;a<=nages;a++){
      Zypr(a)=M(Myear,a);
    }
   for(a=1;a<=oldest;a++){
      if(a==1) psb(a)=1;
      if(a>1){
       if(a<=nages) psb(a)=mfexp(-1.*Zypr(a-1));
       if(a>nages) psb(a)=mfexp(-1.*Zypr(nages));
      }
   }
  for(a=1;a<=oldest;a++){
     if(a==1) psb(a)=psb(a);
      if(a>1) psb(a)=psb(a)*psb(a-1);
   }
    for(a=1;a<=nages;a++){
      Zypr(a)=pM*M(Myear,a);
    }
  maxSPR=0;
  for(a=1;a<=oldest;a++){
    if(rivard==0){
      if(a<=nages) maxSPR+=psb(a)*mfexp(-Zypr(a))*ssbwgt(Wgtyear,a)/1000*fmat(Matyear,a);
      if(a>nages)  maxSPR+=psb(a)*mfexp(-Zypr(nages))*ssbwgt(Wgtyear,nages)/1000*fmat(Matyear,nages);
    }
    if(rivard==1){
```

```
      if(a<=nages) maxSPR+=psb(a)*mfexp(-Zypr(a))*rwgts(Wgtyear,a)/1000*fmat(Matyear,a);
      if(a>nages)  maxSPR+=psb(a)*mfexp(-Zypr(nages))*rwgts(Wgtyear,nages)/1000*fmat(Matyear,nages);
    }
   }
  // Calc SPR for F>0
   FF=calcincr;
   maxs=0;
   maxer=0;
   sumdo=0;
   sumdo1=0;
   cnter=nfs/int(ceil(maxF/calcincr));
   cnter2=0;
   dodo1=0;
    for(a=1;a<=nages;a++){
      if(Fcomb(Selyear,a)>=dodo1) dodo1=Fcomb(Selyear,a);
     }
   for(looper=1;looper<=nfs;looper++){
     for(a=1;a<=nages;a++){
      partialF(a)=FF*Fcomb(Selyear,a)/dodo1;
      }
     for(a=1;a<=nages;a++){
       Zypr(a)=partialF(a)+M(Myear,a);
     }
    for(a=1;a<=oldest;a++){
      if(a==1) psb(a)=1;
      if(a>1){
       if(a<=nages) psb(a)=mfexp(-1.*Zypr(a-1));
       if(a>nages) psb(a)=mfexp(-1.*Zypr(nages));
      }
    }
   for(a=1;a<=oldest;a++){
     if(a==1) psb(a)=psb(a);
      if(a>1) psb(a)=psb(a)*psb(a-1);
    }
     for(a=1;a<=nages;a++){
      partialF(a)=pF*FF*Fcomb(Selyear,a)/dodo1;
      }
     for(a=1;a<=nages;a++){
       Zypr(a)=partialF(a)+pM*M(Myear,a);
     }
   sumdo1=0;
   for(a=1;a<=oldest;a++){
     if(rivard==0){
       if(a<=nages) sumdo1+=psb(a)*mfexp(-Zypr(a))*ssbwgt(Wgtyear,a)/1000*fmat(Matyear,a);
       if(a>nages)  sumdo1+=psb(a)*mfexp(-Zypr(nages))*ssbwgt(Wgtyear,nages)/1000*fmat(Matyear,nages);
     }
     if(rivard==1){
       if(a<=nages) sumdo1+=psb(a)*mfexp(-Zypr(a))*rwgts(Wgtyear,a)/1000*fmat(Matyear,a);
       if(a>nages)  sumdo1+=psb(a)*mfexp(-Zypr(nages))*rwgts(Wgtyear,nages)/1000*fmat(Matyear,nages);
     }
    }
  if(looper==1) ofs39<<0<<" "<<maxSPR<<" "<<maxSPR/maxSPR*100<<endl;
  cnter2+=1;
  if(cnter2==cnter){
     ofs39<<value(FF)<<" "<<sumdo1<<" "<<sumdo1/maxSPR*100<<endl;
     cnter2=0;
   }
 FF+=calcincr;
 }
  ofs39.close();

// Find F at maxSPR
   sumdo=0;
   sumdo1=0;
   FF=0.5;
   diff=FF/2;
   ok=0;
```

```
   dodo=0.00001;
     dodo1=0;
    for(a=1;a<=nages;a++){
       if(Fcomb(Selyear,a)>=dodo1) dodo1=Fcomb(Selyear,a);
      }
   while(ok==0){
      for(a=1;a<=nages;a++){
      partialF(a)=FF*Fcomb(Selyear,a)/dodo1;
      }
     for(a=1;a<=nages;a++){
       Zypr(a)=partialF(a)+M(Myear,a);
     }
    for(a=1;a<=oldest;a++){
       if(a==1) psb(a)=1;
       if(a>1){
        if(a<=nages) psb(a)=mfexp(-1.*Zypr(a-1));
        if(a>nages) psb(a)=mfexp(-1.*Zypr(nages));
       }
    }
   for(a=1;a<=oldest;a++){
      if(a==1) psb(a)=psb(a);
       if(a>1) psb(a)=psb(a)*psb(a-1);
    }
     for(a=1;a<=nages;a++){
      partialF(a)=pF*FF*Fcomb(Selyear,a)/dodo1;
      }
     for(a=1;a<=nages;a++){
       Zypr(a)=partialF(a)+pM*M(Myear,a);
     }
   sumdo1=0;
   for(a=1;a<=oldest;a++){
     if(rivard==0){
       if(a<=nages) sumdo1+=psb(a)*mfexp(-Zypr(a))*ssbwgt(Wgtyear,a)/1000*fmat(Matyear,a);
       if(a>nages)  sumdo1+=psb(a)*mfexp(-Zypr(nages))*ssbwgt(Wgtyear,nages)/1000*fmat(Matyear,nages);
     }
     if(rivard==1){
       if(a<=nages) sumdo1+=psb(a)*mfexp(-Zypr(a))*rwgts(Wgtyear,a)/1000*fmat(Matyear,a);
       if(a>nages)  sumdo1+=psb(a)*mfexp(-Zypr(nages))*rwgts(Wgtyear,nages)/1000*fmat(Matyear,nages);
     }
    }
    dd1=sumdo1/maxSPR*100;
    if(fabs(pspr-dd1)<=dodo) ok=1;
     if(ok==0){
       if(dd1>pspr) FF=FF+diff;
                if(dd1<pspr) FF=FF-diff;
                  diff=diff/2;
      }
  } //ok
  ofstream ofs40("sprref.out");
  ofs40<<pspr<<" "<<FF<<" "<<sumdo1<<endl;
  ofs40.close();

//!!!!!!!!!!!!!!!!!!!!!!!!!!!   Production Model  !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
 ofstream ofs42("Production.out");
// Calculate Spawning Stock, Yield and Recruits At Equilibrium
   sumdo=0;
   sumdo1=0;
   maxs=0;
   ssbmsy=0;
   fmsy=0;
   msy=0;
   pgroup=0;
     dodo1=0;
    for(a=1;a<=nages;a++){
       if(Fcomb(Selyear,a)>=dodo1) dodo1=Fcomb(Selyear,a);
      }
  for(looper=1;looper<=nfs;looper++){
```

```
  if(looper==1) FF=0;
  if(looper>1) FF+=calcincr;
//CAlculate SSB
  for(a=1;a<=nages;a++){
   partialF(a)=FF*Fcomb(Selyear,a)/dodo1;
   }
  for(a=1;a<=nages;a++){
    Zypr(a)=partialF(a)+M(Myear,a);
  }
 for(a=1;a<=oldest;a++){
    if(a==1) psb(a)=1;
    if(a>1){
     if(a<=nages) psb(a)=mfexp(-1.*Zypr(a-1));
     if(a>nages) psb(a)=mfexp(-1.*Zypr(nages));
    }
 }
for(a=1;a<=oldest;a++){
   if(a==1) psb(a)=psb(a);
   if(a>1) psb(a)=psb(a)*psb(a-1);
 }
  for(a=1;a<=nages;a++){
   partialF(a)=pF*FF*Fcomb(Selyear,a)/dodo1;
   }
  for(a=1;a<=nages;a++){
    Zypr(a)=partialF(a)+pM*M(Myear,a);
  }
sumdo1=0;
for(a=1;a<=oldest;a++){
  if(rivard==0){
    if(a<=nages) sumdo1+=psb(a)*mfexp(-Zypr(a))*(ssbwgt(Wgtyear,a)/1000)*fmat(Matyear,a);
    if(a>nages)  sumdo1+=psb(a)*mfexp(-Zypr(nages))*(ssbwgt(Wgtyear,nages)/1000)*fmat(Matyear,nages);
  }
  if(rivard==1){
    if(a<=nages) sumdo1+=psb(a)*mfexp(-Zypr(a))*(rwgts(Wgtyear,a)/1000)*fmat(Matyear,a);
    if(a>nages)  sumdo1+=psb(a)*mfexp(-Zypr(nages))*(rwgts(Wgtyear,nages)/1000)*fmat(Matyear,nages);
  }
 }
dd1=sumdo1;//B/R
//Y/R
  for(a=1;a<=nages;a++){
   partialF(a)=FF*Fcomb(Selyear,a)/dodo1;
   }
  for(a=1;a<=nages;a++){
    Zypr(a)=partialF(a)+M(Myear,a);
  }
 for(a=1;a<=oldest;a++){
    if(a==1) psb(a)=1;
    if(a>1){
     if(a<=nages) psb(a)=mfexp(-1.*Zypr(a-1));
     if(a>nages) psb(a)=mfexp(-1.*Zypr(nages));
    }
 }
for(a=1;a<=oldest;a++){
   if(a==1) psb(a)=psb(a);
    if(a>1) psb(a)=psb(a)*psb(a-1);
 }
sumdo1=0;
for(a=1;a<=oldest;a++){
    if(a<=nages) sumdo1+=partialF(a)/Zypr(a)*(1-mfexp(-Zypr(a)))*psb(a)*(cwgt(Wgtyear,a)/1000);
    if(a>nages)  sumdo1+=partialF(nages)/Zypr(nages)*(1-mfexp(-Zypr(nages)))*psb(a)*(cwgt(Wgtyear,nages)/1000);
  }
 dd2=sumdo1;//Y/R
if(srmodel==1){
  ofs42<<"0"<<" "<<"0"<<" "<<"0"<<" "<<"0"<<endl;
 }
if(srmodel==2){
  maxer =BH_b*(BH_a*dd1-1);//B
```

```
    cl=maxer/dd1; //R
    pgroup=cl*dd2;//Y
    if(pgroup>=msy){
        msy=pgroup;
        fmsy=FF;
        ssbmsy=maxer;
     }
     if(maxer>=0){
       ofs42<<FF<<" "<<maxer<<" "<<cl<<" "<<pgroup<<endl;
     }
   }
  if(srmodel==3){
    maxer =log(r_a*dd1)*r_b;//B
    cl=maxer/dd1; //R
    pgroup=cl*dd2;//Y
      if(pgroup>=msy){
        msy=pgroup;
        fmsy=FF;
        ssbmsy=maxer;
     }
     if(maxer>=0){
       ofs42<<FF<<" "<<maxer<<" "<<cl<<" "<<pgroup<<endl;
     }
   }
  if(srmodel==4){
    maxer =shep_b*pow((shep_a*dd1-1),1./shep_c);//B
    cl=maxer/dd1; //R
    pgroup=cl*dd2;//Y
      if(pgroup>=msy){
        msy=pgroup;
        fmsy=FF;
        ssbmsy=maxer;
     }
    if(maxer>=0){
       ofs42<<FF<<" "<<maxer<<" "<<cl<<" "<<pgroup<<endl;
     }
  }
 }//For looper
ofs42.close();

/// Output Fmsy
 ofstream ofs41("Fmsy.out");
  if(srmodel>1) ofs41<<fmsy<<" "<<ssbmsy<<" "<<msy<<" "<<"99"<<endl;
  if(srmodel==1) ofs41<<"0"<<" "<<"0"<<" "<<"0"<<" "<<"99"<<endl;
  ofs41.close();
```

Appendix B7. Plots of SCA model output

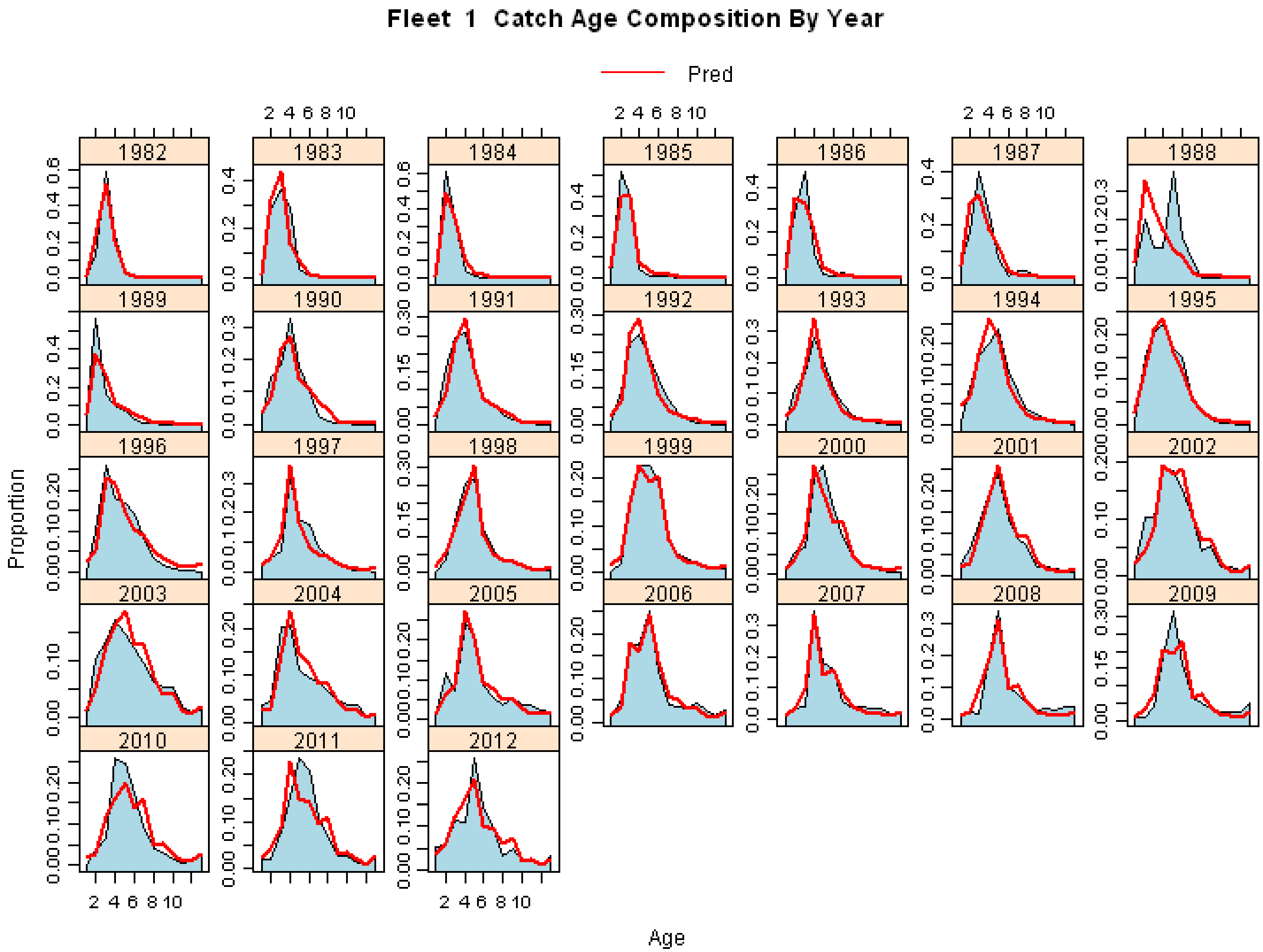


Figure 1. Plots of observed and predicted catch proportions-at-age by year for each fleet.

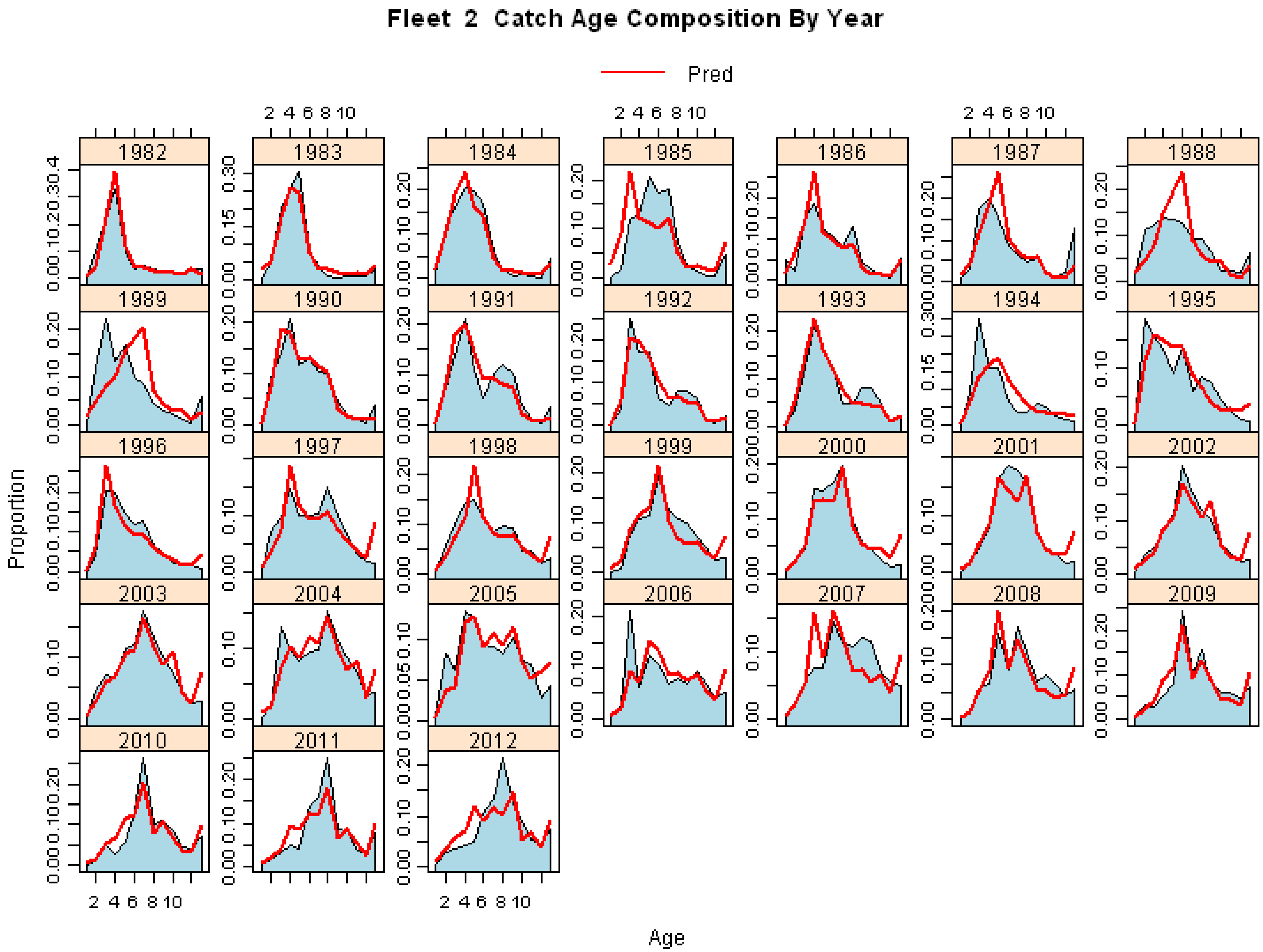


Figure 1 cont.

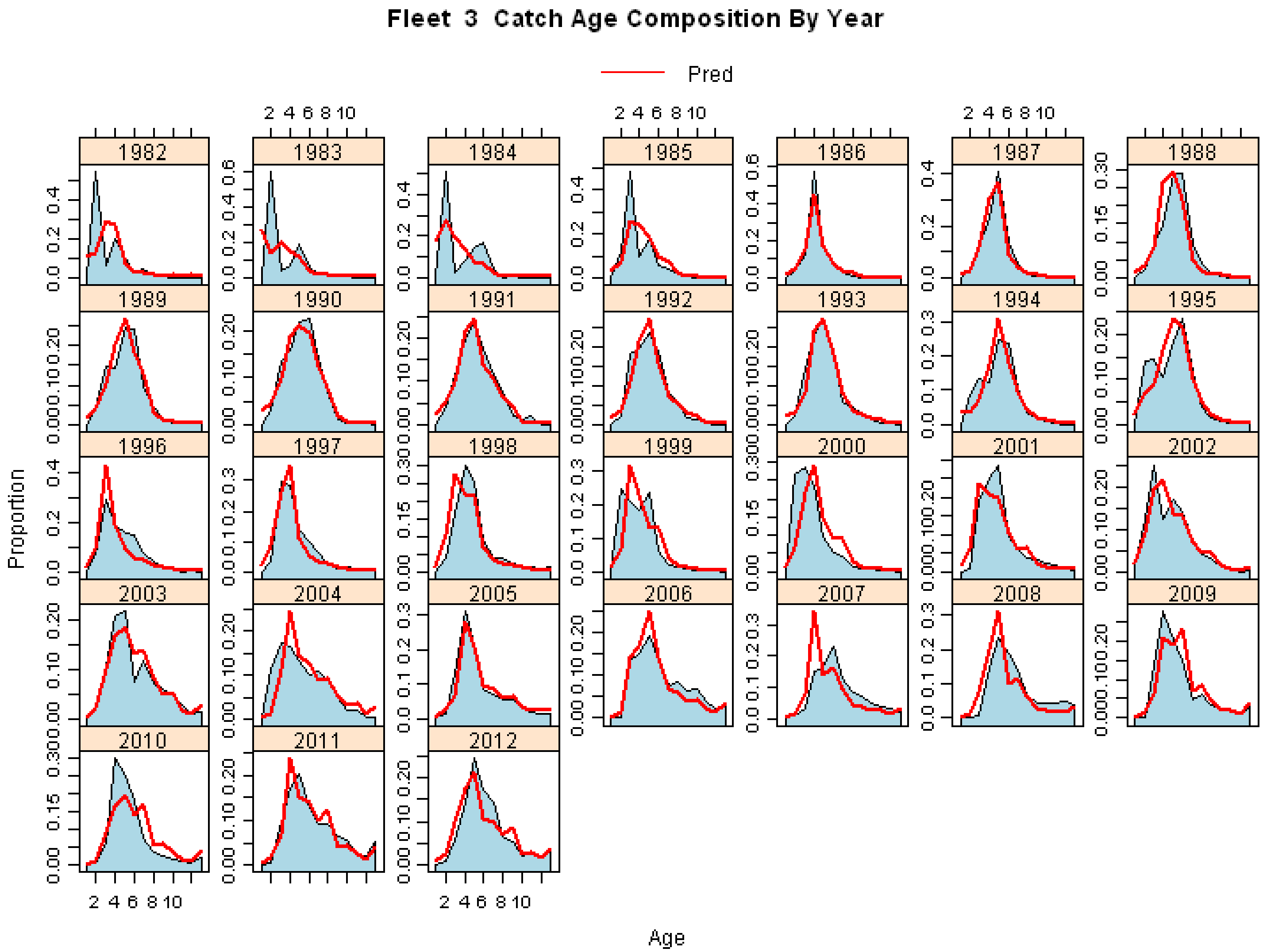


Figure 1 cont.

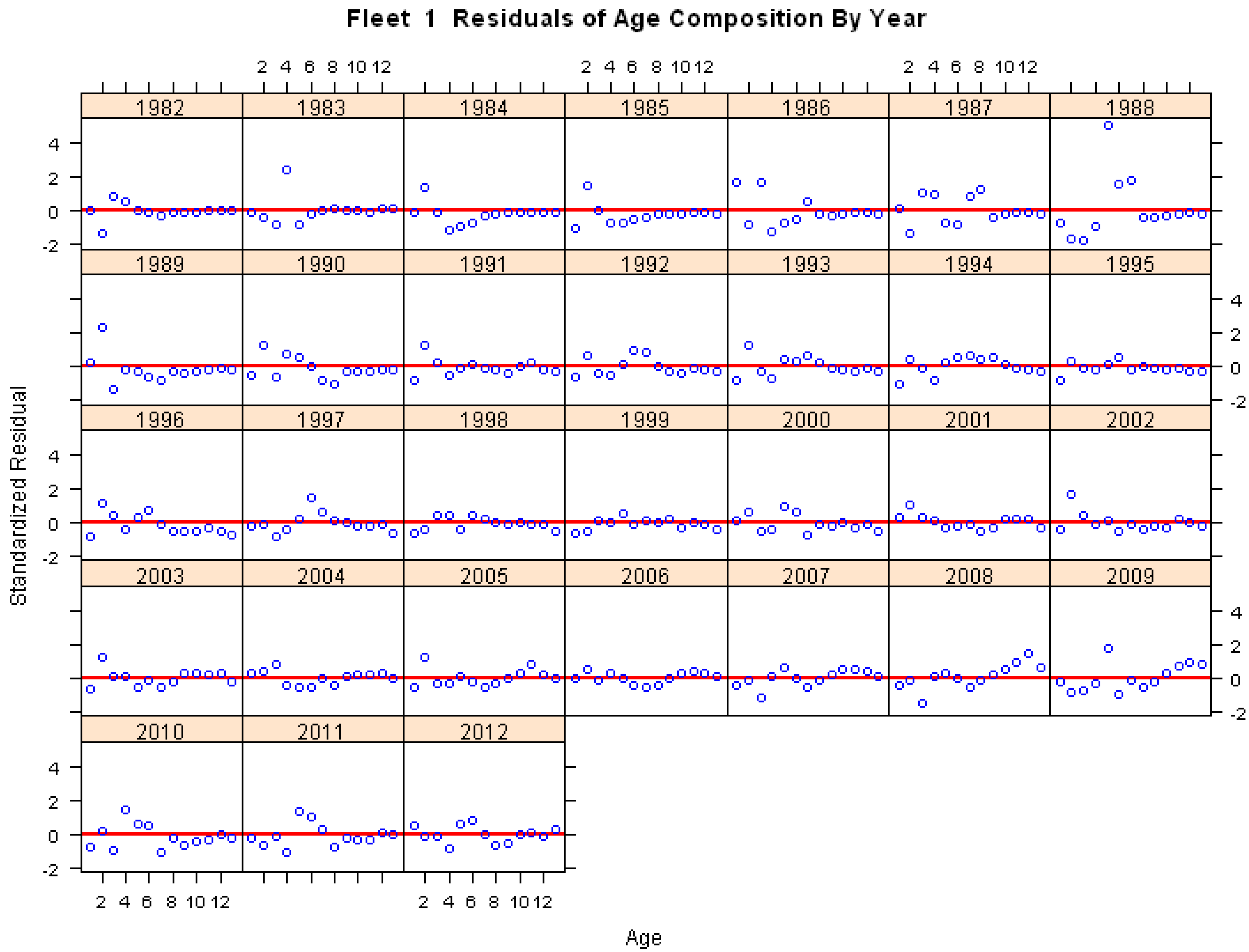


Figure 2. Standardized residuals of catch proportions-at-age by year for each fleet.

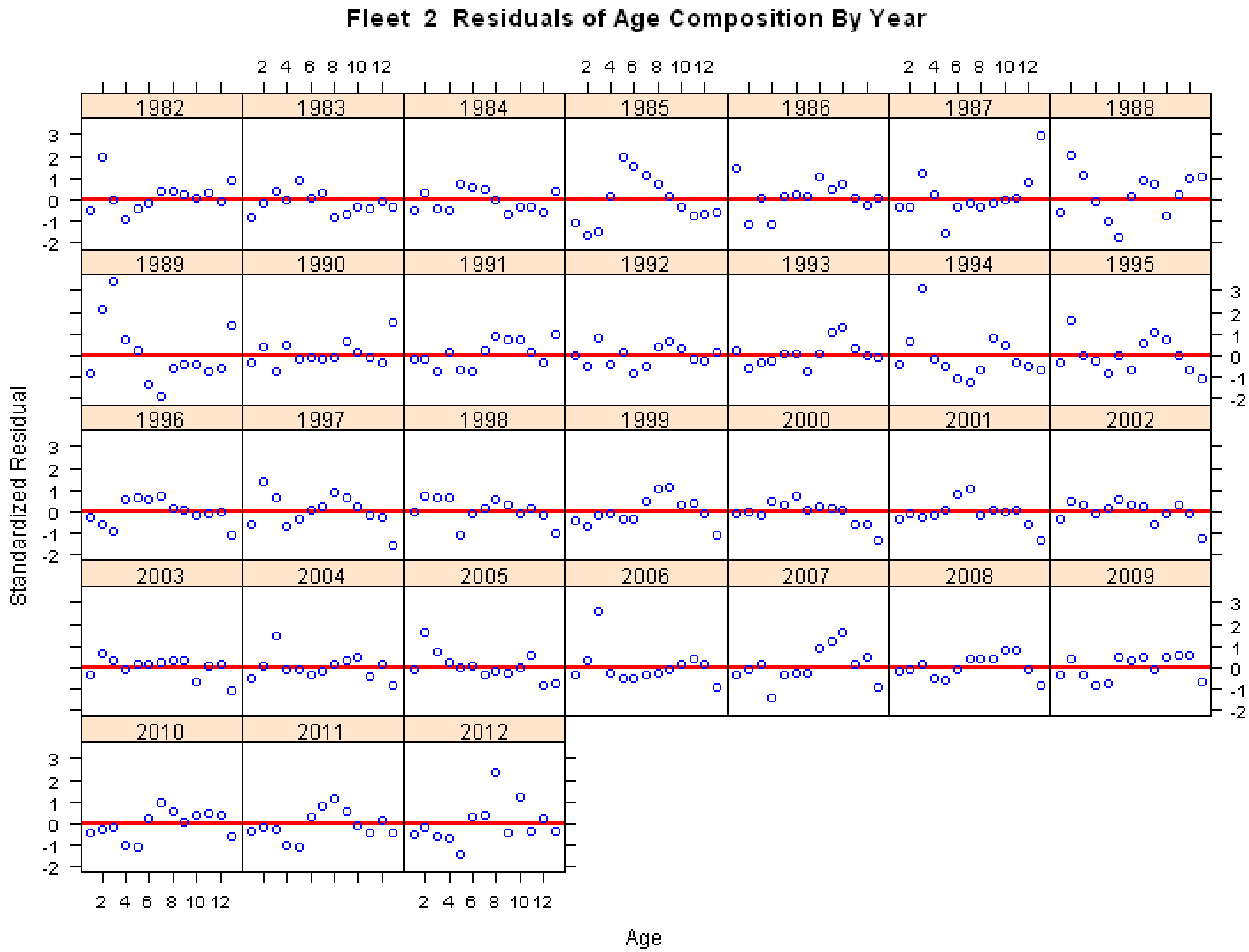


Figure 2 cont.

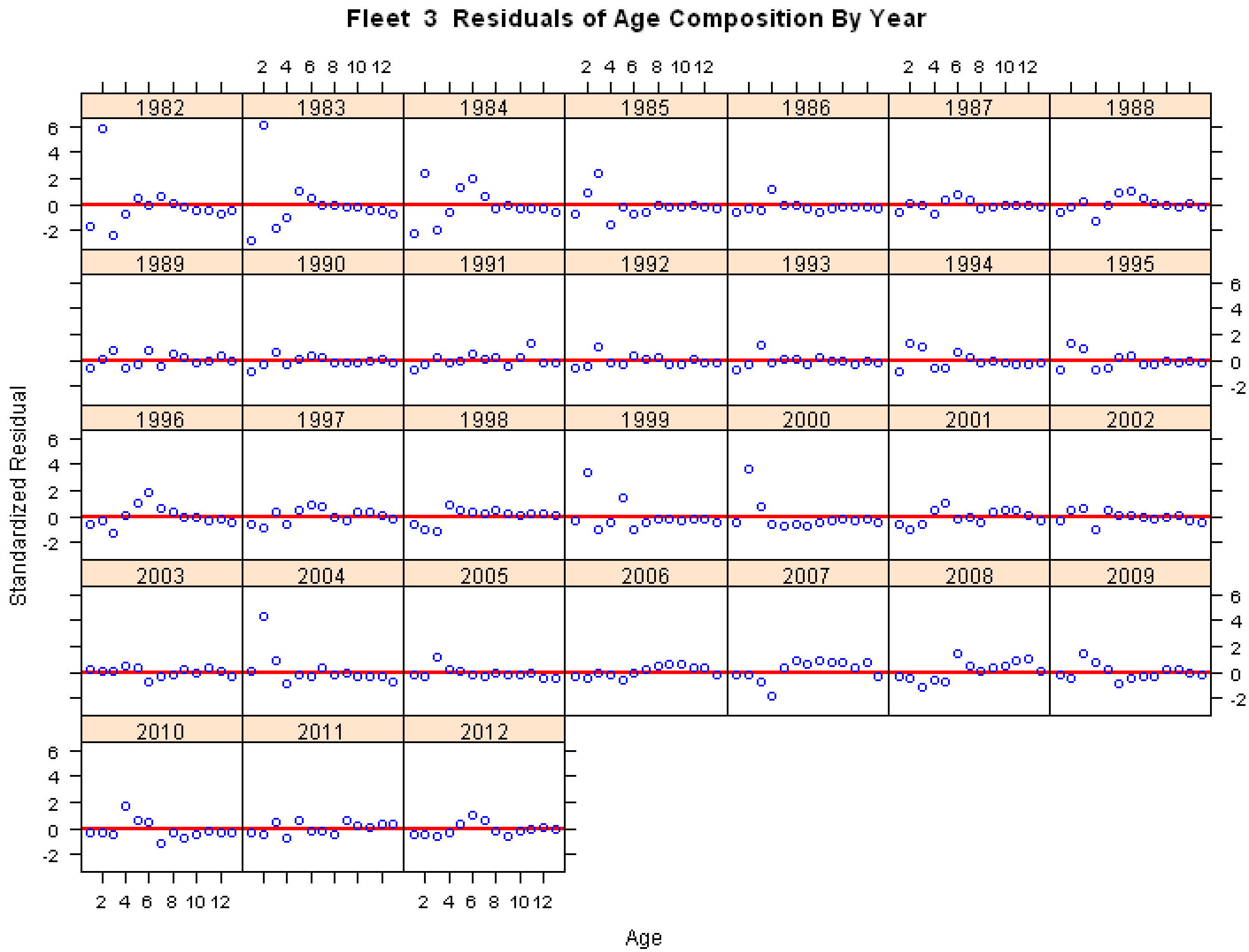


Figure 2 cont.

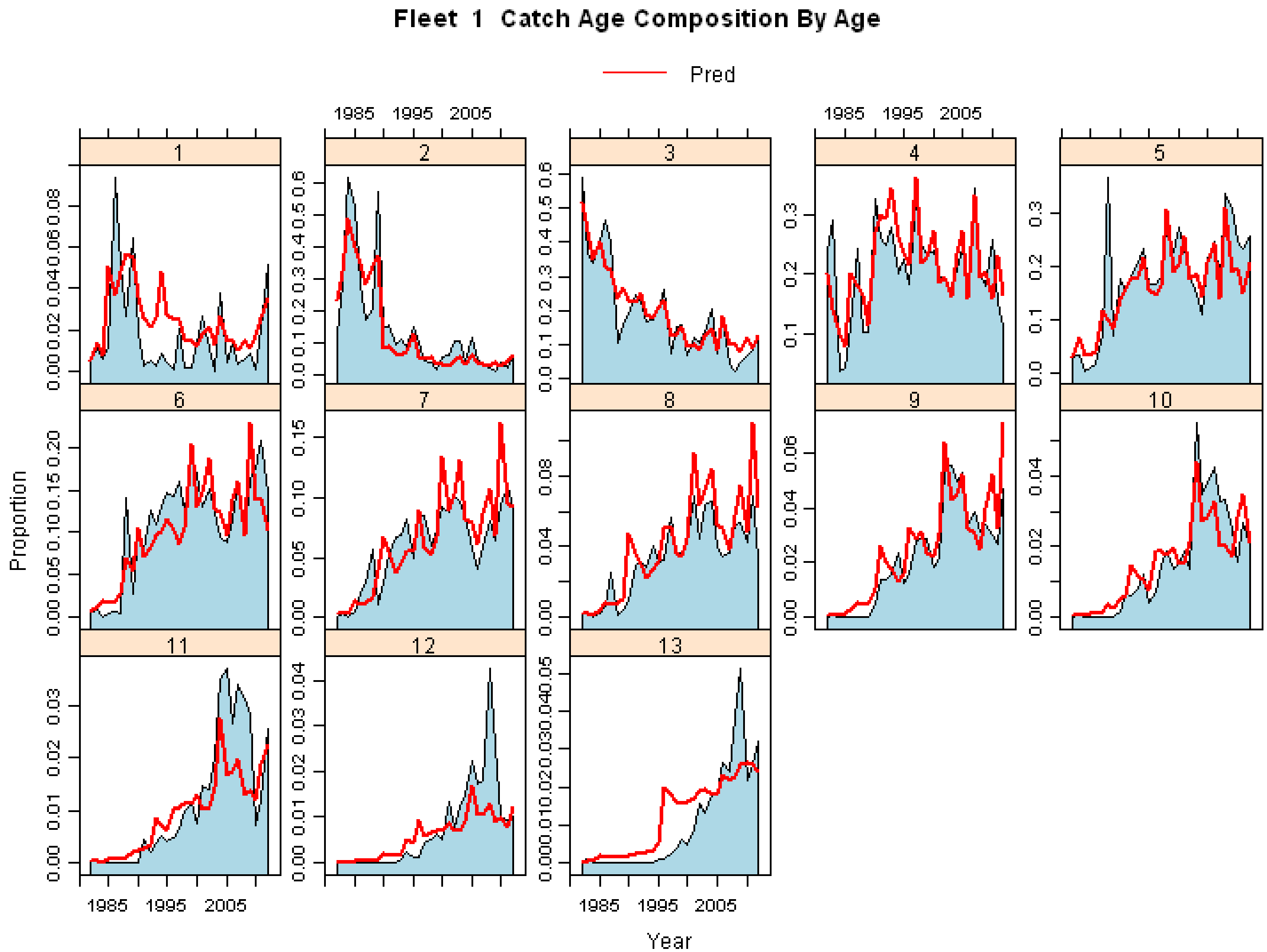


Figure 3 .Observed and predicted catch proportions-at-age by age for each fleet.

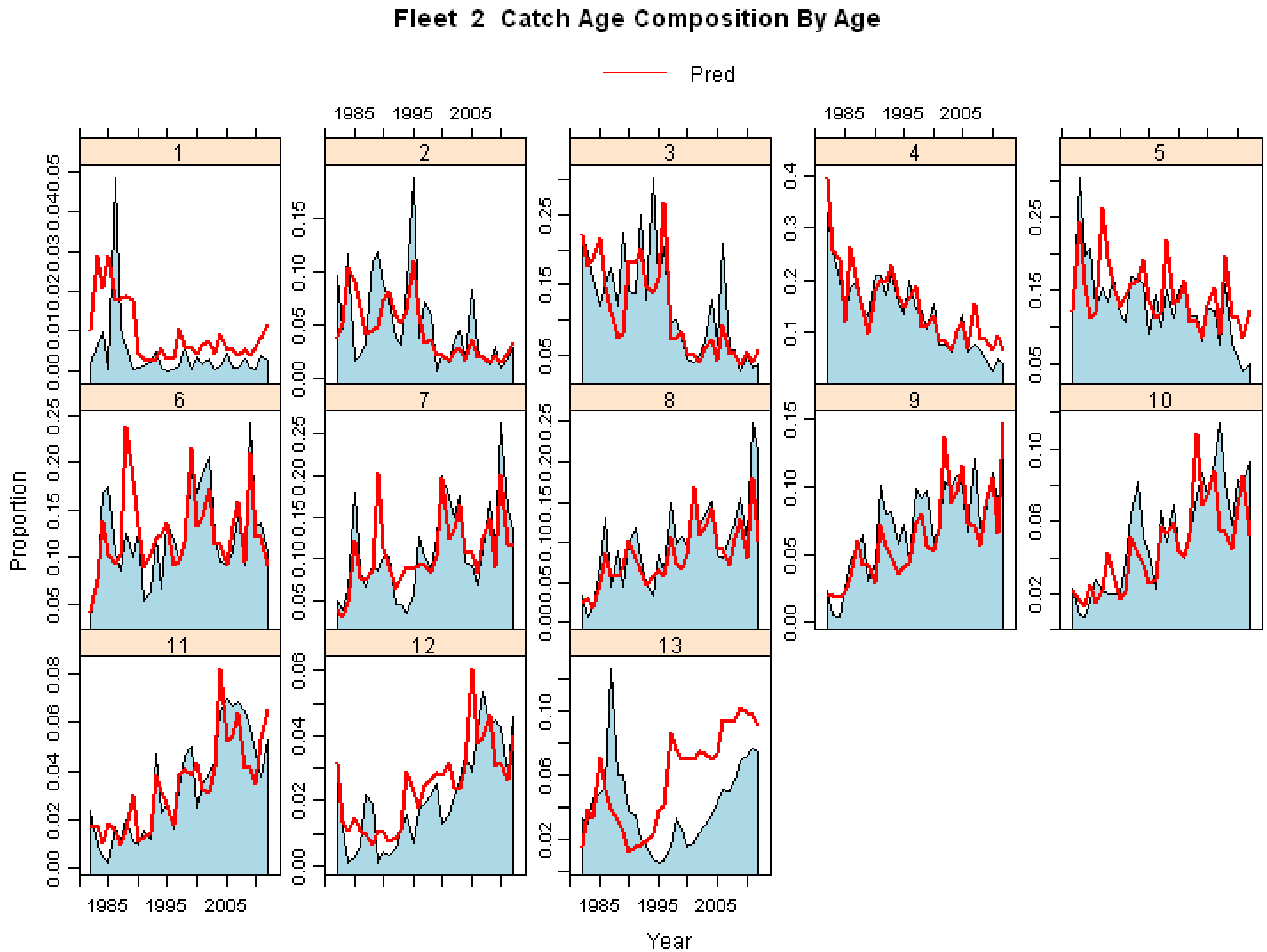


Figure 3 cont.

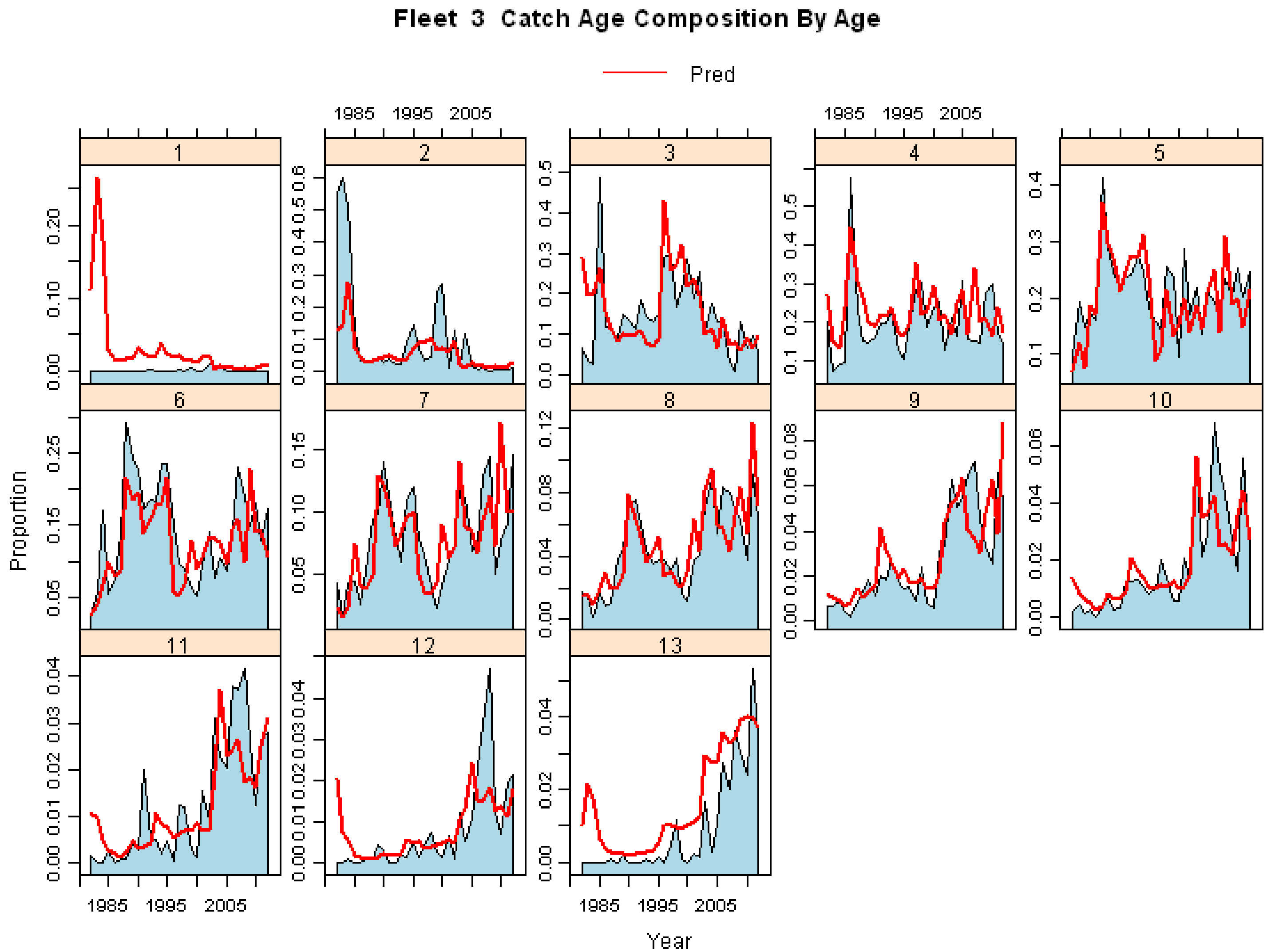


Figure 3 cont.

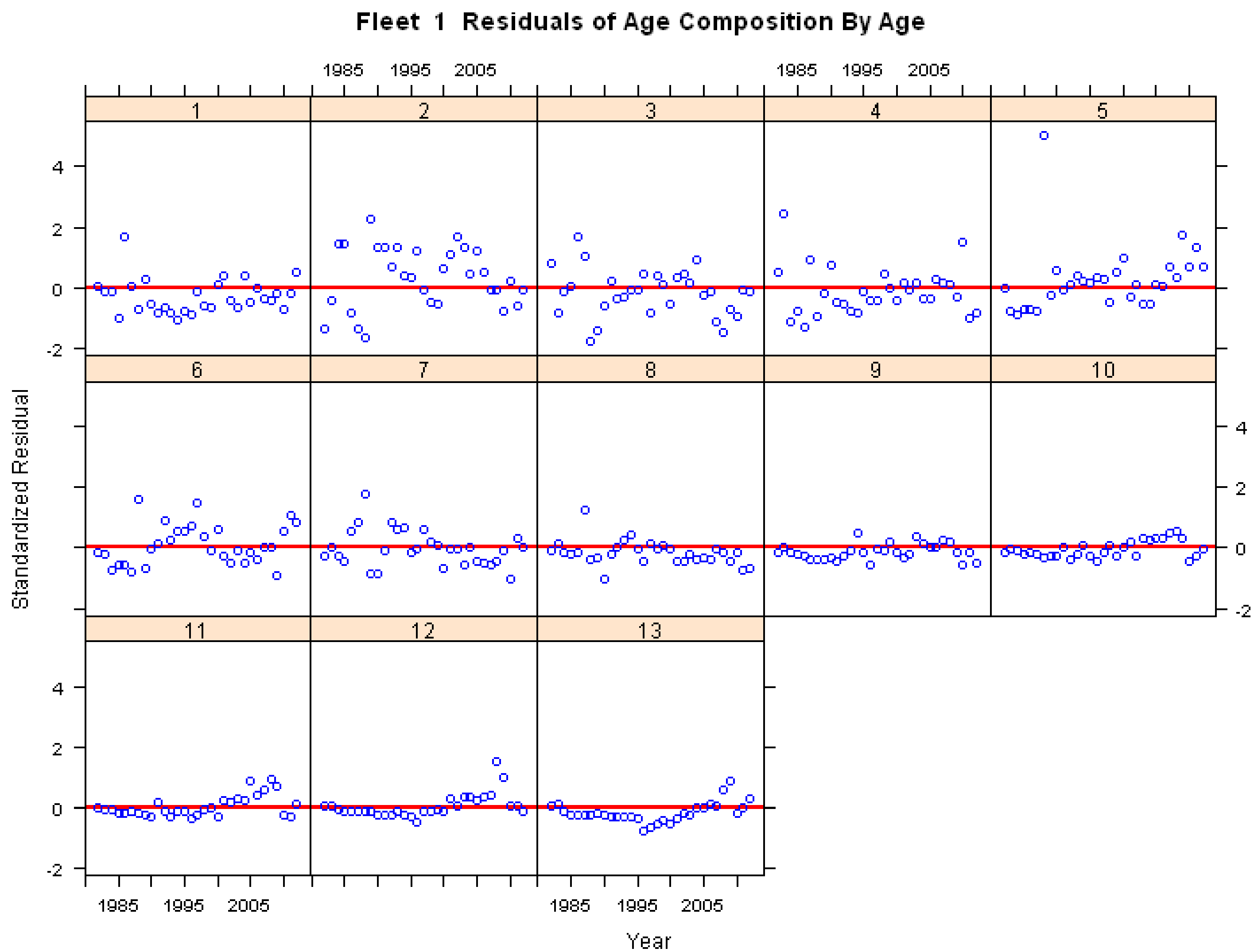


Figure 4. Standardized residuals of catch proportions-at-age by age.

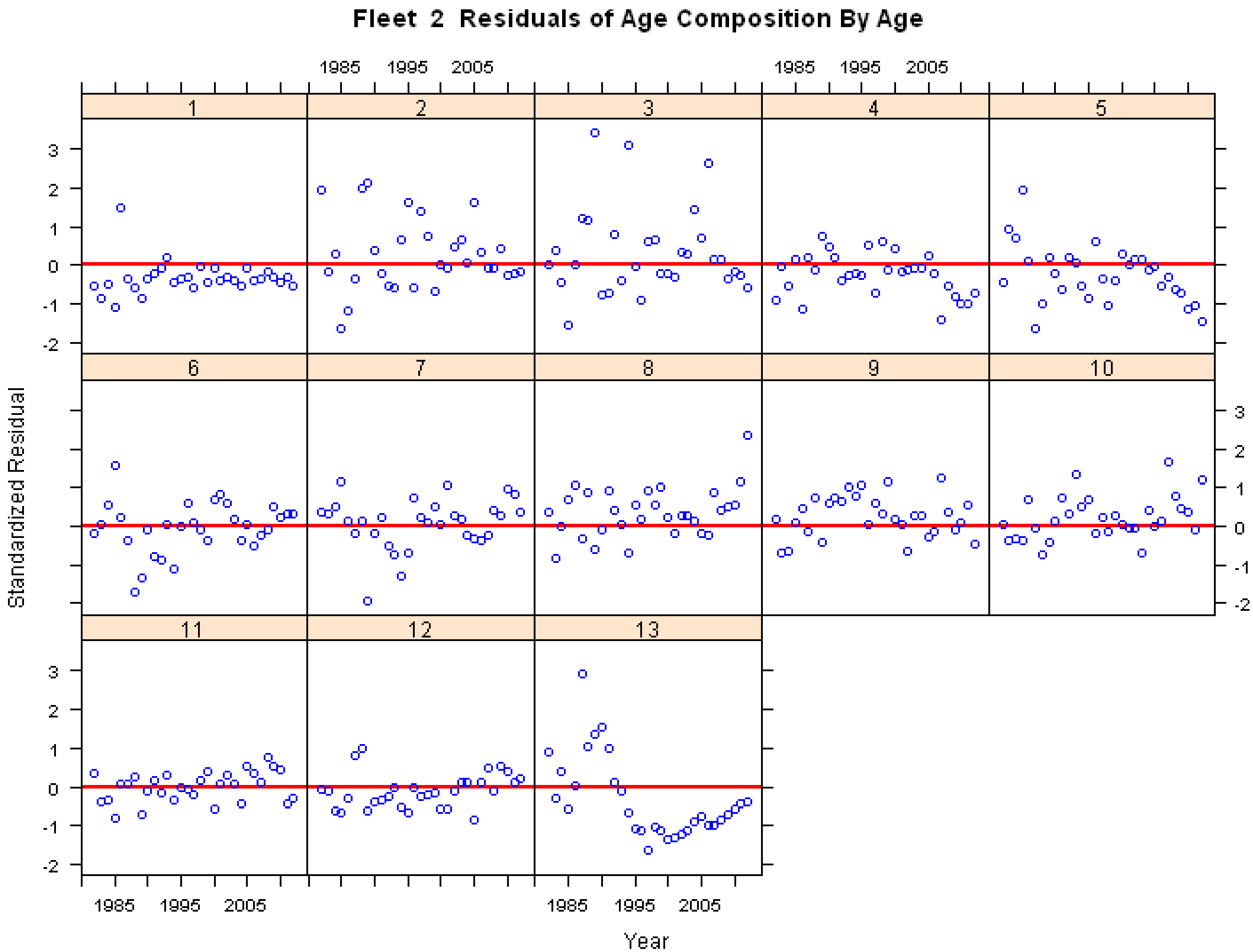


Figure 4 cont.

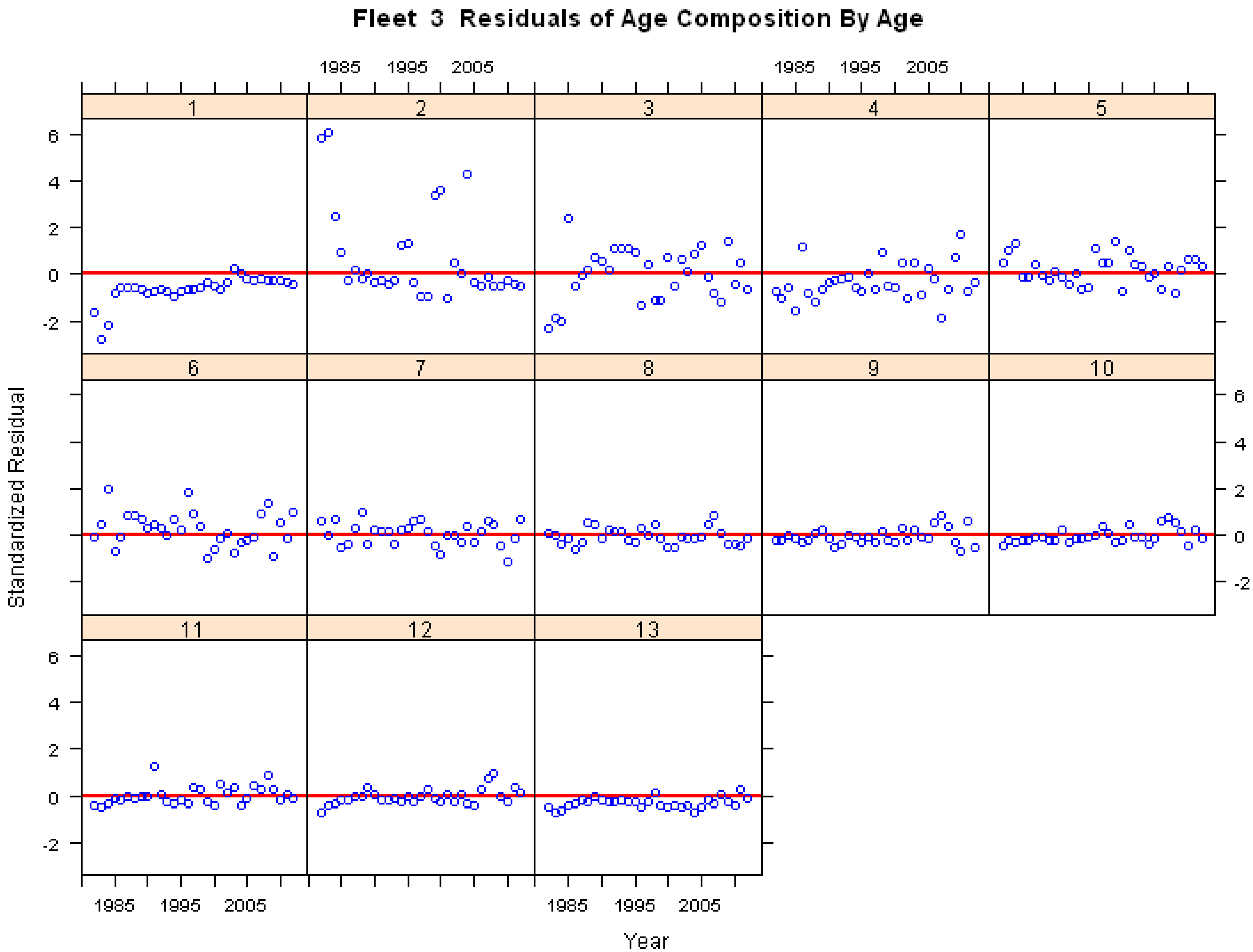


Figure 4 cont.

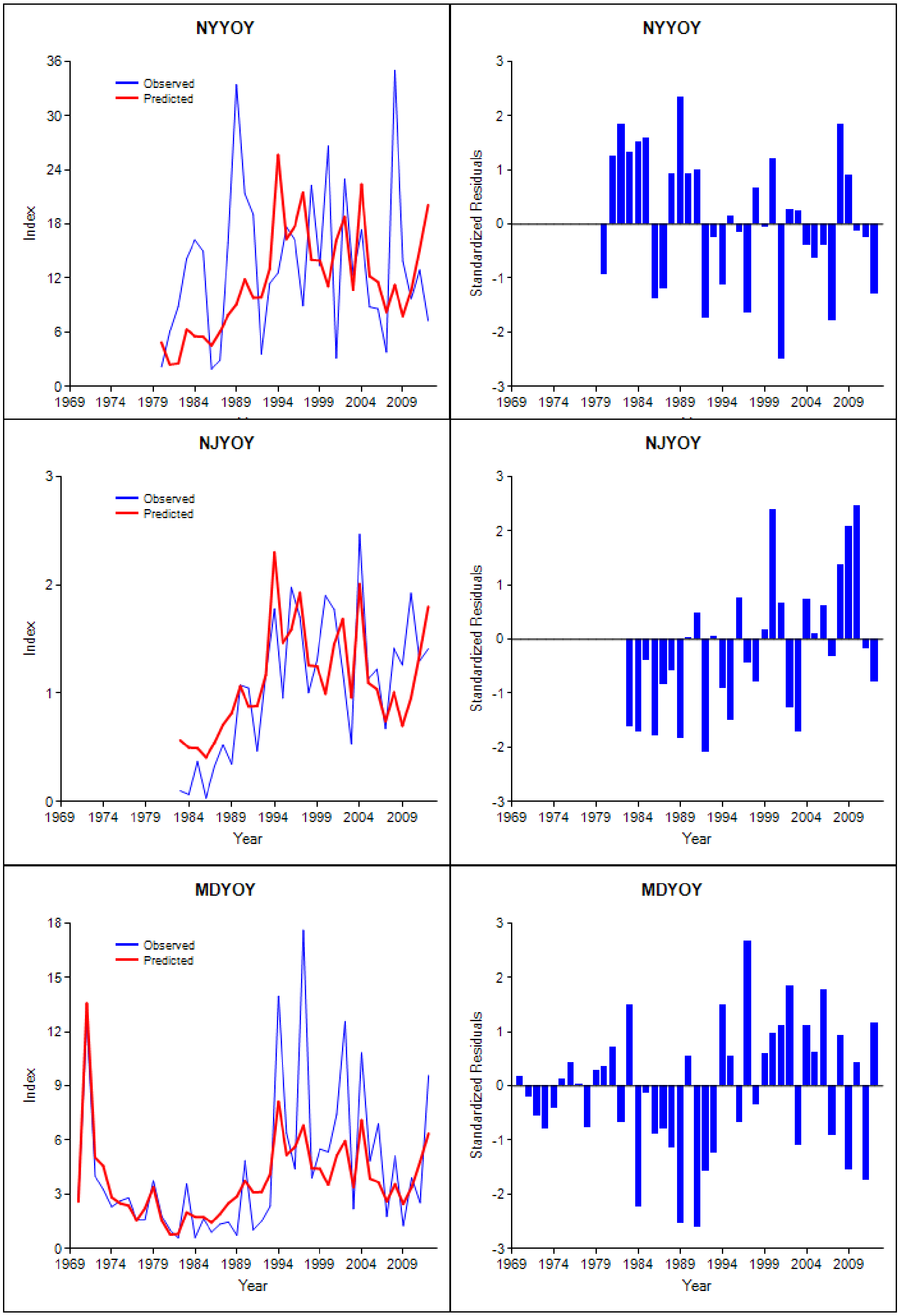


Figure 5. Observed and predicted values and standardized residuals for young-of-the-year and yearling surveys tuned to Age 1 and 2, respectively.

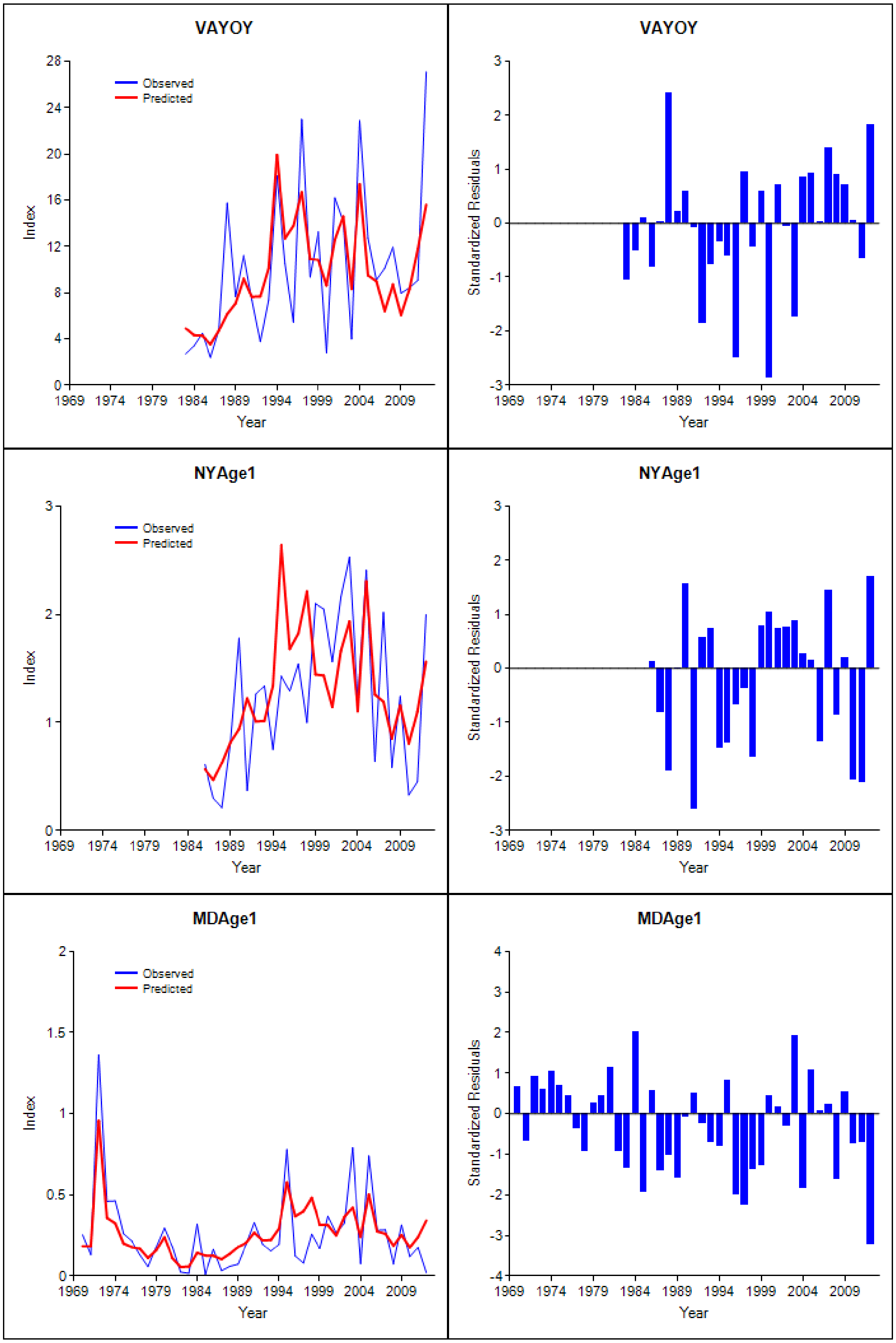


Figure 5 cont.

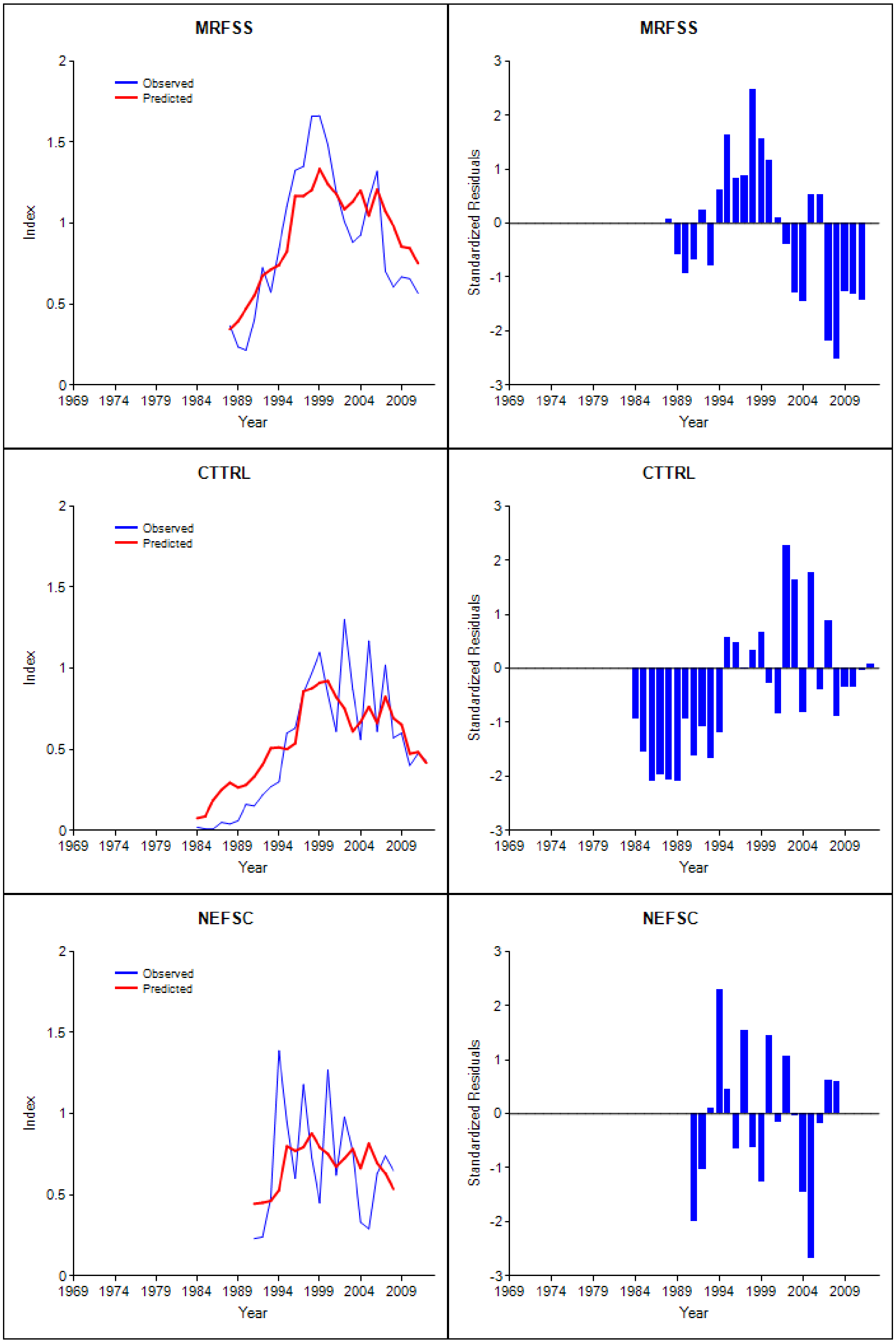


Figure 6. Observed and predicted values and standardized residuals for age-aggregated surveys.

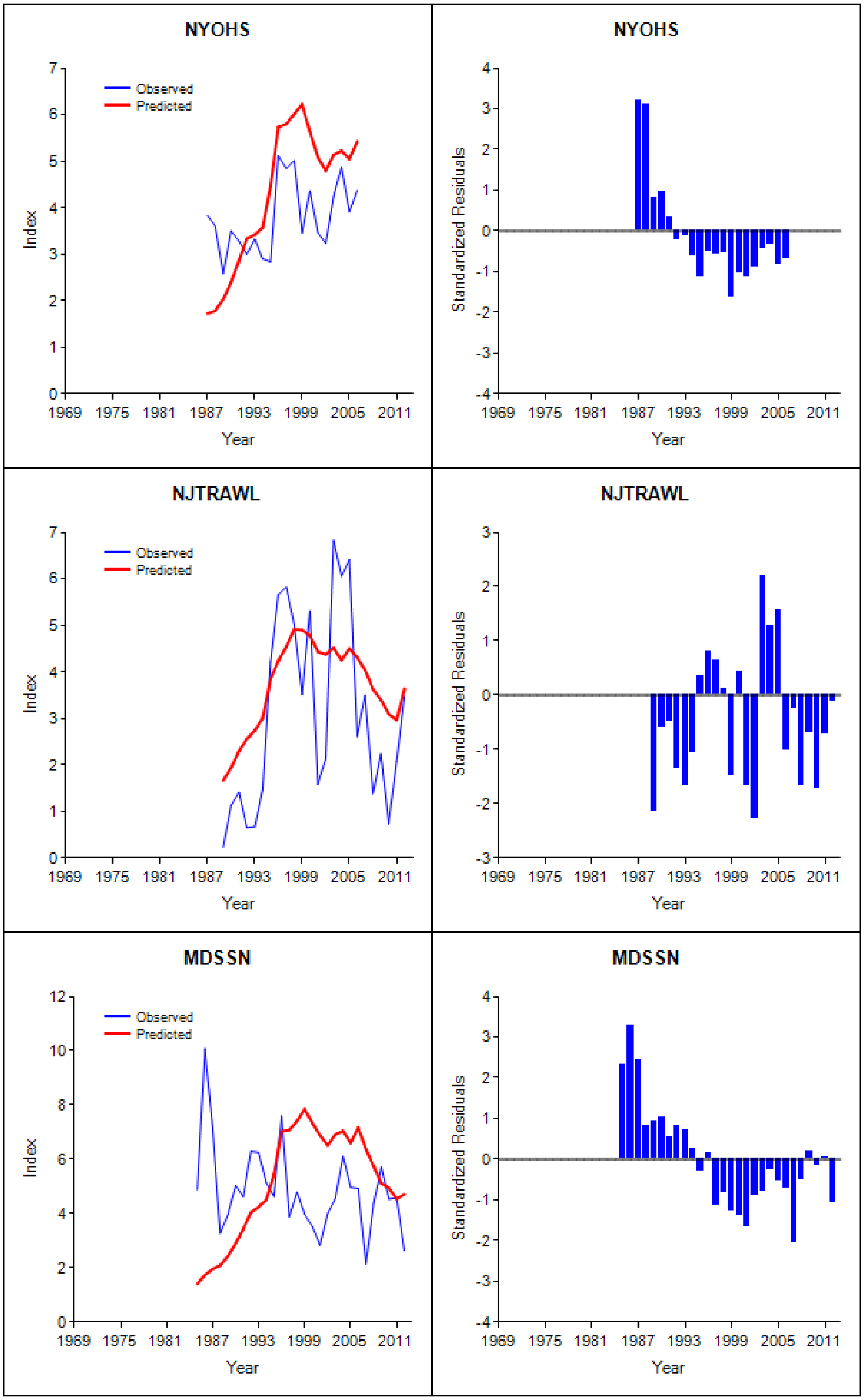


Figure 7. Observed and predicted values of the total index and standardized residuals for surveys with age composition data.

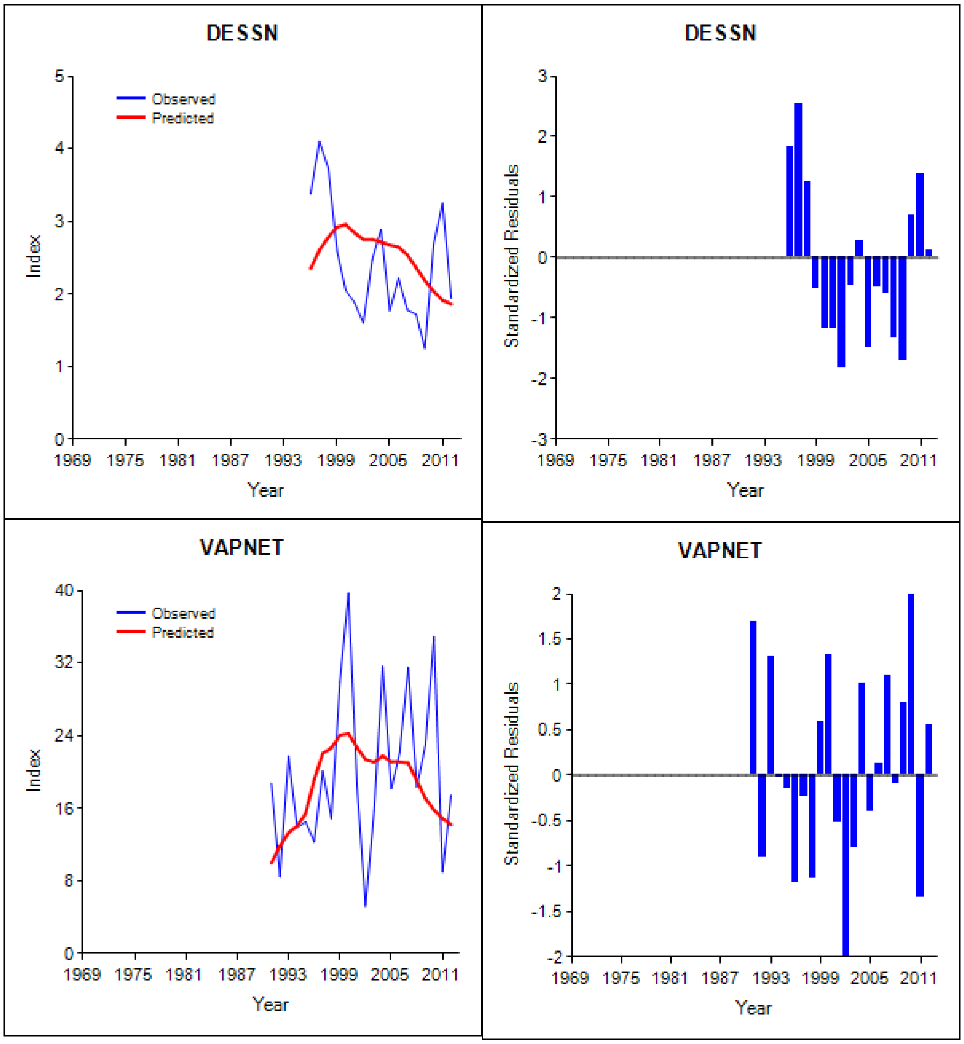


Figure 7 cont.

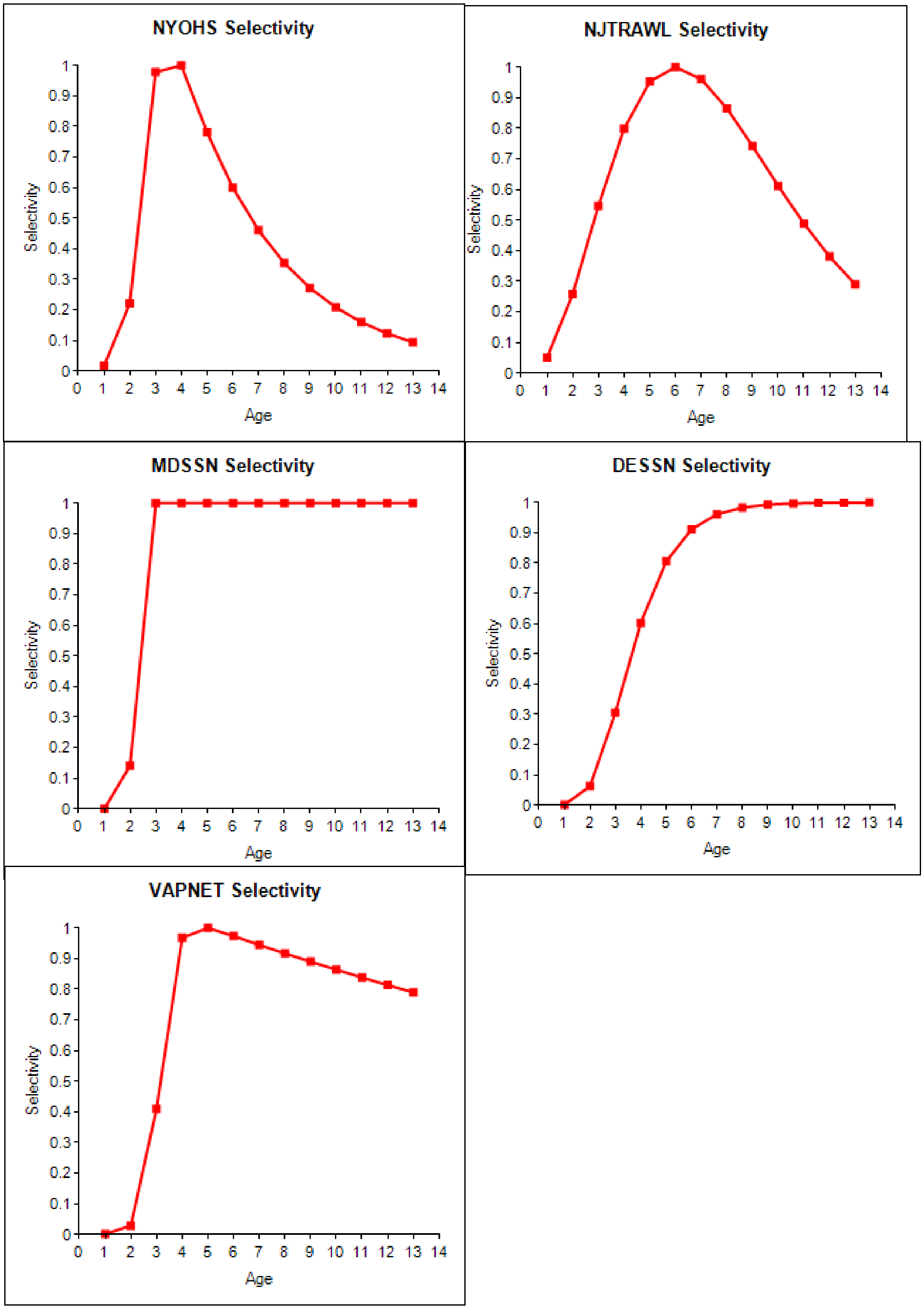


Figure 8. Selectivity patterns estimated for the NYOHS, NJ Trawl, MD SSN, DE SSN surveys and VAPNET.

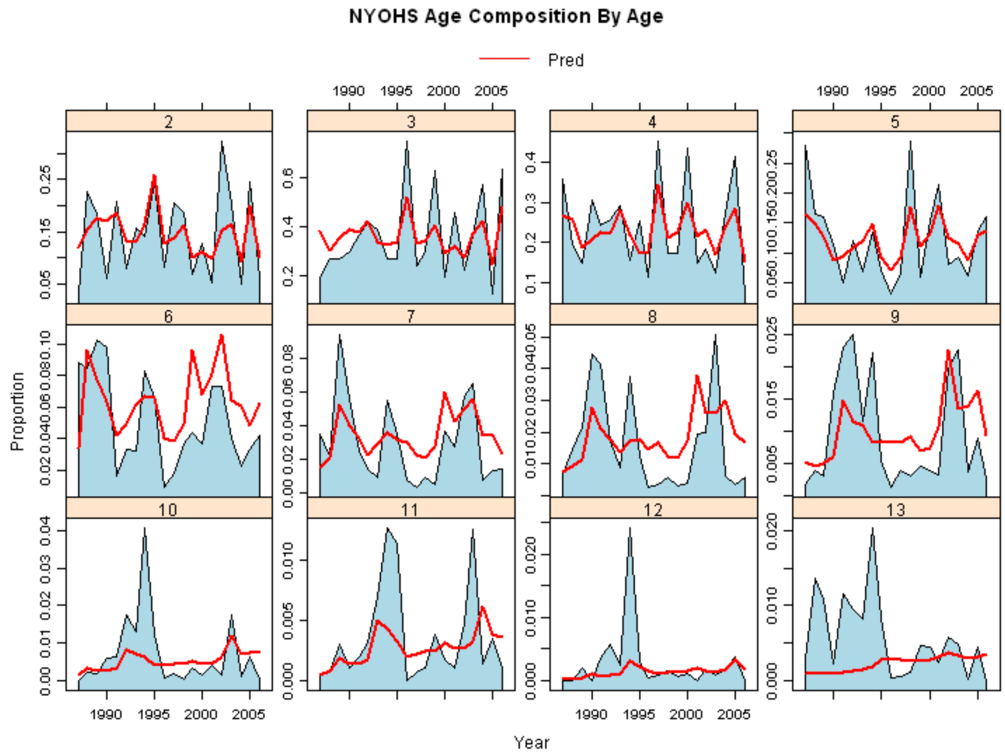
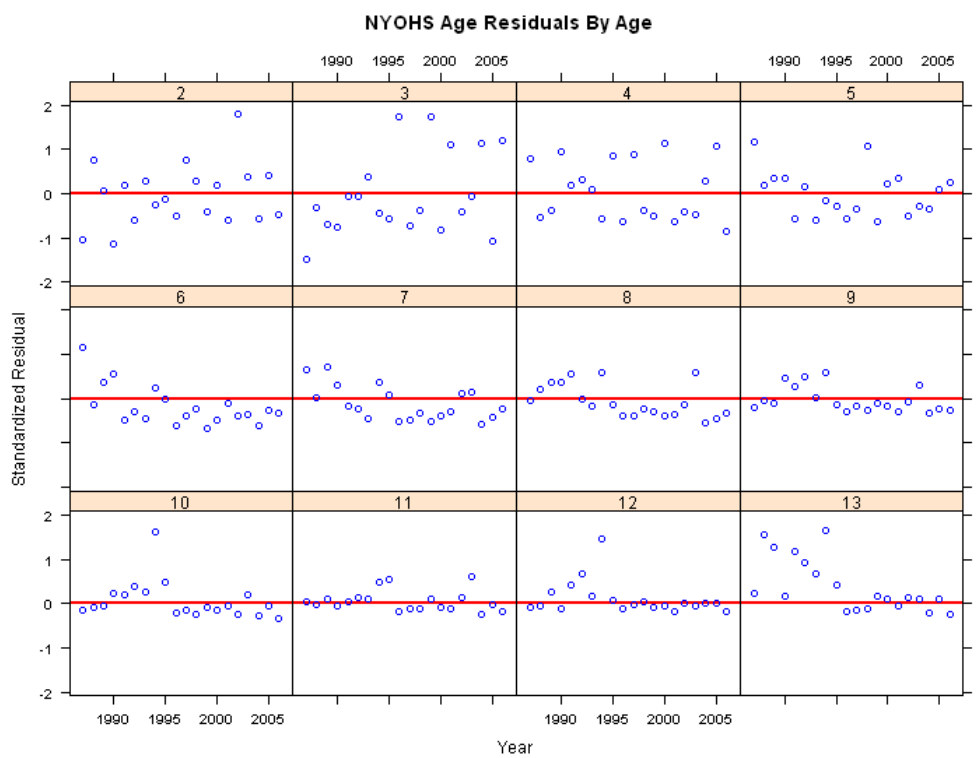
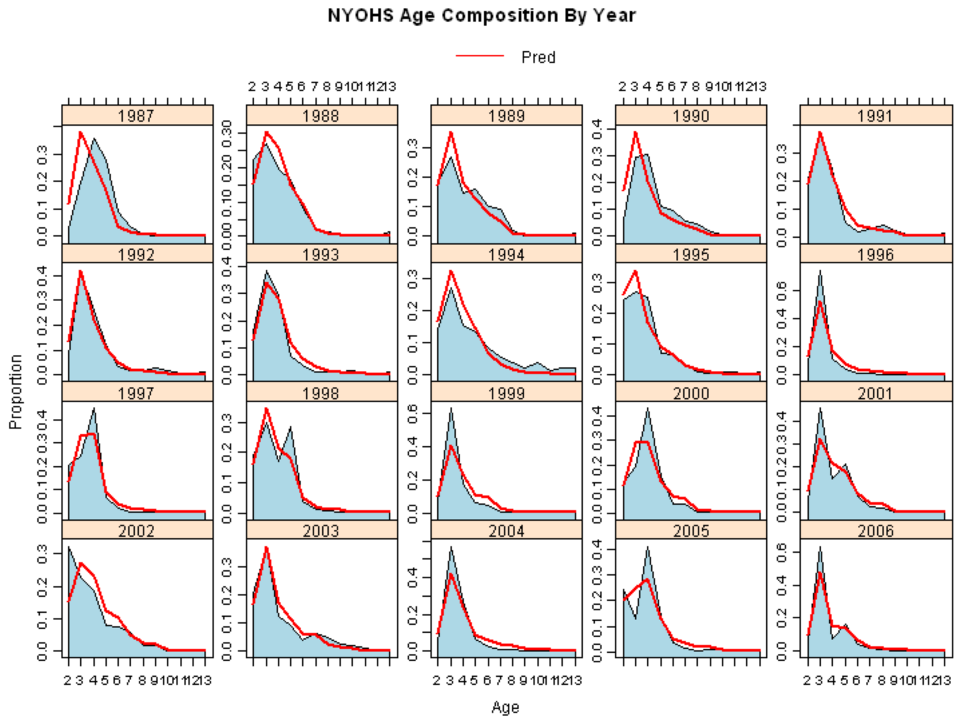


Figure 9. Observed and predicted proportions-at-age and standardized residual for each year by age for the NYOHS survey.





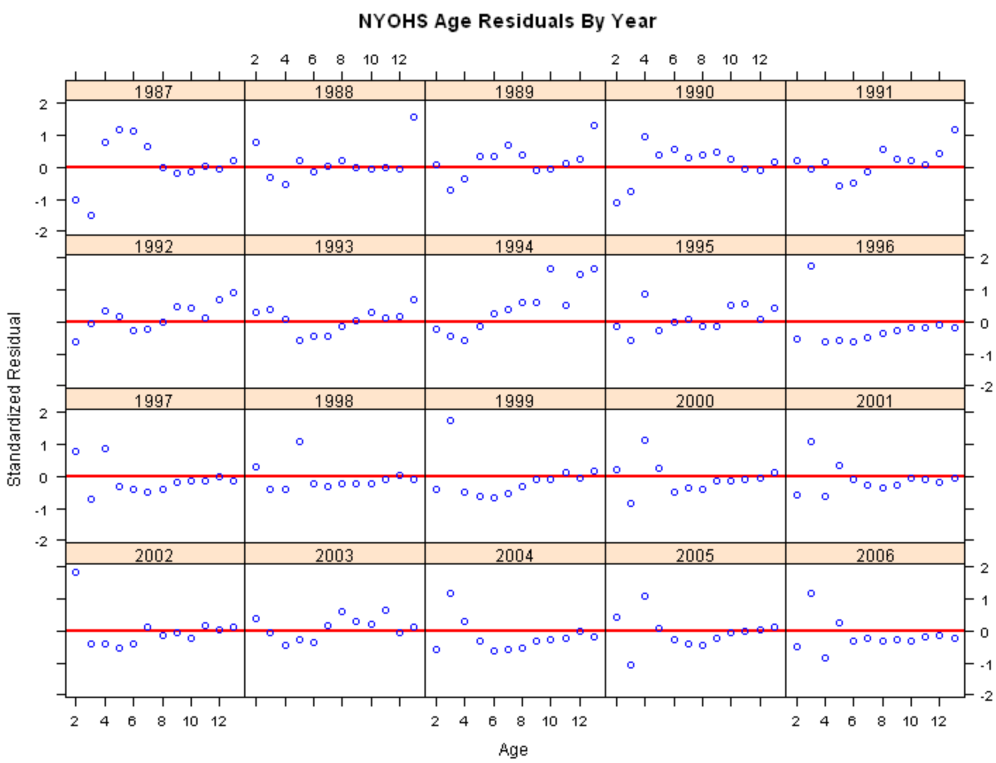
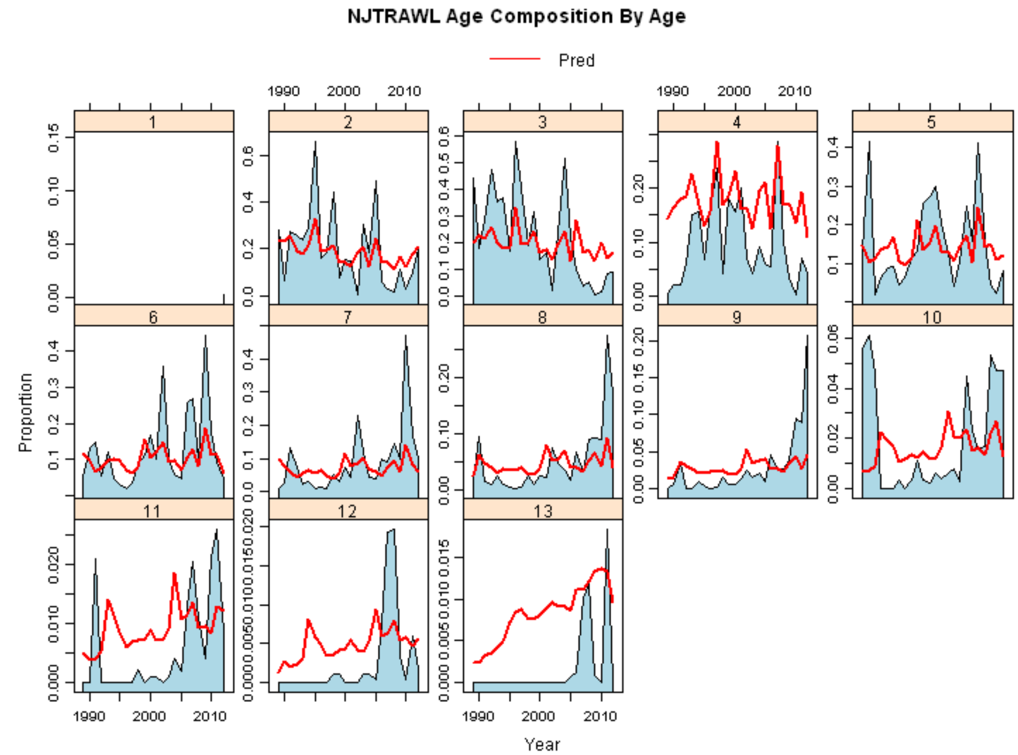


Figure 10. Observed and predicted proportions-at-age and standardized residuals for each age by year for the NYOHS survey.



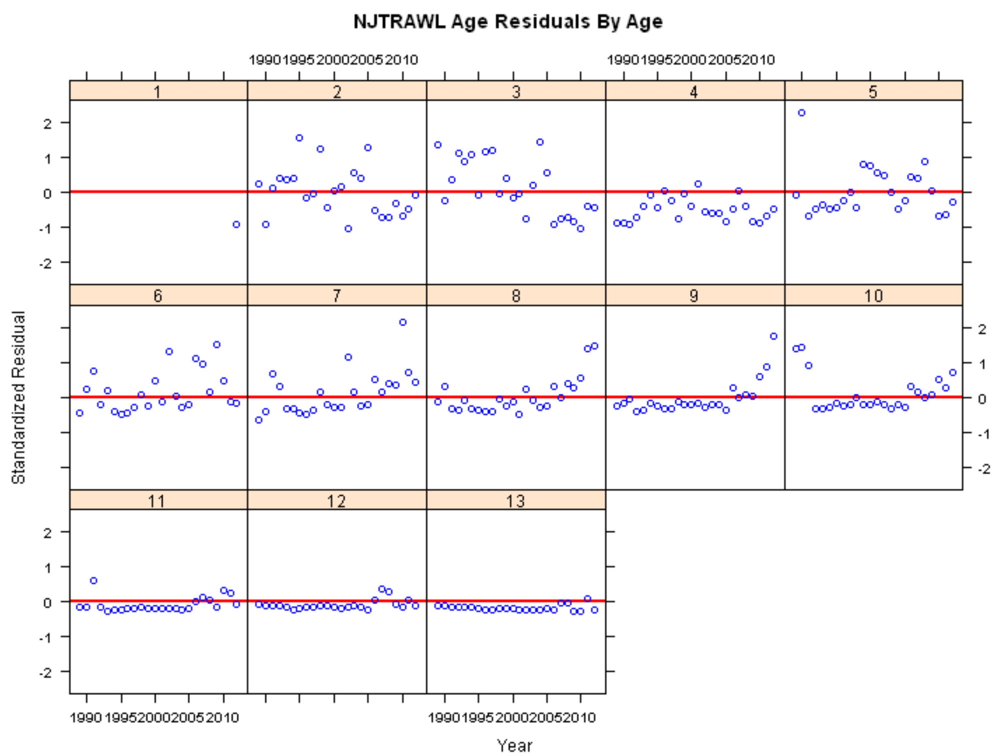
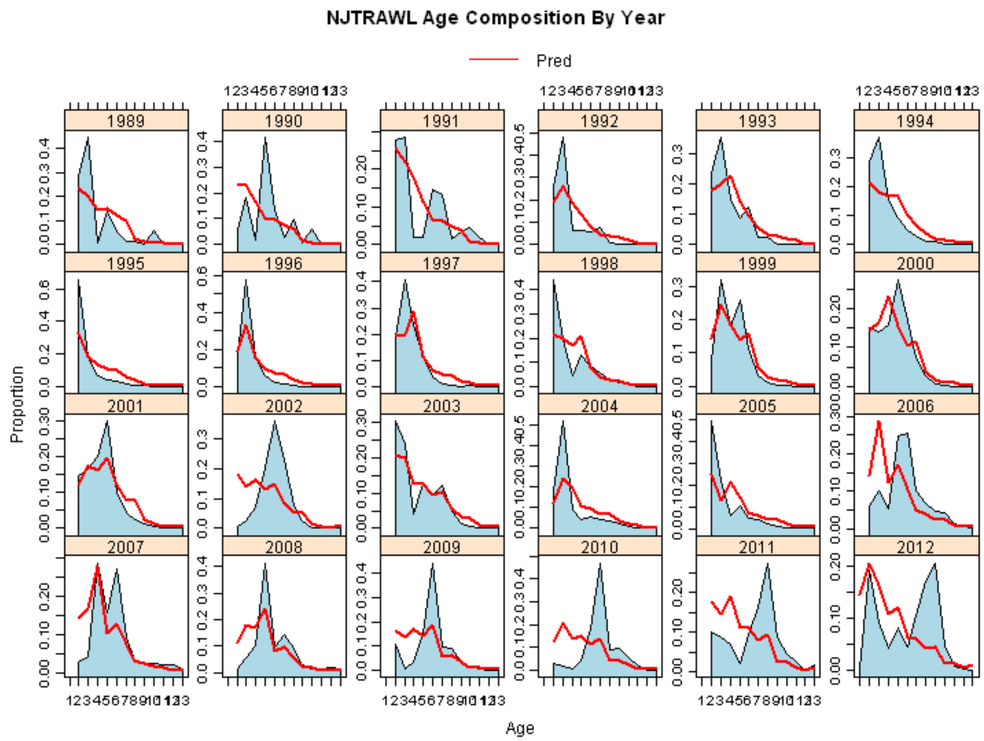


Figure 11. Observed and predicted proportions-at-age and residuals for each year by age for the NJ Trawl survey.



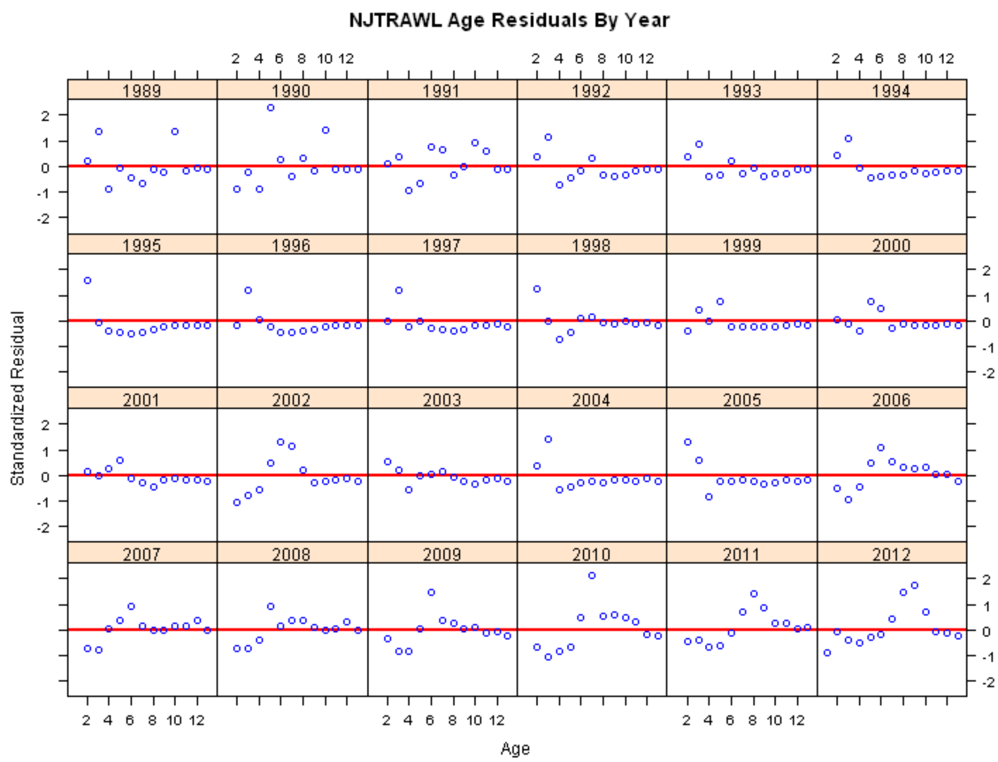
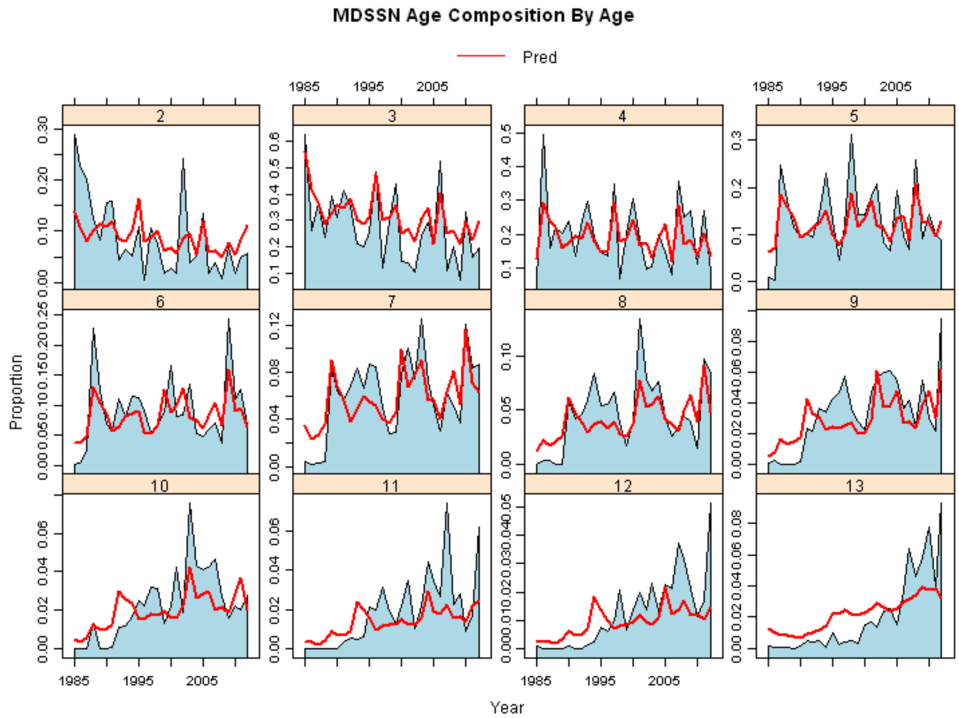


Figure 12. Observed and predicted proportions-at-age and standardized residuals for each age by year for the NJ Trawl survey.



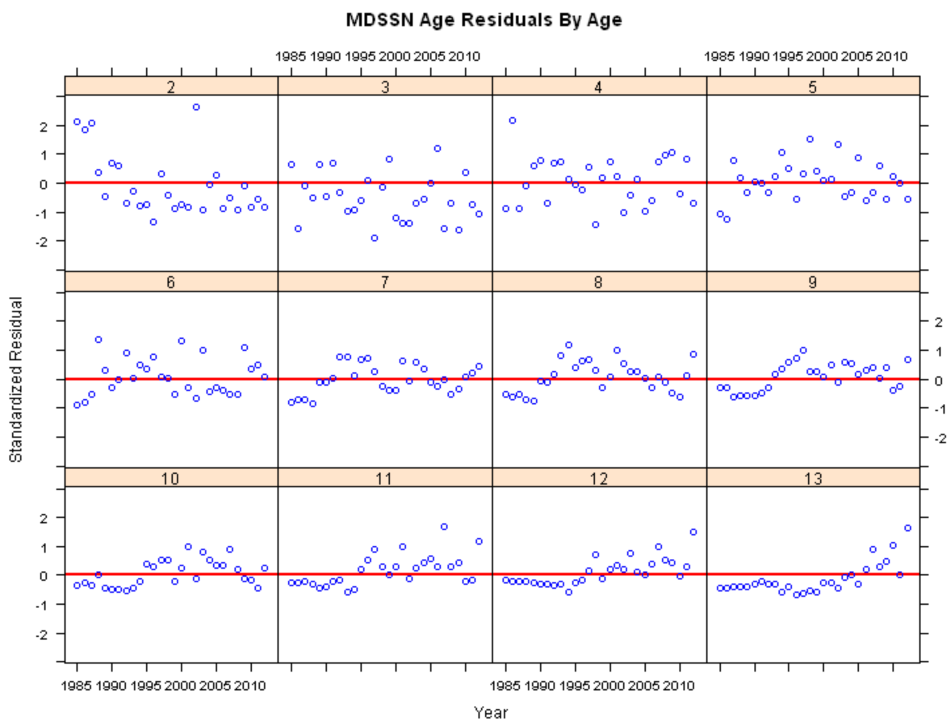
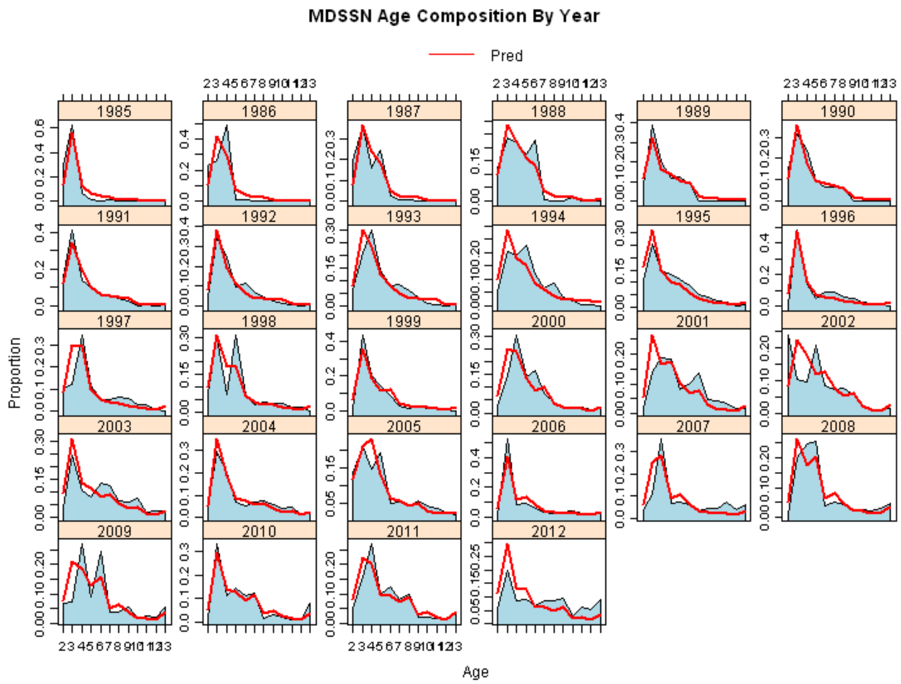


Figure 13. Observed and predicted proportions-at-age and standardized residuals for each year by age for the MD SSN gillnet survey.



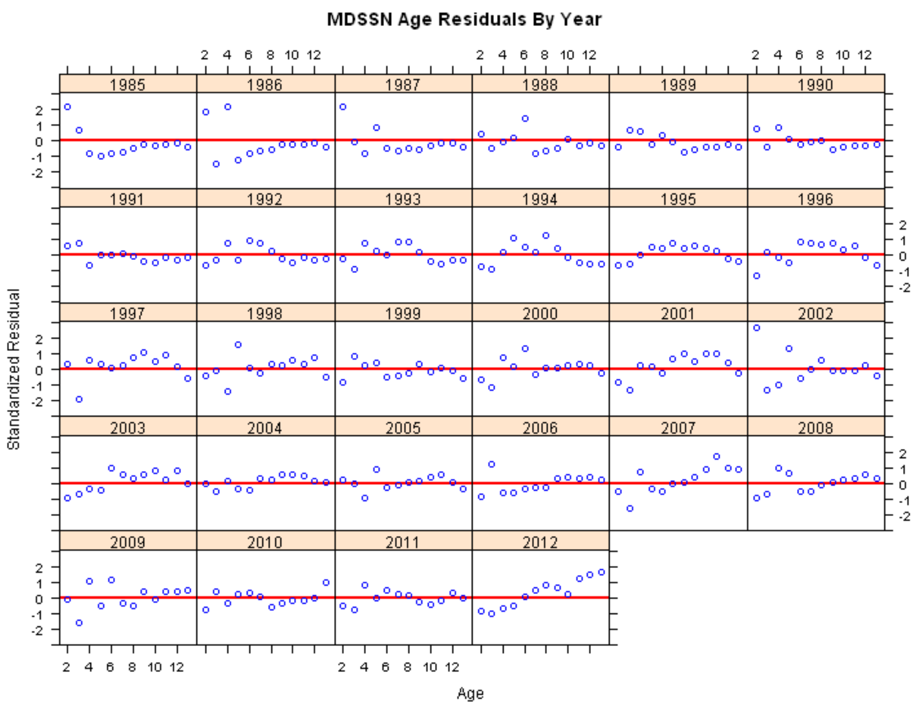
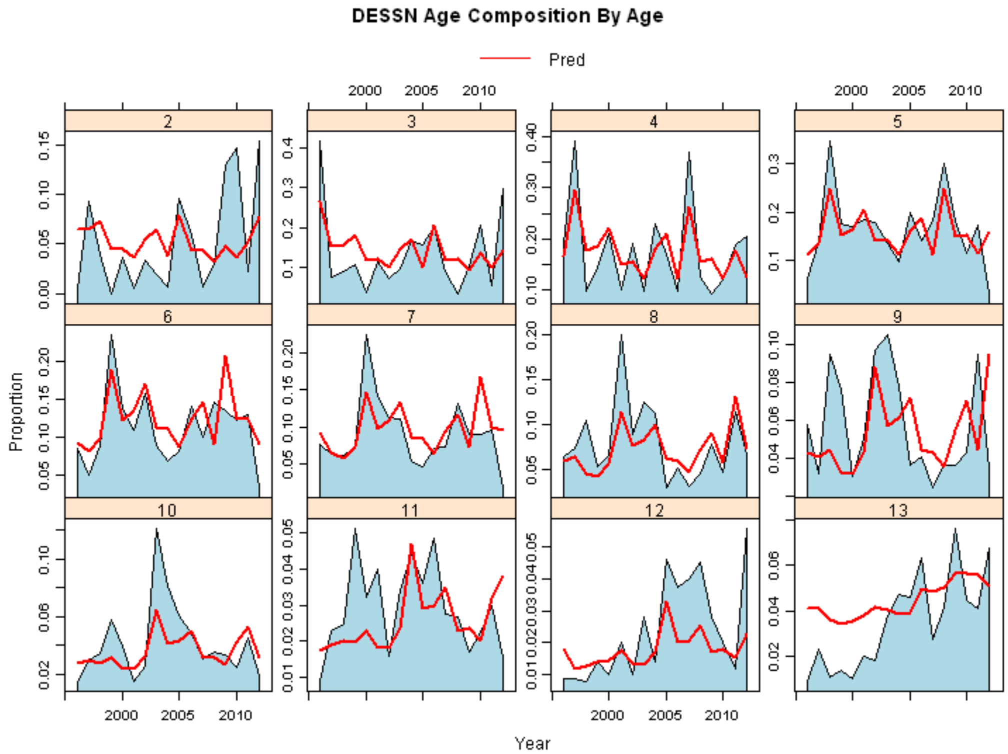


Figure 14. Observed and predicted proportions-at-age for each age by year for the MD SSN gillnet survey.



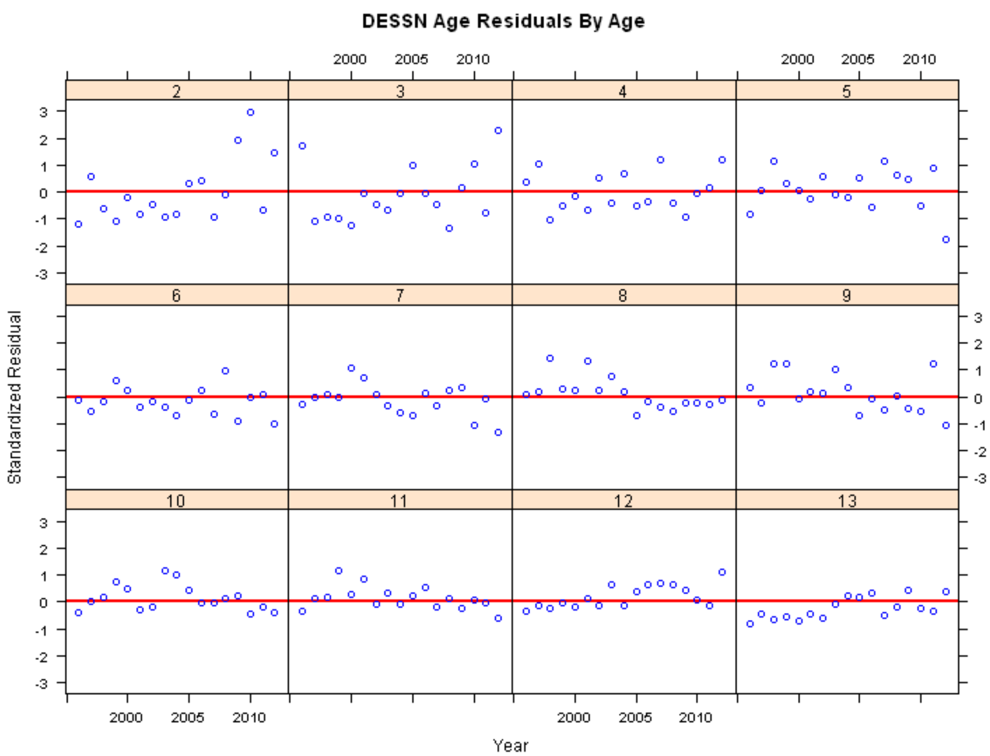
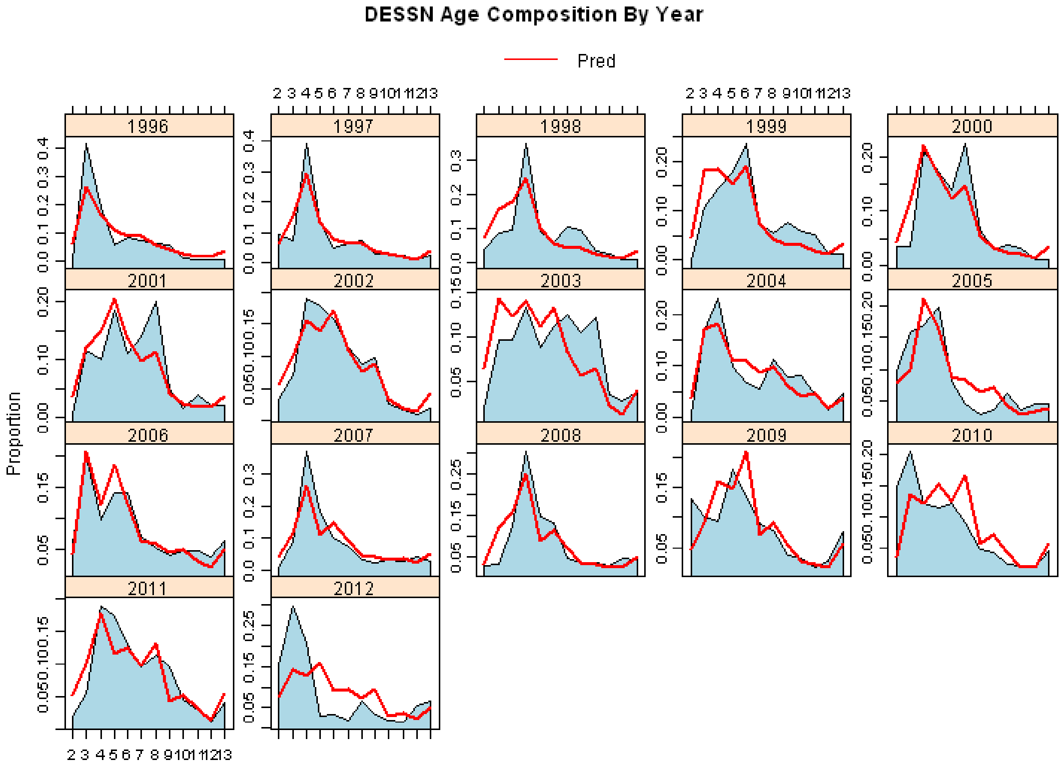


Figure 15. Observed and predicted proportions-at-age and standardized residuals for each year by age for the DE SSN electrofishing survey.



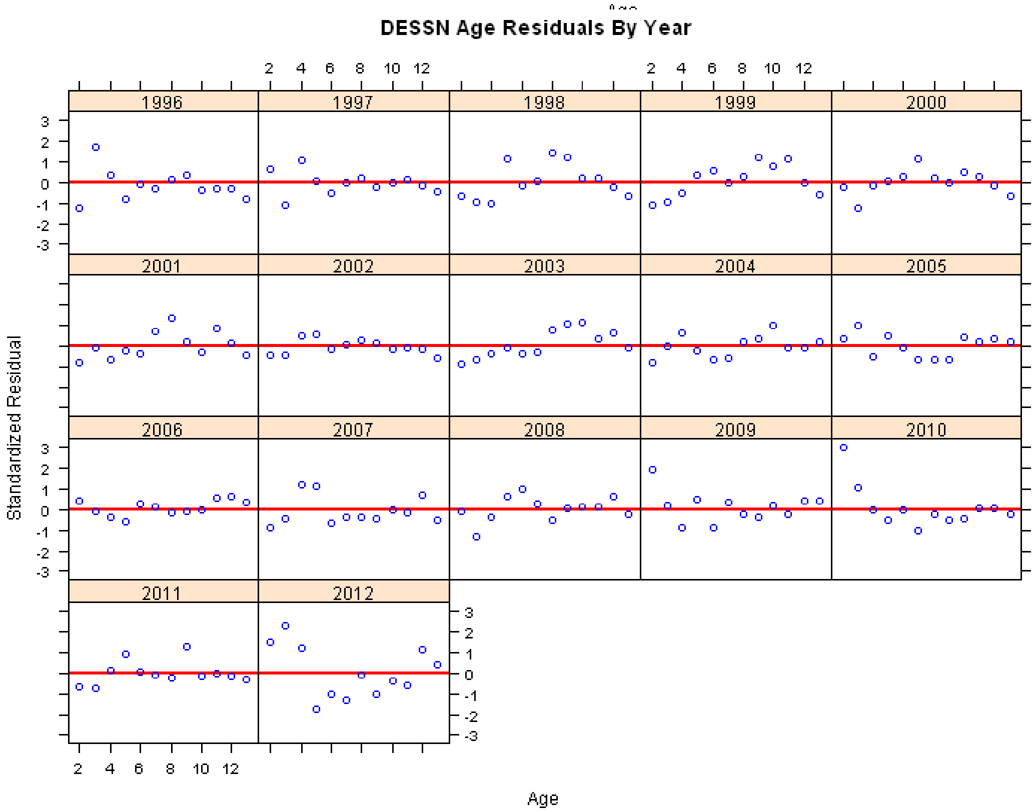
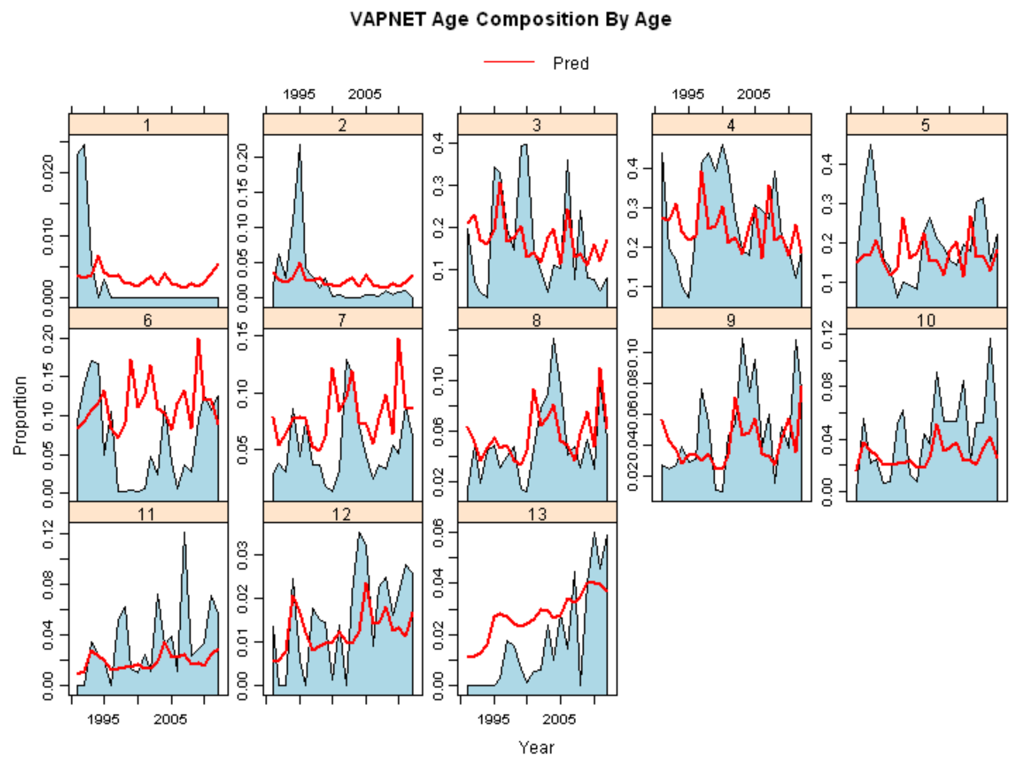


Figure 16. Observed and predicted proportions-at-age and standardized residuals for each age by year for the DE SSN electrofishing survey.



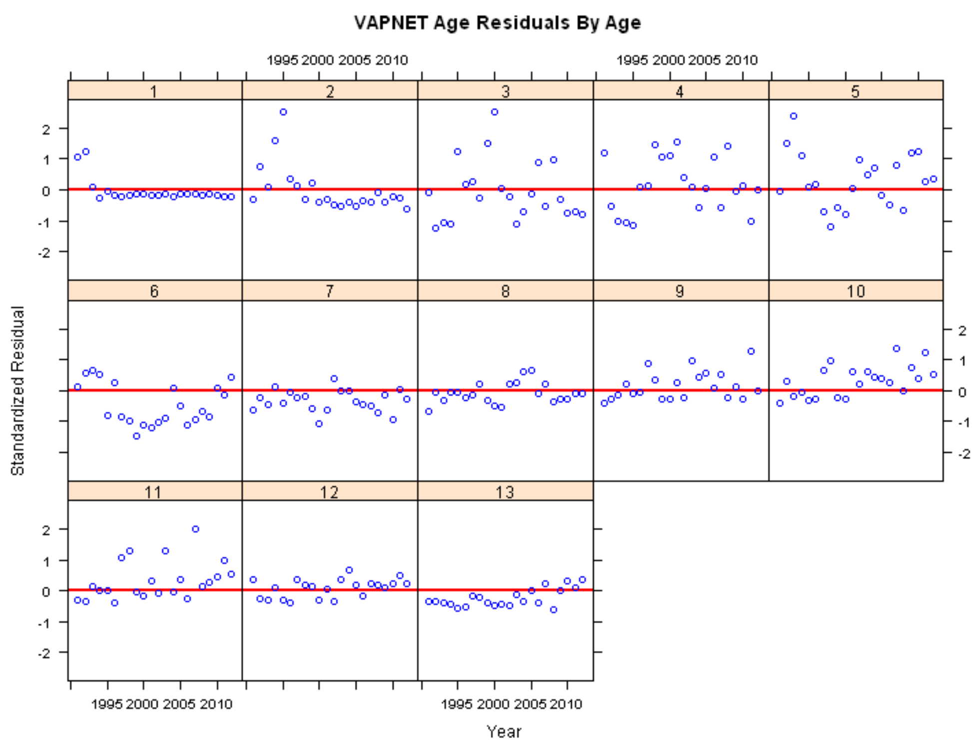
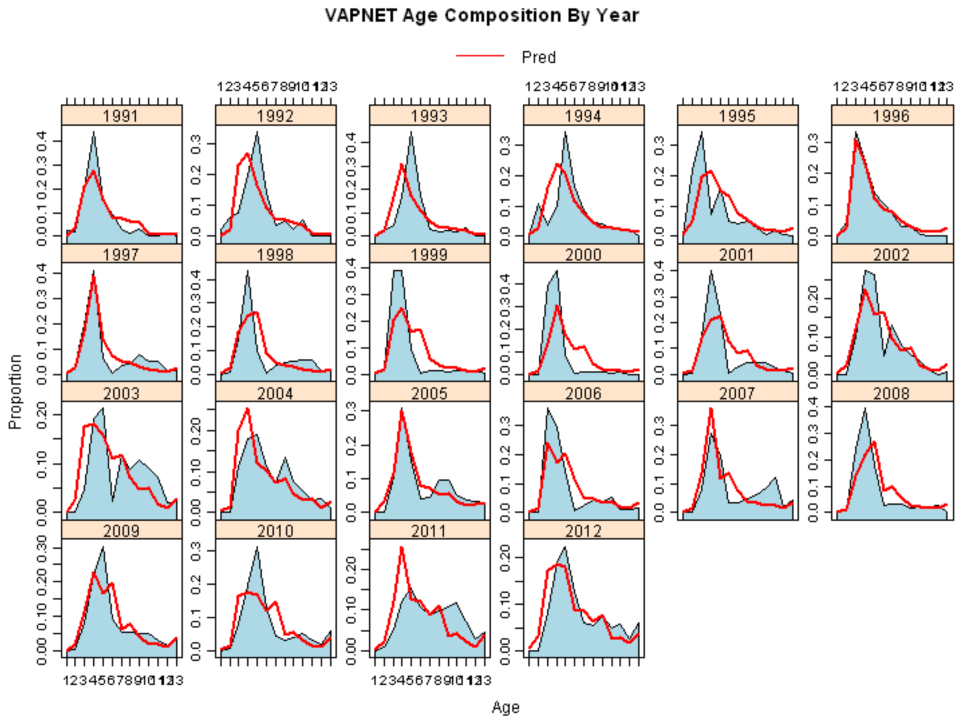


Figure 17. Observed and predicted proportions-at-age and standardized residuals for each year by age for the VAPNET survey.



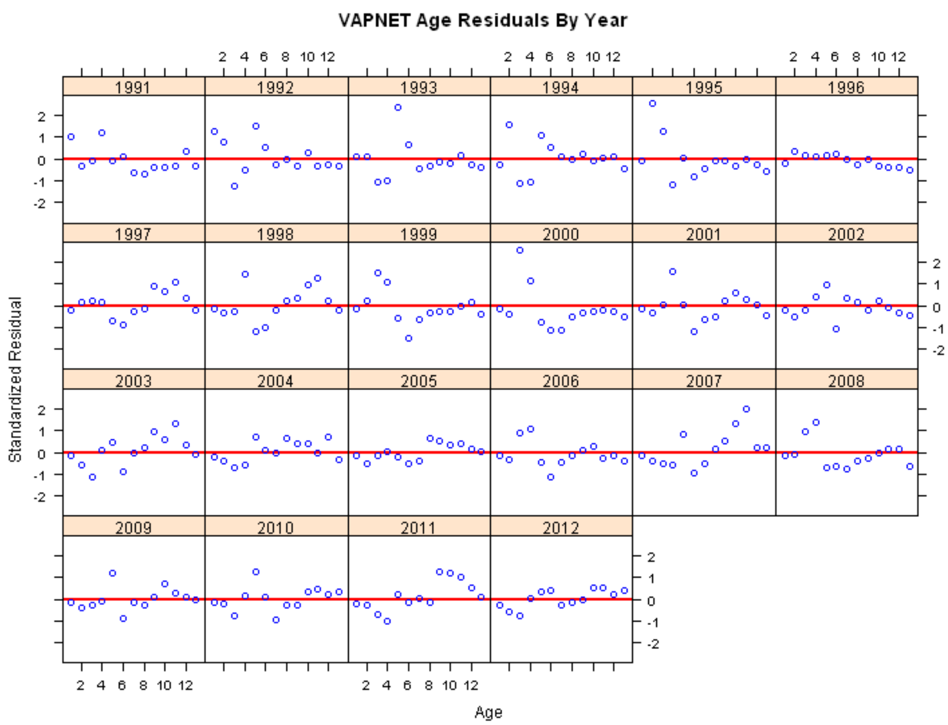


Figure 18. Observed and predicted proportions-at-age and standardized residuals for each age by year for the VAPNET survey.

Appendix B8: Age-Structured Assessment Program (ASAP)

B8.1 Model Structure

As an alternative to the SCA model, an ASAP statistical catch-at-age model (Legault and Restrepo 1998) was applied to the striped bass catch-at-age data and relative abundance indices. The years 1982-1984 experienced unusual selectivity patterns in the fisheries, consequently the time series of catch was begun in 1985, the first year of the Maryland moratorium on striped bass catch. Similar to the SCA, a three fleet model was developed with total weight of each component a function of mean weights-at-age and catch-at-age. Since ASAP cannot account specifically for sex ratio as does SCA, the ASAP maturity input was modified to equal maturity-at-age * sex ratio-at-age, therefore mimicking female only SSB in the subsequent calculations. Selectivity was estimated for each fleet with three time periods: 1985-1989, 1990-1995 and 1996-2012. The selectivity curves were fitted as a double logistic for the Bay fleet and commercial discards (which are primarily within Chesapeake Bay) and a single logistic model for the coastal fleet. The CV for the Bay and Coastal catches was set at 0.05 prior to 1995 and 0.02 from 1995-2012, with commercial discard uncertainty set at 0.1 for the entire time series. Effective sample size was calculated using the Francis method and held constant for the fleet coastal and commercial discard time series but a two-stage estimate in the Bay fleet split at 1995. The configuration of the relative abundance indices was similar to the SCA model, although the survey CVs were increased as necessary to maintain the RMSE around 1.0 to 1.5. However, the CV on the Chesapeake Bay young of year index for 2011 was reduced to the survey estimated value (0.2) in order to force the model to emphasize the most recent strong cohort.

B8.2 Results

The ASAP model was able to produce similar results as the SCA model using the shortened time series. In general the predicted indices from the model followed the trajectory of the observed abundance indices (Figure B8.1), with possible exception of the MD SSN and NY ocean haul seine indices which displayed time trends in the residual patterns (Figure B8.2). The average fishing mortality (ages 8-11) increased steadily between 1987 and 1997, remained stable through 2003, increased again until 2007 (Figure B8.3). Since 2008 F has ranged between 0.19 and 0.23, with 2012 equal to 0.21. Fishing mortality by fleet indicates the largest component of F is from the coastal fishery. Female spawning stock biomass increased steadily between 1986 (11,880 mt) and 2003 (78,020 mt) but has slowly decreased with the 2012 estimated SSB of 58,612 mt (Figure B8.4). Recruitment at age 1 shows large year classes in 1993, 1996, 2003 and 2011 (Figure B8.5). Alternative model configurations in which the CV on the most recent Bay yoy indices was not reduced, 2011 recruitment estimates were about 35% lower (Figure B8.6). The stock and recruitment series provided enough contrast to produce a reasonably well fitted Beverton-Holt stock recruitment model (Figure B8.7). Steepness was estimated was 0.790 with unexploited SSB of 337,205 mt and unexploited R of 121.118 million fish.

The ASAP model results were evaluated for any retrospective problems using a seven year peel. Results suggest an over-estimation of fishing mortality for 2005-2007 (Figure B8.8), with a relative difference in 2005 of 39% (16% in 2007). Between 2008 and 2011 there were no retrospective issues with relative differences ranging from 8.5% to 1.1%. Similarly for SSB, the model estimates tended to under-estimate SSB (Figure B8.9) as much as 31% in 2005 but less than 9% since 2007. Recruitment estimates tended to be more erratic ranging from -35% to 36% (Figure B8.10). The most recent two years tended to under-estimate recruitment by 15% to 20%. An MCMC run using 500 iterations with a thinning factor of 200 was applied to the ASAP results. The 80% confidence interval for annual total 2012 fishing mortality ranged from 0.165 to 0.238 (Figure B8.11). Similarly, 80% CI for 2012 SSB ranged from 51,240 mt to 66,333 mt (Figure B8.12).

B8.3 Comparison with SCA model

Overall the striped bass catch-at-age and relative abundance indices modeled in the ASAP program produced similar results as the SCA model. The estimate of 2011 recruitment was the largest source of uncertainty depending on the amount of uncertainty attributed to the recent Bay indices. In addition, the initial year estimate of abundance and F were slightly lower in ASAP likely due to the added information in the longer time series used in the SCA model. Another point of difference between the two models is the estimate of F_{MSY}. The SCA makes adjustments for the potential log-retransform bias whereas ASAP does not. The reference point generated from the ASAP model was an F_{MSY} of 0.144 while the SCA model was 0.22.

B8.4 Literature Cited

Legault, C.M amd V.R. Restrepo. 1998. A flexible forward age-structured assessment program. ICCAT. Col. Vol. Sci. Pap. 49:246-253.

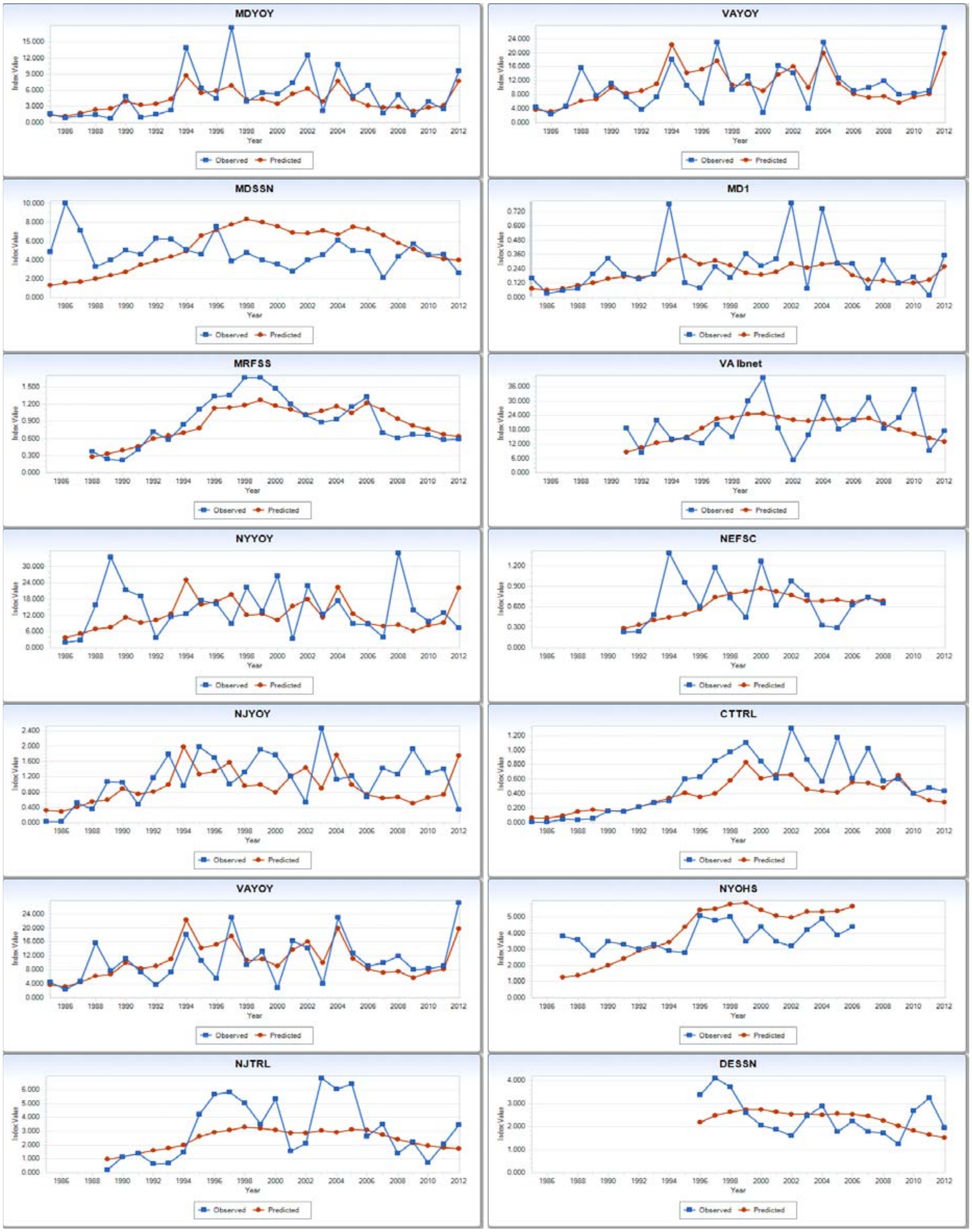


Figure B8.1. Predicted indices vs. observed indices from ASAP striped bass model.

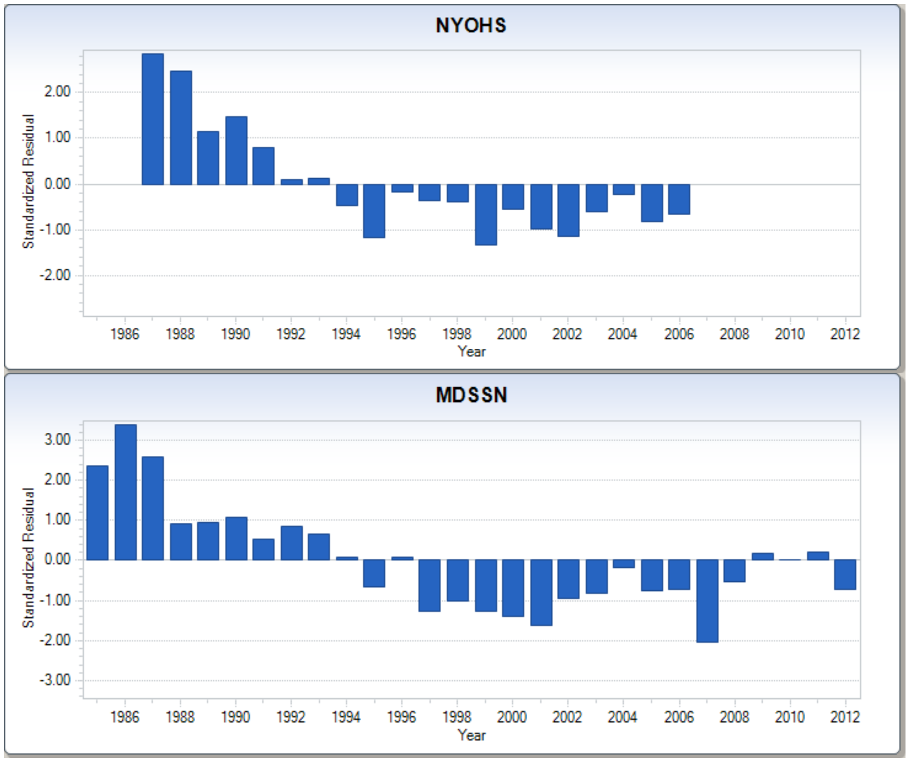


Figure B8.2. Residual patterns from MD spawning stock index and NY ocean haul seine index showing time trended residual patterns.

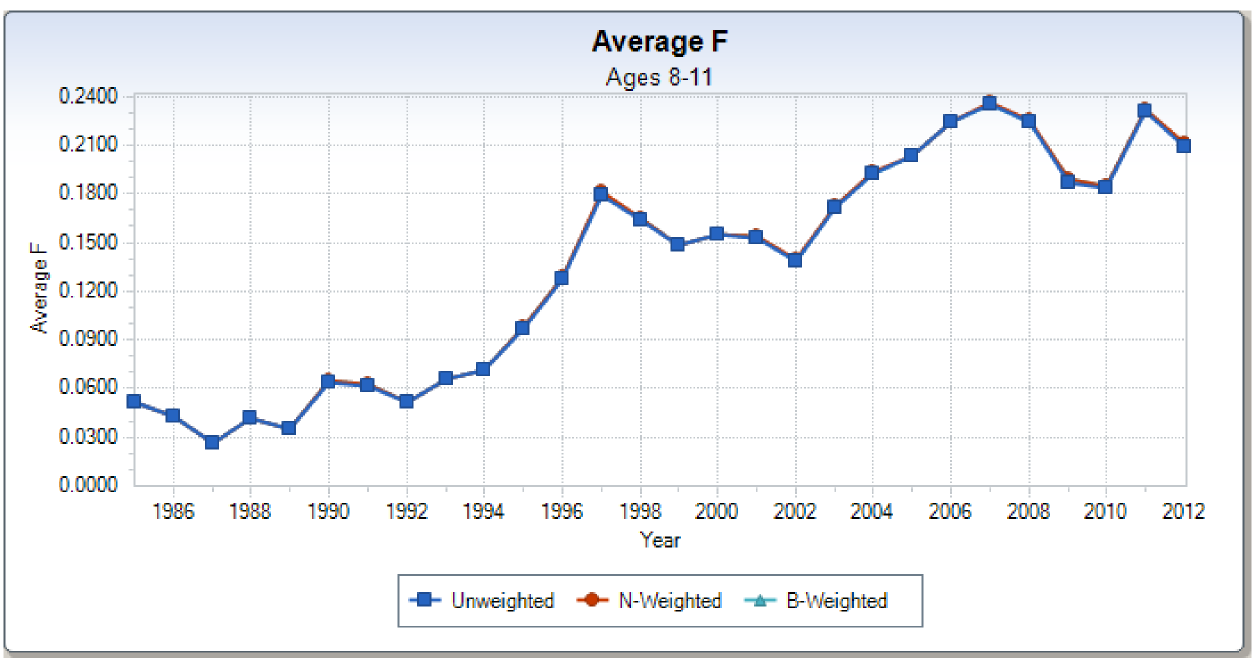


Figure B8.3. Time series of striped bass annual fishing mortality (age 8-11) from ASAP model results.

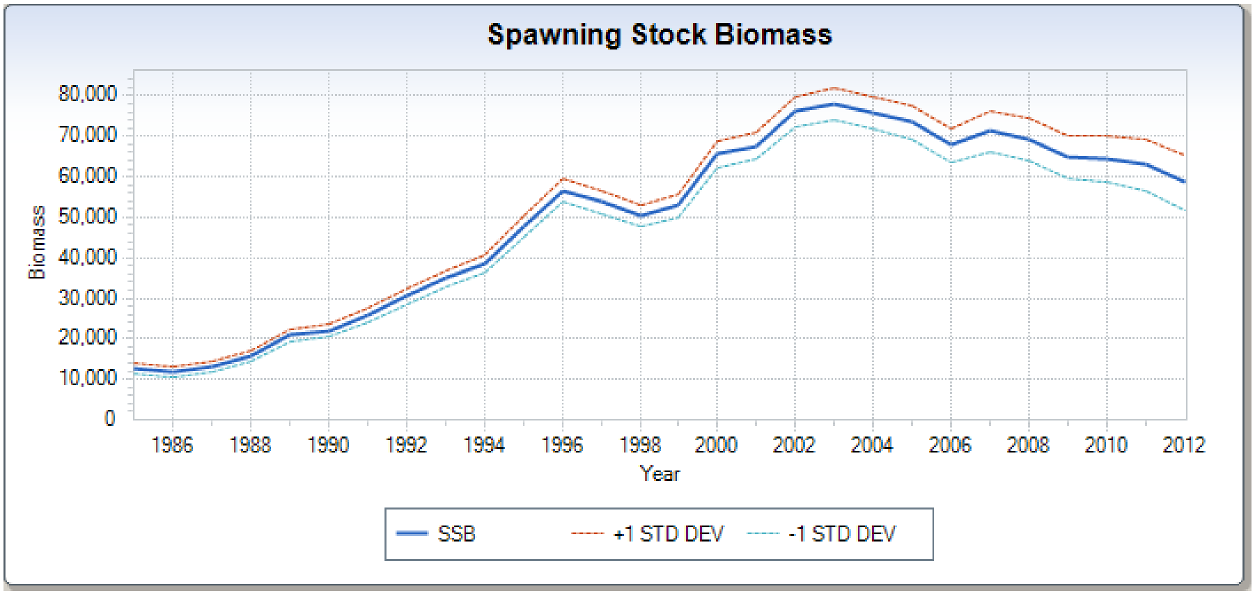


Figure B8.4. Time series of striped bass annual female spawning stock biomass from ASAP model results.

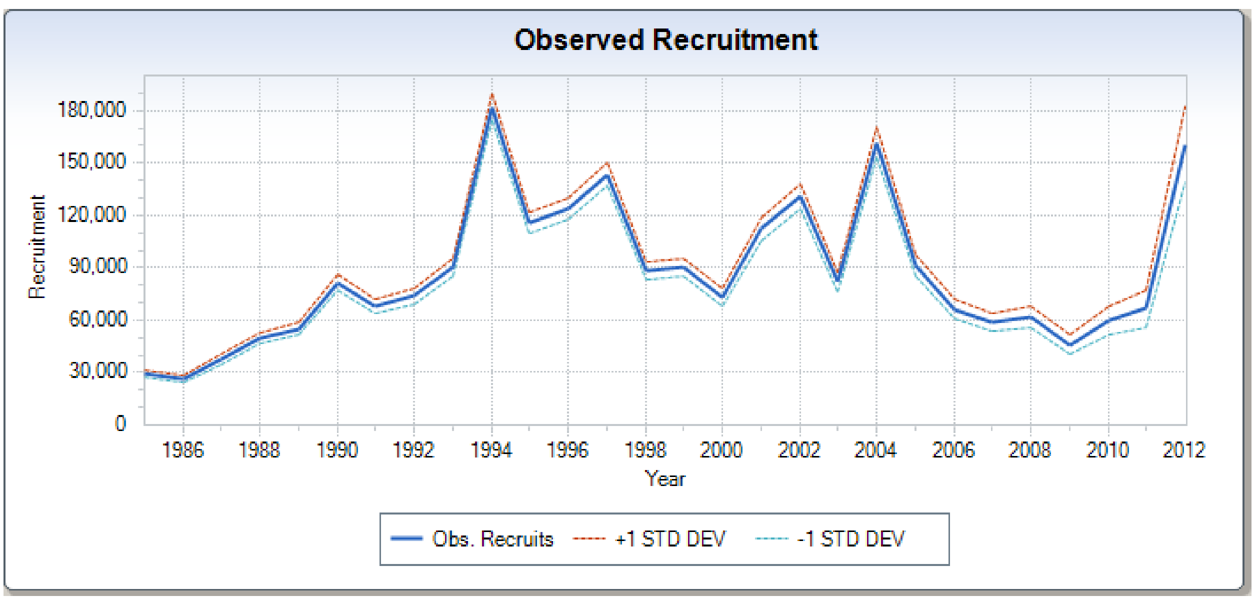


Figure B8.5. Observed striped bass age 1 recruitment estimates from ASAP model.

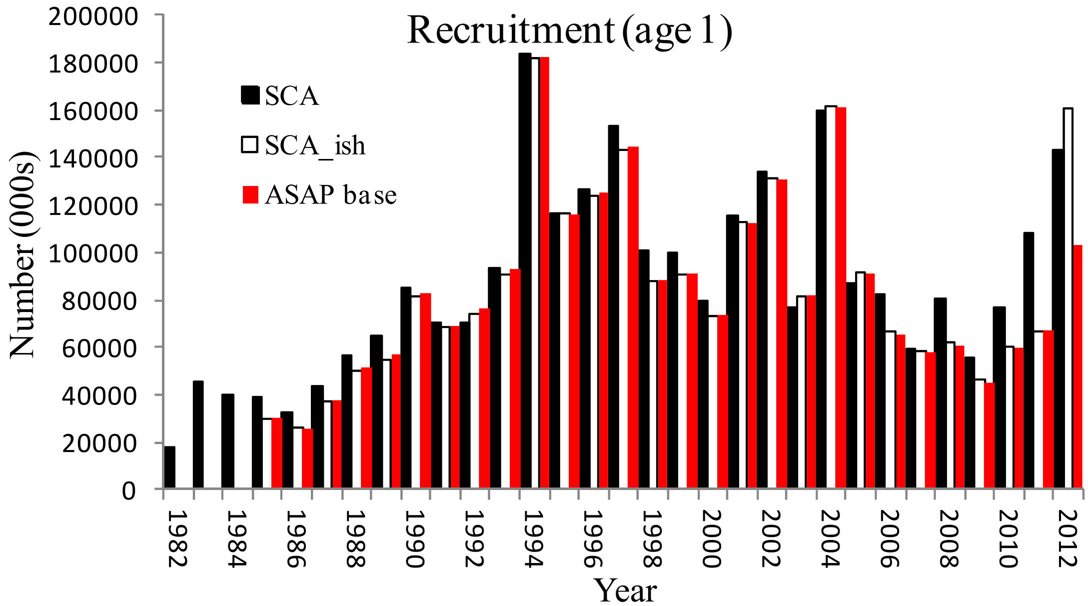


Figure B8.6. Comparison of age 1 recruitment estimates of striped bass from SCA, ASAP run as SCA (SCA_ish) and an alternative model without reduce CV on Chesapeake Bay 2011 yoy index (ASAP base).

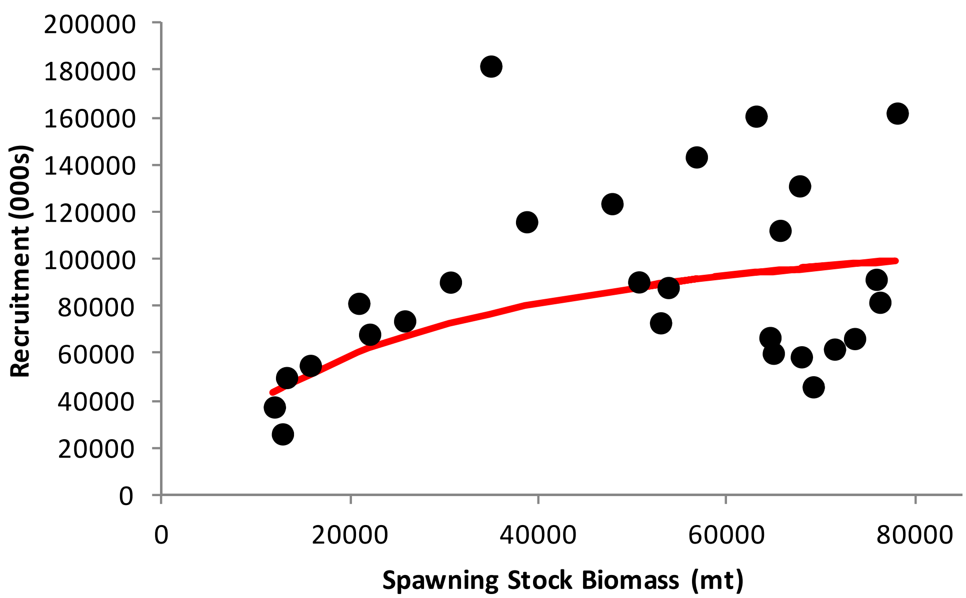


Figure B8.7. Beverton-Holt stock recruitment plot of striped bass generated from ASAP model results.

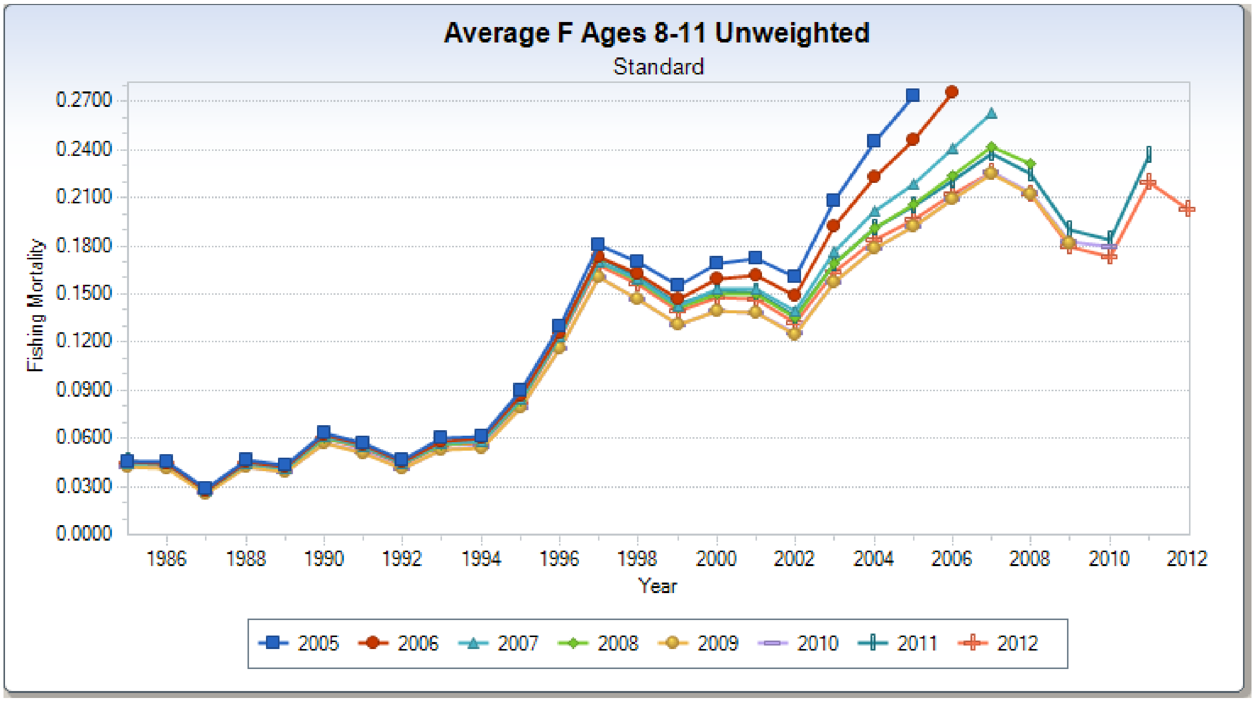


Figure B8.8. Retrospective pattern in striped bass fishing mortality from ASAP model results.

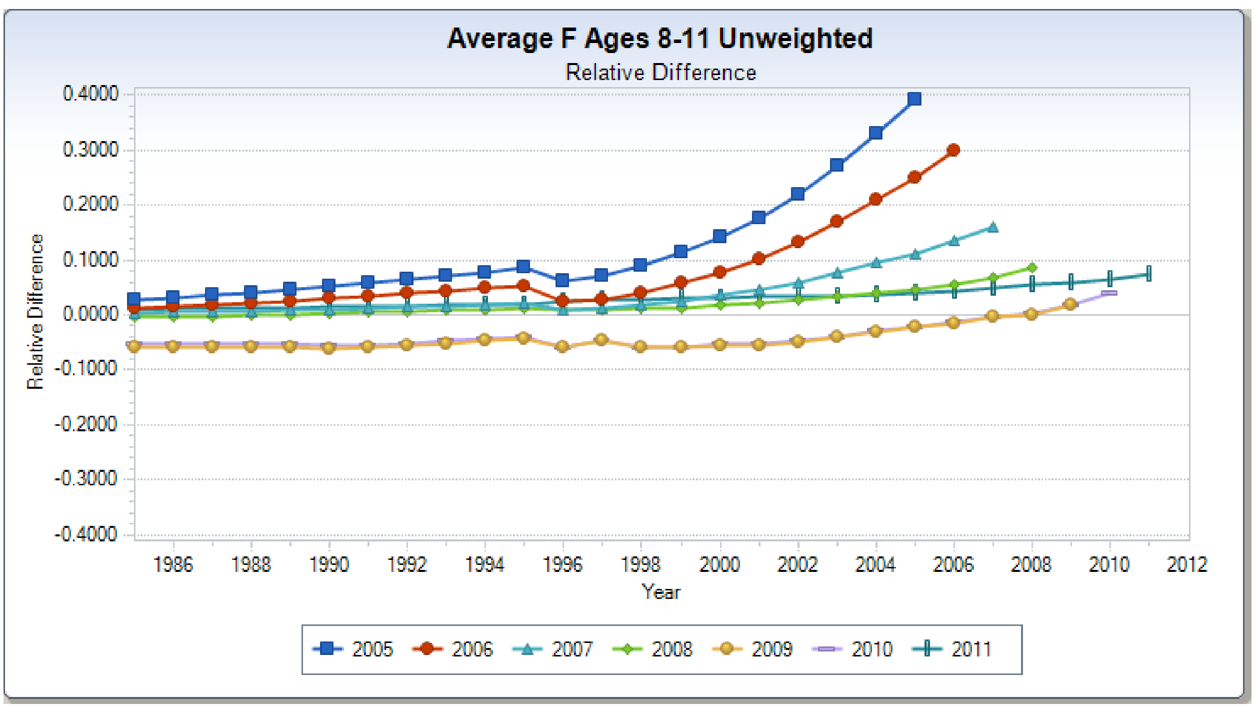


Figure B8.9. Retrospective relative differences in striped bass fishing mortality from ASAP model results.

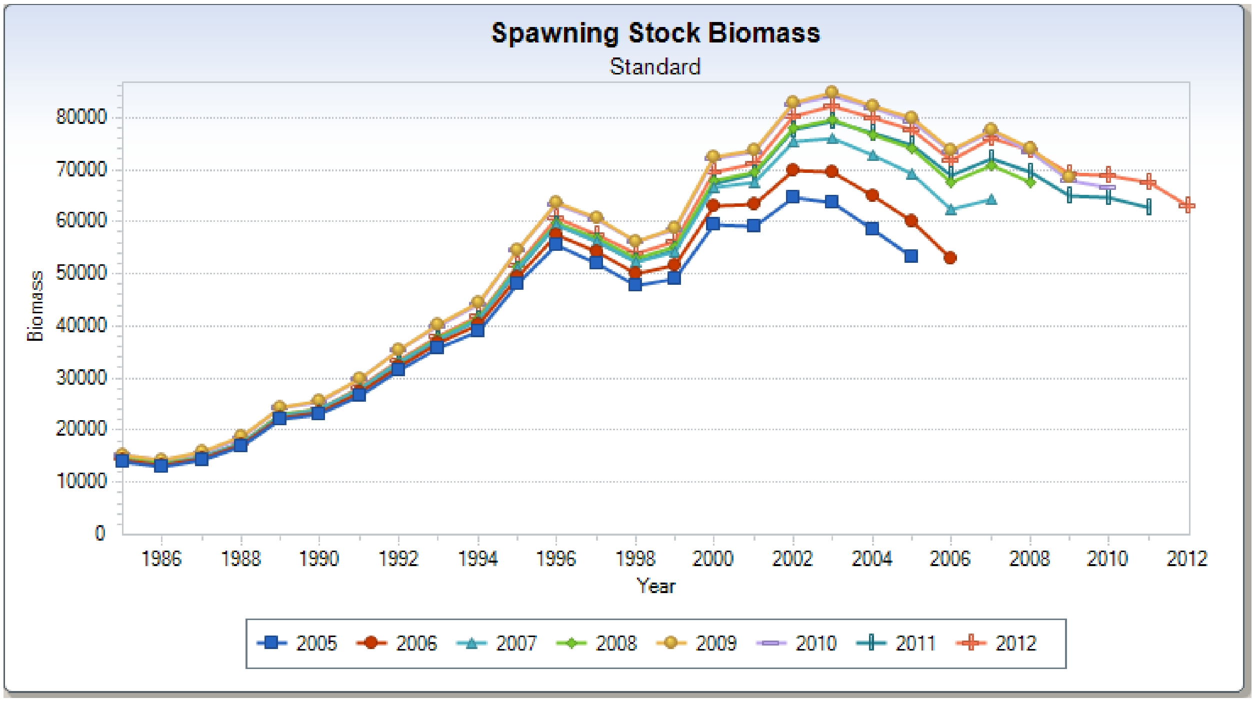


Figure B8.10. Retrospective pattern in striped bass female spawning stock biomass from ASAP model results.

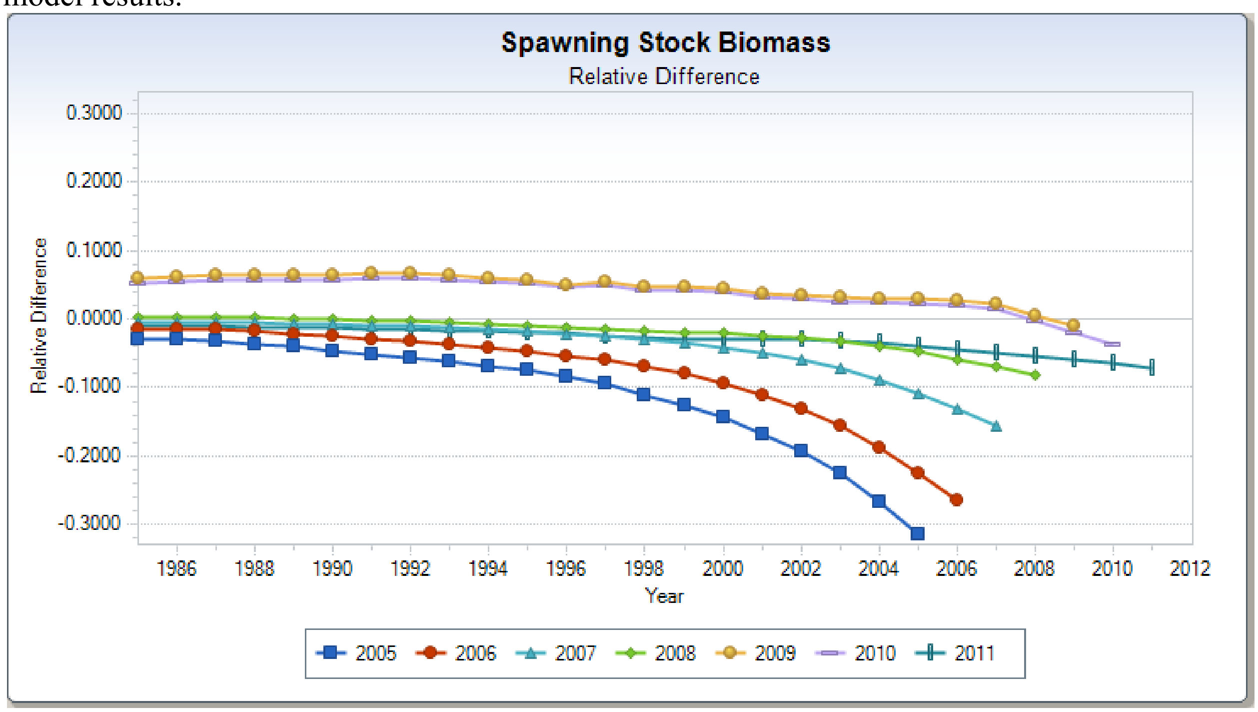


Figure B8.11. Retrospective relative difference pattern in striped bass female spawning stock biomass from ASAP model results.

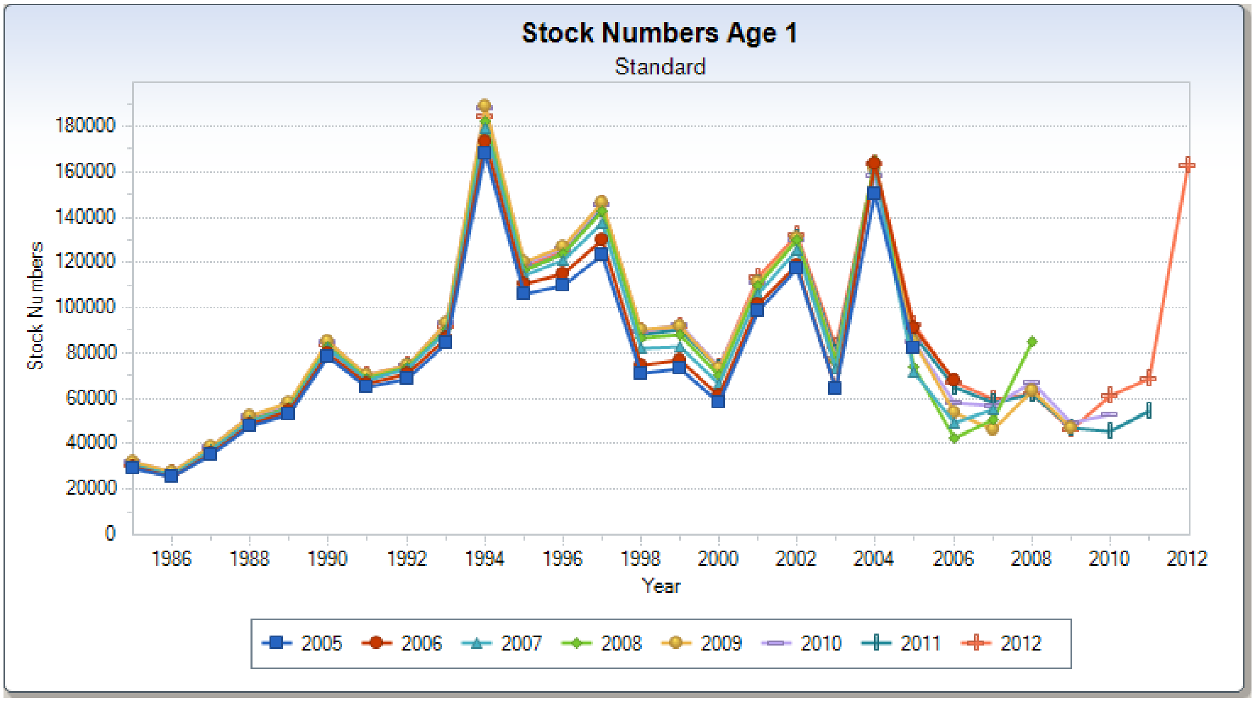


Figure B8.12. Retrospective pattern in striped bass age 1 recruitment from ASAP model results.

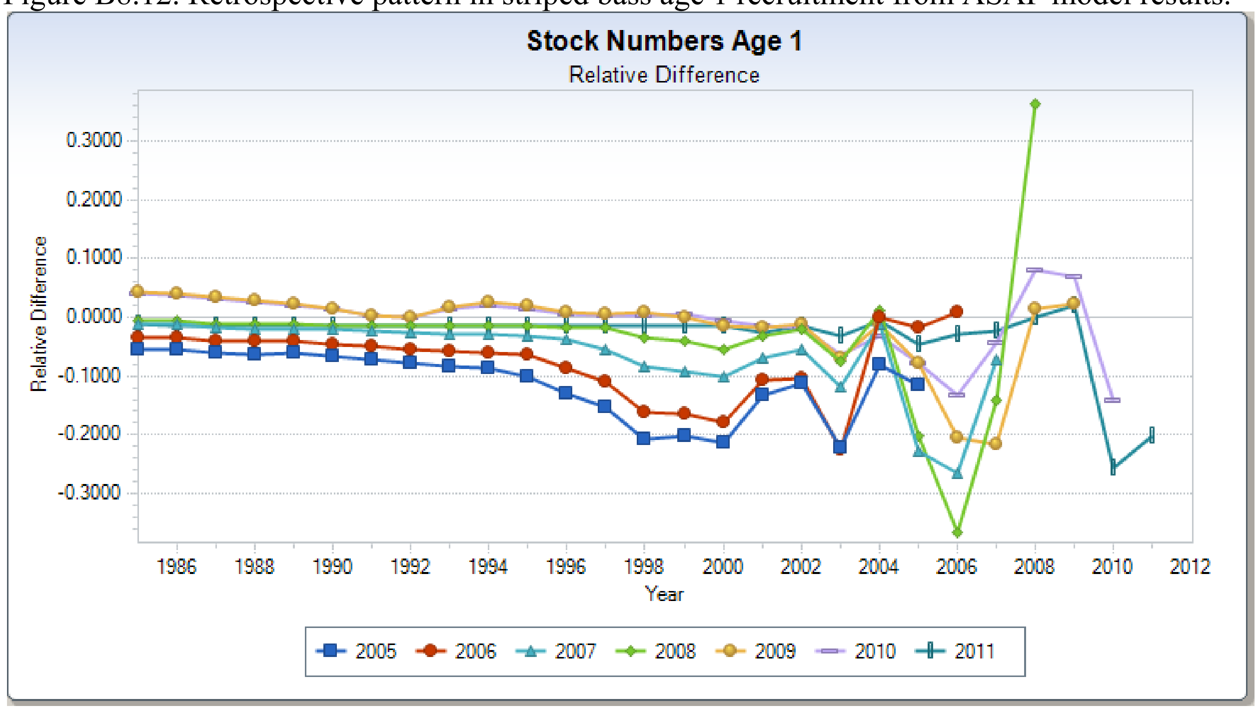


Figure B8.13. Retrospective relative difference pattern in striped bass age 1 recruitment from ASAP model results.

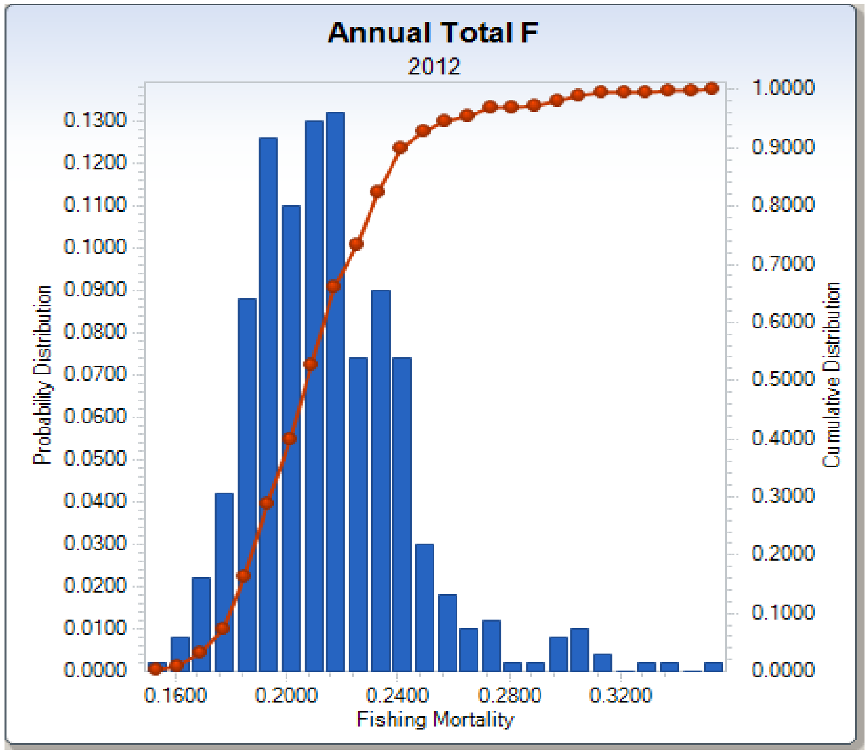


Figure B8.14. MCMC results of total 2012 striped bass fishing mortality from ASAP model results.

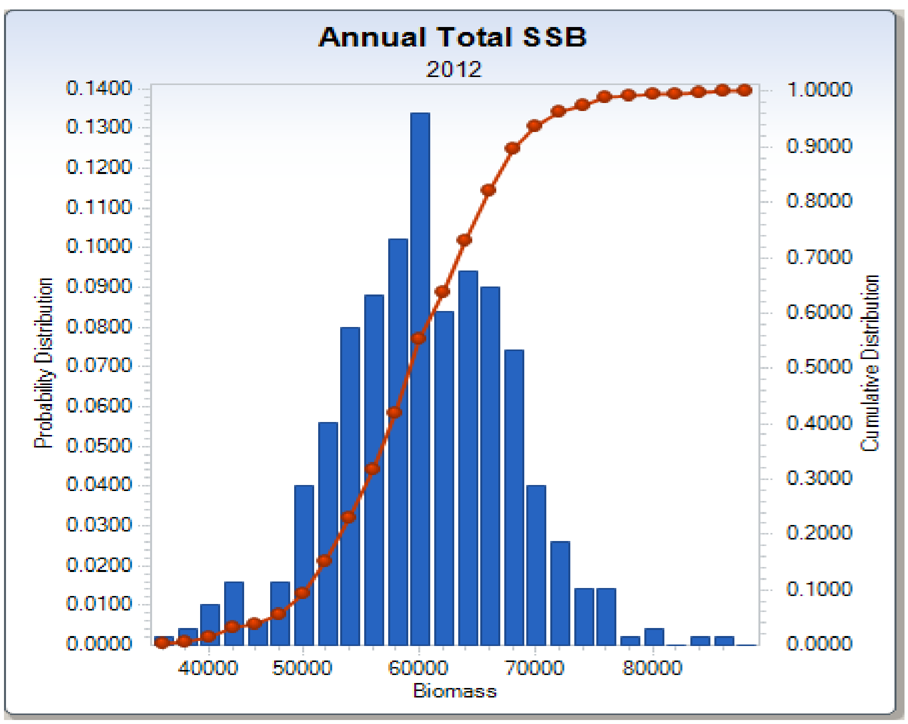


Figure B8.15. MCMC results of total 2012 striped bass female spawning biomass from ASAP model results.

Appendix B9. Estimation of Reporting Rate for Tagging Model, Input Tagging Matrices by Tagging Program, and ADMB Code for IRCR Model

B9.1 Recommendations for striped bass tag reporting rate obtained from a high reward tagging study conducted in 2007 and 2008

Tag reporting rate (λ) is an important parameter in stock assessment tagging models. In the 2011 striped bass stock assessment update, tag reporting rate estimates were used to calculate annual catch rates, live release bias, exploitation rates and survival estimates. A high reward tagging study was conducted in 2007 and 2008 to determine if the tag reporting rate had changed from the previous estimate of 0.43, obtained in 2000. The state agencies of Delaware, Maryland, New York, and Virginia combined to release 5,937 standard tags and 1,244 high reward tags, for this study. Recaptures from this study have resulted in the return of 492 standard tags and 129 high reward tags across all regions. Based on the results of this study, the tagging sub-committee agreed to three main conclusions regarding striped bass tag reporting rate. (1) Tag reporting rate differed greatly depending on which fishery sector recaptured the fish ($\lambda = 0.11$ for commercial fishers, $\lambda = 0.85$ for recreational fishers, $\lambda = 0.55$ unidentified fishers). (2) Tag reporting rate was not homogeneous throughout the striped bass stock. Regional differences in tag reporting rate were determined by the split of harvest among fishery sectors (i.e., the local ratio of commercial to recreational fishing effort drove the regional reporting rate). (3) Tag reporting rates were conditionally independent of fish size given a fishery sector. The tagging sub-committee has agreed to implement a new approach to estimating tag reporting rate. Harvest and catch and release estimates of tag reporting rate will be obtained using fishery sector specific reporting rates and tag return data for the New York producer program, the pooled data of the Delaware, Maryland and Virginia producer programs, and the pooled data of all the coastal programs. A three year moving average will be used to calculated year specific reporting rates. The adoption of this approach will provide tag reporting rates that more closely reflect the regional differences in the striped bass fishery composition

B9.1.1 Introduction

In recent assessments of the striped bass fishery, doubt was raised over the validity of low fishing mortality (*F*) estimates produced by the tagging models. The low *F* estimates obtained could reflect reality, or more likely given the recent static management of the fishery, reflect an artifact created by the tag reporting rate (λ) declining or natural mortality rate (*M*) increasing. Researchers at VIMS and MDDNR have undertaken a study to investigate the effects of the bacterial disease mycobacteriosis on the natural mortality rate of striped bass. Results from this work, as well as the work of several other researchers (Jiang et al. 2007; Gauthier et al. 2008) conclude that *M* has increased in Chesapeake Bay striped bass coincident with the onset of mycobacteriosis. These findings, while significant by themselves, do not rule out the possibility that λ has also changed in the decade since it was last estimated to be 0.43 (Kahn and Shirey 2000).

High reward tagging studies are a commonly accepted method of determining tag reporting rate in both wildlife and fisheries management (Henny and Burnham (1976); Conroy and Blandin (1984); Pollock et al. (1991); Pollock et al. (2001, 2002)). Several studies have used high reward tagging programs in the past to determine tag reporting rates for striped bass resulting in estimates of 0.43 for the coastal fishery (Kahn and Shirey 2000), as well as 0.75 and 0.64 for the Chesapeake Bay (Rugolo and Lange 1993; Hornick et al. 2000 respectively) A high reward tagging study was organized by the striped bass tagging sub-committee, funded by NOAA Chesapeake Bay Office, and conducted in 2007 and 2008 by the State agencies of Delaware, Maryland, New York and Virginia to determine if λ had changed.

The initial analysis of the data was completed during the summer of 2009 and did not result in a consensus agreement on a new value of λ. Details of the initial data analysis are described in the 2009 striped bass stock assessment; Appendix D (ASMFC 2009) and in the 2011 striped bass stock assessment; Appendix G (ASMFC 2011). This appendix discusses the results of the 2007 -2008 high reward tagging study and the current recommendations for estimating tag reporting rate.

B9.1.2 Methods

Representatives from Delaware, Maryland, New York, and Virginia tagged and released fish in the spring of 2007 and 2008. These fish were tagged with either a standard Fish and Wildlife Service tag or a high reward tag. Fishers who captured a tag were able to report the tag to the Fish and Wildlife Service and received a hat or t-shirt for reporting a standard tag or $125 for reporting a high reward tag. Prior to the release of tagged striped bass, participating regions undertook extensive advertising campaigns at boat ramps, tackle shops, and angling clubs in order to increase awareness of the high reward tagging study in the general angling public. In addition, information about the study was circulated to all licensed commercial fisherman that would be pursuing striped bass. Any fish released less than 457mm total length was removed from the data set. This was done to ensure that the tagged population was composed of legal sized striped bass and thus representative of the group for which a tag reporting rate estimate was desired. Virginia released fish in close proximity to cooperative commercial fisherman who regularly recapture tagged fish and were believed to report tags at a rate exceeding that of the general commercial fishing sector. Thus, any fish released by Virginia that was recapture within the first week at liberty was removed from the data set. Prior to analysis, chi-square tests of independence were conducted on the raw tag recovery rates between years and between tag types to determine if data pooling was appropriate.

Estimating fishery sector specific tag reporting rates

Two methods were used to estimate fishery sector specific rates. The ratio of ratios method estimated fishery sector specific tag reporting rates using equation 1 (see below) and subsets of the data determined by which fishery sector, recreational or commercial, returned the tag. The multi-component model estimated fishery sector specific tag reporting rates as intermediate steps in the overall tag reporting rate estimation procedure (see below).

Ratio of ratios model

This method was proposed for estimating tag reporting rate in the current high reward tagging study. Estimates were obtained by comparing the rate of return of standard tags and high reward tags (equation 1) under the assumption that 100% of high reward tags encountered were returned (Henny and Burnham 1976; Pollock et al. 2002). This is essentially a ratio of ratios method, and has the form

$$\lambda_{hat} = (R_{std} / N_{std}) / (R_{high} / N_{high}) , \quad (1)$$

where λ_{hat} is the estimated tag reporting rate for standard tags, Rstd is the number of standard reward tags returned, N_{std} is the number of fish marked with standard reward tags, R_{high} is the number of high-reward tags returned and N_{high} is the number of fish tagged with high-reward tags. This method failed to produce credible results as discussed in ASMFC 2009 and ASMFC 2011 and is not discussed further in this appendix.

Multi-component model

The multi-component fishery tagging model proposed by Paulik (1961), Kimura (1976), and Hearn et al. (1999) and described in Pollock et al. 2002 was used. This approach allowed tag reporting rate estimates to be obtained under the more reasonable assumption that 100% of high reward tags encountered by recreational anglers were returned. This approach was further generalized to allow recreational anglers to return less than 100% of high reward tags encountered. The multi-component method produced fishing sector specific tag reporting rates as intermediate steps in the overall reporting rate estimation and can also provide regional tag reporting rate estimates through appropriate data subsetting. The multi-component approach required landings data to be used as a weighting factor. The weights used were the percentage of total landings attributed to the commercial and recreational fisheries obtained using 2007 and 2008 commercial landings data from striped bass compliance reports and MRFSS recreational landings estimates for the same time period (Table 1). Only the landings data from Delaware/Pennsylvania, Maryland, New York and Virginia were used. Information on recreational catch and release numbers was not used in calculating recreational landings as similar discard information is not readily available for the commercial fishery. The steps in calculating the multi-component lambda estimates are described below.

1). Recreational reporting rate for standard tags is calculated using equation 2

$$\lambda_{rechat} = (R_{std} / N_{std}) / ((R_{high} / N_{high}) / X), \quad (2)$$

where λ_{rechat} is the estimated recreational tag reporting rate, R_{std} is the number of standard-reward tags returned by recreational anglers, N_{std} is the number of fish marked with standard reward tags, R_{high} is the number of high-reward tags returned by recreational anglers, N_{high} is the number of fish tagged with high-reward tags and X is the assumed percentage of high reward tags returned by recreational anglers.

2). Let Y equal the ratio of the % of total landings do to recreational fishers divided by the % of total landings do to commercial fishers. Then the commercial sector tag reporting rate is calculated using equation 3.

$$\lambda_{comhat} = \lambda_{rechat} * (C_{std} / R_{std}) * Y, \quad (3)$$

Where λ_{comhat} is the calculated standard tag reporting rate for commercial fishers, λ_{rechat} is the estimated recreational standard tag reporting rate (equation 2), C_{std} is the number of standard-reward tags returned by commercial fishers, R_{std} is the number of standard-reward tags returned by recreational fishers and Y is as described above.

3). The number of standard tags that should have been recovered in the recreational sector is calculated as

$$R_{true} = R_{std} / \lambda_{rechat} . \quad (4)$$

4). The number of standard tags that should have been recovered in the commercial sector is calculated as

$$C_{true} = C_{std} / \lambda_{comhat} . \quad (5)$$

5). The sum of equation R_{true} and C_{true} is the total number of standard tags that should have been reported. The sum of R_{std} and C_{std} is the total number of standard tags that were actually reported. Thus, the overall standard reporting rate is the number of standard tags that were actually reported divided by the number of standard tags that should have been reported.

To explore sensitivity of the method to failure of the assumption of 100% recreational high reward tag return rate, rates of 100%, 95%, 90%, 85% and 80% were used in the analysis (*X* in equation 1). Fishery sector specific rates were calculated by state of release and with all states combined. To calculate harvest and recreational tag reporting rate, λ_{rechat} was used to estimate the tag reporting rate for recreational fishers, λ_{comhat} was used to estimate the tag reporting rate for commercial fishers and the overall standard reporting rate, calculated in step 5, was used to estimate the tag reporting rate of fishers whose sector was unknown.

Harvest and catch and release tag reporting rate calculation

Data preparation

Tag returns were separated into 457mm and 711mm groups. For each group, annual recaptures were tabulated by fishing sector (recreational, commercial or unknown) and disposition (catch and release or harvested). Recaptures made by researchers were not included when tabulating the data (Fish and Wildlife Service code R). Fish and Wildlife Service recapture code (C) was classified as commercial, (S and H) were classified as recreational and everything else was classified as unknown.

Tag reporting rate calculation

The instantaneous rates tagging model used in the striped bass assessment allows for the use of separate harvest and catch and release tag reporting rates for each year tagging data. For years up to and including 1999, 0.43 was used as the harvest and catch and release (CR) tag reporting rate. This value was estimated in a previous high reward tagging study and had historically been used as the harvest and CR rate in striped bass assessments. Harvest and CR tag reporting rates for the years 2000 - present were calculated as follows. First, an annual total observed tag return value was calculated as the sum of tag returns from the commercial, recreational and unknown fishing sectors accumulated throughout the year. Second, annual expected tag recaptures for each fishing sector were obtained by dividing the annual observed tag returns of each fishing sector by the corresponding annual fishery sector specific tag reporting rate. Third, the total annual expected tag recaptures was calculated by summing the annual expected tag recaptures for each fishing sector.

The annual fishery sector specific tag reporting rates for the years 2000 – present were calculated as follows. Linear interpolation was used to calculate the commercial, recreational and unknown tag reporting rates for the years 2000 to 2006. Linear interpolation was accomplished by assuming the fishery sector specific rates are 0.43 for all sectors in 1999 and 0.11, 0.85 and 0.55 for commercial, recreational and unknown sectors in 2007. A slope was then estimated for each fishery sector and year specific values were predicted. The estimates of 0.11, 0.85 and 0.55 were used as the commercial, recreational and unknown sector specific tag reporting rates for the years 2007 – present.

Year specific tag reporting rates and three year self-weighting moving average tag reporting rates were calculated. The three year moving average (average) rates were calculated to smooth the time series of year-specific tag reporting rate estimates. The average rates were calculated using tag return data from the target year as well as data from one year before and one year after to calculate the target year tag reporting rate. For the year at the beginning of the time series, for which there is no year before, the average rate was calculated using data from the target year and the year after. Likewise, for the year at the end of the time series, the average rate was calculated using the data from the target year and one year before. The average rates are self-weighted because they were calculated using pooled raw data rather than simply averaging three year specific estimates of tag reporting rate. Thus, years with more data contributed more to the average. Once the data from the appropriate years was pooled, the method for calculating the average harvest or catch and release tag reporting rate was identical to the year specific method described above.

B9.1.3 Results

Release recapture data is tabulated by state with release and recapture numbers summed over both years of release and all years of recapture (Table 2). The total number of tags released differs by state, but the percentage of tags released by each state that were high reward was fairly constant, ranging between 16 and 19%.

Chi-square tests of independence

Chi-square tests indicated that the return rate of standard tags was significantly different between 2007 and 2008 ($p = 0.019$). The return rate of standard tags released in 2008 (0.128) was significantly greater than the return rate of standard tags released in 2007 (0.107). Separate tests of the high reward tags and the pooled high reward and standard tags did not show significant differences between the annual return rates for these two groups ($p = 0.40$ and $p = 0.092$ respectively).

Chi-square tests indicated that the return rate of standard tags was significantly different among regions of release ($p < 0.001$). The return rates for standard tags were 0.14, 0.09, 0.16, and 0.07 for Delaware, Maryland, New York, and Virginia respectively. The return rates of high reward tags were 0.21, 0.14, 0.15, and 0.12 for Delaware, Maryland, New York, and Virginia respectively. Chi-square tests indicate that the high reward tag return rates were marginally significantly different ($p = 0.041$). This result was likely do to the relatively high return rate for Delaware. The return rates for the pooled standard and high reward tags differed significantly by region of release ($p < 0.001$). Tests indicate that return rates of tags were not independent of region and should not be pooled across this factor. Pooling across years appeared to be acceptable.

Fishery sector specific tag reporting rates

Tag reporting rates, for the recreational and commercial fishery as well as an overall rate where all tags were combined, were estimated using the multi-component model. Sensitivity to the failure of the 100% recreational high reward tag-return rate assumption was explored and a consensus was reached to use 90% as the high reward tag return rate assumption for recreational anglers. Using the total data from table 2, the multi-component model estimated an overall standard tag reporting rate of 0.55, a recreational standard tag reporting rate of 0.85 and a commercial standard tag reporting rate of 0.11. Regional analysis of the data was done and the assumption of 90% high reward tag return rate for recreational anglers was used for this analysis as well. Standard tag reporting rate estimates for recreational anglers were fairly consistent among Delaware (0.83), Maryland (0.70), and Virginia (0.75), with New York standing out with an estimate of 102% standard tag reporting rate for recreational anglers (Table 3). Standard tag reporting rate by the commercial fishery was consistently low with an estimated 2% reported in Delaware, 11% reported in Maryland, 34% reported in New York, and 28% reported in Virginia (Table 3). Overall standard tag reporting rate varied widely by region, with estimated reporting rates of 26% in Delaware, 39% in Maryland, 91% in New York, and 62% in Virginia (Table 3).

Harvest and catch and release tag reporting rates

Linear interpolation of fishery sector specific rates between 1999, where all rates are fixed at 0.43 and 2007 where the rates are fixed at 0.55, 0.85 and 0.11 for other, recreationally, and commercially caught tags respectively, are presented in Table 4. Year specific and average estimates of tag reporting rate were obtained for harvested and catch and release fish for each state that participated in the high reward tagging study (Table 5 and Figure 1). Average rates, for all individual States, were much less volatile than the year specific rates. Data sets from Delaware, Maryland and Virginia were combined to bolster sample size especially for commercial returns (Table 6). Tag reporting rate trends for New York suggested that they would be better served estimating their own tag reporting rate. Estimates for the coastal programs (Massachusetts, North Carolina, New Jersey and New York) have yet to be obtained using this method; however, preliminary results obtained using coastal program tag return data from 2007 and 2008 shows that a single harvest and catch and release tag reporting rate can be used for all coastal tagging programs (Table 7). Estimates obtained from the preliminary study of 0.72 for catch and release and 0.51 for harvested fish will be used as the tag reporting rates in then Instantaneous rates model for the years 2007 and beyond. For years prior to and including 1999, the coastal programs will use 0.43 as the tag reporting rate for both harvest and catch and release. For the years 2000 – 2006 the coastal program will use values calculated using linear interpolation between 0.43 and the harvest and catch and release values for 2007 presented above (Table 6).

B9.1.4 Discussion

The analysis of the high reward tagging study data revealed four important findings. (1) The assumption of 100% reporting of high reward tags was clearly violated as evidenced by preliminary estimates of standard tag reporting rate exceeding 100% for New York, (2) Estimates of standard tag reporting rate varied widely when the data from the four producer programs were analyzed separately (3) Estimates of harvest and catch and release tag reporting rate were similar among the four coastal area tagging programs and (4) Regardless of location (producer or coastal tagging program), the tag reporting rates of standard reward tags were dramatically different for the commercial and recreational fishing sectors.

Annual variability in harvest and catch and release tag reporting rate estimates resulted from a combination of sampling error and real differences in the annual fishery composition. Tag returns for most of the programs have been historically low and have continued to decline in recent years. This has likely only served to inflate the magnitude of the sampling error. Use of a three year moving average was implemented to smooth the estimated time series of tag reporting rates in order to better capture the temporal trends in fishery composition and tag reporting rate. It was originally determined that each producer area program would generate a separate time series of harvest and catch and release tag reporting rates and a single time series would be used for the coastal program. A single time series of rates was used for the coastal program because preliminary analysis produced very similar results for the individual coastal tagging programs of Massachusetts, New Jersey/ Delaware, New York, and North Carolina. Individual producer area program results were noisy, due primarily to low sample sizes tied to a severe lack of tagging study cooperation from the commercial fishing sector. Data from Virginia, Maryland and Delaware were pooled to boost sample size because these three regions all have significant exposure to commercial fisheries and the time series trends of their individual tag reporting rates showed similar patterns. New York used reporting rates generated from their tagging data and the coastal programs used the single reporting rate time series generated with their data.

There are two main sources of error in the estimation of tag reporting rates as outlined above. First, the fishery sector specific estimates of tag reporting rate may be incorrect. The estimates obtained are dependent on the assumptions of recreational high reward tag reporting rate as well as the weighting scheme used to estimate commercial recoveries, both of which could be incorrectly specified. This represents a significant source of error especially surrounding the commercial tag reporting rate since it is so low. Second, extrapolation of estimates of tag reporting rate through time can introduce two other potential sources of error. Behavior of the fishery sectors to tagging studies may change and the composition of the fishery may change. The method described above allows for the latter source of uncertainty, changes in the composition of the fishery, to be accounted for during extrapolation. Changes in behavior of the fishery sectors cannot be accounted for and would require the use of periodic high reward tagging studies to re-estimate the fishery sector specific tag reporting rates.

The extremely low tag reporting rate of commercial fishing sector represents a significant source of error in this analysis. Tag reporting rates are known to have asymmetric errors, such that even small errors in our ability to estimate the commercial tag reporting rate are propagated into large errors in the harvest and catch and release tag reporting rate estimation. The accuracy of this approach to estimating tag reporting rate would benefit greatly from increased commercial cooperation with tagging studies. The entirety of the tagging assessment methodology would benefit from exploring ways to either increase commercial cooperation with the tagging programs or pursue methods by which estimates of fishing mortality rates could be obtained in the absence of tagging data from the commercial fishery.

B9.1.5 Acknowledgments

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B9.1.6 Literature cited

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Table 1. Recreational and commercial landings of striped bass, in number of fish. Recreational data was obtained from MFRSS including wave 1 estimates and commercial data was obtained from state annual compliance reports.

	Recreational Landings				Commercial Landings			
Year	DE	MD	NY	VA	DE	MD	NY	VA
2007	10,096	679,024	370,722	366,964	30,717	598,495	78,287	140,602
2008	16,994	442,280	448,271	396,950	31,866	594,655	73,263	134,603

Table 2. Numbers of releases and recaptures of standard and high reward tags included in the high reward tagging data analysis. Tag numbers for DE represent releases of animals by both Delaware and Pennsylvania.

	Standard tags			High reward tags		
		Recaptures			Recaptures	
State	Releases	Commercial	Recreational	Releases	Commercial	Recreational
DE	734	4	72	141	1	15
MD	742	8	50	173	3	15
NY	1991	12	196	448	4	39
VA	2470	18	132	482	21	31
Total	5937	42	450	1244	29	100

Table 3. Estimated fishery specific tag reporting rates for the commercial, recreational and unknown fishing sectors. Combined estimate was obtained by pooling raw tag return data from the four States.

Data set	Commercial	Recreational	Unknown
Delaware	0.02	0.83	0.26
Maryland	0.11	0.70	0.39
New York	0.34	1.02	0.91
Virginia	0.28	0.75	0.62
Combined	0.11	0.85	0.55

Table 4. Annual fishery specific tag reporting rates calculated using linear interpolation. For each fishery sector a slope was calculated using the values for 1999 and 2007. All values were rounded to the nearest 1/100th of a percent.

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007
Comm.	0.43	0.39	0.35	0.31	0.27	0.23	0.19	0.15	0.11
Rec.	0.43	0.48	0.54	0.59	0.64	0.69	0.75	0.80	0.85
Other	0.43	0.45	0.46	0.48	0.49	0.51	0.52	0.54	0.55

Table 5. Year specific and three year moving average estimates of tag reporting rate calculated for the four producer area programs. Estimates are displayed based on disposition (harvest or catch and release) of the fish at time of recapture. Tag reporting rate for all producer programs and both recapture dispositions is fixed at 0.43 for all years prior to 2000.

		Harvest											
State	Lambda type *	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Delaware /	yr.	0.42	0.42	0.43	0.44	0.34	0.38	0.31	0.19	0.34	0.22	0.36	0.85
Pennsylvania	3 yr avg.	0.42	0.43	0.43	0.39	0.38	0.34	0.27	0.26	0.23	0.29	0.30	0.46
Maryland	yr.	0.45	0.49	0.51	0.48	0.46	0.46	0.39	0.36	0.45	0.43	0.44	0.53
	3 yr avg.	0.47	0.48	0.49	0.48	0.47	0.43	0.41	0.39	0.41	0.44	0.47	0.49
New York	yr.	0.47	0.50	0.54	0.59	0.56	0.56	0.66	0.63	0.51	0.57	0.63	0.67
	3 yr avg.	0.49	0.50	0.54	0.56	0.57	0.59	0.61	0.59	0.56	0.56	0.62	0.65
Virginia	yr.	0.48	0.54	0.59	0.64	0.66	0.64	0.74	0.68	0.64	0.53	0.74	0.59
	3 yr avg.	0.51	0.53	0.58	0.64	0.65	0.68	0.69	0.68	0.62	0.62	0.61	0.68

		Catch and Release											
State	Lambda type *	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Delaware /	yr.	0.46	0.51	0.59	0.50	0.35	0.61	0.80	0.26	0.19	0.85	0.24	0.11
Pennsylvania	3 yr avg.	0.48	0.50	0.52	0.47	0.51	0.57	0.55	0.33	0.35	0.31	0.32	0.21
Maryland	yr.	0.47	0.49	0.56	0.62	0.49	0.57	0.61	0.85	0.85	0.54	0.38	0.66
	3 yr avg.	0.48	0.50	0.55	0.56	0.56	0.55	0.64	0.72	0.74	0.50	0.50	0.49
New York	yr.	0.48	0.52	0.56	0.63	0.67	0.65	0.73	0.59	0.74	0.78	0.85	0.73
	3 yr avg.	0.50	0.52	0.58	0.62	0.65	0.68	0.66	0.69	0.69	0.78	0.79	0.80
Virginia	yr.	0.47	0.51	0.56	0.64	0.55	0.75	0.80	0.52	0.46	0.63	0.60	0.40
	3 yr avg.	0.49	0.50	0.56	0.58	0.62	0.67	0.63	0.57	0.53	0.56	0.57	0.53

* yr. - year specific tag reporting rate
3 yr avg. - three year moving average

Table 6. Estimated tag reporting rates for the combined data of the Delaware / Pennsylvania, Maryland and Virginia producer programs, the New York producer program, and the combined coastal tag programs. Year specific and three year moving average estimates are displayed based on disposition (harvest or catch and release) of the fish at time of recapture. Tag reporting rate for all programs and both recapture dispositions is fixed at 0.43 for all years prior to 2000.

		Harvest											
State	Lambda type *	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
DE/MD/VA	yr.	0.46	0.50	0.53	0.52	0.52	0.51	0.46	0.51	0.51	0.46	0.53	0.61
	3 yr avg.	0.48	0.49	0.52	0.52	0.52	0.50	0.49	0.49	0.49	0.49	0.52	0.56
New York	yr.	0.47	0.50	0.54	0.59	0.56	0.56	0.66	0.63	0.51	0.57	0.63	0.67
	3 yr avg.	0.49	0.50	0.54	0.56	0.57	0.59	0.61	0.59	0.56	0.56	0.62	0.65
Coastal	yr.	0.44	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.51	0.51	0.51	0.51

		Catch and Release											
State	Lambda type *	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
DE/MD/VA	yr.	0.47	0.50	0.55	0.62	0.51	0.65	0.70	0.58	0.53	0.59	0.42	0.47
	3 yr avg.	0.48	0.50	0.55	0.56	0.59	0.61	0.64	0.61	0.57	0.50	0.48	0.44
New York	yr.	0.48	0.52	0.56	0.63	0.67	0.65	0.73	0.59	0.74	0.78	0.85	0.73
	3 yr avg.	0.50	0.52	0.58	0.62	0.65	0.68	0.66	0.69	0.69	0.78	0.79	0.80
Coastal	yr.	0.47	0.50	0.54	0.57	0.61	0.65	0.68	0.72	0.72	0.72	0.72	0.72

* yr. - year specific tag reporting rate
3 yr avg. - three year moving average

Table 7. Summary of coastal tagging program tag return data from 2007 and 2008 and results of tag reporting rate analysis for harvested and catch and release fish. Adj. Comm and Adj. Rec values were obtained by dividing Comm. Recaps and Rec. recaps by the fishery specific tag reporting rate estimates of 0.11 and 0.85 respectively. Reporting rates are calculated as Obs. Recaps divided by Adj. Recaps.

Catch and Release

	MA	NY	NJ/DE	NC	Total
Comm. Recap	1	0	1	3	5
Rec. recap	26	9	65	75	175
Obs. recaps	27	9	66	78	180
Adj. Comm	9	0	9	27	45
Adj. Rec	31	11	76	88	206
Adj. recaps	40	11	85	115	251
Reporting rate	0.68	0.82	0.78	0.68	0.72

Harvest

	MA	NY	NJ/DE	NC	Total
Comm. Recap	16	4	19	26	65
Rec. recap	91	24	190	217	522
Obs. recaps	107	28	209	243	587
Adj. Comm	145	36	173	236	590
Adj. Rec	107	28	224	255	614
Adj. recaps	252	64	397	491	1204
Reporting rate	0.42	0.44	0.53	0.49	0.51

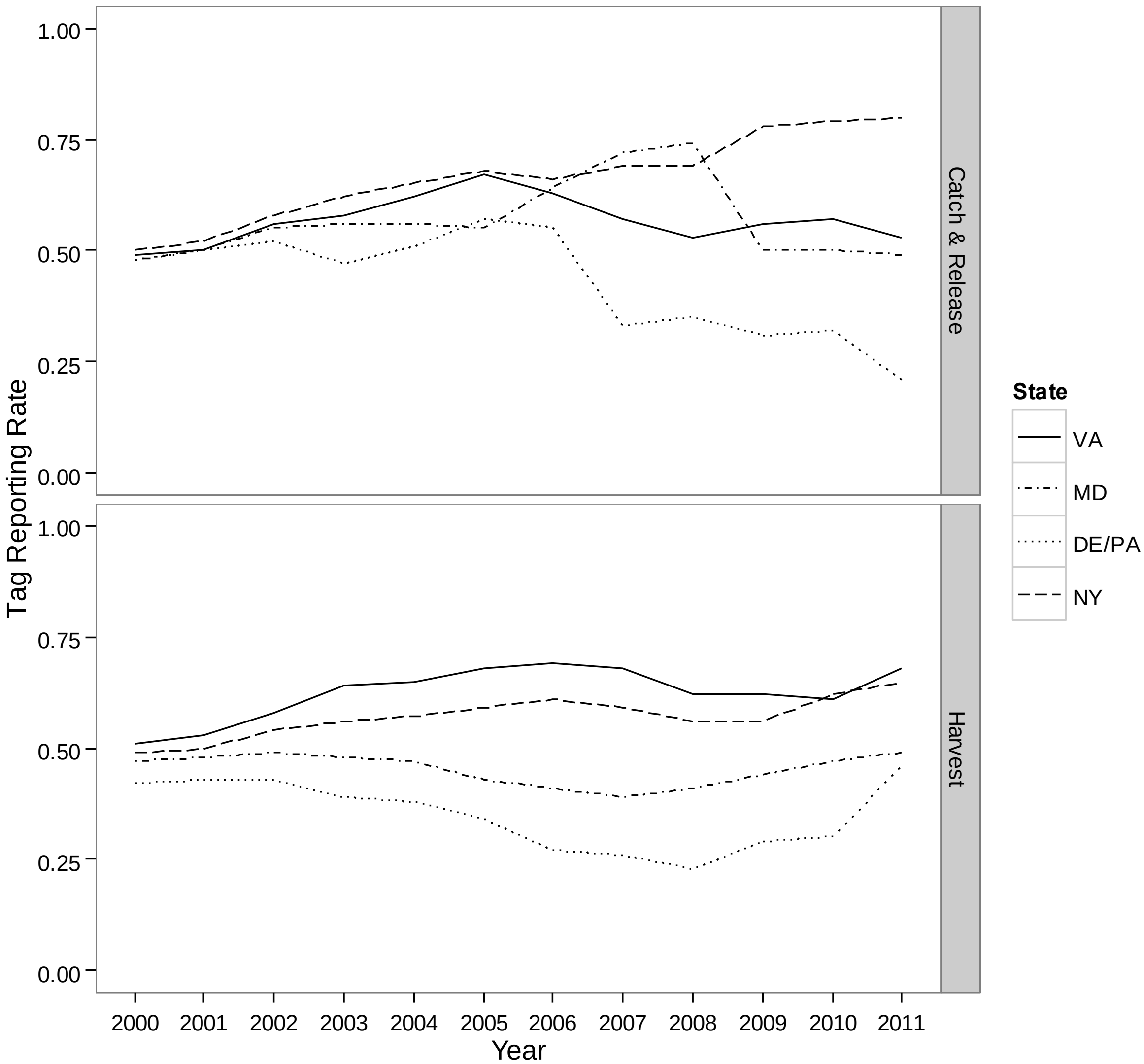

Figure 1. Three year moving average estimates of striped bass tag reporting rate for the four producer programs. Results are presented for harvested and catch and release fish. Tag reporting rate for all regions and both recapture dispositions is fixed at 0.43 for all years prior to 2000.

B9.2 Input Matrices for Tagging Model

Coastal Programs

MADFW - ≥ 28”

Release		Harvested recaptures																			
Number	Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
329	1992	4	9	9	10	8	4	1	2	3	1	1									
651	1993		12	20	13	21	20	12	9	3	1	3	2	1							
461	1994			6	14	26	17	13	7	2	2	2	1		1			1			
218	1995				3	9	8	4	2	2	1		2			1		1			
271	1996					8	8	13	6	8	1	2	2		2						
118	1997						8	4	2	3	1	1		1		1	1				
219	1998							6	14	5	4	4	4								
59	1999								2	3	1	2							1		2
163	2000									9	3	5	3	3		1	1		1		1
411	2001										12	18	10	9	9	3		1	2	1	2
352	2002											10	12	11	6	4	3	2	1		
172	2003												8	3	5	4			5		
613	2004													24	18	9	9	6	5		4
541	2005														15	20	9	13	3	2	4
509	2006															19	9	13	11	11	1
322	2007																7	15	10	1	4
480	2008																	15	19	13	7
385	2009																		17	9	17
457	2010																			14	17
308	2011																				10

Release		Released (Event 1 only)																			
Number	Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
329	1992	12	13	5	3				1												
651	1993		15	16	12	5	1	3	2	1											
461	1994			13	6	5	4	4			1										
218	1995				11	4	1	1	2	2											
271	1996					12	5	3	2	2	1										
118	1997						7	4	1			1									
219	1998							8	6	3	2		1		1						
59	1999								2	1											
163	2000									1	2	3		1							
411	2001										6	5	6	2	1	1		3			
352	2002											14	2	3	3	3	1				
172	2003												1	1	1	2					
613	2004													6	7	4	3	1	1		1
541	2005														8	5	2	1			
509	2006															11	4	1	3		
322	2007																3	4		1	
480	2008																	6	5	3	1
385	2009																		4	3	7
457	2010																			7	3
308	2011																				6

NYOHS/TRL - ≥ 28”

Release		Harvested recaptures																							
Number	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
214	1988	2	3	4	7	2	3	2		2			2												
342	1989		2	9	10	8	10	4	3	1	2	1			2										
246	1990			5	7	5	3	3		1	1	2													
281	1991				15	9	6	3	4	1	4	2	1	1											
287	1992					13	11	6	13	3	3	4	1		1			1							
236	1993						13	8	11	4	5		1												
254	1994							8	11	17	15	5	4	1	3	1	1								
353	1995								31	26	17	14	6	5	1	1	4	1							
110	1996									6	4	7	5	1				1	1						
70	1997										10	4	4		1	1	1		2						
82	1998											6	4	3			1								
85	1999												12	4	3			4							
56	2000													3	5	2	3	1							
93	2001														4	5	7	3	1						
176	2002															17	8	3		3		3	3		1
146	2003																10	4	6	1		1	2		1
154	2004																	8	2	2	1	2	1		1
64	2005																		7	2	1	4	1		
57	2006																			3	5	5			1
25	2007																							1	
144	2008*																					4	7	8	3
26	2009*																							1	1
38	2010*																							2	2
142	2011*																								6

Release		Released (Event 1 only)																							
Number	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
214	1988	21	10	9	2	2	3	1	1																
342	1989		30	17	14	5	3	3																	
246	1990			16	9	4	3																		
281	1991				17	10	4	2	1	1	2	1													
287	1992					25	10	8	4	2		2													
236	1993						14	3	3	2															
254	1994							17	6	3	5	1	1			1									
353	1995								23	10	6		1					2							
110	1996									8		6					1						1		
70	1997										3					1									
82	1998														1	1									
85	1999												2	1	1		1								
56	2000													4	1		1	1							
93	2001														4	1	1	2							
176	2002															13	1	2							
146	2003																4	1					1		
154	2004																	8	2	1					
64	2005																		2						
57	2006																			2					
25	2007																				3				
144	2008*																					4	4	3	
26	2009*																						2		
38	2010*																								1
142	2011*																								2

* NY OHS 1988-2007, NY TRL 2008-2011

NJDB - $\geq$ 28”

Release		Harvested recaptures																						
Number	Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
38	1989		2	4		1	1																	
9	1990			1																				
15	1991			1					1	1														
76	1992					1		1																
91	1993					3	1	2	2	3		1												
308	1994						5	9	10	11	9	4	3	2	1	1								
552	1995							22	30	18	16	10	5	3	3	4	2	1	2	1	1			
589	1996								47	18	30	12	6	5	3	3	6	2		1			2	
68	1997									7	2	1	1		3									
126	1998										19	5	5	2		4	1	1						
101	1999											3	3	5	1		1	3	1					
233	2000												13	15	8	9	6	4		1	1		1	1
522	2001													33	26	21	14	6	5	1	4		1	
359	2002														16	12	11	9	2	3	2		3	
564	2003															34	13	19	5	7	4	4	1	1
847	2004																52	30	17	17	15	11	4	3
180	2005																	12	5	7	3	4	5	
225	2006																		13	7	9	6	2	1
434	2007																			23	22	11	11	6
518	2008																				30	27	18	12
337	2009																					33	10	9
339	2010																						18	13
525	2011																							27

Release		Released (Event 1 only)																						
Number	Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
38	1989	4	1	5	2					1														
9	1990		2					1																
15	1991			2		1				1														
76	1992				7	5	5			1														
91	1993					5	3	3							1									
308	1994						24	16	9	6	2	1	1			1								
552	1995							34	23	18	13	4	1	3			1							
589	1996								36	17	17	2	6	1	2	2	2						1	
68	1997									5														
126	1998										2	5	3	1				1						
101	1999											6	3	2	4	2								
233	2000												10	5	4	4	1	1						
522	2001													20	13	4	3	3	1	1				
359	2002														12	13	6	2		1			1	
564	2003															26	17	10	4	1	3	1		
847	2004																50	19	5	2	3		1	
180	2005																	12	6	5		1	3	1
225	2006																		12	5	4	1		1
434	2007																			16	7	11	3	3
518	2008																				18	7	9	3
337	2009																					10	6	3
339	2010																						8	10
525	2011																							20

NCCOOP - ≥ 28”

Release		Harvested recaptures																							
Number	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
191	1988	4	3	4		6	3	2			1														
411	1989		6	7	7	11	4	2	2	1	1			1											
322	1990			11	6	11	5	1	2	2	2	2	1												
856	1991				23	19	23	20	16	5	11	7	1	1	1	1									
433	1992					22	11	7	10	7	6	7	5	2											1
142	1993						6	3	5	3	2	1			1										
480	1994							14	16	7	6	5	6	1	3	1	2	2							
372	1995								21	13	16	11	5	2	2	5	1	1	2			1			
557	1996									26	17	12	3	3	3	4		3	1	1					
869	1997										67	31	16	9	11		3	3	1		1		1		
106	1998											9	7		2	1	1					1			
179	1999												18	5	5	2		2	2	1	1		2		
164	2000													4	6	1	2	3	2	1					
515	2001														32	18	11	3	9	6	1				
789	2002															39	31	20	13	7	3	1			1
1,578	2003																75	53	29	16	12	7	6	4	3
784	2004																	40	18	15	11	5	3	2	4
557	2005																		17	16	9	5	4	1	1
2,113	2006																			107	80	46	25	22	11
305	2007																				24	20	9	3	6
923	2008																					73	39	27	15
121	2009																						2	3	1
411	2010																							12	9
103	2011																								9

Release		Released (Event 1 only)																							
Number	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
191	1988		8	5	2	3	1	3					1												
411	1989		17	13	11	3	3	1							1										
322	1990			14	11	5	3	1																	
856	1991				45	18	23	14	2	2	1	1													
433	1992					23	17	7	4	1	2	3		1											
142	1993						8	2			1														
480	1994							26	8	1	4	1													
372	1995								22	2	1	3		1											
557	1996									8	3	3	2	2	1										
869	1997										18	13	9	5	1			1				2			
106	1998											3	4							1					
179	1999												3	3				1				1			
164	2000													4		1	1								
515	2001														11	3	4	1	2	2		2			
789	2002															12	11	1	5	3	1	1			
1,578	2003																27	12	8	9	3			1	1
784	2004																	17	8	10	5	1	1	1	
557	2005																		8	5	1	2	1		
2,113	2006																			44	23	11	6	5	1
305	2007																				7	2	2		
923	2008																					23	11	4	5
121	2009																						2		
411	2010																							3	
103	2011																								5

Producer Area Programs

HUDSON - ≥ 28”

Release		Harvested recaptures																							
Number	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
277	1988	11	9	7	9	6	3	2	1	4		1													
387	1989		9	13	9	4	5	7	4					1			1								
445	1990			17	14	11	8	4	4	1	3	1													
364	1991				14	14	8	5	9	5	2	1					1		1	1					
699	1992					34	27	16	11	11	10	7	3	2	1			1							
536	1993						33	16	10	16	10	5	5		1				1						
381	1994							17	24	21	8	6	4	4	4	2		2							
461	1995								27	23	20	18	10	1	1	1	1	1	1						
681	1996									63	43	27	12	2	7	2	3	3	1	1					
184	1997										22	7	8	5	3	2	1		1	1					
530	1998											47	29	13	7	13	5		1	2		1			
503	1999												43	13	21	9	12	4	2	3	1	3	1		1
485	2000													27	17	13	8	8	6	3	3			1	
576	2001														32	23	12	6	5	8	1	3			
196	2002															16	8	7	2	5	3	1	2		
677	2003																39	35	25	10	11	3	1		4
649	2004																	55	25	24	14	5	2	4	1
574	2005																		40	29	16	8	4	7	
707	2006																			44	30	28	9	7	8
399	2007																				26	20	10	5	6
540	2008																					33	26	19	8
396	2009																						31	25	13
458	2010																							37	19
242	2011																								22

Release		Released (Event 1 only)																							
Number	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
277	1988	14	21	11	2	4	2	2			1					1									
387	1989		33	16	7	5	1	2																	
445	1990			45	16	16	4	4							1										
364	1991				23	17	5	4			3			1											
699	1992					54	30	18	10	2	3	3	2												
536	1993						42	20	13	4	5	2	2												
381	1994							26	8	5	2		2	1											
461	1995								23	11	10	3	1	3		1									
681	1996									26	24	6	6	1	2	2		1	2		1				
184	1997										7	4	4	1			1								
530	1998											19	16	4	2	7	1								
503	1999												20	9	6	3	2	3	1	1					
485	2000													18	6	9	10	5							
576	2001														16	16	2	1	1	2	1		1		
196	2002															4	3	2	2	2	1	1	1	1	
677	2003																25	9	10	7	2		1		
649	2004																	19	9	10	4	2		1	2
574	2005																		19	15	5	6			
707	2006																			17	10	7	4		1
399	2007																				9	7	5	2	2
540	2008																					16	8	3	2
396	2009																						13	11	4
458	2010																							12	10
242	2011																								5

DE/PA - ≥ 28”

Release		Harvested recaptures																		
Number	Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
52	1993	3	6	1	4	3	2		1											
81	1994		4	6	4	1	2	1												
173	1995			11	7	2	6	2	4	1										
110	1996				14	3	5	2	2	2	1	1	1					1		
107	1997					14	5	4		4								1		
206	1998						26	7	5	2	4	3	1	1	1		2			
107	1999							8	10	2	2	3	1				1			
148	2000								20	10	2	3		3		1				
220	2001									28	10	9	6	5	3		2	3	1	1
139	2002										14	4	2	3	1	2		1		
286	2003											20	13	10	6	2		3	2	4
168	2004												16	7	5	3		1	2	4
110	2005													7	7	1	1	2	1	1
180	2006														16	7	3	2	2	4
125	2007															8	4	1	1	
140	2008																6	5	2	1
127	2009																	12	6	10
147	2010																		14	7
185	2011																			9

Release		Released (Event 1 only)																		
Number	Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
52	1993	2	2																	
81	1994		3	4	2															
173	1995			8	5	5		1												
110	1996				4	3	3		2											
107	1997					2	1	1												
206	1998						6	2	1	1	1									
107	1999							2	2											
148	2000								4	2	2	1		1						
220	2001									3	4									
139	2002											8		2						
286	2003											13	8	3		2			1	
168	2004												3	2	1	1				
110	2005													5	2	1				
180	2006														4	1	1			
125	2007															3			1	
140	2008																1	2	1	
127	2009																	3		
147	2010																		7	6
185	2011																			5

MDCB - ≥ 28”

Release		Harvested recaptures																								
Number	Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
29	1987						2	1				1														
129	1988		2	1	3	7	2		1	1																
220	1989			3	7	3	3	2	1	5	2															
305	1990				10	8	5	3	1	3		3	1													
395	1991					19	10	13	3	7	3	4	1		2											
436	1992						21	15	11	14	4	8	6	3	2	1										
627	1993							31	25	30	13	14	7	8	1	3	2									
548	1994								25	27	20	16	10	8	4	2			1							
529	1995									45	24	19	12	4	5	2	2	3			2		1			
862	1996										61	35	36	14	6	7	2	1	1							
335	1997											33	19	15	1	2	1	1								
242	1998												23	13	2	3	2			1		1				
177	1999													16	5	6	2	1	2	1		1	1			
248	2000														18	12		4	4	1		2	1		2	
469	2001															21	10	10	5	2	3		1		1	
324	2002																13	18	5	6		3		1		
324	2003																	14	9	8	6	2	3			
367	2004																		13	7	9	2	3	1	1	2
334	2005																			16	11	6	4	2	1	1
235	2006																				14	4	4	4	3	
154	2007																					6	4	3	2	1
128	2008																						6	3	3	3
255	2009																							18	7	1
198	2010																								8	
285	2011																									17

Release		Released (Event 1 only)																								
Number	Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
29	1987			2		1																				
129	1988		4	7	4	7	3	1	2																	
220	1989			6	10	14	3	2	2																	
305	1990				13	8	7	2	1	1			1													
395	1991					26	13	7	2	2		1														
436	1992						23	15	8	2	3	2		2												
627	1993							29	18	11	2	2	1	1												
548	1994								27	15	4		5	2		1		1		1						
529	1995									18	7	6	3	3	1											
862	1996										36	19	7	3	2											
335	1997											8	7	2	1					1						
242	1998												7	3	1	2										
177	1999													3	3	2	1									
248	2000														3	4	4	1								
469	2001															10	9	1	1	1						
324	2002																5	2	1	1	2					
324	2003																	8	2	1	2	2				
367	2004																		4	2	2	1	1		1	1
334	2005																			5	4	1		1		
235	2006																				3	2	2			1
154	2007																					2	1			
128	2008																						1		1	
255	2009																							3	4	1
198	2010																								3	3
285	2011																									3

VARAP - ≥ 28”

Release		Harvested recaptures																					
Number	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
301	1990	10	1	6	1	3	5	1			1	1			1								
390	1991		19	10	12	9	2	1	2		2				1								
40	1992			2	1	1	1				1												
212	1993				11	11	5	2	3														
123	1994					4	4	4	1														
210	1995						18	6	5	2	1	1	2		1								
67	1996								3	1			1										
212	1997								11	12	6	2		1	1	1							
158	1998									16	9	1	3	1									
162	1999										13	2	1	2	1							1	
365	2000											13	11	6	5	3	3		1				
269	2001												9	8	2	6	1						
122	2002													7	3	5	1		1	1			
400	2003														23	13	3	1	2	2	1	2	
686	2004															21	8	8	3	3	1	1	
284	2005																12	7	5	1	3		
175	2006																	10	3	3	2	1	4
840	2007																		33	22	11	2	4
75	2008																			5	1		
241	2009																				5	3	
483	2010																					11	5
190	2011																						7

Release		Released (Event 1 only)																					
Number	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
301	1990	15	8	8			1			1													
390	1991		20	13	4	2	1																
40	1992			2	1	1																	
212	1993				10	7	1		1			1											
123	1994					4	1			1													
210	1995						7	2	3	1		1											
67	1996							1															
212	1997								2	1	2	1											
158	1998									6	4			1									
162	1999										3	3		1									
365	2000											9	7	4	2								
269	2001												7	4	2		1		1				
122	2002													2	2				1				
400	2003														8	8	3						
686	2004															16	2	5	1		1		
284	2005																4	4	1			1	
175	2006																	2	1	1	1		
840	2007																		12	7	1	1	
75	2008																						
241	2009																				1	1	
483	2010																					5	1
190	2011																						1

Coastal Programs – 18” fish

MADFW - ≥ 18”

Release		Harvested recaptures																			
Number	Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
388	1992	5	11	9	10	10	4	2	2	4	1	2									
897	1993		14	22	13	26	22	14	11	4	4	3	2	1							
675	1994			9	15	27	23	16	8	3	2	3	2		2			1			
376	1995				4	10	14	7	4	3	2		4	1		1		1			
443	1996					9	10	14	7	13	2	4	4	1	2						
202	1997						9	4	3	3	1	1		2		1	1				
315	1998							10	14	5	5	4	5	2		1					
87	1999								2	3	2	2		1					1		2
251	2000									9	5	8	3	3		1	2		1		2
598	2001										12	24	13	11	14	5		1	2	2	3
456	2002											15	13	12	8	4	5	2	2	1	
239	2003												8	3	5	7	1		5		
652	2004													24	18	9	9	6	5		4
610	2005														16	20	10	15	3	2	5
574	2006															19	9	13	12	11	2
389	2007																7	15	14	3	4
530	2008																	15	19	13	9
457	2009																		17	10	21
500	2010																			14	18
326	2011																				11

Release		Released (Event 1 only)																			
Number	Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
388	1992	15	14	5	3				1												
897	1993		21	24	18	9	2	4	2	1			1								
675	1994			24	10	15	4	5			1										
376	1995				17	13	2	1	2	3	1										
443	1996					24	12	9	5	2	2										
202	1997						13	6	2	1		2									
315	1998							11	8	4	2	1	2	1	1						
87	1999								2	1											
251	2000									2	3	4		1		1					
598	2001										10	6	8	3	1	2		3			
456	2002											15	3	4	5	4	2				
239	2003												3	2	1	2			1		
652	2004													6	8	4	3	1	1		1
610	2005														11	5	3	1			
574	2006															12	5	1	3		
389	2007																4	8	2	2	1
530	2008																	7	7	3	1
457	2009																		6	3	7
500	2010																			9	3
326	2011																				7

NYOHS/TRL - ≥ 18”

Release		Harvested recaptures																							
Number	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1,623	1988	3	4	12	18	7	13	8	9	6	2	3	4	1		1	1								
1,611	1989		7	19	17	10	25	12	10	4	6	3	2	2	2			1							
808	1990			7	14	6	5	4	2	4	3	3	1												
987	1991				22	11	16	8	11	9	10	6	2	2	2	1	1	1		1					
1,000	1992					15	14	9	19	8	9	11	4	1	1			3		1					
1,250	1993						18	10	15	8	12	4	7	3	1	1	1		1						
1,657	1994							13	19	34	32	21	22	6	7	2	2	2	1	1					
1,506	1995								32	37	31	26	13	9	2	7	6	4				1			
659	1996									9	9	17	12	1		2		3	1						
1,084	1997										17	11	12	3	4	3	3	3	2						1
1,100	1998											10	15	8	5	4	4	1	3	2					
1,049	1999												24	16	23	15	5	9	2	2					
1,003	2000													9	14	6	16	5	4	2	1	3		2	
1,203	2001														20	22	22	11	6	8	4	1	3	1	1
971	2002															24	16	10	3	7	1	6	3	1	1
758	2003																16	7	14	9	1	1	3		2
664	2004																	9	5	3	5	2	3	2	2
1,152	2005																		16	7	10	9	5	3	4
686	2006																			7	12	16	10	2	4
871	2007																				4	4	7	5	7
1,340	2008																					14	20	26	15
268	2009																						5	6	4
119	2010																							3	3
364	2011																								10

Release		Released (Event 1 only)																							
Number	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1,623	1988	101	53	42	18	16	11	5	2																
1,611	1989		148	89	53	19	17	10	4	1		1	2							1					
808	1990			55	21	9	7	3		1															
987	1991				50	31	21	11	3	5	6	2	1												
1,000	1992					63	26	16	10	3	2	2													
1,250	1993						52	20	11	10	2		1	1	1										
1,657	1994							101	31	22	18	2	5			1	1								
1,506	1995								67	42	28	8	5		2	2	1	2							
659	1996									37	11	11	1	2		1	1						1		
1,084	1997										64	16	8	5	2	1									
1,100	1998											54	17	4	4	3	2								
1,049	1999												40	13	14	2	1	1	1						
1,003	2000													42	15	12	4	2							
1,203	2001														50	20	10	4	1	1					
971	2002															53	10	7	2	1					
758	2003																30	13	7	2			1	1	
664	2004																	29	12	8	1				
1,152	2005																		60	15	11		1		
686	2006																			43	12	2	1		1
871	2007																				45	13	3	3	
1,340	2008																					55	31	10	
268	2009																						19	3	
119	2010																							6	2
364	2011																								13

* NY OHS 1988-2007, NY TRL 2008-2011

NJDB - ≥ 18”

Release		Harvested recaptures																						
Number	Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
483	1989	4	7	11	1	7	4	4	1		3	3	1	1										
110	1990		2	1		1	2								1									
297	1991			2	2		3	2	5	1	1			1								1		
765	1992				8	10	2	7	8	4	5	3	2		2									
1,680	1993					11	8	33	32	23	15	10	7	4	1	1	2	1	1	1				
2,287	1994						21	45	69	51	45	24	20	6	8	6	1	4	2	1		1		
1,819	1995							38	63	59	40	30	13	10	8	7	4	3	3	3	2		1	1
1,941	1996								64	55	59	34	24	22	10	7	11	2	1	1	1		2	1
405	1997									11	6	4	2	3	5	1			3					
811	1998										37	17	29	22	9	7	4	5	1	1				
1,796	1999											34	56	47	29	23	17	20	10	4	2		1	
2,397	2000												65	89	52	60	34	19	9	10	5	2	4	3
2,305	2001													80	65	64	30	30	14	5	6	2	1	1
1,828	2002														40	40	42	24	14	8	8	3	3	3
2,190	2003															61	58	52	19	21	16	9	4	3
1,856	2004																83	54	39	28	27	17	7	3
1,162	2005																	38	25	25	13	11	10	1
1,466	2006																		33	38	37	28	14	12
1,090	2007																			47	40	23	26	15
1,407	2008																				48	50	46	32
2,239	2009																					57	62	51
1,195	2010																						33	27
756	2011																							29

Release		Released (Event 1 only)																						
Number	Year	1988	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
483	1989	47	34	22	9	5	5	1	2	2														
110	1990		16	1	3	2	1	1																
297	1991			20	8	6	4	1	1	1	1													
765	1992				56	33	22	6		2	1	1	1		1									
1,680	1993					112	60	34	32	16	7	6	1		1	1				1				
2,287	1994						153	93	92	35	20	7	6	2	3	3								
1,819	1995							128	107	50	41	9	5	8		1	1		2	1				1
1,941	1996								142	83	48	14	15	4	4	2	5		1				1	
405	1997									35	12	9	2	2		3	1	1						
811	1998										63	22	18	8	6	4		3						
1,796	1999											100	56	27	19	8	5	5	3	1				
2,397	2000												149	63	26	16	10	2	2	3	1			
2,305	2001													138	53	30	12	11	1	3	1			1
1,828	2002														70	56	21	11	4	3	1	1	1	1
2,190	2003															129	73	30	15	4	7	1	2	
1,856	2004																122	53	18	6	7	2	3	
1,162	2005																	79	24	13	7	1	4	2
1,466	2006																		83	38	19	6	6	5
1,090	2007																			60	18	19	6	5
1,407	2008																				72	29	18	8
2,239	2009																					140	58	20
1,195	2010																						46	26
756	2011																							29

NCCOOP - ≥ 18”

Release		Harvested recaptures																							
Number	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1,323	1988	12	3	17	35	21	16	9	10	4	3	2							1						
1,153	1989		10	11	10	12	6	2	2	2	4			1											
1,946	1990			44	46	31	24	7	11	8	7	3	6	3	1										
1,779	1991				55	45	40	32	29	14	19	7	3	2	2	1									
1,007	1992					55	36	19	20	11	10	8	7	3											1
527	1993						22	9	9	8	7	5	2		2			1							
4,341	1994							132	101	72	52	45	24	8	6	1	5	2	3	1	3				
639	1995								35	15	23	17	8	3	2	6	1	1	3			1			
661	1996									29	17	13	3	4	3	4		3	1	1					
1,347	1997										86	42	19	11	13			3	3	1		1	1		
460	1998											26	12	6	9	2	5					1			
271	1999												24	8	5	3		2	2	2	1		2		
4,539	2000													146	60	35	17	12	6	4	1	1	1		
2,387	2001														109	57	46	17	16	9	3	1	2		1
3,813	2002															186	109	54	26	16	8	4	3	2	1
1,906	2003																85	57	30	15	13	8	7	4	4
2,468	2004																	119	63	35	19	8	5	2	4
3,960	2005																		91	40	21	7	8	2	1
4,453	2006																			186	120	67	44	33	19
370	2007																				24	22	10	3	6
1,033	2008																					78	42	29	15
146	2009																						3	3	1
566	2010																							16	9
107	2011																								9

Release		Released (Event 1 only)																							
Number	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1,323	1988	3	44	28	15	16	4	4					1	1											
1,153	1989		38	27	19	7	3	3							1										
1,946	1990			83	47	19	19	7	2	3	1				1										
1,779	1991				78	40	40	23	4	5	2	2													
1,007	1992					48	22	14	8	2	3	3		1		1									
527	1993						22	13	8	2	3	1	2												
4,341	1994							184	80	22	15	10	6		1		1	1							
639	1995								27	5	2	5		2											
661	1996									10	5	4	2	2	1										
1,347	1997										34	22	9	6	2			1				2			
460	1998											21	14	2	2		1			1					
271	1999												7	5				1				1			
4,539	2000													133	28	10	6								
2,387	2001														62	24	14	6	2	5	2	2	1		
3,813	2002															85	34	12	6	4	1	3			
1,906	2003																34	14	8	11	3	2		1	1
2,468	2004																	59	23	16	6	2	1	1	
3,960	2005																		37	18	4	5	2		
4,453	2006																			115	50	20	9	6	2
370	2007																				10	2	2		
1,033	2008																					23	11	4	5
146	2009																						2		
566	2010																							4	
107	2011																								5

Producer Programs

HUDSON - ≥ 18”

Release		Harvested recaptures																							
Number	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
826	1988	13	11	12	14	7	6	3	6	5	1	2													
669	1989		10	16	10	4	7	9	4	2				1			1								
783	1990			19	17	11	10	4	6	2	4	1	1		2										
546	1991				14	15	8	7	9	6	3	1		1		1	2		1	1					
1,135	1992					36	31	16	12	18	14	11	6	3	2			1			1				
940	1993						34	22	16	24	13	8	5	3	1	1	2		1						
643	1994							20	25	27	13	9	5	4	4	3	1	2			1				
628	1995								30	25	23	19	11	2	1	1	2	1	1						
1,069	1996									67	47	40	18	2	9	5	3	5	2	1	1				
241	1997										22	7	8	6	3	2	1		1	1					
698	1998											49	35	14	8	14	5	1	1	4	1	1			
798	1999												45	18	25	10	15	6	4	3	1	3	1	1	1
846	2000													32	19	23	13	12	9	5	4			1	
1,069	2001														38	30	15	13	9	9	1	4			1
597	2002															19	11	11	6	6	5	4	4	1	1
1,379	2003																54	56	35	16	15	6	3	3	4
1,273	2004																	65	38	32	18	5	4	5	3
1,325	2005																		46	34	22	9	8	10	
1,130	2006																			46	33	33	14	10	8
755	2007																				29	31	15	7	6
1,236	2008																					42	37	32	10
507	2009																						31	26	13
840	2010																							40	24
337	2011																								24

Release		Released (Event 1 only)																							
Number	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
826	1988	41	49	32	11	11	8	4			4					1									
669	1989		49	30	12	8	3	4	1																
783	1990			71	30	22	11	6						1	1										
546	1991				42	29	7	6	2	1	3			1											
1,135	1992					76	38	27	14	5	6	4	2	1											
940	1993						66	38	20	8	9	4	2												
643	1994							39	16	7	5	1	4	2											
628	1995								30	16	12	4	1	3	1	1									
1,069	1996									53	36	16	10	3	2	2	2	1	3		1				
241	1997										10	6	5	1			1								
698	1998											25	20	4	2	8	2			1					
798	1999												29	17	7	4	2	4	2	1					
846	2000													42	13	12	16	8	2	2			1		
1,069	2001														44	31	10	3	3	2	1		1		
597	2002															26	9	8	2	4	2	1	1	1	
1,379	2003																66	28	19	12	3		1	1	
1,273	2004																	53	25	15	9	2	1	1	2
1,325	2005																		57	30	14	9		1	1
1,130	2006																			36	28	12	7	1	1
755	2007																				22	19	9	2	2
1,236	2008																					48	21	13	4
507	2009																						20	14	5
840	2010																							26	15
337	2011																								10

DE/PA - ≥ 18”

Release		Harvested recaptures																		
Number	Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
265	1993	15	9	5	9	4	3		2	1										
313	1994		15	11	8	7	3	3				1				1				
477	1995			25	13	4	10	3	6	1	1									
313	1996				18	7	7	3	7	2	3	1	2		1			1		
513	1997					29	12	8	5	6	2	2	1	1				1		
716	1998						43	14	11	9	6	7	2	1	1	1	2			
407	1999							18	14	5	5	4	2		1		1			
651	2000								40	22	9	6	3	4		2				
902	2001									56	22	26	10	8	3	2	3	4	1	2
616	2002										36	21	5	7	3	3		1	1	
657	2003											40	20	12	7	3		5	3	3
384	2004												24	8	6	3		1	4	3
326	2005													13	7	2	3	3	1	1
583	2006														27	11	8	4	4	4
393	2007															9	7	1	3	
484	2008																13	8	6	5
375	2009																	17	7	9
447	2010																		18	12
746	2011																			17

Release		Released (Event 1 only)																		
Number	Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
265	1993	14	10	3	3	1	1	2												
313	1994		18	13	8															
477	1995			34	20	10	2	5												
313	1996				19	10	5	1	4			1								
513	1997					27	22	12	2	1										
716	1998						40	8	6	3	2									
407	1999							17	10	4	1	4								
651	2000								33	20	8	8	3	2	1					
902	2001									39	17	12	3	4	1					
616	2002										16	20	4	5						
657	2003											33	14	6		2		1	1	
384	2004												12	5	3	2				
326	2005													28	9	5				
583	2006														33	8	4	3	2	1
393	2007															15	4	2	2	
484	2008																25	12	5	3
375	2009																	23	4	3
447	2010																		27	13
746	2011																			44

MDCB - ≥ 18”

Release		Harvested recaptures																								
Number	Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1,409	1987	1	9		21	21	24	20	8	8	6	3	2	1												
2,240	1988		7	3	30	41	48	25	14	19	7	10	1	1												
2,343	1989			4	53	65	64	34	22	18	11	4	1	2		1										
1,365	1990				35	37	34	16	11	7	4	10	3			1										
1,452	1991					57	56	44	14	22	10	10	5	1	3											
1,615	1992						85	57	40	26	12	11	8	10	2	1										
2,154	1993							98	83	63	39	33	19	15	3	4	2									
1,824	1994								90	94	45	39	28	17	7	2			2						1	
1,353	1995									106	61	40	20	11	8	3	2	5		1	2		1			
1,680	1996										116	69	63	22	10	8	2	1	1							
841	1997											72	42	23	6	2	1	1				1				
919	1998												84	28	10	7	5	1	1	1		1				
592	1999													42	23	10	3	1	2	1		1	1			
931	2000														64	23	11	7	7	2	1	2	1		2	
1,104	2001															55	21	20	8	2	3		1		1	
1,134	2002																55	48	16	7	1	4		2		
791	2003																	43	24	11	9	2	4			1
682	2004																		28	15	10	2	3	1	2	2
876	2005																			40	26	10	5	3	1	1
525	2006																				30	9	5	6	3	
381	2007																					14	8	4	2	2
360	2008																						17	8	4	4
718	2009																							52	11	6
668	2010																								37	11
1,098	2011																									66

Release		Released (Event 1 only)																								
Number	Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1,409	1987	52	34	25	21	21	23	9	2	3		1														
2,240	1988		84	59	56	35	23	18	8	4	1	2														
2,343	1989			74	73	47	33	15	11	5	2	1														
1,365	1990				48	31	28	9	4	2	1		1													
1,452	1991					57	50	20	17	9	1	1			1			1								
1,615	1992						81	39	24	17	8	5		2												
2,154	1993							71	61	31	17	7	4	1												
1,824	1994								87	45	22	8	9	4		2		1		1						
1,353	1995									62	31	11	7	5	1	2										
1,680	1996										83	38	13	3	2											
841	1997											36	17	2	2	1		1		1						
919	1998												45	11	9	2										
592	1999													18	13	4	3									
931	2000														42	8	6	2								
1,104	2001															37	11	3	2	2						
1,134	2002																29	12	5	1	2	1				
791	2003																	20	6	4	3	2				
682	2004																		17	5	3	1	2		1	1
876	2005																			16	6	2		2		
525	2006																				16	5	2			1
381	2007																					8	4		1	
360	2008																						6	1	2	
718	2009																							9	5	2
668	2010																								14	4
1,098	2011																									16

VARAP - ≥ 18”

Release		Harvested recaptures																					
Number	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1,464	1990	21	20	24	10	8	9	2			1	1			1								
2,481	1991		48	38	22	14	3	1	2	1	4				1								
130	1992			7	4	1	3				1												
621	1993				18	17	12	5	4	1													
195	1994					6	7	4	1	2													
698	1995						24	12	9	4	1	1	2		1								
376	1996							3	10	3	2	1	1	1			1						
712	1997								26	17	10	2		1	1	1							
784	1998									28	16	1	3	1									
853	1999										30	7	4	2	2							1	
1,765	2000											44	23	11	7	4	5	1	1				
797	2001												31	14	5	7	1						
315	2002													10	4	6	1	1	1	1			
852	2003														32	20	5	3	3	2	1	2	
1,477	2004															45	14	8	4	3	1	1	
921	2005																27	17	6	1	4	1	
668	2006																	27	4	5	5	3	4
1,961	2007																		63	34	16	3	5
523	2008																			17	4		
867	2009																				26	7	2
2,050	2010																					29	7
416	2011																						13

Release		Released (Event 1 only)																					
Number	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1,464	1990	76	28	18	9	1	1		1	2													
2,481	1991		93	33	24	10	2	1															
130	1992			6	3	3		1		1													
621	1993				26	16	3	1	1	1		1											
195	1994					6	1		3	1													
698	1995						20	7	8	1		1											
376	1996							10	7	3													
712	1997								14	6	4	1											
784	1998									21	7			1	1								
853	1999										22	12	1	2									
1,765	2000											49	23	7	3								
797	2001												20	6	7		1		1				
315	2002													7	3	2			1				
852	2003														12	11	3	1	1				
1,477	2004															25	5	5	1		1		
921	2005																14	8	2	1		1	
668	2006																	19	6	1	1		
1,961	2007																		34	10	1	1	
523	2008																			7	2	2	
867	2009																				16	2	
2,050	2010																					14	2
416	2011																						5

Chesapeake Bay (MD and VA combined) - 18-28” males

Release		Harvested recaptures																								
Number	Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1,308	1987	1	6		18	19	21	17	6	7	4	2	2													
1,852	1988		4	2	23	26	37	23	10	12	6	6														
1,916	1989			1	39	51	57	30	19	9	6	3		1												
1,171	1990				22	28	26	11	10	4	3	6	2													
1,089	1991					34	43	29	9	10	4	5	3		1											
1,149	1992						62	41	26	9	5	2		2												
1,628	1993							66	54	34	18	15	10	2												
1,255	1994								58	63	19	16	15	8	3											
1,129	1995									61	31	16	7	5	2	1		1								
982	1996										48	31	24	6	4	1										
955	1997											48	25	10	5											
1,274	1998												69	22	6	4	2	1	1							
1,075	1999													39	20	7	1	1								
2,032	2000														75	21	16	5	3	2						
1,120	2001															54	17	10	3							
996	2002																42	26	12	1	1	1				
900	2003																	35	21	5	5	1	1			
1,070	2004																		36	12		1				
1,136	2005																			38	25	4	1	2		
747	2006																				30	5	1	5	1	
1,304	2007																					37	14	6	1	
660	2008																						22	7	1	1
1,018	2009																							53	7	7
1,935	2010																								46	13
997	2011																									53

Release		Released (Event 1 only)																								
Number	Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1,308	1987	49	31	18	18	16	21	8	1			1														
1,852	1988		64	42	37	25	18	11	5	3	1	1														
1,916	1989			53	50	26	24	8	8	5	2	1														
1,171	1990				40	20	17	6	2	1	1															
1,089	1991					38	31	15	12	4																
1,149	1992						57	17	12	13	5	3														
1,628	1993							41	42	18	11	5	4													
1,255	1994								54	27	14	4	3	2		1										
1,129	1995									67	19	9	4	1		2										
982	1996										46	20	5													
955	1997											38	12	1	1											
1,274	1998												48	12	7		1	1								
1,075	1999													29	18	3	3									
2,032	2000														73	17	3	2								
1,120	2001															38	4	7	1	1						
996	2002																30	8	4							
900	2003																	16	6	3	1					
1,070	2004																		22	4	1		1			
1,136	2005																			20	5	2		1		
747	2006																				26	7				
1,304	2007																					27	6		1	
660	2008																						13	2	3	
1,018	2009																							19	1	1
1,935	2010																								20	2
997	2011																									13

B9.3 AD Model Builder code for the instantaneous rates catch/release model (IRCR).

```
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//
// Jiang et. al  Instantaneous rates model for catch and release
// Age-Independent model
//
//
// Gary Nelson, Massachusetts Division of Marine Fisheries
// Version 2.0 6/29/2012
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
DATA_SECTION
// Starting and ending year of the release year
 init_int styrR;
 init_int endyrR;
//Starting and ending year of recovery years
 init_int styr;
 init_int endyr;
 //Total Releases by Year
 init_vector N(styrR,endyrR);
//Recapture Matrix for harvest fish
 init_imatrix rh(styrR,endyrR,styr,endyr);
//Recapture Matrix for releases fish
 init_imatrix rr(styrR,endyrR,styr,endyr);
 //---Reporting Rate for harvested fish----------
 init_vector lh(styr,endyr);
 //---Initial probability of tag shedding and tag-induced mortality for harvested fish--
 init_vector phih(styr,endyr);
 //---Reporting Rate for released fish----------
 init_vector lr(styr,endyr);
 //---Initial probability of tag shedding and tag-induced mortality for released fish--
 init_vector phir(styr,endyr);
 //Hooking Mortality
 init_vector h(styr,endyr);
//Number of Natural Mortality Periods and Beginnng Years
 init_int mp;
 init_ivector mp_int(1,mp);
 int pp;
//Number of Fishing  Mortality Periods and Beginning Years
 init_int fp;
 init_ivector fp_int(1,fp);
 int qq;
//Number of Tag Mortality Periods
 init_int fap;
 init_ivector fap_int(1,fap);
 int ss;
 int tp;
 LOCAL_CALCS
  pp=mp+1;
  qq=fp+1;
  ss=fap+1;
  tp=mp+fp+fap+(4*(endyr-styr+1));
 END_CALCS
 matrix sigma(1,tp,1,tp+1);
 !! set_covariance_matrix(sigma);
 //looping variables
 int y;
 int t;
 int a;
 int d;
 int cnt;
 int total;
 int Ntags;
 int looper;
 int df_r;
```

```
 int df_h;
 int hless;
 int rless;
PARAMETER_SECTION
 number dodo;
 number dodo1;
 number probs;
 number AIC;
 number AICc;
 number K;
 number up_df;
 number up_count;
 number up_chi;
 number up_chat;
 number p_chi;
 number p_df;
 number p_chat;
 //-------------F estimates-------------------------------
 init_bounded_vector e_F(1,fp,-30.,1.6,1);
 vector F(styr,endyr);
 vector fp_yr(1,qq);
 //-------------M estimates-------------------------------
 init_bounded_vector e_M(1,mp,-30,1.6,1);
 vector M(styr,endyr);
 vector mp_yr(1,pp);
 //--------------Tag Mortality----------------------------
 init_bounded_vector e_FA(1,fap,-30.,1.6,1);
 vector FA(styr,endyr);
 vector fap_yr(1,ss);
 //------------------Tag Number of Tags-------------------
 vector tags(styrR,endyrR);
 //----------------Mortality Calculations------------
 matrix s(styrR,endyrR,styr,endyr);
 matrix u_h(styrR,endyrR,styr,endyr);
 matrix u_r(styrR,endyrR,styr,endyr);
 vector S_fish(styr,endyr);
 //---------Predicted Cell recoveries-------------
 vector sum_prob_h(styrR,endyrR);
 vector sum_prob_r(styrR,endyrR);
 matrix s_prob(styrR,endyrR,styr,endyr);
 matrix exp_prob_h(styrR,endyrR,styr,endyr);
 matrix ll_h(styrR,endyrR,styr,endyr);
 matrix exp_prob_r(styrR,endyrR,styr,endyr);
 matrix ll_r(styrR,endyrR,styr,endyr);
 vector ll_ns(styrR,endyrR);
 matrix exp_r_h(styrR,endyrR,styr,endyr);
 matrix exp_r_r(styrR,endyrR,styr,endyr);
 matrix pool_r(styrR,endyrR,styr,endyr);
 matrix pool_h(styrR,endyrR,styr,endyr);
 matrix pool_r_e(styrR,endyrR,styr,endyr);
 matrix pool_h_e(styrR,endyrR,styr,endyr);
 matrix chi_r(styrR,endyrR,styr,endyr);
 matrix chi_h(styrR,endyrR,styr,endyr);
 matrix p_chi_r(styrR,endyrR,styr,endyr);
 matrix p_chi_h(styrR,endyrR,styr,endyr);
 matrix pear_r(styrR,endyrR,styr,endyr);
 matrix pear_h(styrR,endyrR,styr,endyr);
 matrix stdres_r(styrR,endyrR,styr,endyr);
 matrix stdres_h(styrR,endyrR,styr,endyr);
 vector exp_ns(styrR,endyrR);
 vector chi_ns(styrR,endyrR);
 vector pear_ns(styrR,endyrR);
 vector stdres_ns(styrR,endyrR);
 sdreport_vector S(styr,endyr);
 sdreport_vector FM(styr,endyr);
 sdreport_vector FT(styr,endyr);
```

```
 sdreport_vector NM(styr,endyr);
 //----------Likelihood Values-----------------------------------------
 number f_tag;
 objective_function_value f;
INITIALIZATION_SECTION
 e_F -1.6;
 e_FA -1.6;
 e_M -1.6;
RUNTIME_SECTION
 maximum_function_evaluations 100, 500, 5000;
 convergence_criteria 1e-5, 1e-7, 1e-16;
PRELIMINARY_CALCS_SECTION
 F.initialize();
 FA.initialize();
 M.initialize();
PROCEDURE_SECTION
 calc_number_tags();
 calc_M_vector();
 calc_F_vector();
 calc_FA_vector();
 calc_fish_surv();
 calc_s();
 calc_s_prob();
 calc_u_h();
 calc_u_r();
 calc_exp_prob_h();
 calc_exp_prob_r();
 calc_LL();
 calc_Chisquare();
 calc_pooled_cells();
 evaluate_the_objective_function();
FUNCTION calc_number_tags
  cnt=0;
  for (t=styrR;t<=endyrR;t++)
   {
    Ntags=0;
    for (y=styr+cnt;y<=endyr;y++)
      {
       Ntags+=rh(t,y)+rr(t,y);
      }
      tags(t)=Ntags;
      cnt+=1;
   }
FUNCTION calc_M_vector
 for(t=1;t<=mp;t++)
   {
                mp_yr(t)=mp_int(t);

   }
       mp_yr(pp)=endyr+1;

 for(t=styr;t<=endyr;t++)
   {
     for(d=1;d<=mp;d++)
       {

        if(t>=mp_yr(d) && t<mp_yr(d+1))
                     { M(t)=mfexp(e_M(d));
          NM(t)=M(t);
        }
       }
   }

FUNCTION calc_F_vector
 for(t=1;t<=fp;t++)
   {
```

```
                fp_yr(t)=fp_int(t);

  }
      fp_yr(qq)=endyr+1;

 for(t=styr;t<=endyr;t++)
  {
    for(d=1;d<=fp;d++)
     {

       if(t>=fp_yr(d) && t<fp_yr(d+1))
                   { F(t)=mfexp(e_F(d));
         FM(t)=F(t);
        }
     }
  }

FUNCTION calc_FA_vector
  for(t=1;t<=fap;t++)
  {
                fap_yr(t)=fap_int(t);

  }
      fap_yr(ss)=endyr+1;

 for(t=styr;t<=endyr;t++)
  {
    for(d=1;d<=fap;d++)
     {

       if(t>=fap_yr(d) && t<fap_yr(d+1))
                   { FA(t)=mfexp(e_FA(d));
         FT(t)=FA(t);
        }
     }
  }

FUNCTION calc_fish_surv
  for (t=styr;t<=endyr;t++)
  {
    S_fish(t)=mfexp(-1*(F(t)+h(t)*FA(t)+M(t)));
    S(t)=S_fish(t);

  }

FUNCTION calc_s
  cnt=0;
 for (t=styrR;t<=endyrR;t++)
  {
   for (y=styr+cnt;y<=endyr;y++)
     {

      if(t==y){s(t,y)=1;}
      if(t!=y)
       {

        s(t,y)=mfexp(-F(y-1)-FA(y-1)-M(y-1));

       }
     }
     cnt+=1;
  }
FUNCTION calc_u_h
  cnt=0;
 for (t=styrR;t<=endyrR;t++)
  {
```

```
   for (y=styr+cnt;y<=endyr;y++)
     {

      u_h(t,y)=(F(y)/(F(y)+FA(y)+M(y)))*(1-mfexp(-F(y)-FA(y)-M(y)));
     }
     cnt+=1;
  }

FUNCTION calc_u_r
  cnt=0;
 for (t=styrR;t<=endyrR;t++)
  {
   for (y=styr+cnt;y<=endyr;y++)
     {
      u_r(t,y)=(FA(y)/(F(y)+FA(y)+M(y)))*(1-mfexp(-F(y)-FA(y)-M(y)));
     }
     cnt+=1;
  }
FUNCTION calc_s_prob
 cnt=0;
 for (t=styrR;t<=endyrR;t++)
  {
   looper=0;
   for (y=styr+cnt;y<=endyr;y++)
     {
		probs=1;

		for(a=y-looper;a<=y;a++)
         {
          probs=probs*s(t,a);
         }
         s_prob(t,y)=probs;
         looper+=1;
     }
   cnt+=1;
  }
FUNCTION calc_exp_prob_h
  cnt=0;
 for (t=styrR;t<=endyrR;t++)
  {
   dodo=0;
   for (y=styr+cnt;y<=endyr;y++)
     {
       exp_prob_h(t,y)=lh(y)*phih(y)*s_prob(t,y)*u_h(t,y);
		dodo+=exp_prob_h(t,y);
     }
   sum_prob_h(t)=dodo;
   cnt+=1;
  }

FUNCTION calc_exp_prob_r
  cnt=0;
 for (t=styrR;t<=endyrR;t++)
  {
   dodo=0;
   for (y=styr+cnt;y<=endyr;y++)
     {
       exp_prob_r(t,y)=lr(y)*phir(y)*s_prob(t,y)*u_r(t,y);
		dodo+=exp_prob_r(t,y);
     }
   sum_prob_r(t)=dodo;
   cnt+=1;
  }

FUNCTION calc_LL
 cnt=0;
```

```
 for (t=styrR;t<=endyrR;t++)
  {
   for (y=styr+cnt;y<=endyr;y++)
    {
     ll_h(t,y)=0;
     ll_r(t,y)=0;
      if(rh(t,y)!=0)
       {
        ll_h(t,y)=rh(t,y)*log(exp_prob_h(t,y));
       }
      if(rr(t,y)!=0)
      {
        ll_r(t,y)=rr(t,y)*log(exp_prob_r(t,y));
      }
    }
   cnt+=1;
  }
 for (t=styrR;t<=endyrR;t++)
  {
    ll_ns(t)=(N(t)-tags(t))*log(1-(sum_prob_h(t)+sum_prob_r(t)));
  }

FUNCTION evaluate_the_objective_function
 f_tag=0;
 cnt=0;
 for (t=styrR;t<=endyrR;t++)
  {
   for (y=styr+cnt;y<=endyr;y++)
    {
     f_tag+=ll_h(t,y)+ll_r(t,y);
    }
   cnt+=1;
  }

  for (t=styrR;t<=endyrR;t++)
  {
    f_tag+=ll_ns(t);
  }
  f=f_tag*-1.;

FUNCTION calc_Chisquare
  cnt=0;
 up_count=0;
 for (t=styrR;t<=endyrR;t++)
  {
   for (y=styr+cnt;y<=endyr;y++)
    {
     up_count+=1;
    }
    cnt+=1;
  }
 cnt=0;
 for (t=styrR;t<=endyrR;t++)
  {
   for (y=styr+cnt;y<=endyr;y++)
    {
     exp_r_r(t,y)=exp_prob_r(t,y)*N(t);
     exp_r_h(t,y)=exp_prob_h(t,y)*N(t);
    }
   cnt+=1;
  }
  cnt=0;
  for (t=styrR;t<=endyrR;t++)
  {
   for (y=styr+cnt;y<=endyr;y++)
    {
```

```
      chi_r(t,y)=square(rr(t,y)-exp_r_r(t,y))/exp_r_r(t,y);
      chi_h(t,y)=square(rh(t,y)-exp_r_h(t,y))/exp_r_h(t,y);
      pear_r(t,y)=(rr(t,y)-exp_r_r(t,y))/sqrt(exp_r_r(t,y));
      pear_h(t,y)=(rh(t,y)-exp_r_h(t,y))/sqrt(exp_r_h(t,y));
      stdres_h(t,y)=(rh(t,y)-exp_r_h(t,y))/sqrt(exp_r_h(t,y)*(1.-exp_r_h(t,y)/N(t)));
      stdres_r(t,y)=(rr(t,y)-exp_r_r(t,y))/sqrt(exp_r_r(t,y)*(1.-exp_r_r(t,y)/N(t)));
    }
    cnt+=1;
  }
  for (t=styrR;t<=endyrR;t++)
  {
      exp_ns(t)=N(t)*(1-(sum_prob_h(t)+sum_prob_r(t)));
  }

 //Not seen chi
 for (t=styrR;t<=endyrR;t++)
  {
      chi_ns(t)=0;
      chi_ns(t)=square((N(t)-tags(t))-exp_ns(t))/exp_ns(t);
      pear_ns(t)=((N(t)-tags(t))-exp_ns(t))/sqrt(exp_ns(t));
      stdres_ns(t)=((N(t)-tags(t))-exp_ns(t))/sqrt(exp_ns(t)*(1.-exp_ns(t)/N(t)));
  }
 //total chi square
 up_chi=sum(chi_r)+sum(chi_h)+sum(chi_ns);
 K=fap+mp+fp;
 up_df=up_count*2-K;
 up_chat=up_chi/up_df;
 AIC=-1.*2*f_tag+2*K;
 AICc=AIC+(2*K*(K+1))/(sum(N)-K-1);
FUNCTION calc_pooled_cells
// Pool harvested cells
 cnt=0;
 for (t=styrR;t<=endyrR;t++)
  {
      for(y=styr+cnt;y<=endyr;y++)
      {
         pool_h_e(t,y)=0;
         pool_h(t,y)=0;
         pool_h_e(t,y)=exp_r_h(t,y);
         pool_h(t,y)=rh(t,y);

      }
    cnt+=1;
  }
 cnt=0;
 hless=0;
 for(t=styrR;t<=endyrR;t++)
  {
   for(y=endyr;y>=styr+cnt;y--)
      {
        if(pool_h_e(t,y)>=2.)
          {
           pool_h(t,y)=pool_h(t,y);
           pool_h_e(t,y)=pool_h_e(t,y);
          }
        if(pool_h_e(t,y)>=0 && pool_h_e(t,y)<2.)
          { if (y!=styr+cnt)
             {
             hless+=1;
              pool_h_e(t,y-1)=pool_h_e(t,y-1)+pool_h_e(t,y);
              pool_h(t,y-1)=pool_h(t,y-1)+pool_h(t,y);
              pool_h(t,y)=0;
              pool_h_e(t,y)=0;
             }
             if (y==styr+cnt) break;
          }
```

```
      }//for
      cnt+=1;
    }//for

// Pool released cells
 cnt=0;
 for (t=styrR;t<=endyrR;t++)
  {
     for(y=styr+cnt;y<=endyr;y++)
     {
        pool_r_e(t,y)=0;
        pool_r(t,y)=0;
        pool_r_e(t,y)=exp_r_r(t,y);
        pool_r(t,y)=rr(t,y);

     }
    cnt+=1;
  }
 cnt=0;
  rless=0;
  for(t=styrR;t<=endyrR;t++)
  {
   for(y=endyr;y>=styr+cnt;y--)
     {
       if(pool_r_e(t,y)>=2.)
         {
          pool_r(t,y)=pool_r(t,y);
          pool_r_e(t,y)=pool_r_e(t,y);
         }
       if(pool_r_e(t,y)>=0 && pool_r_e(t,y)<2.)
         { if (y!=styr+cnt)
            {
             rless+=1;
             pool_r_e(t,y-1)=pool_r_e(t,y-1)+pool_r_e(t,y);
             pool_r(t,y-1)=pool_r(t,y-1)+pool_r(t,y);
             pool_r(t,y)=0;
             pool_r_e(t,y)=0;
            }
            if (y==styr+cnt) break;
         }
      }//for
      cnt+=1;
    }//for
 p_df=up_df;
//Pooled Chi-square
 cnt=0;
 for (t=styrR;t<=endyrR;t++)
  {
   for (y=styr+cnt;y<=endyr;y++)
    {
      p_chi_h(t,y)=0;
      p_chi_r(t,y)=0;

      if(pool_h_e(t,y)!=0)
       {
        p_chi_h(t,y)=square(pool_h(t,y)-pool_h_e(t,y))/pool_h_e(t,y);
       }
      if(pool_r_e(t,y)!=0)
       {
        p_chi_r(t,y)=square(pool_r(t,y)-pool_r_e(t,y))/pool_r_e(t,y);
       }
    }
    cnt+=1;
  }
 p_chi=sum(p_chi_h)+sum(p_chi_r)+sum(chi_ns);
 p_chat=p_chi/p_df;
```

```
REPORT_SECTION
 report<<"Log-L"<<"  "<<"\t"<<"K"<<"\t"<<"AIC"<<"        "<<"AICc"<<"      "<<"Eff. Sample Size"<<endl;
 report<<f_tag<<"   "<<"\t"<<K<<"\t"<<AIC<<"\t"<<AICc<<"\t"<<sum(N)<<endl;
 report<<" "<<endl;
 report<<" "<<endl;
 report<<"*******Model Statistics*******************"<<endl;
 report<<"Unpooled Chi-square     "<<"  "<<up_chi<<endl;
 report<<"Upooled df            "<<"  "<<up_df<<endl;
 report<<"Unpooled c-hat         "<<"  "<<up_chat<<endl;
 report<<"Pooled Chi-square      "<<"  "<<p_chi<<endl;
 report<<"Pooled df             "<<"  "<<p_df<<endl;
 report<<"Pooled c-hat          "<<"  "<<p_chat<<endl;
 report <<"*****************************************"<<endl;
 report<<"  "<<endl;
 report<<"  "<<endl;
 report << "S for fish" << endl;
 report << S_fish << endl;
 report<<" "<<endl;
 report<<"*************************Observed and Calculated Data***************************************"<<endl;
 report << "Obs Recoveries of harvest fish "<< endl;
 report<<rh<<endl;
 report <<" "<<endl;
 report << "Obs Recoveries of release fish "<< endl;
 report<<rr<<endl;
 report <<" "<<endl;
 report << "Total Released "<< endl;
 report<<N<<endl;
 report <<" "<<endl;
 report <<"Total Recovered Tags"<<endl;
 report <<tags<<endl;
 report<<" "<<endl;
 report << "s matrix" << endl;
 report <<s<<endl;
 report<<" "<<endl;
 report << "S_prob matrix" << endl;
 report <<s_prob<<endl;
 report<<" "<<endl;
 report << "Exploitation Rate of harvested fish" << endl;
 report <<u_h<<endl;
 report<<" "<<endl;
 report << "Exploitation Rate of released fish" << endl;
 report <<u_r<<endl;
 report<<" "<<endl;
 report <<"Expected Probability of harvested fish"<<endl;
 report<<exp_prob_h<<endl;
 report <<" "<<endl;
  report <<"Expected Probability of released fish"<<endl;
 report<<exp_prob_r<<endl;
 report <<" "<<endl;
 report<<"Not Seen Probability"<<endl;
 report<<1-(sum_prob_h+sum_prob_r)<<endl;
 report<<" "<<endl;
 report <<"Expected Number of harvested fish"<<endl;
 report<<exp_r_h<<endl;
 report <<" "<<endl;
  report <<"Expected Number of released fish"<<endl;
 report<<exp_r_r<<endl;
 report <<" "<<endl;
 report <<"Expected Number of not seen"<<endl;
 report<<exp_ns<<endl;
 report <<" "<<endl;
 report <<"Cell Likelihoods of harvested fish"<<endl;
 report<<ll_h<<endl;
 report <<" "<<endl;
  report <<"Cell Likelihoods of released fish"<<endl;
```

```
report<<ll_r<<endl;
report <<" "<<endl;
report <<"Cell Likelihoods of unseen"<<endl;
report<<ll_ns<<endl;
report <<" "<<endl;
report <<"Unpooled Chi-squares of Harvested Fish"<<endl;
report<<chi_h<<endl;
report <<" "<<endl;
report <<"Unpooled Chi-squares of Released Fish"<<endl;
report<<chi_r<<endl;
report <<" "<<endl;
report <<"Chi-squares of Not Seen"<<endl;
report<<chi_ns<<endl;
report <<" "<<endl;
 report <<"Pooled Cells of Harvested Fish"<<endl;
report<<pool_h<<endl;
report <<" "<<endl;
report <<"Pooled Expected Cells of Harvested Fish"<<endl;
report<<pool_h_e<<endl;
report <<" "<<endl;
report <<"Pooled Cells of Released Fish"<<endl;
report<<pool_r<<endl;
report <<" "<<endl;
report <<"Pooled Expected Cells of Harvested Fish"<<endl;
report<<pool_r_e<<endl;
report <<" "<<endl;
report <<"Pooled Chi-squares of Harvested Fish"<<endl;
report<<p_chi_h<<endl;
report <<" "<<endl;
report <<"Pooled Chi-squares of Released Fish"<<endl;
report<<p_chi_r<<endl;
report <<" "<<endl;
report <<"Pearson Residuals for released fish"<<endl;
report<<pear_r<<endl;
report <<" "<<endl;
report <<"Pearson Residuals for harvested fish"<<endl;
report<<pear_h<<endl;
report <<" "<<endl;
report <<"Pearson Residuals for not seen"<<endl;
report<<pear_ns<<endl;
report <<" "<<endl;
FINAL_SECTION
//Calculate F and sd
d=mp+fp+fap;
//Calculate S and Sd
 ofstream ofs1("S.std");
for(y=styr;y<=endyr;y++)
  {
        d+=1;
    ofs1<<S(y)<<"\t"<<sigma(d,1)<<endl;

  }
  ofstream ofs2("F.std");
  for(y=styr;y<=endyr;y++)
  {
        d+=1;
    ofs2<<FM(y)<<"\t"<<sigma(d,1)<<endl;
  }
//Calculate FA and sd
  ofstream ofs3("Ft.std");
  for(y=styr;y<=endyr;y++)
  {
        d+=1;
    ofs3<<FT(y)<<"\t"<<sigma(d,1)<<endl;
  }
//Calculate M and Sd
```

```
 ofstream ofs4("M.std");
 for(y=styr;y<=endyr;y++)
   {
              d+=1;
     ofs4<<NM(y)<<"\t"<<sigma(d,1)<<endl;

   }
//Calculate harvest residuals
 ofstream ofs5("hresid.std");
    ofs5<<stdres_h<<endl;
//Export release residuals
 ofstream ofs6("rresid.std");
     ofs6<<stdres_r<<endl;
//Export not seen residuals
 ofstream ofs7("nsresid.std");
      ofs7<<stdres_ns<<endl;
```

Appendix B10: Scale-Otolith Bias in Ageing Striped Bass

Atlantic striped bass have been aged using scales for over 70 years (Merriman, 1941). Scales have long been a popular ageing structure because their collection does not require the fish to be killed or a market-quality fish to be damaged. However, scales have fallen out of favor with the recognition that that scales can underestimate the age of older fish, a phenomenon which has been documented in striped bass (Secor *et al.*, 1995).

ASMFC convened an ageing workshop for striped bass in 2003 to discuss the scale-otolith issue. Prior to the workshop, an exchange was conducted using 102 scales from known age fish; these fish had been tagged with coded wire tags (CWT) at age-0 and released. State personnel from MA, NJ, DE, VA, MD, and NC read the scales and the results were compared with the known ages.

The known-age scale exchange found general overestimation of year 1 and 2 specimens by one year and good agreement on scale readings from 3-7 years (Figure 1). Ages 9 through 12 (very low sample size was available from these ages) were interpreted reasonably accurately by experienced readers but were underestimated by all other readers. Age 8 was underestimated by all readers, which may have been due to a scale quality issue.

Workshop participants felt that scales were reliable for striped bass up to age 10-12 (about 800mm), but that otoliths should be used for animals older or larger than that (ASMFC 2003). The workshop recommended collecting paired samples from larger fish to better assess the reliability of scales for ageing older animals and the degree of bias between scales and otoliths.

Because of the difficulty and expense of collecting and processing otoliths, most states do not currently have sufficient otolith samples to develop a conversion matrix for their scale ages. Virginia has a large collection of paired samples dating back to 1999, and Massachusetts has samples from 2002-2004 and 2010-2012. Both states tended to age scale samples younger than the corresponding otolith sample for older ages (Figures 2, 3). VA also tended to age scale samples older than otolith samples for the youngest (< 5 years) fish.

The Technical Committee considered using VA's annual conversion matrices to convert scale ages from other states into otolith ages. One concern that was raised was that different states may need different correction factors between scales and otoliths. The comparison of scales and known ages at the 2003 workshop suggested that experienced readers were closer to the true ages and thus would need less of a correction than less experienced readers. To assess the consistency of scale-ageing across states, a set of 256 scale samples from VA was sent to MD, NJ, NY, RI, and MA to be aged by their scale readers prior to the assessment workshop, and the results were compared to VA's scale ages and corresponding otolith ages.

There was a regional pattern in the differences between the ages assigned by VA and the ages assigned by the other states (Figure 4). The mid-Atlantic states of MD and NJ agreed much more with the ages assigned by VA, while the north Atlantic states of MA and RI tended to underage older fish compared to VA's ages. This may be a function of geographic differences in the scales themselves (due to regional differences in growth that are harder for readers from other regions to interpret), or of differences in preparation, reading technique, or reader experience. Ages assigned by all states using scales underaged the older fish compared to the ages VA assigned using otoliths, and the north Atlantic states again had a lower rate of agreement (Figure 5). However, a separate exchange of MA otoliths between VA and MA found very good agreement between the two states and no evidence of bias (Figure 6), consistent with other observations that otoliths tend to be easier to age precisely than scales.

These results indicated that applying a single correction matrix would likely not fully correct all ages and might introduce additional bias in samples aged by more experienced personnel.

While the use of scales remains a concern in this assessment, the currently available paired samples are not sufficient to convert scales ages on a coastwide basis. The TC recommends that sampling of otoliths, especially of larger fish, continues and more work is done to characterize the scale-otolith bias at the state level for all states that contribute to the age-length keys used in the assessment.

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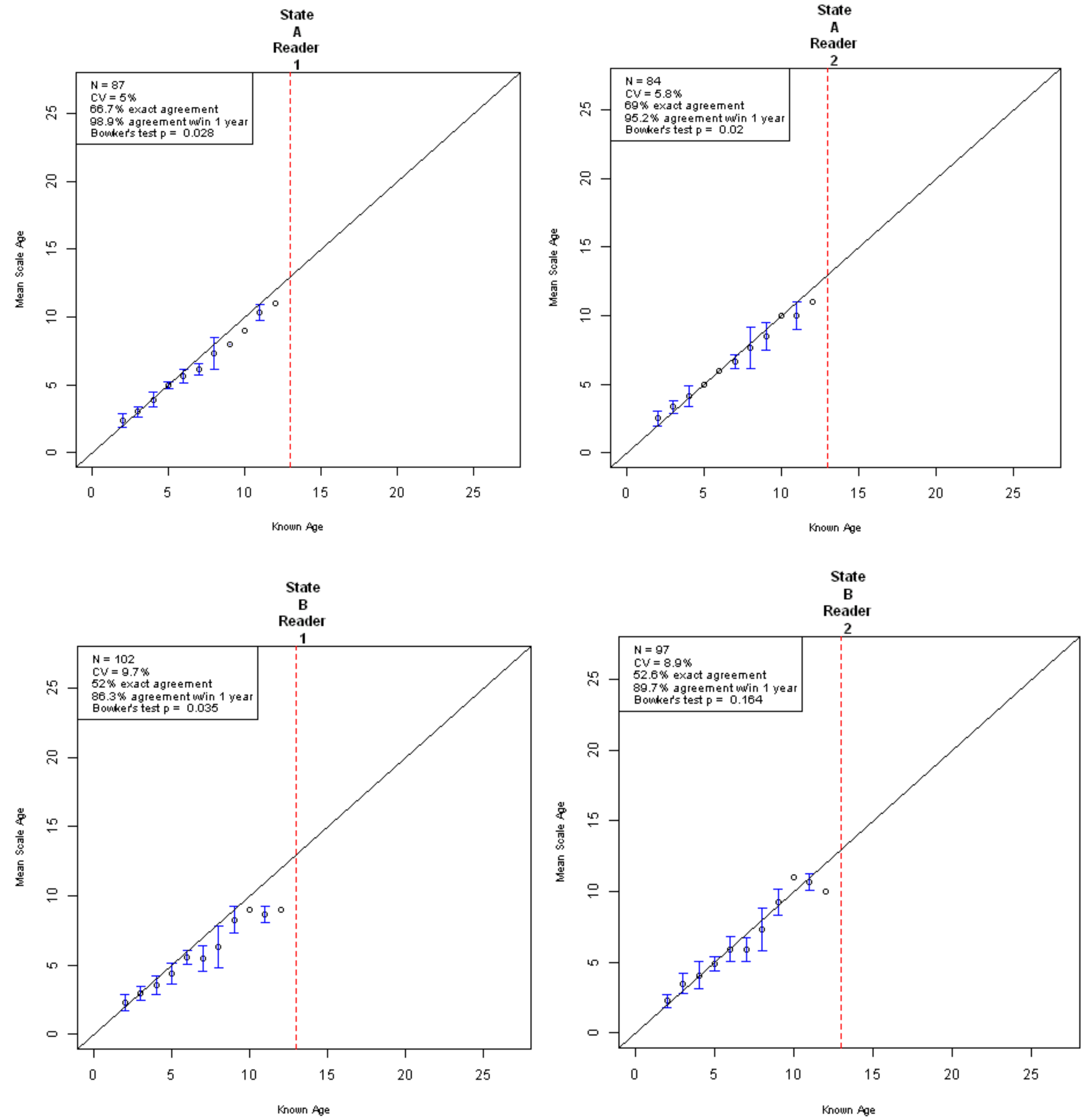

Figure 1: State scale age readings compared to the known age of CWT striped bass. Error bars indicate ±1 standard deviation. Dashed red line indicates the age of the plus group in the model (age 13+).

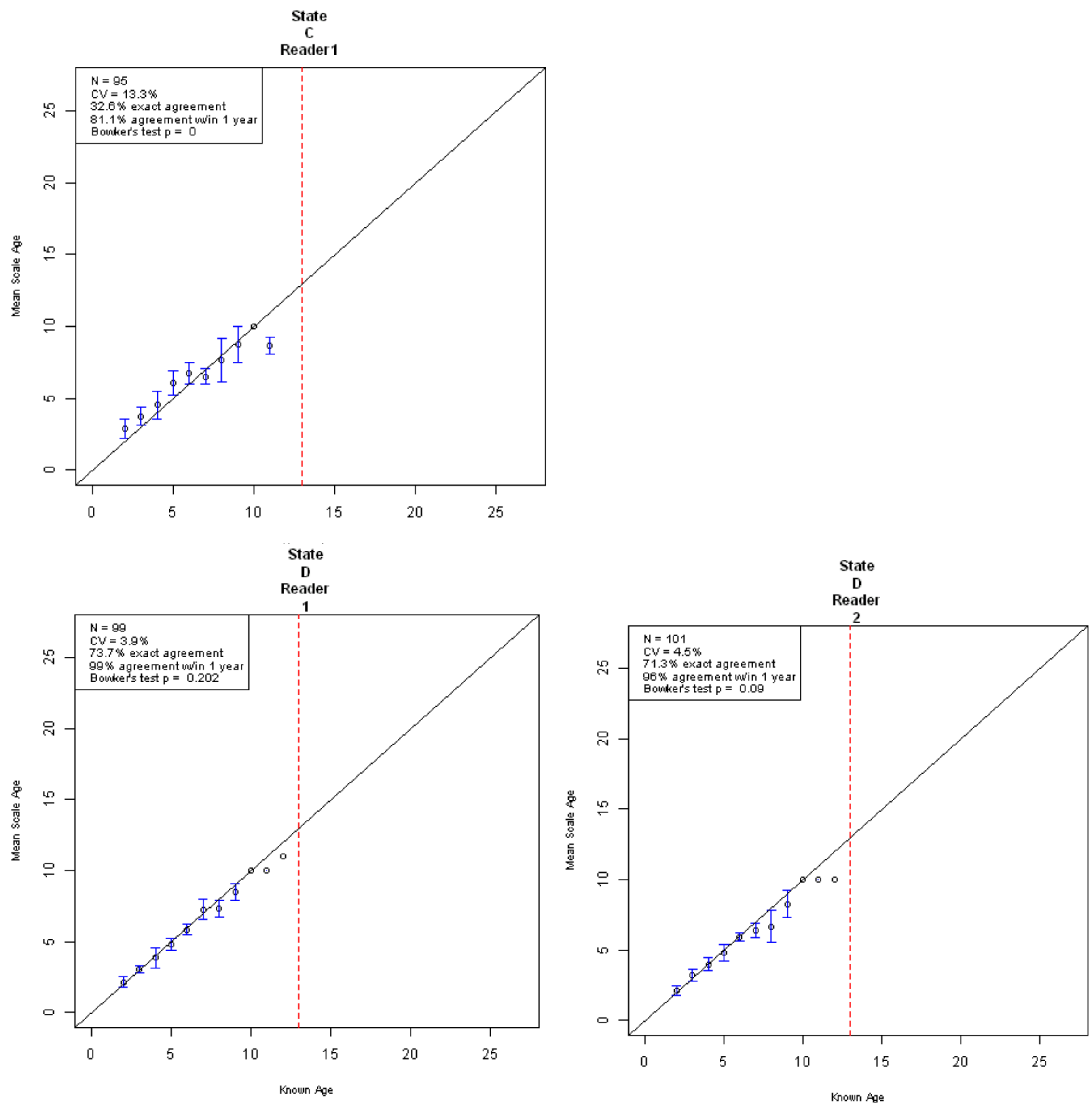

Figure 1 (cont.): State scale age readings compared to the known age of CWT striped bass. Error bars indicate ±1 standard deviation. Dashed red line indicates the age of the plus group in the model (age 13+).

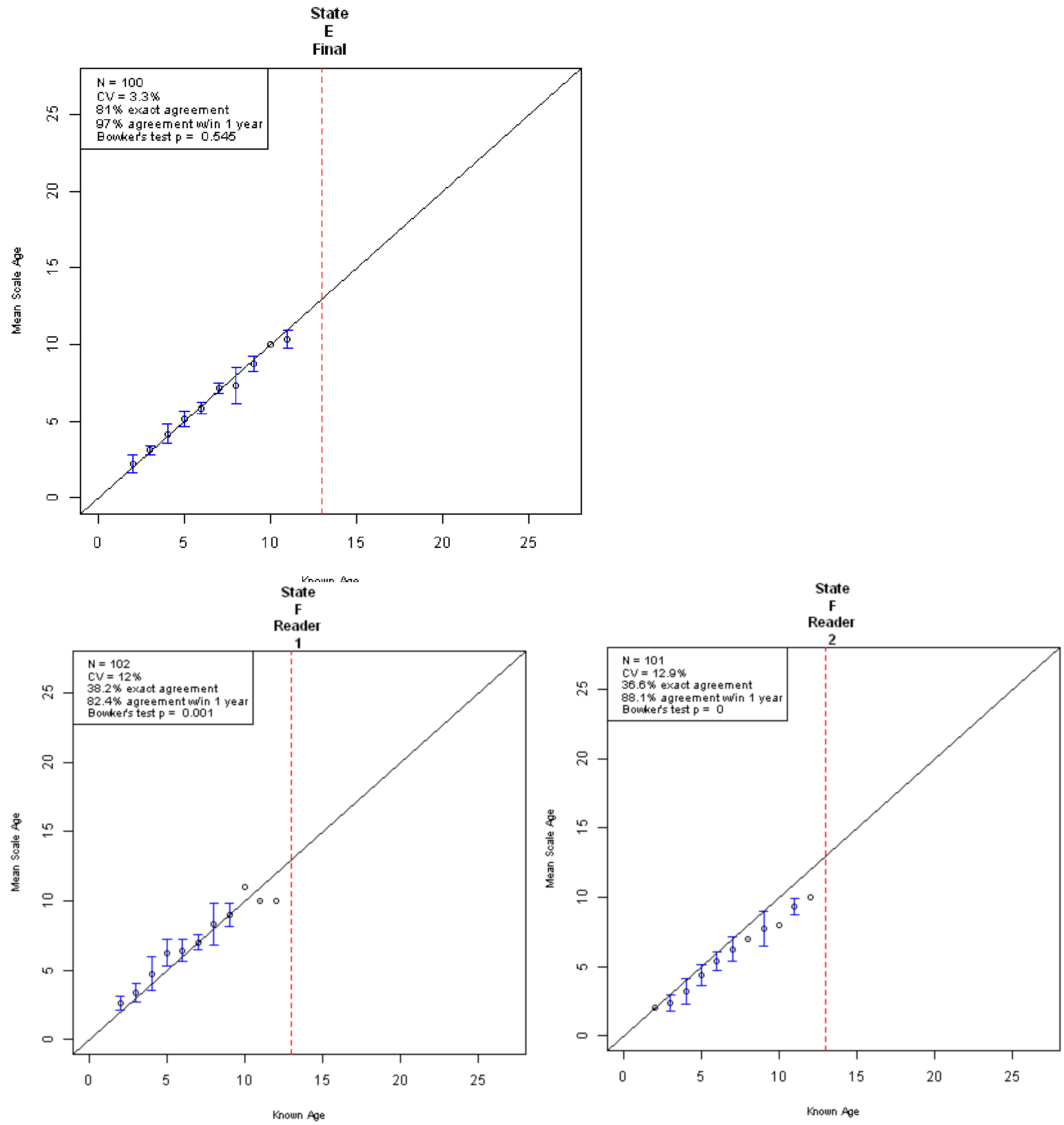

Figure 1 (cont.): State scale age readings compared to the known age of CWT striped bass. Error bars indicate ±1 standard deviation. Dashed red line indicates the age of the plus group in the model (age 13+).

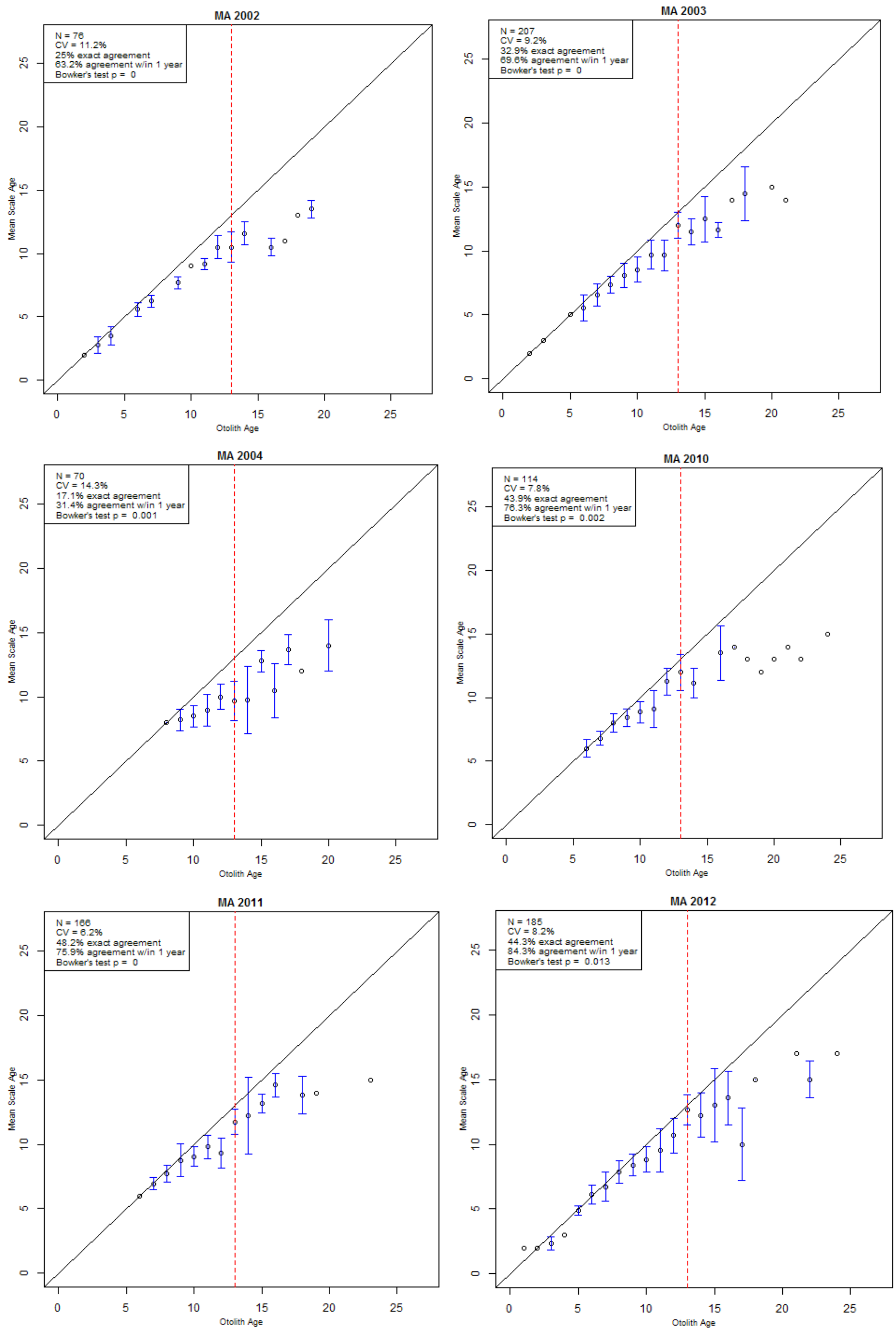

Figure 2: Massachusetts scale-otolith comparisons by year. Error bars indicate ±1 standard deviation. Dashed red line indicates the age of the plus group in the model (age 13+).

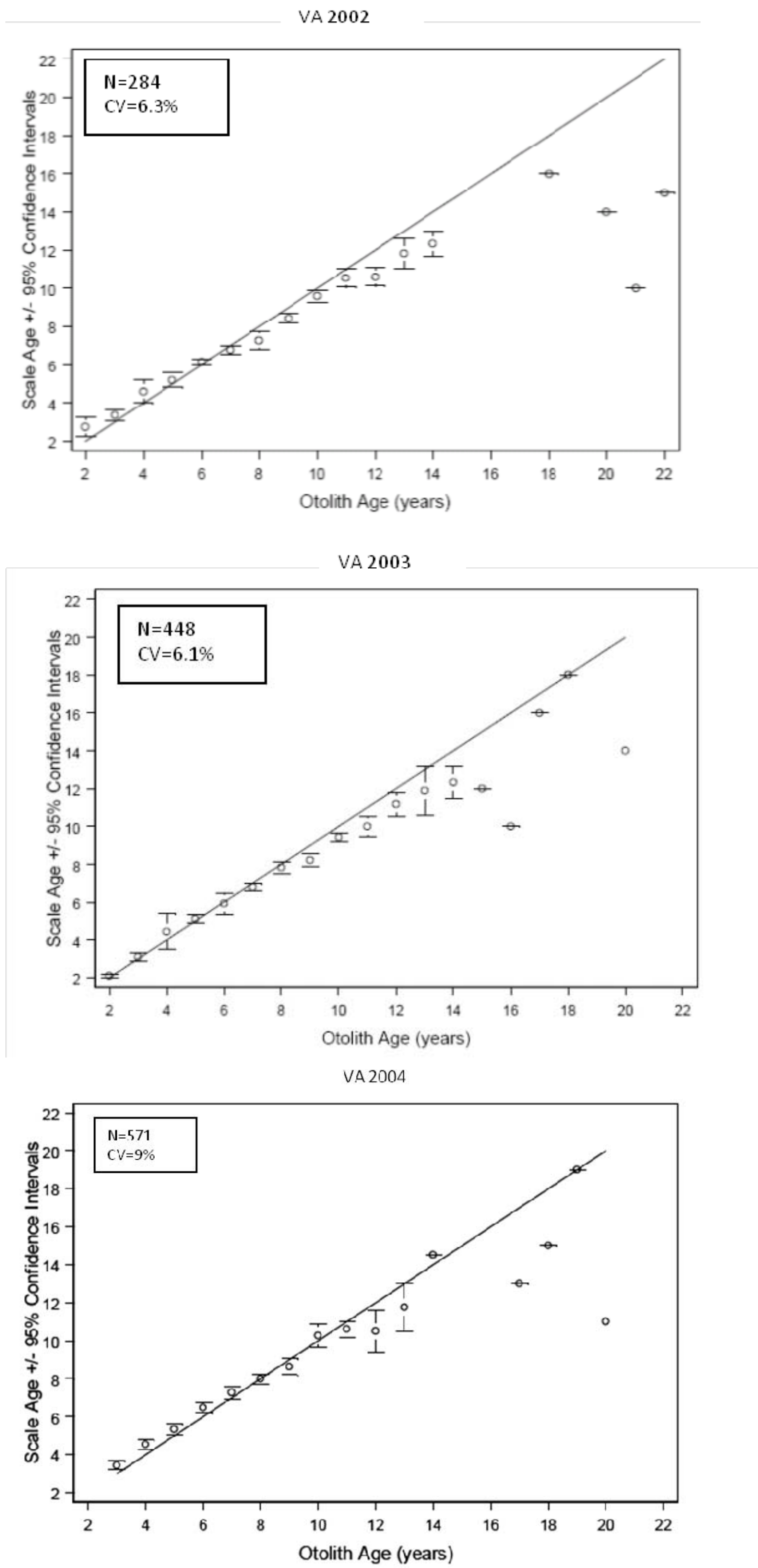

Figure 3: Virginia scale-otolith comparisons by year. Error bars indicate 95% confidence intervals. From VMRC Summary Report on Finfish Ageing 2002, 2003, 2004.

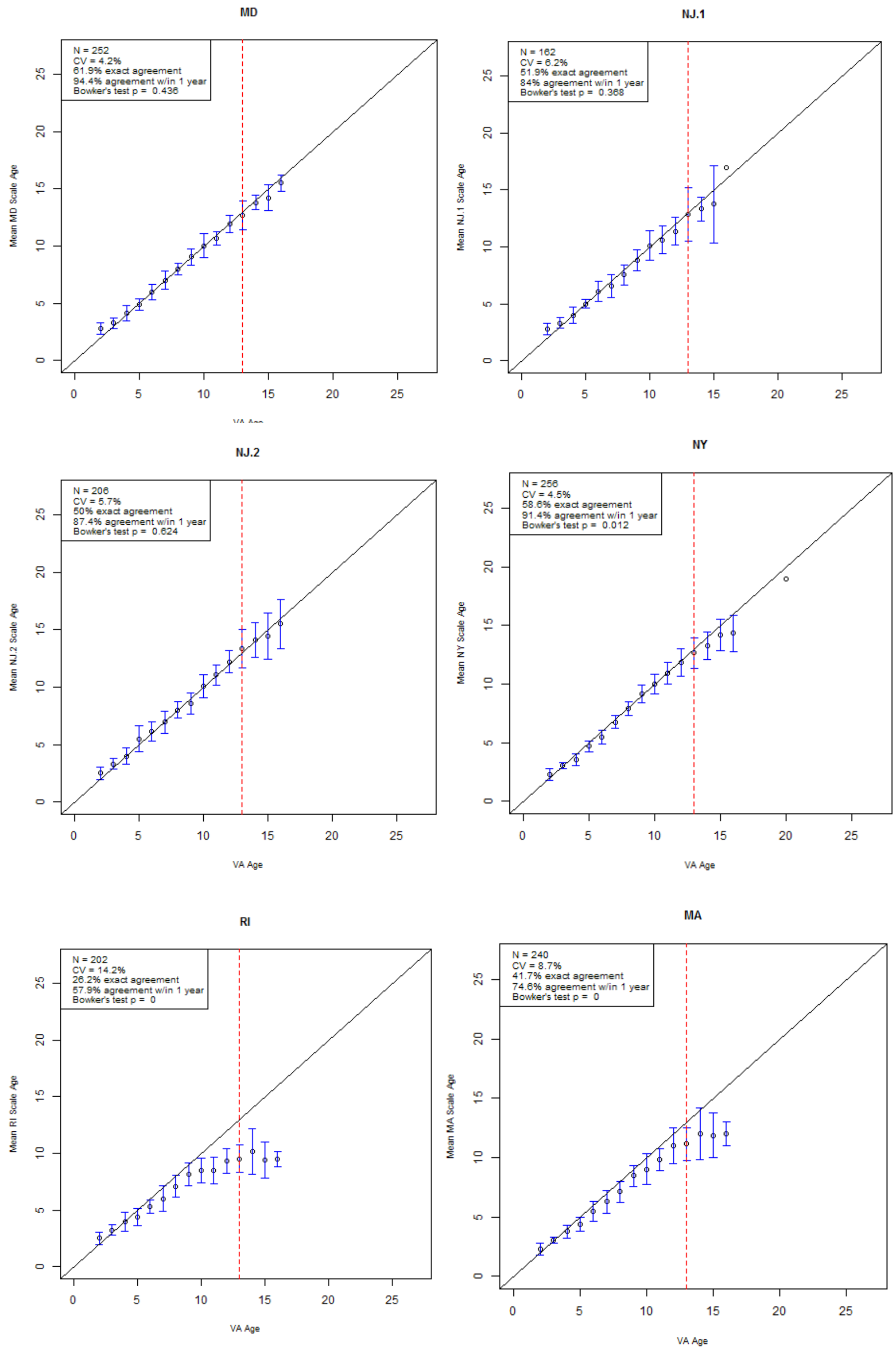

Figure 4: State scale age readings of striped bass compared to the scale ages assigned by Virginia. Error bars indicate ±1 standard deviation. Dashed red line indicates the age of the plus group in the model (age 13+).

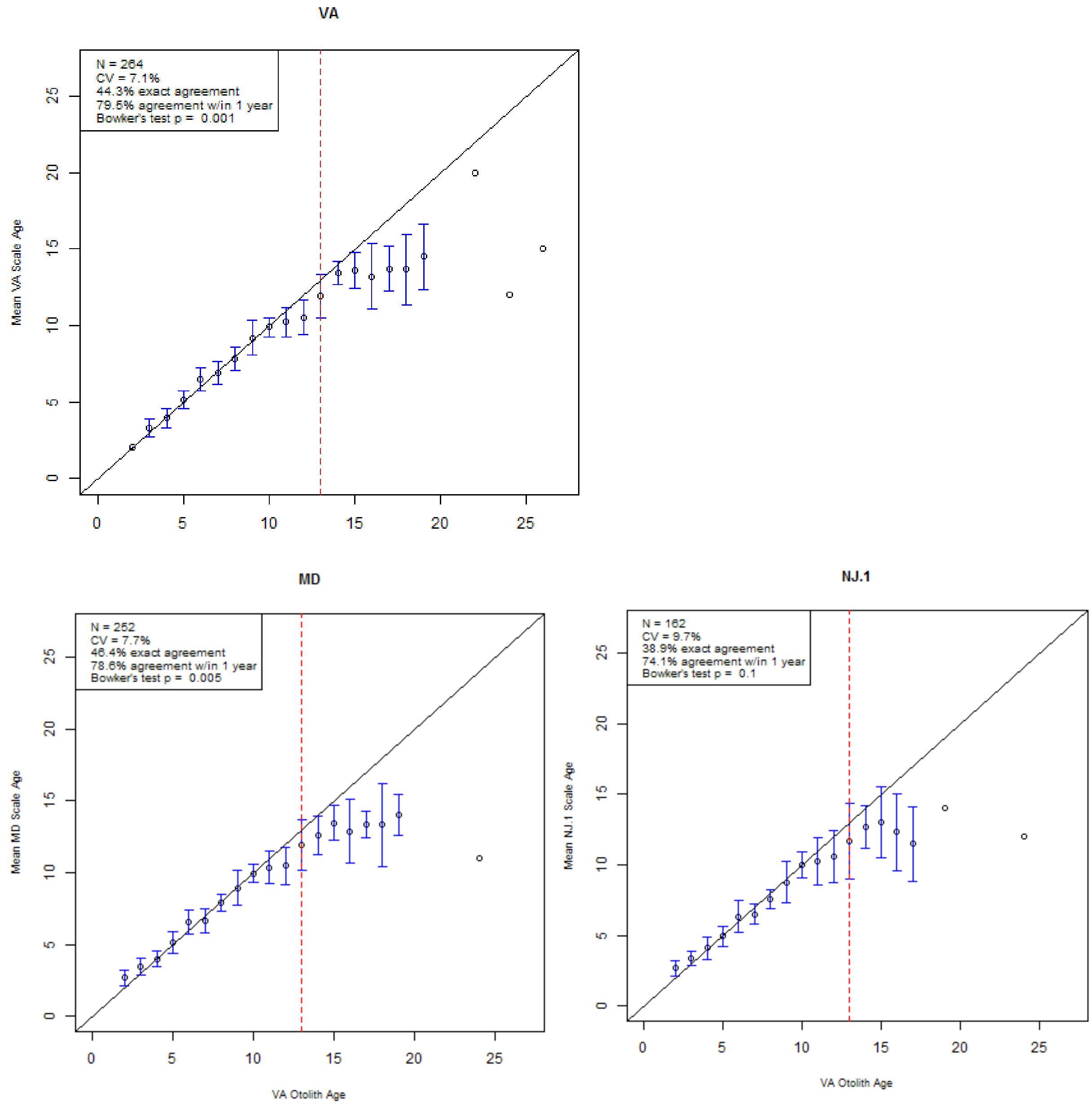

Figure 5: State scale age readings of striped bass compared to the otolith ages assigned by Virginia. Error bars indicate ±1 standard deviation. Dashed red line indicates the age of the plus group in the model (age 13+).

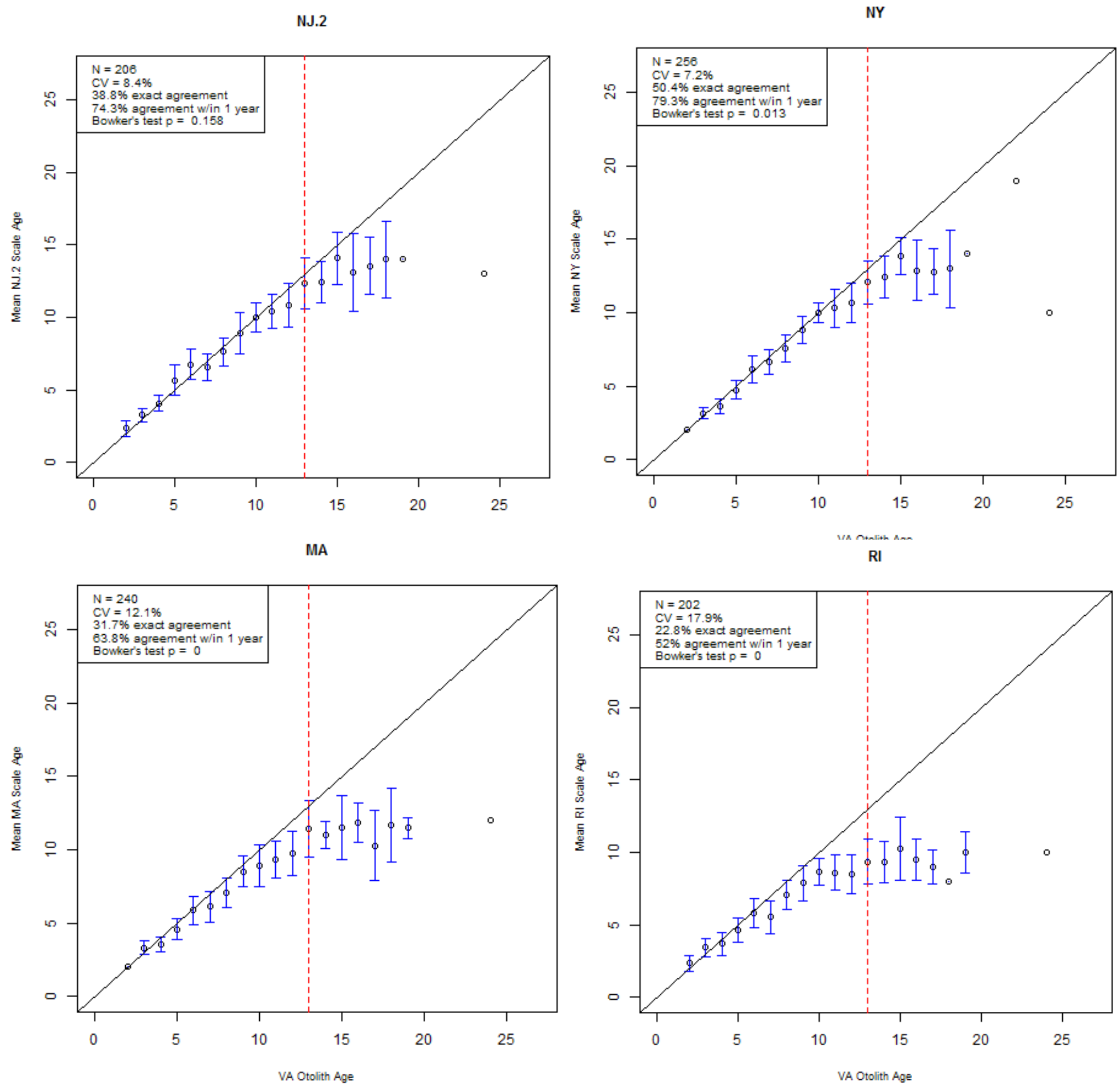

Figure 5 (cont.): State scale age readings of striped bass compared to the otolith ages assigned by Virginia. Error bars indicate ±1 standard deviation. Dashed red line indicates the age of the plus group in the model (age 13+).

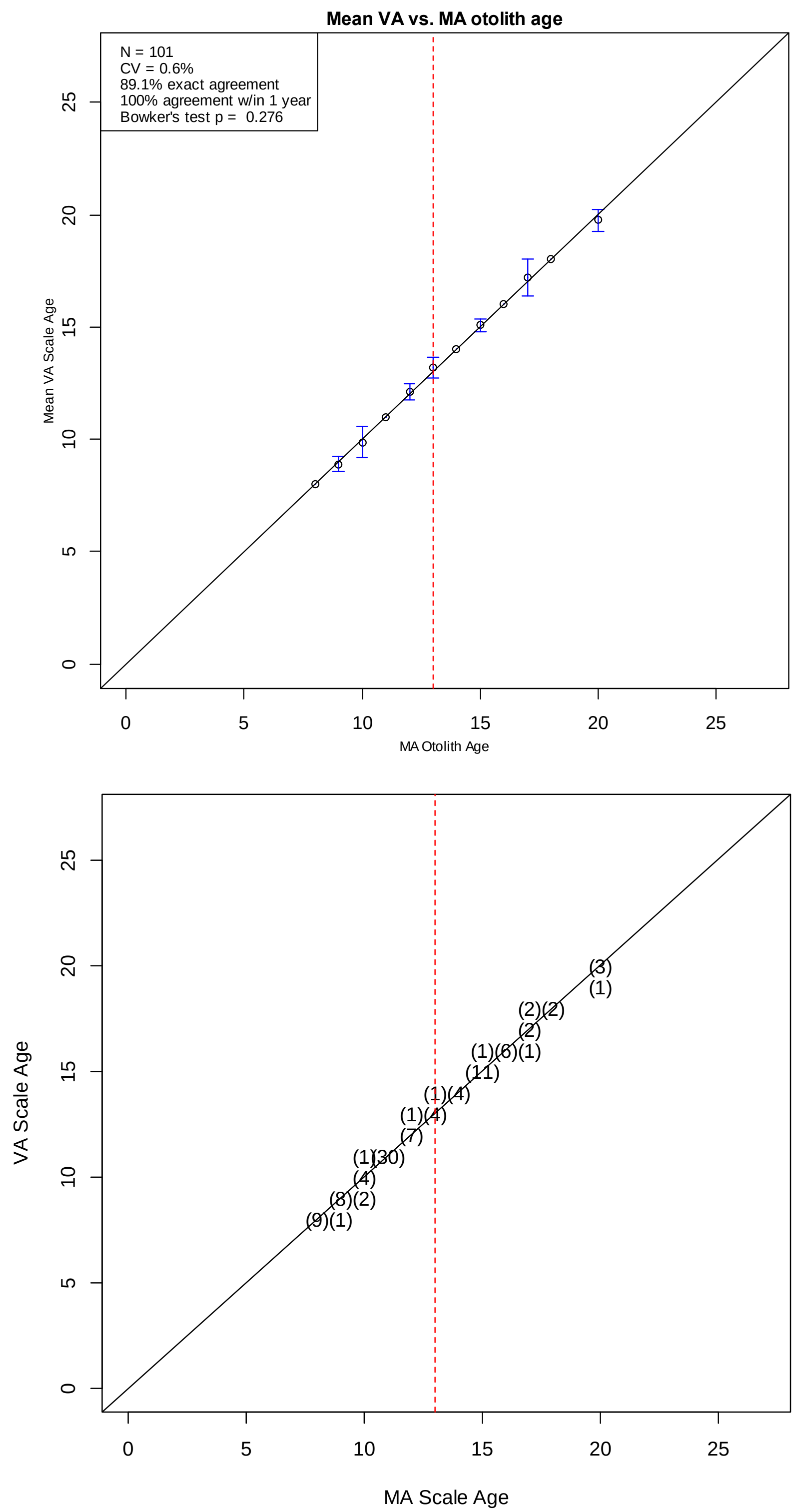

Figure 6: Comparisons of VA and MA otolith ages. Error bars indicate ±1 standard deviation. Dashed red line indicates the age of the plus group in the model (age 13+). Numbers in parentheses indicate sample size.

Appendix B11. Biological Reference Point Calculations Revisited

The Striped Bass Technical Committee developed an alternative, projection-based approach to the fishing mortality reference points that would align with the current spawning biomass reference points (SSB_{1995}). The estimate of F_{MSY}, used as a biological reference point (BRP) in the previous assessment, was sensitive to the choice and parameterization of the stock-recruitment model in the Statistical Catch at Age model (SCA). The proposed fishing mortality reference point was calculated using a stochastic projection by drawing recruitment from empirical estimates and a distribution of starting population abundance at age. The objective was to determine fishing mortality rates that would achieve the historical SSB target and threshold currently used in management. Empirical estimates of recruitment, selectivity, and the starting population came from the SCA model results. Estimates of recruitment were restricted to 1990 and later, when the stock was considered restored.

However, the SARC panel was concerned that projections did not achieve model-based estimates of SSB_{MSY} when the population was fished at F_{MSY}. To address these concerns, additional runs of the projections were completed at the Review Workshop. The major issue appeared to be the mismatch between the projection model assumptions and reference point model recruitment assumptions. The projection model used empirical estimates of recruitment while the model-based reference points predicted recruitment from either a Beverton-Holt or Shepherd stock-recruitment curve.

Accordingly, the projections were run with recruitment calculated from stock-recruitment curves instead of empirical recruitment observations. The striped bass SCA model was used to estimate both the bias-corrected and uncorrected parameters for a Beverton-Holt and Shepherd stock-recruitment curve. When these analyses were redone at the workshop, it was found that the model could not fit the Shepherd curve adequately (parameter estimates were consistently at the bounds), so the Shepherd curve was replaced with a Ricker curve to examine the effects of over-compensation in the stock-recruitment relationship.

Reference points (SSB_{MSY} and F_{MSY}) were calculated using the bias-corrected stock-recruitment curves. The uncorrected stock-recruitment curve with a model estimate of uncertainty was used for the projections. As before, projections were done using the AgePro program from the NOAA Fisheries Toolbox, and empirical estimates of selectivity and the starting population structure came from the SCA model results. The population was projected forward using the model-based estimate of F_{MSY} for 100 years, and the final equilibrium SSB was compared to the model-based estimates of SSB_{MSY}.

Estimates of equilibrium SSB under F_{MSY} were consistent with model-based estimates of SSB_{MSY} when the projections were done with model-based recruitment (Table B11.1). Results indicated that the differences in equilibrium SSB between projections done with empirical recruitment and projections done with model-based recruitment were caused by lower median recruitment in the empirical recruitment projections.

The SARC panel also asked to see a distribution of the projection-based SSB target and threshold values relative to observed recruitment, to ensure that attempting to attain those values would allow the population to persist at levels that could provide robust recruitment. The distribution of equilibrium SSB values obtained by fishing at the proposed empirical F target and threshold is shown in Figure B11.1.

Table B11.1. Comparison of model-based and projection-based BRPs for striped bass.

	Beverton-Holt[1]	Ricker[1]	Empirical Target[2]	Empirical Threshold[2]
F reference point	F_{MSY} = 0.201	F_{MSY} = 0.341	F_{proxy} = 0.175	F_{proxy} = 0.213
SSB_{MSY} (mt)	75,100	42,128	n/a	n/a
Median projected SSB (mt)	69,193	41,534	72,380	57,904

1: Model-based reference points (F_{MSY} and SSB_{MSY}) and projected values using model-based recruitment.

2: Empirical target and threshold F_{proxy} reference points from projections using observed recruitment to attain SSB threshold and target (SSB_{1995} and 125% SSB_{1995}, respectively).

Figure B11.1. Observed recruitment vs. spawning stock biomass plotted with equilibrium SSB values projected from fishing at the target and threshold F rate reference points using empirical recruitment.