Appendix A

The following information is the result of requests for additional information made by CIE reviewers during the SARC.

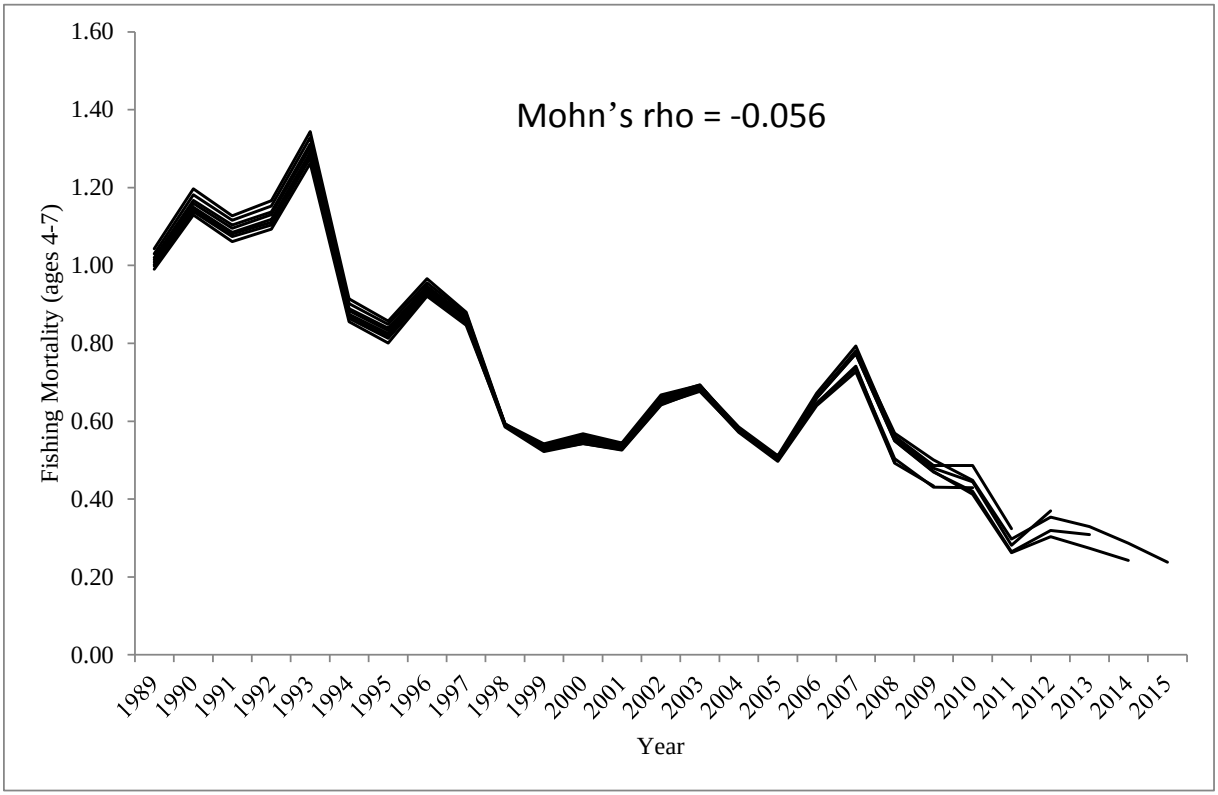

Figure A174. Retrospective pattern of black sea bass fishing mortality from Two Area model combined.

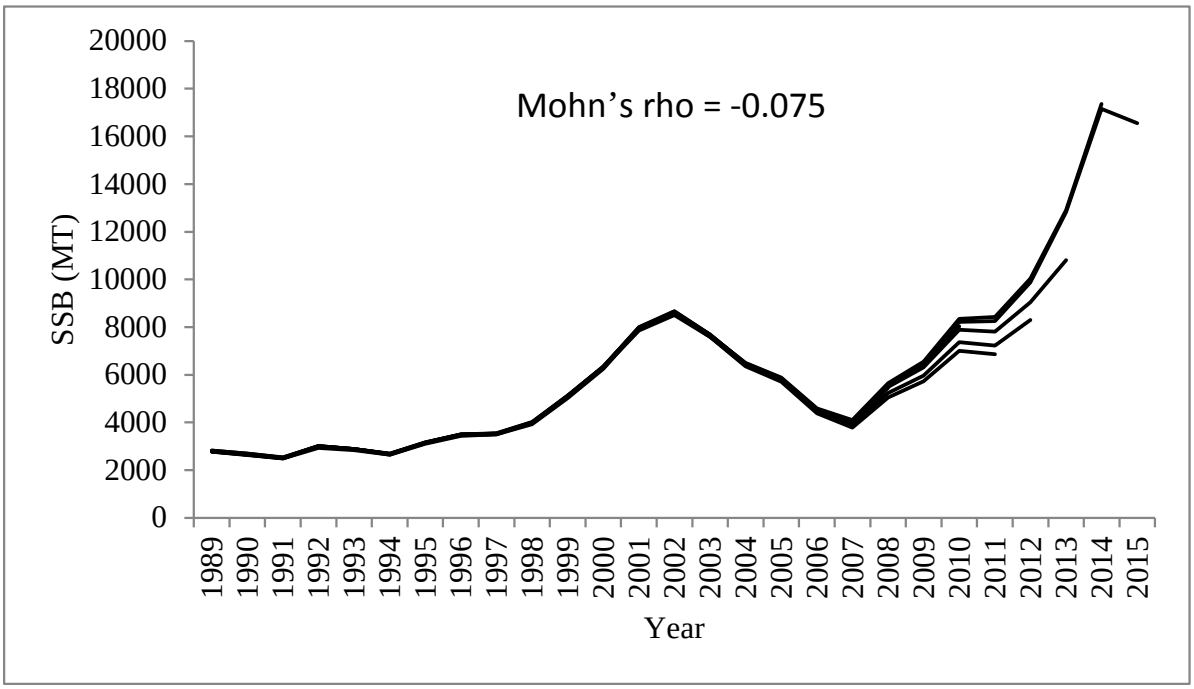

Figure A175. Retrospective pattern of black sea bass SSB (mt) from Two Area model combined.

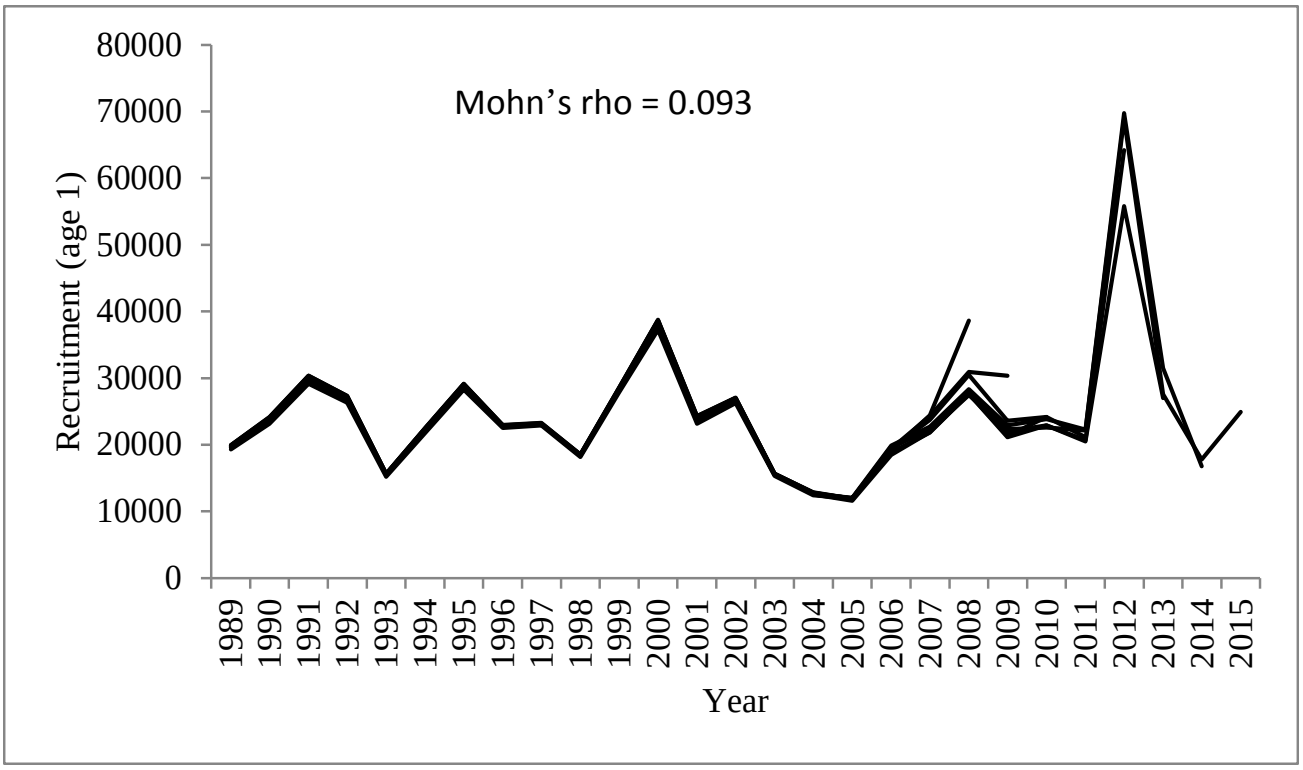

Figure A176. Retrospective pattern of black sea bass age 1 recruitment from Two Area model combined.

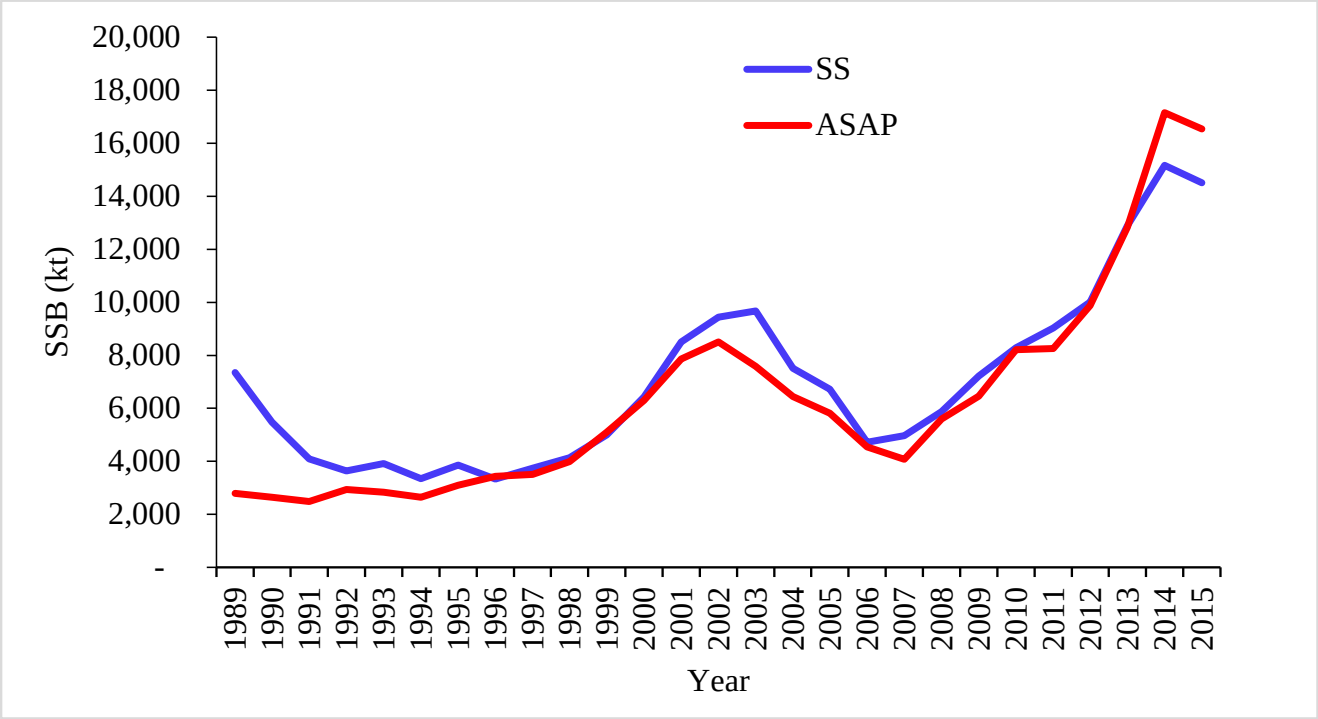

Figure A177. Comparison of black seas bass SSB from the ASAP Two Area model (combined) and Stock Synthesis exploratory model.

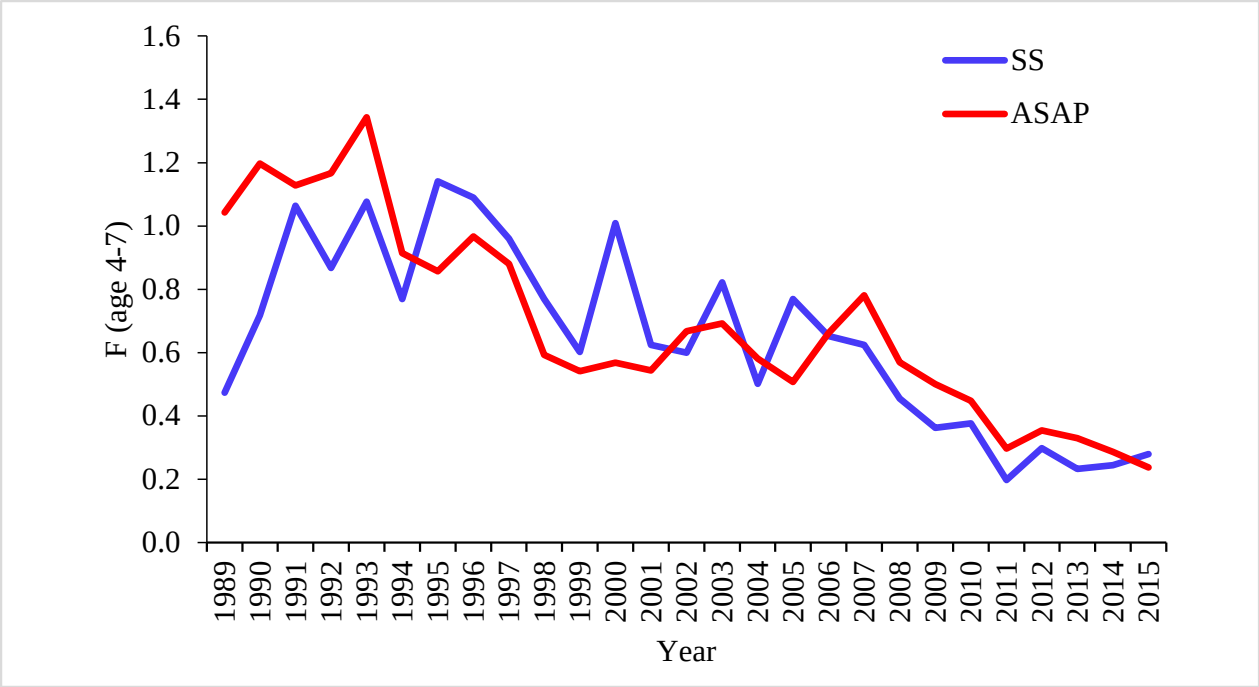

Figure A178. Comparison of black seas bass fishing mortality SSB from the ASAP Two Area model (combined) and Stock Synthesis exploratory model.

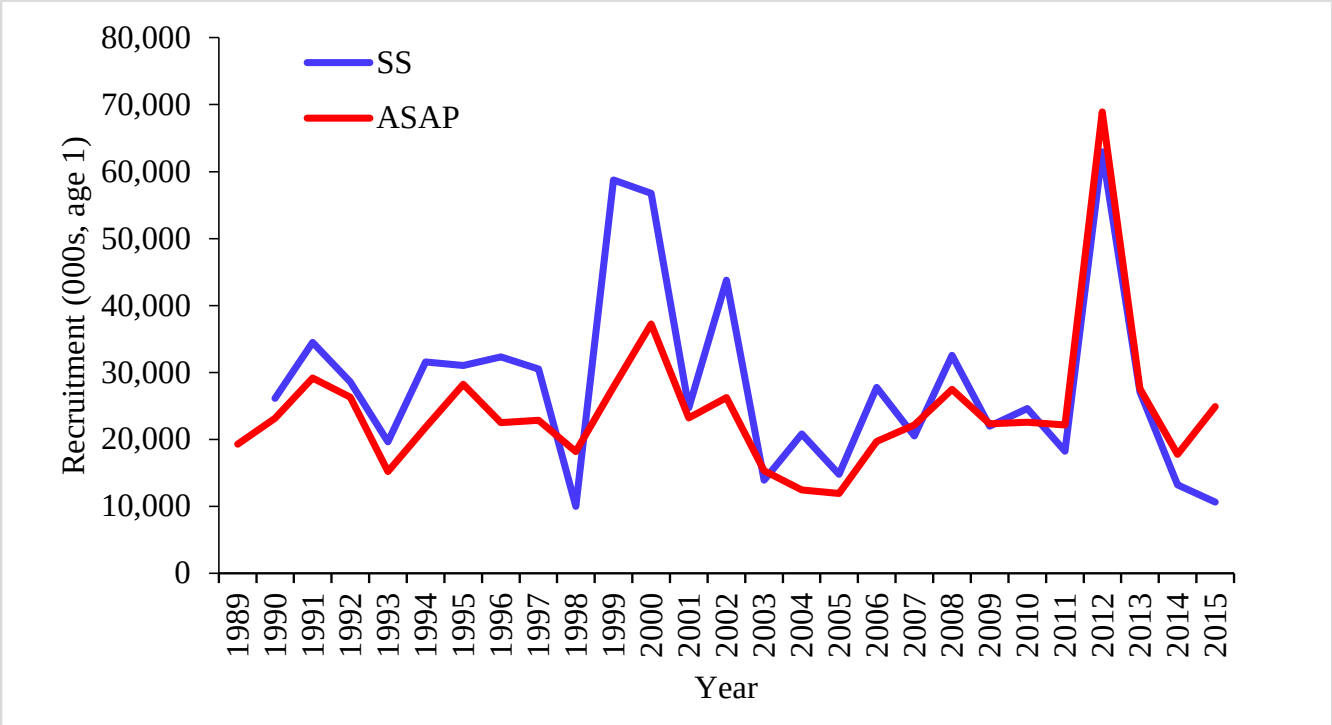

Figure A179. Comparison of black seas bass recruitment SSB from the ASAP Two Area model (combined) and Stock Synthesis exploratory model.

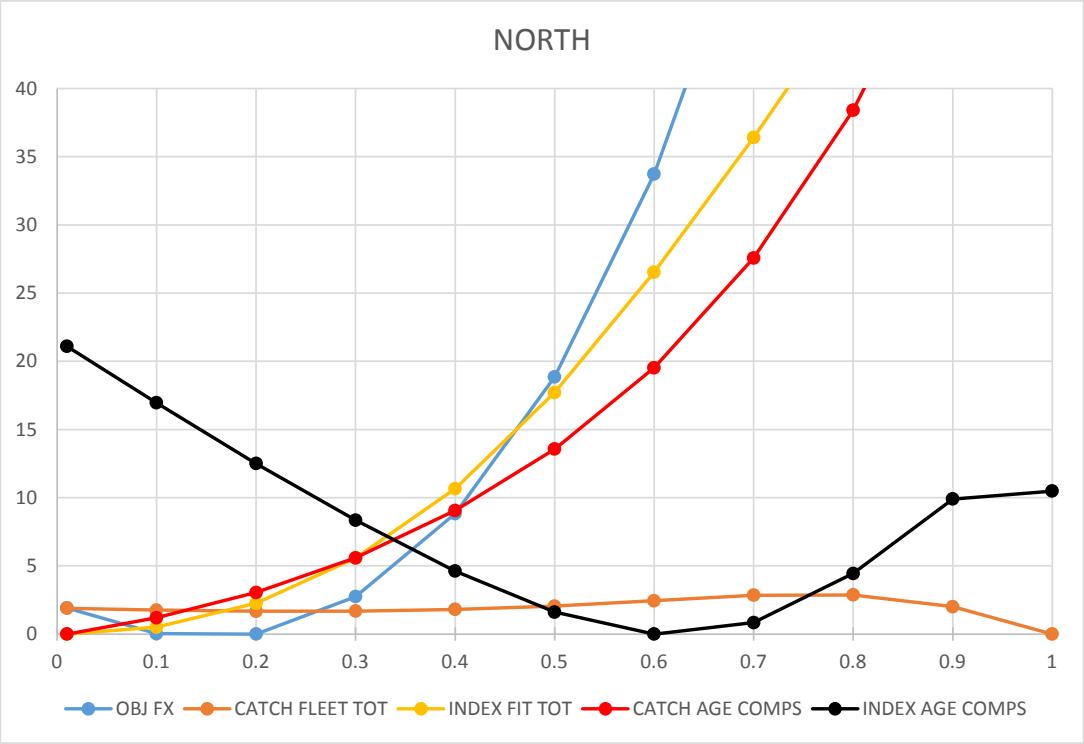

Figure A180. Black sea bass likelihood profiles by component across varying natural mortality values using North ASAP model.

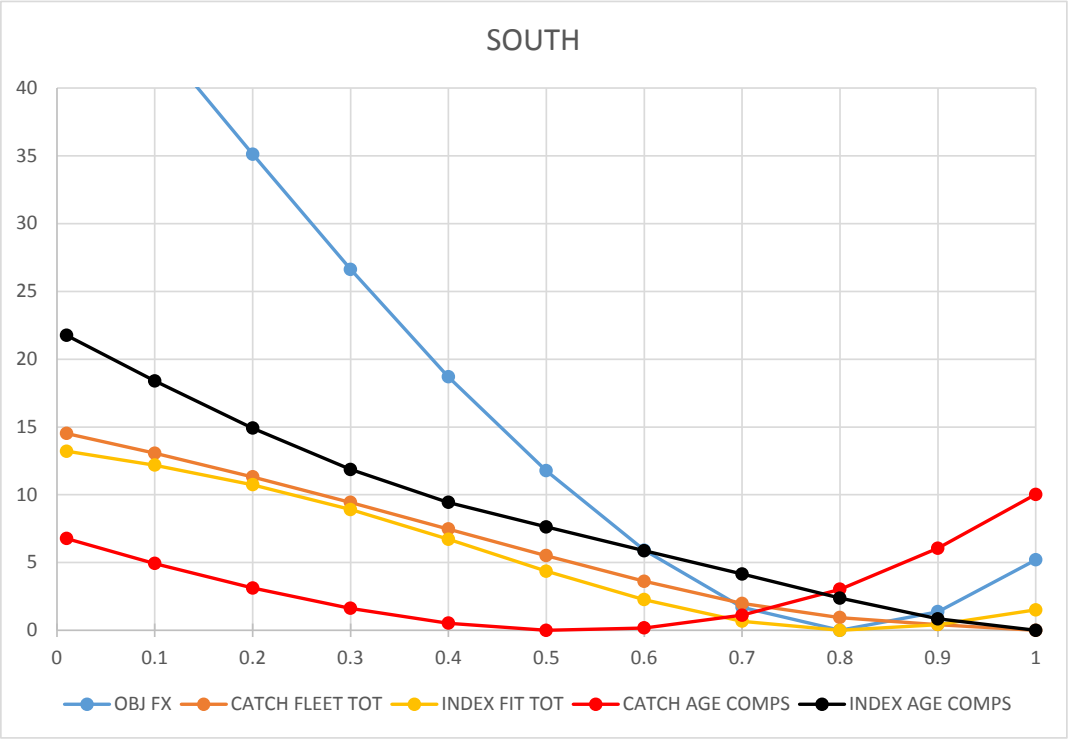

Figure A181. Black sea bass likelihood profiles by component across varying natural mortality values using South ASAP model.

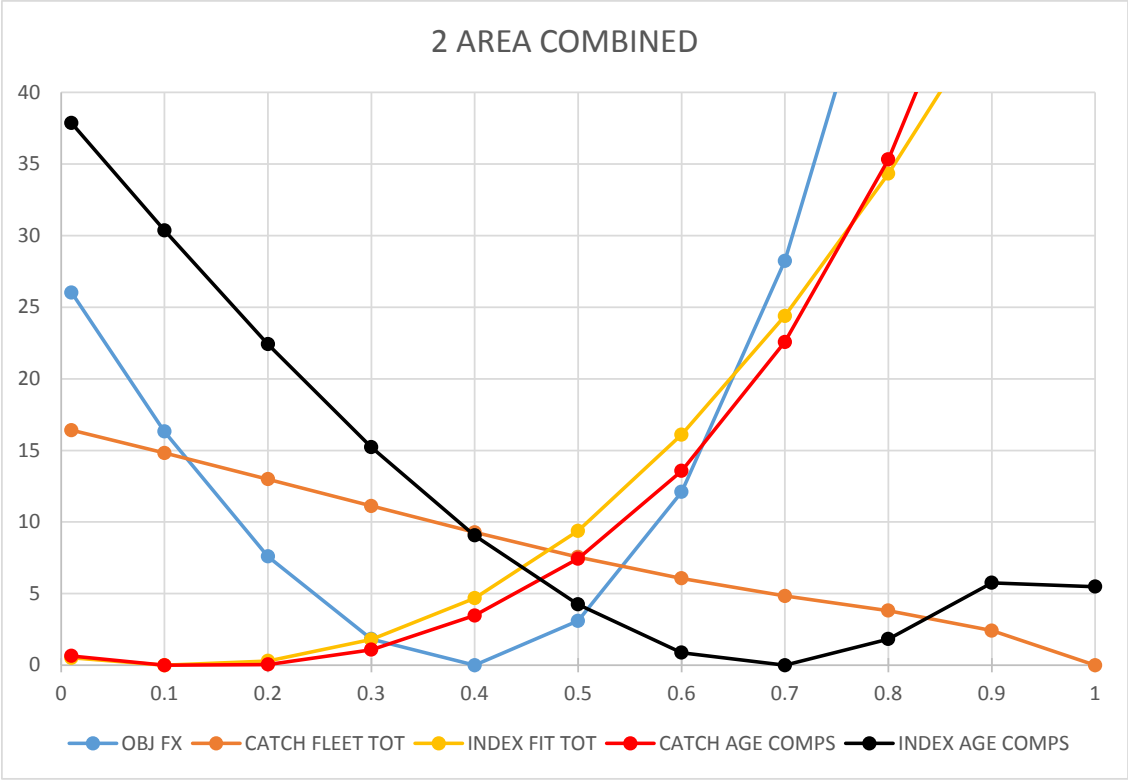

Figure A182. Black sea bass likelihood profiles by component across varying natural mortality values using Two Area combined ASAP model.

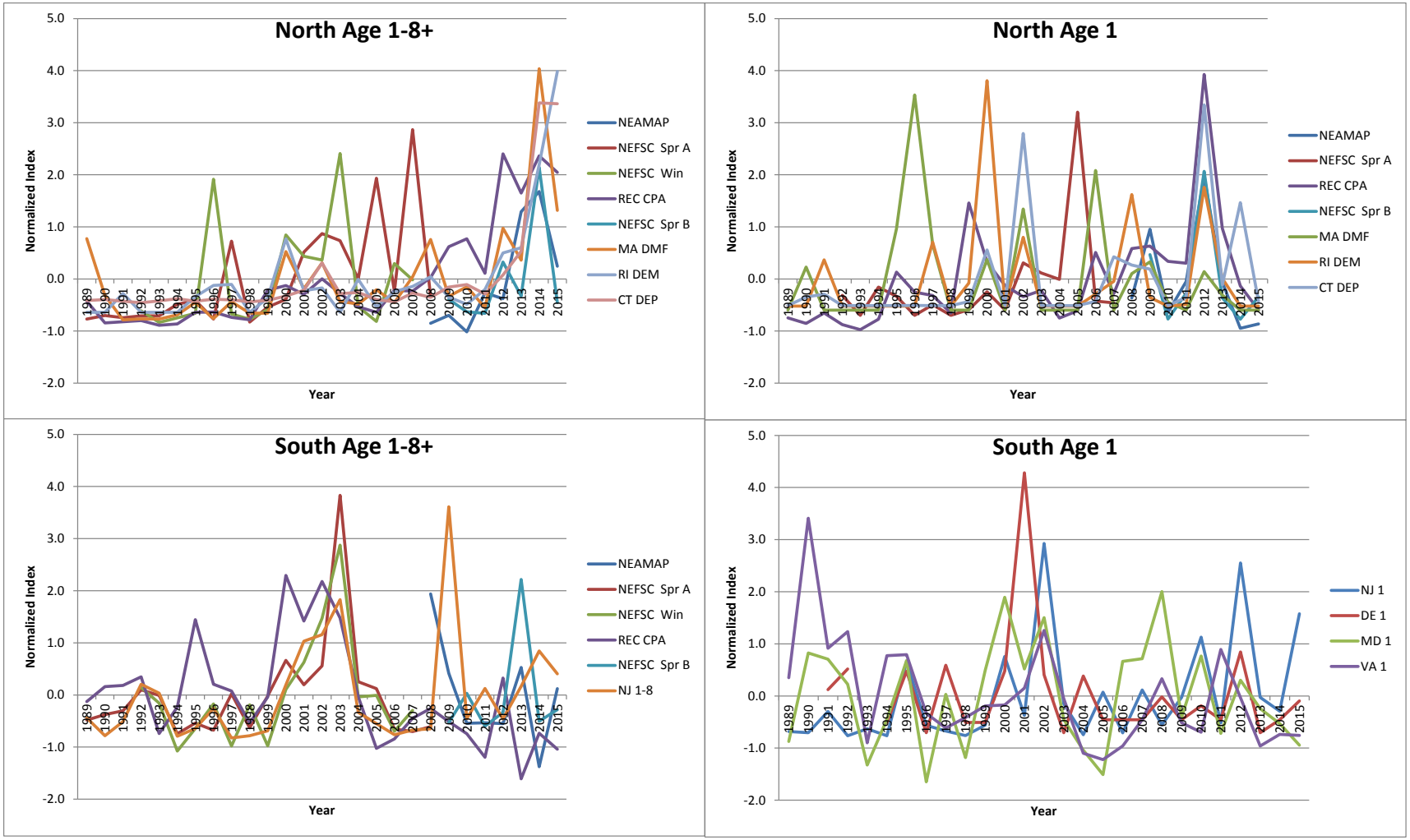

Figure A183. Black sea bass survey standardized indices by area and age groups.

Table A48. Summary of black sea bass survey index rank, CVs, CV multipliers and residual mean square error for overall and regional models.

Rank	**NORTH** Index	Index avg. CV	model CV	CV multiplier	RMSE
1	REC CPA	-	0.40		0.74
2	NEFSC spring Alb	0.65	0.70	1.08	1.49
3	BIGELOW	0.38	0.65	1.71	1.06
3	NEAMAP	0.48	0.30	0.63	1.16
4	MADMF	0.36	0.50	1.39	1.60
4	RI	0.53	0.80	1.51	1.16
4	CT	0.31	0.60	1.94	1.41
5	NY	0.46	0.60	1.30	1.88

Rank	**SOUTH** Index	Index avg. CV	model CV	CV multiplier	RMSE
1	REC CPA	-	0.35		0.68
2	NEFSC spring Alb	0.41	0.70	1.71	1.20
3	BIGELOW	0.36	0.70	1.94	1.45
3	NEFSC winter	0.26	0.70	2.69	1.11
4	NJ	0.32	0.50	1.56	1.36
5	NEAMAP (age 1)	0.22	0.40	1.82	0.77
5	DE	-	0.60		1.38
5	MD	-	0.60		1.16
5	VIMS	0.18	0.60	3.33	1.13

Rank	**OVERALL** Index	Index avg. CV	model CV	CV multiplier	RMSE
1	REC CPA	-	0.5		0.47
2	NEFSC spring Alb	0.38	0.6	1.58	1.23
3	BIGELOW	0.30	0.4	1.33	1.25
3	NEFSC winter	0.25	0.7	2.80	1.00
3	NEAMAP	-	0.4		0.72
4	MADMF	0.36	0.5	1.39	1.97
4	RI	0.53	0.8	1.51	0.96
4	CT	0.31	0.6	1.94	1.85
5	NY	0.46	0.8	1.74	1.65
4	NJ	0.32	0.5	1.56	1.16
5	DE	-	0.6		1.48
5	MD	-	0.4		1.67
5	VIMS	0.18	0.6	3.33	1.31

Ranked by:
Area coverage
Time series length
Ages represented

Retrospective analysis for Black sea bass Stock Synthesis model 'run_164'

Additional analyses requested by SARC 63 review panel Gavin Fay[1]

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November 30, 2016

On 11/29/16, the Review panel requested to see retrospective analyses for the 'base' version of the SS black sea bass model.

Retrospective analyses were conducted for the 'run_164' model detailed in WG documents Appendix X. Model peels using data only up to 2008 did not include the Bigelow survey indices or lengths. Note that for some peels some surveys will have a very small number of years of data (e.g. Bigelow, NEAMAP). An eight year peel was used to reflect the same extent of model/data years as the ASAP assessment models (the SS model used the 2016 spring survey data).

Table 1. Mohn's ρ statistics for spawning biomass (SSB), fishing mortality (F), and recruitment (Recruits) based on an eight year peel.

Quantity	Mohn's ρ
SSB	-0.073
F	0.008
Recruits	-0.128

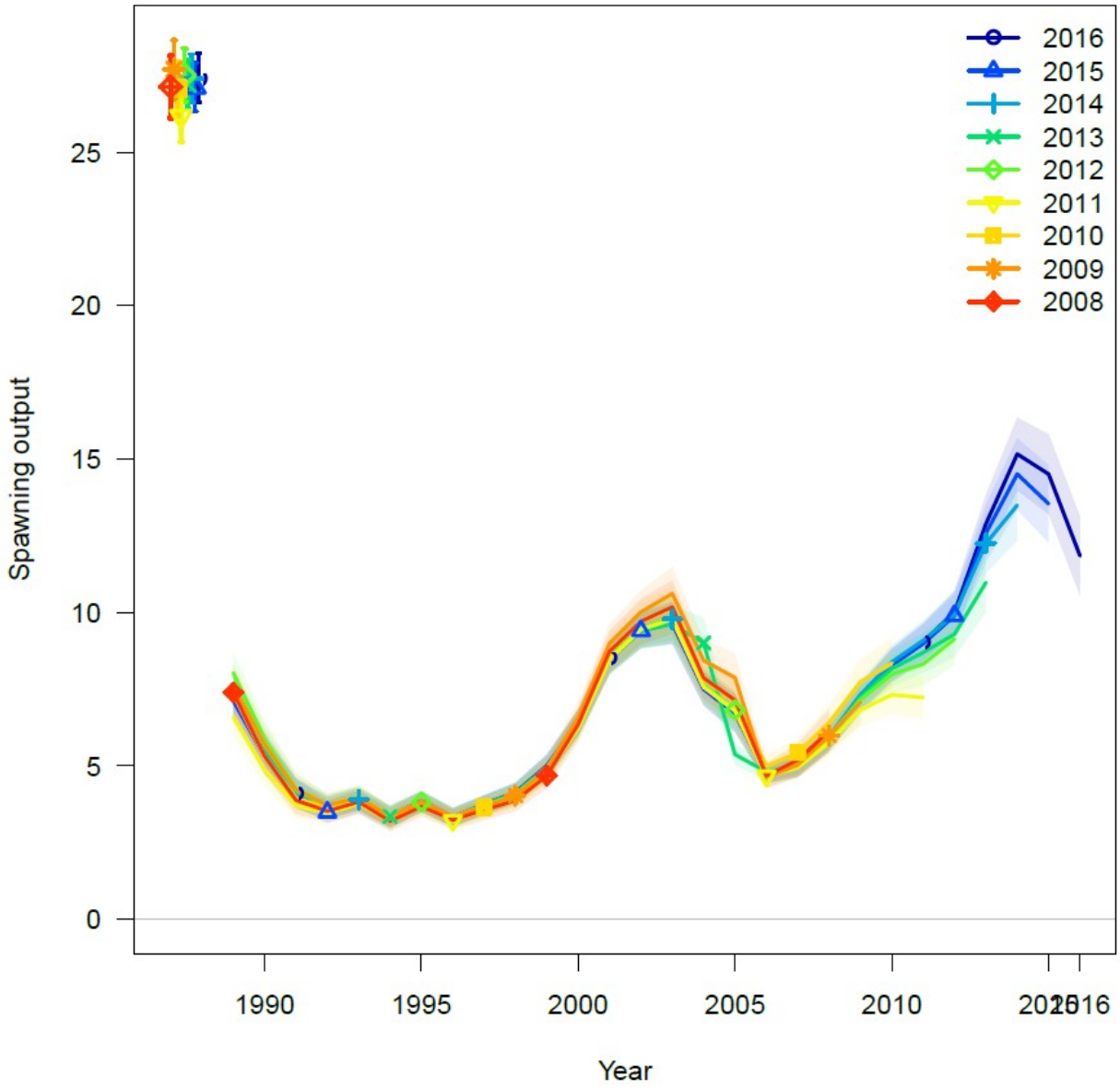

Figure A184. Retrospective analysis for black sea bass spawning biomass in SS exploratory model results

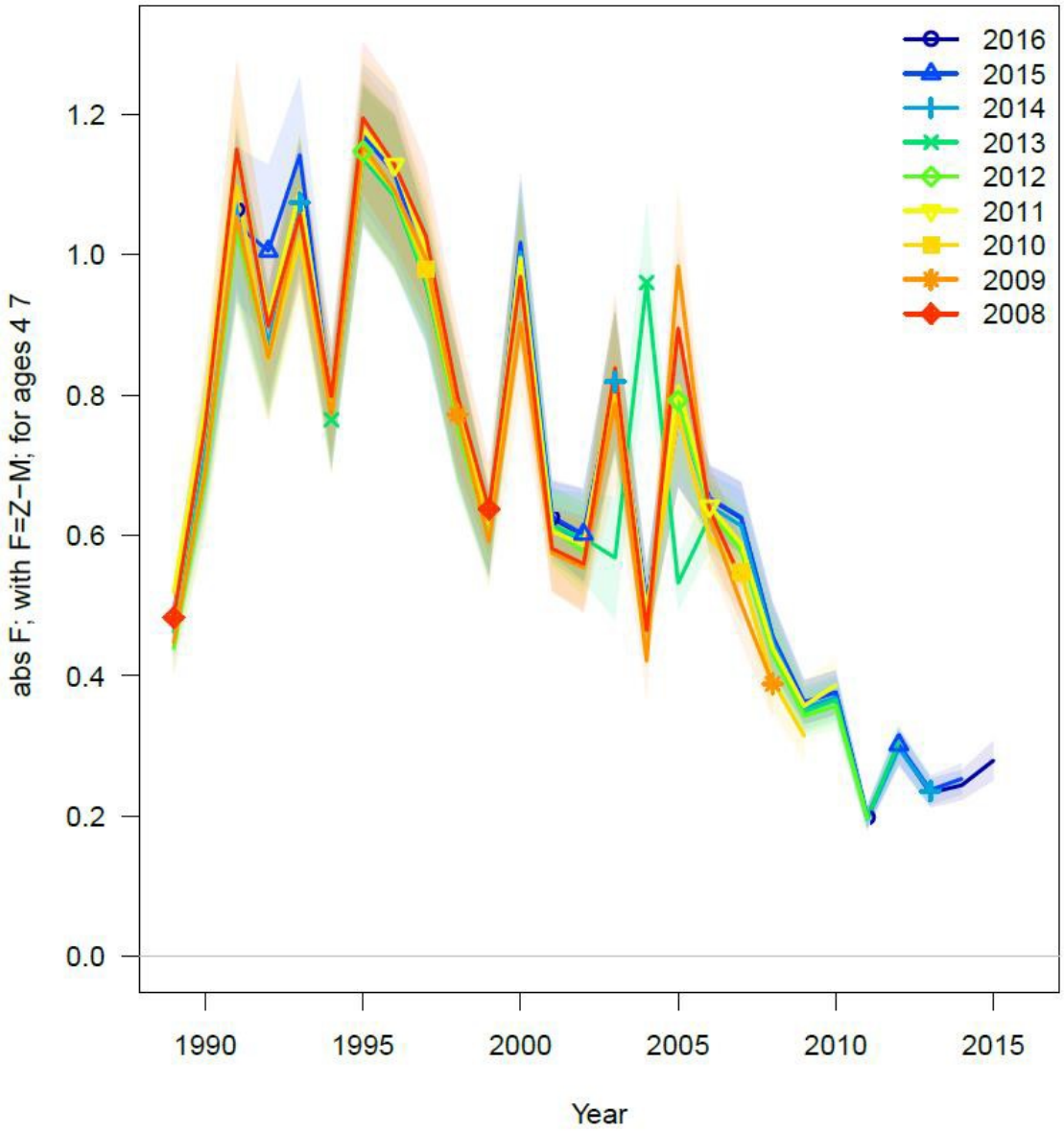

Figure A185. Retrospectives for time series of black sea bass fishing mortality in SS exploratory model results.

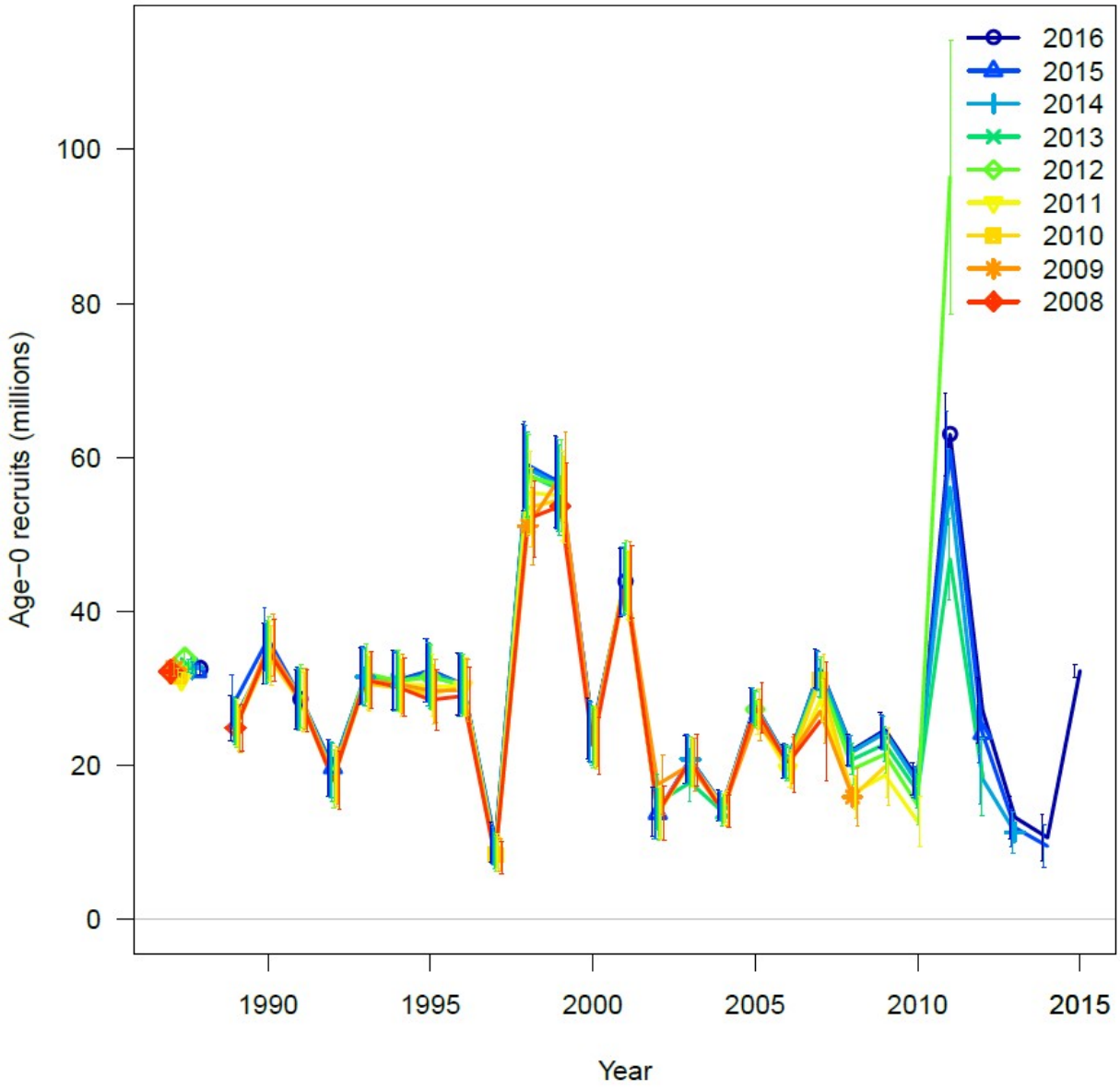

Figure A186. Retrospectives for time series of numbers of black sea bass Age 0 recruits (Recruitment in Table 1) in SS exploratory model results.

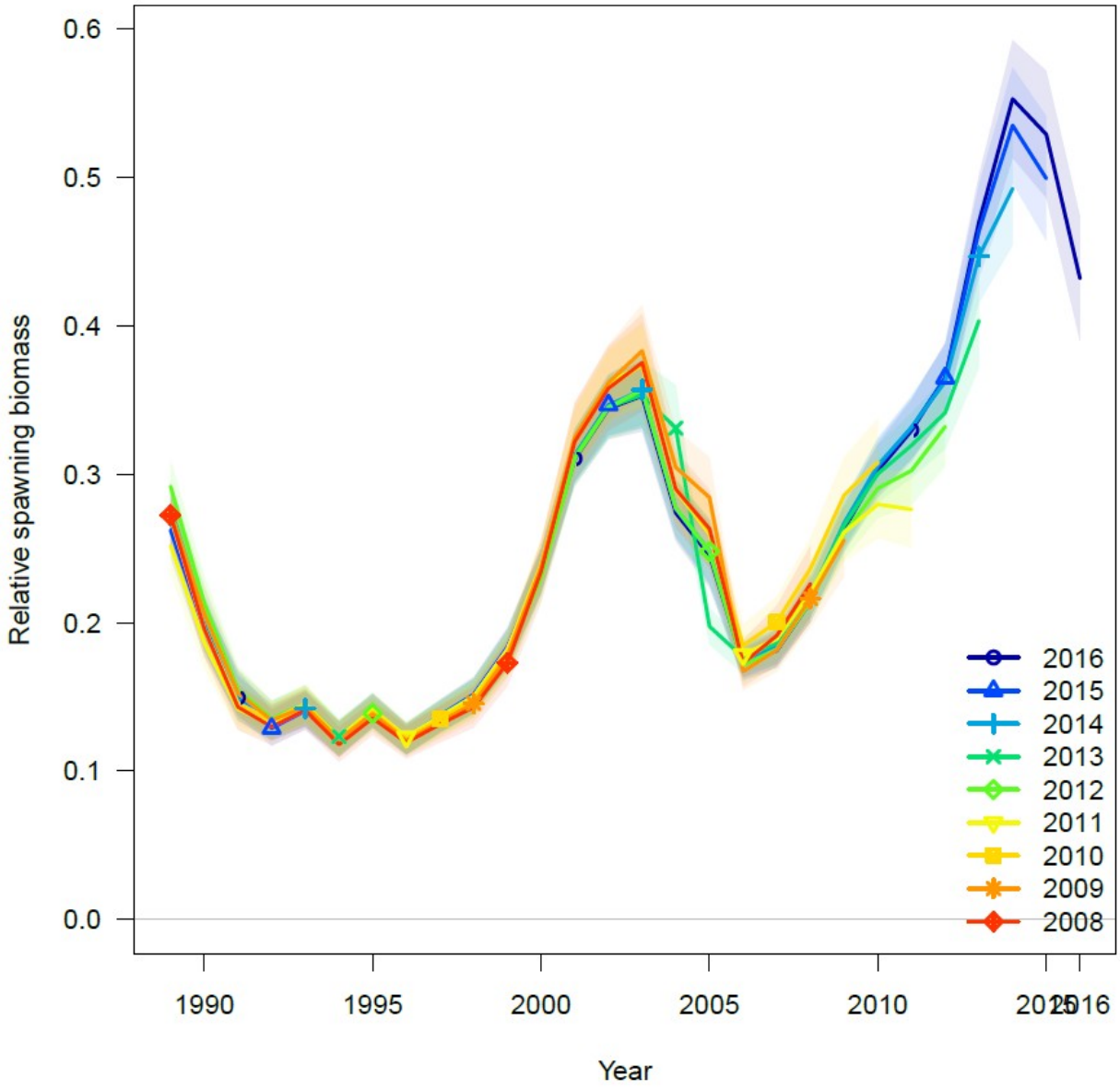

Figure A187. Retrospectives for time series of black sea bass relative spawning biomass (B/B0) in SS exploratory model results.

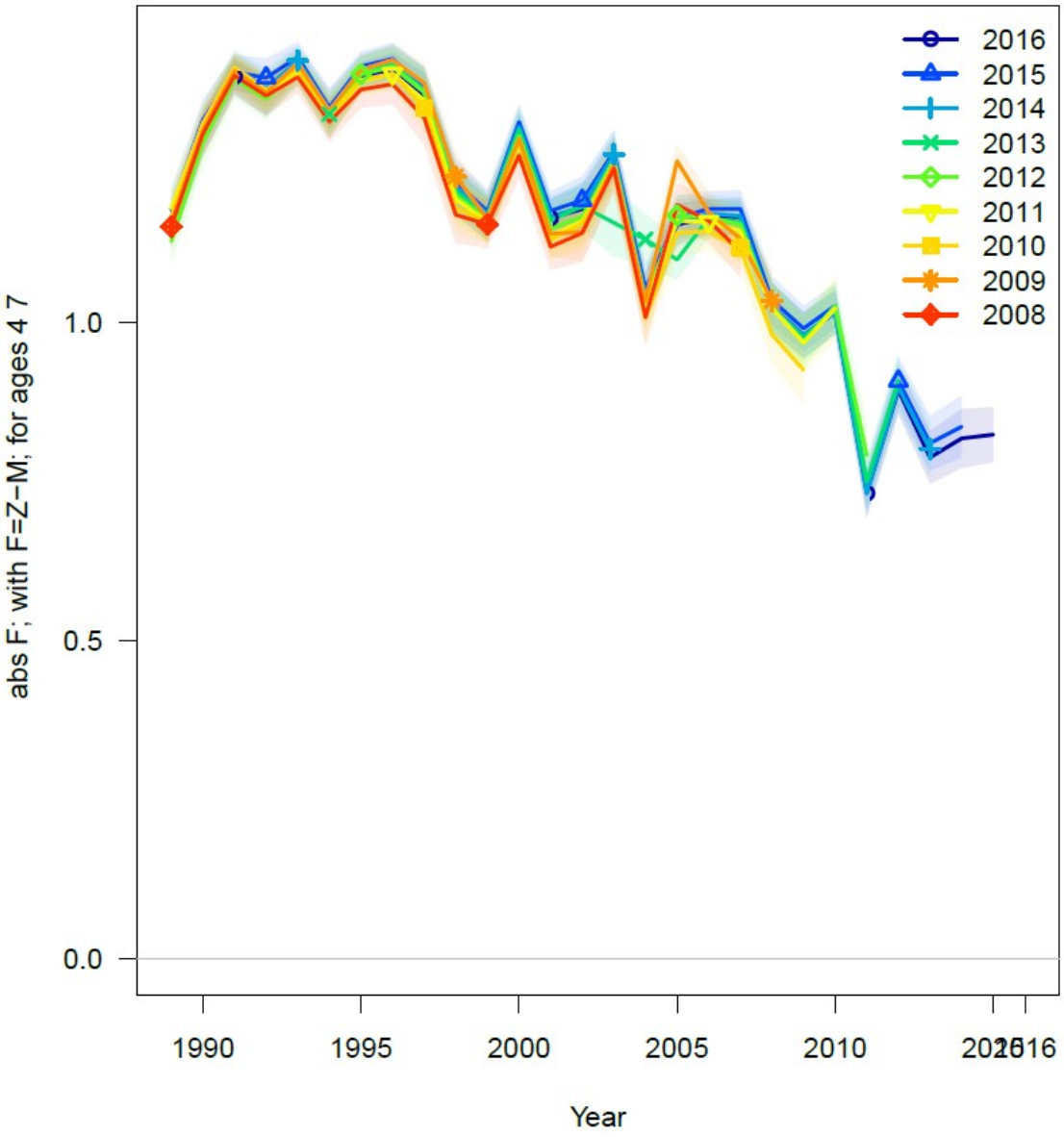

Figure A188. Retrospectives for time series of black sea bass F relative to F40% in SS exploratory model results.

Appendix A1- Black sea bass age validation and comparison among age readers

SARC 62 Working Paper

Validation of Black Sea bass, Centropristis striata, Ages Using Oxytetracycline Marking and Scale Margin Increments

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Abstract

Black sea bass age determination methods, as well as timing and periodicity of annulus formation were examined using scales and otoliths collected from the US commercial fishery and research vessel bottom trawl survey cruises. Edge analysis of 714 scale samples collected during 2011 was conducted. We examined both otolith and scale structures from 55 individuals marked with oxytetracycline sacrificed at regular intervals over two year period. Results indicated that annulus formation takes place annually during the summer (July-September) and that no other marks appeared on the scales or otoliths of marked individuals during the study period. A side-by-side comparison of precision and bias was performed between scales and otoliths, as well as, between laboratories. We concluded that scales and otoliths were of equal utility ageing black sea bass. There was good agreement between labs (82%); however the Bowker's test showed there was a bias. The bias was due to the disagreements between age 0 and age 1. Specific resolutions were established to clarify the bias; including processing methodologies and various calibrations to known ages. These validation and precision comparison results demonstrate that black sea bass ages from scales and otoliths from both laboratories can be used in the assessment.

Introduction

The black sea bass, *Centropristis striata* (Linnaeus), is a protogynously hermaphroditic serranid found off the east coast of the United States. This important commercial and recreational species is widely distributed on the continental shelf from Nantucket Sound, MA, southward to the Florida Keys (Miller 1959; Fisher 1978) with a maximum abundance between New Jersey and North Carolina (Kendall and Mercer 1982). Based upon several criteria including tagging studies, seasonal distribution, differences in time of spawning, and growth rates, Mercer (1978) defined black sea bass, north and south of Cape Hatteras , NC, as two separate stocks. The southern stock occupies coral and sponge reefs (Struhsaker 1969; Powles and Barans 1980) and does not appear to undergo seasonal migrations. Black sea bass north of Cape Hatteras inhabit coastal waters of the Middle Atlantic and southern New England regions during their spawning period from late spring to early autumn, but migrate to deeper waters along the continental slope for the winter months (Musick and Mercer 1977). Tag returns also suggested that individuals north of Cape Hatteras constitute a unit stock (Kolek 1990), and a study of meristic and morphometric characters indicated phenotypic variations occur latitudinally (Shepherd 1991). Analytical assessments of the northern stock of black sea bass have been hindered in part due to the lack of confidence on the age composition of the landings and population.

The first step in evaluating the age composition of a stock is to verify the accuracy and precision of the ageing method. Numerous studies examining the biology of black sea bass have used a variety of structures to age this species (Lavenda 1949; Dias 1971; Cupka et al. 1973; Briggs 1978; Mercer 1978; Alexander 1981; Low 1981; Link 1984; and Wenner et al. 1986). Lavenda (1949) aged black sea bass collected off New Jersey from cellulose acetate impressions of scales and described annuli as “bunching of circuli” assumed to form during winter. This method was not validated however, and subsequent studies suggested that Lavenda’s ages were overestimated (Dias 1971; Mercer 1978; Link 1984). The only study to attempt a validation of ages derived from examination of black sea bass scales was conducted by Briggs (1978) using marginal increment analysis and back-calculation. However, the results of this study had limitations since sample size was small and the coverage area did not represent the entire northern stock. If black sea bass ages derived from scales are to be used, to conduct proper analytical assessments, accuracy of those ages needs to be ascertained by collecting samples that cover the entire northern stock.

Otoliths have been used to age black sea bass from below Cape Hatteras (Cupka et al. 1973; Wenner et al. 1986), areas north and south of Cape Hatteras (Mercer 1978), and southern New England waters off of Long Island, NY (Alexander 1981). There have been various validation studies on black sea bass otoliths. Cupka et al. (1973) used otoliths from fishes collected off South Carolina and used back-calculation methods to validate his methods. Mercer (1978) examined otoliths from fish collected in the mid-Atlantic bight and used back-calculation, marginal increment and length-frequency modal analyses to validate ages. However both these studies only sampled southern and mid-Atlantic bight and due to the differences in growth patterns, might not representative of the northern stock.

Dias (1971) found otoliths to be superior to scales, vertebrae, and subopercular bones for black sea bass in Virginia waters. Dery (1985) indicated that examination of the sections of

pelvic spine and scales were acceptable alternatives to otoliths as ageing structures based on evaluation of average percent error (Beamish and Fournier 1981) values calculated between structures. Due to the different migration patterns and inhabitation displayed by the north stock, Black sea bass could have clearer marks deposited onto the scales compared to their southern counterparts. If that is the case, scale age estimates could be as precise as otoliths for northern stock black sea bass.

Age structures (scales or otoliths) were collected from the US commercial fishery by the National Marine Fisheries Service (NMFS), Northeast Fisheries Science Center (NEFSC) since 1980. The objective of this study was to validate age determination methods of black sea bass from the northern stock. To accomplish this, we used reference marks in both scales and otoliths formed by injections of oxytetracycline in laboratory-held fish, edge analysis and marginal increment analysis from samples collected from the commercial fishery and surveys to verify the timing and periodicity of annulus formation. Once accuracy and precision of both hard-parts are ascertained, we compared precision between hardparts and laboratories.

Materials and Methods

Edge Analysis

Edge analysis was performed on 714 scale samples collected monthly during January to December 2011 from the US commercial fishery (Table 1). All samples were comprised of black sea bass collected from waters north of Cape Hatteras, NC to Nantucket Sound (Figure 1). Scale samples were impressed on plastic laminate (Dery 1983) and viewed with a microprojector at 20x or 50x magnification. A combination of the aging criteria described by Lanvenda (1949) and Dery and Mayo (1988) were used to determine annuli, which they defined as “areas of closely spaced circuli with cutting and crossing-over marks, forming dark bands about the scale.” To examine annulus formation, presence or absence of annulus on the edge of the scale were made on each sample. Monthly percentage of presence/absence were plotted to determine timing and periodicity of annulus formation (Figure 2).

Timing and Periodicity of Annulus Formation

During May and June, 1990, 55 live black sea bass (25-43 cm total length, TL) were obtained from commercial fishermen and were transported to the NEFSC, Woods Hole Laboratory. Fishes were held in five 200-gallon aerated tanks filled with ambient water from the adjacent Great Harbor, Woods Hole, MA. Daily water temperatures and photoperiods were monitored and adjusted to simulate seasonal environmental changes. Individuals were fed to satiation three times a week on a diet of butterfish, herring, squid and clams.

After a one month acclimation period, experiments were performed on 16 individuals to determine appropriate methods of injection and dosages of oxytetracycline following procedures described by Weber and Ridgway (1962) and McFarlane and Beamish (1987). Individual black sea bass were separated into four groups, anesthetized in a 1.5 mg methylmodate/l sea water solution, measured (TL, mm), weighed (0.1 gm), injected with varying doses of oxytetracycline and tagged (Floy t-anchor type). Experimental dosages for the four groups were 15, 25, 50, and 75 mg oxytetracycline/kg of total body weight. In each group, two fish were given intraperitoneal and two given intermuscular injections.

Fourteen days after the injections, one individual from each injection-type and dosage group was sacrificed and scales and sagittal otoliths excised. Each structure was viewed at 2x magnification under epifluorescent ultraviolet light at 405 nm wavelength, 455 nm dichroic mirror, and 455 nm barrier filter. We determined that intermuscular injections at 50 mg/kg dosages, were the most effective for this species, providing clear, well defined fluorescent bands on the scales and otoliths. All remaining black sea bass (n = 39) were then tagged and injected inter-muscularly with 50 mg/kg dosage and placed in the holding tanks. Individuals were randomly selected and sacrificed at one to two months intervals for two years (Figure 3 & 4). To examine incremental growth and annulus formation, measurements (mm) from the last annulus to the edge of the scale and otolith were made on each sacrificed fish. Mean marginal increments were calculated in each monthly sample and mean monthly increments plotted to determine timing and periodicity of annulus formation (Figure 5).

Measures of Precision

A comparison of calcified ageing structures was conducted between the Northeast Fisheries Science Center (NEFSC) and the Virginia Institute of Marine Science (VIMS), two organizations that routinely age black sea bass samples from northern stock. The NEFSC supplied 200 paired otolith samples for this comparison. A single whole otolith from each pair was retained by the NEFSC and read whole following the Center's protocols. Specifically these whole otoliths were cleaned to remove sacculous membrane and read under a stereo dissecting microscope using reflected light against a black background in a petri dish containing water. Magnification ranged from a 12x zoom objective lens to a 50x zoom objective lens. The second otoliths of each pair were sent to VIMS to be sectioned under their current processing methodology and protocols.

At VIMS, the whole otoliths were first mounted to a thin square of Rite-in-the-Rain brand paper using a clear pliable bonding agent called Crystal Bond. The Crystal Bond is heated to 70 degrees Celsius in a Pyrex dish on a hot plate to create a viscous liquid state. The Crystal Bond will cool at room temperature and become a solid again within 30 seconds. The small paper squares used to mount the otoliths have a double line thin cross printed on them to properly position the otolith for sectioning. The otolith is positioned with the double vertical lines on the paper perpendicular to the succal groove while passing directly through the nucleus with the succal grove side of the otolith mounted down. The positioning takes place over a 10-15 second span while the Crystal Bond is hardening. A thin transverse section was cut through the otolith's nucleus, or core, using two diamond wafering blades on a Buehler IsoMet slow-speed saw lined up with the printed cross on the paper square. The two blades are spaced using three honed sections of old wafering blades that are 0.18mm thick. The transverse section was then cut to a 0.54mm thickness. The section was then mounted to a glass slide with Crystal Bond. The assigned number was written on the slide once the section was mounted. The sections were then polished briefly using 400-800 fine grit sandpaper and again covered over with Crystal Bond to assure the clarity in the section.

The samples were read under a stereo dissecting microscope with transmitted light using magnification of 25x zoom objective lens, which is preferred for standardization. 12x and 50x objectives were used occasionally depending on the size of the section and the number of visible annuli. Confidence of each read for a specimen was recorded. Confidence assignments ranged from 5 to 1, 5 being most confident and 1 being least confident. Factors that coincided with

confidence were light, opaqueness, deformations in the crystalline calcium structure and quality of the processed section.

To measure in between laboratories precision, a subsample of 200 fish representing both spring and fall of 2012 and 2013 Bottom Trawl Surveys (Table ?). Between and within reader precision was measured using Chang's (1982) average coefficient of variation (CV) with the formula presented in Campana and Jones (1992).

$$100\% * \sqrt{\frac{\sum_{i=1}^{R} \frac{(X_{ij} - \overline{X}_j)^2}{R-1}}{\overline{X}_j}}$$

Where Xij is the ith age determination of the jth fish, Xj is the mean age of the jth fish, and R is the number of times each fish is aged.

Measures of bias

A Bowker's test (Hoenig et al. 1995, Bowker 1948) was used to test for departures from symmetry within the age-frequency table. Such asymmetries indicate the presence of a bias, although the test has low sensitivity when few disagreements exist. Where ages differ from one another, the Bowker's test compares values on the age-frequency table which represent symmetric errors, such as the paired ages (3,4) and (4,3). If all such values are dissimilar, the test will return a significant P value. This test statistic is calculated as a chi-square variable, as follows:

$$X^2 = \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} \frac{(n_{ij} - n_{ji})^2}{n_{ij} + n_{ji}}$$

where m is the maximum age in the data set, and nij is the number of fish in the ith row and jth column (Hoenig et al. 1995, Bowker 1948). The value of the degrees of freedom is equal to the number of non-zero nij-nji comparisons in this calculation, to a maximum of m(m-1)/2.

Results

We aged and performed edge analysis on 714 black sea bass. Ages ranged from 2 to 5; reflecting the dominance of these age classes in the commercial landings. Percent presence of annuli on the edge for all ages had the same general pattern. Percent presence of annuli on the edge increased from about July to September, declined precipitously in October, and no annuli on the edge was found from November through June. These results suggest the black sea bass scales annulus formation took place during the summer months (July-September). Circuli spacing was relatively constant and there were no false annuli or spawning checks evident on the scales collected during the study period, indicating that annuli are formed annually for age groups 2-5.

Black sea bass injected with oxytetracycline had clear, compact, well defined fluorescent bands on scales and otoliths. This indicated that the tetracycline was incorporated within 24-48 hours of injection on only the newly developing edges of the structures (Figure 3 and Figure 4). Measurements and age determinations made on captive individuals marked with oxytetracycline showed the same annual pattern on their scales as the samples collected from wild fish. The age of these fish ranged from about 2-5, similar to the age composition of the commercial fishery. Injections were made at the time of annulus formation in June 1990 and the fish were sacrificed at one to two months intervals through two full growing seasons. It was not possible to track the growth or age of individual fish because all tags placed on the black sea bass at the time of injection were lost over the course of the study period. Fishes "removed" tags by biting and pulling them from others.

The laboratory study showed the same pattern of growth on the scales and otoliths in both years: increasing marginal increments from about September to May and minimal edge deposition from July to August. This corresponded exactly to the marginal increment pattern described for wild fish (Figure 5). Sacrificed individuals ranged from age 2-4 (4% age 2, 25% age 3, and 71% age 4) in 1991 and were age 4 (87%) and 5 (13%) in 1992.

Precision at the NEFSC using scales was quite high with a 90.6% agreement and a CV of 1.60%. Agreement for otoliths was a little lower with 88.9% agreement and a CV of 2.09%. Between scales and otoliths agreement was 75.3% agreement with a CV of 4.55%. None of the tests showed any bias. The VIMS sectioned otolith samples were independently read twice by each senior ageing personnel. Each read was temporally separated by two weeks to promote independence of these reads. After the VIMS first read, there was slight over-ageing occurring from the Reader 1 reads. Overall agreement was 77.6% with a high CV of 16.14%. Corrections were noted after the first round reads and second round read agreement had significant improvement. Agreement for the second read was 97.4% with a CV of 1.02%. Neither of the tests for the reads showed any bias. Ages from the second read were used as the VIMS final ages. Consensus ages were reached for the few samples that were still in disagreement after the reads and tests of symmetry were conducted. Agreement between labs using otoliths was good with an 82.1% agreement. However, the CV was high with 8.88% and there was systematic bias ($p=0.04$).

Discussion

Our study validated a method commonly used to age C. striata. Marks on scales and sagittal otoliths occurred annually, with no other visible marks. Annulus formation takes place once annually during the summer corroborating the results of Briggs (1978) and Dery (1985), either as minimized spacing of circuli, "bunching" with clear crossing over marks on the lateral sides of the scales, or the formation of hyaline zones on otoliths (Lavenda 1949; Dery and Mayo 1988). This is probably the result of minimized somatic growth and a transfer of energy to the reproductive process during this period. Oxytetracycline injections confirmed that sagittal otoliths and scales were both suitable structures for ageing this species. This is important since both methods are currently used, but from the standpoint of non-lethal and efficient collection and sample processing, scales would be the preferred ageing structure to use.

The importance of validating the accuracy of age determinations and attempting to validate all of the ages found in a population (Beamish and McFarlane 1983) cannot be

overstated. Important biological reference points used currently in the management of fisheries depend upon accurate age data. Yield and spawning stock biomass per recruit models, and cohort based analytical assessments are grounded on basic age data whether in the form of growth curve parameters, estimated mean size at age, or maturity at age.

The precision comparison between the NEFSC and VIMS of the 200 paired whole and sectioned otoliths was close to passing the 80% agreement standard set by the NEFSC Fishery Biology Program ageing group. The initial study compared the paired otoliths collected by the NEFSC and processed and read by the two agencies to their preferred methodology of ageing; NEFSC read whole otoliths while VIMS read transverse sections of the opposite pair. The overall agreement was 79.1% with a 9.96% CV and a p-value of 0.02, displaying some bias between the agencies (Figure 6). The error bars represent 95% confidence intervals. The bias derived from an age 0 and age 1 discrepancy. Despite the overall average passing minimum criteria, the two agencies agreed to take a further look into those discrepancies. Pictures of the samples in which there was a disagreement were taken by each agency to confirm their final ages.

After a period of time the precision comparison was revisited and the samples with the disagreements were reread by both agencies. The adjusted overall agreement after the rereads was slightly improved to 82.1% with an 8.8% CV and 0.04 p-value (Figure 7). The final ages from the second reread showed there was still a bias between the labs for ages 0. The age 0 sample bias from the original reads and the rereads is a byproduct of the clarity of the first annulus on sectioned otoliths versus the whole otoliths. The first annulus often forms very tight to the nucleus of the otolith, thus making first annulus location and assignment difficult. The bias resulted in samples under-aged by the NEFSC and overaged by VIMS. This bias only occurred for fish smaller than 15cms collected in the fall. Therefore we recommend that the stock assessment use only fish greater than 15cms in the fall.

Analysis of overall reader agreement spanning across several black sea bass workshops, exchanges and comparisons there has often been shows a peer-influenced bias resulting in higher agreement between readers and between across agencies at these juxtaposed workshops. In addition to the black sea bass workshops, this observation has been acknowledged with additional species workshops and exchanges. The improved (and almost perfect) agreement at these workshops is a result of verbal and physical bias. The proximity of additional readers often improved confidence of the readers, as well as influenced agreement, which resulted in a marginally improved overall agreement of the group at the workshop, opposed to the original independent reads. Additionally, readers could tend to drift from their calibrated reads over time. The drift should be considered a bias and should be accounted for by conducting calibration reads from a species specific sets of otoliths by that species with known established ages. Both VIMS and the NEFSC conduct calibration reads when it is applicable for final age assignment of a species. It should be noted that overall agreement for the two agencies passed necessary criteria to be declared acceptable for assessments. Further work between the two laboratories will continue to improve overall agreement for black sea bass as well as other managed species for various assessments.

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Table 1
Numbers of black sea bass collected in 2011 by size and by month for edge analysis

	Month												
Size (cm)	1	2	3	4	5	6	7	8	9	10	11	12	Total
25			1					1					2
26	1		2		1		1	2					7
27			5		2	1	3	3		2	1	3	20
28	2	3	4		6	1	4	5	5	6	10	7	53
29	4	4	4		6	4		6	5	5	11	2	51
30	10	2	4		3	3	3	10	6		4		45
31	9	5	4		5	1	1	4	6	2	2	3	42
32	10	2	4		5	1	5	5	3	5	13	1	54
33	7	2	5		7	5	9	2	5	1	9	3	55
34	6	2	5		14	5	12	3	1	6	5	3	62
35	1	1	4	1	3	1	8		2	9	4	9	43
36	5	5	1	1	5	2	10		2	9	2	8	50
37	1	7			3	5	3		5	9	3	3	39
38	1	5	4	2	1	2	2		1	7		3	28
39	2	4	1	2		2			3	3	1		18
40	1	3	4	1		3			5	1		3	21
41		5	1	2		1	1	1	3	1		2	17
42		2	4	4		3			2	2			17
43		3	2	2		2		1	5	1			16
44	1	1	1	4		6		1	1			2	17
45		2		2		3		1	1			1	10
46		1	1	3		2		3	3	2			15
47				4				2	1	1			8
48			2	5				1	1				9
49			1					1		1			3
50				2					1	4			7
51								1		2			3
53								2					2
Total	61	59	64	35	61	53	62	55	67	79	65	53	714

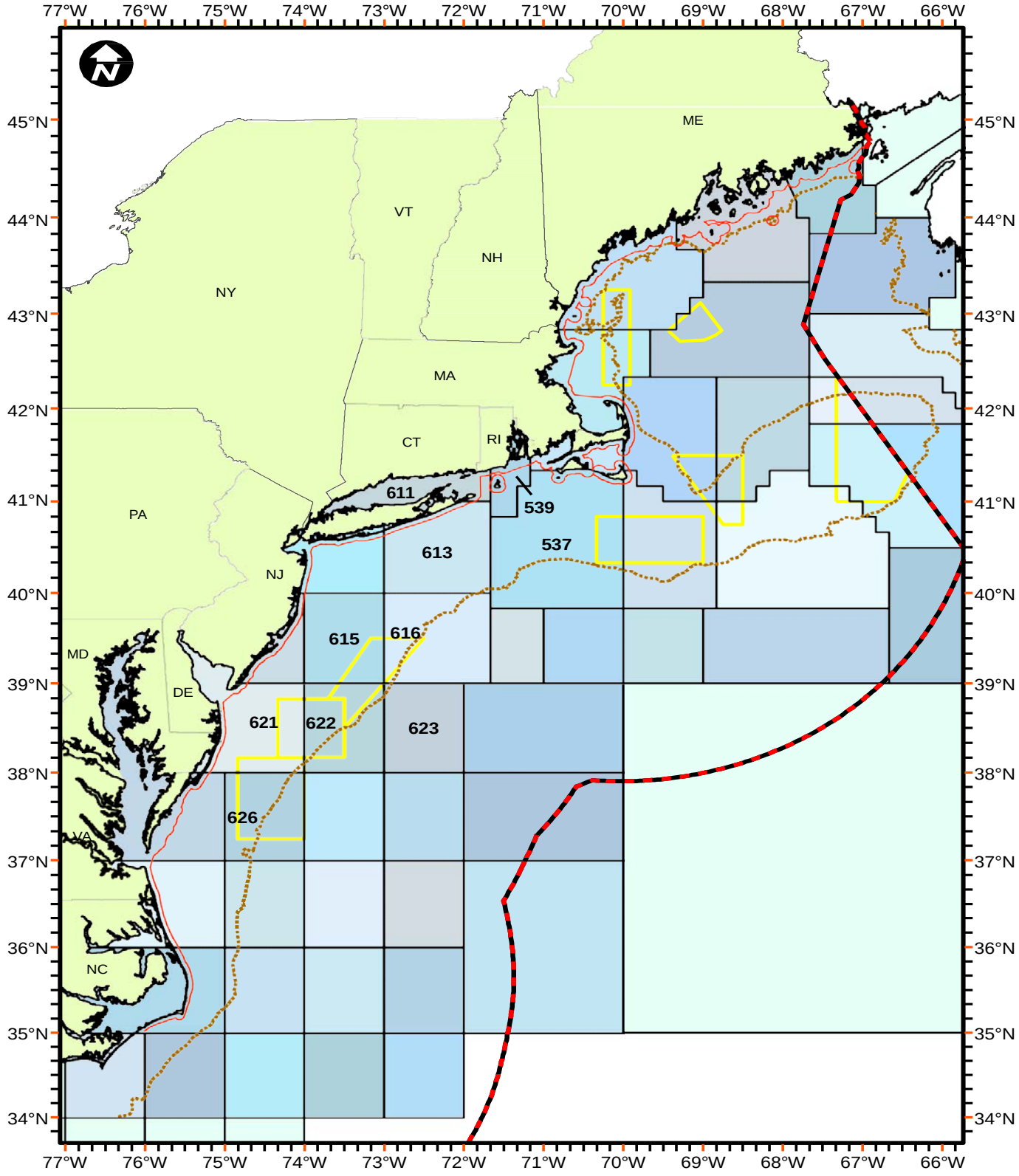

Figure 1. NEFSC statistical areas where black sea bass were collected in 2011 from the US commercial fishery.

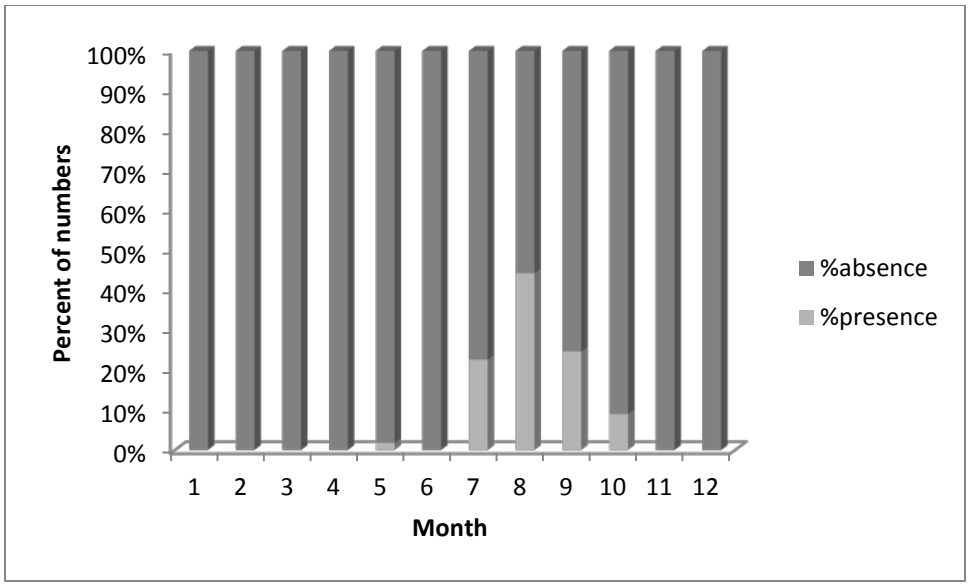

Figure 2. Percent absence and presence of annuli on the margin of scales from age 2 to 5 black sea bass collected in 2011.

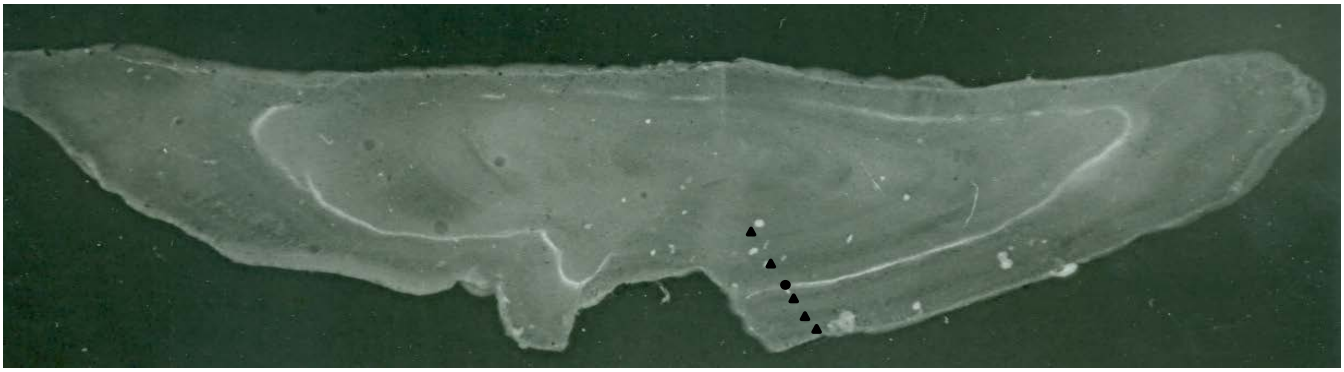

Figure 3. Otolith viewed under ultraviolet light from a 5 year old black sea bass injected with 50 mg/kg oxytetracycline in June 1990 and sacrificed in September 1992. Note distinct fluorescent band resulting from injection (solid circle) and 2 annuli preceding and following the mark (solid triangles).

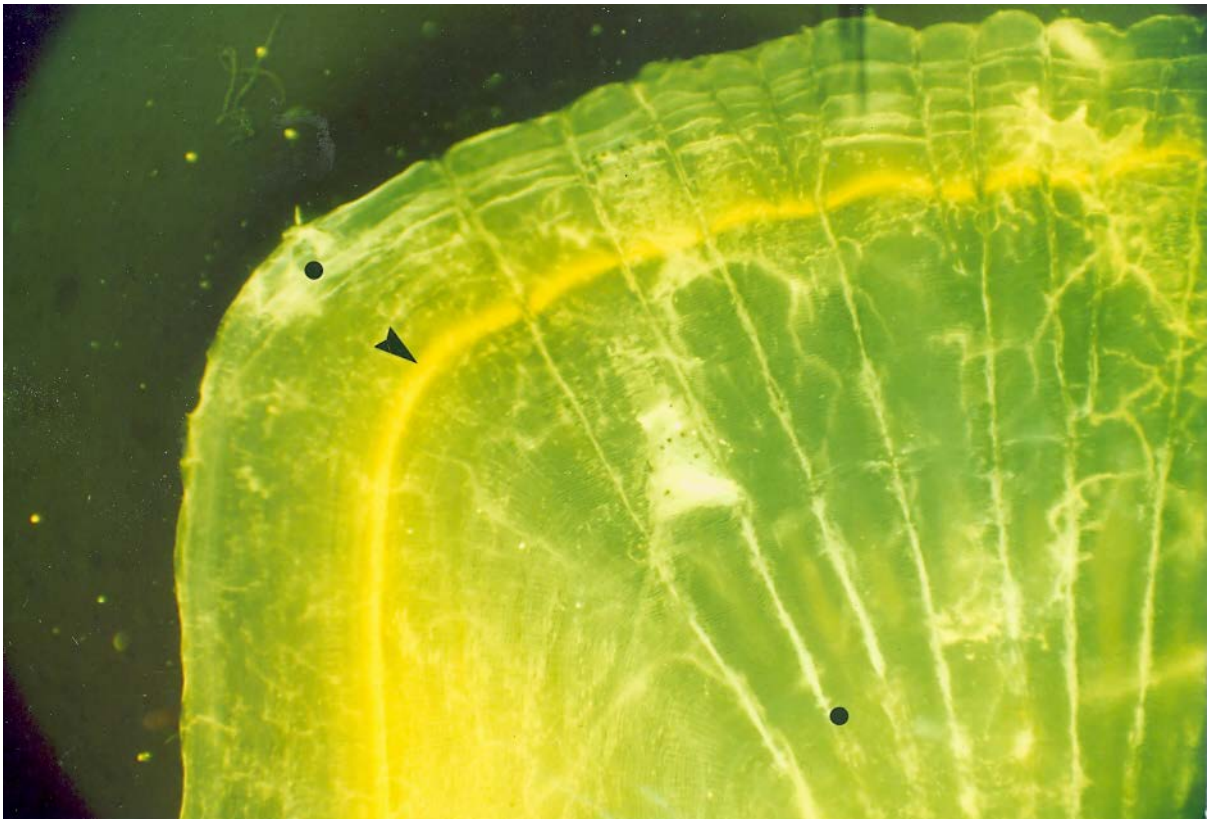

Figure 4. Scale viewed under ultraviolet light from a 3 year old black sea bass injected with 50 mg/kg oxytetracycline in June 1990 and sacrificed in September 1991. Note distinct fluorescent band resulting from injection (triangle) and 1 annuli preceding and following the mark (solid circles).

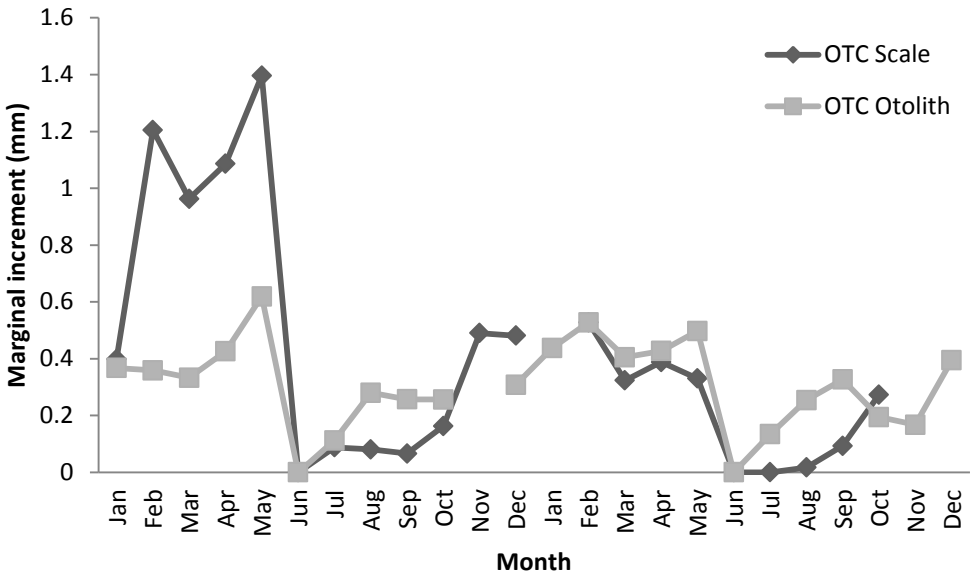

Figure 5. Mean monthly scale and otolith marginal increments measured from laboratory-held individuals injected with 50 mg/kg oxytetracycline in June 1990 and sacrificed at regular intervals during 1991 and 1992.

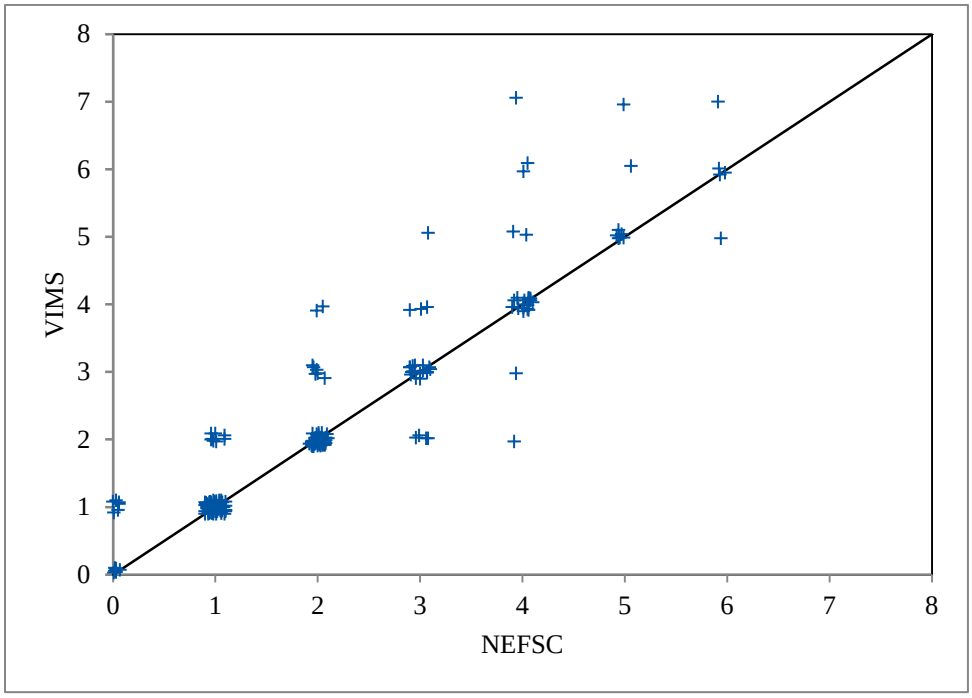

Figure 6. Precision comparison between NEFSC and VIMS original 79.1 % overall agreement. Results showed bias with age 0 samples.

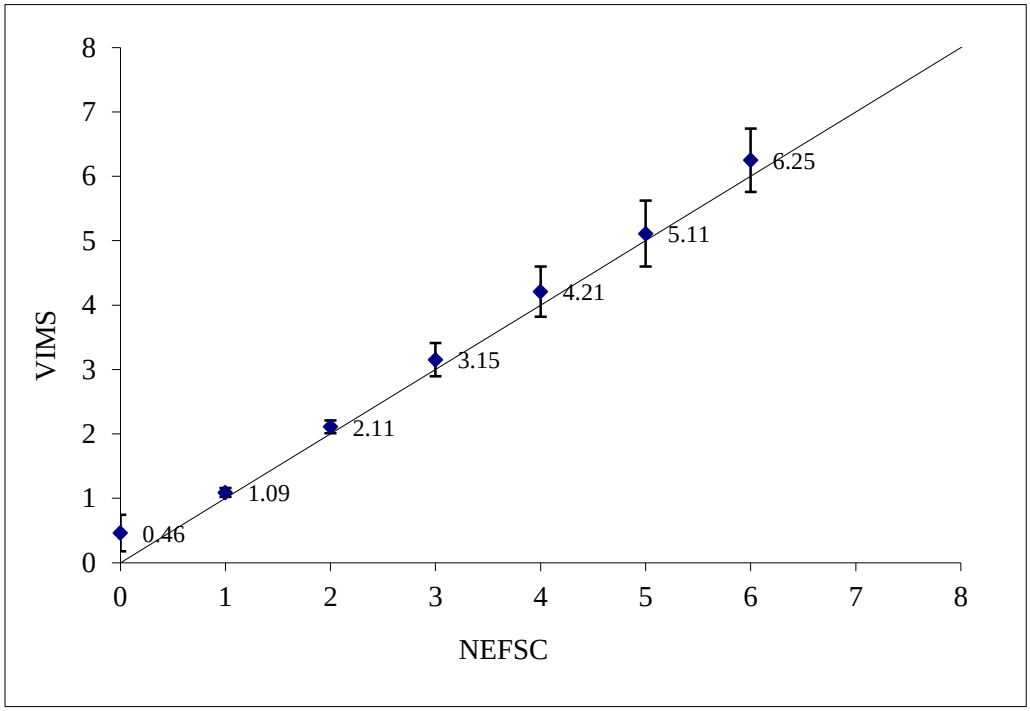

Figure 7. Second precision comparison results after bias was addressed between NEFSC and VIMS with 82.1 % overall agreement. Results still showed bias with age 0 samples.

Appendix A2- Report of NEFSC outreach efforts for SAW/SARC Black Sea Bass stock assessment

Port-Based Black Sea Bass Outreach Project

Executive Summary

From August 8 through September 8, 2016, NOAA Fisheries staff in the Northeast executed an outreach project to gather local ecological knowledge from fishermen about black sea bass habitat use and food habits. Stock assessment analysts are interested in the results, but the main objective of the project was to test methods for collaboration between the NEFSC and GAR to improve information flow with fishermen at the port level. Nearly 100 contacts yielded information on one or more questions, summarized in Tables 1-3.

The project centered around three questions from the lead stock assessment analyst. These were:

- Are adult black sea bass preying on juvenile black sea bass?
- Are other large fish eating a lot of adult black sea bass?
- Do you use black sea bass away from wrecks, reefs, piers and other structured habitat?

NEFSC and GARFO communications and outreach staff developed hand-out materials (Appendix) and note-taking protocols. NOAA Fisheries Greater Atlantic Regional Fisheries Office port agents, located at ports in New England and the mid-Atlantic, talked mostly with fishermen (anglers, charter/party, and commercial fishermen) about these questions during their regular rounds and made notes on these conversations. Respondents also included academics and bait-and- tackle shop staff. Most of the gear types were some kind of hook – either rod-and-reel (recreational) or hook-and-line (commercial) although fluke nets, pot/trap, draggers and otter trawlers were also represented.

Port agents who commented on the project afterward were very positive about being better looped into science important for fishermen. They also commented that having a few specific questions targeting a particular question or information gap proved an effective way of generating conversation. Ideally, these qualitative data would be incorporated into the data flow informing the assessment and at a minimum some feedback should go to them and by extension to respondents.

This suggests that leveraging port agent functions to gather ecological knowledge presents an opportunity to engage locally and in a meaningful way. This has multiple benefits, including more knowledgeable stakeholders, scientists, and port agents.

Results

<u>Cannibalism</u>

The fishermen who have seen cannibalism say that they see juvenile black sea bass in the stomachs of adult black sea bass. The frequency of observed cannibalism was only 7%.

Table 1. Responses from fishermen if they have observed cannibalism of juveniles by adult black sea bass, combined by region.

State	No Response	Cannibalism NOT present	Cannibalism Present	Grand Total
NH/MA/RI	2	18		20
NJ	2	42		44
NY	1	20	2	23
MD/VA	1	2	4	7
Grand Total	6	82	6	94

Predation

Primary adult sea bass predators observed by fishermen were dogfish, bluefish and striped bass. Others listed were sharks, monkfish, cod, cormorants, tuna, mahi mahi, and flounder (mostly juveniles).

Table 2. Responses from fishermen regarding adult black sea bass predators, combined by region*.

	Predators (frequency)					
State	**Bluefish**	**Striped Bass**	**Sharks/Dogfish**	**Birds**	**Others**	**No Response**
NH/MA/RI	6	6				13
NJ	12	2	6	2	4	7
NY	9	6			2	2
MD/VA	4		3		2	2

*This was based on what species the fisherman named, most named multiple species so this will not add up to 94

Habitat Use

Quite a few fishermen say that they've caught black sea bass on sandy and open bottoms. A few said open water and others said artificial reefs, outfall pipes and even fish pots.

- MA:
  - Mostly recreational (rod-and-reel/hook-and-line) in open bottom. Of these 12 responses, 7 caught fish on open bottom (2 were blank, 3 no)

- MD:
    - Only 2 responses (university researcher and hook-and-line party boat), neither of which were open bottom. University researcher said he saw BSB primarily "near" structures (<1 mile).

- NH:
    - Only 1 response, recreational fisher (rod-and-reel) not on open bottom.

- NJ:
    - 44 responses (20 yes to open bottom, 15 no to open bottom, 9 blank). Of the yes to open bottom, 4 were from rod-and-reel (split between bait and tackle shops and charter party boats). Of the commercial vessels, they used pots (4), gillnets (1), draggers (1), and a fluke net (1). The remaining 9 yes responses were hook-and-line from bait and tackle shops (1), rec fishermen (2), and party boat charters (6).

- NY:
    - 23 responses (15 yes to open bottom, 2 no, 6 blank). Of the 4 commercial vessels, BSB were collected by otter trawl (2) and lobster/fish pots (2). 7 party boat charters and 2 rec fishermen were using hook-and-line. 1 scuba diver used a spear and 1 rec marina manager used hook-and-line.
    - Some say BSB were caught while fishing for fluke on sandy bottoms and over mussel beds with other groundfish. Some guys are saying that fish pots are structures so BSB are naturally attracted to them, even if they are not meant to catch BSB specifically.

- RI:
    - All were found in open bottoms (7 responses). 2 of the 7 were commercial vessel/fleet manager, both using otter trawl. The remaining 5 were all rod-and-reel (3 on party charter boats and 2 rec fishermen).
    - There was a note saying that it's common to see BSB in open waters because they are eating crustaceans and some say they are being caught while fishing for fluke in the sandy bottoms.

- VA:
    - Only 1 yes to open water response by a commercial vessel using rod-and-reel (3 no's and 1 blank).
    - There was a note mentioning that the trawlers catch a lot of BSB in open water while the fish are moving.

Table 3. Responses from fishermen if they have observed black seas bass around structured habitat (wrecks, reefs, etc) or in open water, combined by region.

State	No Response	Structure	Open Bottom	Grand Total
NH/MA/RI	3	3	14	20
NJ	9	15	20	44
NY	6	2	15	23
MD/VA	1	5	1	7
Grand Total	19	25	50	94

Table 4. Responses from fisherman regarding their gear type while observing black seas bass around structured habitat (wrecks, reefs, etc) or in open water, combined by region.

	No Response			Structure			Open Bottom			
State	**Net**	**Hook**	**No Response/ Other Gear**	**Net**	**Hook**	**No Response/ Other Gear**	**Net**	**Hook**	**No Response/ Other Gear**	**Grand Total**
NH/MA/RI		2	1		3		3	8	3	20
NJ	2	2	5		12	3	3	13	4	44
NY		3	3		2		3	10	2	23
MD/VA		1			2	3		1		7
Grand Total	2	8	9	0	19	6	9	32	9	94

Appendix

2016 Black Sea Bass Outreach Project

NOAA FISHERIES

Northeast Fisheries Science Center

Three Questions About Black Sea Bass

Follow the project here: http://bit.ly/2aqxpPA

What we are doing

The NEFSC is trying some new ways to connect with fishermen about upcoming fishery stock assessments, like the one coming up for black sea bass. We are hoping to get more information from you on predation and habitat use. While we have data on both, we know that people who have on-the-water experience are also a great source of information. We also hope to learn more about how to better connect you with the science we do.

Our three questions

* Are adult black sea bass preying on juvenile black sea bass?
* Are other large fish eating a lot of adult black sea bass?
* Do you see black sea bass away from wrecks, reefs, piers and other structured habitat?

Any other specific information that could help us better understand black sea bass status

Why these three things?

Predation mortality is difficult to estimate. If there is cannibalism on juveniles then we need to learn more about it. For larger, older black sea bass, the most likely predators are fish that we do not sample often – for example tunas, sharks, very large bluefish. If predation is significant, we need to document it. Both natural and fishing mortality estimates are used to calculate total mortality. If adults spend significant time on rubble or softer bottom, then inshore trawl survey data may become more important to the assessment.

What's Next?

We'll summarize this information in a document for those working on the black sea bass assessment and post online with other assessment documents. It may help corroborate, refute, or explain results, identify research directions, and inform managers as they make decisions. **See our weblink for project updates.**

For more information

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U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service

Diver Outreach

to Support the Black Sea Bass Stock Assessment

Credit: Tracey Saxby, Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/)

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September 30, 2016

Executive Summary

This report describes the results obtained from a pilot outreach study conducted by the NOAA Northeast Fisheries Science Center (NEFSC) in September 2016 to gather qualitative information about black sea bass (BSB) predation and habitat use from the commercial and recreational diving community in southern New England. The objectives of this study were to obtain information to supplement the 2016 BSB Stock Assessment and to learn how to best engage people with on-the-water experience in the science conducted by the NEFSC.

This pilot study was successful and achieved both objectives within a relatively short timeframe. At least 90 divers provided observations that included information on the extent of the BSB population, potential BSB population trends, and BSB habitat use. Considering that project participants were providing observations from recent dives conducted for other recreational, commercial, or scientific purposes, they still provided useful information about the BSB population. This suggests that with advance notice of NEFSC science questions, the diving community can be an even more valuable source of information on fish populations and ecology.

Divers observed that the BSB population is growing and expanding into non-structured habitat areas including coves, eelgrass beds, and other inshore areas, as well as sandy and muddy habitats. Divers also noted that BSB are potentially outcompeting other fish like tautog. Despite not targeting predator-prey interactions, divers provided at least one observation of BSB cannibalism and offered feedback on the best way to obtain this type of information from divers in the future.

After reviewing the results of this pilot outreach effort, we offer recommendations for future data collection and outreach to the diving community. Most notably, future data collection efforts should take advantage of the ample time that divers spend in the water by communicating early in the season about the types of observations and locations where information is needed. Similarly, NEFSC could target specific types of divers (e.g., spear fishermen) for information on specific observations (e.g., predation). In terms of outreach, we recommend that future efforts use methodologies similar to what worked here (i.e, diver-to-diver personal interactions at existing meetings, dive shops, and club dives). It would also be valuable to attend larger events and dive expos in order to reach many members of the diving community at once. Divers were enthusiastic participants of this study, and would also be interested in seeing how their experience was used to inform fisheries science and management.

Table of Contents

Executive Summary 7

Table of Contents 8

List of Figures 9

1 Introduction and Study Objectives 10

1.1 2016 Black Sea Bass Stock Assessment 10

1.2 Engaging the diving community in NEFSC science 11

2 Methodology 12

2.1 Team structure, project management and report development 13

2.2 Outreach – data collection and analysis 13

3 Results 14

3.1 Summary of outreach 14

3.2 Black Sea Bass predation and habitat use 15

3.3 Outreach to the diving community 16

4 Conclusion and Recommendations 16

Recommendations regarding future outreach and data collection *17*

Appendix A: Google Form 19

Appendix B: Commercial fishing outreach handout 20

Appendix C: References 21

List of Figures

Figure 1. Map of the Black Sea Bass diver outreach study area. 12
Figure 2. Organizational chart of the Black Sea Bass diver outreach project team and information flow. 13
Figure 3. Primary ports from which divers originated in the Black Sea Bass diver outreach project..... 15

1 Introduction and Study Objectives

In September of 2016, the NOAA Northeast Fisheries Science Center (NEFSC) conducted outreach to the commercial and recreational diving community with the intent of gathering qualitative information about black sea bass (BSB) predation and habitat use from people who spend time on and in the water and are likely to observe fish activity. The objectives for this outreach were twofold; to inform the 2016 BSB Stock Assessment and to learn how to best engage people with on-the-water experience in the science conducted by the NEFSC.

1.1 2016 Black Sea Bass Stock Assessment

Black sea bass have a broad range, inhabiting Atlantic coastal waters from the Gulf of Maine to Florida and the Gulf of Mexico. The species occurs in three distinct populations – the northern stock, which is relevant to this study, occurs north of Cape Hatteras, NC, with most fish concentrated in the area between Cape Hatteras and Cape Cod, MA. There's also a southern stock occurring south of Cape Hatteras and a separate Gulf of Mexico population. During the warmer months from May to October, BSB concentrate closer to shore in depths of less than 120 feet. In the cooler months, BSB can primarily be found further offshore in depths of 180 to 360 feet or greater. There is evidence that BSB may recently be occurring in higher numbers at the northern end of its range as a result of rising ocean temperatures.

Black sea bass commonly inhabit rocky bottoms or other areas with structure, such as around reefs, wrecks and jetties. However, anecdotal evidence and data from inshore trawls suggest BSB are not exclusive to rocky or structured habitat. Black sea bass typically feed on a variety of small fishes, crabs, shrimp, squid, and clams. Predators include weakfish, bluefish, striped bass, sharks, tunas, and potentially other BSB depending on the age and size of the fish.

Black sea bass are a popular commercial and recreational fish species. Commercially, BSB are typically caught using pots, otter trawls or by hand-line. The recreational fishery accounts for a large percentage of the total catch, primarily via rod-and-reel. The fishery is managed jointly by the Atlantic States Marine Fisheries Commission (ASFMC) and the Mid-Atlantic Fishery Management Council (MAFMC) through the Summer Flounder, Scup and Black Sea Bass Fishery Management Plan. Black sea bass may potentially become a more important commercial and recreational fishery in southern New England due to possible increased population from rising ocean temperatures and due to declines in other fisheries in the area, such as lobster.

The Northeast Regional Stock Assessment Workshop (SAW) is the formal scientific process for preparing, presenting and reviewing stock assessments for managed fish species. Stock assessments evaluating the status of fish populations are prepared by working groups, peer-reviewed by independent experts, and presented to managers to inform fisheries management decisions, such as determining catch limits or understanding how fisheries may respond to management measures or natural changes. Stock assessments are developed using statistical models that rely on fisheries-dependent catch data, such as vessel trip reports, and fisheries-independent survey or observational data, such scientific trawl surveys.

Stock assessments may also be supplemented with qualitative information from commercial and recreational operators or scientists who observe fish species.

The 2016 BSB Stock Assessment is scheduled to be completed and peer-reviewed by the Stock Assessment Review Committee (SARC) during SAW/SARC 62 review from November 29 to December 2, 2016. The previous stock assessment for BSB was conducted and reviewed in 2011 during the 53rd SAW. During the 53rd SARC, the review panel rejected the stock assessment, due in part to the reliance of the stock assessment model on data from inshore trawl surveys, which do not sample complex structured habitat areas where BSB are known to frequent. An additional factor that affected the reliability of the model was the difficultly in estimating BSB mortality due to predation or other natural causes.

Therefore, the NEFSC decided to engage the fishing and diving communities to obtain information on both predation and habitat use to supplement and support the interpretation of stock assessment results during SAW/SARC 62 in 2016. This resulted in specific questions aimed at obtaining qualitative information about which fish are preying on juvenile and adult BSB and whether BSB are spending time away from structured habitat in areas that are better sampled by inshore trawl surveys.

1.2 Engaging the diving community in NEFSC science

A second objective of this study was to identify the best ways to connect with divers, and to determine divers' level of interest in providing information and participating in science conducted by the NEFSC. NEFSC has been engaging commercial and recreational anglers in collaborative research and stock assessments, recognizing that people with on-the-water experience are great sources of information. Commercial and recreational divers are an obvious community to also engage due to the amount of time spent in and observing fish habitat. Collectively, the experience within these communities represents a source of ecological knowledge that could be used to inform fisheries science and management.

Diving is an important commercial and recreational activity in southern New England, occurring in both the coastal zone and further offshore. Popular dive sites include a range of natural areas such as reefs, banks, canyons, and other areas with interesting habitat, as well as around manmade features, such as wrecks and artificial reefs. Divers also engage in a range of activities including wildlife viewing, photography and video, fishing and spearfishing, training and teaching, searching for historic and cultural artifacts, and scientific research. Consequently, there is a robust diving community that includes dive shops, charter operators, clubs and associations, and conferences and expos. This robust community provides an excellent opportunity for researchers to obtain anecdotal or qualitative evidence to support and inform scientific assessments.

2 Methodology

This pilot study aims to provide NEFSC with local, anecdotal, qualitative, ecological knowledge to supplement and inform the BSB stock assessment. While numerous stakeholders may have first-hand knowledge of BSB in the ecosystem, this study focused solely on commercial and recreational divers. A separate effort was conducted simultaneously by NEFSC to engage the commercial fishing industry on BSB behavior and ecology through NOAA National Marine Fisheries Service (NMFS) port agents.

Due to the distribution of the BSB stock, this study focused on engaging divers based in Southern New England, from Connecticut through coastal Rhode Island and Southern Massachusetts (Figure 1).

As a pilot project conducted in a short timeframe, the approaches used for this study were simple. There is the potential to expand the breadth and type of outreach in the future.

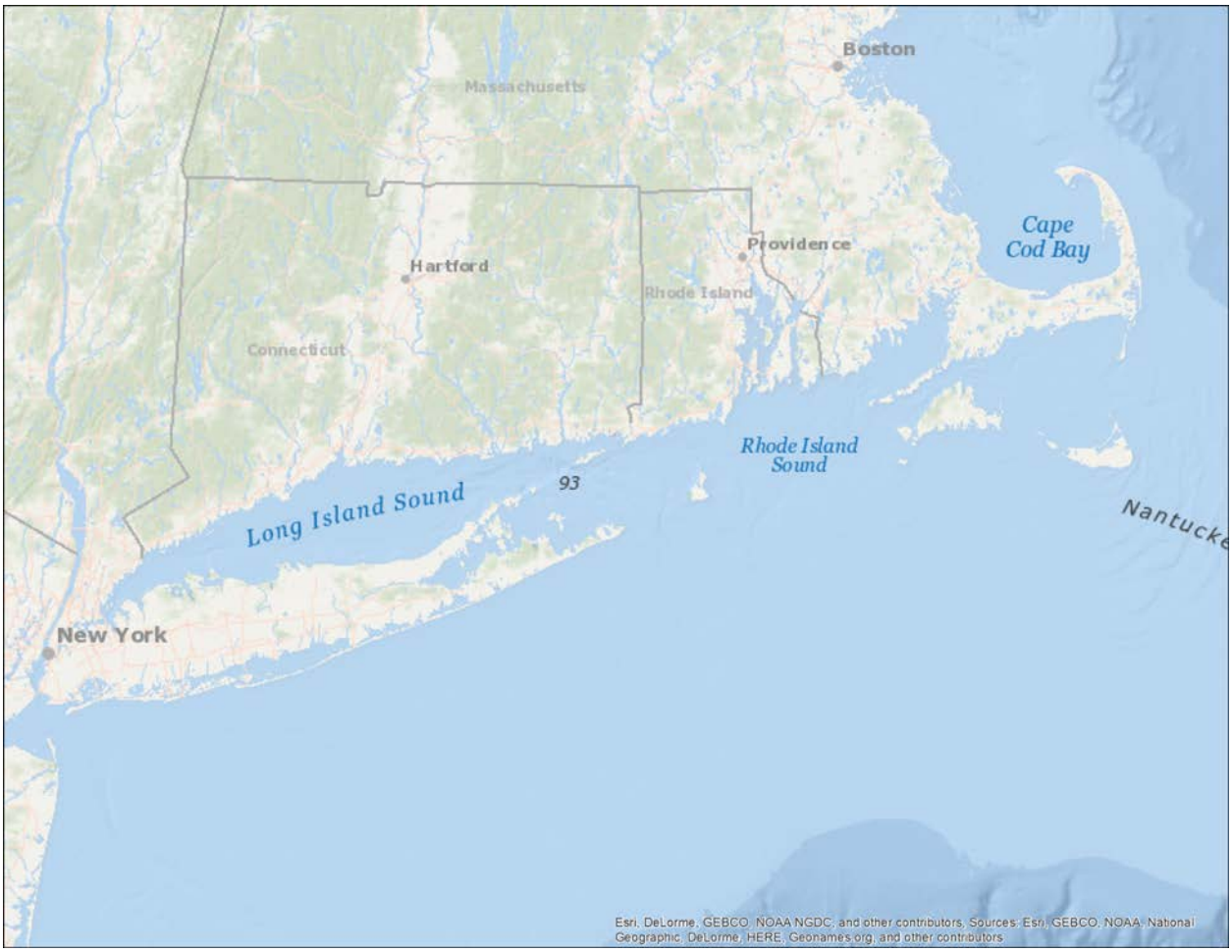


Figure 1. Map of the Black Sea Bass diver outreach study area.

2.1 Team structure, project management and report development

Overall project objectives, scope, and implementation were determined and coordinated by NEFSC. NEFSC developed the questionnaire and organized a project team through Integrated Statistics, Inc. that consisted of two main groups: the data collection team and the data analysis team (Figure 2). The data collection team included two well-respected and experienced divers who conducted outreach: Bill Palmer (based out of Connecticut) and John Langella (based out of Rhode Island). The data analysis team included a project manager who interacted with the data collection team to understand their methods, approaches and results, synthesized data, conducted background research, developed the report, and oversaw the project (N. Napoli); and a researcher, data synthesizer, and report developer (E. Shumchenia). The data analysis team delivered the final report to Integrated Statistics, Inc. and NEFSC, who coordinated its inclusion in the BSB Stock Assessment. Team structure and the flow of information are shown in Figure 2.

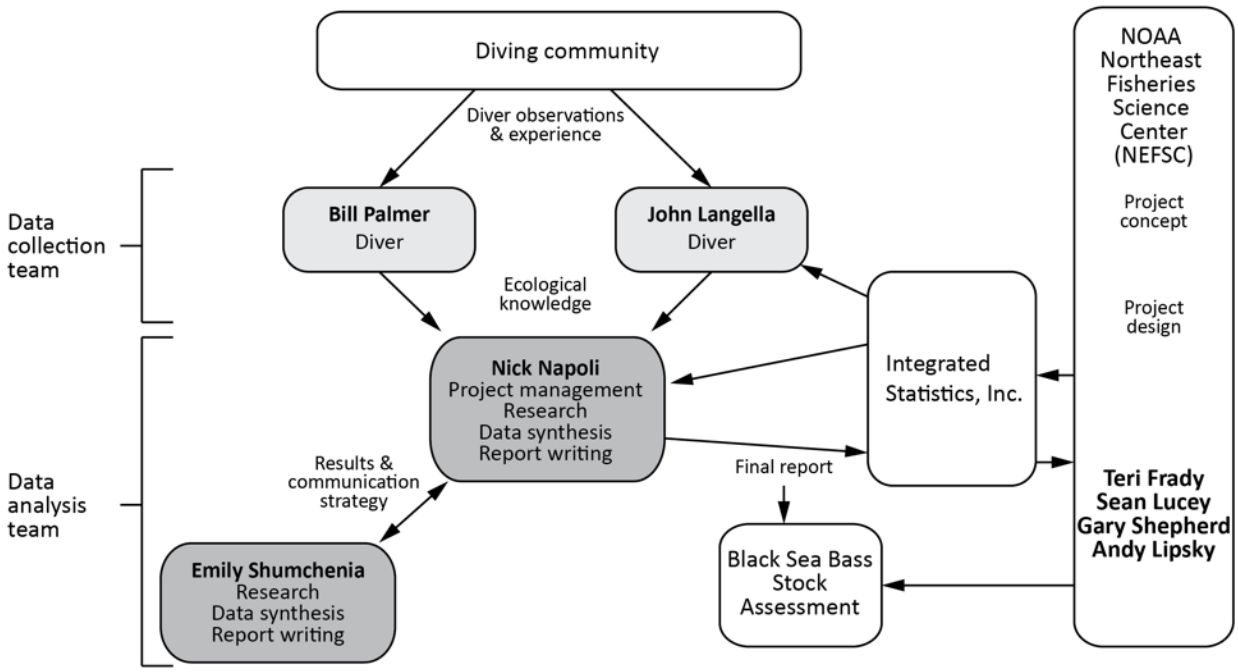


Figure 2. Organizational chart of the Black Sea Bass diver outreach project team and information flow.

2.2 Outreach – data collection and analysis

Direct outreach to the diving community was conducted by the data collection team. The data collection team personally interacted with divers directly at various local events, dive club and dive association meetings, and on charters. They also spoke with divers over the phone and via email.

For each conversation and/or interaction, the data collection team asked a series of brief questions and recorded information about where divers were based, and for what purpose they dive (e.g.,

recreationally or commercially). They also noted whether the divers were dive shop owners/employees or were members of a dive club or other local association.

In order to obtain information about BSB behavior and ecology, divers were asked to describe their observations of predator-prey interactions. Specifically, divers were asked to describe interactions where adult BSB have preyed on juvenile BSB as well as interactions where other fish species may have preyed on adult BSB. The data collection team requested information about the location and habitat setting of any BSB observations that were shared by the diving community.

The series of questions asked by the data collection team were intentionally simple and the entire questionnaire was short to ensure that every interaction was brief and informal. After each interaction, the data collection team entered the responses of the interviewed divers into a Google Form where the responses were recorded (see Appendix A). The form results were then delivered to the data analysis team. In a separate study, the same questions were asked of commercial fishermen, and were included in a flyer that was distributed among the fishing community. This flyer (Appendix B) may also have reached members of the diving community.

The data analysis team summarized the types of contact, the type of divers providing information, the number of responses, and the geographic distribution of the respondents. Based on all of the responses from the diving community, the data analysis team summarized observations of BSB habitat use and predation. Finally, through personal communication with the data collection team and analysis of the responses, the data analysis team developed an understanding of the divers' perception of this outreach study and prepared recommendations to NEFSC for future outreach to the diving community.

3 Results

3.1 Summary of outreach

All of the outreach for this effort was personal (i.e., conversational). The large majority of diver contact occurred in-person, with only a few conversations occurring via phone calls with the data collection team's personal contacts. In-person outreach was conducted during charters, at dive shops, with dive clubs, and at events where the diving community is usually present (e.g., beach clean-ups, spearfishing competitions, and club dives). As such, the majority of the divers providing information were recreational divers, dive club members, and dive shop owners and staff.

We estimated conservatively that between 90-100 divers were engaged through this effort. Total engagement was estimated because a proportion of the outreach was conducted at group events. For example, there were instances where the data collection team presented questions and held discussions with an audience or group of greater than 10 individuals at a time, by attending a club dive or other event. In these cases, the data collection team noted an individual's responses as well as group consensus on a particular topic.

Respondents were based in Connecticut, Rhode Island and southern Massachusetts. Specifically, divers who responded were located between Fairfield County, CT and Boston, MA. Figure 3 shows the primary ports from which divers originated, but it is likely not comprehensive because some divers did not provide this information.

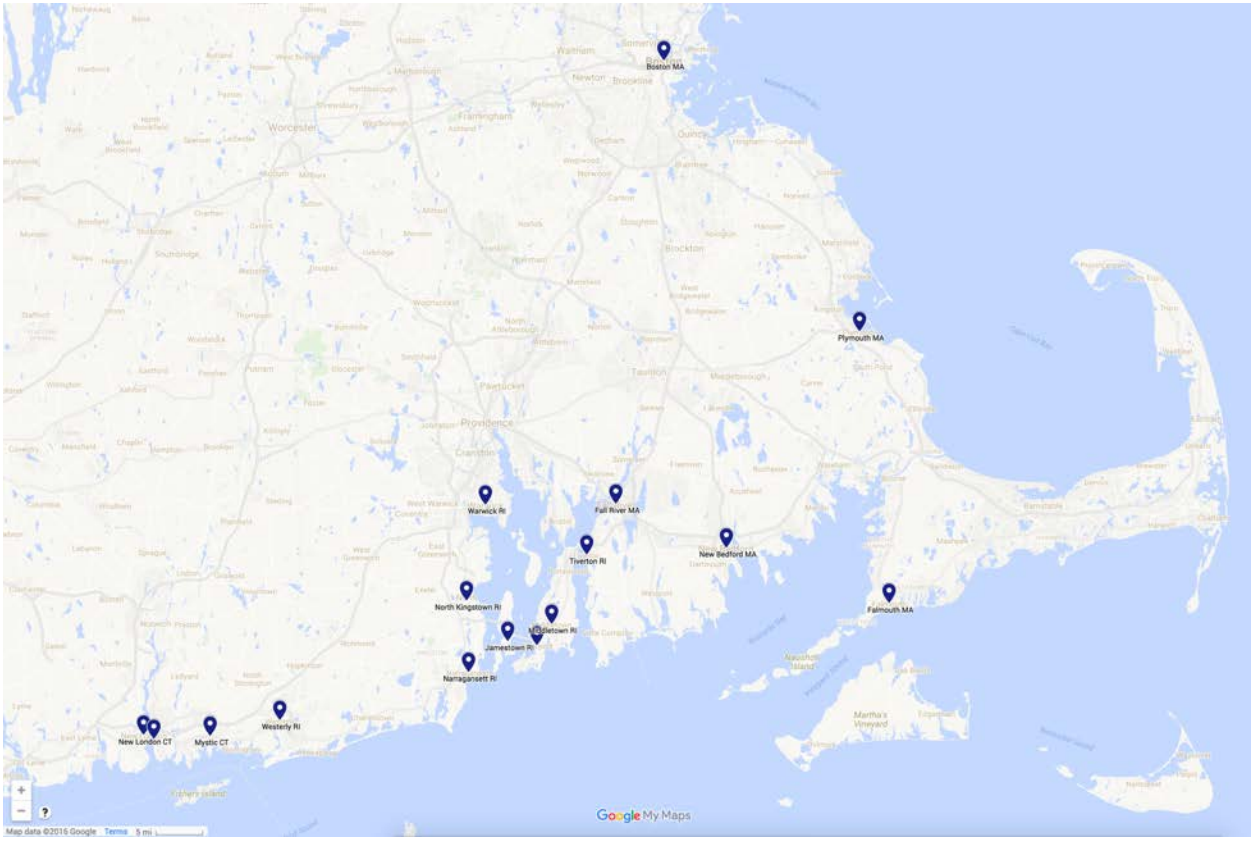


Figure 3. Primary ports from which divers originated in the Black Sea Bass diver outreach project.

3.2 Black Sea Bass predation and habitat use

One diver reported seeing a small BSB in the stomach of a large BSB when cleaning a speared fish. However, the majority of divers did not observe any predation events involving BSB (either as prey or predator), primarily because they were not deliberately looking for this type of behavior. Several divers noted that spear fishermen in general are the type of diver most likely to observe predation directly, or to obtain information about predation via stomach contents when they are cleaning fish. Additional diver suggestions included deploying video cameras in areas where BSB frequent, or reviewing videos and other imagery captured by divers themselves.

Divers' observations were largely concentrated in areas around structures or rocky areas; most divers did not specifically target soft bottom environments. The overall perception of the dive community was that the BSB population is growing. In addition, divers noticed BSB in more locations and habitats than in their previous experiences, with one diver indicating that BSB "seem to be taking over as a dominant

species." Another diver observed BSB in Narragansett Bay, where they had not observed them previously. There were several observations of BSB in areas where there used to be many tautog; these observations led to the divers' assertion that BSB are outcompeting tautog. There was a single observation of BSB in a muddy area, two observations of BSB in eelgrass, and one observation of several BSB in sand by a marine biologist collecting other samples. Many divers observed larger BSB than previous years, as well as many juveniles and smaller BSB. One diver noted observing many BSB near shore. A diver reported seeing BSB in Boston Harbor, and another reported seeing BSB in the Sakonnet River.

In summary, although there was a single indirect observation of BSB predation and several observations of BSB in soft bottom or nearshore areas, divers were not targeting these types of activities or locations for observation. If divers were aware of the interest in better understanding predation or habitat use, they likely could have provided more observations. Considering that divers were not prepared to collect information on predation and habitat use before their dives, they still provided generally good information about these activities—indicating that with advance notice, the diving community could be an even more valuable source of information on fish populations and ecology.

3.3 Outreach to the diving community

Divers were overwhelmingly willing to provide information on fish populations and ecology based on their observations in the field. Divers enjoyed sharing their experiences and appreciated the informal, brief, and diver-to-diver nature of the outreach.

When asked about their preferences for future outreach, divers indicated that individual outreach from other divers (as in this study) was preferred. Divers felt that attending dive club or association meetings, including individual club dives, were good ways to reach the community. In addition, divers mentioned specific dive shows, expos, or conferences that would provide good opportunities to reach many divers at once including *Beneath the Sea* and *Boston Sea Rovers* (see Appendix C for details).

At least one diver noted that he is more willing to provide observations from his dives than to share specific information about the location of dives due to concerns about potentially losing access to dive sites. Divers also indicated that they did not prefer responding via questionnaire (online or distributed), nor did they think that separate and specific meetings (i.e., outside of existing dive events/meetings) would be effective forms of engagement in the future.

4 Conclusion and Recommendations

This pilot study was successful and achieved both objectives within a brief time period (one month). Divers provided information on the extent of the BSB population, potential BSB population trends, and BSB habitat use. This study also found that divers were extremely willing to inform the science and offer feedback on the best ways to engage the diving community.

Diver observations indicate that the BSB population is growing and expanding into other habitat areas including coves and eelgrass beds, as well as sandy and muddy habitats. BSB are potentially outcompeting other fish like tautog. Divers shared many observations about habitat use even though they were not prepared to look for BSB and were not spending much time away from structured habitat. In the future, even more information (and potentially more detailed information) could be obtained if divers were asked prior to the dive season to observe specific habitat types and/or locations.

This study obtained limited information on BSB predation, but that was primarily because divers were not looking for it. Despite not targeting predator-prey interactions, divers provided at least one observation of BSB cannibalism and offered feedback on the best way to obtain this type of information from divers in the future (i.e., specifically engage spear fishermen). Overall, divers are excellent sources of information, and they are overwhelmingly willing to share information and experiences if they are approached by other divers and/or at their own events.

Recommendations regarding future outreach and data collection

- Use well-respected divers to help design outreach and communications to the diving community, and to make the actual contacts with divers to collect information.
- Develop flyers and a project website so that divers can understand project objectives, obtain more information, submit feedback, and see project results.
- Attend a few large diving related events and expos (such as *Beneath the Sea* and *Boston Sea Rovers* in the region, and the *Dive Equipment Manufacturers Association Show*, which is a large national event), which typically occur in the off-season for some of the regional diving community, to let divers know the kind of information that NEFSC is interested in obtaining in the coming year. Consider getting a booth or teaming up with other government agencies and environmental organizations who attend these events.
- Attend dive club events, diving association meetings, spearfishing competitions, beach cleanups, and other events throughout the season to collect information and remind divers about project objectives.

- Given that divers are enthusiastic and willing to provide information, consider asking and/or hiring divers to target specific areas, observe specific interactions, or even to deploy cameras to monitor an area of interest for a short period of time during a dive (such as an hour or two).
- Consider asking and/or hiring divers to review imagery and video collected by the dive community (note: review could be conducted during the off-season by individual divers or clubs/associations).

- Target divers who are spear fishermen or biologists for information about predation.
- Keep most outreach informal and brief, and allow divers who participate to maintain some level of anonymity.
- Post and communicate the results of every outreach project so that divers see how their information was summarized and is being used to support NEFSC science.

Annex A: Google Form

The Google Form can be accessed at: https://docs.google.com/forms/d/e/1FAIpQLSebWpCHxKx1ECsj2lLGH5FJKkV0Rnc6-fWkH-jdL1GXesKG5g/viewform

Black Sea Bass Diver Outreach

* Required

Date of collection *

Date
mm/dd/yyy

Collected by:

- John
- Bill
- Other :

Type of contact *

- In person
- Phone
- Email
- Other

Port respondent dives out of

Your answer

State

- CT
- MA
- ME
- NH
- NJ
- NY
- Other

Diver type

- Commercial
- Recreational
- Dive shop owner/operator/staff
- Dive club member

Have you seen evidence that adult BSB prey on juvenile BSB? *

- Yes
- No

If yes, how often do you see it?

- Frequently
- Occasionally
- Rarely

If yes, please describe what you see & when and where you see it

Your answer

Do you see evidence of other large fish preying on adult BSB?

- Yes
- No

If yes, please describe what you see & when and where you see it

Your answer

Other comments

Your answer

NEXT

Never submit passwords through Google Forms.

This form was created inside of National Oceanic and Atmospheric Administration. Report Abuse - Terms of Service - Additional Terms

Google Forms

Annex B: Commercial fishing outreach handout

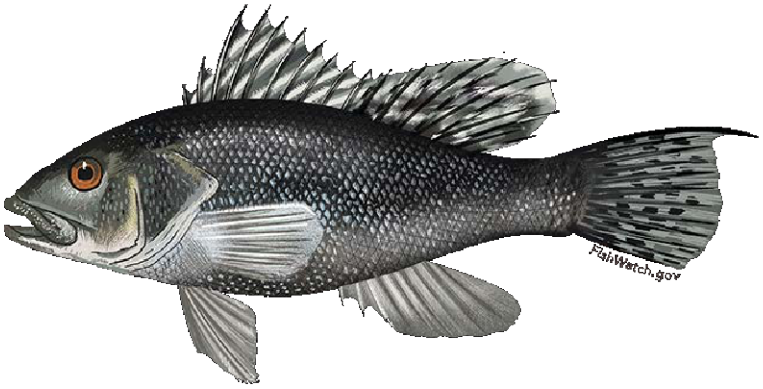
2016 Black Sea Bass Outreach Project

NOAA FISHERIES

Northeast Fisheries Science Center

Three Questions About Black Sea Bass

Follow the project here: http://bit.ly/2aqxpPA



What we are doing

The NEFSC is trying some new ways to connect with fishermen about upcoming fishery stock assessments, like the one coming up for black sea bass. We are hoping to get more information from you on predation and habitat use. While we have data on both, we know that people who have on-the-water experience are also a great source of information. We also hope to learn more about how to better connect you with the science we do.

Our three questions

* Are adult black sea bass preying on juvenile black sea bass?
* Are other large fish eating a lot of adult black sea bass?
* Do you see black sea bass away from wrecks, reefs, piers and other structured habitat?

Any other specific information that could help us better understand black sea bass status

Why these three things?

Predation mortality is difficult to estimate. If there is cannibalism on juveniles then we need to learn more about it. For larger, older black sea bass, the most likely predators are fish that we do not sample often – for example tunas, sharks, very large bluefish. If predation is significant, we need to document it. Both natural and fishing mortality estimates are used to calculate total mortality. If adults spend significant time on rubble or softer bottom, then inshore trawl survey data may become more important to the assessment.

What's Next?

We'll summarize this information in a document for those working on the black sea bass assessment and post online with other assessment documents. It may help corroborate, refute, or explain results, identify research directions, and inform managers as they make decisions. **See our weblink for project updates.**

For more information

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U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service

Appendix C: References

Background and Context for Black Sea Bass

Resource	Accessed via
Northeast Regional Stock Assessment Workshop	http://www.nefsc.noaa.gov/saw/
SAW/SARC Review Process	http://www.nefsc.noaa.gov/saw/pdfs/SARCprocess-1pager-2011.pdf
Terms of Reference for the SAW-62	http://www.nefsc.noaa.gov/saw/saw62/Final_SARC62_TORs.pdf
BSB Working Group	http://www.nefsc.noaa.gov/saw/SAW_WG/BSB_WG/
SAW/SARC Reports	http://www.nefsc.noaa.gov/saw/reports.html
SAW/SARC 53 Panelist Reports	http://www.nefsc.noaa.gov/saw/saw53/
53rd SAW Assessment Report (includes final decision on 2011 BSB Stock Assessment)	http://www.nefsc.noaa.gov/saw/saw53/crd1203.pdf
Bottom Trawl Survey Protocols	http://www.nefsc.noaa.gov/publications/crd/crd1406/crd1406.pdf
BSB EFH Source Document	http://www.nefsc.noaa.gov/nefsc/publications/tm/tm143/tm143.pdf
ASMFC	http://www.asmfc.org/species/black-sea-bass
MAFMC	http://www.mafmc.org/sf-s-bsb/
Gary Shepherd, NEFSC, BSB lead assessment scientist	Personal communication in September 2016

Diving

Resource	Accessed via
Bill Palmer, diver and charter captain	Several personal communications in September 2016; http://thunderfishcharters.com/
John Langella, diver and charter captain	Several personal communications in September 2016
Characterization of Coastal and Marine Recreational Activity in the US Northeast	http://neoceanplanning.org/wp-content/uploads/2015/10/Recreation-Study_Final-Report.pdf
Northeast Ocean Data Portal	http://www.northeastoceandata.org/data-explorer/?recreation
Beneath the Sea Scuba and Dive Travel Show	http://www.beneaththesea.org/
Boston Sea Rovers	https://www.bostonsearovers.com/

Appendix A3- Report on the influence of structured habitat on sampling black sea with trawl gear

Investigating the utility of inshore trawl surveys for developing black sea bass abundance indices
Black Sea Bass Stock Assessment Working Group
November 2016

Introduction

Fishery independent trawl survey data are used regularly in stock assessments of Mid Atlantic species to provide scientifically based estimates of trends in population abundance and size composition. The utility of trawl surveys for structure oriented species is greatly diminished, however, due to the inability to sample near structure with trawl gear. Black sea bass are known to inhabit areas of structure (Steimle et al 1999), and the use of trawl survey indices has been raised as a concern during several peer reviews of black sea bass stock assessments (*e.g.* NEFSC 1997, 1998, Trzcinski 2011).

There is a growing body of evidence that suggests that black sea bass are not as structure oriented as previously thought. Studies show that black sea bass feed extensively in non-reef habitat (Steimle and Figley, 1996; Lindquist et al., 1994) and are more flexible with regards to habitat use than other Serranidae (Kendall et al., 2008; Ross et al., 2015). Fabrizio et al (2013, 2014) recently found that black sea bass have large home ranges for a "reef" species, and may spend substantial time away from structure. These studies suggest that black sea bass are not obligate reef dwellers, and may in fact be relatively vulnerable to trawl gear.

During development of the 2016 benchmark stock assessment for the northern black sea bass stock, the NEFSC Black Sea Bass Stock Assessment Working Group mined available data to address concerns about trawl survey indices raised during past peer reviews. The goal of this report is to investigate catch characteristics of black sea bass from different gears and different habitat types to evaluate whether trawl surveys can be used to develop reliable indices of abundance for black sea bass.

Methods

Data for this investigation came from a number of different sources including ventless trap surveys, trawl surveys, habitat mapping, and outreach with commercial and recreational fishermen. Analytical methods include trawl / trap comparisons, comparisons of trawl and trap data in structured and non-structured habitat, trawl survey CPUE as a function of distance from known structure, and anecdotal information on habitat utilization. The effectiveness of trawl gear in capturing black sea bass was evaluated by comparing length frequency data between pot and trawl captured fish and between fish from different habitats, and also by comparing gear specific catch rates from different habitats. Collectively, these pieces of information will give an indication of whether fish captured by trawls are representative of the full population.

Massachusetts

Massachusetts Division of Marine Fisheries (MA DMF) has conducted a ventless trap survey of lobsters within Buzzards Bay and Vineyard Sound since 2007 (no sampling 2013). The survey occurs monthly from June to September, using standardized traps in a depth stratified design (Figure 1). The survey has

collected information on black sea bass abundance in all years, but only began collecting black sea bass length data in 2015.

MA DMF has conducted spring (May) and fall (October) trawl surveys of nearshore ocean waters since 1978. The survey uses standardized sampling procedures in a depth and area stratified design (Figure 1). Black sea bass are frequently encountered in the survey and are routinely counted and subsampled for size.

MA DMF trawl and ventless trap survey data were compared to evaluate length frequency distributions of the two gears. Prior to analysis, both datasets were subset spatially and temporally to allow as direct a comparison as possible. Specifically, data from September trap survey sets less than 40 meters deep were compared to fall trawl survey stations in region 1 only (Figure 1).

Length data from the MA DMF trawl survey and ventless pot survey were compared using density plots of length frequency distribution. Initial plots indicated that the trawl survey sampled young of year fish (< 12 cm) better than the traps, so subsequent analyses subset the trawl data to only fish greater than 12 cm. Density plots of age 1+ fish were created and compared with a finite mixture model using the mixtools package in R (ftp://www.r-project.org/pub/R/web/packages/mixtools/vignettes/mixtools.pdf). The model identifies overlapping normal distributions within each density plot, and estimates a mean (mu) and standard deviation (sigma) for each. For this analysis each normal distribution is assumed to be an individual age class. Starting values for the optimization were selected from random uniform distributions from 12 to 45 (size range of data) for mu and 2.5 to 7 for sigma (estimated from NMFS fall trawl survey length at age data). Each mixture model was run 1000 times to characterize uncertainty in parameter estimates. Parameter values were extracted after each run and rounded to the nearest cm. Dominant mu values were identified using counts within each centimeter bin.

The mixture model also provides an estimate of the relative proportion of each sample within each distribution (age class), reported as lambda. Lambda values were extracted from each iteration and plotted against mu values to compare groupings from the different surveys.

Rhode Island

Rhode Island Department of Environmental Management (RI DEM) began a ventless fish pot survey within Narragansett Bay in 2013. The survey area is divided into 5 regions and gridded into 0.5 degree squares. Areas of structure (hard bottom, ship wrecks, pilings, etc) were identified in each station (grid square) using side scan sonar and nautical chart descriptions (Figure 2). Monthly sampling (June through October) is distributed equally between areas of structure and non-structure, and stations in each habitat type are drawn randomly. The survey records numbers and lengths of captured species, including black sea bass.

RI DEM has conducted a trawl survey in Narragansett Bay and surrounding areas since 1979. The trawl survey is comprised of both a seasonal (spring, fall) random stratified survey and a monthly (Jan – Dec) fixed station survey (1990+). All segments are used for this analysis. Sampling stations are established by dividing Narragansett Bay into a grid of cells. Monthly sampling occurs at 13 fixed stations, while the 26 stations sampled during the seasonal survey include 12 of the fixed stations plus 14 stations randomly

selected from a predefined grid. Black sea bass are frequently encountered in the survey and are routinely counted and subsampled for weight and size.

Length data from the RI DEM trawl survey and ventless pot survey were compared using simple visual analysis. To provide as direct a comparison as possible, the trawl survey was subset to include only the months that the ventless pot survey was conducted. Similar to the MA DMF analysis, initial investigations indicated that the trawl survey samples young of year fish better than the pots, so fish less than 15 cm were removed from the comparison. Additionally, the mixture model analysis as described for the MA data sources was repeated to compare length frequency data from the two RI surveys.

The RI DEM ventless pot survey is stratified by habitat type (structure vs. non-structure) based on side scan sonar mapping of Narragansett Bay. An ANOVA was conducted to test for differences in catch rates of black sea bass between structured and non-structured habitat. A similar analysis was conducted using a negative binomial model.

The RI DEM trawl survey was post stratified into structured and non-structured habitat using the side scan sonar mapping and nautical chart information (Figure 2). Differences in catch rates of black sea bass between structured and non-structured habitat were tested using ANOVA and negative bionomial models.

New Jersey

New Jersey Division of Fish and Wildlife (NJ DFW) has conducted a trawl survey of nearshore ocean waters (0-30 m) since 1989. The survey is conducted 5 times per year using a depth and area stratified design (Figure 3). Black sea bass are frequently encountered in the survey and are routinely counted and subsampled for size.

Since 1984, NJ DFW has constructed and maintained a network of 15 artificial reefs ranging from 2 to 25 nautical miles offshore at depths from 40 to 135 feet (Figure 3). Each reef site has defined boundaries ranging in area from 0.5 to over 4.0 square miles, within which are numerous patch reefs of deployed material. The reefs are widely utilized by structure oriented species and are frequented by commercial and recreational fishermen targeting black sea bass.

The R package "geosphere" (https://cran.r-project.org/web/packages/geosphere/geosphere.pdf) was used to estimate distances between NJ DFW trawl survey stations and artificial reef site boundaries in order to evaluate trawl survey catch as a function of distance from these reefs. Waypoints were created between the start and end location of each trawl tow, and the shortest distance (meters) between each waypoint and the reef polygon was found using the dist2Line function. Results were binned into kilometer wide distance bins (0-999 m = bin 0; 1000-1999 m = bin 1, etc)., and data were subset to only those tows where all waypoints occurred within the same distance bin (*i.e.* the tow was roughly parallel to the nearest reef site boundary).

Characteristics of the trawl catch as a function of distance were evaluated in a number of ways.

- The percent positive tows was calculated in each distance bin, and 95% confidence bounds were estimated using the exact binomial test. These were compared to the overall percent positive tows to check for deviations from the overall values.
- Geometric mean catch per tow in each bin was compared with the overall mean catch per tow.
- A negative binomial regression of catch vs. distance was conducted using the glm.nb function in R.
- Negative binomial parameter values for mu and size (dispersion) were calculated for each bin and compared with overall parameter estimates.

To test for differences in catch characteristics by fish size/age, each of the analyses using NJ trawl survey data was conducted on all fish combined, young of year fish (<15 cm), and fish age 1+.

Rutgers University

Rutgers University (RU) received funding from the NJ DFW to conduct a pilot fish pot survey of NJ artificial reef locations. One of the objectives of the study is to investigate catch, and some factors that may influence catch, of black sea bass on reef and non-reef locations. Sampling will occur in 2016 during spring, summer, and fall deployments on two reef sites (Sea Girt and Little Egg). At each reef site, a number of pots will be deployed on various reef materials within the reef boundary, and an equal number of pots will be deployed on sand habitat from 1 to 3 km outside the reef boundary. Sampling is still ongoing, but preliminary data were provided to NJ DFW for use in this analysis (O. Jensen and D. Zemeckis, Rutgers University, pers. comm.).

Preliminary black sea bass length data from the RU pot survey were compared using simple visual analysis to check for differences in length frequencies between the two habitat types. Data from spring and summer sampling were combined into a single data set for the analysis.

Catch per unit effort from the RU pot study was also considered for investigation. Only data from spring sampling were available, however, and preliminary analyses indicated that CPUE increased throughout the spring sampling period at both reef and sand locations. This raised concerns that there might be seasonal (*e.g.* temperature) components to the available CPUE data that may affect results, so the analysis was dropped from further consideration.

NMFS

During an outreach project in 2016, the NMFS Northeast Fishery Science Center (NEFSC) held conversations with 94 interested parties from the commercial and recreational fishing sectors to collect anecdotal information on their black sea bass observations. Several of the questions focused on habitat use and gear interactions, including whether participants had observed black sea bass away from structured habitat. Responses were tallied to provide a general summary of industry-based observations, but no statistical analyses were conducted on the results.

Results

Massachusetts

There were 2072 and 186 length measurements from the trawl survey and trap survey data sets, respectively. These lengths came from 8 trawl stations and 45 trap sets.

Initial density plots indicated dramatic differences in the size distribution of each survey (Figure 4). The MA DMF trawl survey showed a peak at sizes less than 10 cm, indicating a large quantity of YOY fish in the survey. Although fish of this size were present in the MA DMF trap survey, they comprised a much smaller portion of total catch.

After subsetting the data to include only fish greater than or equal to 12 cm, both datasets indicated at least two size modes (Figure 5). The first mode, at approximately 20 cm, indicates the presence of age-1 black sea bass. The second grouping indicated the presence of fish age >1 in both surveys. Based on this sample, the trap survey appeared to capture a larger proportion of fish between 20 and 30 cm than the trawl, but the trawl had a greater proportion of fish greater than 35 cm.

The finite mixture distributions for each survey identified similar mu values. The five most common size bins in the trawl survey occurred at 21, 28, 31, 35 and 40 cm, compared to 19, 27, 31, 32, 36 and 43[1] cm in the trap survey. Dominant mu values were similar, and in several cases, coincided (Figure 6). Both surveys identified mu groupings at ~20 cm, ~27 cm, ~31 cm, and ~36 cm. The most substantial difference in mean size occurred at larger sizes; the largest mu occurred at 40 cm in the trawl survey compared to 43 cm in the trap survey.

Plotting lambda against mu helped to visualize the relative proportion of the sample at a particular mean (Figure 7). Clusters represent the proportion of the catch at a given size. Both surveys indicated up to 20-25% of the catch occurred around the mode near 20 cm, and as much as 70% occurred around the mode near 36 cm. The majority of the remaining fish occurred around the 28 cm mode for the trap survey and at the 40 cm mode in the trawl survey.

Rhode Island

The RI DEM trawl survey conducted a total of 441 trawl tows in 2013 – 2015. Of these, 149 were positive for black sea bass (Table 1). During the same period, the RI DEM pot survey had 281 pot sets with black sea bass out of 772 total sets. The trawl survey captured 2,691 individuals compared to the 2,166 in the pot survey. Similar to the MA DMF analysis, the RI DEM analysis found a much larger proportion (66%) of young of year fish in the trawl compared to the fish pots (Figure 8). Subsetting the data to fish greater than 15 cm resulted in strong similarities in size distribution between the two gears (Figure 8).

As was seen in the MA DMF analysis, length frequencies from RI indicated at least two size modes in all years of the trawl survey, and in 2015 for the pot survey. The first mode, at approximately 6 cm, indicates the presence of age-0 black sea bass. The second grouping indicated the presence of fish age >1 in both surveys. Based on this sample, the trap survey appeared to capture a larger proportion of fish between 25 and 35 cm than the trawl, but the trawl had a greater proportion of fish greater than 35 cm (Figure 8).

[1] 36 and 43 cm occur the same number of times in the trap survey, so six modes are reported instead of five.

Table 1. Summary data from the RI DEM trawl survey and pot survey for 2013-2015.

Year	Trawl tows	Positive trawl tows	Positive pot sets	All trawl lengths	Trawl lengths, age 1+	Pot lengths
2013	166	55	83	178	108	355
2014	138	42	108	473	434	1021
2015	137	52	90	2040	361	790
Total	441	149	281	2691	903	2166

The finite mixture distributions for each survey identified similar mu values with a large area of overlap between the two gears (Figure 9). The five most common size bins in the trawl survey occurred at 26, 28, 33, 38 and 41 cm, compared to 23, 29, 30, 34, and 35 cm in the trap survey. It is interesting to note that these mu values were in a similar range to the MA DMF analysis. Dominant mu values were similar for the two gears, generally ranging from 25 to 35 cm. The most substantial difference in mean size occurred at larger sizes; the largest mu occurred at 41 cm in the trawl survey compared to 35 cm in the trap survey.

Plotting lambda against mu helped to visualize the relative proportion of the sample at a particular mean (Figure 10). Clusters represent the proportion of the catch at a given size. Both gears show a signal of as much as 50-80% of the catch in a bin centered near 30 cm.

Visual comparison of sea bass length frequencies by habitat type in the pot survey indicated similar distributions in 2013 and 2014 (Figure 11). Results from 2015 were unusual in that pots in both habitat types caught YOY fish. A larger proportion of these small fish were observed in structured habitat compared to areas without structure, but both habitat types showed modes in the same locations.

The ANOVA comparing catch of black sea bass in RI DEM fish pots on structured and non-structured habitat indicates no difference in catch between habitat type ($p = 0.423$; Figure 12). The three largest catches of black sea bass in the RI DEM pot survey occurred in non-structured habitat. Similarly, the negative binomial test found no significant difference in catch between the two habitat types ($p = 0.231$).

Neither the ANOVA nor the negative binomial test comparing catch of black sea bass in the RI DEM trawl survey indicate significant differences in catch between the two habitat types ($p = 0.844$ and 0.30, respectively).

New Jersey

NJ DFW has conducted a total of 5,100 trawl tows, ranging from less than 1 km to more than 50 km from an artificial reef site perimeter. Distances were binned as described in the methods section by kilometer distances from a given reef. Of these tows, 1,081 occurred wholly within a given 1 km wide distance bin (Figure 13). Distance bins 0-19 had at least 15 tows each and were retained for analysis, but bins 20 and greater (20+ km from a reef) generally had fewer than 5 tows per bin (Figure 14) and were not included in the analysis.

NJ trawl survey black sea bass catch per tow was less than 190 fish in all but one tow which had an anomalously high catch of 1,463 black sea bass (Figure 15). Review of diagnostic plots from the negative

binomial glm identified this tow as an outlier (Cook's distance > 4.0, not shown), and it was therefore removed from all analyses.

Approximately 43% of all tows were positive for black sea bass of any size (Figure 16). Percent positive by distance bin ranged from approximately 23 to 61%. There was no apparent trend in percent positive tows with distance from a reef, and all 95% CI overlapped the overall mean. Similar results were found for young of year fish (<15 cm), with an overall percent positive of 21% and bin specific values ranging from 9 to 36%. For large fish (age 1+), there appeared to be a general decreasing trend in percent of positive tows within the first five kilometers from the reef, but all except one of the 95% CI encompassed the overall mean for this size group (32%). The lower confidence bound of bin 0 (0 to 0.99 km) of 36% exceeded the overall mean for this size group.

Overall geometric mean CPUE for all fish was estimated at 1.02 fish per tow (Figure 17). Catch per tow within the first kilometer (CPUE = 1.97) was nearly double the overall mean, but was equal to the catch in bin 9, and similar to catch from 14 to 16.9 km from the reef. 95% CIs from these and all other bins overlapped zero and therefore encompassed the overall mean. For age 1+ fish, catch within the first kilometer was higher than all other bins, while bin 12 produced the greatest catch of YOY fish (Figure 17). For these two size groups, residuals seem well distributed between bin means and overall means of 0.70 and 0.29 fish per tow for age 1+ and YOY, respectively.

Preliminary results of the negative binomial regressions of catch as a function of distance indicated one tow with significant leverage on the results (N = 1,463 fish, Cook's distance > 4.0; Figure 15), and it was therefore removed from the analysis. Without that one tow, slope estimates for all three size groups were positive, but not significantly different from zero (Figure 18).

Estimated mean catch assuming a negative binomial distribution was mu = 4.52 across all distance bins and fish sizes (Figure 19). Bin specific estimates ranged from 1.89 fish (bin 6) to 18.88 fish (bin 9). Mean catch within the first kilometer from a reef (mu = 8.25) was the third highest of all the bins. Upper 95% confidence intervals fell below the grand mean in bins 2, 3, 5, 6, 7, and 18. When considering only age 1+ fish, the mean catch within the first kilometer was also ranked 3rd of all bins, while the inner kilometer ranked 9th for YOY fish.

Rutgers University

There were 543 and 545 length measurements from the RU pot study in sand and reef habitat, respectively. Length frequency distributions were generally similar between the two habitats (Figure 20), although no statistical tests were conducted to quantify this finding. Pots set in sand habitats had a slightly higher proportion of fish in the 20-30 cm range, while 30-40 cm fish were slightly more prevalent in pots set within the reef boundaries.

NMFS

A total of 94 conversations were held with commercial and recreational fishery representatives regarding their black sea bass interactions, although only 75 provided information on habitat use and gear interactions. These responses represent a range of sectors, including commercial hook and line, pot/trap, and trawl fishermen; recreational anglers; for-hire captains; and bait/tackle shops. Regarding the question

of where survey participants have encountered black sea bass, two-thirds (n = 50) of those who provided an answer said they have seen black sea bass on open bottom, compared to 25 respondents saying they've seen sea bass on structured habitat (Table 2). Comments from some participants suggest the sea bass are attracted to fish pots as structure or captured by trawls while the fish are "moving", while others indicate the fish are feeding on mussel beds or on crustaceans in sandy habitat. Several respondents indicated they caught sea bass while fishing for summer flounder (*Paralichthys dentatus*) on sandy bottom.

Table 2. Summarized results of industry responses to where they have observed black seas bass, combined by region.

State	No response	Structure	Open bottom	Total
NH/MA/RI	3	3	14	20
NY	6	2	15	23
NJ	9	15	20	44
MD/VA	1	5	1	7
Total	19	25	50	94

Discussion

Fish pot/trap gear are generally considered more appropriate than trawls for sampling structure oriented species (Powles and Barans 1980; Bacheler et al 2013). A long standing research recommendation of black sea bass stock assessments has been the development of a fish pot survey in structured habitat. Attempts to develop new surveys are often hindered by agency funding availability. In 2012 a cooperative (industry based) pot study was developed for black sea bass in the mid Atlantic (DeCelles and Cadrin 2014), but a review of the survey by the MAFMC SSC identified several issues with survey design (Jones et al 2014). Rutgers University has received funding to conduct a pilot fish pot survey in New Jersey, but even if the survey is maintained, sufficient data will not be available for use in stock assessment for many years. In the absence of long term directed pot survey data, the purpose of this report is to mine available trawl and pot data to address the concerns of previous peer reviews regarding the use of trawl survey abundance indices for black sea bass for stock assessment. Investigating catch characteristics of the two gears in different habitat types should provide evidence as to whether trawls are suitable for tracking black sea bass population trends.

Comparison of length frequency distributions in structured and non-structured habitat suggest there is no difference in the sizes of black sea bass in the two habitat types. This is directly evident from the RU pot study on reef and sand habitat, and the RI DEM comparison of pot catches in structured and non-structured habitat, and is supported by the results of both the MA DMF and RI DEM length comparisons from pot (structured) and trawl (non-structured) gear. Differences in gear selectivity make the cross-gear comparisons more difficult to interpret. In particular, the trawl surveys had a very high proportion of young of year fish (< 15 cm) that were generally not observed in the pots. Even after the data were subset to just age 1+ fish, some differences were still evident; pots appeared to catch intermediate size fish (approximately 25-35 cm) better than trawls, but trawls had a higher proportion of large (> 35 cm) fish. Regardless, the finite moment analysis conducted for the MA DMF and RI DEM studies identified modes at similar sizes with a large area of overlap in modes between the gear, as well as similar proportional distributions by size (lambda), despite a relatively small sample size. These results indicate that the size

distributions of black sea bass in structured and non-structured habitat are comparable, and therefore trawl surveys are sampling the same size range of fish as would be encountered around structure.

This investigation also found that catch rates of black sea bass were similar on structured and non-structured habitat. Gear-specific comparisons using RI DEM data showed no difference in catch rates between the two habitat types for either pots or trawls. In addition, examination of NJ trawl survey data indicated that catch rates of black sea bass (represented as the slope of the negative binomial glm) are nearly constant with respect to distance from artificial reef sites (0 - 19 km) for all size groups considered. These results are corroborated by proportion of positive tows and both geometric mean and negative binomial mean catch per tow by kilometer wide distance bin from the NJ trawl survey. We recognize that the NJ trawl catch rates may be influenced by other types of structure not accounted for in the analysis (*e.g.* natural hard bottom, shipwrecks, cable crossings, fishing gear). However, known areas of untrawlable bottom where structure oriented species might congregate are maintained on a "hang log" and are generally avoided by the survey. The results of the catch rate comparisons indicate that availability of black sea bass is the same on both structured and non-structured habitats.

The results of this analysis regarding availability of black sea bass to trawl gear are further supported by the NEFSC conversations with commercial and recreational industry members, as well as previous scientific studies. Two thirds of the respondents in the NEFSC outreach effort indicated they have encountered black sea bass on open bottom. Some respondents noted that the fish were feeding on crustaceans in sandy areas, which is supported by the results of Lindquist et al (1994) and Steimle and Figley (1996) who found that a large component of sea bass diet consists of sand dwelling prey, or prey that occur in both reef and soft bottom habitats. Steimle and Figley (1996) speculate that this is not unexpected for a species that migrates long distances over open bottom (Moser and Shepherd 2009). Kendall et al (2008) found that presence of black sea bass was best explained, not by the amount of relief or cover provided by structure, but by the percent cover of sessile organisms. Fabrizio et al (2013) found that black sea bass preferred areas with a high proportion of "coarse grained, placed material" or high variability in seafloor slope. Unfortunately, the authors provide no information to quantify "coarse grained," although anecdotal information suggests deployed material in the study area consists of dredged material smaller than a basketball (H. Carberry, NJ DFW Artificial Reef Program, pers. comm.) Regardless, it was reported that preference for these coarse grained habitats declined dramatically during the fall (Fabrizio et al 2013). Further, Fabrizio et al (2014) found that, during inshore residency, black sea bass on the same study site had an average home range of 1.37 sq km, with some exhibiting home ranges over 4.8 sq km. Fish movement was highest during the summer, was not dependent on time of day, and encompassed a range of habitat types. Finally, Nieland and Shepherd (2011) found that catches of black sea bass in the NEFSC inshore trawl survey were greater over open bottom than around structure.

The data analyzed for this report indicate that both the size distribution and availability (catch rate) of black sea bass are similar in structured and non-structured habitat. These findings are supported by both scientific and anecdotal information that black sea bass are not dependent on areas of high relief and are commonly found in areas of open bottom. Taken together, these results suggest that trawl surveys operating in open bottom areas are sampling the same population of black sea bass as would be found in structured habitats where trawls cannot operate. As such, the Black Sea Bass Stock Assessment Working

Group concludes that inshore trawl surveys are appropriate for sampling black sea bass and characterizing size structure and changes in population abundance.

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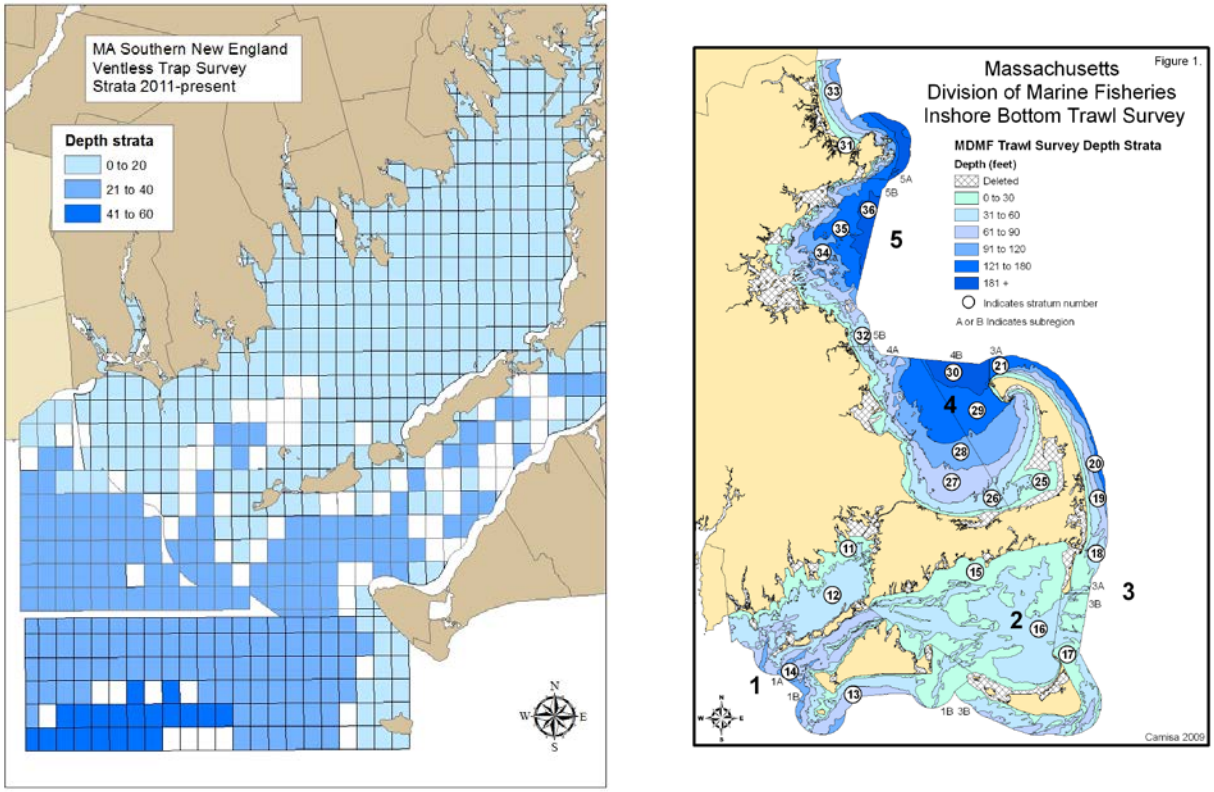


Figure 1. Location and stratification of MA DMF ventless trap survey (left) and trawl survey.

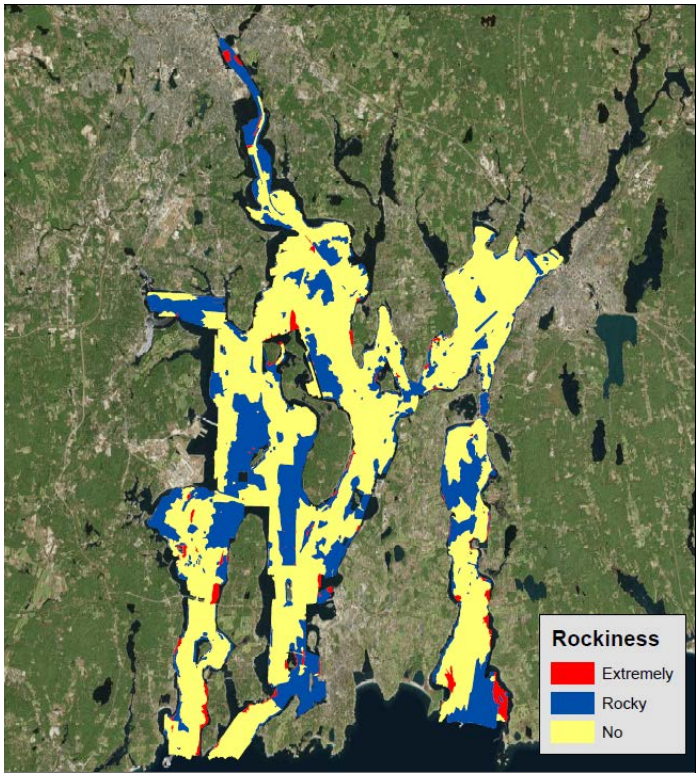


Figure 2. Side scan sonar and nautical chart based classification of habitat type in Narragansett Bay, RI.

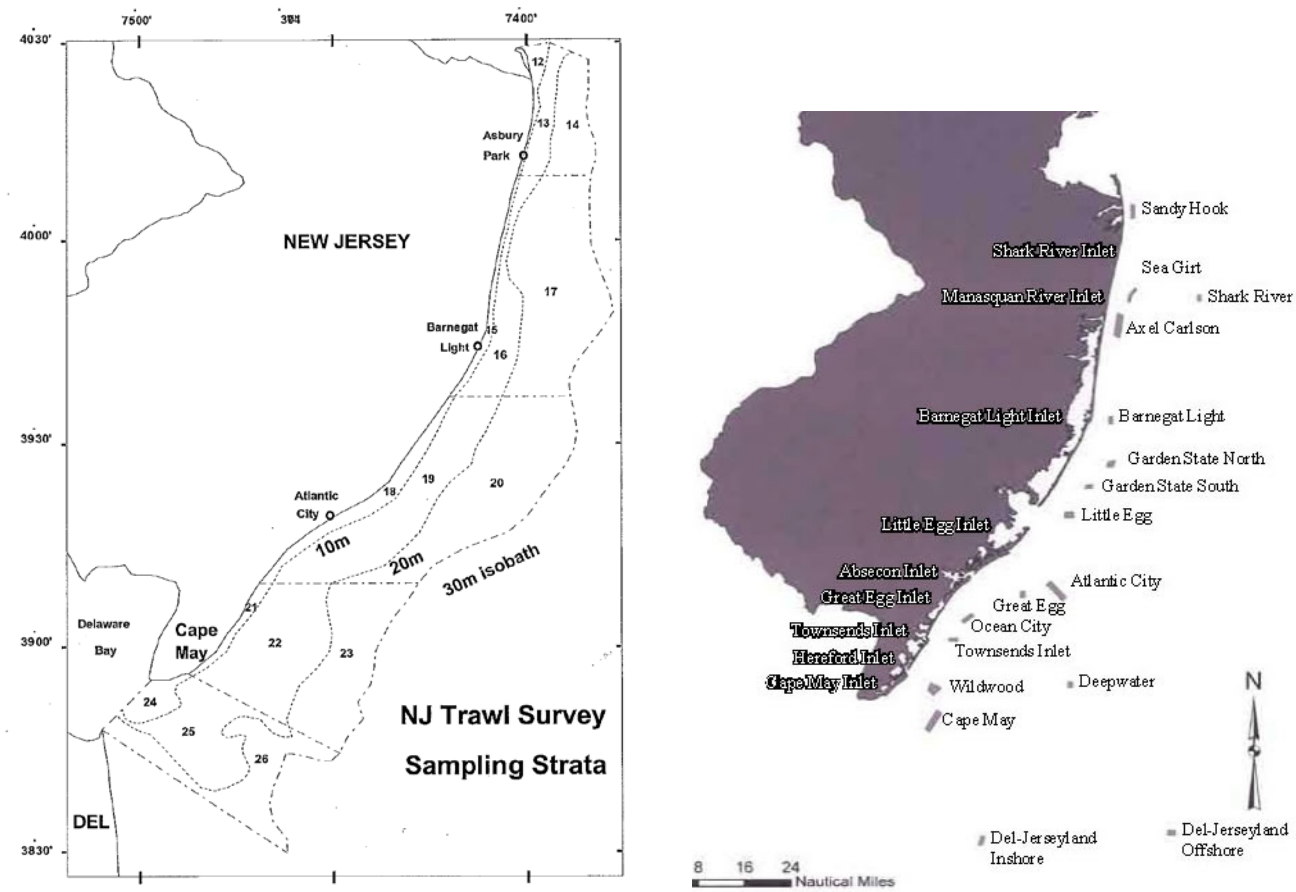


Figure 3. New Jersey Ocean Trawl Survey stratification (left) and artificial reef network.

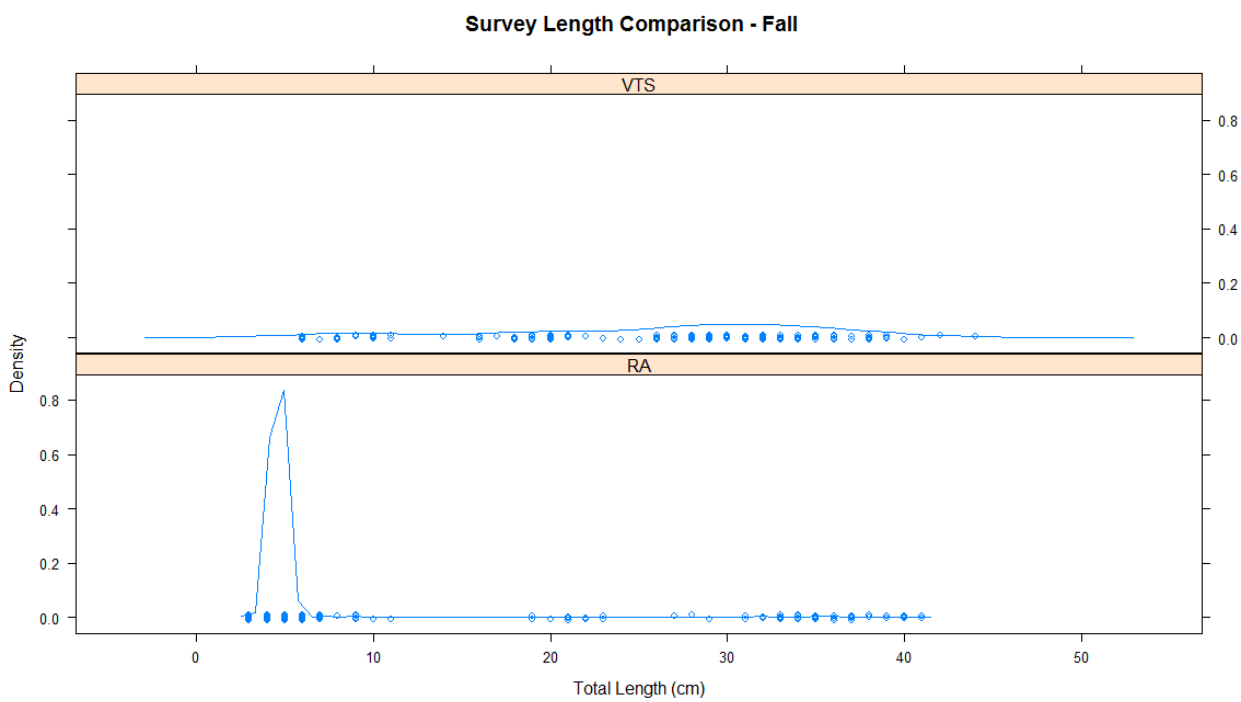


Figure 4. Density plots of the raw length frequency data from the MA ventless trap survey (top) and trawl survey showing the high proportion of YOY in the trawl survey.

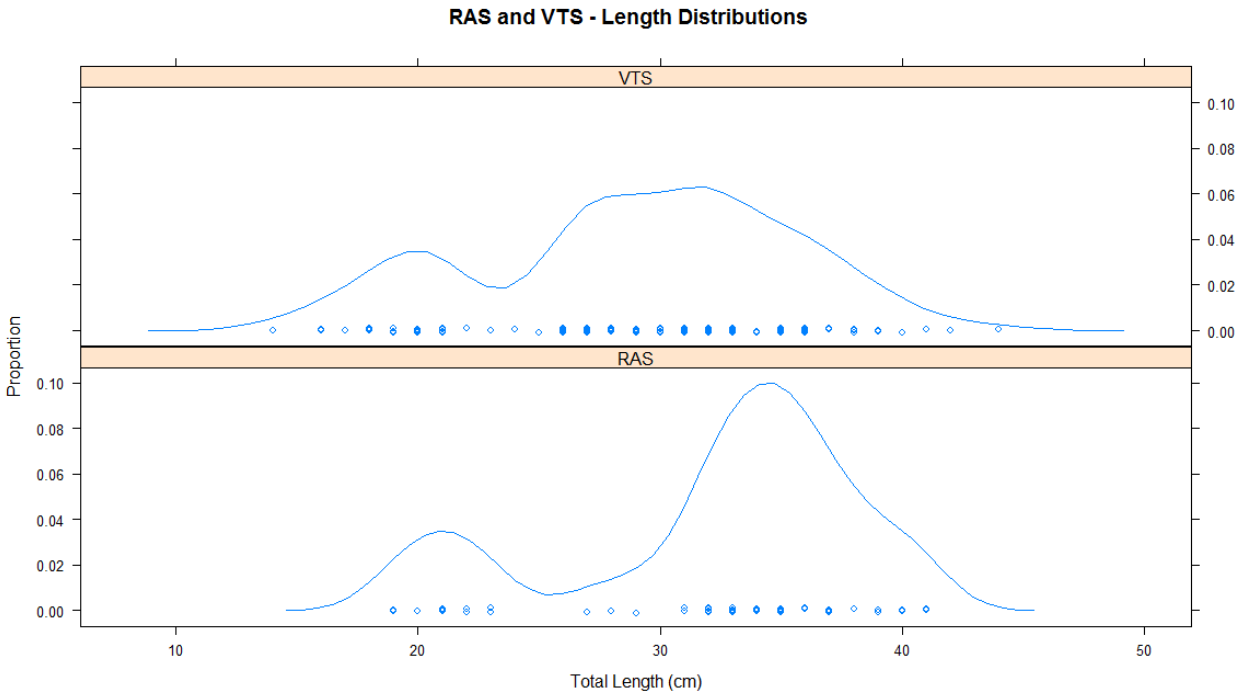


Figure 5. Density plots of the MA ventless trap and trawl survey length frequencies, subset to only age 1+ fish (> 12 cm).

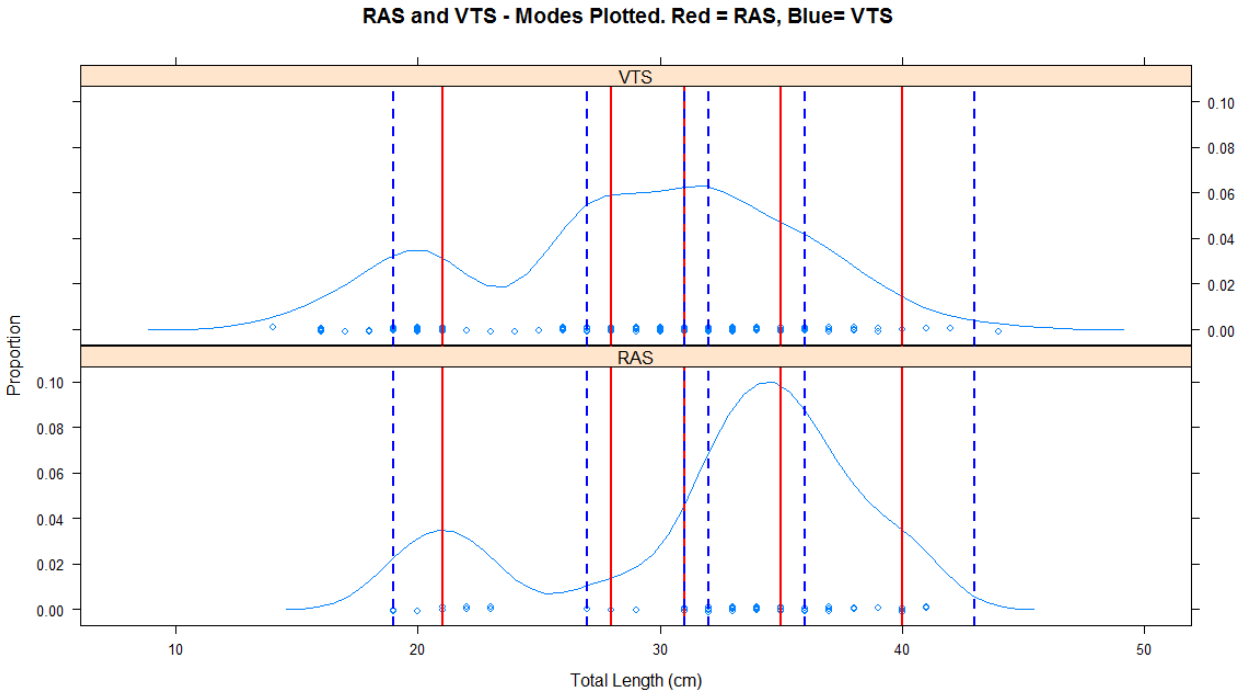


Figure 6. Density plots comparing length distribution of BSB >12 cm captured in the MA DMF trap survey and trawl survey. Dominant mu values overlaid in red (trawl) and blue (trap). Mu value at 31 represents an overlapping value.

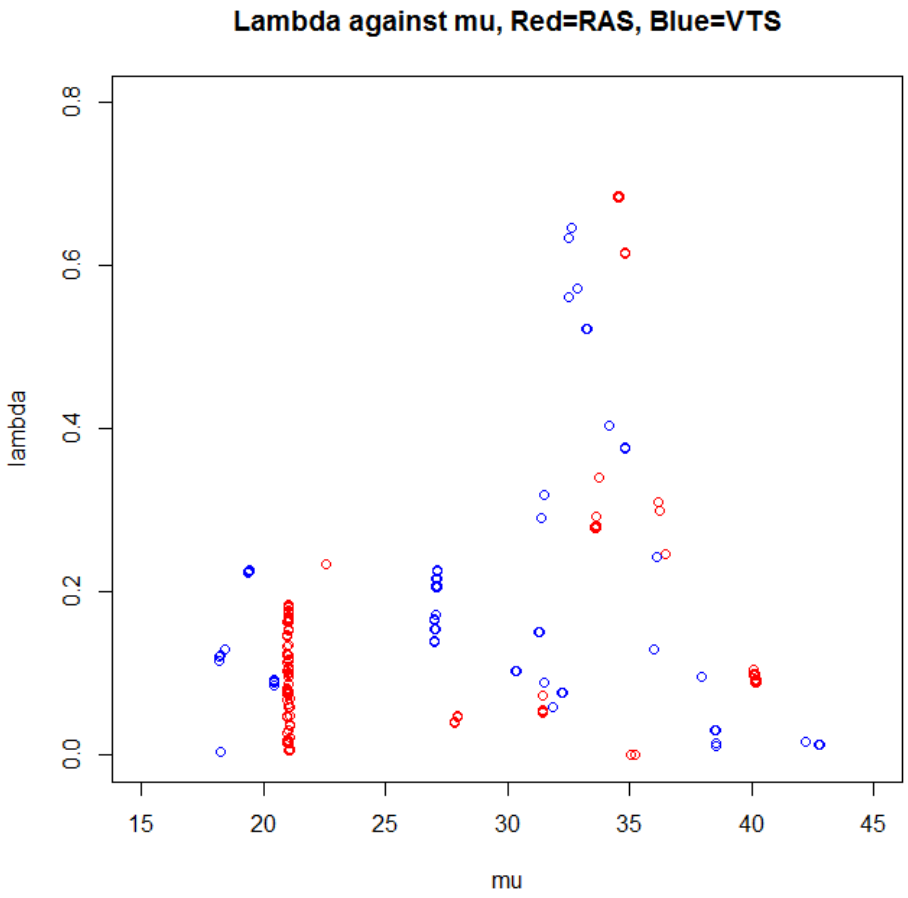


Figure 7. Lambda (proportion in mixture group) against mu, trawl survey (red) and trap survey (blue) for the finite mixture distributions. A total of 5000 points are plotted on this figure. Points jittered slightly.

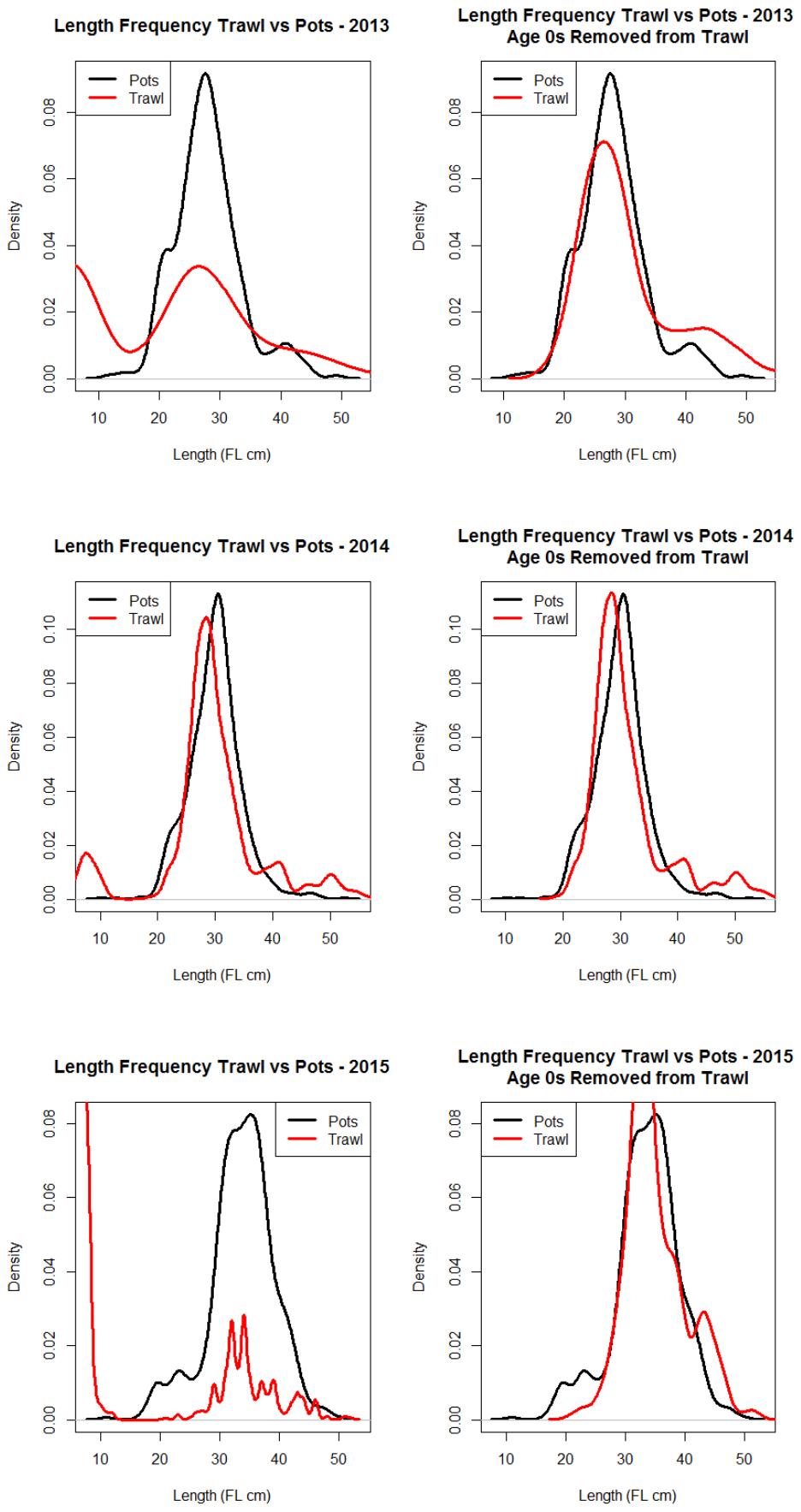


Figure 8. Length frequency distributions of the RI fish pot and trawl surveys for all fish (left panels) and age 1+ only.

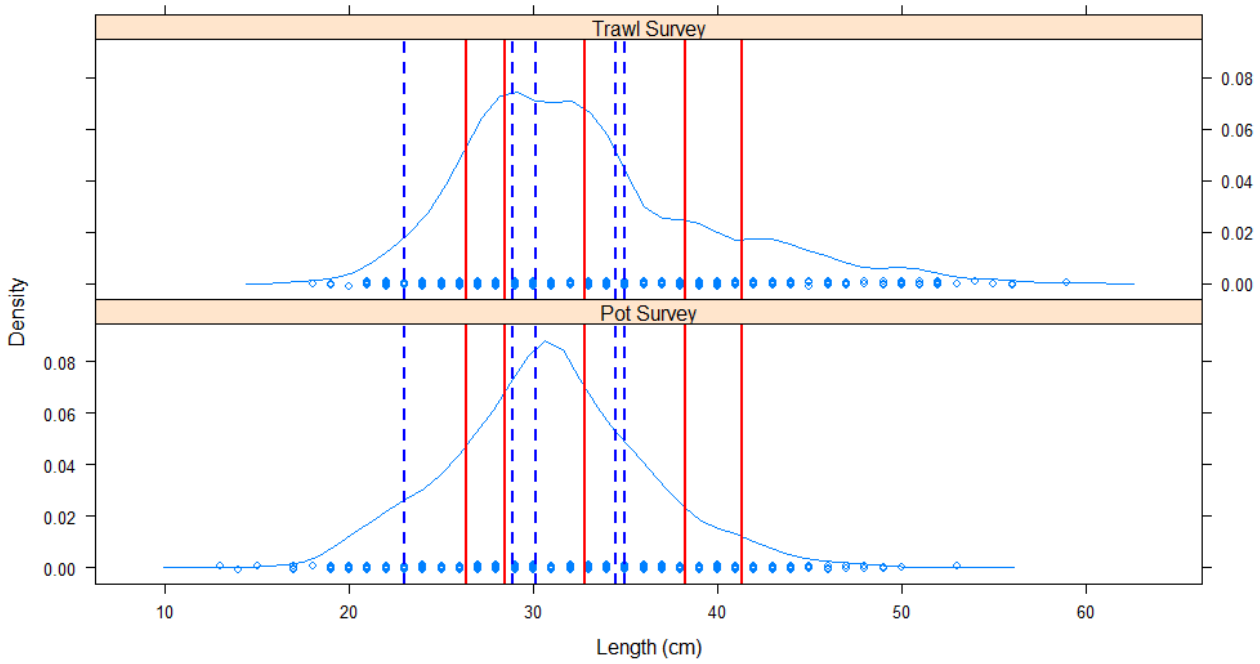


Figure 9. Density plots comparing length distribution of BSB captured in the RIDEM trap survey and trawl survey. Dominant mu values overlaid in red (trawl) and blue (trap). Mu value at 27 represents a value that is statistically the same.

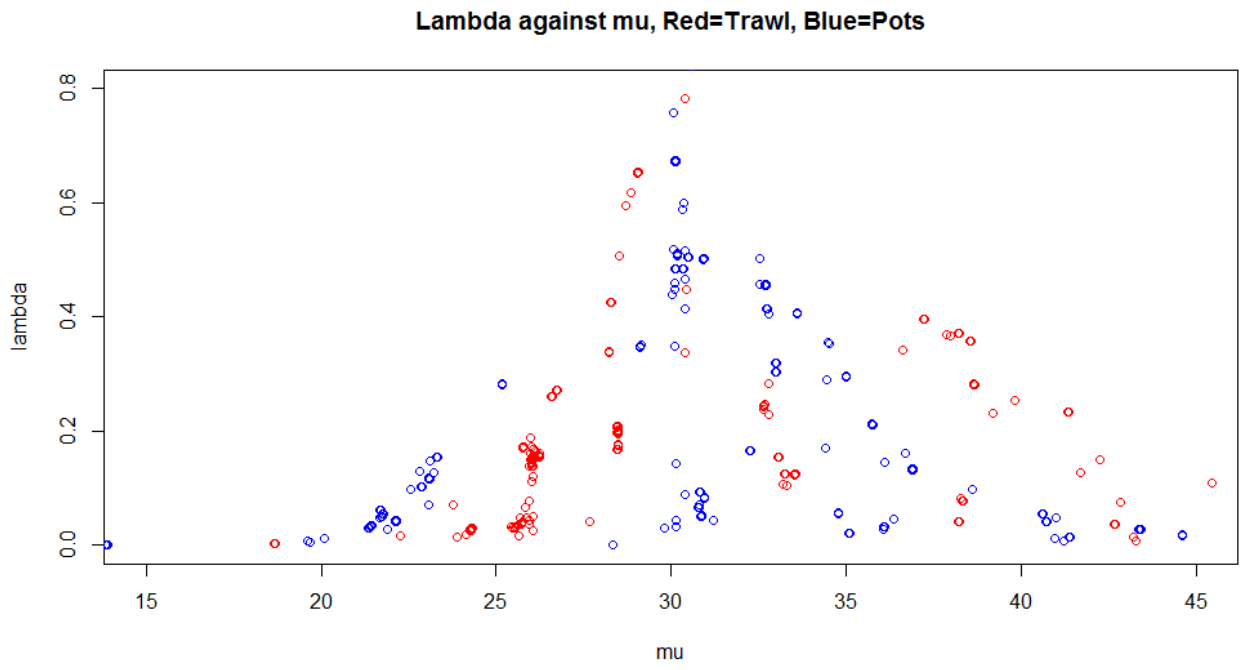


Figure 10. Lambda (proportion in mixture group) against mu, trawl survey (red) and trap survey (blue) for the finite mixture distributions. A total of 5000 points are plotted on this figure. Points jittered slightly.

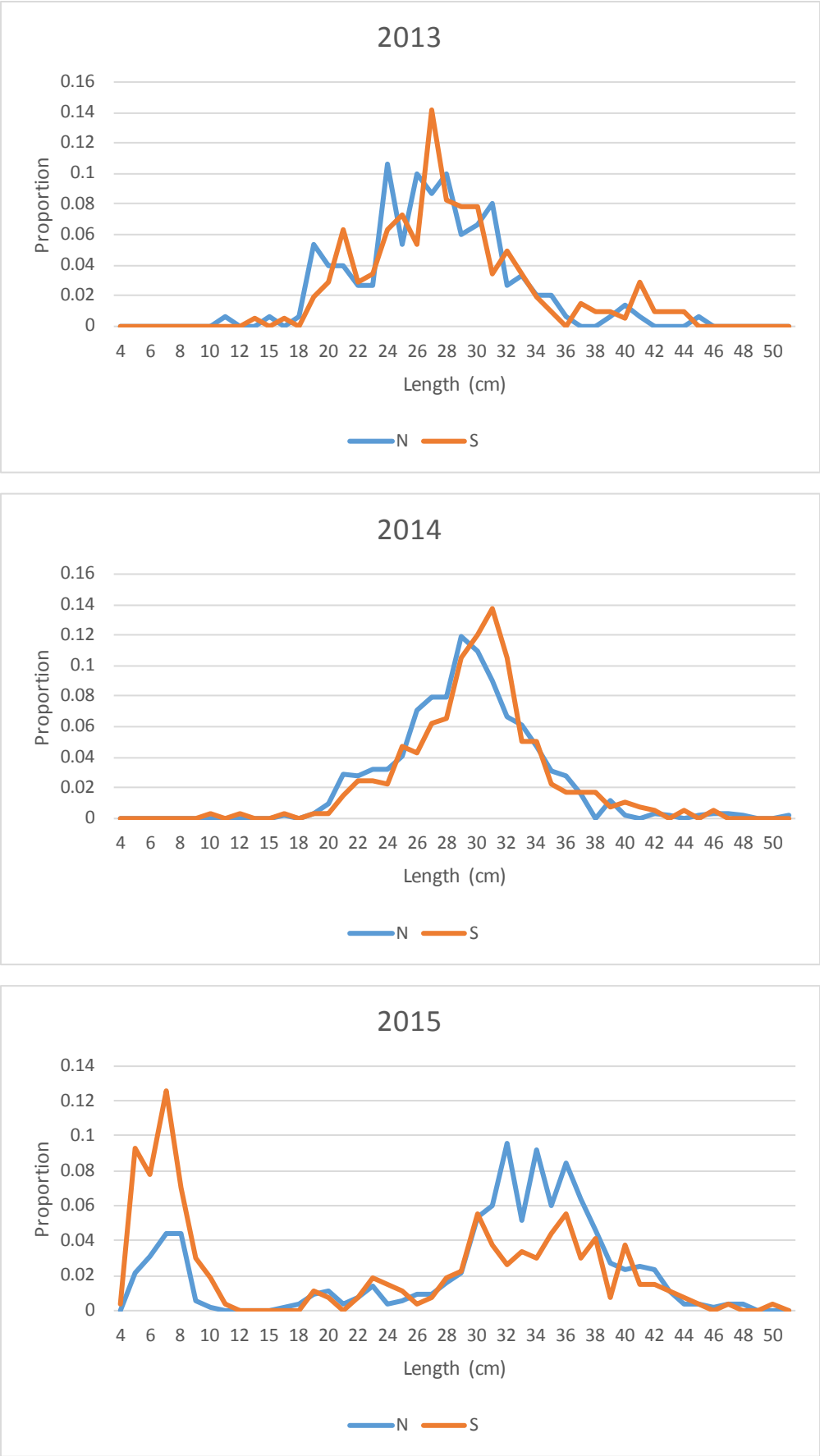
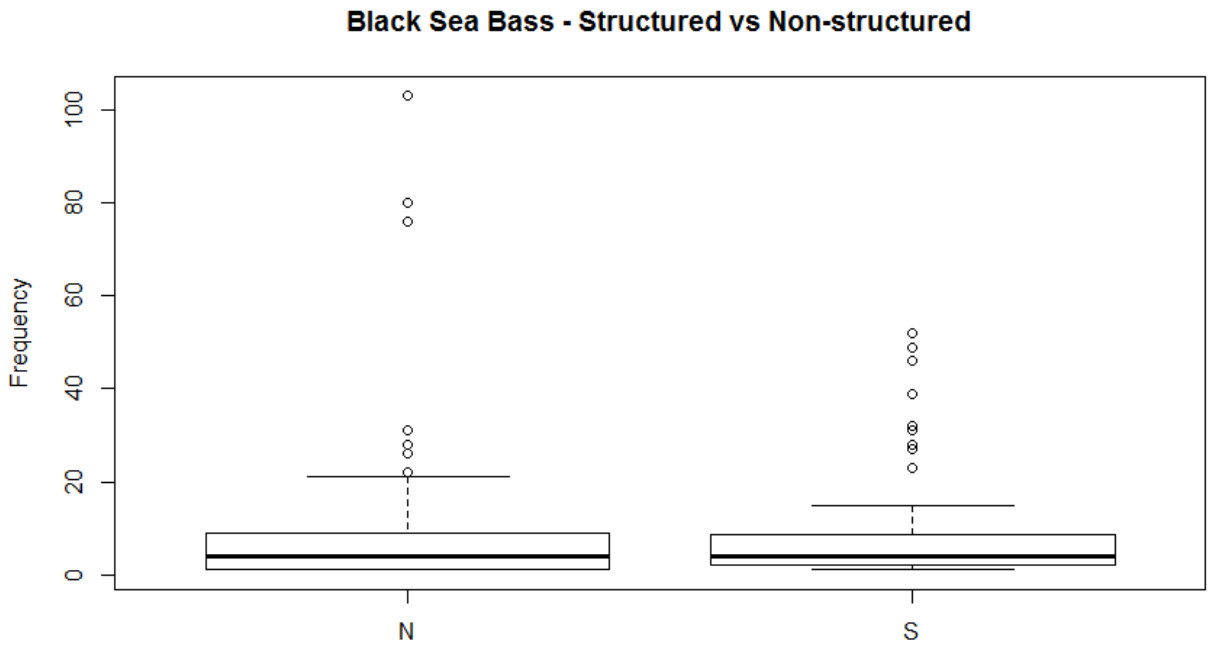


Figure 11. Black sea bass length composition by habitat type in the RI DEM pot survey.



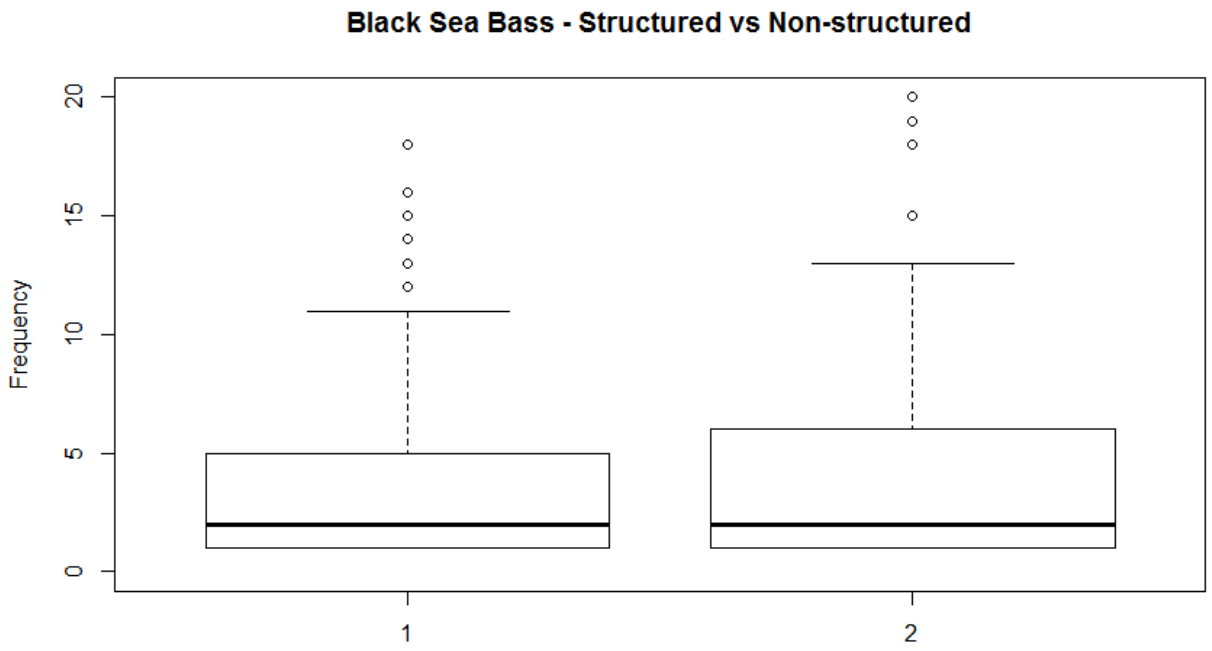


Figure 12. ANOVA results of black sea bass catch in structured vs. non-structured habitat for the RI DEM fish pot survey (top) and trawl survey.

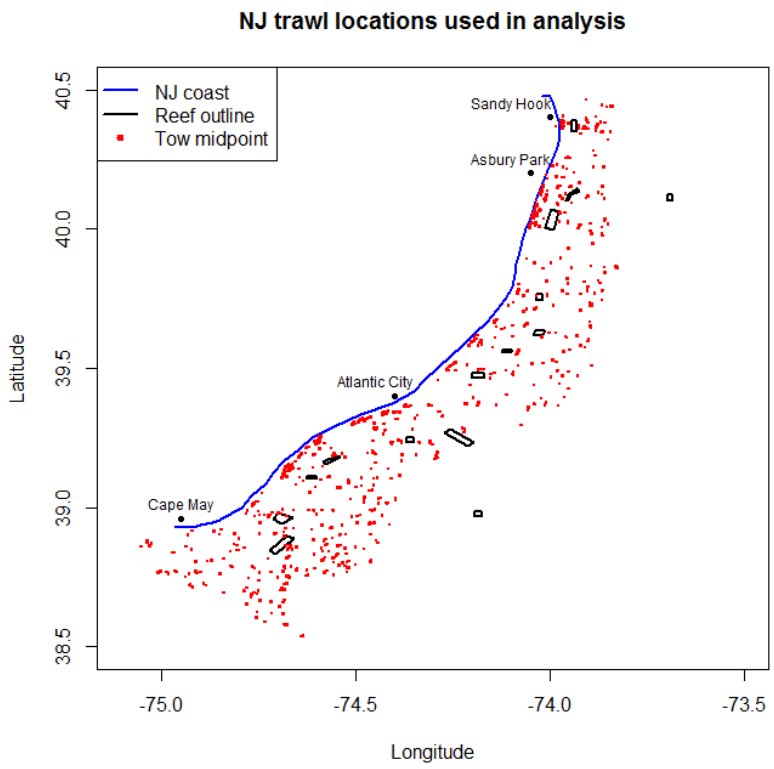


Figure 13. Location of NJ trawl survey tows that occurred wholly within a given 1 km distance bin relative to artificial reef locations.

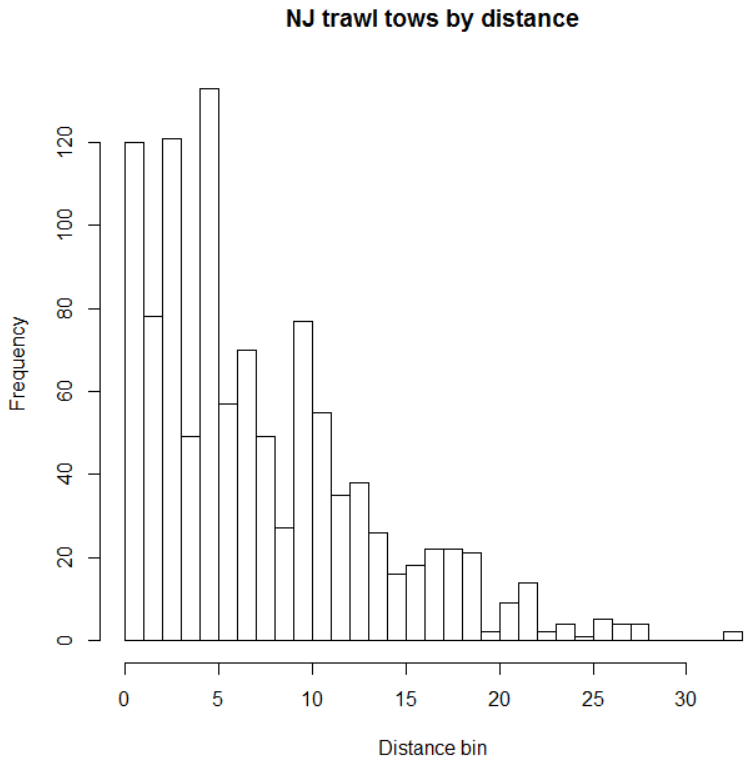


Figure 14. Frequency distribution of NJ trawl survey tows within each distance bin. Bins 20 and greater generally had fewer than 15 tows each and were dropped from subsequent analysis.

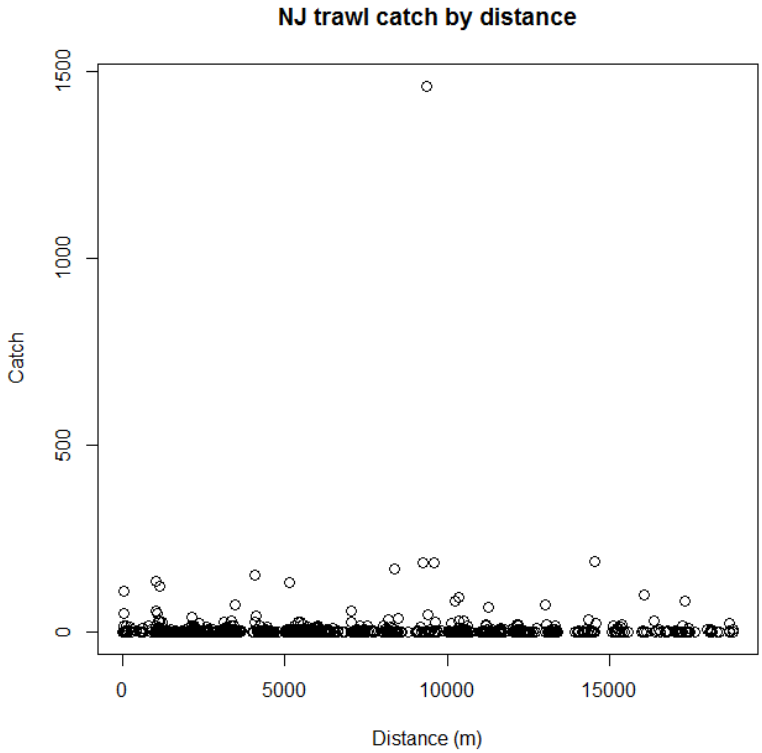


Figure 15. NJ trawl survey catch of black sea bass by distance from the NJ artificial reef sites. The one outlier was found to have significant leverage (Cook's distance > 4.0) and was removed from the analysis.

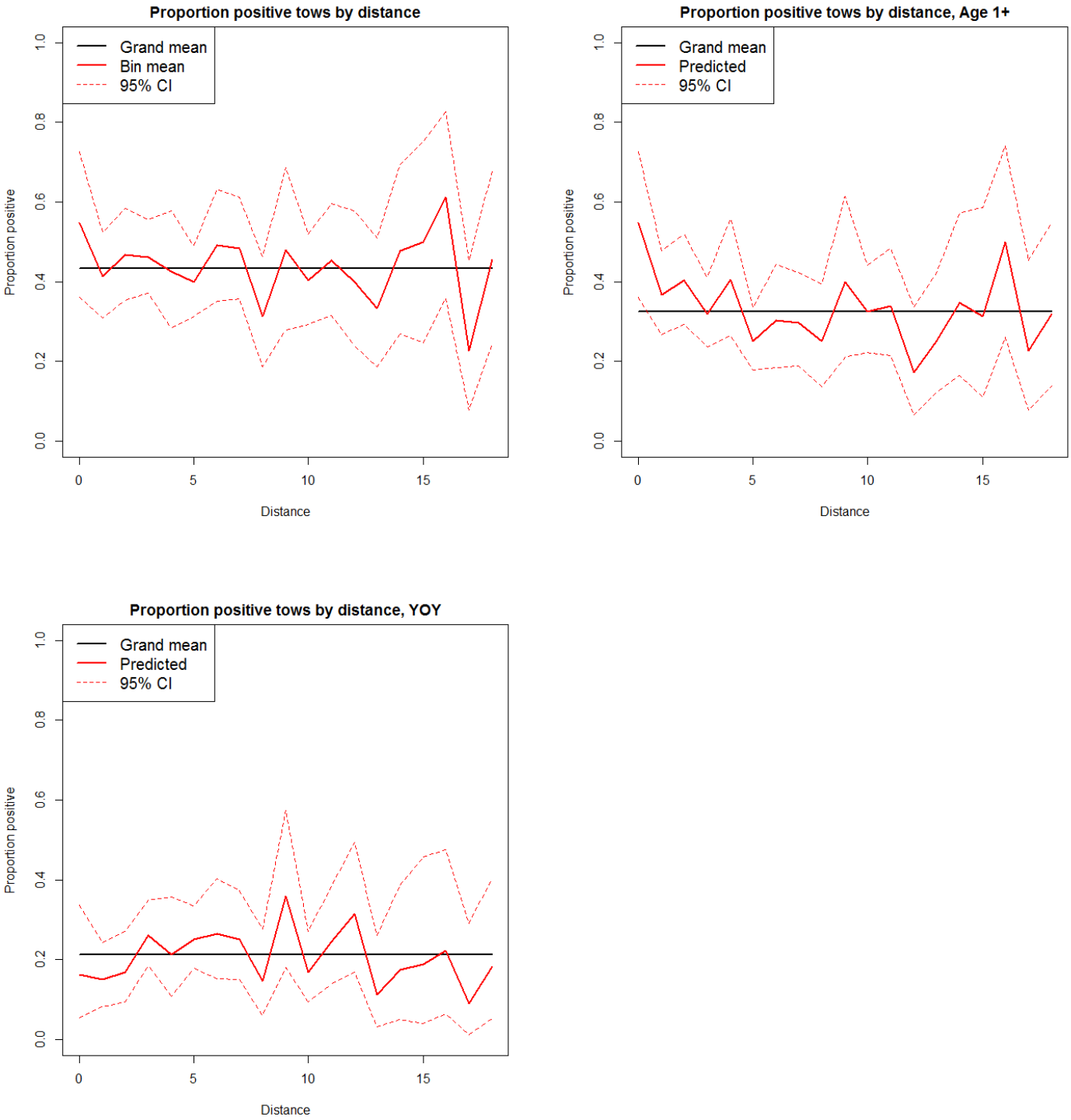


Figure 16. Proportion of NJ trawl survey stations that were positive for black sea bass for all size fish (top left), age 1+ fish (top right) and young of year fish. In each plot, the heavy black line is the overall percent positive across all distance bins. The red solid and dashed lines are the mean and 95% CI percent positive for each distance bin. 95% CIs were estimated using the exact binomial test.

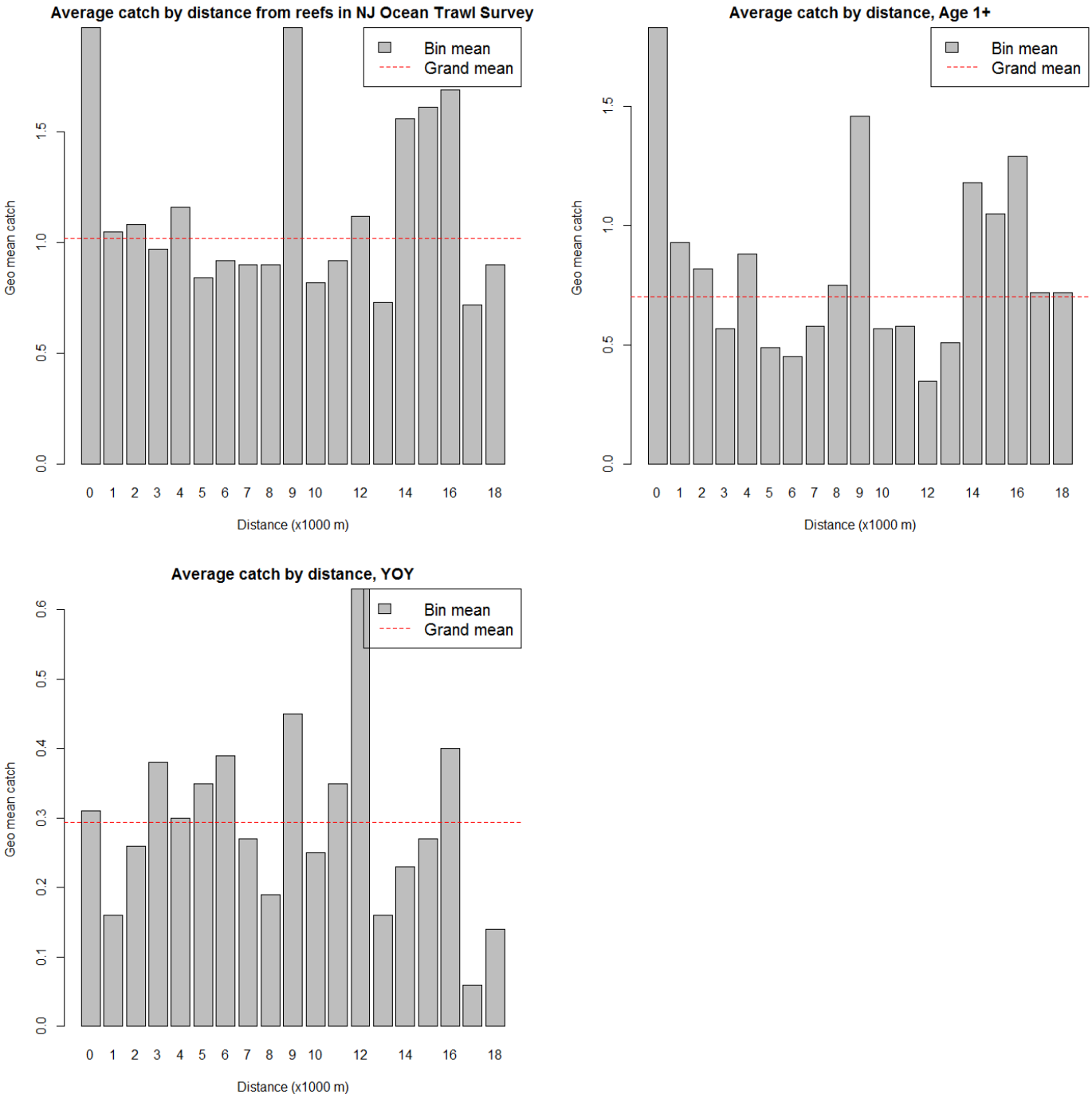
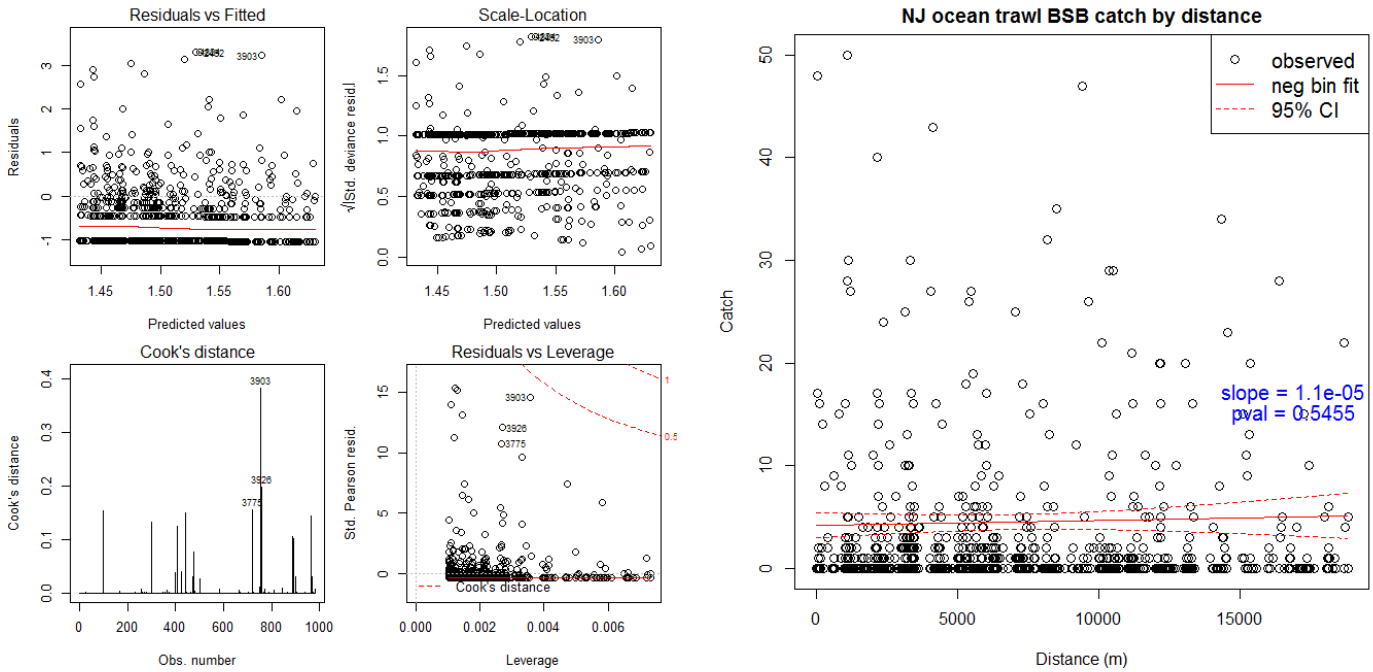


Figure 17. Geometric mean catch per tow in the NJ trawl survey, for all fish (top left), age 1+ fish (top right), and young of year fish. For each plot, the red dashed line is the overall mean for the size group, and the bars are the mean catch by distance bin. All 95% CI overlapped 0.



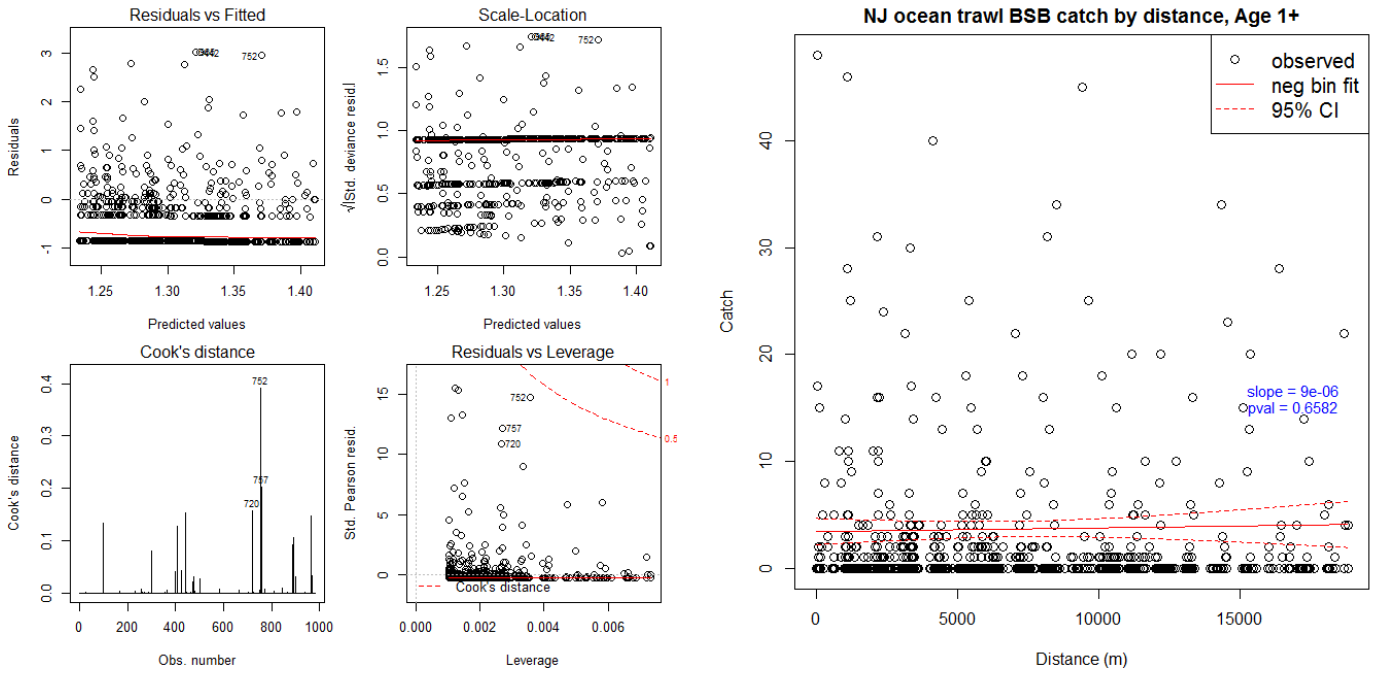


Figure 18. Diagnostic plots and observed vs. predicted results of the negative binomial glm of catch vs distance for all fish (top), age 1+ fish (bottom), and young of year fish (next page). One outlier tow (N = 1,463 fish; Cook's distance > 4.0) was removed from the analysis.

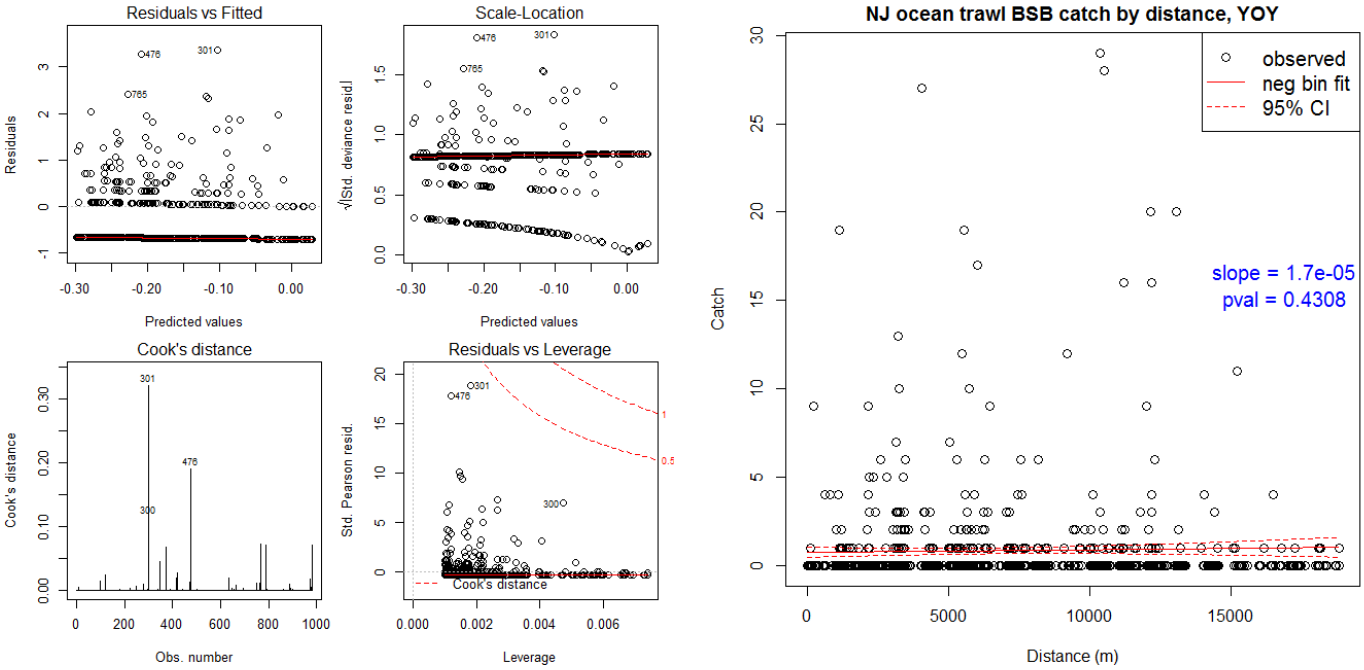


Figure 18 (cont).

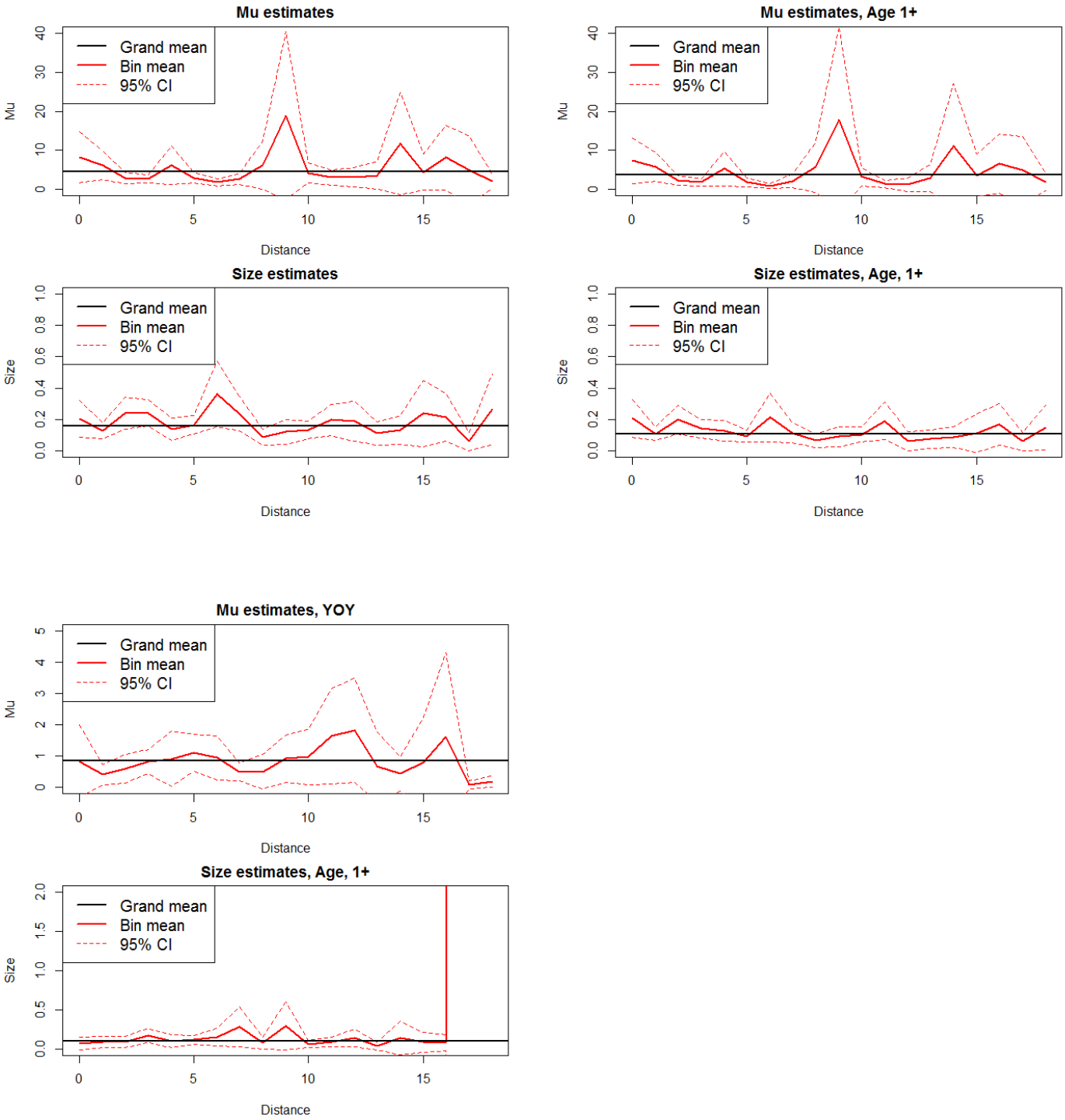
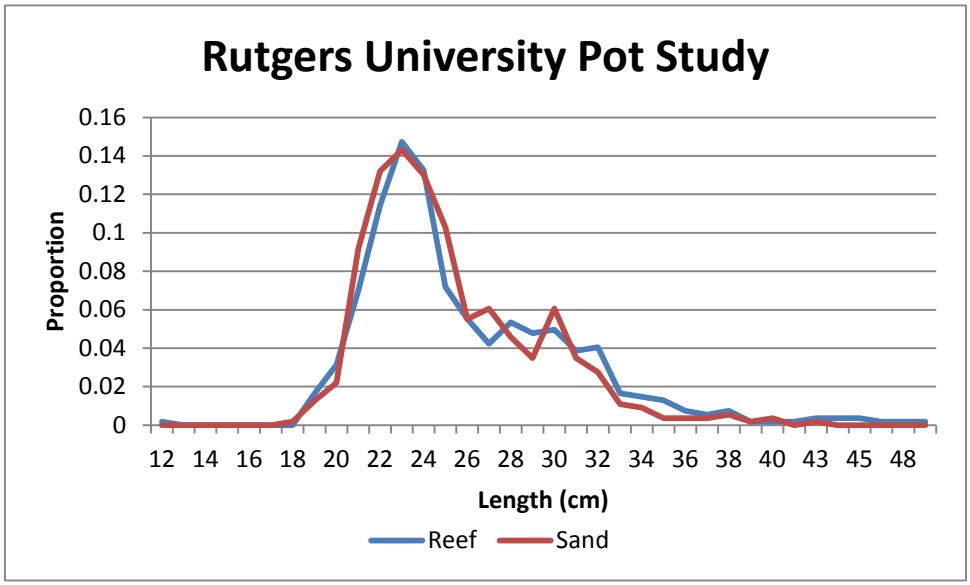


Figure 19. Estimates of negative binomial mean catch and dispersion (size) by distance bin for all fish (top left), age 1+ fish (top right), and young of year fish. In each plot, the heavy black line is the overall value across all distance bins. The red solid and dashed lines are the estimated values and 95% CIs for each distance bin.



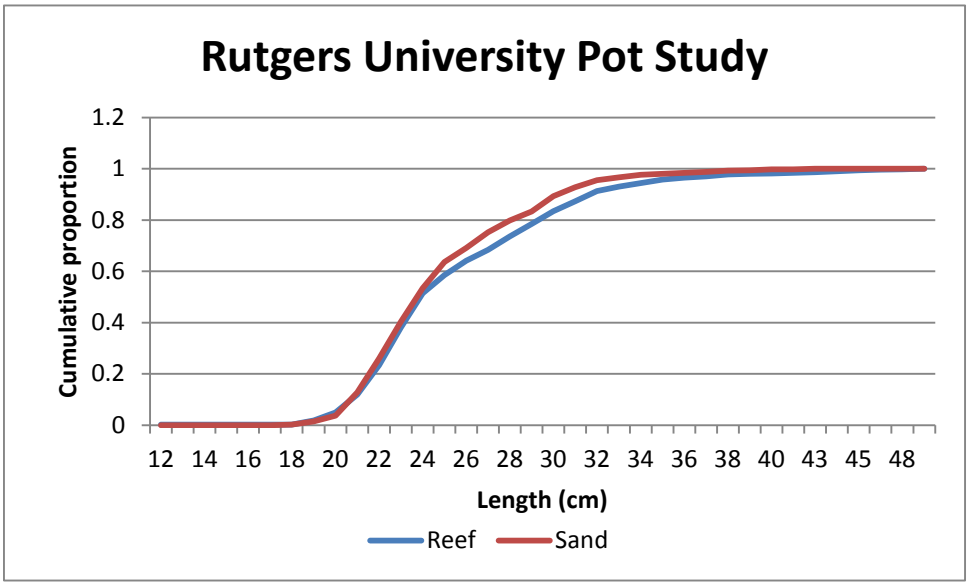


Figure 20. Length frequency distributions of black sea bass on reef and sand habitat from the Rutgers University pot study.

Appendix A4- History of black sea bass fishery management

Fishery Management History

Management Overview

The Atlantic States Marine Fisheries Commission (ASMFC or Commission) and Mid-Atlantic Fishery Management Council (MAFMC or Council) work cooperatively to develop fishery regulations for black sea bass from Maine through Cape Hatteras, North Carolina. The Council and Commission work in conjunction with the National Marine Fisheries Service (NMFS), which serves as the federal implementation and enforcement entity. The Fishery Management Plan (FMP) defines the management unit as black sea bass (*Centropristis striata*) in US waters in the western Atlantic Ocean from Cape Hatteras, North Carolina to the US-Canadian border (MAFMC 1996).

Commercial and recreational black sea bass fisheries are managed using annual catch limits, commercial quotas, recreational harvest limits, minimum fish sizes, gear regulations, permit requirements, and other provisions as prescribed by the FMP. Based on the allocation percentages in the FMP, 49% of the total allowable landings of black sea bass is allocated to the commercial fishery as a commercial quota and 51% is allocated to the recreational fishery as a recreational harvest limit. These measures are described in more detail in subsequent sections of this document.

The Council and the Commission's Summer Flounder, Scup, and Black Sea Bass Management Board (the Board) developed a cooperative management process for black sea bass including complementary FMPs, regular joint meetings, and joint decision-making on most aspects of management. This cooperative management endeavor was developed because a significant portion of the catch is taken from both state waters (0-3 miles offshore) and federal waters (3-200 miles offshore, also known as the Exclusive Economic Zone or EEZ). Primary responsibility for management in federal waters falls to the Council, while the Commission has primary jurisdiction over the fisheries in state waters. Many measures, however, including annual catch limits, are jointly established on a coastwide basis and apply in both federal and state waters.

The Commission operates under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) of 1993. Commission member states include all Atlantic coast states, and for black sea bass, states that have declared an interest in the fishery include Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina. All states that are included in a Commission fishery management plan must implement required conservation provisions of the FMP, or the Secretary of Commerce may impose a moratorium for fishing in the noncompliant state's waters.

The Council operates under the authority of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), passed in 1976 and amended in 1996 and 2007. The MSA extended U.S. jurisdiction to 200 nautical miles and established eight regional fishery management councils with representation from the coastal states and fishery stakeholders. The Mid-Atlantic Council's representation includes 21 voting members and four non-voting members. Seven of the voting members represent the constituent states' fish and wildlife agencies from the states of New York through North Carolina. Thirteen members are private citizens who are knowledgeable about recreational fishing, commercial fishing, or marine conservation. The four

non-voting members represent the Atlantic States Marine Fisheries Commission, the U.S. Fish and Wildlife Service, the U.S. Department of State, and the U.S. Coast Guard.

As mandated under the MSA, the Council's Scientific and Statistical Committee (SSC) gives ongoing scientific advice for annual catch limits and other issues as needed. Other technical issues and analyses are addressed through the joint Summer Flounder, Scup, and Black Sea Bass Monitoring Committee and the Commission's Black Sea Bass Technical Committee. The Monitoring Committee is a joint committee of the Council and the Commission made up of staff representatives of the Mid-Atlantic and South Atlantic Fishery Management Councils, the Atlantic States Marine Fisheries Commission, the Greater Atlantic Regional Office, and the Northeast Fisheries Science Center. The Monitoring and Technical Committees annually review the performance of management measures and recommend any adjustments necessary to account for the current stock status, catch limits, and issues facing the commercial and recreational fisheries.

The Council and Commission each have Summer Flounder, Scup, and Black Sea Bass Advisory Panels, comprised of commercial, recreational, and environmental stakeholders with an interest in these fisheries. The Advisory Panels provide ongoing advice to the Council and Commission regarding on-the-water trends and issues in the fisheries.

In an annual process known as "specifications," the Council and Commission review catch and landings limits and a specific set of commercial and recreational measures that can be modified annually. The Council and Board meet jointly each year to consider the annual catch limits for the upcoming fishing year or years, along with the commercial and recreational size limits, seasons, gear requirements, and possession limits. Multi-year specifications may be set for black sea bass for up to three years at a time. The Council and Board consider the recommendations of the SSC, the Monitoring Committee, Advisory Panel members, and public comments before recommending commercial quotas, recreational harvest limits, and other annual management measures for all three species.

More substantial modifications to the FMP or regulations are undertaken through FMP amendments, addenda, and framework actions. FMP "amendments" include major changes to the management regime that require extensive analysis, and are typically developed jointly by both the Council and the Commission. For less complicated actions, the Commission may also make changes through an "addendum" process, while the Council can make minor changes to the FMP through a "framework adjustment" process, both of which typically take less time and resources than an amendment requires.

The Council submits any recommended changes in regulations or FMP elements to the NMFS Greater Atlantic Regional Administrator to consider for implementation. The Regional Administrator reviews the recommendations in this document and may revise them, if necessary, to achieve FMP objectives and to meet statutory requirements. The Commission's actions do not require review by NMFS, and member states are responsible for implementing the Board's decisions.

FMP Development

The Council and Commission jointly developed and adopted the FMP for the black sea bass fishery in 1996, and the Secretary of Commerce approved the FMP in October of that year (MAFMC 1996). The Council had conducted preliminary work to support the development of an FMP starting in 1978; however, a plan was not completed at that time (MAFMC 2002). Development resumed in the early 1990s. In 1996, NOAA NMFS requested that scup and black sea bass regulations be incorporated into a pre-existing FMP in order to reduce the number of separate fisheries regulations issued by the federal government. As a result, the federal scup and black sea bass FMPs were developed by incorporating them into the existing federal Summer Flounder FMP through Amendment 8 (for scup) and Amendment 9 (for black sea bass).

The objectives of the FMP for black sea bass have remained unchanged since 1996, and are to: 1) reduce fishing mortality to ensure overfishing does not occur, 2) reduce fishing mortality on immature black sea bass to increase spawning stock biomass, 3) improve yield from the fishery, 4) promote compatible regulations among states and between federal and state jurisdictions, 5) promote uniform and effective enforcement, and 6) minimize regulations necessary to achieve the stated objectives.

The original joint FMP established a management program and recovery strategy for black sea bass that included commercial quotas, recreational harvest limits, commercial gear requirements, minimum size limits, permit requirements, and reporting requirements. This strategy was intended to reduce fishing mortality on black sea bass over an 8-year time frame.

The FMP has been modified many times since its original adoption in 1996, via FMP amendments, addenda, and framework actions. FMP “amendments” include major changes to the management regime that require extensive analysis, and are typically developed jointly by both the Council and the Commission. The Commission may also make changes through an “addendum” process, while the Council can make minor changes to the FMP through a “framework adjustment” process. During the annual specifications process, the Council and Commission also review catch and landings limits and a specific set of commercial and recreational measures that can be modified annually.

A more detailed description of the specific management measures implemented under the FMP, and their evolution over time, is contained in the sections below. A summary of all major amendments, addenda, and framework adjustments to the FMP since 1996 is presented in Table 1. The original FMP, subsequent amendments, addenda, and frameworks are available at: www.mafmc.org/fisheries/fmp/sf-s-bsb and http://www.asmfc.org/species/black-sea-bass.

Catch and Harvest Limits

The Council and Board meet jointly each year to recommend annual catch and landings limits for black sea bass. The MSA requires the Council's SSC to provide ongoing scientific advice for fishery management decisions, including recommendations for annual catch limits, preventing overfishing, and achieving maximum sustainable yield. The Council and Board may specify catch and landings limits for up to three years at a time. The Council's catch limit recommendations for the upcoming fishing year(s) cannot exceed the annual Acceptable Biological Catch (ABC) recommendation of the SSC.

In addition, the Monitoring Committee established in the FMP is responsible for recommending management measures designed to achieve the annual catch limits. Each year, the Council and Commission's Summer Flounder, Scup, and Black Sea Bass Advisory Panels also provide input on the management measures for these species.

Each year, the Council and Board consider the recommendations of the SSC, Monitoring Committee, and the Advisory Panels before setting catch limits for the upcoming year, or reviewing the measures already in place. Following joint approval of annual catch limits by the Council and Board, the Council submits the preferred measures to NMFS for final approval and implementation.

The FMP has not always required annual catch limits. From 1996 through 2011, the Council and Commission approved annual total allowable landings (TAL) limits, divided into landings limits for the commercial and recreational sectors in the form of commercial quotas and recreational harvest limits. These limits did not account for discards. In 2007, the reauthorized MSA implemented new requirements for Councils to specify annual catch limits (including landings and discards) and accountability measures. The reauthorized act also required the use of scientific advice from each Council's SSC as the upper bounds for catch limits. In response to these new requirements, the Council modified the annual specifications process, approving an "Omnibus ACLs and AMs Amendment" in 2011 (Amendment 15 to the FMP) to bring all Council FMPs into compliance with the new MSA requirements. This amendment, effective in 2012, instituted a system of scientifically-based catch limits, a Council risk policy and control rule, and requirements for overage accountability (accountability measures or AMs).

The Council and Commission continue to specify annual landings limits (commercial quotas and recreational harvest limits) for black sea bass in addition to the overall and sector-specific annual catch limits. The overall annual catch limit (acceptable biological catch or ABC) is divided into commercial and recreational Annual Catch Limits (ACLs), based on the landings allocation prescribed in the FMP and the recent distribution of discards between the commercial and recreational fisheries. The Monitoring Committee is responsible for recommending annual catch targets (ACTs), which may be set equal to or less than the ACLs to account for management uncertainty.

Based on the allocation percentages in the FMP, 49% of the total allowable landings of black sea bass is allocated to the commercial fishery as a commercial quota and 51% is allocated to the recreational fishery as a recreational harvest limit. These allocation percentages were established by Amendment 9 (1996), using the average landings by sector over the years 1983-1992.

Projected discards from each sector are removed from sector-specific ACTs to derive landings limits (commercial quotas and recreational harvest limits). The sum of the commercial quota and recreational harvest limit is equivalent to the total allowable landings in a given year. The relationship between the different catch and landings components of the fishery is given in Figure 1. Table 2 shows black sea bass catch and landings limits from 1996 through 2016.

Commercial Fishery Measures

The Commission divides the coastwide black sea bass commercial quota among the states based on the allocation percentages given in Table 3, and states set measures to achieve their state-specific commercial quotas.

When the black sea bass FMP was first developed, the initially proposed state-by-state commercial quota contained within was disapproved by NOAA in July 1996. The Regional Director concluded that the state-by-state quota provision was not consistent with National Standard 7 of the MSA, specifically that the provisions that apply to the area of north of Cape Hatteras, North Carolina would impose significant administrative and enforcement costs on NMFS and North Carolina (MAFMC 2002). Based on the notice from the Regional Director, the Council voted to replace the state-by-state quota system with a coastwide commercial quota allocated in quarterly periods over the year, starting in 1999 (Table 4). Quota periods were allocated based on the percentage share of commercial landings from 1988-1992.

The FMP required that any commercial harvest in excess of the quota for a given period be subtracted from the same period in the following year. This system was leading to significant quota period overages, lengthy closures of the commercial fishery, high uncertainty regarding quota availability, and increased discards of legal sized black sea bass in mixed fisheries during closed periods. Additionally, a decrease in market demand for black sea bass resulted from the fluctuating supply.

In August 2002, the Board and Council passed Amendment 13 (MAFMC 2002). This amendment addressed a number of items, but most notably for black sea bass, it eliminated the quarterly commercial quota system and established an annual coastwide commercial quota. This coastwide commercial quota was intended to facilitate the Commission's development and implementation of state-by-state commercial allocations, independent of federal monitoring and enforcement constraints. Thus, the commercial allocation percentages are contained only within the Commission's version of the FMP and not the Council's. This allows the states to manage their commercial allocation as they see fit to ensure that the overall quota is achieved but not exceeded in a given year. Since 2002, the Council and Board have annually approved a coastwide commercial quota that the Commission then divides among the states according to the percentages given in Table 3. These state commercial quota percentages were established in Amendment 13 (effective 2003), based on historical landings by state over the years 1980-2001. The state quotas are monitored and enforced by the states during the fishing year, and the Commission reviews compliance annually to account for state level overages.

In addition to commercial quotas, the commercial black sea bass fishery is also managed with restrictions on commercial minimum fish size, minimum mesh size for trawl vessels, seasonal possession limits that trigger the minimum mesh size requirement, and pot and trap gear

requirements. A moratorium permit is also required to fish commercially for black sea bass in federal waters. Management measures in the commercial black sea bass fishery, other than quotas and harvest limits, have remained constant since 2007. Changes to the coastwide commercial management measures over time are shown in Table 5.

The current minimum size for retention of black sea bass in the commercial fishery is 11 inches total length.

Any federally-permitted vessel which uses otter trawl gear and catches more than 500 pounds of black sea bass from January through March, or more than 100 pounds from April through December, must use nets with a minimum mesh size of 4.5-inch diamond mesh applied throughout the codend for at least 75 continuous meshes forward of the end of the net. For codends with less than 75 meshes, the entire net must have a minimum mesh size of 4.5-inch diamond mesh.

Pots and traps used to target black sea bass commercially must have two escape vents in the lower corners of the section known as the parlor. The escape vents must measure 1.375 inches by 5.75 inches if rectangular, 2 inches by 2 inches if square, or have a diameter of 2.5 inches if circular. Black sea bass traps and pots also must contain a ghost panel with degradable fasteners and hinges, covering an opening of at least 3.0 inches by 6.0 inches.

Since the implementation of Amendment 9 in 1996, Federal regulations have prohibited otter trawl vessels holding black sea bass moratorium permits from using roller rig trawl gear equipped with rollers greater than 18 inches in diameter. An 18- inch diameter corresponded to the maximum roller diameter used by some states to regulate this gear in state waters. The intent of this regulation was to prevent bottom trawl vessels from accessing black sea bass in areas with especially rough bottoms, thus protecting sea bass in those areas from harvest, allowing more fish to grow to maturity and spawn, and increasing biomass.

States use a combination of trip limits, closed seasons, mandatory reporting and limited access permits to constrain landings to state allocations. Additionally, many states constrain commercial fishing efforts through further dividing the state allocation into seasonal, trimesters, and quarterly quotas over the course of the year. Massachusetts through New Jersey and North Carolina use different trip limits linked to seasonal quotas: Massachusetts in most years has used a two season quota with different trip limits specific to gear type and seasonal quota; Rhode Island, New York, North Carolina have used 5 quota periods; Connecticut has used a trimester quota; and New Jersey has had a quarterly quota system. The states of Delaware through Virginia manage their state quotas through individual fishing quotas (ITQs); for Delaware, the number of ITQs are specific to the gear type within the fishery (pot fishery and hook & line); Maryland breaks its quota into ITQs based on the number of commercial permits; Virginia breaks down its state allocation into quotas for the directed and bycatch fisheries, with ITQs for each fisheries.

Recreational Fishery Measures

The recreational black sea bass fishery is managed using a combination of possession limits (bag limits), size limits, and seasons that are expected to constrain landings to the annual harvest limit. For-hire (party or charter) vessels carrying passengers in federal waters must obtain a federal

party/charter permit, and may need to obtain state permits as well. No special permits are required for private boat or shore anglers fishing for black sea bass, however, anglers are subject to broader fishing license requirements of the state from which they are fishing.

The Monitoring Committee meets annually each fall to review recreational data and make recommendations regarding possession limits, minimum sizes, and seasons for the upcoming fishing year. The Council and Commission meet jointly each December to consider the advice of the Monitoring Committee and the Advisory Panel, before adopting recreational measures for the upcoming year.

Until 2010, the black sea bass recreational fishery was managed with coastwide measures as dictated by the FMP, which included an identical minimum fish size, possession limit, and an open season that were implemented in both state and federal waters. Starting in 2011 through present (2016), the Board has approved several FMP addenda (XXI through XXVII) that have allowed for "ad hoc regional management" in state waters, essentially resulting in state-specific measures implemented in state waters from Massachusetts through New Jersey (Table 6). These measures have varied substantially among the states over time, and have also varied from the measures implemented in federal waters.

The Council and Commission jointly approve federal waters measures each December, which apply from 3-200 miles at sea within the entire management unit (Table 7). State waters measures in the states Delaware through North Carolina have typically mirrored the federal regulations. In recent years, the majority of recreational harvest has taken place in the state waters of Massachusetts through New Jersey, such that when the coastwide recreational harvest limit has been exceeded, these states have typically adjusted their measures to achieve the bulk of the required reduction.

The recent efforts to address needed reductions to achieve the coastwide RHL through ad-hoc regional management has led to increasingly restrictive, complex management measures. Season length, size limit, and possession limit all vary dramatically from state to state.

Literature Cited

MAFMC 1996. Fishery Management Plan for Black Sea Bass. Dover, DE. Available at: http://www.mafmc.org/s/SFSCBSB_Amend_9.pdf.

MAFMC. 2002. Amendment 13 to the Black Sea Bass Fishery Management Plan. Dover, DE. Available at: https://mafmc.squarespace.com/s/SFSCBSB_Amend_13_Vol_1compressed.pdf.

Table 1. Summary of management actions taken in the FMP, including Amendments, Addenda, and Framework adjustments to the FMP from 1996 to present. FMP actions applicable only to summer flounder or scup are not included.

Year	Document	MAFMC, ASMFC, or Joint	Management Action(s)
1996	Original FMP (ASMFC)/ Amendment 9 (MAFMC)	Joint	Incorporated Black Sea Bass into MAFMC Summer Flounder FMP/ established Commission's black sea bass FMP for ASMFC; Established black sea bass management measures, including commercial quotas, recreational harvest limits, size limits, gear restrictions, permits, and reporting requirements.
1999	Amendment 12	Joint	Revised FMP to comply with new requirements of the Sustainable Fisheries Act of 1996; revised overfishing definitions for black sea bass; established framework adjustment process
2001	Framework 1	MAFMC	Established quota set-aside for research for summer flounder, scup, and black sea bass
2001	Addendum 4	ASMFC	Outlined annual specifications process for summer flounder, scup, black sea bass regarding commercial and recreational management measures (improved timeliness of regulation setting and state/federal compatibility)
2002	Addendum 6	ASMFC	Established possession limits for quarters 2, 3 and 4 for the 2002 black sea bass commercial fishing season; instituted a system by which the Board can set initial possession limits, triggers, and adjusted possession limits for the black sea bass fishery during the annual specification setting process
2003	Amendment 13	Joint	Revised black sea bass commercial quota system from quarterly quota to coastwide quota, with state-by-state allocations to be implemented by the Commission; updated Essential Fish Habitat (EFH) requirements
2004	Addendum 7	ASMFC	Continued state-by-state commercial quota allocation system from Amendment 13, maintained commercial management measures through 2007.
2004	Addendum 8	ASMFC	Allowed setting multi-year landings limits for up to 3 years at a time
2004	Framework 5	MAFMC	Allowed setting multi-year landings limits for up to 3 years at a time
2007	Framework 7	MAFMC	Added flexibility to automatically define and update stock status determination criteria with new assessments, rather than writing them into the FMP
2007	Amendment 17	MAFMC	Standardized bycatch reporting methodology (all Council species)
2007	Addendum 19	ASMFC	Continued state-by-state commercial quota allocation system from Amendment 13, maintained commercial management measures without a sunset clause; added flexibility for stock status determination criteria (automatically updated with new assessments rather than written into FMP)
2009	Addendum 20	ASMFC	Specified how state-level commercial overages would be accounted for annually; streamlined the state quota transfers process and established policies and protocols to guide the allocation of transfers from states with underages to states with overages.
2011	Amendment 15	MAFMC	Established Annual Catch Limits (ACLs) and Accountability Measures (AMs) to comply with reauthorized

Year	Document	MAFMC, ASMFC, or Joint	Management Action(s)
			Magnuson-Stevens Act
2011	Addendum 21	ASMFC	Allowed for regionally-based recreational management measures in state waters in 2011 (rather than single set of coastwide measures)
2012	Addendum 22	ASMFC	Allowed continued use of regional recreational measures in state waters in 2012
2013	Addendum 23	ASMFC	Allowed continued use of regional recreational measures in state waters in 2013
2013	Amendment 19	MAFMC	Revised recreational Accountability Measures for black sea bass and other Council-managed recreational fisheries
2014	Addendum 25	ASMFC	Set ad hoc regional recreational management for black sea bass in 2014, with the option of extending into 2015
2015	Framework 8	MAFMC	Modified recreational black sea bass season start date (done outside typical specifications process due to timing issue)
2015	Amendment 18	MAFMC	Removed some of the restrictions for upgrading vessels listed on Federal fishing permits; Eliminated requirement for vessel owners to submit "did not fish" reports for the months or weeks when their vessel was not fishing
2016	Addendum 27	ASMFC	Continued ad hoc regional recreational management for black sea bass in 2016, with the option of extending into 2017

Table 2. Summary of catch limits and landings limits for commercial and recreational black sea bass fisheries and landings from Maine through Cape Hatteras, NC 1996 through 2016. Numbers may not add precisely due to rounding.

Management measures	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Acceptable Biological (ABC)[a]	-	-	-	-	-	-	-	-	-	-	-
Total Allowable Catch (TAC)	-	-	-	-	-	-	-	-	-	-	-
TAL (m lb)	-	-	6.17	6.17	6.17	6.17	6.80	6.80	8.00	8.20	8.00
Commercial ACL	-	-	-	-	-	-	-	-	-	-	-
Commercial quota (initial)[b]			3.03	3.03	3.03	3.03	3.33	3.33	3.92	4.02	3.92
Commercial quota (adjusted)[b]	-	-	-	-	2.63	2.64	3.13	3.01	3.77	3.95	3.83
Recreational ACL	-	-	-	-	-	-	-	-	-	-	-
Recreational harvest limit (initial)[b]	-	-	3.15	3.15	3.15	3.15	3.47	3.47	4.08	4.18	4.08
Recreational harvest limit (adjusted)[b]	-	-	-	-	-	-	3.43	3.43	4.01	4.13	3.99

Management measures	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Acceptable Biological (ABC)[a]	-	-	-	4.50	4.50	4.50	5.50	5.50	5.50	6.67
Total Allowable Catch (TAC)	-	-	2.300	4.50	4.50	4.50	5.50	5.50	5.50	6.67
Total Allowable Landings (TAL)	5.00	4.22	2.30	3.70	3.60	3.60	4.54	4.54	4.54	5.53
Commercial ACL	-	-	-	-	-	1.98	2.60	2.60	2.60	3.15
Commercial quota (initial)[b]	2.45	2.07	1.13	1.81	1.76	1.76	2.21	2.21	2.21	2.71
Commercial quota (adjusted)[b]	2.38	2.03	1.09	1.76	1.71	1.71	2.17	2.17	-	-
Recreational ACL	-	-	-	-	-	1.86	2.90	2.90	2.90	3.52
Recreational harvest limit (initial)[b]	2.55	2.15	1.17	1.89	1.84	1.36	2.33	2.33	2.33	2.82
Recreational harvest limit (adjusted)[b]	2.47	2.11	1.14	1.83	1.78	1.32	2.26	2.26	-	-

[a] The ABC is the annual Acceptable Biological Catch for the entire black sea bass fishery, including both landings and discards, as required under the MSA. ABCs were implemented starting in 2010. Conceptually, the ABC is equivalent to the Total Allowable Catch (TAC), however, the term "TAC" was replaced with "ABC" based on the language in the reauthorized MSA.

[b] Commercial quotas and recreational harvest limits reflect the removal of projected discards from the sector-specific ACLs. For 2000-2014, these limits include "initial" limits as well as those adjusted for Research Set Aside (RSA). Quotas and harvest limits for 2015-2016 do not reflect an adjustment for RSA due to the suspension of the program in 2014.

Table 3. Current allocation of commercial black sea bass quota among states established in the Commission's FMP.

State	Allocation (percent)
Maine	0.5
New Hampshire	0.5
Massachusetts	13.0
Rhode Island	11.0
Connecticut	1.0
New York	7.0
New Jersey	20.0
Delaware	5.0
Maryland	11.0
Virginia	20.0
North Carolina	11.0
Total	100

Table 4. Former coastwide quarterly allocation system (1999-2002).

Quarter	Dates	% of Commercial Quota
I	January 1-March 31	38.64%
II	April 1-June 30	29.26%
II	July 1-September 30	12.33%
IV	October 1-December 31	19.77%

Table 5. Summary of black sea bass coastwide (state and federal waters) commercial management measures, 1996-2016.

Management measures	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Com. fish size (in)	9	9	10	10	10	10	11	11	11	11	11
Min. mesh size (in, diamond)	4.0	4.0	4.0	4.0	4.0	4.0	4.5[a]	4.5[a]	4.5[a]	4.5[a]	4.5[a]
Minimum mesh size threshold (lb)	100 (year-round)	100 (year-round)	1,000 (year-round)	1,000 (year-round)	1,000 (year-round)	1,000 (year-round)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)
Pot or trap vent size (in)	2” circular; or 1 ½” square; or 1 1/8 x 5 ¾” rectangle	2” circular; or 1 ½” square; or 1 1/8 x 5 ¾” rectangle	2” circular; or 1 ½” square; or 1 1/8 x 5 ¾” rectangle	2” circular; or 1 ½” square; or 1 1/8 x 5 ¾” rectangle	2” circular; or 1 ½” square; or 1 1/8 x 5 ¾” rectangle	2” circular; or 1 ½” square; or 1 1/8 x 5 ¾” rectangle	2 3/8” circular; or 2” square; or 1 3/8 x 5¾” rectangle	2 3/8” circular; or 2” square; or 1 3/8 x 5¾” rectangle	2 3/8” circular; or 2” square; or 1 3/8 x 5¾” rectangle	2 3/8” circular; or 2” square; or 1 3/8 x 5¾” rectangle	2 3/8” circular; or 2” square; or 1 3/8 x 5¾” rectangle
Pot or trap vents required	1	1	1	1	1	1	1	1	1	1	1

Management measures	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Com. fish size (in)	11	11	11	11	11	11	11	11	11	11
Min. mesh size (in, diamond)	4.5[a]	4.5[a]	4.5[a]	4.5[a]	4.5[a]	4.5[a]	4.5[a]	4.5[a]	4.5[a]	4.5[a]
Minimum mesh size threshold (lb)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)	500 (Jan-Mar); 100 (Apr-Dec)
Pot or trap vent size (in)	2 ½” circular; or 2” square; or 1 3/8 x 5 ¾” rectangle	2 ½” circular; or 2” square; or 1 3/8 x 5 ¾” rectangle	2 ½” circular; or 2” square; or 1 3/8 x 5 ¾” rectangle	2 ½” circular; or 2” square; or 1 3/8 x 5 ¾” rectangle	2 ½” circular; or 2” square; or 1 3/8 x 5 ¾” rectangle	2 ½” circular; or 2” square; or 1 3/8 x 5 ¾” rectangle	2 ½” circular; or 2” square; or 1 3/8 x 5 ¾” rectangle	2 ½” circular; or 2” square; or 1 3/8 x 5 ¾” rectangle	2 ½” circular; or 2” square; or 1 3/8 x 5 ¾” rectangle	2 ½” circular; or 2” square; or 1 3/8 x 5 ¾” rectangle
Pot or trap vents required	2	2	2	2	2	2	2	2	2	2

[a]Large trawls are required to possess a minimum of 75 meshes of 4.5 inches diamond mesh in the codend, or for nets with codends less than 75 meshes, the entire net must have a minimum mesh size of 4.5 inches throughout.

Table 6. State by state recreational black sea bass regulations from 2011- 2015

State	2011	2012	2013	2014	2015
MA	14 inch, 10 fish, May 22-October 11	14 inch, 10 fish, May 11-June 24 & 20 fish, June 25-October 31	**Private and For-hire**: 14 inch, 4 fish, May 11-October 31; **For-hire LOA**: 14 inch, 10 fish, May 11-June 4; 20 fish, July 1-August 11 & September 1-October 10	**Private and For-hire**: 14 inch, 4 fish, May 11-October 31; **For-hire LOA**: 14 inch, 10 fish, May 11-June 4; 20 fish, July 1-August 11 & September 1-October 11	**Private and For-hire:** 14 inch, 8 fish, May 23-August 27
RI	13 inch, 12 fish, July 11-December 31	13 inch, 15 fish, June 15-December 31	13 inch, 3 fish, June 15-August 31 & 7 fish, September 1-December 31	13 inch, 3 fish, June 29-August 31 & 7 fish, September 1- December 31	14 inch, 1 fish, July 2-August 31 & 7 fish, September 1- December 31
CT	13 inch, 25 fish, July 1-October 11 & November 1 to December 31		**Private**: 13 inch, 3 fish, June 15-August 31 & 8 fish, September 1- October 29; **For-hire** 13 inch 8 fish June 15-November 30	**Private and Shore**: 13 inch, 3 fish, June 21- August 31; **Party/Charter**: 13 inch, 8 fish, June 21-December 31	14 inch, 3 fish, June 1-August 31 & 8 fish, September 1 to December 31
NY	13 inch, 10 fish, June 13-October 1 & November 1-December 31		13 inch, 8 fish, July 10-December 31	13 inch, 8 fish, July 15-December 31	14 inch, 8 fish, July 15-October 31 & 10 fish, November 1- December 31
NJ	12.5 inch, 25 fish, May 28-September 11 & November 1-December 31	12.5 inch, 25 fish, May 19-September 3; September 23-October 14 & November 1-December 31	12.5 inch, 20 fish, May 19-August 8; September 27-October 14 & November 1-December 31	12.5 inch, 3 fish, July 1-August 31; 15 fish, May 19-June 30; September 1-6 & October 18-December 31	12.5 inch, 2 fish, July 1-July 31; 15 fish, May 27-June 30 & October 22-December 31
DE	12.5 inch, 25 fish, May 22-October 11 & November 1-December 31	12.5 inch, 25 fish, May 19-October 14 & November 1-December 31	12.5 inch, 15 fish, January 1-February 28; 20 fish, May 19- October 14 & November 1-December 31	12.5 inch, 15 fish, May 19-September 18 & October 18-December 31	12.5 inch, 15 fish, May 15-September 21 & October 22-December 31
MD					
VA					
NC	12.5", 25 fish, July 1-September 25 & November 1-December 31				

Table 7. State and federal waters (1997-2010) and federal waters only (2011-2016) recreational measures for black sea bass, north of Cape Hatteras, NC.

Measure	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Possession Limit	-	-[a]	-[a]	-[a]	25	25	25	25	25	25
Size Limit (TL in)	9	10	10	10	11	11.5	12	12	12	12
Open Season	1/1-12/31	1/1-7/30 and 8/16-12/31	1/1-12/31	1/1-12/31	1/1-2/28 and 5/10-12/31	1/1-12/31	1/1-9/1 and 9/16-11/30	1/1-9/7 and 9/22-11/30	1/1-9/7 and 9/22-11/30	1/1-12/31
Measure	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Possession Limit	25	25	25	25	25	25	20	15	15	15
Size Limit (TL in)	12	12	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Open Season	1/1-12/31	1/1-12/31	1/1-12/31	1/1-10/5	5/22-10/1 and 11/1-12/31	1/1-2/29, 5/19-10/14 and 11/1-12/31	5/19-10/14 and 11/1-12/31	5/19-9/21 and 10/18-12/31	5/15-9/21 and 10/22-12/31	5/15-9/21 and 10/22-12/31

[a] There was no federal possession limit but some states implemented a 20 fish possession limit in these years.

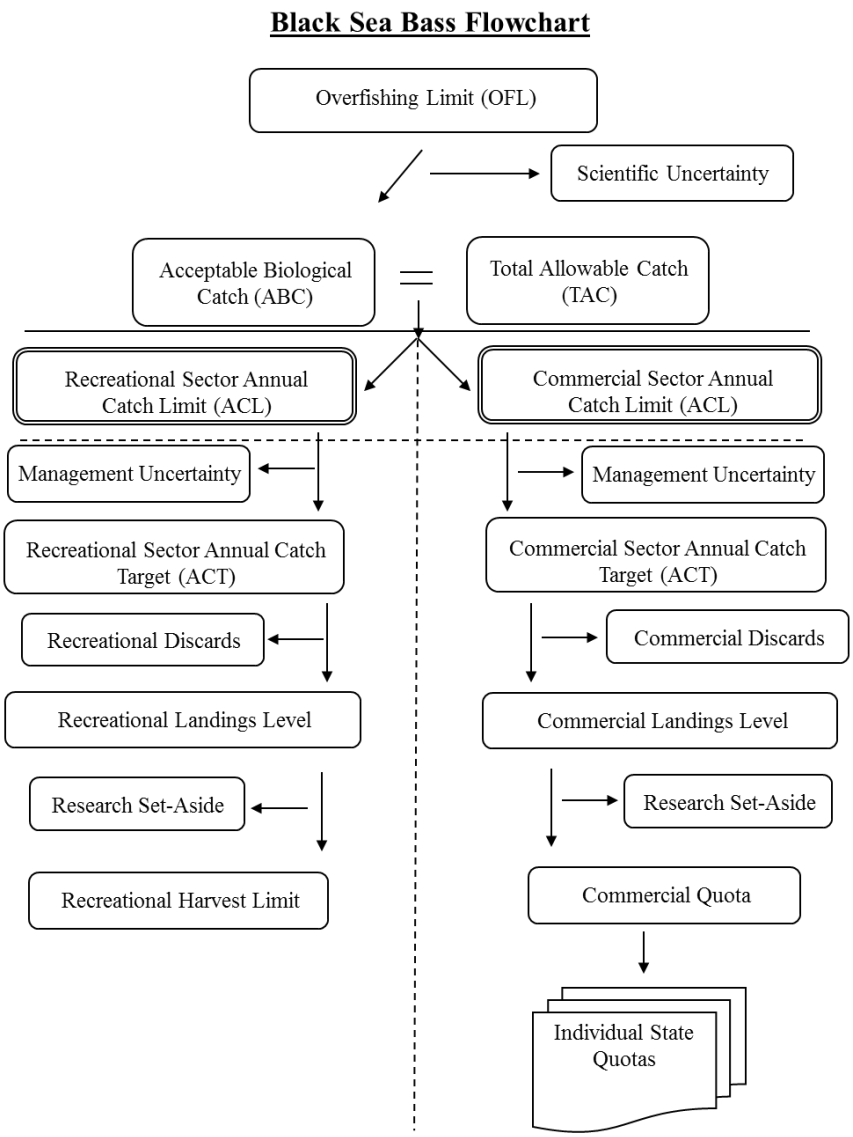


Figure 1: Flowchart for black sea bass catch and landings limits. The allowance for Research Set-Aside has been suspended indefinitely pending overhaul of the program.

Appendix A5- Report to the MAFMC SSC on proposed split of the northern stock of Black Sea Bass into sub-units for assessment purposes

Black Sea Bass Benchmark Stock Assessment Review

Term of Reference 1 – Spatial issues

Proposed partitioning of northern black sea bass stock for purposes of developing spatial stock assessment models

January 2016

SAW/SARC Black Sea Bass Working Group

SAW/SARC Black Sea Bass Working Group

John Maniscalco – NY DEC chair

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Introduction

A benchmark assessment of the northern stock of black sea bass was most recently reviewed in SAW/SARC 53 (NEFSC 2012), conducted in December of 2011. The conclusion of the review panel was that the assessment results were not appropriate for use in making management decisions. *The Panel identified substantial concerns over the potential for spatial structure and incomplete mixing within the stock area that compromised the ability of the forward projecting catch at age model to index abundance and fishing mortality reliably based on the data available.*
A new benchmark assessment has been scheduled for SARC review in December 2016. The first of the draft terms of reference for the assessment attempts to address the spatial issue:

1. Evaluate the distribution, movement and potential for spatial structure of the stock, the ability of existing data to support alternative spatial structure, and their consequences for the stock assessment.

Since development of the assessment hinges on the conclusions reached in evaluation of spatial structure in TOR1, the Black Sea Bass working group has recommended that this component of the TOR be reviewed by the MAFMC SSC prior to initiation of data and model development. In doing so, this aspect of the TOR will be considered completed and will not be reviewed by the SAW/SARC review panel.

General distribution

Black sea bass (*Centropristis striata*) are distributed throughout the Gulf of Mexico, South Atlantic and the Atlantic north of Cape Hatteras, NC. The northern extent of the range has historically been considered Cape Cod, MA however a recent range expansion has moved the northern end of the range to coastal Maine. Genetic studies have identified a unique stock in the Gulf of Mexico (Bowen and Avise, 1990). The Atlantic group can be divided into separate

stocks north and south of Cape Hatteras, NC (Roy et al. 2012, McCartney and Burton 2013, Lewandowski 2014) although the genetic patterns suggest some limited exchange between northern and southern stocks around Cape Hatteras. There is north to south variation in genetic structure suggesting limited mixing within the northern stock (M. McCartney, pers. comm.)

Within the northern stock, sea bass undergo seasonal migrations (Musick and Mercer 1977, Moser and Shepherd 2009), moving offshore to the edge of the continental shelf in fall then returning to inshore spawning areas during spring. Tagging shows fish in the MD to NC area generally move east-west between inshore areas and the shelf edge. The movement becomes increasingly northwest/southeast further up the coast to northern NJ. As the orientation of the coast between Long Island, NY and Cape Cod, MA changes, the migration distances of fish from these areas increases and becomes more of a north/south direction. Black sea bass tagged in southern New England may migrate in the fall as far south as VA/NC, returning to their point of origin the following spring (Kolek 1990, Moser and Shepherd 2009)

Term of reference 1 calls for the evaluation of spatial aspects of the northern black sea bass stock. The intent of this document is to provide information that supports a logical decision on how to divide the stock. The recommended boundary is partly a pragmatic decision and does not necessarily represent distinct sub-stocks beyond those which could potentially improve the diagnostics of the assessment model. Additionally, it will allow for simulation testing to determine the importance of defining spatially explicit dynamics to the overall population dynamics. The recommendation does not imply that available data will be adequate to support an age structured spatial model (sea bass was reviewed as recently as 2008 as a data poor stock).

The Black Sea Bass Working Group met June 29-July 2 and December 16 2015 in Warwick RI to consider the evidence for spatial grouping within the northern stock. The conclusion of the group was that sufficient evidence exists to split the current single stock into two spatial units north and south of the Hudson Canyon. Justification for the boundary along Hudson Canyon was based on examination of tagging data, commercial fisheries data, genetic studies, recreational harvest trends, state and federal trawl survey indices and physical oceanographic information. Although alternative spatial divisions are possible (e.g. a division seaward of Delaware Bay), the WG felt that the available information had the strongest support for a Hudson Canyon boundary. The information also suggests that additional sub-units may also exist. However the WG felt that the available data are not adequate to develop an assessment with more than two primary sub-groups. It was also noted that the offshore winter catches in the southern strata represent a mixture of both areas. Subsequent model development will examine options for representing the mixed catch.

Natural Boundaries

The proposed spatial units for the stock assessment would be defined by NMFS statistical areas for the commercial catch (area 612 and 616 would be part of the northern group, 615 to the

south; Figure 1a), state boundaries for recreational catch and state survey indices (NY and east in the northern group, NJ and south in the southern group) and strata groups for NMFS (Figure 1a) and NEAMAP surveys (Figure 1b). None of these boundaries correspond exactly with the Hudson Canyon or are aligned among each other, and the boundary is not precisely located. Therefore there will be some overlap between the spatial groups. The split into north and south will bisect commercial statistical area 616 which contributes a substantial portion of the commercial trawl catch (~21%) but only approximately 5% of total catch (Table1). The proposed boundary would include 616 in the northern group. However, the intent of this approach is not to define distinct sub-stocks but rather to locate the approximate boundary of spatial processes to allow greater spatial resolution within the assessment model framework.

Physical Oceanography processes

The proposed north-south boundary for black sea bass is defined by the Hudson Canyon. The canyon is a submarine canyon beginning about 100 km from the mouth of the Hudson River between New York and New Jersey and extending southwest about 600 km to the edge of the continental shelf. It is a dominant feature in the geomorphology of the northeast continental shelf (Figure 2). As indicated by conventional and electronic tags (below), black sea bass follow a migration route from southern New England that takes them to the edge of the shelf north of the Canyon before moving south. The route may be influenced by a combination of bottom habitat, temperature, salinity and oceanographic features of the region such as discharge from the Hudson River.

Freshwater discharge from the Hudson River likely influences larval dispersal and recruitment patterns in the New York Bight as well as migration. The Coriolis force influences the pattern of freshwater discharged from the river generally moving it to the south (right) and along the coast of New Jersey. However, recent studies (Chant et al., 2008) have demonstrated a seasonal bulge of freshwater can be forced to the north, along the coast of Long Island (Figure 3). Under low discharge conditions and downwelling winds, the water moves to the south along coastal New Jersey, however if freshwater discharge is high the bulge can be forced to the north. This condition is especially prevalent with upwelling wind patterns. The upwelling winds can also create a transport pathway across the shelf along the north side of the Canyon. Oceanographic models show that coastal transport pathways (south along the New Jersey coast) are dominant in winter months while the mid-shelf transport pathway (to the north of the Canyon) are dominant in the summer. It is likely that these oceanographic features such as salinity gradients and currents limit transport of larval sea bass originating in the northern sea bass region from moving into the southern region.

Tagging Studies

Two tagging studies have been conducted which help identify the migratory pathways and seasonal distribution of black sea bass. In 1988 two thousand black sea bass were tagged and

released in Nantucket Sound, MA (MADMF, 1989). Recoveries over the next two years followed the winter movements along the edge of the continental shelf as far south as NC then returning to MA for spring spawning (Figure 4). Another project from 2002 to 2004 (Moser and Shepherd 2009) involved tagging black sea bass along the coast from NC to MA with conventional and electronic archival tags. Over the next several years tag returns followed the inshore/offshore movements, with tagged fish generally returning to the area of release. Fish that were released north of the Hudson Canyon remained inshore until autumn then moved south/southeast to the shelf edge and followed the shelf edge south until late spring. Those fish then returned to the general area of release (Figures 5-8). Fish that were released in the southern areas moved offshore in the fall along a pathway that was more east/southeast. They also moved inshore during spring to the area of release. Among the fish released in the northern area (NY-MA), 93.1% of recoveries occurred north of Hudson Canyon while 6.9% were recovered south of the canyon (offshore, Table 2). By comparison, among fish released in the southern area (NJ-NC), 99.3% were recovered in the south while only 0.7% were recovered north of the Hudson Canyon. Of those recovered in the north, most originated in northern NJ near the intersection of the north/south split. Archival tag data suggests that fish move along the bottom of the continental shelf during seasonal migrations (Figure 6). The conclusion from tagging is that black sea bass originating in the south stay south of Hudson Canyon whereas those originating in the north mix in the southern offshore strata during the winter but otherwise remain in the north. It was noted that the migratory pathway of fish tagged in NY seemed to be along the northern edge of the canyon to the shelf edge whereas fish in NJ moved in more southeast direction. The result was an area east of NJ where few sea bass were captured. This “hole” with few sea bass was also apparent in the distribution of commercial catches.

Commercial Fisheries

Black sea bass commercial fisheries operate throughout the range of the northern stock. The primary gear types are pots (both fish and lobster pots), hand lines and otter trawls. The distribution of catches based on vessel trip reports (VTR) between 2004 and 2014 were examined for geographic patterns (Figure 9). The seasonality of the fishery by gear is apparent with hand lines and pots being primarily inshore fisheries. There was a notable presence of pot catches along the Hudson Canyon, primarily from lobster traps. Trawl fisheries are dominated by offshore catches along the shelf edge in the winter (February-April) although there is a pattern of trawl catches across the shelf north of Hudson Canyon which are generally absent south of the Canyon (Figure 10). There is also evidence of winter trawl catches along the southern edge of Georges Bank and into the Gulf of Maine.

Recreational Fisheries

Recreational for-hire vessels which hold federal permits for black sea bass are required to submit vessel trip reports. The VTR logs report fishing location (lat-lon and statistical area), number of fish landed, number discarded and the number of anglers. Black sea bass catch per angler (CPA)

was calculated per year and statistical area for the VTR time series since 1996. In the northern areas, the annual CPA shows increasing trends since 2004 for stat areas 538-611 whereas stat areas 612, 613, and 616 remained relatively level or declining (Figure 11). These three areas border the north- south split. CPA for statistical areas in the southern region, particularly the inshore stat areas, is generally level or declining. These results suggest that the pattern of the catch per angler from the fishery south of Long Island and possibly resource trends are more similar to those in southern areas. Uncertainty in the CPA estimates were not calculated.

An analysis was conducted on black sea bass size data from Marine Recreational Information Program (MRIP) (Appendix II). The analysis included a mixed-effects generalized linear model with an identity link that included fixed effects for state and size limit and a random effect for year or year and wave to identify differences in size related to location. The analysis showed that average size followed a gradient from north to south, with northern states reporting larger fish than their southern counterparts. The largest difference in size between adjacent states appears to occur between NY and NJ, providing further evidence for a potential split in the fishery at Hudson Canyon.

MRIP patterns

Black sea bass CPUE (catch per angler trip) was generated from MRFSS/MRIP data by state for 1982-2014 using effort associated with catches of a suite of species commonly occurring with sea bass catches (Appendix I). This approach to estimating effort by guild reduces possible bias associated with species specific effort (A Jaccard index like approach). Results show that MA through NY, and to a lesser extent NJ, all experienced increased CPUE immediately following the large 2011 year class. Common trends among states could be roughly grouped as MA through CT; NY and NJ; and DE through VA (northern NC was not included in the analysis). The northern states (MA-CT) showed a substantial increase in CPUE during recent years, whereas trends were less distinct and possibly declining for NY – VA. This pattern also supports the north south delineation as noted above.

Fisheries Independent Indices

Recent analysis of winter distributions relative to oceanographic features concluded that preferences differed by region. Differences were most apparent north and south of Hudson Canyon, somewhat stronger than a cutoff at Delaware Bay (Miller et al. 2016). Patterns in recruitment, the 2011 year class in particular, highlighted the regional differences in recruitment. This cohort was the greatest in the age one (2012) spring survey time series for MA, RI, CT and NY, however, the NJ trawl survey did not show an unusually strong 2011 cohort among the five regions (Figure 1c; Figure 12, 13). Among the regional NJ survey indices, the strength of the cohort was greatest in the most northern NJ region, adjacent to the proposed Hudson Canyon boundary. The strong 2011 cohort was not evident in surveys from MD or VA. A Spearman Rank Order correlation from spring surveys shows the highest correlation generally occurs

between adjacent states. These survey data suggest that some patterning occurs in recruitment and it is not a homogenous mix throughout the stock.

There was consensus among the WG that the most reasonable response to the Term of Reference was to consider a spatial boundary near Hudson Canyon for assessment model development and simulation testing, which reflects a natural discontinuity in spatial processes in the black sea bass resource.

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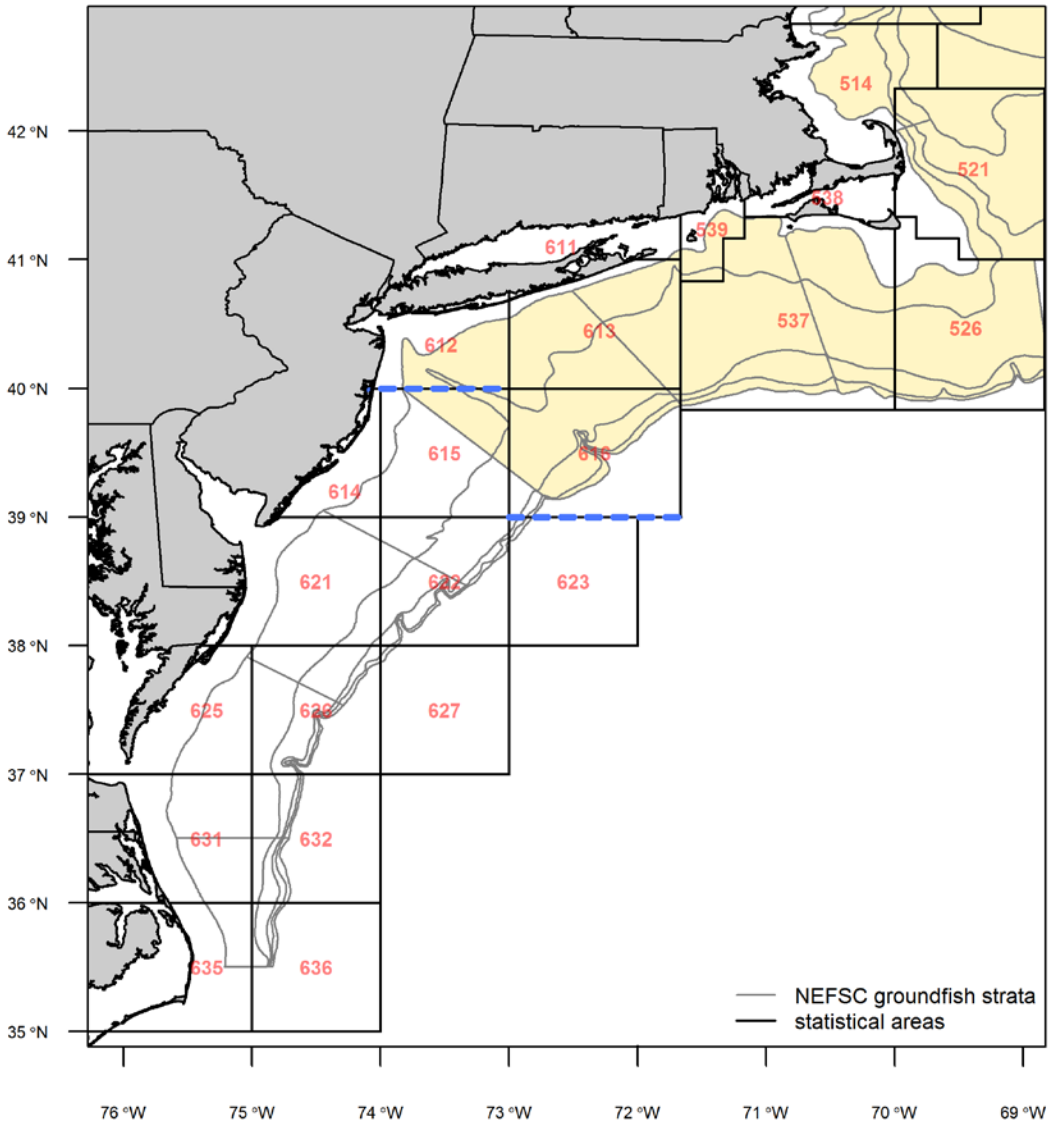

Figure 1a. NEFSC survey strata and commercial statistical areas. Yellow shaded area northern unit. Dotted blue show border of statistical areas between north and south.

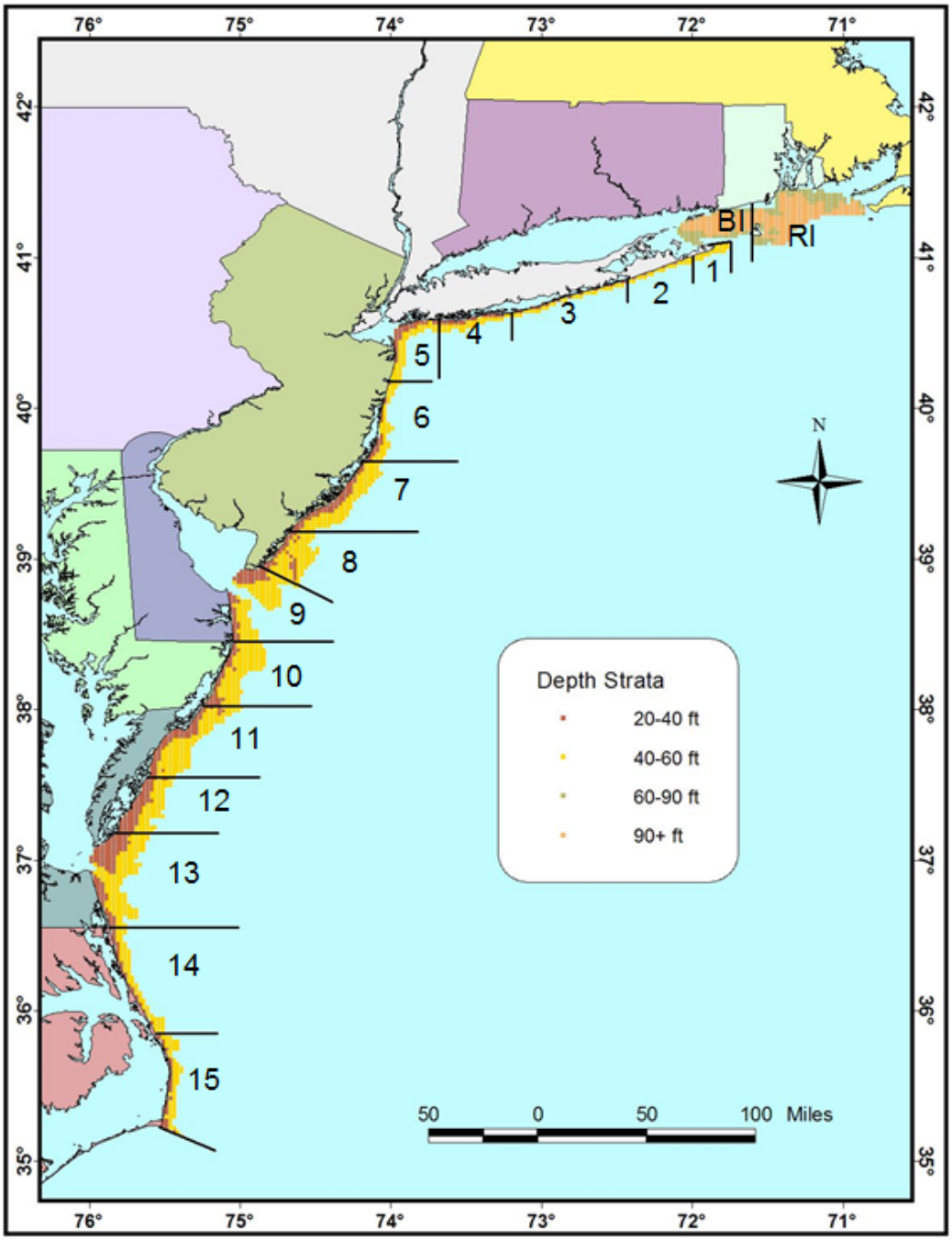

Figure 1b. NEAMAP sampling area including region boundaries and depth strata.

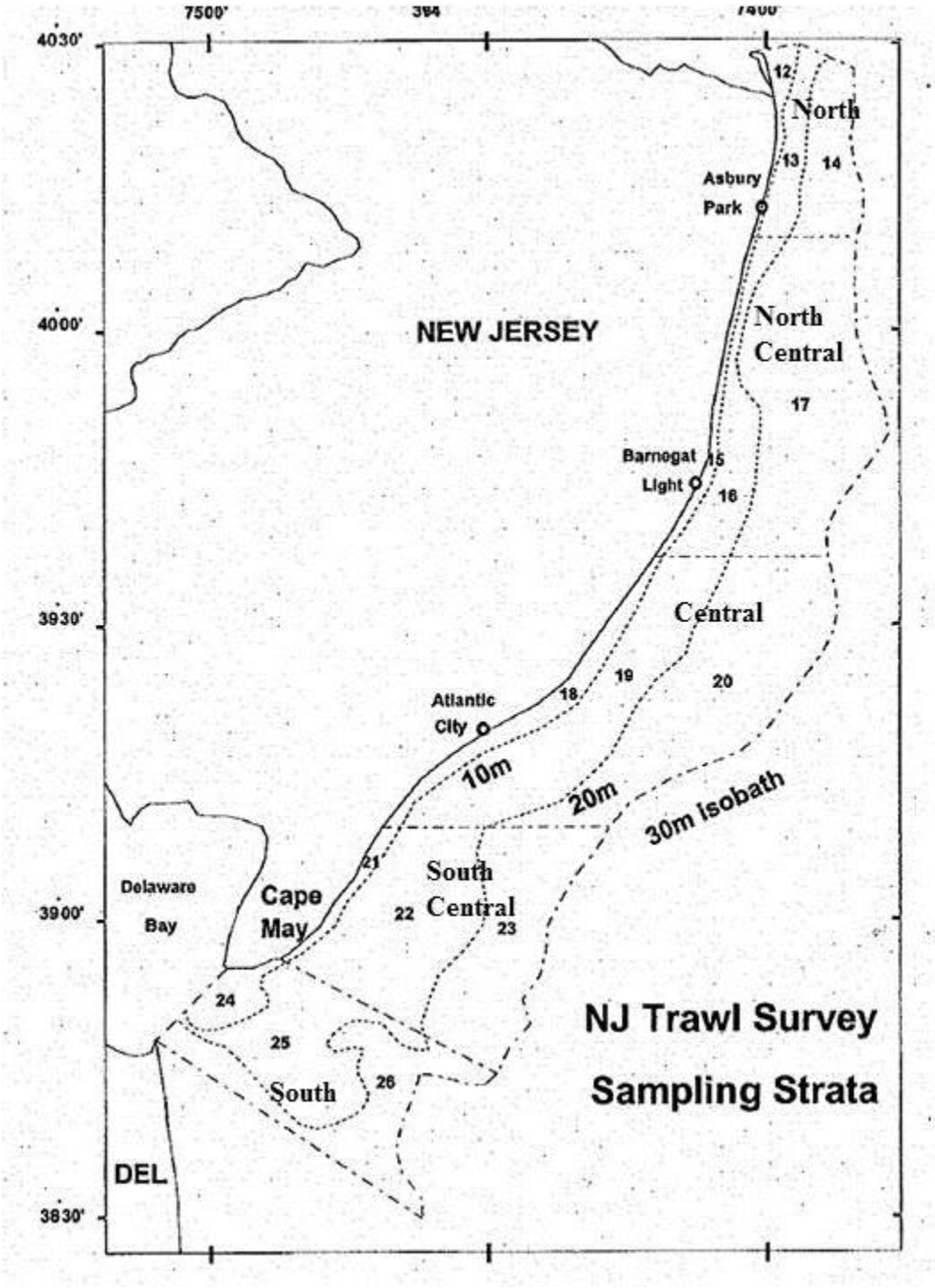

Figure 1c. Map of sampling strata for NJ trawl survey. The five north to south regions are identified.

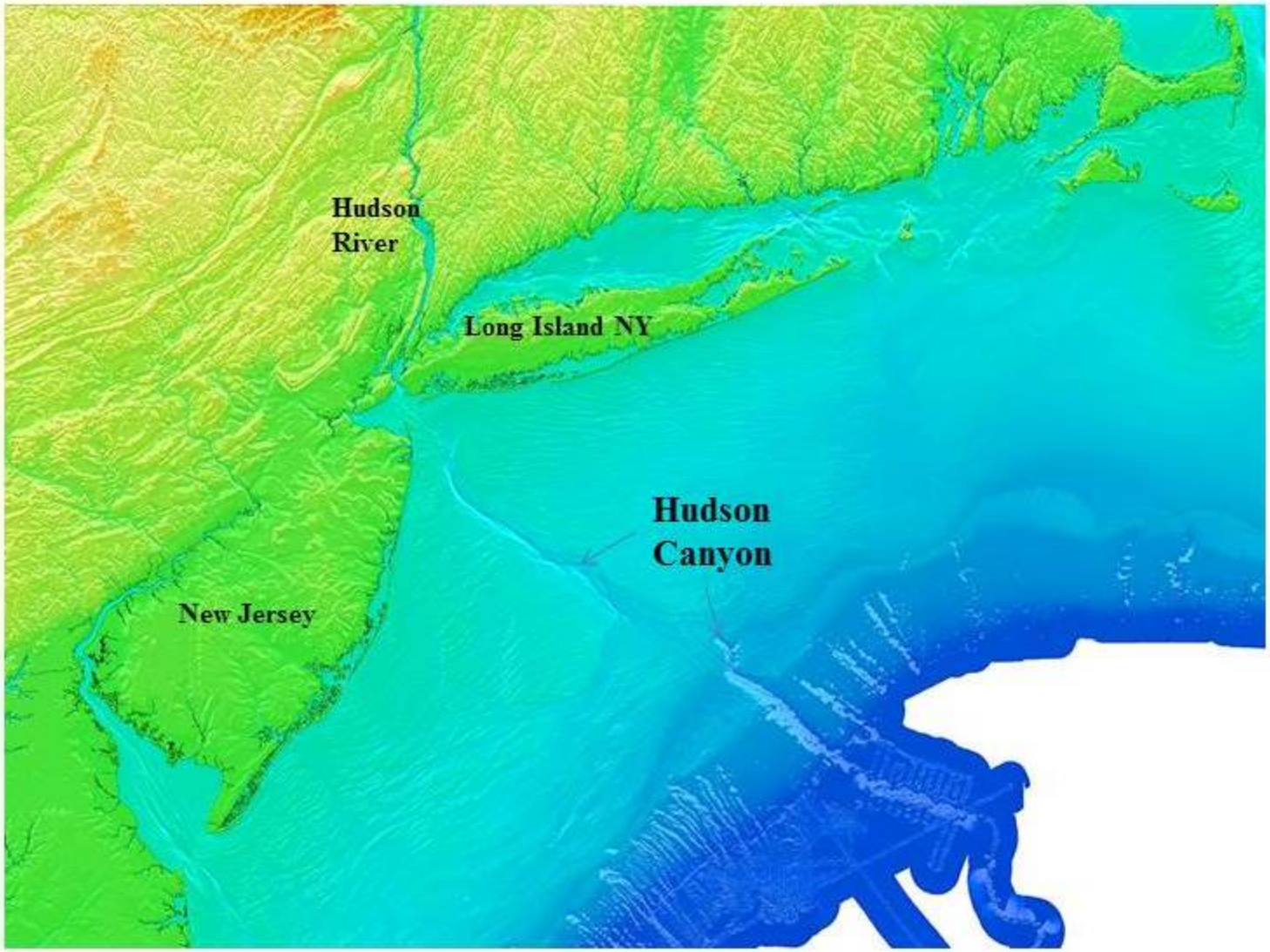

Figure 2. Topography of Hudson Canyon.

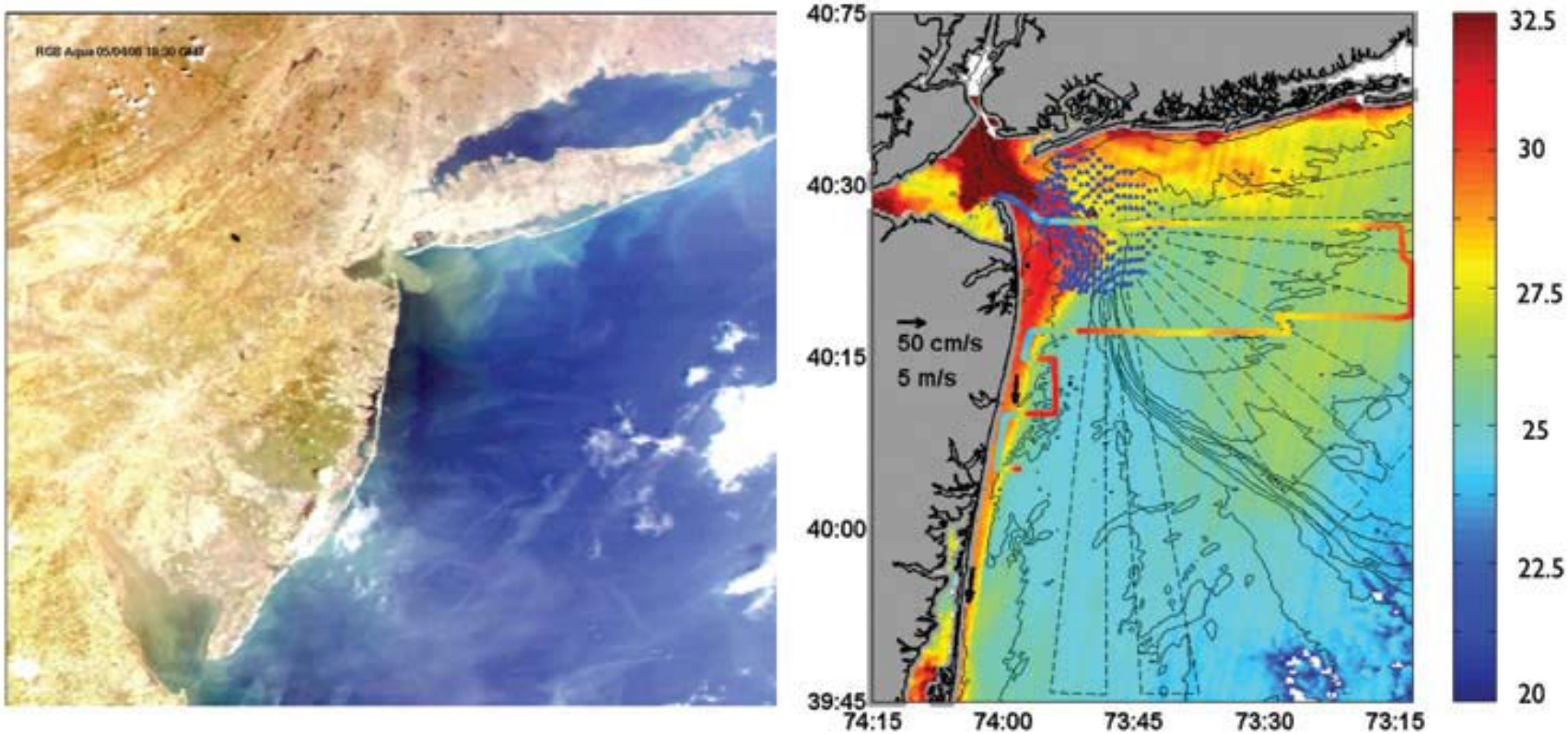

Figure 3. (Left panel) RGB (red-green-blue) image from April 5, 2005, during peak river discharge. Note that the plume is exiting the estuary and heading to the east toward Long Island. (Right panel) Image obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) on April 9 for absorption at 448 nm; the color scale is relative, with red representing high absorption and blue representing low absorption. Blue arrows show the Coastal Ocean Dynamics Applications Radar (CODAR) field, black from shelf moorings, white from NOAA mooring at the Narrows; the red vector represents winds from Ambrose. The color bar is for surface salinity from the ship track shown in the figure. All current data have been low-pass filtered. **(Figure 3 from Chant, 2008)**

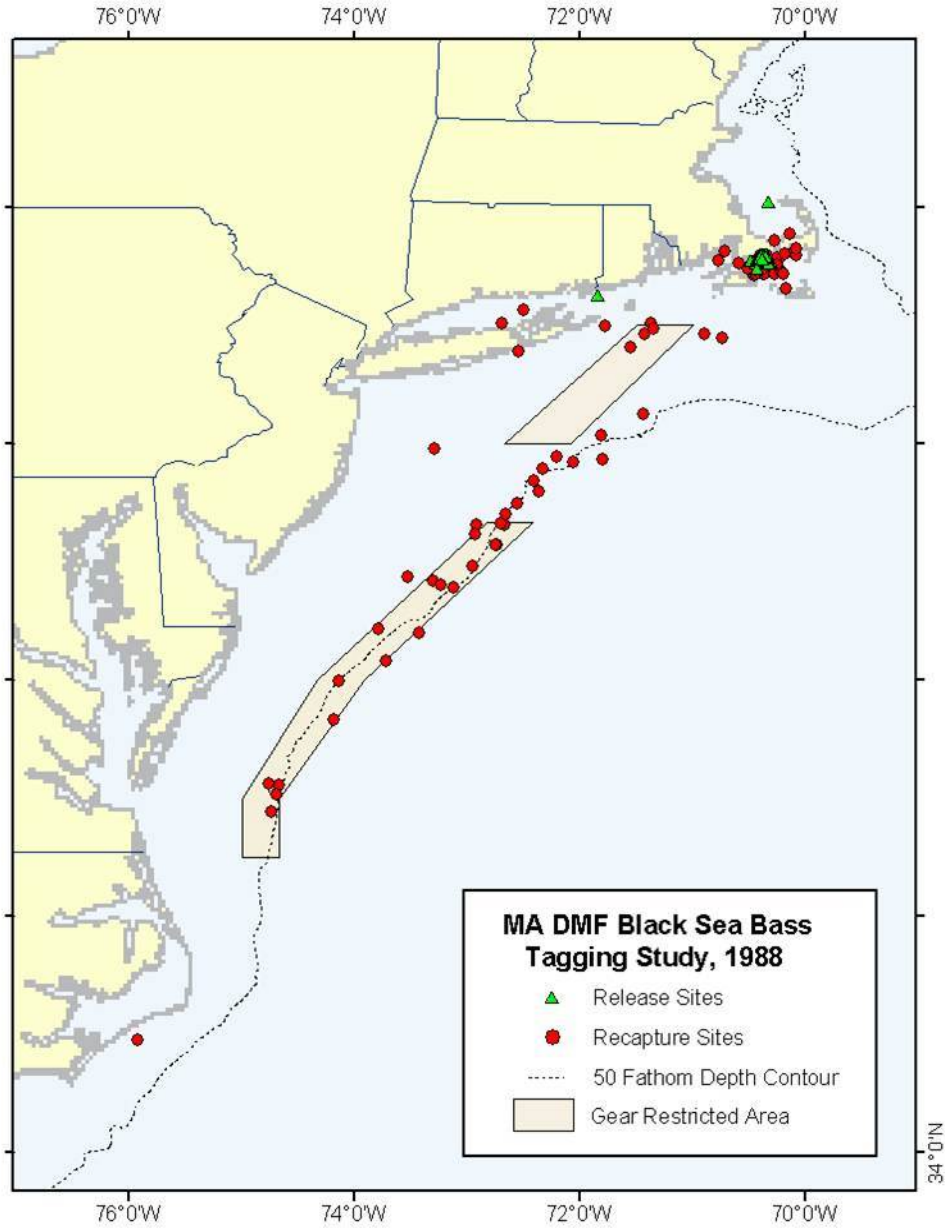

Figure 4. Tag recoveries of black sea bass tagged and released in Nantucket Sound by MA Division of Marine Fisheries, 1988.

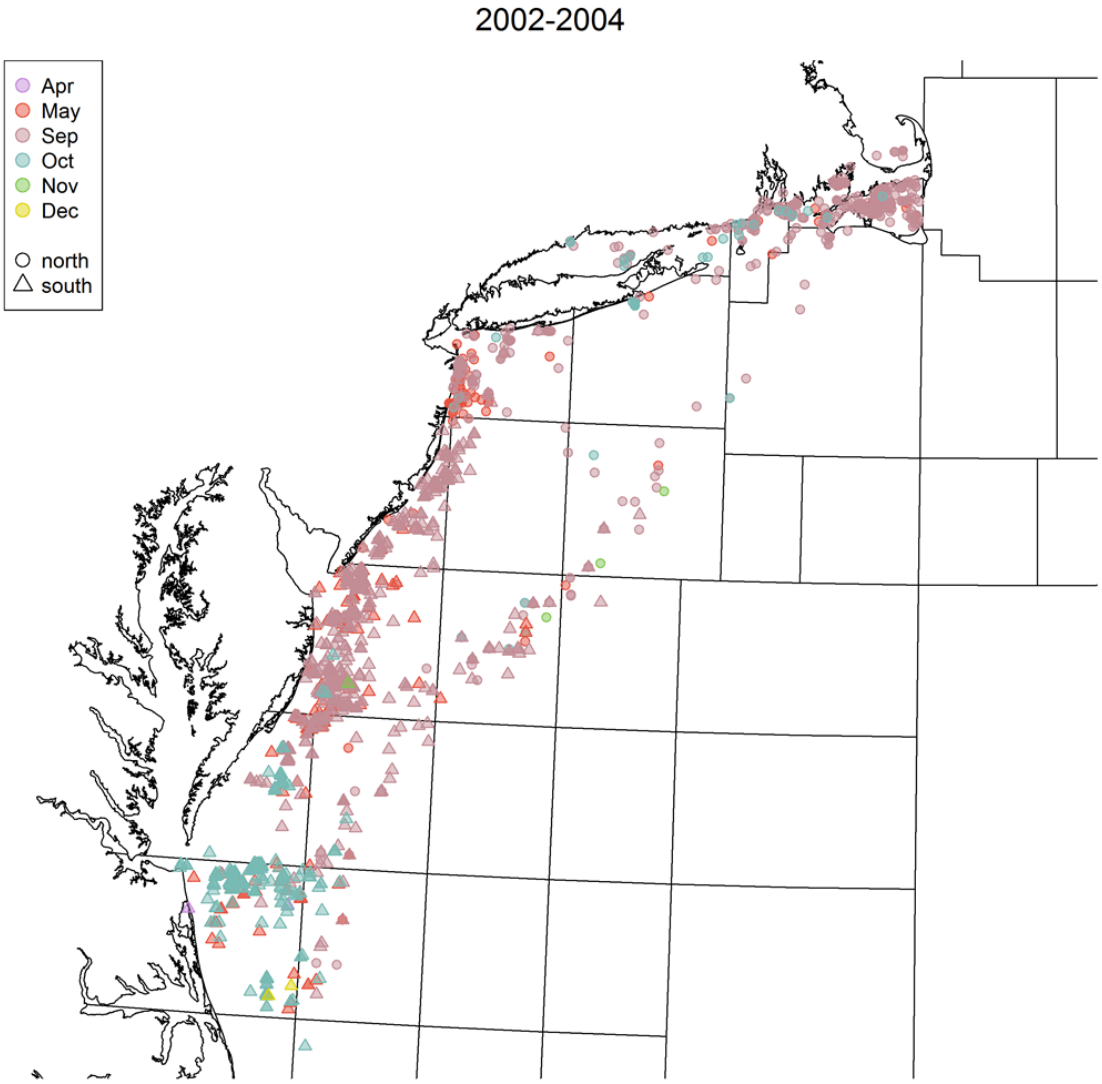

Figure 5. Black sea bass tag recoveries by month from NEFSC tagging program 2002-2004. Releases from north (circles) and south (triangles) of the Hudson Canyon areas are presented.

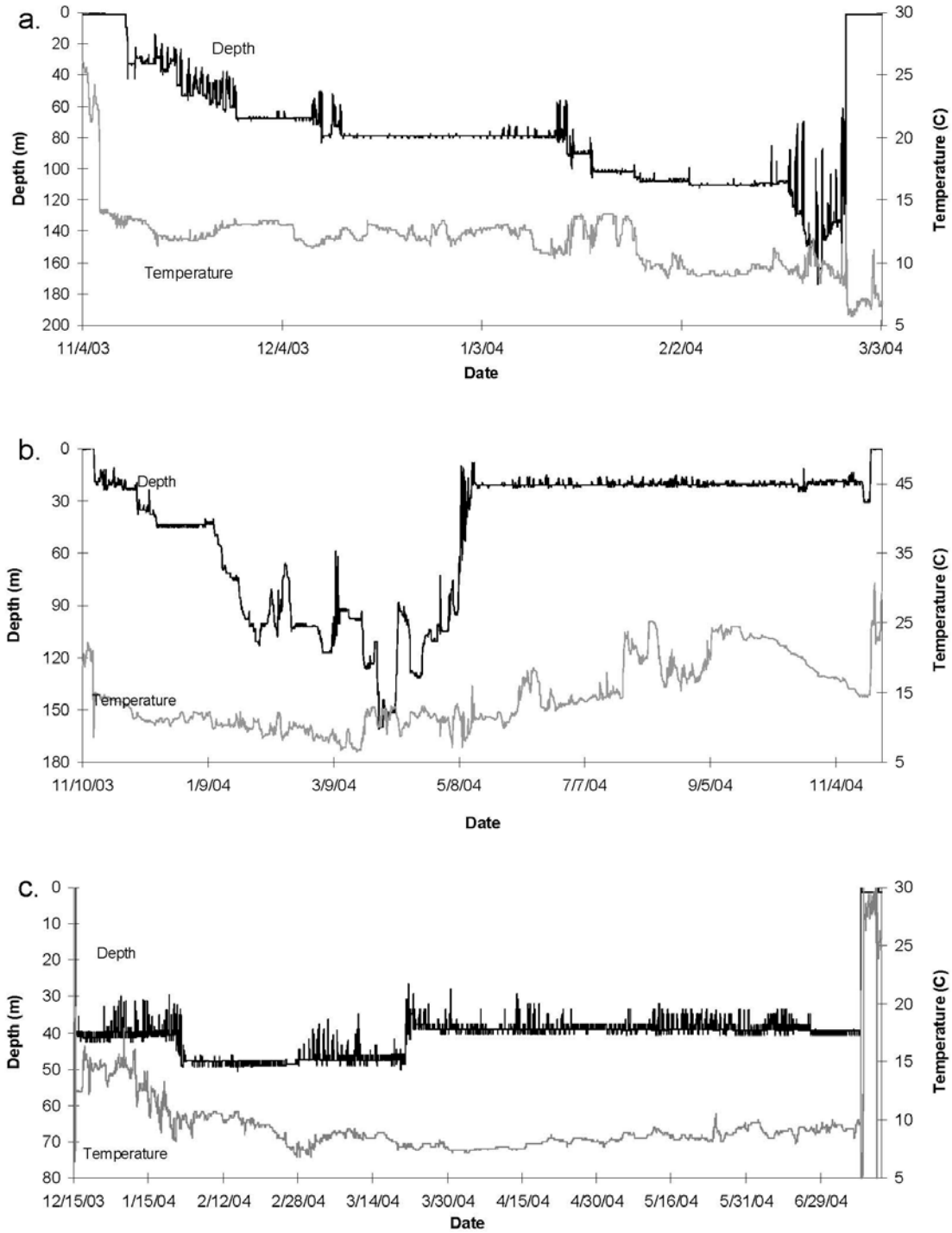

Figure 6. Temperature and depth data collected from data storage tags; (A) northern release, tag "A", (B) central release, tag "C", and (C) southern release, tag "E" (from Moser & Shepherd 2009)

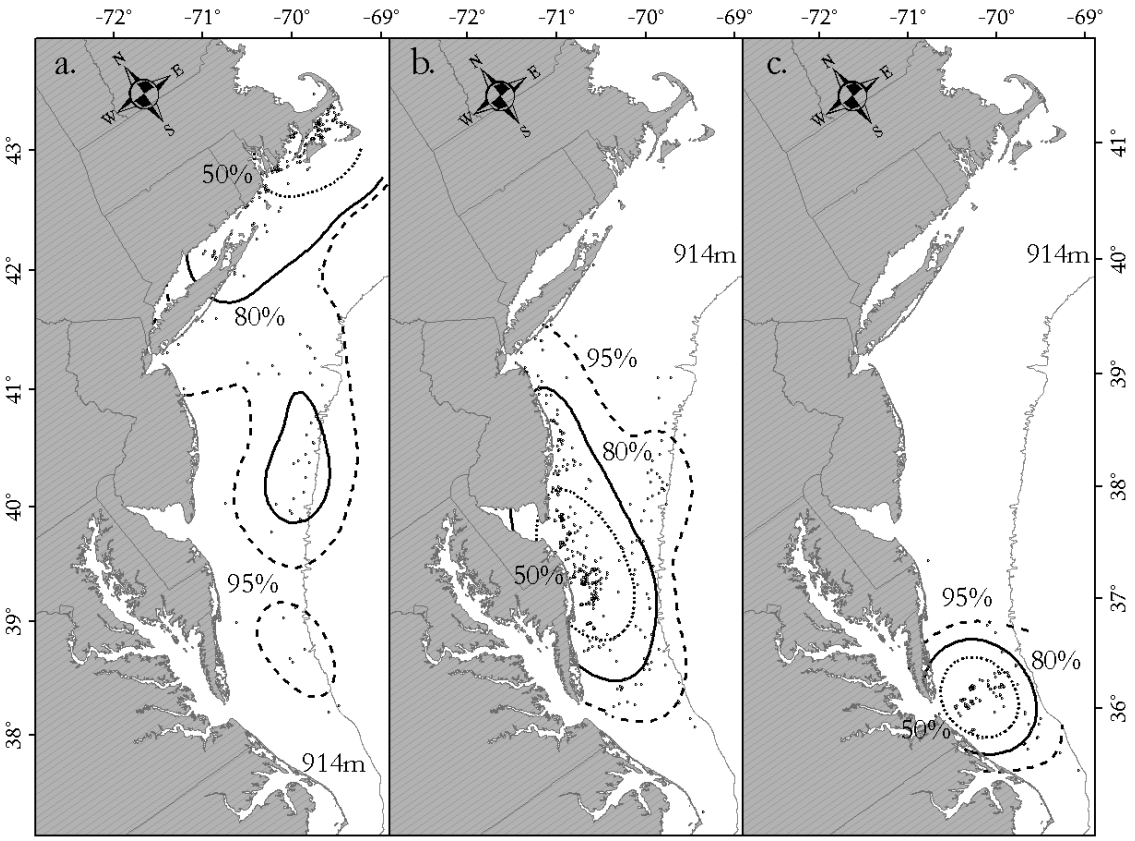

Figure 7. Percent volume contours of black sea bass tag recaptures released from a) the Northern area, b) the Central area, and c) the Southern area. The area within the dashed line contains 95% of tag recaptures, the solid line contains 80% of tag recaptures and the dotted line contains 50% of the recaptured tags from the respective area. Small circles indicate the respective tag recapture locations for tags released in that area. (Figure 6 from Moser and Shepherd 2009).

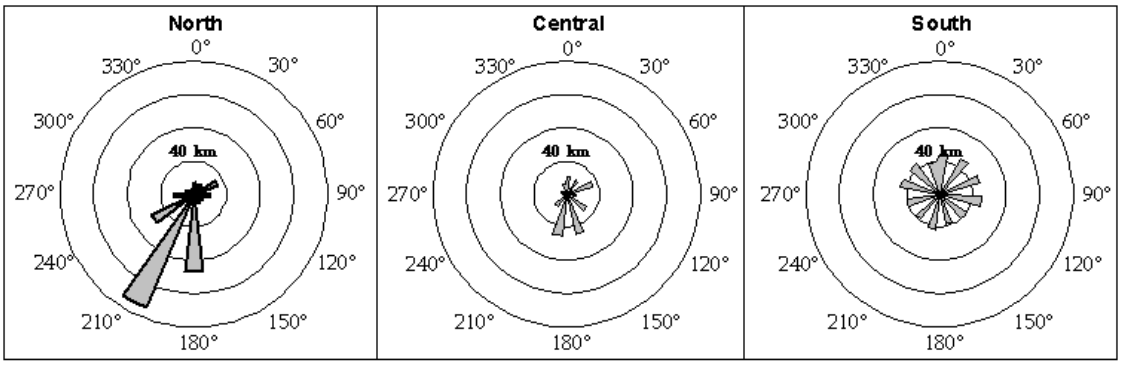

Figure 8. Rose diagrams of the direction and distance by area from black sea bass tag recaptures (Figure 7 from Moser and Shepherd, 2009).

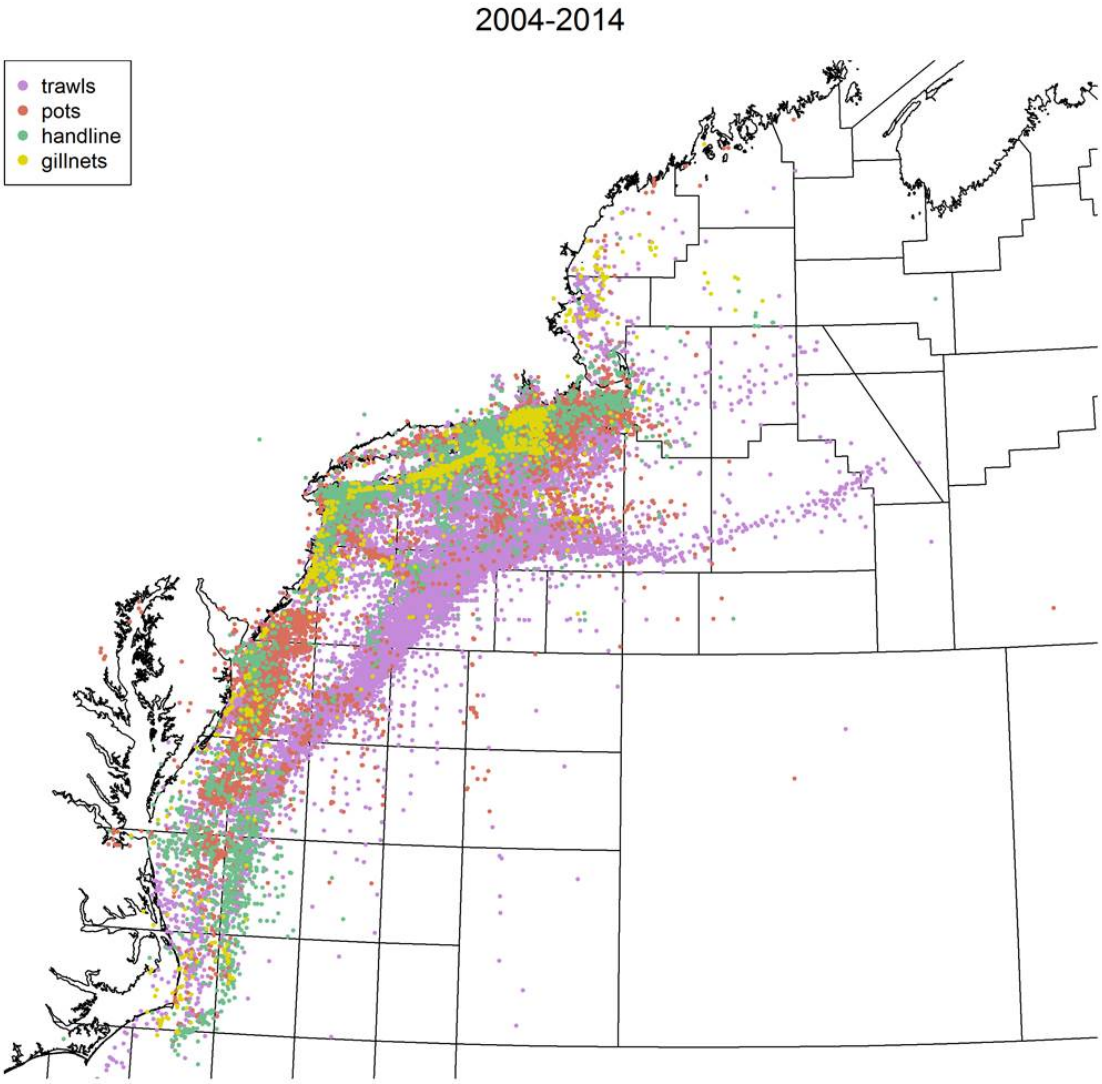

Figure 9. Black sea bass catch locations by gear from VTR logs, 2002-2014.

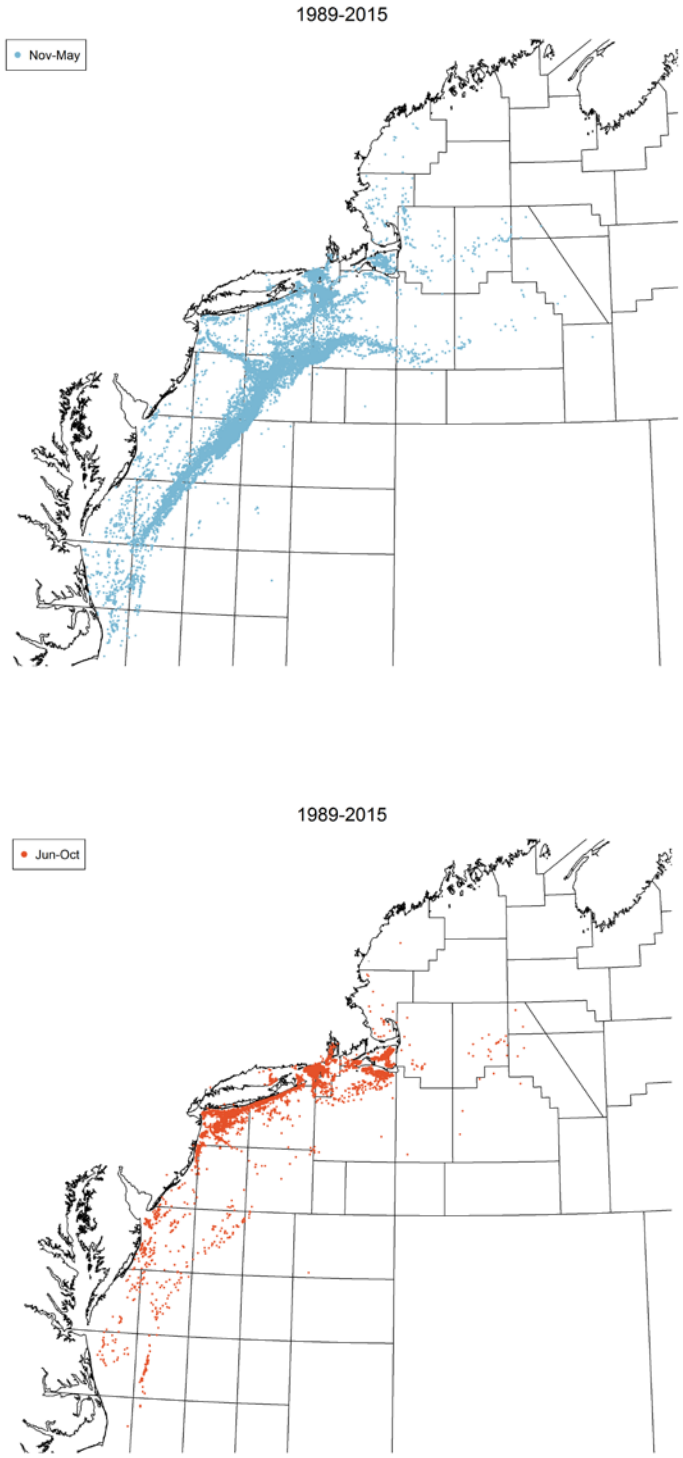

Figure 10. NEFSC Observed trawl trips with black sea bass, 1989-2015 grouped by season (May- November June-October).

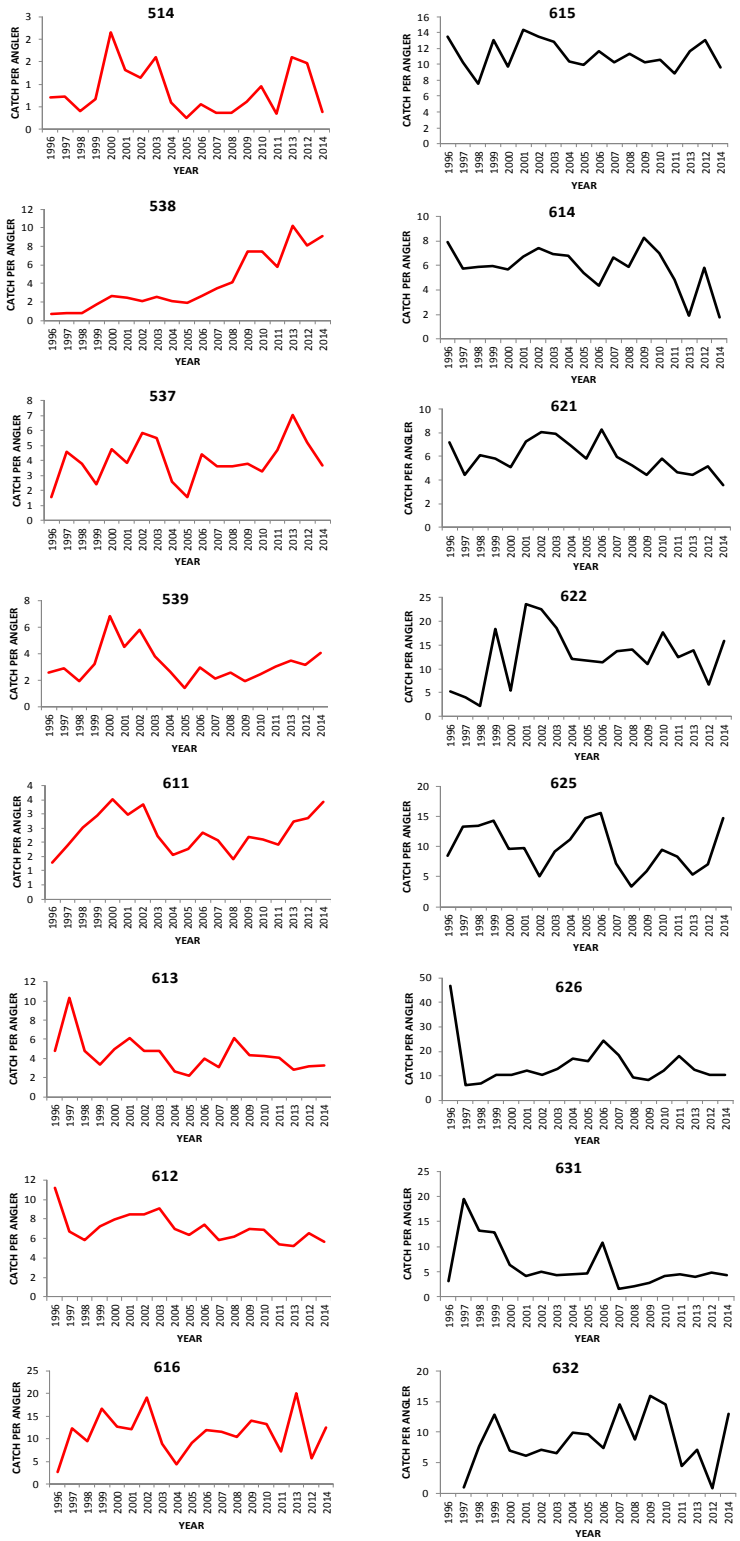

Figure 11. Catch per angler by statistical area calculated from for-hire Vessel Trip Reports, 1996-2014. Northern statistical areas in red, southern in black.

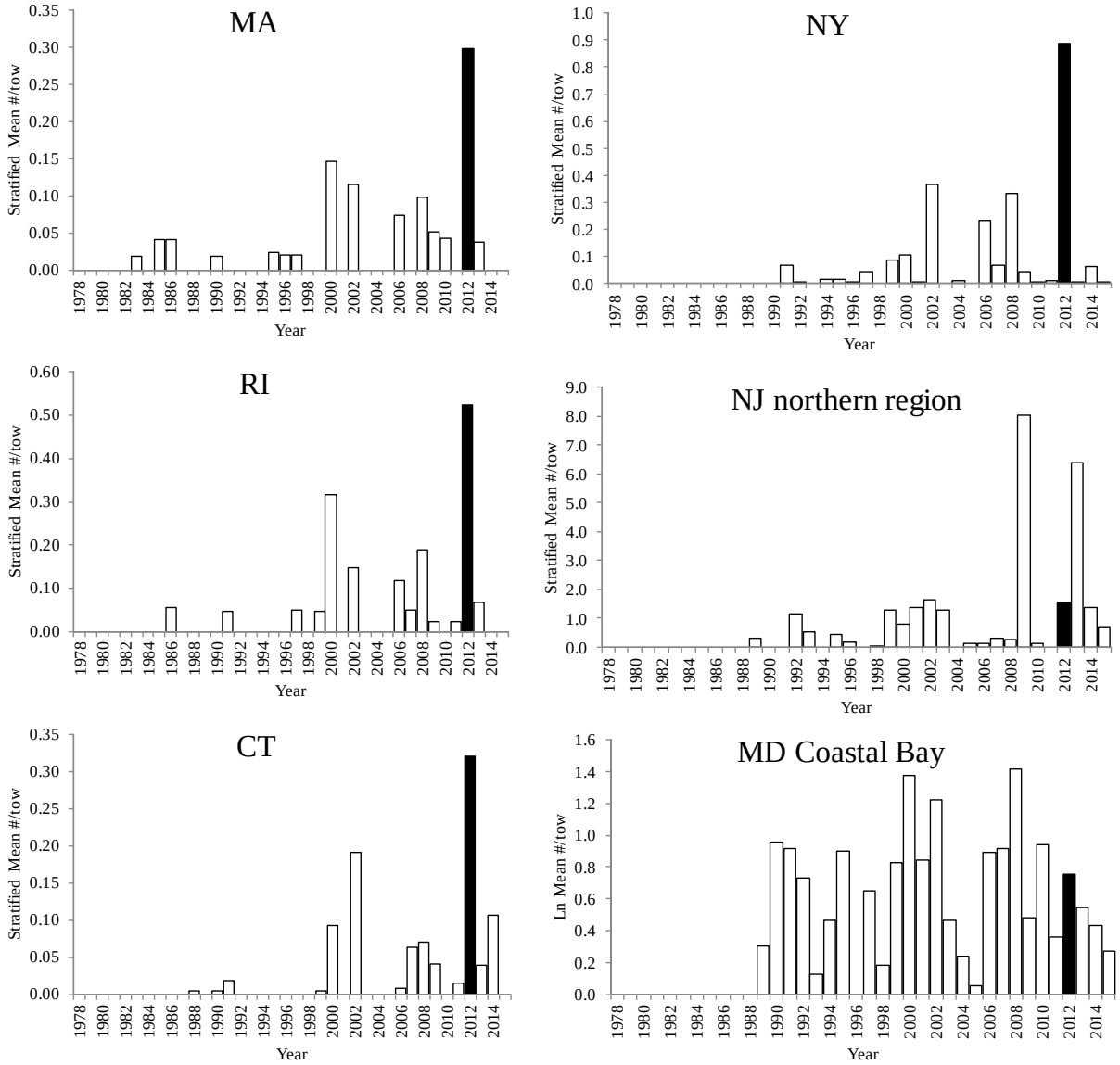

Figure 12. Presence of 2011 cohort of black sea bass in spring 2012 surveys in northern areas, as indicated by black column. Northern NJ indices included to show weaker 2011 cohort south of the suggested area split.

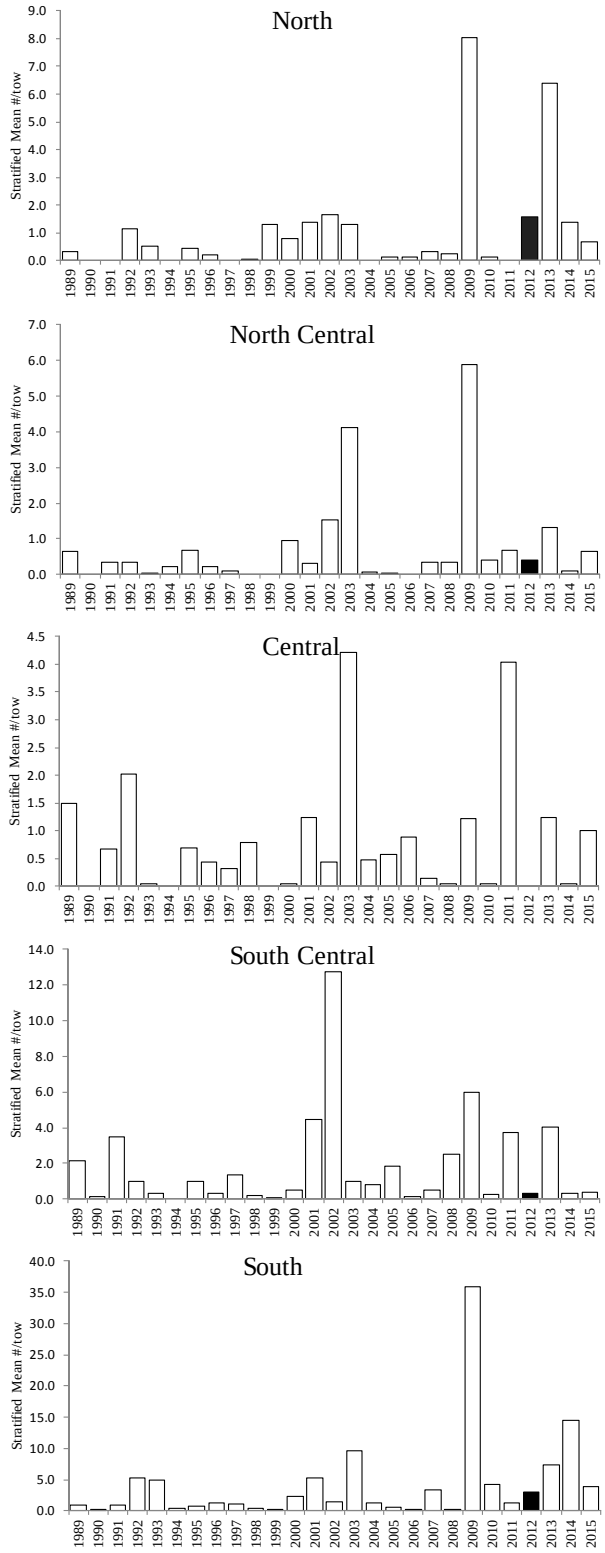

Figure 13. New Jersey June trawl survey mean number per tow by year for each region of black sea bass le 20 cm. 2011 cohort indicated by black column.

Table 1. Otter trawl landings (MT) 2000-2014 Maine to North Carolina (Cape Hatteras) and percent by statistical area. Northern areas in red, southern in black.

Reported Stat Area	MT	Pct
511	19.4	0.3%
513	2.0	0.0%
514	15.8	0.2%
515	0.3	0.0%
521	10.4	0.2%
522	1.2	0.0%
525	12.1	0.2%
526	29.2	0.4%
533	1.5	0.0%
534	0.8	0.0%
537	**393.8**	**5.9%**
538	207.2	3.1%
539	244.8	3.7%
541	1.3	0.0%
542	0.1	0.0%
543	0.0	0.0%
561	0.5	0.0%
562	4.2	0.1%
611	231.6	3.5%
612	130.8	2.0%
613	**405.7**	**6.1%**
614	15.1	0.2%
615	**408.1**	**6.1%**
616	**1384.2**	**20.7%**
621	267.6	4.0%
622	**1738.4**	**25.9%**
623	134.3	2.0%
624	0.9	0.0%
625	25.5	0.4%
626	**575.9**	**8.6%**
627	22.7	0.3%
628	0.8	0.0%
631	50.8	0.8%
632	36.9	0.6%
633	0.1	0.0%
634	0.0	0.0%
635	323.3	4.8%
636	3.1	0.0%
	North	46.2%
	South	53.8%

Table 2. Percent recoveries of NEFSC tags by statistical areas north and south of Hudson Canyon. Statistical area 616 is a boundary area bisected by the northern and southern split.

2002-2007

		Recovery location	
Release location	**Overall**	North	South
	North	93.1%	6.9%
	South	0.7%	99.3%

		616 Recoveries
Release location	North	71.4%
	South	28.6%

Table 3. Relationship among state survey indices of black sea bass, 1984-2013.

Spearman Correlat Coefficients

	VA	MD	NJ	CT	RI	MA	NMFS
VA	1.0	0.421	0.131	0.269	0.030	0.015	0.228
MD		1.0	0.424	0.536	0.554	0.404	0.492
NJ			1.0	0.560	0.478	0.331	0.533
CT				1.0	0.857	0.565	0.525
RI					1.0	0.627	0.382
MA						1.0	0.414
NMFS							1.0

Prob > |r| under H Rho=0

	VA	MD	NJ	CT	RI	MA
MD	**0.041**					
NJ	**0.541**	**0.035**				
CT	**0.205**	**0.006**	**0.004**			
RI	**0.888**	**0.004**	**0.016**	**<.0001**		
MA	**0.944**	**0.045**	**0.106**	**0.002**	**0.0002**	
NMFS	**0.284**	**0.013**	**0.006**	**0.005**	**0.037**	**0.023**

Number of Observations

	VA	MD	NJ	CT	RI	MA	NMFS
VA	24.0						
MD		25.0					
NJ			25.0				
CT				27.0			
RI					30.0		
MA						30.0	
NMFS							30.0

Appendix I

Estimation of recreational CPUE to evaluate regional differences in black sea bass distribution and abundance.

To investigate the potential for spatial heterogeneity in abundance and availability, state specific recreational (fishery dependent) catch per unit effort indices were developed using data from the Marine Recreational Fisheries Statistics Survey (MRFSS[1]). For this exercise, catch was estimated using the raw (unexpanded) Type 2 and Type 3 MRFSS data files. Estimates of potential effort for a given species can be difficult using the MRFSS data due to the self-reported nature of the data. In an attempt to account for potential effort (rather than just positive trips or self-reported directed trips), effort estimates were based on effort for a species guild. Species to include in a guild were identified using the Jaccard index of similarity (Jaccard 1912). Estimation of the similarity coefficient can be summarized as follows.

1) Determine the number of trips (MRFSS intercepts) that caught the target species
2) Determine which non-target species were caught on trips when the target species was caught.
3) Determine the number of trips (MRFSS intercepts) that caught a given non-target species.
4) Divide the number of trips that caught both the target and non-target species by the number of trips that caught either the target species or the non-target species.

Mathematically, this can be expressed as

$$J = \frac{N_{11}}{N_{10} + N_{01} + N_{11}}$$

where N is the number of trips and the subscripts of 0 and 1 are binary for observation of the target and non-target species. High values of *J* suggest high correlation between the target and non-target species (*e.g.* habitat utilization), so observation of the non-target species implies presence of the target species even if it is not observed. For the current analysis, species guilds were composed of the target species and the five species with the highest similarity coefficients. Any trip that caught any one of the guild species was considered a potential black sea bass trip. Species guilds, and therefore effort estimates, were developed for each state individually to allow development of state-specific CPUE indices. It was assumed that there was no temporal variation in species associations (guild composition) over time for a given state. State specific species guilds and effort (# of intercepts of potential trips) time series are shown in Tables 1 and 2, respectively.

[1] Although the MRFSS was officially replaced by the MRIP in 2012, MRFSS-based raw data files are available through 2014, allowing a continuous time series of MRFSS data for this analysis.

For each potential black sea bass trip identified through the guild analysis, trip level CPUE was estimated as the black sea bass catch divided by the number of anglers contributing to the catch. Because observed (Type A) and unobserved (Type B1 and B2) catch are handled separately by MRFSS and do not necessarily have the same number of anglers associated with the two types of catch on a given trip, it was necessary to develop separate CPUE estimates for observed and unobserved fish and sum them (CPUE = CPUE_A + CPUE_B). Admittedly, this is not ideal, but should not have an overall large effect on the results.

Trip specific CPUE was then modeled in R using a negative binomial GLM. Full models for the positive and binomial components are as follows.

lnCPUE ~ YEAR + AREA + WAVE + STATE + MODE + HRSF
success ~ YEAR + AREA + WAVE + STATE + MODE + HRSF

For each component, the final model included only the factors that explained greater than 5% of the total deviance.

State specific MRFSS CPUE indices show strong regional patterns throughout the time series. During the 1980s and 1990s, CPUE showed a pattern of general decline from south to north (Figures 1A, 2). When standardized to their respective time series means, northern states (MA-NY) exhibit a strong increasing trend in CPUE beginning around the mid-2000s while CPUE in southern states remains relatively stable (Figure 1B). In addition, a spike in CPUE during 2012 in the northern states suggests evidence of a strong 2011 year class which is less evident or absent from the southern states. A Pearson correlation analysis conducted in Excel indicates that the four northern states are relatively strongly correlated with each other over their time series, but not with the four southern states (Table 3). The southern states correlate well only with neighboring states.

Length frequency of the total catch (harvest and discards) was evaluated using the MRFSS Type 9 data to determine if the increase in CPUE in 2012 could be attributed to the 2011 year class. The 2011 year class would be approximately 15 cm (6 inches) in the spring of 2012 and would grow throughout the summer and fall. Data from 2010 and 2011 show that only a small portion of the catch is from sizes less than 9” (Figure 4). In 2012, however, several states that showed increases in CPUE also had much higher proportions of fish less than 9”, suggesting the appearance of the 2011 year class.

The robustness of the data used to develop the CPUE was evaluated in a couple of ad-hoc ways. First, trends in effort were evaluated to check for abrupt or systematic changes in effort that might influence CPUE. Effort trends showed high interannual variability (Table 2, Figure 3), but

no obvious flags were evident. Second, uncertainty in catch estimates (PSE) was evaluated as an indicator of how well sampled black sea bass are. A high PSE would indicate that seas bass are not well represented in the intercept survey, resulting in possibly biased catch and CPUE estimates. There are occasional PSE values greater than the MRIP rule of thumb of 50%, particularly in RI and CT, but nothing to indicate persistent systematic bias in catch estimates (Table 4). These two checks on data quality, although not comprehensive, indicate that the data used to develop state specific fishery dependent CPUE trends are robust.

Literature cited

Jaccard, Paul (1912), "The distribution of the flora in the alpine zone", New Phytologist 11: 37–50.

Table 1a. State specific guild species based on Jaccard similarity.

Massachusetts		**Rhode Island**	
Species	J_val	Species	J_val
BASS, BLACK SEA	1	BASS, BLACK SEA	1
SCUP	0.3111	SCUP	0.2283
TAUTOG	0.0685	FLOUNDER, SUMMER	0.1417
SEAROBIN, NORTHERN	0.0599	DOGFISH, SPINY	0.0596
FLOUNDER, SUMMER	0.0574	SKATES	0.0579
SEAROBINS, NORTH AMERICAN	0.0411	SEAROBINS, NORTH AMERICAN	0.0567

Connecticut		**New York**	
Species	J_val	Species	J_val
BASS, BLACK SEA	1	BASS, BLACK SEA	1
SCUP	0.1764	SCUP	0.1713
FLOUNDER, SUMMER	0.0799	TAUTOG	0.0972
SEAROBIN, STRIPED	0.0649	CUNNER	0.076
DOGFISH, SMOOTH	0.0503	FLOUNDER, SUMMER	0.0582
SEAROBINS, NORTH AMERICAN	0.0472	SEAROBINS, NORTH AMERICAN	0.0535

New Jersey		**Delaware**	
Species	J_val	Species	J_val
BASS, BLACK SEA	1	BASS, BLACK SEA	1
SCUP	0.1273	FLOUNDER, SUMMER	0.1587
FLOUNDER, SUMMER	0.1126	CROAKER, ATLANTIC	0.1295
TAUTOG	0.101	WEAKFISH	0.1192
SEAROBIN, STRIPED	0.0859	DOGFISH, SMOOTH	0.1169
DOGFISH, SMOOTH	0.0637	SEAROBINS, NORTH AMERICAN	0.1074

Maryland		**Virginia**	
Species	J_val	Species	J_val
BASS, BLACK SEA	1	BASS, BLACK SEA	1
FLOUNDER, SUMMER	0.1787	TOADFISH, OYSTER	0.1426
TAUTOG	0.1212	SPOT	0.1348
DOGFISH, SPINY	0.0746	CROAKER, ATLANTIC	0.1315
SEAROBINS, NORTH AMERICAN	0.0643	FLOUNDER, SUMMER	0.1236
CROAKER, ATLANTIC	0.0609	PIGFISH	0.1051

Table 2a. Number of intercepted trips that caught one or more of the guild species.

Year	MA	RI	CT	NY	NJ	DE	MD	VA
1982	327	95	44	550	801	263	92	283
1983	540	97	87	486	521	316	1033	727
1984	354	100	94	382	285	239	301	525
1985	107	61	94	574	417	269	336	2202
1986	278	124	155	1993	553	356	241	2478
1987	111	151	217	609	805	342	187	962
1988	559	368	225	736	920	814	280	688
1989	380	537	181	2018	951	780	295	1921
1990	492	441	227	2656	1511	1057	405	704
1991	641	404	293	2915	2248	1146	653	838
1992	378	757	315	2432	1679	1189	553	1104
1993	530	589	185	2424	1248	1156	290	904
1994	546	560	178	1840	1225	1007	368	2731
1995	436	577	192	498	1262	987	451	1577
1996	402	713	240	951	1453	1053	221	1405
1997	416	725	352	949	1678	1278	456	1704
1998	440	933	336	918	1436	1394	781	1905
1999	409	835	415	1125	1536	1097	1136	1251
2000	591	1175	436	793	1488	1134	1164	1435
2001	472	1200	475	1604	3066	1427	825	2376
2002	549	1311	453	1347	1917	1344	944	2163
2003	650	1469	706	2072	2750	1525	701	2101
2004	457	1389	361	1350	2264	1340	818	2044
2005	410	944	288	1489	2135	1913	641	1568
2006	533	990	251	1545	1538	1286	621	847
2007	429	988	334	1664	1746	1050	712	2786
2008	462	607	329	1531	1905	1100	866	2653
2009	513	360	210	1323	1796	1087	690	2248
2010	598	482	408	1406	1802	1030	951	2064
2011	546	426	228	1375	1557	796	591	1473
2012	656	625	404	1376	1405	810	541	1215
2013	1088	811	572	1346	1473	1802	635	1848
2014	938	1241	739	1096	1998	1444	735	1585

Table 3a. Pearson correlation matrix

	MA	*RI*	*CT*	*NY*	*NJ*	*DE*	*MD*	*VA*
MA	1							
RI	0.921032	1						
CT	0.819008	0.886534	1					
NY	0.73479	0.777109	0.563307	1				
NJ	0.154482	0.263051	0.078605	0.557828	1			
DE	-0.11359	-0.01062	-0.20418	0.14154	0.624653	1		
MD	-0.35072	-0.18669	-0.27056	0.021814	0.287495	0.429996	1	
VA	-0.34106	-0.26166	-0.21521	-0.1138	0.23191	0.254441	0.631746	1

Table 4a. MRFSS/MRIP estimated total catch (A+B1+B2) and PSE for black sea bass.

	MASSACHUSETTS		RHODE ISLAND		CONNECTICUT		NEW YORK		NEW JERSEY		DELAWARE		MARYLAND		VIRGINIA	
Year	Number	PSE	Number	PSE	Number	PSE	Number	PSE	Number	PSE	Number	PSE	Number	PSE	Number	PSE
1982	312,250	21.1	4,312	48.6	4,164	64.8	256,585	22.2	1,088,204	17.9	172,868	45.9	3,902,529	46.9	5,605,006	53.2
1983	229,352	19.6	2,724	63.9			371,300	17.7	3,548,522	20.5	68,460	25.8	376,454	15	2,513,631	21.9
1984	90,648	27.7	29,937	32.2	8,058	100	448,232	28.9	521,152	24.9	42,490	29.8	761,352	30	1,182,816	15.4
1985	21,218	36.2	31,531	90.4	69,606	27.8	481,744	15.7	2,695,768	13.7	89,956	35.4	516,019	19	1,985,338	11.9
1986	588,979	16.6	67,556	34	215,929	36.2	1,411,077	10.7	21,113,838	22	305,528	19.8	947,476	25.5	4,161,215	7.9
1987	206,023	40.4	133,634	26.6	5,966	40.6	891,267	17.9	1,139,948	23.1	93,259	24.4	813,319	23.8	1,613,840	9.3
1988	211,871	24.6	20,694	27.8	24,980	20.9	526,442	28.2	762,416	15.5	190,573	15.4	3,319,704	12.2	2,740,840	16.4
1989	53,901	28.3	37,641	21.8	48,482	26.7	841,659	10.3	2,792,690	8.2	354,350	12.3	850,858	14.4	1,369,048	7.6
1990	42,164	25.2	13,183	22.2	1,596	47.5	413,239	18.3	2,122,012	10.6	236,302	10.6	1,955,774	12.9	4,232,790	8.7
1991	33,028	37.1	14,144	38.9	40,170	35.4	427,307	9.3	4,505,700	6.5	668,945	10.5	1,920,796	14.1	3,068,840	10.5
1992	8,706	23.8	21,296	15.2	9,805	33.3	277,440	10.2	2,644,693	7.9	414,457	10.3	1,854,172	17.2	2,323,914	9
1993	20,199	18.2	34,870	17.5	11,689	47.9	248,316	16.7	5,168,030	22.8	414,672	17.9	1,139,428	12.7	1,927,908	9.8
1994	13,102	33.2	18,262	63.5	1,179	100	544,671	16.1	3,230,892	12.1	272,412	19.4	654,653	15.2	2,291,948	8.9
1995	24,219	22.4	82,657	15.9	14,798	39.1	432,799	24.4	6,523,686	14.8	523,823	19.5	3,330,668	12.7	2,931,661	8.8
1996	38,164	28.7	124,782	18.3	24,692	25.7	390,165	20.7	3,725,316	10	177,745	12.7	868,965	17.4	2,735,589	11.4
1997	44,776	19.5	71,334	25.1	19,743	36.3	739,711	31.8	6,163,957	8.3	363,551	12.2	957,738	11.8	2,168,345	9.4
1998	48,881	26.3	52,132	17	18,052	22.4	91,071	29.1	1,507,758	10.4	335,909	14.3	1,108,665	12.6	1,729,729	15.1
1999	46,636	24.8	145,934	19.6	175,312	38.9	820,126	14.9	2,177,475	10.6	253,967	14	1,646,599	11.5	1,778,424	15.1
2000	334,813	20.6	598,203	17.5	103,852	29.8	1,557,919	12.2	7,507,432	7.3	971,135	9.6	3,657,110	11.3	2,017,500	11.5
2001	202,235	18.8	273,836	10	25,703	23.7	805,530	11.1	6,289,262	5.4	1,205,807	9.2	2,442,880	8.9	2,411,569	6.9
2002	451,743	16.7	319,206	13.5	309,073	23.7	1,631,621	10.7	6,078,194	7.5	1,840,740	6.7	1,261,170	9.6	2,573,020	8.3
2003	314,391	17	274,913	9.4	60,448	18.1	1,056,270	11.2	6,198,410	4.8	1,139,115	7.6	1,014,236	11	2,006,661	8.6
2004	234,948	20.7	50,743	13.5	56,489	39.6	758,317	21.4	4,198,714	16.7	320,111	15.4	274,304	23.9	1,293,395	20
2005	321,806	30.5	149,331	44.5	53,060	60.5	1,214,108	40.7	3,046,704	12.3	343,513	15.7	653,047	20.9	1,151,109	31.8
2006	279,766	21.4	202,188	22.2	88,970	38.4	1,595,176	17	2,613,254	13.6	442,750	15.2	766,117	20.5	1,438,461	23.6
2007	547,369	24.5	161,563	18.8	124,695	29	1,958,670	11.7	3,147,182	12.2	677,104	14.5	615,796	28.4	1,306,724	18.4
2008	648,622	19.7	180,592	21	254,700	49.3	1,914,203	28.5	5,011,393	16.7	486,986	18.1	700,342	30.7	1,288,607	14.2
2009	1,118,368	17.5	169,685	27.5	205,812	43.3	1,802,039	15.5	3,721,405	14.1	330,300	19.2	486,704	15.5	1,267,535	17.9
2010	1,635,235	25.7	372,471	22.1	105,654	23.1	1,706,547	16.7	4,557,067	27.9	252,104	22.9	705,459	21	554,415	17.8
2011	575,404	15.8	271,023	27.3	53,960	44.3	1,167,316	16.7	1,450,706	16	254,001	21.2	400,637	18.6	463,000	20.6
2012	1,598,155	15.9	868,760	14.8	1,116,877	22.7	2,792,093	18.3	4,552,538	11.8	244,629	20.8	323,080	22.9	887,459	19.1
2013	1,680,320	12.3	752,891	18.5	1,391,183	18.5	1,725,106	16.9	2,893,499	15.1	285,960	18.2	379,472	12.1	615,160	15.8
2014	1,924,973	19	1,073,183	13.1	1,807,603	16.7	1,721,029	14.4	2,711,020	10.4	253,166	16.8	569,026	24.3	577,543	17.6

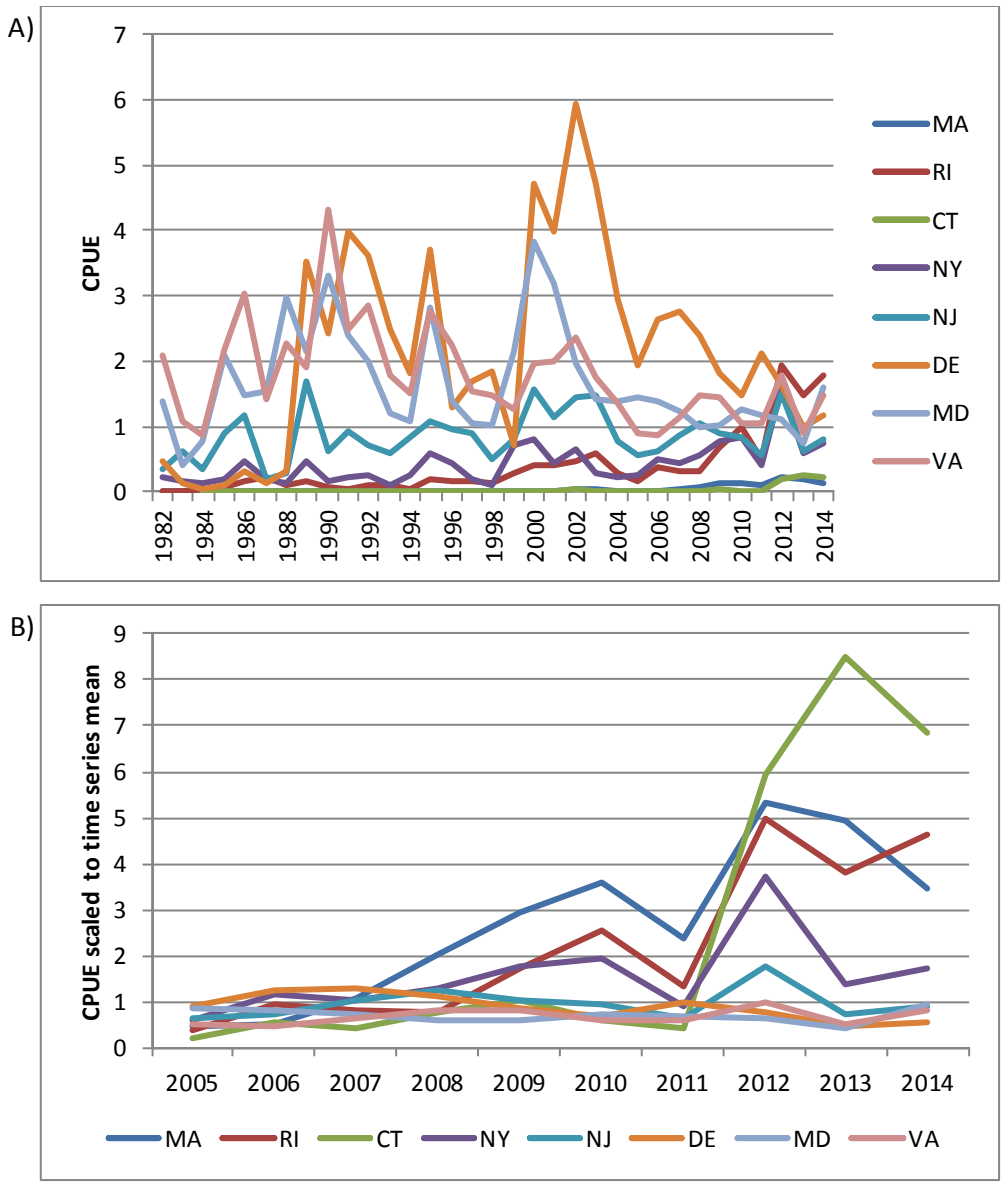

Figure 1a. State specific MRFSS CPUE estimates for black sea bass. A) Original scale. B) Standardized to time series mean.

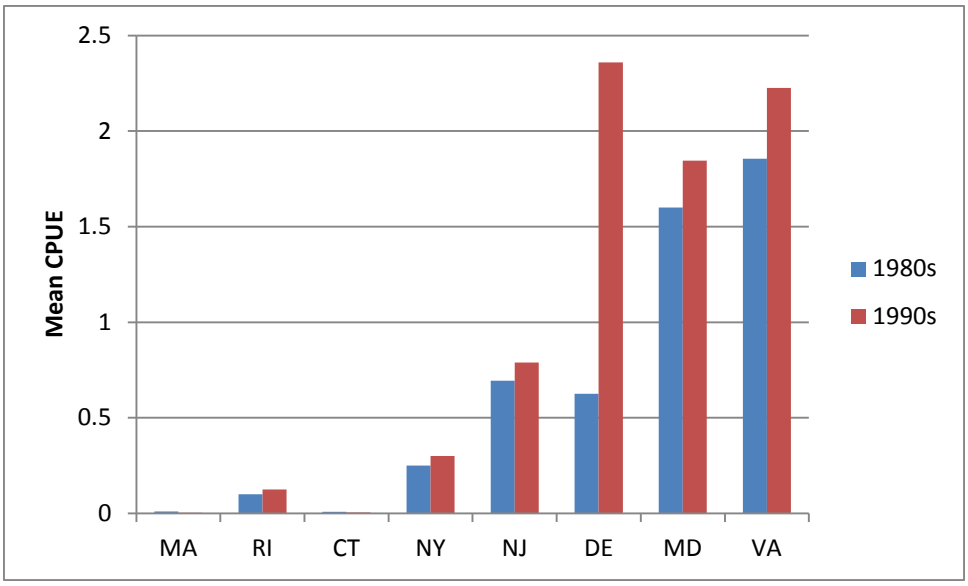

Figure 2a. Decadal mean CPUE by state exhibiting north-south clinal pattern.

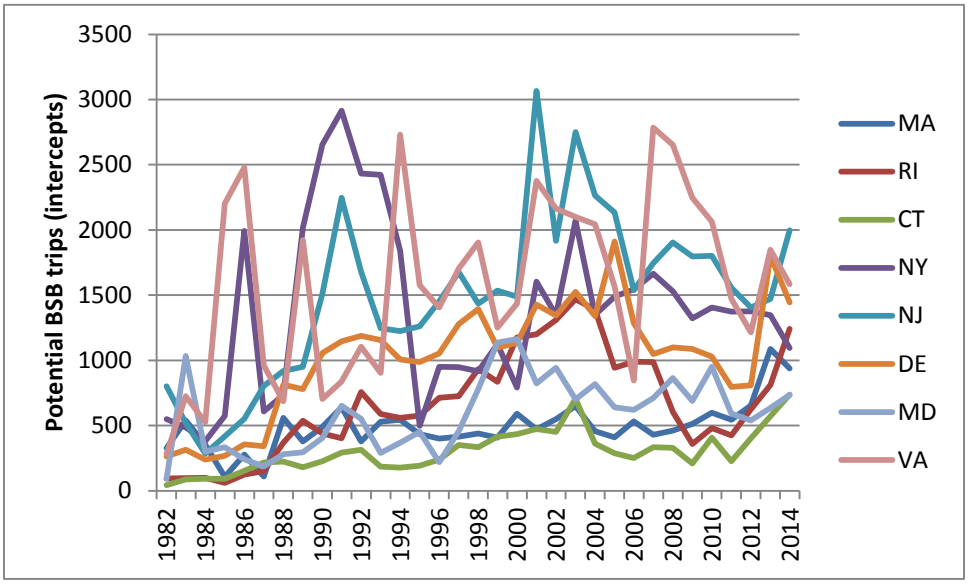

Figure 3a. Estimated number of potential black sea bass trips (intercepts) based on guild species associations.

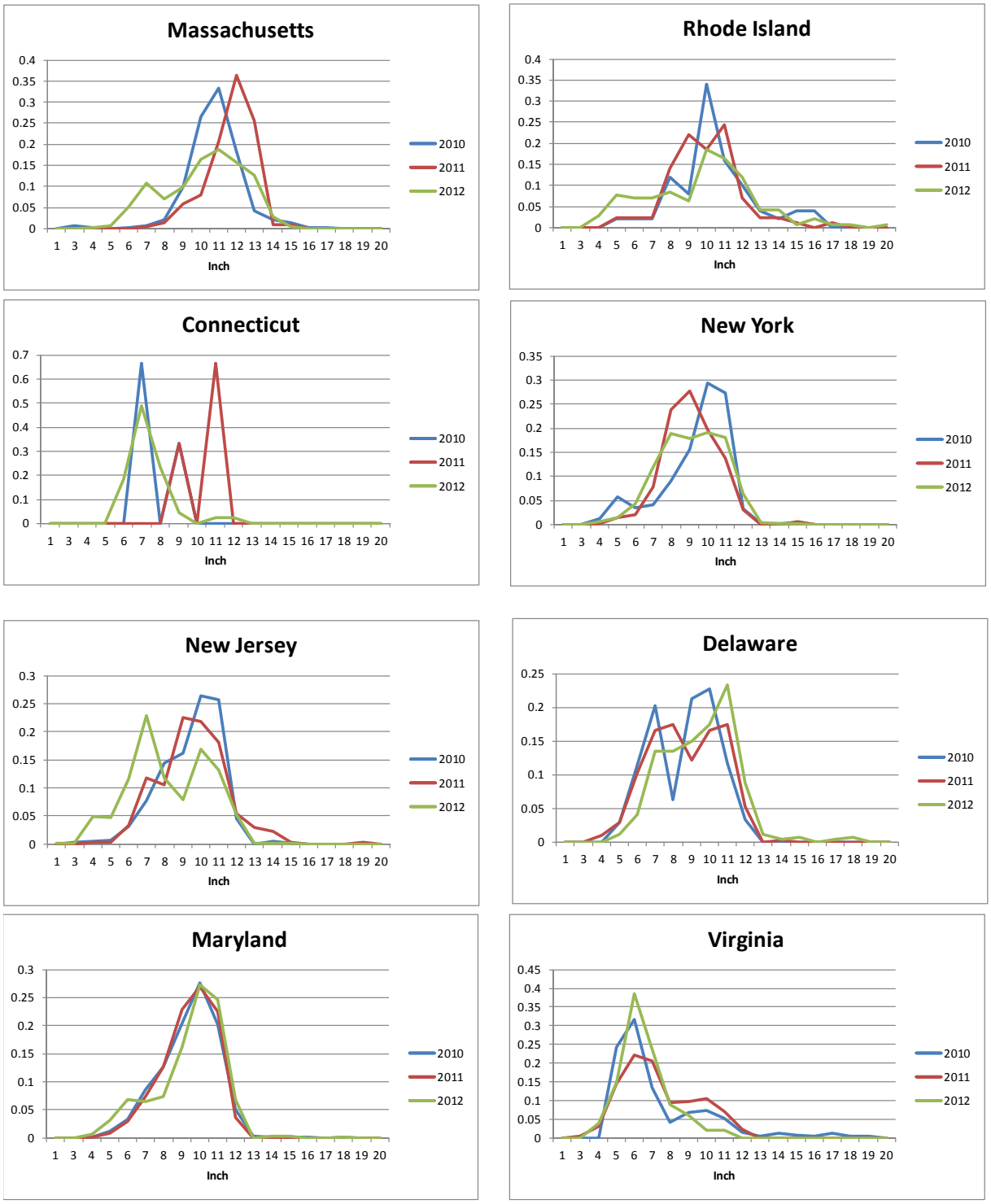

Figure 4a. Length frequency distributions of black sea bass catch (harvest and discards) from the MRFSS Type 9 data files.

Appendix II

Black Sea Bass – Patterns in Recreational Harvest

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January 12th, 2016

Summary: This summarizes an analysis of black sea bass size data extracted from the Marine Recreational Information Program (MRIP). The analysis focused on the use of a mixed-effects generalized linear model with an identity link that included fixed effects for state and size limit and a random effect for year or year and wave to identify differences in size related to location. We found that average size followed a gradient from north to south, with northern states reporting larger fish than their southern counterparts. The largest difference in size between adjacent states appears to occur between NY and NJ, providing further evidence for a potential split in the fishery at Hudson Canyon.

Introduction: Available information indicates that a natural break in the black sea bass population may occur at Hudson Canyon, between the waters of NY and NJ. For example, a tagging study conducted by Moser and Shepherd found that although most black sea bass appeared to overwinter in the same general area, black sea bass that were initially tagged north of Hudson Canyon were likely to return to areas north of Hudson Canyon. Similarly, individuals initially captured south of Hudson Canyon were more likely to return to waters south of Hudson Canyon.

Further resolution may be provided by data from the recreational fishery. The ASMFC summer flounder/scup/black sea bass TC/MAFMC summer flounder/scup/black sea bass MC have discussed the characteristics of the recreational fisheries in their respective states at great length. Members from northern states (NY north) report that their fisheries are dominated by large black sea bass (>12”), whereas members form more southerly states (NJ south) have indicated that larger fish are relatively rare in their waters. The objective of this analysis is to determine if a difference in fishery characteristics, manifested as a difference in size, can be identified among states.

Methods: All data was extracted by John Maniscalco from the MRIP database through NOAA’s MRIP website (http://www.st.nmfs.noaa.gov/st1/recreational/queries/). The first dataset that was queried contained average weight, in pounds, by state and by year. Average weight, for the purpose of this analysis, is considered the average weight of an individual black sea bass captured in a given state in a given year. The MRIP determines average weight based on weights recorded directly through MRIP interviews, weights based on imputed length values, and on weighting factors, determined from a phone survey, assigned to each wave and each mode of the fishery.

Because size limits for black sea bass have varied over time, ranging from no limit prior to 1996 and becoming as large as 14” in some states in recent years, a column of size limits, at the resolution of state to state, was added to the dataset of average weights, states, and years.

Concerns were raised at a recent SAW WG meeting that wave specific fishery characteristics may contribute to variability in average weight and that the effects of wave should be explicitly addressed. Accordingly, we constructed a dataset that included average weight, by wave, by state, and by year. This dataset also included the minimum length limit that applied during a particular year in a particular state.

Because an initial inspection of the data by state and then by year indicated that the data more or less followed a Gaussian distribution (Figures 1-5), we employed a mixed-effects generalized linear model with an identity link to analyze the data. We used the lme4 package in R to perform the analysis. We chose the mixed-effects approach so that we could incorporate a random effect for year. This approach allowed us to compartmentalize variance into among-year and overall components. In this fashion, we could see at what level variance was explained by the inclusion of different parameters of interest.

Our first analysis considered average weight, for a year, as the response variable, year as a random effect, and combinations of state, the presence of length limit, and a length limit, if applicable, and an interaction between state and a length limit, if applicable, as fixed effects. All candidate models were evaluated based on Akaike’s Information Criteria with the small sample size adjustment (AICc), with the best model selected based on the lowest AICc. We used the AICcmodavg package in R to calculate AICc. Model fit was assessed by examining model residuals and by calculating the reduction in variance from a model that included no fixed effects and a random effect of year (the unconditional model). We applied Tukey’s Honestly Significant Differences (HSD) through the multcomp package in R to identify statistically significant differences, at $\alpha = 0.10$, among states.

Our second analysis mimicked the previous analysis but also considered wave as a random effect. Because obviously incorrect average weights appeared in the dataset (>5lbs), any data points where average weight exceeded 5 lbs were excluded from further consideration. Candidate models were constructed and evaluated in a fashion similar to the previous analysis.

Results: Our unconditional model for the first analysis indicated that 44% of the total variance was at the among-year level. Of the five models considered, the model with the lowest AICc was the model that included a fixed effect for size limit and state. This model decreased the among-year variance by 94% and the remaining variance by 37%. The model that only included state as a fixed effect resulted in an increase in among-year variance of 5% and a decrease in remaining variance of 35%, indicating that the effect of state explains a substantial portion of the variance that occurs within years. The model that only included effects for size limit explains nearly 100% of among-year variance and less than 6% of remaining variance.

The Tukey HSD test for this portion of the analysis indicated that there were three groups present. Group A consisted of MA, RI, and CT. Group B consisted of RI, CT, and NY. Group C consisted of NJ, MD, DE, and VA.

Based on the best model, parameter estimates for the effect of each state indicated that black sea bass from more northerly states had a larger average weight than those from more southerly states. Massachusetts appeared to have the largest black sea bass, followed by Rhode Island, Connecticut, New York, Virginia, New Jersey, Maryland, and Delaware. The presence of a size limit resulted in increases in average weight that increased as size limit increased.

The unconditional model for the second analysis indicated that 25% of the total variance occurs at the among-year level, that 6% of the total variance occurs at the among-wave level, and that 63% of the total variance occurs at the among-year level. Of the candidate models considered for this part of the analysis, the model with the lowest AICc was the model that included a fixed effect for size limit and state. This model explained 94% of among-year variance, resulted in an increase of 175% of the among-wave variance, and a decrease of 27% of the remaining variance. The model that only included state as an effect explained 10% of among-year variance, resulted in an increase of 176% in among-wave variance, and a decrease of 27% of the remaining variance. The model that only included size limit as a fixed effect explained 95% of among-year variance, increased among-wave variance by 10%, and explained 3% of the remaining variance.

The Tukey HSD test for this section of the analysis indicated that four groups were present. Group A contained MA, RI, and CT. Group B contained CT and NY. Group C contained NJ, MD and VA. Lastly, Group D contained MD, DE, and VA.

Similar to the previous analysis, the best model indicated that the average weight for a black sea bass from the more northerly states exceeded that of the more southerly states. Massachusetts had the largest average weight, followed by Rhode Island, Connecticut, New York, New Jersey, Virginia, Maryland, and Delaware. And, as before, when a size limit was present average weight increased and average weight increased with increases in size limit.

Discussion/Interpretation: The results from both portions of the analysis have important implications for understanding regional differences in black sea bass fisheries. By compartmentalizing variance into different components, we were able to identify where variance was contained and what levels of variance were explained by the inclusion of different predictor variables. First, the relatively small portion of variance contained at the among-wave level, 6%, indicates that little of the overall variation in the data occurs because of differences between waves. Second, the proportion of variance contained at the among-year level, which was 44% in the analysis that did not include an effect of wave and 25% in the analysis that included wave, indicates that a substantial portion of the variance occurred among-years. The inclusion of size limit, which explained >90% of the among-year variance, indicated that most of the among-year variance is explained by size limit. Third, the proportion of remaining variance that is explained by state, which was 35% in the analysis that did not include wave and 27% in the model that did include wave, indicates that most of the remaining variance in average weight is explained by state. This indicates that the state of capture has a clear signal in the MRIP dataset.

One issue that potentially confounded our conclusions is the fact that the more northerly states have diverged from the more southerly states, in terms of a minimum size, in recent years. Accordingly, state and size limit effects may be inherently correlated and confounded. However,

because our models adequately captured the nested structure of the data by incorporating random effects for year and wave, our conclusion that state explains a substantial portion of the variance indicates that substantial differences in the fishery characteristics exist on a state to state basis.

As expected, black sea bass from northern states such as MA and RI appear to be larger than those from more southerly states. The results of the Tukey HSD from both portions of our analysis indicate a clear break in average weight at the NY-NJ border. Our first analysis, which did not include an effect of wave, indicated a significant difference in weight between of 0.23 lbs ($p=0.00281$) between NY and NJ. The second analysis, which included a random effect for wave, found a significant difference in weight of 0.24 lbs ($p<0.001$) between NY and NJ. This provides additional evidence for a break in the fishery at the Hudson Canyon split.

Figure 1b: Boxplot of average black sea bass weight, in lbs, from the MRIP survey, by state. Notches indicate approximate 95% confidence interval for the median.

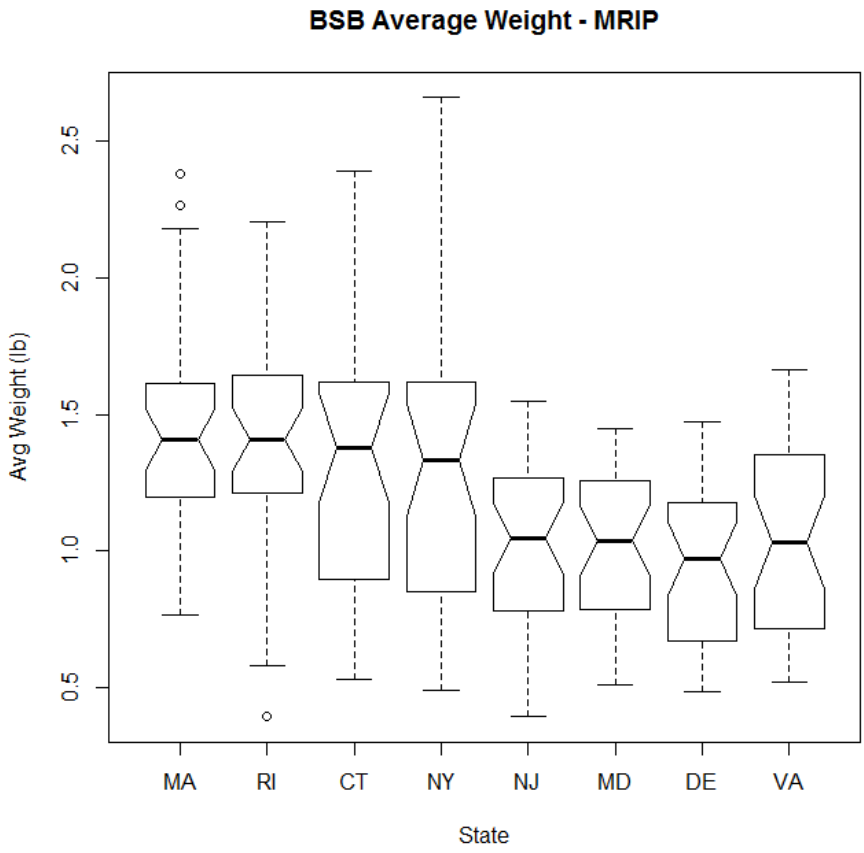


Figure 2b: Boxplot of average black sea bass weight, in lbs, from the MRIP survey, by year. Notches indicate approximate 95% confidence interval for the median.

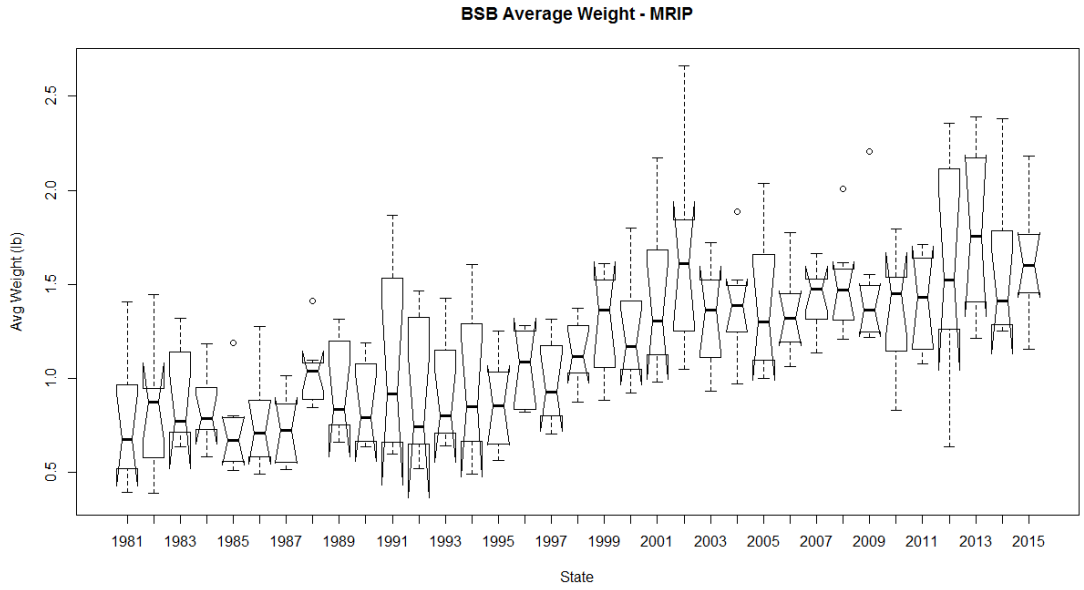
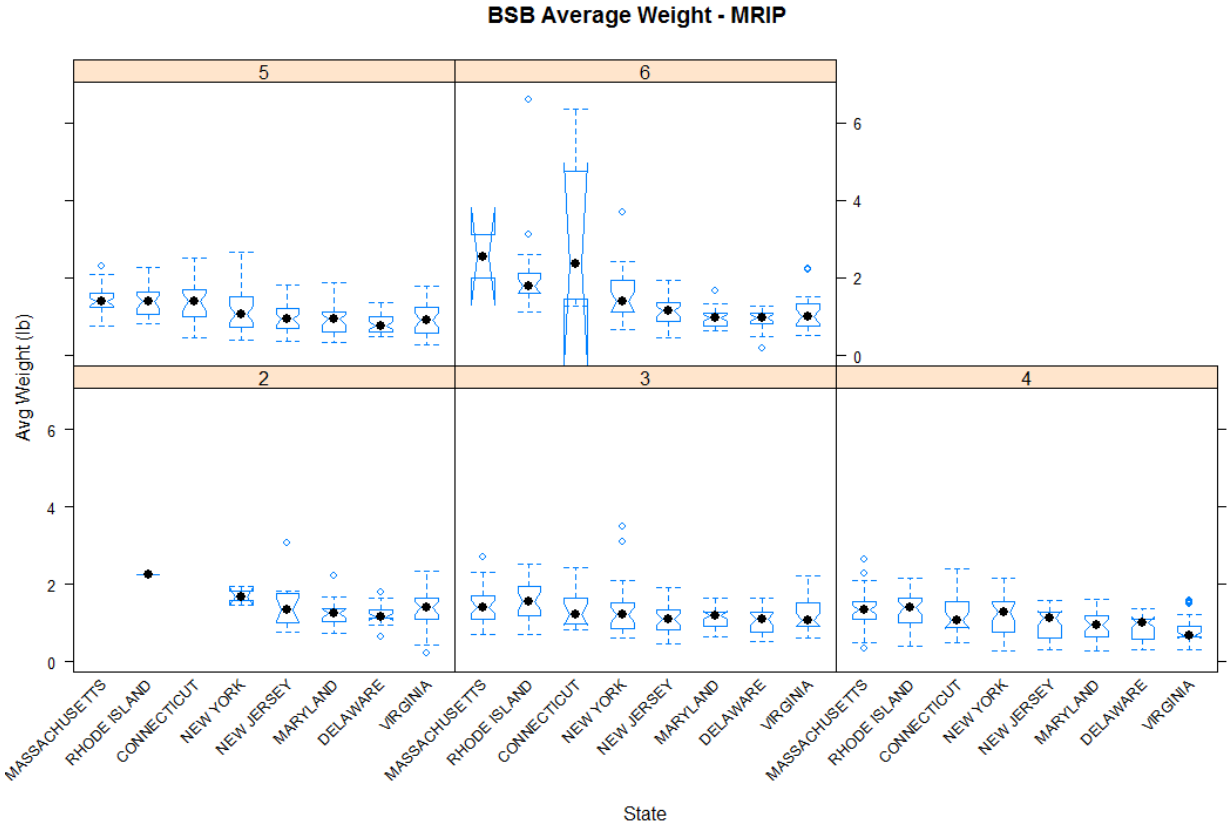


Figure 3b: Boxplot of average black sea bass weight, in lbs, from the MRIP survey, by wave and state. Notches indicate approximate 95% confidence interval for the median.



Report to the Mid-Atlantic Fishery Management Council's Scientific and Statistical Committee

On

Proposed partitioning of northern black sea bass stock for purposes of developing spatial stock assessment models

By

Mid-Atlantic Fishery Management Council's
Black Sea Bass Review Panel

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March 3, 2016

Background

A genetically distinct northern stock of black sea bass has been identified (McCartney and Burton, 2011; McCartney et al., 2013; Roy et al., 2012) which supports important commercial and recreational fisheries from Massachusetts to Virginia. The most recent assessment for this species, conducted in 2012 (Northeast Fisheries Science Center, 2012), was not found to provide a reliable basis for management (Miller et al., 2011). Concern over how incomplete mixing of fish within the stock was incorporated in the 2012 assessment was the primary reason why the assessment was not accepted by the SARC 53 peer-review panel.

It is anticipated that the Southern Demersal Working Group will complete a new assessment for black sea bass by the end of 2016. A central issue for the team conducting this new assessment will be to respond to concerns raised in the Miller et al. (2011) report. Accordingly, the chair of the Southern Demersal Working Group (SDWG, John Maniscalco) and the chair of the Stock Assessment Workshop (SAW; Dr. James Weinberg) requested that the Mid-Atlantic Fishery Management Council's Scientific and Statistical Committee (SSC) provide a critical review of the SDWG's January 2016 report which proposed a partitioning of the northern black sea bass stock for the purposes of trying to develop assessment models that incorporate stock spatial structure.

In response to this request the SSC empaneled a four-member ad hoc review panel comprising Drs. Thomas Miller (Vice Chair SSC), Robert Latour (SSC), Katie Drew (Atlantic States Marine Fisheries Commission), and John Wiedenmann (Rutgers University). The review panel was charged with a single term of reference:

> *Determine whether the spatial partitioning of the black sea bass stock proposed by the BSB SAW WG is reasonable and appropriate to use as a starting point for developing stock assessment models. In making this determination consider whether available scientific data have been taken into account and analyzed properly, and whether the conclusions based on those data are reasonable given the current fisheries data.*

On February 16, 2016, the review panel received a copy of the Working Group's report (SAW/SARC Black Sea Bass Working Group, 2016) developed as result of its December 16, 2015 meeting. The Review Panel met with the Working Group assessment lead (Dr. G. Shepherd, NOAA Fisheries NEFSC), the chair of the SDWG and the chair of the SAW on February 23, 2016 to receive as briefing of the Working Group's recommendations of a proposed spatial segregation of the black sea bass stock. The Review Panel considered four components of its charge in reaching its conclusions: (1) Justification for the Spatial Structure; (2) Inclusion of Data; (3) Data Analysis, and (4) Appropriateness of Conclusions. This report provides the Review Panel's consensus conclusions of the Working Group's Report.

Justification of Spatial Structure

The Review Panel recognized two primary justifications for incorporating spatial structure in a future assessment model of black sea bass. The Panel recognized that these separate justifications are not necessarily exclusive, but, importantly for this review, they require different standards be met in determining whether appropriate data were included and analyzed and whether appropriate justifications have been drawn.

1) Biological differences among components of the stock components.

The existence of differing biological characteristics among stock components is perhaps the principal justification for including spatial structure in assessment models. When present, these differences may result in separate assessment models and management policies for each stock component. Ultimately, the presence of such patterns in productivity may result in a revision of stock definitions.

Characteristics usually used to identify stock structure include genetics, life history traits (size at age, growth, age at maturity, fecundity) that lead to differing potential productivities, and life cycle trajectories (spawning seasons, locations, nursery areas, migration pathways).

In this case the spatial structure is imposed on the assessment model by the underlying biology. As a result, clear and compelling differences in biological characteristics must be demonstrated prior to model specification.

2) Resolving tensions among different data sources in the model.
Fishery independent surveys or fishing fleets often do not cover the entire stock area. Yet, single area stock assessments assume complete mixing and that each survey or catch stream represents independent information from the entire stock. However, in many cases the regional surveys or catch streams conflict, suggesting differing trends in abundance. Two approaches have been developed to address the tension created in the assessment model inherent in these conflicting data sources. One approach uses statistical methods to try to reconcile the data prior to use in the analysis; another approach is to let the model try to account for the regional differences by perhaps including spatial structure. Of course, the differences in the fishery-independent surveys and catch streams which necessitated adopting spatial structure may reflect underlying, but as yet unrecognized biological differences.

In this case the spatial structure is a convenience used to avoid pathological problems in parameter estimation or model fit. As a result, a much lower standard of data is required to establish the spatial structure in the model.

Inclusion of data

The SAW/SARC Black Sea Bass Working Group reviewed the known genetic data which clearly identify a stock separation around Cape Hatteras, NC into a northern Atlantic black sea bass population and a southern Atlantic black sea bass population. There are no more refined data that address the potential for stock structure within the northern population.

No data were presented by the SAW/SARC Black Sea Bass Working Group related to life history differences among proposed spatial units within the northern stock. These data have been extensively analyzed previously (Shepherd 20xx) and are suggestive of a clinal gradient in life histories (size at age, growth etc.) rather than any specific breaks within the northern stock. Clinal gradients are present in other mid-Atlantic species as well, including summer flounder and tautog. Omission of such data from the report limited conclusions regarding biological differences between proposed sub-units.

Most of the analyses presented by the SAW/SARC Black Sea Bass Working Group related to potential differences in life history trajectories. The group presented information on the oceanographic conditions in the Mid-Atlantic Bight and concluded that the general southerly residual flow on the shelf would mean that larval dispersal from a putative southern sub-unit within the northern stock would be separated from a putative northern sub-unit within the northern stock.

The extensive tagging database on the northern stock of black sea bass was presented and analyzed in some detail. The general pattern involving extensive seasonal migrations evident in black sea bass between inshore summer areas and offshore wintering grounds that was noted (Moser and Shepherd, 2009). Moreover, the tagging data indicate a considerable degree of local homing by black seabass such that adult fish are likely to return to the same summer regions. The tagging data also indicate a latitudinal trend in the distance migrated and the fealty of the migration – with more northern fish (those that summer in MA waters) migrating further and experiencing higher rates of straying than southern fish (those that summer in VA waters).

The SAW/SARC Black Sea Bass Working Group did present data on differences in the recruitment of an apparently strong year class in the northern sub-unit of the northern stock in 2011 that was not present in the southern sub-unit, which is evidence of a separation of the recruitment dynamics of these two sub-units in one year. No additional analyses were present to indicate whether this pattern had been repeated in earlier years. Evidence was presented that survey indices were more similar for neighboring regions than for distant regions, but no clustering of the time series was presented.

The SAW/SARC Black Sea Bass Working Group also examined patterns and trends in the commercial fishing data – both among and within the principal sectors based catches from the Vessel Trip Reports (VTR). Analysis of these data indicated real limits to the spatial resolution possible in any proposed spatial structure.

No comparative data on the spatial structure of other species that have a similar broad distribution were presented.

Data Analysis

All analyses presented in the SAW/SARC Working Group report (2016) were found to be both appropriate and reliable.

Inferences on Spatial Structure

Based on their analyses, the SAW/SARC Working Group recommended establish a northern and southern sub-unit of the northern stock of black sea bass, with a dividing line approximating the position of the Hudson Canyon.

The Review Panel concluded that this separation is reasonable and appropriate to use as a starting point for developing stock assessment models.

However, the Review Panel note that the justification is not based on overwhelming biological evidence of a difference in stock characteristics north and south of this dividing line. The principal justification for

the division is the parsimonious one – in that it provides sufficient data in both putative sub-units for parameter estimation in stock assessment modeling while aligning broadly with potential physical and biological characteristics related to life history characteristics and life history trajectories.

The Review Panel notes that if a spatial model is successfully developed around this sub-unit definition, and if it indicates differences in productivity between the putative northern and southern stock sub-units, additional analyses will be required to determine if the line of separation selected herein is the appropriate basis of stock definition based on biological characteristics.

Comment on Process

The report provided to the Review Panel by the SAW/SARC Black Sea Bass Working Group (2016) was produced in partial response to their first term of reference: "Evaluate the distribution, movement and potential for spatial structure of the stock, the ability of existing data to support alternative spatial structure, and their consequences for the stock assessment." Yet, because this was a working paper report and not the complete assessment, the Review Panel were not provided with all of the data and analyses that would be presented in the full benchmark assessment. Consequently our ability to critically evaluate the full range of data pertinent to the Working Group's TOR was limited.

The time frame available for reviewing material prior to the Review Panel meeting was limited. The original Working Group meeting was on December 16, 2015, and the Working Group report was dated January 29, 2016. The Review Panel received materials on January 29, 2016, prior to a February 23, 2016 meeting. If a detailed review of material is required in future consultations, more consideration needs to be given to the scheduling of events.

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Appendix A6 –The implication of spatial patterns in a simulated black sea bass population.

SAW62 Black Sea Bass Model Meeting Working Paper

Simulation testing assessment models for Black Sea Bass

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Abstract – Alternative configurations of Stock Synthesis (SS), including spatially-explicit models with a boundary near Hudson Canyon, were developed for the data available for assessing black sea bass. Alternative SS configurations were tested. A complex operating model including spatial, seasonal, age, length, sex, and fleet structure was developed to produce pseudo-datasets that were characteristic of the information available for assessment, and the alternative SS configurations were fitted to the pseudo-datasets. Results suggest that a 2-area seasonal model performed better than simpler alternatives, however a 2-area model that did not include explicit fish movement between areas but did allow for different year class strengths by area performed almost as well as the correctly specified model. The 2-area assessment model also appeared to be robust to not assuming sex change, even when the true dynamics of the operating model included hermaphroditism.

Introduction

The SARC 53 Review Panel "*identified substantial concerns over the potential for spatial structure and incomplete mixing within the stock area that compromised the ability of the forward projecting catch at age model to index abundance and fishing mortality reliably based on the data available*." (NEFSC 2012). In response to this concern, an initial SAW62 term of reference was to evaluate the distribution, movement and potential for spatial structure of the stock, the ability of existing data to support alternative spatial structure, and their consequences for the stock assessment. The SAW62 Black Sea Bass Working Group reviewed the information available and formed a consensus that the most reasonable response to the Term of Reference was to consider a spatial boundary near Hudson Canyon for assessment model development and simulation testing, which reflects a natural discontinuity in spatial processes in the black sea bass resource. A Mid Atlantic Fishery Management Council SSC Review Panel concluded that "this separation is reasonable and appropriate to use as a starting point for developing stock assessment models."

The revised SAW62 Terms of Reference include:
ToR1: Summarize the conclusions of the February 2016 SSC peer review regarding the potential for spatial partitioning of the black sea bass stock. The consequences for the stock assessment will be addressed in TOR-6.
ToR6: Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock), using measures that are appropriate to the assessment model, for the time series (integrating results from TORs-1,-4, & -5 as appropriate), and estimate their uncertainty. Include a historical retrospective analysis and past projection performance evaluation to allow a comparison with most recent assessment results.

The Mid-Atlantic Fishery Management Council solicited research for "Development of a Quantitative Stock Assessment for Black Sea Bass" (request for proposals May 2015), specifically to participate in the development of a new quantitative stock assessment for BSB which addresses the concerns raised about the stock assessment model developed for review at SARC53 and to work collaboratively with stock assessment scientists at the NEFSC and the ASMFC Technical Committee to facilitate the development of a stock assessment model which will ultimately form the basis for setting annual catch limits for BSB, including forward projecting statistical catch-at-age and catch-at-length models.

We are collaborating with stock assessment scientists at NEFSC, ASMFC and MAFMC SSC to develop and test the performance of a set of alternative configurations of statistical catch at age estimation models for black sea bass using Stock Synthesis (SS). Alternative configurations include a range of hypotheses for the spatial and seasonal structure of black sea bass population dynamics. Simulation testing is designed to evaluate the relative performance of alternative data decisions and model configurations for recovering known parameter values and whether the model configurations are estimable given the available data.

Methods

The analytical approach uses Stock Synthesis (SS, Methot & Wetzel 2013) as a platform for testing alternative spatial and temporal configurations of an assessment model for black sea bass. SS is a flexible statistical catch at age framework that among other features has the ability to handle spatial and seasonal structure in population and fishing dynamics, is flexible in the parameterization of life history (can consider hermaphroditism), allows for mirroring of parameters such as selectivity among fishing fleets (which will aid design of the various model congfigurations), and can fit to size composition and tag-recapture data in addition to age structure and abundance indices. Standardized diagnostic plotting package in R (r4ss) allows for rapid comparison of model results between assessment runs and simulation testing packages in R (r4ss and ss3sim, Anderson et al. 2014) are available that can be tailored for treatment of spatial dynamics.

<u>Operating Model</u>

The operating model concept is used to evaluate the performance of estimation models using simulated data in several steps (Hilborn & Walters 1992):

1. Specify a population and fishery model of how we believe the real system behaves (the 'operating model').
2. Develop an estimation model (usually simpler than the 'operating model').
3. Simulate the typical pseudo-datasets that have the same properties as the available data (including imprecision and bias) using the operational model.
4. Apply the estimation model to simulated pseudo-datasets.
5. Compare estimates to 'known' operating model parameters to evaluate precision & accuracy of the estimated parameters.

Simulation testing of estimation models has been widely applied to determine model performance (e.g., NRC 1998, Deroba et al. 2015)

We used simulations to test the performance of spatial assessment models given the uncertainty regarding the spatial and seasonal dynamics.

Population model ('2 area') - The main operating model consists of a spatially structured seasonal population model. The model contains two areas, north and south, aimed to characterize sea bass populations north and south of Hudson canyon. The model has two seasons, spring (season 1), and fall (season 2), each of equal length (6 months duration).

A single stock of black sea bass is modeled, with a single stock recruit relationship. Recruitment of age 0 fish occurs at the start of season 2, and is allocated spatially to both areas. The proportion of fish recruiting to area 1 is allowed to vary over time so that spatial differences in year class strength can be represented. Overall recruitment follows a Beverton Holt relationship with steepness set to 0.95 (very little density dependence) and a standard deviation for the annual recruitment deviations from this relationship of 0.7, as per the previous assessment.

The modeled population age range is from 0-15, with 15 being a plus group (the pseudo-data generated are modeled according to fewer age bins). The length structure of the population is modeled in 2cm bins, with the smallest bin being of length 2-4cm, and the largest being fish 70-72cm. This upper bound is higher than lengths of observed fish because it is necessary to appropriately capture the distribution of length at age for the oldest fish (i.e. fish of length close to the maximum length, L_∞) so that growth for these fish is calculated correctly.

Both males and females are modeled, with hermaphroditism being modeled explicitly according to sex change rate parameters at age determined by Jensen (pers. comm). At recruitment, 63% of fish are assumed to be female. The rate of sex change is not assumed to vary over time.
Two growth patterns are modeled to represent possible regional differences in growth north and south. Recruits are assigned to growth patterns by spatial location of recruitment (all fish recruiting in the north are assigned growth pattern 1). Growth is modeled according to a von Bertalanffy growth curve, with separate t_0 parameters north and south, and separate k parameters for both sexes of each growth pattern. L_∞ and variability in length at age are assumed to be the same for each growth pattern and for both sexes. The CV of length at age is assumed to decrease linearly with respect to mean length age. Full estimation of separate growth parameters by sex and growth pattern are possible in SS, the choices made here reflect pragmatic choices based on initial fits to available data, but modeling of growth could be further considered. Growth parameters are assumed to be the same for both seasons, though a separate weight-length relationship is assumed for each season.

Movement of fish between areas was modeled to represent offshore mixing during the winter. At the end of season 2, a fraction of fish in growth pattern 1 (northern fish) move from the Northern to the Southern area. At the end of season 1, a fraction of growth pattern 1 fish move from the South to the North (This rate is ostensibly very high to 'force' fish back to their natal inshore area, however there have been some recaptures of north released fish in south inshore region and so the fraction remaining is modeled to be non-zero). The two movement rates are modeled as being constant for all years and ages.

Fishing fleets - A total of 12 fishing fleets are modeled to accommodate gear, spatial, and seasonal differences in availability. 3 gear types are modeled, commercial trawl, commercial non-trawl, and recreational fishing (all gears combined), with fleets then being split by area (north and south), and by season (1 and 2). Selectivity of each fleet is modeled separately as a function of length, with the trawl and recreational fleets having a logistic (flat-top) selectivity, and the non-trawl fleets allowing for dome shaped selectivity via a double normal pattern. Selectivity for each fleet is modeled to vary over time by assuming a step change in selectivity (block) between 1997 and 1998 (to reflect coast wide management changes). Retention is assumed to follow a logistic curve for each fleet, with a block change in 1997/1998, and annual deviations in the asymptote of the retention pattern to reflect both size-based changes and other drivers in discarding rate. The retained catch of commercial fleets is evaluated in biomass, whereas the recreational fleets are modeled in numbers.

Initial conditions - The model is started in year 1989, reflective of availability of removals data for all fleets. An initial fishing mortality is assumed for each fleet based on an annual retained catch set equal to the average retained catch by fleet for the period 1989-1993.
The age structure of the population is also modeled to not be in equilibrium by modeling annual recruitment deviations from 1984 on.

<u>Conditioning the operating model</u>
To produce operating models with values for parameters that produce dynamics that are characteristic of observations for black sea bass, the operating model was fit to available data for black sea bass for the years 1989-2016. These data included:
1. Retained catch by year for all fishing fleets (fixed inputs),
2. Discard observations (in either biomass or numbers) for each fleet for those years and seasons when these data were available,
3. Length compositions of the retained catch for each fleet,
4. Length compositions of the discards for each fleet (pre-2004 composition for recreational fleets are modeled in inches rather than centimeters via the SS generalized size composition),
5. Commercial age-at-length compositions by area, season, and sex,
6. Survey indices of abundance (details of various surveys below),
7. Survey length compositions,
8. Survey age-at-length compositions by area, season, and sex (pooled with commercial data), these ages came from the NEFSC Spring and Fall bottom trawl surveys, and the Massachusetts spring and fall trawl surveys.
9. Tag recapture data from 2002-2004 releases.
10. Age imprecision matrices (by season) based on NEFSC multiple reads (fixed inputs).

Fishery independent surveys included during conditioning were:
1. NEFSC Spring Bottom Trawl Survey, North
2. NEFSC Spring Bottom Trawl Survey, South
3. NEFSC Winter Bottom Trawl Survey, North
4. NEFSC Winter Bottom Trawl Survey, South
5. NEAMAP Spring Survey, North
6. NEAMAP Fall Survey, North
7. NEAMAP Spring Survey, South

8. NEAMAP Fall Survey, South
9. Rhode Island Spring Trawl survey (North), Age 1+
10. Massachusetts Spring Trawl survey (North), Age 1+
11. New Jersey Spring Trawl survey (South), Age 1+

Additional survey indices exist and are included in the data generation, to potentially use in some estimation models, but these were not part of the operating model conditioning. Selectivity for all surveys was modeled with a double normal selectivity pattern, allowing for the possibility of dome-shaped selectivity. Power parameters for the relationship between the index and vulnerable biomass (or numbers) were estimated to reflect non-linearity in this relationship, associated with structure-oriented behavior that might result in trawl surveys being not fully effective at providing an index of abundance (hyper-depletion scenario).

A minimal number of adjustments (decreases) were made to the sample sizes of composition data to roughly equate input multi nominal sample sizes with model suggested effective sample size. As much as possible, data that were available for black sea bass were used (rather than using pooled/aggregated data). Raw estimates of CV and sample size were used when available. Index data for which these were not available were initially assigned a CV of 30%, composition data were assigned an initial sample size of 25 (some of these were adjusted downwards as noted above). Operating models were constructed using Stock Synthesis (v3.24Y).

The time series of spawning biomass in the conditioned 2-area operating model is shown in Figure 1 Spawning biomass is calculated on both males and females. The trajectory for biomass of black sea bass in the operating model is increasing toward the end of the time series, with a recent increase in the proportion of biomass in the northern area. Full diagnostic plots of dynamics and predictions for the operating model can be found by opening the SS_output.html file at the following Dropbox link:
https://www.dropbox.com/s/c9w9288begsw6we/plots.zip?dl=0

To avoid potential bias from patterns in the estimated recruitment residuals in the fit to the data, a new set of recruitment deviations with the same variability as assumed during the conditioning (standard deviation of 0.7) were generated to project the population model prior to generating pseudo-data. This new vector of recruitment residuals was resampled until the population model was still able to take the full input catch time series. Other process error in the model includes the annual deviations in spatial recruitment allocation, and the annual changes in asymptotic retention rate. These were not adjusted from the estimated values, and so there is potential here for introducing bias.

'1 area' Operating model
An alternative operating model, that modeled the black sea bass population as a single area, and took a 'areas as fleets' approach to representing spatial heterogeneity, was also conditioned following the steps and data described above. The fleet and survey structure for this model was identical to the 2-area model, except that all fleets and surveys operated in the same model area. Only a single growth pattern was modeled.

Data generation

The parametric bootstrap functionality of Stock Synthesis was used to generate the pseudo-data sets from the operating model. SS allows for generation of bootstrap datasets that are parametric bootstraps of the original dataset, but also allows for the creation of simulated data sets from data files that have different data structures – thus allowing for multiple scenarios regarding data availability to be tested.

In addition to the data streams discussed above, data were also generated for the following surveys:

1. Connecticut Spring Age 1+ (North)
2. New York Spring Age 1 (North)
3. Delaware Spring Age 1 (South)
4. Maryland Spring Age 1 (South)
5. VIMS Age 1 (South)

Areas above relate to the model areas. These surveys were modeled with age-based selectivity, set to 1 for age 1s and 0 for all other ages. The age 1 indices are typically very over-dispersed, with zero values, so a density dependent relationship between abundance and the index was modeled, and the actual age 1 indices were converted to z scores, then exponentiated and the exp(z) modeled as log-normal. These indices were not used in the simulations presented here.

Data were also generated for the catch at age for each fleet and survey, by inputting the real data as 'ghost' data. This functionality of Synthesis means that the model predictions for catch at age can be visually compared to the calculated observations even though these data are not being fit to within the model. Generating these data allows for alternative estimation approaches that fit to these data rather than the age-at-length data directly. Note that using this approach does not quite approximate the often necessary analyst's procedure of pooling data to create annual age-length-keys to apply to length compositions because the year/season/fleet-appropriate model predicted age-length keys are used to construct the predictions used to generate the catch at age data.

Estimation models

Alternative spatial and seasonal configurations were developed using SS that reflect current understanding and work developed during SARC 53, including: a single coast-wide mixed stock dynamics (an 'areas as fleets' approach), and spatially and seasonally structured models (for example, models that explicitly consider areas North and South of Hudson Canyon, with seasonal movement to account for mixing in southern offshore areas).

A set of estimation models were fit to the data generated for the above operating models. Estimation models were provided with the known values for several parameters (rate of natural mortality, steepness, and the standard deviation of the stock recruit relationship) as the goal was to evaluate performance given the uncertainties related to spatial structure, movement, and sex change. The movement parameterization for the spatial estimation models was likewise constrained to match the true pattern of movement from the operating model (i.e. the seasonal movement of northern fish to the south in the winter), although the parameters determining the

magnitude of movement were not assumed known to the estimation models. The estimation models included:

1. Self test. i.e. Estimation model is the same as the operating model.
2. Seasonal and spatial model, but with no movement modeled among areas.
3. Seasonal and spatial model, but assuming that the spatial distribution of recruitments is constant over time.
4. Seasonal and spatial model, but with no movement and assuming that the spatial distribution of recruitments is constant over time.
5. 1 area model, seasonal areas as fleets model, spatial differences in catch characterized by fleet specific selectivity patterns.
6. Seasonal and spatial model, no sex change, 50:50 assumed recruitment split male/female.

It is certainly possible to develop even simpler estimation models, for example by only modeling a single season, and mirroring selectivity patterns between gears and seasons and areas. However, the range of model complexity above reflects considerations by the WG as plausible options for modeling black sea bass dynamics. Simpler estimation models could include:

7. 1 season areas as fleets model, selectivity patterns by gear and season modeled separately.
8. 1 season and 1 area model, selectivity patterns by gear modeled separately.
9. 1 season and 1 area model, same selectivity assumed for all fleets.
10. Availability of additional state trawl surveys.

Performance measures

Performance of the estimation models was evaluated by comparing the estimates for key derived quantities to the known values from the operating model(s). These included calculating the % relative error of estimate for:

1. Final depletion (spawning stock biomass in terminal year relative to unfished spawning biomass),
2. Current (2016) spawning biomass.
3. Annual recruitment (median percent relative error across all years)
4. Current recruitment (median percent relative error over the period 2011-2015 (last five years),
5. Current (2015) F (computed as the average total F over ages 4-7).
6. Catch at MSY

Spatial models can also be evaluated in terms of their ability to recreate spatial distributions in biomass trend, by computing spawning depletion, spawning biomass, and recruitment by area and comparing these to the area-specific quantities from the operating model.
The population sex ratio was also calculated.

Results & Discussion

Notes from estimation of operating model

1. There appears to be evidence for growth differences north and south, at least in terms of initial size. This is most reflected in the NEFSC spring bottom trawl survey, where age 1 fish in the north are approximately 2cm larger than those in the south.

2. Adding time varying discarding rate provides a lot of flexibility for the model to fit the discard data, which is relatively uncertain. The visual fits to the model when a time-invariant asymptotic discard rate is estimated are not appreciably different. The most variable appears to be the southern trawl fleet in the spring, where the model estimates large changes in the retention parameters to fit the discards. Consequences of modeling discards this way is that the model sometimes estimates very high fishing mortality in some years resulting in large decreases in biomass that are not immediately apparent in the index data. Without time varying discard it is not possible for the model to estimate increases in discards in the north in recent years.
3. As noted in the meetings of the technical committee, the indices of abundance in the north are much more coherent than those in the south. Consequently, models appear to fit the northern data better, because there is less conflict. This coherence is not solely, but in part due to the very large year class in 2011 in the north, which shows up in all data streams and is tracked through time in the abundance index and length compositions.
4. Several of the northern indices are estimated to have a non-linear relationship with abundance. All the age 1 indices are estimated to have high values for the power parameter (indicating hyperdepletion) – in part this is due to the high over dispersion of these indices that include zero values rather than necessarily a true non-linear relationship (e.g. An incorrect observation model is being used for these data, options are limited to lognormal or normal).
5. Models estimate black sea bass to have increased, particularly in the northern region, and models generally estimate current spawning biomass to be above biomass reference points.
6. Simple assumptions were made regarding the timing of surveys and fishery catches (i.e. all take place in the middle of the season). This is a simplification of the actual timing of these data (e.g. Many of the inshore catch in season 1 is caught in the last 2 months of the semester, similarly much of the catch in season 2 is caught early in the semester). These differences in timing could influence the estimation of growth, particularly emphasized due to the seasonal growth pattern whereby age 0 fish in the fall are essentially the same size as age 1s in the spring. This is also the case for older ages but is less pronounced. This issue will warrant consideration in size-based approaches to modeling Black Sea bass. To reduce the influence of new recruits on the estimation of growth we removed age 0 fish from the fall age data (And set selectivity for the fall age at length data to 0 for age 0).

Deterministic results

To better evaluate the effect of model mis-specification, a set of deterministic simulations were conducted, with no recruitment variability in the operating model. The estimation models were fit to the deterministic output from the operating model (i.e. no observation error). The 2 area model (self test) was able to replicate the operating model dynamics (Figure 2), with the no movement model showing minimal bias in spawning biomass, despite the model being mis-specified. The 1 area model fit to the deterministic data from the 2 area model over-estimated spawning biomass at the beginning of the time series and over-estimated at the end (Figure 2).

Simulations with process and observation error

Addressing bias. Self-tests with both process error in the operating model and observation error in the pseudo-data resulted in appreciable bias of estimates. Several steps were made to remove the bias. First, the recruitment residuals estimated when conditioning the operating model were replaced with a vector generated from the same distribution as that assumed in the assessment. Secondly, the level of bias adjustment applied to the estimated recruitments in the estimation model during the simulations was tuned following the protocol outlined by Methot and Taylor (2011) – the appropriate modification required was evaluated from the fits to the first five pseudo-datasets, and the average suggested from these runs was then used for the remainder of the simulations. Several authors have found this approach to be a reasonable approximation in simulation mode. Third, a bug was found in the Stock Synthesis parametric bootstrap routine for the generation of the tag-recapture pseudo-data – such that the pseudo-data being generated were not consistent with their use in the likelihood function. This code was fixed to address this problem. Additional analyses compared the performance of various levels of complexity with respect to process error in the simulations, given that the deterministic fits were able to replicate the operating model dynamics.
Despite a reduction in bias from the above steps, bias remains in the simulation results. Consequently we believe it remains prudent to compare the relative performance of simulation testing scenarios rather than focus on the absolute level of bias.

Results
The self-test on the 2 area 2 season operating model revealed some bias in estimation (Figs 3-8, Table 1). It is possible that the bias correction is not fully accounted for properly when recruits are allocated spatially. In addition, unlike with recruitment deviations, there is no means to bias correct for additional process error (proportion of recruitment to the north, and deviations in retention). In general, the degree of bias in the self-test was low (absolute relative error <20%), with the 2016 relative spawning biomass being the most biased (Figure 6, unsurprising as this estimate is a function of over-estimation of B0 and under-estimation of current spawning biomass). An unintended constraint on the proportion of recruits allocated to the north was identified during the October 20 2016 WG review meeting, which meant that the fraction of recruits to the north was restricted to be a maximum of 50% of the total. Fits to the real black sea bass data that removed this constraint were improved, although general inference of stock status and trends were robust. This constraint was not fixed in the simulations presented here, however a subset were performed with the constraint removed in both the operating and estimation models for the self-test, with little impact on performance. Similarly, a version of the operating model that included time-varying movement from north to south as a function of bottom temperature did not fit the data much better than the model with a constant movement rate and so simulations were not performed under this scenario.

Not estimating the movement rate (mixing of northern fish to the south during season 1) resulted in little difference in estimation performance from the self-test (Figs 3-8, 'no move'). The proportion of fish moving north to south in the operating model was relatively low (10-15%). Not estimating movement had little effect on estimation performance, but not estimating time-varying spatial allocation of total recruitments (changes from year to year in the percentage of the total recruitment recruiting to the northern area) and instead estimating a fixed proportion

over time had a large effect on estimation performance (Figs 3-8, 'fixed_rec' and 'fr_nm'). In this scenario, spawning biomass was overestimated, F under-estimated, and current stock status over-estimated compared to the 2 area self-test.

The 'no move' scenario is comparable to conducting separate north and south assessments, because the steepness of the stock-recruit relationship is set high such that biomass does not affect expected recruitment. The 'no move' scenario therefore approximates the structure of the ASAP north and south models, which fit separate stock assessment models to the spatially disaggregated data. The simulation testing here suggests that this may be a reasonable approximation for a black sea bass population that exhibits seasonal migration as understood through the available data and knowledge for the species.

Comparing the performance of a non-spatial model ('1 area') that emulated spatial differences in data streams through modeling selectivity (the 'areas as fleets' approach) showed that this model performed poorly relative to the spatial and seasonal model when the true dynamics were spatially structured (via spatial recruitment and seasonal movement between areas). The 1 area model estimated more negative stock size (lower current spawning biomass), and a more positive bias estimate of fishing mortality (2015 F), resulting in a negative estimates of current biomass relative to unfished (Bratio 2016), compared to the self-test. The 1 area model had separate selectivities by gear and season – in initial investigations assessment models that aggregated these fleets/seasons by mirroring selectivity among fleets in the estimation model performed slightly worse.

Assumptions related to hermaphroditism were explored using a version of the 2 area estimation model that did not include sex change and instead assumed a sex ratio of 50:50 at birth ('no hermaph'). This model performed slightly worse compared to the self test (estimates of quantities had slightly more bias and were less precise), although the mis-specification of sex change was not as important as those related to fixing recruitment allocations through time or fitting a structurally different (1 area) model.

Although the operating model was conditioned on the available data, results correspond to one realization of the operating model dynamics, and therefore do not properly integrate uncertainty regarding values for model parameters (and process error). However, this is true for the data set applied to all estimation models. Results suggest that the 2 area spatial and seasonal model perform better than the considered alternatives given the assumption (as supported by the data) that there are seasonal and spatial dynamics leading to differences in observed data streams. The results also indicate that a 'no move' scenario has comparable performance.

1 area operating model

The '1 area', '2 area', and 'no move' estimation models were also fit to pseudo-data generated from a single area operating model (Figures 9-14). When the true dynamics of the operating model were governed by the single area model, the 2 area model performed worse than the self-test (i.e. the estimation model is 1 area and not mis-specified). Previous studies suggest that application of a spatially structured model should be less precise but without additional bias. However, the 2 area estimation model used here is structurally constrained to only represent the seasonal movement pattern based on black sea bass dynamics. Consequently, the 2 area model in

the current form is not able to represent the 1 area model, even given certain values for the model parameters (for example, it cannot estimate free movement in all directions in both seasons). Should the constraints on movement parameters be relaxed, it would be expected that the bias relative to the self-test would be reduced but that the precision of estimates should also become poorer.

Acknowledgments
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Table 1. Median and 50% intervals (italics) for %REE of derived quantities for the set of estimation models fit to the 2 area operating model.

	Bratio_2016			F 2015			R0			SPB 2016			SPB_Virgin			TotYield_MSY		
2 area	-0.2	*-0.22*	*-0.16*	0.11	*0.09*	*0.14*	0.08	*0.07*	*0.1*	-0.14	*-0.15*	*-0.1*	0.07	*0.06*	*0.09*	0.06	*0.04*	*0.08*
no move	-0.19	*-0.22*	*-0.17*	0.12	*0.1*	*0.14*	0.07	*0.07*	*0.08*	-0.14	*-0.16*	*-0.1*	0.07	*0.05*	*0.08*	0.07	*0.05*	*0.08*
fixed rec	0.2	*0.15*	*0.22*	-0.34	*-0.35*	*-0.31*	0.19	*0.17*	*0.21*	0.46	*0.39*	*0.5*	0.21	*0.2*	*0.25*	0.14	*0.12*	*0.16*
fixed rec no move	0.08	*0.04*	*0.17*	-0.29	*-0.34*	*-0.27*	0.21	*0.2*	*0.23*	0.33	*0.3*	*0.45*	0.25	*0.23*	*0.26*	0.16	*0.14*	*0.18*
no hermaph	-0.26	*-0.31*	*-0.23*	0.19	*0.16*	*0.3*	0.05	*0.04*	*0.07*	-0.11	*-0.19*	*-0.09*	0.18	*0.17*	*0.2*	0.02	*-0.01*	*0.05*
1 area	-0.44	*-0.48*	*-0.42*	0.45	*0.39*	*0.54*	0.01	*-0.01*	*0.02*	-0.38	*-0.43*	*-0.36*	0.1	*0.08*	*0.11*	0.15	*0.14*	*0.17*

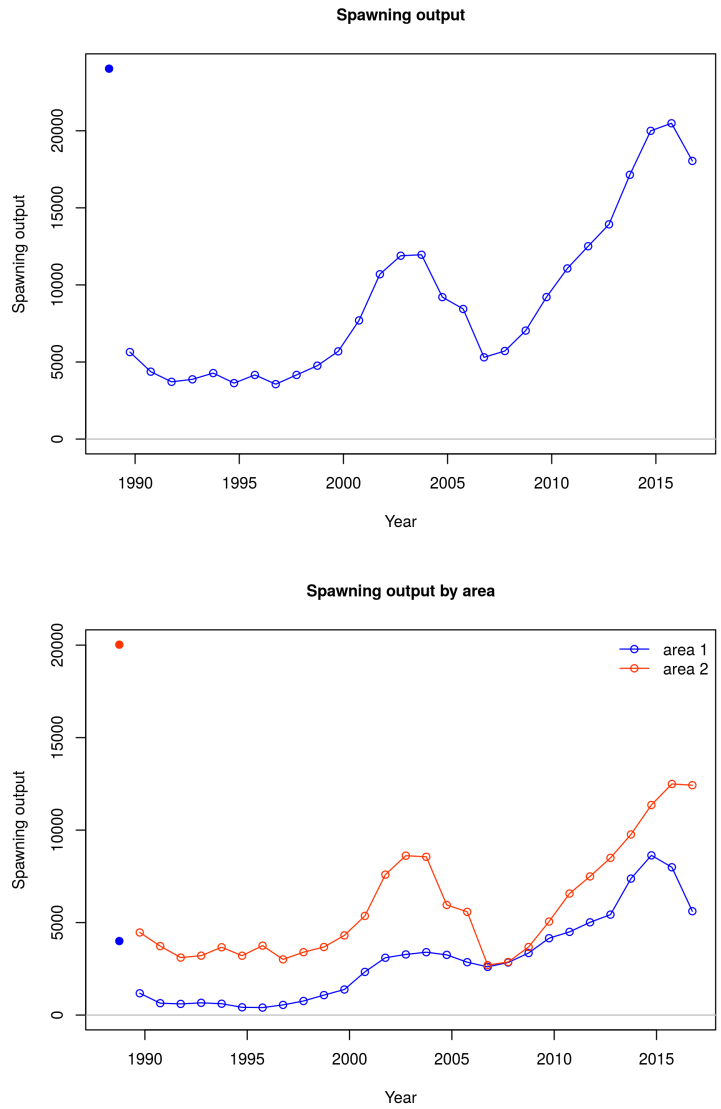


Figure 1. Spawning biomass trajectory for the 2 area operating model.

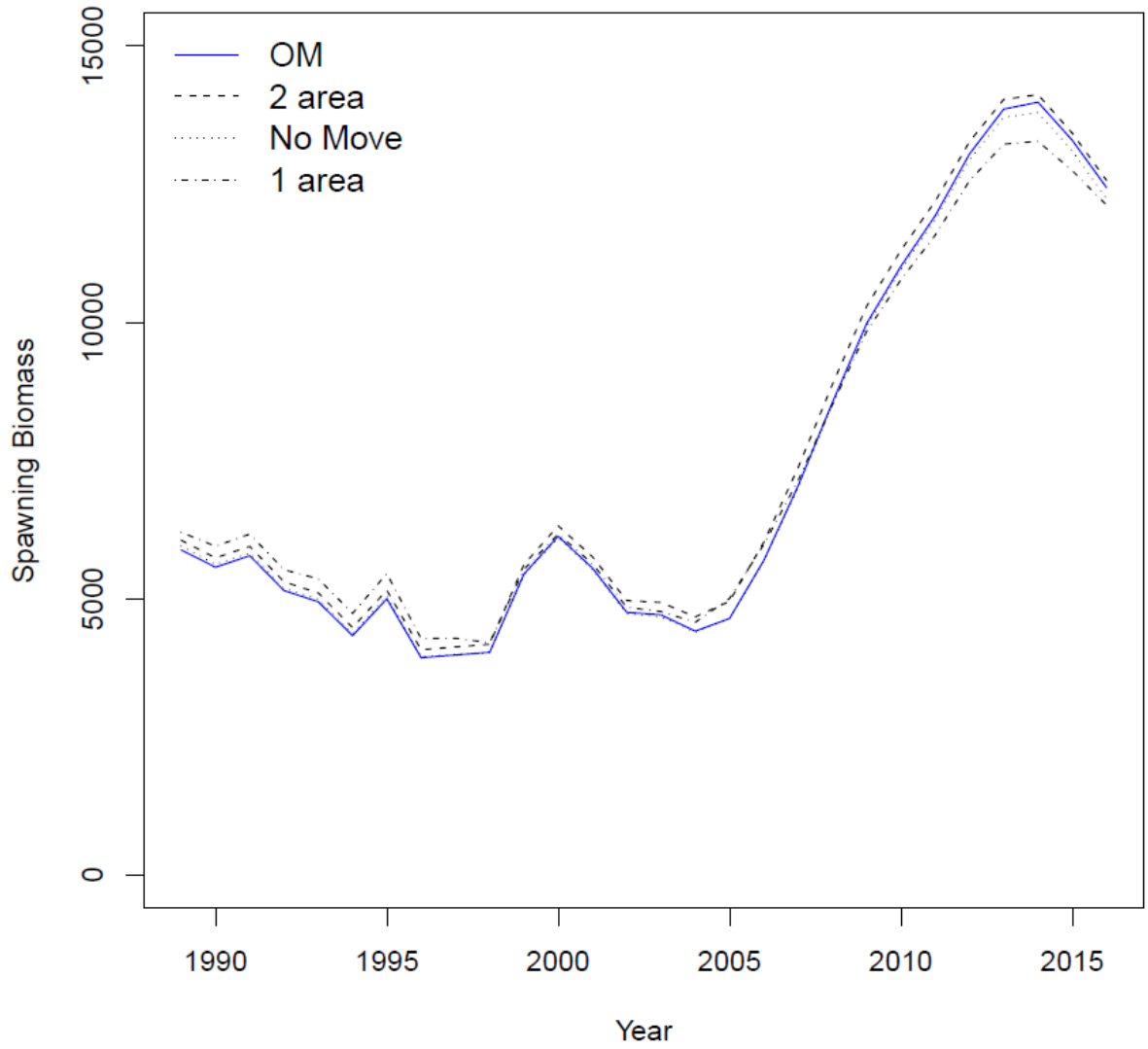


Figure 2. Estimates of spawning biomass relative to the operating model with no recruitment variability, based on fits of the 2 area, no move, and 1 area models to deterministic data generated from the 2 area operating model.

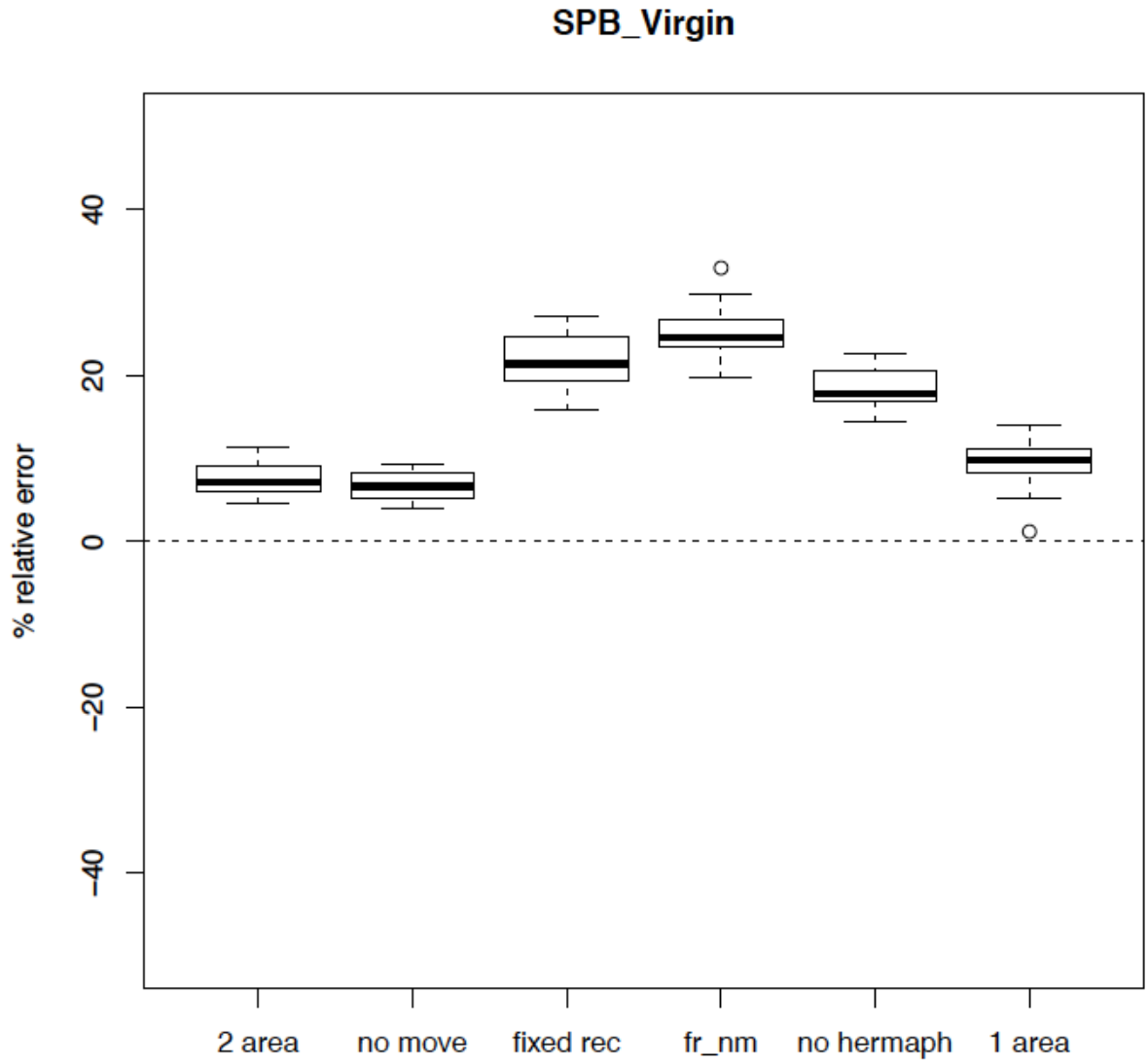


Figure 3. Distribution for the percent relative error of estimate (%REE) of unfished spawning biomass for estimation models fit to pseudo-data generated from the 2 area operating model. '2 area' is the self-test with the estimation model equivalent to the operating model. 'no move' is the 2 area estimation model but with no movement between the north and south areas. The estimation model '1 area' is a single area model, but with fleets and seasons modeled separately. 'Fixed rec' is the 2 area seasonal and spatial model but does not allow for spatially varying year class strength (spatial allocation of proportion of total recruitment is fixed over time). 'fr nm' implements the time-invariant proportional recruitment allocation but in the 'no move' model. 'No hermaph' is the 2 area model but no hermaphroditism is modeled and a 50:50 sex ratio at birth is assumed.

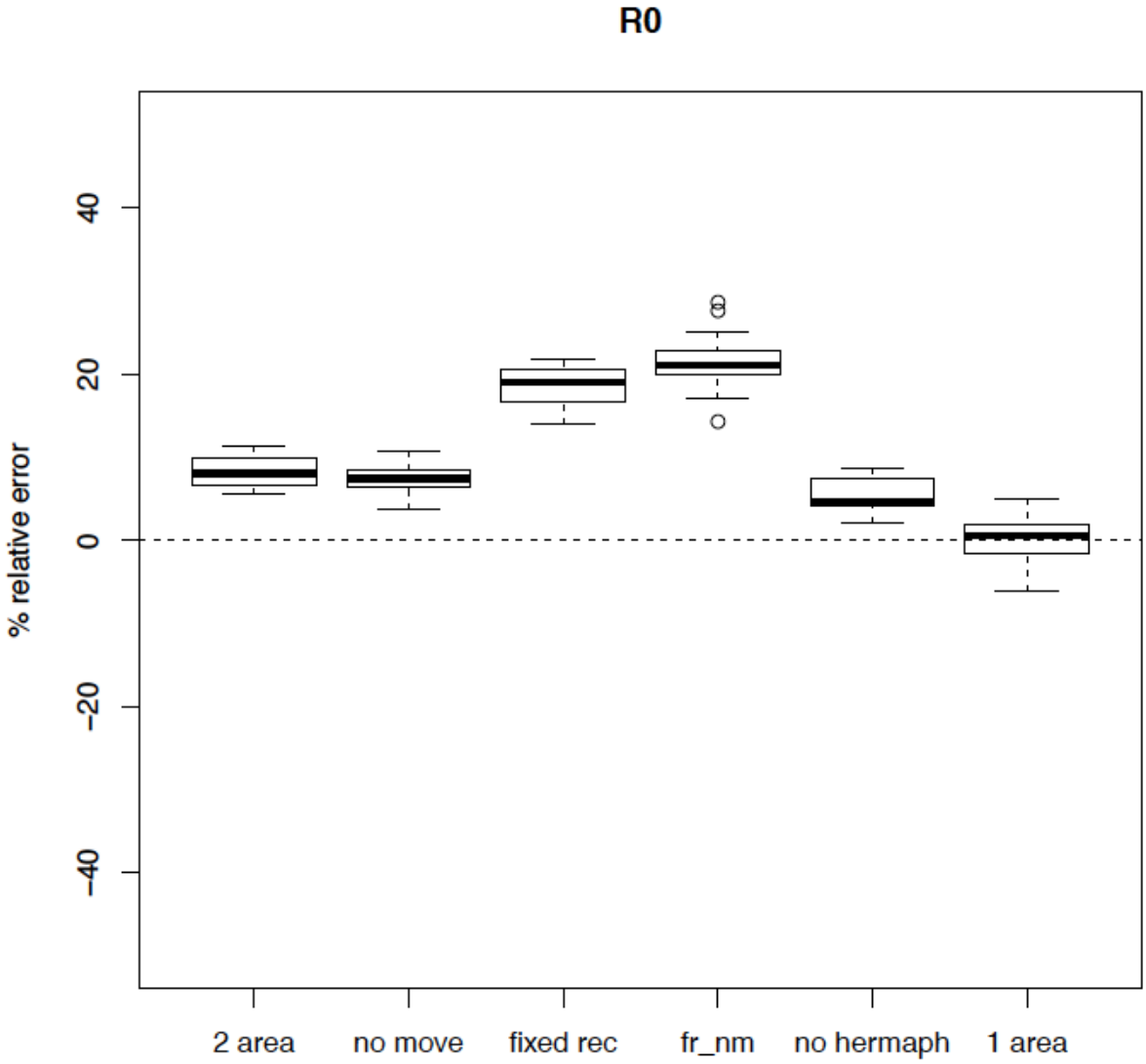


Figure 4. Distribution for the percent relative error of estimate (%REE) of unfished recruitment, for estimation models fit to pseudo-data generated from the 2 area operating model. Model labels as in Figure 3.

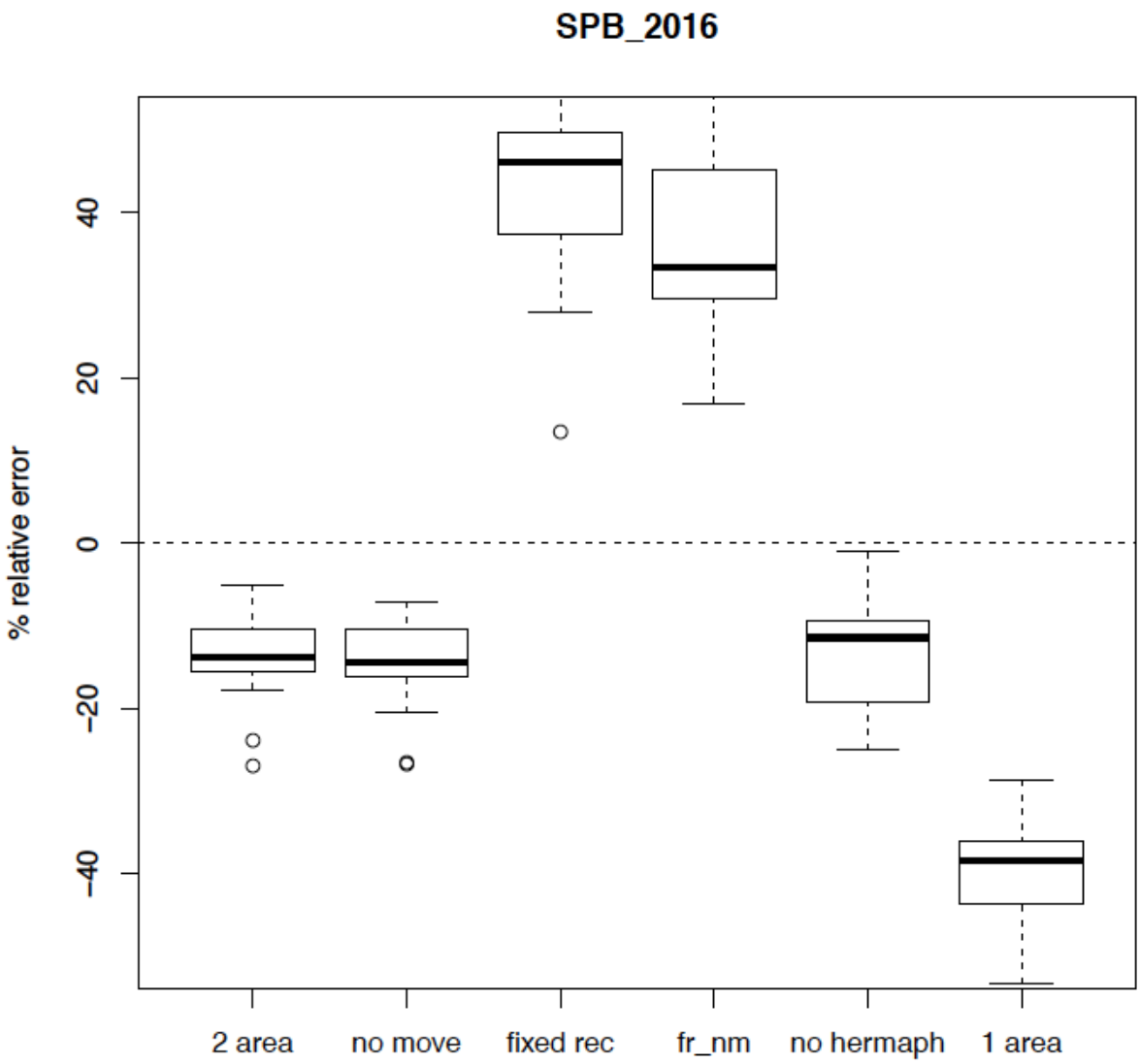


Figure 5. Distribution for the percent relative error of estimate (%REE) of 2016 spawning biomass, for estimation models fit to pseudo-data generated from the 2 area operating model. Model labels as in Figure 3.

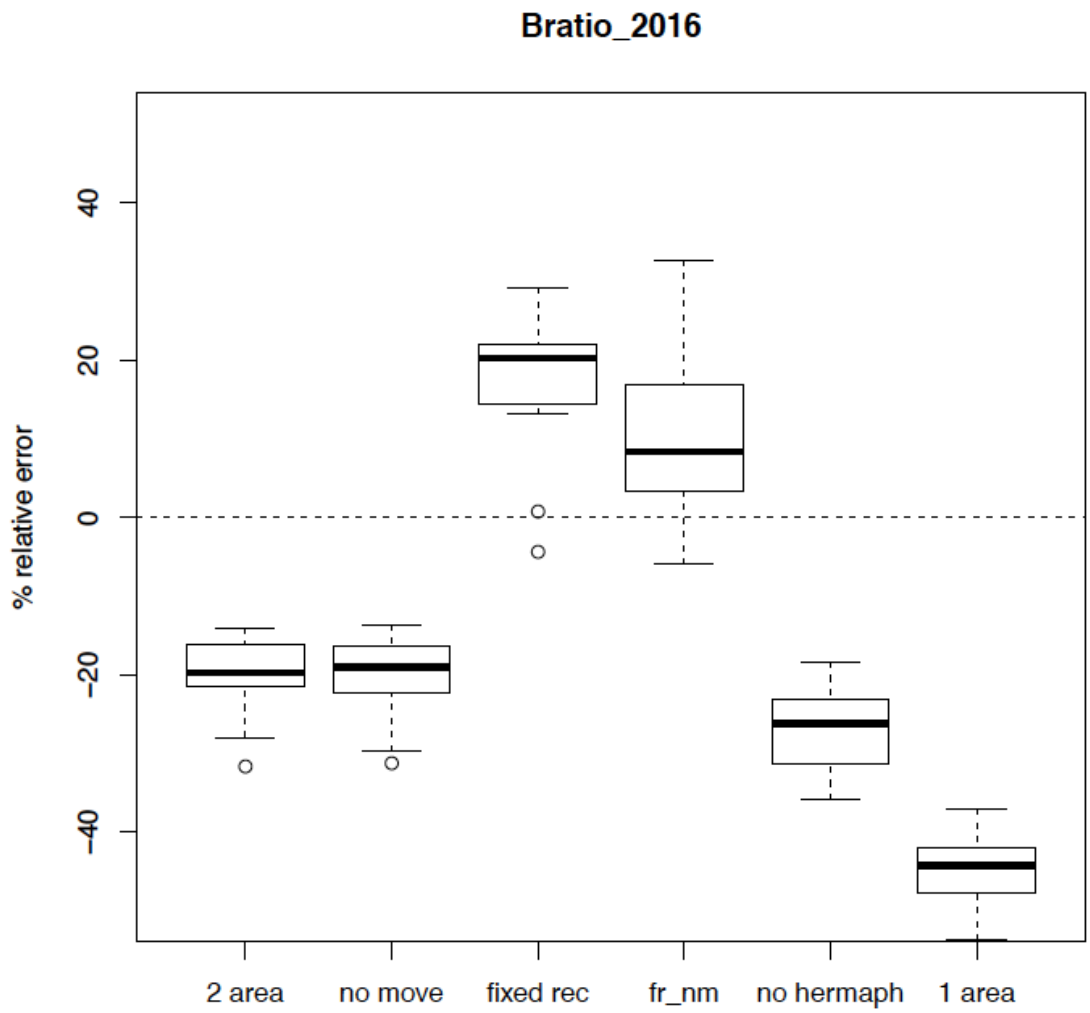


Figure 6. Distribution for the percent relative error of estimate (%REE) of 2016 spawning biomass relative to unfished, for estimation models fit to pseudo-data generated from the 2 area operating model. Model labels as in Figure 3..

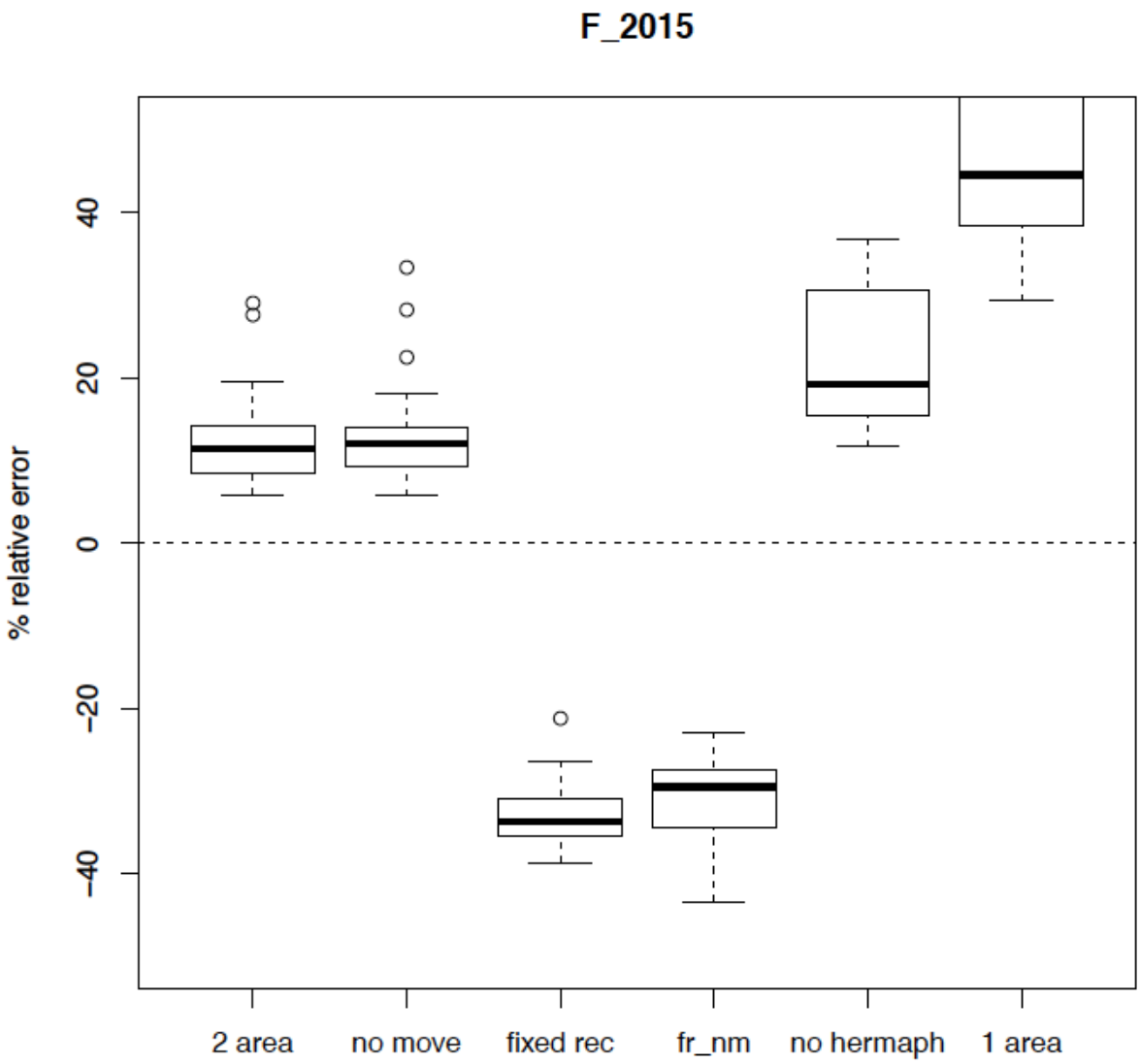


Figure 7. Distribution for the percent relative error of estimate (%REE) of 2015 fishing mortality, for estimation models fit to pseudo-data generated from the 2 area operating model. Model labels as in Figure 3..

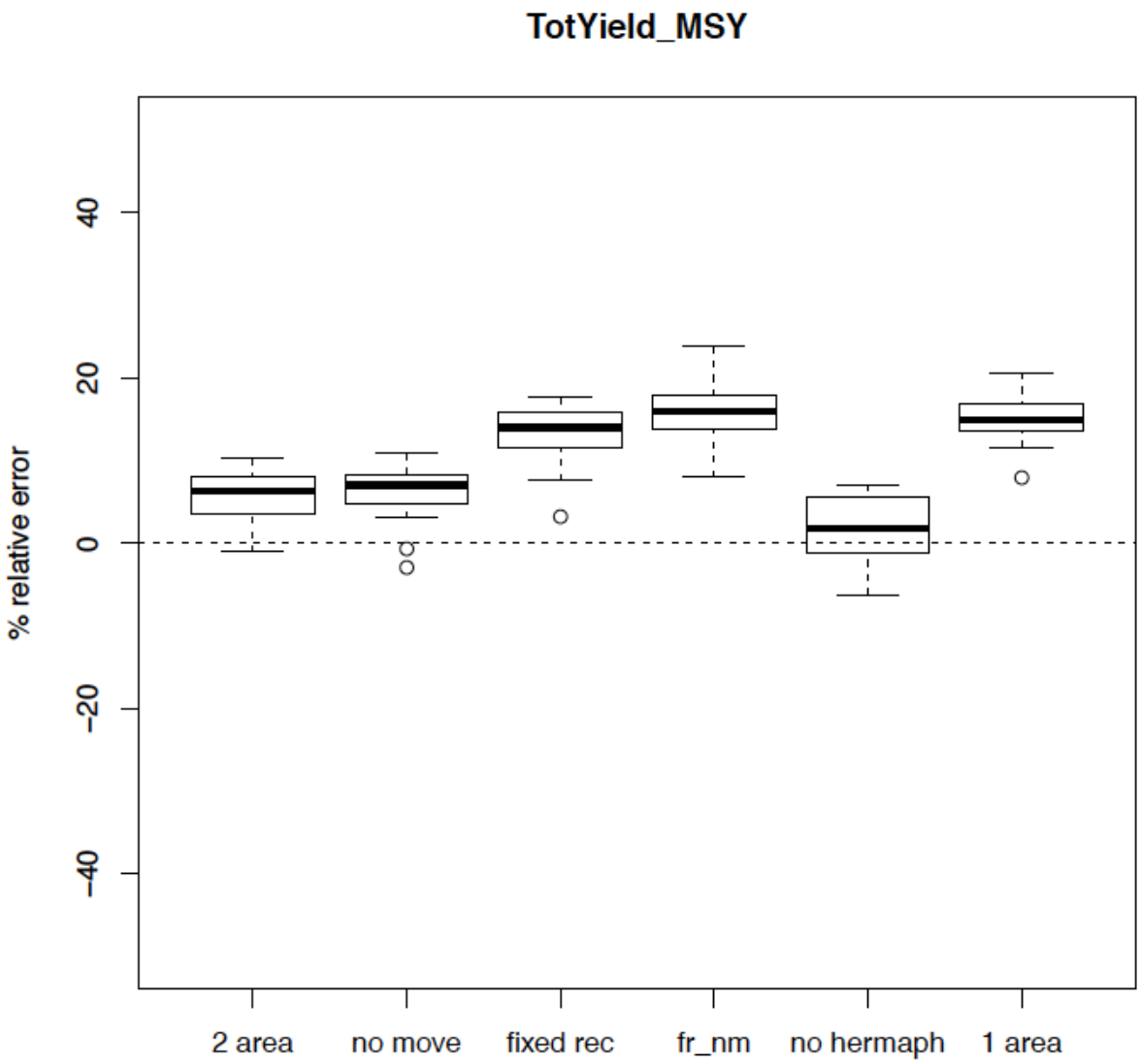


Figure 8. Distribution for the percent relative error of estimate (%REE) of the total catch (retained plus discard) at maximum sustainable yield (given terminal year fishing pattern by fleet and season), for estimation models fit to pseudo-data generated from the 2 area operating model. Model labels as in Figure 3.

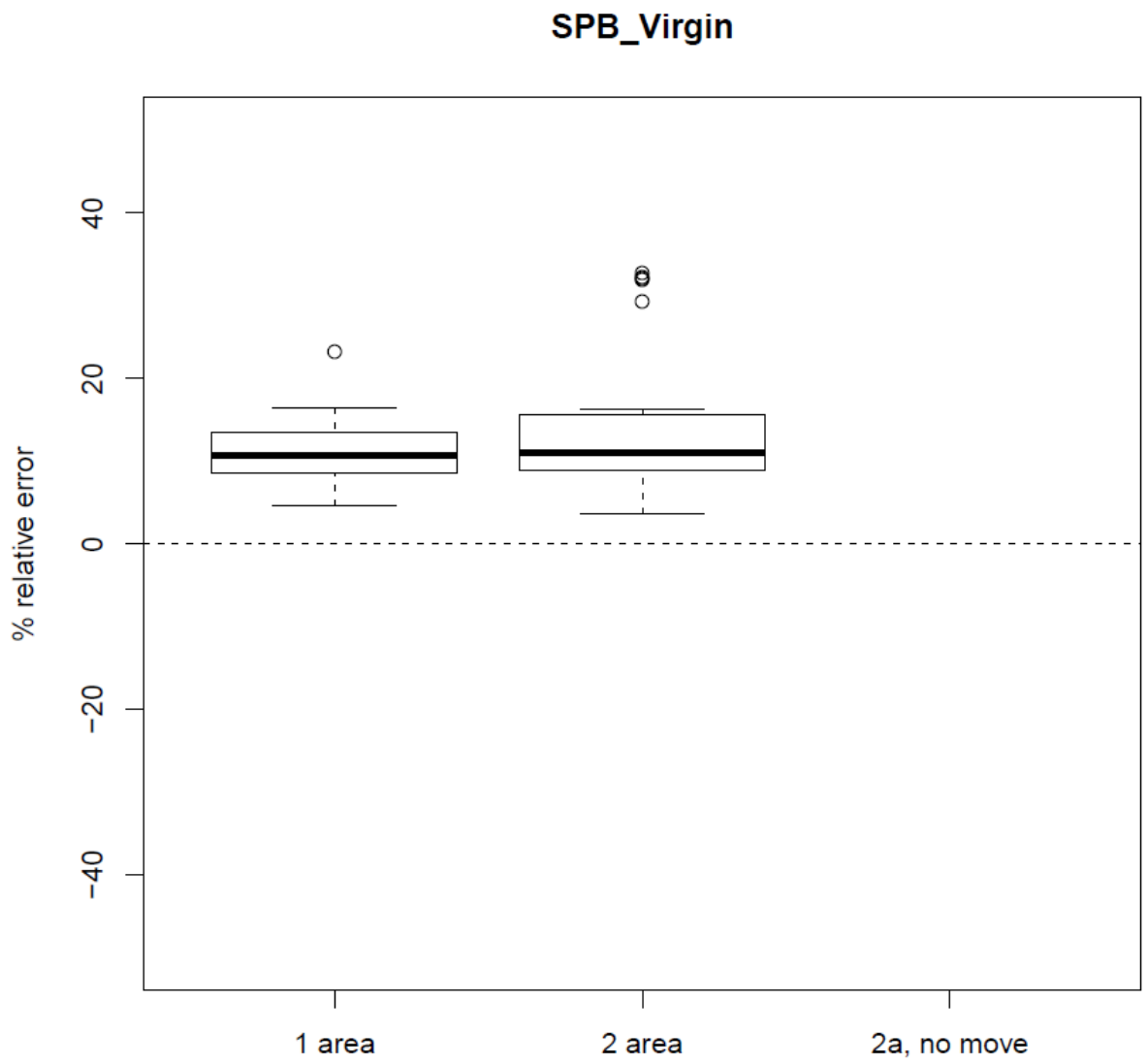


Figure 9. Distribution for the percent relative error of estimate (%REE) of unfished spawning biomass for estimation models fit to pseudo-data generated from the 1-area operating model. '1 area' is the self-test with the estimation model equivalent to the operating model. '2 area' is the 2 area estimation model, and 'no move' is the 2 area estimation model but with no movement between the north and south areas.

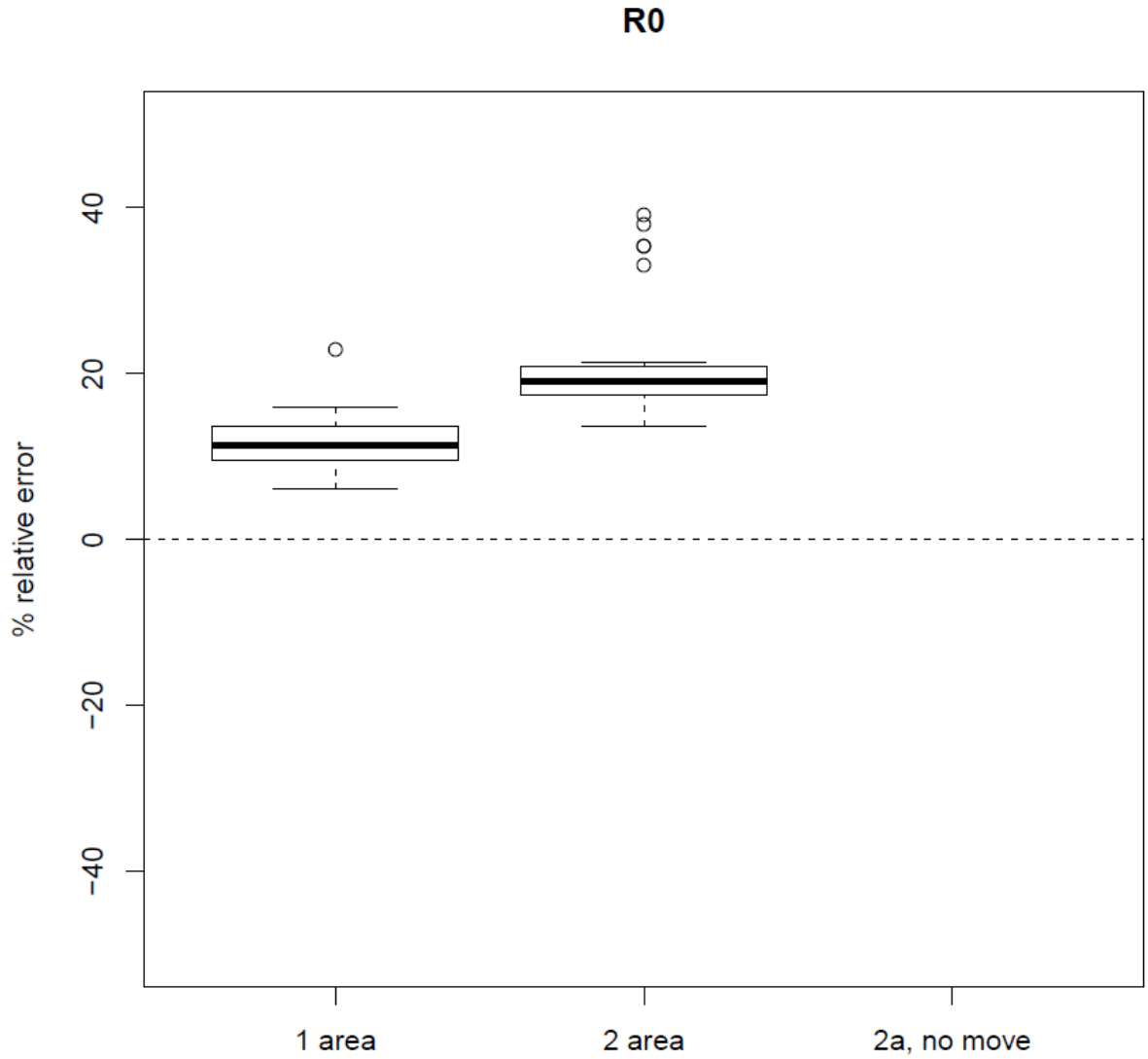


Figure 10. Distribution for the percent relative error of estimate (%REE) of unfished recruitment, for estimation models fit to pseudo-data generated from the 1-area operating model. Labels as in Figure 10.

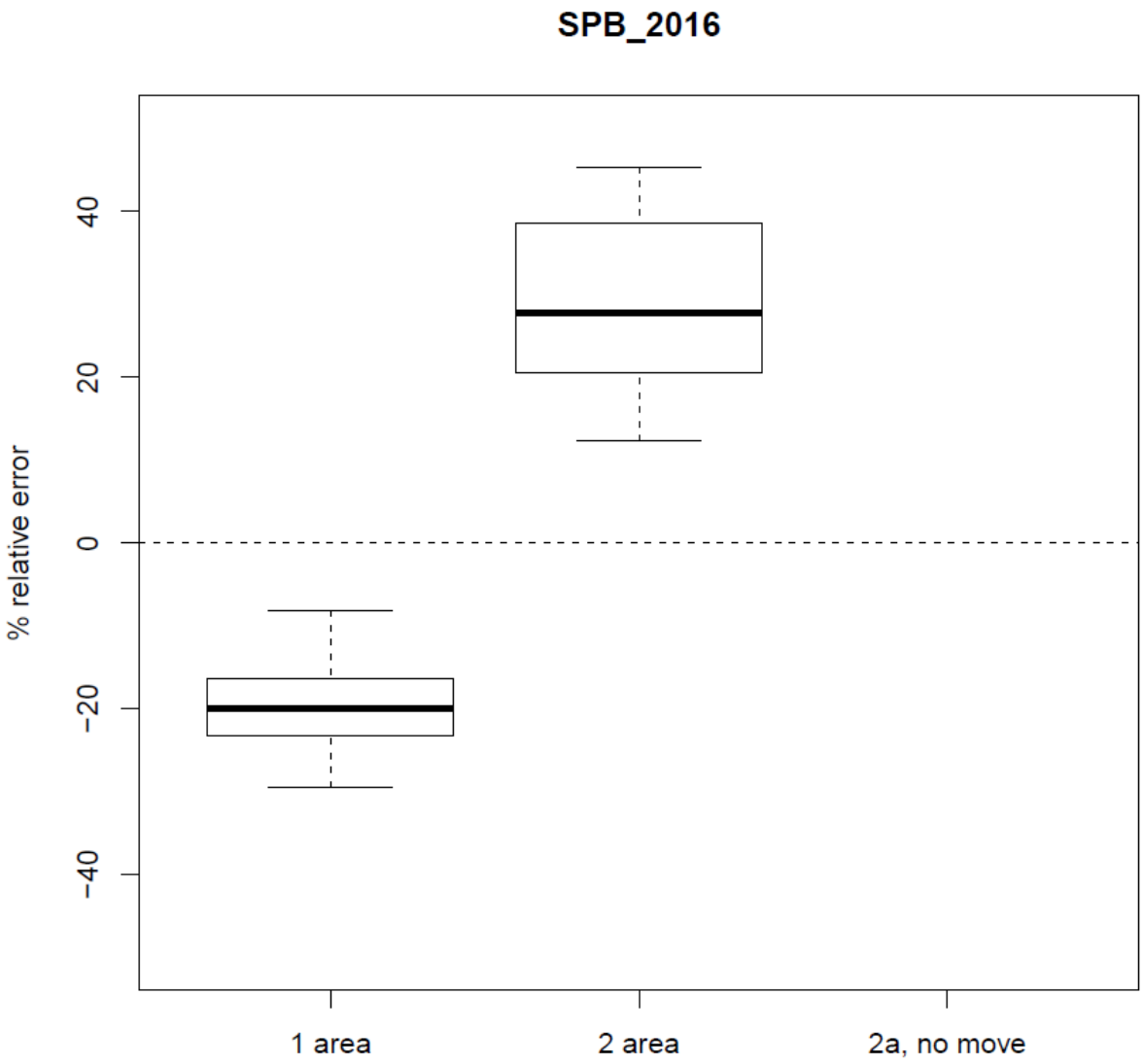


Figure 11. Distribution for the percent relative error of estimate (%REE) of 2016 spawning biomass, for estimation models fit to pseudo-data generated from the 1-area operating model. Labels as in Figure 10.

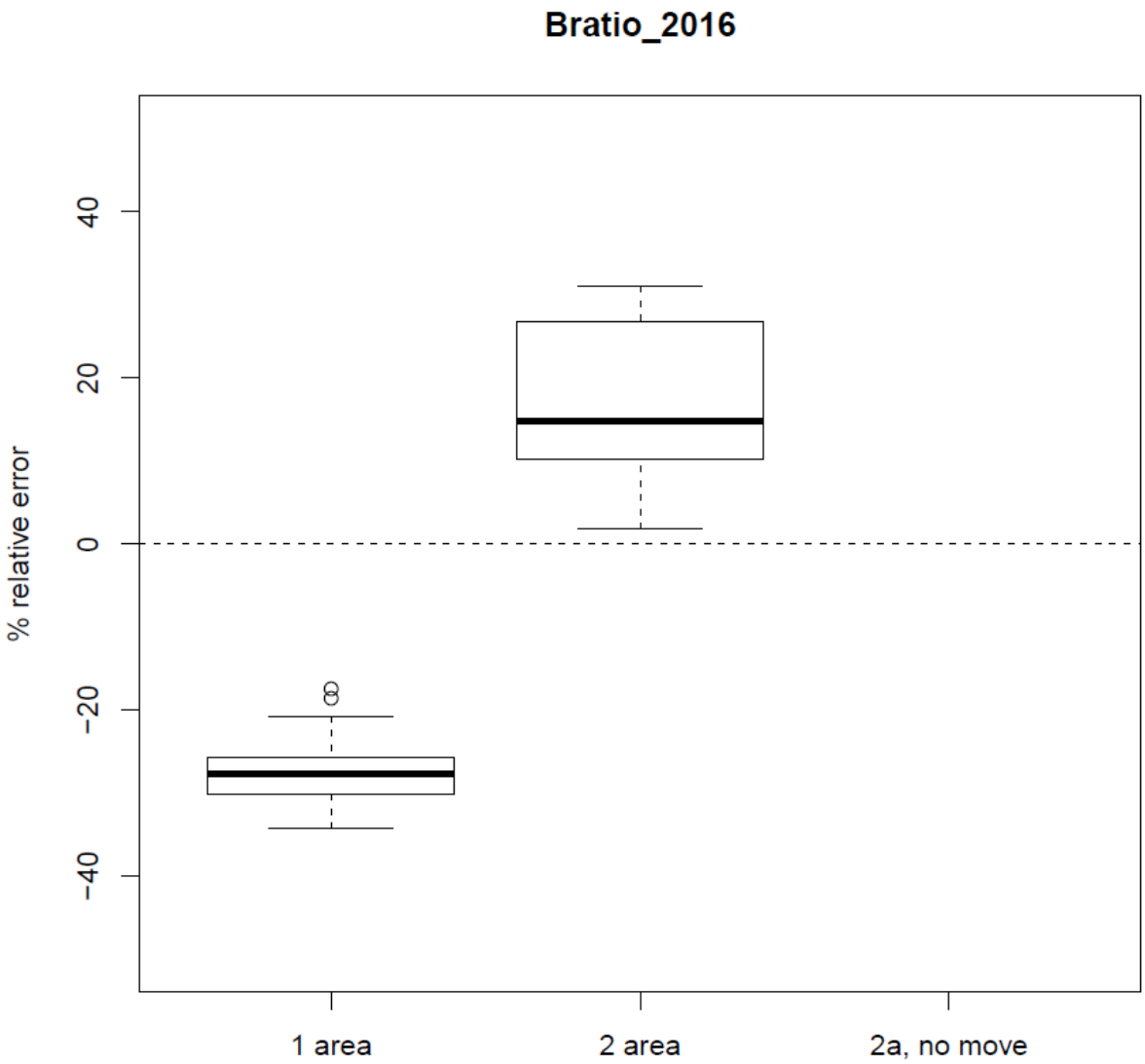


Figure 12. Distribution for the percent relative error of estimate (%REE) of 2016 spawning biomass relative to unfished, for estimation models fit to pseudo-data generated from the 1-area operating model. Labels as in Figure 10.

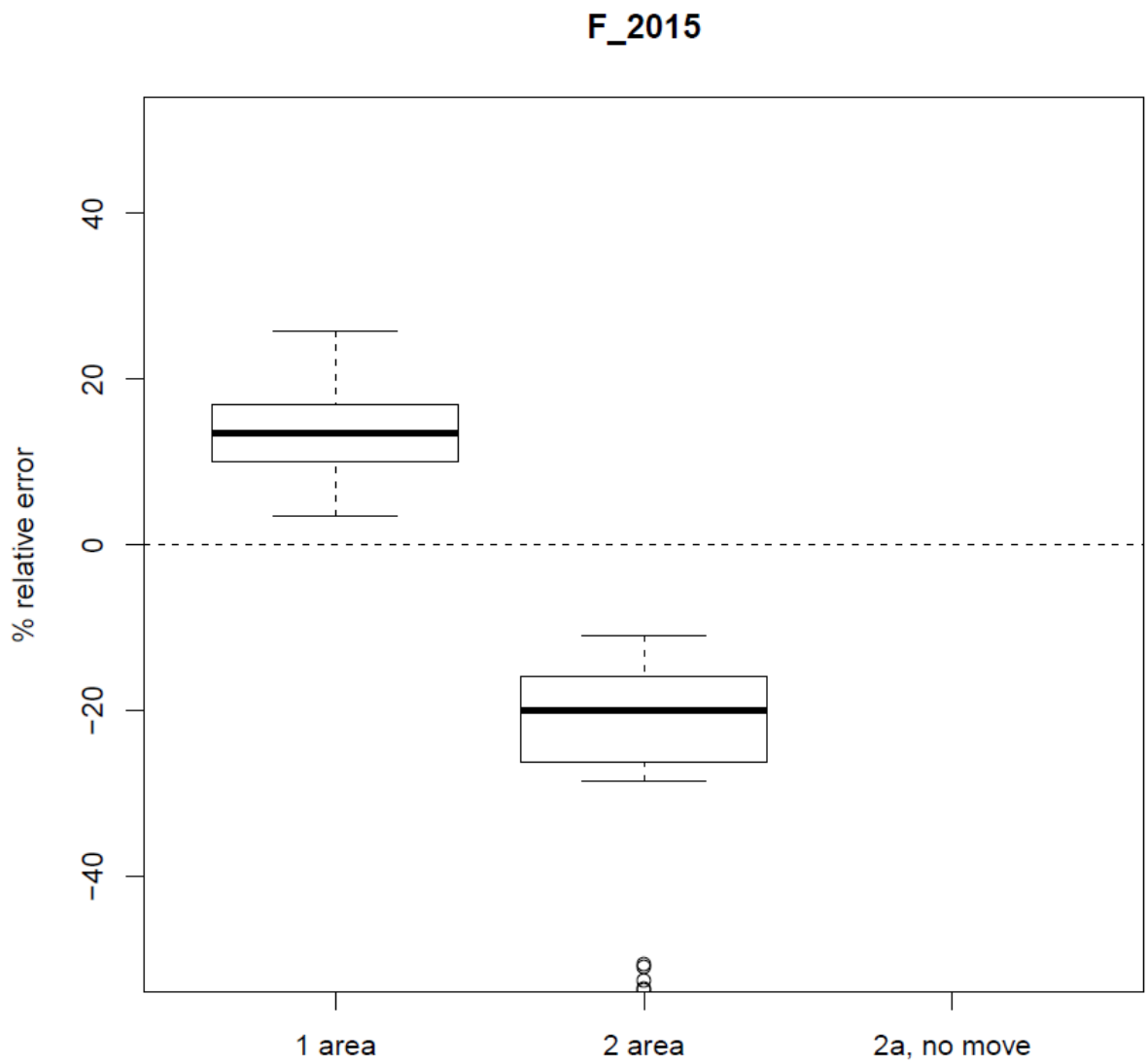


Figure 13. Distribution for the percent relative error of estimate (%REE) of 2015 fishing mortality, for estimation models fit to pseudo-data generated from the 1-area operating model. Labels as in Figure 10.

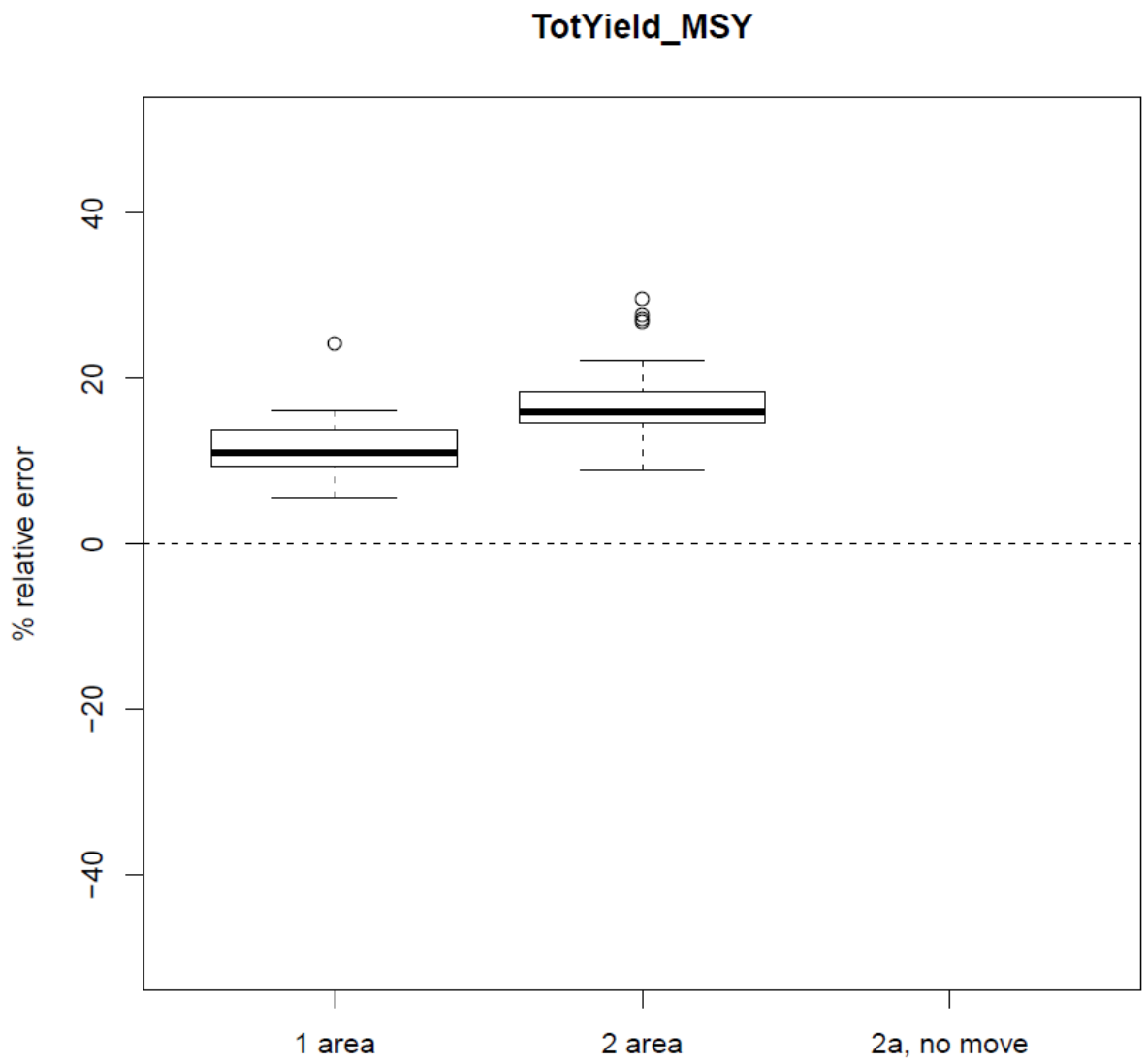
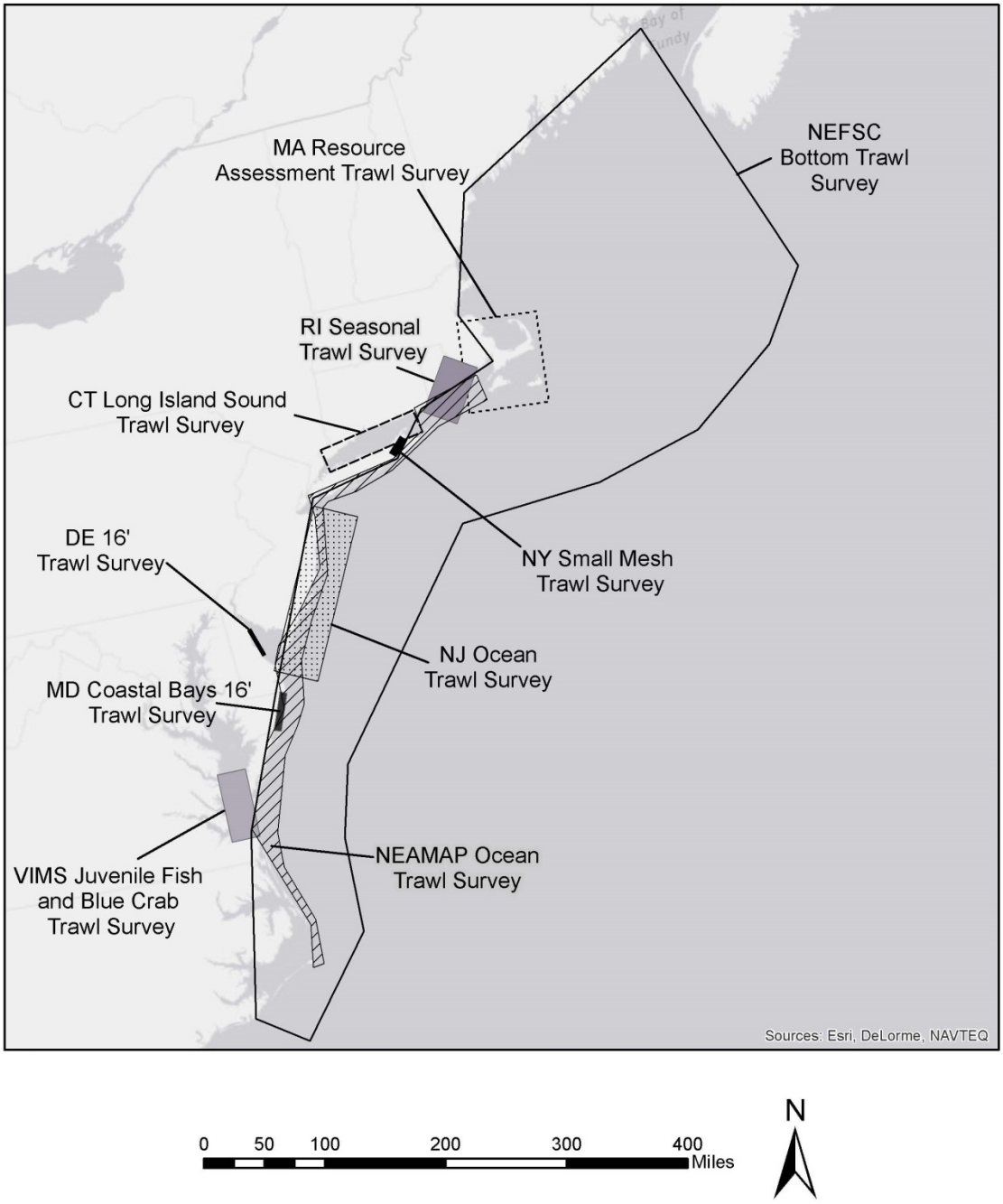


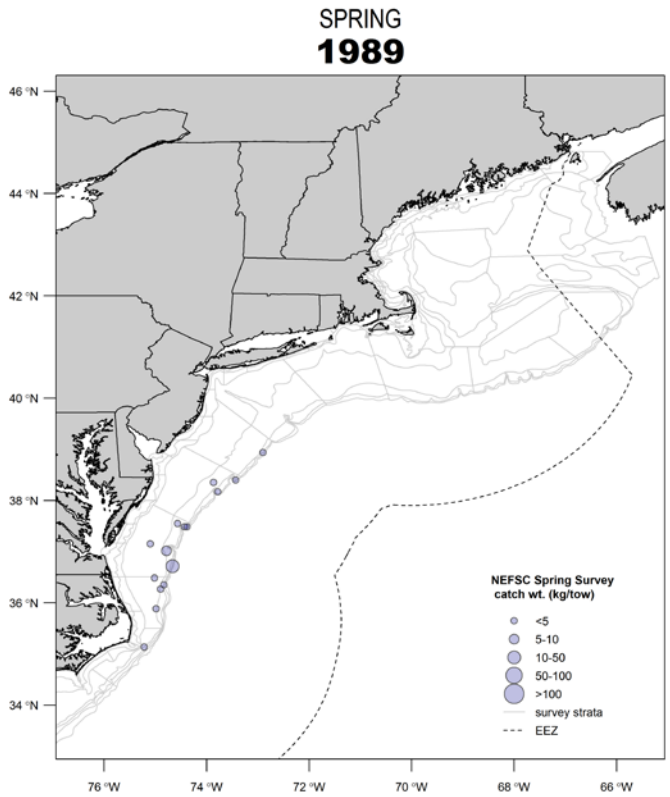
Figure 14. Distribution for the percent relative error of estimate (%REE) of the total catch (retained plus discard) at maximum sustainable yield (given terminal year fishing pattern by fleet and season).

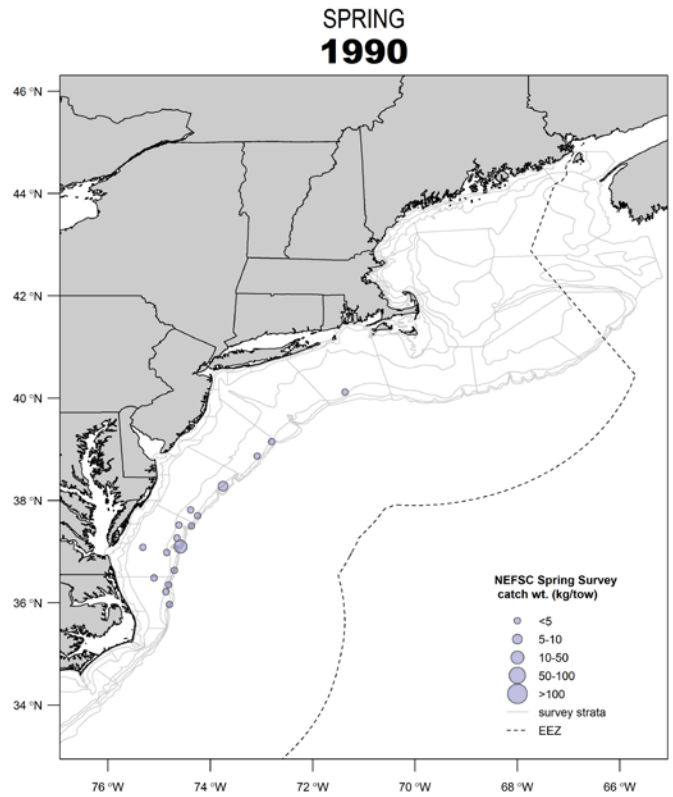
Appendix A7 – Distribution maps of black sea bass from NEFSC spring survey and commercial fishery.

Black sea bass distribution maps – Distribution of State and Federal surveys and NEFSC spring survey distribution maps, 1989-2015

Spatial extent of state and federal surveys contributing to the assessment




SPRING
1989
46 °N
44 °N
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ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NEFSC Spring Survey
catch wt. (kg/tow)
<5
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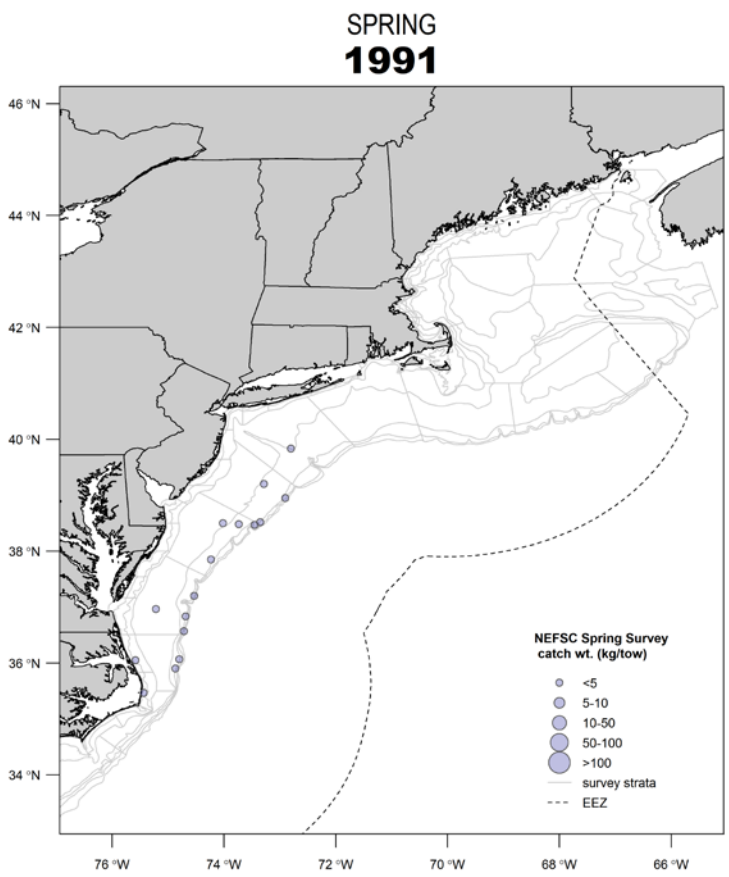
10-50
50-100
>100
survey strata
EEZ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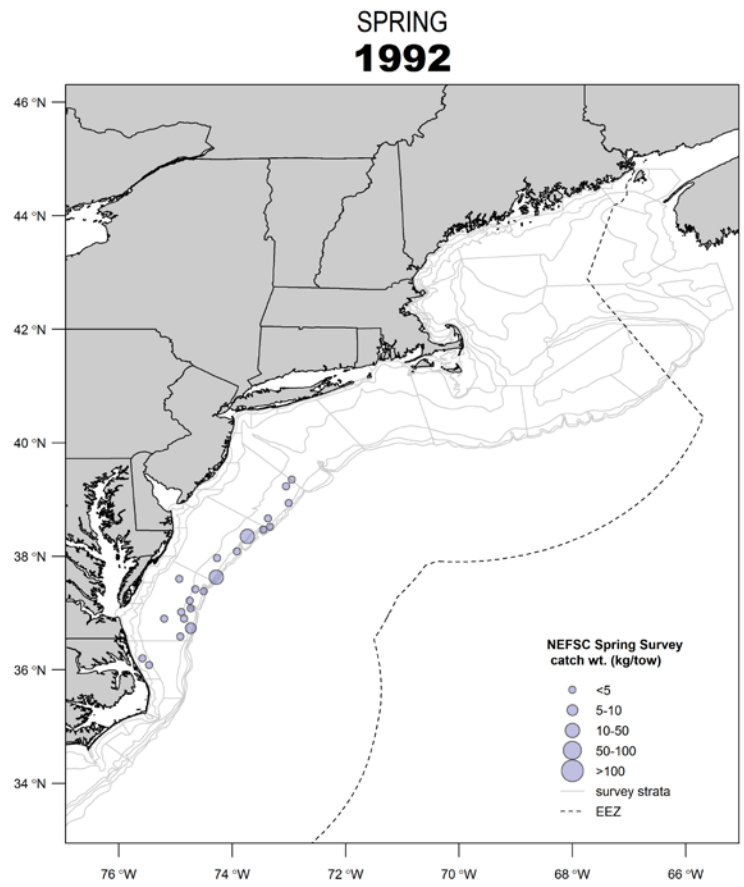
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ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1992
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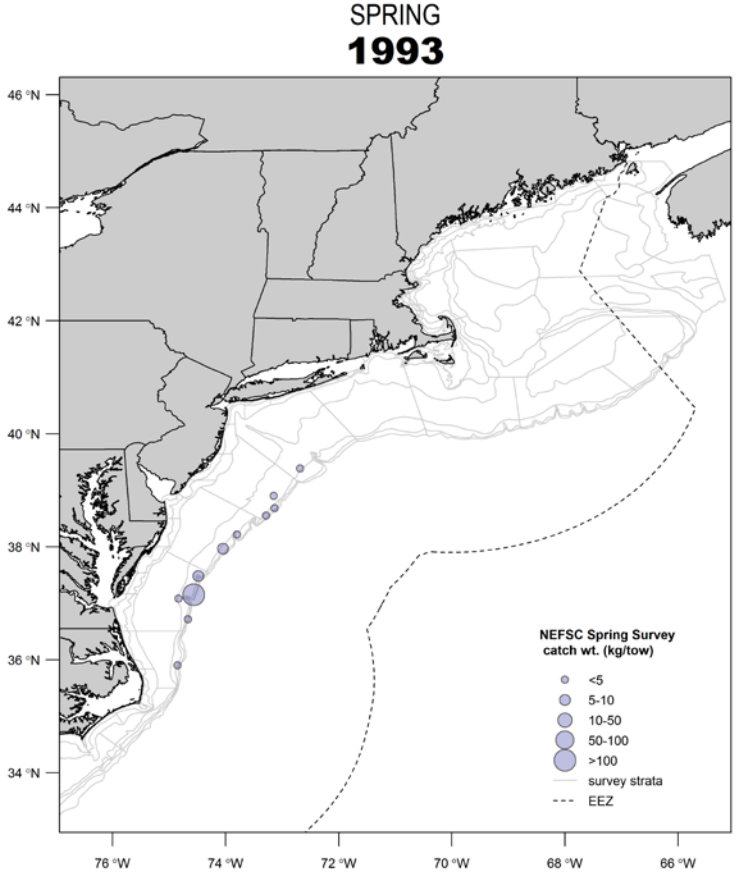
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ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1993
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NEFSC Spring Survey
catch wt. (kg/tow)
<5
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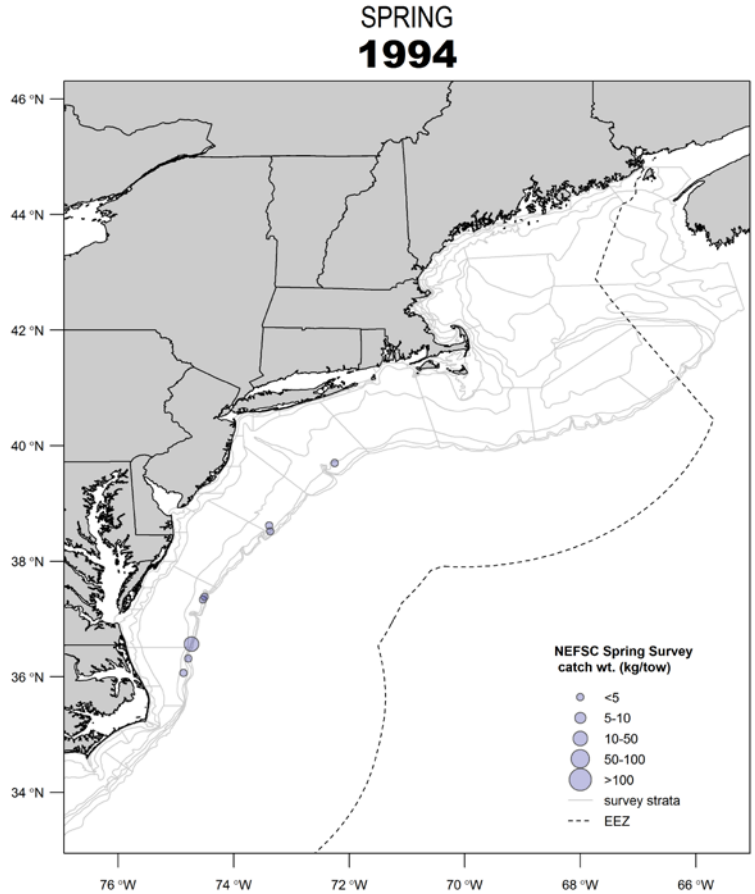
10-50
50-100
>100
survey strata
EEZ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1994
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NEFSC Spring Survey
catch wt. (kg/tow)
<5
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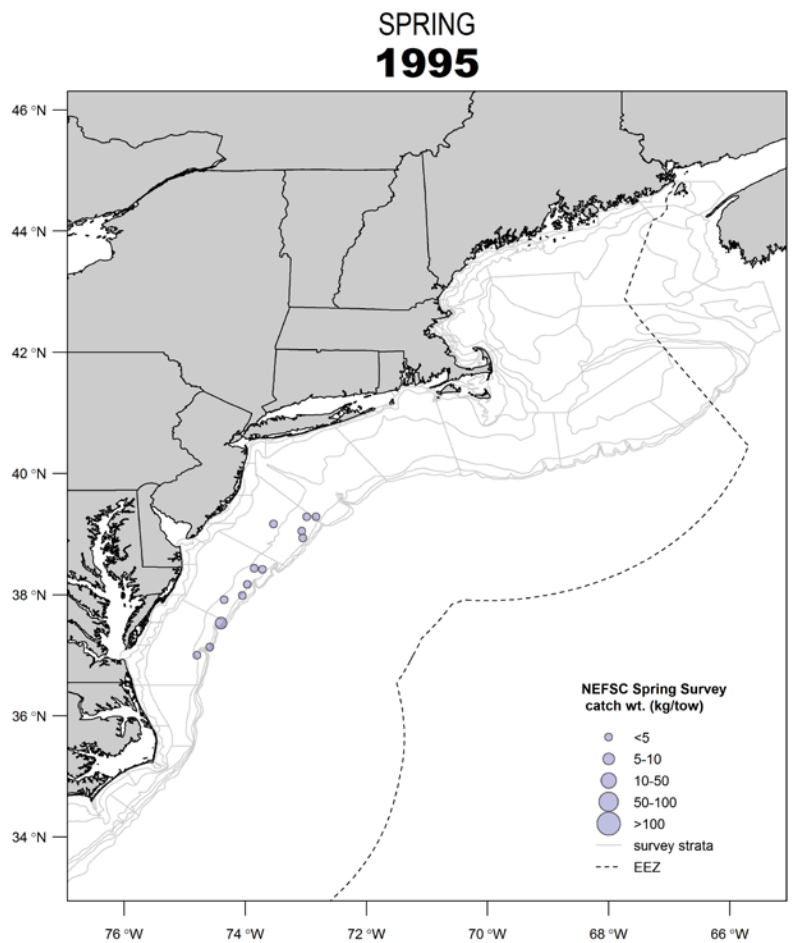
10-50
50-100
>100
survey strata
EEZ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1995
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74 °W
72 °W
70 °W
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NEFSC Spring Survey
catch wt. (kg/tow)
<5
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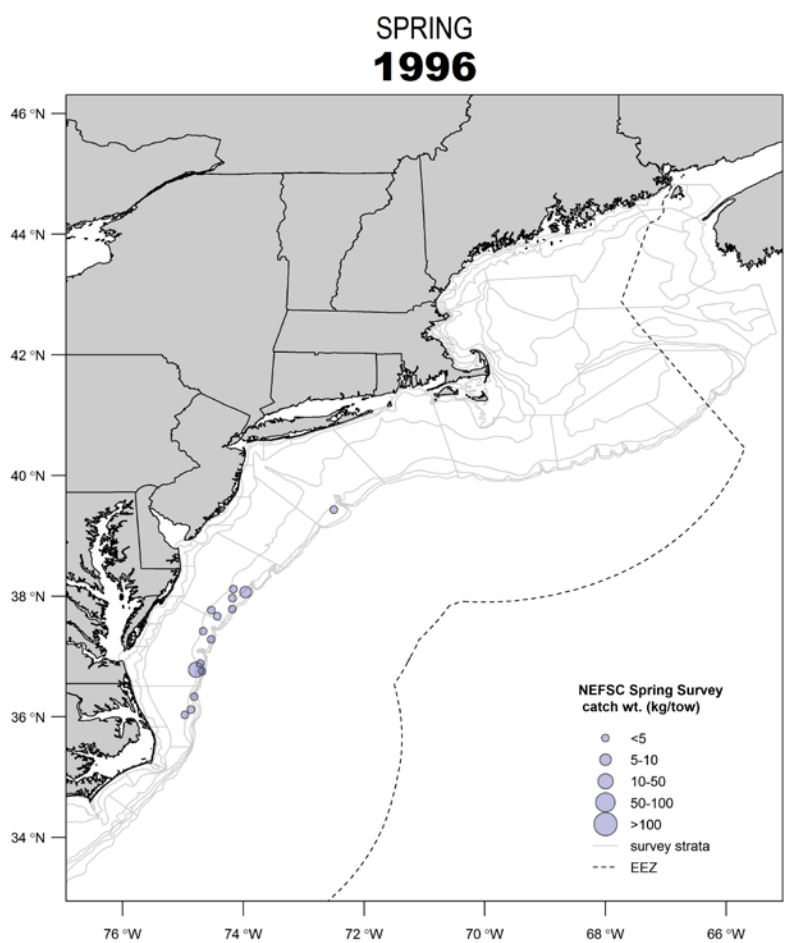
10-50
50-100
>100
survey strata
EEZ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1996
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74 °W
72 °W
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NEFSC Spring Survey
catch wt. (kg/tow)
<5
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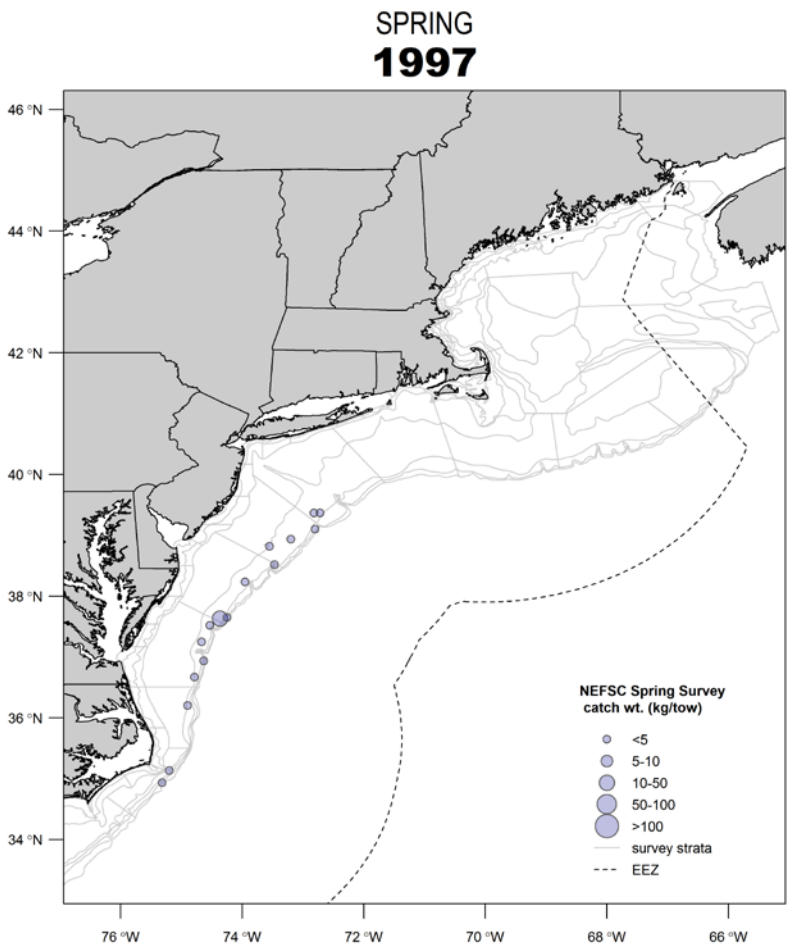
10-50
50-100
>100
survey strata
EEZ


SPRING
1997
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74 °W
72 °W
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NEFSC Spring Survey
catch wt. (kg/tow)
<5
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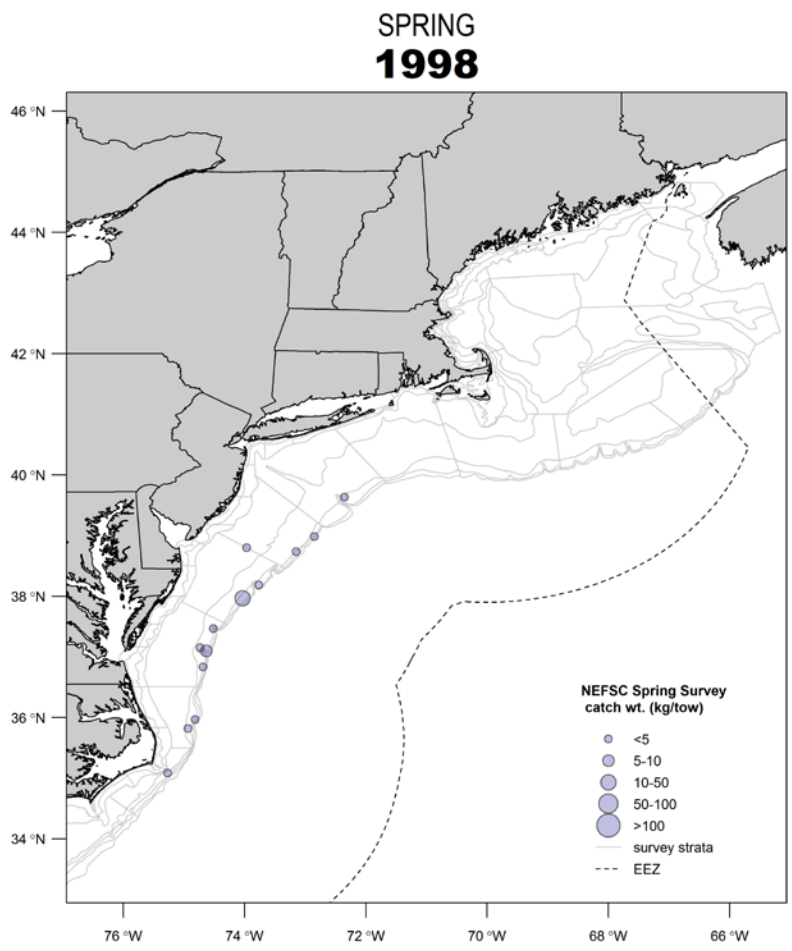
10-50
50-100
>100
survey strata
EEZ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1998
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44 °N
42 °N
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34 °N
76 °W
74 °W
72 °W
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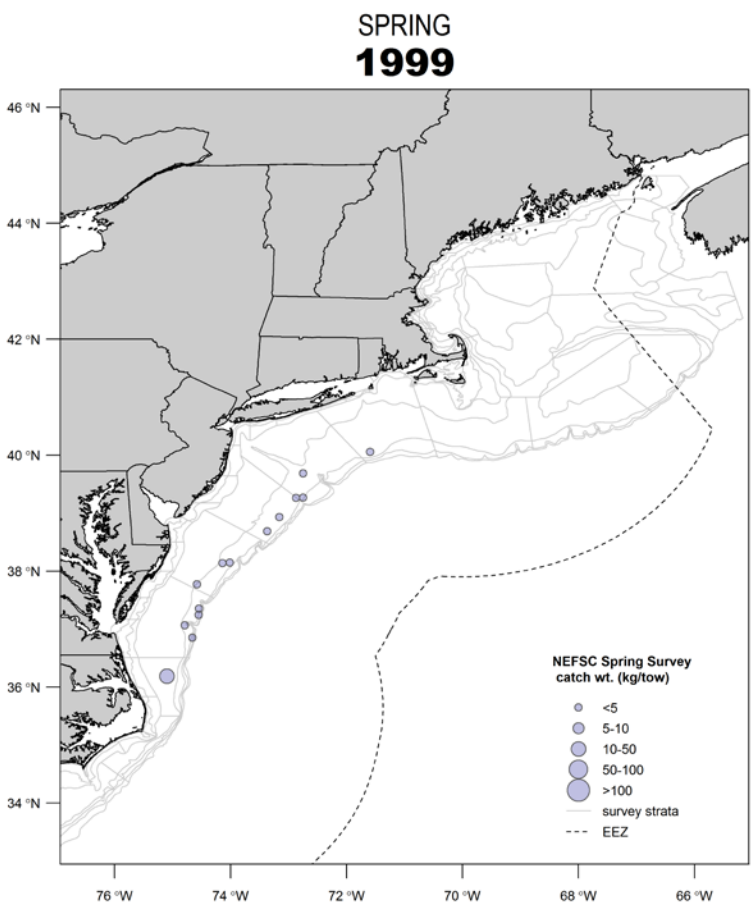
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ


SPRING
1999
46 °N
44 °N
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74 °W
72 °W
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NEFSC Spring Survey
catch wt. (kg/tow)
<5
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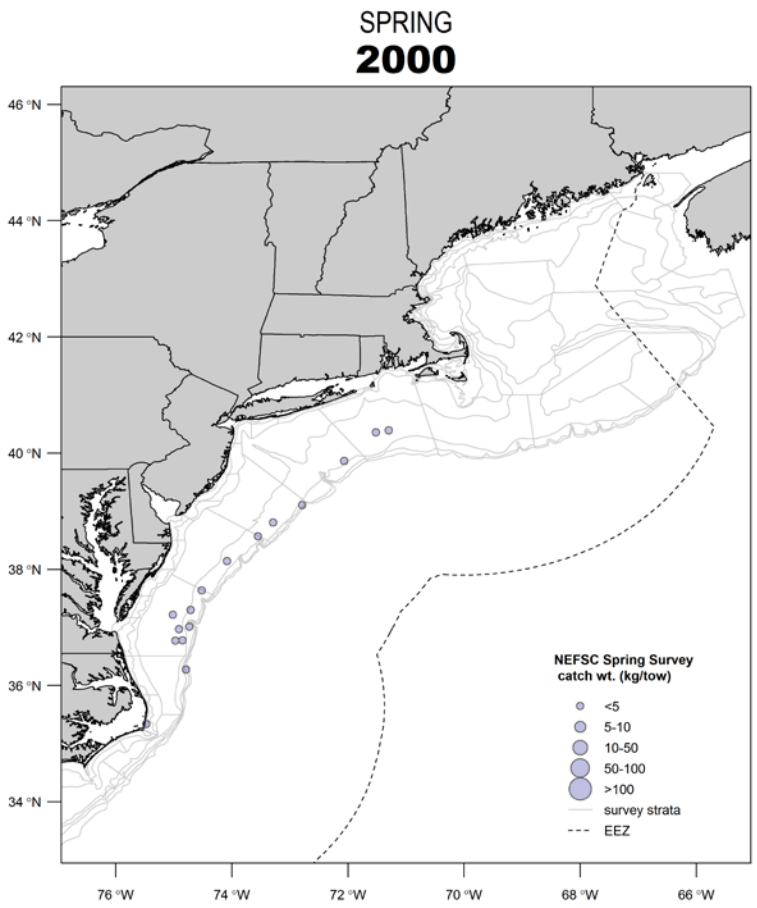
>100
survey strata
EEZ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2000
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42 °N
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38 °N
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34 °N
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74 °W
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NEFSC Spring Survey
catch wt. (kg/tow)
<5
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10-50
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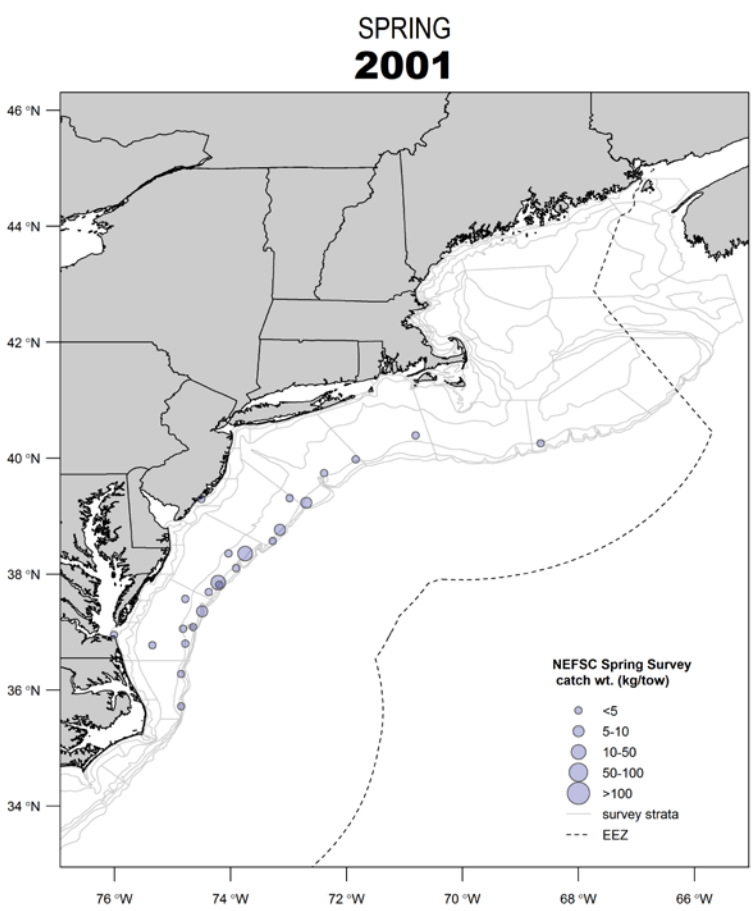
>100
survey strata
EEZ


SPRING
2001
46 °N
44 °N
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
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NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
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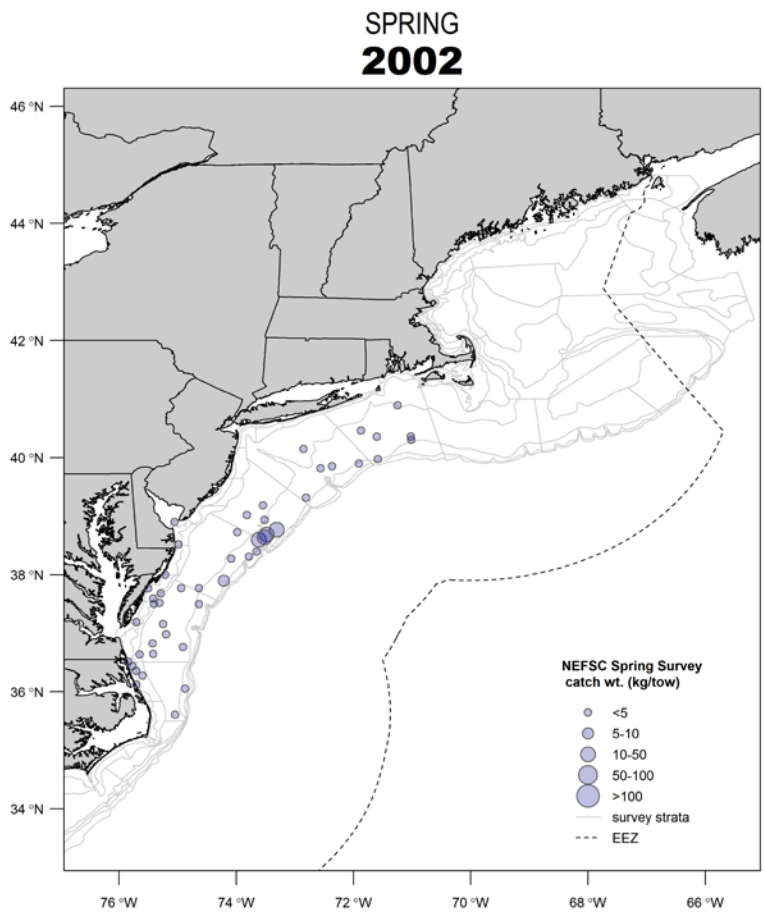
>100
survey strata
EEZ


SPRING
2002
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36 °N
34 °N
76 °W
74 °W
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NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
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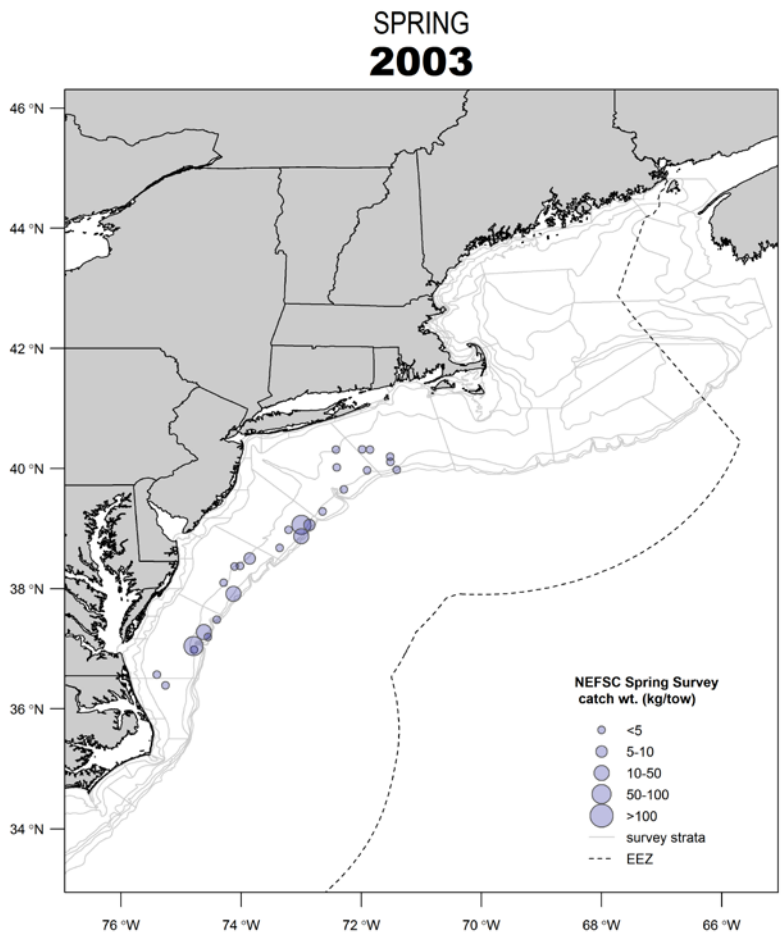
>100
survey strata
EEZ


SPRING
2003
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74 °W
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NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
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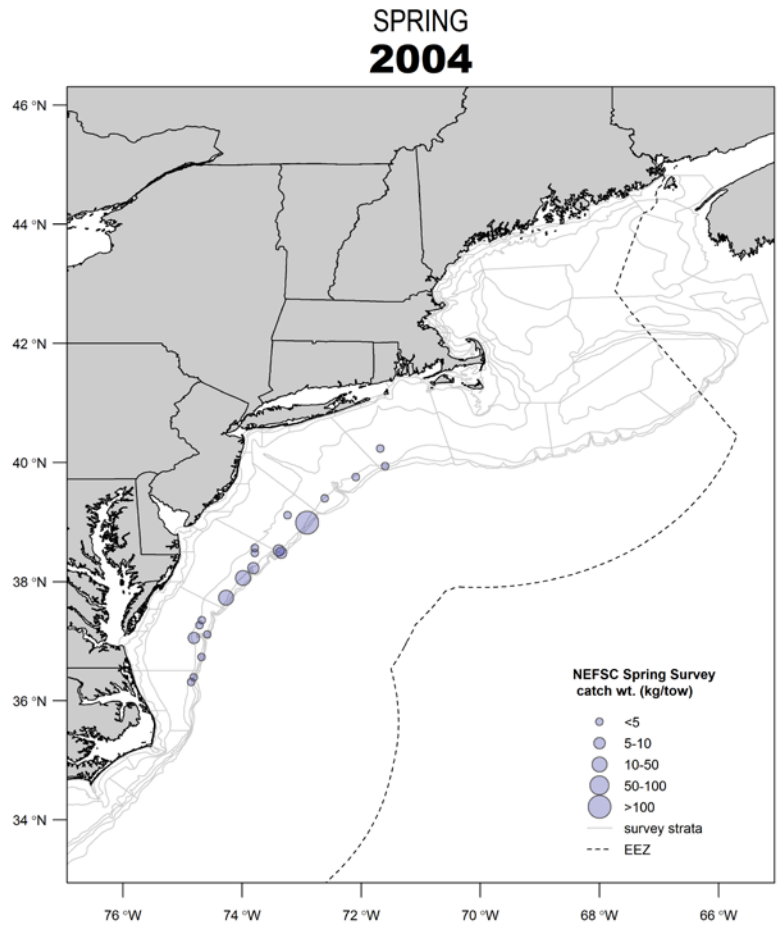
>100
survey strata
EEZ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2004
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40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
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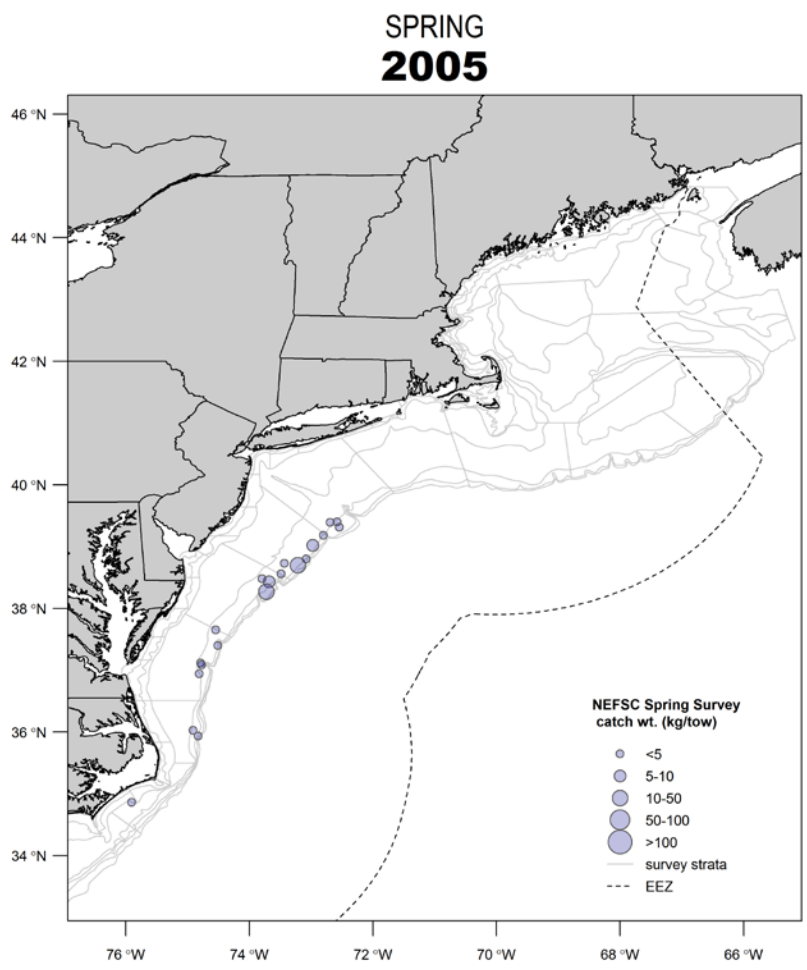
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ


SPRING
2005
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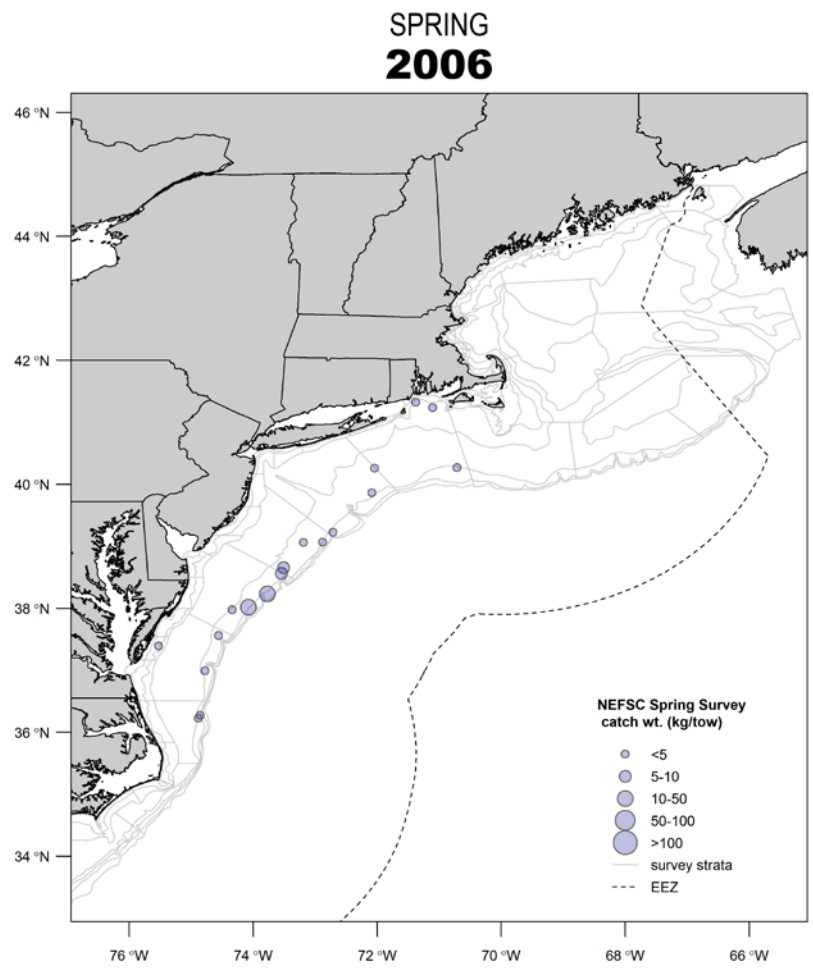
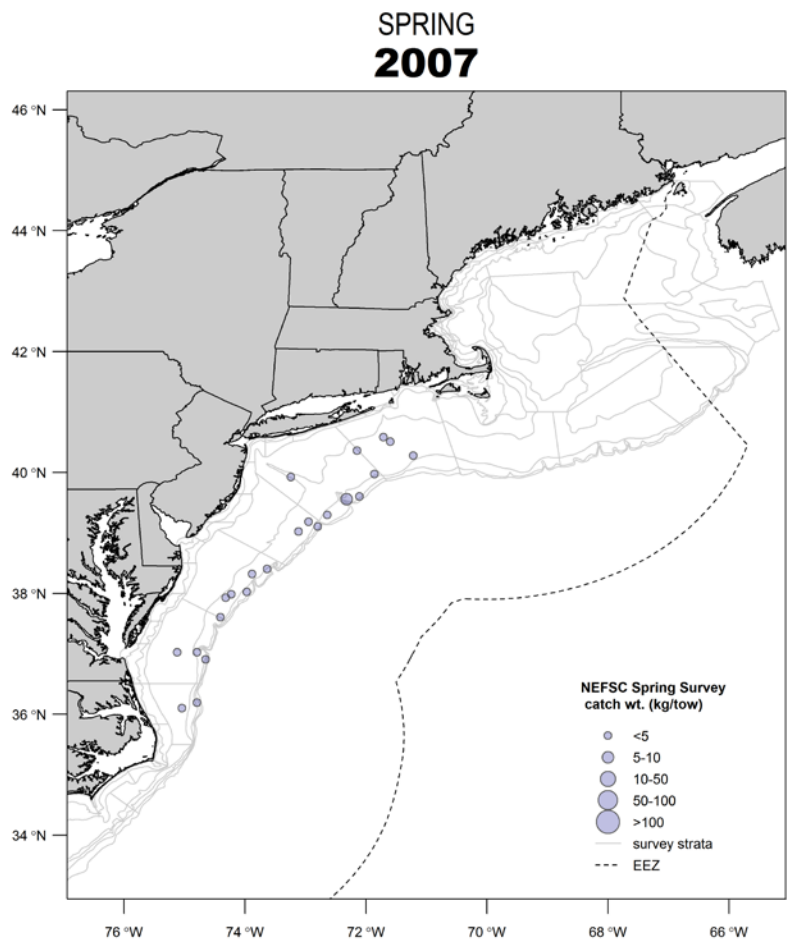
44 °N
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ


SPRING
2006
46 °N
44 °N
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ


SPRING
2007
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42 °N
40 °N
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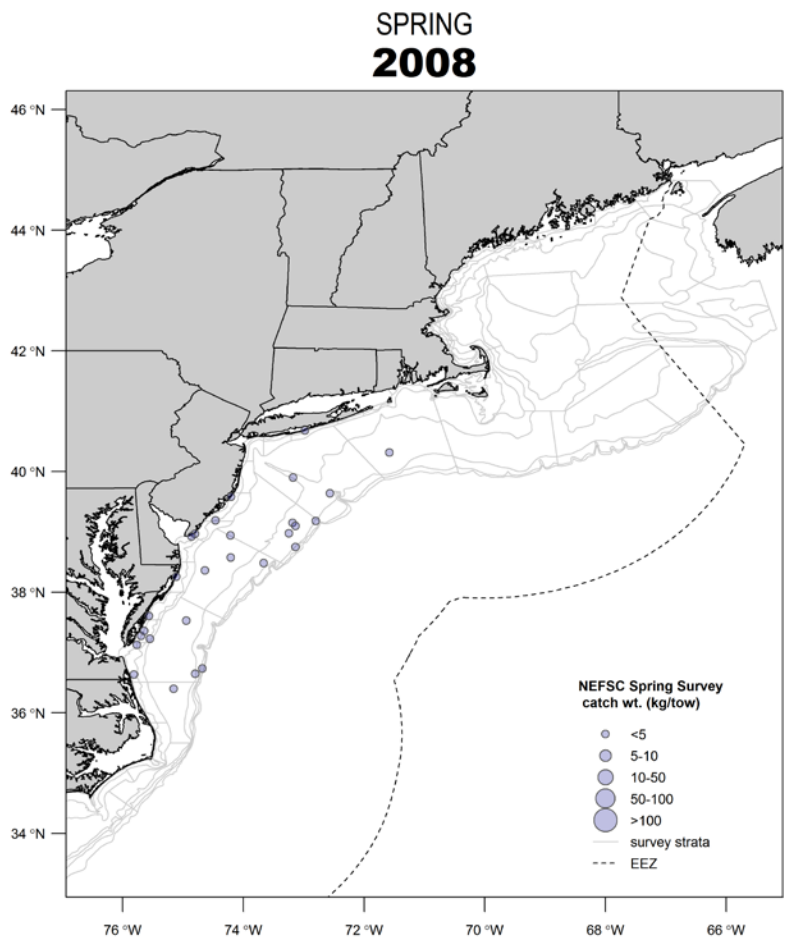
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ


SPRING
2008
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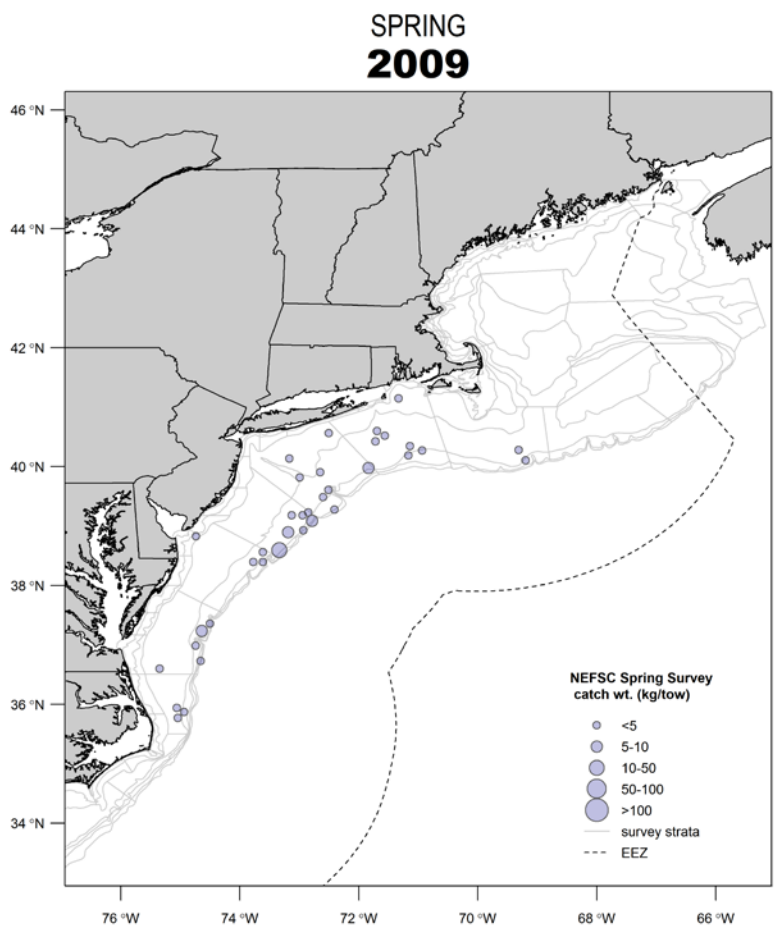
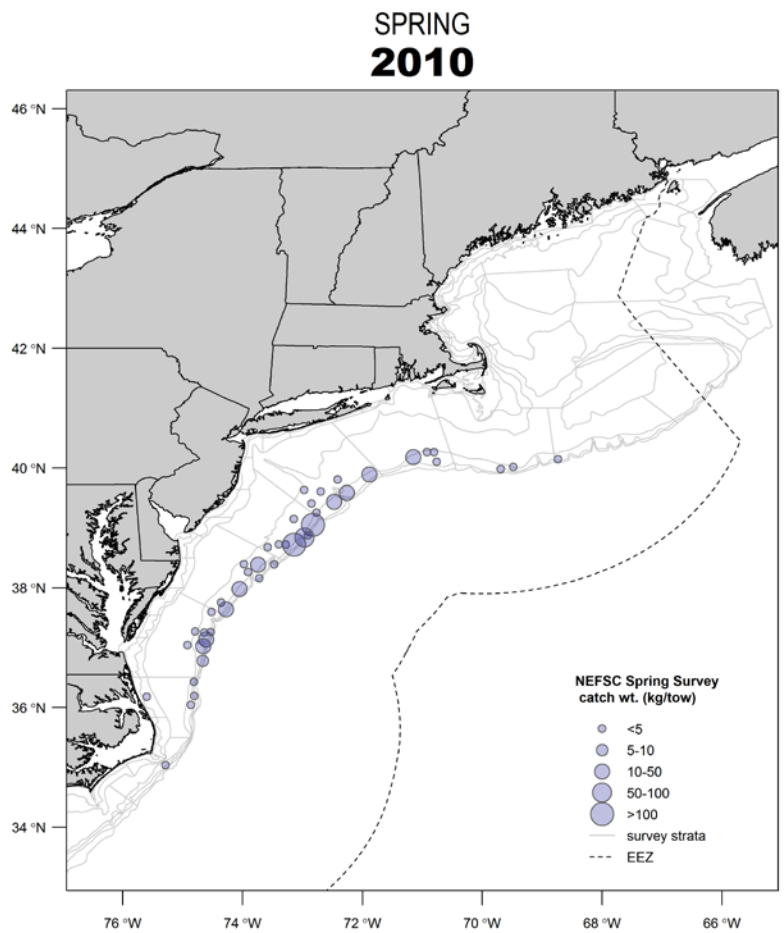
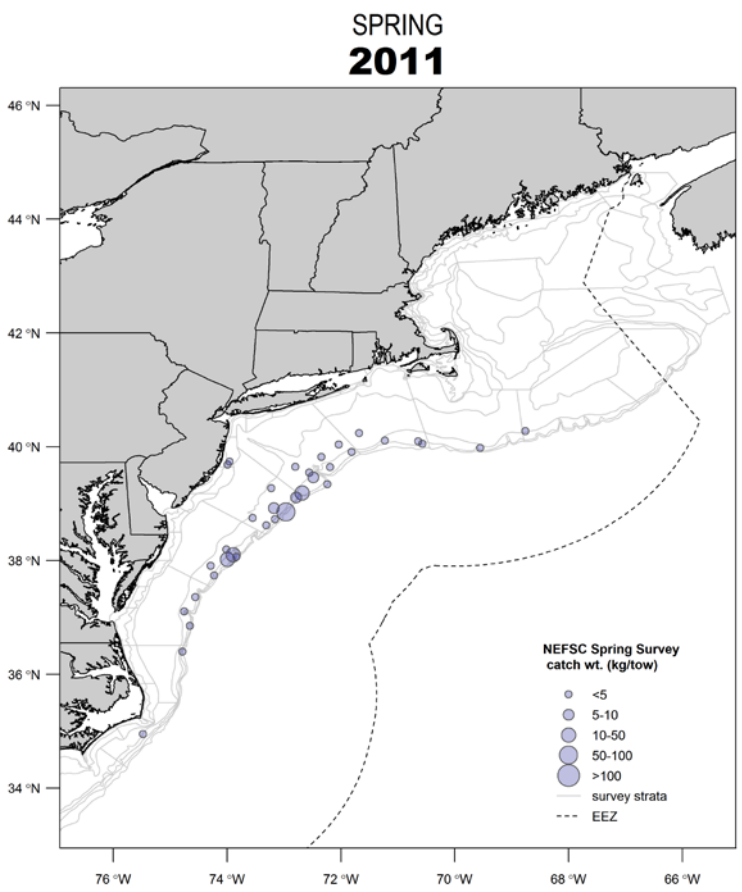
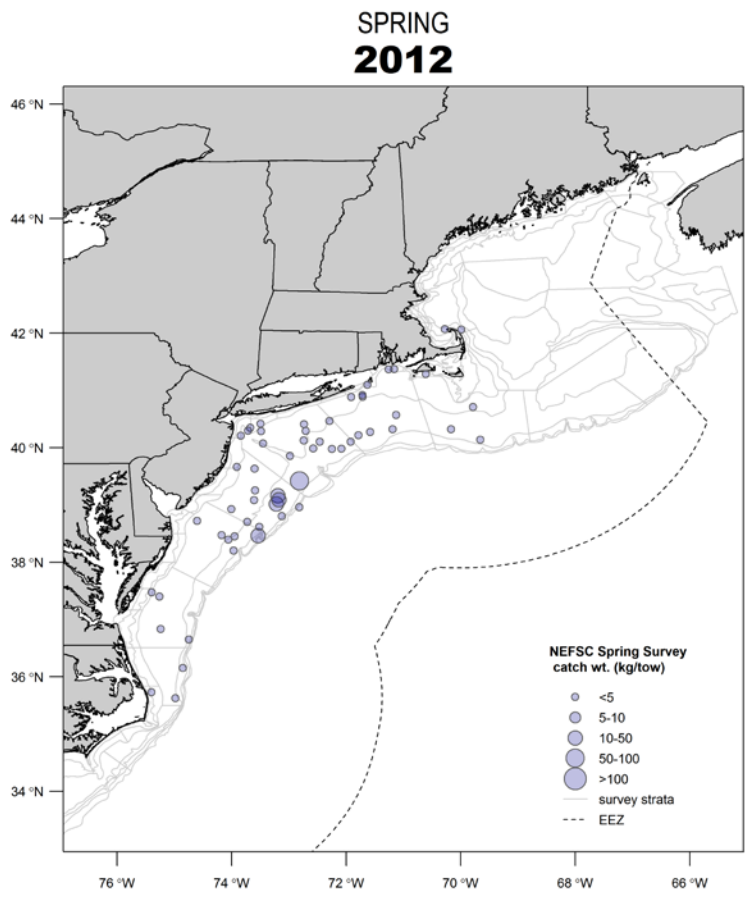
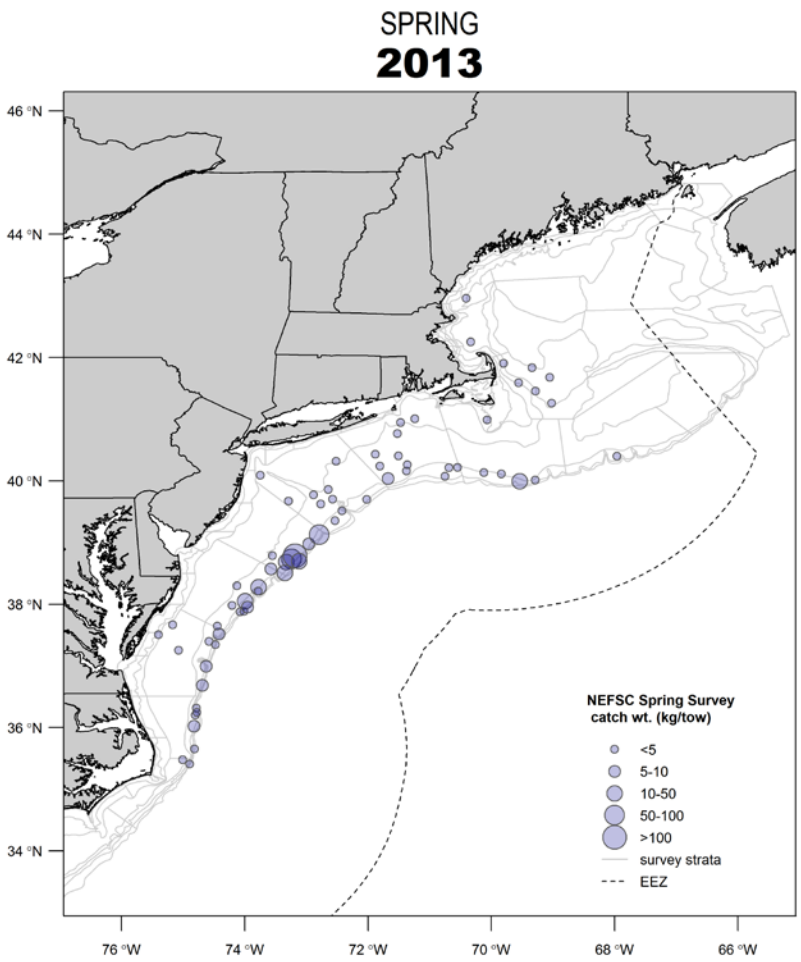
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ

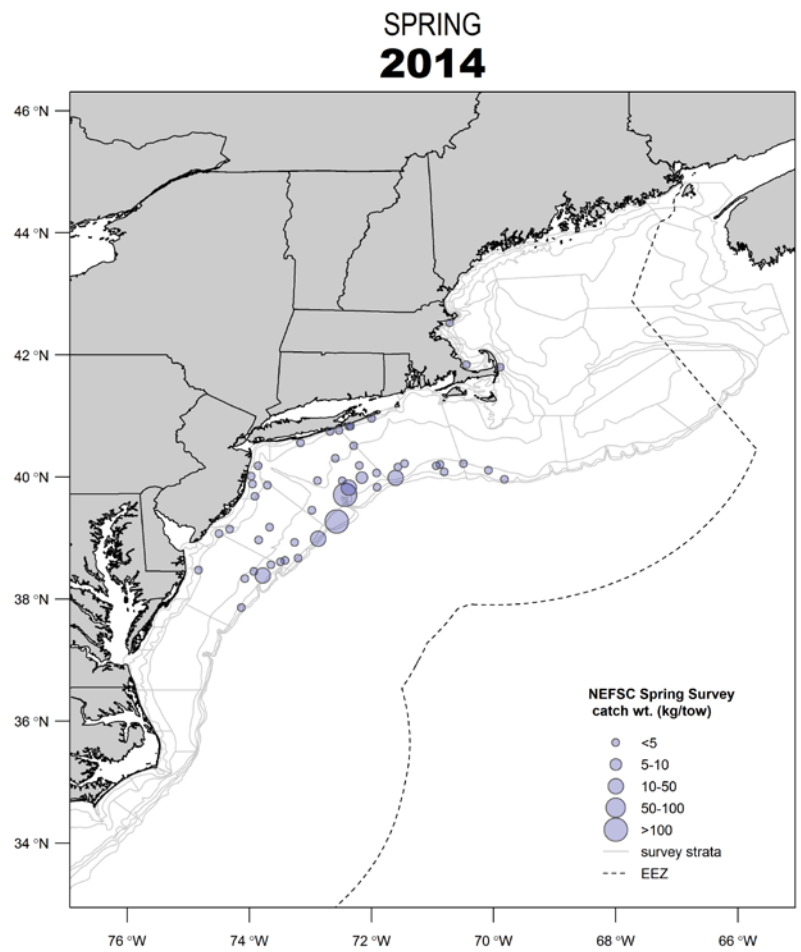

SPRING
2009
46 °N
44 °N
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ

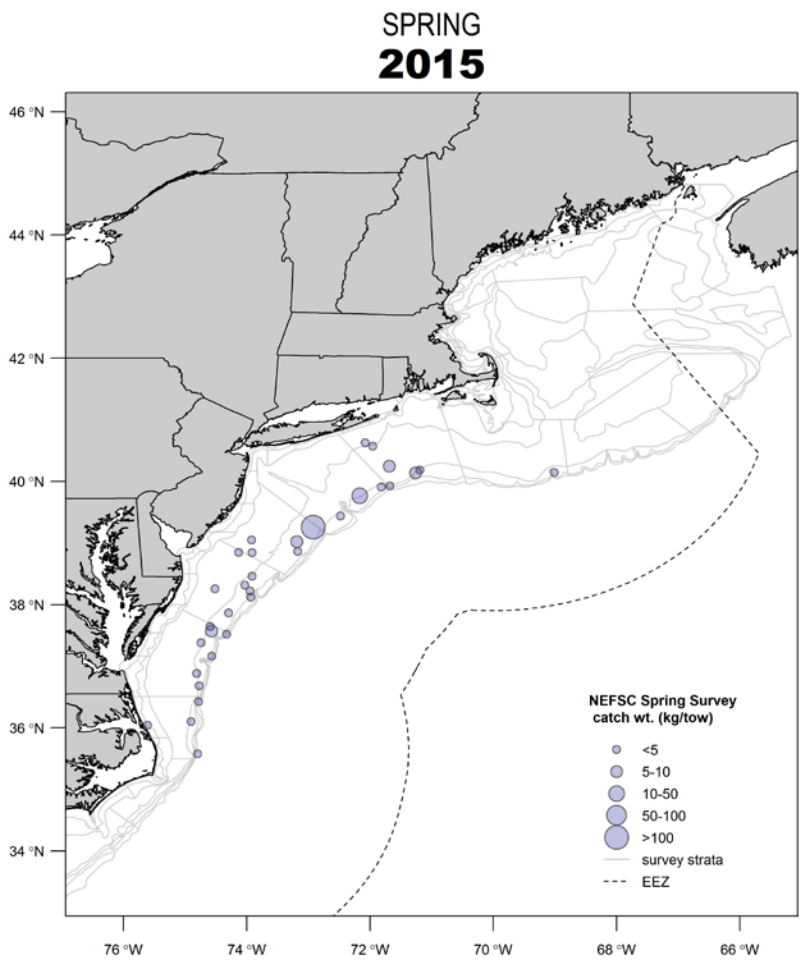

SPRING
2010
46 °N
44 °N
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ

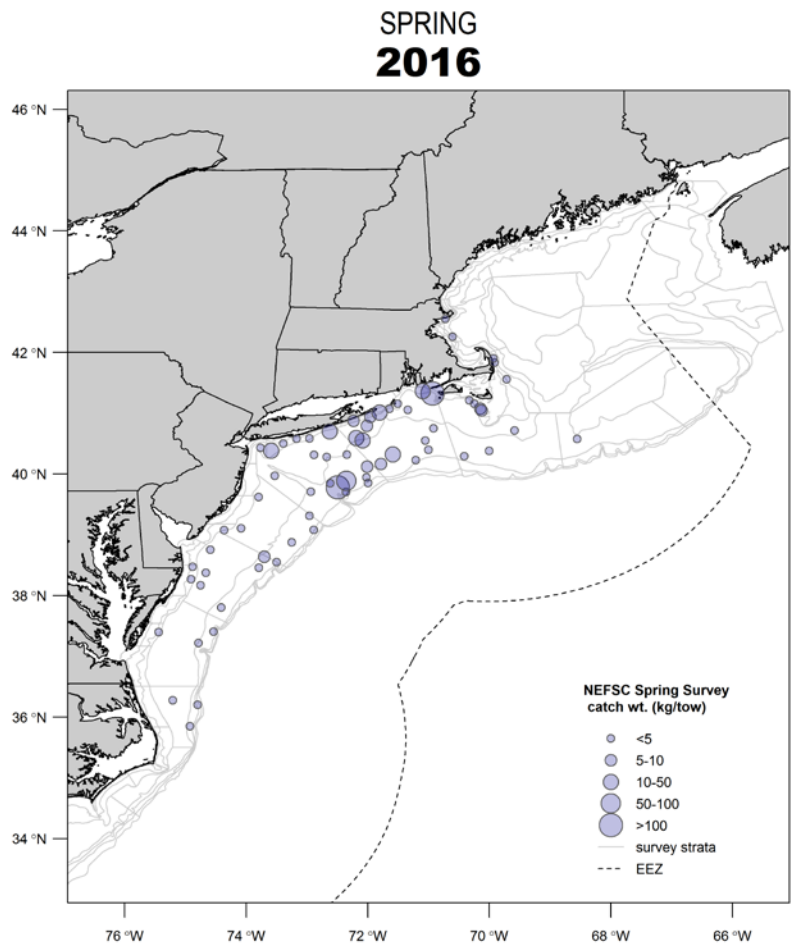

SPRING
2011
46 °N
44 °N
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ


SPRING
2012
46 °N
44 °N
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ

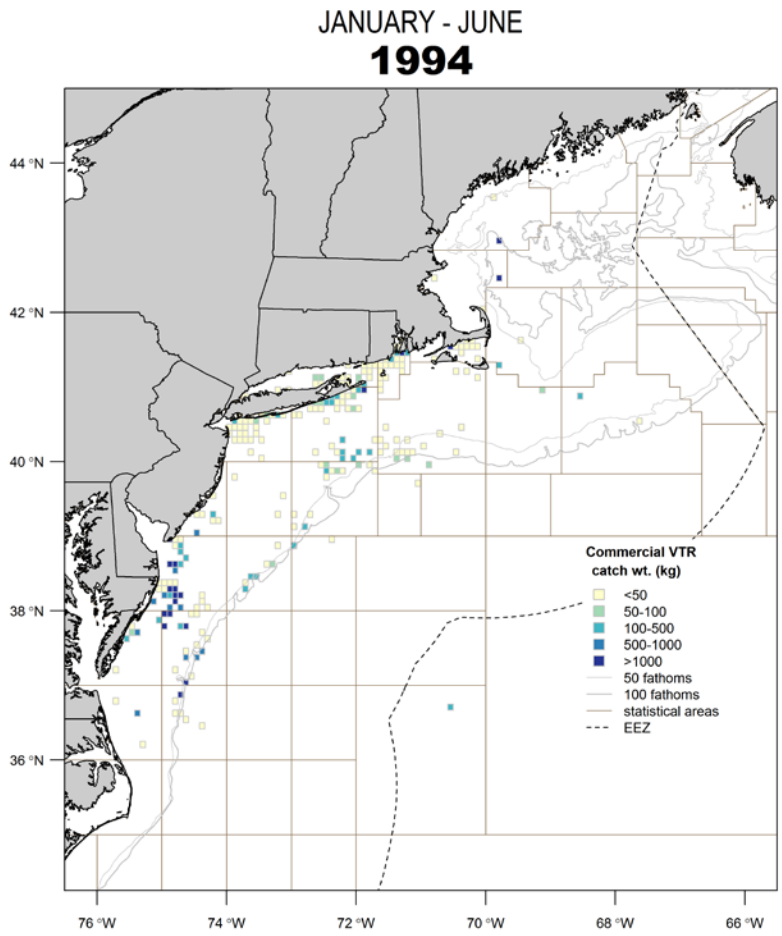

SPRING
2013
46 °N
44 °N
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ

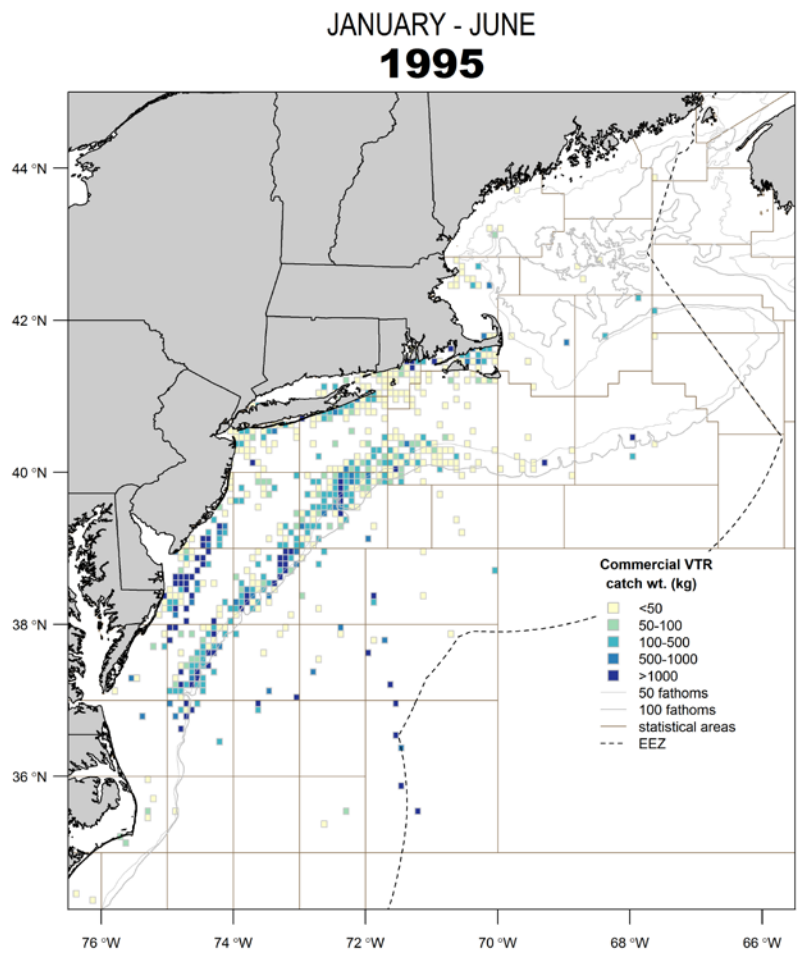

SPRING
2014
46 °N
44 °N
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ

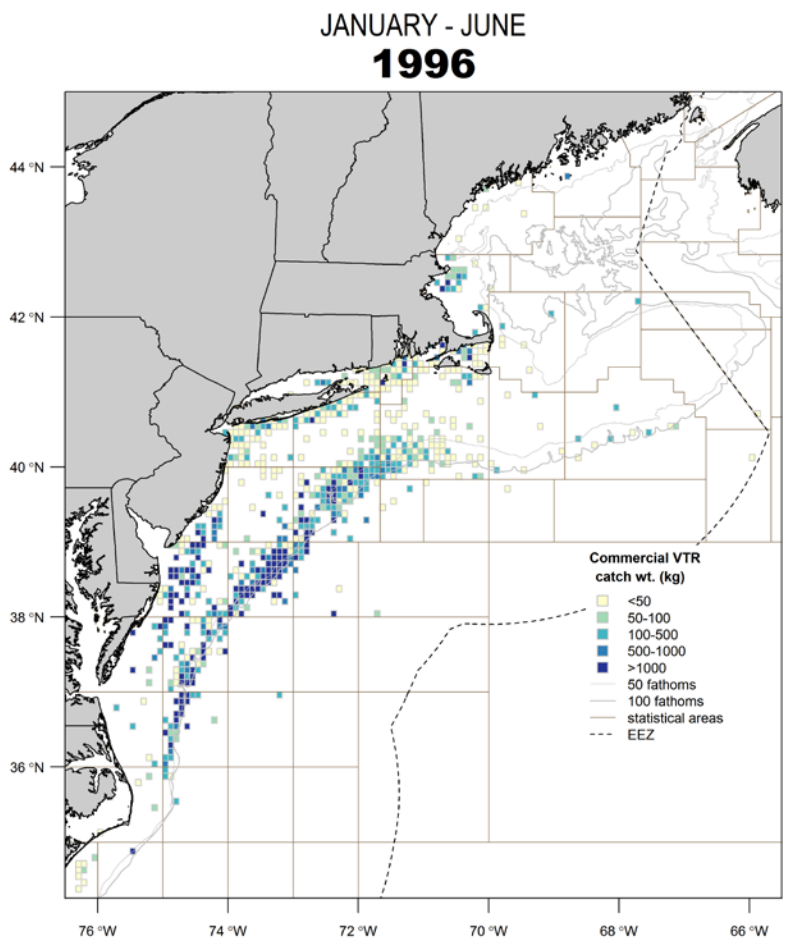

SPRING
2015
46 °N
44 °N
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ

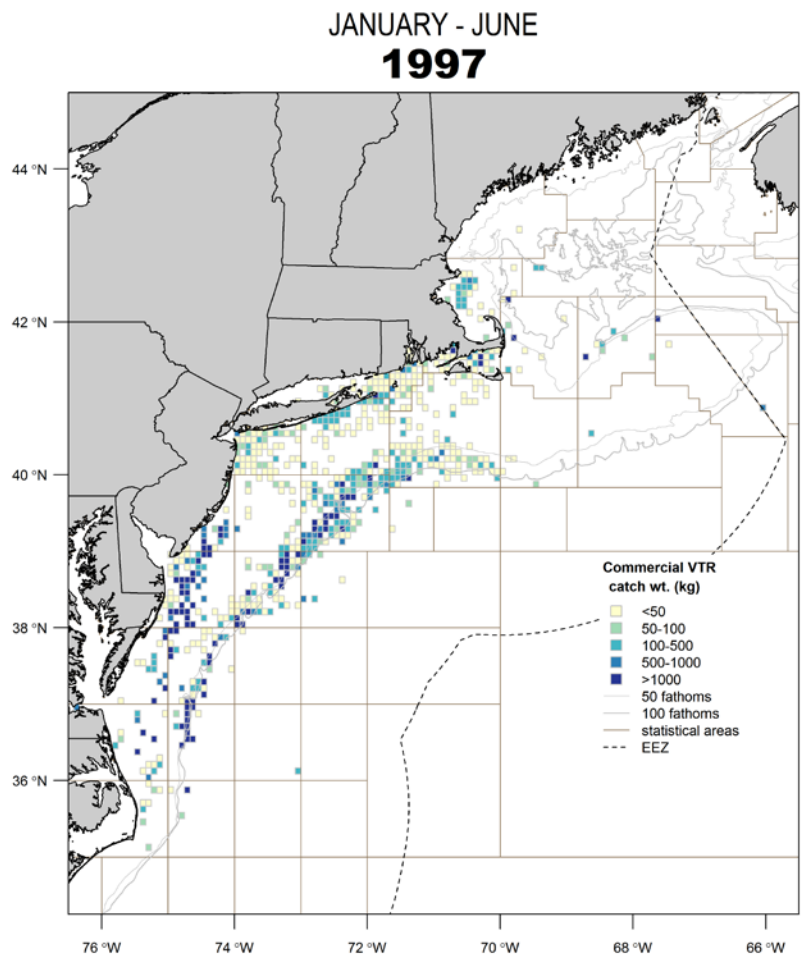

SPRING
2016
46 °N
44 °N
42 °N
40 °N
38 °N
36 °N
34 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
NEFSC Spring Survey
catch wt. (kg/tow)
<5
5-10
10-50
50-100
>100
survey strata
EEZ

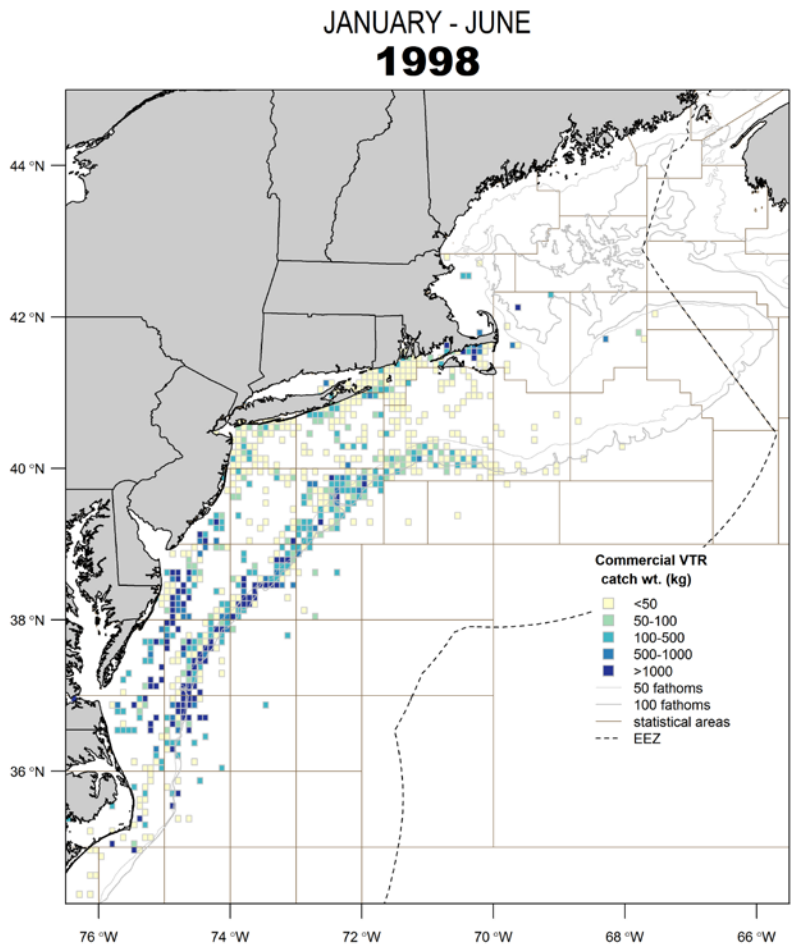
Black sea bass distribution maps – Annual commercial catch (kg) from vessel trip reports (VTR) by season, 1994-2016

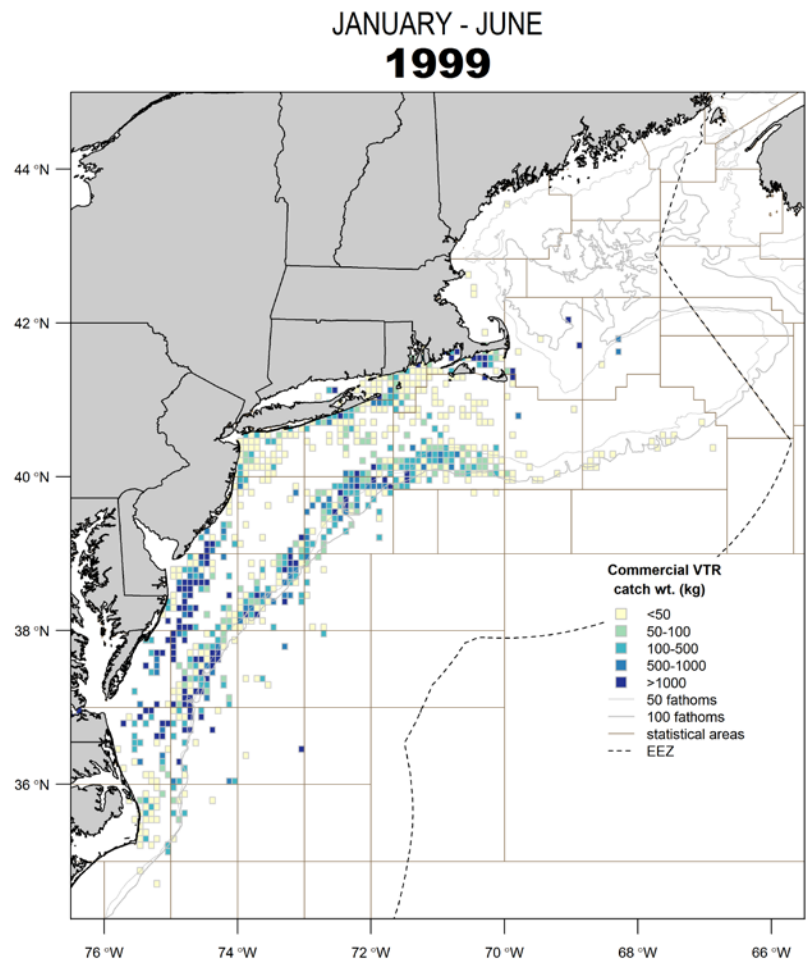

JANUARY - JUNE
1994
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ

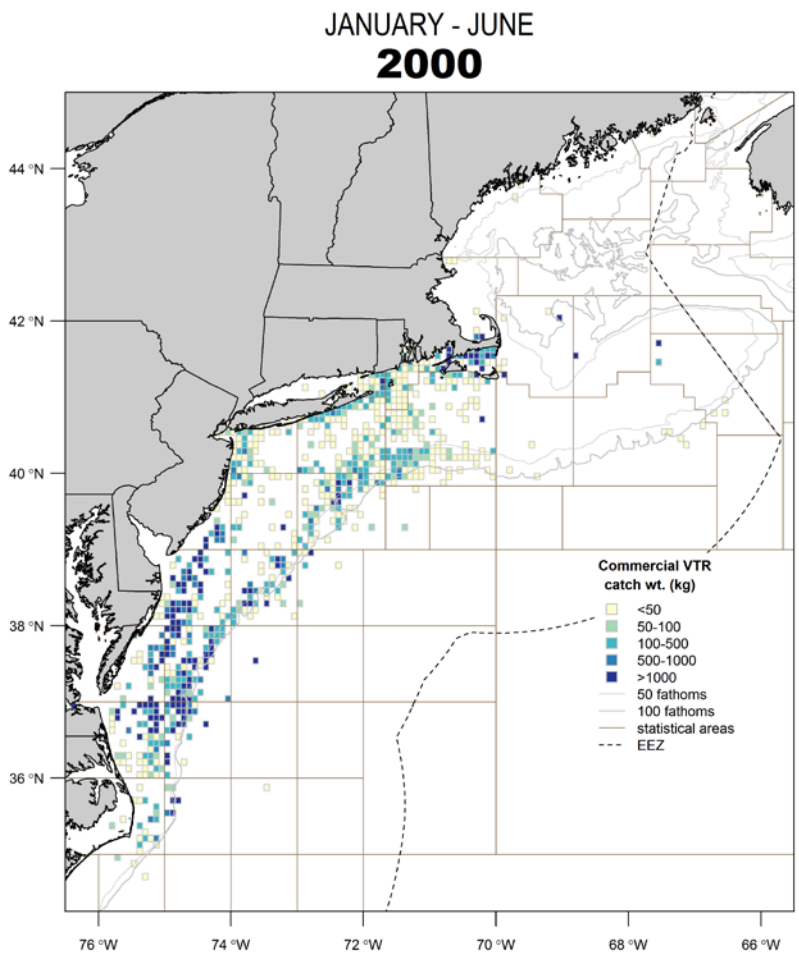

JANUARY - JUNE
1995
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
1996
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
1997
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
1998
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
1999
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2000
44 °N
42 °N
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38 °N
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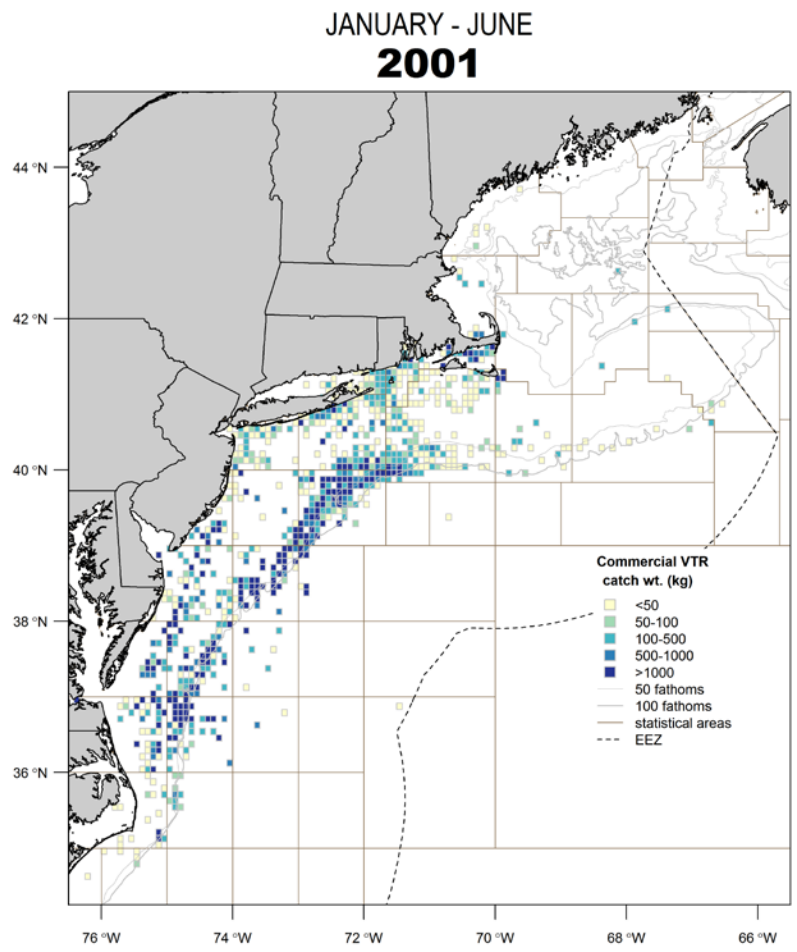
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2001
44 °N
42 °N
40 °N
38 °N
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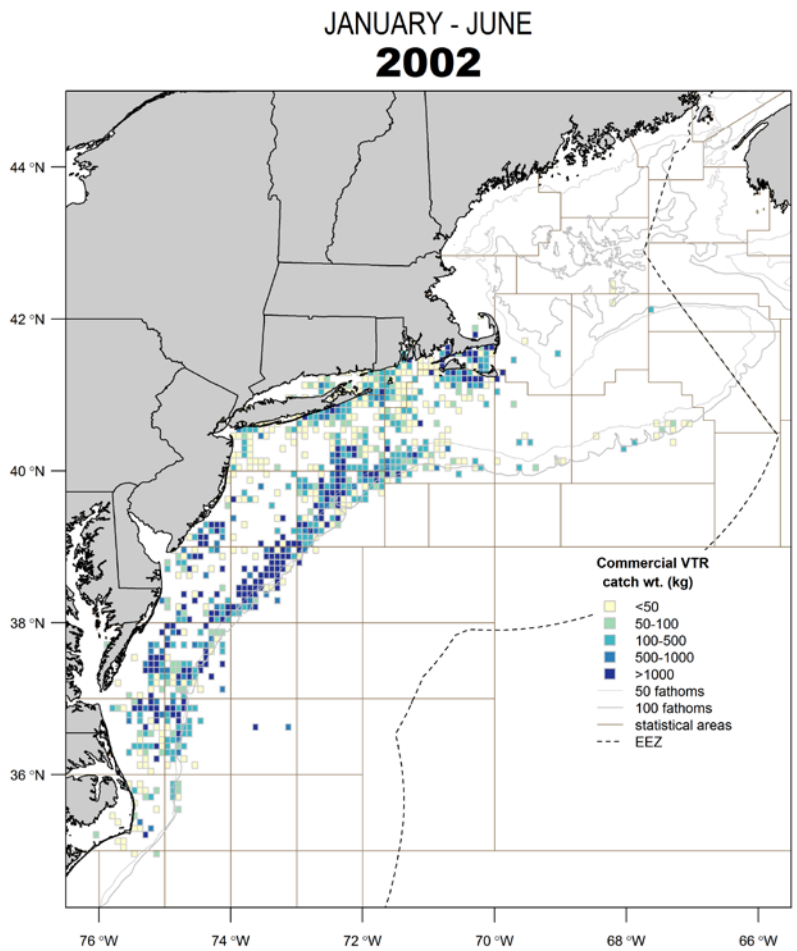
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ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2002
44 °N
42 °N
40 °N
38 °N
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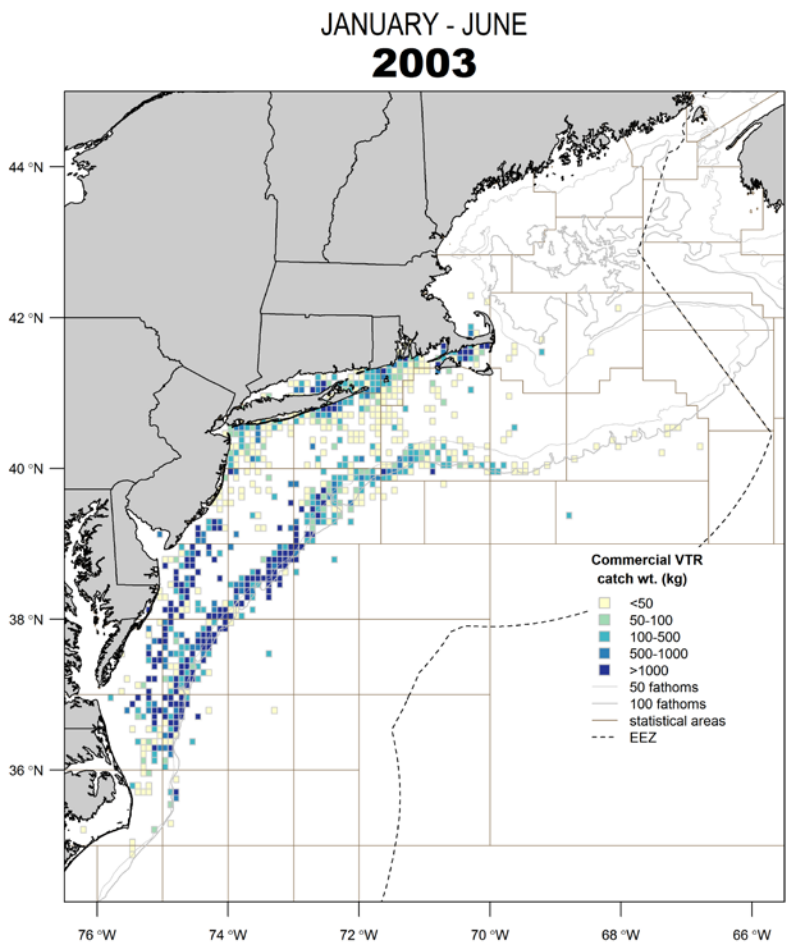
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2003
44 °N
42 °N
40 °N
38 °N
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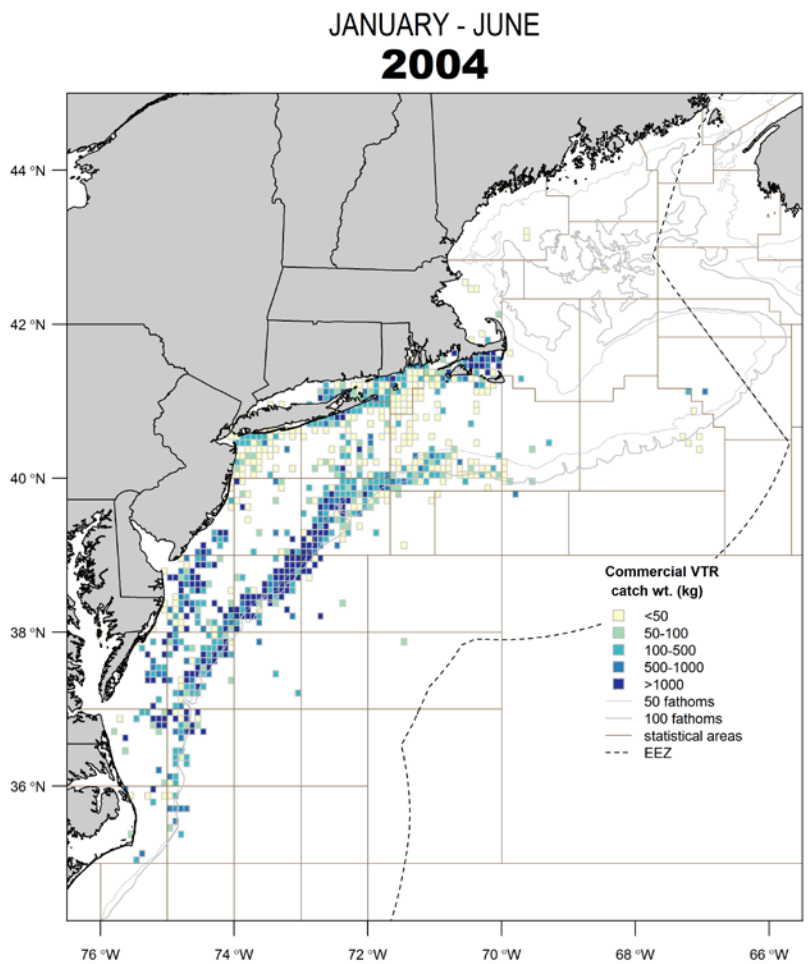
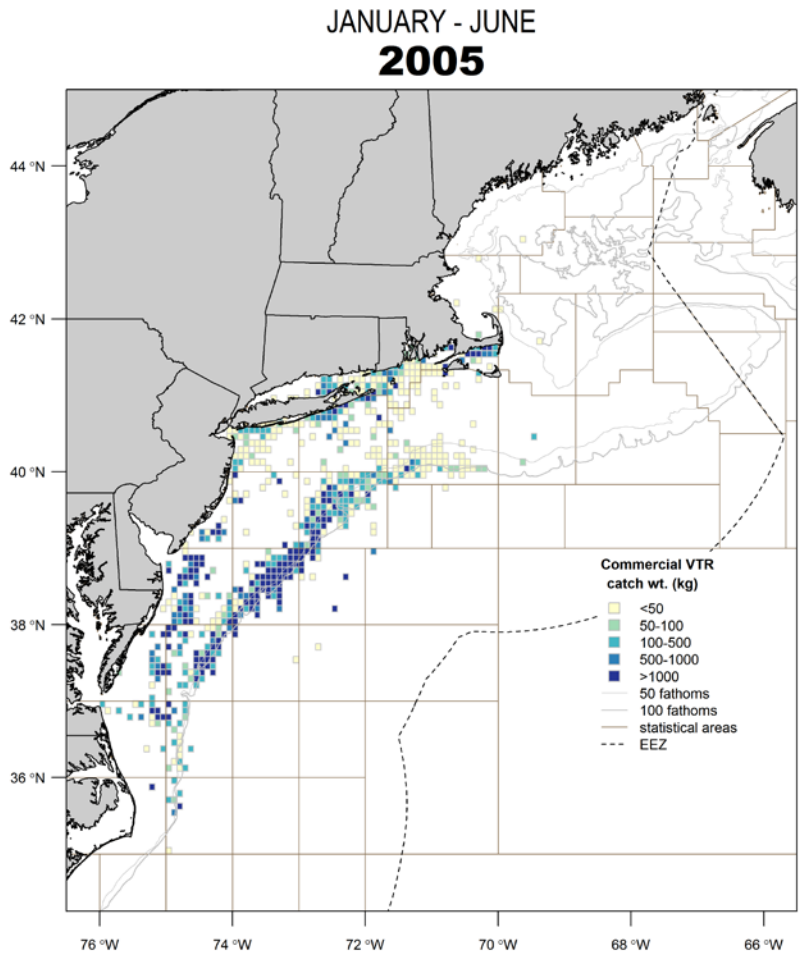
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2004
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2005
44 °N
42 °N
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36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
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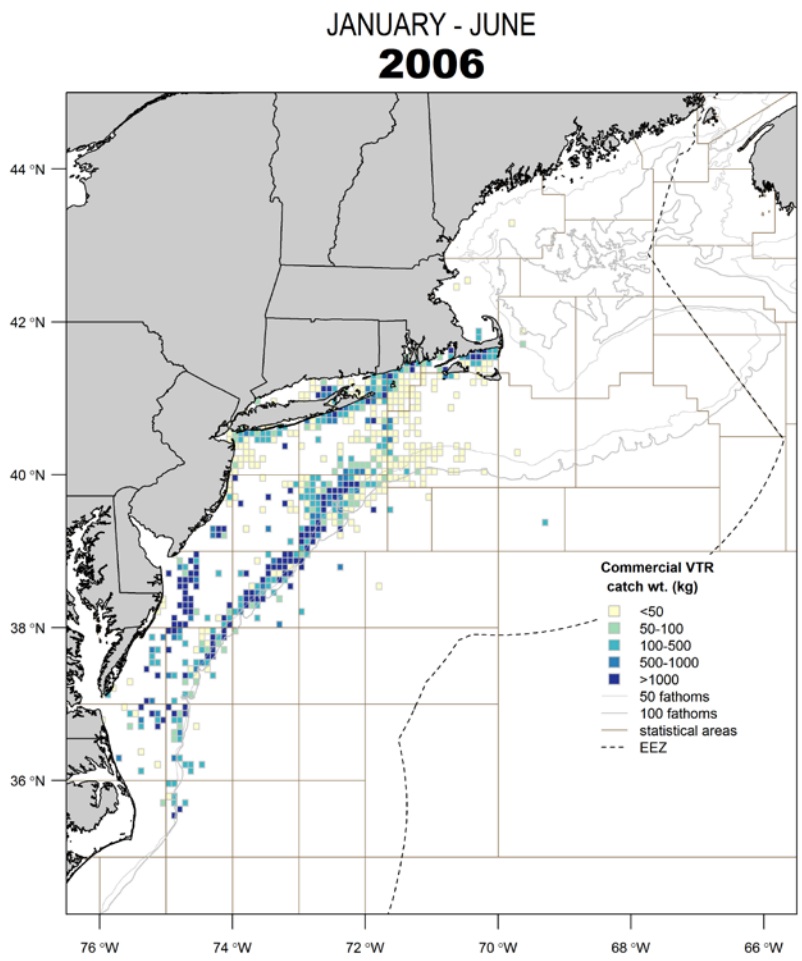
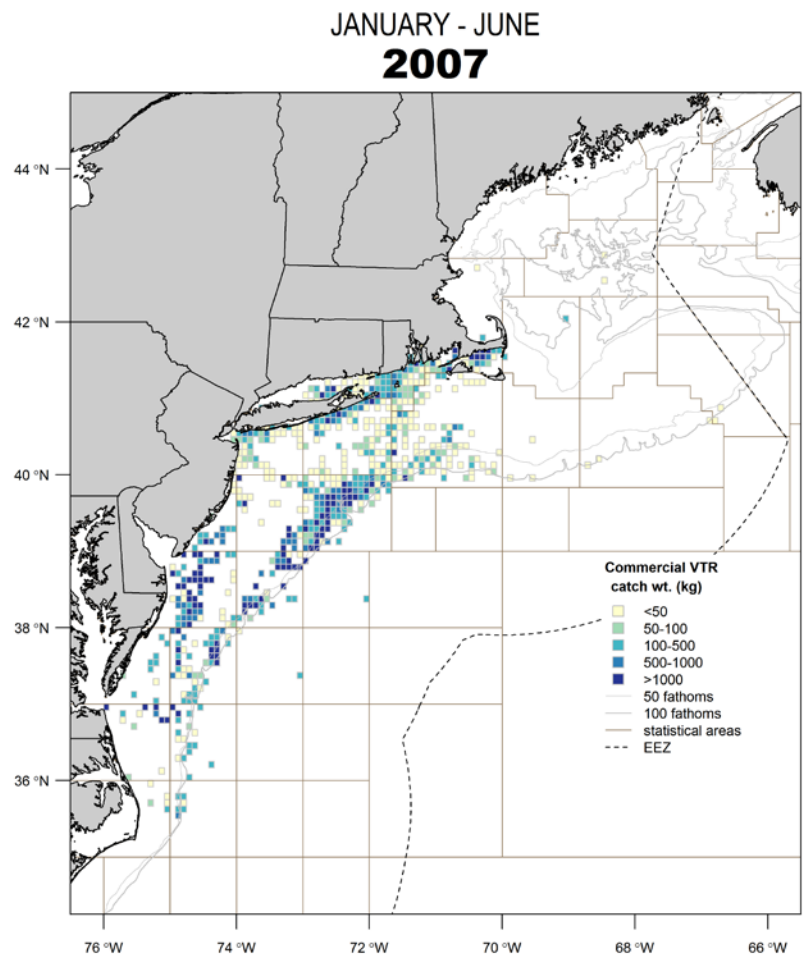
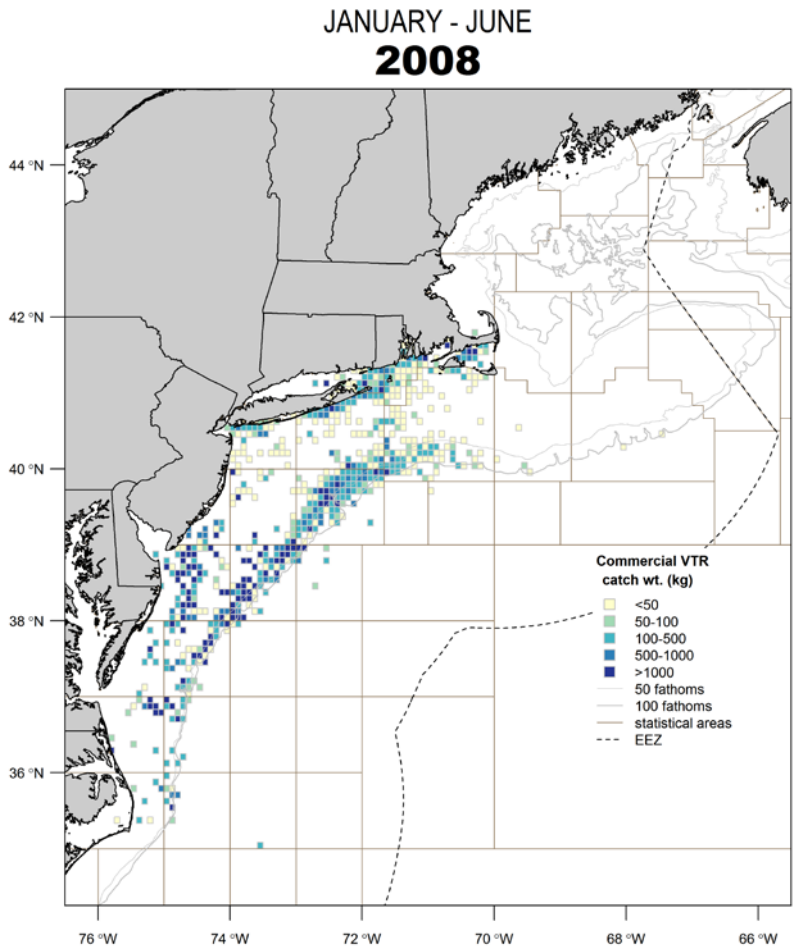
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2006
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2007
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2008
44 °N
42 °N
40 °N
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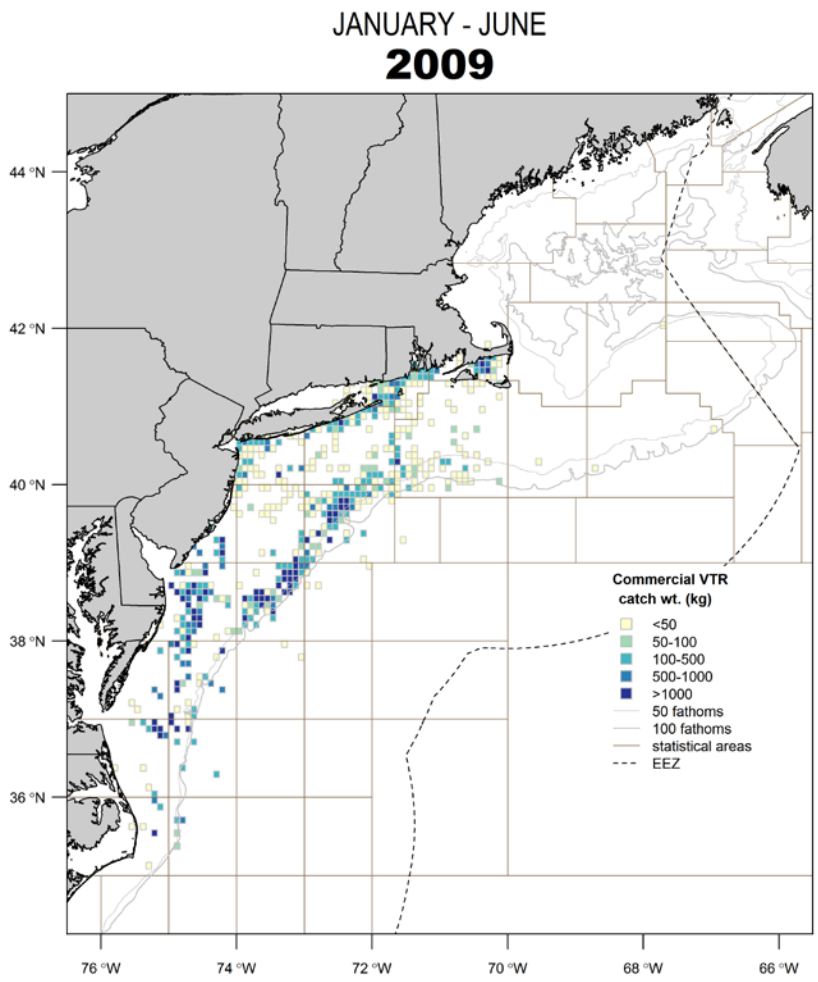
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2009
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40 °N
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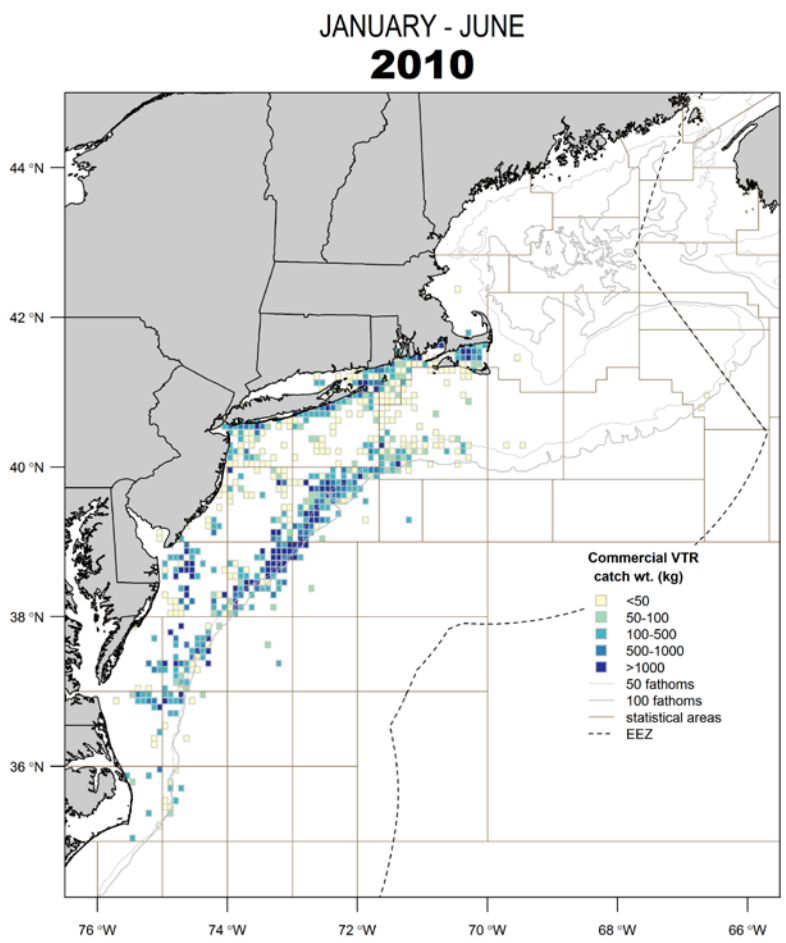
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2010
44 °N
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40 °N
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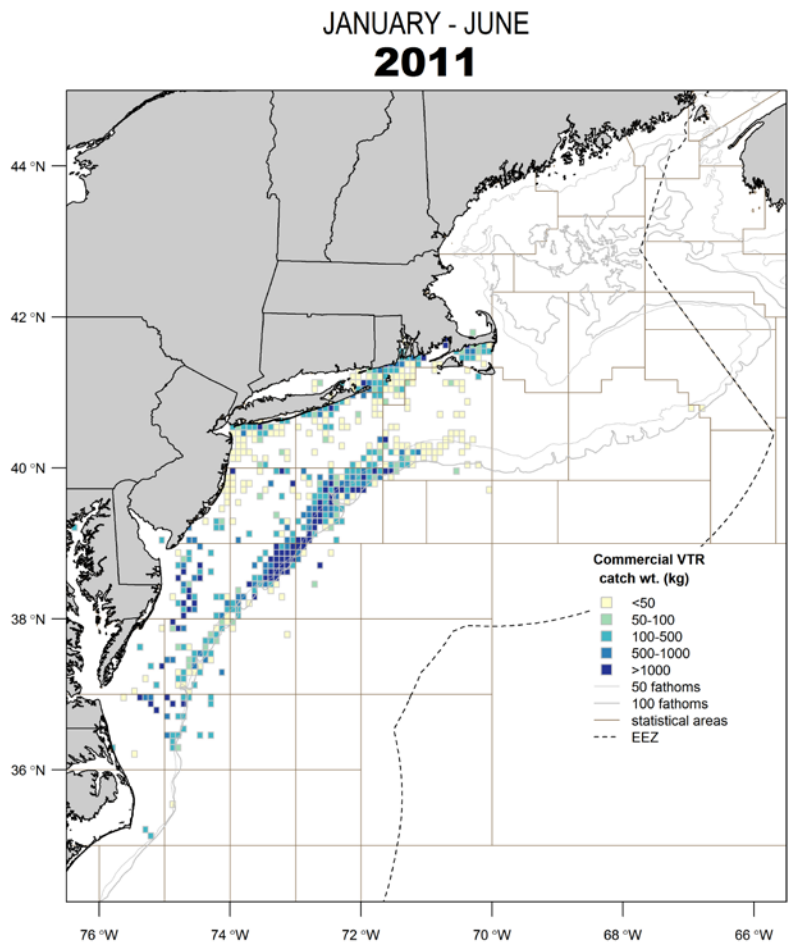
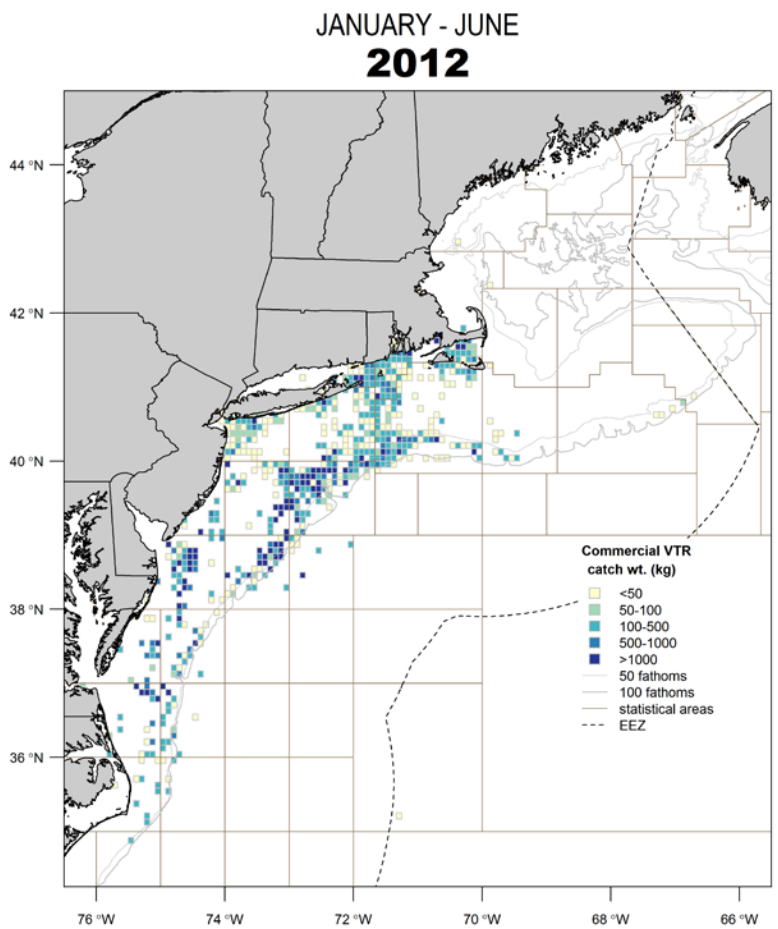
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2011
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ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2012
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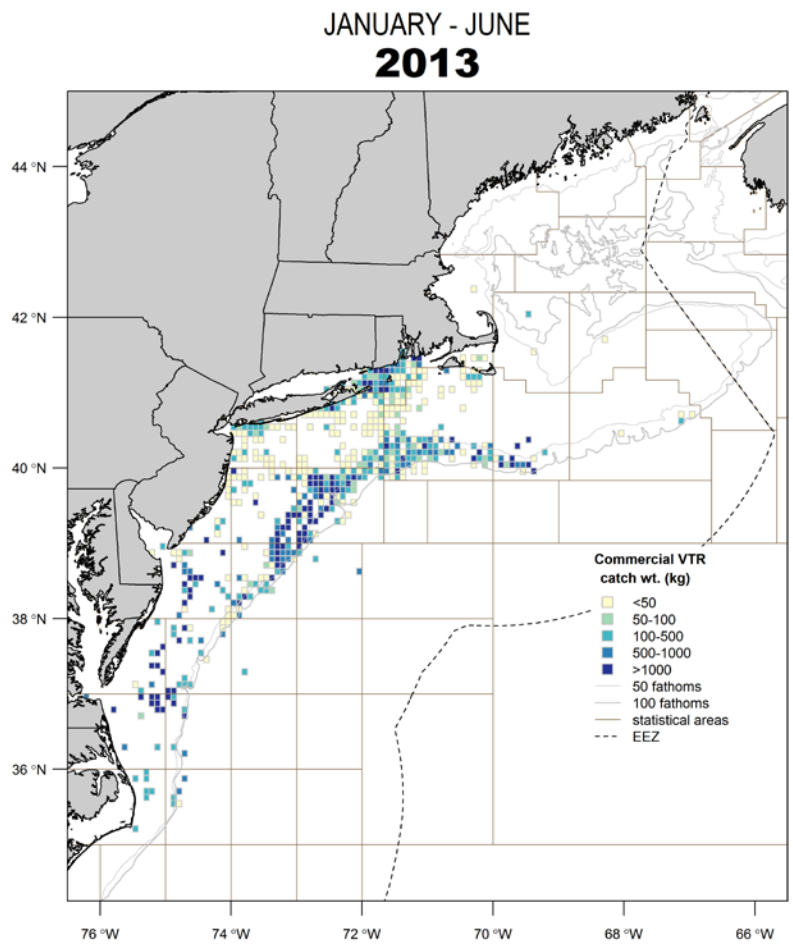
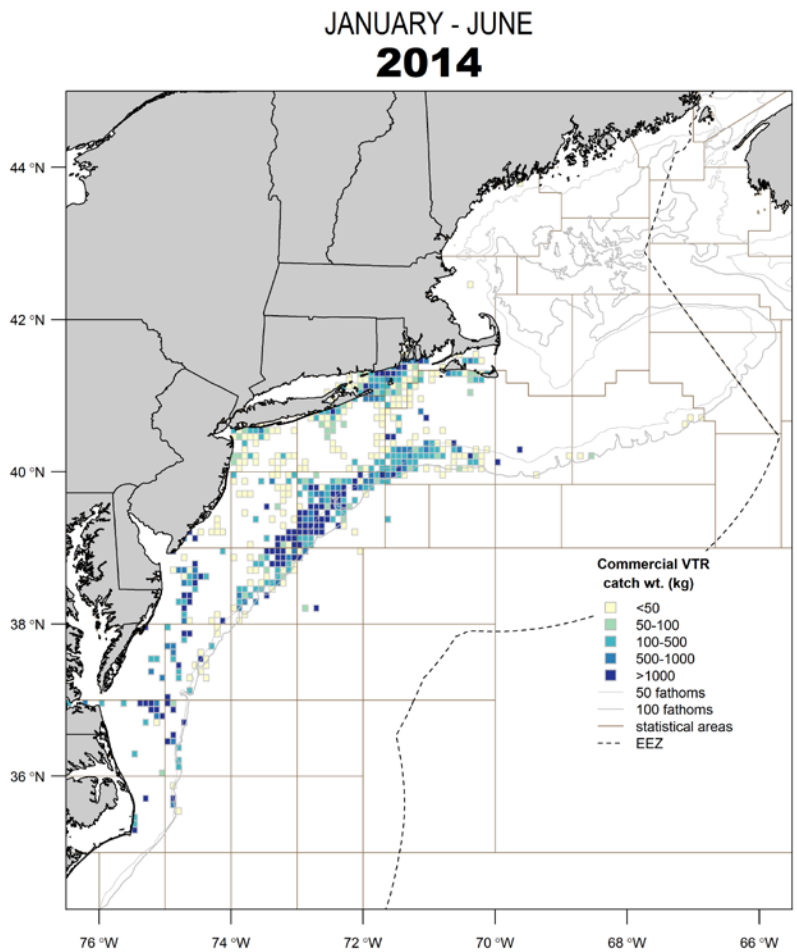
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2013
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2014
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40 °N
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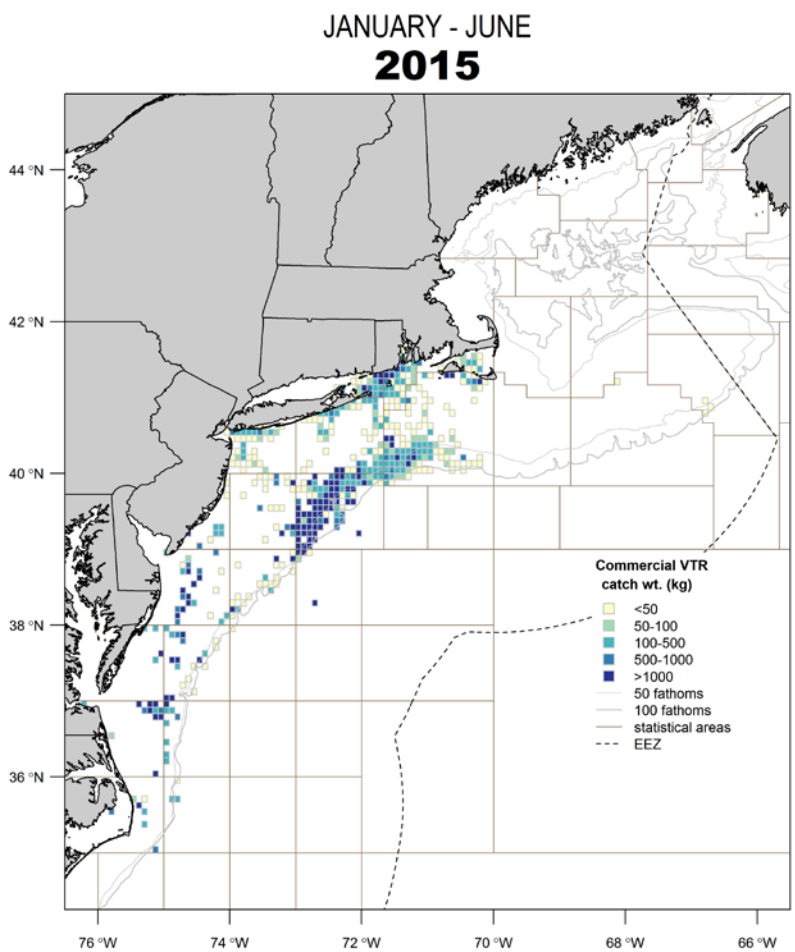
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2015
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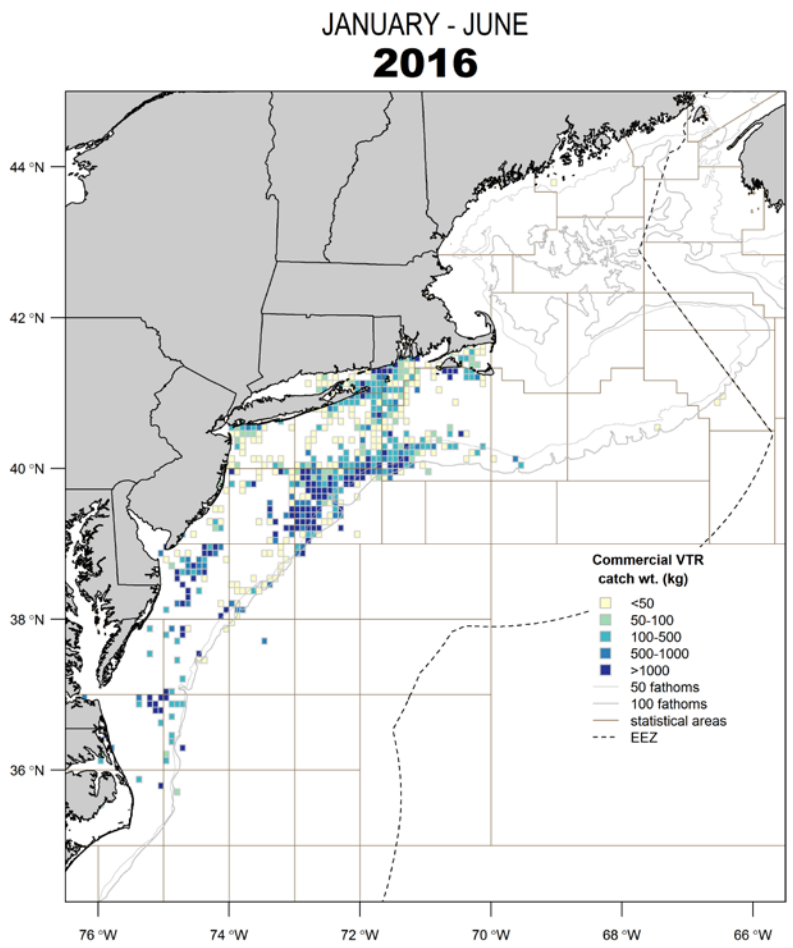
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JANUARY - JUNE
2016
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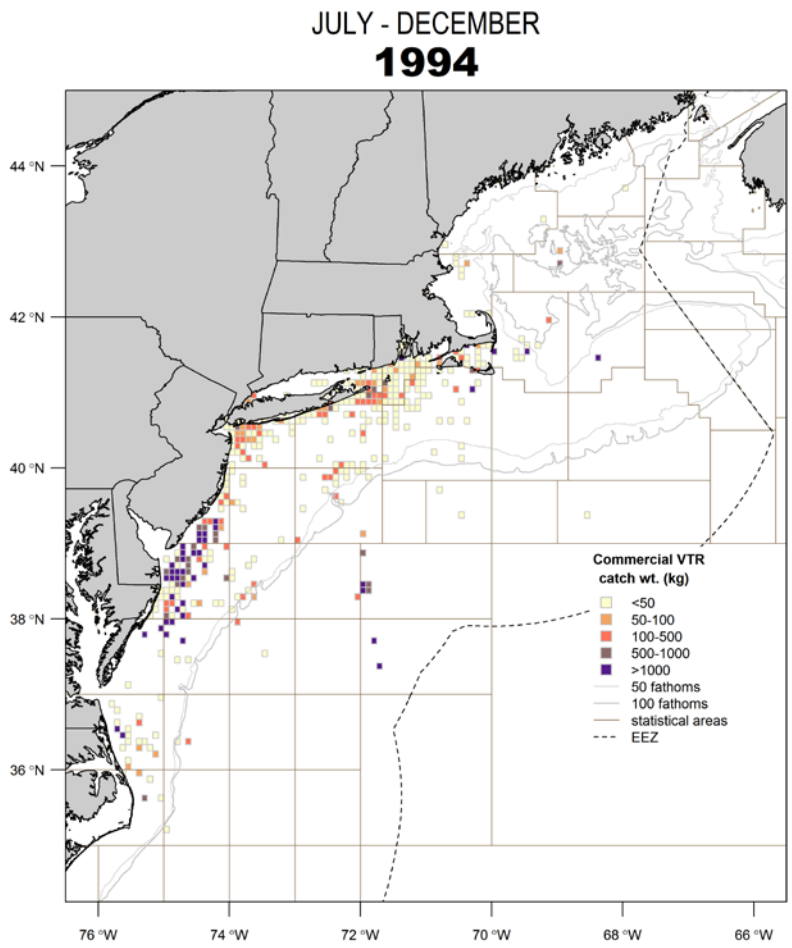
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JULY - DECEMBER
1994
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42 °N
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38 °N
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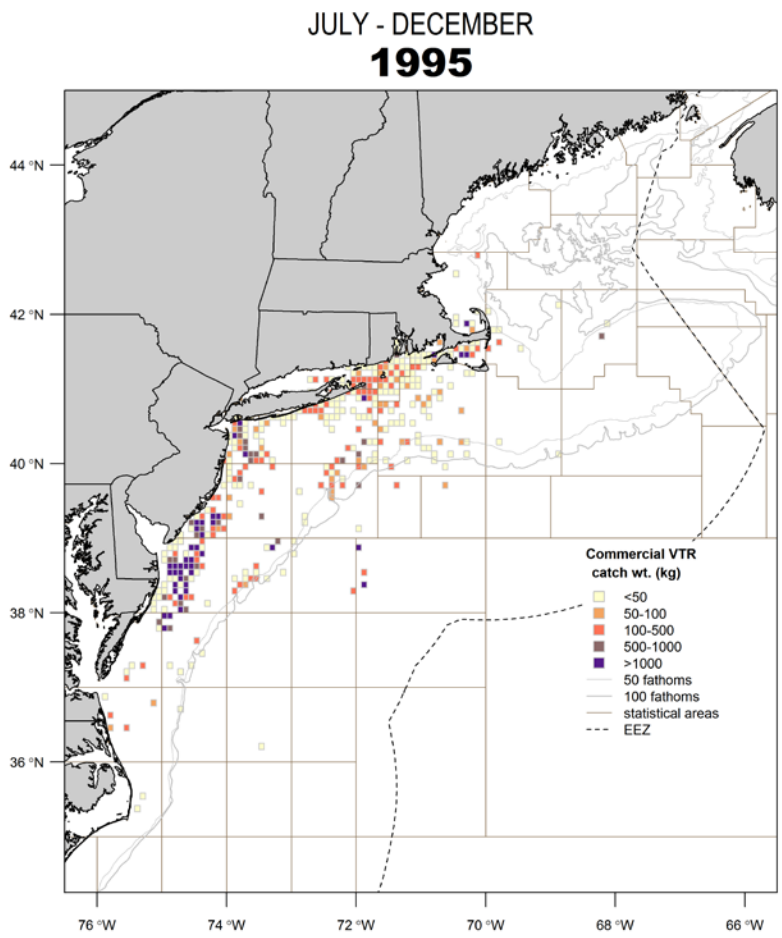
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ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1995
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72 °W
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catch wt. (kg)
<50
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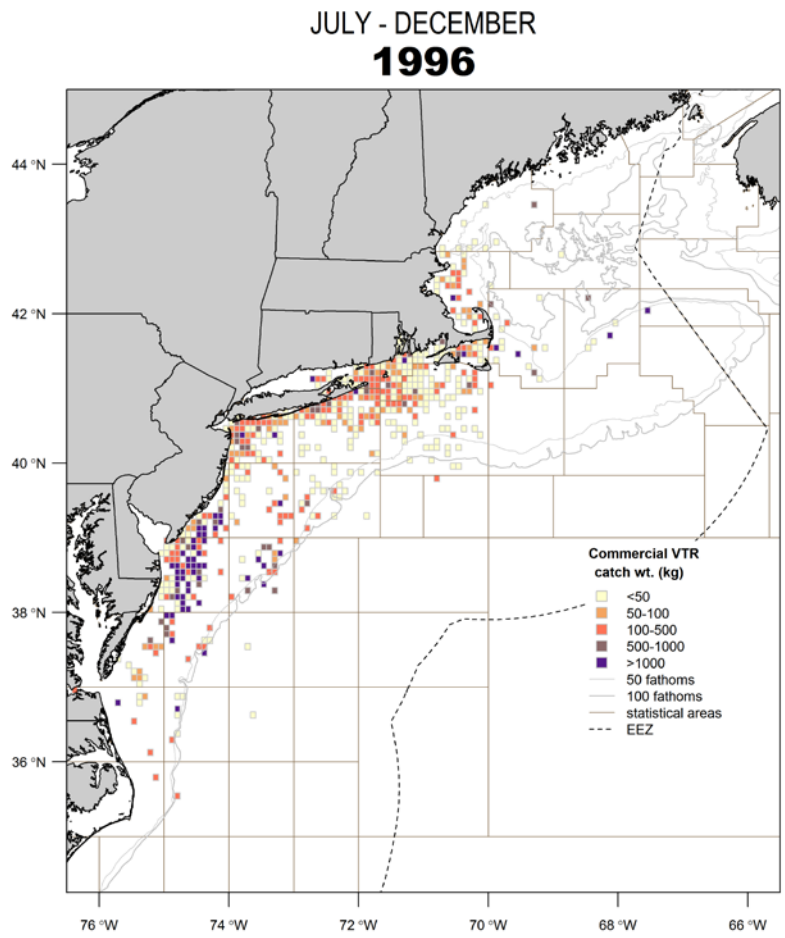
50 fathoms
100 fathoms
statistical areas
EEZ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1996
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72 °W
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Commercial VTR
catch wt. (kg)
<50
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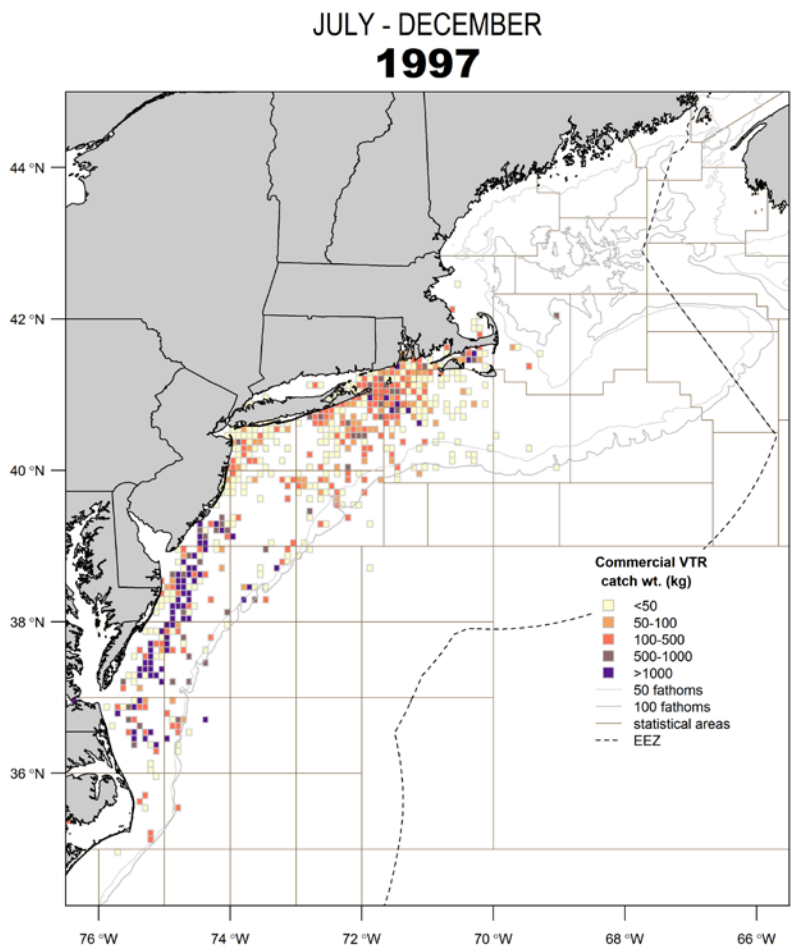
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ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1997
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72 °W
70 °W
68 °W
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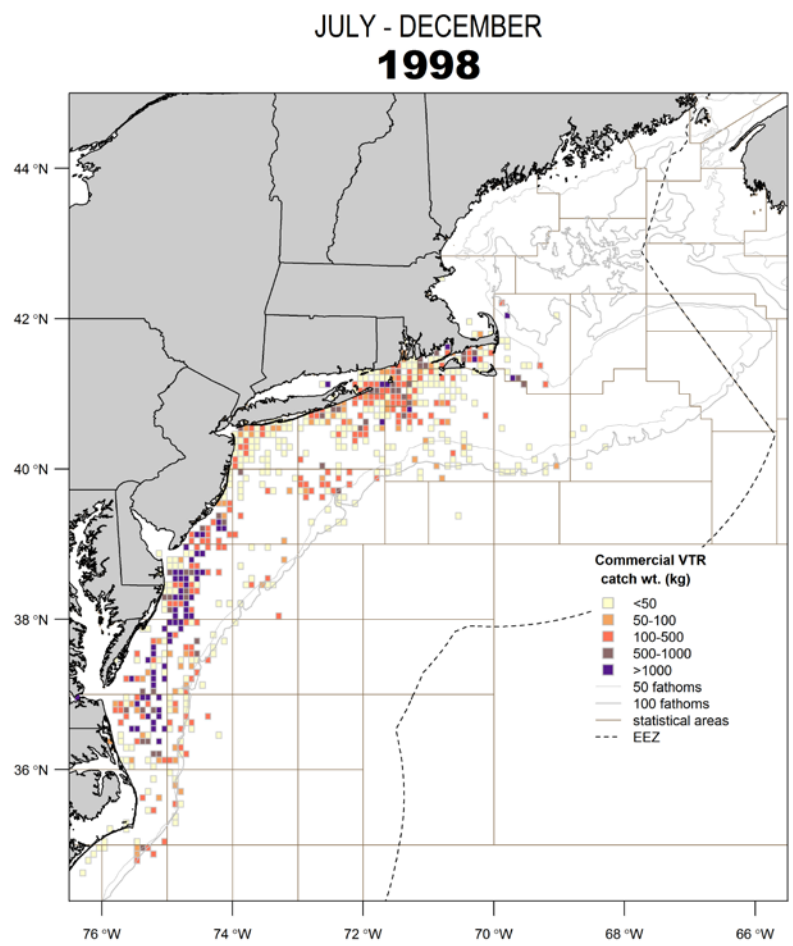
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JULY - DECEMBER
1998
44 °N
42 °N
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38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
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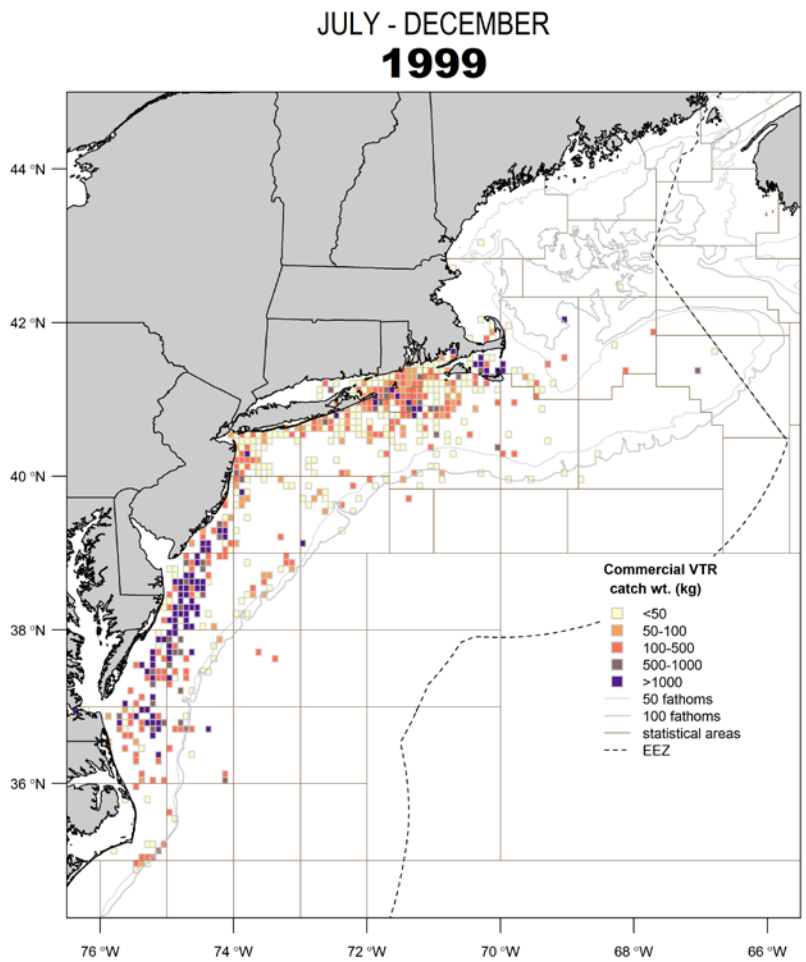
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JULY - DECEMBER
1999
44 °N
42 °N
40 °N
38 °N
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76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
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100-500
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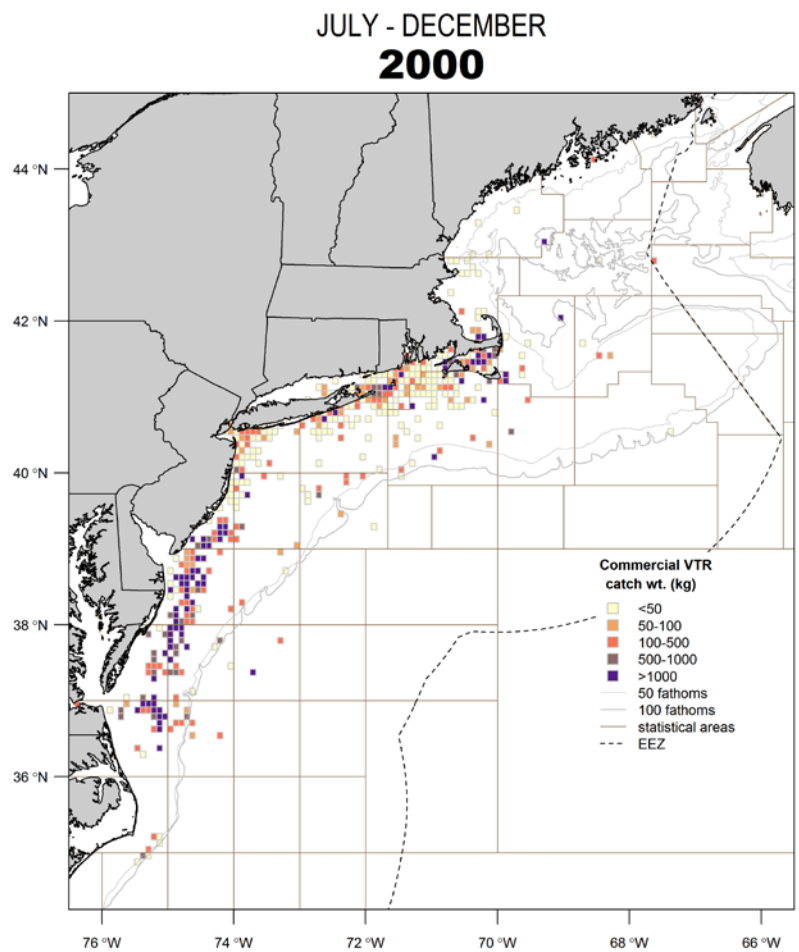
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JULY - DECEMBER
2000
44 °N
42 °N
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76 °W
74 °W
72 °W
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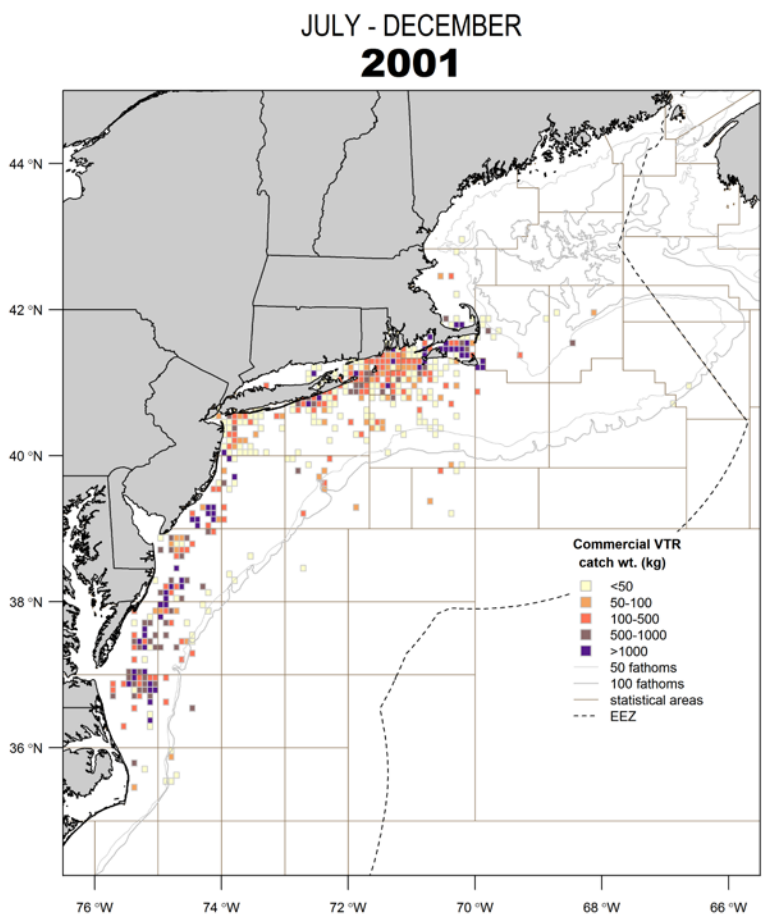
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JULY - DECEMBER
2001
44 °N
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36 °N
76 °W
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70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
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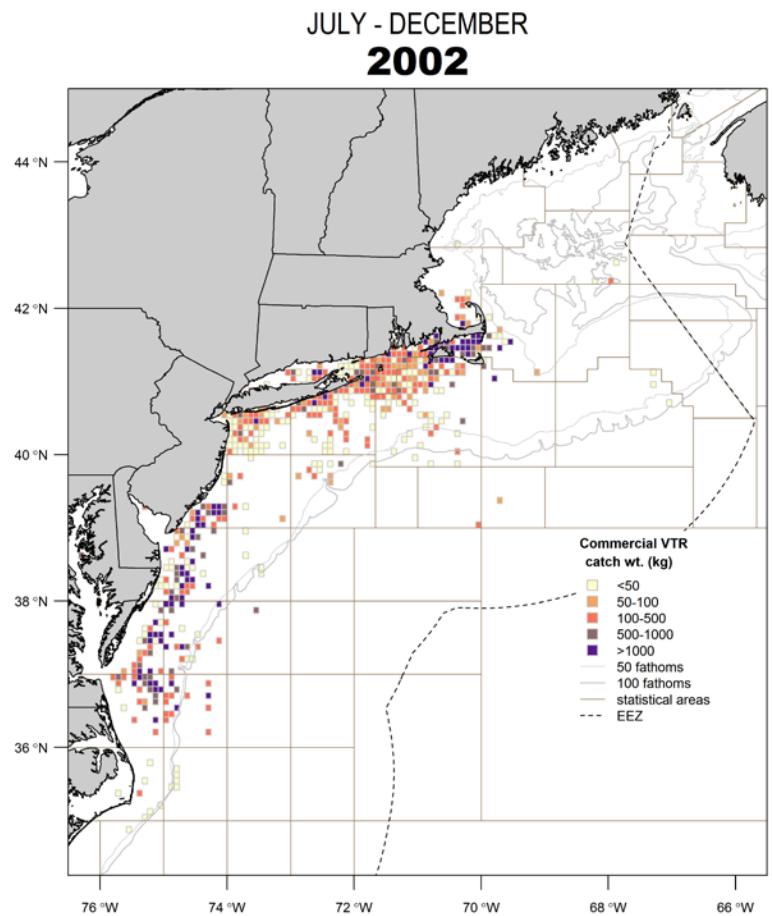
50 fathoms
100 fathoms
statistical areas
EEZ


JULY - DECEMBER
2002
44 °N
42 °N
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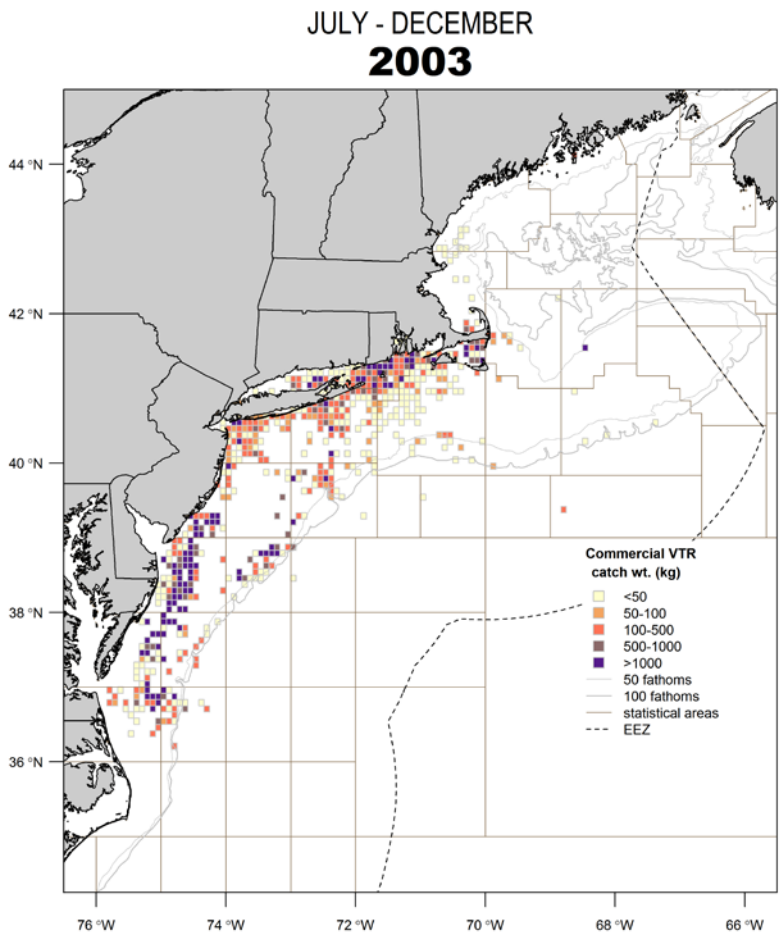
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JULY - DECEMBER
2003
44 °N
42 °N
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38 °N
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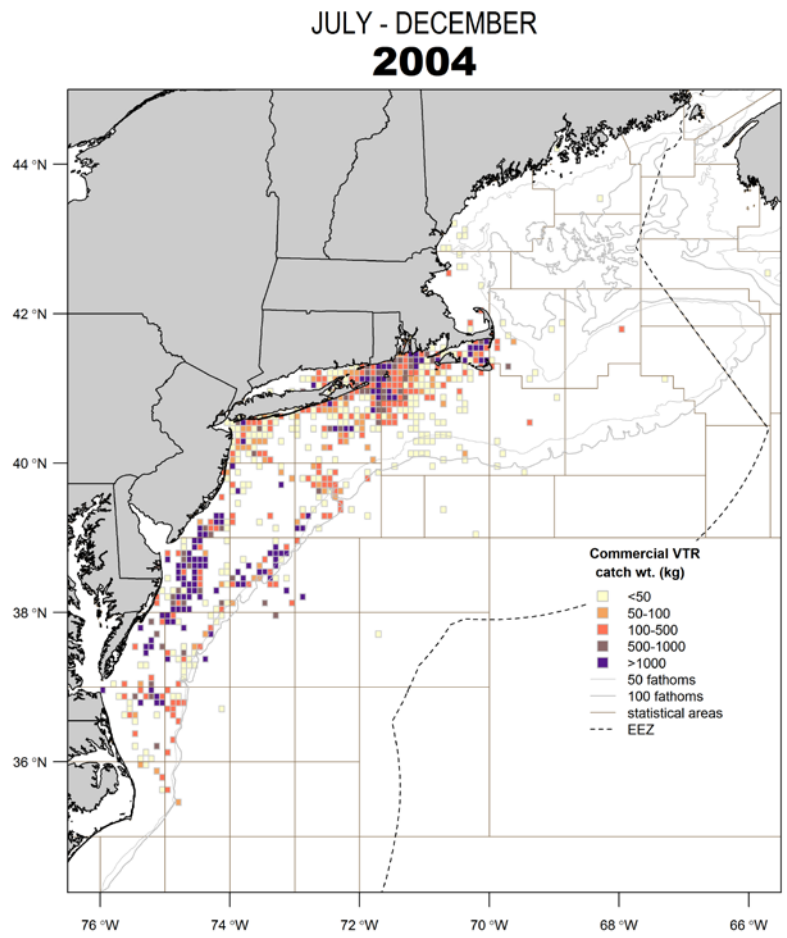
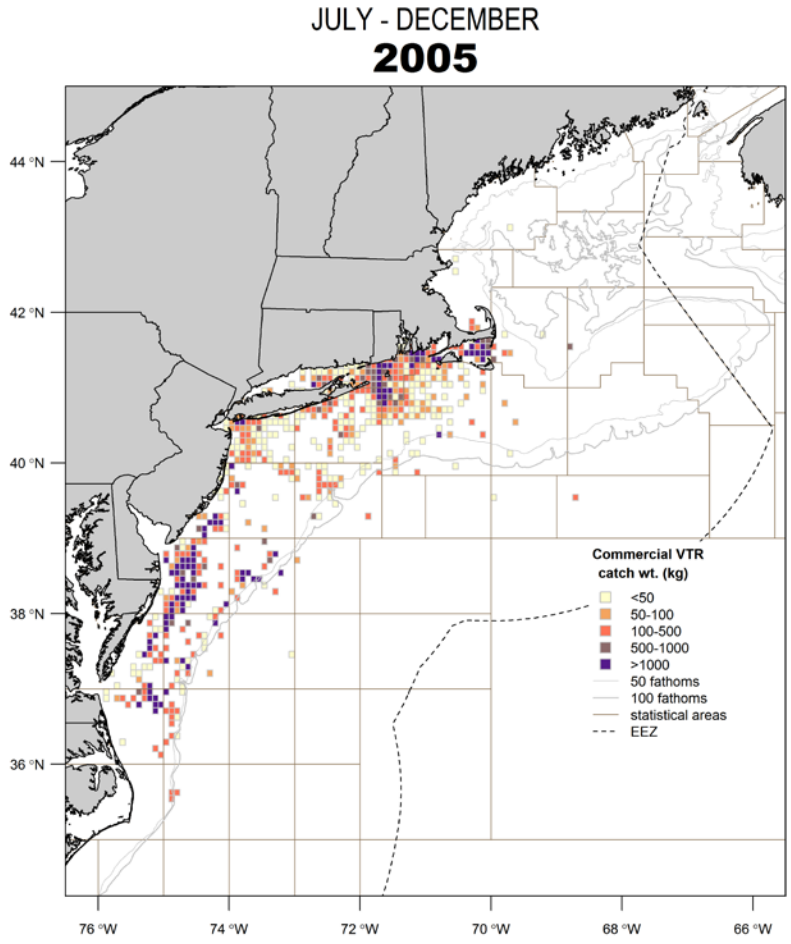
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JULY - DECEMBER
2004
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JULY - DECEMBER
2005
44 °N
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76 °W
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72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
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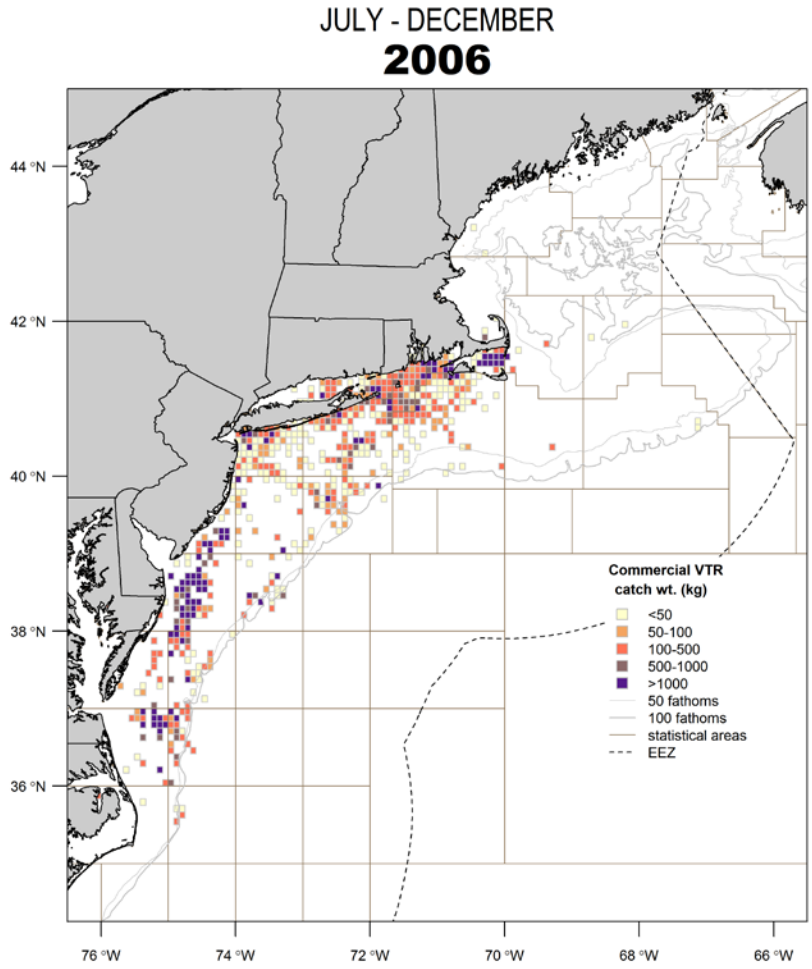
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JULY - DECEMBER
2006
44 °N
42 °N
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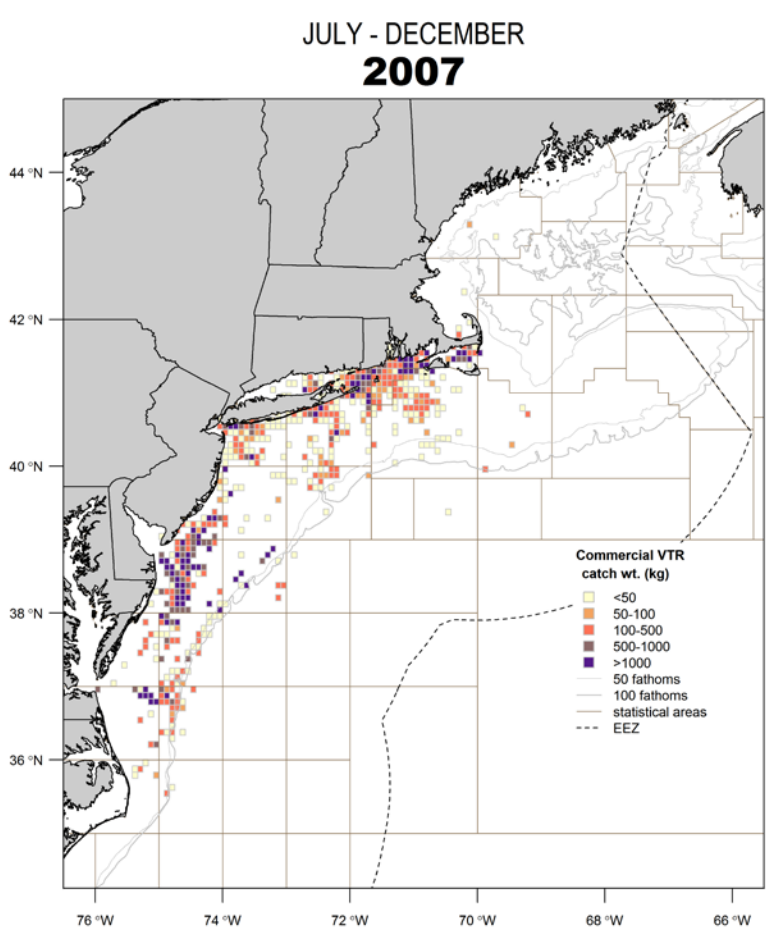
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JULY - DECEMBER
2007
44 °N
42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
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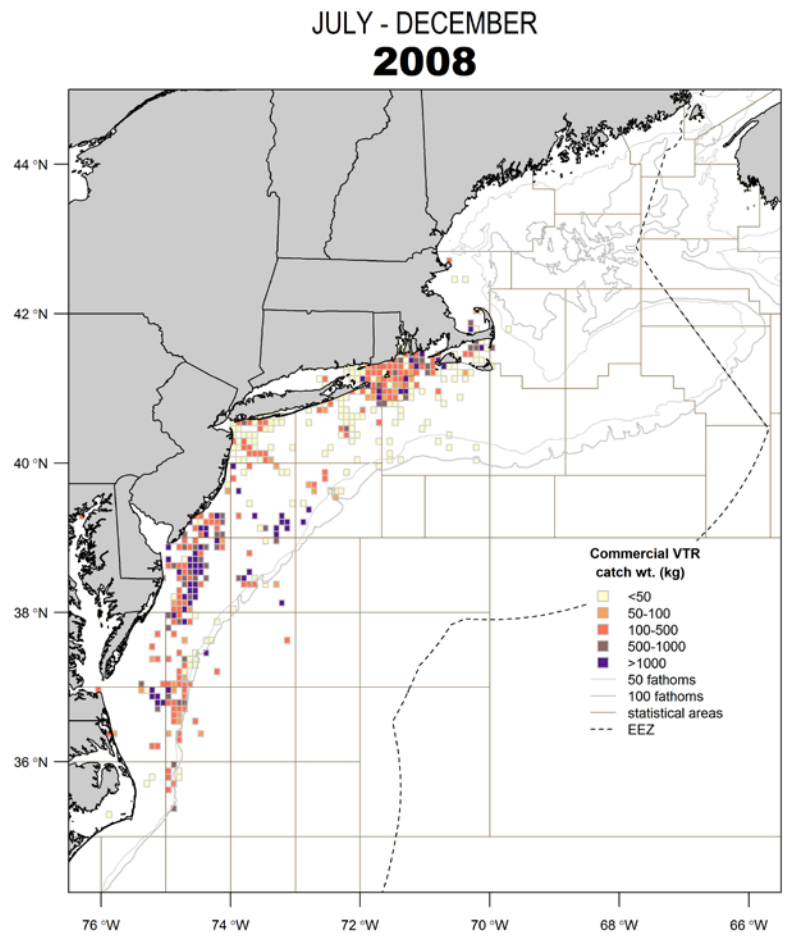
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ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500-1000
>1000
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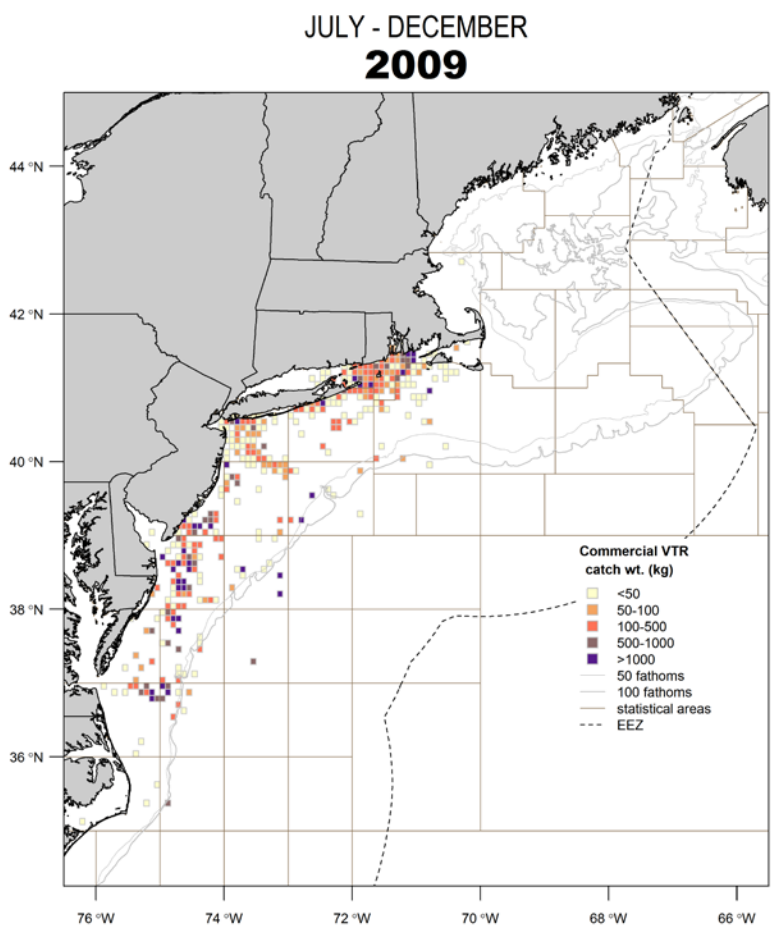
100 fathoms
statistical areas
EEZ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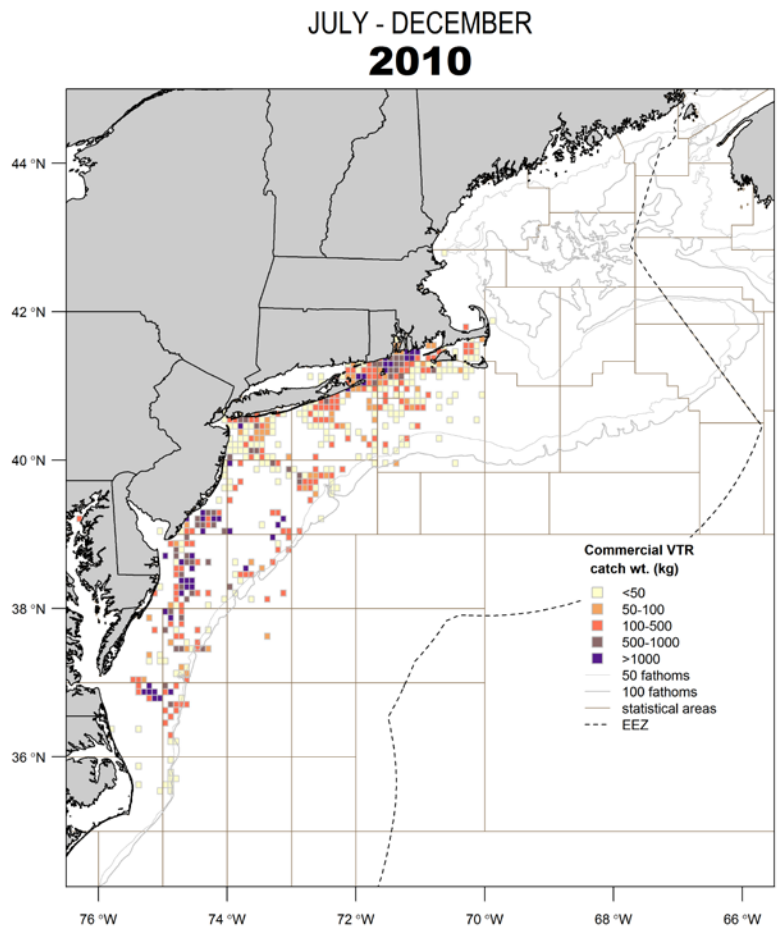
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ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42 °N
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76 °W
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72 °W
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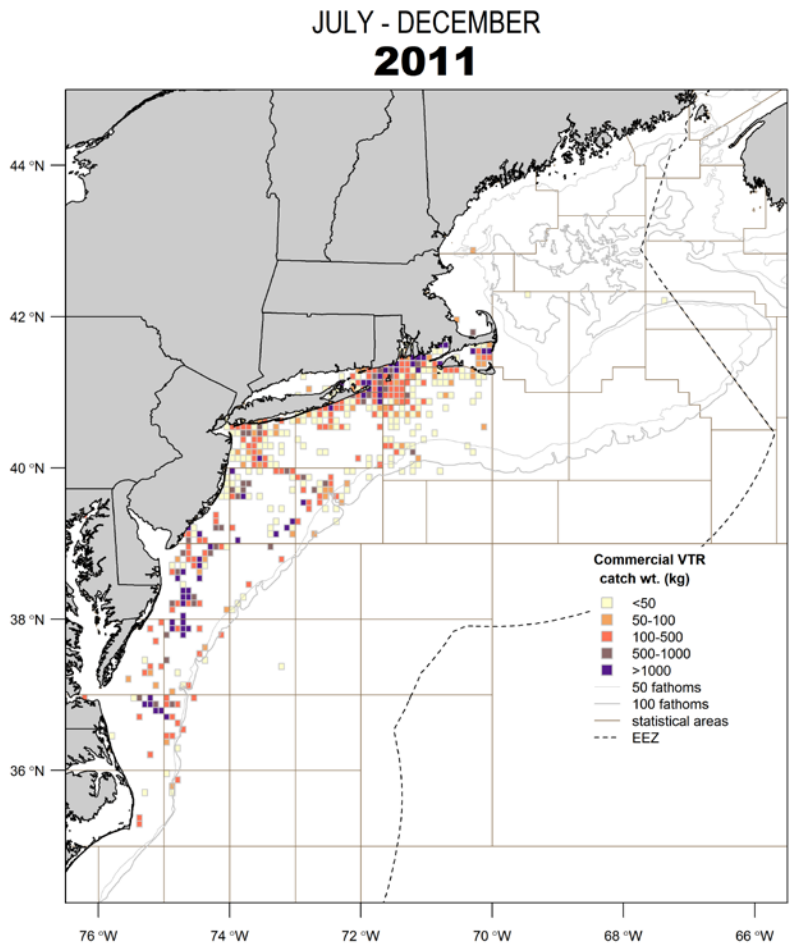
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ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2011
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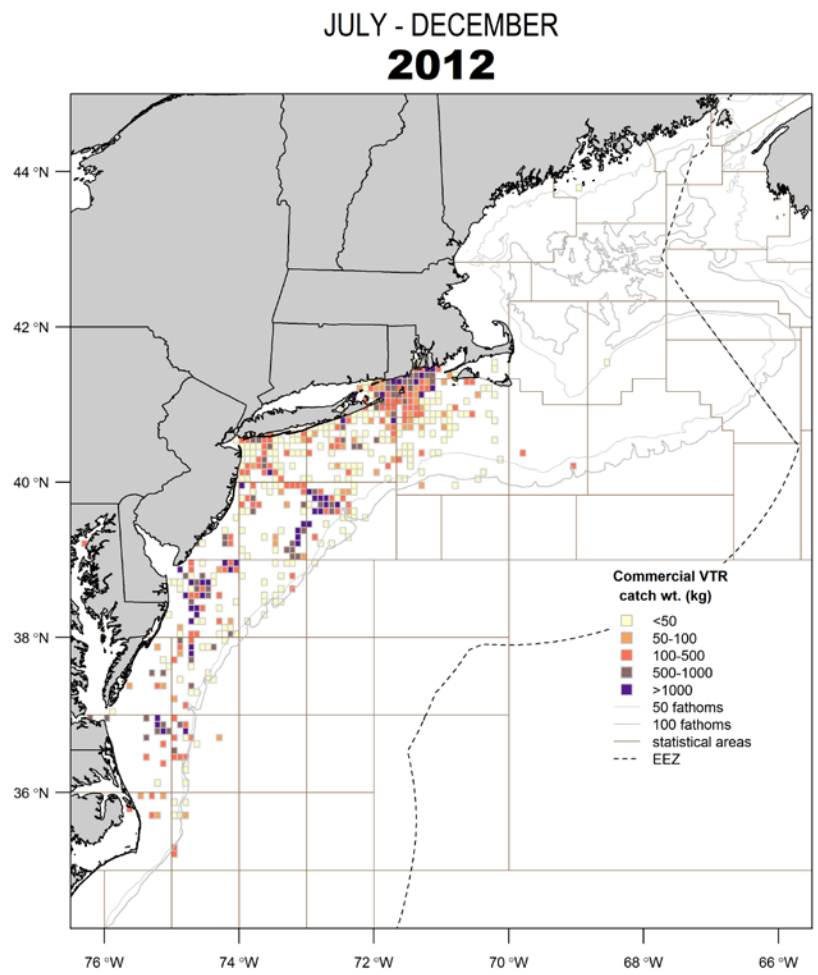
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ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Commercial VTR
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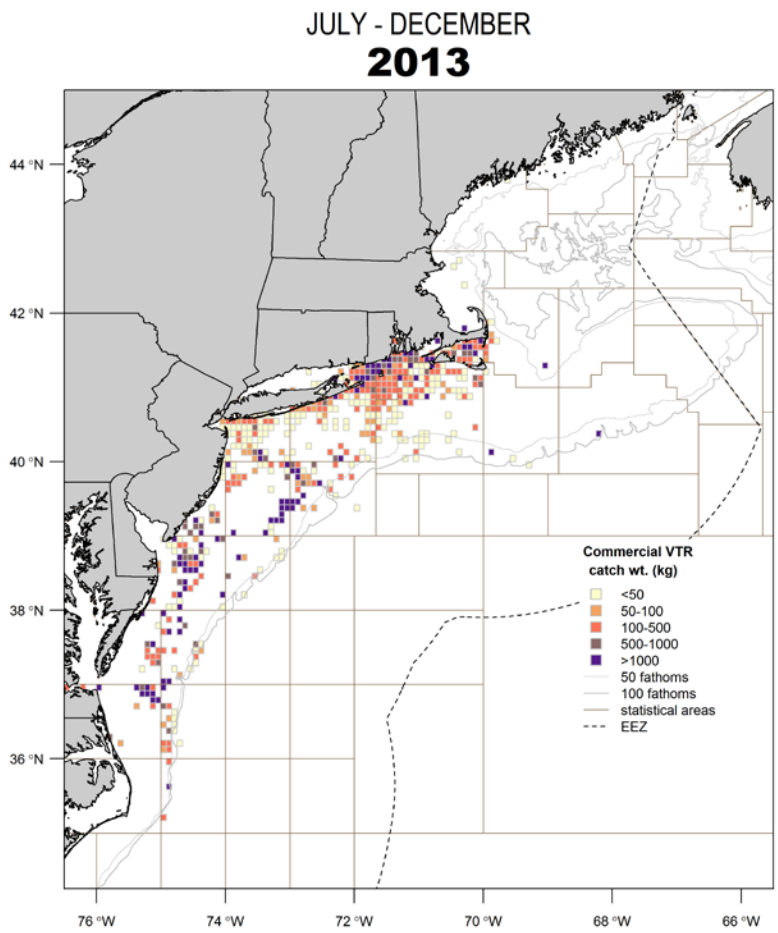
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ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2013
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76 °W
74 °W
72 °W
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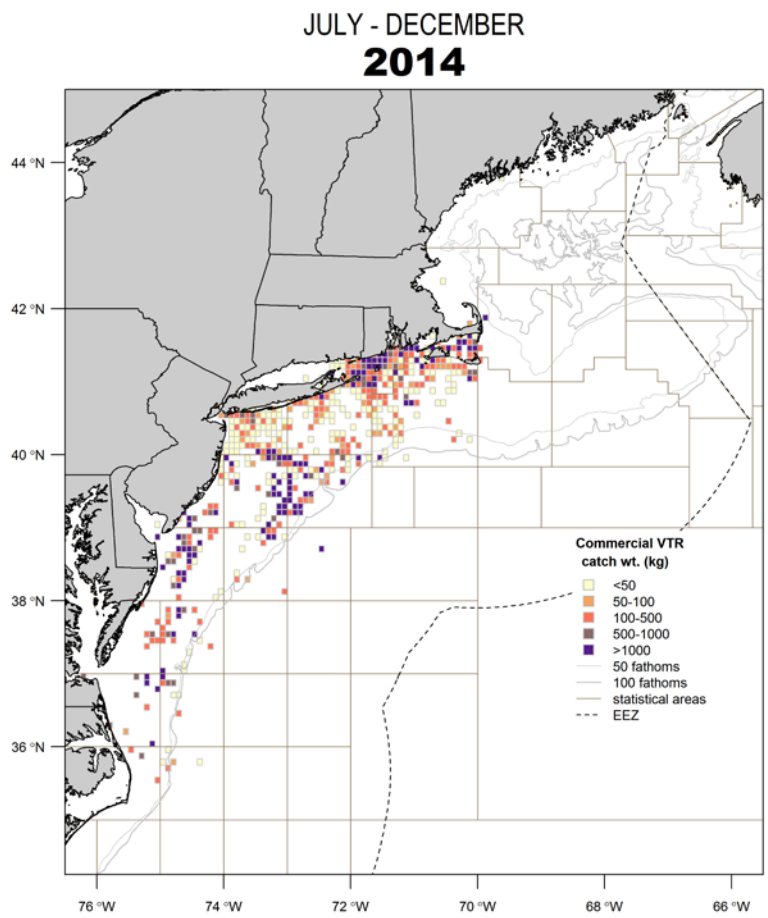
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ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2014
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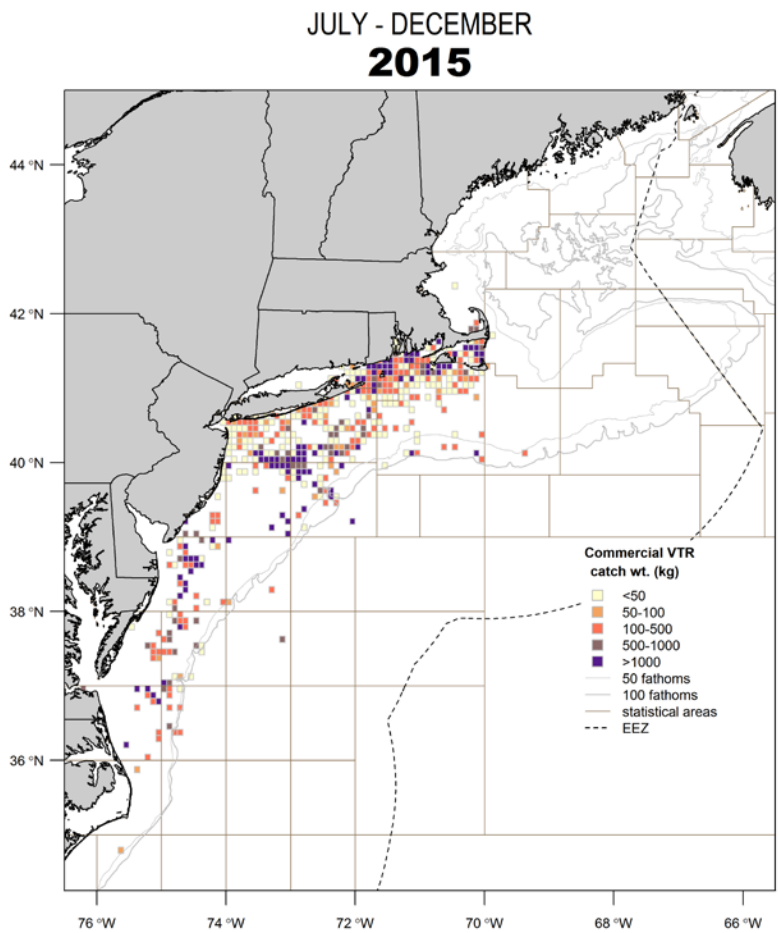
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ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74 °W
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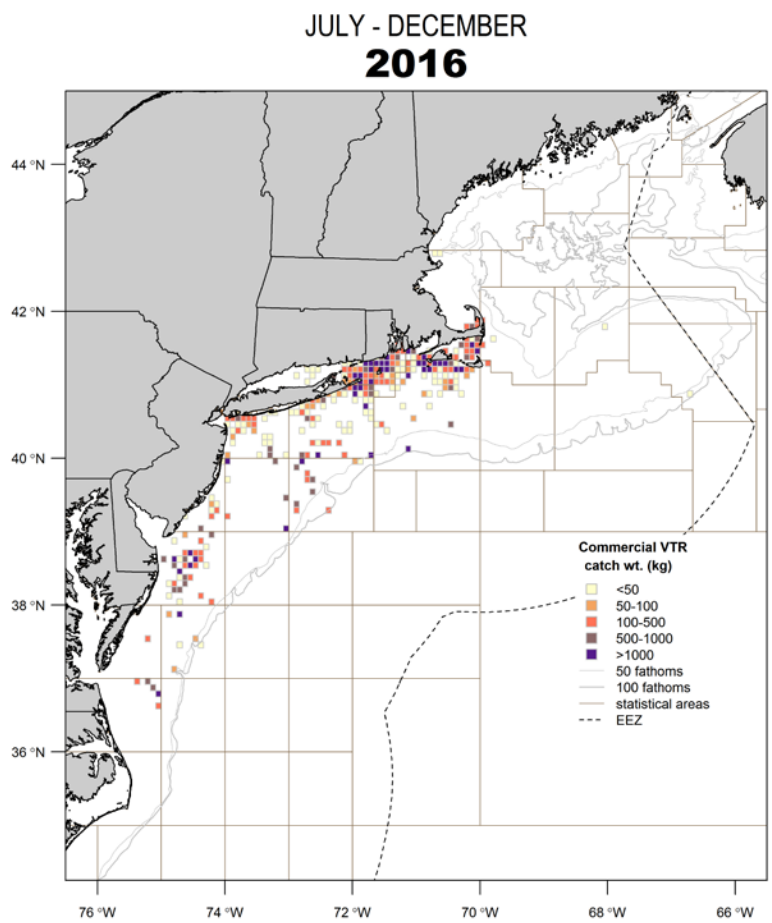
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ


JULY - DECEMBER
2016
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42 °N
40 °N
38 °N
36 °N
76 °W
74 °W
72 °W
70 °W
68 °W
66 °W
Commercial VTR
catch wt. (kg)
<50
50-100
100-500
500-1000
>1000
50 fathoms
100 fathoms
statistical areas
EEZ

Appendix A8 – Evaluation of methods to create age-length keys for black sea bass

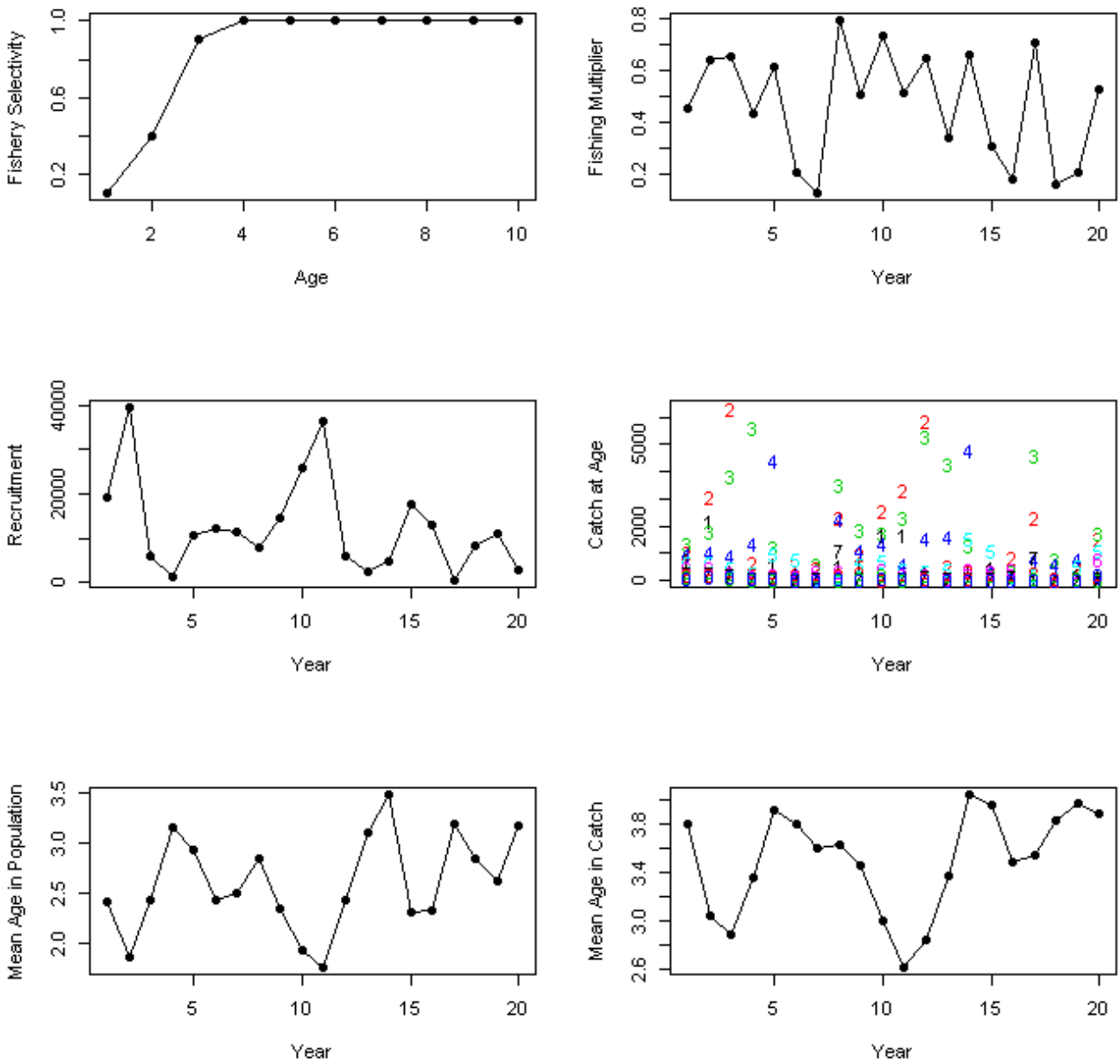
ALK simulation to test efficacy of multinomial approach

The ability of the multinomial method to fill holes in age-length keys was evaluated through simulation. Holes in an age-length key occur when fish of a given length are caught, but no ages are available for that length. The simulation approach created a known catch at age from a population with specified biological and fishery characteristics, estimated the catch at age from length and age samples many times, and compared the distribution of estimated catch at age with the true catch at age over the entire time period of the simulated fishery. The simulated population had ten ages estimated for twenty years from catch by a flat-topped selectivity fishery operating at an intensity of 0.1 to 0.9 annually. The natural mortality of the population was 0.2 and the von Bertalanffy growth had a coefficient of variation of 15% and a range of sizes from 1 to 100 cm. Each year 1000 fish were sampled for length and 20 of these fish were aged to create the age-length key for that year. Holes in the annual age-length key were filled using year-specific multinomial estimates of proportions at age. Distributions of estimated catch at age and mean age in the catch were computed from 100 random length and age samples. A second set of simulations used age-length keys formed by combining data from the previous and following years to see how much performance degraded when age-length keys from neighboring years instead of that specific year were used.

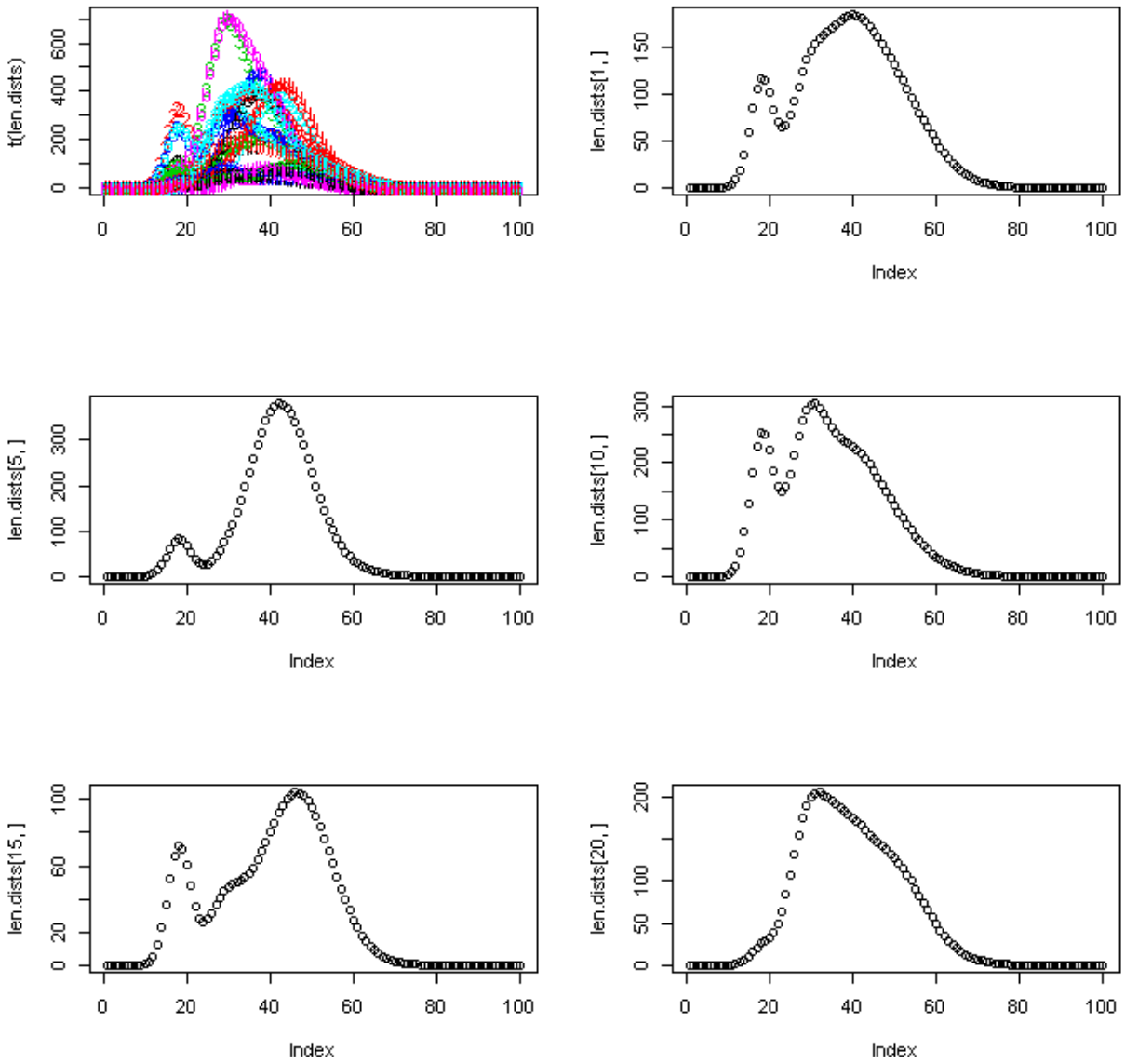
Results demonstrated the multinomial method to filling age-length key holes provided unbiased and relatively precise estimates of catch at age and mean age in the catch on average, with individual realizations that captured the important peaks and troughs in the annual catch at age frequencies. Removing the age data from a given year and using neighboring years decreased the precision of the estimates and caused some mean age of the catch distributions to not contain the true values, although the overall pattern over years was correct and the individual years still often captured the important features of the catch at age distributions.

Generalizing the results of these simulations to the real world is difficult due to the challenge of collecting truly random samples from the catch. Samples are typically

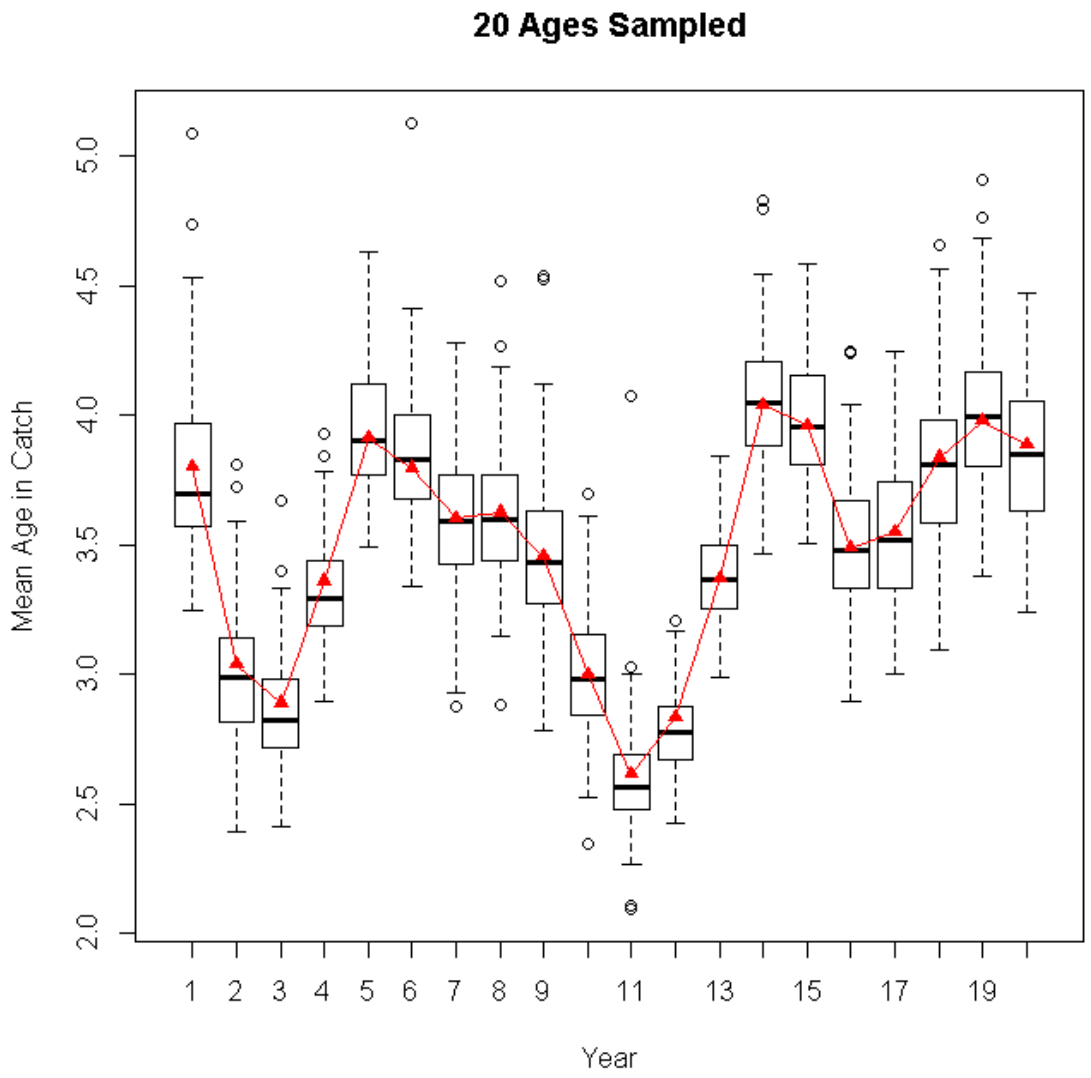
collected in groups, for example, 100 lengths and 20 ages will be collected from the catch of one boat. This creates a strong correlation in the collected data and means the individual samples are not independent, as they are assumed to be in the simulations. This means that the 20 ages randomly collected in the simulations must be expanded to a real world value. If an expansion of 4-5 fold is applied, the resulting number of ages in the real world would be 80-100.



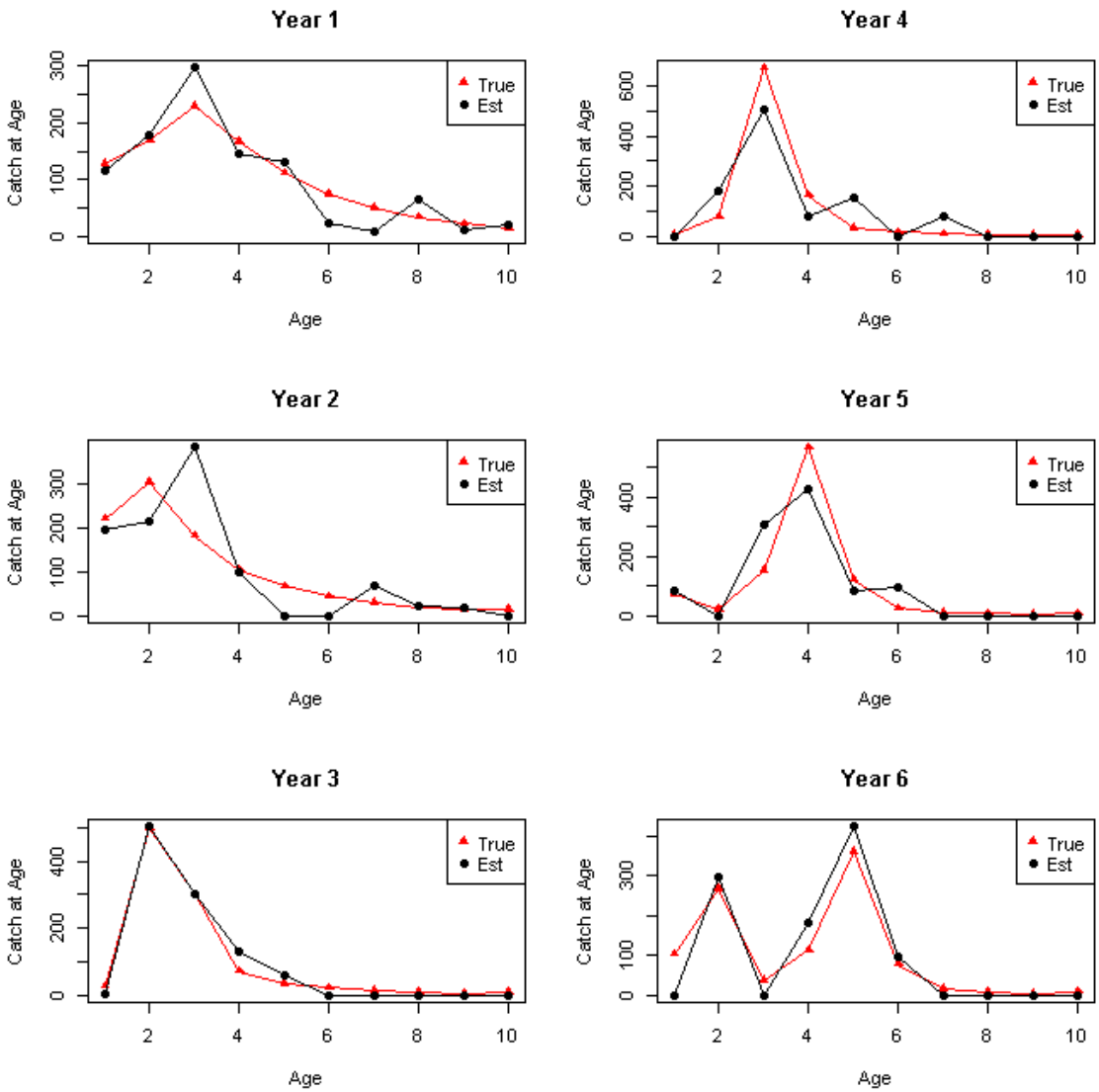
Appendix A8, Figure 1a. Fishery and biological characteristics of simulated base population.



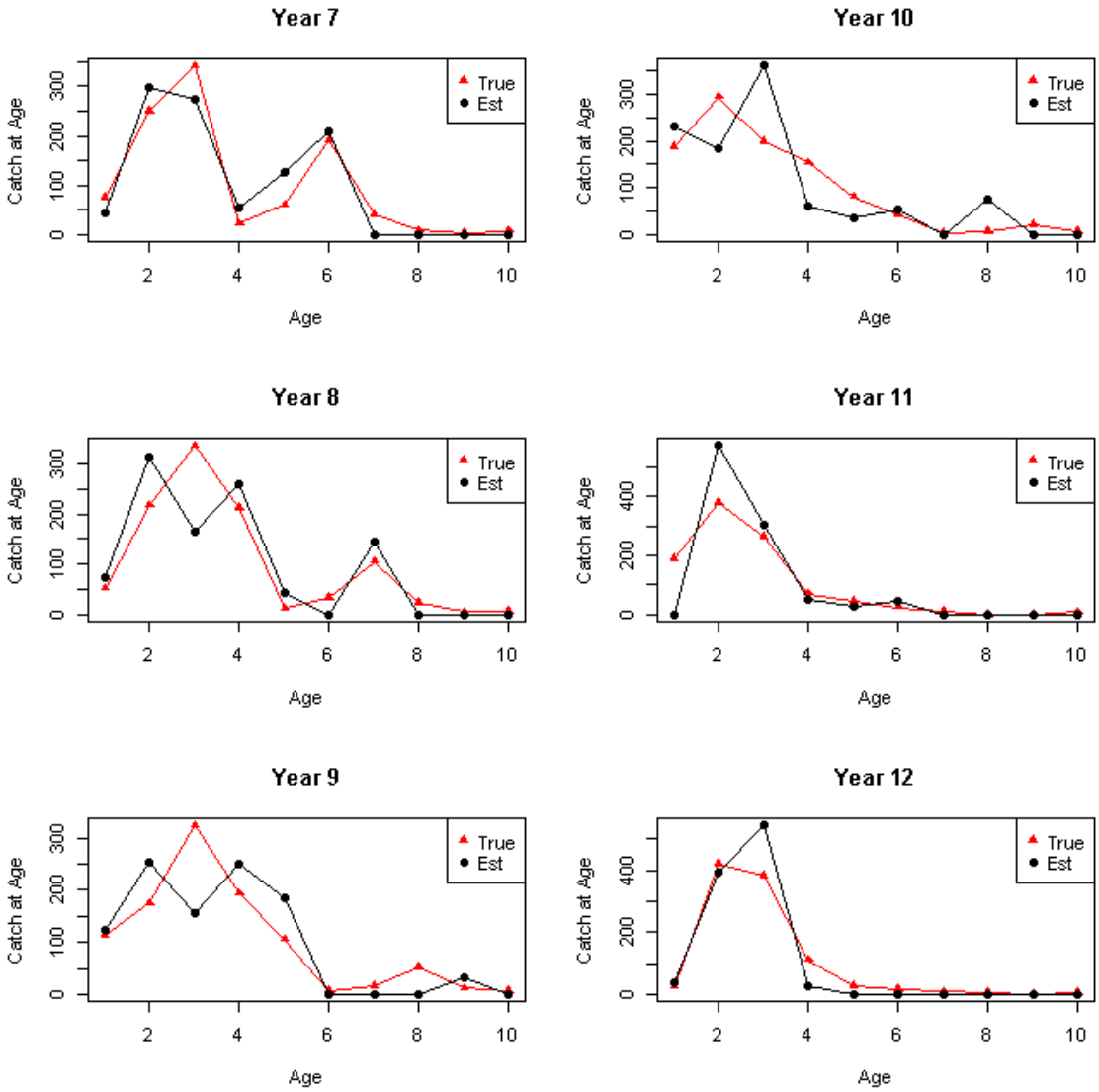
Appendix A8, Figure 2a. Size distributions of simulated population at years 1,5,10,15 and 20.



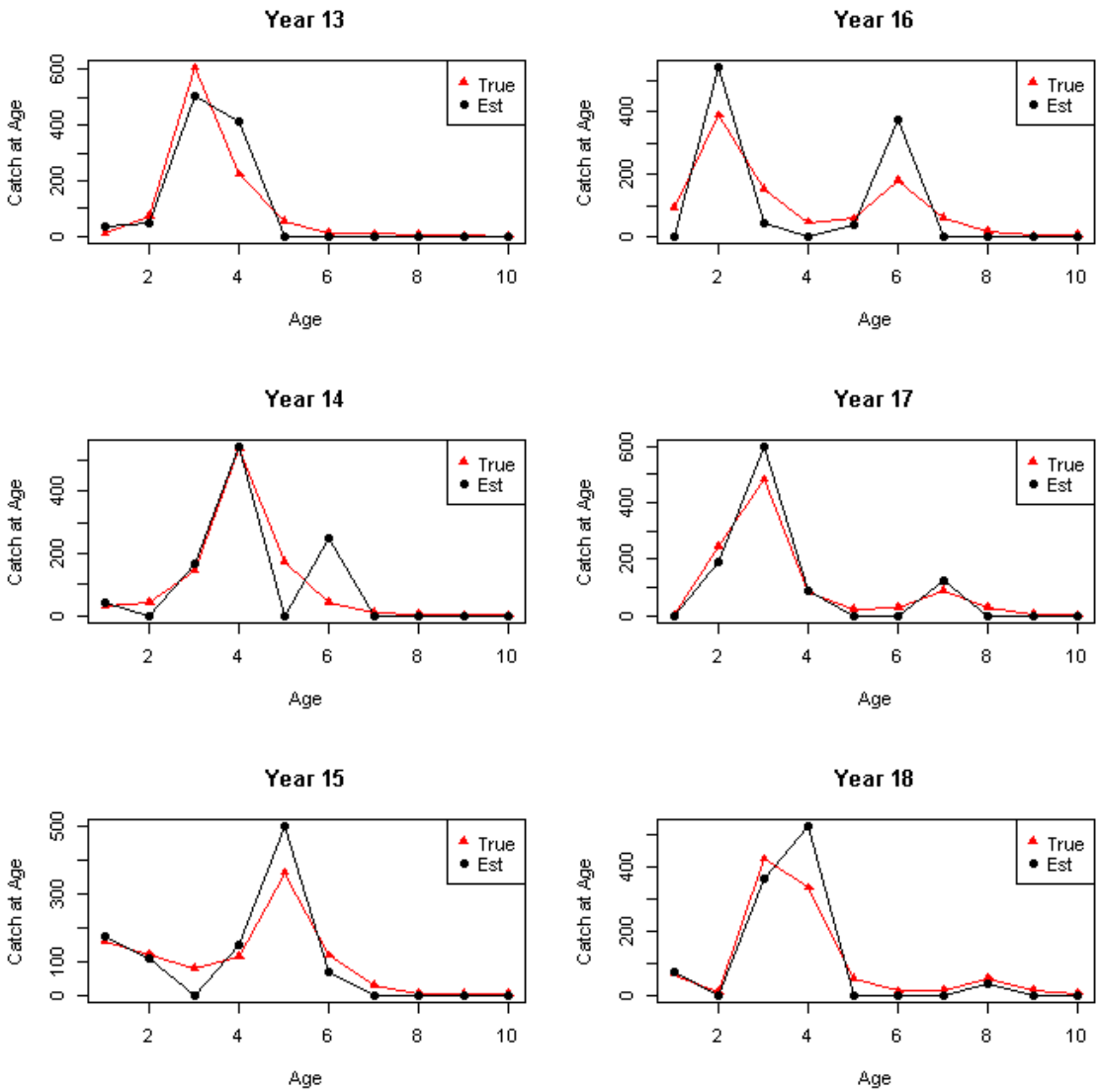
Appendix A8, Figure 3a. Mean age in the simulated catch based on 20 age samples compared to the true value.



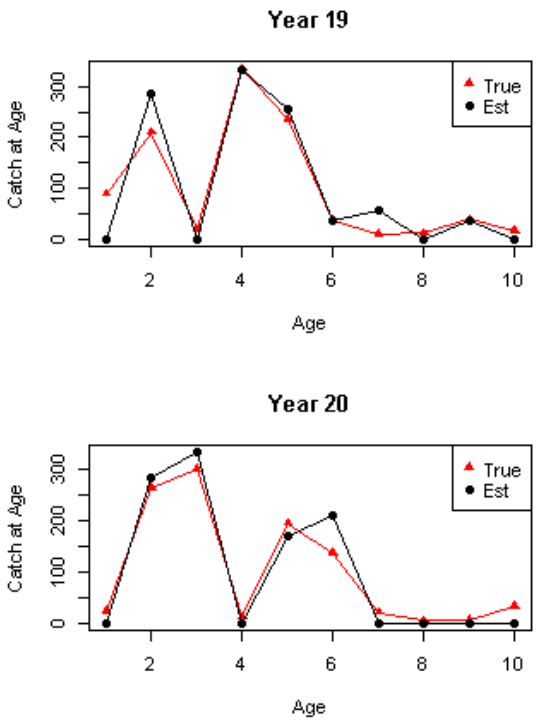
Appendix A8, Figure 4a. Age distribution of the simulated population for year 1 to 6 compared to the estimated age composition using an age sample of 20 fish.



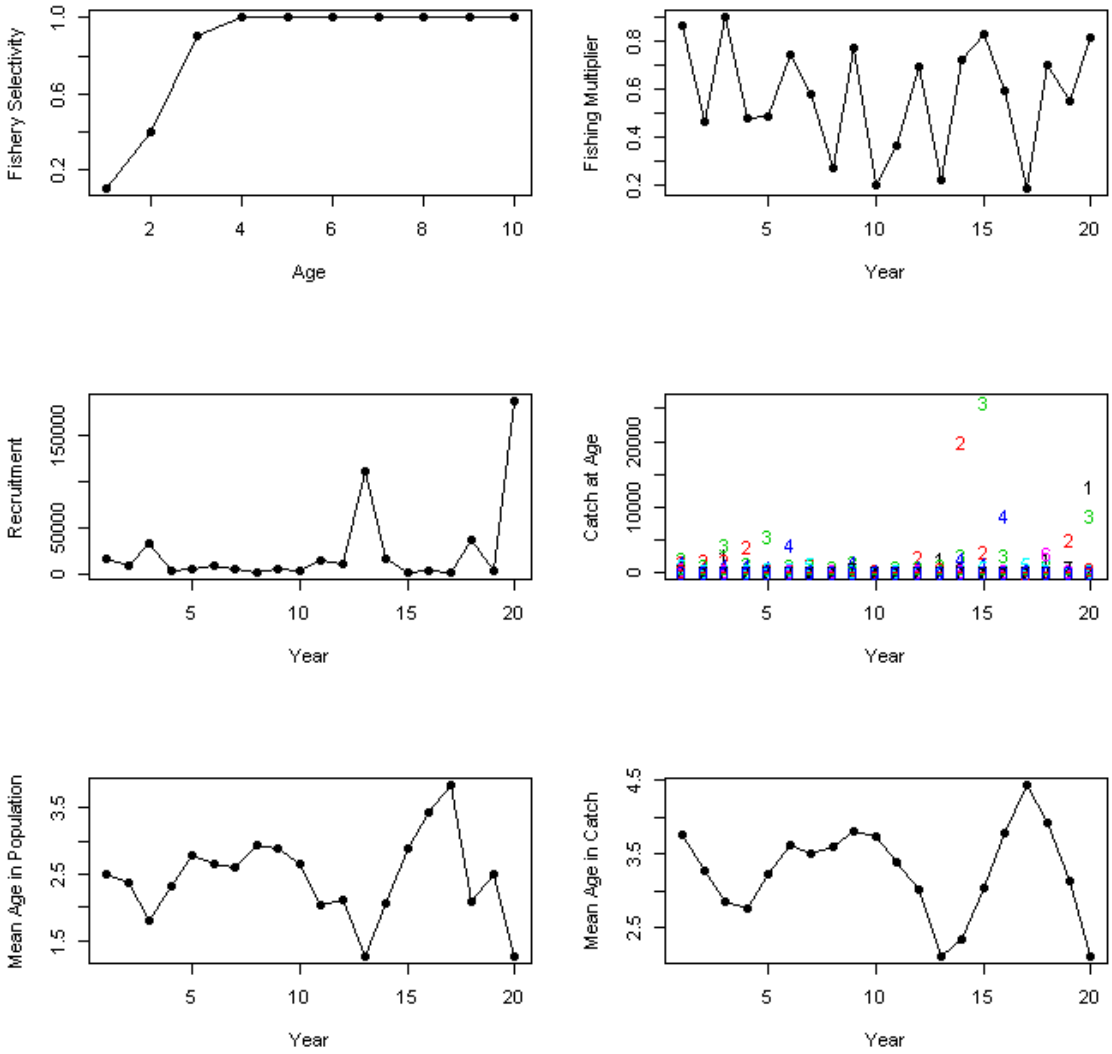
Appendix A8, Figure 5a. Age distribution of the simulated population for year 7 to 12 compared to the estimated age composition using an age sample of 20 fish.



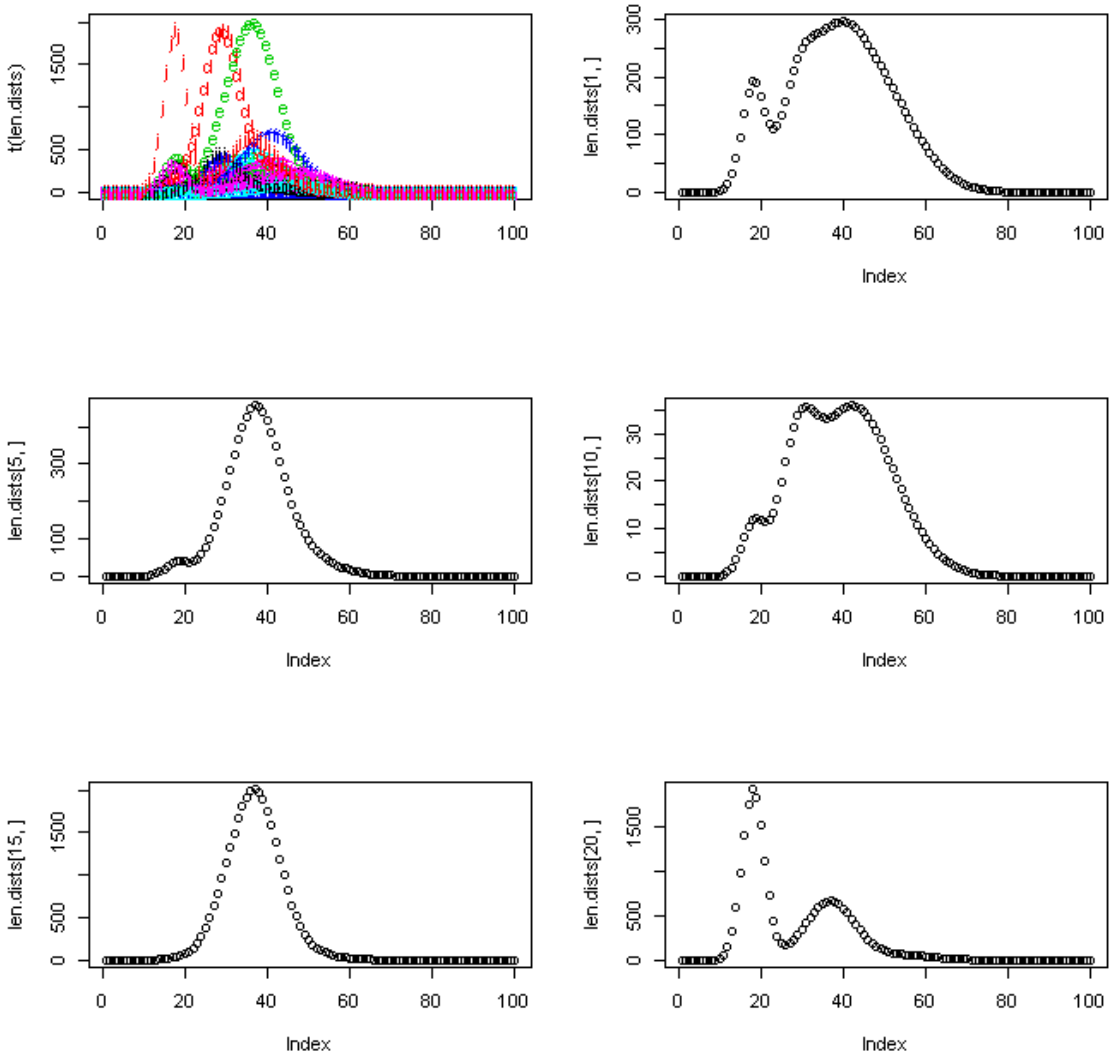
Appendix A8, Figure 6a. Age distribution of the simulated population for year 13 to 18 compared to the estimated age composition using an age sample of 20 fish.



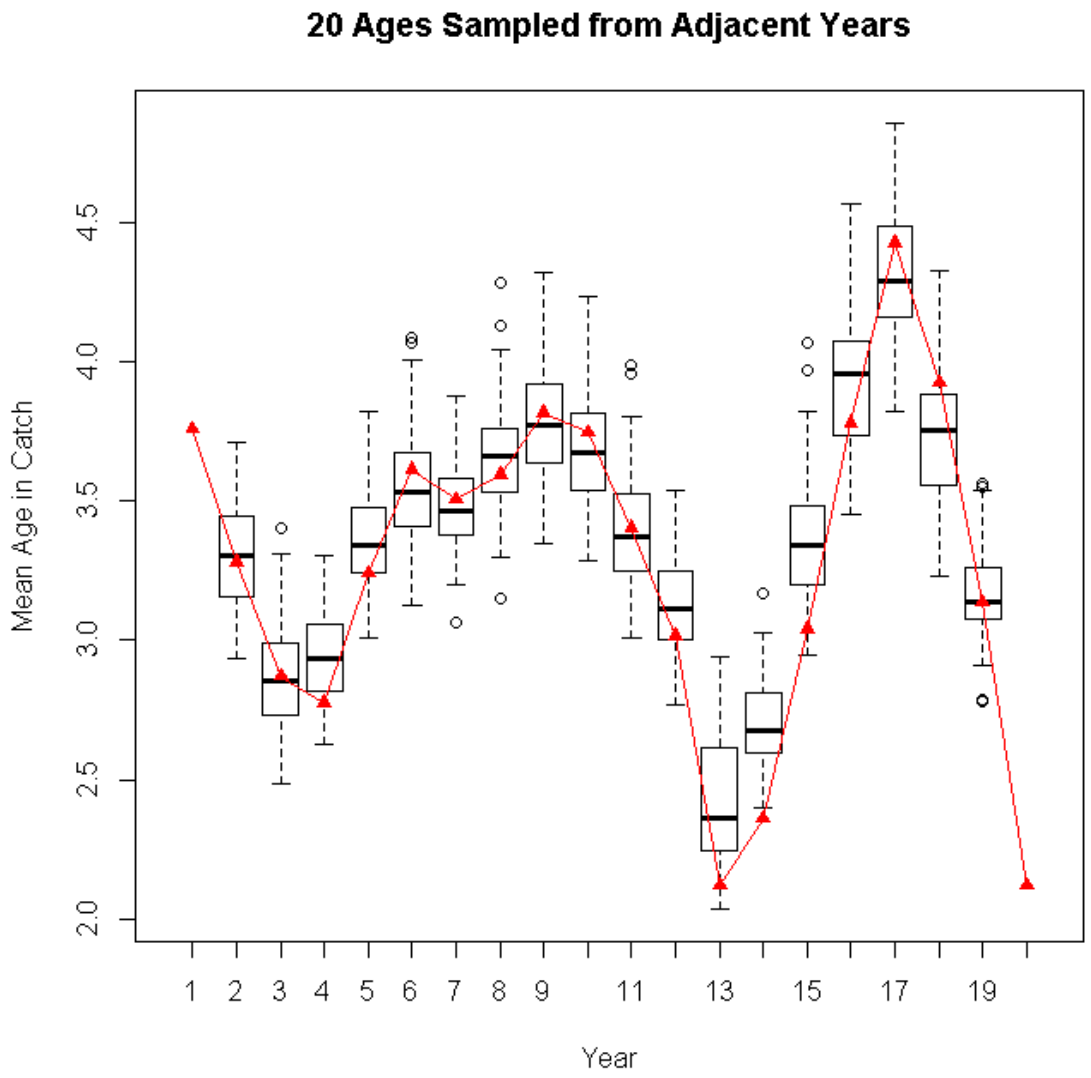
Appendix A8, Figure 7a. Age distribution of the simulated population for year 19 to 20 compared to the estimated age composition using an age sample of 20 fish.



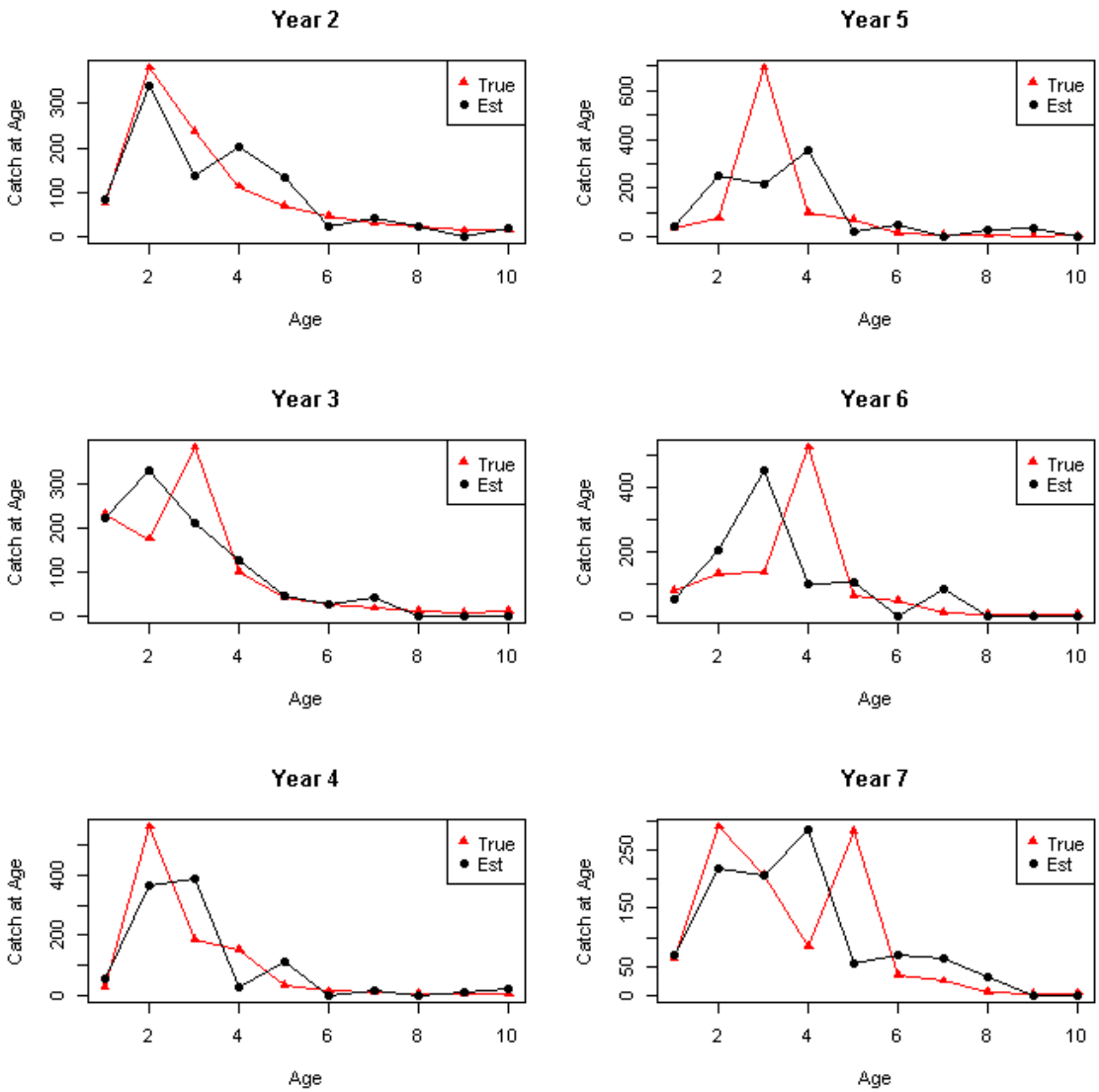
Appendix A8, Figure 8a. Fishery and biological characteristics of second simulated base population.



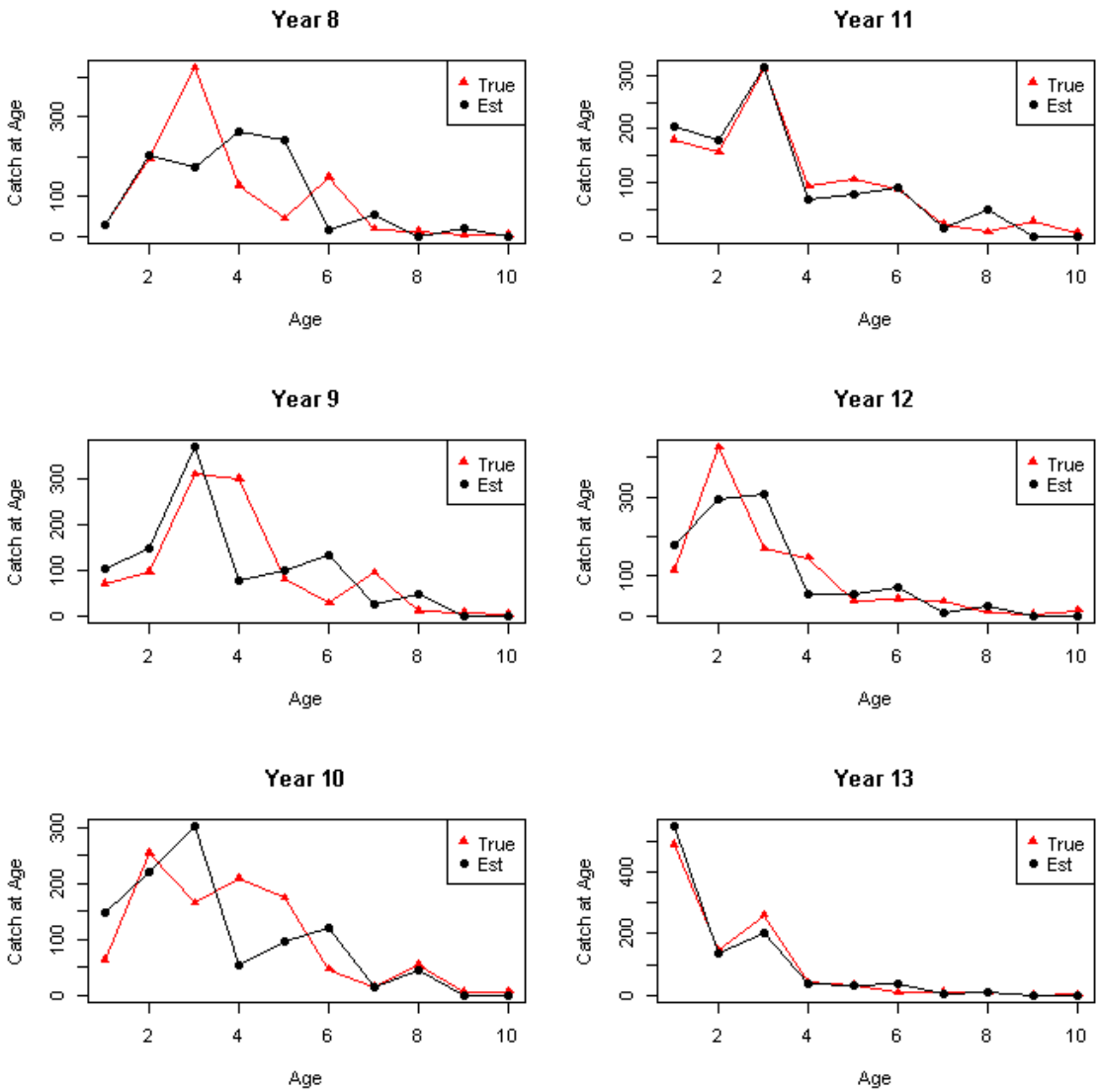
Appendix A8, Figure 9a. Size distributions of second simulated population at years 1,5,10,15 and 20.



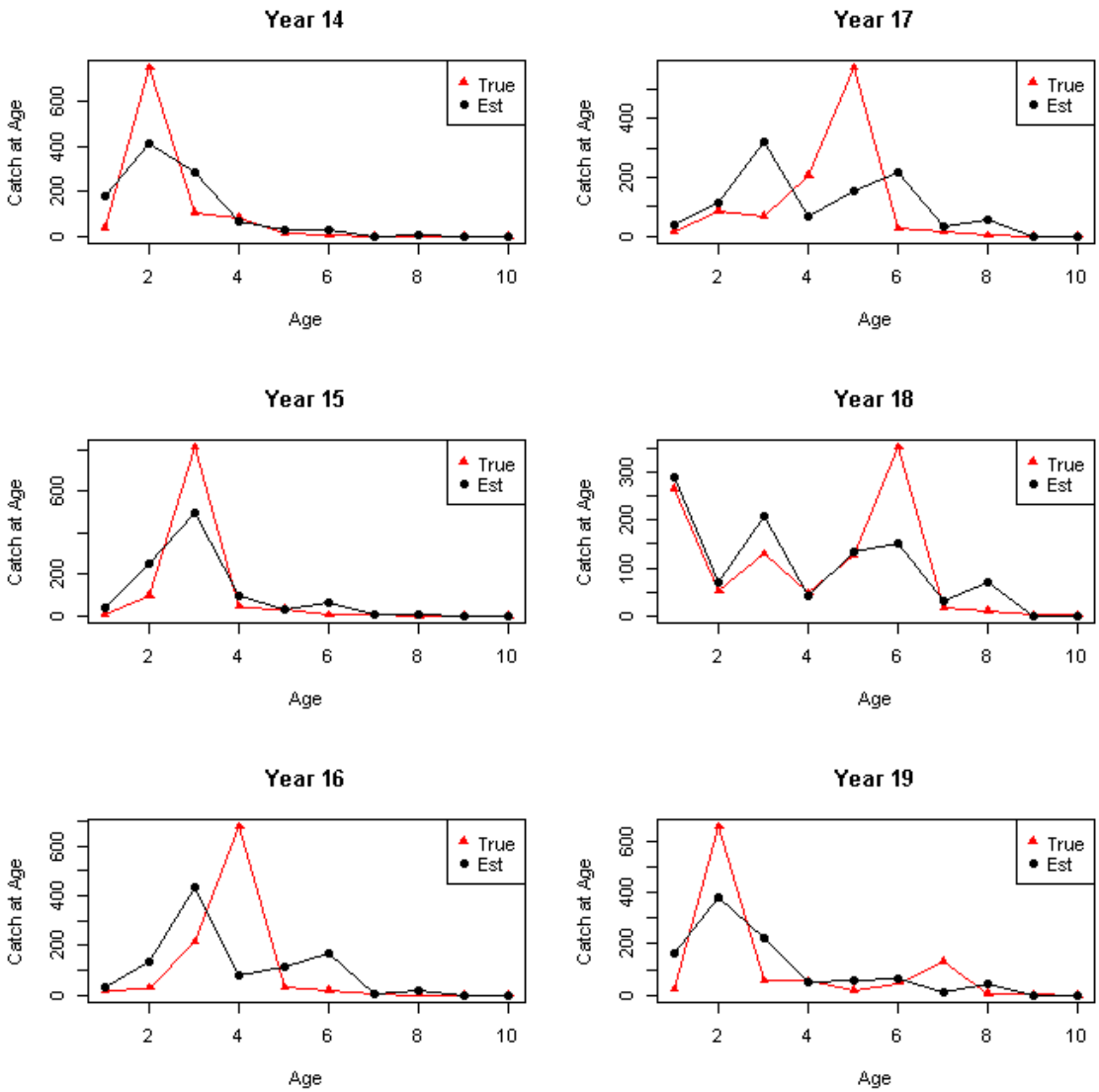
Appendix A8, Figure 10a. Mean age in the simulated catch based on 20 age samples sampled from adjacent years compared to the true value.



Appendix A8, Figure 11a. Age distribution of the simulated population for year 2 to 7 compared to the estimated age composition using an age sample of 20 fish from adjacent year.



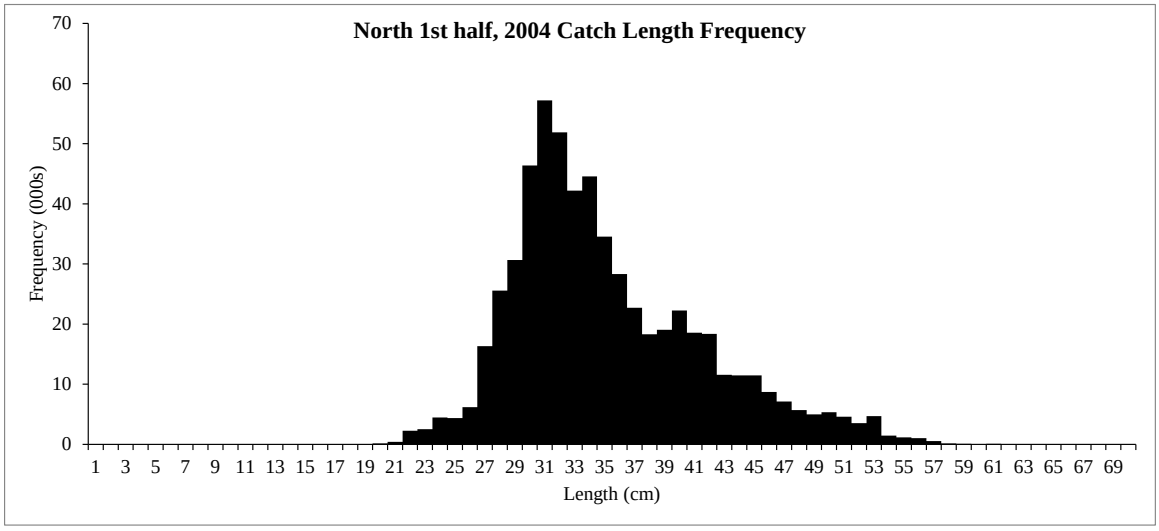
Appendix A8, Figure 12a. Age distribution of the simulated population for year 8 to 13 compared to the estimated age composition using an age sample of 20 fish from adjacent year.



Appendix A8, Figure 13a. Age distribution of the simulated population for year 14 to 19 compared to the estimated age composition using an age sample of 20 fish from adjacent year.

Further examination of effect on catch at age from combining adjacent year age data

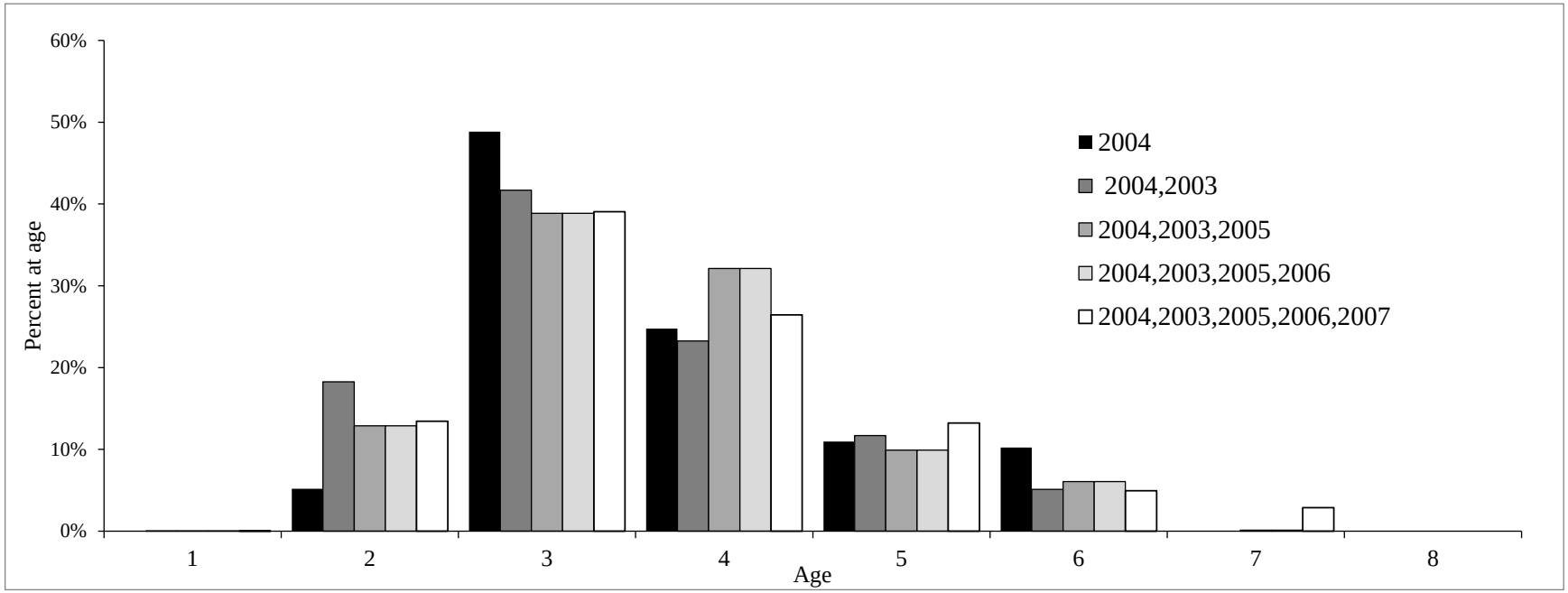
Due to a lack of age data for every year and season used in the black sea bass assessment, it was necessary to combine years to create adequate sample sizes. To examine the impact on the catch at age, two scenarios were considered. Using empirical black sea bass catch length data from spring 2004 and spring 2013, as series of age keys were applied. The base year age data was combined with adjacent years with an increasing series of years (i.e. ALK in year t, year [t ,t-1] year [t, t-1, t+1], etc.) The resulting catches at age were compared across a series of age key combinations. A simple chi test implies no significant differences between the base CAA proportion at age and subsequent scenarios. In the 2013 data, the original age data set sample size of 164 was more robust to additional age data than the 2004 data with the base year of only 22 fish. The WG concluded that although the addition of adjacent years age data had some effect on the CAA distribution, it was not enough to significantly change the perception of the catch age distribution.



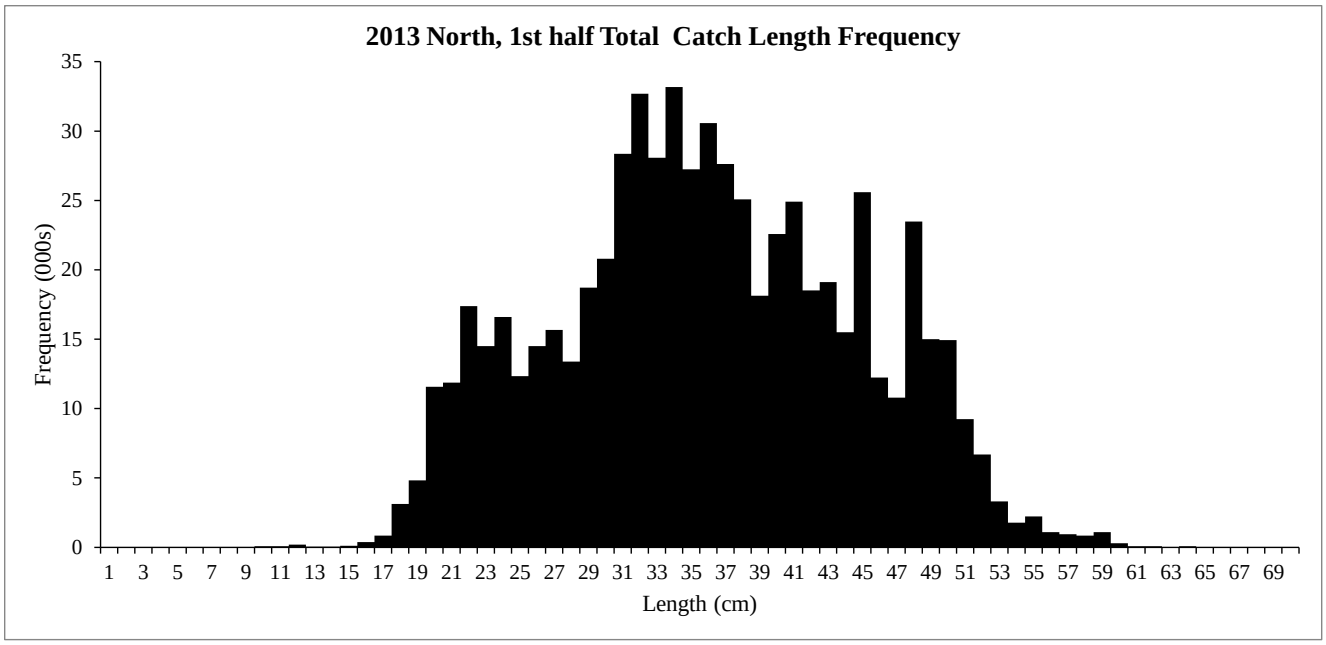
Appendix A8, Figure 1b. Length distribution of 2004 catch, January-June, from the north area. Alternative age keys were applied to the lengths to examine proportions at age.

Appendix A8, Table 1b. Age data scenarios applied to 2004 catch length distribution and resulting proportion at age.

Scenario	Percent at age in CAA Age1	Age2	Age3	Age4	Age5	Age6	Age7	ALK sample sizes	Total sample size	Chi- test PR
2004	0.0%	5.2%	48.8%	24.8%	11.0%	10.2%		22	22	
2004,2003	0.0%	18.3%	41.7%	23.2%	11.7%	5.1%	0.0%	49,22	71	0.99911
2004,2003,2005	0.0%	12.9%	38.9%	32.1%	9.9%	6.1%	0.1%	22,49,23	94	0.99989
2004,2003,2005,2006	0.0%	12.9%	38.9%	32.1%	9.9%	6.1%	0.1%	22,49,23,22	116	0.99989
2004,2003,2005,2006,2007	0.0%	13.4%	39.1%	26.4%	13.2%	5.0%	2.9%	22,49,23,22,74	190	0.99988



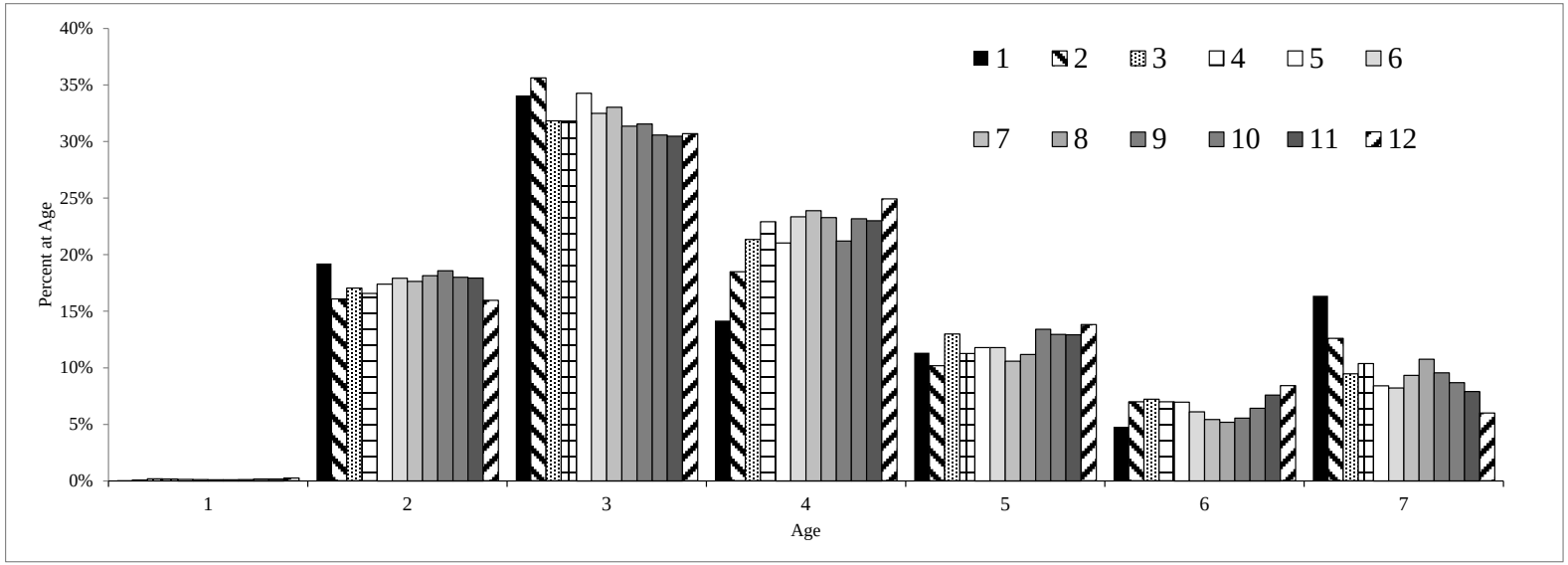
Appendix A8, Table 2b. Frequency distribution of catch age for 2004 with addition of age data from adjacent years.



Appendix A8, Figure 3b. Length distribution of 2013 catch, January-June, from the north area. Alternative age keys were applied to the lengths to examine proportions at age

Appendix A8, Table 2b. Age data scenarios applied to 2004 catch length distribution and resulting proportion at age.

Sceneario		Percent at age in CAA							total sample size	chi test
	2013 Base	0%	19%	34%	14%	11%	5%	16%	164	
1	avg with 2014	0%	16%	36%	18%	10%	7%	13%	742	1.00000
2	avg with 2012,2014	0%	17%	32%	21%	13%	7%	9%	990	0.99999
3	avg with 2011,2012,2014	0%	17%	32%	23%	11%	7%	10%	1092	0.99998
4	avg with 2010,2011,2012,2014	0%	17%	34%	21%	12%	7%	8%	1272	0.99999
5	avg with 2009,2010,2011,2012,2014	0%	18%	32%	23%	12%	6%	8%	1393	0.99998
6	avg with 2008, 2009,2010,2011,2012,2014	0%	18%	33%	24%	11%	5%	9%	1413	0.99998
7	avg with 2007,2008, 2009,2010,2011,2012,2014	0%	18%	31%	23%	11%	5%	11%	1487	0.99999
8	avg with 2006,2007,2008, 2009,2010,2011,2012,2014	0%	19%	32%	21%	13%	6%	10%	1509	0.99999
9	avg with 2005,2006,2007,2008, 2009,2010,2011,2012,2014	0%	18%	31%	23%	13%	6%	9%	1532	0.99997
10	avg with 2004,2005,2006,2007,2008, 2009,2010,2011,2012,2014	0%	18%	30%	23%	13%	8%	8%	1554	0.99996
11	2012,2014	0%	16%	31%	25%	14%	8%	6%	826	0.99986



Appendix A8, Figure 4b. Frequency distribution of catch age for 2004 with addition of age data from adjacent years.

Appendix A9 – Black sea bass exploratory Stock Synthesis model

The following Appendix is the results of a Stock Synthesis model for black sea bass prepared as a working paper. The model and results were not fully reviewed by the BSB Working Group or CIE reviewers. Therefore it is presented here as an exploratory model to support the results of the black sea bass assessment.

SAW62 Black Sea Bass Model Meeting Working Paper

Stock Synthesis Application to Black Sea Bass

Gavin Fay[1], Jay McNamee[2] and Steve Cadrin[1]
[1]*University of Massachusetts Dartmouth, School for Marine Science & Technology*
[2]*Rhode Island Department of Environmental Management*

November 8 2016

Abstract – Stock Synthesis (SS) was applied to the fishery and survey as specified by the SAW62 Black Sea Bass Working Group as well as the available tagging data to estimate stock size and fishing mortality. The SS model was structured spatially (north and south of a boundary near Hudson Canyon), seasonally, by fleet and demographically by length, age, and sex. The model fits available fishery, survey and tagging data relatively well. Results suggest that the stock has increased in the last decade from strong recruitment, fishing mortality decreased to relatively low values in the last decade, selectivity of all fleets shifted to older ages after the 1997 management actions, and seasonal movement rates between regions is relatively low. Sensitivity analyses indicate that these results are robust to alternative model configurations.

Introduction

The SARC 53 Review Panel "*identified substantial concerns over the potential for spatial structure and incomplete mixing within the stock area that compromised the ability of the forward projecting catch at age model to index abundance and fishing mortality reliably based on the data available*." (NEFSC 2012). In response to this concern, an initial SAW62 term of reference was to evaluate the distribution, movement and potential for spatial structure of the stock, the ability of existing data to support alternative spatial structure, and their consequences for the stock assessment. The SAW62 Black Sea Bass Working Group reviewed the information available and reached a consensus that the most reasonable response to the Term of Reference was to consider a spatial boundary near Hudson Canyon for assessment model development and simulation testing, which reflects a natural discontinuity in spatial processes in the black sea bass resource. A Mid Atlantic Fishery Management Council Review Panel concluded that "this separation is reasonable and appropriate to use as a starting point for developing stock assessment models."

The revised SAW62 Terms of Reference include:
ToR1: Summarize the conclusions of the February 2016 SSC peer review regarding the potential for spatial partitioning of the black sea bass stock. The consequences for the stock assessment will be addressed in TOR-6.
ToR6: Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock), using measures that are appropriate to the assessment model, for the time series (integrating results from TORs-1,-4, & -5 as appropriate), and estimate their uncertainty. Include a historical retrospective analysis and past projection performance evaluation to allow a comparison with most recent assessment results.

The Mid-Atlantic Council solicited research for "Development of a Quantitative Stock Assessment for Black Sea Bass" (request for proposals May 2015), specifically to participate in the development of a new quantitative stock assessment for BSB which addresses the concerns raised about the stock assessment model developed for review at SARC53 and to work collaboratively with stock assessment scientists at the NEFSC and the ASMFC Technical Committee to facilitate the development of a stock assessment model which will ultimately form the basis for setting annual catch limits for BSB, including forward projecting statistical catch-at-age and catch-at-length models.

We collaborated with stock assessment scientists at NEFSC, ASMFC and MAFMC SSC to develop and test the performance of a set of alternative configurations of statistical catch at age estimation models for black sea bass using Stock Synthesis (SS).

Methods

The analytical approach uses Stock Synthesis (SS v3.24Z, Methot & Wetzel 2013) as a platform for developing and testing alternative spatiotemporal configurations of an estimation model for black sea bass. SS is a flexible statistical catch at age framework that among other features has the ability to handle spatial and seasonal structure in population and fishing dynamics, is flexible in the parameterization of life history characteristics (e.g., hermaphroditism), allows for mirroring of parameters such as selectivity among fishing fleets (which will aid design of the various model configurations), and can fit to size composition and tag-recapture data in addition to age structure and abundance indices. Standardized diagnostic plotting package in R (r4ss) allows for rapid comparison of model results between assessment runs.

The '2-area' estimation model was developed to condition an operating model for simulation testing (see Fay et al. SAW62 WP on simulation). The model consists of a spatially structured seasonal population model. The model contains two areas, north and south, aimed to characterize sea bass populations north and south of Hudson canyon. The model has two seasons, spring (season 1), and fall (season 2), each of equal length (6 months duration).

A single stock of Black Sea bass is modeled, with a single stock recruit relationship. Recruitment of age 0 fish occurs at the start of season 2, and is allocated spatially to both areas. The proportion of fish recruiting to area 1 is allowed to vary over time so spatial differences in year class strength can be represented. Overall recruitment follows a Beverton Holt relationship with steepness set to 0.95 and a standard deviation for the annual recruitment deviations from this relationship of 0.7, as assumed for previous assessments. However, there is some evidence that recruitment is more variable.

The modeled population age range is from 0-15, with 15 being a plus group (data generated are modeled according to fewer age bins). Length structure of the population is modeled in 2cm bins, with the smallest bin being of length 2-4cm, and the largest being fish 70-72cm. This upper bound is larger than observed fish because it is necessary to appropriately capture the distribution of length at age for the oldest fish (I.e. fish of length close to L infinity_) so that

growth for these fish is calculated correctly. Growth parameters are assumed to be the same for both seasons, though a separate weight-length relationship is assumed for each season.

Both males and females are modeled, with hermaphroditism being modeled explicitly according to sex change rate parameters at age determined by Jensen (pers. Comm). At recruitment, 63% of fish are assumed to be female. The rate of sex change is not assumed to vary over time. Two growth patterns are modeled to represent possible regional differences in growth north and south. Recruits are assigned to growth patterns by spatial location of recruitment (all fish recruiting in the north are assigned growth pattern 1). Growth is modeled according to a von Bertalanffy growth curve, with separate a0 parameters north and south, and separate k parameters for both sexes of each growth pattern. L infinity and variability in length at age is assumed to be the same for each growth pattern and for both sexes. The CV of length at age is assumed to decrease linearly with respect to mean length age. Full estimation of separate growth parameters by sex and growth pattern are possible in SS, the choices made here reflect pragmatic choices based on initial fits to available data, but modeling of growth could be further considered.

Movement between areas is modeled to represent offshore mixing during the winter. At the end of season 2, a fraction of fish in growth pattern 1 (northern fish) move from North to the Southern area. At the end of season 1, a fraction of growth pattern 1 fish move from the South to the North (This rate is ostensibly very high to 'force' fish back to their natal inshore area, however there have been some recaptures of north released fish in south inshore region and so the fraction remaining is modeled to be non-zero). The two movement rates are modeled as being constant for all years and ages.

Twelve fishing fleets are modeled to accommodate gear, spatial, and seasonal differences in availability. 3 gear types are modeled, commercial trawl, commercial non-trawl, and recreational fishing (all gears combined), with fleets then being split by area (north and south), and by season (1 and 2). Selectivity of each fleet is modeled separately as a function of length, with the trawl and recreational fleets having a logistic (flat-top) selectivity, and the non-trawl fleets allowing for dome shaped selectivity via a double normal pattern. Selectivity for each fleet is modeled to vary over time by assuming a selectivity block between 1997 and 1998 (to reflect coast wide management changes). Retention is assumed to follow a logistic curve for each fleet, with a block change in 1997/1998, and annual deviations in the pattern to reflect both size-based changes and other drivers in discarding rate. The retained catch of commercial fleets is evaluated in biomass, whereas the recreational fleets are modeled in numbers.

The model is started in year 1989, reflective of availability of removals data for all fleets. An initial fishing mortality is assumed for each fleet based on an annual retained catch set equal to the average retained catch by fleet for the period 1989-1993. The age structure of the population is also modeled to not be in equilibrium by modeling annual recruitment deviations to 1984.

The 2-area estimation model was fit to available data for Black Sea bass for the years 1989-2016, based on the SAW62 Black Sea Bass Data and Model Workshop decisions. The data included in the revised model were:

1. Retained catch by year for all fishing fleets,
2. Discard observations (in either biomass or numbers) for each fleet for those years and seasons when these data were available,
3. Length compositions of the retained catch for each fleet,
4. Length compositions of the discards for each fleet,
5. Commercial age-at-length compositions by area and season,
6. Survey indices of abundance (details of various surveys below),
7. Survey length compositions by sex,
8. Survey age-at-length compositions by area and season (pooled with commercial data), these ages came from the NEFSC Spring and Fall bottom trawl surveys, and the Massachusetts spring and fall trawl surveys.
9. Tag recapture data from 2002-2004 releases.
10. Age imprecision matrices (by season) based on NEFSC multiple reads (fixed inputs).

Fishery independent surveys and fishery catch rates:

1. NEFSC Spring Bottom Trawl Survey, North
2. NEFSC Spring Bottom Trawl Survey, South
3. NEFSC Winter Bottom Trawl Survey, South
4. NEAMAP Spring Survey, North
5. NEAMAP Spring Survey Age 1, South
6. Massachusetts Spring Trawl survey (North), Age 1+
7. Rhode Island Spring Trawl survey (North), Age 1+
8. Connecticut Spring Age 1 (North), Age 1+
9. New York Spring Age 1 (North)
10. New Jersey Spring Trawl survey (South), Age 1+
11. Delaware Spring Age 1 (South)
12. Maryland Spring Age 1 (South)
13. Recreational CPUE Spring, North
14. Recreational CPUE Fall, North
15. Recreational CPUE Spring, South
16. Recreational CPUE Fall, South

A correction was made to the VIMS Age 1 series after the model workshop, so the series was excluded from this demonstration. Selectivity for all surveys was modeled with a double normal selectivity pattern, allowing for the possibility of dome-shaped selectivity. Power parameters for the relationship between the index and vulnerable biomass (or numbers) were estimated in some scenarios to reflect non-linearity in this relationship, associated with structure-oriented behavior that might result in trawl surveys being not fully effective at providing an index of abundance (Hyper depletion scenario). The model assumed linearity in the relationship between changes in the index and abundance for all surveys.

A minimal amount of adjustments (decreases) to sample size of composition data was made to roughly equate input multi nominal sample sizes with model suggested effective sample size. As much as possible, disaggregated data that were available for Black Sea bass were used (rather than using pooled/aggregated data). Raw estimates of CV and sample size were used when available. Index data for which these were not available were initially assigned a CV of 30%, composition data were assigned an initial sample size of 25 (some of these were adjusted downwards as noted above).

Age-1 surveys were modeled with age-based selectivity, set to 1 for age 1 and 0 for all other ages. The age-1 indices are typically over-dispersed, with zero values. Two approaches were explored: 1) using the raw indices and 2) age-1 indices were converted to z scores, then exponentiated, and the exp(z) modeled as log-normal.

Several SS configurations fit the available date similarly. The configuration selected for demonstration (run 164) reflected all of the data decisions from the Working Group (except the VIMS survey was excluded because of a late correction to the data), fit to observed survey values, assuming linear survey catchability, estimating recruitment deviations since 1987 and estimating deviations in the asymptote of retention functions.

- Run 165 estimated recruitment deviations since 1984.
- Run 166 estimated power parameters for age-1 survey catchabilities.
- Run 167 estimated power parameters for catchabilities of age-1 surveys and recreational CPUE.
- Run 168 estimated power parameters for all catchabilities.
- Run 169 included all available surveys with power parameters for all catchabilities.
- Run 170 estimated deviations in the inflection point of retention functions.
- Run 171 fit to z-score transforms of survey observations to include zeros.

Results

The model generally fit the available data well, with some exceptions. Discards were estimated within the confidence limits of empirical estimates (Figure 1), with a few exceptions (e.g., some recreational fishery discards). The model fit most trends in survey and CPUE indices (Figure 2), with some exceptions (e.g., large positive residuals in some northern surveys in some recent years). The model fit the primary length modes well (e.g., Figure 3), but some discard and survey length distributions did not fit as well, usually associated with low sample sizes. The model fit age-at-length well (Figure 4). The model fit tag recaptures relatively well (Figure 5).

Estimates of spawning biomass (males and females) show different trends in each region (Figure 6). Northern biomass generally increasing since the late 1990s to a peak of 10kt in 2014, followed by a decrease to 7kt in 2016. Southern biomass increased in the late 1990s to 7kt in 2004, decreased in the late 2000s, then increased to 4kt in 2016. Estimates of fully-recruited fishing mortality (ages 4-7) were relatively high (>0.4) in the 1990s, decreased in the 2000s to 0.2 to 0.4 since 2009 (Figure 7). Estimates of selectivity indicate selectivity on older ages after 1997 in all fleets (Figure 8; note that only female selectivities are plotted, but males and

females are assumed to have the same size selectivity). Estimates of recruitment were different between areas, with strong recruitment in the south in 199 and 2000, but strong recruitment in the north in 2011 (Figure 9). The stock-recruit relationship suggests wide variation but no trend in recruitment in the estimated series of spawning biomass (Figure 9). The estimate of annual movement rates of northern fish to the south in the fall and from the south to the north in the spring were low (11%). Growth estimates are presented in Figure 10. Sensitivity analyses produced similar general results, except that run 165 (recruitment deviations since 1984) produced greater estimates of recent stock size and (Figure 11).

Discussion

The SS applications indicate that the spatial, seasonal, length, age, sex, fleet structured model fits the available data well. All SS explorations indicate that the stock has increased in the last decade in both areas from strong recruitment, fishing mortality decreased to relatively low values in the last decade, selectivity of all fleets shifted to older ages after the 1997 management actions, and seasonal movement rates between regions is low. Results are similar to the regional ASAP analyses, which provide a more parsimonious modeling approach.

As noted by the Working Group, the indices of abundance in the north are much more coherent than those in the south. Consequently, models appear to fit the northern data better, because there is less conflict. This coherence is partly due to the very large year class in 2011 in the north, which shows up in all data streams and is tracked through time in the abundance index and length compositions.

Several of the northern survey indices are estimated to have a non-linear relationship with abundance. All the age-1 indices are estimated to have high values for the power parameter (indicating hyperdepletion). This result is partly due to the high over dispersion of these indices that include zero values rather than a true non-linear relationship (i.e., an incorrect observation model is being used for these data, options are limited to lognormal or normal).

Adding time varying discarding rate provides flexibility for the model to fit the discard data, which is relatively uncertain. Model fits from a time-invariant asymptotic discard rate are similar. The most temporally variable discards appear to be from the southern trawl fleet in spring, for which the model estimates large changes in the retention parameters to fit the discards. Consequences of modeling discards this way is that the model sometimes estimates relatively high fishing mortality in some years resulting in large decreases in biomass that are not immediately apparent in the index data. Without time varying discard, it is not possible for the model to estimate increases in discards in the north in recent years.

There appears to be evidence for growth differences north and south, at young ages. This is most reflected in the NEFSC spring bottom trawl survey, where age-1 fish in the north are approximately 2cm larger than those in the south. When estimating growth, model fits suggest a lower maximum length than assumed in previous assessments (L infinity ~55cm), attributing larger fish to the variability in length at age.

Simple assumptions were made regarding the timing of surveys and fishery catches (i.e., all take place in the middle of the season). This is a simplification of the actual timing of these data (e.g., Many of the inshore catch in season 1 is caught in the last 2 months of the semester, similarly much of the catch in season 2 is caught early in the semester). These differences in timing could influence the estimation of growth, particularly emphasized due to the seasonal growth pattern whereby age 0 fish in the fall are essentially the same size as age 1s in the spring. This is also the case for older ages but is less pronounced. This issue will warrant consideration in size-based approaches to modeling Black Sea bass. To reduce the influence of new recruits on the estimation of growth, we removed age 0 fish from the fall age data and set selectivity for the fall age at length data to 0 for age 0.

Acknowledgments
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Methot, R.D. Jr and Wetzel, C.R. 2013. Stock Synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fish Res 142: 86–99.

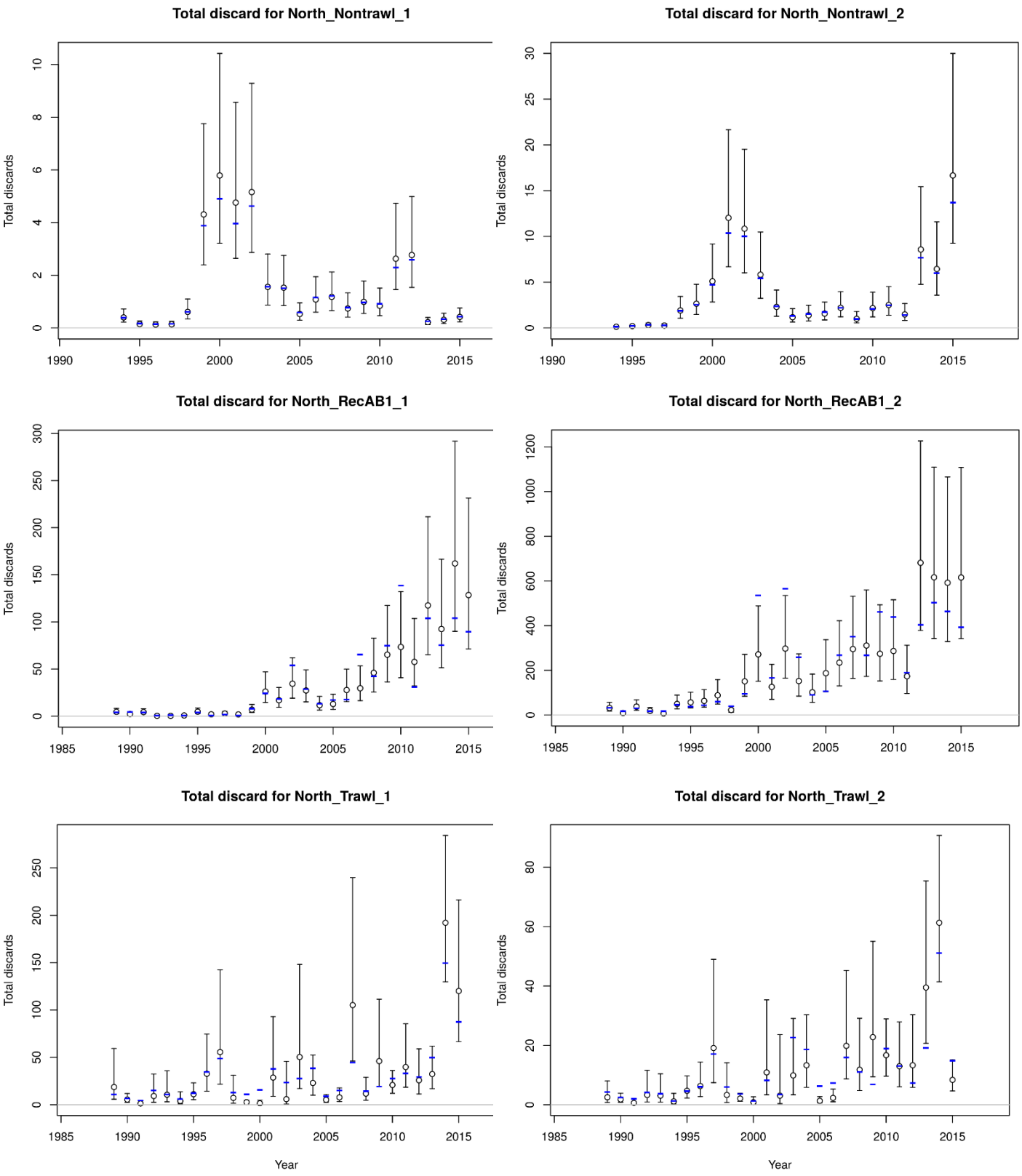


Figure 1. Estimates of discards from data (circle and error bar) and model (blue marker) by fleet (rows) and season (columns: spring, left; fall, right) from SS.

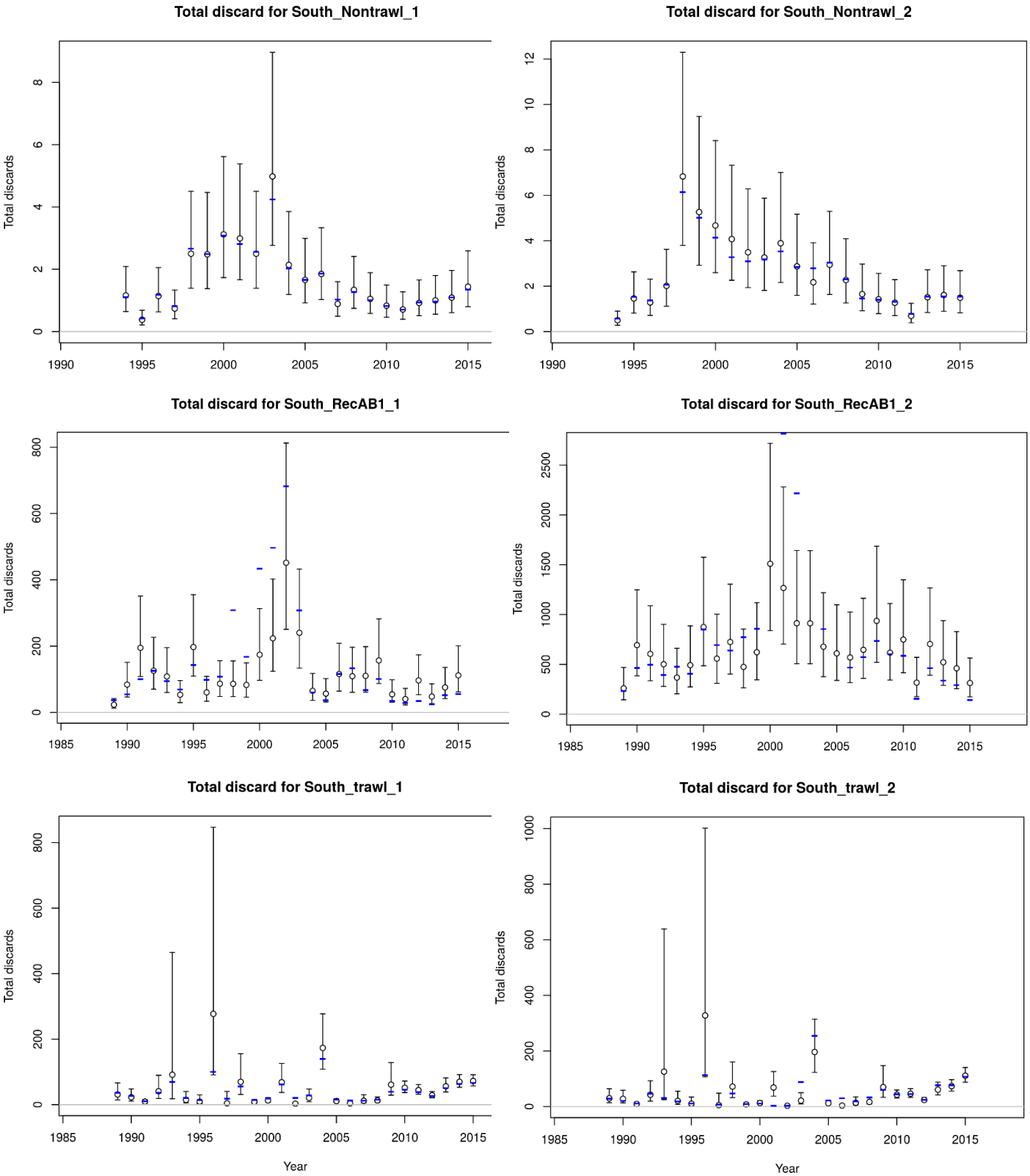


Figure 1 continued. Estimates of discards from data (circle and error bar) and model (blue marker) by fleet (rows) and season (columns: spring, left; fall, right) from SS.

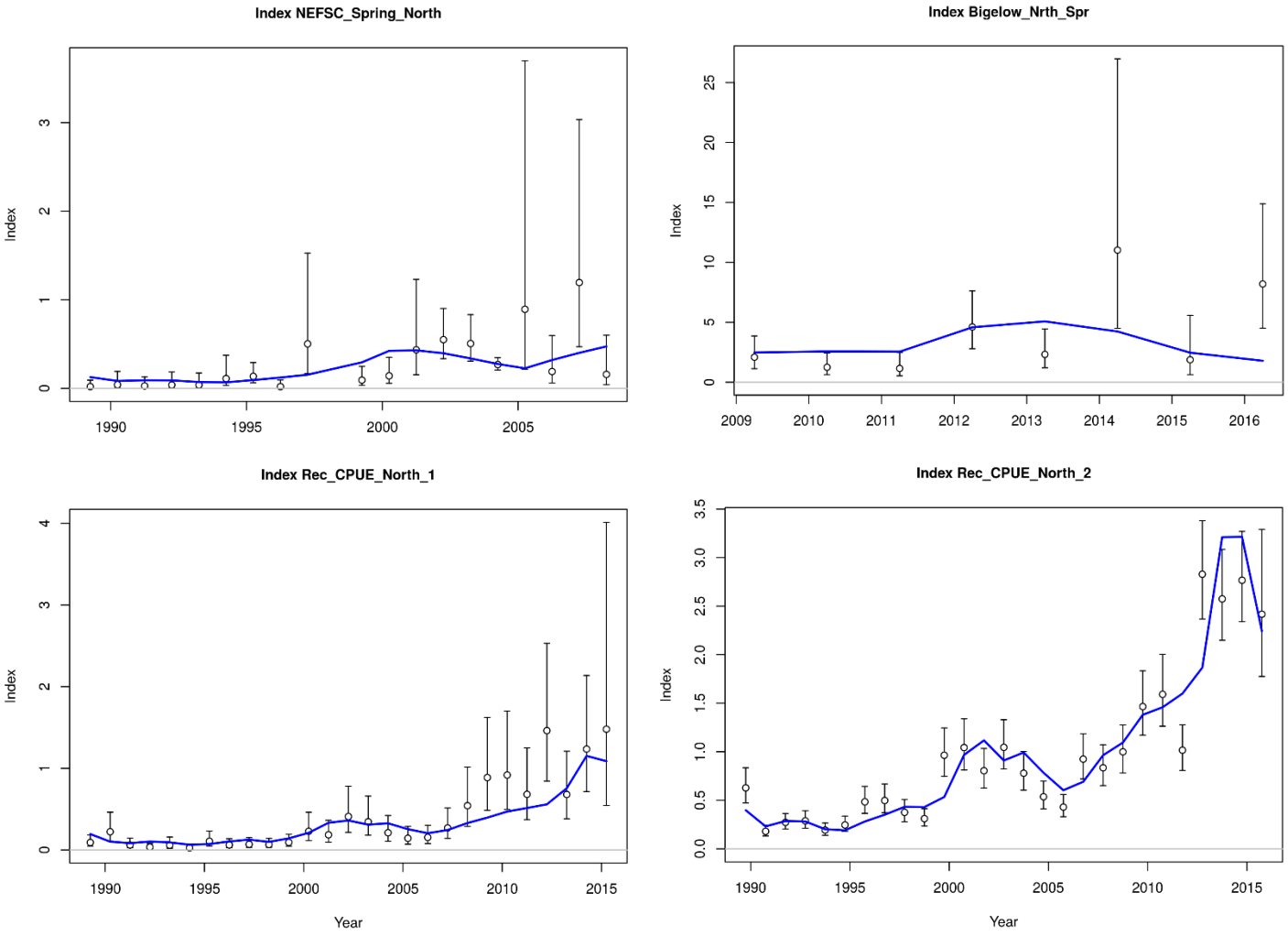
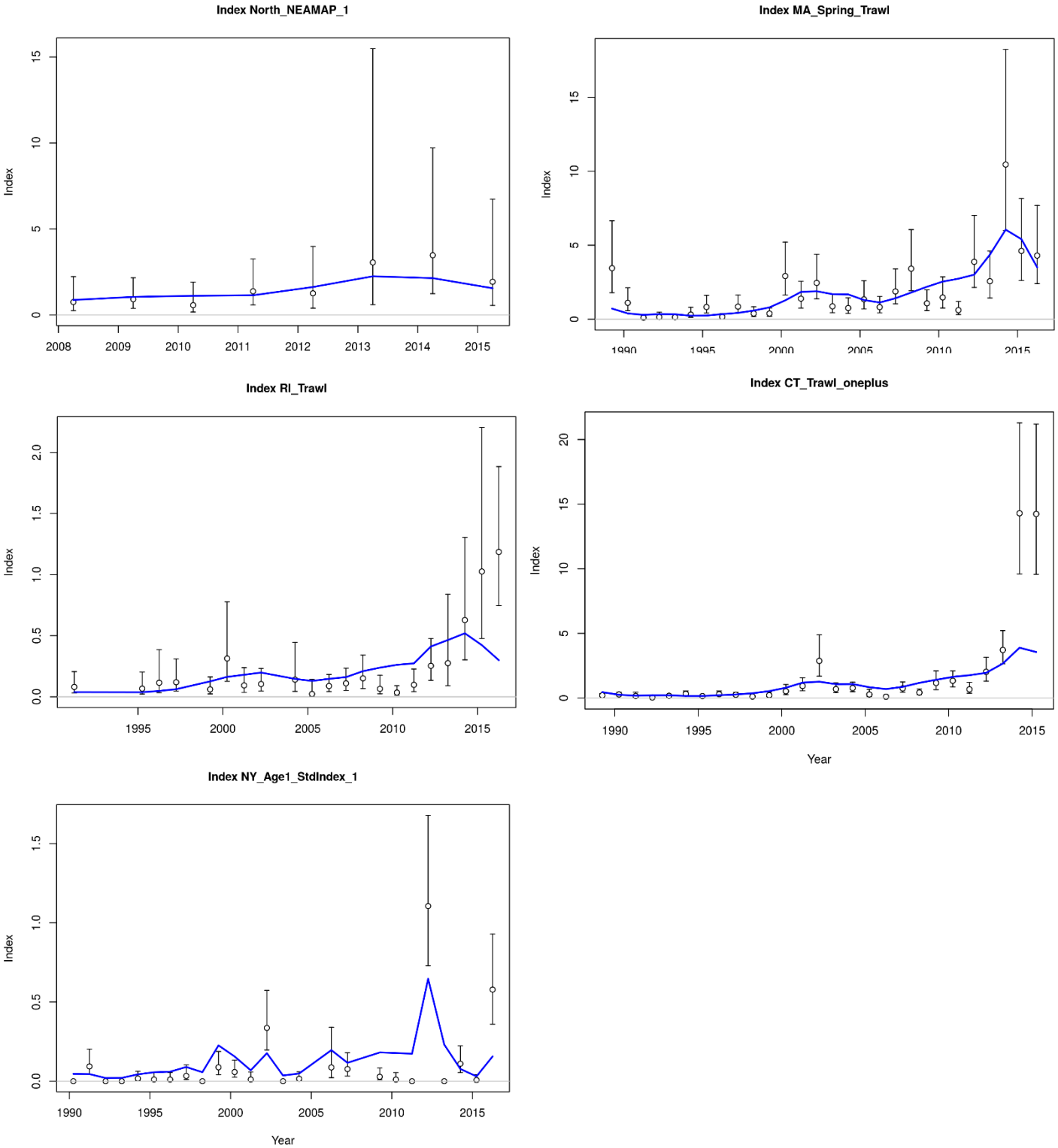


Figure 2. Survey and CPUE indices, observed (circles and error bars) and predicted (blue line), from SS.



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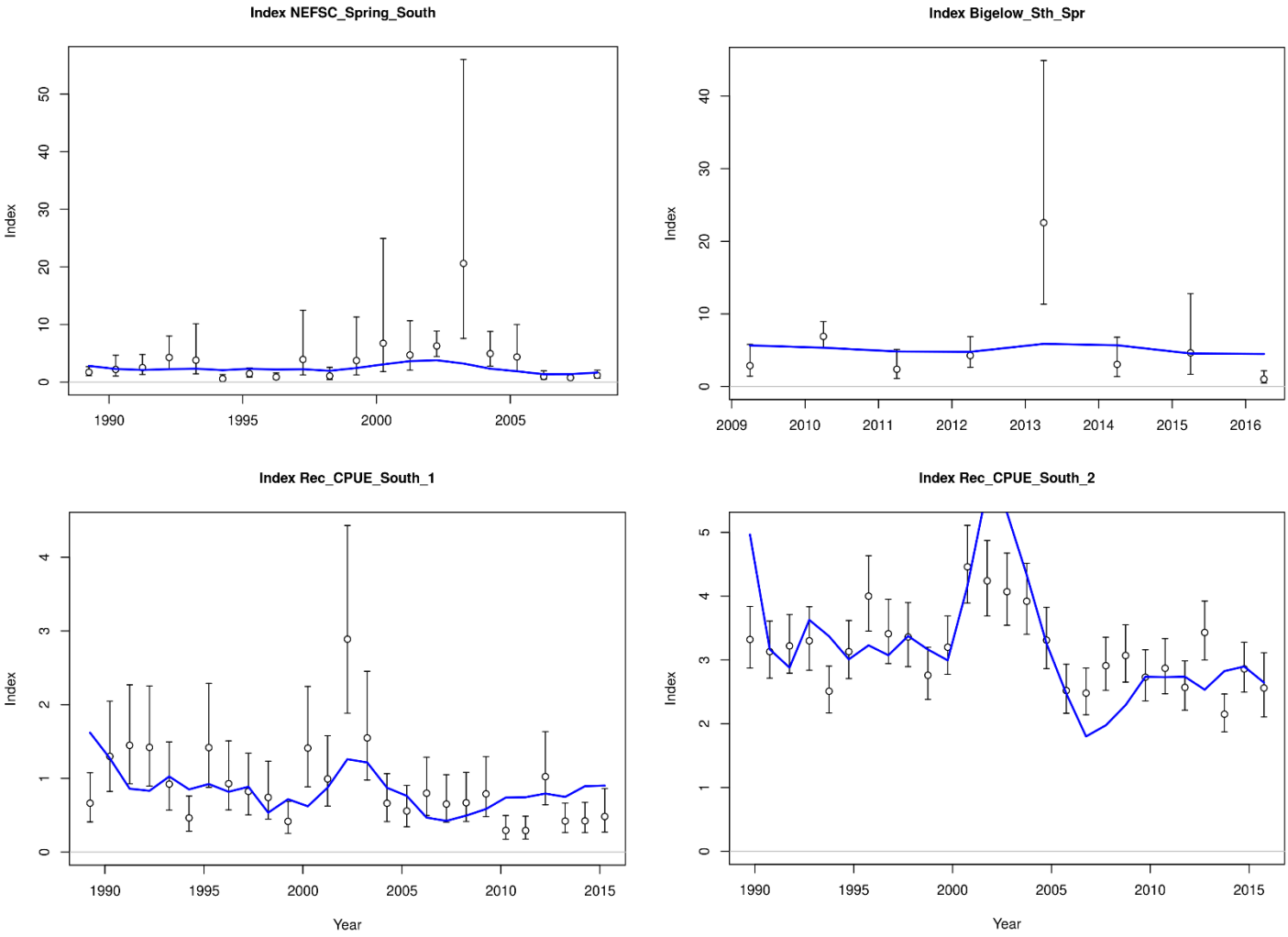

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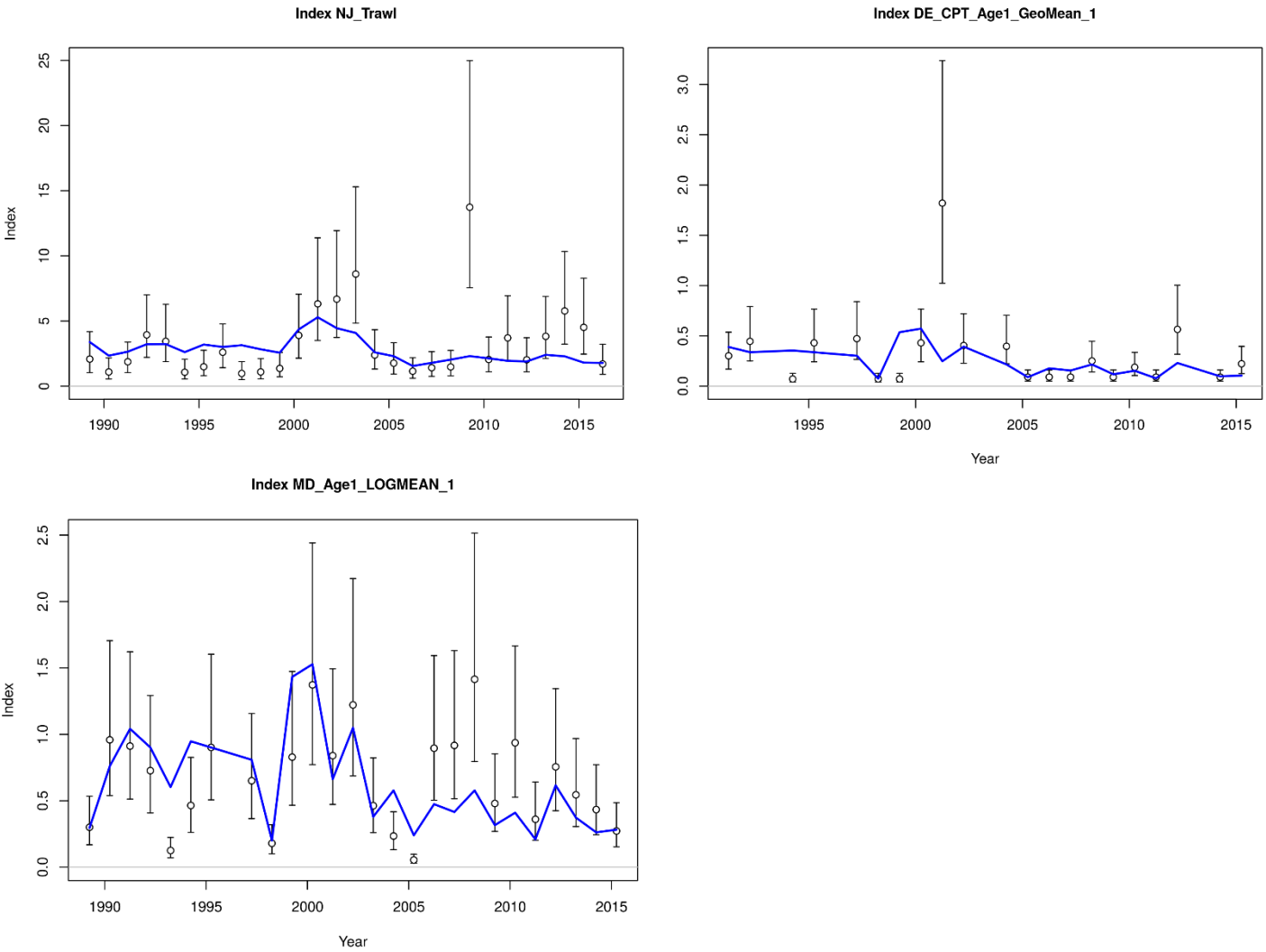

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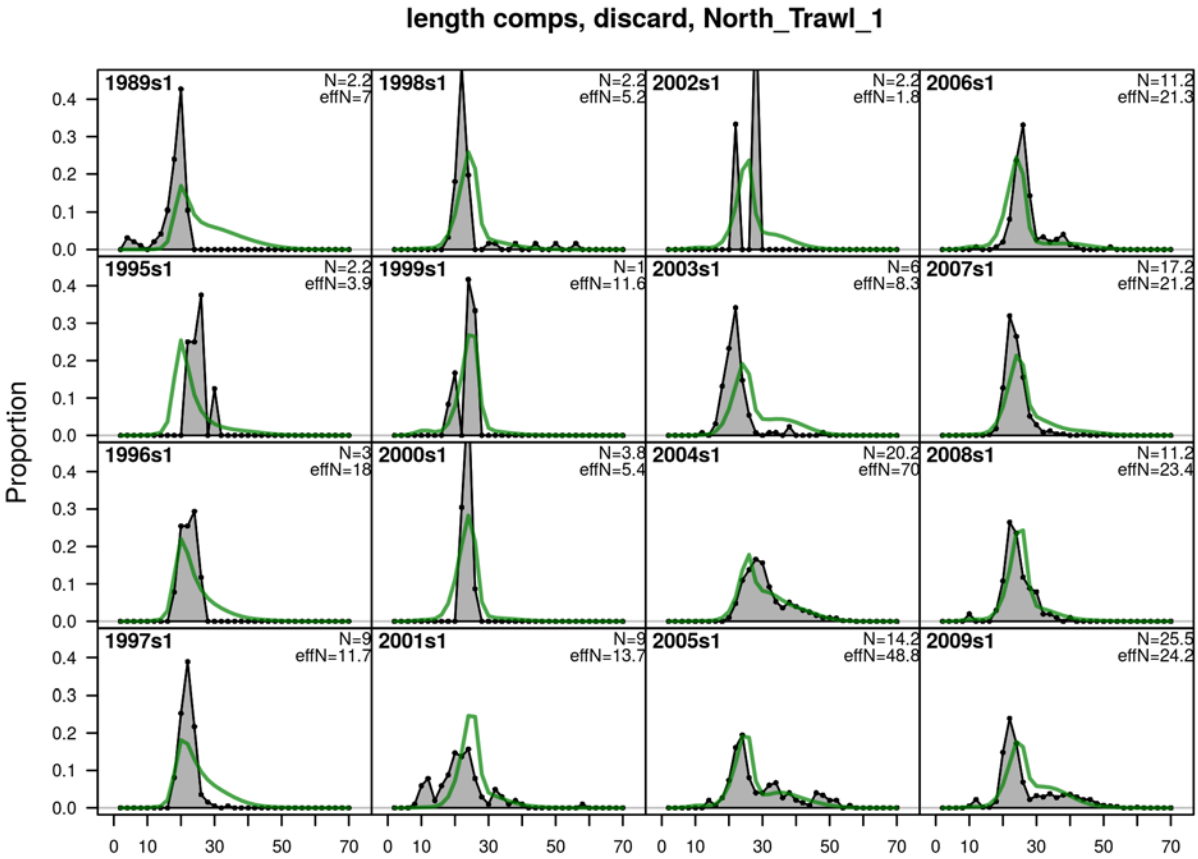


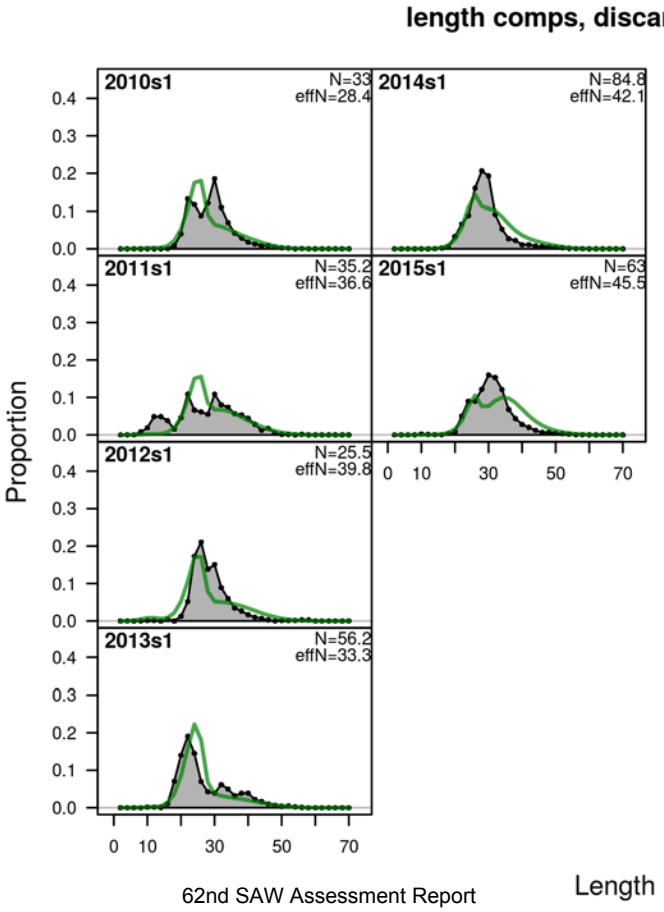
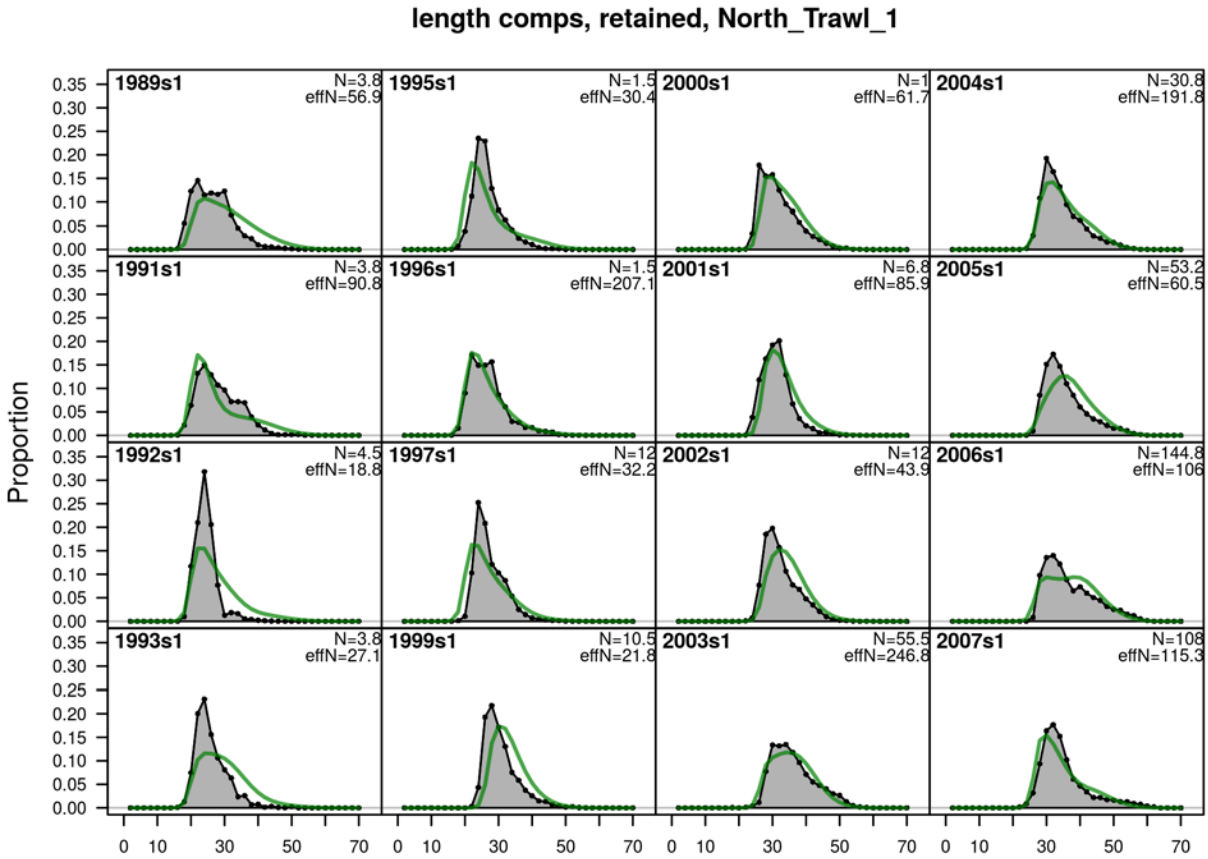
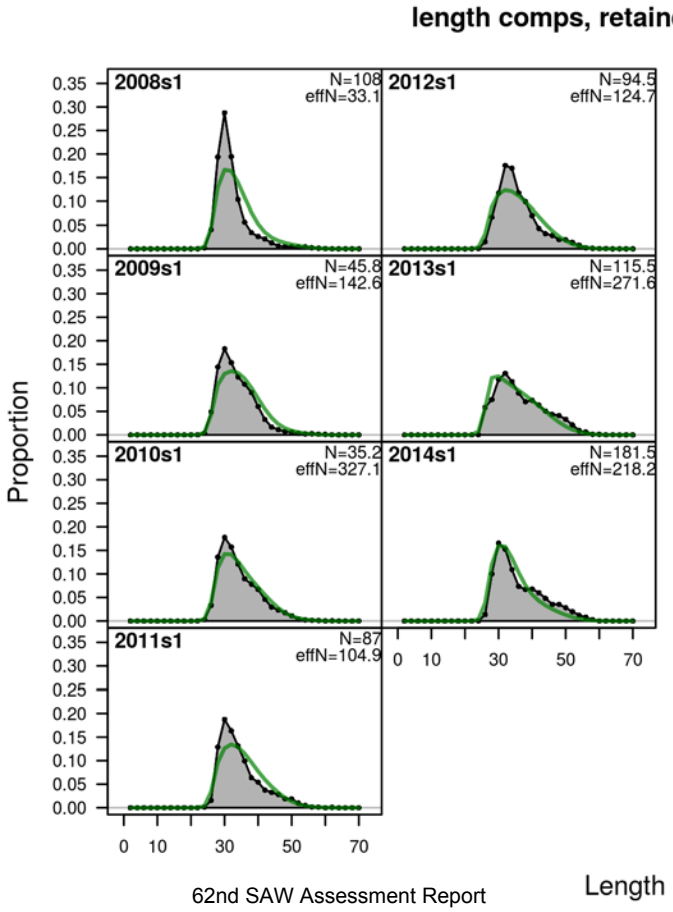


Figure 3. Length distributions, observed (black line) and model predictions (green lines) from SS.





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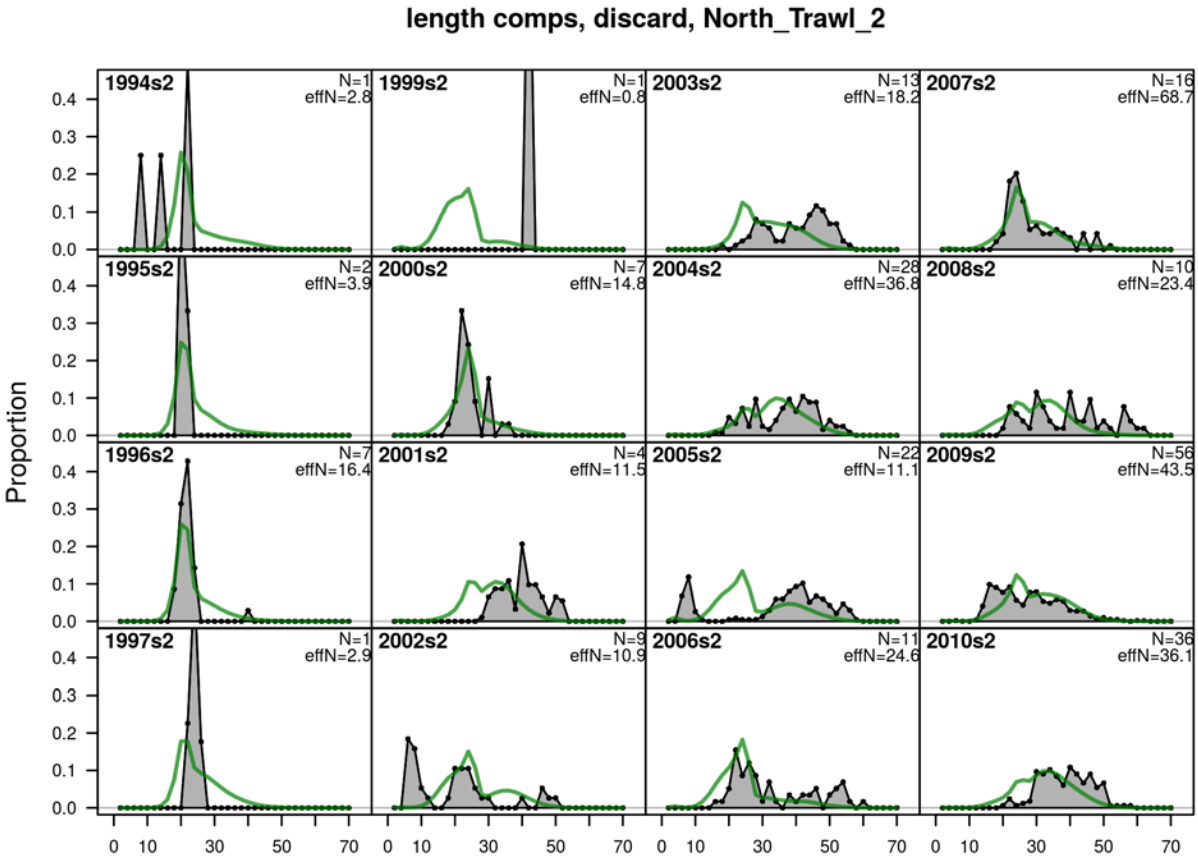

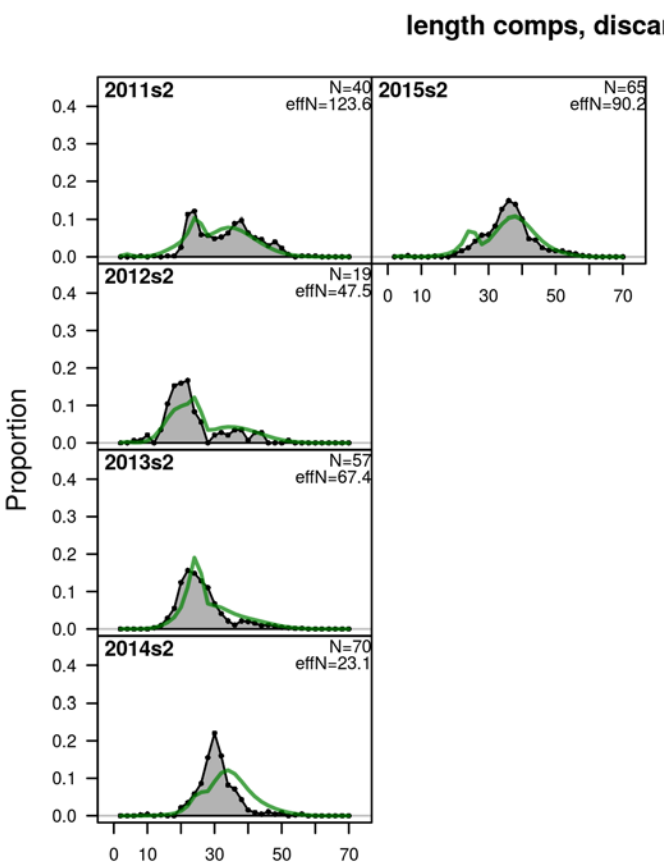

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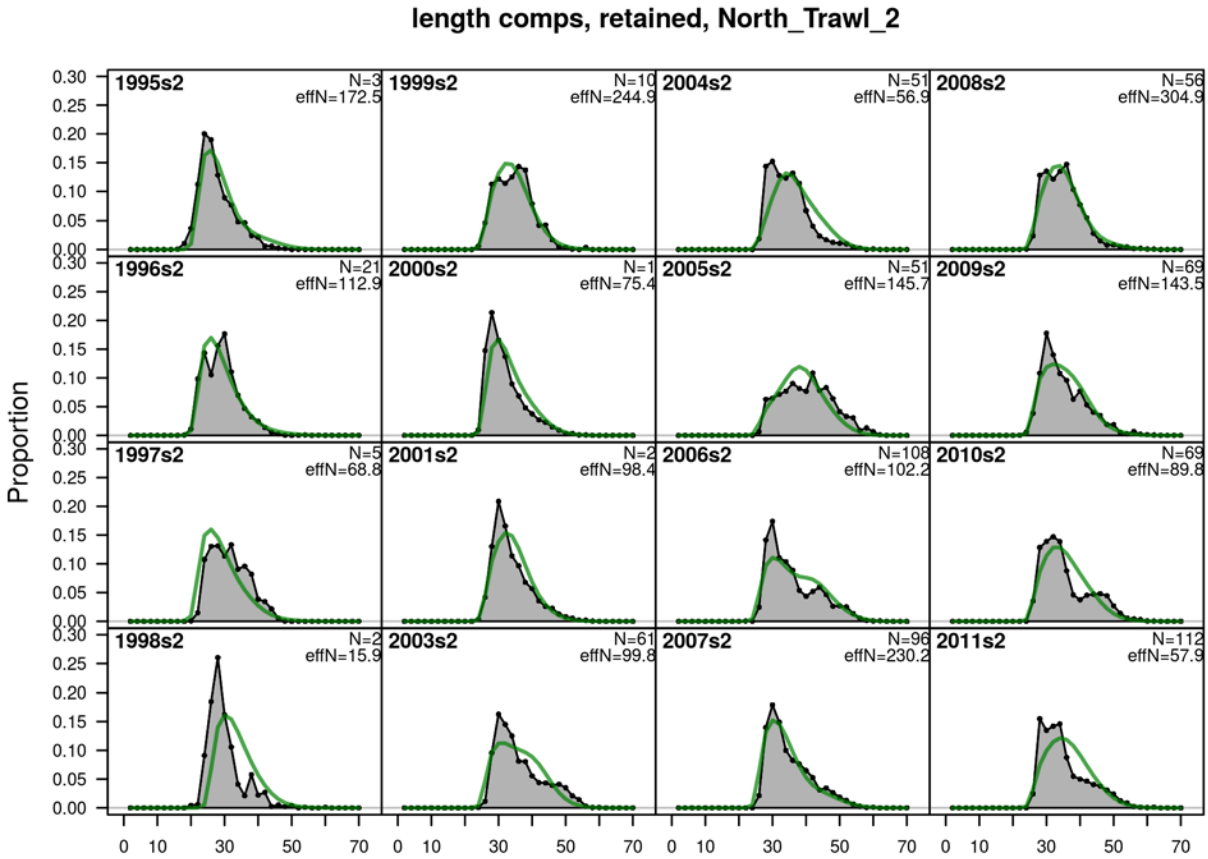

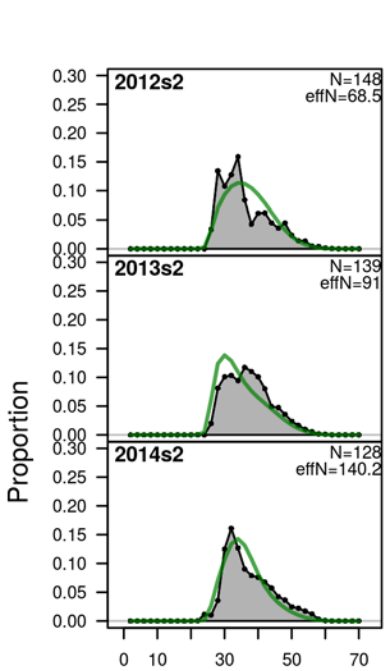

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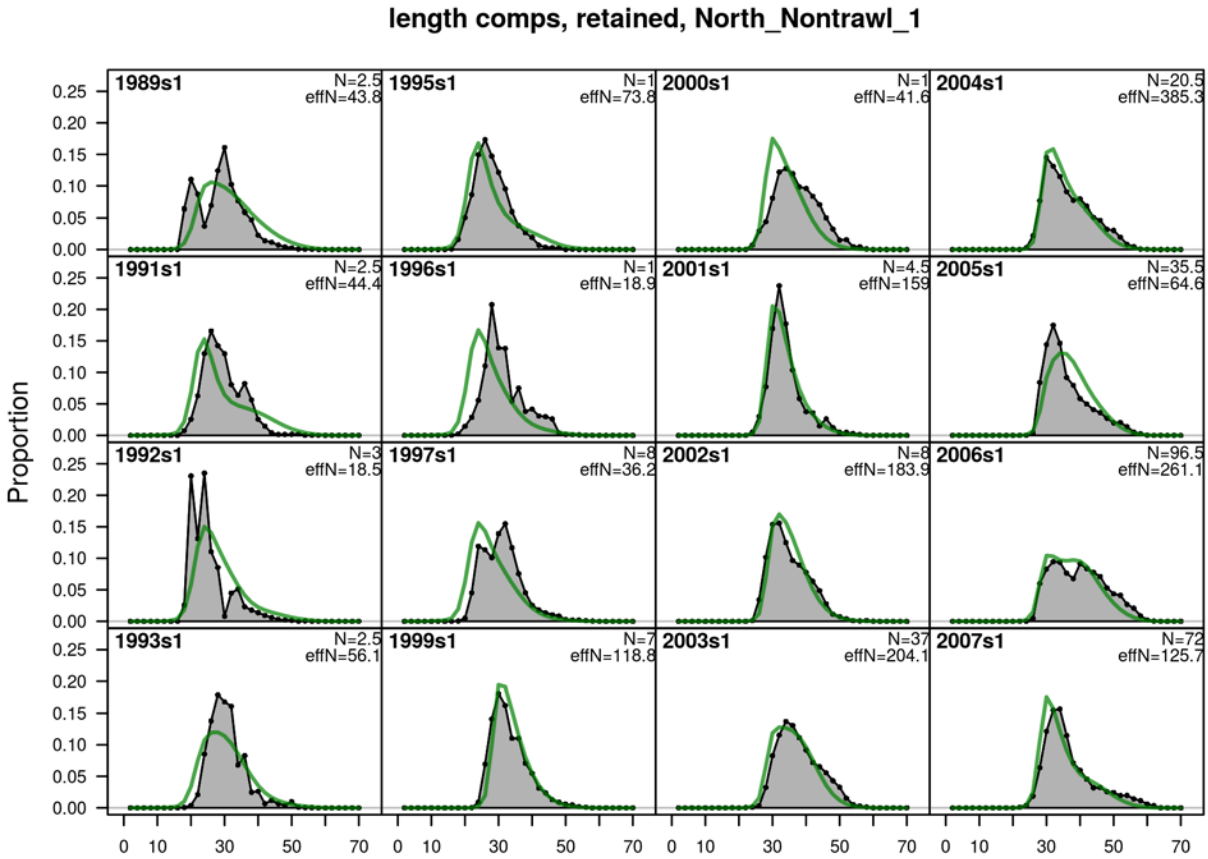

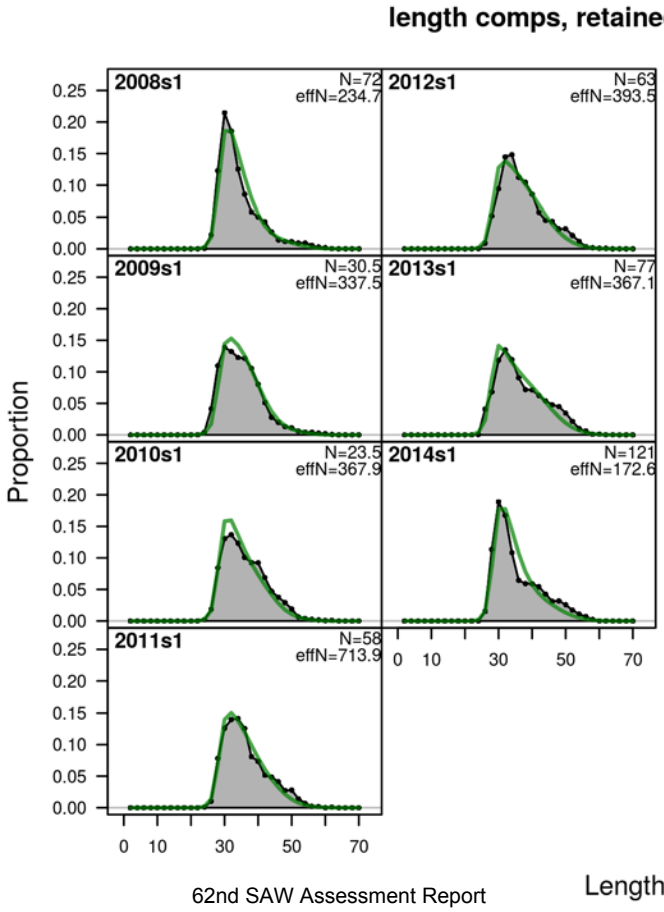

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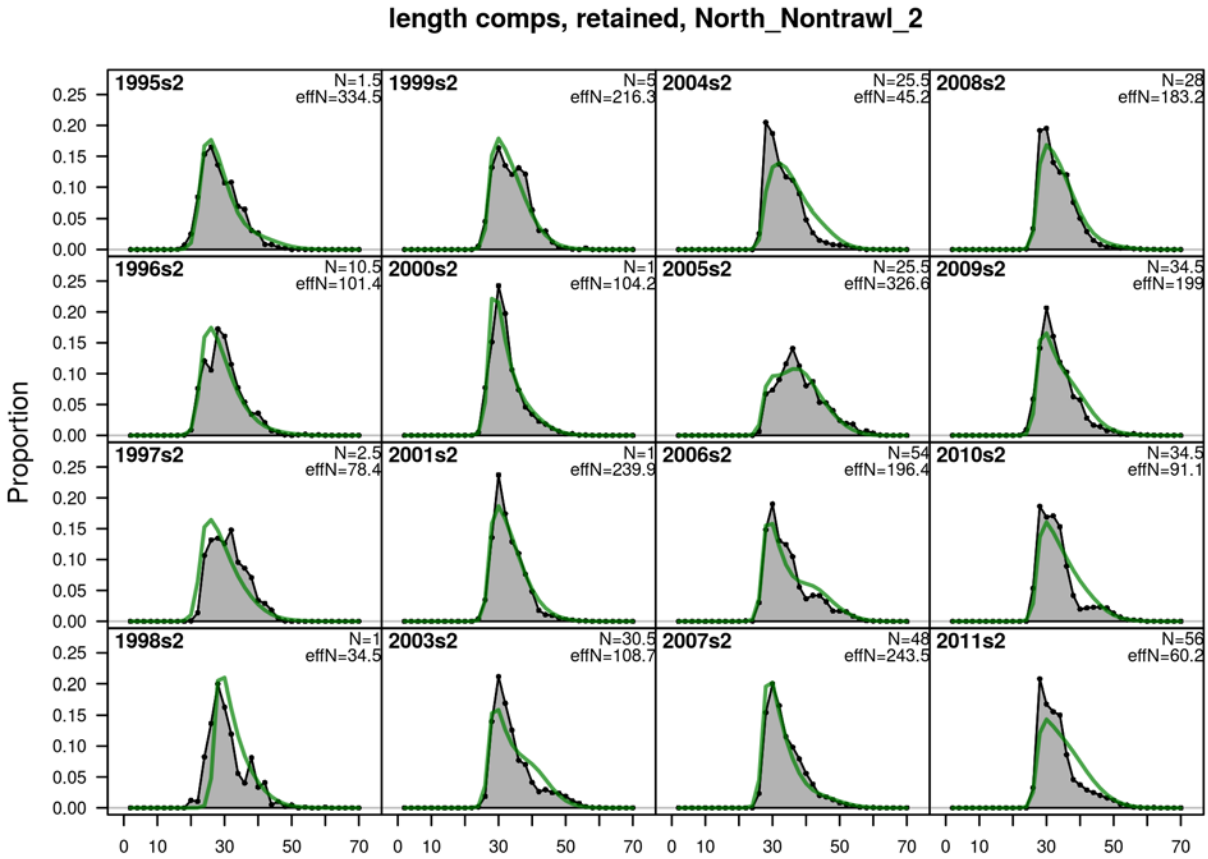

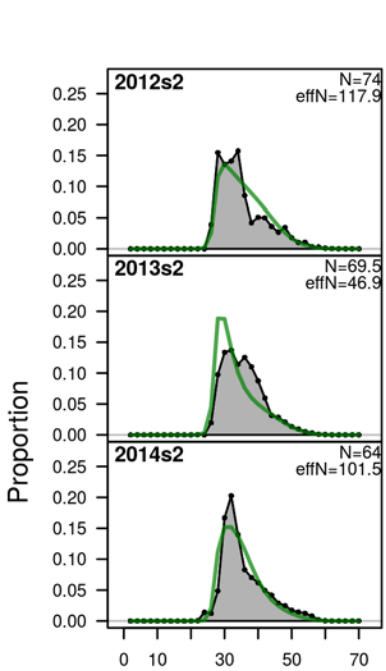

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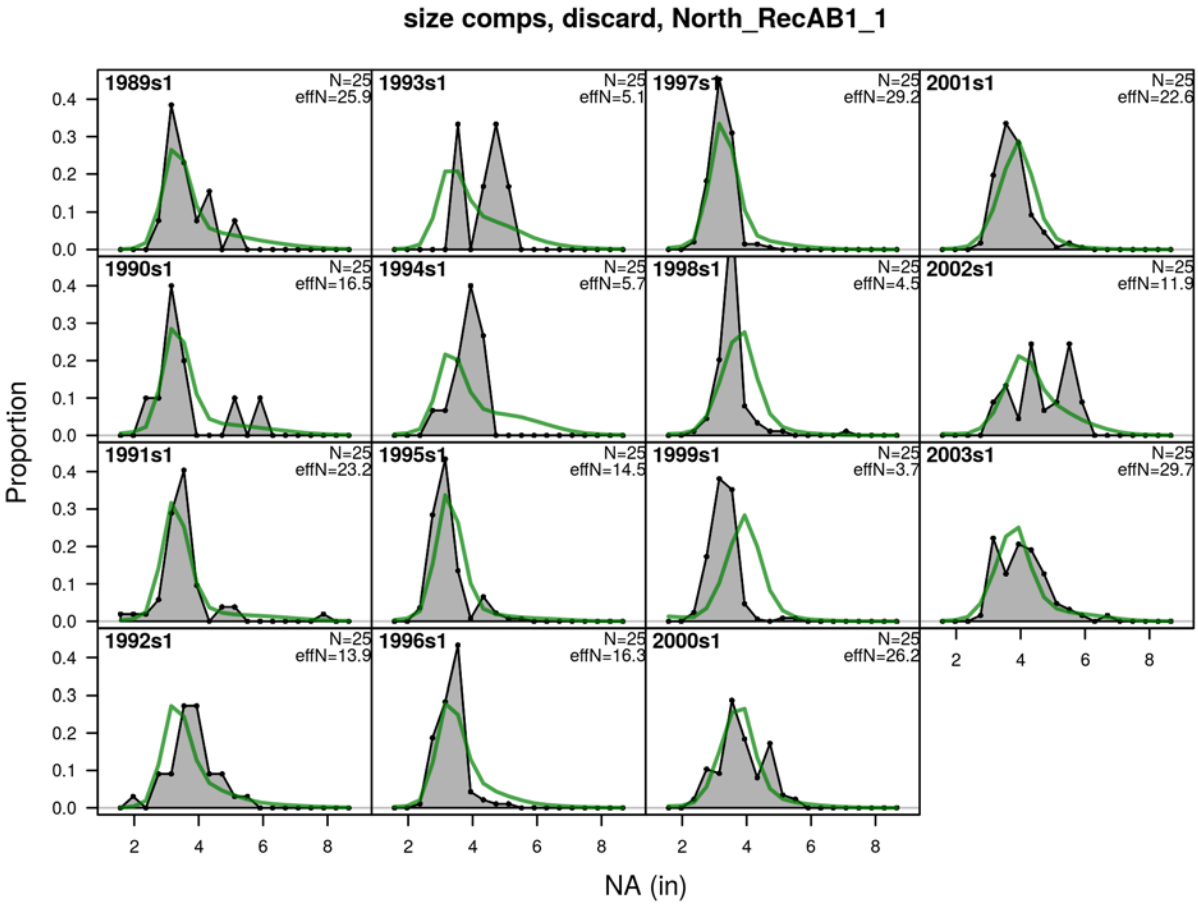

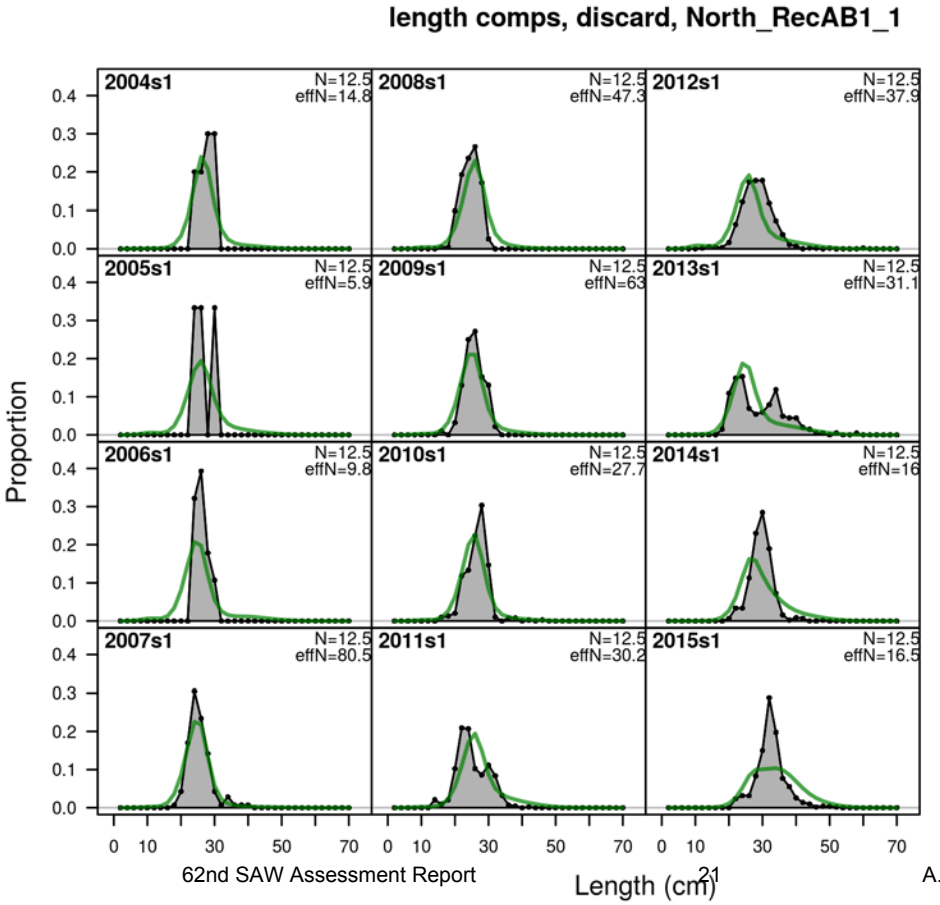

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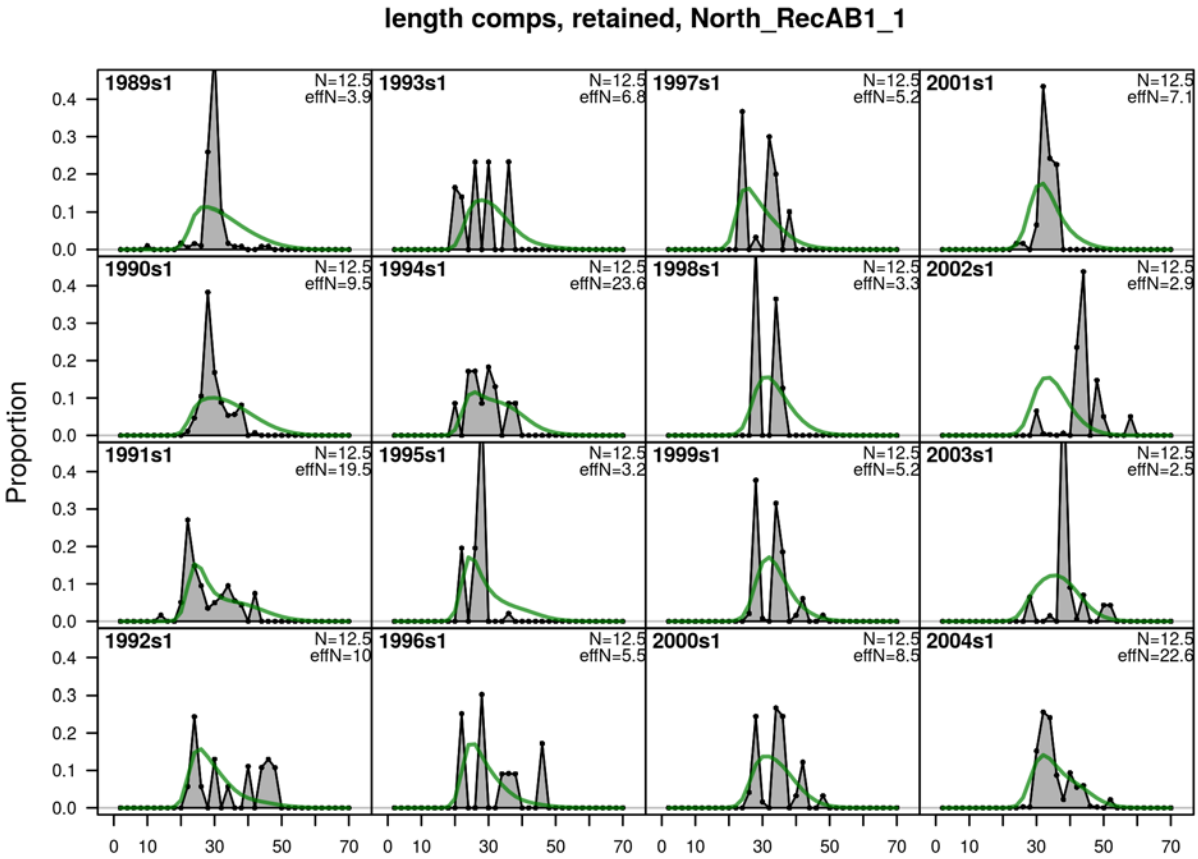

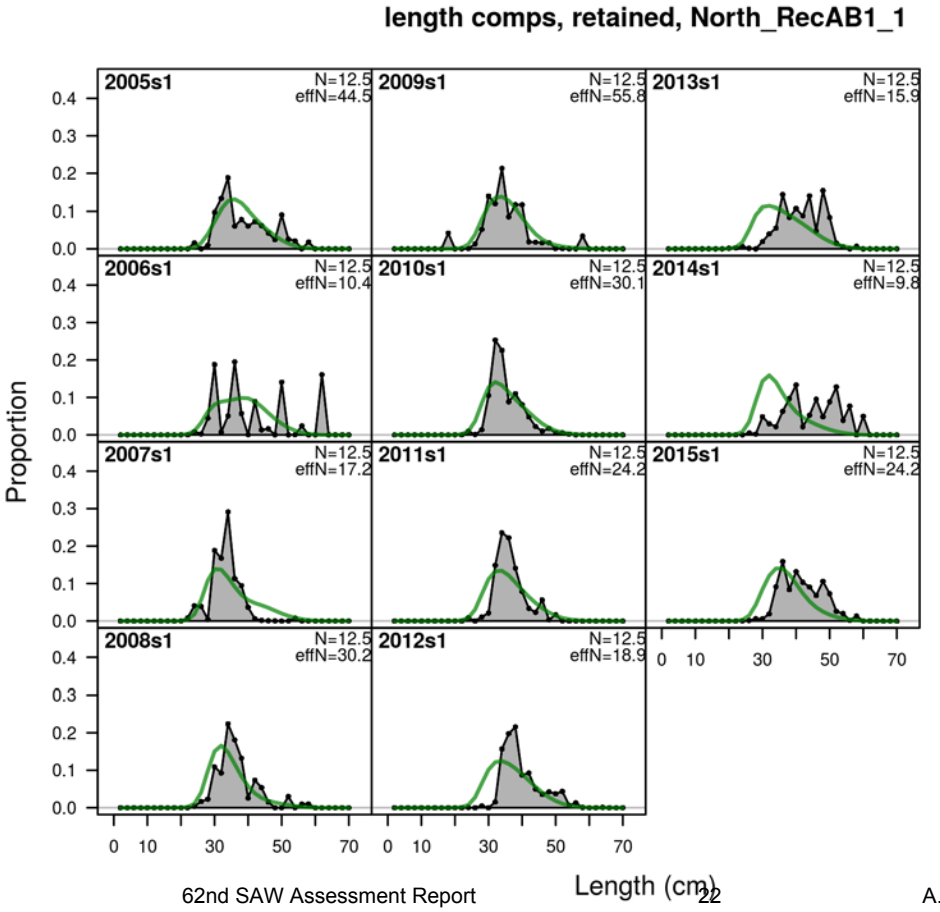

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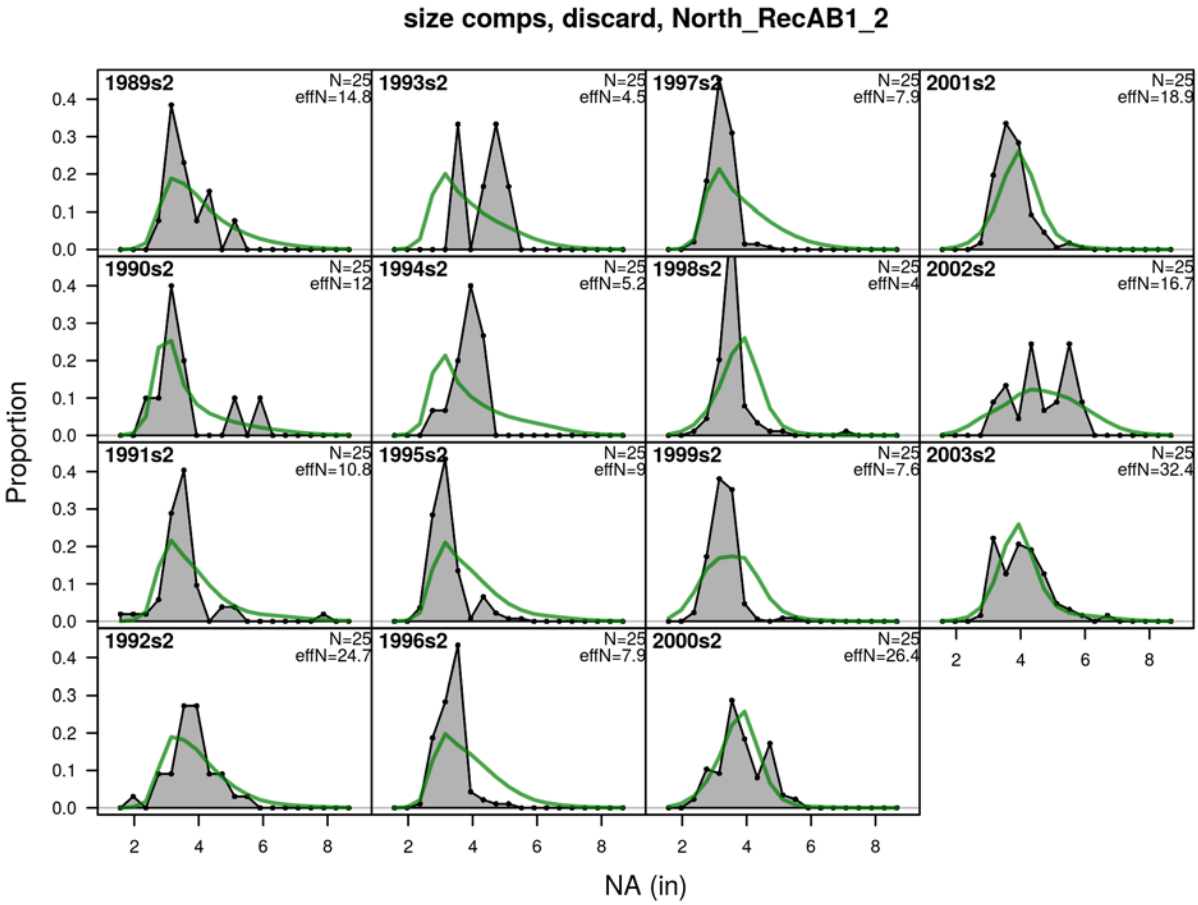

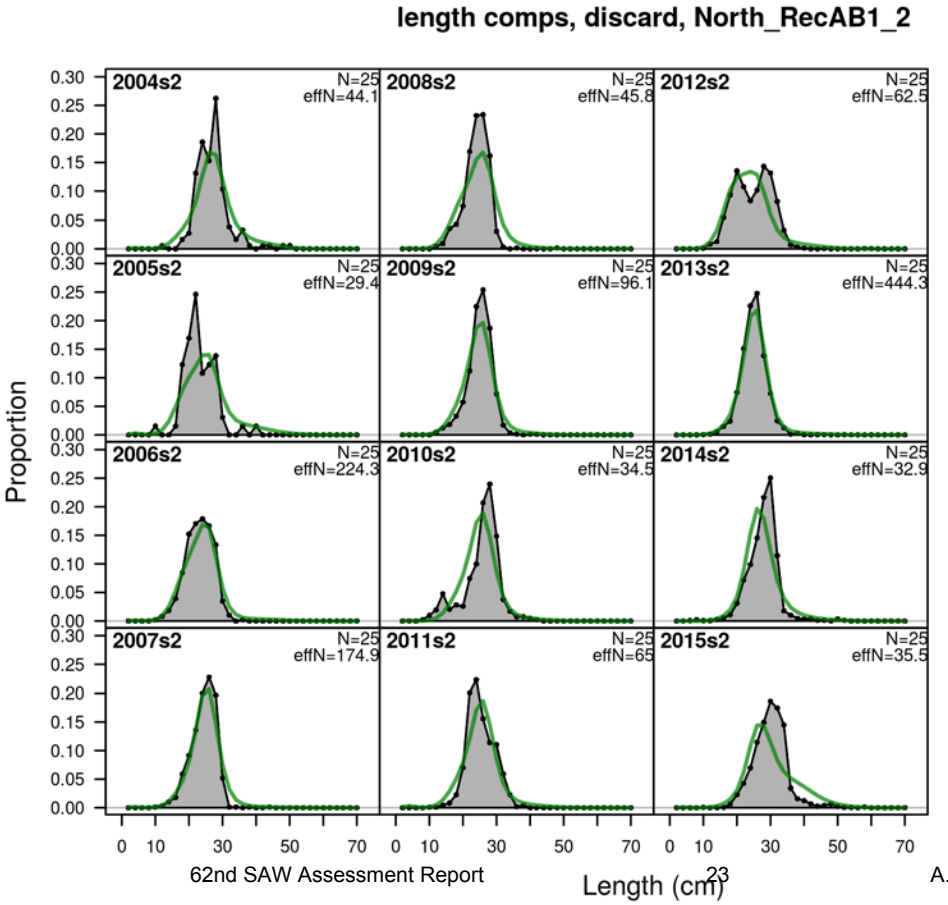

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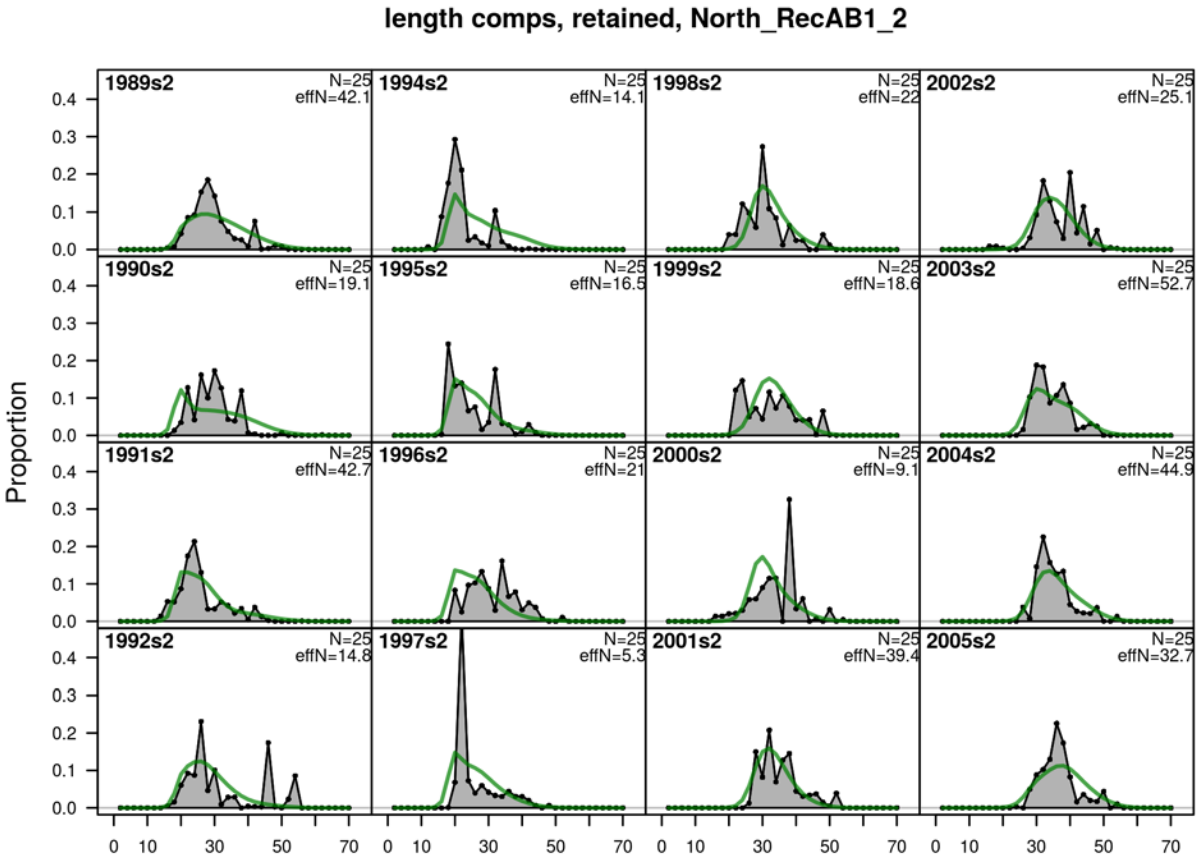

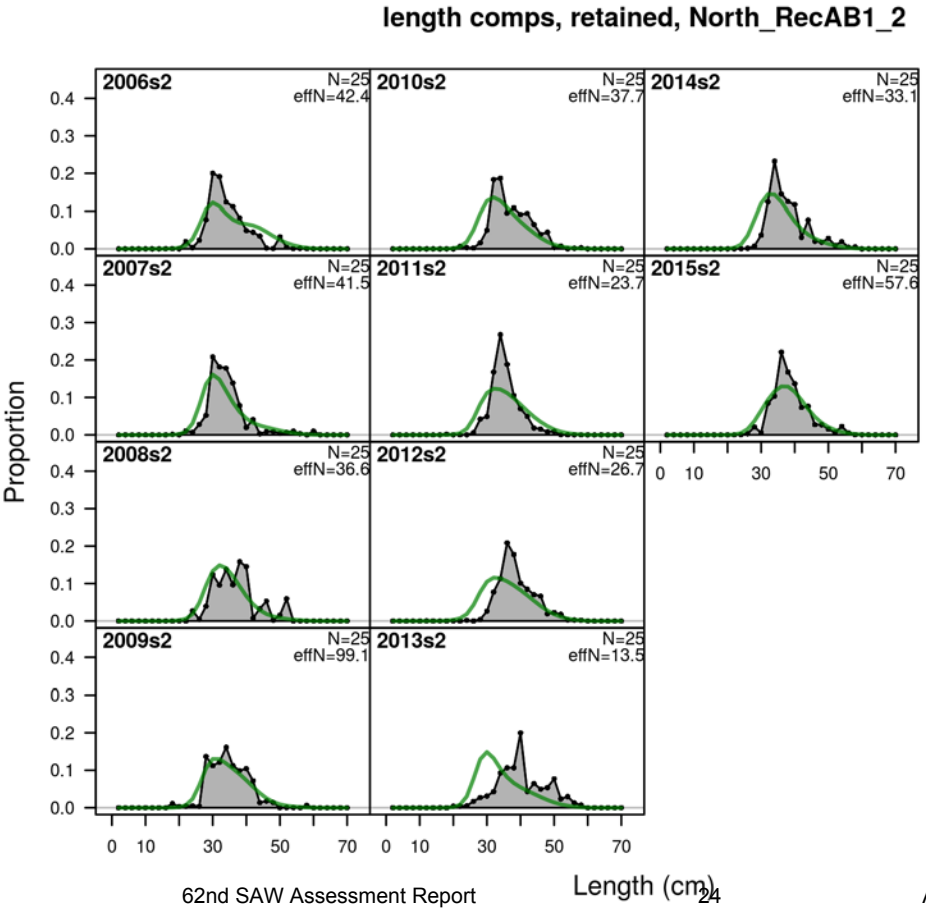

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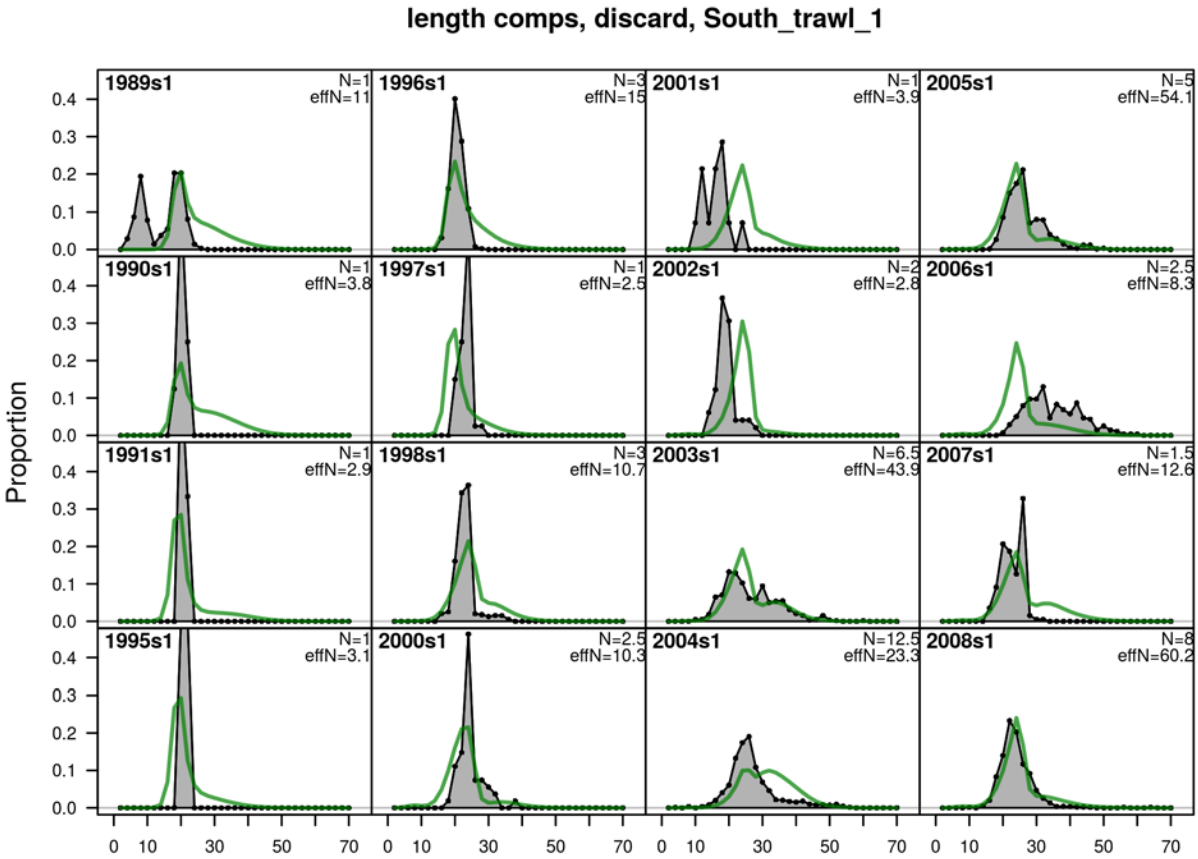

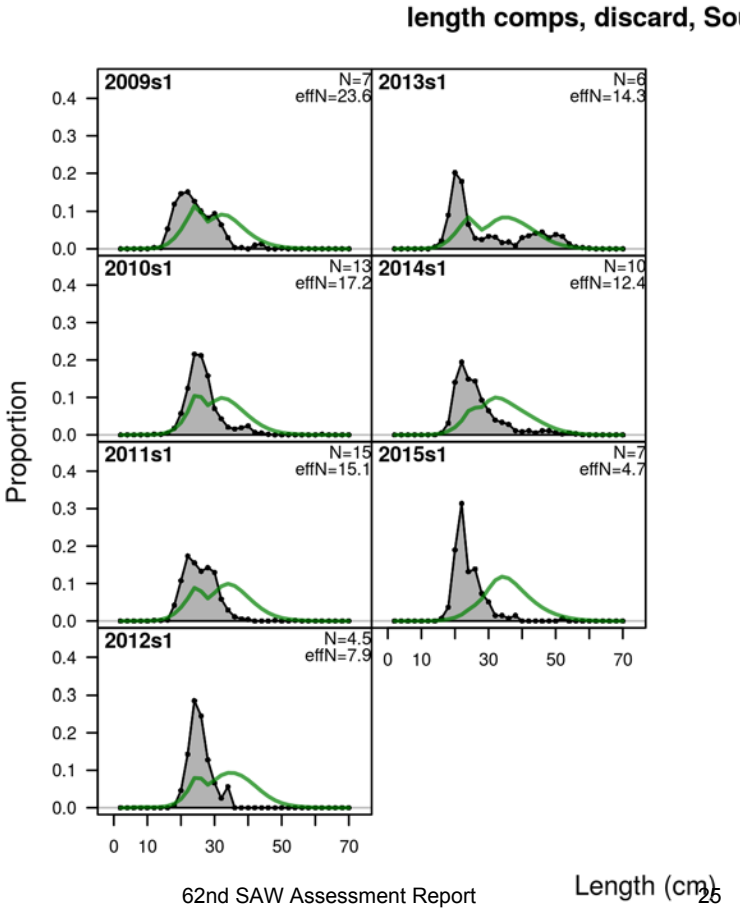

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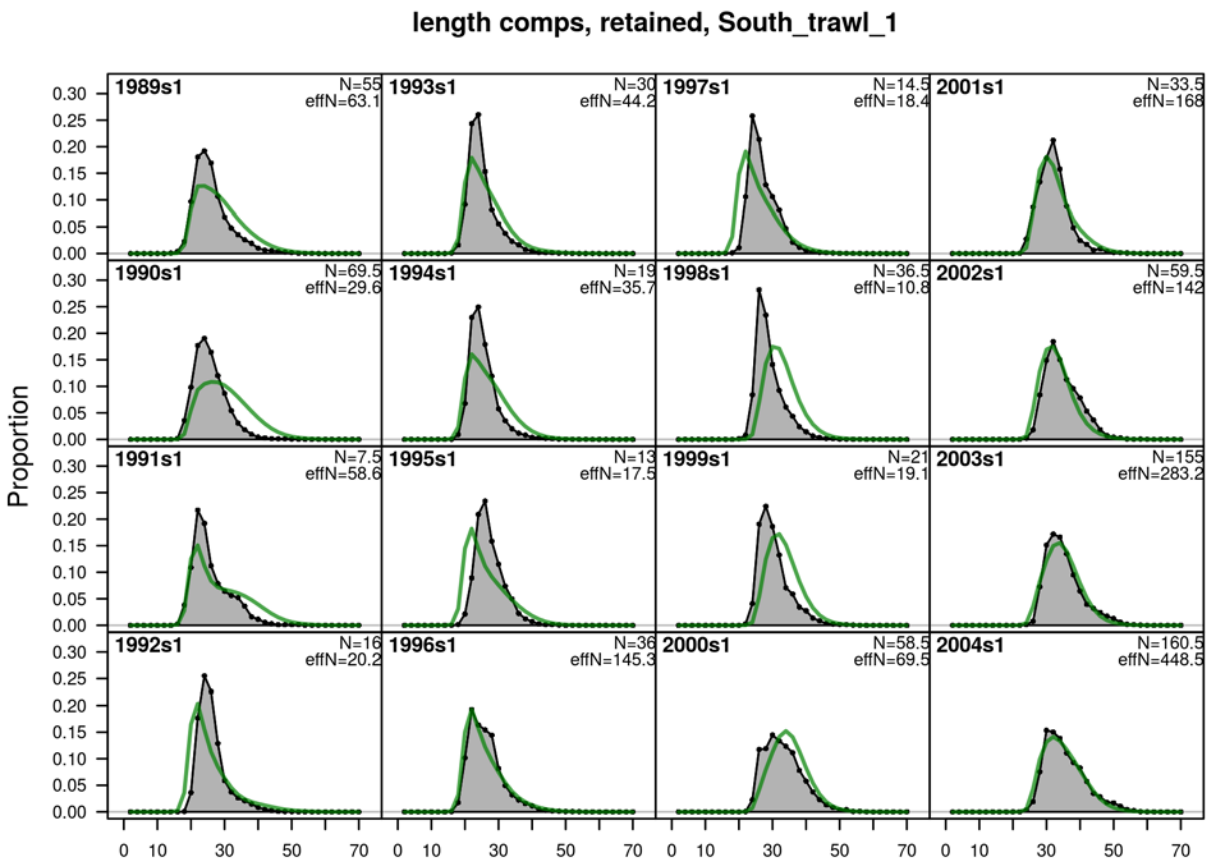

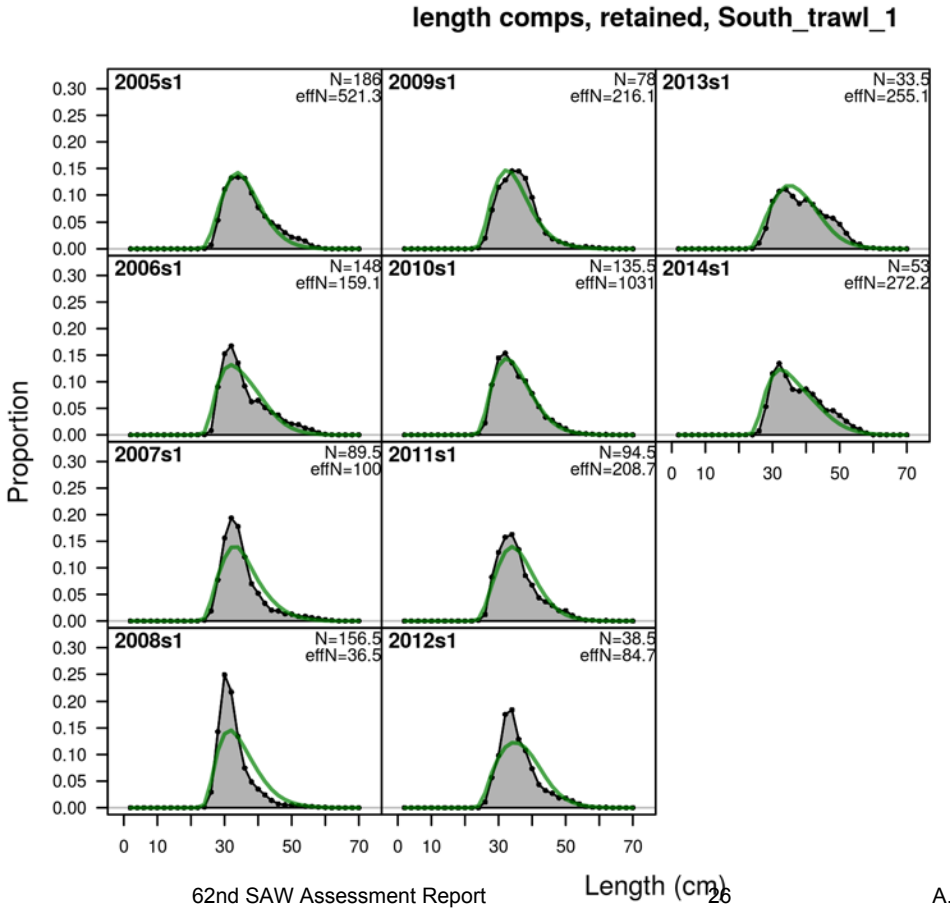

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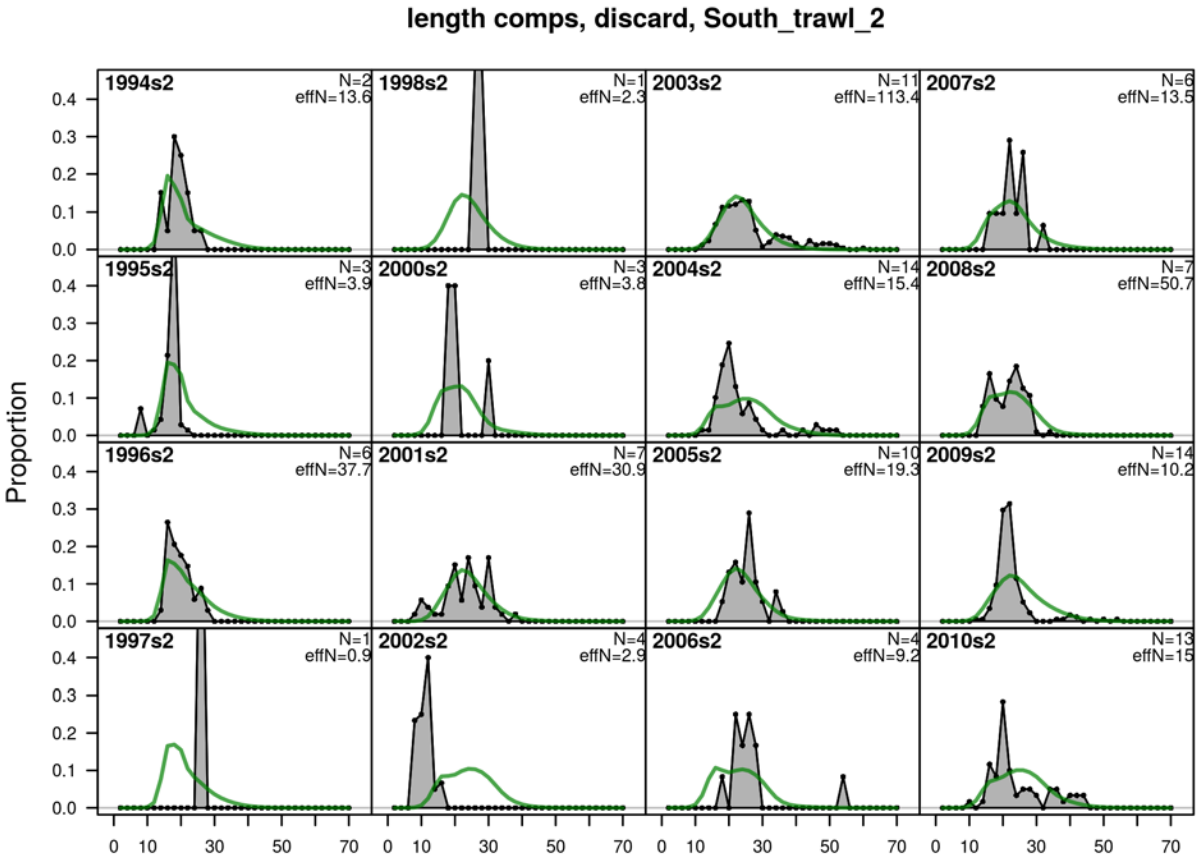

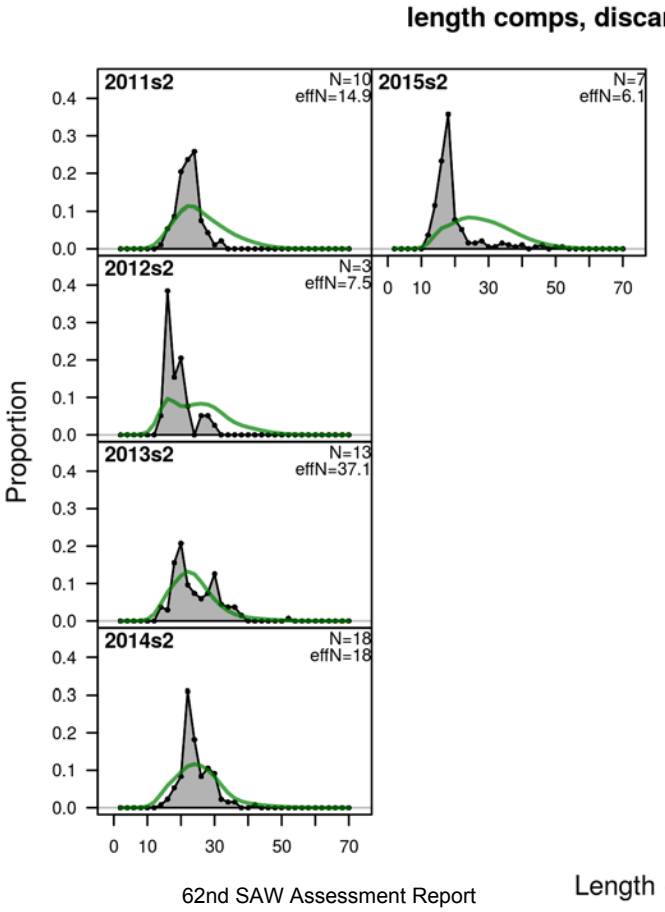

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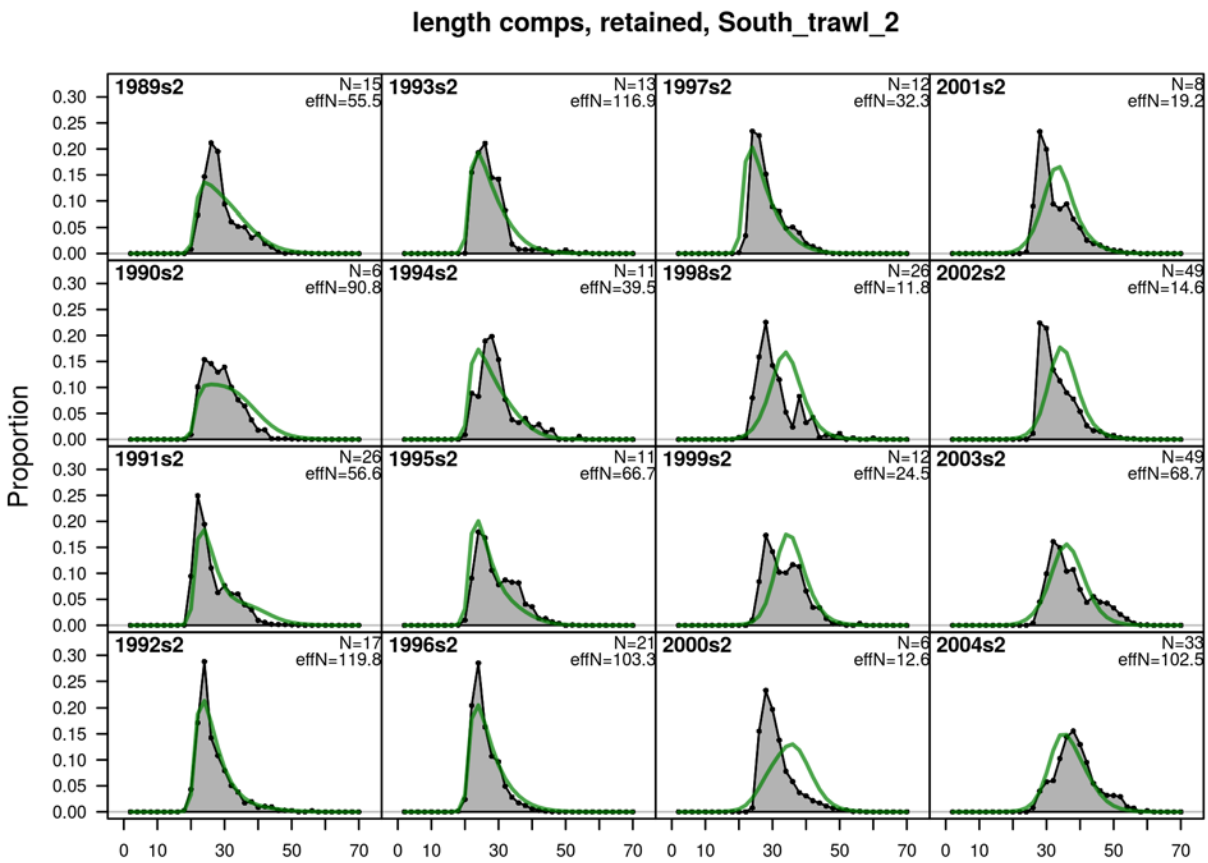


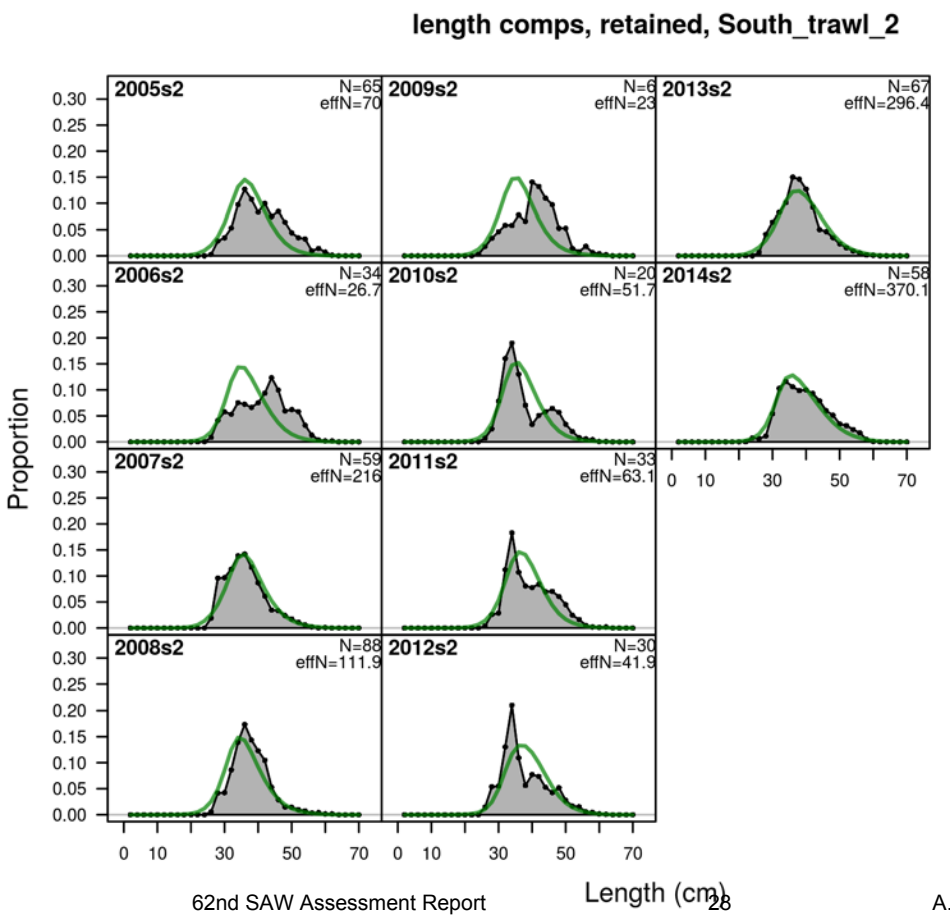
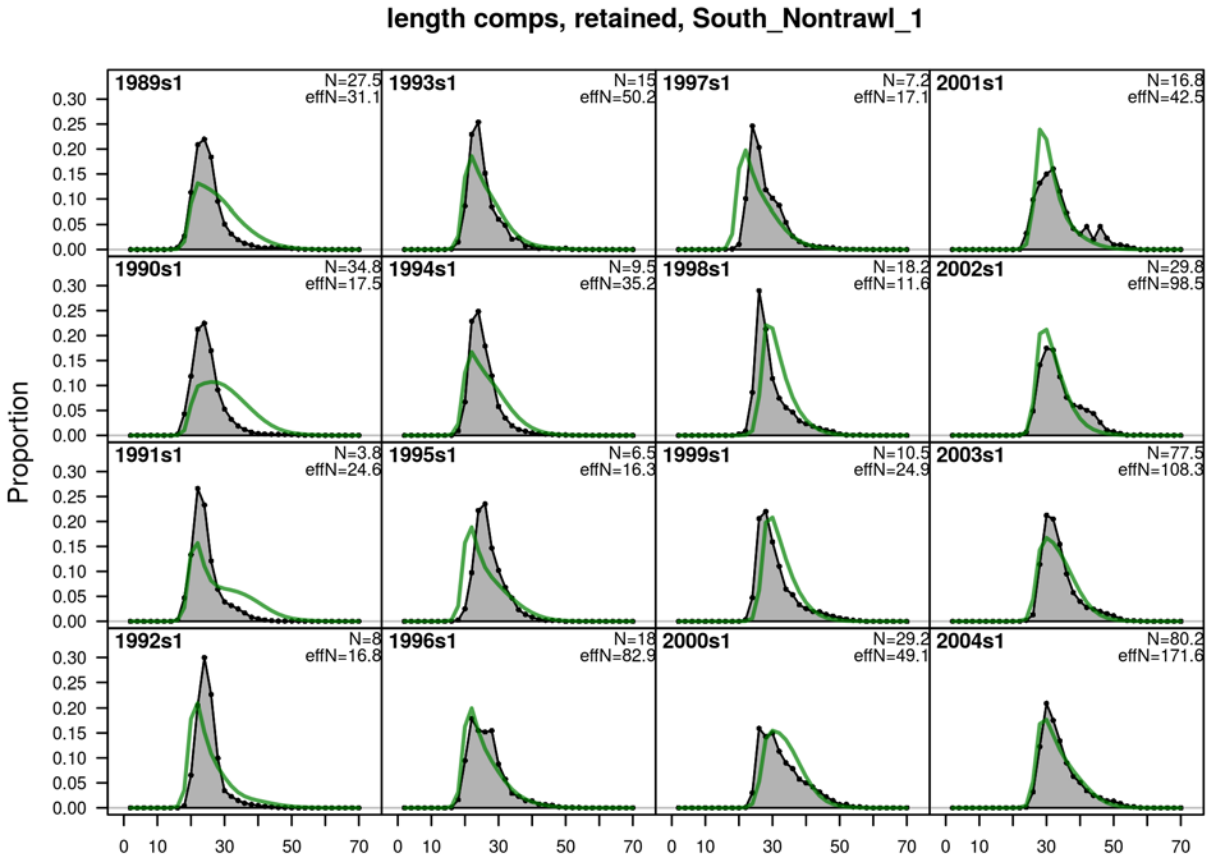


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



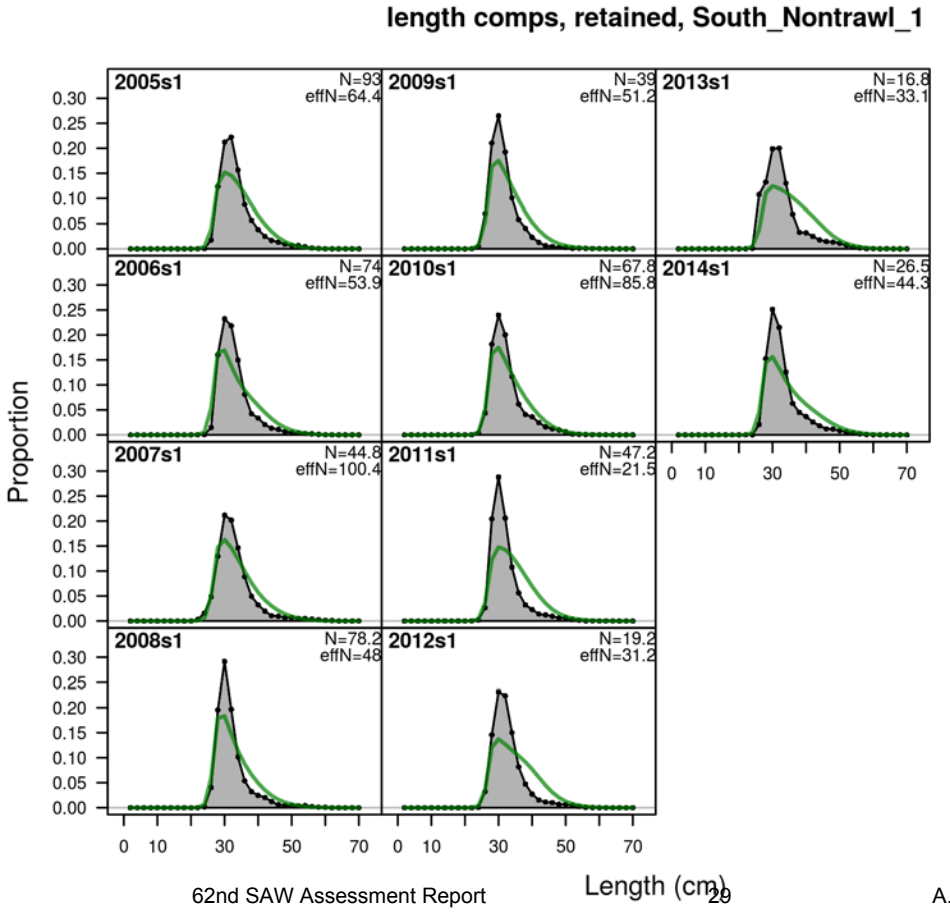
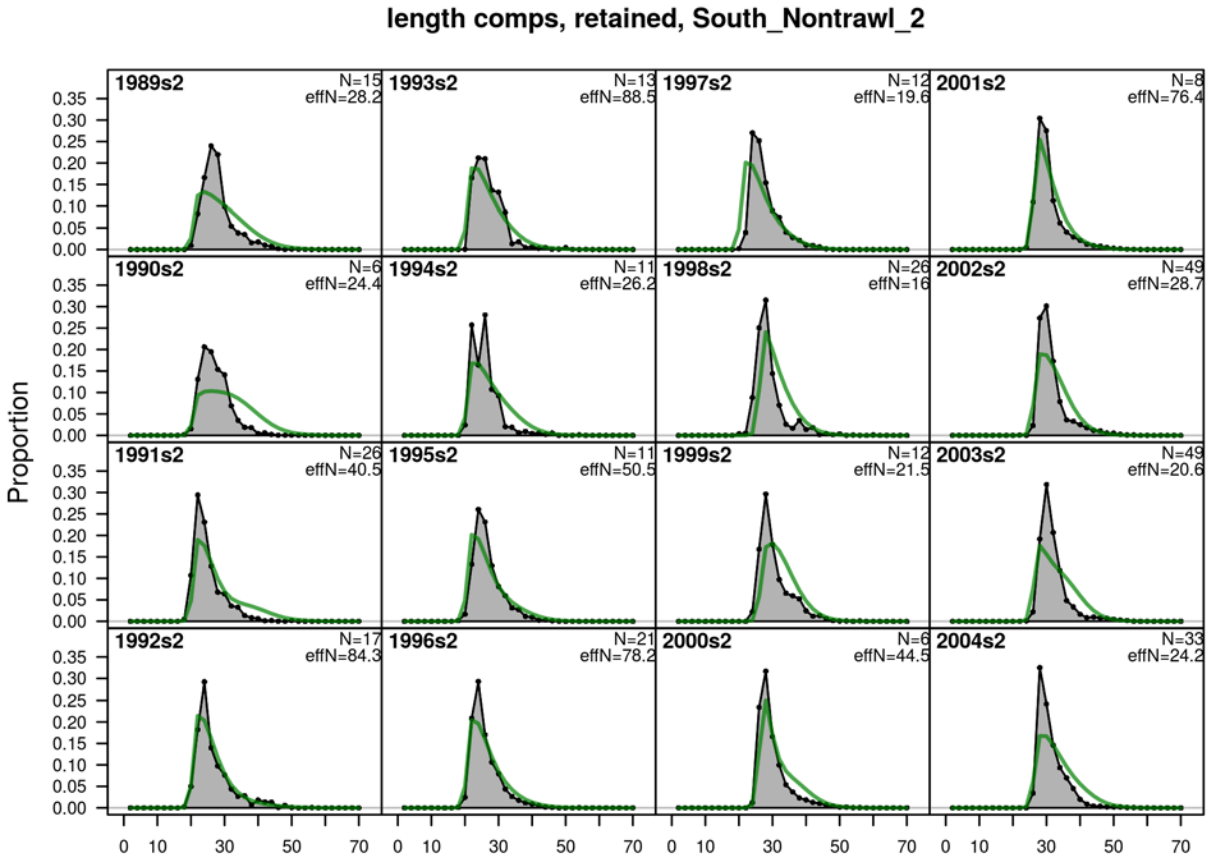


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



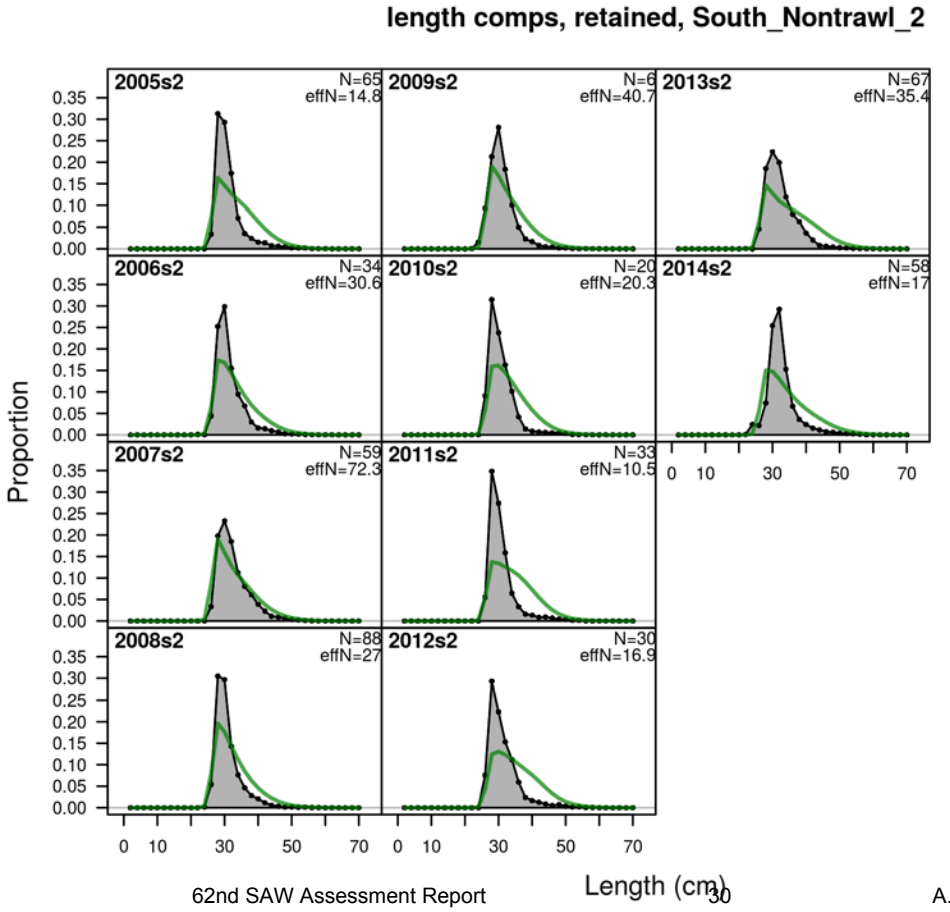
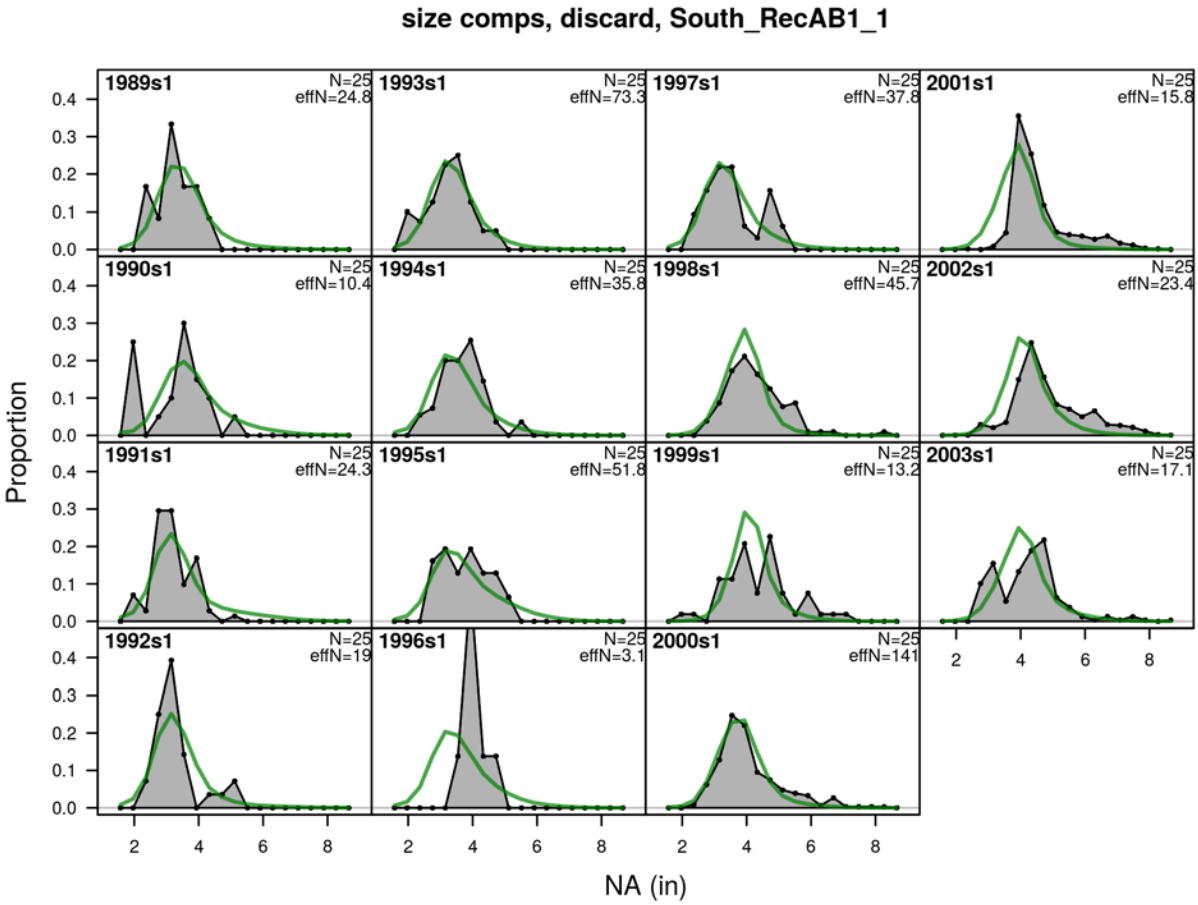


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



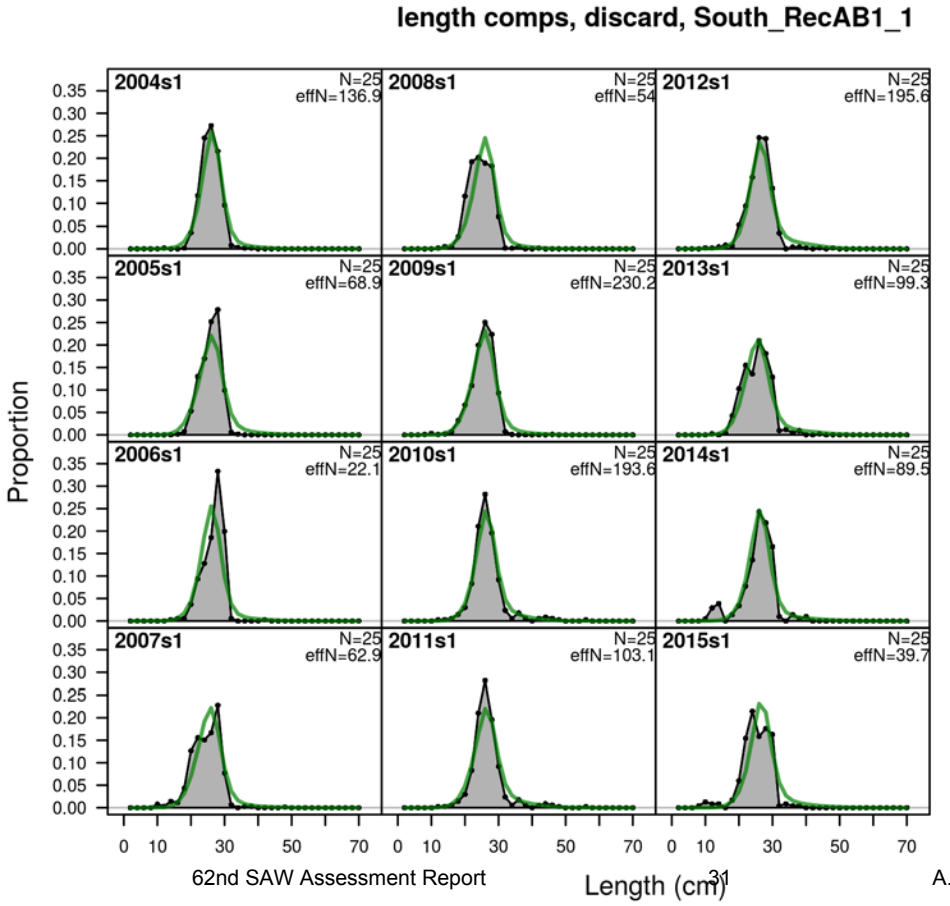
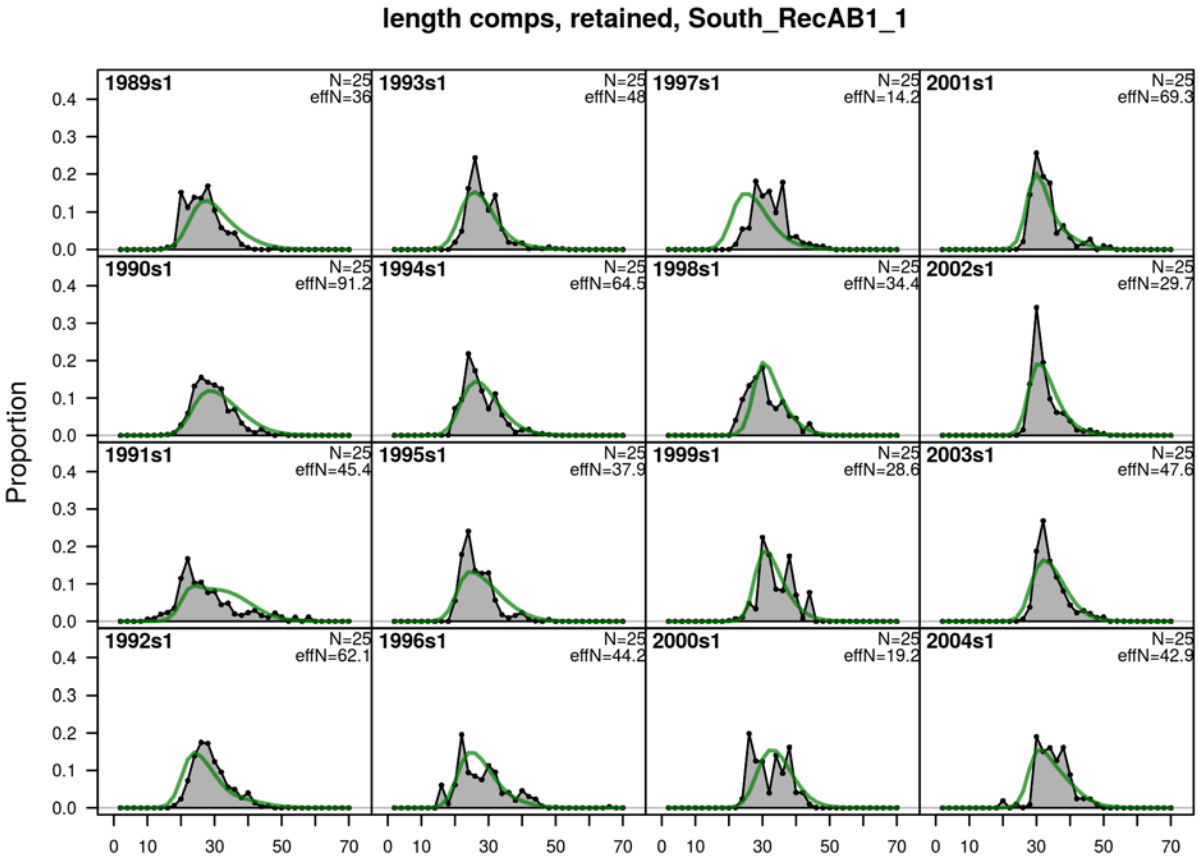


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



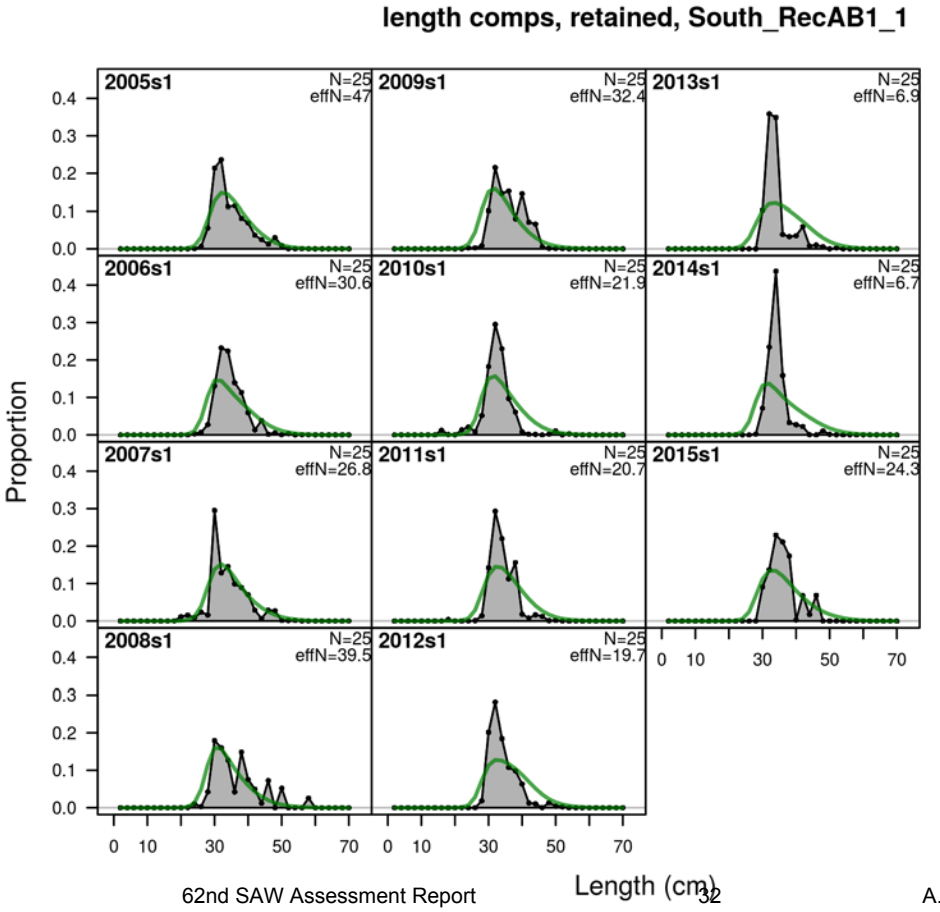
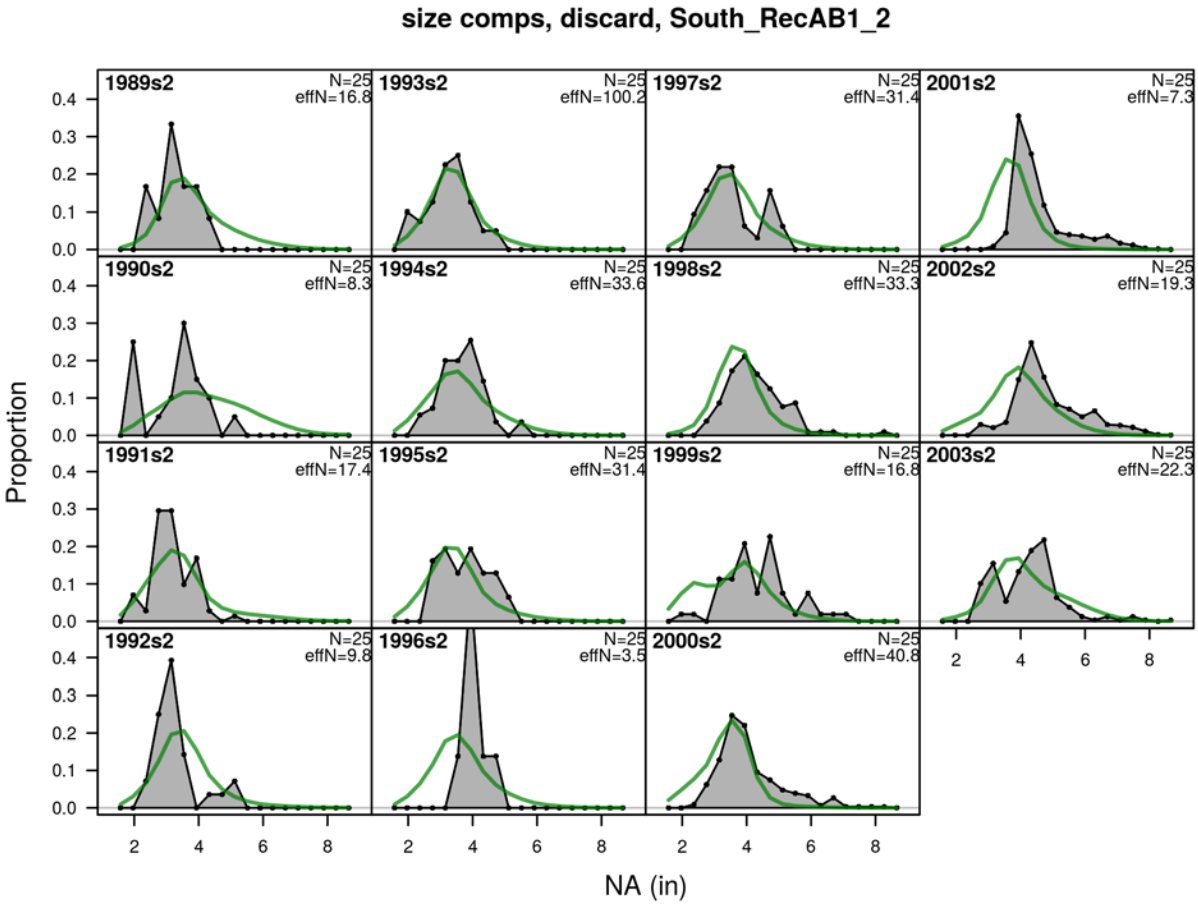


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



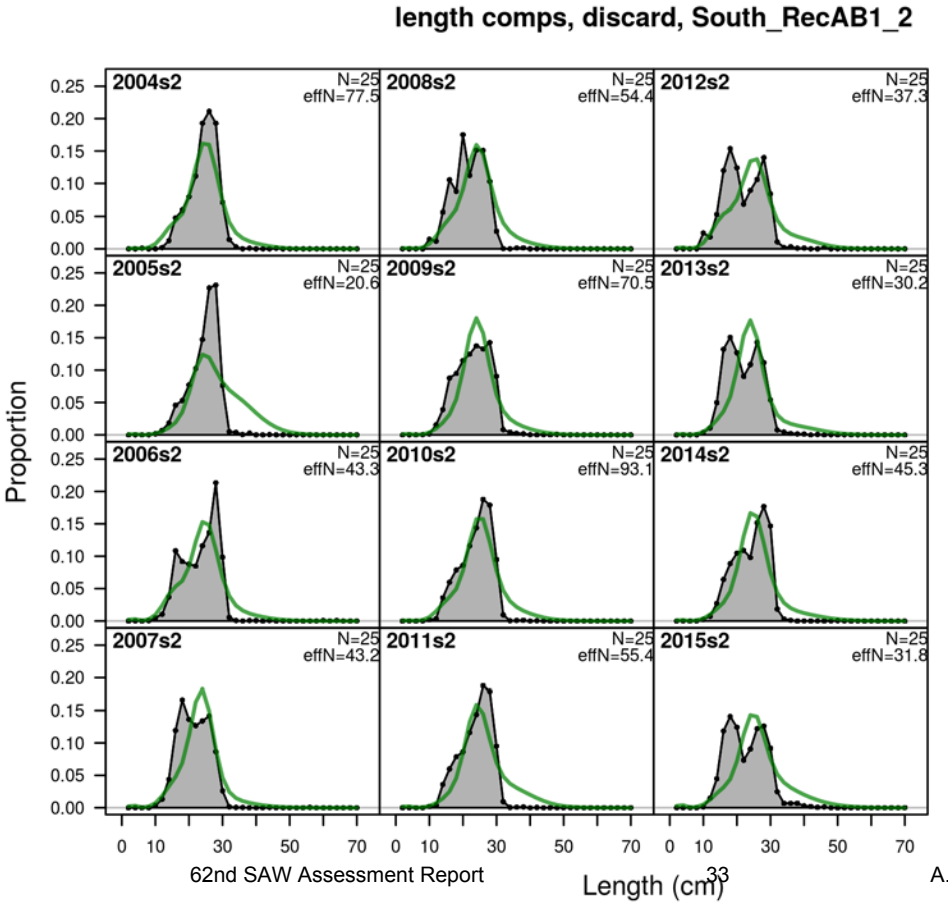
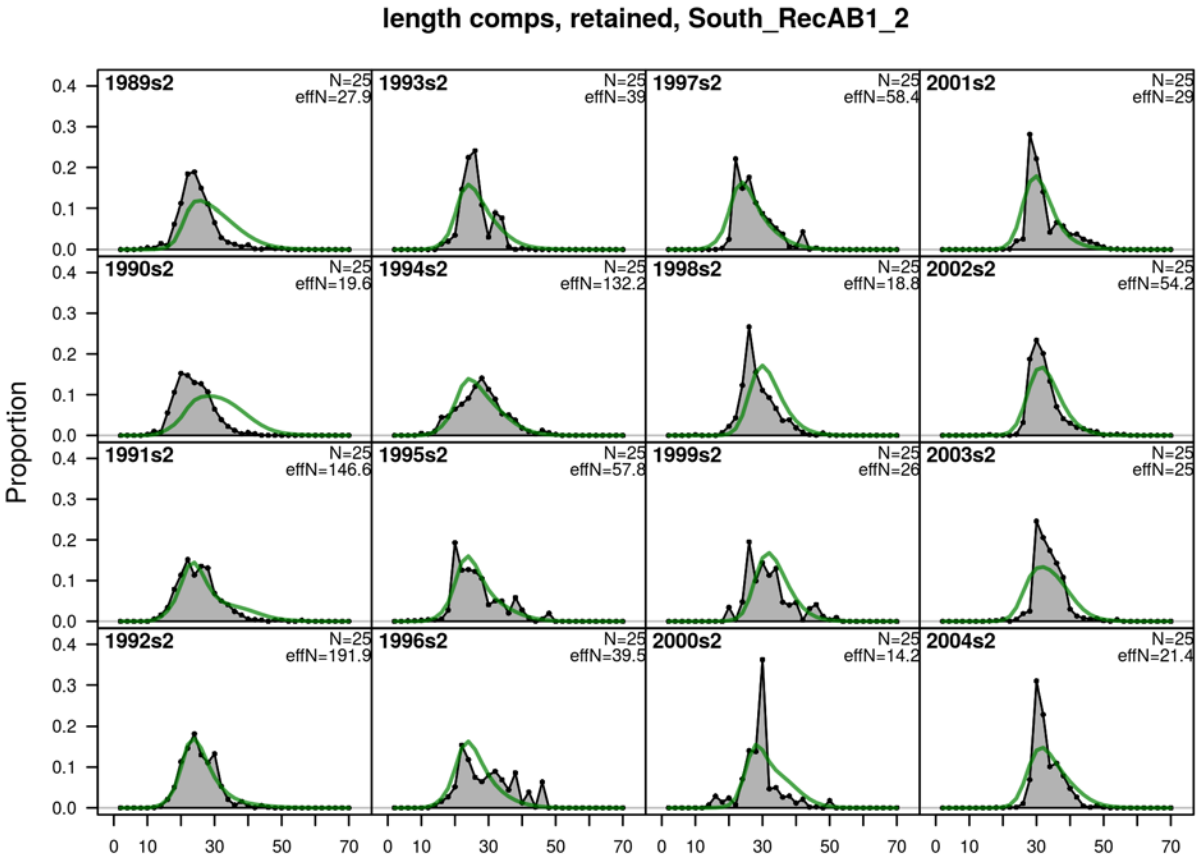


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



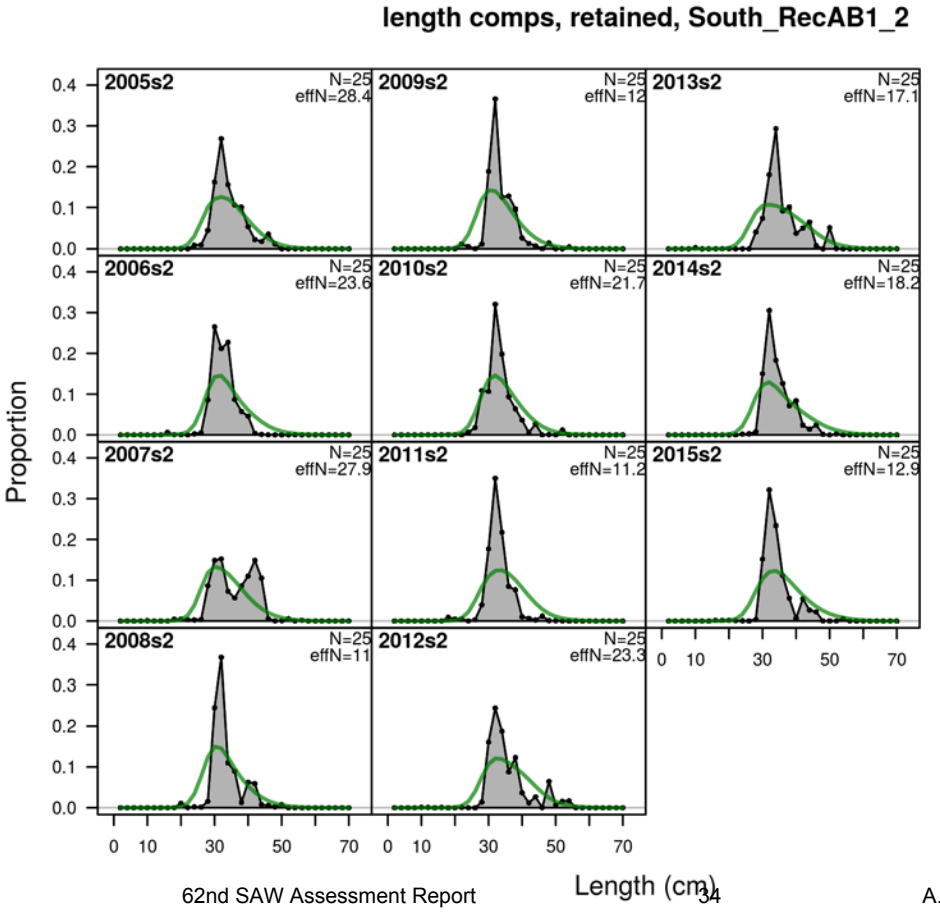
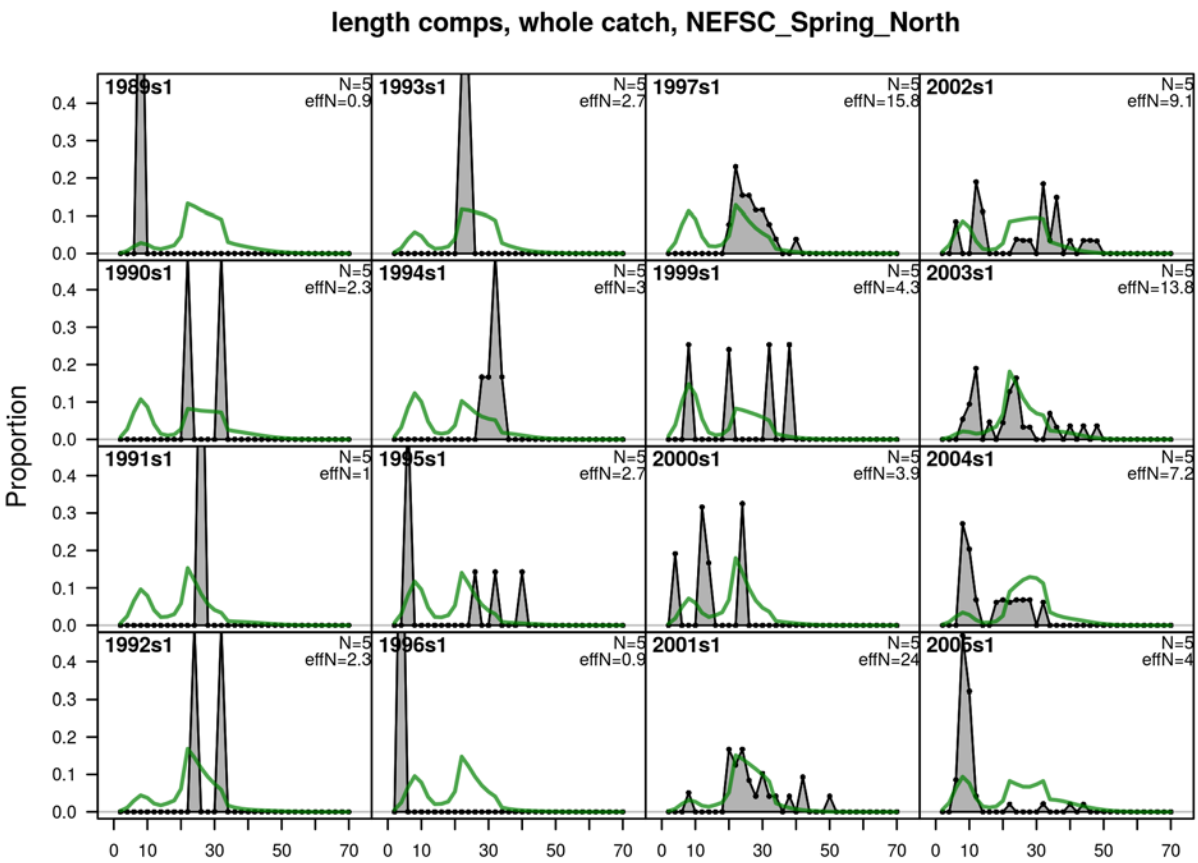


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



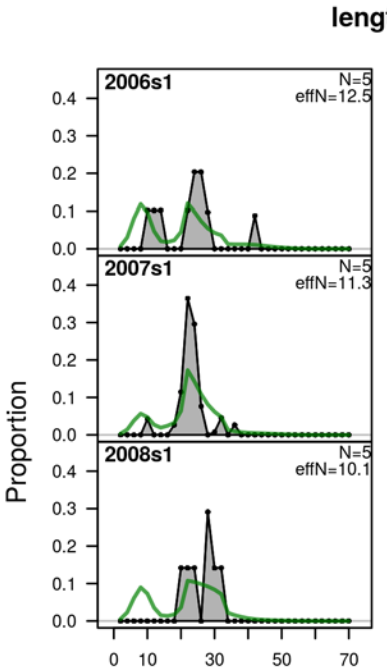
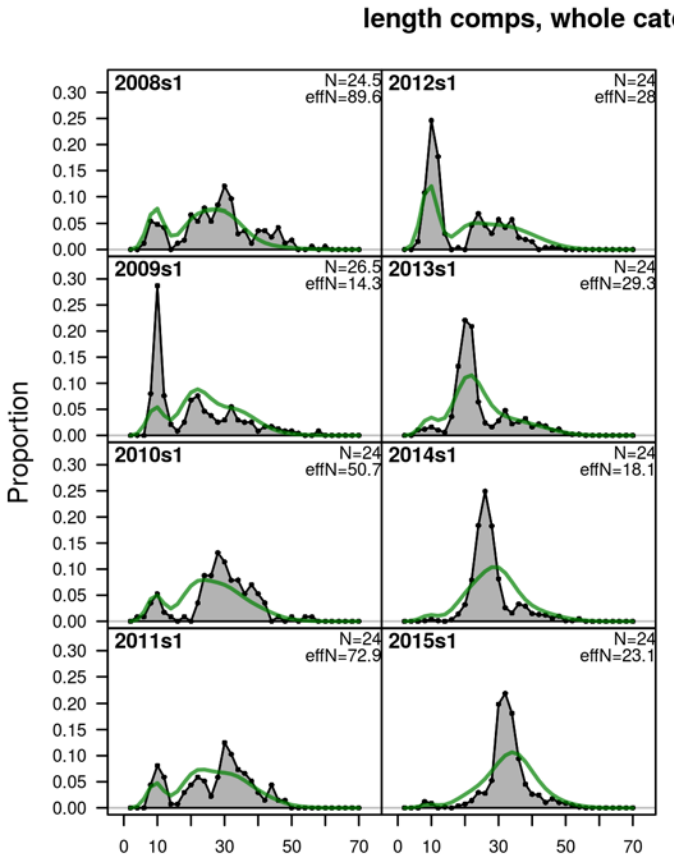


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



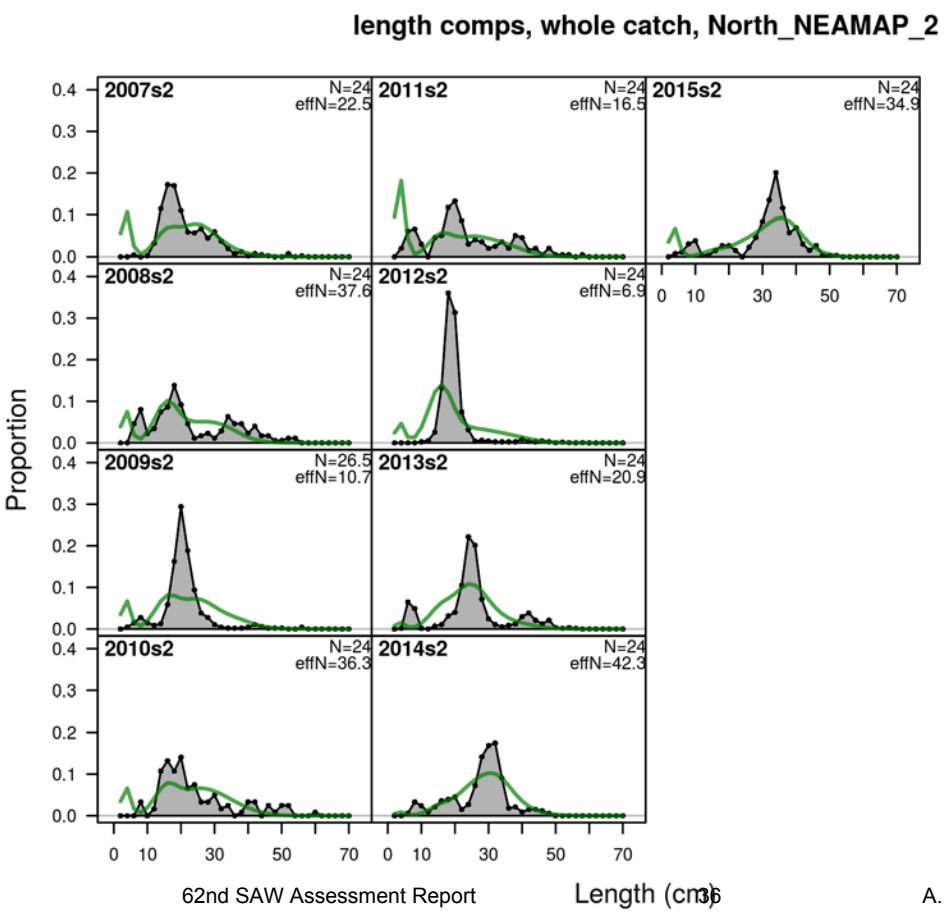
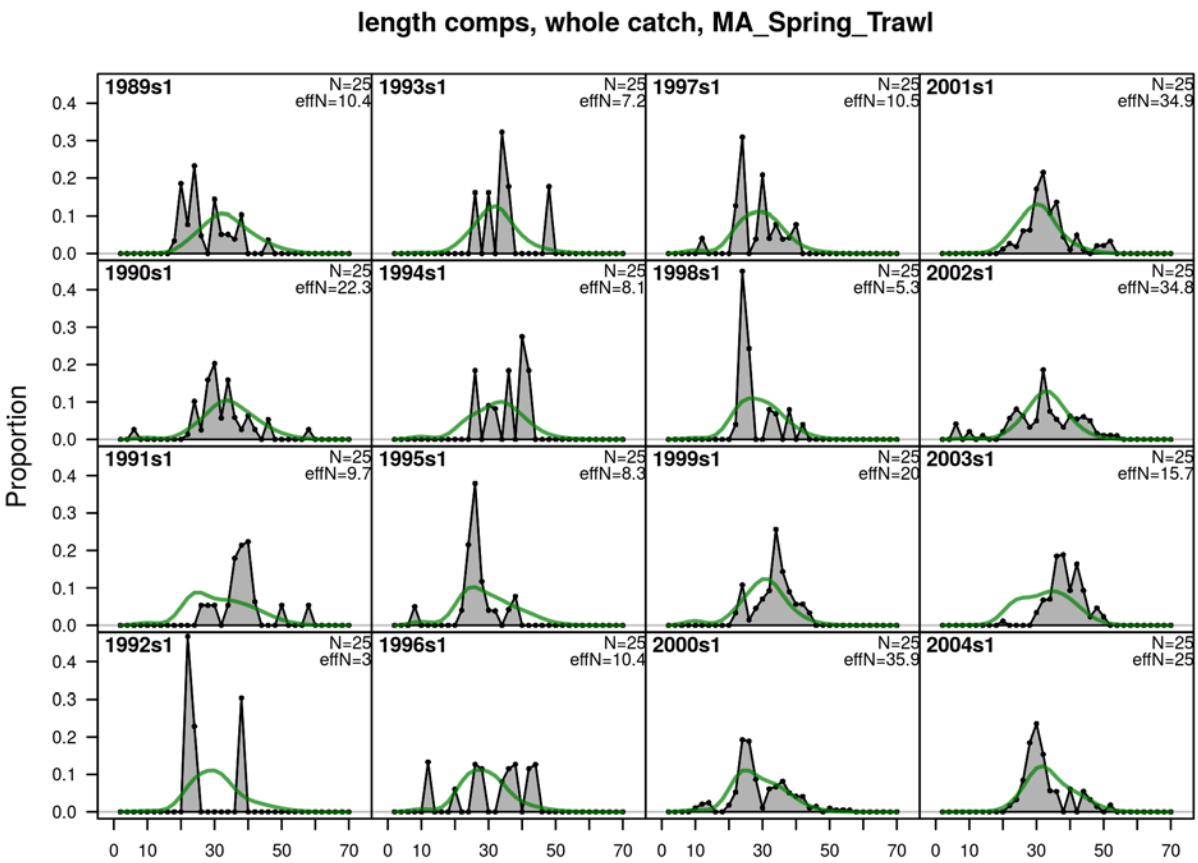


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



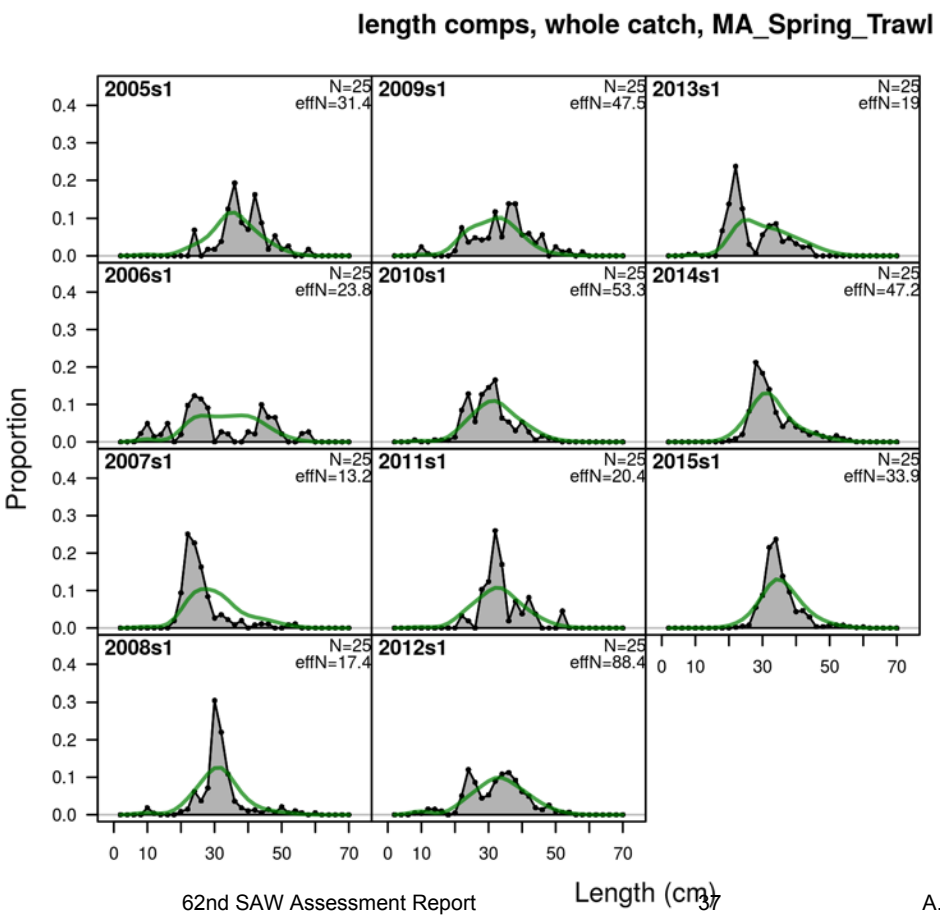
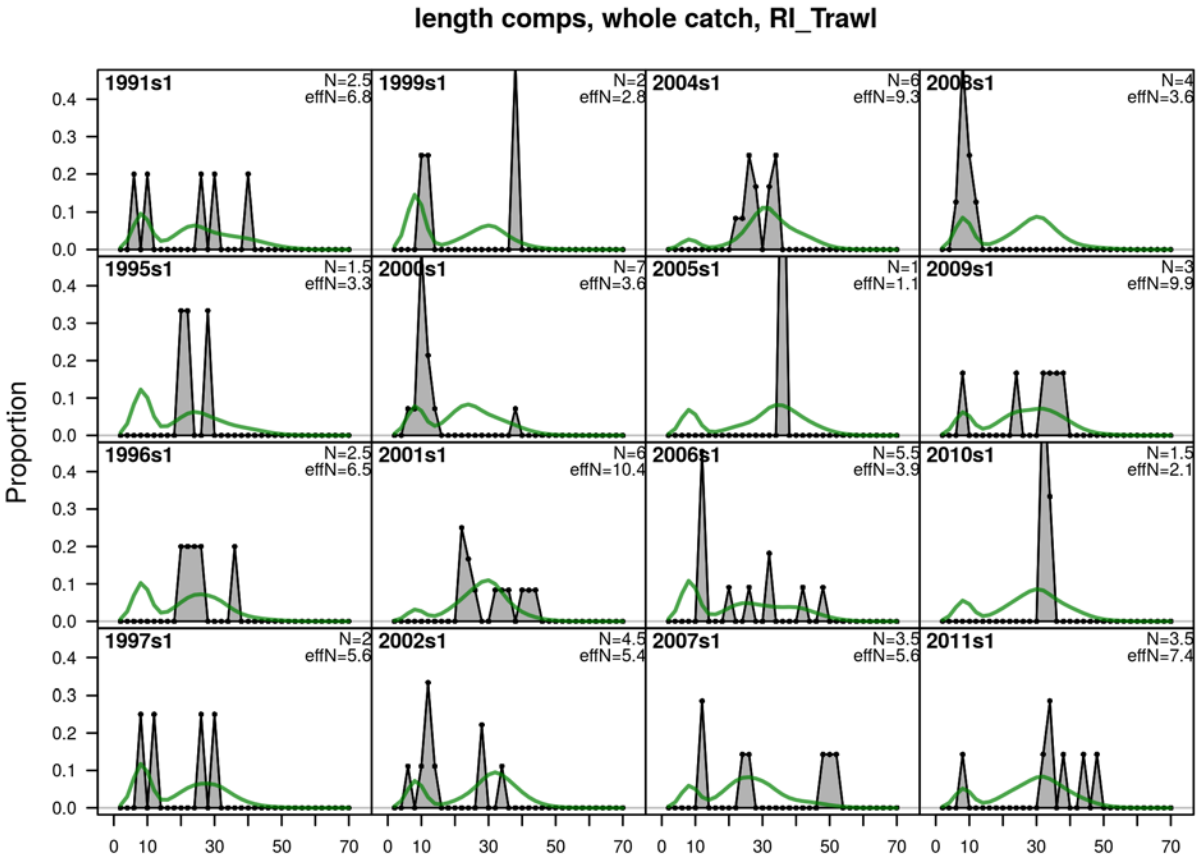


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



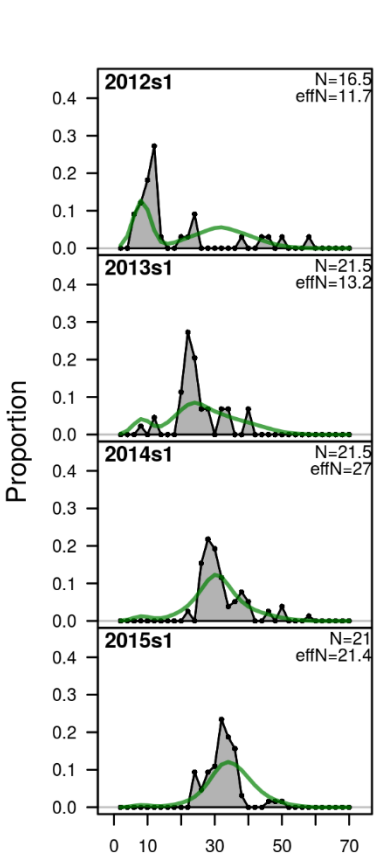
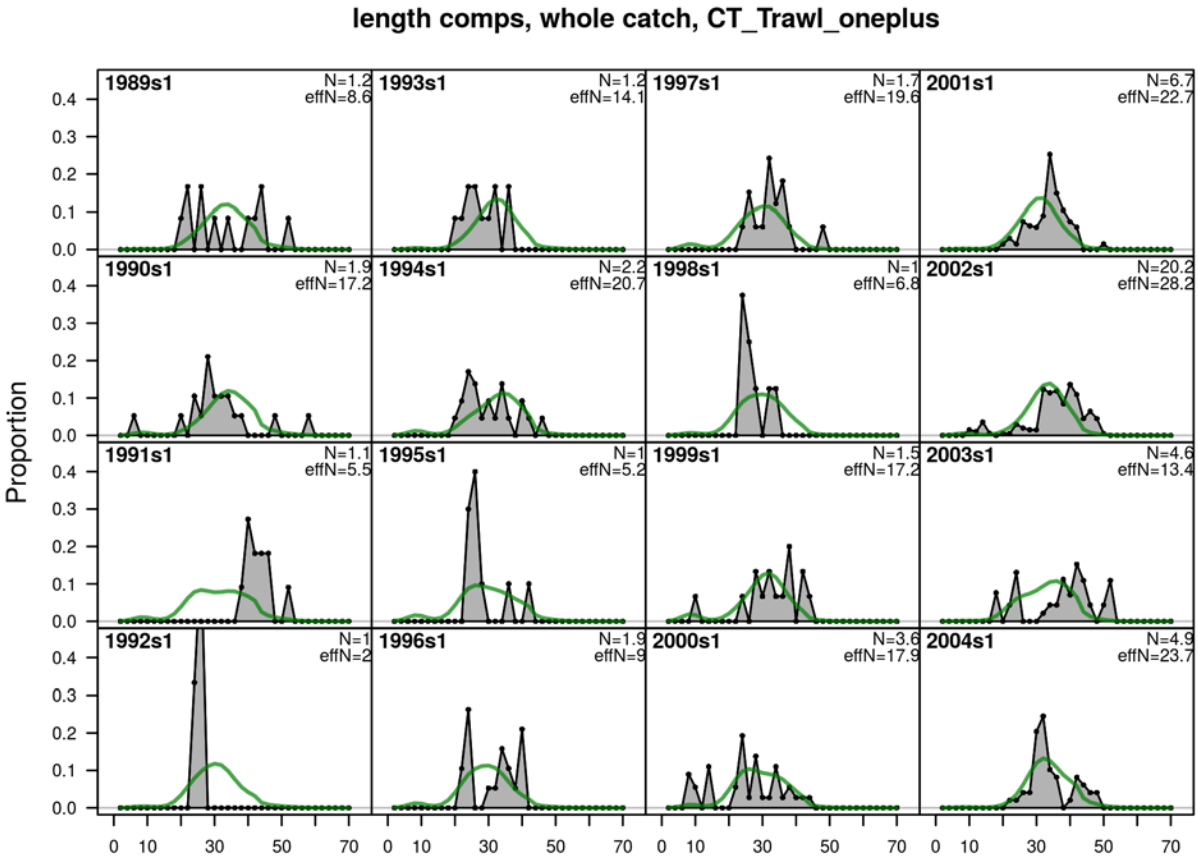


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



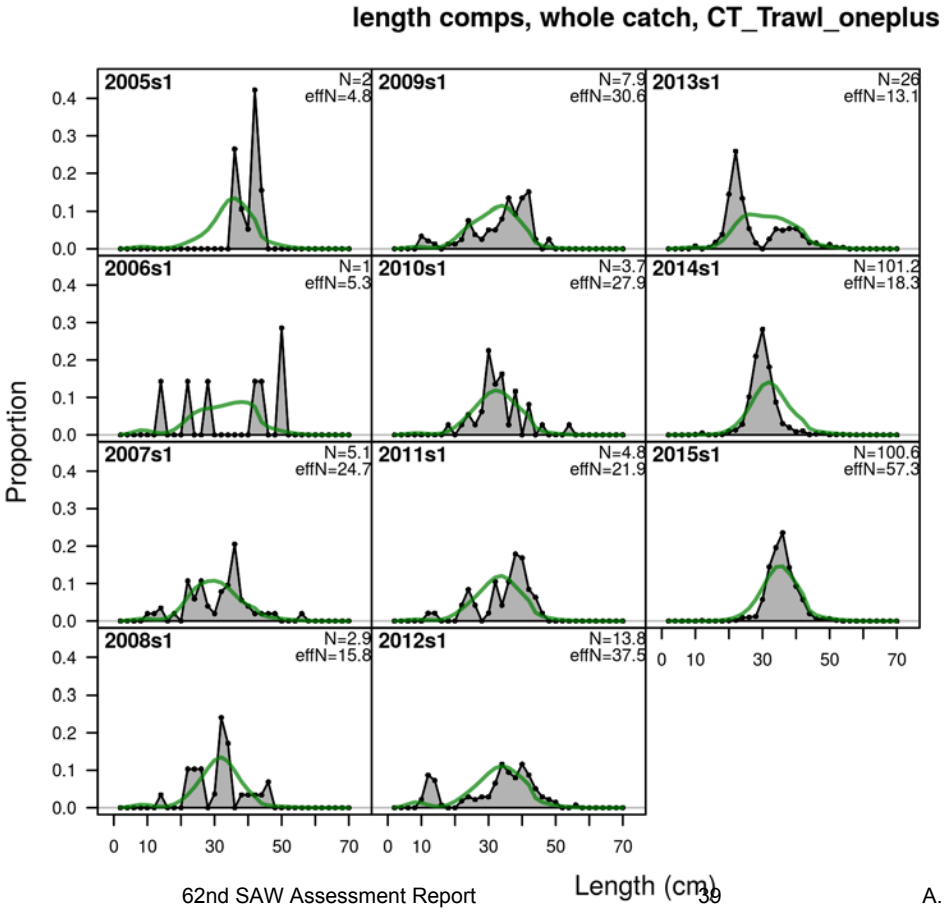
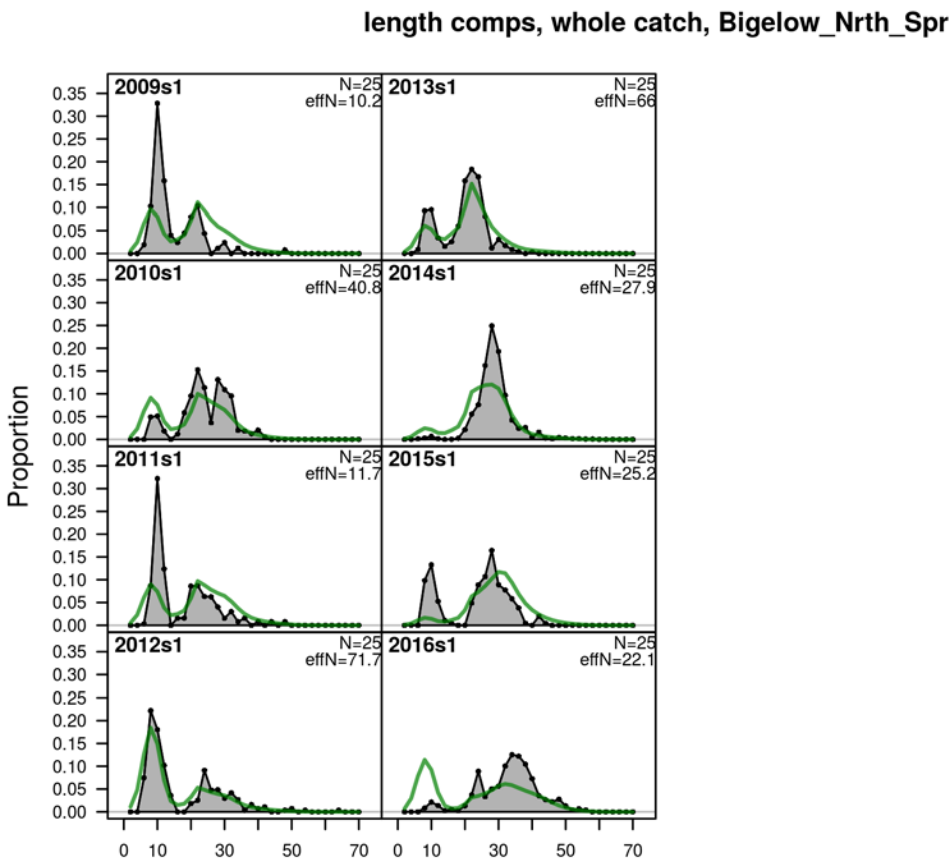


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



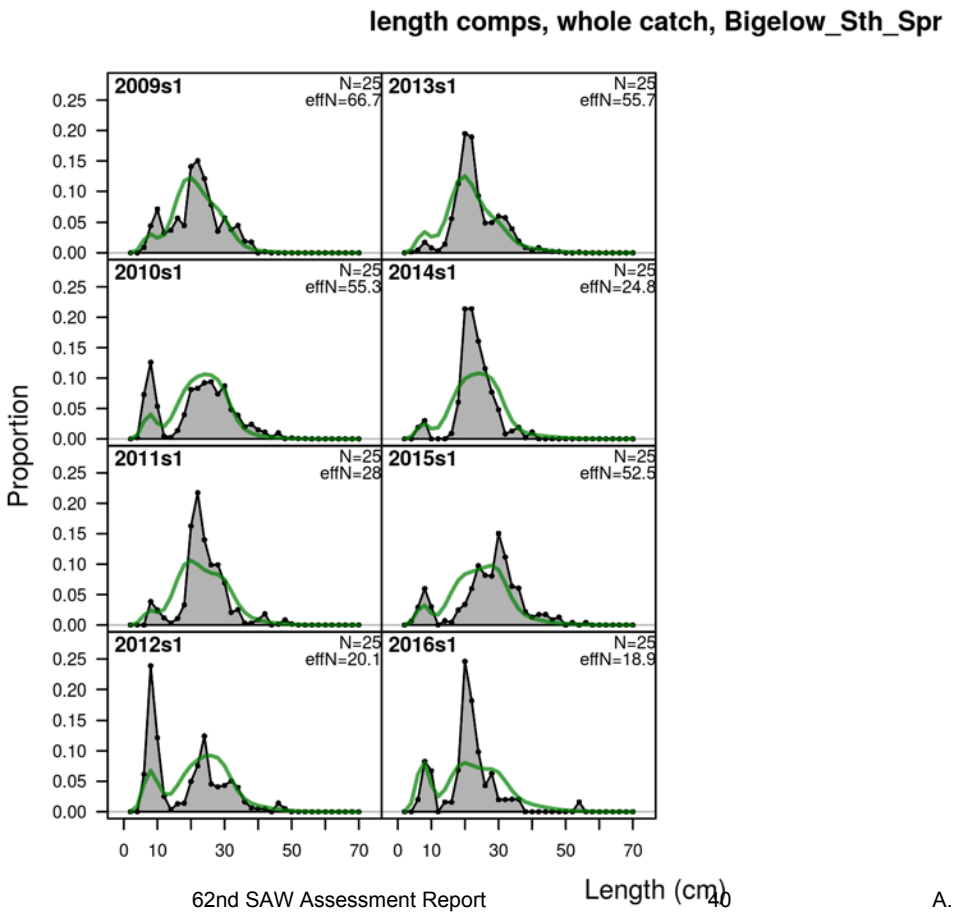
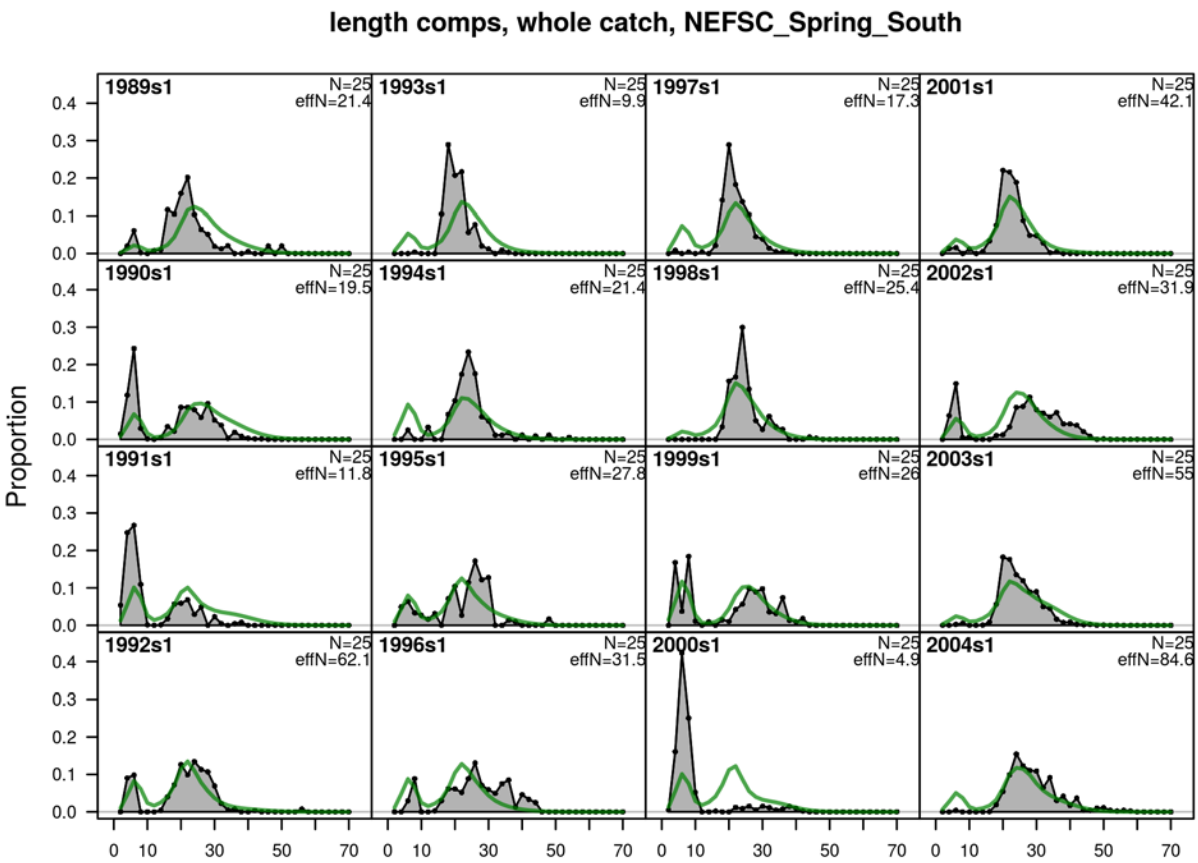


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



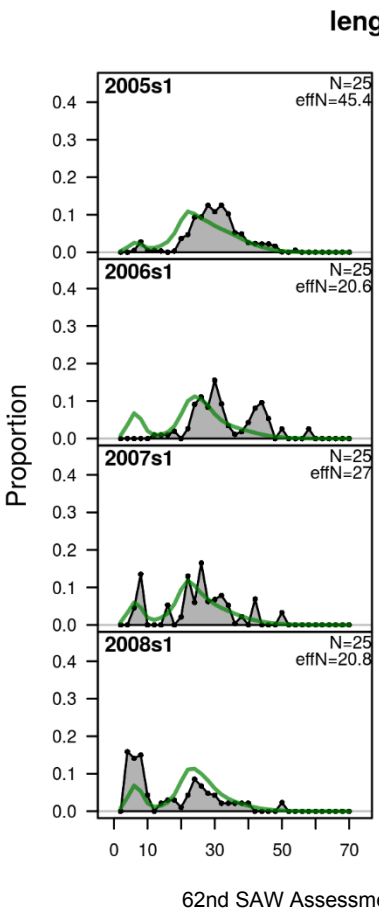
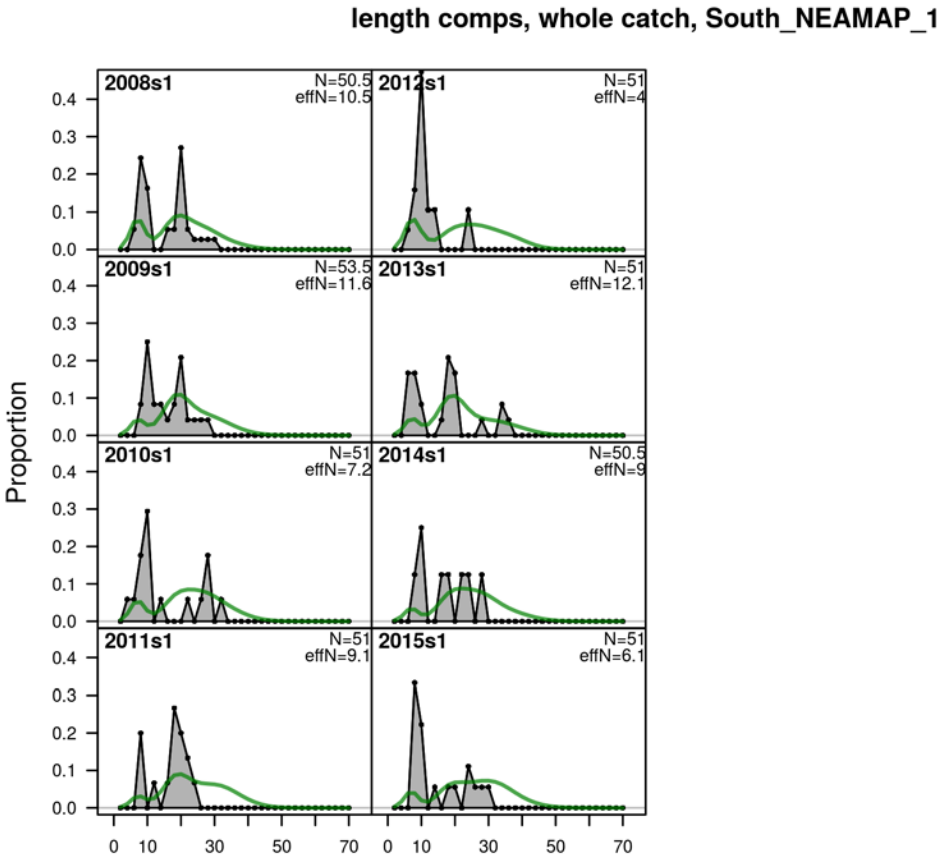


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



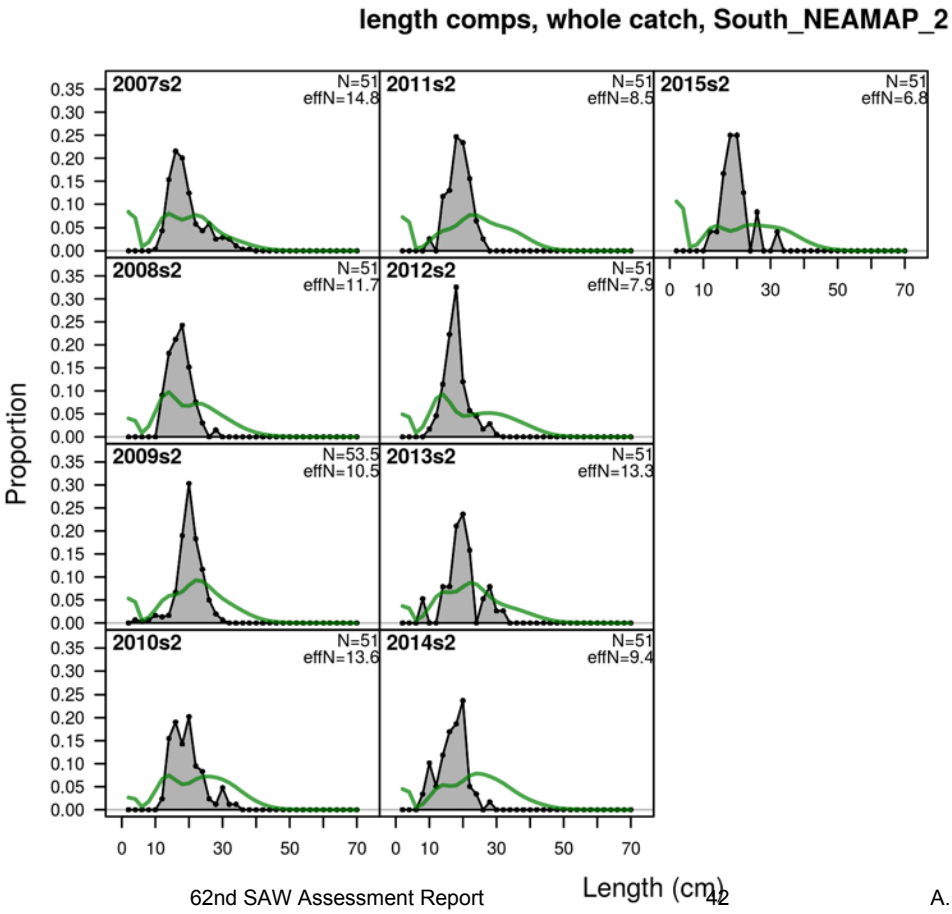
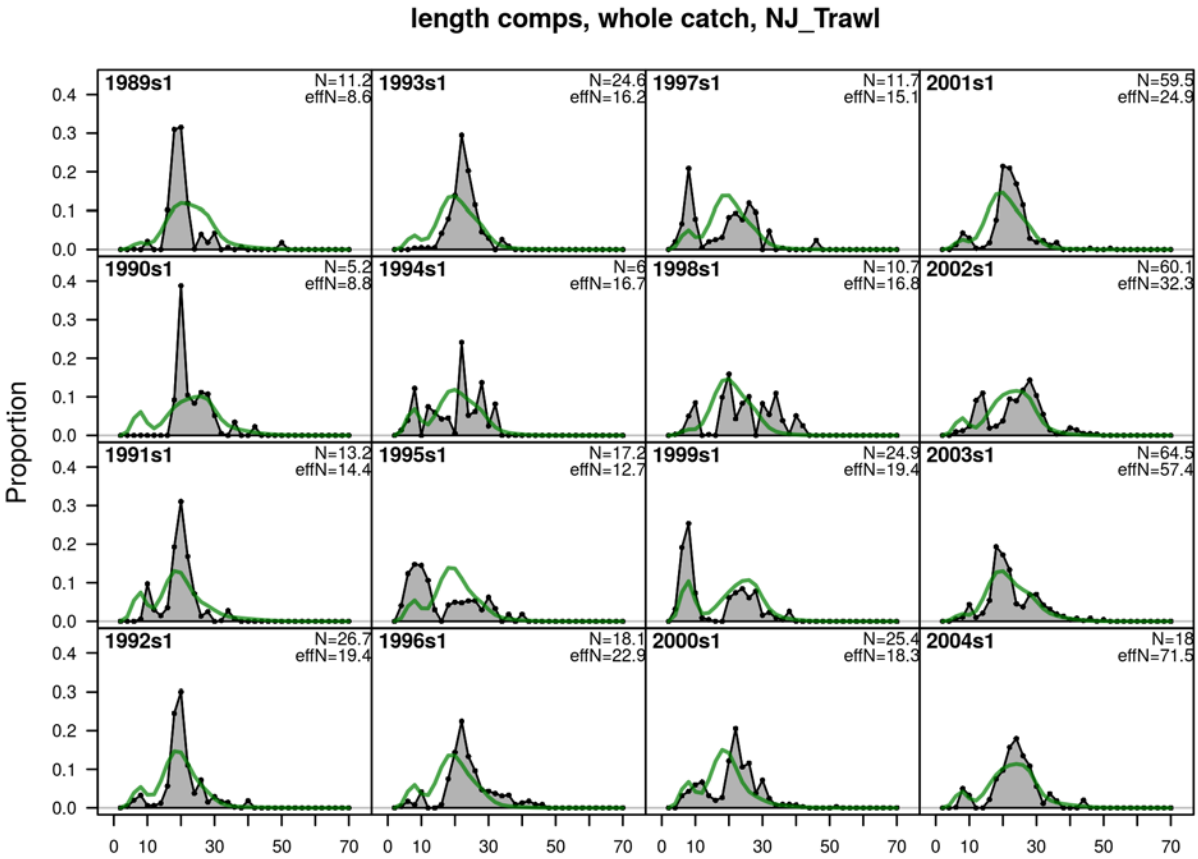


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.



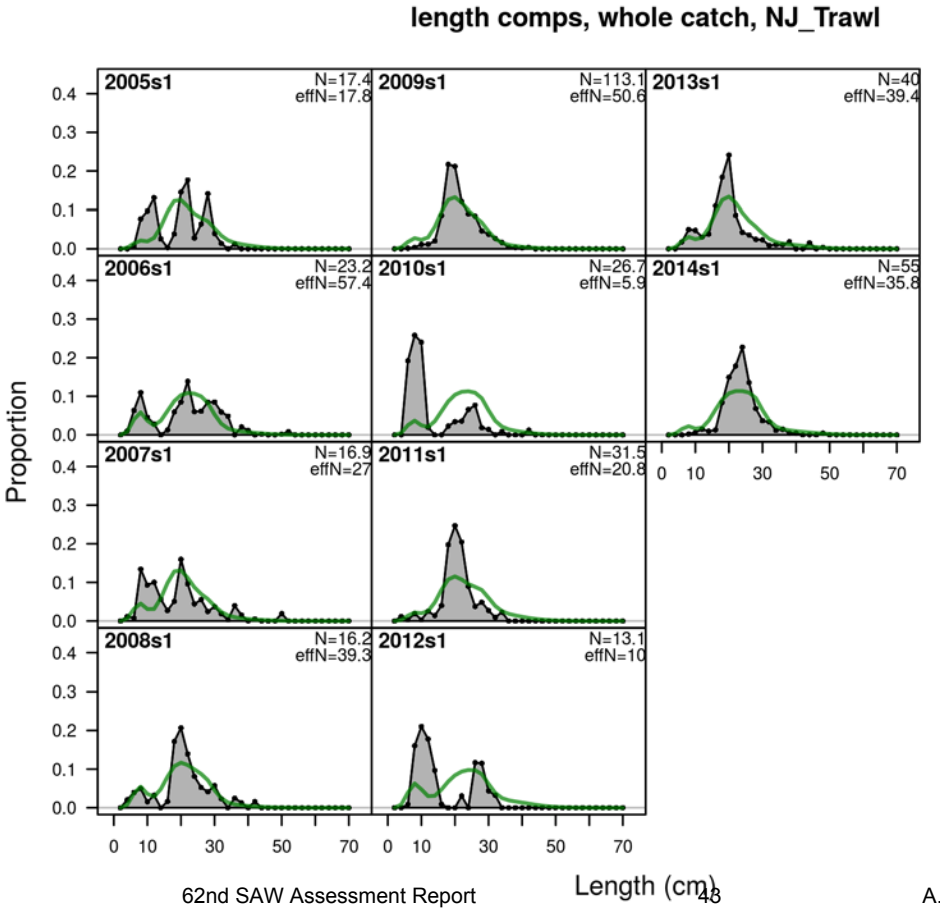


Figure 3 continued. Length distributions, observed (black line) and model predictions (green lines) from SS.

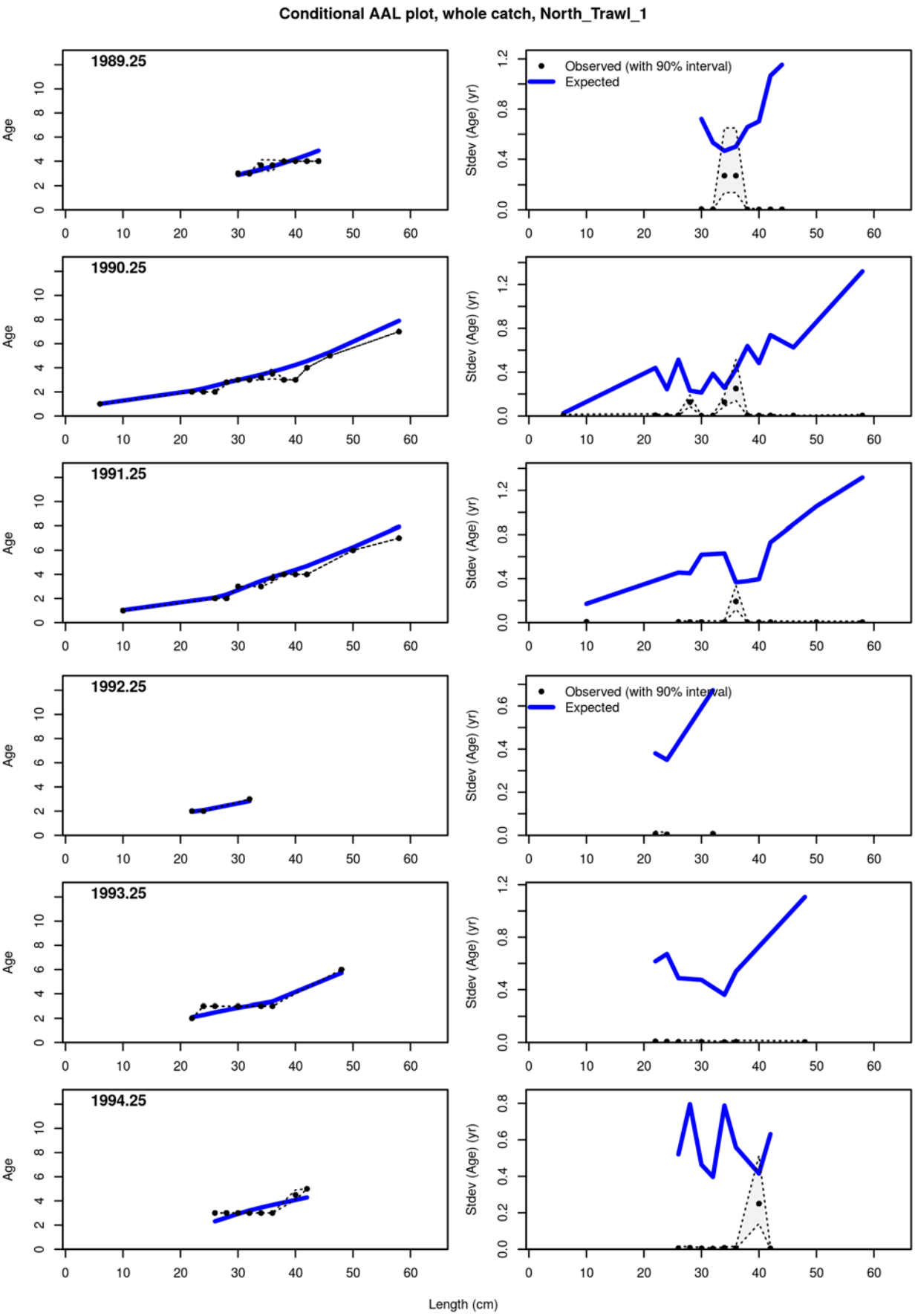


Figure 4. Observed and predicted mean age-at-length by size-class with 90% CIs (left) and SE of mean age-at-length with 90% CIs (right).

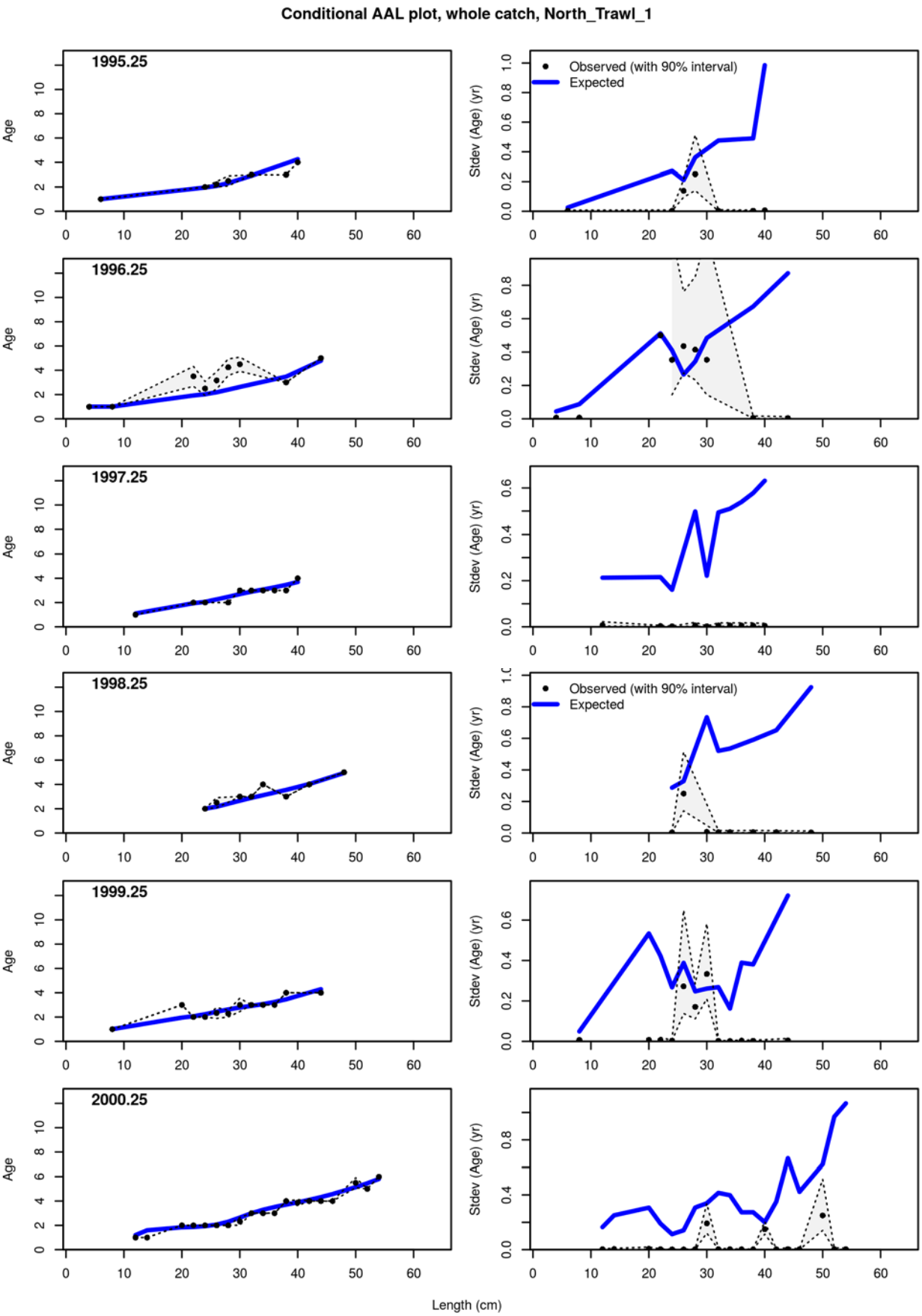


Figure 4 continued. Observed and predicted mean age-at-length by size-class with 90% CIs (left) and SE of mean age-at-length with 90% CIs (right).

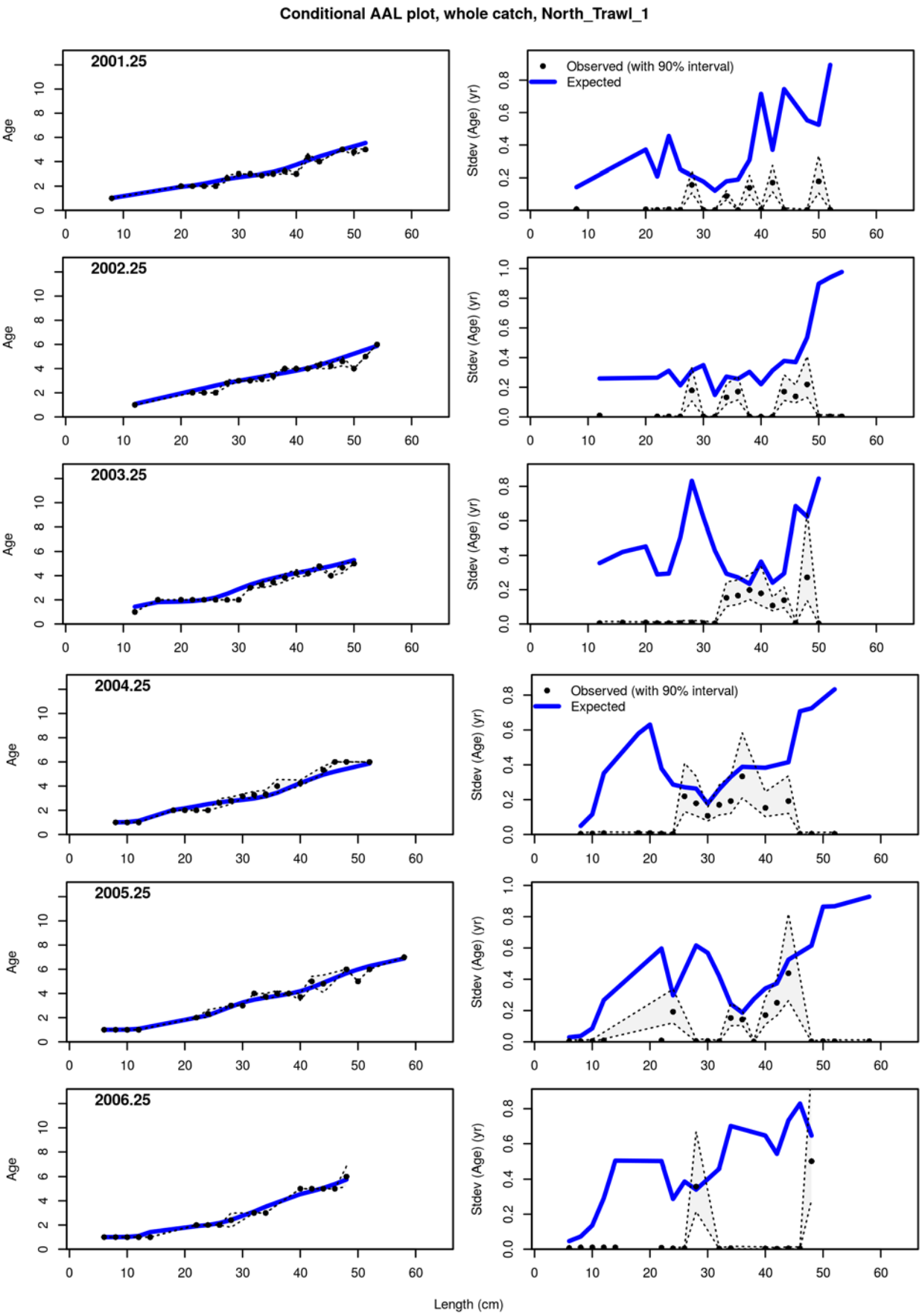


Figure 4 continued. Observed and predicted mean age-at-length by size-class with 90% CIs (left) and SE of mean age-at-length with 90% CIs (right).

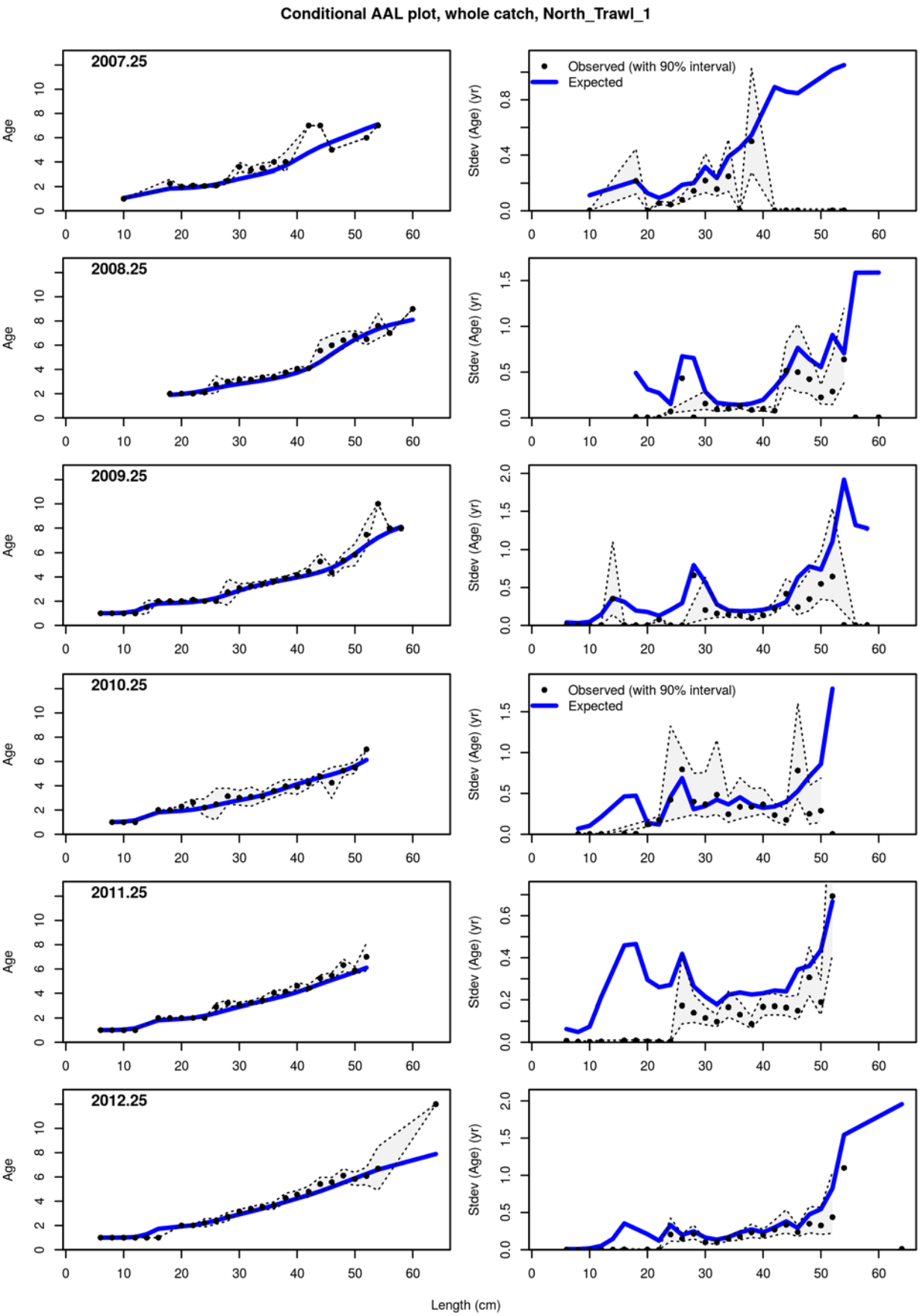
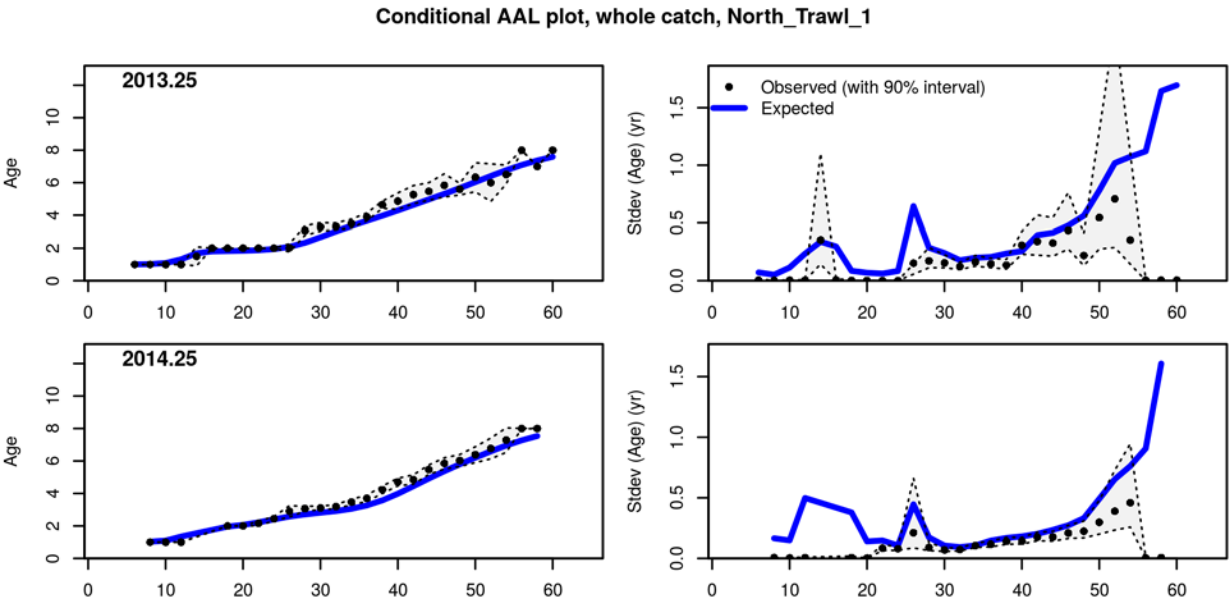


Figure 4 continued. Observed and predicted mean age-at-length by size-class with 90% CIs (left) and SE of mean age-at-length with 90% CIs (right).



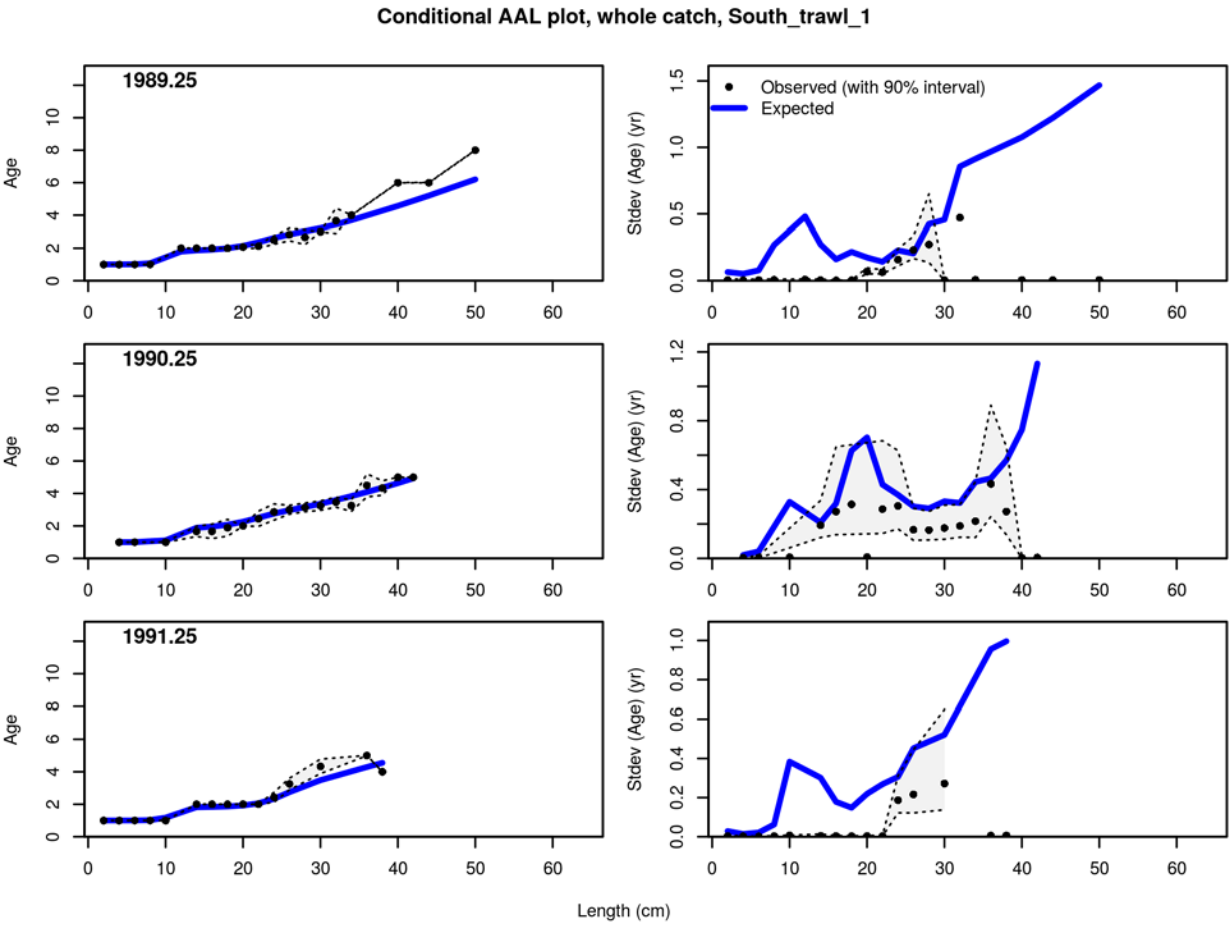


Figure 4 continued. Observed and predicted mean age-at-length by size-class with 90% CIs (left) and SE of mean age-at-length with 90% CIs (right).

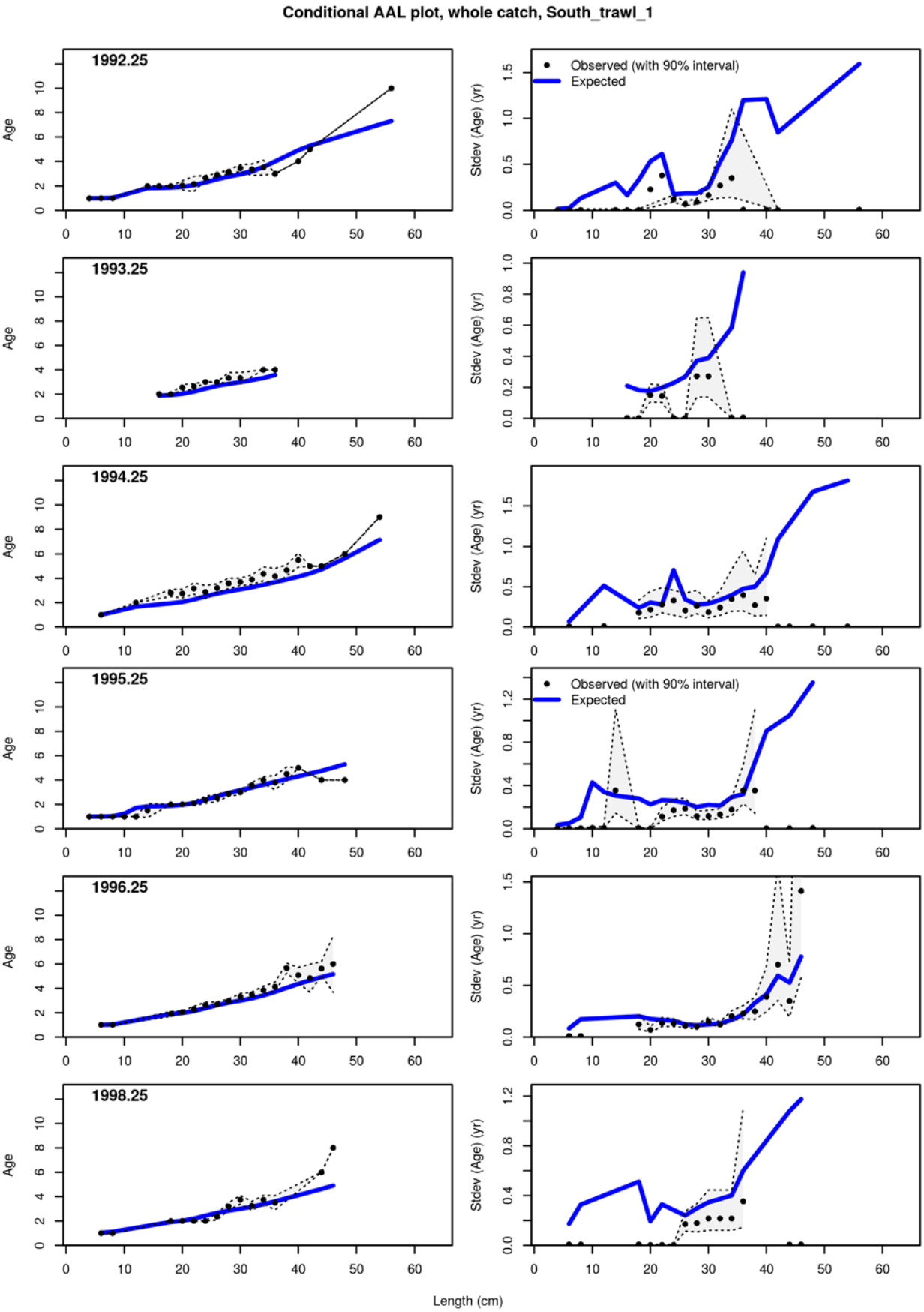


Figure 4 continued. Observed and predicted mean age-at-length by size-class with 90% CIs (left) and SE of mean age-at-length with 90% CIs (right).

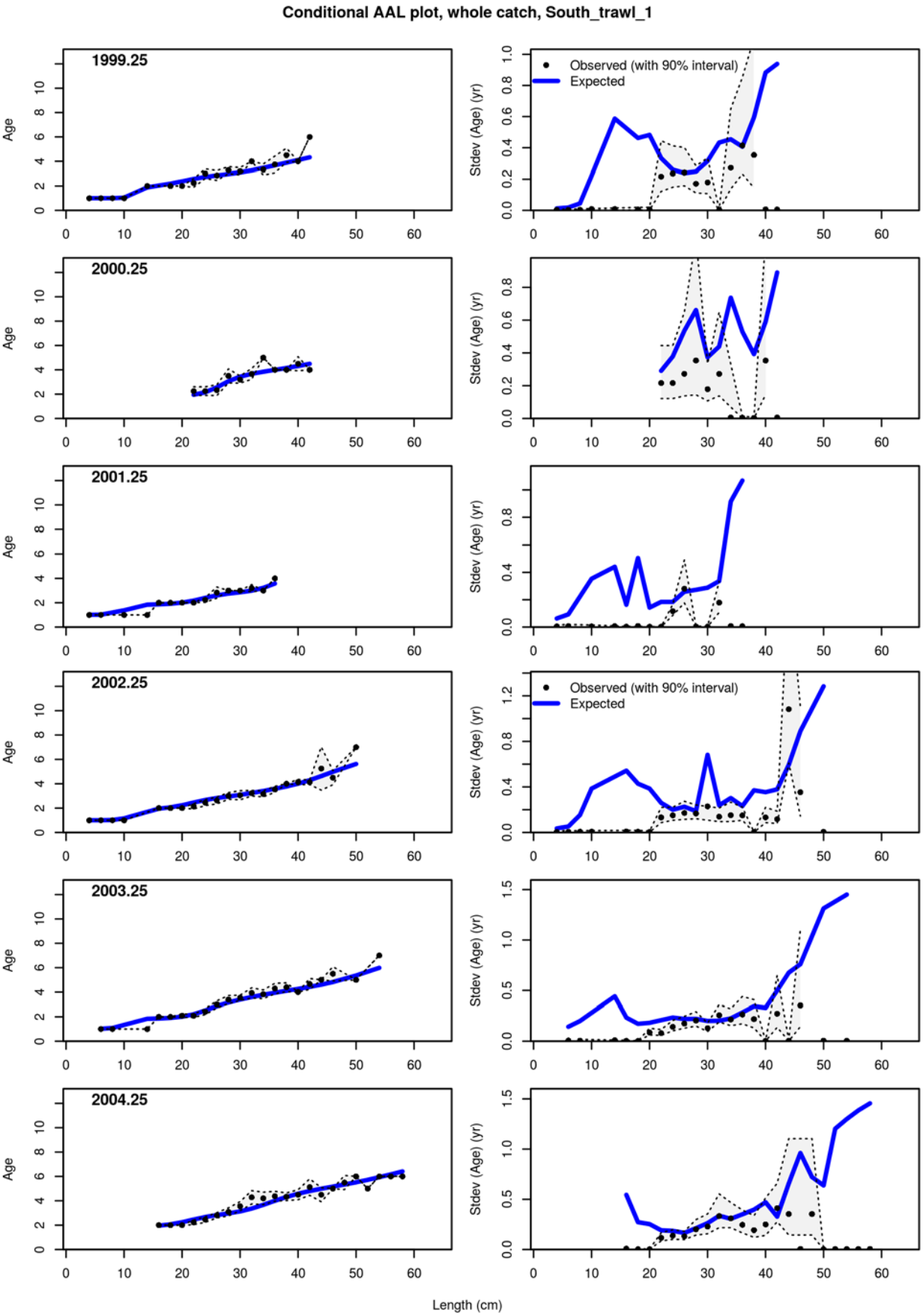


Figure 4 continued. Observed and predicted mean age-at-length by size-class with 90% CIs (left) and SE of mean age-at-length with 90% CIs (right).

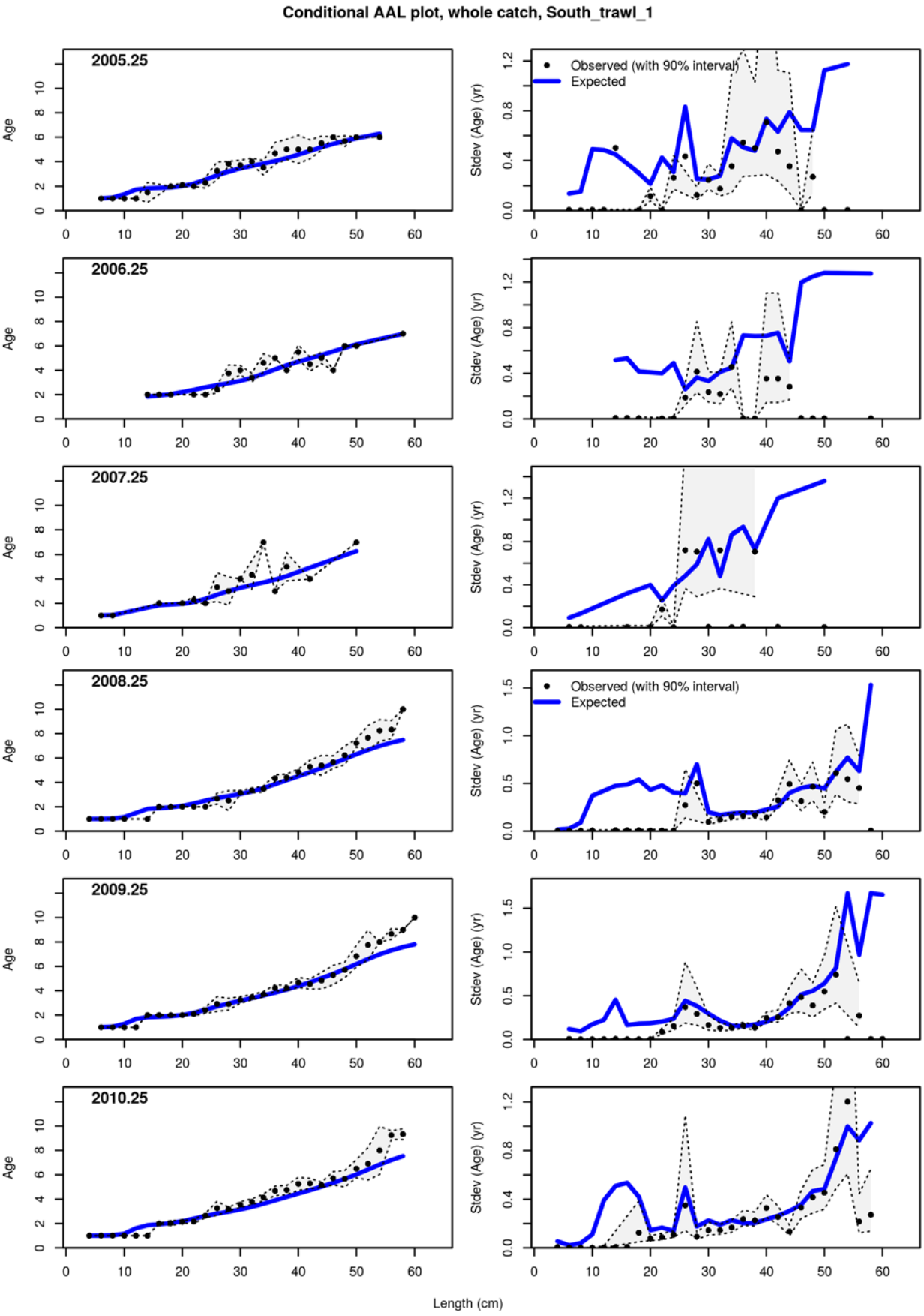


Figure 4 continued. Observed and predicted mean age-at-length by size-class with 90% CIs (left) and SE of mean age-at-length with 90% CIs (right).

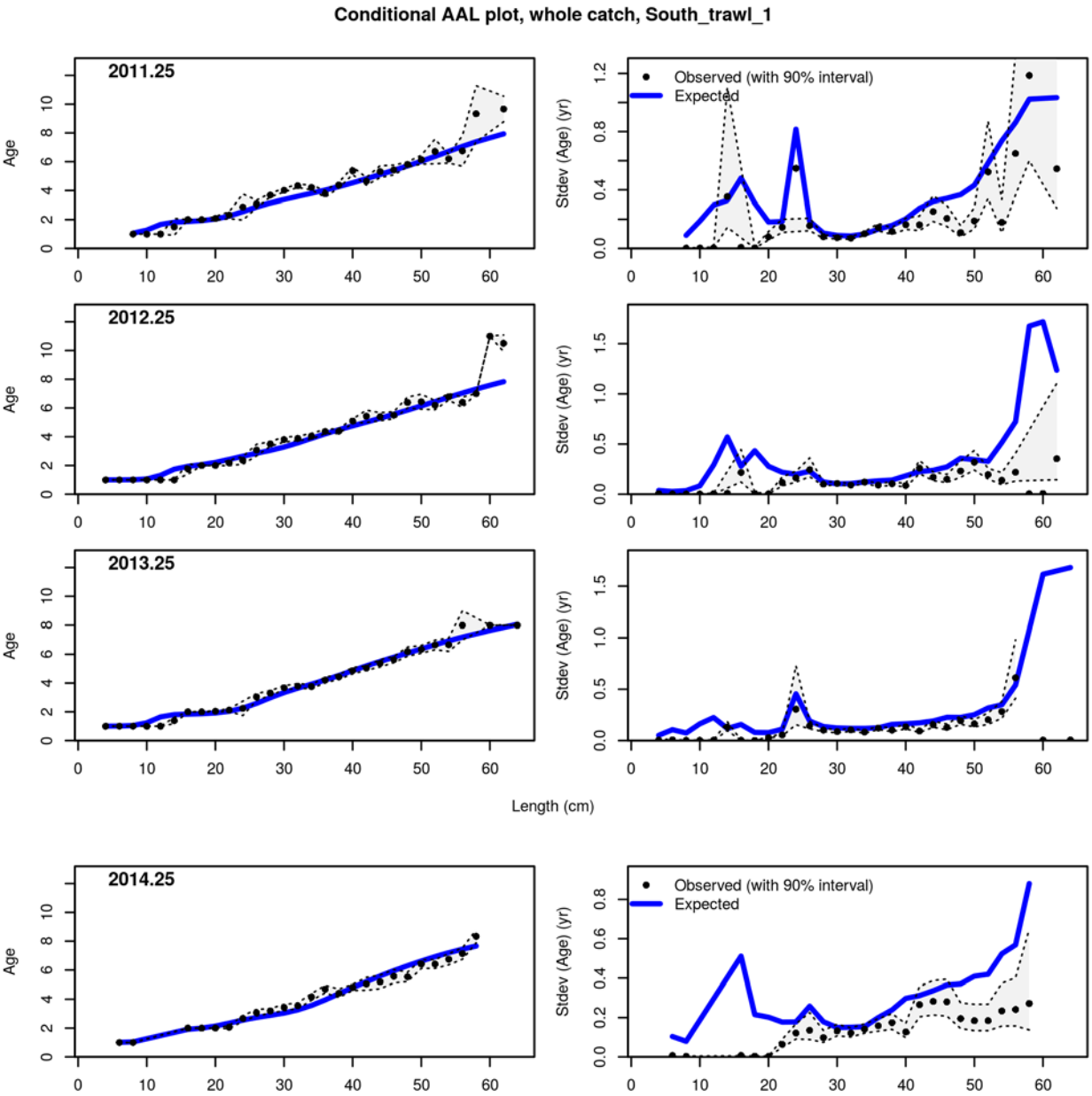


Figure 4 continued. Observed and predicted mean age-at-length by size-class with 90% CIs (left) and SE of mean age-at-length with 90% CIs (right).

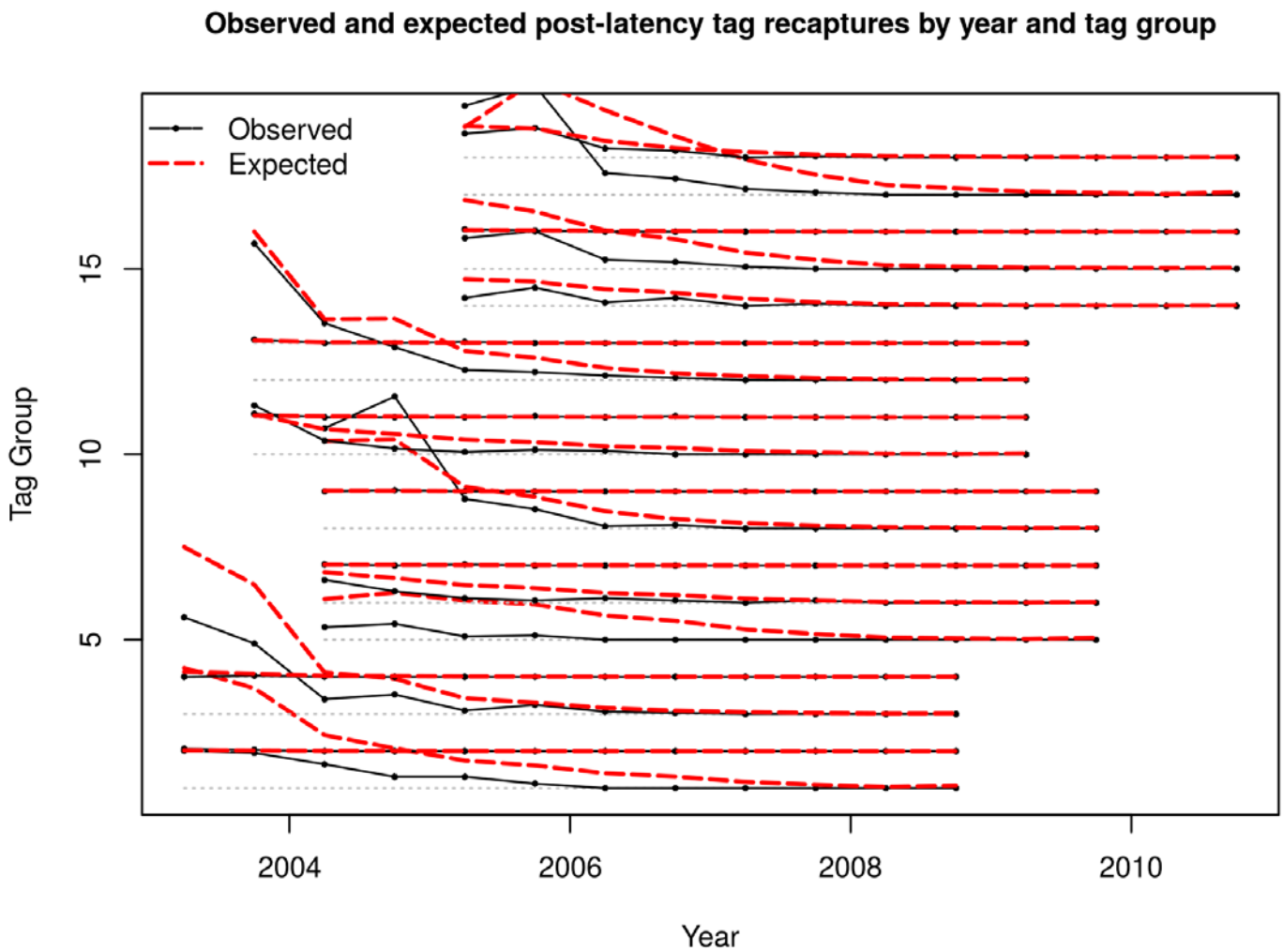


Figure 5. Observed and predicted tag recaptures from SS.

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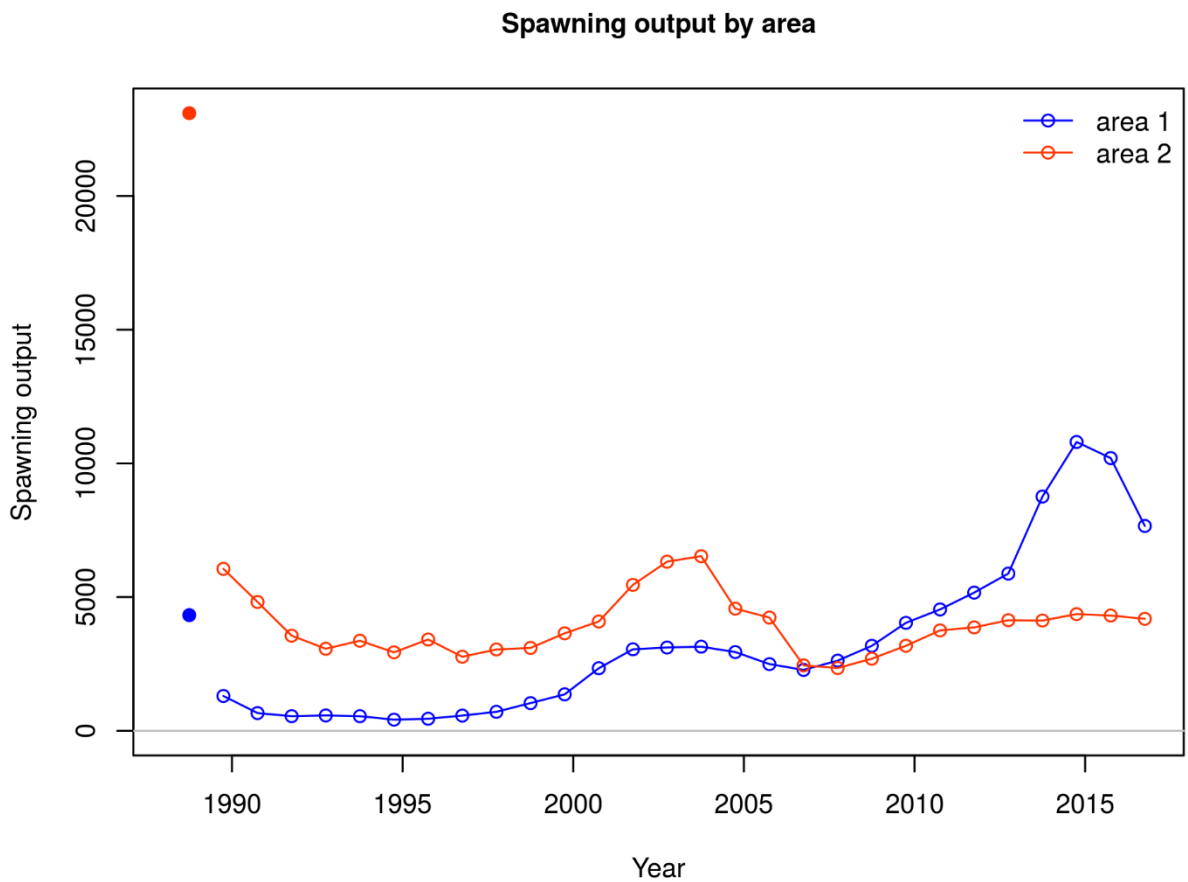

Figure 6. Estimated spawning stock biomass (mt, males and females) from the SS model.

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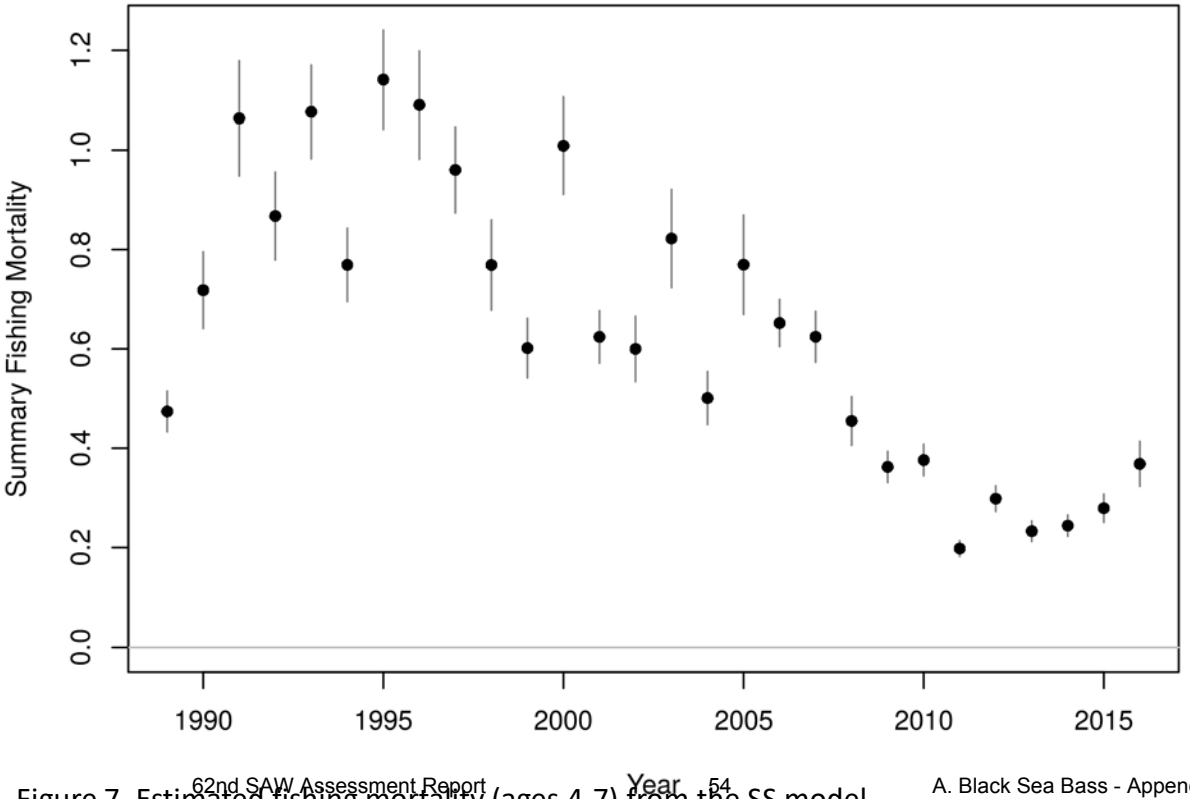

Figure 7. Estimated fishing mortality (ages 4-7) from the SS model.

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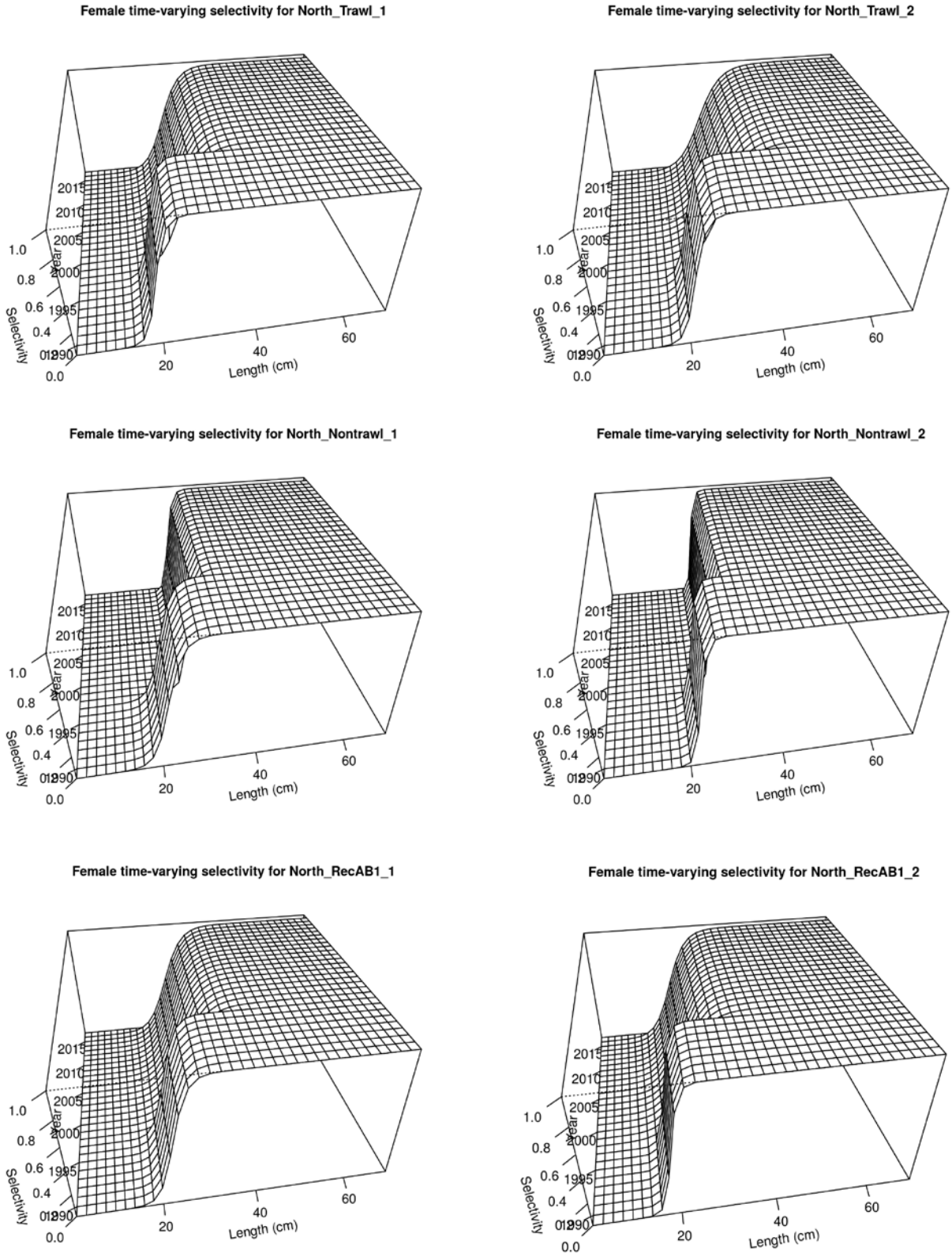
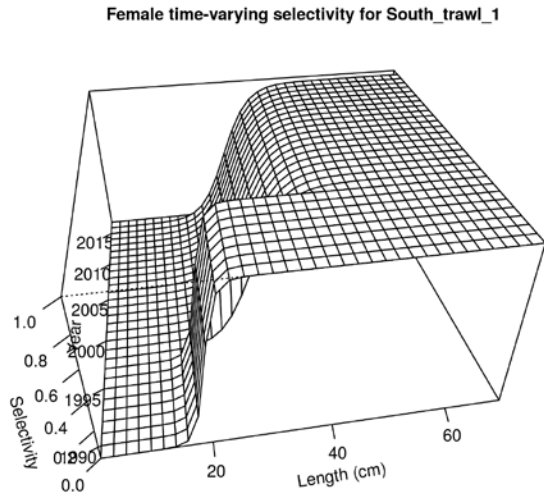
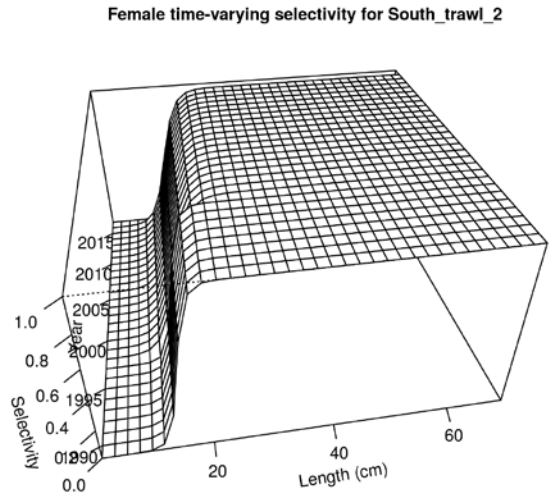
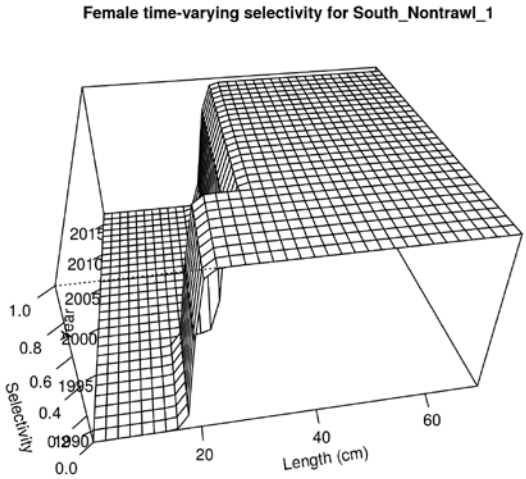
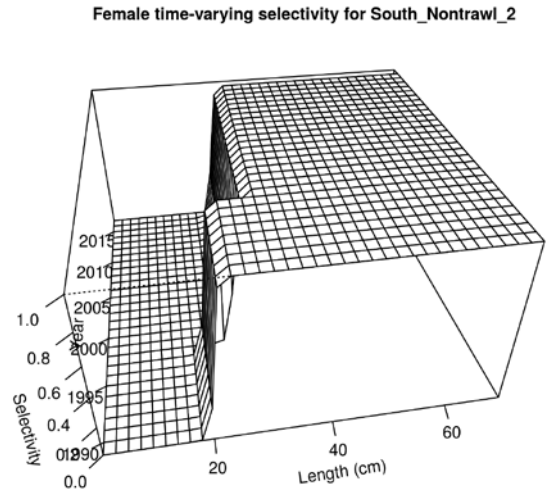


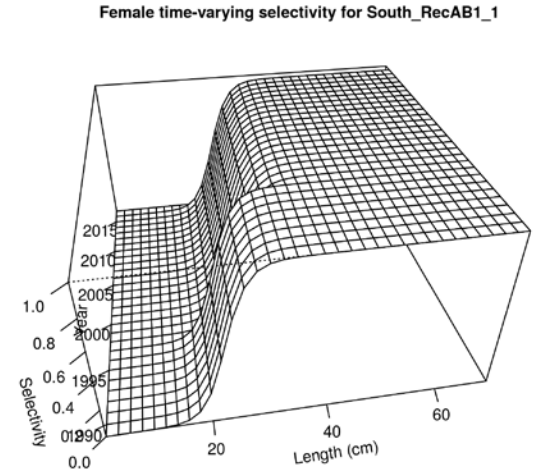
Figure 8. Estimates of selectivity by fleet (rows) and season (columns: spring, left; fall, right) from SS.











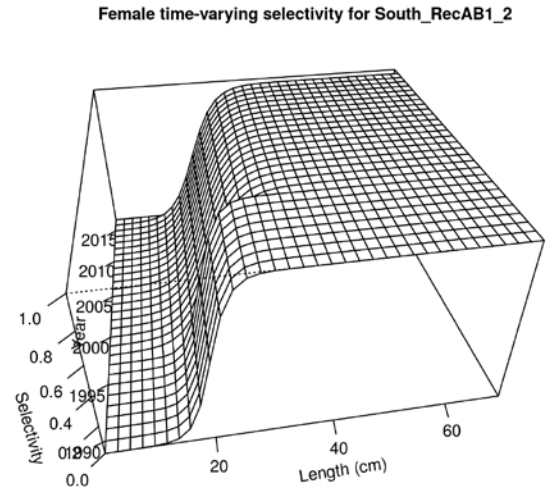


Figure 8 continued. Estimates of selectivity by fleet (rows) and season (columns: spring, left; fall, right).

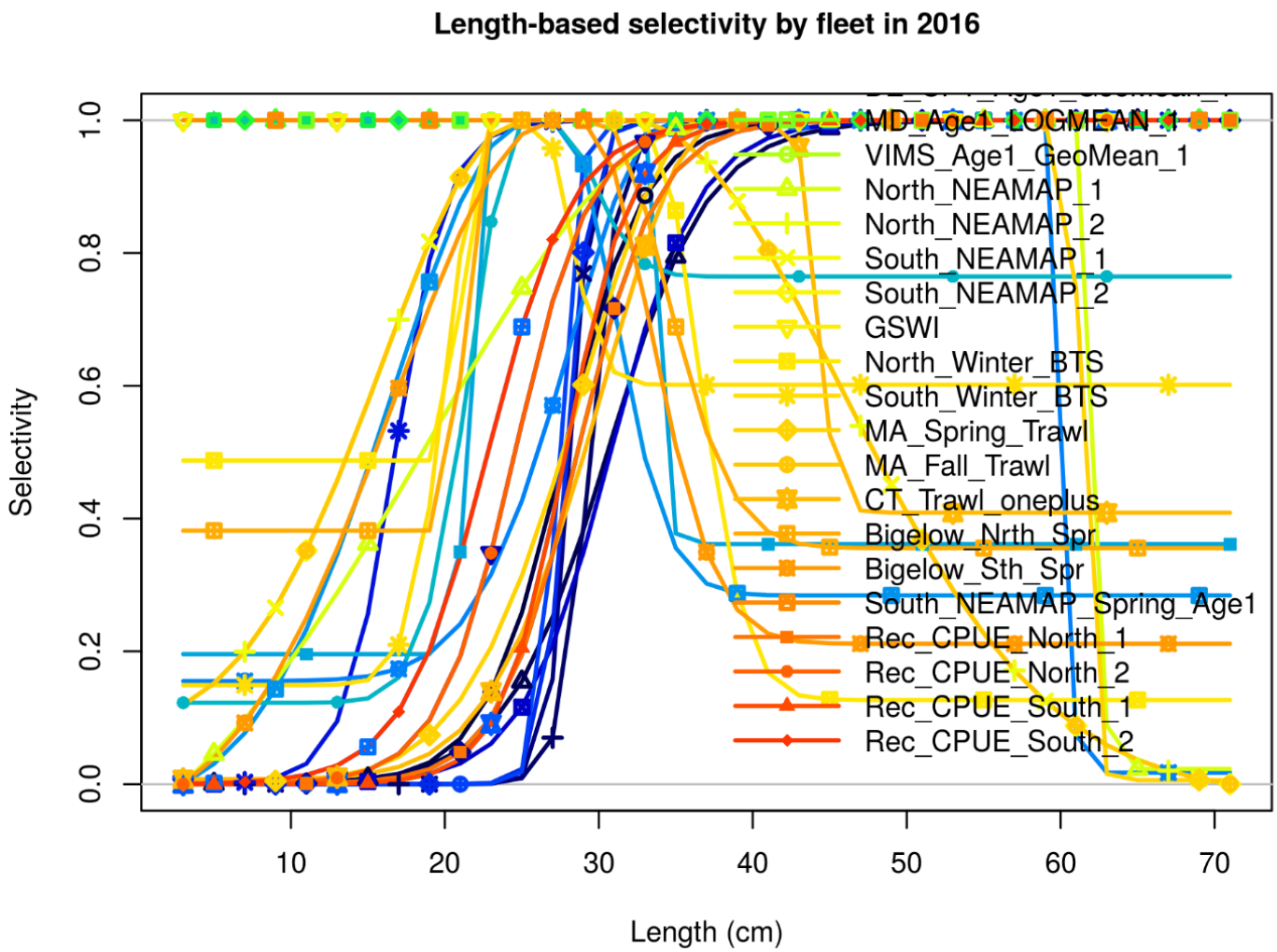


Figure 8 continued. Estimates of selectivity by fleet and season from SS (last digit of fleet label indicates season; 1: spring; 2: fall).

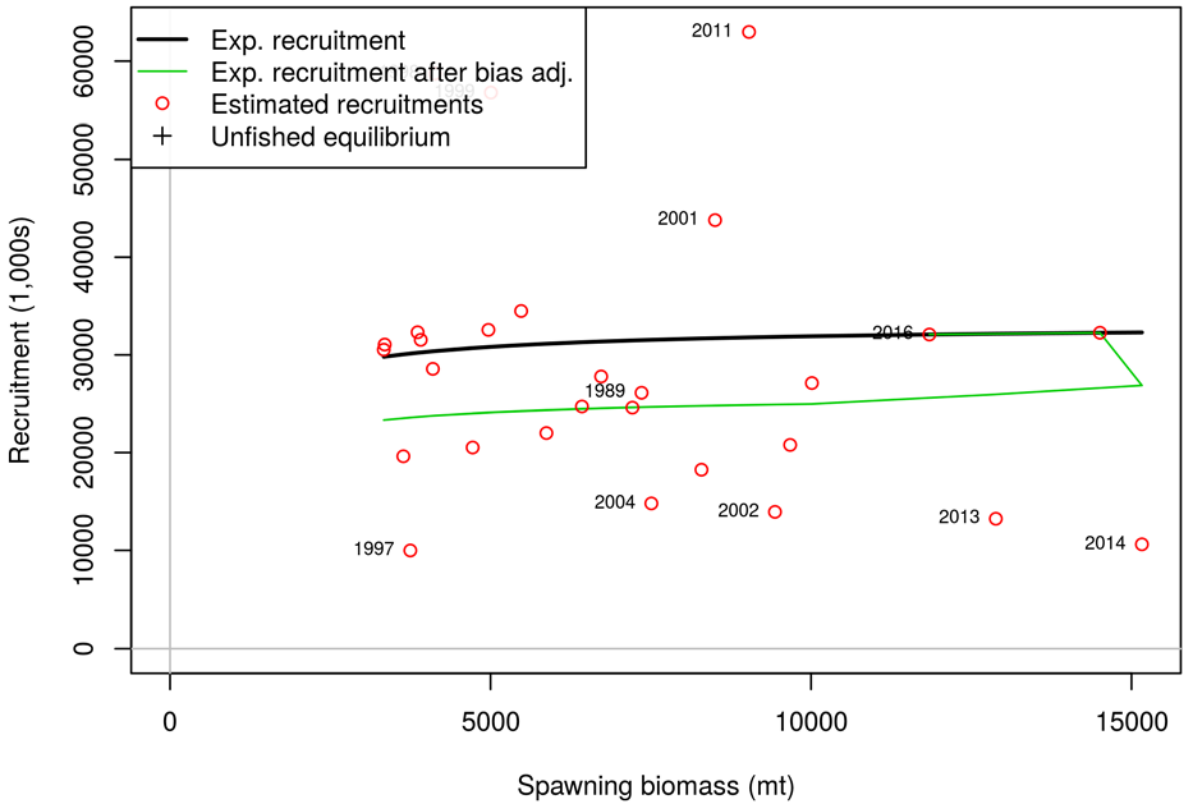


Figure 9. Estimates of spawning stock biomass and recruitment (above) and recruitment by area (below).

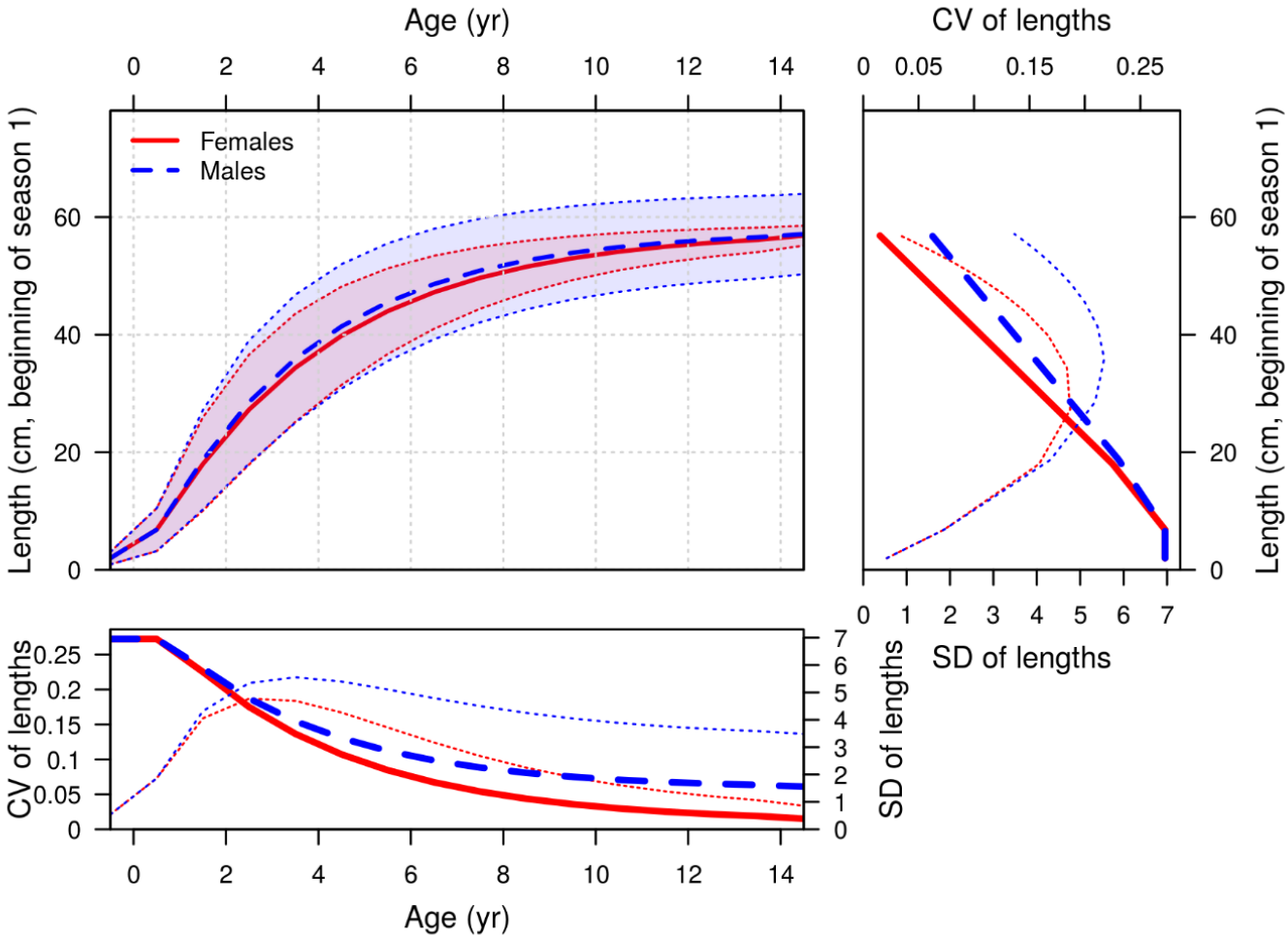


Figure 10. Estimates of size at age by sex from SS.

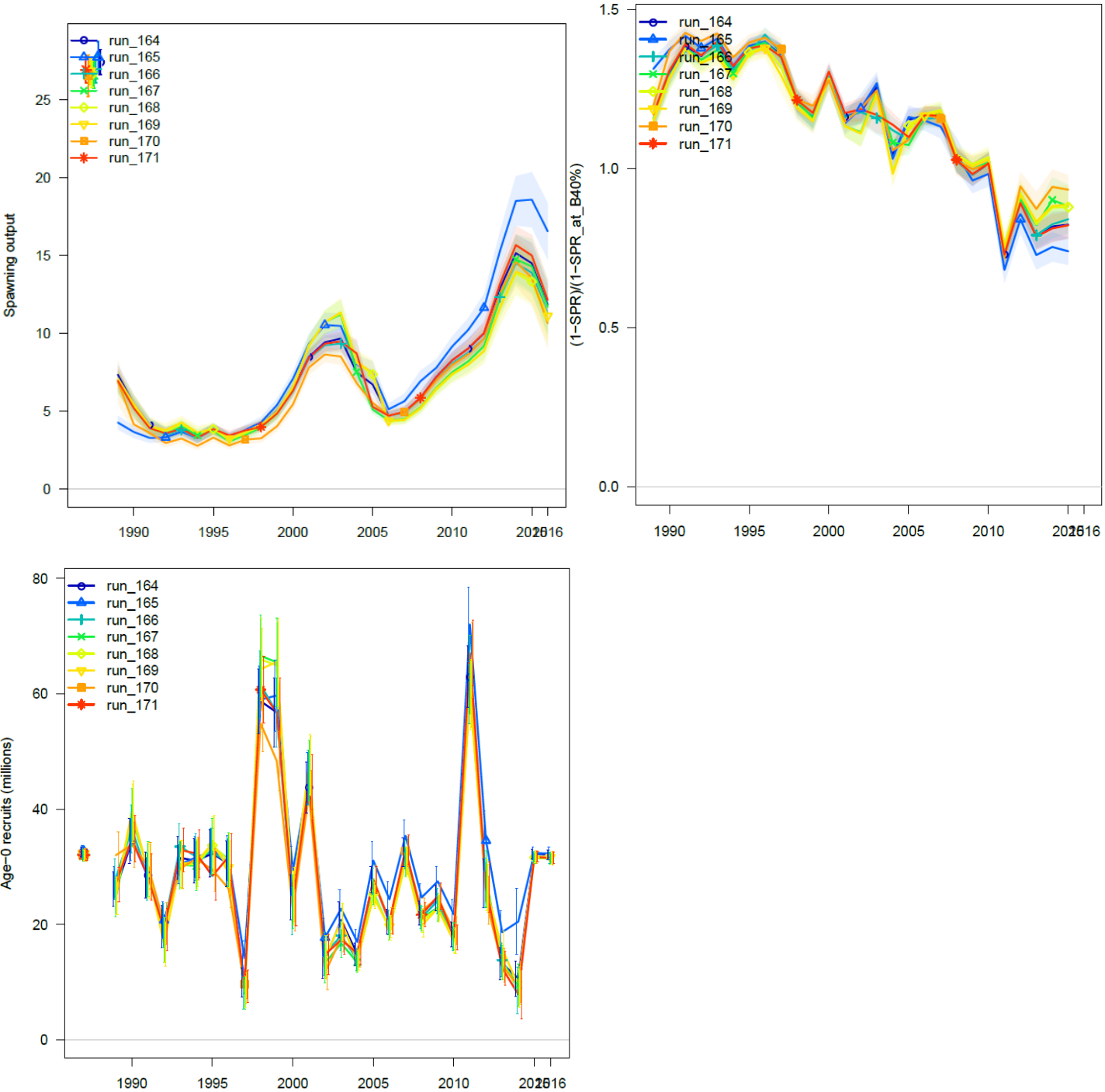
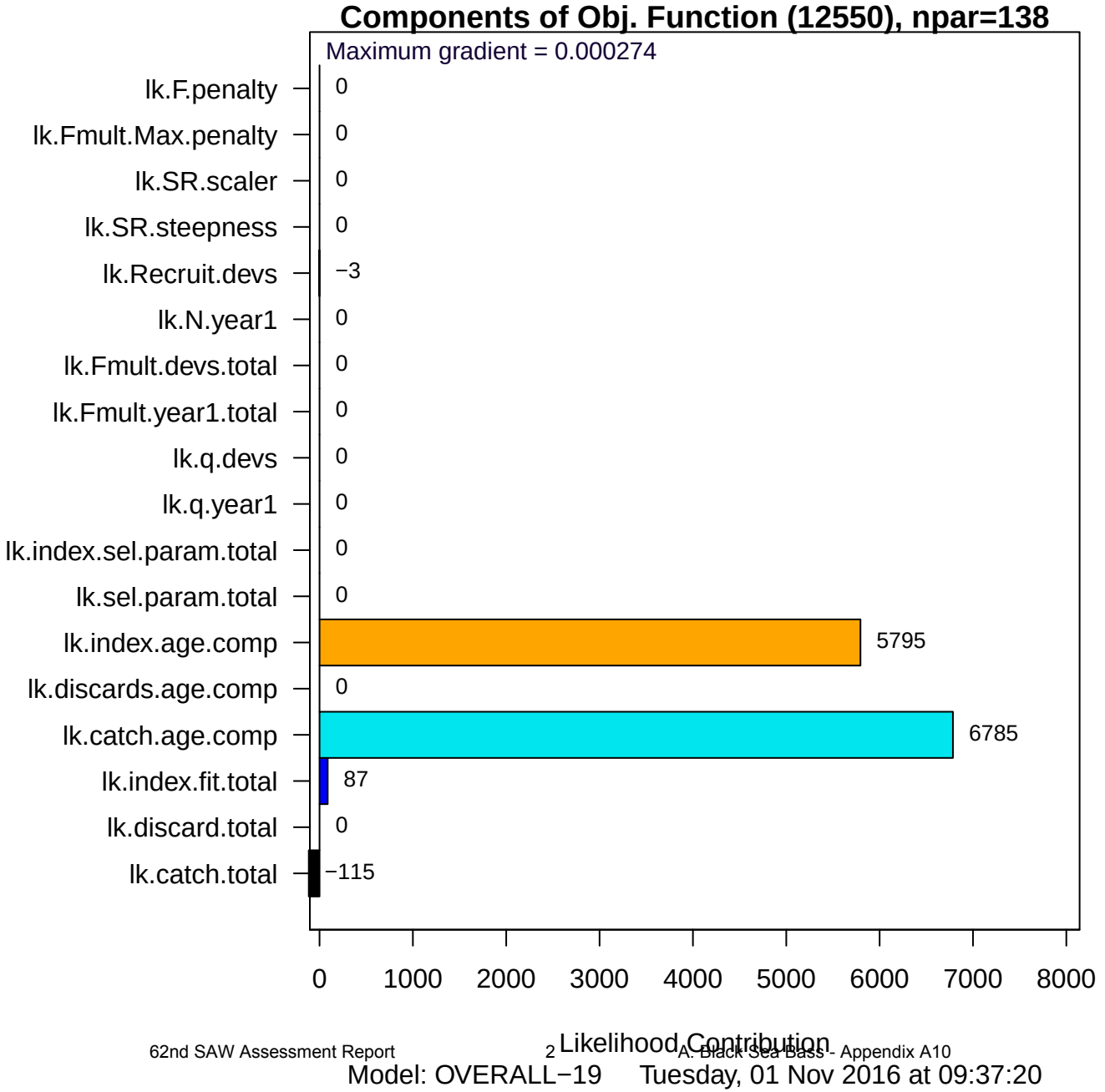
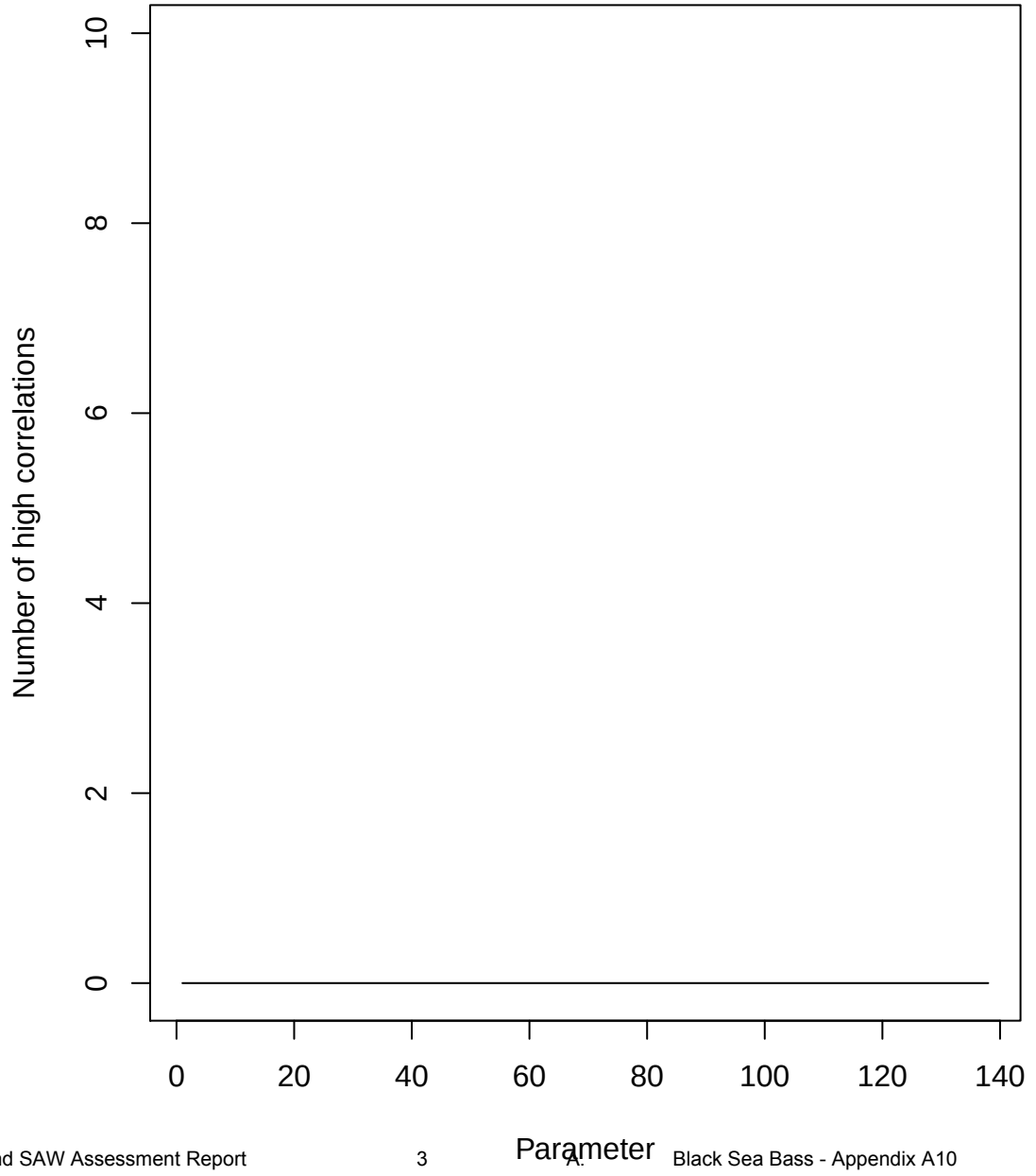


Figure 11. Sensitivity analyses from several configurations of SS (run number settings are described in text)

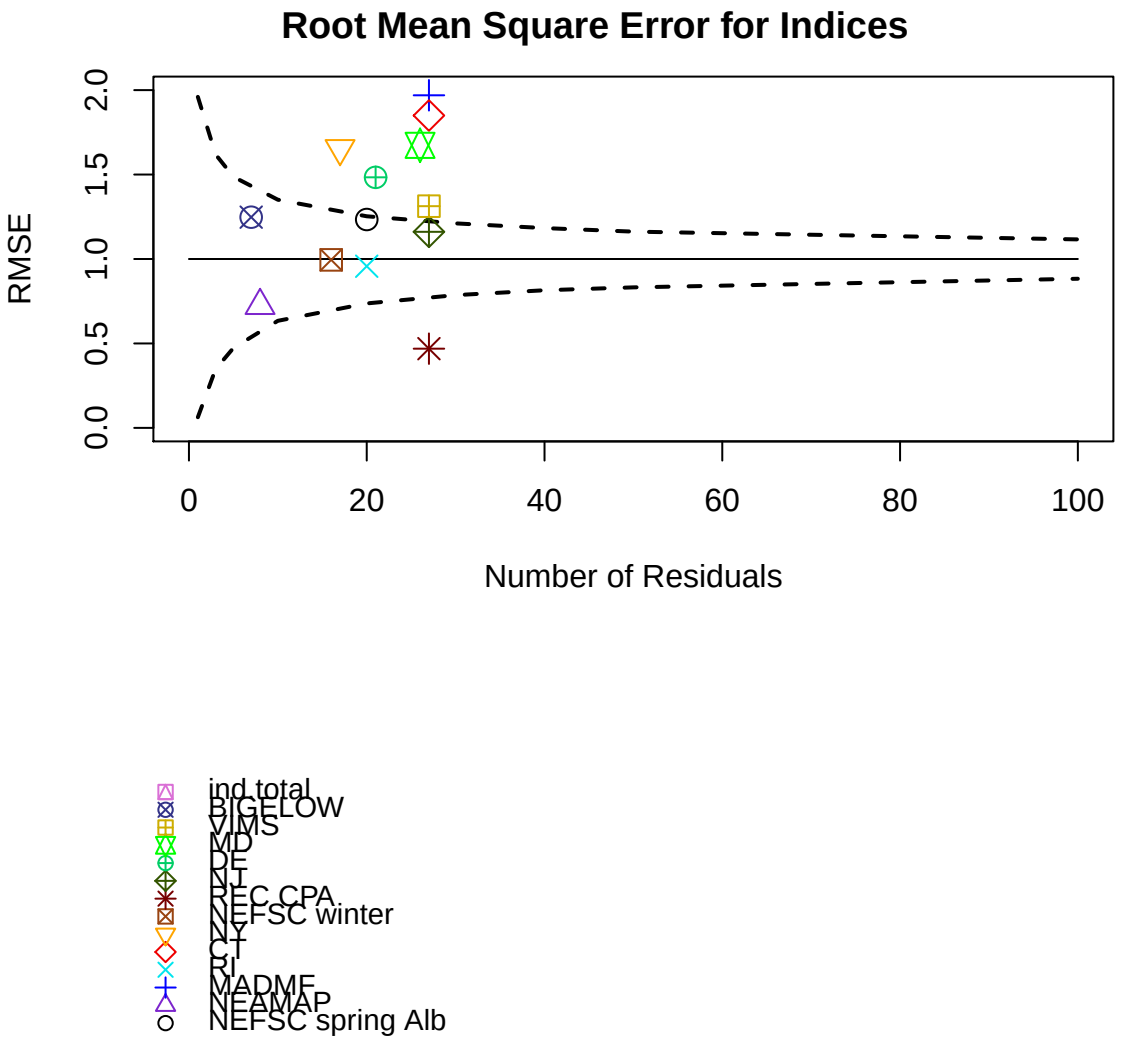
Appendix A10 – Diagnostic and result plots for black sea bass Overall model

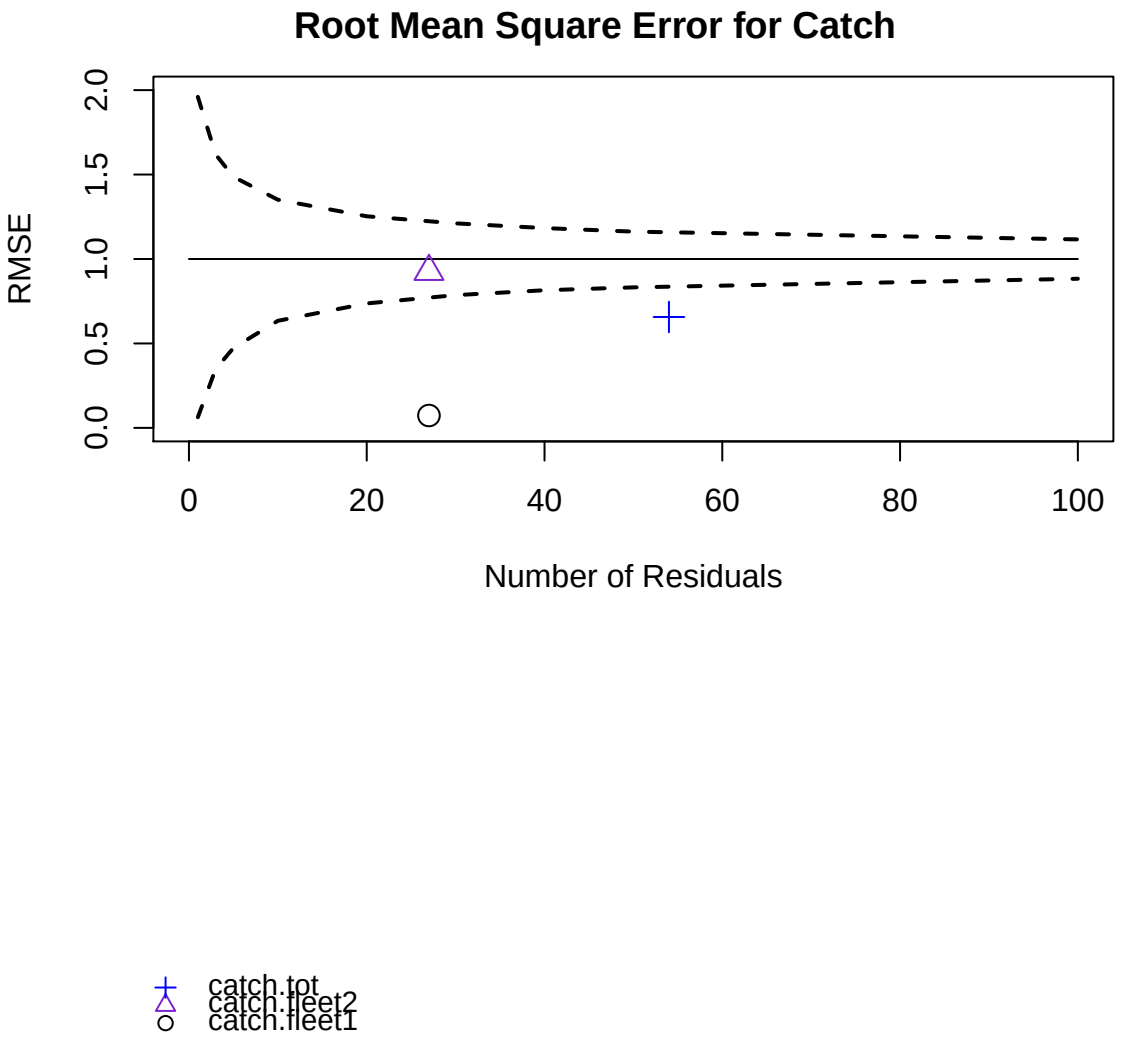

Components of Obj. Function (12550), npar=138
Maximum gradient = 0.000274
lk.F.penalty
lk.Fmult.Max.penalty
lk.SR.scaler
lk.SR.steepness
lk.Recruit.devs
lk.N.year1
lk.Fmult.devs.total
lk.Fmult.year1.total
lk.q.devs
lk.q.year1
lk.index.sel.param.total
lk.sel.param.total
lk.index.age.comp
lk.discards.age.comp
lk.catch.age.comp
lk.index.fit.total
lk.discard.total
lk.catch.total
0
0
0
0
−3
0
0
0
0
0
0
0
5795
0
6785
87
0
−115
0
1000
2000
3000
4000
5000
6000
7000
8000
Likelihood Contribution
Model: OVERALL−19
Tuesday, 01 Nov 2016 at 09:37:20


Number of high correlations
0
2
4
6
8
10
0
20
40
60
80
100
120
140
Parameter

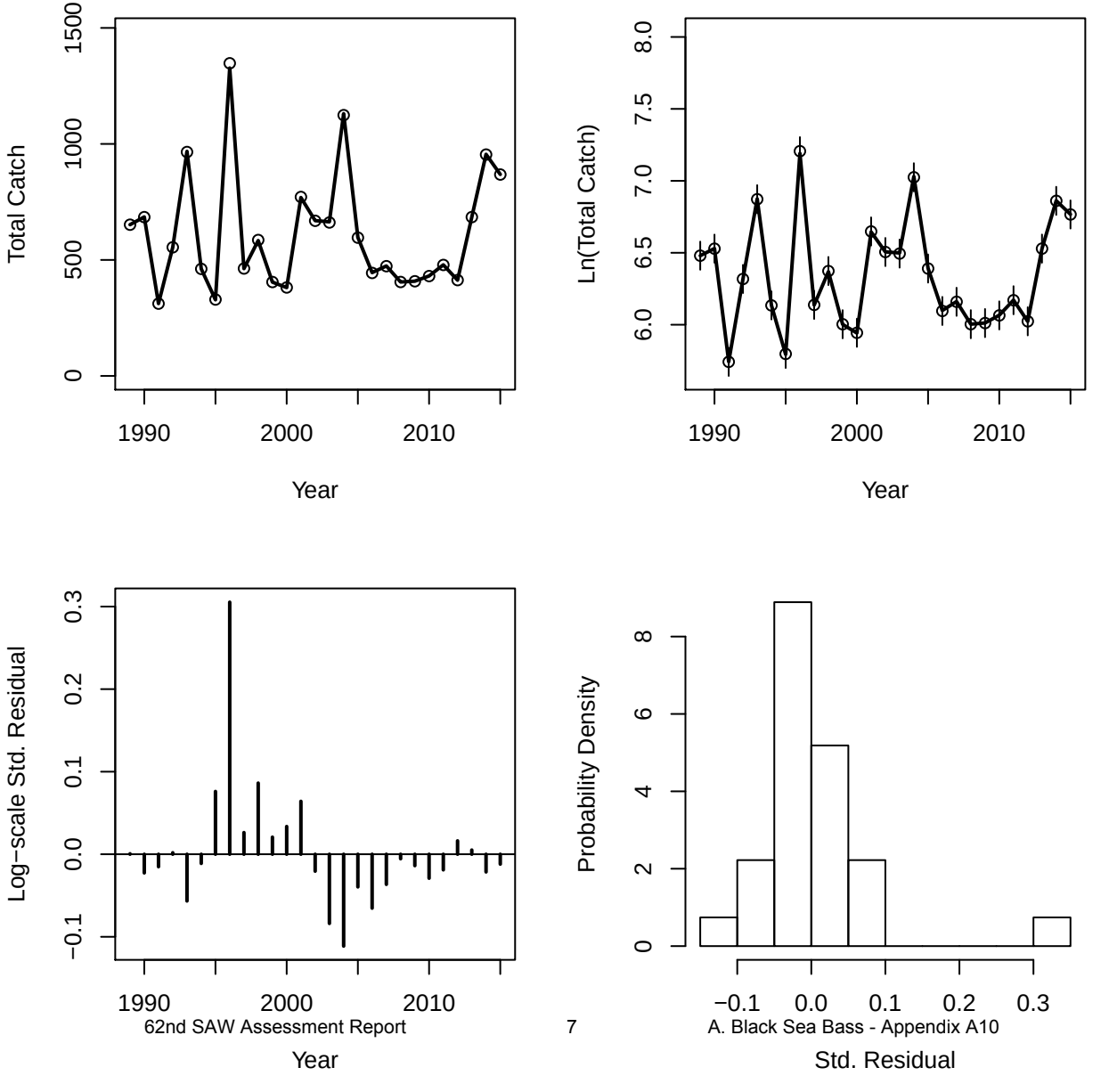
Root Mean Square Error computed from Standardized Residuals

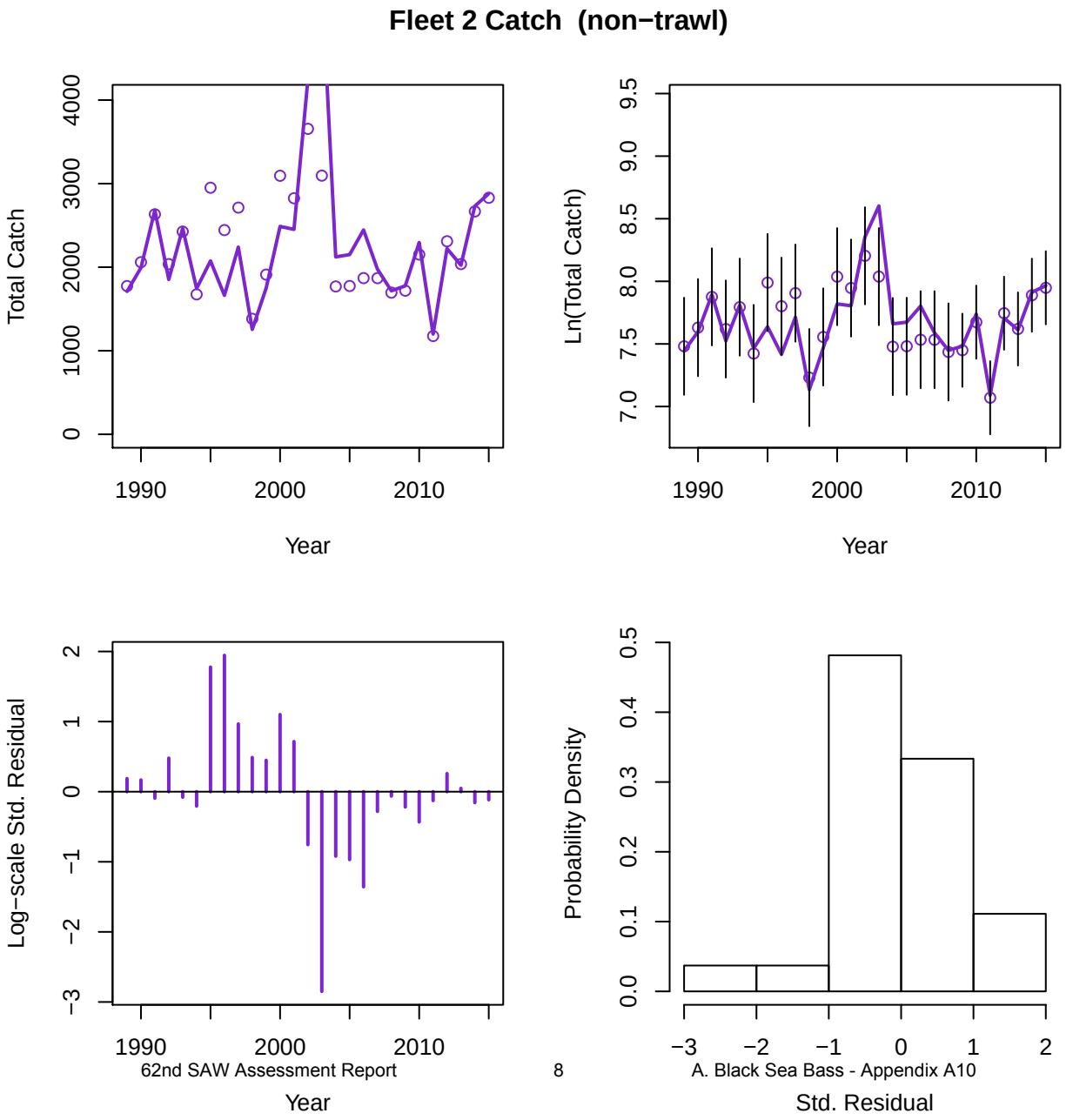
Component	# resids	RMSE
catch.fleet1	27	0.0736
catch.fleet2	27	0.926
catch.tot	54	0.657
discard.fleet1	0	0
discard.fleet2	0	0
discard.tot	0	0
ind01	20	1.23
ind02	8	0.724
ind03	27	1.97
ind04	20	0.957
ind05	27	1.85
ind06	17	1.65
ind07	16	0.995
ind08	27	0.469
ind09	27	1.16
ind10	21	1.48
ind11	26	1.67
ind12	27	1.31
ind13	7	1.25
ind.total	270	1.4
N.year1	0	0
Fmult.year1	0	0
Fmult.devs.fleet1	0	0
Fmult.devs.fleet2	0	0
Fmult.devs.total	0	0
recruit.devs	27	0.425
fleet.sel.params	0	0
index.sel.params	0	0
q.year1	0	0
q.devs	0	0
SR.steepness	0	0
SR.scaler	0	0

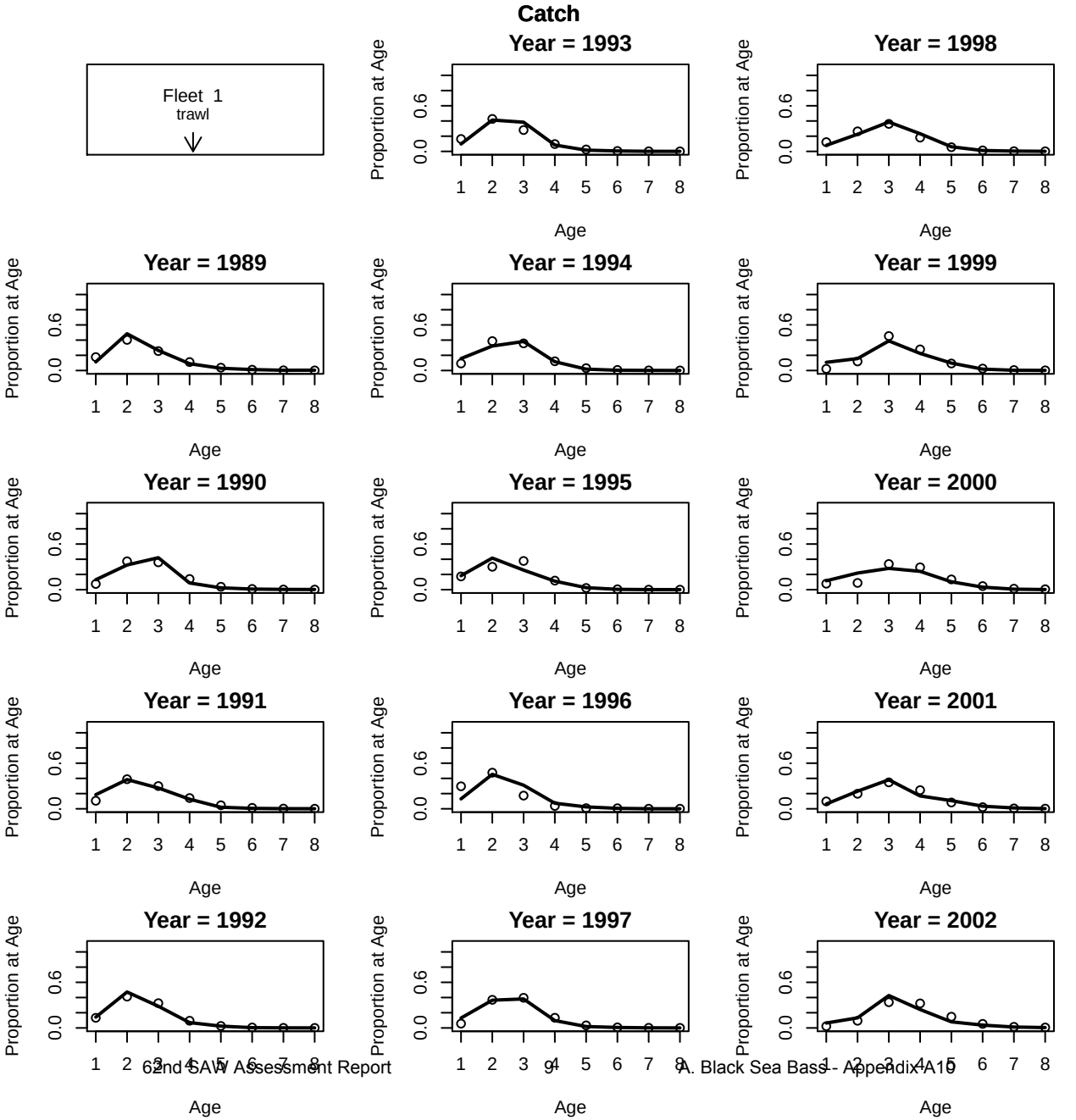

Root Mean Square Error for Indices
RMSE
0.0
0.5
1.0
1.5
2.0
0
20
40
60
80
100
Number of Residuals
ind total
BIGELOW
VIMS
MD
DE
NJ
REC CPA
NEFSC winter
NY
CT
RI
MADMF
NEAMAP
NEFSC spring Alb

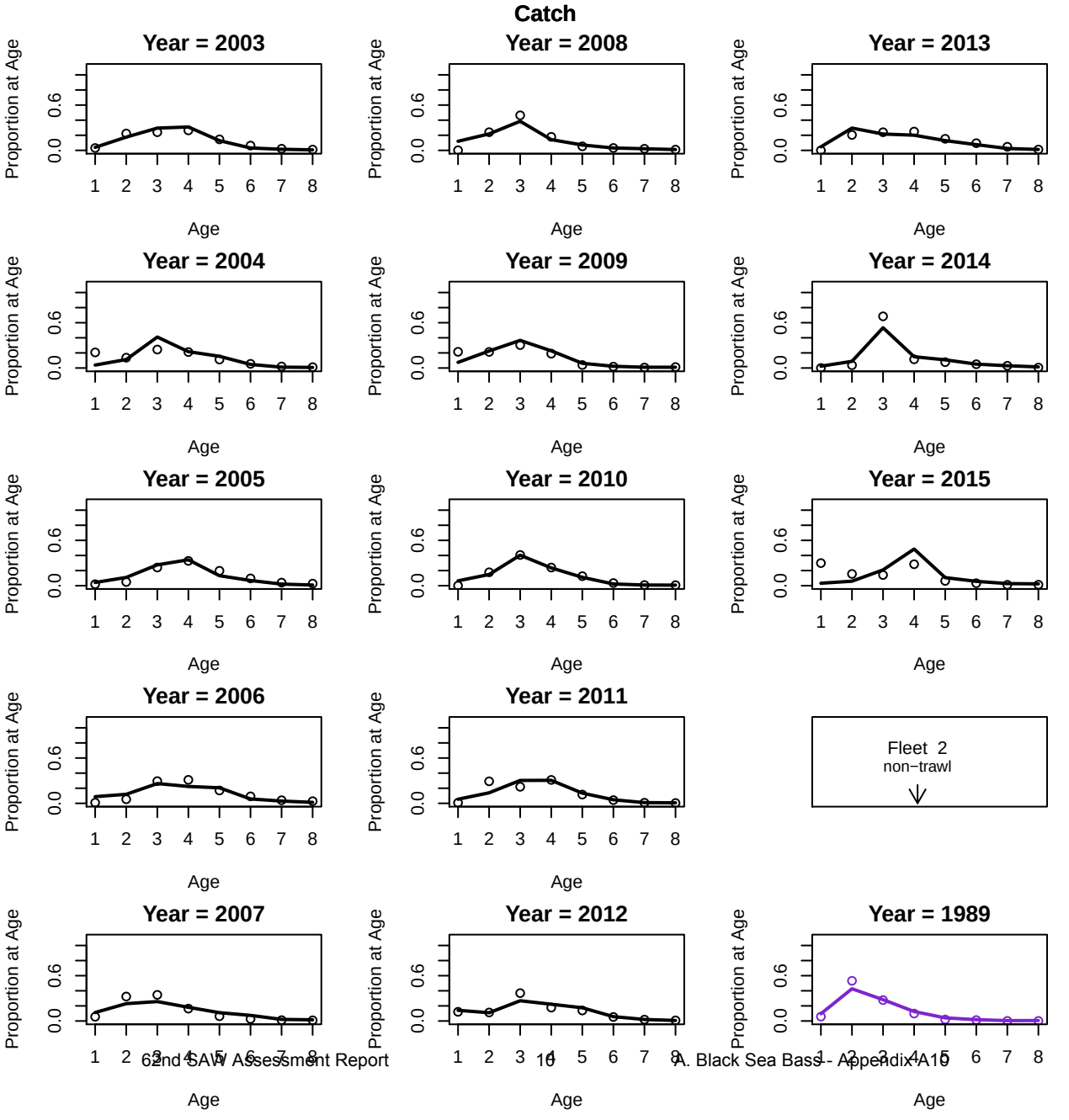

Root Mean Square Error for Catch
RMSE
0.0
0.5
1.0
1.5
2.0
0
20
40
60
80
100
Number of Residuals
catch.tot
catch.fleet2
catch.fleet1

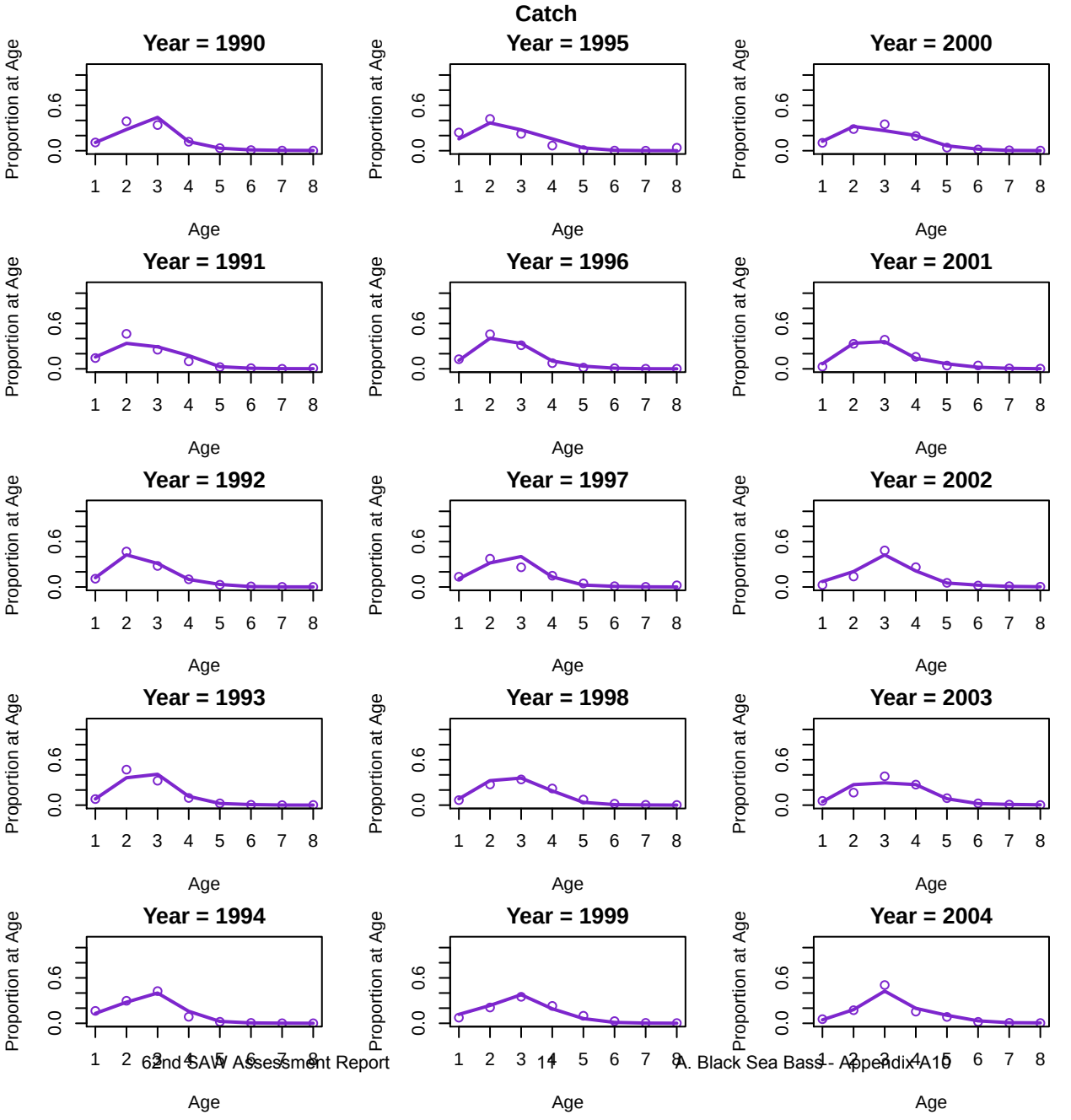
Fleet 1 Catch (trawl)

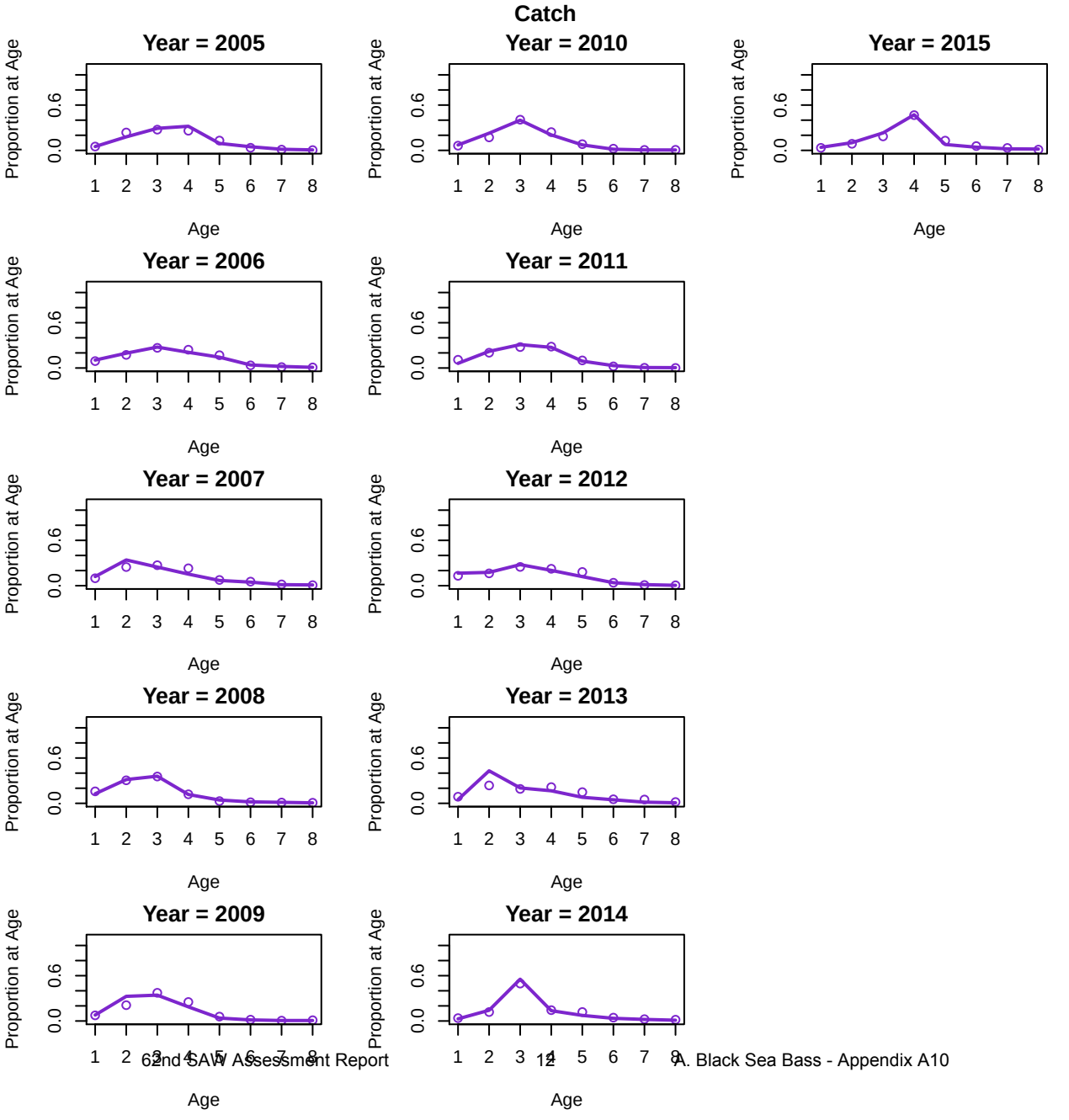



Fleet 2 Catch (non−trawl)
Total Catch
Year
Ln(Total Catch)
Year
Log−scale Std. Residual
Year
Probability Density
Std. Residual

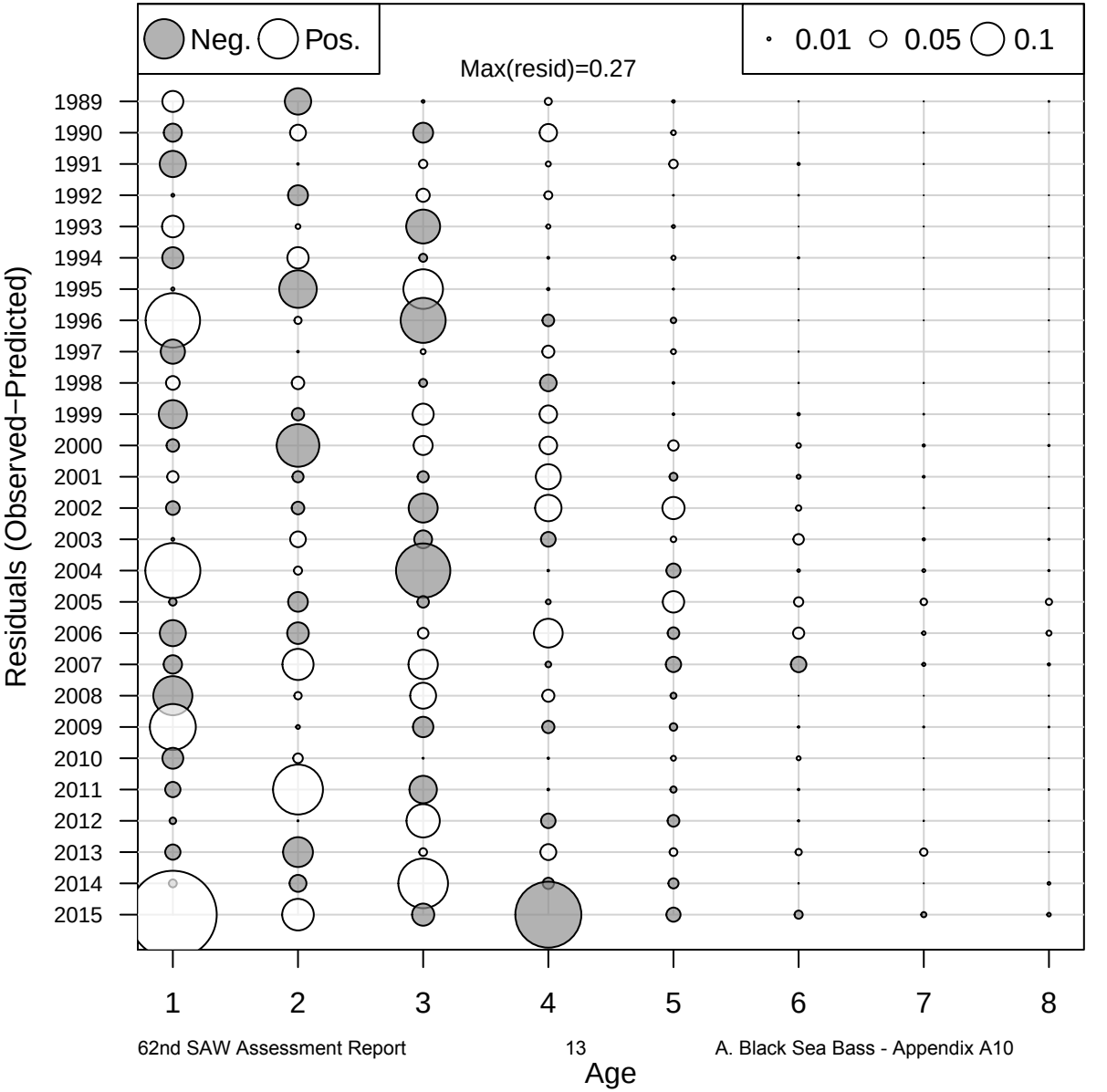

Catch
Fleet 1
trawl
Year = 1993
Year = 1998
Year = 1989
Year = 1994
Year = 1999
Year = 1990
Year = 1995
Year = 2000
Year = 1991
Year = 1996
Year = 2001
Year = 1992
Year = 1997
Year = 2002
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8


Catch
Year = 2003
Year = 2008
Year = 2013
Year = 2004
Year = 2009
Year = 2014
Year = 2005
Year = 2010
Year = 2015
Year = 2006
Year = 2011
Fleet 2
non−trawl
Year = 2007
Year = 2012
Year = 1989
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

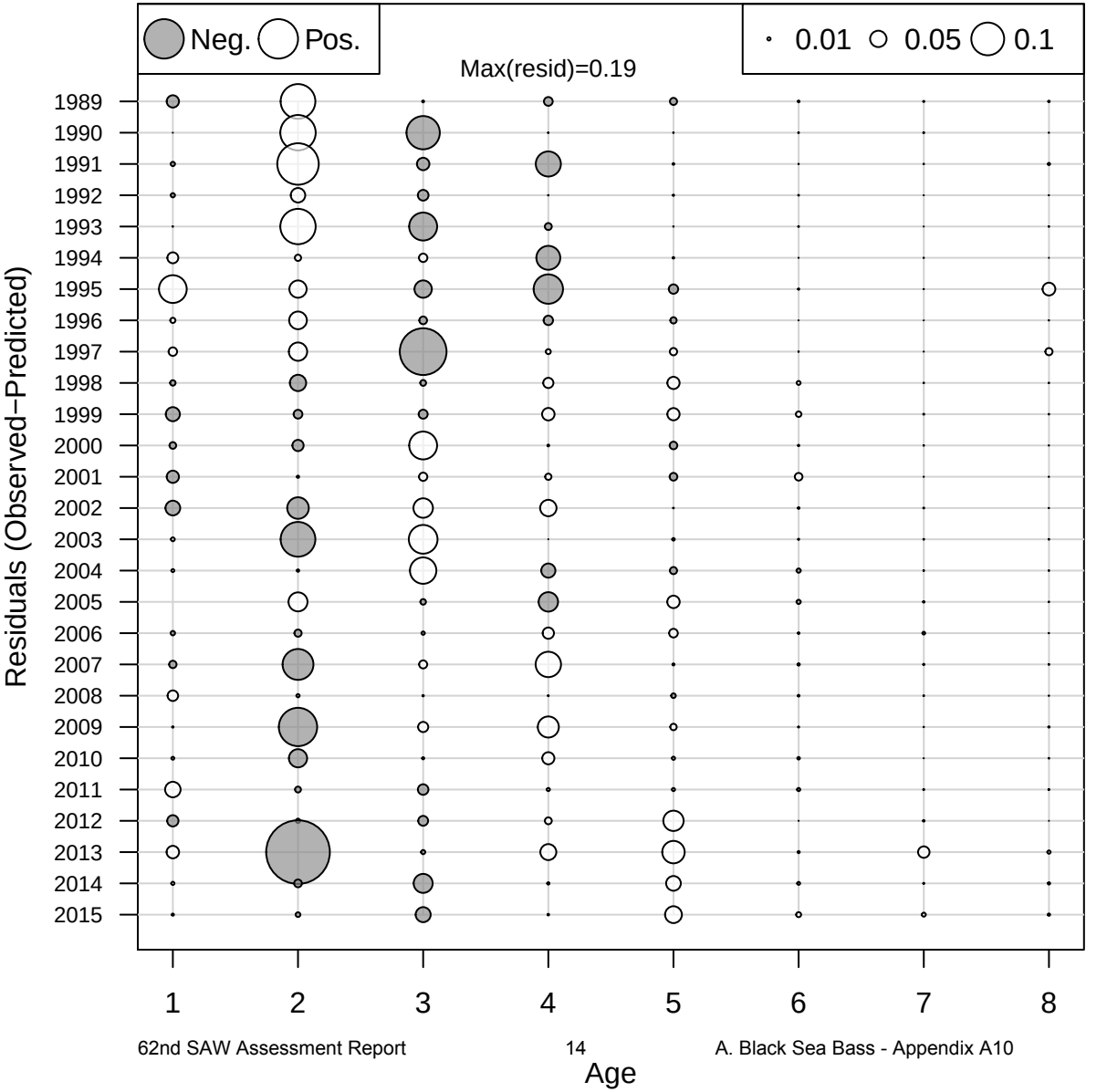

Catch
Year = 1990
Year = 1991
Year = 1992
Year = 1993
Year = 1994
Year = 1995
Year = 1996
Year = 1997
Year = 1998
Year = 1999
Year = 2000
Year = 2001
Year = 2002
Year = 2003
Year = 2004
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

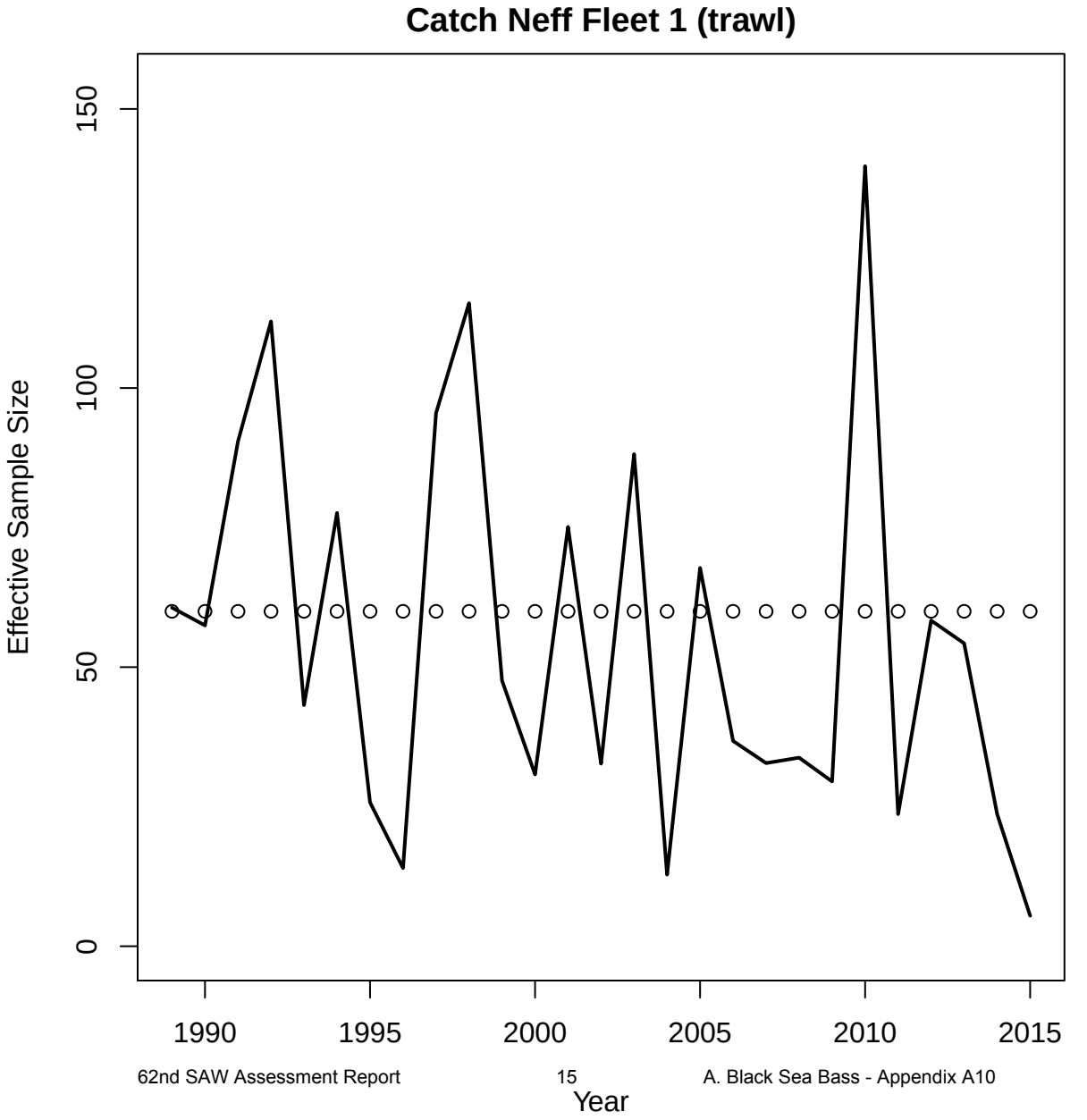

Catch
Year = 2005
Year = 2010
Year = 2015
Year = 2006
Year = 2011
Year = 2007
Year = 2012
Year = 2008
Year = 2013
Year = 2009
Year = 2014
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

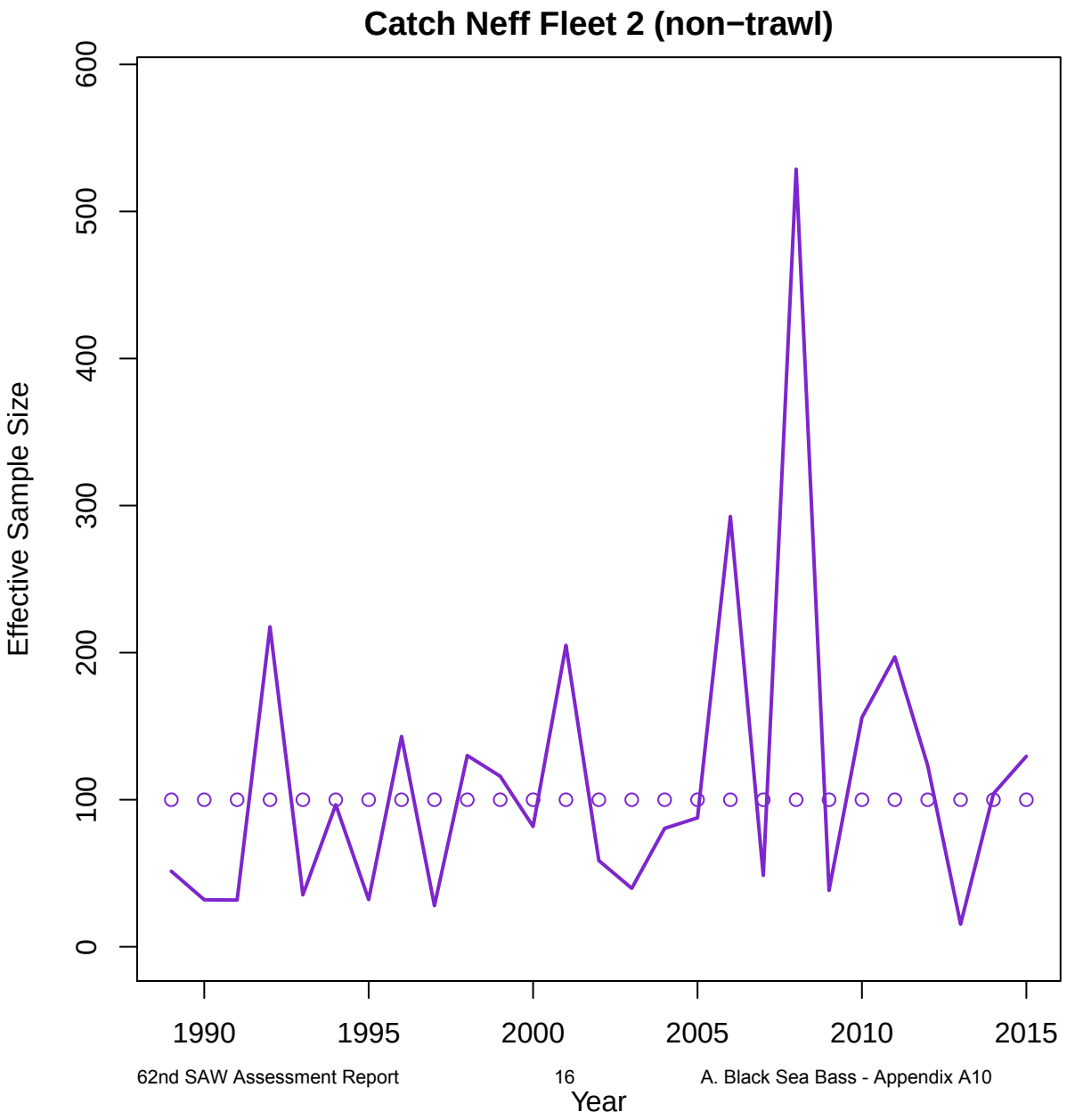
Age Comp Residuals for Catch by Fleet 1 (trawl)

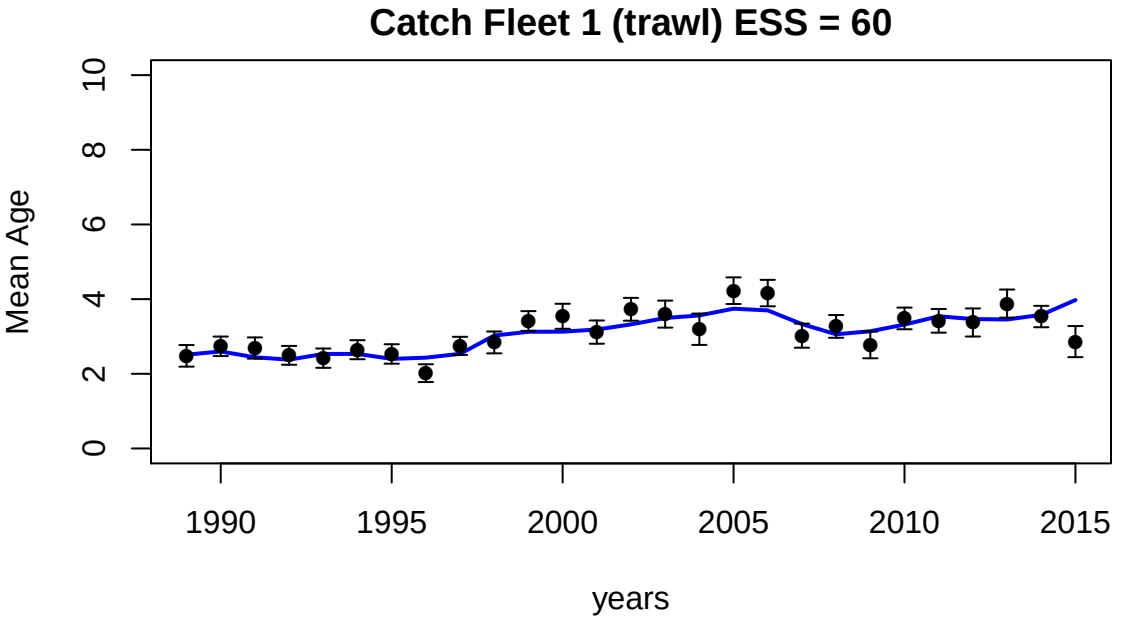


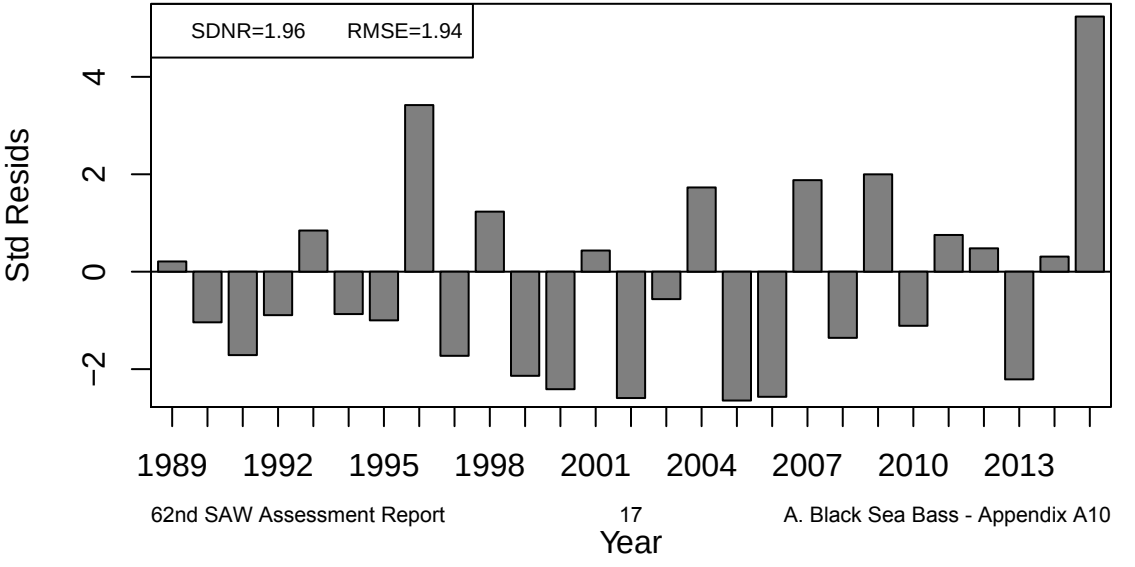
Age Comp Residuals for Catch by Fleet 2 (non−trawl)

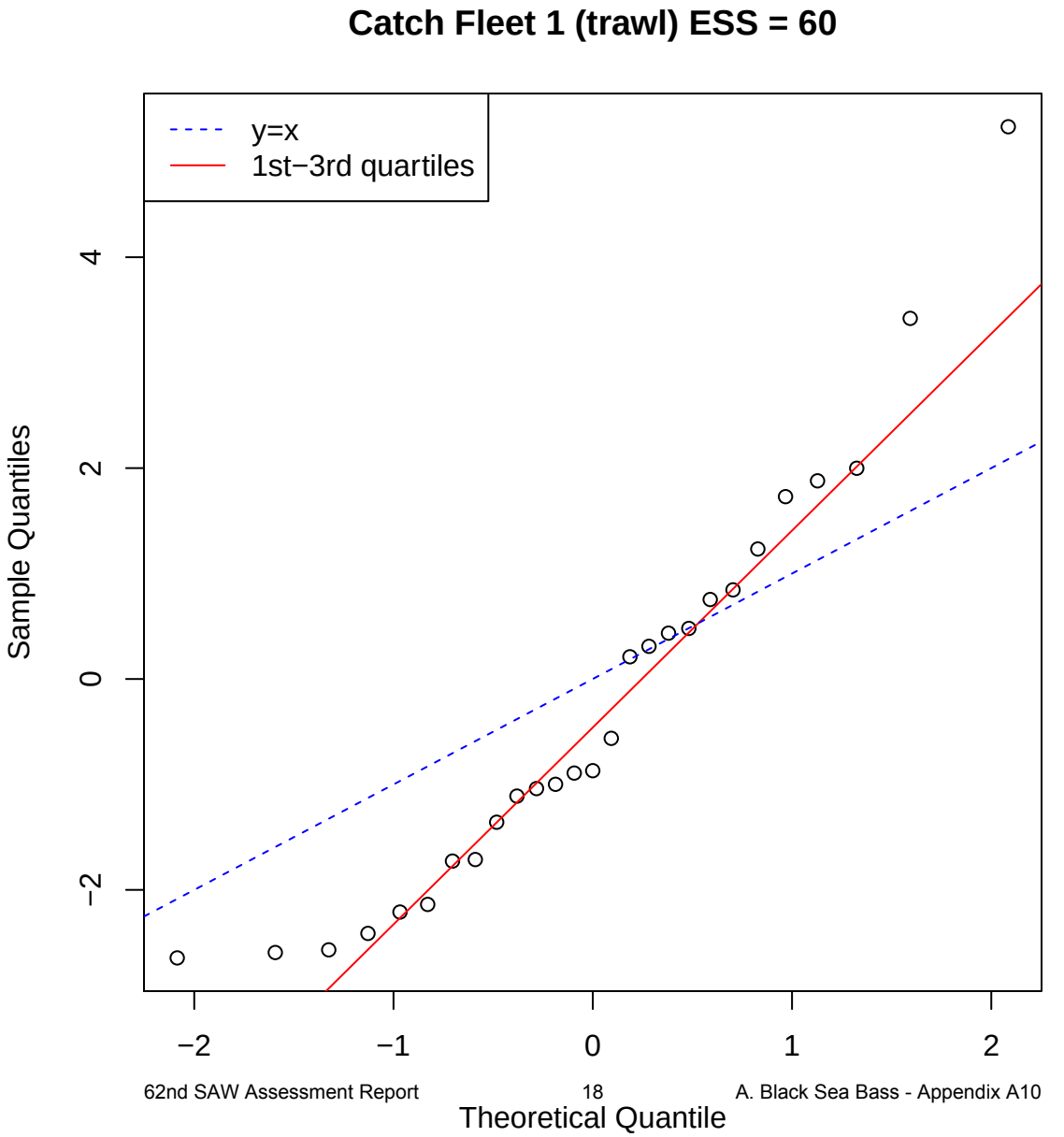


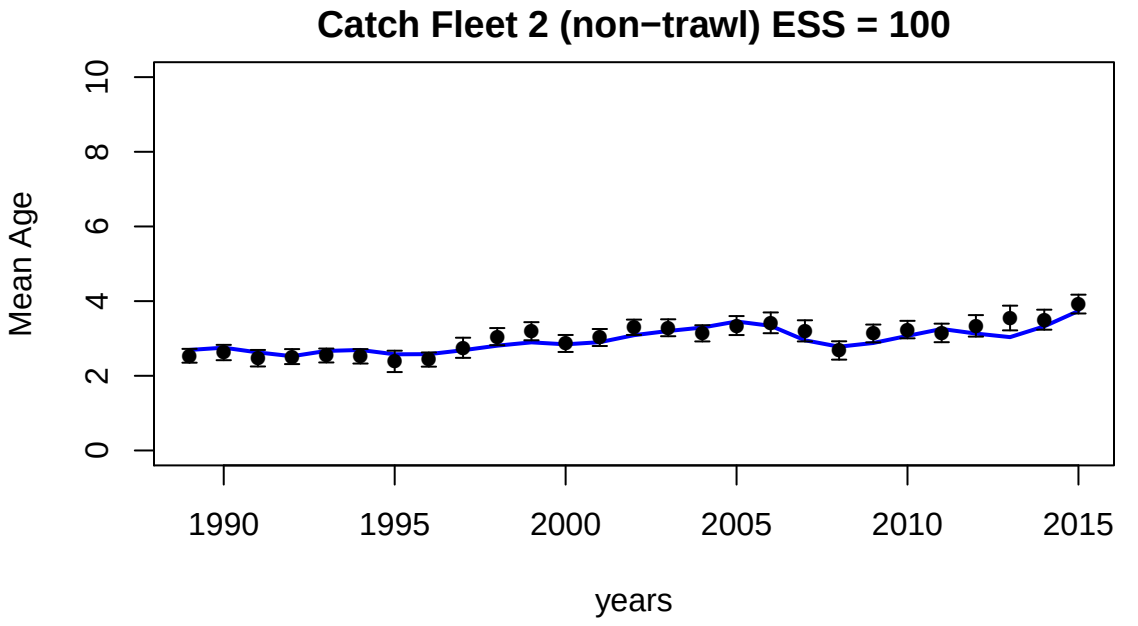

Catch Neff Fleet 1 (trawl)
Effective Sample Size
0
50
100
150
1990
1995
2000
2005
2010
2015
Year

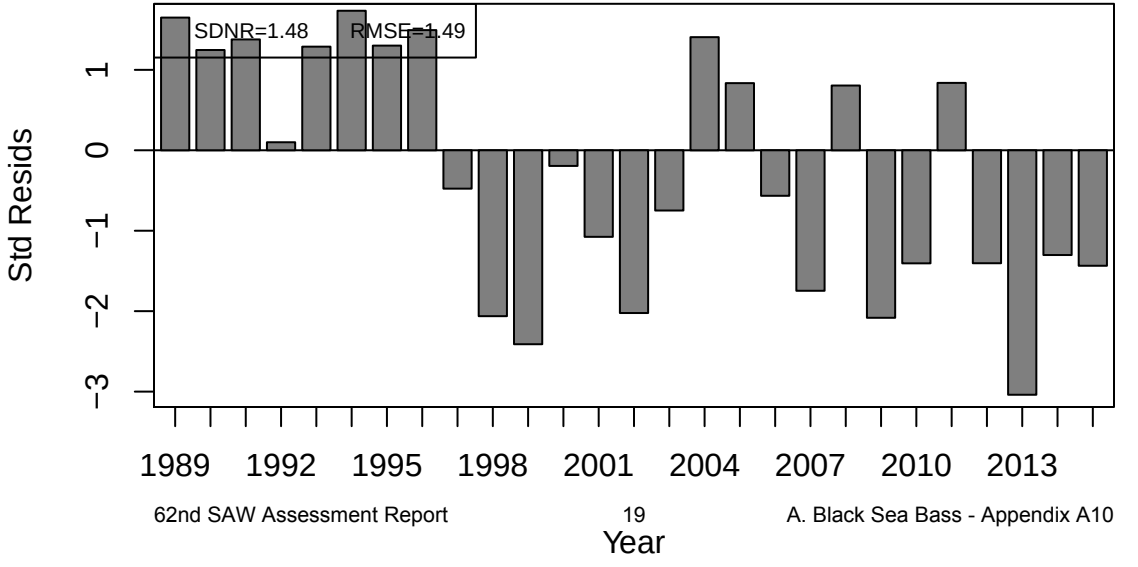

Catch Neff Fleet 2 (non−trawl)
Effective Sample Size
0
100
200
300
400
500
600
1990
1995
2000
2005
2010
2015
Year

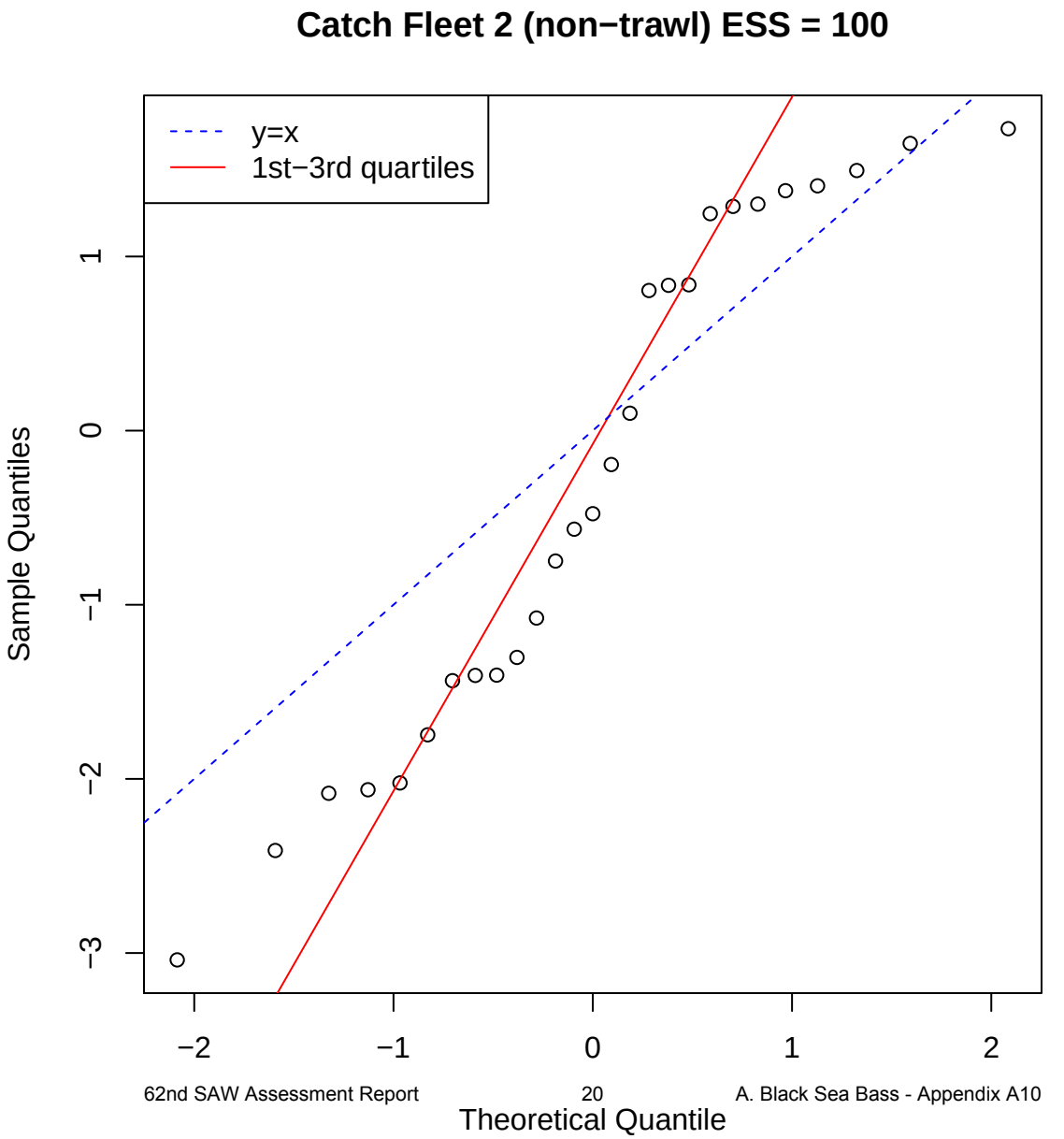

Catch Fleet 1 (trawl) ESS = 60
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
years


SDNR=1.96
RMSE=1.94
Std Resids
−2
0
2
4
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

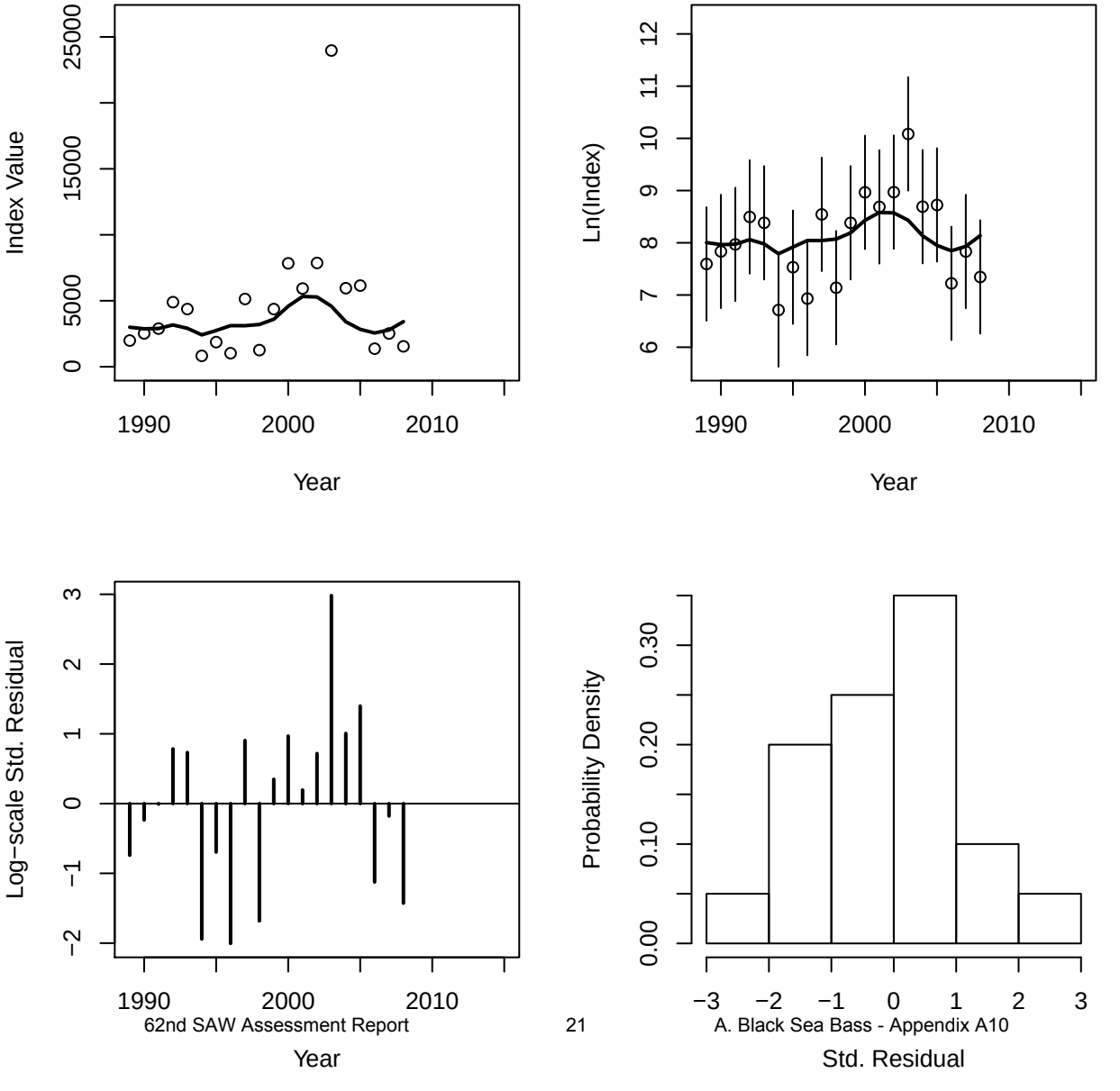

Catch Fleet 1 (trawl) ESS = 60
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
0
2
4
−2
−1
0
1
2


Catch Fleet 2 (non−trawl) ESS = 100
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
years

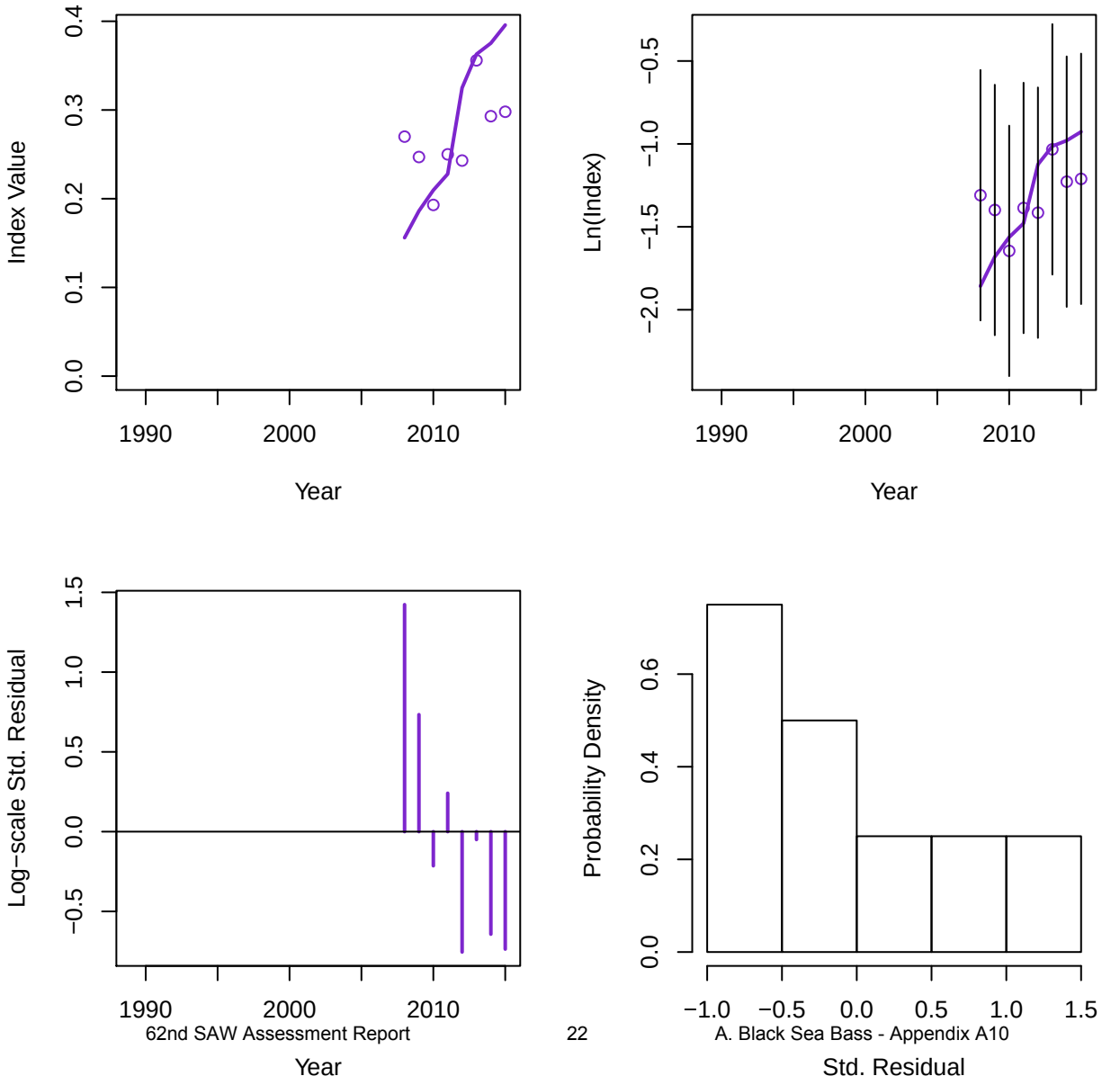

SDNR=1.48
RMSE=1.49
Std Resids
−3
−2
−1
0
1
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year


Catch Fleet 2 (non−trawl) ESS = 100
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−3
−2
−1
0
1
−2
−1
0
1
2

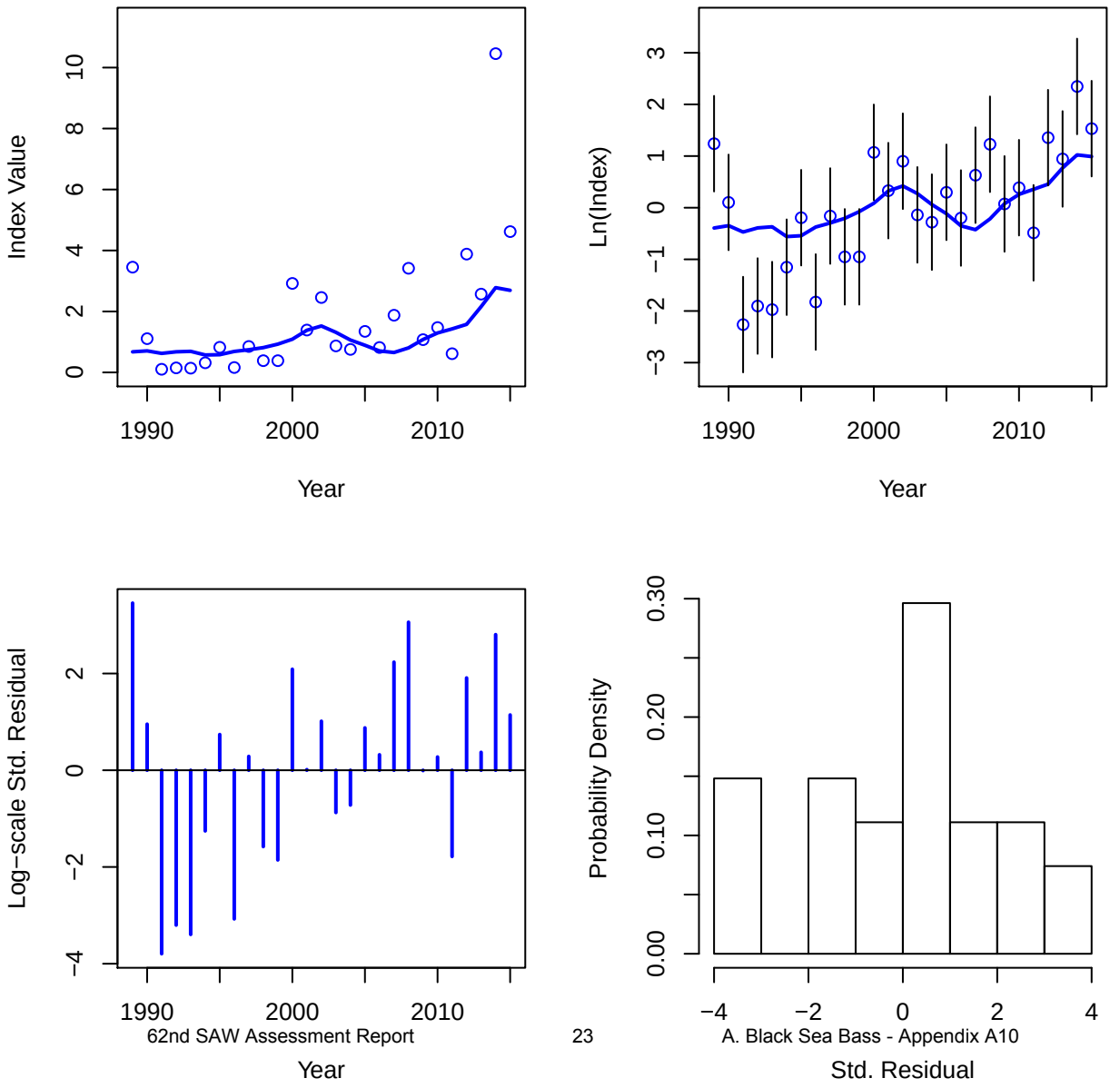
Index 1 (NEFSC spring Alb)



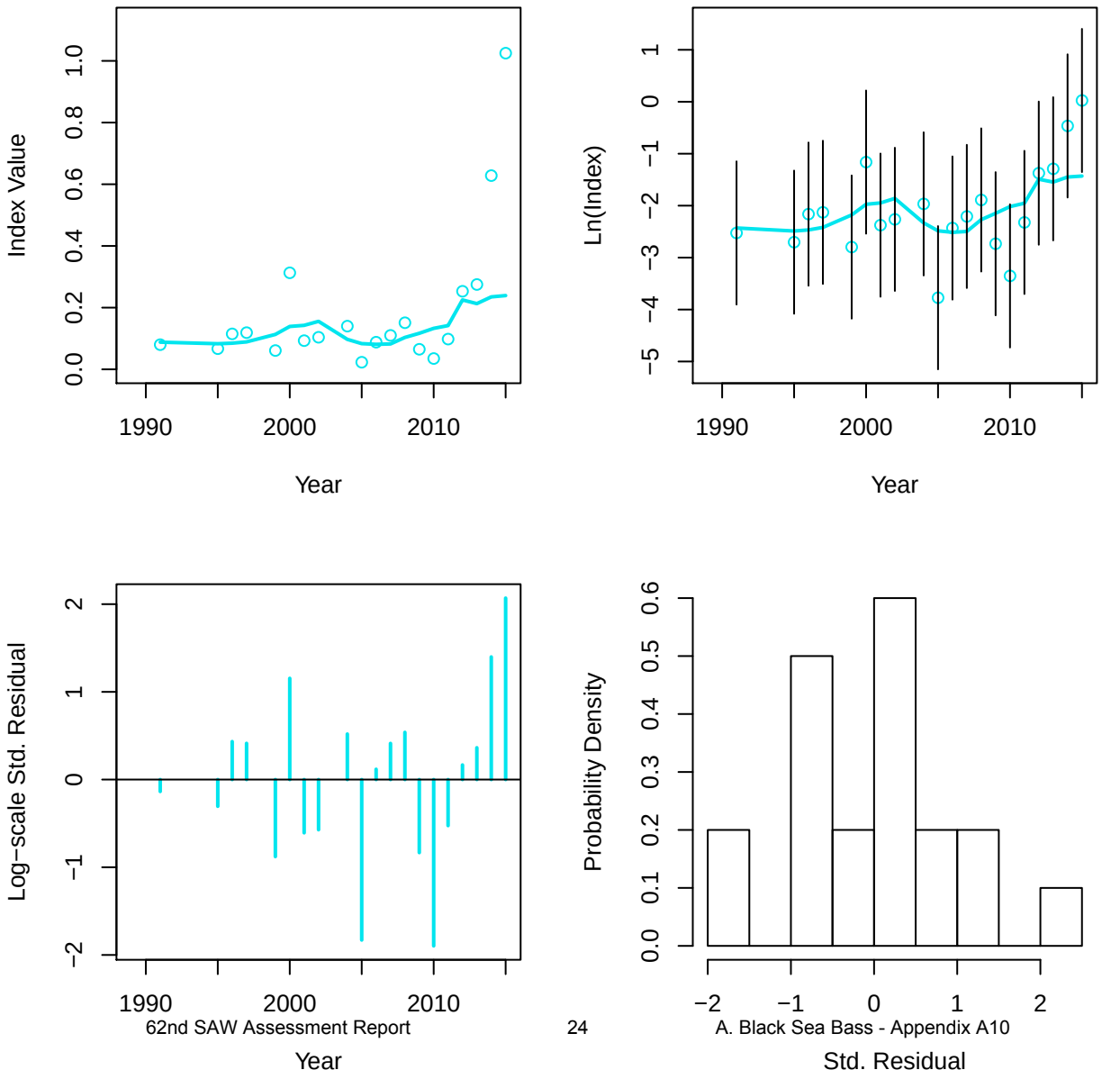
Index 2 (NEAMAP)



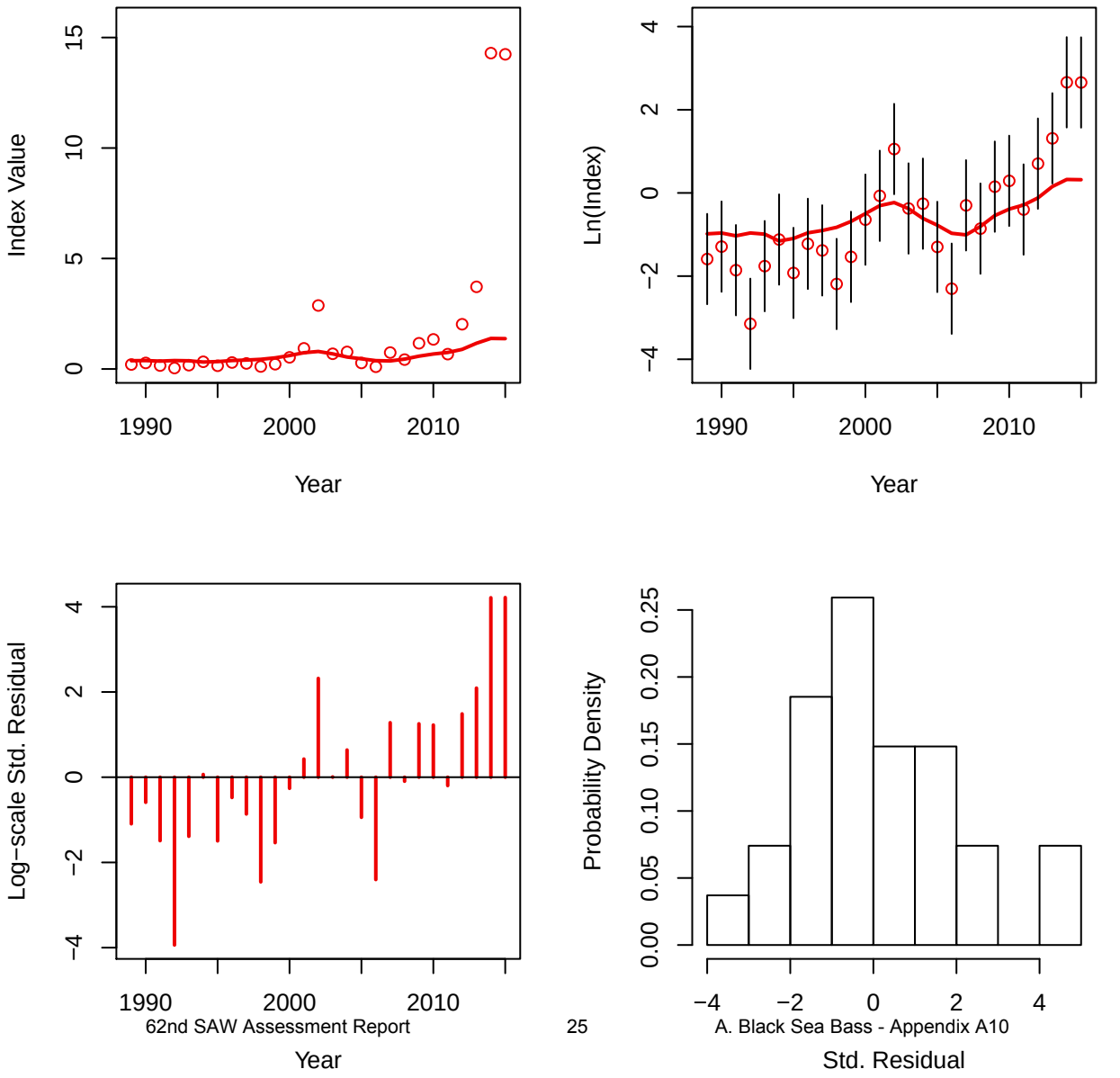
Index 3 (MADMF)



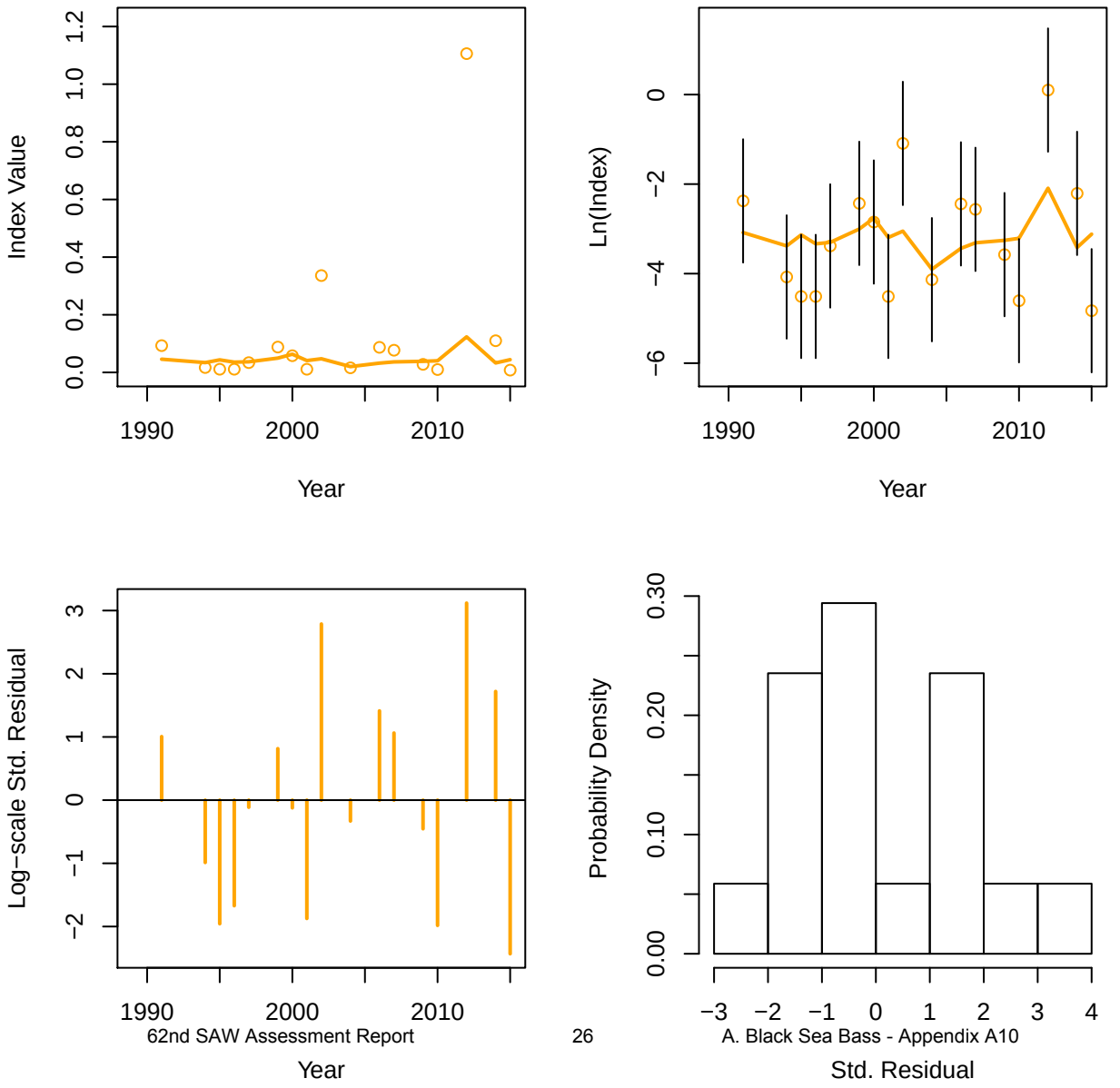
Index 4 (RI)


Index Value
0.0
0.2
0.4
0.6
0.8
1.0
1990
2000
2010
Year
Ln(Index)
−5
−4
−3
−2
−1
0
1
1990
2000
2010
Year
Log−scale Std. Residual
−2
−1
0
1
2
1990
2000
2010
Year
Probability Density
0.0
0.1
0.2
0.3
0.4
0.5
0.6
−2
−1
0
1
2
Std. Residual

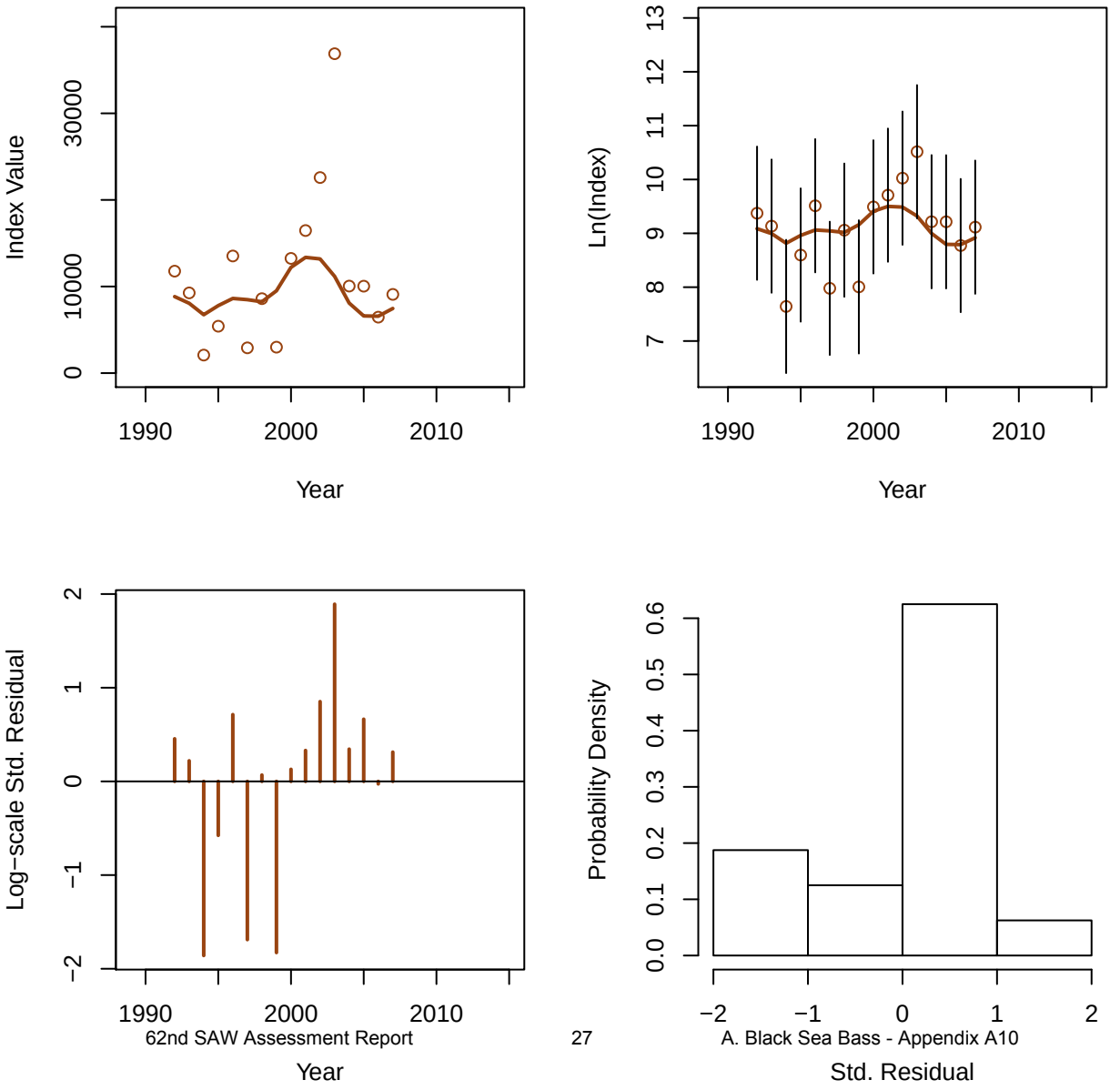
Index 5 (CT)


Index Value
0
5
10
15
1990
2000
2010
Year
Ln(Index)
−4
−2
0
2
4
1990
2000
2010
Year
Log−scale Std. Residual
−4
−2
0
2
4
1990
2000
2010
Year
Probability Density
0.00
0.05
0.10
0.15
0.20
0.25
−4
−2
0
2
4
Std. Residual

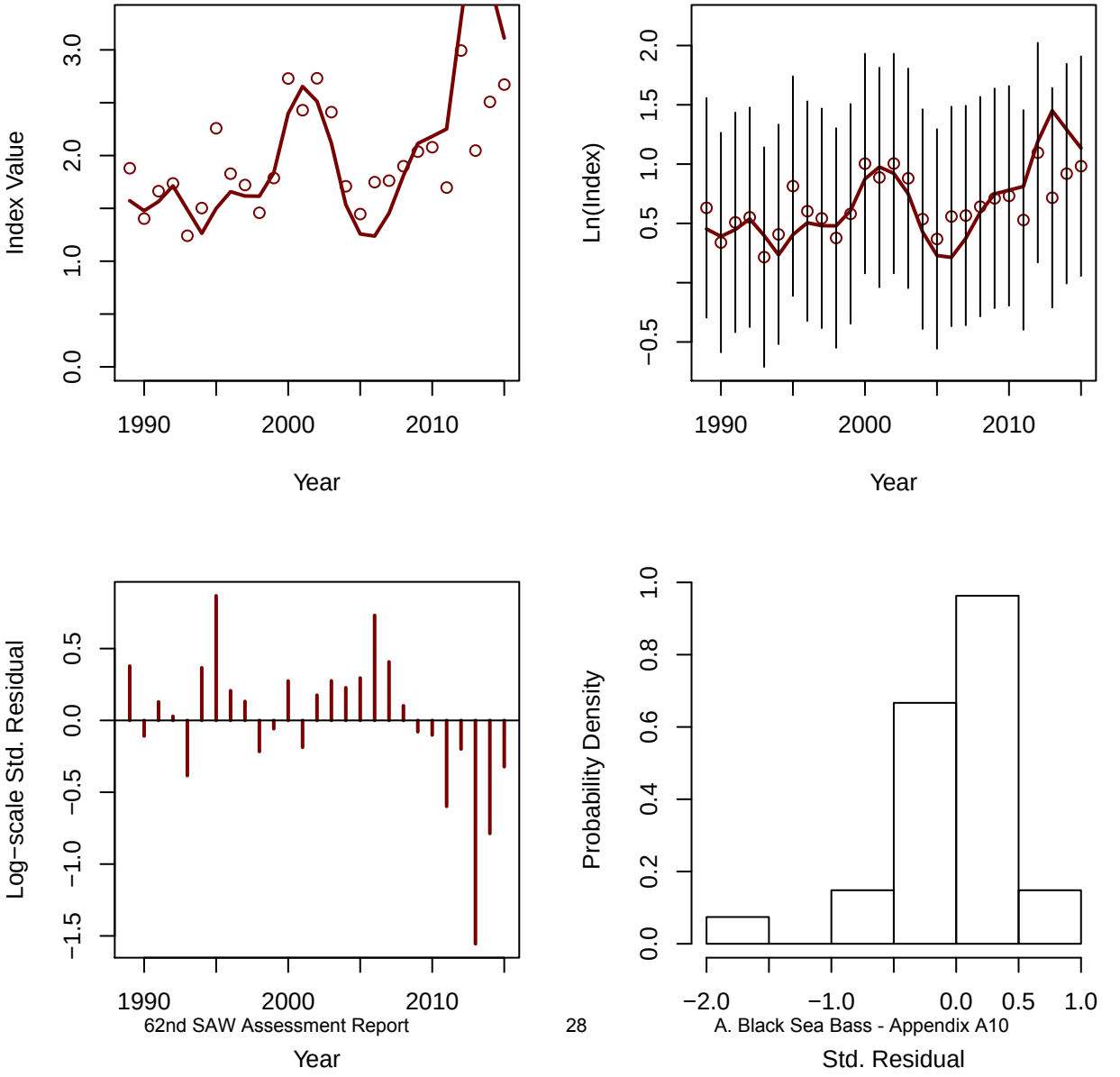
Index 6 (NY)


Index Value
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1990
2000
2010
Year
Ln(Index)
0
−2
−4
−6
1990
2000
2010
Year
Log−scale Std. Residual
3
2
1
0
−1
−2
1990
2000
2010
Year
Probability Density
0.00
0.10
0.20
0.30
−3
−2
−1
0
1
2
3
4
Std. Residual

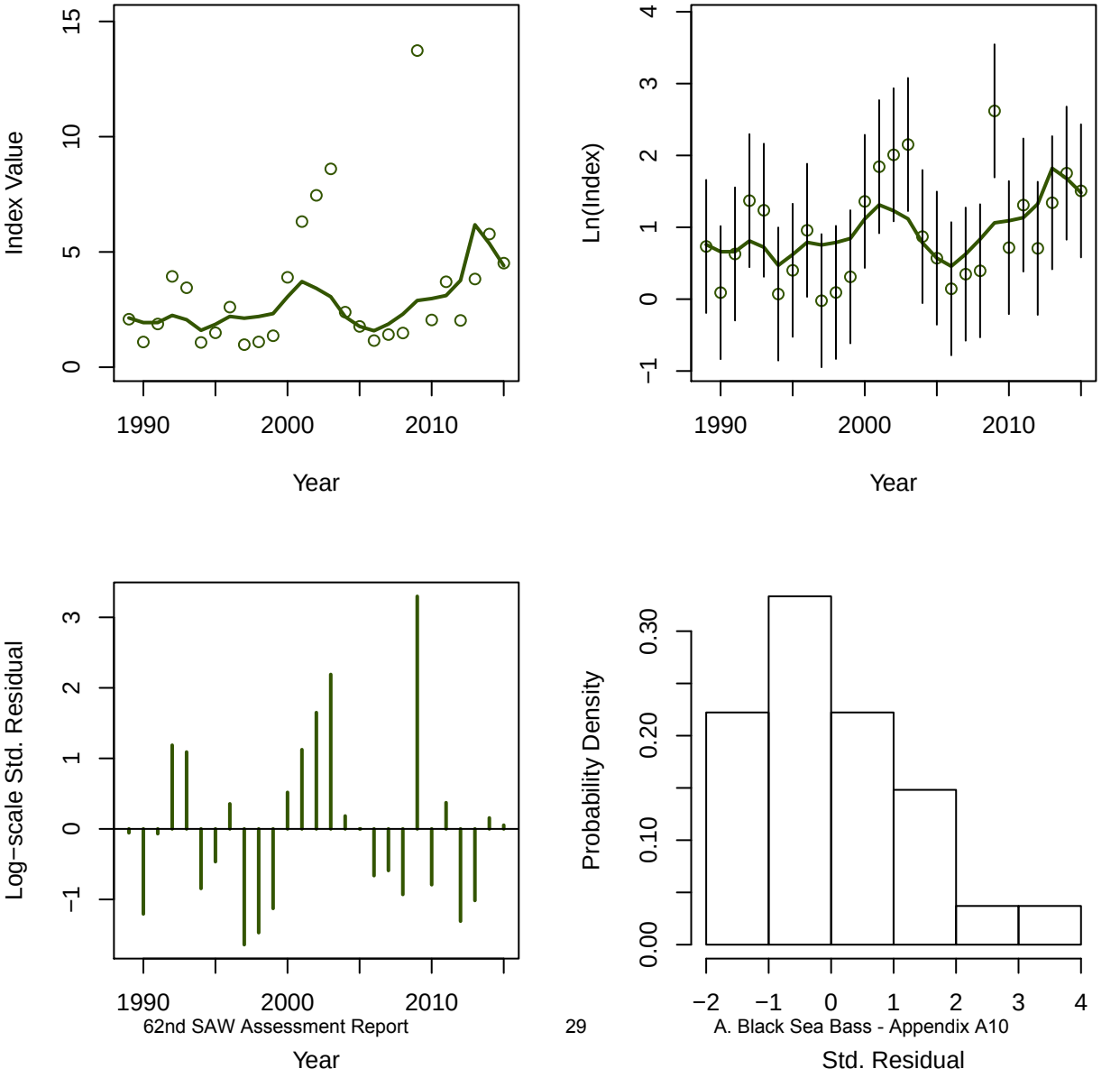
Index 7 (NEFSC winter)



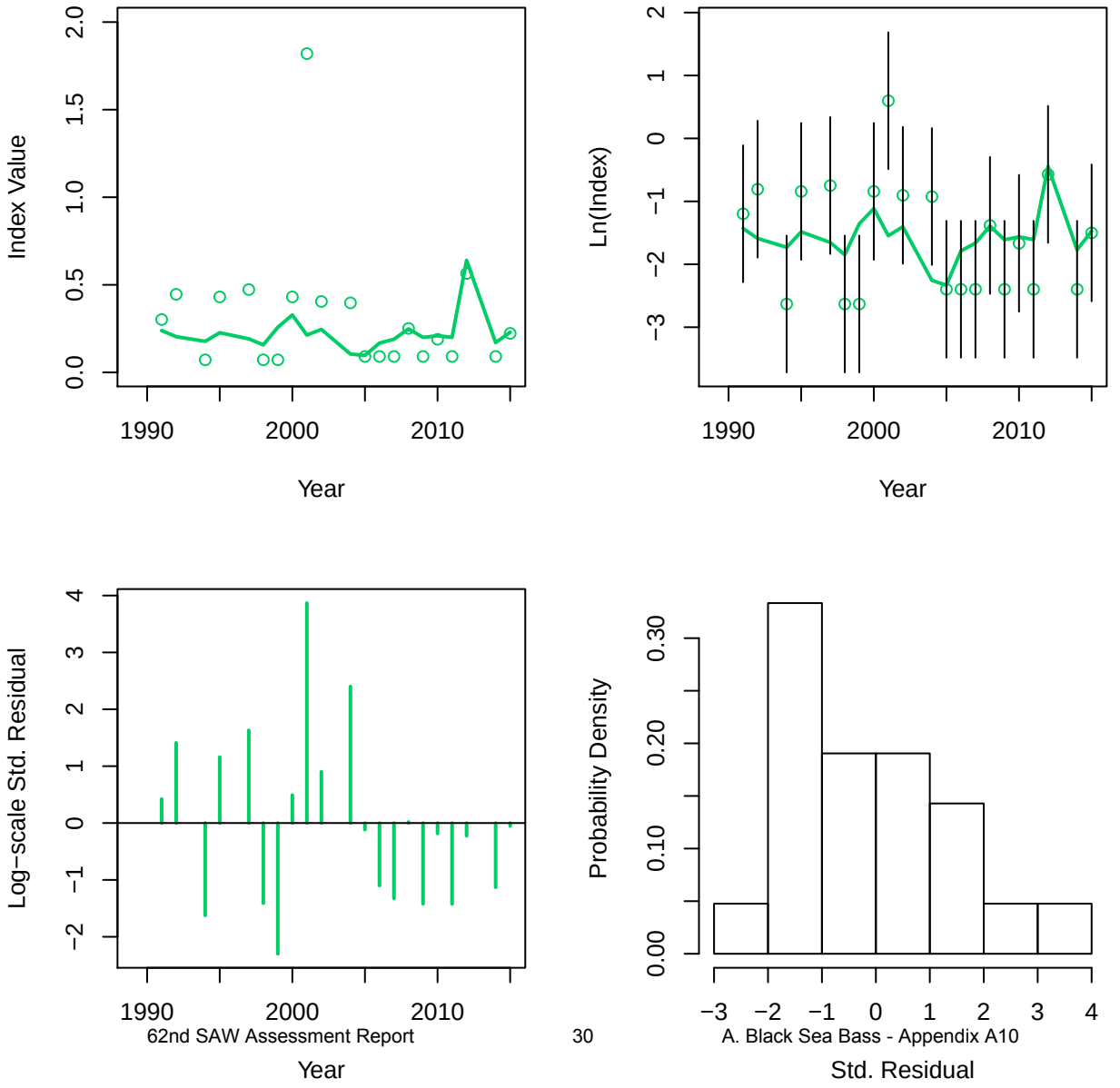
Index 8 (REC CPA)



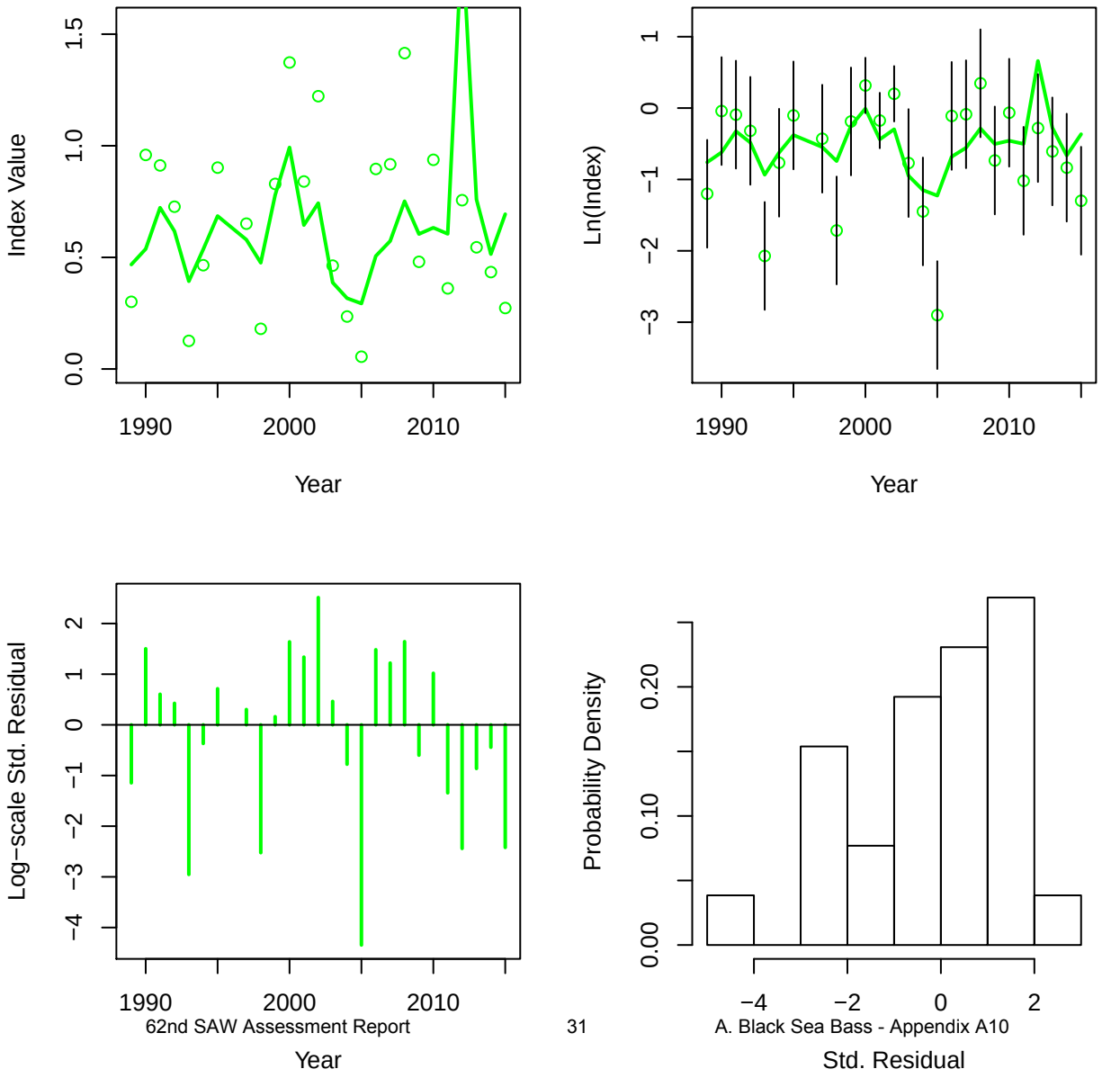
Index 9 (NJ)


Index Value
Year
Ln(Index)
Year
Log−scale Std. Residual
Year
Probability Density
Std. Residual

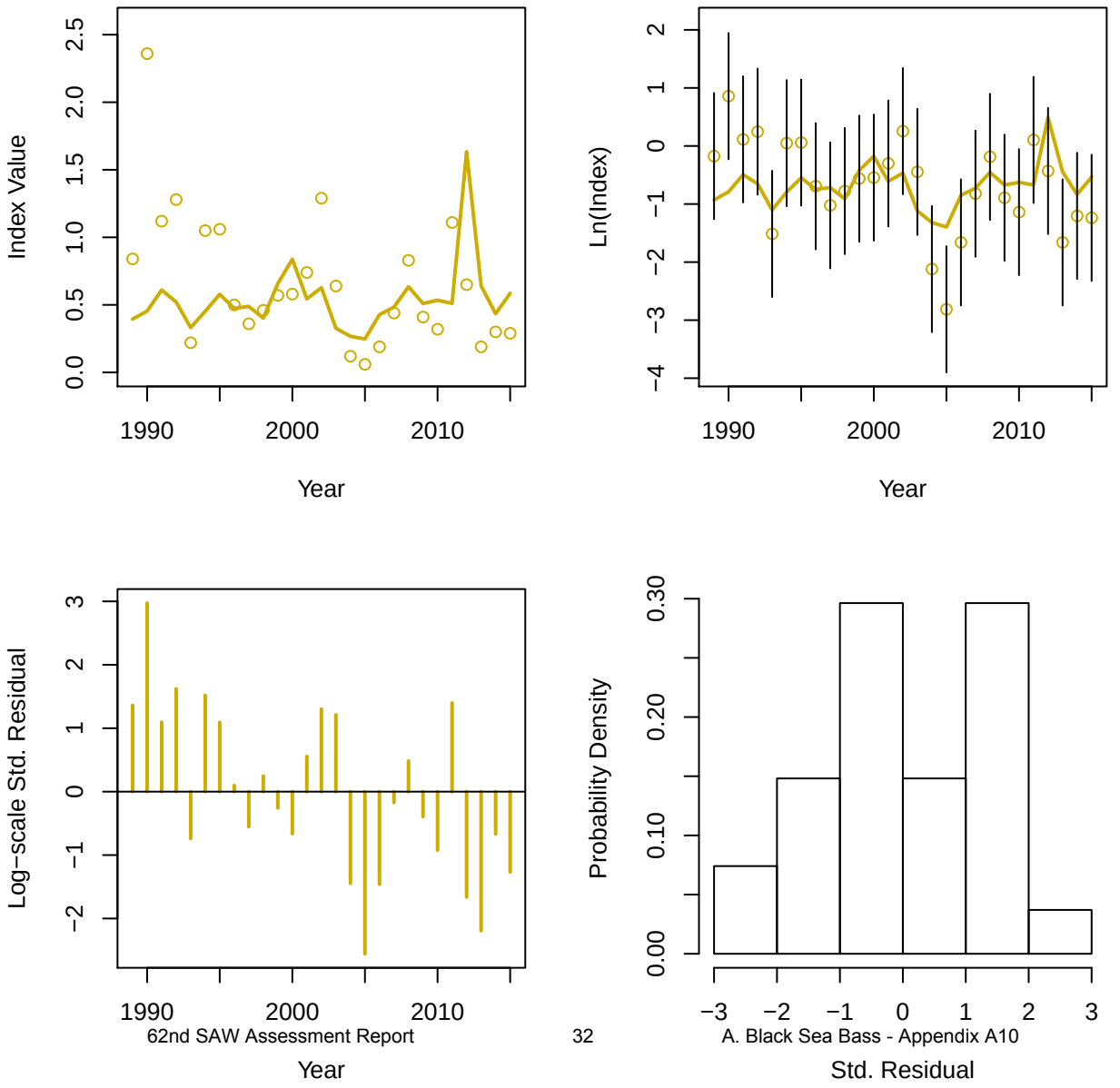
Index 10 (DE)


Index Value
0.0
0.5
1.0
1.5
2.0
1990
2000
2010
Year
Ln(Index)
−3
−2
−1
0
1
2
1990
2000
2010
Year
Log−scale Std. Residual
−2
−1
0
1
2
3
4
1990
2000
2010
Year
Probability Density
0.00
0.10
0.20
0.30
−3
−2
−1
0
1
2
3
4
Std. Residual

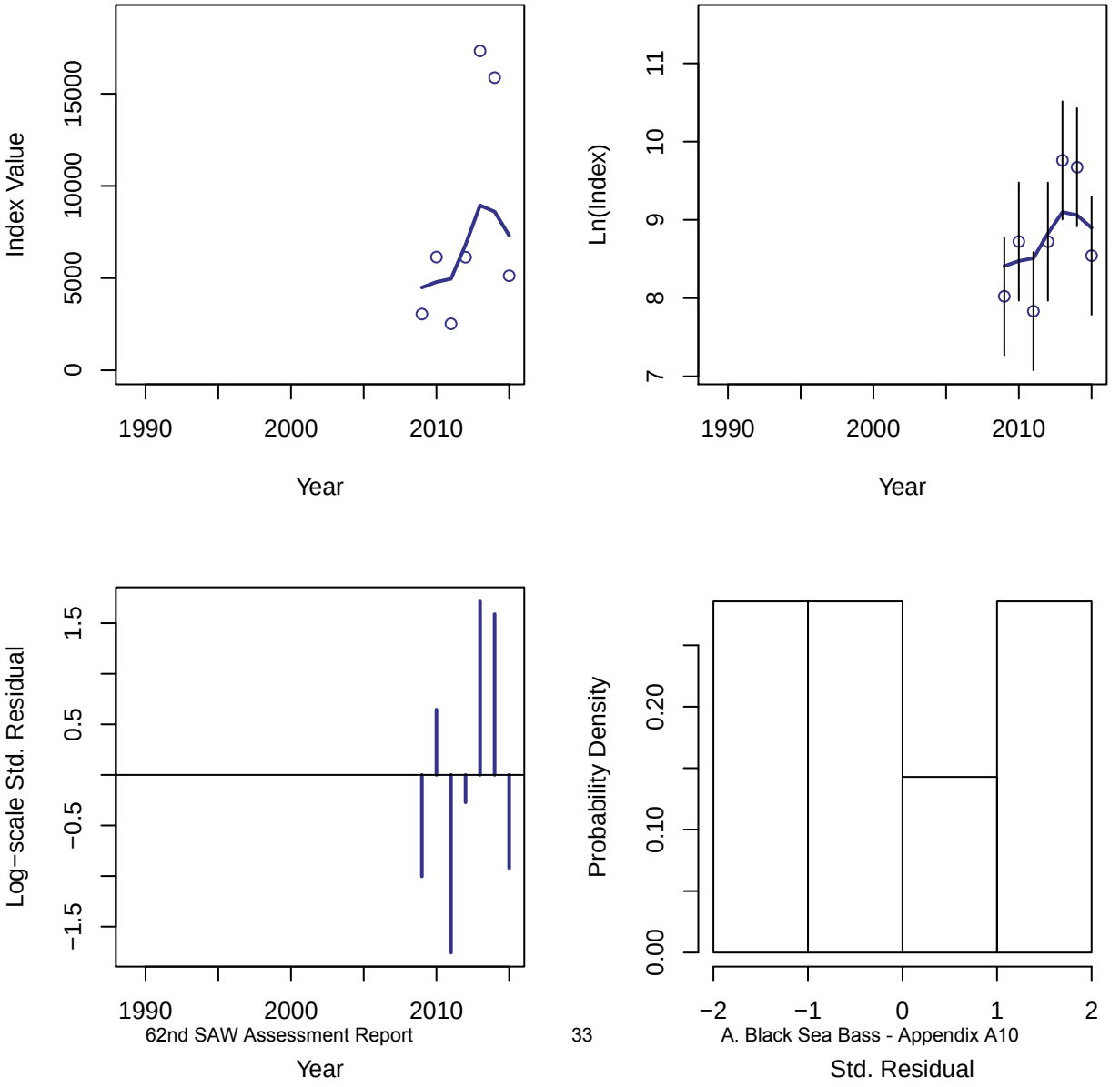
Index 11 (MD)


Index Value
0.0
0.5
1.0
1.5
1990
2000
2010
Year
Ln(Index)
−3
−2
−1
0
1
1990
2000
2010
Year
Log−scale Std. Residual
−4
−3
−2
−1
0
1
2
1990
2000
2010
Year
Probability Density
0.00
0.10
0.20
−4
−2
0
2
Std. Residual

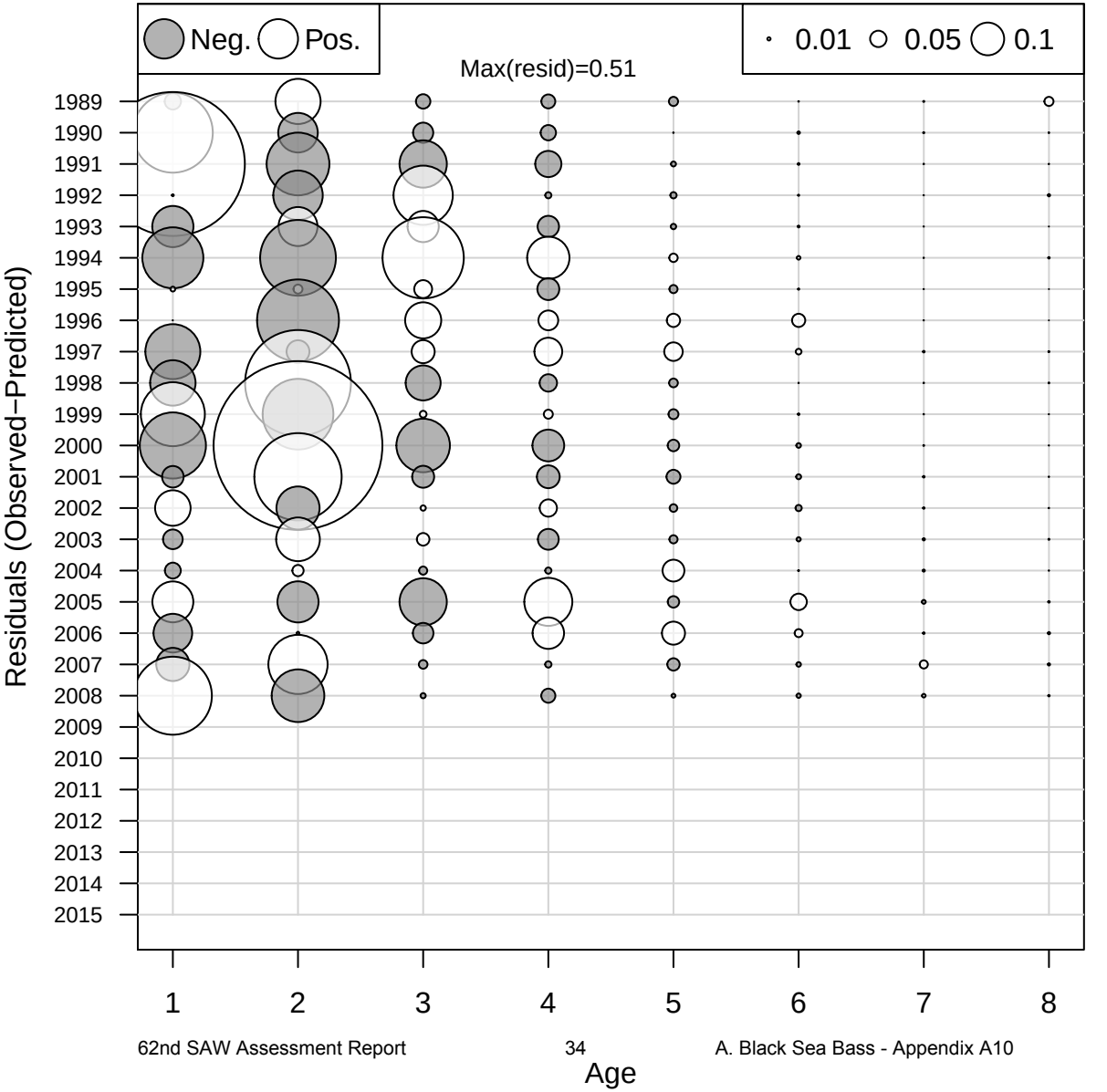
Index 12 (VIMS)



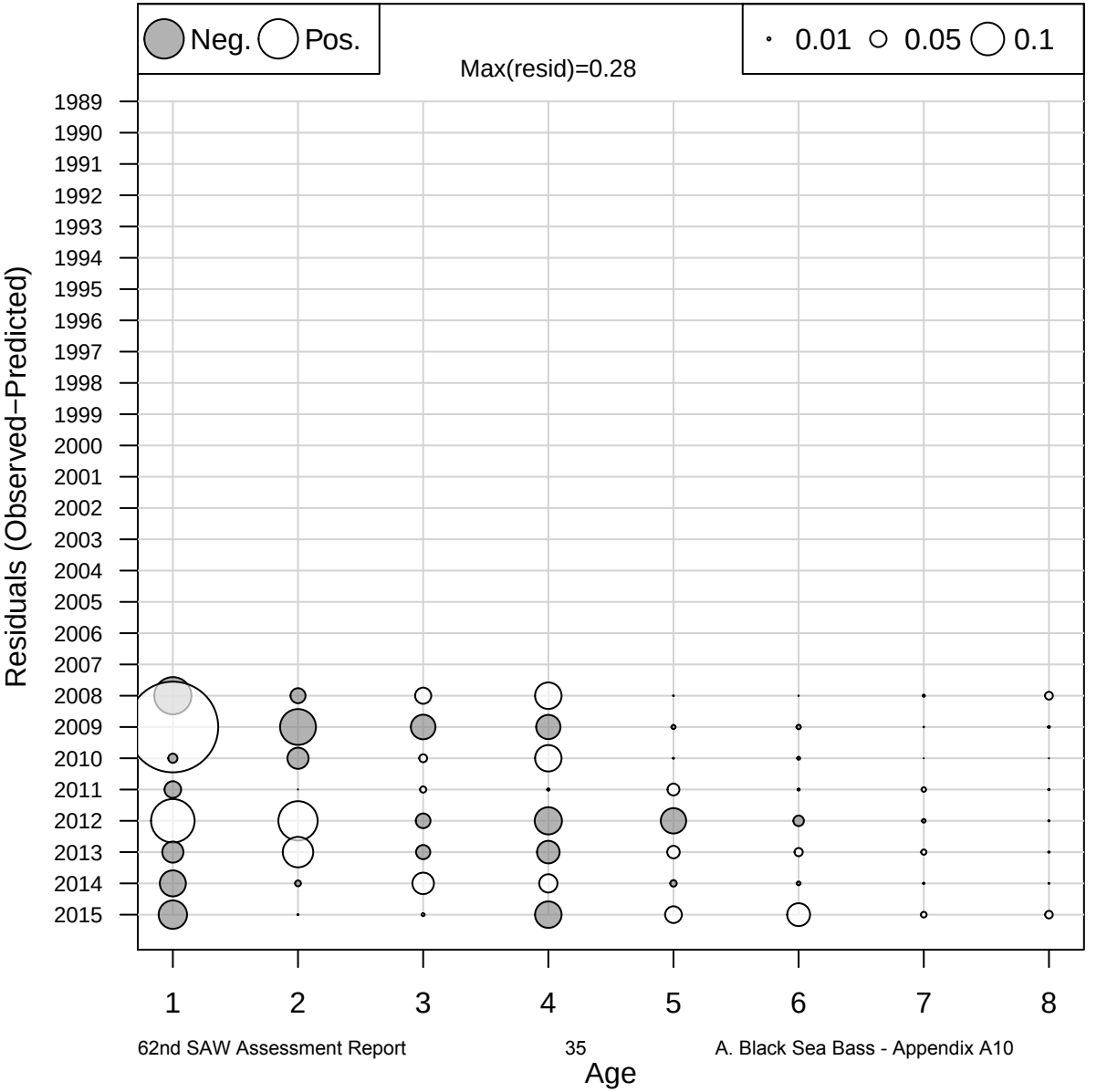
Index 13 (BIGELOW)



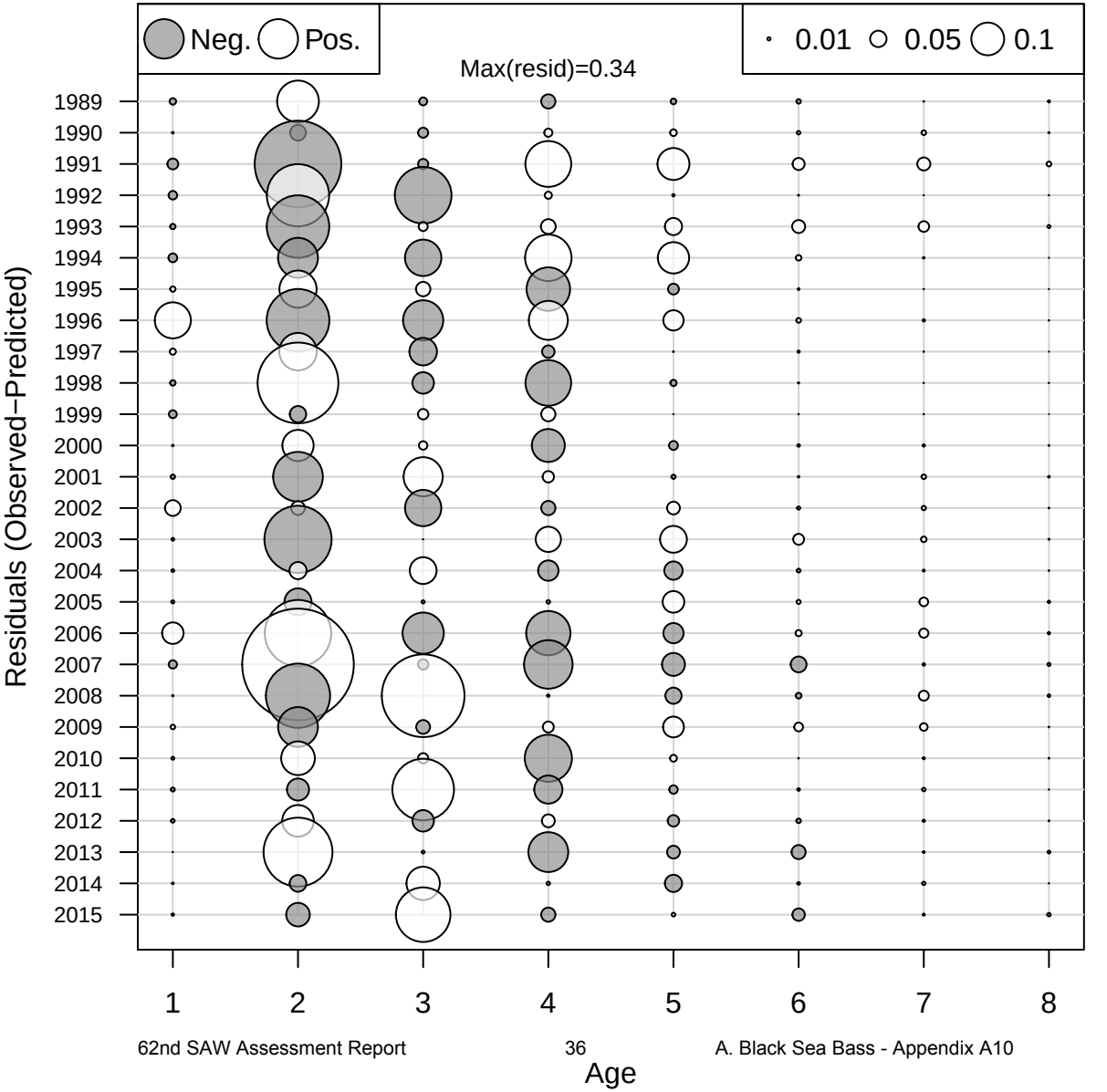
Age Comp Residuals for Index 1 (NEFSC spring Alb)



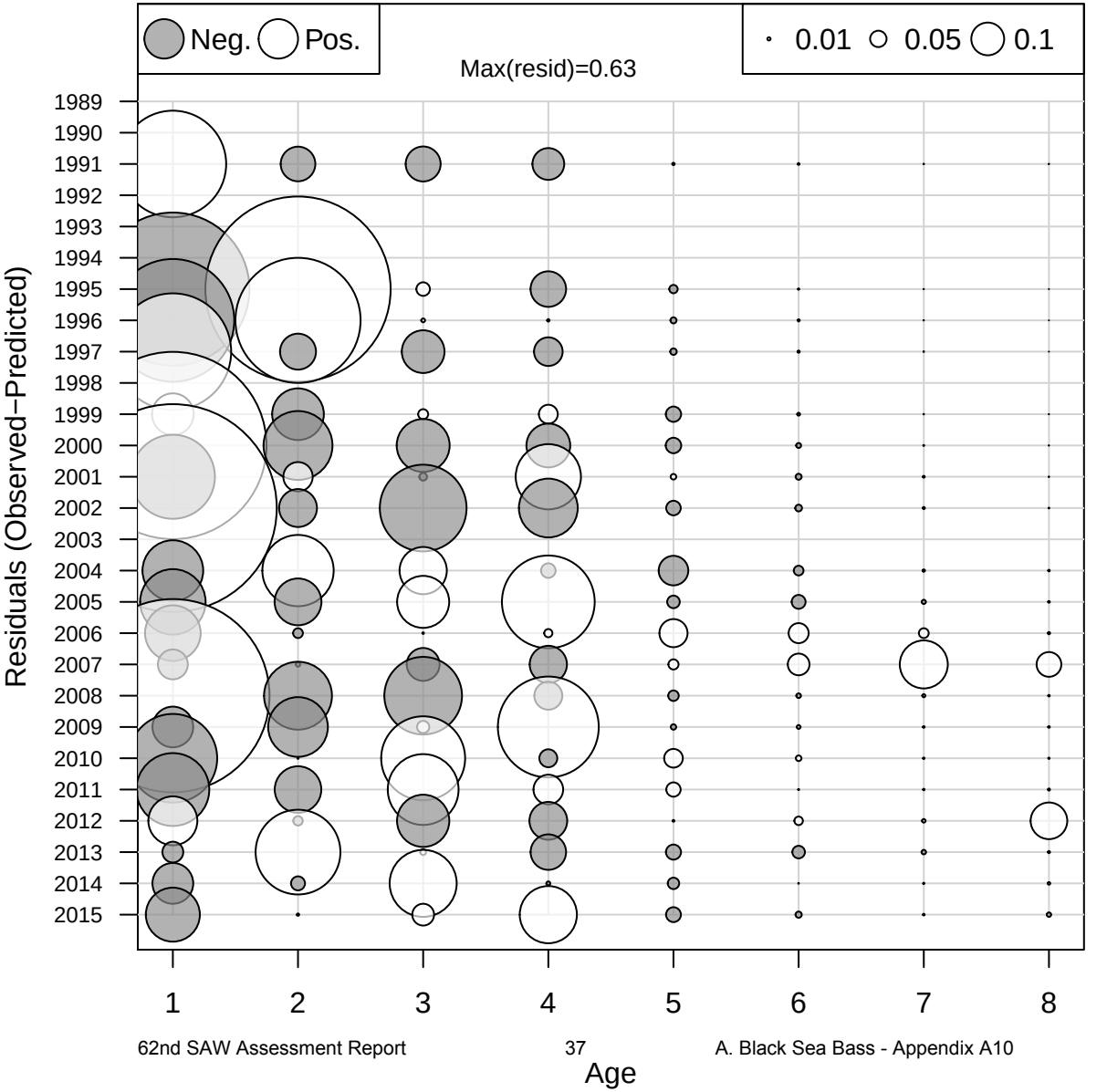
Age Comp Residuals for Index 2 (NEAMAP)



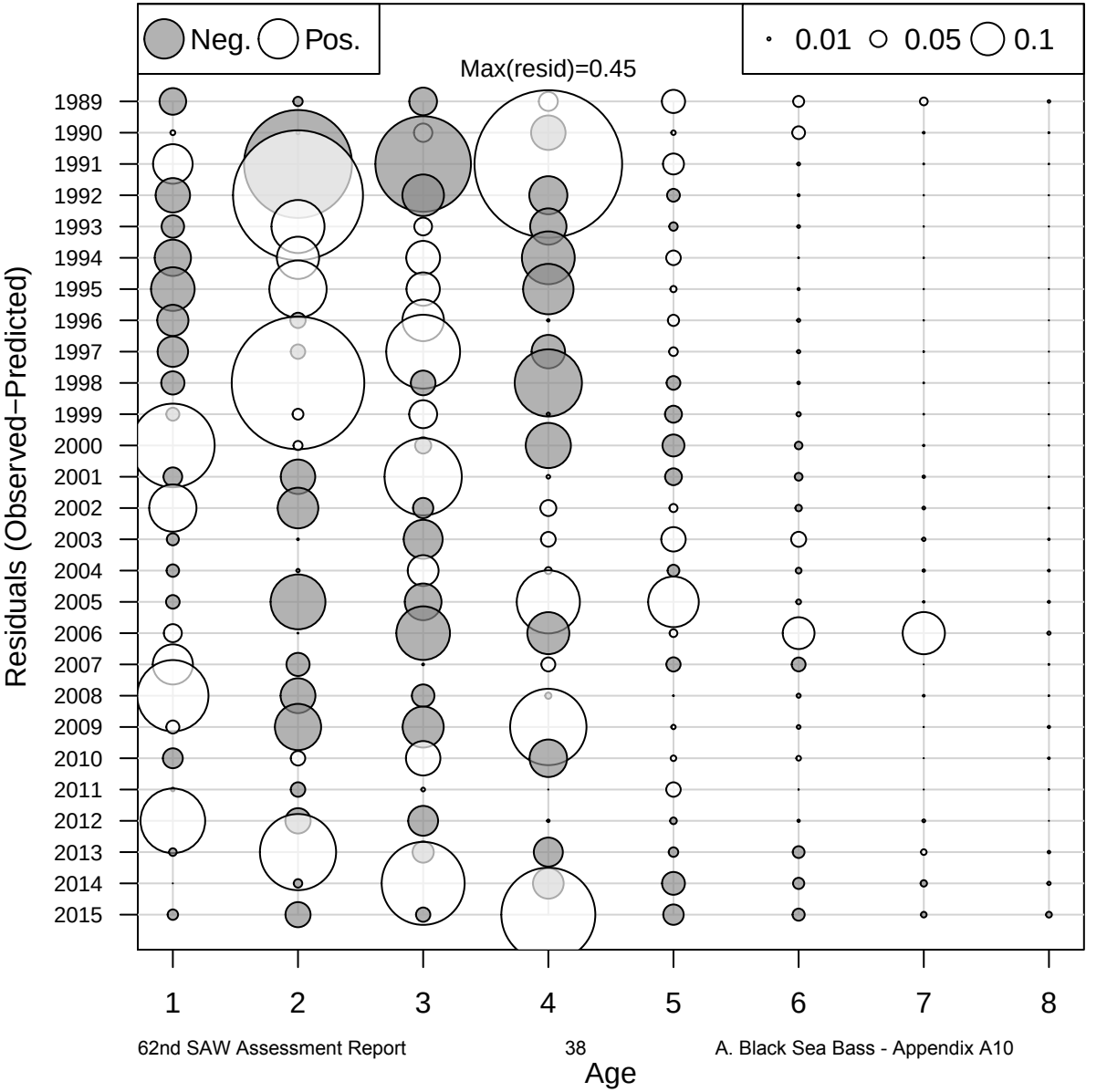
Age Comp Residuals for Index 3 (MADMF)



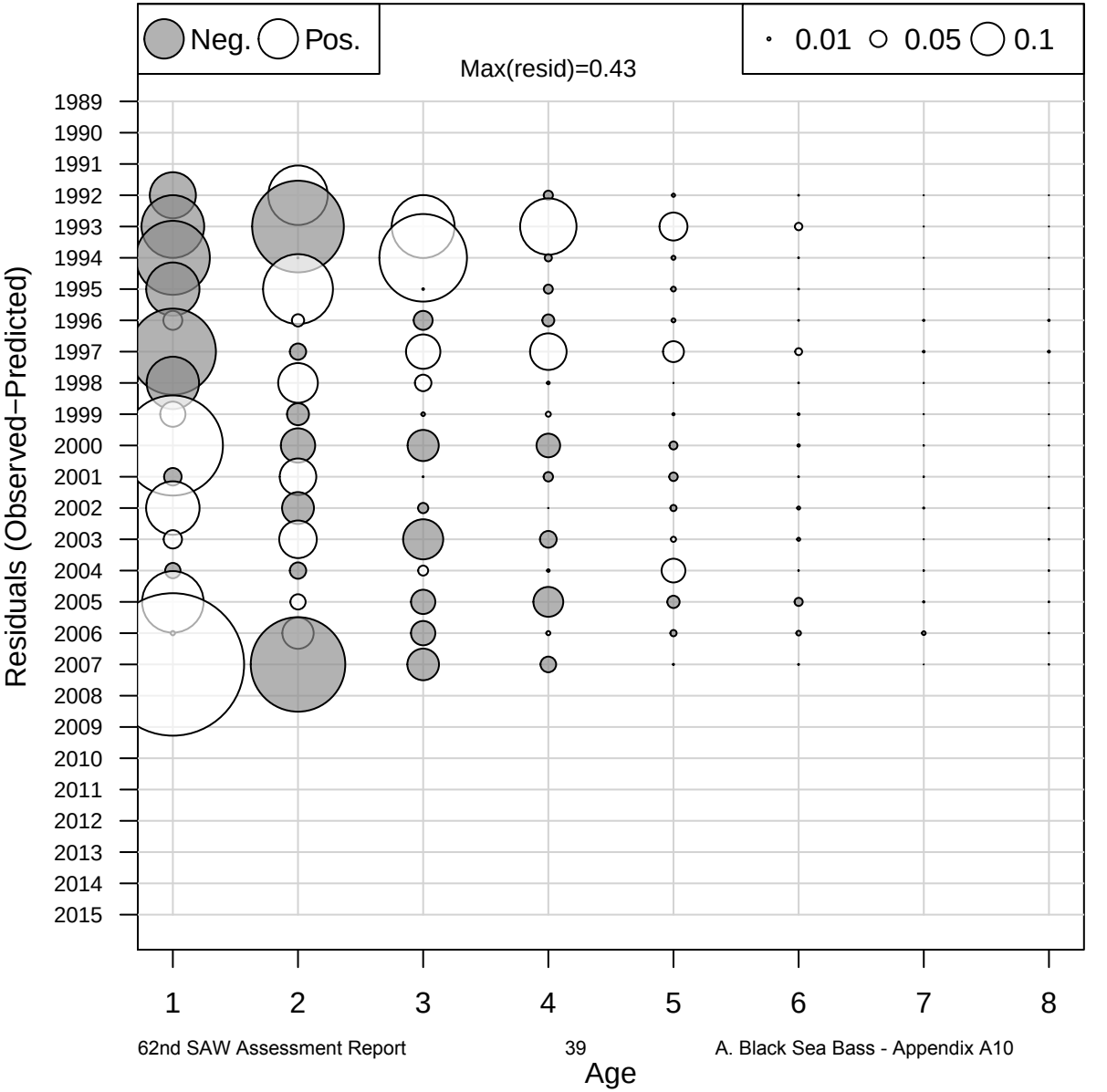
Age Comp Residuals for Index 4 (RI)



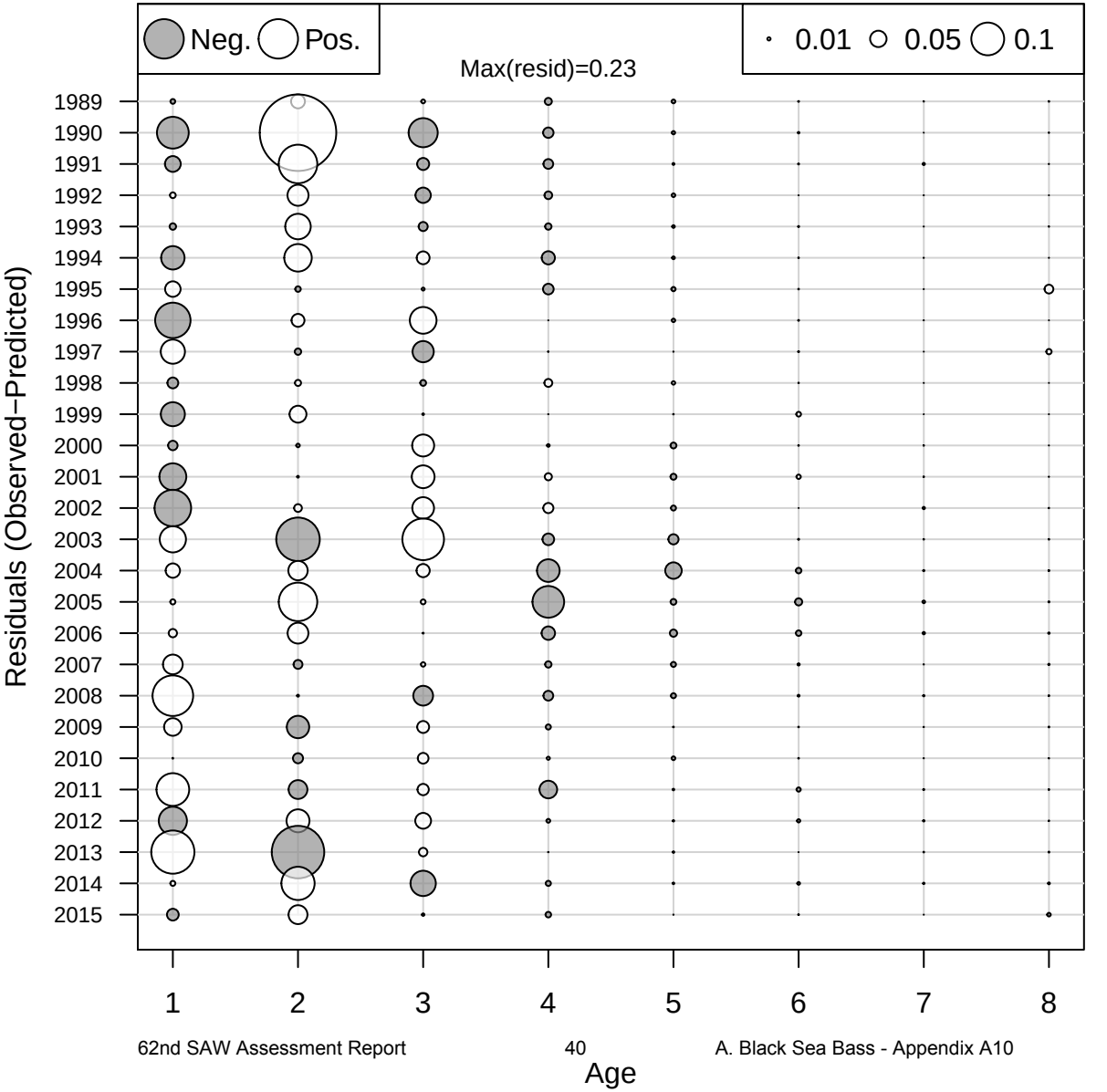
Age Comp Residuals for Index 5 (CT)



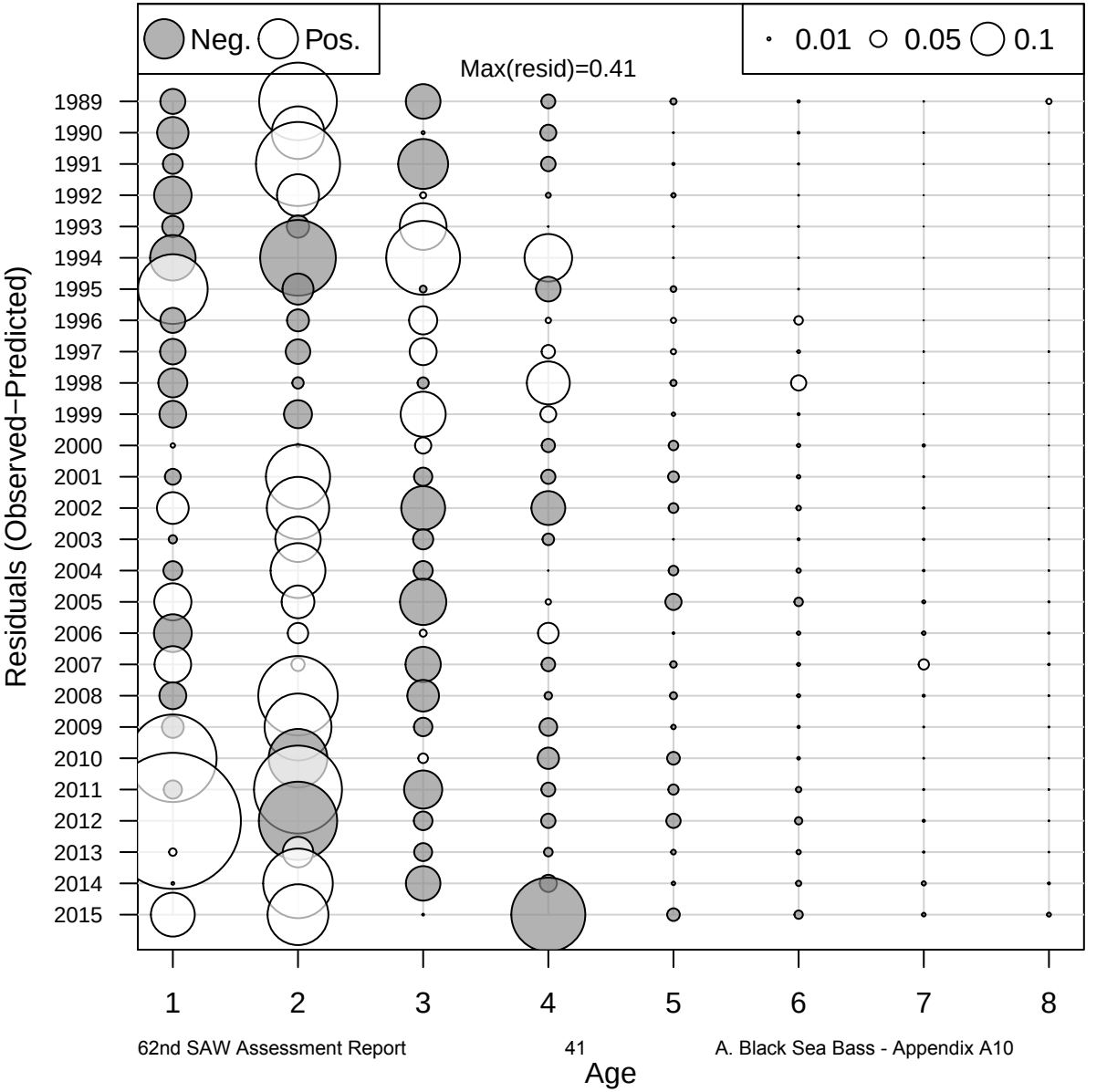
Age Comp Residuals for Index 7 (NEFSC winter)



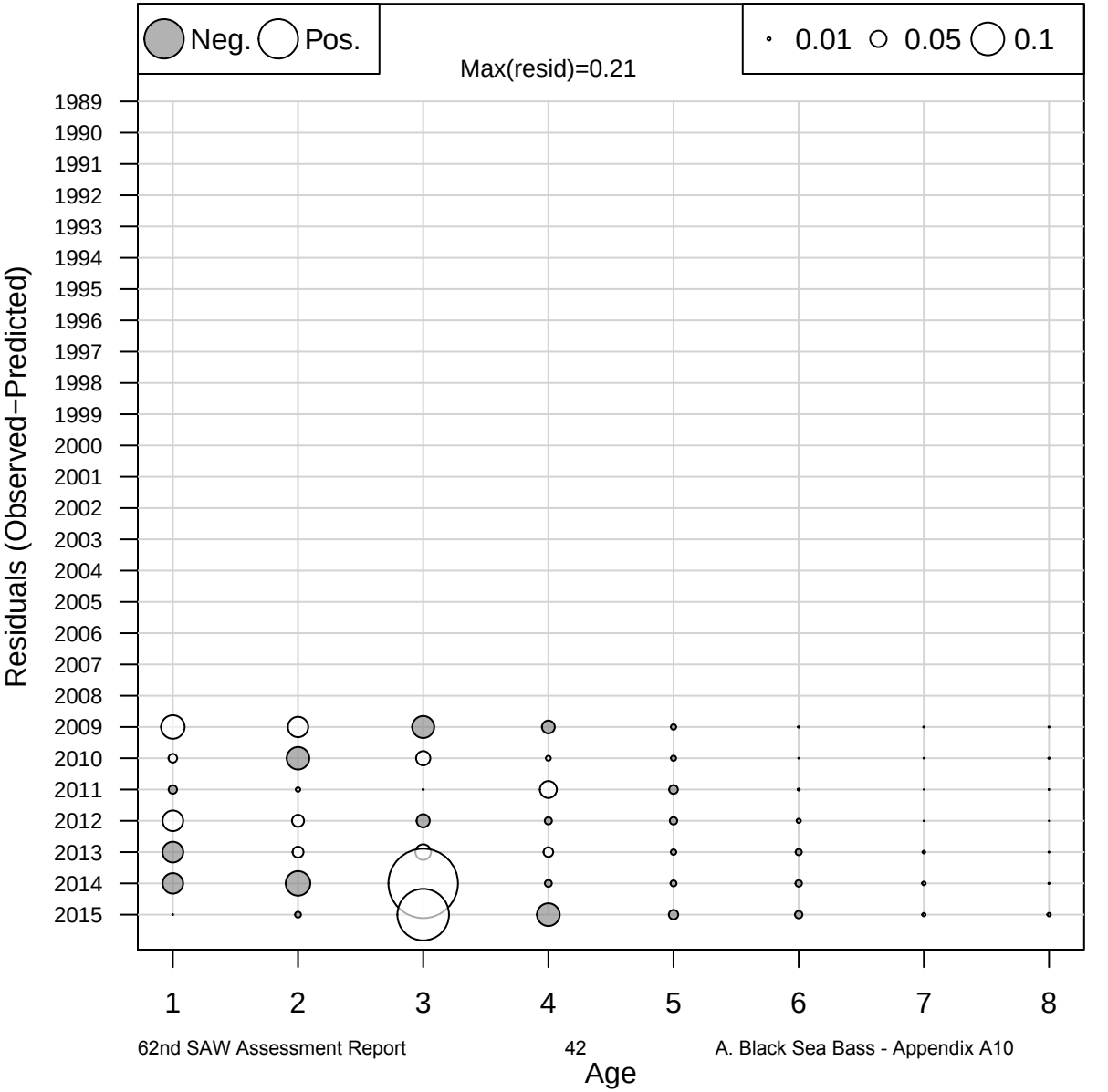
Age Comp Residuals for Index 8 (REC CPA)

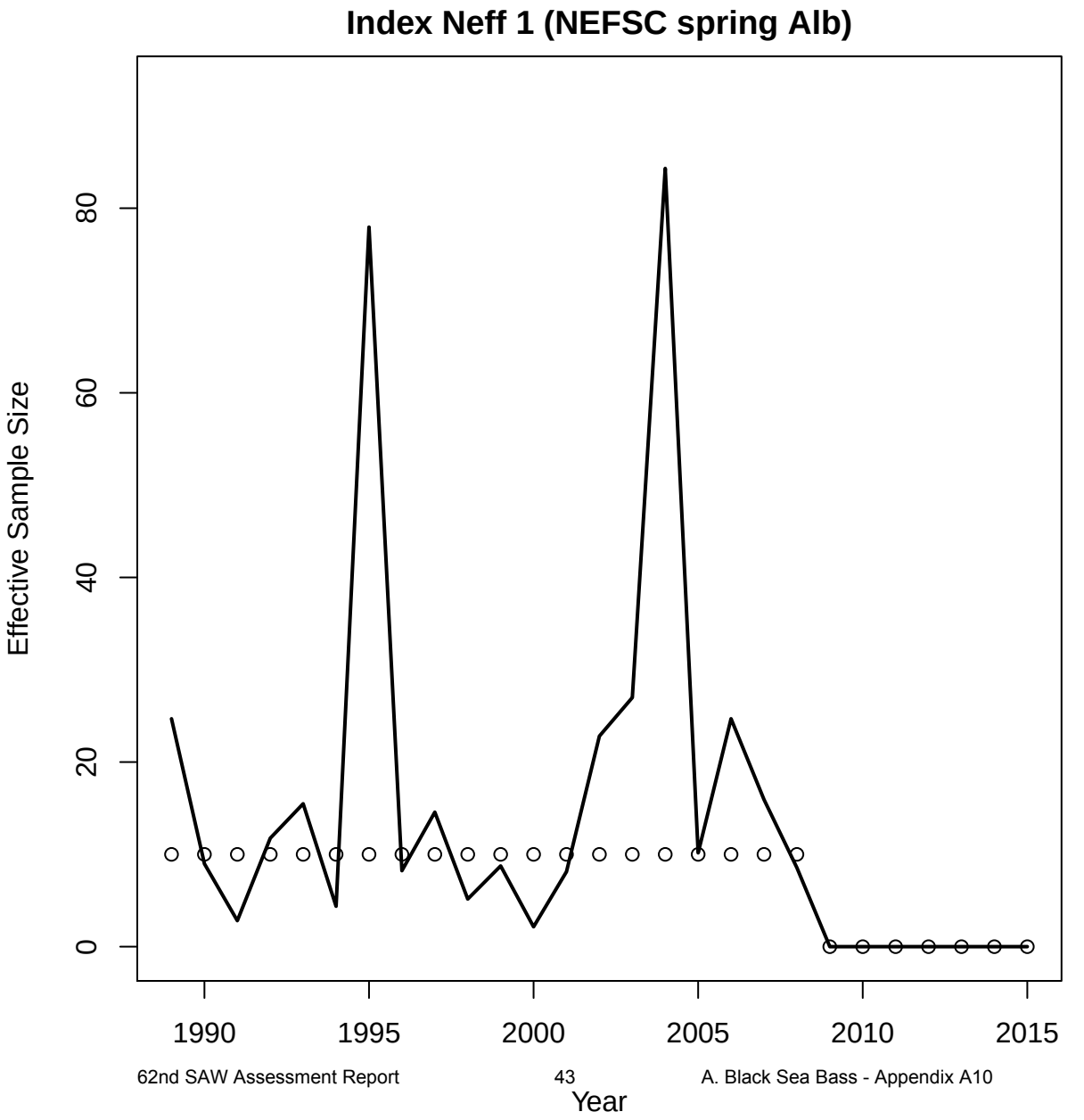


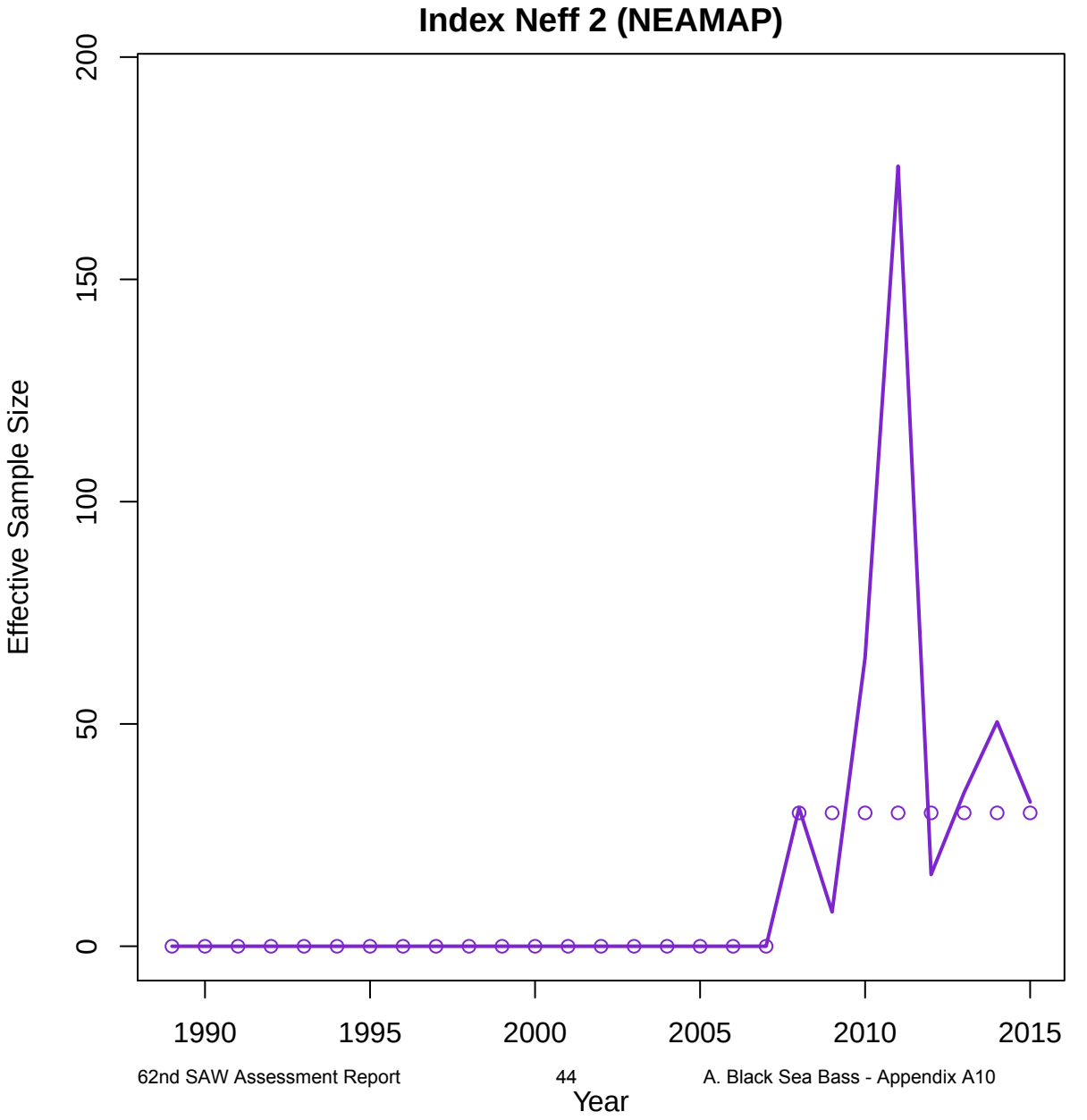
Age Comp Residuals for Index 9 (NJ)

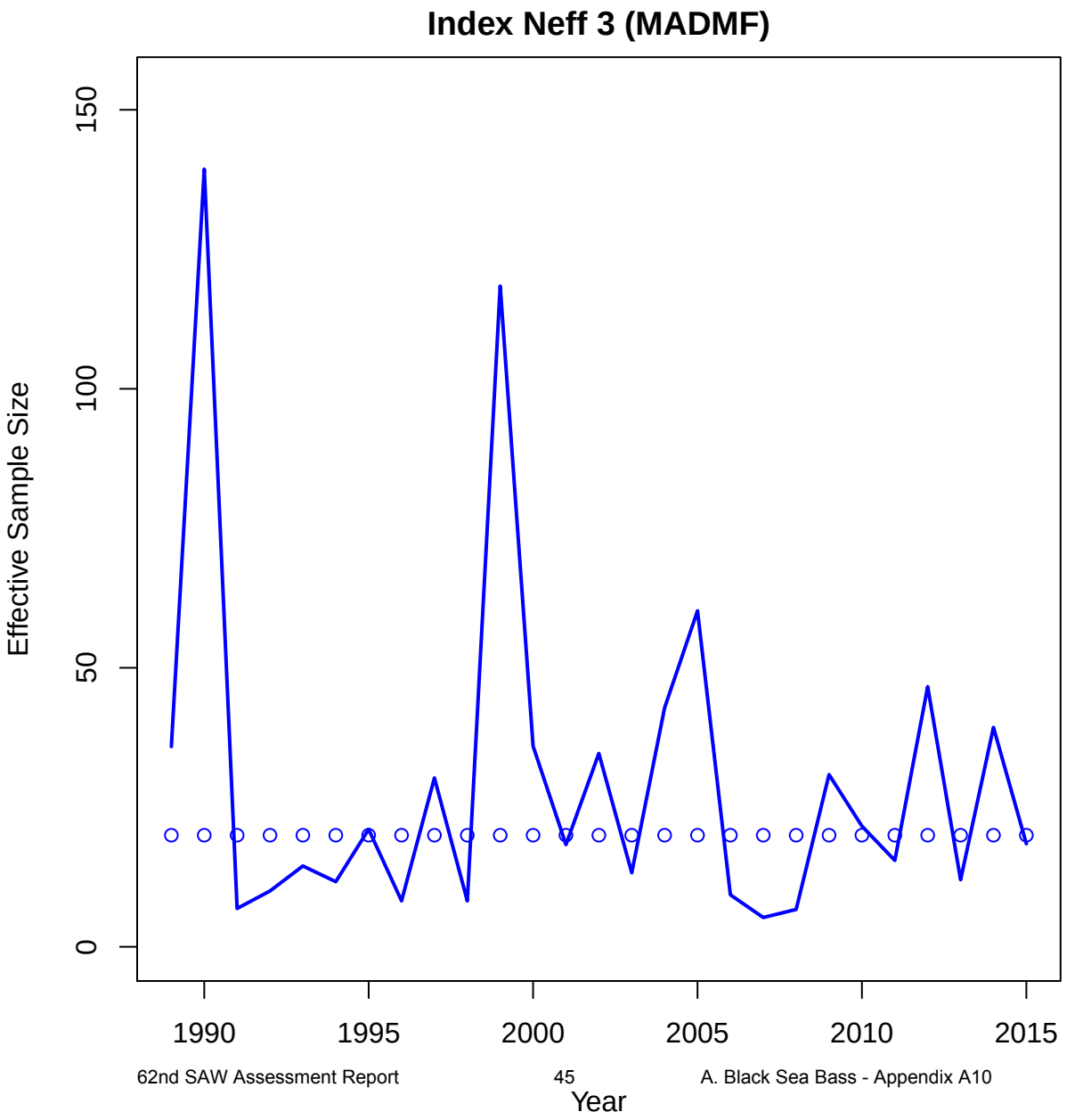


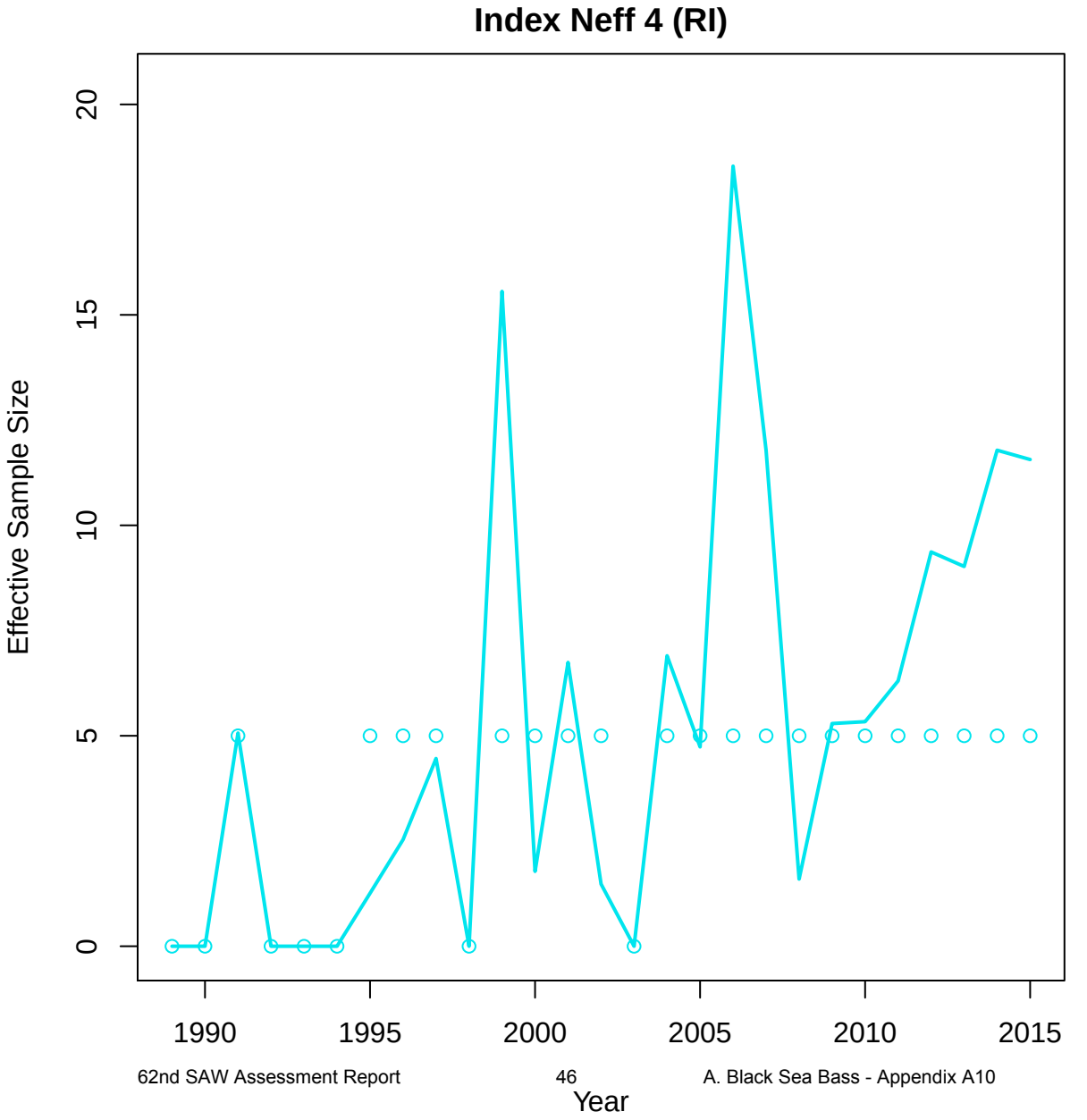
Age Comp Residuals for Index 13 (BIGELOW)

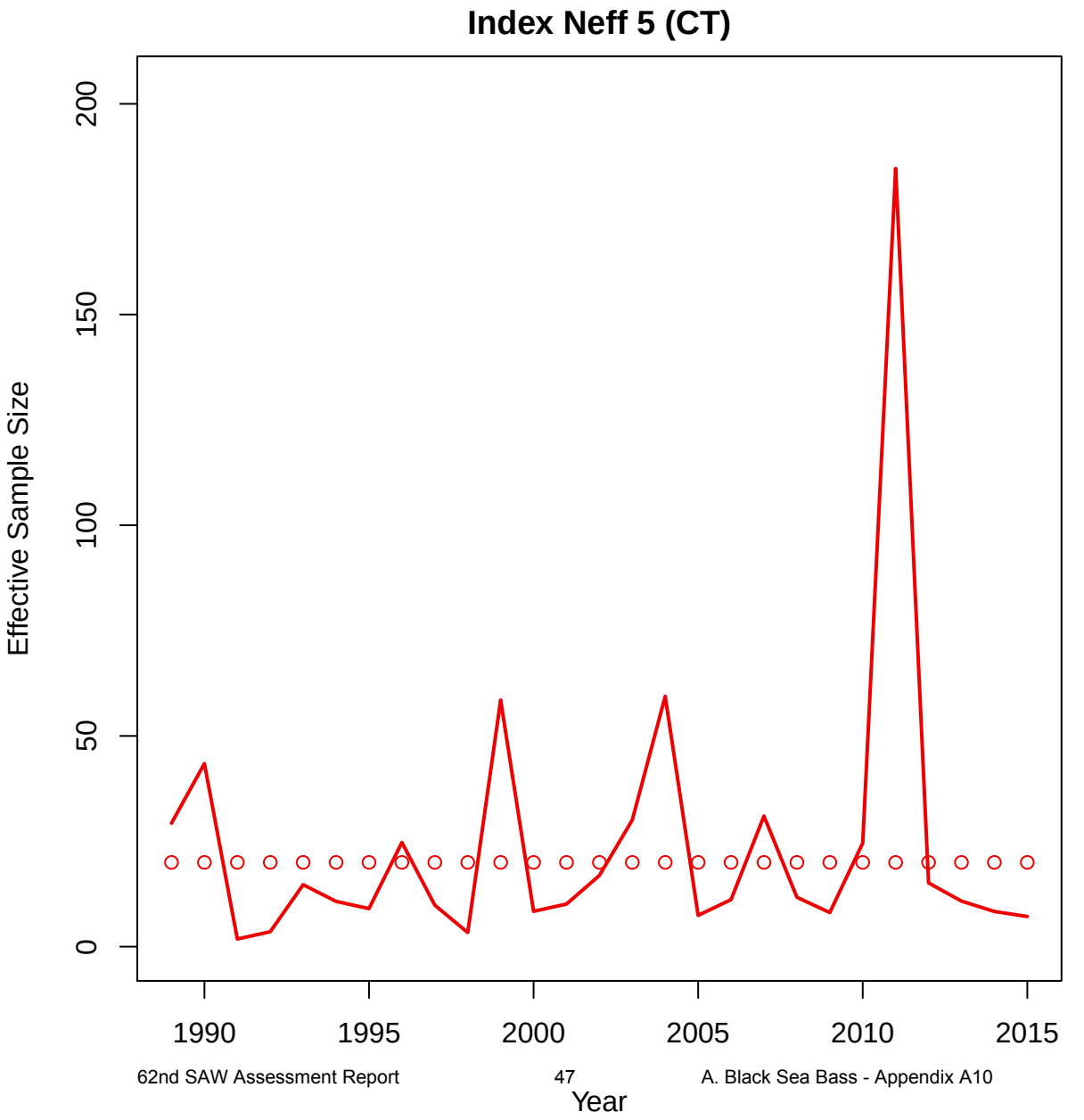


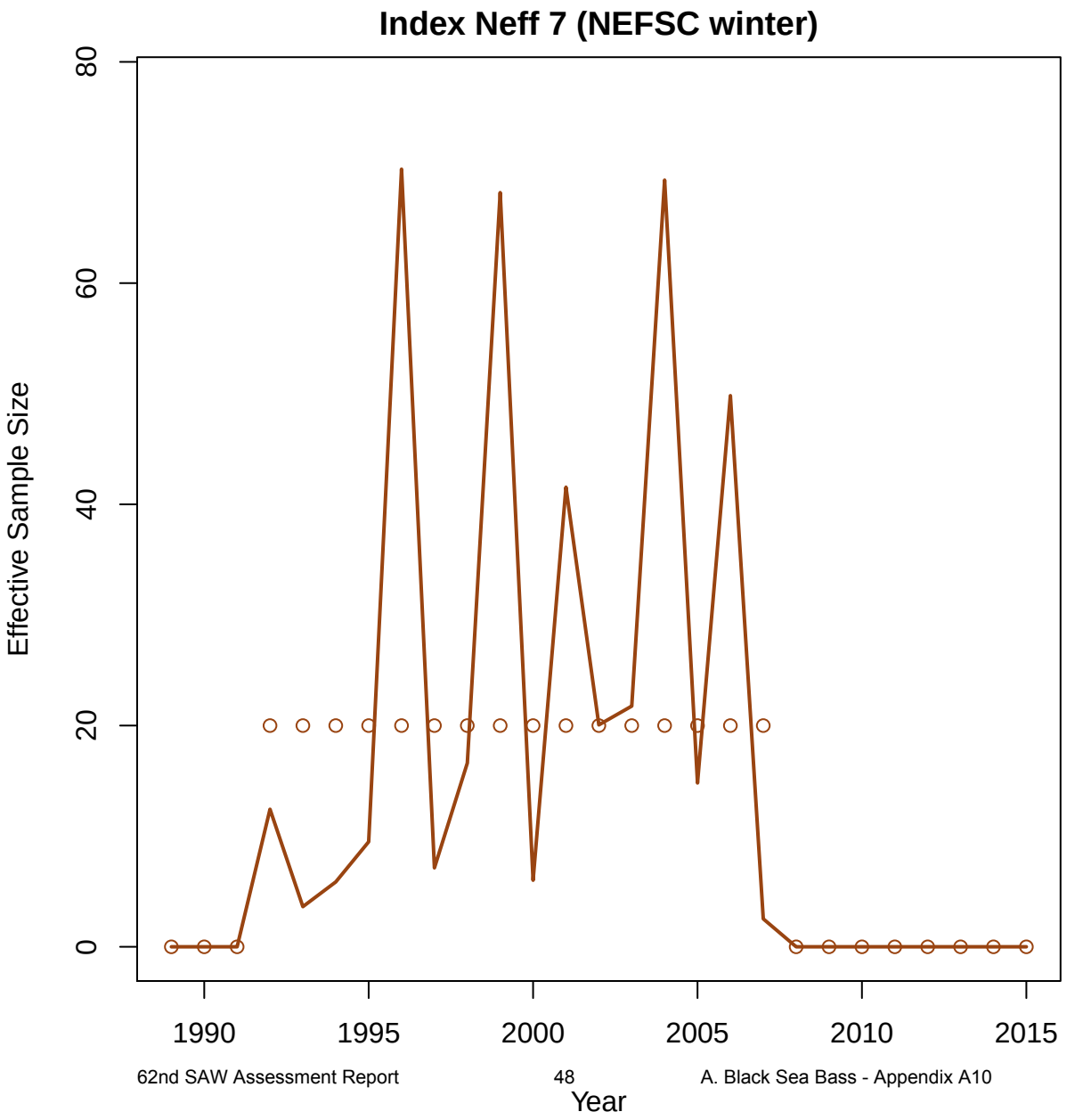

Index Neff 1 (NEFSC spring Alb)
Effective Sample Size
0
20
40
60
80
1990
1995
2000
2005
2010
2015
Year

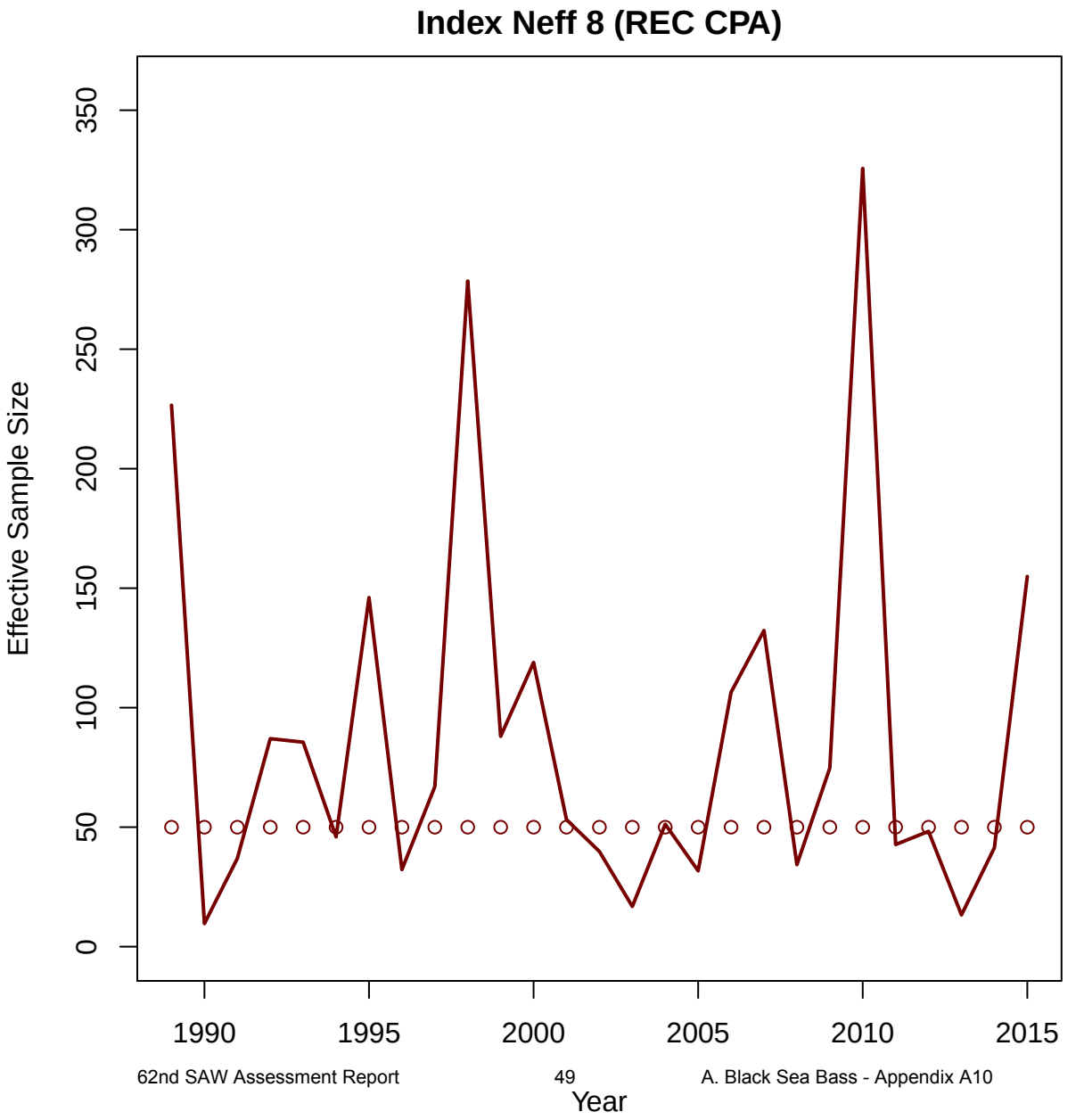

Index Neff 2 (NEAMAP)
Effective Sample Size
0
50
100
150
200
1990
1995
2000
2005
2010
2015
Year

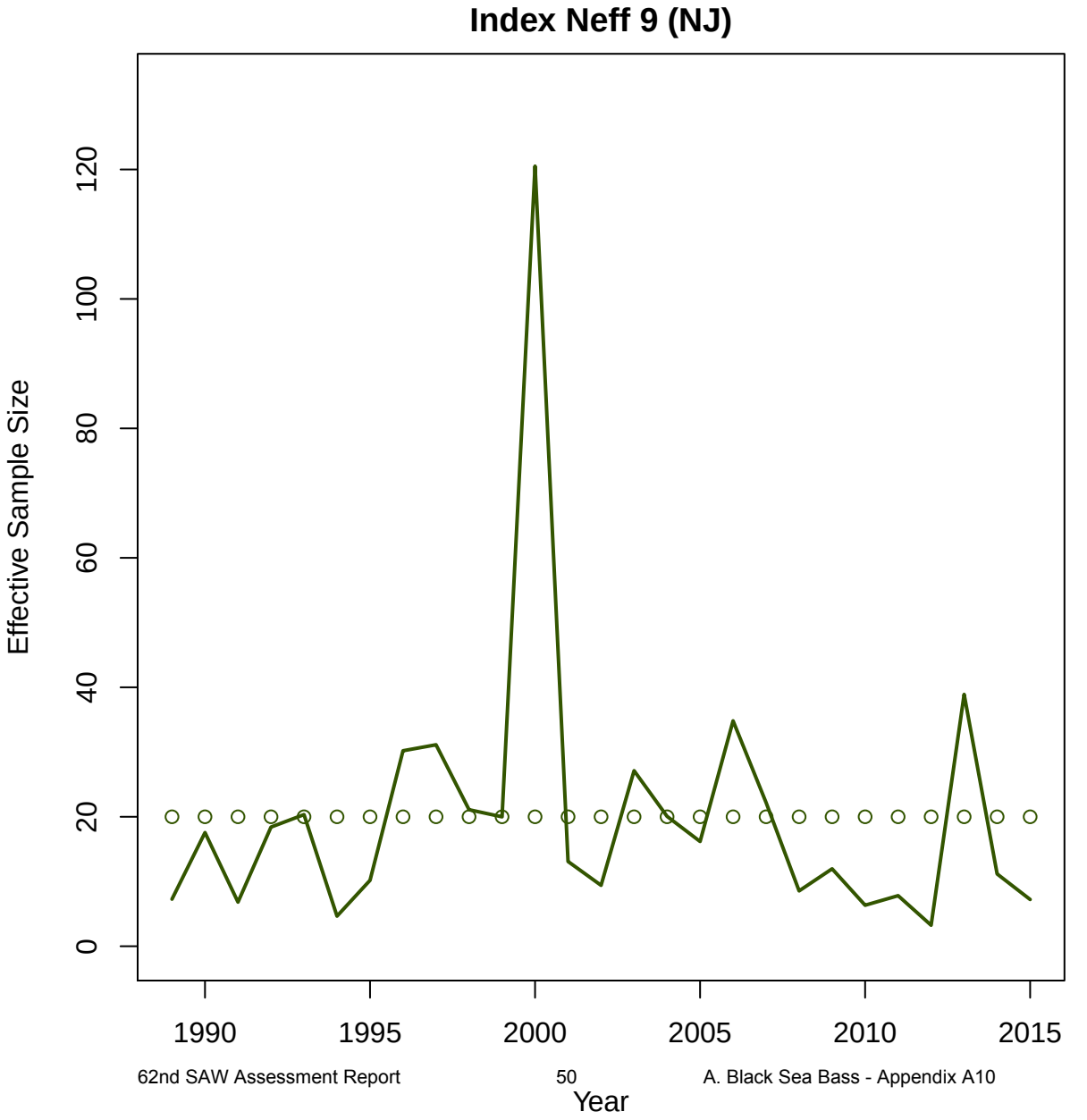

Index Neff 3 (MADMF)
Effective Sample Size
0
50
100
150
1990
1995
2000
2005
2010
2015
Year

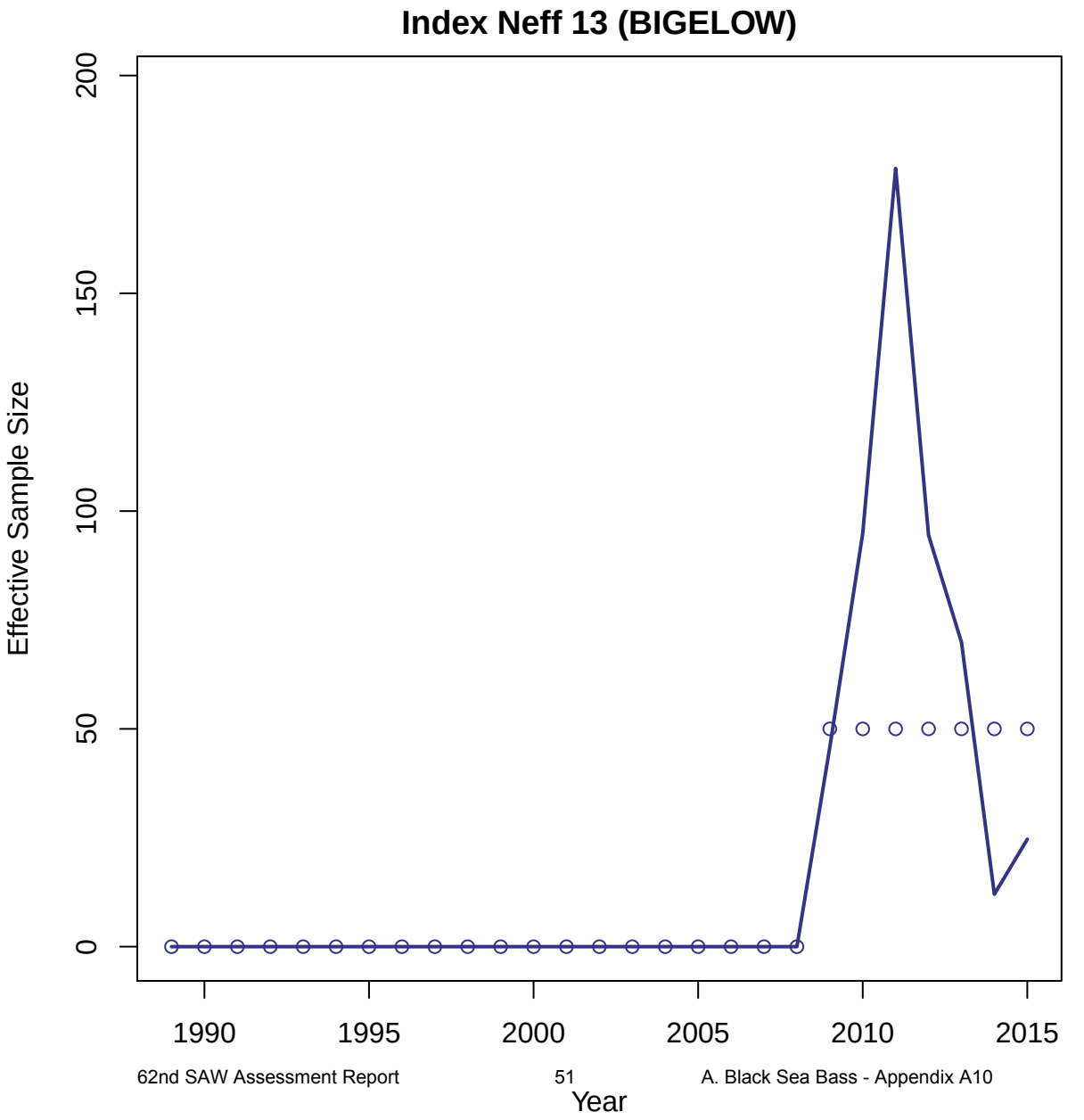

Index Neff 4 (RI)
Effective Sample Size
0
5
10
15
20
1990
1995
2000
2005
2010
2015
Year

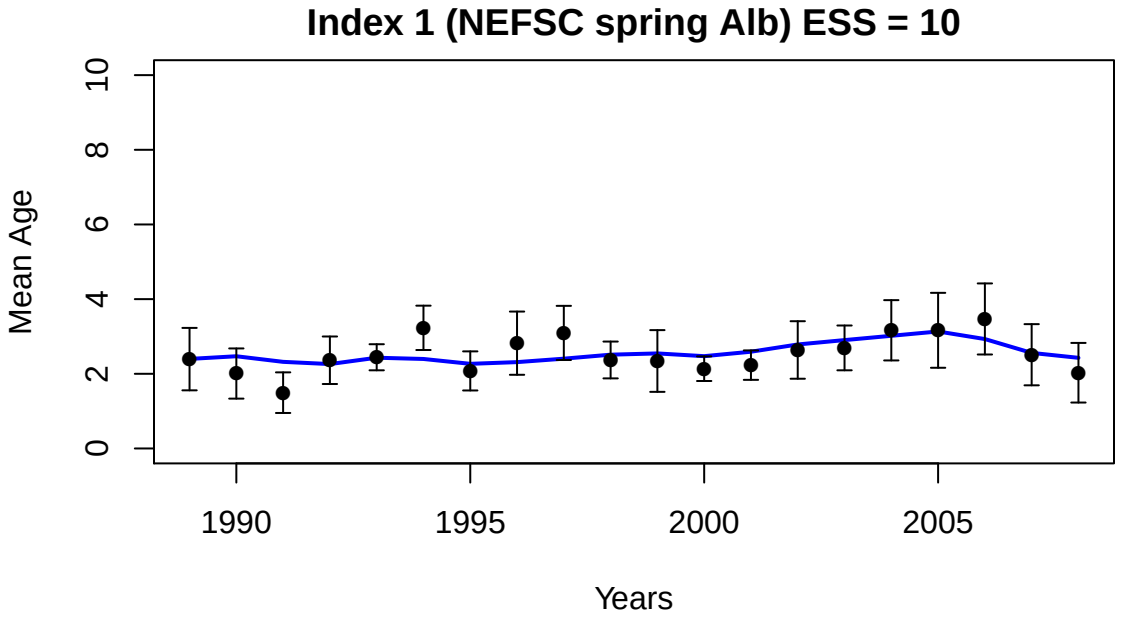

Index Neff 5 (CT)
Effective Sample Size
0
50
100
150
200
1990
1995
2000
2005
2010
2015
Year

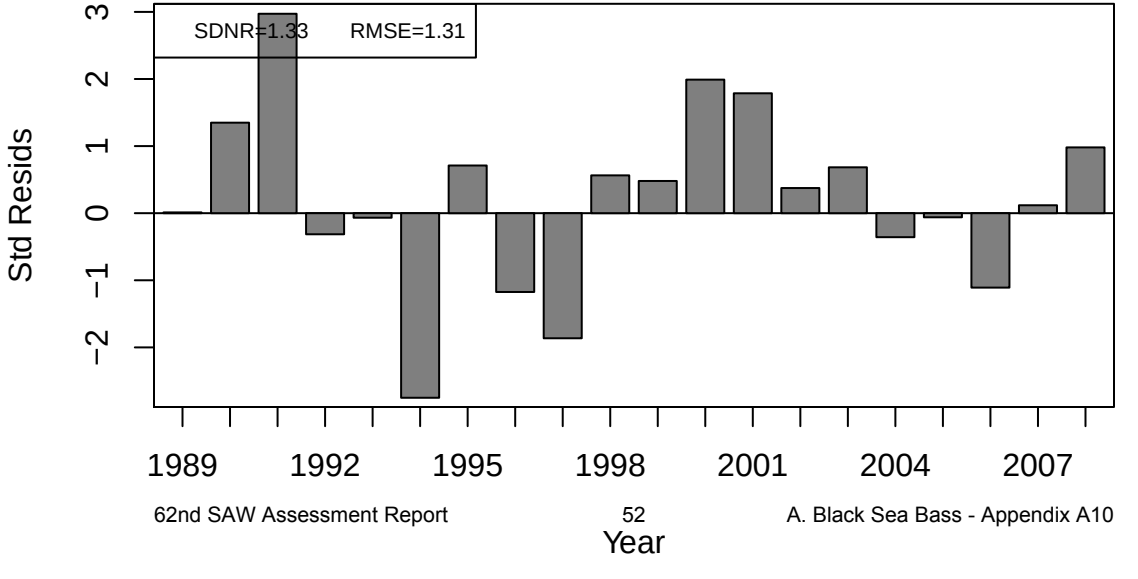

Index Neff 7 (NEFSC winter)
Effective Sample Size
0
20
40
60
80
1990
1995
2000
2005
2010
2015
Year

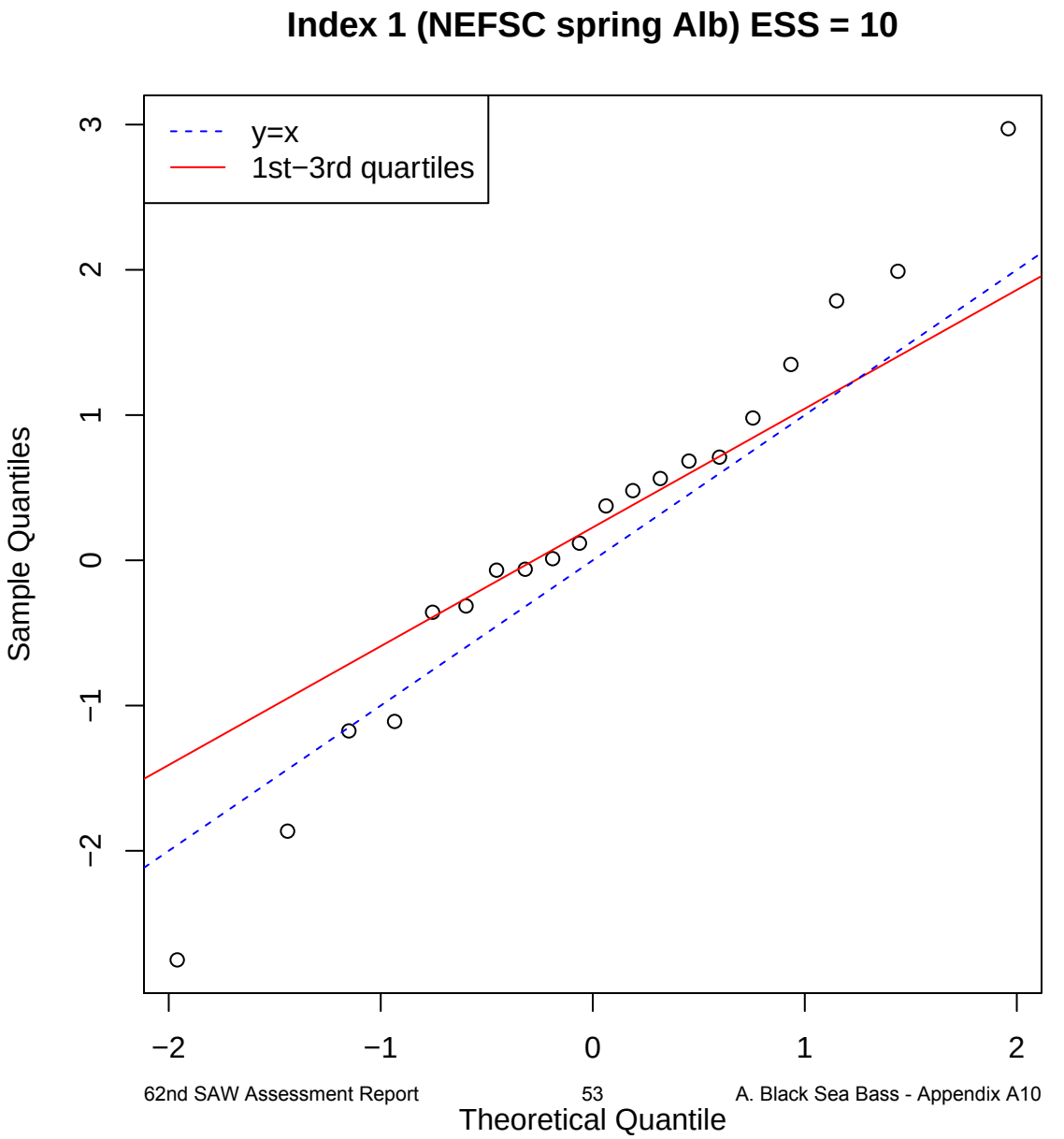

Index Neff 8 (REC CPA)
Effective Sample Size
0
50
100
150
200
250
300
350
1990
1995
2000
2005
2010
2015
Year

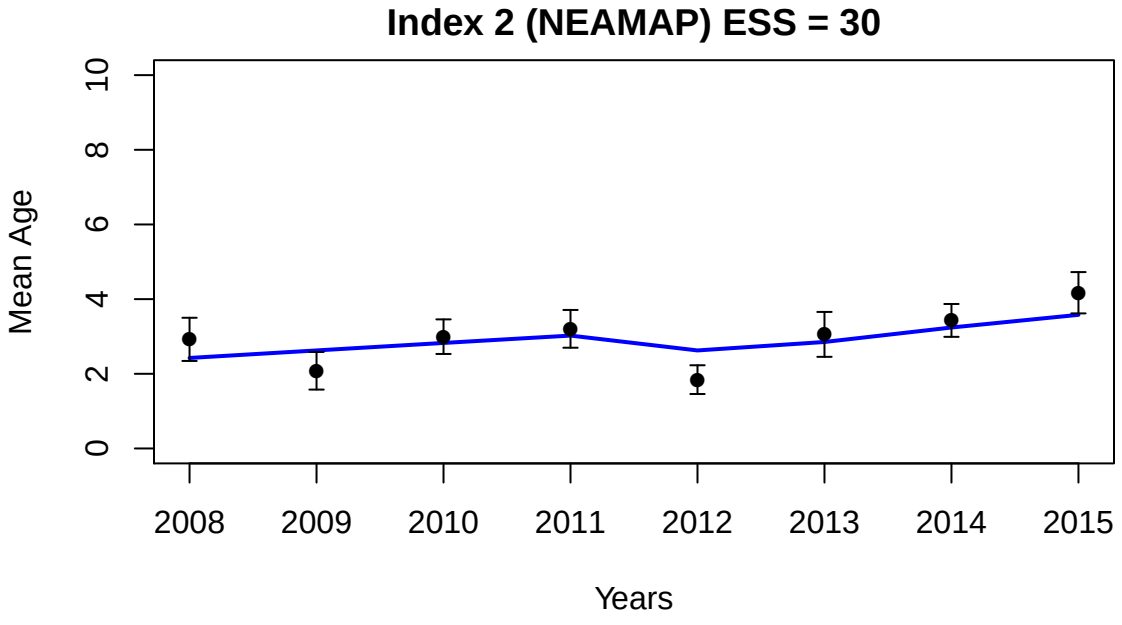

Index Neff 9 (NJ)
Effective Sample Size
0
20
40
60
80
100
120
1990
1995
2000
2005
2010
2015
Year

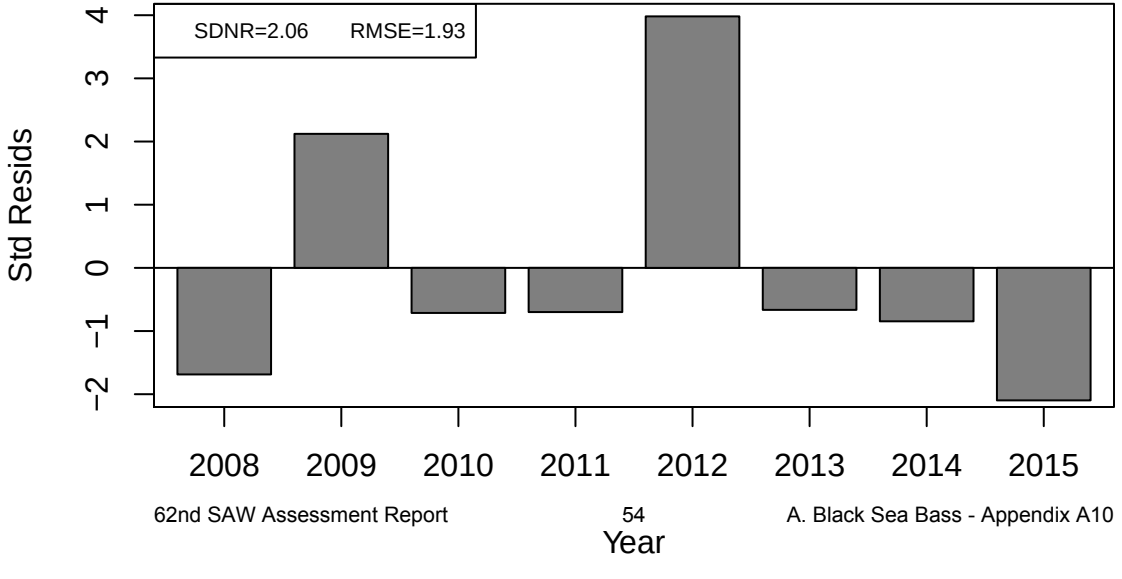

Index Neff 13 (BIGELOW)
Effective Sample Size
0
50
100
150
200
1990
1995
2000
2005
2010
2015
Year

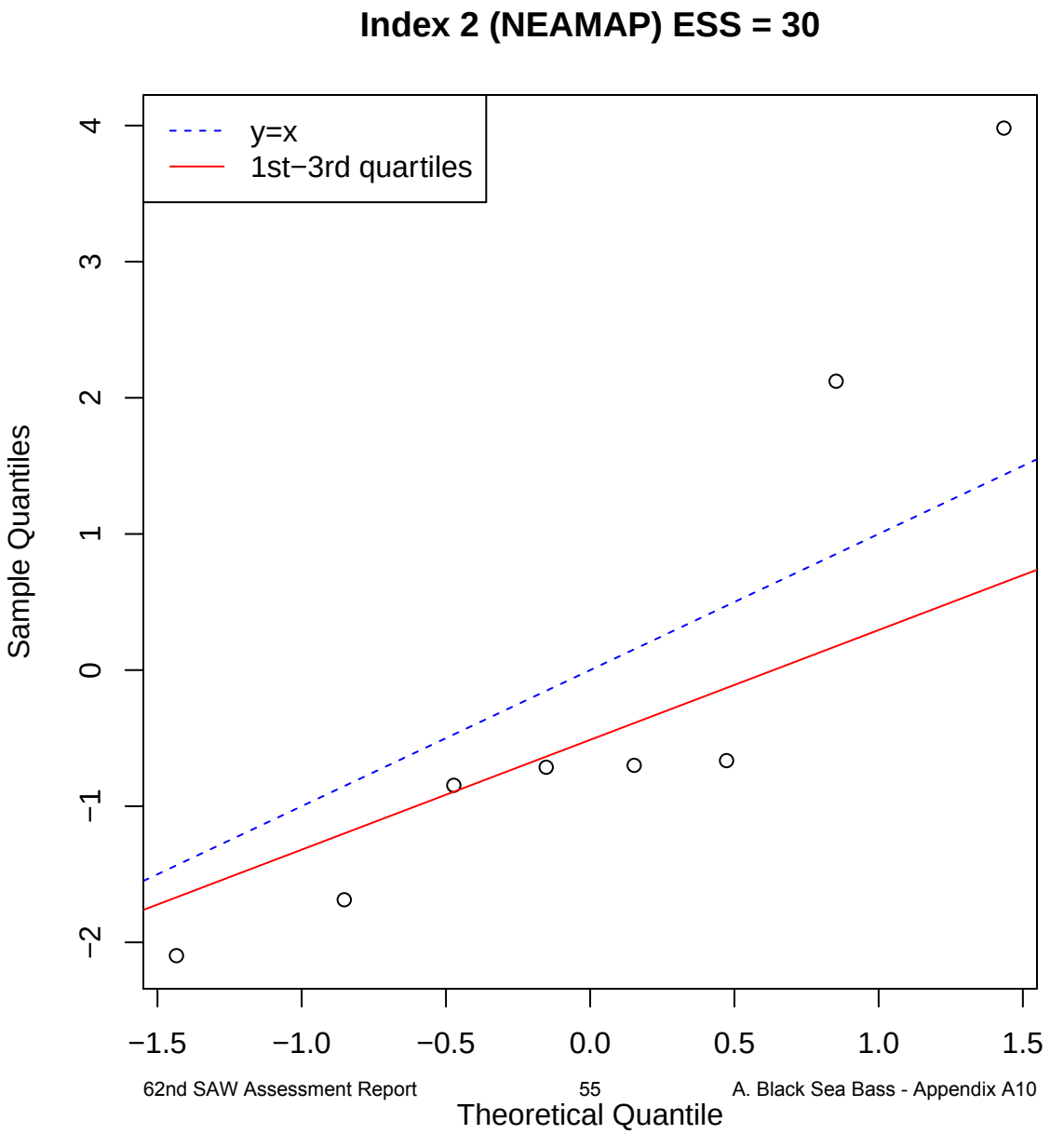

Index 1 (NEFSC spring Alb) ESS = 10
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
Years

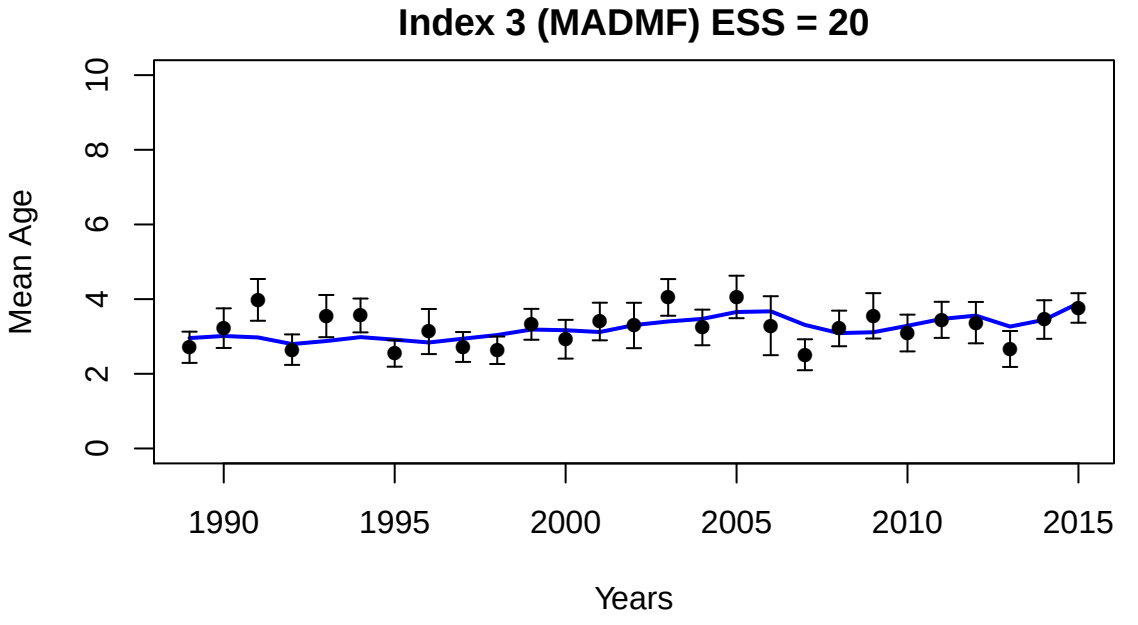

SDNR=1.33
RMSE=1.31
Std Resids
−2
−1
0
1
2
3
1989
1992
1995
1998
2001
2004
2007
Year

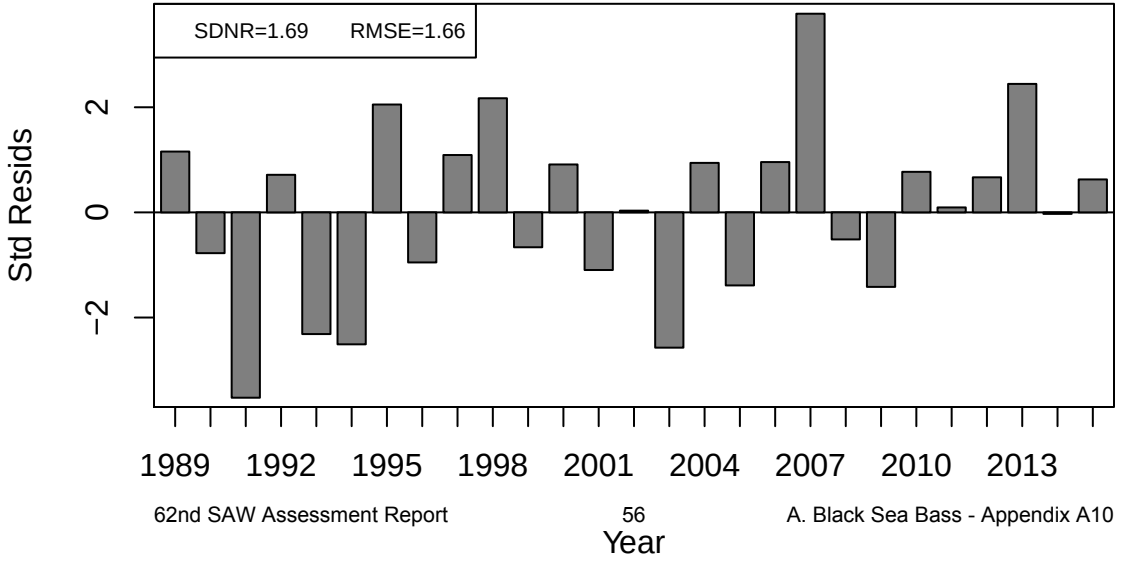

Index 1 (NEFSC spring Alb) ESS = 10
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
−1
0
1
2
3

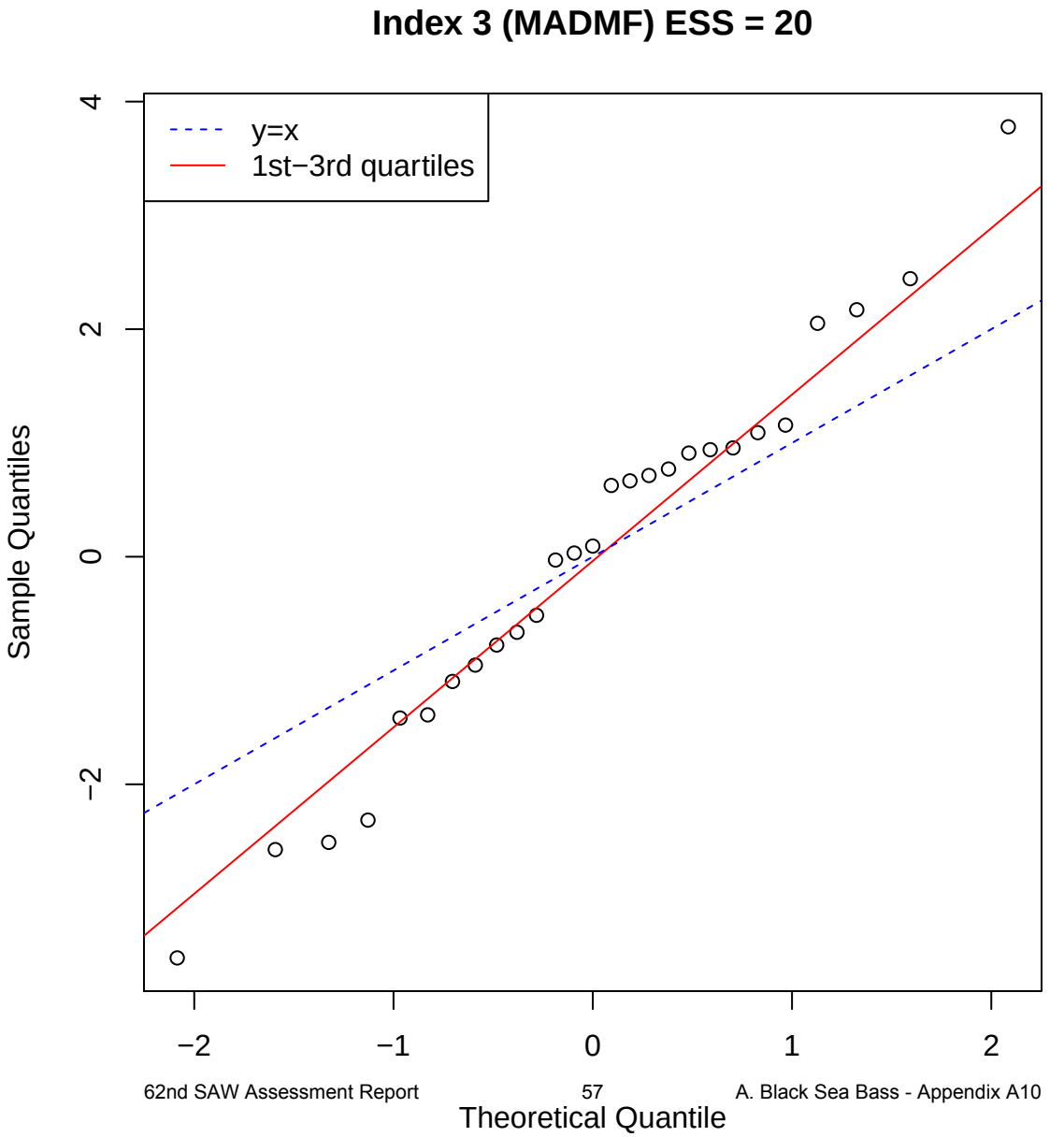

Index 2 (NEAMAP) ESS = 30
Mean Age
0
2
4
6
8
10
2008
2009
2010
2011
2012
2013
2014
2015
Years

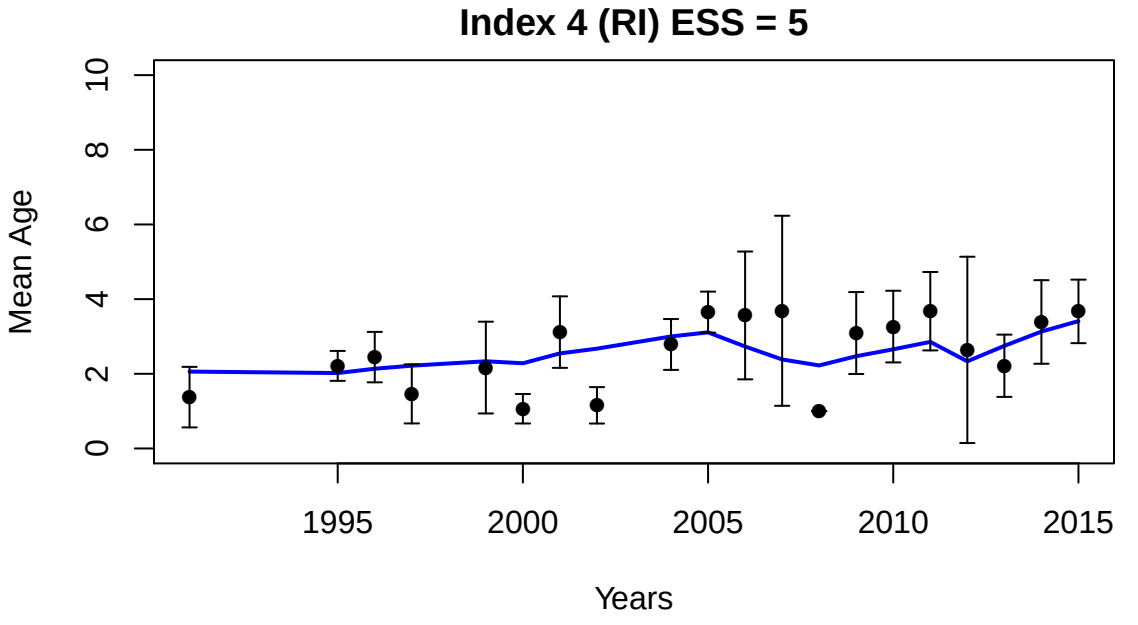

SDNR=2.06
RMSE=1.93
Std Resids
−2
−1
0
1
2
3
4
2008
2009
2010
2011
2012
2013
2014
2015
Year

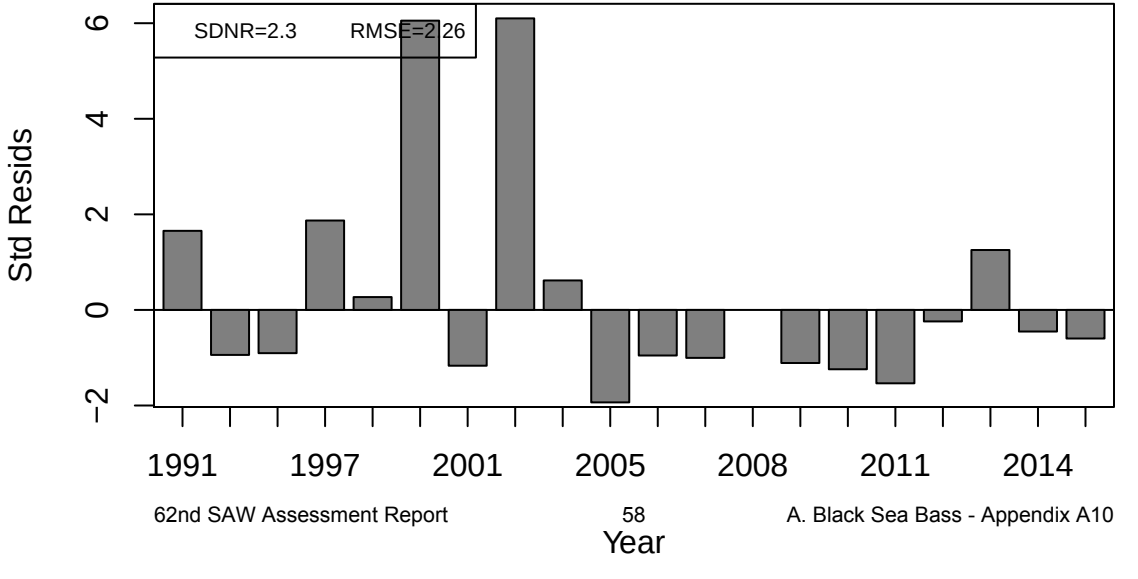

Index 2 (NEAMAP) ESS = 30
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
−1
0
1
2
3
4
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5

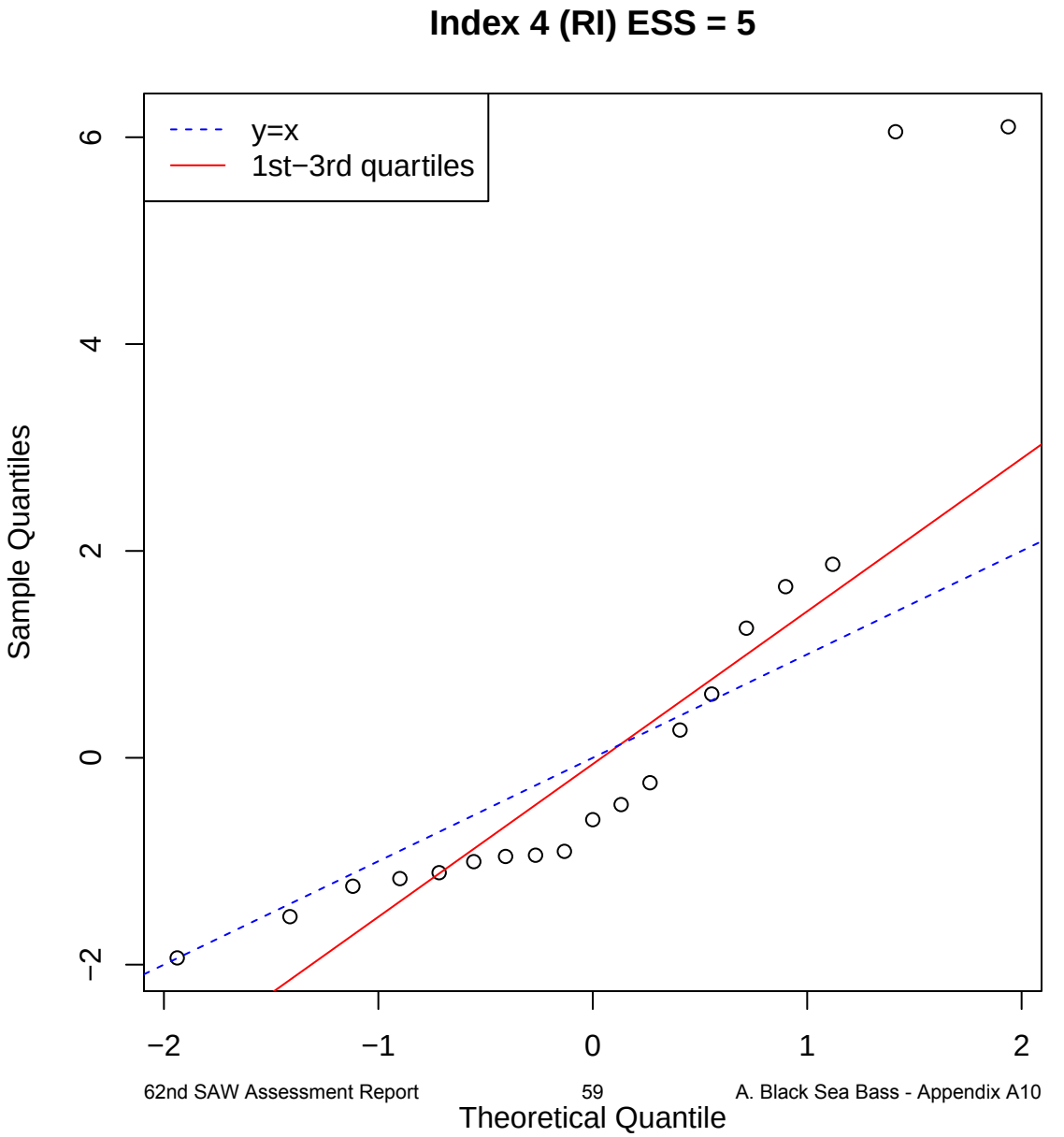

Index 3 (MADMF) ESS = 20
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

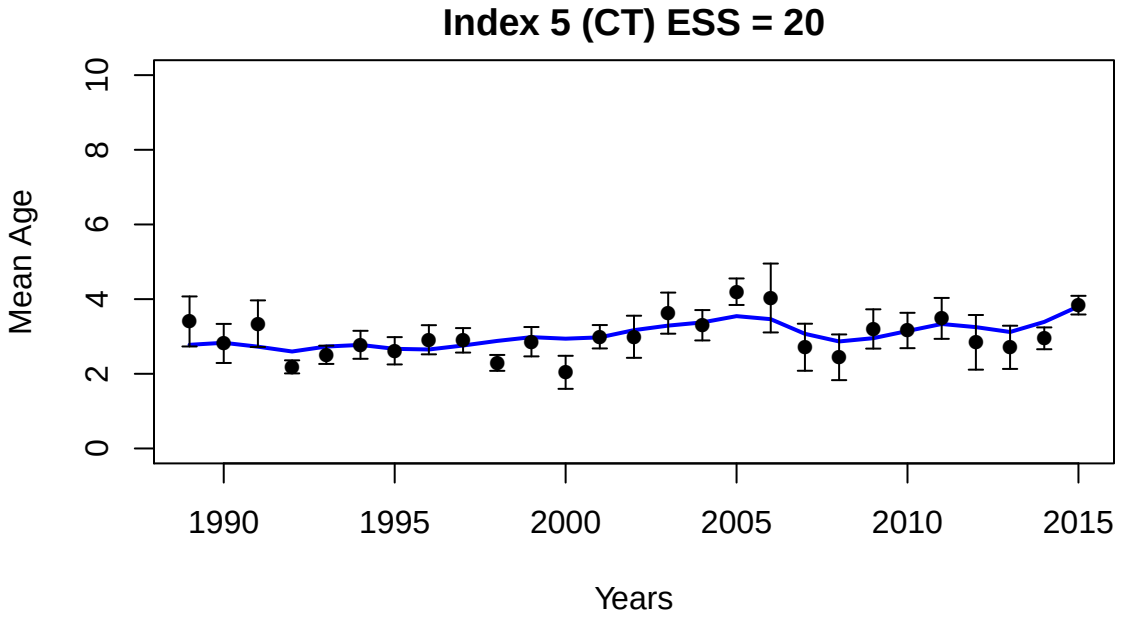

SDNR=1.69
RMSE=1.66
Std Resids
−2
0
2
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

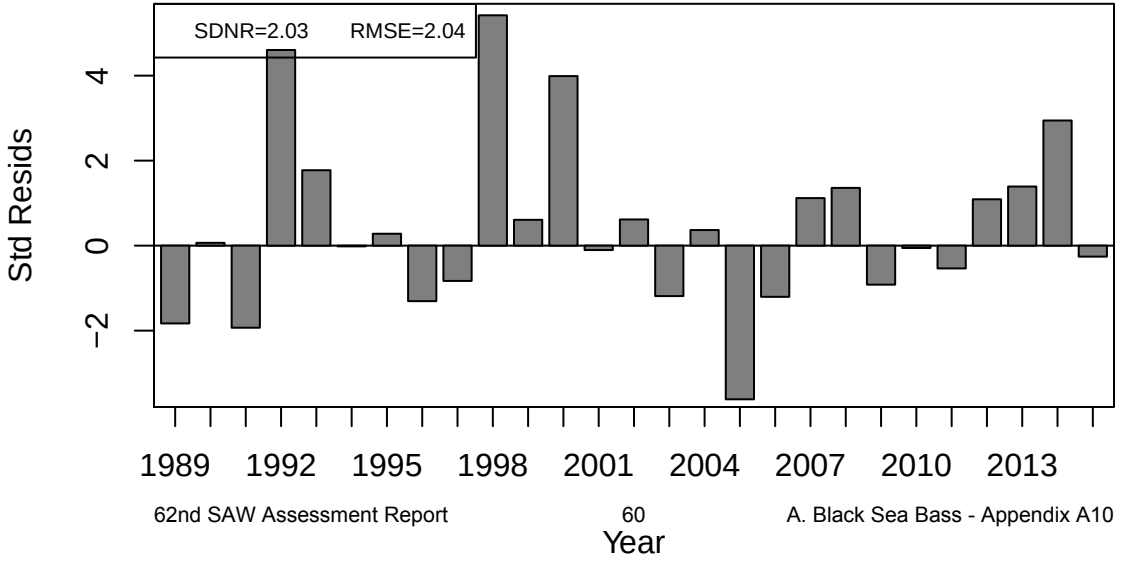

Index 3 (MADMF) ESS = 20
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
4
2
0
−2
−2
−1
0
1
2

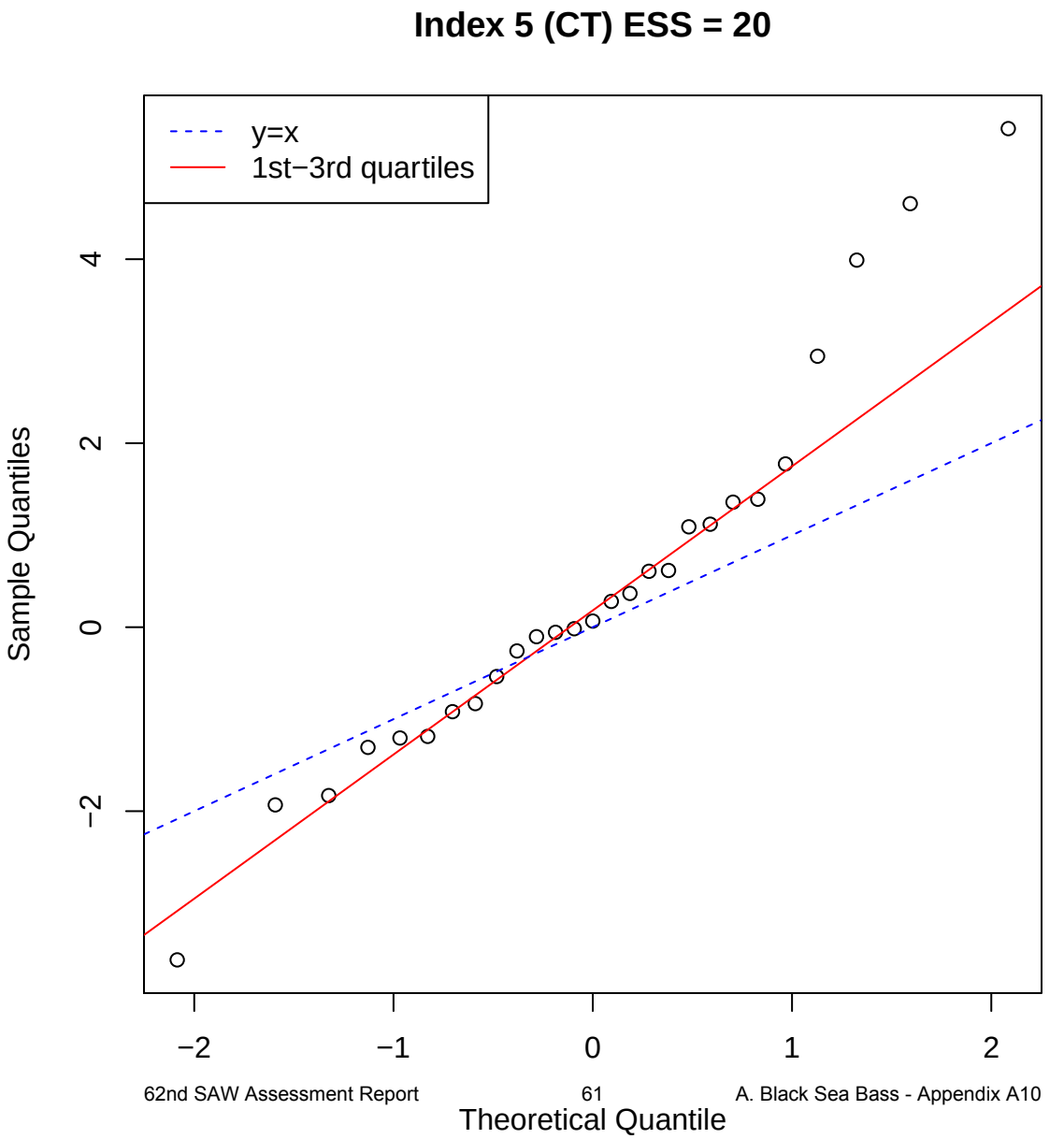

Index 4 (RI) ESS = 5
Mean Age
0
2
4
6
8
10
1995
2000
2005
2010
2015
Years

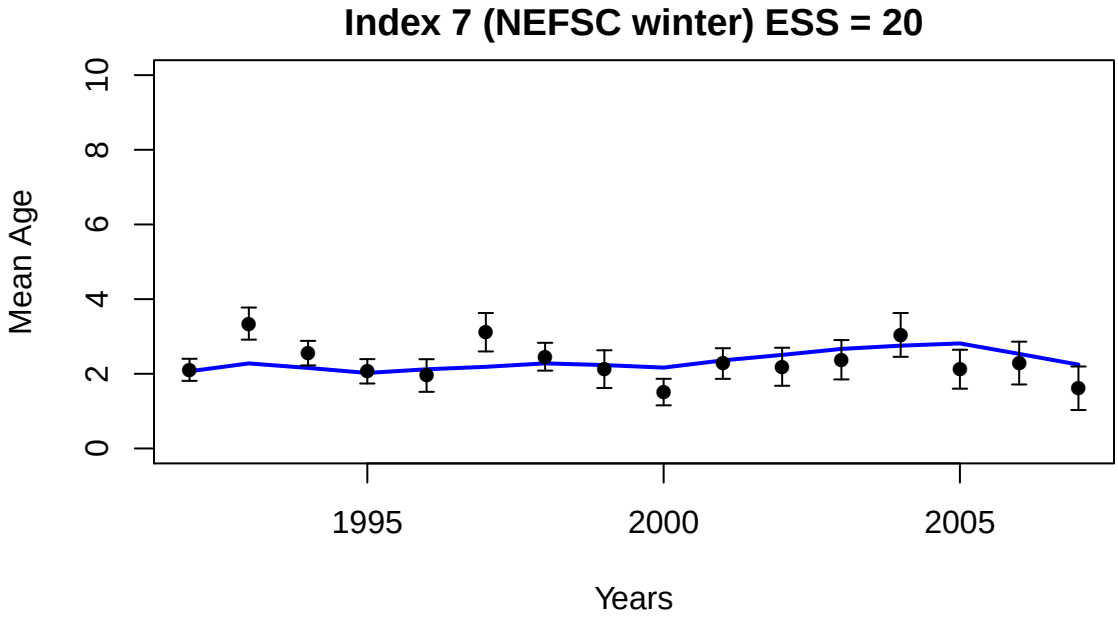

SDNR=2.3
RMSE=2.26
Std Resids
−2
0
2
4
6
1991
1997
2001
2005
2008
2011
2014
Year

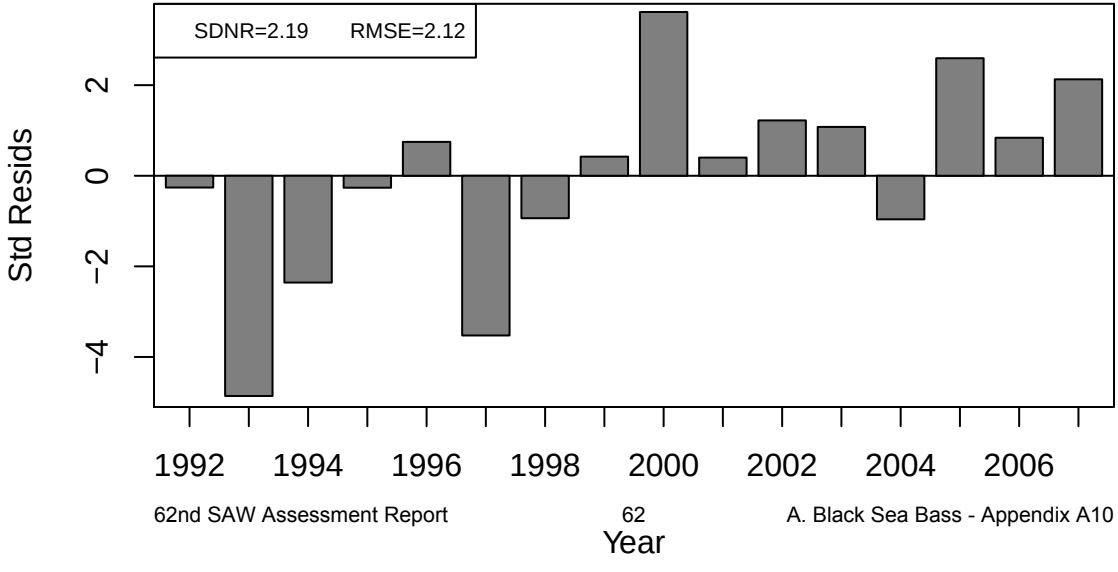

Index 4 (RI) ESS = 5
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
0
2
4
6
−2
−1
0
1
2

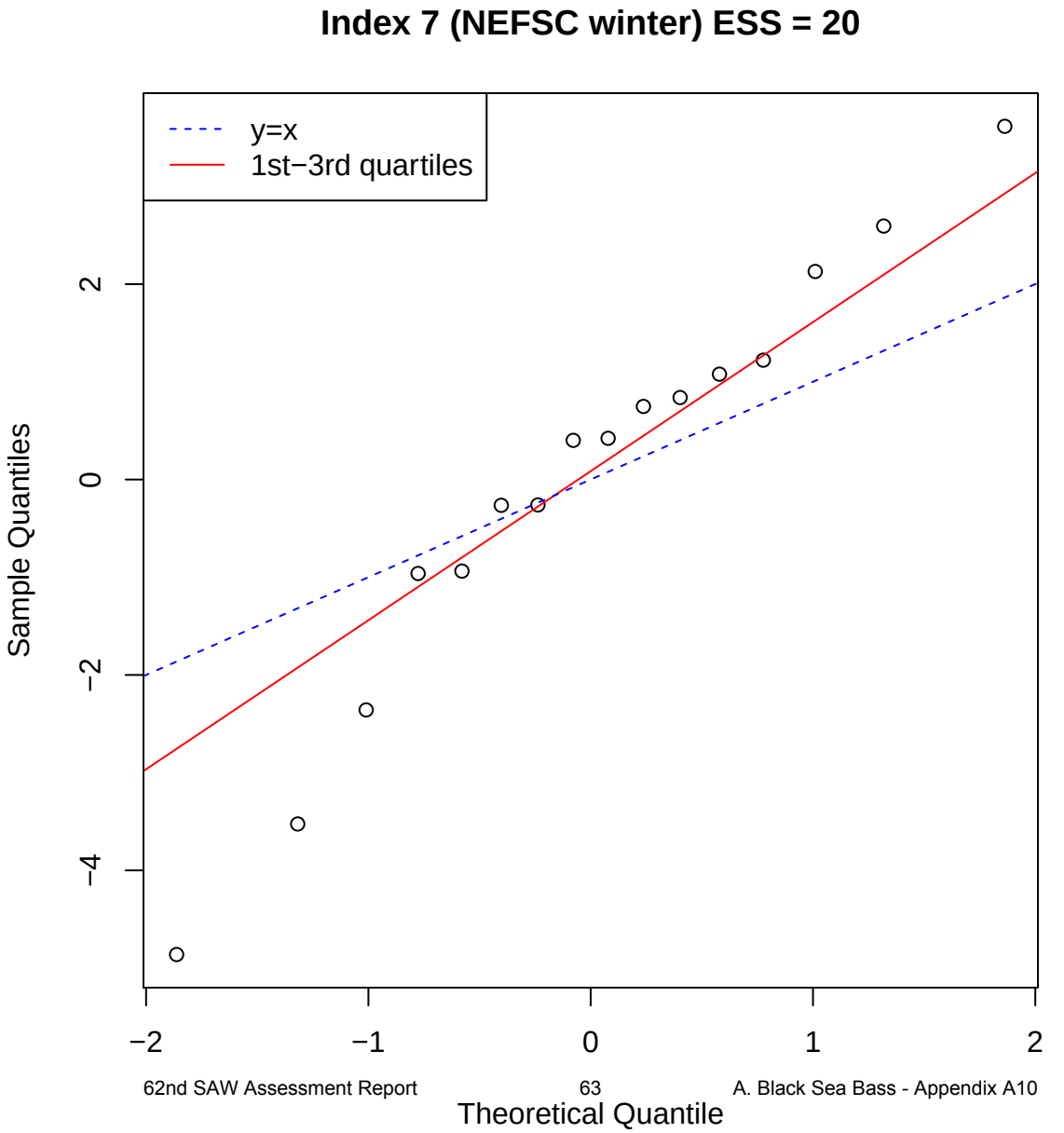

Index 5 (CT) ESS = 20
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

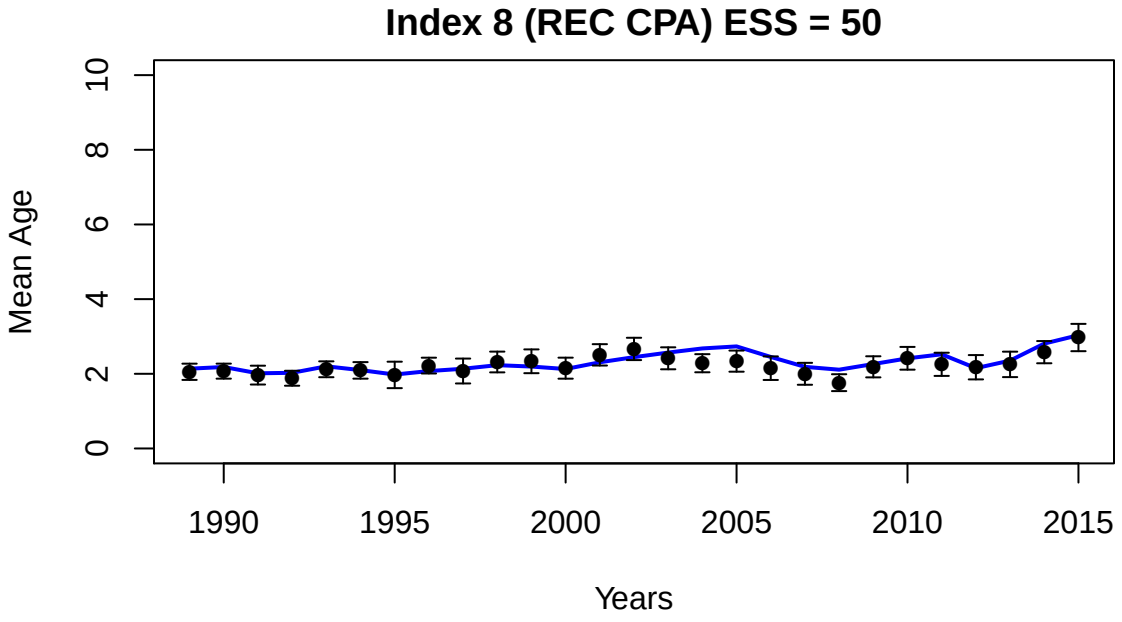

SDNR=2.03
RMSE=2.04
Std Resids
−2
0
2
4
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

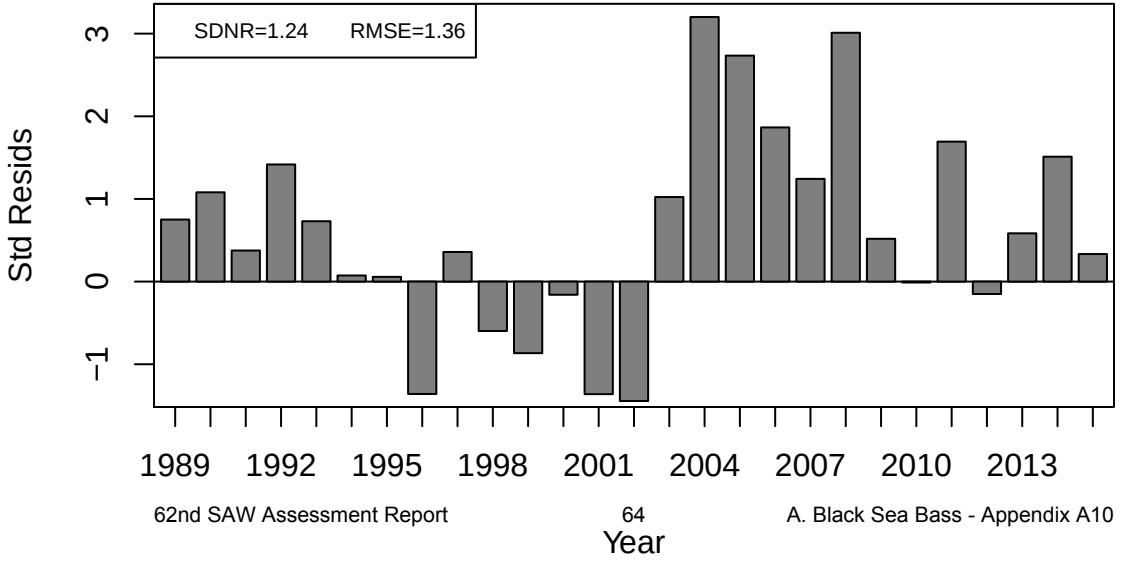

Index 5 (CT) ESS = 20
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
0
2
4
−2
−1
0
1
2

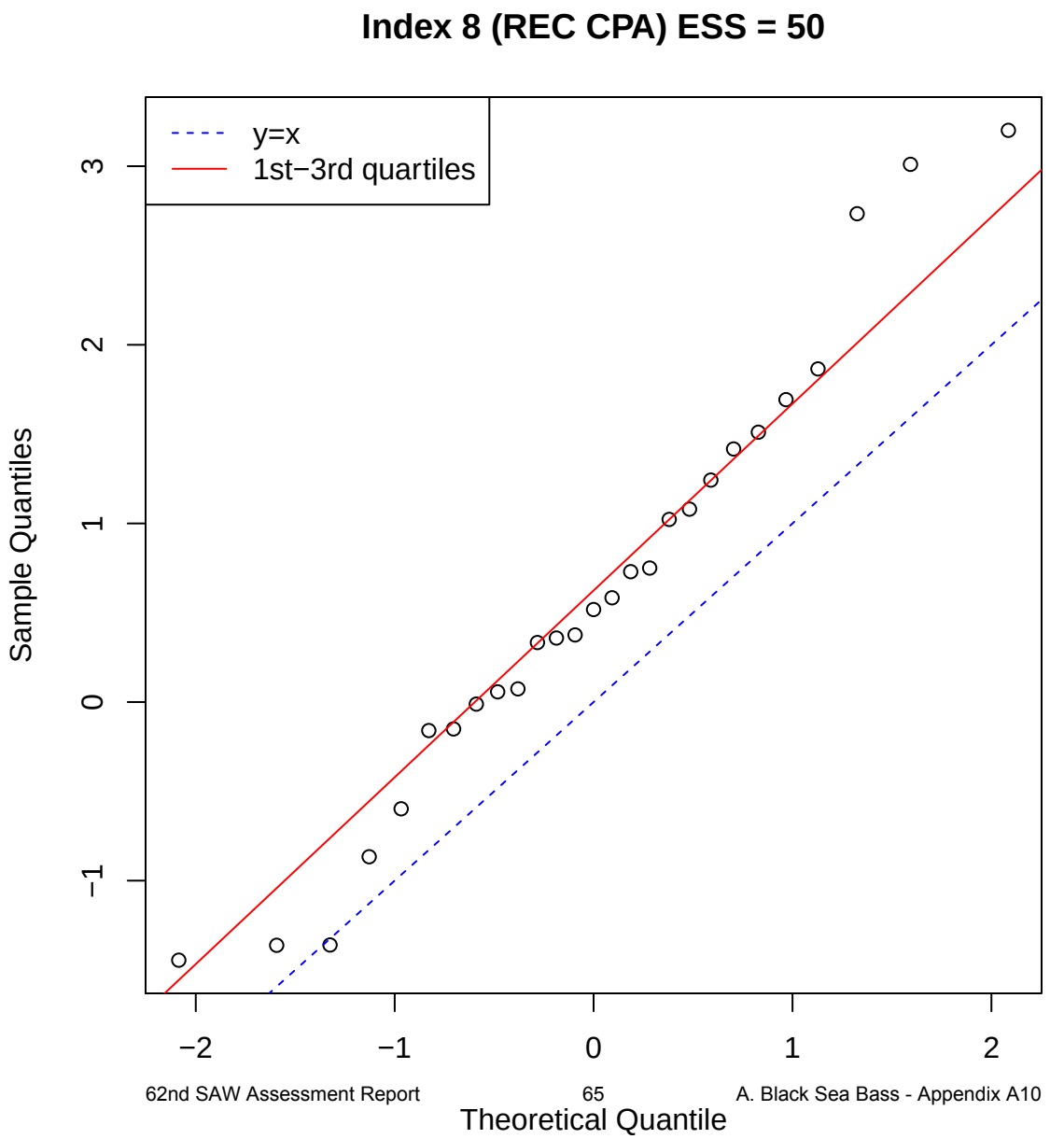

Index 7 (NEFSC winter) ESS = 20
Mean Age
0
2
4
6
8
10
1995
2000
2005
Years

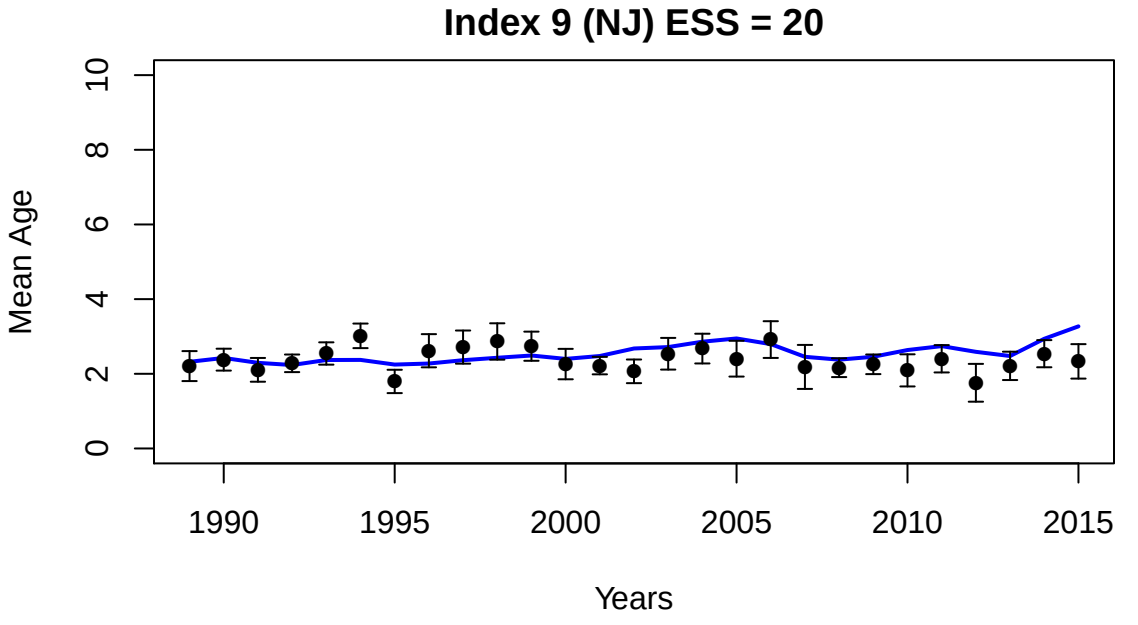

SDNR=2.19
RMSE=2.12
Std Resids
−4
−2
0
2
1992
1994
1996
1998
2000
2002
2004
2006
Year

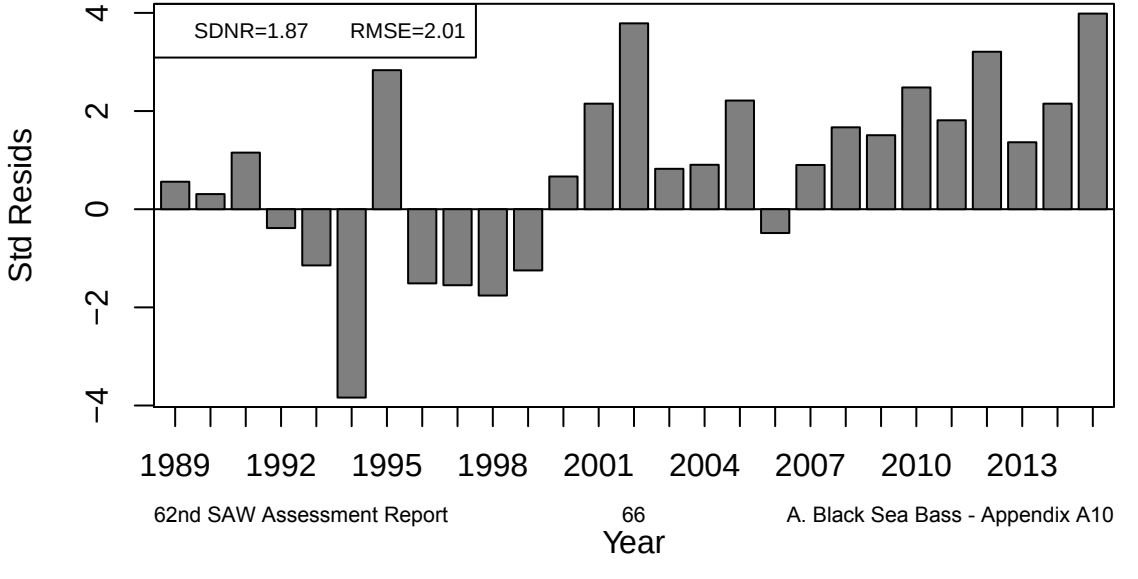

Index 7 (NEFSC winter) ESS = 20
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
2
0
−2
−4
−2
−1
0
1
2

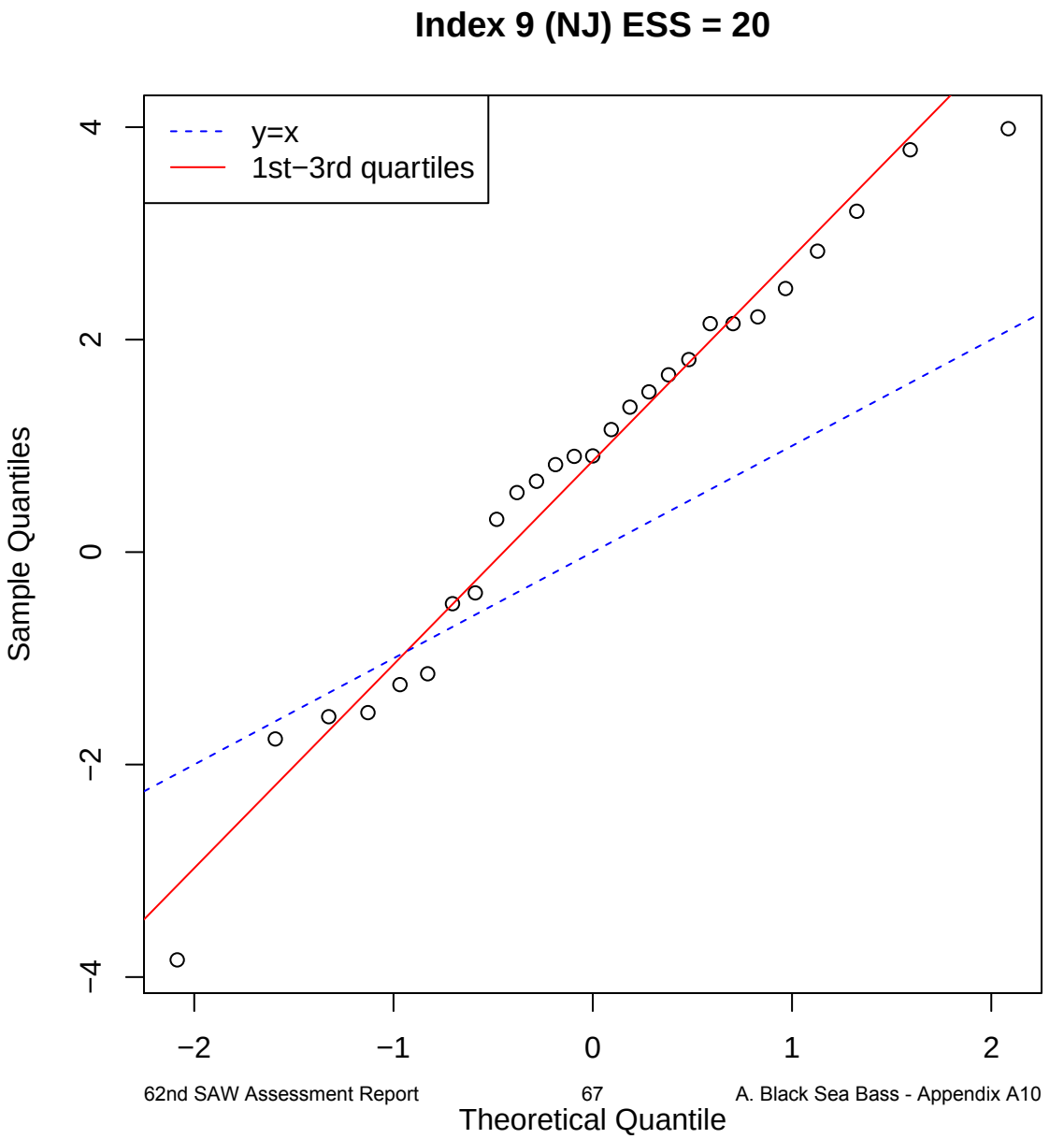

Index 8 (REC CPA) ESS = 50
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

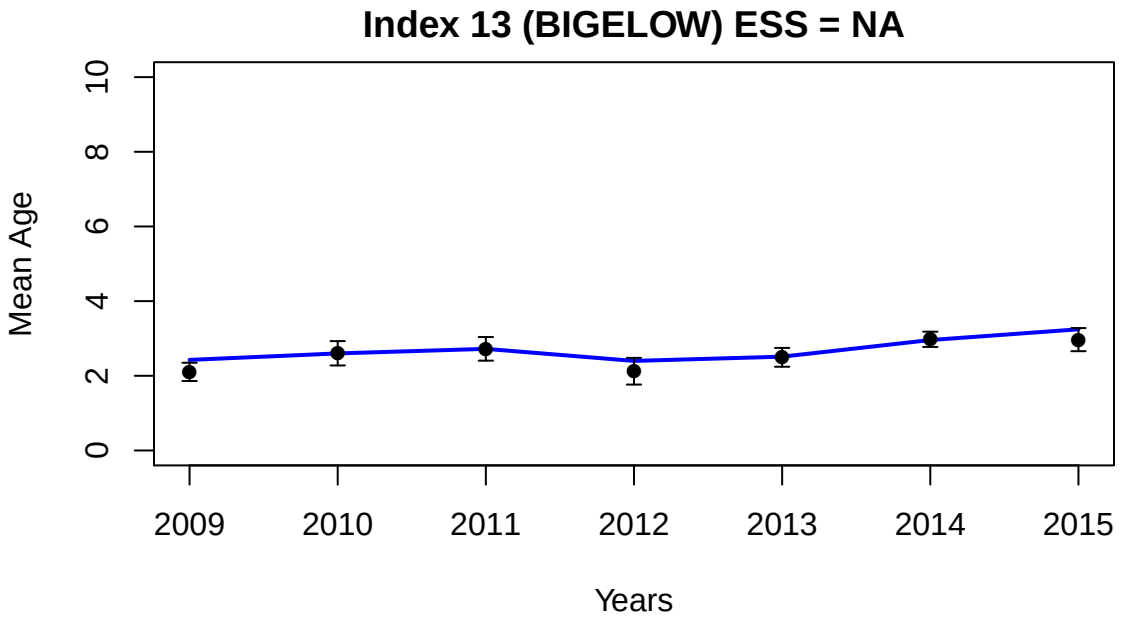

SDNR=1.24
RMSE=1.36
Std Resids
−1
0
1
2
3
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

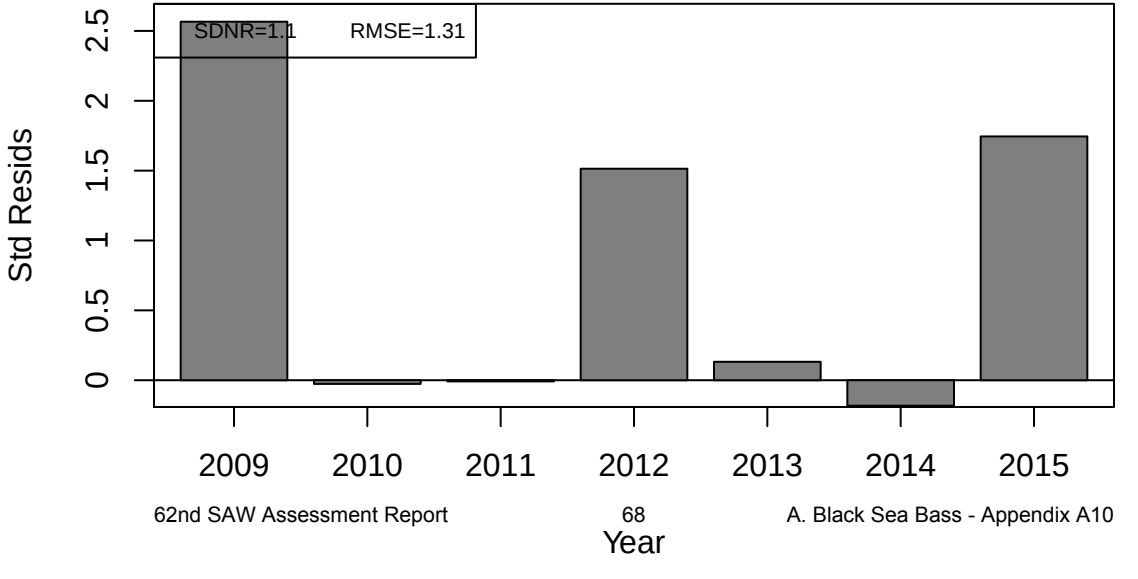

Index 8 (REC CPA) ESS = 50
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
−1
0
1
2
3

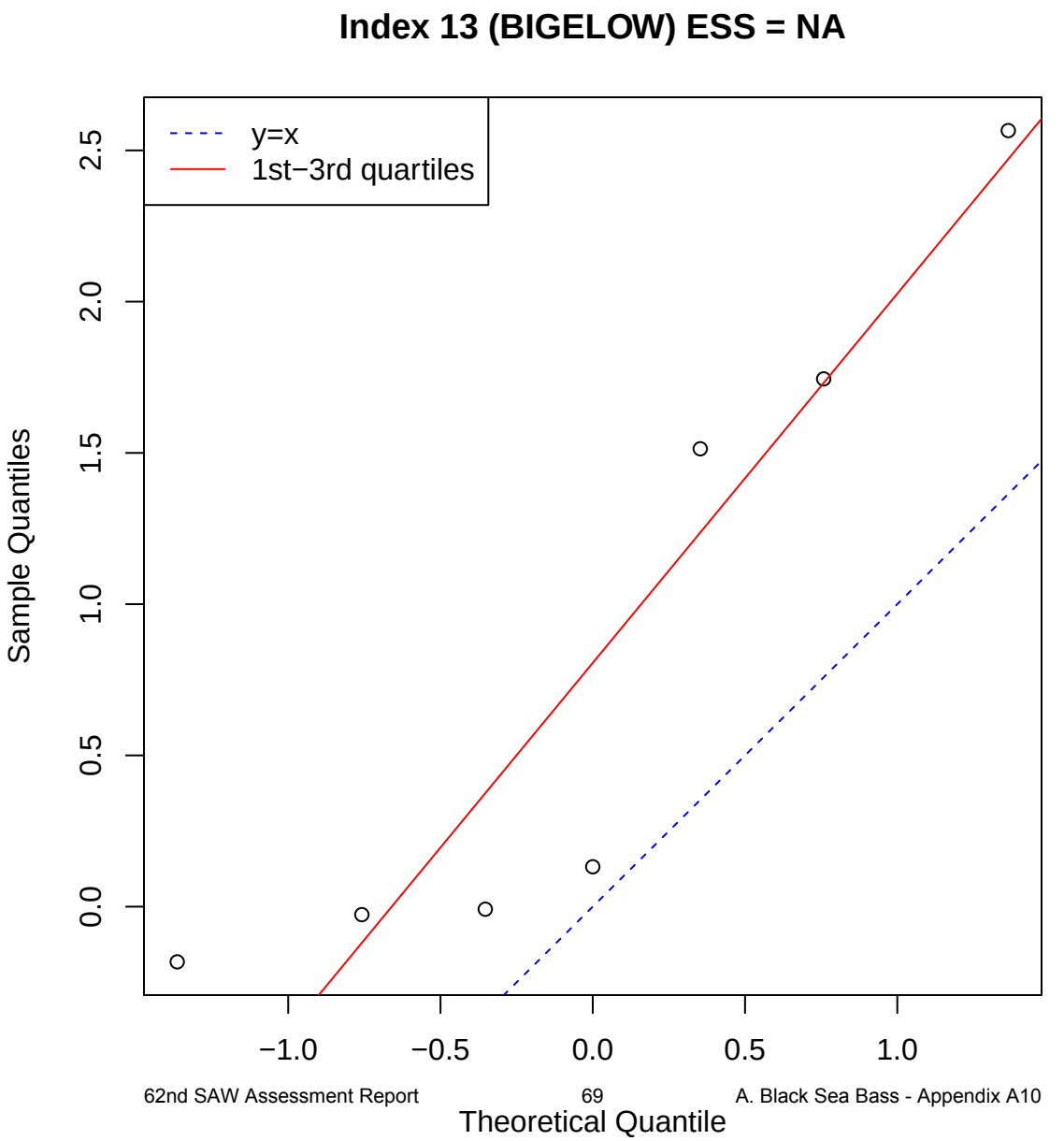

Index 9 (NJ) ESS = 20
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

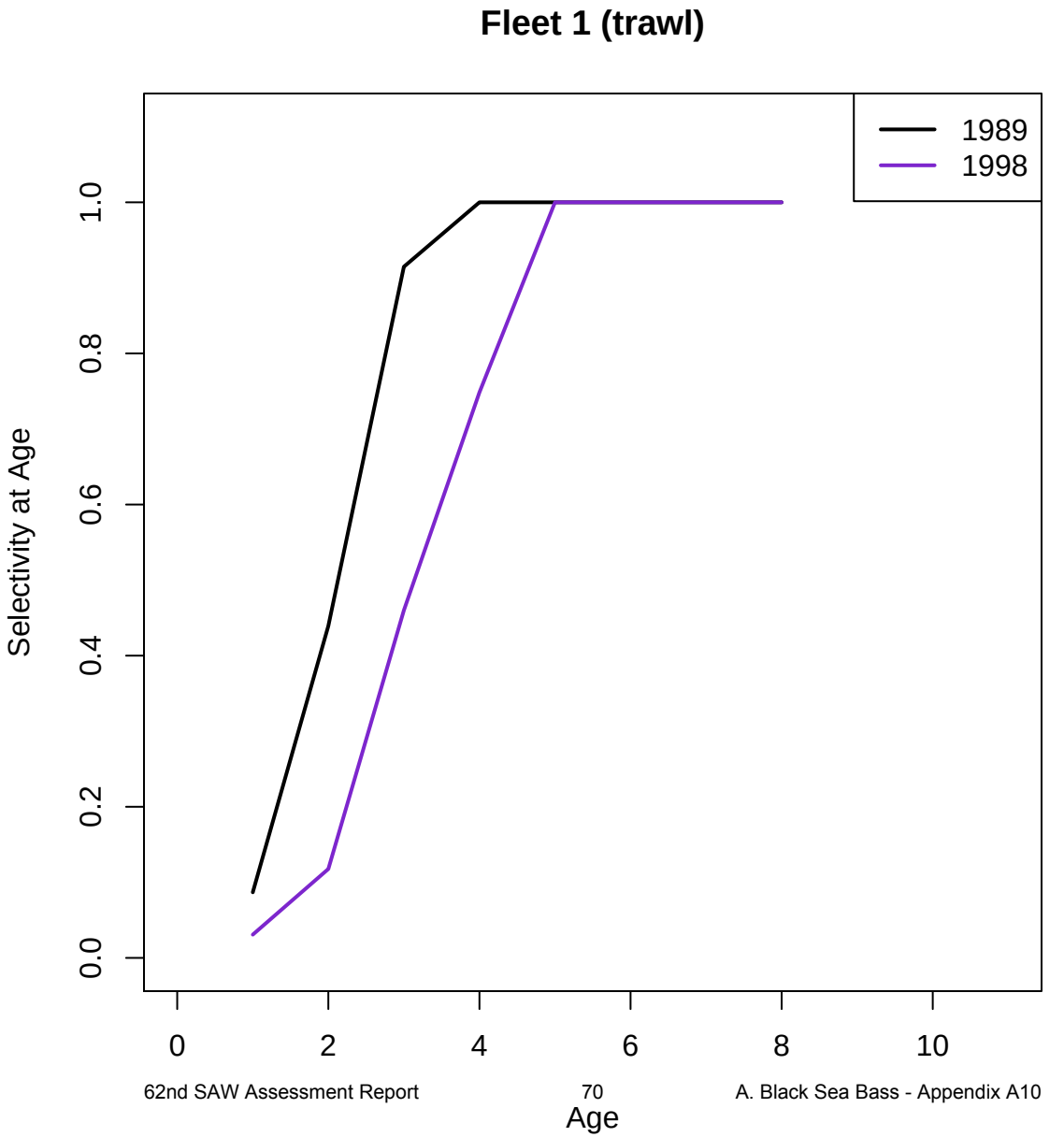

SDNR=1.87
RMSE=2.01
Std Resids
−4
−2
0
2
4
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

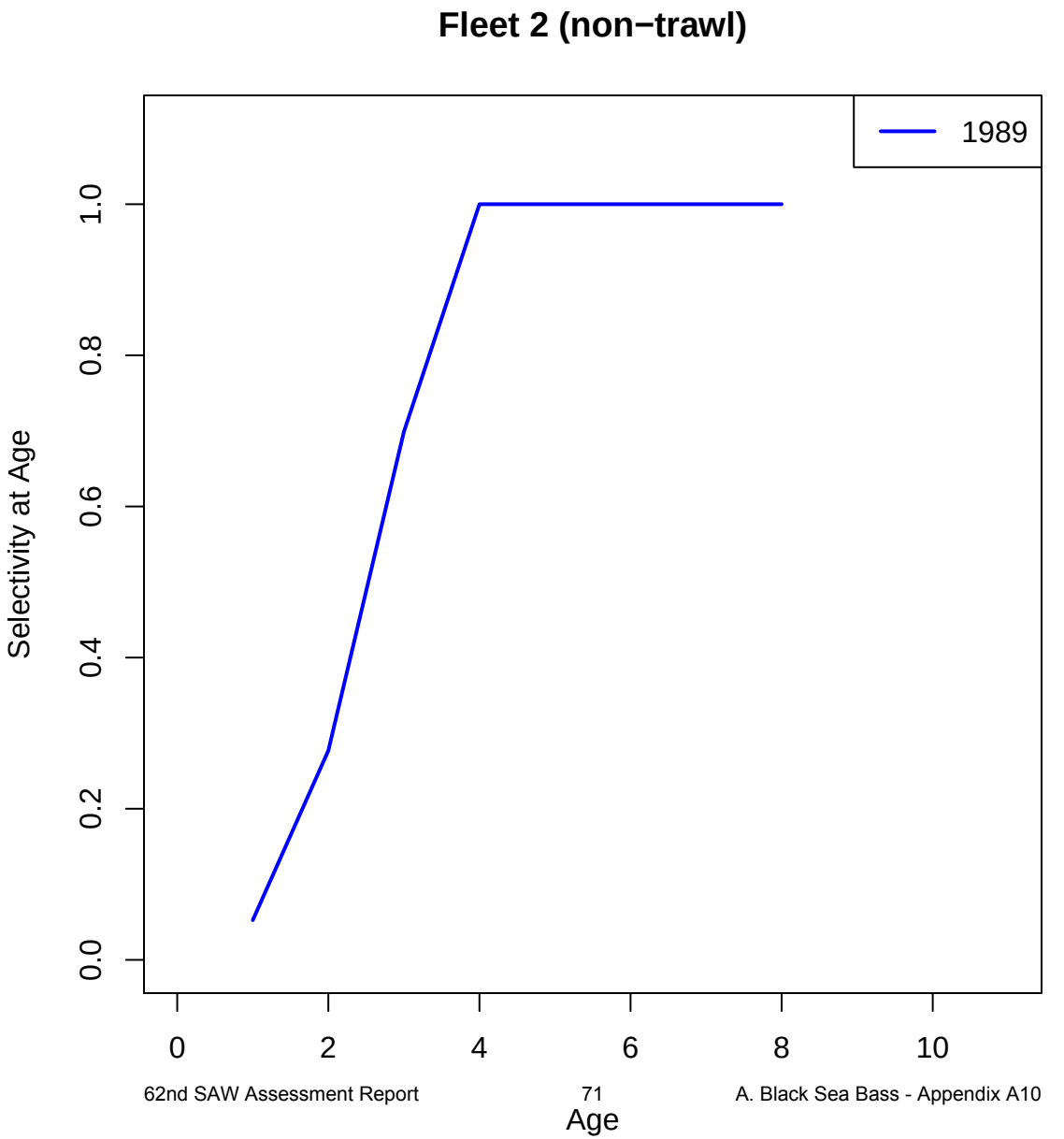

Index 9 (NJ) ESS = 20
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
4
2
0
−2
−4
−2
−1
0
1
2

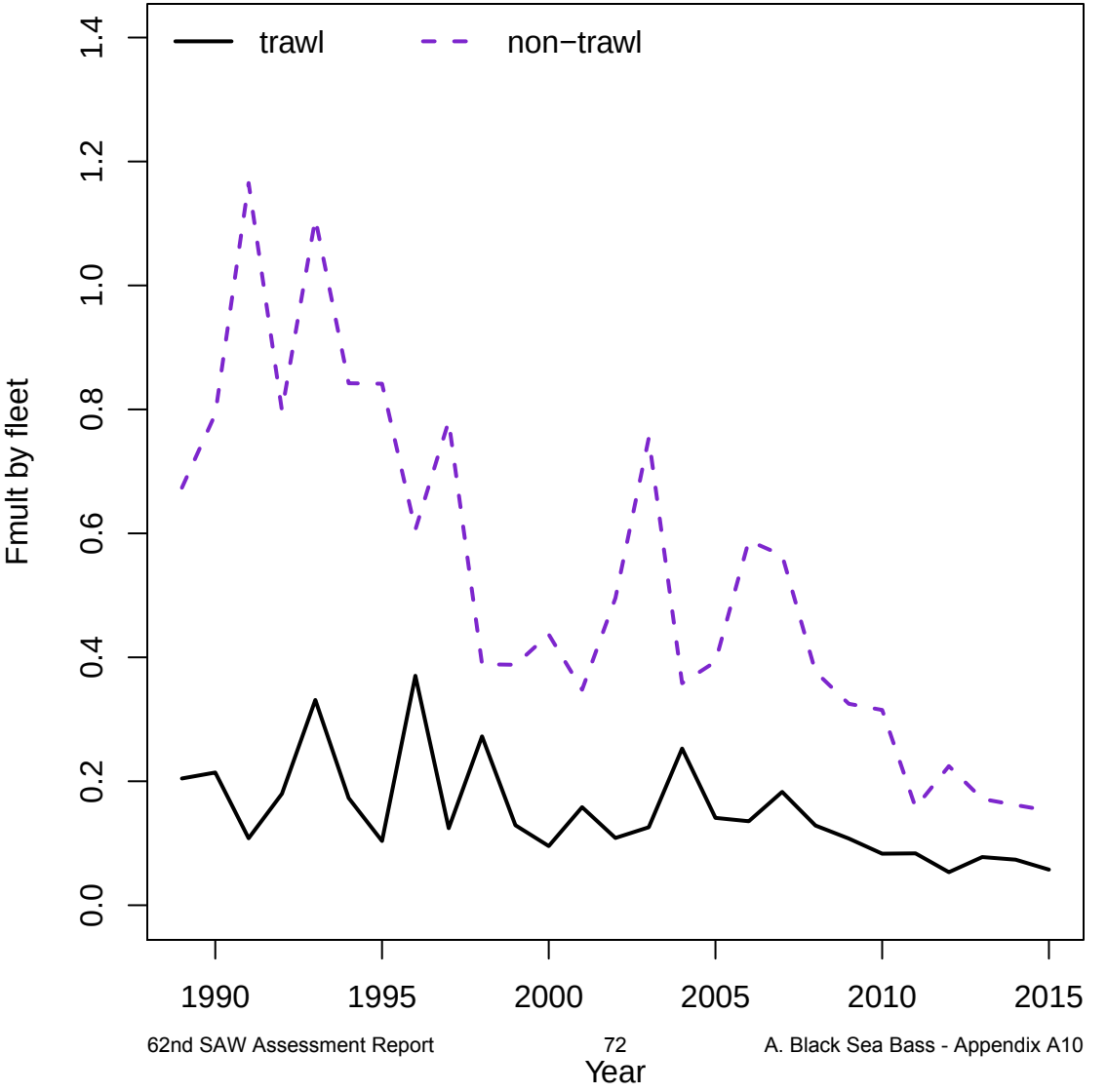

Index 13 (BIGELOW) ESS = NA
Mean Age
0
2
4
6
8
10
2009
2010
2011
2012
2013
2014
2015
Years

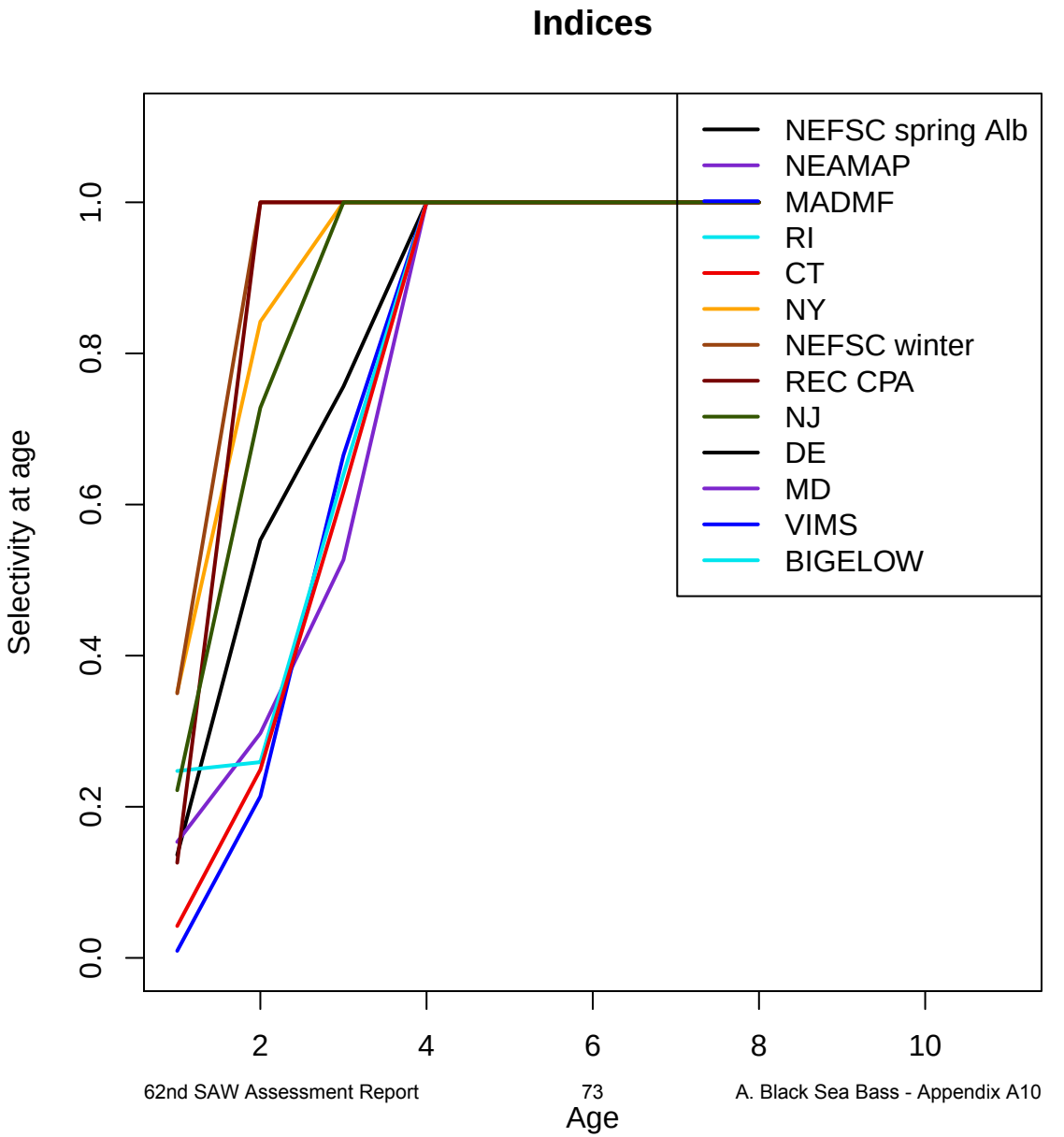

SDNR=1.1
RMSE=1.31
Std Resids
0
0.5
1
1.5
2
2.5
2009
2010
2011
2012
2013
2014
2015
Year

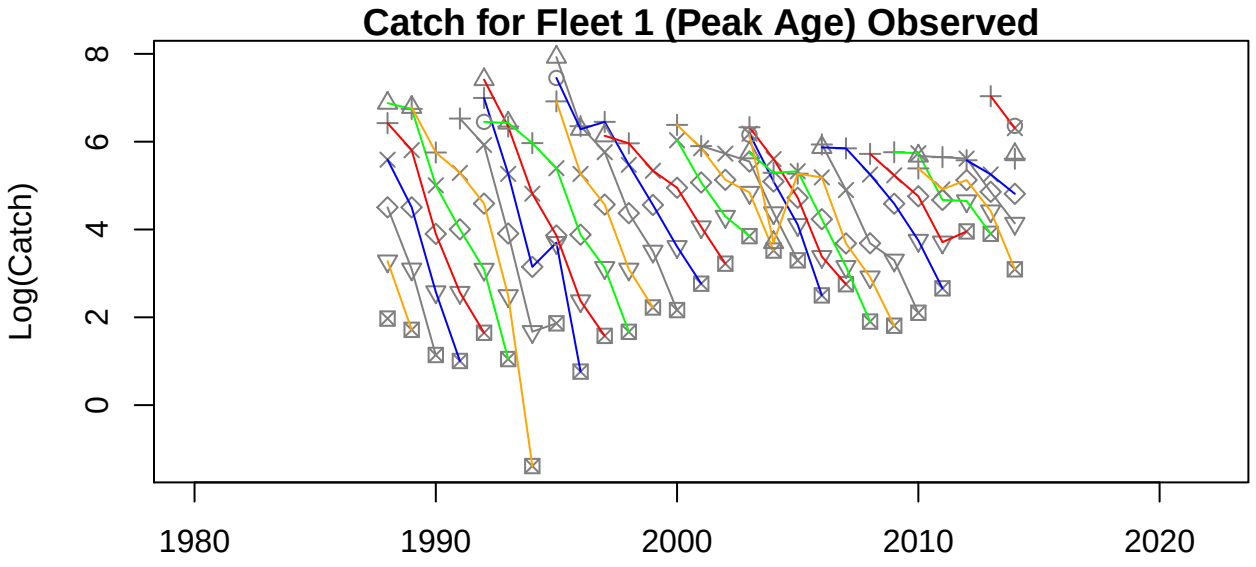

Index 13 (BIGELOW) ESS = NA
y=x
1st−3rd quartiles
Sample Quantiles
0.0
0.5
1.0
1.5
2.0
2.5
−1.0
−0.5
0.0
0.5
1.0
Theoretical Quantile

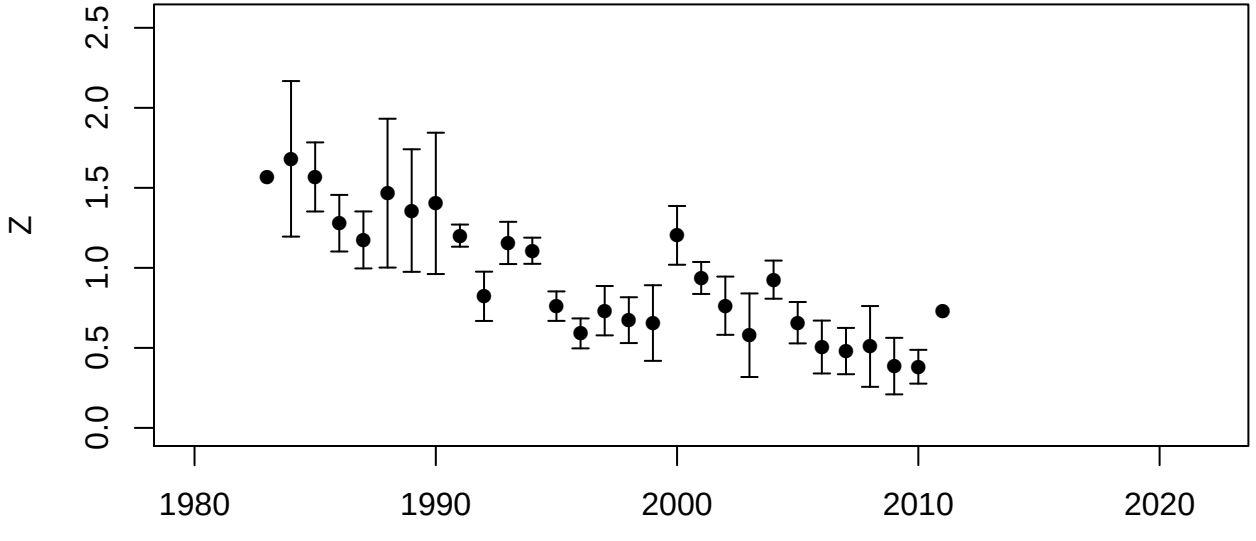

Fleet 1 (trawl)
1989
1998
Selectivity at Age
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
Age

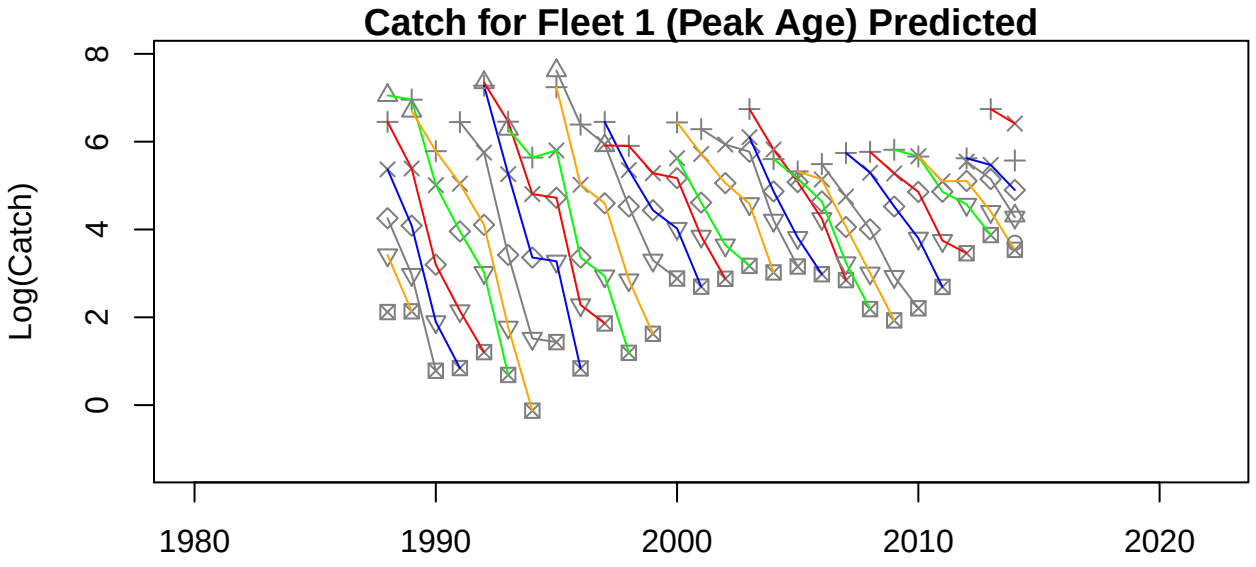

Fleet 2 (non−trawl)
1989
Selectivity at Age
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
Age

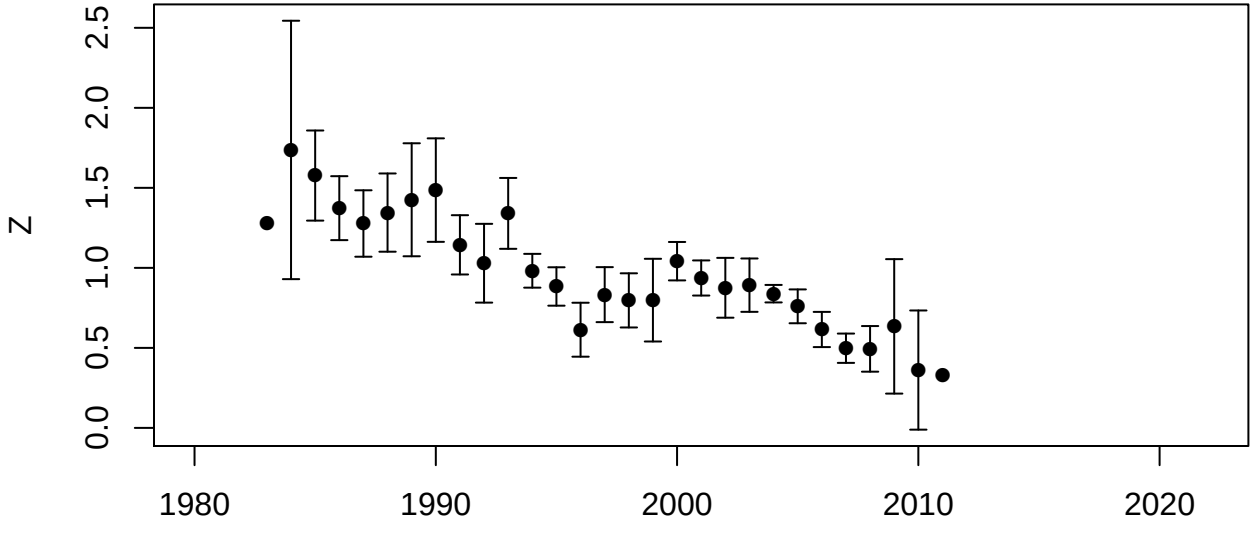

trawl
non−trawl
Fmult by fleet
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1990
1995
2000
2005
2010
2015
Year

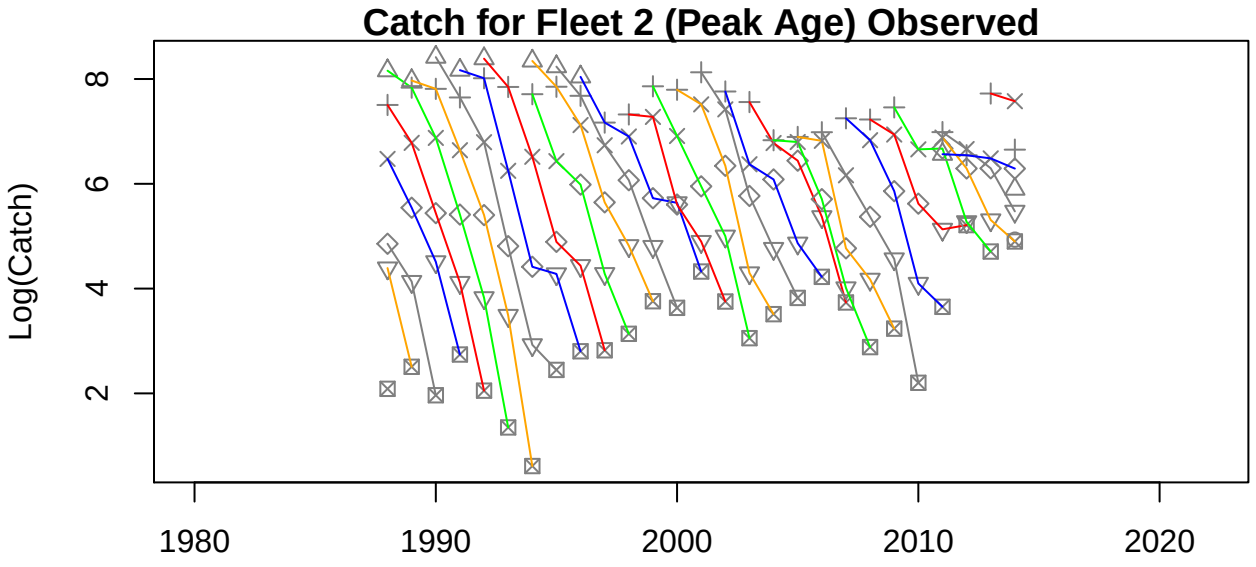

Indices
NEFSC spring Alb
NEAMAP
MADMF
RI
CT
NY
NEFSC winter
REC CPA
NJ
DE
MD
VIMS
BIGELOW
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
10
Age

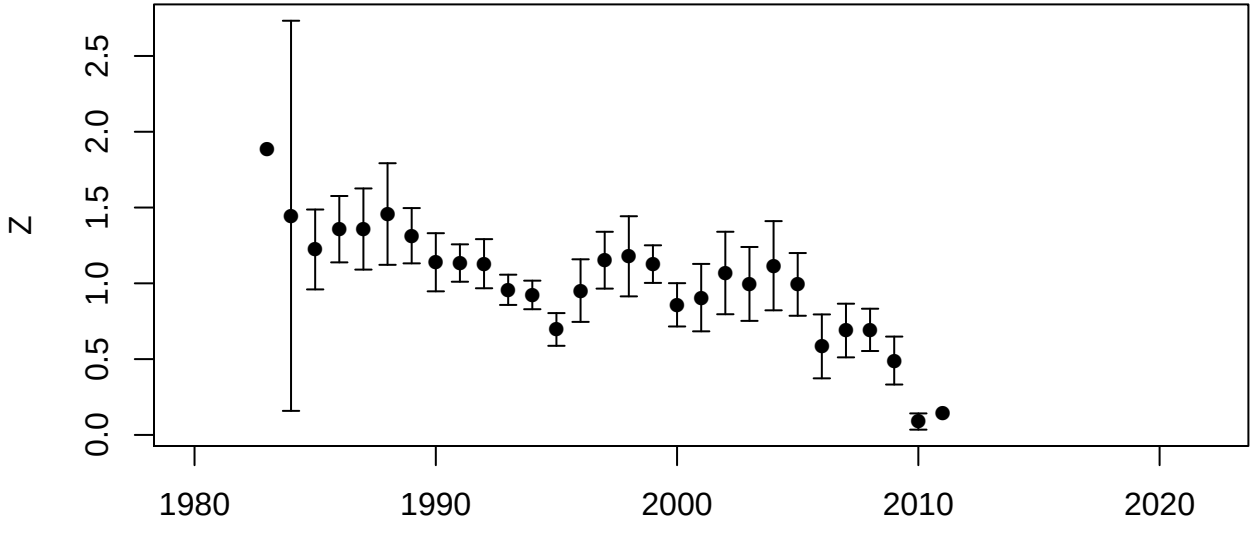

Catch for Fleet 1 (Peak Age) Observed
Log(Catch)
0
2
4
6
8
1980
1990
2000
2010
2020

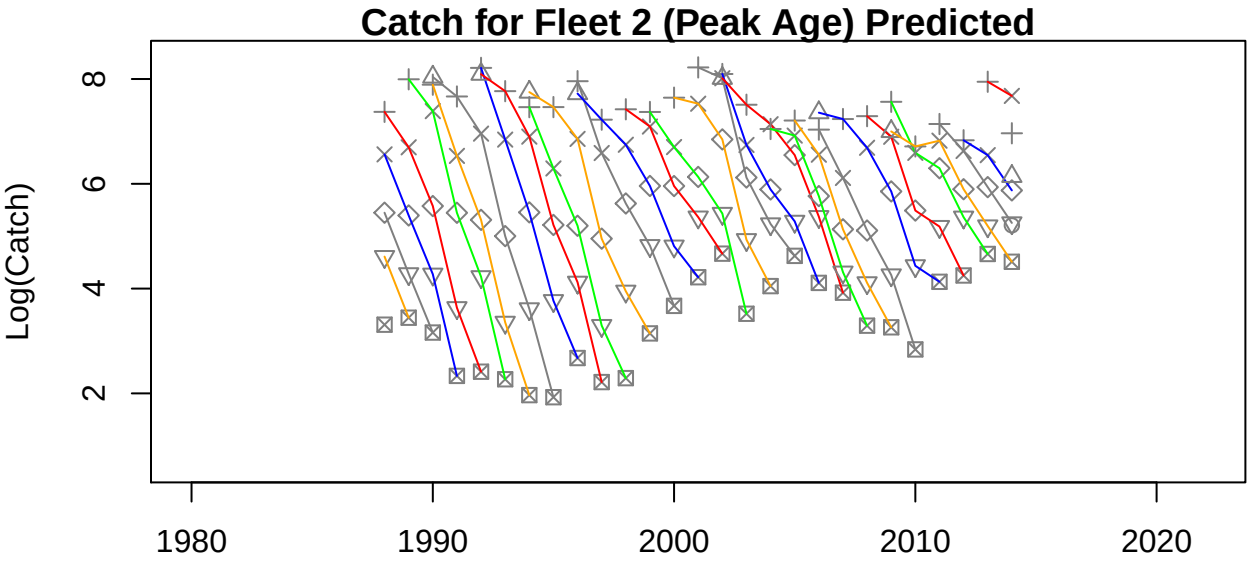

Z
0.0
0.5
1.0
1.5
2.0
2.5
1980
1990
2000
2010
2020
Year Class

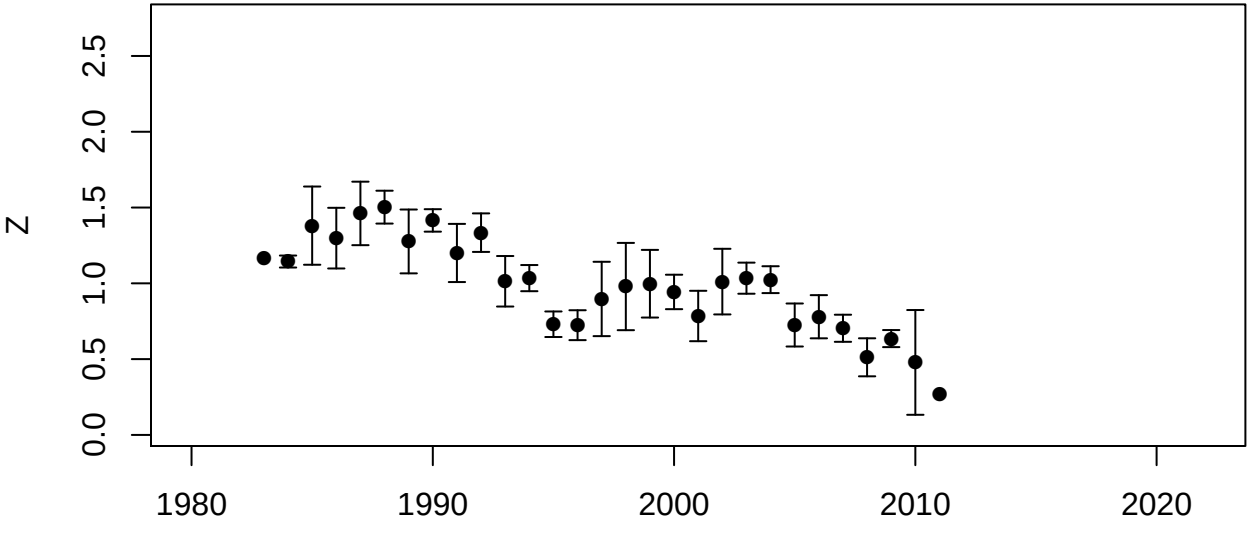

Catch for Fleet 1 (Peak Age) Predicted
Log(Catch)
0
2
4
6
8
1980
1990
2000
2010
2020

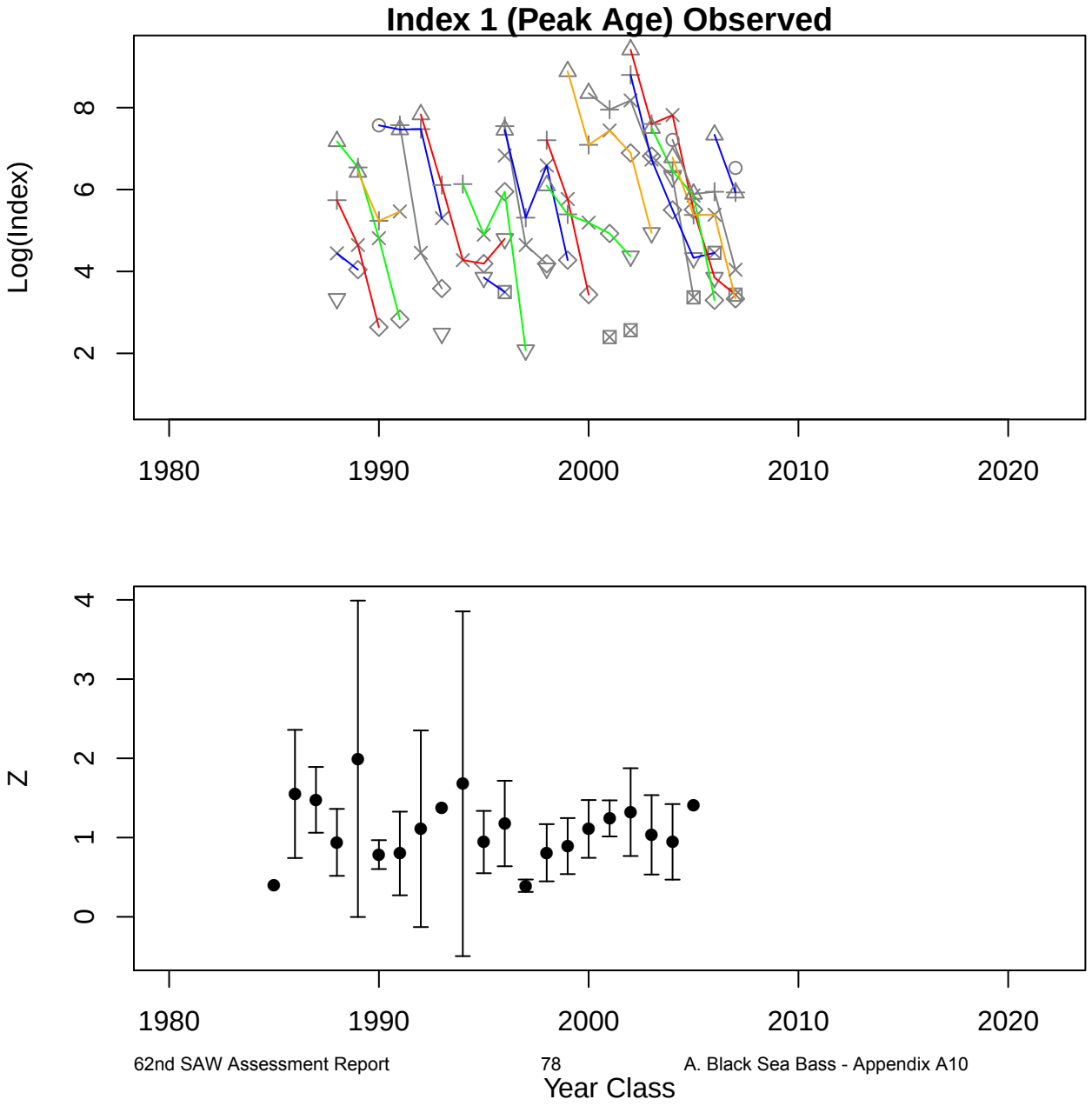

Z
0.0
0.5
1.0
1.5
2.0
2.5
1980
1990
2000
2010
2020
Year Class

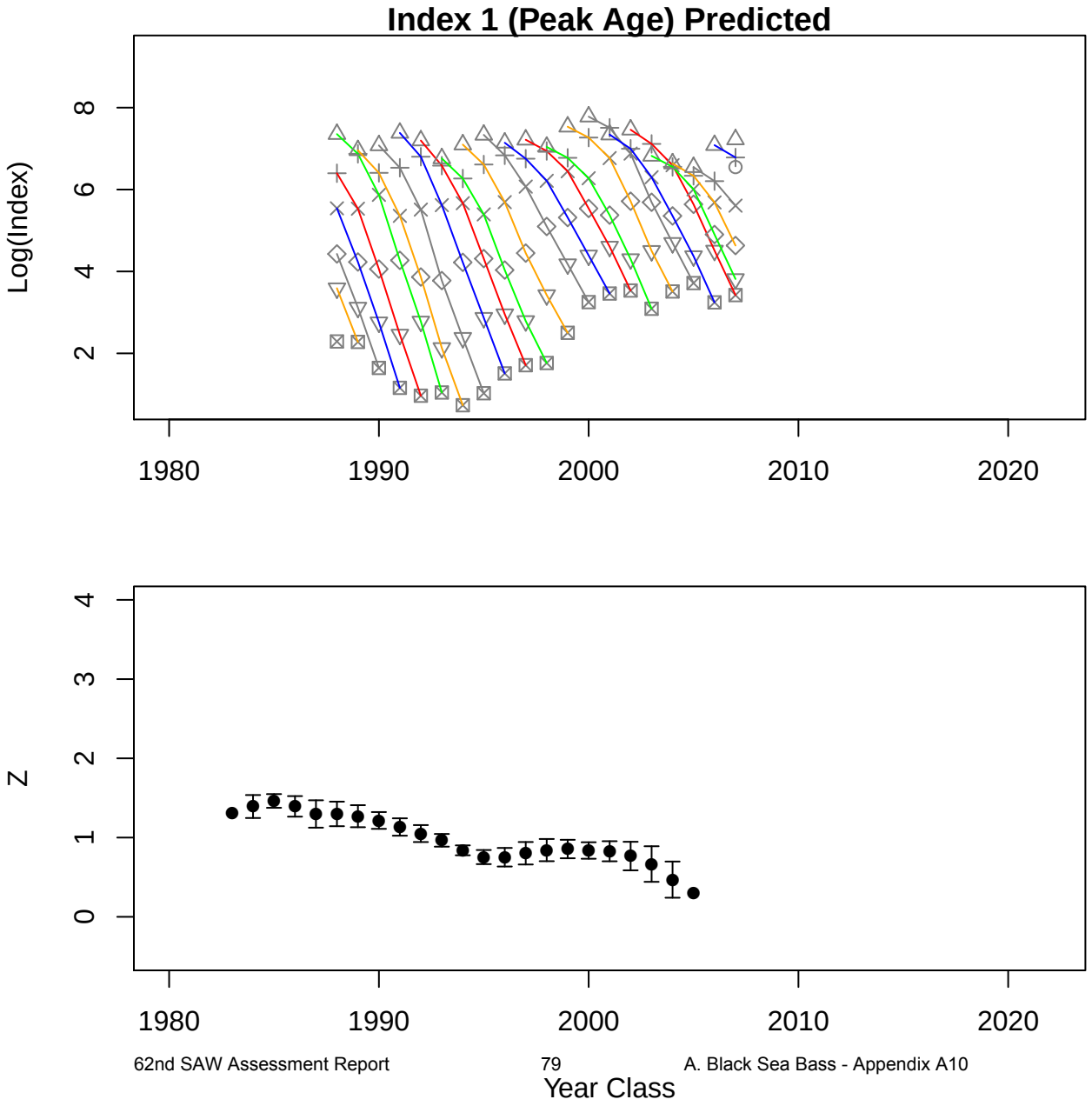

Catch for Fleet 2 (Peak Age) Observed
Log(Catch)
2
4
6
8
1980
1990
2000
2010
2020

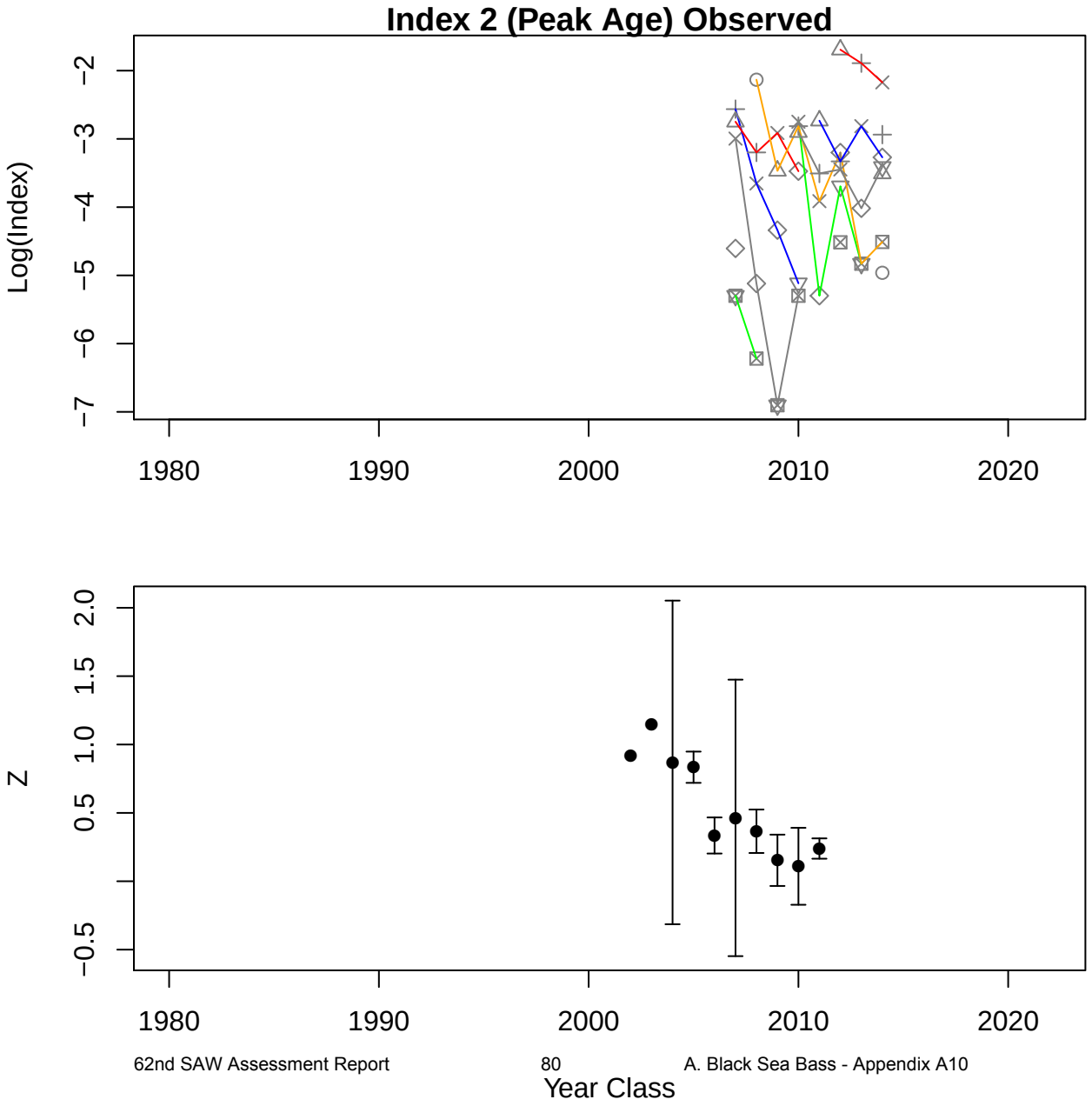

Z
0.0
0.5
1.0
1.5
2.0
2.5
1980
1990
2000
2010
2020
Year Class

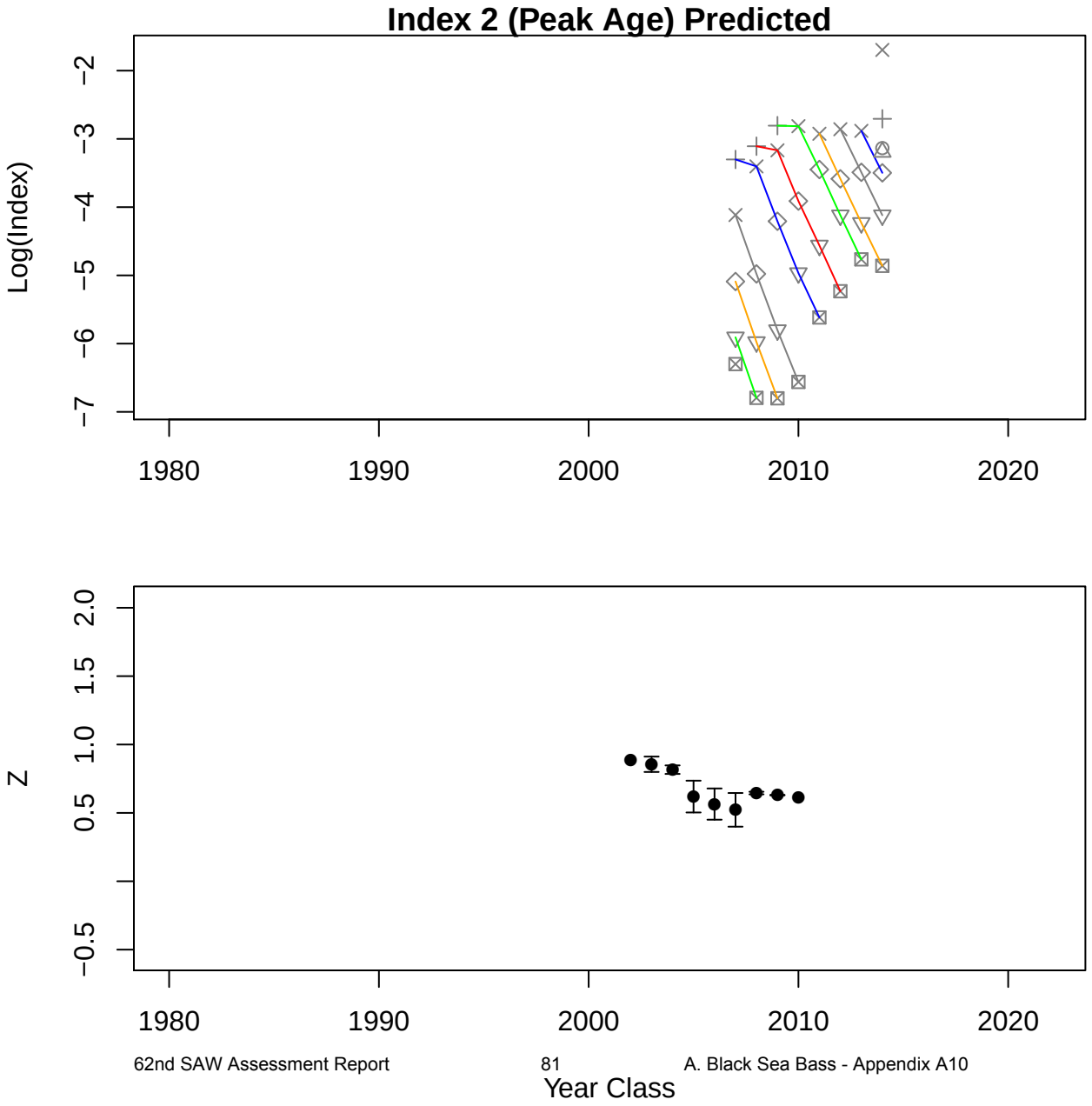

Catch for Fleet 2 (Peak Age) Predicted
Log(Catch)
2
4
6
8
1980
1990
2000
2010
2020

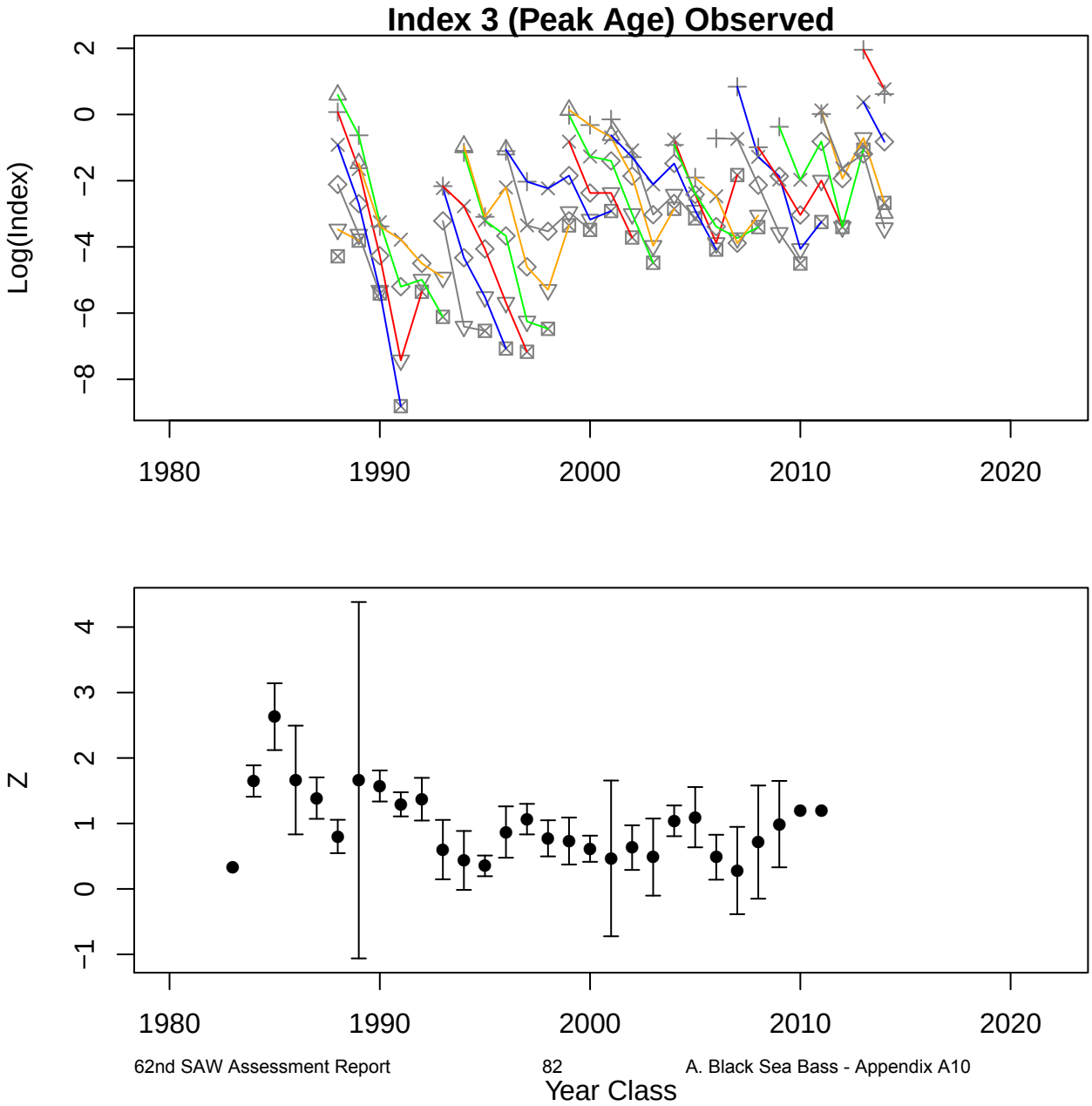

Z
0.0
0.5
1.0
1.5
2.0
2.5
1980
1990
2000
2010
2020
Year Class

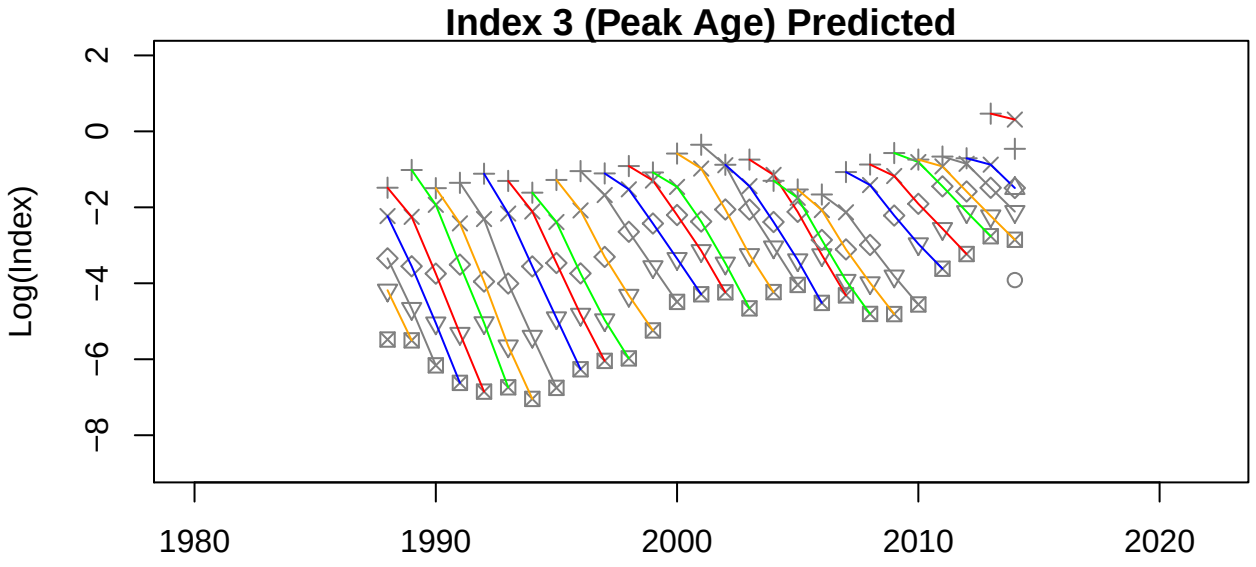

Index 1 (Peak Age) Observed
Log(Index)
2
4
6
8
1980
1990
2000
2010
2020
Z
0
1
2
3
4
1980
1990
2000
2010
2020
Year Class

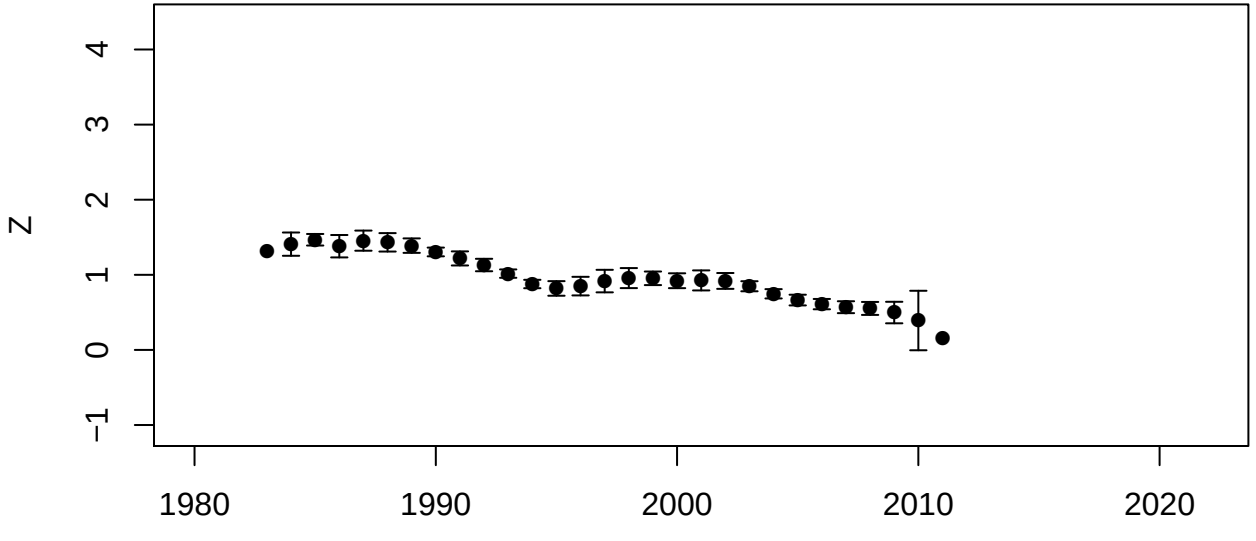

Index 1 (Peak Age) Predicted
Log(Index)
2
4
6
8
1980
1990
2000
2010
2020
Z
0
1
2
3
4
1980
1990
2000
2010
2020
Year Class

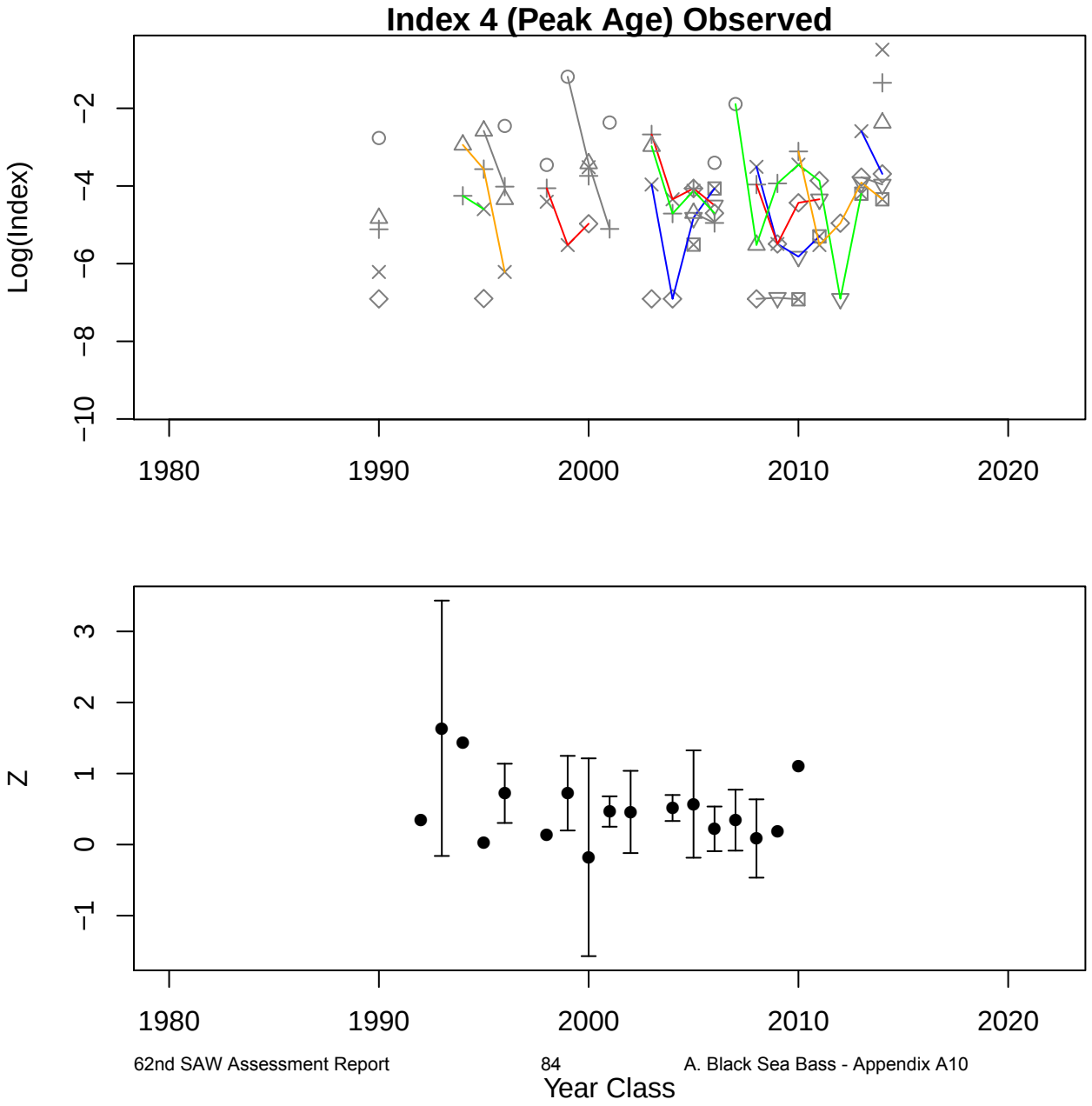

Index 2 (Peak Age) Observed
Log(Index)
−2
−3
−4
−5
−6
−7
1980
1990
2000
2010
2020
Z
2.0
1.5
1.0
0.5
−0.5
1980
1990
2000
2010
2020
Year Class

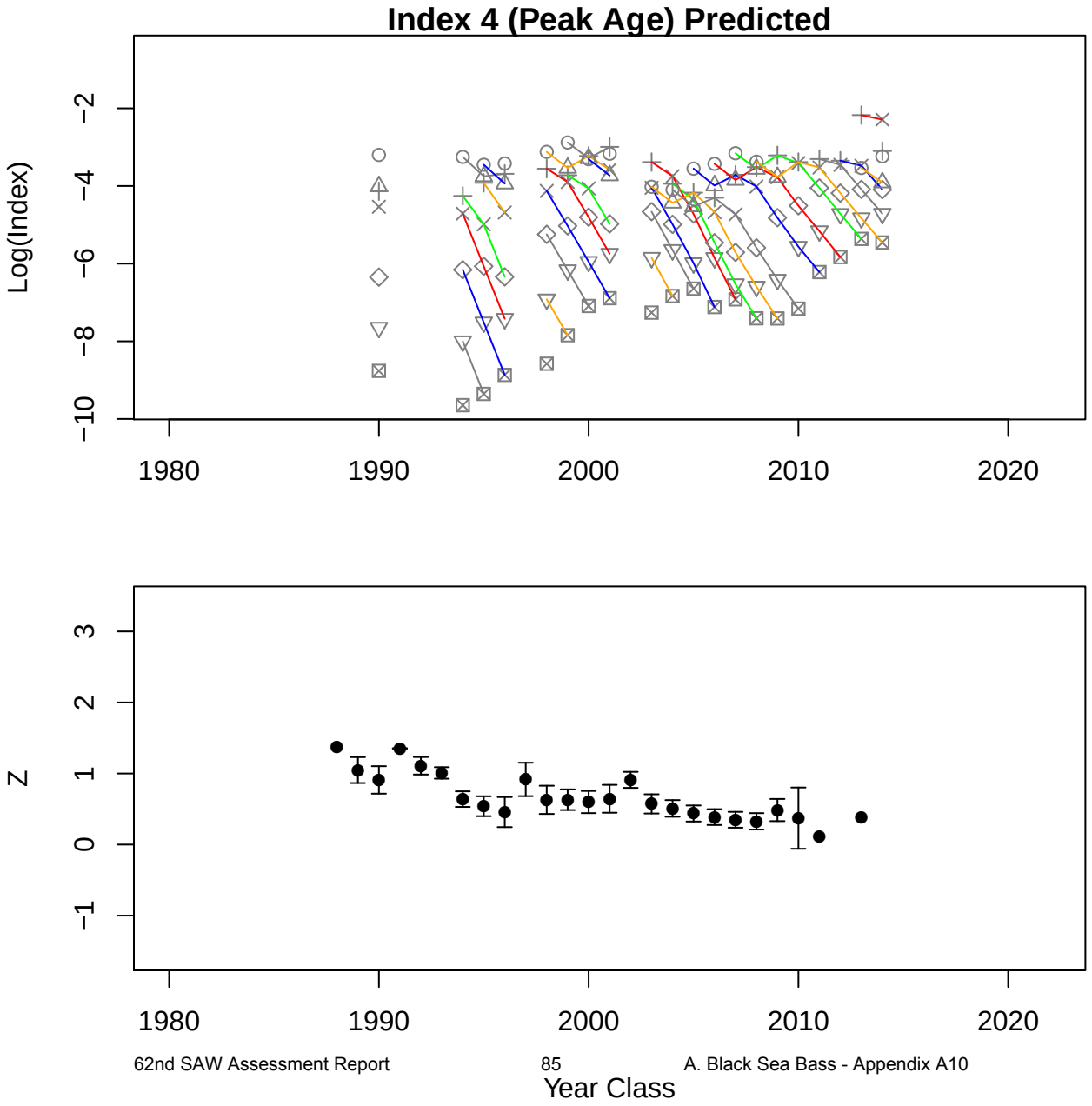

Index 2 (Peak Age) Predicted
Log(Index)
−2
−3
−4
−5
−6
−7
1980
1990
2000
2010
2020
Z
2.0
1.5
1.0
0.5
−0.5
1980
1990
2000
2010
2020
Year Class

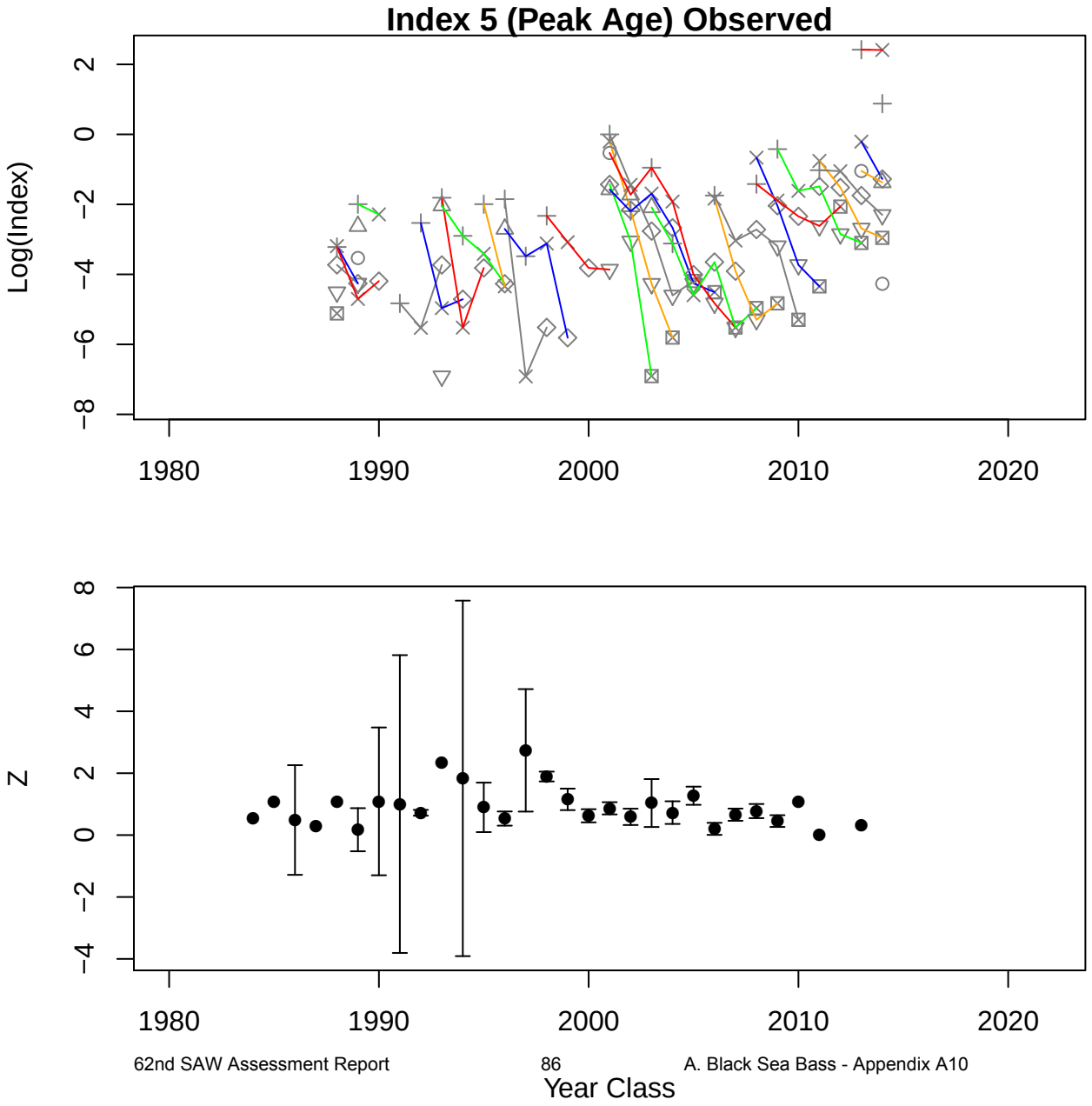

Index 3 (Peak Age) Observed
Log(Index)
2
0
−2
−4
−6
−8
1980
1990
2000
2010
2020
Z
4
3
2
1
0
−1
1980
1990
2000
2010
2020
Year Class

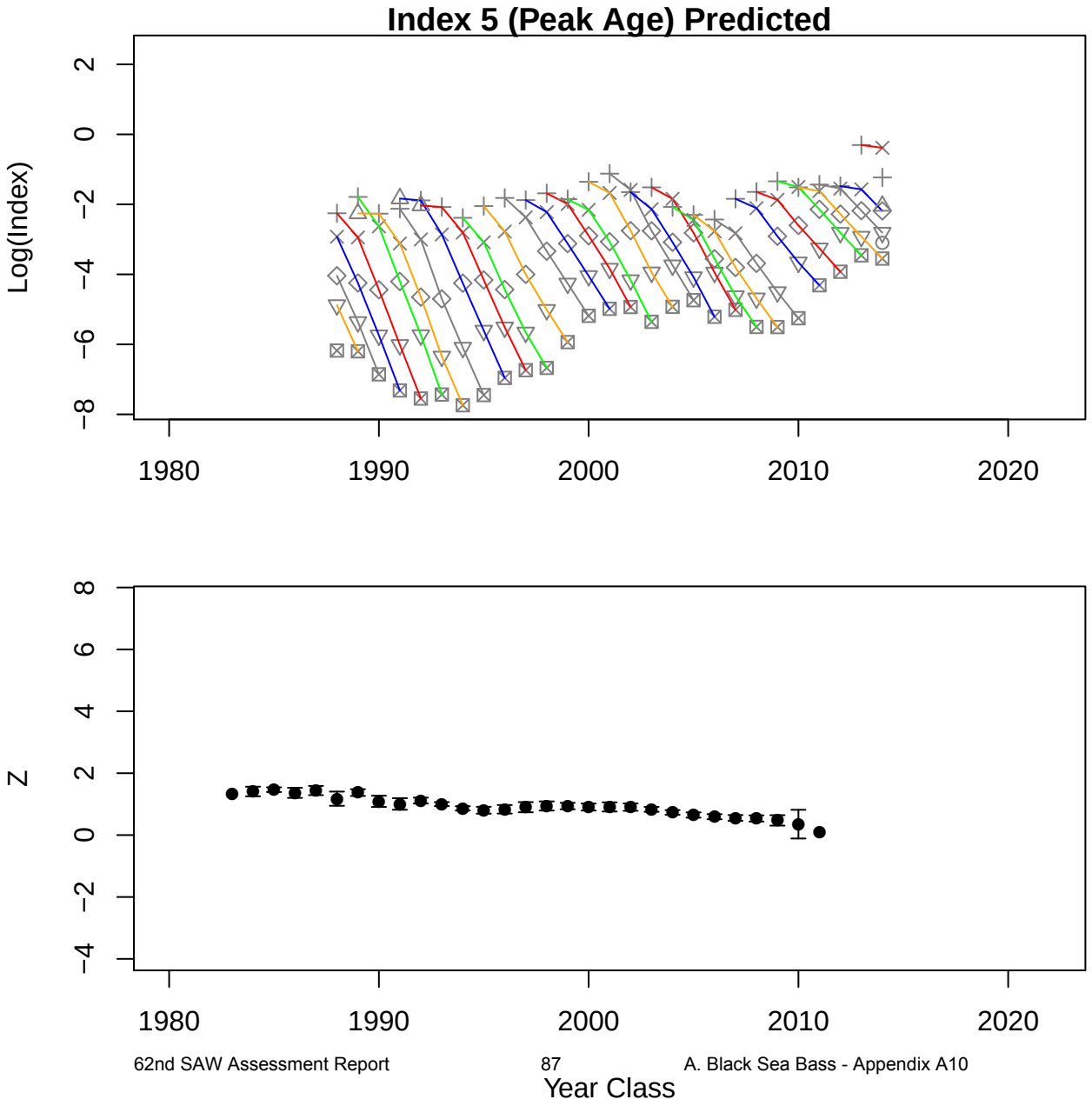

Index 3 (Peak Age) Predicted
Log(Index)
2
0
−2
−4
−6
−8
1980
1990
2000
2010
2020

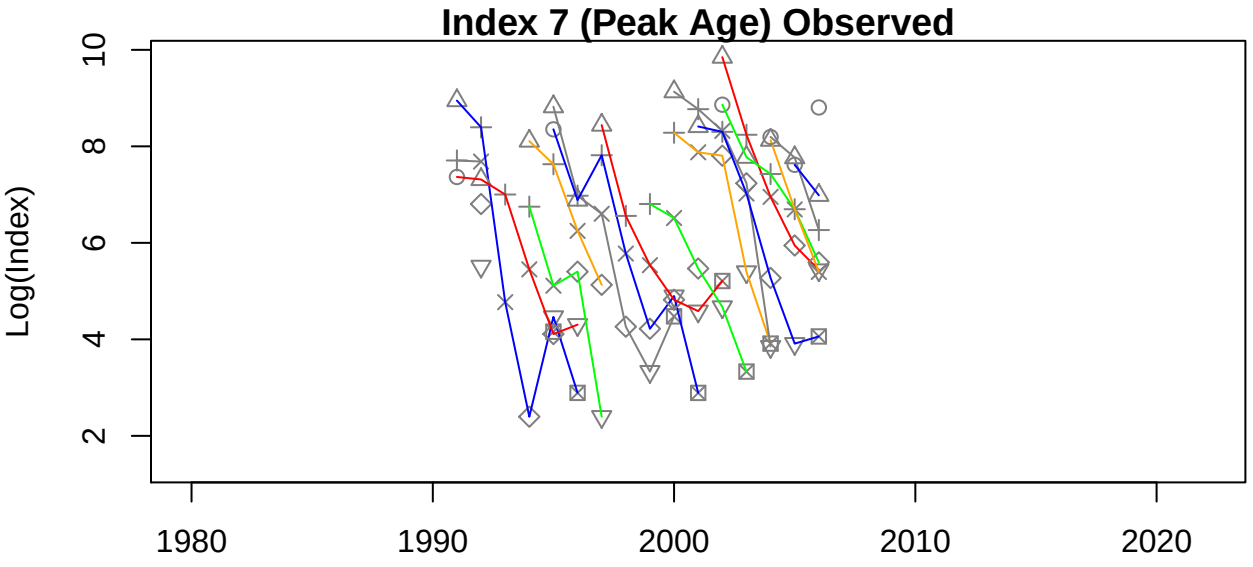

Z
4
3
2
1
0
−1
1980
1990
2000
2010
2020
Year Class

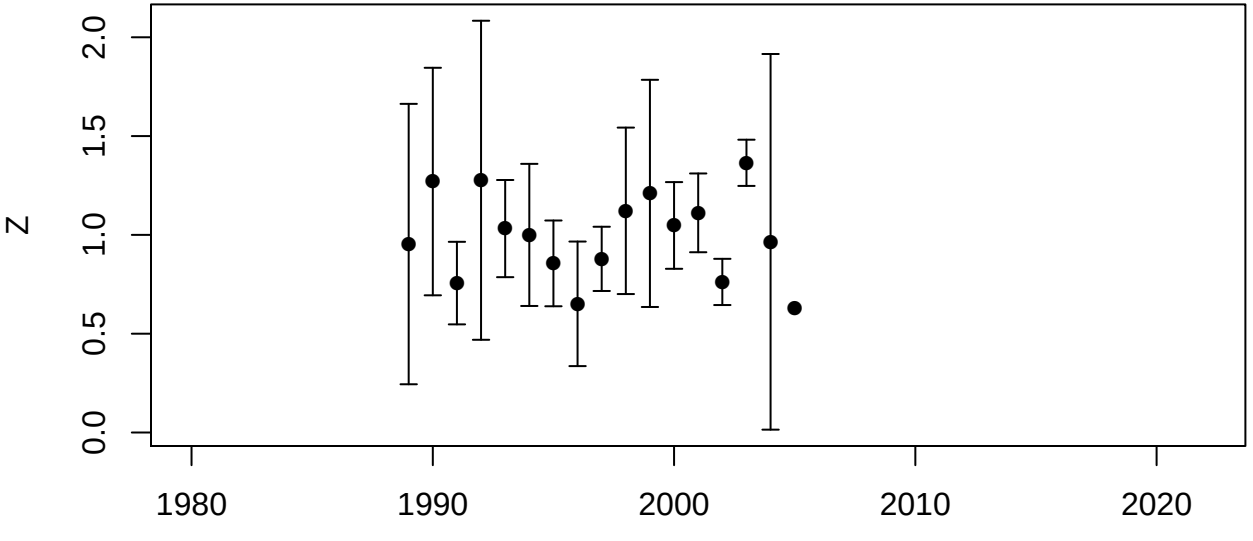

Index 4 (Peak Age) Observed
Log(Index)
−2
−4
−6
−8
−10
1980
1990
2000
2010
2020
Z
3
2
1
0
−1
1980
1990
2000
2010
2020
Year Class

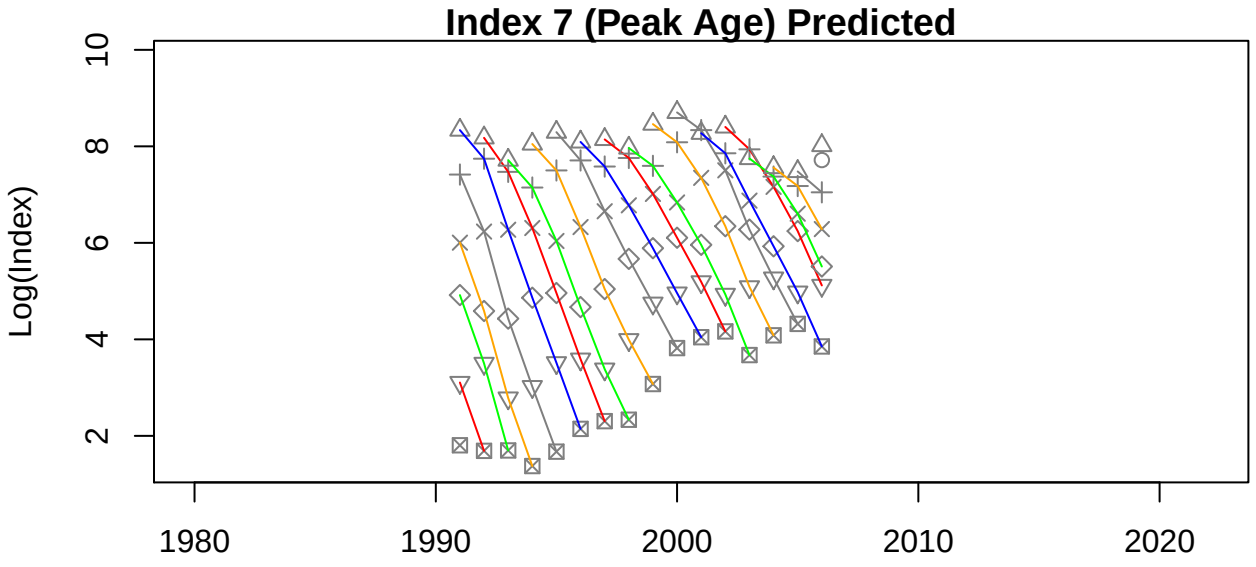

Index 4 (Peak Age) Predicted
Log(Index)
−2
−4
−6
−8
−10
1980
1990
2000
2010
2020
Z
3
2
1
0
−1
1980
1990
2000
2010
2020
Year Class

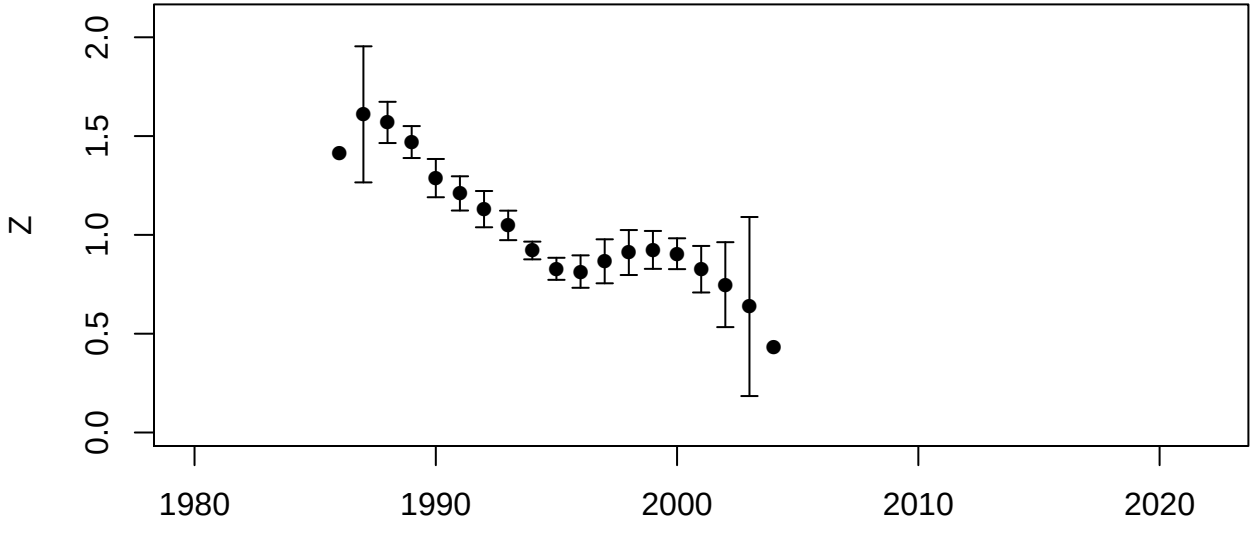

Index 5 (Peak Age) Observed
Log(Index)
2
0
−2
−4
−6
−8
1980
1990
2000
2010
2020
Z
8
6
4
2
0
−2
−4
1980
1990
2000
2010
2020
Year Class


Index 5 (Peak Age) Predicted
Log(Index)
2
0
−2
−4
−6
−8
1980
1990
2000
2010
2020
Z
8
6
4
2
0
−2
−4
1980
1990
2000
2010
2020
Year Class

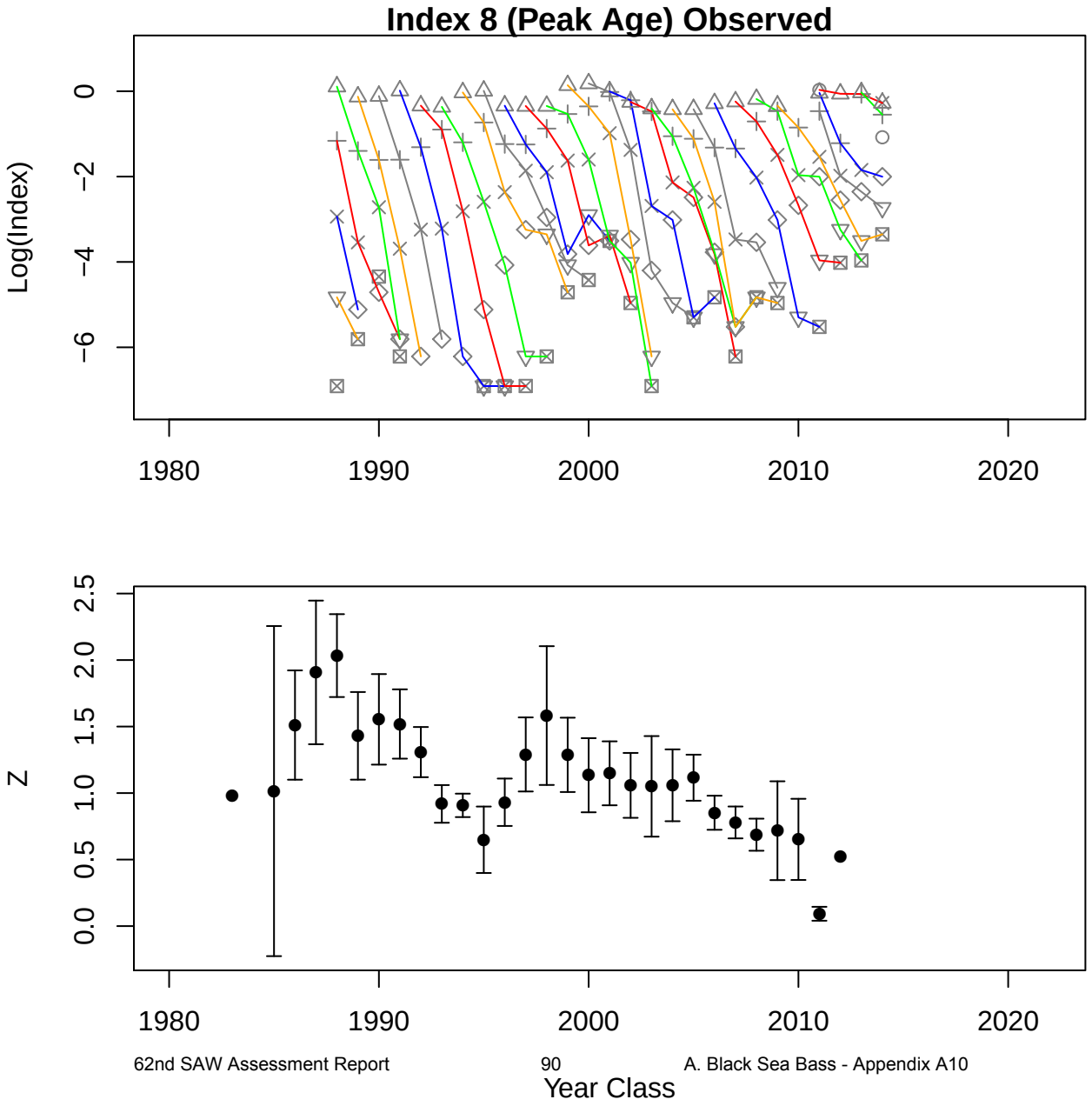

Index 7 (Peak Age) Observed
Log(Index)
10
8
6
4
2
1980
1990
2000
2010
2020

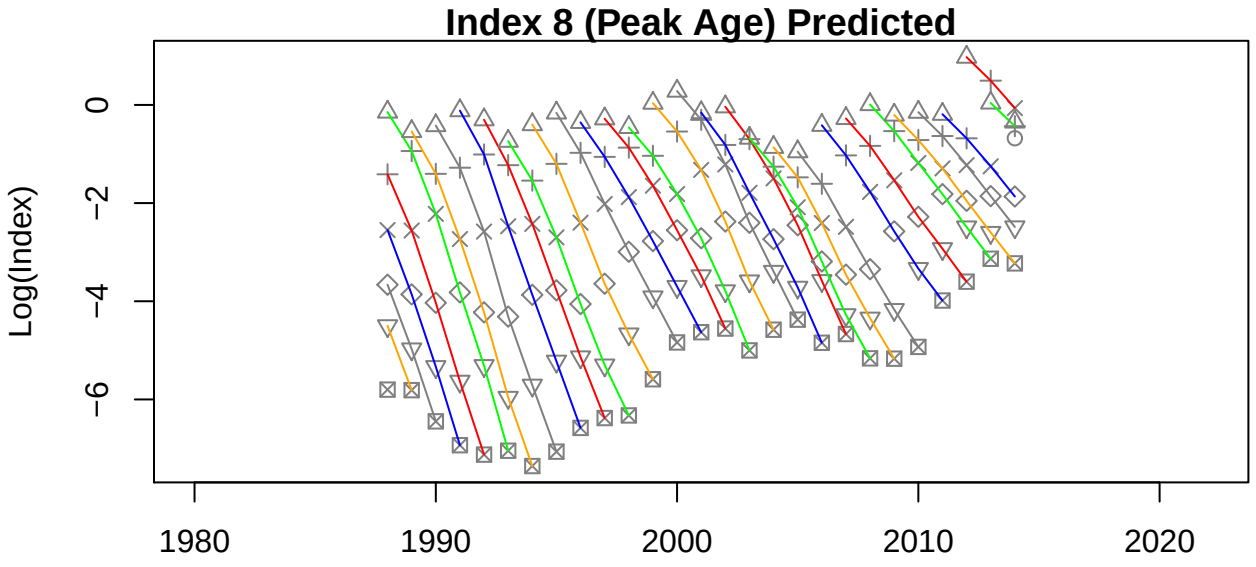

Z
2.0
1.5
1.0
0.5
0.0
1980
1990
2000
2010
2020
Year Class

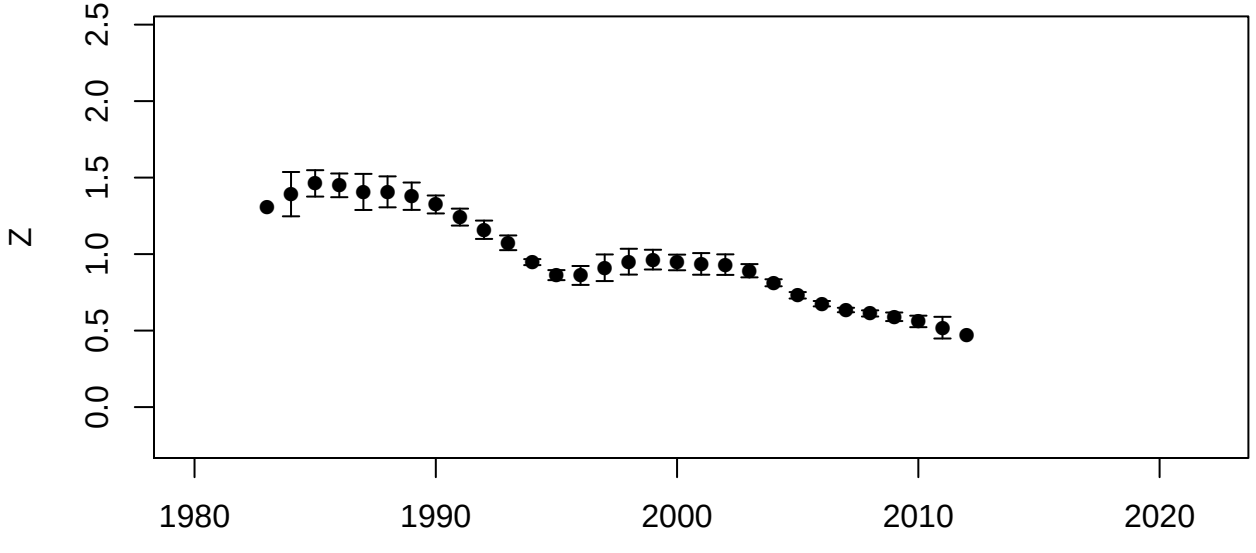

Index 7 (Peak Age) Predicted
Log(Index)
10
8
6
4
2
1980
1990
2000
2010
2020

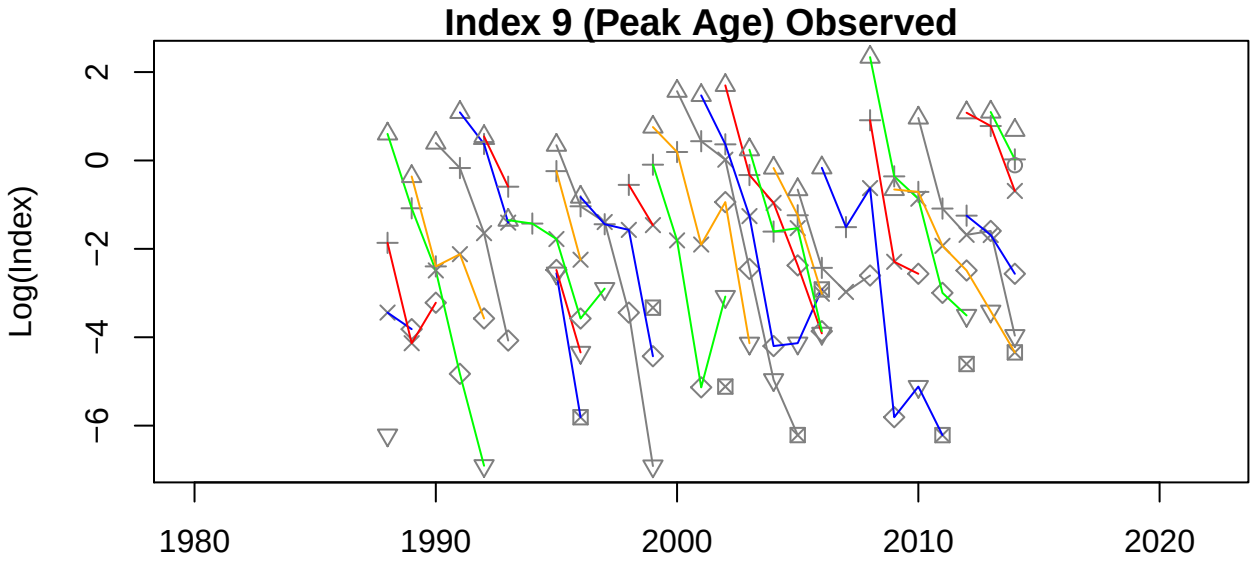

Z
2.0
1.5
1.0
0.5
0.0
1980
1990
2000
2010
2020

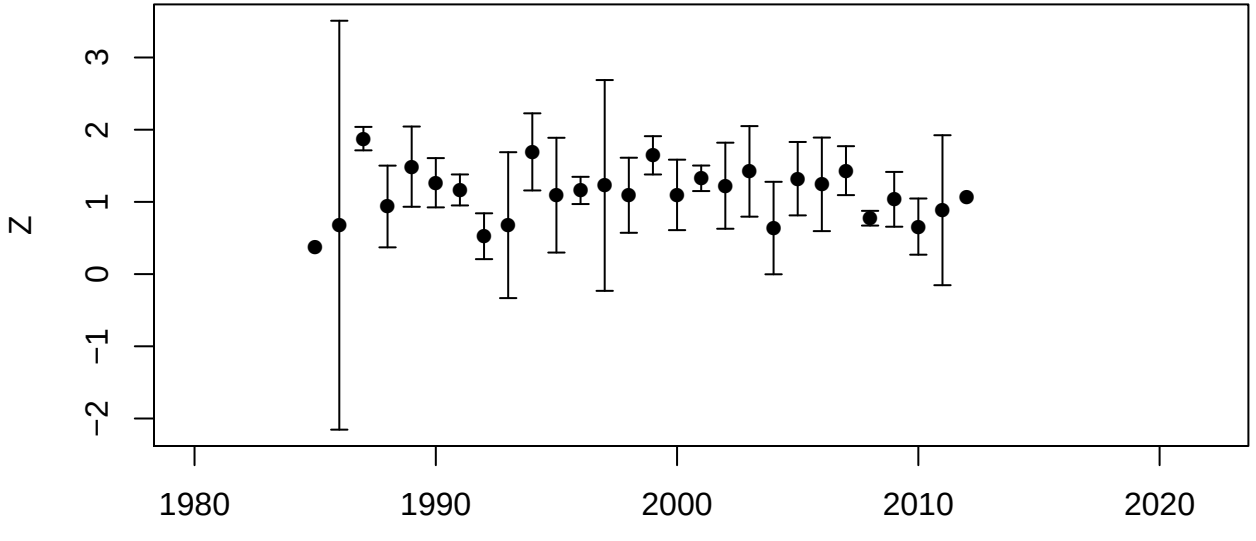
Year Class


Index 8 (Peak Age) Observed
Log(Index)
0
−2
−4
−6
1980
1990
2000
2010
2020
Z
2.5
2.0
1.5
1.0
0.5
0.0
1980
1990
2000
2010
2020
Year Class

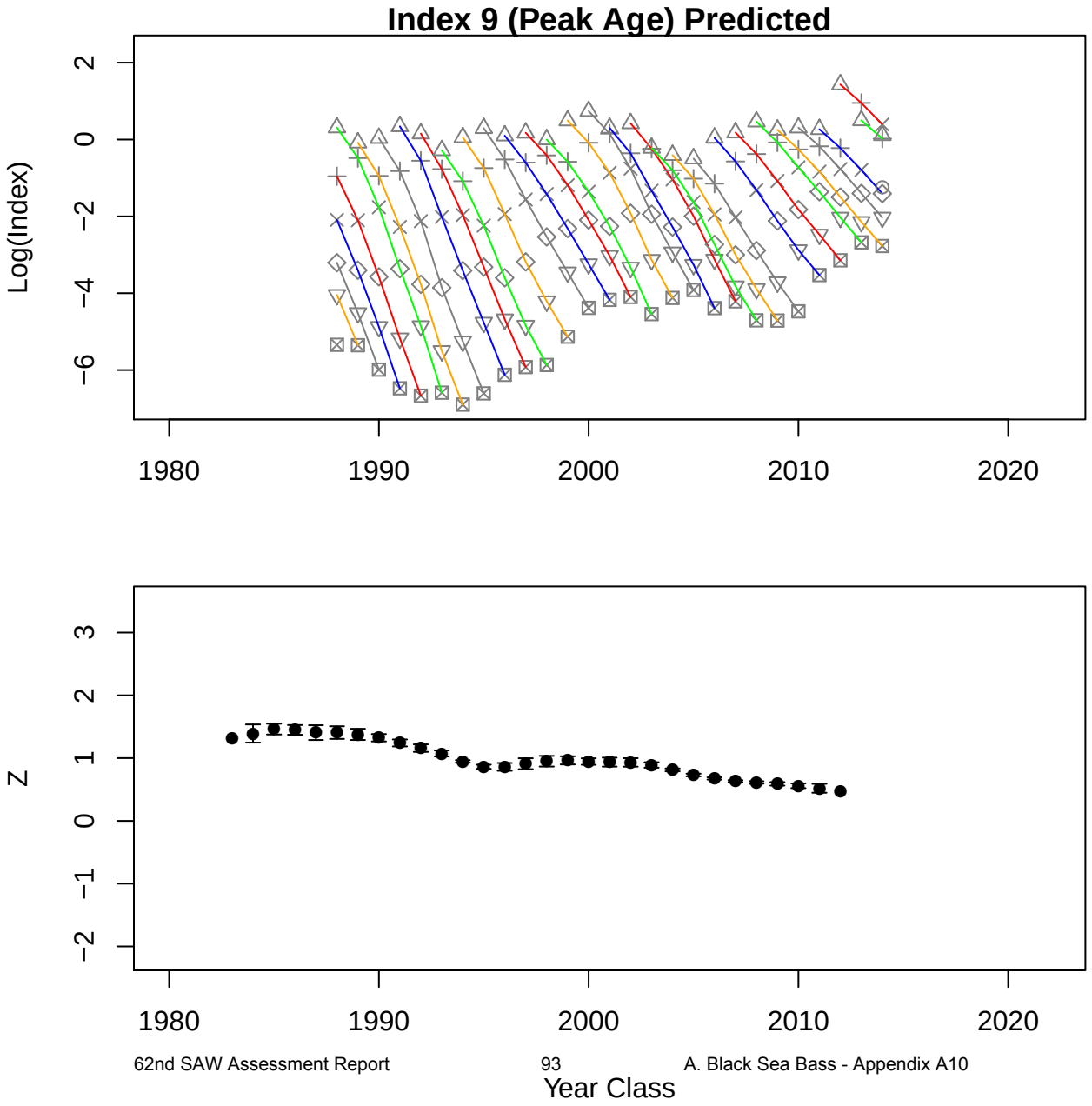

Index 8 (Peak Age) Predicted
Log(Index)
0
−2
−4
−6
1980
1990
2000
2010
2020

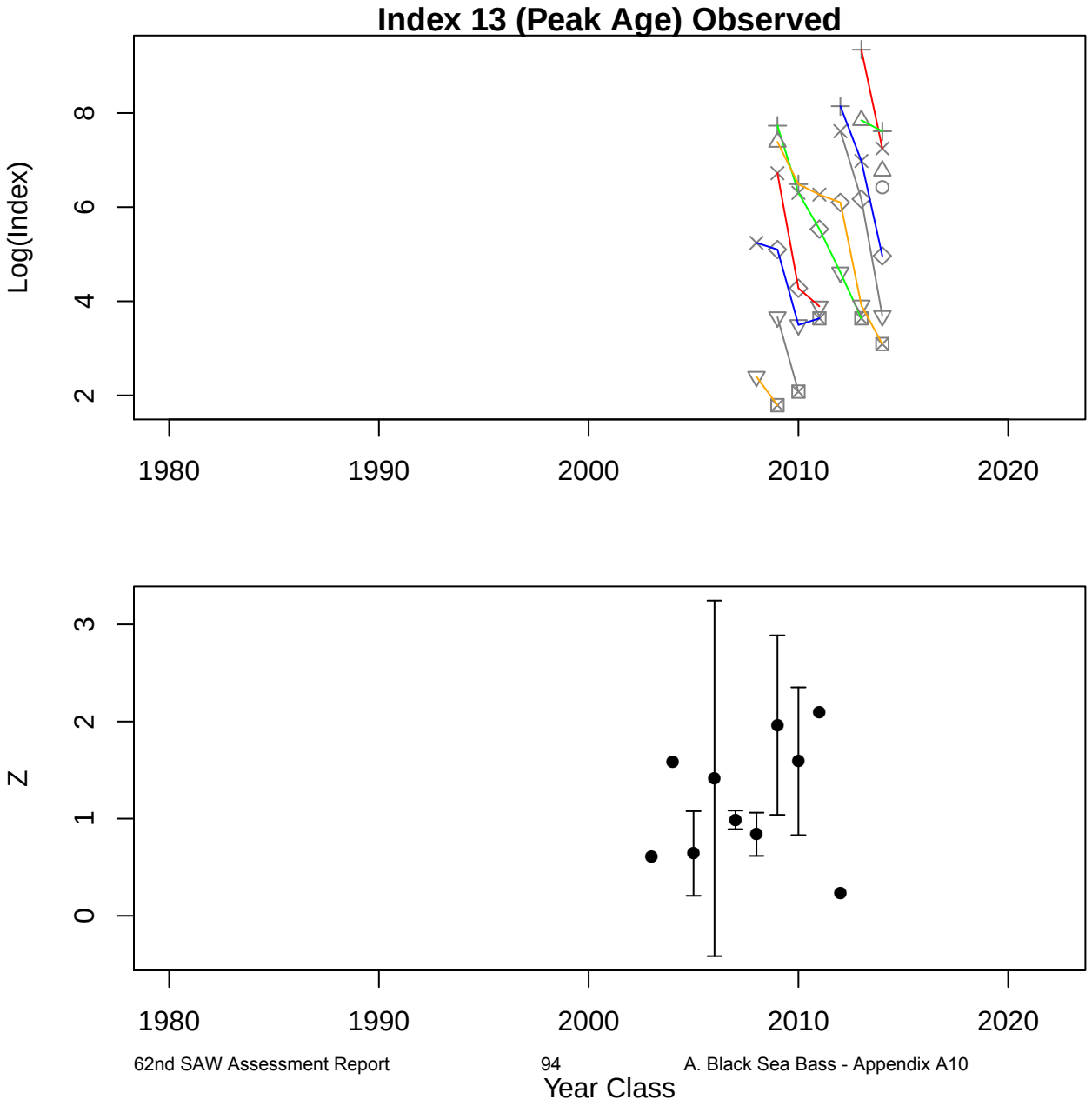

Z
0.0
0.5
1.0
1.5
2.0
2.5
1980
1990
2000
2010
2020
Year Class

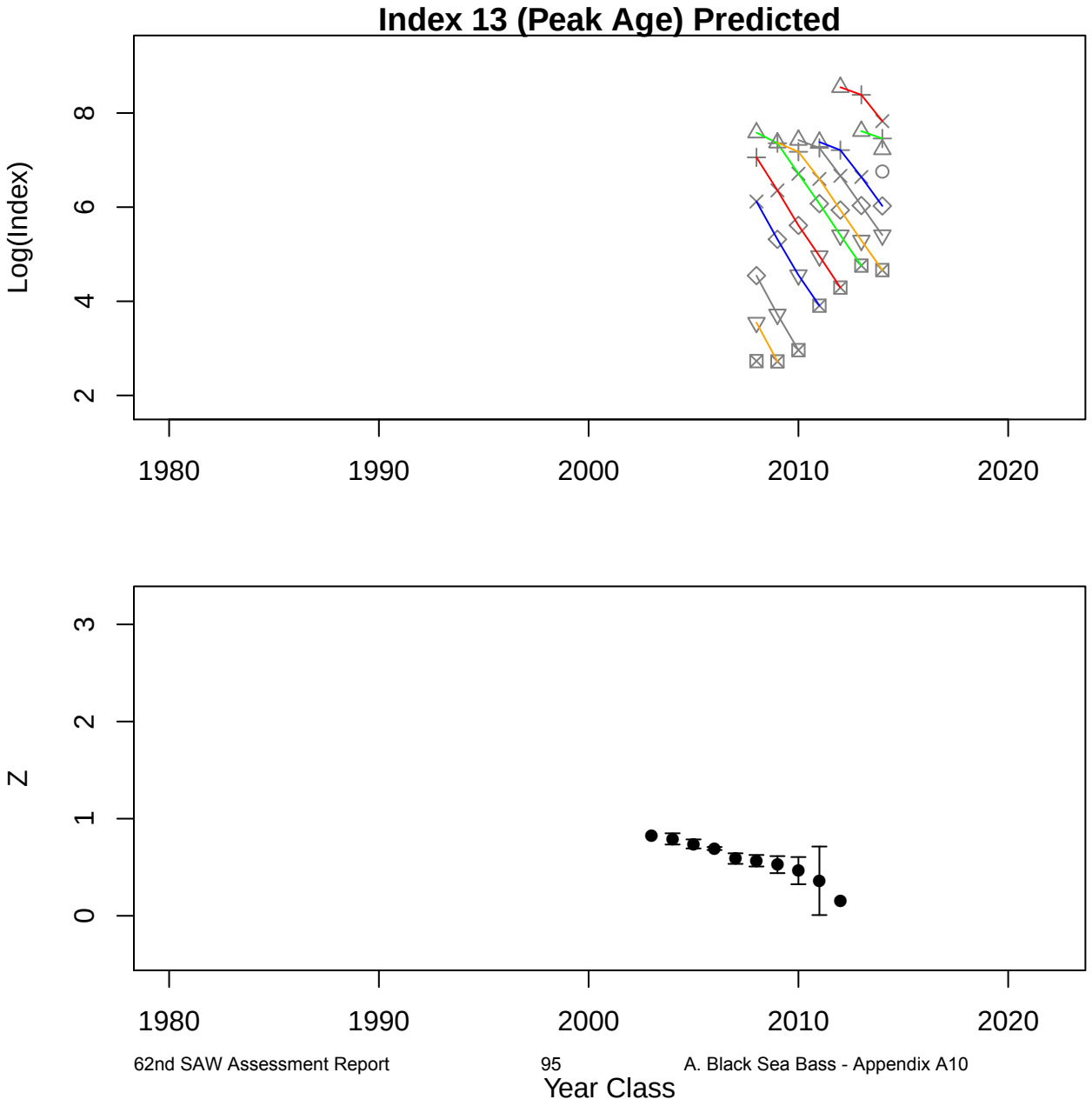

Index 9 (Peak Age) Observed
Log(Index)
2
0
−2
−4
−6
1980
1990
2000
2010
2020


Z
3
2
1
0
−1
−2
1980
1990
2000
2010
2020

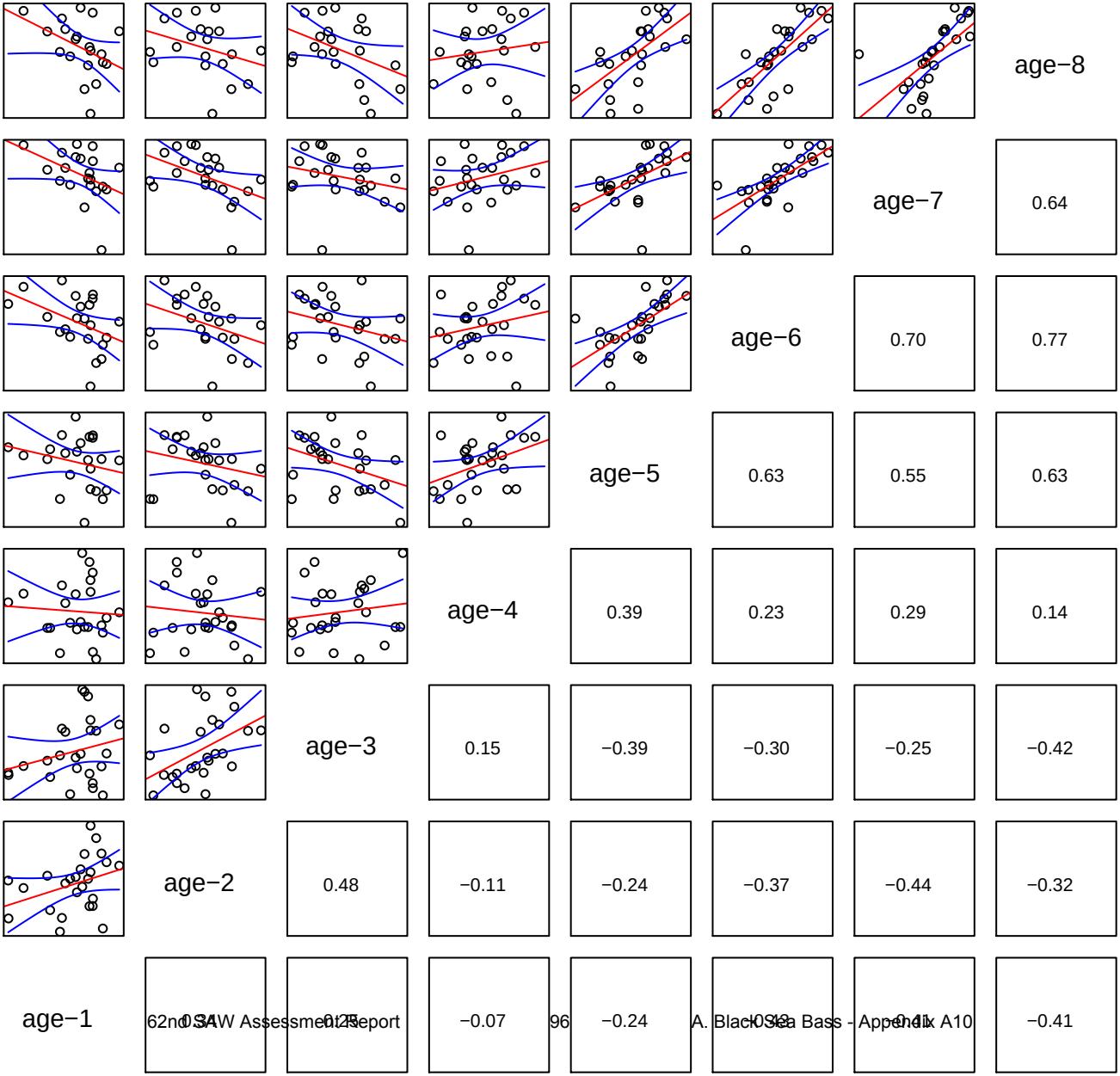
Year Class


Index 9 (Peak Age) Predicted
Log(Index)
2
0
−2
−4
−6
1980
1990
2000
2010
2020
Z
3
2
1
0
−1
−2
1980
1990
2000
2010
2020
Year Class

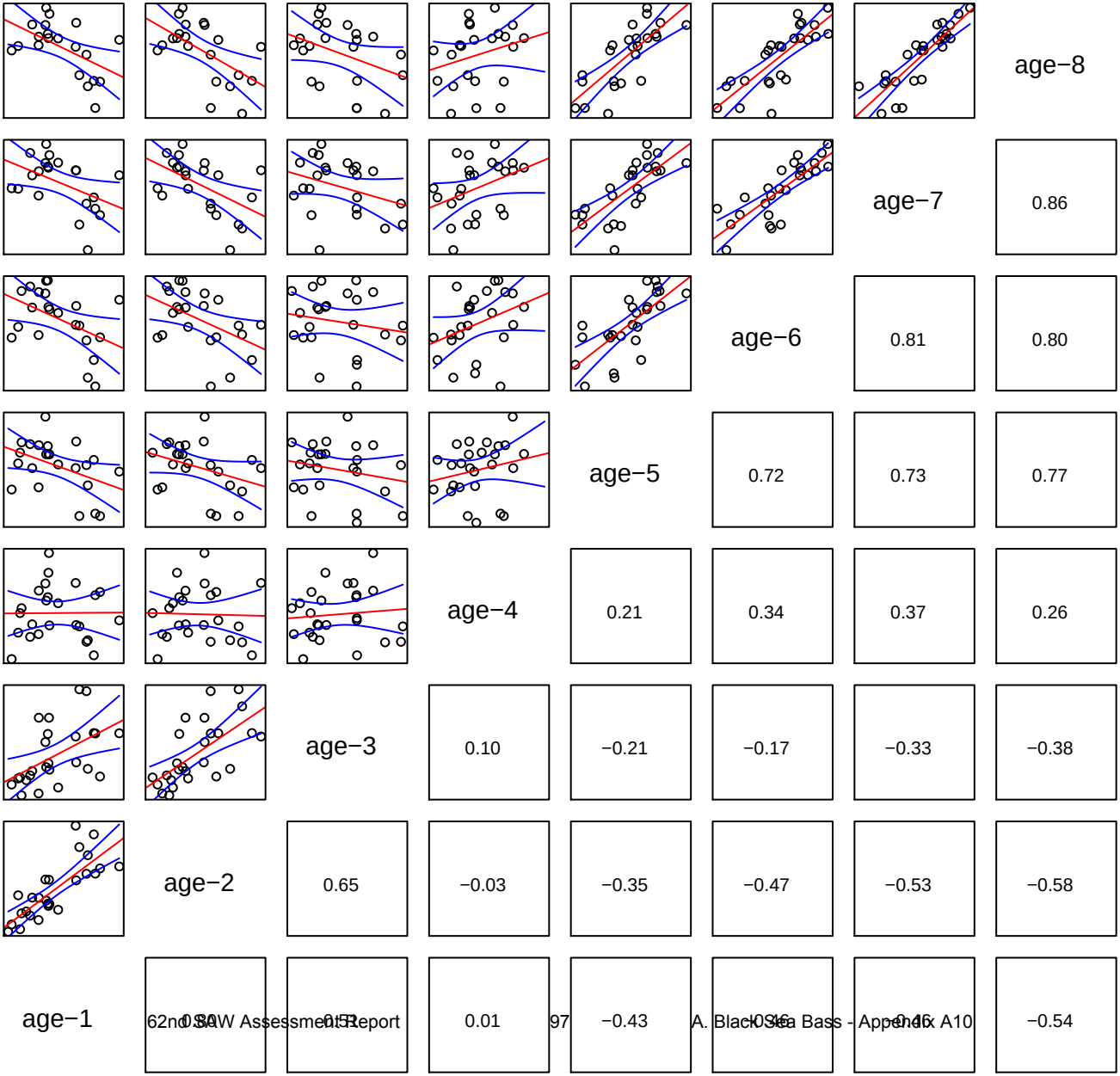

Index 13 (Peak Age) Observed
Log(Index)
2
4
6
8
1980
1990
2000
2010
2020
Z
0
1
2
3
1980
1990
2000
2010
2020
Year Class


Index 13 (Peak Age) Predicted
Log(Index)
2
4
6
8
1980
1990
2000
2010
2020
Z
0
1
2
3
1980
1990
2000
2010
2020
Year Class

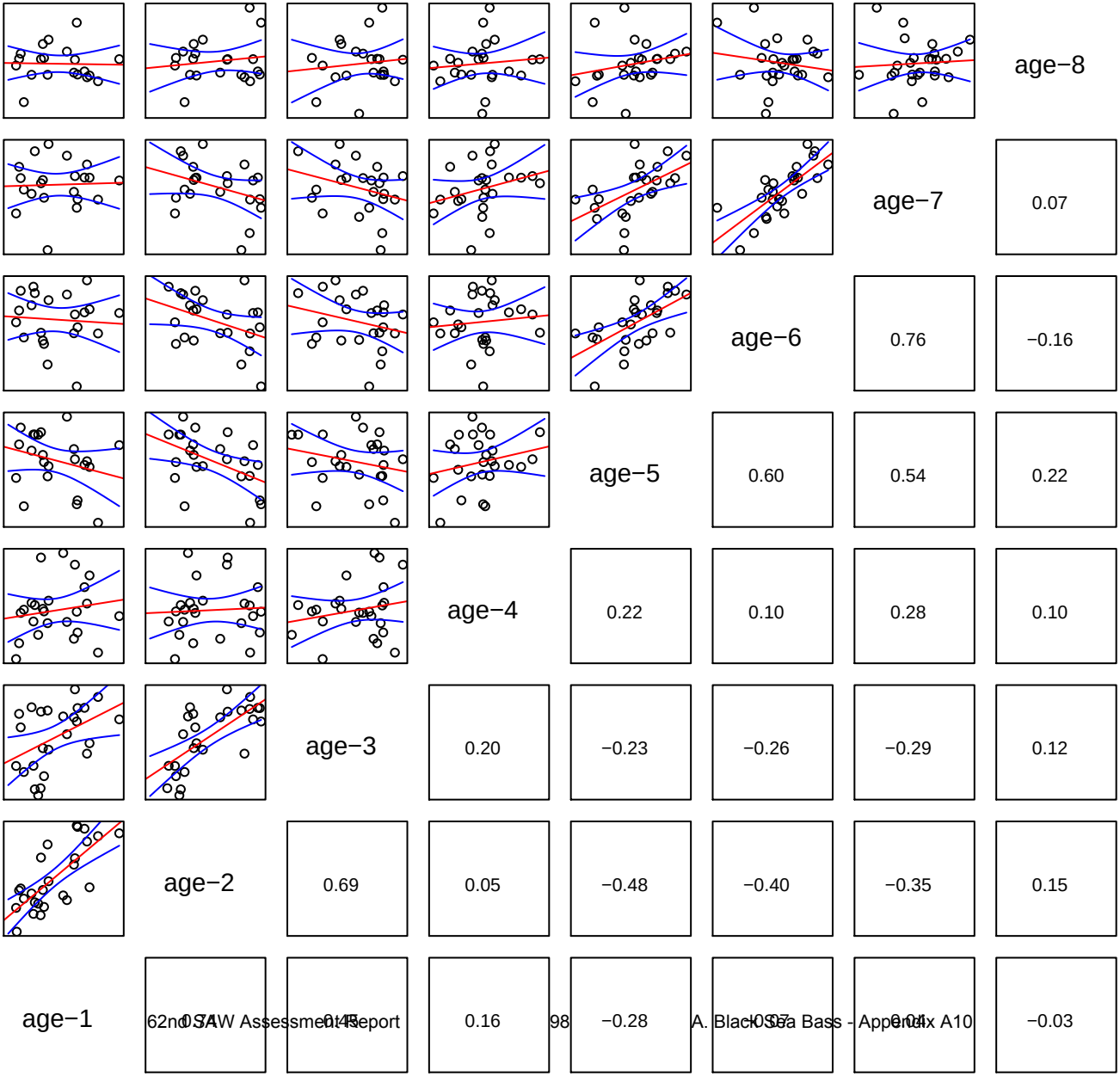
Catch for Fleet 1 Observed



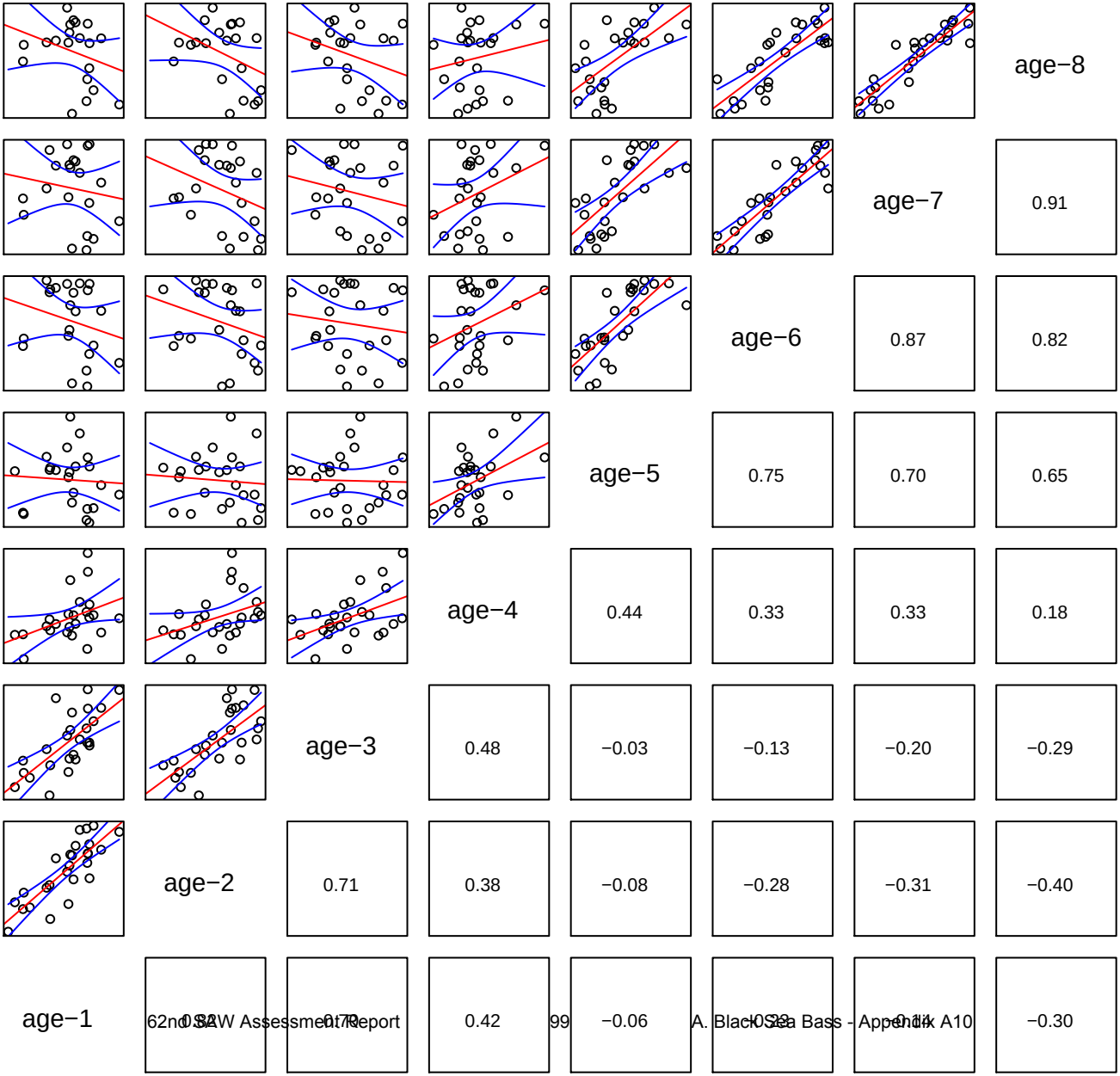
Catch for Fleet 1 Predicted



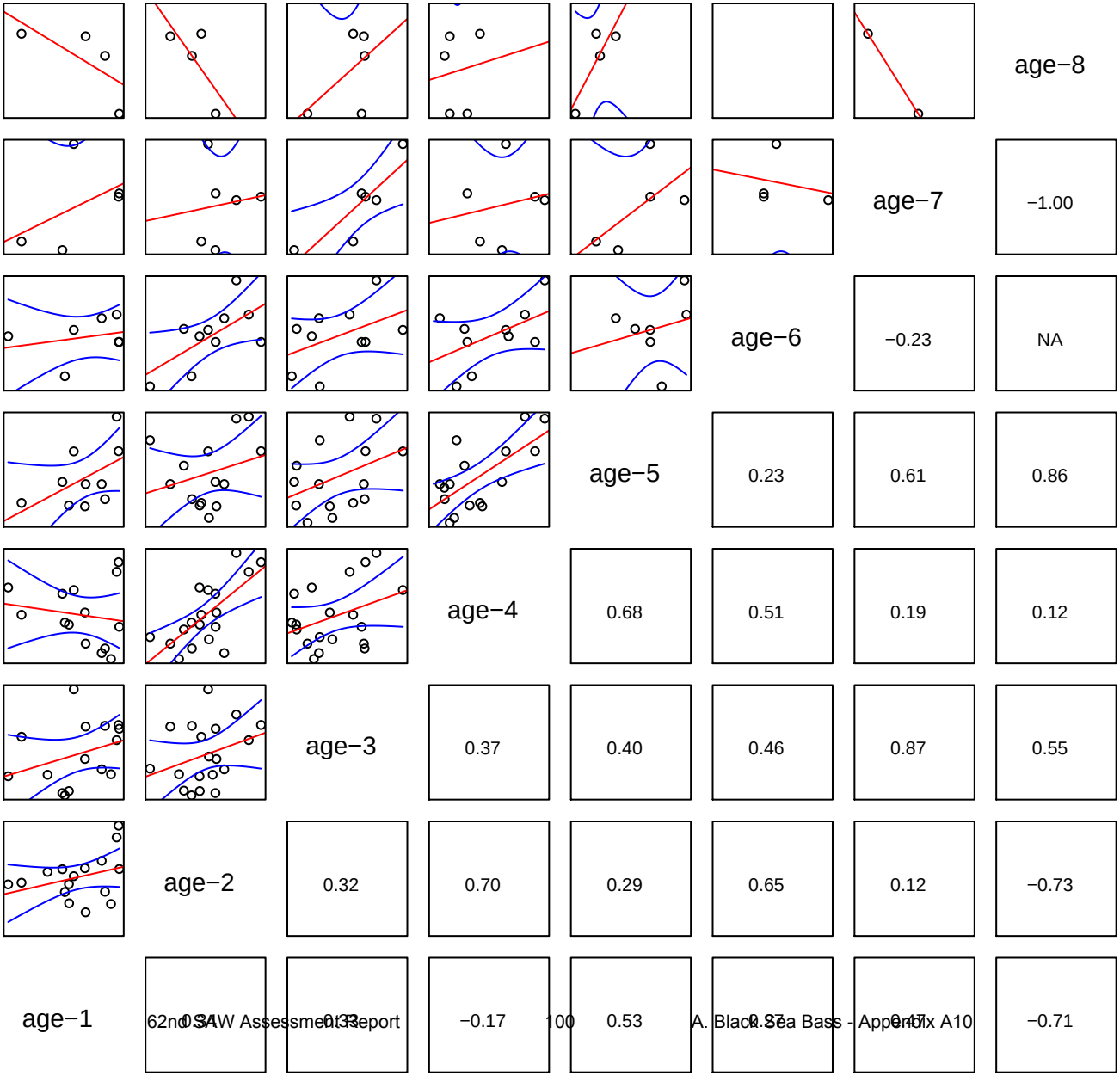
Catch for Fleet 2 Observed



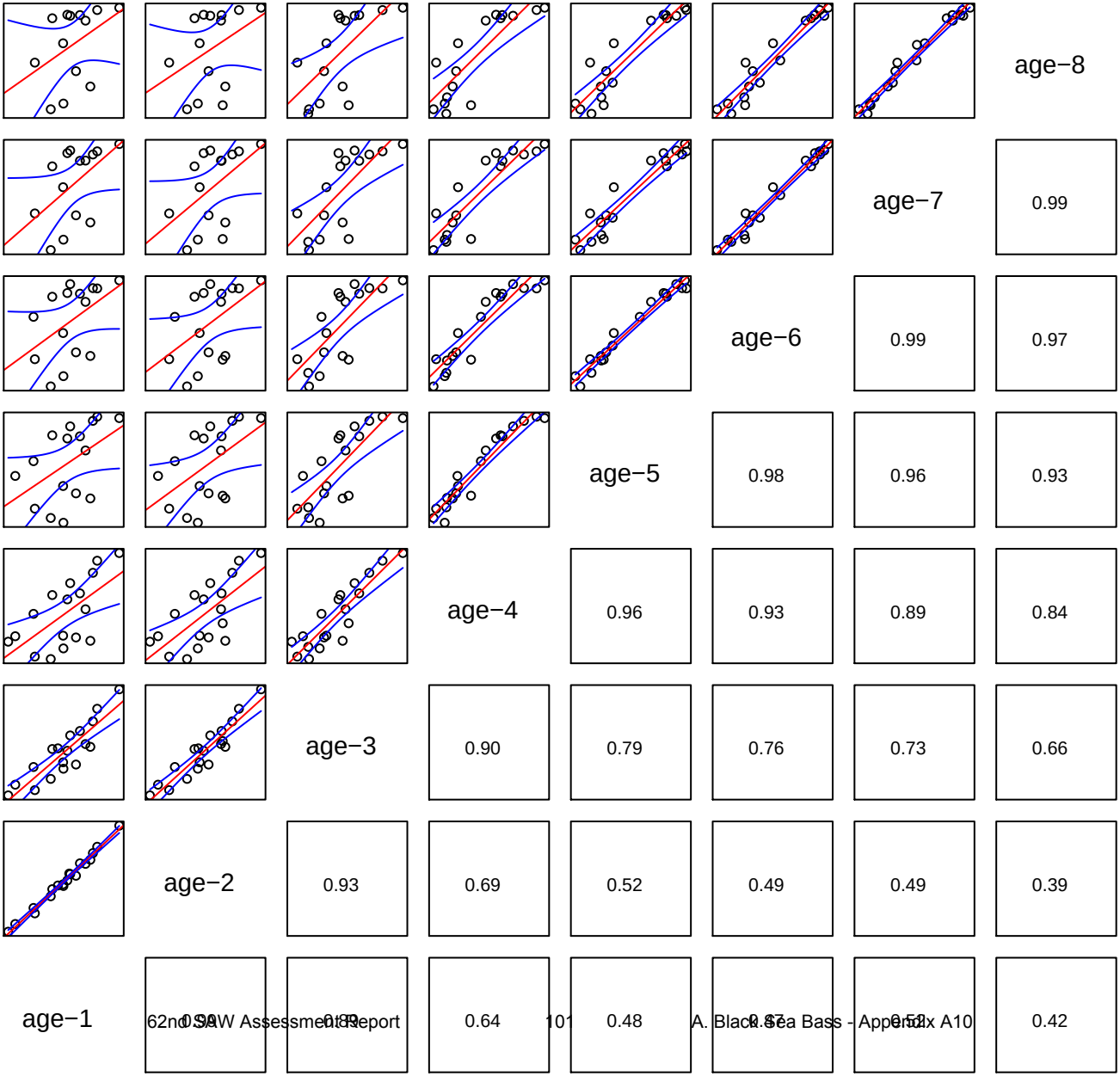
Catch for Fleet 2 Predicted



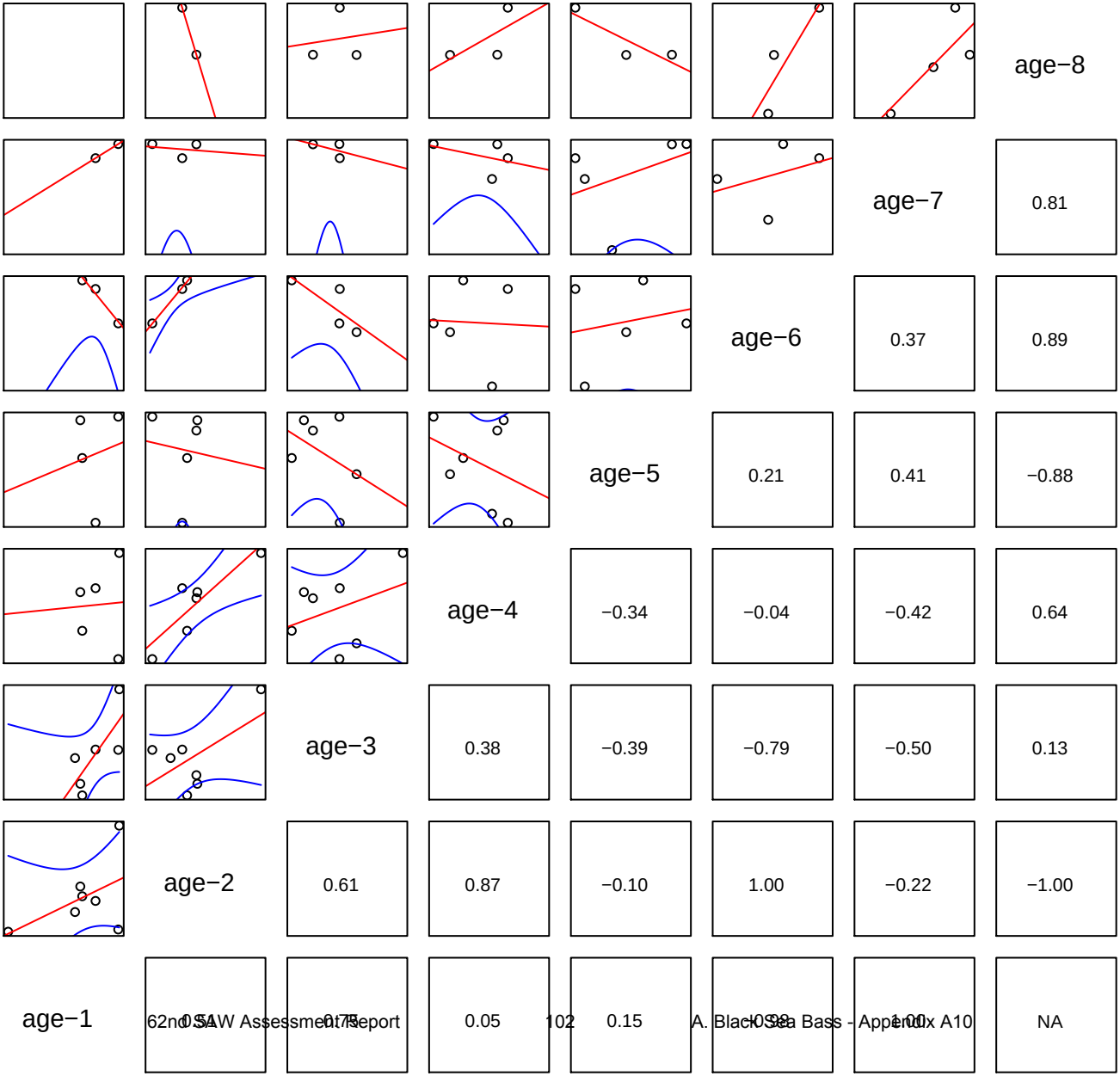
Index 1 Observed



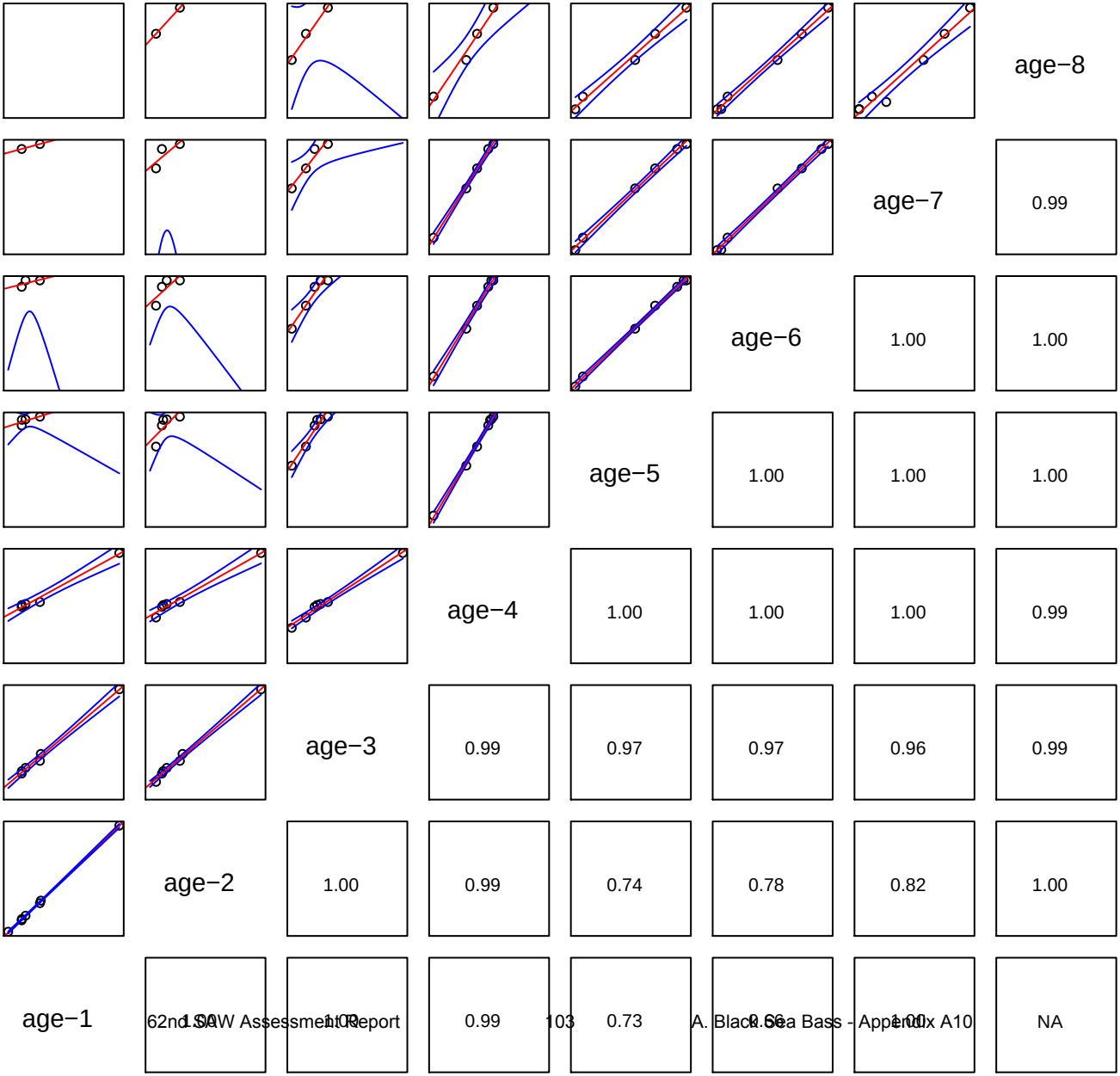
Index 1 Predicted



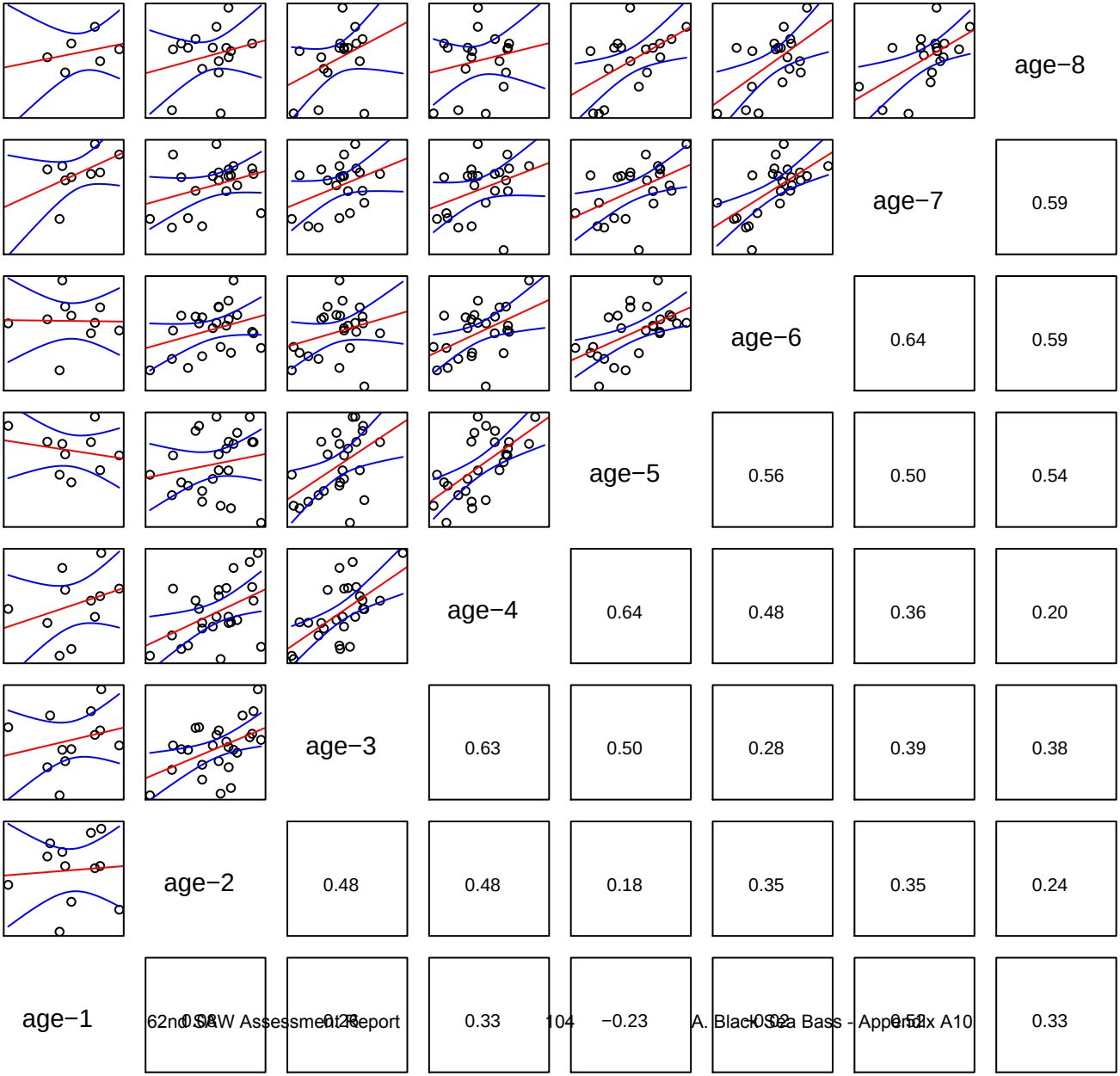
Index 2 Observed



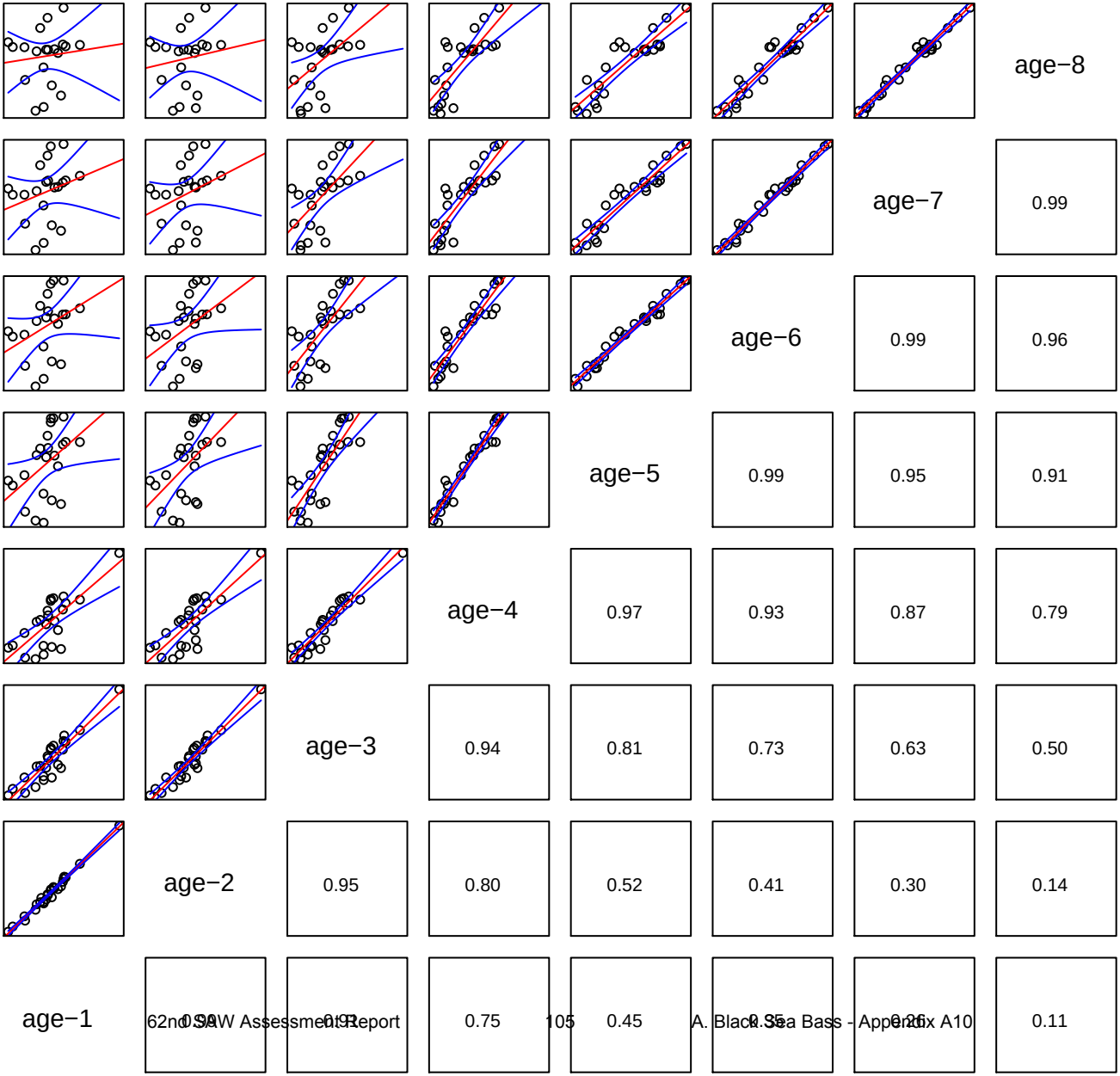
Index 2 Predicted



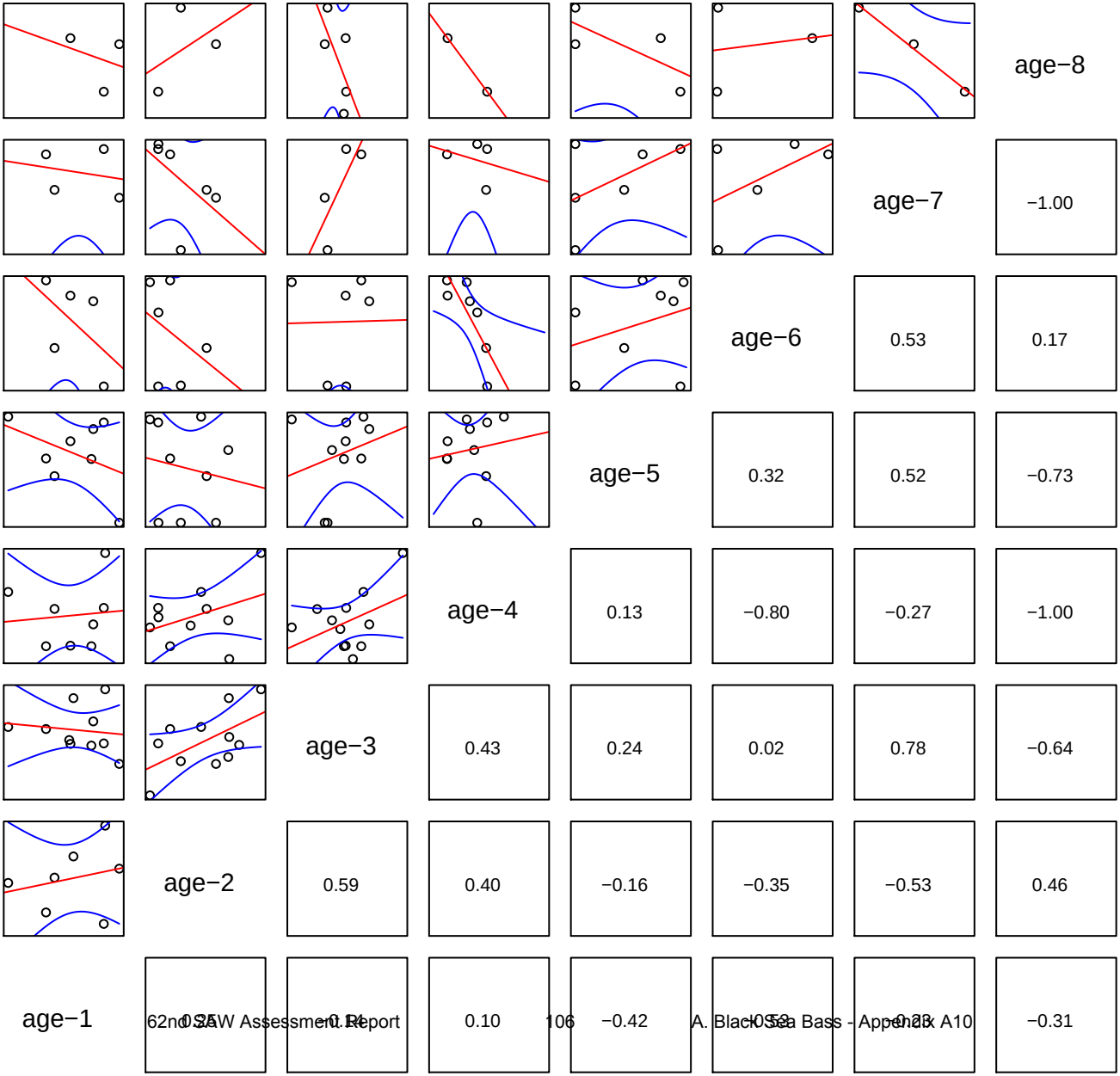
Index 3 Observed



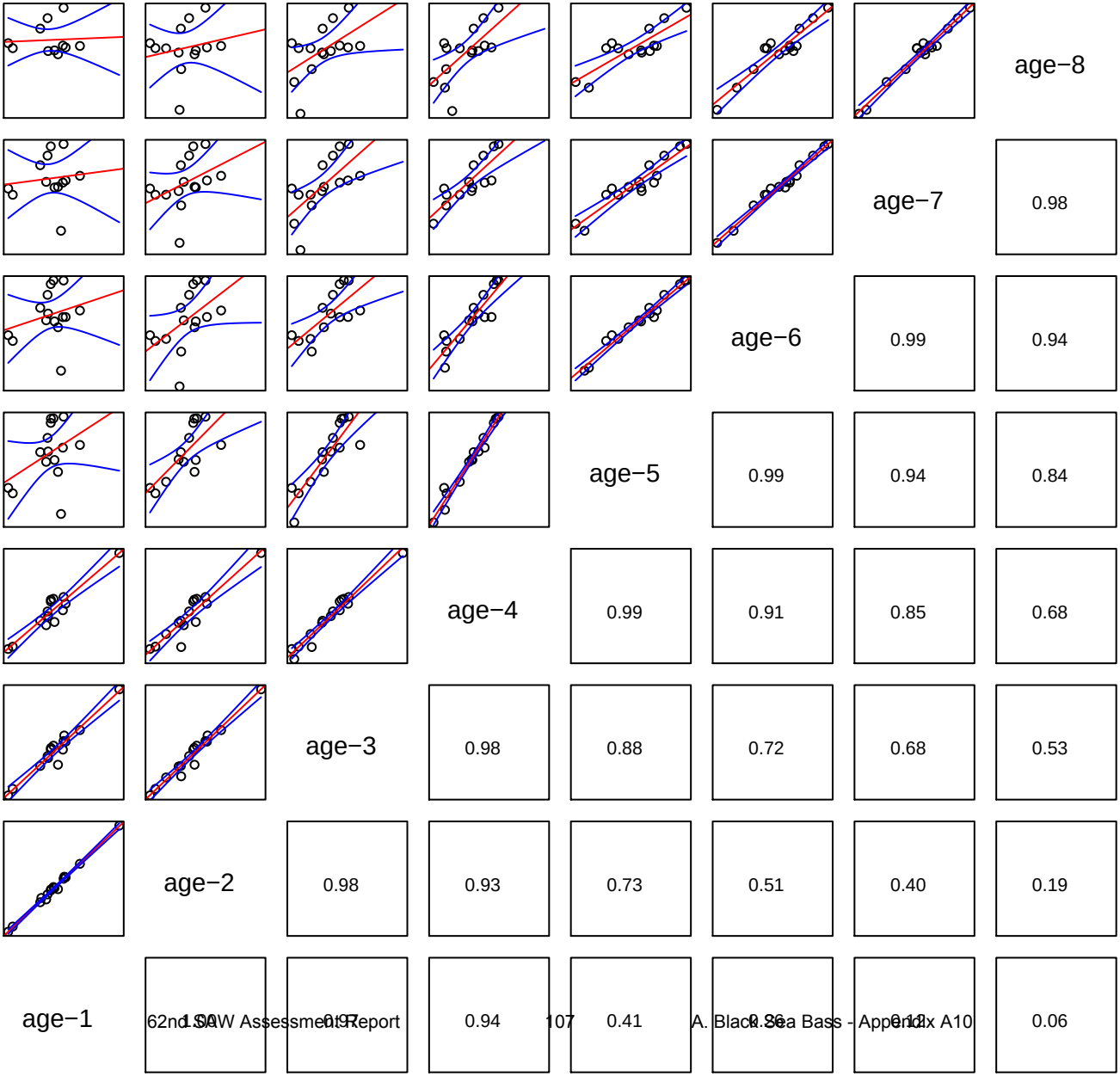
Index 3 Predicted



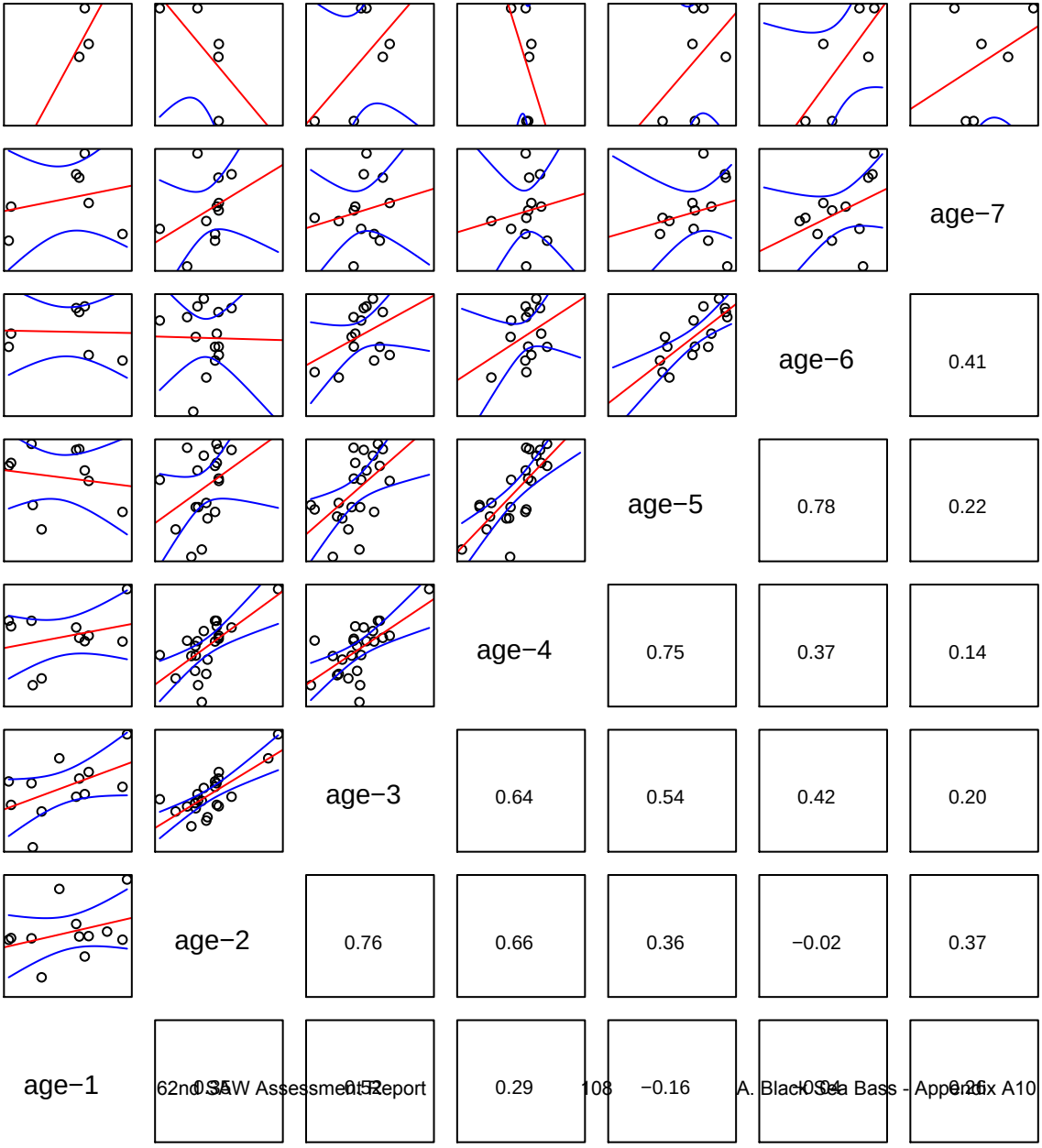
Index 4 Observed



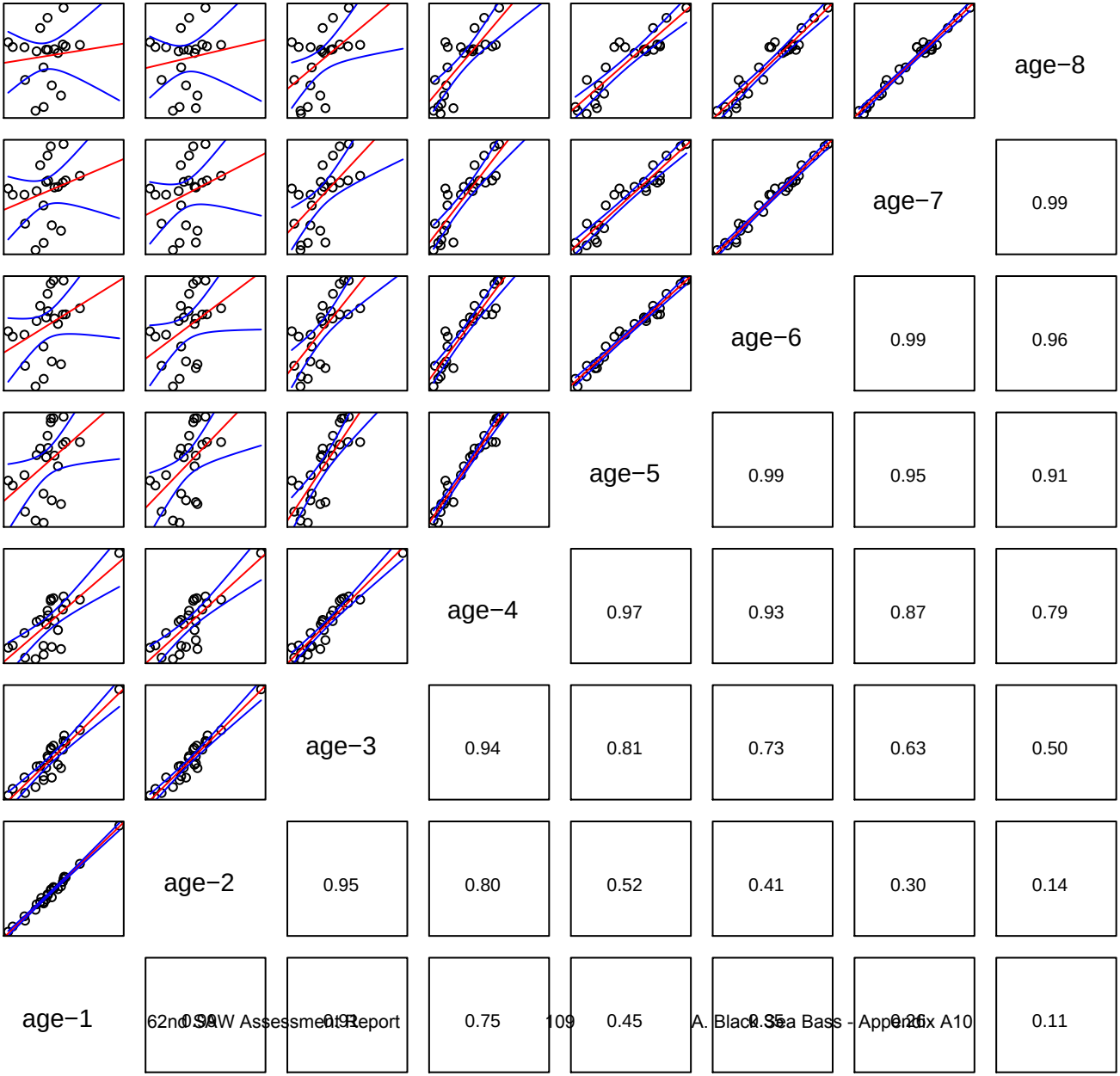
Index 4 Predicted



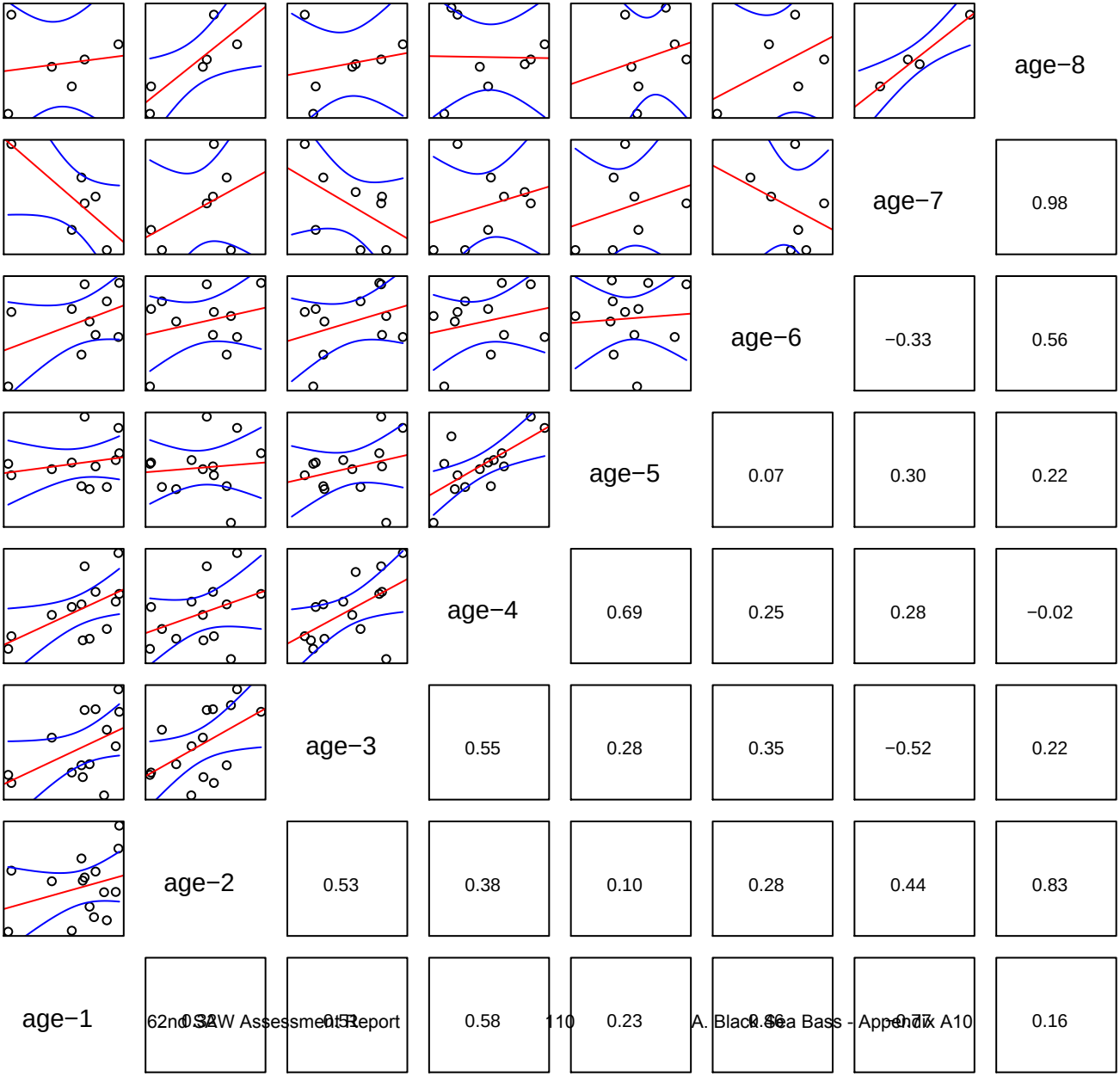
Index 5 Observed



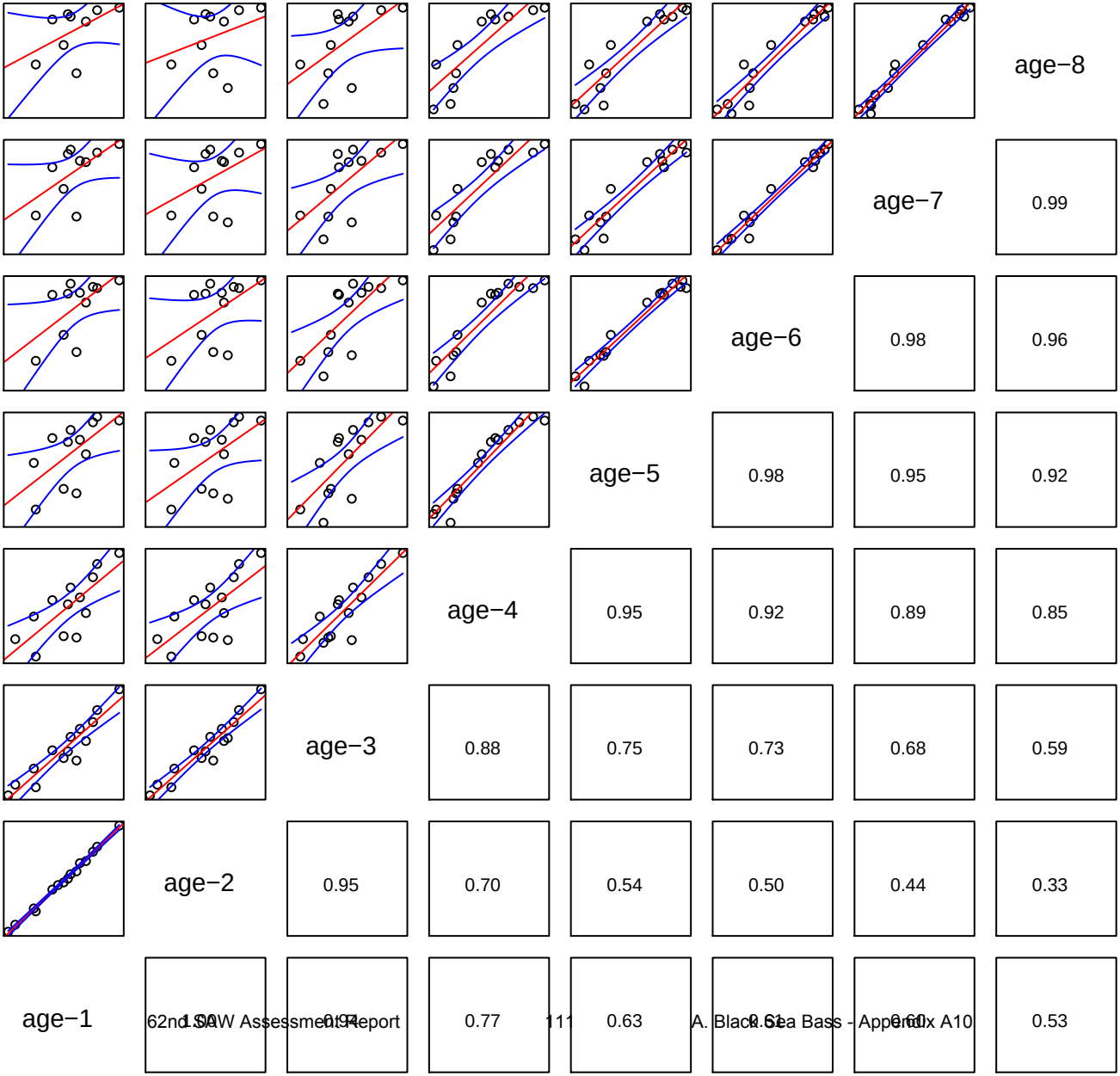
Index 5 Predicted



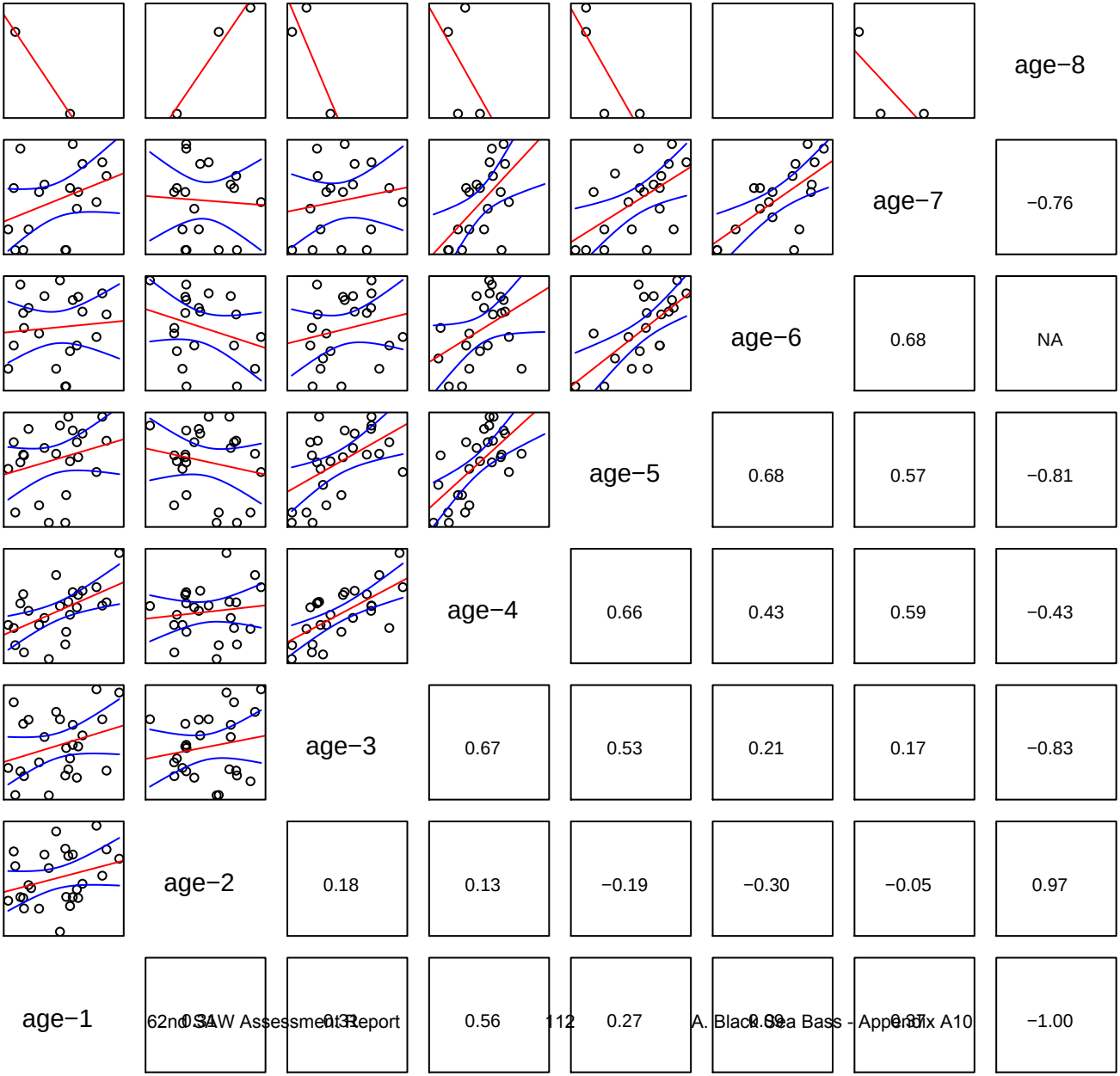
Index 7 Observed



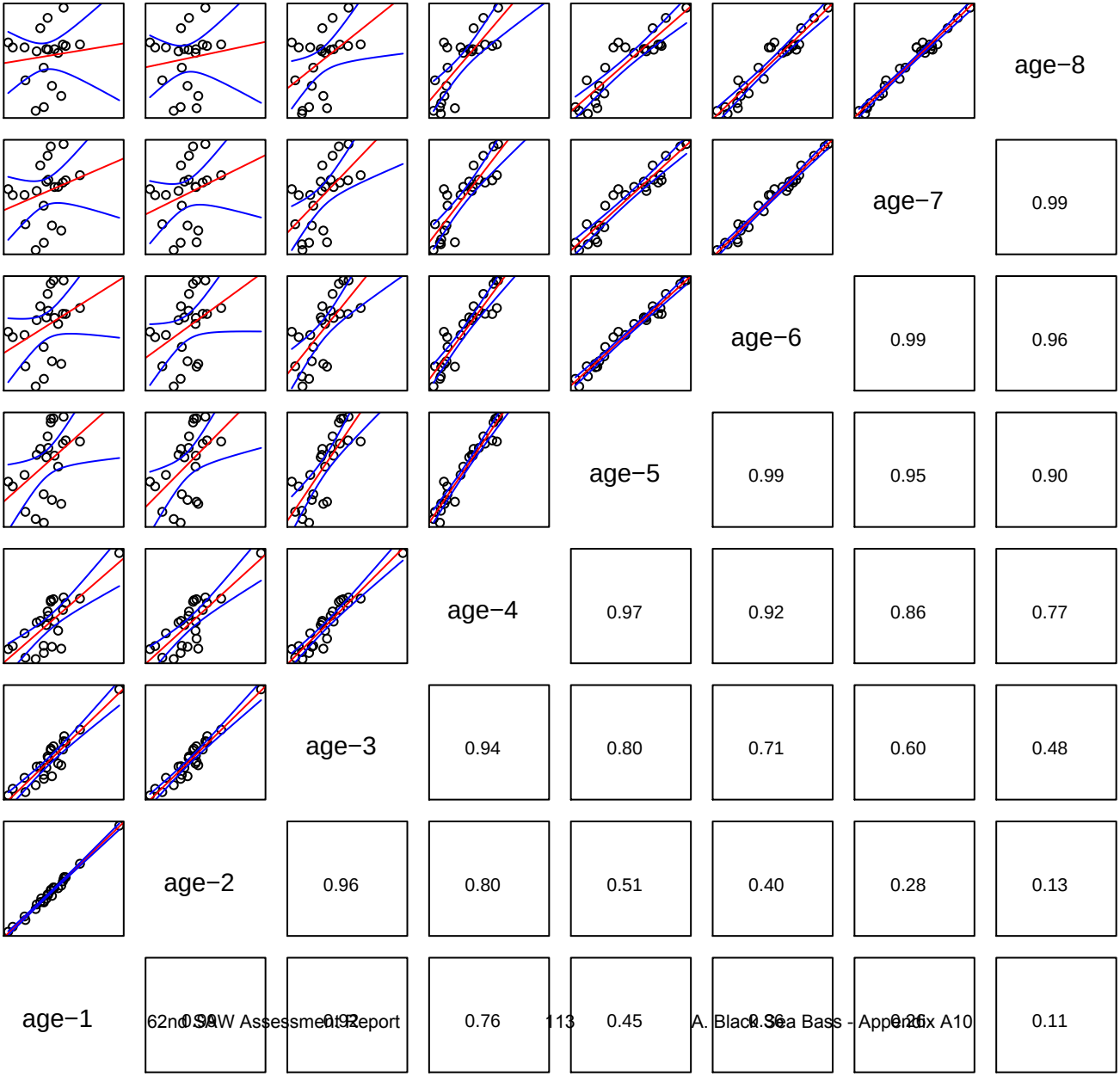
Index 7 Predicted



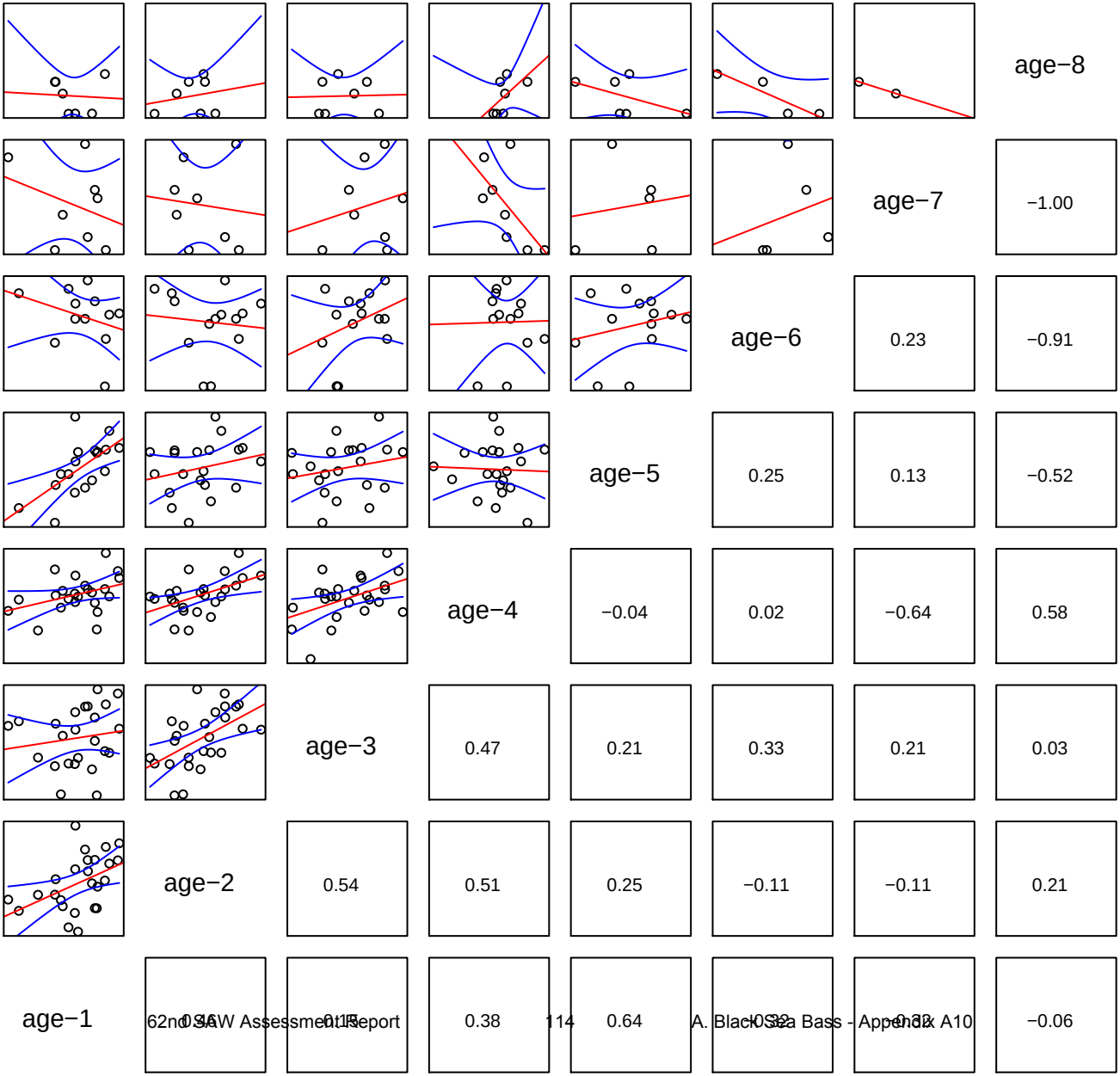
Index 8 Observed



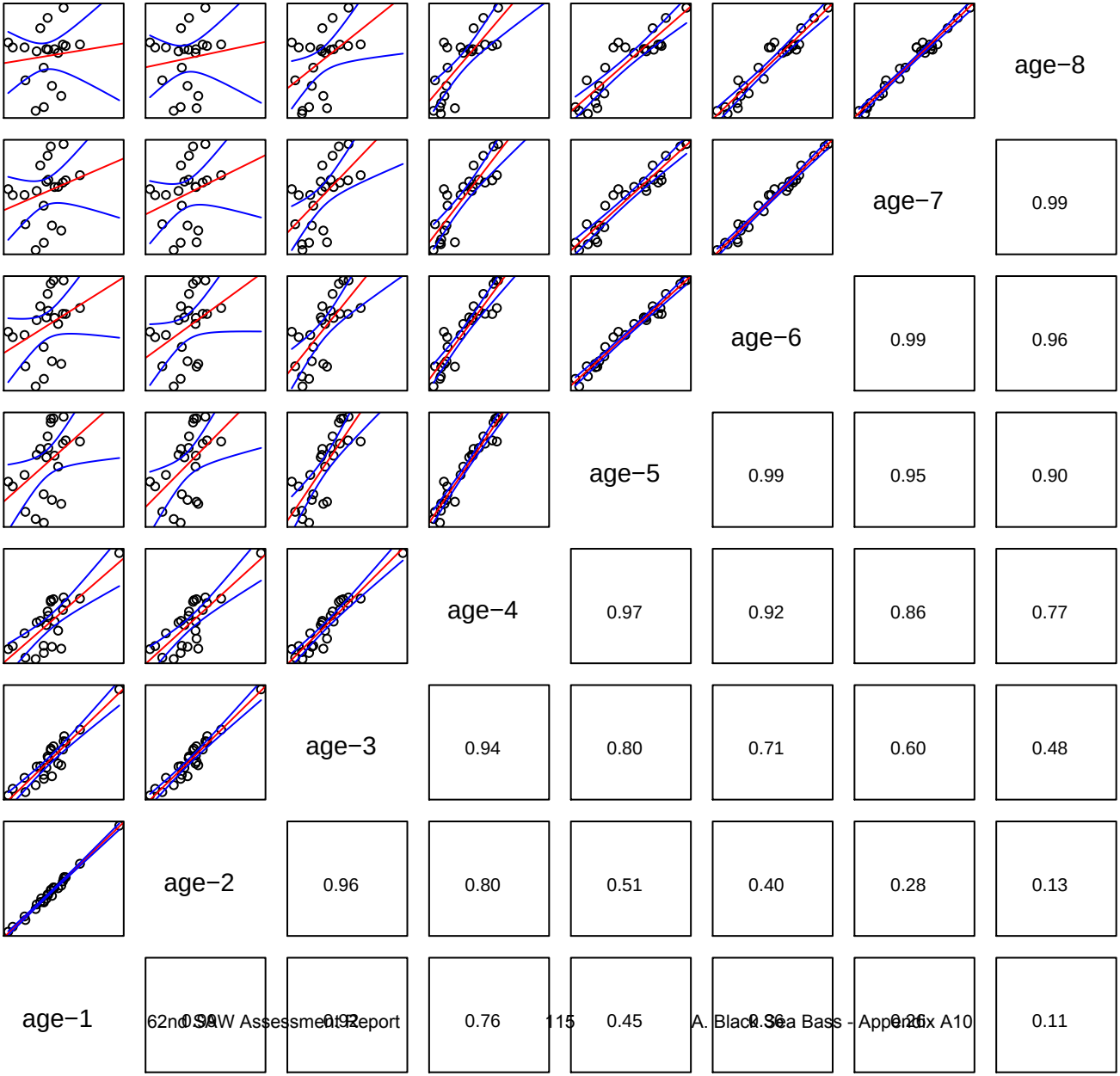
Index 8 Predicted



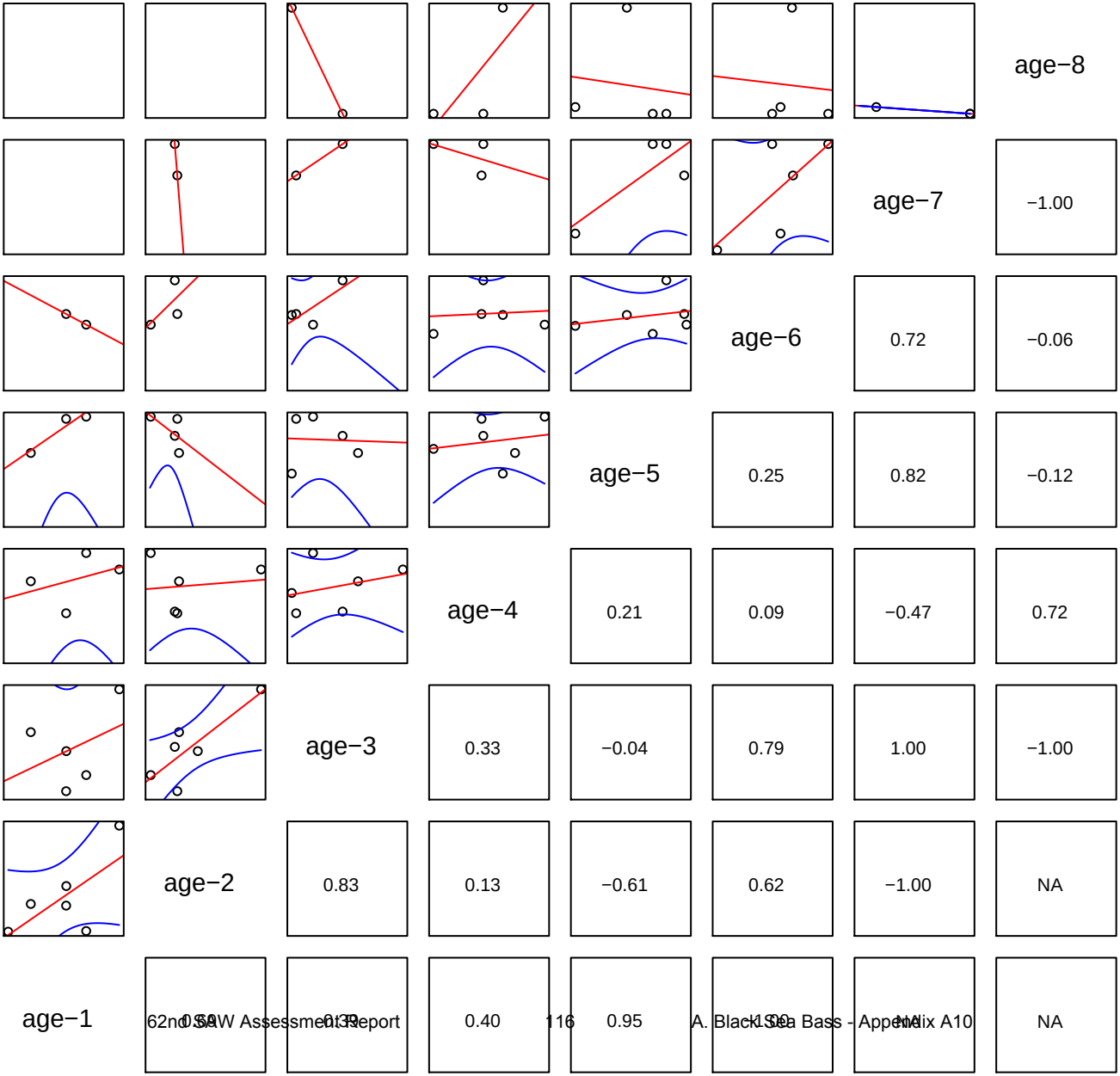
Index 9 Observed



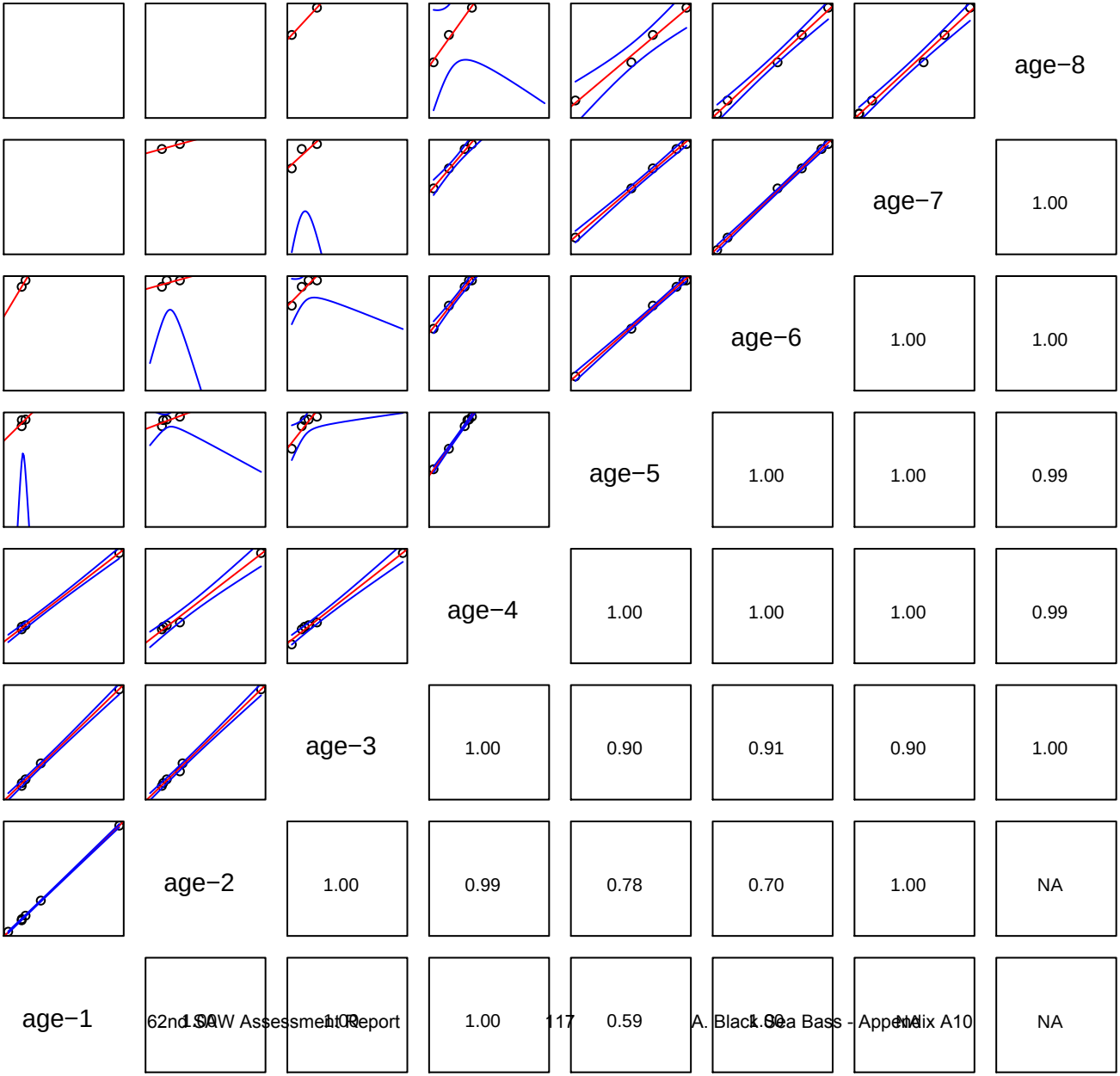
Index 9 Predicted

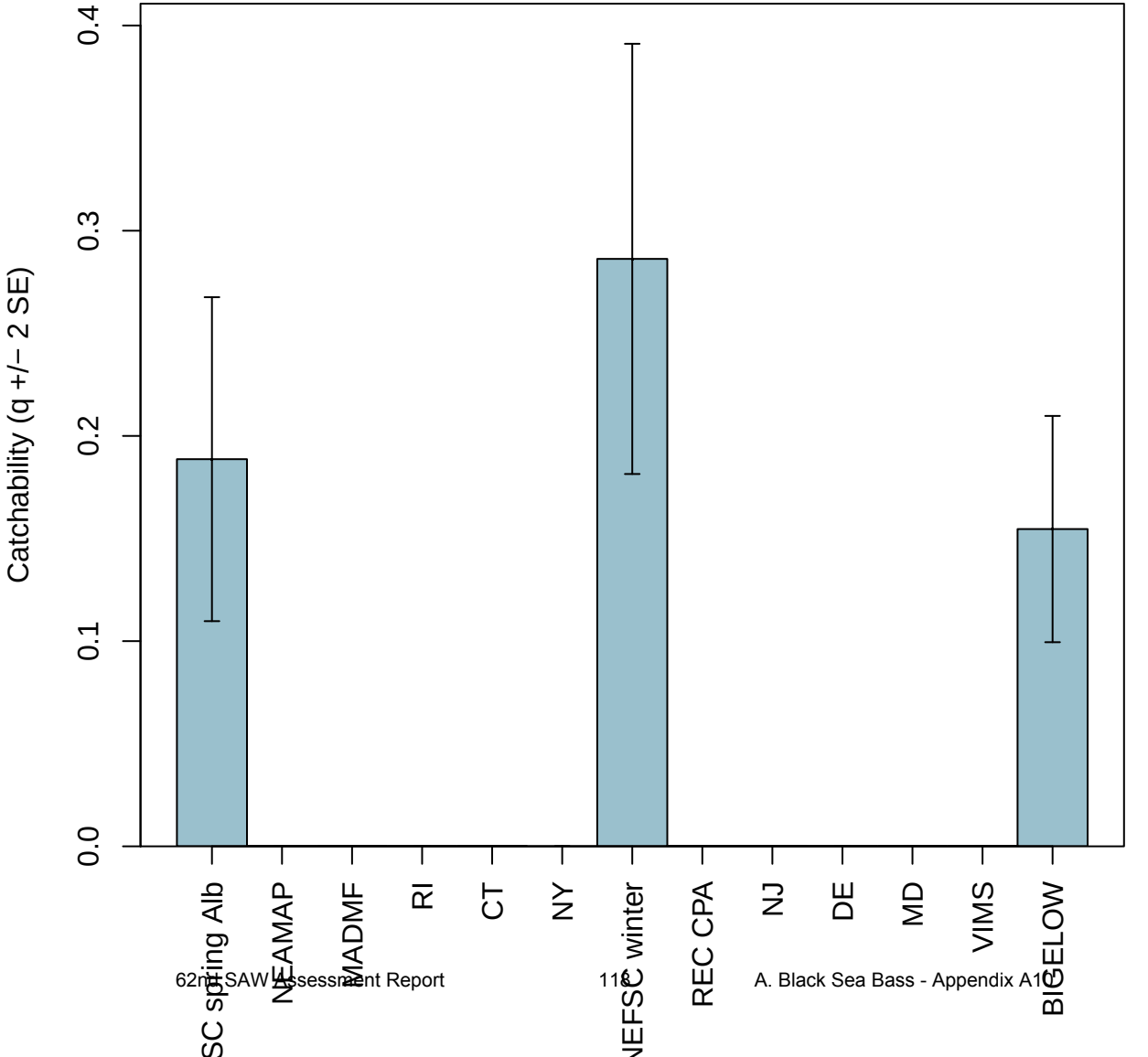


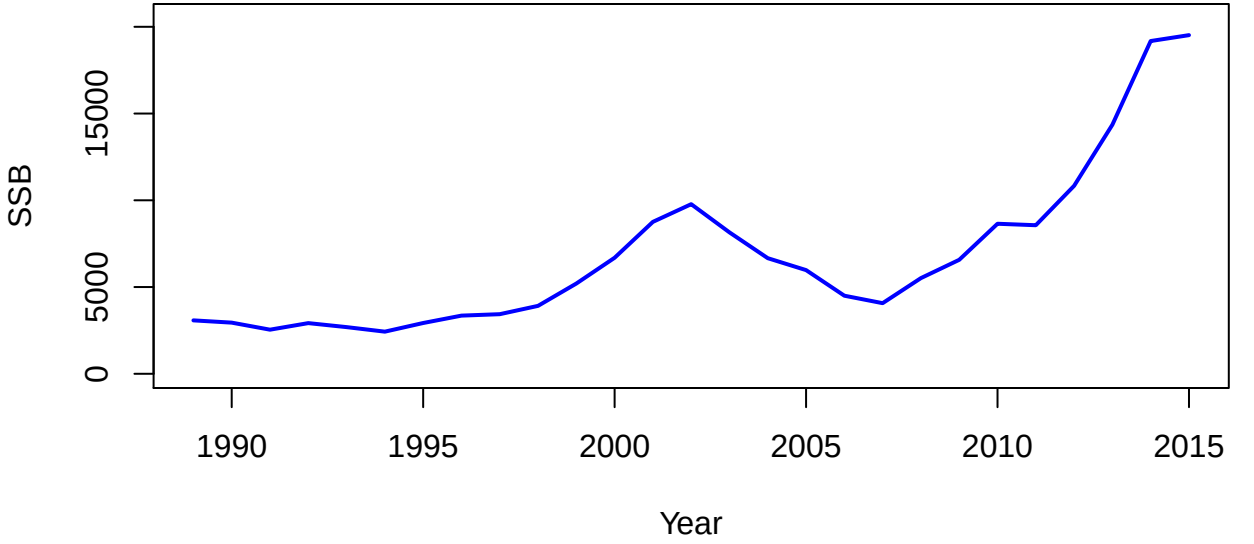
Index 13 Observed

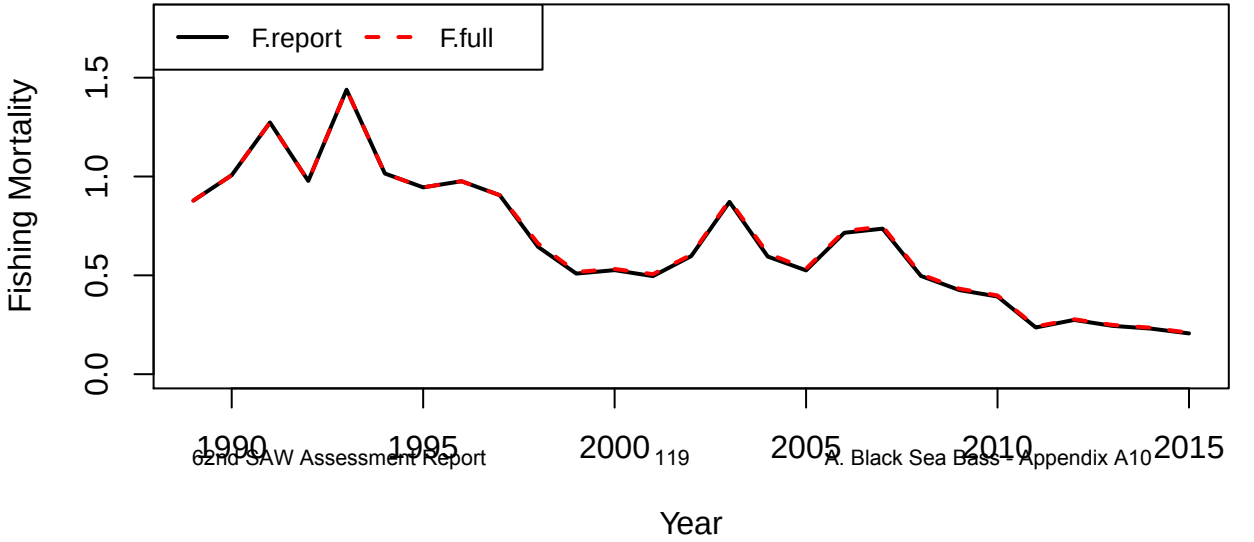


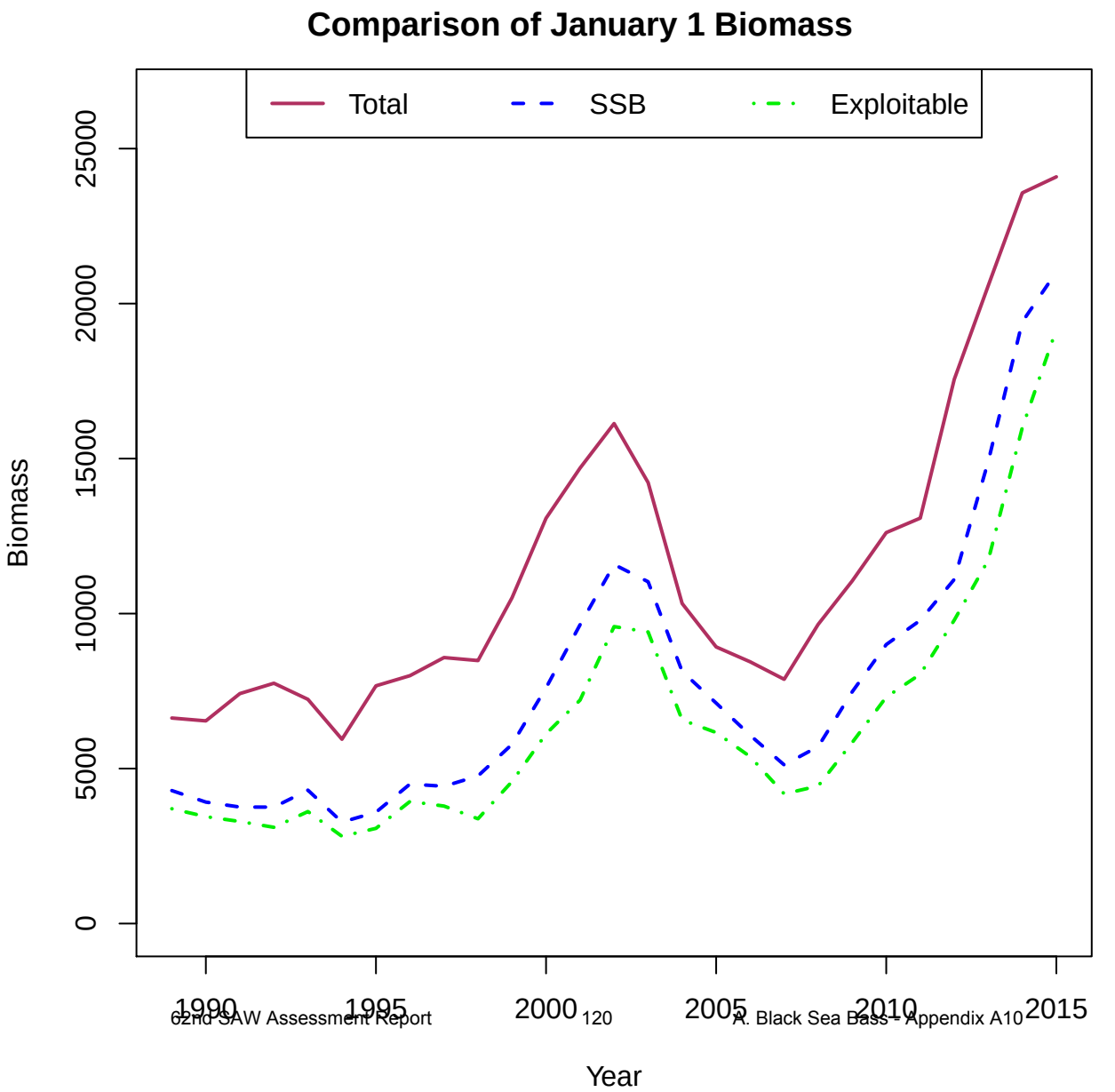
Index 13 Predicted

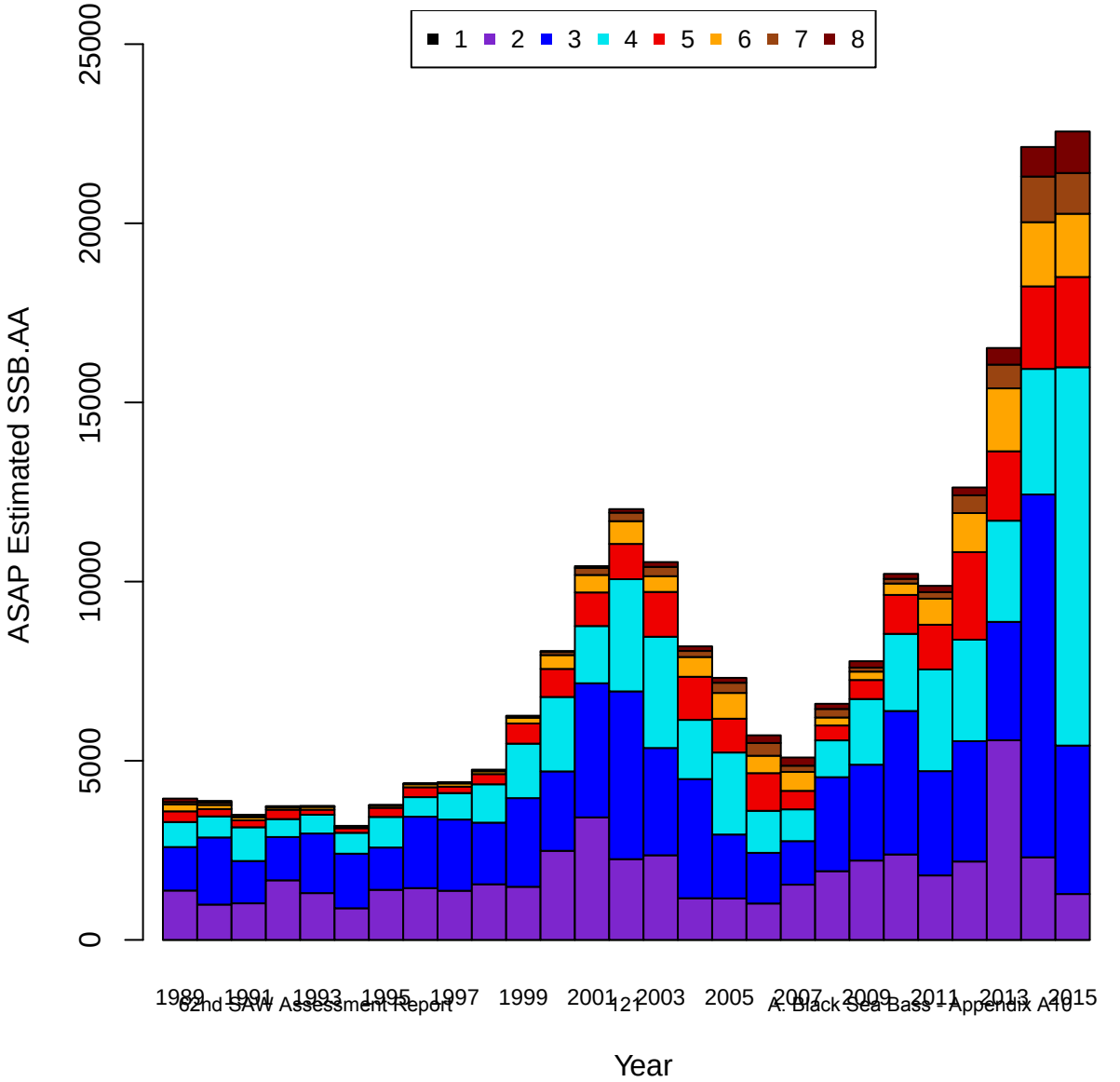


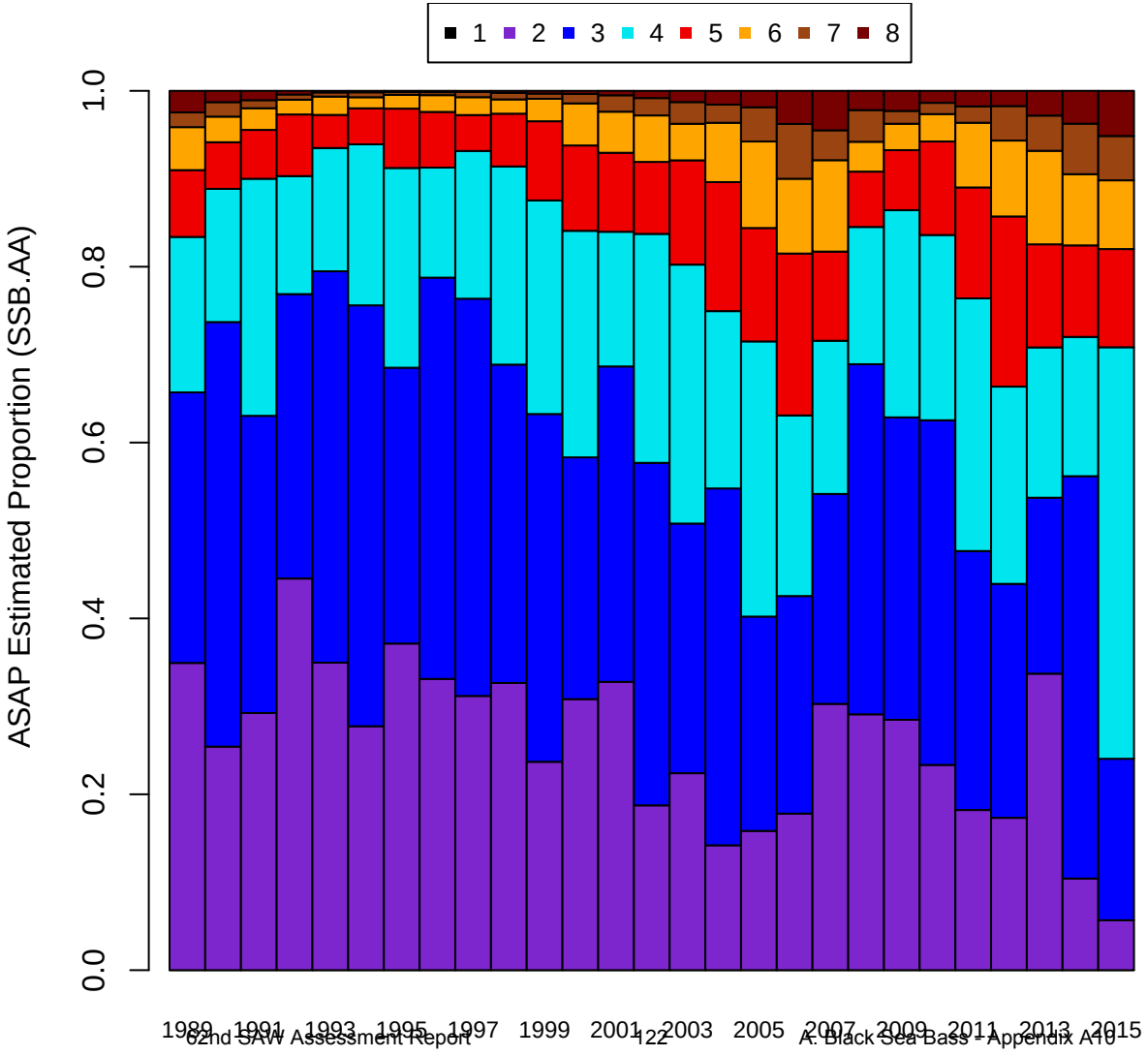

Catchability (q +/− 2 SE)
0.0
0.1
0.2
0.3
0.4
SC spring Alb
NEAMAP
MADMF
RI
CT
NY
NEFSC winter
REC CPA
NJ
DE
MD
VIMS
BIGELOW

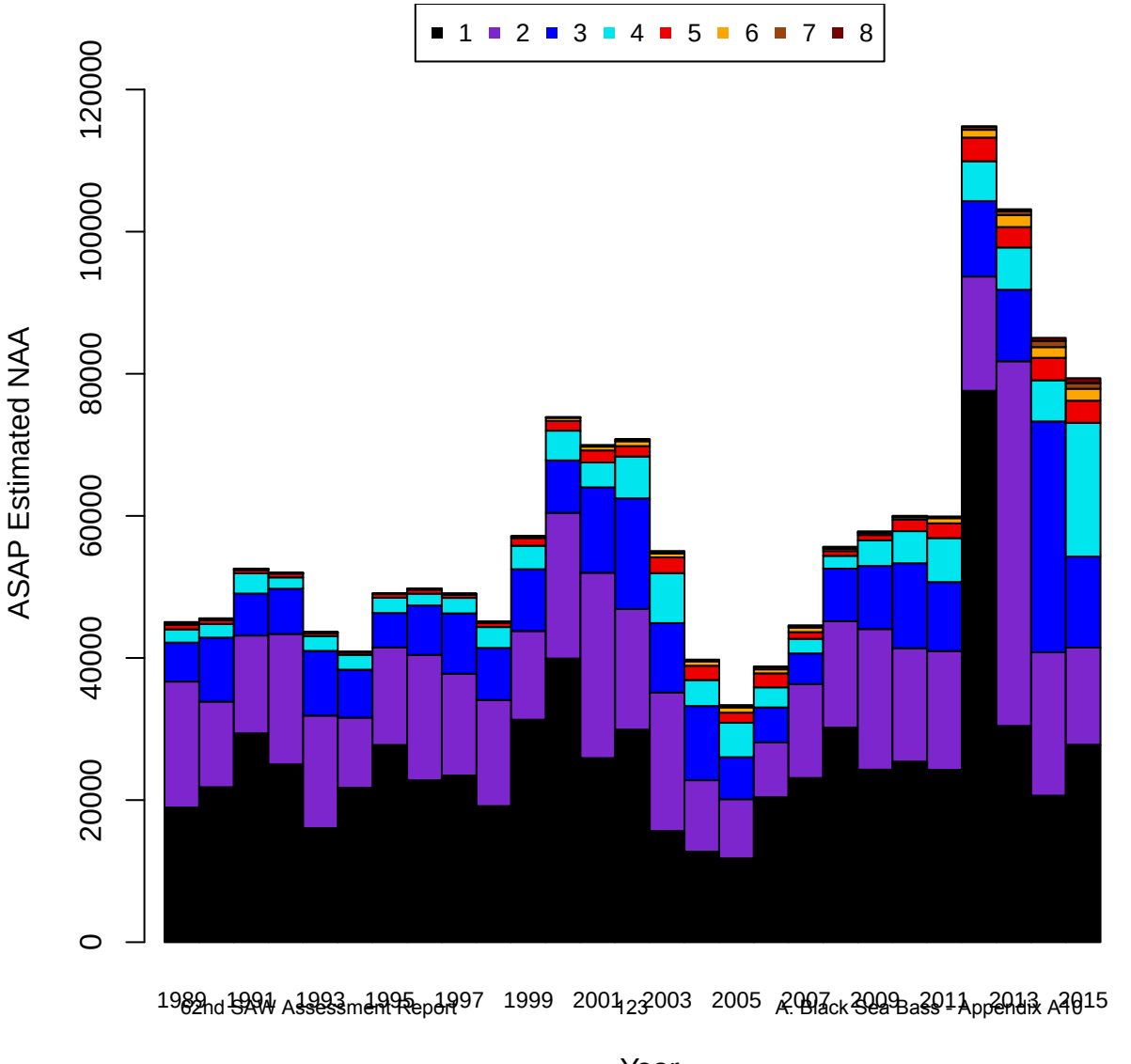

SSB
0
5000
15000
1990
1995
2000
2005
2010
2015
Year

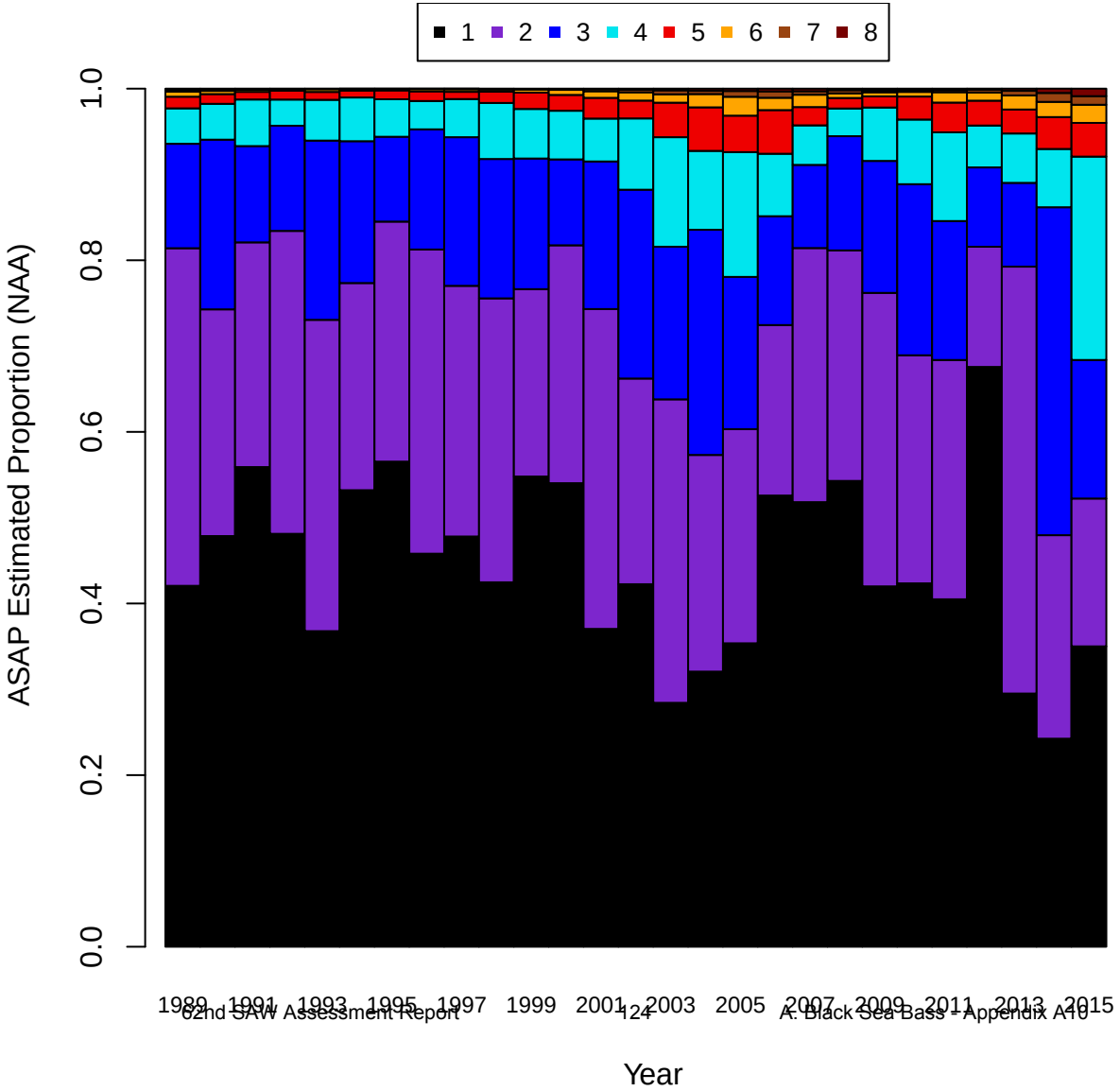

F.report
F.full
Fishing Mortality
0.0
0.5
1.0
1.5
1990
1995
2000
2005
2010
2015
Year

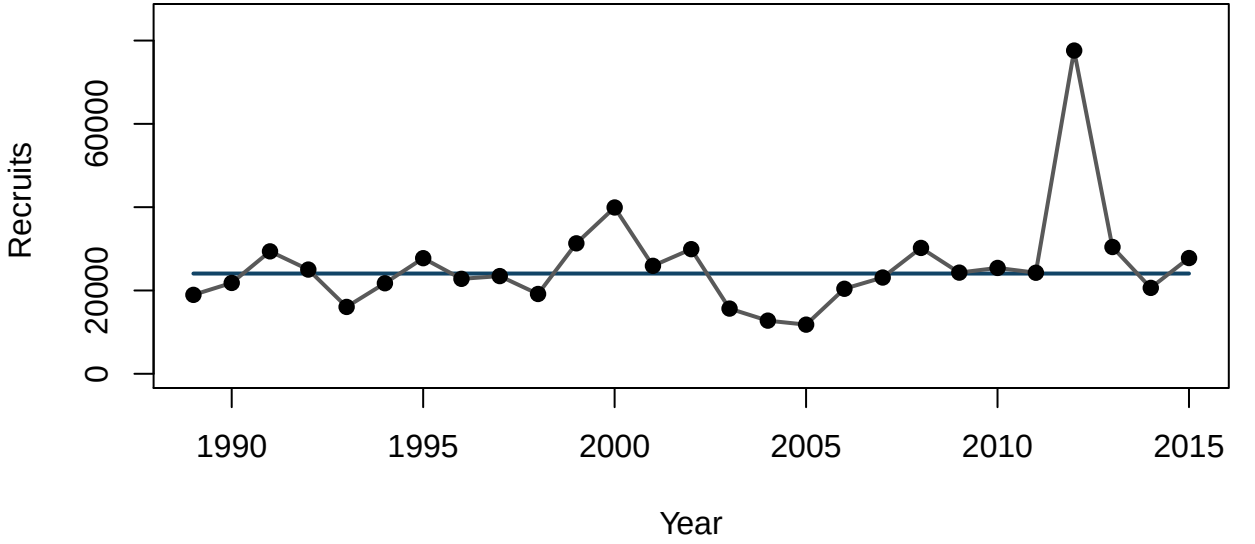

Comparison of January 1 Biomass
Total
SSB
Exploitable
Biomass
0
5000
10000
15000
20000
25000
1990
1995
2000
2005
2010
2015
Year

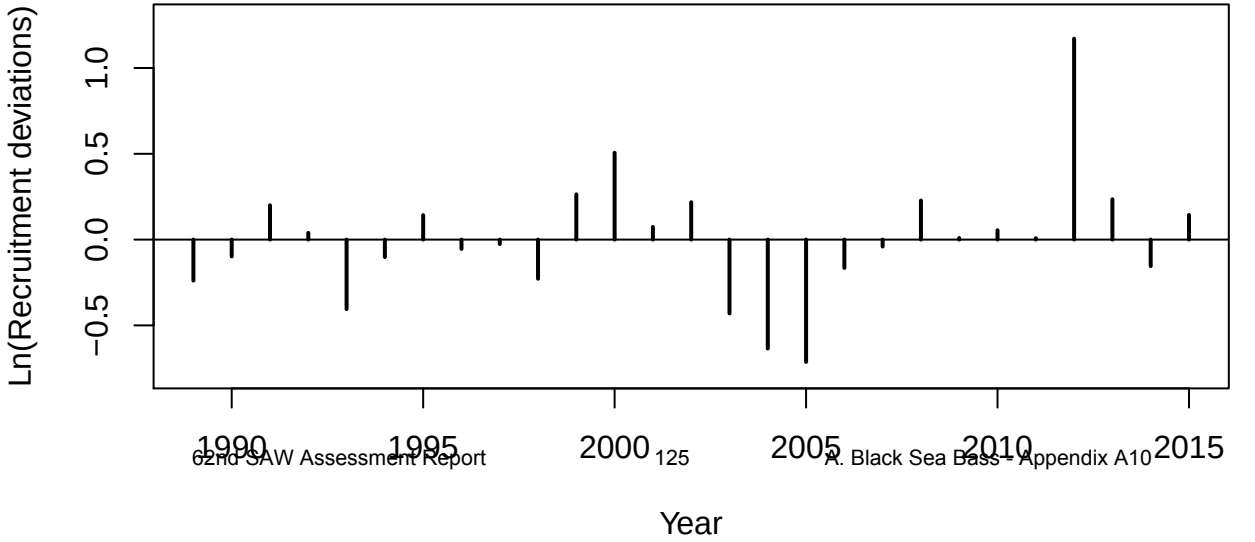

1 2 3 4 5 6 7 8
ASAP Estimated SSB.AA
0
5000
10000
15000
20000
25000
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

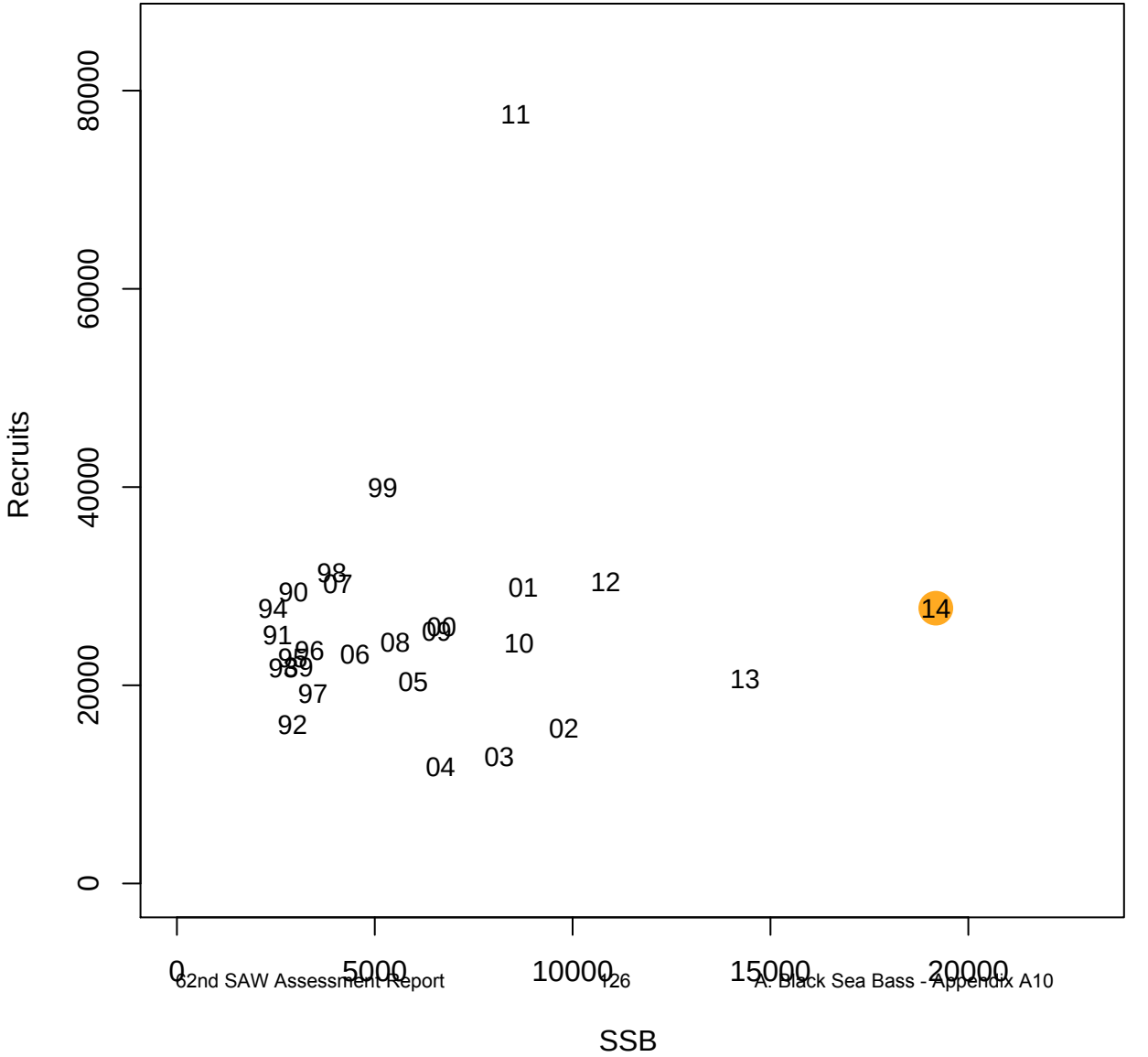

1 2 3 4 5 6 7 8
ASAP Estimated Proportion (SSB.AA)
0.0
0.2
0.4
0.6
0.8
1.0
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

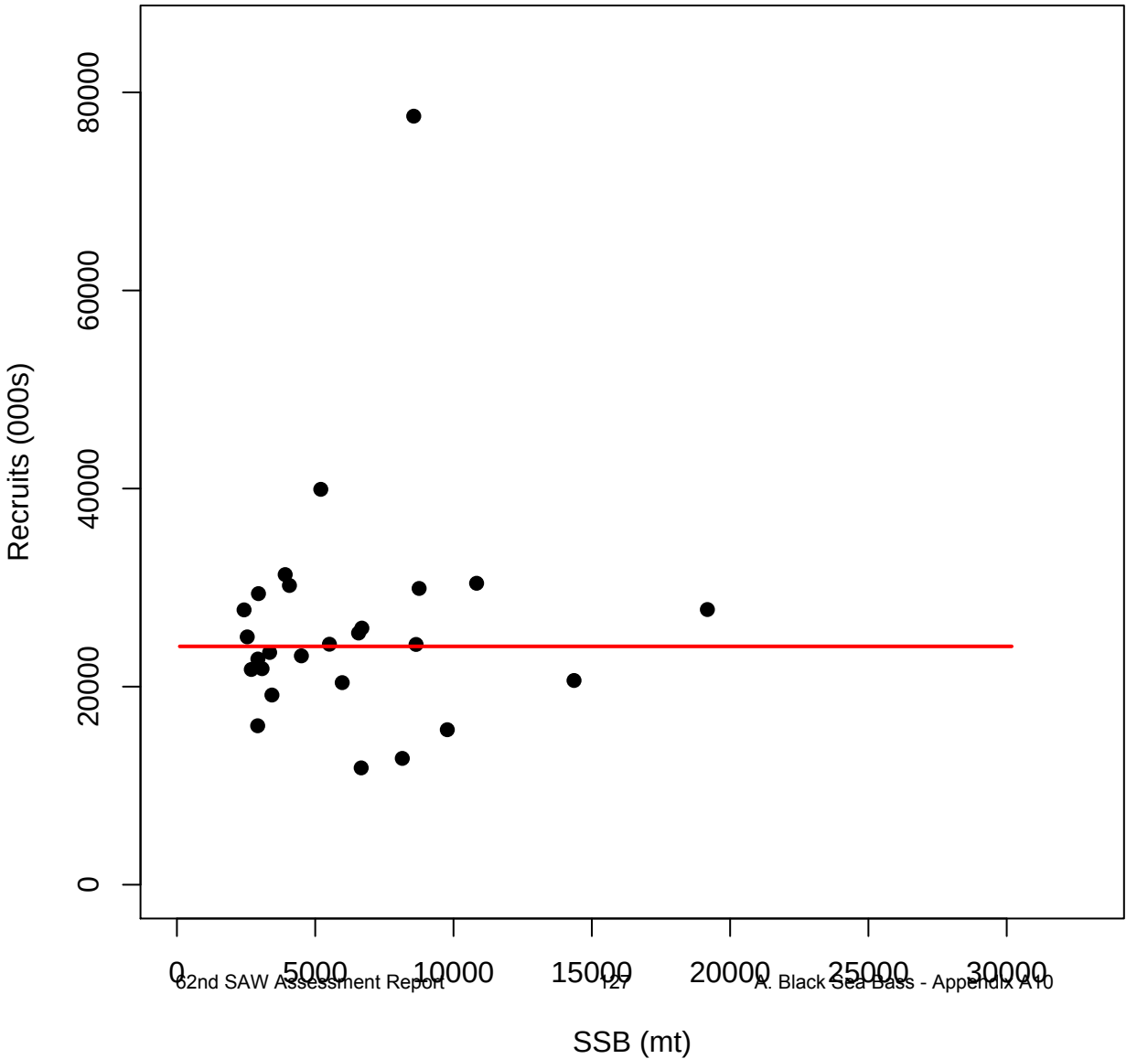

1 2 3 4 5 6 7 8
ASAP Estimated NAA
0
20000
40000
60000
80000
100000
120000
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

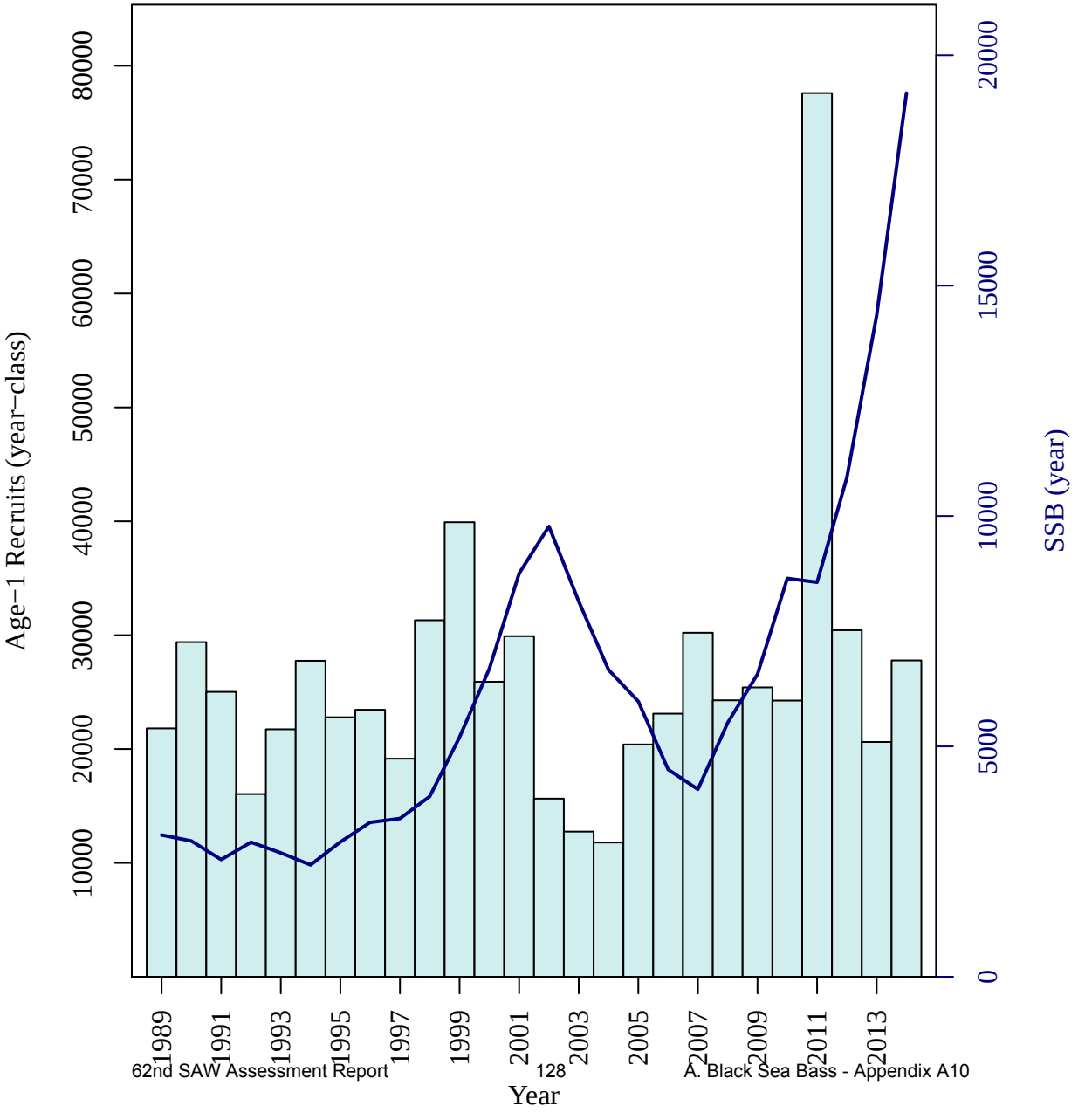

1 2 3 4 5 6 7 8
ASAP Estimated Proportion (NAA)
0.0
0.2
0.4
0.6
0.8
1.0
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

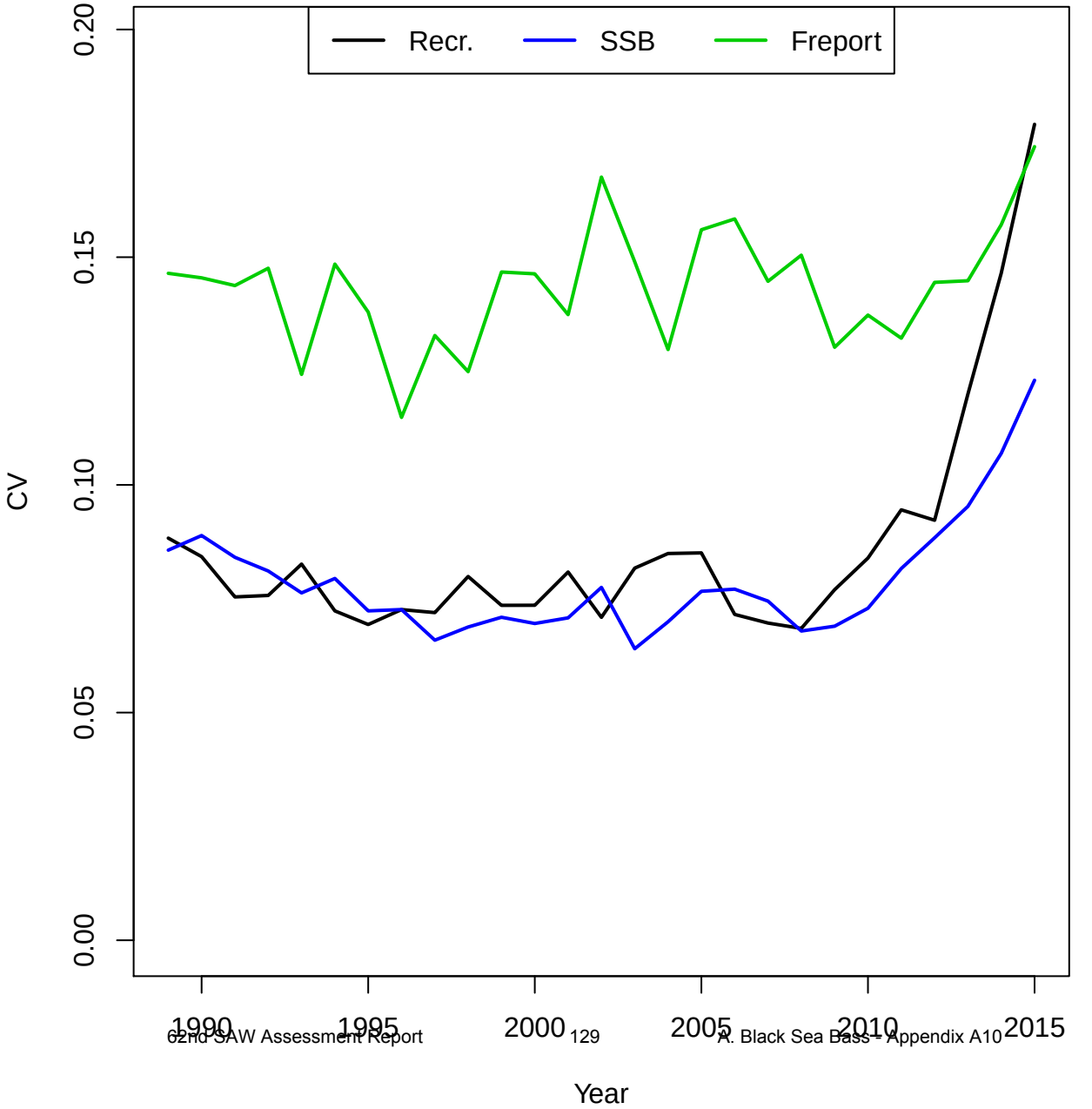

Recruits
0
20000
60000
1990
1995
2000
2005
2010
2015
Year

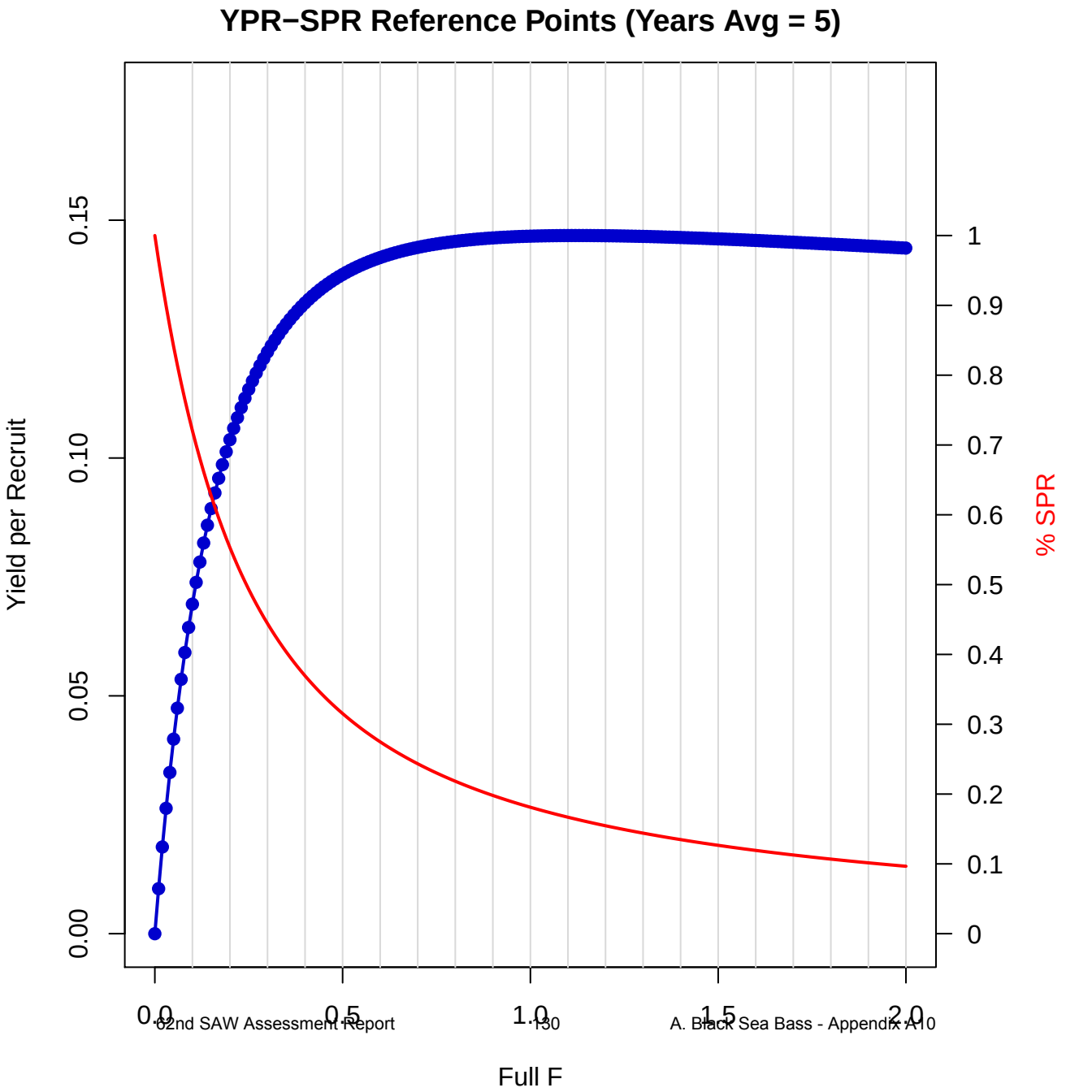

Ln(Recruitment deviations)
−0.5
0.0
0.5
1.0
1990
1995
2000
2005
2010
2015
Year


Recruits
SSB
0
20000
40000
60000
80000
0
5000
10000
15000
20000
11
99
98
90
07
94
91
96
06
08
09
00
01
12
10
14
13
05
97
92
02
03
04


Recruits (000s)
0
20000
40000
60000
80000
0
5000
10000
15000
20000
25000
30000
SSB (mt)

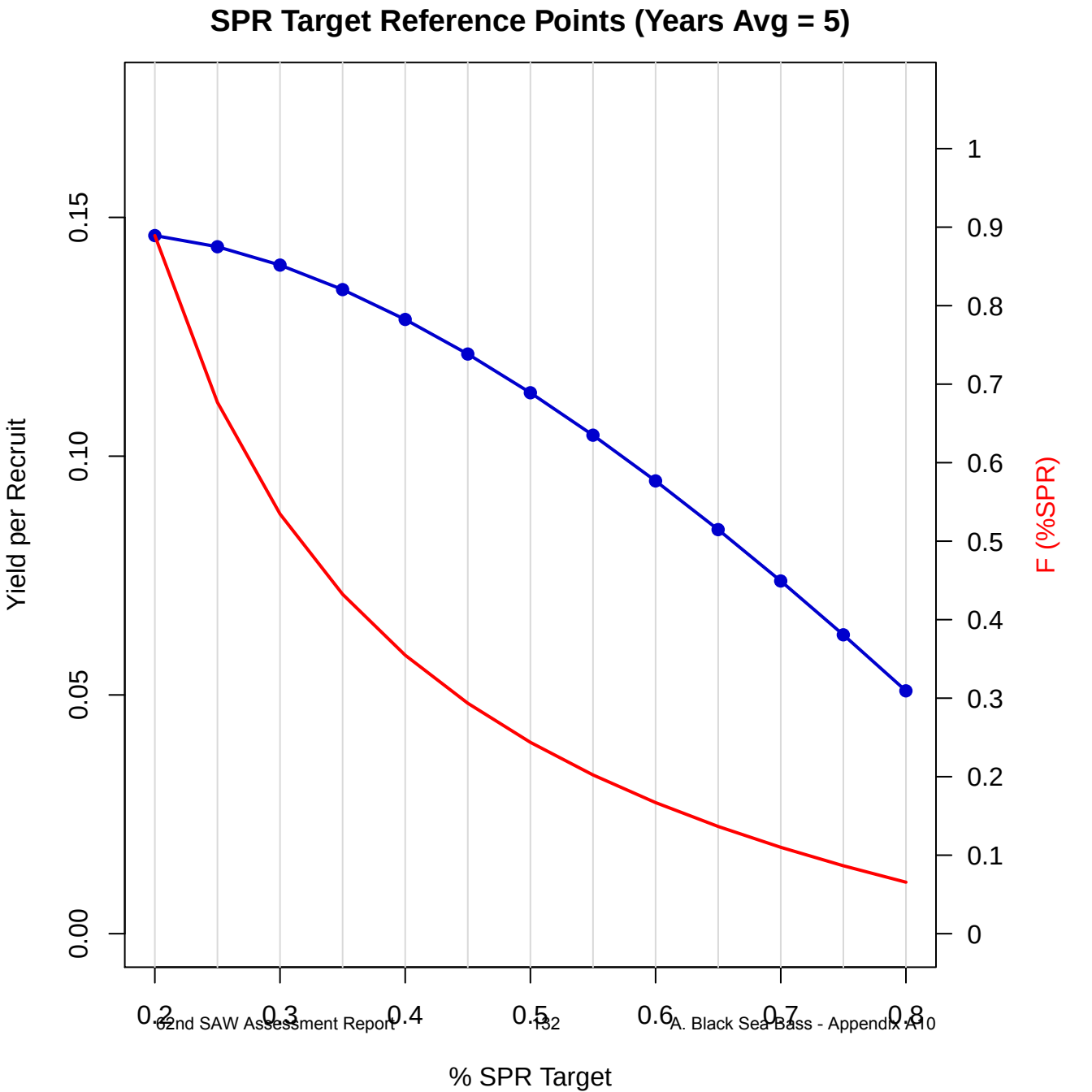

Age−1 Recruits (year−class)
10000
20000
30000
40000
50000
60000
70000
80000
SSB (year)
0
5000
10000
15000
20000
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Year


Recr.
SSB
Freport
CV
0.00
0.05
0.10
0.15
0.20
1990
1995
2000
2005
2010
2015
Year


YPR−SPR Reference Points (Years Avg = 5)
Yield per Recruit
% SPR
Full F
0.00
0.05
0.10
0.15
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.0
0.5
1.0
1.5
2.0

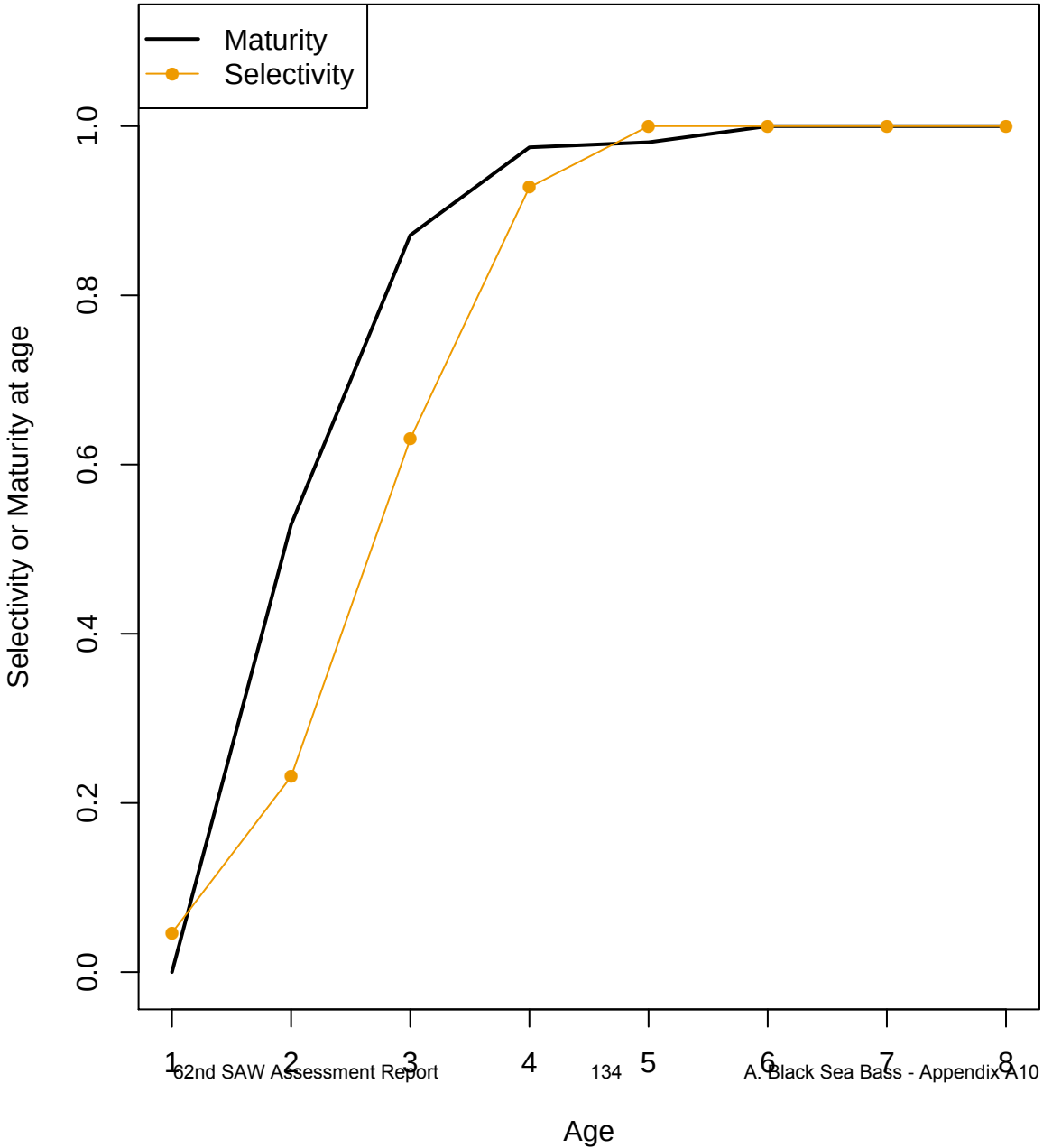
YPR−SPR Reference Points (Years Avg = 5)

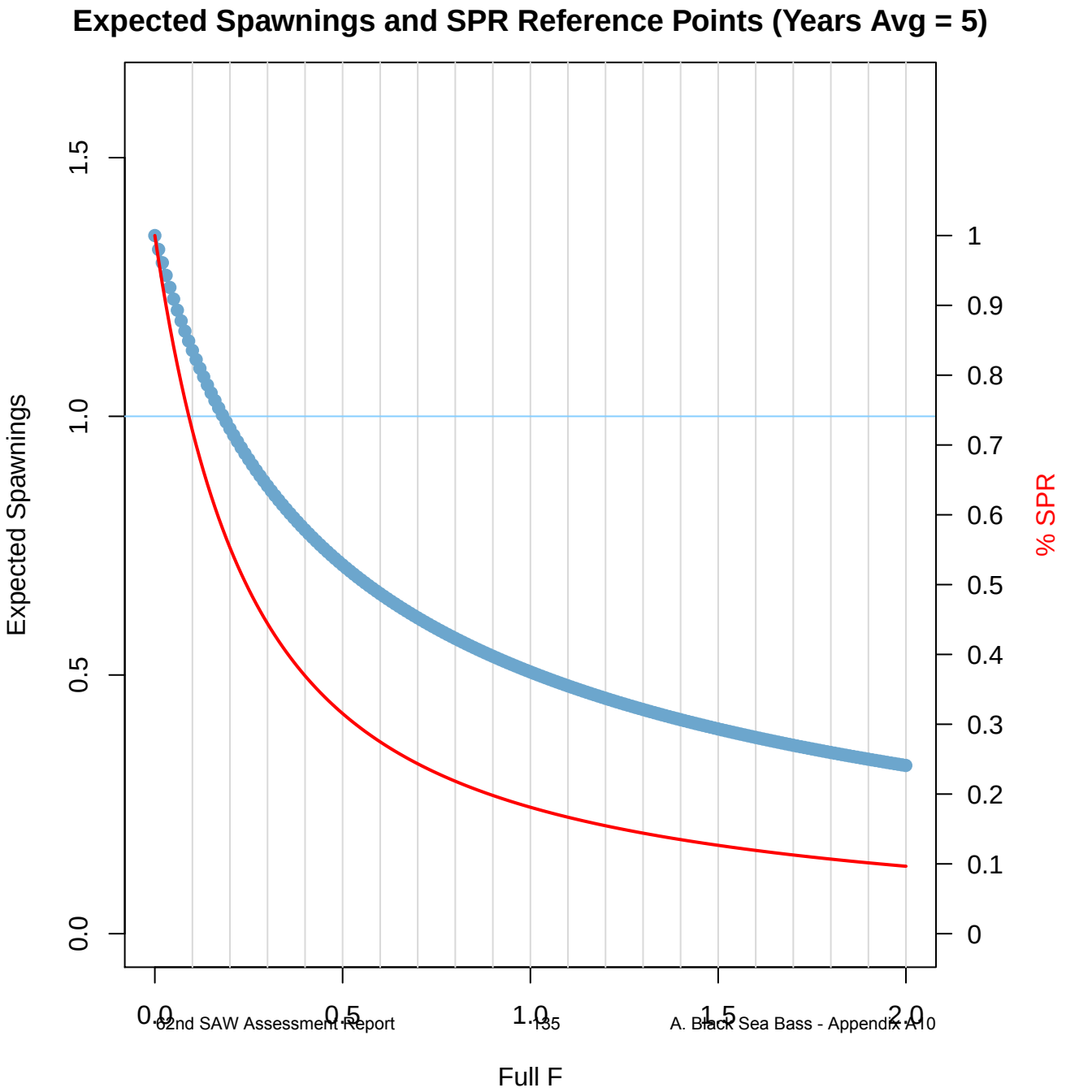
F	YPR	SPR	F	YPR	SPR	F	YPR	SPR
0	0	1	0.35	0.1282	0.4035	0.7	0.1443	0.2434
0.01	0.0095	0.9644	0.36	0.1291	0.3962	0.71	0.1444	0.2406
0.02	0.0182	0.9308	0.37	0.1301	0.3892	0.72	0.1446	0.2379
0.03	0.0264	0.8992	0.38	0.131	0.3823	0.73	0.1447	0.2353
0.04	0.0339	0.8693	0.39	0.1318	0.3757	0.74	0.1449	0.2327
0.05	0.0409	0.8411	0.4	0.1326	0.3693	0.75	0.145	0.2302
0.06	0.0474	0.8143	0.41	0.1333	0.3631	0.76	0.1451	0.2277
0.07	0.0535	0.789	0.42	0.1341	0.3572	0.77	0.1452	0.2253
0.08	0.0591	0.765	0.43	0.1347	0.3514	0.78	0.1453	0.223
0.09	0.0644	0.7422	0.44	0.1354	0.3457	0.79	0.1454	0.2206
0.1	0.0693	0.7206	0.45	0.136	0.3403	0.8	0.1455	0.2184
0.11	0.0739	0.7	0.46	0.1366	0.335	0.81	0.1456	0.2161
0.12	0.0781	0.6804	0.47	0.1371	0.3298	0.82	0.1457	0.214
0.13	0.0821	0.6618	0.48	0.1376	0.3249	0.83	0.1458	0.2118
0.14	0.0859	0.644	0.49	0.1381	0.32	0.84	0.1459	0.2097
0.15	0.0894	0.6271	0.5	0.1386	0.3153	0.85	0.146	0.2077
0.16	0.0927	0.6109	0.51	0.139	0.3107	0.86	0.146	0.2057
0.17	0.0957	0.5954	0.52	0.1394	0.3063	0.87	0.1461	0.2037
0.18	0.0986	0.5806	0.53	0.1398	0.302	0.88	0.1461	0.2018
0.19	0.1013	0.5665	0.54	0.1402	0.2978	0.89	0.1462	0.1999
0.2	0.1039	0.5529	0.55	0.1406	0.2937	0.9	0.1463	0.198
0.21	0.1062	0.54	0.56	0.1409	0.2897	0.91	0.1463	0.1962
0.22	0.1085	0.5275	0.57	0.1412	0.2858	0.92	0.1464	0.1944
0.23	0.1106	0.5156	0.58	0.1416	0.282	0.93	0.1464	0.1926
0.24	0.1126	0.5042	0.59	0.1418	0.2784	0.94	0.1464	0.1909
0.25	0.1144	0.4932	0.6	0.1421	0.2748	0.95	0.1465	0.1892
0.26	0.1162	0.4826	0.61	0.1424	0.2713	0.96	0.1465	0.1875
0.27	0.1179	0.4724	0.62	0.1426	0.2679	0.97	0.1466	0.1859
0.28	0.1194	0.4627	0.63	0.1429	0.2645	0.98	0.1466	0.1842
0.29	0.1209	0.4533	0.64	0.1431	0.2613	0.99	0.1466	0.1827
0.3	0.1223	0.4442	0.65	0.1433	0.2581	1	0.1466	0.1811
0.31	0.1236	0.4355	0.66	0.1435	0.255	1.01	0.1467	0.1796
0.32	0.1248	0.427	0.67	0.1437	0.252	1.02	0.1467	0.1781
0.33	0.126	0.4189	0.68	0.1439	0.2491	1.03	0.1467	0.1766
0.34	0.1271	0.4111	0.69	0.1441	0.2462	1.04	0.1467	0.1751


SPR Target Reference Points (Years Avg = 5)
Yield per Recruit
0.00
0.05
0.10
0.15
F (%SPR)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
% SPR Target

SPR Target Reference Points (Years Avg = 5)

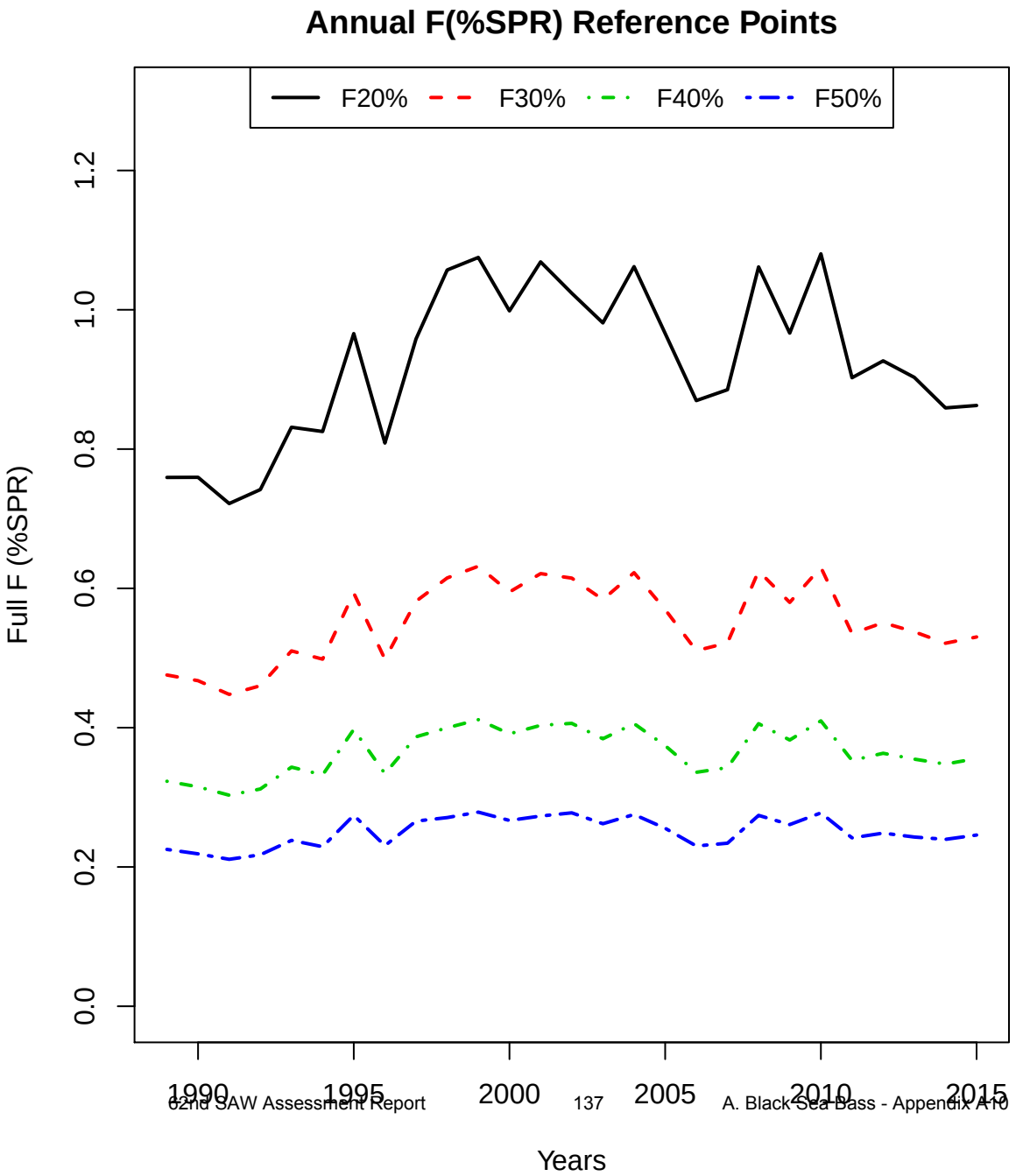
% SPR	F(%SPR)	YPR
0.2	0.8893	0.1462
0.25	0.6768	0.1439
0.3	0.5347	0.14
0.35	0.4324	0.1349
0.4	0.3548	0.1286
0.45	0.2935	0.1214
0.5	0.2437	0.1133
0.55	0.2022	0.1044
0.6	0.167	0.0948
0.65	0.1366	0.0846
0.7	0.11	0.0739
0.75	0.0865	0.0626
0.8	0.0656	0.0509

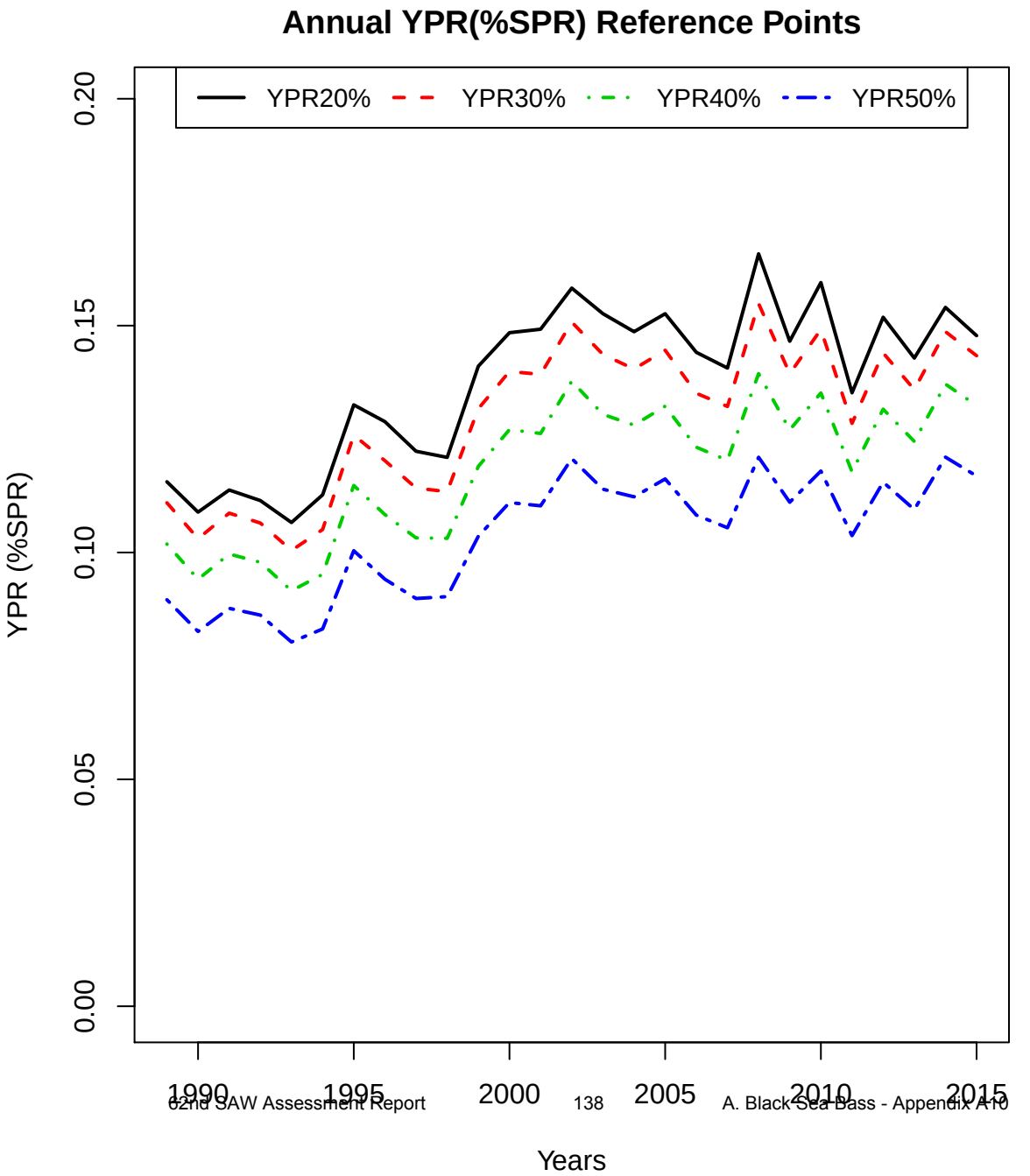

Maturity
Selectivity
Selectivity or Maturity at age
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
8
Age


Expected Spawnings and SPR Reference Points (Years Avg = 5)
Expected Spawnings
% SPR
Full F
0.0
0.5
1.0
1.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.0
0.5
1.0
1.5
2.0

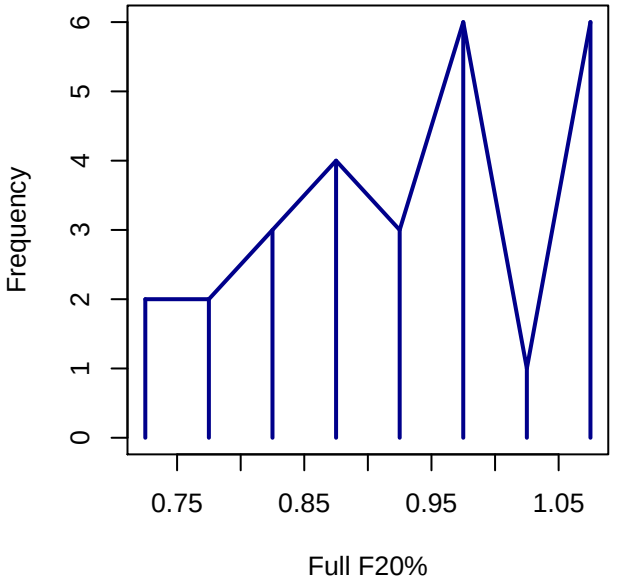
Expected Spawnings & SPR Reference Points (Years Avg = 5)

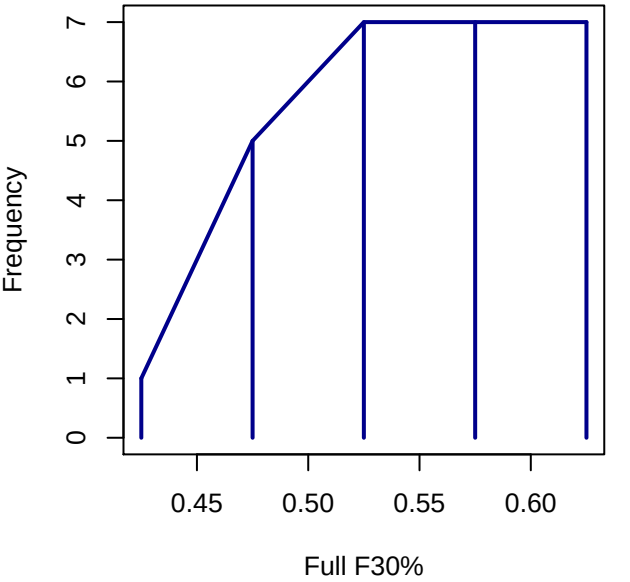
F	E[Sp]	SPR	F	E[Sp]	SPR	F	E[Sp]	SPR
0	1.3494	1	0.35	0.8205	0.4035	0.7	0.6106	0.2434
0.01	1.3226	0.9644	0.36	0.8121	0.3962	0.71	0.6064	0.2406
0.02	1.297	0.9308	0.37	0.8039	0.3892	0.72	0.6022	0.2379
0.03	1.2725	0.8992	0.38	0.796	0.3823	0.73	0.598	0.2353
0.04	1.2491	0.8693	0.39	0.7882	0.3757	0.74	0.594	0.2327
0.05	1.2266	0.8411	0.4	0.7805	0.3693	0.75	0.59	0.2302
0.06	1.2051	0.8143	0.41	0.7731	0.3631	0.76	0.586	0.2277
0.07	1.1845	0.789	0.42	0.7658	0.3572	0.77	0.5821	0.2253
0.08	1.1647	0.765	0.43	0.7587	0.3514	0.78	0.5783	0.223
0.09	1.1457	0.7422	0.44	0.7517	0.3457	0.79	0.5745	0.2206
0.1	1.1274	0.7206	0.45	0.7449	0.3403	0.8	0.5708	0.2184
0.11	1.1098	0.7	0.46	0.7382	0.335	0.81	0.5671	0.2161
0.12	1.0928	0.6804	0.47	0.7317	0.3298	0.82	0.5635	0.214
0.13	1.0764	0.6618	0.48	0.7252	0.3249	0.83	0.56	0.2118
0.14	1.0606	0.644	0.49	0.719	0.32	0.84	0.5564	0.2097
0.15	1.0453	0.6271	0.5	0.7128	0.3153	0.85	0.553	0.2077
0.16	1.0305	0.6109	0.51	0.7068	0.3107	0.86	0.5495	0.2057
0.17	1.0163	0.5954	0.52	0.7008	0.3063	0.87	0.5462	0.2037
0.18	1.0025	0.5806	0.53	0.695	0.302	0.88	0.5428	0.2018
0.19	0.9891	0.5665	0.54	0.6893	0.2978	0.89	0.5396	0.1999
0.2	0.9761	0.5529	0.55	0.6837	0.2937	0.9	0.5363	0.198
0.21	0.9636	0.54	0.56	0.6782	0.2897	0.91	0.5331	0.1962
0.22	0.9514	0.5275	0.57	0.6728	0.2858	0.92	0.5299	0.1944
0.23	0.9395	0.5156	0.58	0.6675	0.282	0.93	0.5268	0.1926
0.24	0.9281	0.5042	0.59	0.6623	0.2784	0.94	0.5237	0.1909
0.25	0.9169	0.4932	0.6	0.6572	0.2748	0.95	0.5207	0.1892
0.26	0.9061	0.4826	0.61	0.6522	0.2713	0.96	0.5177	0.1875
0.27	0.8955	0.4724	0.62	0.6473	0.2679	0.97	0.5147	0.1859
0.28	0.8852	0.4627	0.63	0.6424	0.2645	0.98	0.5118	0.1842
0.29	0.8753	0.4533	0.64	0.6376	0.2613	0.99	0.5089	0.1827
0.3	0.8655	0.4442	0.65	0.633	0.2581	1	0.506	0.1811
0.31	0.8561	0.4355	0.66	0.6283	0.255	1.01	0.5032	0.1796
0.32	0.8468	0.427	0.67	0.6238	0.252	1.02	0.5004	0.1781
0.33	0.8378	0.4189	0.68	0.6193	0.2491	1.03	0.4976	0.1766
0.34	0.829	0.4111	0.69	0.6149	0.2462	1.04	0.4949	0.1751

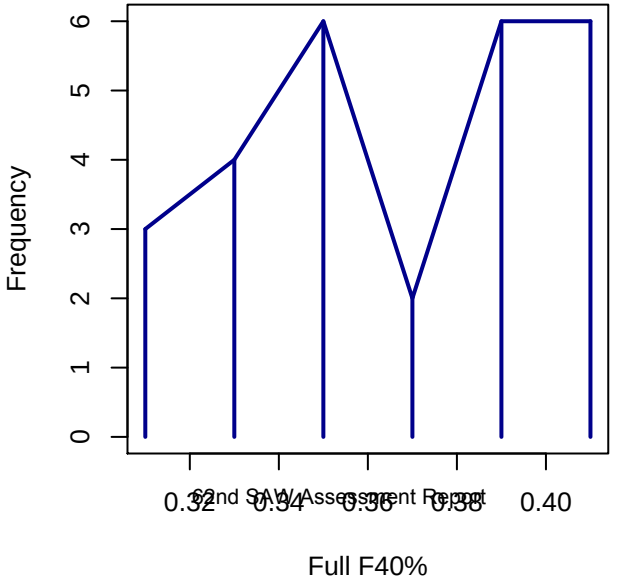

Annual F(%SPR) Reference Points
F20%
F30%
F40%
F50%
Full F (%SPR)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1990
1995
2000
2005
2010
2015
Years

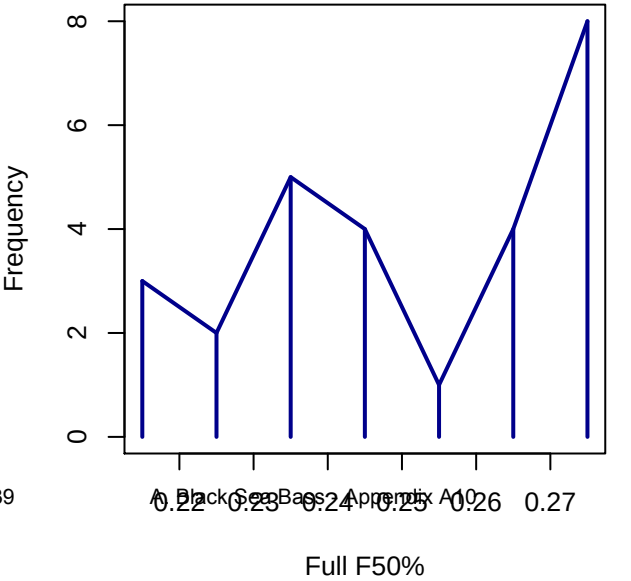

Annual YPR(%SPR) Reference Points
YPR20%
YPR30%
YPR40%
YPR50%
YPR (%SPR)
0.00
0.05
0.10
0.15
0.20
1990
1995
2000
2005
2010
2015
Years

Annual F (%SPR) Reference Points

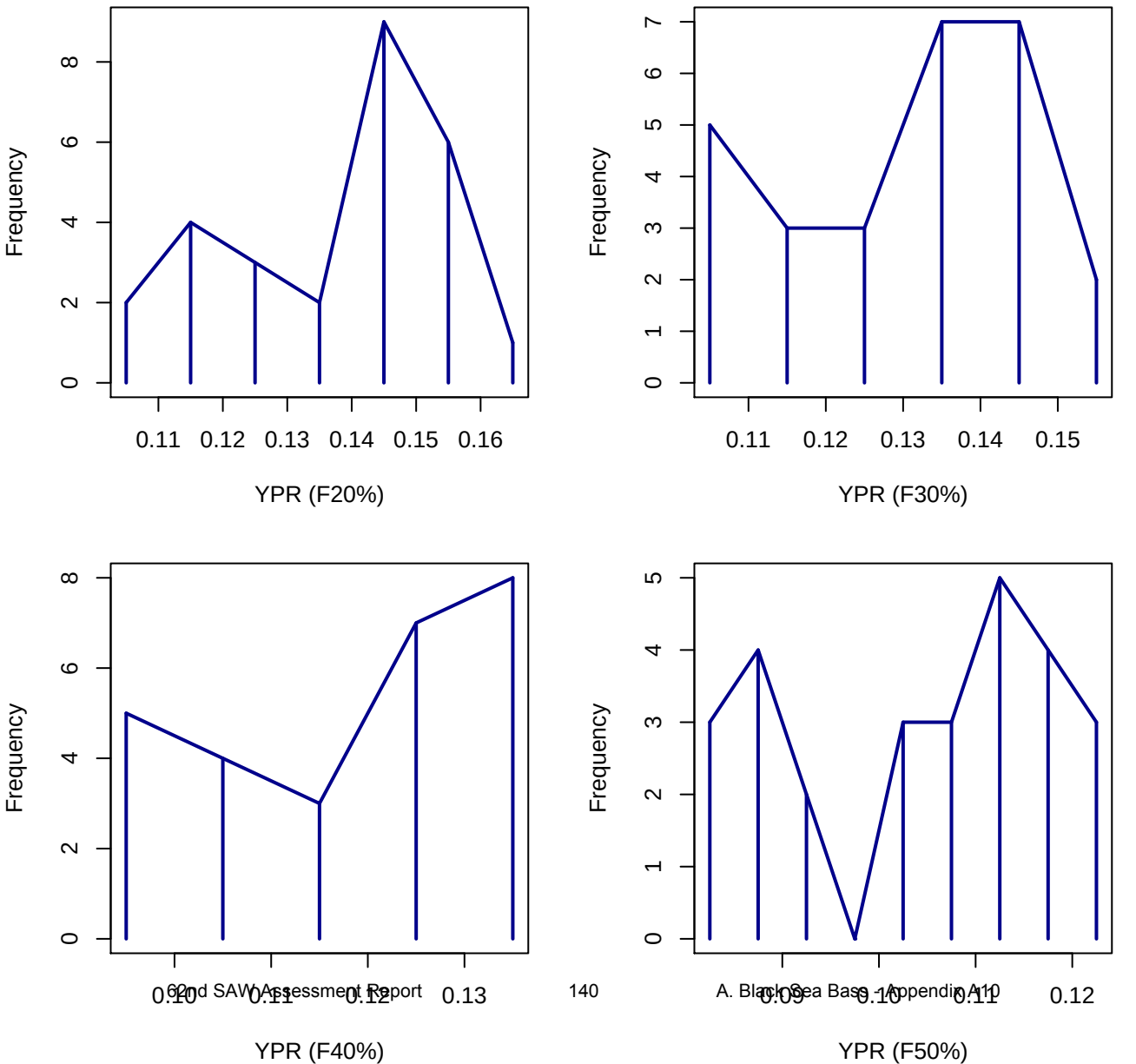


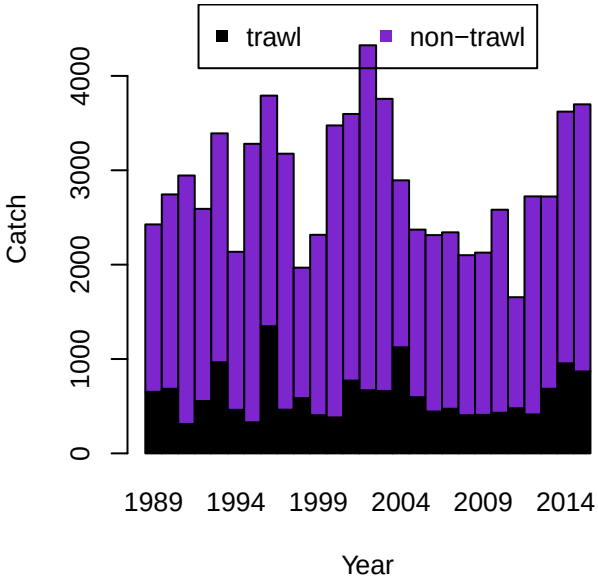


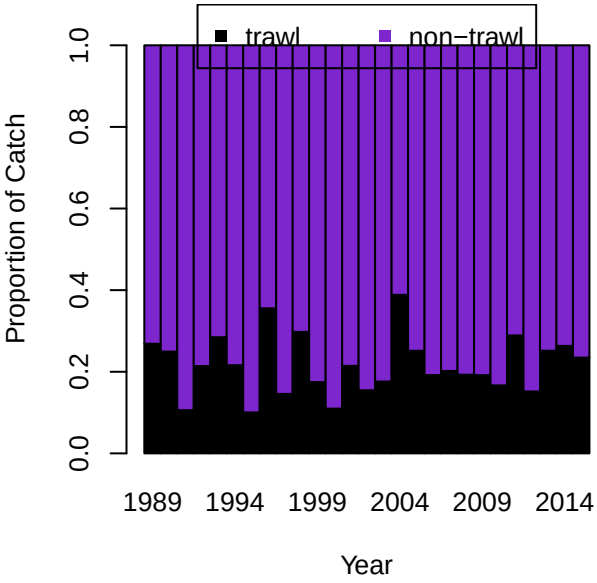


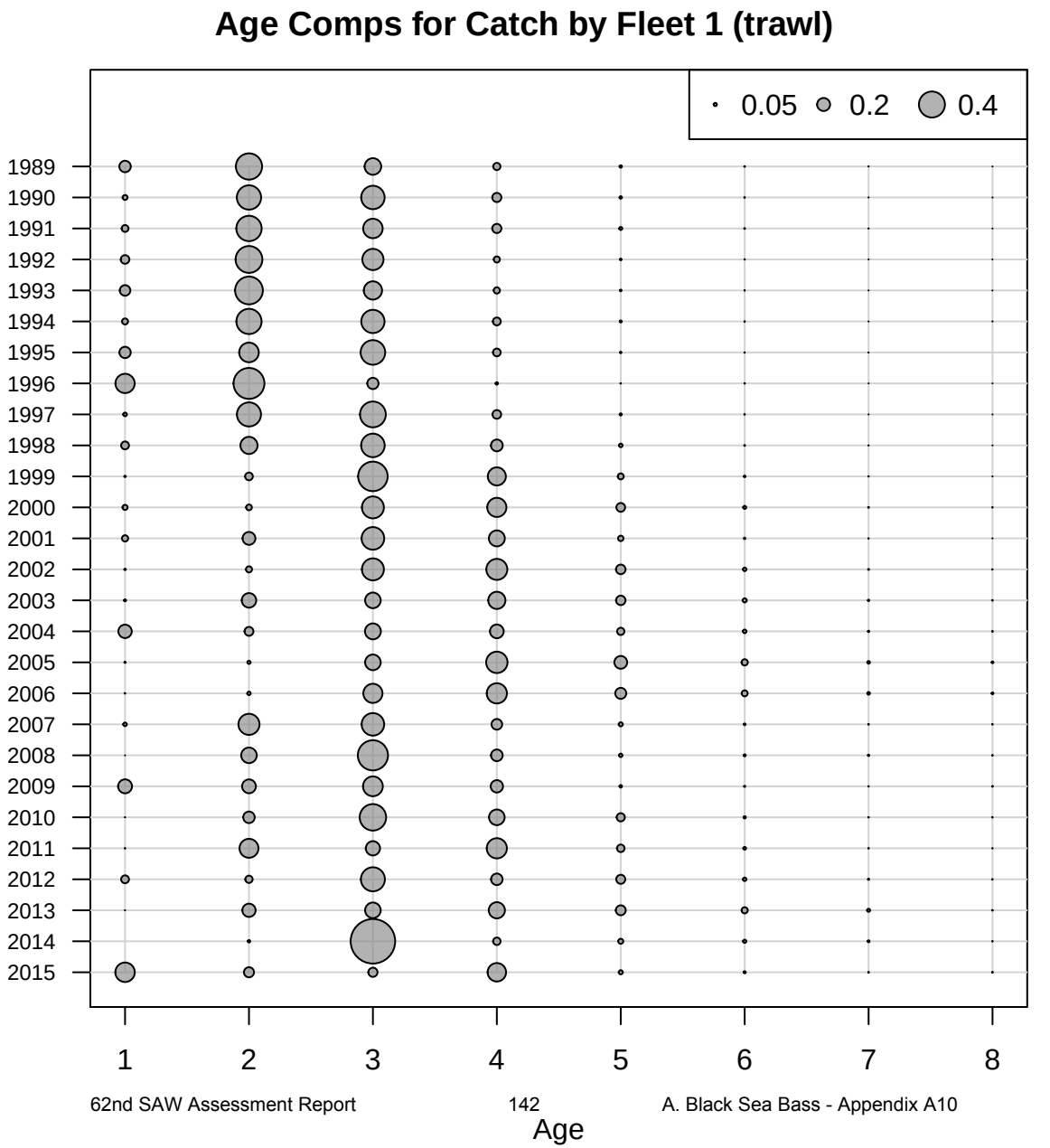


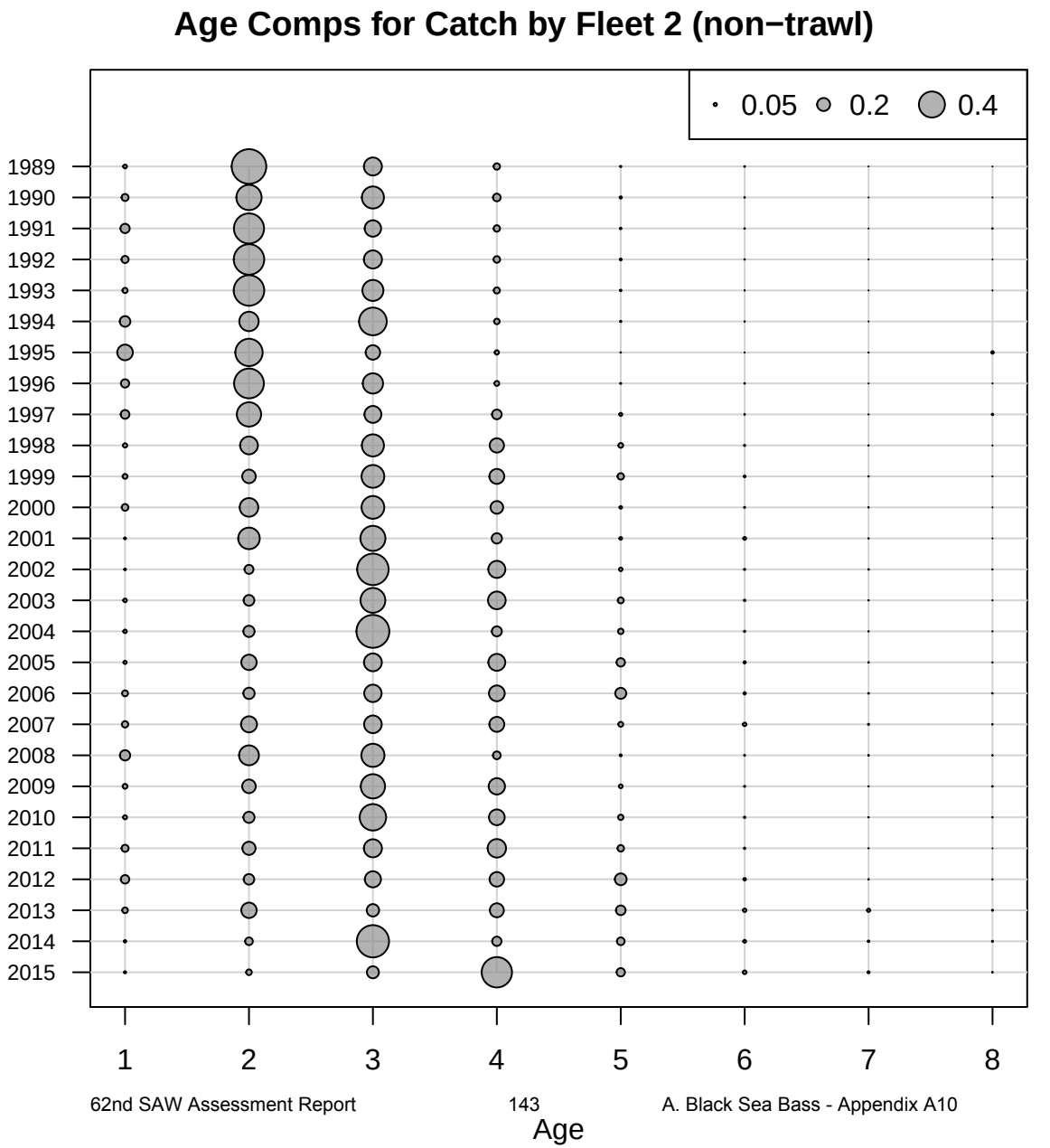
Annual YPR (%SPR) Reference Points

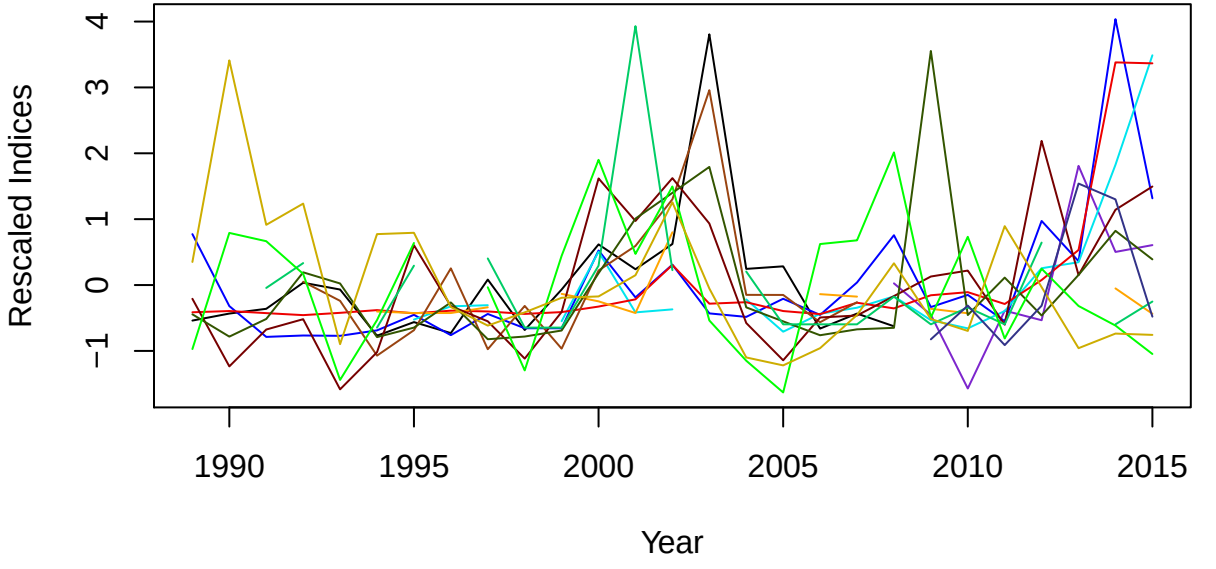


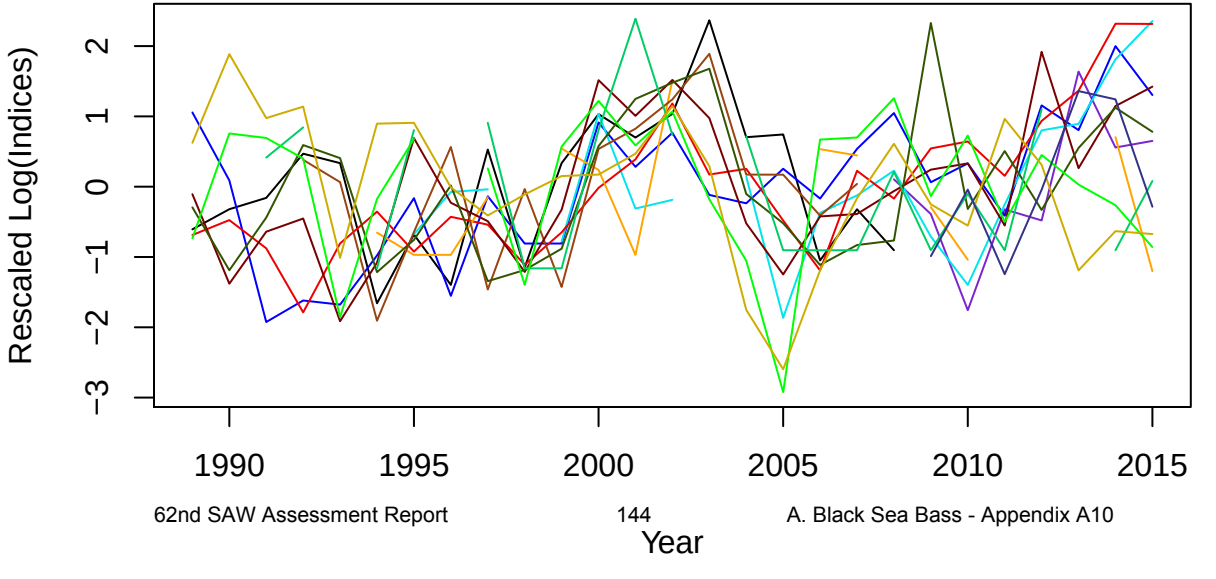

trawl
non−trawl
Catch
0
1000
2000
3000
4000
1989
1994
1999
2004
2009
2014
Year

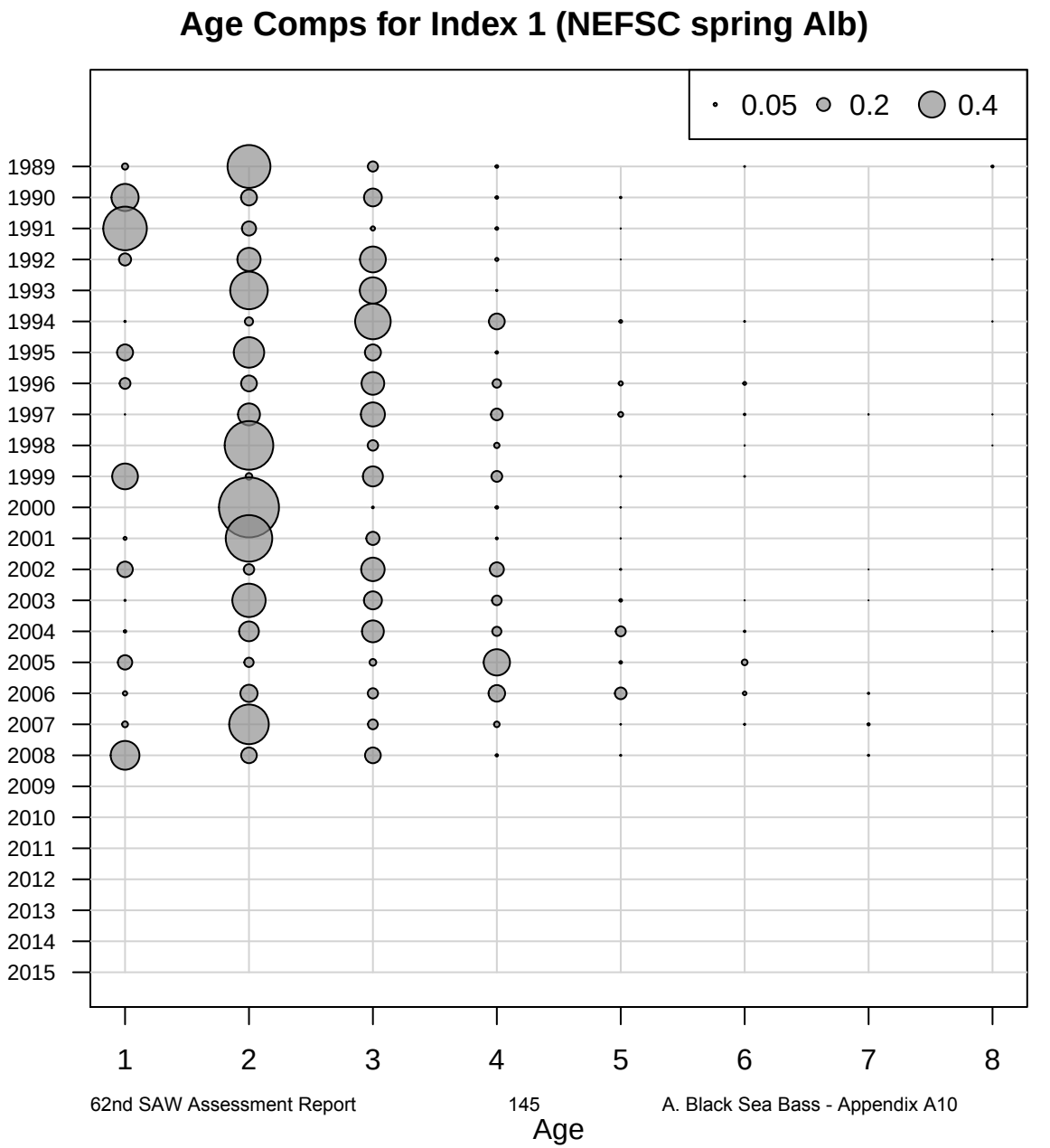

trawl
non−trawl
Proportion of Catch
0.0
0.2
0.4
0.6
0.8
1.0
1989
1994
1999
2004
2009
2014
Year

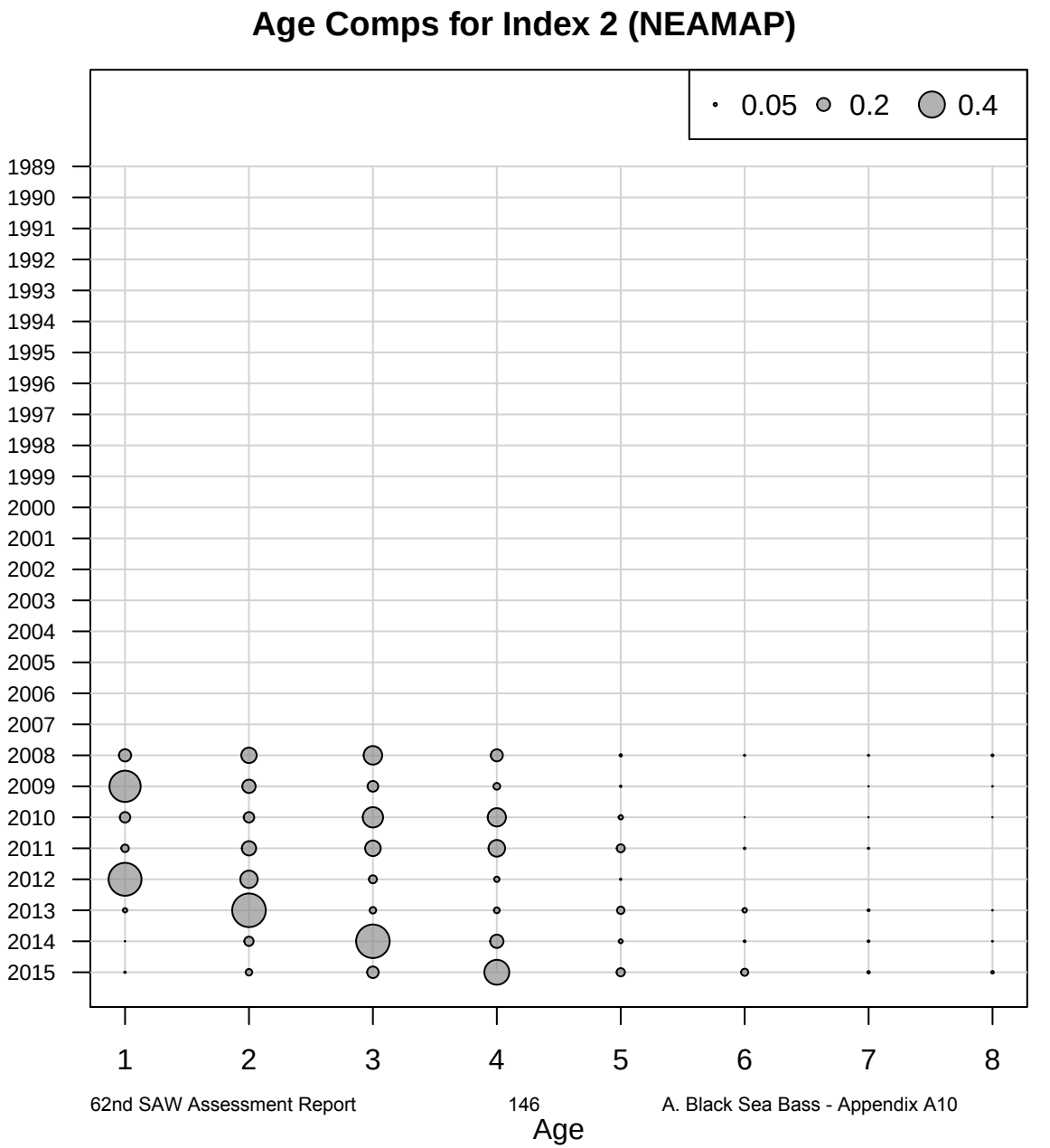

Age Comps for Catch by Fleet 1 (trawl)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age


Age Comps for Catch by Fleet 2 (non−trawl)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

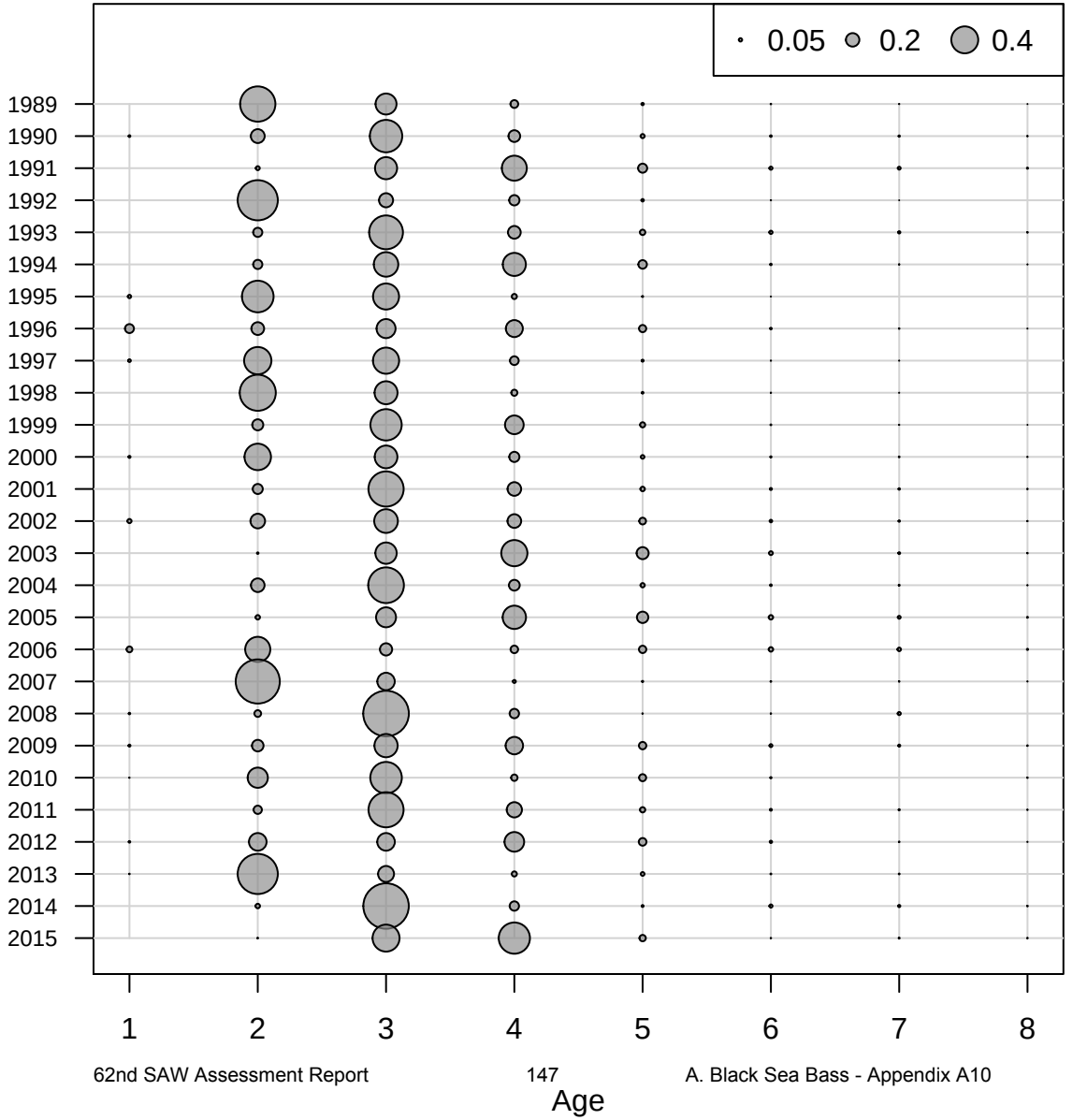

Rescaled Indices
4
3
2
1
0
−1
1990
1995
2000
2005
2010
2015
Year


Rescaled Log(Indices)
2
1
0
−1
−2
−3
1990
1995
2000
2005
2010
2015
Year

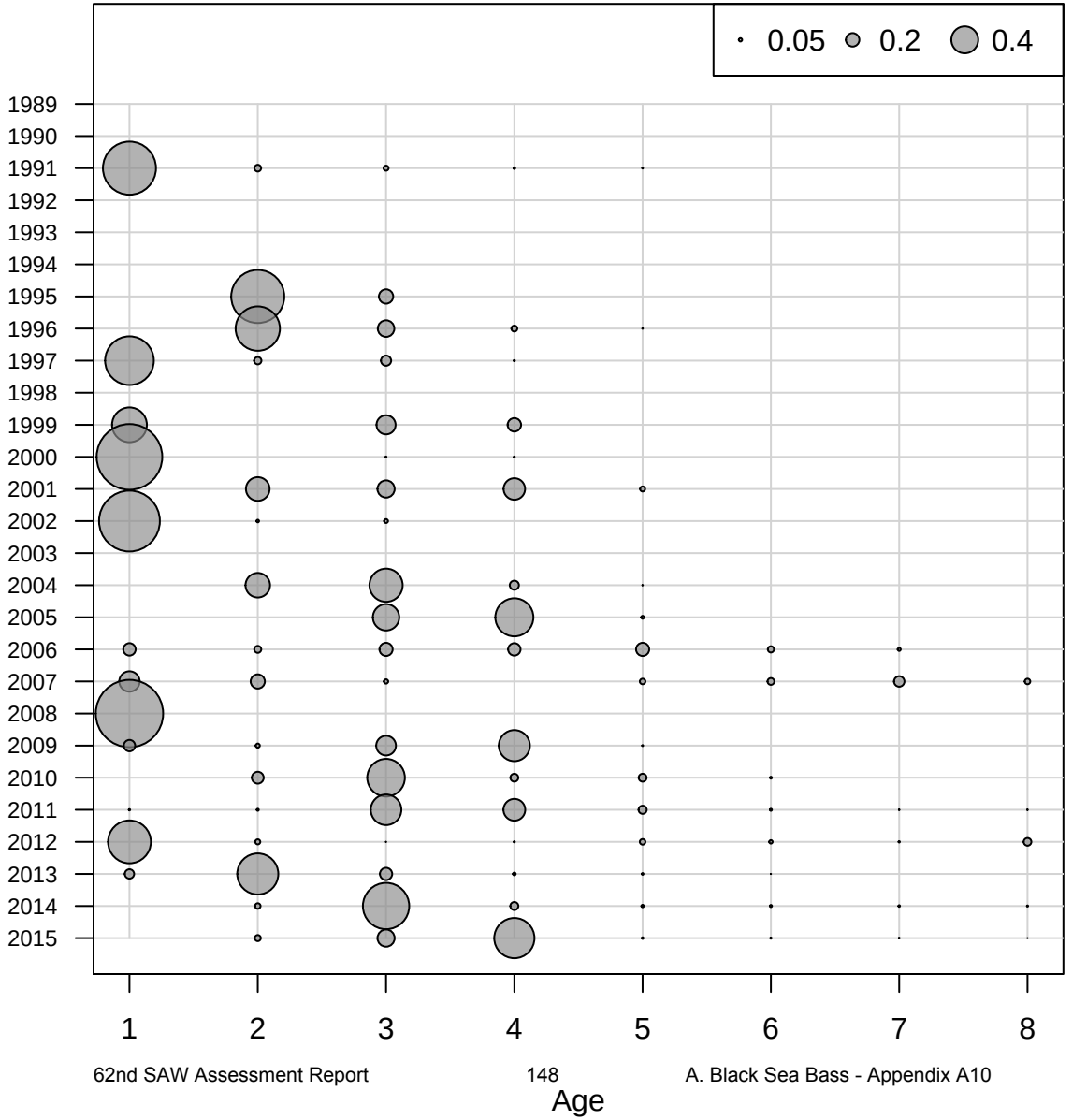

Age Comps for Index 1 (NEFSC spring Alb)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

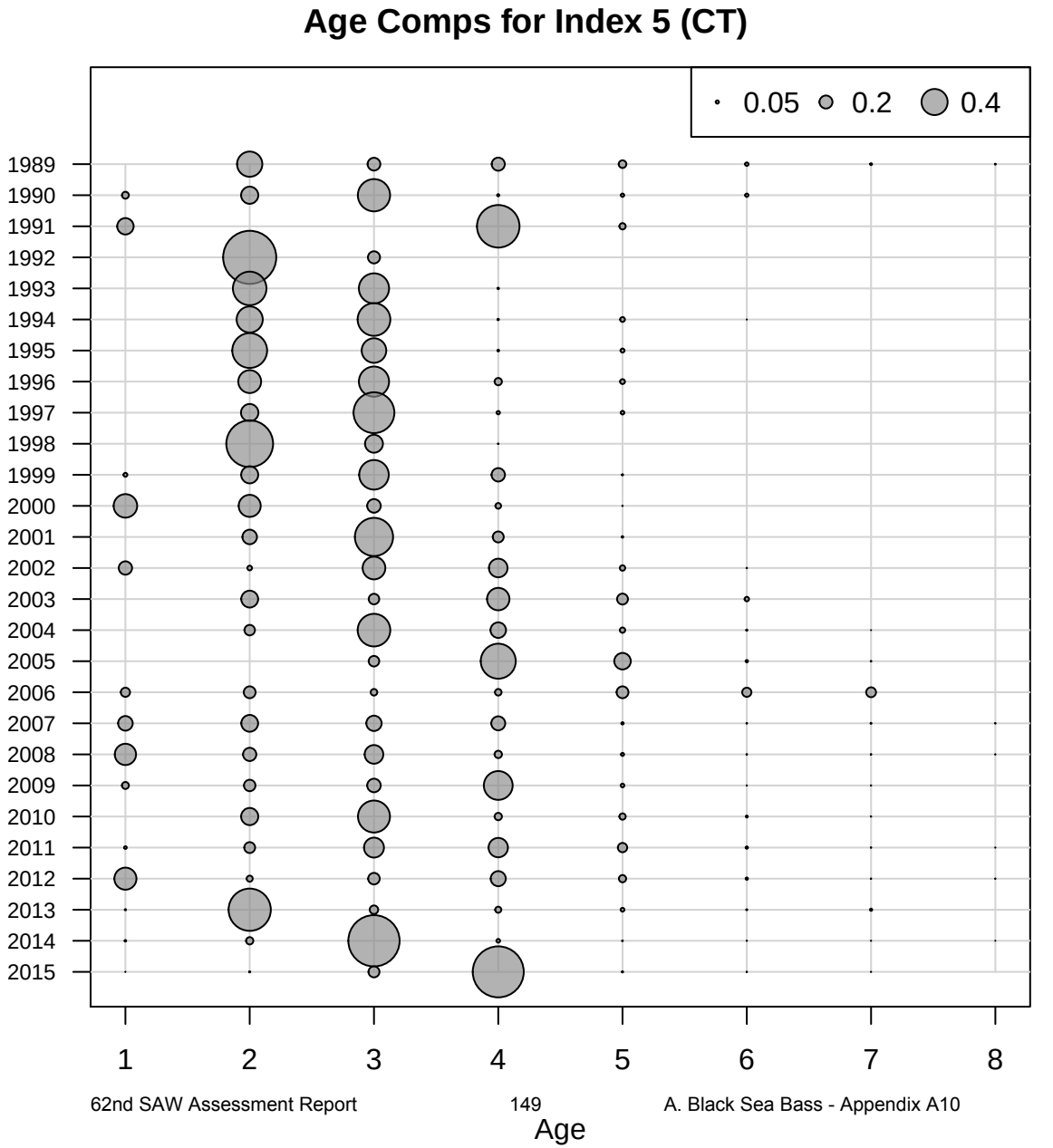

Age Comps for Index 2 (NEAMAP)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

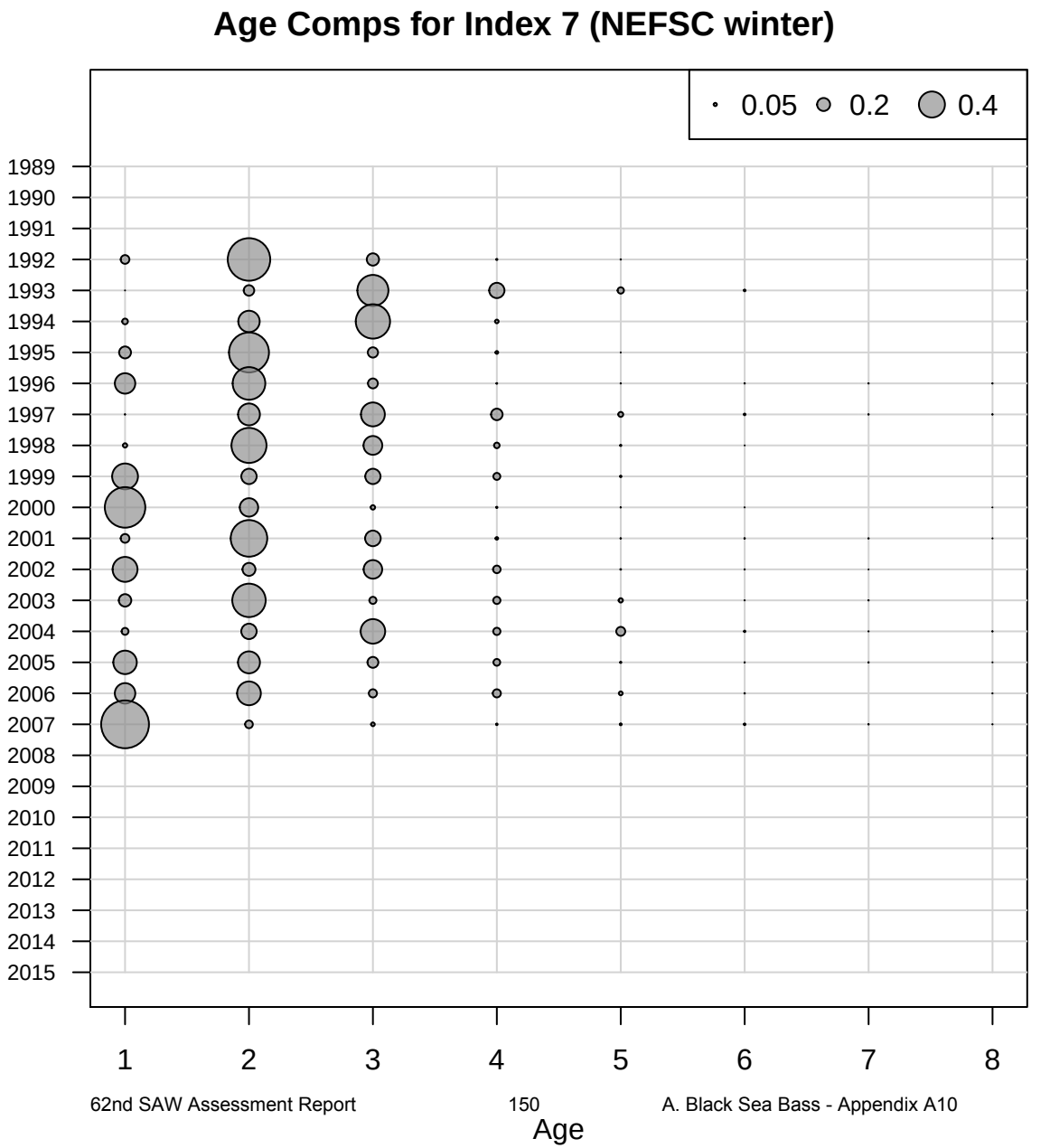
Age Comps for Index 3 (MADMF)



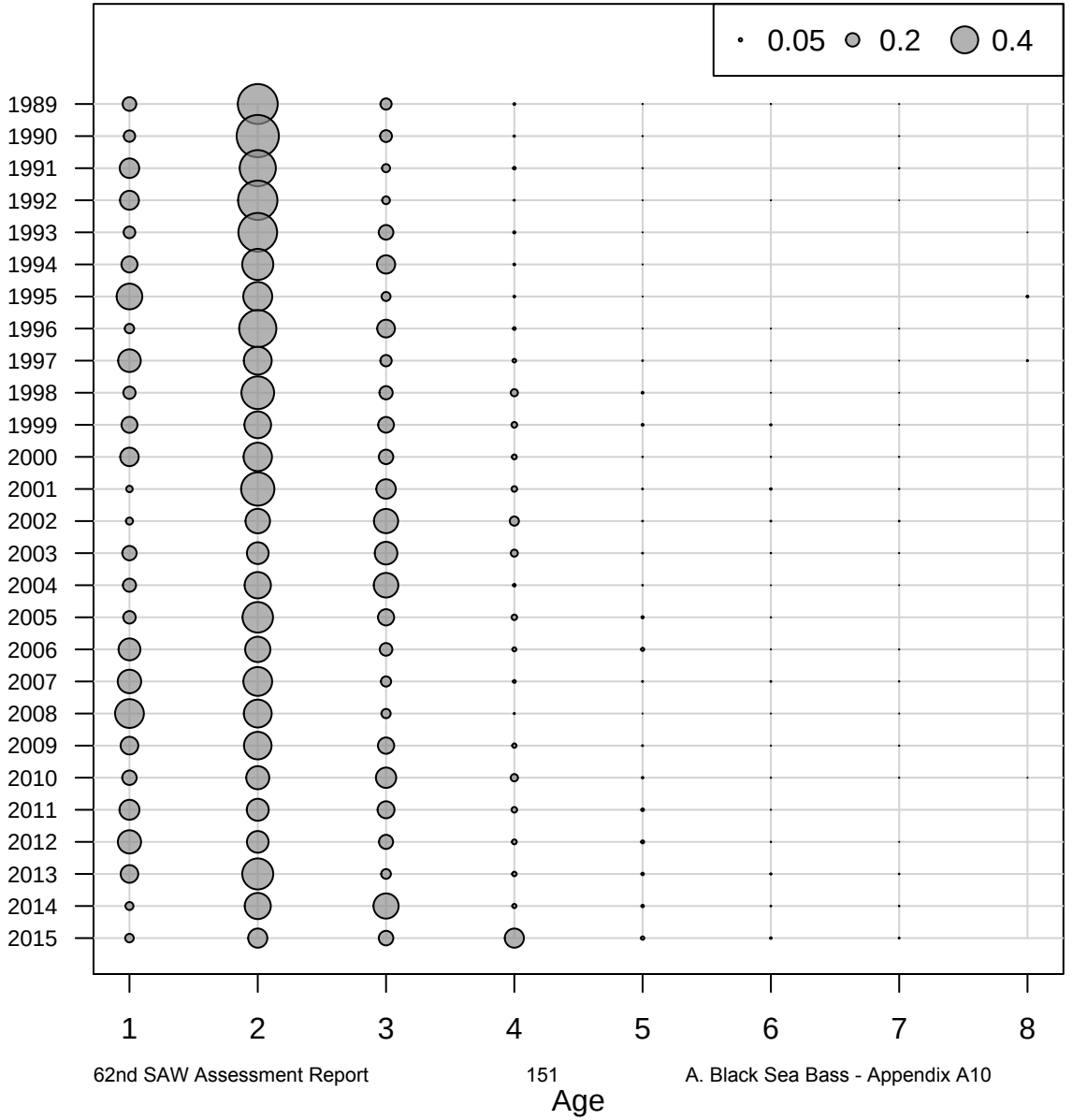
Age Comps for Index 4 (RI)



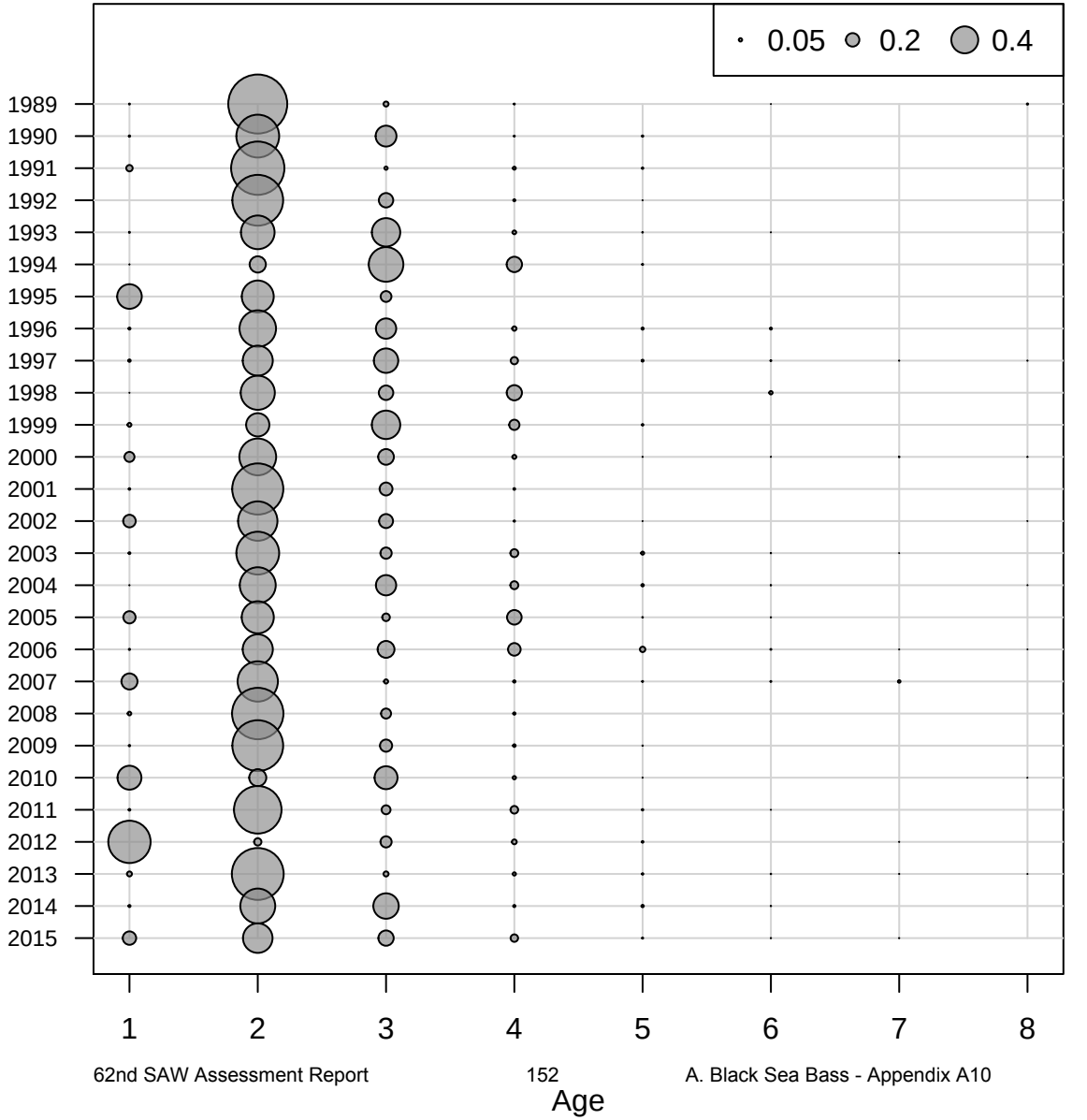

Age Comps for Index 5 (CT)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age


Age Comps for Index 7 (NEFSC winter)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

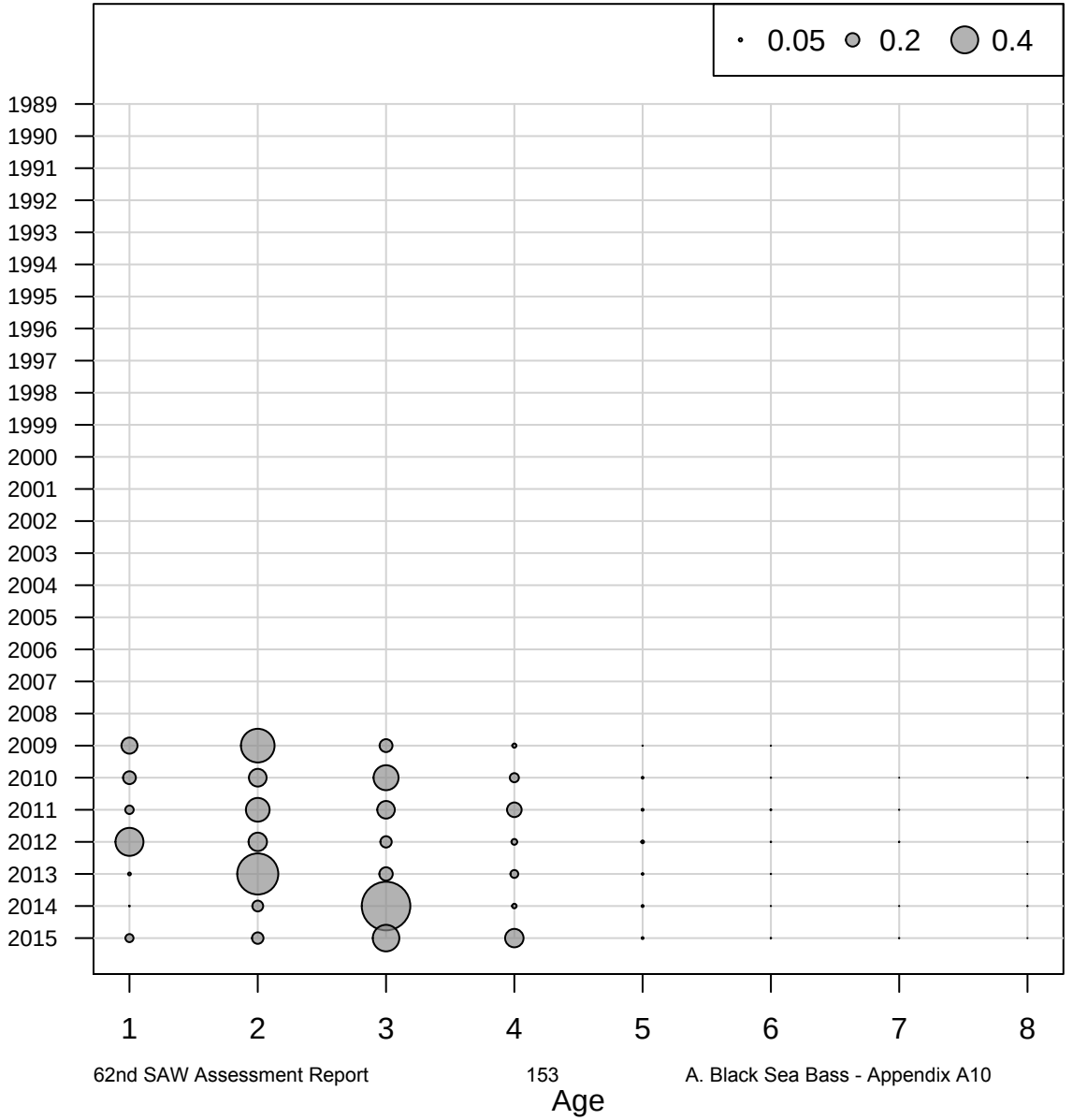
Age Comps for Index 8 (REC CPA)

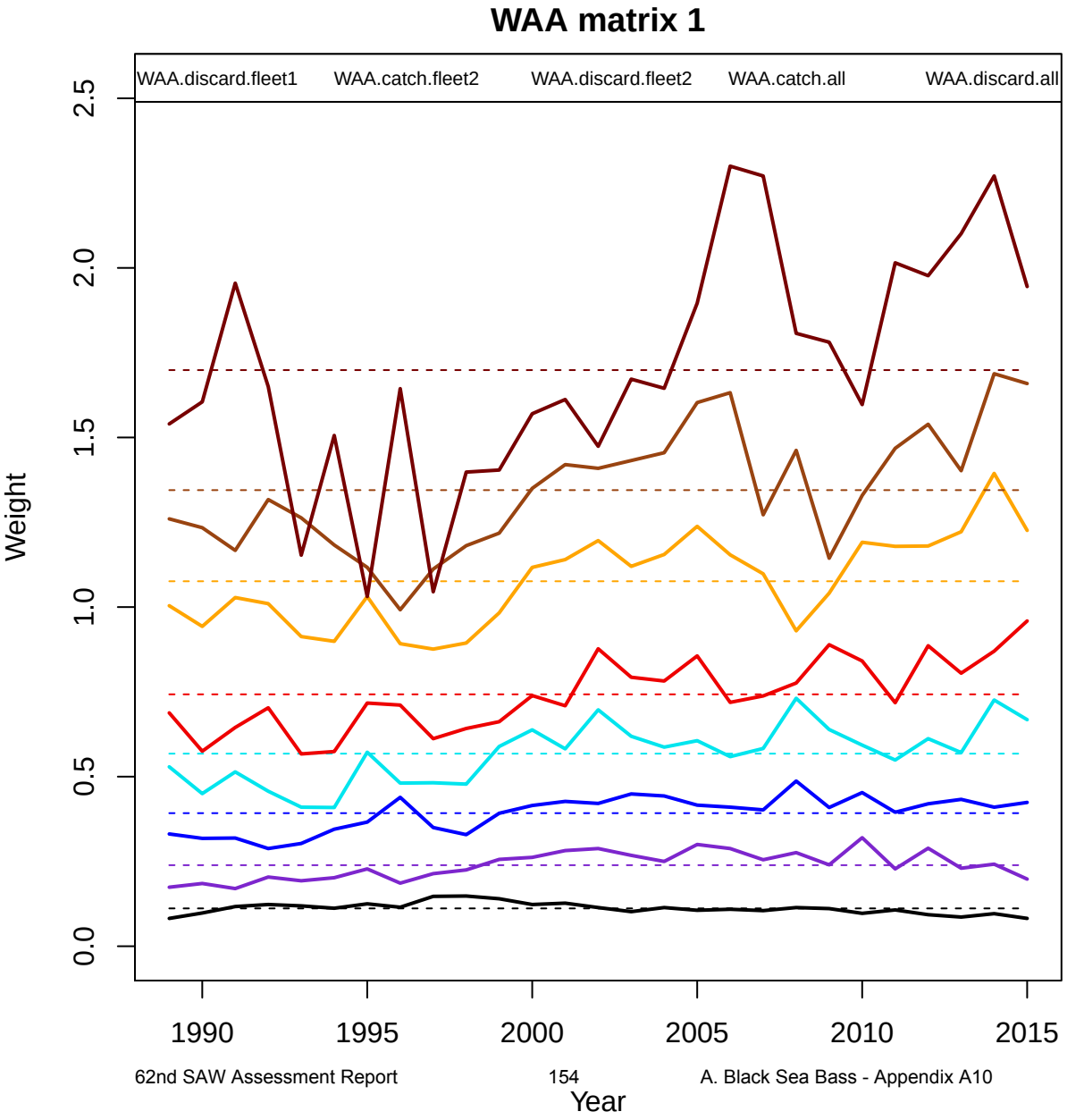


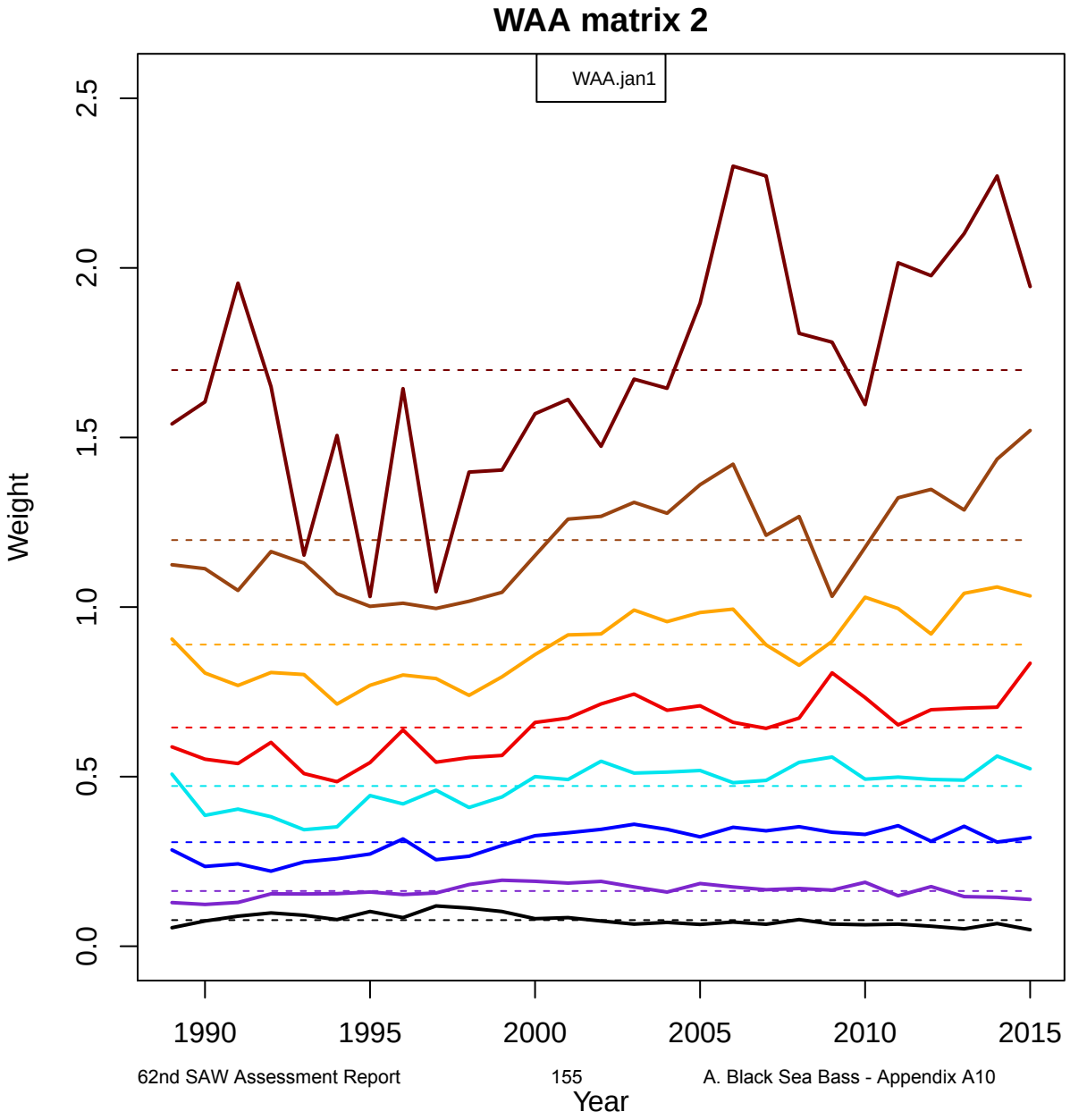
Age Comps for Index 9 (NJ)

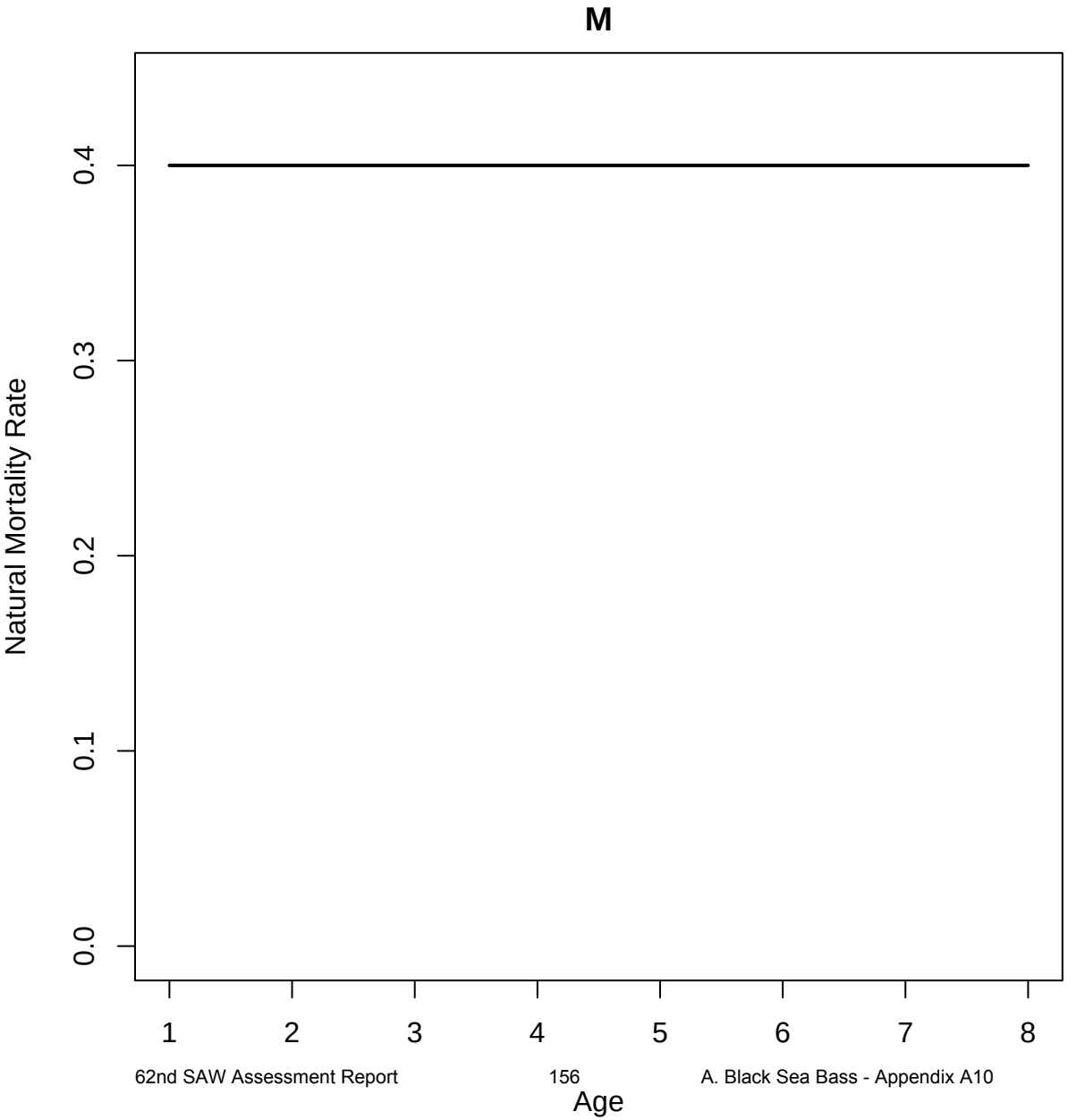


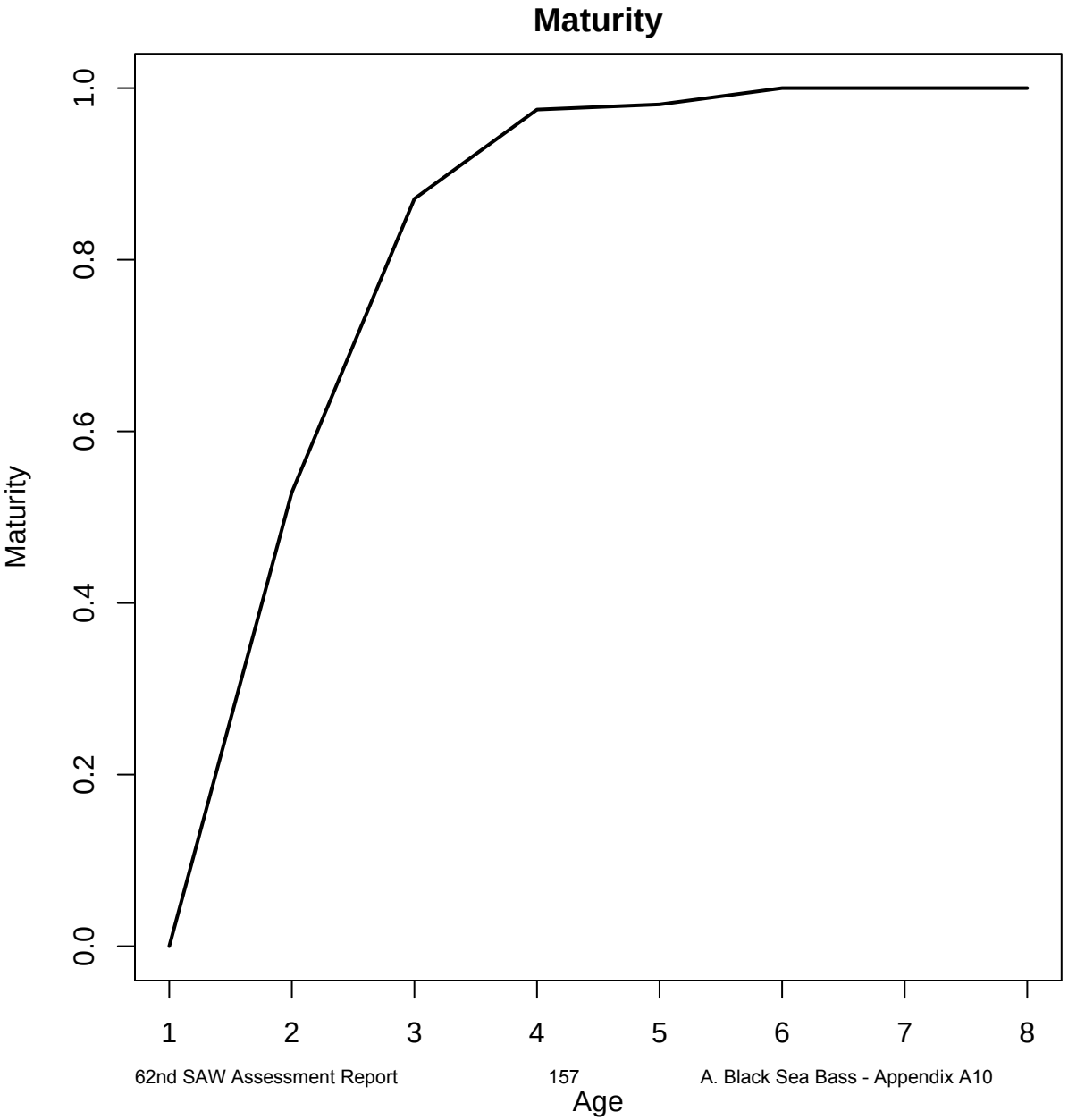
Age Comps for Index 13 (BIGELOW)



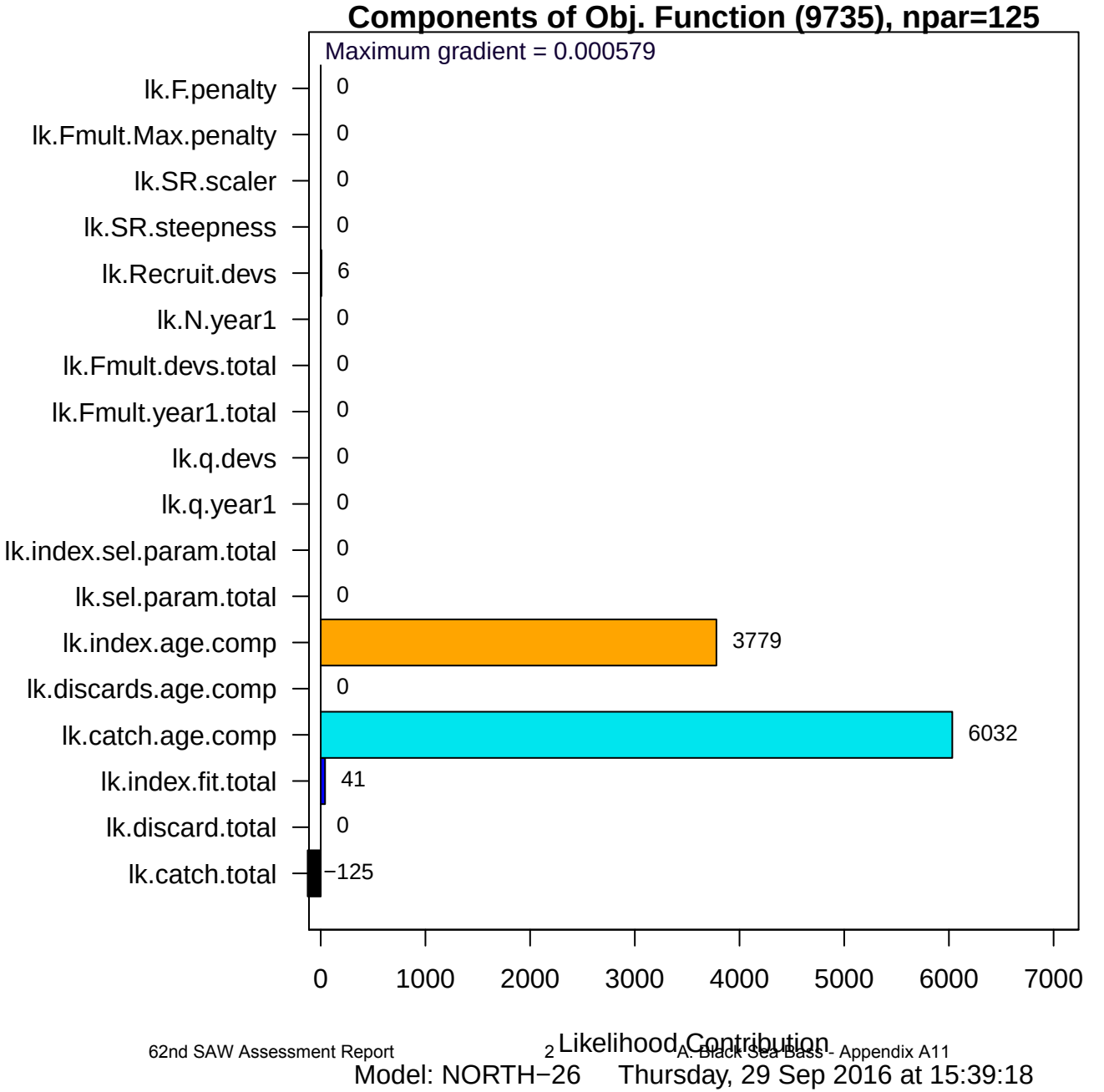

WAA matrix 1
WAA.discard.fleet1
WAA.catch.fleet2
WAA.discard.fleet2
WAA.catch.all
WAA.discard.all
Weight
0.0
0.5
1.0
1.5
2.0
2.5
1990
1995
2000
2005
2010
2015
Year

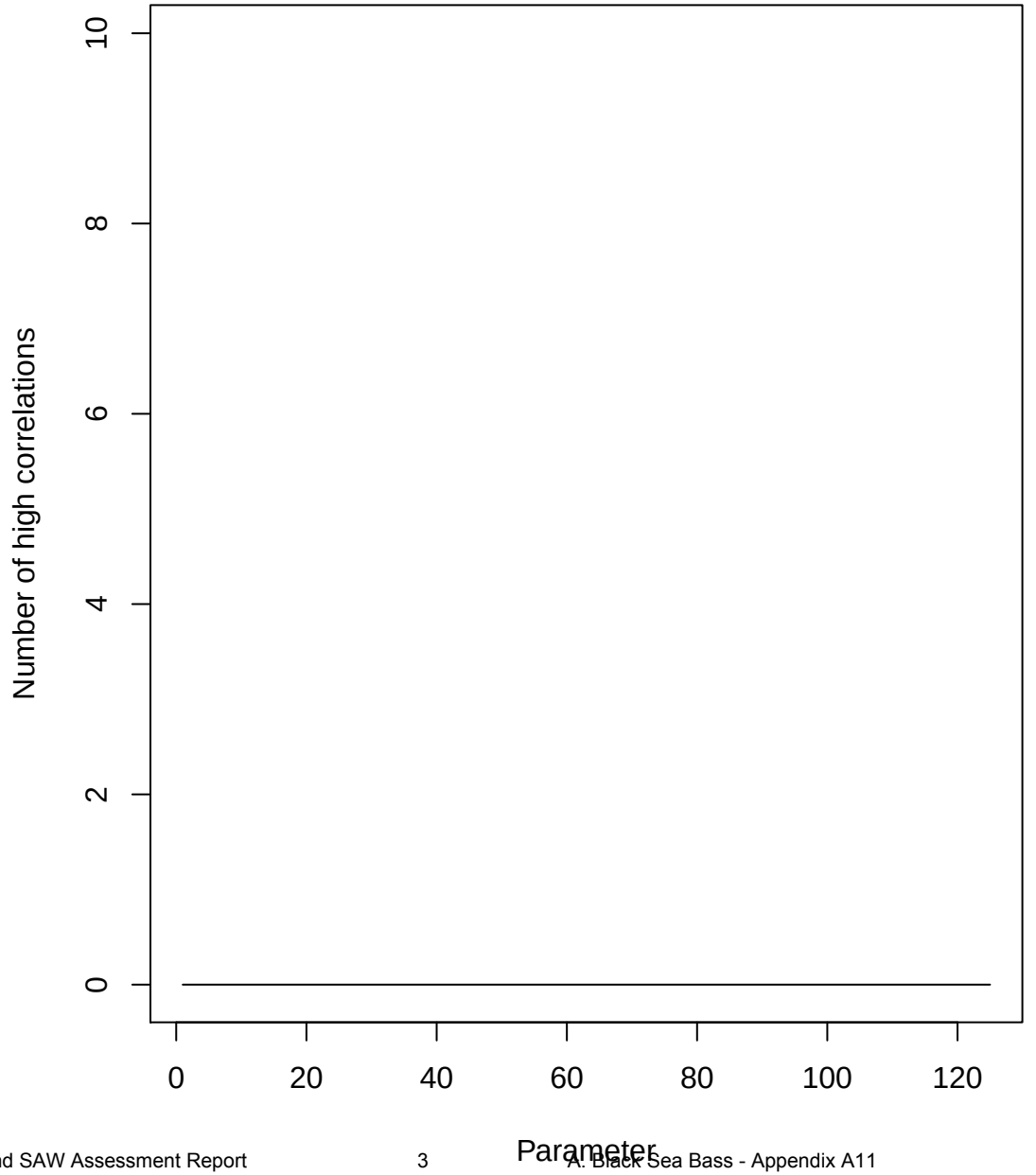

WAA matrix 2
WAA.jan1
Weight
0.0
0.5
1.0
1.5
2.0
2.5
1990
1995
2000
2005
2010
2015
Year


M
Natural Mortality Rate
0.0
0.1
0.2
0.3
0.4
1
2
3
4
5
6
7
8
Age


Maturity
Maturity
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
8
Age

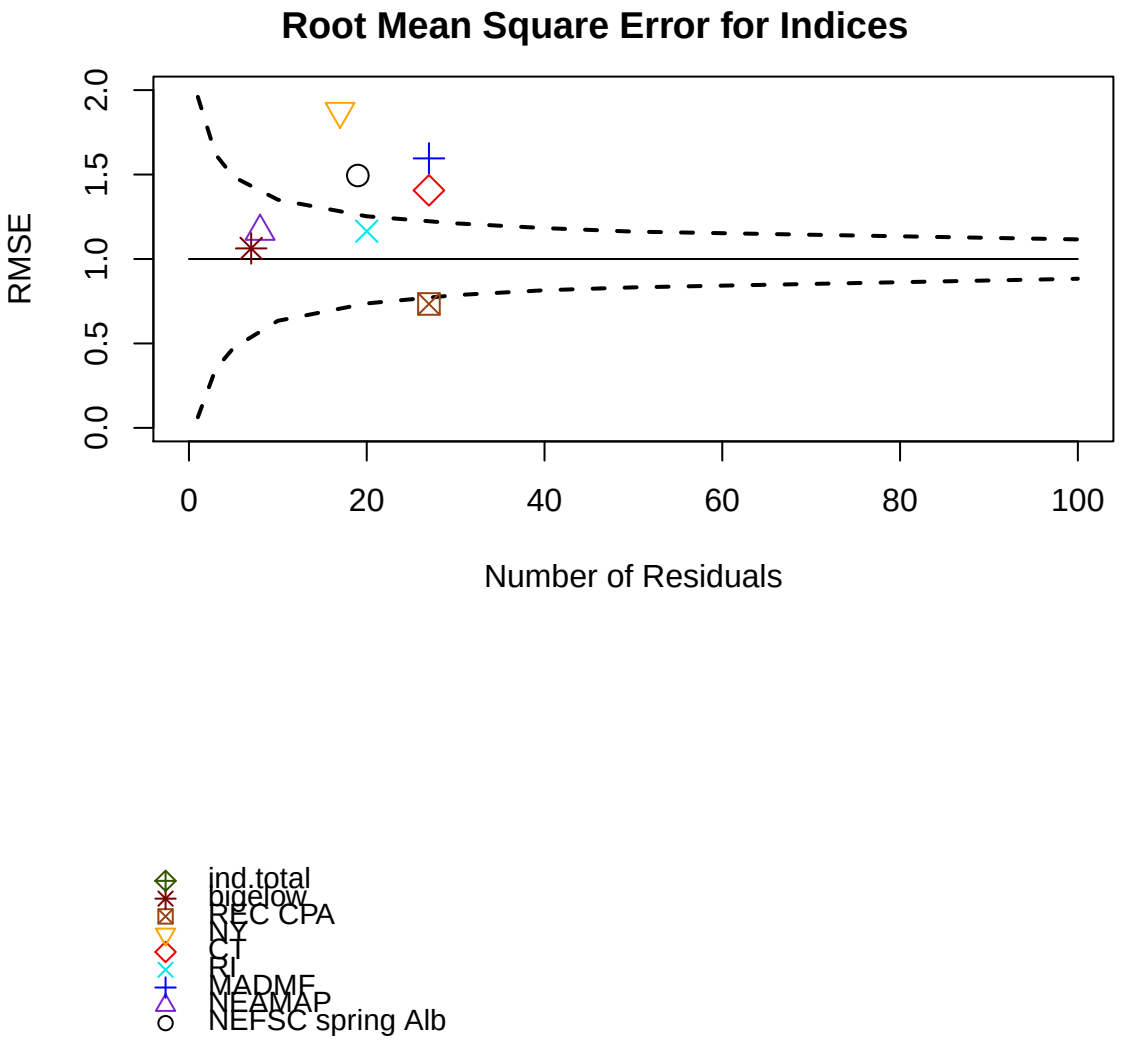
Appendix A11 – Diagnostic and result plots for black sea bass North model.

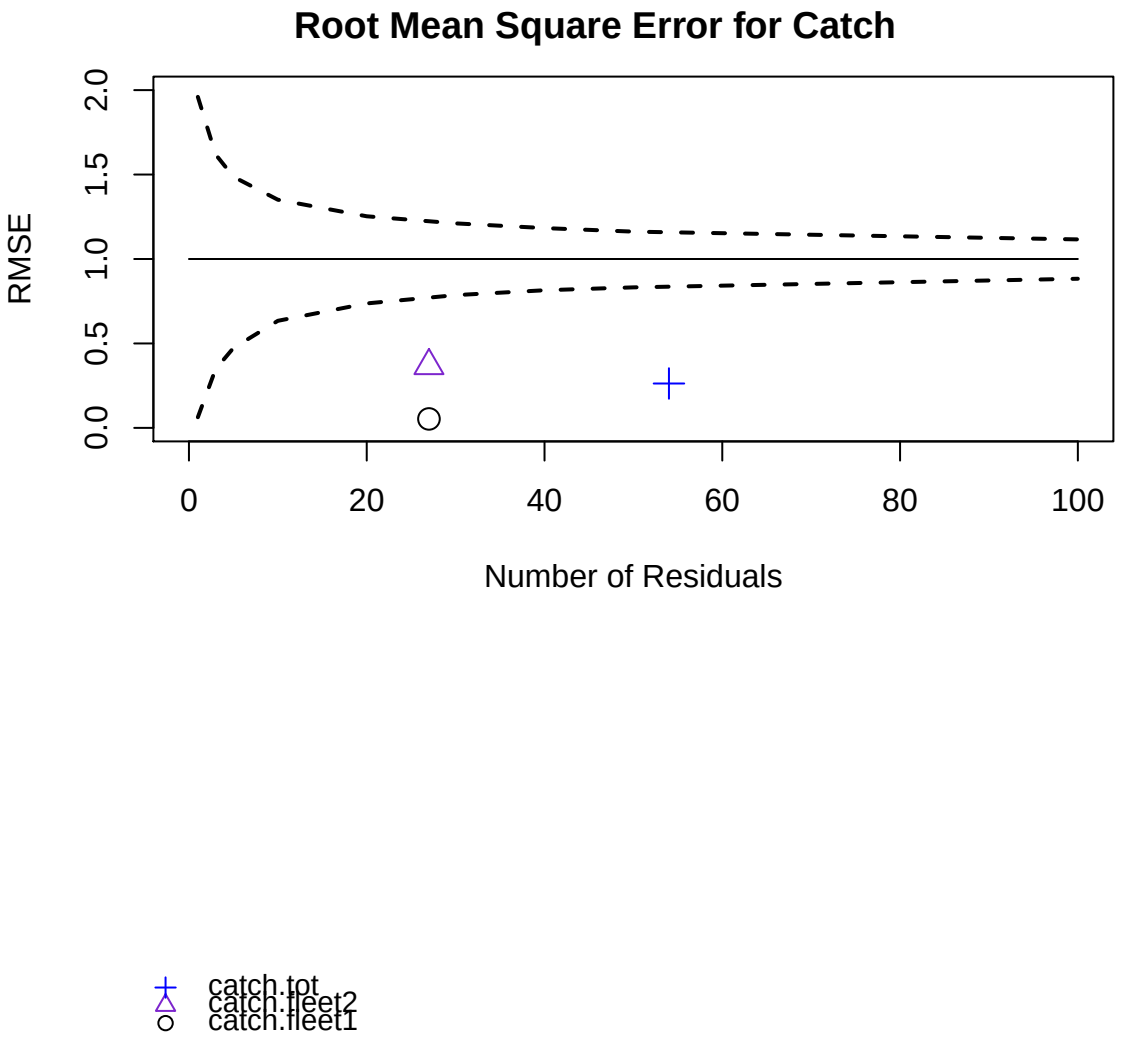

Components of Obj. Function (9735), npar=125
Maximum gradient = 0.000579
lk.F.penalty
lk.Fmult.Max.penalty
lk.SR.scaler
lk.SR.steepness
lk.Recruit.devs
lk.N.year1
lk.Fmult.devs.total
lk.Fmult.year1.total
lk.q.devs
lk.q.year1
lk.index.sel.param.total
lk.sel.param.total
lk.index.age.comp
lk.discards.age.comp
lk.catch.age.comp
lk.index.fit.total
lk.discard.total
lk.catch.total
0
0
0
0
6
0
0
0
0
0
0
0
3779
0
6032
41
0
−125
0
1000
2000
3000
4000
5000
6000
7000
Likelihood Contribution
Model: NORTH−26
Thursday, 29 Sep 2016 at 15:39:18


Number of high correlations
0
2
4
6
8
10
0
20
40
60
80
100
120
Parameter

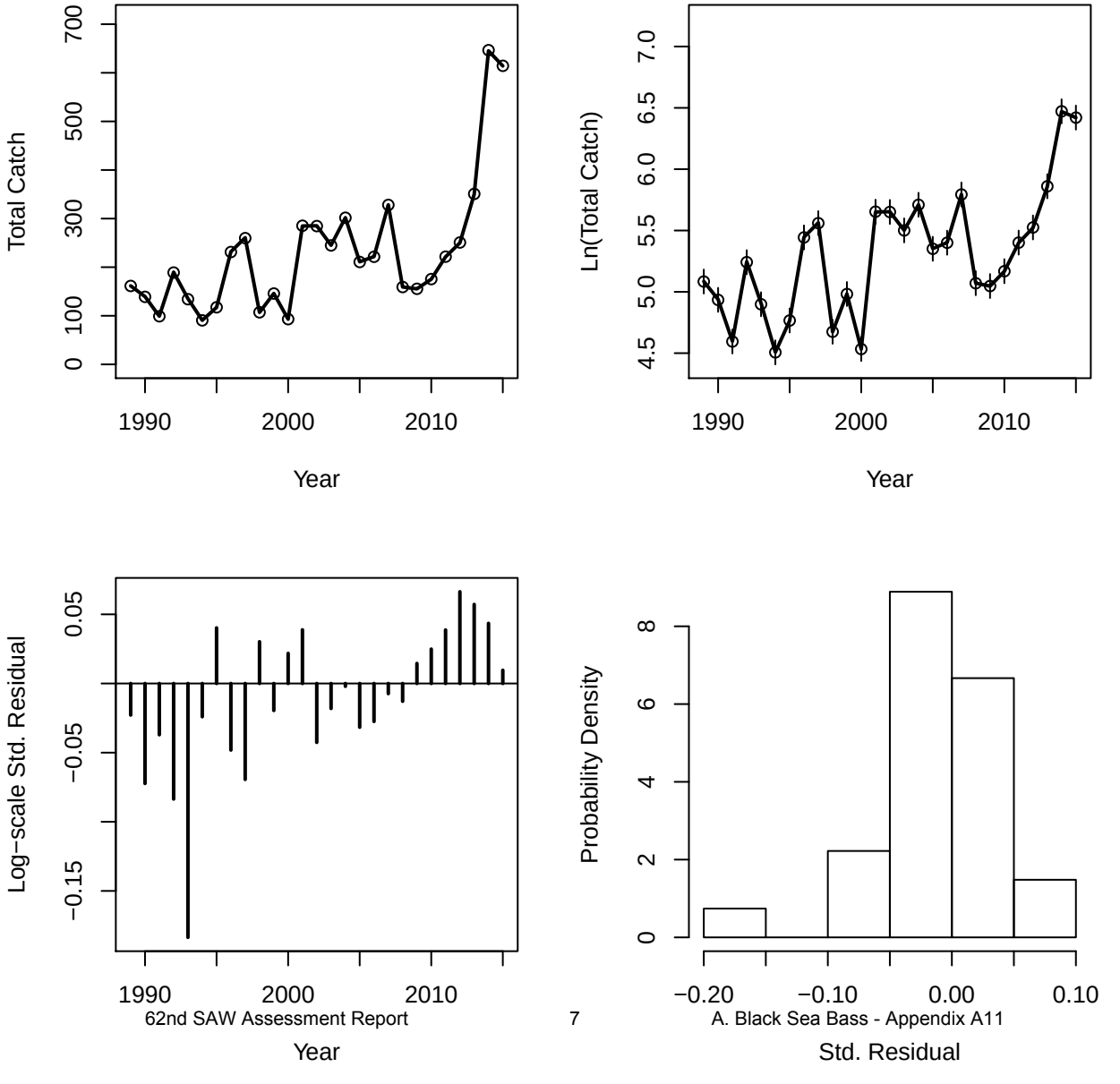
Root Mean Square Error computed from Standardized Residuals

Component	# resids	RMSE
catch.fleet1	27	0.0532
catch.fleet2	27	0.368
catch.tot	54	0.263
discard.fleet1	0	0
discard.fleet2	0	0
discard.tot	0	0
ind01	19	1.49
ind02	8	1.16
ind03	27	1.6
ind04	20	1.16
ind05	27	1.41
ind06	17	1.87
ind07	27	0.734
ind08	7	1.06
ind.total	152	1.37
N.year1	0	0
Fmult.year1	0	0
Fmult.devs.fleet1	0	0
Fmult.devs.fleet2	0	0
Fmult.devs.total	0	0
recruit.devs	27	0.913
fleet.sel.params	0	0
index.sel.params	0	0
q.year1	0	0
q.devs	0	0
SR.steepness	0	0
SR.scaler	0	0

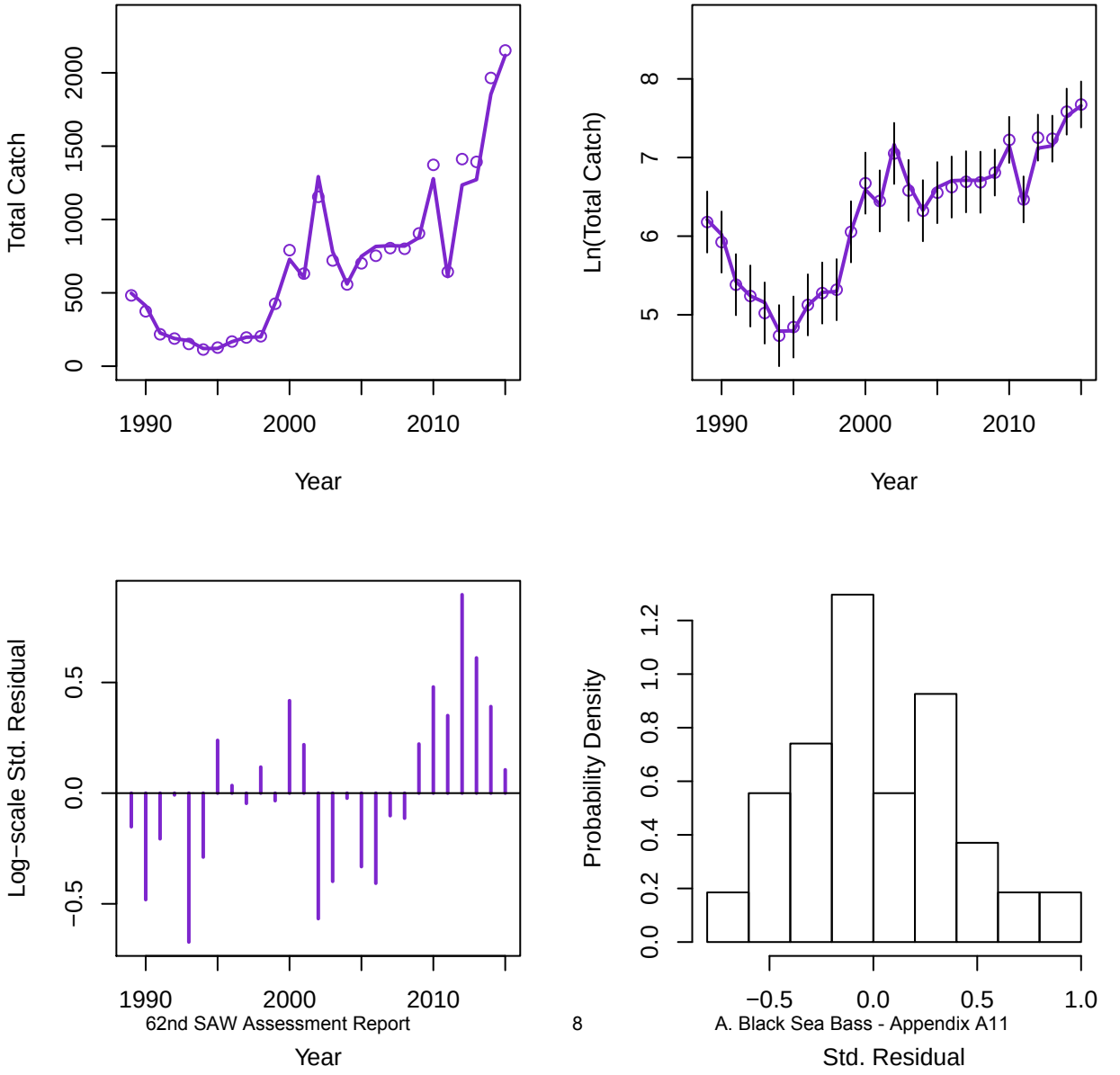

Root Mean Square Error for Indices
RMSE
0.0
0.5
1.0
1.5
2.0
0
20
40
60
80
100
Number of Residuals
ind.total
bigelow
REC CPA
NY
CT
RI
MADMF
NEAMAP
NEFSC spring Alb

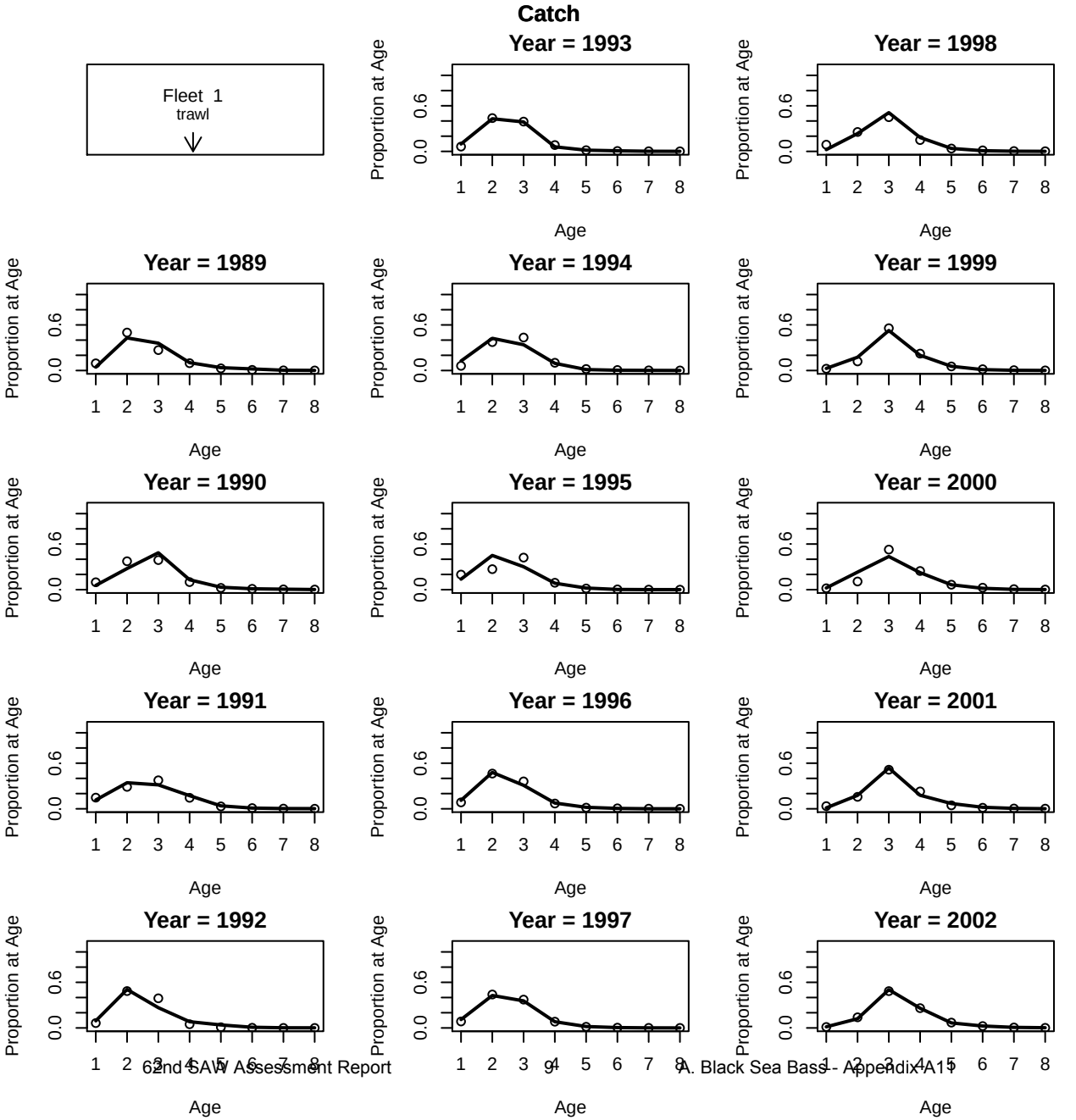

Root Mean Square Error for Catch
RMSE
0.0
0.5
1.0
1.5
2.0
0
20
40
60
80
100
Number of Residuals
catch.tot
catch.fleet2
catch.fleet1

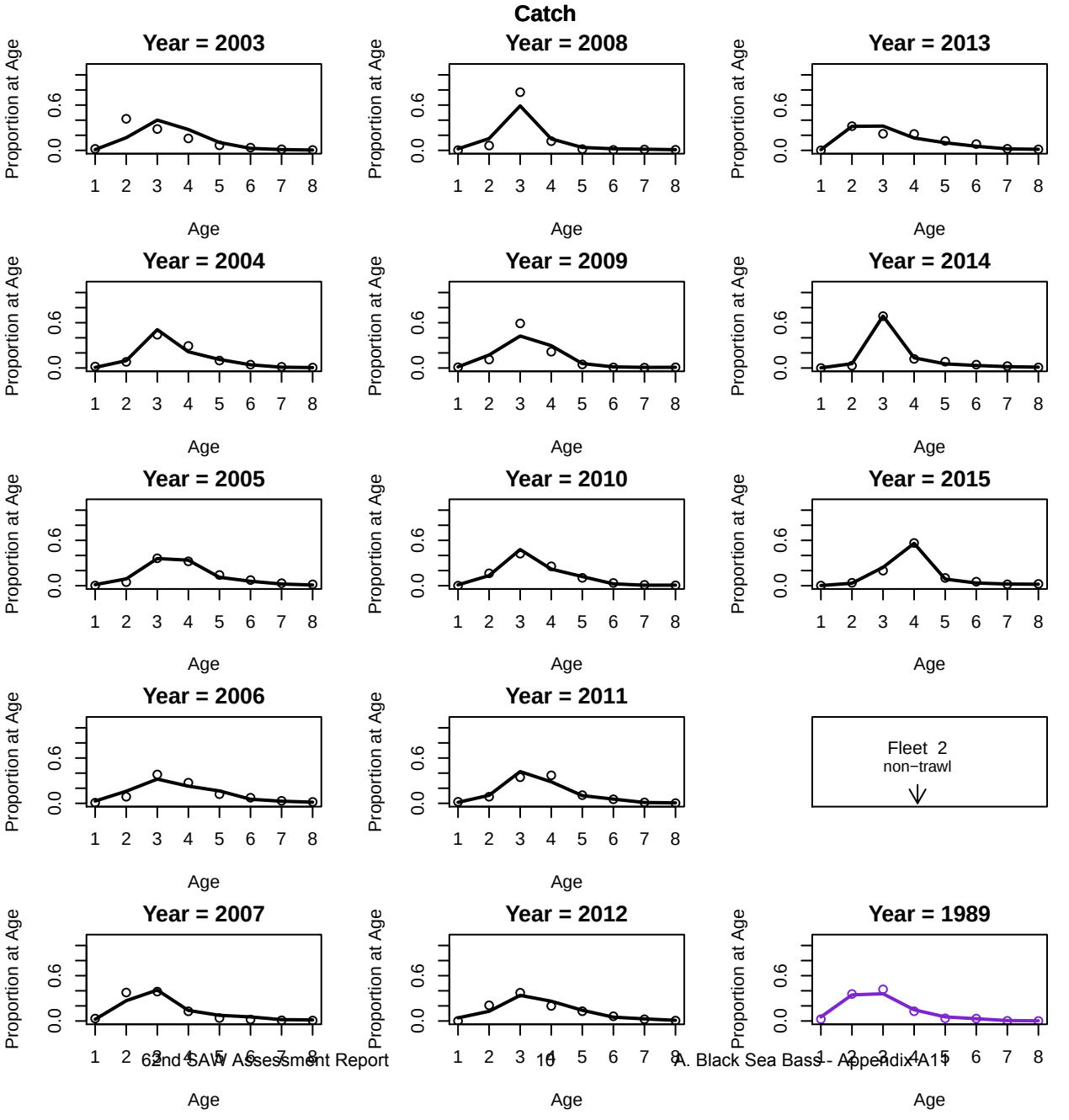
Fleet 1 Catch (trawl)

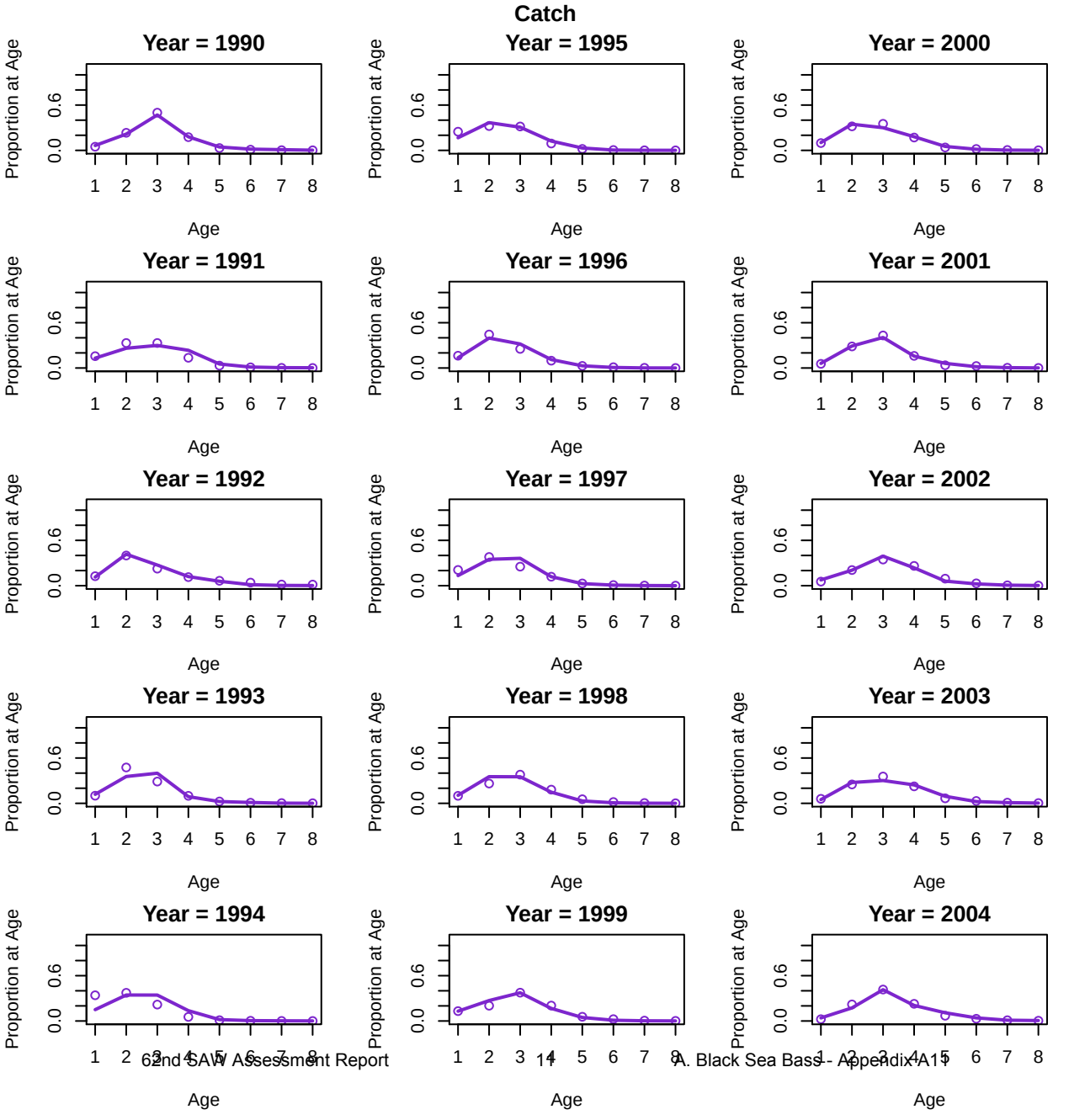


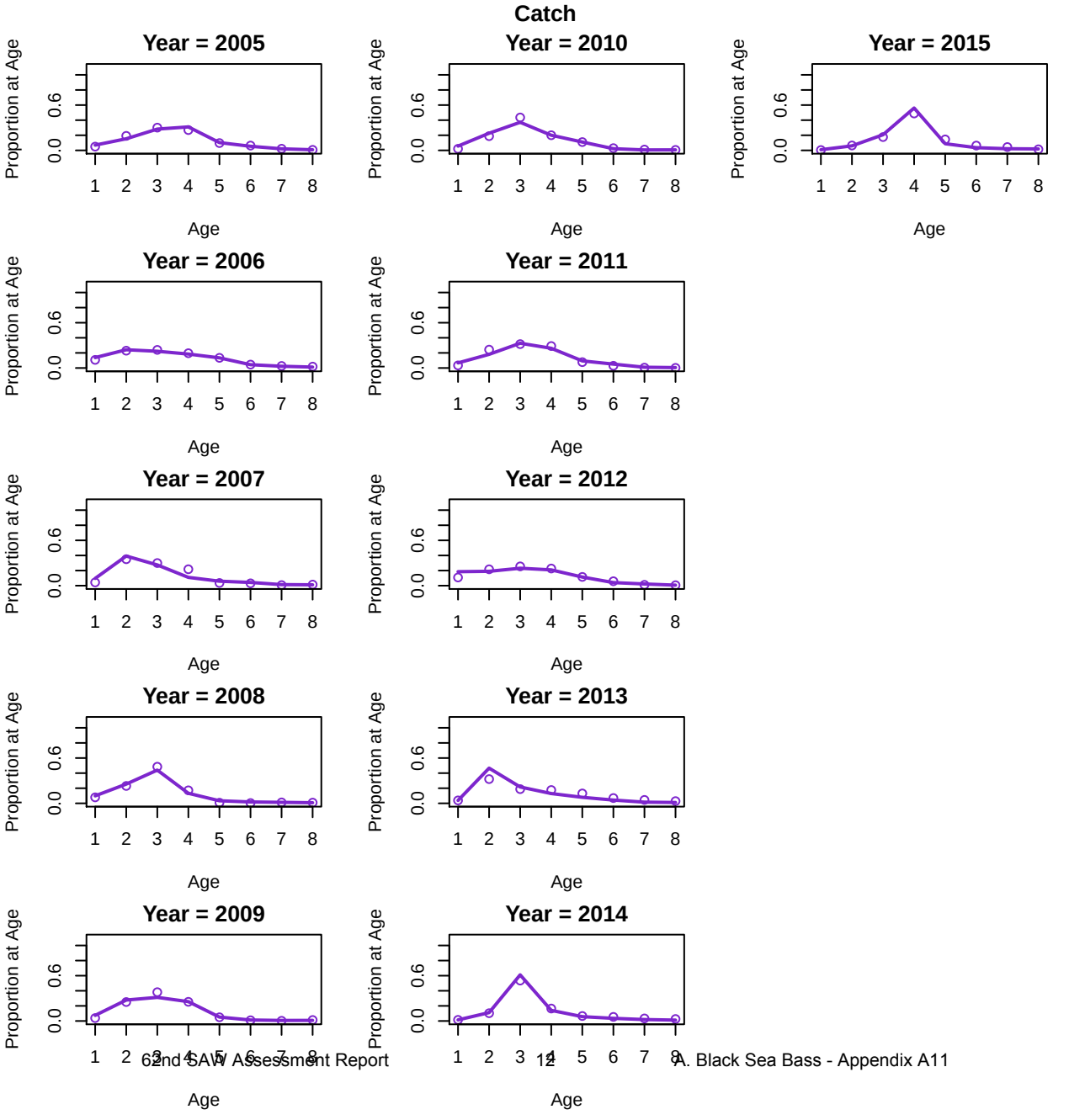
Fleet 2 Catch (non−trawl)



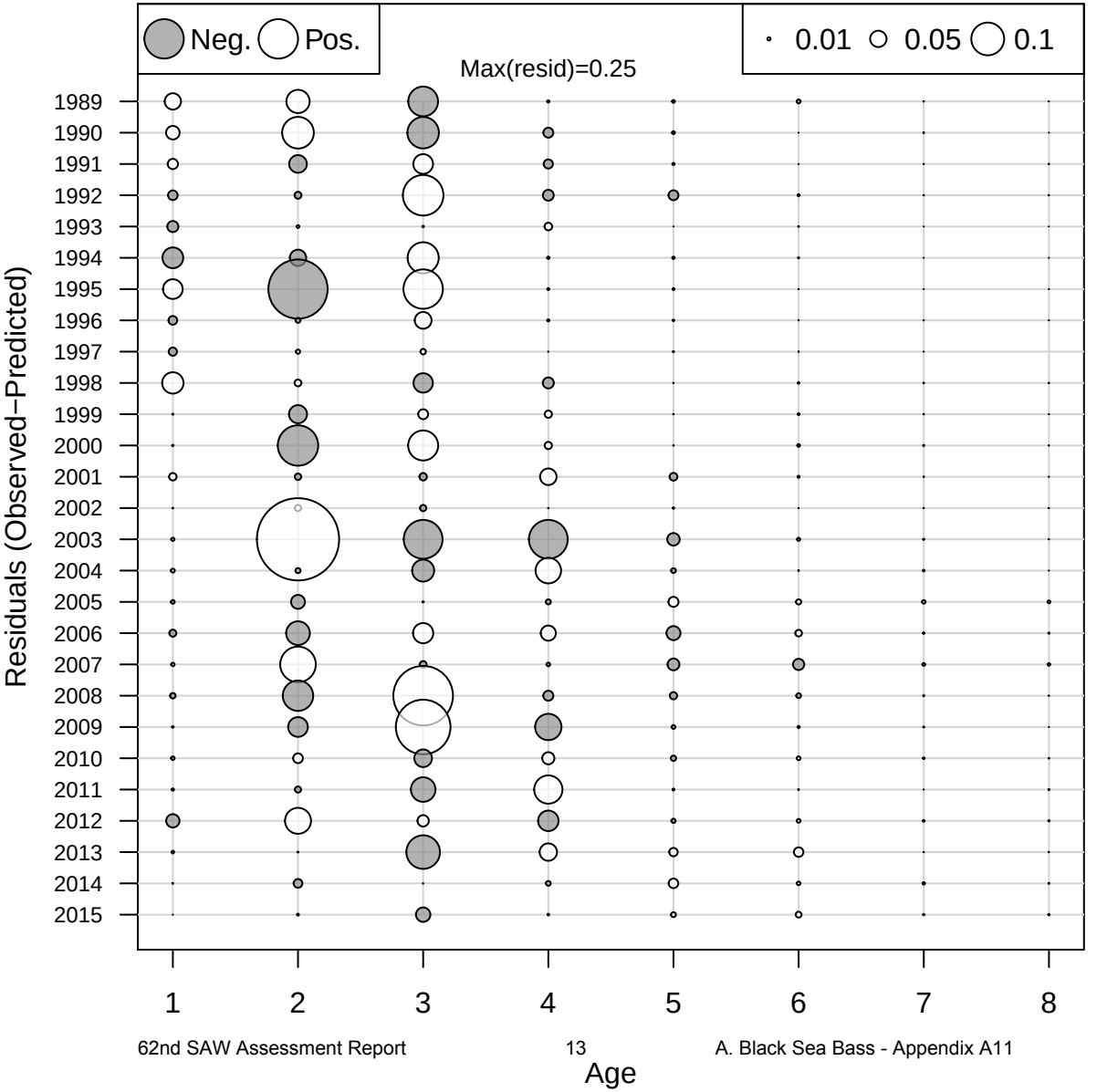

Catch
Fleet 1
trawl
Year = 1993
Year = 1998
Year = 1989
Year = 1994
Year = 1999
Year = 1990
Year = 1995
Year = 2000
Year = 1991
Year = 1996
Year = 2001
Year = 1992
Year = 1997
Year = 2002
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8


Catch
Year = 2003
Year = 2008
Year = 2013
Year = 2004
Year = 2009
Year = 2014
Year = 2005
Year = 2010
Year = 2015
Year = 2006
Year = 2011
Fleet 2
non−trawl
Year = 2007
Year = 2012
Year = 1989
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

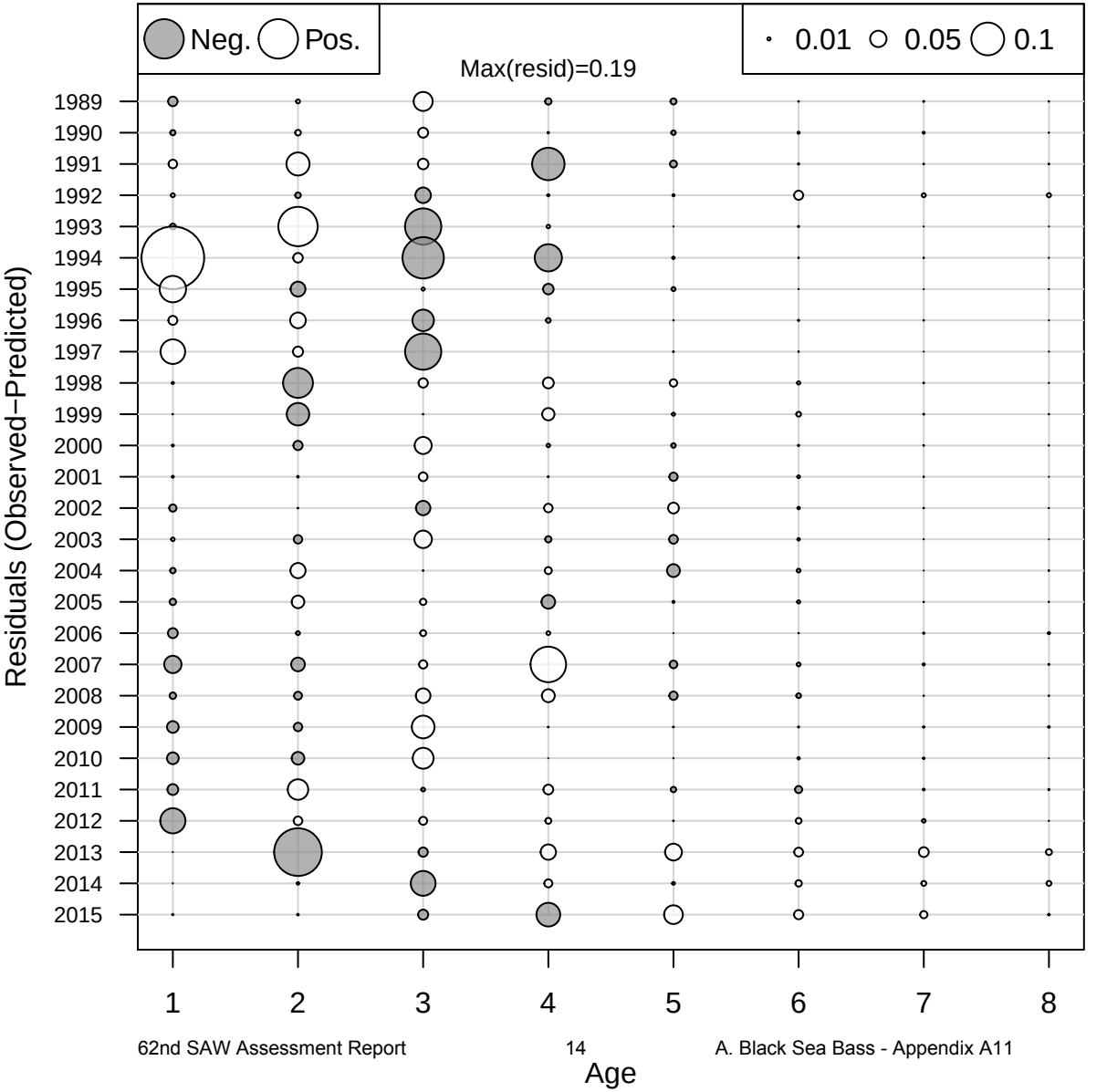

Catch
Year = 1990
Year = 1991
Year = 1992
Year = 1993
Year = 1994
Year = 1995
Year = 1996
Year = 1997
Year = 1998
Year = 1999
Year = 2000
Year = 2001
Year = 2002
Year = 2003
Year = 2004
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

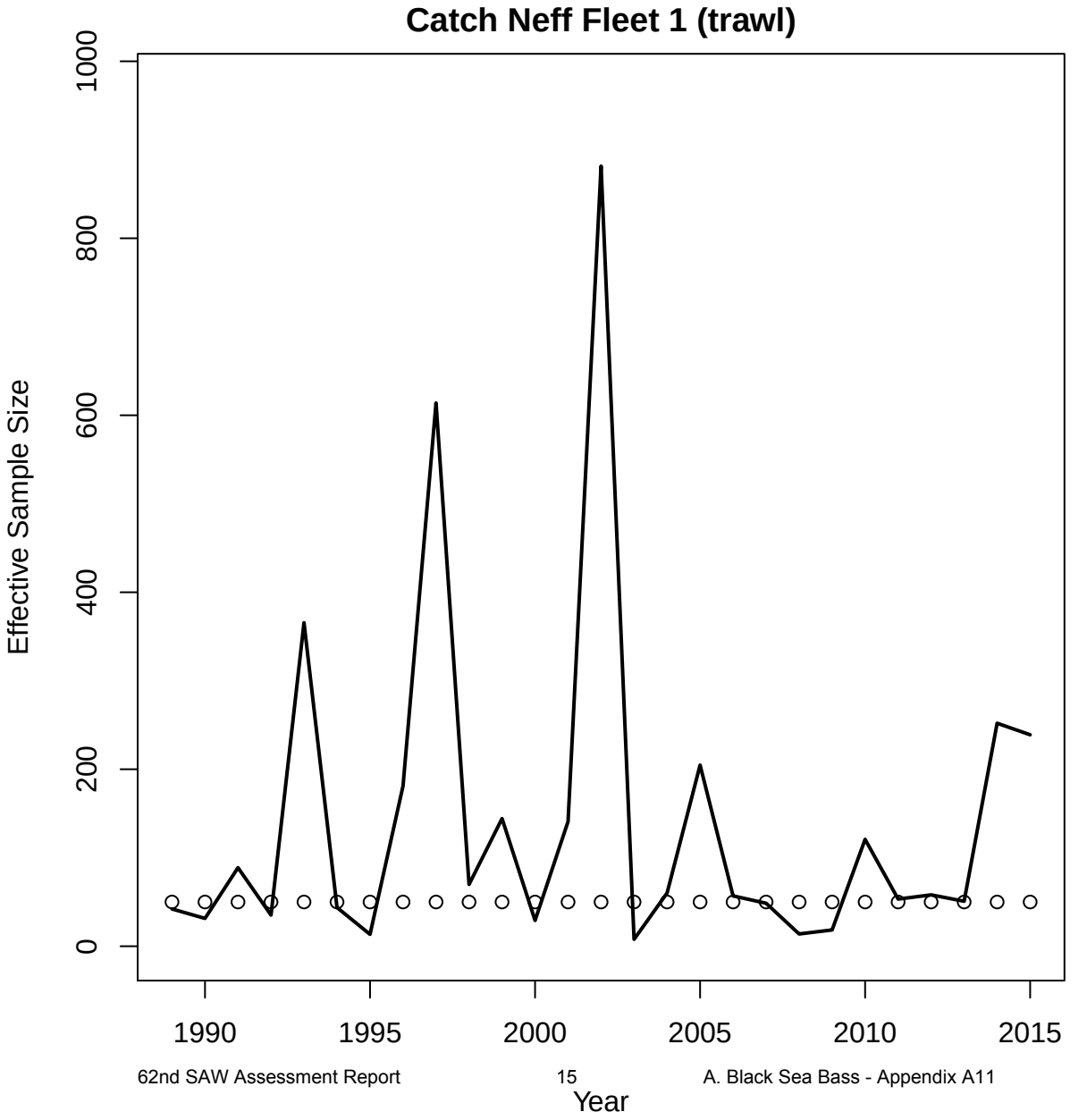

Catch
Year = 2005
Year = 2010
Year = 2015
Year = 2006
Year = 2011
Year = 2007
Year = 2012
Year = 2008
Year = 2013
Year = 2009
Year = 2014
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

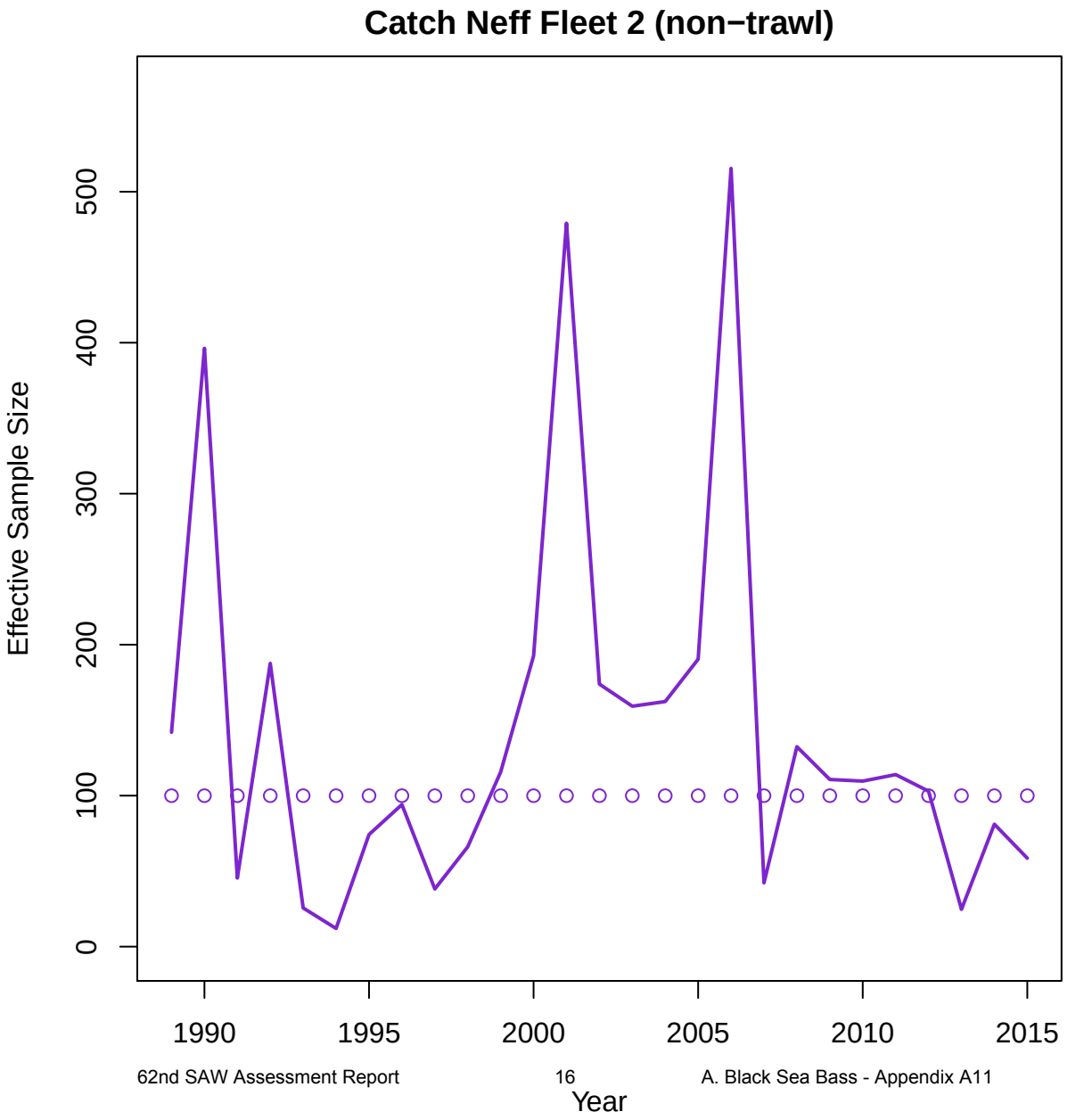
Age Comp Residuals for Catch by Fleet 1 (trawl)

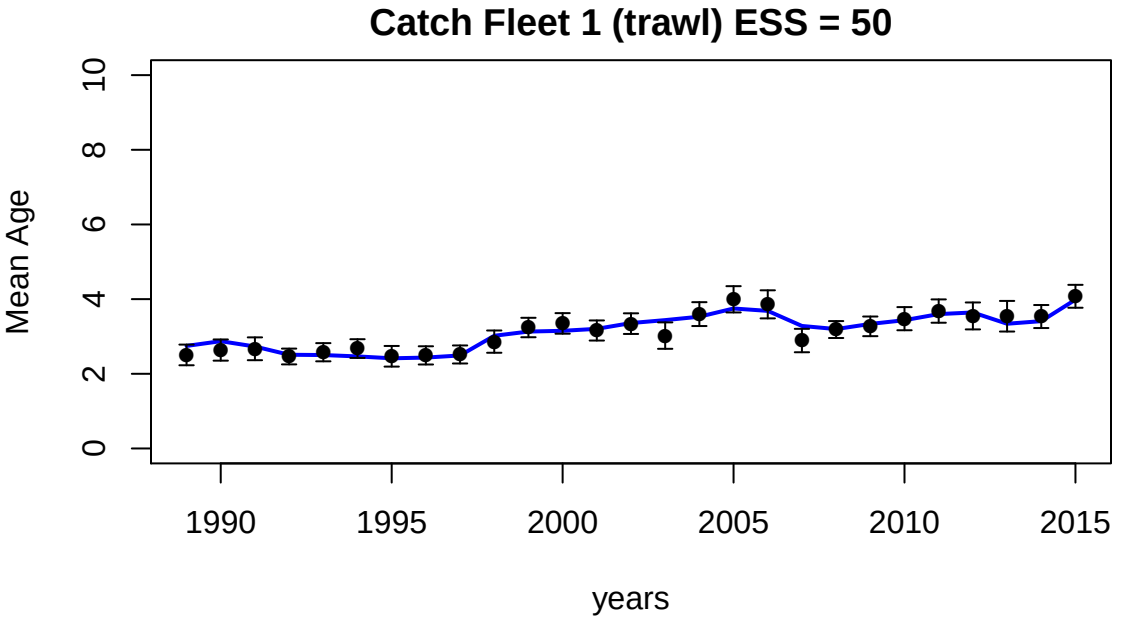


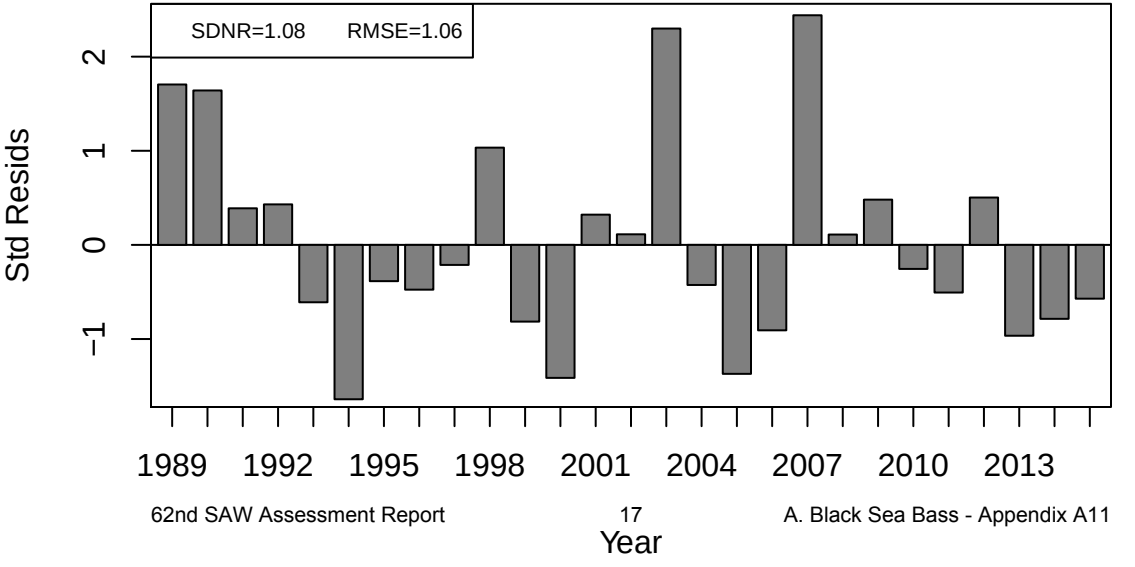
Age Comp Residuals for Catch by Fleet 2 (non−trawl)

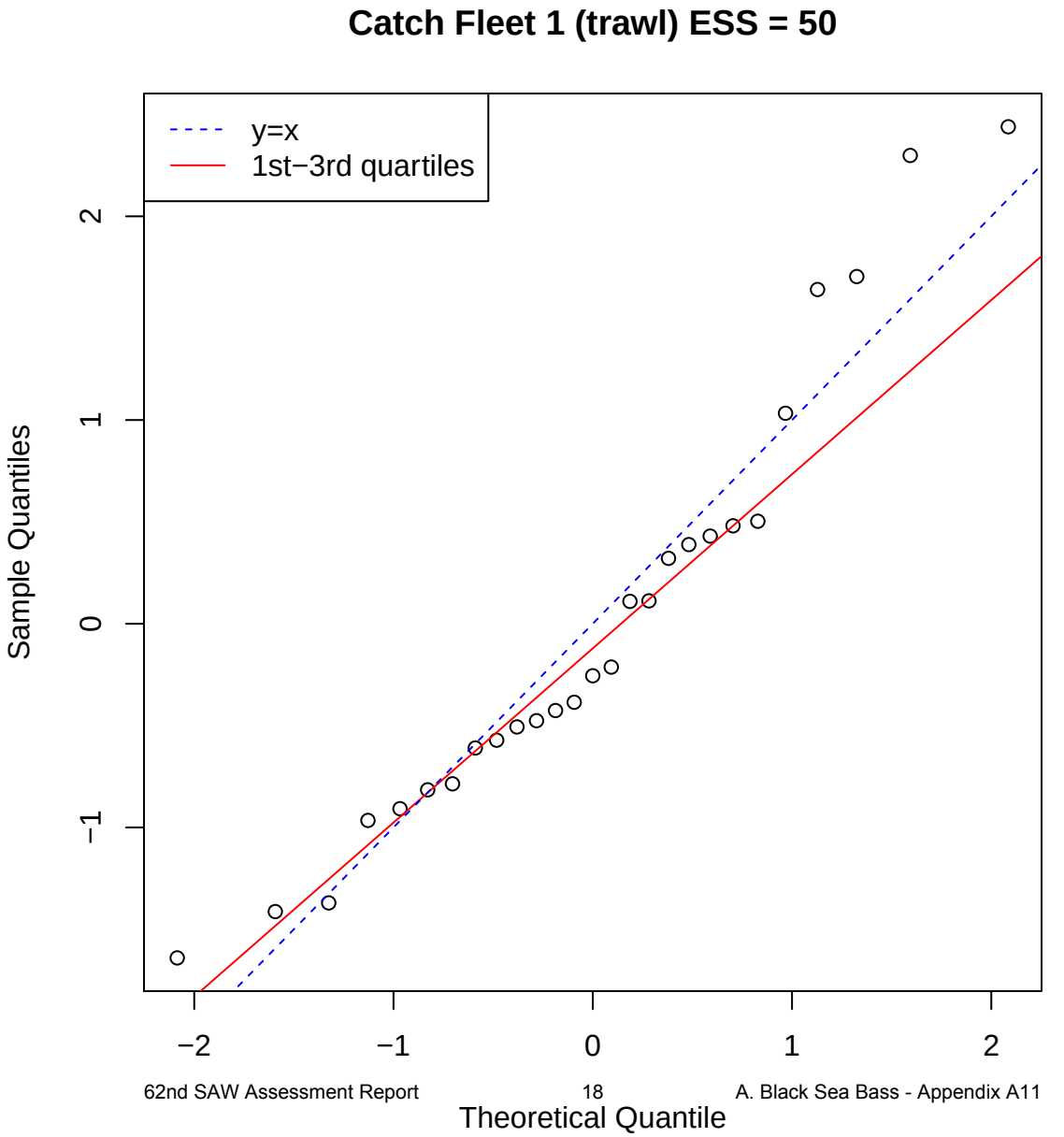


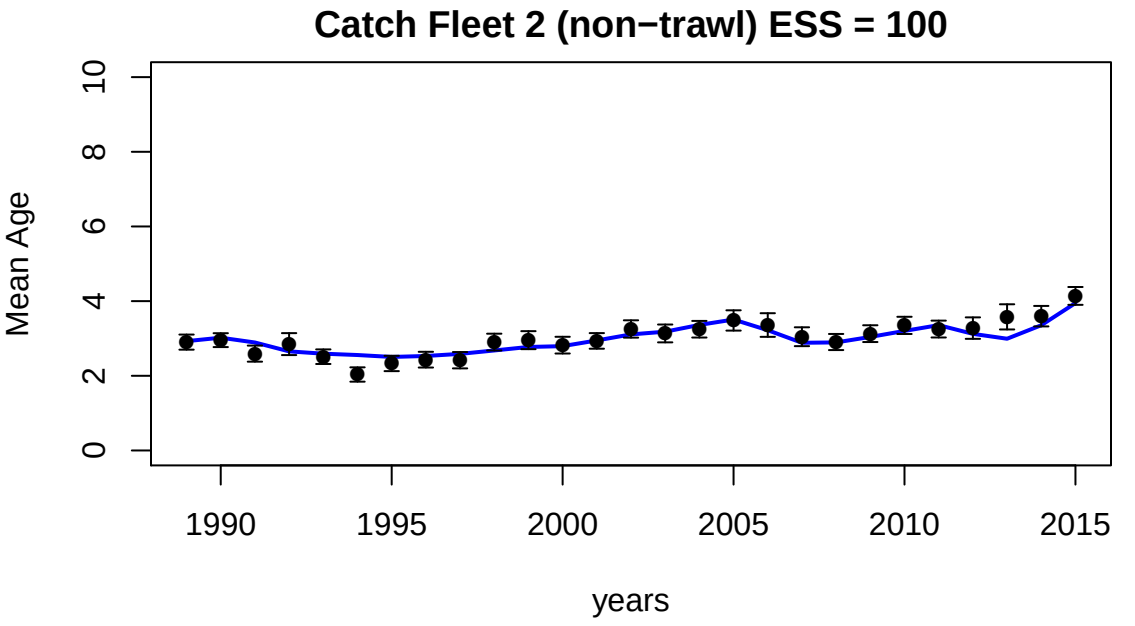

Catch Neff Fleet 1 (trawl)
Effective Sample Size
0
200
400
600
800
1000
1990
1995
2000
2005
2010
2015
Year

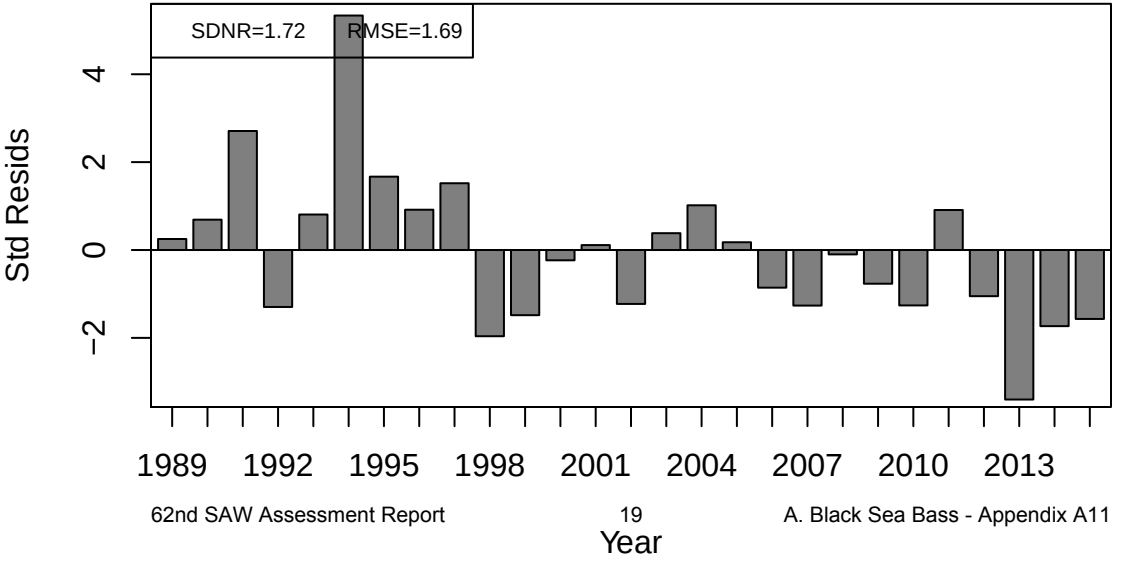

Catch Neff Fleet 2 (non−trawl)
Effective Sample Size
0
100
200
300
400
500
1990
1995
2000
2005
2010
2015
Year

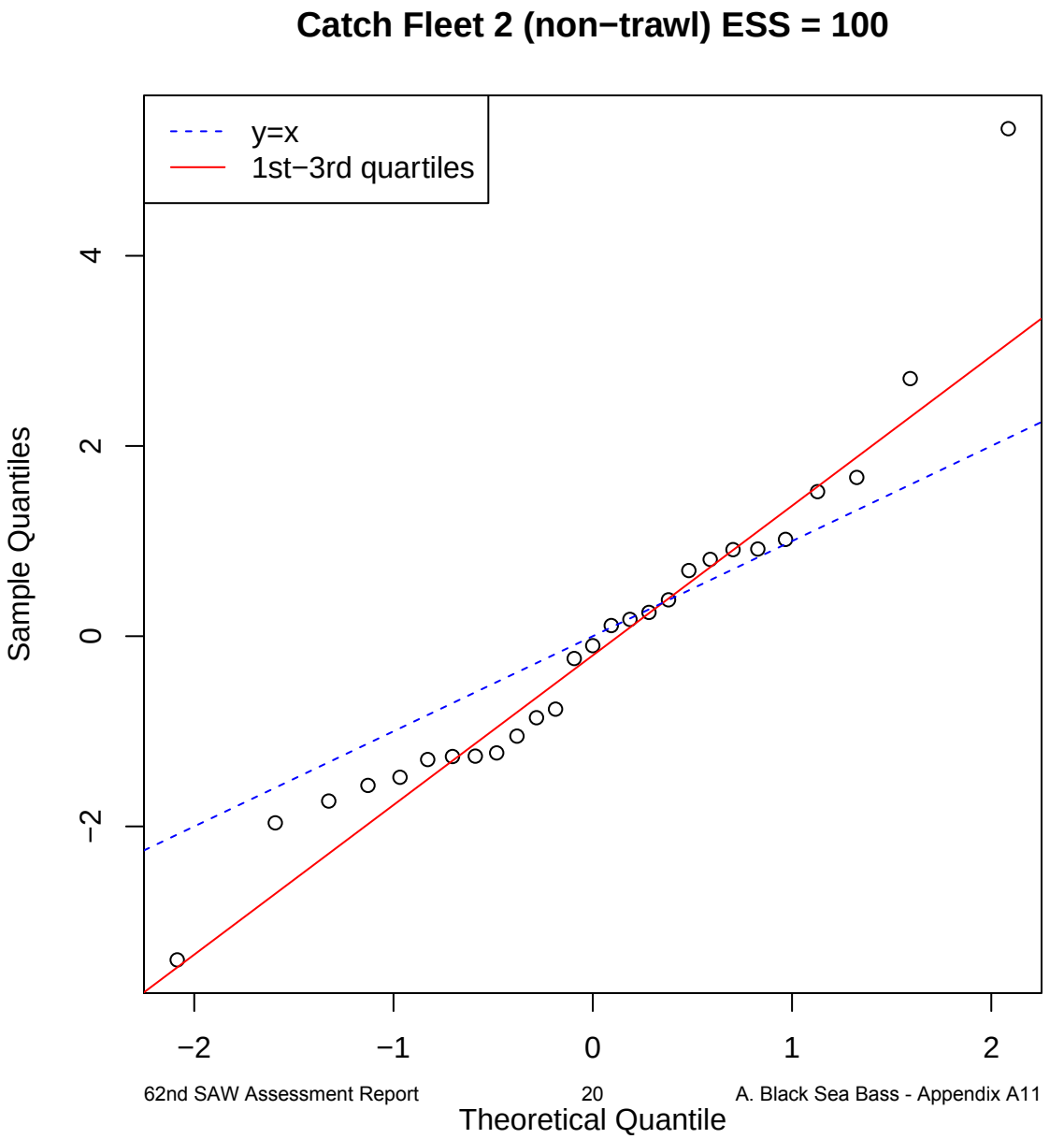

Catch Fleet 1 (trawl) ESS = 50
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
years


SDNR=1.08
RMSE=1.06
Std Resids
−1
0
1
2
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

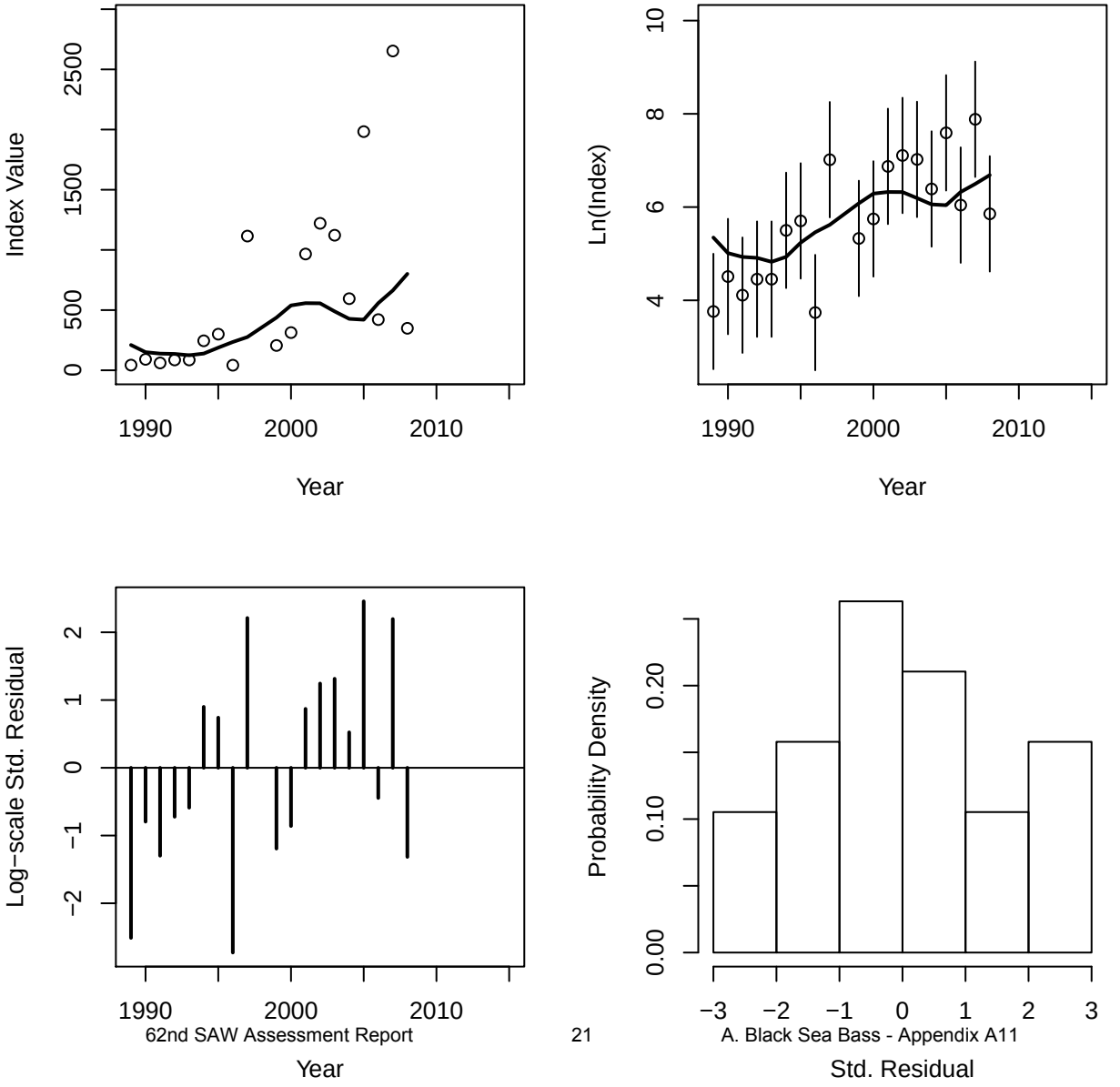

Catch Fleet 1 (trawl) ESS = 50
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
−1
0
1
2


Catch Fleet 2 (non−trawl) ESS = 100
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
years

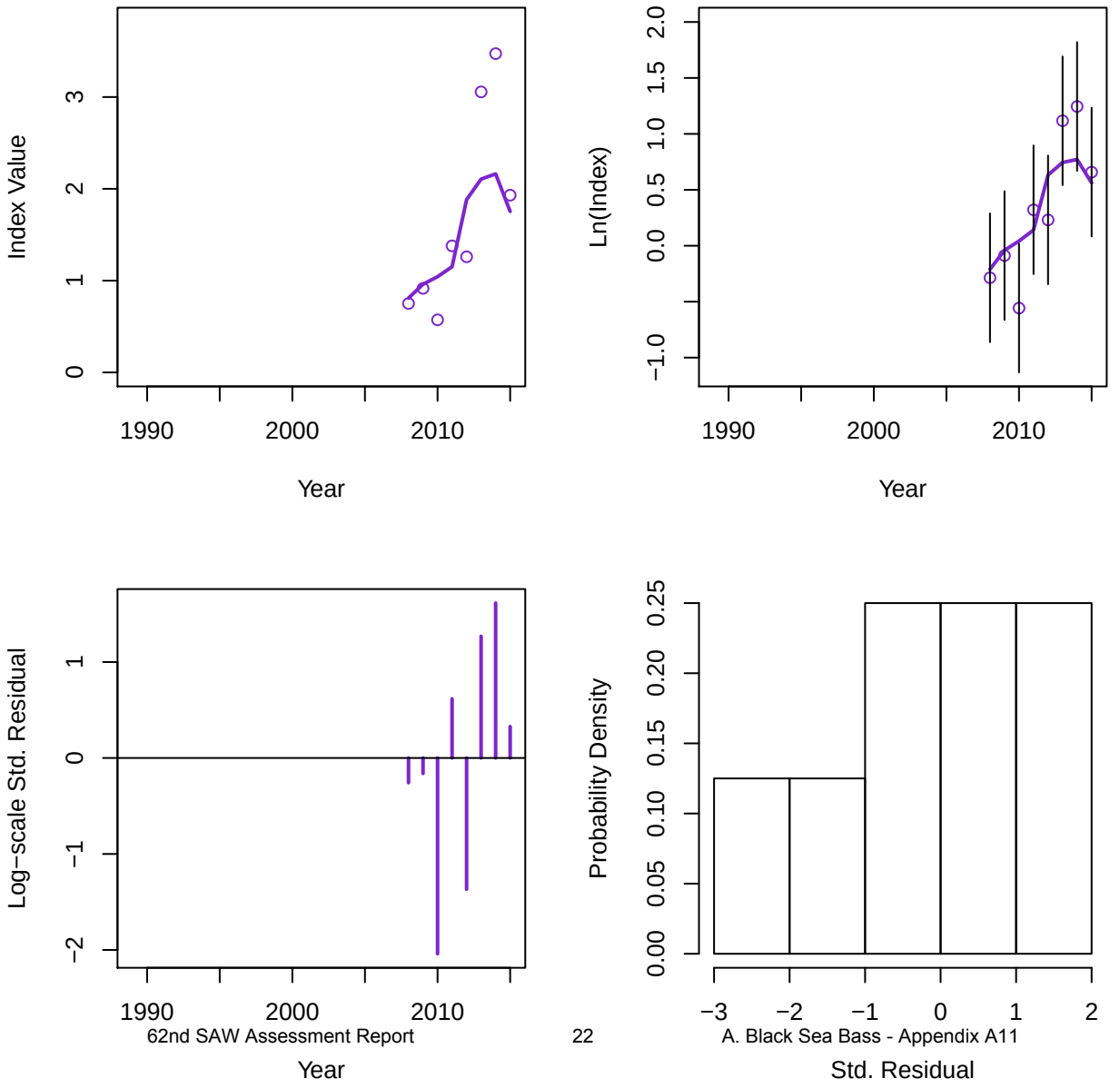

SDNR=1.72
RMSE=1.69
Std Resids
−2
0
2
4
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year


Catch Fleet 2 (non−trawl) ESS = 100
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
0
2
4
−2
−1
0
1
2

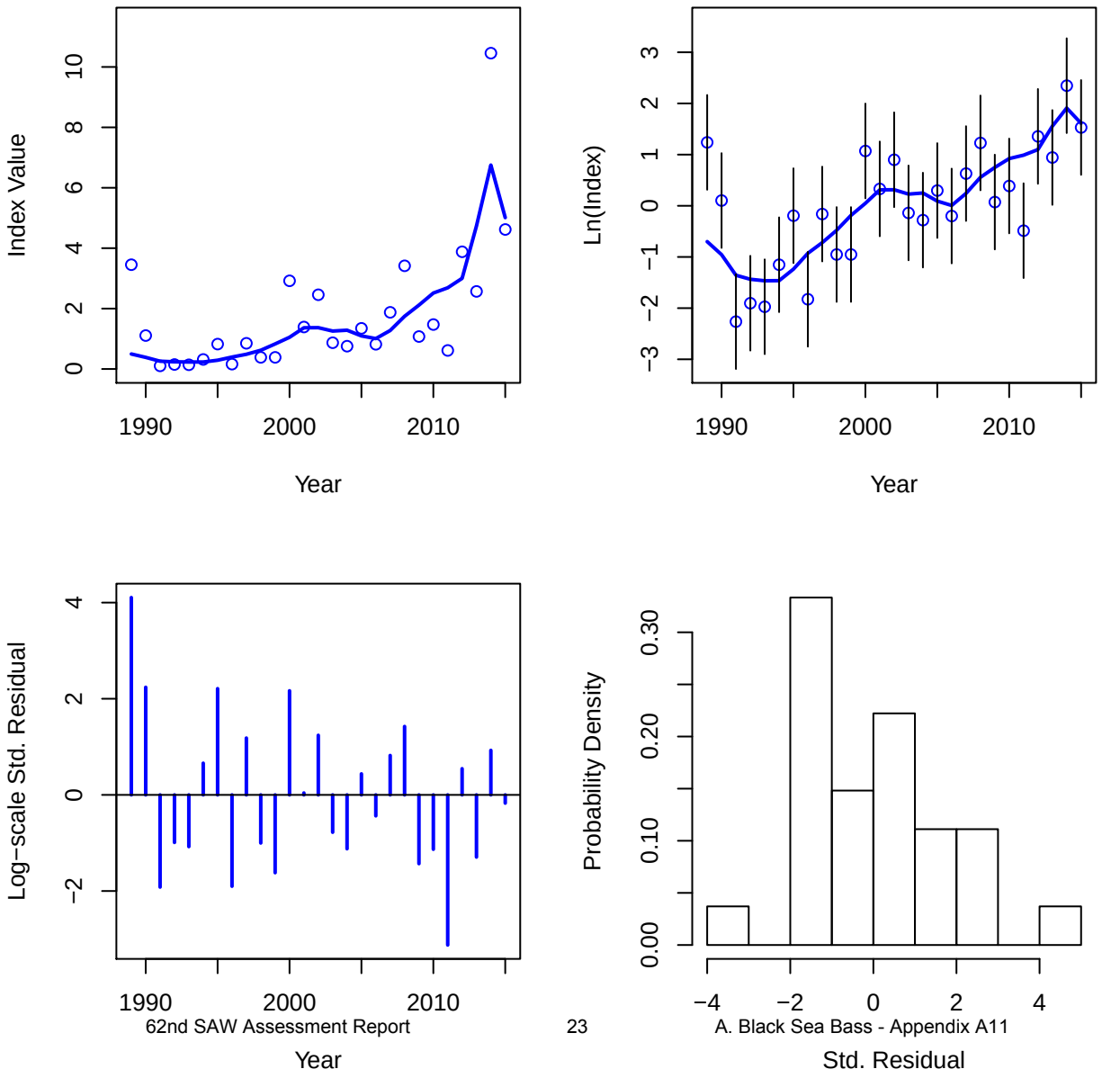
Index 1 (NEFSC spring Alb)



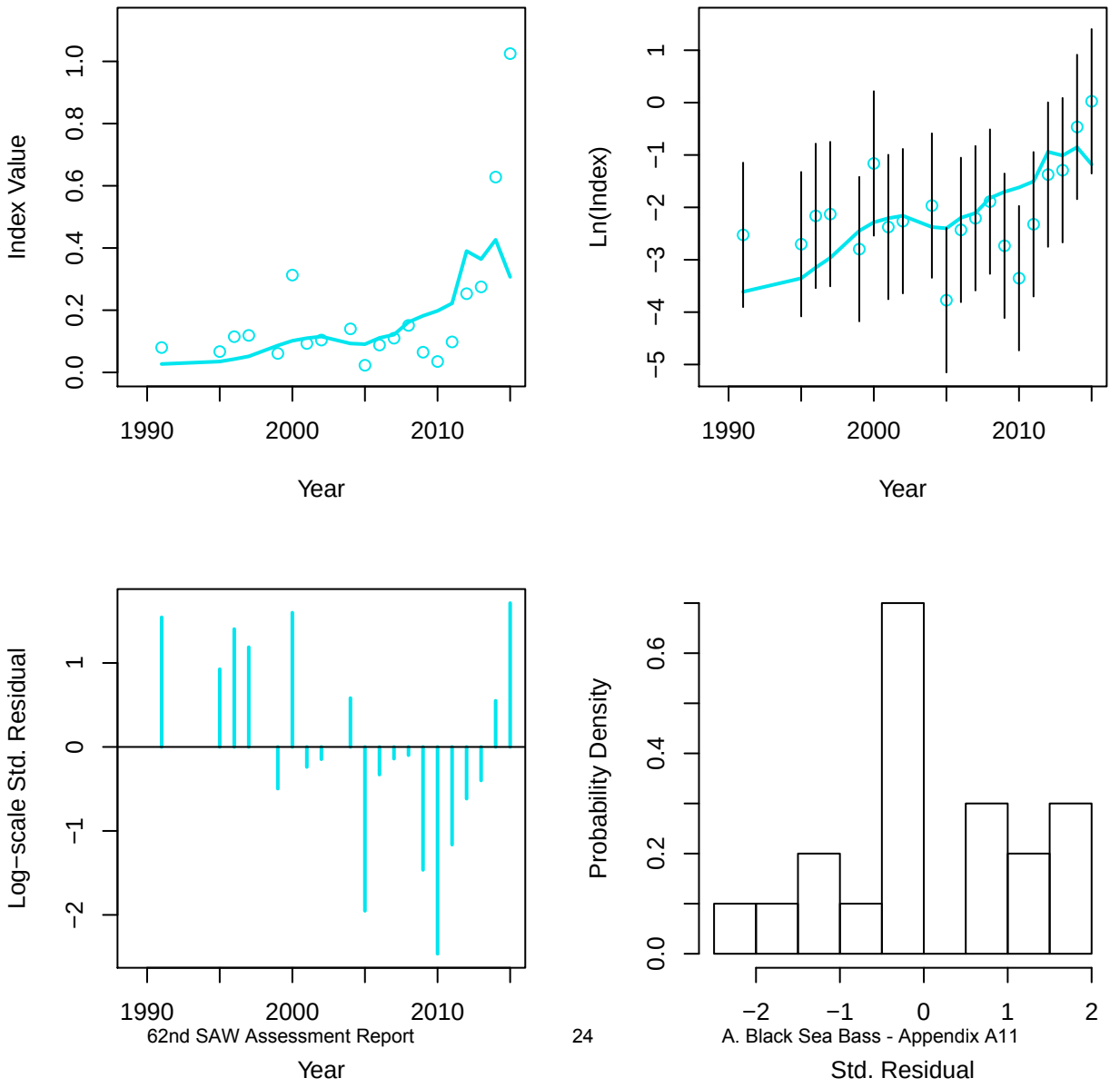
Index 2 (NEAMAP)



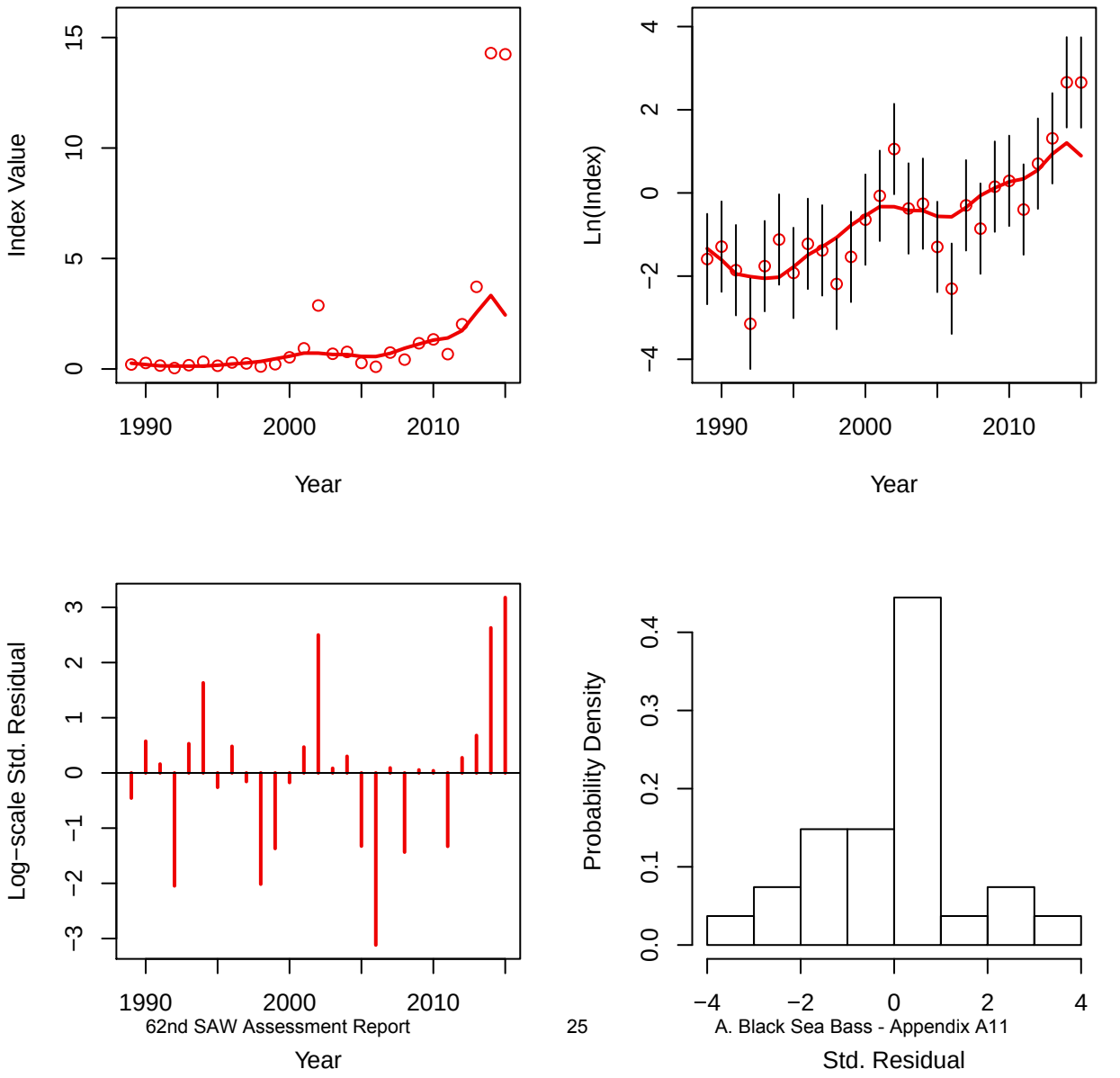
Index 3 (MADMF)



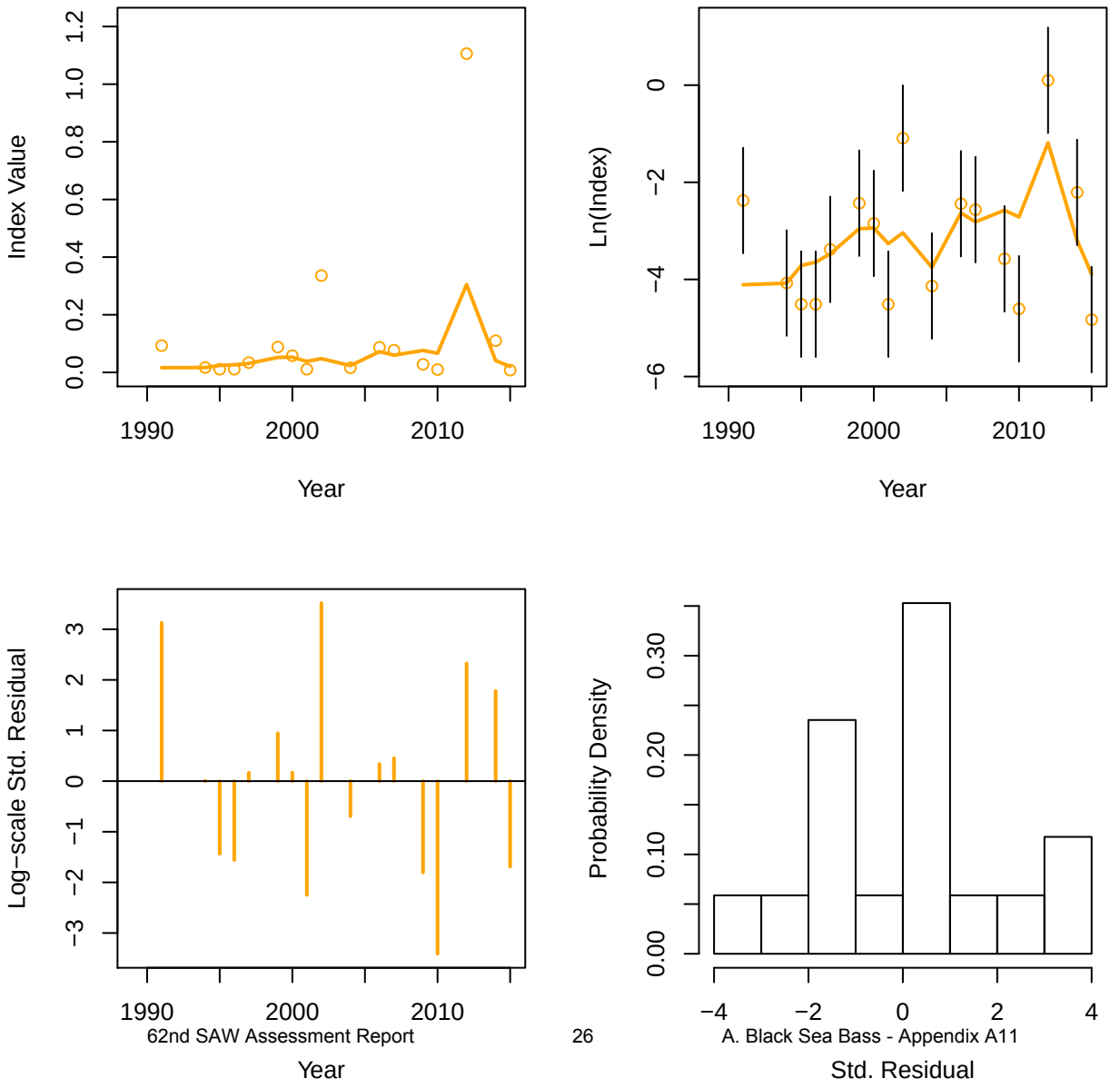
Index 4 (RI)


Index Value
0.0
0.2
0.4
0.6
0.8
1.0
1990
2000
2010
Year
Ln(Index)
−5
−4
−3
−2
−1
0
1
1990
2000
2010
Year
Log−scale Std. Residual
−2
−1
0
1
1990
2000
2010
Year
Probability Density
0.0
0.2
0.4
0.6
−2
−1
0
1
2
Std. Residual

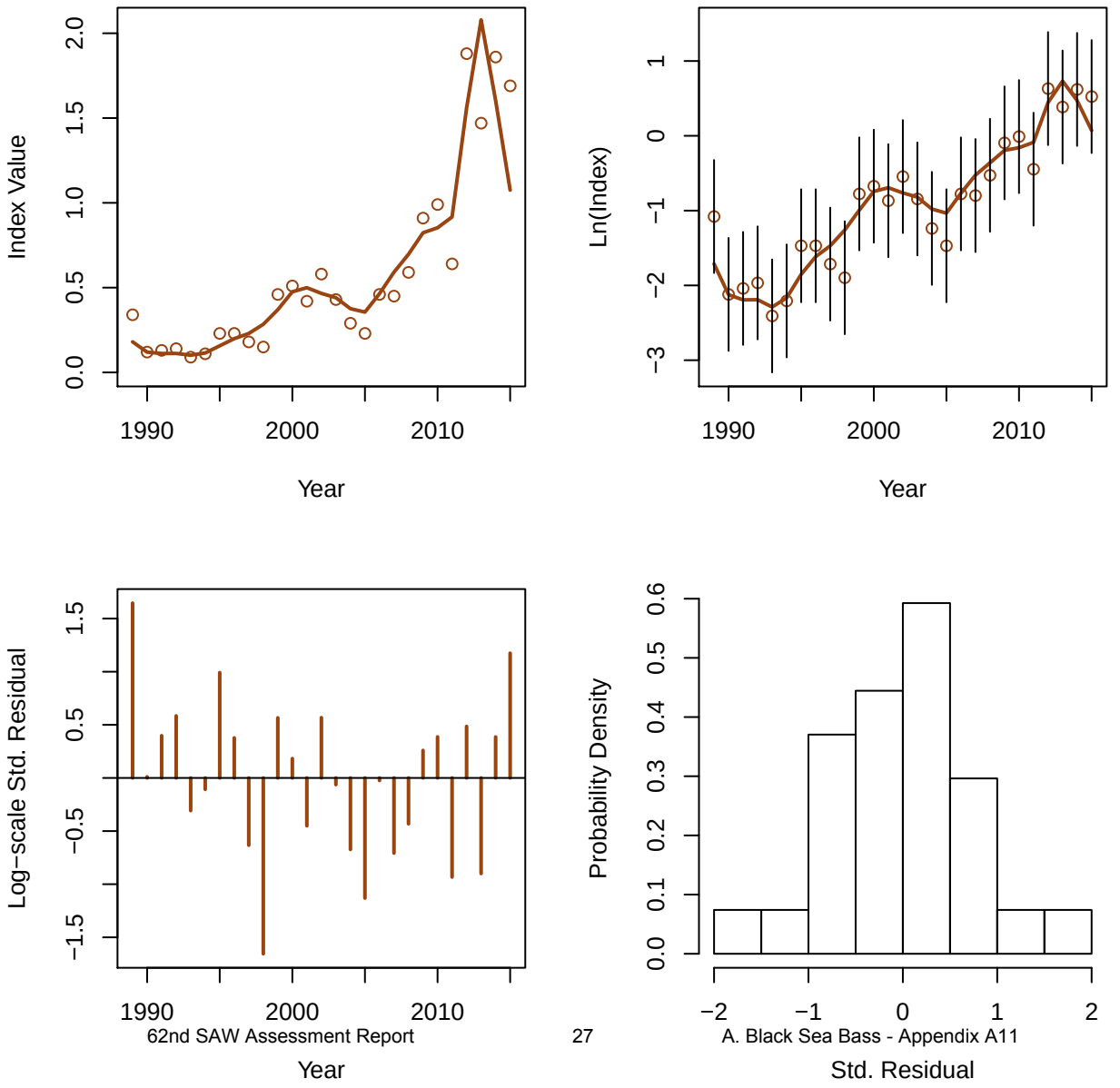
Index 5 (CT)


Index Value
0
5
10
15
1990
2000
2010
Year
Ln(Index)
−4
−2
0
2
4
1990
2000
2010
Year
Log−scale Std. Residual
−3
−2
−1
0
1
2
3
1990
2000
2010
Year
Probability Density
0.0
0.1
0.2
0.3
0.4
−4
−2
0
2
4
Std. Residual

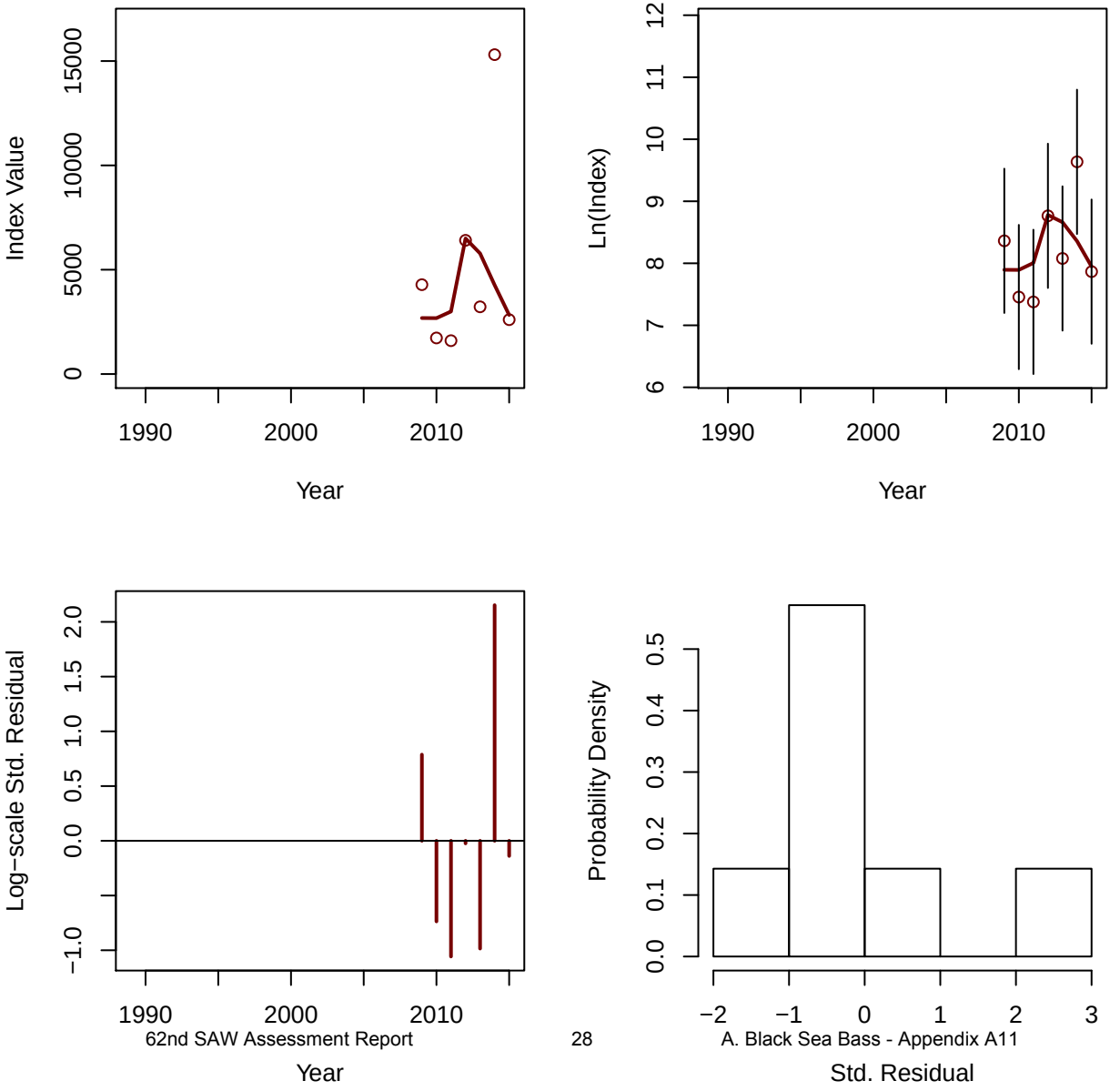
Index 6 (NY)


Index Value
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1990
2000
2010
Year
Ln(Index)
0
−2
−4
−6
1990
2000
2010
Year
Log−scale Std. Residual
−3
−2
−1
0
1
2
3
1990
2000
2010
Year
Probability Density
0.00
0.10
0.20
0.30
−4
−2
0
2
4
Std. Residual

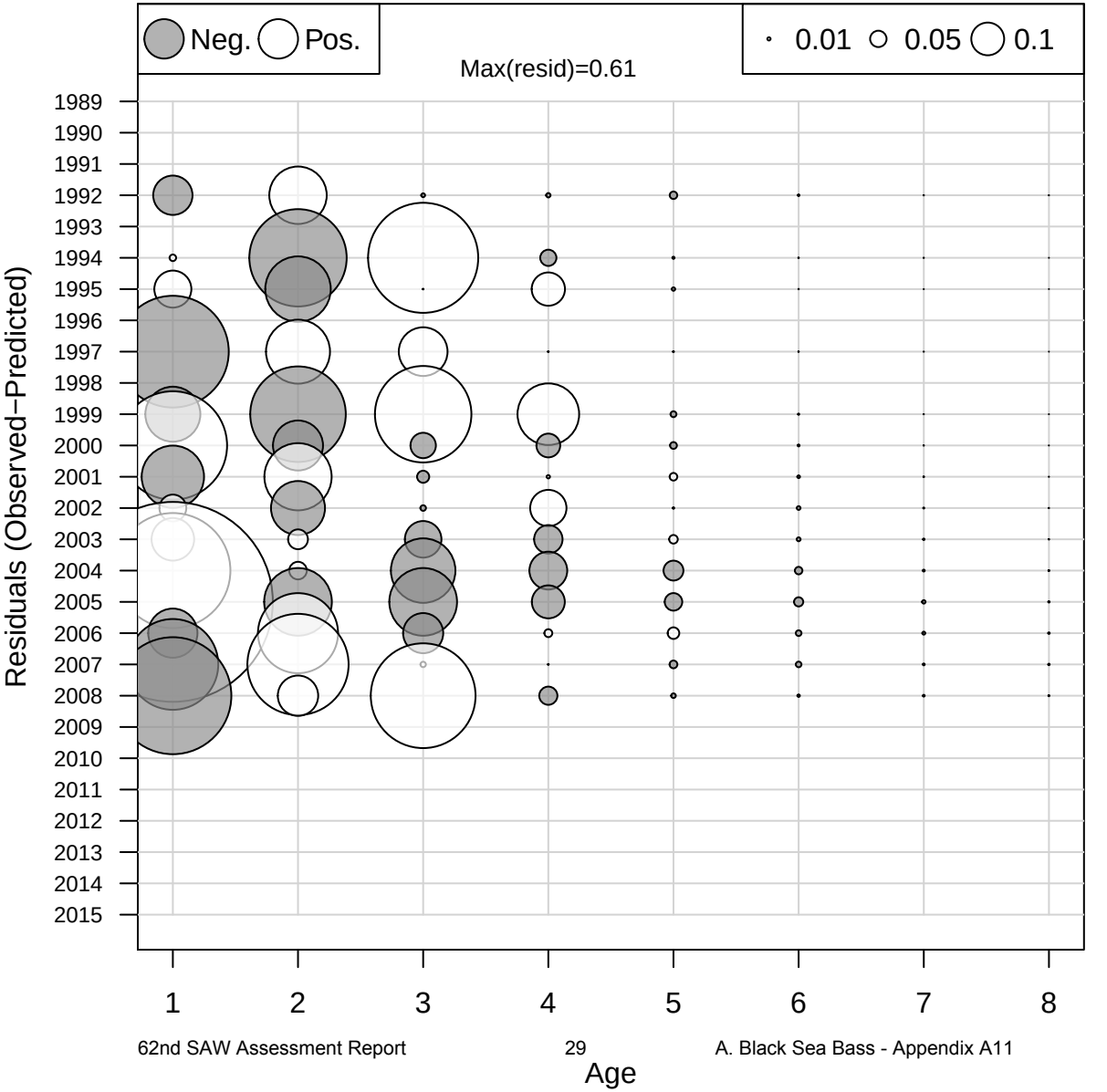
Index 7 (REC CPA)



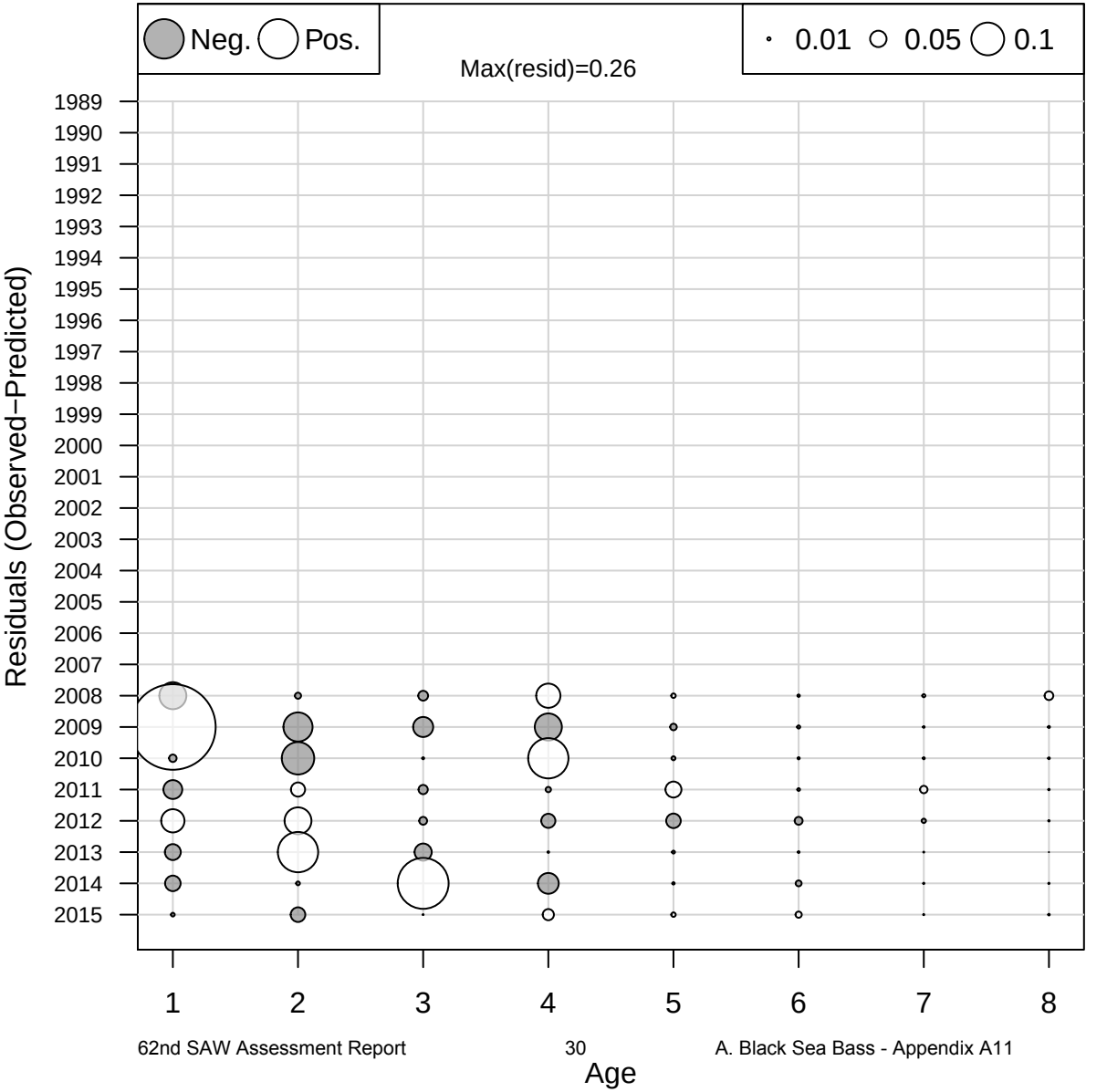
Index 8 (bigelow)



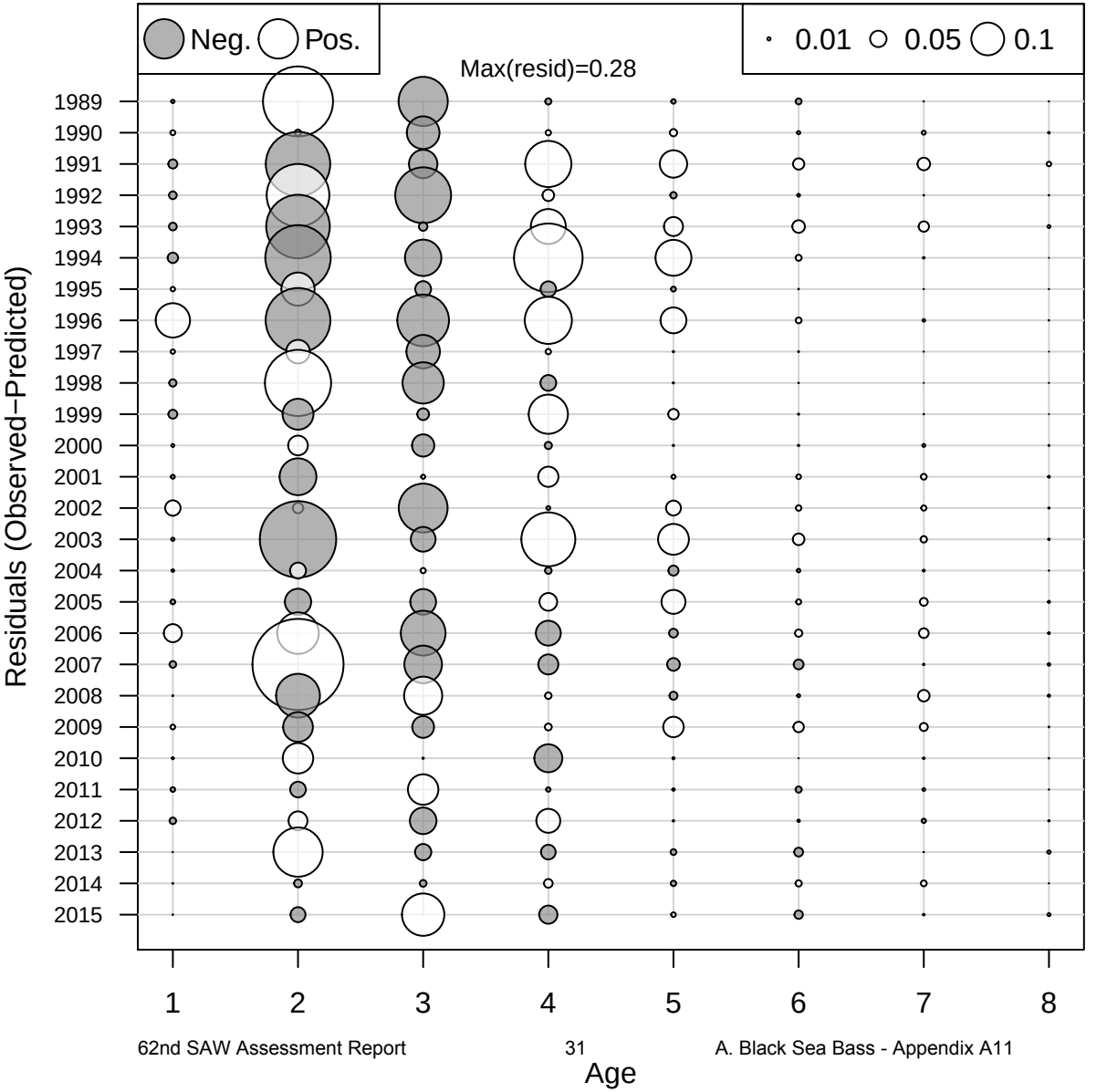
Age Comp Residuals for Index 1 (NEFSC spring Alb)



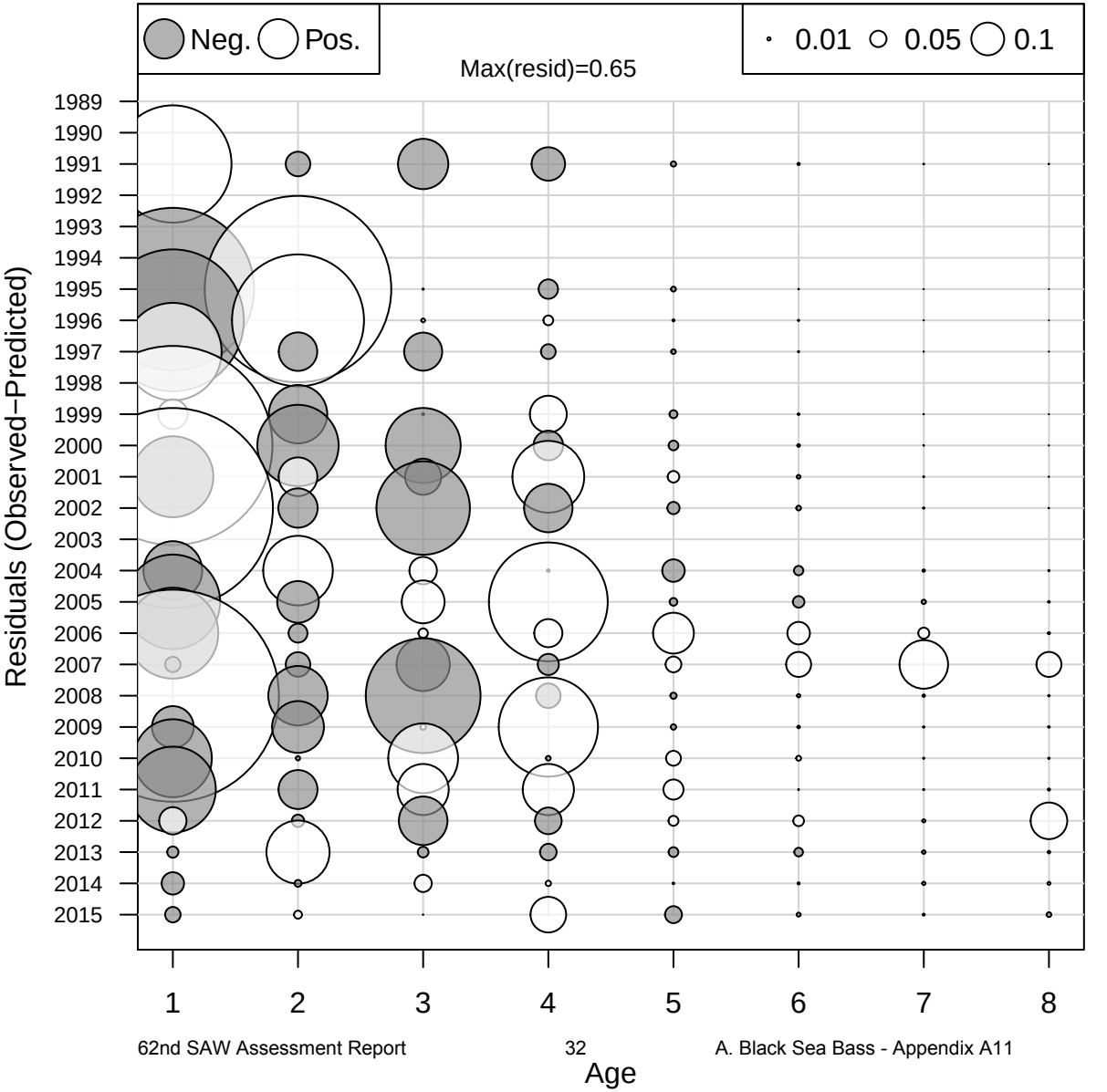
Age Comp Residuals for Index 2 (NEAMAP)



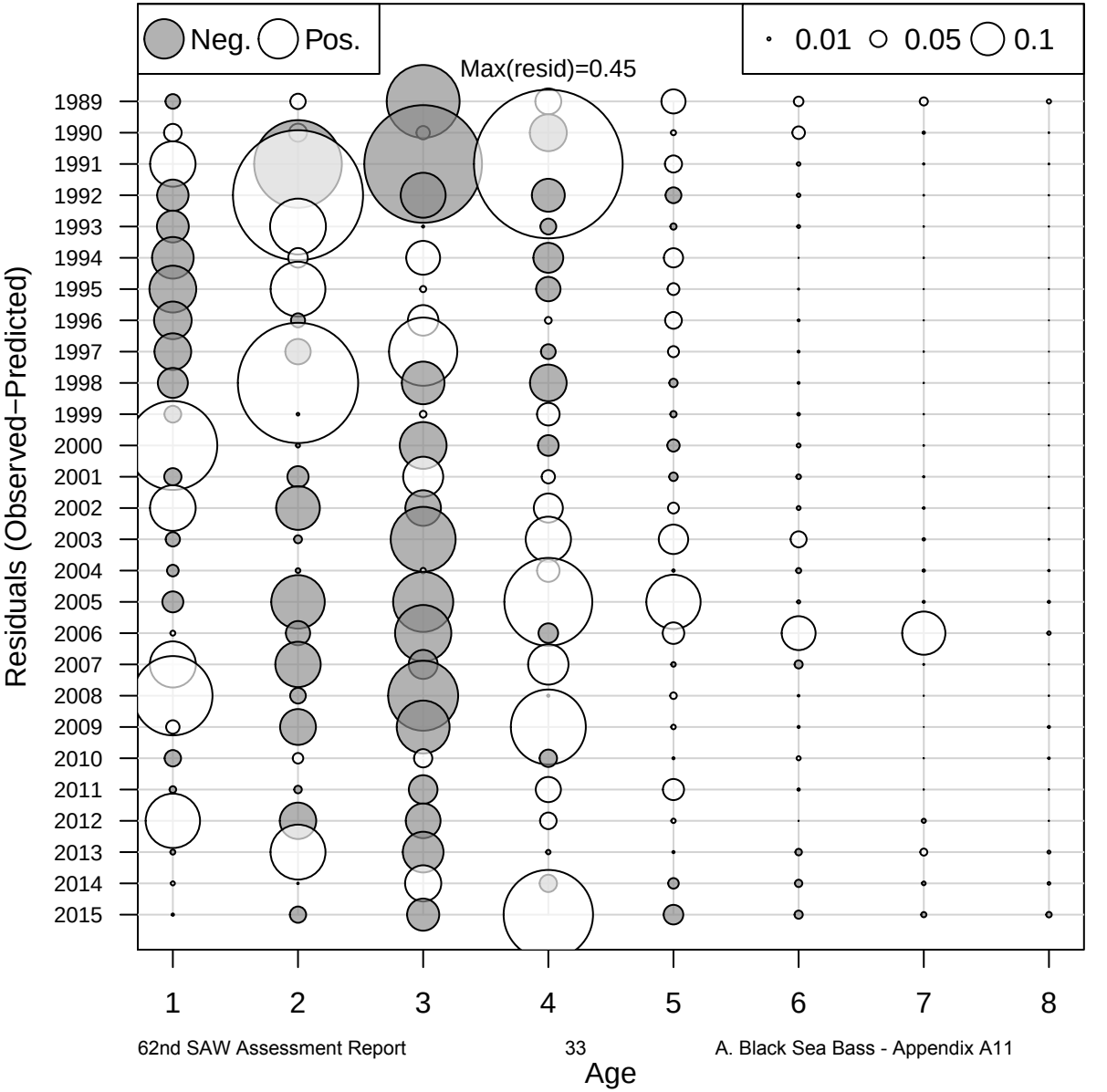
Age Comp Residuals for Index 3 (MADMF)

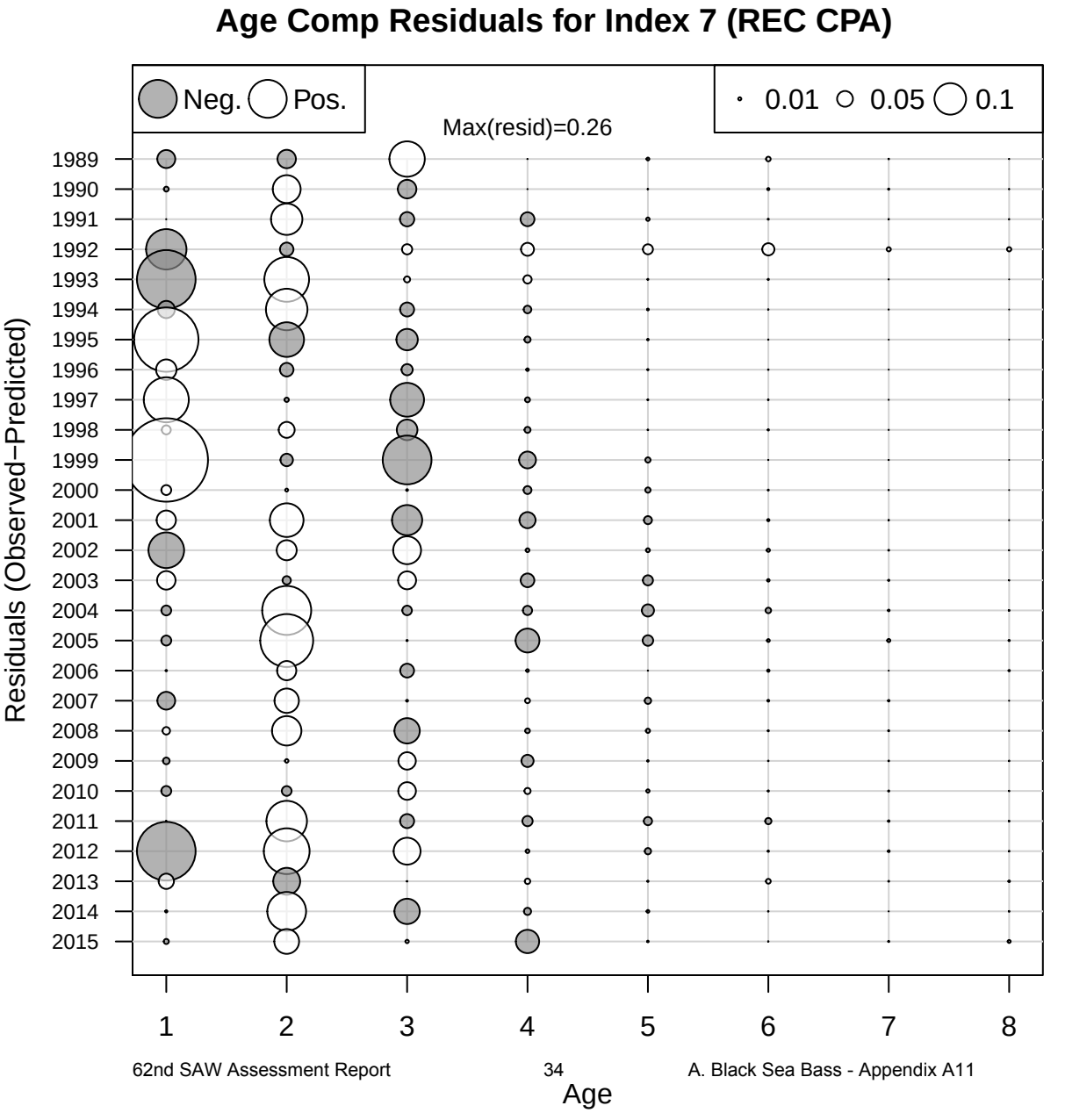


Age Comp Residuals for Index 4 (RI)

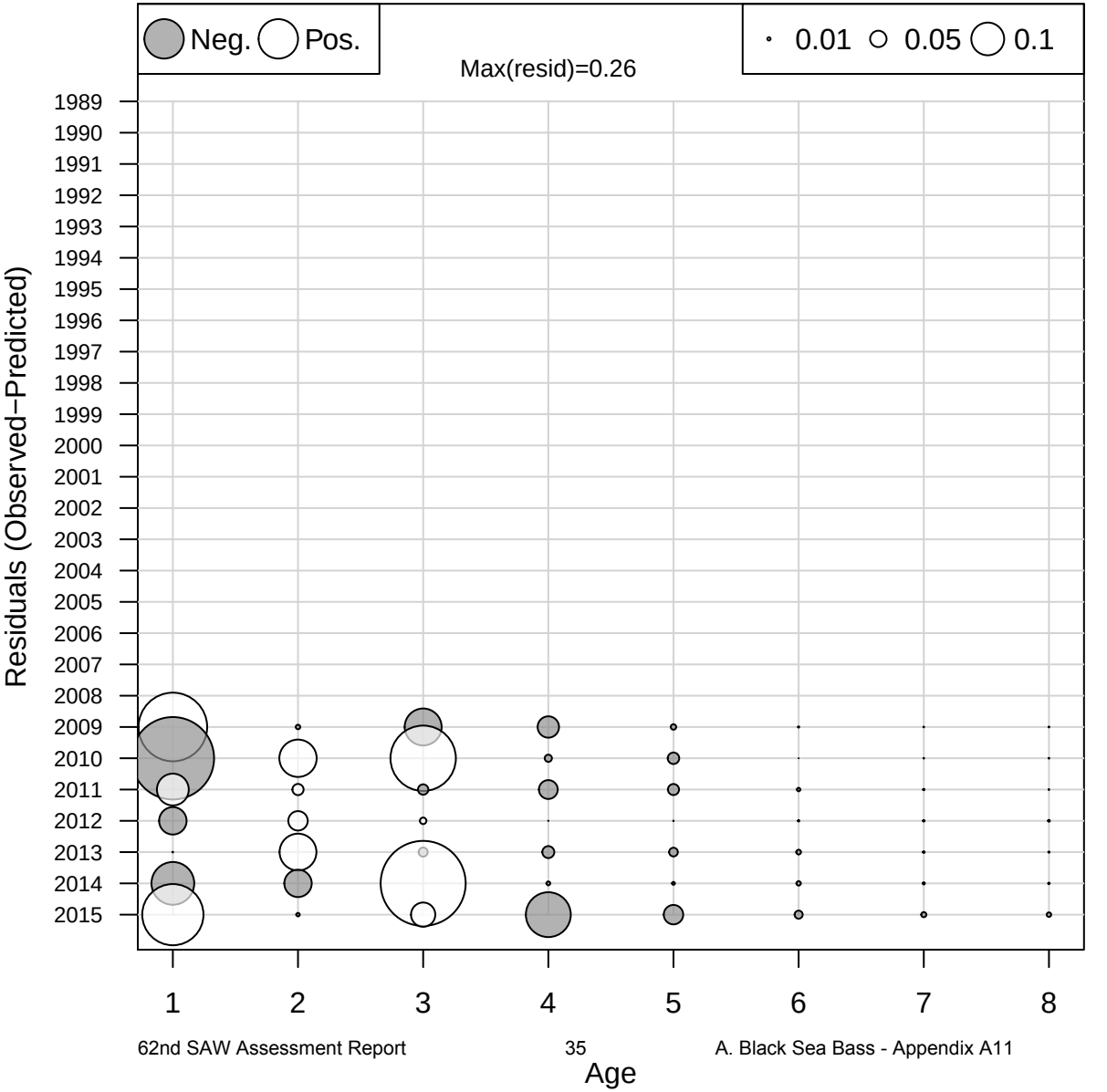


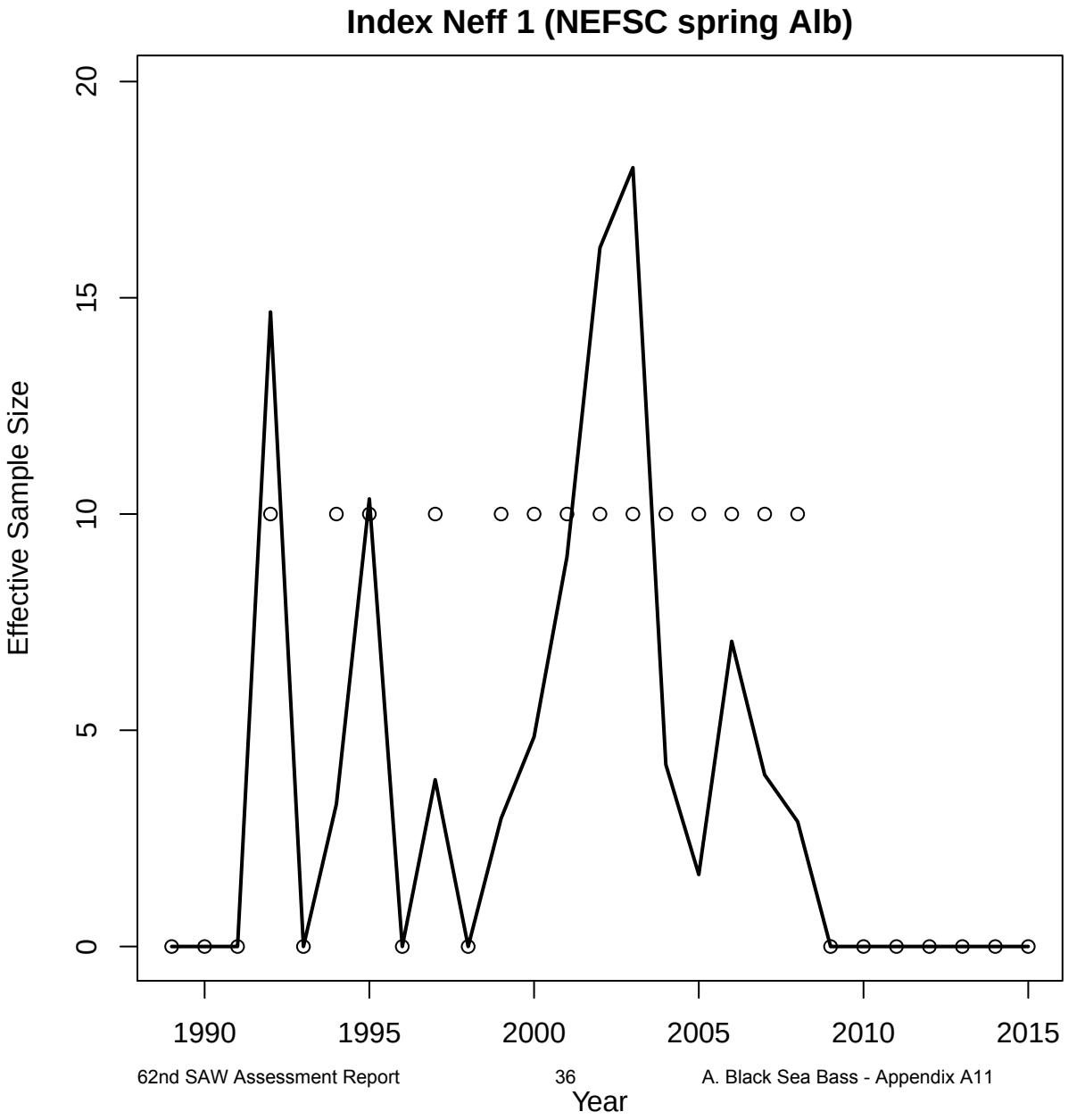
Age Comp Residuals for Index 5 (CT)

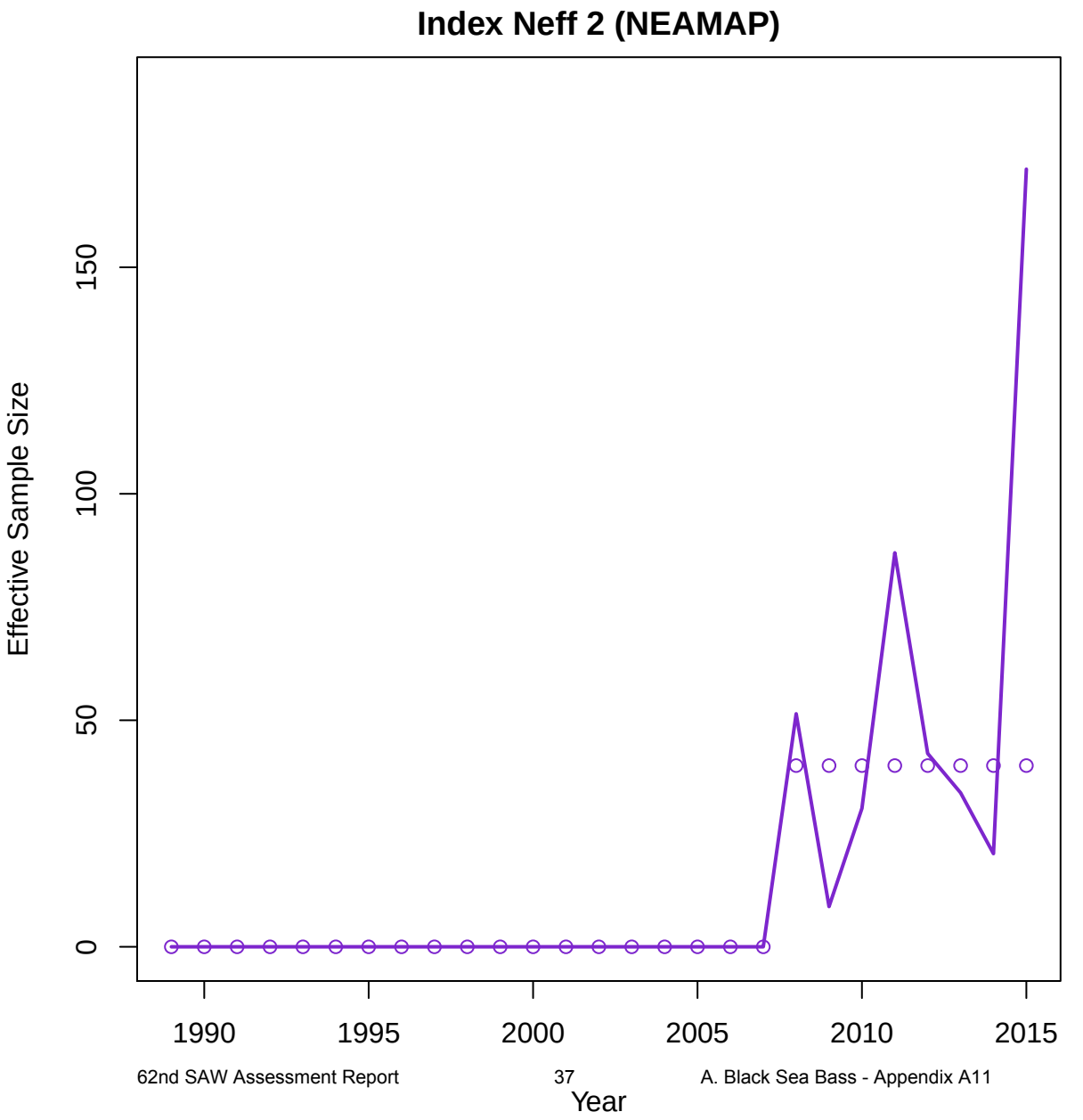


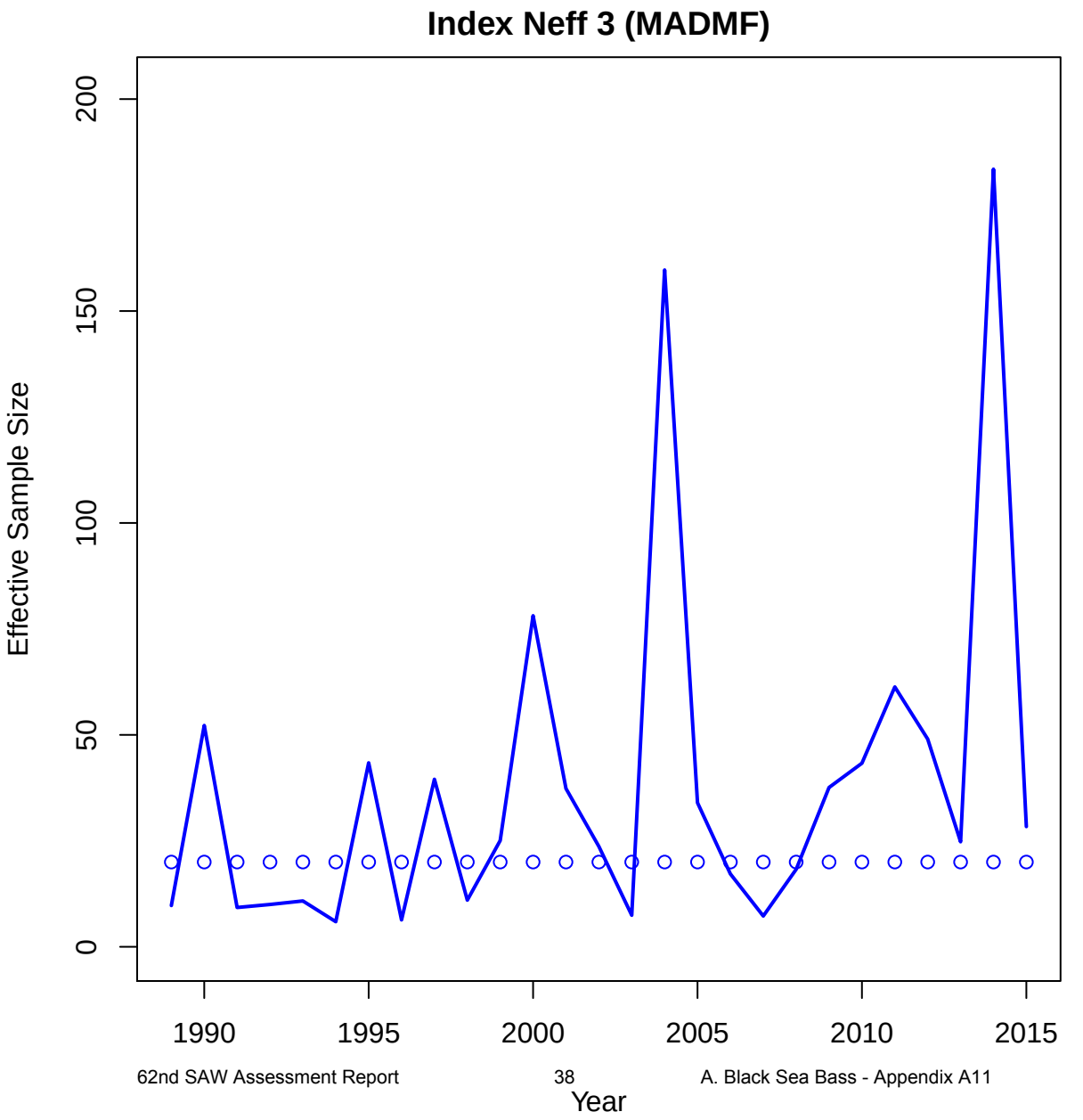

Age Comp Residuals for Index 7 (REC CPA)
Neg.
Pos.
0.01
0.05
0.1
Max(resid)=0.26
Residuals (Observed−Predicted)
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

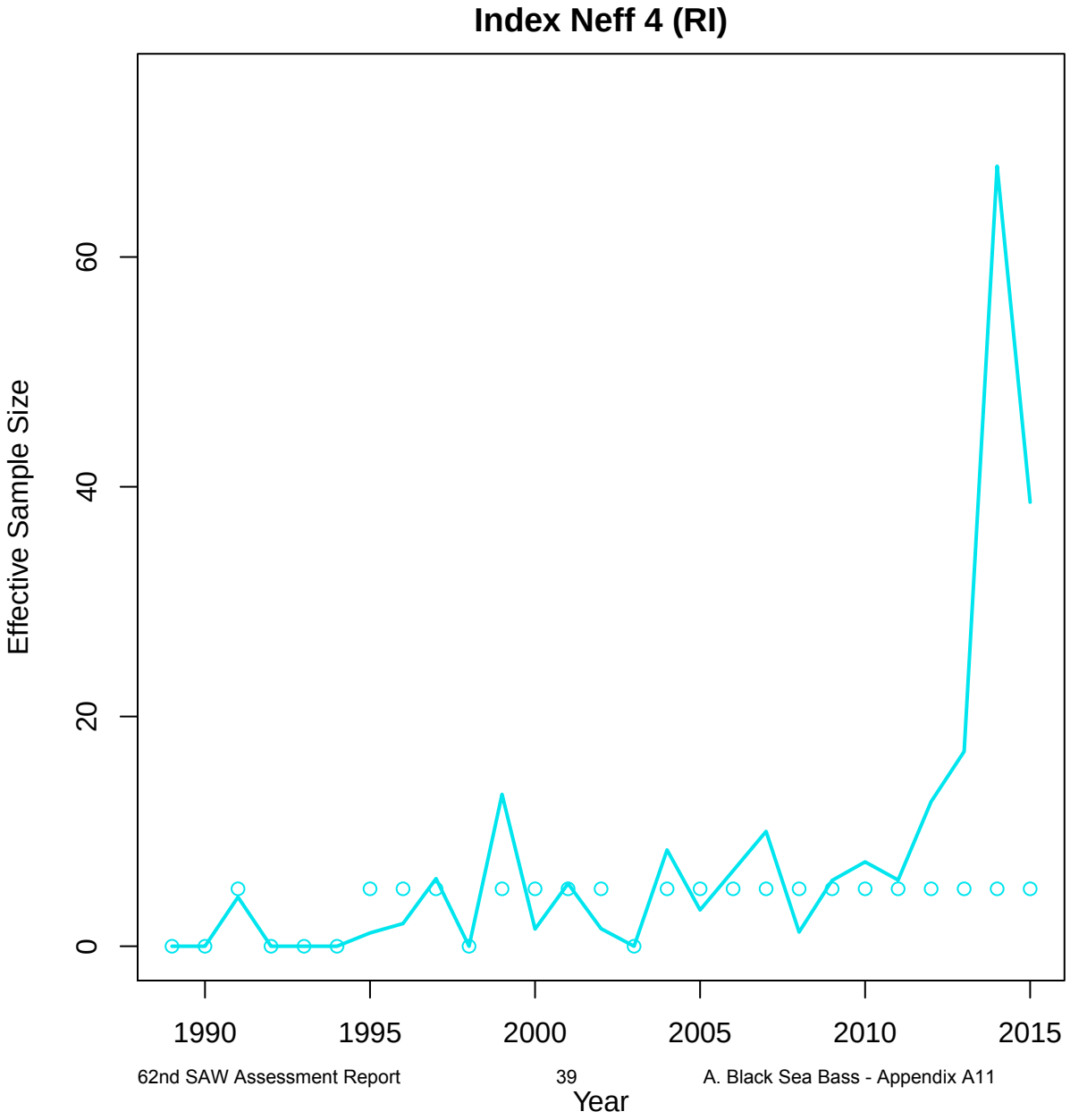
Age Comp Residuals for Index 8 (bigelow)

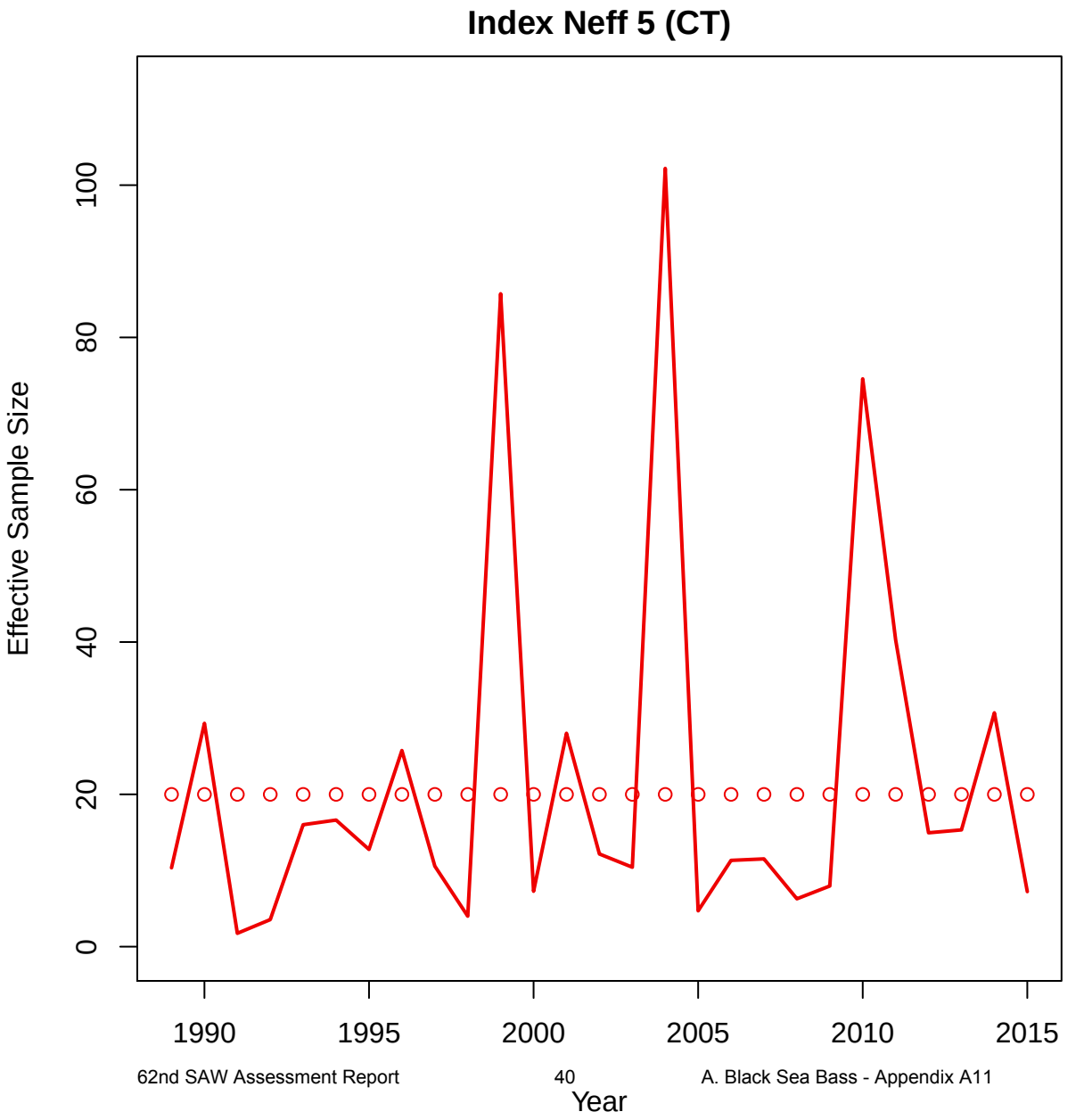


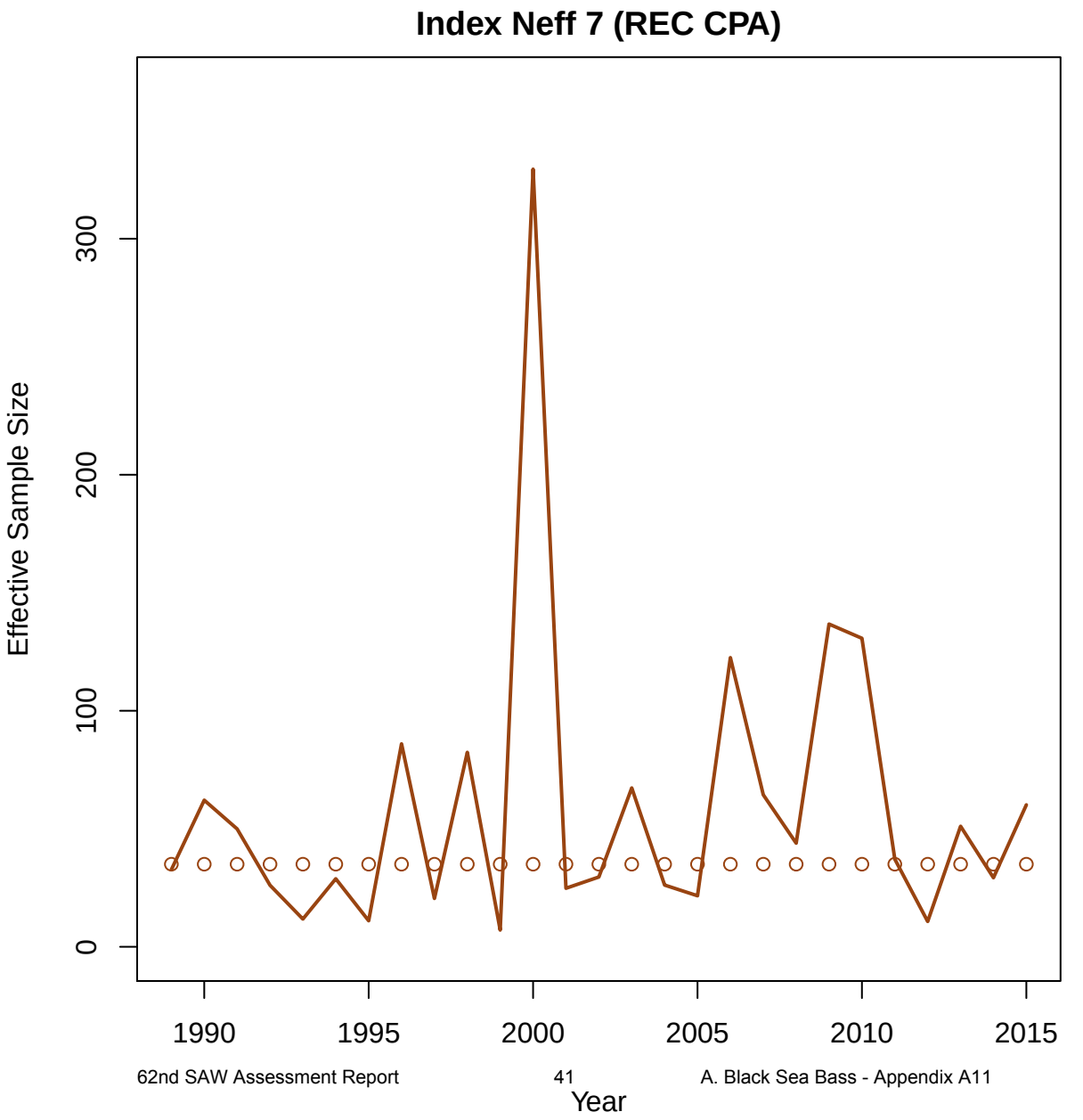

Index Neff 1 (NEFSC spring Alb)
Effective Sample Size
0
5
10
15
20
1990
1995
2000
2005
2010
2015
Year

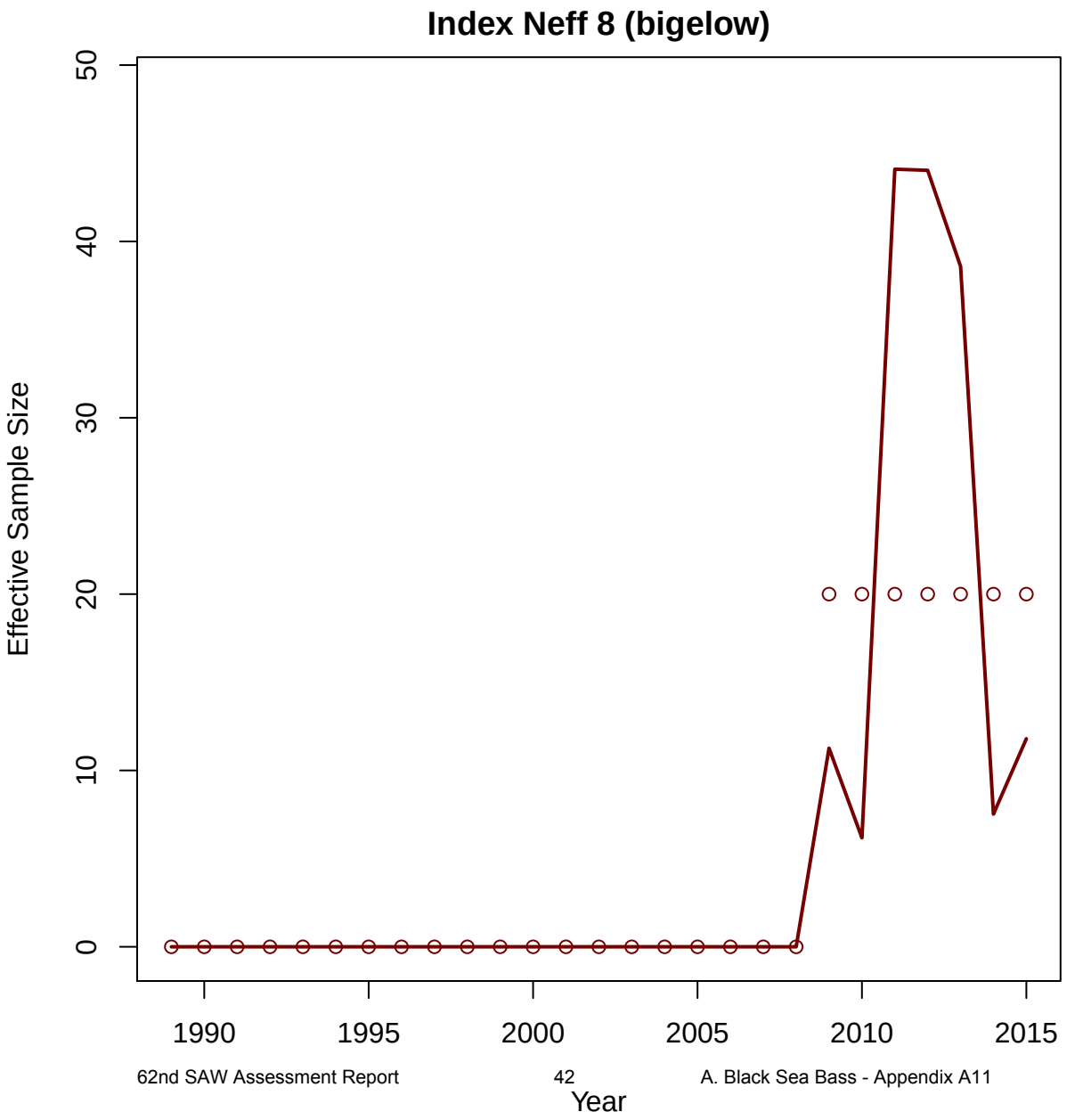

Index Neff 2 (NEAMAP)
Effective Sample Size
0
50
100
150
1990
1995
2000
2005
2010
2015
Year

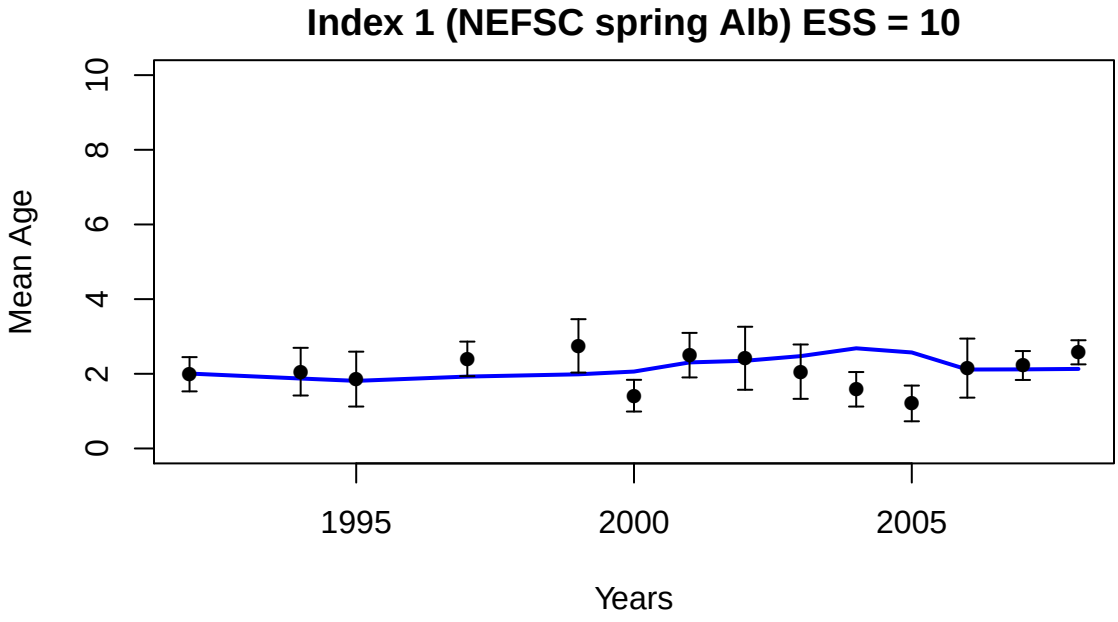

Index Neff 3 (MADMF)
Effective Sample Size
0
50
100
150
200
1990
1995
2000
2005
2010
2015
Year

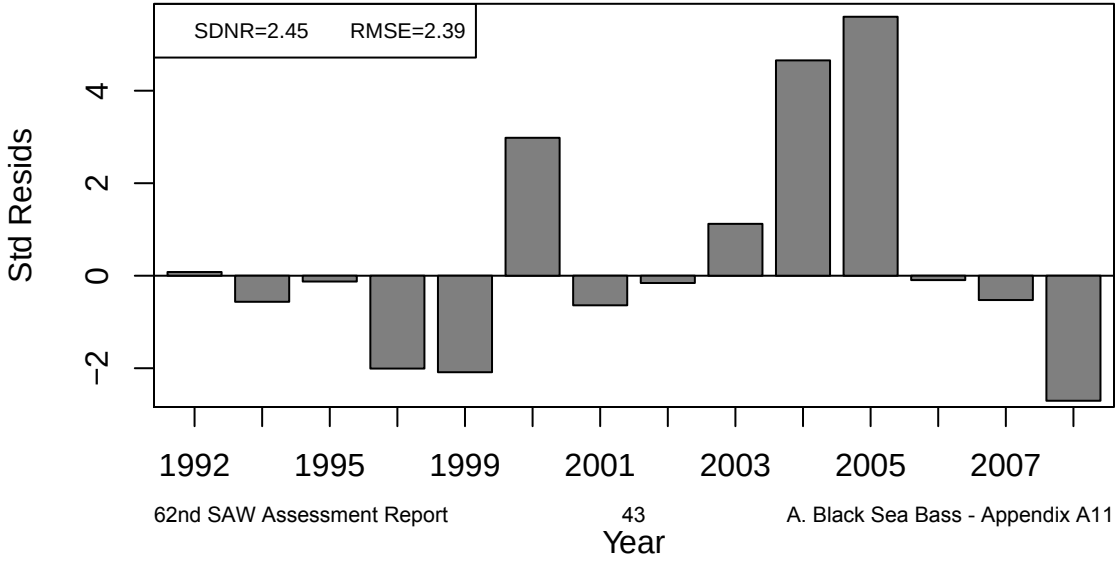

Index Neff 4 (RI)
Effective Sample Size
0
20
40
60
1990
1995
2000
2005
2010
2015
Year

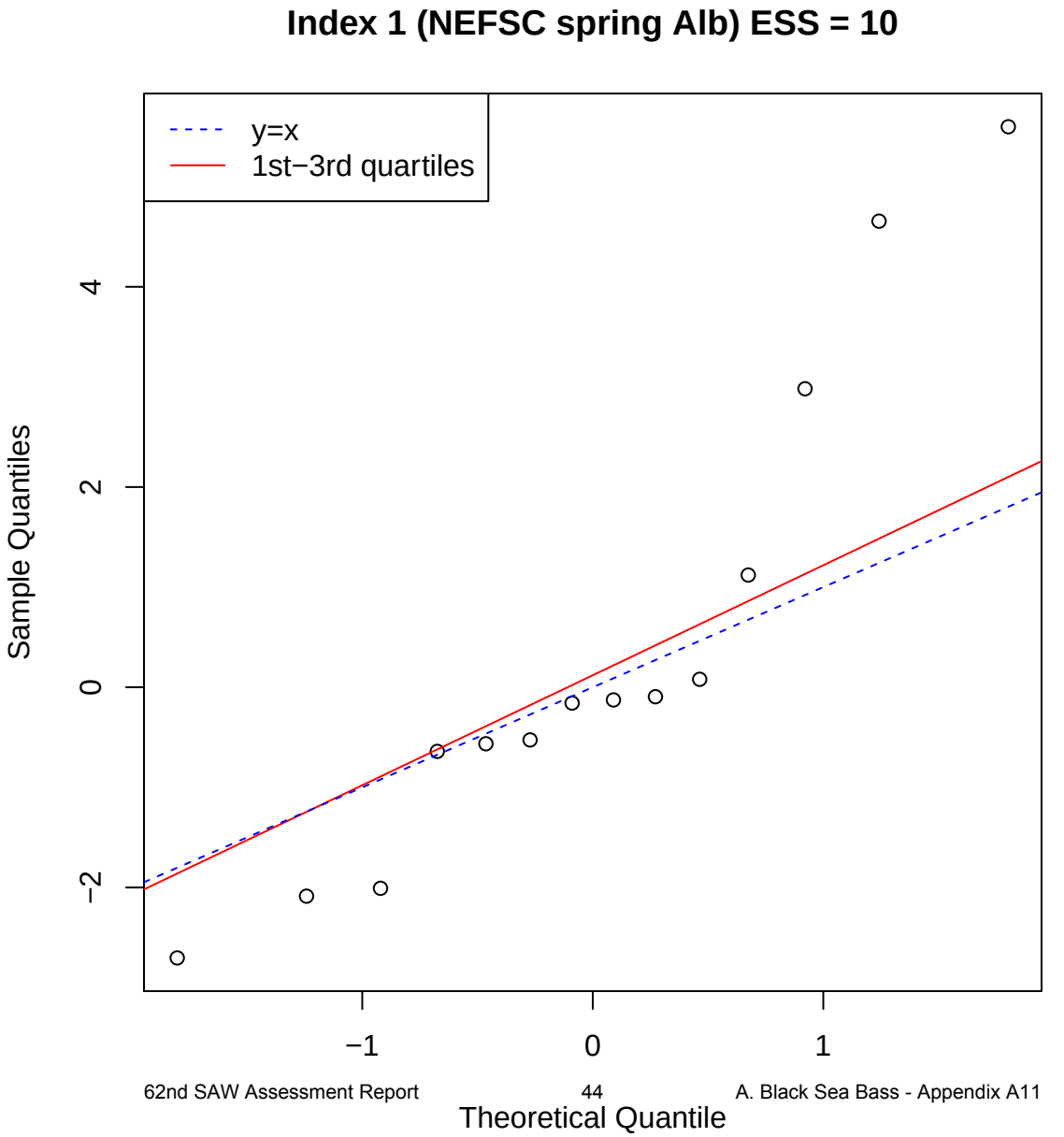

Index Neff 5 (CT)
Effective Sample Size
0
20
40
60
80
100
1990
1995
2000
2005
2010
2015
Year

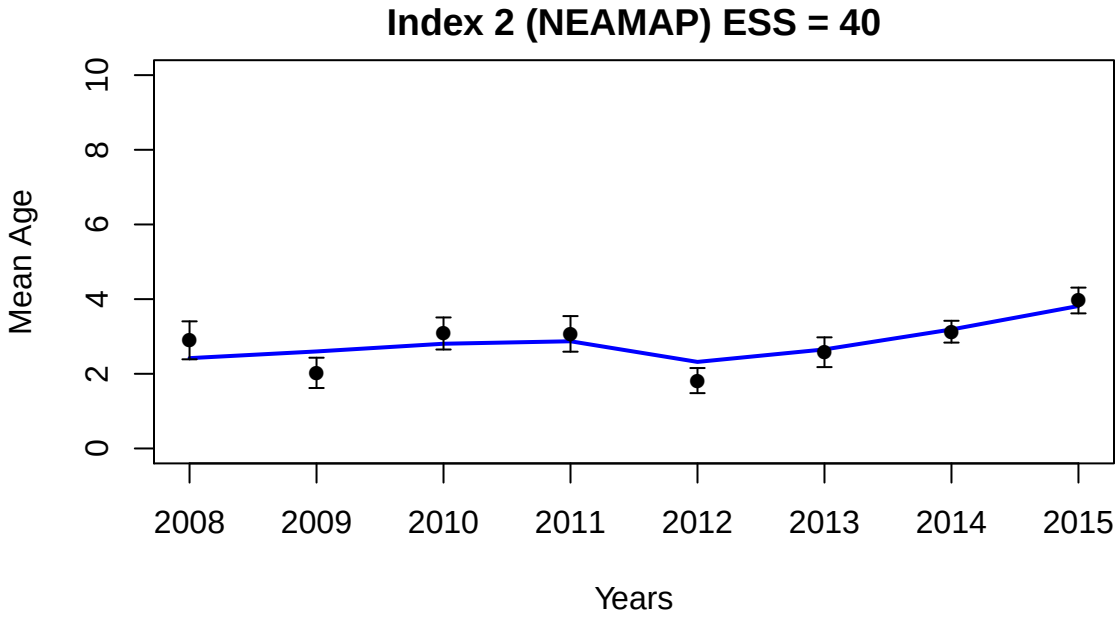

Index Neff 7 (REC CPA)
Effective Sample Size
0
100
200
300
1990
1995
2000
2005
2010
2015
Year

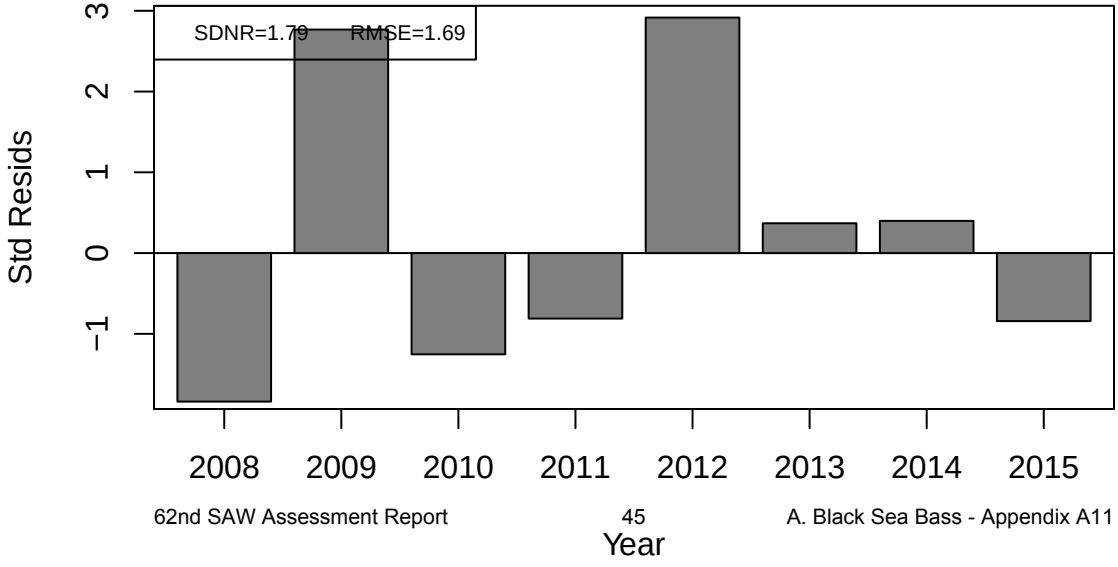

Index Neff 8 (bigelow)
Effective Sample Size
0
10
20
30
40
50
1990
1995
2000
2005
2010
2015
Year

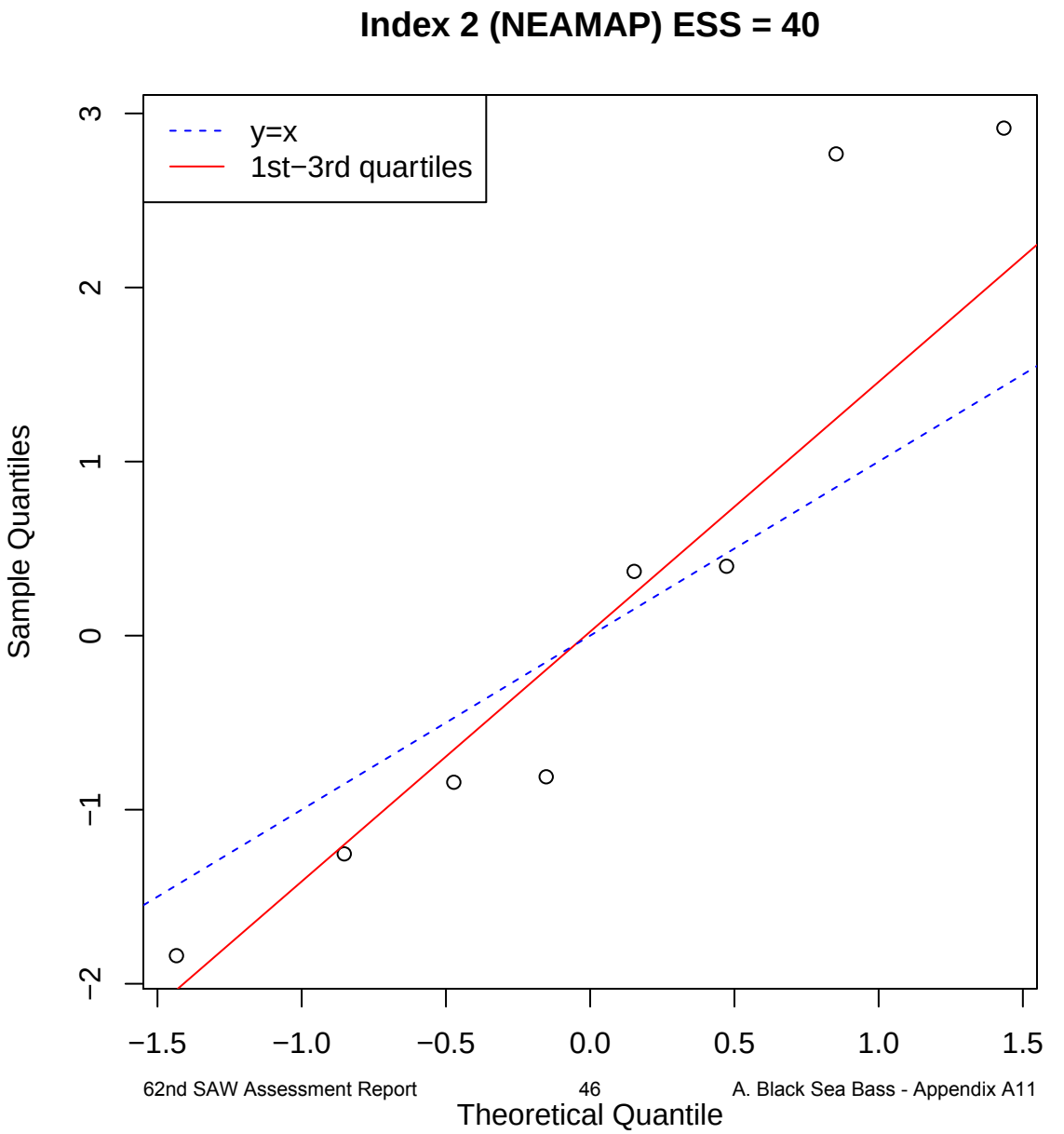

Index 1 (NEFSC spring Alb) ESS = 10
Mean Age
0
2
4
6
8
10
1995
2000
2005
Years

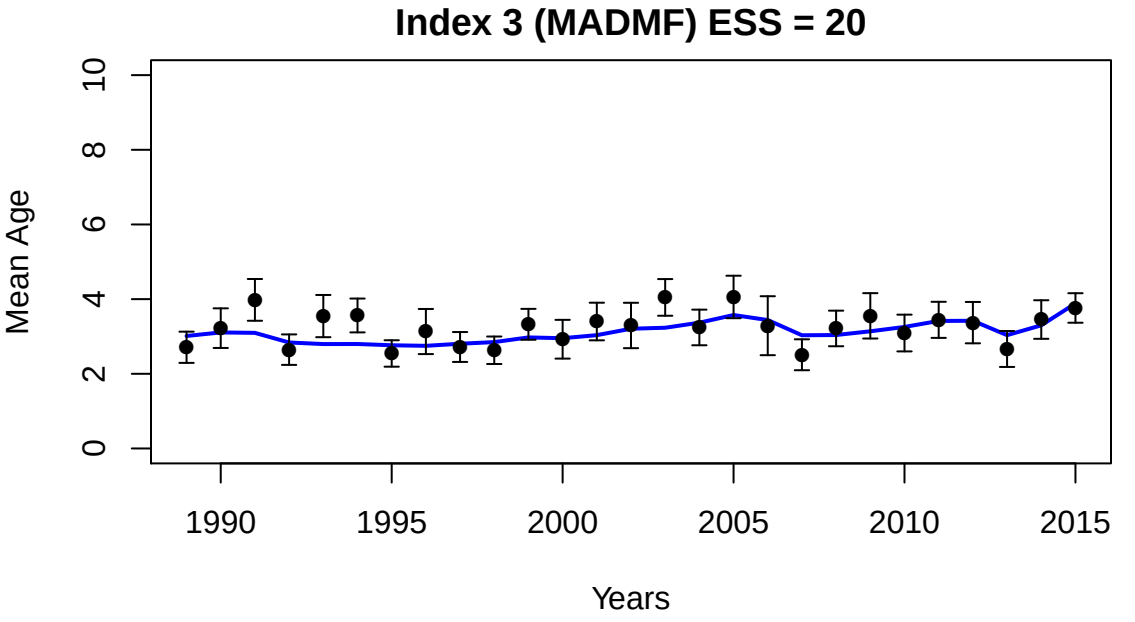

SDNR=2.45
RMSE=2.39
Std Resids
−2
0
2
4
1992
1995
1999
2001
2003
2005
2007
Year

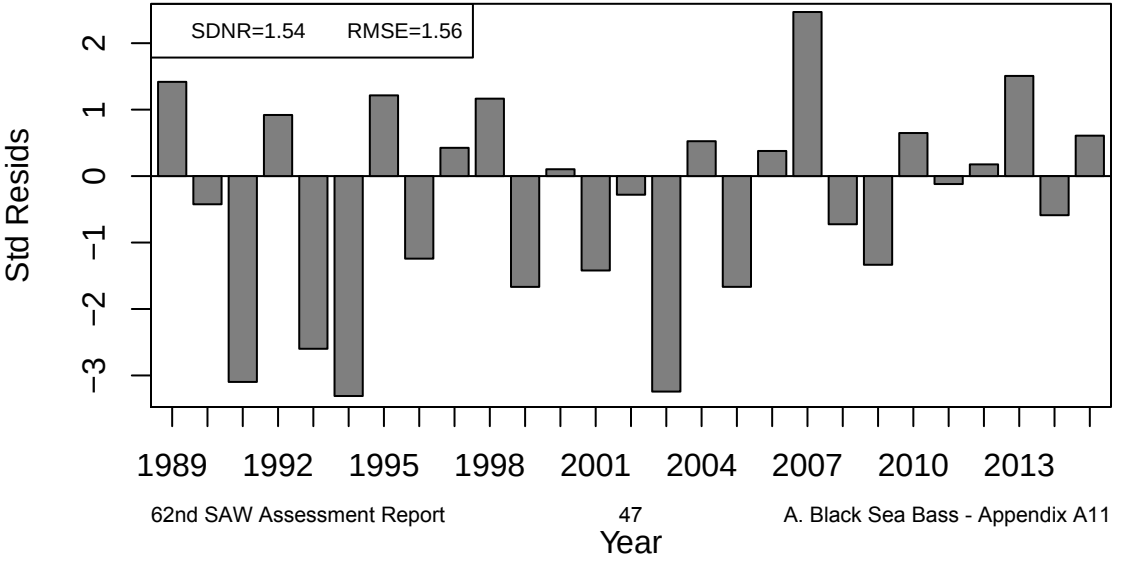

Index 1 (NEFSC spring Alb) ESS = 10
y=x
1st−3rd quartiles
Sample Quantiles
4
2
0
−2
−1
0
1
Theoretical Quantile

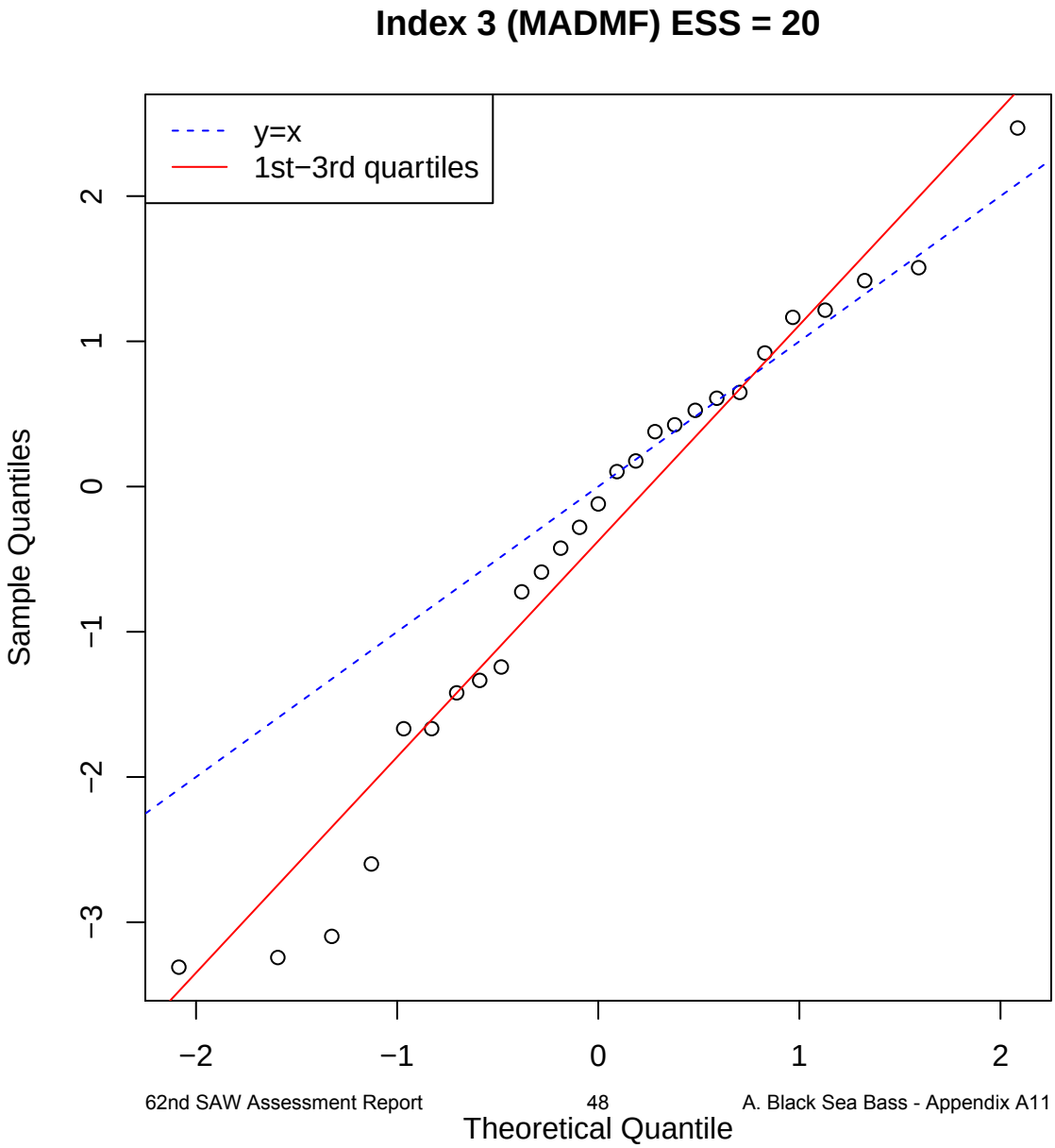

Index 2 (NEAMAP) ESS = 40
Mean Age
0
2
4
6
8
10
2008
2009
2010
2011
2012
2013
2014
2015
Years

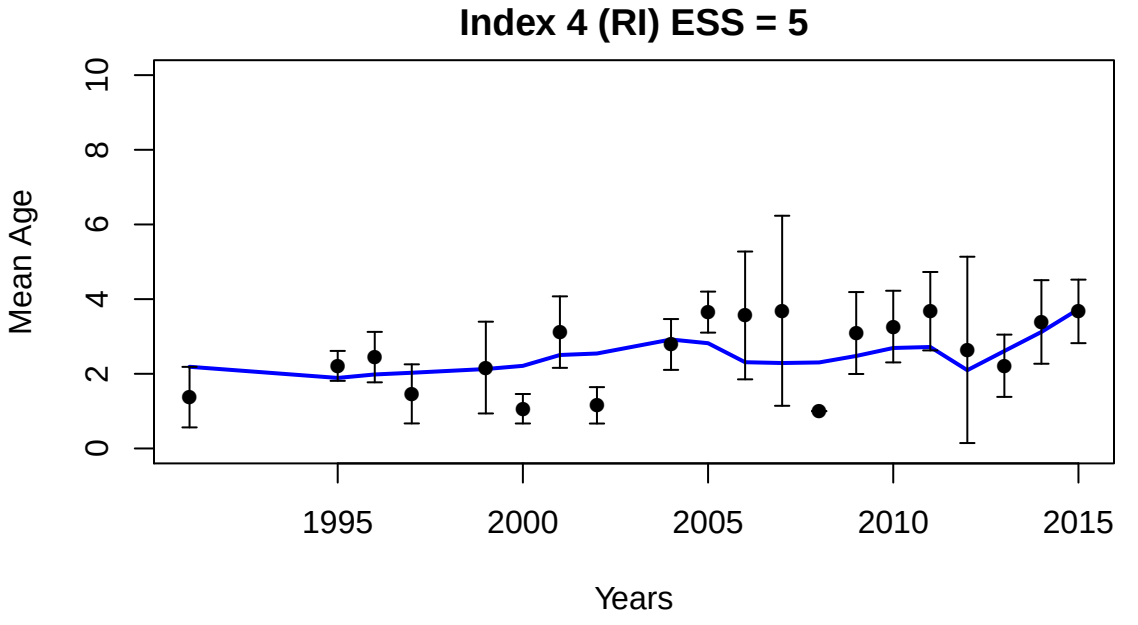

SDNR=1.79 RMSE=1.69
Std Resids
−1
0
1
2
3
2008
2009
2010
2011
2012
2013
2014
2015
Year

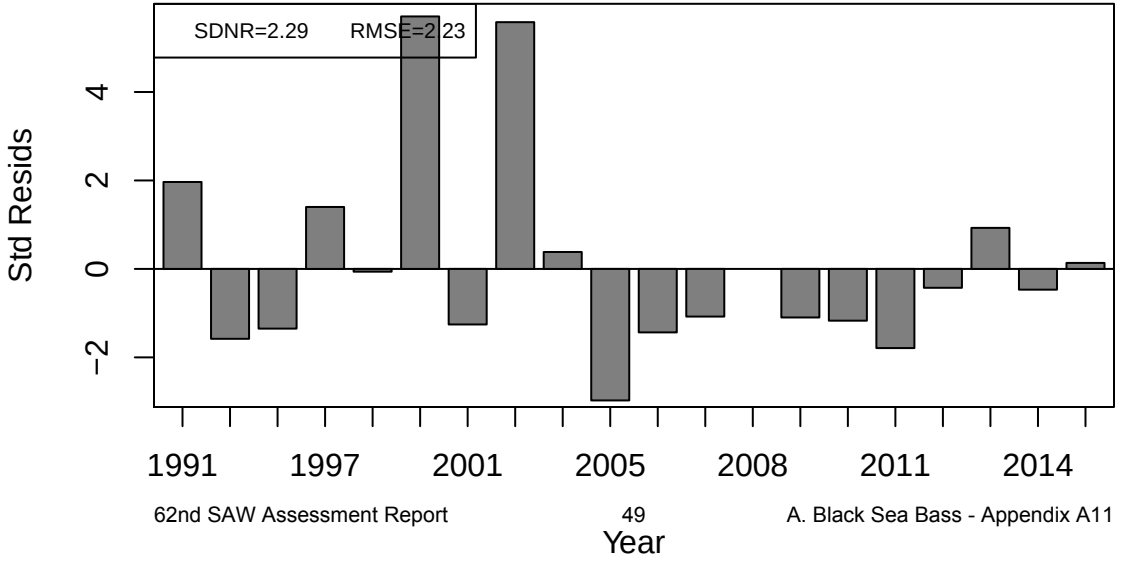

Index 2 (NEAMAP) ESS = 40
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
3
2
1
0
−1
−2
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5

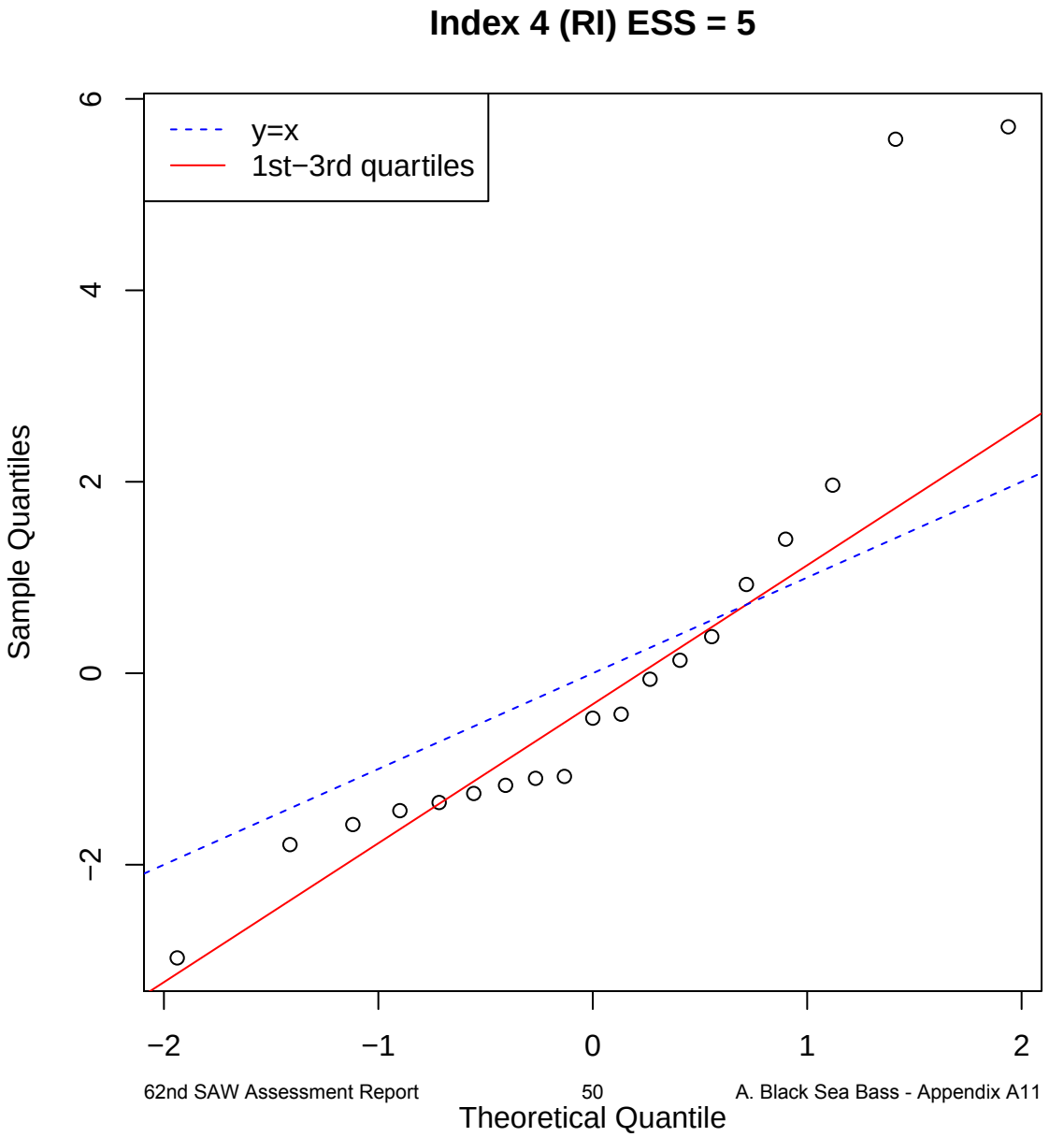

Index 3 (MADMF) ESS = 20
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

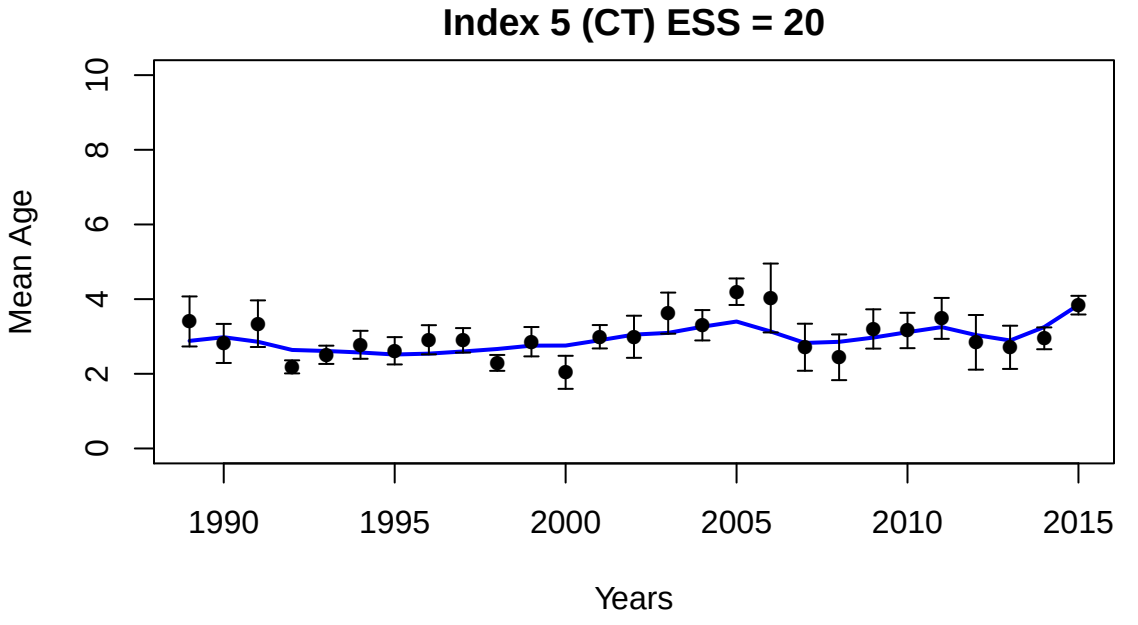

SDNR=1.54
RMSE=1.56
Std Resids
−3
−2
−1
0
1
2
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

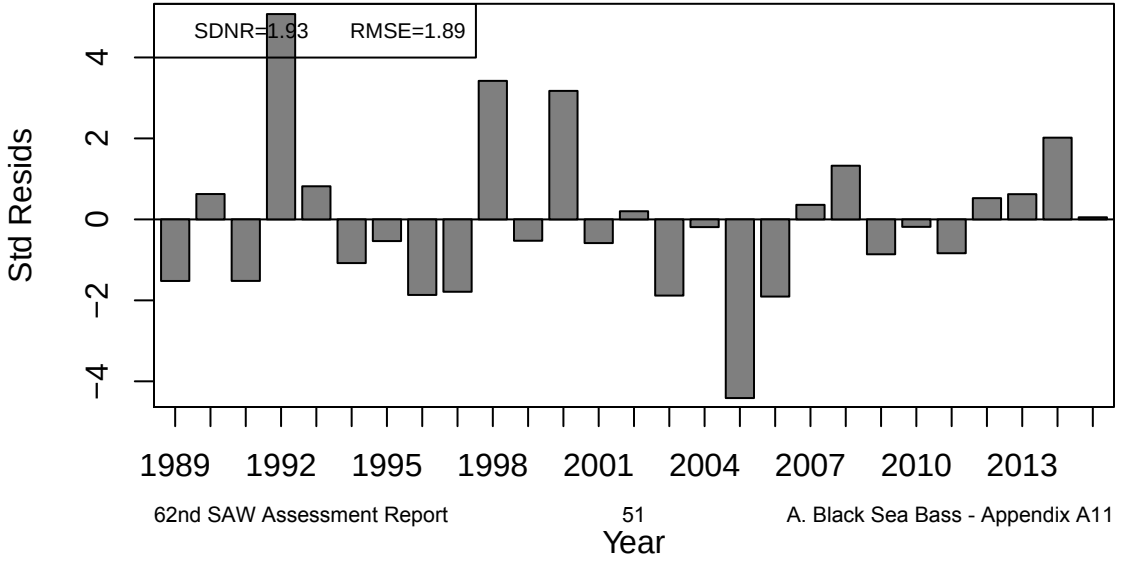

Index 3 (MADMF) ESS = 20
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−3
−2
−1
0
1
2

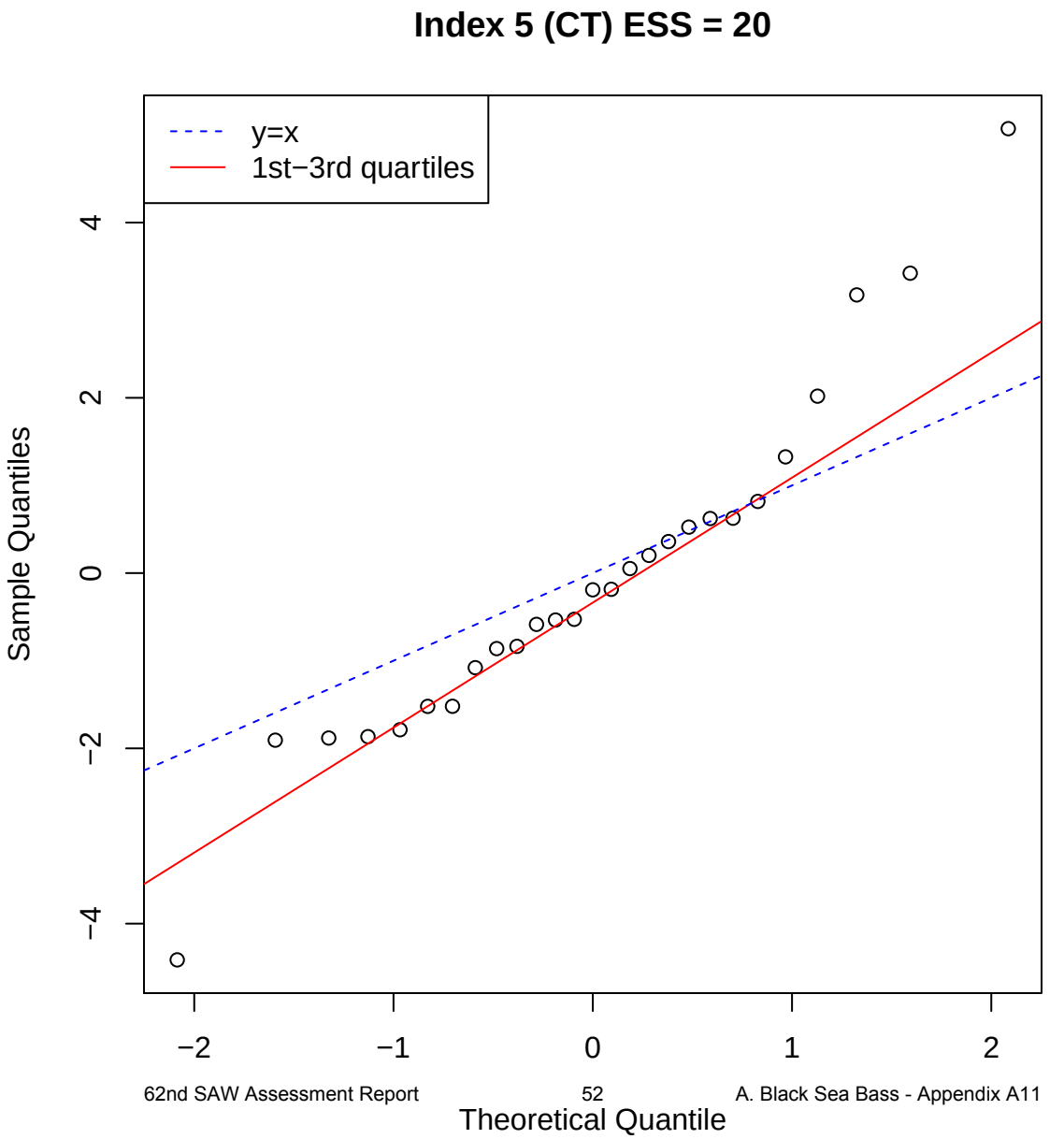

Index 4 (RI) ESS = 5
Mean Age
0
2
4
6
8
10
1995
2000
2005
2010
2015
Years

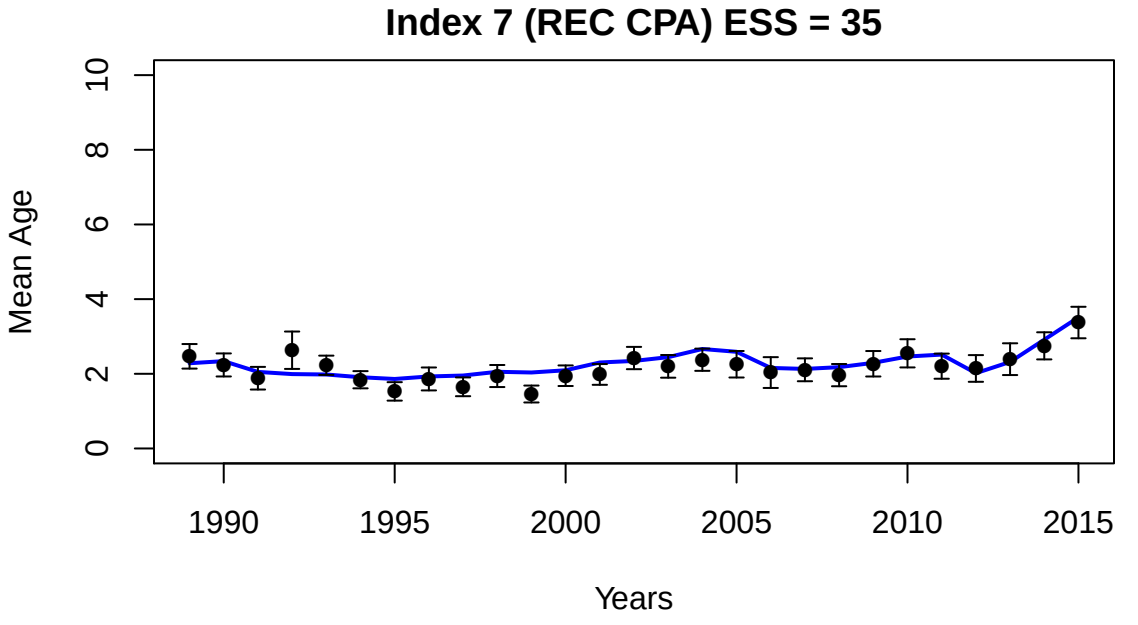

SDNR=2.29
RMSE=2.23
Std Resids
−2
0
2
4
1991
1997
2001
2005
2008
2011
2014
Year

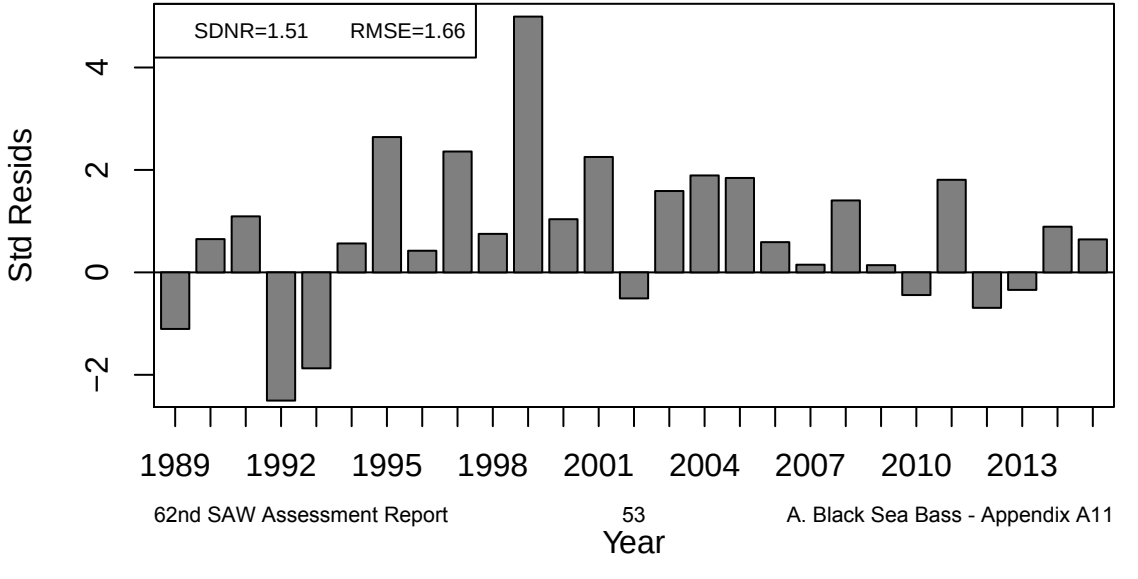

Index 4 (RI) ESS = 5
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
6
4
2
0
−2
−2
−1
0
1
2

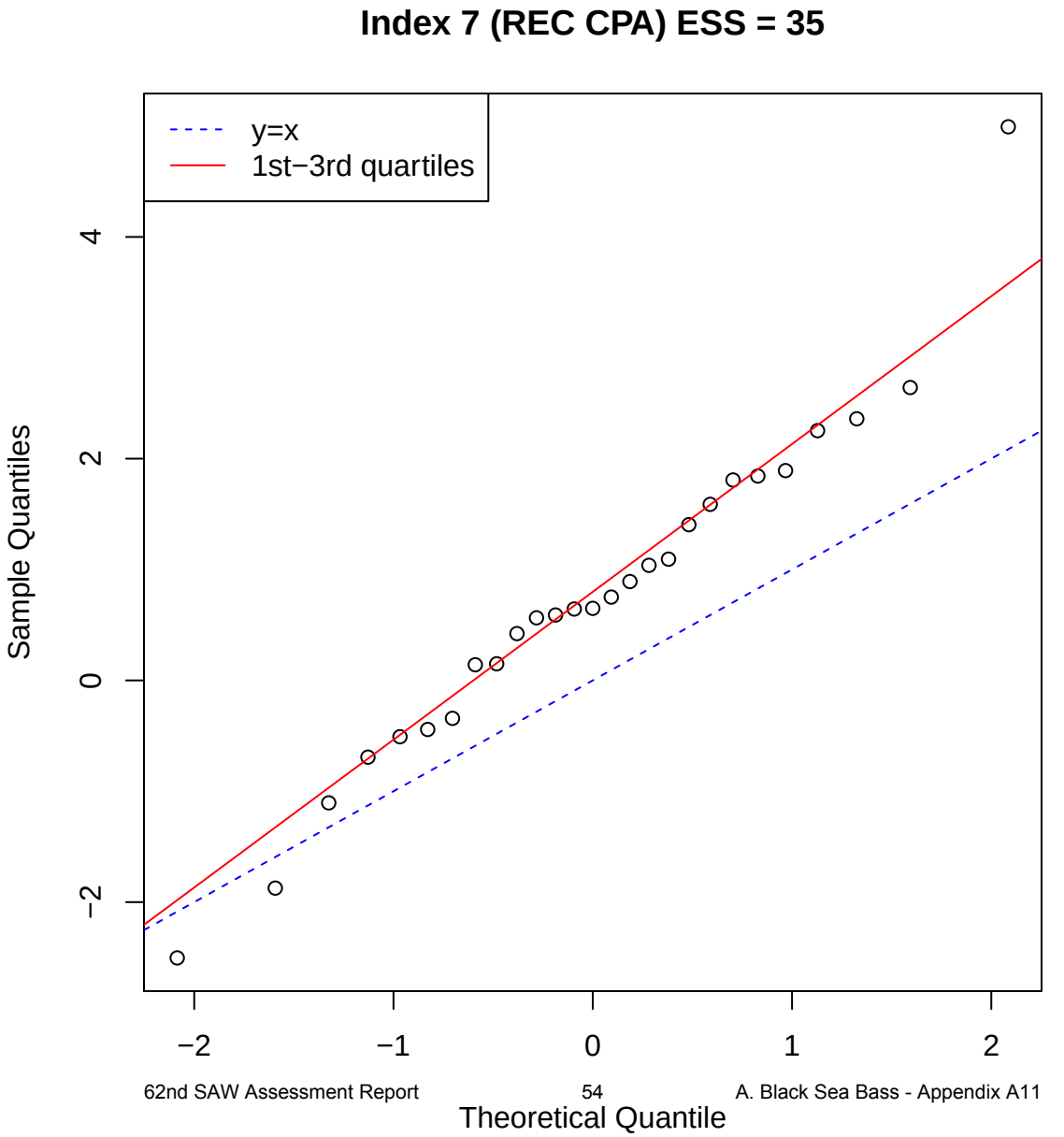

Index 5 (CT) ESS = 20
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

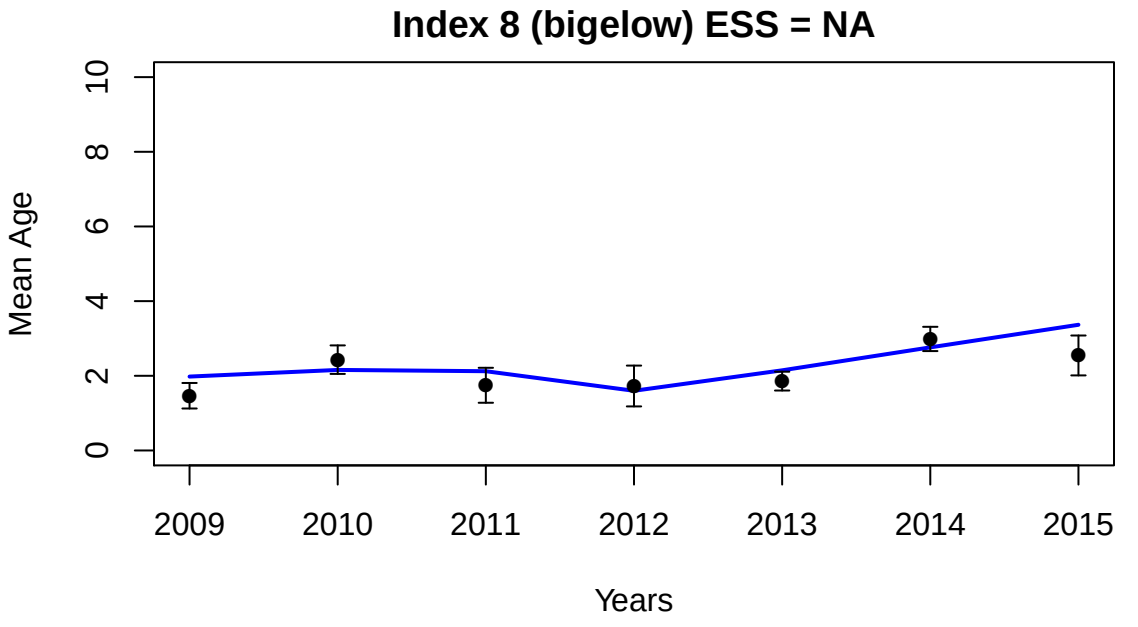

SDNR=1.93
RMSE=1.89
Std Resids
−4
−2
0
2
4
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

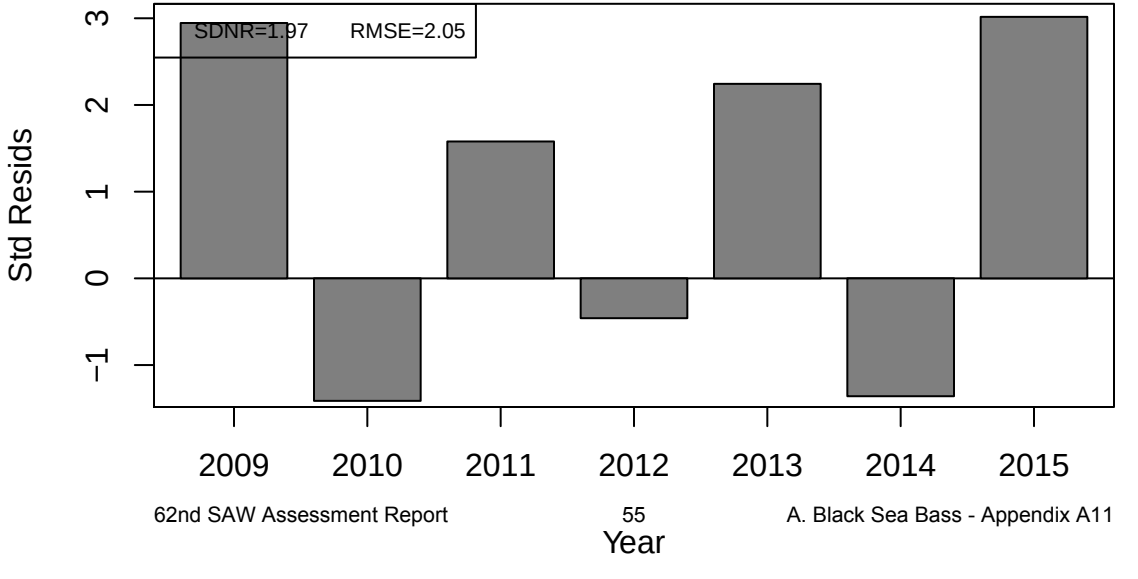

Index 5 (CT) ESS = 20
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
4
2
0
−2
−4
−2
−1
0
1
2

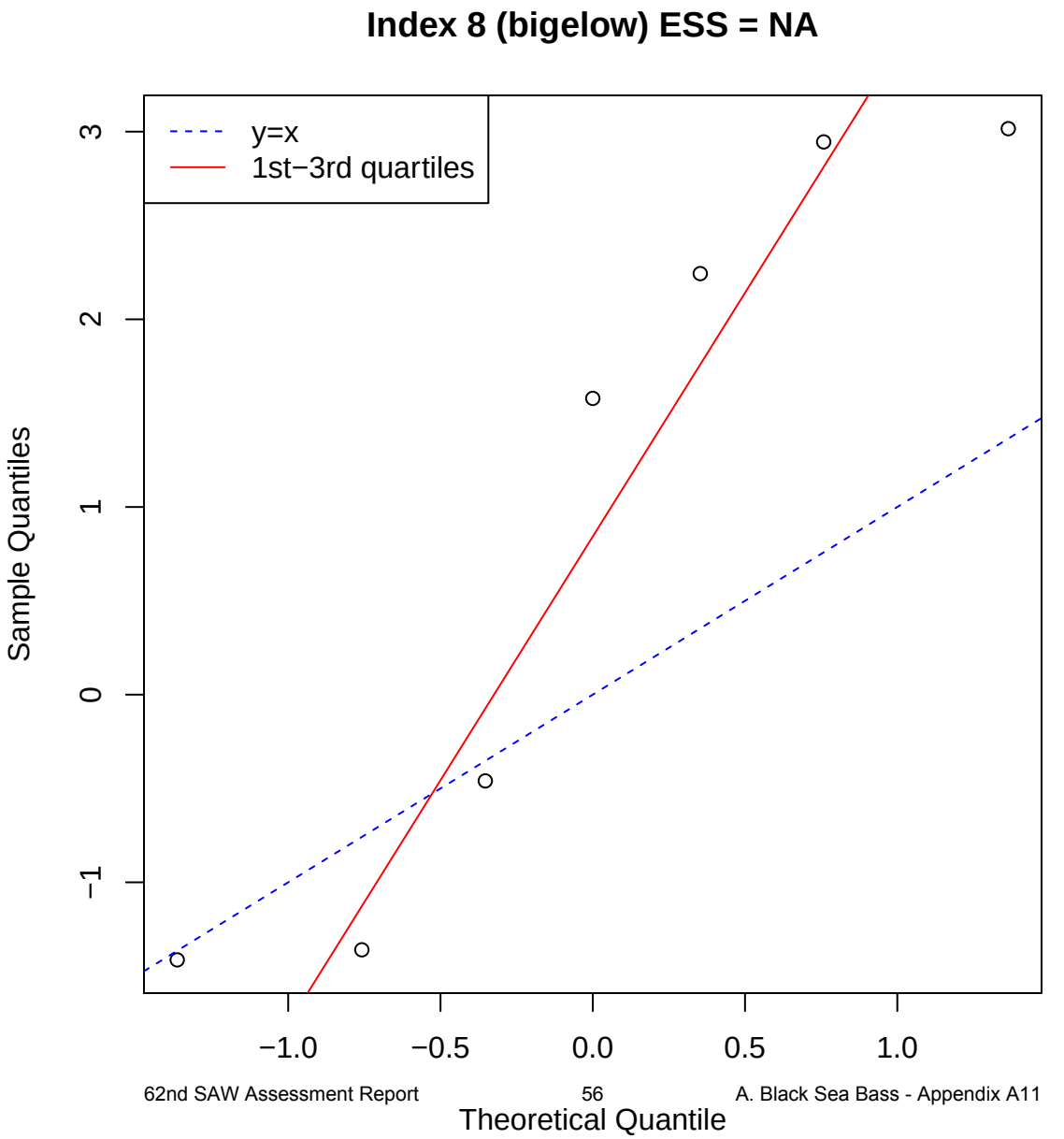

Index 7 (REC CPA) ESS = 35
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

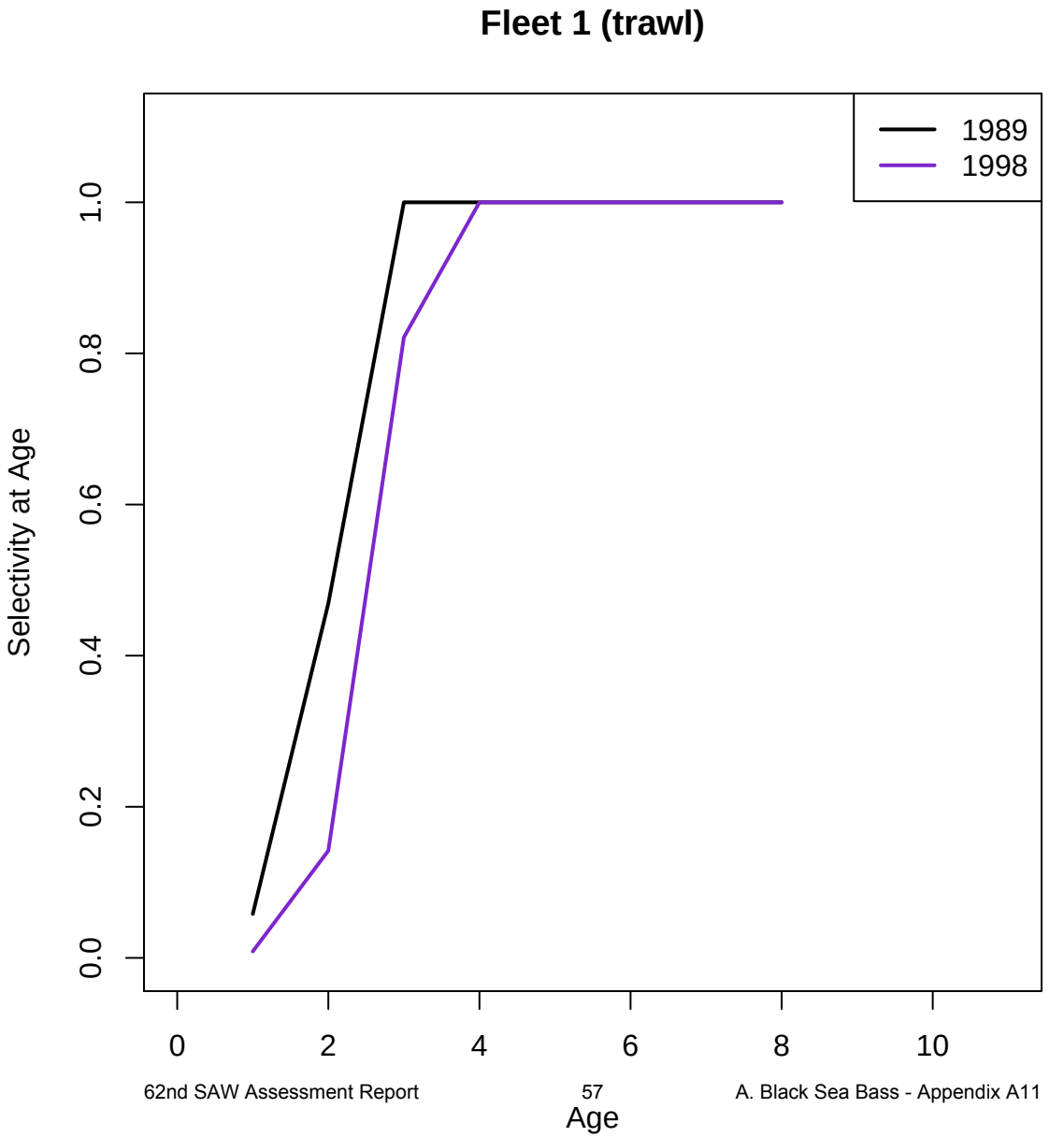

SDNR=1.51
RMSE=1.66
Std Resids
−2
0
2
4
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

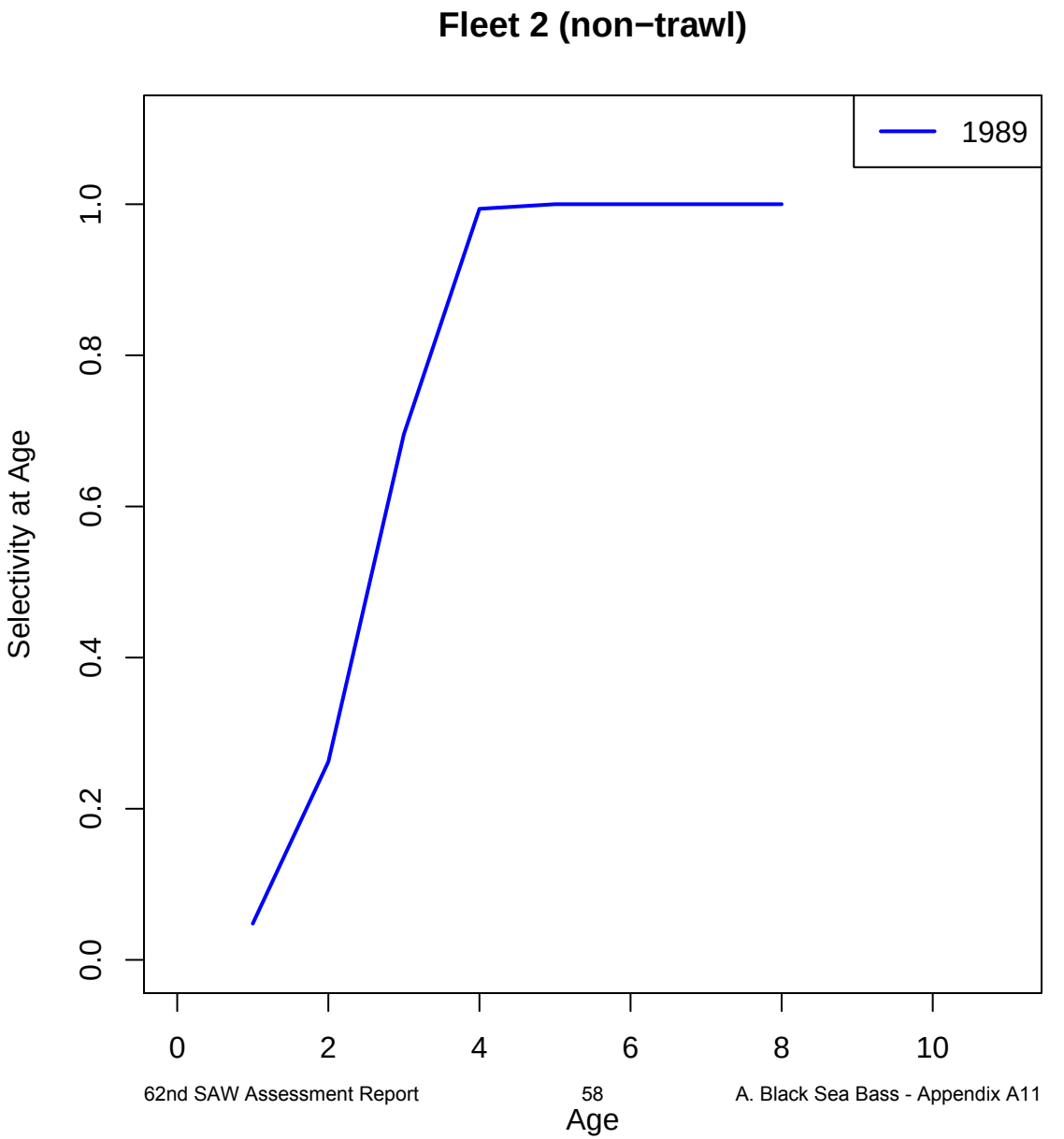

Index 7 (REC CPA) ESS = 35
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
0
2
4
−2
−1
0
1
2

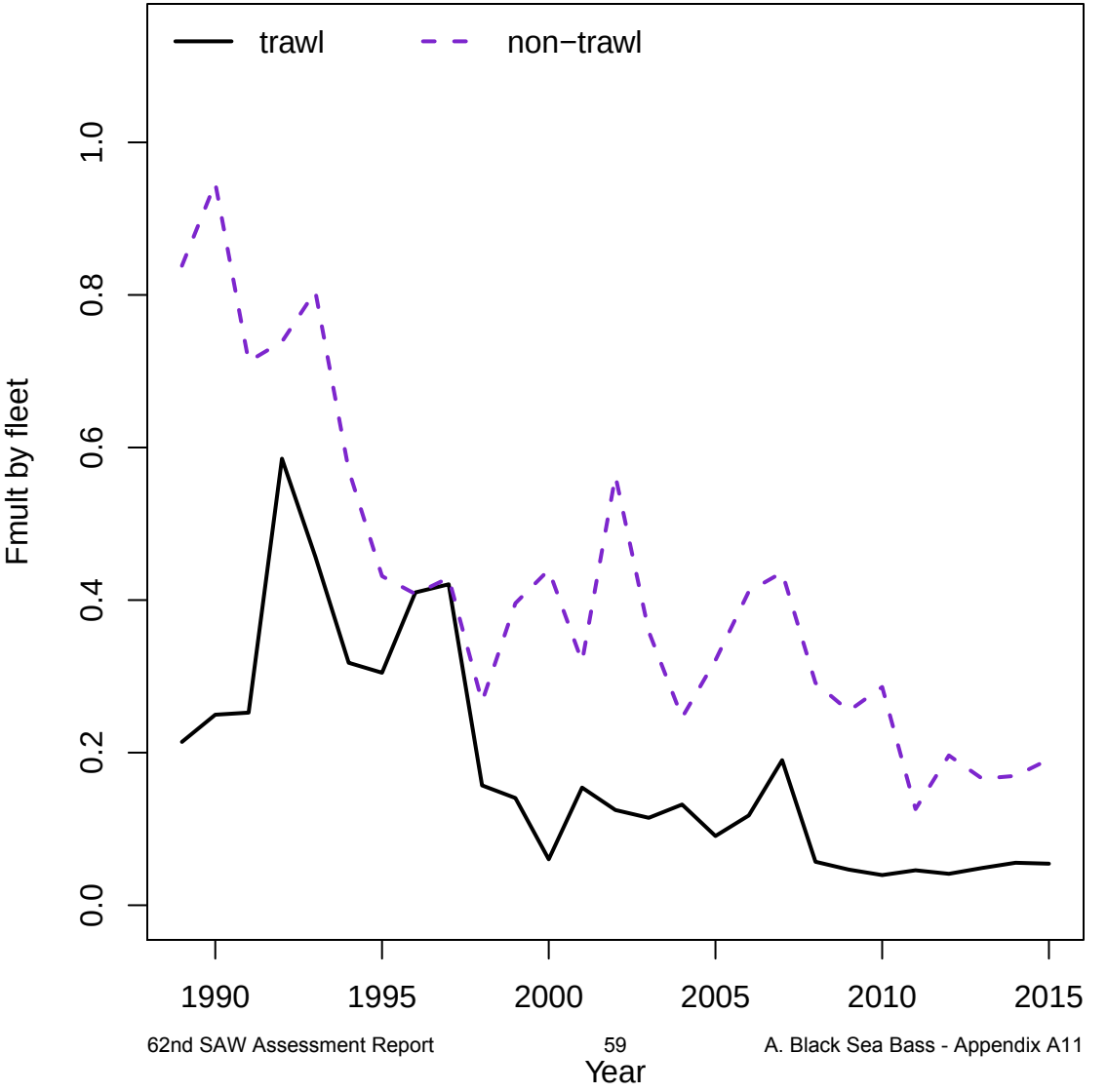

Index 8 (bigelow) ESS = NA
Mean Age
0
2
4
6
8
10
2009
2010
2011
2012
2013
2014
2015
Years

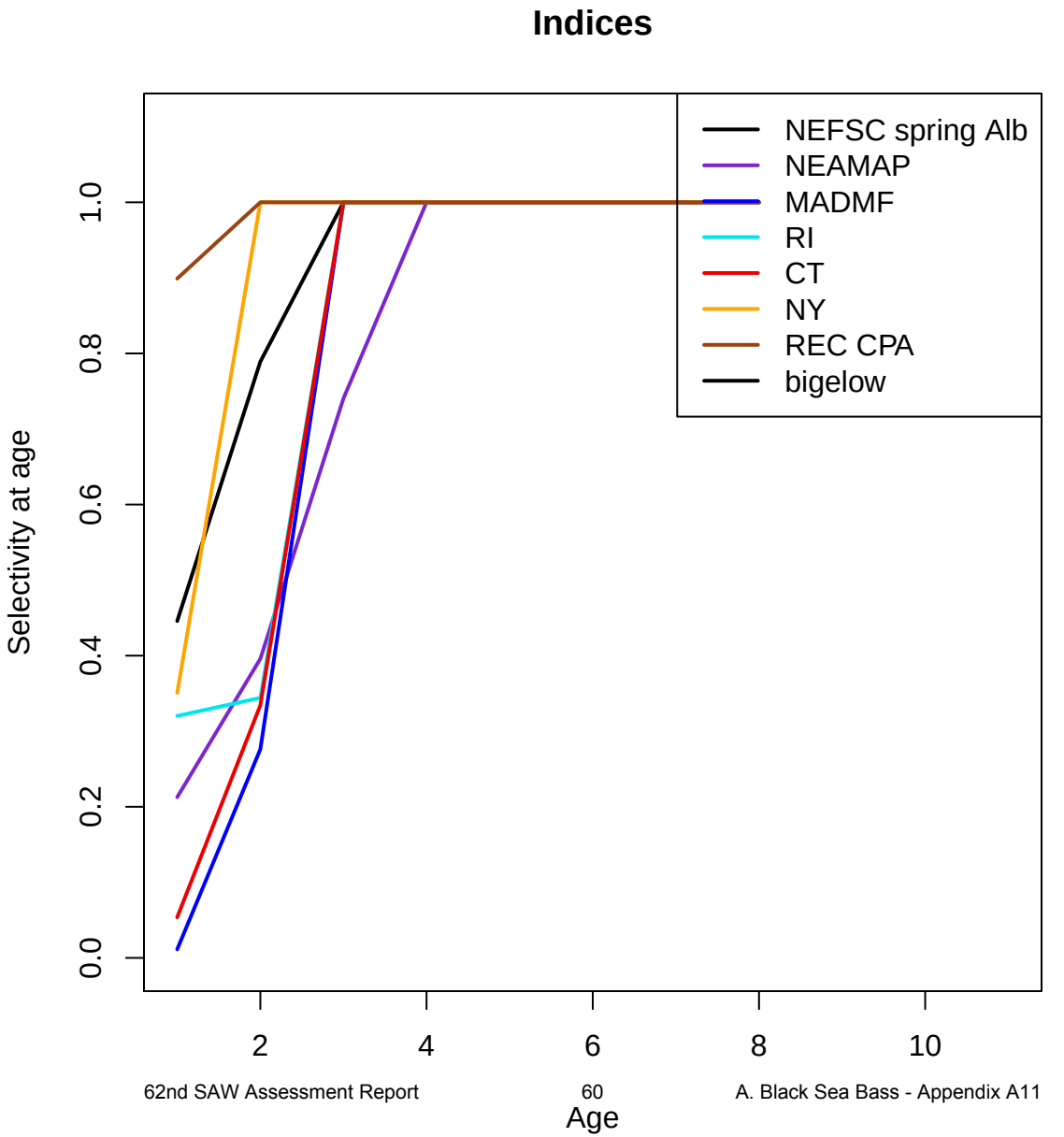

SDNR=1.97
RMSE=2.05
Std Resids
−1
0
1
2
3
2009
2010
2011
2012
2013
2014
2015
Year

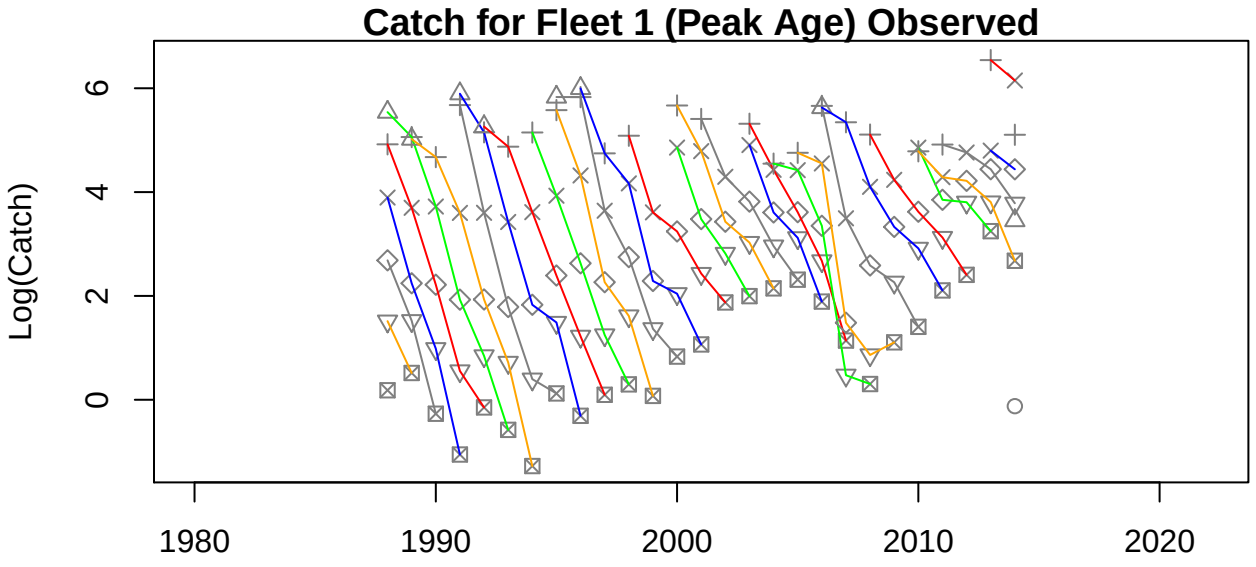

Index 8 (bigelow) ESS = NA
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−1
0
1
2
3
−1.0
−0.5
0.0
0.5
1.0

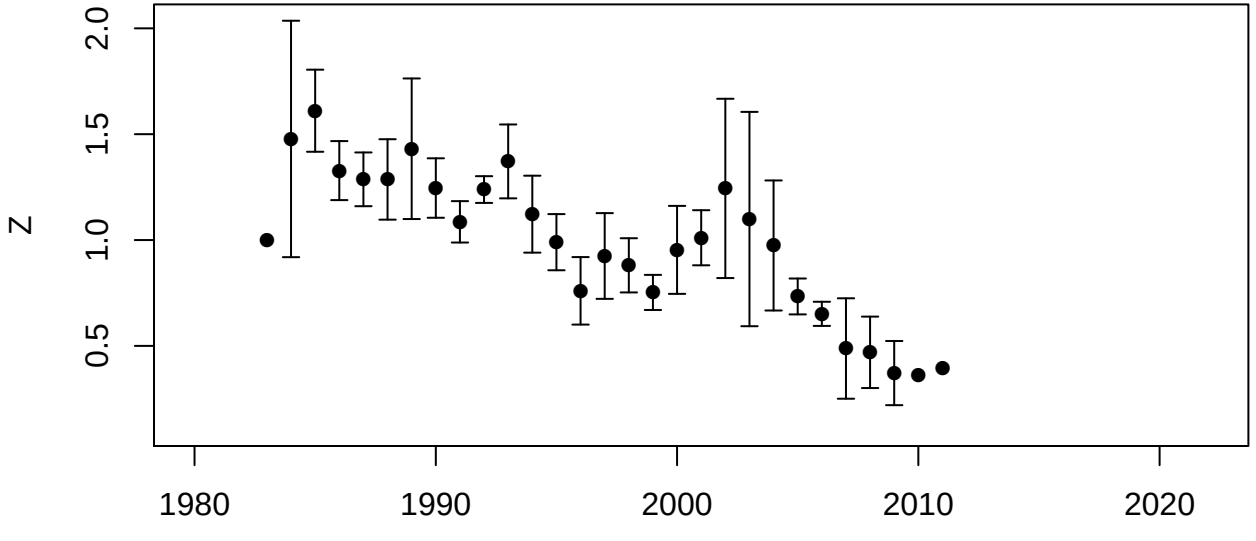

Fleet 1 (trawl)
1989
1998
Selectivity at Age
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
Age

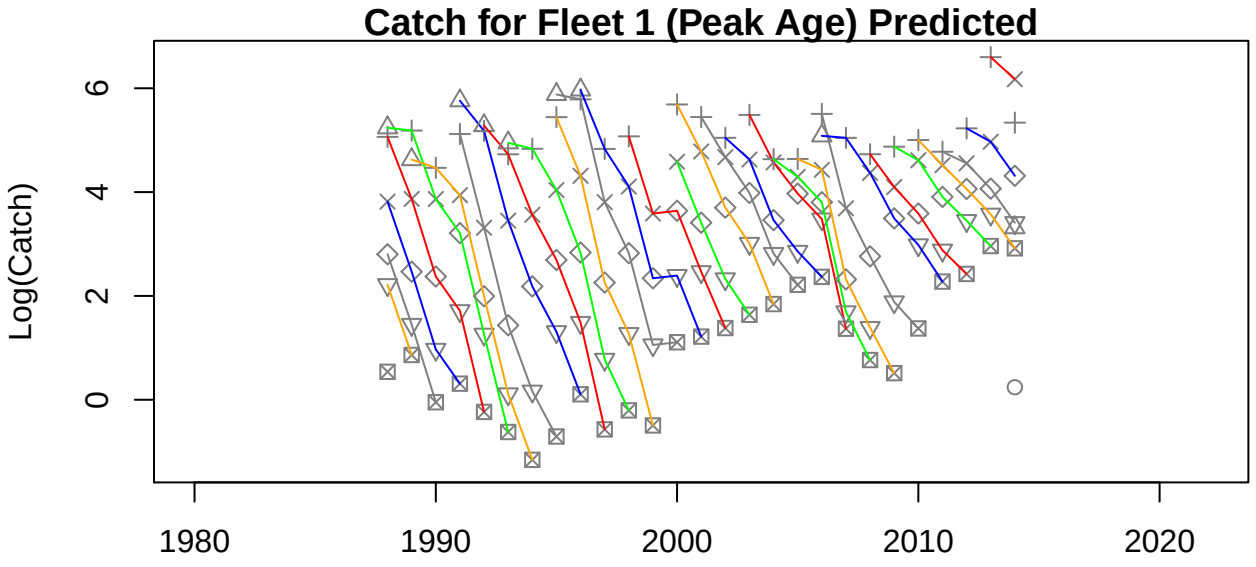

Fleet 2 (non−trawl)
1989
Selectivity at Age
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
Age

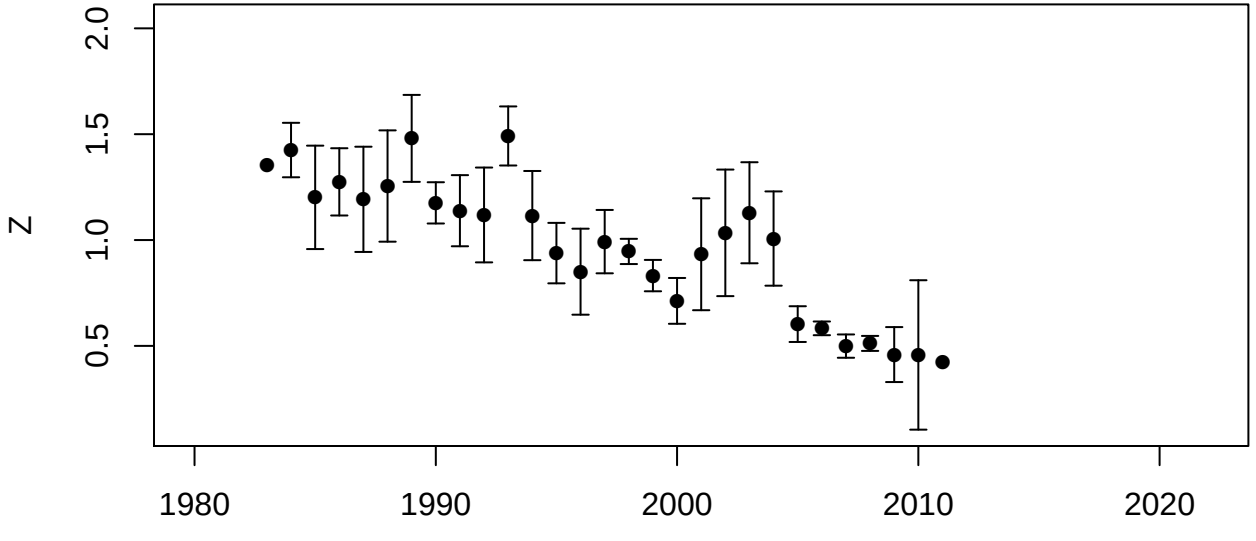

trawl
non−trawl
Fmult by fleet
0.0
0.2
0.4
0.6
0.8
1.0
1990
1995
2000
2005
2010
2015
Year

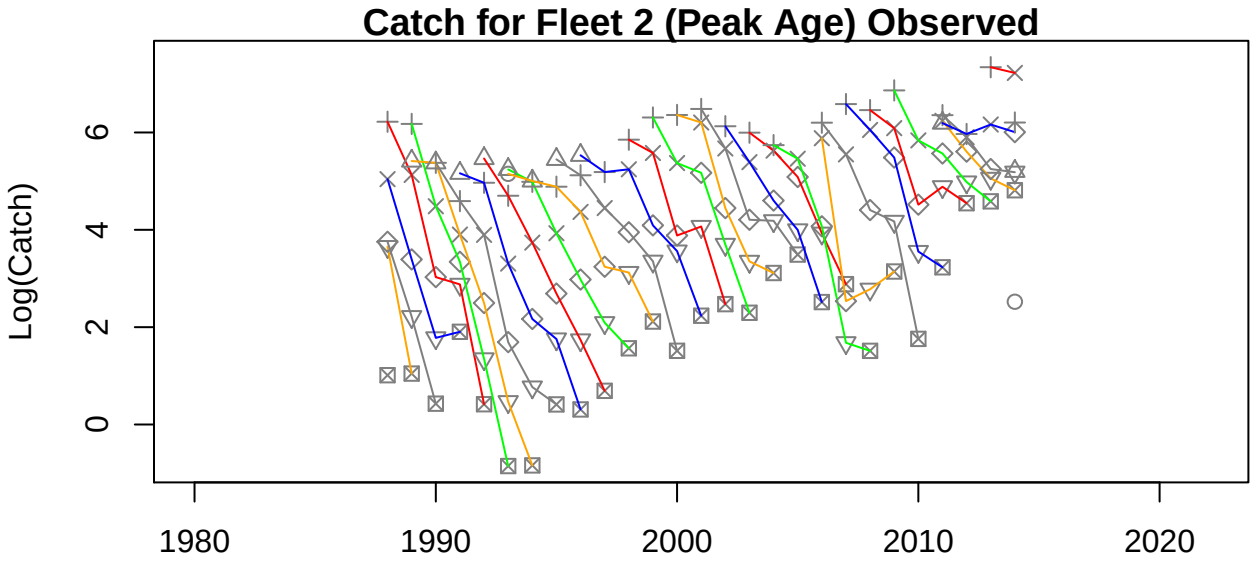

Indices
NEFSC spring Alb
NEAMAP
MADMF
RI
CT
NY
REC CPA
bigelow
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
10
Age

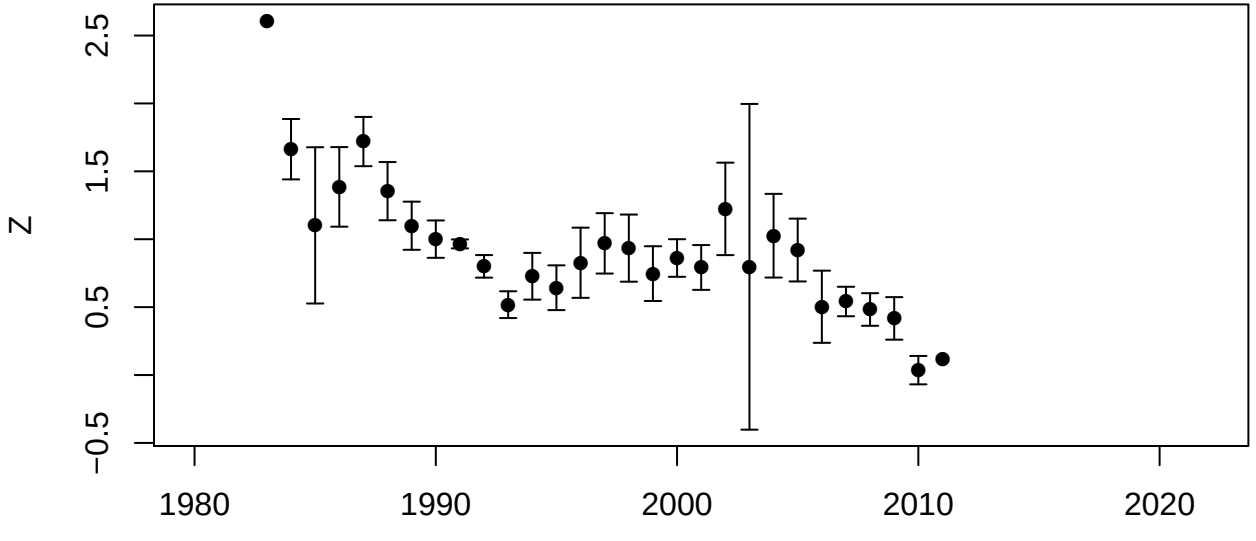

Catch for Fleet 1 (Peak Age) Observed
Log(Catch)
0
2
4
6
1980
1990
2000
2010
2020

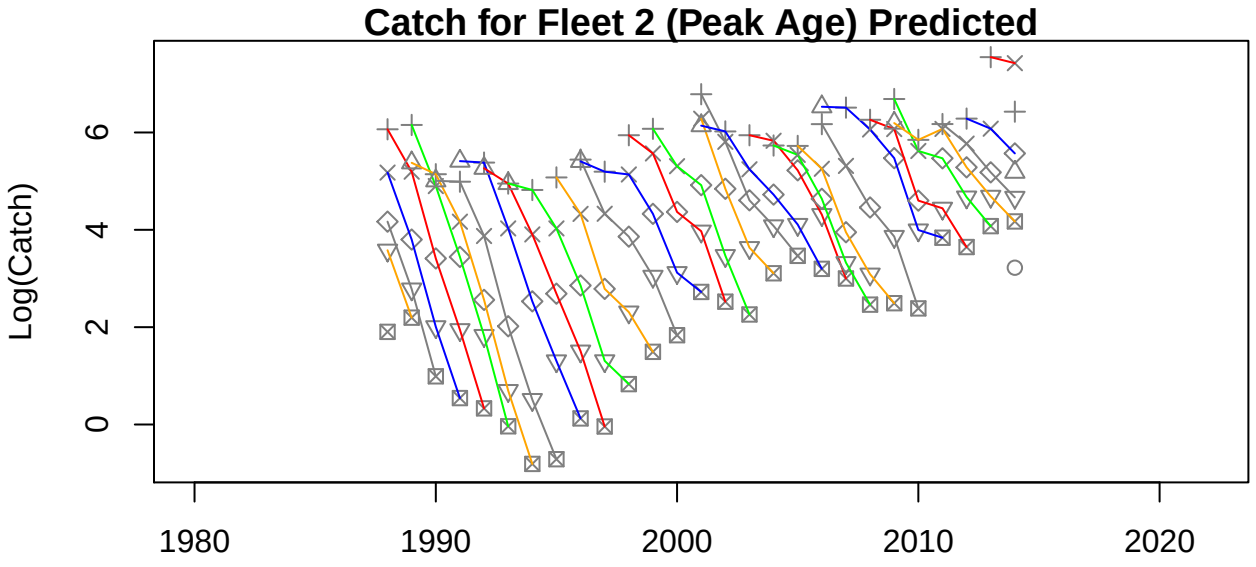

Z
0.5
1.0
1.5
2.0
1980
1990
2000
2010
2020
Year Class

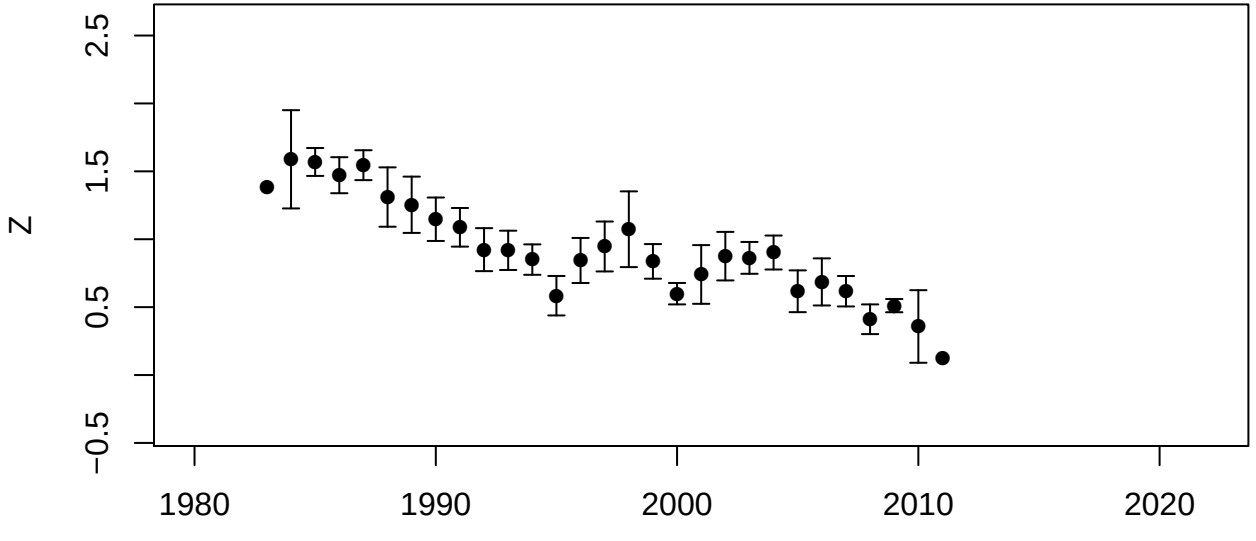

Catch for Fleet 1 (Peak Age) Predicted
Log(Catch)
0
2
4
6
1980
1990
2000
2010
2020

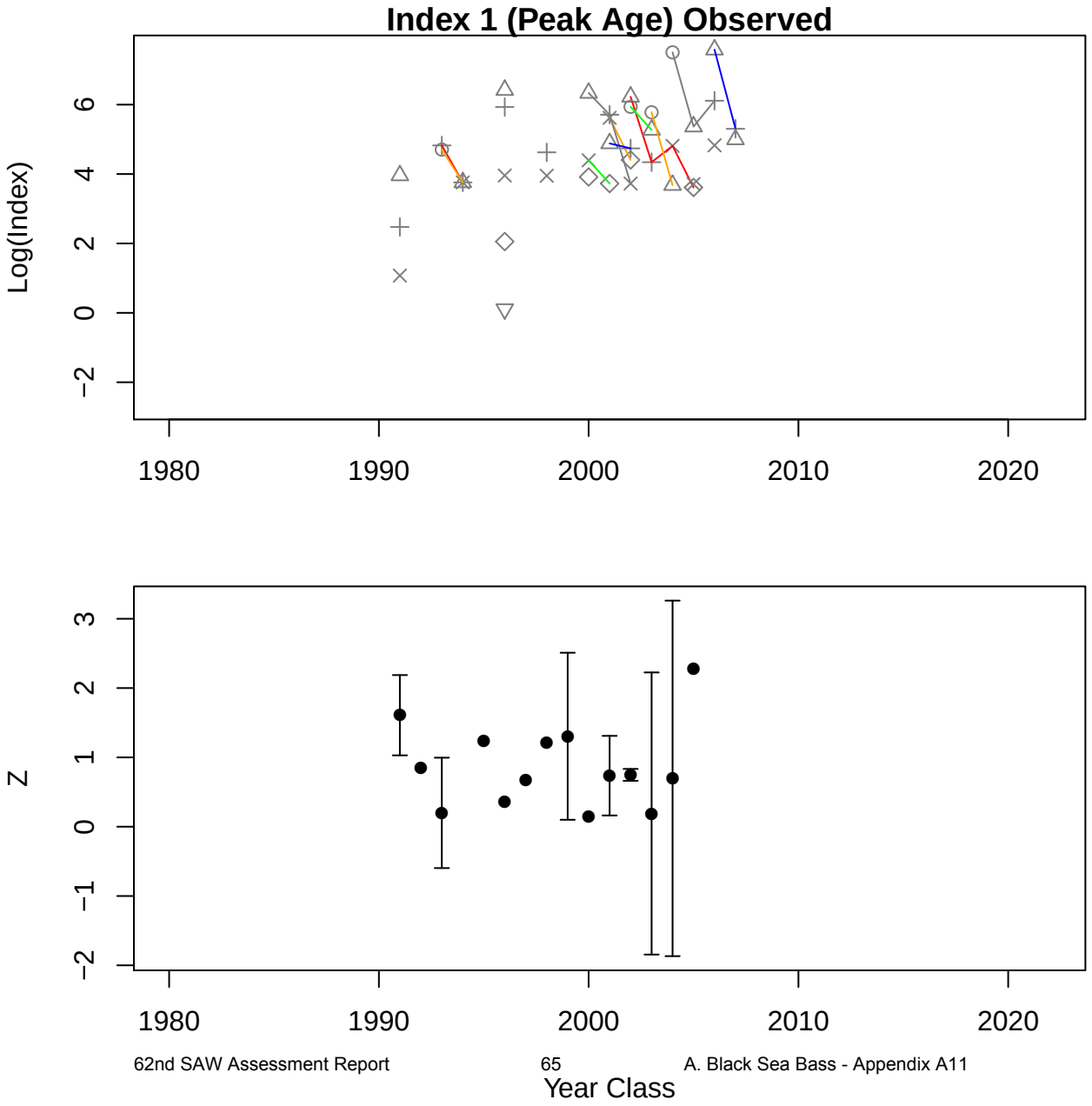

Z
0.5
1.0
1.5
2.0
1980
1990
2000
2010
2020
Year Class

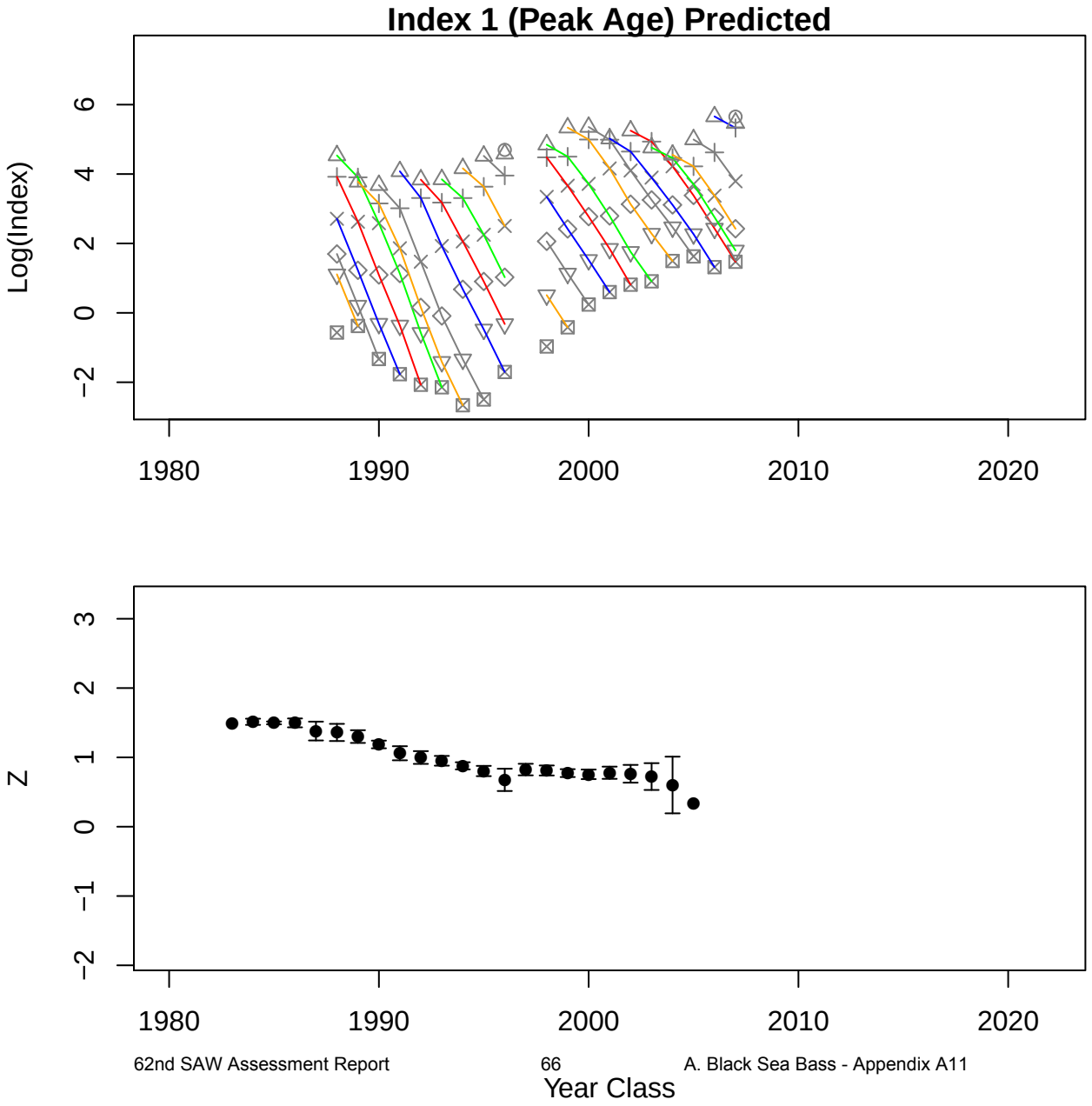

Catch for Fleet 2 (Peak Age) Observed
Log(Catch)
0
2
4
6
1980
1990
2000
2010
2020

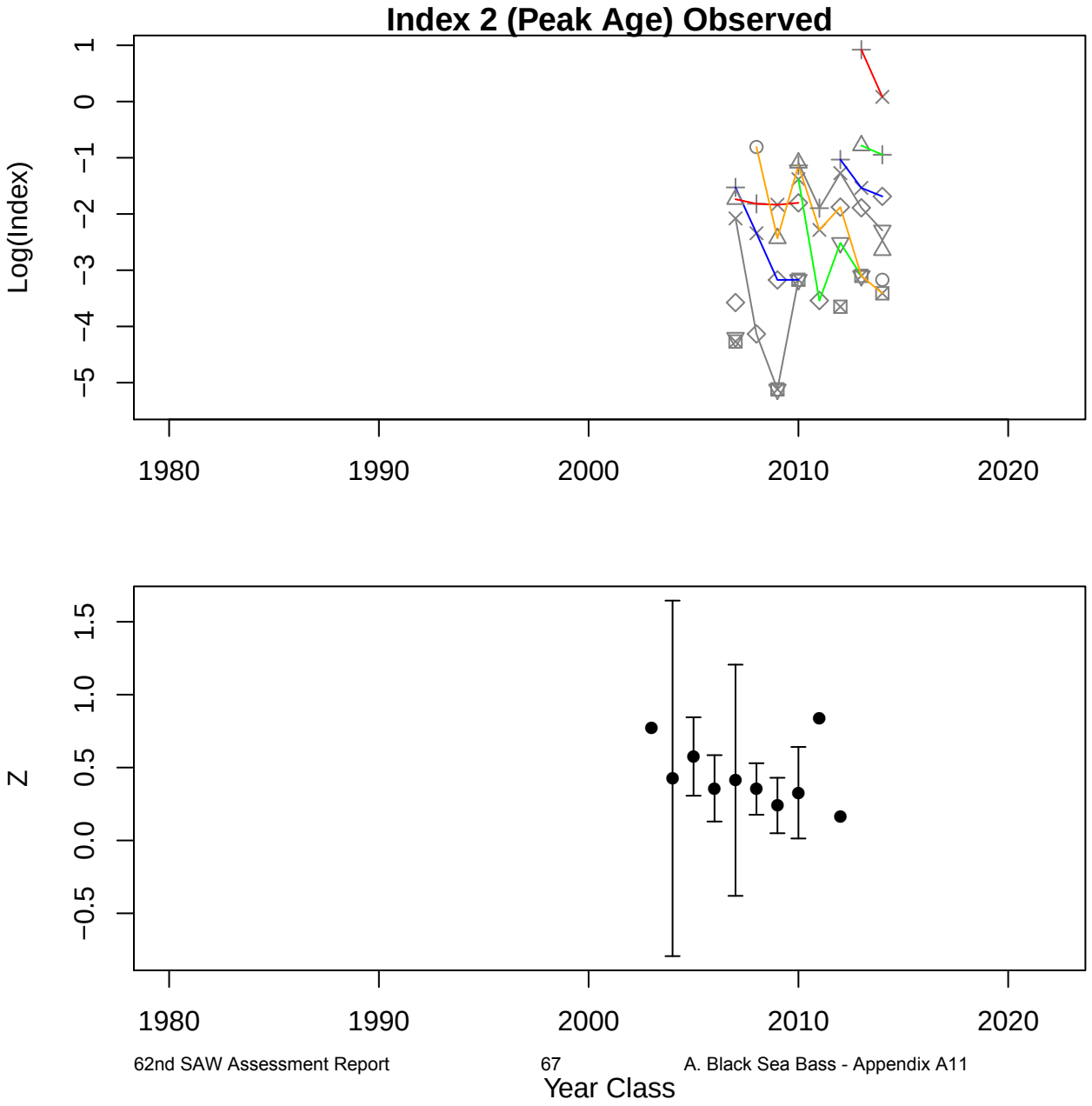

Z
−0.5
0.5
1.5
2.5
1980
1990
2000
2010
2020
Year Class

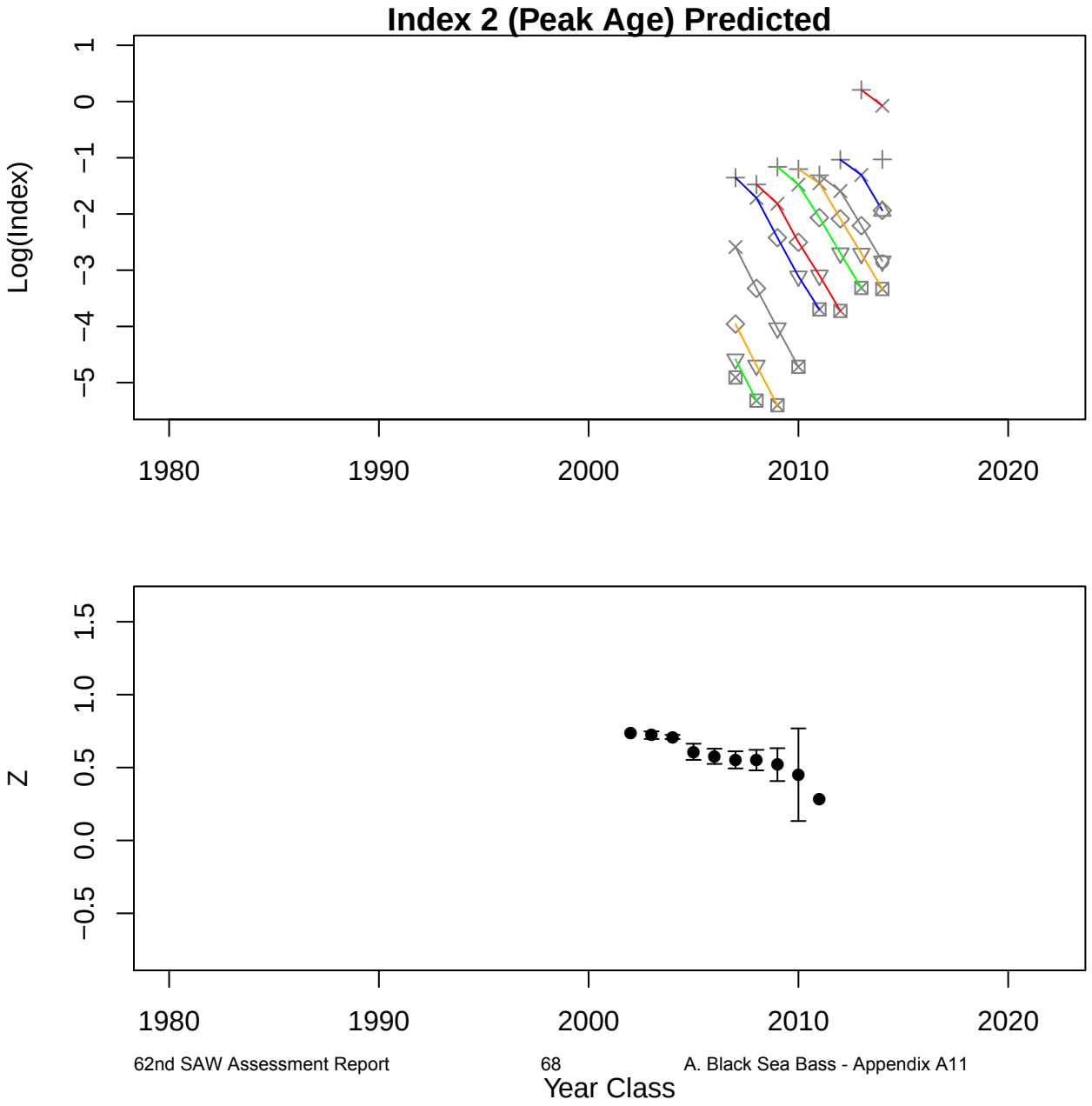

Catch for Fleet 2 (Peak Age) Predicted
Log(Catch)
0
2
4
6
1980
1990
2000
2010
2020

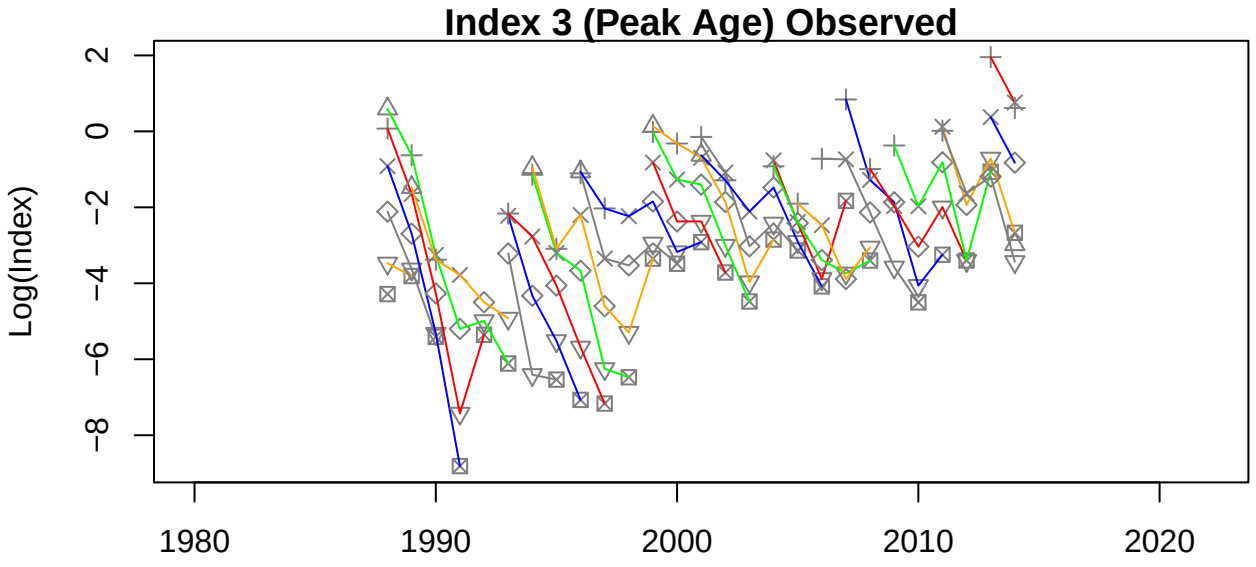

Z
−0.5
0.5
1.5
2.5
1980
1990
2000
2010
2020
Year Class

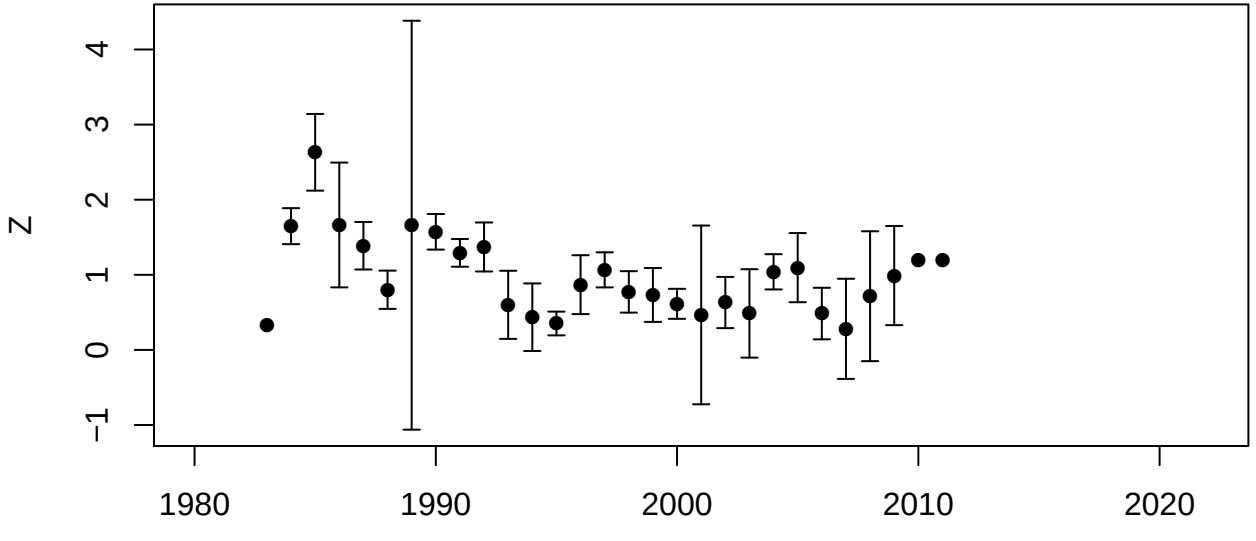

Index 1 (Peak Age) Observed
Log(Index)
6
4
2
0
−2
1980
1990
2000
2010
2020
Z
3
2
1
0
−1
−2
1980
1990
2000
2010
2020
Year Class


Index 1 (Peak Age) Predicted
Log(Index)
6
4
2
0
−2
1980
1990
2000
2010
2020
Z
3
2
1
0
−1
−2
1980
1990
2000
2010
2020
Year Class

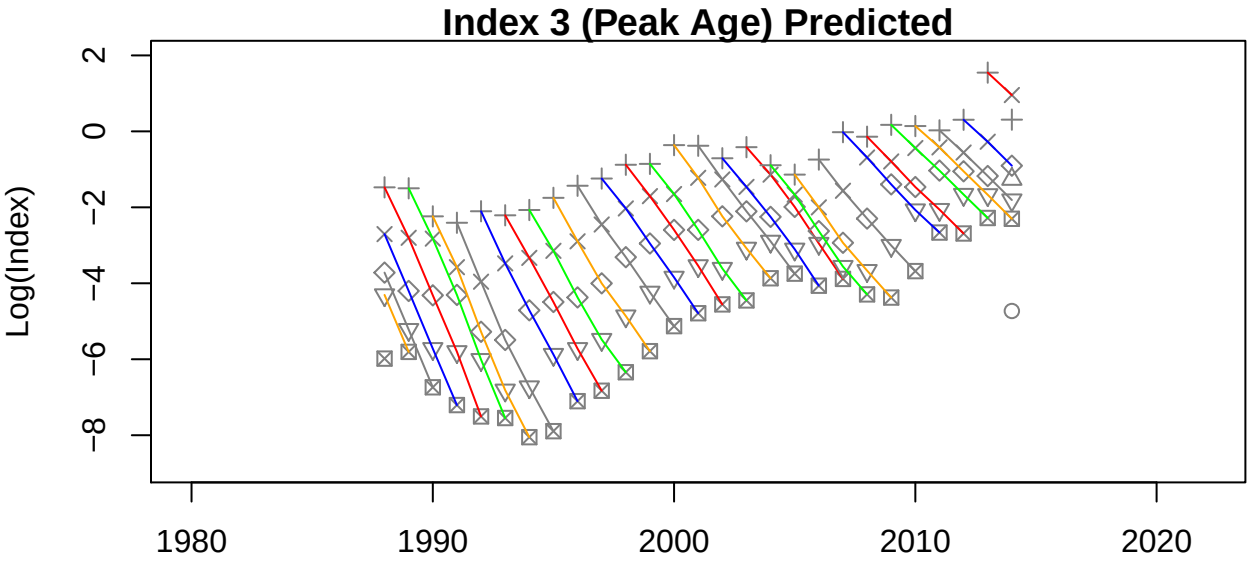

Index 2 (Peak Age) Observed
Log(Index)
1
0
−1
−2
−3
−4
−5
1980
1990
2000
2010
2020
Z
1.5
1.0
0.5
0.0
−0.5
1980
1990
2000
2010
2020
Year Class

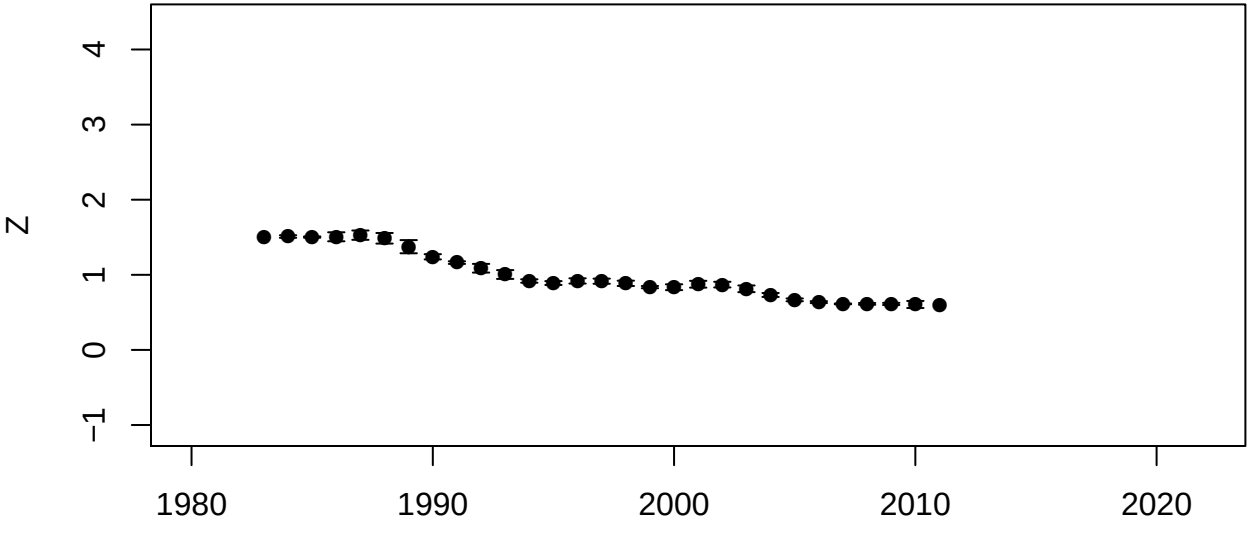

Index 2 (Peak Age) Predicted
Log(Index)
1
0
−1
−2
−3
−4
−5
1980
1990
2000
2010
2020
Z
1.5
1.0
0.5
0.0
−0.5
1980
1990
2000
2010
2020
Year Class

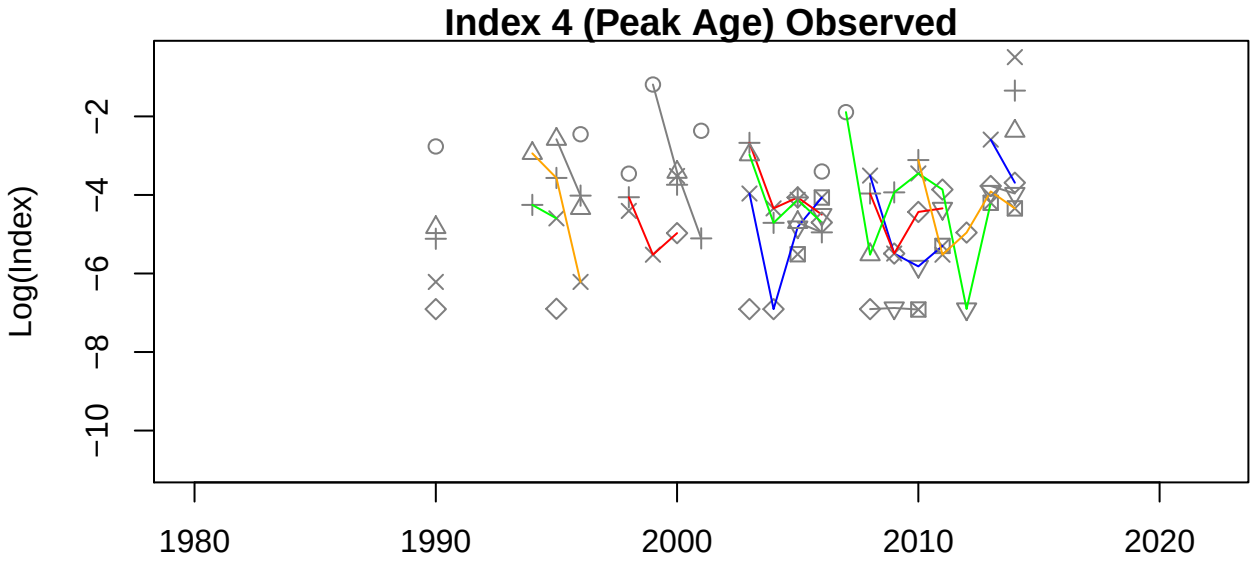

Index 3 (Peak Age) Observed
Log(Index)
2
0
−2
−4
−6
−8
1980
1990
2000
2010
2020

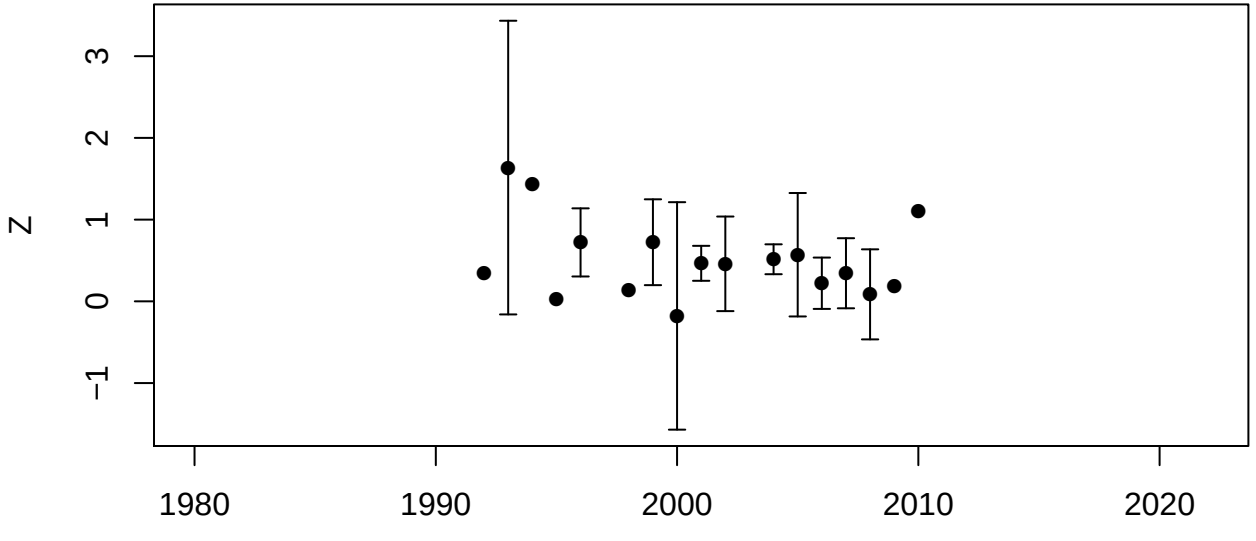

Z
4
3
2
1
0
−1
1980
1990
2000
2010
2020

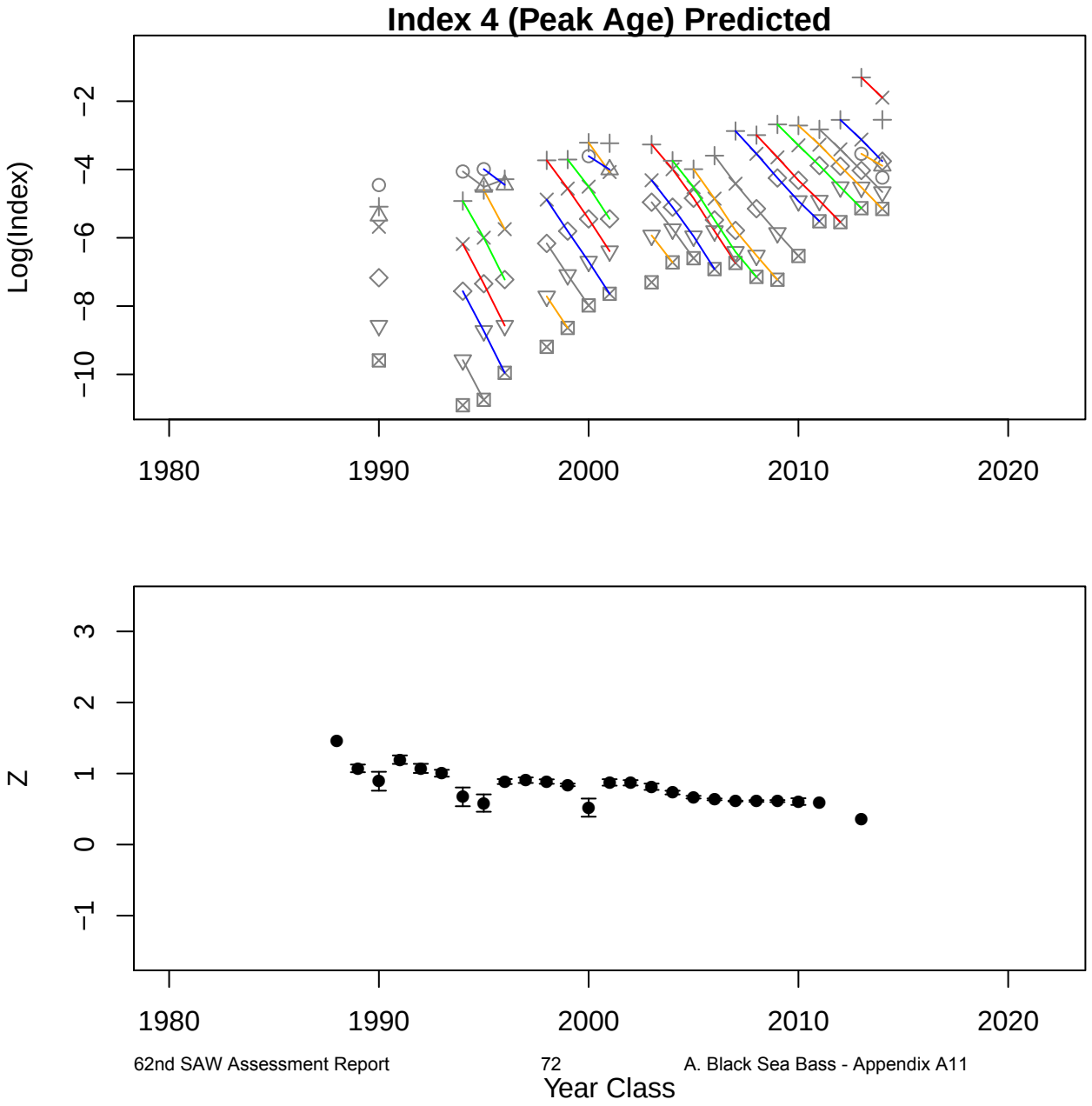
Year Class

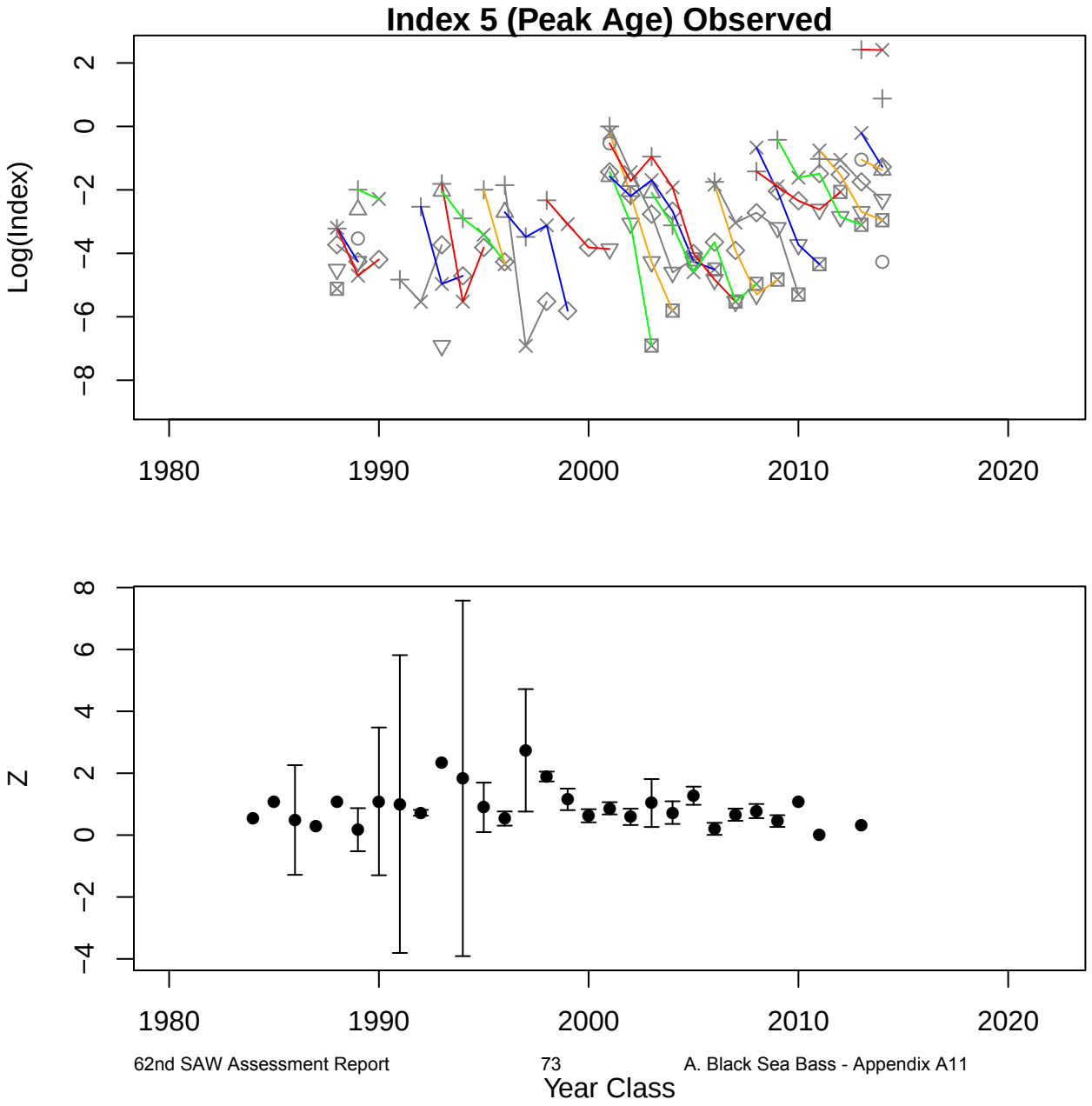

Index 3 (Peak Age) Predicted
Log(Index)
2
0
−2
−4
−6
−8
1980
1990
2000
2010
2020

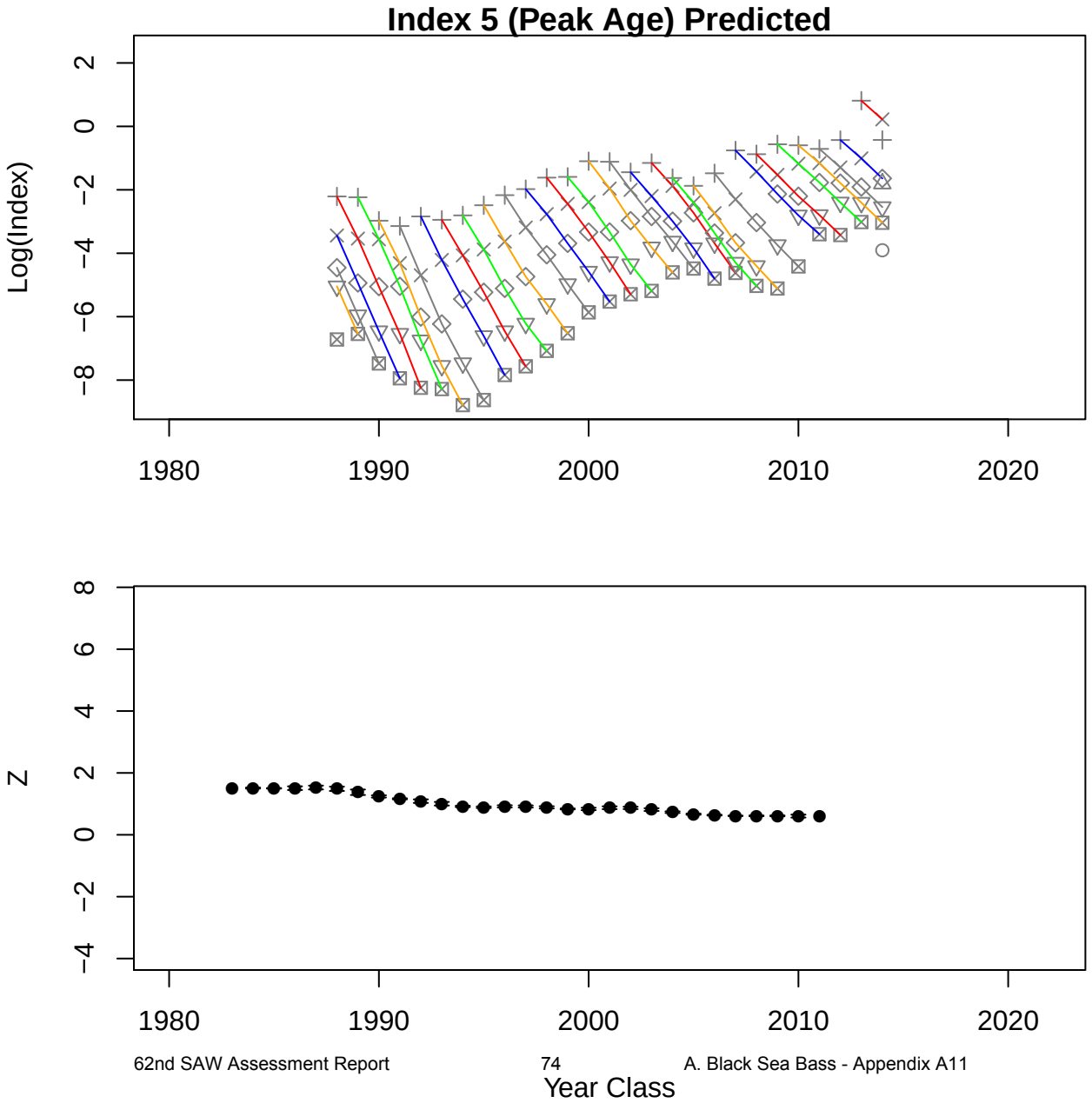

Z
4
3
2
1
0
−1
1980
1990
2000
2010
2020
Year Class

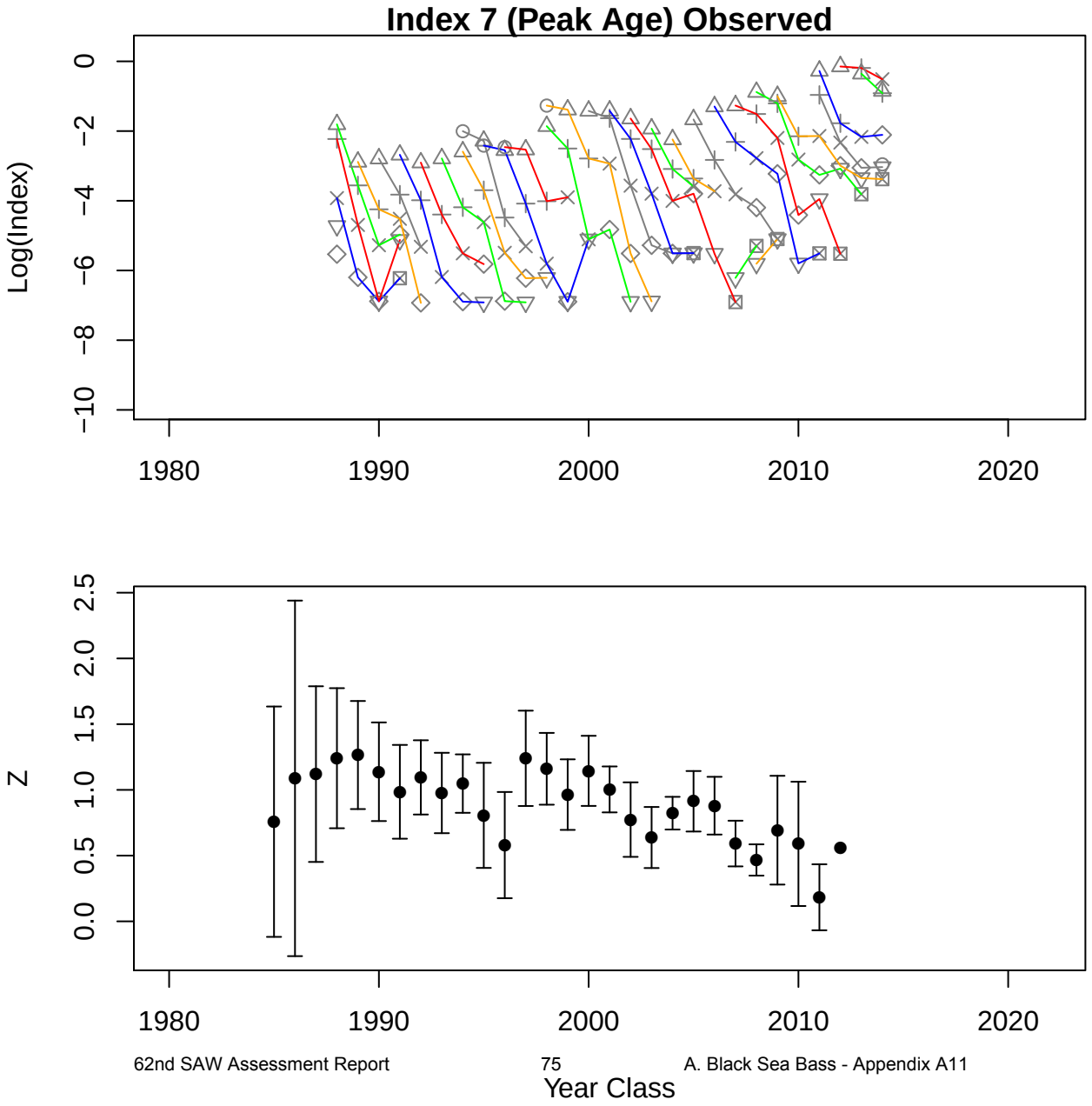

Index 4 (Peak Age) Observed
Log(Index)
−2
−4
−6
−8
−10
1980
1990
2000
2010
2020

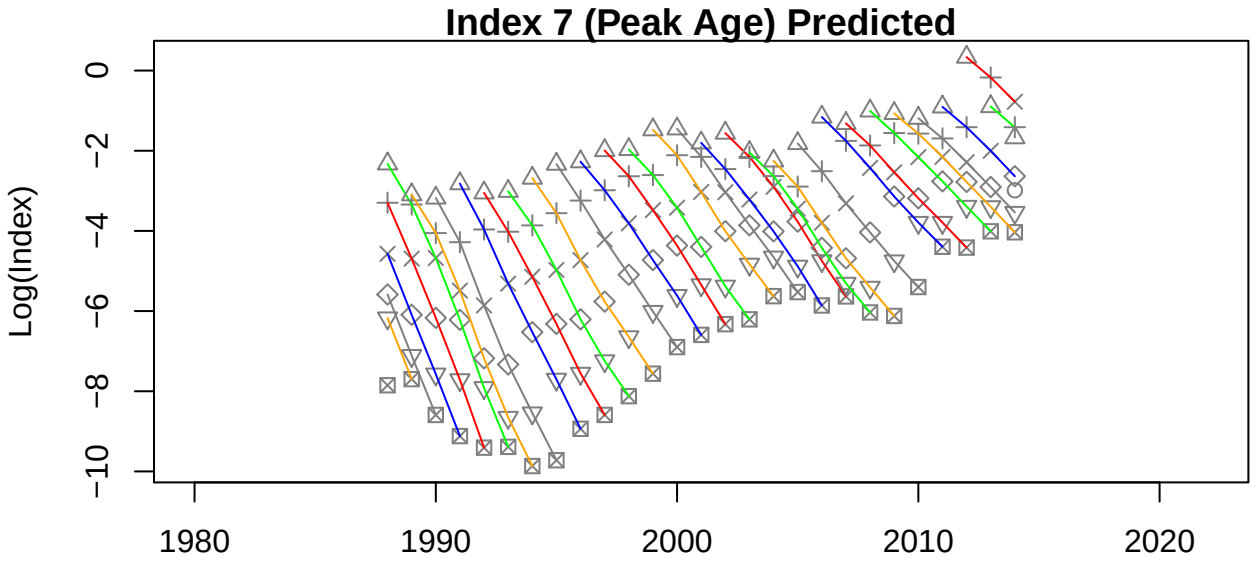

Z
3
2
1
0
−1
1980
1990
2000
2010
2020
Year Class

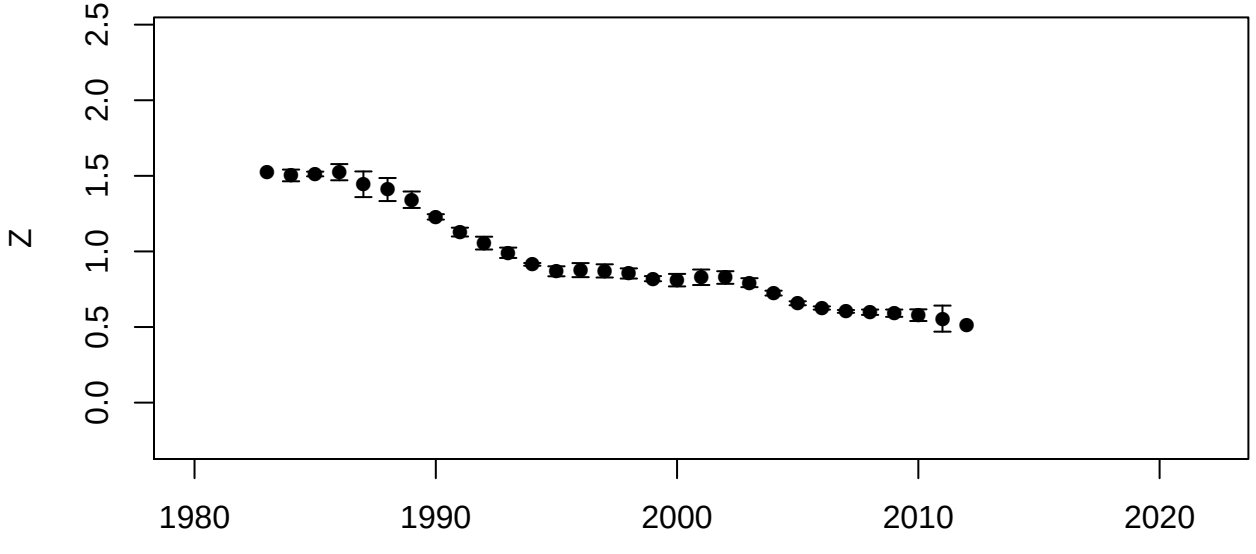

Index 4 (Peak Age) Predicted
Log(Index)
−2
−4
−6
−8
−10
1980
1990
2000
2010
2020
Z
3
2
1
0
−1
1980
1990
2000
2010
2020
Year Class

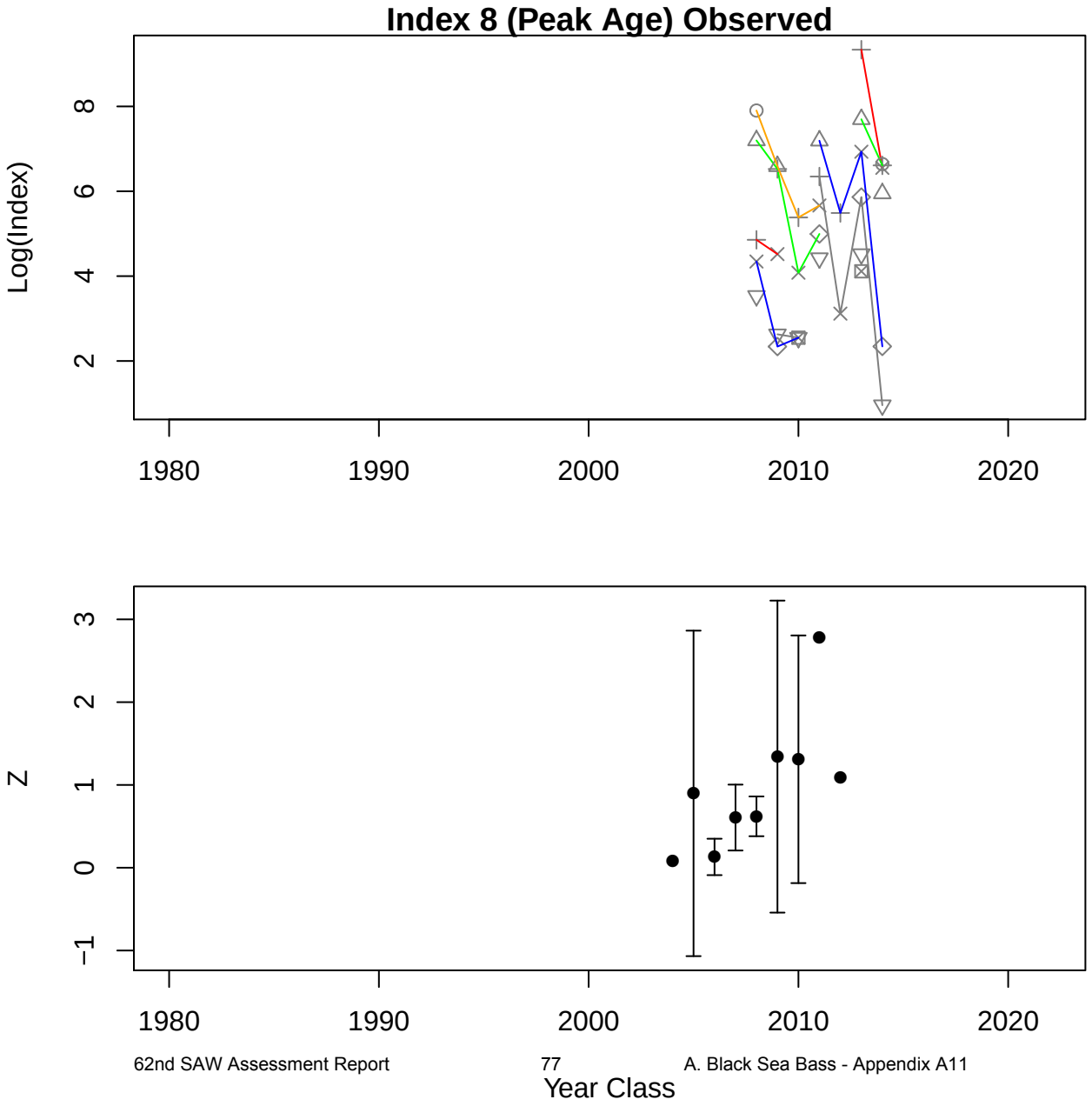

Index 5 (Peak Age) Observed
Log(Index)
2
0
−2
−4
−6
−8
1980
1990
2000
2010
2020
Z
8
6
4
2
0
−2
−4
1980
1990
2000
2010
2020
Year Class

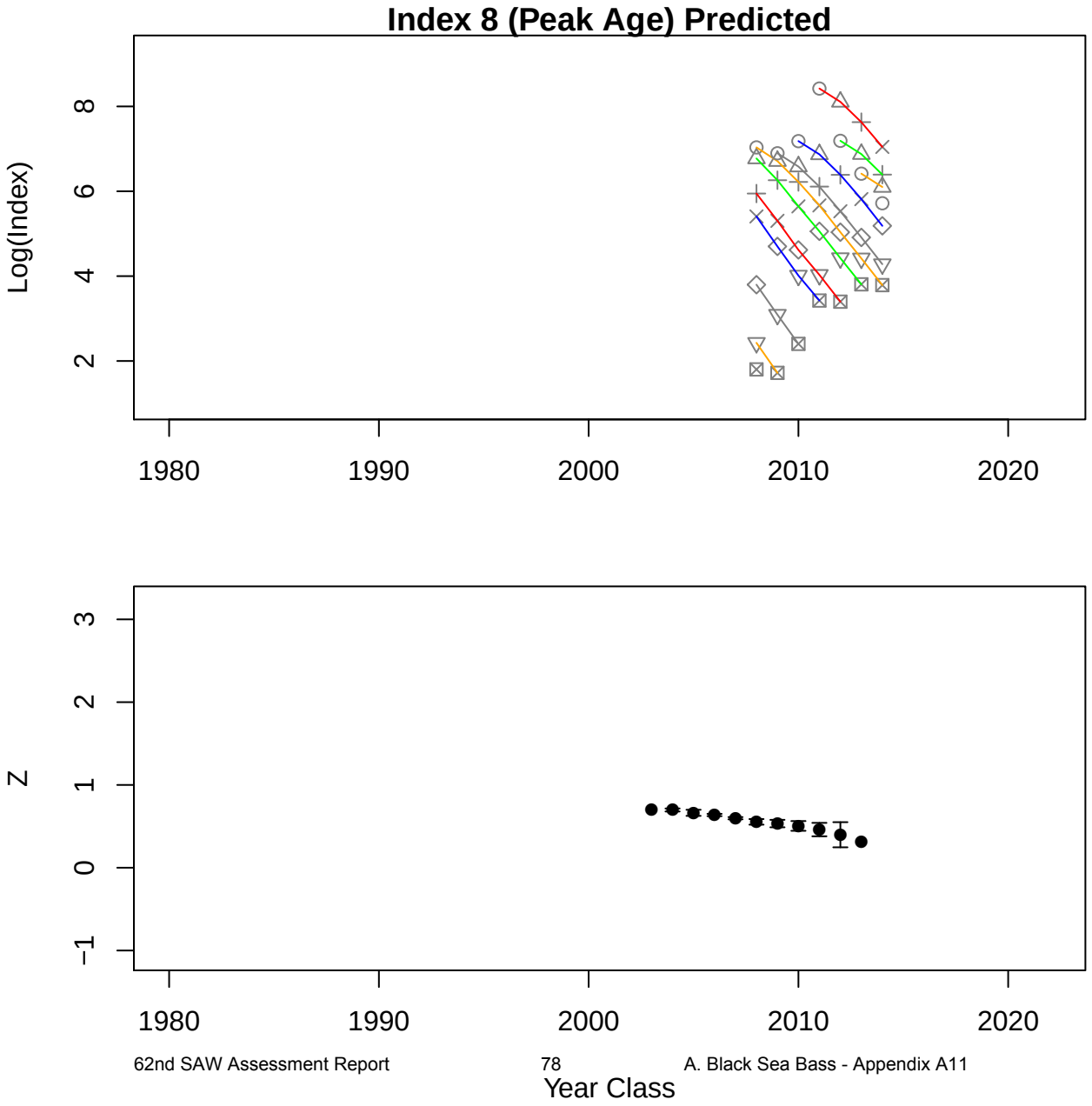

Index 5 (Peak Age) Predicted
Log(Index)
2
0
−2
−4
−6
−8
1980
1990
2000
2010
2020
Z
8
6
4
2
0
−2
−4
1980
1990
2000
2010
2020
Year Class


Index 7 (Peak Age) Observed
Log(Index)
0
−2
−4
−6
−8
−10
1980
1990
2000
2010
2020
Z
2.5
2.0
1.5
1.0
0.5
0.0
1980
1990
2000
2010
2020
Year Class

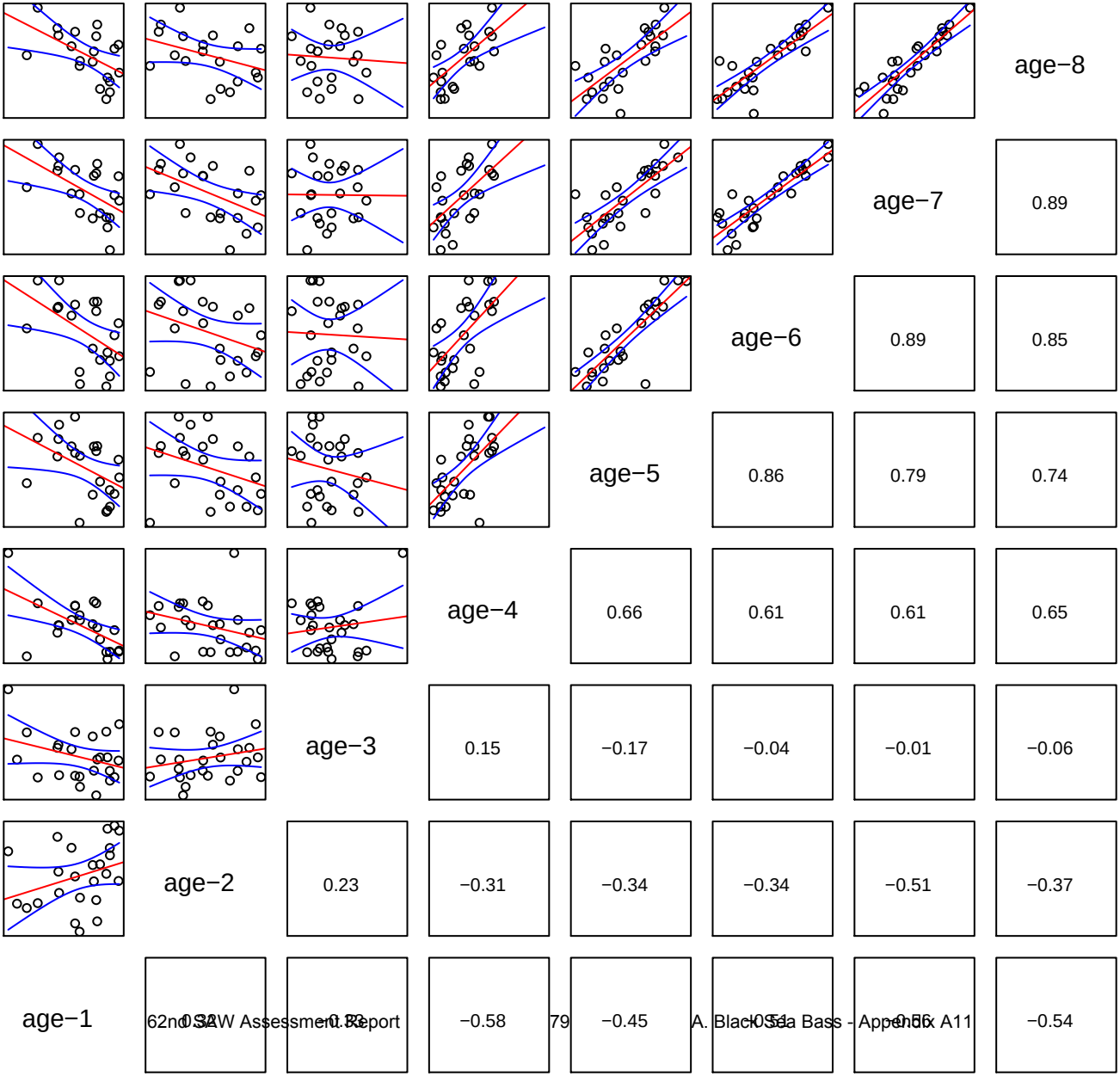

Index 7 (Peak Age) Predicted
Log(Index)
0
−2
−4
−6
−8
−10
1980
1990
2000
2010
2020


Z
2.5
2.0
1.5
1.0
0.5
0.0
1980
1990
2000
2010
2020
Year Class

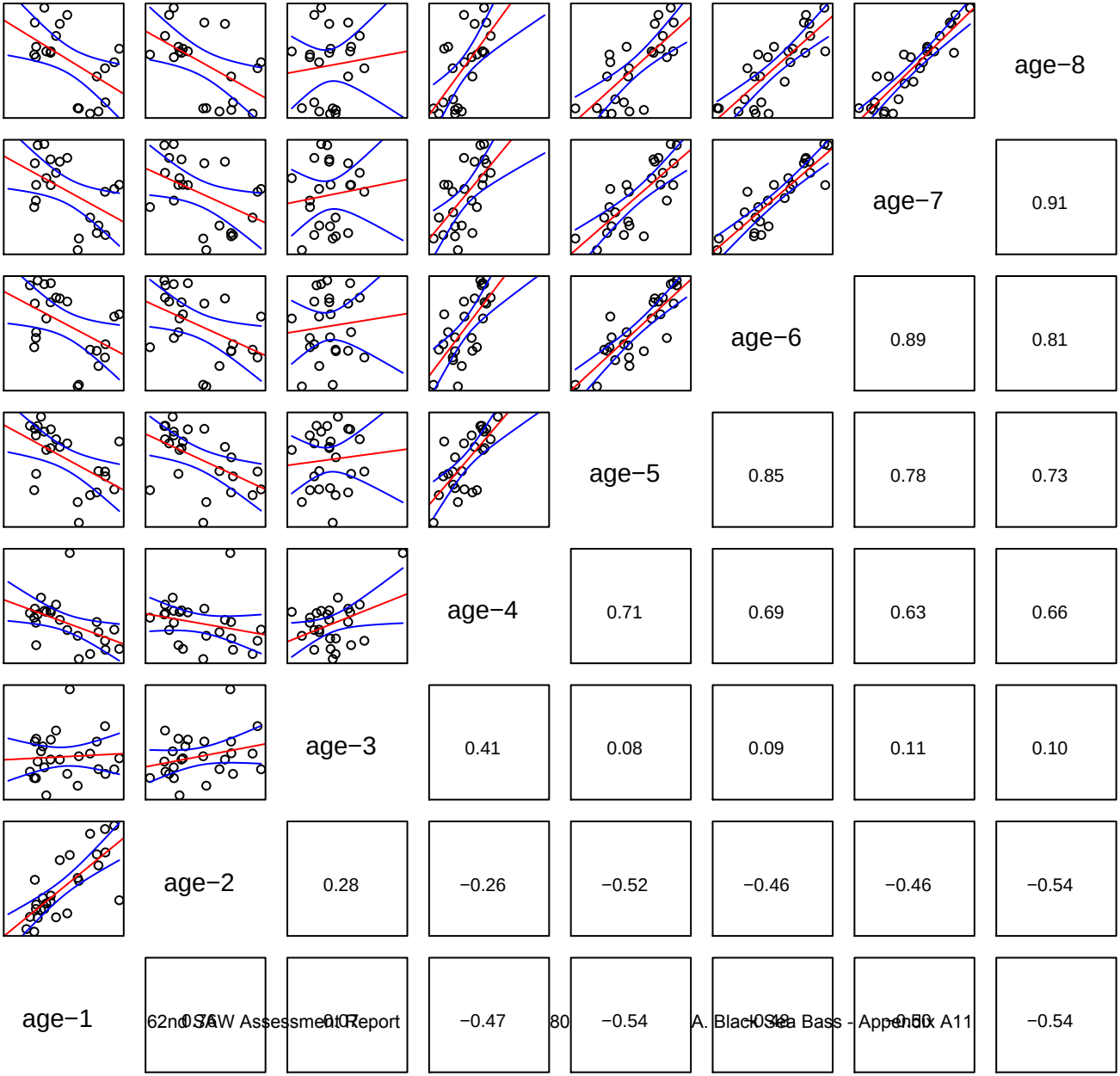

Index 8 (Peak Age) Observed
Log(Index)
2
4
6
8
1980
1990
2000
2010
2020
Z
−1
0
1
2
3
1980
1990
2000
2010
2020
Year Class


Index 8 (Peak Age) Predicted
Log(Index)
2
4
6
8
1980
1990
2000
2010
2020
Z
−1
0
1
2
3
1980
1990
2000
2010
2020
Year Class

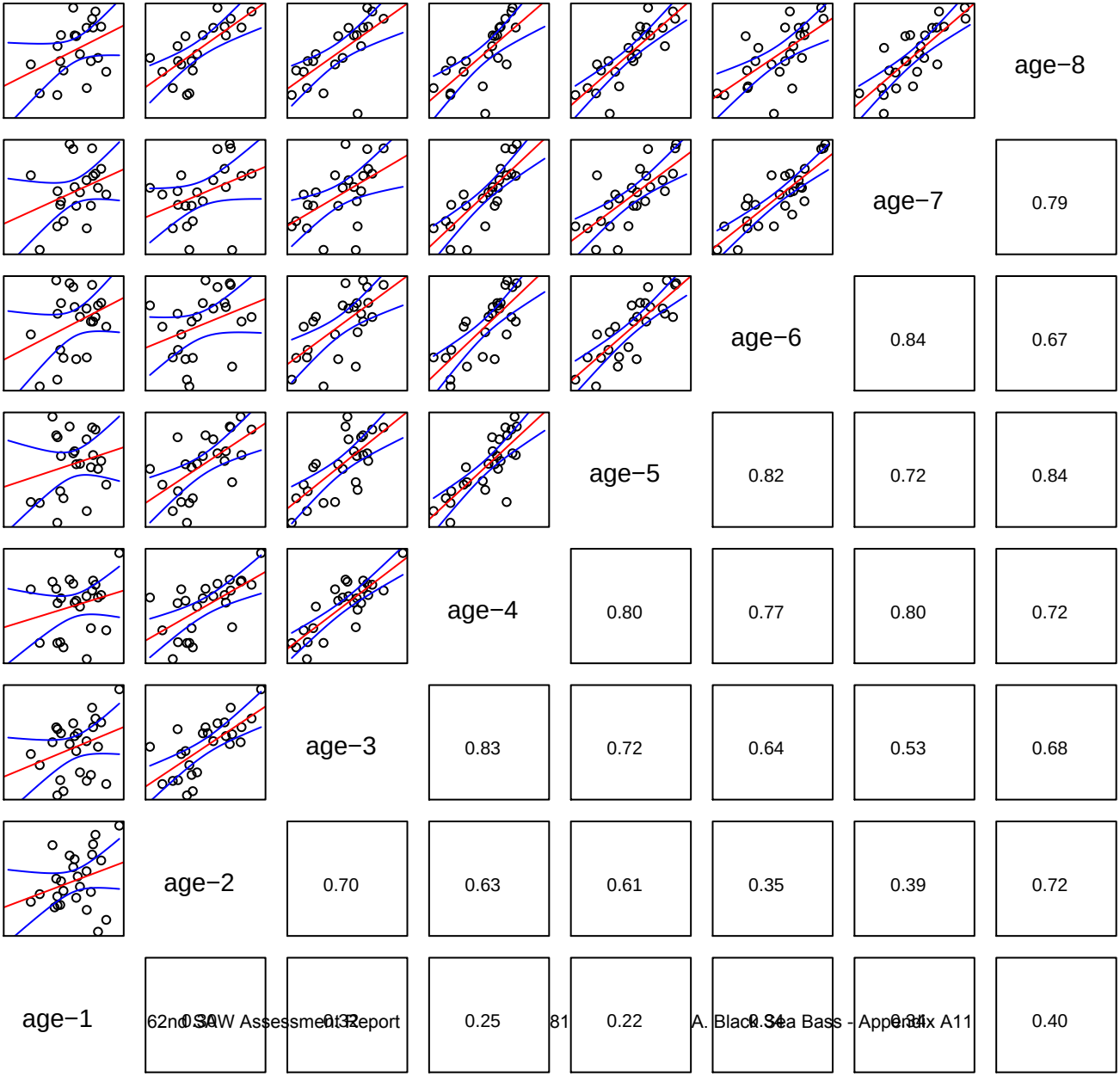
Catch for Fleet 1 Observed



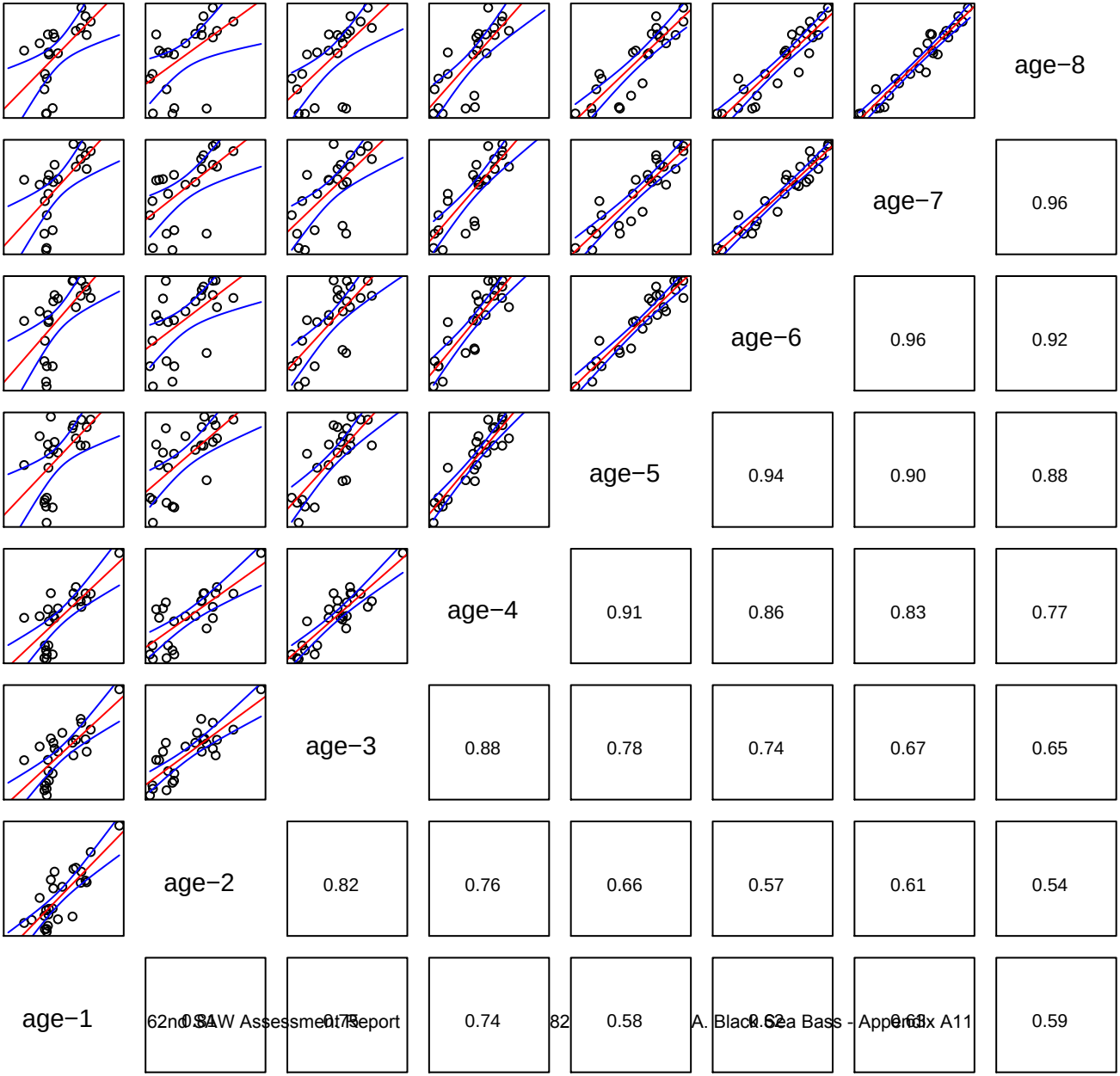
Catch for Fleet 1 Predicted



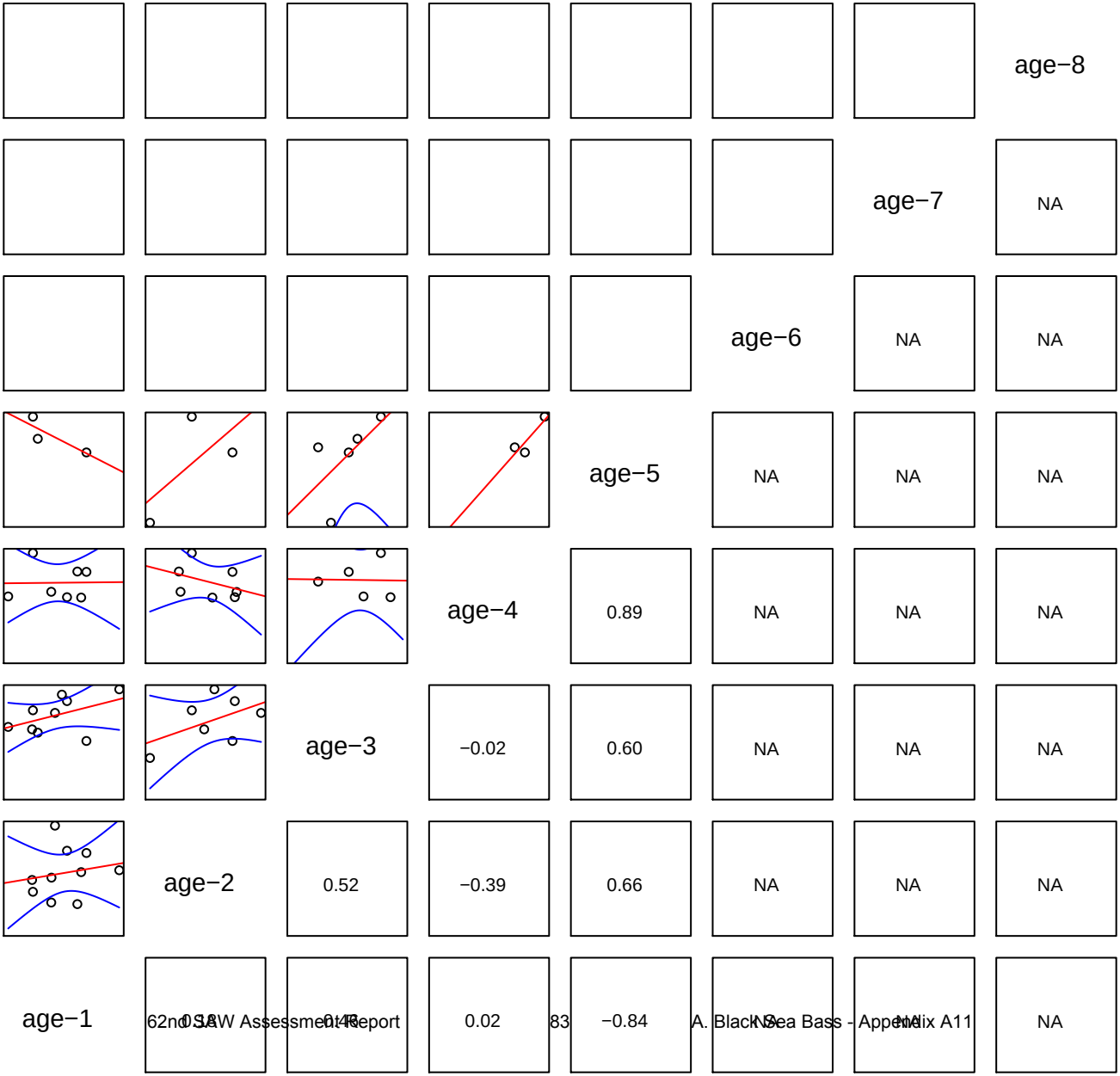
Catch for Fleet 2 Observed



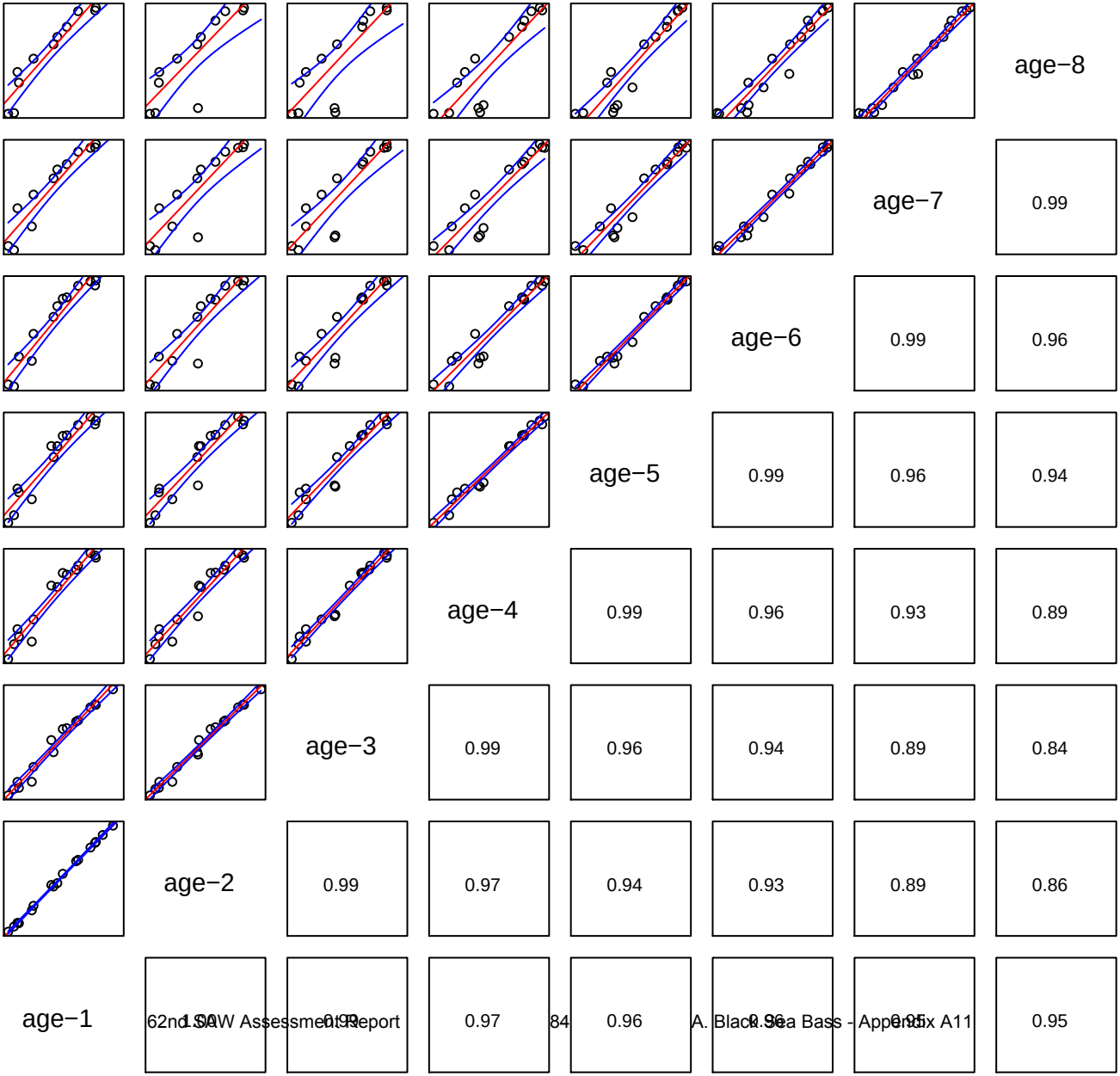
Catch for Fleet 2 Predicted



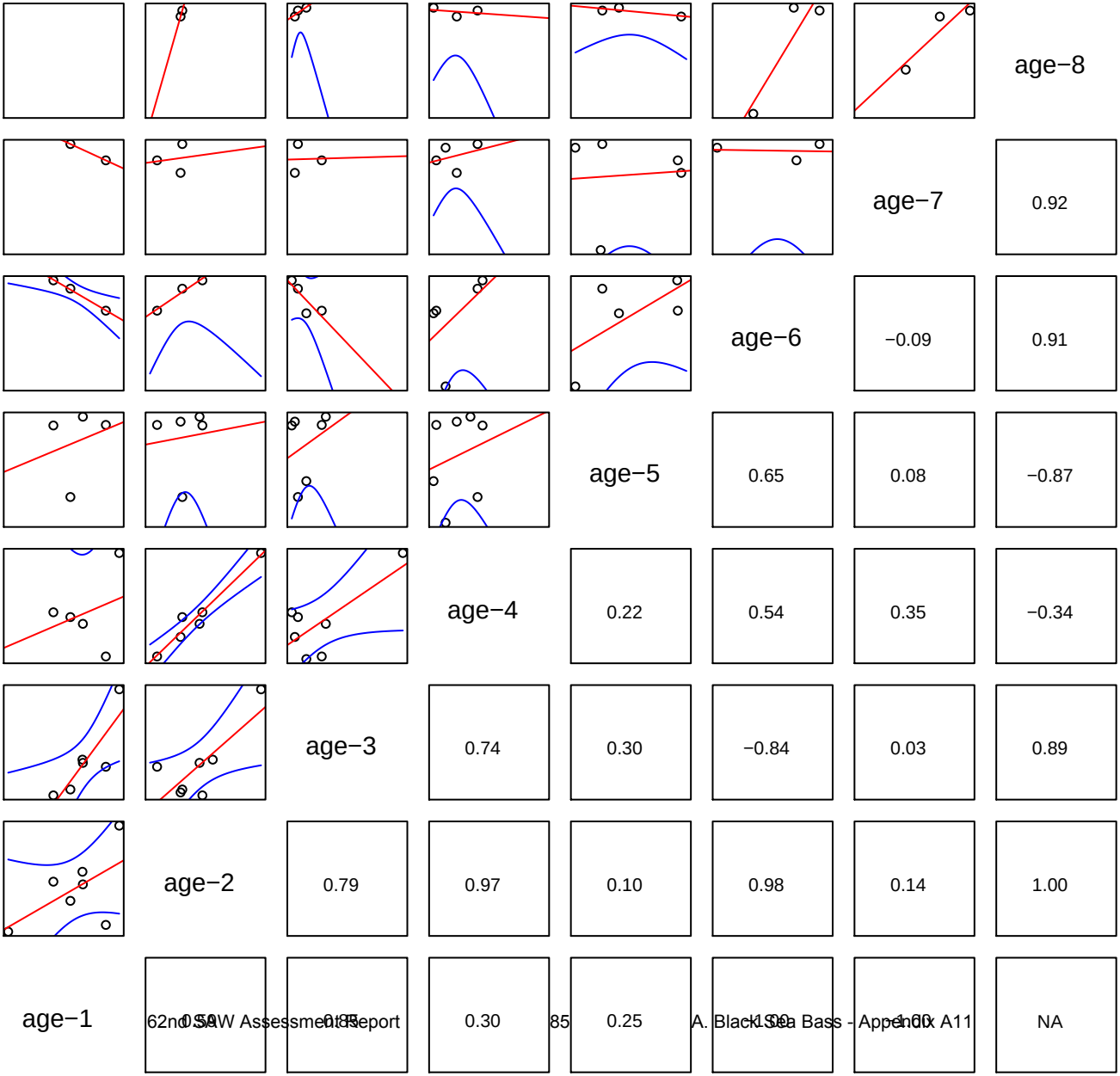
Index 1 Observed



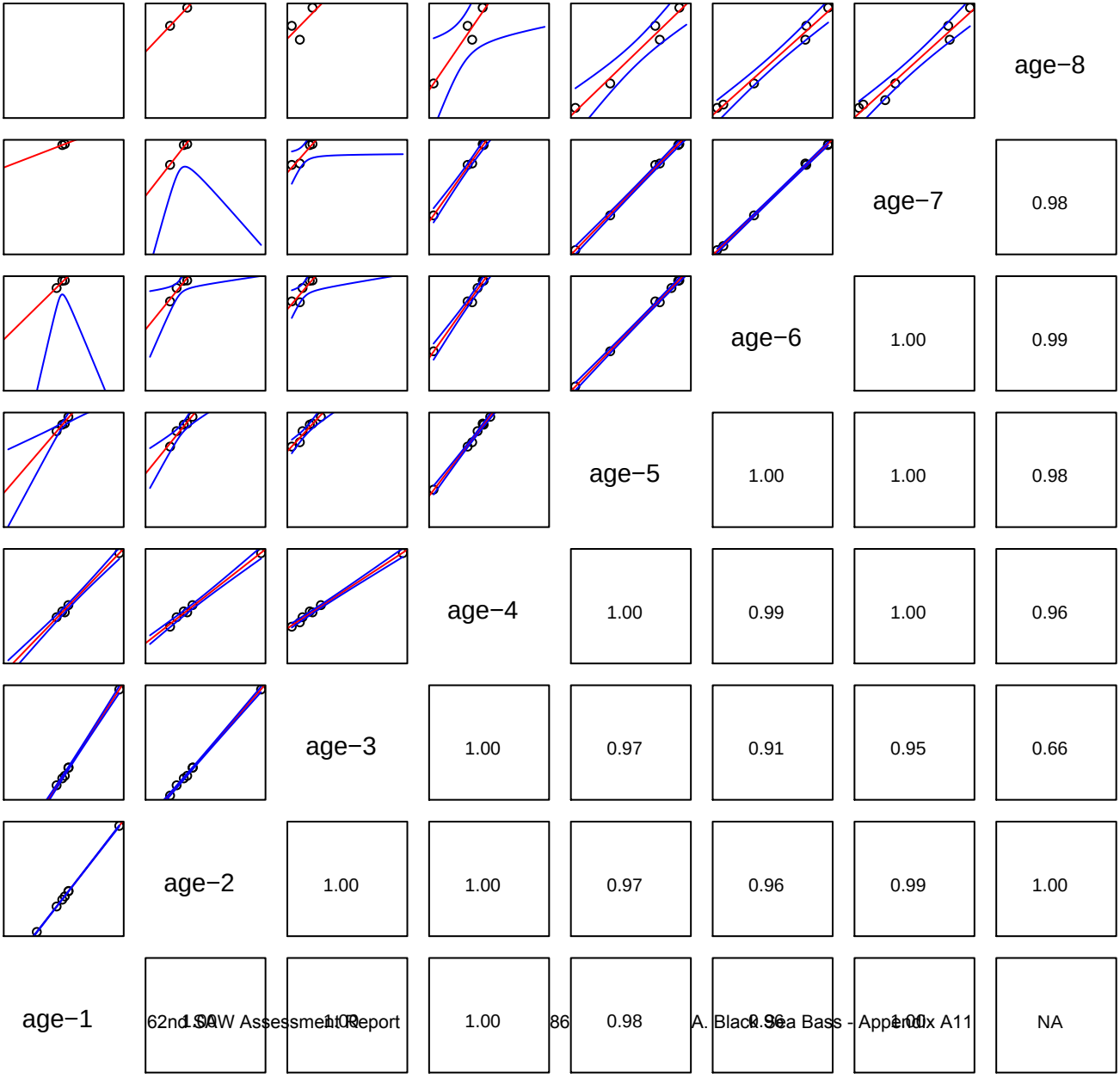
Index 1 Predicted



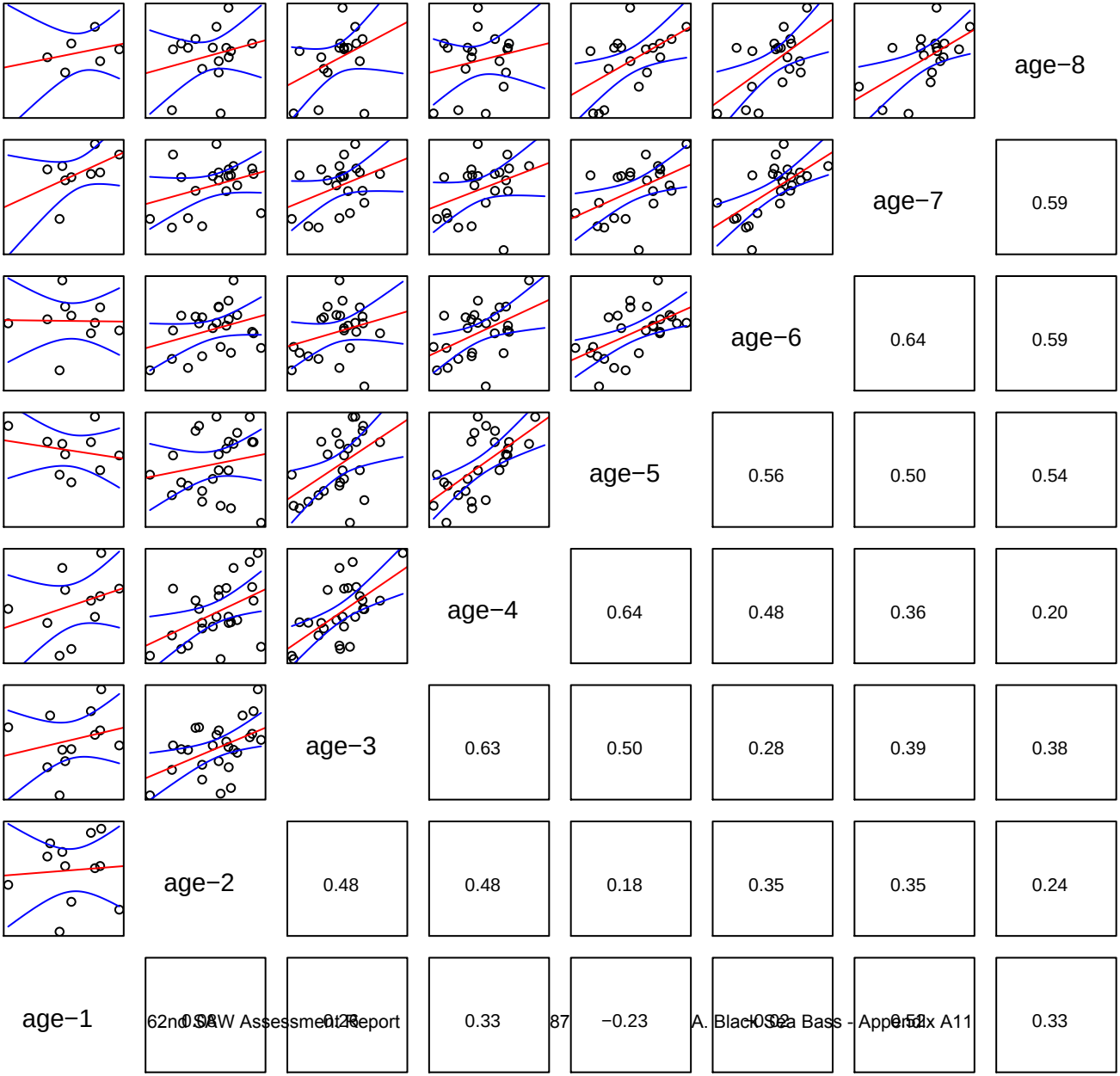
Index 2 Observed



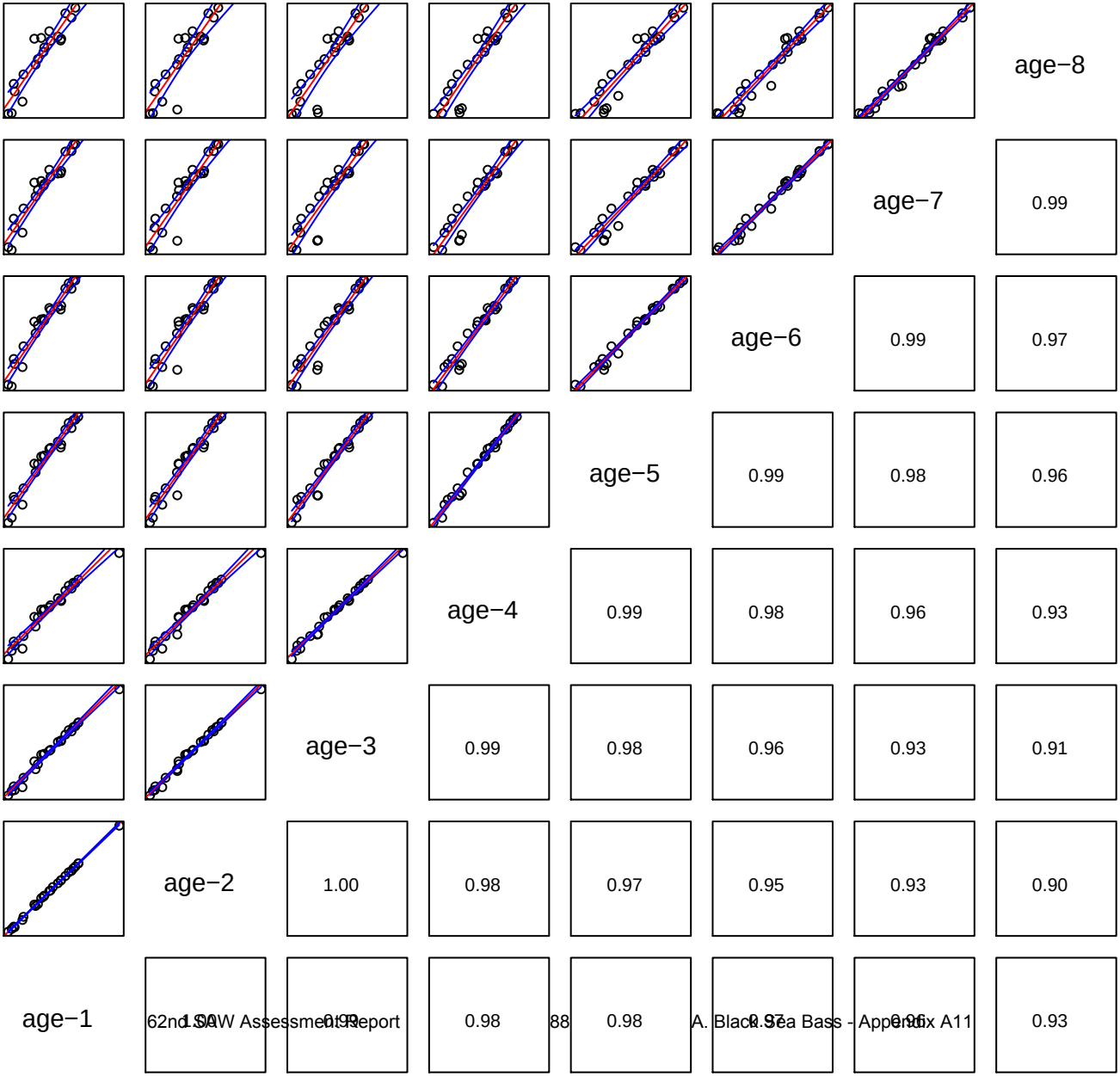
Index 2 Predicted



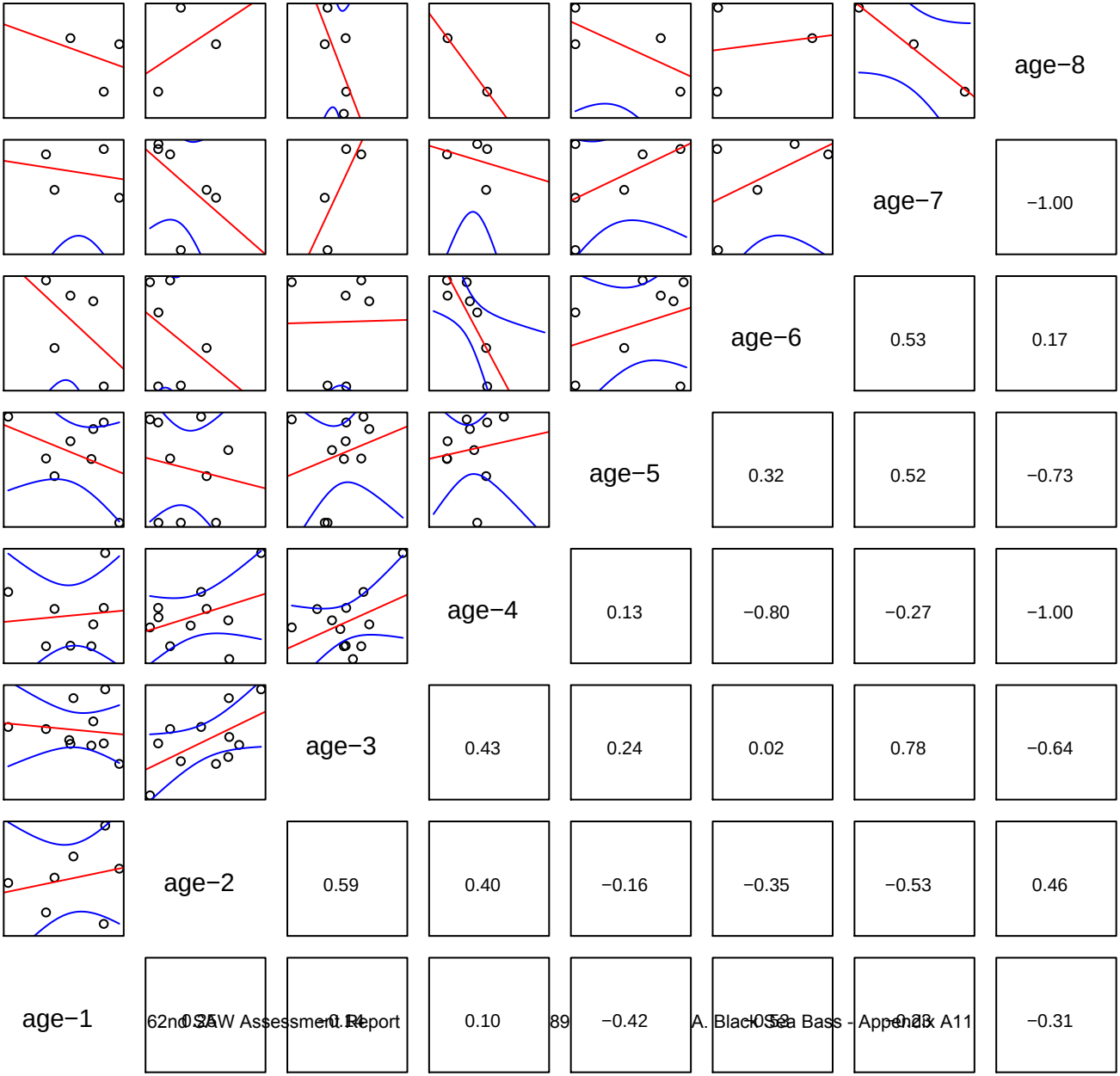
Index 3 Observed



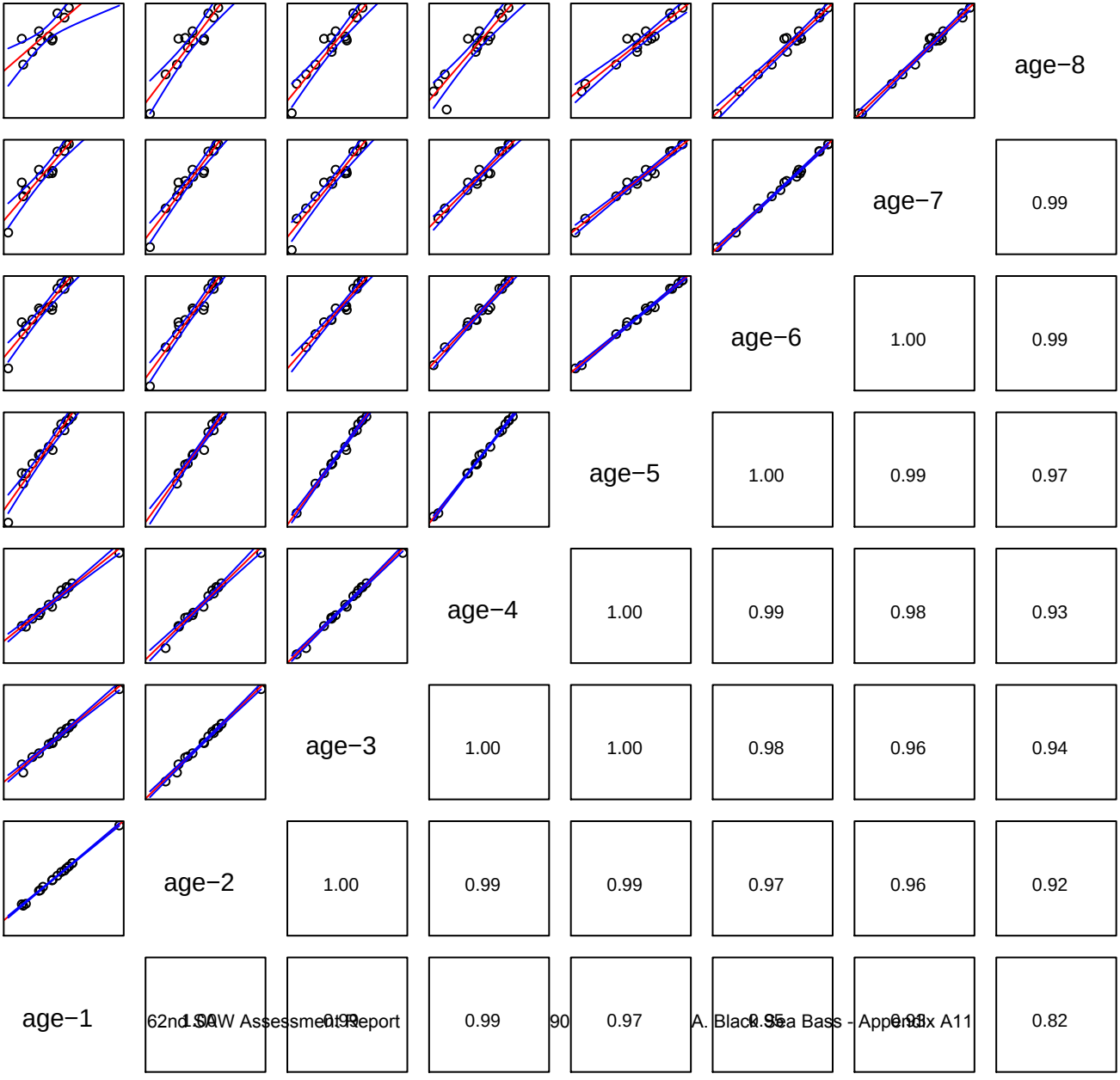
Index 3 Predicted



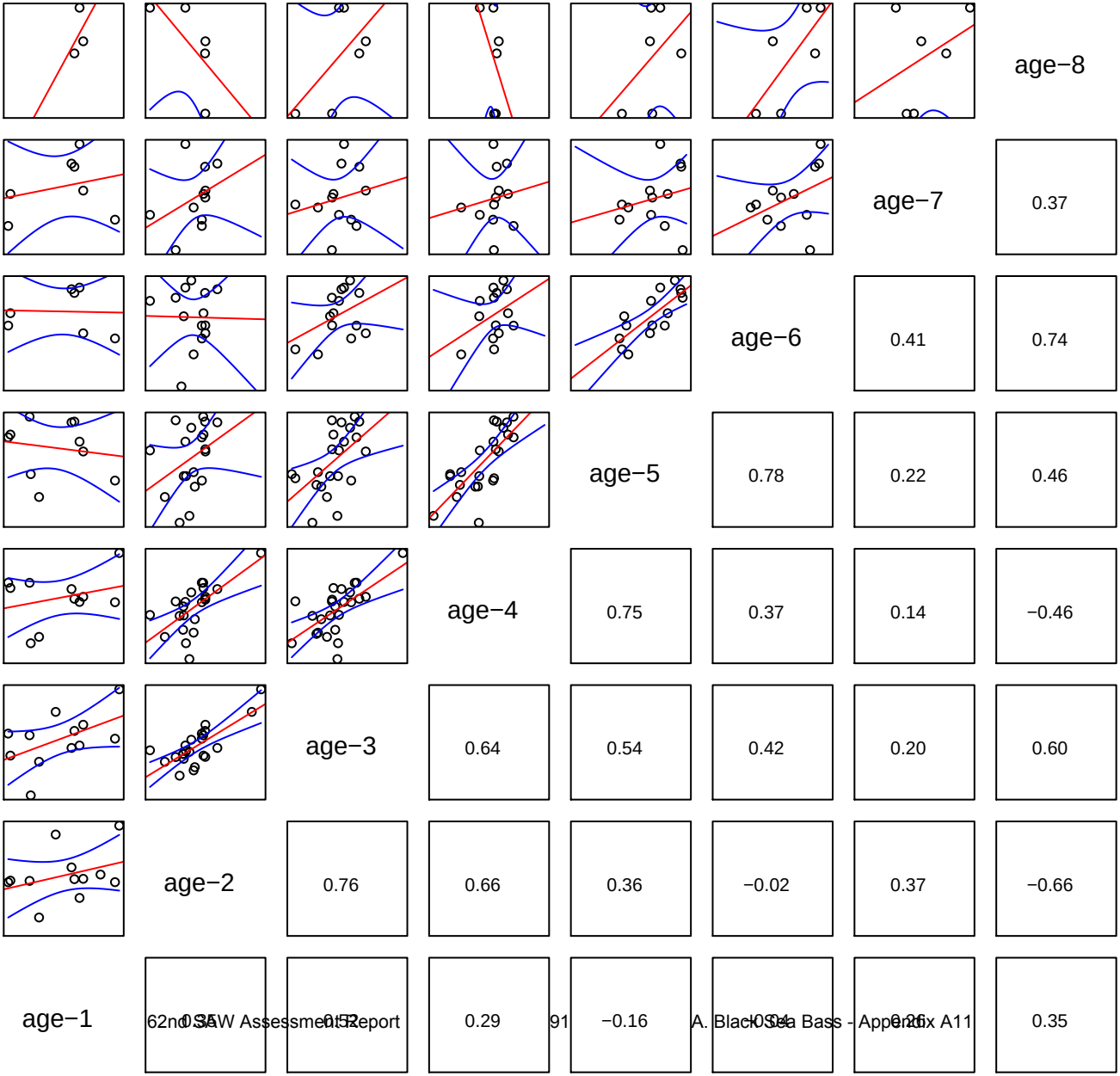
Index 4 Observed



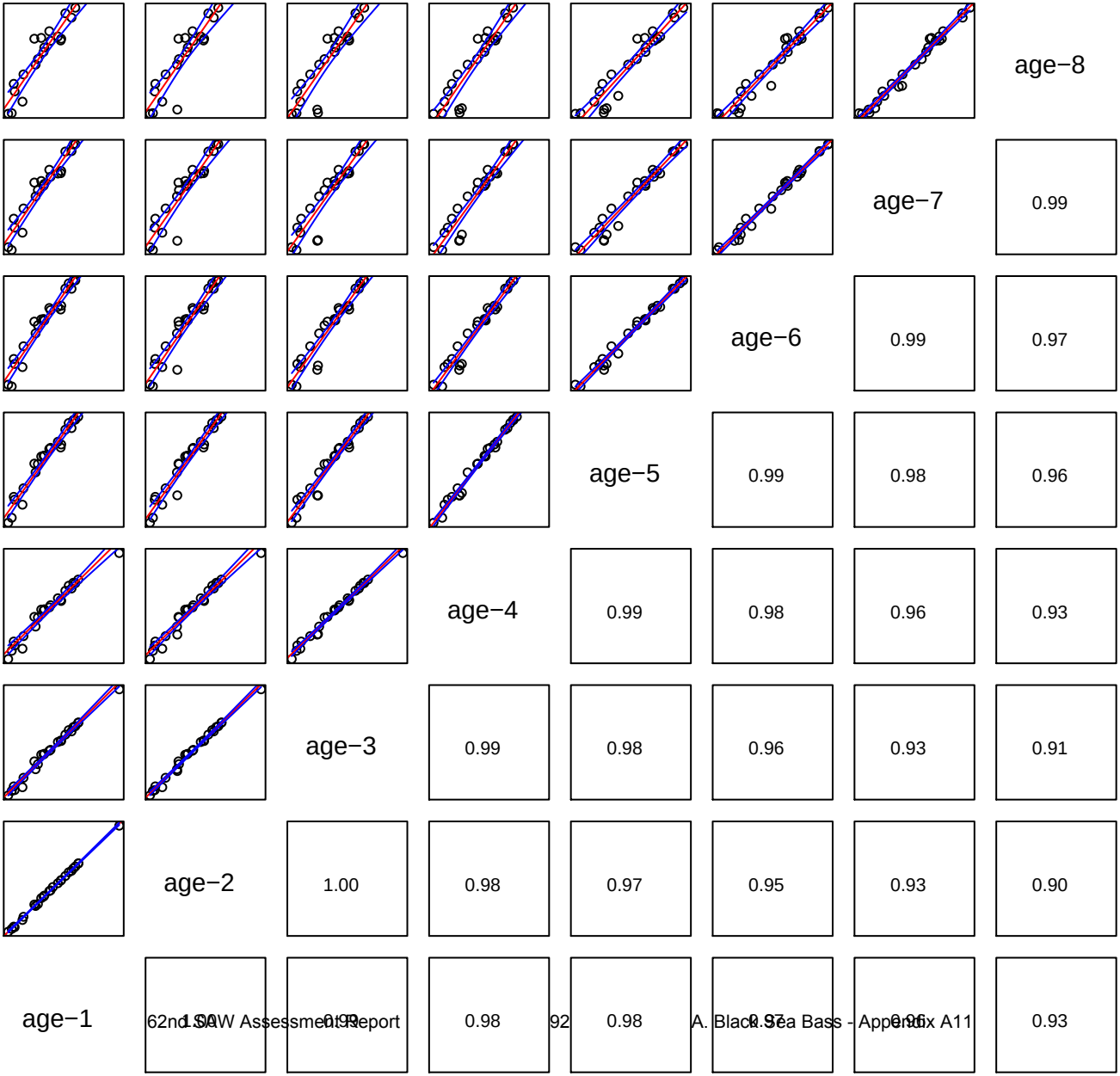
Index 4 Predicted



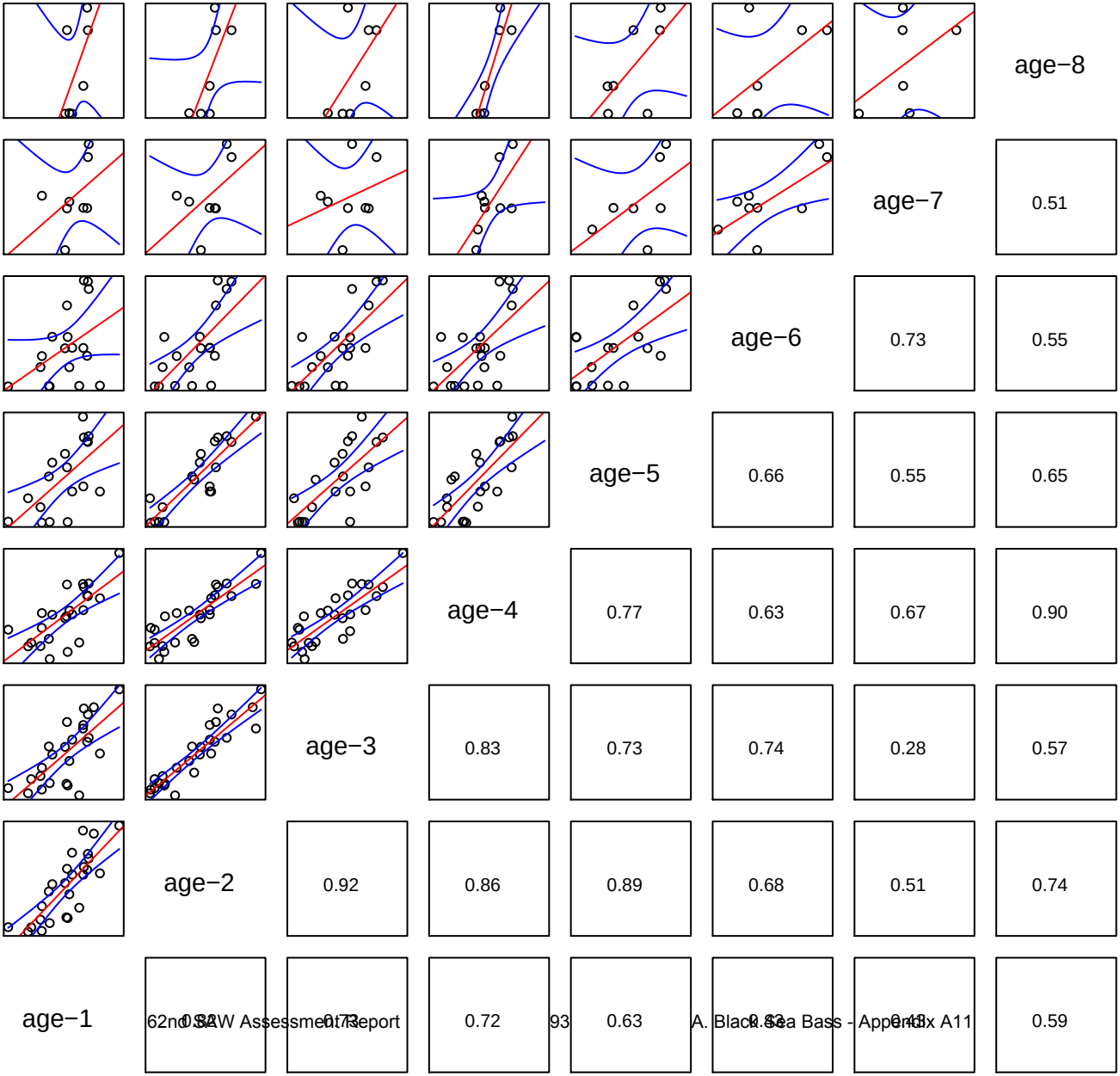
Index 5 Observed



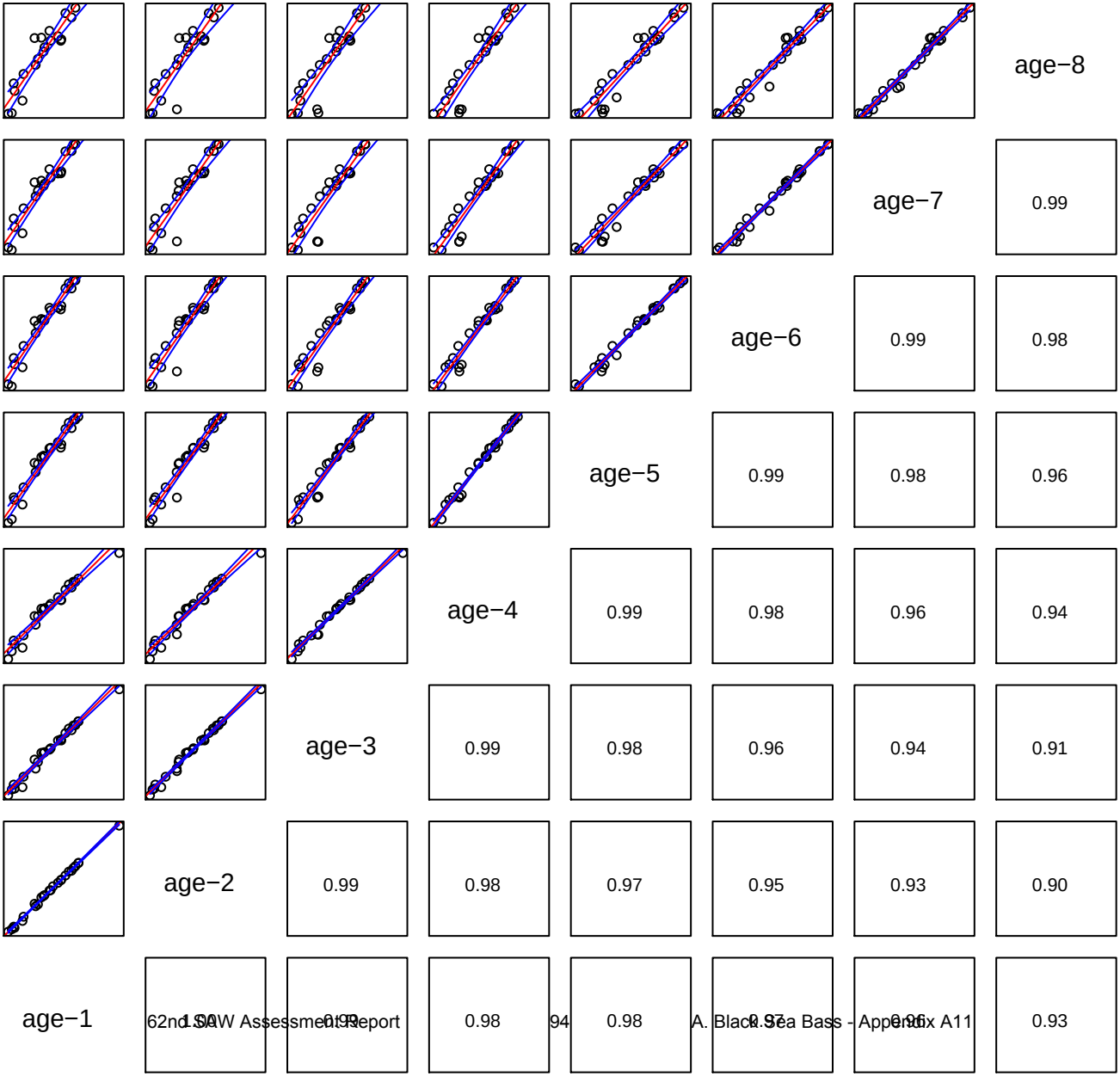
Index 5 Predicted



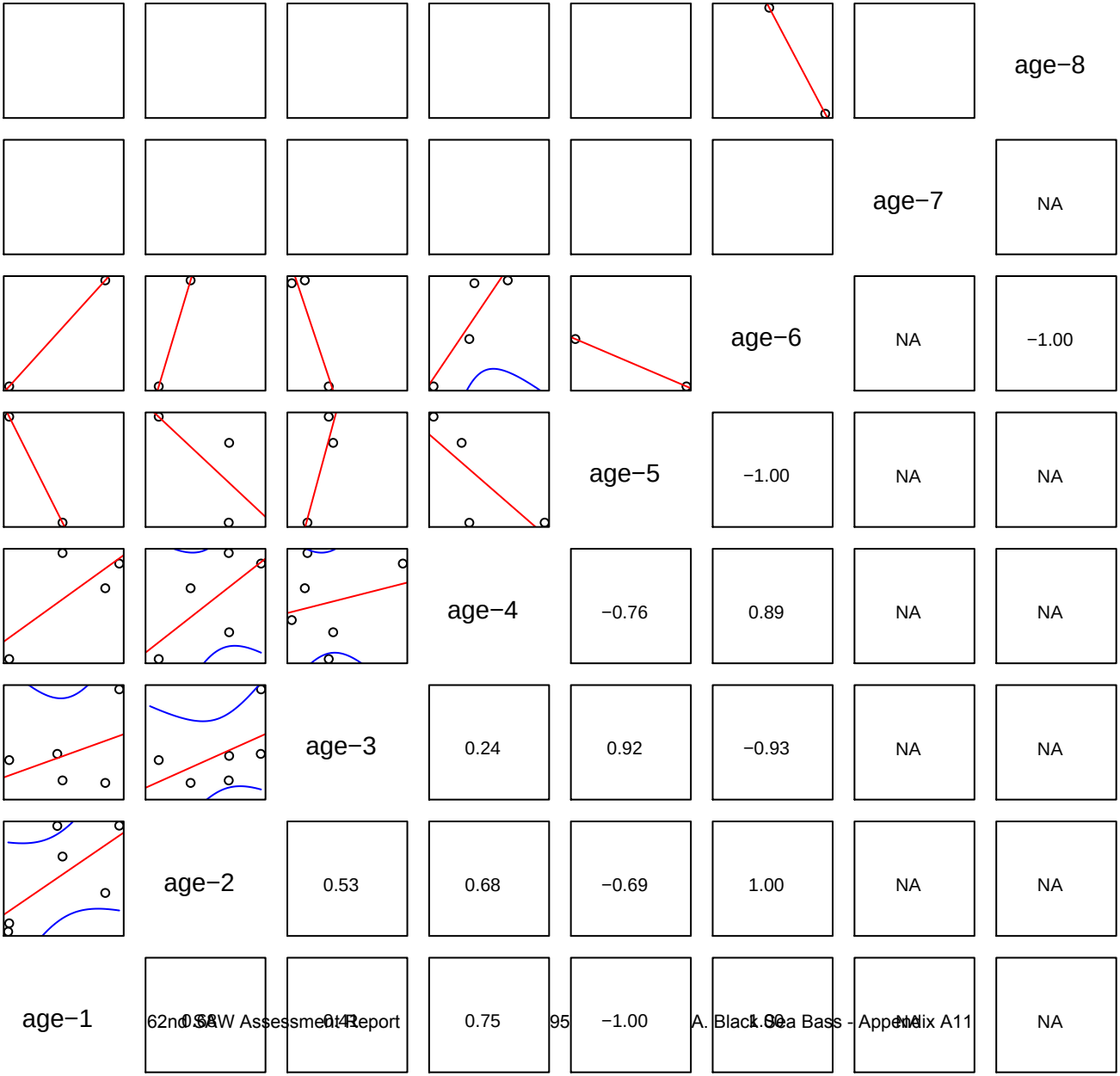
Index 7 Observed



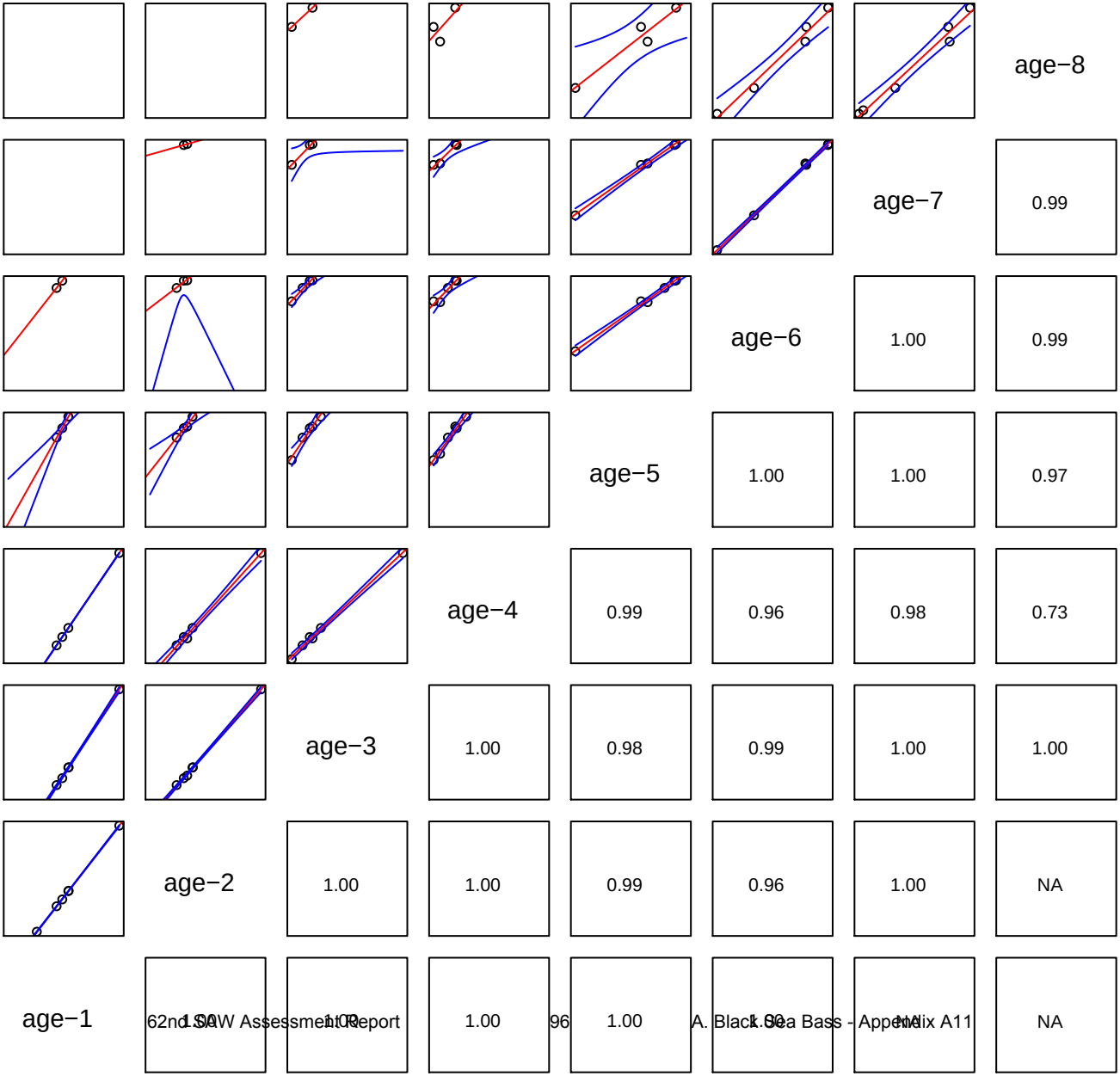
Index 7 Predicted

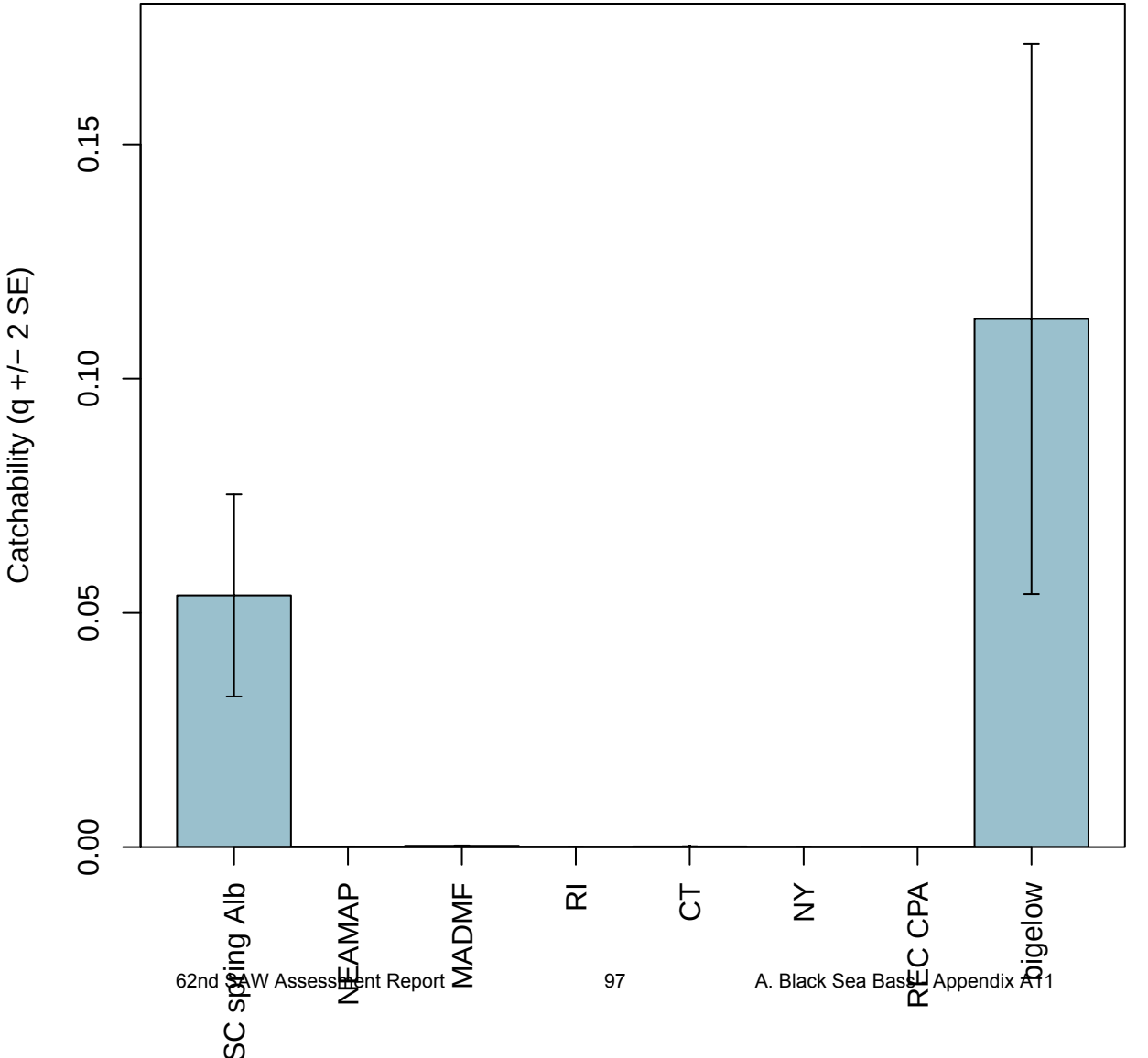


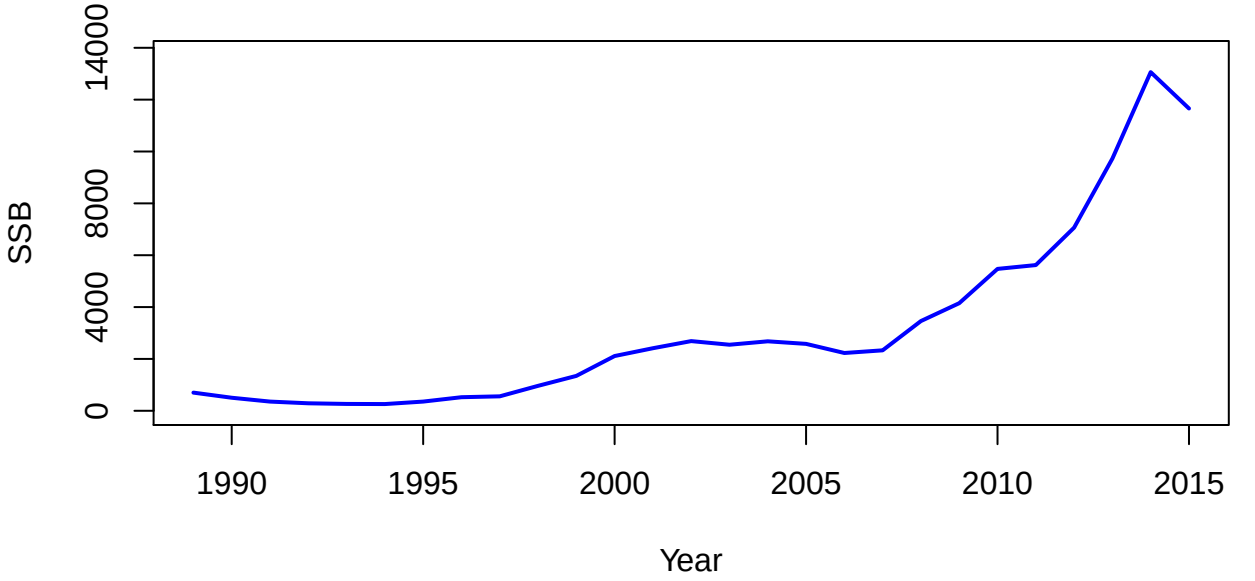
Index 8 Observed

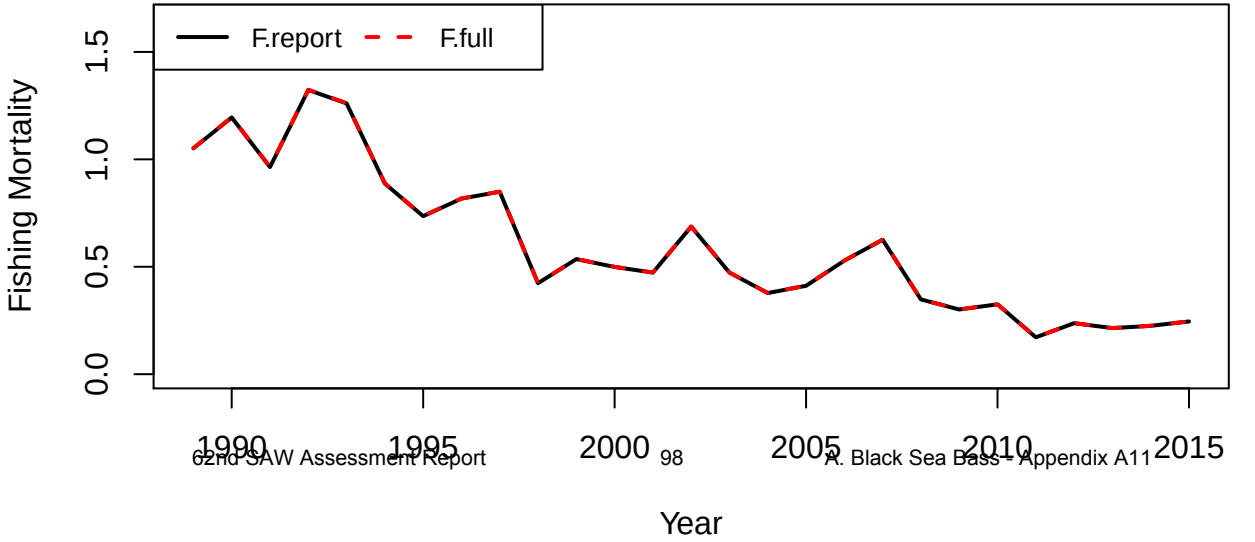


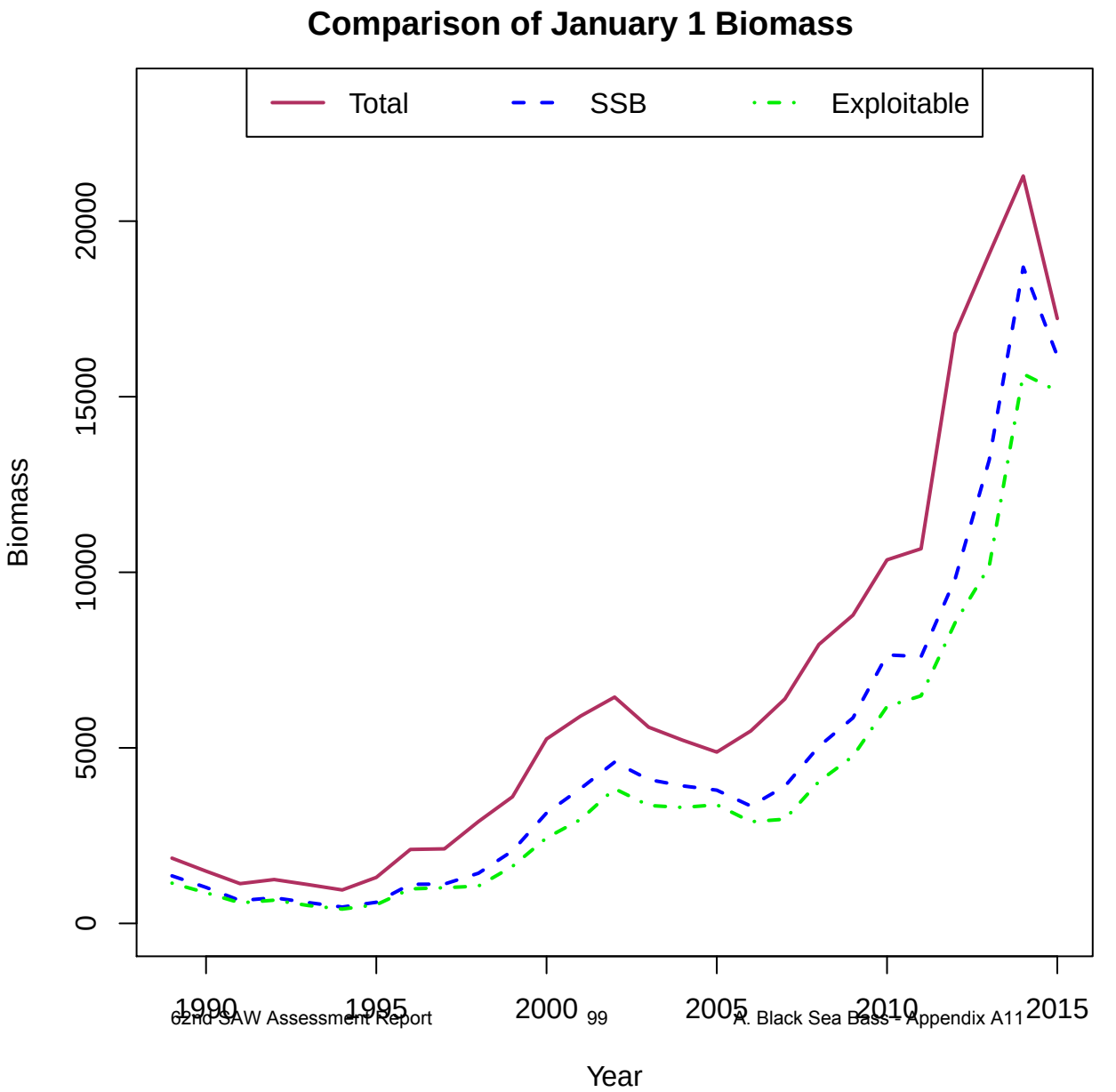
Index 8 Predicted

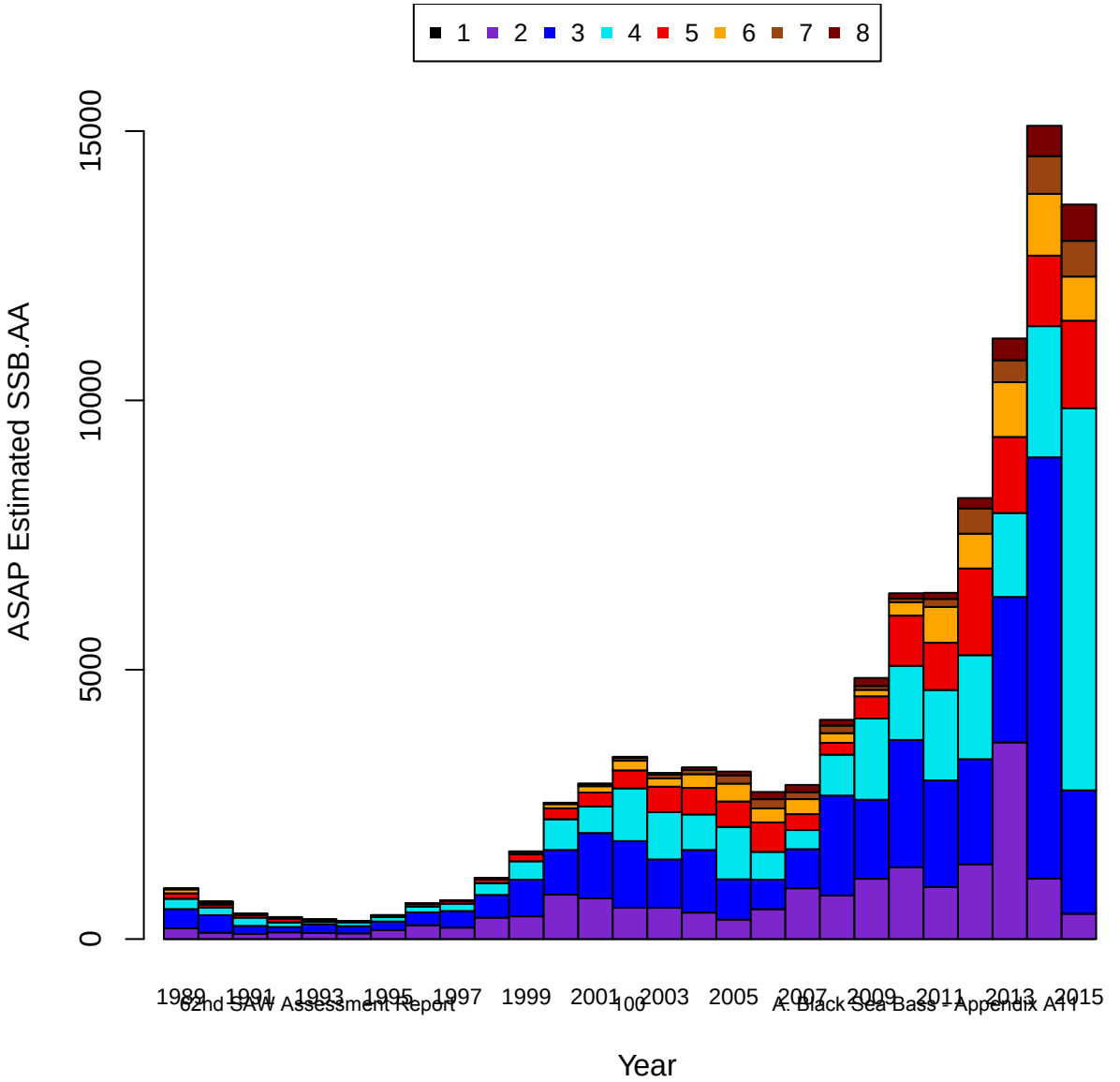


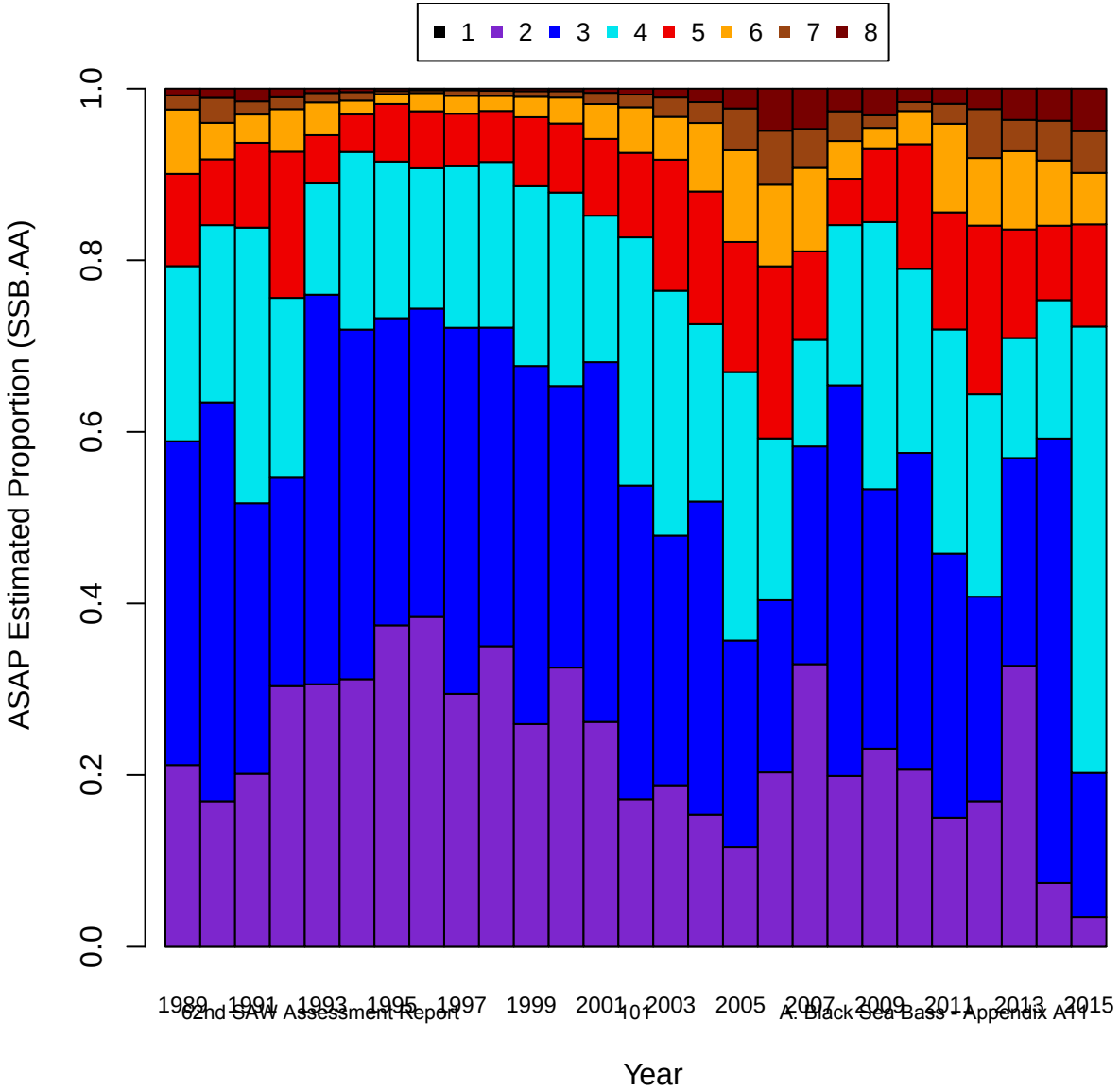

Catchability (q +/− 2 SE)
0.00
0.05
0.10
0.15
SC spring Alb
NEAMAP
MADMF
RI
CT
NY
REC CPA
bigelow

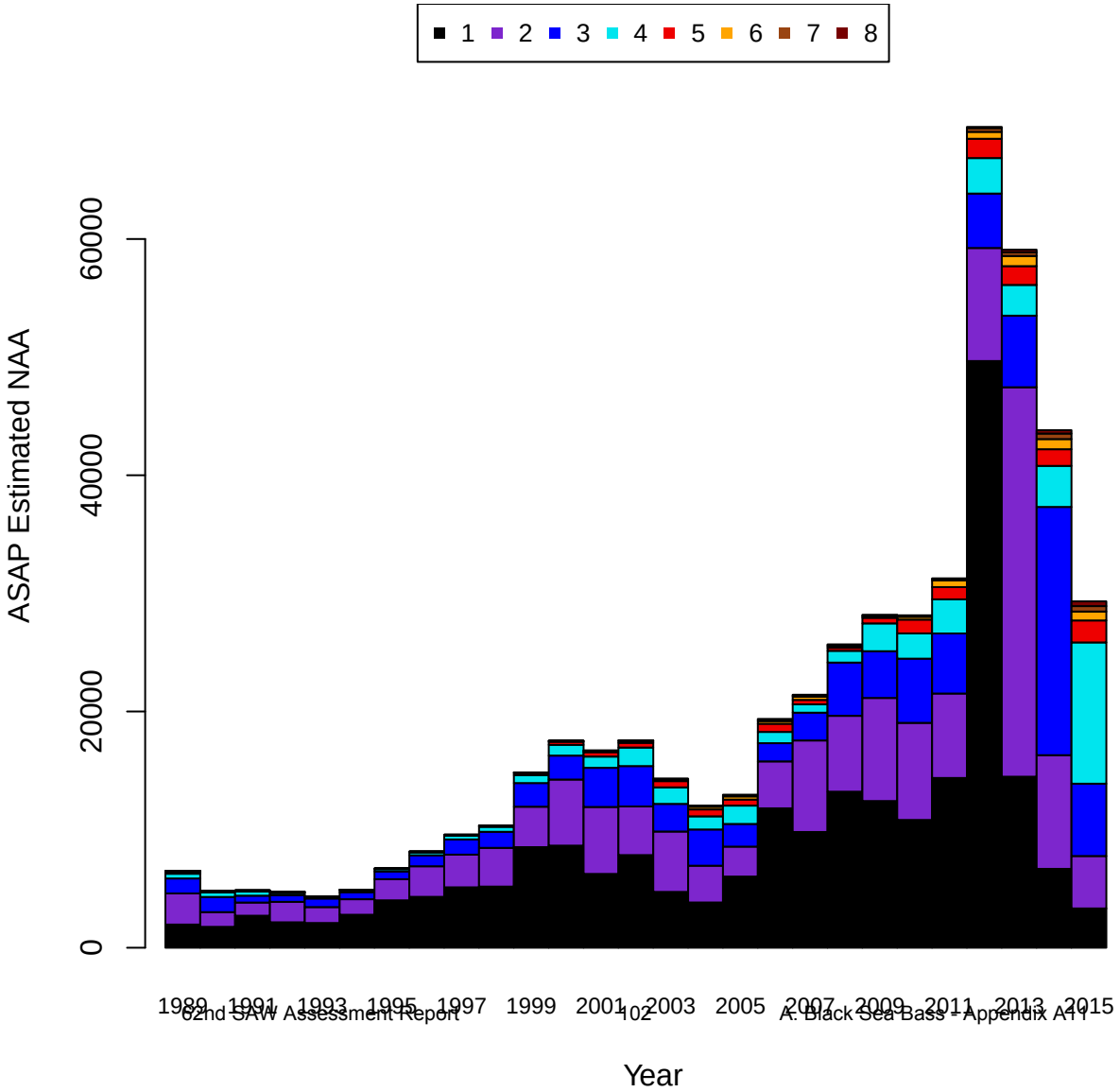

SSB
0
4000
8000
14000
1990
1995
2000
2005
2010
2015
Year

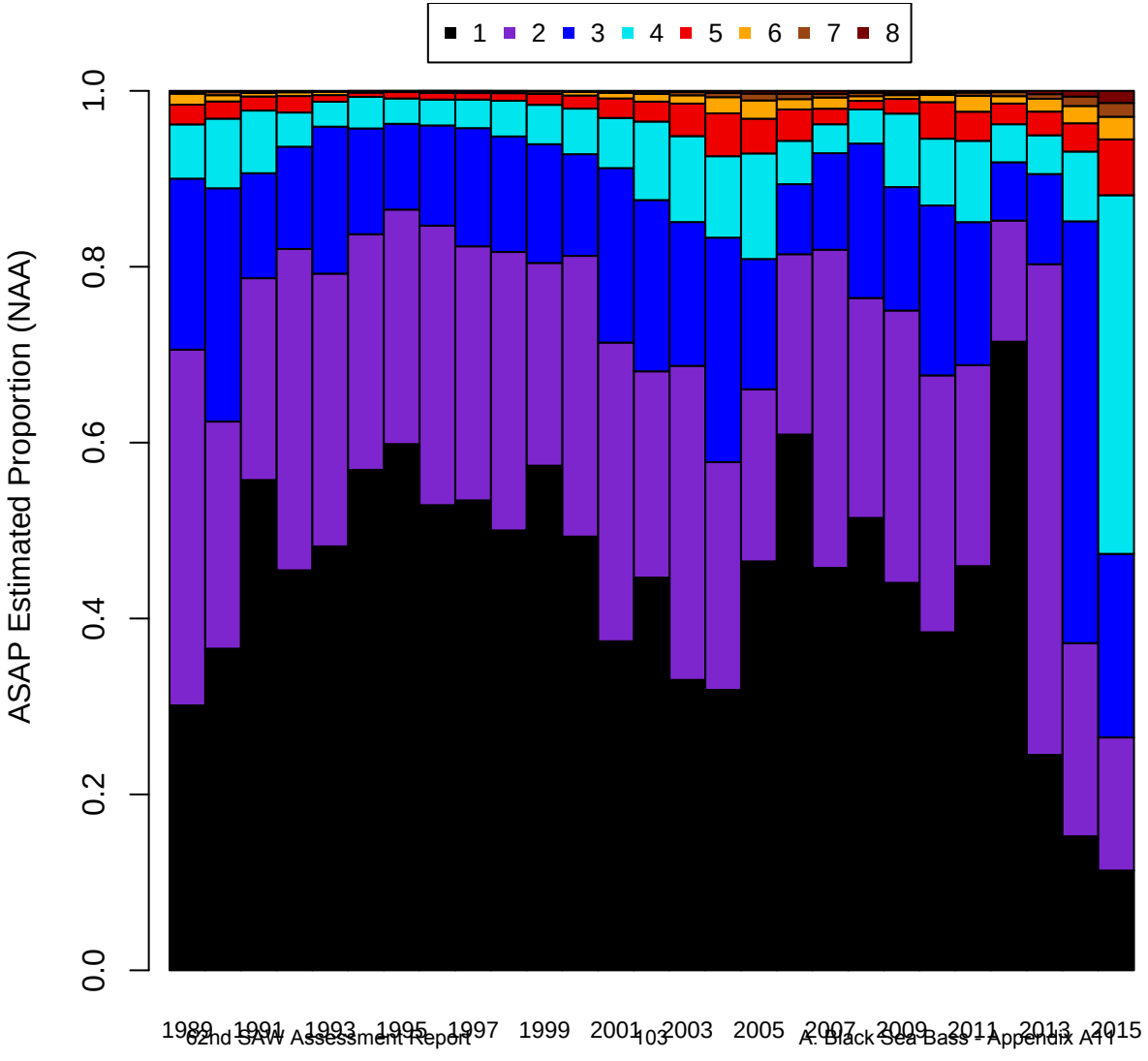

F.report
F.full
Fishing Mortality
0.0
0.5
1.0
1.5
1990
1995
2000
2005
2010
2015
Year

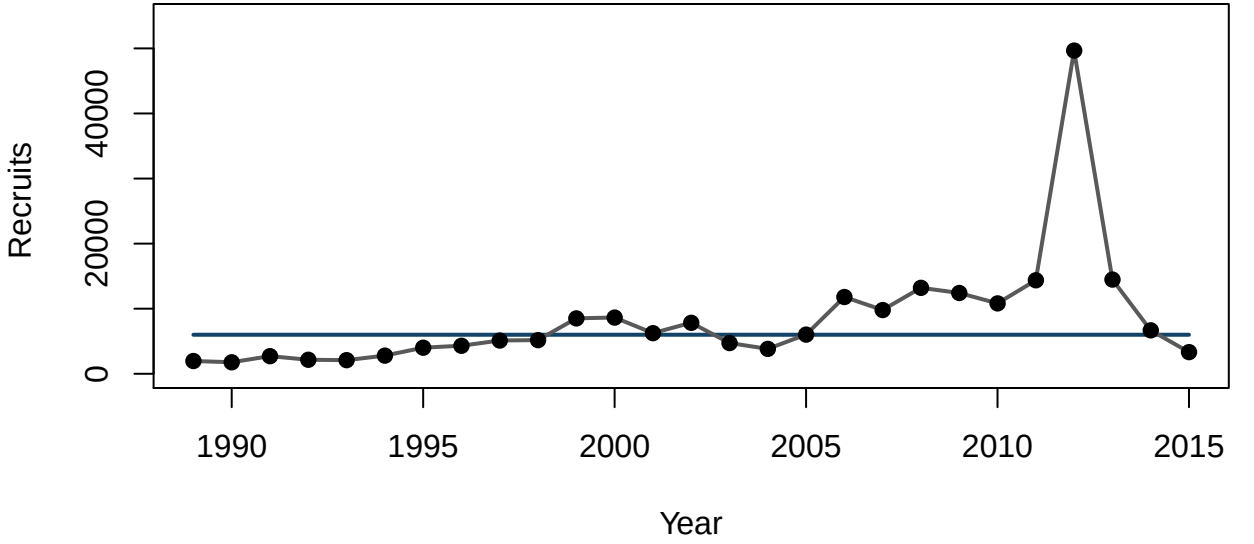

Comparison of January 1 Biomass
Total
SSB
Exploitable
Biomass
0
5000
10000
15000
20000
1990
1995
2000
2005
2010
2015
Year

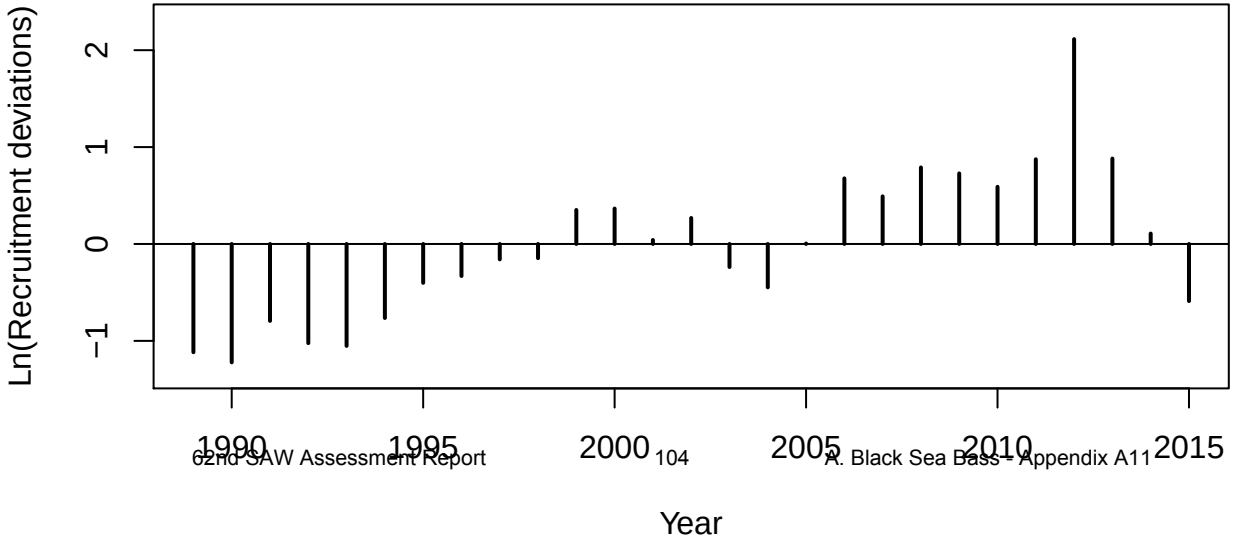

1 2 3 4 5 6 7 8
ASAP Estimated SSB.AA
0
5000
10000
15000
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

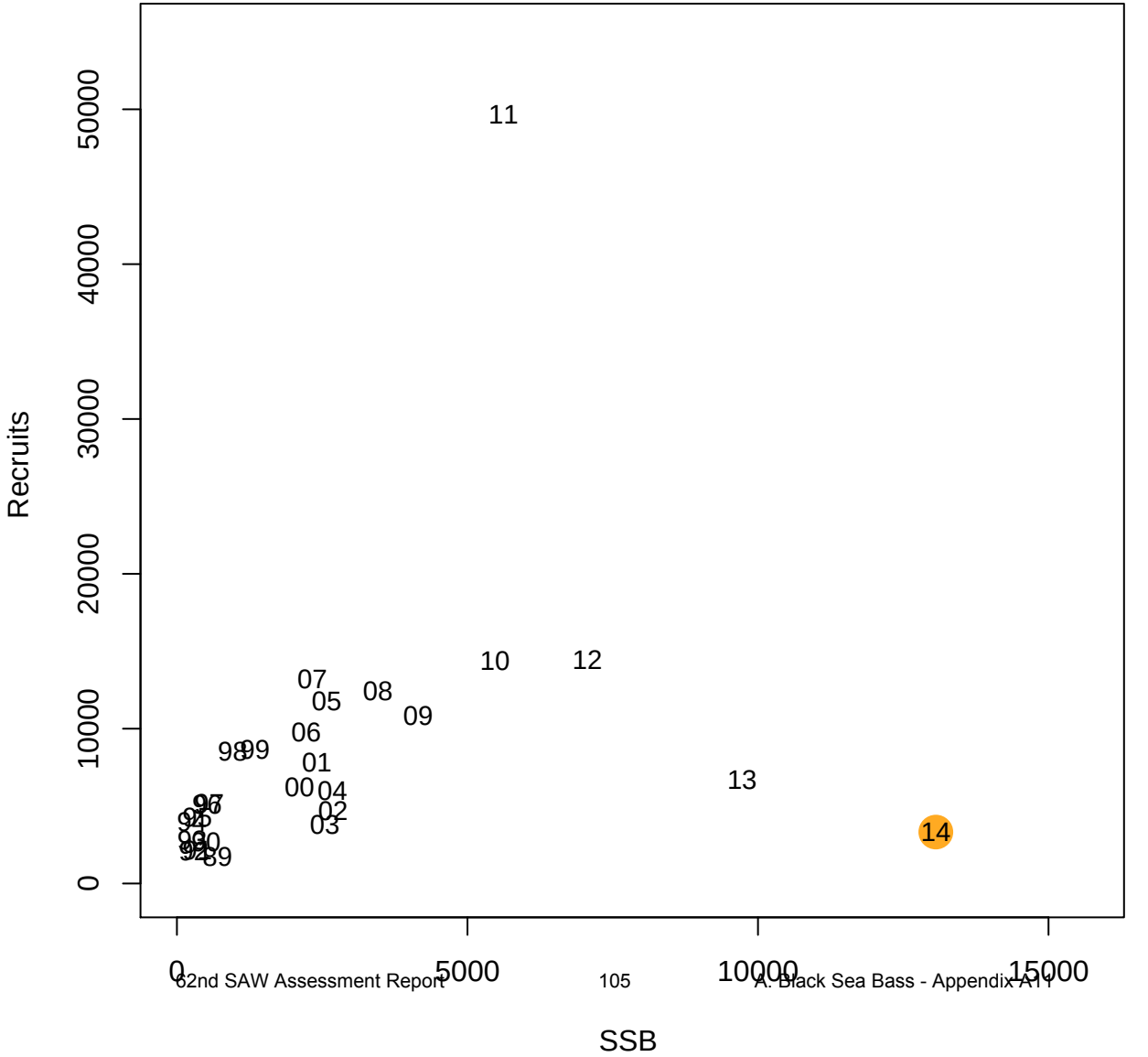

1 2 3 4 5 6 7 8
ASAP Estimated Proportion (SSB.AA)
0.0
0.2
0.4
0.6
0.8
1.0
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

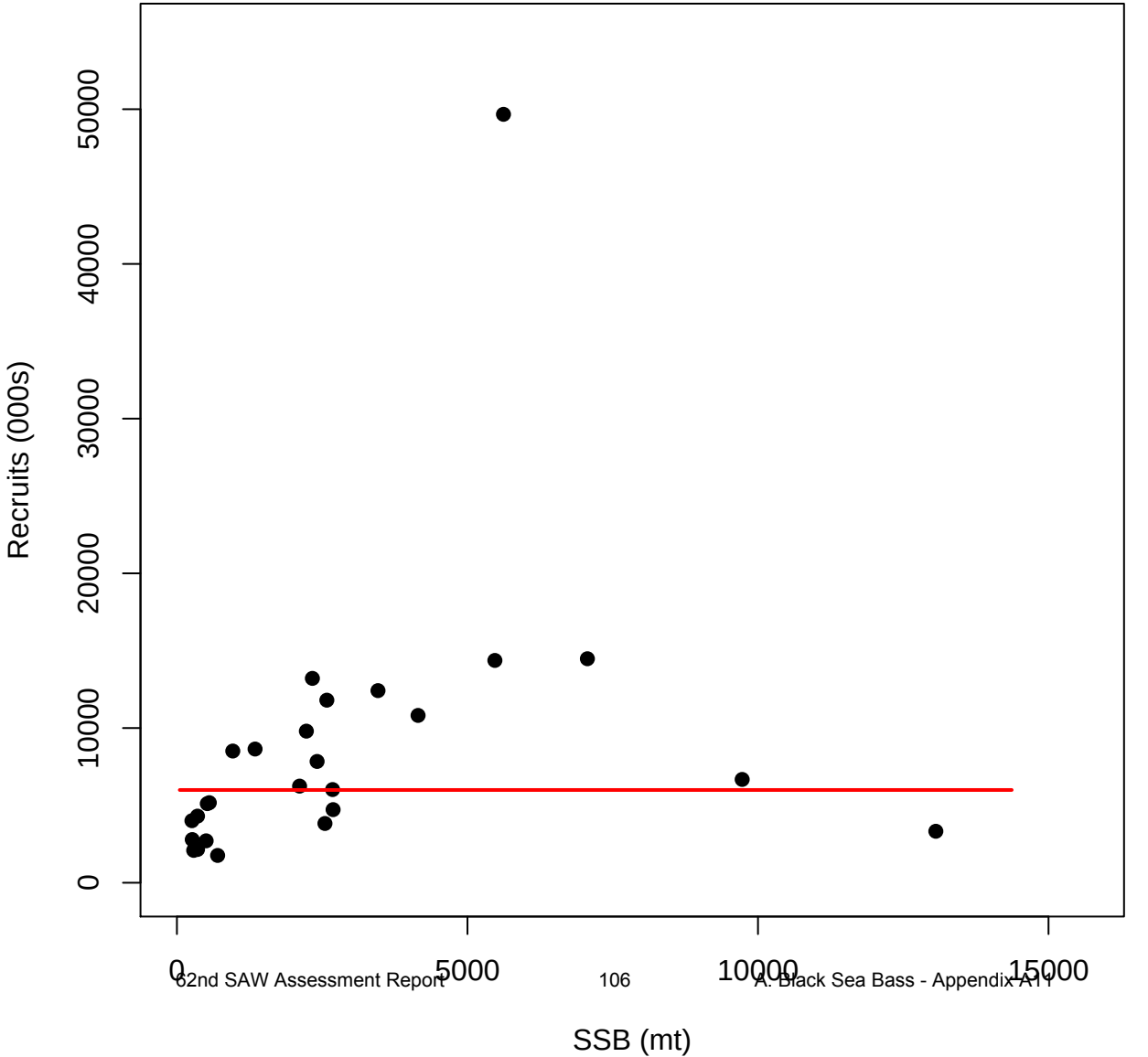

1 2 3 4 5 6 7 8
ASAP Estimated NAA
0
20000
40000
60000
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

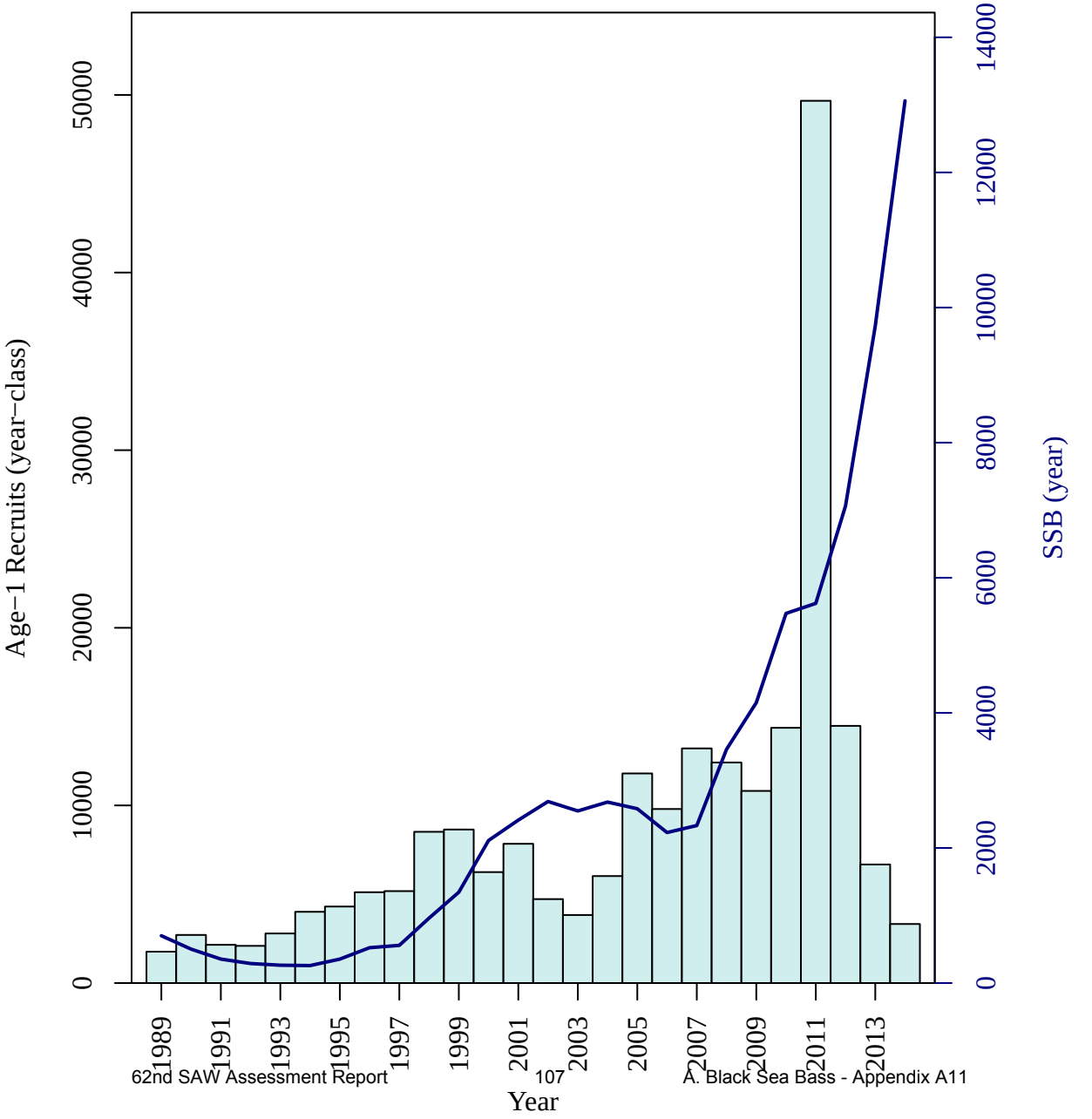

1 2 3 4 5 6 7 8
ASAP Estimated Proportion (NAA)
0.0
0.2
0.4
0.6
0.8
1.0
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

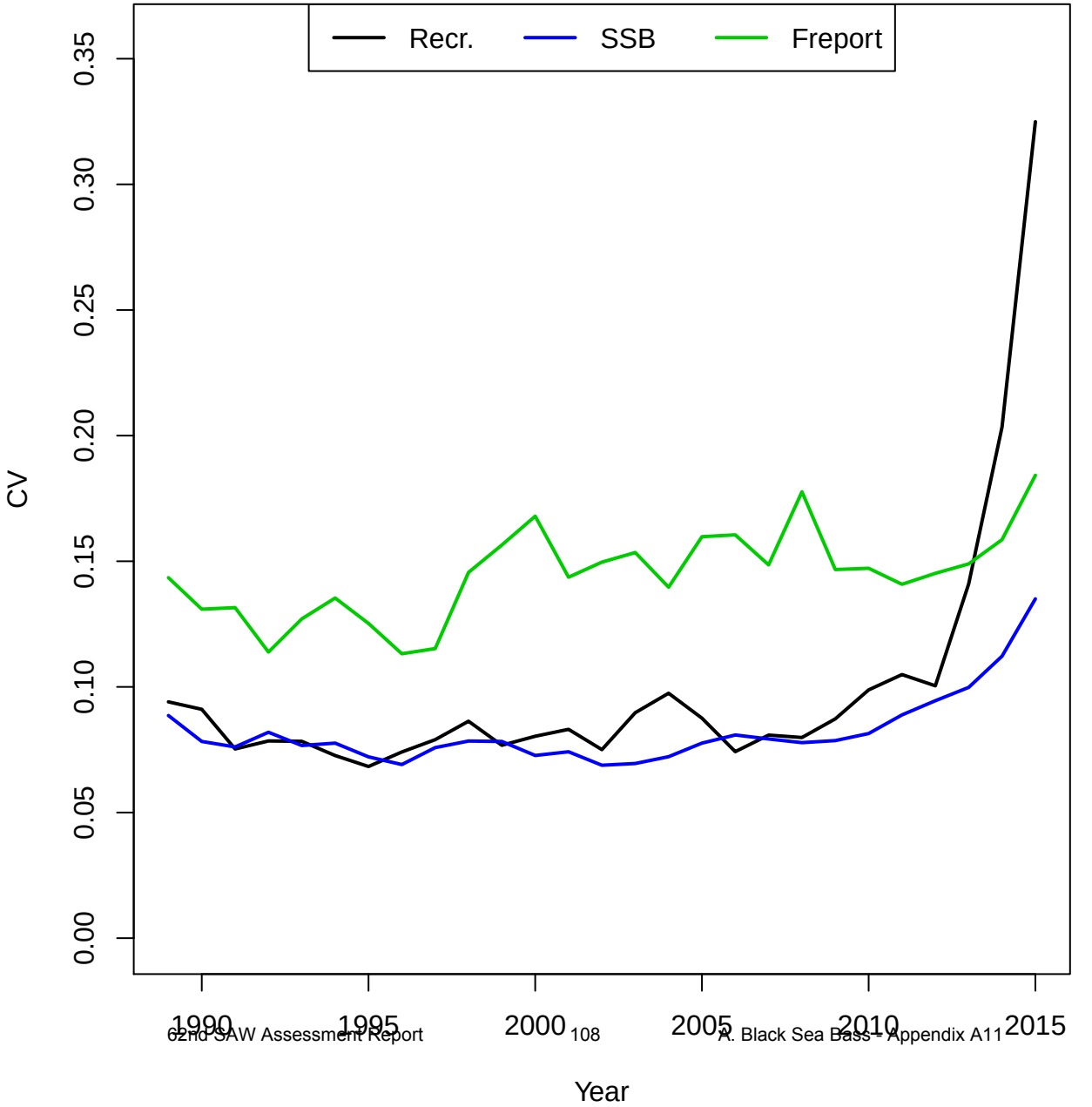

Recruits
0
20000
40000
1990
1995
2000
2005
2010
2015
Year

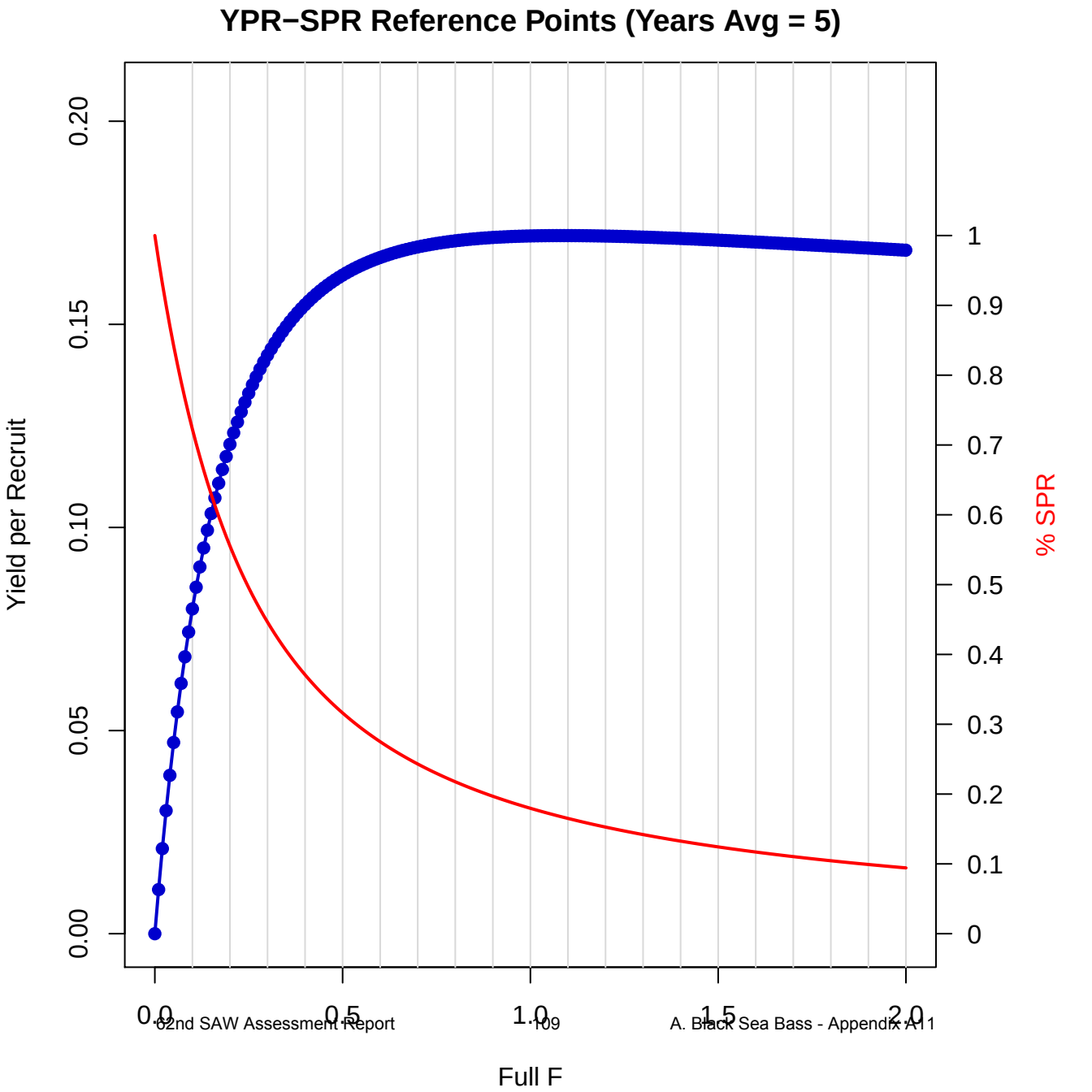

Ln(Recruitment deviations)
−1
0
1
2
1990
1995
2000
2005
2010
2015
Year


Recruits
SSB
0
10000
20000
30000
40000
50000
0
5000
10000
15000
11
10
12
07
05
08
09
06
98
99
01
00
04
02
03
13
14
89


Recruits (000s)
0
10000
20000
30000
40000
50000
0
5000
10000
15000
SSB (mt)

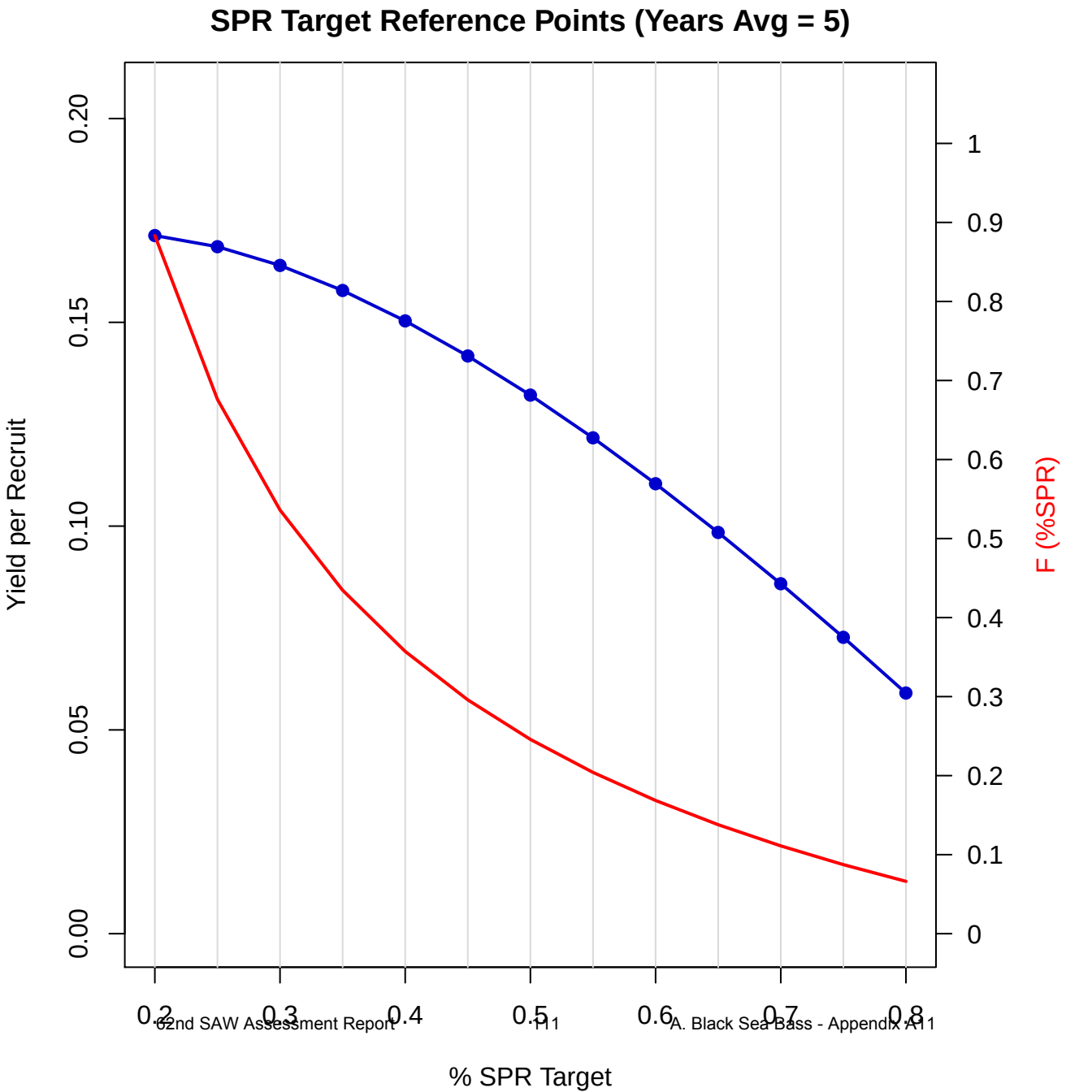

Age−1 Recruits (year−class)
0
10000
20000
30000
40000
50000
SSB (year)
0
2000
4000
6000
8000
10000
12000
14000
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Year


Recr.
SSB
Freport
CV
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
1990
1995
2000
2005
2010
2015
Year


YPR−SPR Reference Points (Years Avg = 5)
Yield per Recruit
% SPR
Full F
0.00
0.05
0.10
0.15
0.20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.0
0.5
1.0
1.5
2.0

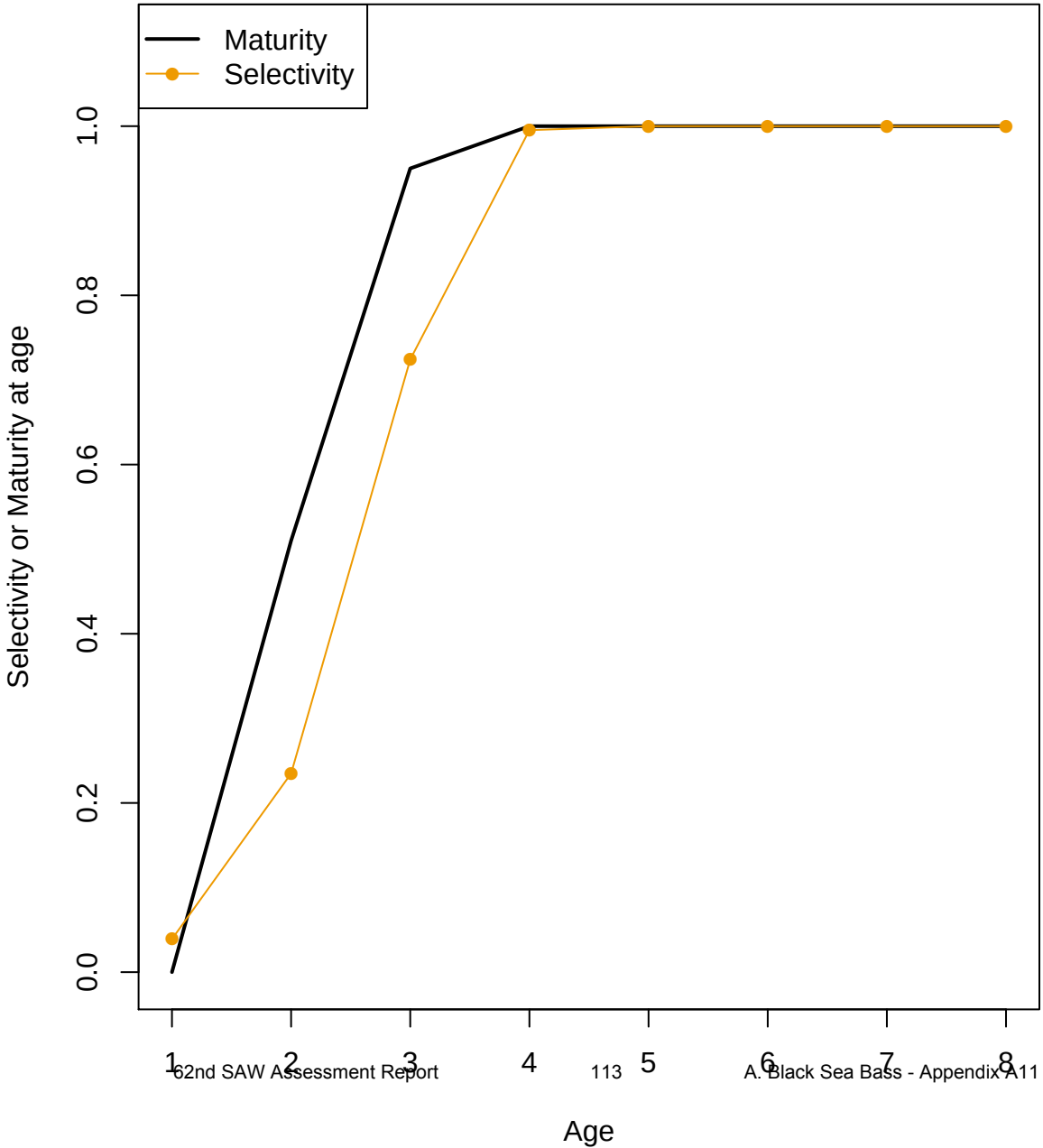
YPR−SPR Reference Points (Years Avg = 5)

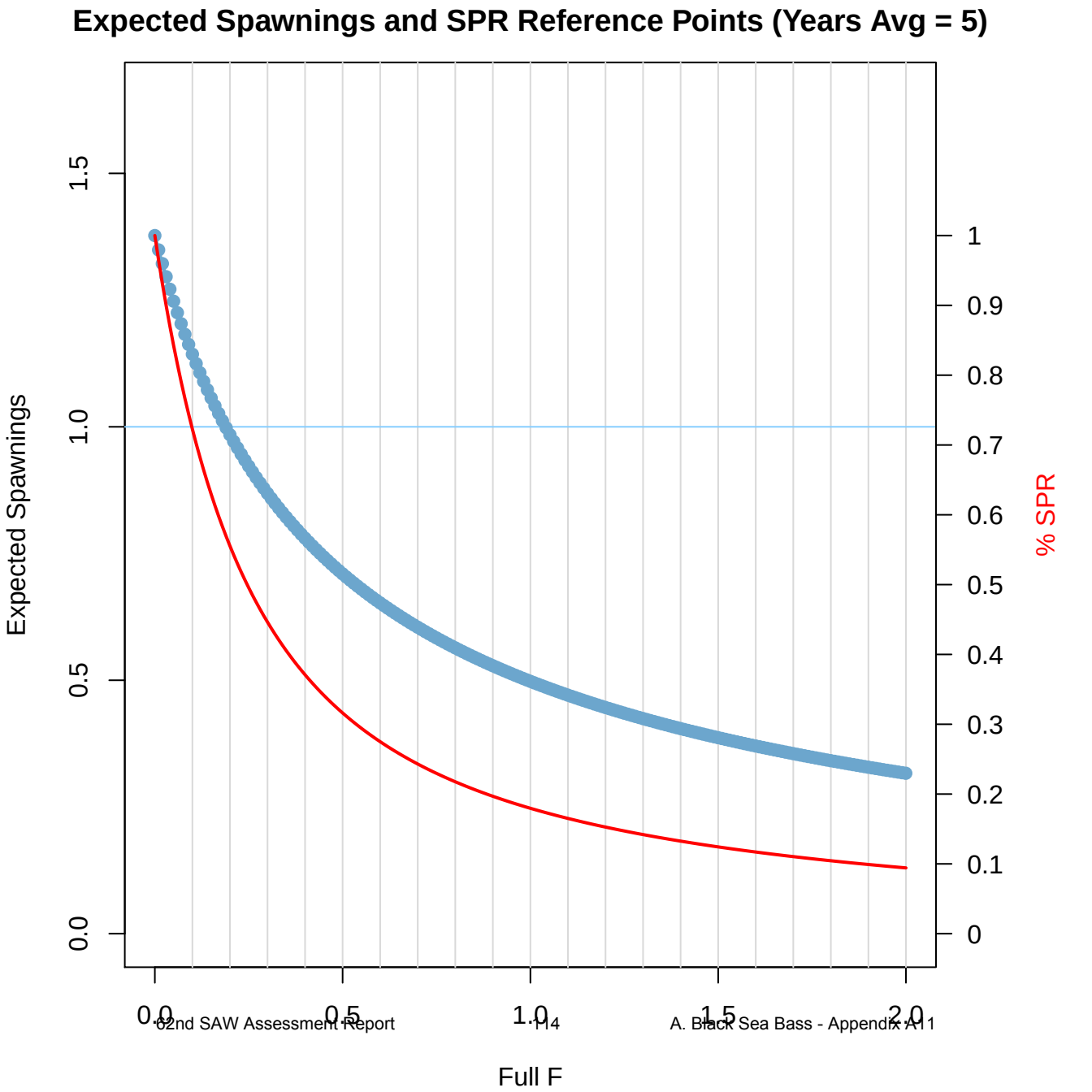
F	YPR	SPR	F	YPR	SPR	F	YPR	SPR
0	0	1	0.35	0.1495	0.4053	0.7	0.1691	0.243
0.01	0.0109	0.9647	0.36	0.1507	0.398	0.71	0.1693	0.2402
0.02	0.0209	0.9315	0.37	0.1518	0.3908	0.72	0.1694	0.2375
0.03	0.0303	0.9001	0.38	0.1529	0.384	0.73	0.1696	0.2348
0.04	0.039	0.8704	0.39	0.1539	0.3773	0.74	0.1698	0.2322
0.05	0.0471	0.8424	0.4	0.1549	0.3708	0.75	0.1699	0.2296
0.06	0.0546	0.8159	0.41	0.1558	0.3646	0.76	0.1701	0.2271
0.07	0.0616	0.7907	0.42	0.1566	0.3585	0.77	0.1702	0.2247
0.08	0.0682	0.7668	0.43	0.1575	0.3526	0.78	0.1703	0.2222
0.09	0.0743	0.7442	0.44	0.1582	0.347	0.79	0.1705	0.2199
0.1	0.08	0.7227	0.45	0.159	0.3414	0.8	0.1706	0.2176
0.11	0.0853	0.7022	0.46	0.1597	0.3361	0.81	0.1707	0.2153
0.12	0.0903	0.6827	0.47	0.1603	0.3309	0.82	0.1708	0.2131
0.13	0.095	0.6641	0.48	0.161	0.3258	0.83	0.1709	0.2109
0.14	0.0993	0.6464	0.49	0.1616	0.3209	0.84	0.171	0.2088
0.15	0.1034	0.6294	0.5	0.1621	0.3161	0.85	0.171	0.2067
0.16	0.1073	0.6133	0.51	0.1627	0.3115	0.86	0.1711	0.2046
0.17	0.1109	0.5978	0.52	0.1632	0.307	0.87	0.1712	0.2026
0.18	0.1143	0.5831	0.53	0.1637	0.3026	0.88	0.1713	0.2007
0.19	0.1175	0.5689	0.54	0.1641	0.2984	0.89	0.1713	0.1987
0.2	0.1205	0.5554	0.55	0.1646	0.2942	0.9	0.1714	0.1968
0.21	0.1233	0.5424	0.56	0.165	0.2902	0.91	0.1714	0.195
0.22	0.126	0.5299	0.57	0.1654	0.2862	0.92	0.1715	0.1931
0.23	0.1285	0.518	0.58	0.1658	0.2824	0.93	0.1715	0.1913
0.24	0.1308	0.5065	0.59	0.1661	0.2786	0.94	0.1716	0.1896
0.25	0.133	0.4955	0.6	0.1665	0.275	0.95	0.1716	0.1878
0.26	0.1351	0.4849	0.61	0.1668	0.2714	0.96	0.1717	0.1861
0.27	0.1371	0.4747	0.62	0.1671	0.268	0.97	0.1717	0.1845
0.28	0.139	0.4648	0.63	0.1674	0.2646	0.98	0.1717	0.1828
0.29	0.1407	0.4554	0.64	0.1677	0.2613	0.99	0.1718	0.1812
0.3	0.1424	0.4463	0.65	0.1679	0.2581	1	0.1718	0.1796
0.31	0.144	0.4375	0.66	0.1682	0.2549	1.01	0.1718	0.1781
0.32	0.1455	0.429	0.67	0.1684	0.2518	1.02	0.1718	0.1765
0.33	0.1469	0.4209	0.68	0.1686	0.2488	1.03	0.1718	0.175
0.34	0.1482	0.413	0.69	0.1689	0.2459	1.04	0.1718	0.1735


SPR Target Reference Points (Years Avg = 5)
Yield per Recruit
0.00
0.05
0.10
0.15
0.20
F (%SPR)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
% SPR Target

SPR Target Reference Points (Years Avg = 5)

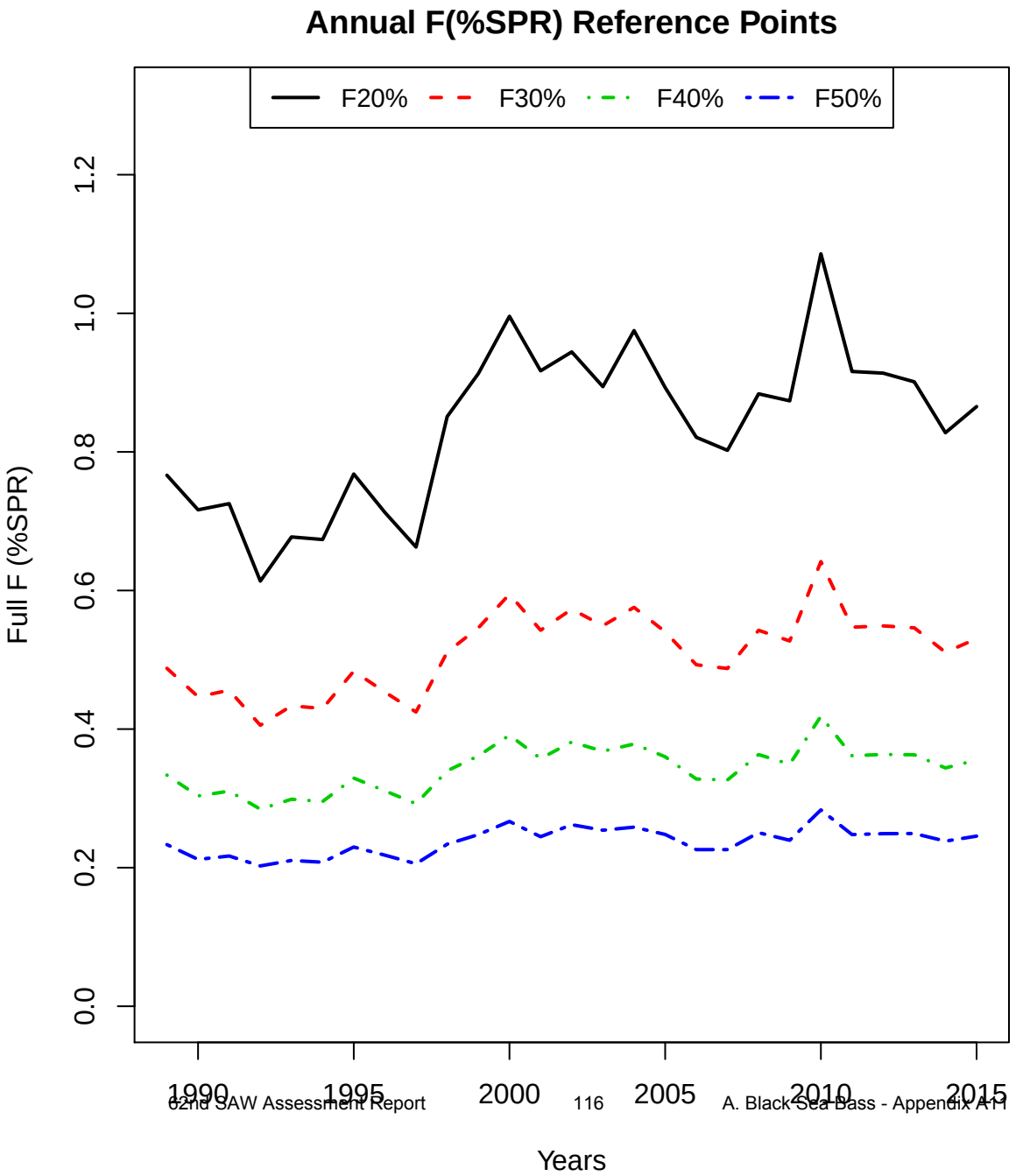
% SPR	F(%SPR)	YPR
0.2	0.8834	0.1713
0.25	0.6761	0.1686
0.3	0.5361	0.164
0.35	0.4346	0.1578
0.4	0.3572	0.1503
0.45	0.2959	0.1417
0.5	0.2458	0.1321
0.55	0.2041	0.1217
0.6	0.1686	0.1104
0.65	0.1379	0.0984
0.7	0.1111	0.0859
0.75	0.0874	0.0727
0.8	0.0662	0.059

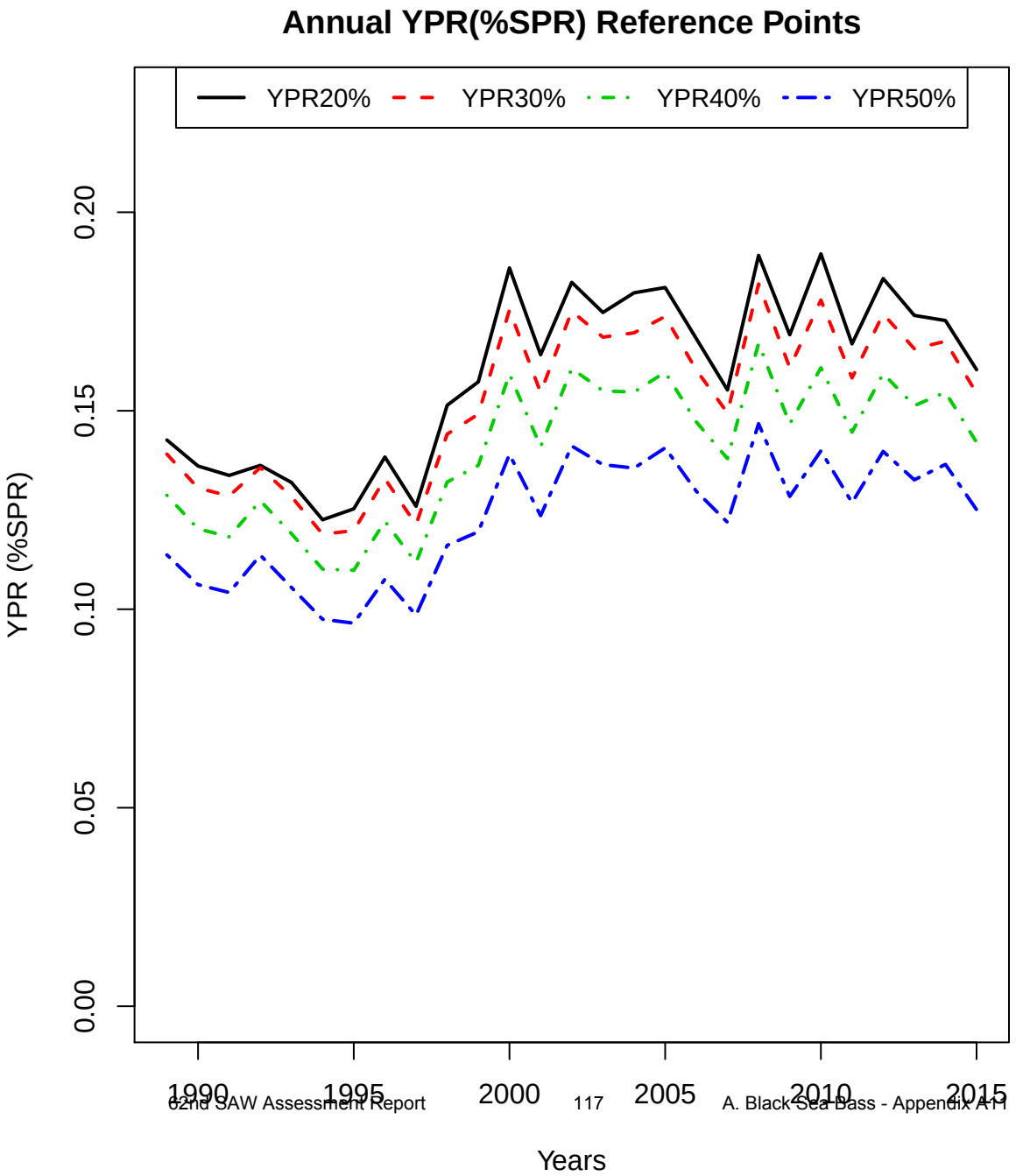

Maturity
Selectivity
Selectivity or Maturity at age
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
8
Age


Expected Spawnings and SPR Reference Points (Years Avg = 5)
Expected Spawnings
% SPR
Full F
0.0
0.5
1.0
1.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.0
0.5
1.0
1.5
2.0

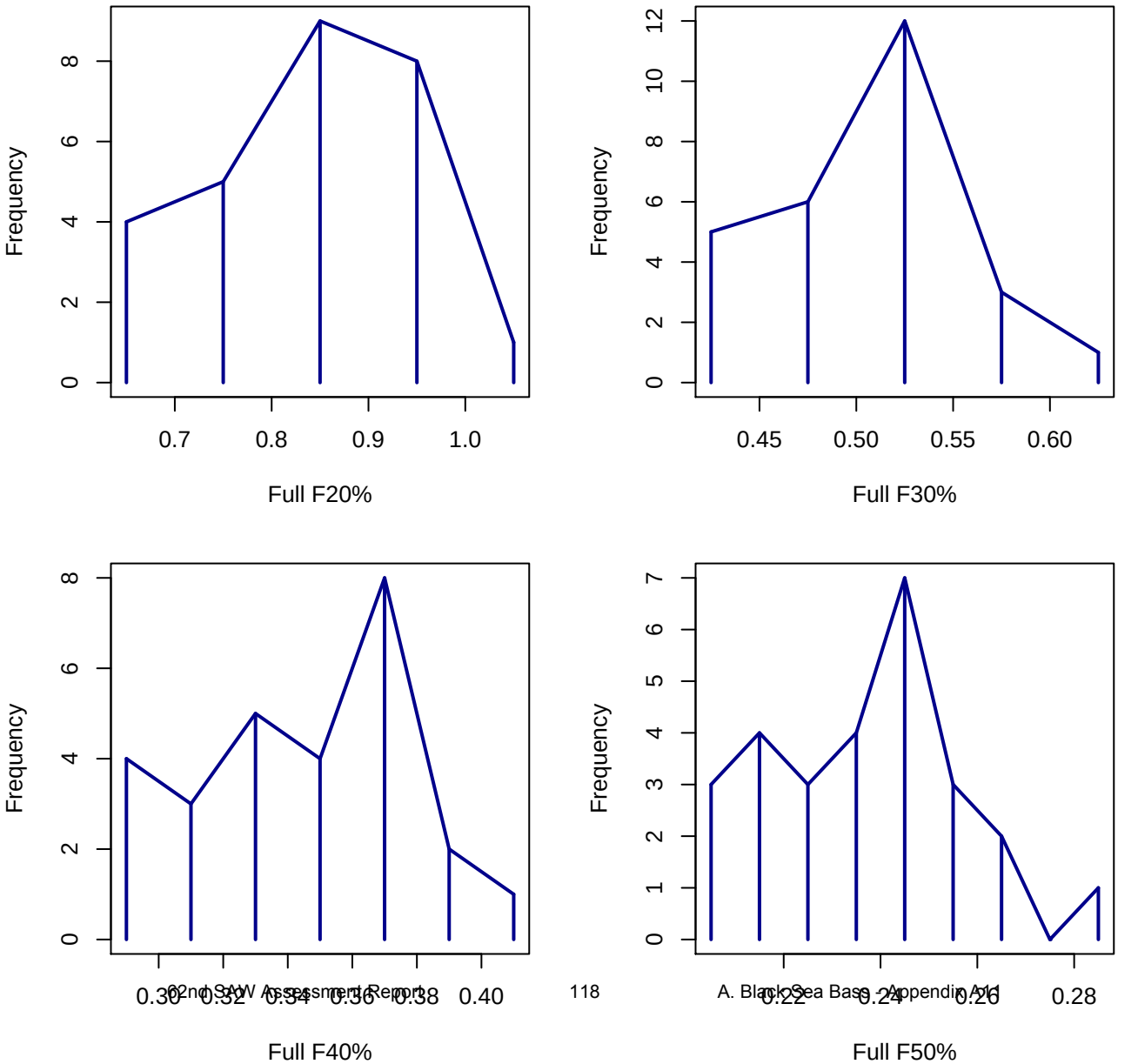
Expected Spawnings & SPR Reference Points (Years Avg = 5)

F	E[Sp]	SPR	F	E[Sp]	SPR	F	E[Sp]	SPR
0	1.3774	1	0.35	0.8217	0.4053	0.7	0.6046	0.243
0.01	1.349	0.9647	0.36	0.813	0.398	0.71	0.6002	0.2402
0.02	1.322	0.9315	0.37	0.8045	0.3908	0.72	0.5959	0.2375
0.03	1.2961	0.9001	0.38	0.7962	0.384	0.73	0.5917	0.2348
0.04	1.2714	0.8704	0.39	0.7881	0.3773	0.74	0.5875	0.2322
0.05	1.2478	0.8424	0.4	0.7802	0.3708	0.75	0.5834	0.2296
0.06	1.2251	0.8159	0.41	0.7725	0.3646	0.76	0.5794	0.2271
0.07	1.2034	0.7907	0.42	0.7649	0.3585	0.77	0.5754	0.2247
0.08	1.1825	0.7668	0.43	0.7575	0.3526	0.78	0.5715	0.2222
0.09	1.1625	0.7442	0.44	0.7503	0.347	0.79	0.5676	0.2199
0.1	1.1432	0.7227	0.45	0.7432	0.3414	0.8	0.5638	0.2176
0.11	1.1247	0.7022	0.46	0.7362	0.3361	0.81	0.56	0.2153
0.12	1.1068	0.6827	0.47	0.7295	0.3309	0.82	0.5564	0.2131
0.13	1.0896	0.6641	0.48	0.7228	0.3258	0.83	0.5527	0.2109
0.14	1.073	0.6464	0.49	0.7163	0.3209	0.84	0.5491	0.2088
0.15	1.0569	0.6294	0.5	0.7099	0.3161	0.85	0.5456	0.2067
0.16	1.0414	0.6133	0.51	0.7037	0.3115	0.86	0.5421	0.2046
0.17	1.0265	0.5978	0.52	0.6976	0.307	0.87	0.5386	0.2026
0.18	1.012	0.5831	0.53	0.6915	0.3026	0.88	0.5352	0.2007
0.19	0.9979	0.5689	0.54	0.6857	0.2984	0.89	0.5319	0.1987
0.2	0.9844	0.5554	0.55	0.6799	0.2942	0.9	0.5286	0.1968
0.21	0.9712	0.5424	0.56	0.6742	0.2902	0.91	0.5253	0.195
0.22	0.9584	0.5299	0.57	0.6686	0.2862	0.92	0.5221	0.1931
0.23	0.9461	0.518	0.58	0.6632	0.2824	0.93	0.5189	0.1913
0.24	0.934	0.5065	0.59	0.6578	0.2786	0.94	0.5158	0.1896
0.25	0.9224	0.4955	0.6	0.6525	0.275	0.95	0.5127	0.1878
0.26	0.911	0.4849	0.61	0.6474	0.2714	0.96	0.5096	0.1861
0.27	0.9	0.4747	0.62	0.6423	0.268	0.97	0.5066	0.1845
0.28	0.8893	0.4648	0.63	0.6373	0.2646	0.98	0.5036	0.1828
0.29	0.8788	0.4554	0.64	0.6324	0.2613	0.99	0.5007	0.1812
0.3	0.8687	0.4463	0.65	0.6275	0.2581	1	0.4978	0.1796
0.31	0.8588	0.4375	0.66	0.6228	0.2549	1.01	0.4949	0.1781
0.32	0.8492	0.429	0.67	0.6181	0.2518	1.02	0.4921	0.1765
0.33	0.8398	0.4209	0.68	0.6135	0.2488	1.03	0.4893	0.175
0.34	0.8306	0.413	0.69	0.609	0.2459	1.04	0.4865	0.1735

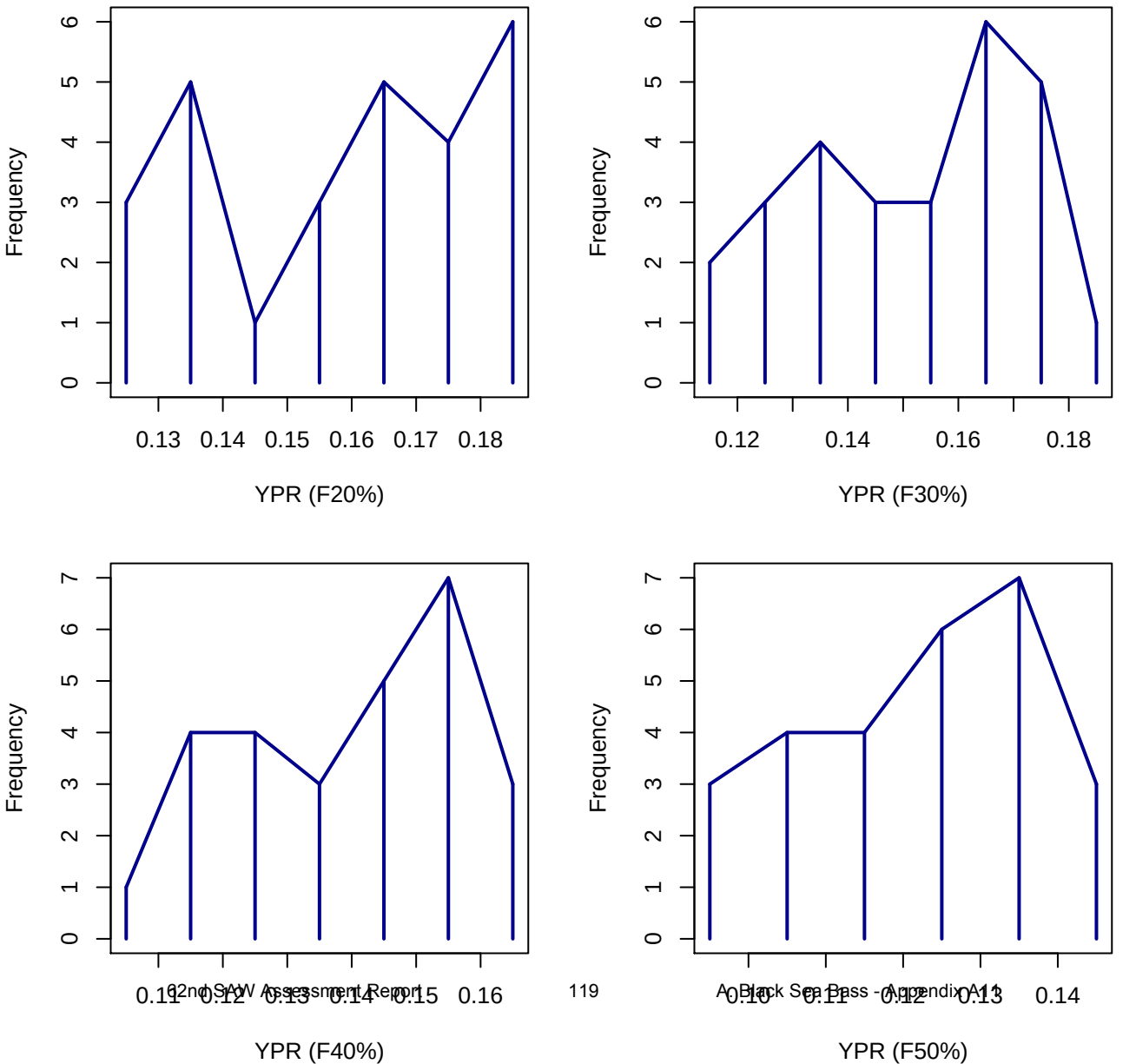

Annual F(%SPR) Reference Points
F20%
F30%
F40%
F50%
Full F (%SPR)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1990
1995
2000
2005
2010
2015
Years

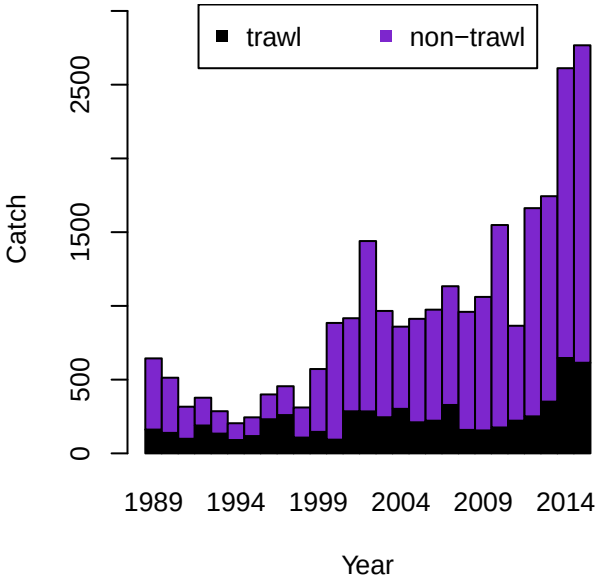

Annual YPR(%SPR) Reference Points
YPR20%
YPR30%
YPR40%
YPR50%
YPR (%SPR)
0.00
0.05
0.10
0.15
0.20
1990
1995
2000
2005
2010
2015
Years

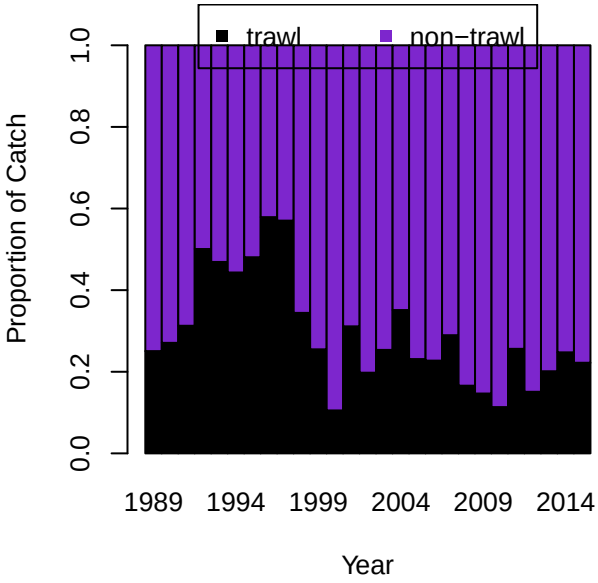
Annual F (%SPR) Reference Points

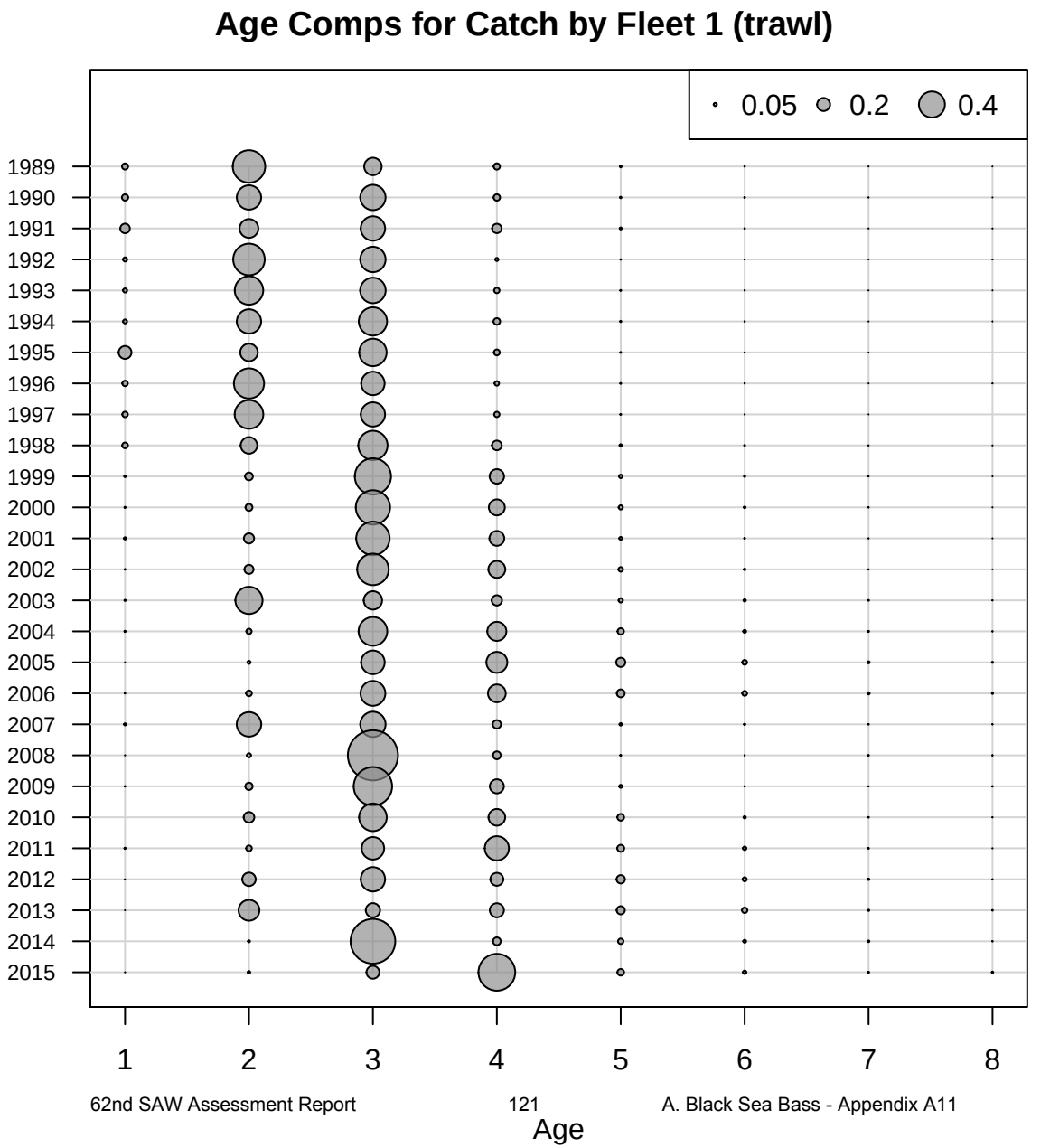


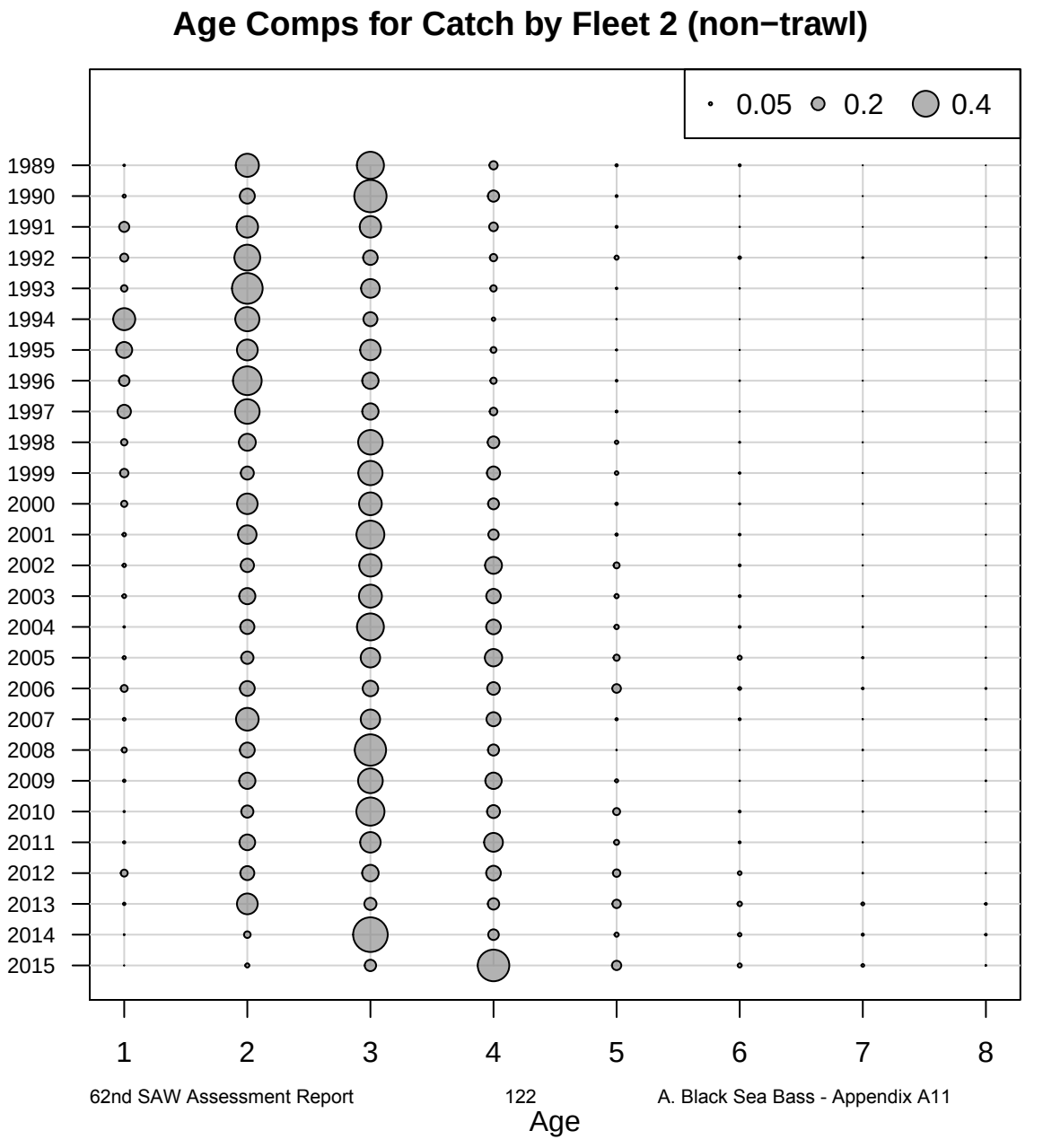
Annual YPR (%SPR) Reference Points

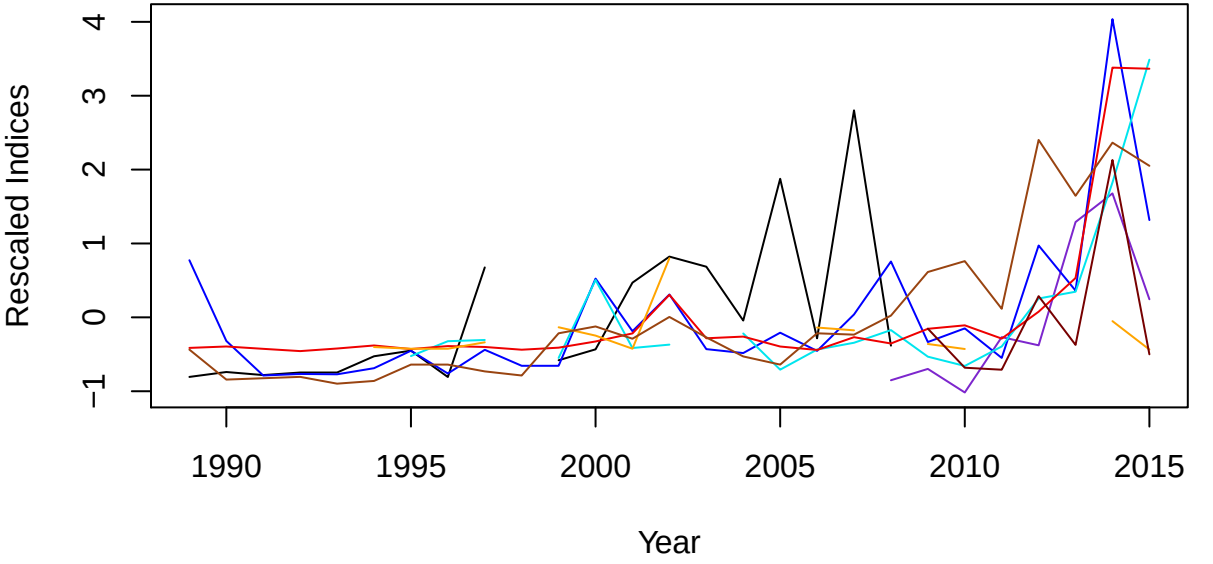


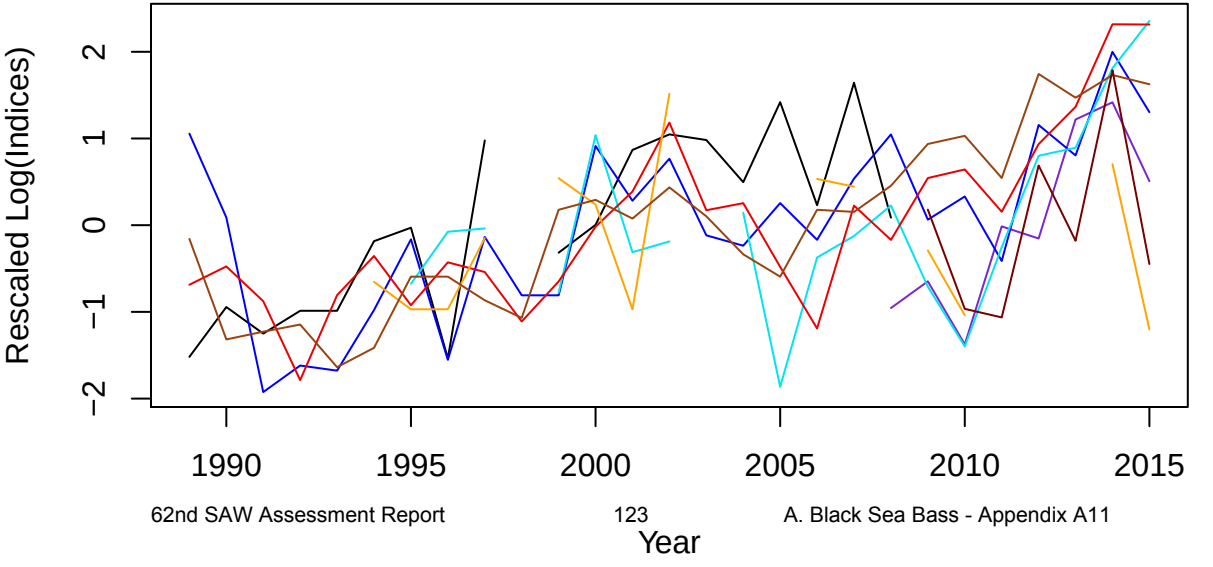

trawl
non−trawl
Catch
0
500
1500
2500
1989
1994
1999
2004
2009
2014
Year

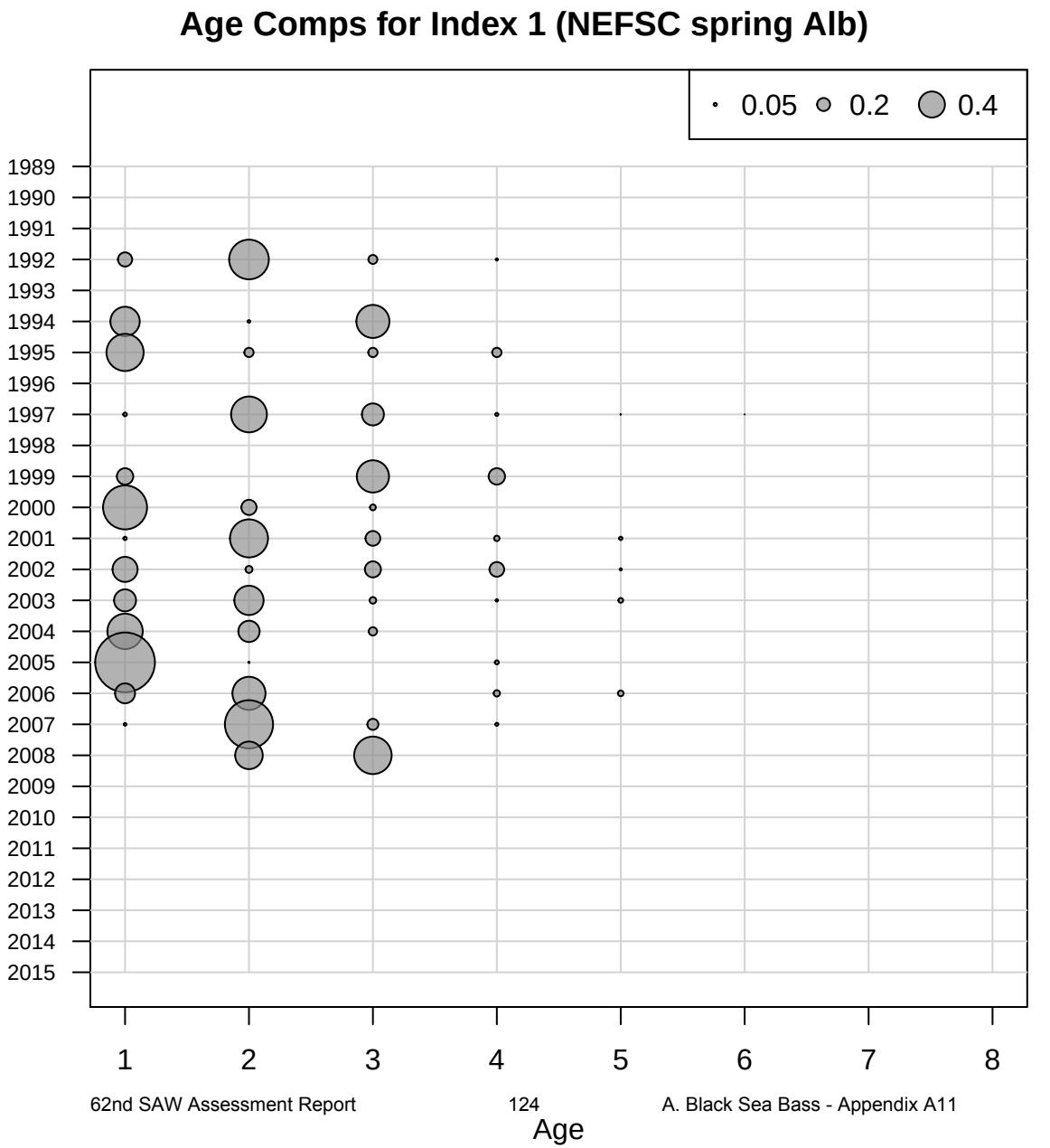

trawl
non−trawl
Proportion of Catch
0.0
0.2
0.4
0.6
0.8
1.0
1989
1994
1999
2004
2009
2014
Year


Age Comps for Catch by Fleet 1 (trawl)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

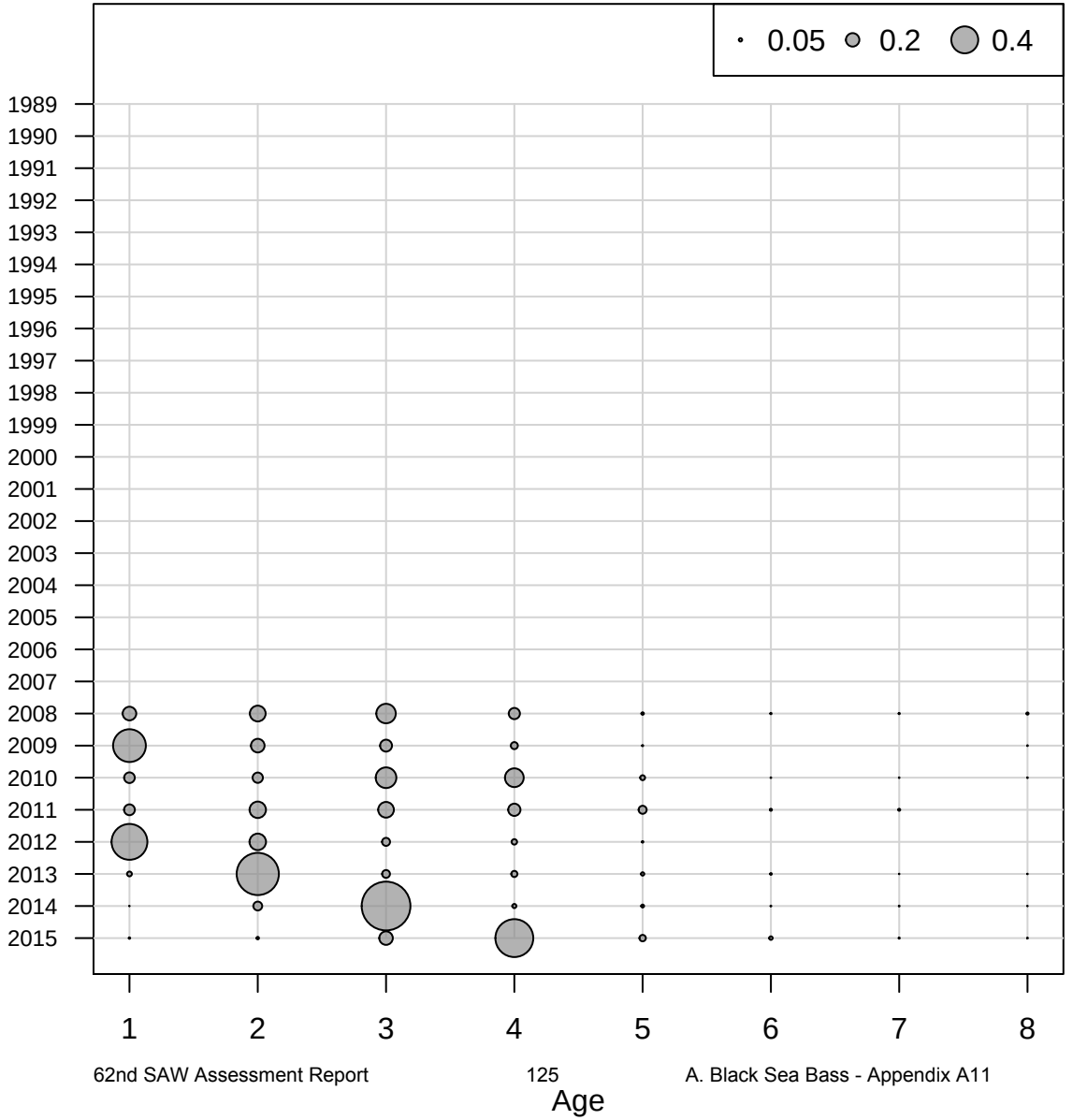

Age Comps for Catch by Fleet 2 (non−trawl)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age


Rescaled Indices
4
3
2
1
0
−1
1990
1995
2000
2005
2010
2015
Year

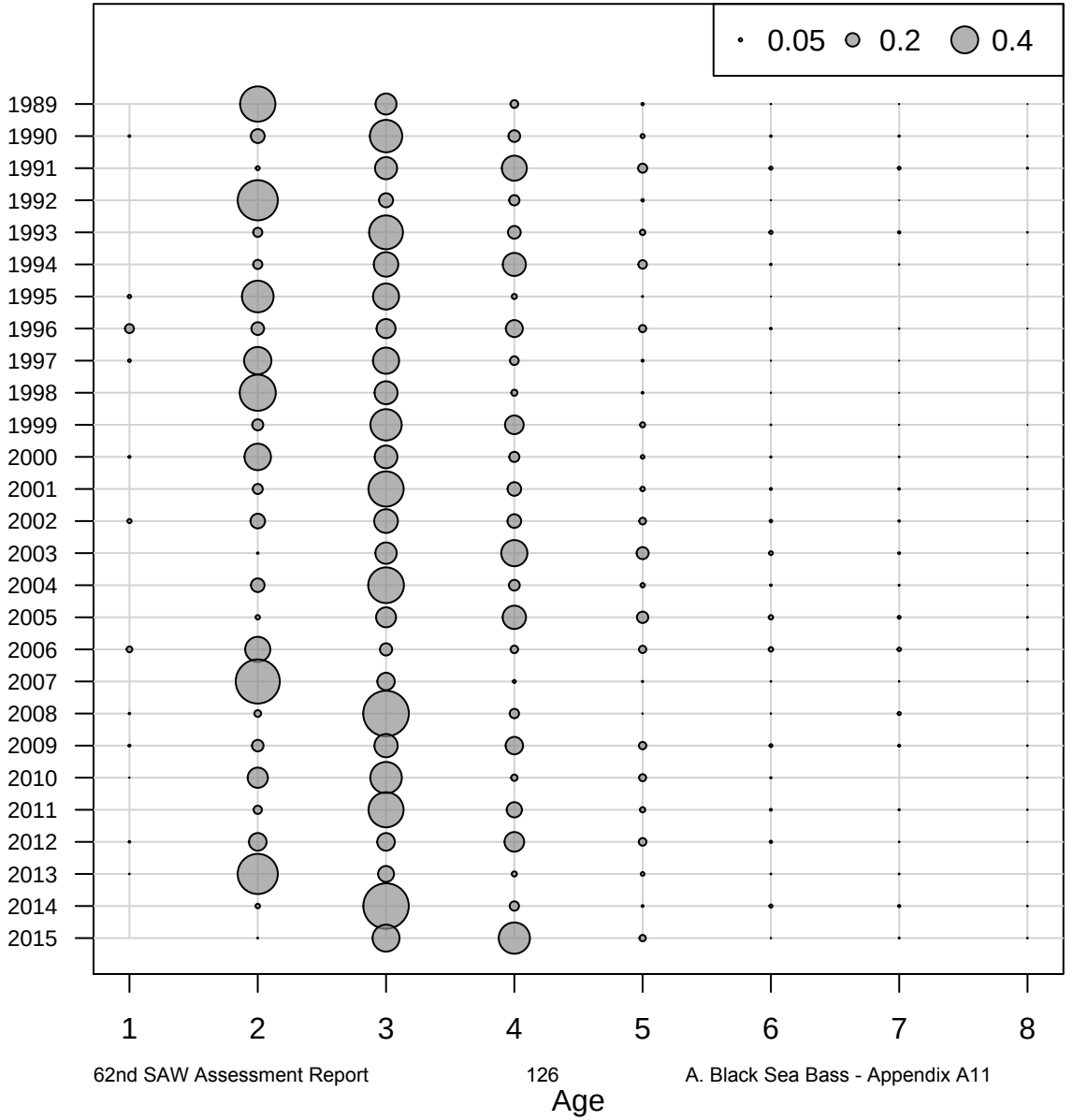

Rescaled Log(Indices)
2
1
0
−1
−2
1990
1995
2000
2005
2010
2015
Year


Age Comps for Index 1 (NEFSC spring Alb)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

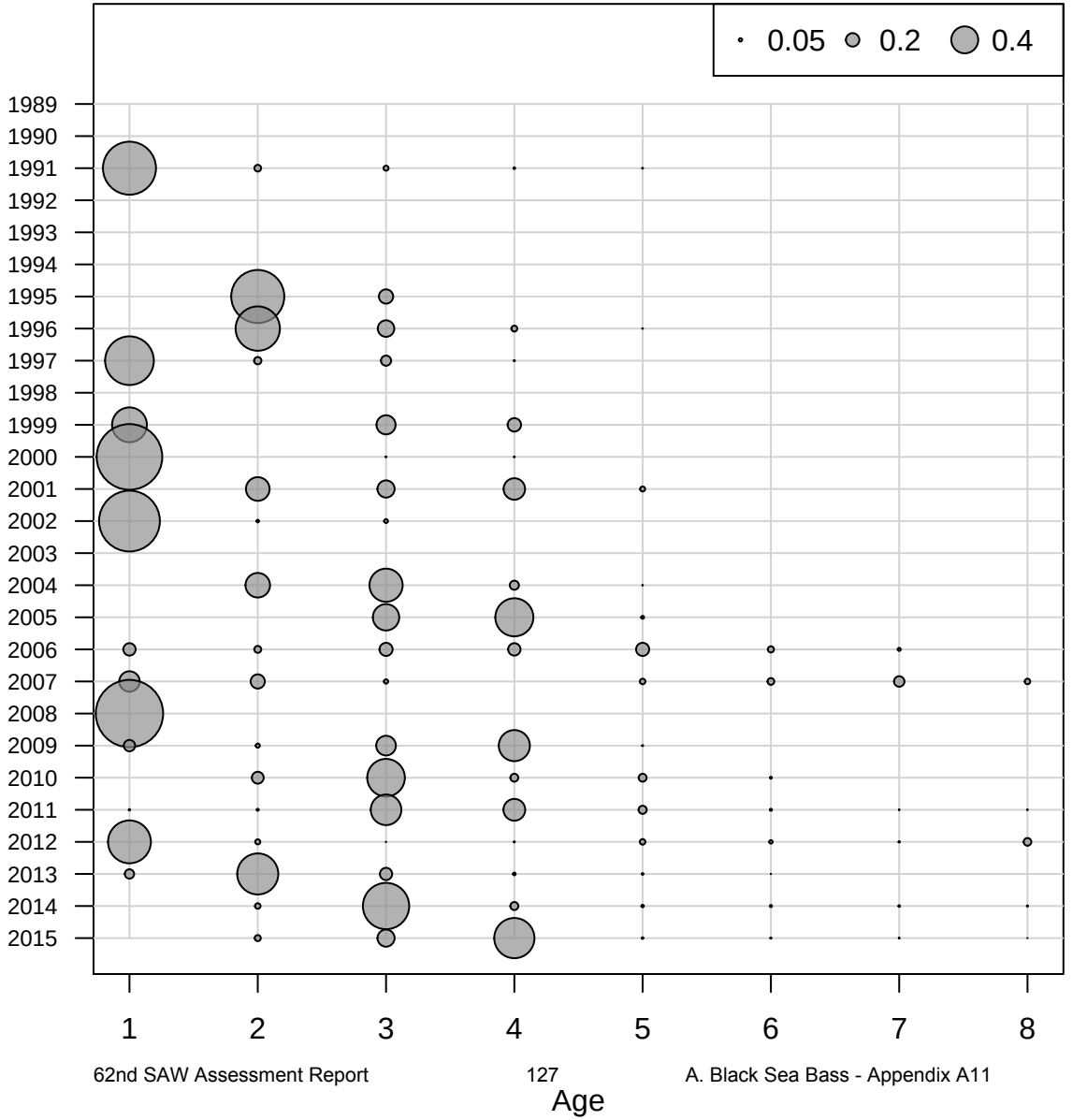
Age Comps for Index 2 (NEAMAP)

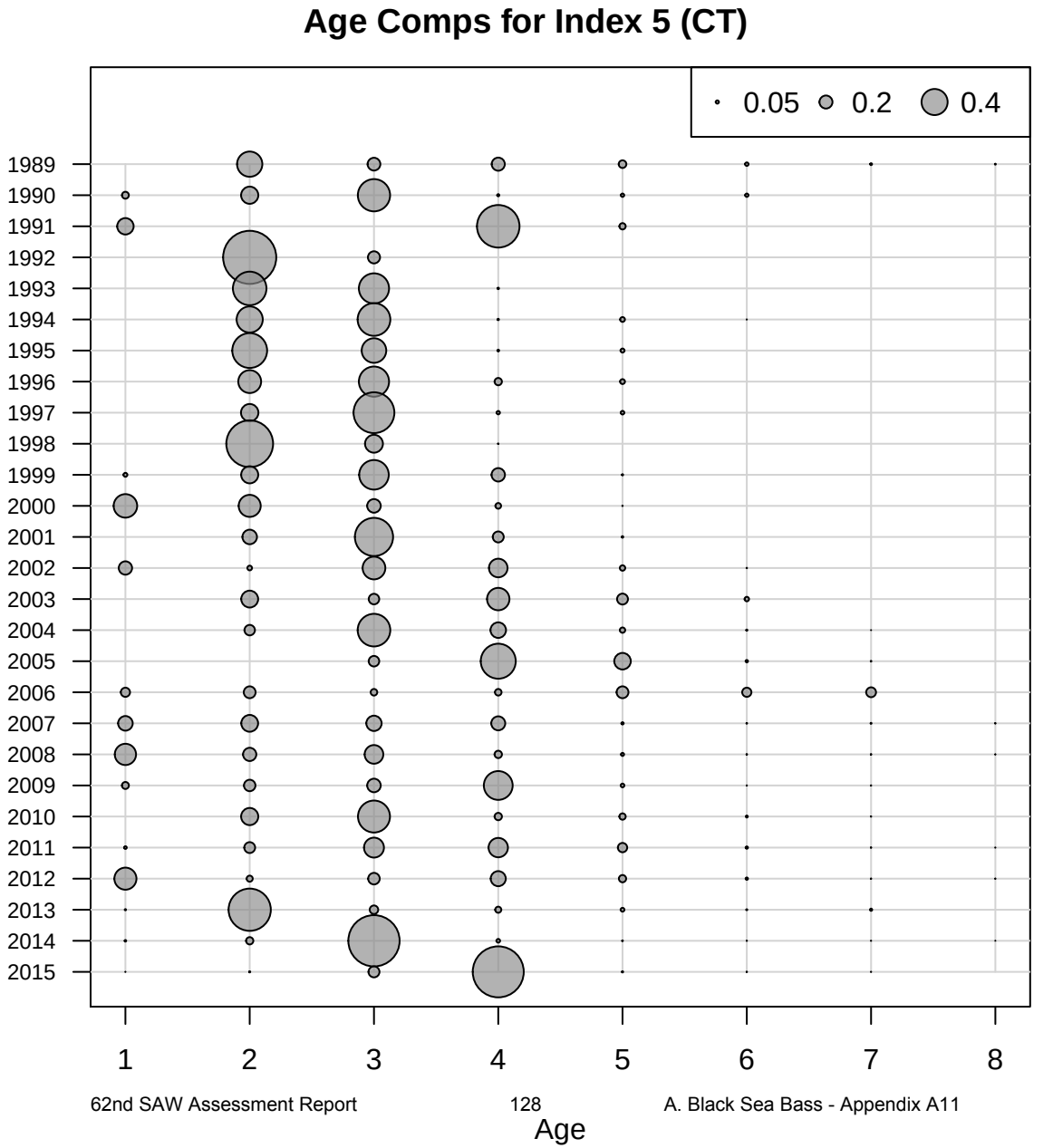


Age Comps for Index 3 (MADMF)

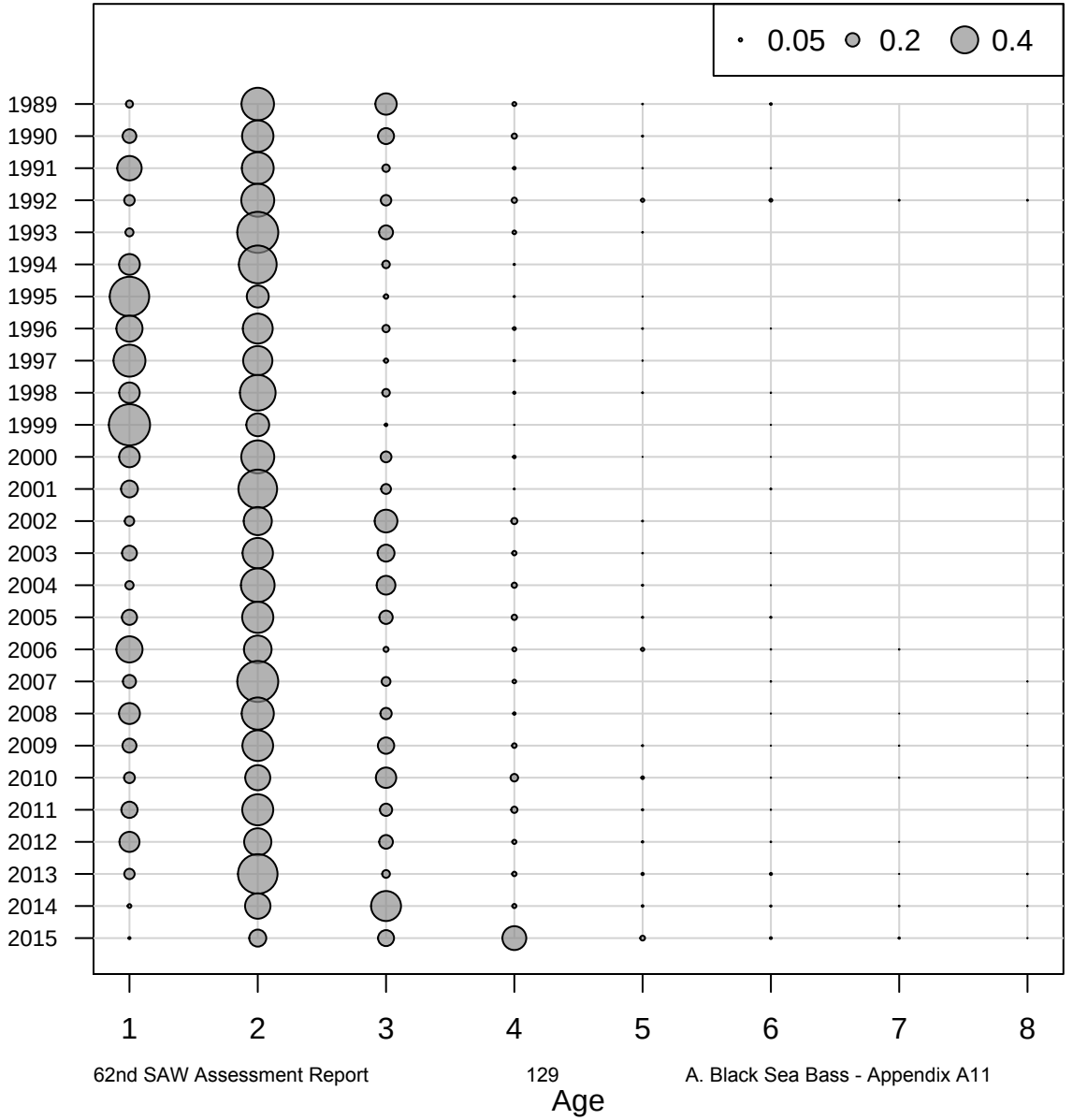


Age Comps for Index 4 (RI)

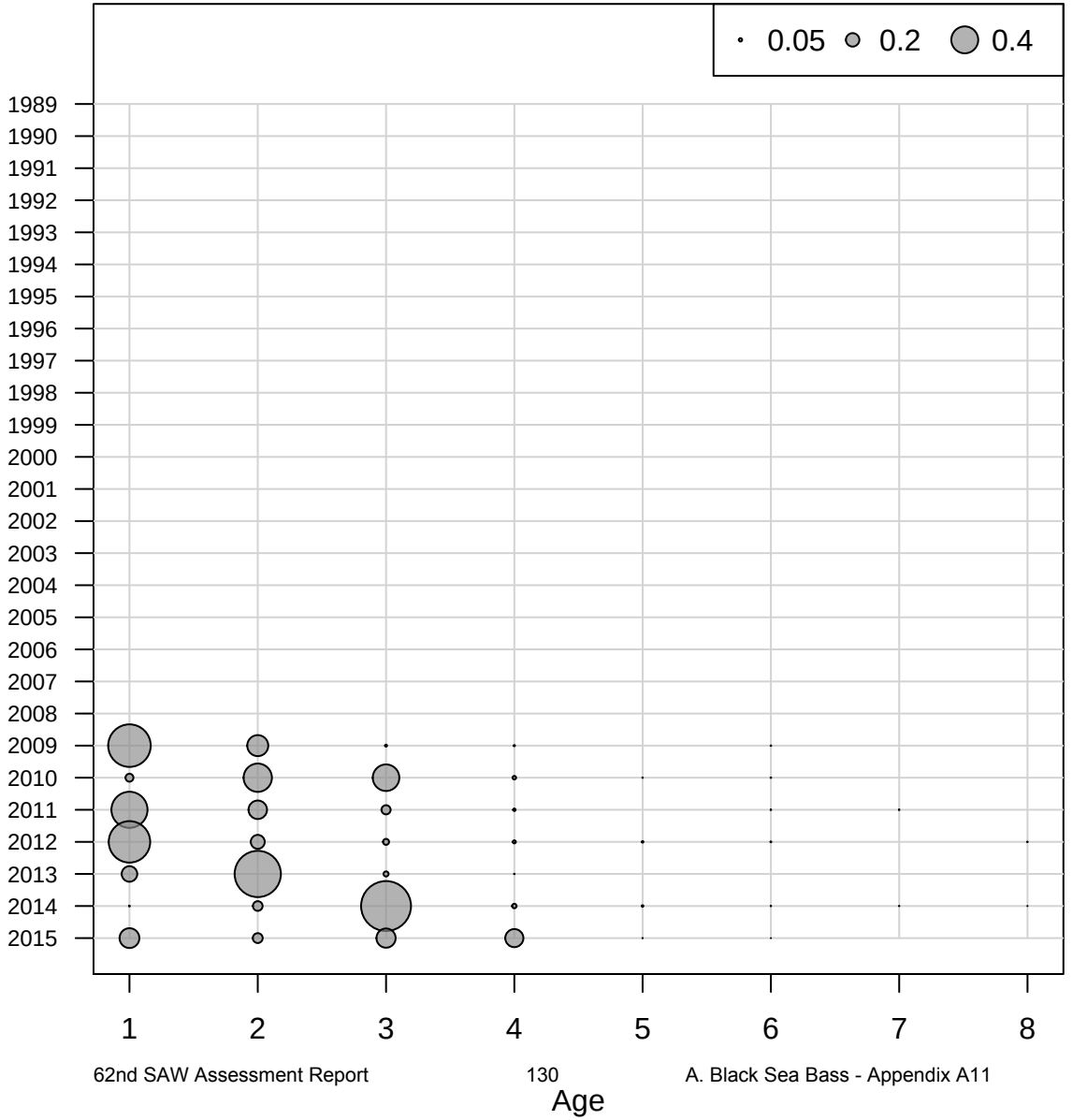


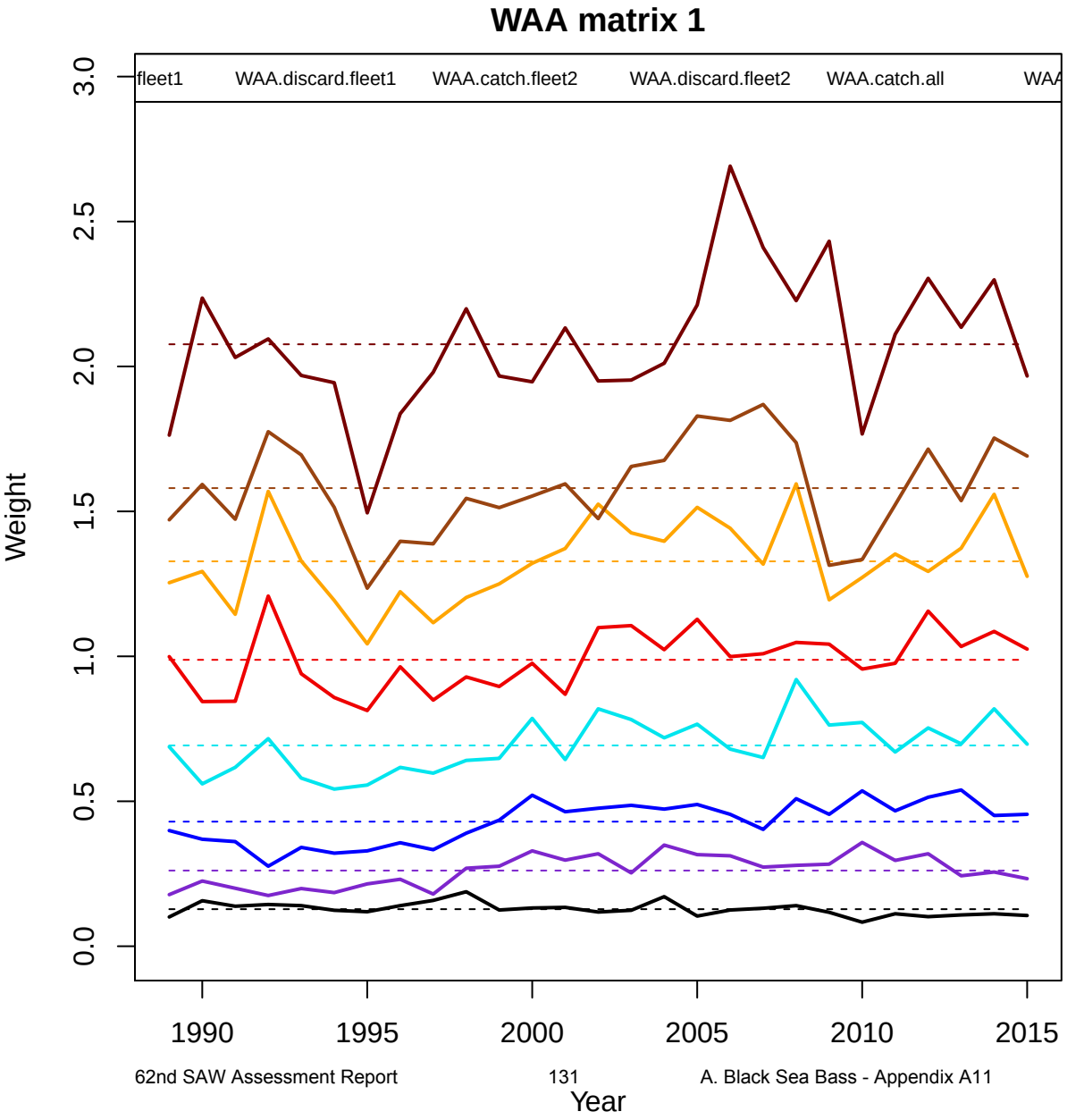

Age Comps for Index 5 (CT)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

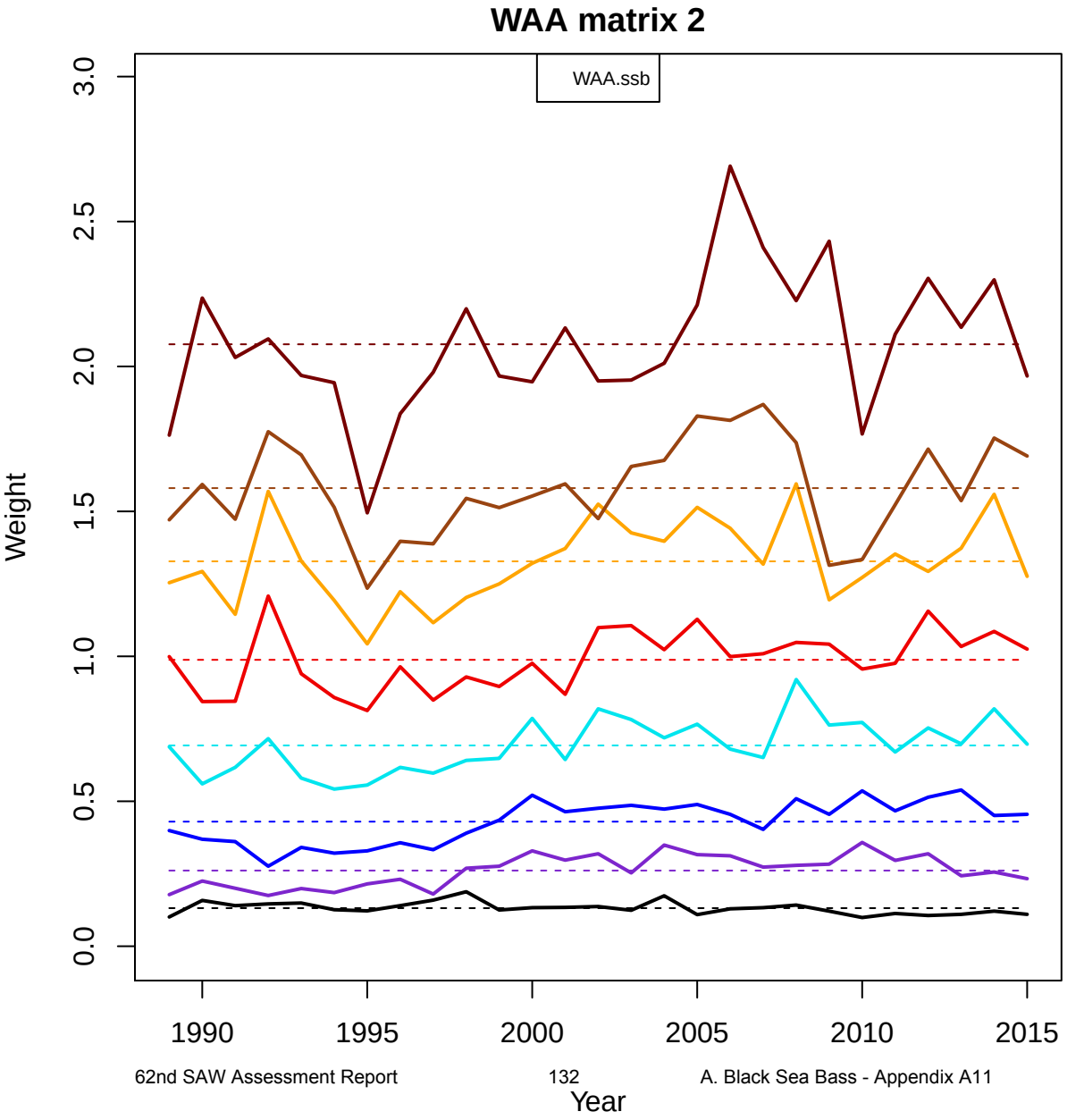
Age Comps for Index 7 (REC CPA)

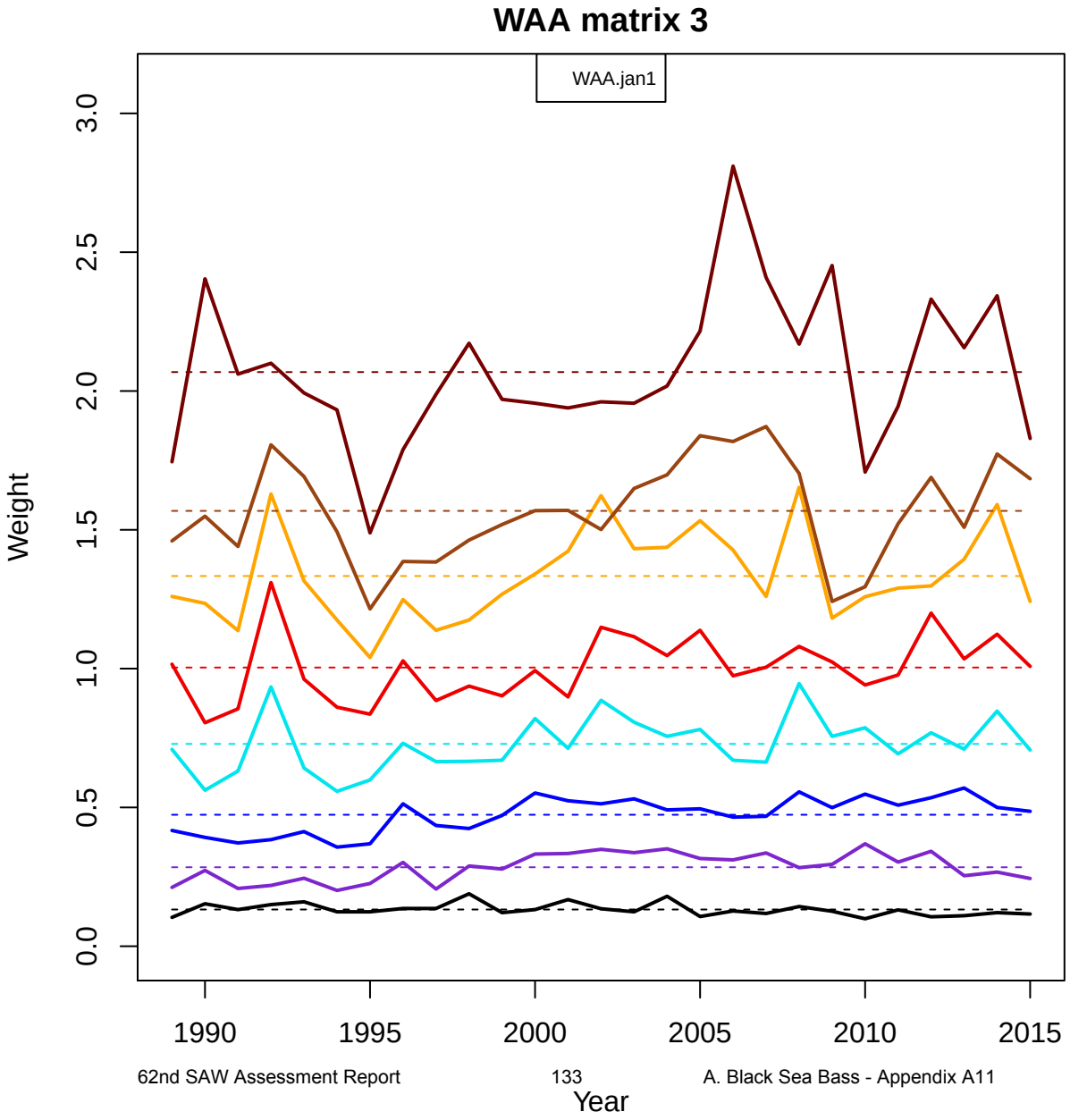


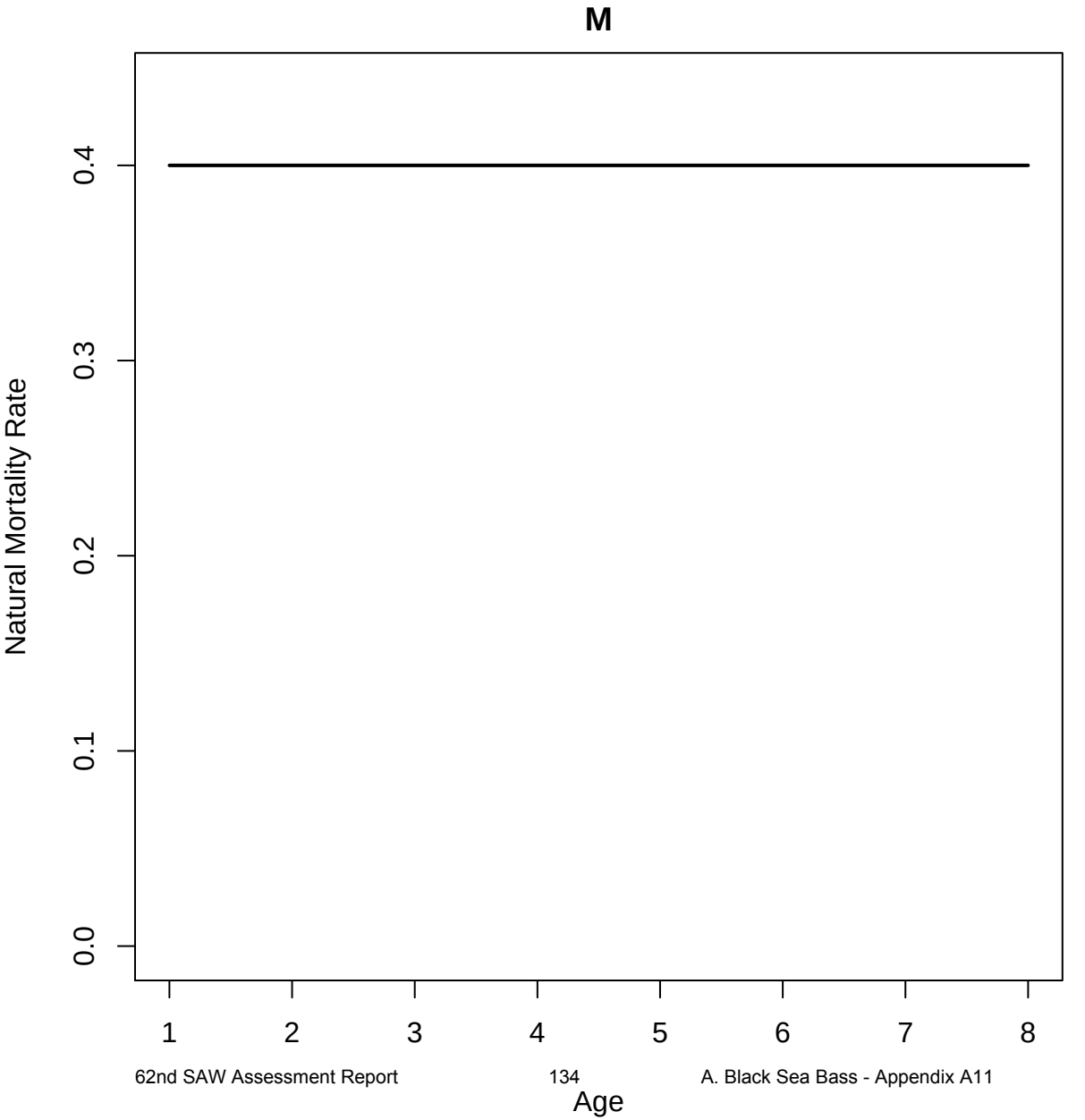
Age Comps for Index 8 (bigelow)

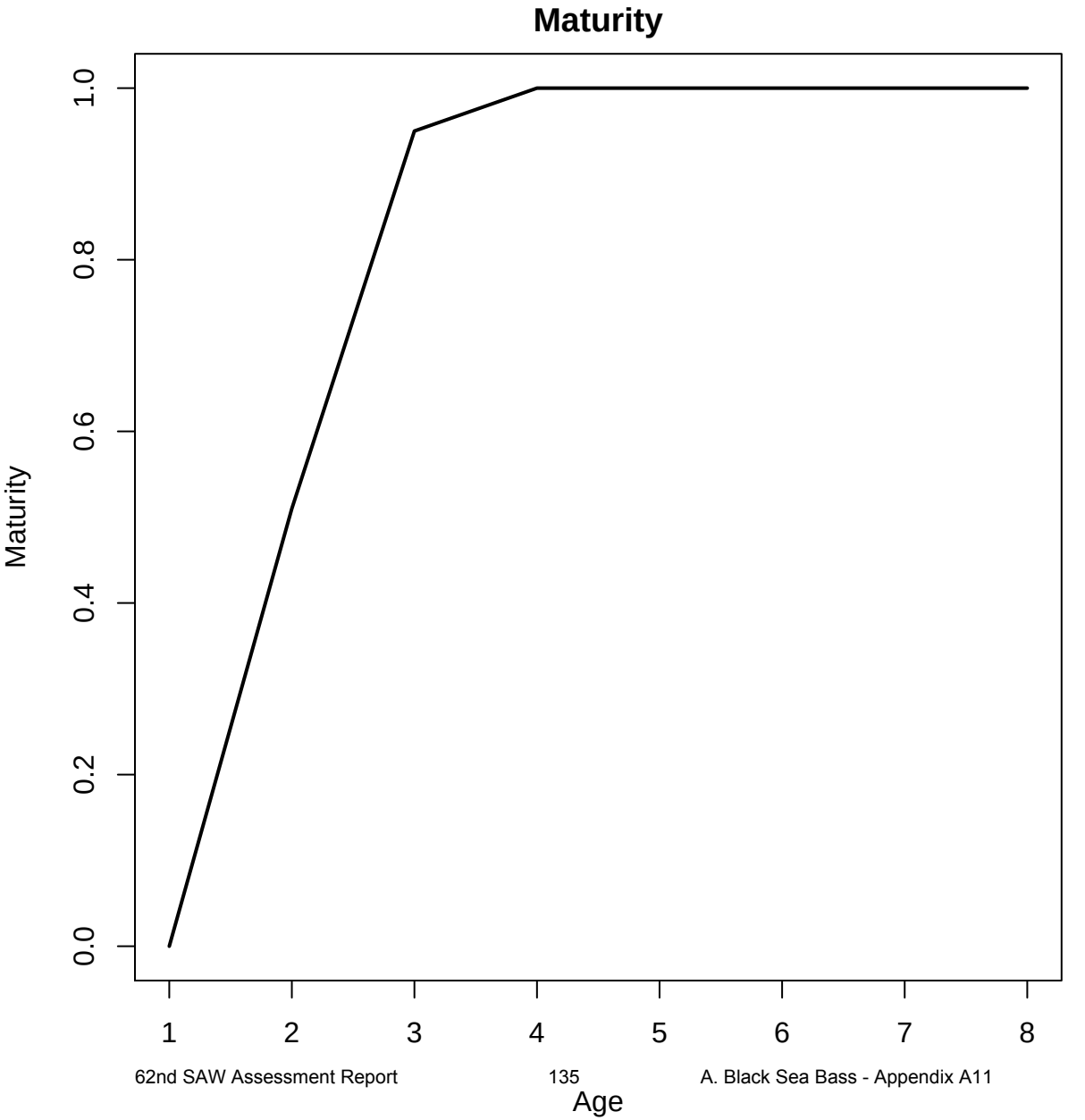



WAA matrix 1
fleet1
WAA.discard.fleet1
WAA.catch.fleet2
WAA.discard.fleet2
WAA.catch.all
WAA
Weight
0.0
0.5
1.0
1.5
2.0
2.5
3.0
1990
1995
2000
2005
2010
2015
Year

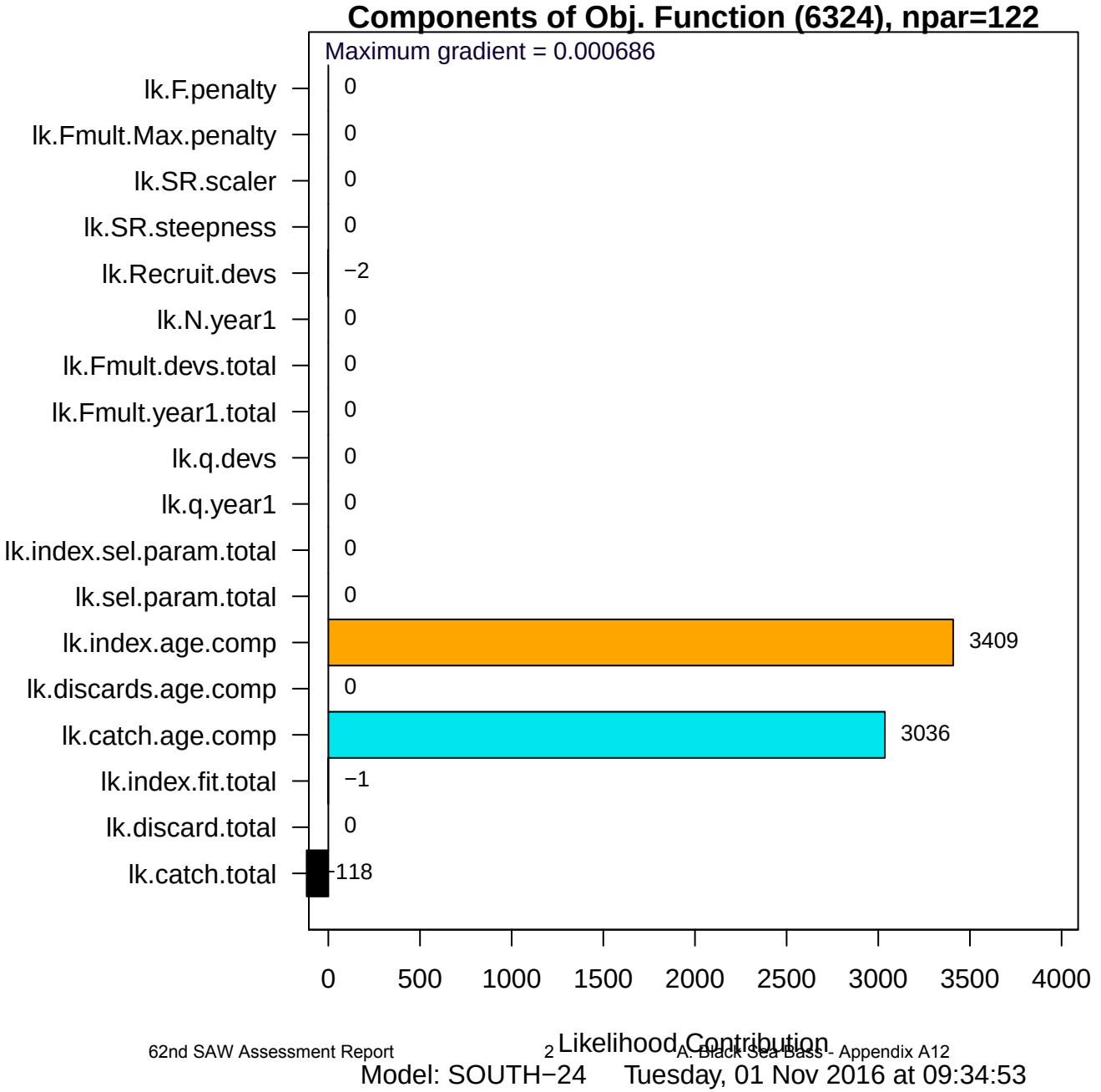

WAA matrix 2
WAA.ssb
Weight
0.0
0.5
1.0
1.5
2.0
2.5
3.0
1990
1995
2000
2005
2010
2015
Year

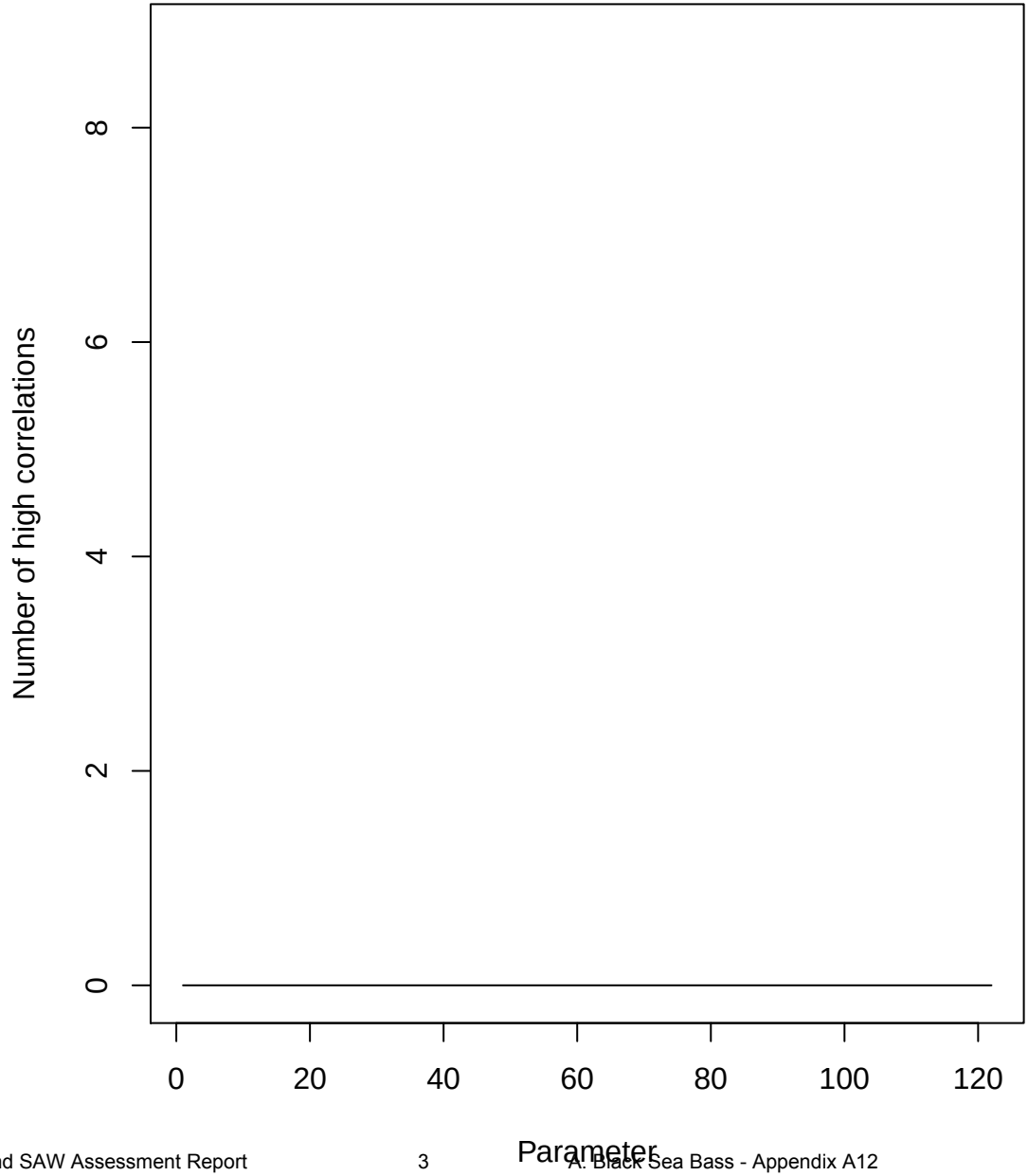

WAA matrix 3
WAA.jan1
Weight
0.0
0.5
1.0
1.5
2.0
2.5
3.0
1990
1995
2000
2005
2010
2015
Year


M
Natural Mortality Rate
0.0
0.1
0.2
0.3
0.4
1
2
3
4
5
6
7
8
Age


Maturity
Maturity
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
8
Age

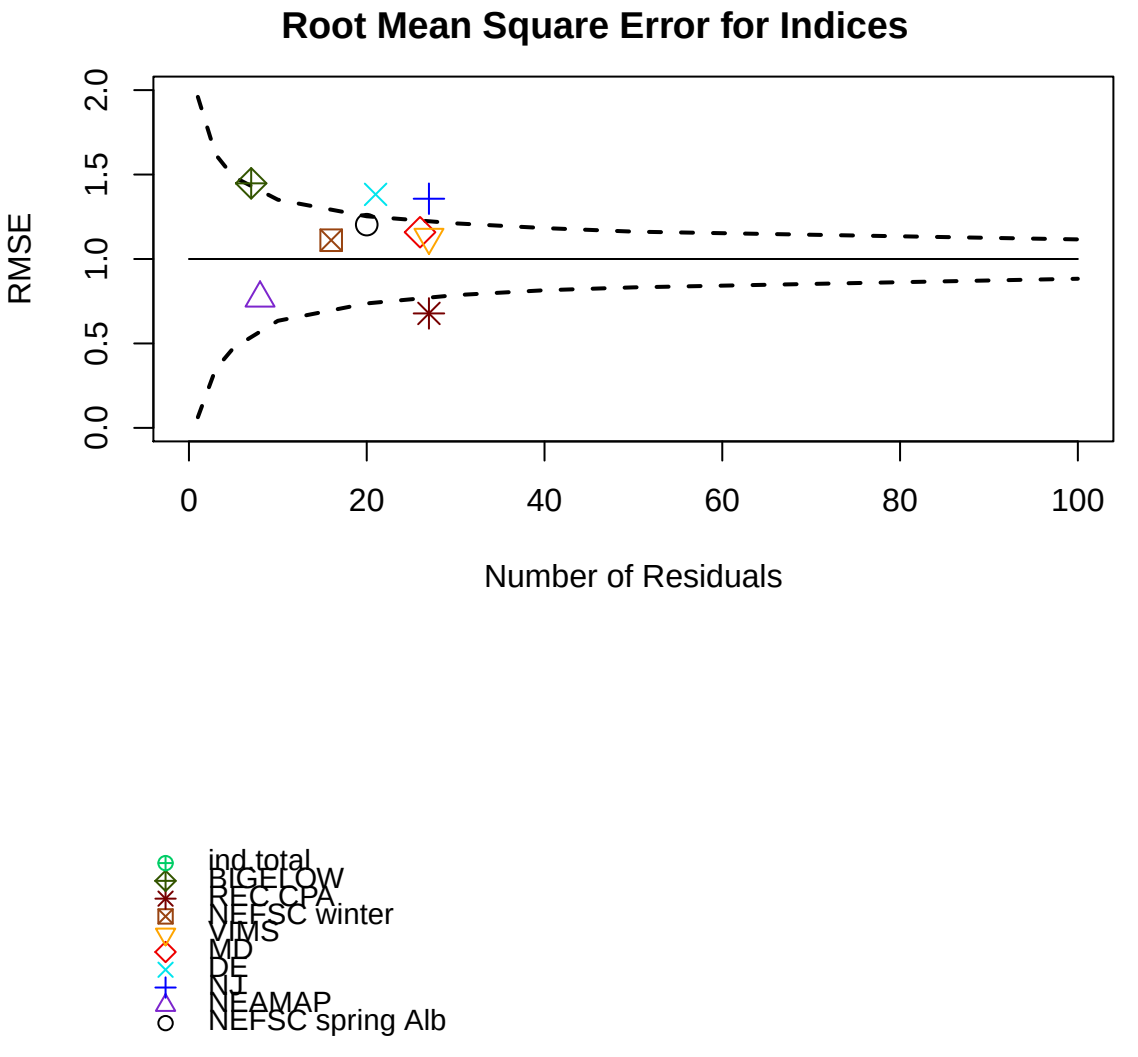
Appendix A12 – Diagnostic and result plots for black sea bass South model

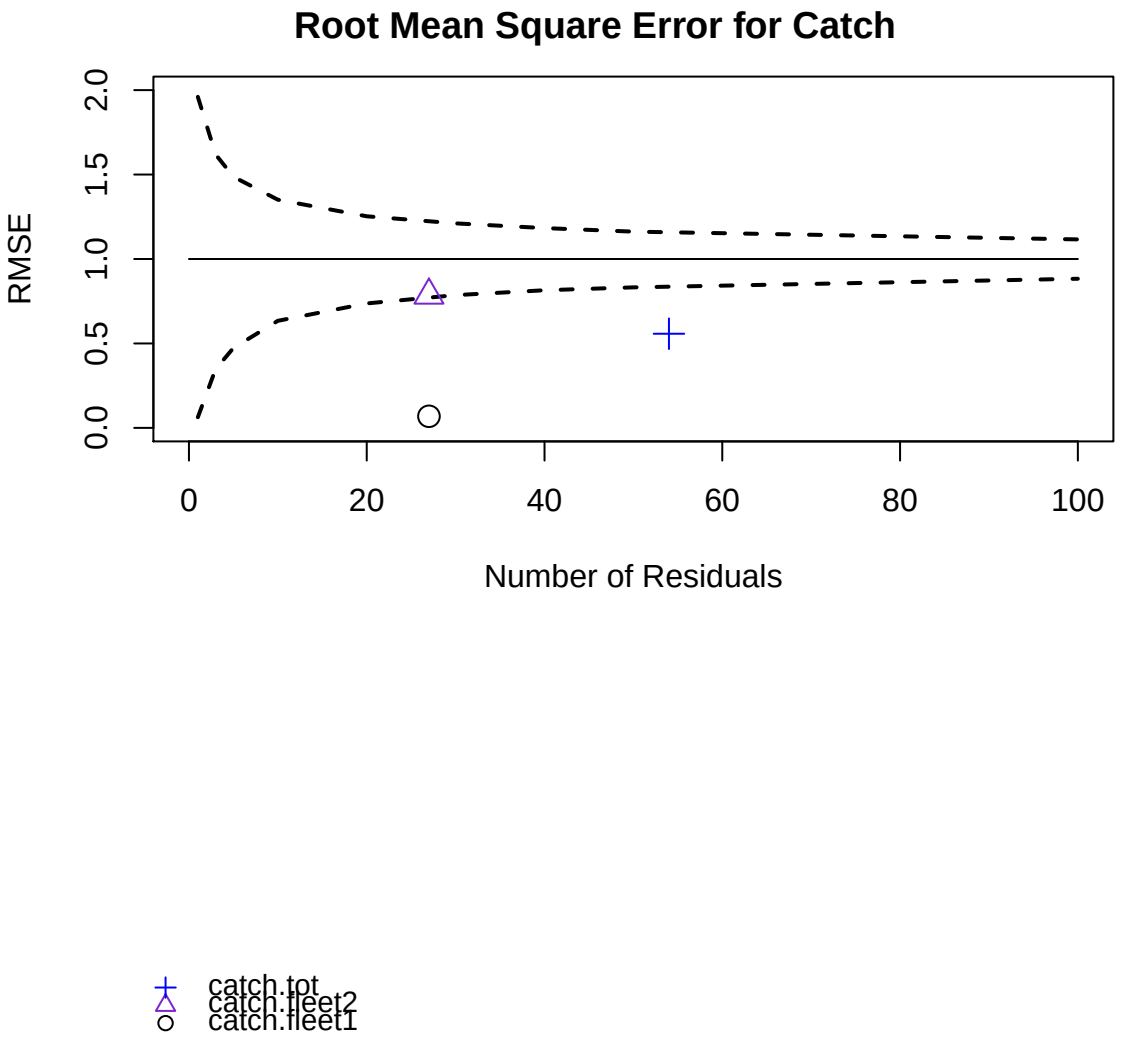

Components of Obj. Function (6324), npar=122
Maximum gradient = 0.000686
lk.F.penalty
lk.Fmult.Max.penalty
lk.SR.scaler
lk.SR.steepness
lk.Recruit.devs
lk.N.year1
lk.Fmult.devs.total
lk.Fmult.year1.total
lk.q.devs
lk.q.year1
lk.index.sel.param.total
lk.sel.param.total
lk.index.age.comp
lk.discards.age.comp
lk.catch.age.comp
lk.index.fit.total
lk.discard.total
lk.catch.total
0
0
0
0
−2
0
0
0
0
0
0
0
3409
0
3036
−1
0
−118
0
500
1000
1500
2000
2500
3000
3500
4000
Likelihood Contribution
Model: SOUTH−24
Tuesday, 01 Nov 2016 at 09:34:53


Number of high correlations
0
2
4
6
8
0
20
40
60
80
100
120
Parameter

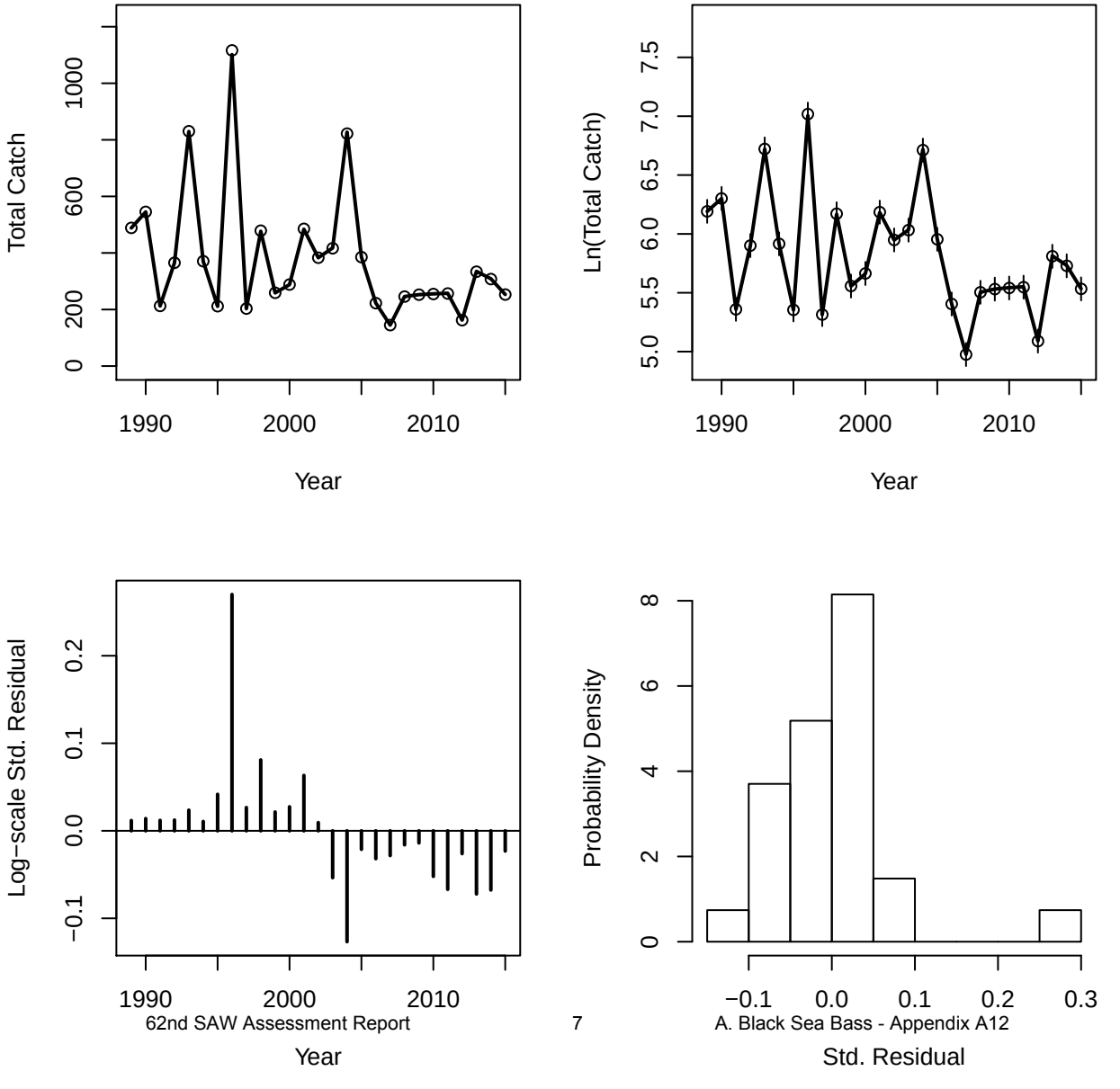
Root Mean Square Error computed from Standardized Residuals

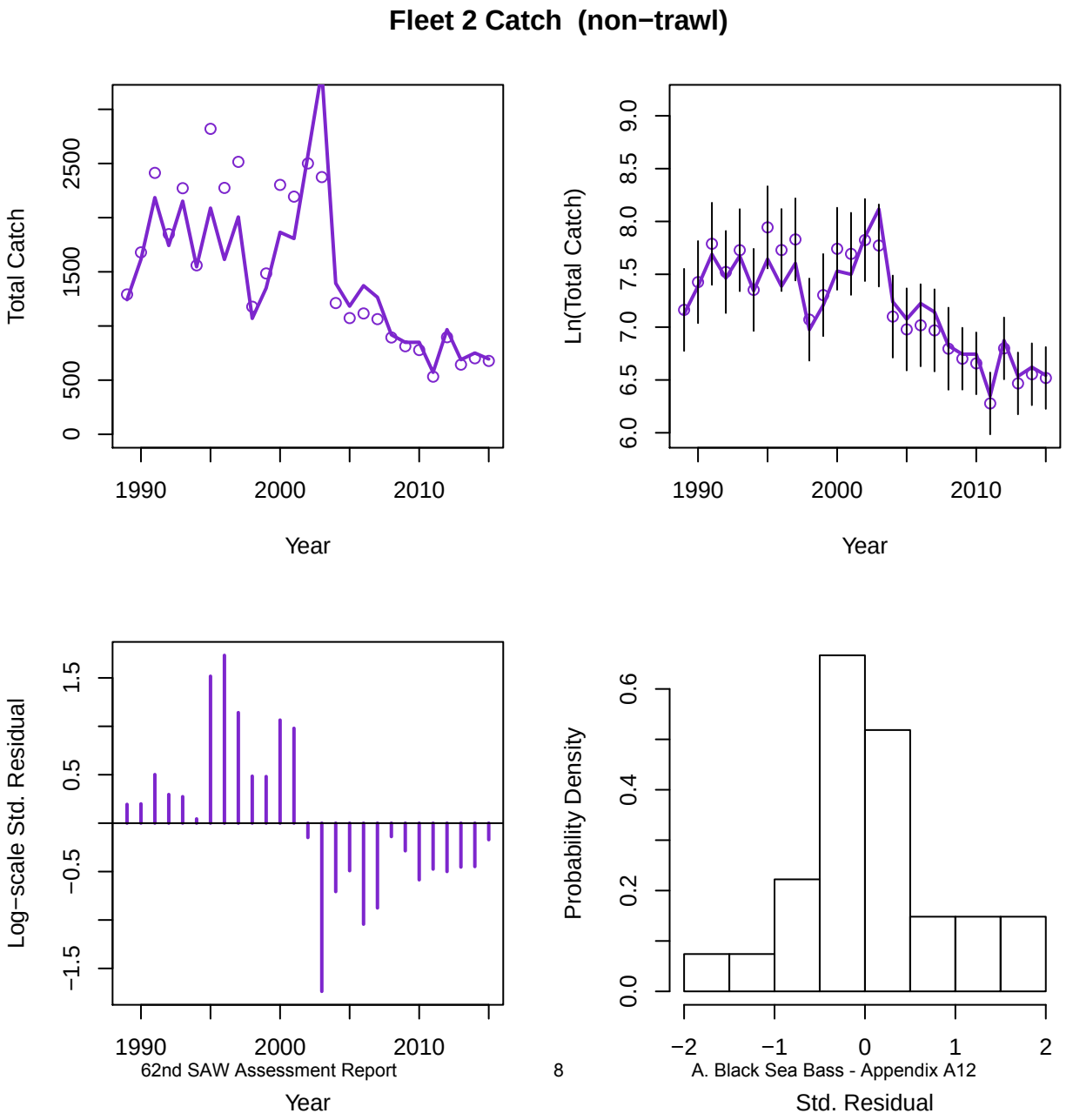
Component	# resids	RMSE
catch.fleet1	27	0.0689
catch.fleet2	27	0.785
catch.tot	54	0.557
discard.fleet1	0	0
discard.fleet2	0	0
discard.tot	0	0
ind01	20	1.2
ind02	8	0.768
ind03	27	1.36
ind04	21	1.38
ind05	26	1.16
ind06	27	1.13
ind07	16	1.11
ind08	27	0.678
ind09	7	1.45
ind.total	179	1.16
N.year1	0	0
Fmult.year1	0	0
Fmult.devs.fleet1	0	0
Fmult.devs.fleet2	0	0
Fmult.devs.total	0	0
recruit.devs	27	0.482
fleet.sel.params	0	0
index.sel.params	0	0
q.year1	0	0
q.devs	0	0
SR.steepness	0	0
SR.scaler	0	0

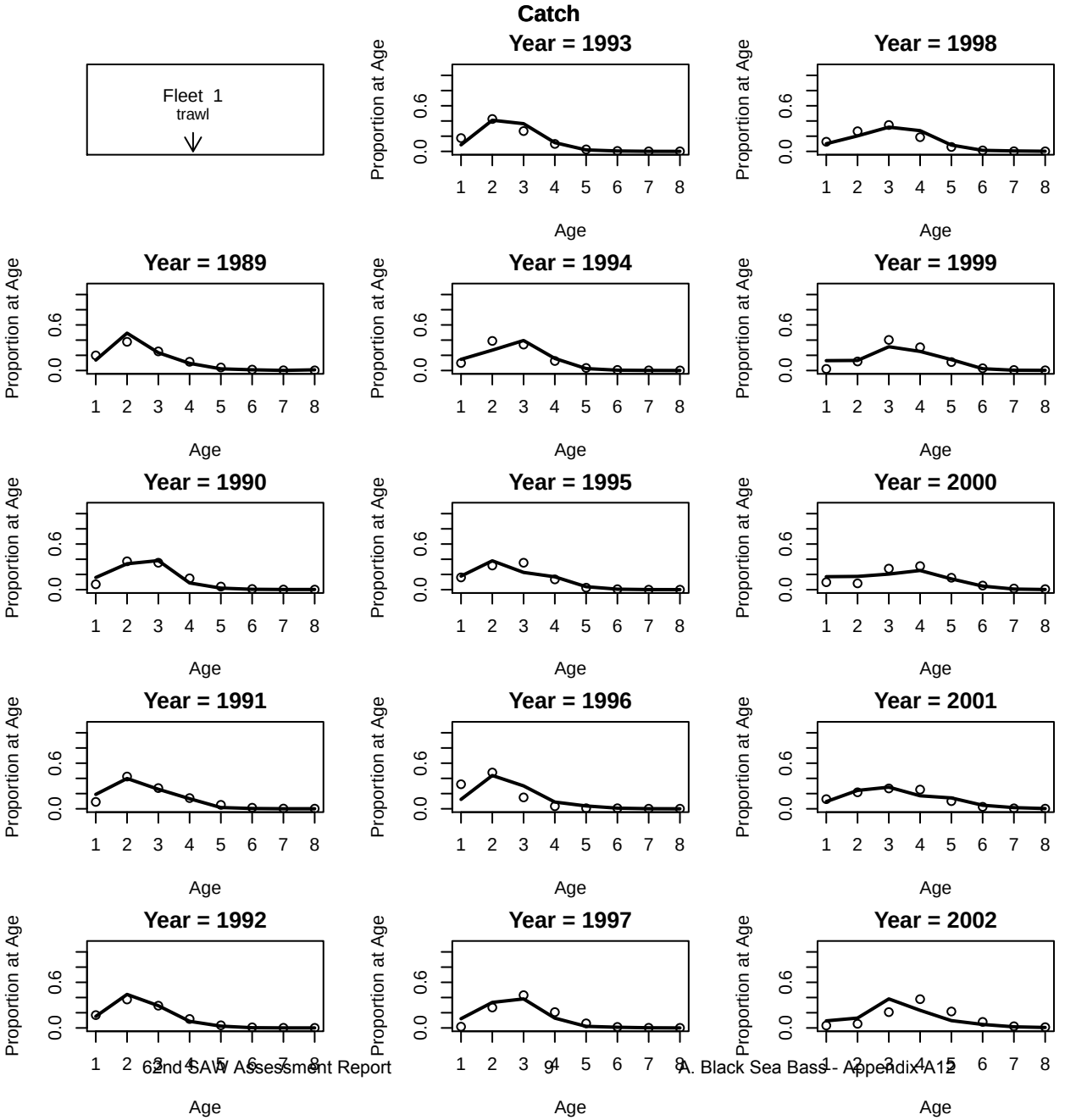

Root Mean Square Error for Indices
RMSE
0.0
0.5
1.0
1.5
2.0
0
20
40
60
80
100
Number of Residuals
ind total
BIGELOW
REC CPA
NEFSC winter
VIMS
MD
DE
NJ
NEAMAP
NEFSC spring Alb

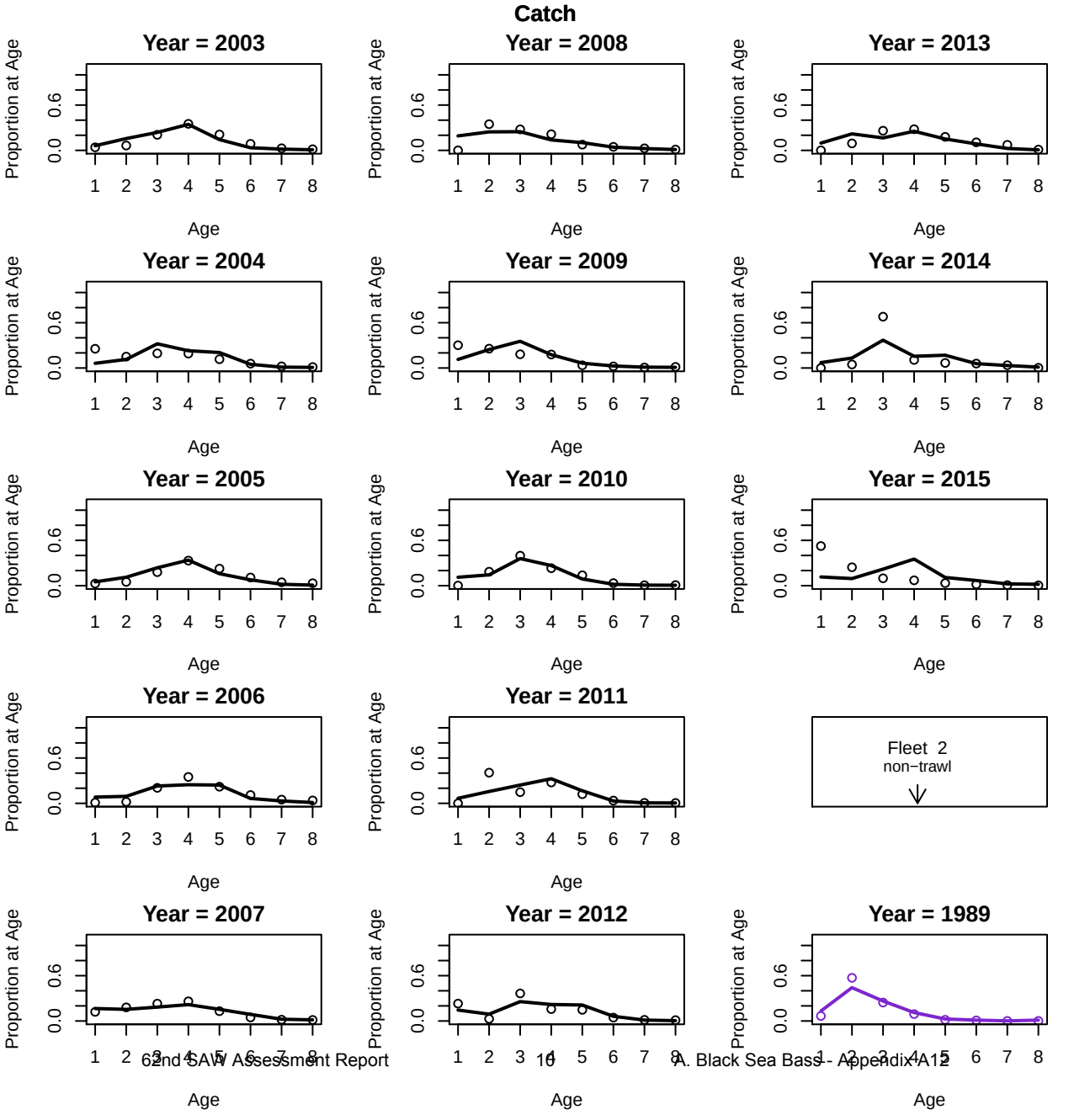

Root Mean Square Error for Catch
RMSE
0.0
0.5
1.0
1.5
2.0
0
20
40
60
80
100
Number of Residuals
catch.tot
catch.fleet2
catch.fleet1

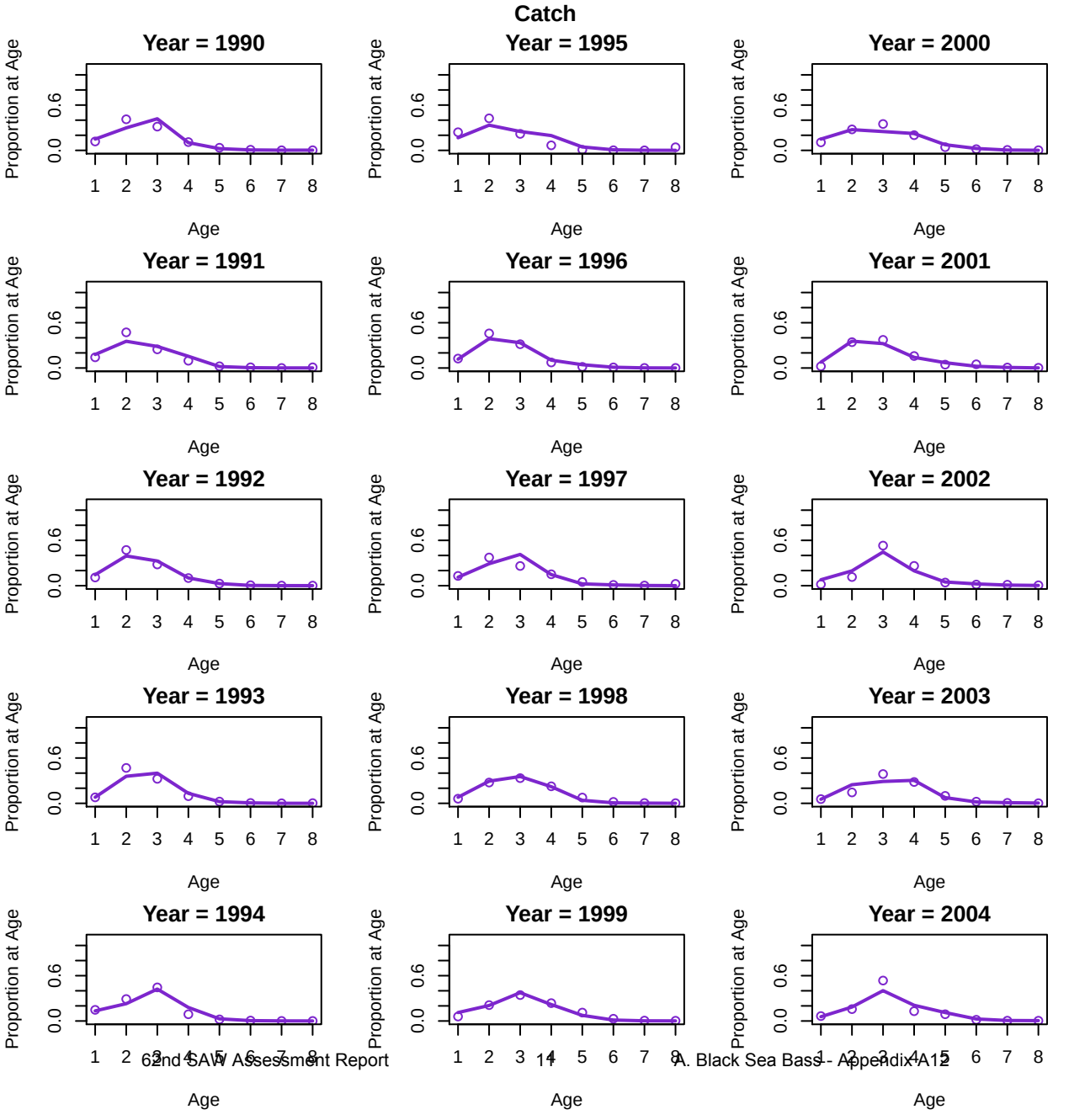
Fleet 1 Catch (trawl)

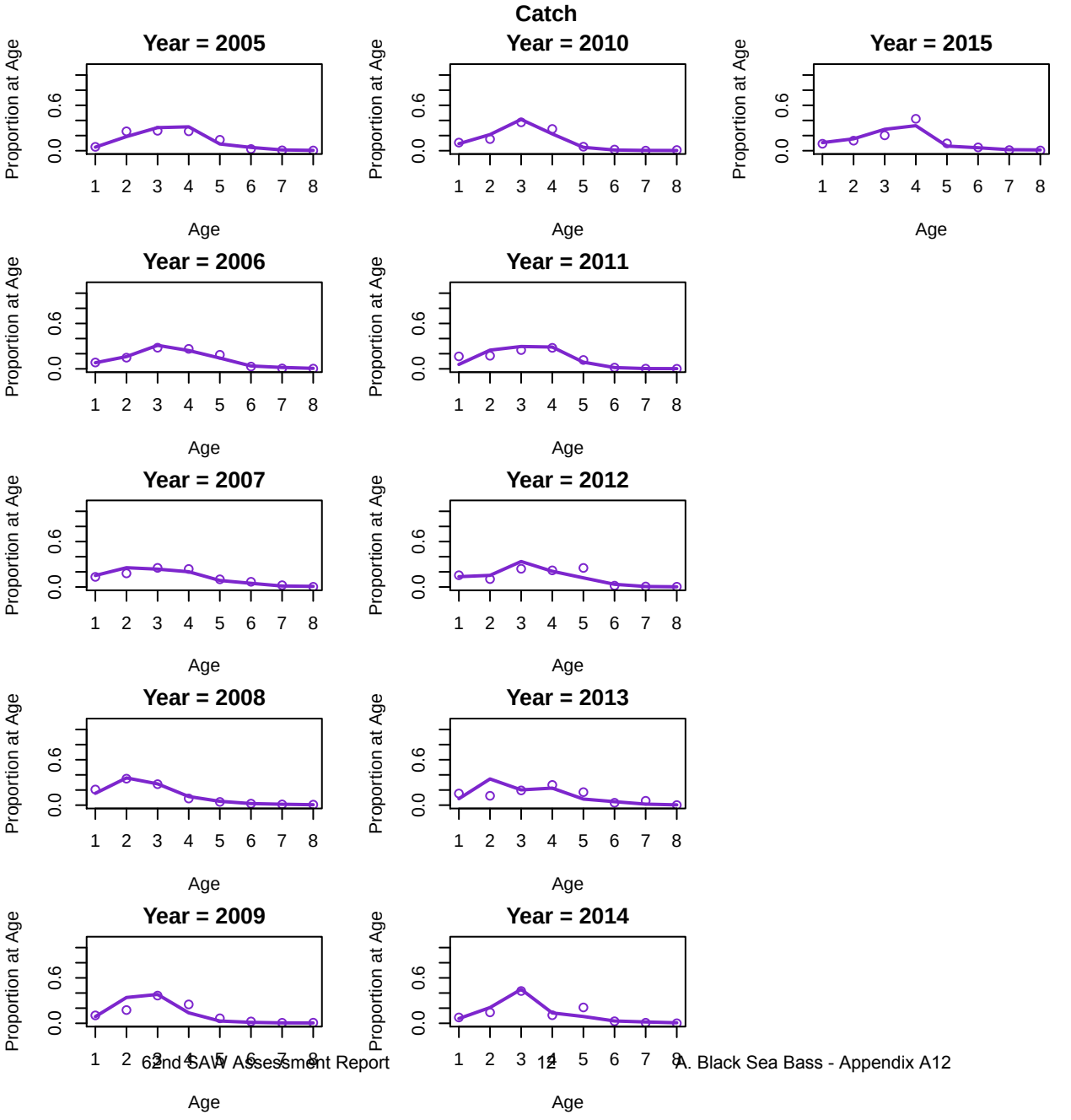



Fleet 2 Catch (non−trawl)
Total Catch
0
500
1500
2500
1990
2000
2010
Year
Ln(Total Catch)
6.0
6.5
7.0
7.5
8.0
8.5
9.0
1990
2000
2010
Year
Log−scale Std. Residual
−1.5
−0.5
0.5
1.5
1990
2000
2010
Year
Probability Density
0.0
0.2
0.4
0.6
−2
−1
0
1
2
Std. Residual

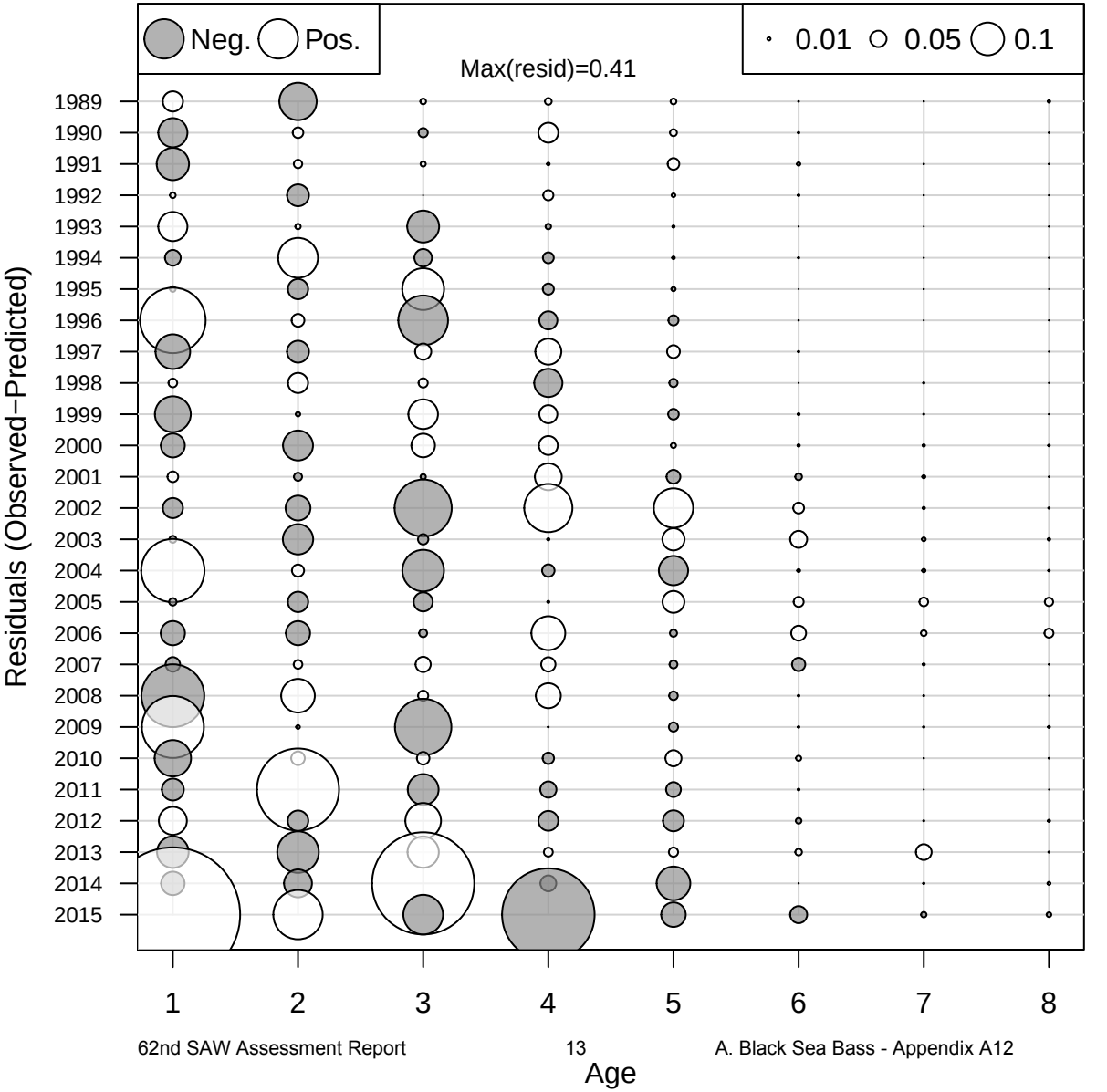

Catch
Fleet 1
trawl
Year = 1993
Year = 1998
Year = 1989
Year = 1994
Year = 1999
Year = 1990
Year = 1995
Year = 2000
Year = 1991
Year = 1996
Year = 2001
Year = 1992
Year = 1997
Year = 2002
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

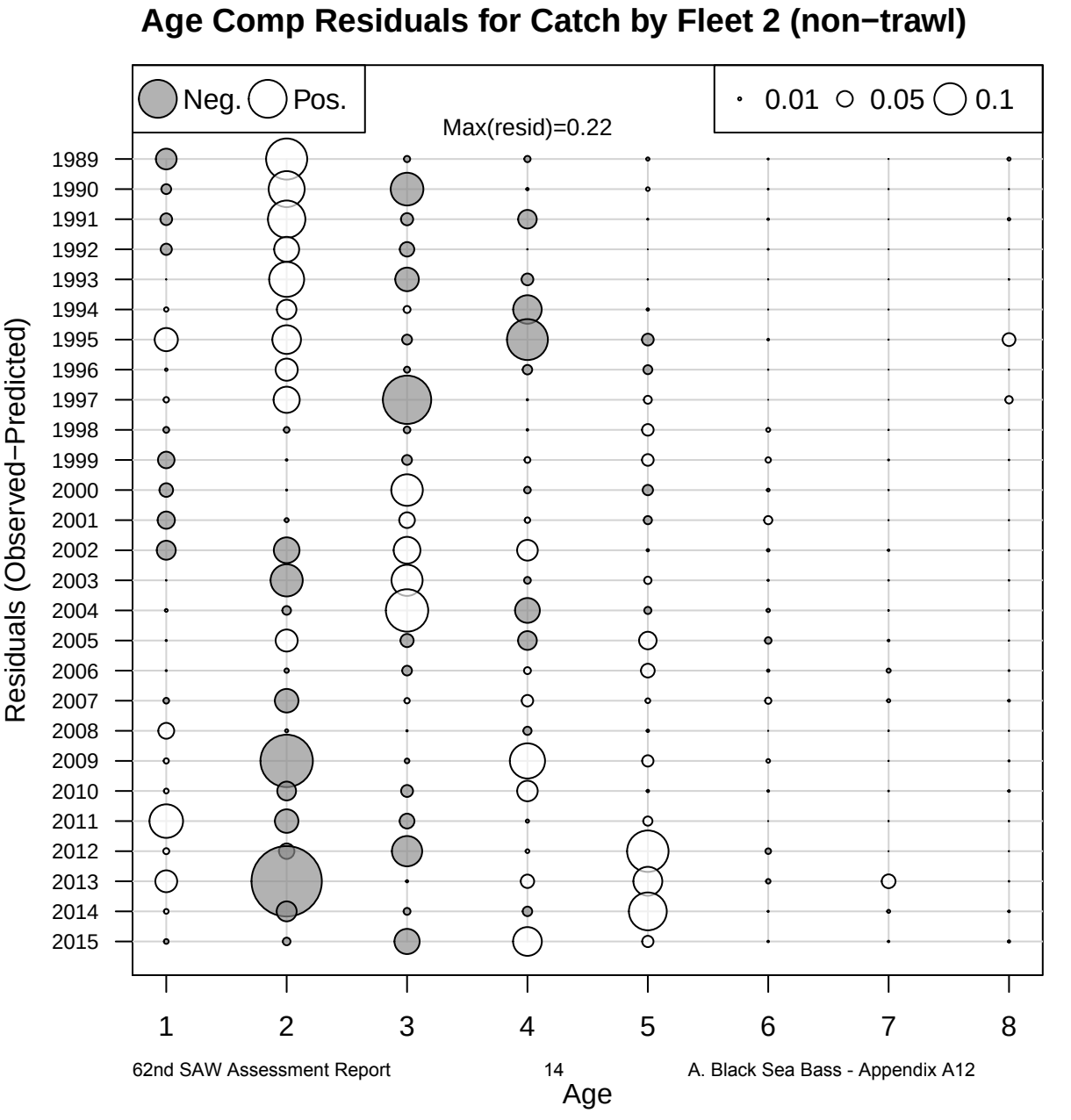

Catch
Year = 2003
Year = 2008
Year = 2013
Year = 2004
Year = 2009
Year = 2014
Year = 2005
Year = 2010
Year = 2015
Year = 2006
Year = 2011
Fleet 2
non−trawl
Year = 2007
Year = 2012
Year = 1989
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

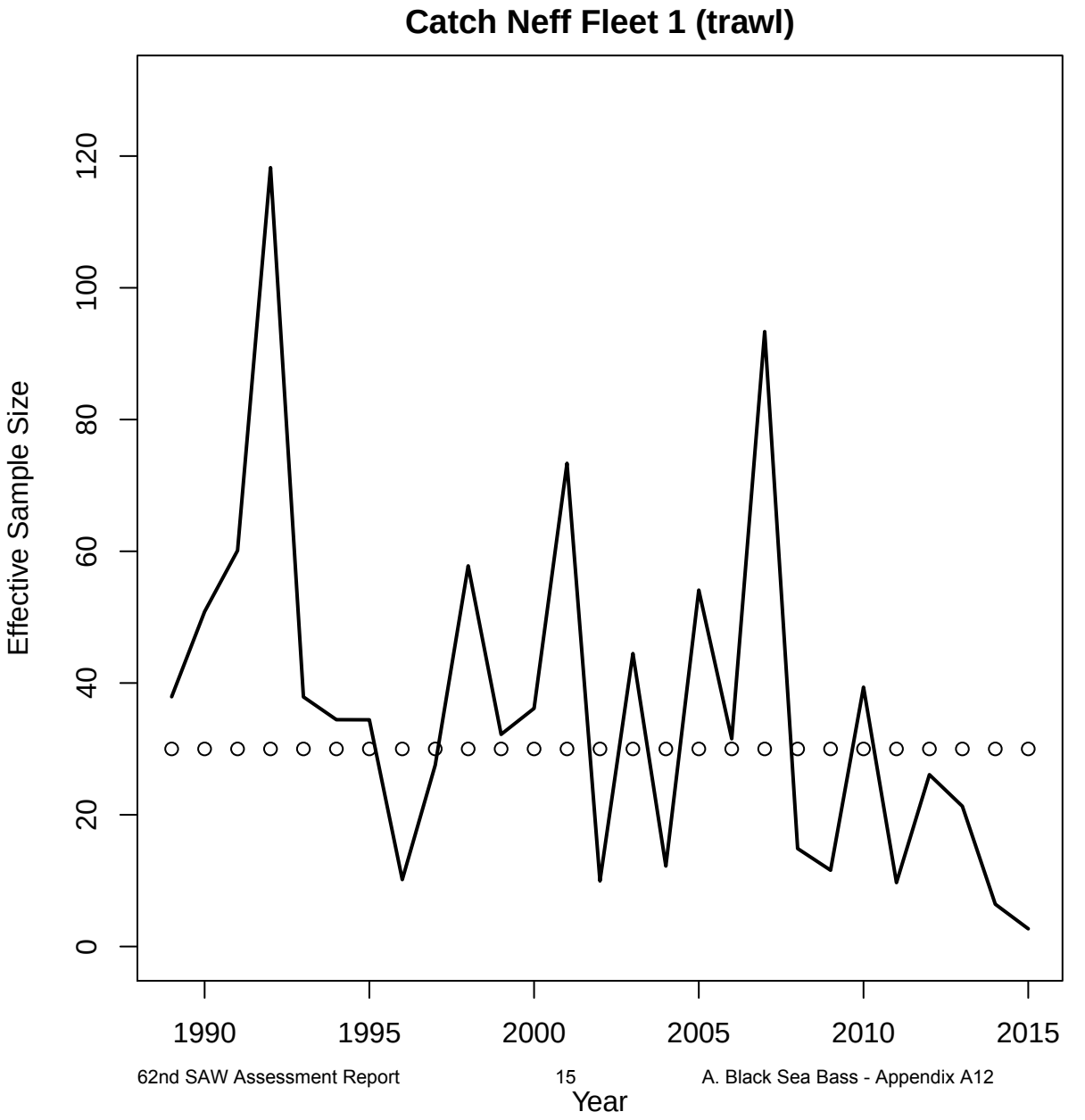

Catch
Year = 1990
Year = 1991
Year = 1992
Year = 1993
Year = 1994
Year = 1995
Year = 1996
Year = 1997
Year = 1998
Year = 1999
Year = 2000
Year = 2001
Year = 2002
Year = 2003
Year = 2004
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

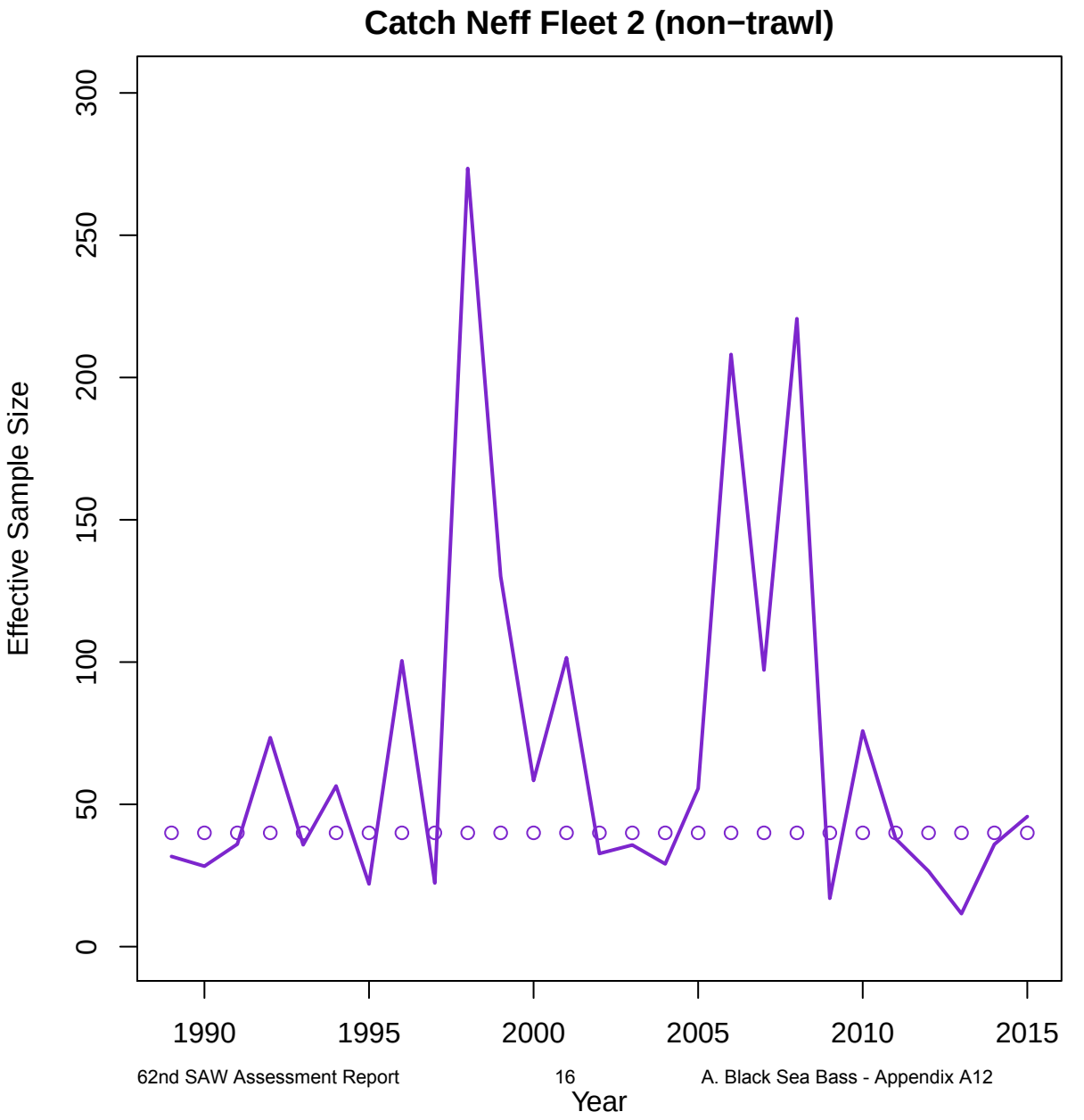

Catch
Year = 2005
Year = 2010
Year = 2015
Year = 2006
Year = 2011
Year = 2007
Year = 2012
Year = 2008
Year = 2013
Year = 2009
Year = 2014
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

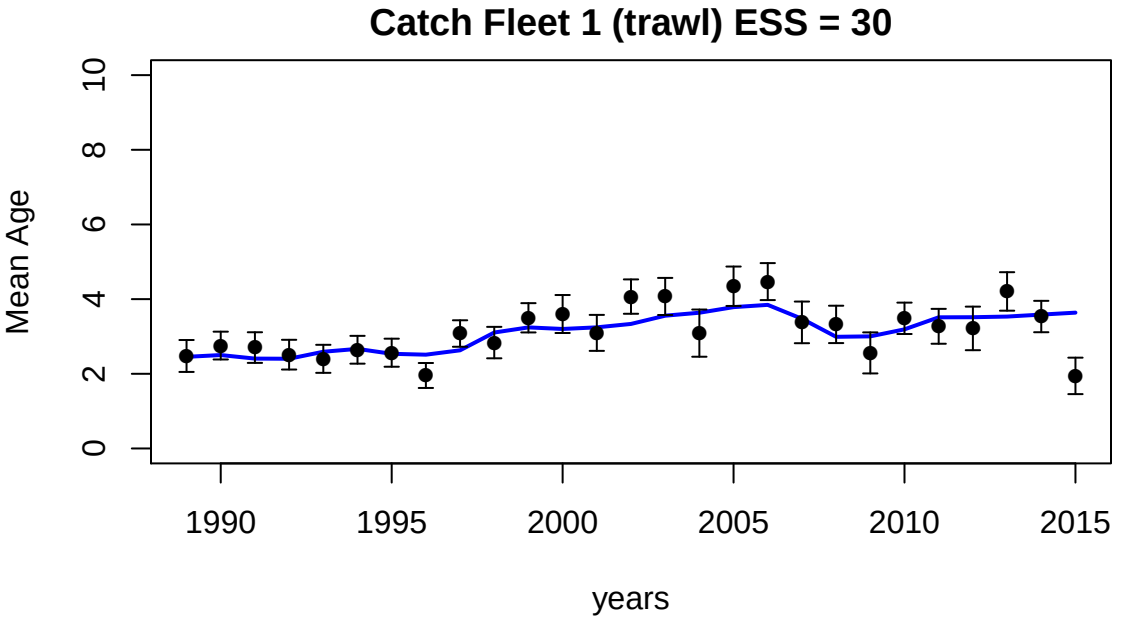
Age Comp Residuals for Catch by Fleet 1 (trawl)

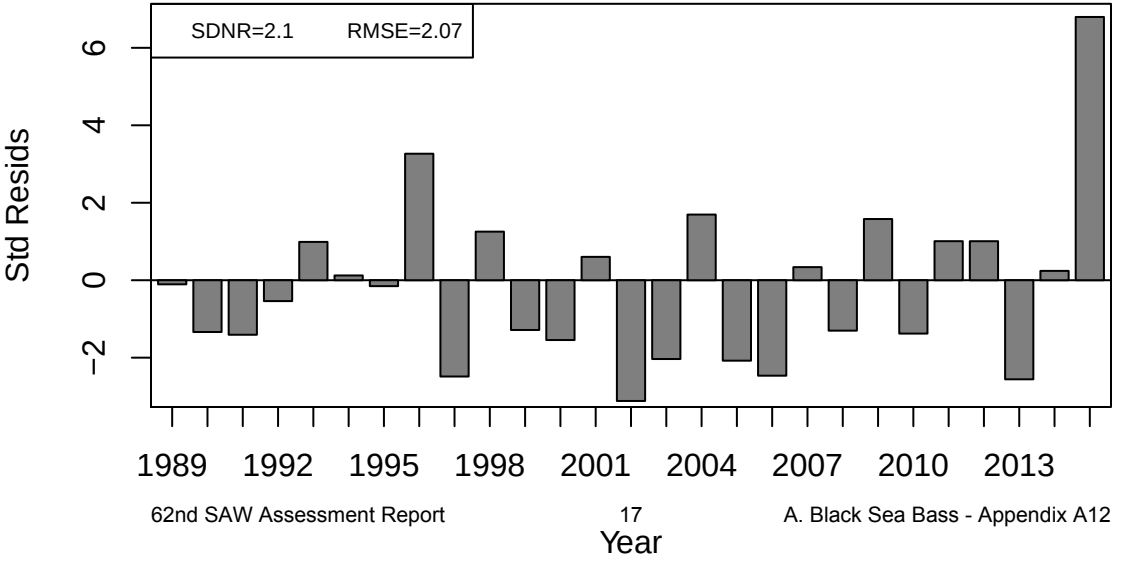


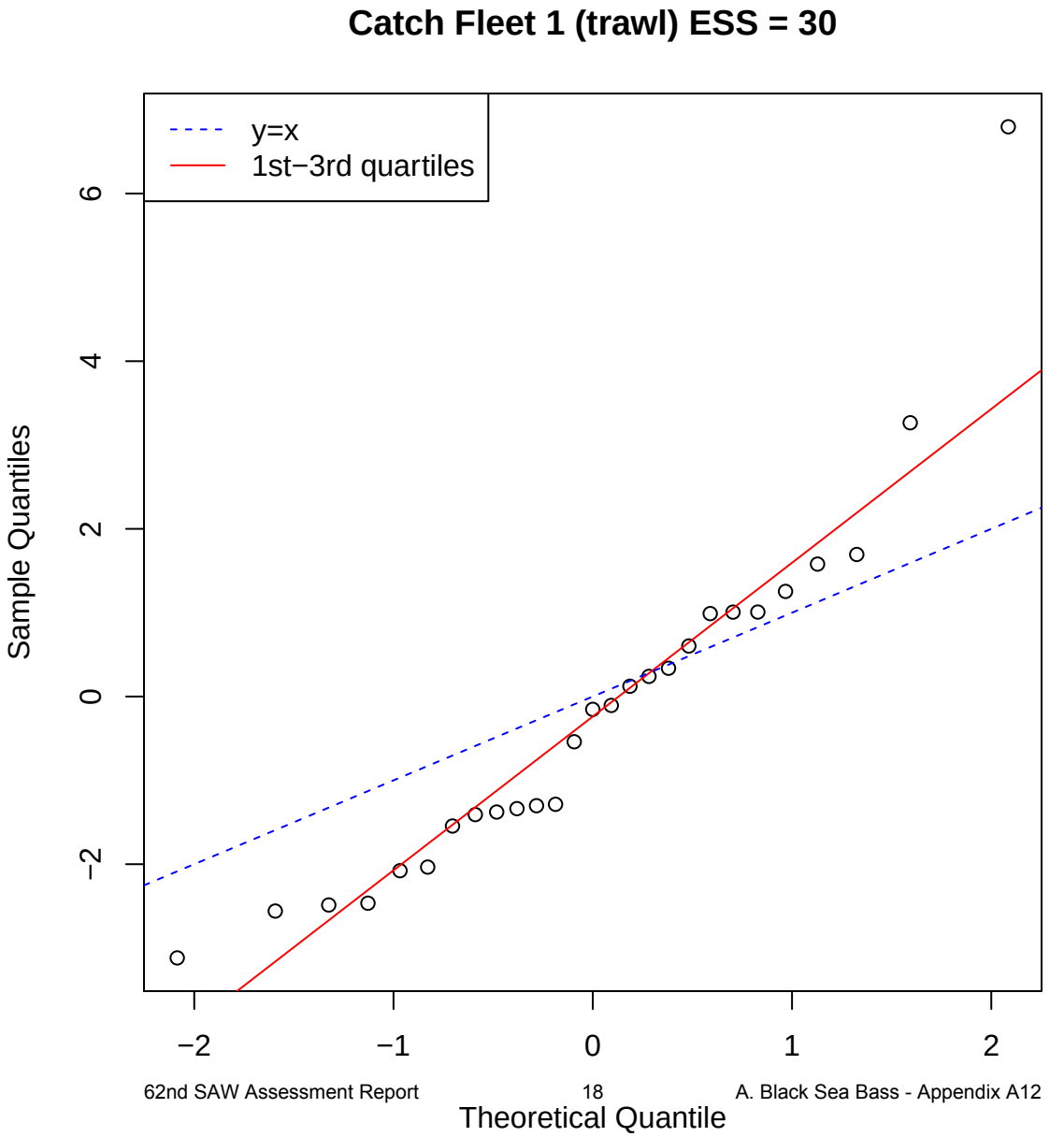

Age Comp Residuals for Catch by Fleet 2 (non−trawl)
Neg.
Pos.
0.01
0.05
0.1
Max(resid)=0.22
Residuals (Observed−Predicted)
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

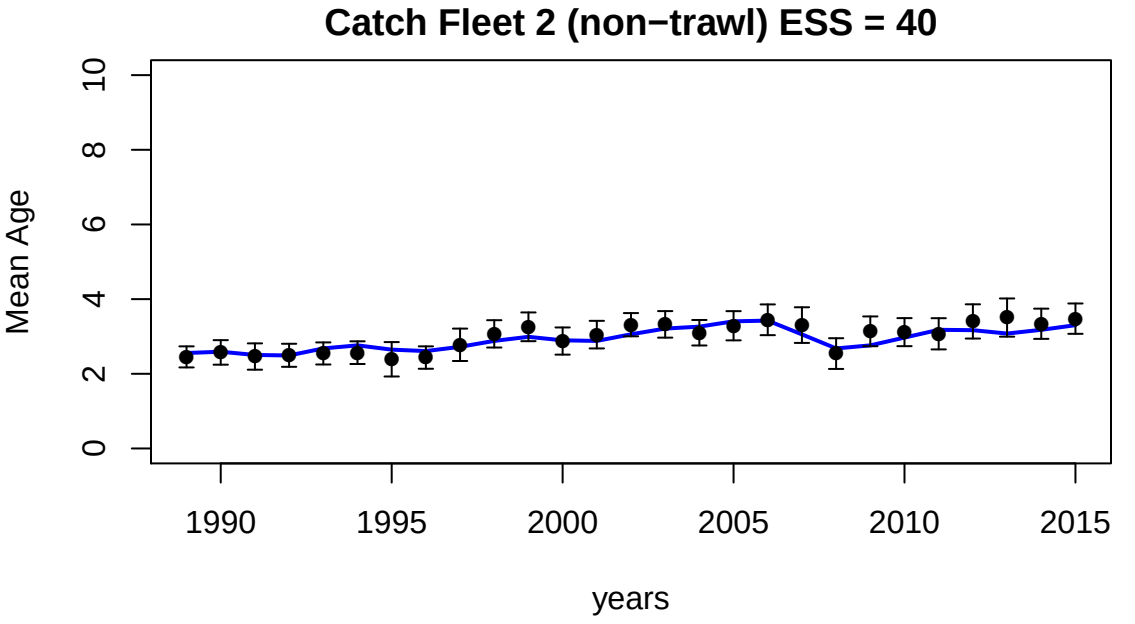

Catch Neff Fleet 1 (trawl)
Effective Sample Size
0
20
40
60
80
100
120
1990
1995
2000
2005
2010
2015
Year

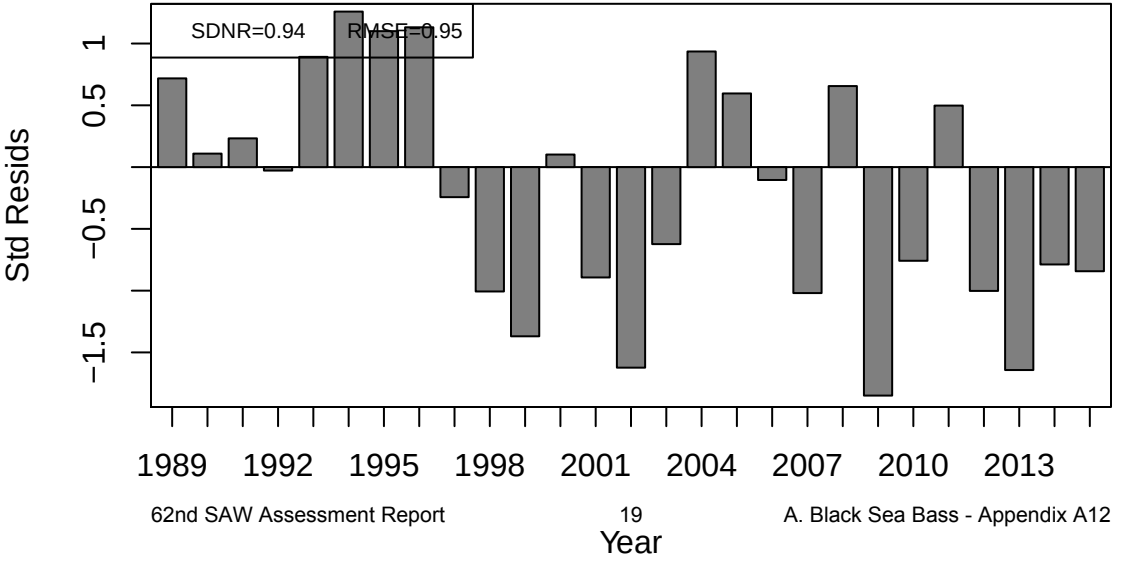

Catch Neff Fleet 2 (non−trawl)
Effective Sample Size
0
50
100
150
200
250
300
1990
1995
2000
2005
2010
2015
Year

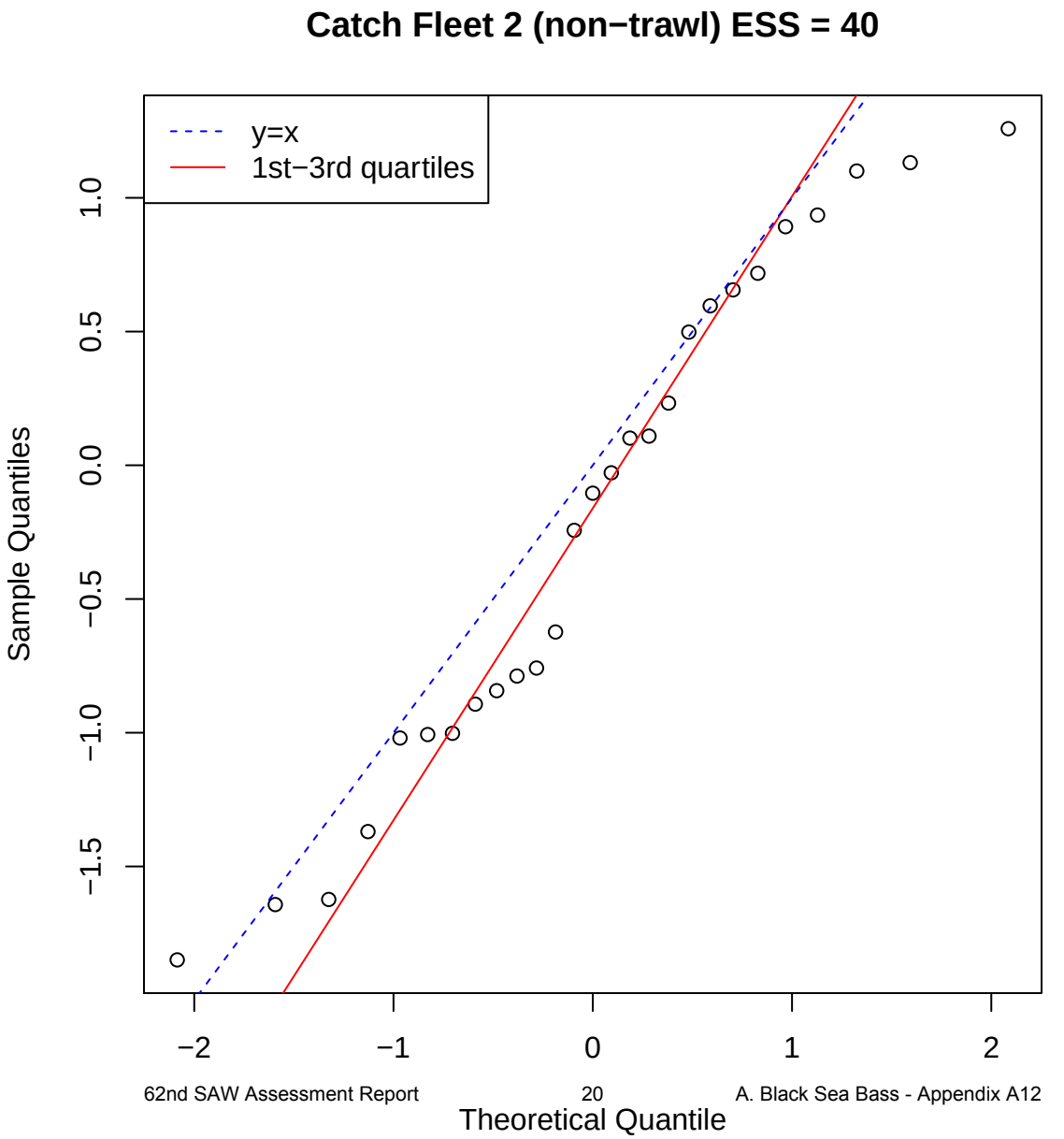

Catch Fleet 1 (trawl) ESS = 30
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
years


SDNR=2.1
RMSE=2.07
Std Resids
−2
0
2
4
6
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

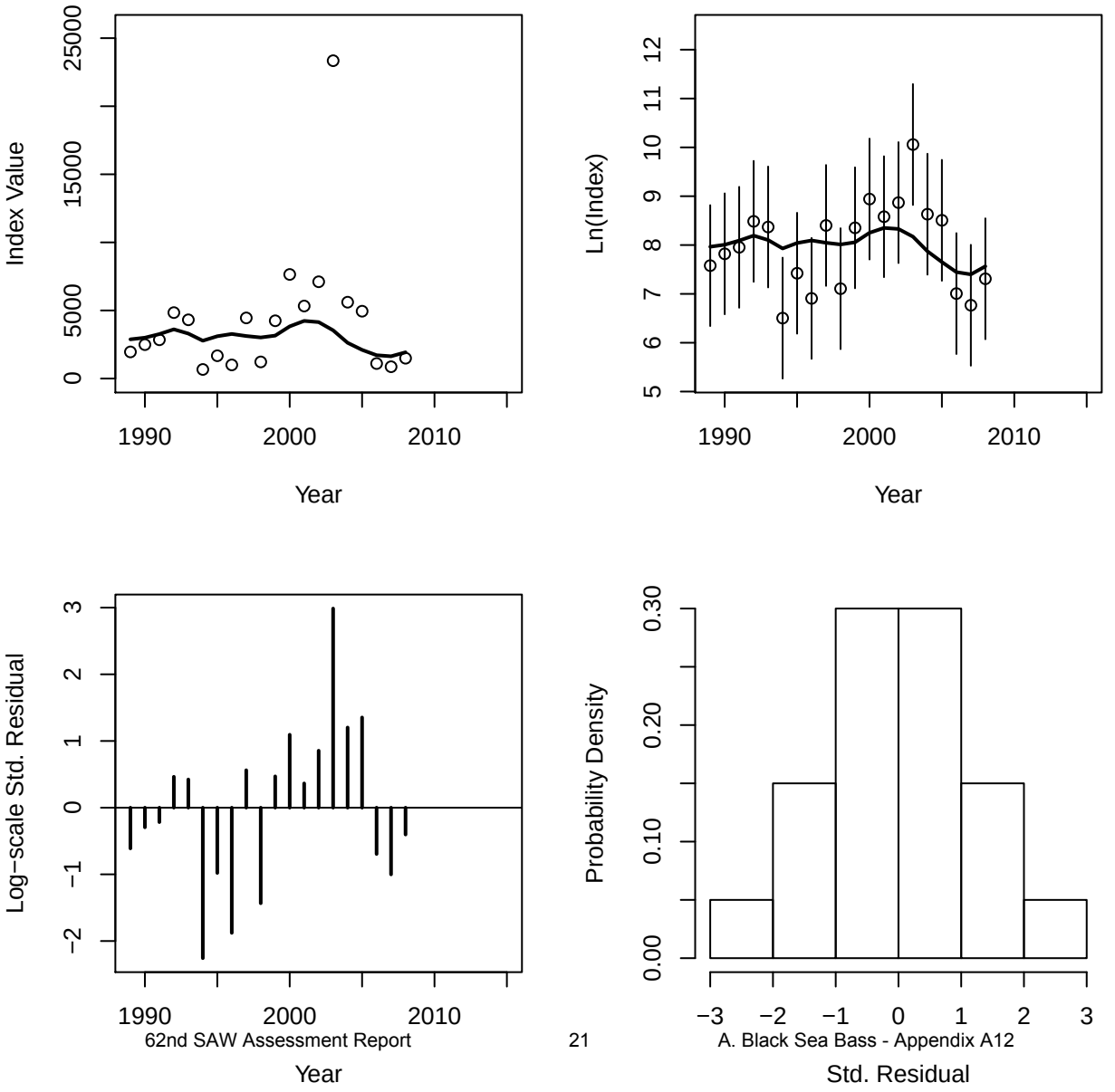

Catch Fleet 1 (trawl) ESS = 30
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
6
4
2
0
−2
−2
−1
0
1
2


Catch Fleet 2 (non−trawl) ESS = 40
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
years

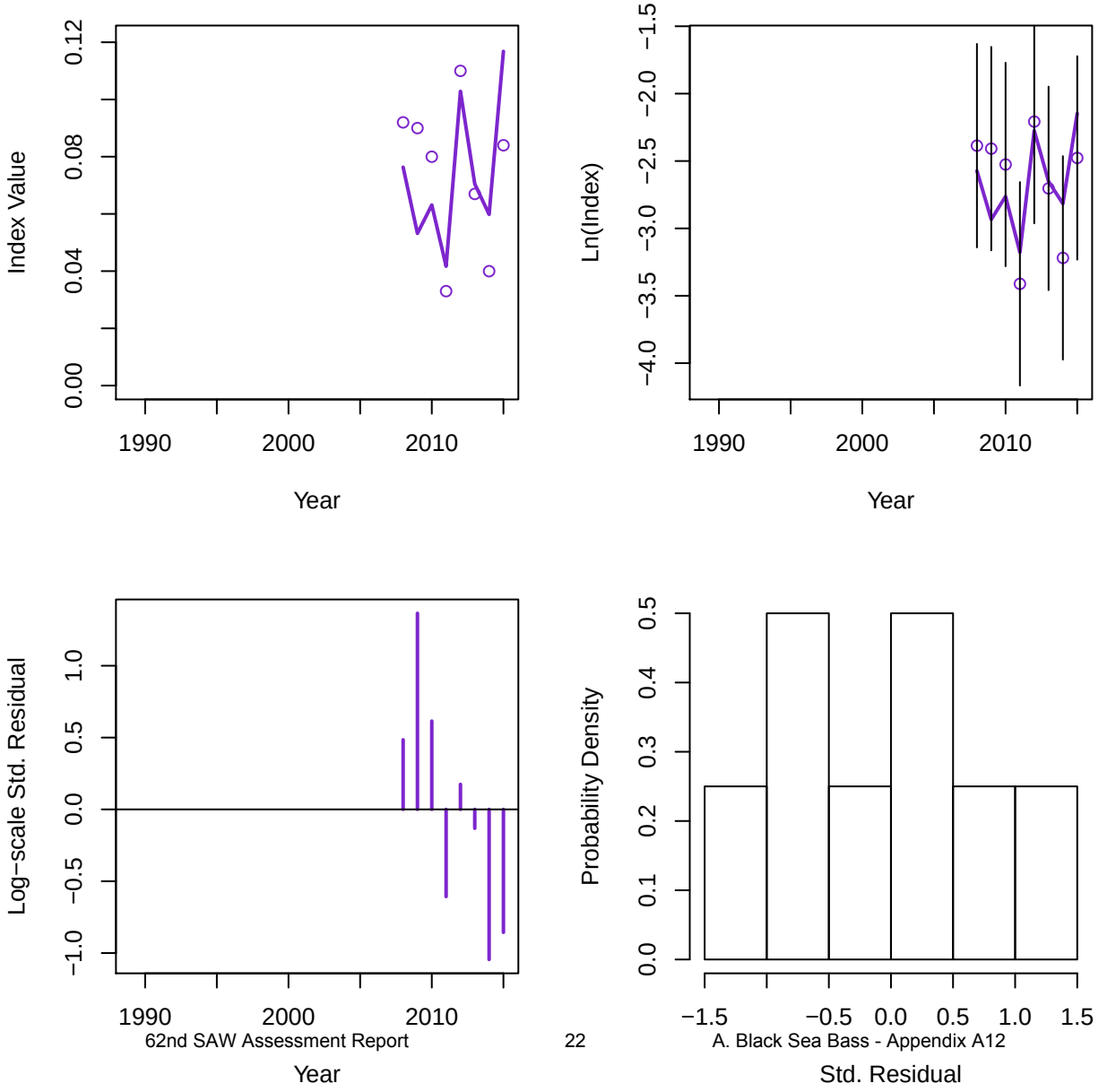

SDNR=0.94
RMSE=0.95
Std Resids
1
0.5
−0.5
−1.5
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year


Catch Fleet 2 (non−trawl) ESS = 40
y=x
1st−3rd quartiles
Sample Quantiles
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2
−1
0
1
2
Theoretical Quantile

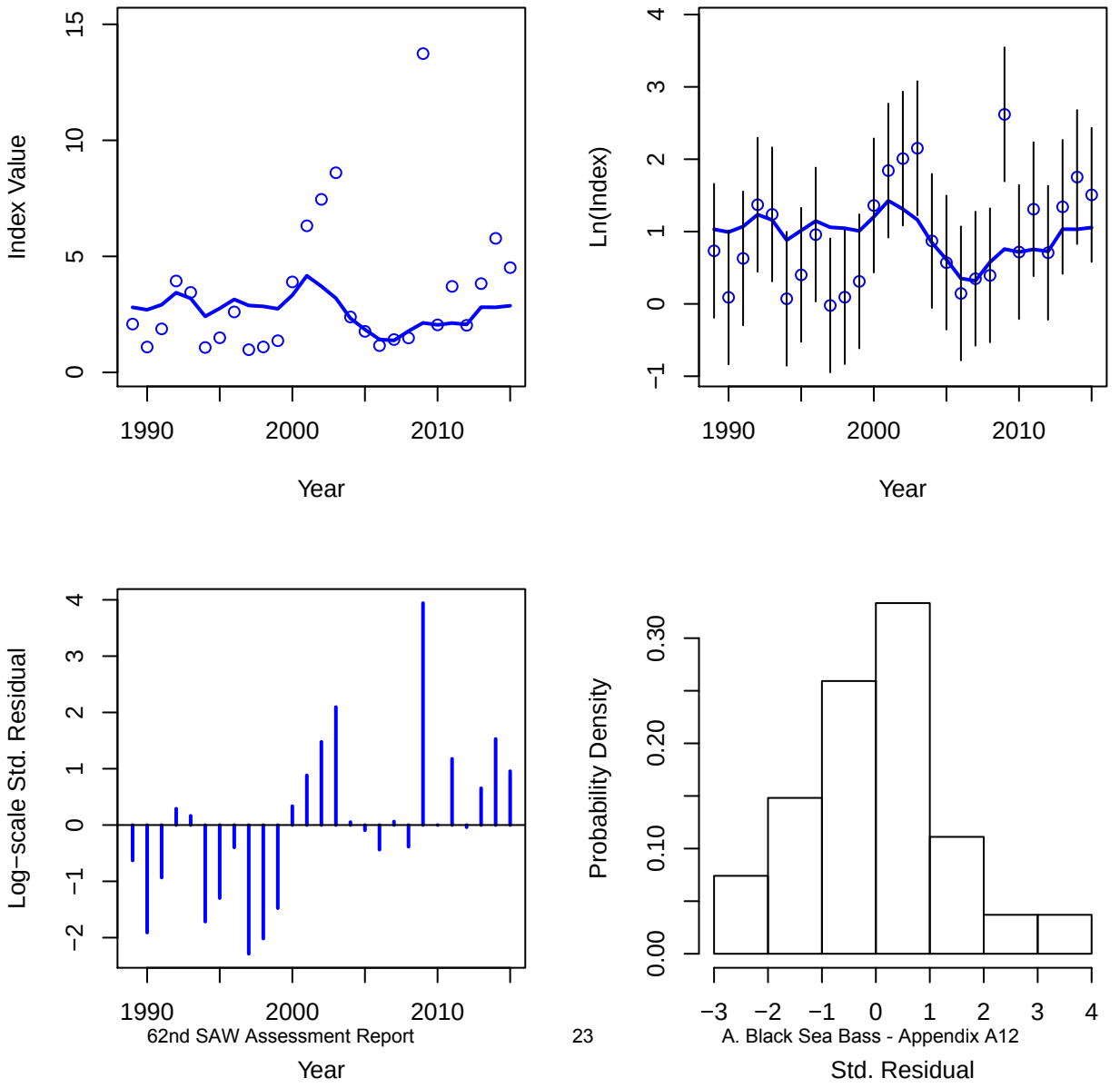
Index 1 (NEFSC spring Alb)



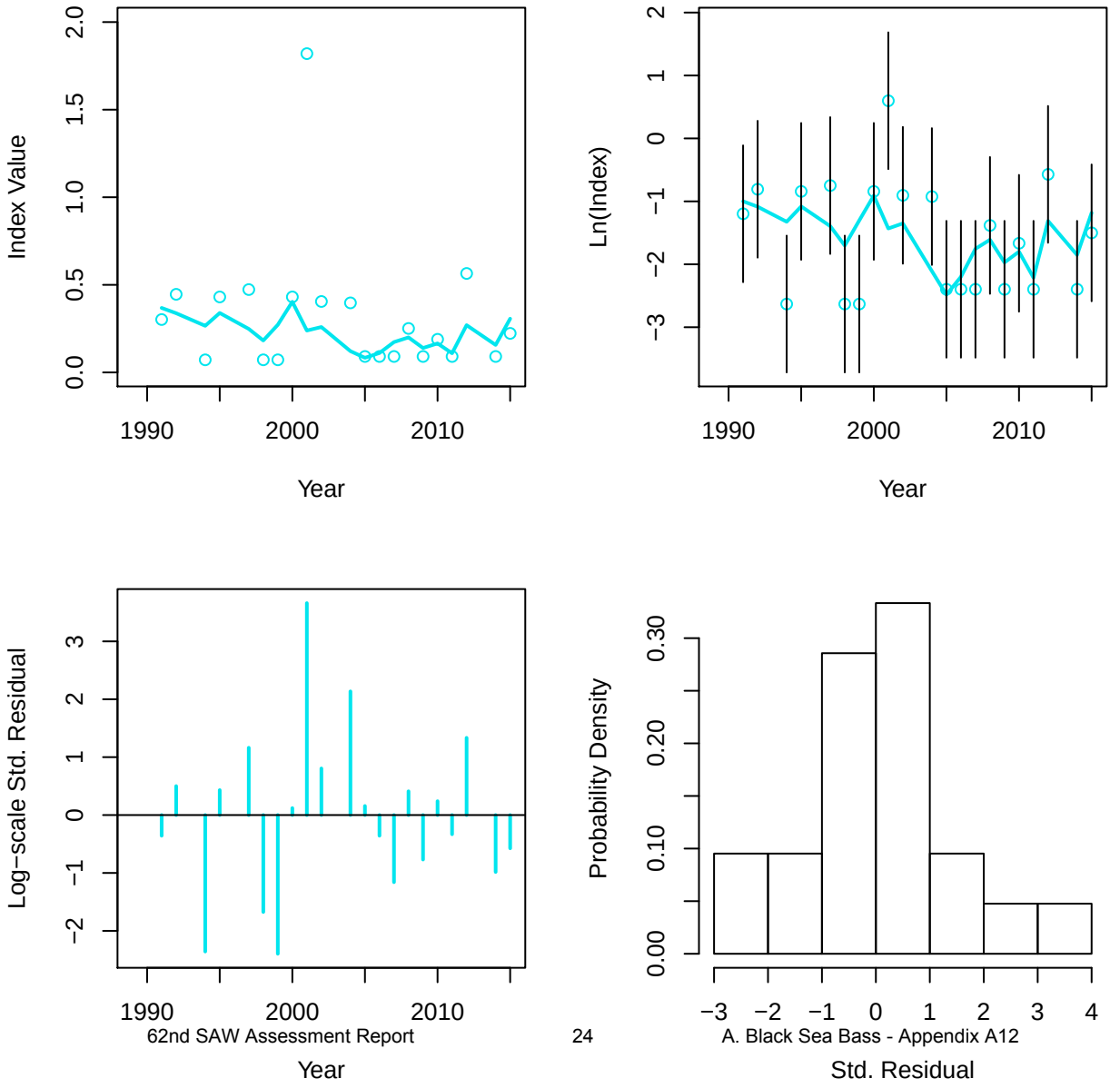
Index 2 (NEAMAP)



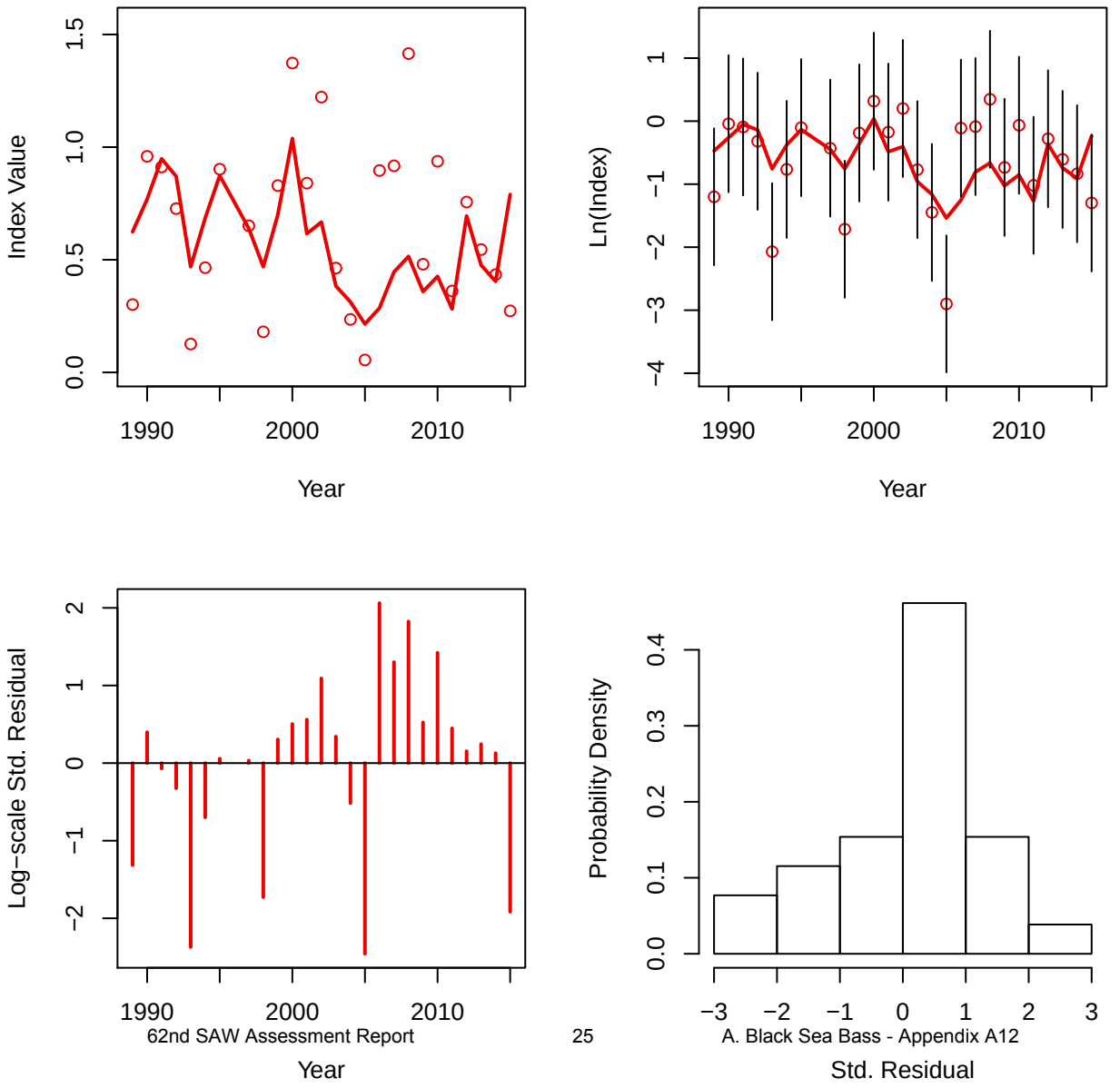
Index 3 (NJ)


Index Value
Year
Ln(Index)
Year
Log−scale Std. Residual
Year
Probability Density
Std. Residual

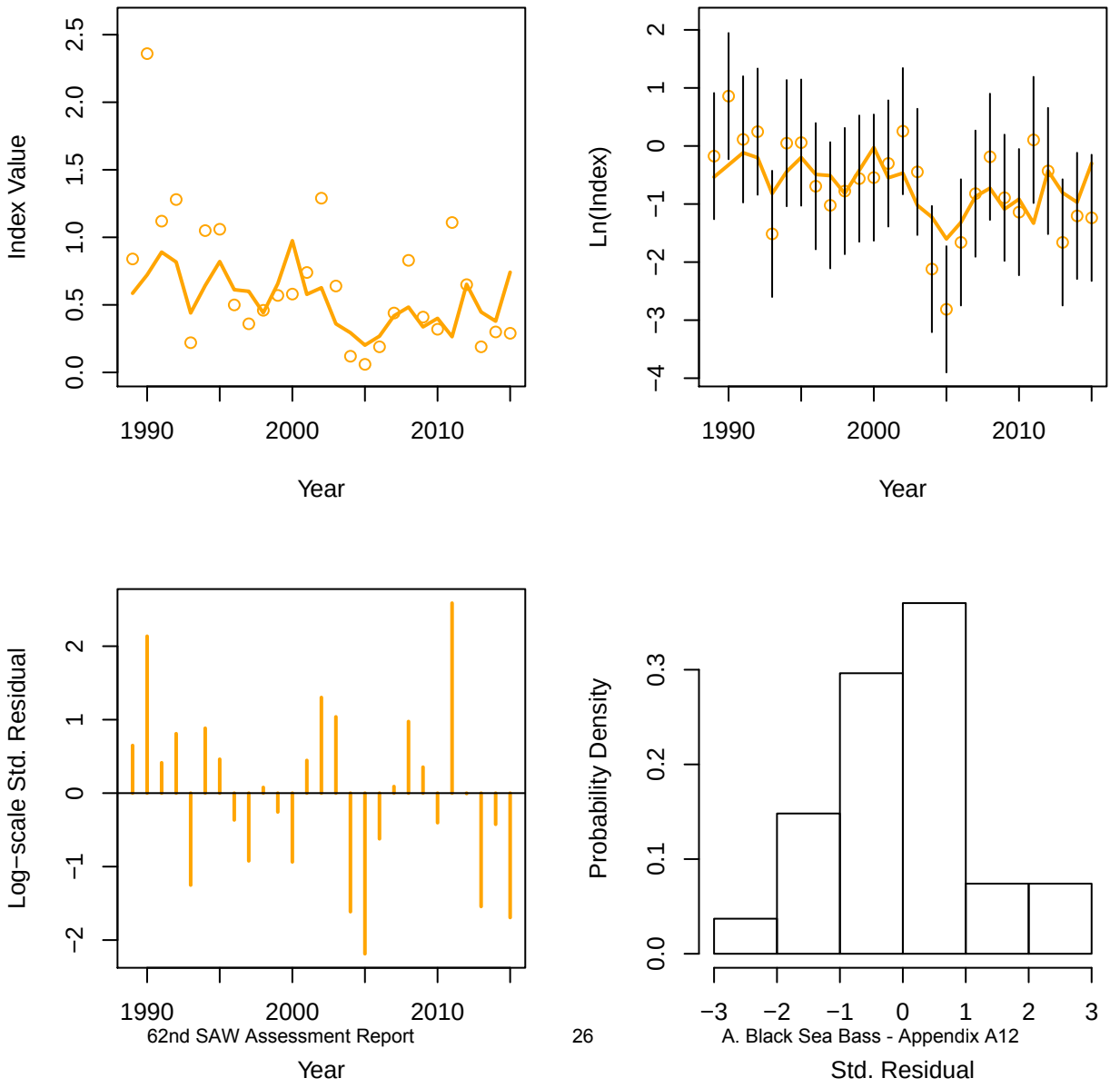
Index 4 (DE)


Index Value
0.0
0.5
1.0
1.5
2.0
1990
2000
2010
Year
Ln(Index)
−3
−2
−1
0
1
2
1990
2000
2010
Year
Log−scale Std. Residual
−2
−1
0
1
2
3
1990
2000
2010
Year
Probability Density
0.00
0.10
0.20
0.30
−3
−2
−1
0
1
2
3
4
Std. Residual

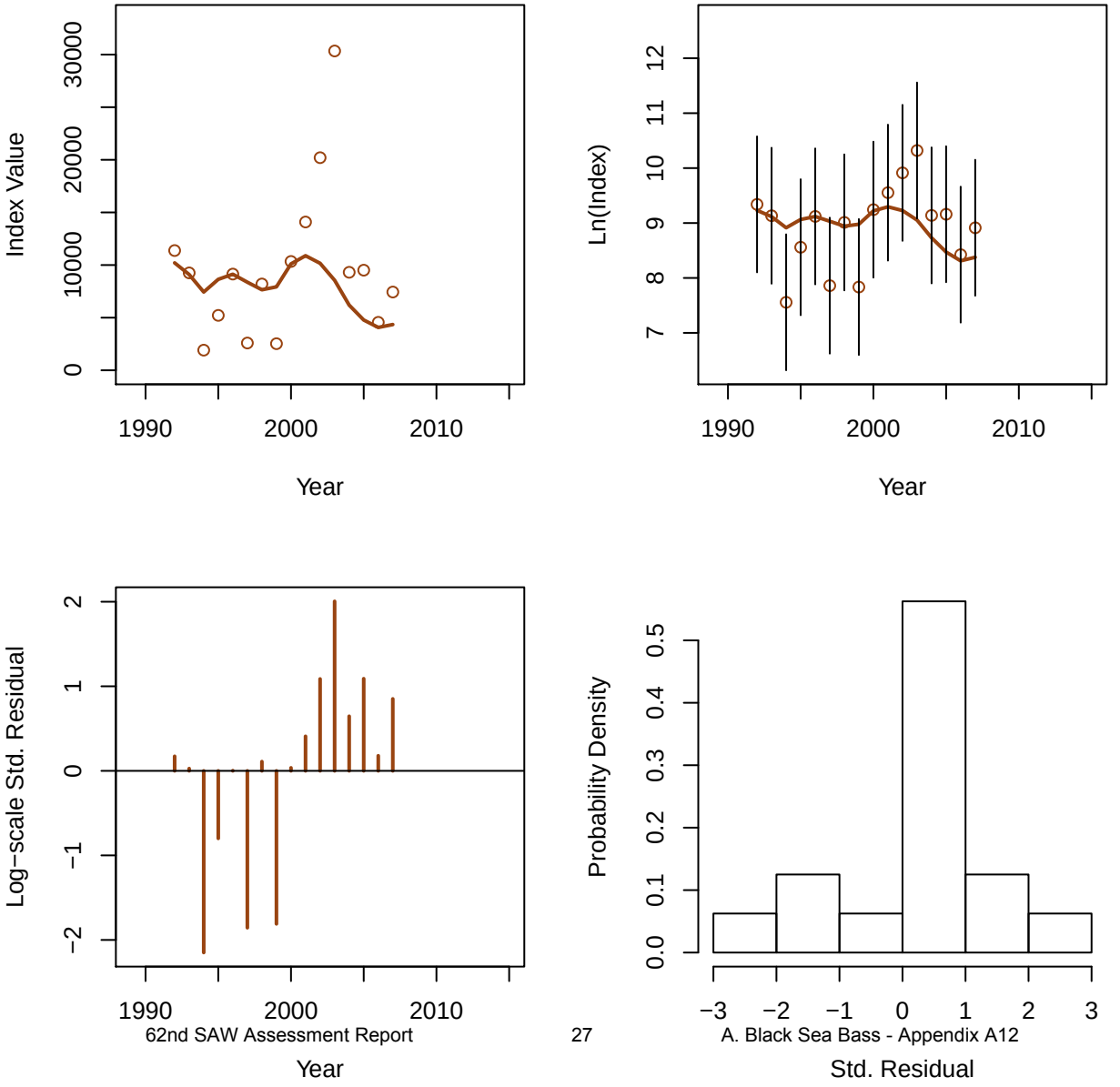
Index 5 (MD)


Index Value
0.0
0.5
1.0
1.5
1990
2000
2010
Year
Ln(Index)
−4
−3
−2
−1
0
1
1990
2000
2010
Year
Log−scale Std. Residual
−2
−1
0
1
2
1990
2000
2010
Year
Probability Density
0.0
0.1
0.2
0.3
0.4
−3
−2
−1
0
1
2
3
Std. Residual

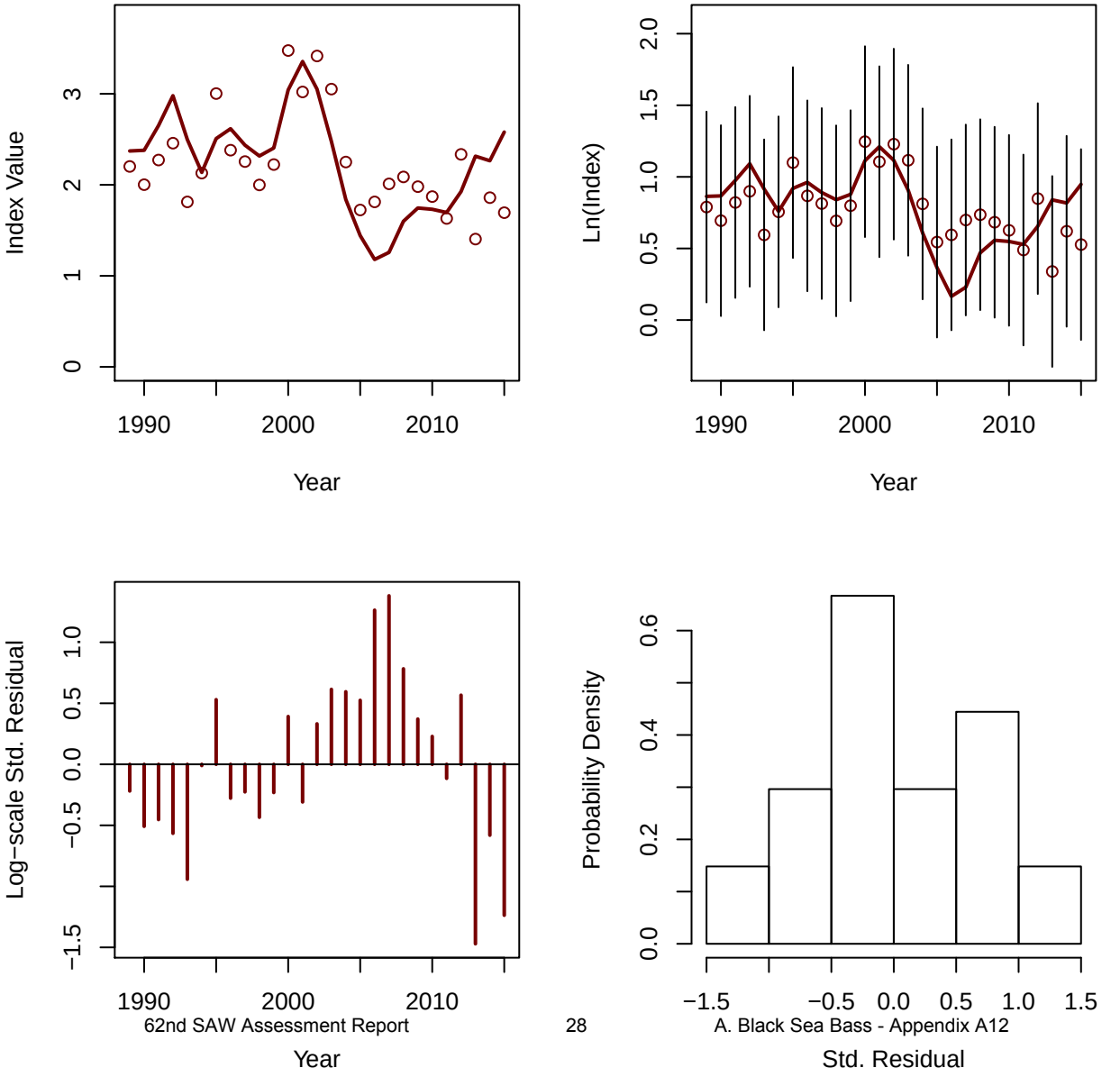
Index 6 (VIMS)


Index Value
0.0
0.5
1.0
1.5
2.0
2.5
1990
2000
2010
Year
Ln(Index)
−4
−3
−2
−1
0
1
2
1990
2000
2010
Year
Log−scale Std. Residual
−2
−1
0
1
2
1990
2000
2010
Year
Probability Density
0.0
0.1
0.2
0.3
−3
−2
−1
0
1
2
3
Std. Residual

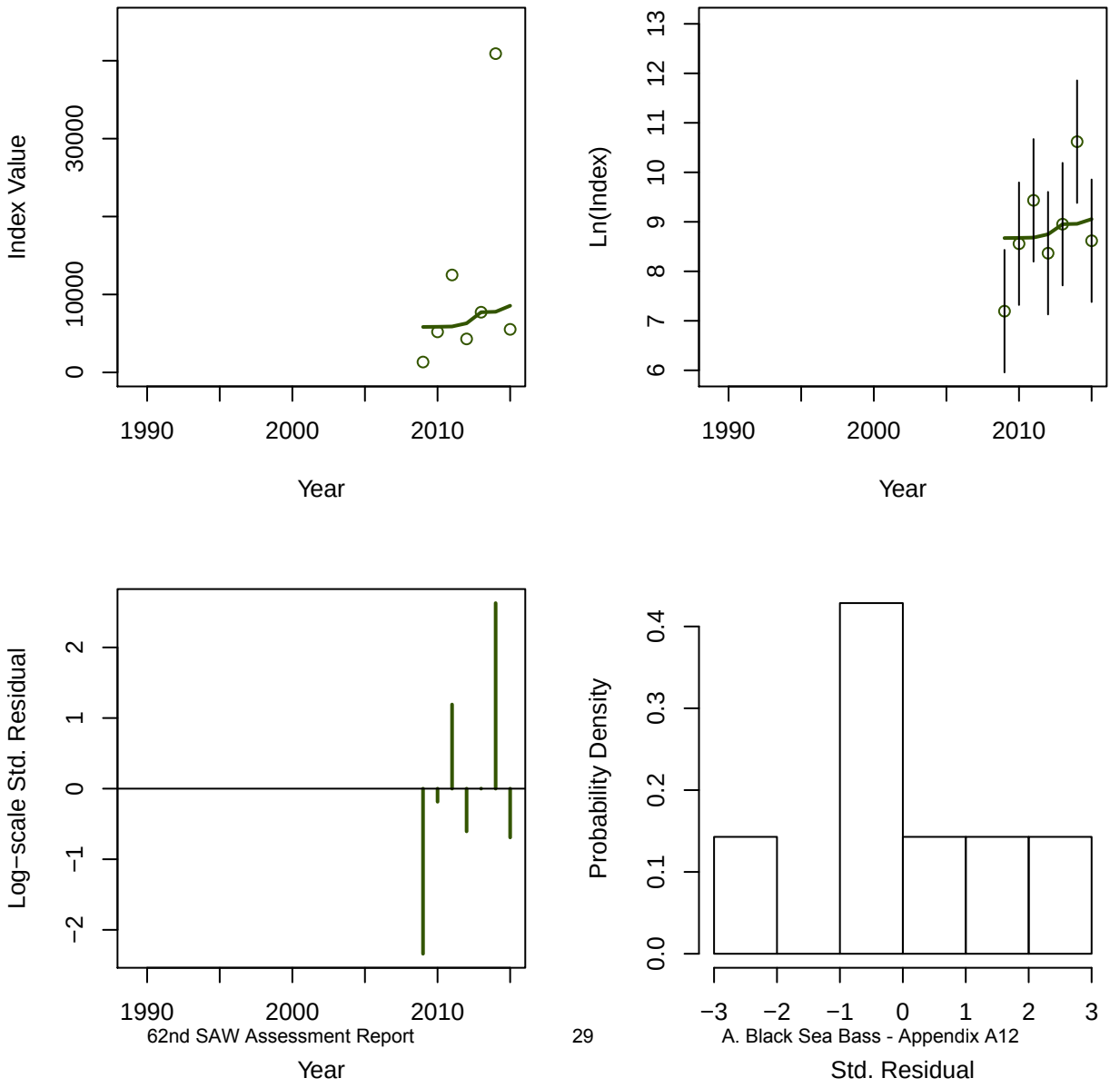
Index 7 (NEFSC winter)



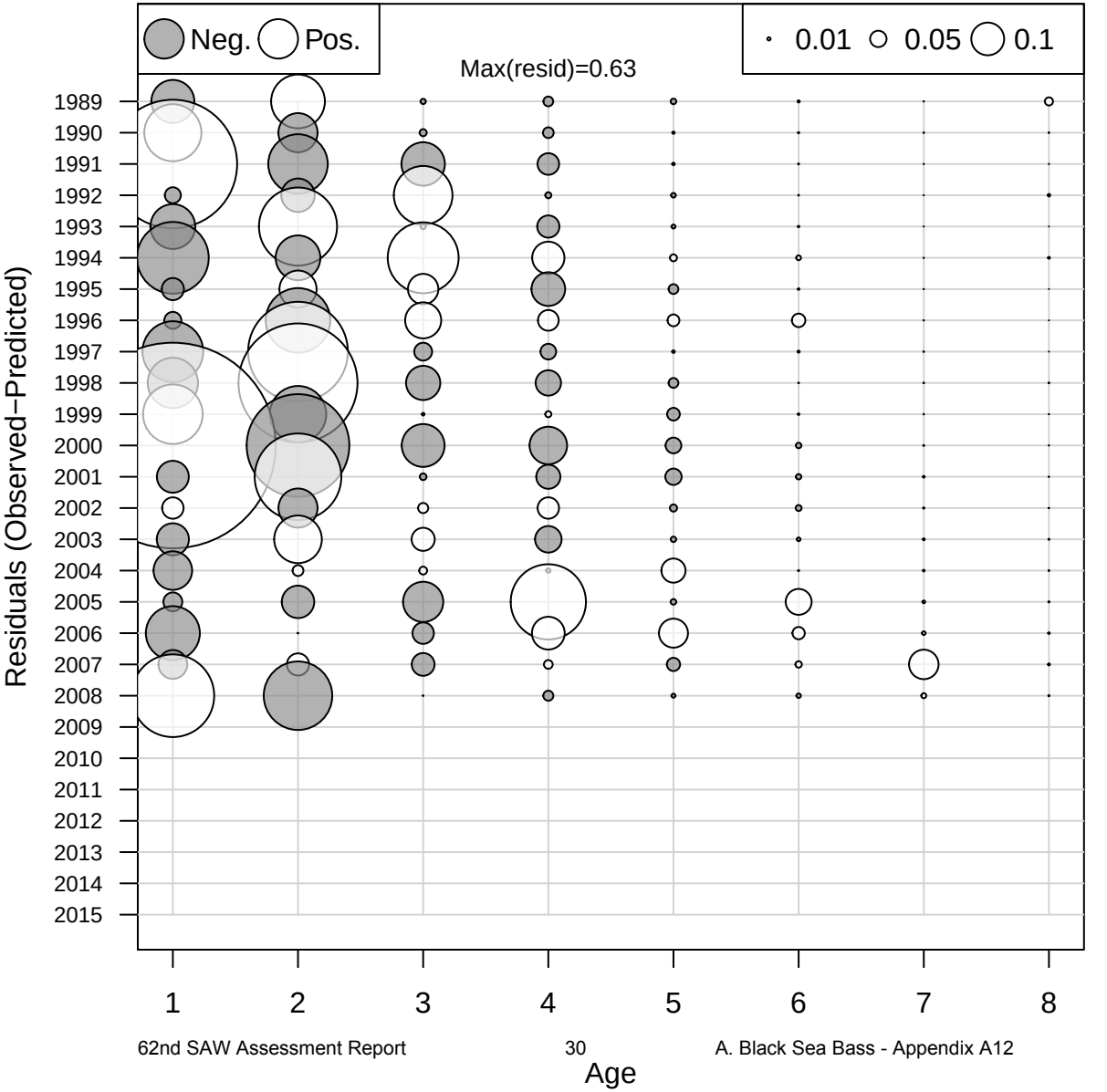
Index 8 (REC CPA)



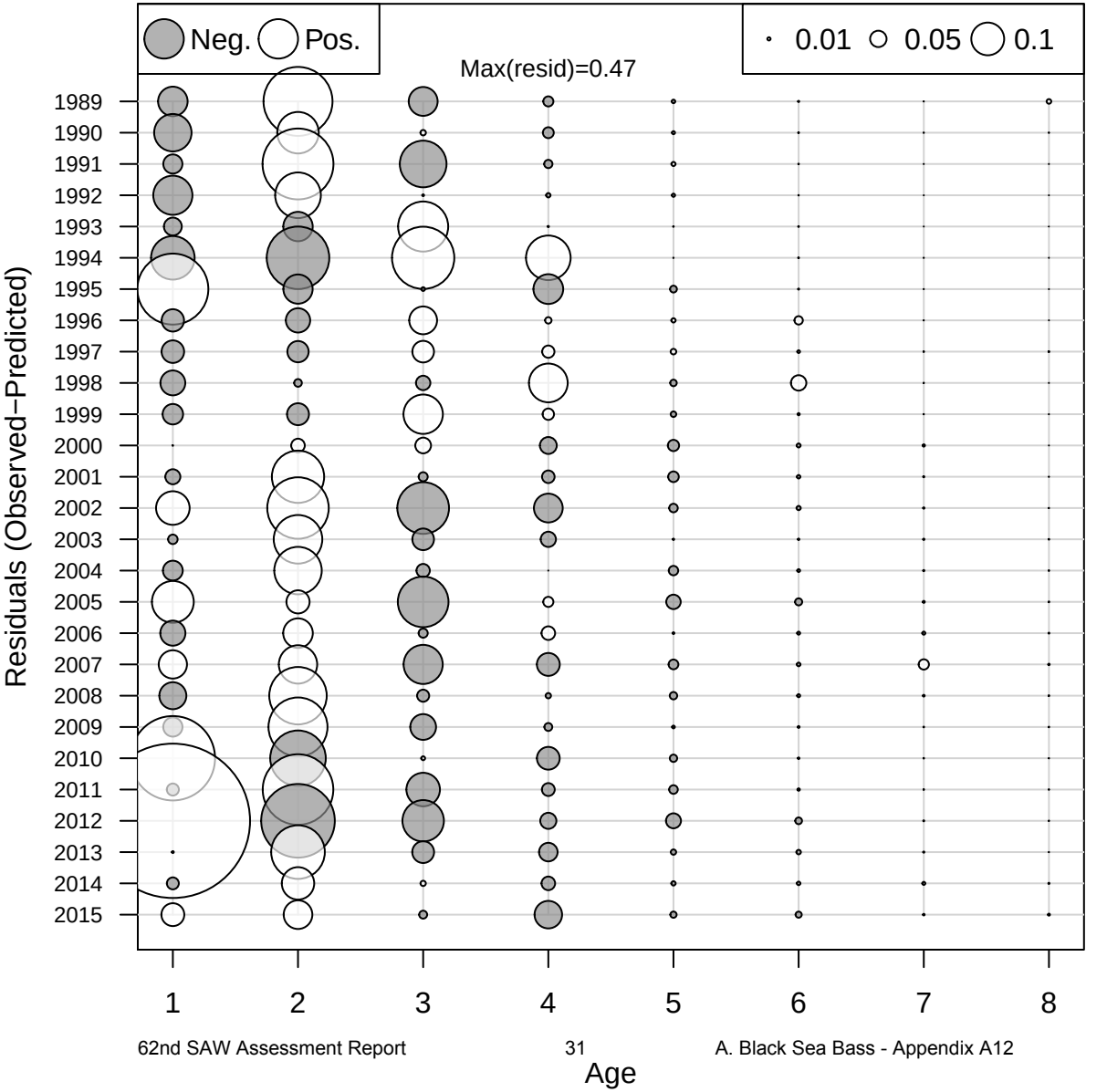
Index 9 (BIGELOW)



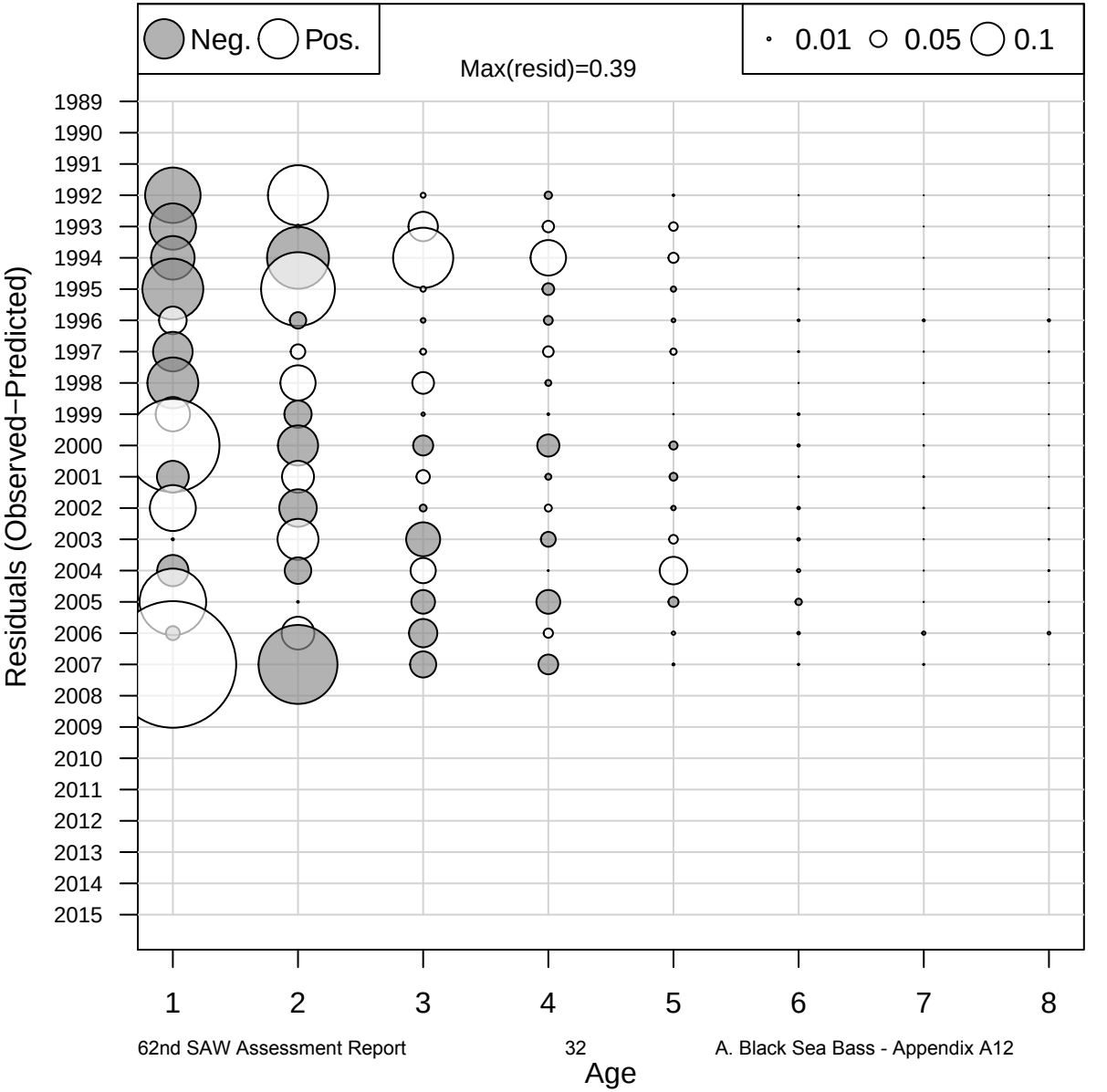
Age Comp Residuals for Index 1 (NEFSC spring Alb)



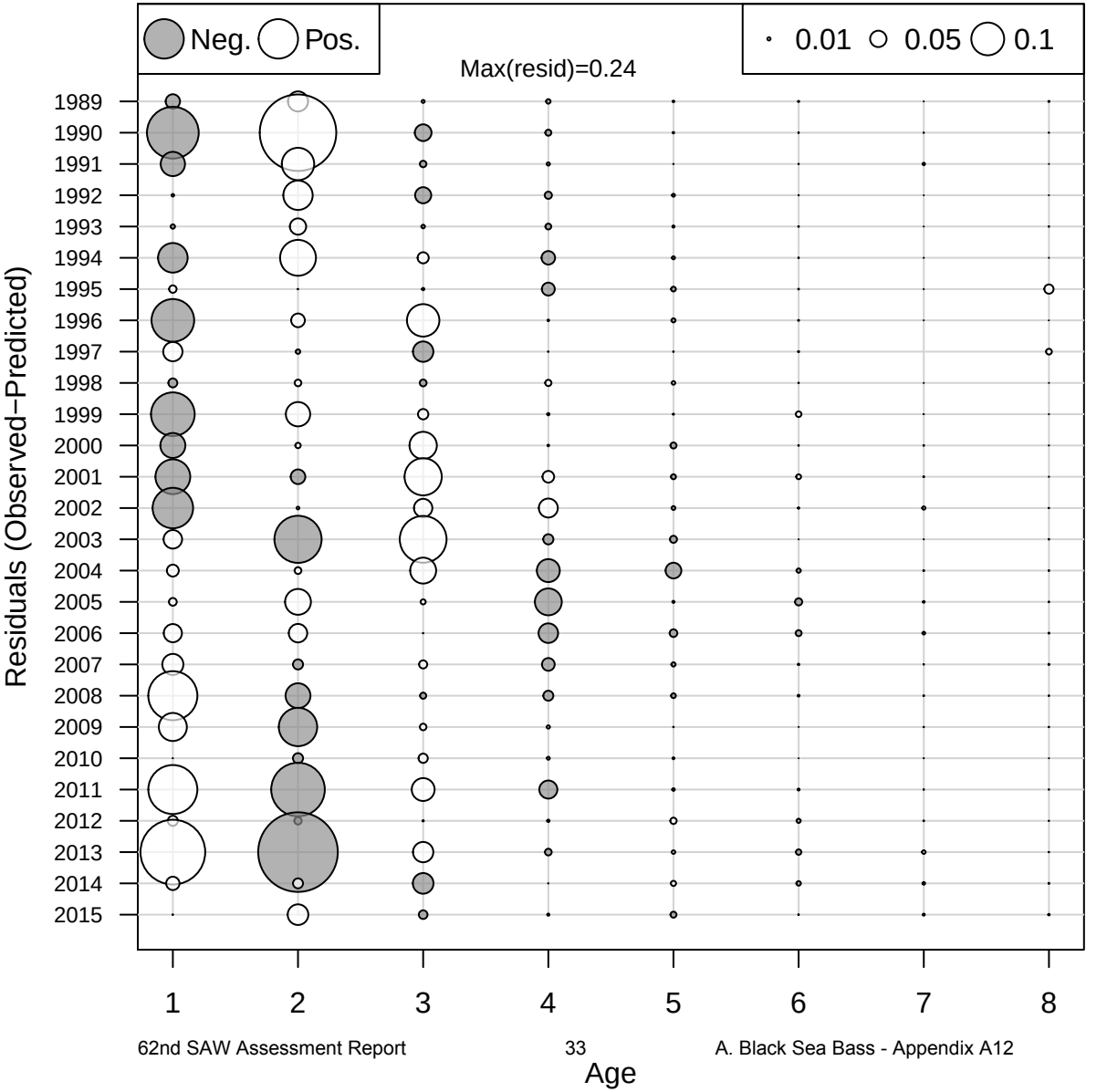
Age Comp Residuals for Index 3 (NJ)



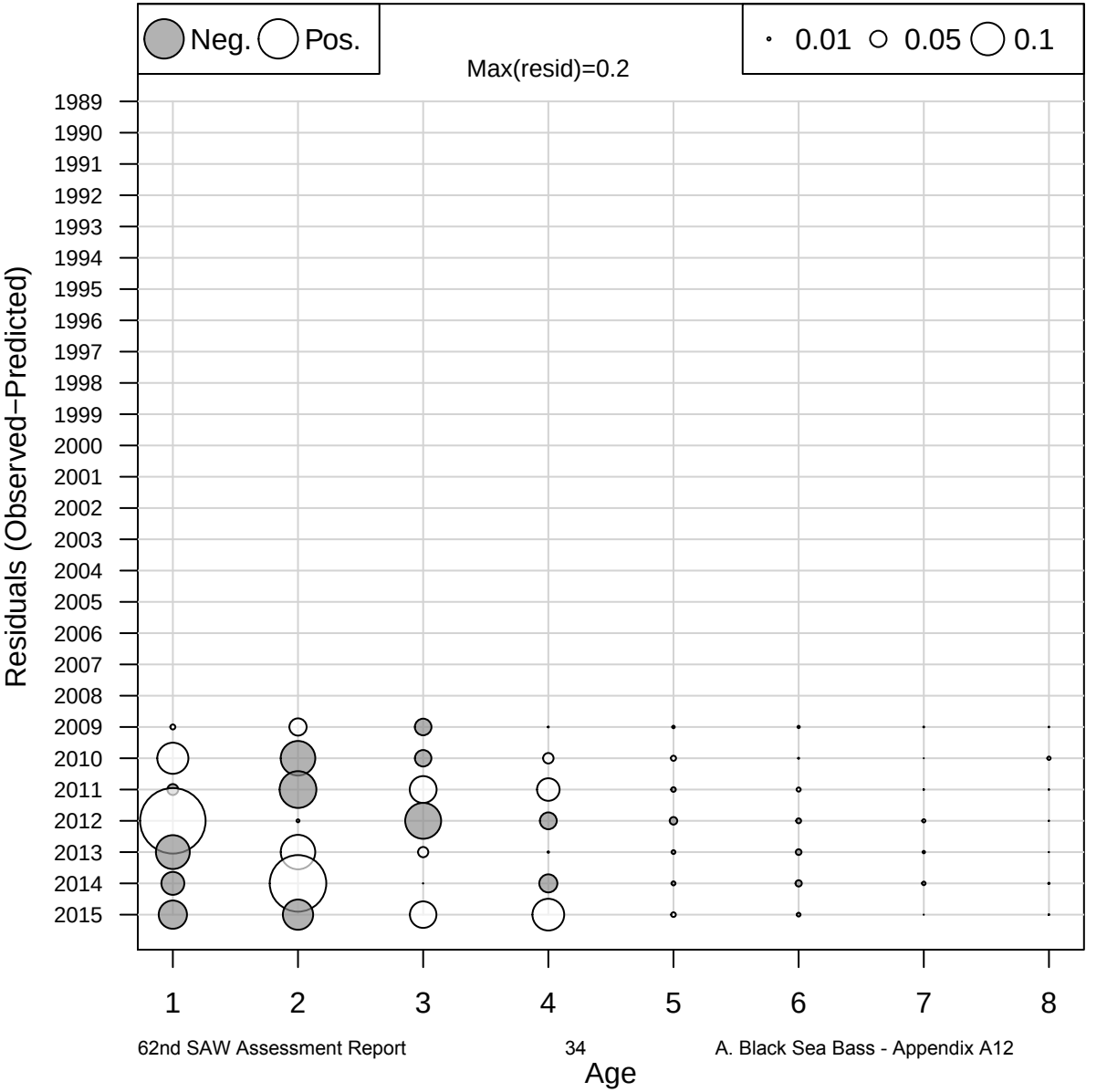
Age Comp Residuals for Index 7 (NEFSC winter)

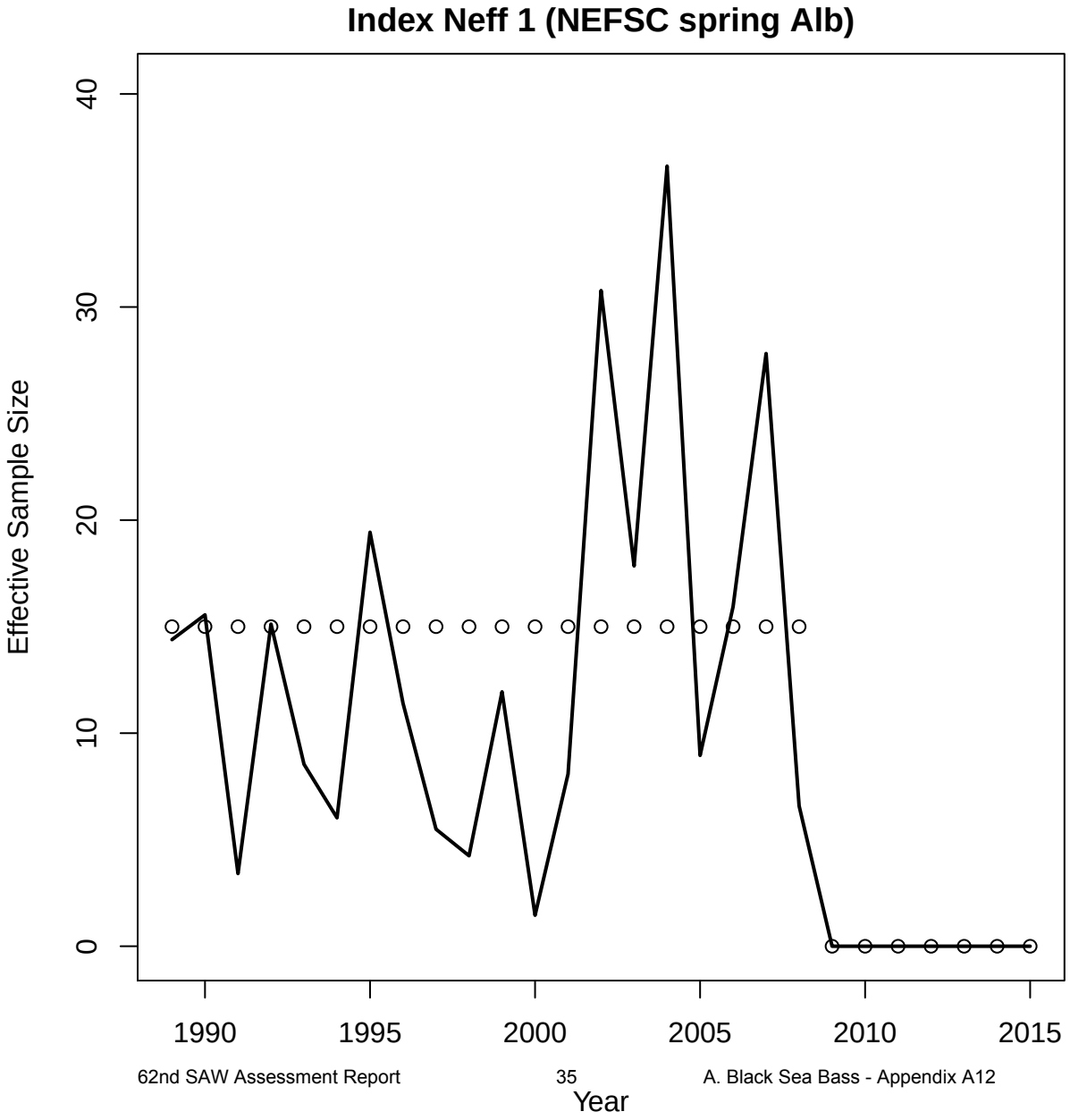


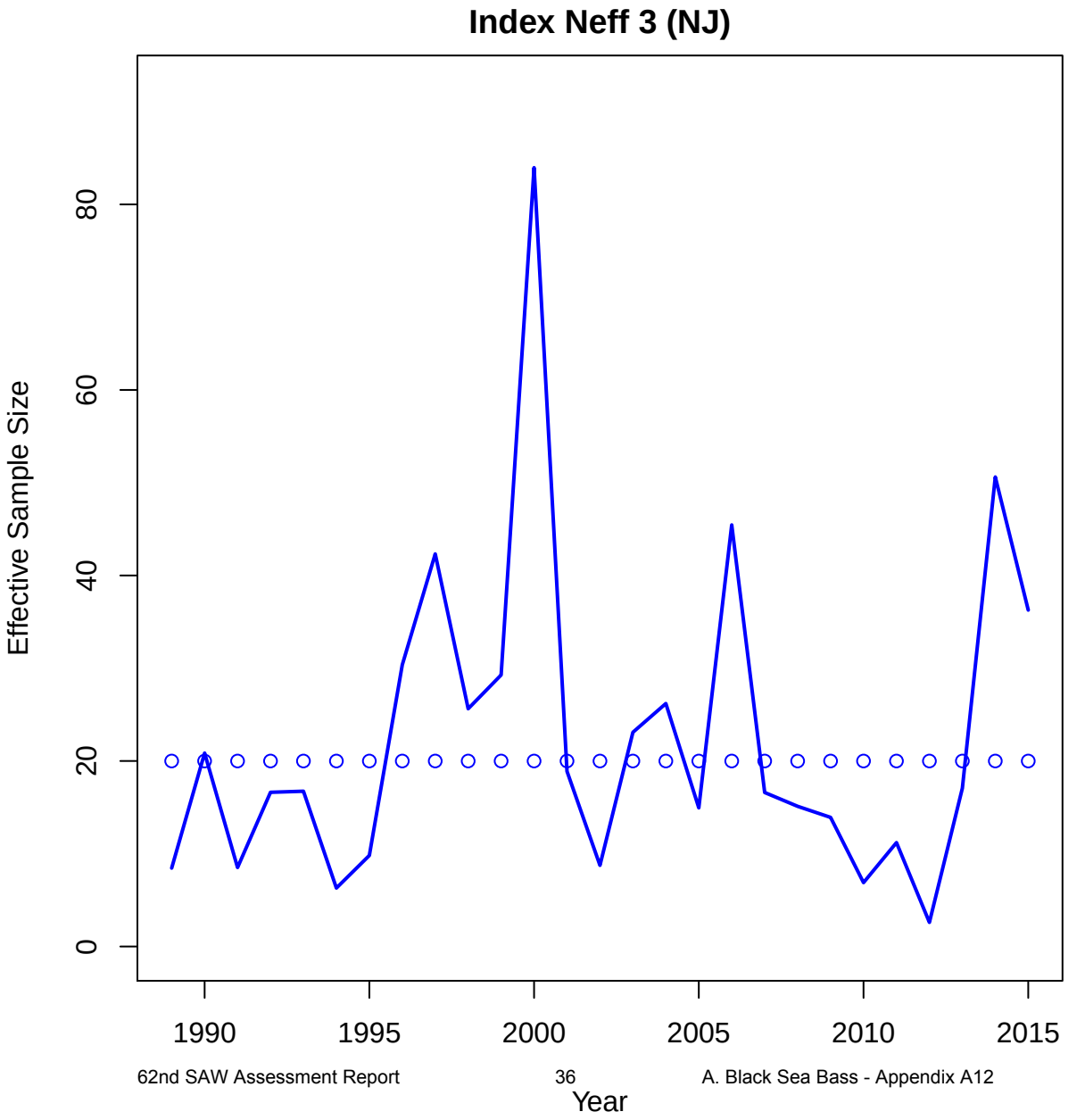
Age Comp Residuals for Index 8 (REC CPA)

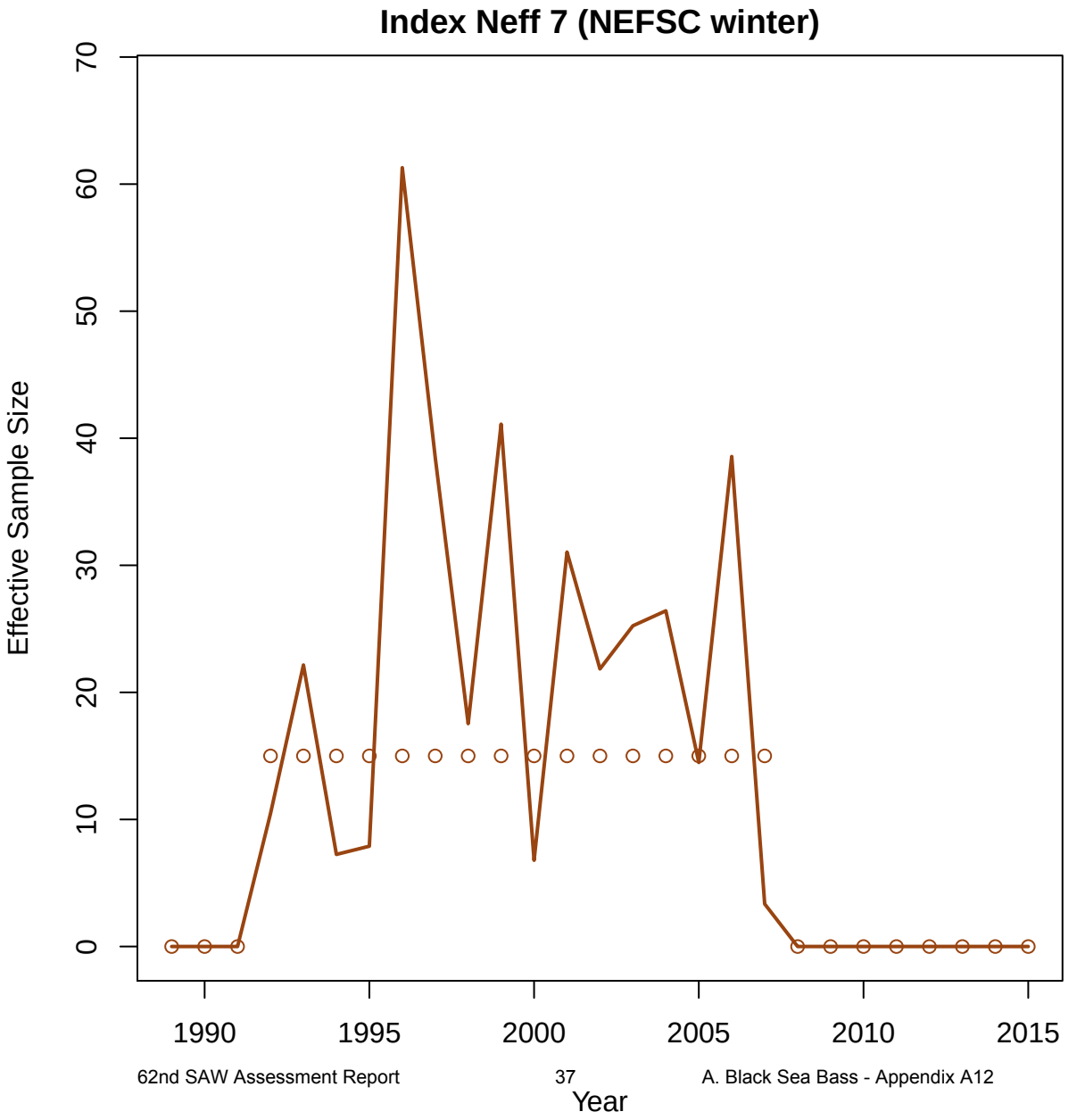


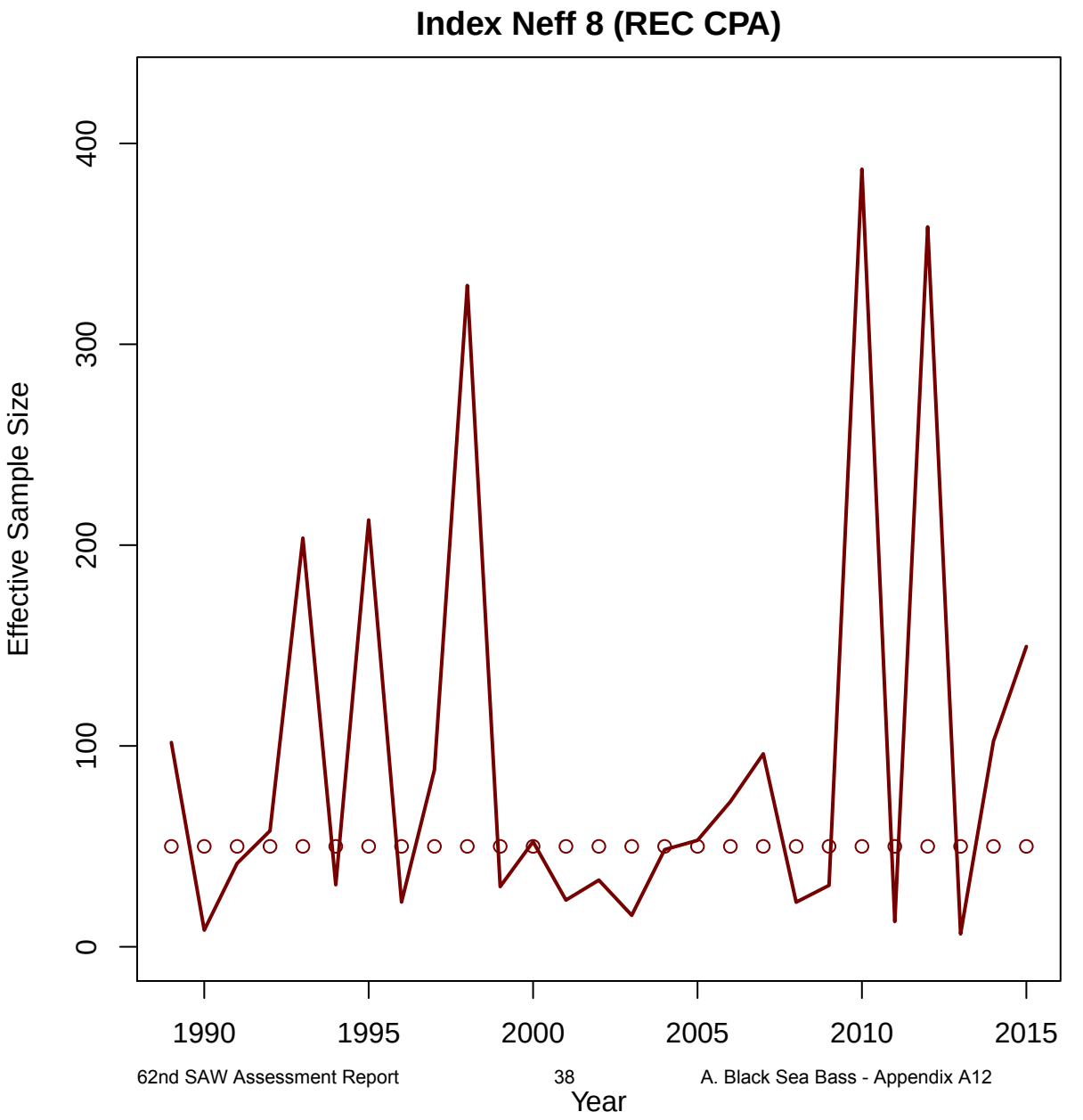
Age Comp Residuals for Index 9 (BIGELOW)

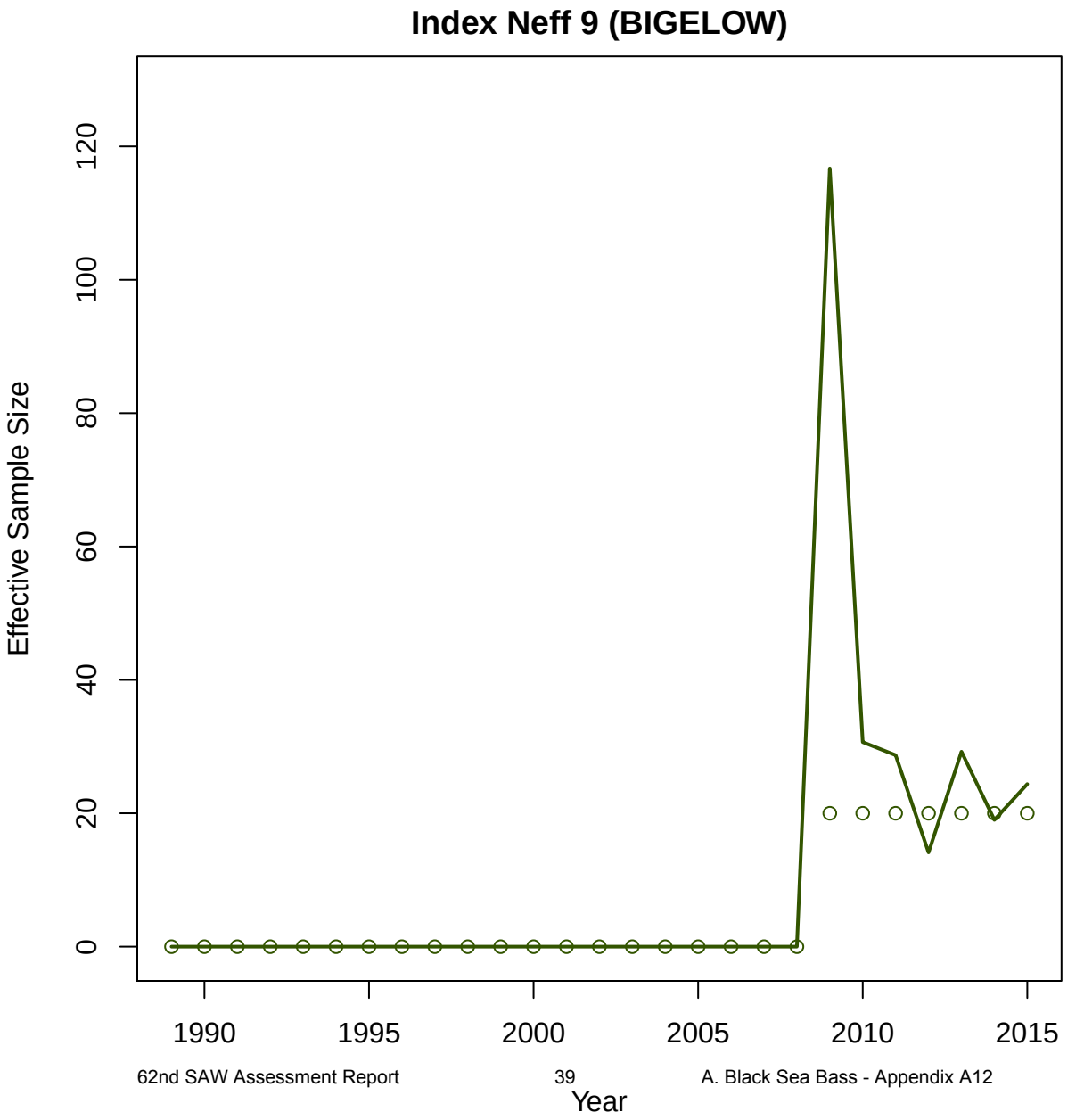


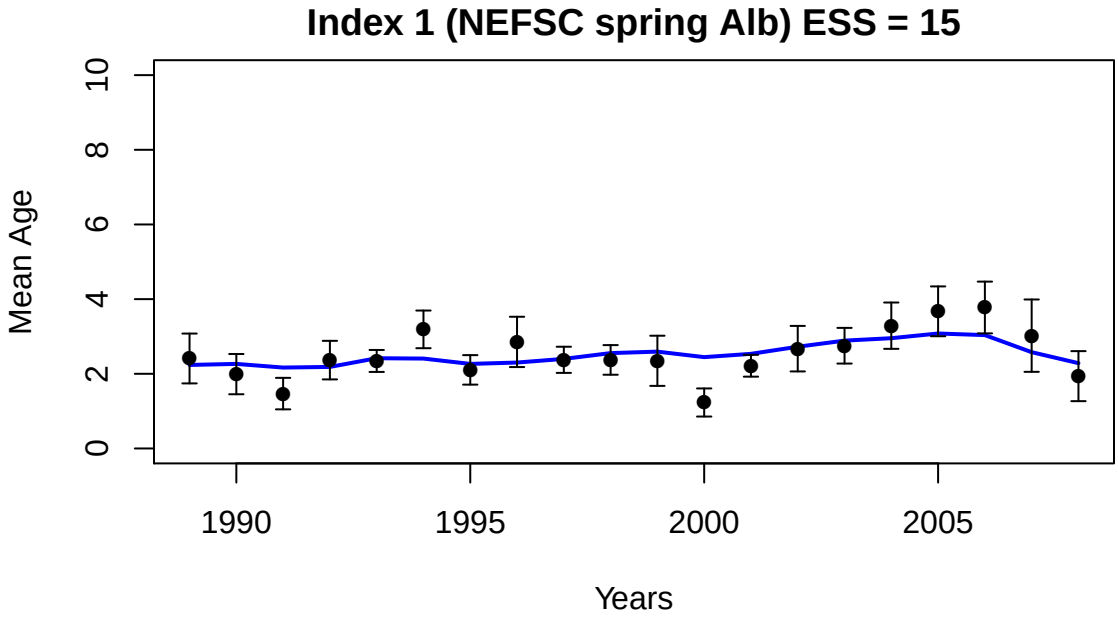

Index Neff 1 (NEFSC spring Alb)
Effective Sample Size
0
10
20
30
40
1990
1995
2000
2005
2010
2015
Year

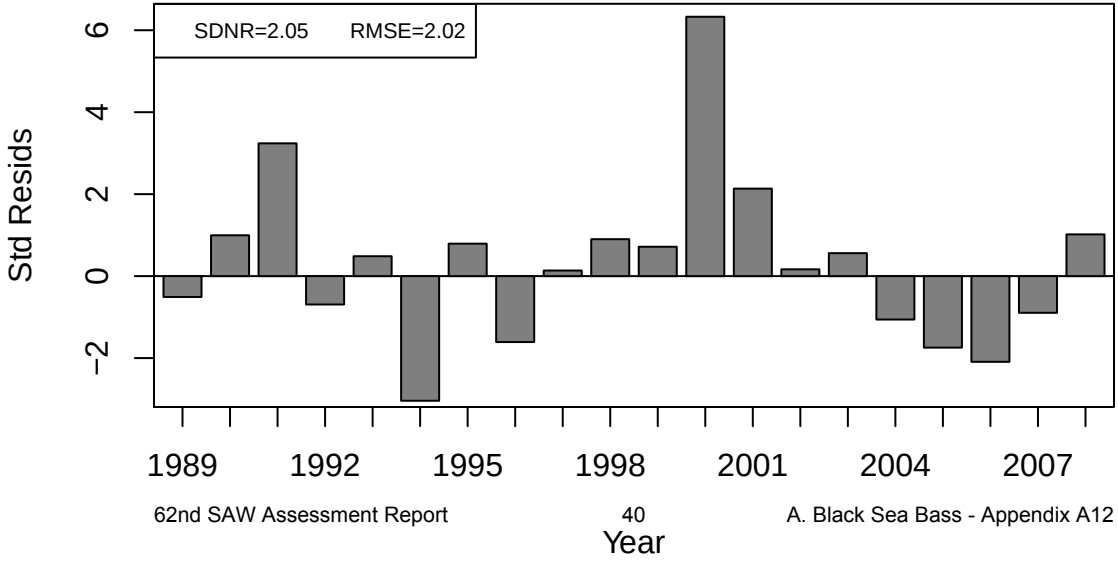

Index Neff 3 (NJ)
Effective Sample Size
0
20
40
60
80
1990
1995
2000
2005
2010
2015
Year

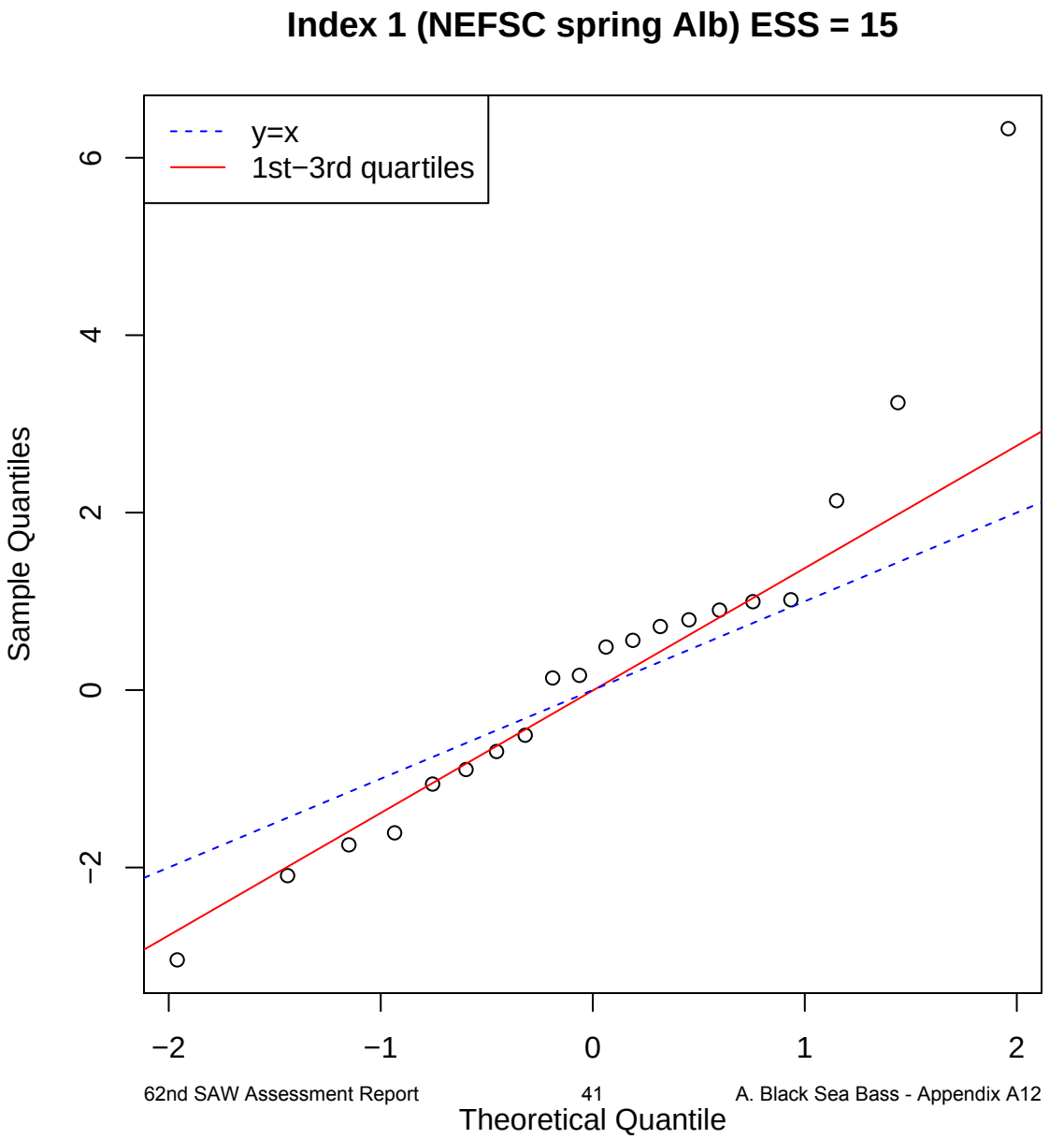

Index Neff 7 (NEFSC winter)
Effective Sample Size
0
10
20
30
40
50
60
70
1990
1995
2000
2005
2010
2015
Year

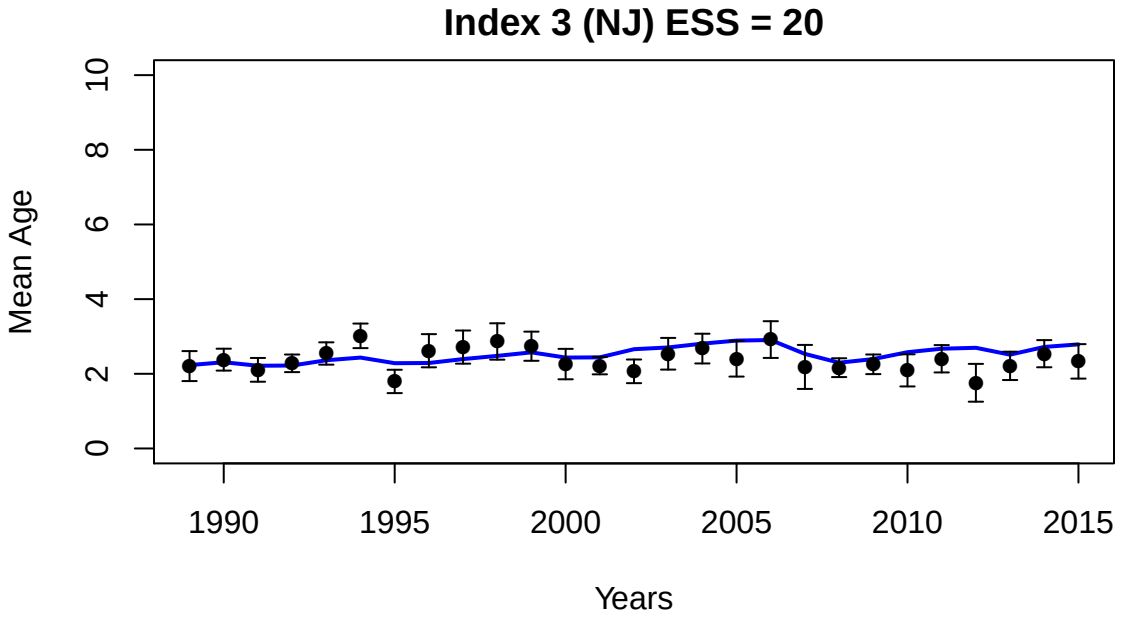

Index Neff 8 (REC CPA)
Effective Sample Size
0
100
200
300
400
1990
1995
2000
2005
2010
2015
Year

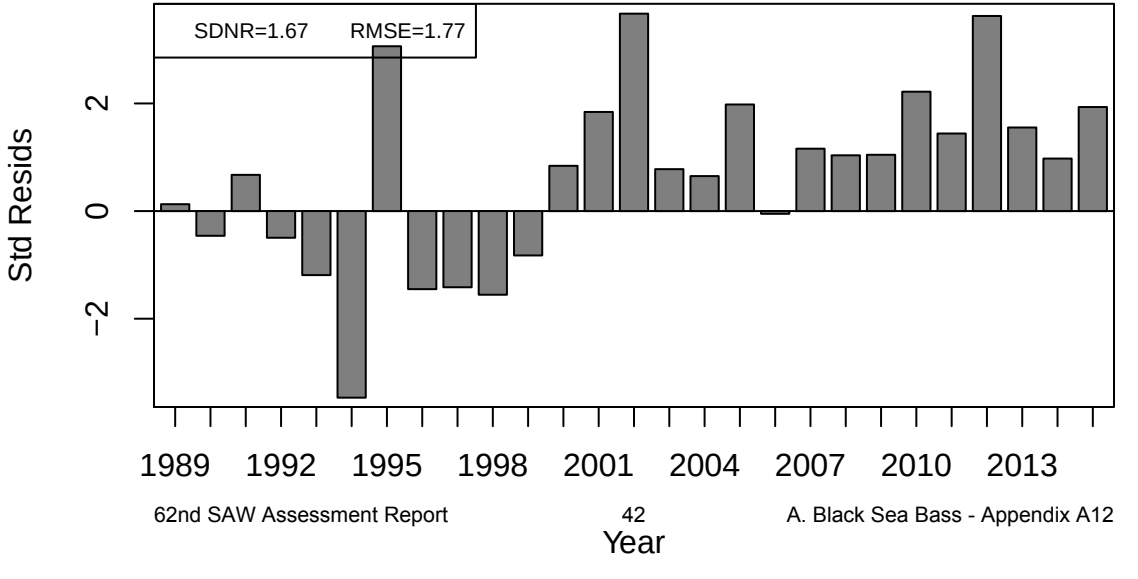

Index Neff 9 (BIGELOW)
Effective Sample Size
0
20
40
60
80
100
120
1990
1995
2000
2005
2010
2015
Year

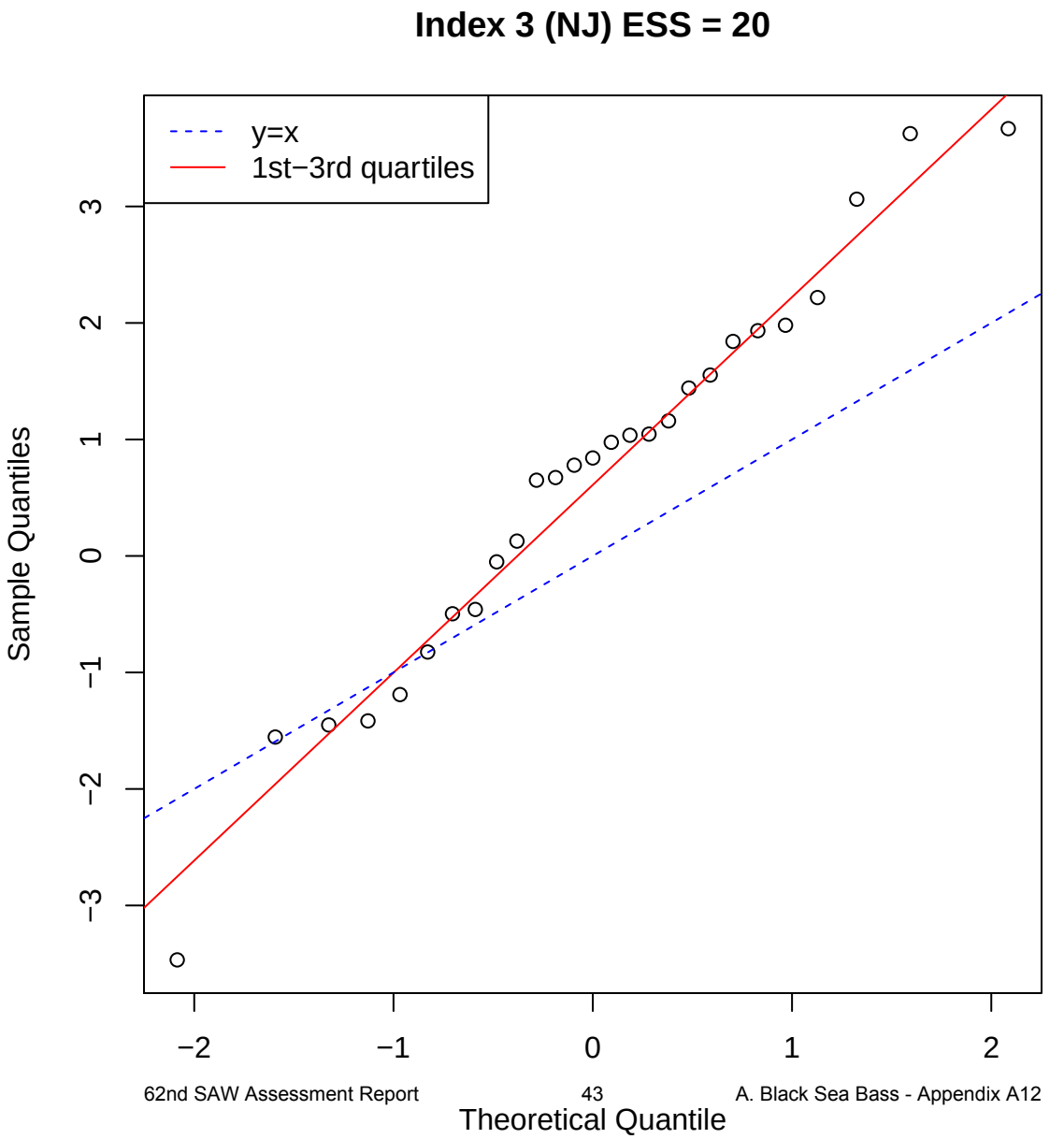

Index 1 (NEFSC spring Alb) ESS = 15
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
Years

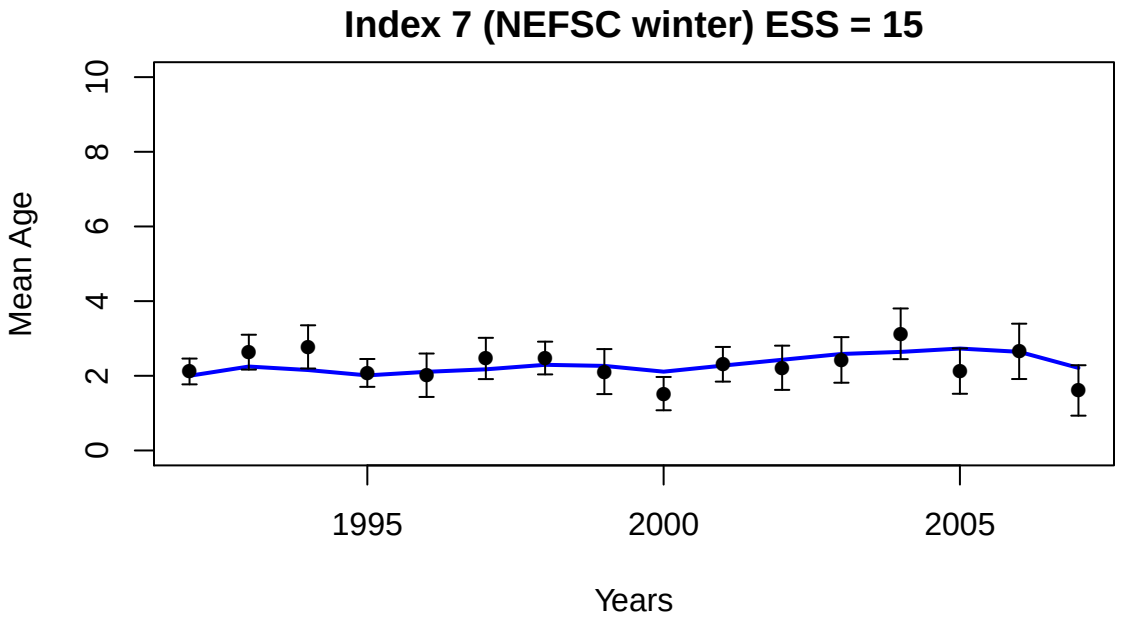

SDNR=2.05
RMSE=2.02
Std Resids
−2
0
2
4
6
1989
1992
1995
1998
2001
2004
2007
Year

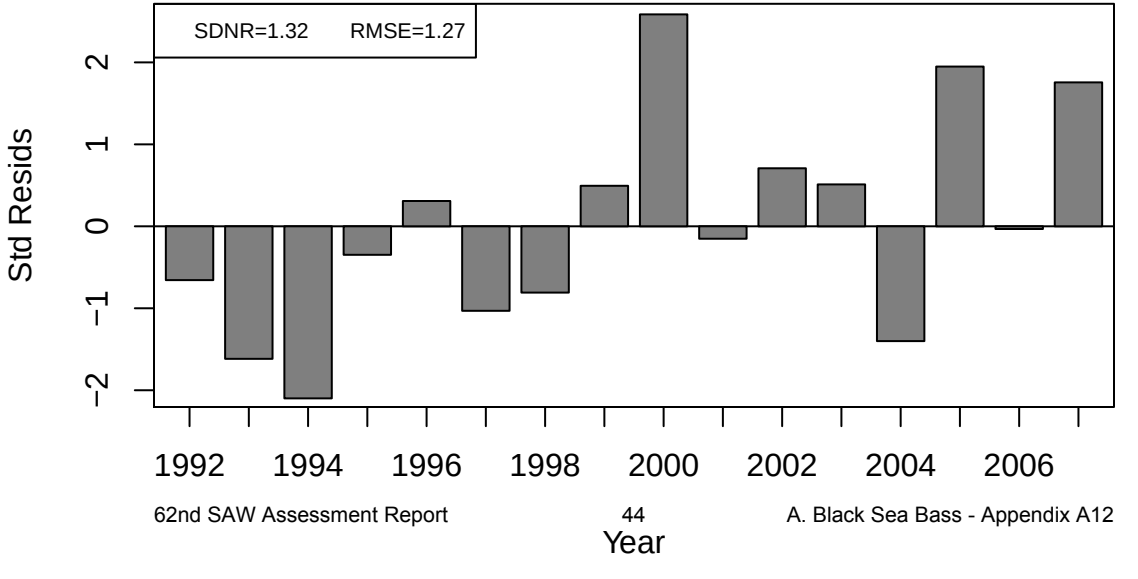

Index 1 (NEFSC spring Alb) ESS = 15
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
0
2
4
6
−2
−1
0
1
2

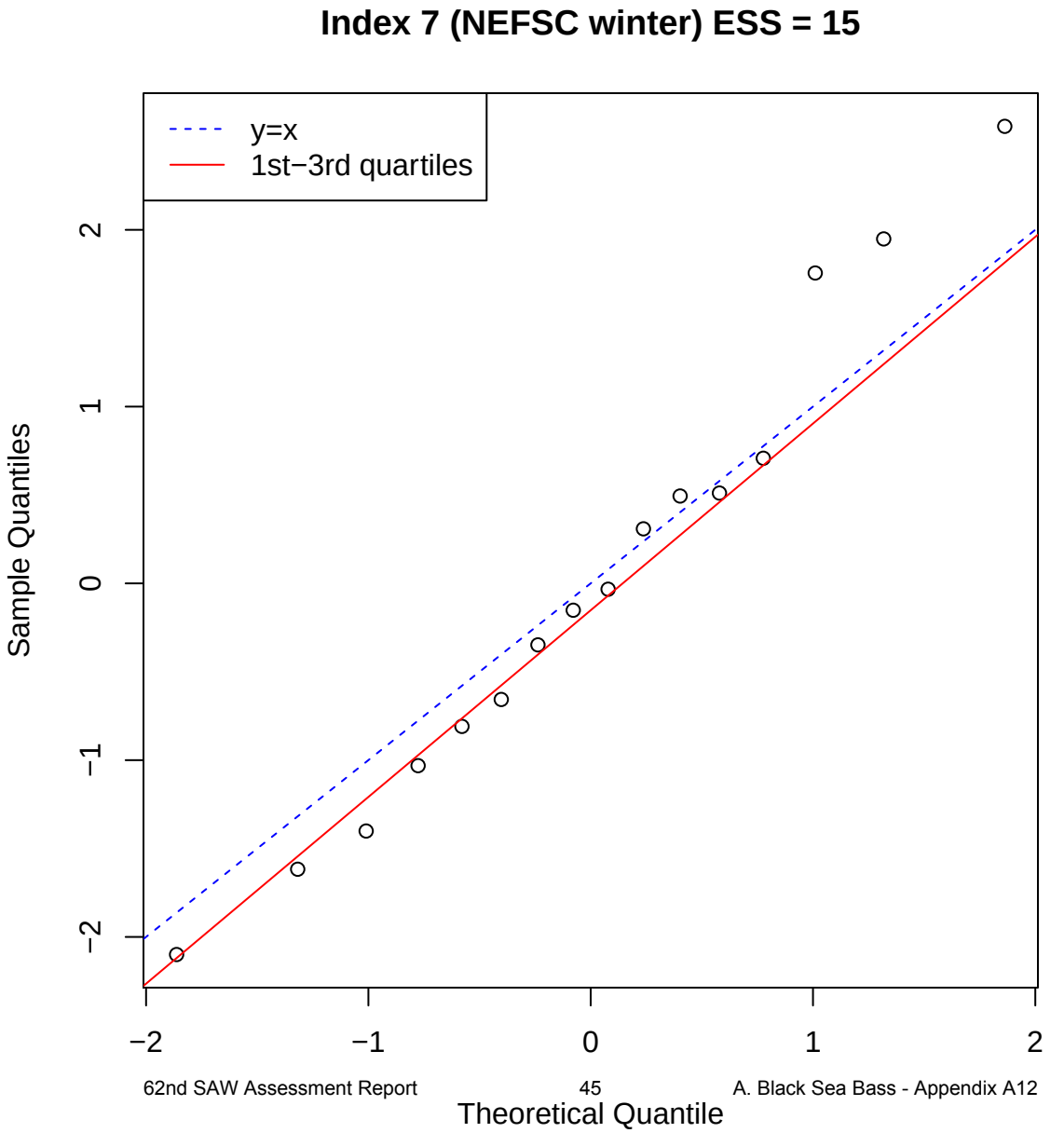

Index 3 (NJ) ESS = 20
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

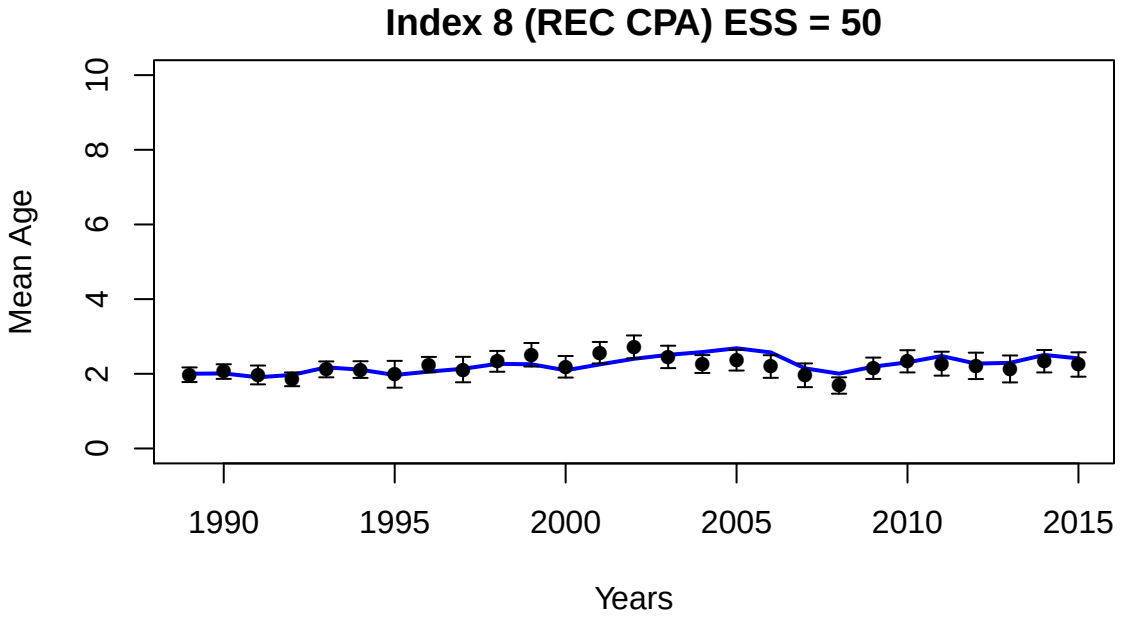

SDNR=1.67
RMSE=1.77
Std Resids
−2
0
2
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

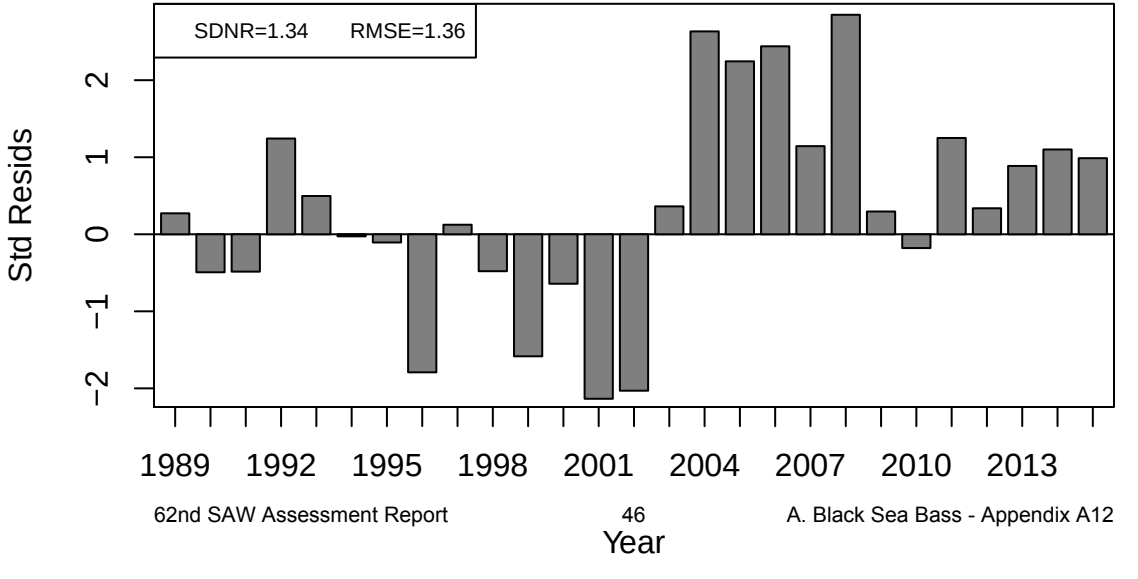

Index 3 (NJ) ESS = 20
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−3
−2
−1
0
1
2
3
−2
−1
0
1
2

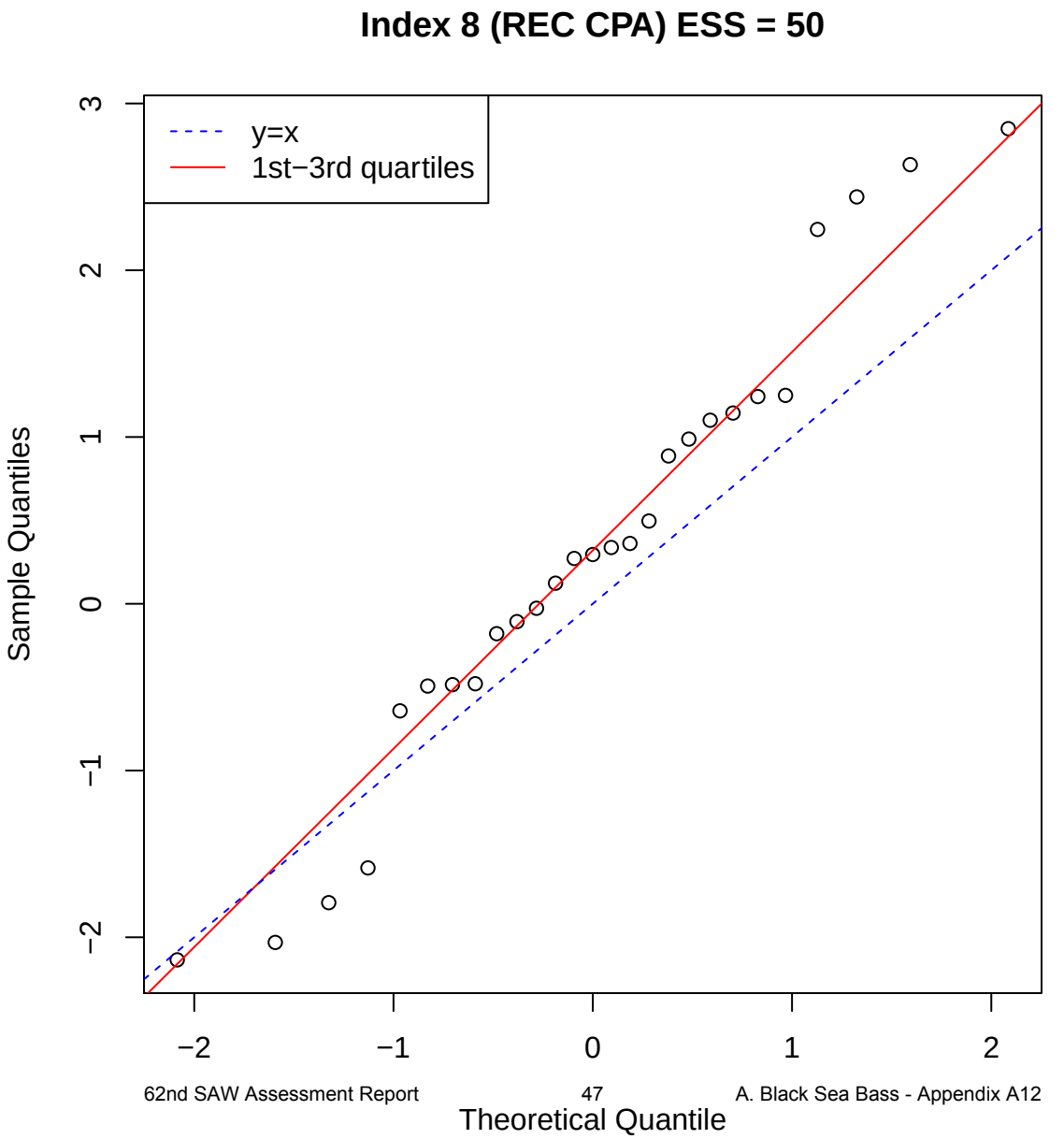

Index 7 (NEFSC winter) ESS = 15
Mean Age
0
2
4
6
8
10
1995
2000
2005
Years

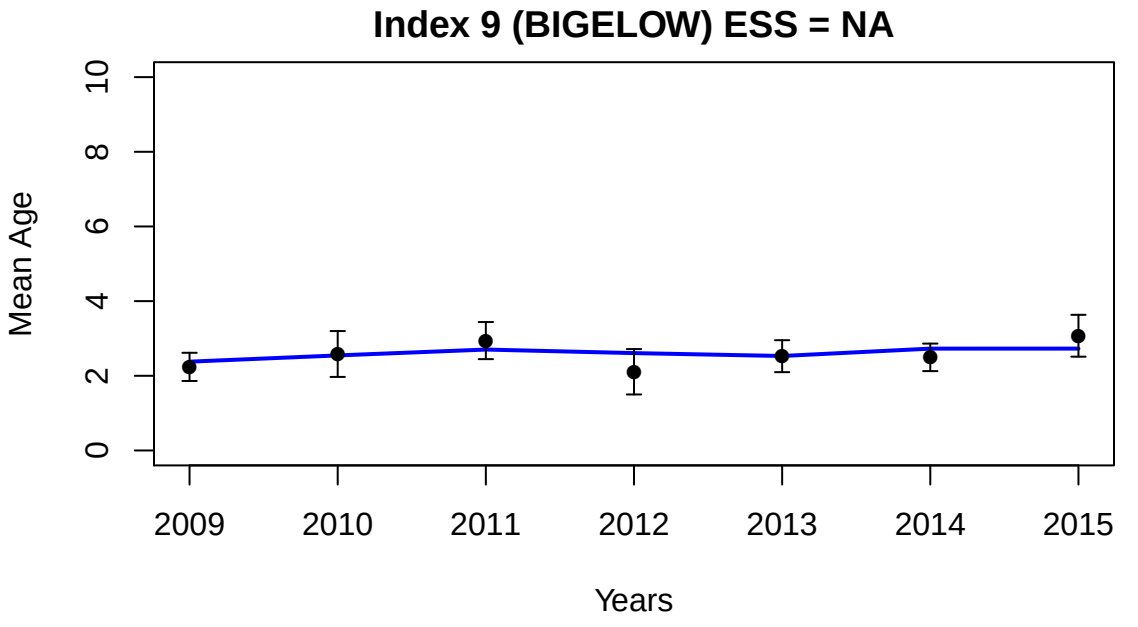

SDNR=1.32
RMSE=1.27
Std Resids
−2
−1
0
1
2
1992
1994
1996
1998
2000
2002
2004
2006
Year

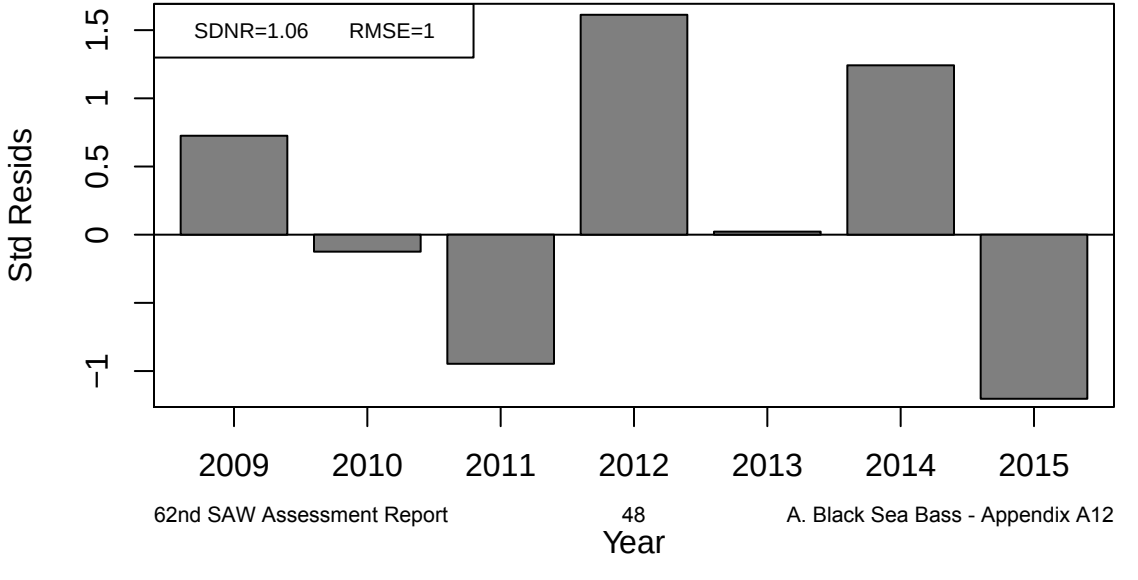

Index 7 (NEFSC winter) ESS = 15
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
−1
0
1
2

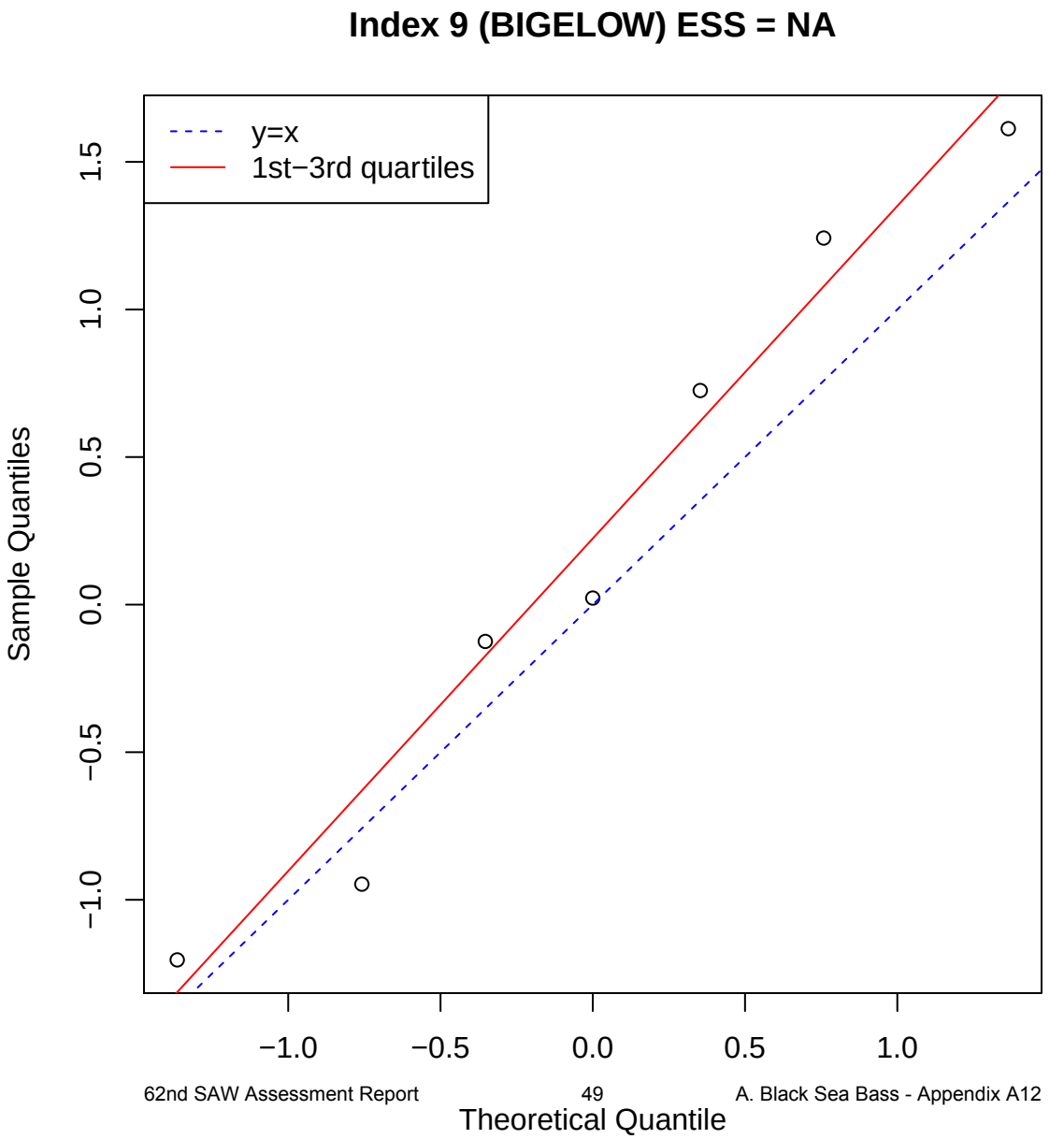

Index 8 (REC CPA) ESS = 50
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

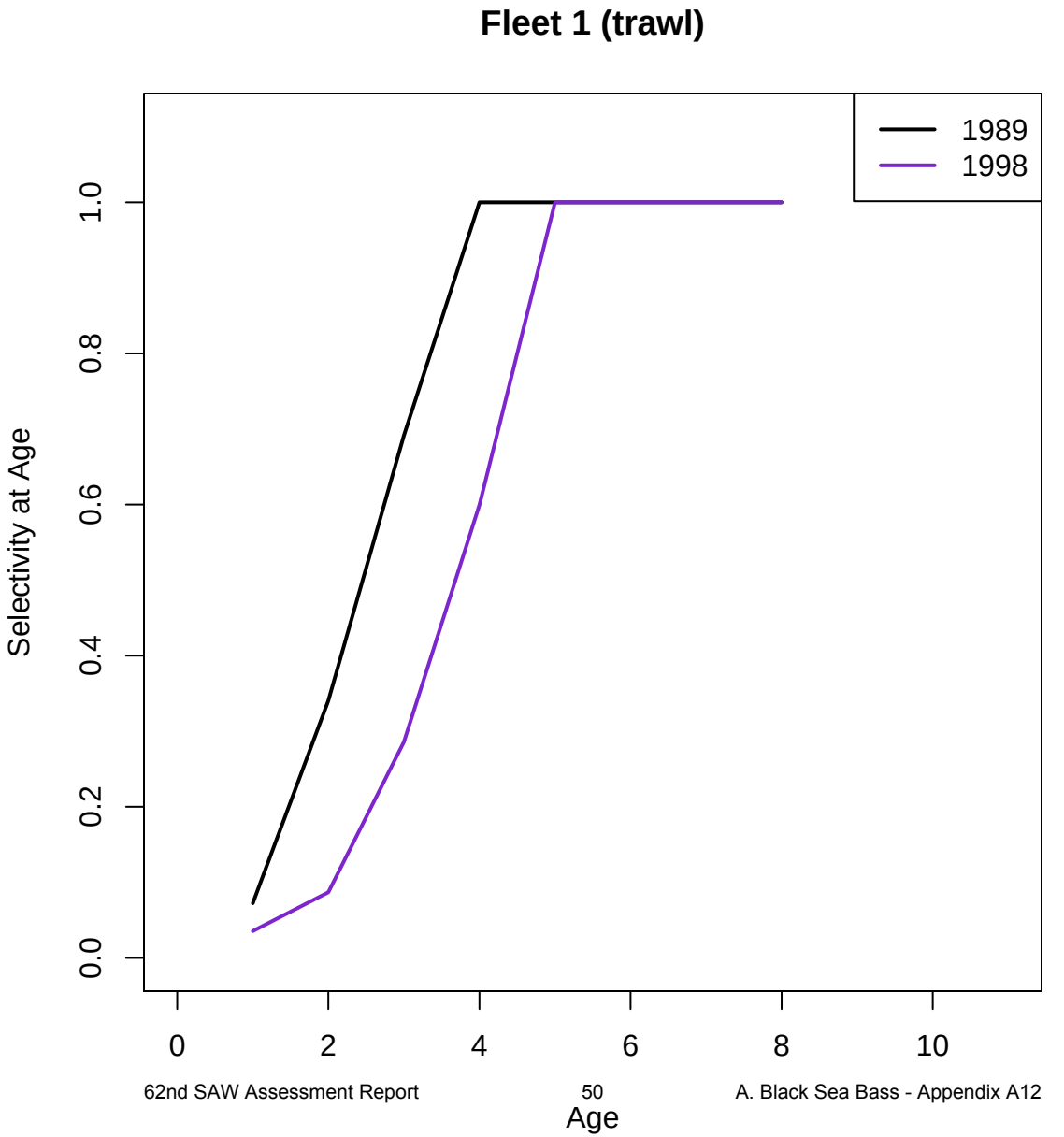

SDNR=1.34
RMSE=1.36
Std Resids
−2
−1
0
1
2
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

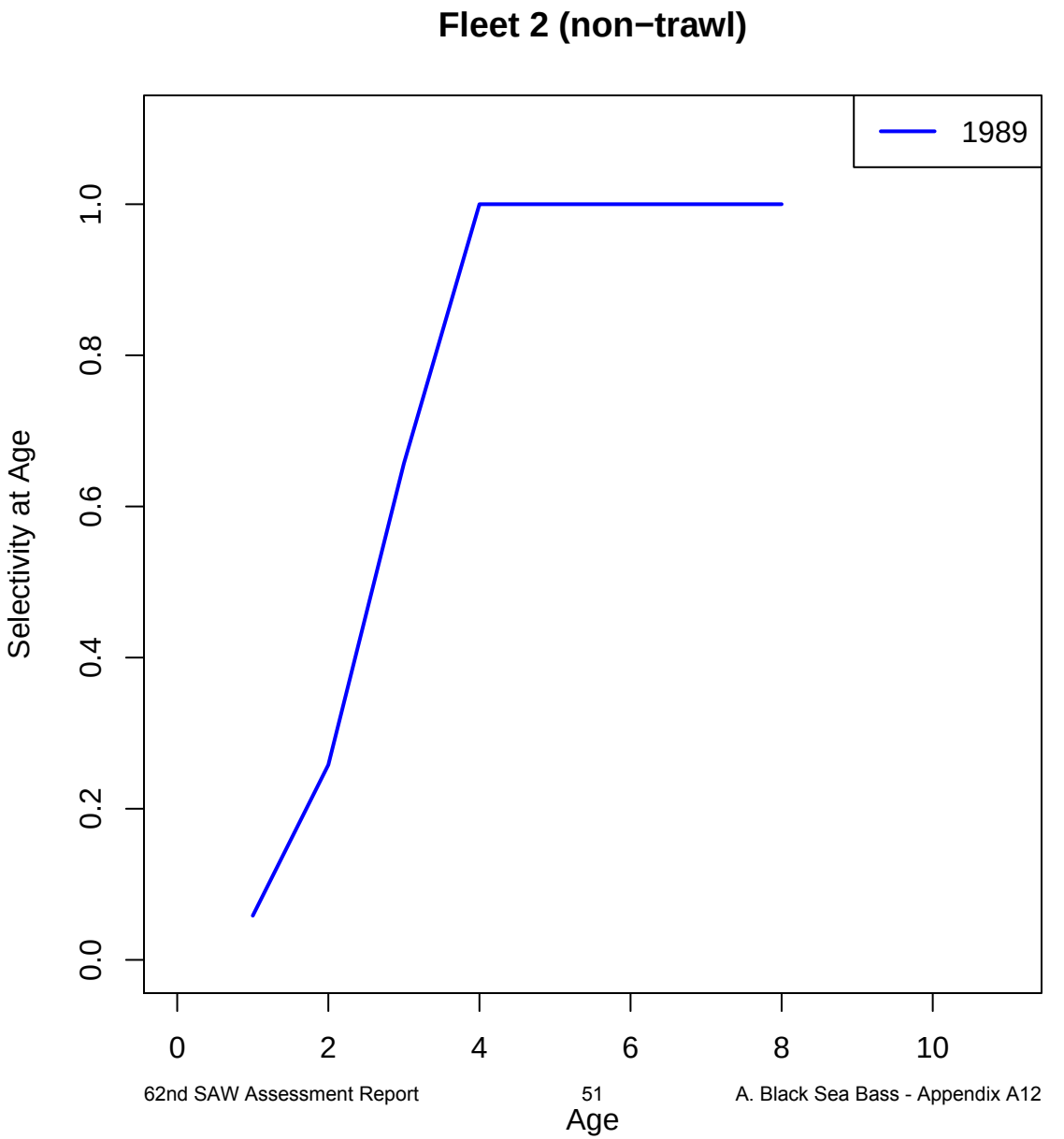

Index 8 (REC CPA) ESS = 50
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
−1
0
1
2
3

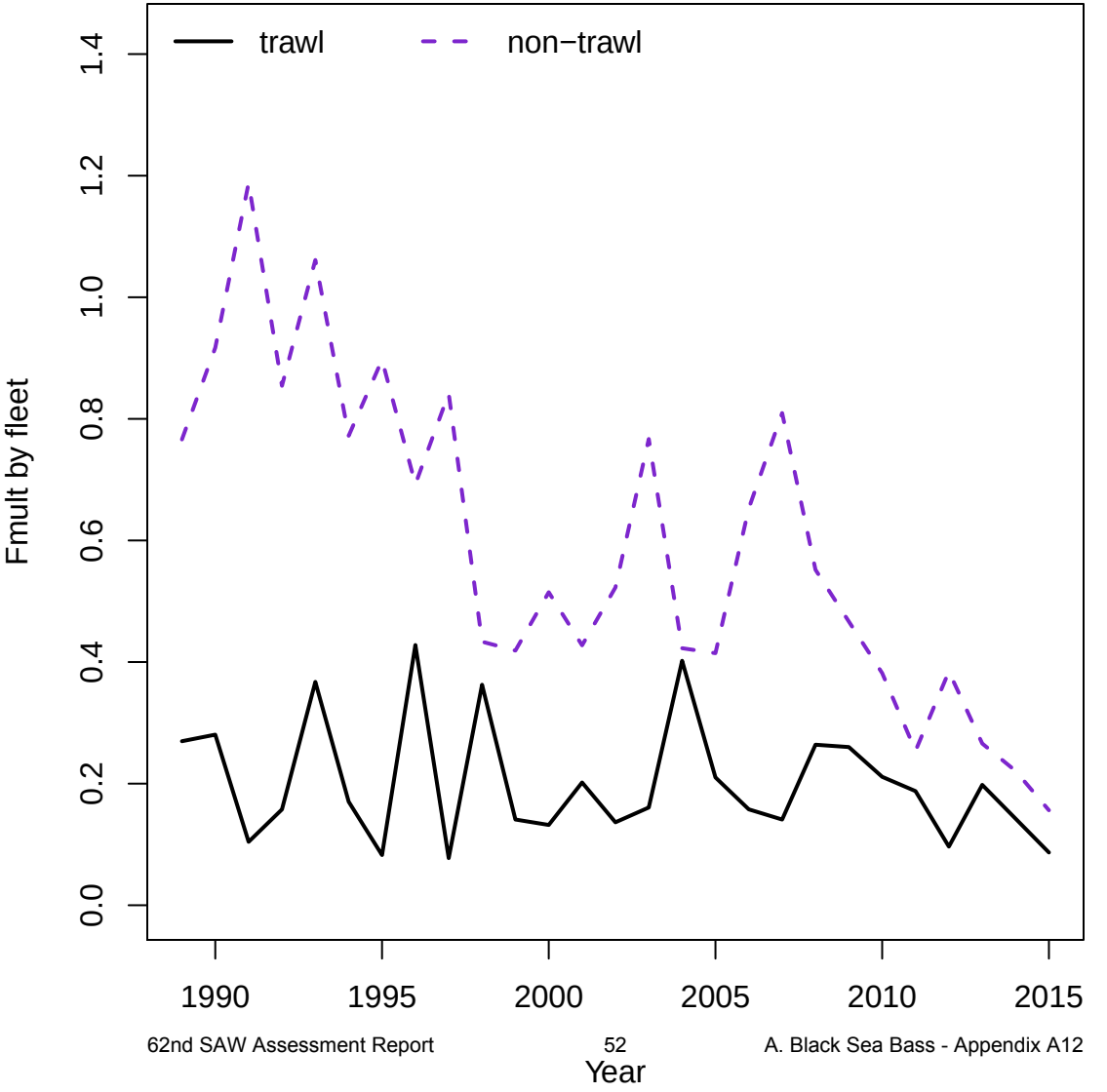

Index 9 (BIGELOW) ESS = NA
Mean Age
0
2
4
6
8
10
2009
2010
2011
2012
2013
2014
2015
Years

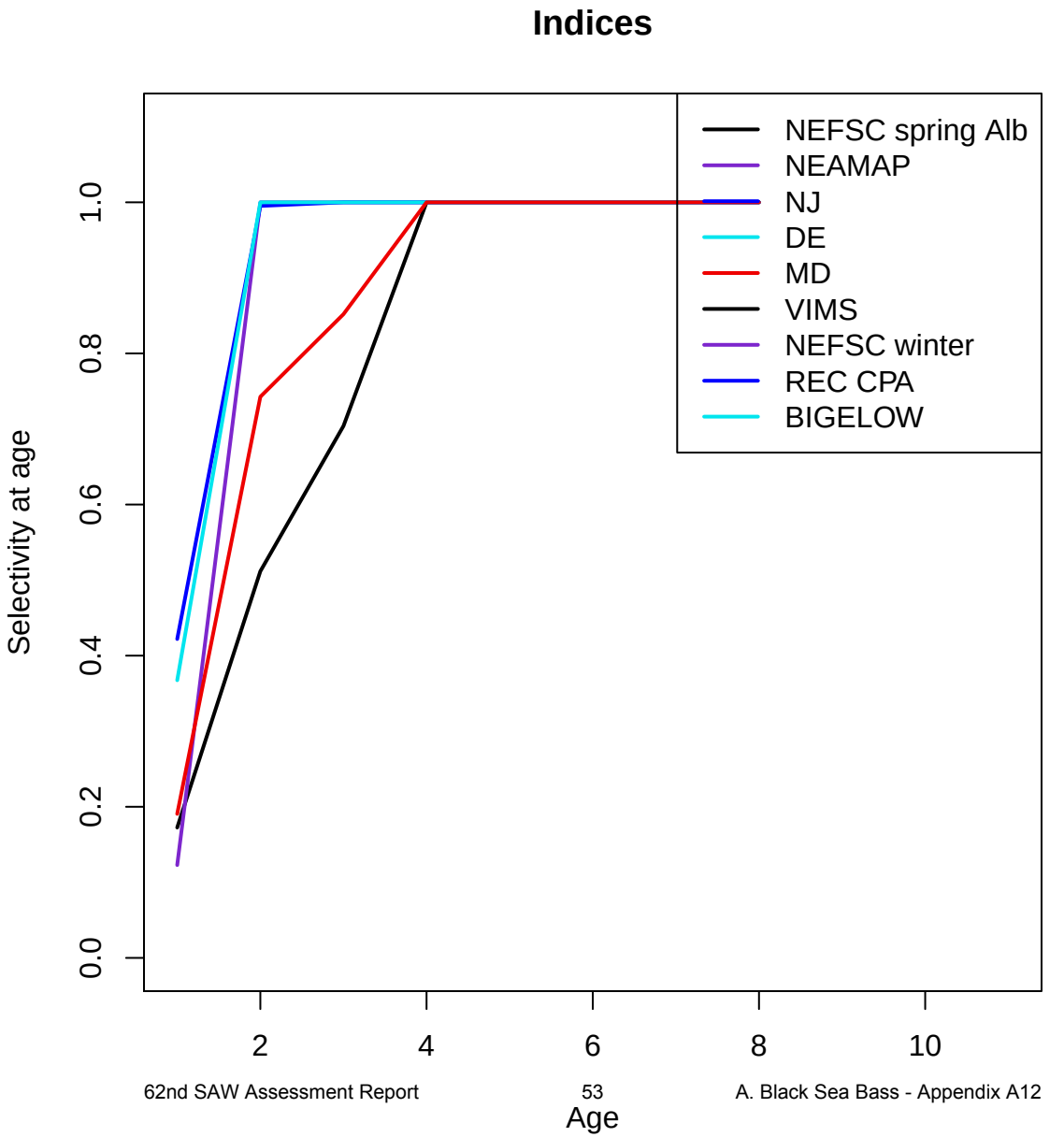

SDNR=1.06 RMSE=1
Std Resids
−1
0
0.5
1
1.5
2009
2010
2011
2012
2013
2014
2015
Year

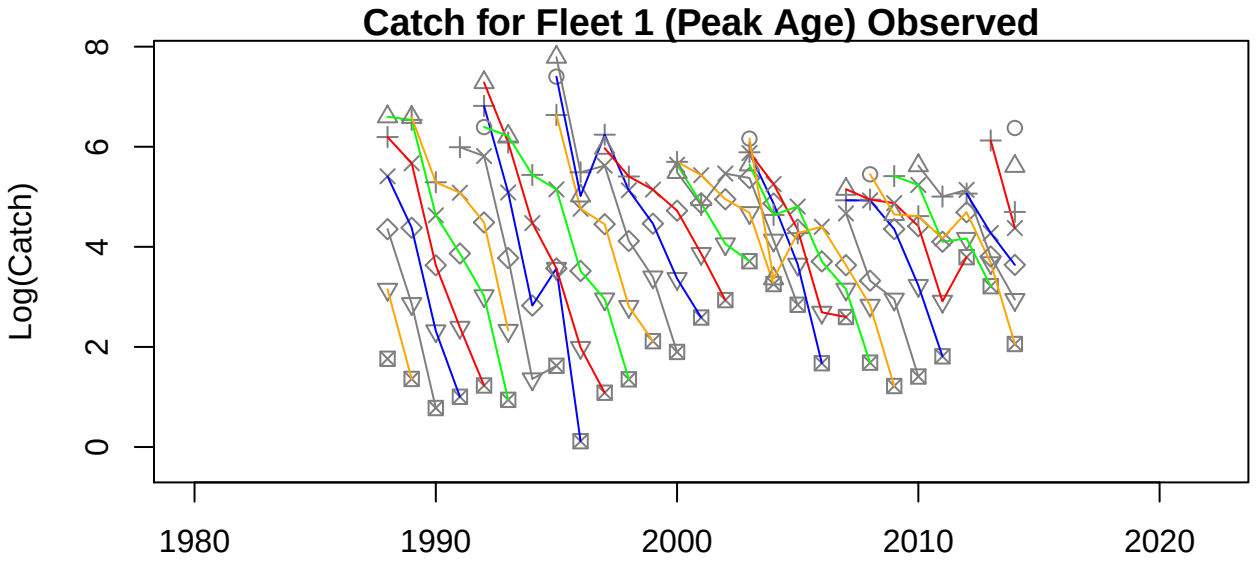

Index 9 (BIGELOW) ESS = NA
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−1.0
−0.5
0.0
0.5
1.0
1.5

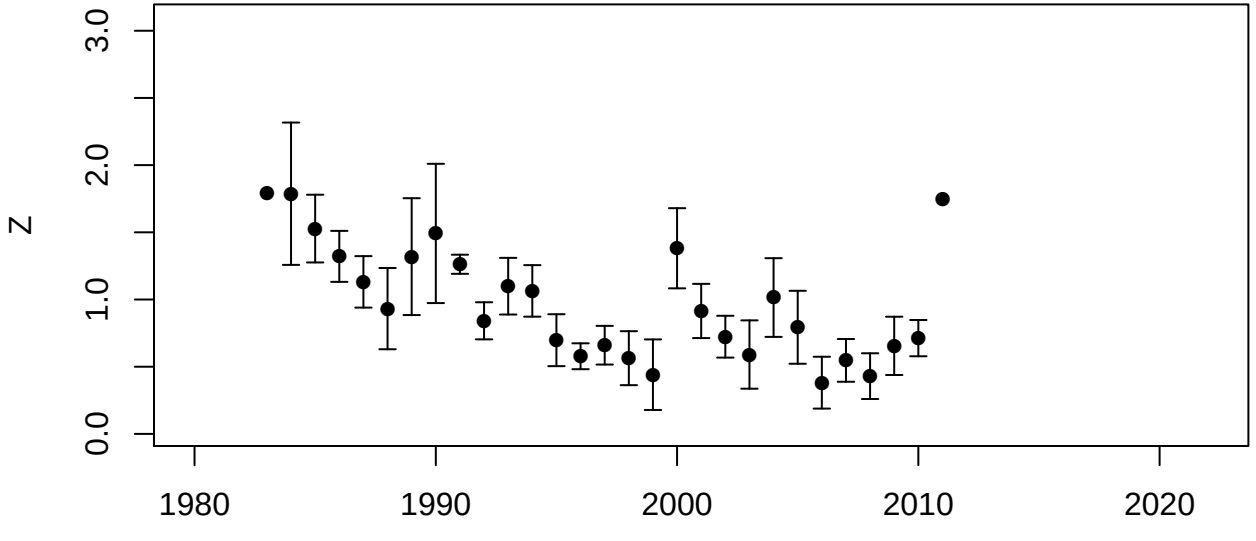

Fleet 1 (trawl)
1989
1998
Selectivity at Age
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
Age

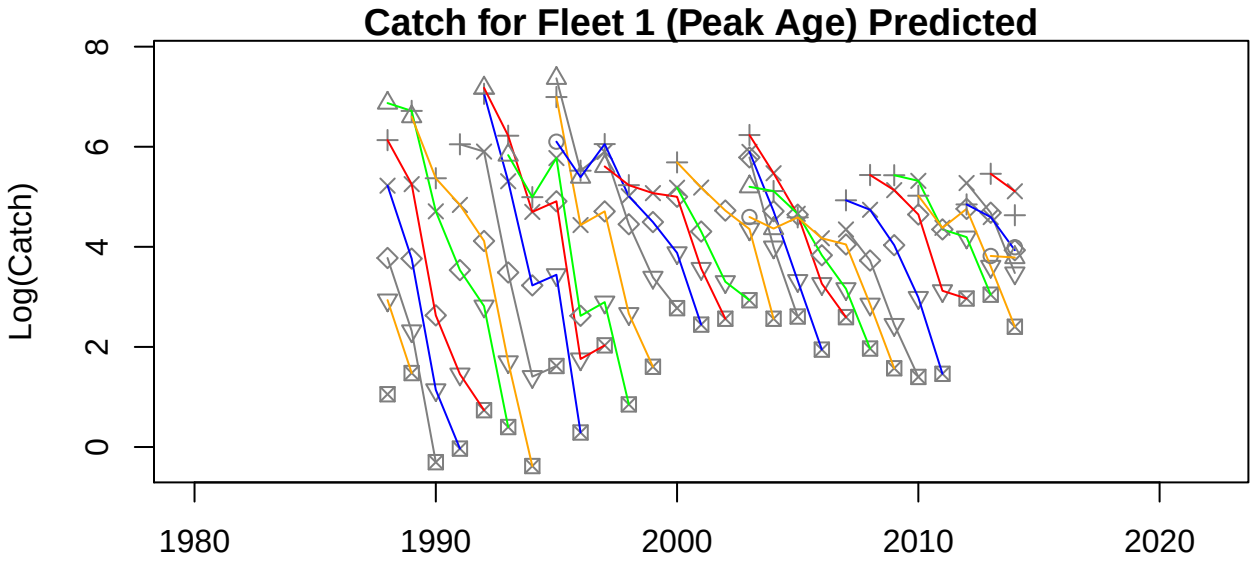

Fleet 2 (non−trawl)
1989
Selectivity at Age
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
Age

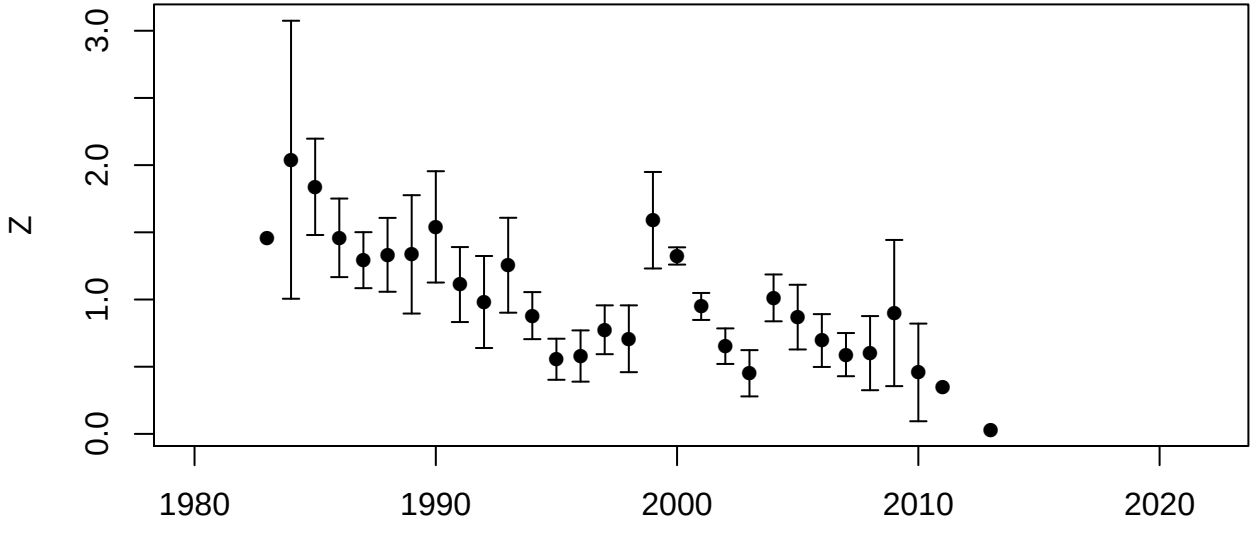

trawl
non−trawl
Fmult by fleet
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1990
1995
2000
2005
2010
2015
Year

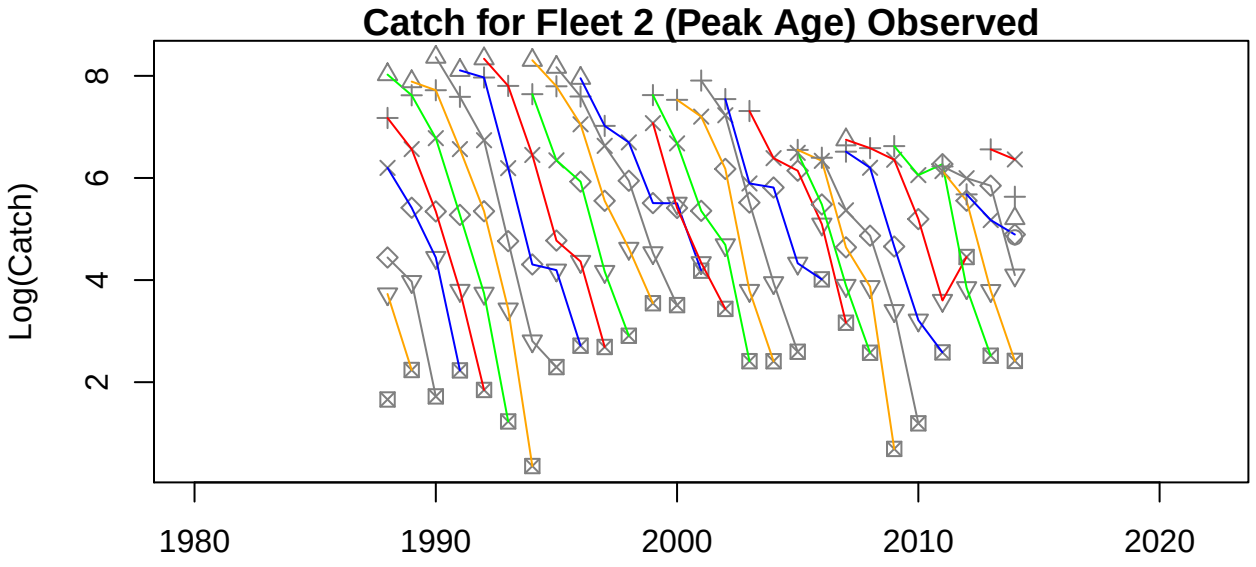

Indices
NEFSC spring Alb
NEAMAP
NJ
DE
MD
VIMS
NEFSC winter
REC CPA
BIGELOW
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
10
Age

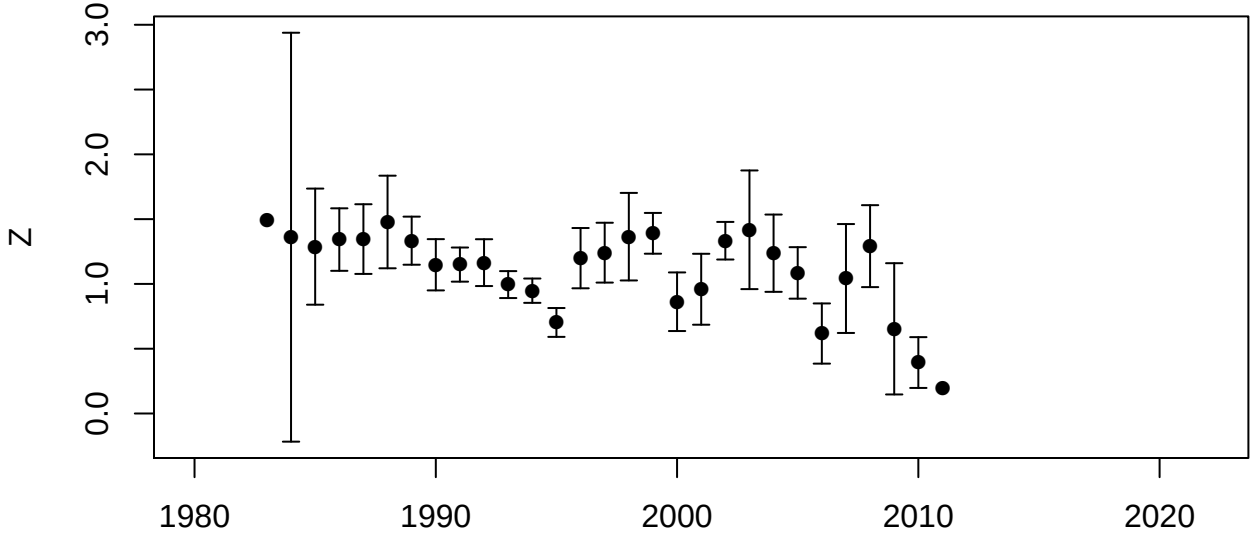

Catch for Fleet 1 (Peak Age) Observed
Log(Catch)
0
2
4
6
8
1980
1990
2000
2010
2020

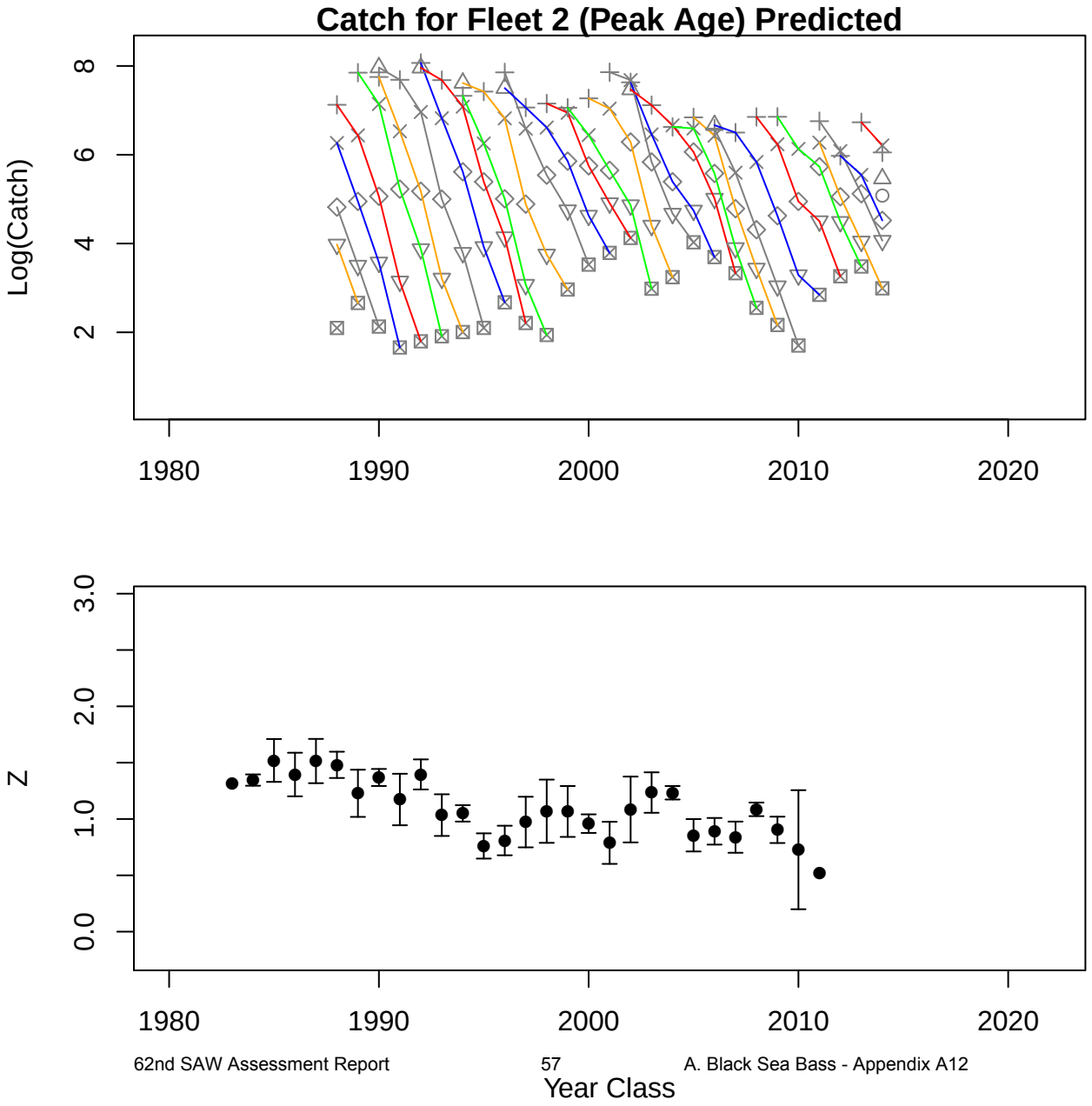

Z
0.0
1.0
2.0
3.0
1980
1990
2000
2010
2020
Year Class

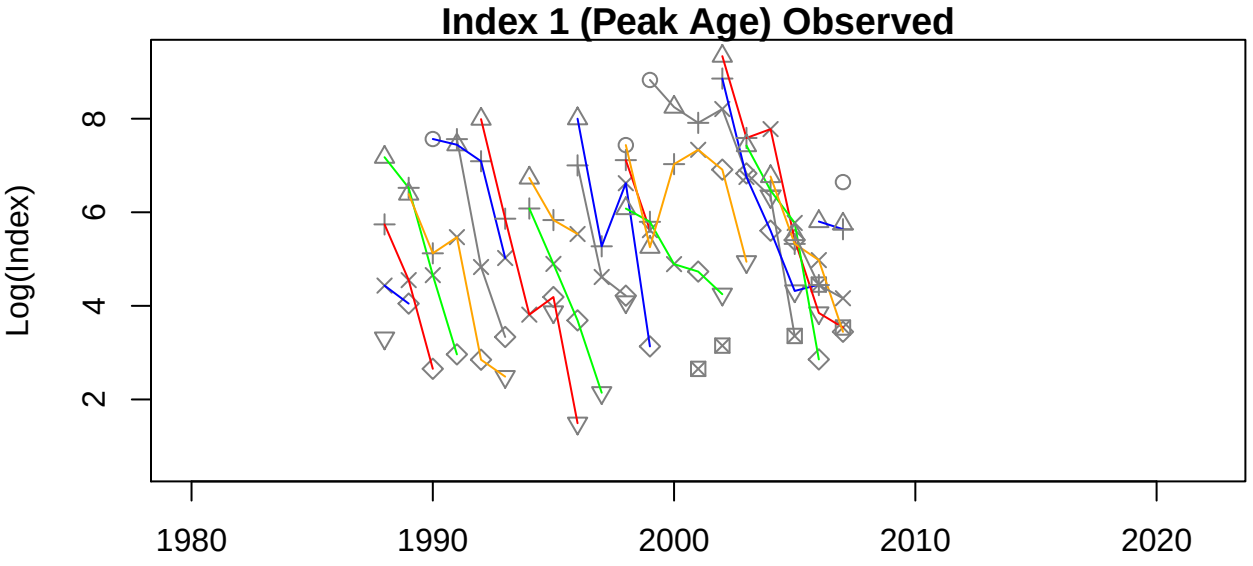

Catch for Fleet 1 (Peak Age) Predicted
Log(Catch)
0
2
4
6
8
1980
1990
2000
2010
2020

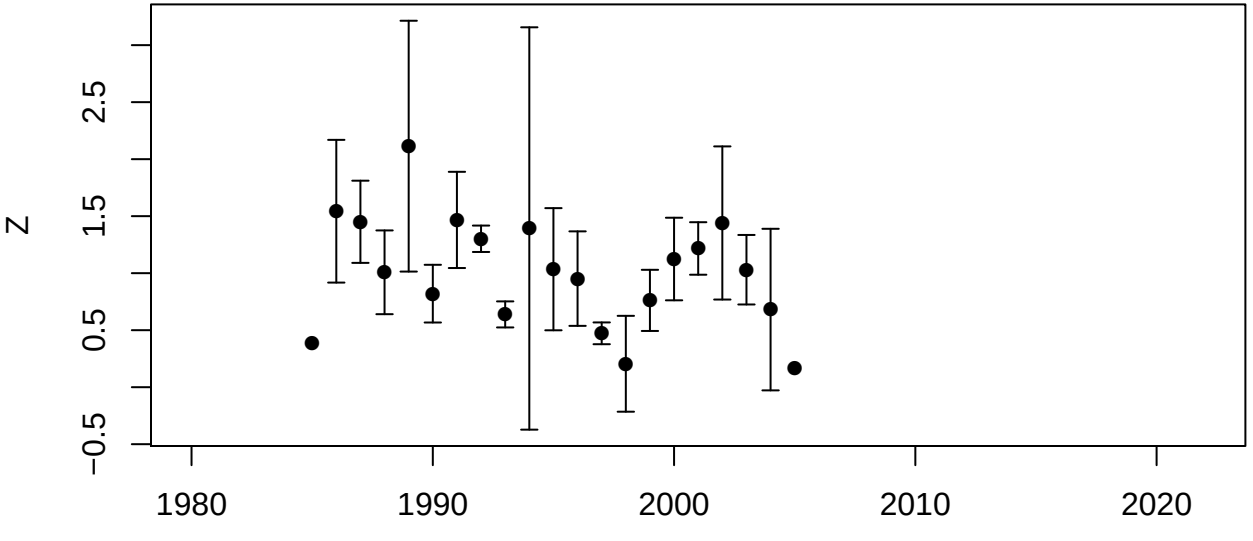

Z
0.0
1.0
2.0
3.0
1980
1990
2000
2010
2020
Year Class

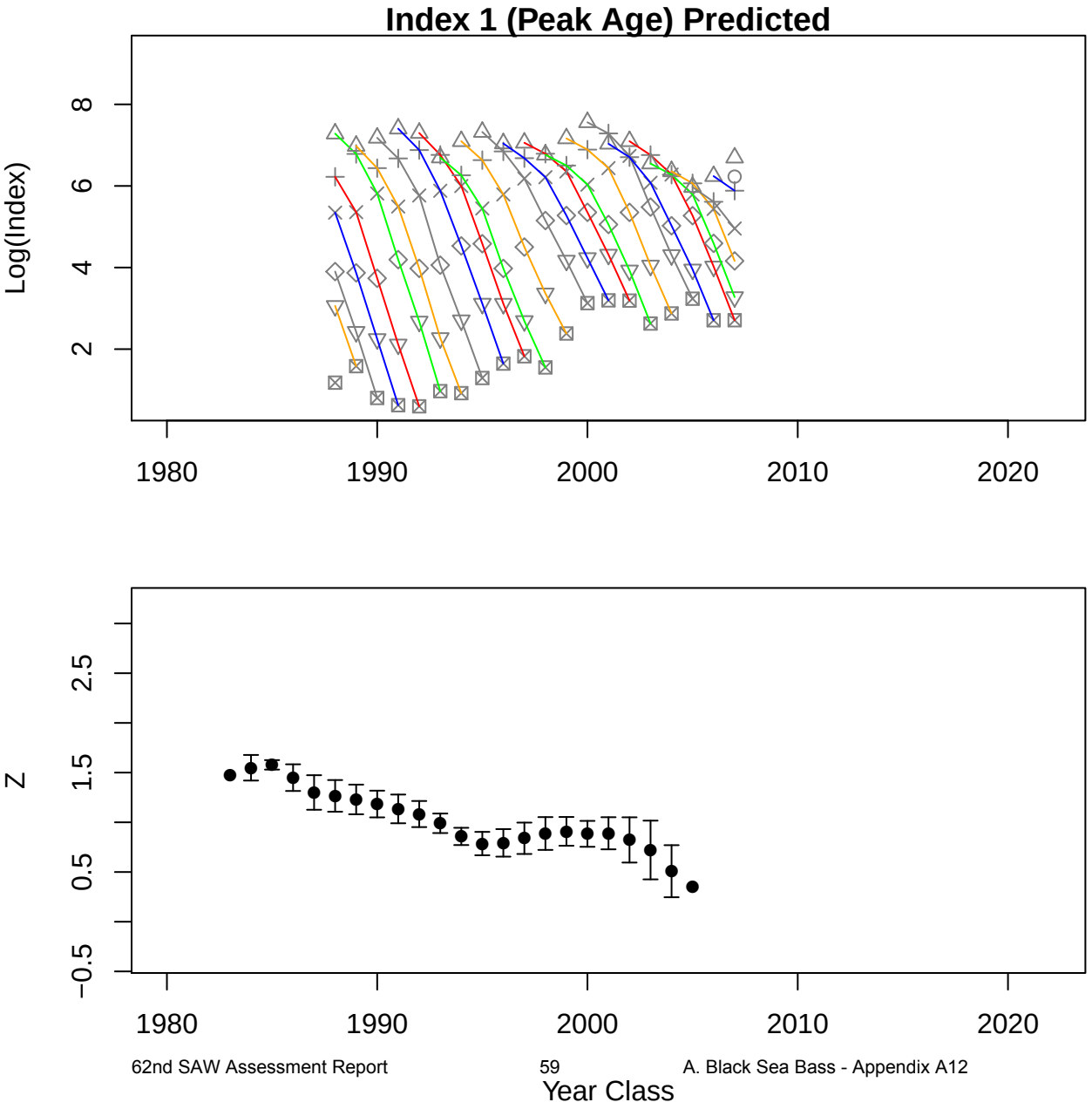

Catch for Fleet 2 (Peak Age) Observed
Log(Catch)
2
4
6
8
1980
1990
2000
2010
2020

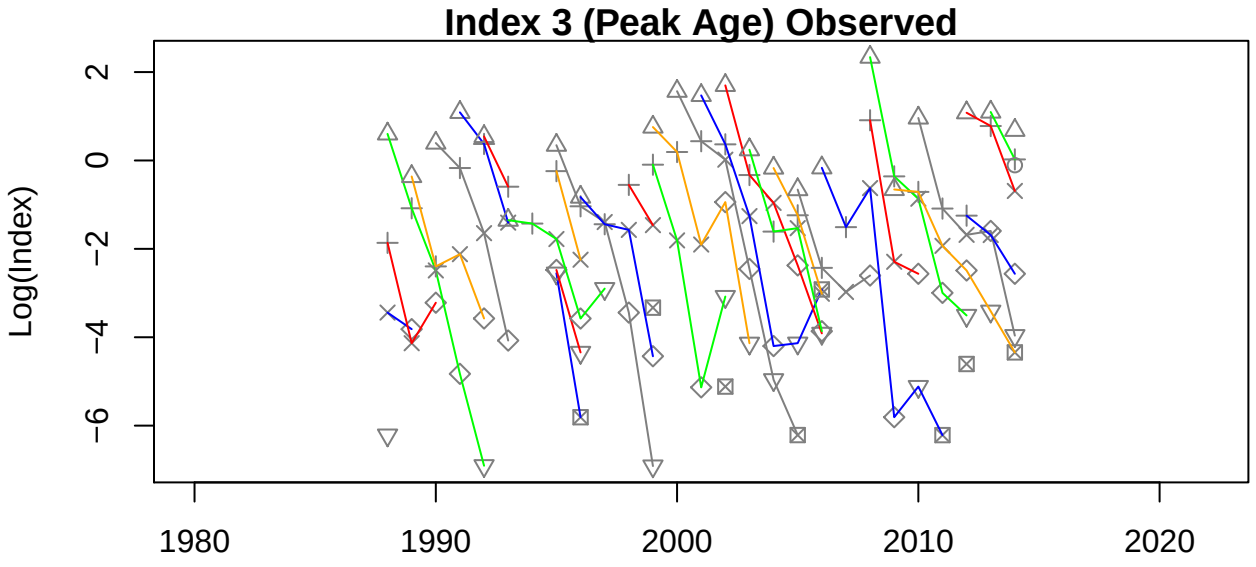

Z
0.0
1.0
2.0
3.0
1980
1990
2000
2010
2020
Year Class

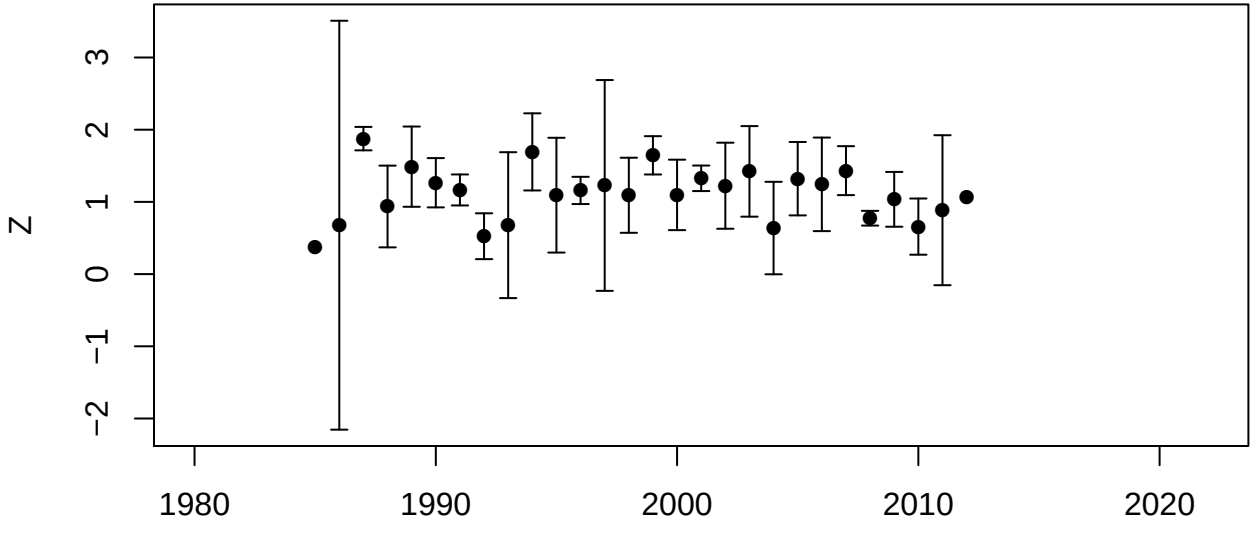

Catch for Fleet 2 (Peak Age) Predicted
Log(Catch)
2
4
6
8
1980
1990
2000
2010
2020
Z
0.0
1.0
2.0
3.0
1980
1990
2000
2010
2020
Year Class


Index 1 (Peak Age) Observed
Log(Index)
2
4
6
8
1980
1990
2000
2010
2020

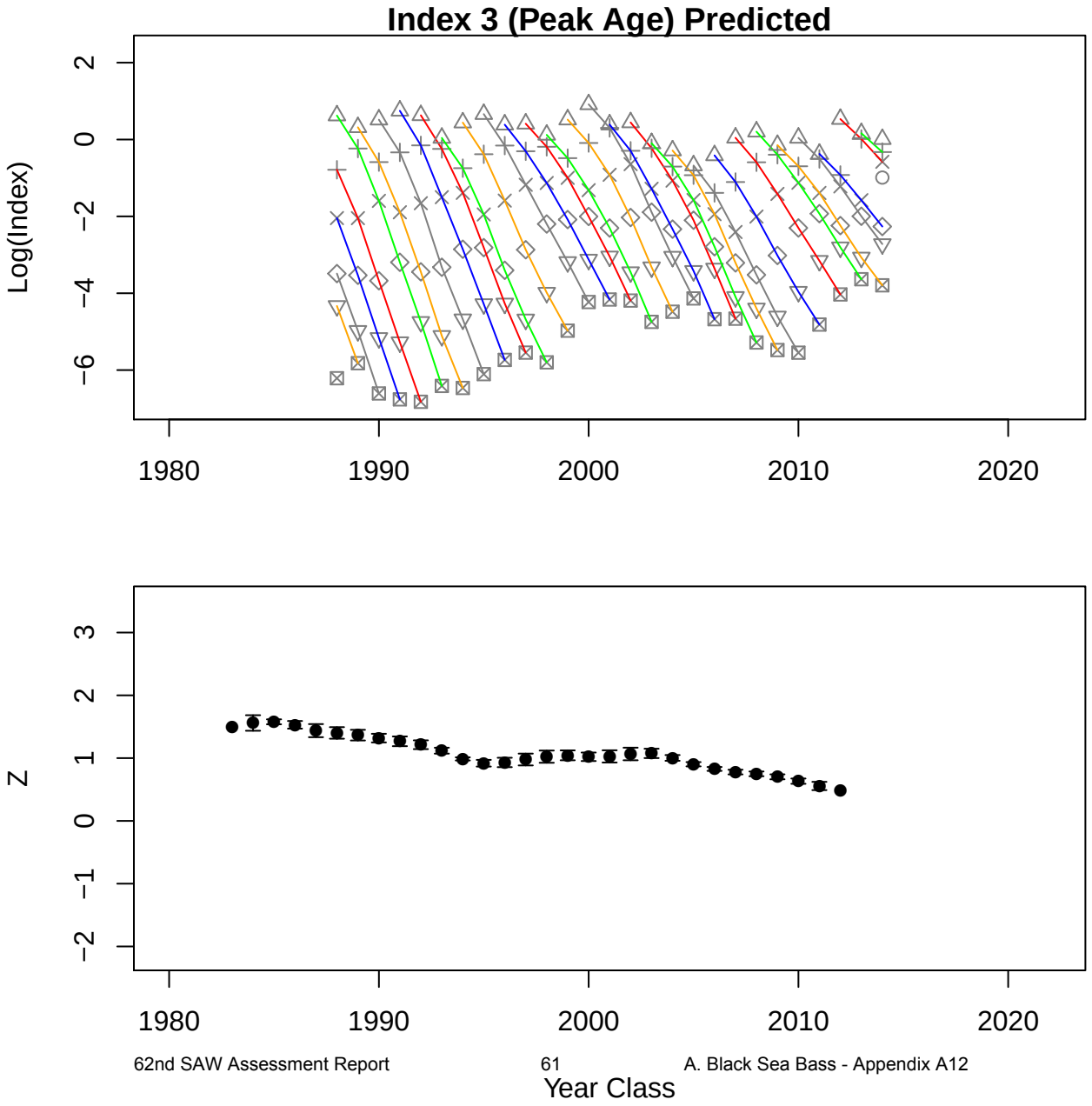

Z
−0.5
0.5
1.5
2.5
1980
1990
2000
2010
2020
Year Class

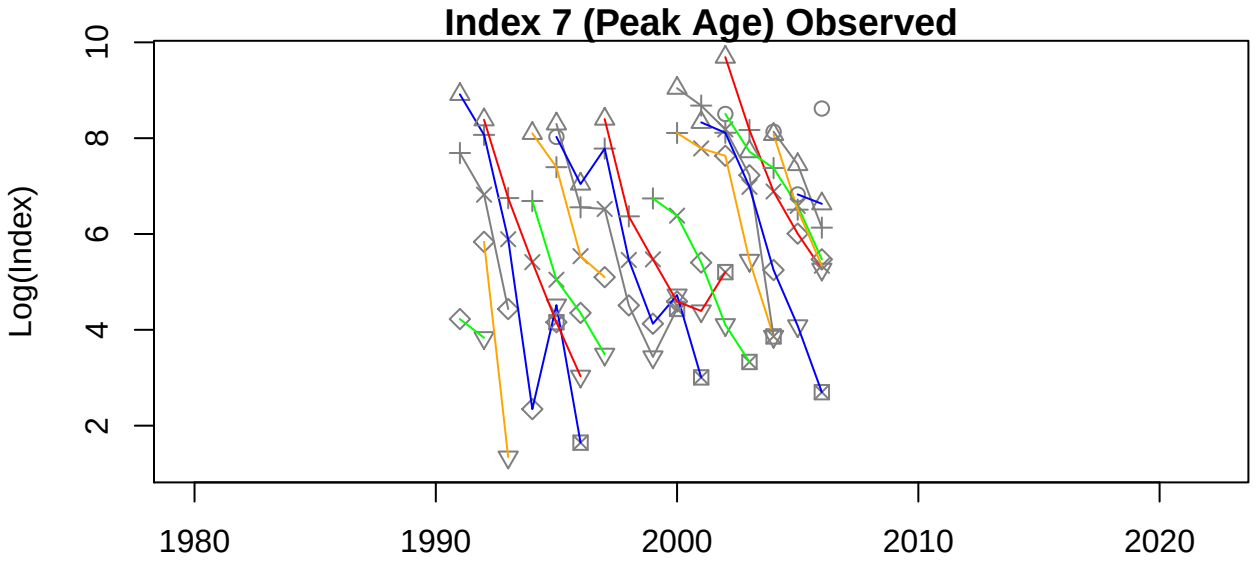

Index 1 (Peak Age) Predicted
Log(Index)
2
4
6
8
1980
1990
2000
2010
2020
Z
−0.5
0.5
1.5
2.5
1980
1990
2000
2010
2020
Year Class

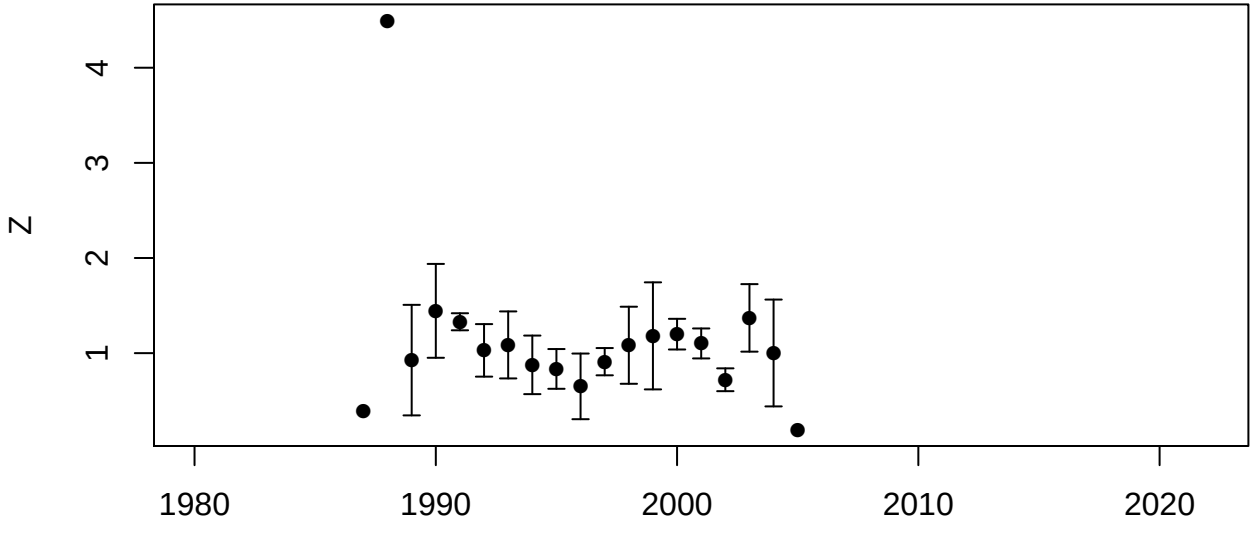

Index 3 (Peak Age) Observed
Log(Index)
2
0
−2
−4
−6
1980
1990
2000
2010
2020


Z
3
2
1
0
−1
−2
1980
1990
2000
2010
2020

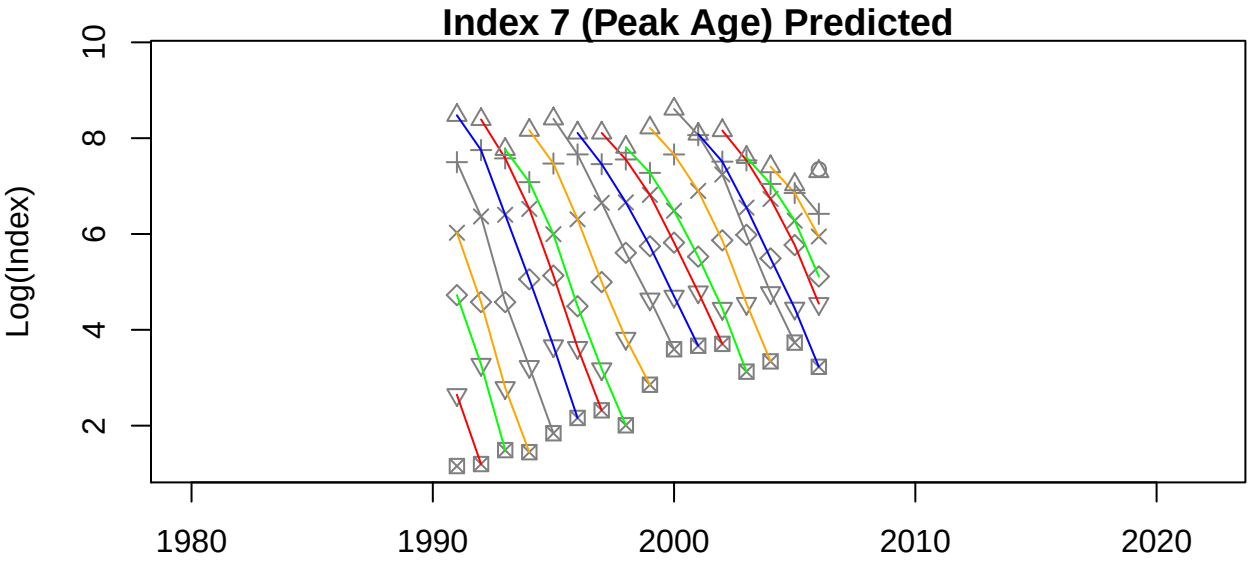
Year Class

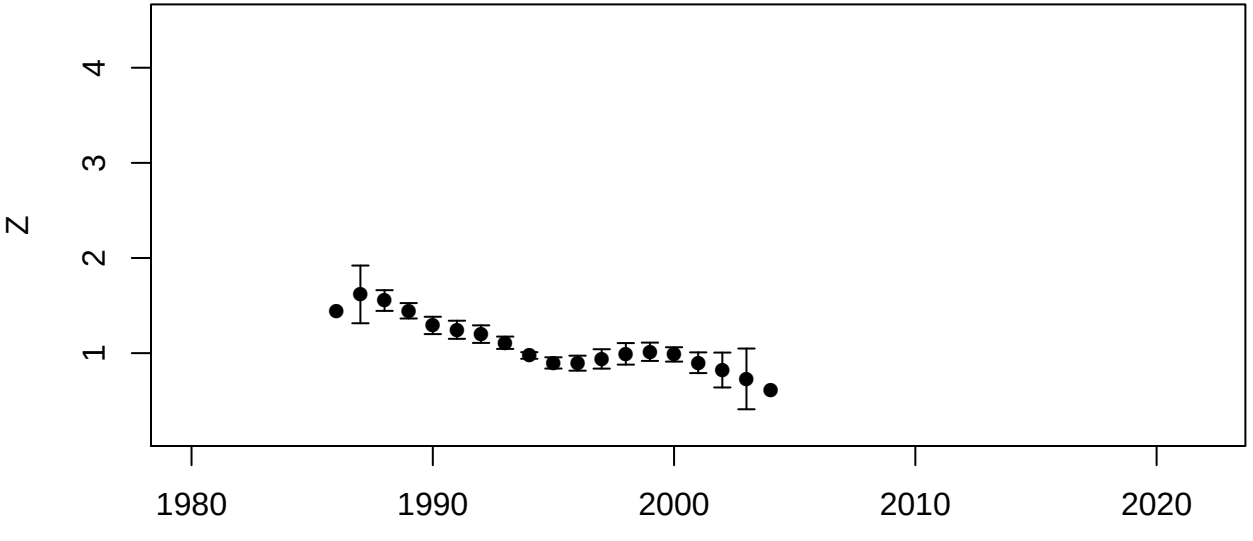

Index 3 (Peak Age) Predicted
Log(Index)
2
0
−2
−4
−6
1980
1990
2000
2010
2020
Z
3
2
1
0
−1
−2
1980
1990
2000
2010
2020
Year Class


Index 7 (Peak Age) Observed
Log(Index)
10
8
6
4
2
1980
1990
2000
2010
2020

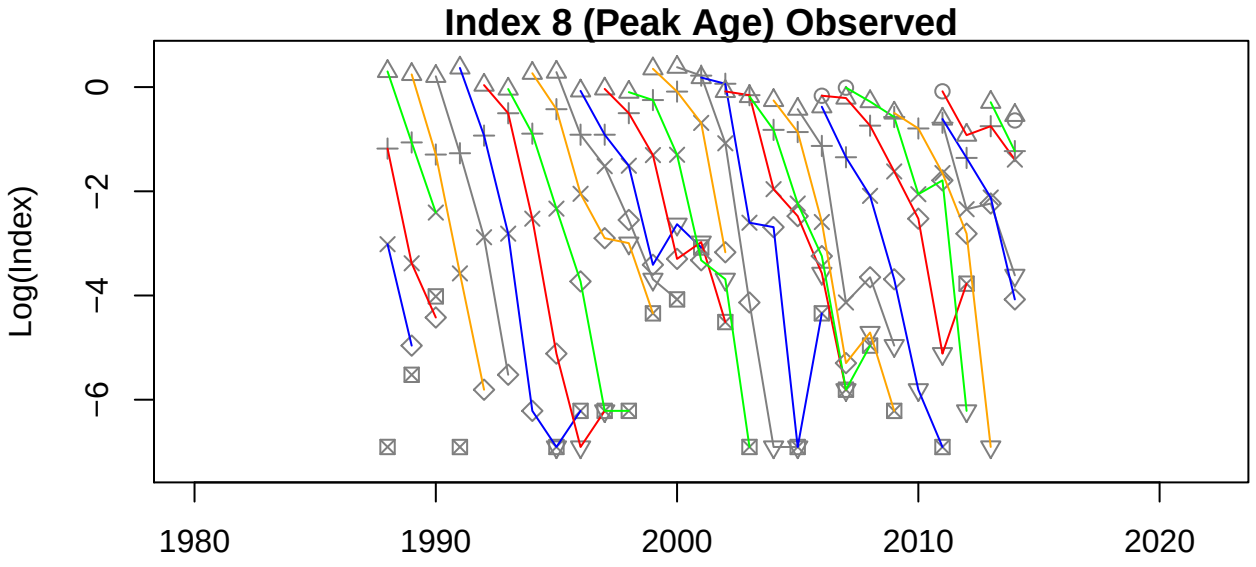

Z
4
3
2
1
1980
1990
2000
2010
2020

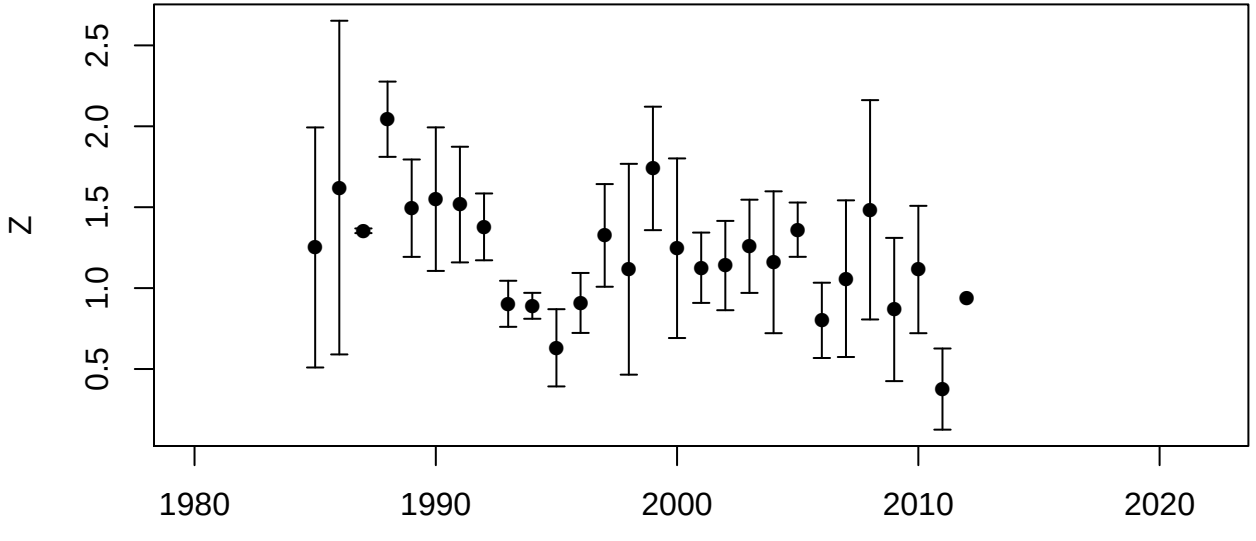
Year Class


Index 7 (Peak Age) Predicted
Log(Index)
10
8
6
4
2
1980
1990
2000
2010
2020

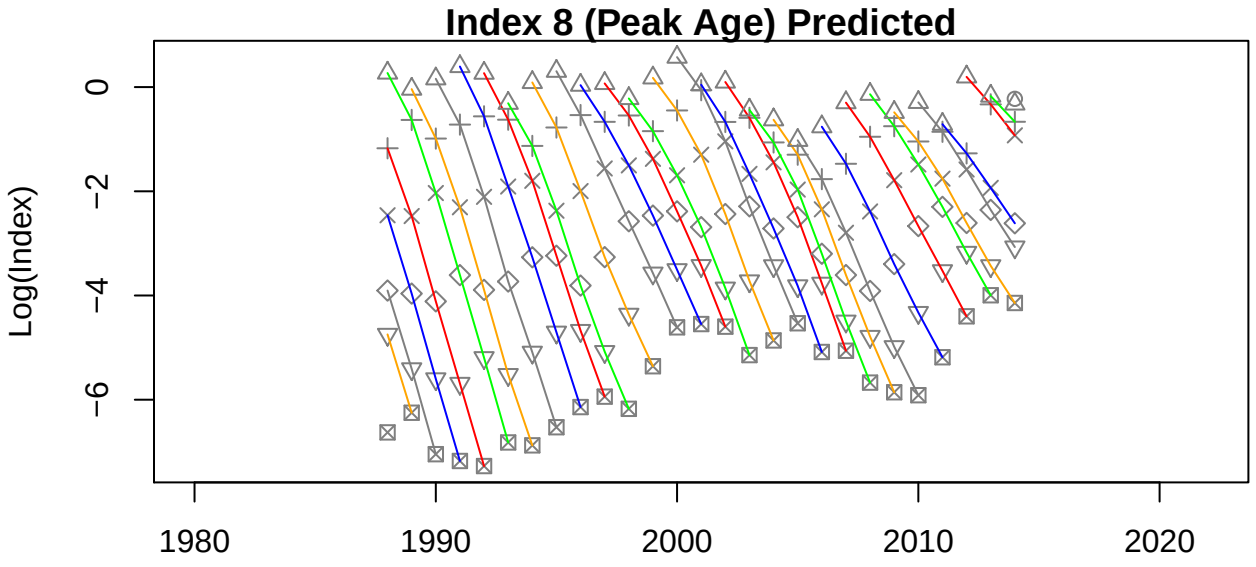

Z
4
3
2
1
1980
1990
2000
2010
2020

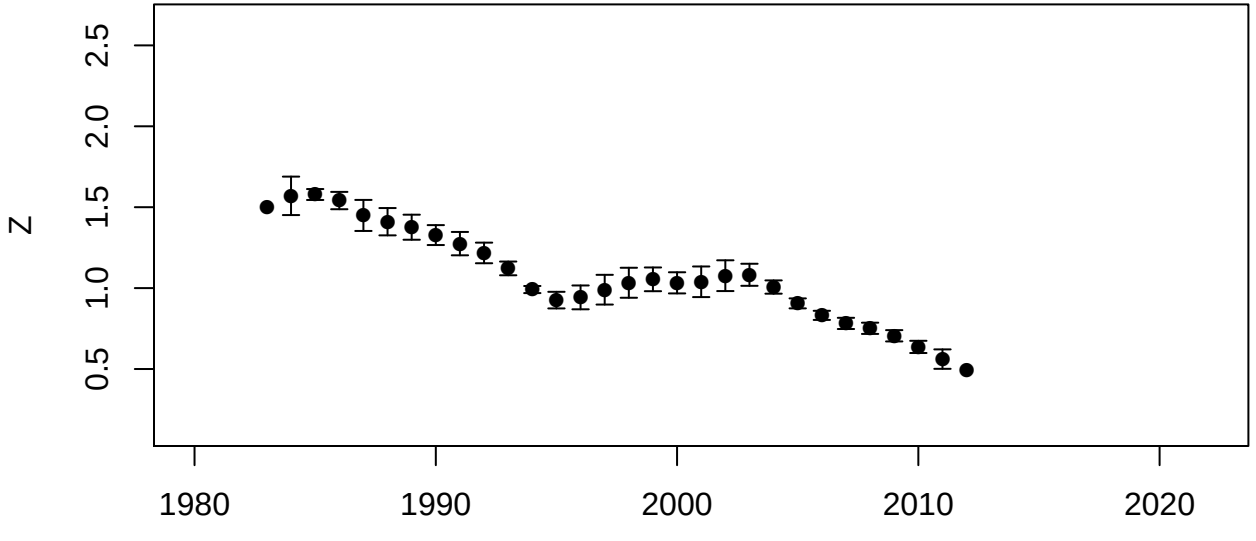
Year Class


Index 8 (Peak Age) Observed
Log(Index)
0
−2
−4
−6
1980
1990
2000
2010
2020

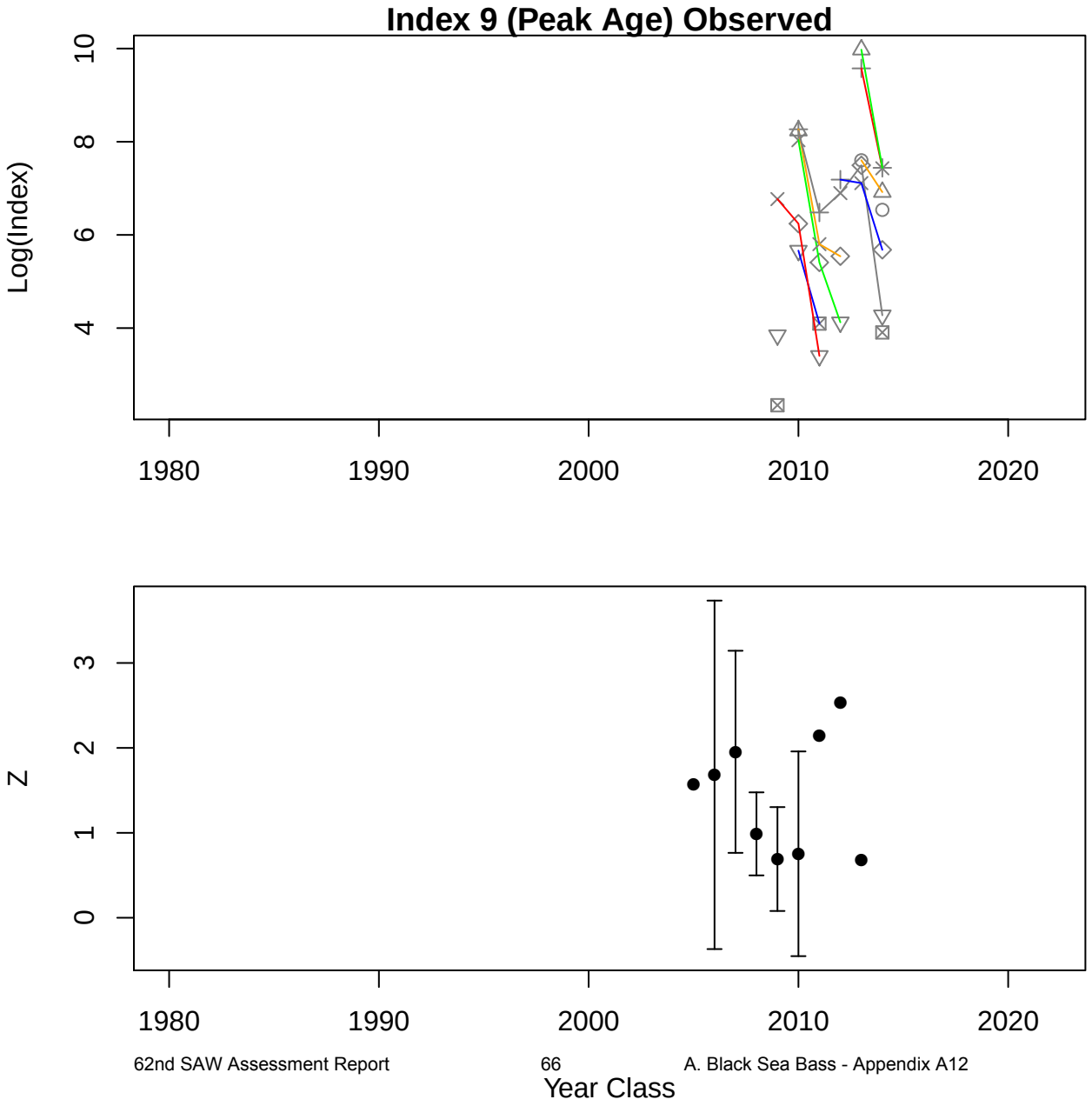

Z
2.5
2.0
1.5
1.0
0.5
1980
1990
2000
2010
2020

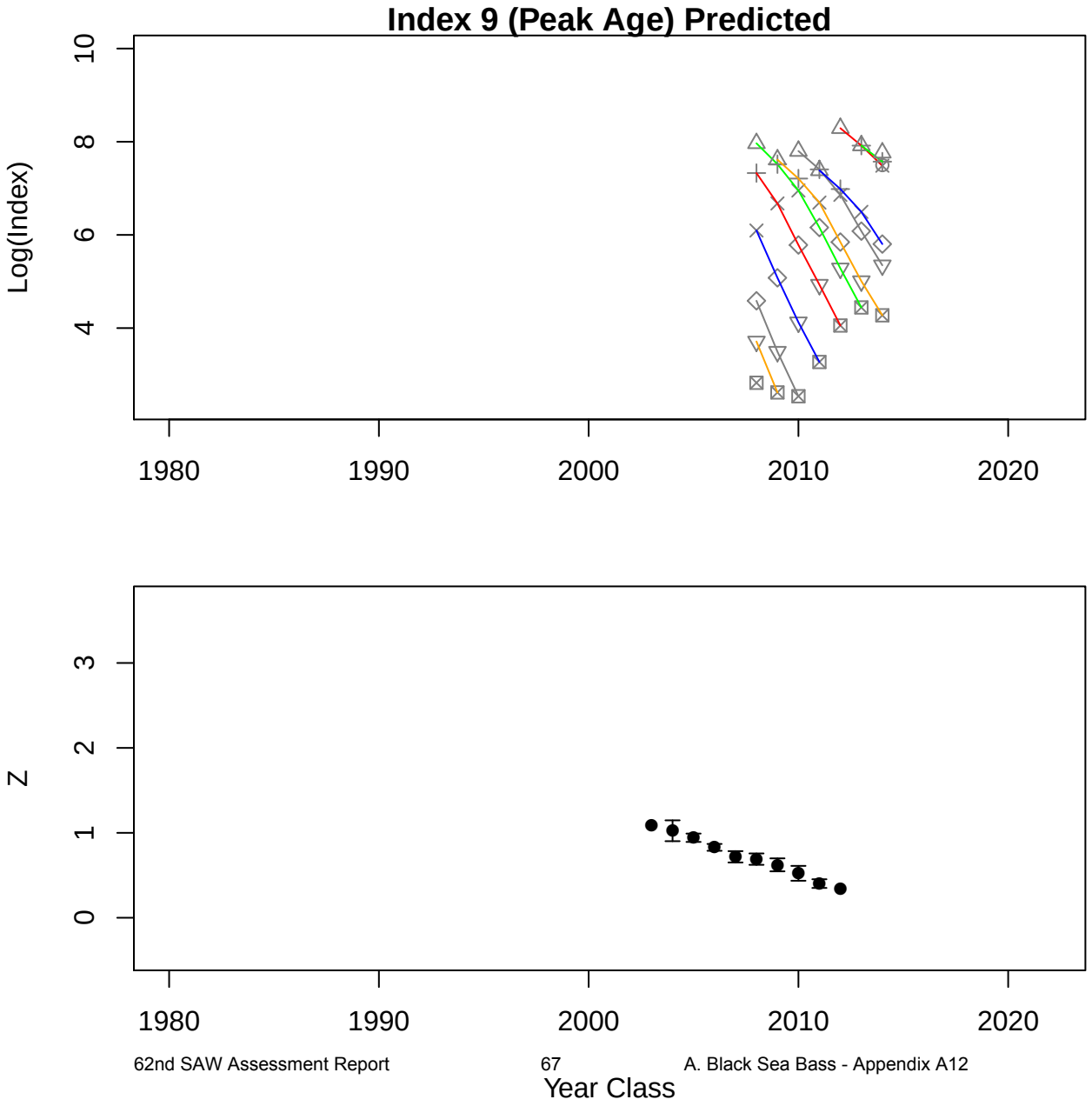
Year Class


Index 8 (Peak Age) Predicted
Log(Index)
0
−2
−4
−6
1980
1990
2000
2010
2020

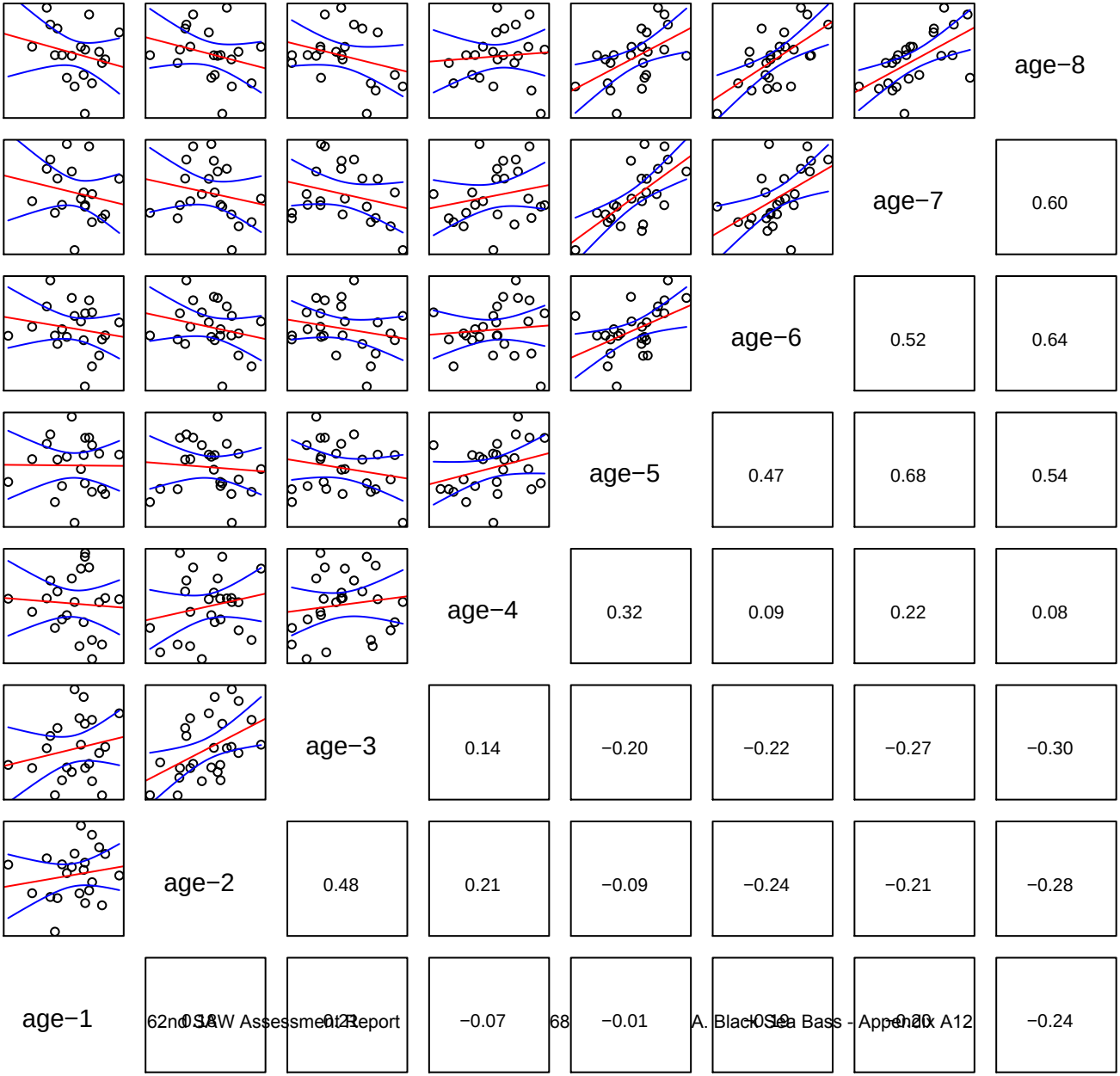

Z
2.5
2.0
1.5
1.0
0.5
1980
1990
2000
2010
2020

Year Class

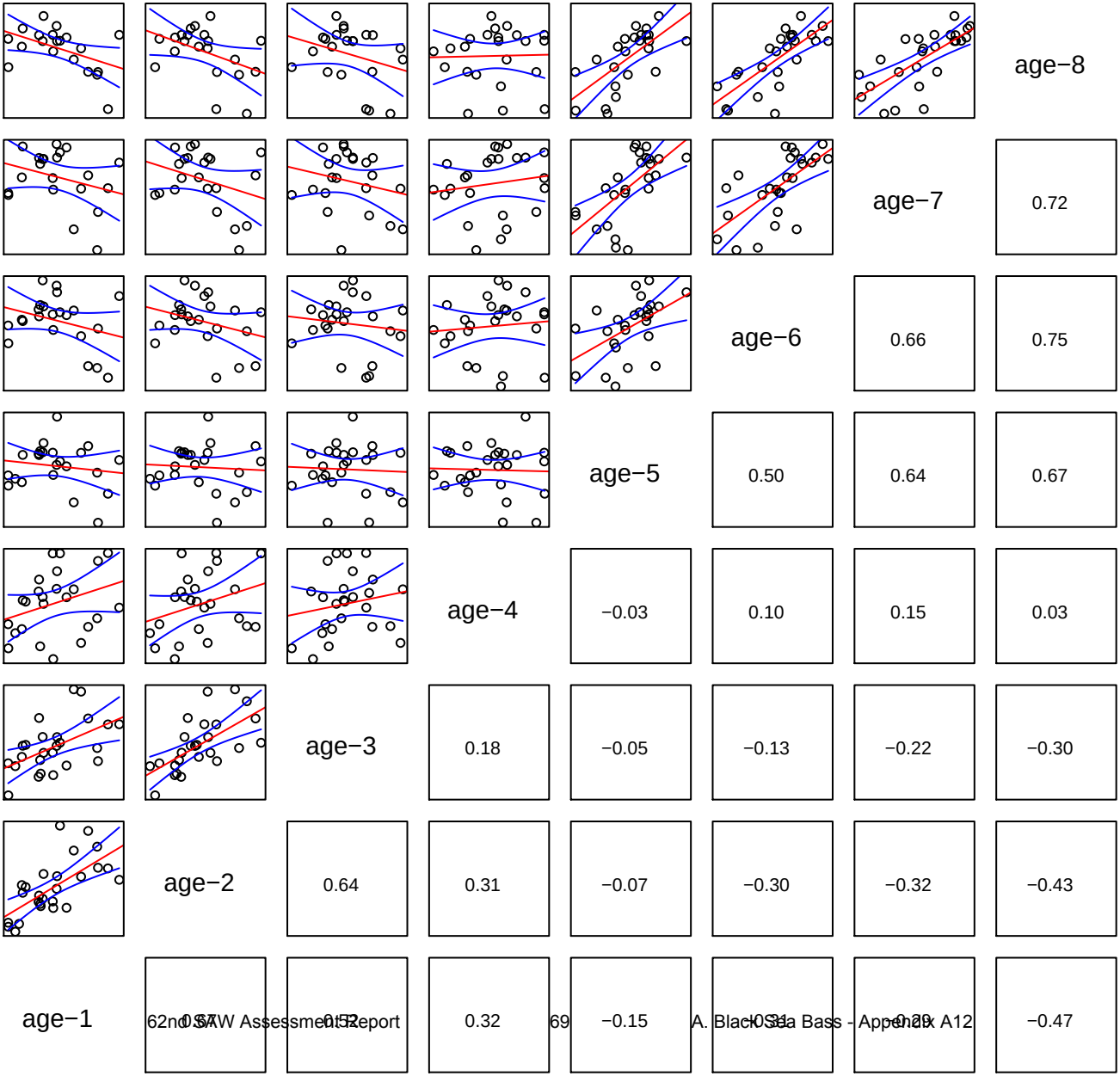

Index 9 (Peak Age) Observed
Log(Index)
10
8
6
4
1980
1990
2000
2010
2020
Z
3
2
1
0
1980
1990
2000
2010
2020
Year Class


Index 9 (Peak Age) Predicted
Log(Index)
10
8
6
4
1980
1990
2000
2010
2020
Z
3
2
1
0
1980
1990
2000
2010
2020
Year Class

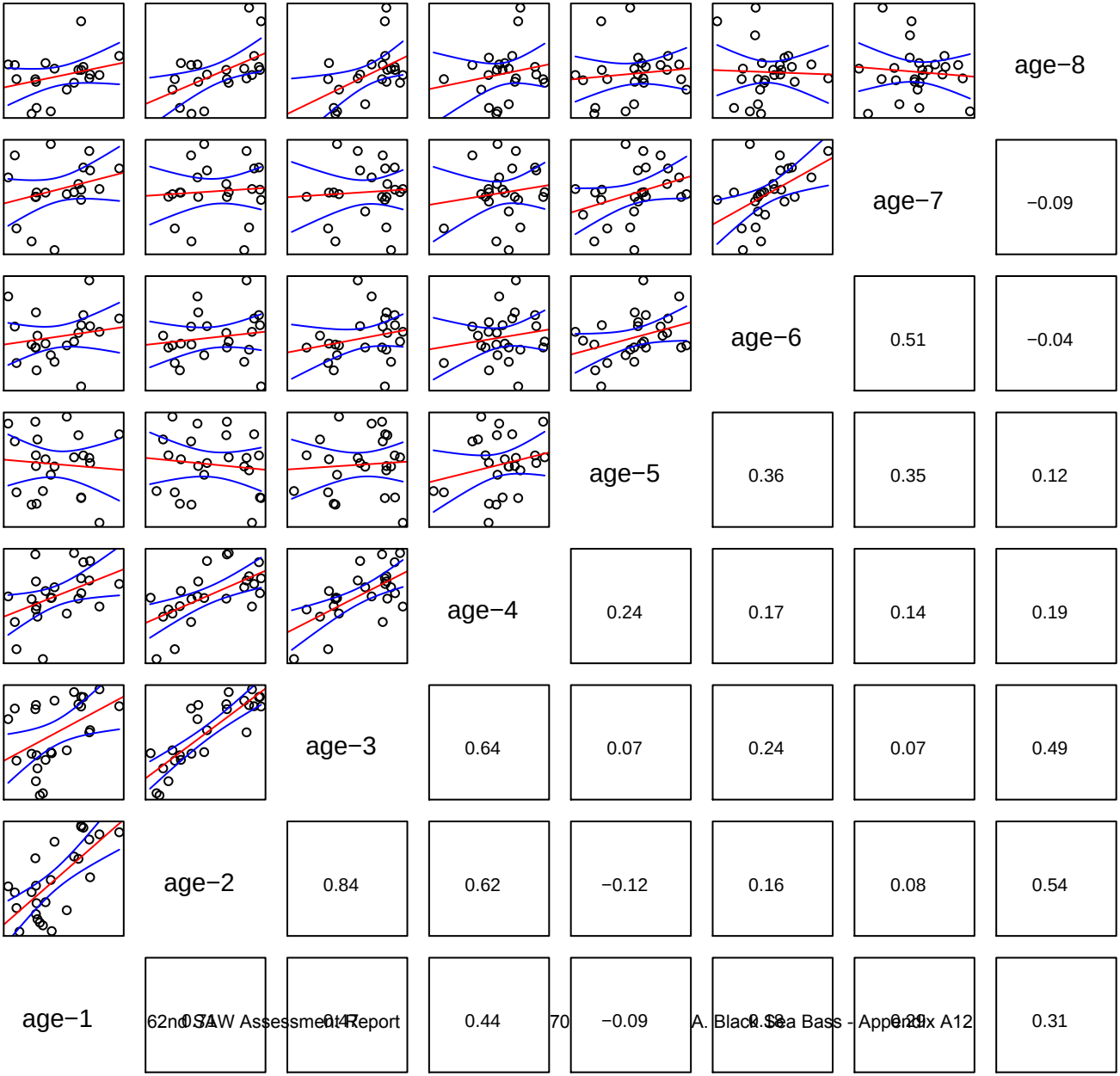
Catch for Fleet 1 Observed



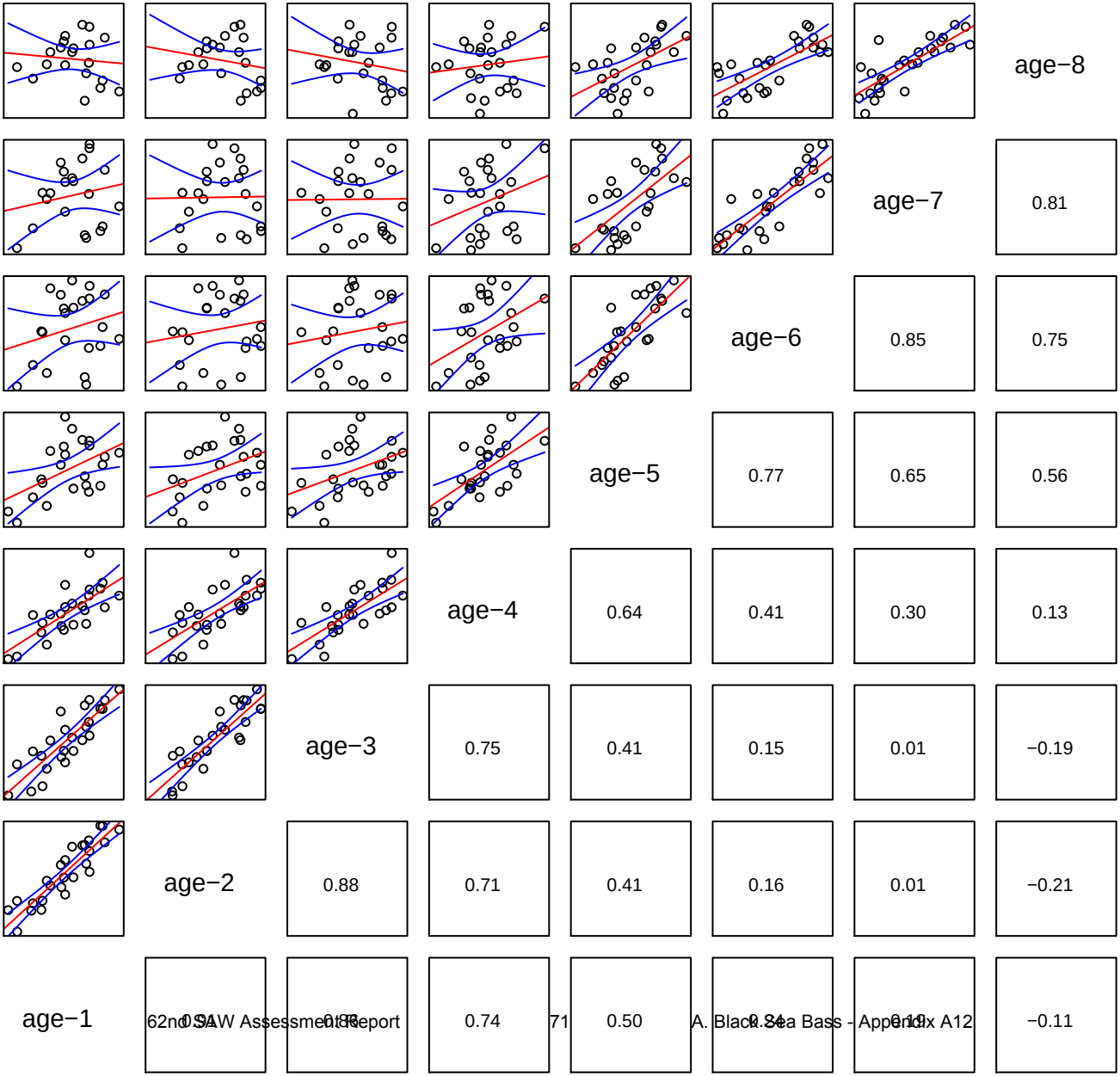
Catch for Fleet 1 Predicted



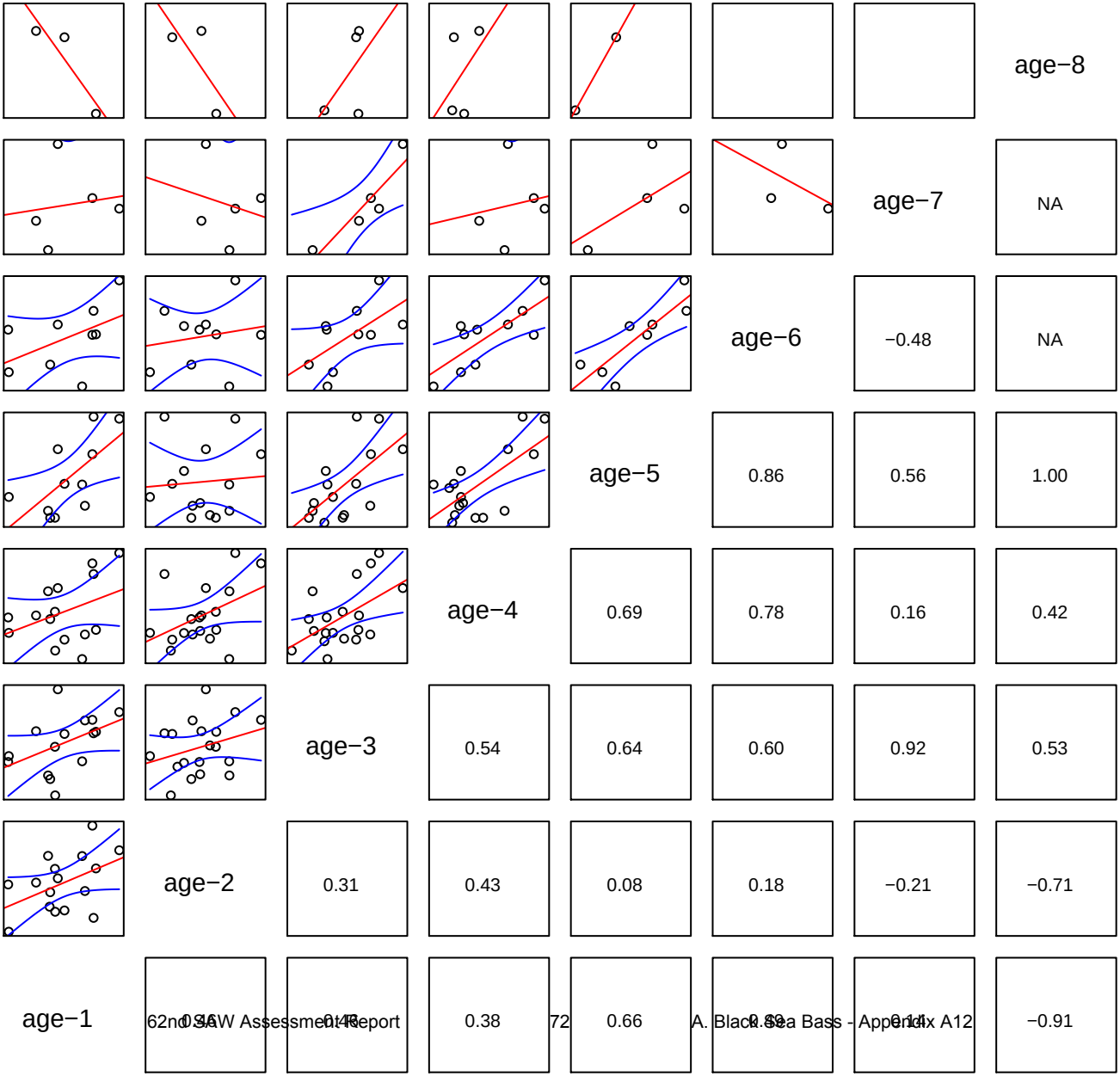
Catch for Fleet 2 Observed



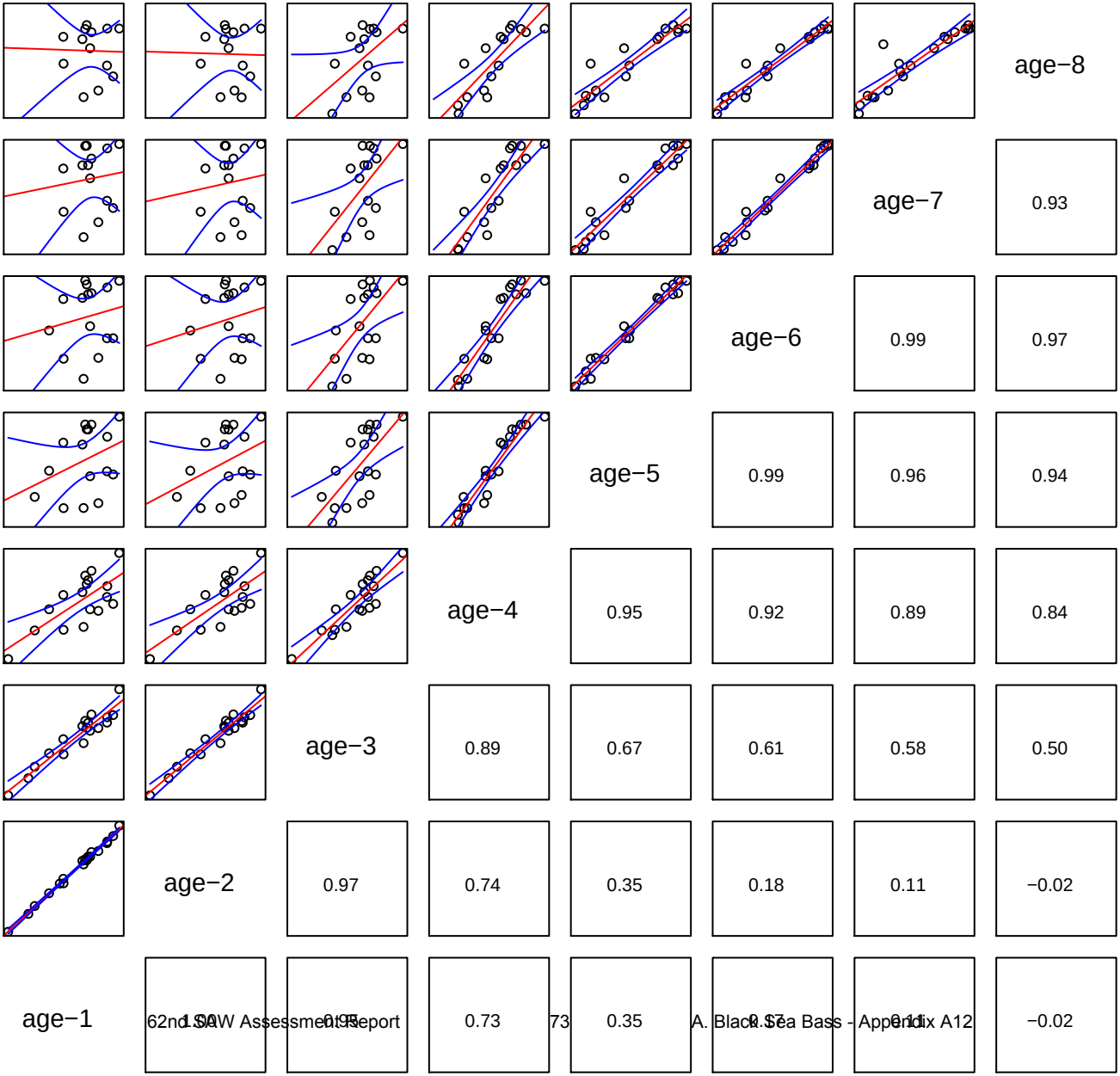
Catch for Fleet 2 Predicted



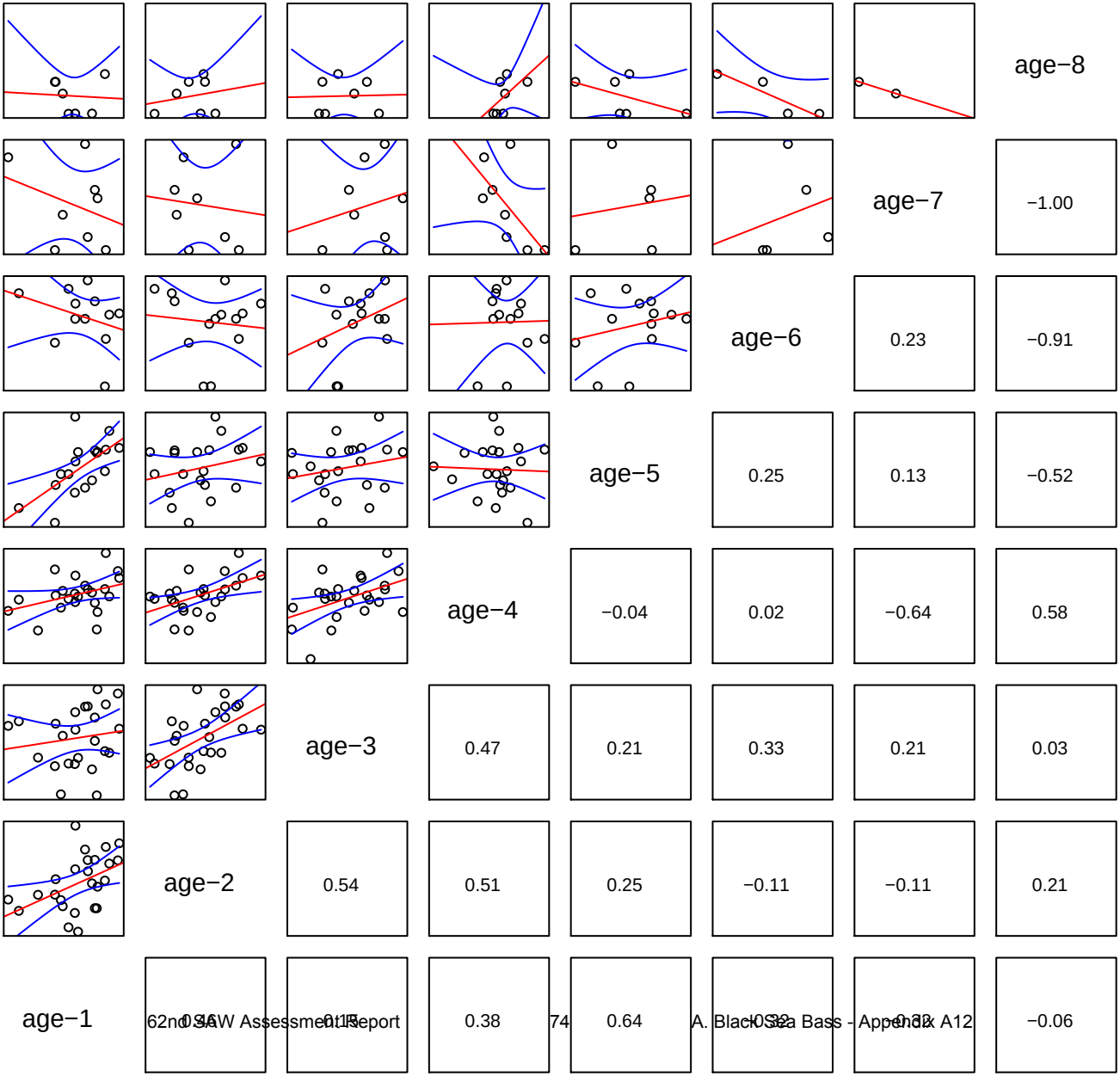
Index 1 Observed



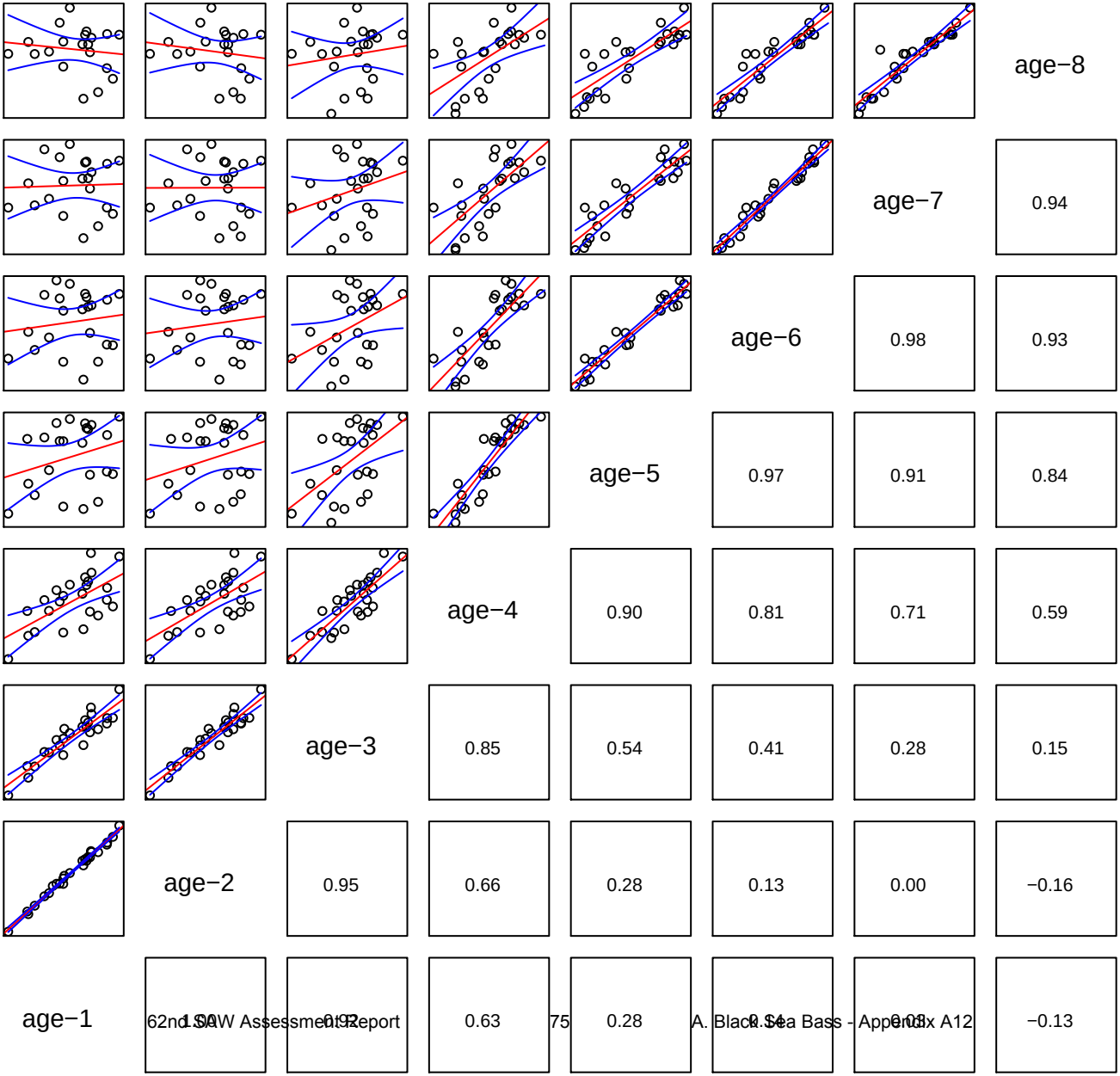
Index 1 Predicted



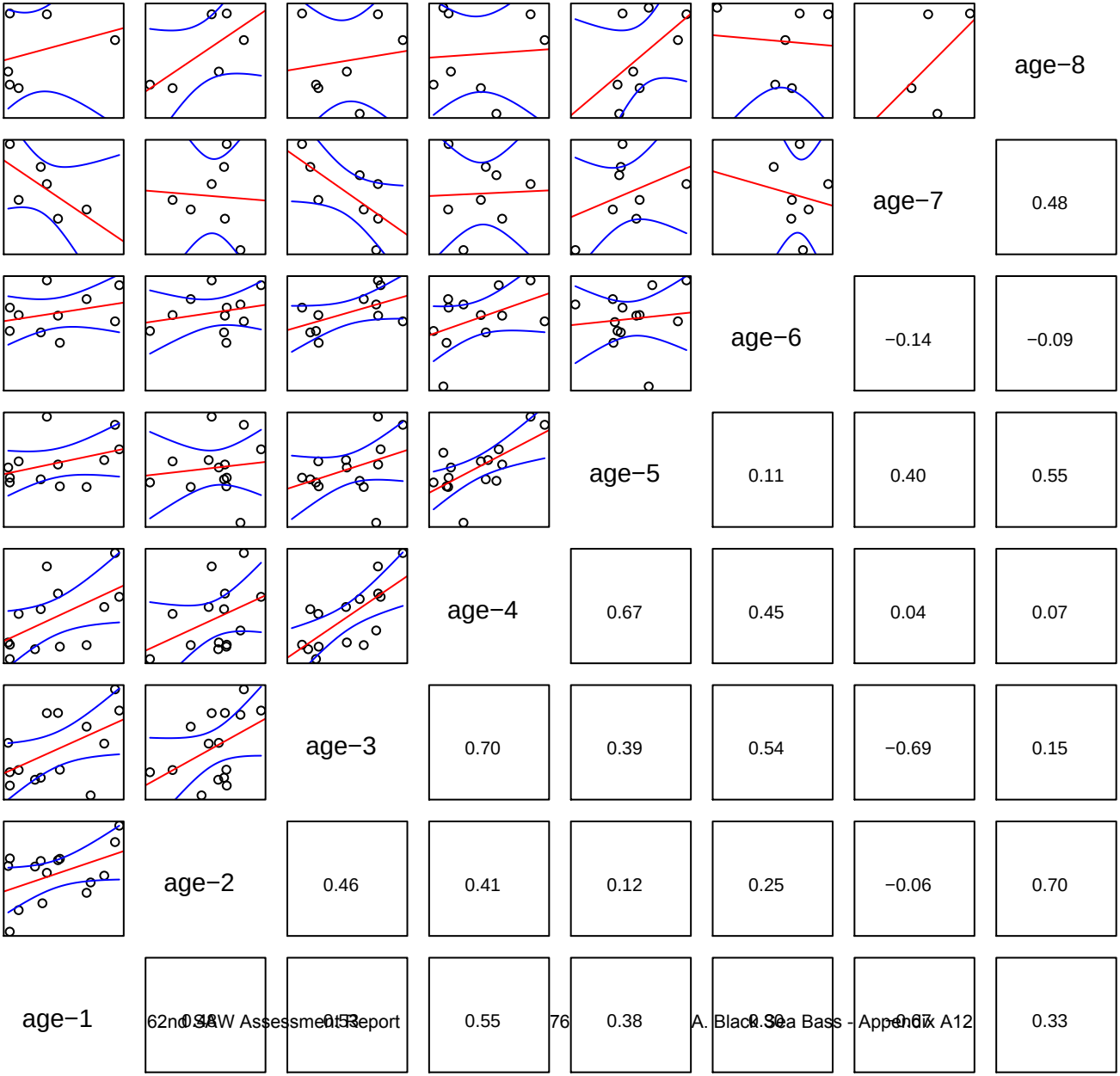
Index 3 Observed



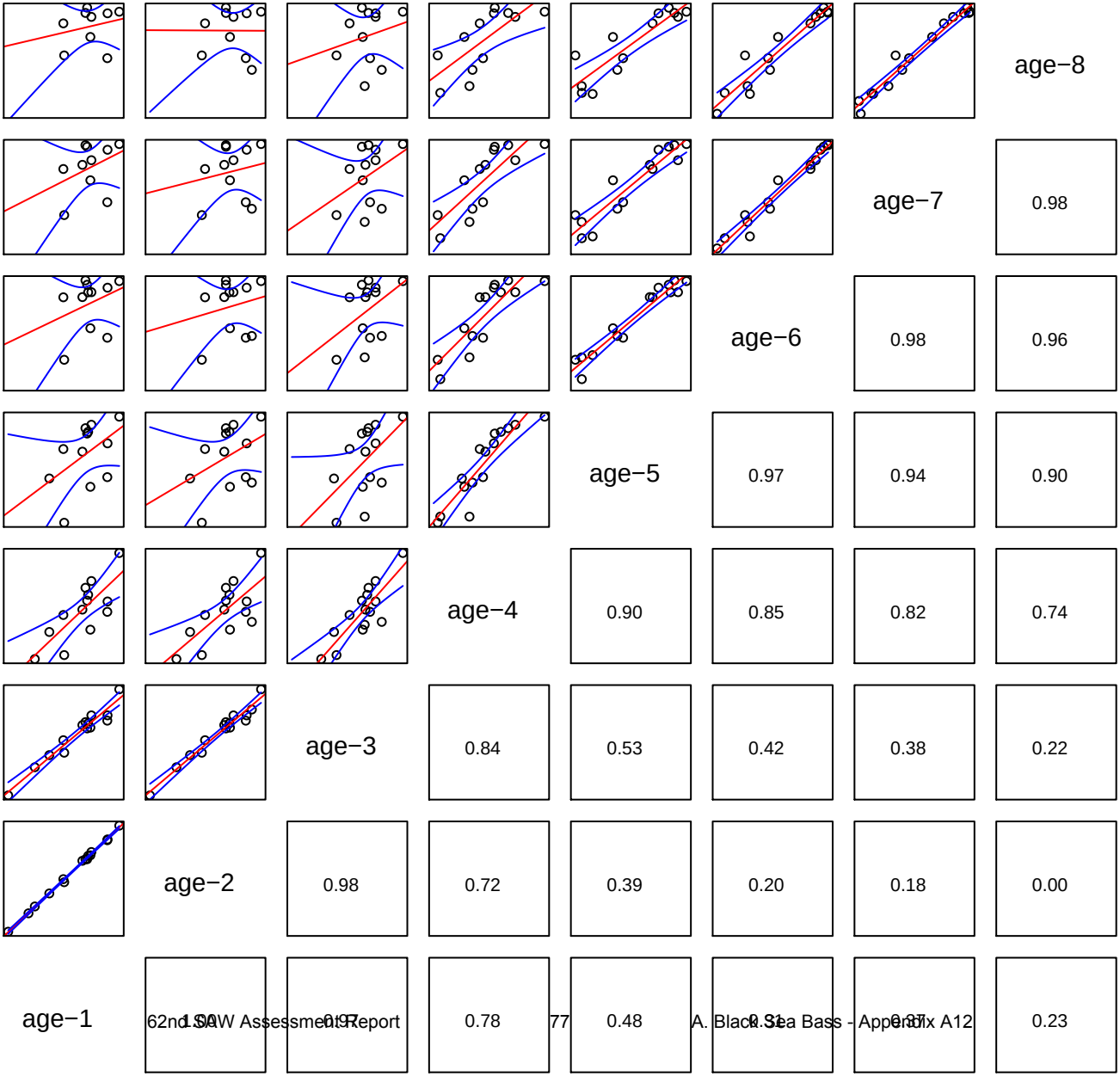
Index 3 Predicted



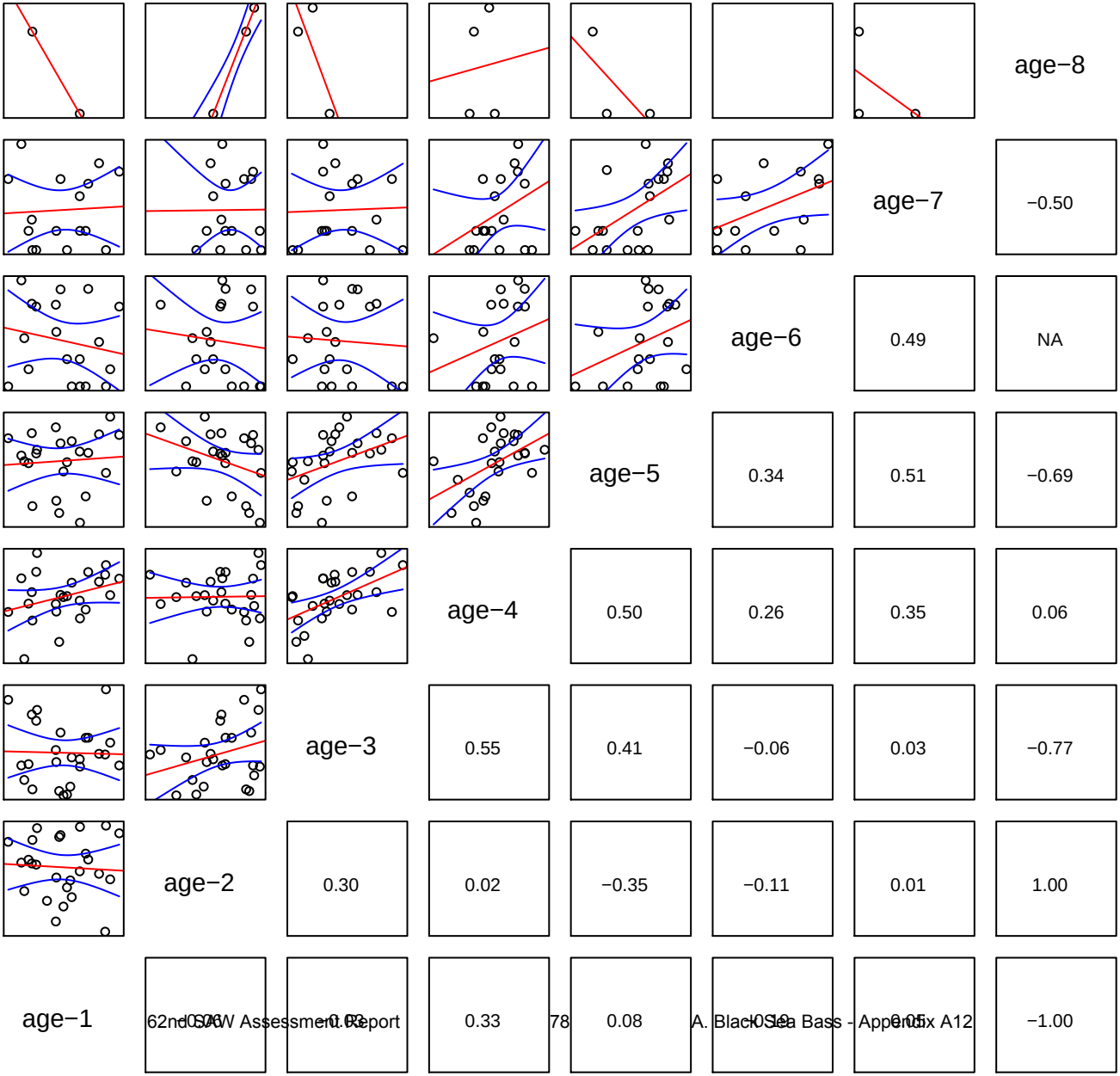
Index 7 Observed



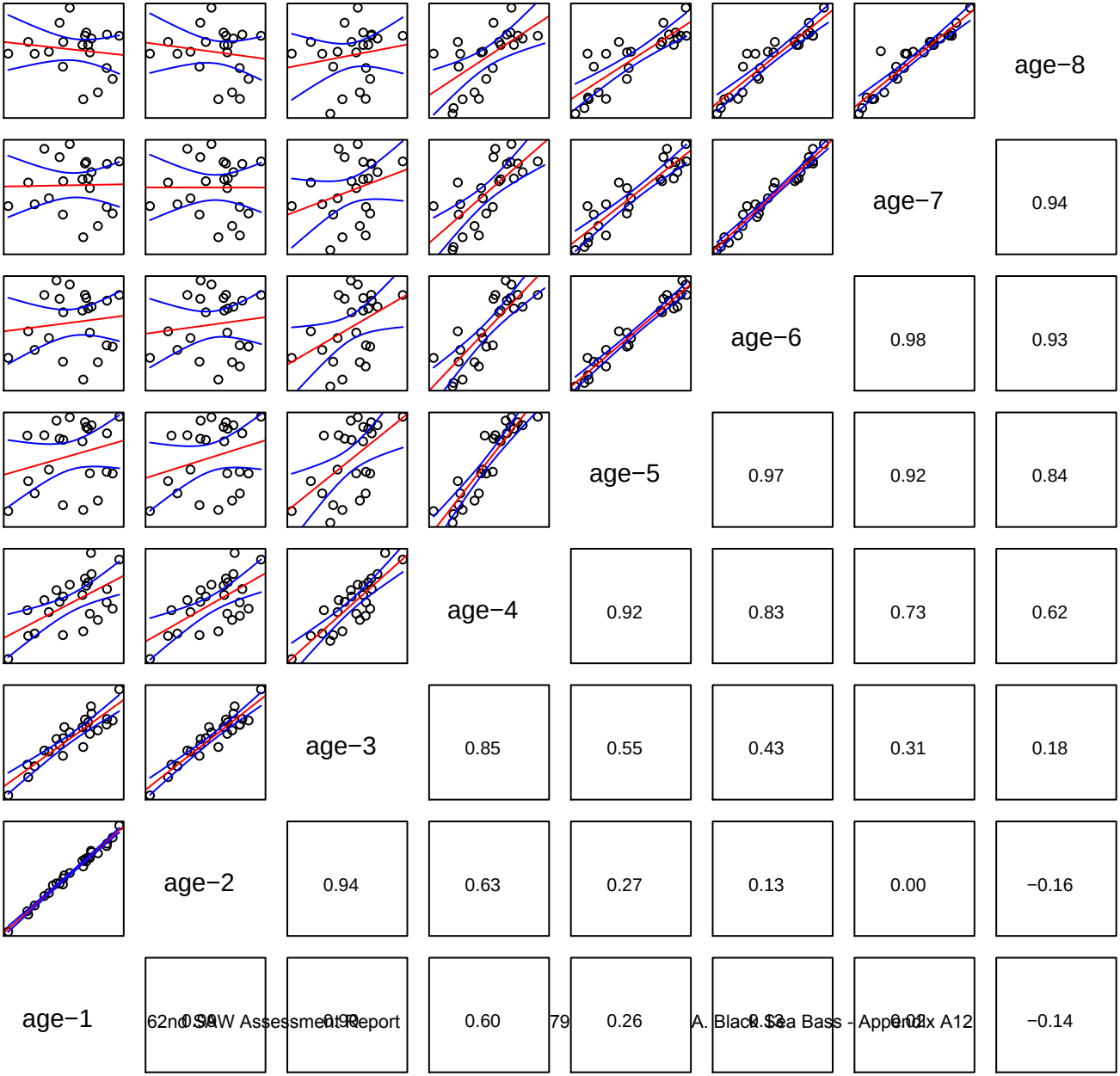
Index 7 Predicted



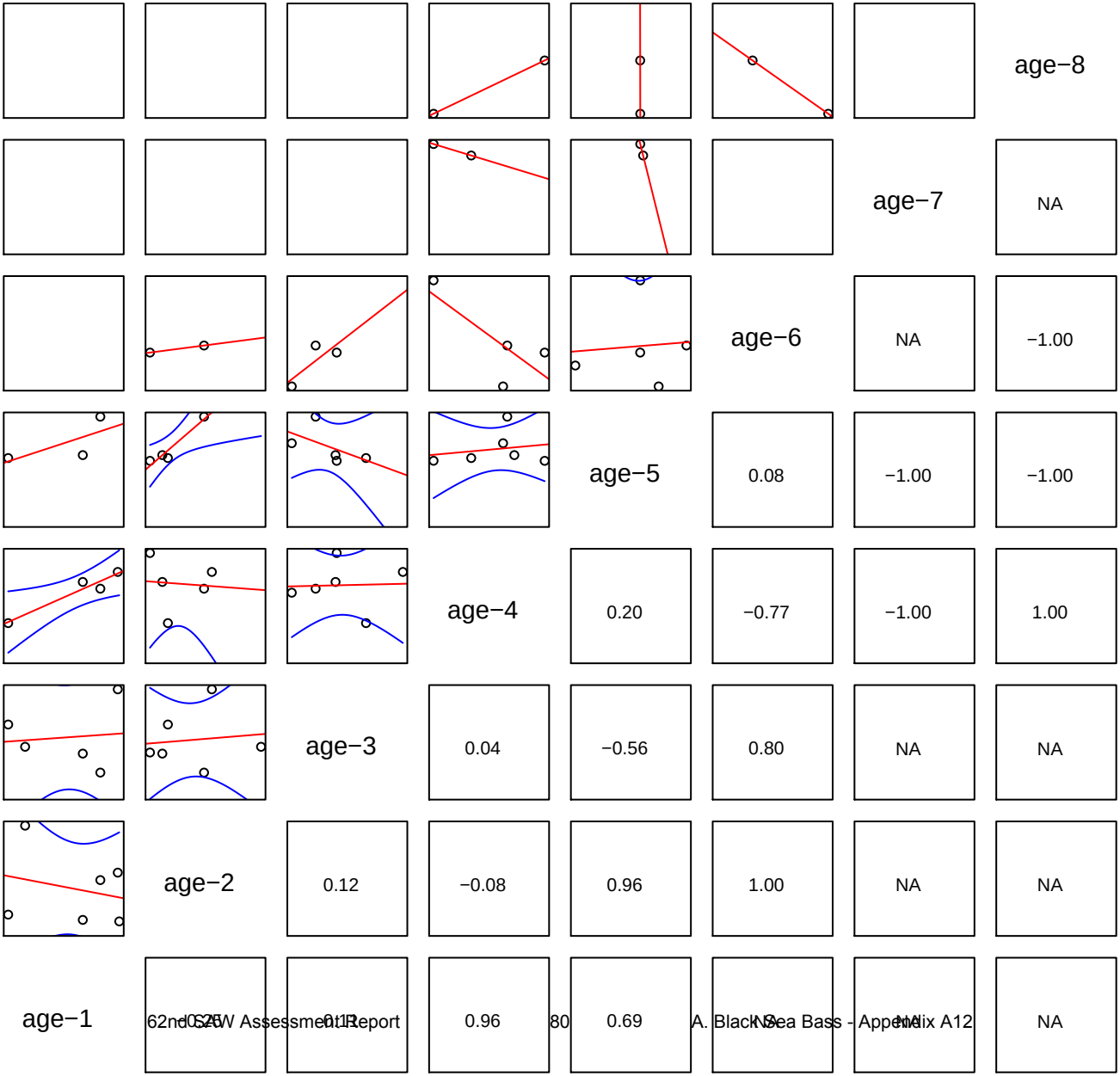
Index 8 Observed



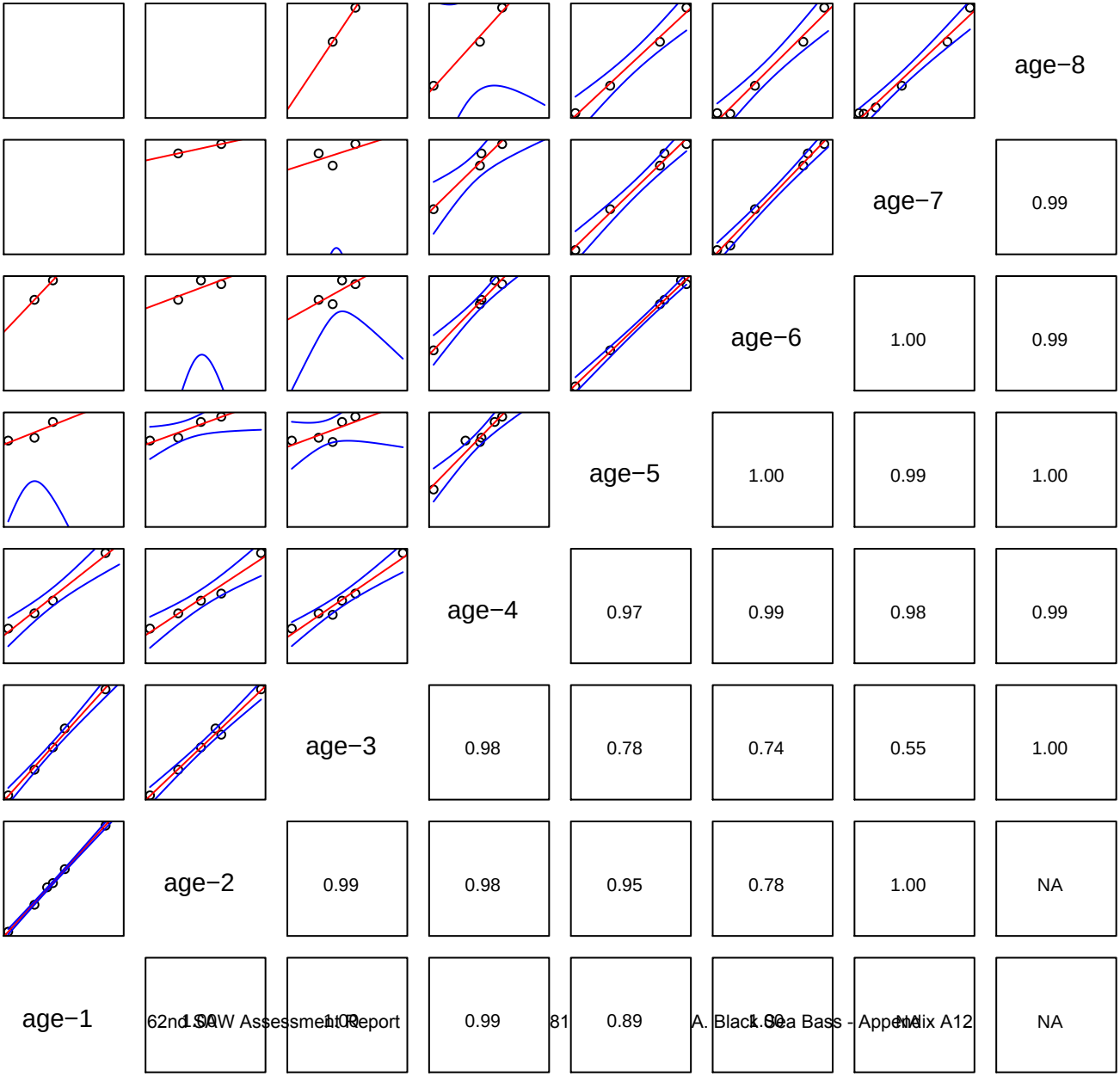
Index 8 Predicted

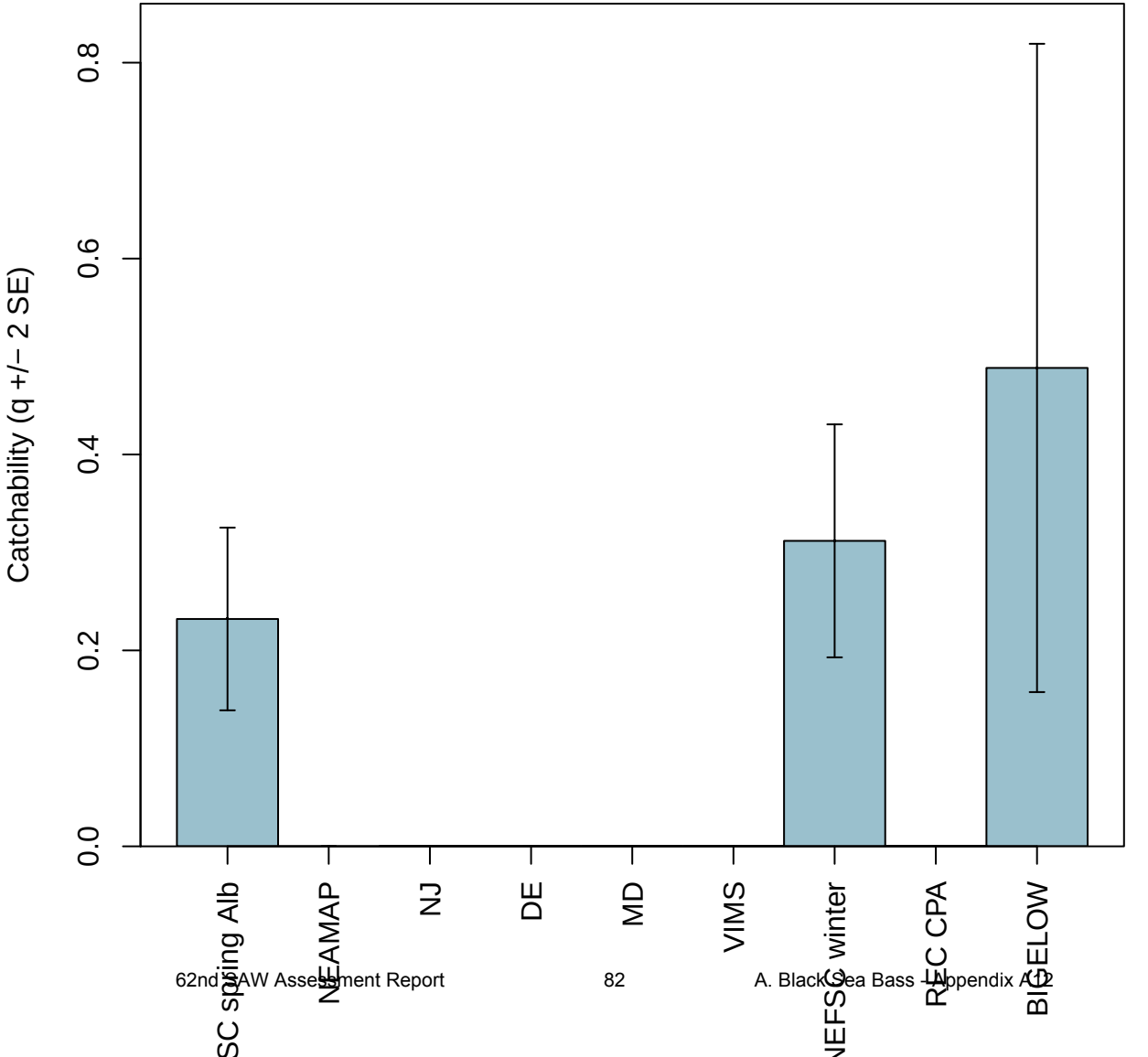


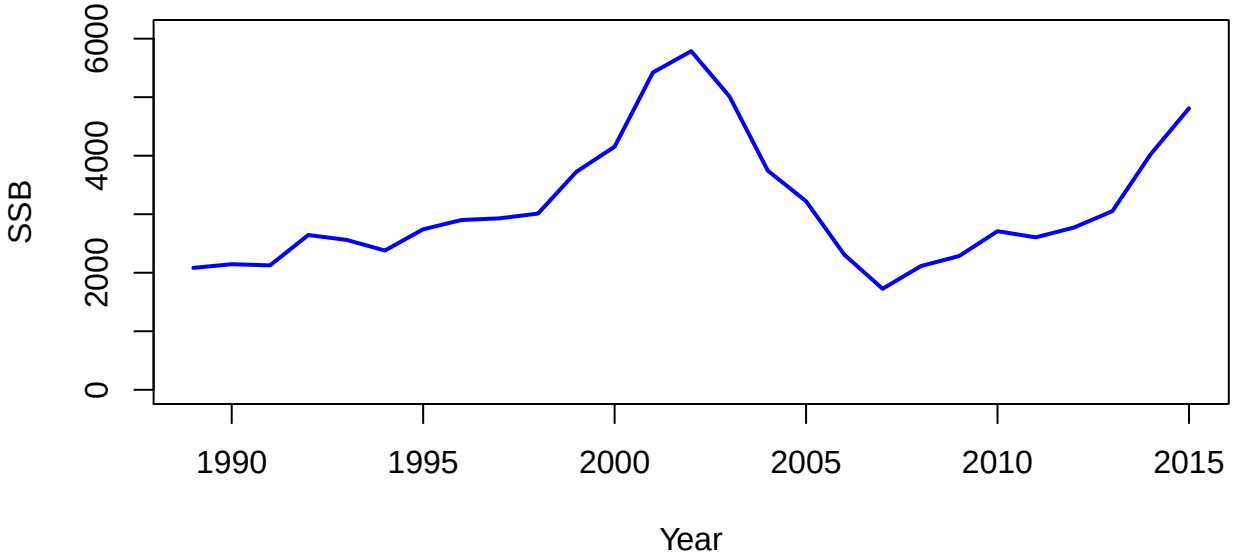
Index 9 Observed

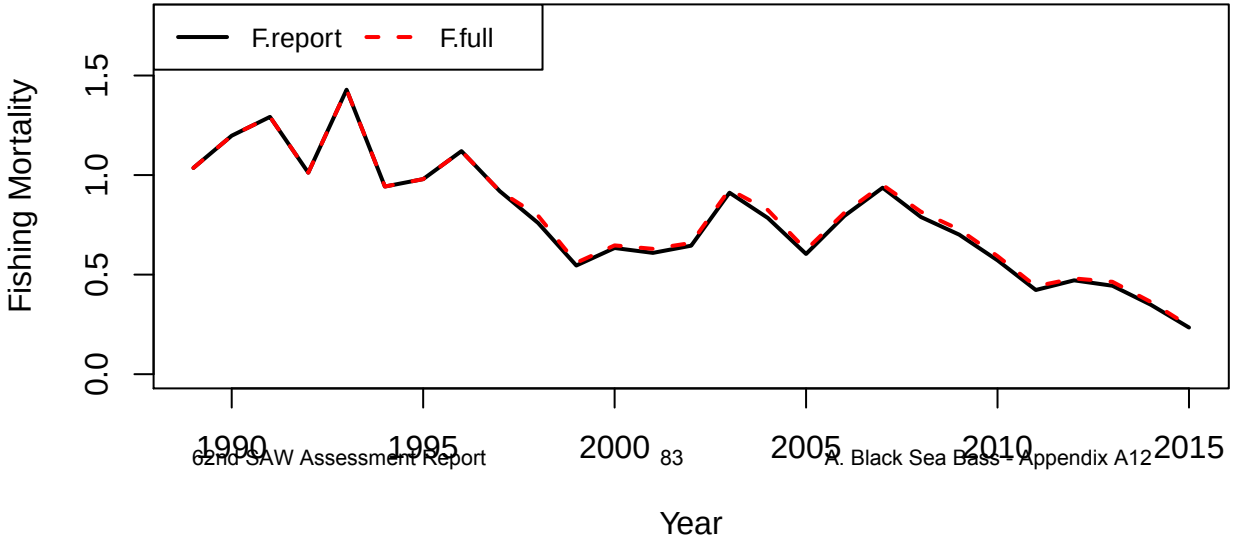


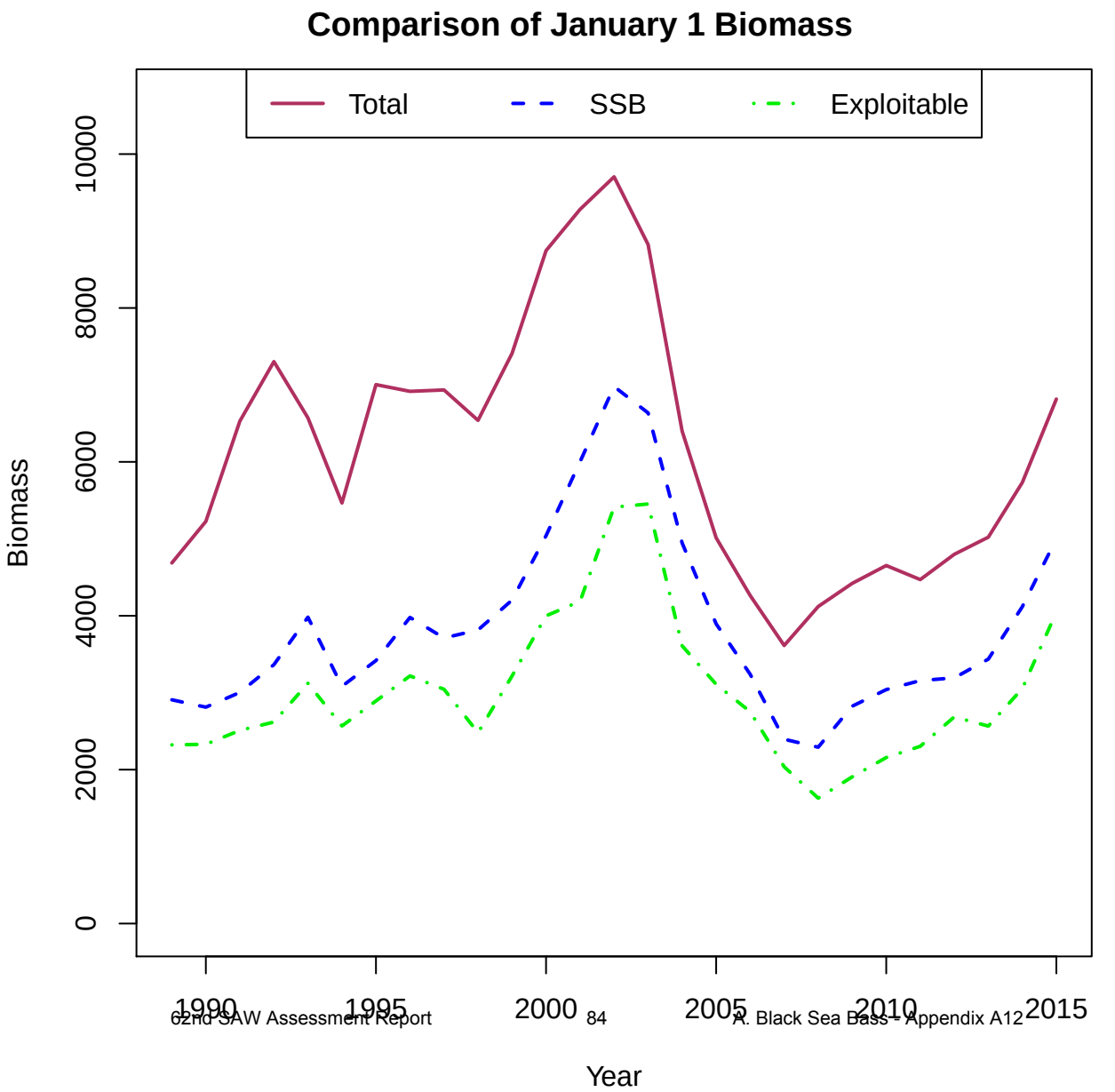
Index 9 Predicted

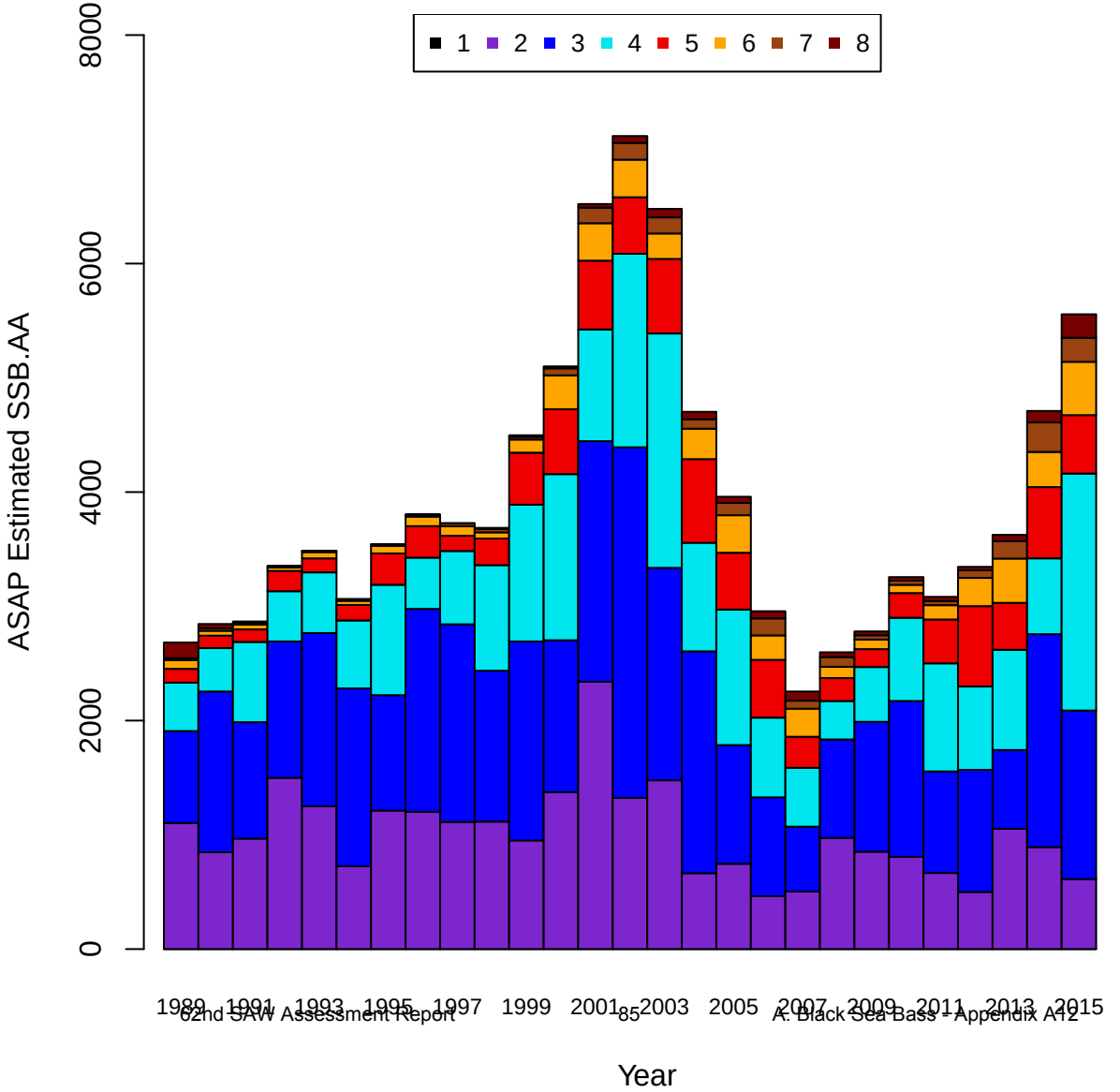


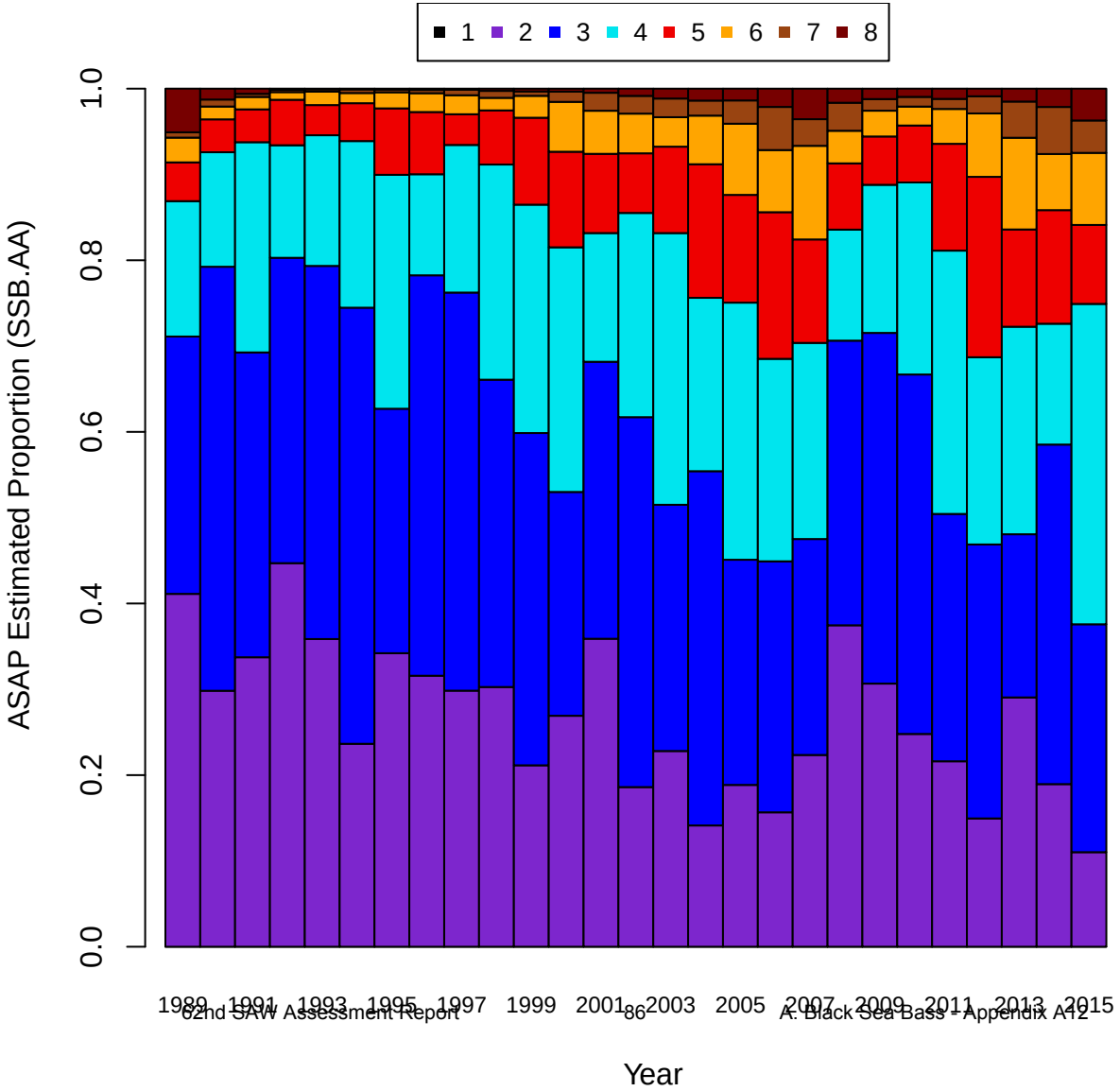

Catchability (q +/− 2 SE)
0.0
0.2
0.4
0.6
0.8
SC spring Alb
NEAMAP
NJ
DE
MD
VIMS
NEFSC winter
RFC CPA
BIGELOW

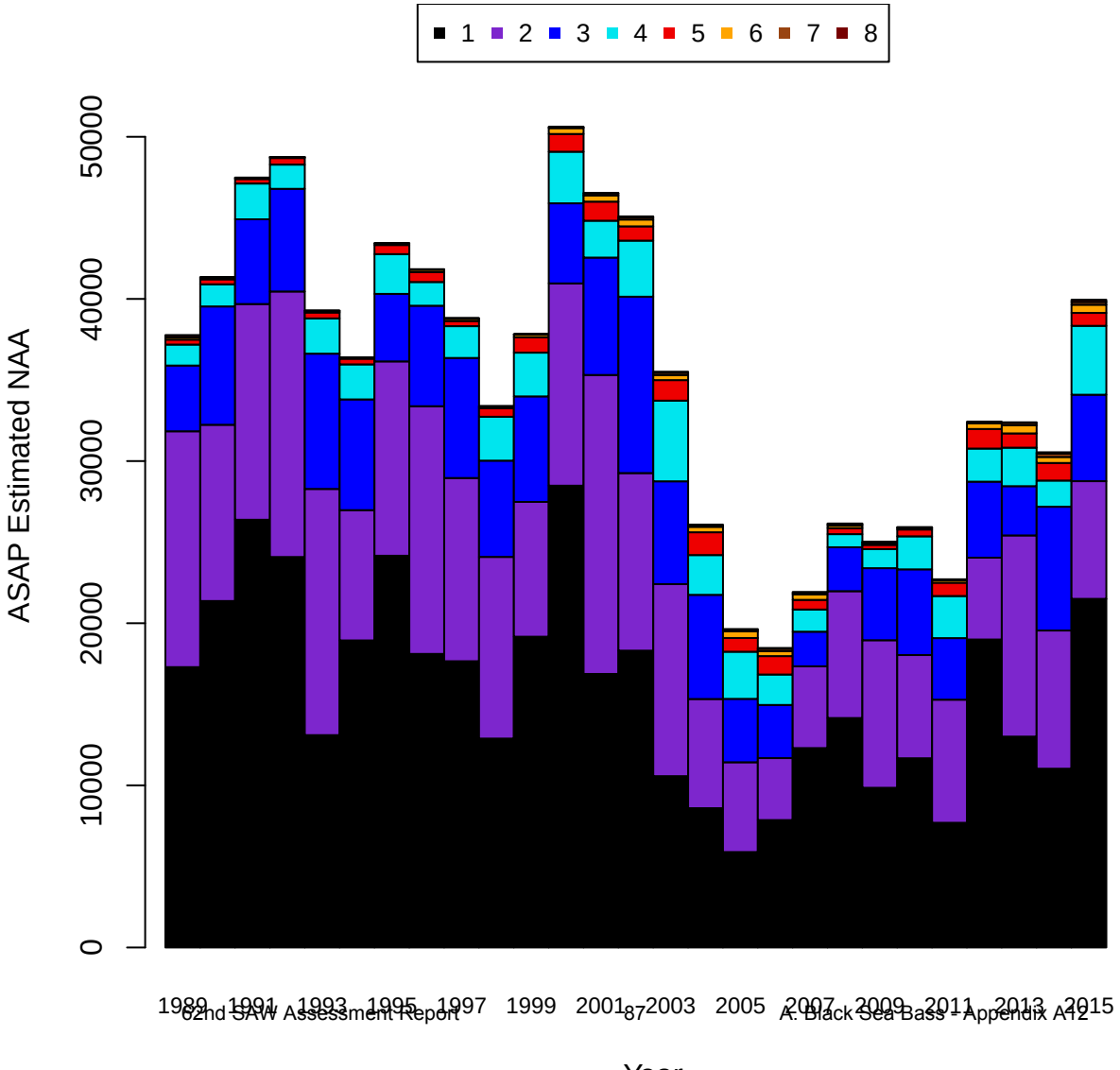

SSB
0
2000
4000
6000
1990
1995
2000
2005
2010
2015
Year

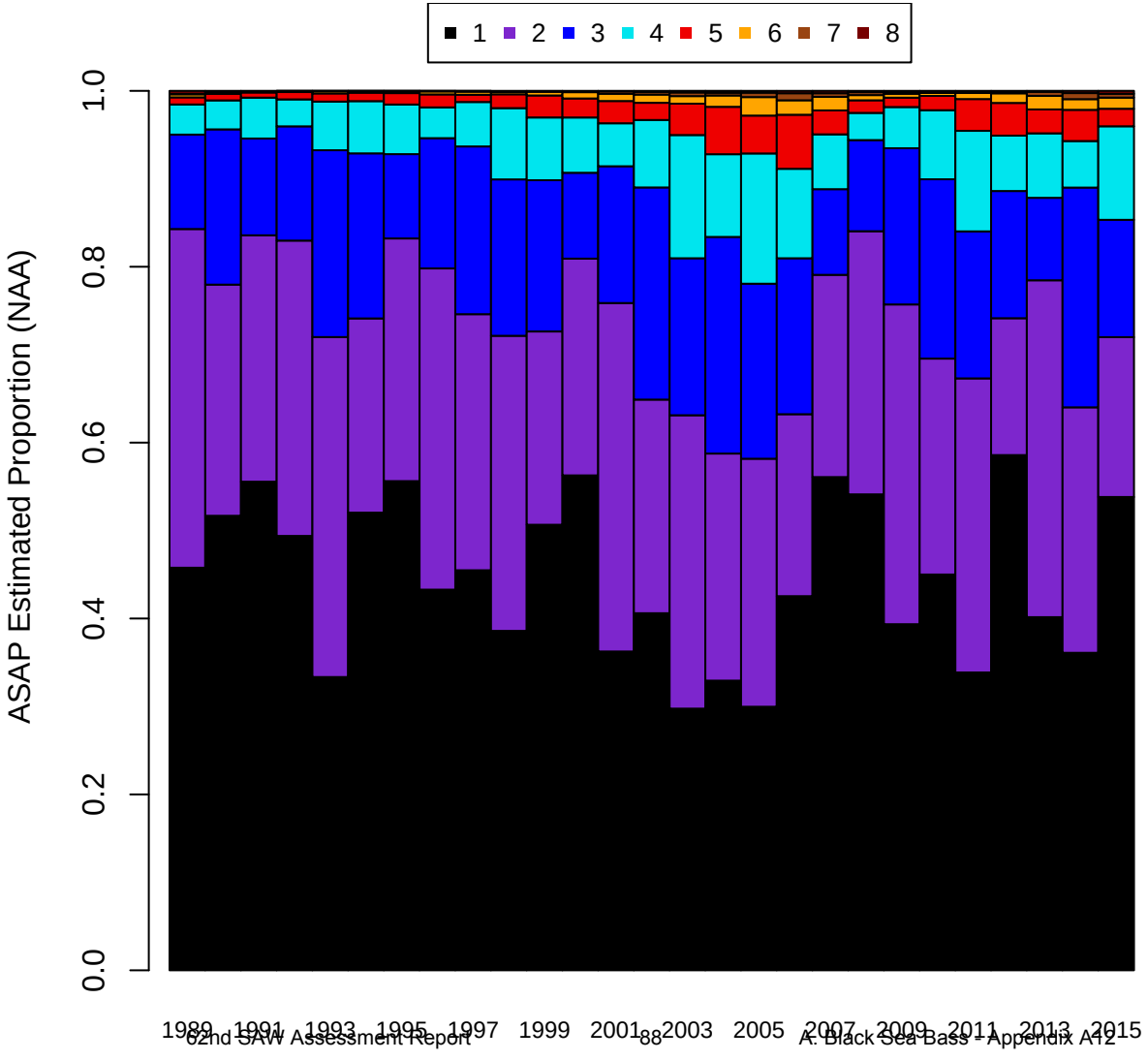

F.report
F.full
Fishing Mortality
0.0
0.5
1.0
1.5
1990
1995
2000
2005
2010
2015
Year

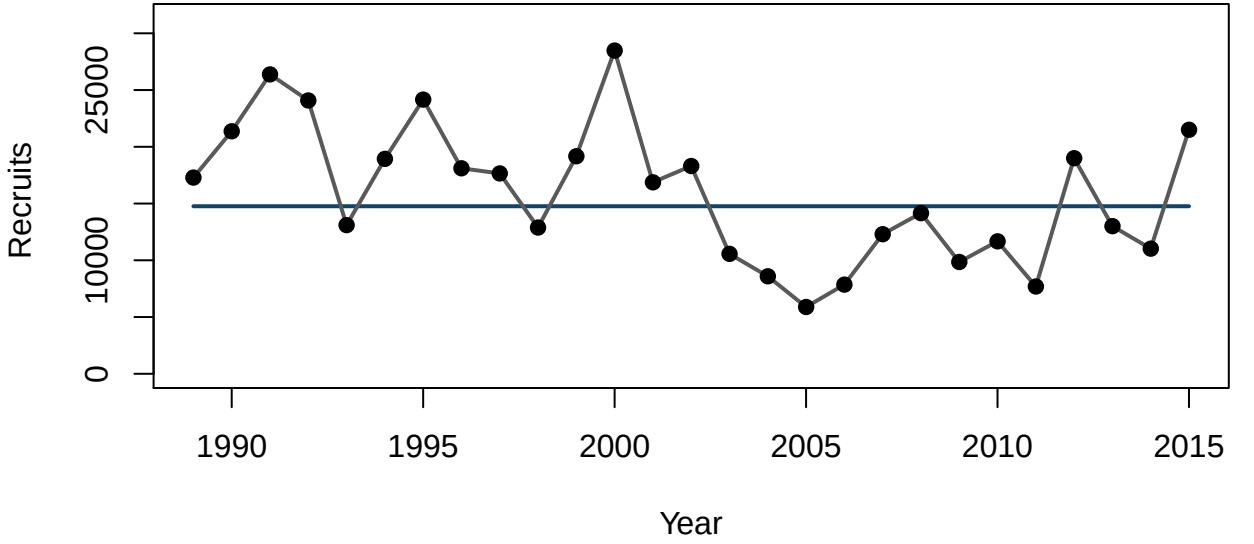

Comparison of January 1 Biomass
Total
SSB
Exploitable
Biomass
0
2000
4000
6000
8000
10000
1990
1995
2000
2005
2010
2015
Year

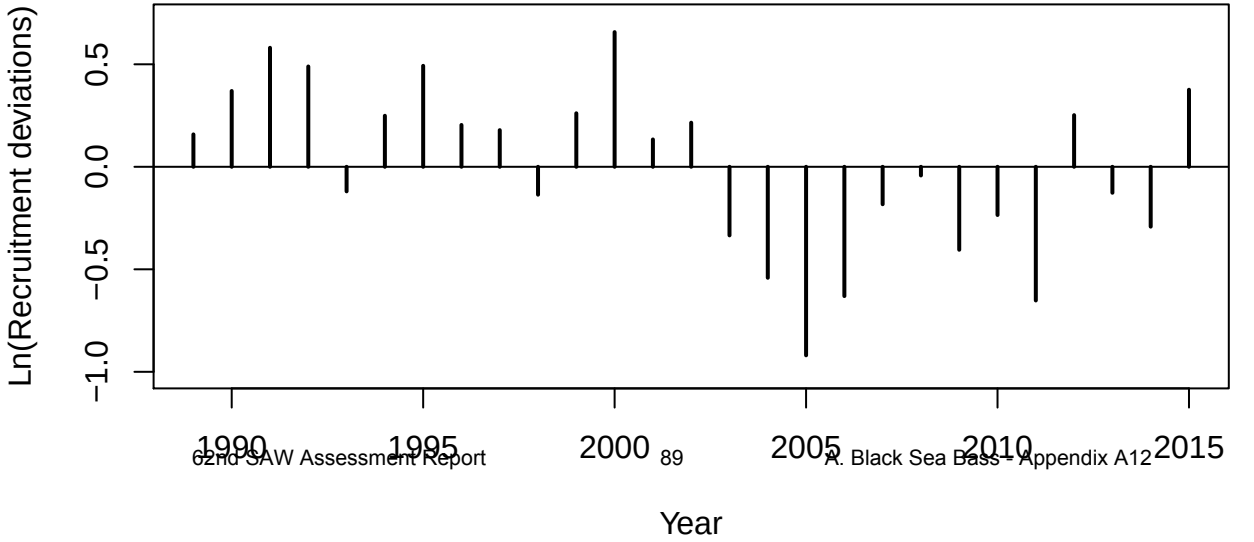

1 2 3 4 5 6 7 8
ASAP Estimated SSB.AA
0
2000
4000
6000
8000
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

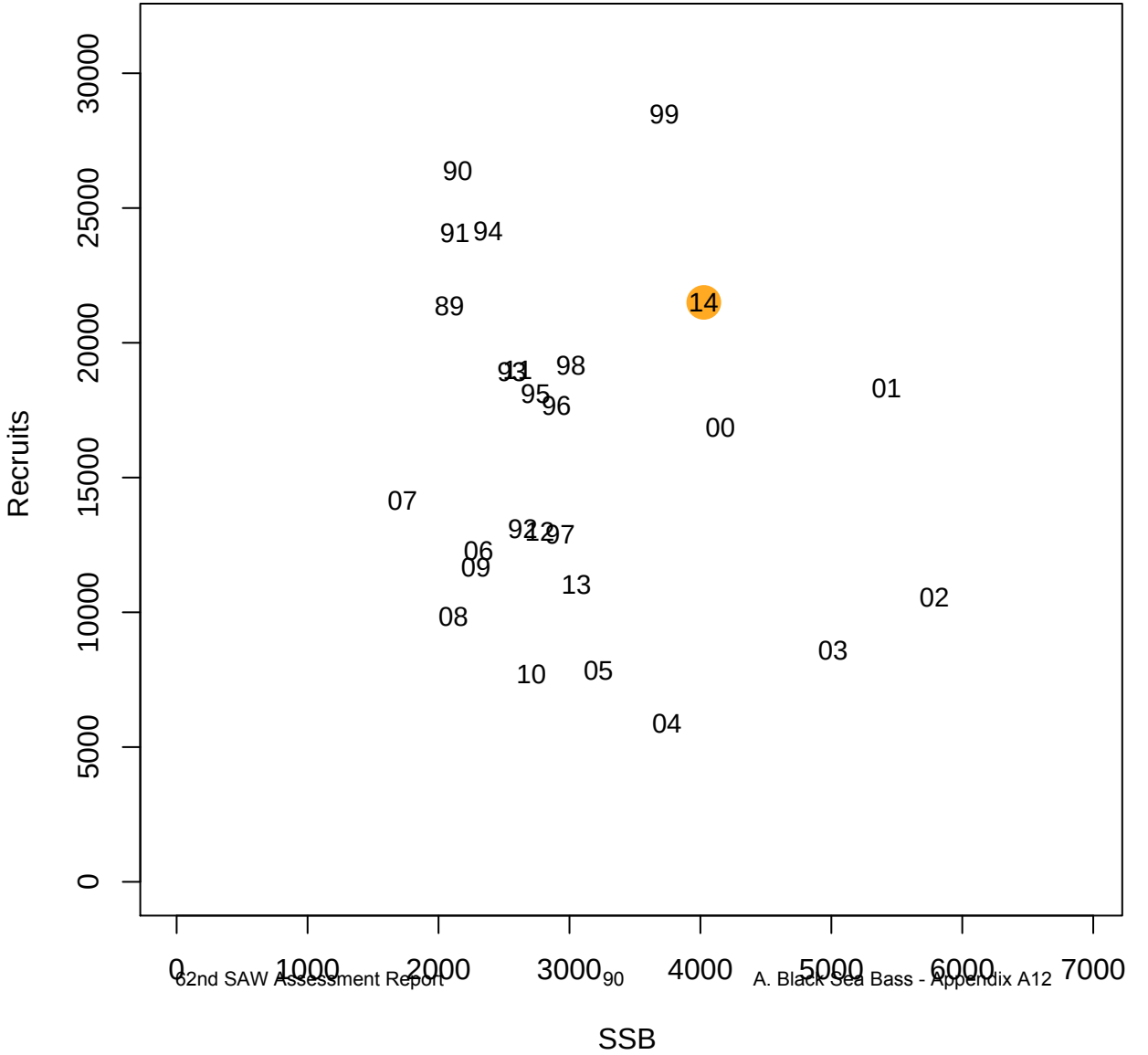

1 2 3 4 5 6 7 8
ASAP Estimated Proportion (SSB.AA)
0.0
0.2
0.4
0.6
0.8
1.0
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

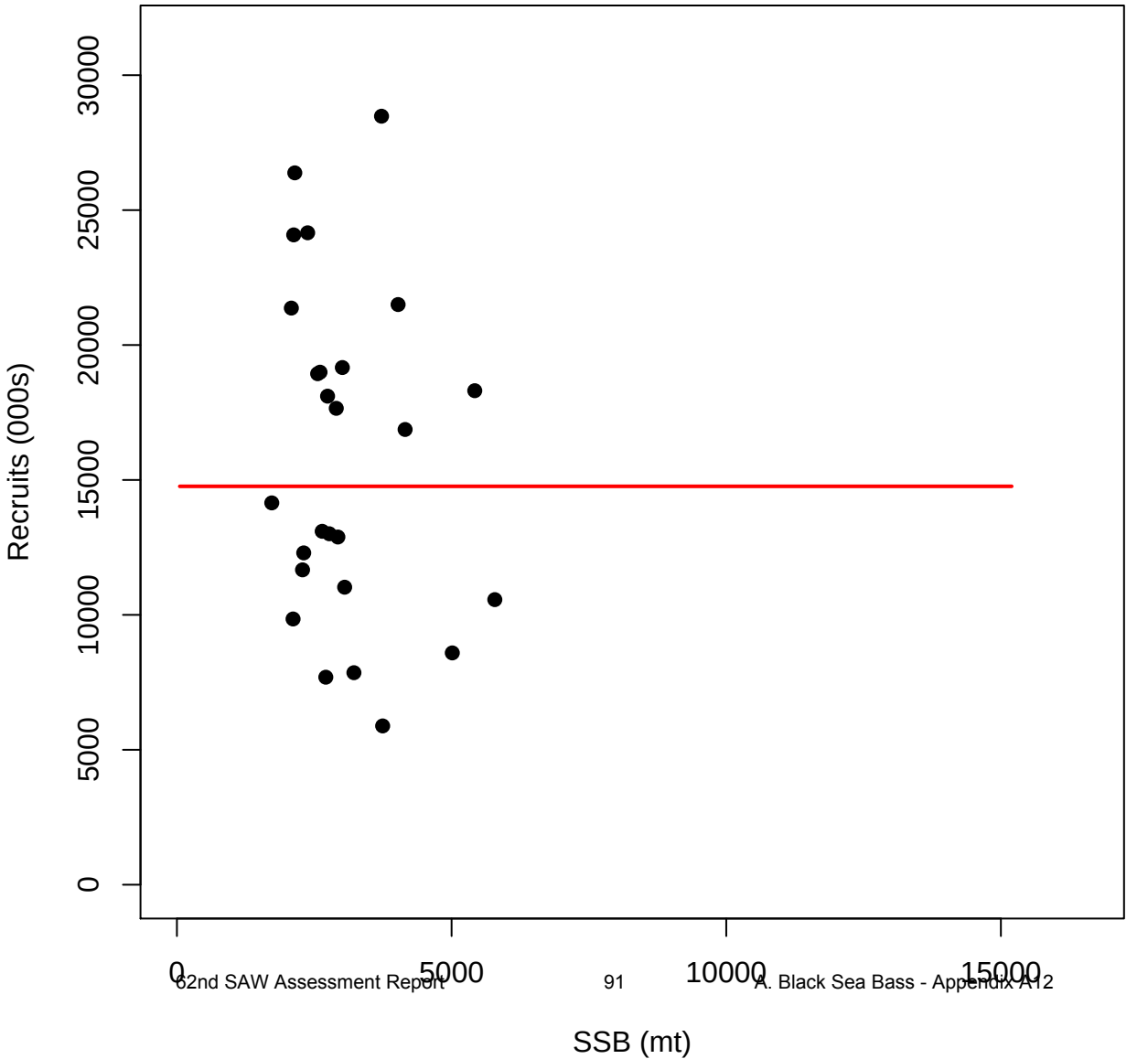

1 2 3 4 5 6 7 8
ASAP Estimated NAA
0
10000
20000
30000
40000
50000
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

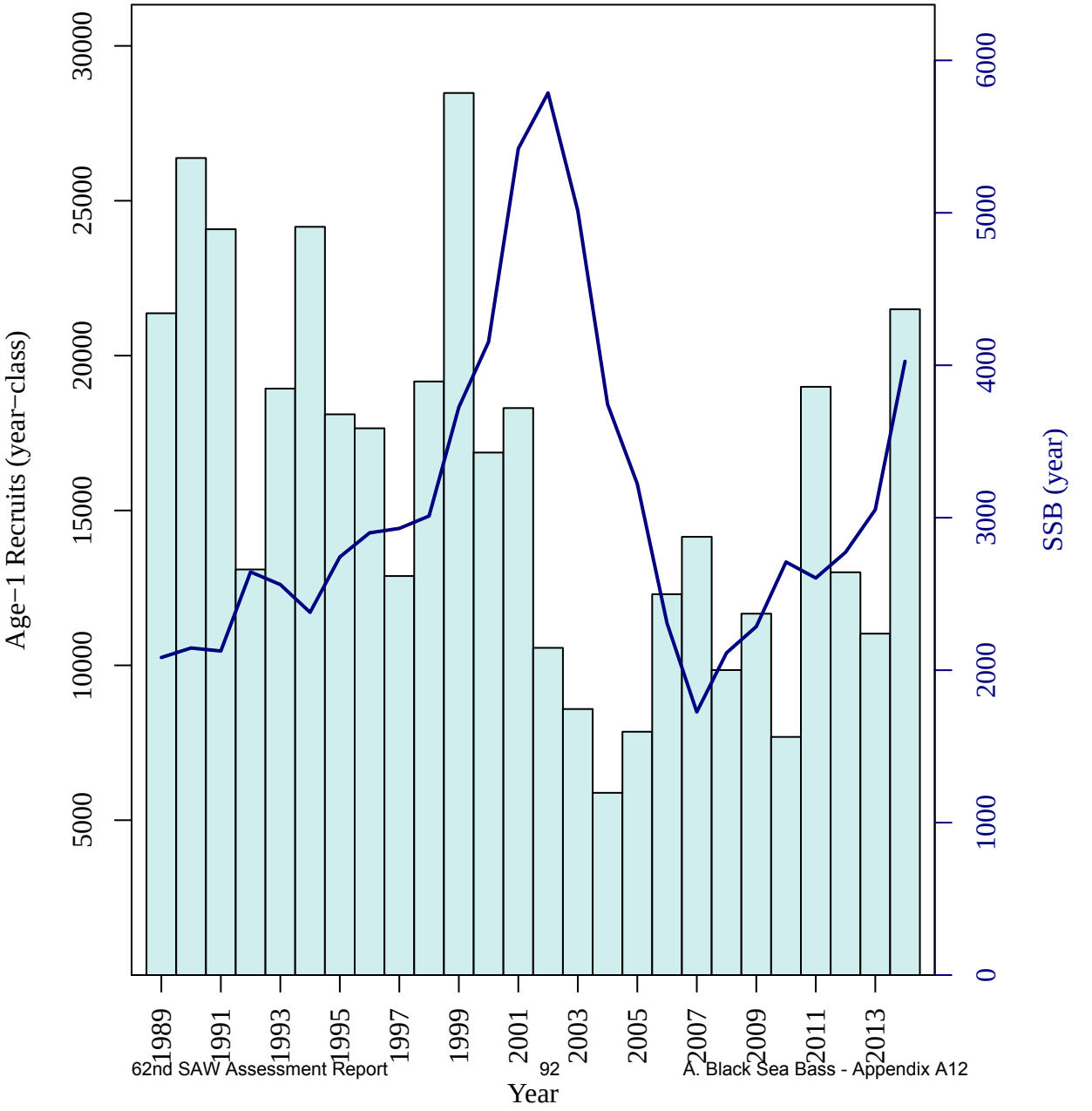

1 2 3 4 5 6 7 8
ASAP Estimated Proportion (NAA)
0.0
0.2
0.4
0.6
0.8
1.0
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

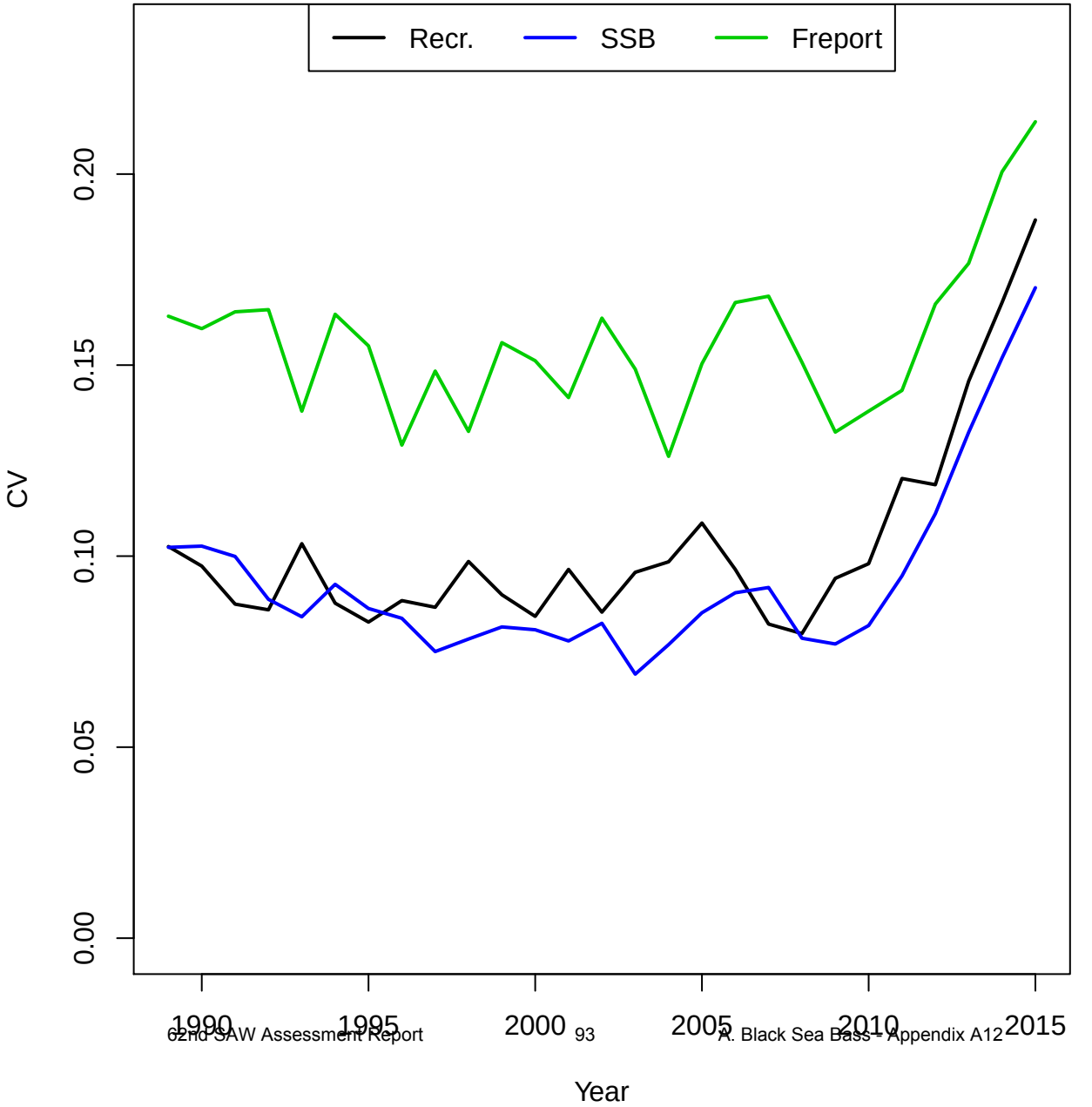

Recruits
0
10000
25000
1990
1995
2000
2005
2010
2015
Year

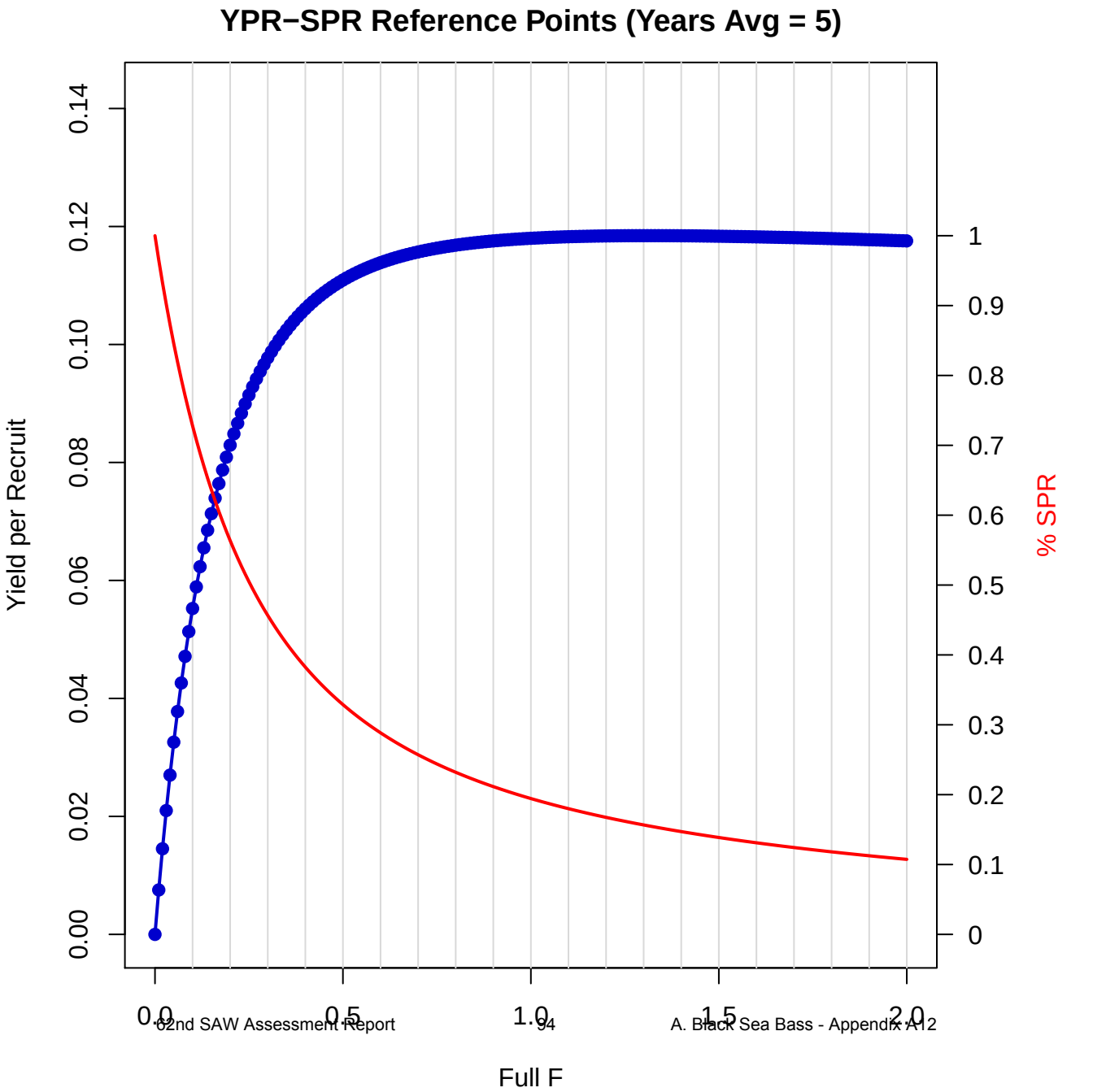

Ln(Recruitment deviations)
−1.0
−0.5
0.0
0.5
1990
1995
2000
2005
2010
2015
Year


Recruits
SSB
0
5000
10000
15000
20000
25000
30000
0
1000
2000
3000
4000
5000
6000
7000
99
90
91
94
89
14
98
01
95
96
00
07
06
09
13
02
08
03
10
05
04


Recruits (000s)
0
5000
10000
15000
20000
25000
30000
0
5000
10000
15000
SSB (mt)

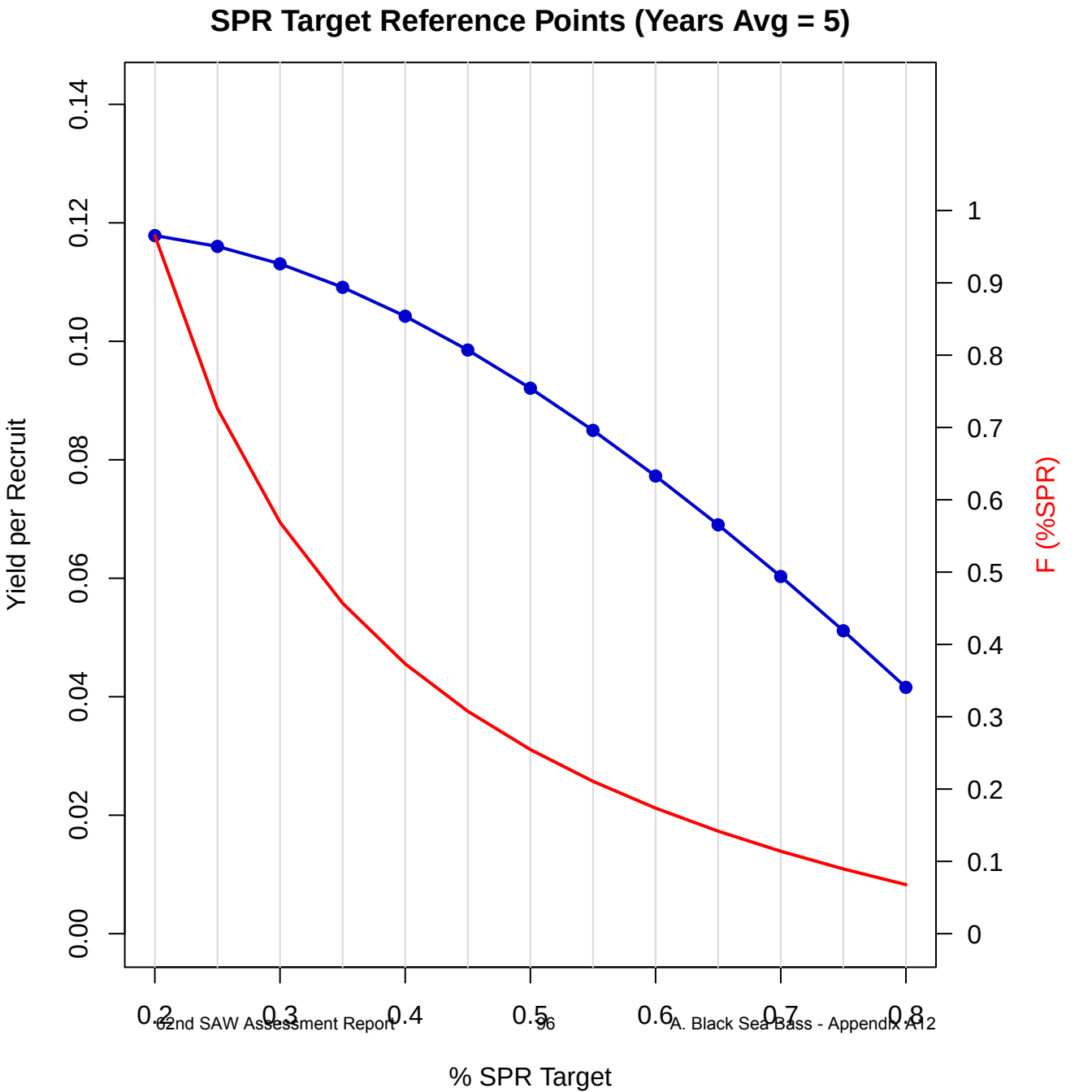

Age−1 Recruits (year−class)
5000
10000
15000
20000
25000
30000
SSB (year)
0
1000
2000
3000
4000
5000
6000
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Year


Recr.
SSB
Freport
CV
0.00
0.05
0.10
0.15
0.20
1990
1995
2000
2005
2010
2015
Year


YPR−SPR Reference Points (Years Avg = 5)
Yield per Recruit
% SPR
Full F
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.0
0.5
1.0
1.5
2.0

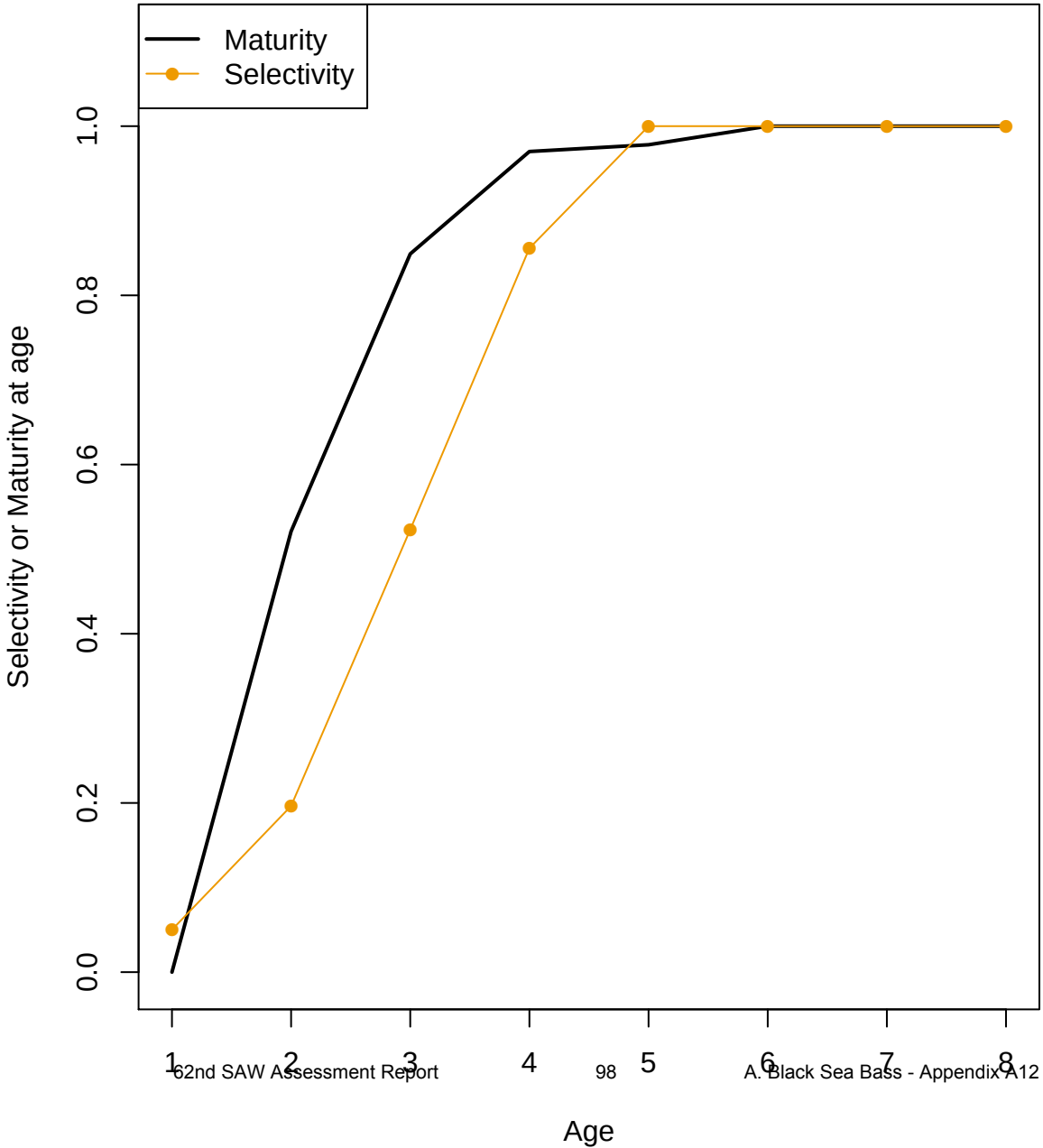
YPR−SPR Reference Points (Years Avg = 5)

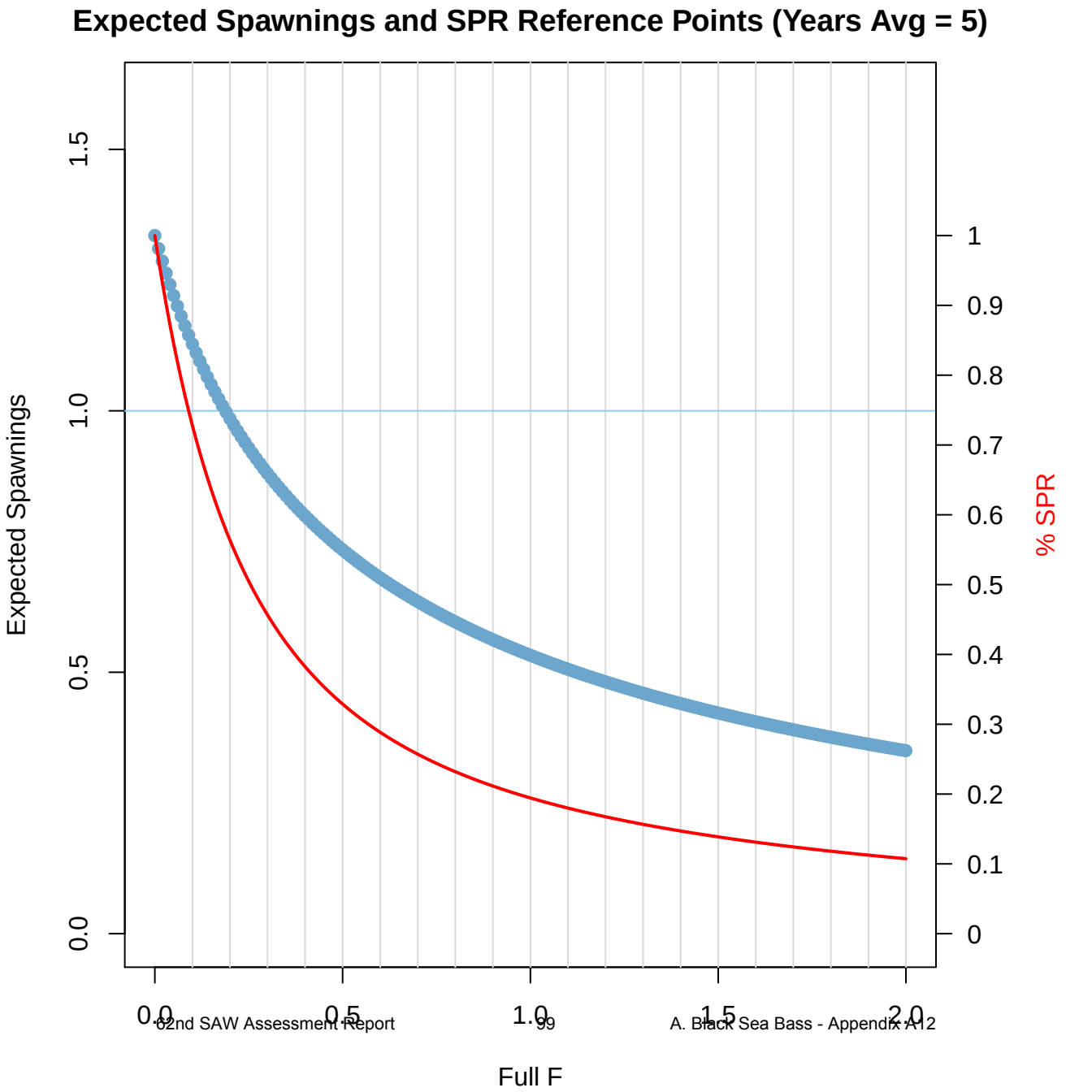
F	YPR	SPR	F	YPR	SPR	F	YPR	SPR
0	0	1	0.35	0.1025	0.4164	0.7	0.1157	0.2571
0.01	0.0075	0.9654	0.36	0.1033	0.4091	0.71	0.1158	0.2544
0.02	0.0145	0.9328	0.37	0.104	0.4021	0.72	0.1159	0.2517
0.03	0.021	0.902	0.38	0.1047	0.3954	0.73	0.1161	0.249
0.04	0.027	0.8729	0.39	0.1054	0.3889	0.74	0.1162	0.2464
0.05	0.0326	0.8454	0.4	0.106	0.3825	0.75	0.1163	0.2439
0.06	0.0378	0.8194	0.41	0.1067	0.3764	0.76	0.1164	0.2414
0.07	0.0426	0.7947	0.42	0.1072	0.3704	0.77	0.1165	0.239
0.08	0.0471	0.7713	0.43	0.1078	0.3647	0.78	0.1166	0.2366
0.09	0.0513	0.749	0.44	0.1083	0.3591	0.79	0.1167	0.2343
0.1	0.0552	0.7279	0.45	0.1088	0.3537	0.8	0.1168	0.232
0.11	0.0589	0.7078	0.46	0.1093	0.3484	0.81	0.1169	0.2298
0.12	0.0623	0.6886	0.47	0.1097	0.3433	0.82	0.117	0.2276
0.13	0.0655	0.6704	0.48	0.1101	0.3384	0.83	0.1171	0.2255
0.14	0.0685	0.653	0.49	0.1105	0.3336	0.84	0.1171	0.2233
0.15	0.0713	0.6363	0.5	0.1109	0.3289	0.85	0.1172	0.2213
0.16	0.074	0.6205	0.51	0.1113	0.3243	0.86	0.1173	0.2193
0.17	0.0764	0.6053	0.52	0.1116	0.3199	0.87	0.1174	0.2173
0.18	0.0787	0.5908	0.53	0.1119	0.3156	0.88	0.1174	0.2153
0.19	0.0809	0.5769	0.54	0.1123	0.3114	0.89	0.1175	0.2134
0.2	0.0829	0.5636	0.55	0.1126	0.3074	0.9	0.1175	0.2115
0.21	0.0848	0.5509	0.56	0.1128	0.3034	0.91	0.1176	0.2097
0.22	0.0866	0.5386	0.57	0.1131	0.2995	0.92	0.1176	0.2079
0.23	0.0883	0.5269	0.58	0.1134	0.2958	0.93	0.1177	0.2061
0.24	0.0899	0.5156	0.59	0.1136	0.2921	0.94	0.1177	0.2043
0.25	0.0914	0.5048	0.6	0.1138	0.2885	0.95	0.1178	0.2026
0.26	0.0928	0.4944	0.61	0.1141	0.285	0.96	0.1178	0.2009
0.27	0.0942	0.4844	0.62	0.1143	0.2816	0.97	0.1179	0.1992
0.28	0.0954	0.4748	0.63	0.1145	0.2783	0.98	0.1179	0.1976
0.29	0.0966	0.4655	0.64	0.1147	0.2751	0.99	0.118	0.196
0.3	0.0977	0.4565	0.65	0.1149	0.2719	1	0.118	0.1944
0.31	0.0988	0.4479	0.66	0.115	0.2688	1.01	0.118	0.1929
0.32	0.0998	0.4396	0.67	0.1152	0.2658	1.02	0.1181	0.1913
0.33	0.1007	0.4316	0.68	0.1154	0.2628	1.03	0.1181	0.1898
0.34	0.1016	0.4238	0.69	0.1155	0.2599	1.04	0.1181	0.1883


SPR Target Reference Points (Years Avg = 5)
Yield per Recruit
F (%SPR)
% SPR Target
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

SPR Target Reference Points (Years Avg = 5)

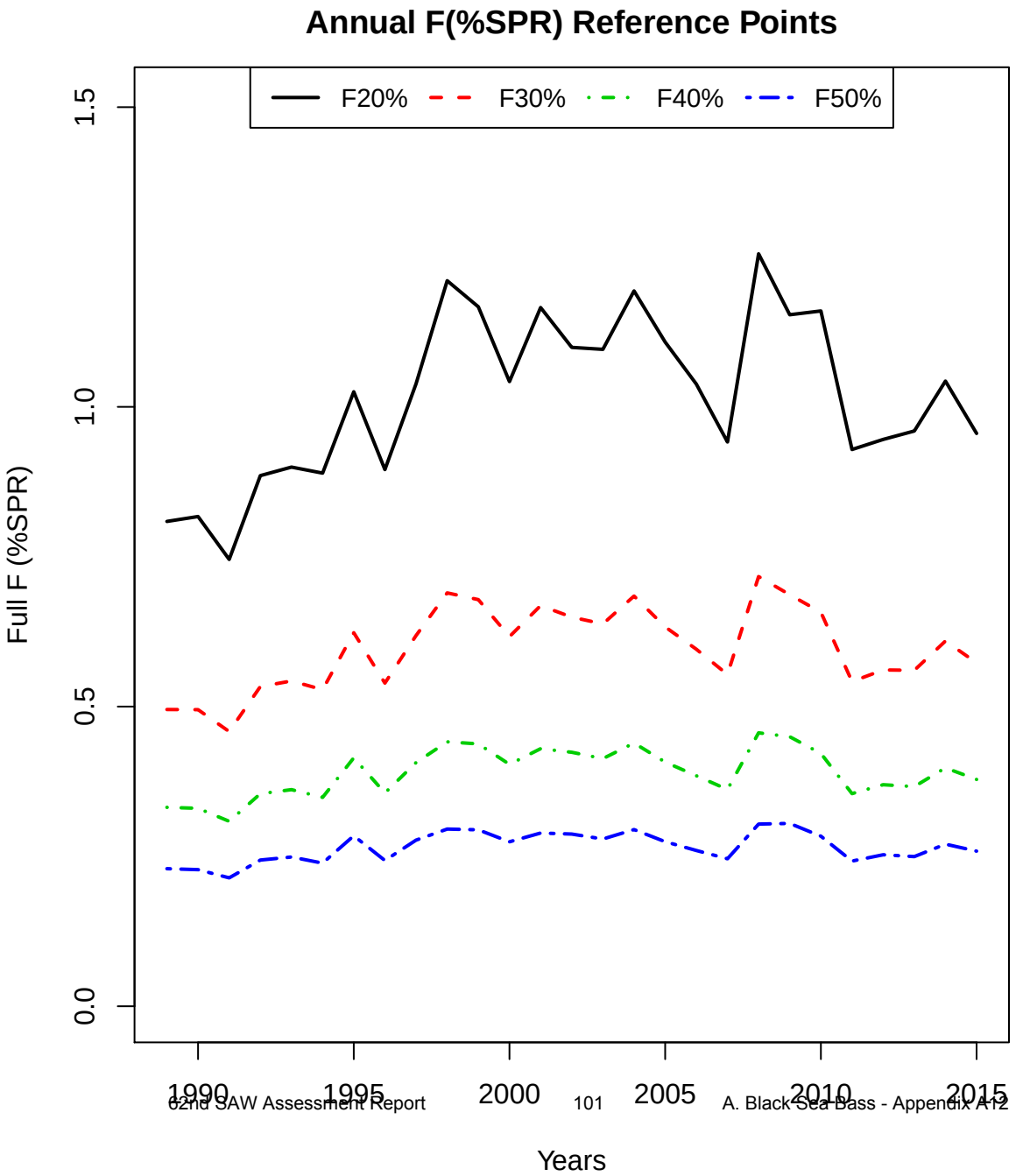
% SPR	F(%SPR)	YPR
0.2	0.9654	0.1179
0.25	0.7263	0.116
0.3	0.5688	0.1131
0.35	0.457	0.1091
0.4	0.3731	0.1042
0.45	0.3076	0.0985
0.5	0.2546	0.0921
0.55	0.2107	0.085
0.6	0.1736	0.0773
0.65	0.1417	0.069
0.7	0.114	0.0603
0.75	0.0895	0.0511
0.8	0.0678	0.0416

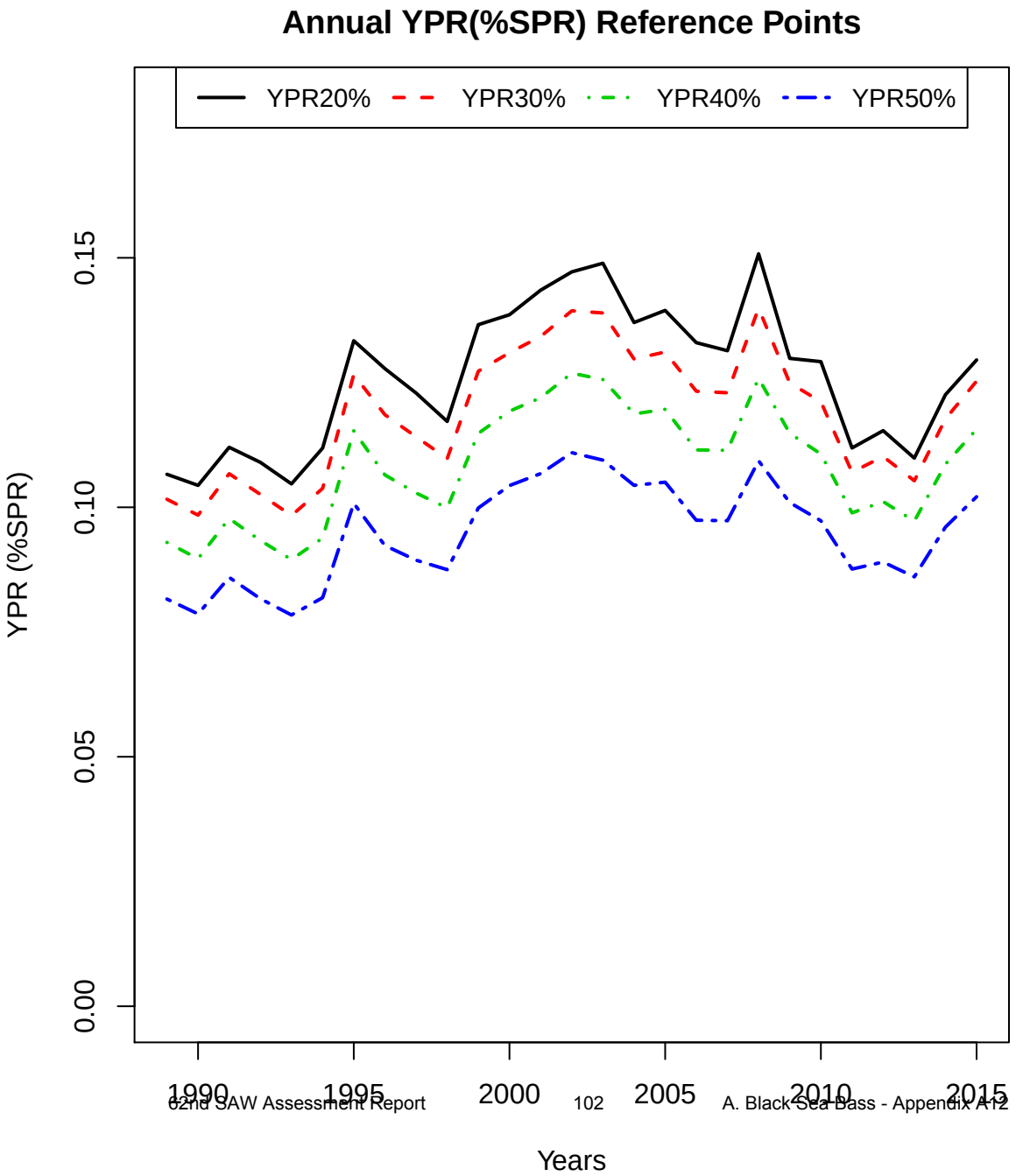

Maturity
Selectivity
Selectivity or Maturity at age
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
8
Age


Expected Spawnings and SPR Reference Points (Years Avg = 5)
Expected Spawnings
% SPR
Full F
0.0
0.5
1.0
1.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.0
0.5
1.0
1.5
2.0

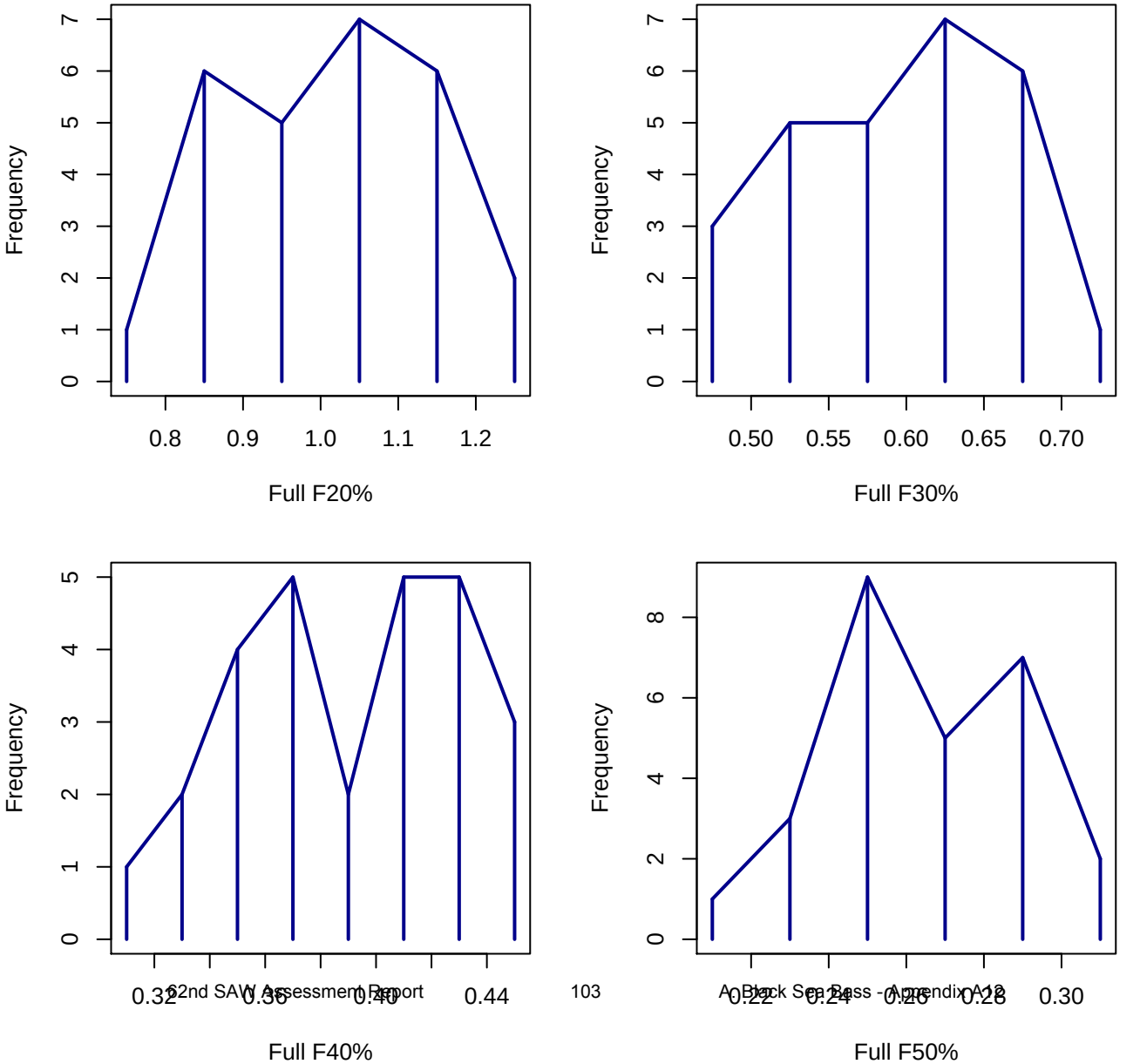
Expected Spawnings & SPR Reference Points (Years Avg = 5)

F	E[Sp]	SPR	F	E[Sp]	SPR	F	E[Sp]	SPR
0	1.3352	1	0.35	0.8374	0.4164	0.7	0.6352	0.2571
0.01	1.3102	0.9654	0.36	0.8294	0.4091	0.71	0.631	0.2544
0.02	1.2862	0.9328	0.37	0.8216	0.4021	0.72	0.6269	0.2517
0.03	1.2634	0.902	0.38	0.814	0.3954	0.73	0.6229	0.249
0.04	1.2415	0.8729	0.39	0.8065	0.3889	0.74	0.6189	0.2464
0.05	1.2205	0.8454	0.4	0.7992	0.3825	0.75	0.615	0.2439
0.06	1.2004	0.8194	0.41	0.7921	0.3764	0.76	0.6111	0.2414
0.07	1.1811	0.7947	0.42	0.7851	0.3704	0.77	0.6073	0.239
0.08	1.1625	0.7713	0.43	0.7783	0.3647	0.78	0.6036	0.2366
0.09	1.1447	0.749	0.44	0.7716	0.3591	0.79	0.5999	0.2343
0.1	1.1275	0.7279	0.45	0.765	0.3537	0.8	0.5962	0.232
0.11	1.111	0.7078	0.46	0.7586	0.3484	0.81	0.5926	0.2298
0.12	1.095	0.6886	0.47	0.7523	0.3433	0.82	0.5891	0.2276
0.13	1.0796	0.6704	0.48	0.7462	0.3384	0.83	0.5856	0.2255
0.14	1.0647	0.653	0.49	0.7401	0.3336	0.84	0.5821	0.2233
0.15	1.0503	0.6363	0.5	0.7342	0.3289	0.85	0.5787	0.2213
0.16	1.0364	0.6205	0.51	0.7284	0.3243	0.86	0.5754	0.2193
0.17	1.023	0.6053	0.52	0.7226	0.3199	0.87	0.572	0.2173
0.18	1.01	0.5908	0.53	0.717	0.3156	0.88	0.5688	0.2153
0.19	0.9973	0.5769	0.54	0.7115	0.3114	0.89	0.5655	0.2134
0.2	0.9851	0.5636	0.55	0.7061	0.3074	0.9	0.5623	0.2115
0.21	0.9732	0.5509	0.56	0.7008	0.3034	0.91	0.5592	0.2097
0.22	0.9617	0.5386	0.57	0.6956	0.2995	0.92	0.556	0.2079
0.23	0.9505	0.5269	0.58	0.6905	0.2958	0.93	0.553	0.2061
0.24	0.9396	0.5156	0.59	0.6854	0.2921	0.94	0.5499	0.2043
0.25	0.9291	0.5048	0.6	0.6805	0.2885	0.95	0.5469	0.2026
0.26	0.9188	0.4944	0.61	0.6756	0.285	0.96	0.5439	0.2009
0.27	0.9088	0.4844	0.62	0.6708	0.2816	0.97	0.541	0.1992
0.28	0.899	0.4748	0.63	0.6661	0.2783	0.98	0.5381	0.1976
0.29	0.8895	0.4655	0.64	0.6615	0.2751	0.99	0.5352	0.196
0.3	0.8803	0.4565	0.65	0.6569	0.2719	1	0.5324	0.1944
0.31	0.8713	0.4479	0.66	0.6524	0.2688	1.01	0.5296	0.1929
0.32	0.8625	0.4396	0.67	0.648	0.2658	1.02	0.5268	0.1913
0.33	0.8539	0.4316	0.68	0.6437	0.2628	1.03	0.5241	0.1898
0.34	0.8455	0.4238	0.69	0.6394	0.2599	1.04	0.5214	0.1883

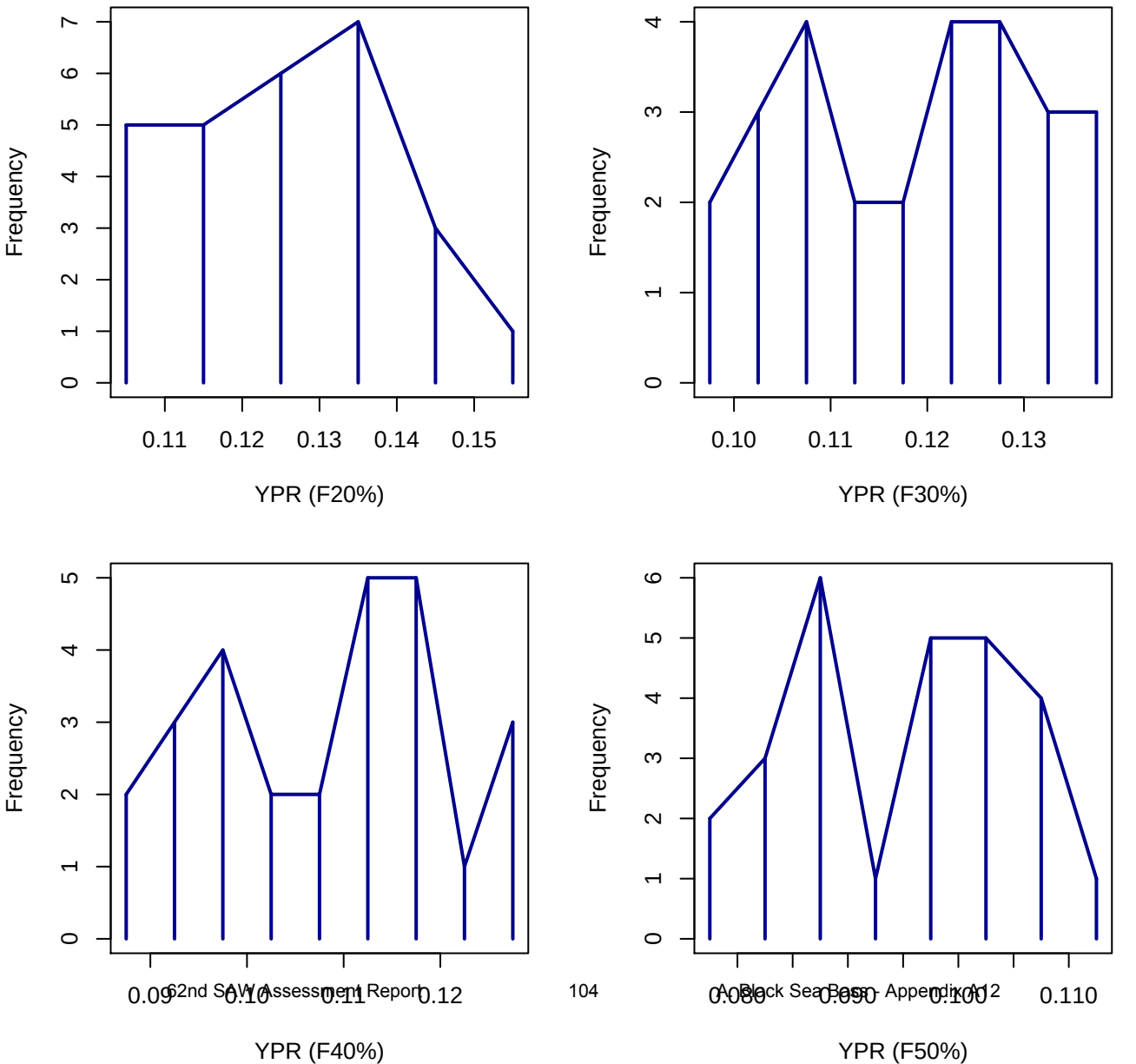

Annual F(%SPR) Reference Points
F20%
F30%
F40%
F50%
Full F (%SPR)
0.0
0.5
1.0
1.5
1990
1995
2000
2005
2010
2015
Years

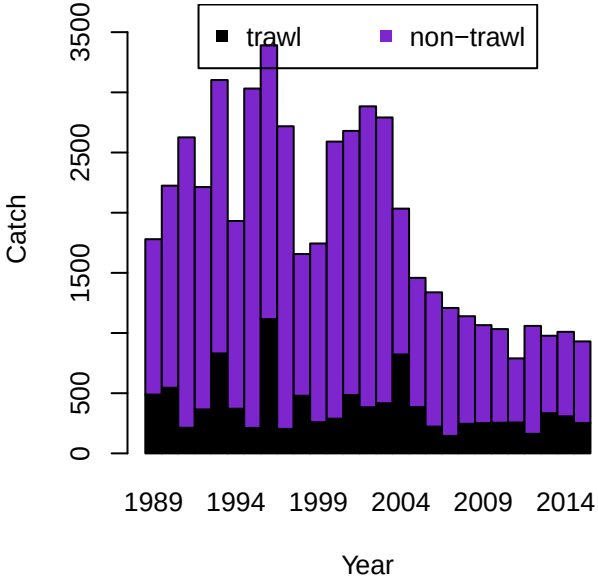

Annual YPR(%SPR) Reference Points
YPR20%
YPR30%
YPR40%
YPR50%
YPR (%SPR)
0.00
0.05
0.10
0.15
1990
1995
2000
2005
2010
2015
Years

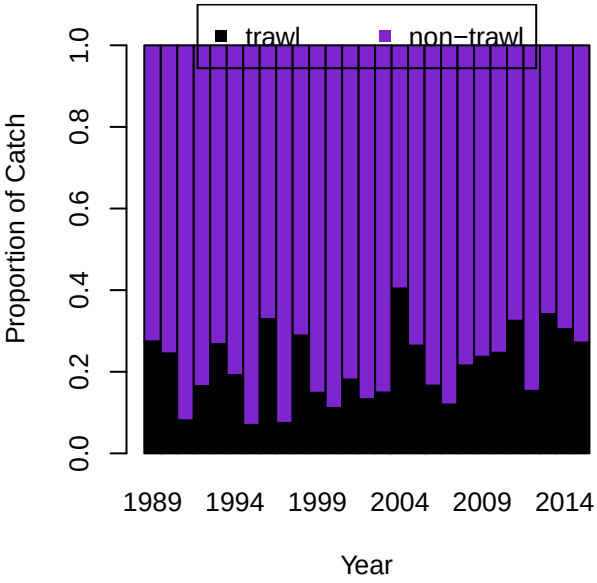
Annual F (%SPR) Reference Points

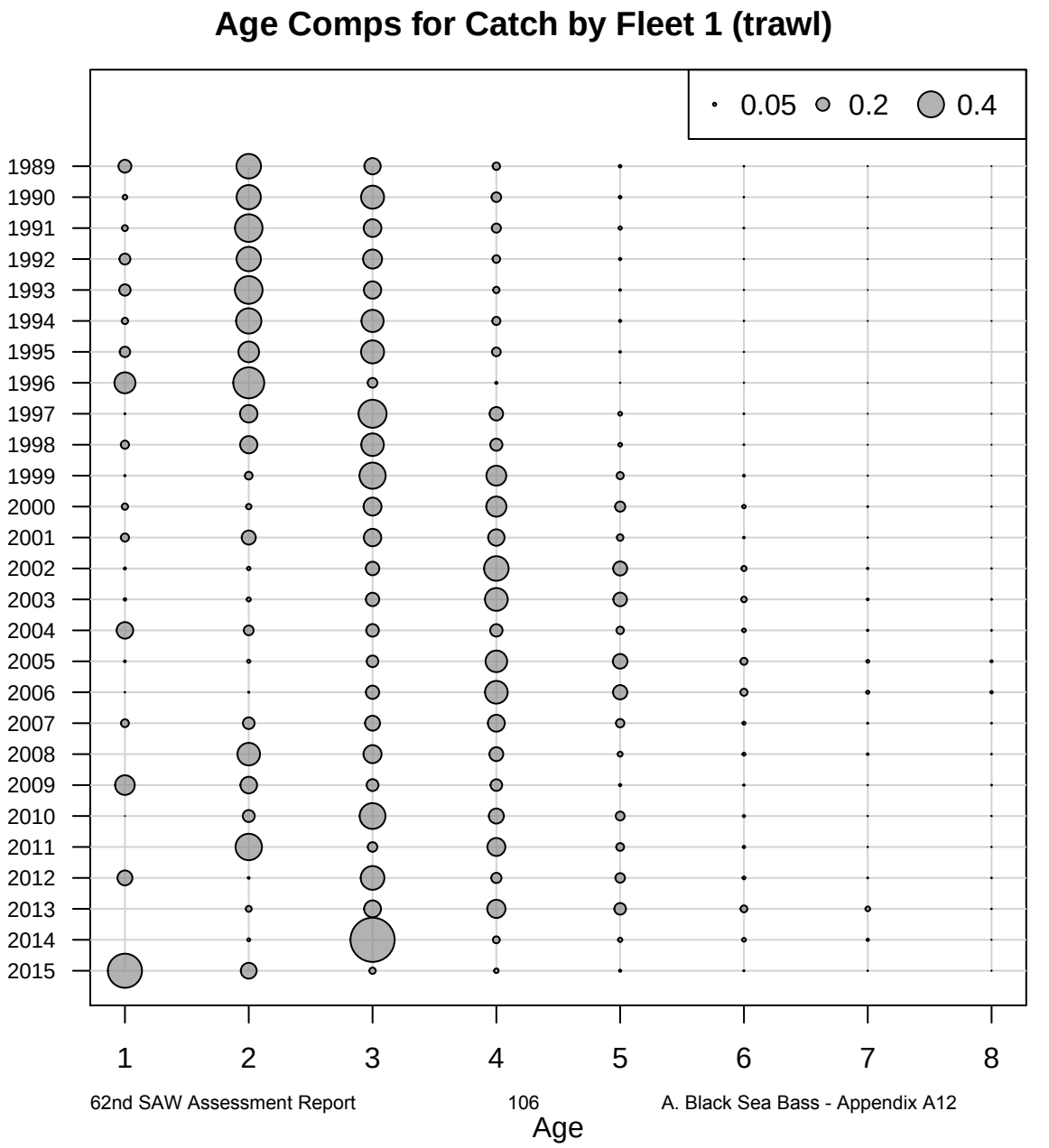


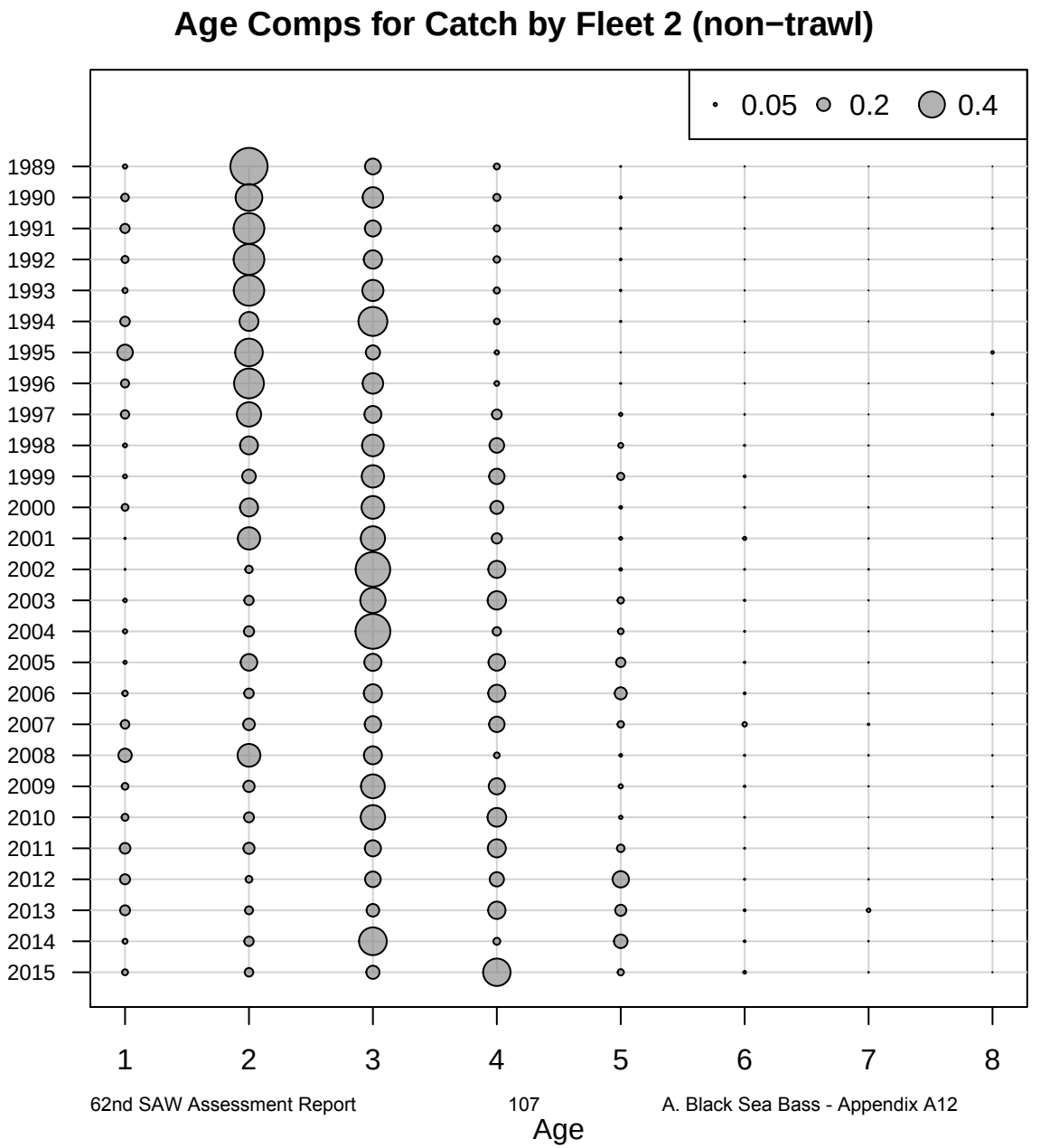
Annual YPR (%SPR) Reference Points

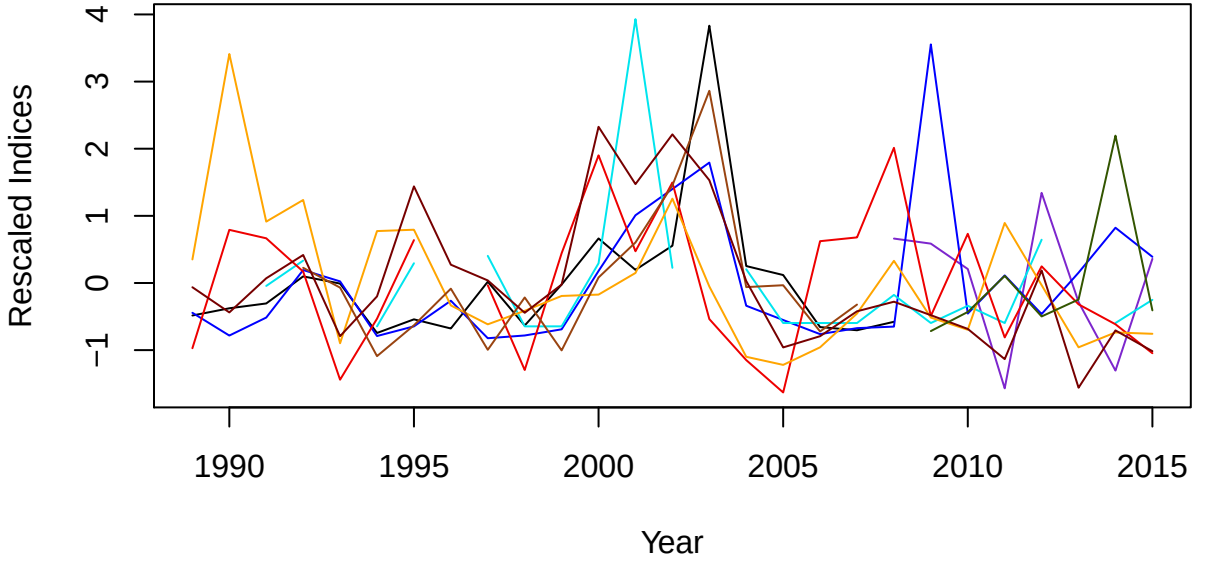


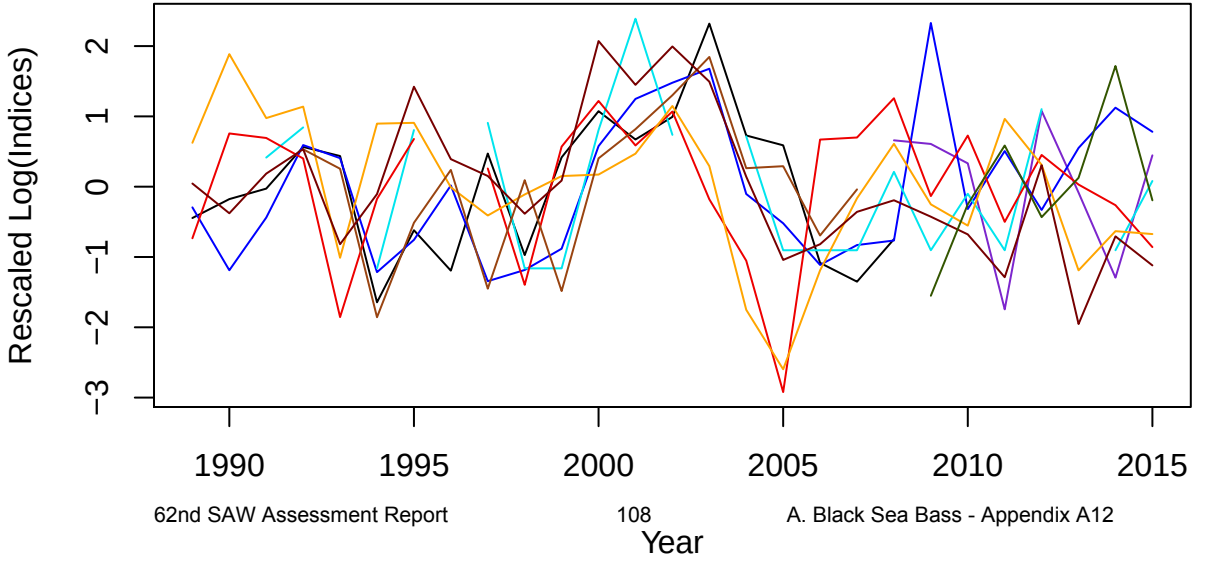

trawl
non−trawl
Catch
0
500
1500
2500
3500
1989
1994
1999
2004
2009
2014
Year

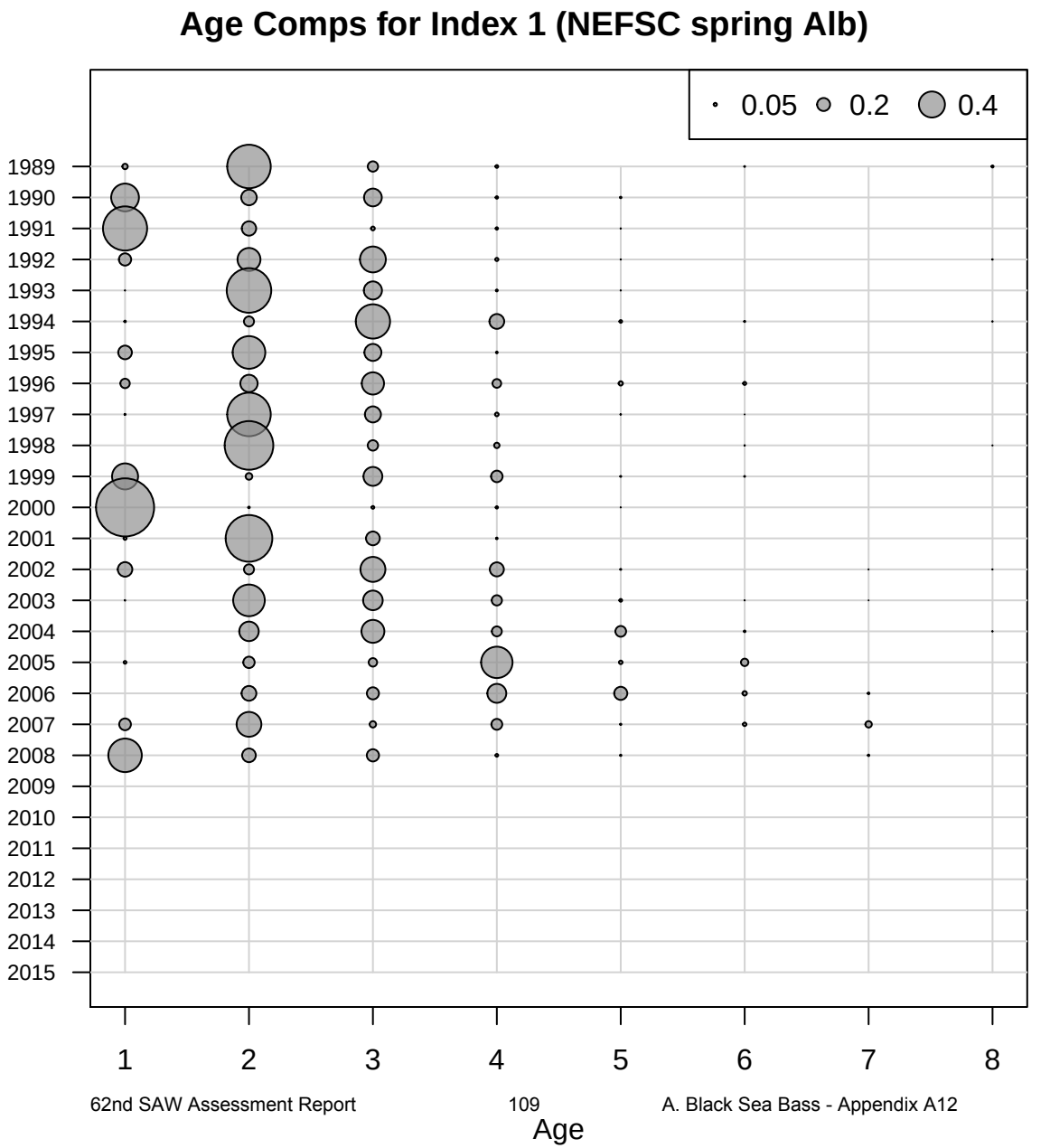

trawl
non−trawl
Proportion of Catch
0.0
0.2
0.4
0.6
0.8
1.0
1989
1994
1999
2004
2009
2014
Year


Age Comps for Catch by Fleet 1 (trawl)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

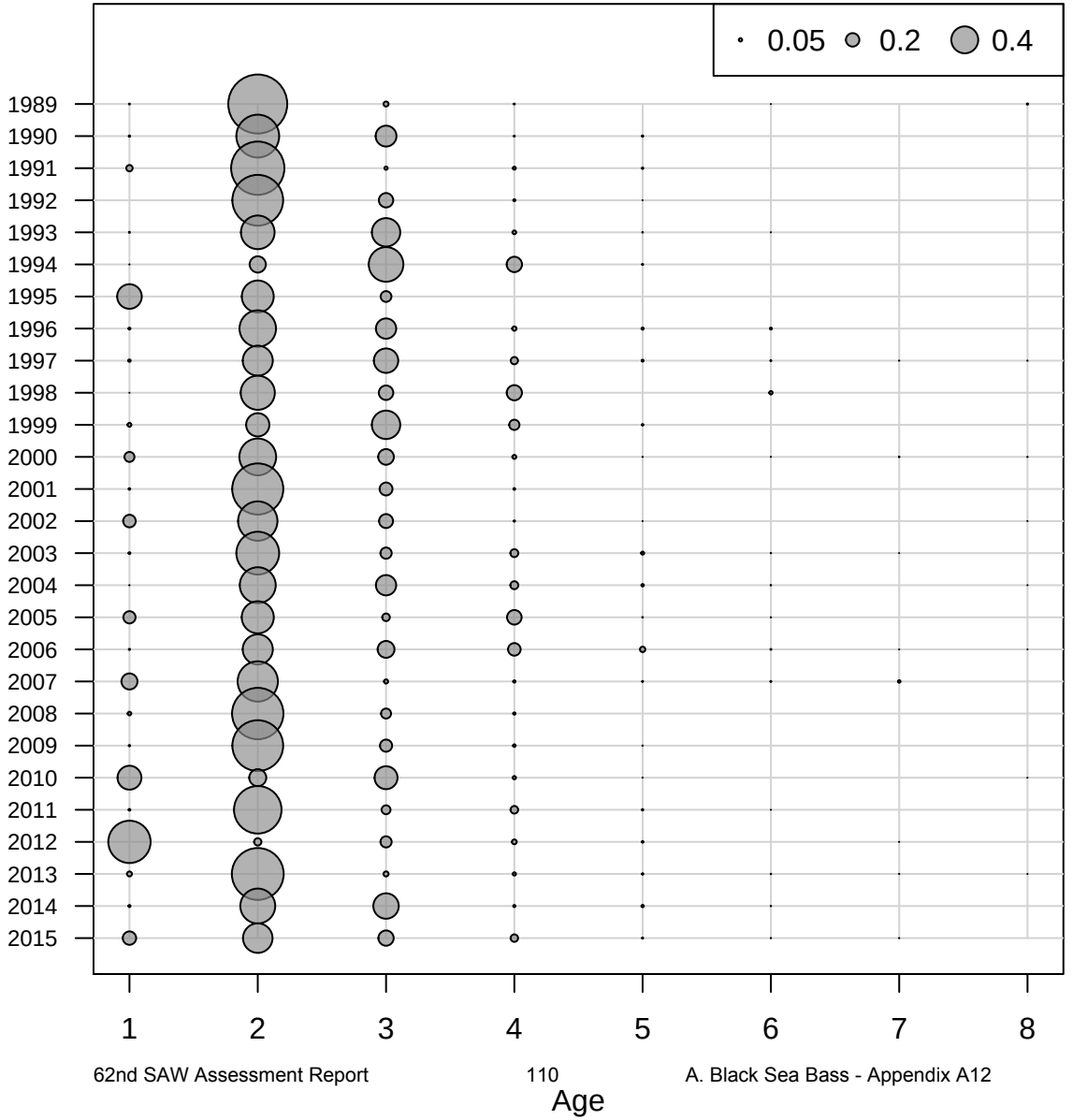

Age Comps for Catch by Fleet 2 (non−trawl)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age


Rescaled Indices
4
3
2
1
0
−1
1990
1995
2000
2005
2010
2015
Year

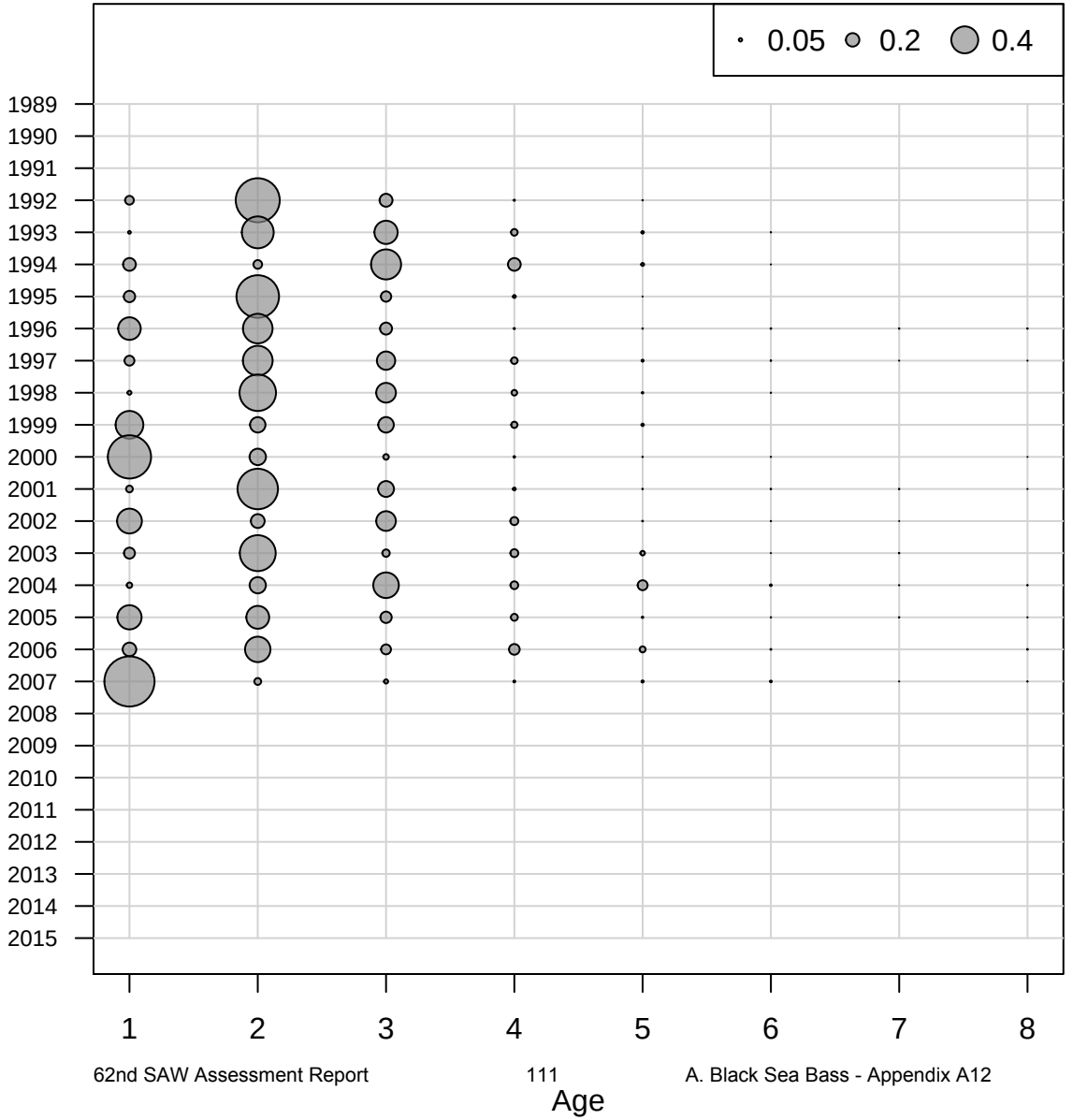

Rescaled Log(Indices)
2
1
0
−1
−2
−3
1990
1995
2000
2005
2010
2015
Year

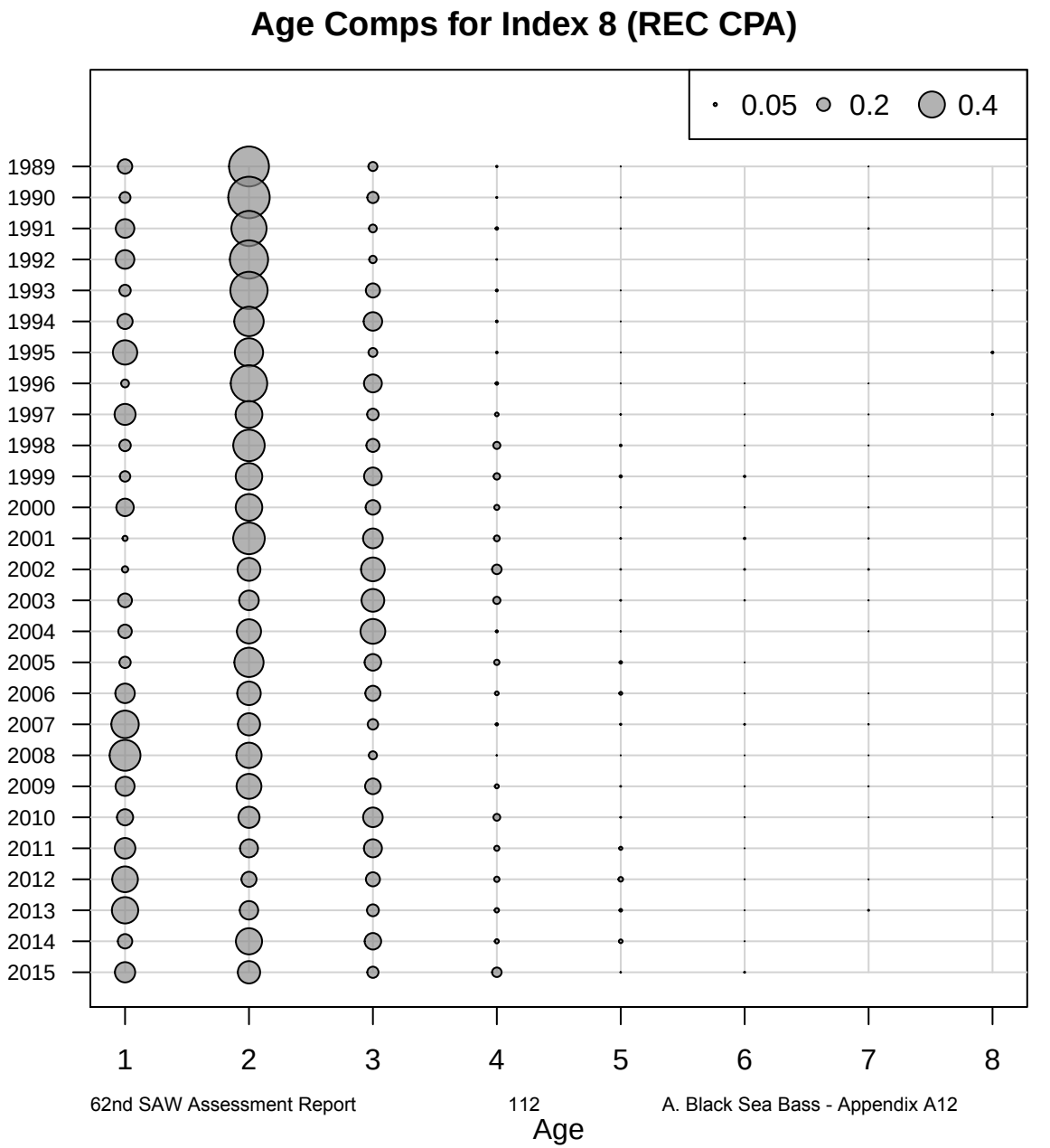

Age Comps for Index 1 (NEFSC spring Alb)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

Age Comps for Index 3 (NJ)

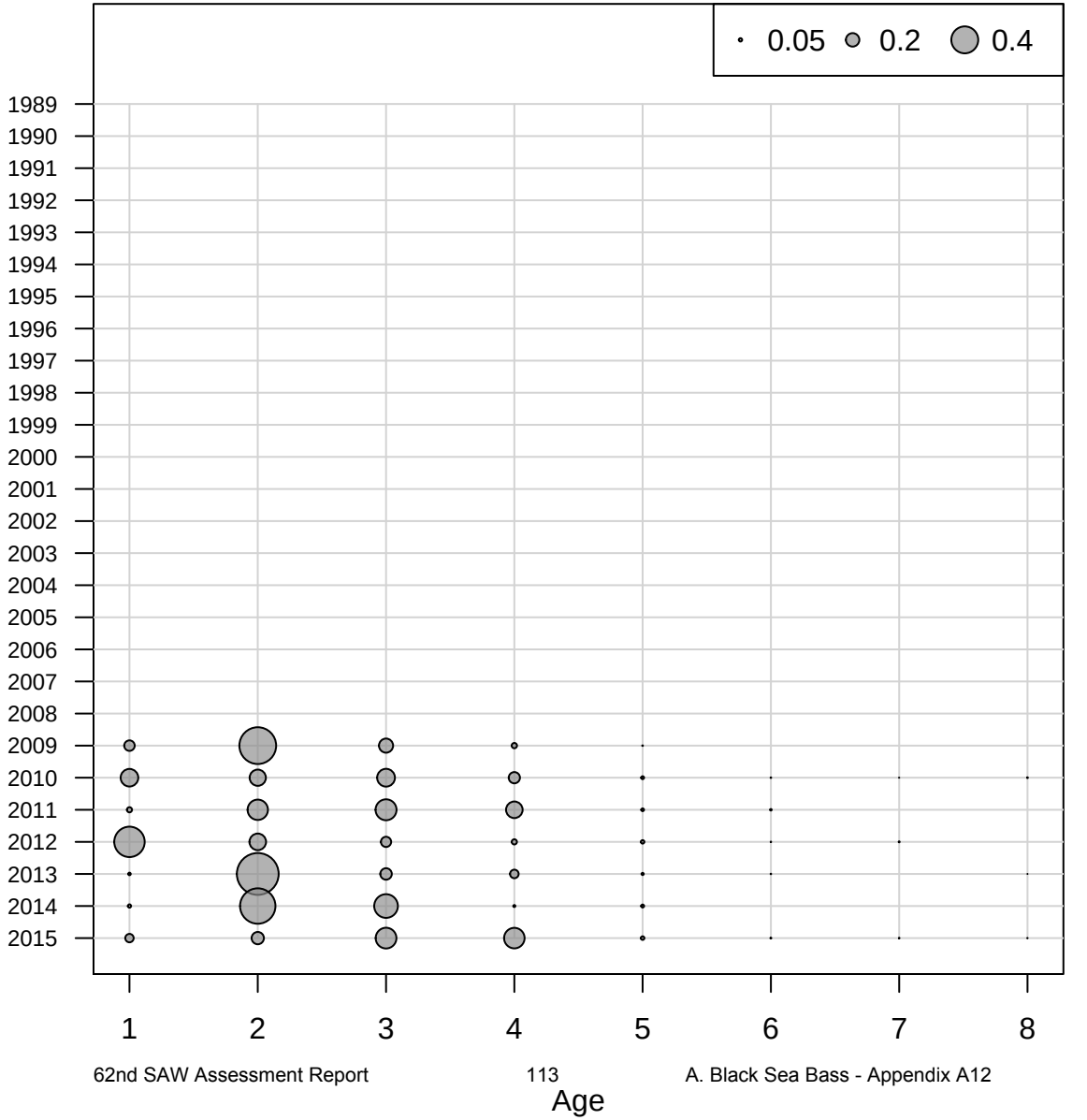


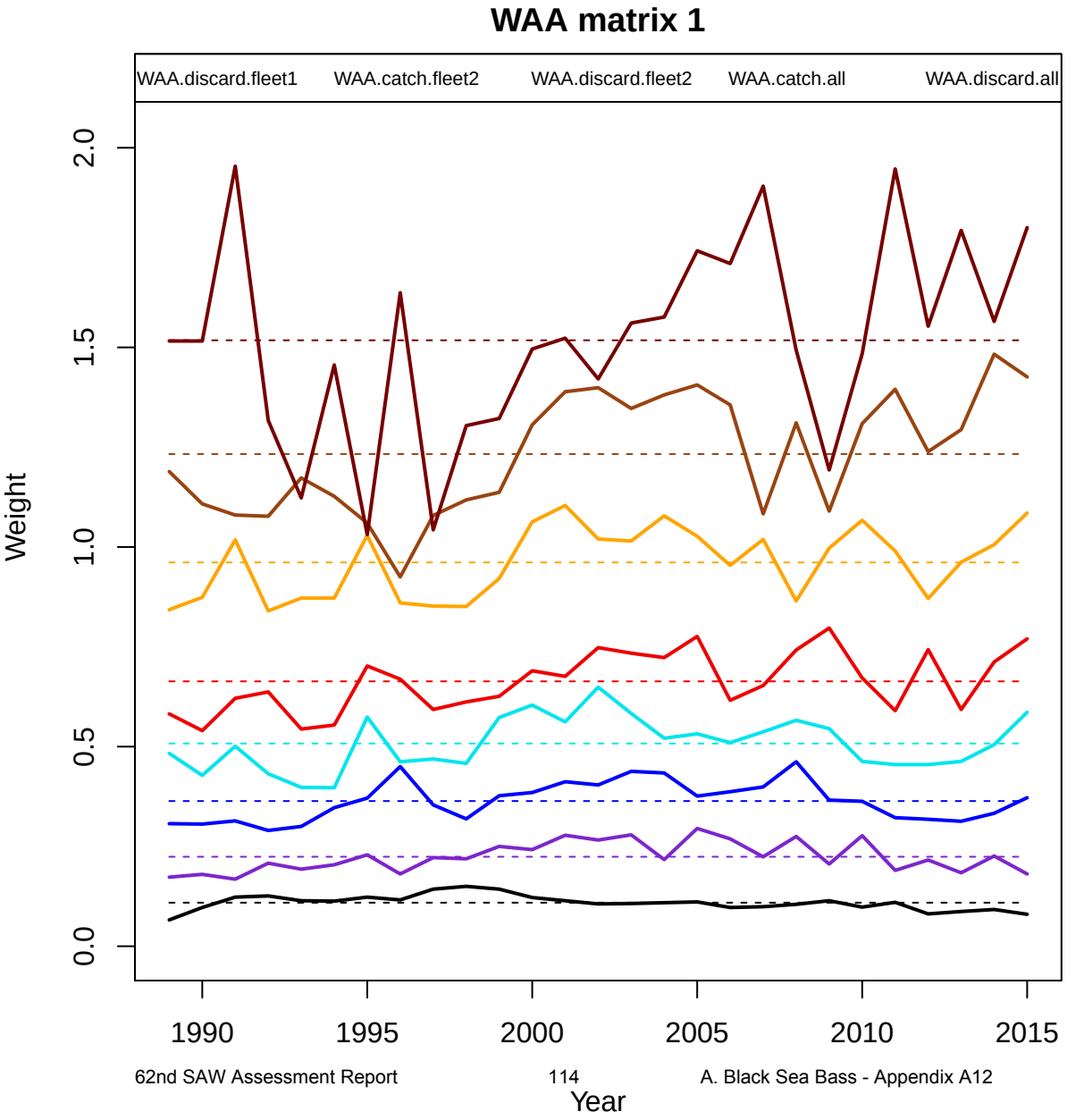
Age Comps for Index 7 (NEFSC winter)

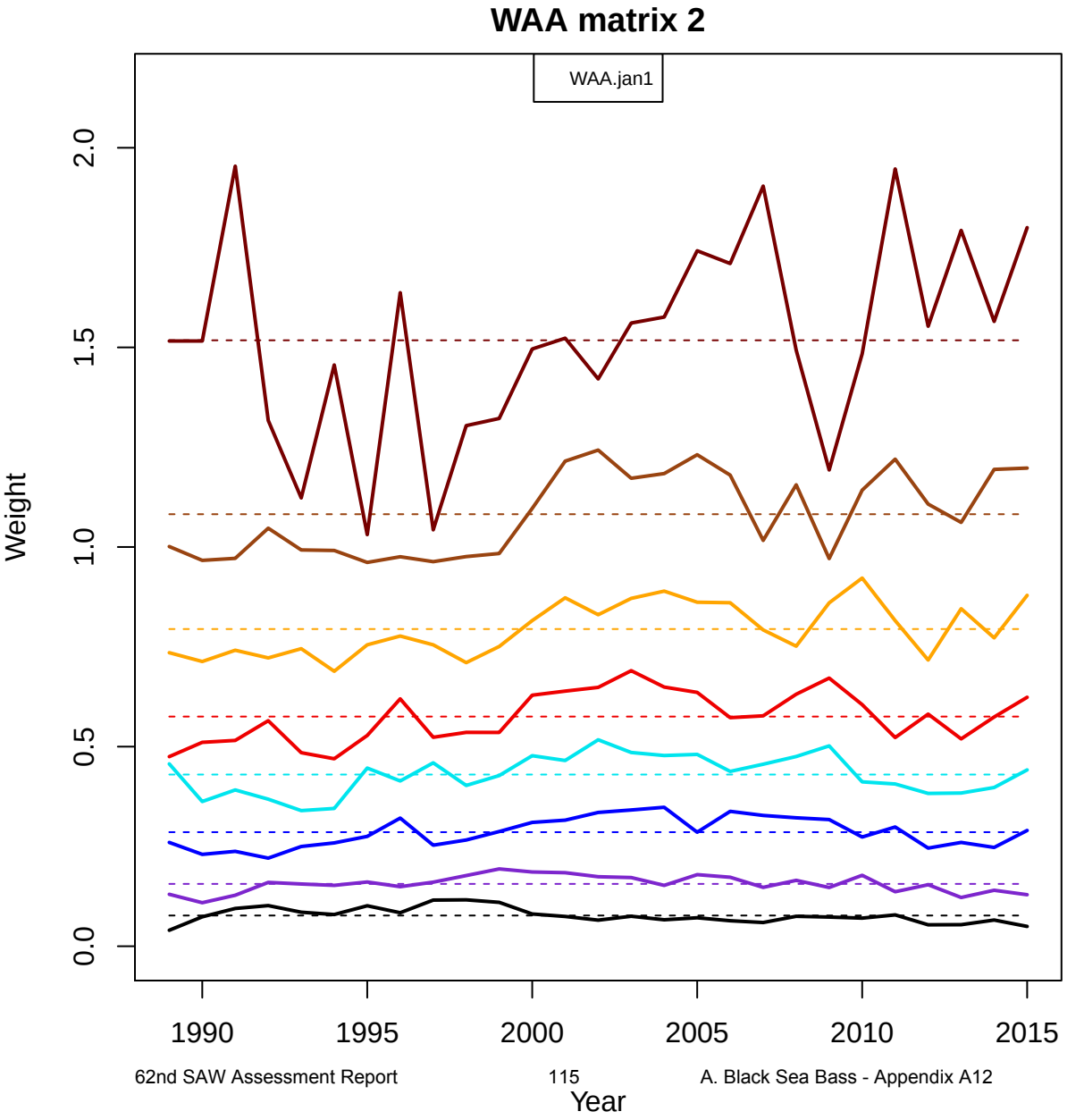


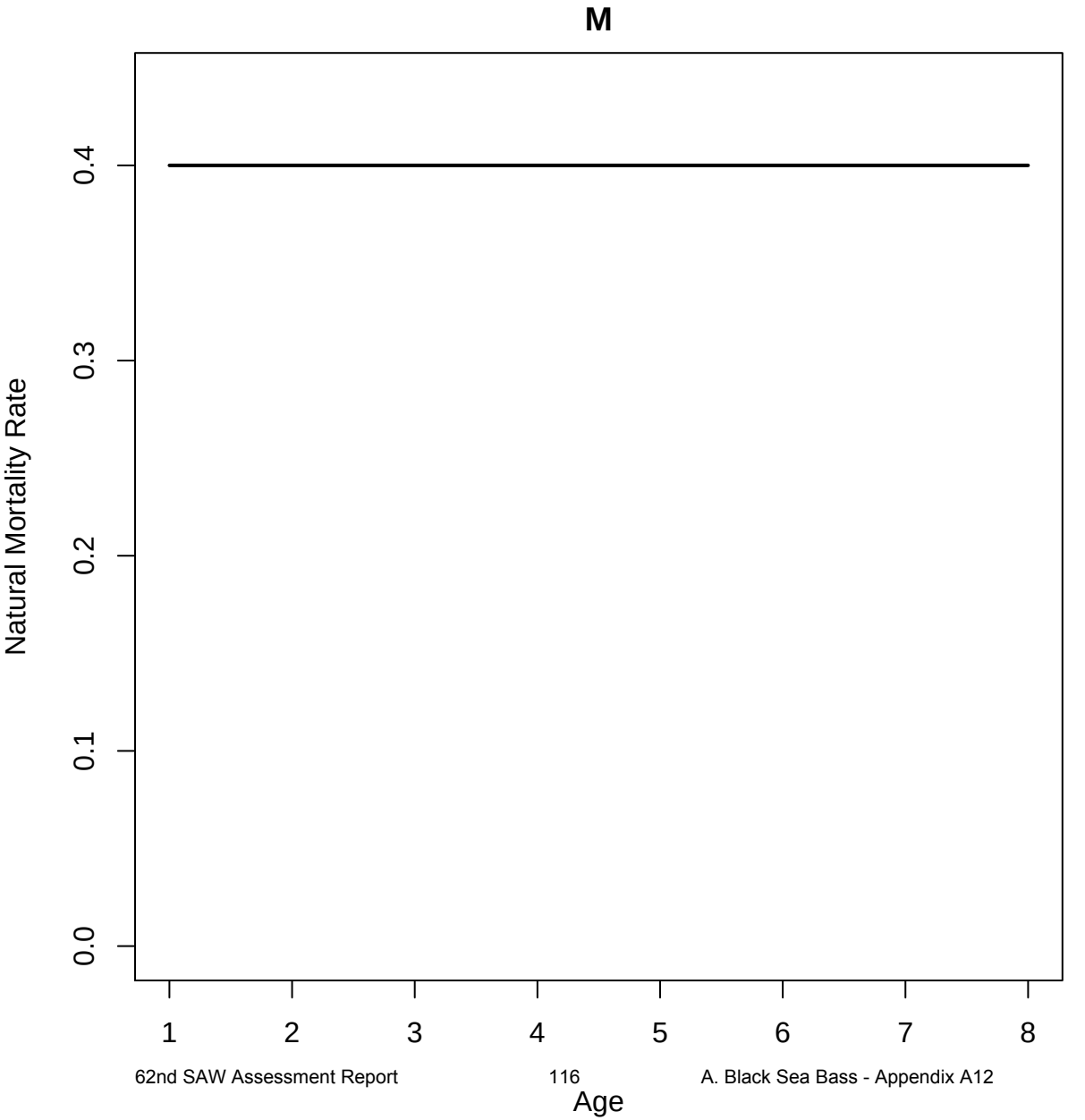

Age Comps for Index 8 (REC CPA)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

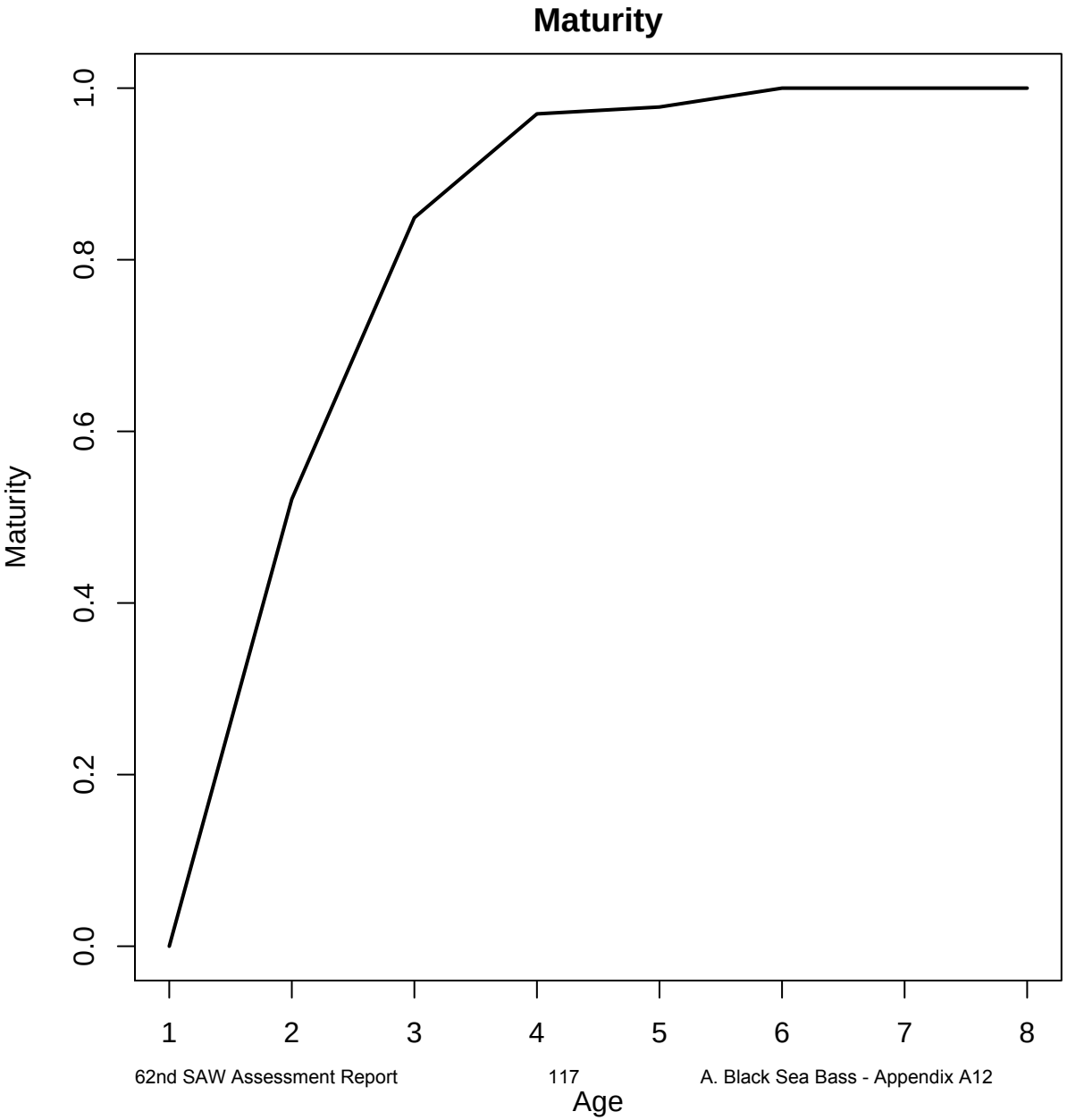
Age Comps for Index 9 (BIGELOW)



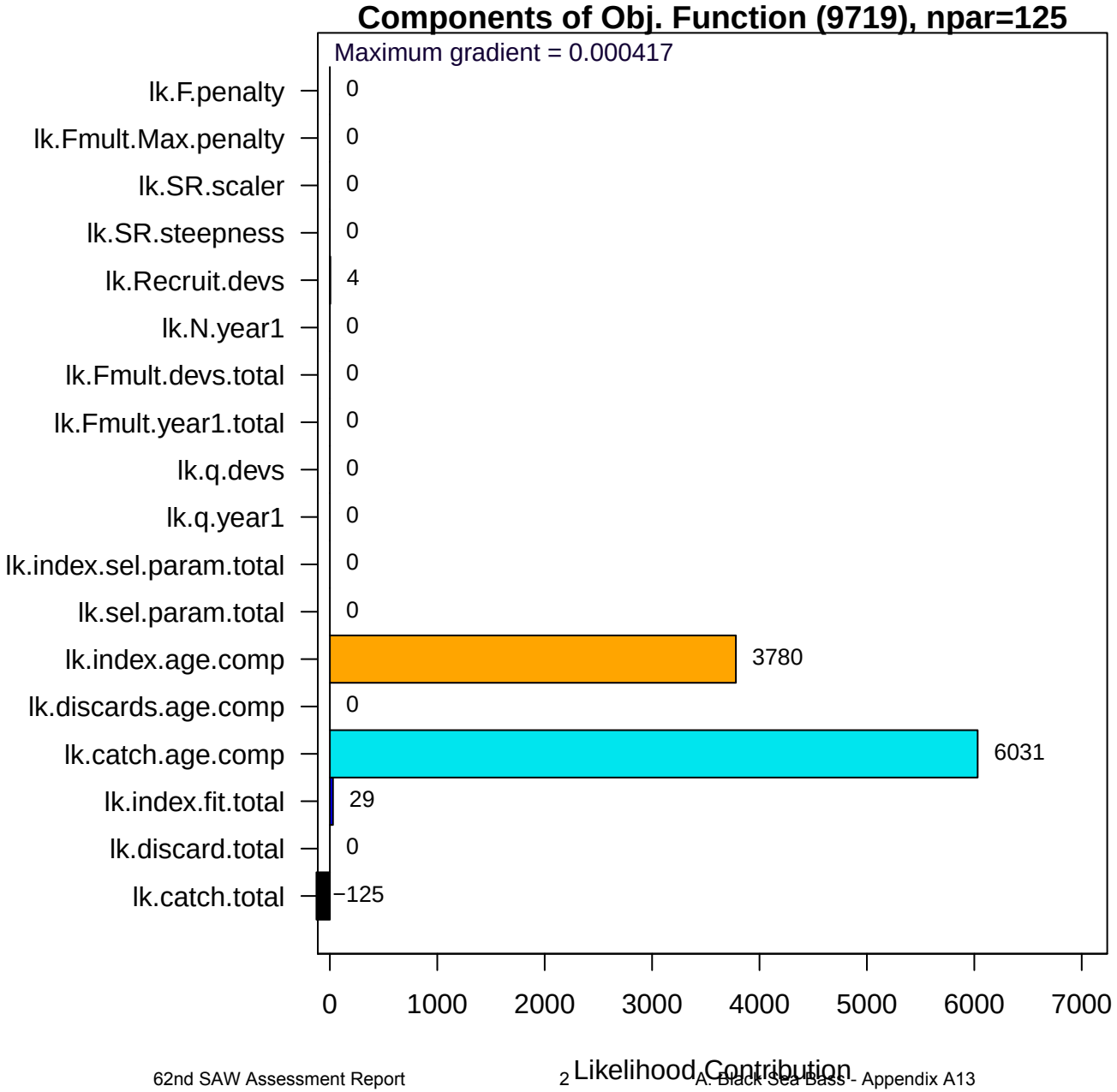

WAA matrix 1
WAA.discard.fleet1
WAA.catch.fleet2
WAA.discard.fleet2
WAA.catch.all
WAA.discard.all
Weight
0.0
0.5
1.0
1.5
2.0
1990
1995
2000
2005
2010
2015
Year


WAA matrix 2
WAA.jan1
Weight
0.0
0.5
1.0
1.5
2.0
1990
1995
2000
2005
2010
2015
Year

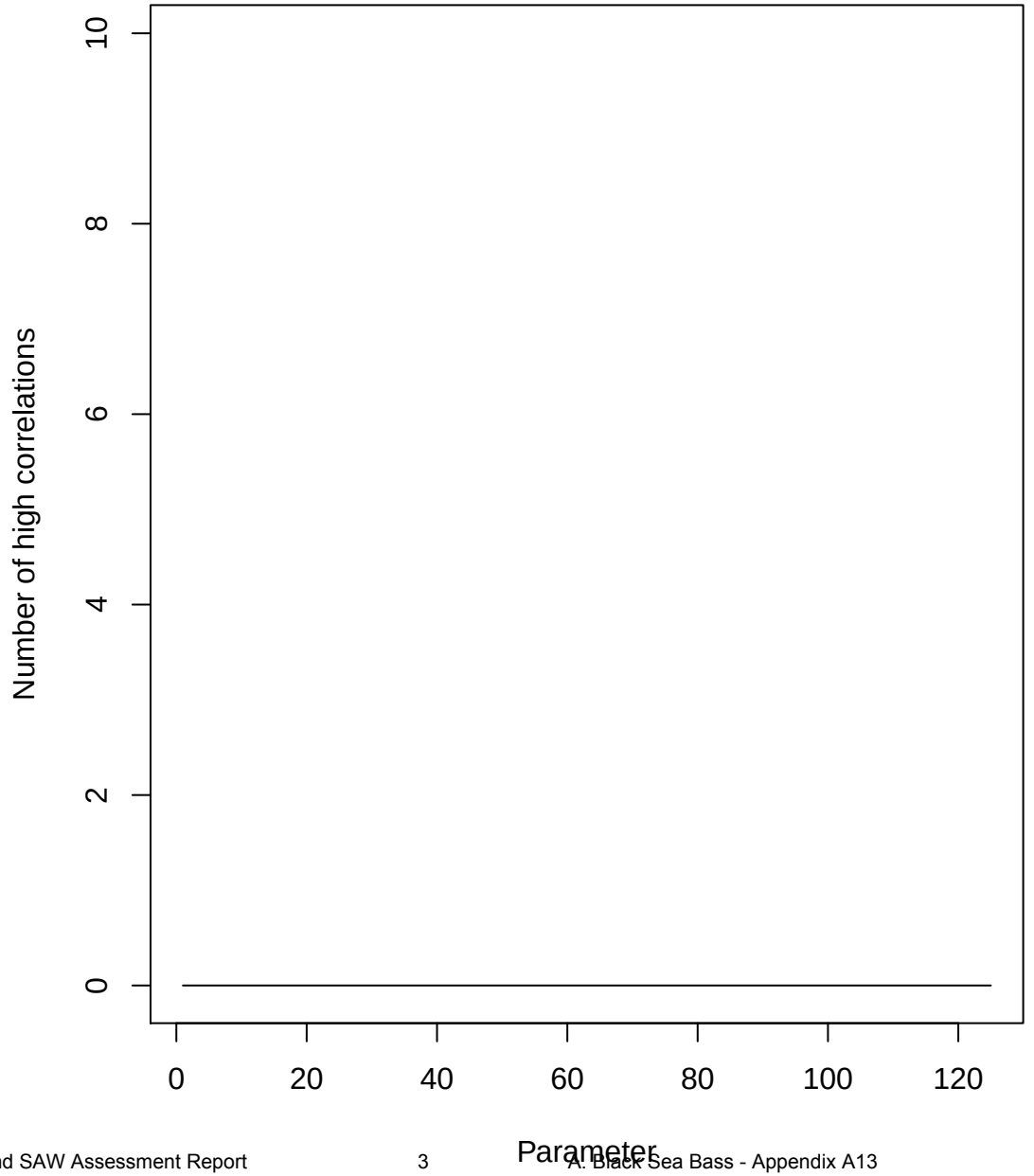

M
Natural Mortality Rate
0.0
0.1
0.2
0.3
0.4
1
2
3
4
5
6
7
8
Age


Maturity
Maturity
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
8
Age

Appendix A13 – Diagnostic and result plots for black sea bass North Area Exchange model.

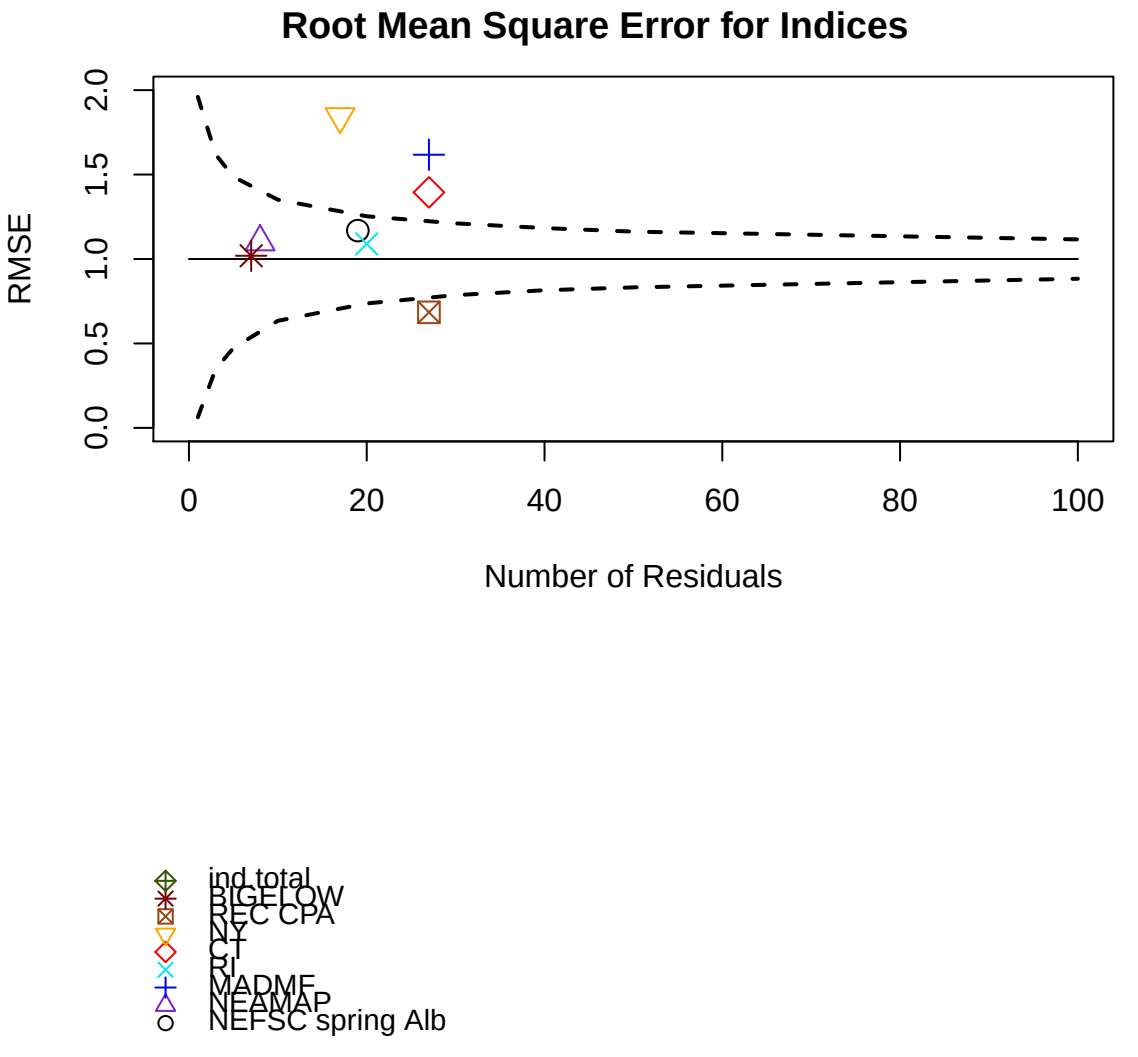


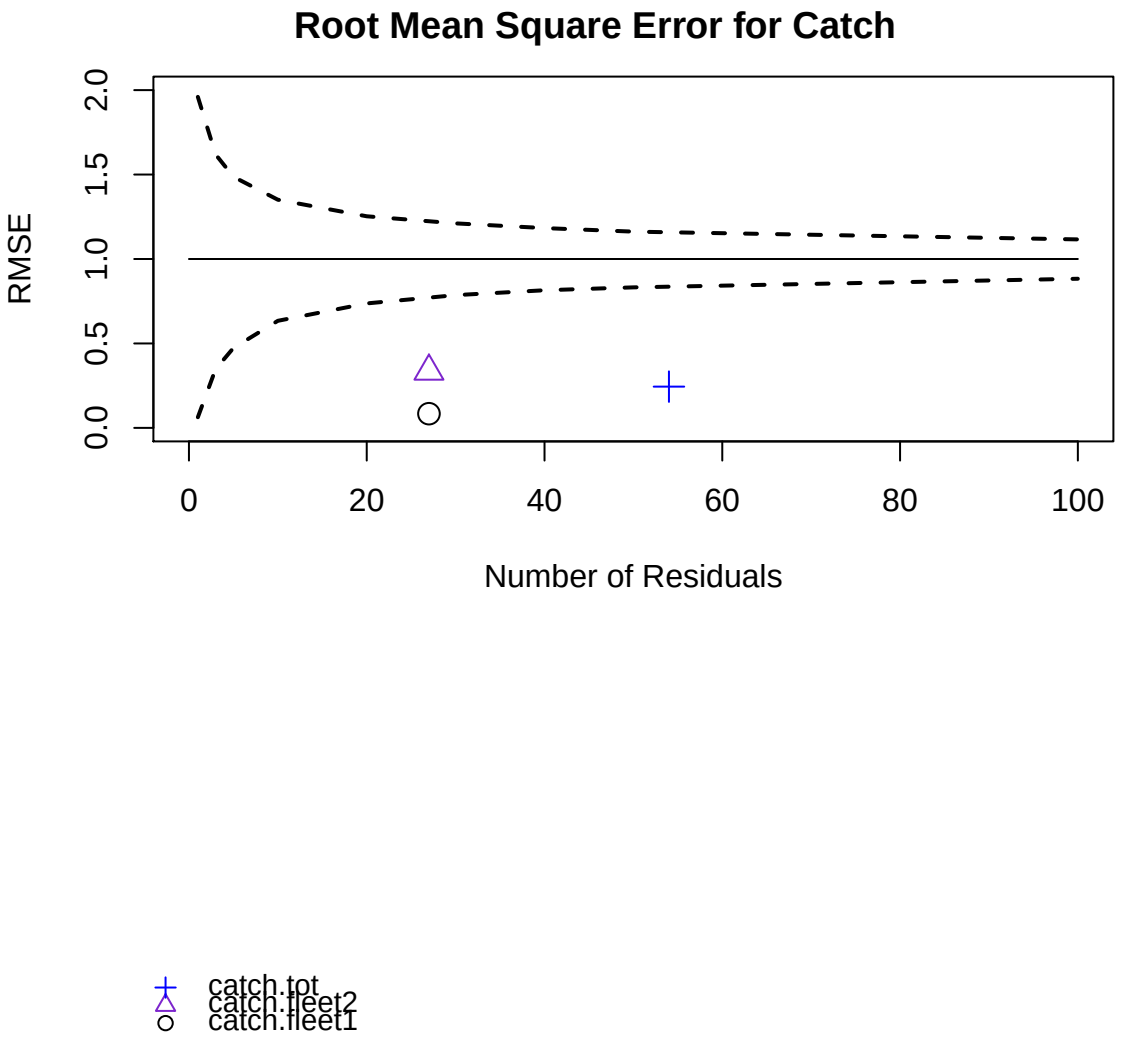
Model: NORTH.RECEIVE.R_0.2.P_0.45 Friday, 30 Sep 2016 at 13:02:


Number of high correlations
0
2
4
6
8
10
0
20
40
60
80
100
120
Parameter

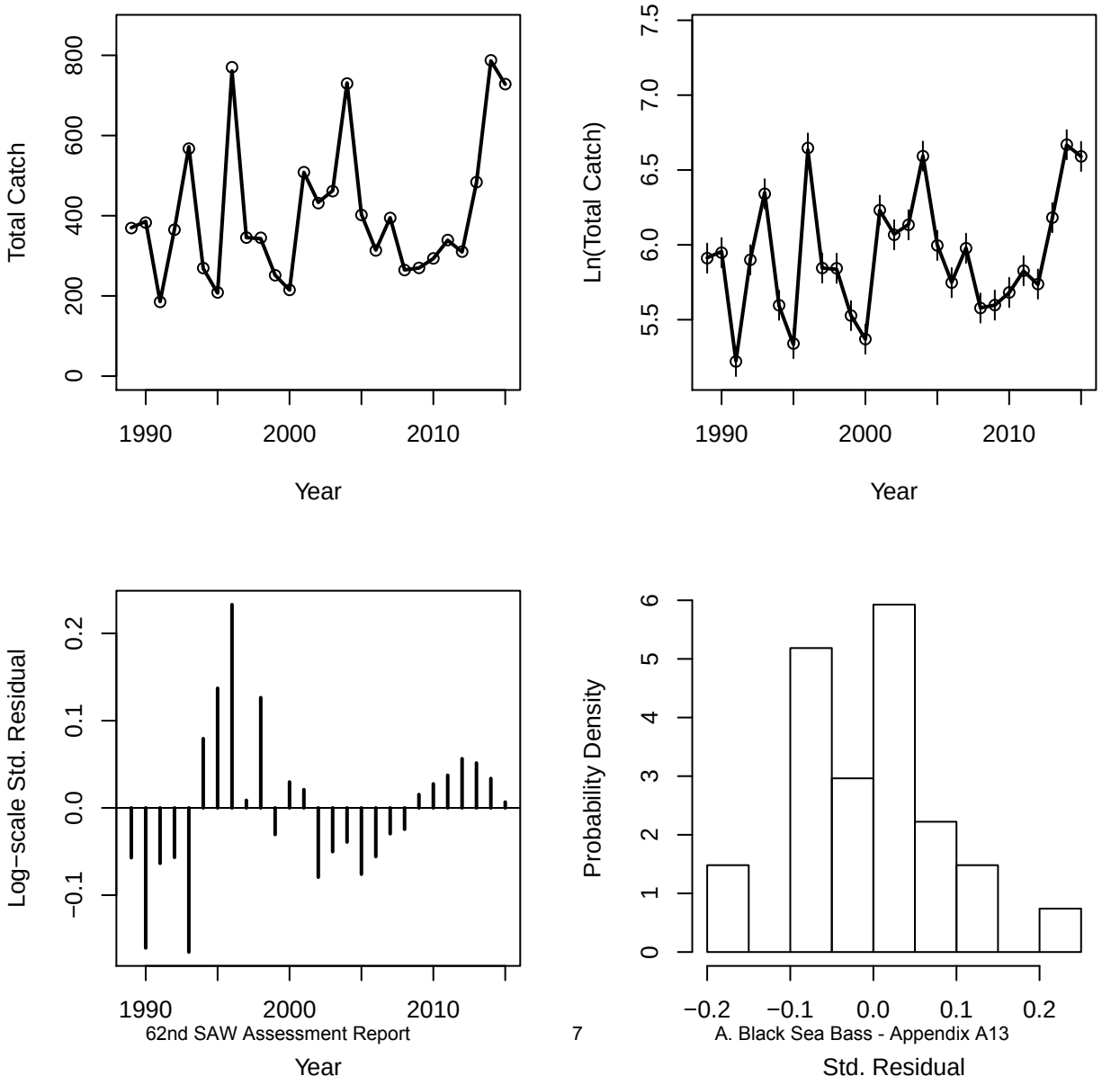
Root Mean Square Error computed from Standardized Residuals

Component	# resids	RMSE
catch.fleet1	27	0.0842
catch.fleet2	27	0.335
catch.tot	54	0.244
discard.fleet1	0	0
discard.fleet2	0	0
discard.tot	0	0
ind01	19	1.17
ind02	8	1.1
ind03	27	1.62
ind04	20	1.09
ind05	27	1.39
ind06	17	1.84
ind07	27	0.684
ind08	7	1.02
ind.total	152	1.31
N.year1	0	0
Fmult.year1	0	0
Fmult.devs.fleet1	0	0
Fmult.devs.fleet2	0	0
Fmult.devs.total	0	0
recruit.devs	27	0.809
fleet.sel.params	0	0
index.sel.params	0	0
q.year1	0	0
q.devs	0	0
SR.steepness	0	0
SR.scaler	0	0

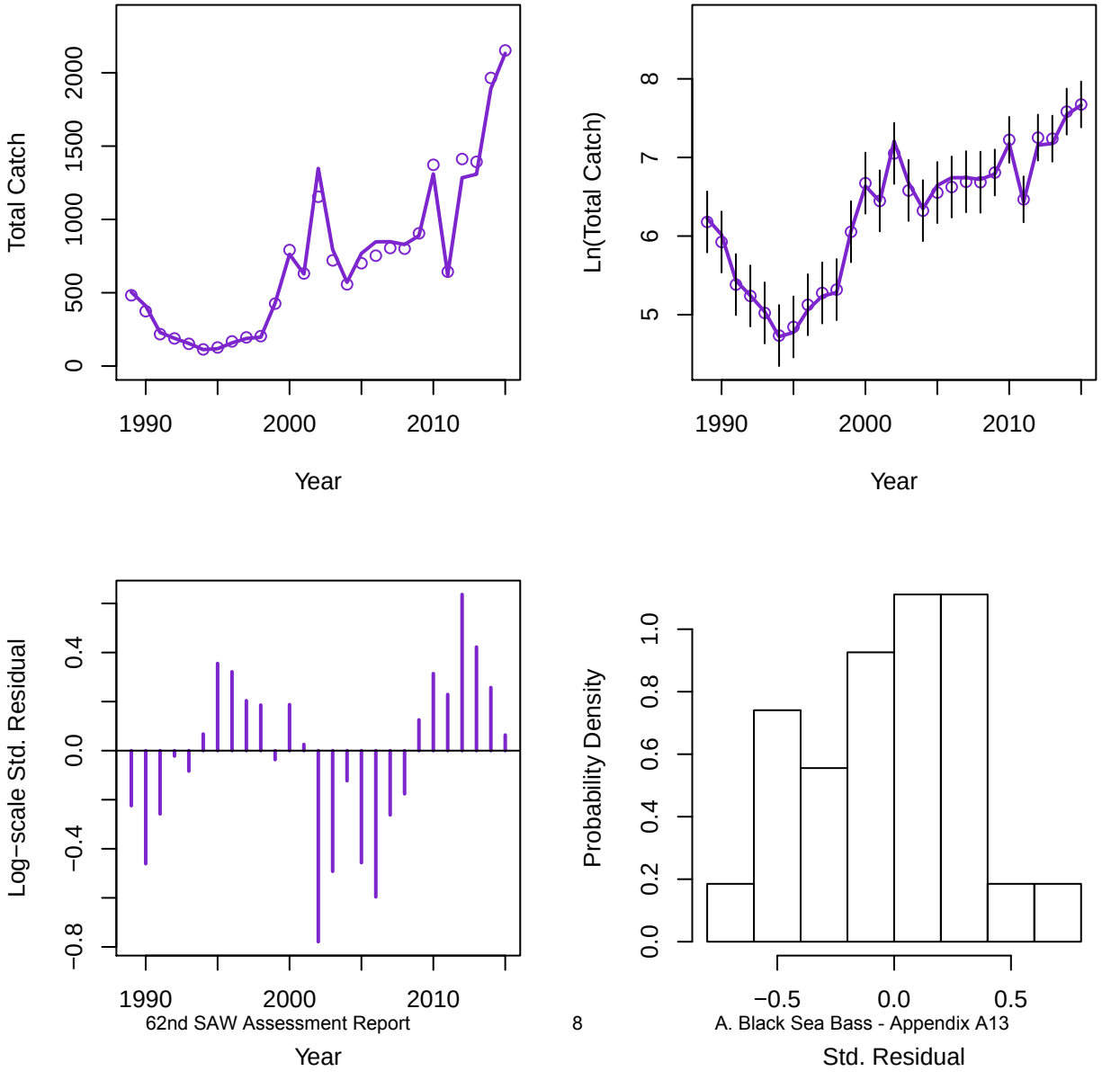

Root Mean Square Error for Indices
RMSE
0.0
0.5
1.0
1.5
2.0
0
20
40
60
80
100
Number of Residuals
ind total
BIGELOW
REC CPA
NY
CT
RI
MADMF
NEAMAP
NEFSC spring Alb

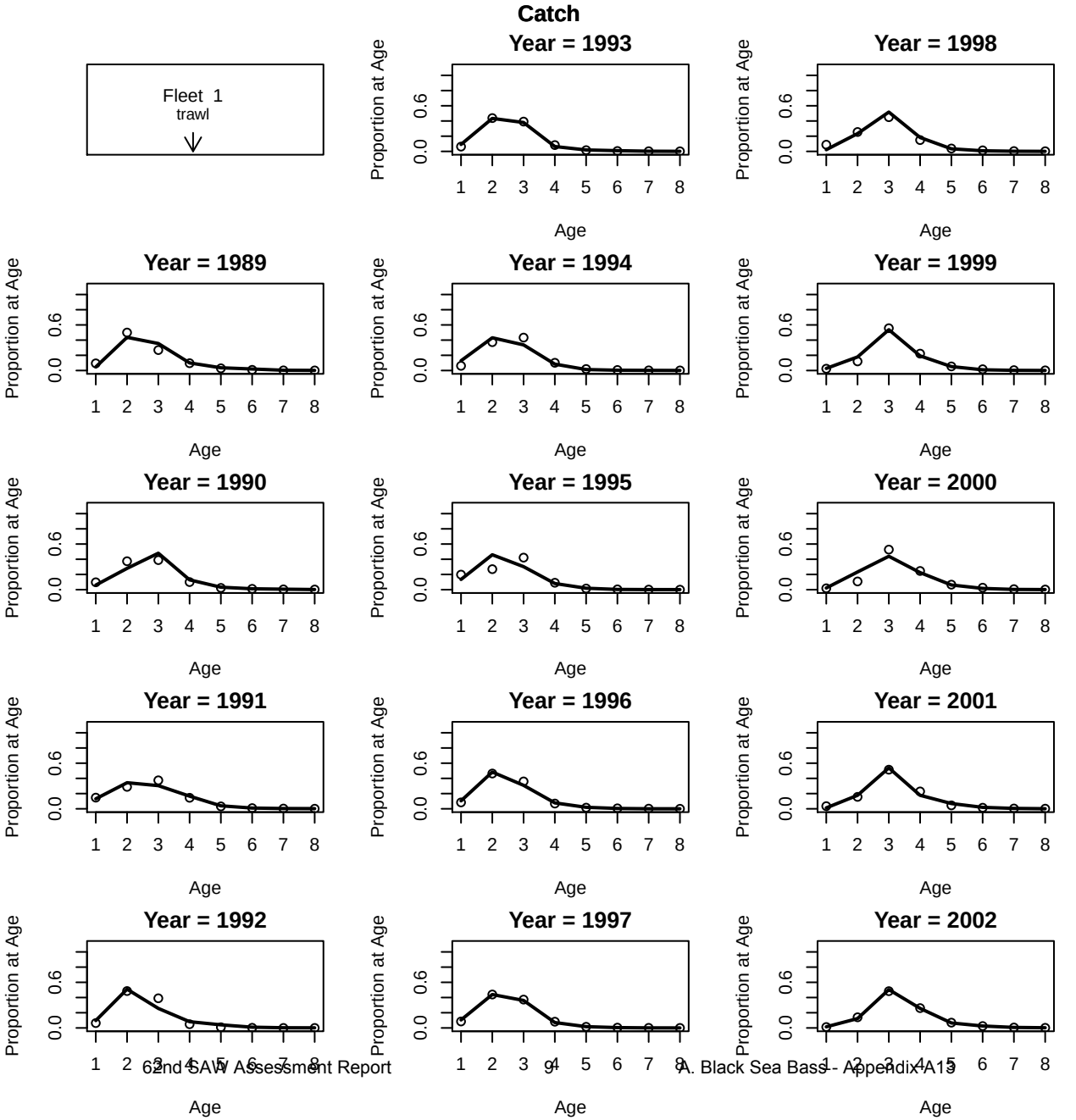

Root Mean Square Error for Catch
RMSE
0.0
0.5
1.0
1.5
2.0
0
20
40
60
80
100
Number of Residuals
catch.tot
catch.fleet2
catch.fleet1

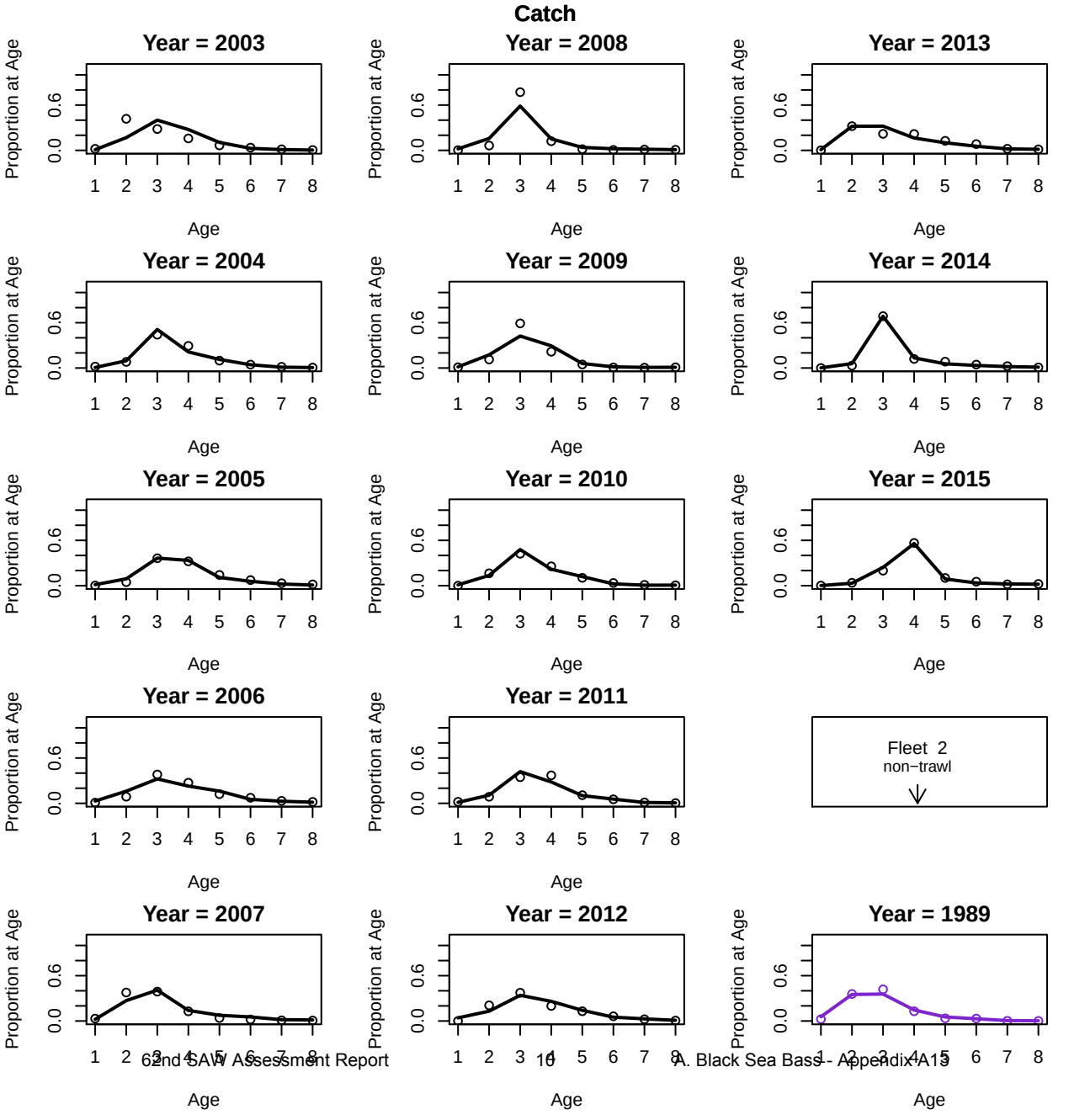
Fleet 1 Catch (trawl)

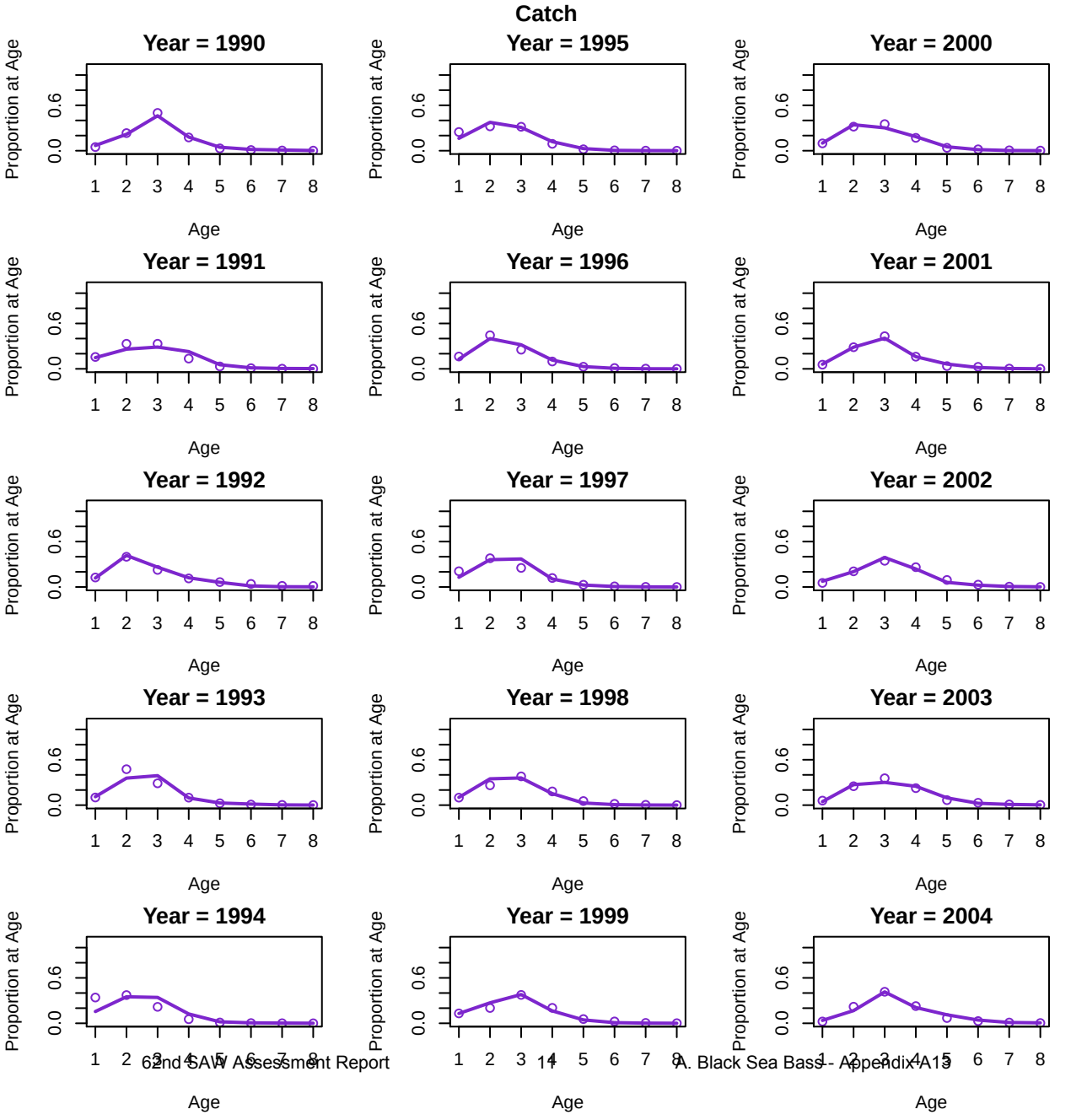


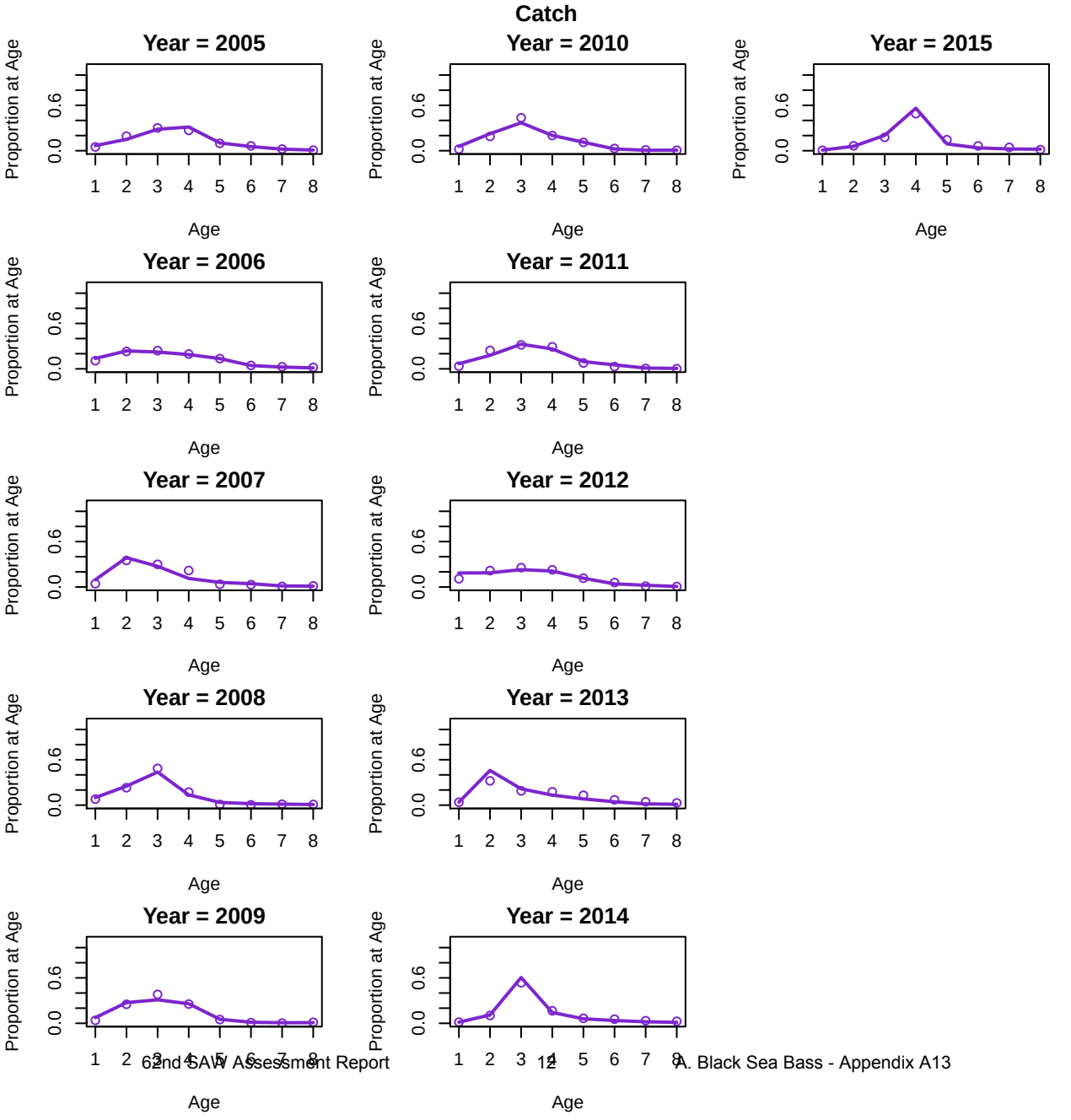
Fleet 2 Catch (non−trawl)



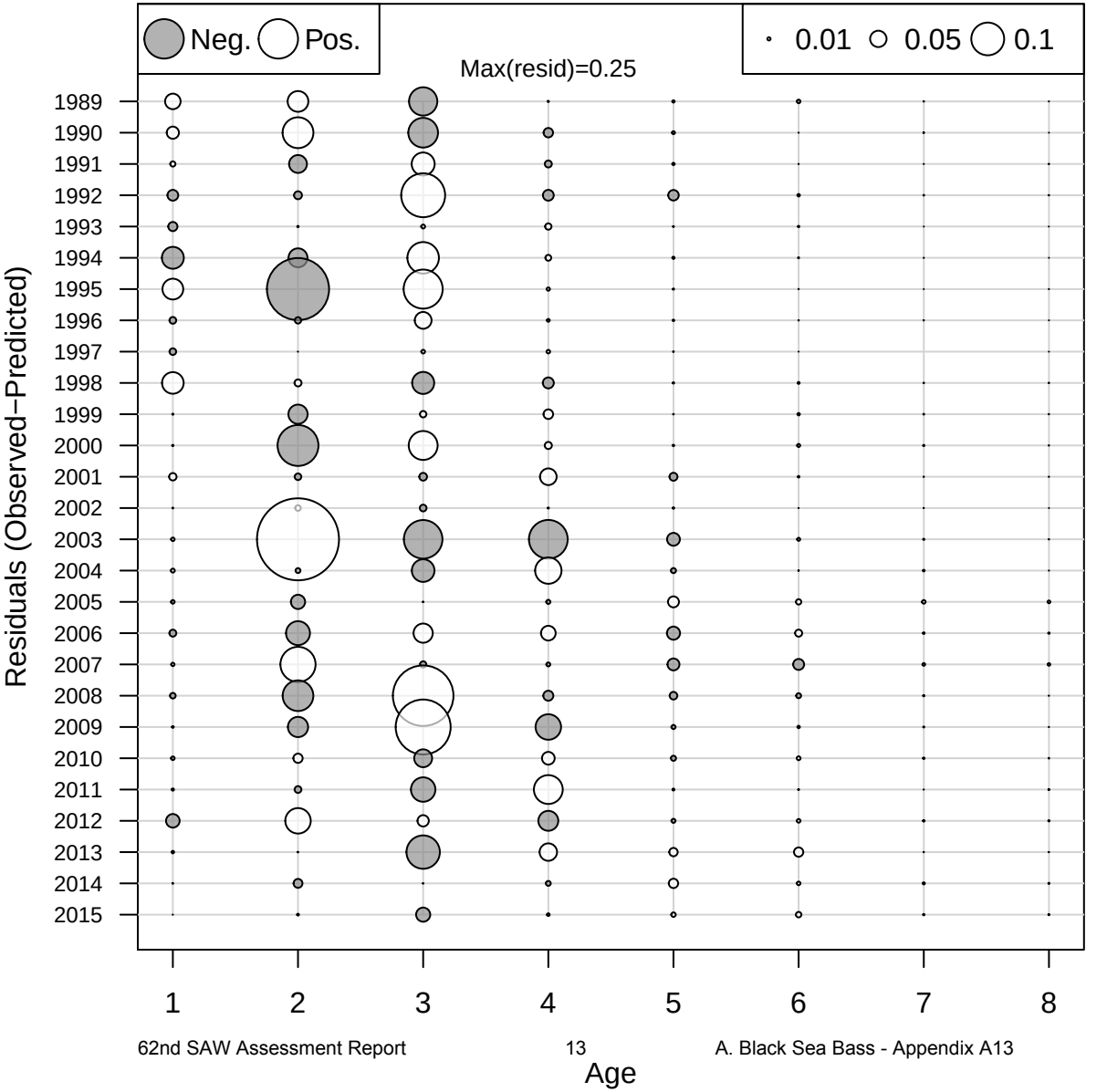

Catch
Fleet 1
trawl
Year = 1993
Year = 1998
Year = 1989
Year = 1994
Year = 1999
Year = 1990
Year = 1995
Year = 2000
Year = 1991
Year = 1996
Year = 2001
Year = 1992
Year = 1997
Year = 2002
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

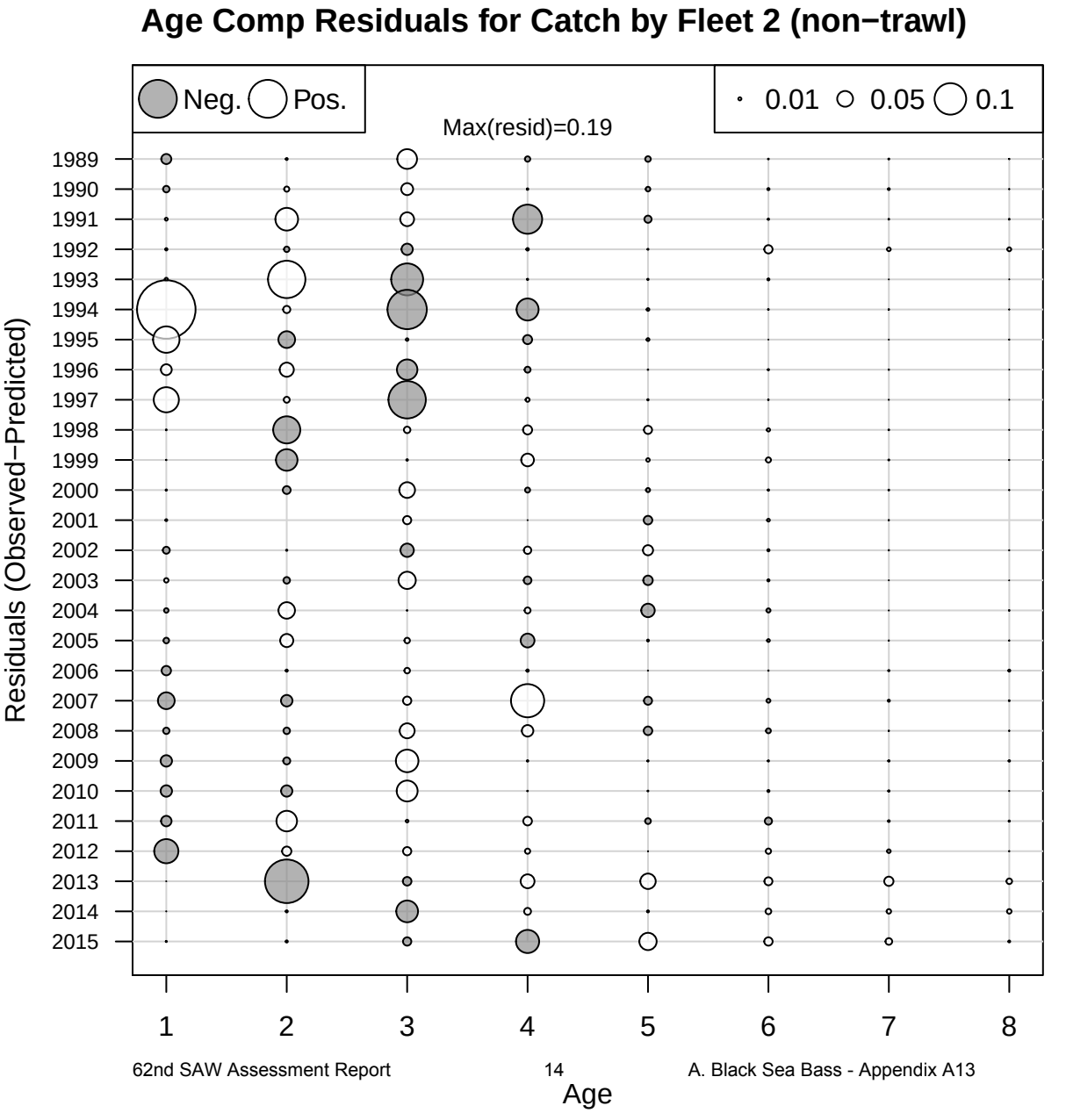

Catch
Year = 2003
Year = 2008
Year = 2013
Year = 2004
Year = 2009
Year = 2014
Year = 2005
Year = 2010
Year = 2015
Year = 2006
Year = 2011
Fleet 2
non−trawl
Year = 2007
Year = 2012
Year = 1989
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

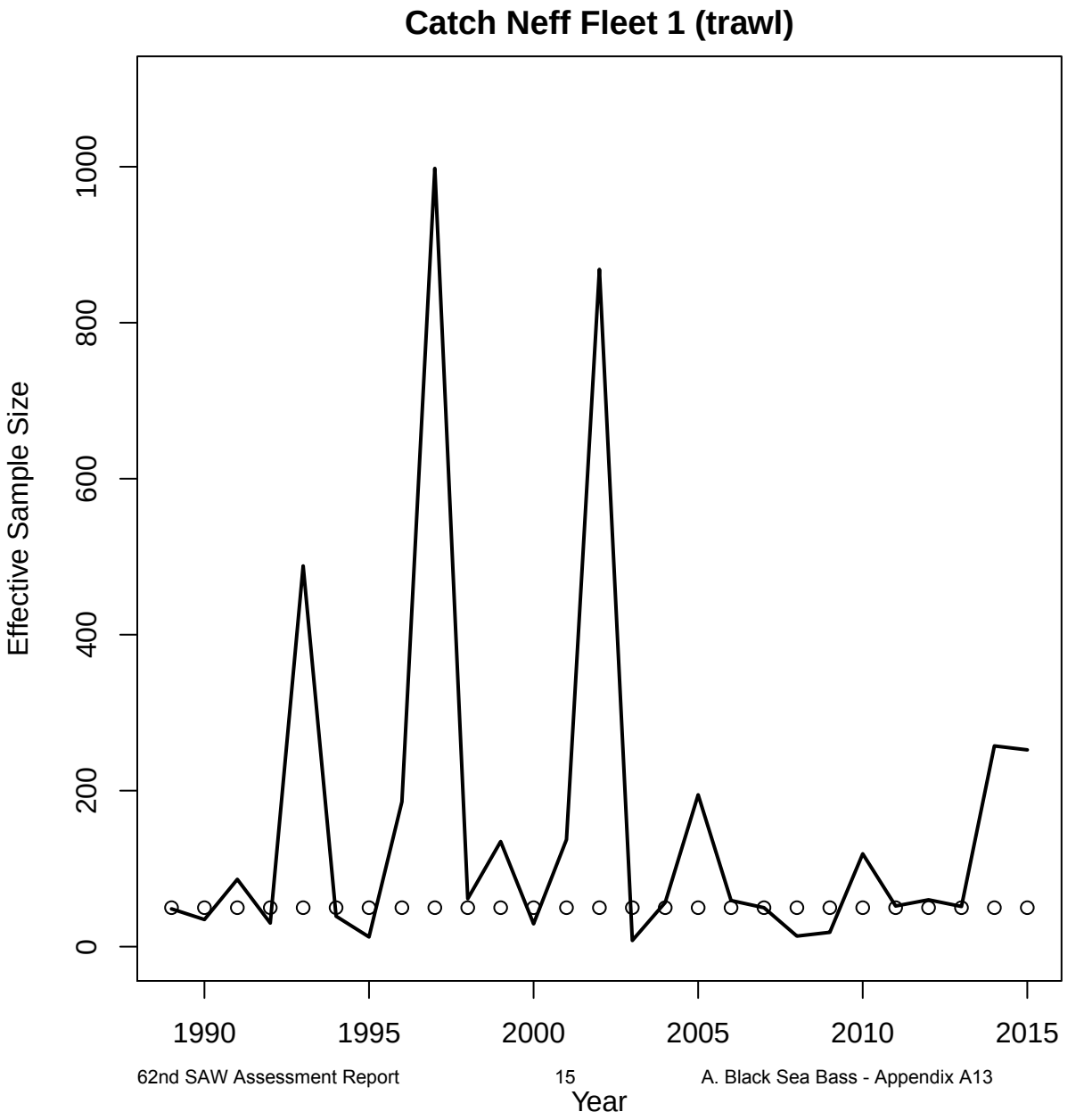

Catch
Year = 1990
Year = 1991
Year = 1992
Year = 1993
Year = 1994
Year = 1995
Year = 1996
Year = 1997
Year = 1998
Year = 1999
Year = 2000
Year = 2001
Year = 2002
Year = 2003
Year = 2004
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

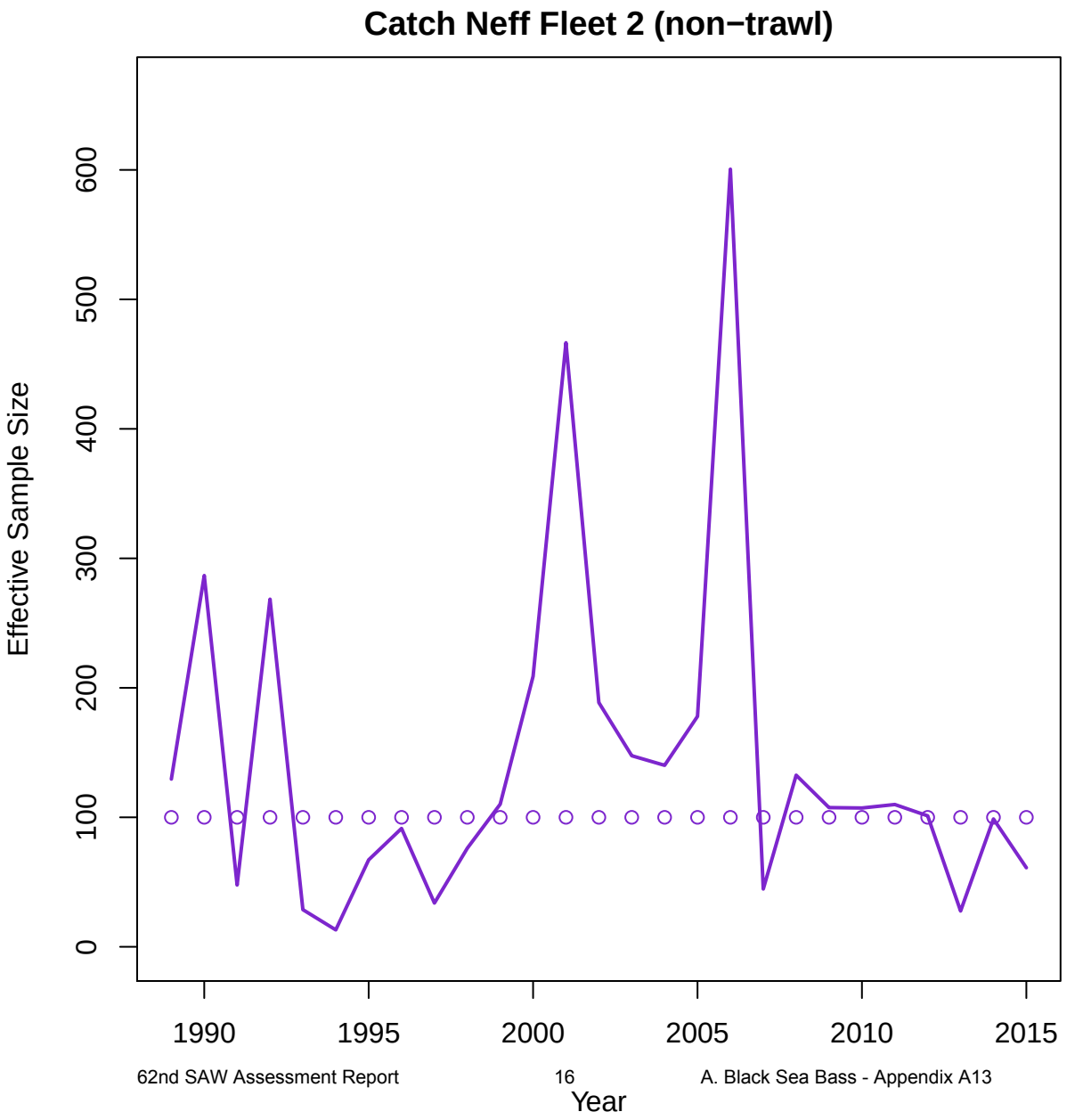

Catch
Year = 2005
Year = 2010
Year = 2015
Year = 2006
Year = 2011
Year = 2007
Year = 2012
Year = 2008
Year = 2013
Year = 2009
Year = 2014
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

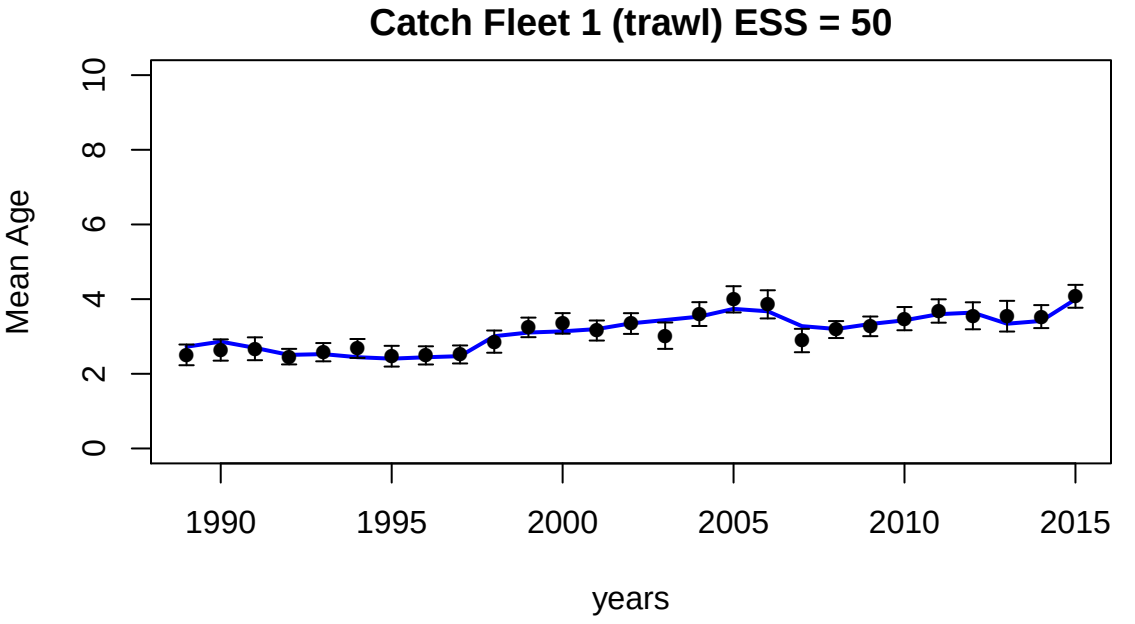
Age Comp Residuals for Catch by Fleet 1 (trawl)

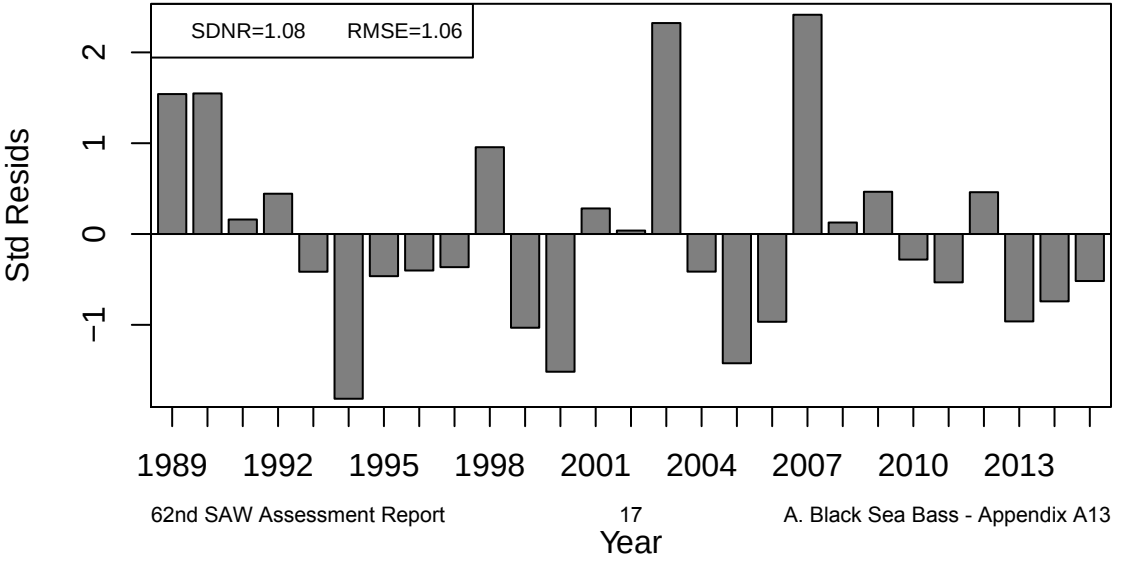


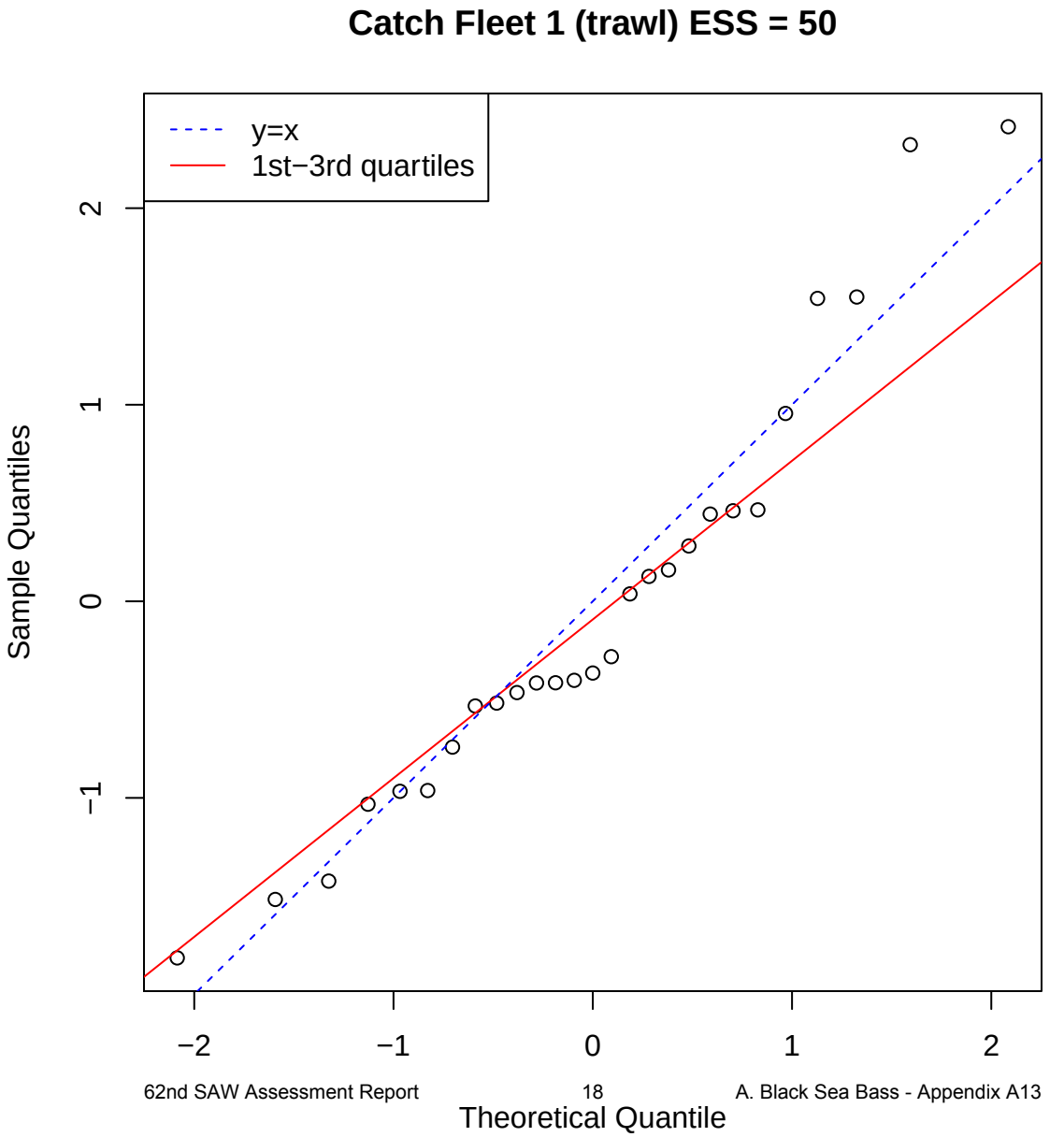

Age Comp Residuals for Catch by Fleet 2 (non−trawl)
Neg.
Pos.
0.01
0.05
0.1
Max(resid)=0.19
Residuals (Observed−Predicted)
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

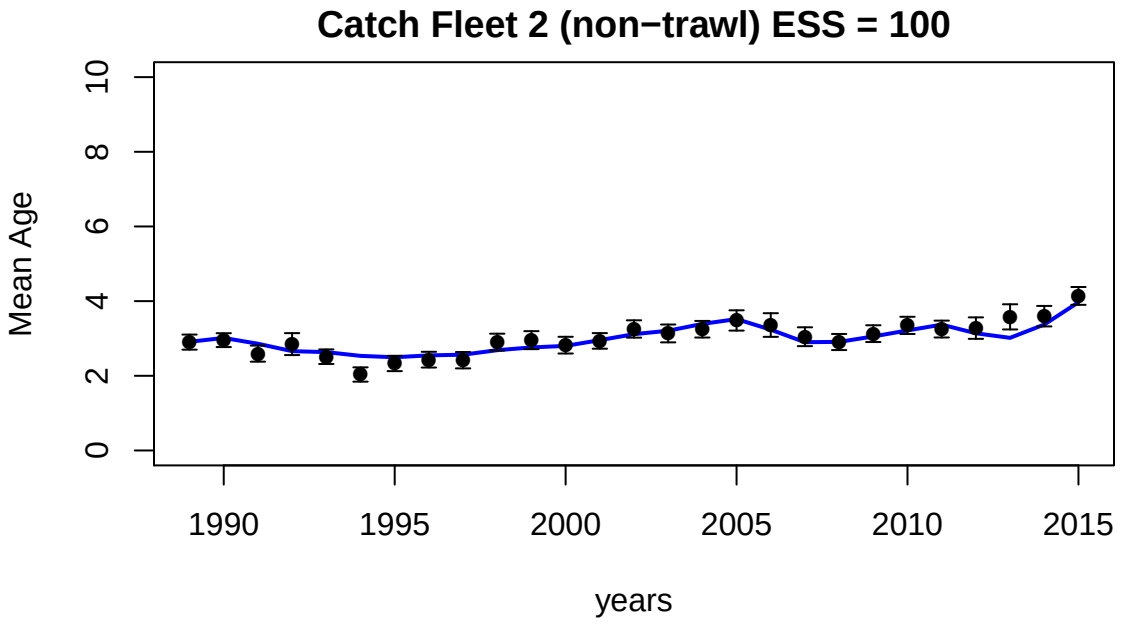

Catch Neff Fleet 1 (trawl)
Effective Sample Size
0
200
400
600
800
1000
1990
1995
2000
2005
2010
2015
Year

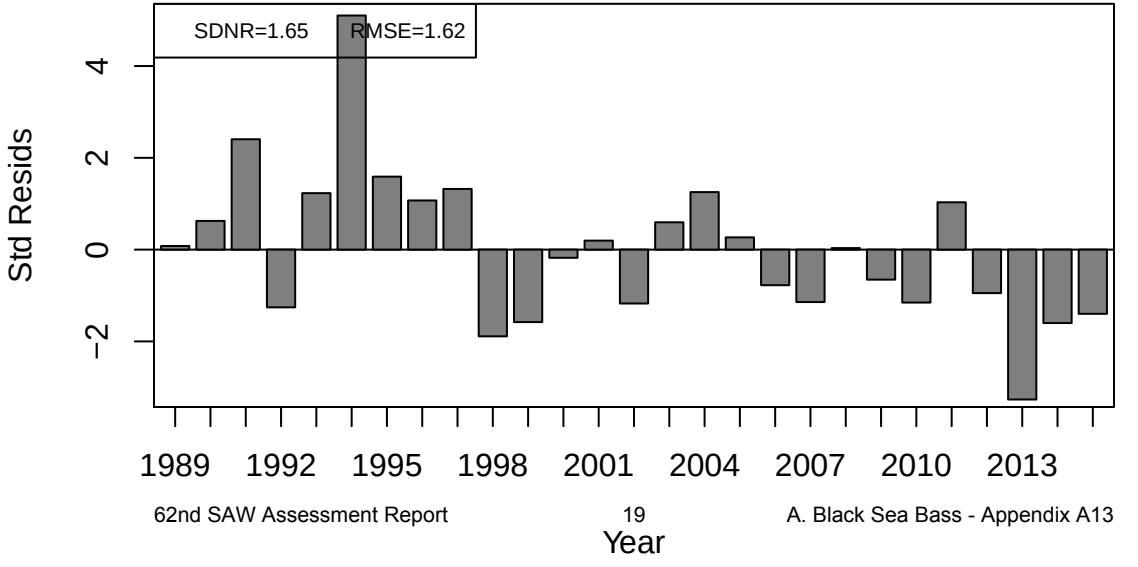

Catch Neff Fleet 2 (non−trawl)
Effective Sample Size
0
100
200
300
400
500
600
1990
1995
2000
2005
2010
2015
Year

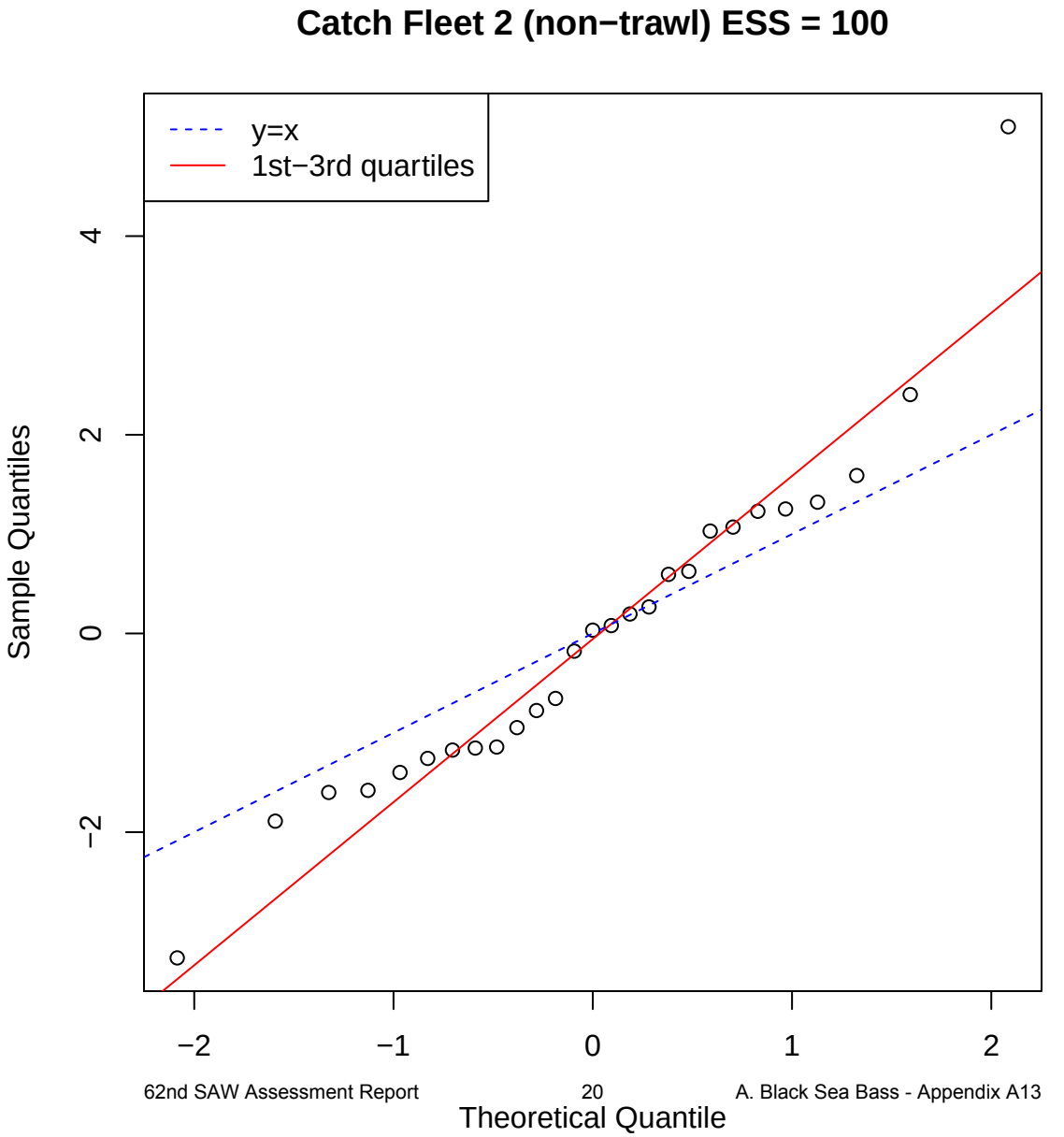

Catch Fleet 1 (trawl) ESS = 50
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
years

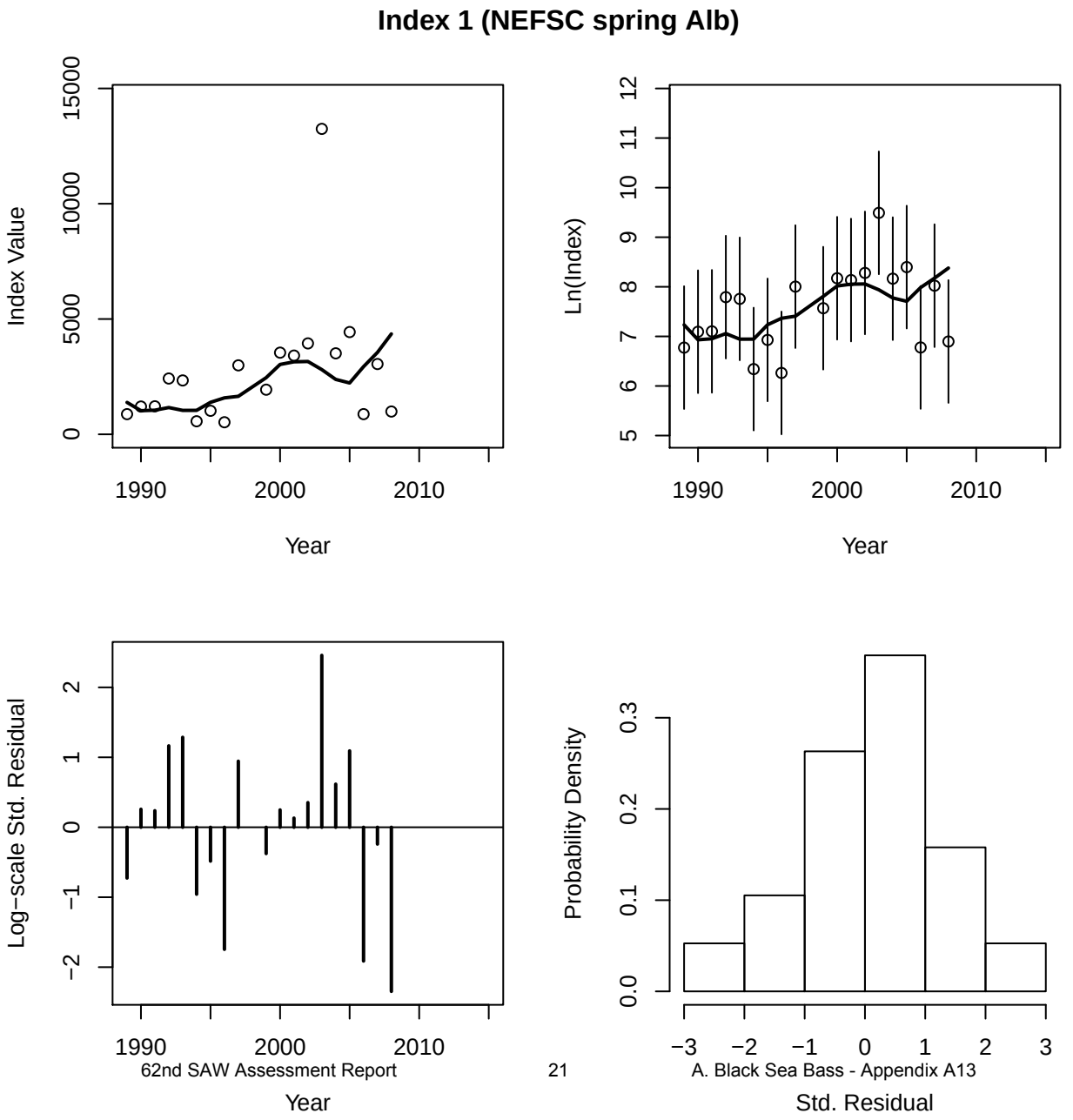

SDNR=1.08
RMSE=1.06
Std Resids
−1
0
1
2
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year


Catch Fleet 1 (trawl) ESS = 50
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
−1
0
1
2

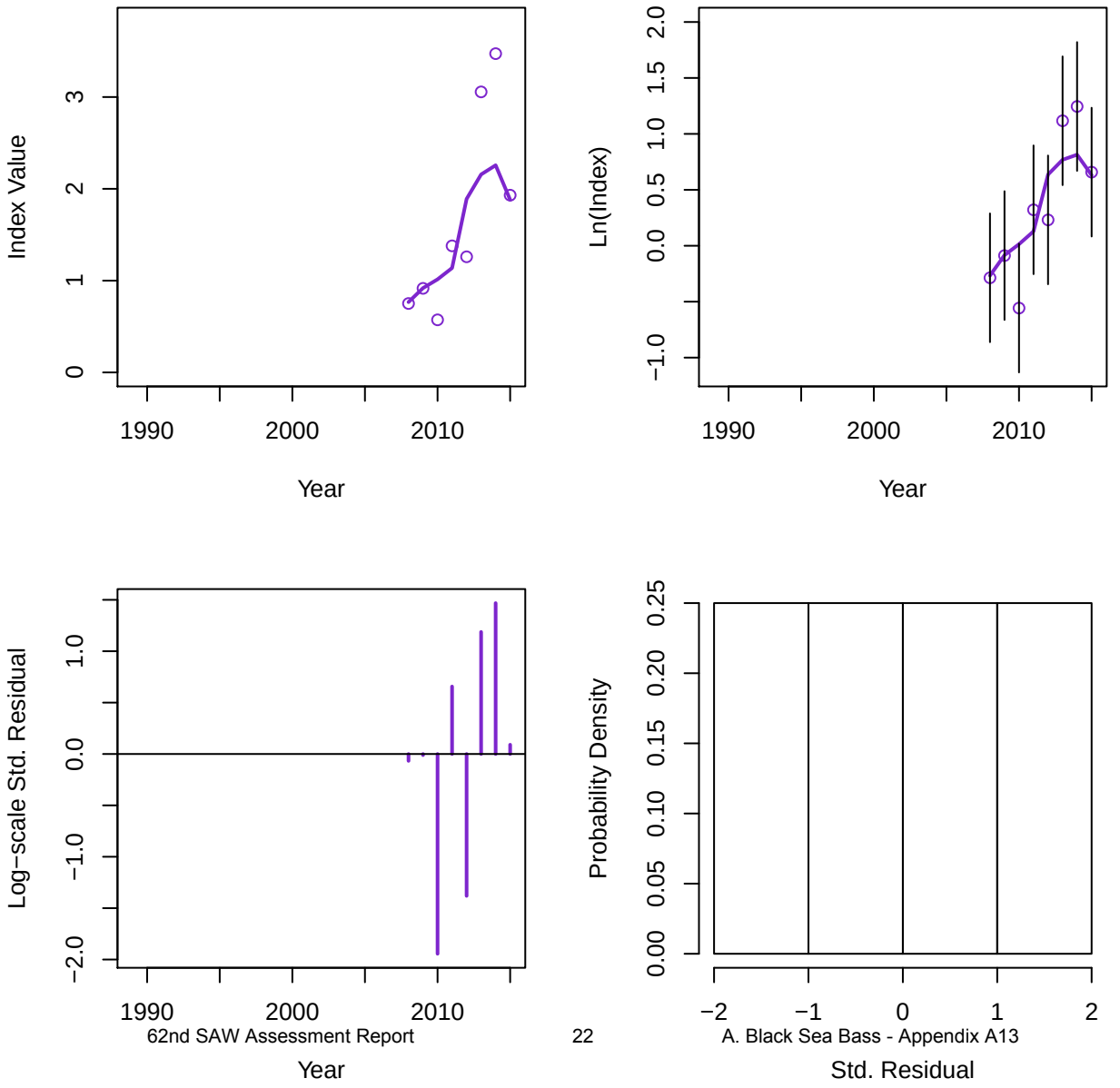

Catch Fleet 2 (non−trawl) ESS = 100
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
years


SDNR=1.65
RMSE=1.62
Std Resids
−2
0
2
4
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

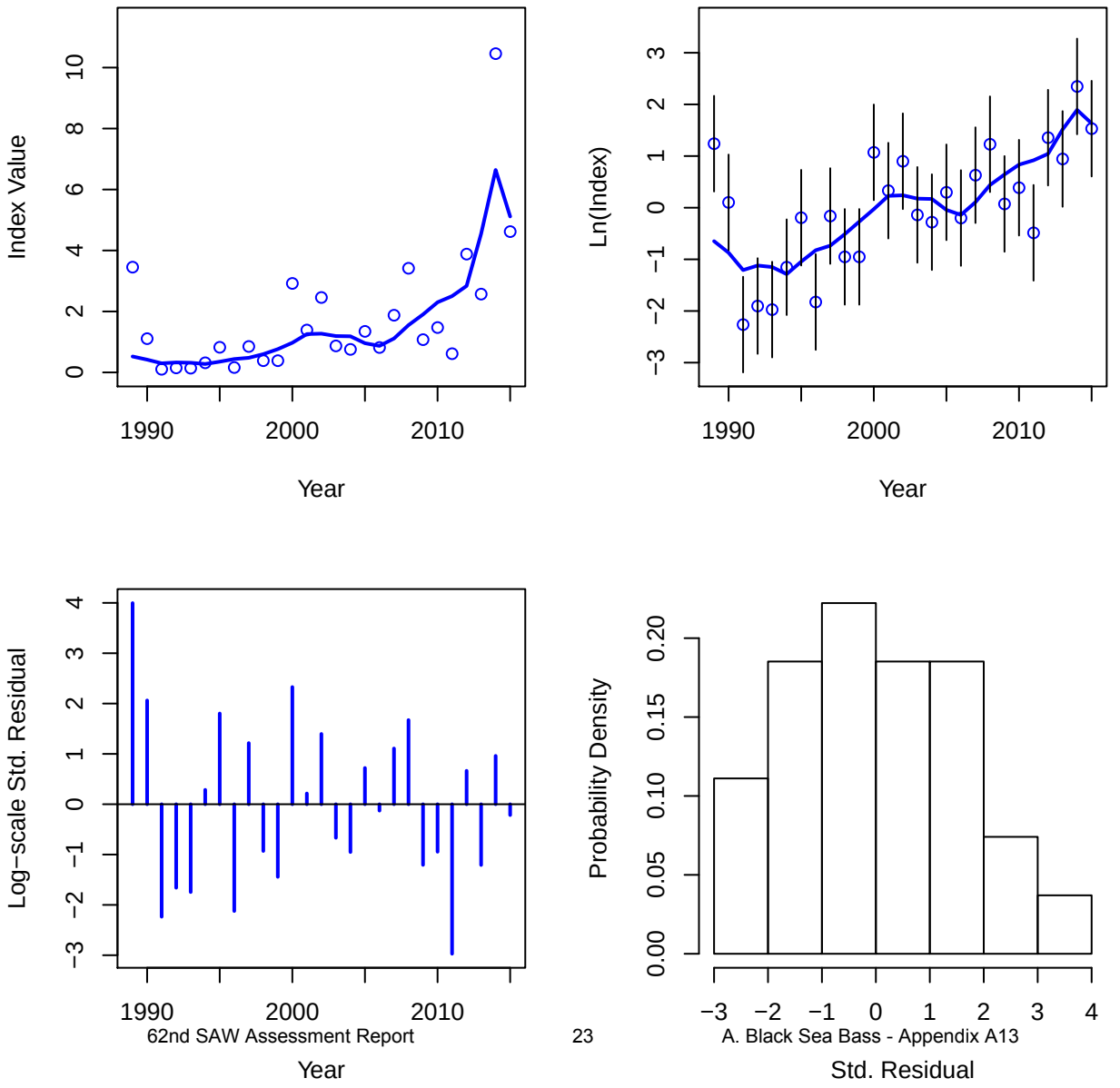

Catch Fleet 2 (non−trawl) ESS = 100
y=x
1st−3rd quartiles
Sample Quantiles
4
2
0
−2
−2
−1
0
1
2
Theoretical Quantile


Index 1 (NEFSC spring Alb)
Index Value
0
5000
10000
15000
1990
2000
2010
Year
Ln(Index)
5
6
7
8
9
10
11
12
1990
2000
2010
Year
Log−scale Std. Residual
−2
−1
0
1
2
1990
2000
2010
Year
Probability Density
0.0
0.1
0.2
0.3
−3
−2
−1
0
1
2
3
Std. Residual

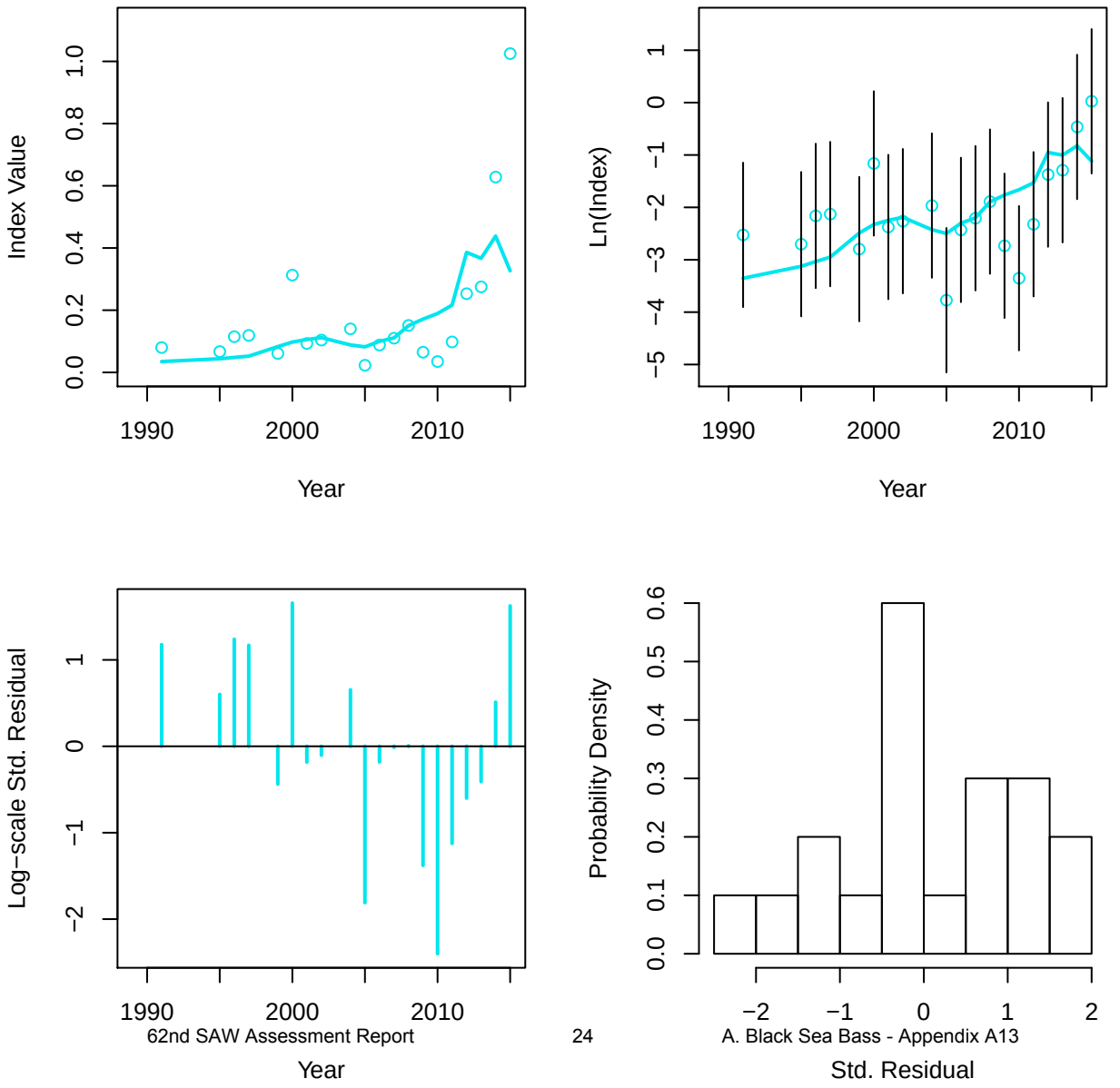
Index 2 (NEAMAP)



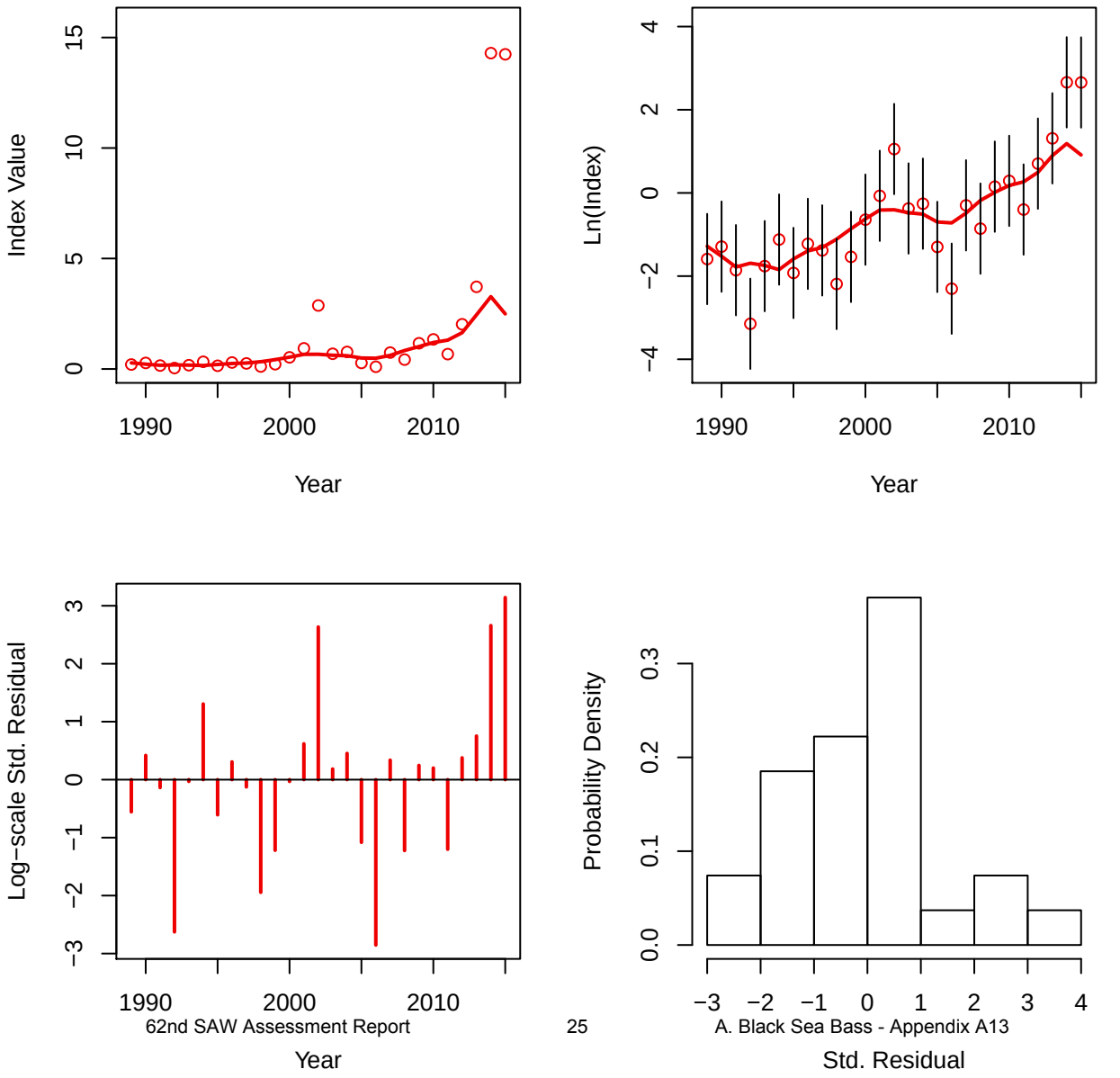
Index 3 (MADMF)



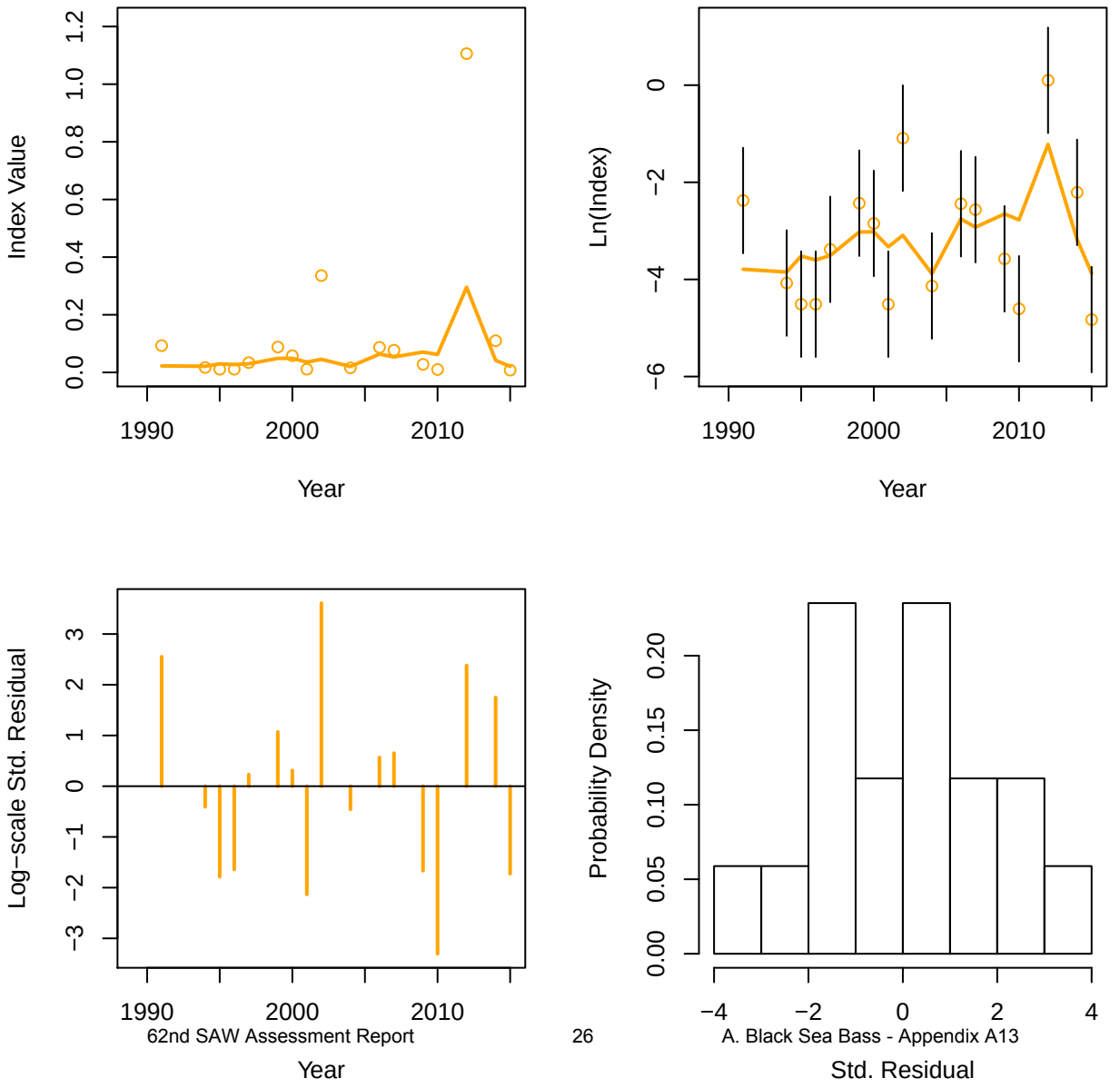
Index 4 (RI)


Index Value
0.0
0.2
0.4
0.6
0.8
1.0
1990
2000
2010
Year
Ln(Index)
−5
−4
−3
−2
−1
0
1
1990
2000
2010
Year
Log−scale Std. Residual
−2
−1
0
1
1990
2000
2010
Year
Probability Density
0.0
0.1
0.2
0.3
0.4
0.5
0.6
−2
−1
0
1
2
Std. Residual

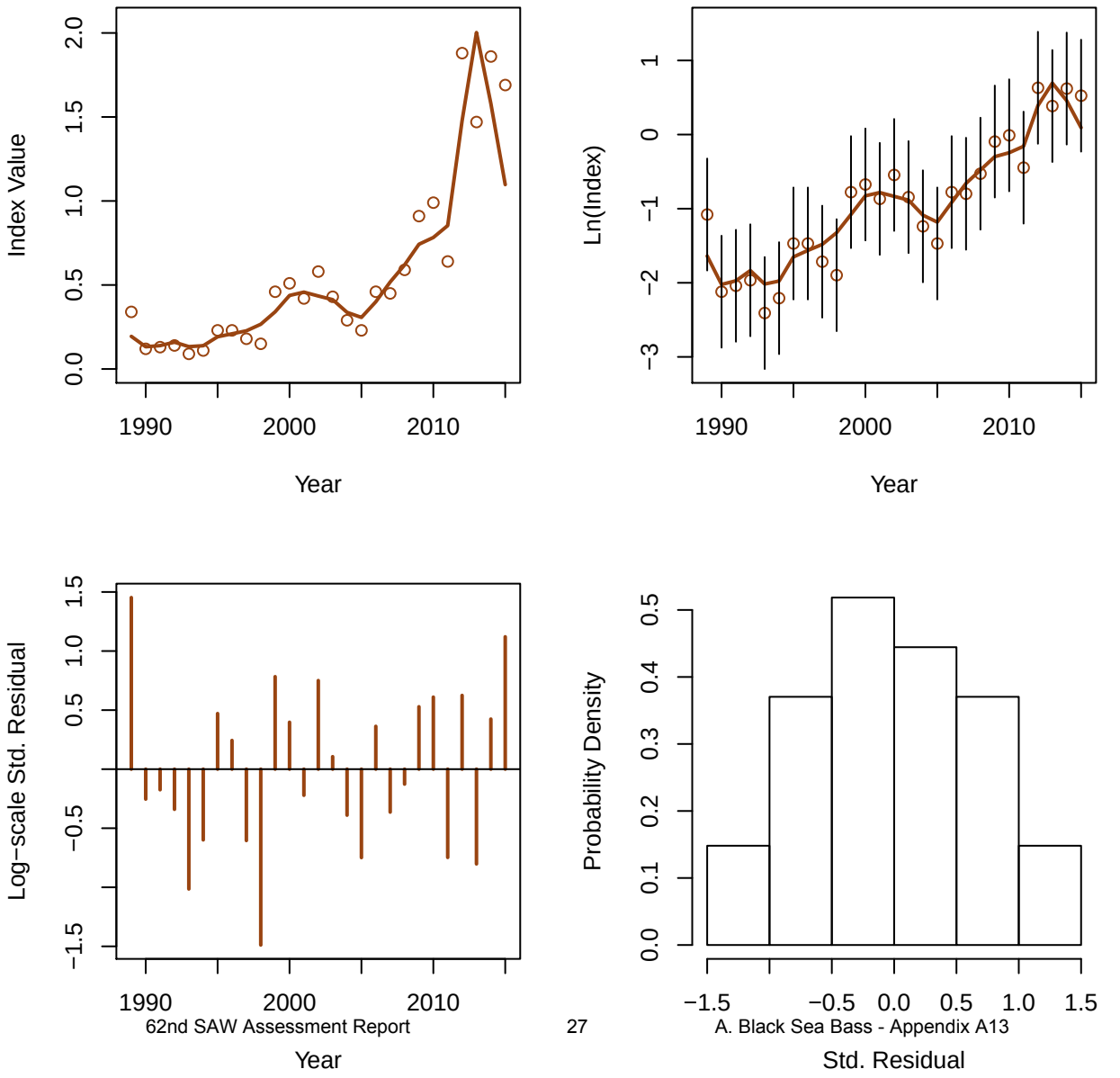
Index 5 (CT)


Index Value
0
5
10
15
1990
2000
2010
Year
Ln(Index)
−4
−2
0
2
4
1990
2000
2010
Year
Log−scale Std. Residual
−3
−2
−1
0
1
2
3
1990
2000
2010
Year
Probability Density
0.0
0.1
0.2
0.3
−3
−2
−1
0
1
2
3
4
Std. Residual

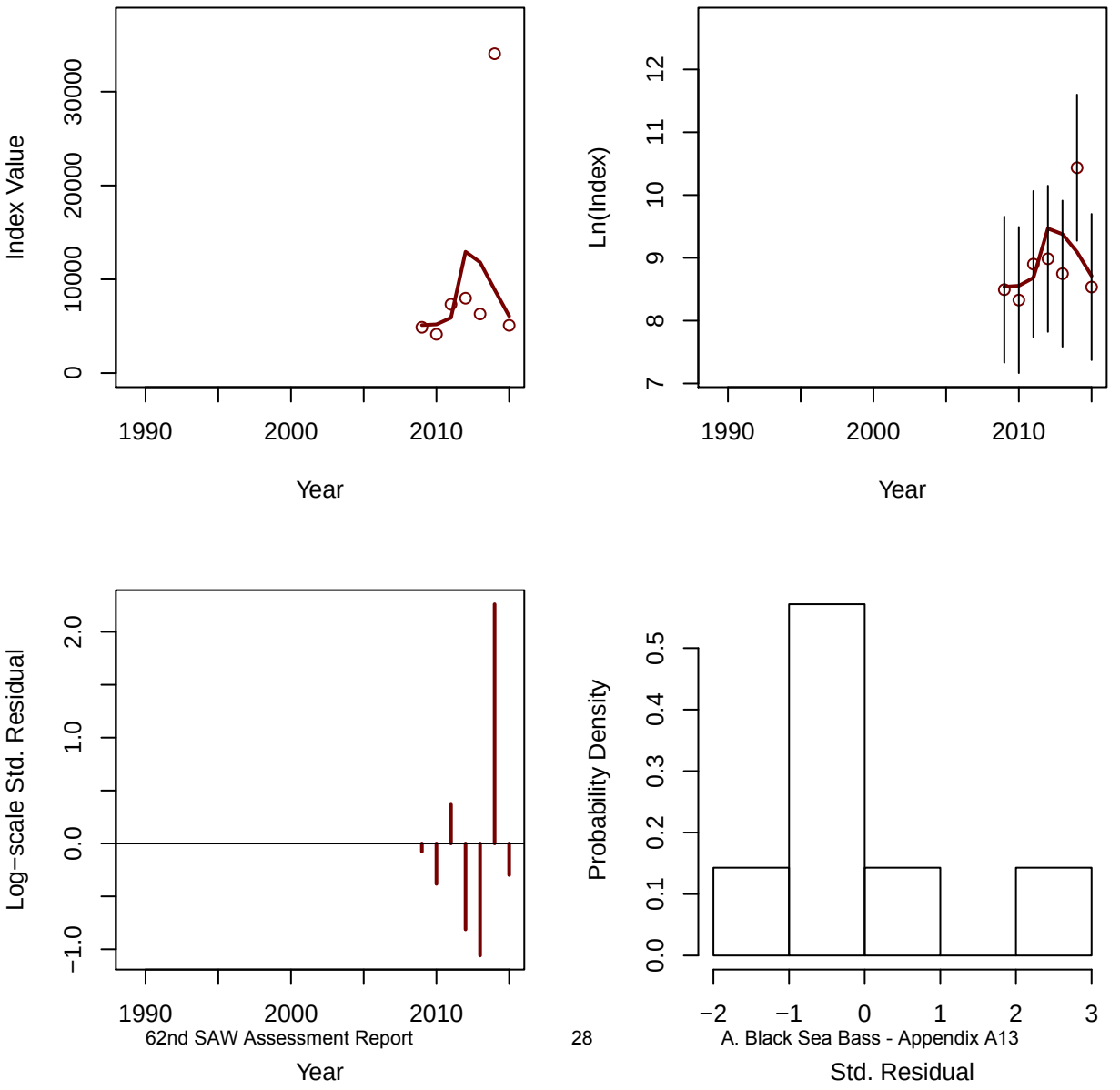
Index 6 (NY)


Index Value
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1990
2000
2010
Year
Ln(Index)
0
−2
−4
−6
1990
2000
2010
Year
Log−scale Std. Residual
−3
−2
−1
0
1
2
3
1990
2000
2010
Year
Probability Density
0.00
0.05
0.10
0.15
0.20
−4
−2
0
2
4
Std. Residual

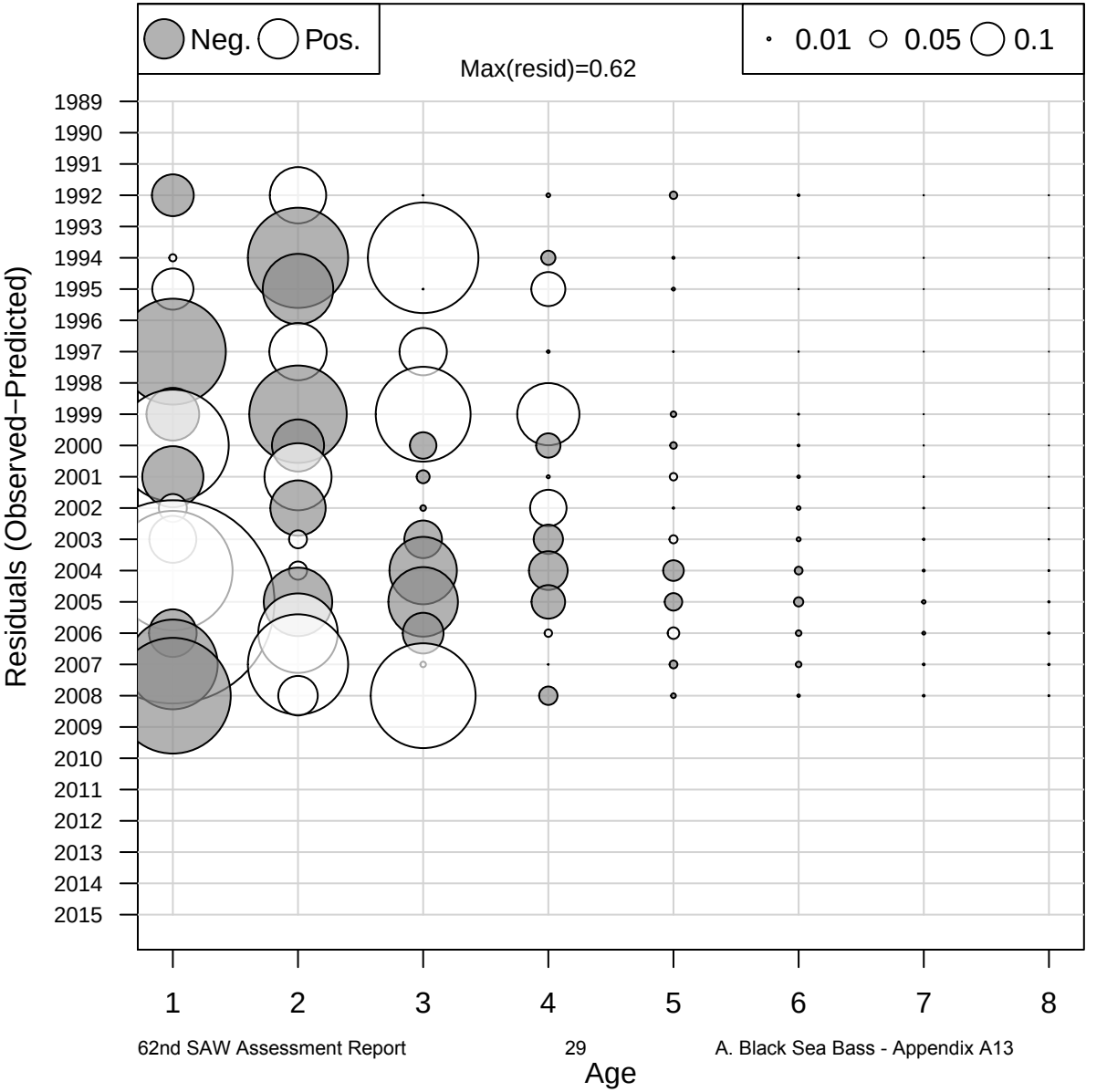
Index 7 (REC CPA)



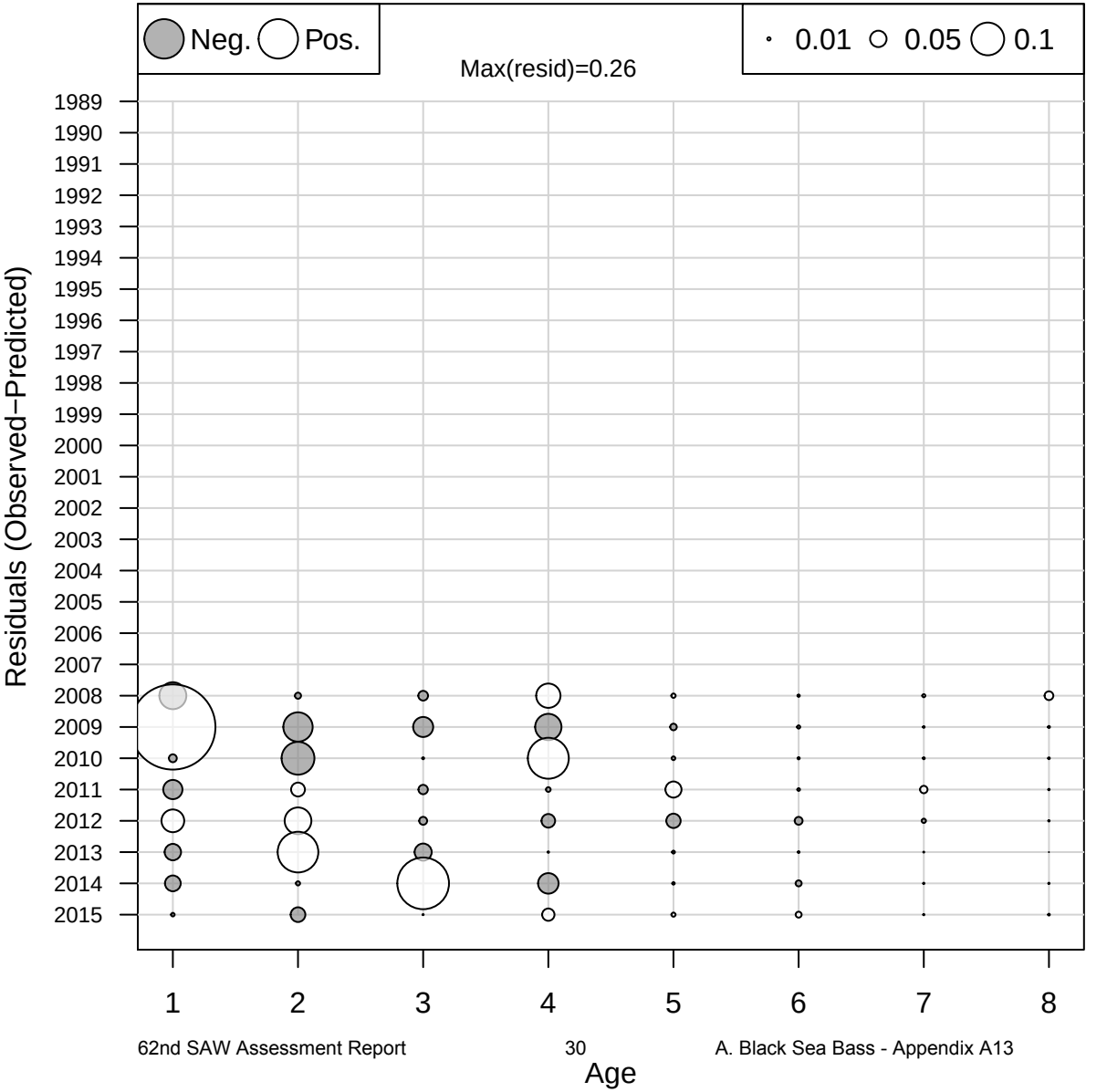
Index 8 (BIGELOW)



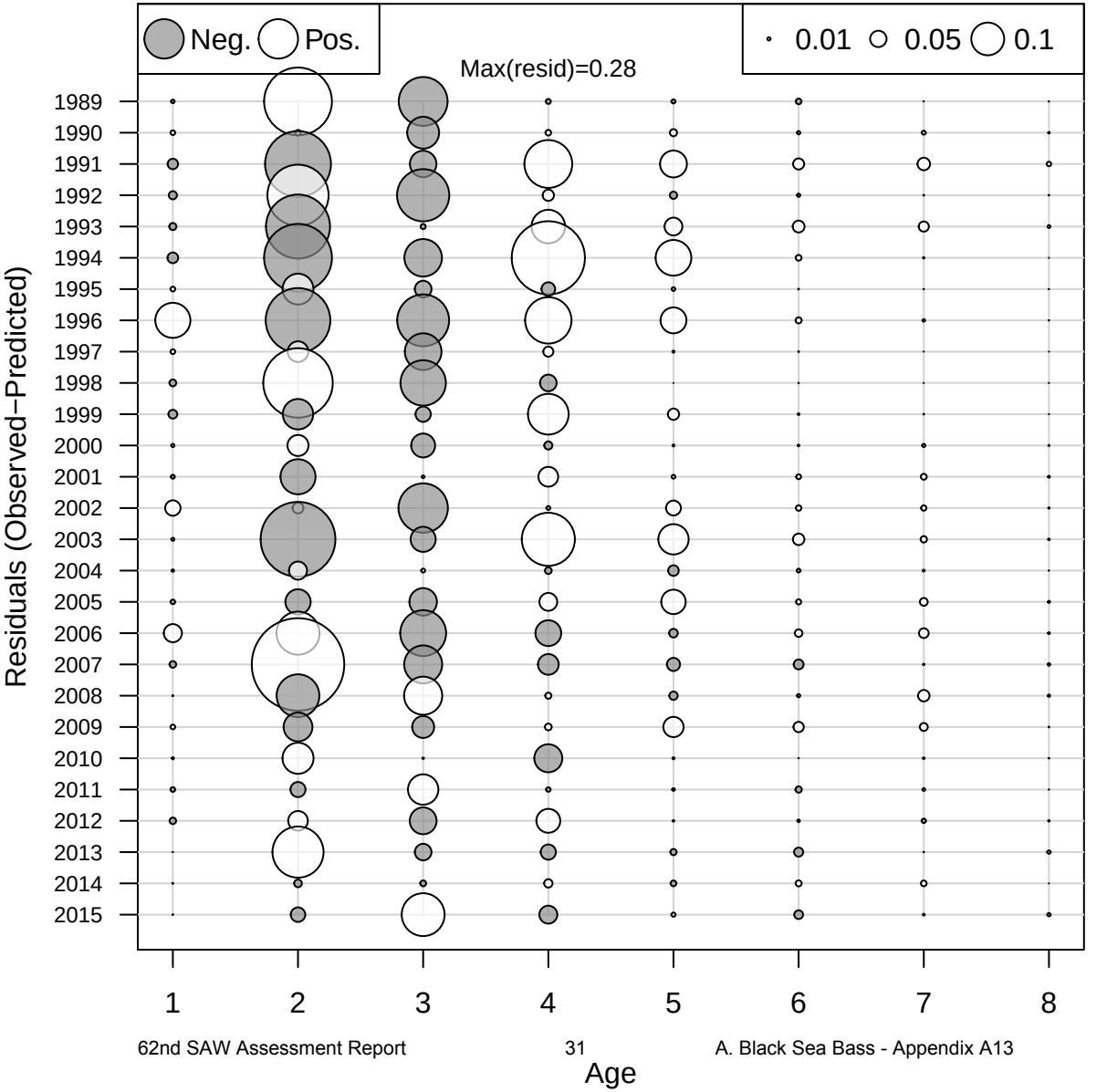
Age Comp Residuals for Index 1 (NEFSC spring Alb)

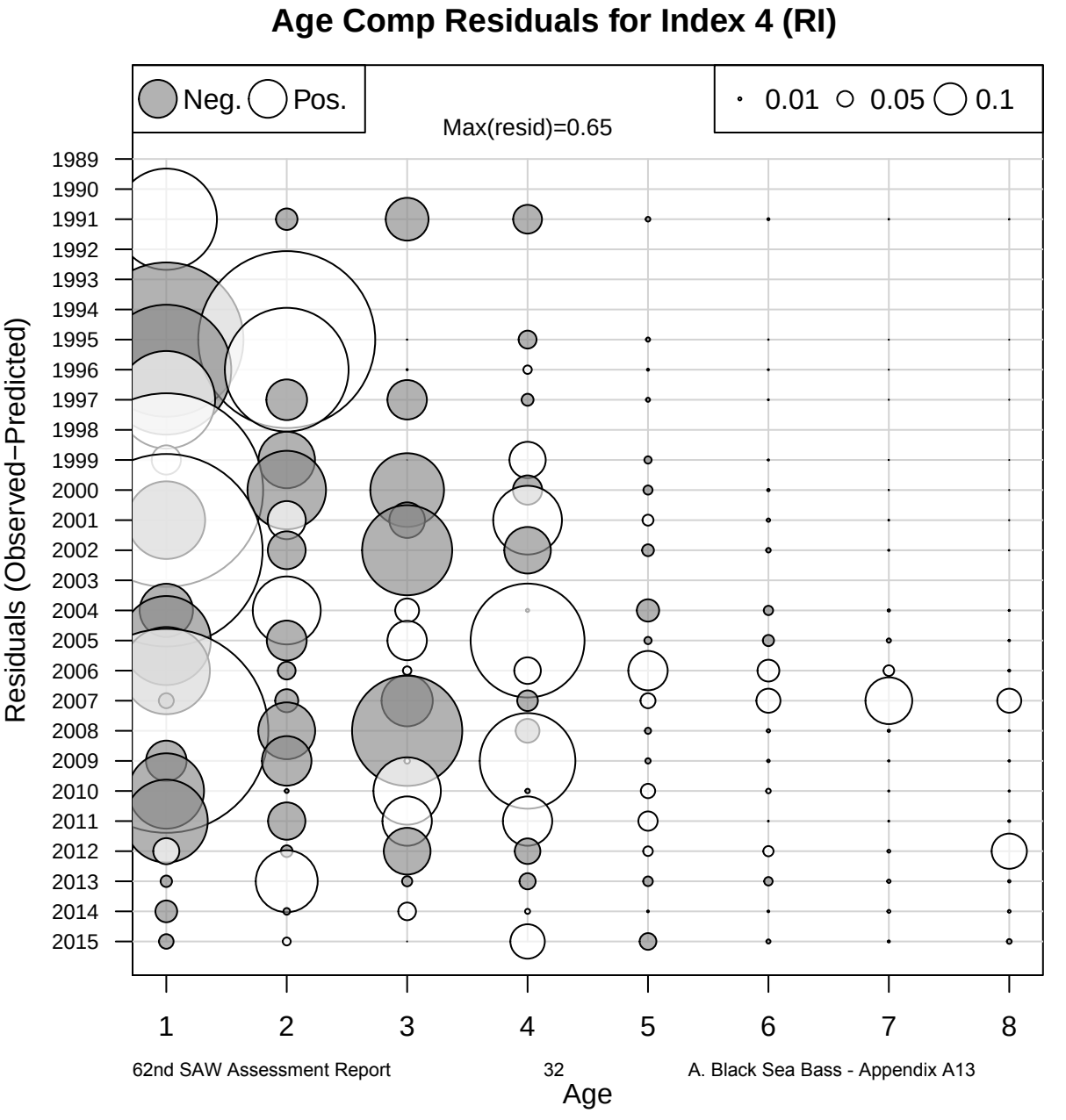


Age Comp Residuals for Index 2 (NEAMAP)

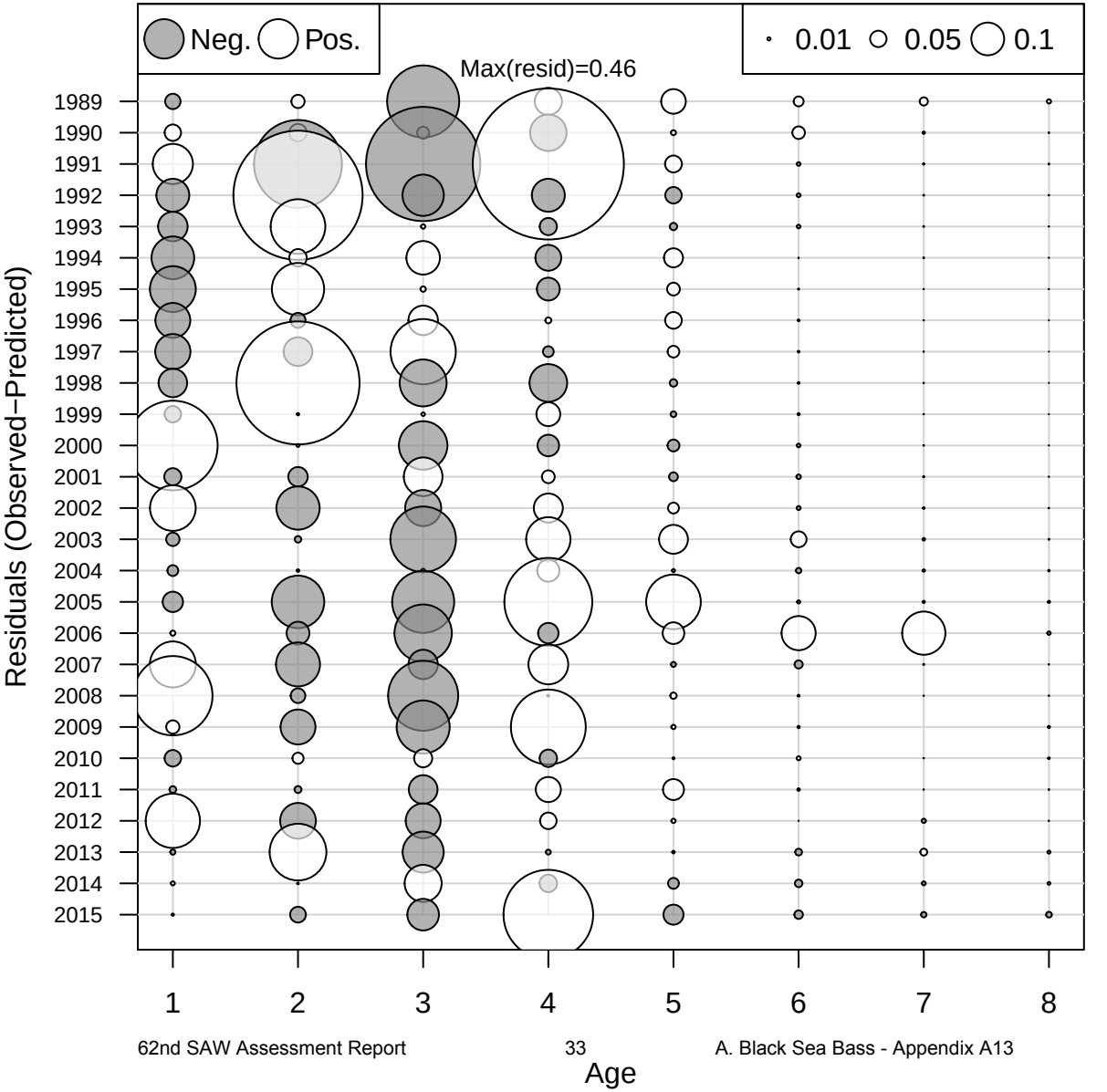


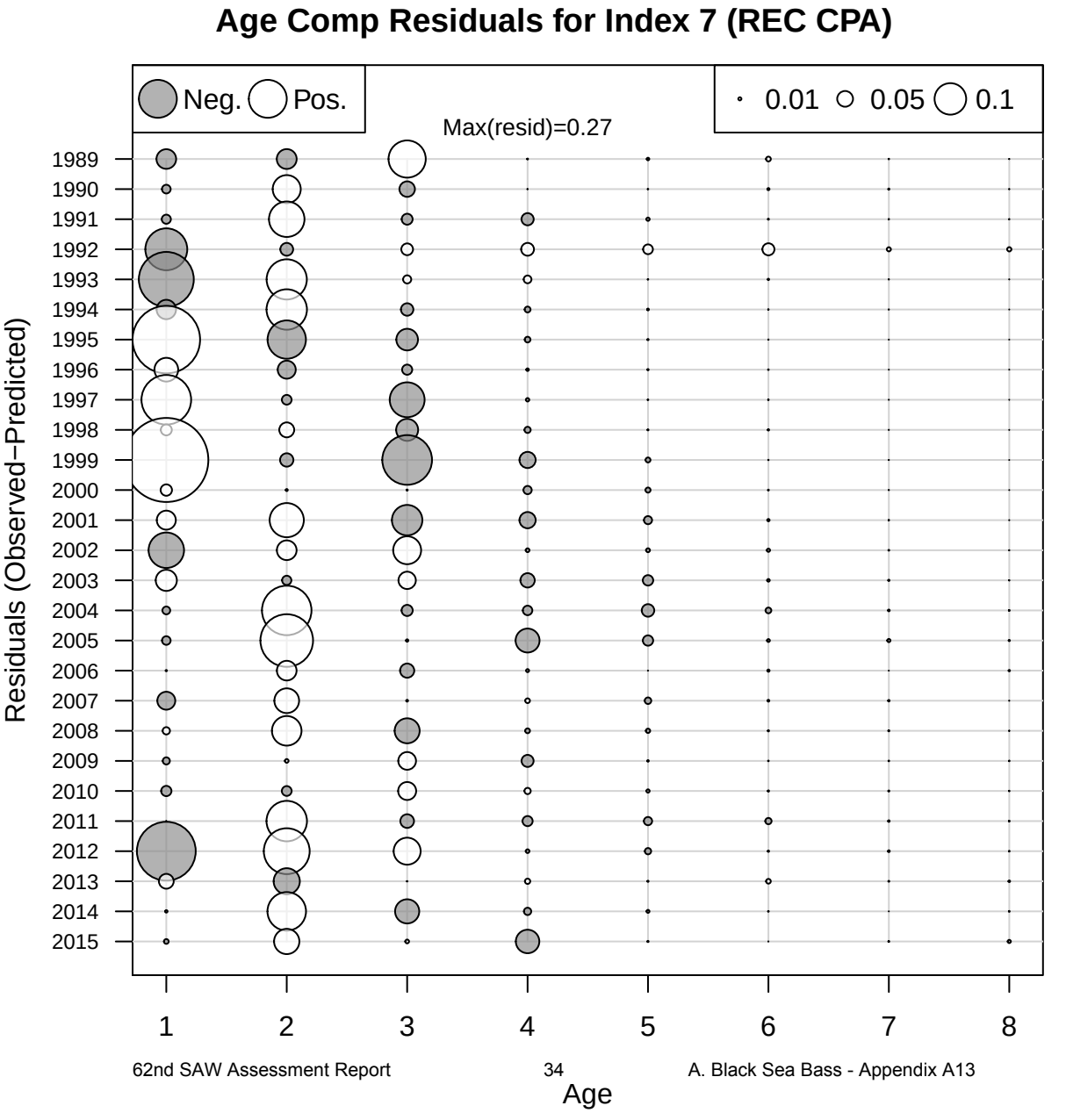
Age Comp Residuals for Index 3 (MADMF)



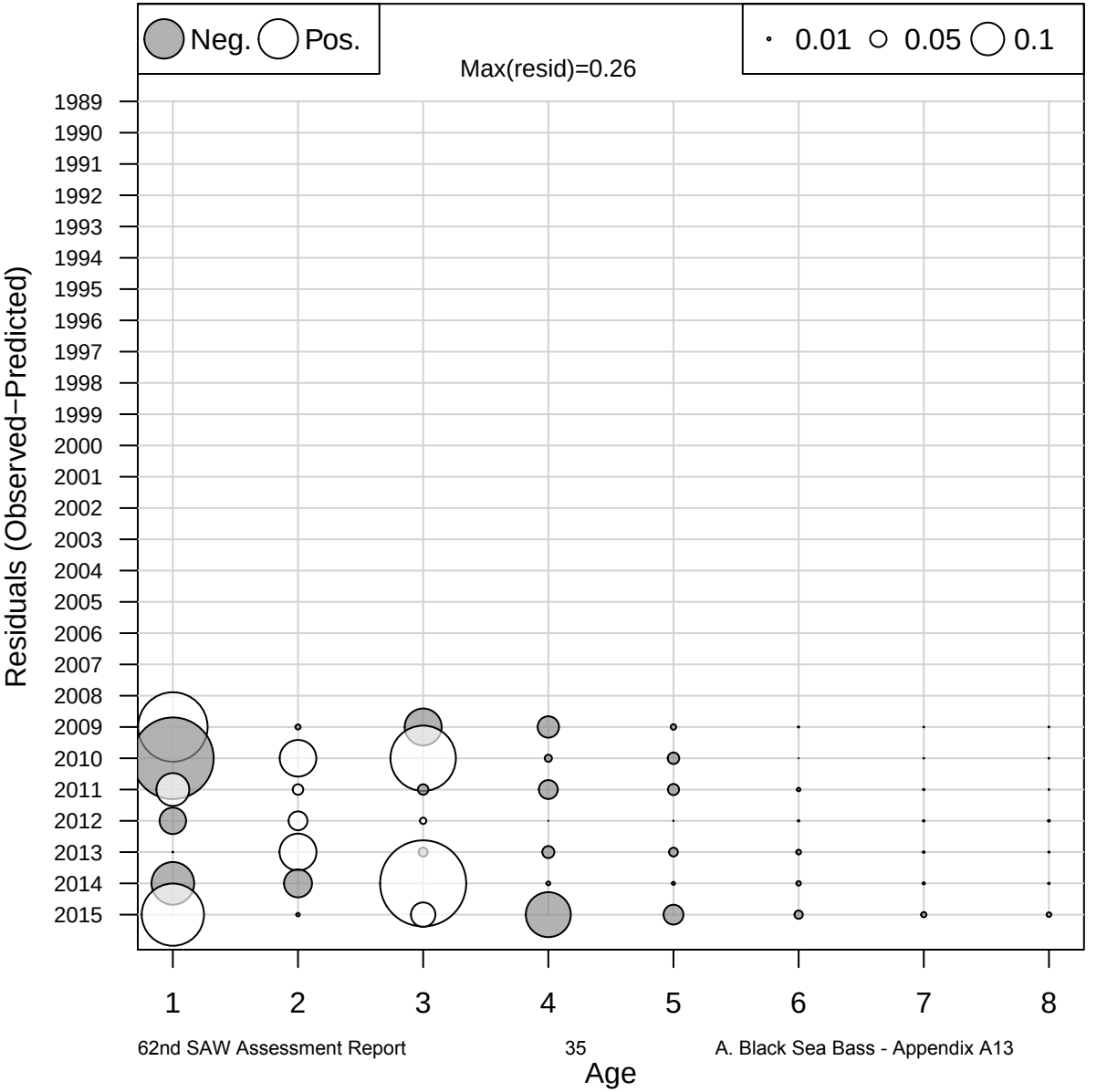

Age Comp Residuals for Index 4 (RI)
Neg.
Pos.
0.01
0.05
0.1
Max(resid)=0.65
Residuals (Observed−Predicted)
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

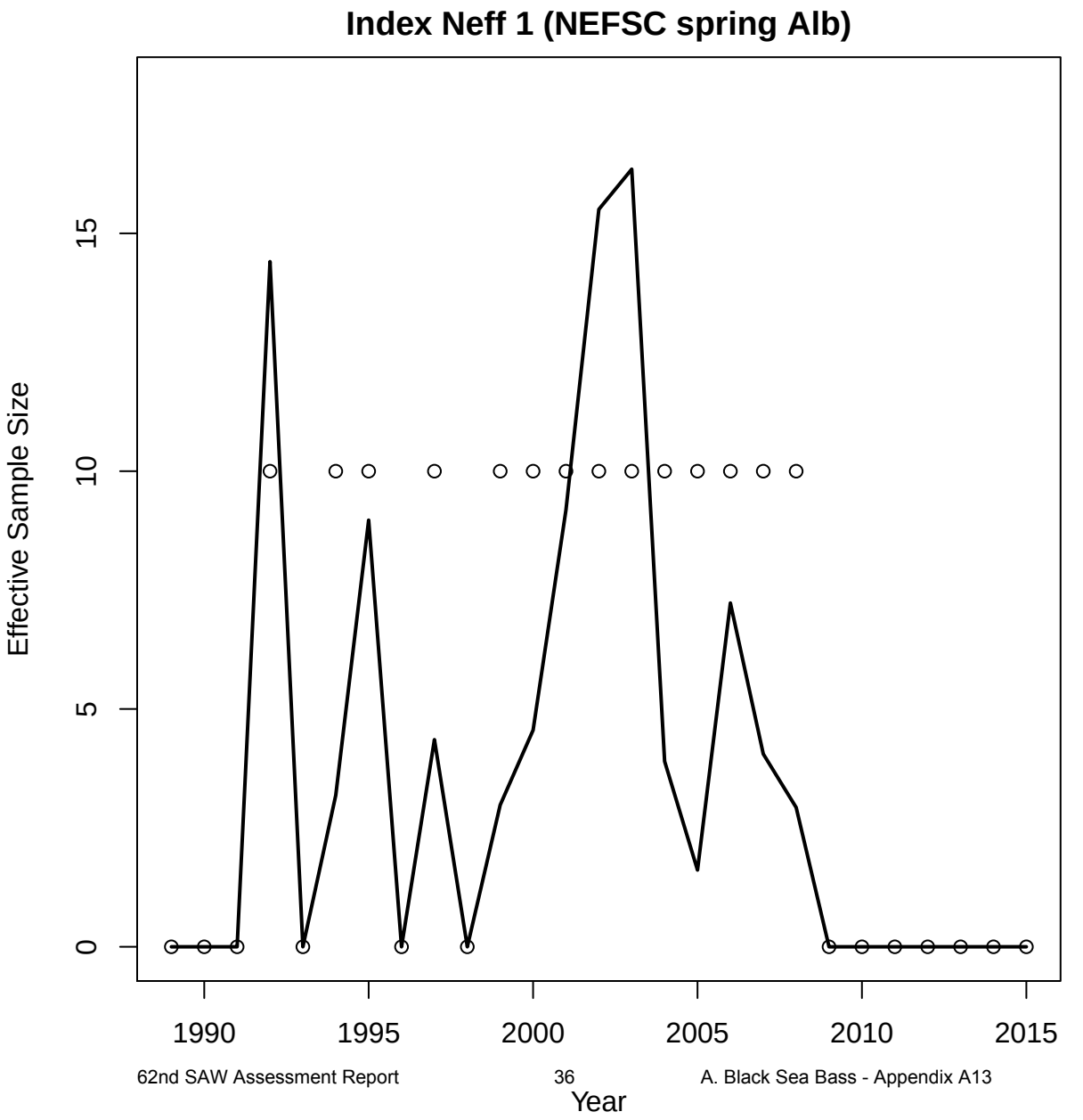
Age Comp Residuals for Index 5 (CT)

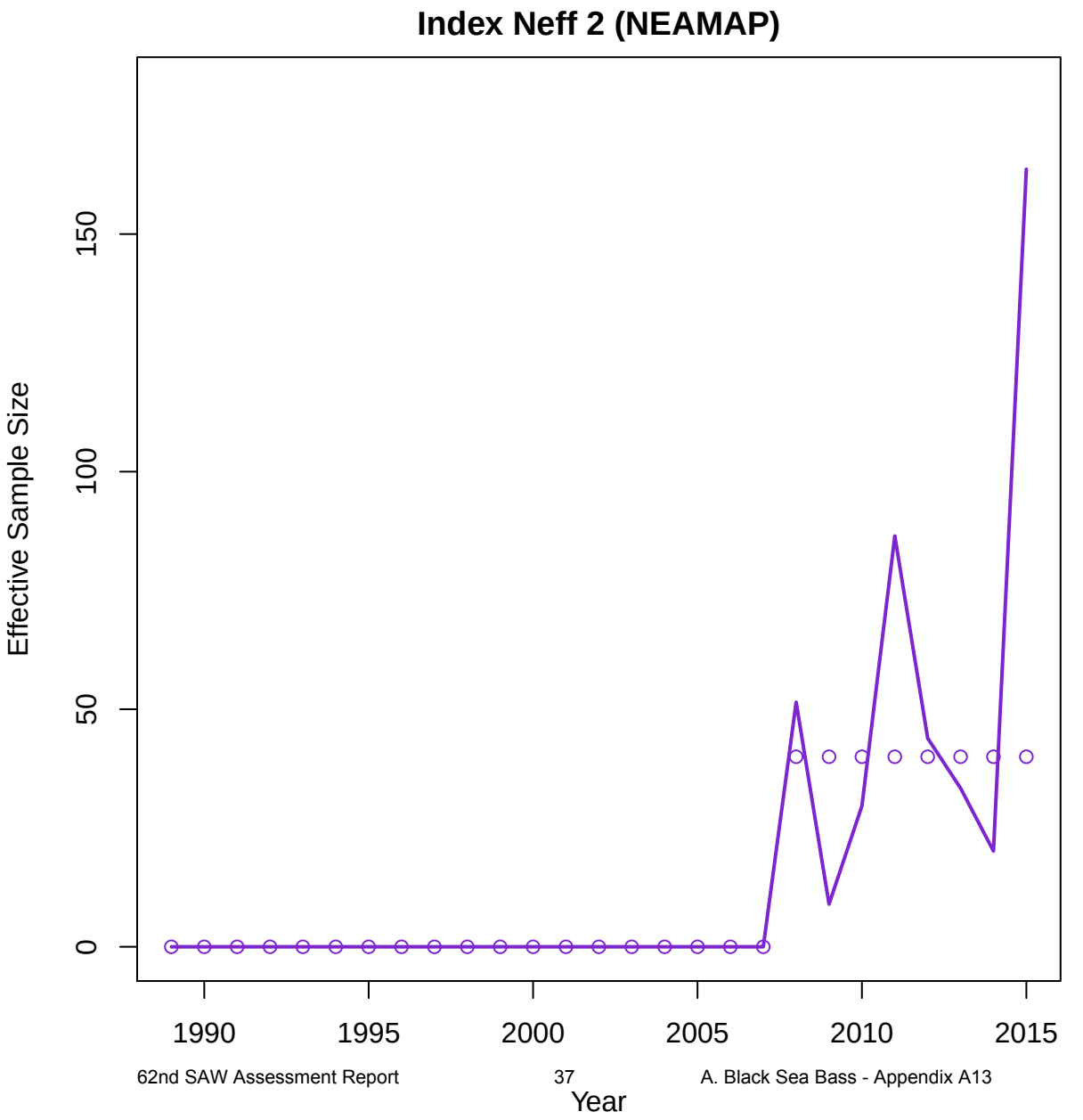


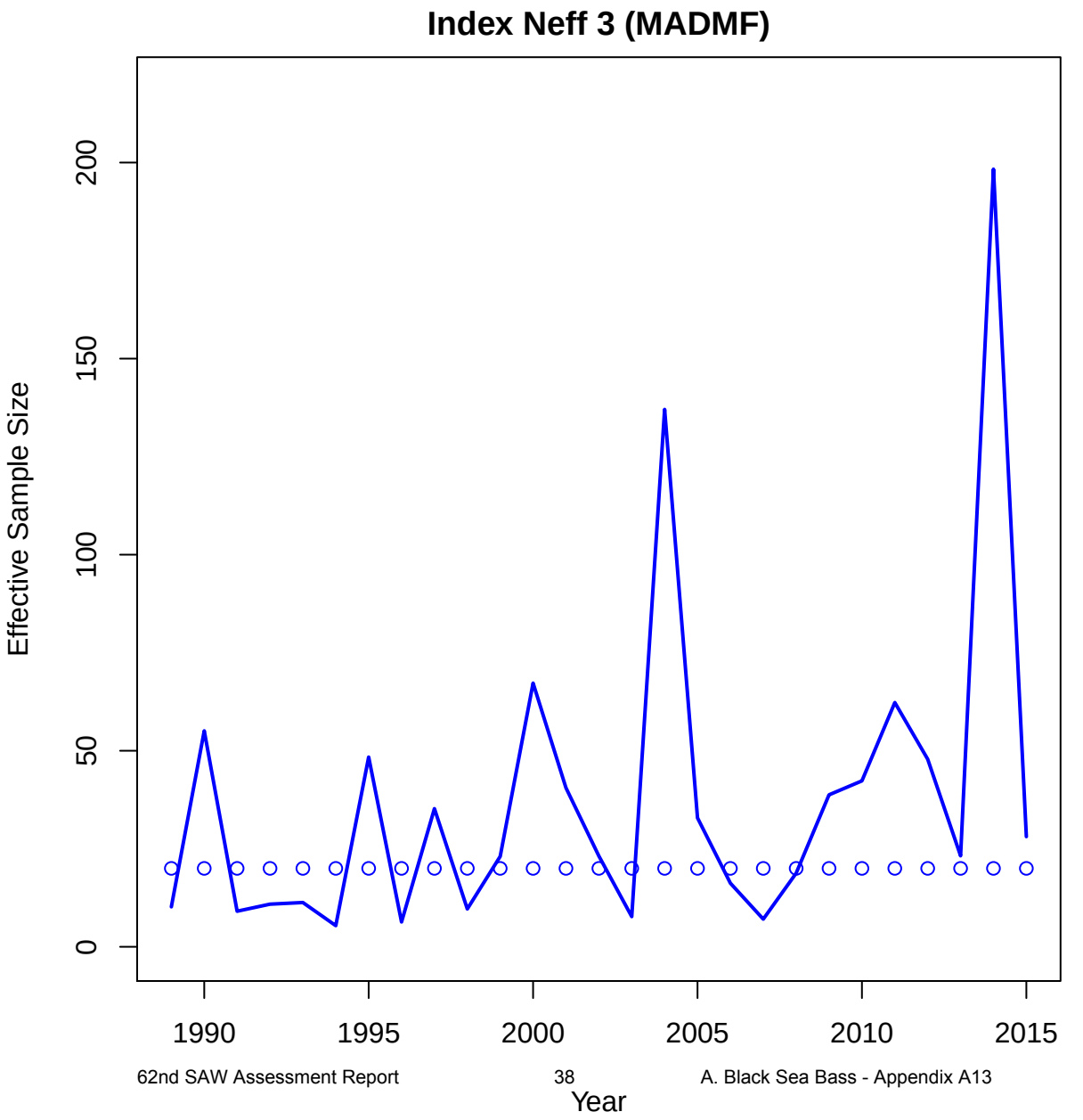

Age Comp Residuals for Index 7 (REC CPA)
Neg.
Pos.
0.01
0.05
0.1
Max(resid)=0.27
Residuals (Observed−Predicted)
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

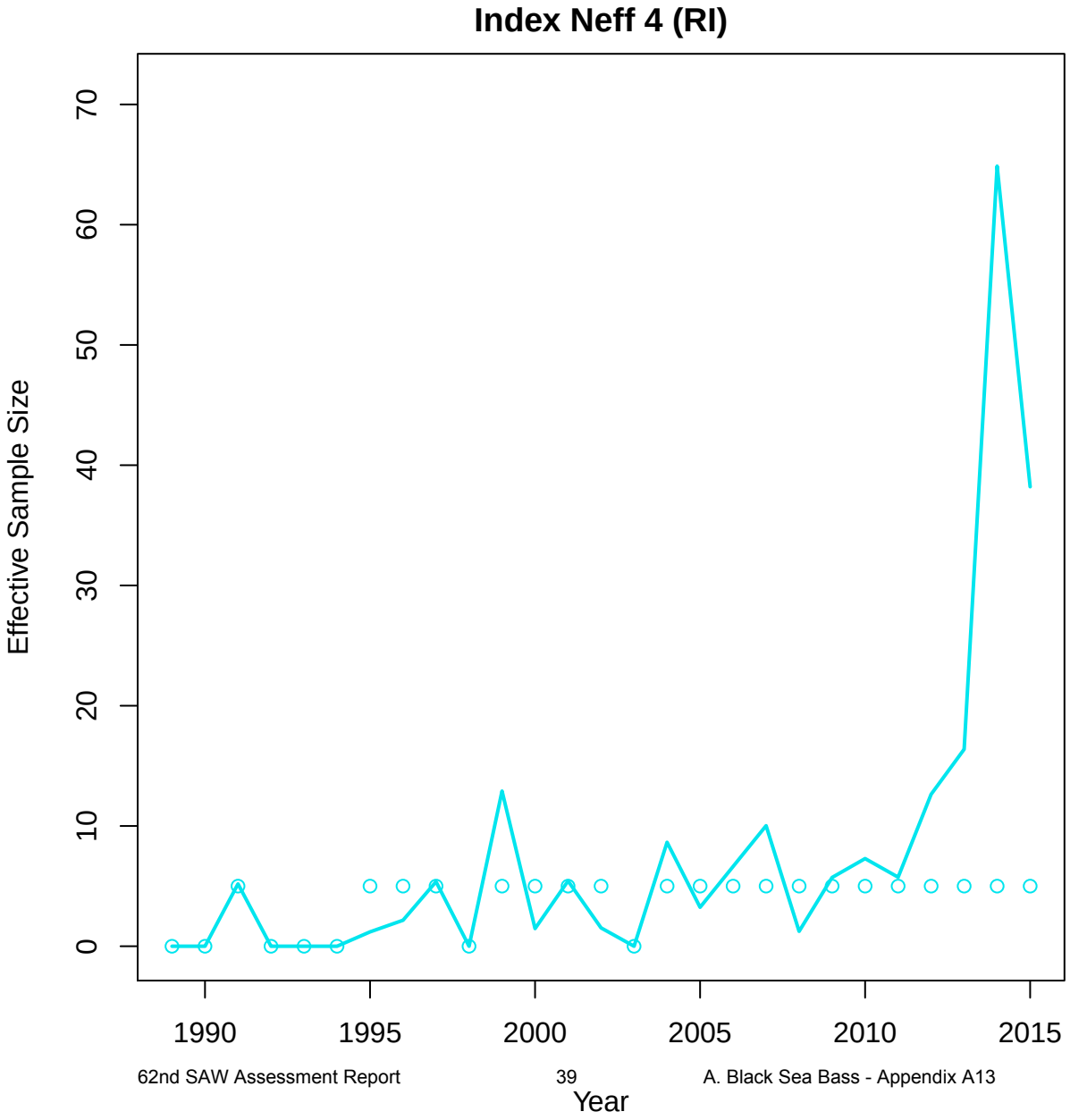
Age Comp Residuals for Index 8 (BIGELOW)

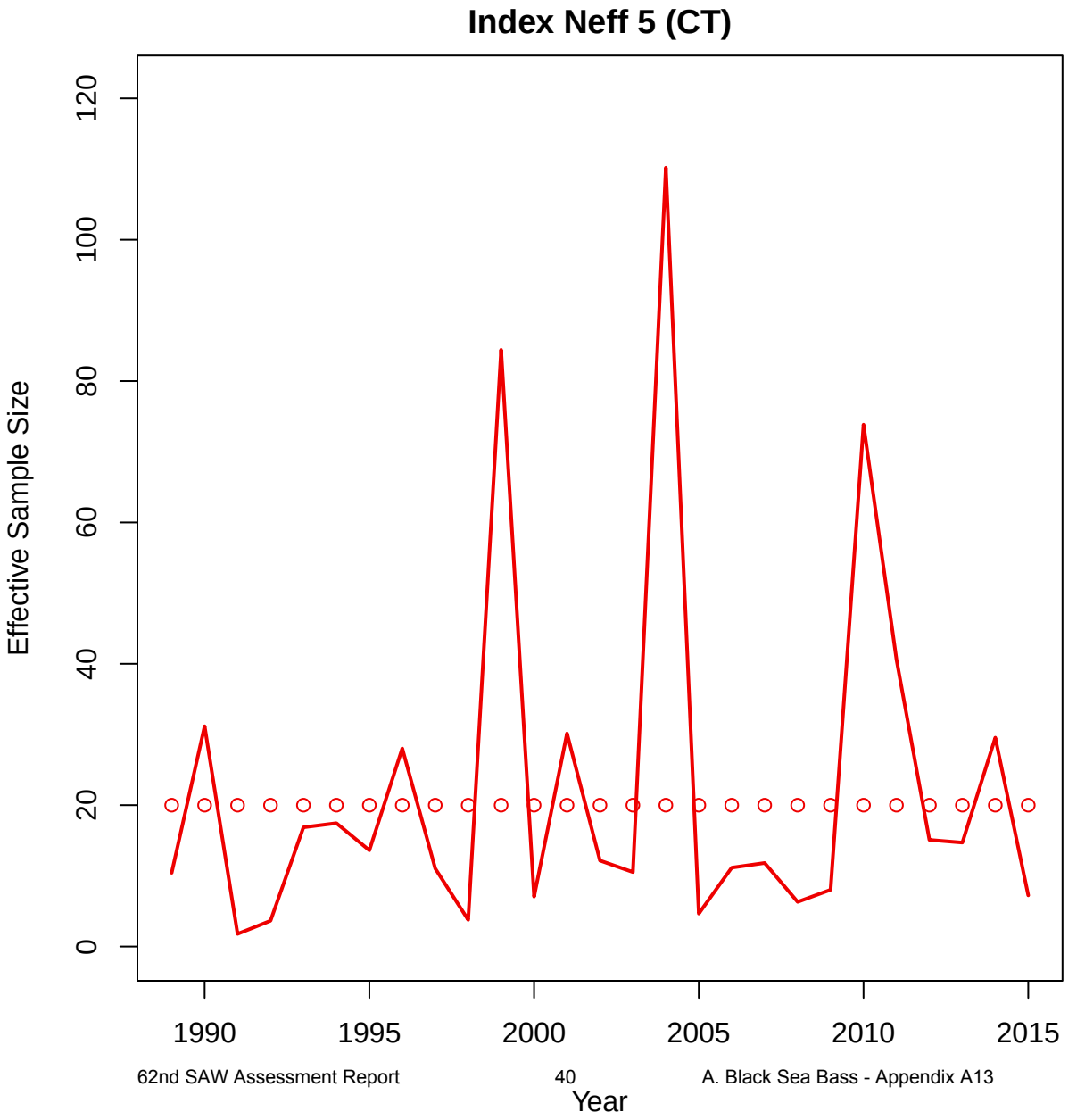


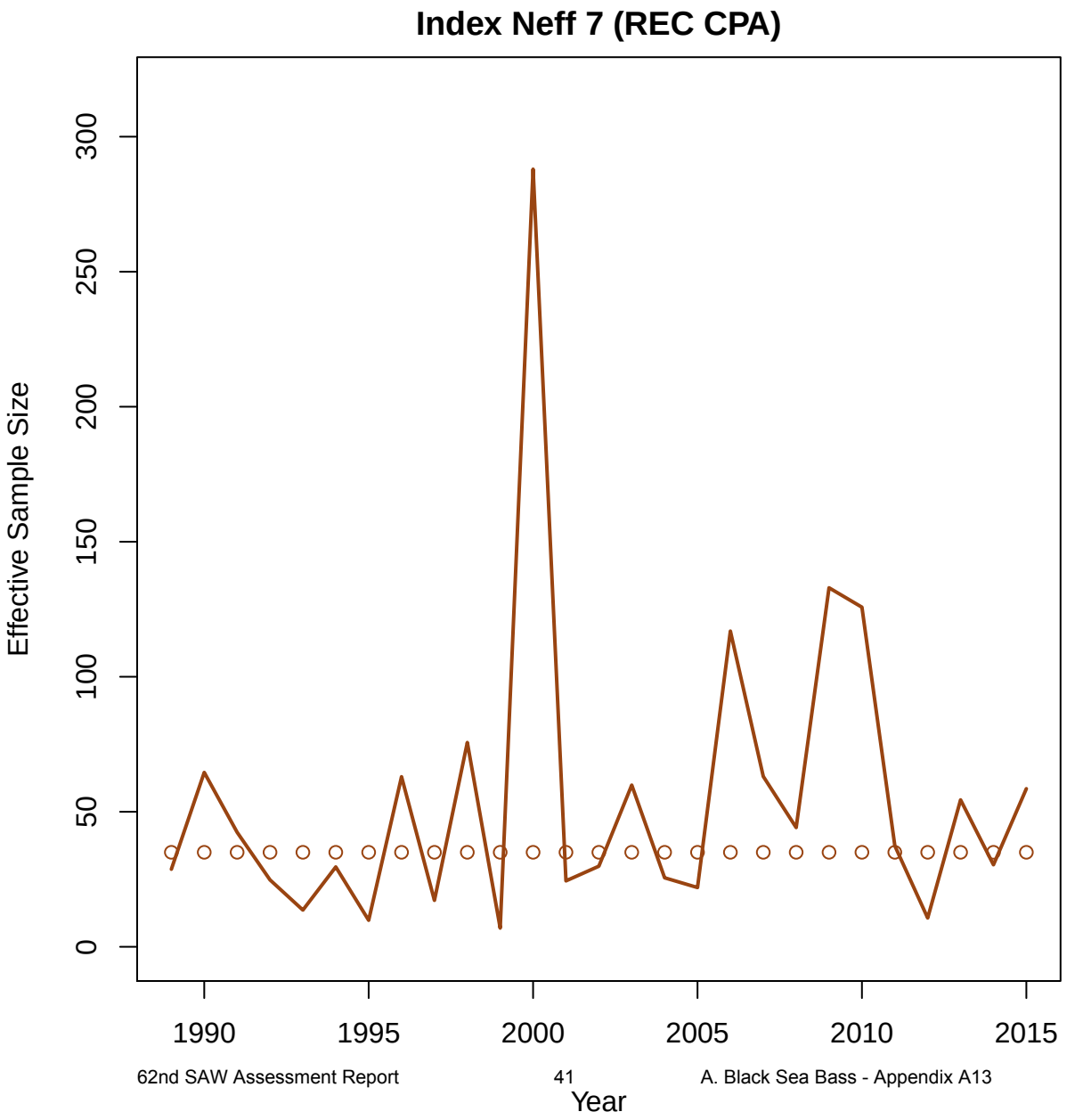

Index Neff 1 (NEFSC spring Alb)
Effective Sample Size
0
5
10
15
1990
1995
2000
2005
2010
2015
Year

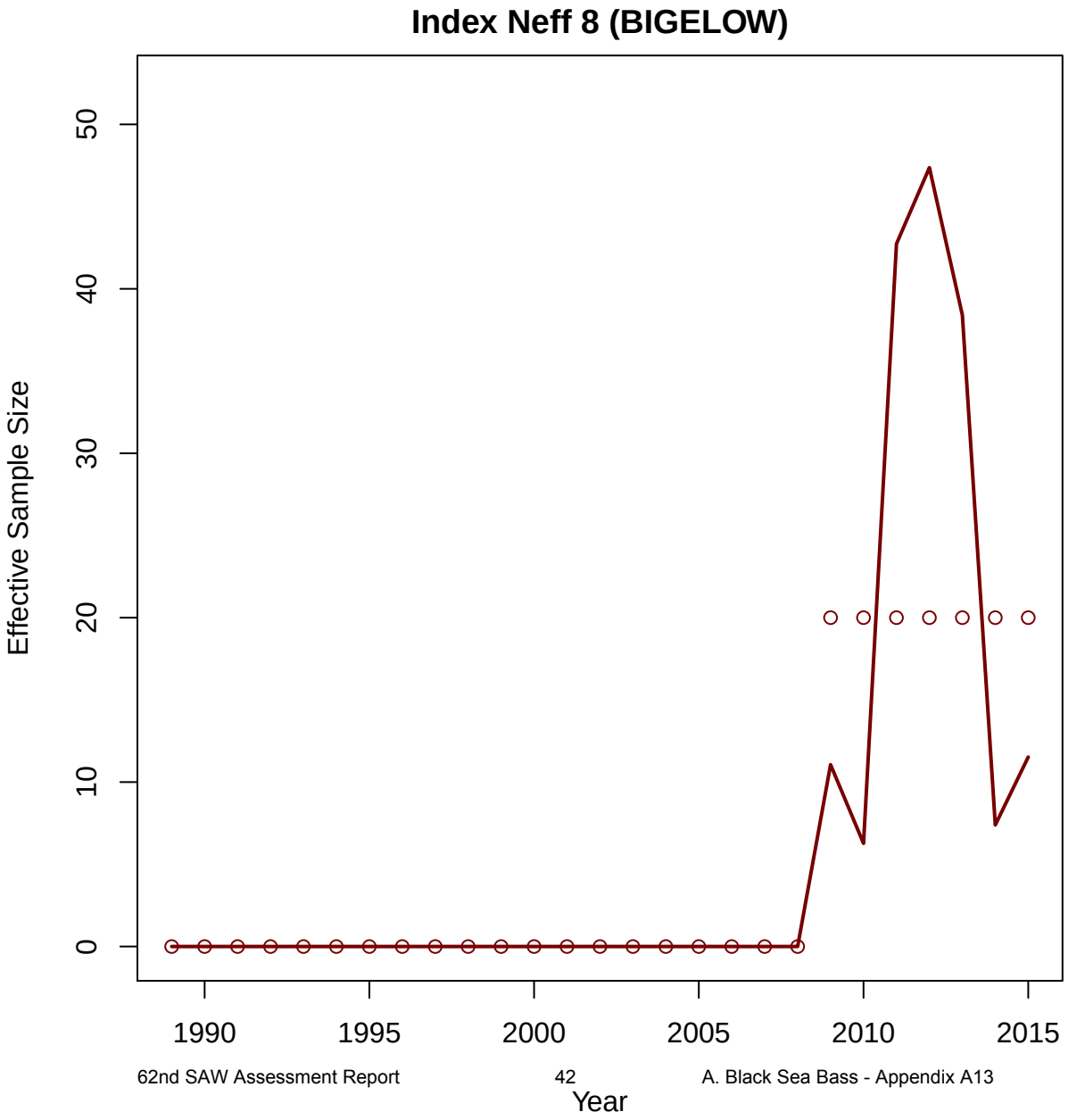

Index Neff 2 (NEAMAP)
Effective Sample Size
0
50
100
150
1990
1995
2000
2005
2010
2015
Year

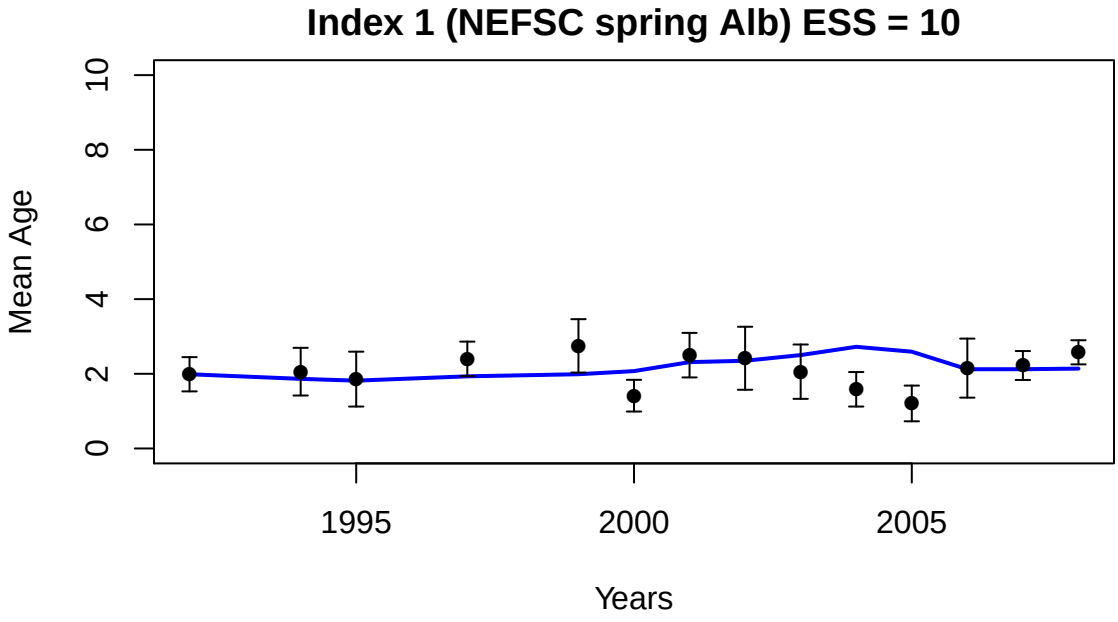

Index Neff 3 (MADMF)
Effective Sample Size
0
50
100
150
200
1990
1995
2000
2005
2010
2015
Year

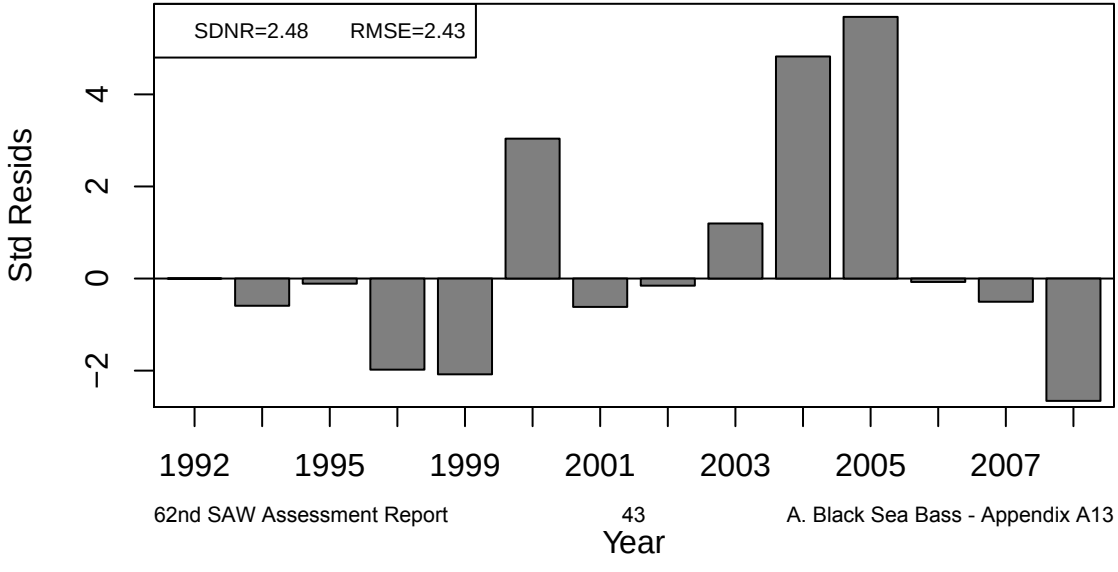

Index Neff 4 (RI)
Effective Sample Size
0
10
20
30
40
50
60
70
1990
1995
2000
2005
2010
2015
Year

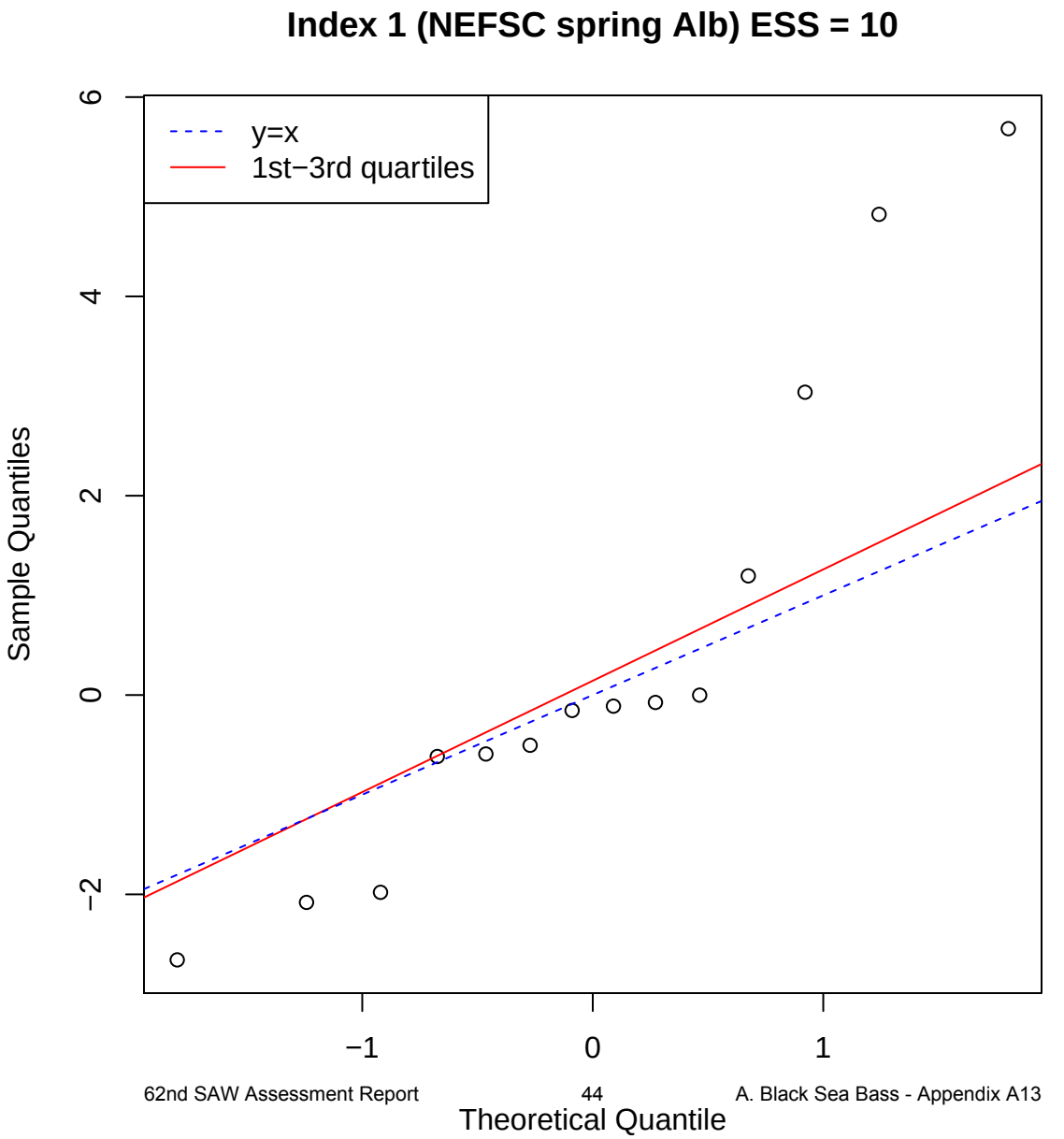

Index Neff 5 (CT)
Effective Sample Size
0
20
40
60
80
100
120
1990
1995
2000
2005
2010
2015
Year

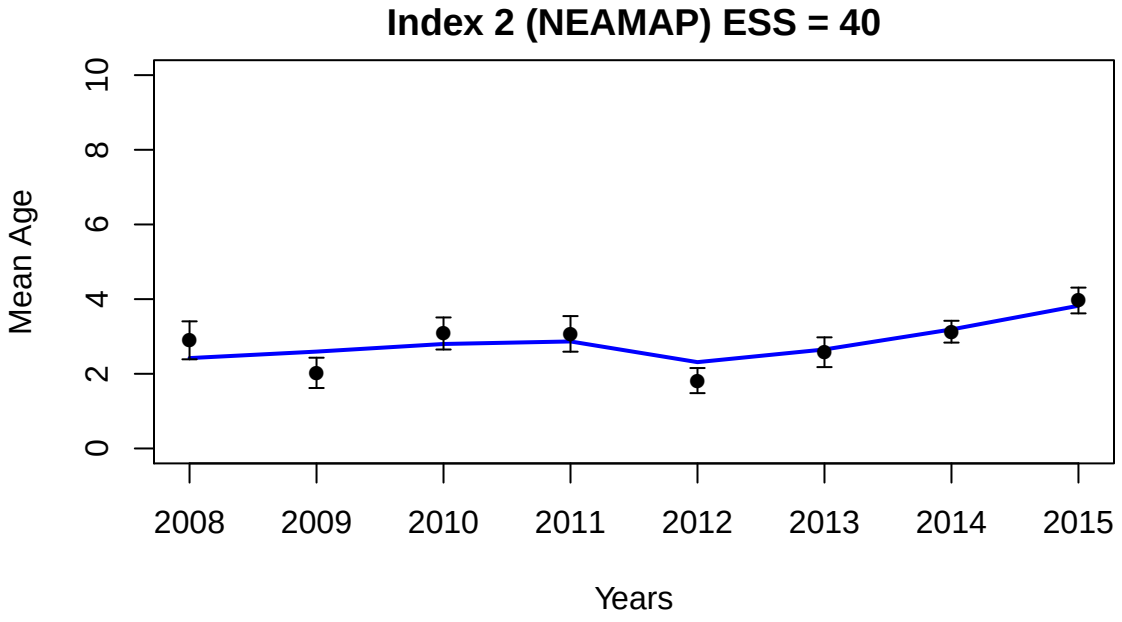

Index Neff 7 (REC CPA)
Effective Sample Size
0
50
100
150
200
250
300
1990
1995
2000
2005
2010
2015
Year

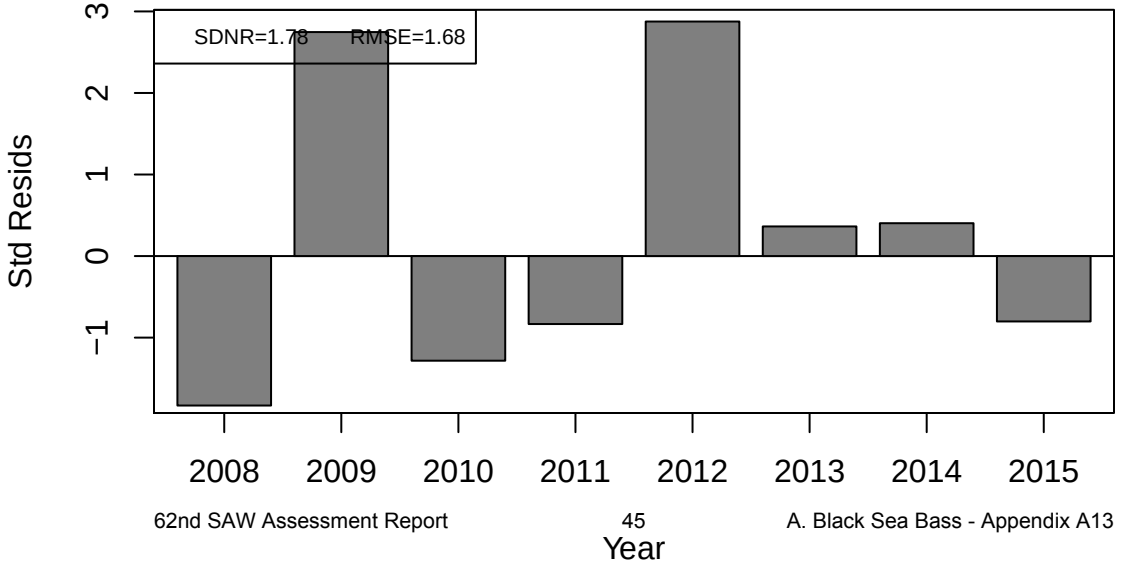

Index Neff 8 (BIGELOW)
Effective Sample Size
0
10
20
30
40
50
1990
1995
2000
2005
2010
2015
Year

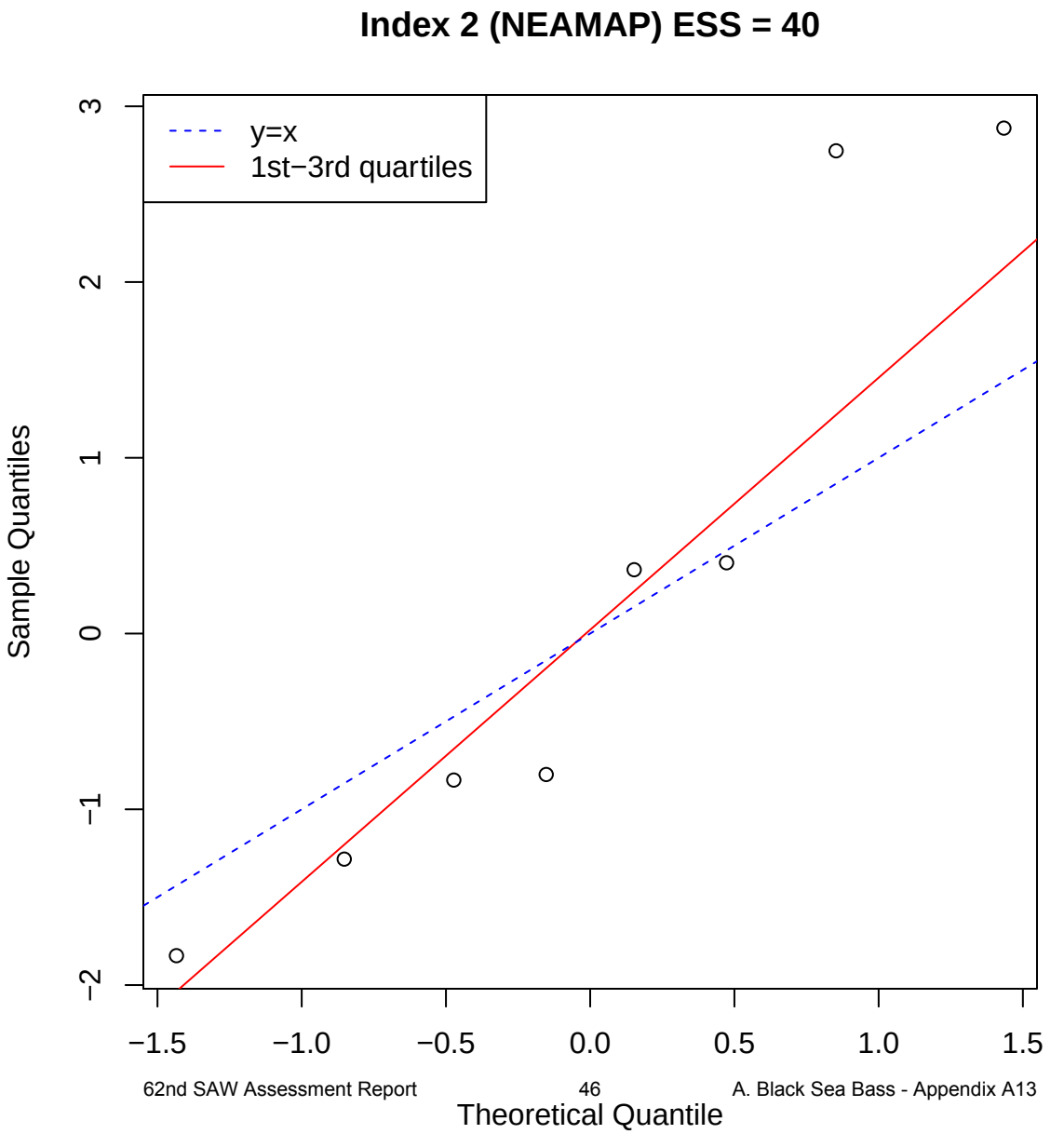

Index 1 (NEFSC spring Alb) ESS = 10
Mean Age
0
2
4
6
8
10
1995
2000
2005
Years

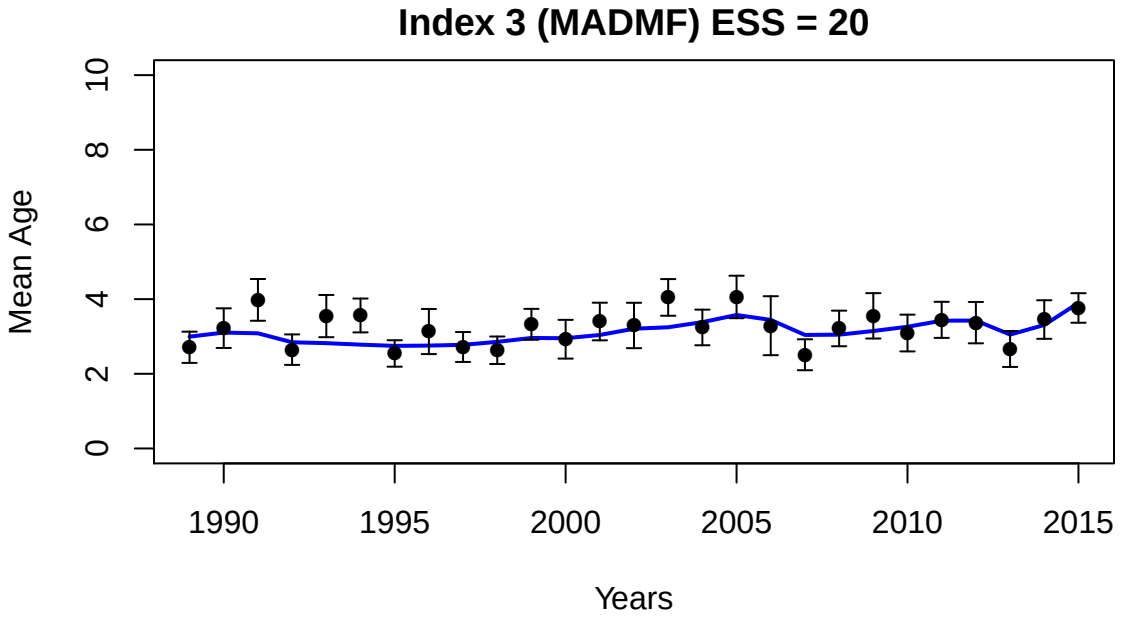

SDNR=2.48
RMSE=2.43
Std Resids
−2
0
2
4
1992
1995
1999
2001
2003
2005
2007
Year

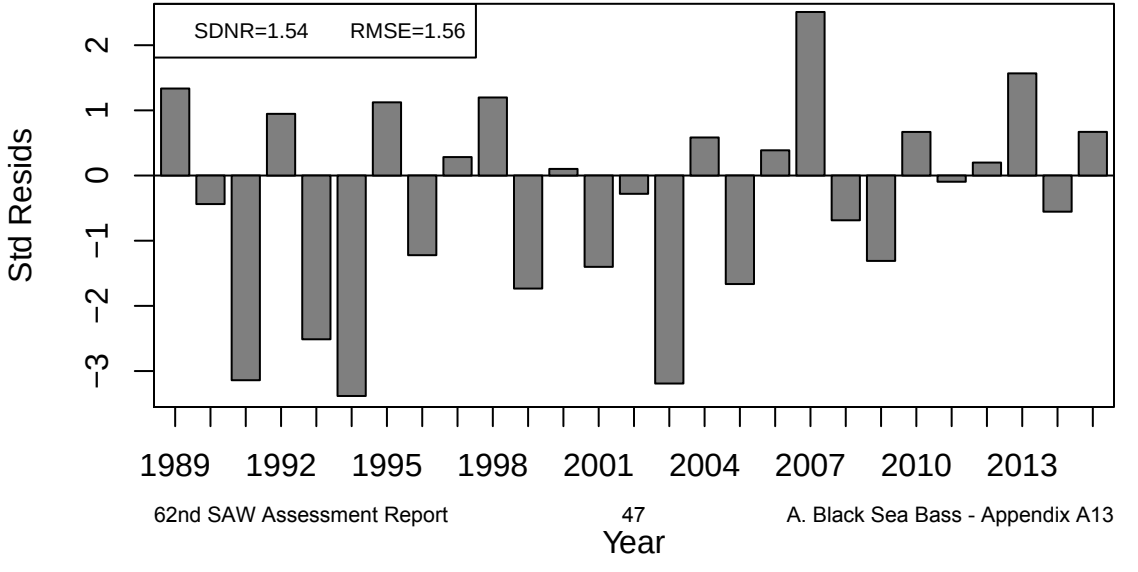

Index 1 (NEFSC spring Alb) ESS = 10
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
6
4
2
0
−2
−1
0
1

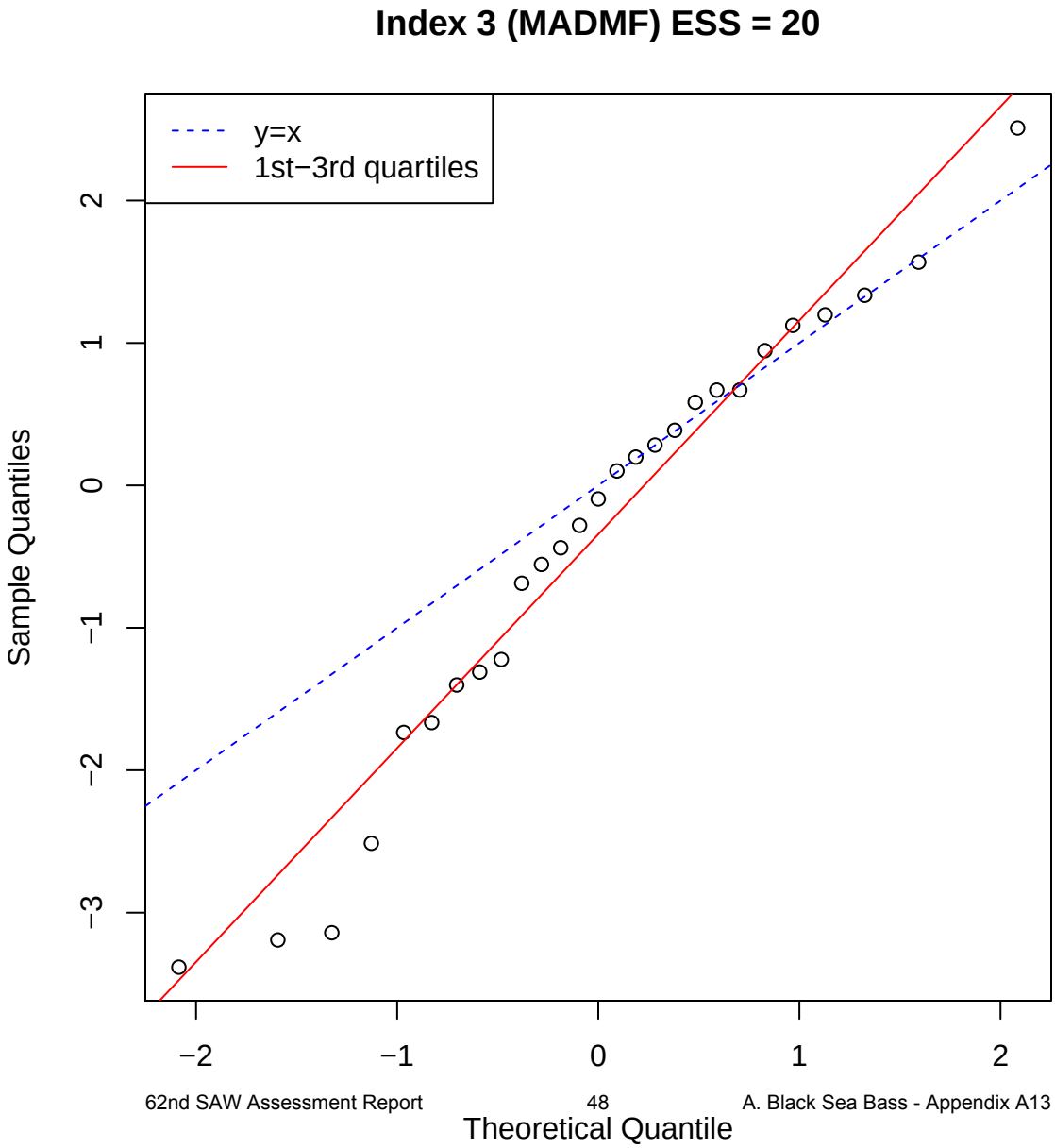

Index 2 (NEAMAP) ESS = 40
Mean Age
0
2
4
6
8
10
2008
2009
2010
2011
2012
2013
2014
2015
Years

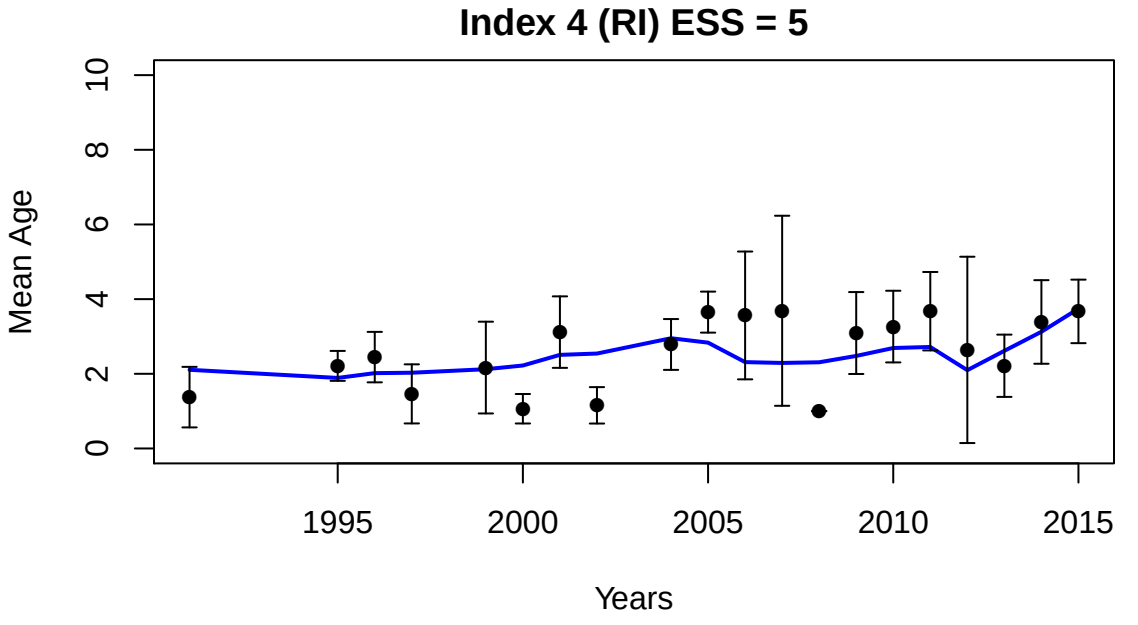

SDNR=1.78 RMSE=1.68
Std Resids
−1
0
1
2
3
2008
2009
2010
2011
2012
2013
2014
2015
Year

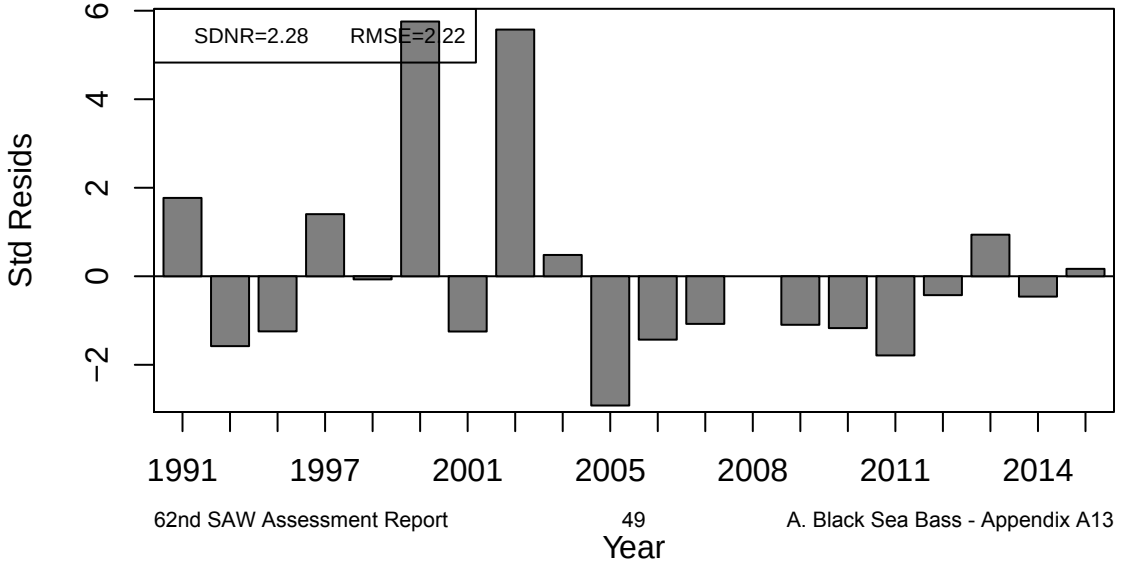

Index 2 (NEAMAP) ESS = 40
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
3
2
1
0
−1
−2
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5

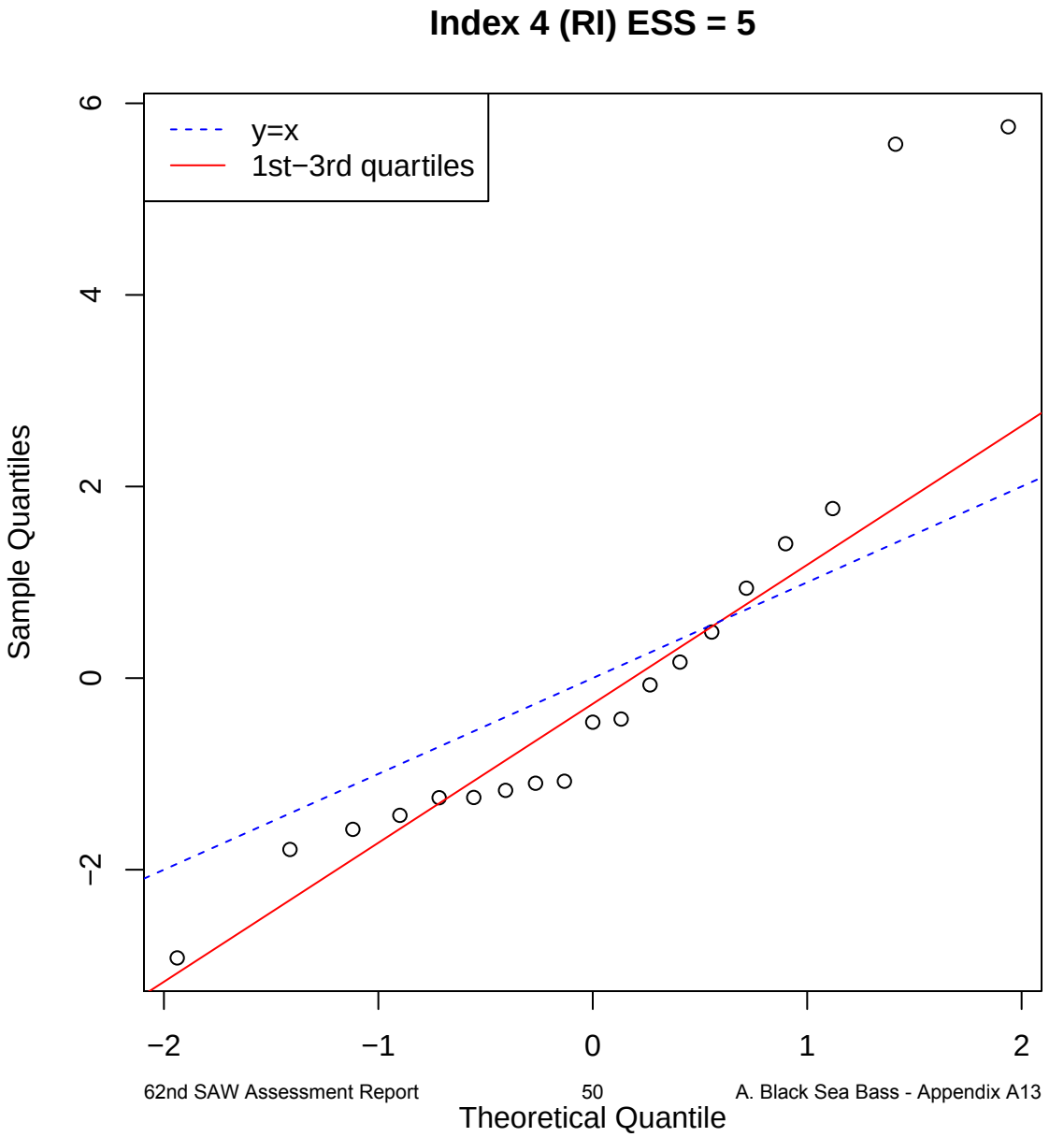

Index 3 (MADMF) ESS = 20
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

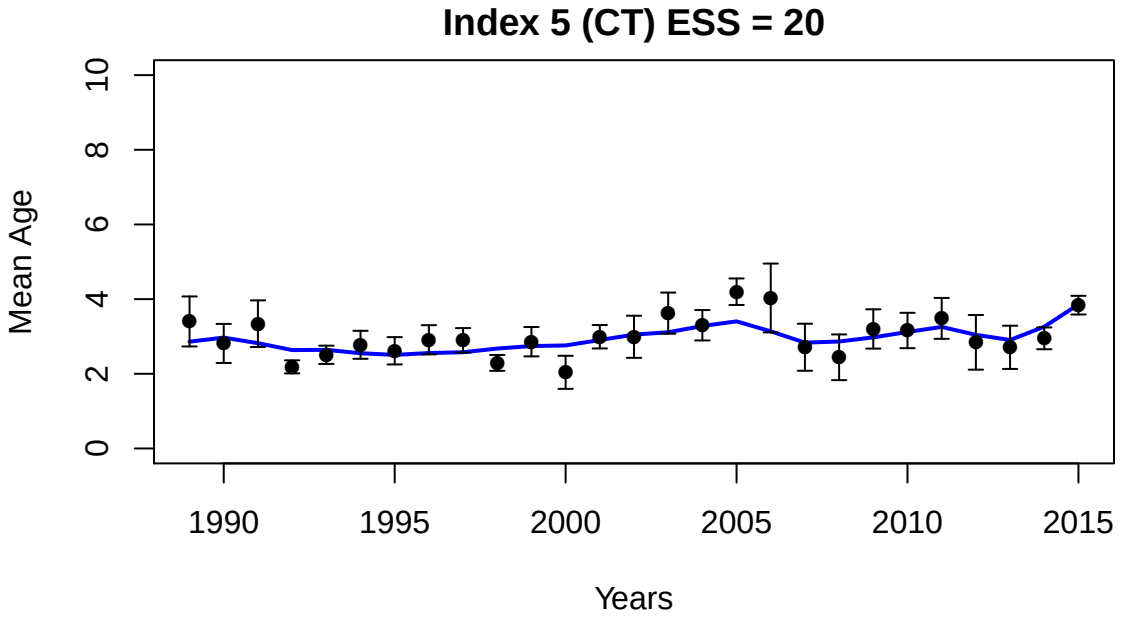

SDNR=1.54
RMSE=1.56
Std Resids
−3
−2
−1
0
1
2
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

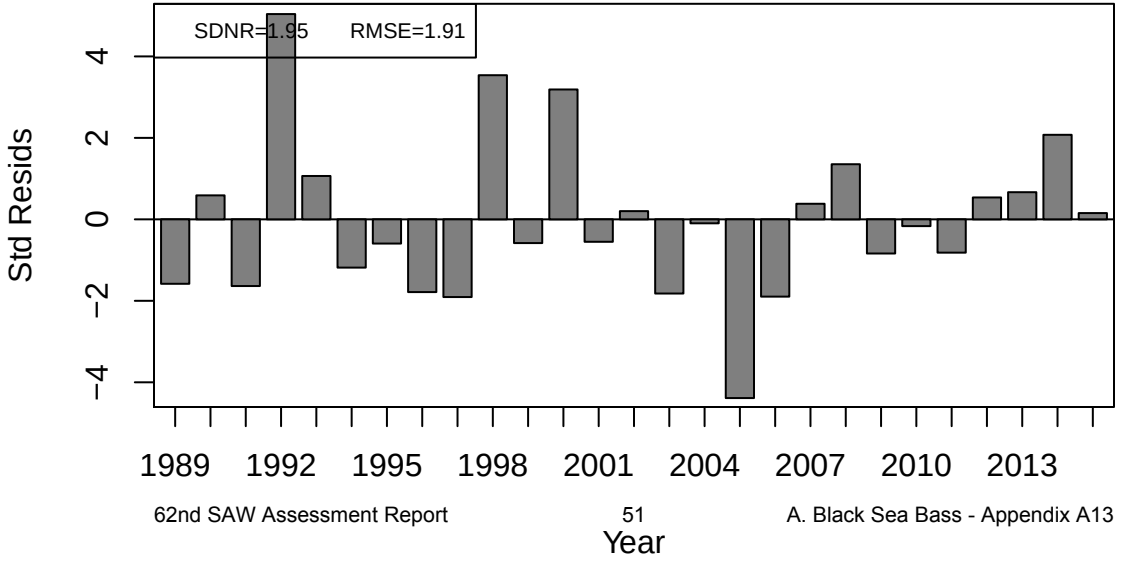

Index 3 (MADMF) ESS = 20
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−3
−2
−1
0
1
2

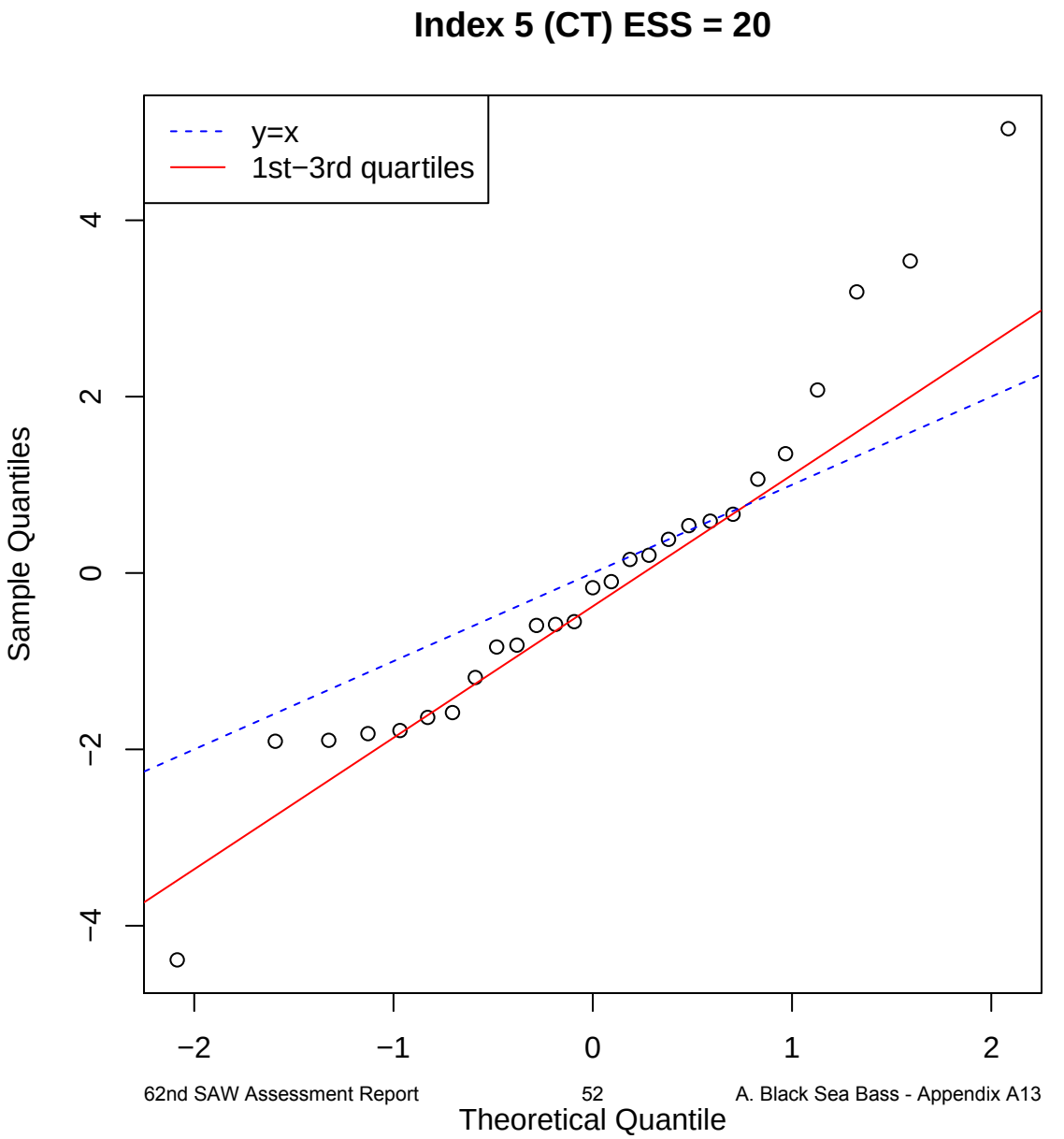

Index 4 (RI) ESS = 5
Mean Age
0
2
4
6
8
10
1995
2000
2005
2010
2015
Years

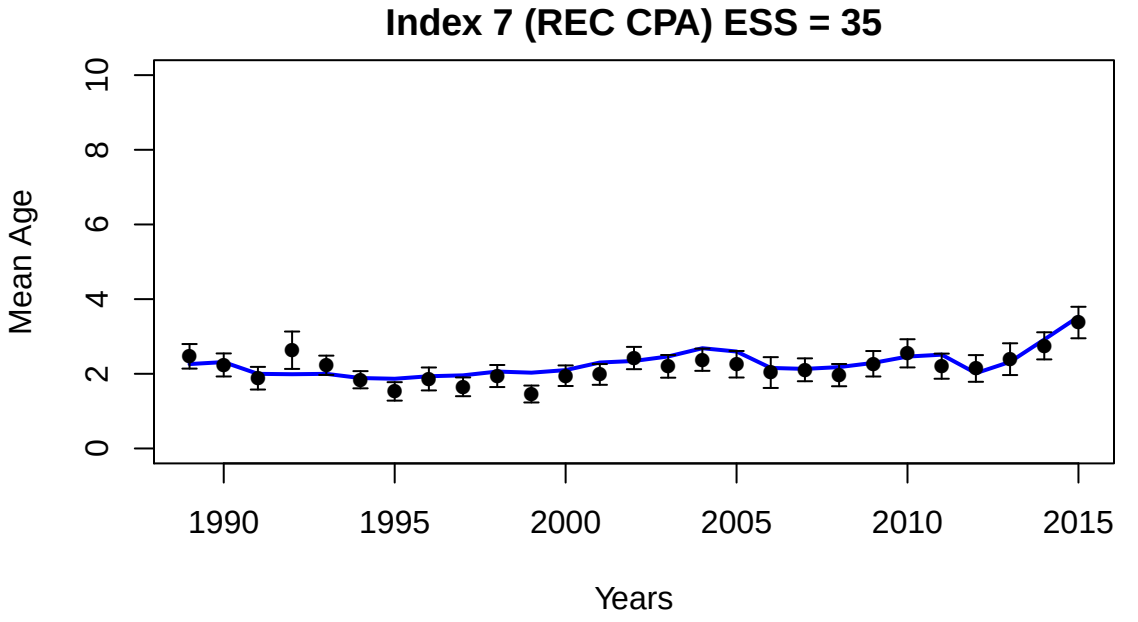

SDNR=2.28
RMSE=2.22
Std Resids
−2
0
2
4
6
1991
1997
2001
2005
2008
2011
2014
Year

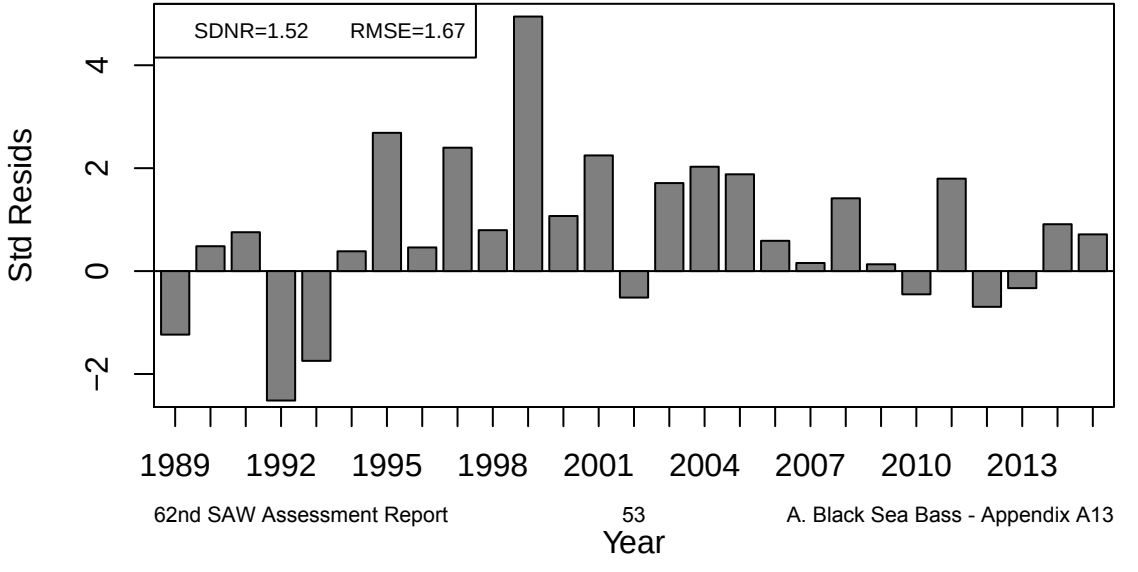

Index 4 (RI) ESS = 5
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
6
4
2
0
−2
−2
−1
0
1
2

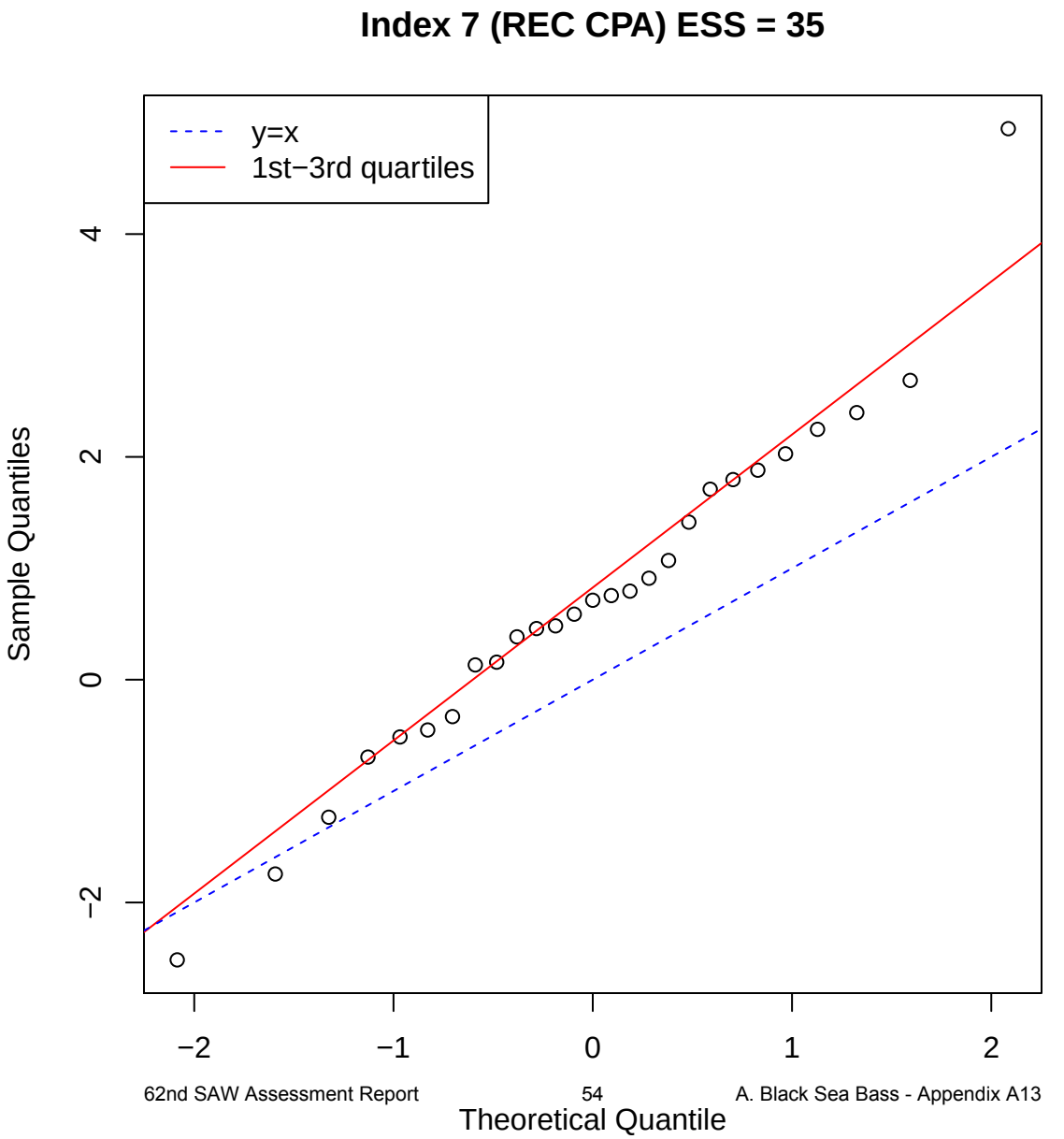

Index 5 (CT) ESS = 20
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

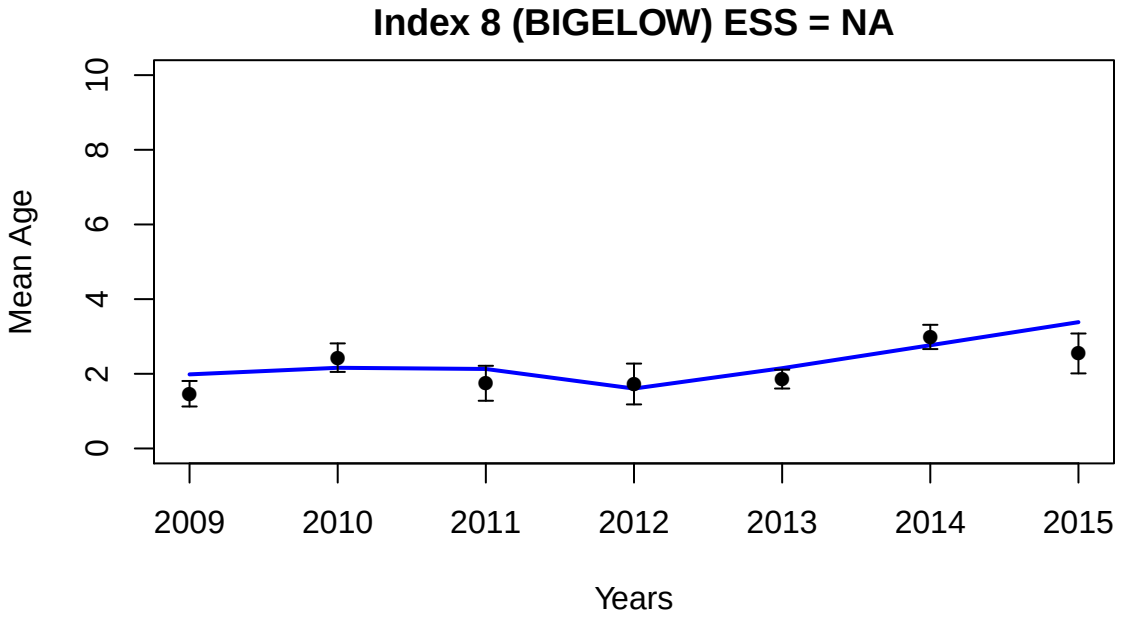

SDNR=1.95
RMSE=1.91
Std Resids
−4
−2
0
2
4
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

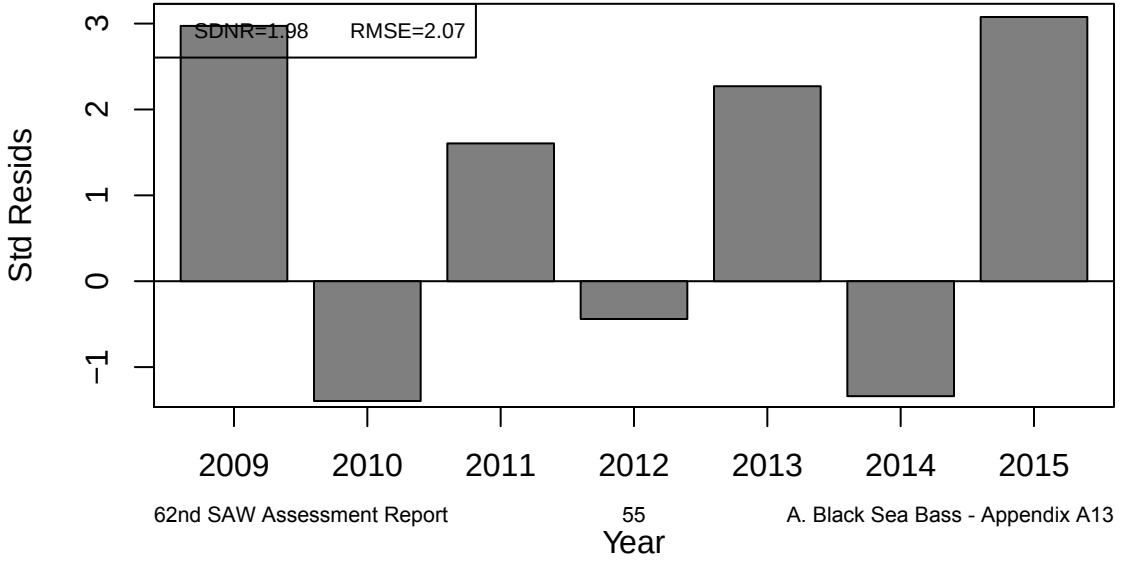

Index 5 (CT) ESS = 20
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
4
2
0
−2
−4
−2
−1
0
1
2

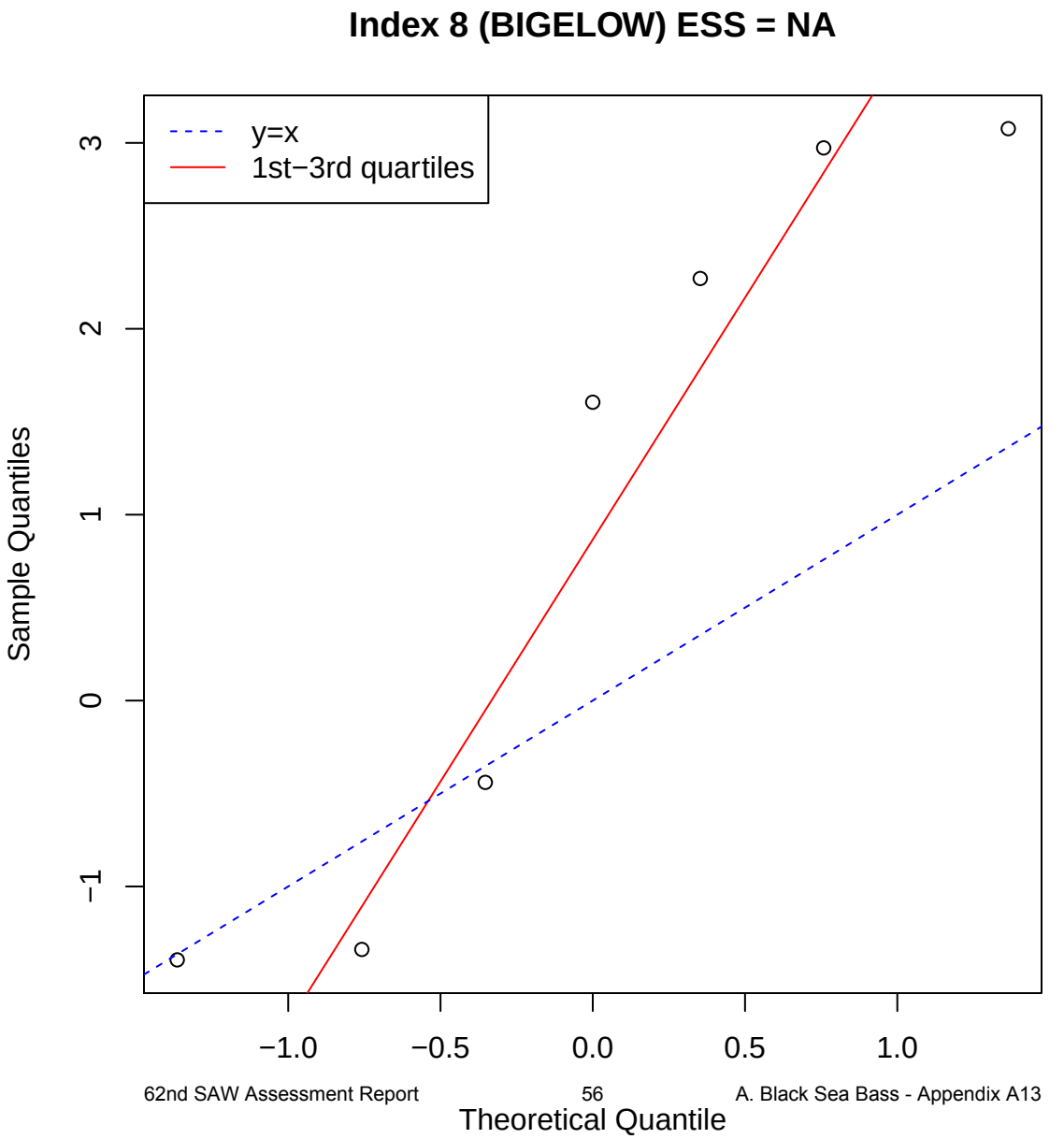

Index 7 (REC CPA) ESS = 35
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

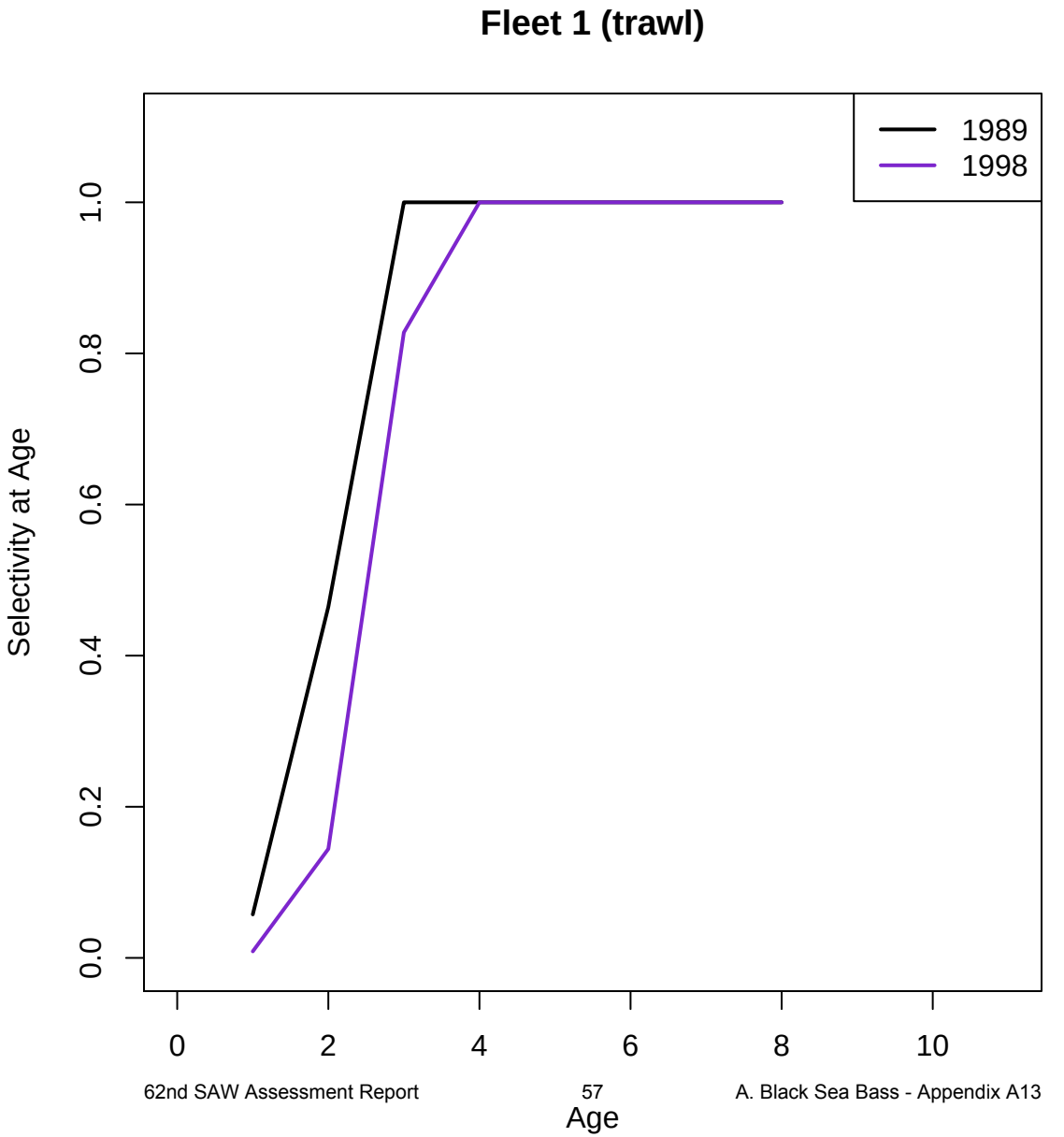

SDNR=1.52
RMSE=1.67
Std Resids
−2
0
2
4
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

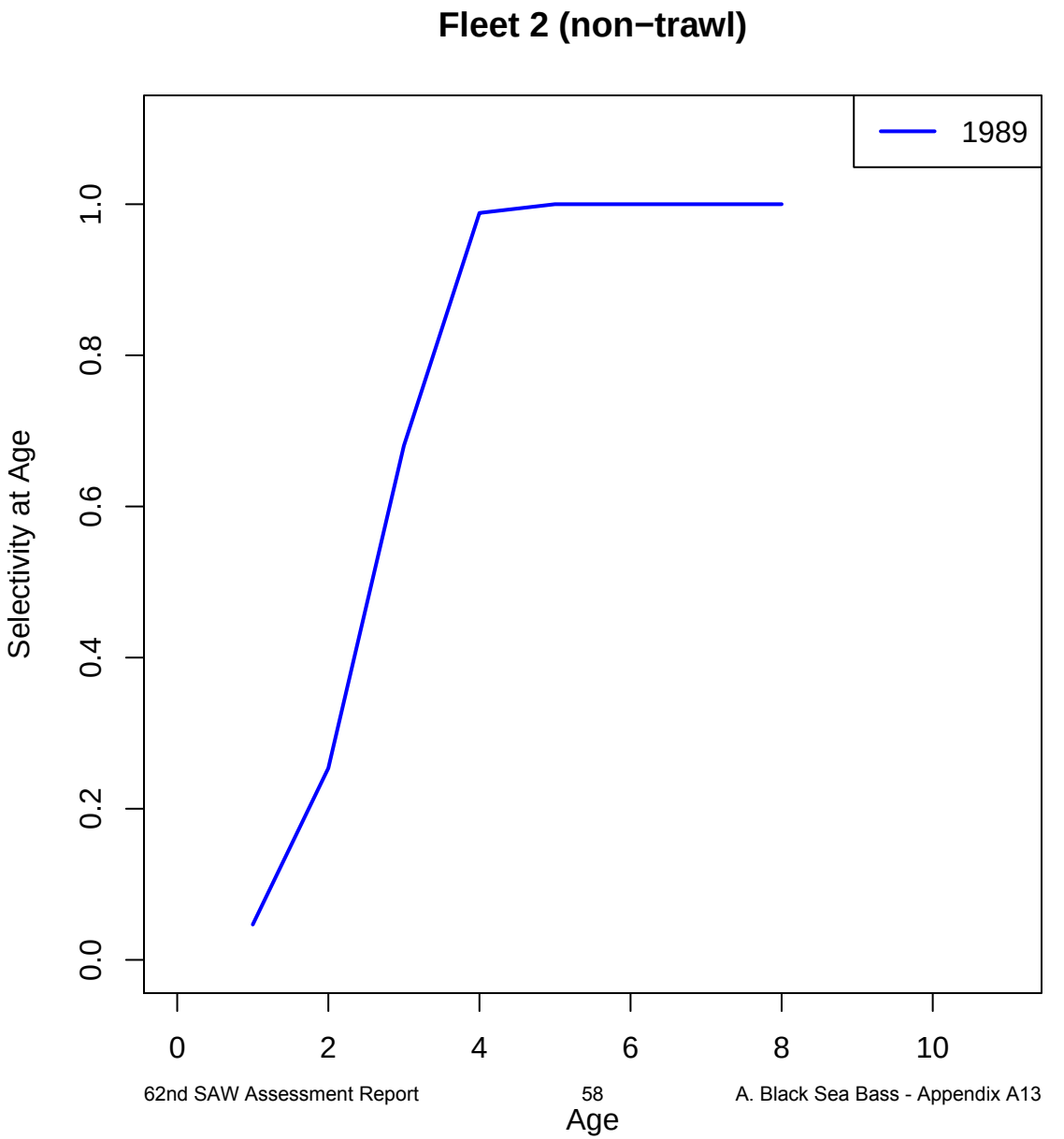

Index 7 (REC CPA) ESS = 35
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
0
2
4
−2
−1
0
1
2

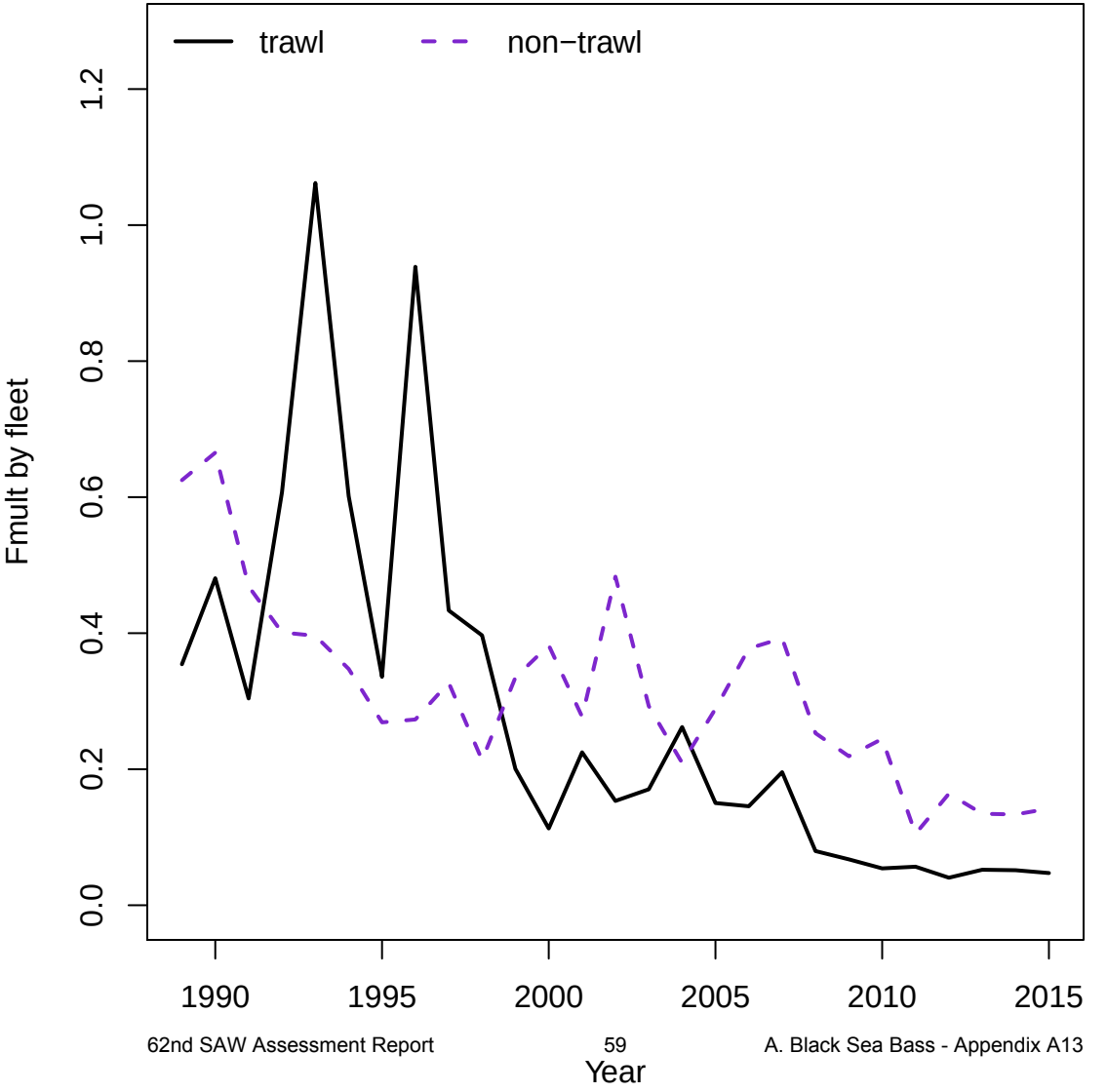

Index 8 (BIGELOW) ESS = NA
Mean Age
0
2
4
6
8
10
2009
2010
2011
2012
2013
2014
2015
Years

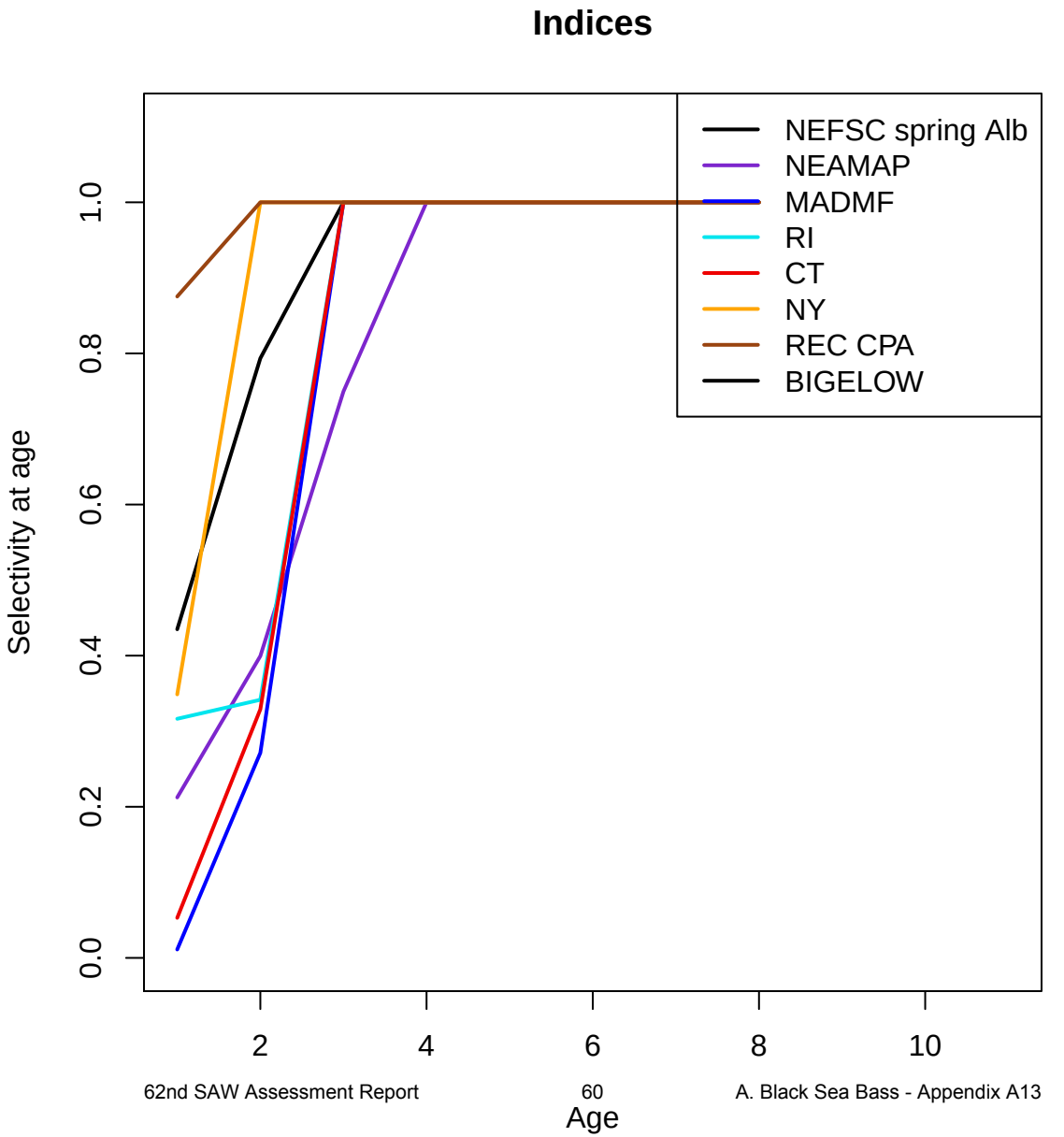

SDNR=1.98
RMSE=2.07
Std Resids
−1
0
1
2
3
2009
2010
2011
2012
2013
2014
2015
Year

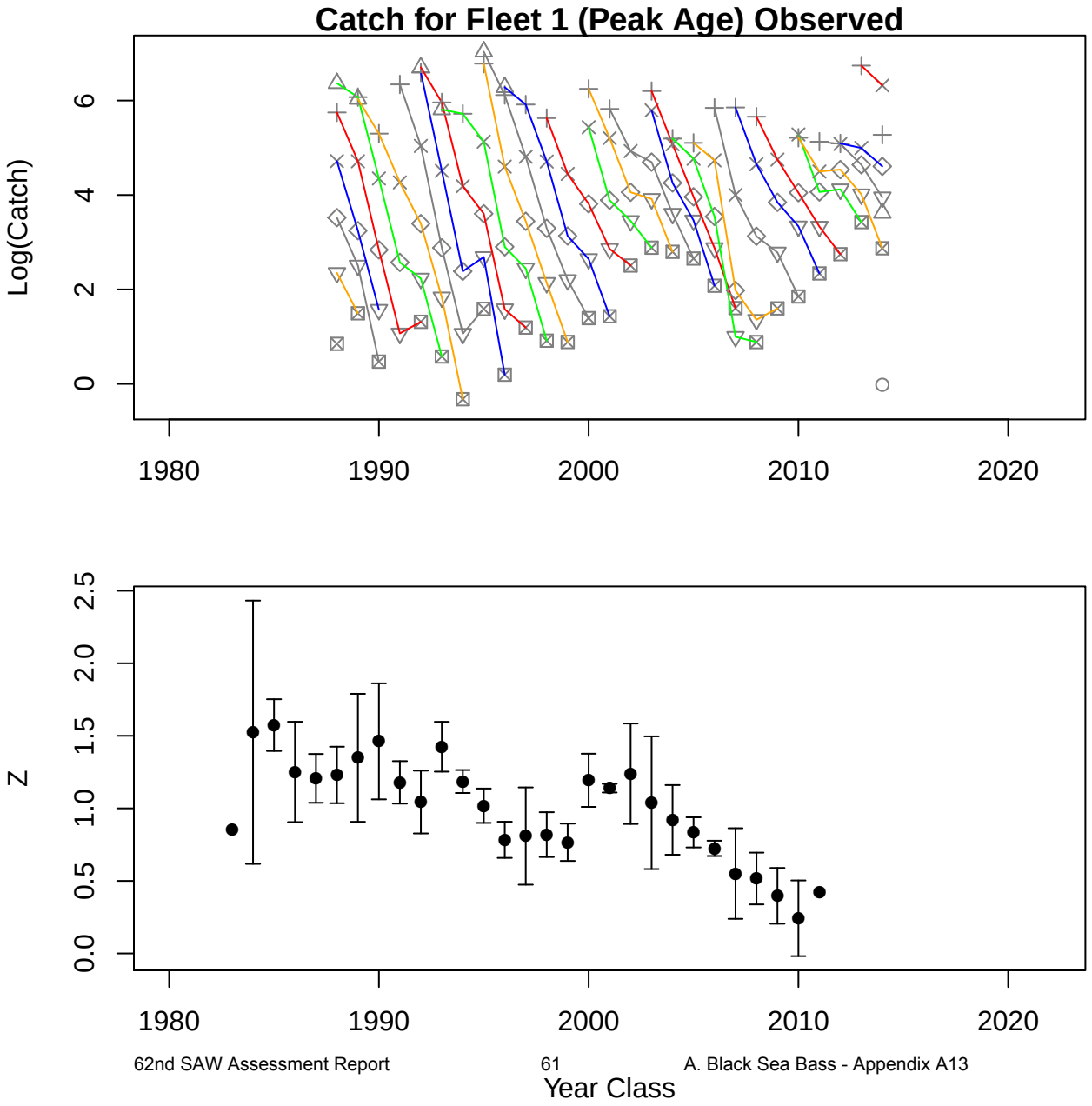

Index 8 (BIGELOW) ESS = NA
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−1
0
1
2
3
−1.0
−0.5
0.0
0.5
1.0

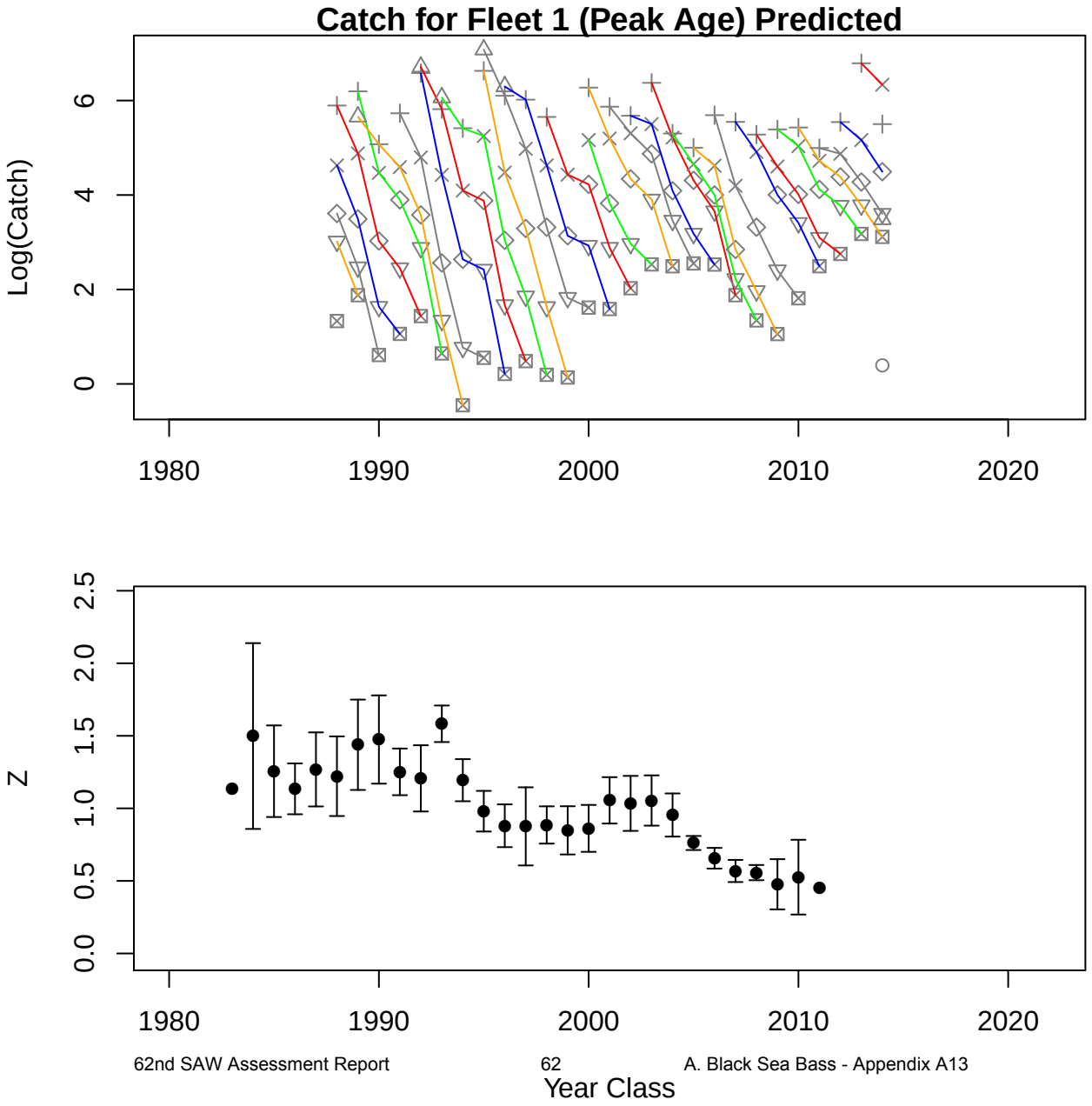

Fleet 1 (trawl)
1989
1998
Selectivity at Age
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
Age

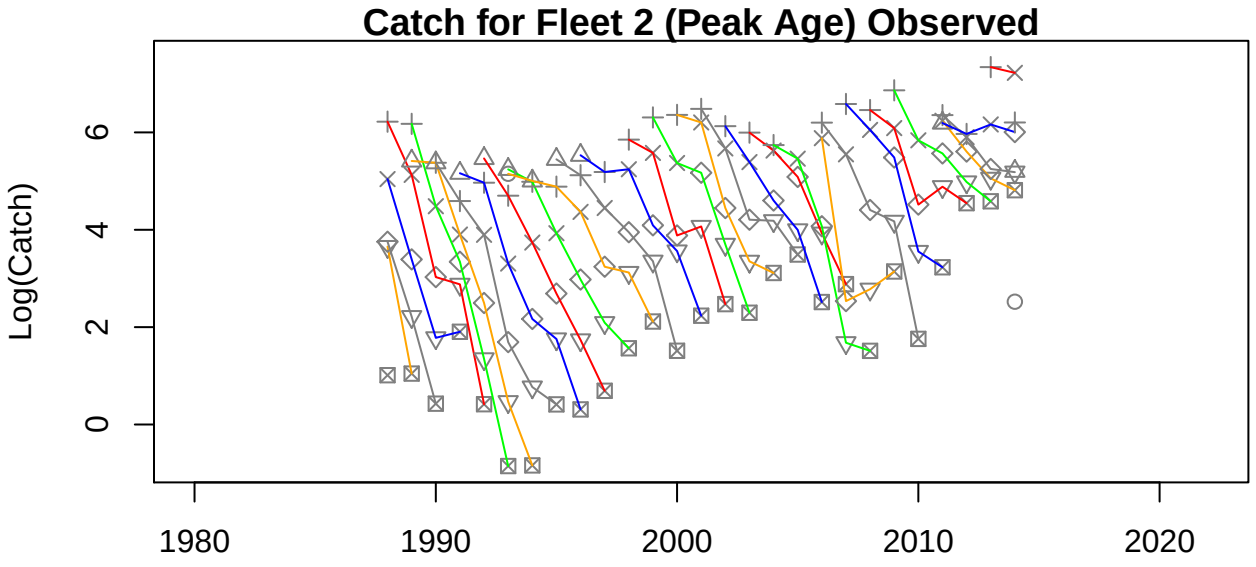

Fleet 2 (non−trawl)
1989
Selectivity at Age
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
Age

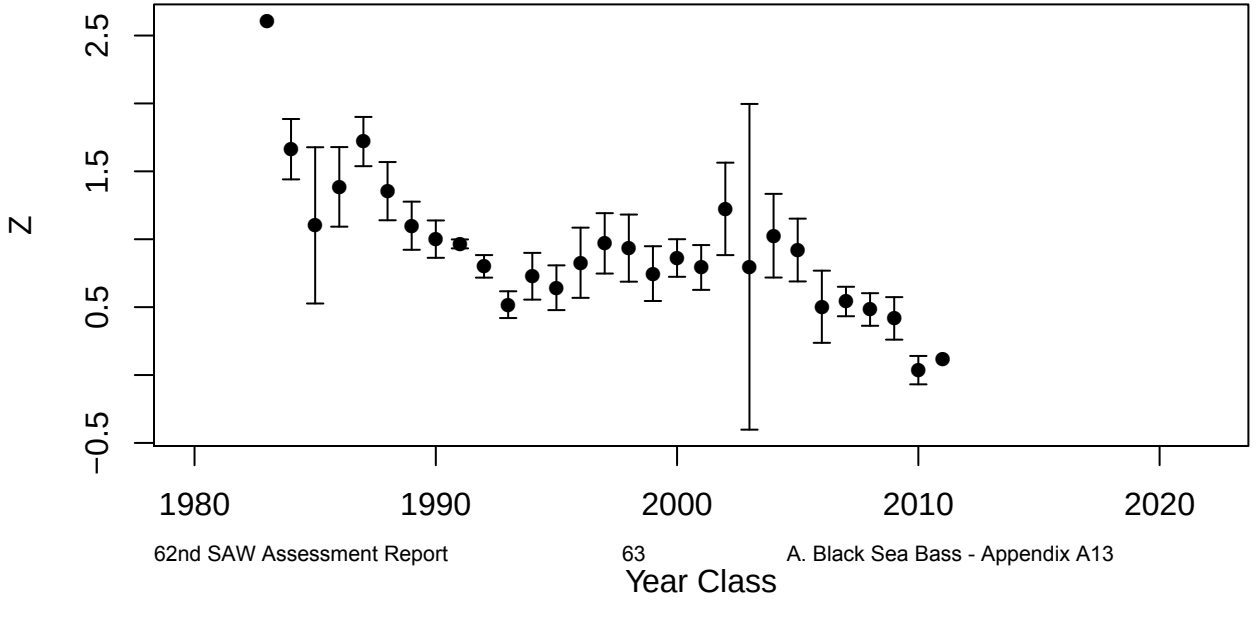

trawl
non−trawl
Fmult by fleet
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1990
1995
2000
2005
2010
2015
Year

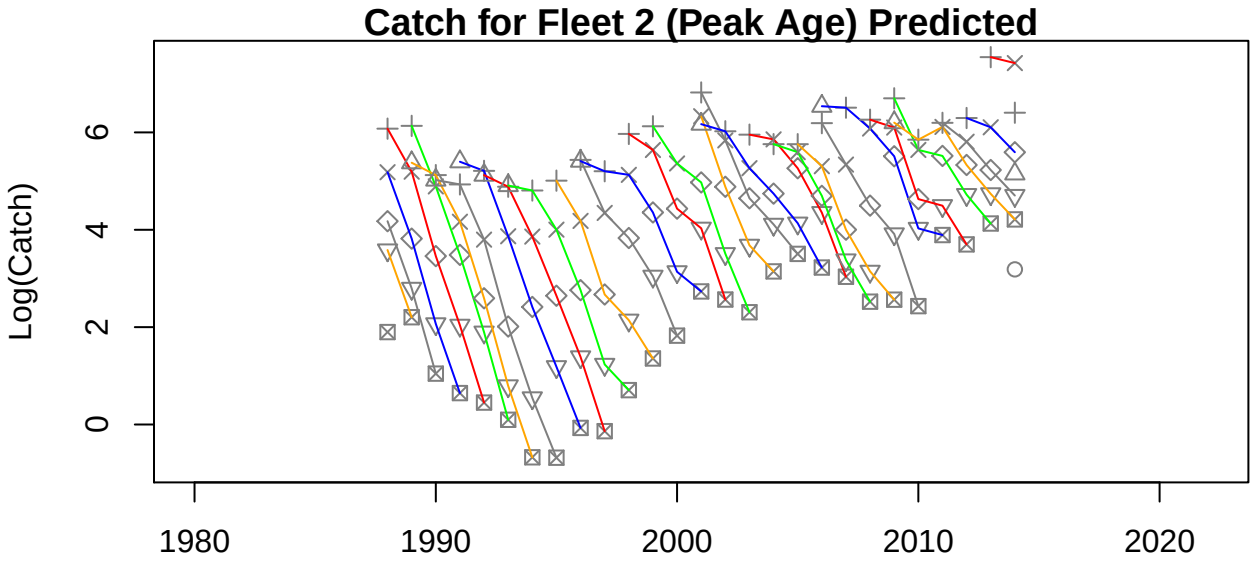

Indices
NEFSC spring Alb
NEAMAP
MADMF
RI
CT
NY
REC CPA
BIGELOW
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
10
Age

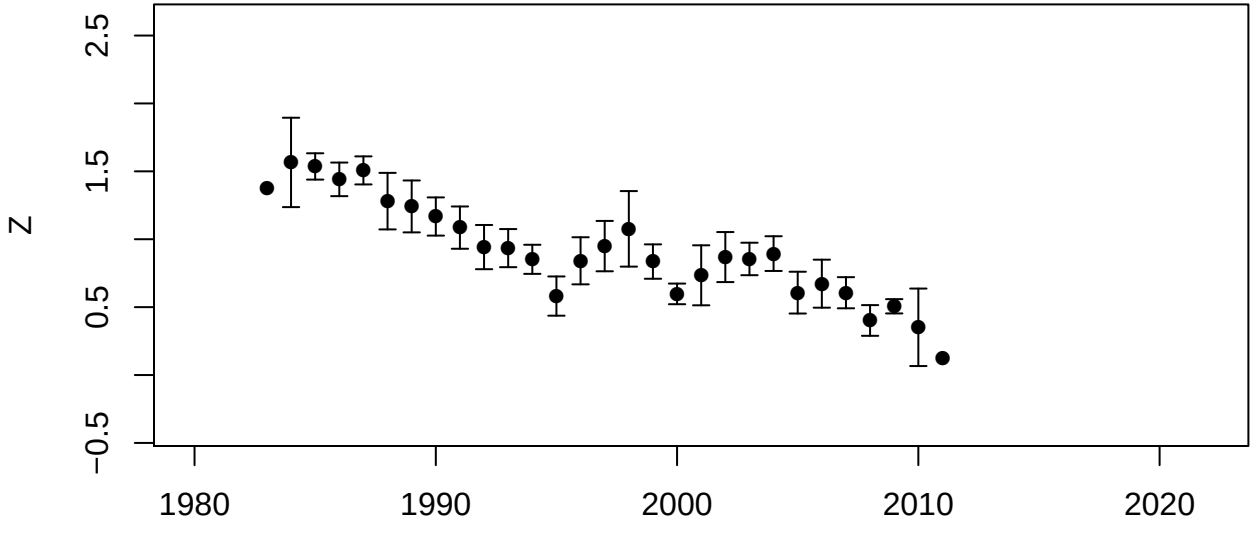

Catch for Fleet 1 (Peak Age) Observed
Log(Catch)
0
2
4
6
1980
1990
2000
2010
2020
Z
0.0
0.5
1.0
1.5
2.0
2.5
1980
1990
2000
2010
2020
Year Class

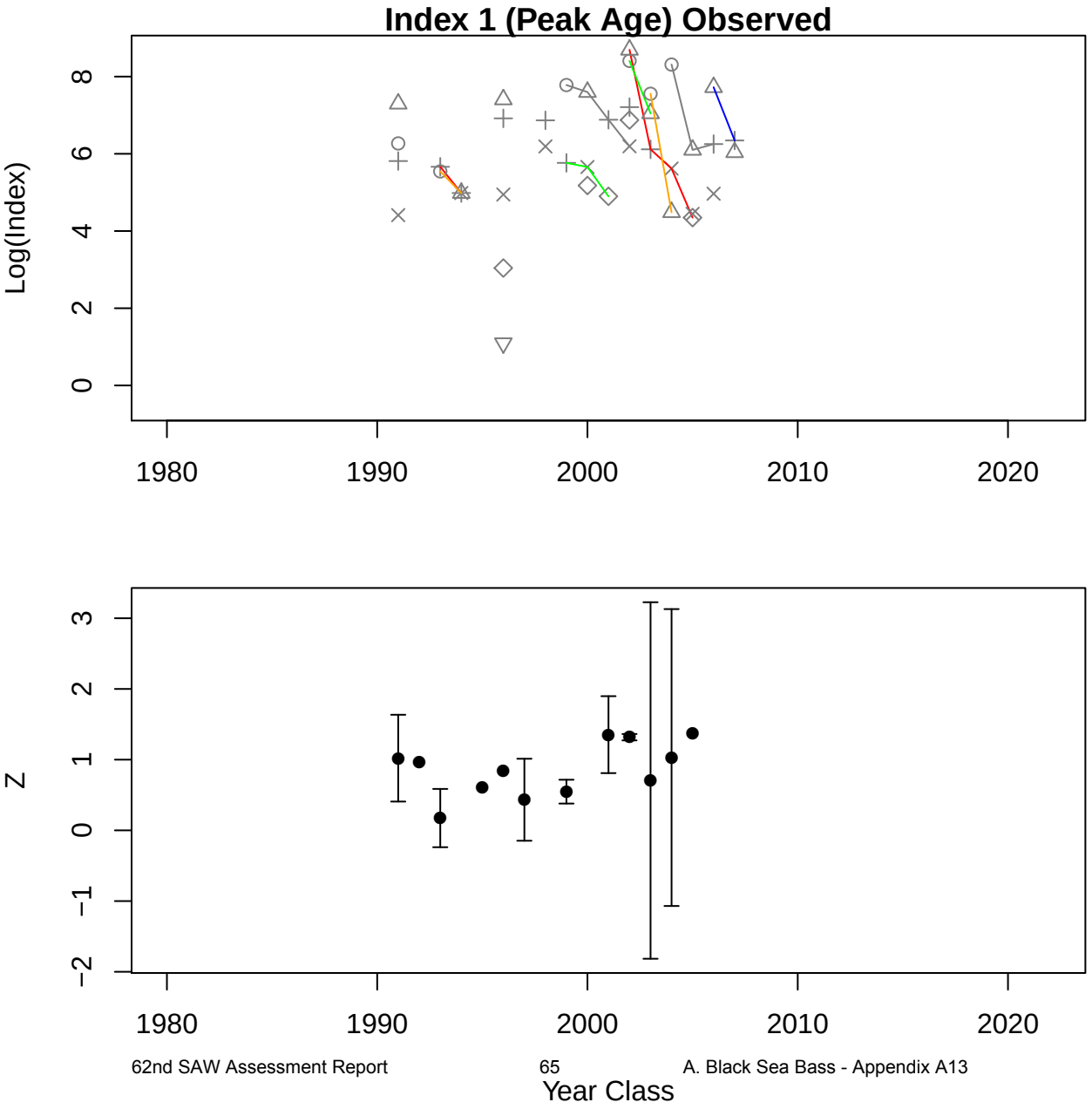

Catch for Fleet 1 (Peak Age) Predicted
Log(Catch)
0
2
4
6
1980
1990
2000
2010
2020
Z
0.0
0.5
1.0
1.5
2.0
2.5
1980
1990
2000
2010
2020
Year Class

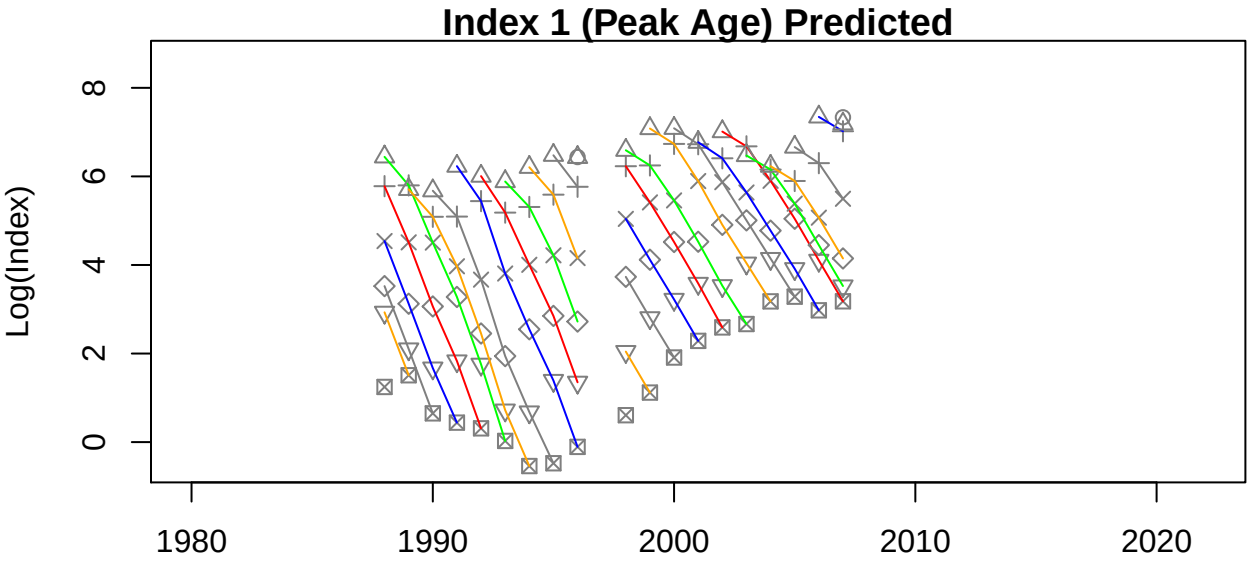

Catch for Fleet 2 (Peak Age) Observed
Log(Catch)
0
2
4
6
1980
1990
2000
2010
2020

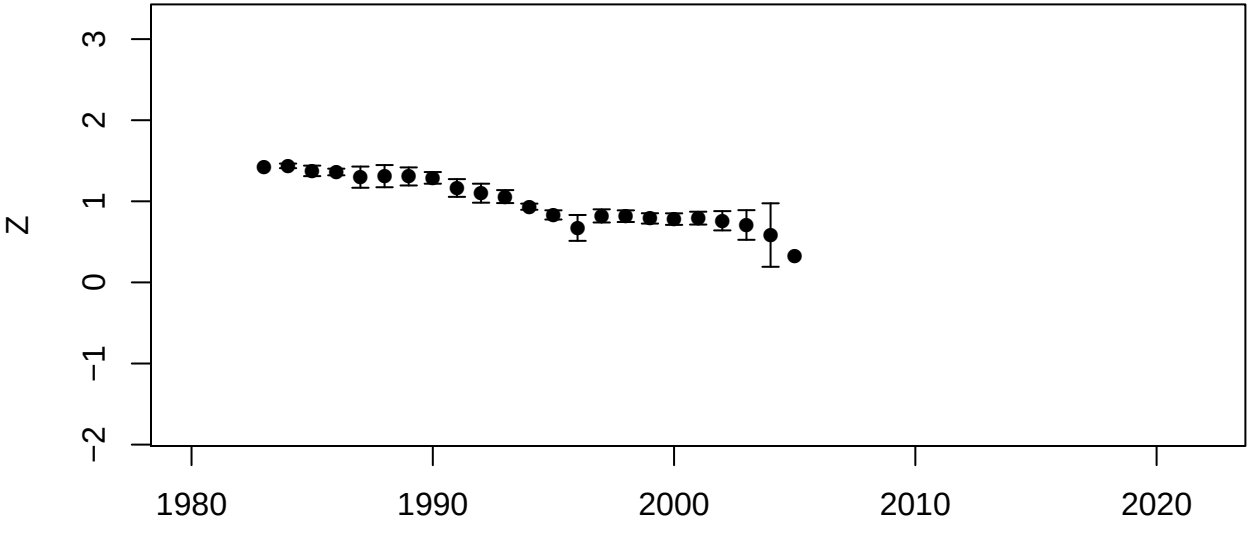

Z
−0.5
0.5
1.5
2.5
1980
1990
2000
2010
2020
Year Class


Catch for Fleet 2 (Peak Age) Predicted
Log(Catch)
0
2
4
6
1980
1990
2000
2010
2020

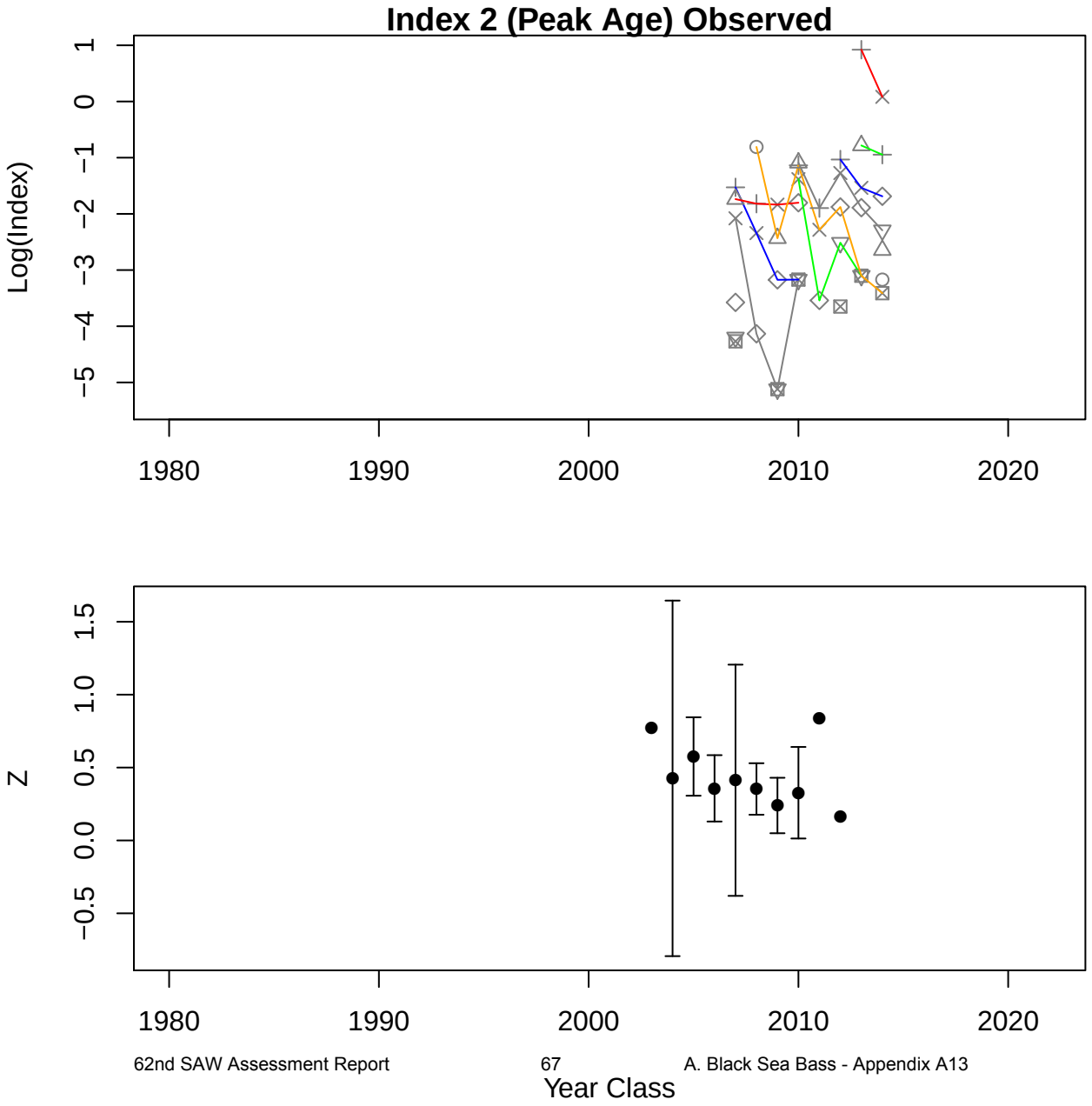

Z
−0.5
0.5
1.5
2.5
1980
1990
2000
2010
2020
Year Class

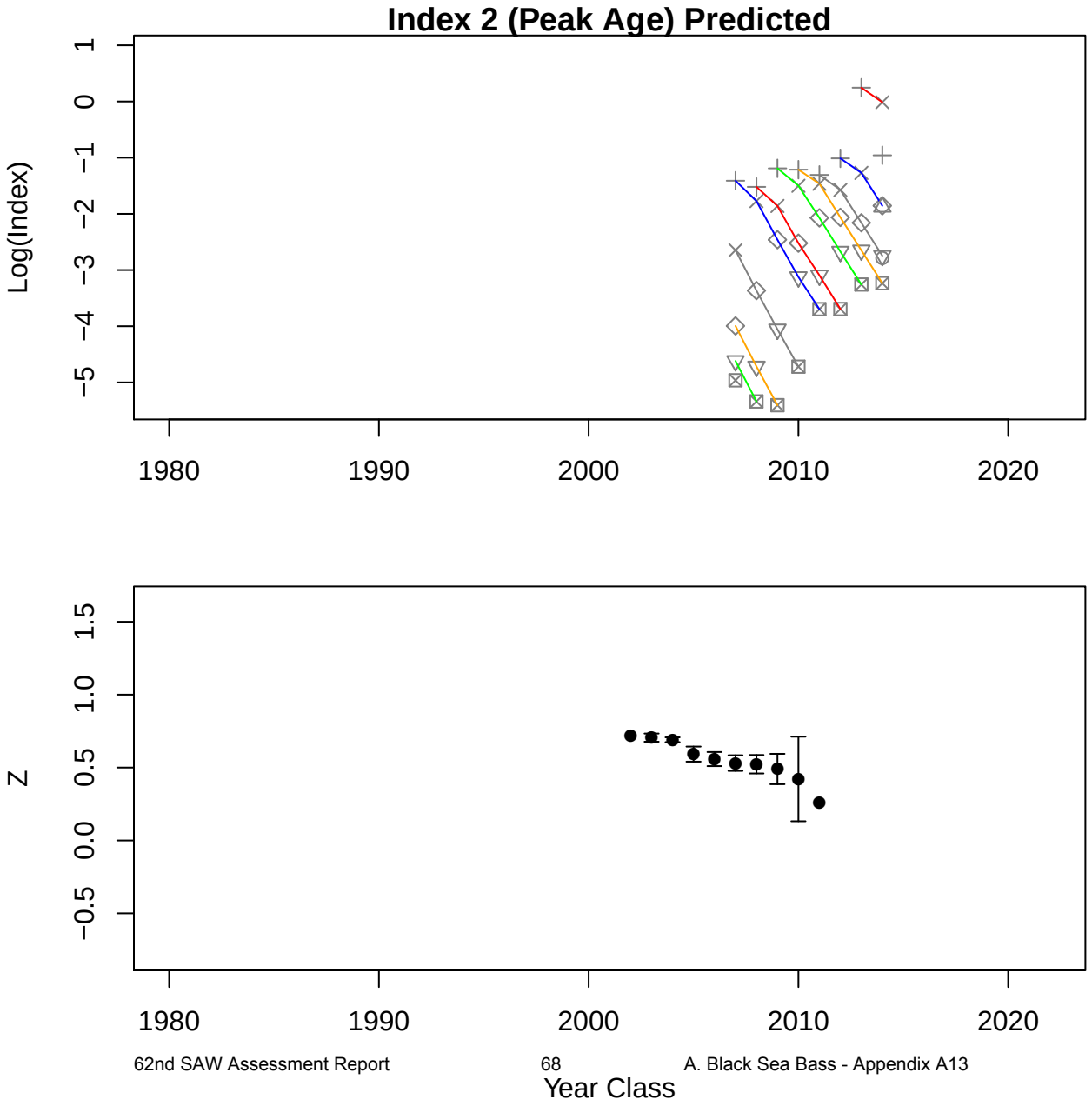

Index 1 (Peak Age) Observed
Log(Index)
0
2
4
6
8
1980
1990
2000
2010
2020
Z
−2
−1
0
1
2
3
1980
1990
2000
2010
2020
Year Class

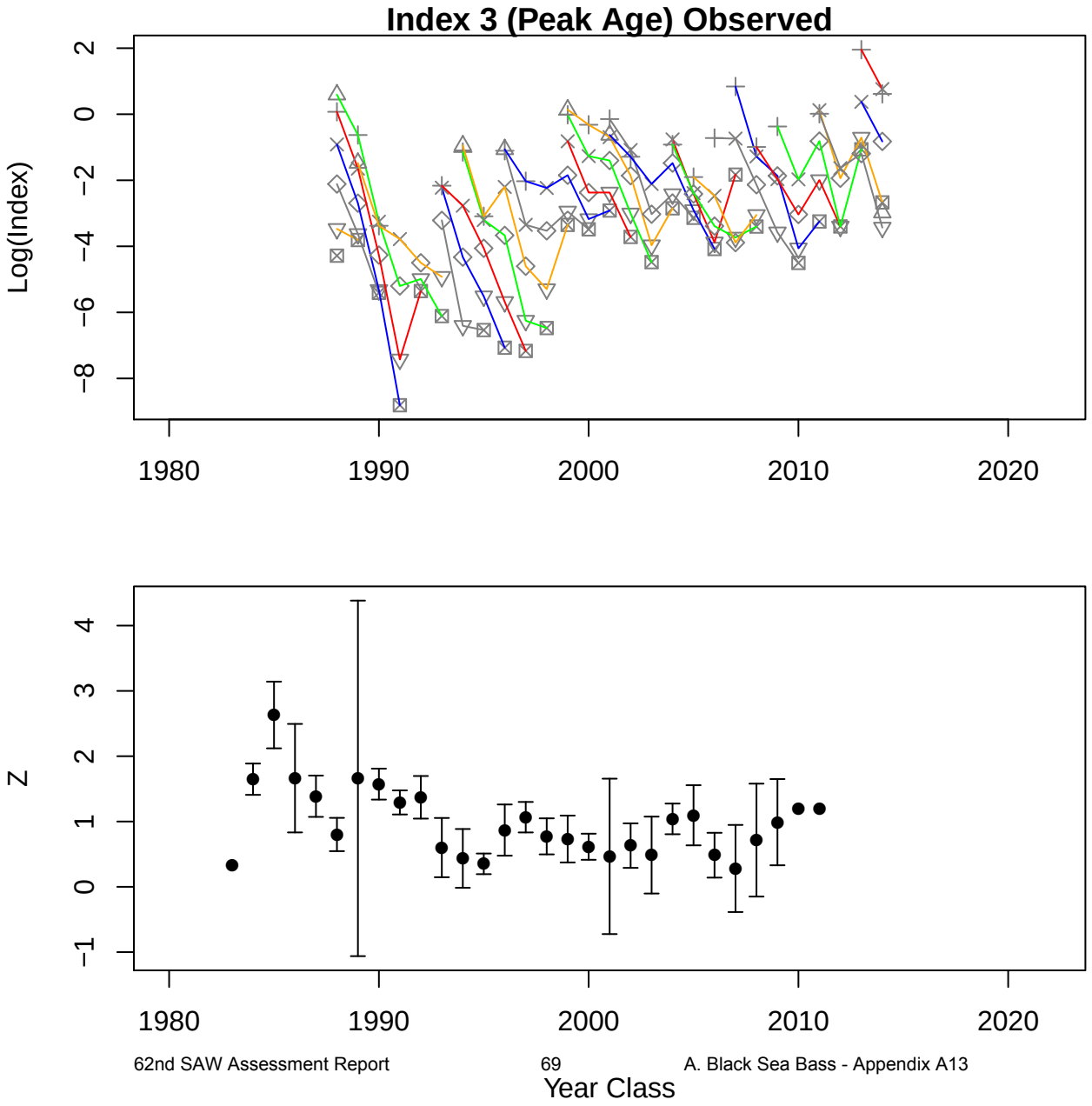

Index 1 (Peak Age) Predicted
Log(Index)
0
2
4
6
8
1980
1990
2000
2010
2020

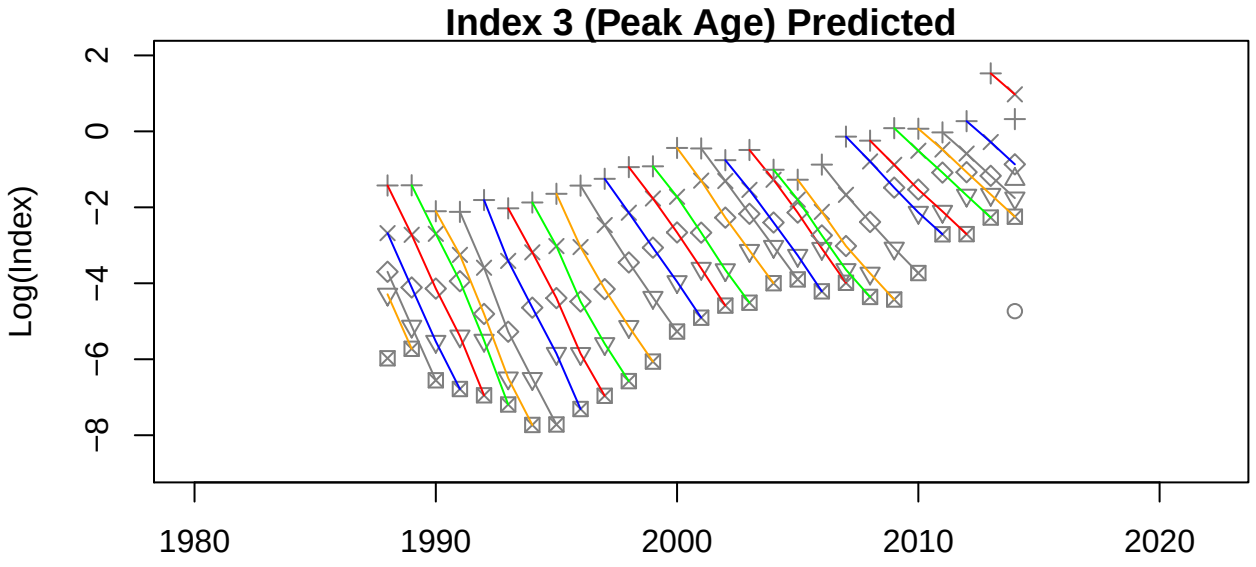

Z
−2
−1
0
1
2
3
1980
1990
2000
2010
2020

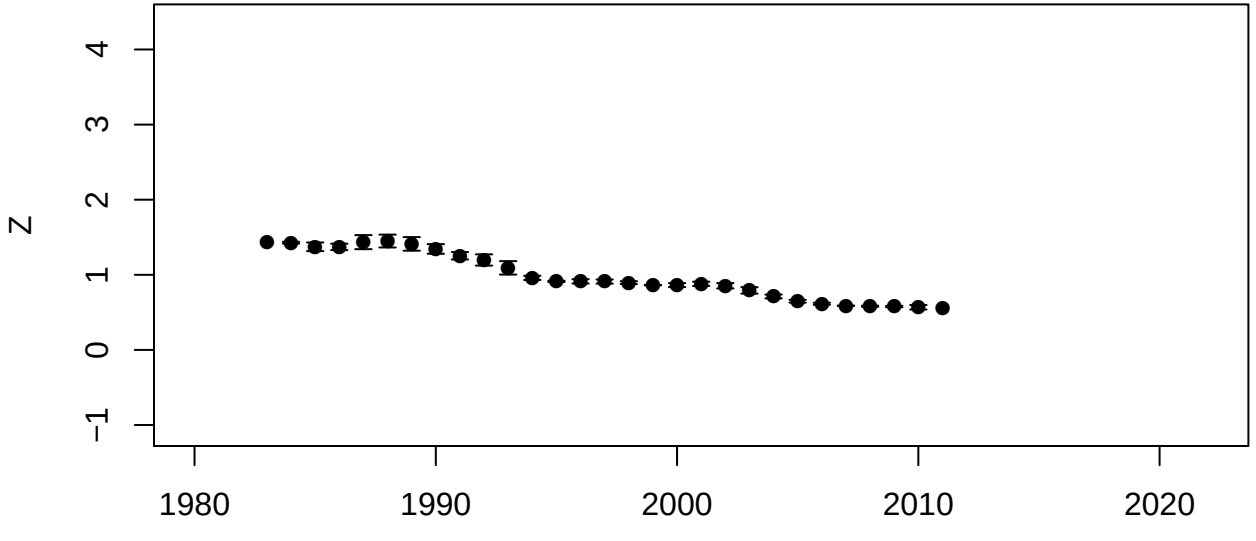
Year Class


Index 2 (Peak Age) Observed
Log(Index)
1
0
−1
−2
−3
−4
−5
1980
1990
2000
2010
2020
Z
1.5
1.0
0.5
0.0
−0.5
1980
1990
2000
2010
2020
Year Class

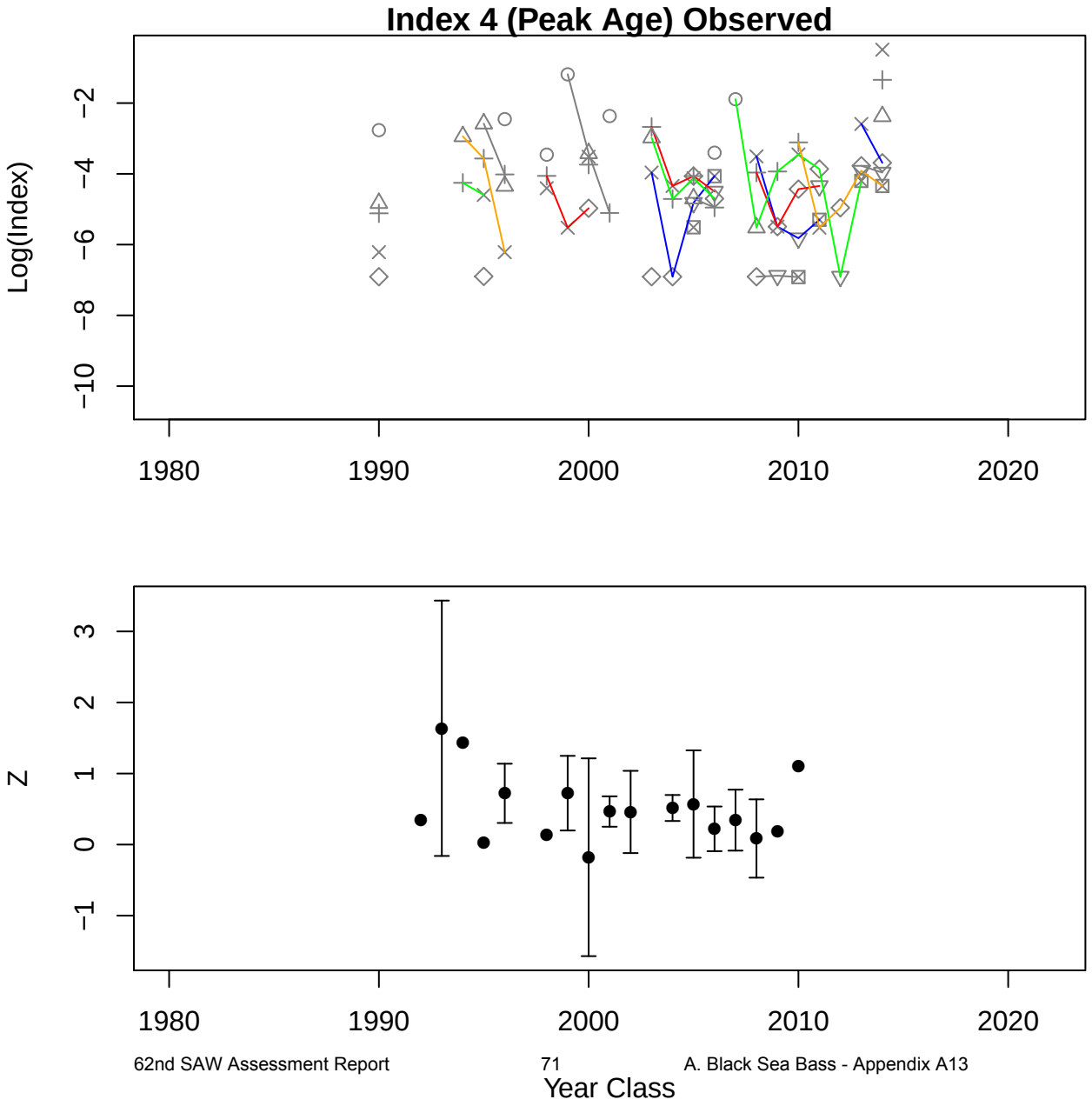

Index 2 (Peak Age) Predicted
Log(Index)
1
0
−1
−2
−3
−4
−5
1980
1990
2000
2010
2020
Z
1.5
1.0
0.5
0.0
−0.5
1980
1990
2000
2010
2020
Year Class

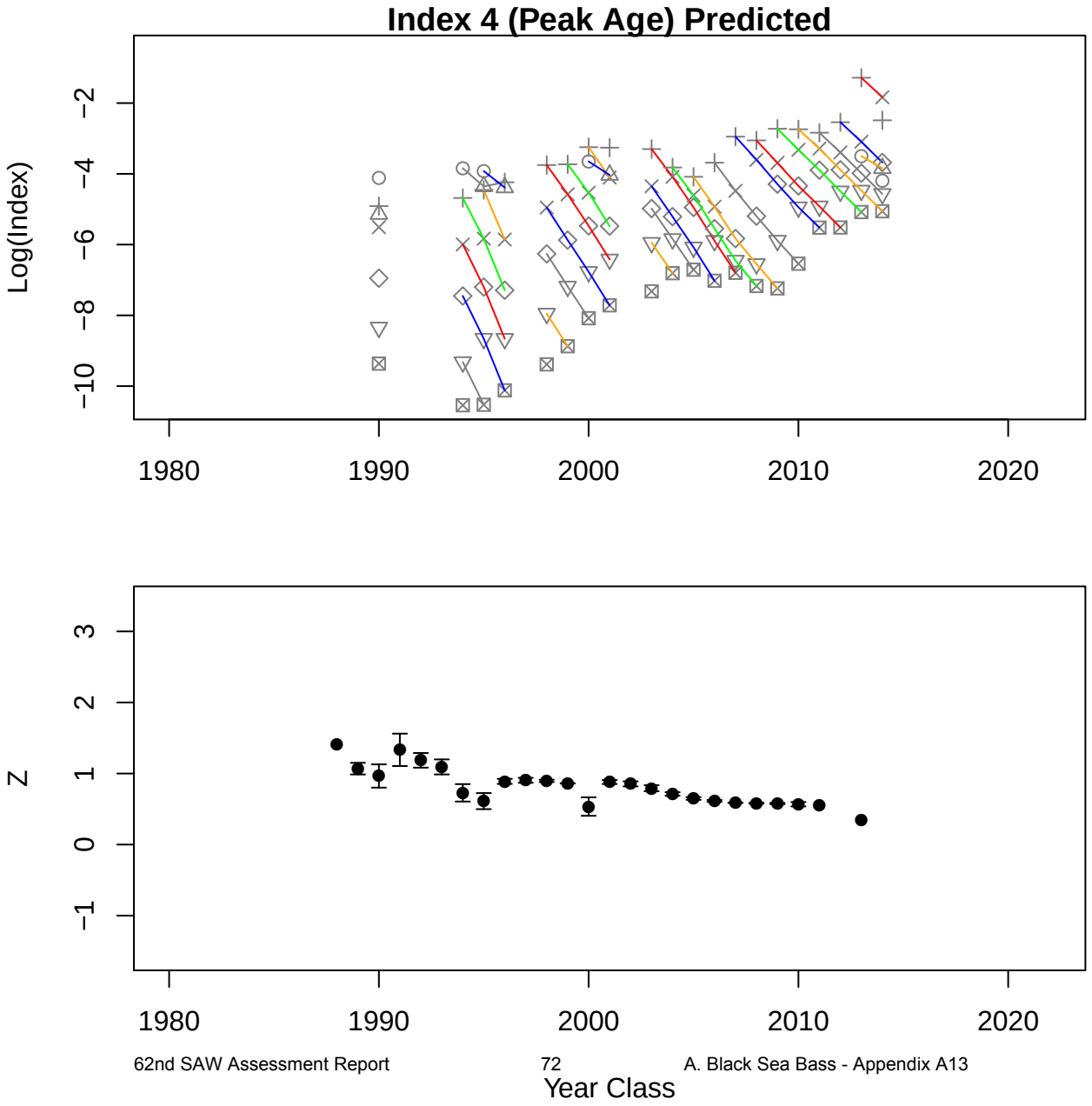

Index 3 (Peak Age) Observed
Log(Index)
2
0
−2
−4
−6
−8
1980
1990
2000
2010
2020
Z
4
3
2
1
0
−1
1980
1990
2000
2010
2020
Year Class

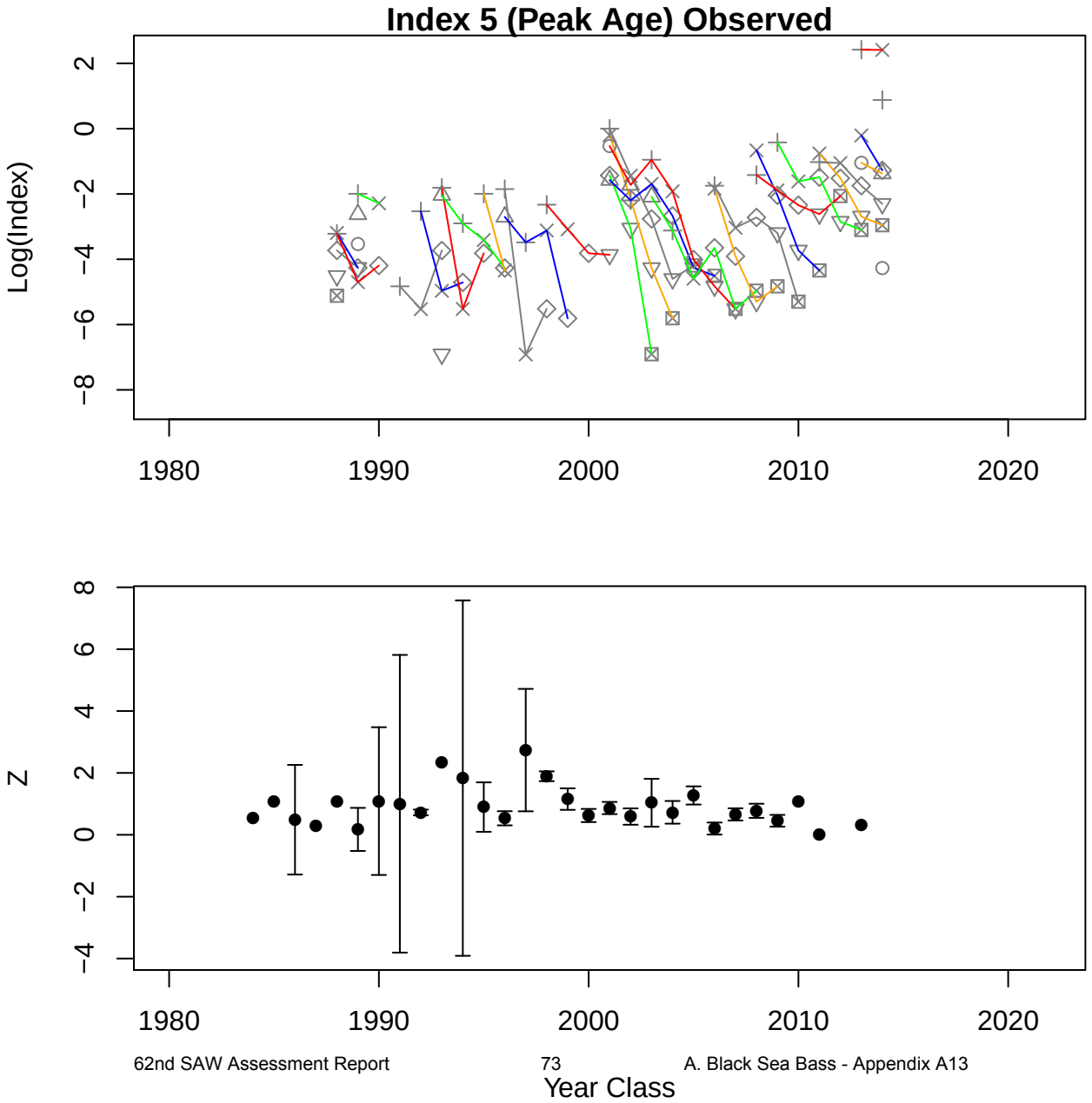

Index 3 (Peak Age) Predicted
Log(Index)
2
0
−2
−4
−6
−8
1980
1990
2000
2010
2020

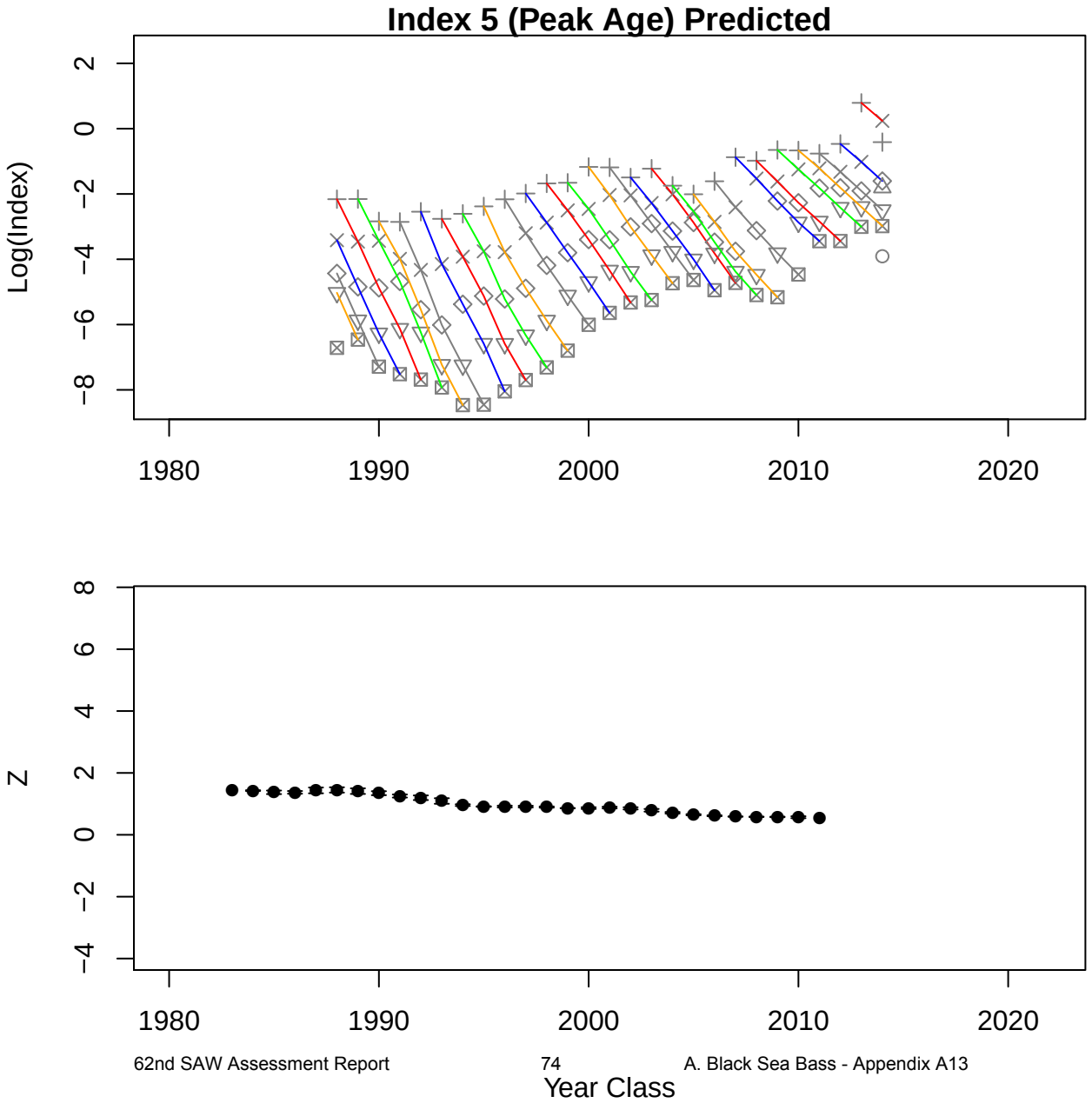

Z
4
3
2
1
0
−1
1980
1990
2000
2010
2020

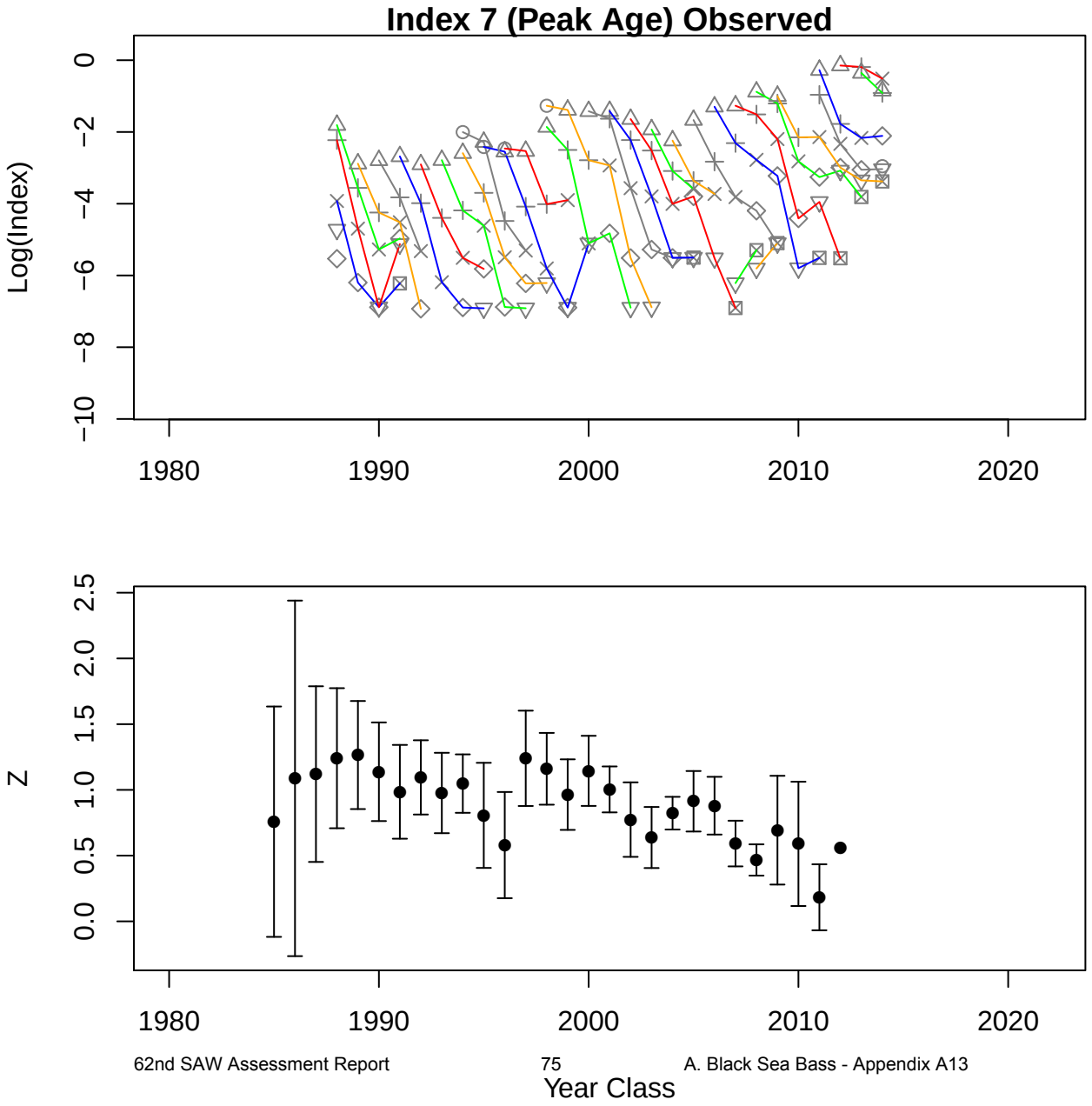
Year Class

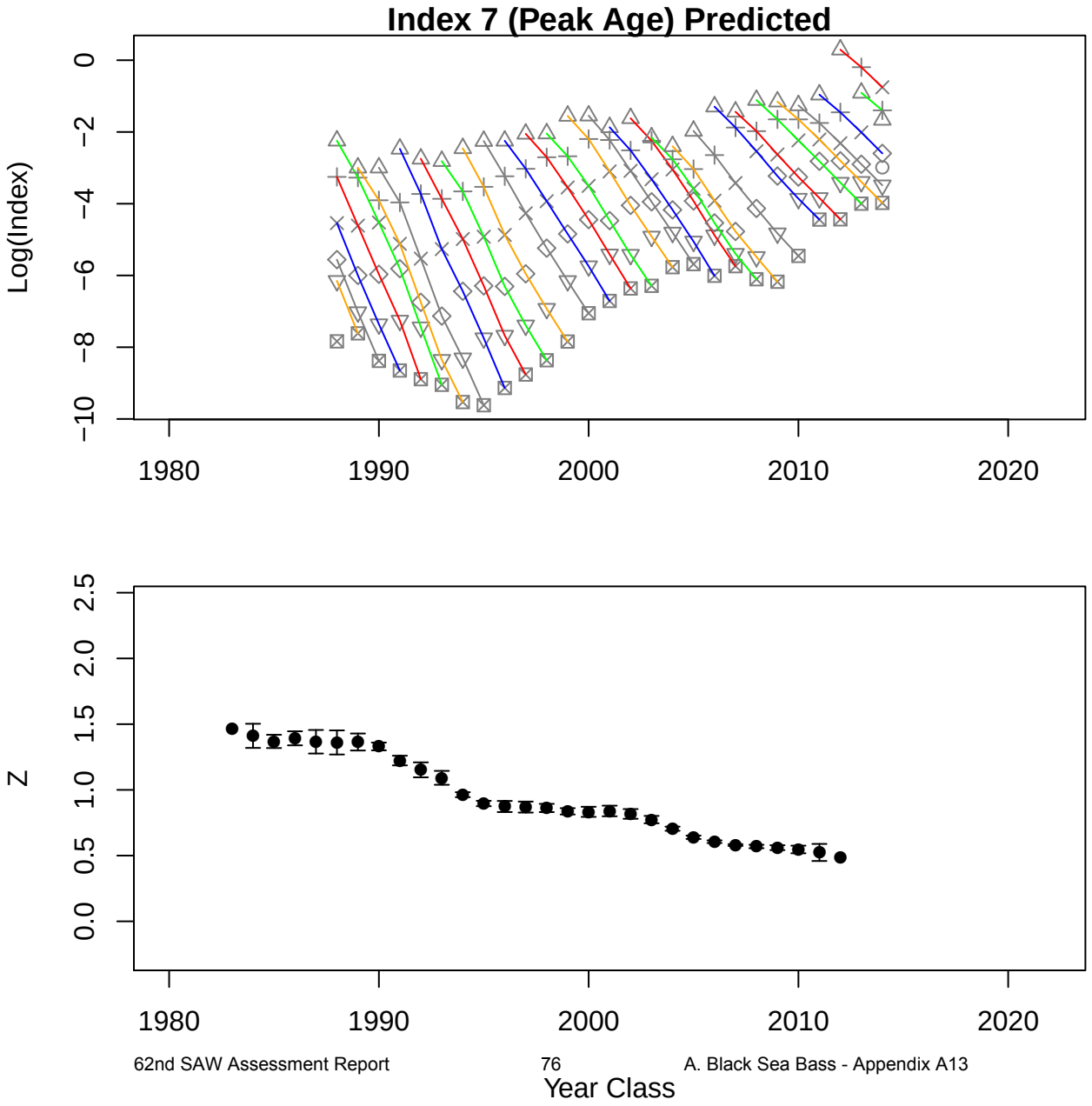

Index 4 (Peak Age) Observed
Log(Index)
−2
−4
−6
−8
−10
1980
1990
2000
2010
2020
Z
3
2
1
0
−1
1980
1990
2000
2010
2020
Year Class

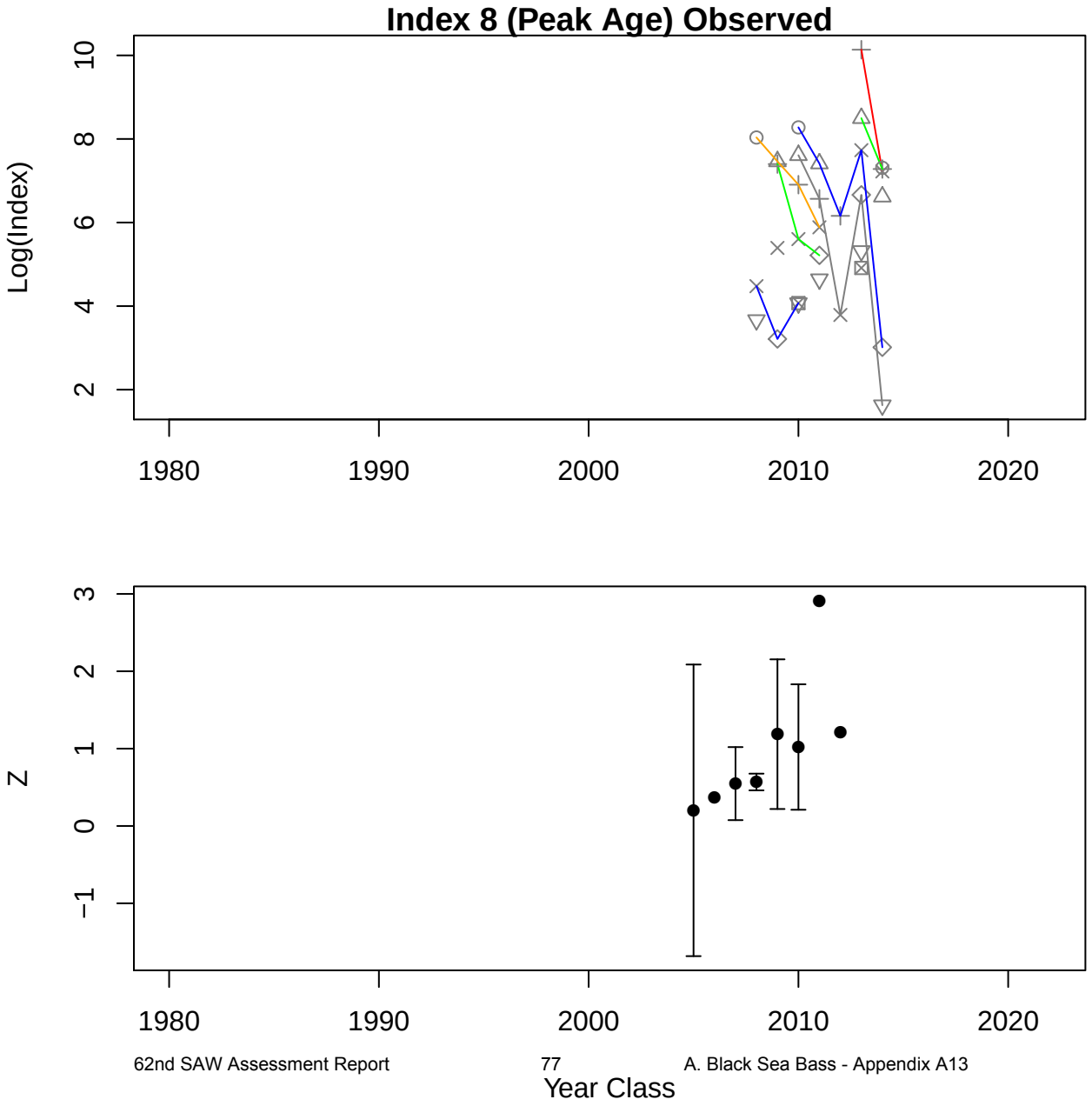

Index 4 (Peak Age) Predicted
Log(Index)
−2
−4
−6
−8
−10
1980
1990
2000
2010
2020
Z
3
2
1
0
−1
1980
1990
2000
2010
2020
Year Class

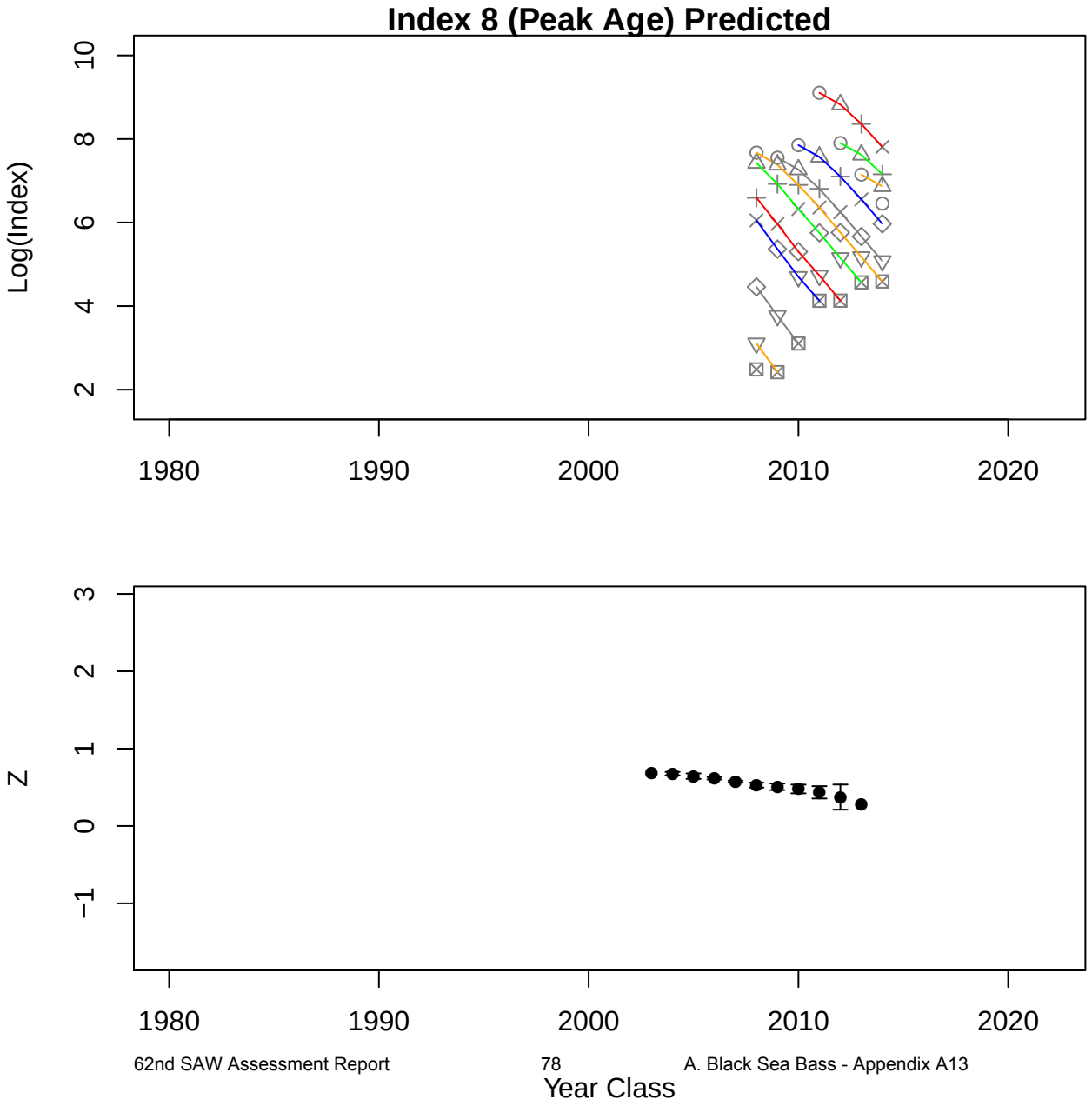

Index 5 (Peak Age) Observed
Log(Index)
2
0
−2
−4
−6
−8
1980
1990
2000
2010
2020
Z
8
6
4
2
0
−2
−4
1980
1990
2000
2010
2020
Year Class


Index 5 (Peak Age) Predicted
Log(Index)
2
0
−2
−4
−6
−8
1980
1990
2000
2010
2020
Z
8
6
4
2
0
−2
−4
1980
1990
2000
2010
2020
Year Class

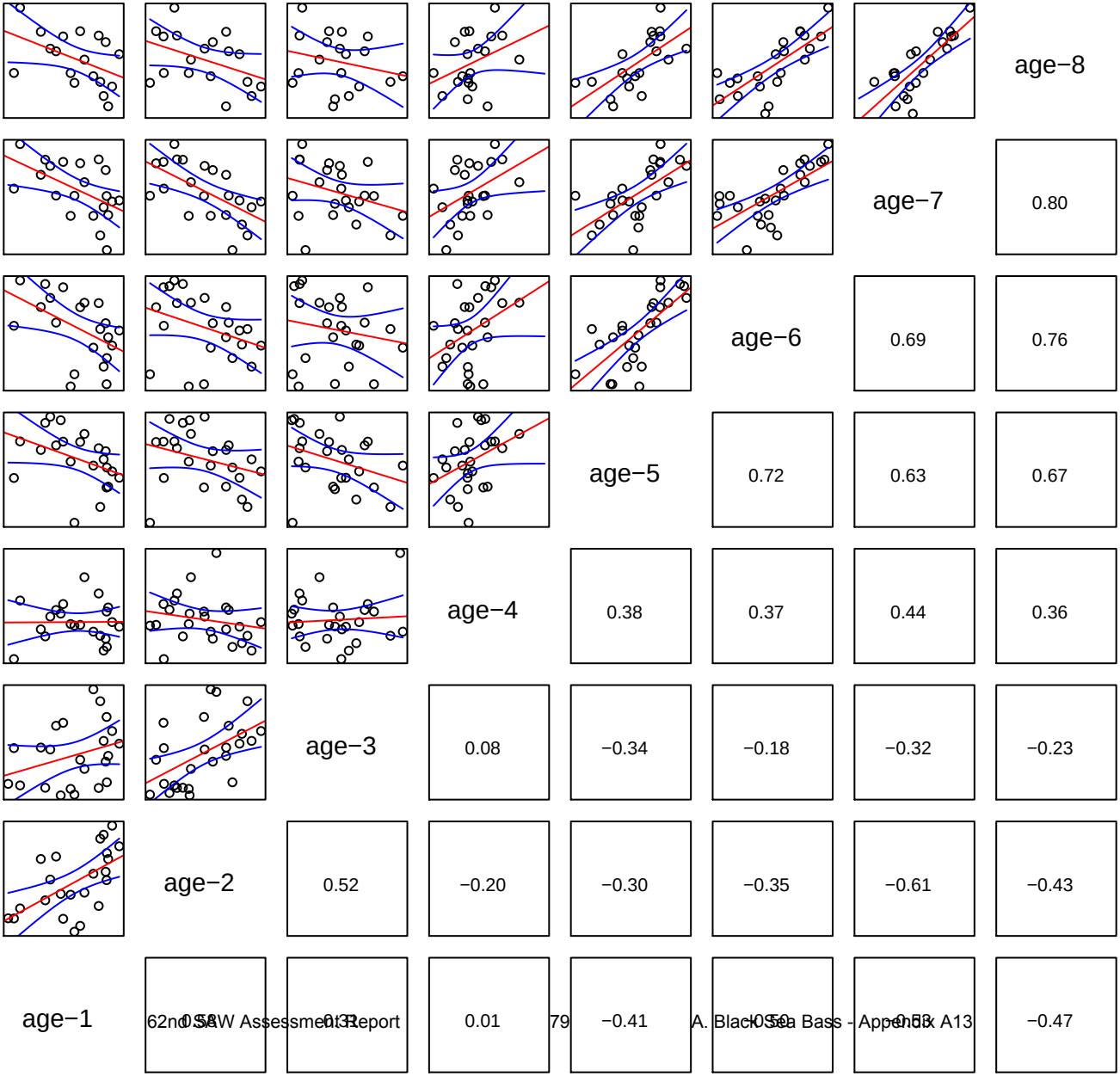

Index 7 (Peak Age) Observed
Log(Index)
0
−2
−4
−6
−8
−10
1980
1990
2000
2010
2020
Z
2.5
2.0
1.5
1.0
0.5
0.0
1980
1990
2000
2010
2020
Year Class


Index 7 (Peak Age) Predicted
Log(Index)
0
−2
−4
−6
−8
−10
1980
1990
2000
2010
2020
Z
2.5
2.0
1.5
1.0
0.5
0.0
1980
1990
2000
2010
2020
Year Class

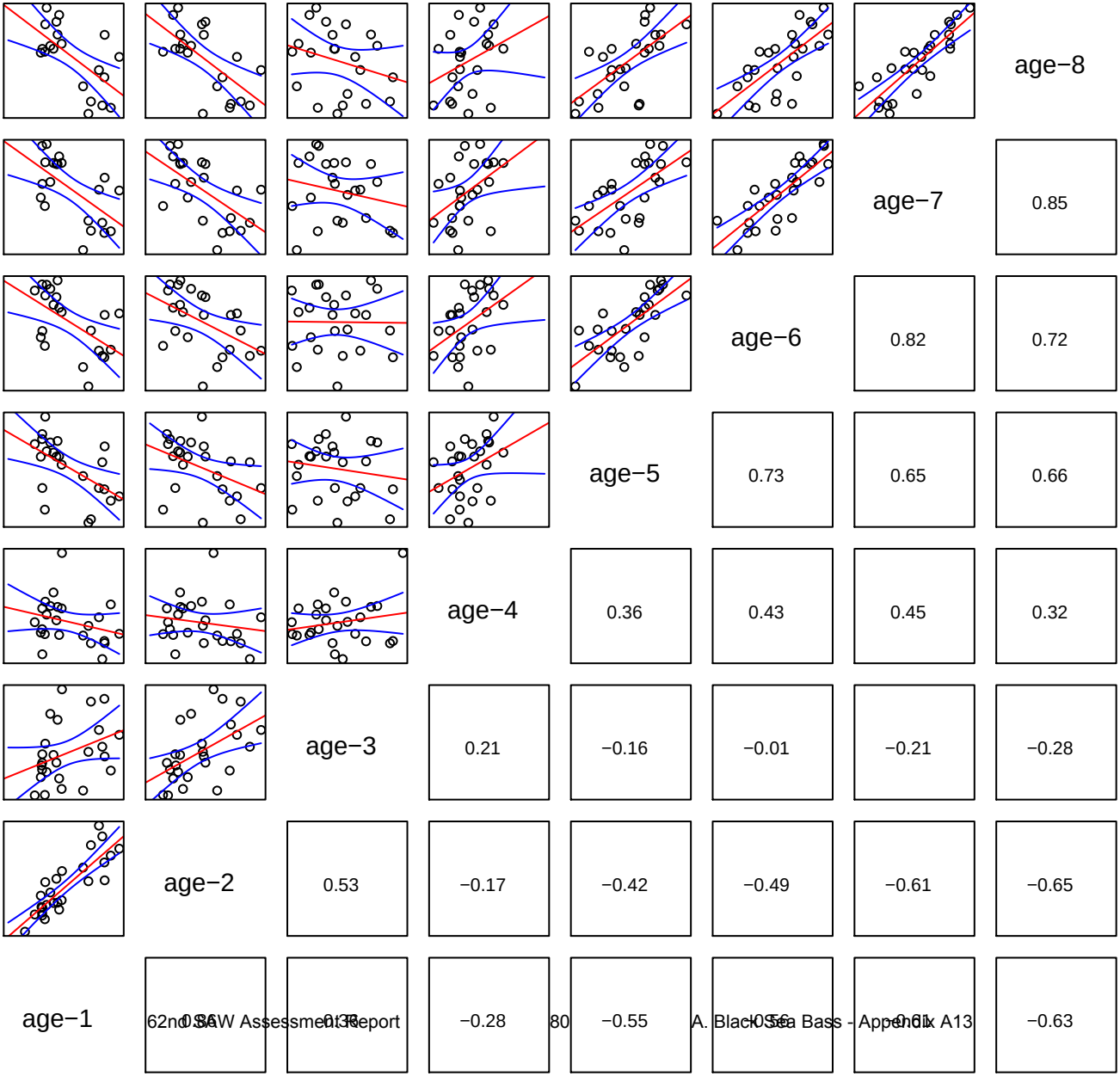

Index 8 (Peak Age) Observed
Log(Index)
10
8
6
4
2
1980
1990
2000
2010
2020
Z
3
2
1
0
−1
1980
1990
2000
2010
2020
Year Class


Index 8 (Peak Age) Predicted
Log(Index)
10
8
6
4
2
1980
1990
2000
2010
2020
Z
3
2
1
0
−1
1980
1990
2000
2010
2020
Year Class

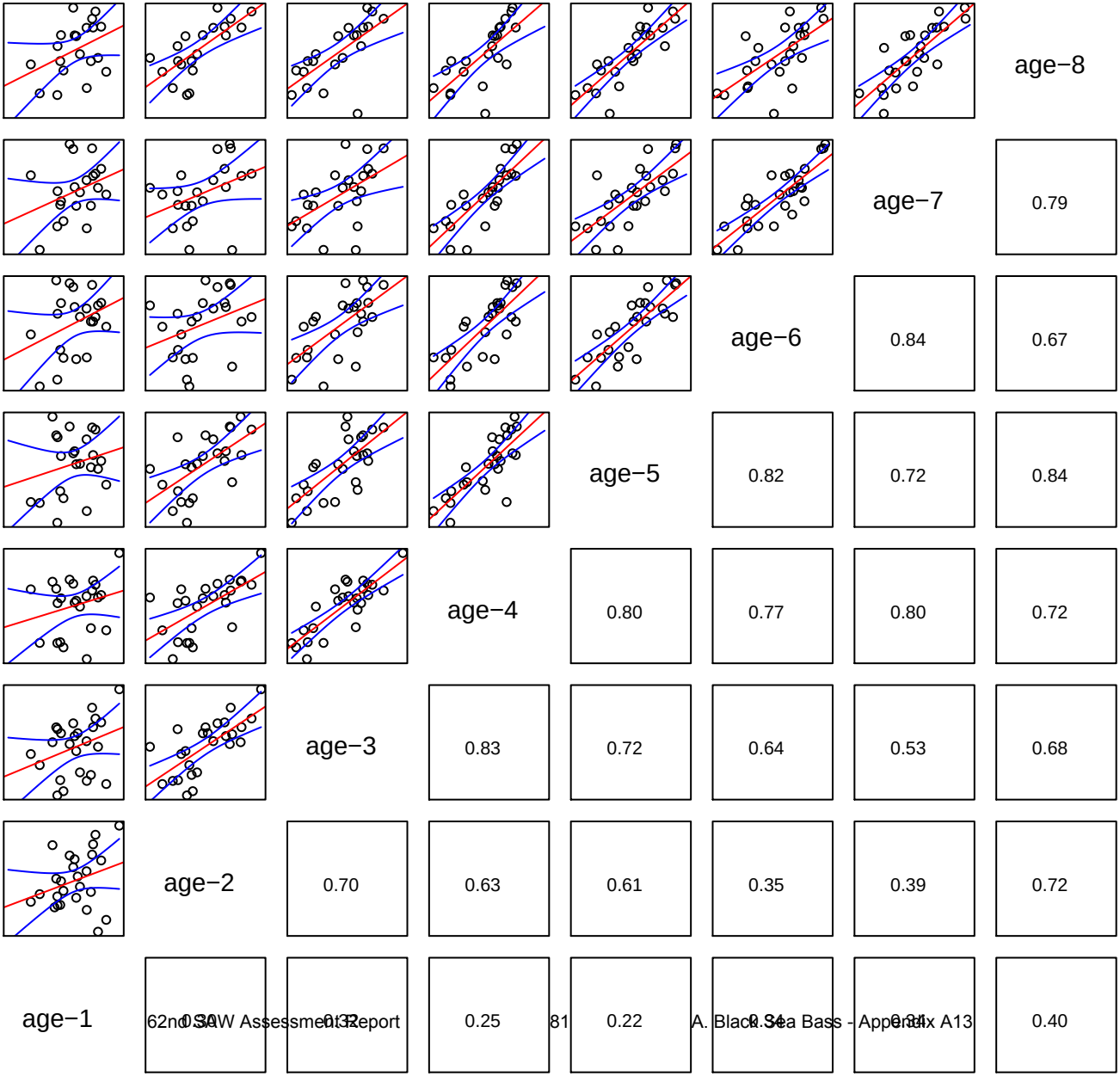
Catch for Fleet 1 Observed



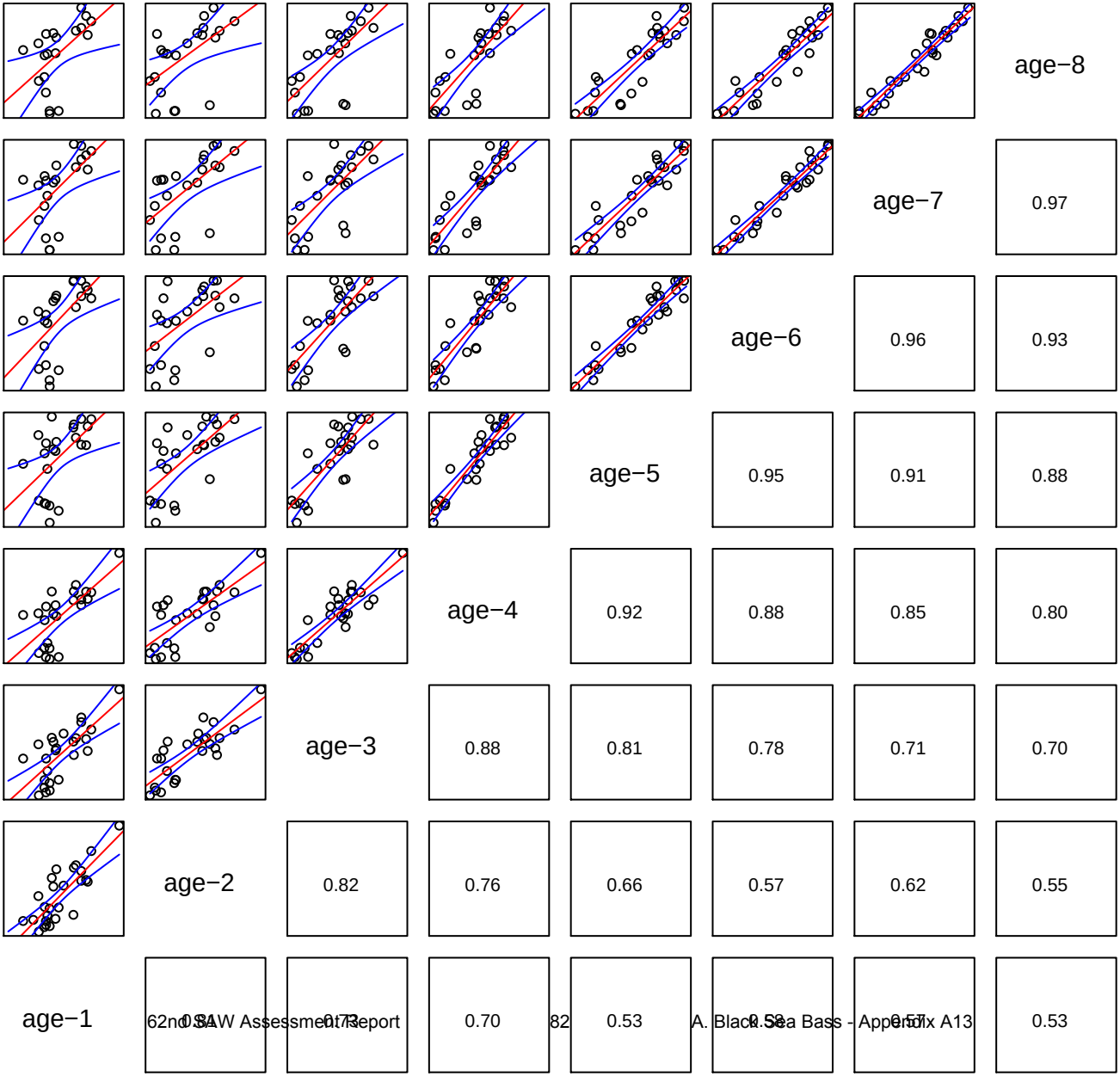
Catch for Fleet 1 Predicted



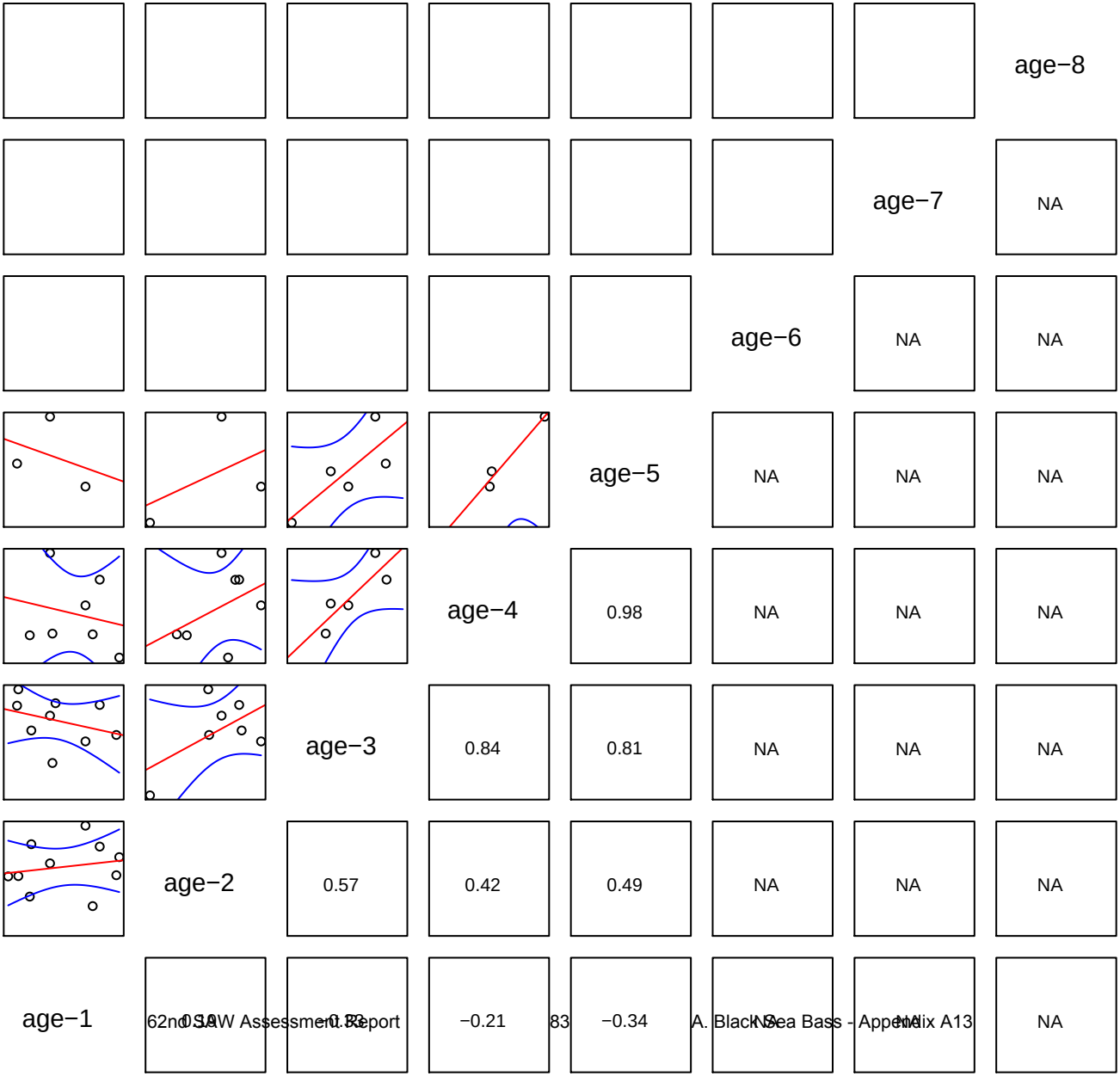
Catch for Fleet 2 Observed



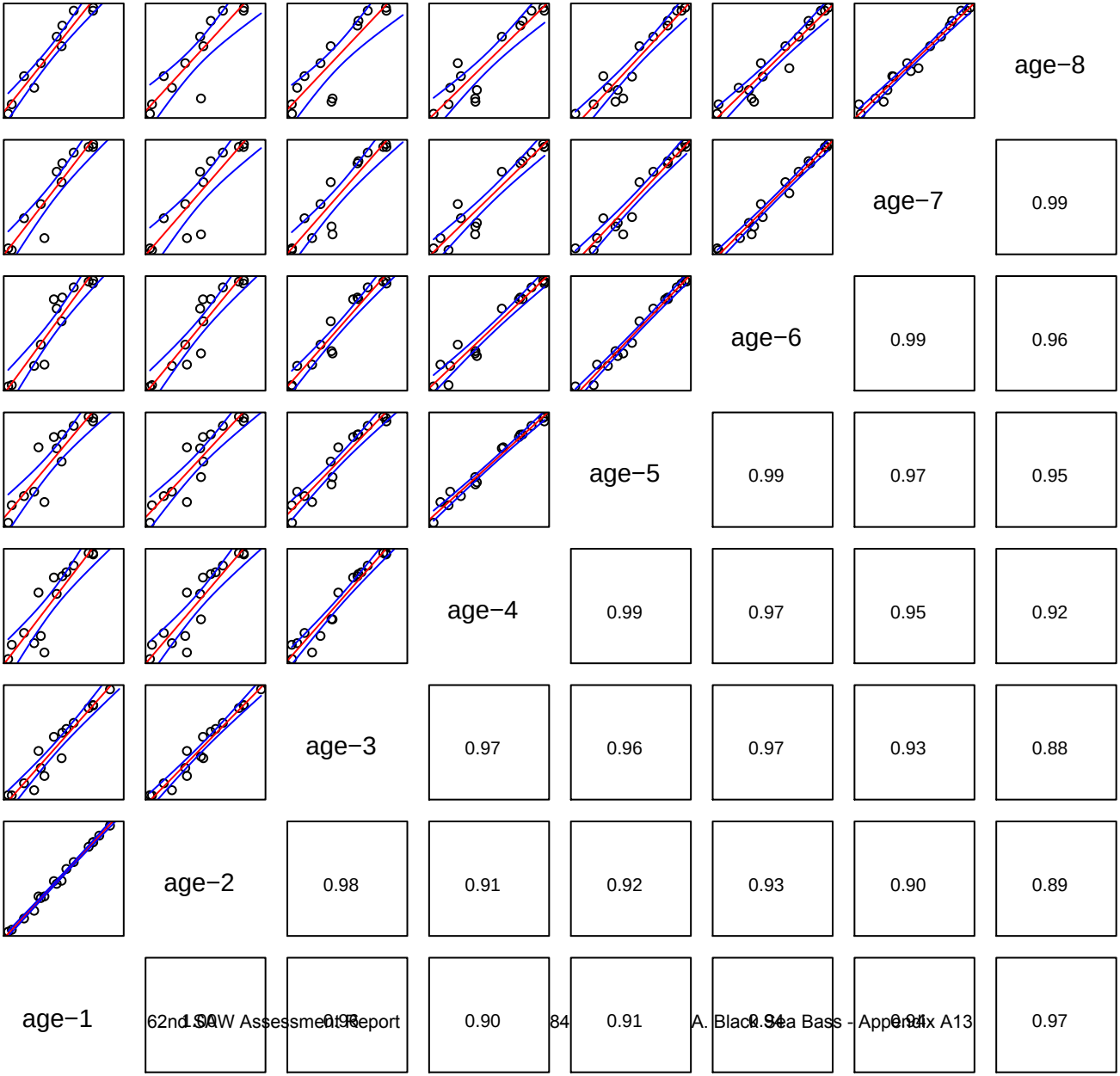
Catch for Fleet 2 Predicted



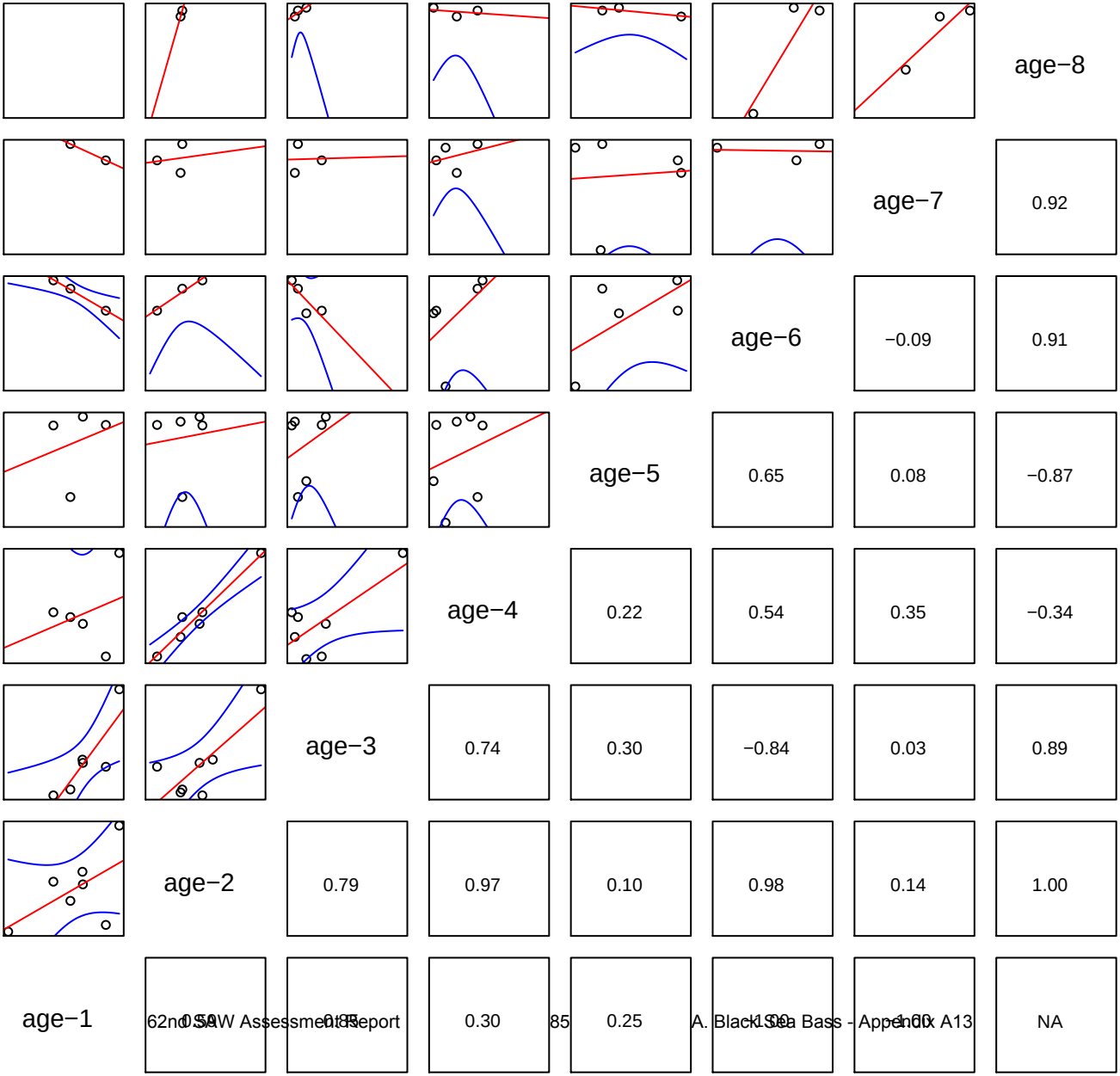
Index 1 Observed



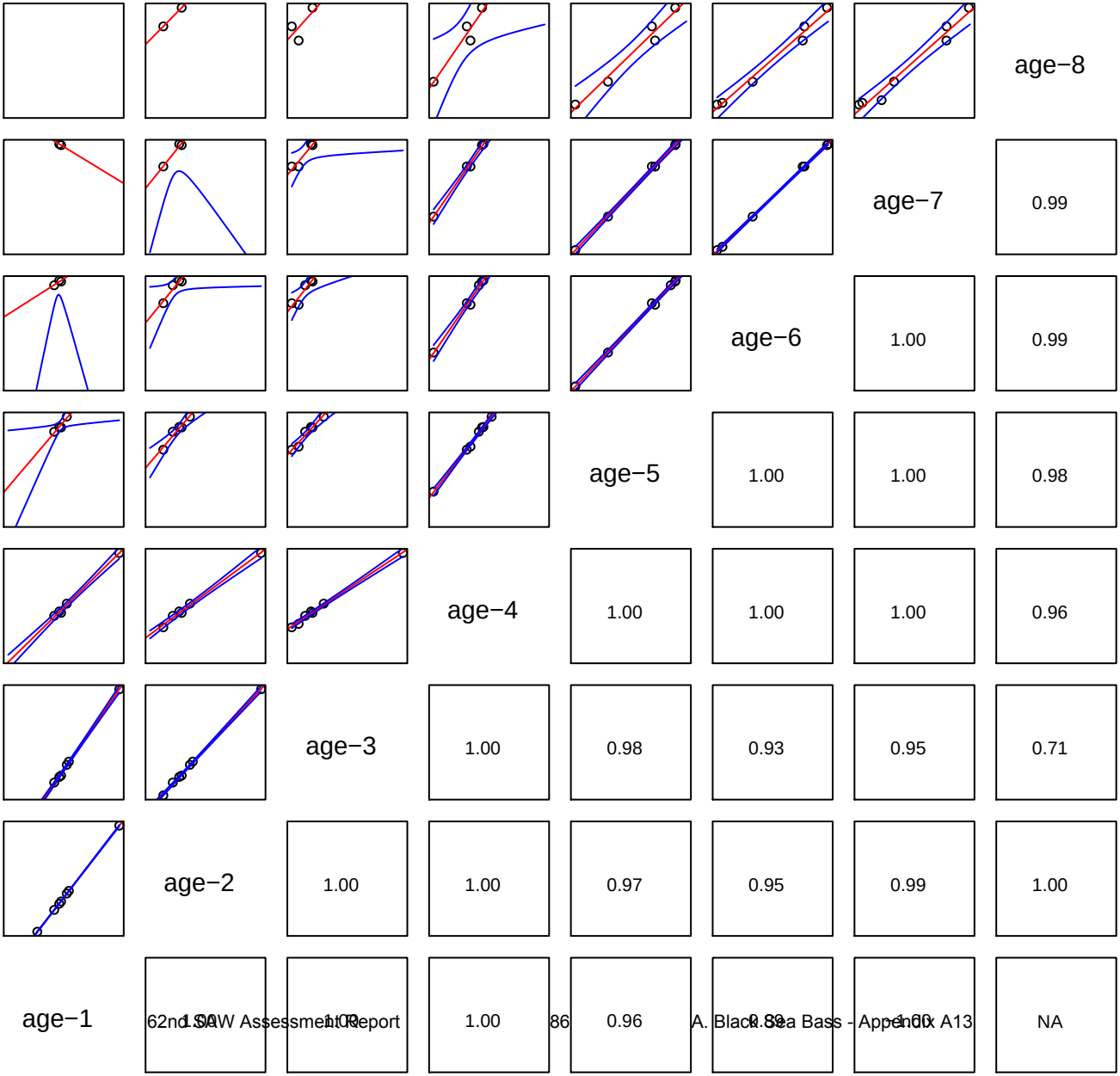
Index 1 Predicted



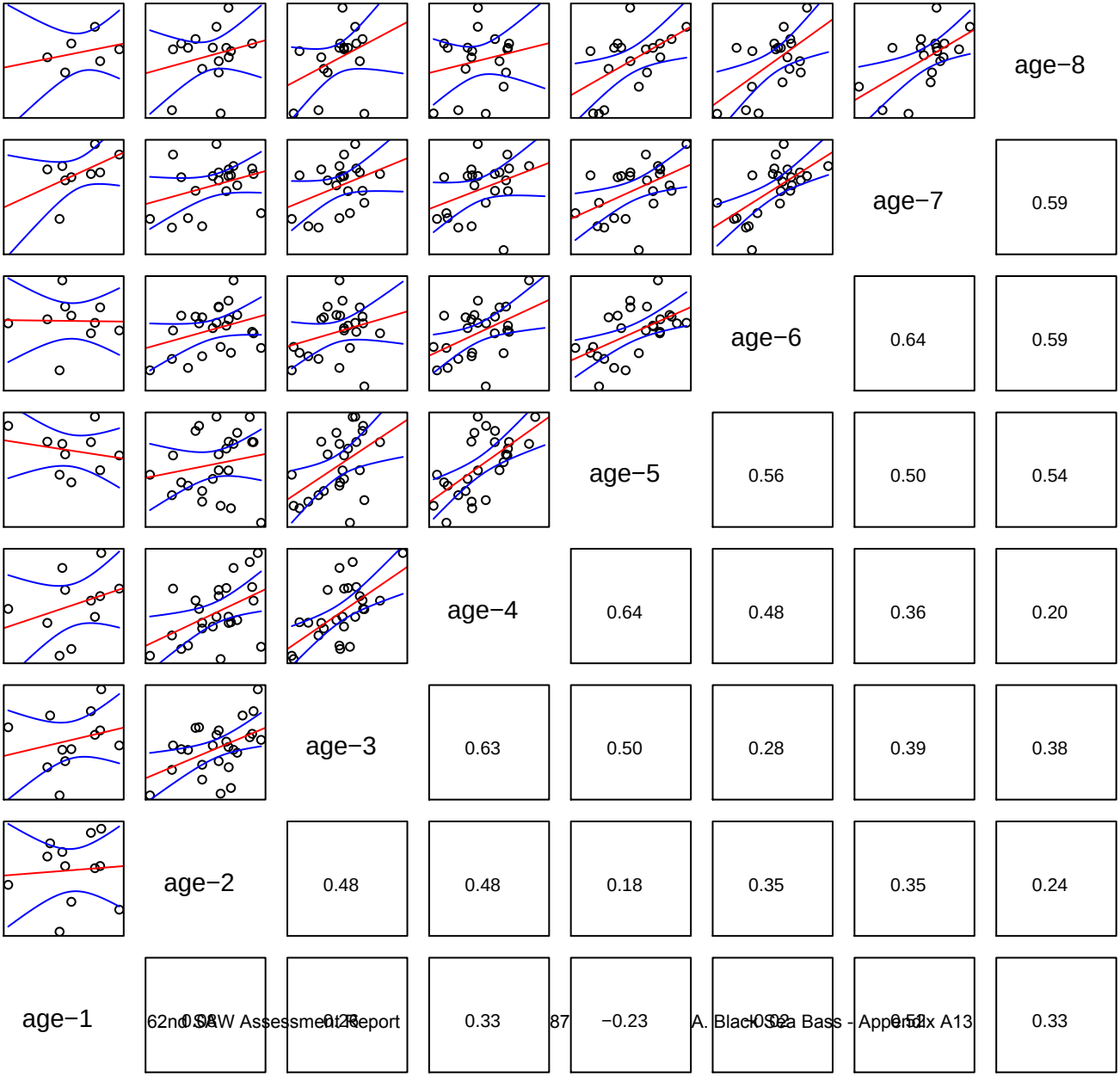
Index 2 Observed



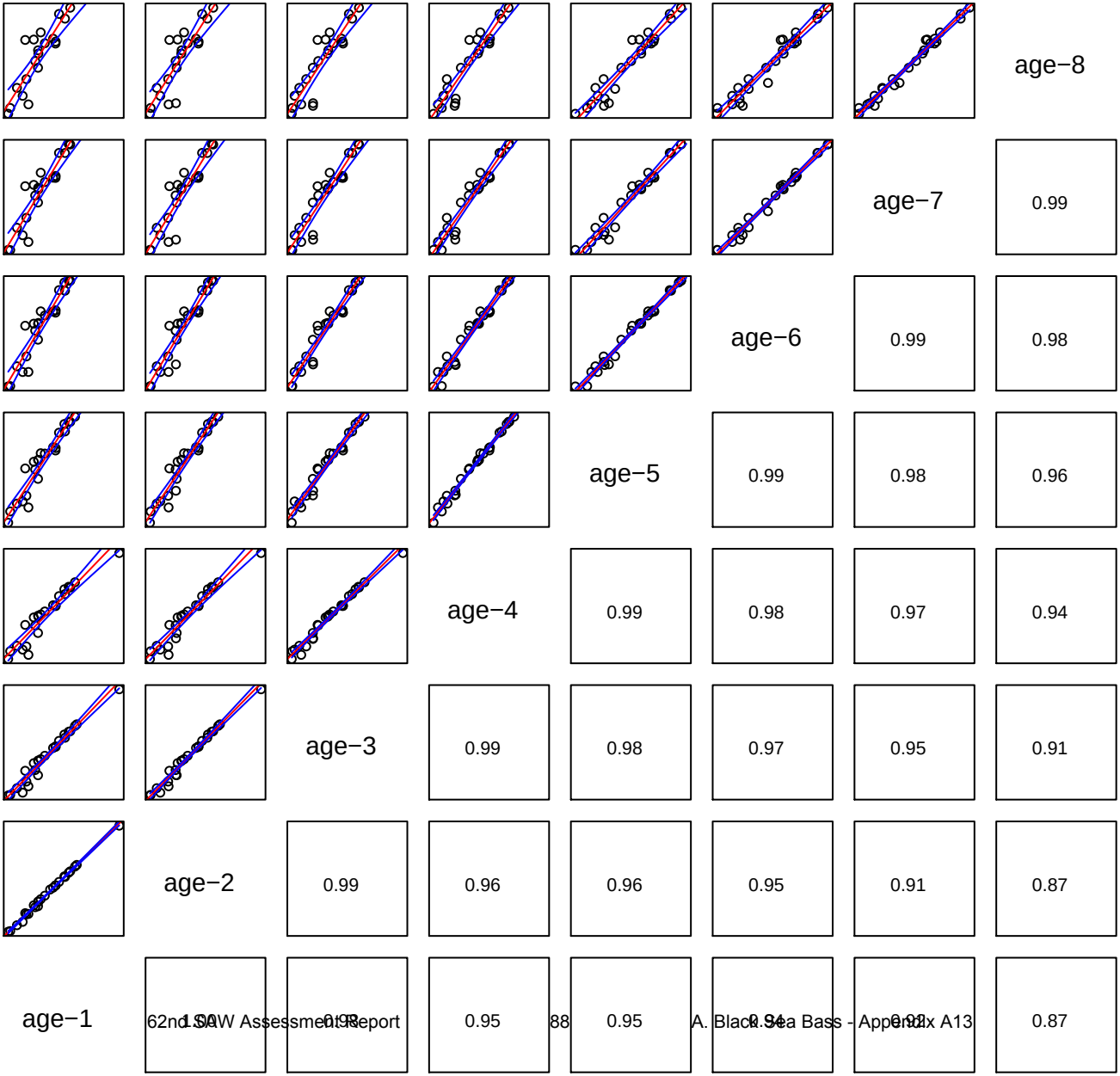
Index 2 Predicted



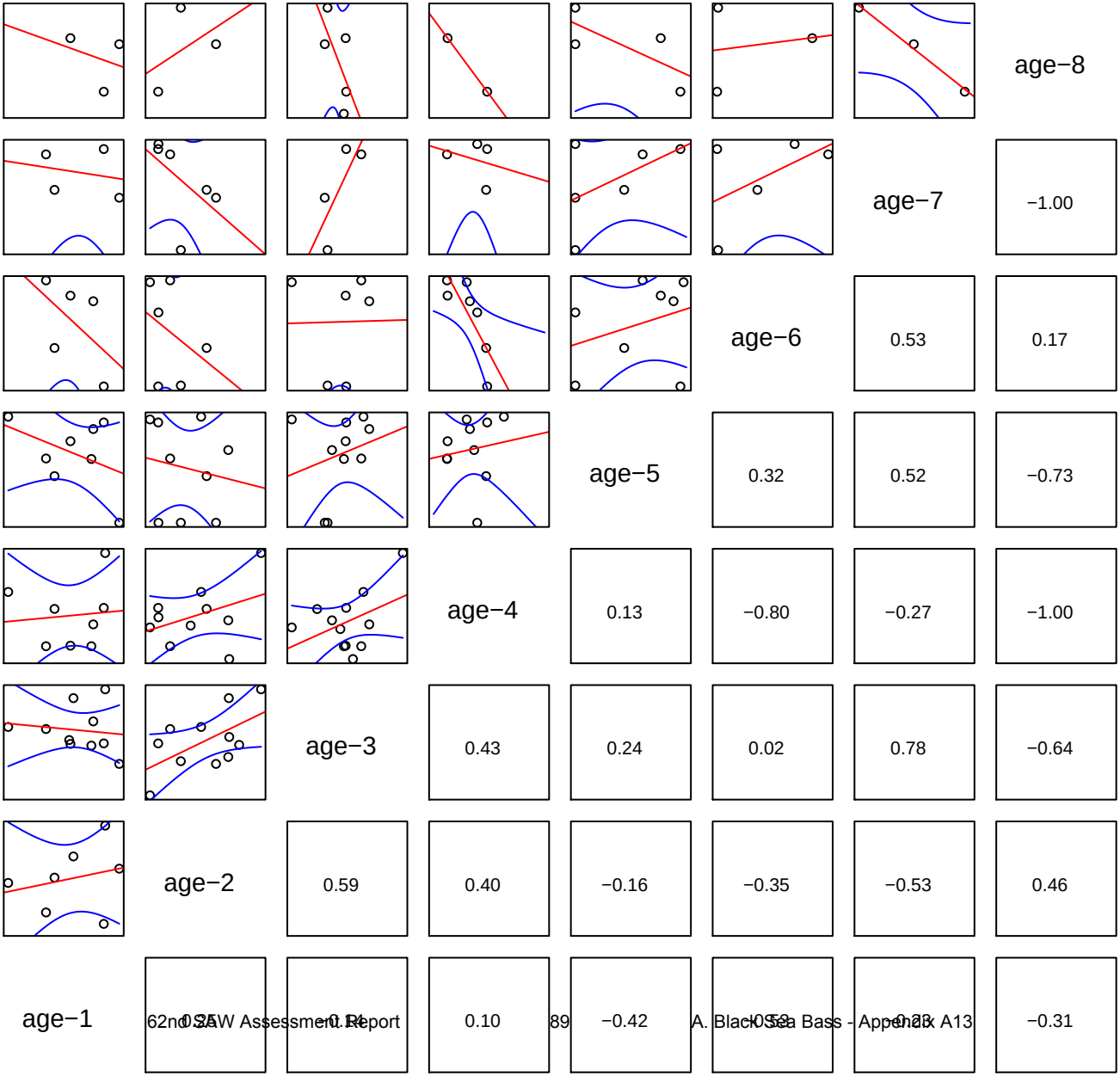
Index 3 Observed



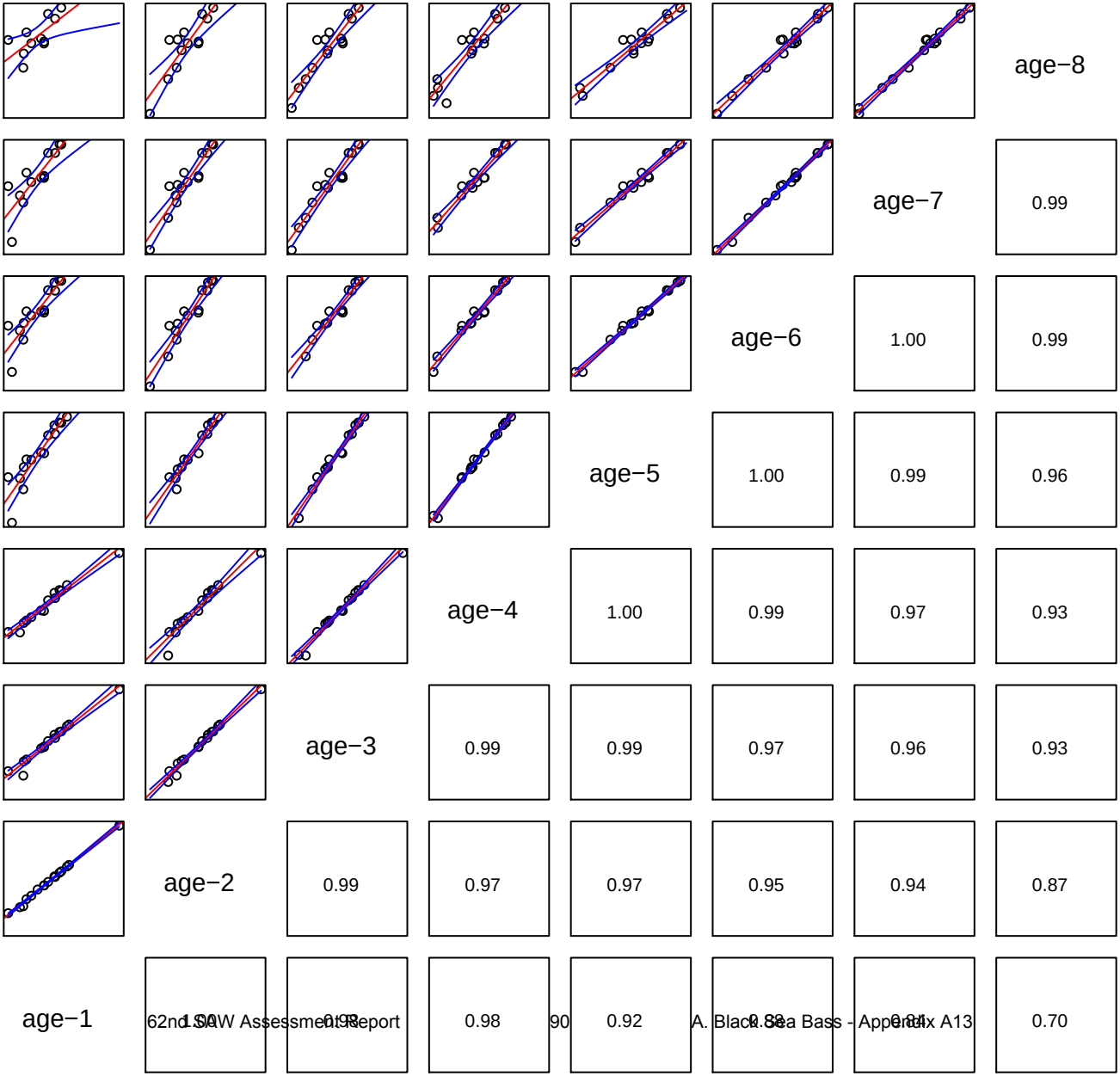
Index 3 Predicted



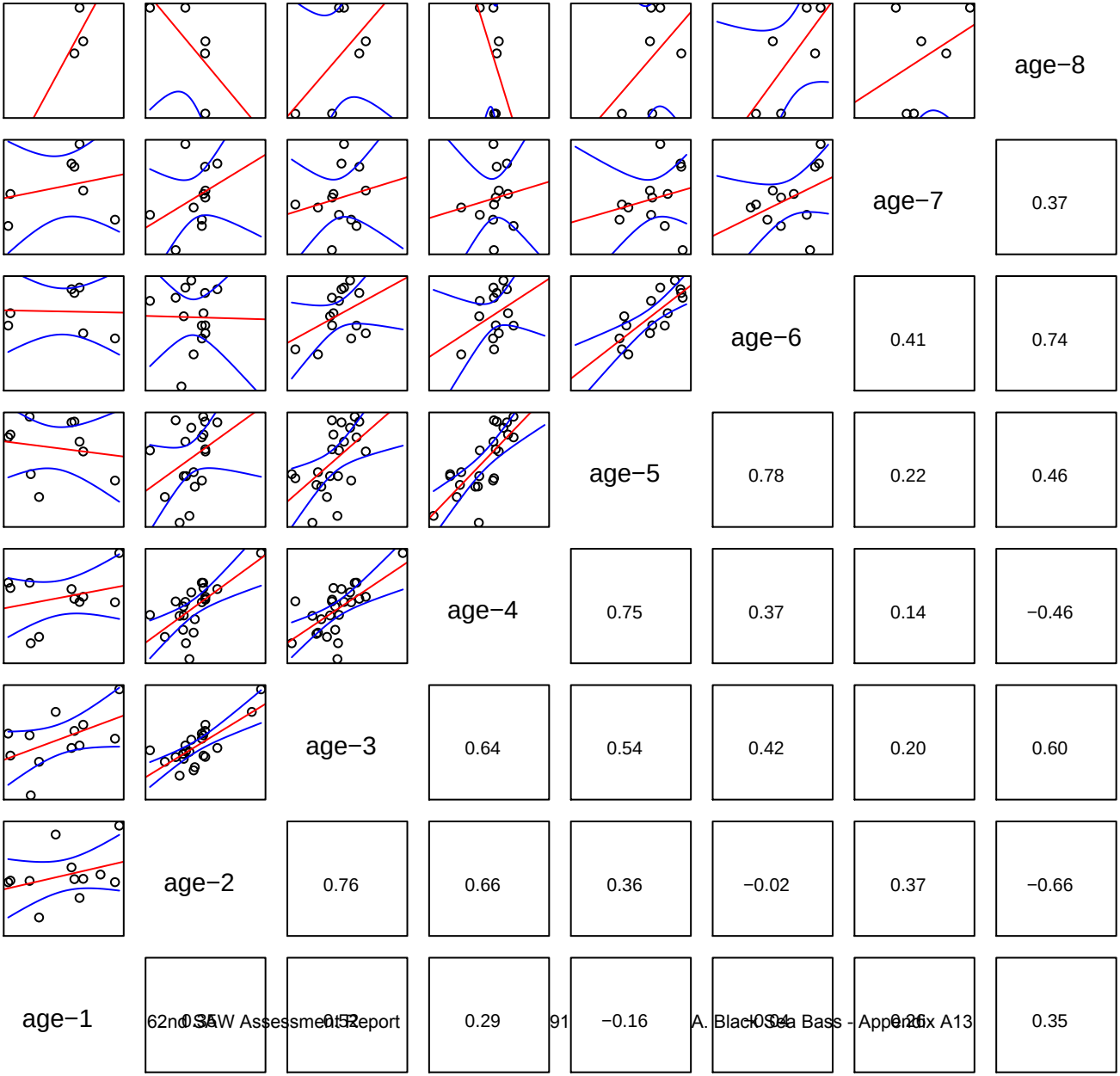
Index 4 Observed



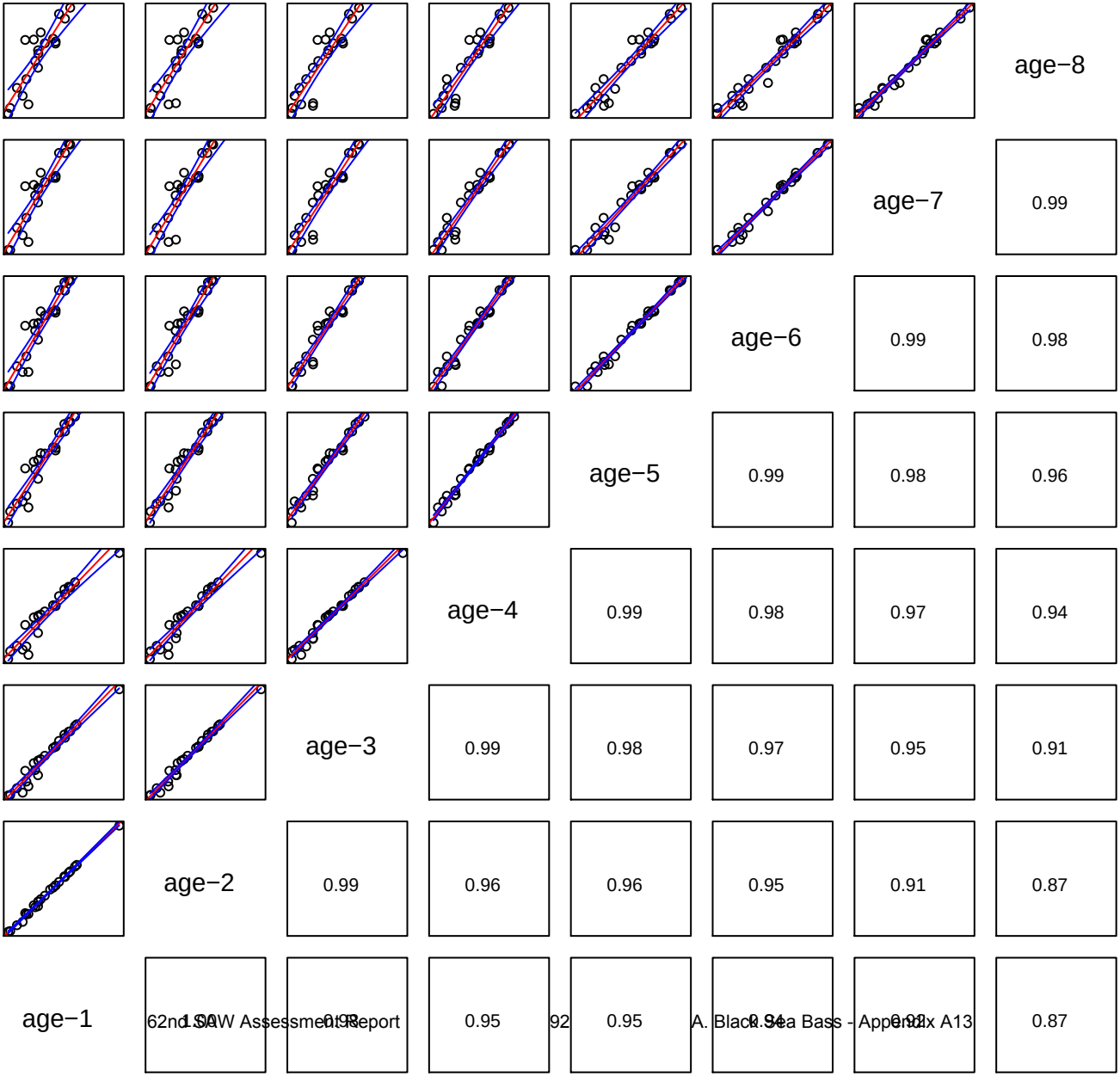
Index 4 Predicted



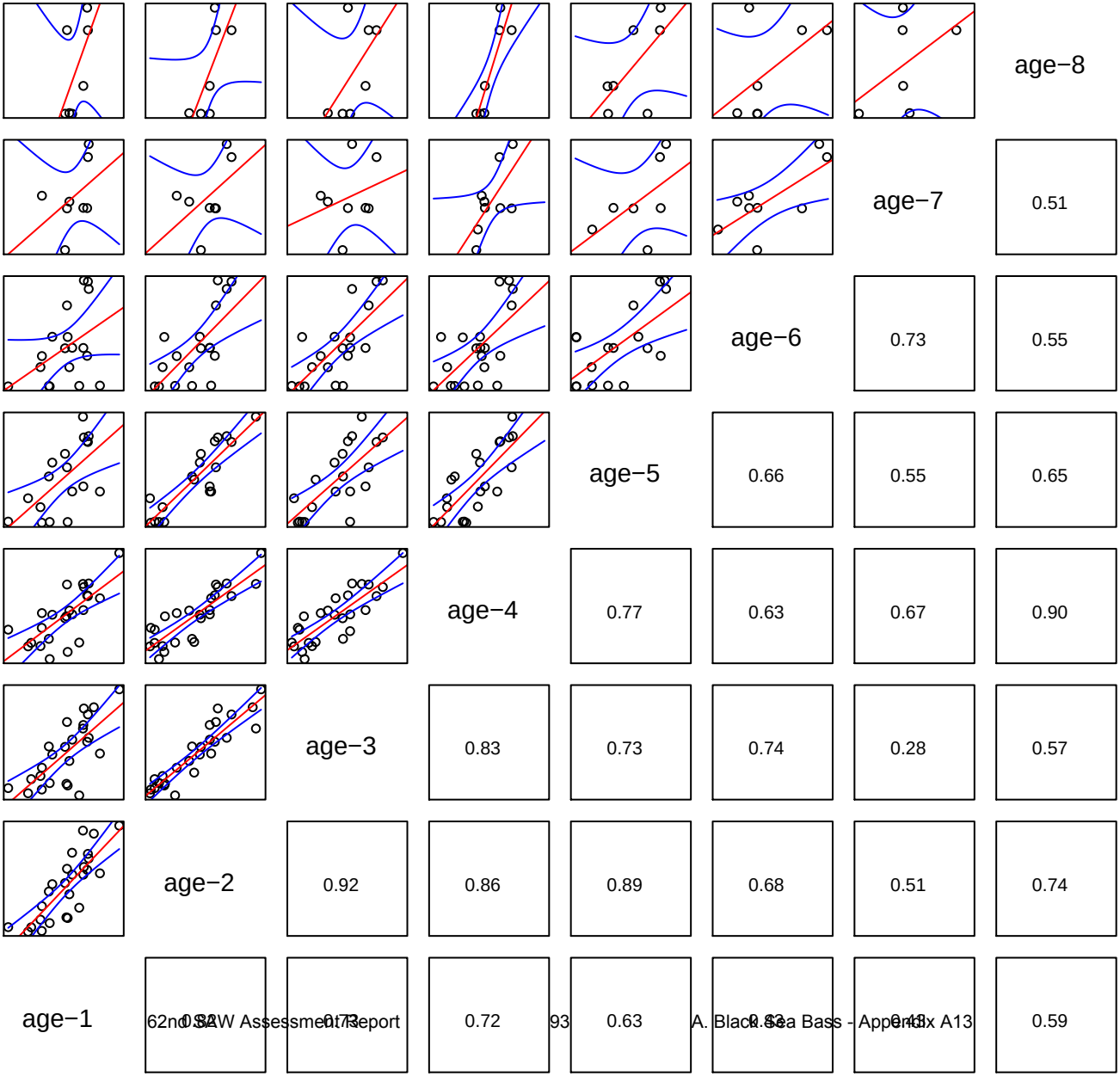
Index 5 Observed



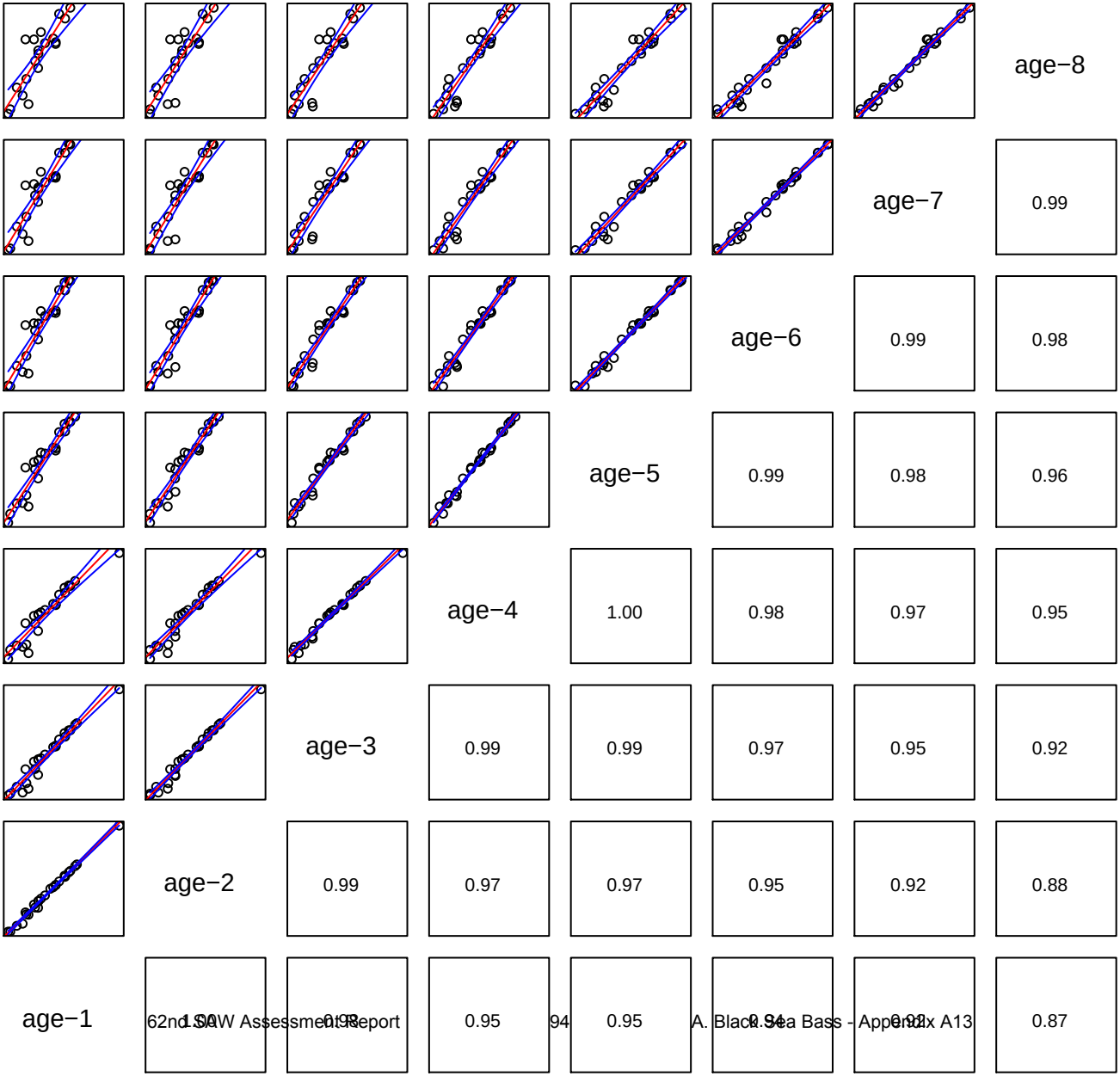
Index 5 Predicted



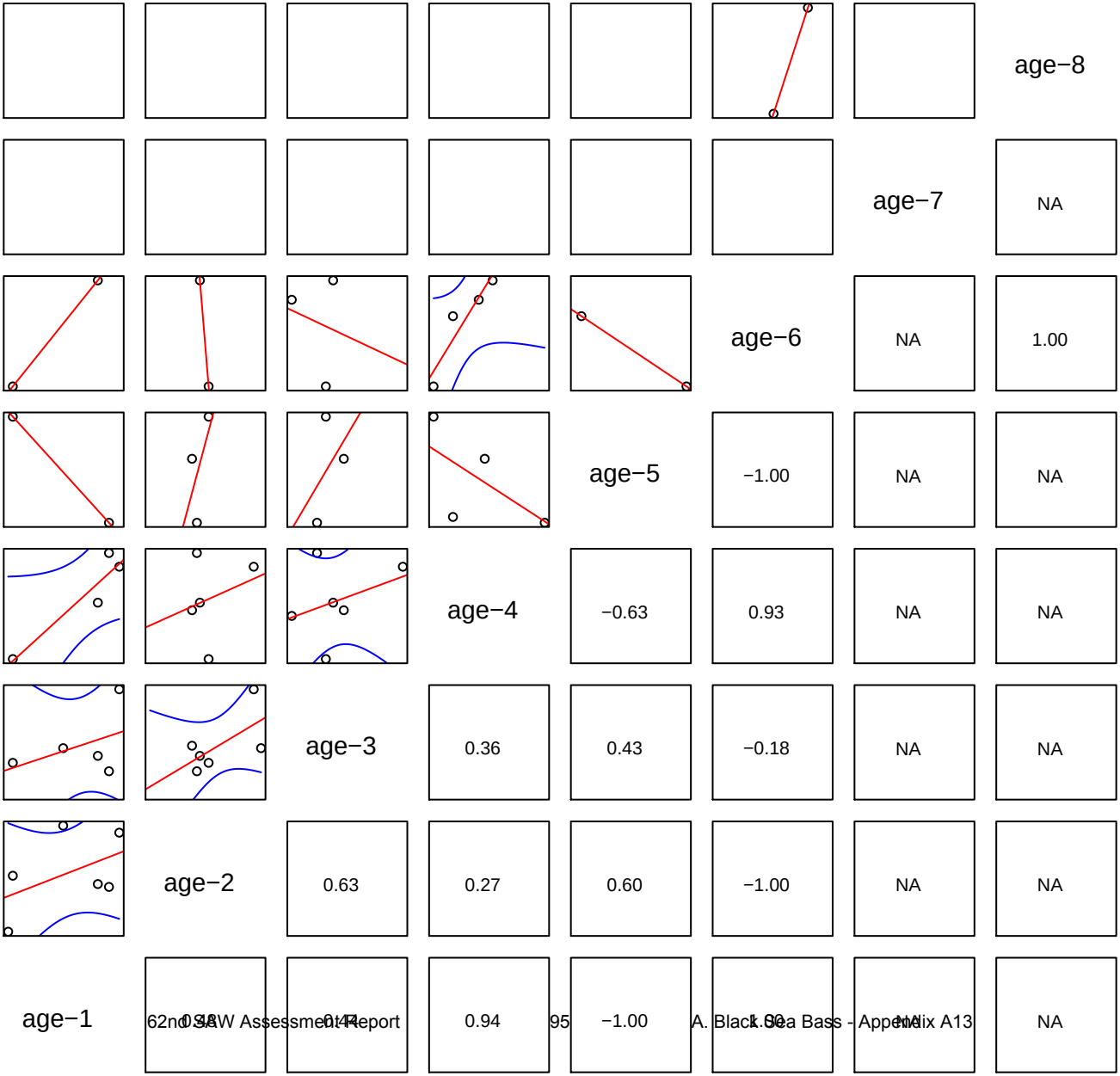
Index 7 Observed



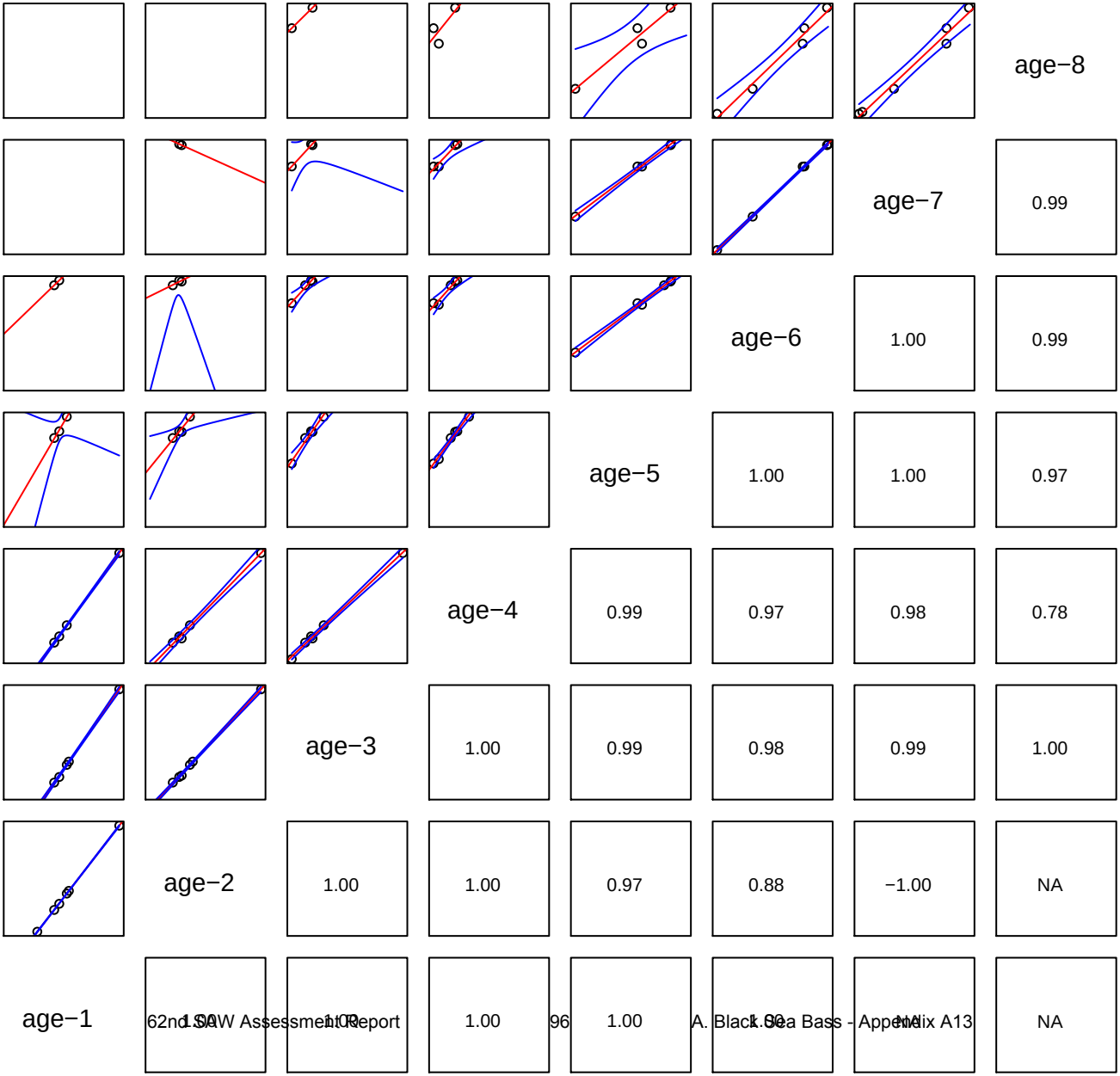
Index 7 Predicted

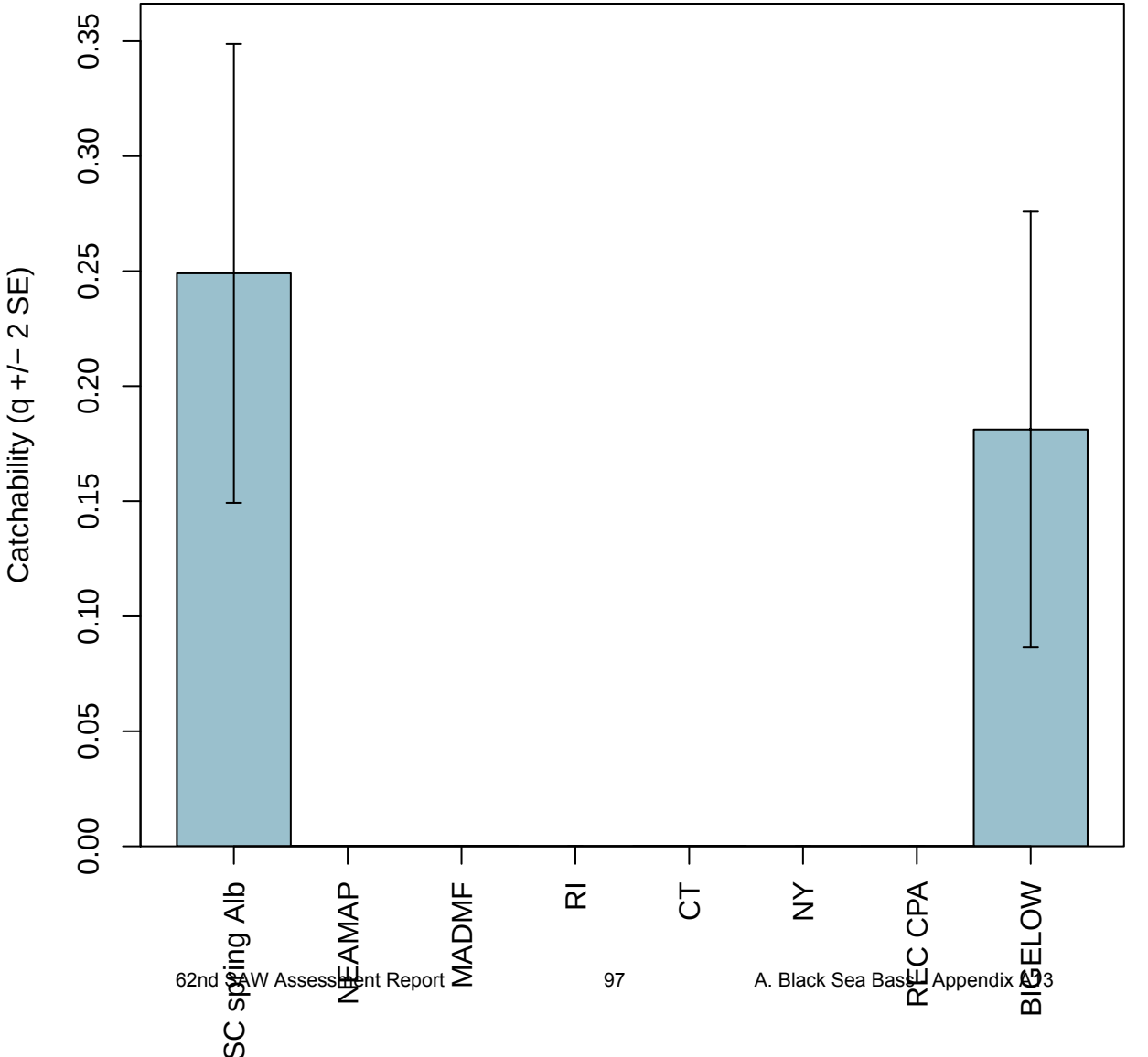


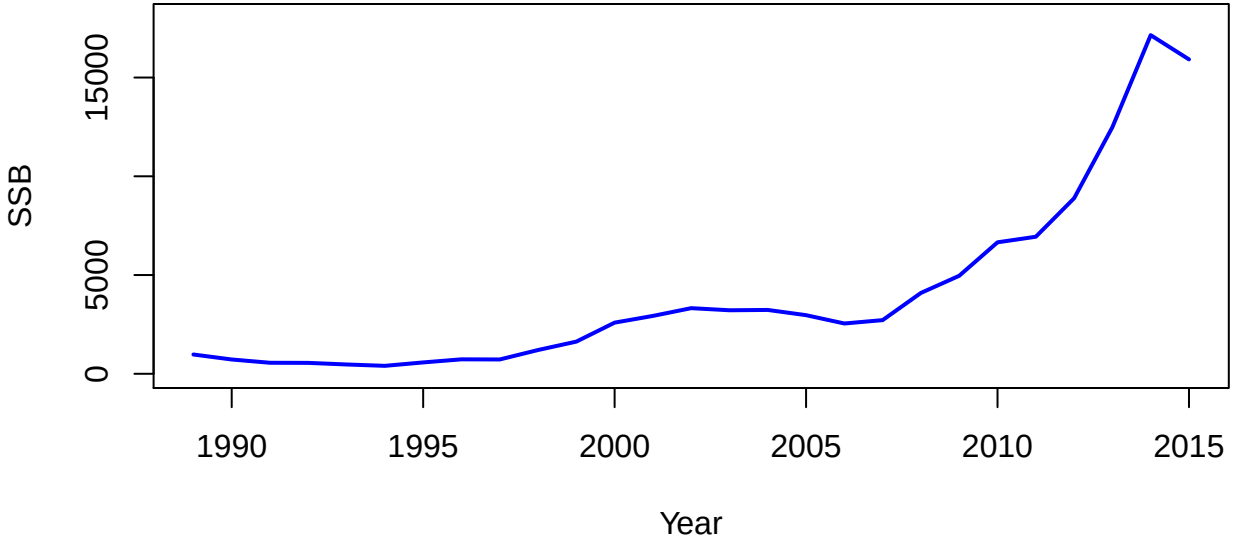
Index 8 Observed

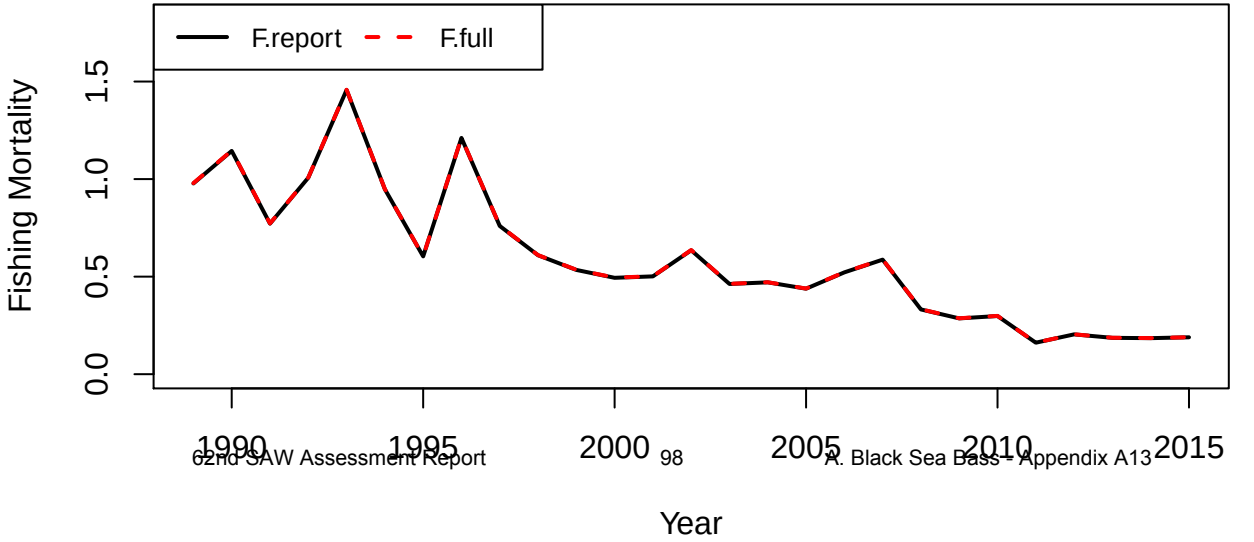


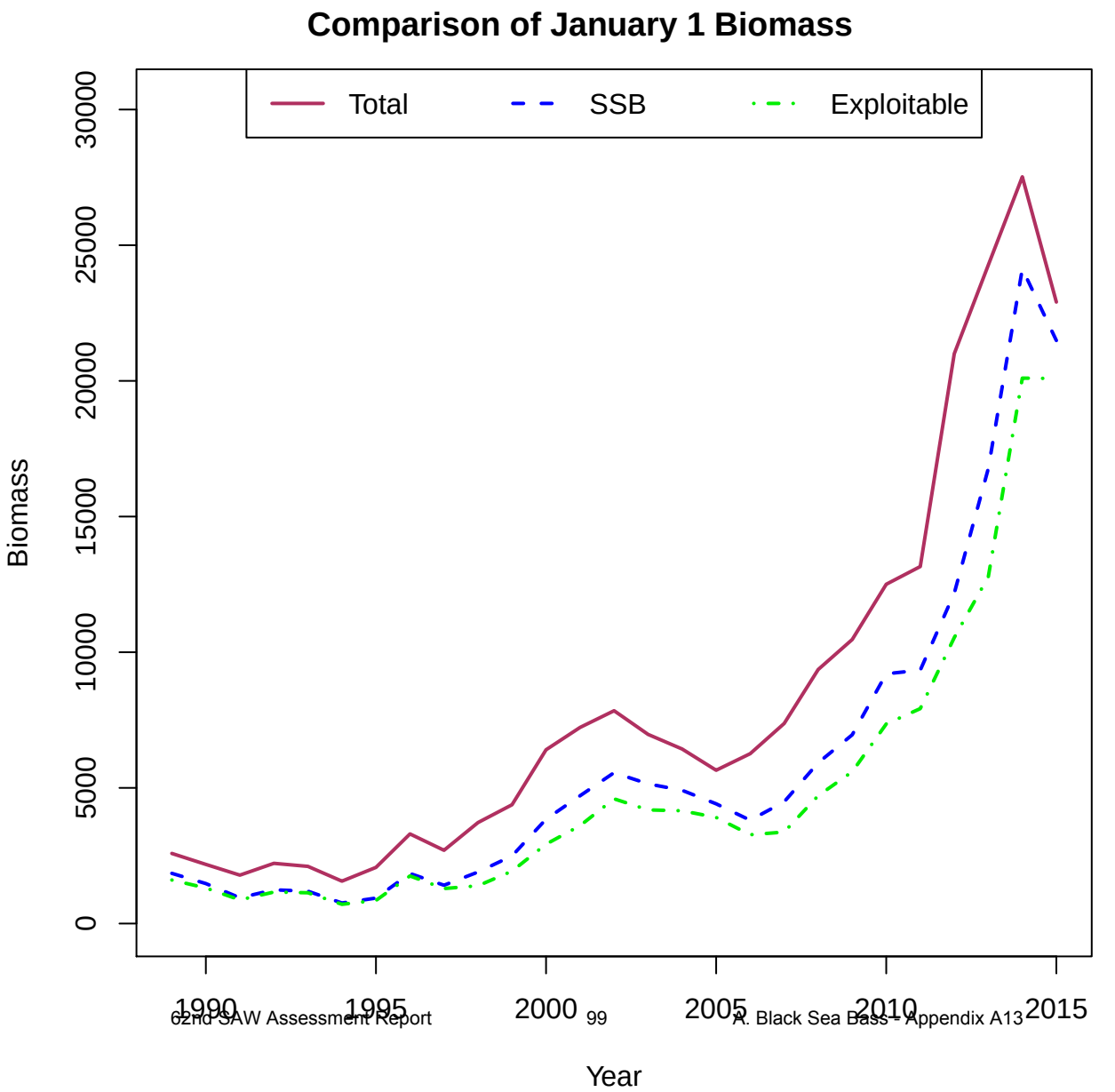
Index 8 Predicted

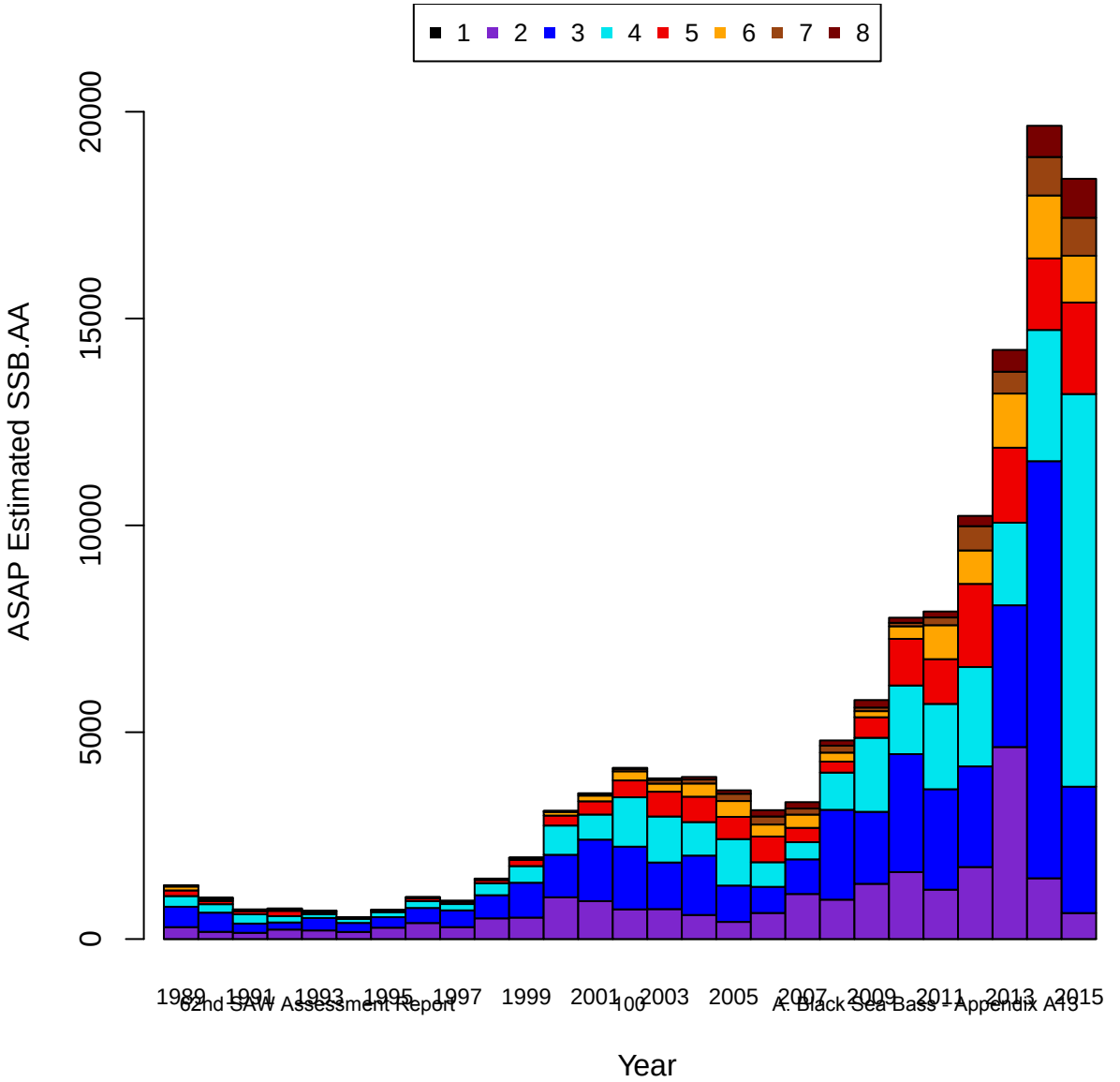


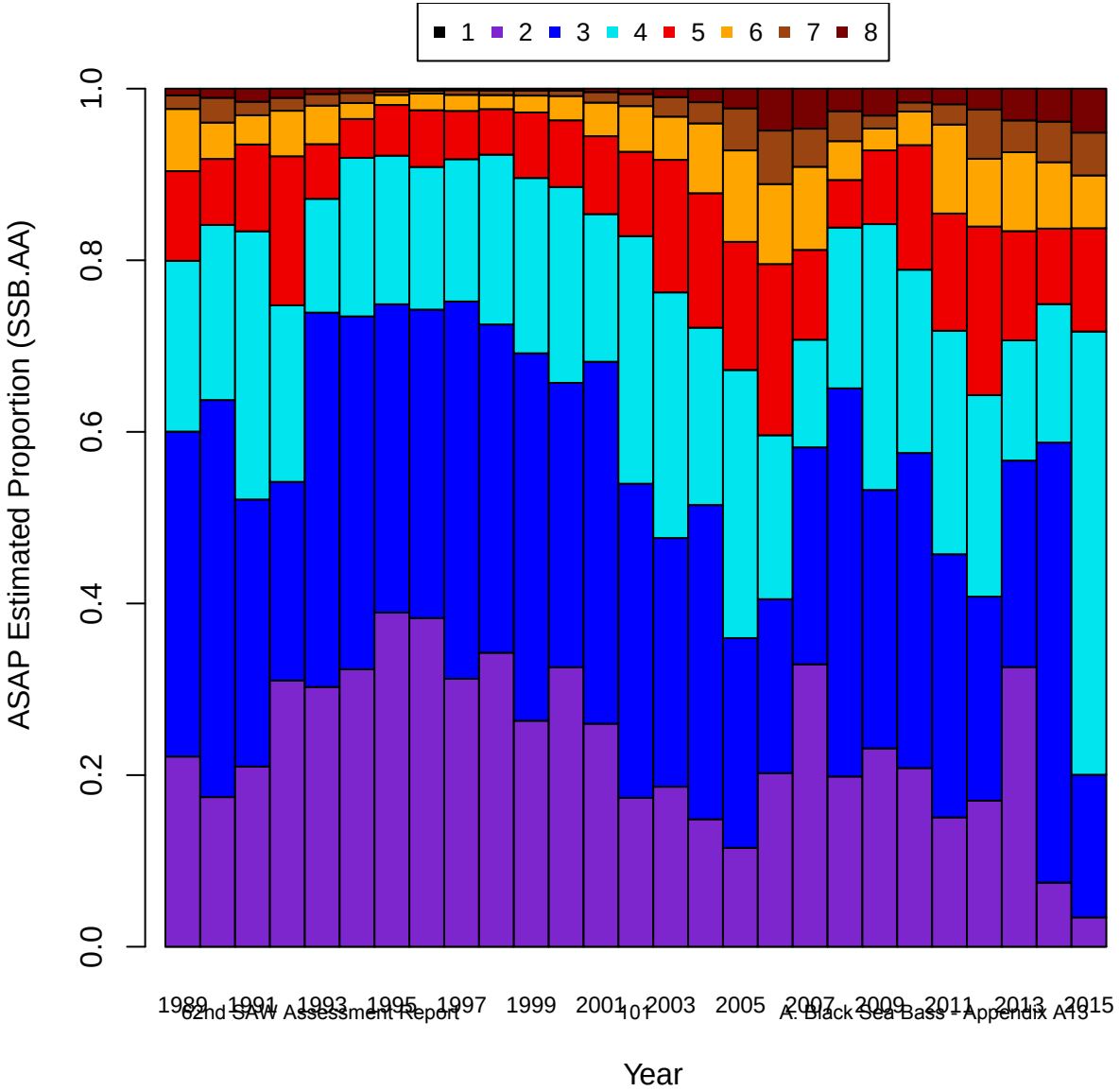

Catchability (q +/− 2 SE)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
SC spring Alb
NEAMAP
MADMF
RI
CT
NY
REC CPA
BIGELOW

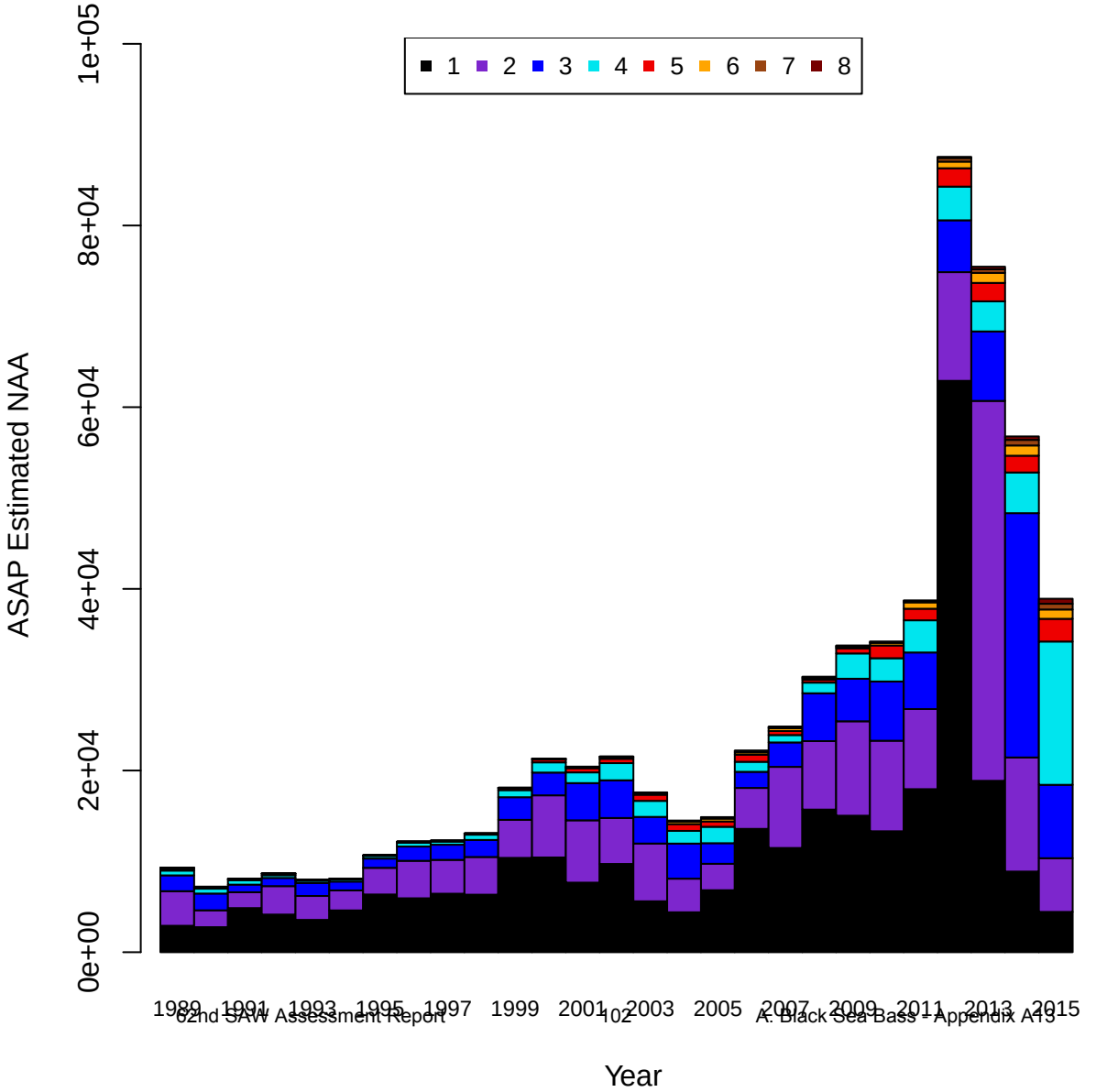

SSB
0
5000
15000
1990
1995
2000
2005
2010
2015
Year

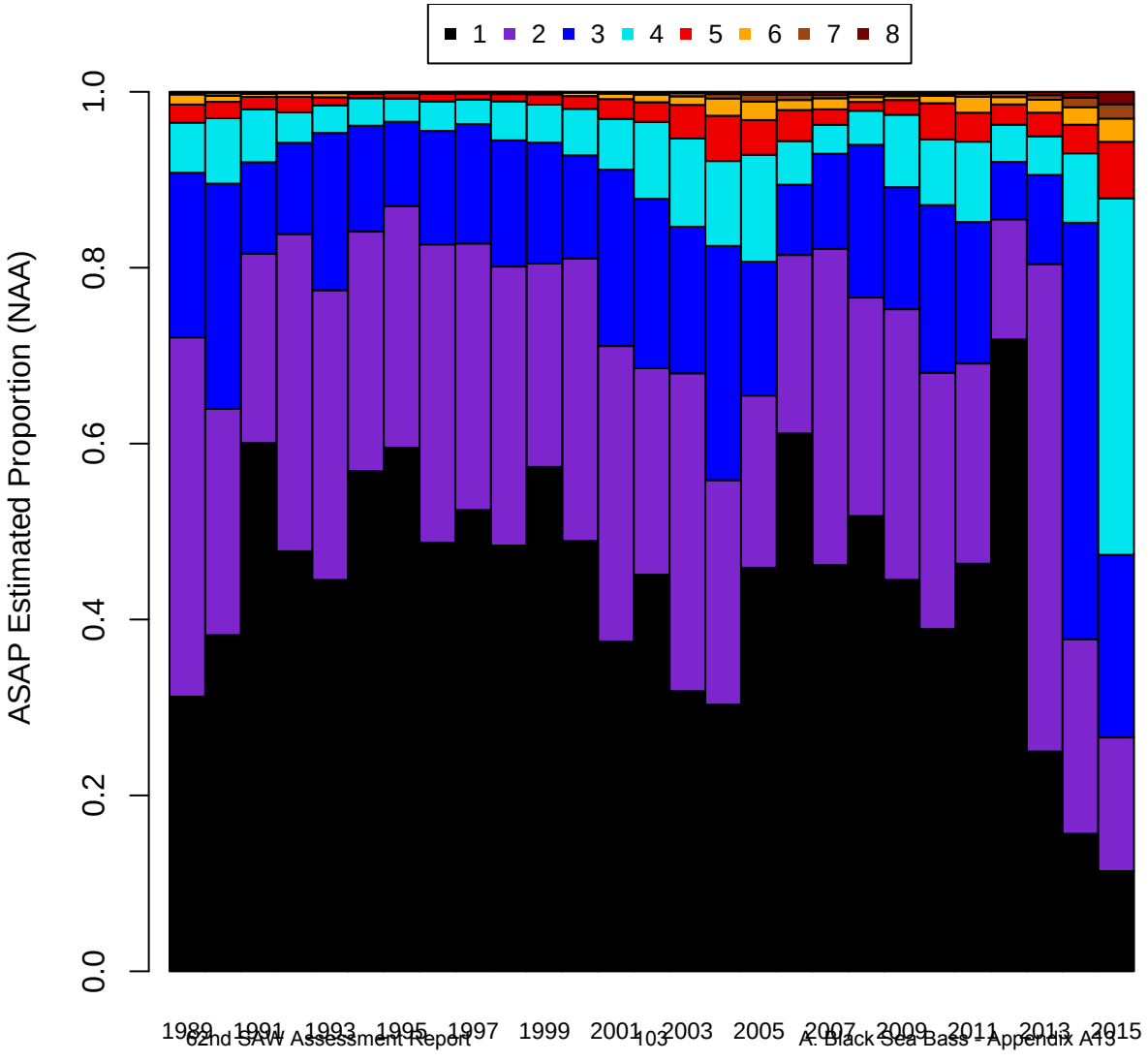

F.report
F.full
Fishing Mortality
0.0
0.5
1.0
1.5
1990
1995
2000
2005
2010
2015
Year

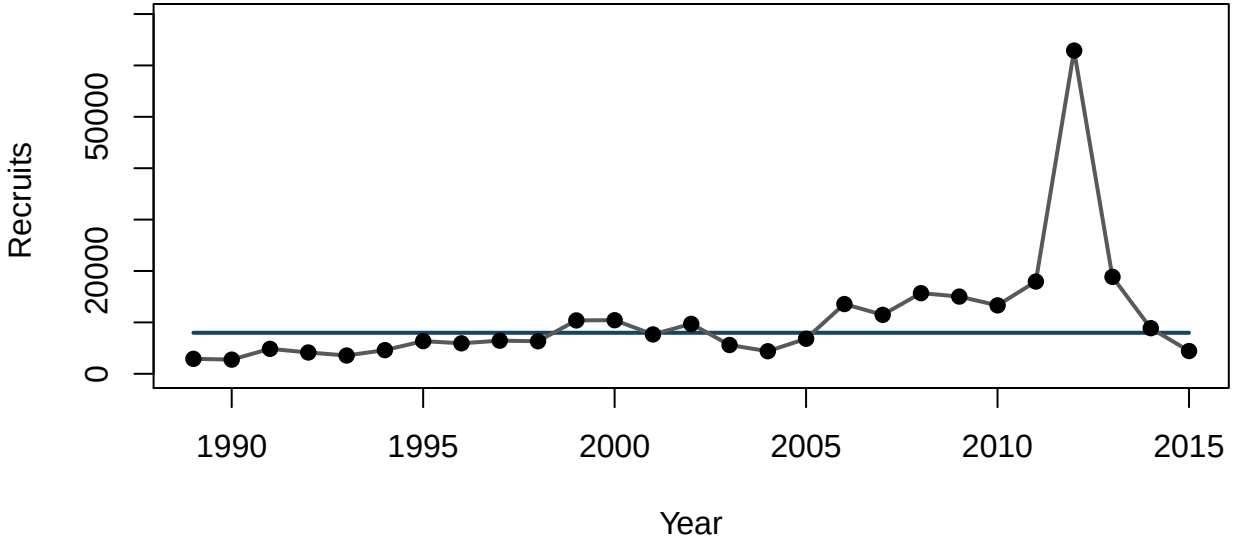

Comparison of January 1 Biomass
Total
SSB
Exploitable
Biomass
0
5000
10000
15000
20000
25000
30000
1990
1995
2000
2005
2010
2015
Year

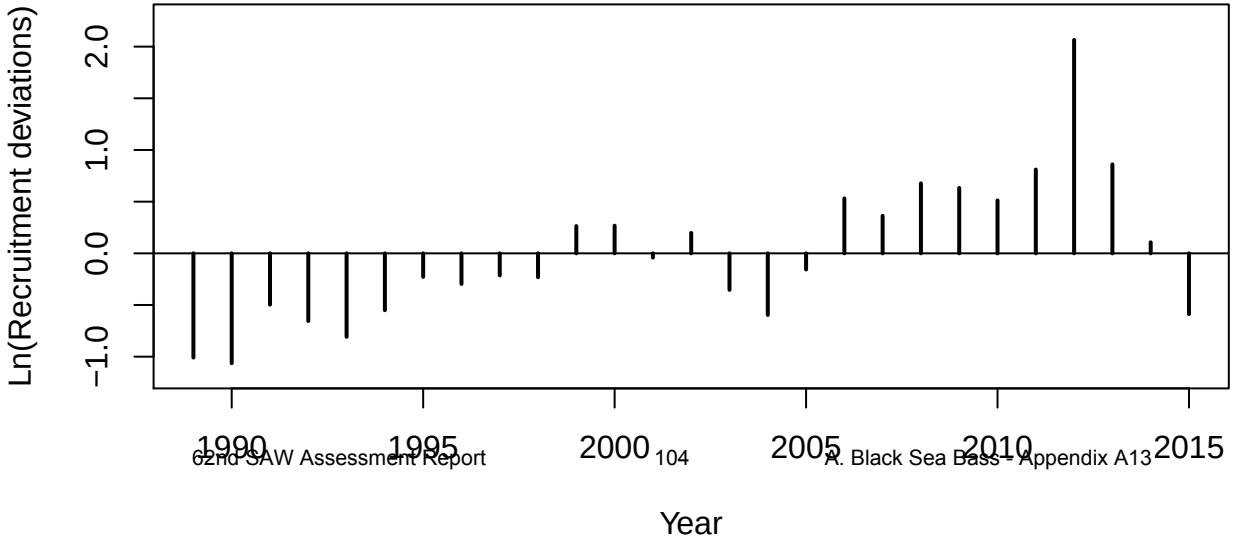

1 2 3 4 5 6 7 8
ASAP Estimated SSB.AA
0
5000
10000
15000
20000
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

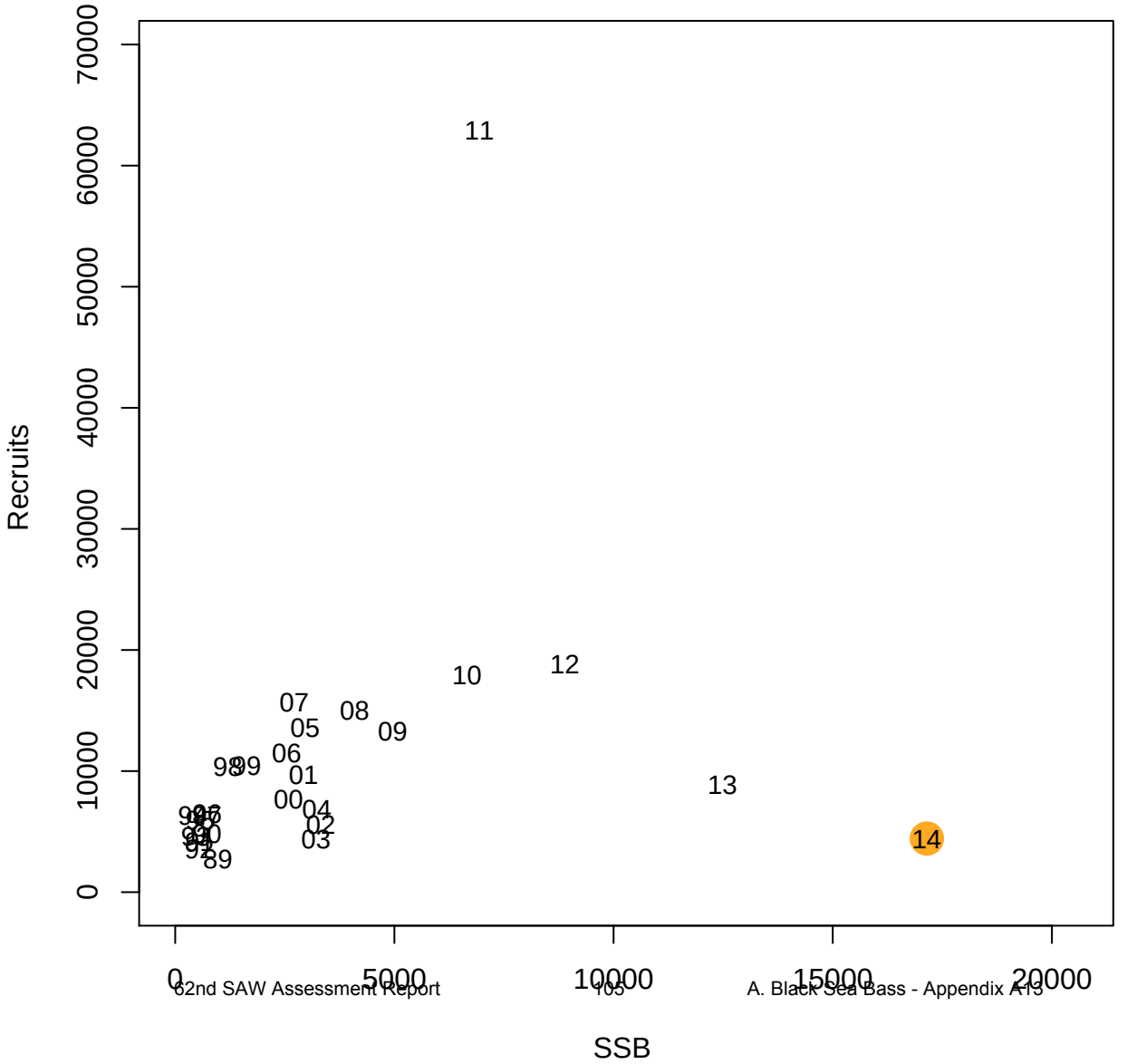

1 2 3 4 5 6 7 8
ASAP Estimated Proportion (SSB.AA)
0.0
0.2
0.4
0.6
0.8
1.0
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

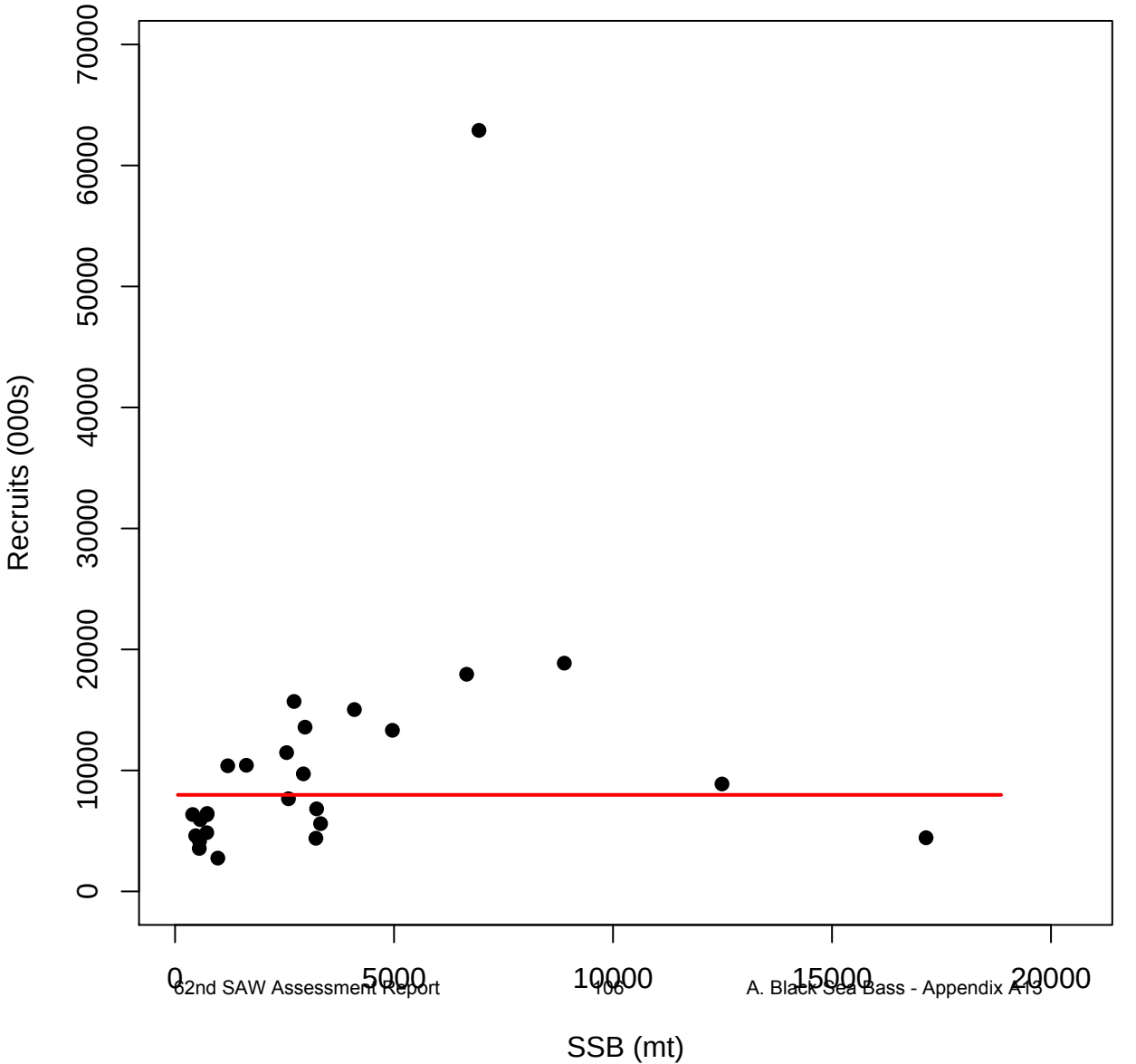

1 2 3 4 5 6 7 8
ASAP Estimated NAA
0e+00
2e+04
4e+04
6e+04
8e+04
1e+05
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

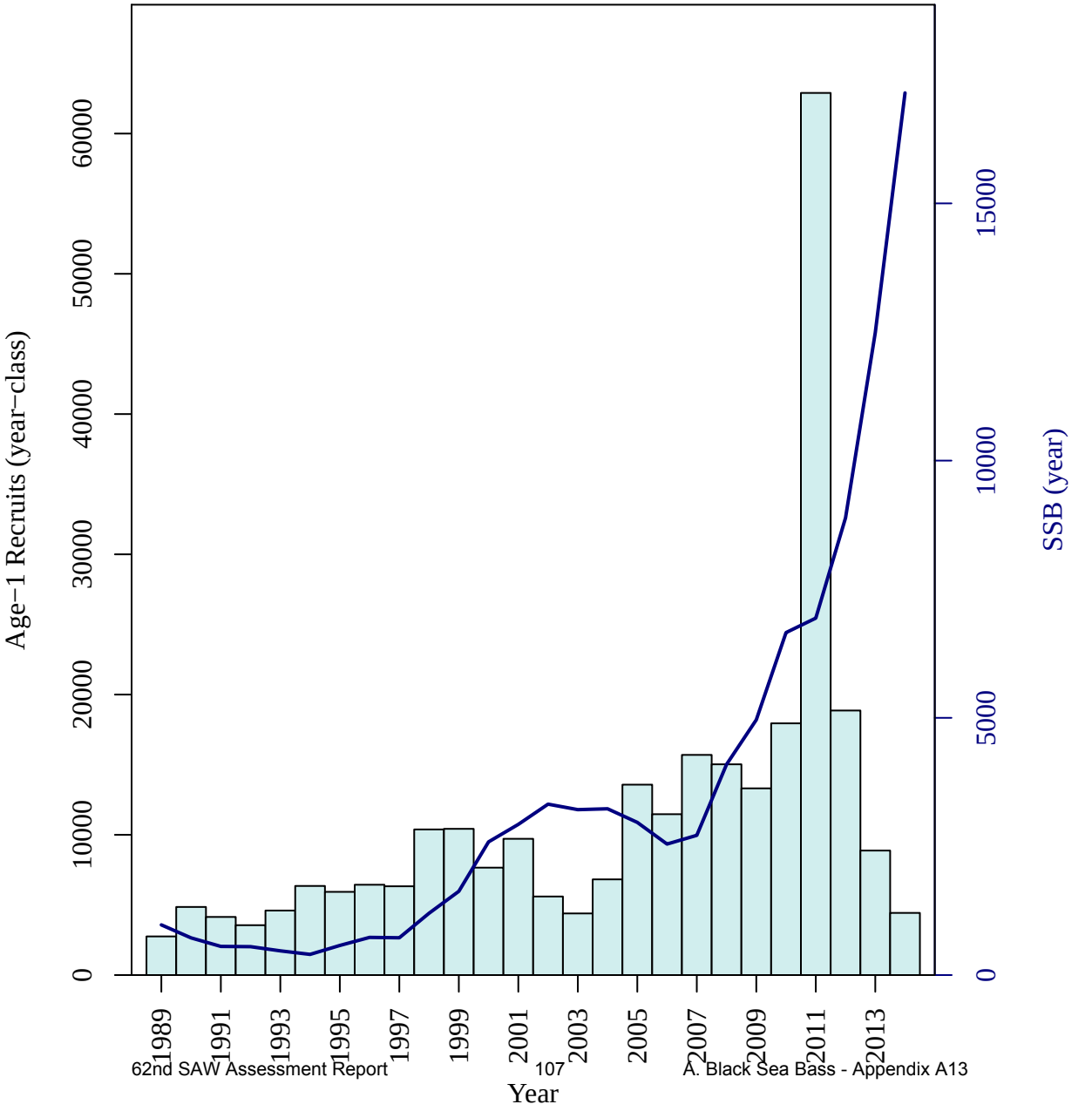

1 2 3 4 5 6 7 8
ASAP Estimated Proportion (NAA)
0.0
0.2
0.4
0.6
0.8
1.0
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

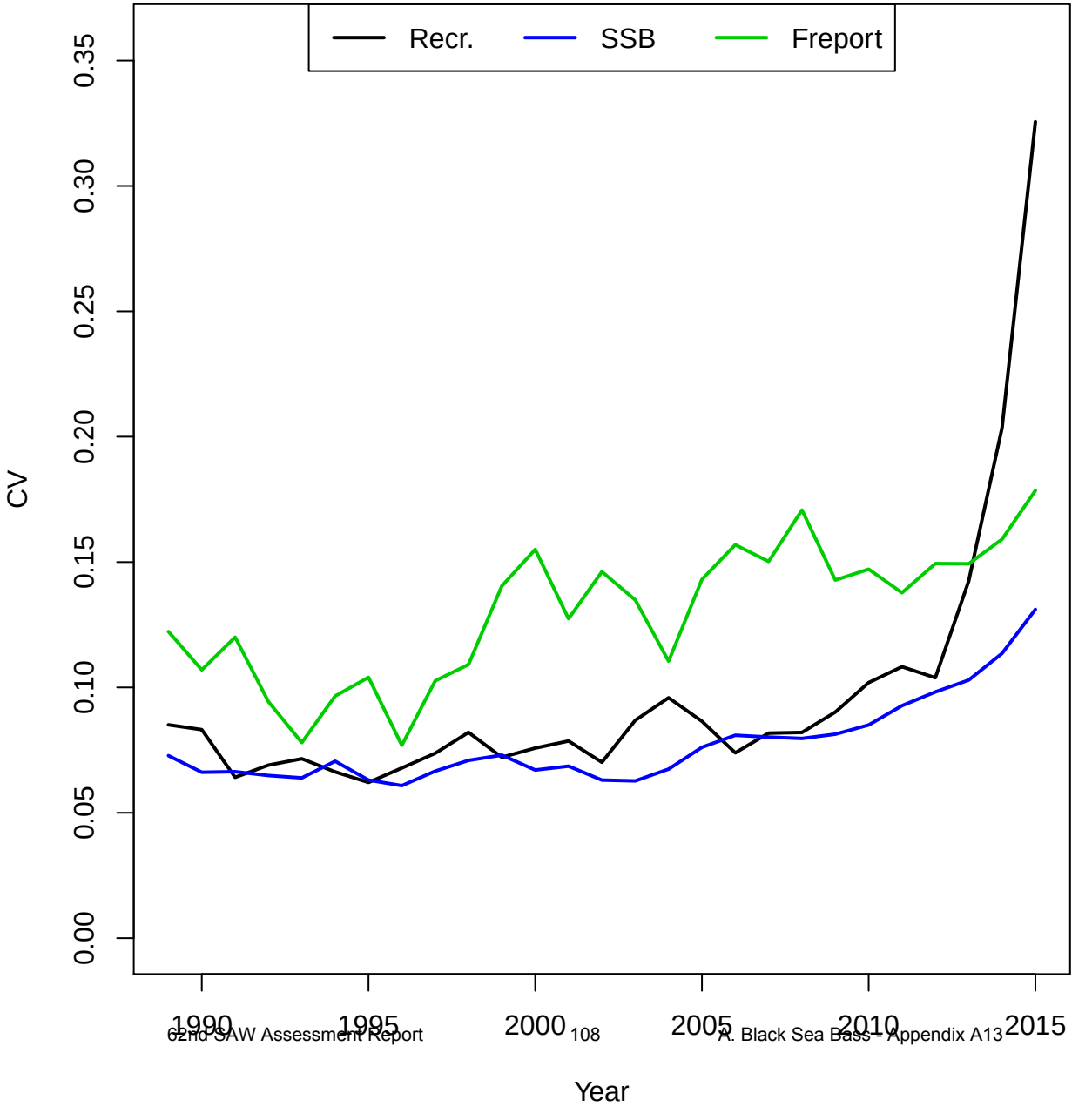

Recruits
0
20000
50000
1990
1995
2000
2005
2010
2015
Year

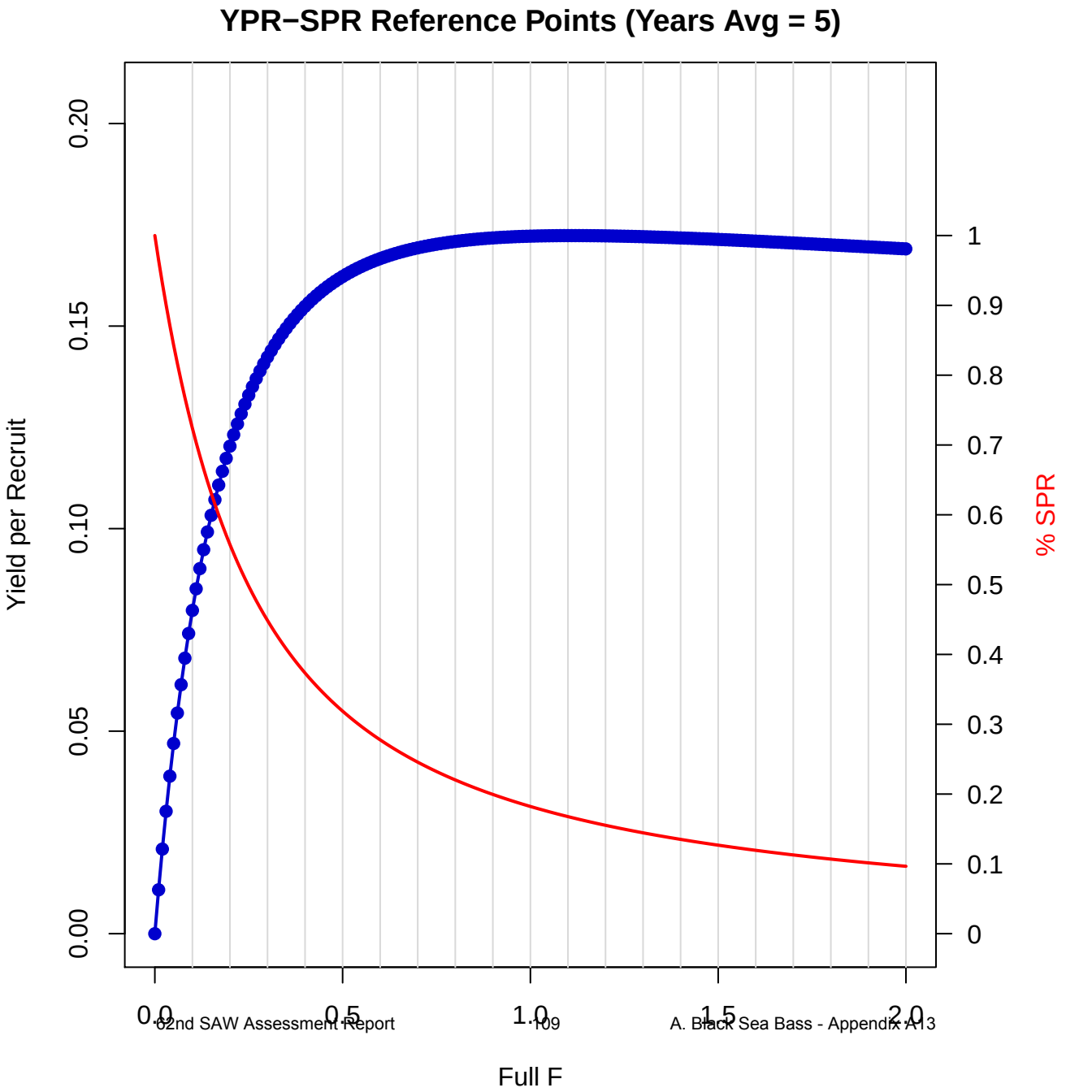

Ln(Recruitment deviations)
−1.0
0.0
1.0
2.0
1990
1995
2000
2005
2010
2015
Year


Recruits
SSB
0
10000
20000
30000
40000
50000
60000
70000
0
5000
10000
15000
20000
11
12
10
07
08
05
09
06
01
13
00
04
02
03
14
89


Recruits (000s)
0
10000
20000
30000
40000
50000
60000
70000
0
5000
10000
15000
20000
SSB (mt)

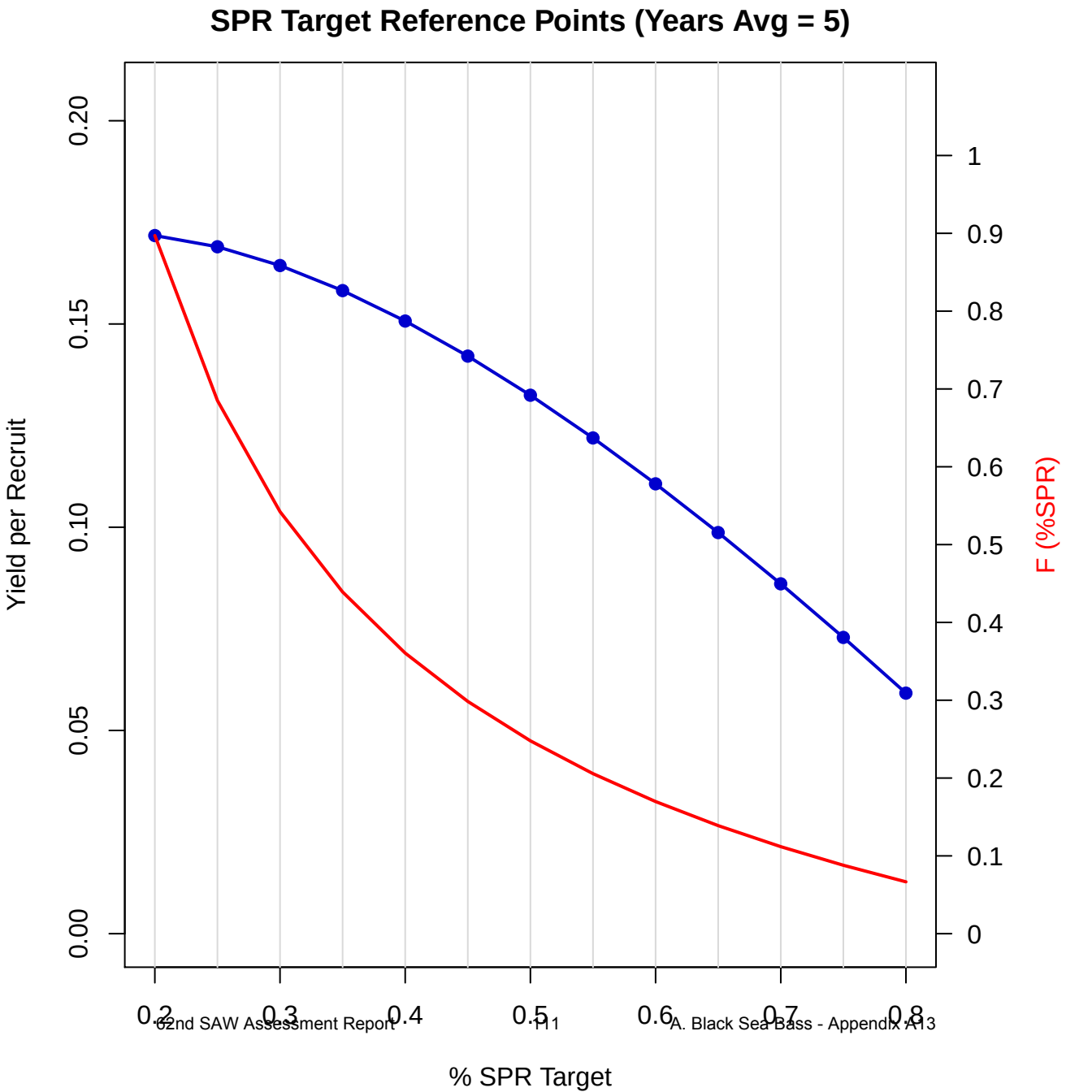

Age−1 Recruits (year−class)
0
10000
20000
30000
40000
50000
60000
SSB (year)
0
5000
10000
15000
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Year


Recr.
SSB
Freport
CV
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
1990
1995
2000
2005
2010
2015
Year


YPR−SPR Reference Points (Years Avg = 5)
Yield per Recruit
% SPR
Full F
0.00
0.05
0.10
0.15
0.20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.0
0.5
1.0
1.5
2.0

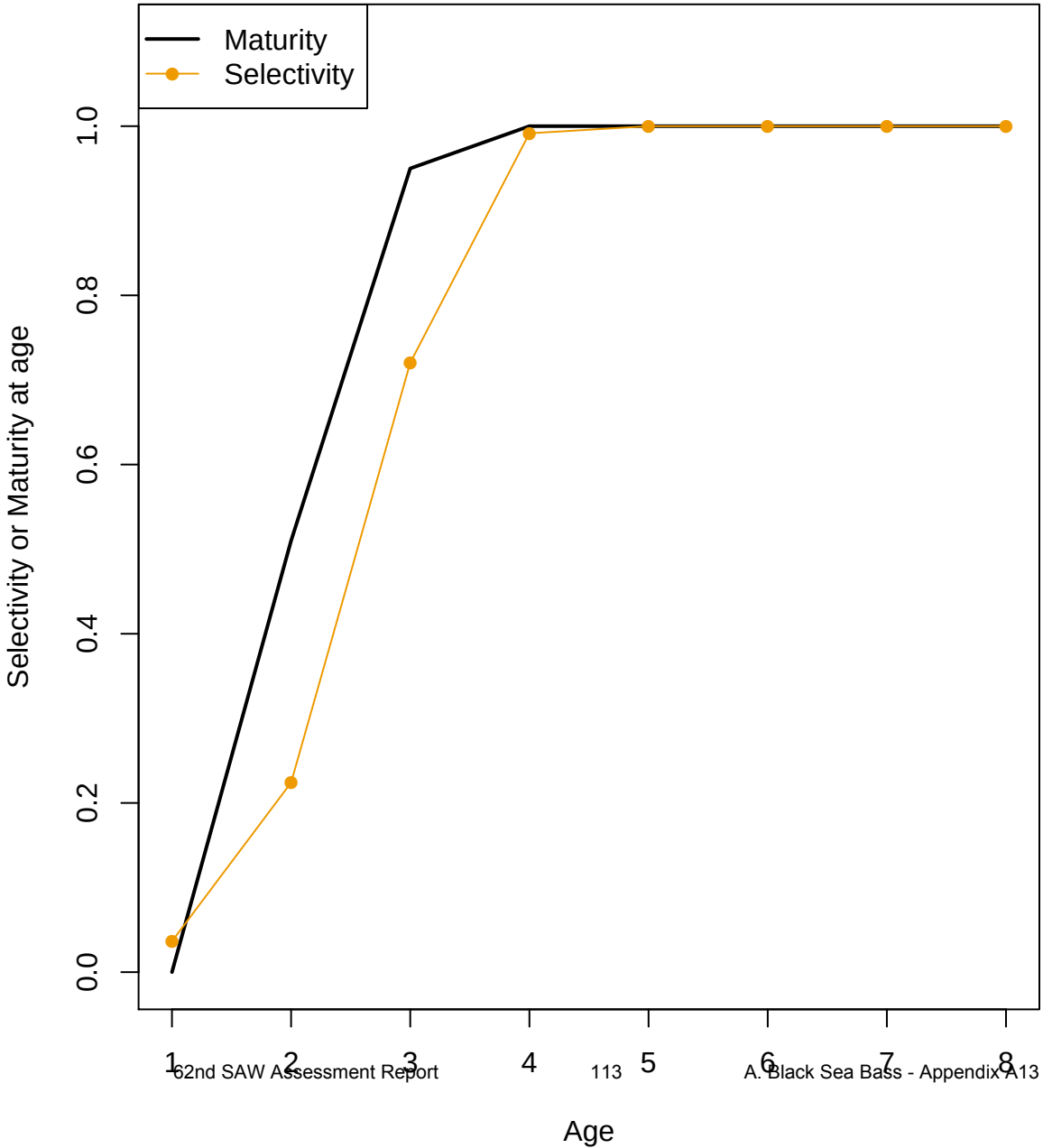
YPR−SPR Reference Points (Years Avg = 5)

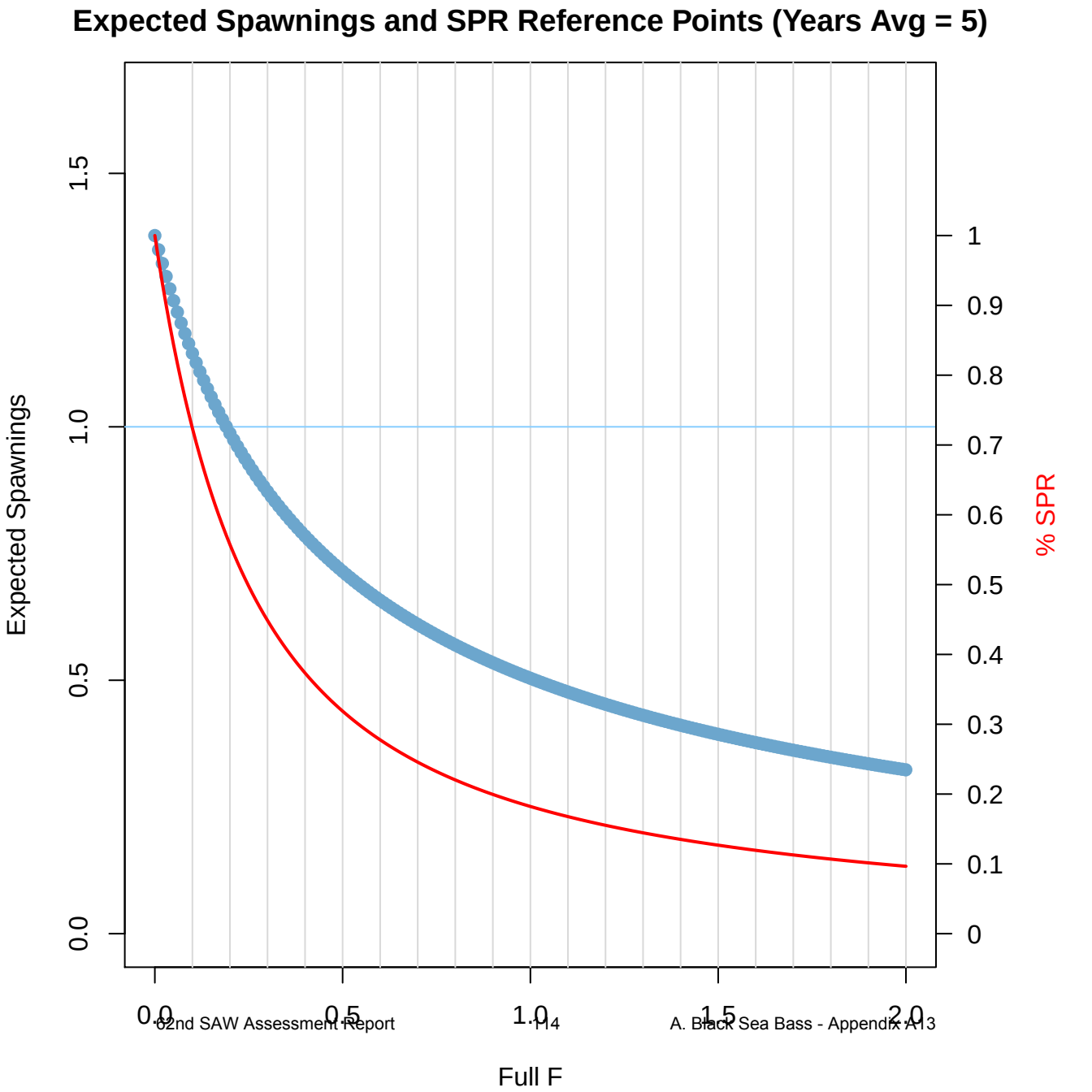
F	YPR	SPR	F	YPR	SPR	F	YPR	SPR
0	0	1	0.35	0.1495	0.4078	0.7	0.1693	0.2457
0.01	0.0108	0.9649	0.36	0.1507	0.4004	0.71	0.1695	0.2429
0.02	0.0209	0.9318	0.37	0.1518	0.3933	0.72	0.1697	0.2401
0.03	0.0302	0.9006	0.38	0.1529	0.3864	0.73	0.1699	0.2375
0.04	0.0389	0.8711	0.39	0.1539	0.3798	0.74	0.17	0.2348
0.05	0.047	0.8432	0.4	0.1549	0.3733	0.75	0.1702	0.2323
0.06	0.0545	0.8168	0.41	0.1558	0.3671	0.76	0.1704	0.2298
0.07	0.0615	0.7917	0.42	0.1567	0.361	0.77	0.1705	0.2273
0.08	0.068	0.768	0.43	0.1575	0.3552	0.78	0.1706	0.2249
0.09	0.0741	0.7454	0.44	0.1583	0.3495	0.79	0.1708	0.2225
0.1	0.0798	0.724	0.45	0.159	0.344	0.8	0.1709	0.2202
0.11	0.0851	0.7036	0.46	0.1597	0.3386	0.81	0.171	0.218
0.12	0.0901	0.6842	0.47	0.1604	0.3335	0.82	0.1711	0.2157
0.13	0.0948	0.6657	0.48	0.1611	0.3284	0.83	0.1712	0.2136
0.14	0.0992	0.648	0.49	0.1617	0.3235	0.84	0.1713	0.2114
0.15	0.1033	0.6312	0.5	0.1622	0.3187	0.85	0.1714	0.2093
0.16	0.1071	0.6151	0.51	0.1628	0.3141	0.86	0.1715	0.2073
0.17	0.1108	0.5997	0.52	0.1633	0.3096	0.87	0.1716	0.2053
0.18	0.1142	0.585	0.53	0.1638	0.3052	0.88	0.1716	0.2033
0.19	0.1173	0.5709	0.54	0.1643	0.301	0.89	0.1717	0.2014
0.2	0.1203	0.5574	0.55	0.1647	0.2968	0.9	0.1718	0.1995
0.21	0.1232	0.5444	0.56	0.1652	0.2928	0.91	0.1718	0.1976
0.22	0.1258	0.532	0.57	0.1656	0.2888	0.92	0.1719	0.1958
0.23	0.1283	0.5201	0.58	0.1659	0.285	0.93	0.1719	0.194
0.24	0.1307	0.5087	0.59	0.1663	0.2813	0.94	0.172	0.1922
0.25	0.1329	0.4977	0.6	0.1667	0.2776	0.95	0.172	0.1905
0.26	0.135	0.4871	0.61	0.167	0.2741	0.96	0.1721	0.1888
0.27	0.137	0.4769	0.62	0.1673	0.2706	0.97	0.1721	0.1871
0.28	0.1389	0.4671	0.63	0.1676	0.2672	0.98	0.1722	0.1854
0.29	0.1407	0.4577	0.64	0.1679	0.2639	0.99	0.1722	0.1838
0.3	0.1424	0.4486	0.65	0.1682	0.2607	1	0.1722	0.1822
0.31	0.1439	0.4399	0.66	0.1684	0.2576	1.01	0.1722	0.1807
0.32	0.1454	0.4314	0.67	0.1687	0.2545	1.02	0.1723	0.1791
0.33	0.1468	0.4232	0.68	0.1689	0.2515	1.03	0.1723	0.1776
0.34	0.1482	0.4154	0.69	0.1691	0.2486	1.04	0.1723	0.1761


SPR Target Reference Points (Years Avg = 5)
Yield per Recruit
0.00
0.05
0.10
0.15
0.20
F (%SPR)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
% SPR Target

SPR Target Reference Points (Years Avg = 5)

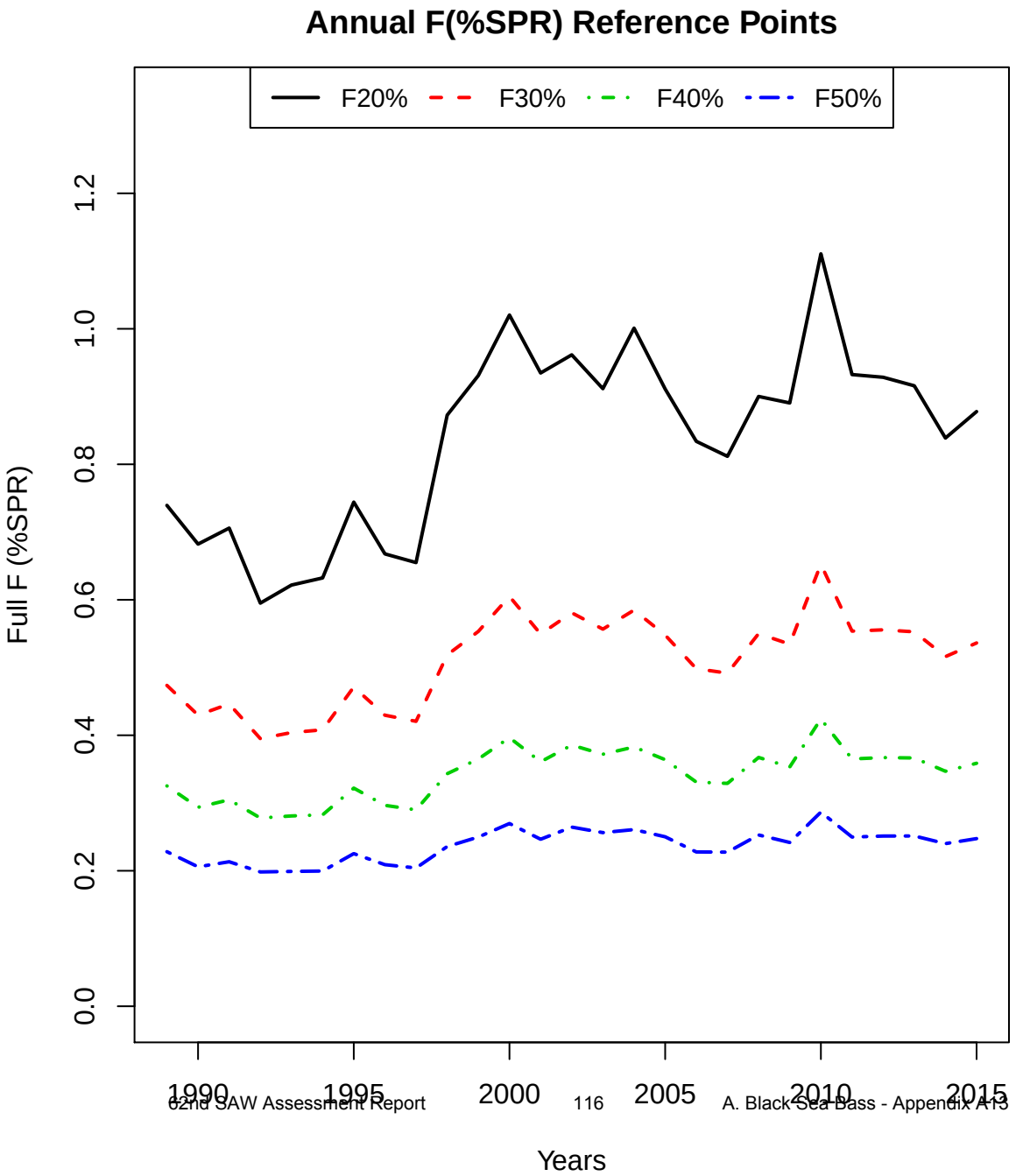
% SPR	F(%SPR)	YPR
0.2	0.8971	0.1718
0.25	0.6851	0.169
0.3	0.5423	0.1644
0.35	0.4391	0.1582
0.4	0.3606	0.1507
0.45	0.2985	0.1421
0.5	0.2478	0.1325
0.55	0.2056	0.122
0.6	0.1698	0.1107
0.65	0.1388	0.0987
0.7	0.1118	0.0861
0.75	0.0879	0.0729
0.8	0.0666	0.0592

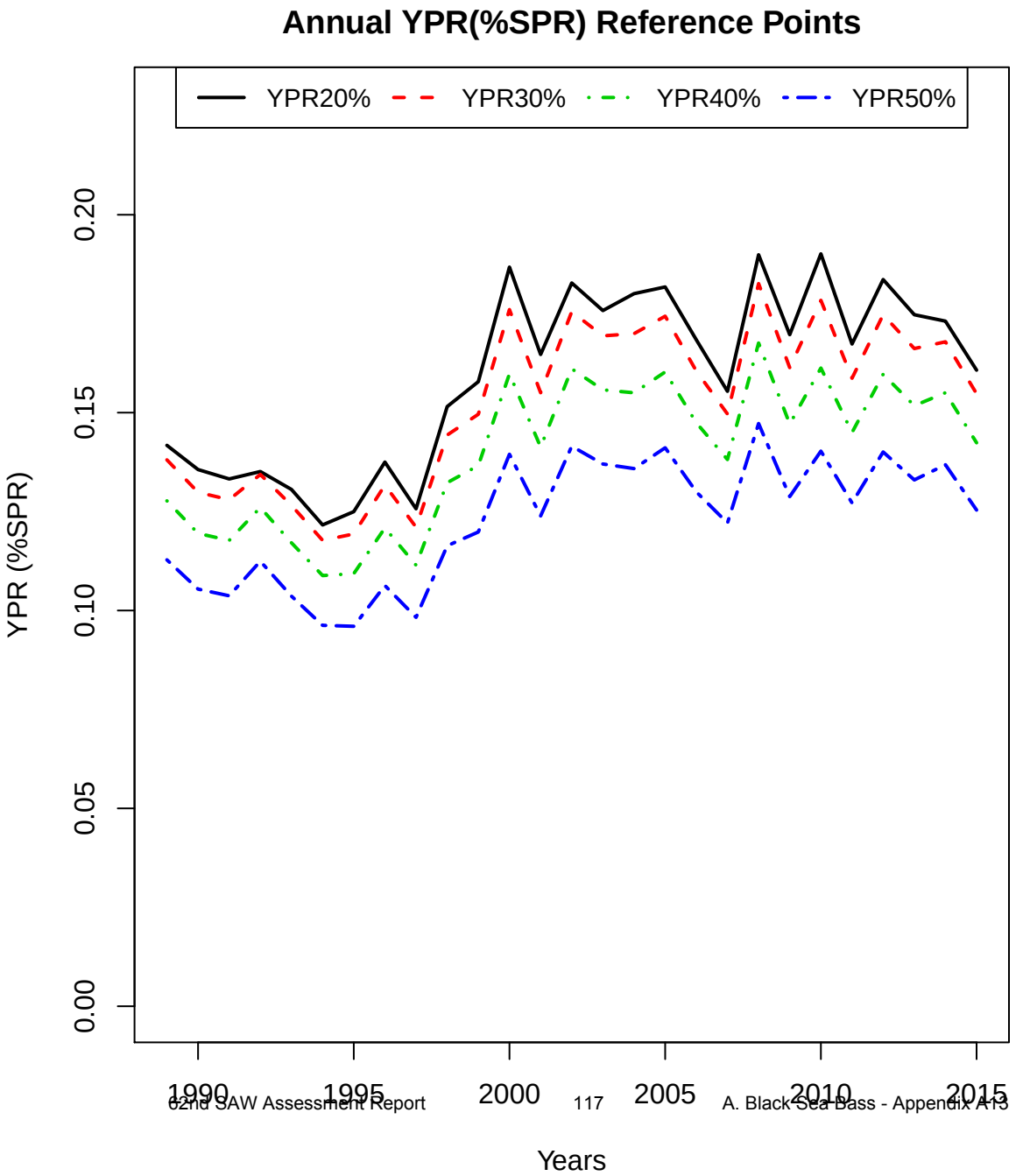

Maturity
Selectivity
Selectivity or Maturity at age
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
8
Age


Expected Spawnings and SPR Reference Points (Years Avg = 5)
Expected Spawnings
% SPR
Full F
0.0
0.5
1.0
1.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.0
0.5
1.0
1.5
2.0

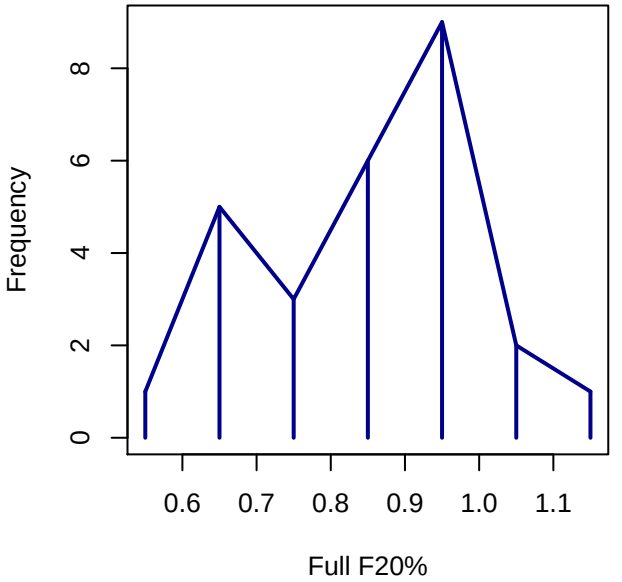
Expected Spawnings & SPR Reference Points (Years Avg = 5)

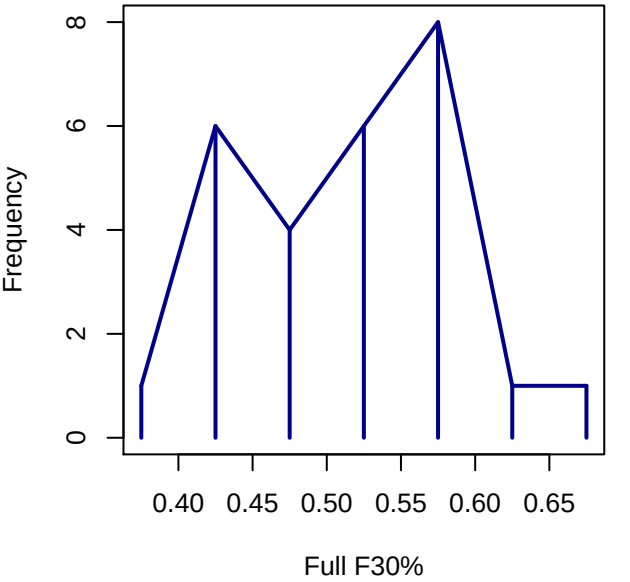
F	E[Sp]	SPR	F	E[Sp]	SPR	F	E[Sp]	SPR
0	1.3774	1	0.35	0.8259	0.4078	0.7	0.6102	0.2457
0.01	1.3492	0.9649	0.36	0.8173	0.4004	0.71	0.6059	0.2429
0.02	1.3224	0.9318	0.37	0.8088	0.3933	0.72	0.6016	0.2401
0.03	1.2968	0.9006	0.38	0.8006	0.3864	0.73	0.5974	0.2375
0.04	1.2723	0.8711	0.39	0.7925	0.3798	0.74	0.5933	0.2348
0.05	1.2488	0.8432	0.4	0.7847	0.3733	0.75	0.5892	0.2323
0.06	1.2263	0.8168	0.41	0.777	0.3671	0.76	0.5852	0.2298
0.07	1.2048	0.7917	0.42	0.7695	0.361	0.77	0.5812	0.2273
0.08	1.1841	0.768	0.43	0.7621	0.3552	0.78	0.5773	0.2249
0.09	1.1642	0.7454	0.44	0.7549	0.3495	0.79	0.5735	0.2225
0.1	1.1451	0.724	0.45	0.7479	0.344	0.8	0.5697	0.2202
0.11	1.1266	0.7036	0.46	0.741	0.3386	0.81	0.5659	0.218
0.12	1.1089	0.6842	0.47	0.7343	0.3335	0.82	0.5623	0.2157
0.13	1.0918	0.6657	0.48	0.7277	0.3284	0.83	0.5586	0.2136
0.14	1.0753	0.648	0.49	0.7212	0.3235	0.84	0.5551	0.2114
0.15	1.0594	0.6312	0.5	0.7149	0.3187	0.85	0.5516	0.2093
0.16	1.044	0.6151	0.51	0.7087	0.3141	0.86	0.5481	0.2073
0.17	1.0292	0.5997	0.52	0.7026	0.3096	0.87	0.5447	0.2053
0.18	1.0148	0.585	0.53	0.6966	0.3052	0.88	0.5413	0.2033
0.19	1.0009	0.5709	0.54	0.6908	0.301	0.89	0.5379	0.2014
0.2	0.9874	0.5574	0.55	0.685	0.2968	0.9	0.5346	0.1995
0.21	0.9743	0.5444	0.56	0.6794	0.2928	0.91	0.5314	0.1976
0.22	0.9616	0.532	0.57	0.6739	0.2888	0.92	0.5282	0.1958
0.23	0.9494	0.5201	0.58	0.6684	0.285	0.93	0.525	0.194
0.24	0.9374	0.5087	0.59	0.6631	0.2813	0.94	0.5219	0.1922
0.25	0.9258	0.4977	0.6	0.6579	0.2776	0.95	0.5188	0.1905
0.26	0.9146	0.4871	0.61	0.6527	0.2741	0.96	0.5158	0.1888
0.27	0.9036	0.4769	0.62	0.6477	0.2706	0.97	0.5128	0.1871
0.28	0.893	0.4671	0.63	0.6427	0.2672	0.98	0.5098	0.1854
0.29	0.8826	0.4577	0.64	0.6378	0.2639	0.99	0.5069	0.1838
0.3	0.8726	0.4486	0.65	0.633	0.2607	1	0.504	0.1822
0.31	0.8627	0.4399	0.66	0.6283	0.2576	1.01	0.5012	0.1807
0.32	0.8532	0.4314	0.67	0.6237	0.2545	1.02	0.4983	0.1791
0.33	0.8439	0.4232	0.68	0.6191	0.2515	1.03	0.4955	0.1776
0.34	0.8348	0.4154	0.69	0.6146	0.2486	1.04	0.4928	0.1761

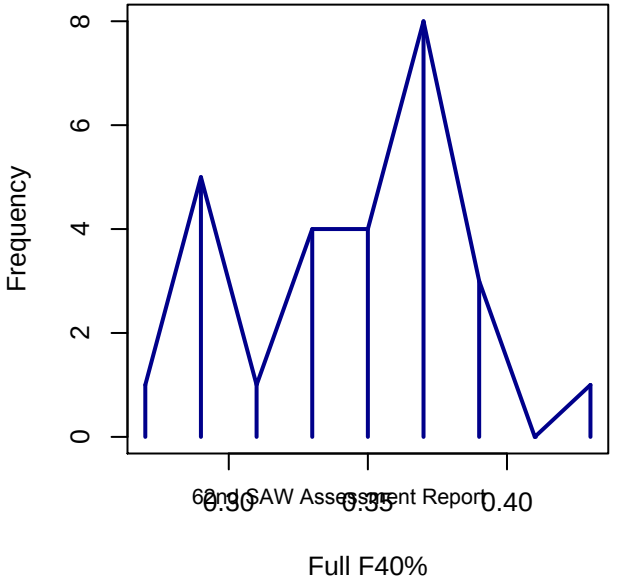

Annual F(%SPR) Reference Points
F20%
F30%
F40%
F50%
Full F (%SPR)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1990
1995
2000
2005
2010
2015
Years

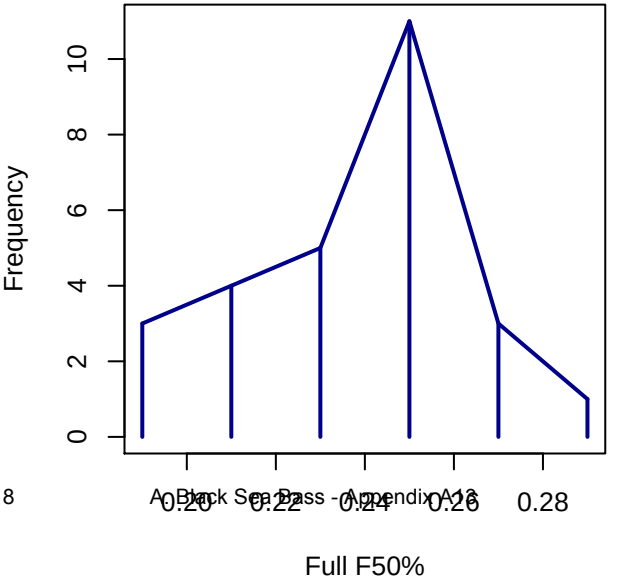

Annual YPR(%SPR) Reference Points
YPR20%
YPR30%
YPR40%
YPR50%
YPR (%SPR)
0.00
0.05
0.10
0.15
0.20
1990
1995
2000
2005
2010
2015
Years

Annual F (%SPR) Reference Points

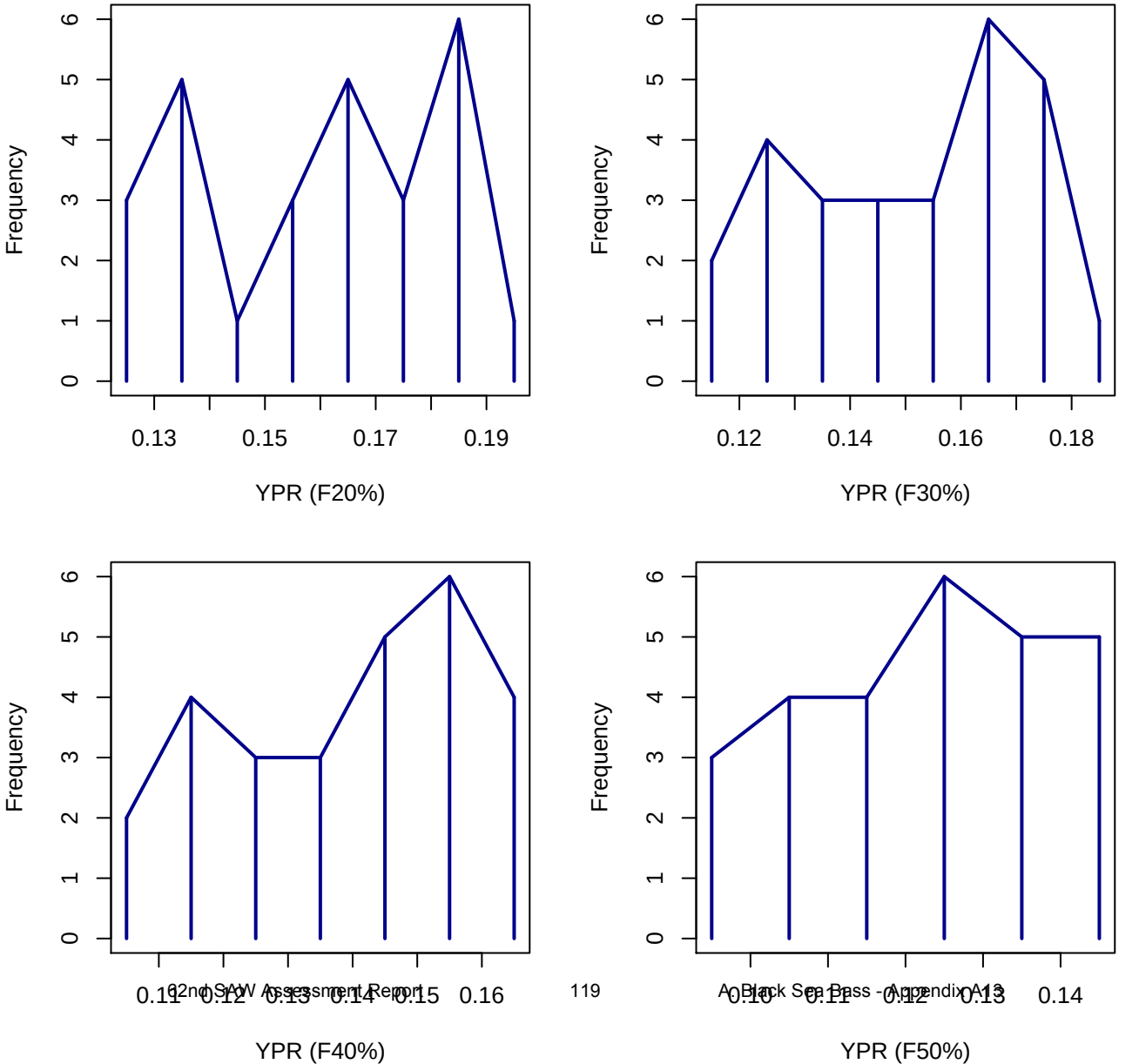


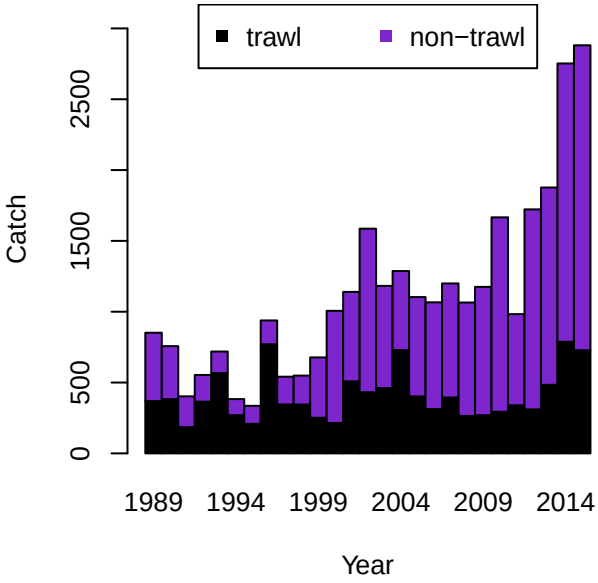


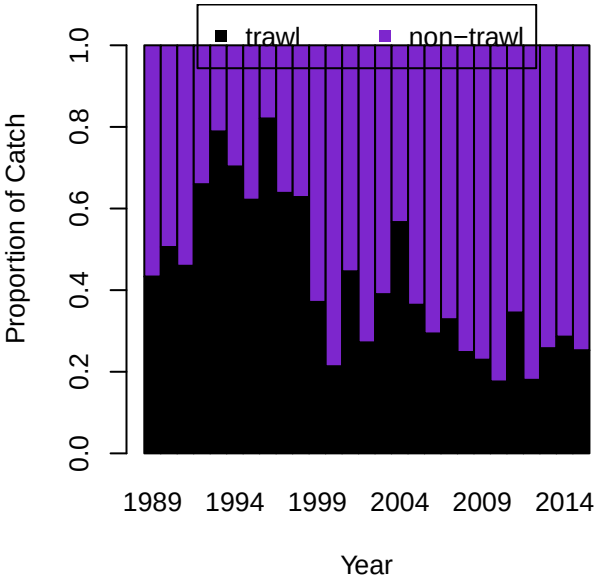




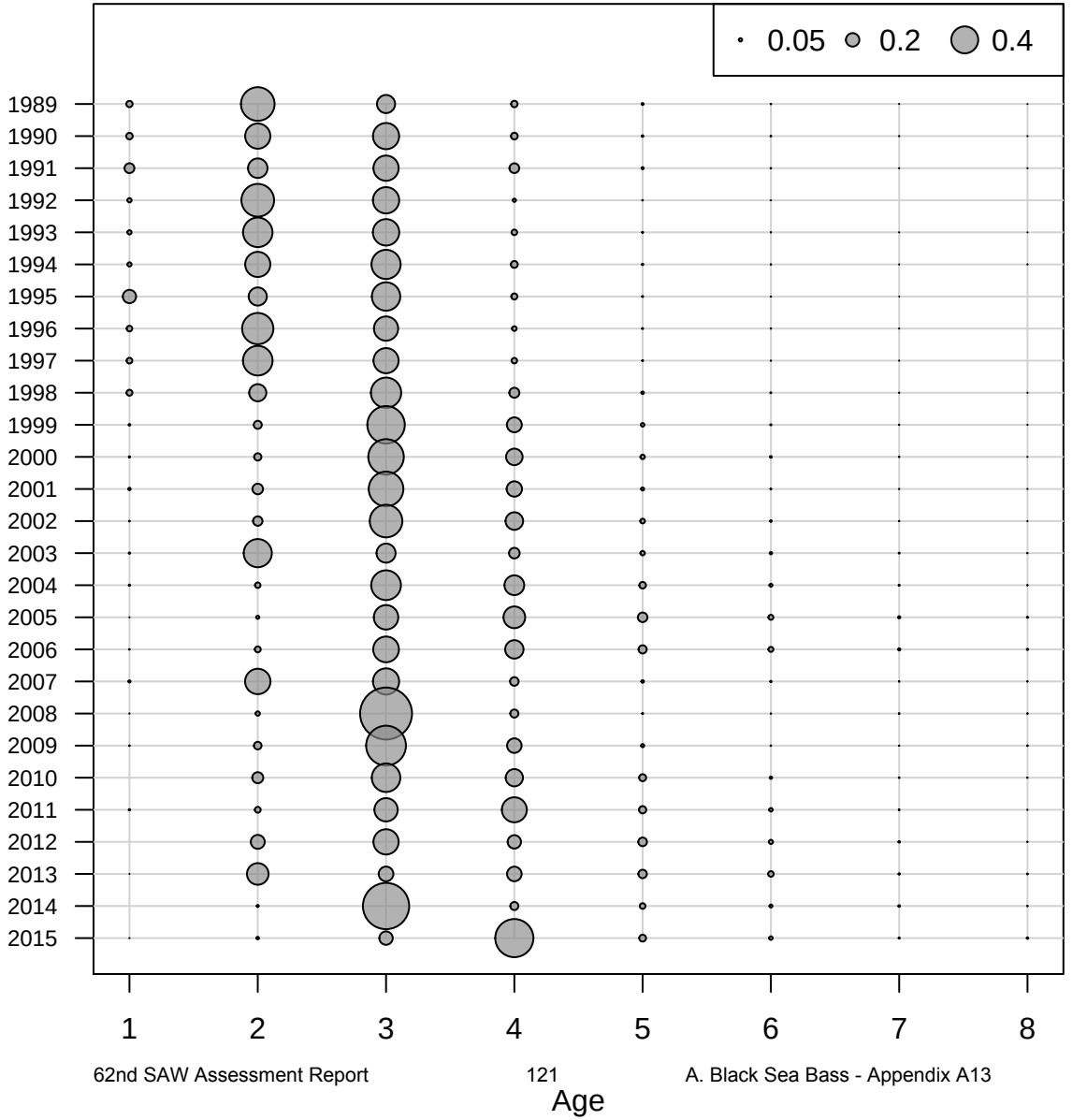
Annual YPR (%SPR) Reference Points

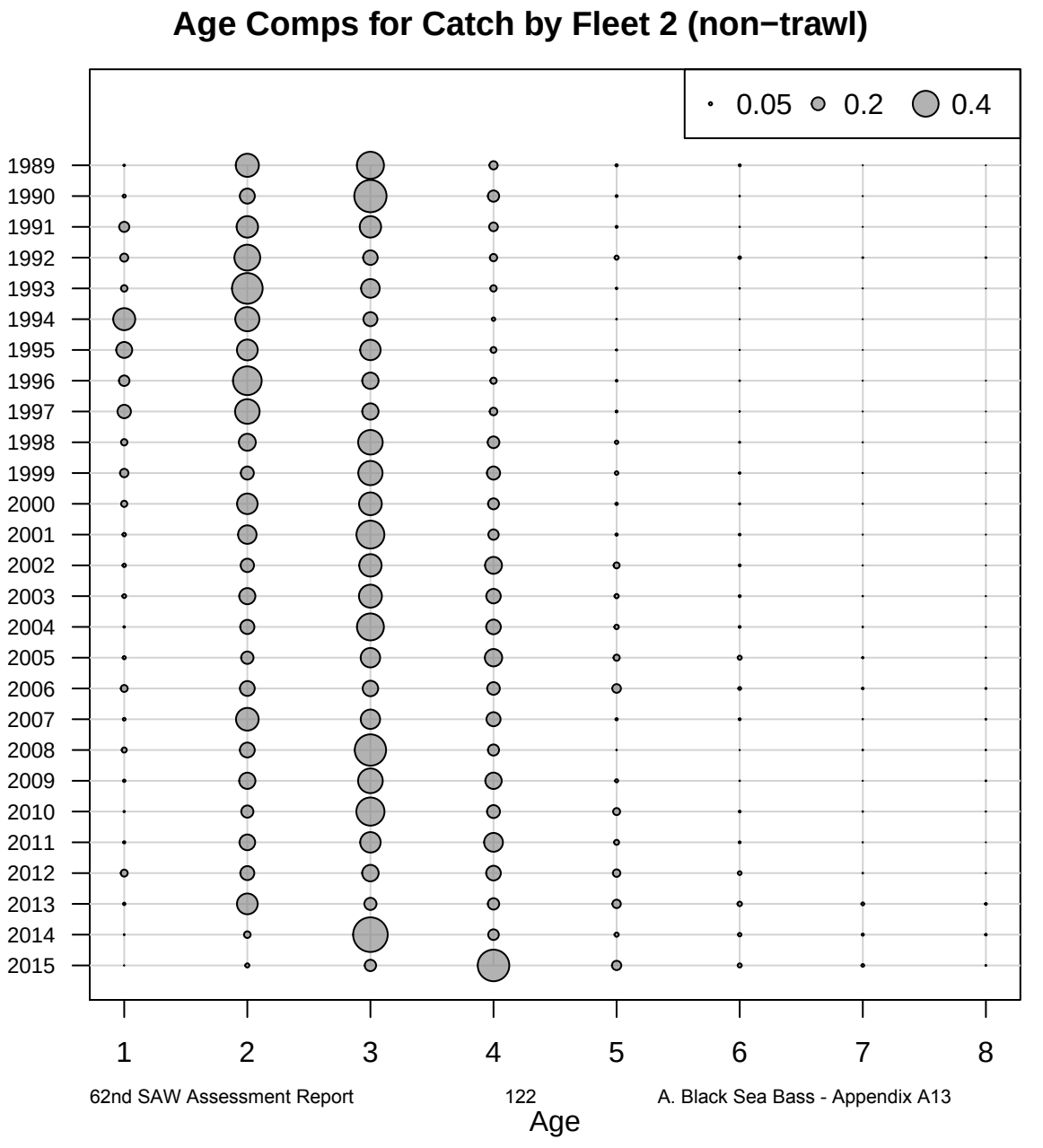


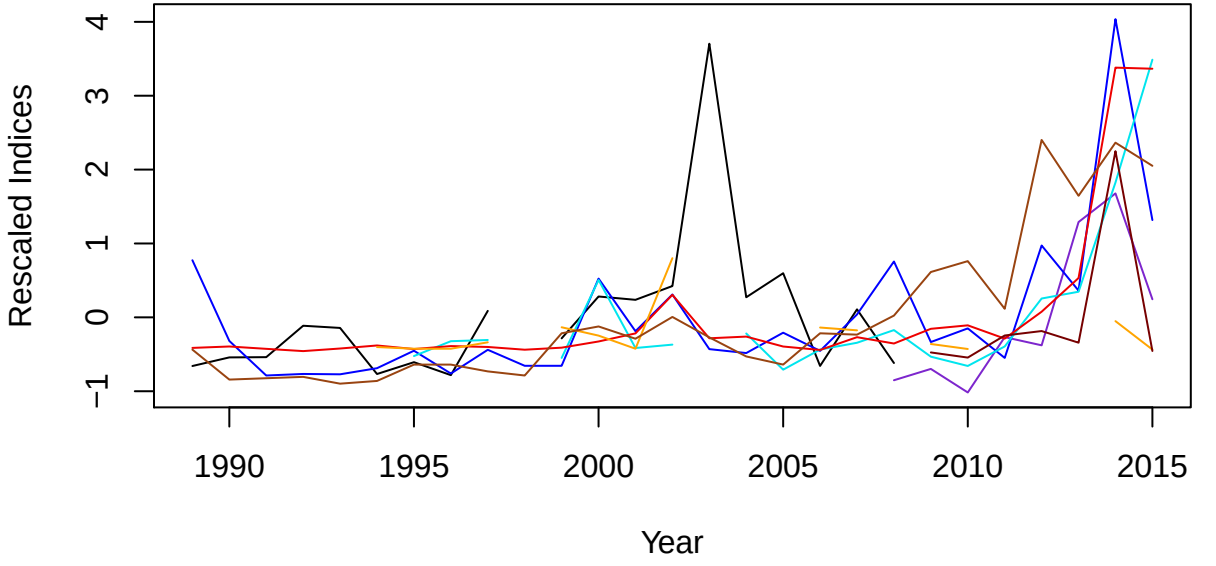

trawl
non−trawl
Catch
0
500
1500
2500
1989
1994
1999
2004
2009
2014
Year

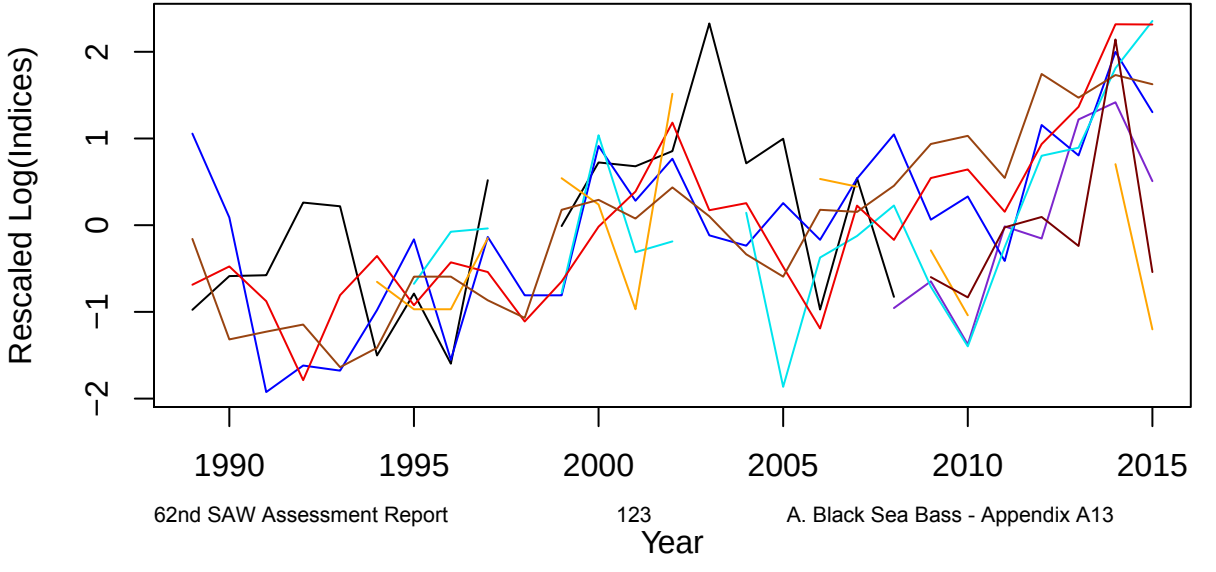

trawl
non−trawl
Proportion of Catch
0.0
0.2
0.4
0.6
0.8
1.0
1989
1994
1999
2004
2009
2014
Year

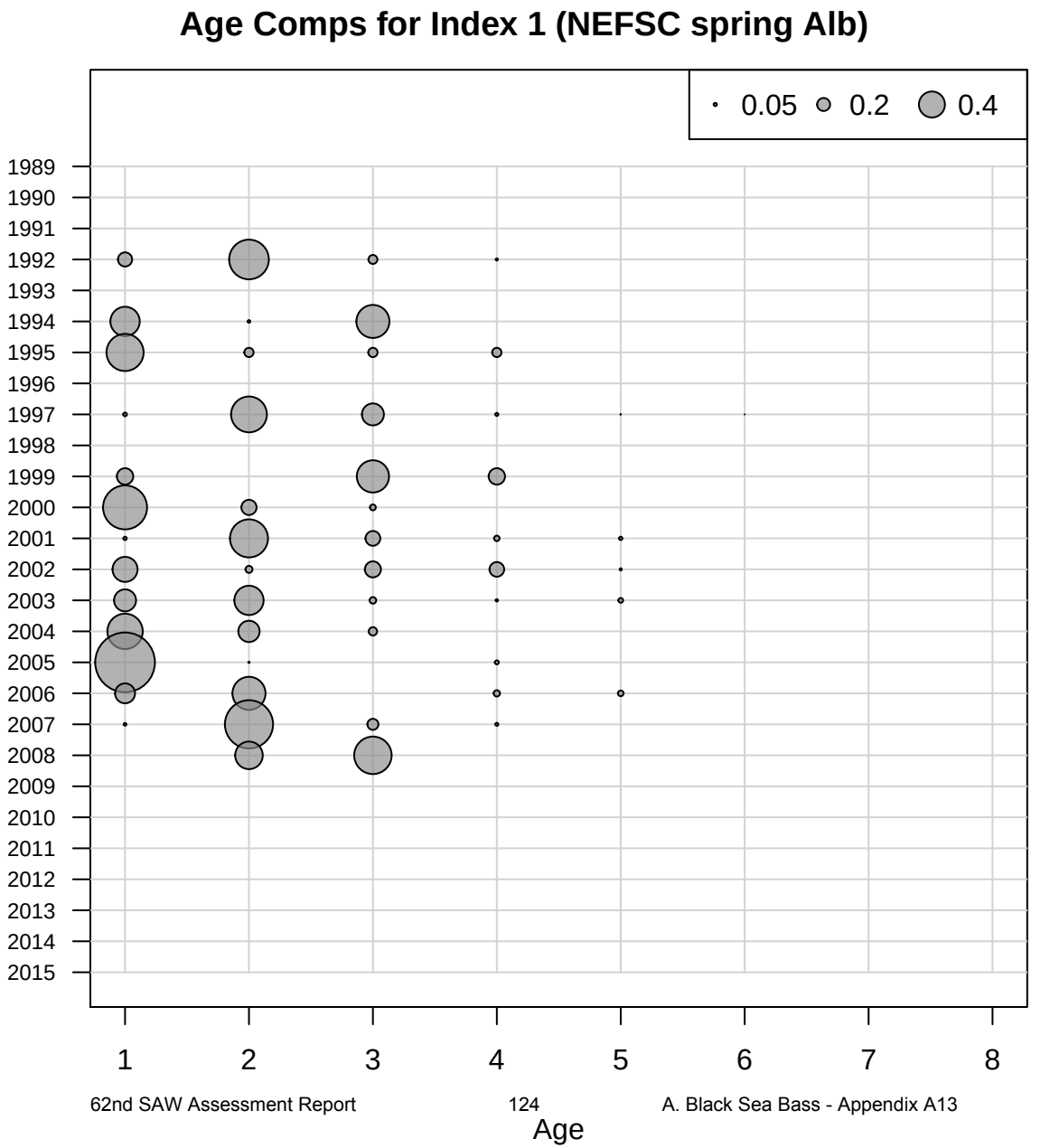
Age Comps for Catch by Fleet 1 (trawl)



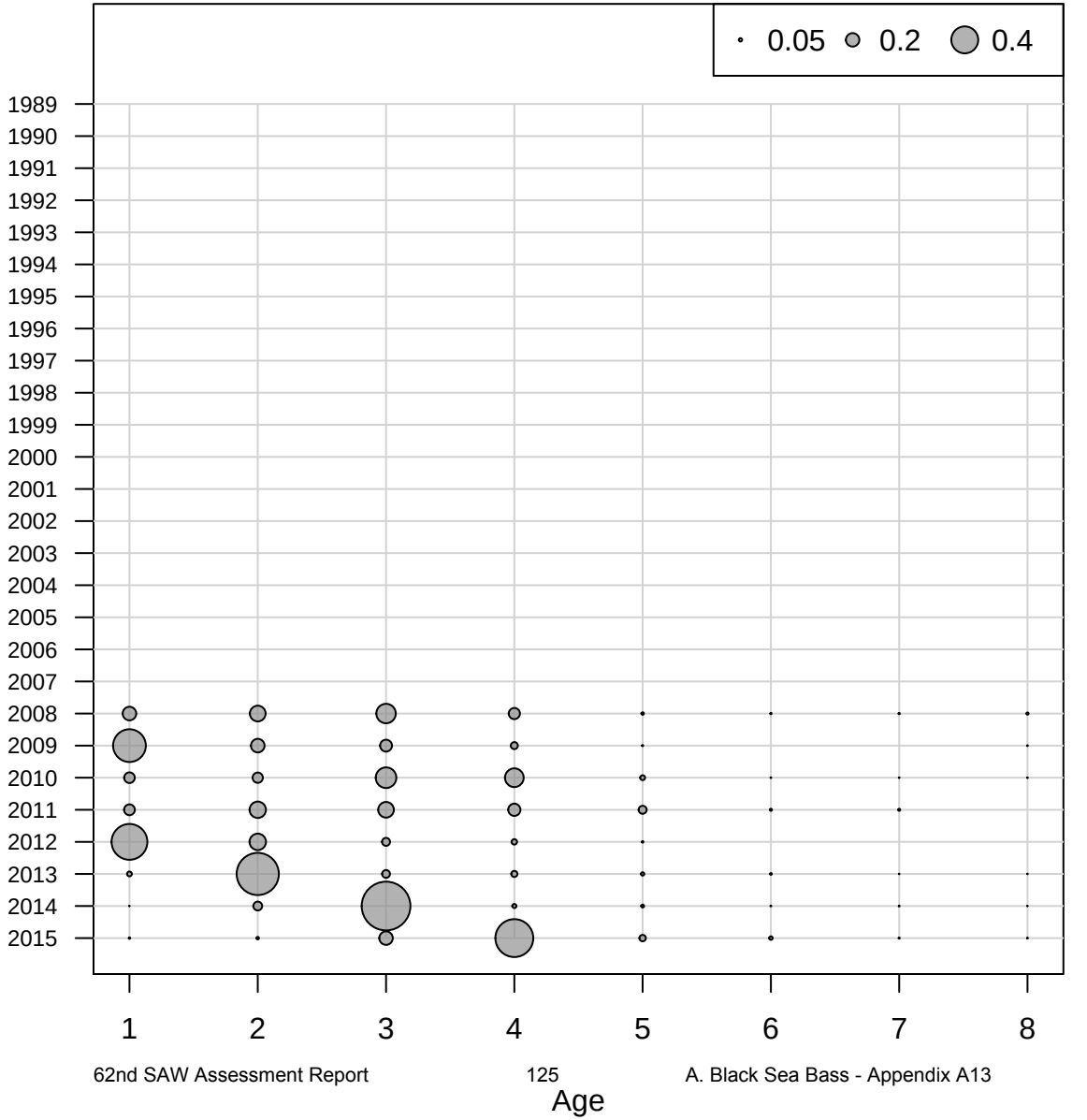

Age Comps for Catch by Fleet 2 (non−trawl)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age


Rescaled Indices
4
3
2
1
0
−1
1990
1995
2000
2005
2010
2015
Year

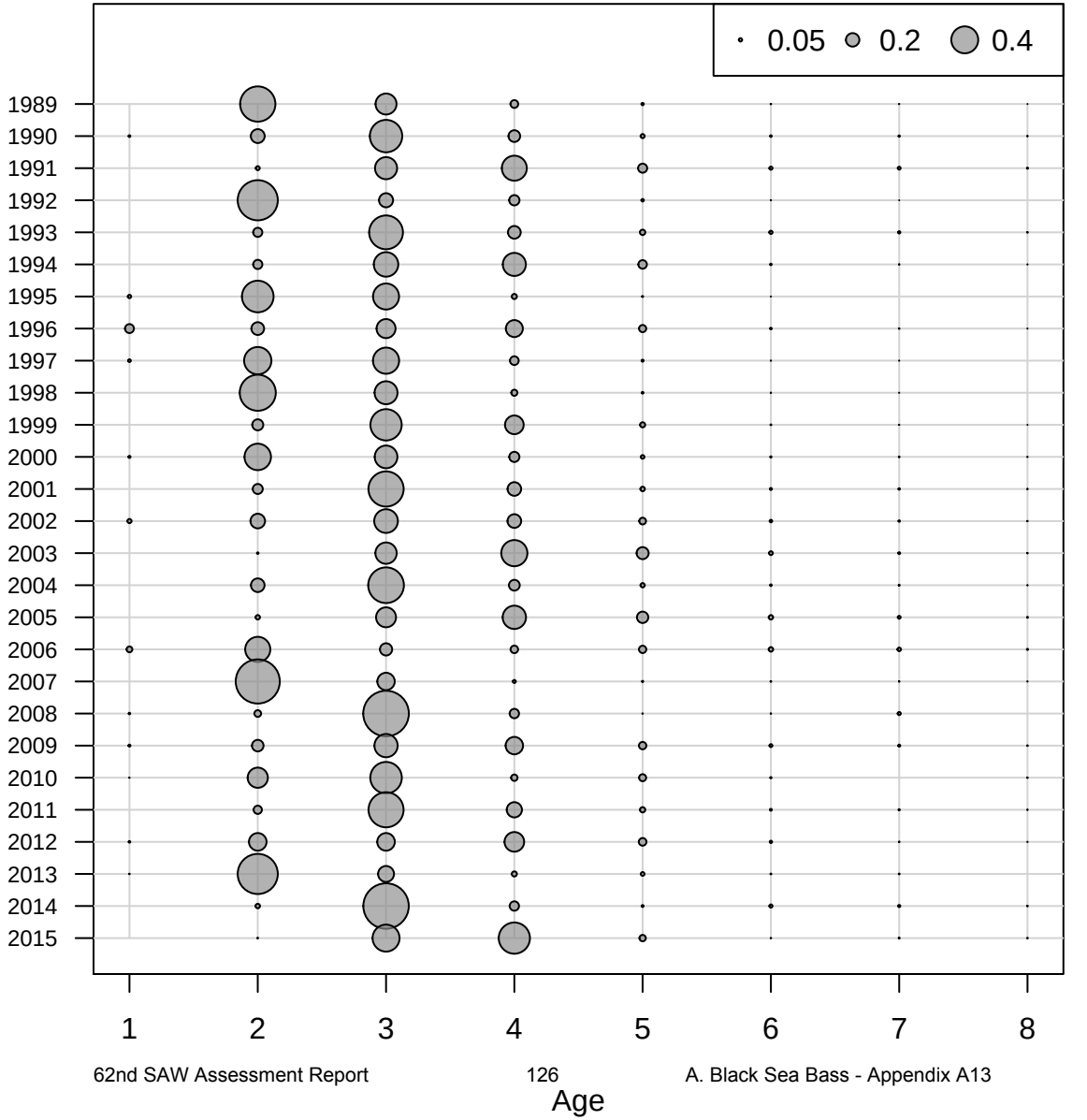

Rescaled Log(Indices)
2
1
0
−1
−2
1990
1995
2000
2005
2010
2015
Year

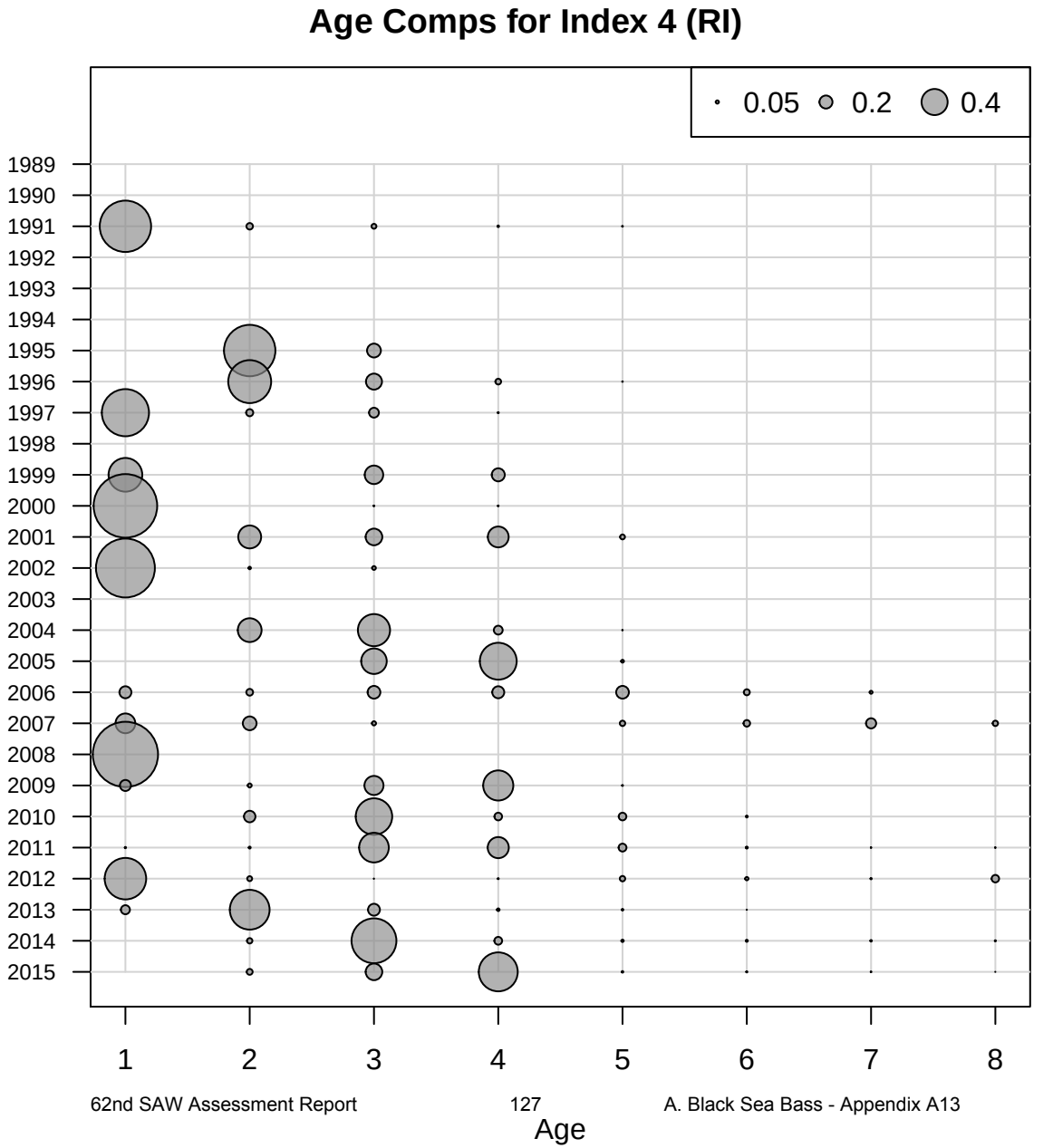

Age Comps for Index 1 (NEFSC spring Alb)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

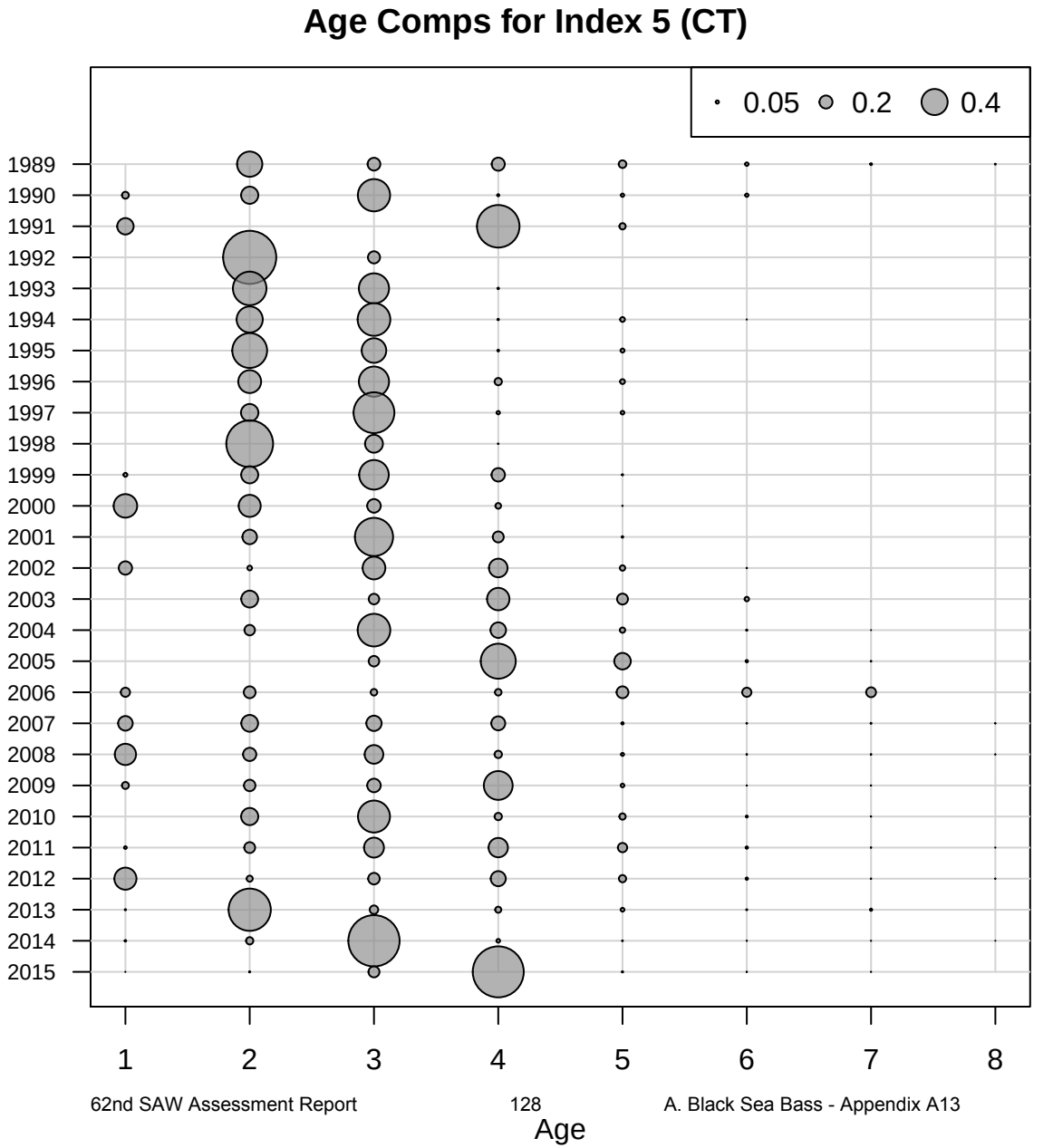
Age Comps for Index 2 (NEAMAP)

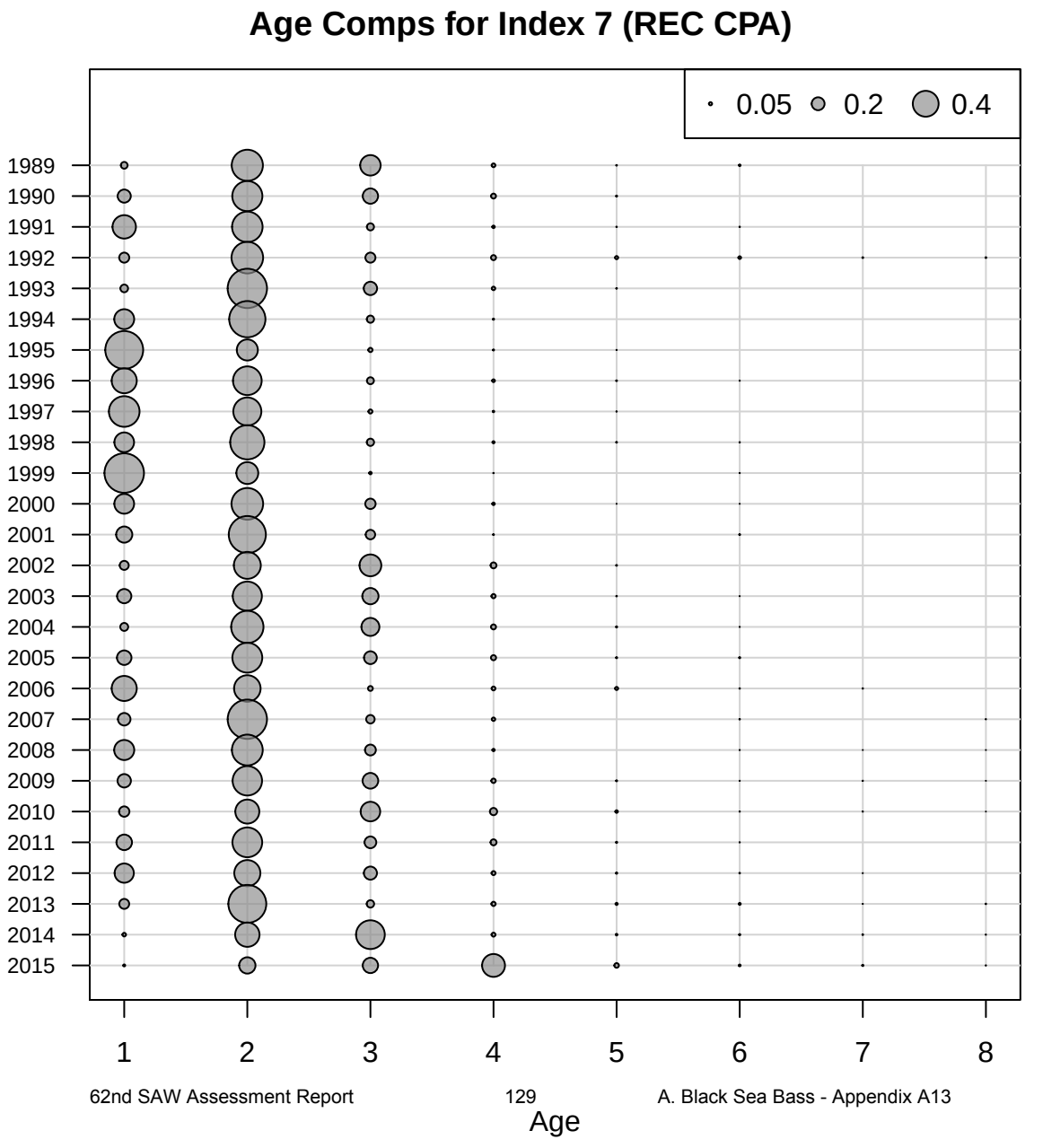


Age Comps for Index 3 (MADMF)

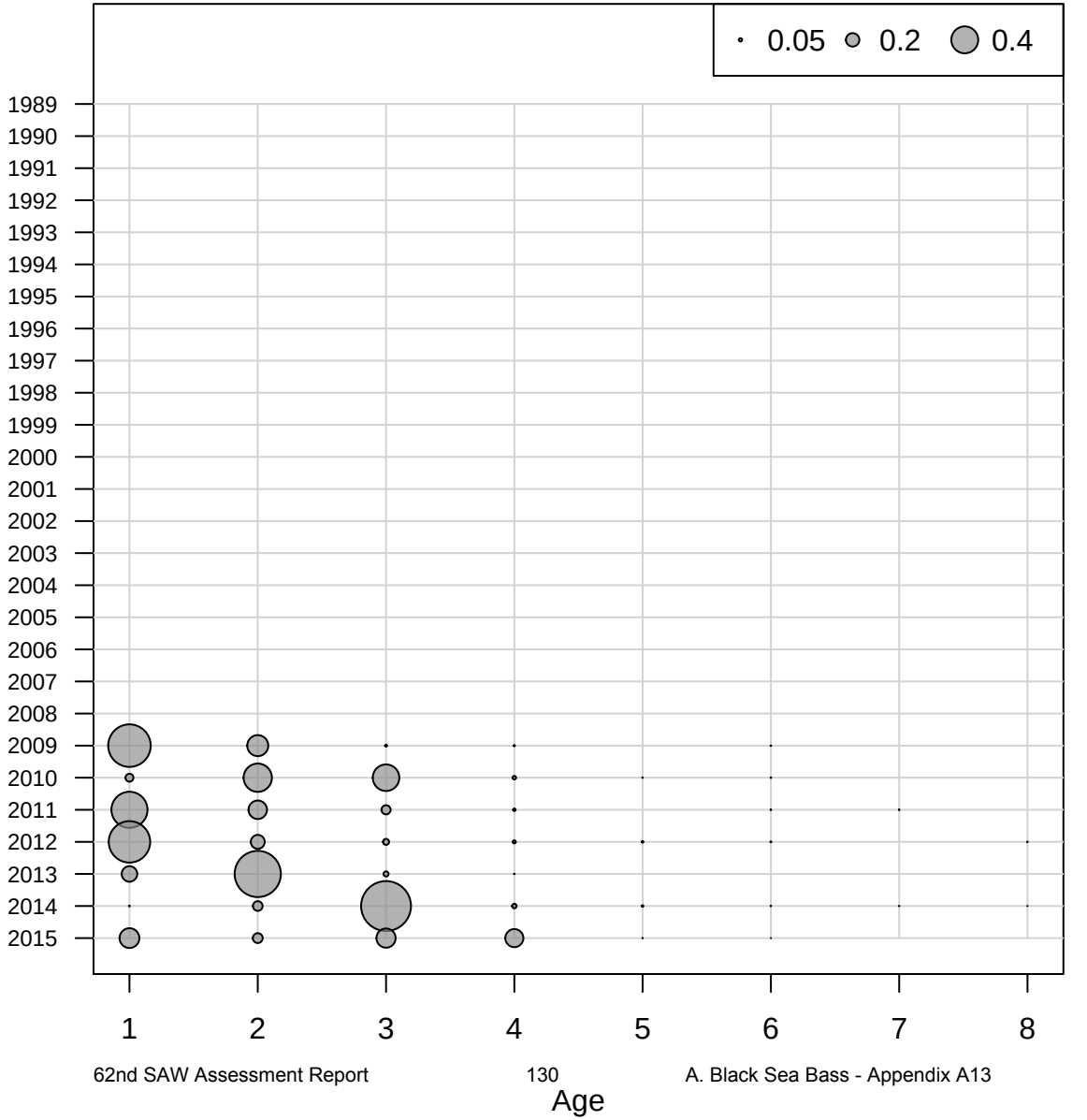


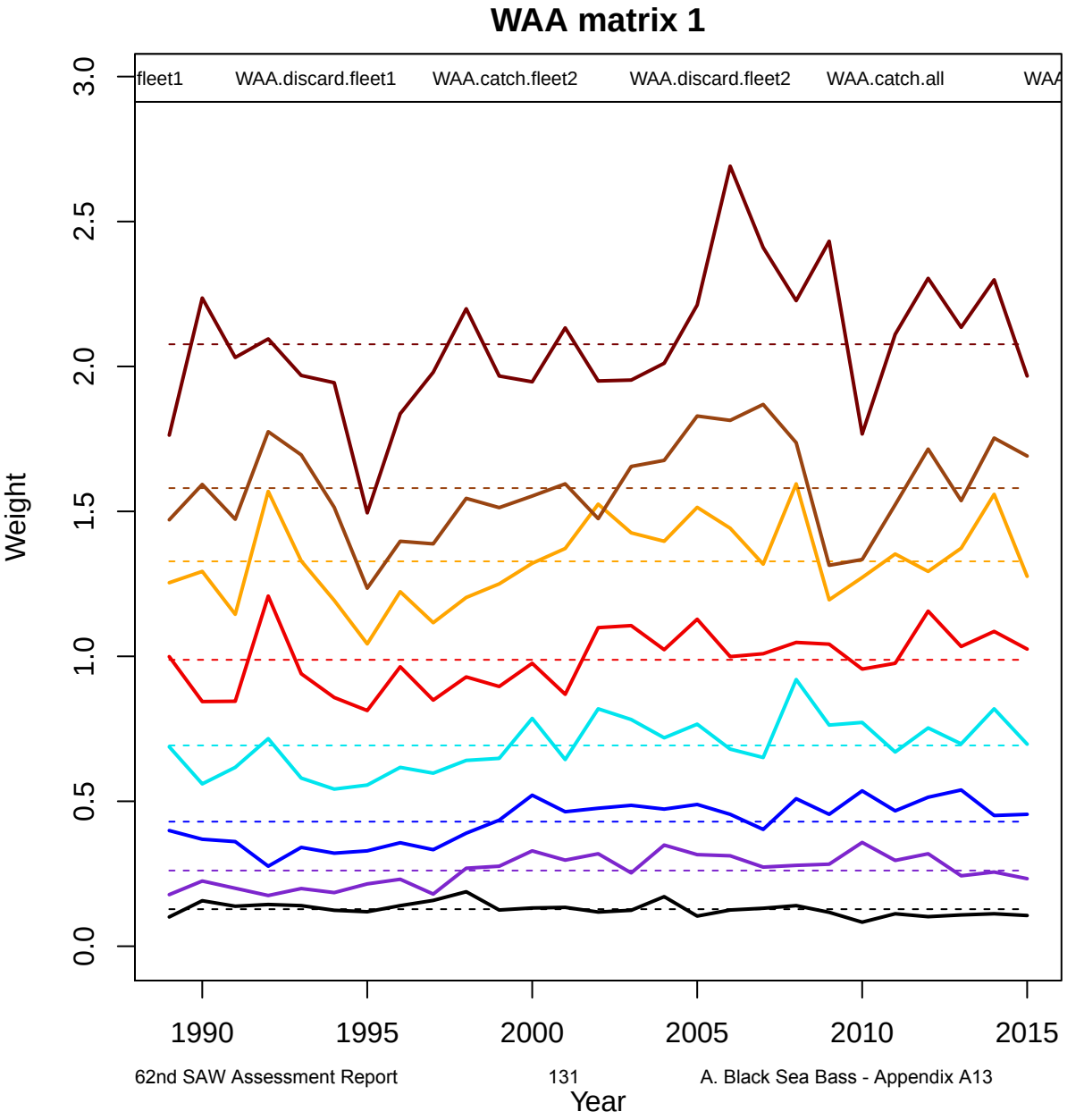

Age Comps for Index 4 (RI)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

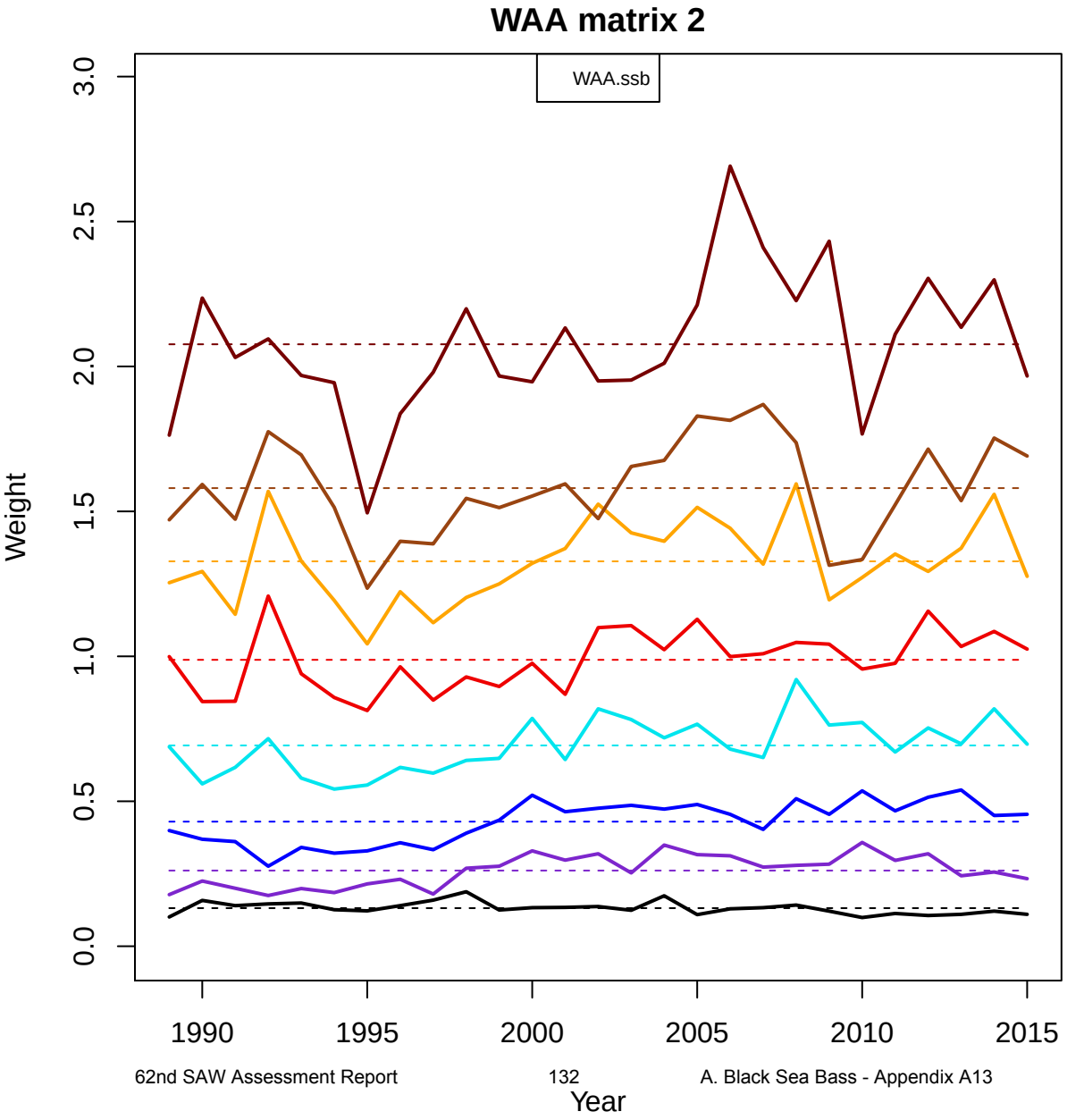

Age Comps for Index 5 (CT)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

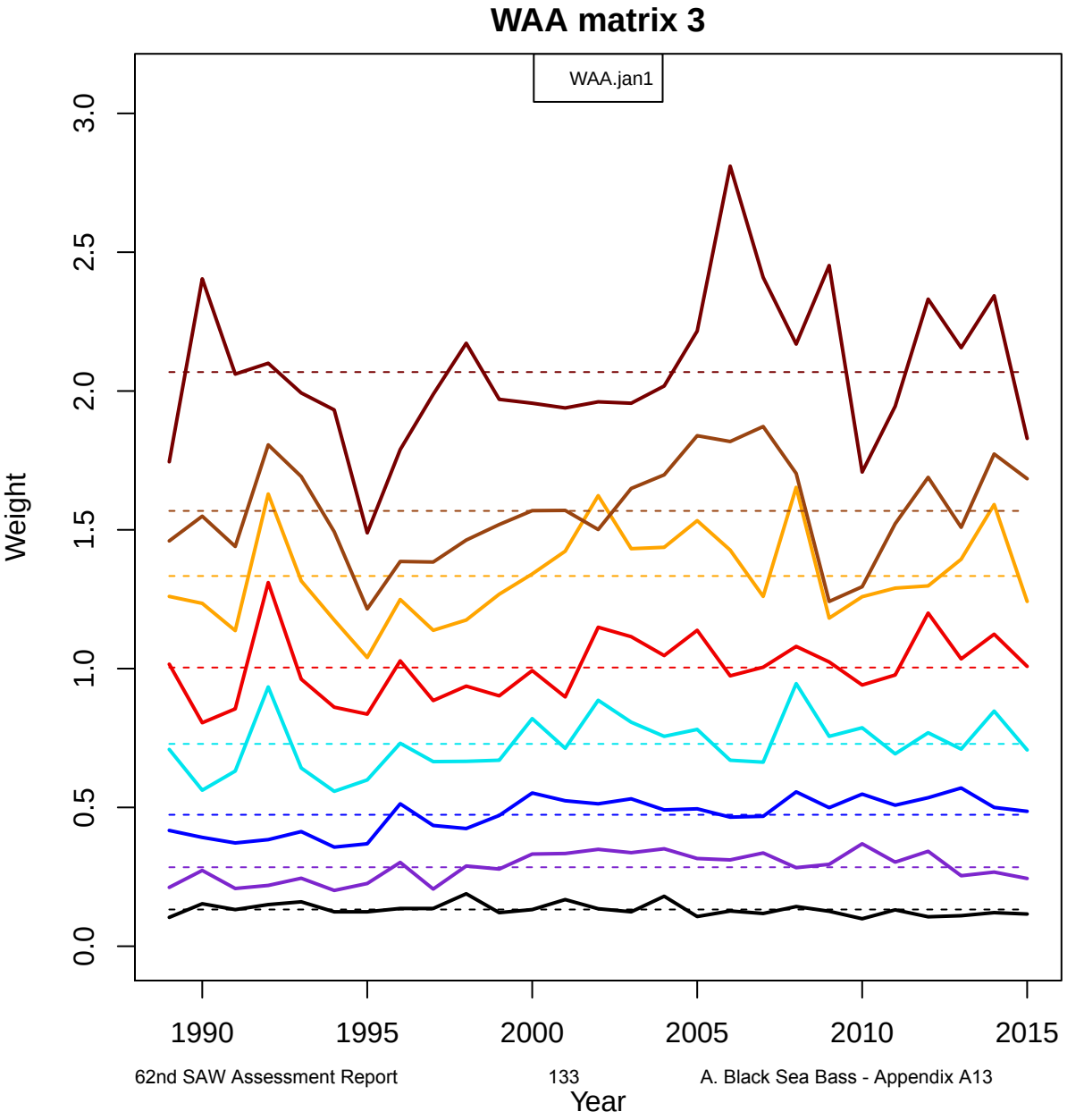

Age Comps for Index 7 (REC CPA)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

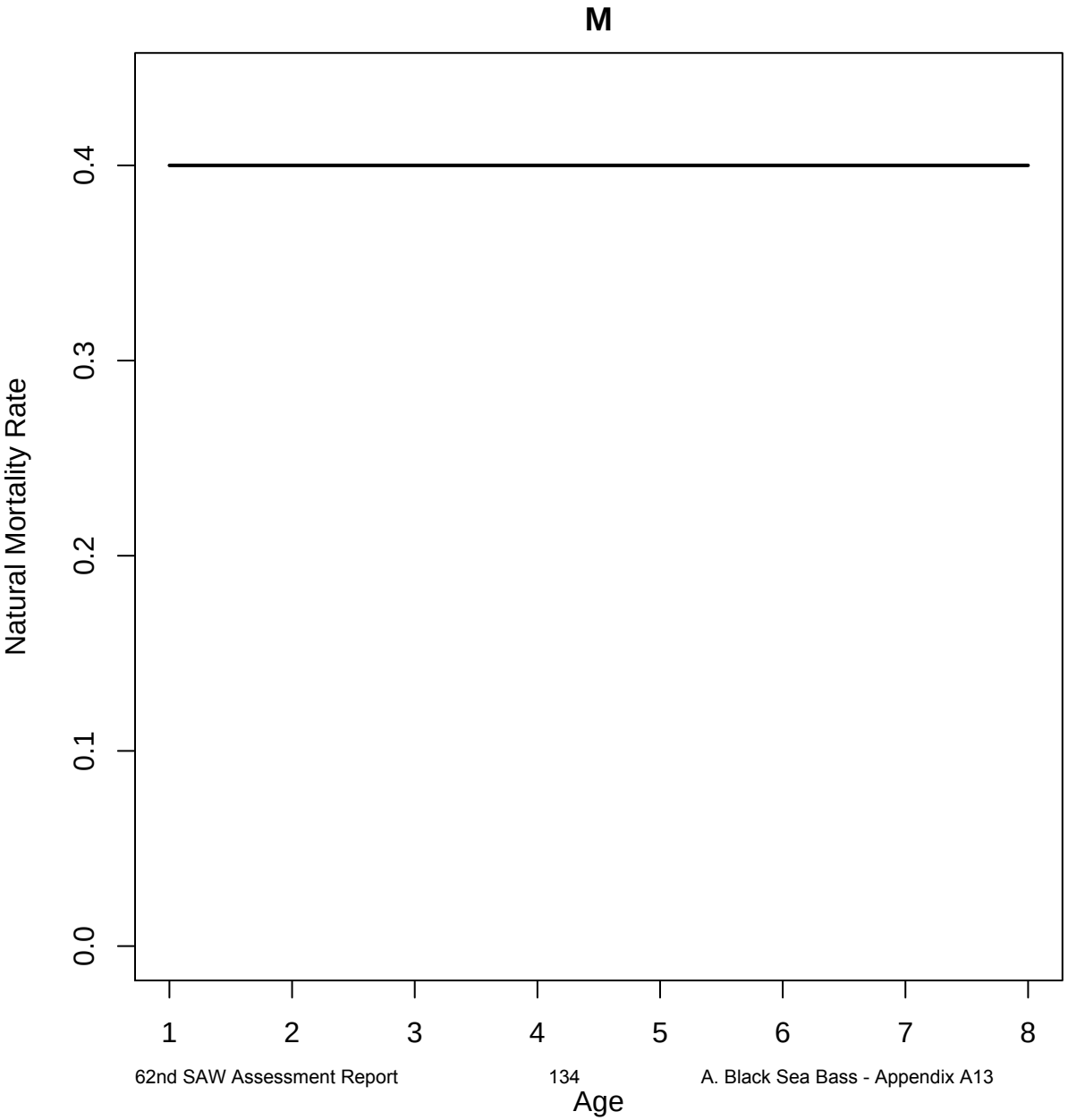
Age Comps for Index 8 (BIGELOW)

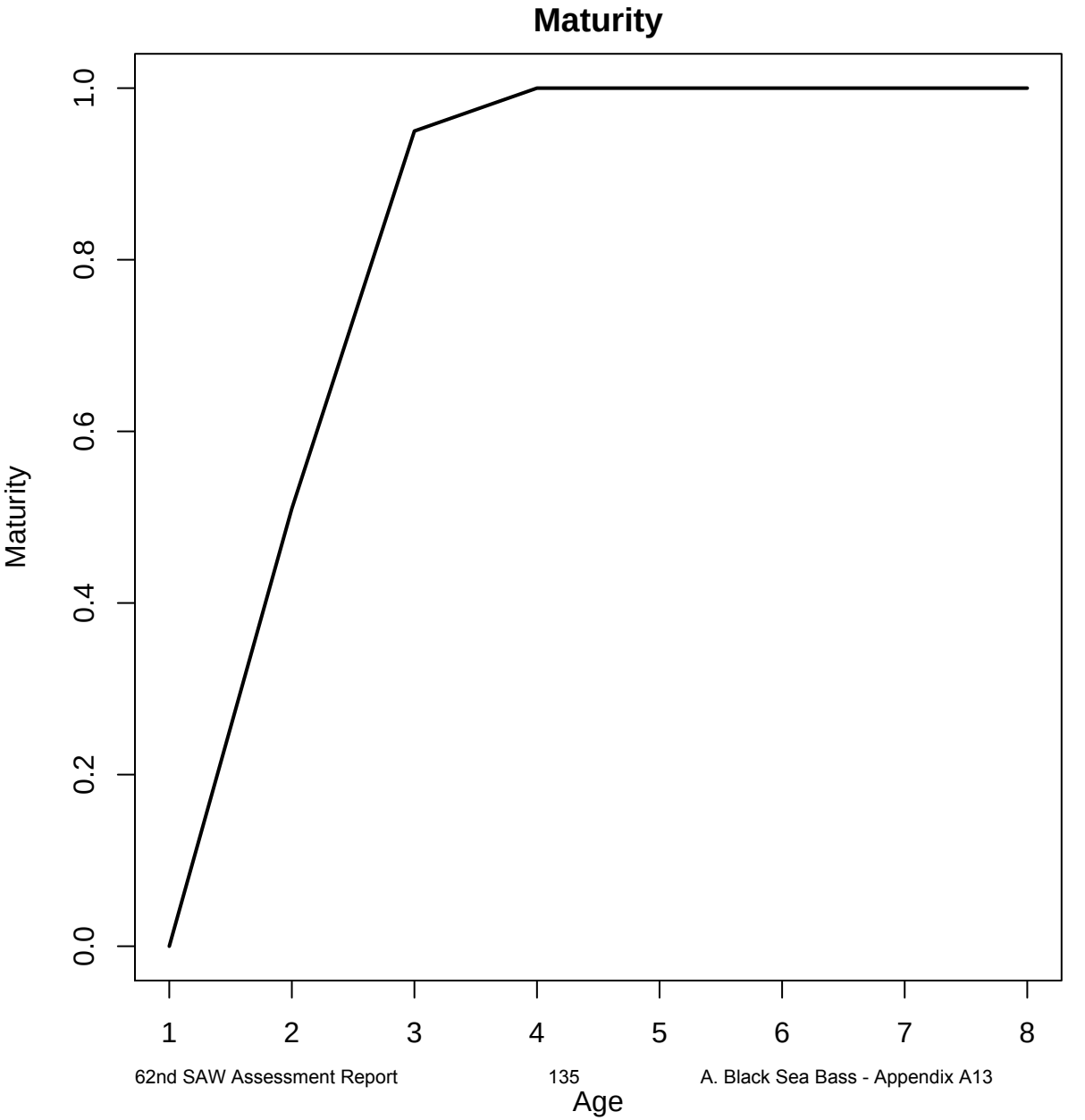



WAA matrix 1
fleet1
WAA.discard.fleet1
WAA.catch.fleet2
WAA.discard.fleet2
WAA.catch.all
WAA
Weight
0.0
0.5
1.0
1.5
2.0
2.5
3.0
1990
1995
2000
2005
2010
2015
Year

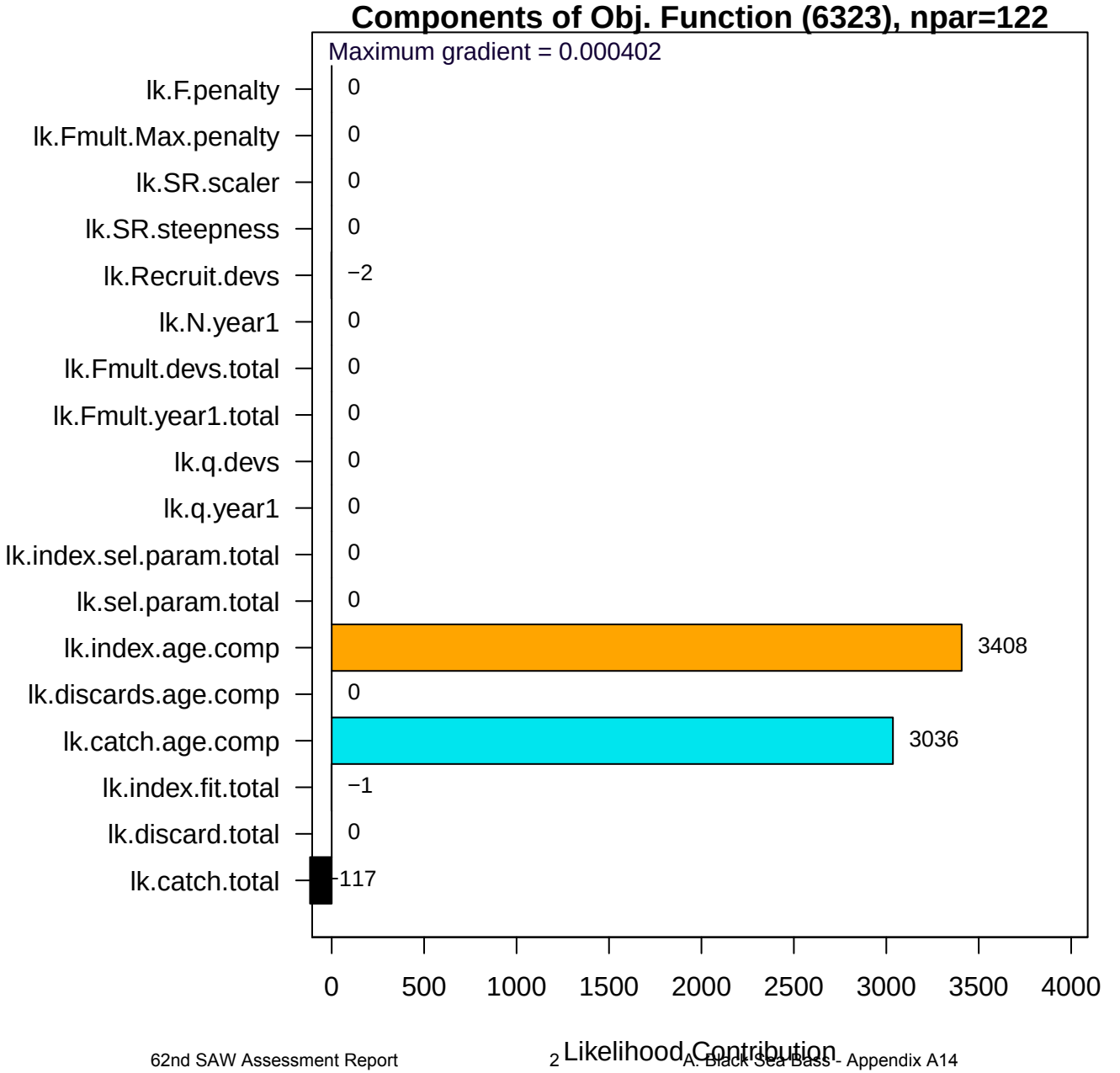

WAA matrix 2
WAA.ssb
Weight
0.0
0.5
1.0
1.5
2.0
2.5
3.0
1990
1995
2000
2005
2010
2015
Year


WAA matrix 3
WAA.jan1
Weight
0.0
0.5
1.0
1.5
2.0
2.5
3.0
1990
1995
2000
2005
2010
2015
Year

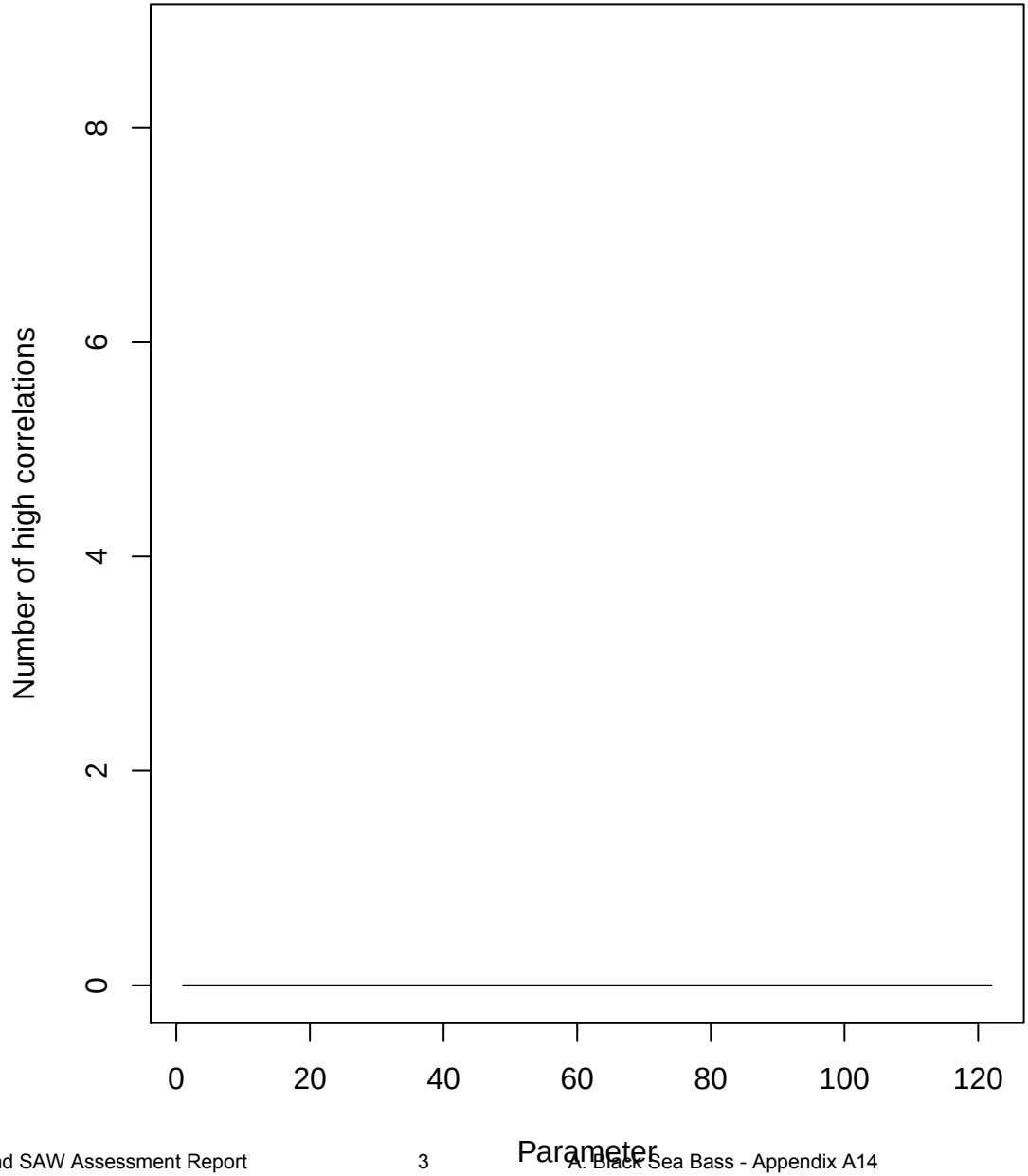

M
Natural Mortality Rate
0.0
0.1
0.2
0.3
0.4
1
2
3
4
5
6
7
8
Age


Maturity
Maturity
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
8
Age

Appendix A14 – Diagnostic and result plots for black sea bass South Area Exchange model.

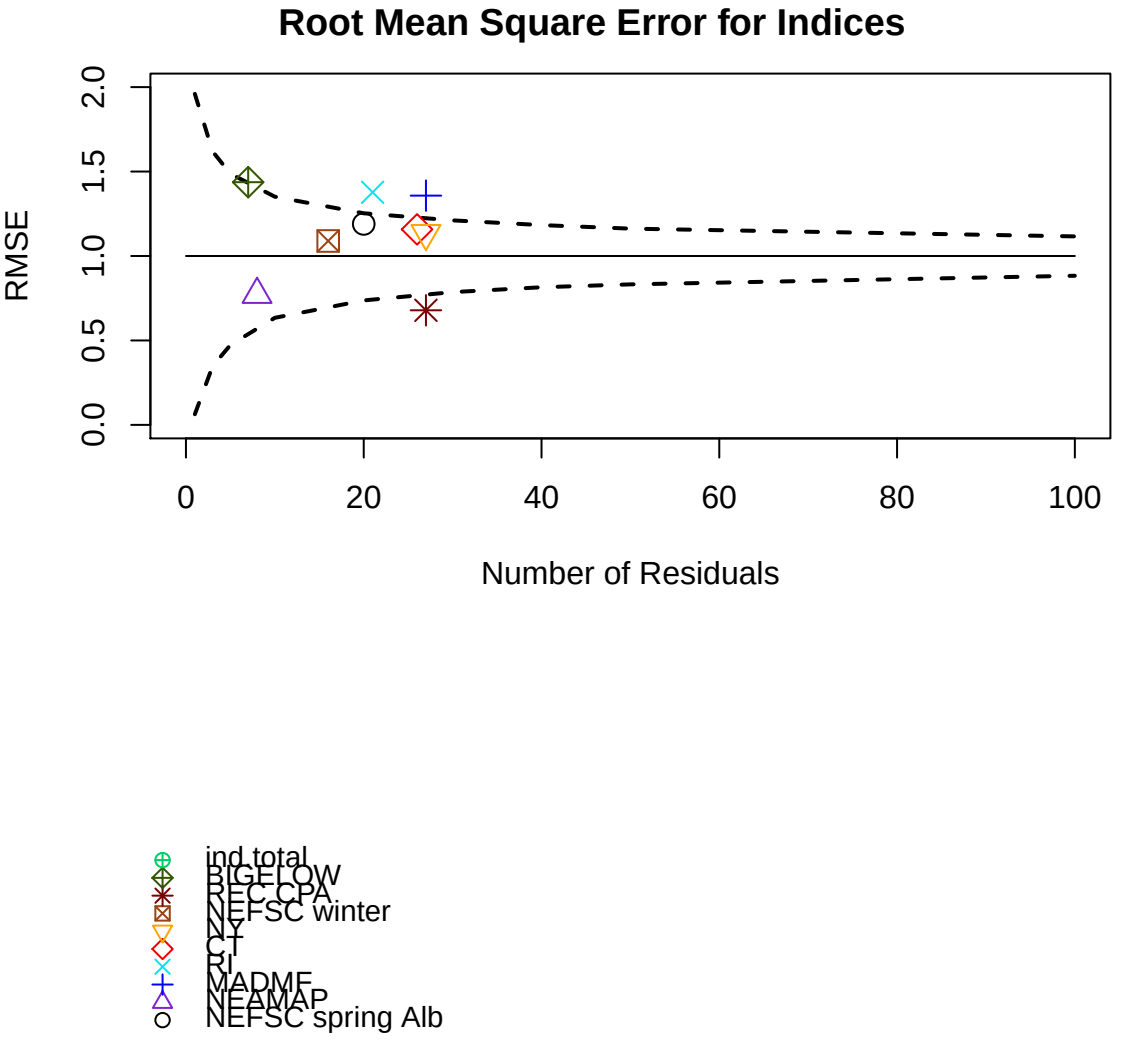


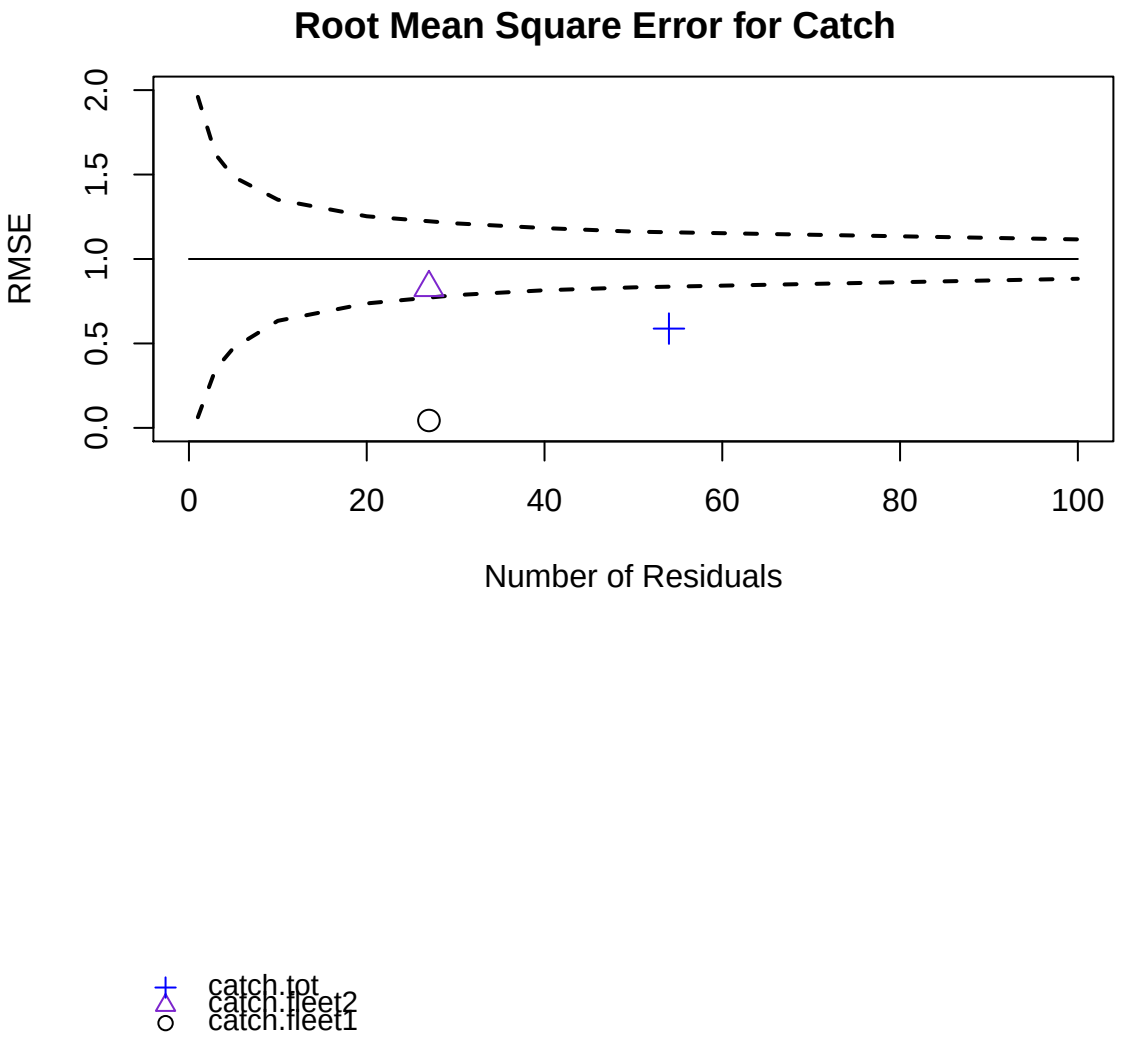
Model: south.donate.R_0.1.P_0.40 Tuesday, 01 Nov 2016 at 13:21:16


Number of high correlations
0
2
4
6
8
0
20
40
60
80
100
120
Parameter

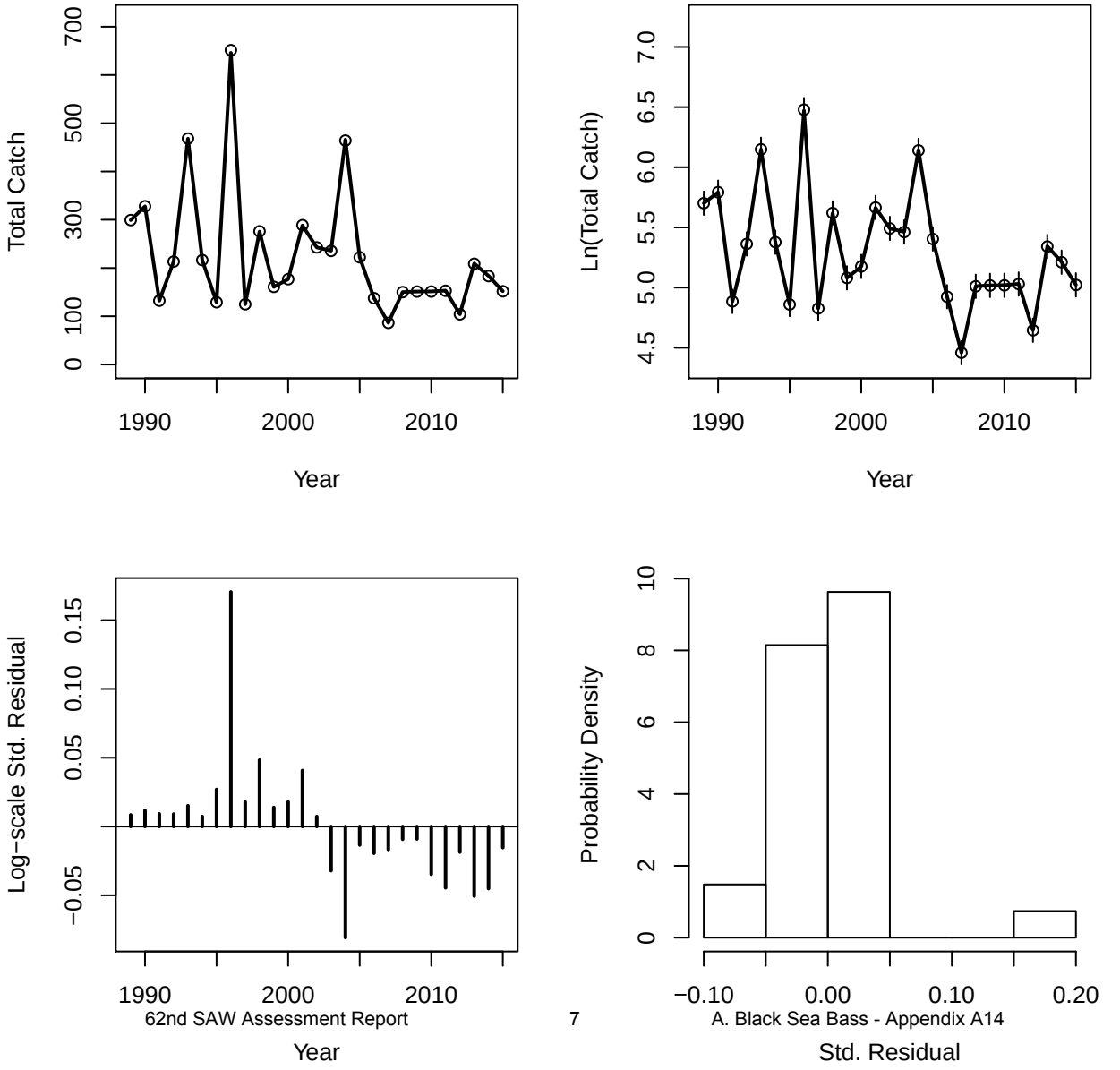
Root Mean Square Error computed from Standardized Residuals

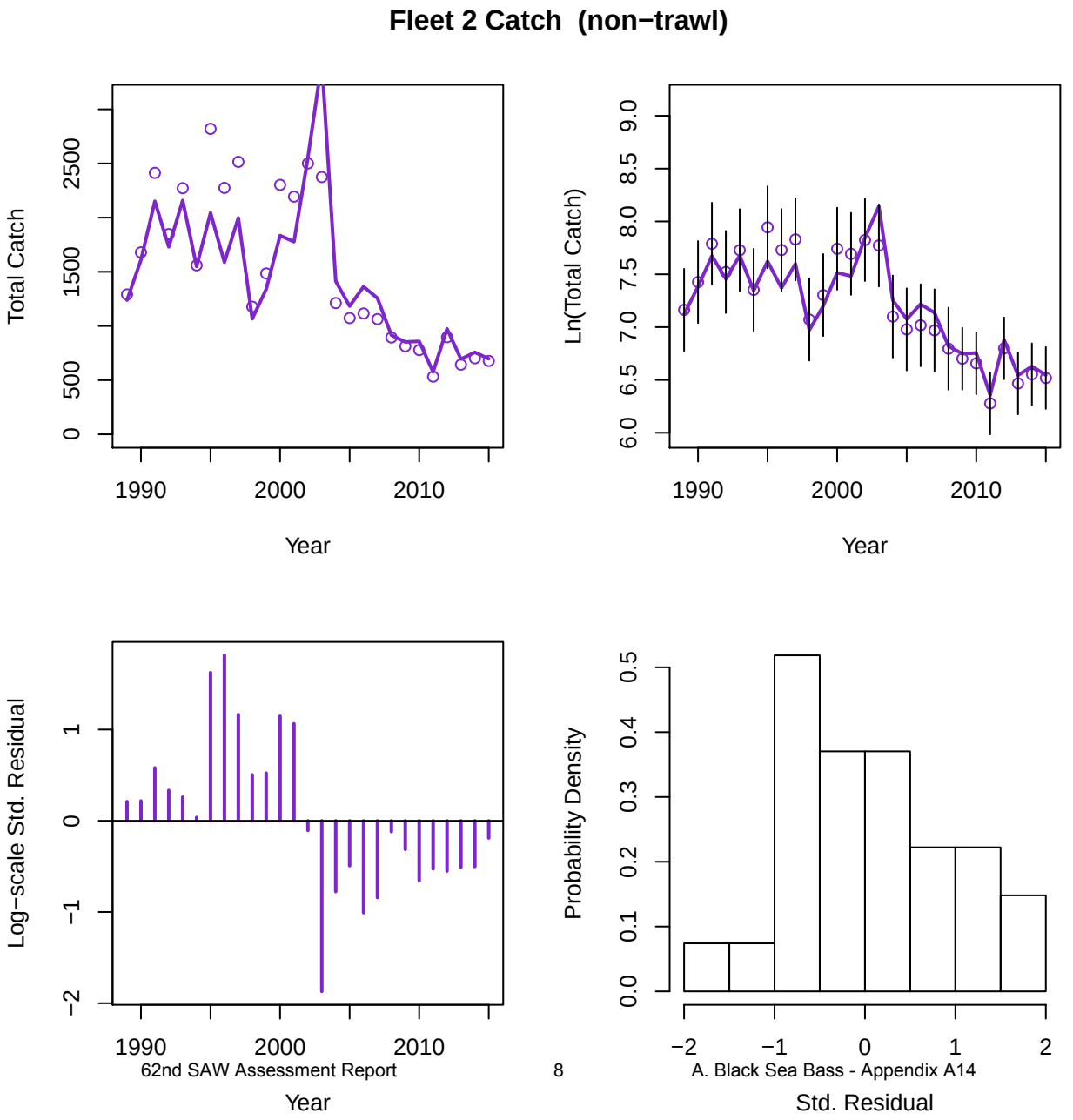
Component	# resids	RMSE
catch.fleet1	27	0.044
catch.fleet2	27	0.83
catch.tot	54	0.588
discard.fleet1	0	0
discard.fleet2	0	0
discard.tot	0	0
ind01	20	1.19
ind02	8	0.772
ind03	27	1.36
ind04	21	1.38
ind05	26	1.16
ind06	27	1.13
ind07	16	1.09
ind08	27	0.678
ind09	7	1.44
ind.total	179	1.15
N.year1	0	0
Fmult.year1	0	0
Fmult.devs.fleet1	0	0
Fmult.devs.fleet2	0	0
Fmult.devs.total	0	0
recruit.devs	27	0.478
fleet.sel.params	0	0
index.sel.params	0	0
q.year1	0	0
q.devs	0	0
SR.steepness	0	0
SR.scaler	0	0

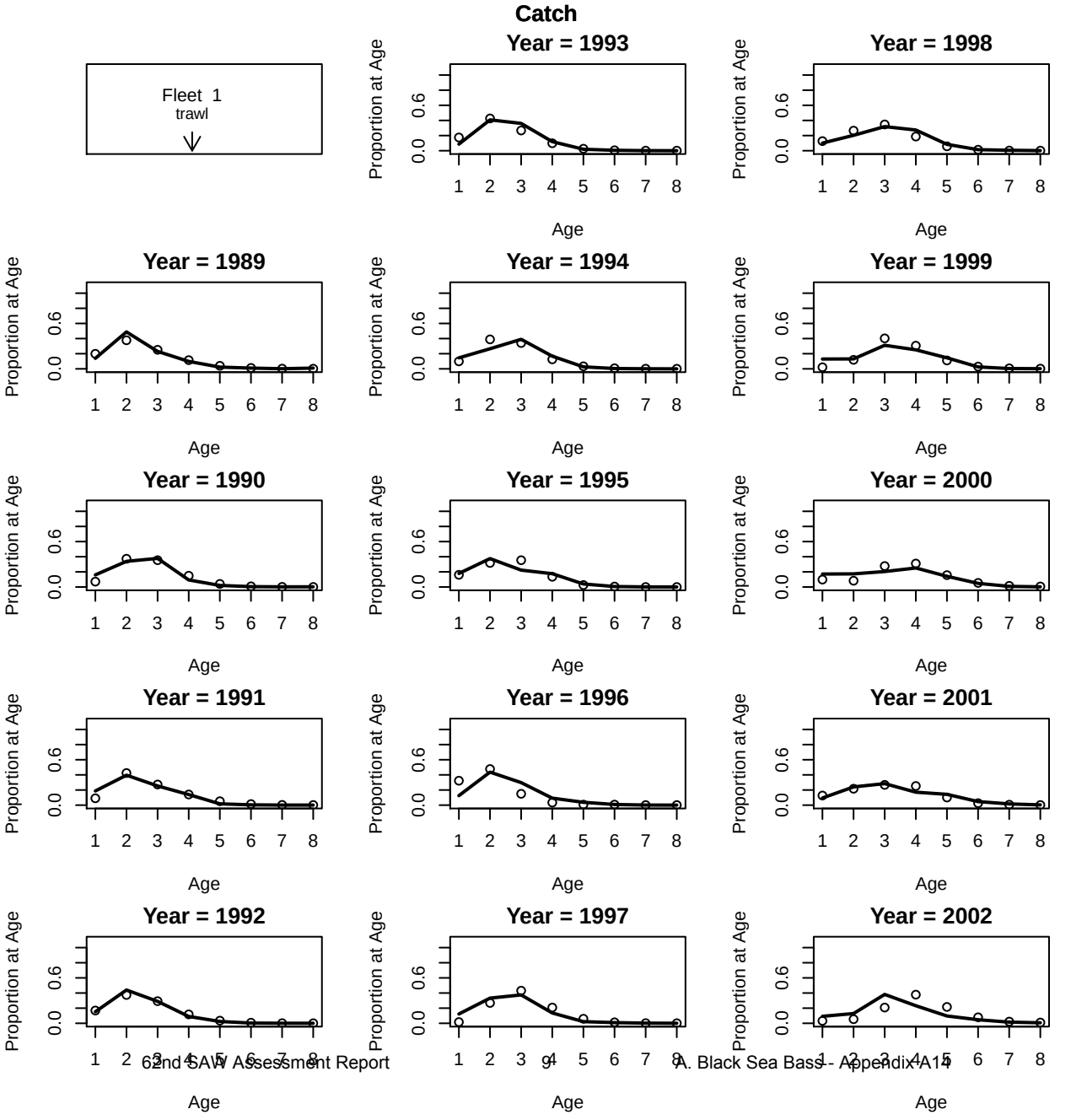

Root Mean Square Error for Indices
RMSE
0.0
0.5
1.0
1.5
2.0
0
20
40
60
80
100
Number of Residuals
ind total
BIGELOW
REC CPA
NEFSC winter
NY
CT
RI
MADMF
NEAMAP
NEFSC spring Alb

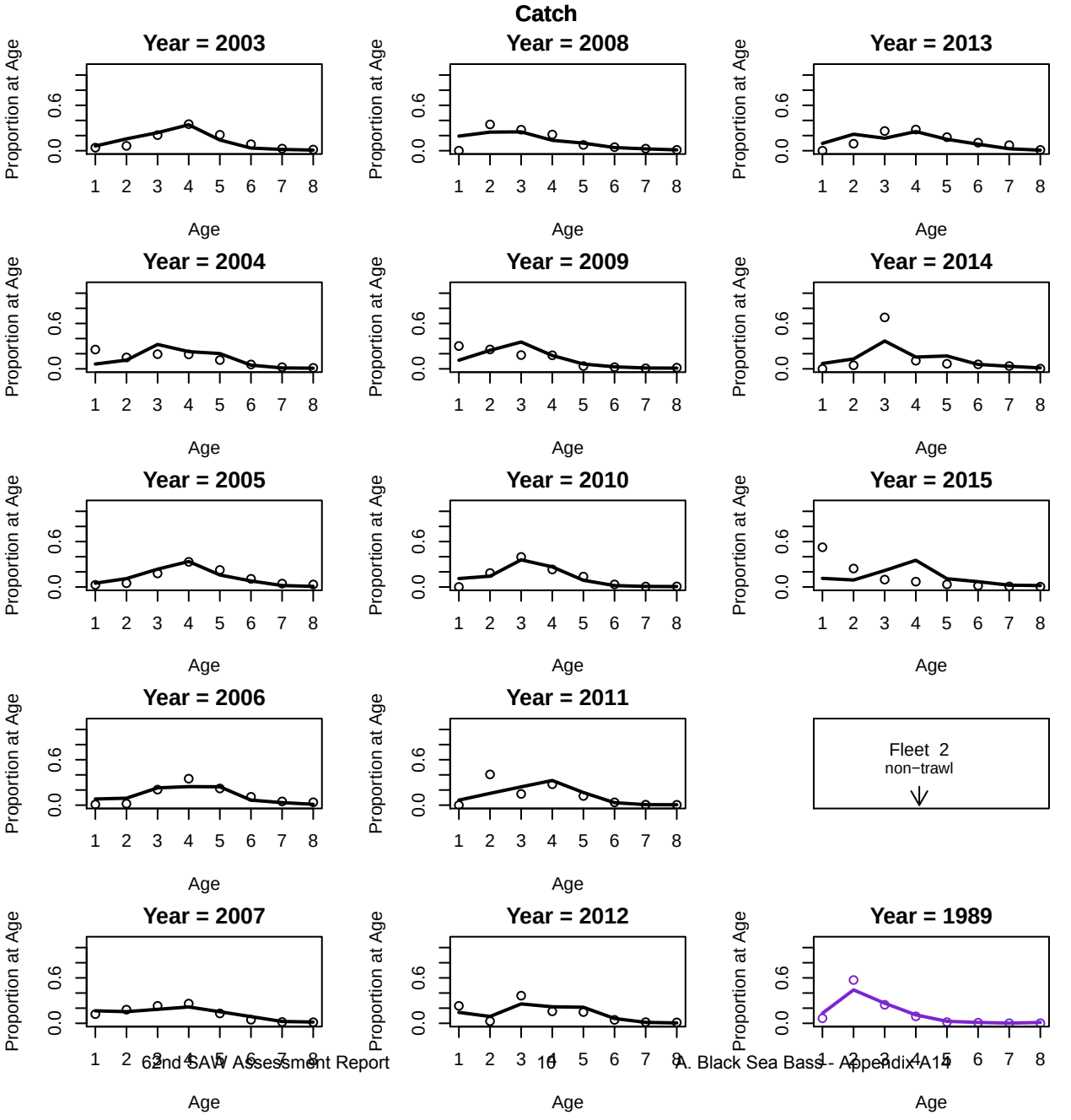

Root Mean Square Error for Catch
RMSE
0.0
0.5
1.0
1.5
2.0
0
20
40
60
80
100
Number of Residuals
catch.tot
catch.fleet2
catch.fleet1

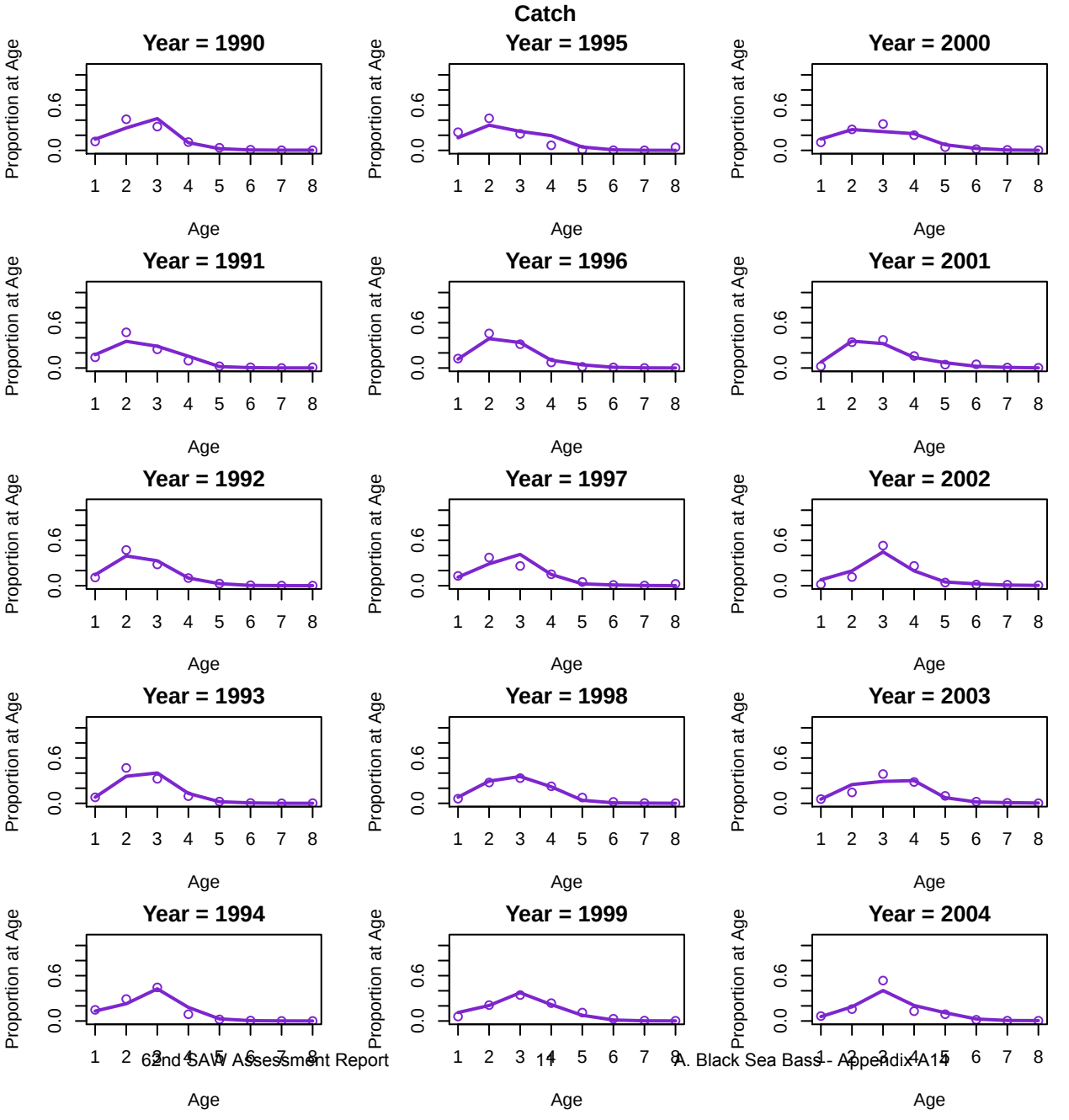
Fleet 1 Catch (trawl)

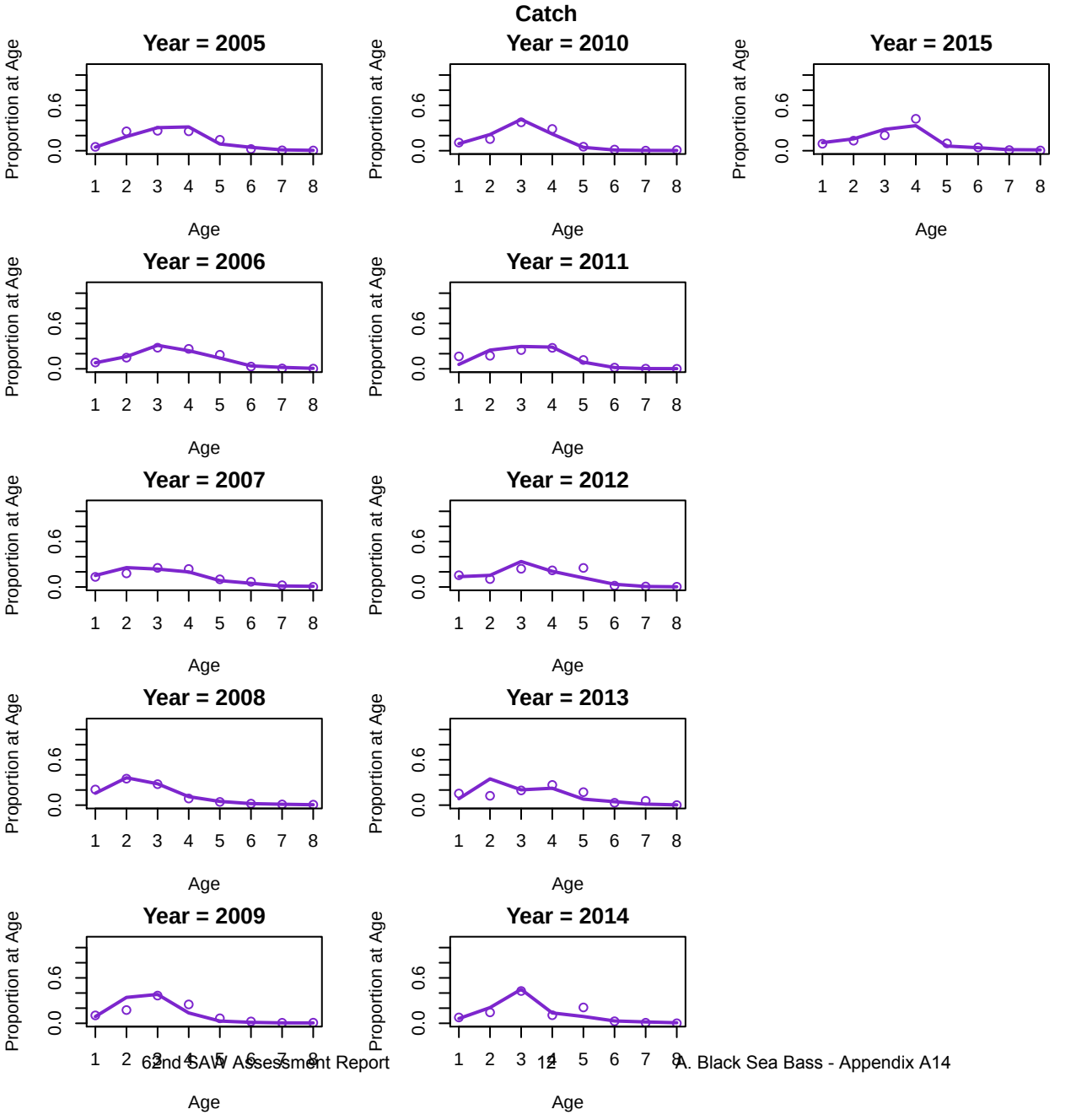



Fleet 2 Catch (non−trawl)
Total Catch
0
500
1500
2500
1990
2000
2010
Year
Ln(Total Catch)
6.0
6.5
7.0
7.5
8.0
8.5
9.0
1990
2000
2010
Year
Log−scale Std. Residual
−2
−1
0
1
1990
2000
2010
Year
Probability Density
0.0
0.1
0.2
0.3
0.4
0.5
−2
−1
0
1
2
Std. Residual

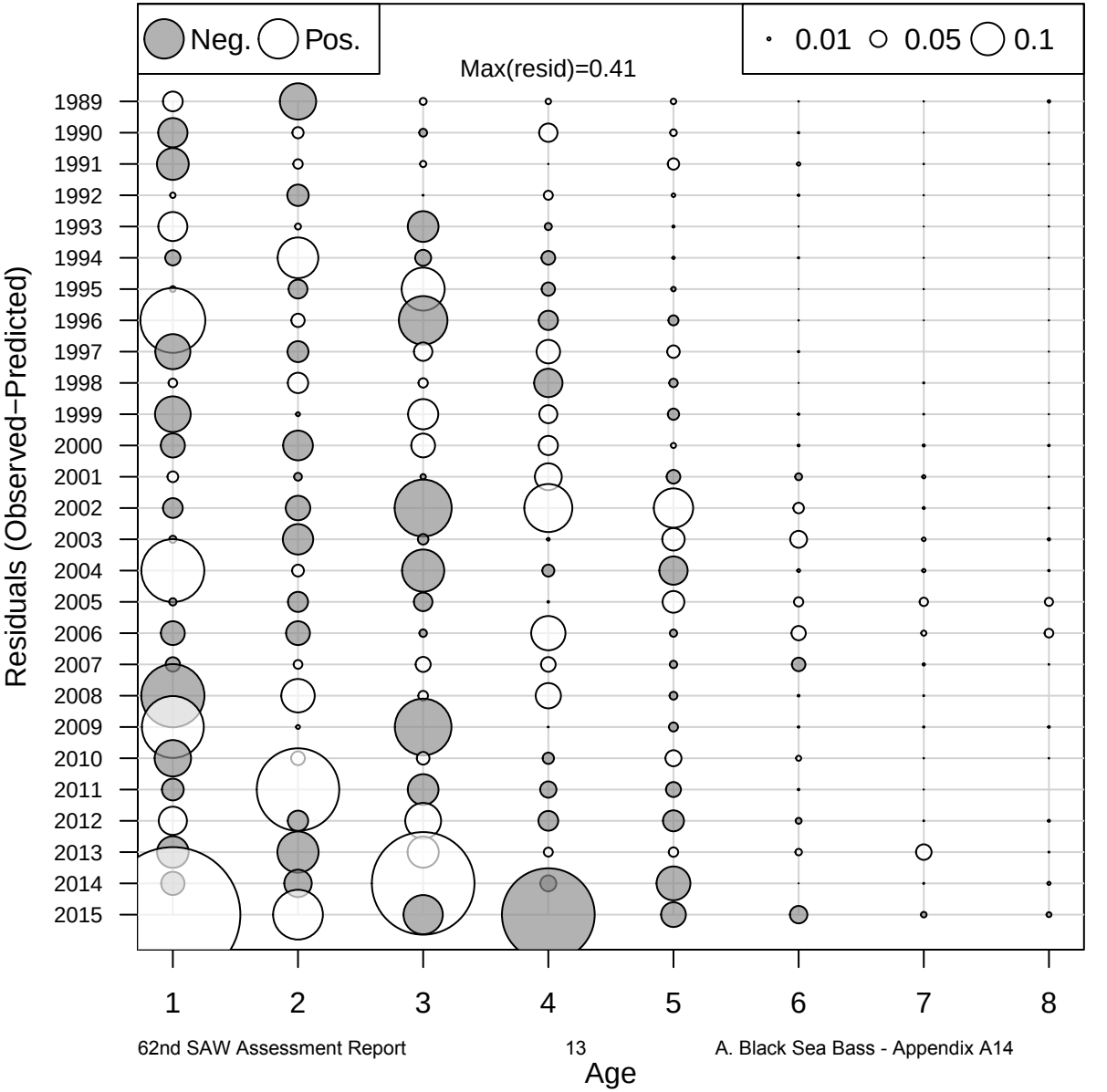

Catch
Fleet 1
trawl
Year = 1993
Year = 1998
Year = 1989
Year = 1994
Year = 1999
Year = 1990
Year = 1995
Year = 2000
Year = 1991
Year = 1996
Year = 2001
Year = 1992
Year = 1997
Year = 2002
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8


Catch
Year = 2003
Year = 2008
Year = 2013
Year = 2004
Year = 2009
Year = 2014
Year = 2005
Year = 2010
Year = 2015
Year = 2006
Year = 2011
Fleet 2
non−trawl
Year = 2007
Year = 2012
Year = 1989
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

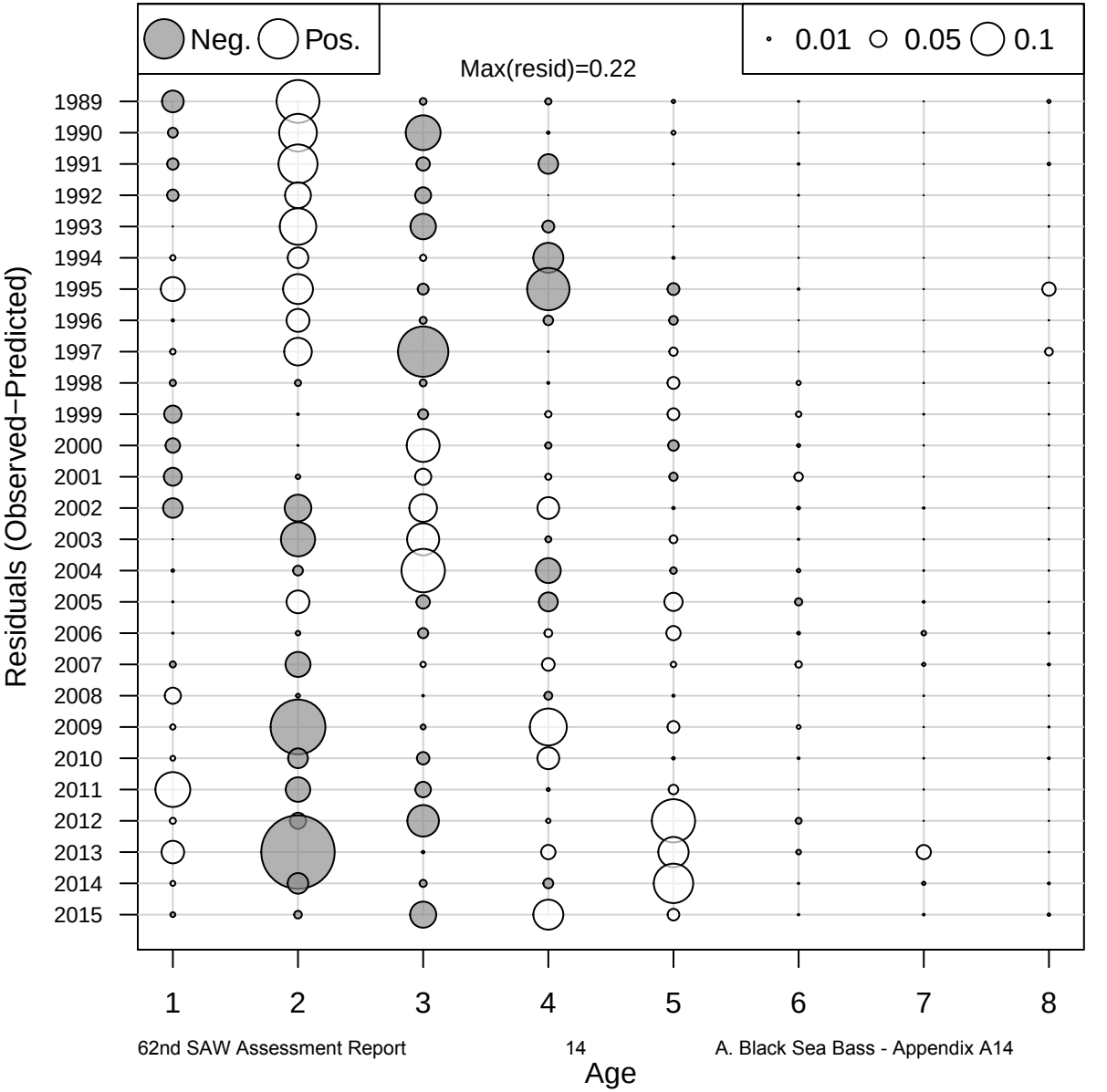

Catch
Year = 1990
Year = 1991
Year = 1992
Year = 1993
Year = 1994
Year = 1995
Year = 1996
Year = 1997
Year = 1998
Year = 1999
Year = 2000
Year = 2001
Year = 2002
Year = 2003
Year = 2004
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

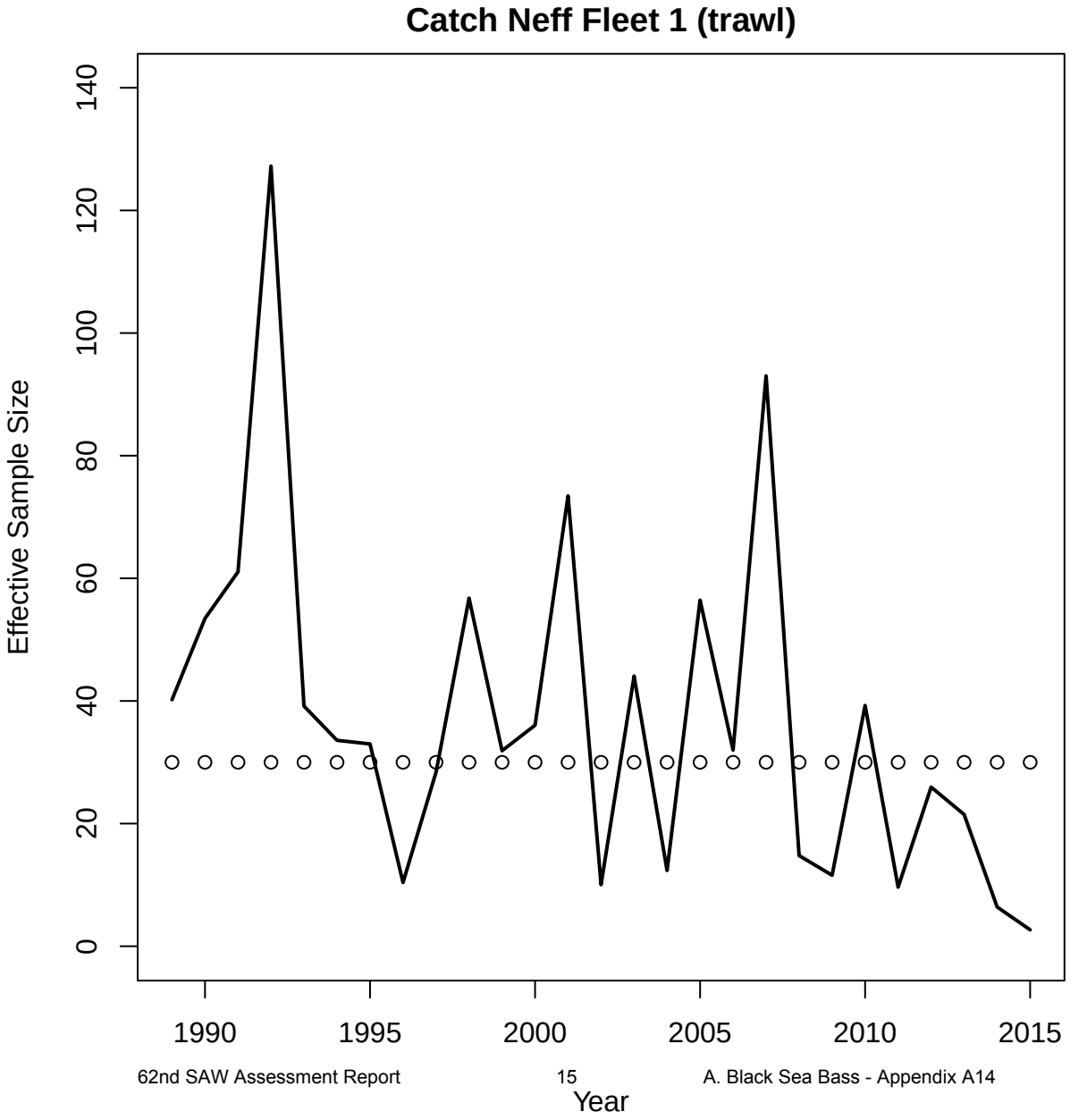

Catch
Year = 2005
Year = 2010
Year = 2015
Year = 2006
Year = 2011
Year = 2007
Year = 2012
Year = 2008
Year = 2013
Year = 2009
Year = 2014
Proportion at Age
Age
0.0
0.6
1 2 3 4 5 6 7 8

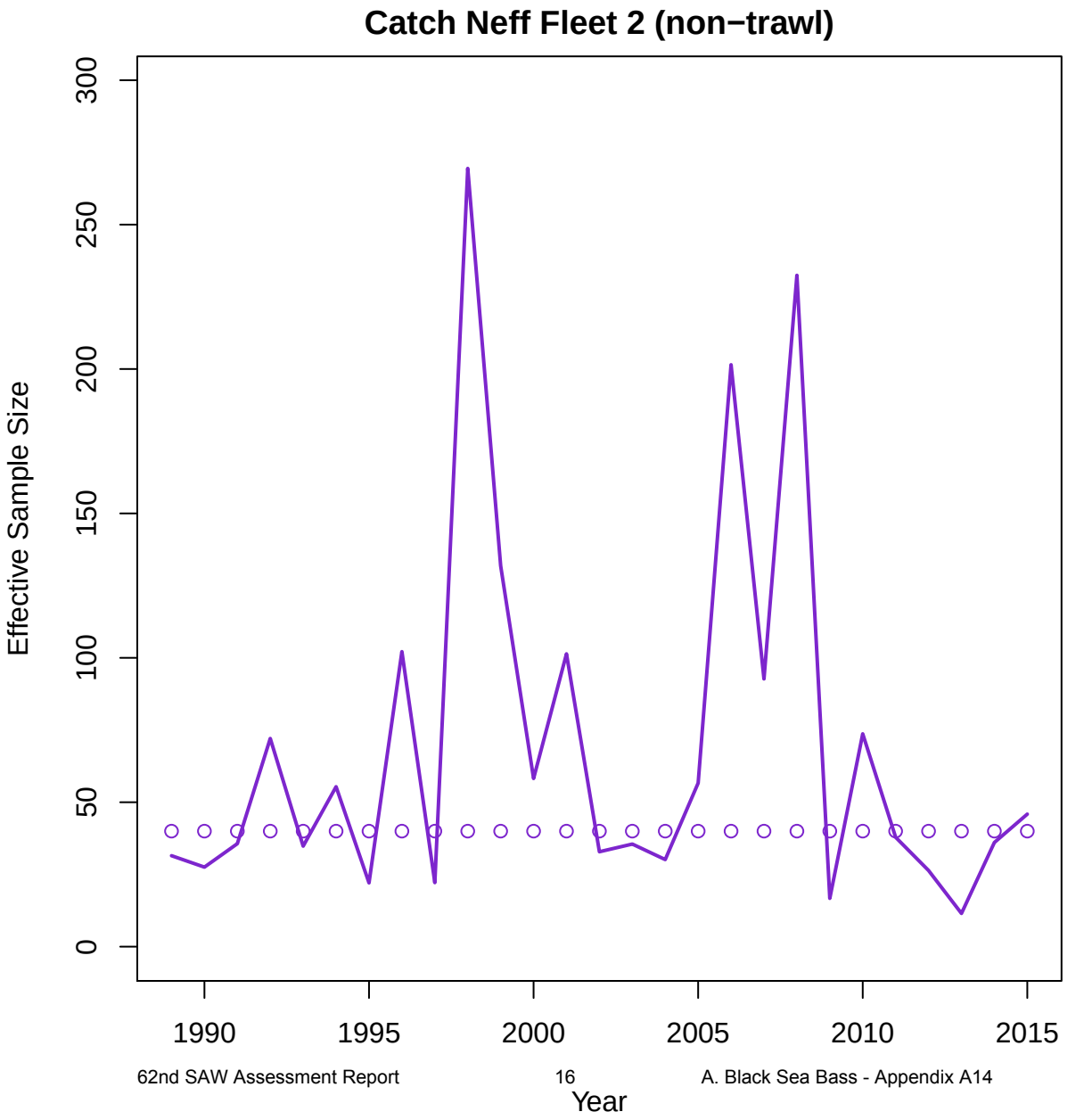
Age Comp Residuals for Catch by Fleet 1 (trawl)

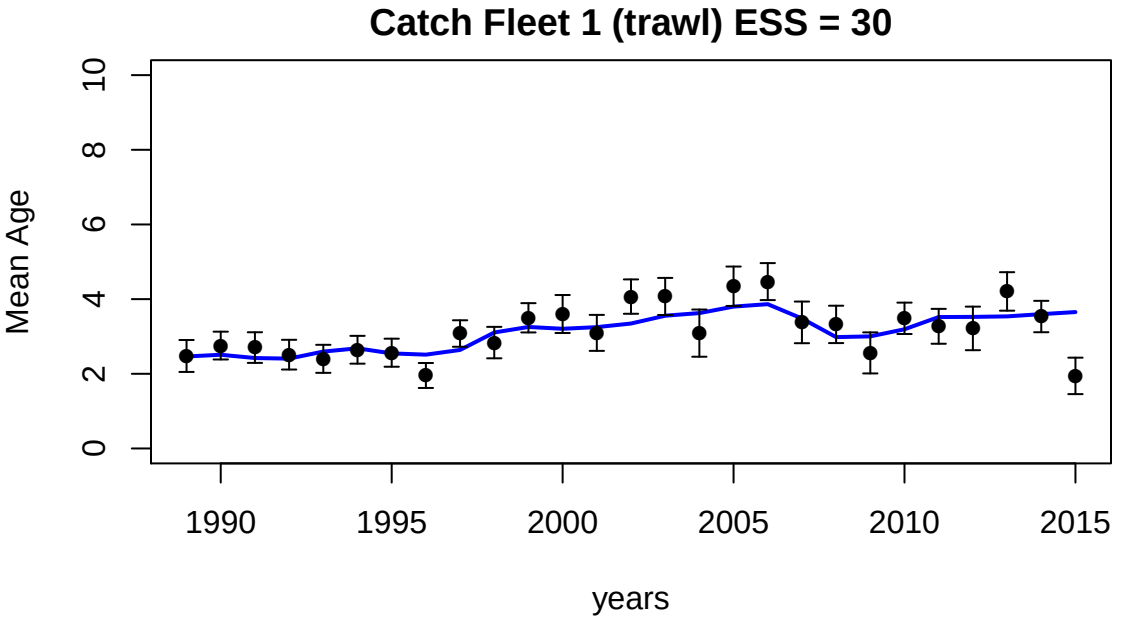


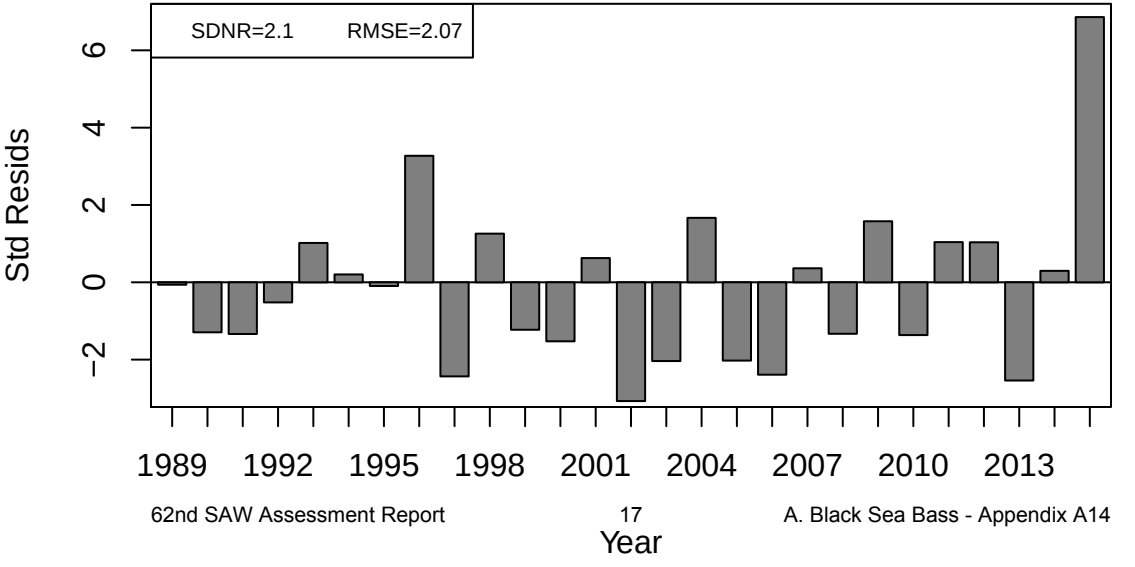
Age Comp Residuals for Catch by Fleet 2 (non−trawl)

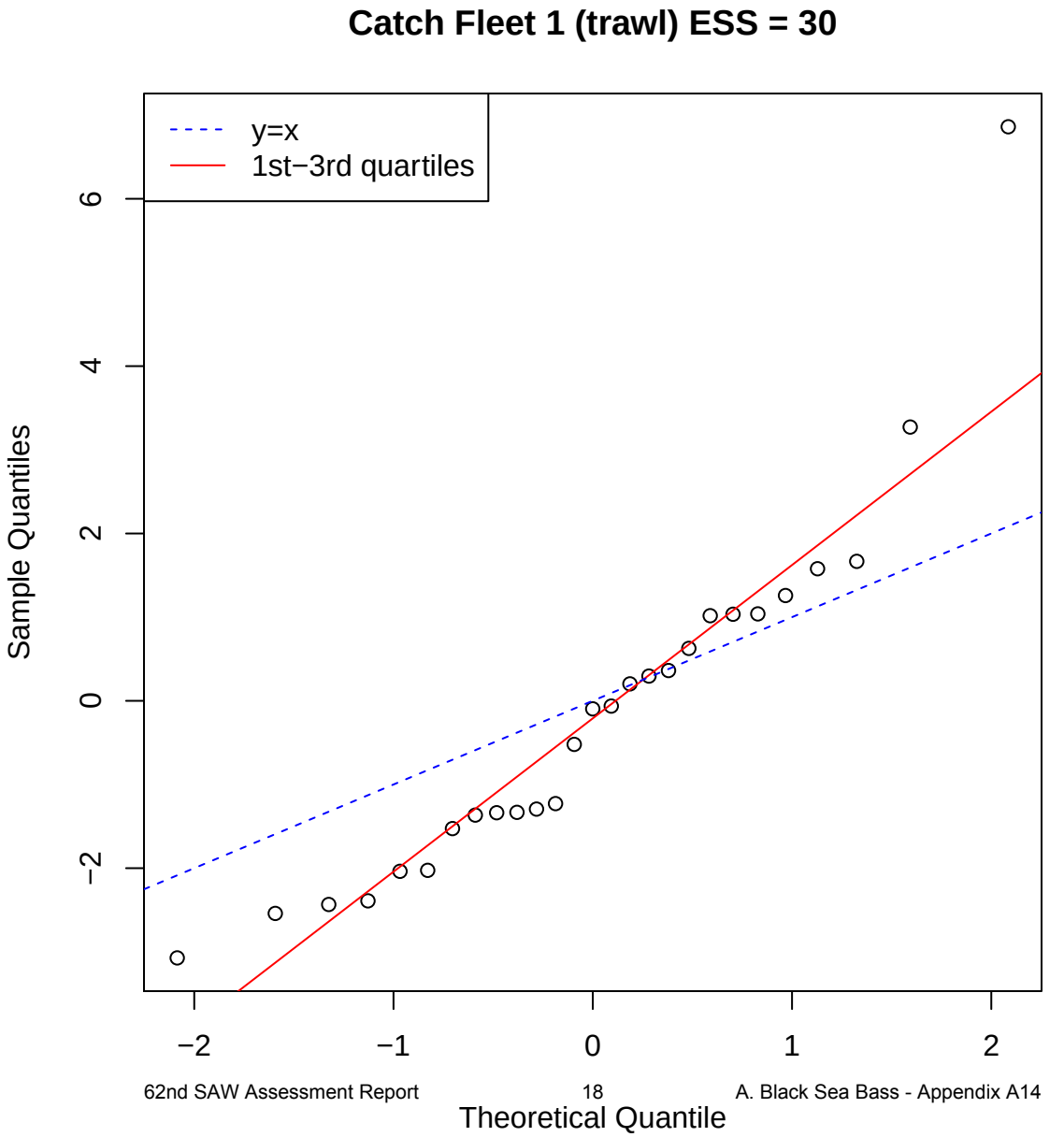


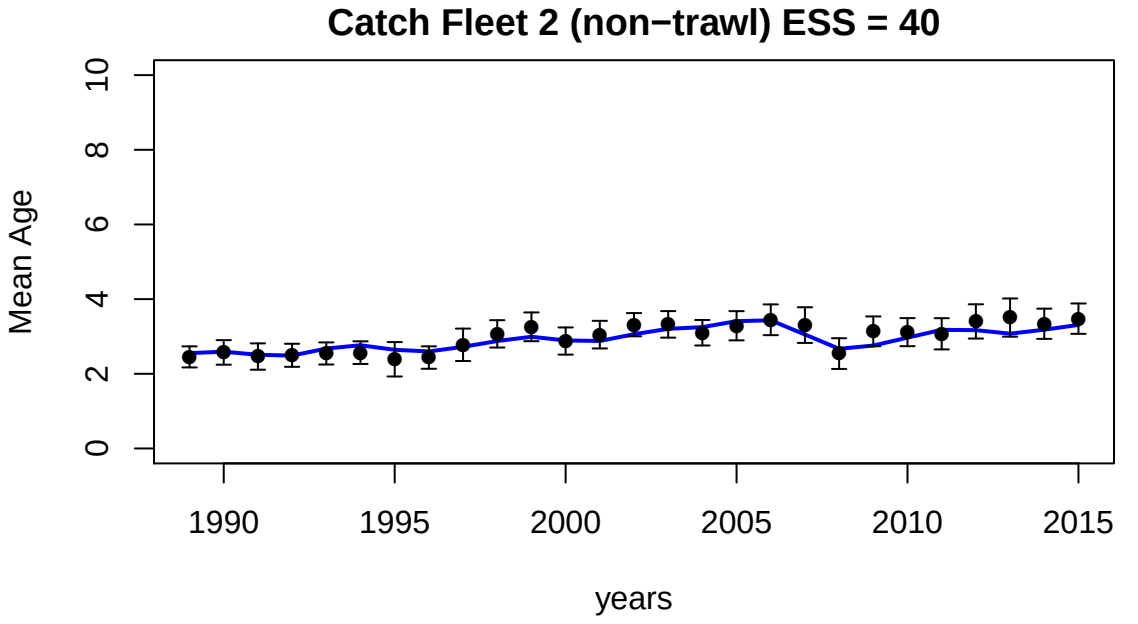

Catch Neff Fleet 1 (trawl)
Effective Sample Size
0
20
40
60
80
100
120
140
1990
1995
2000
2005
2010
2015
Year

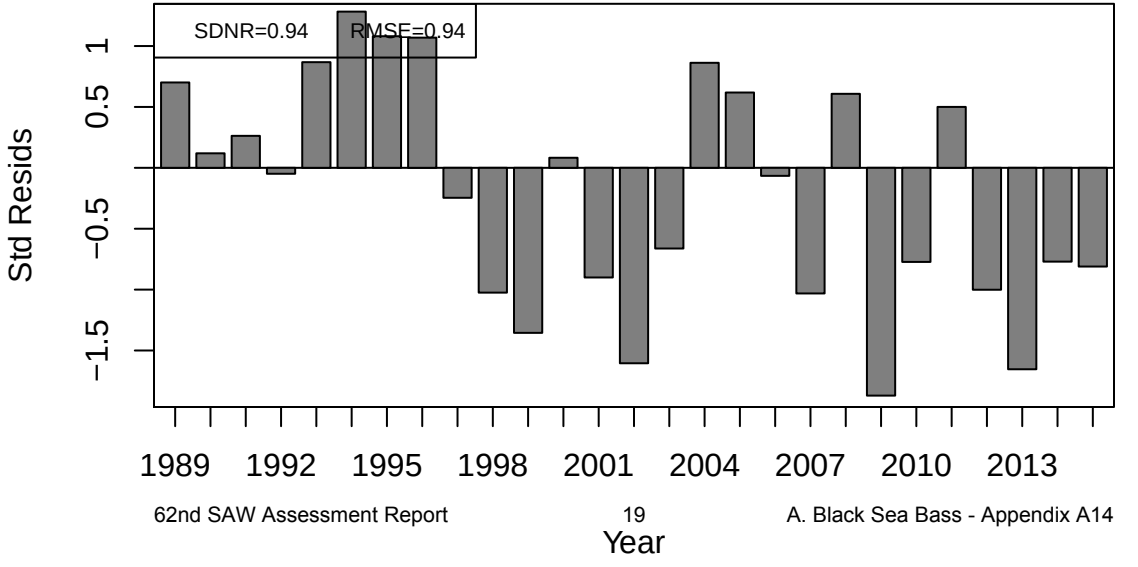

Catch Neff Fleet 2 (non−trawl)
Effective Sample Size
0
50
100
150
200
250
300
1990
1995
2000
2005
2010
2015
Year

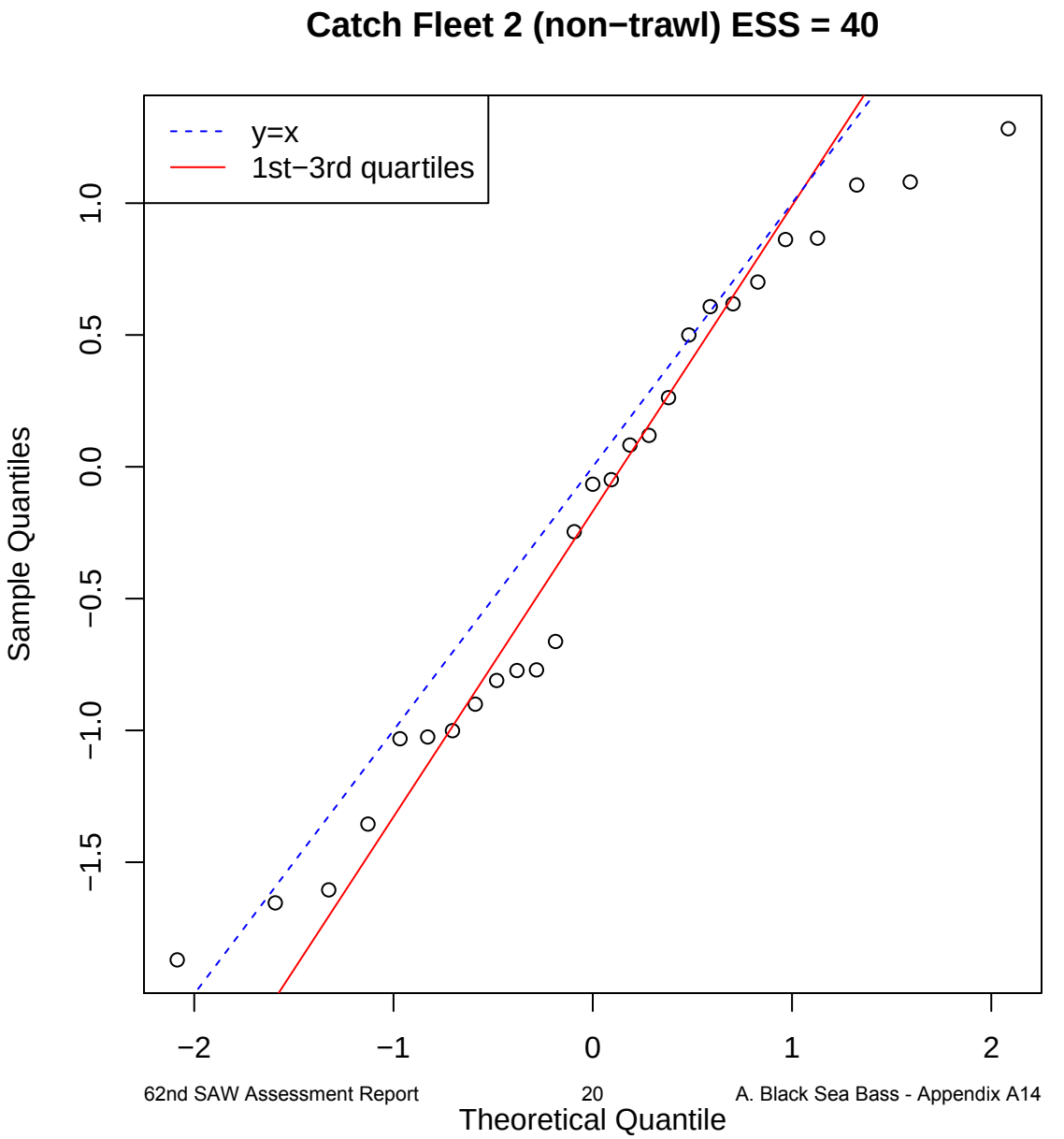

Catch Fleet 1 (trawl) ESS = 30
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
years


SDNR=2.1
RMSE=2.07
Std Resids
−2
0
2
4
6
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

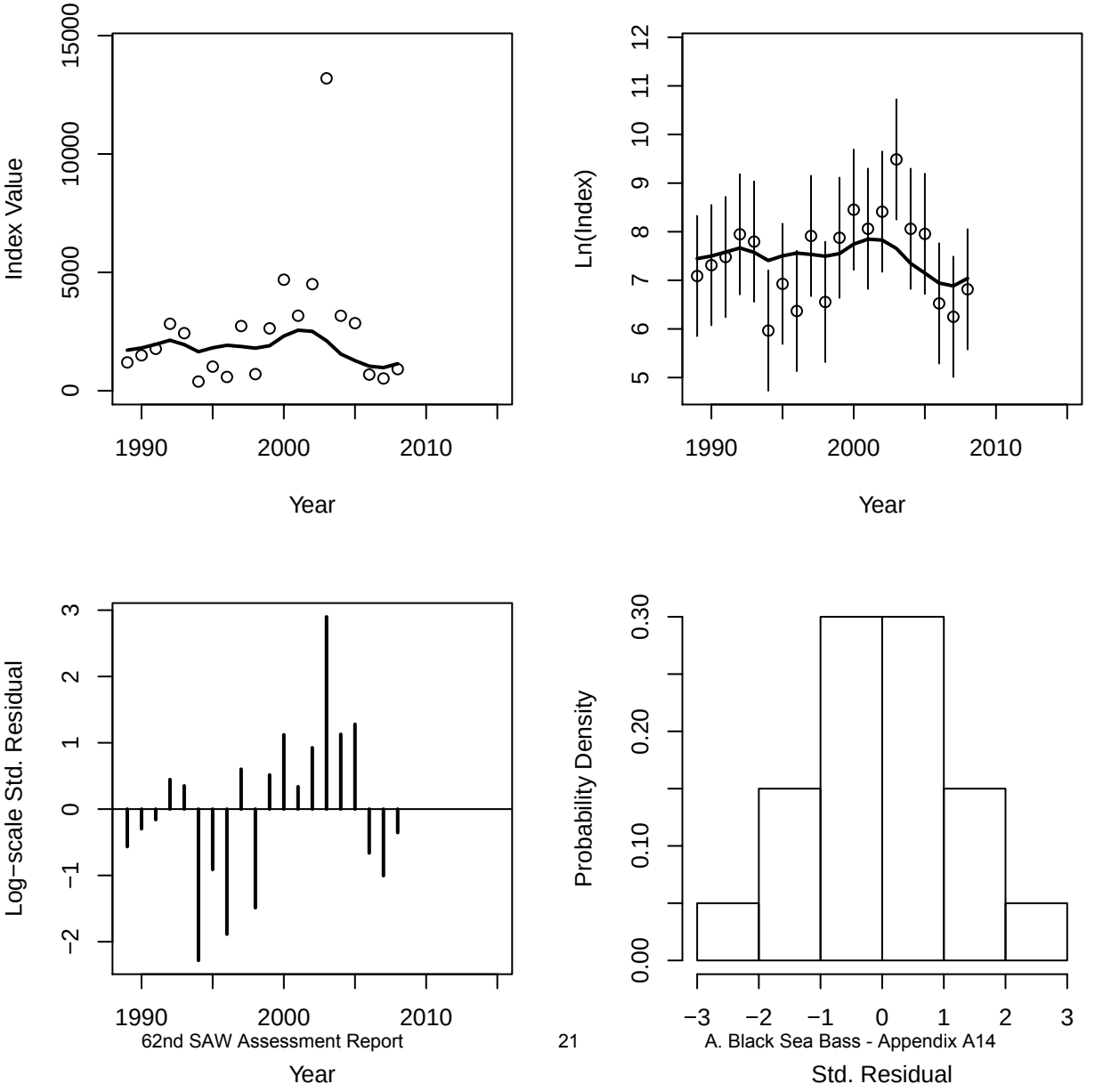

Catch Fleet 1 (trawl) ESS = 30
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
6
4
2
0
−2
−2
−1
0
1
2


Catch Fleet 2 (non−trawl) ESS = 40
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
years

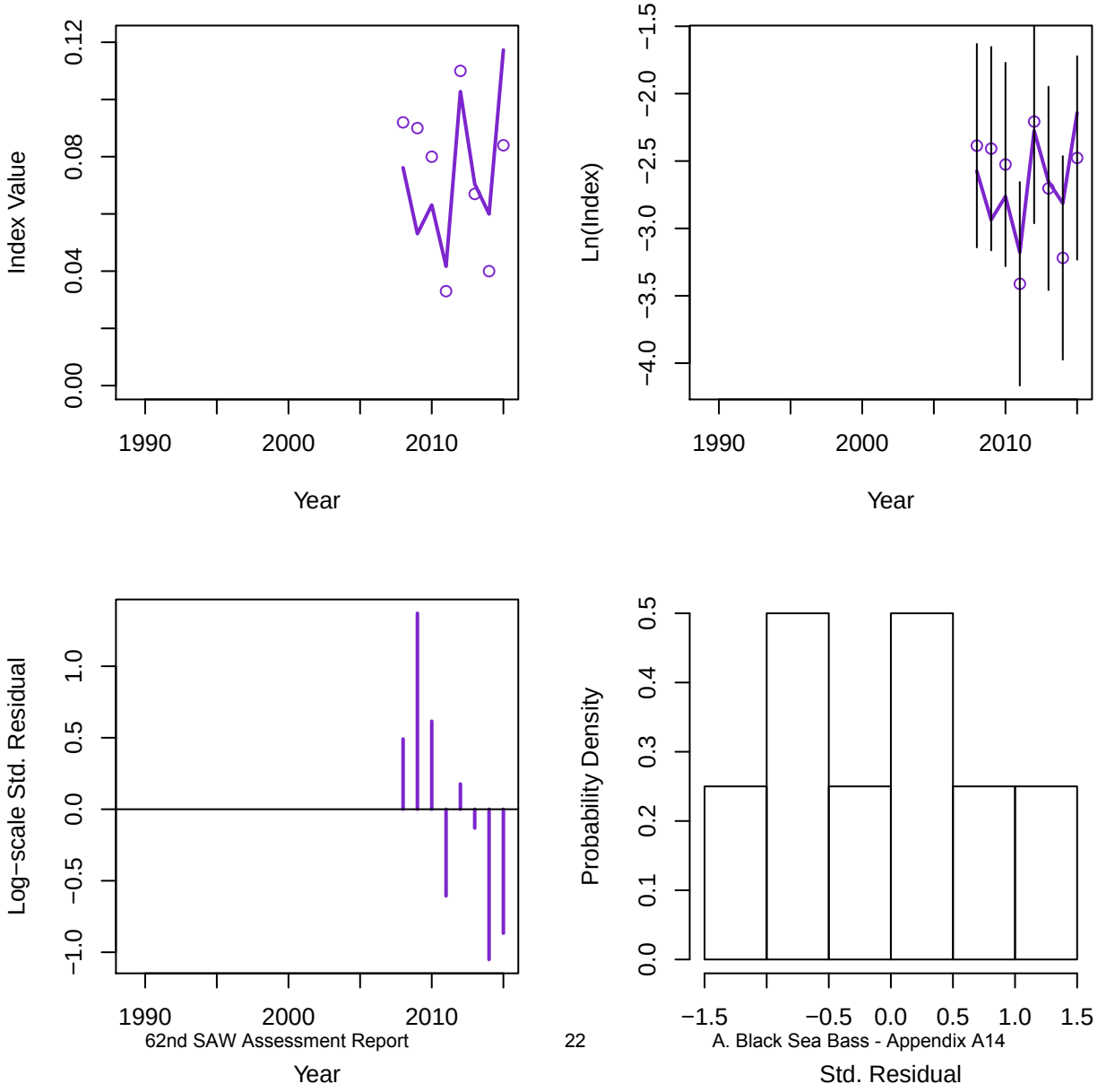

SDNR=0.94
RMSE=0.94
Std Resids
1
0.5
−0.5
−1.5
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year


Catch Fleet 2 (non−trawl) ESS = 40
y=x
1st−3rd quartiles
Sample Quantiles
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2
−1
0
1
2
Theoretical Quantile

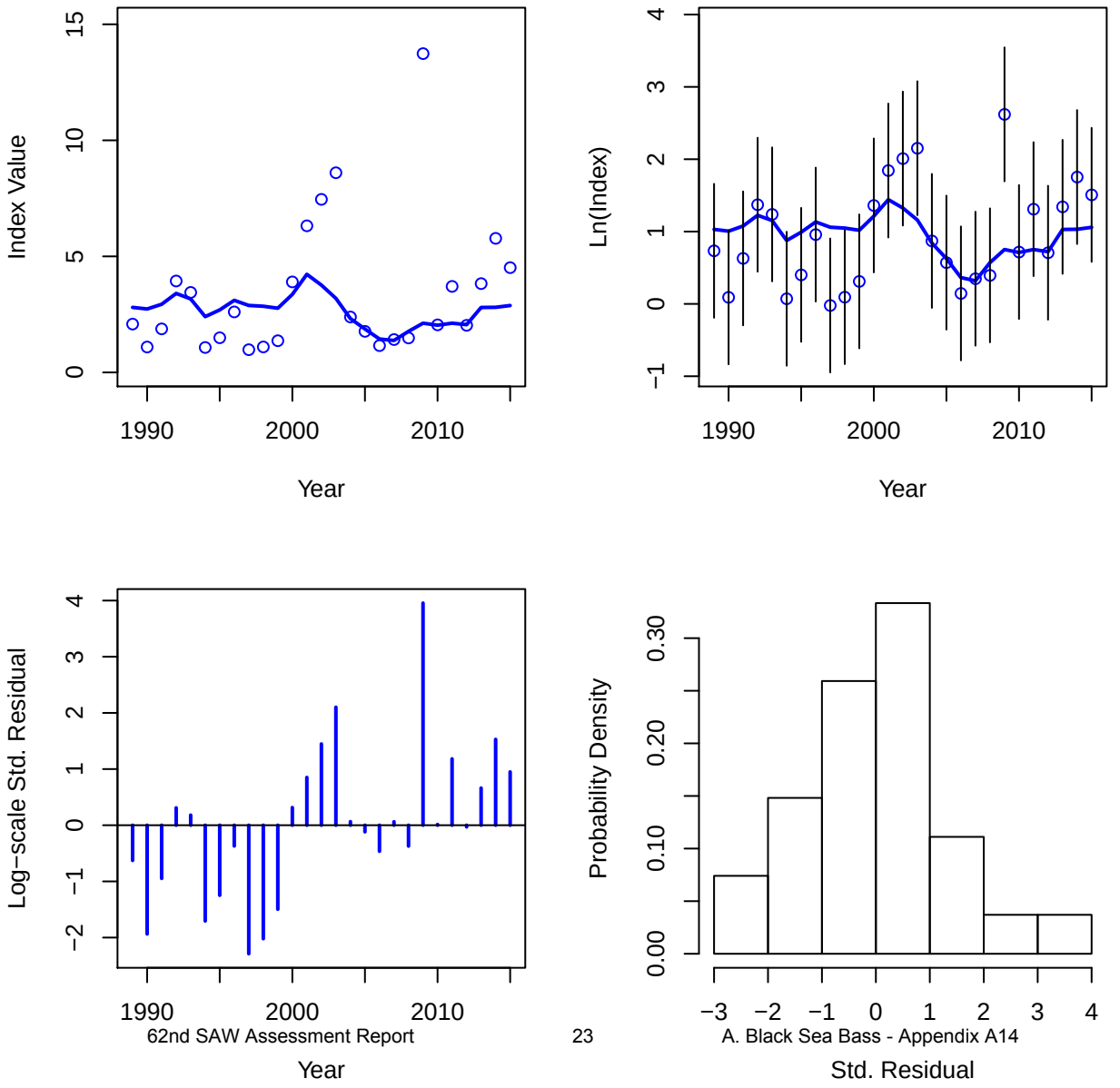
Index 1 (NEFSC spring Alb)



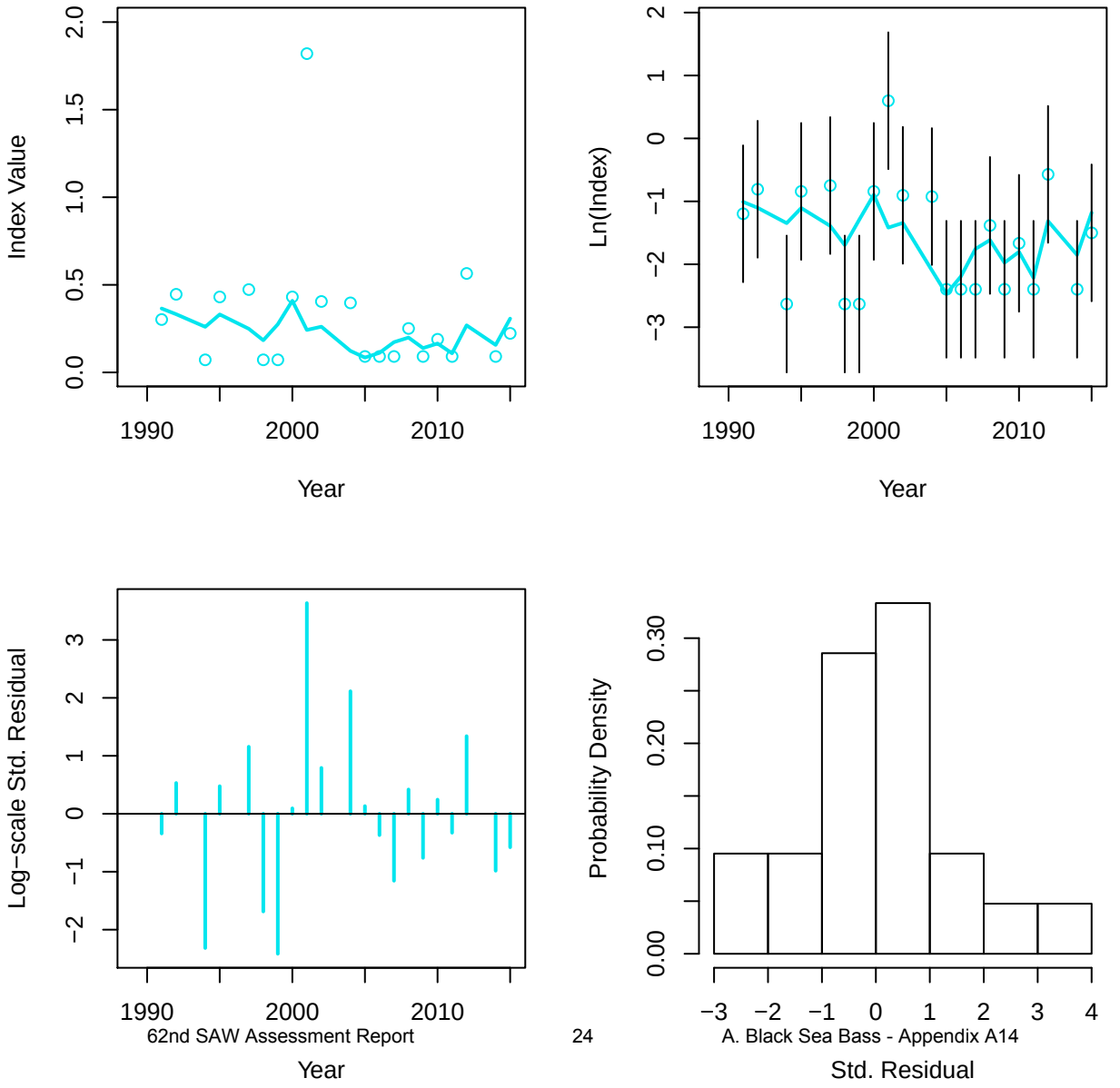
Index 2 (NEAMAP)



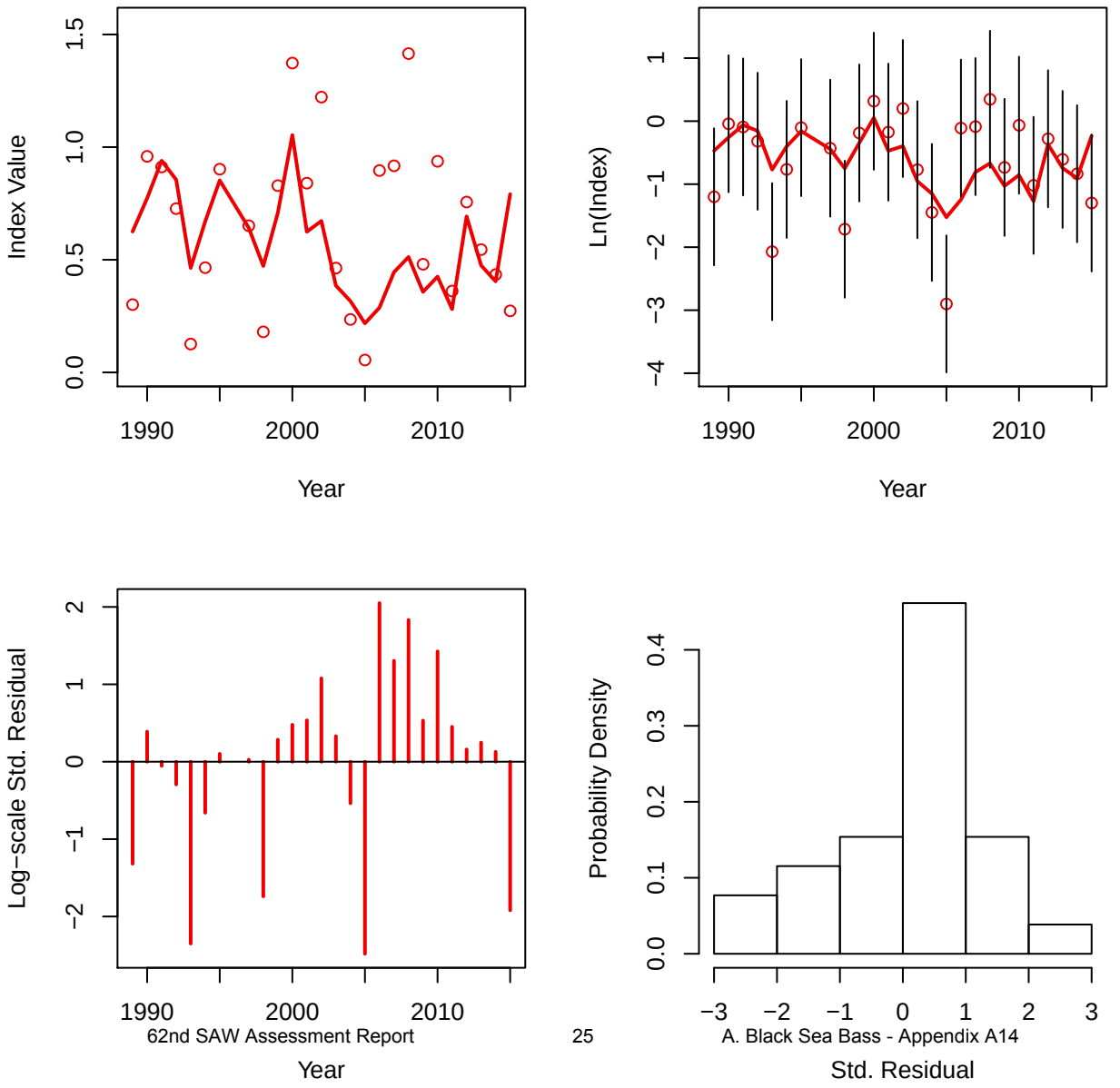
Index 3 (MADMF)



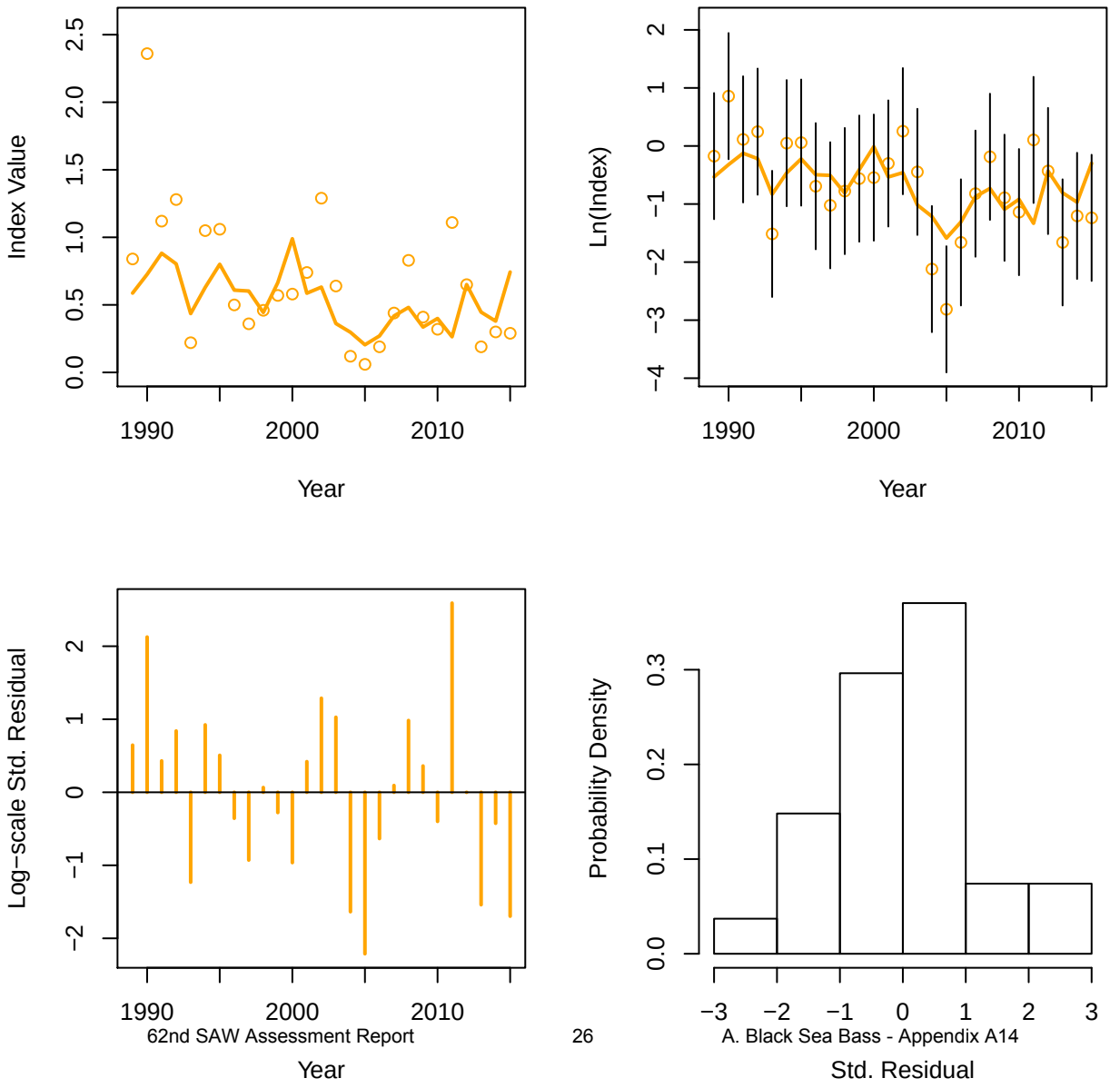
Index 4 (RI)


Index Value
0.0
0.5
1.0
1.5
2.0
1990
2000
2010
Year
Ln(Index)
−3
−2
−1
0
1
2
1990
2000
2010
Year
Log−scale Std. Residual
−2
−1
0
1
2
3
1990
2000
2010
Year
Probability Density
0.00
0.10
0.20
0.30
−3
−2
−1
0
1
2
3
4
Std. Residual

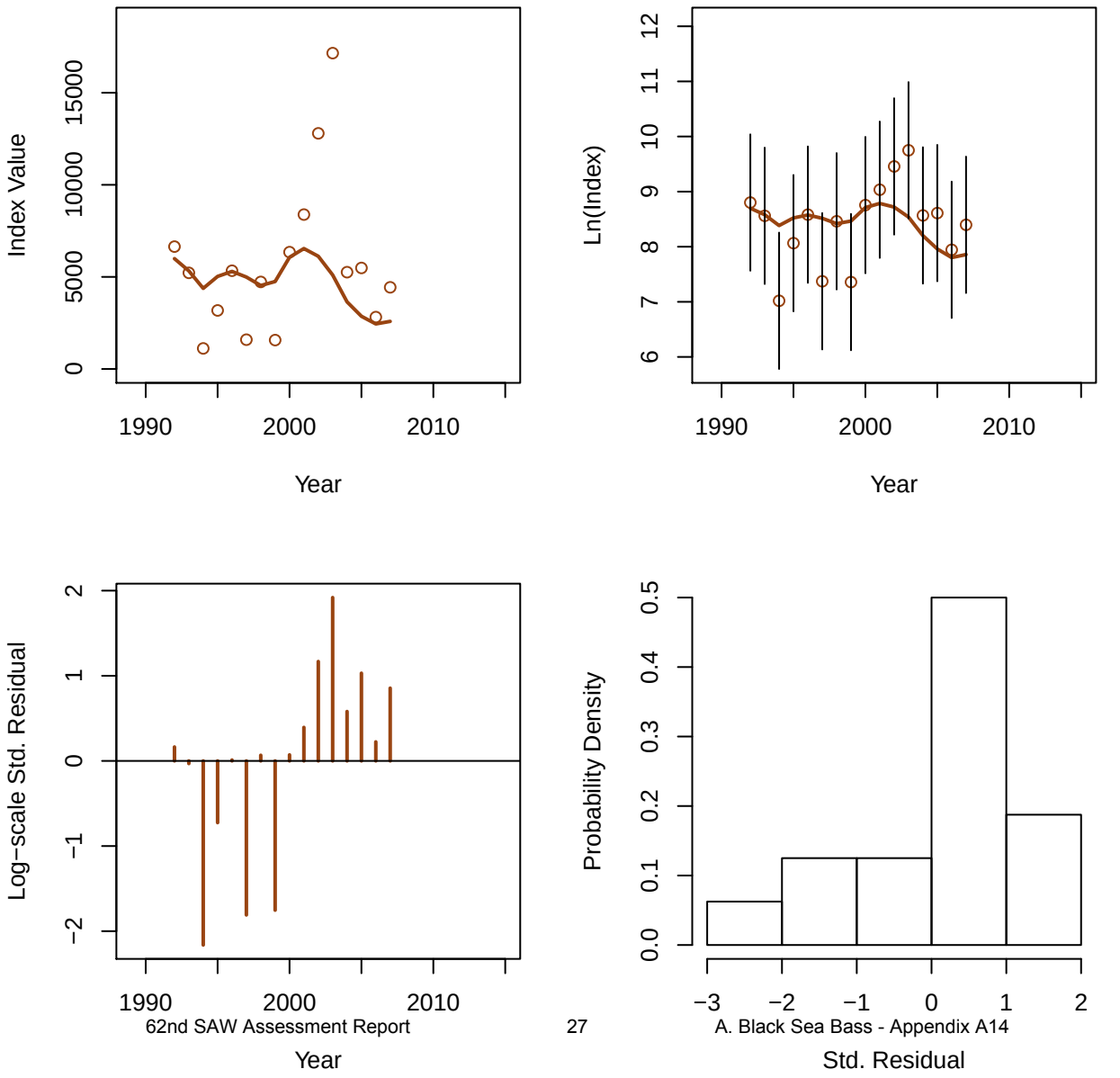
Index 5 (CT)


Index Value
0.0
0.5
1.0
1.5
1990
2000
2010
Year
Ln(Index)
−4
−3
−2
−1
0
1
1990
2000
2010
Year
Log−scale Std. Residual
−2
−1
0
1
2
1990
2000
2010
Year
Probability Density
0.0
0.1
0.2
0.3
0.4
−3
−2
−1
0
1
2
3
Std. Residual

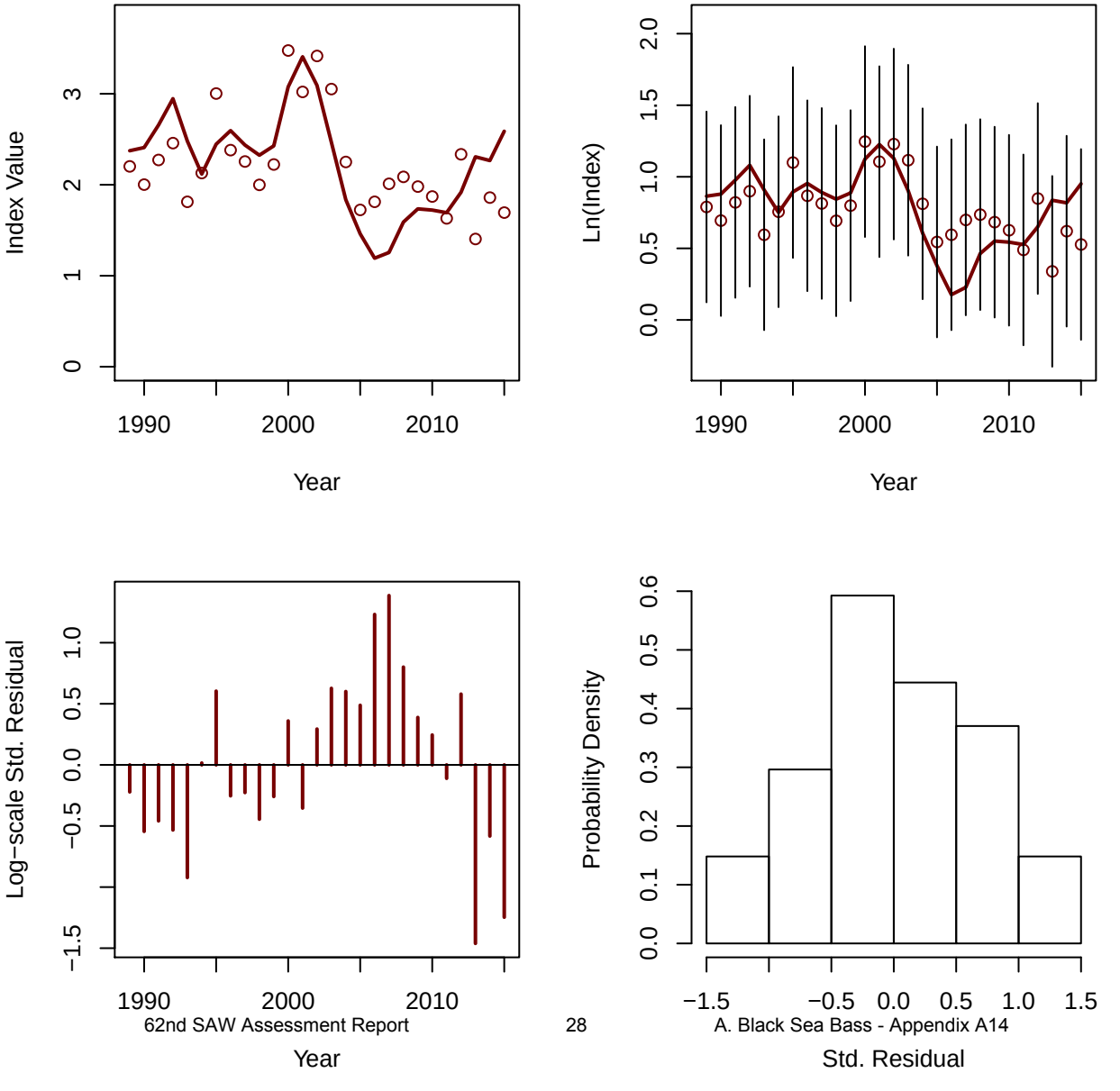
Index 6 (NY)


Index Value
0.0
0.5
1.0
1.5
2.0
2.5
1990
2000
2010
Year
Ln(Index)
−4
−3
−2
−1
0
1
2
1990
2000
2010
Year
Log−scale Std. Residual
−2
−1
0
1
2
1990
2000
2010
Year
Probability Density
0.0
0.1
0.2
0.3
−3
−2
−1
0
1
2
3
Std. Residual

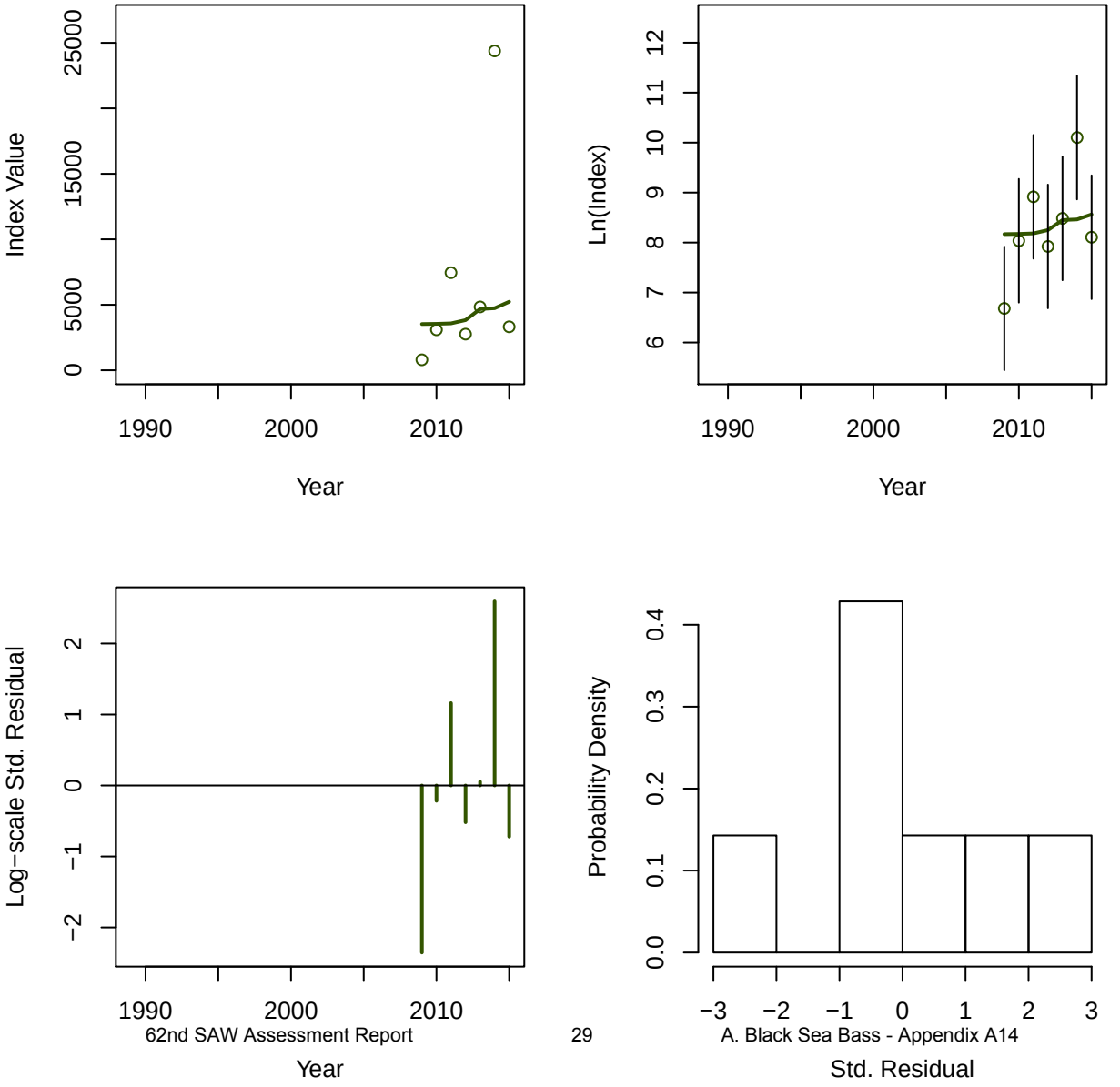
Index 7 (NEFSC winter)



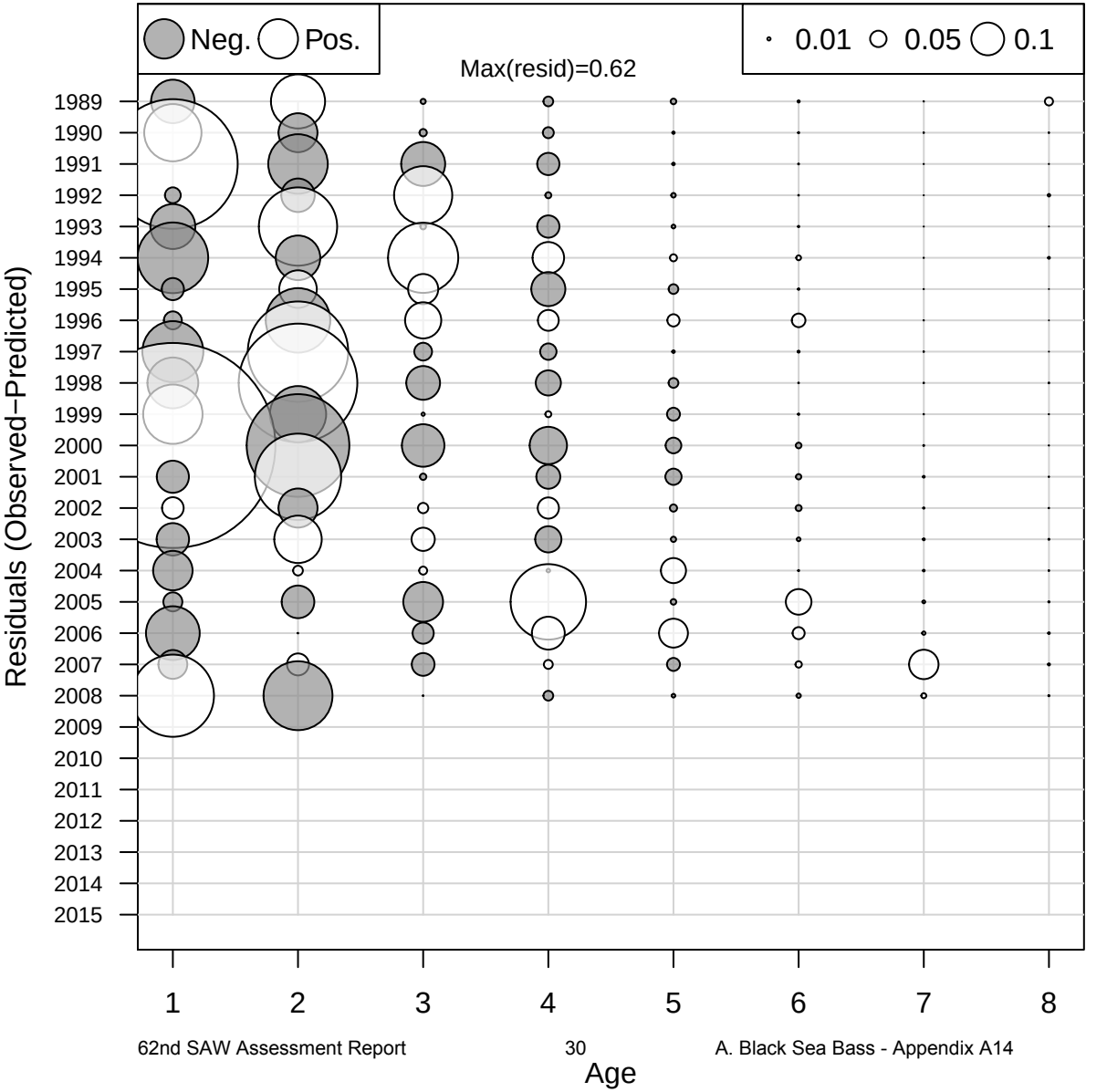
Index 8 (REC CPA)



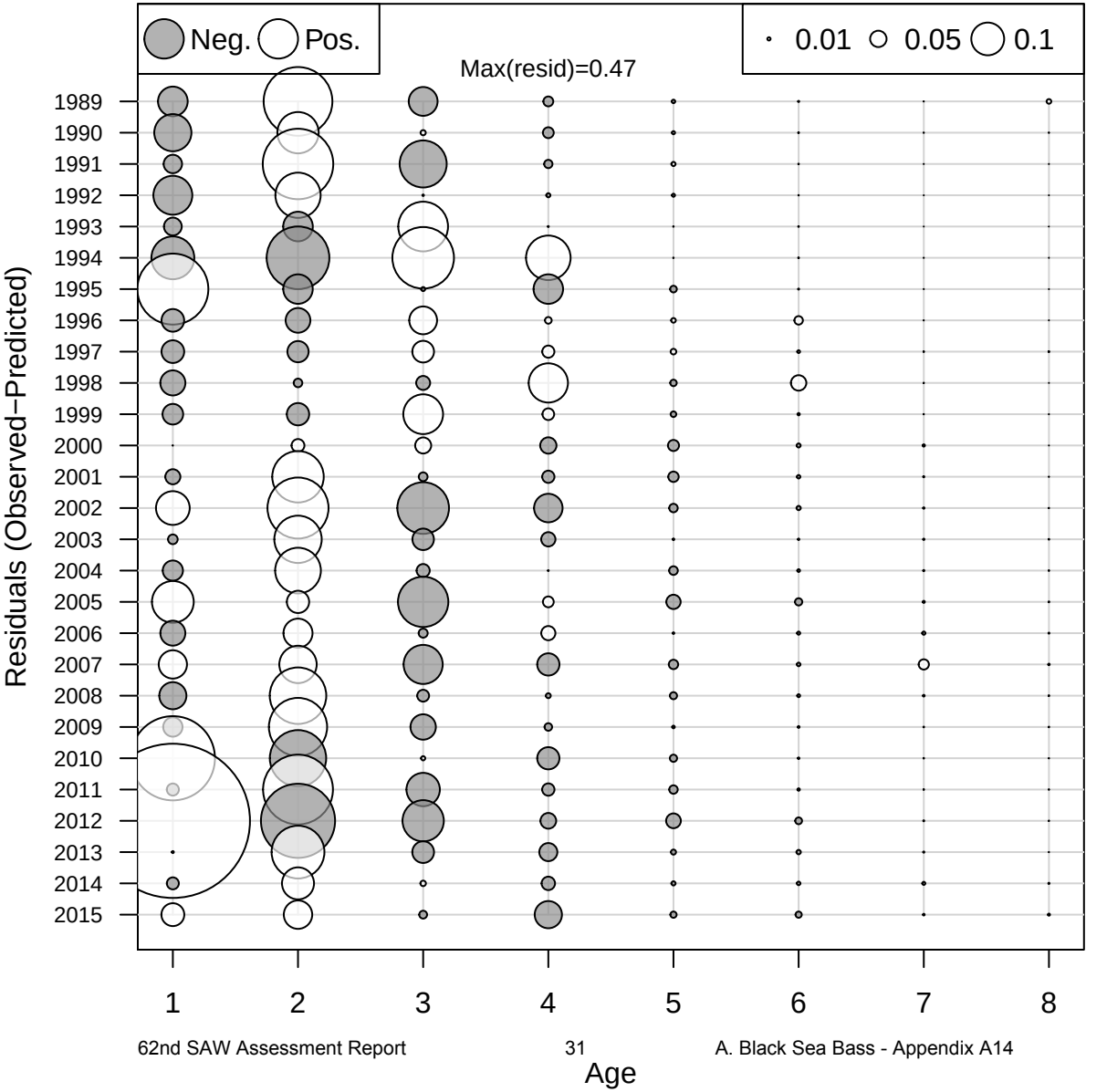
Index 9 (BIGELOW)



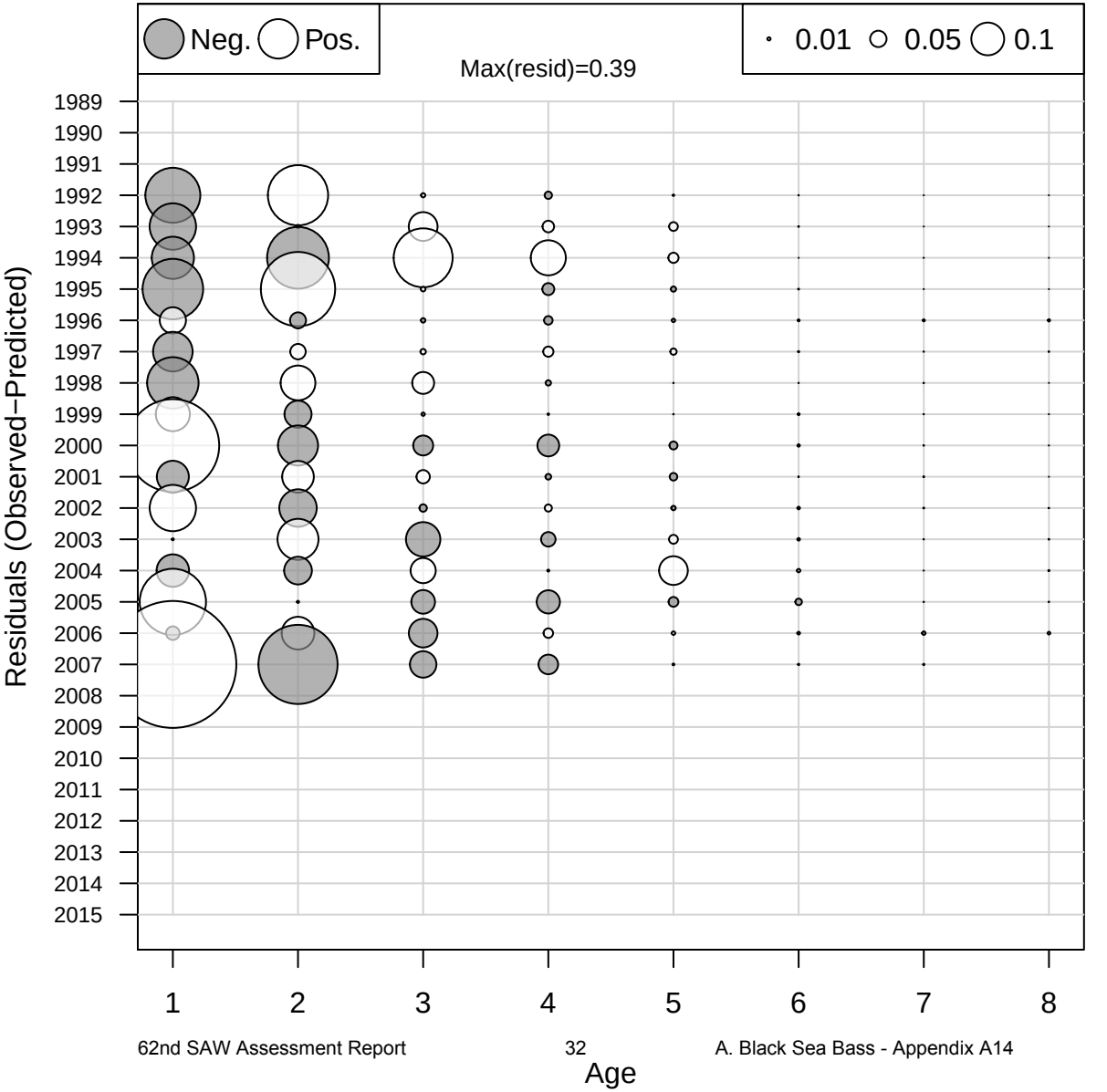
Age Comp Residuals for Index 1 (NEFSC spring Alb)



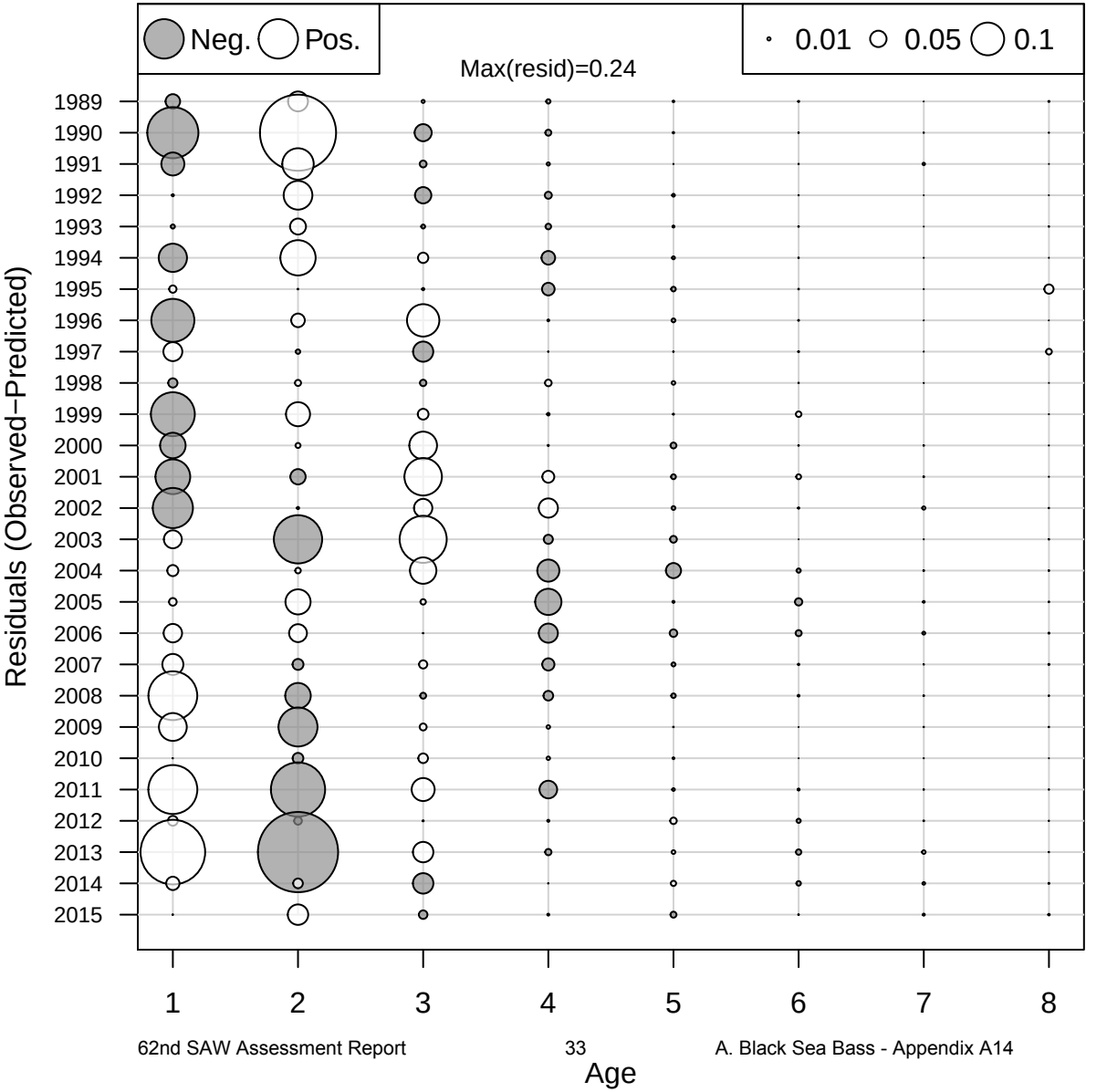
Age Comp Residuals for Index 3 (MADMF)



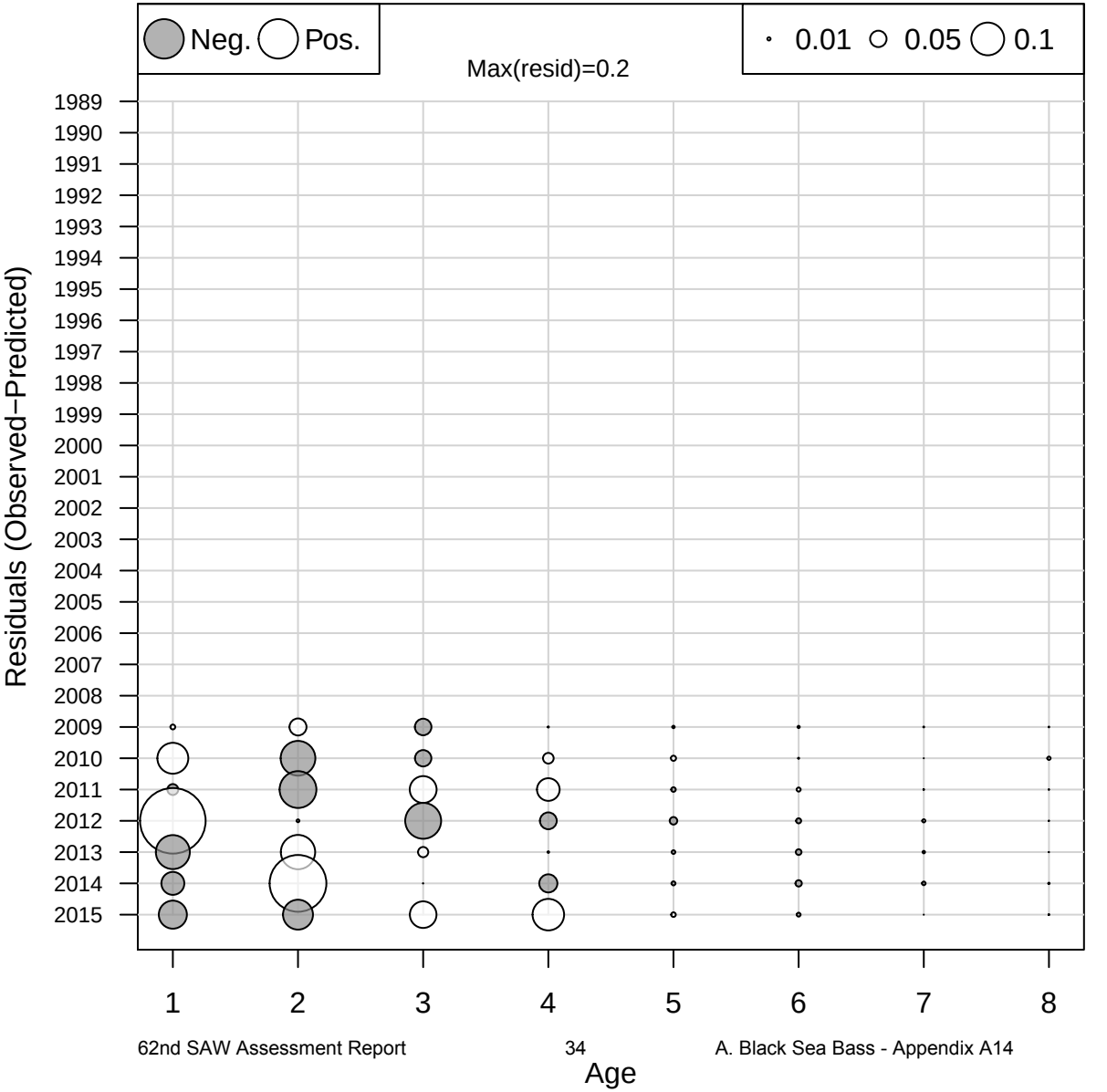
Age Comp Residuals for Index 7 (NEFSC winter)

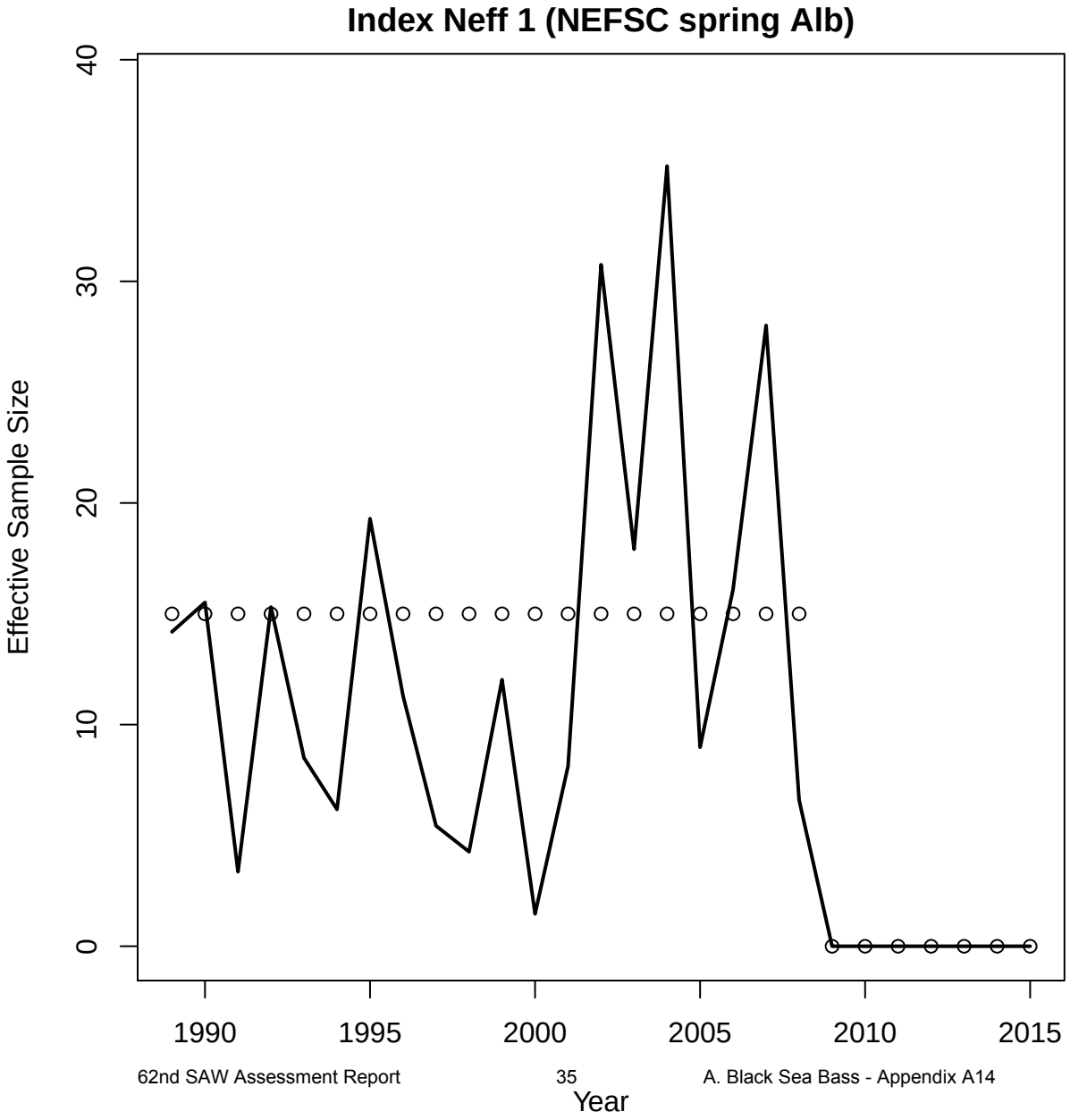


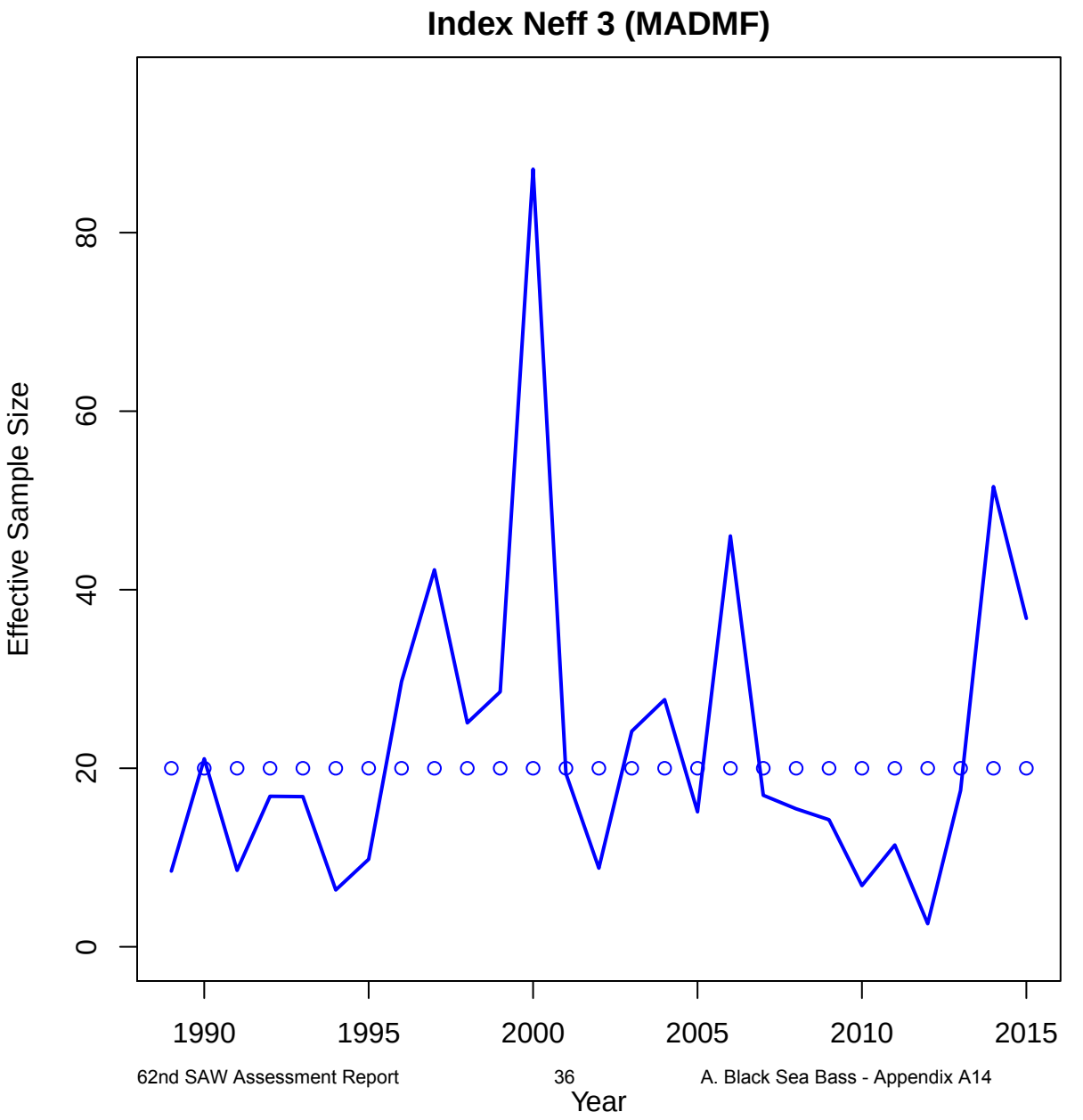
Age Comp Residuals for Index 8 (REC CPA)

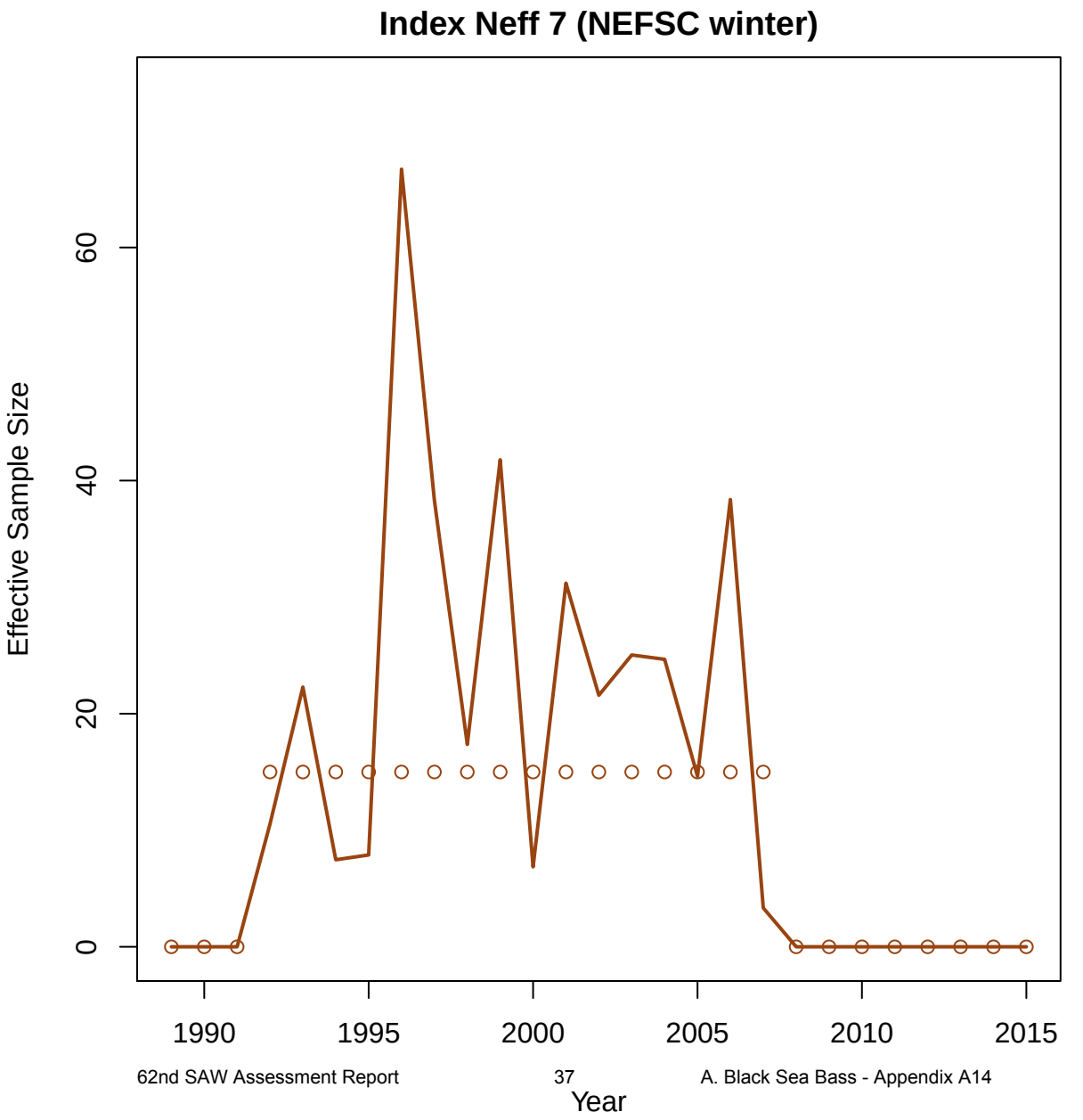


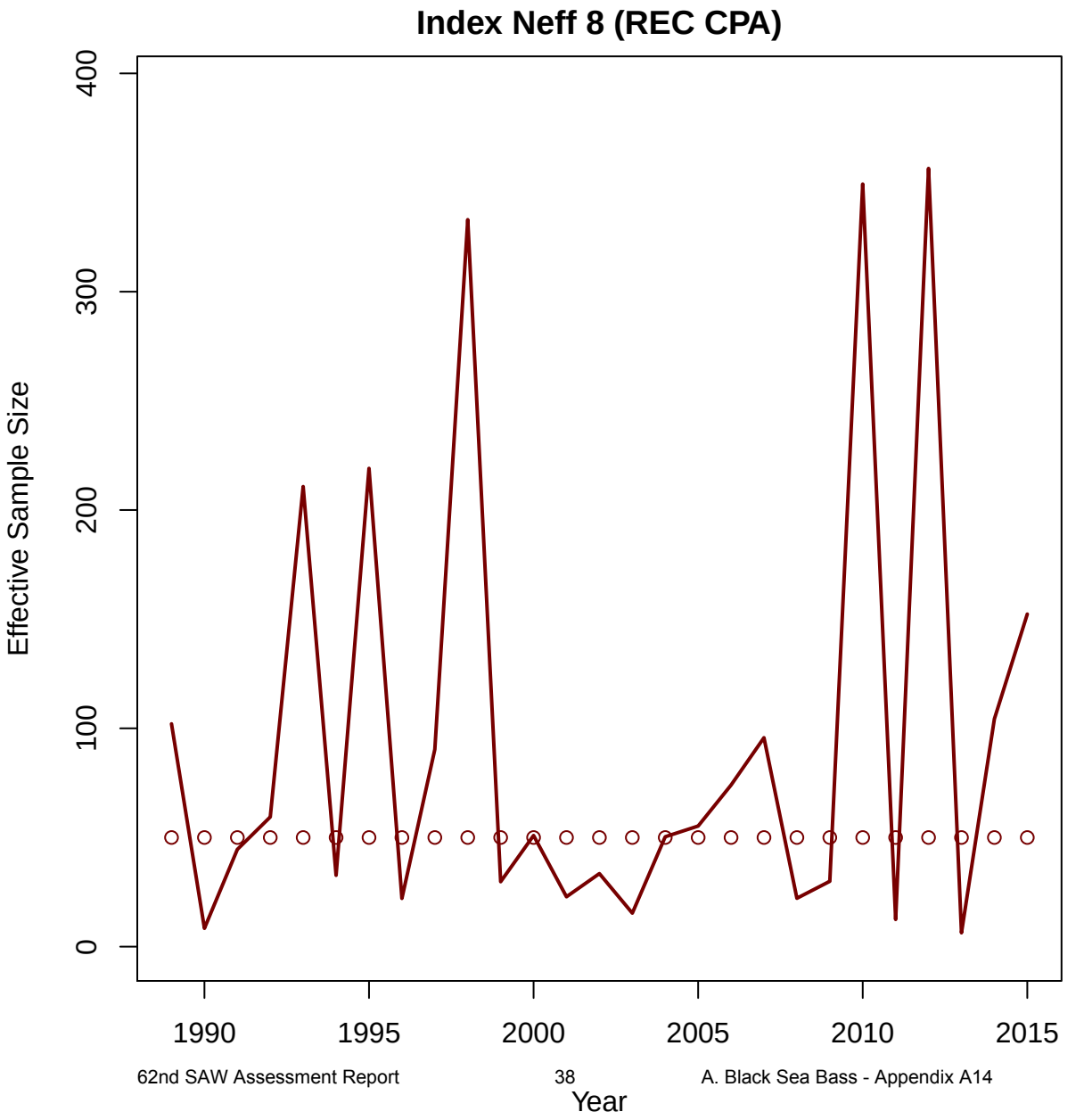
Age Comp Residuals for Index 9 (BIGELOW)

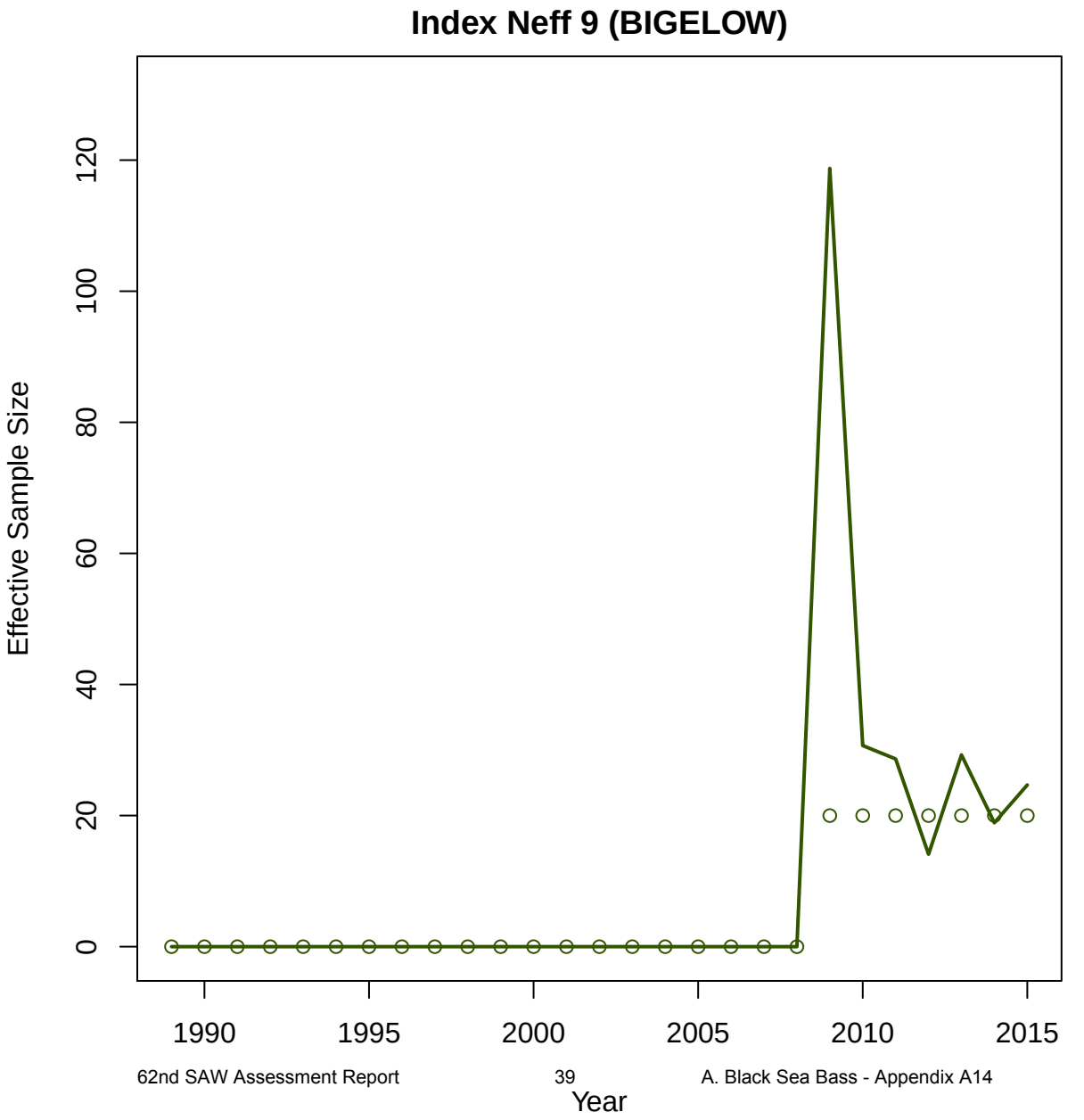


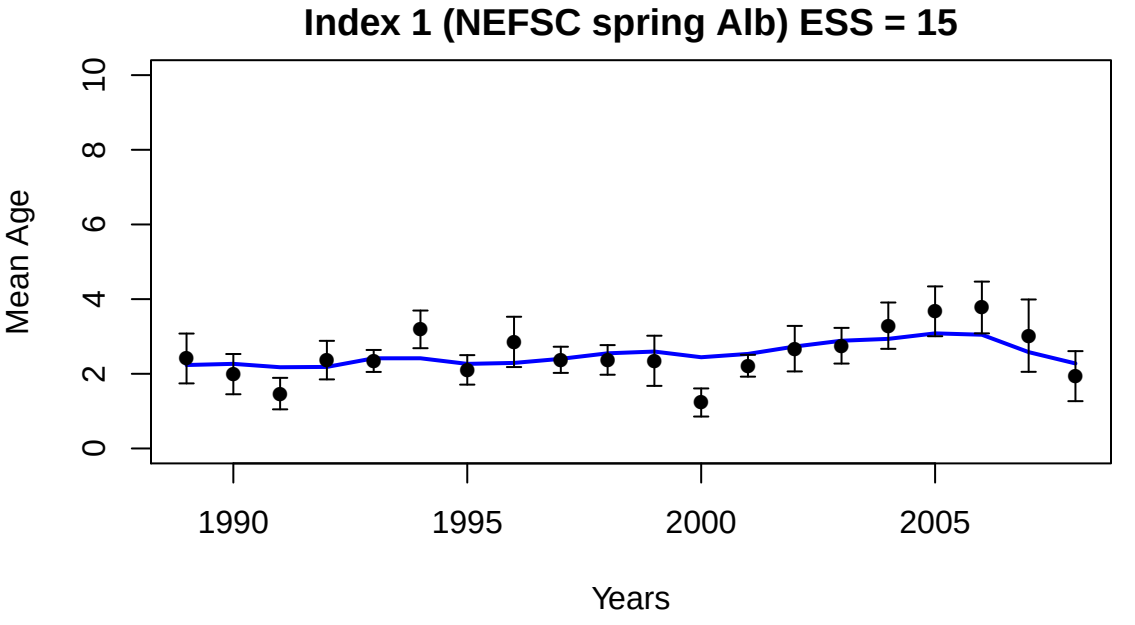

Index Neff 1 (NEFSC spring Alb)
Effective Sample Size
0
10
20
30
40
1990
1995
2000
2005
2010
2015
Year

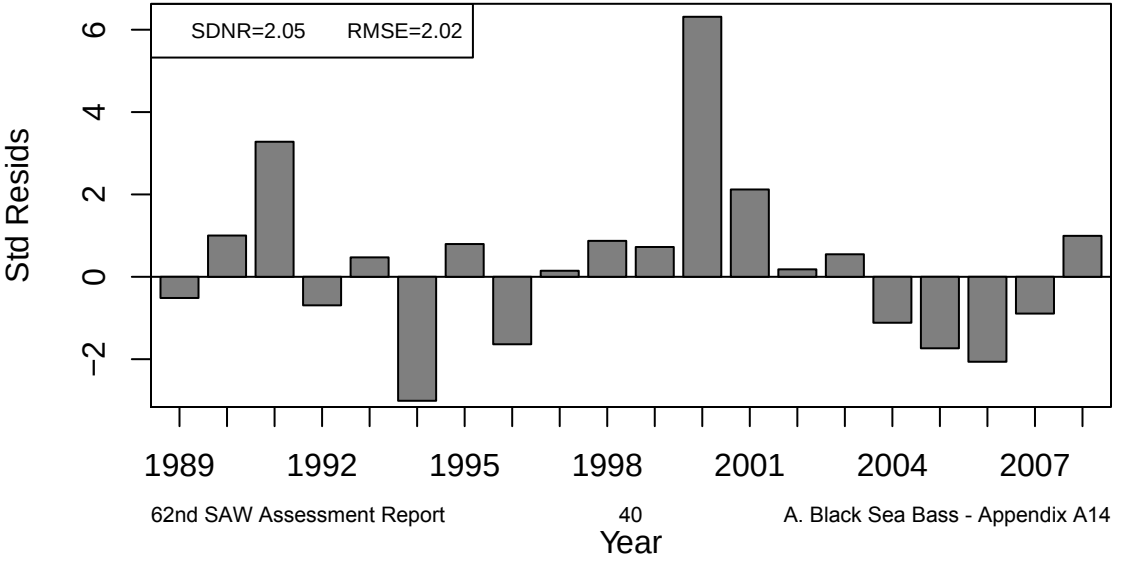

Index Neff 3 (MADMF)
Effective Sample Size
0
20
40
60
80
1990
1995
2000
2005
2010
2015
Year

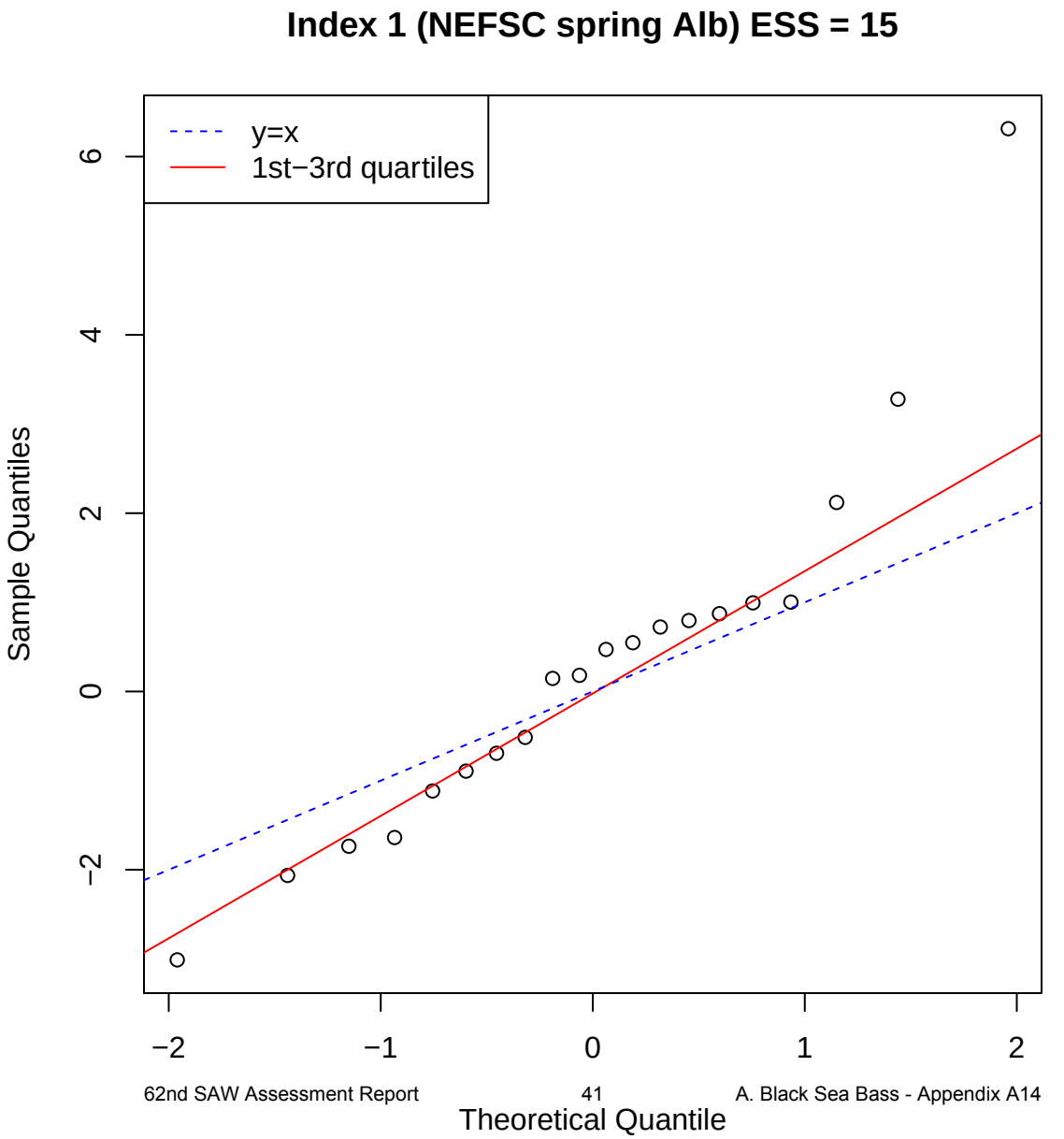

Index Neff 7 (NEFSC winter)
Effective Sample Size
0
20
40
60
1990
1995
2000
2005
2010
2015
Year

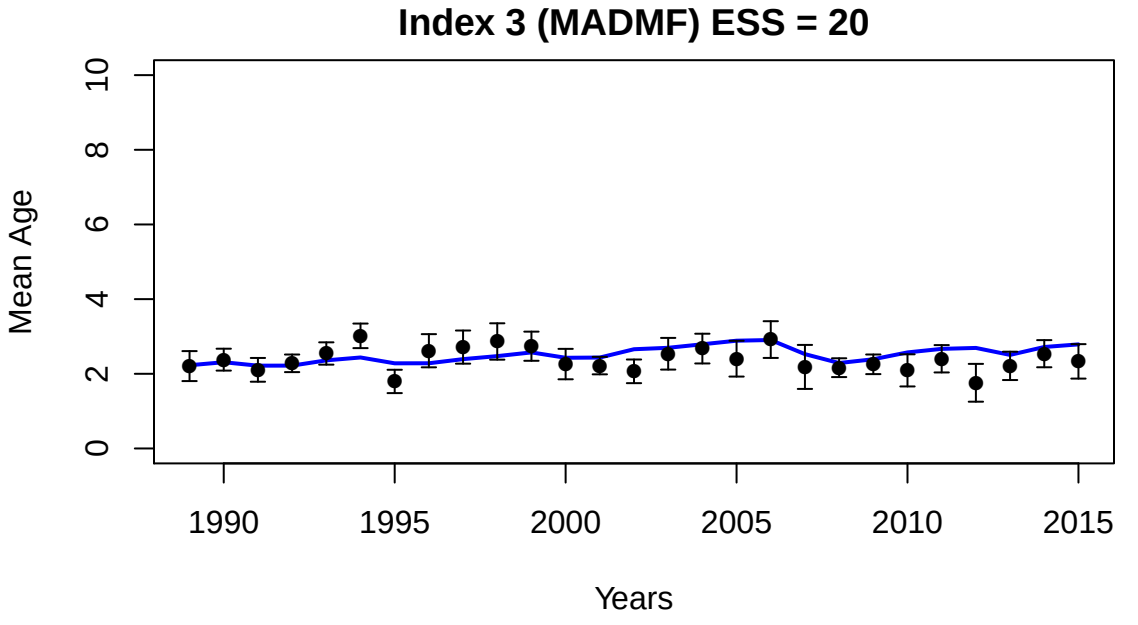

Index Neff 8 (REC CPA)
Effective Sample Size
0
100
200
300
400
1990
1995
2000
2005
2010
2015
Year

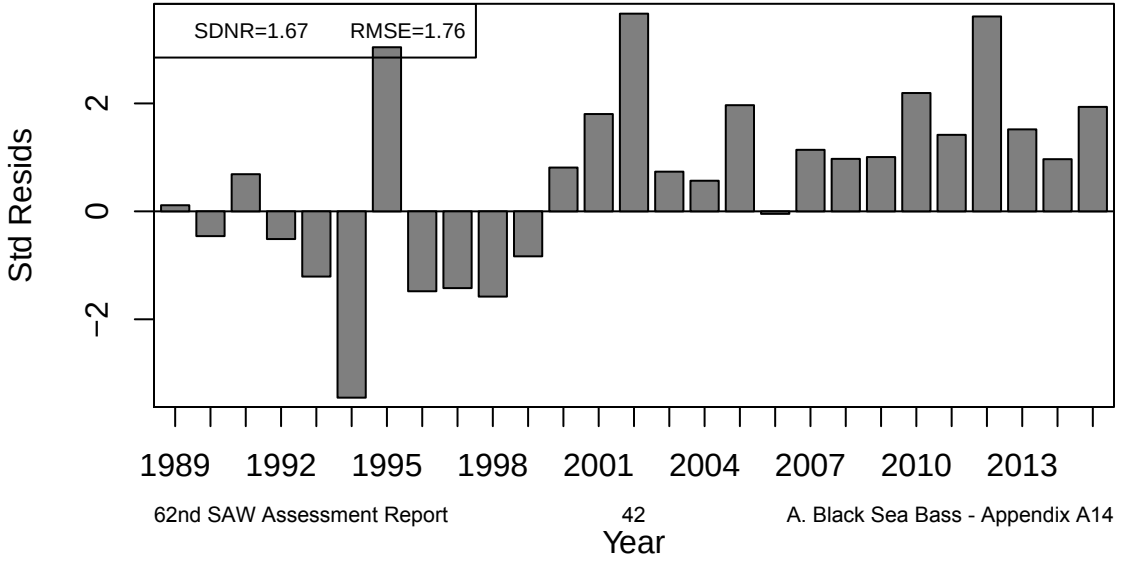

Index Neff 9 (BIGELOW)
Effective Sample Size
0
20
40
60
80
100
120
1990
1995
2000
2005
2010
2015
Year

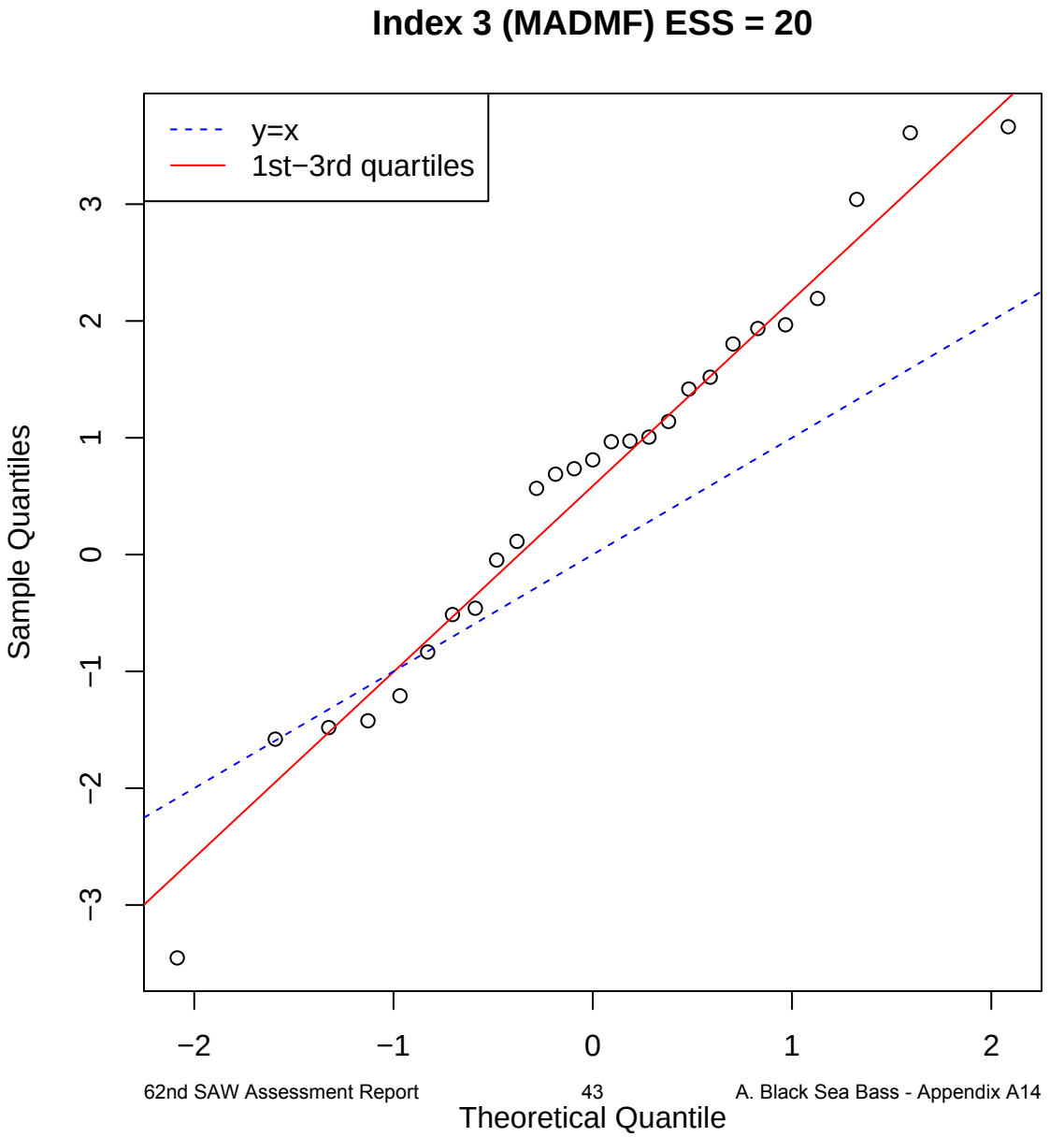

Index 1 (NEFSC spring Alb) ESS = 15
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
Years

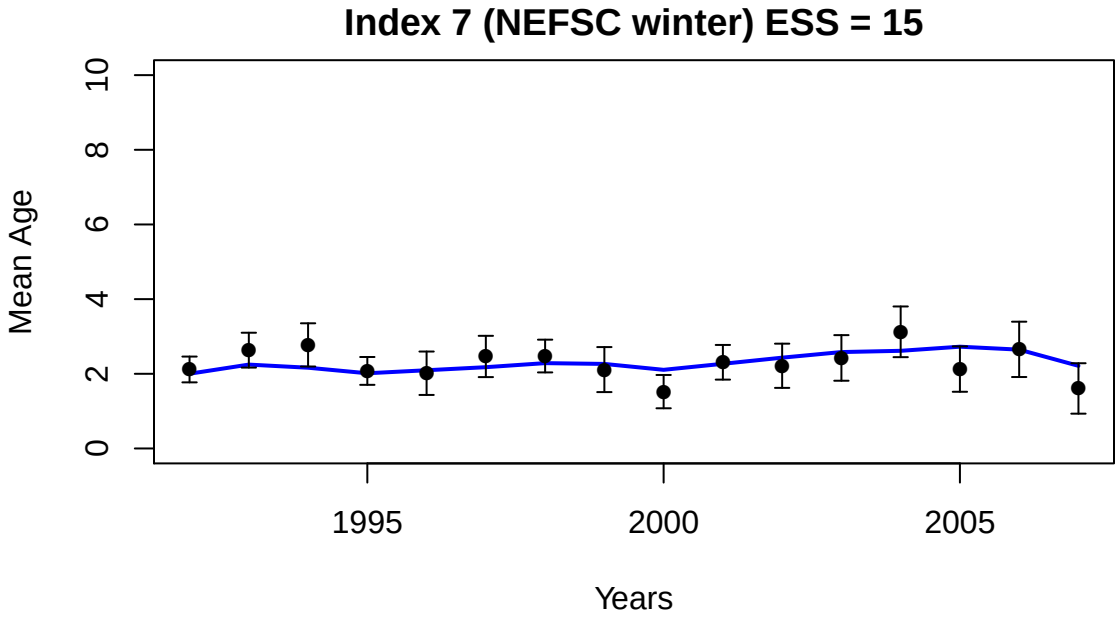

SDNR=2.05
RMSE=2.02
Std Resids
−2
0
2
4
6
1989
1992
1995
1998
2001
2004
2007
Year

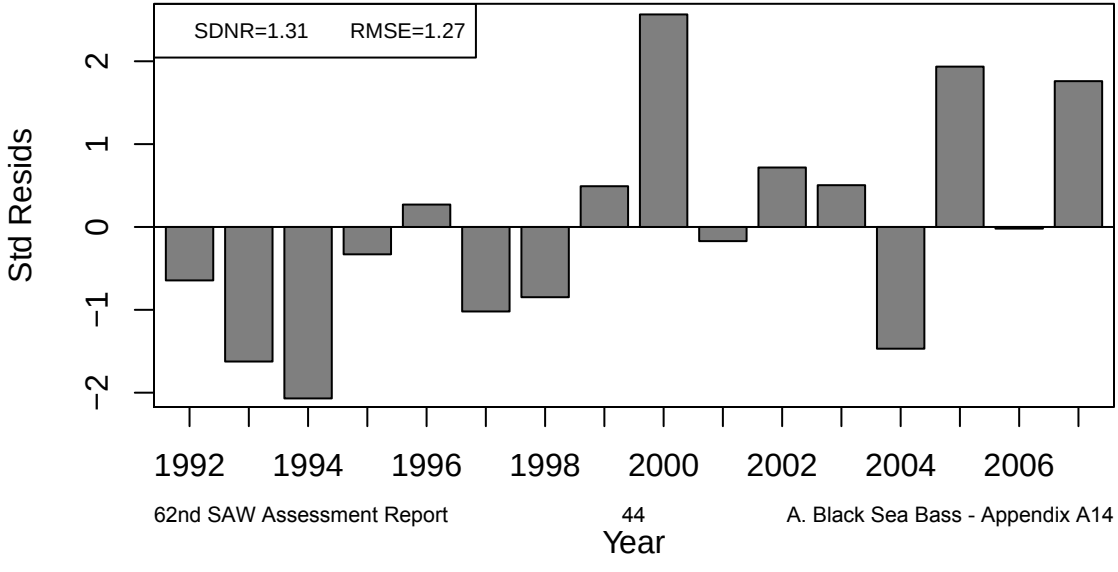

Index 1 (NEFSC spring Alb) ESS = 15
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
0
2
4
6
−2
−1
0
1
2

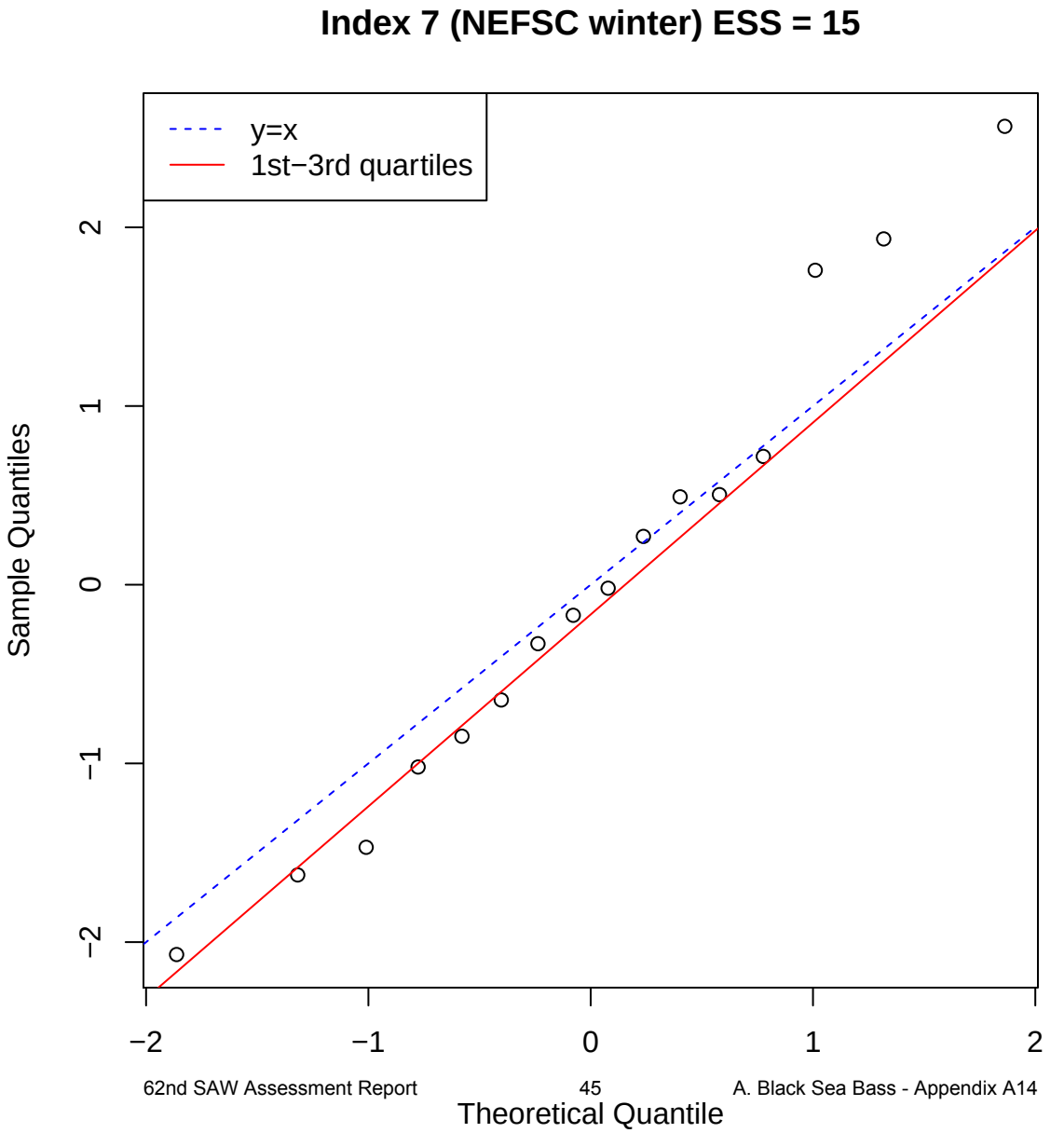

Index 3 (MADMF) ESS = 20
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

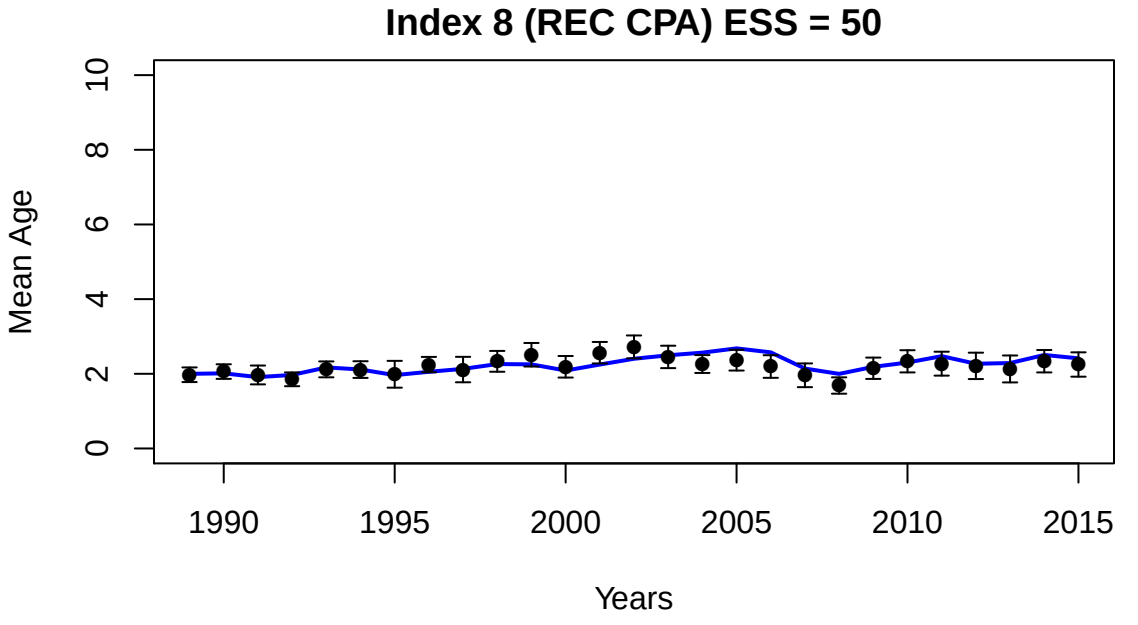

SDNR=1.67
RMSE=1.76
Std Resids
−2
0
2
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

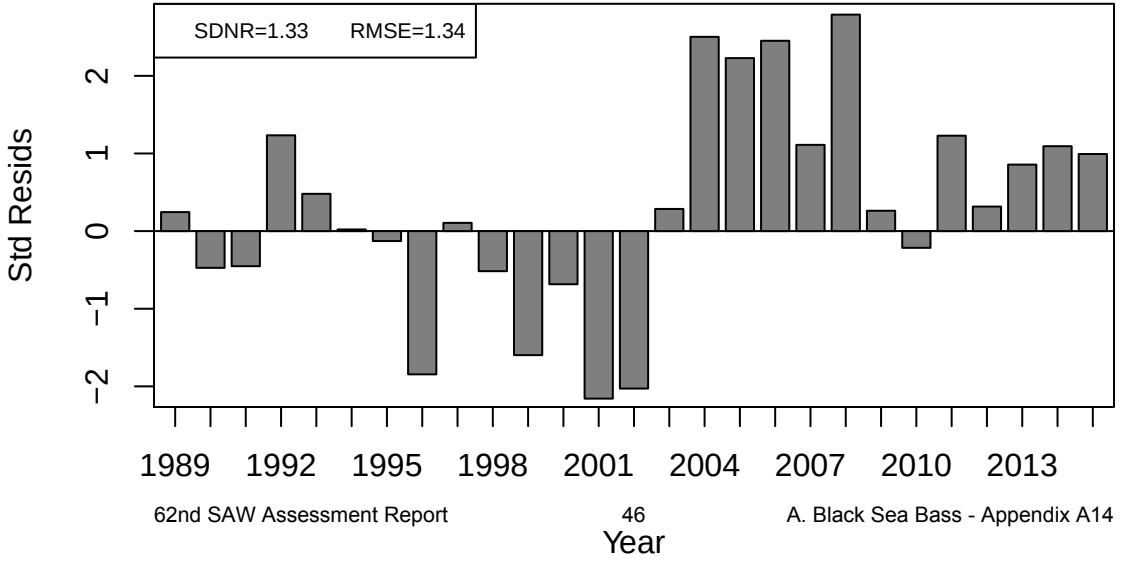

Index 3 (MADMF) ESS = 20
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−3
−2
−1
0
1
2
3
−2
−1
0
1
2

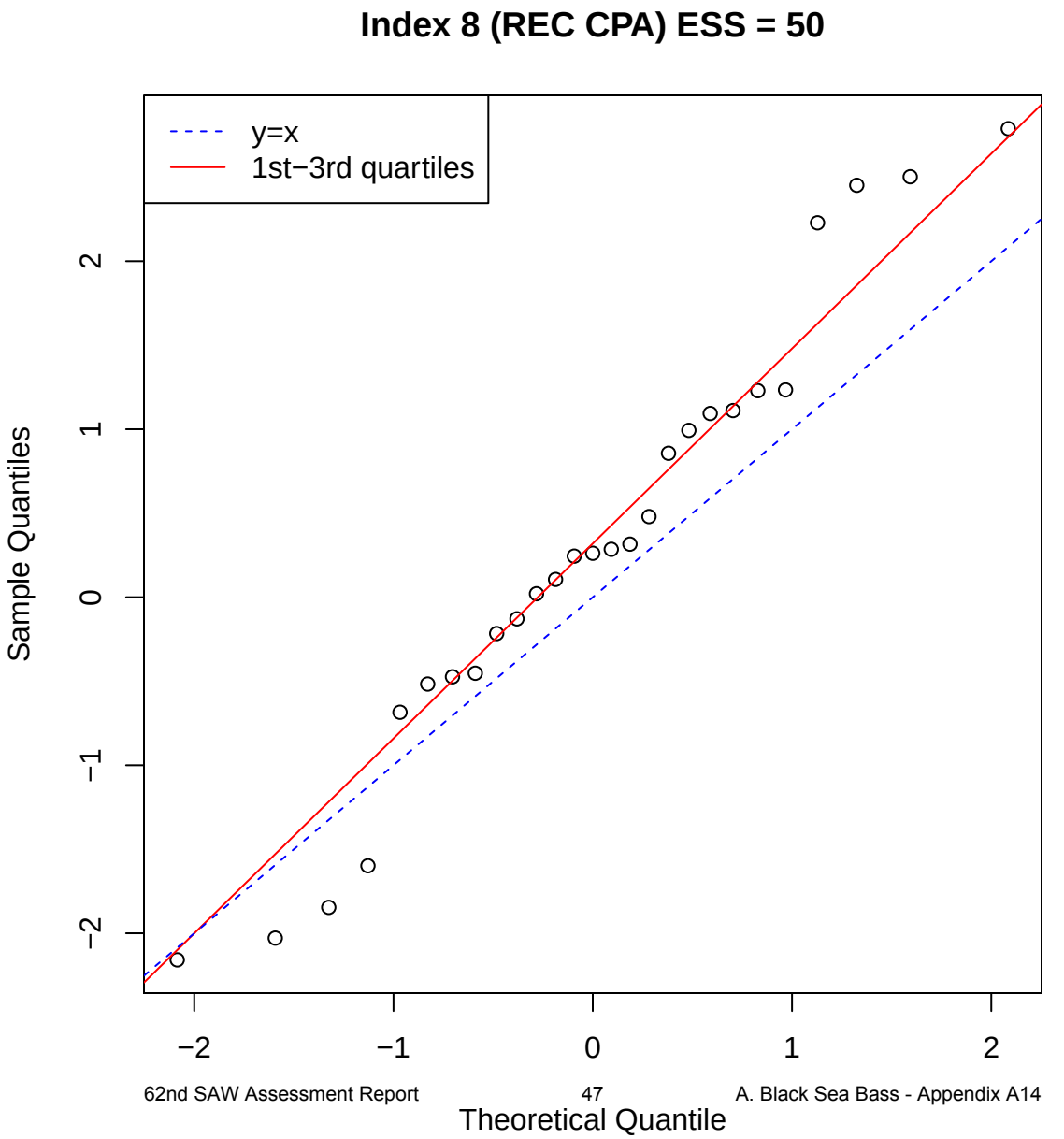

Index 7 (NEFSC winter) ESS = 15
Mean Age
0
2
4
6
8
10
1995
2000
2005
Years

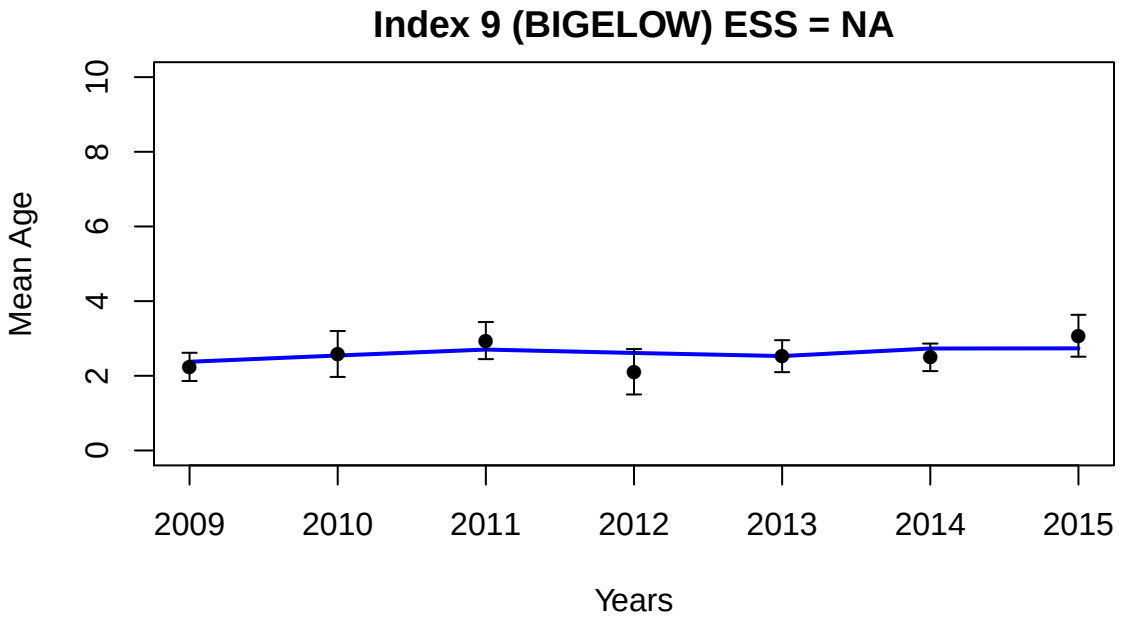

SDNR=1.31
RMSE=1.27
Std Resids
−2
−1
0
1
2
1992
1994
1996
1998
2000
2002
2004
2006
Year

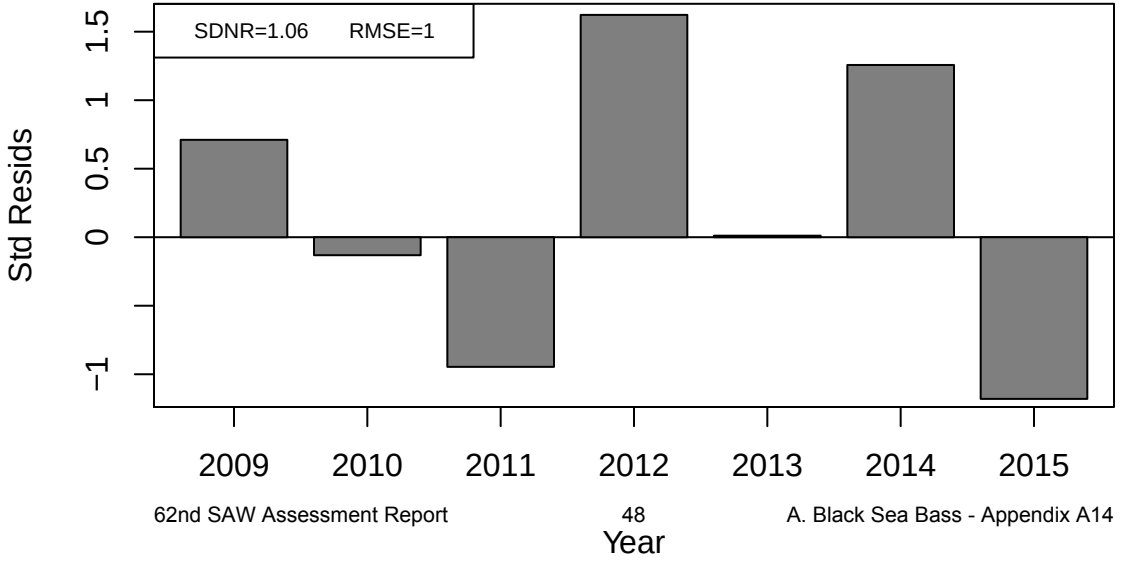

Index 7 (NEFSC winter) ESS = 15
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
−1
0
1
2

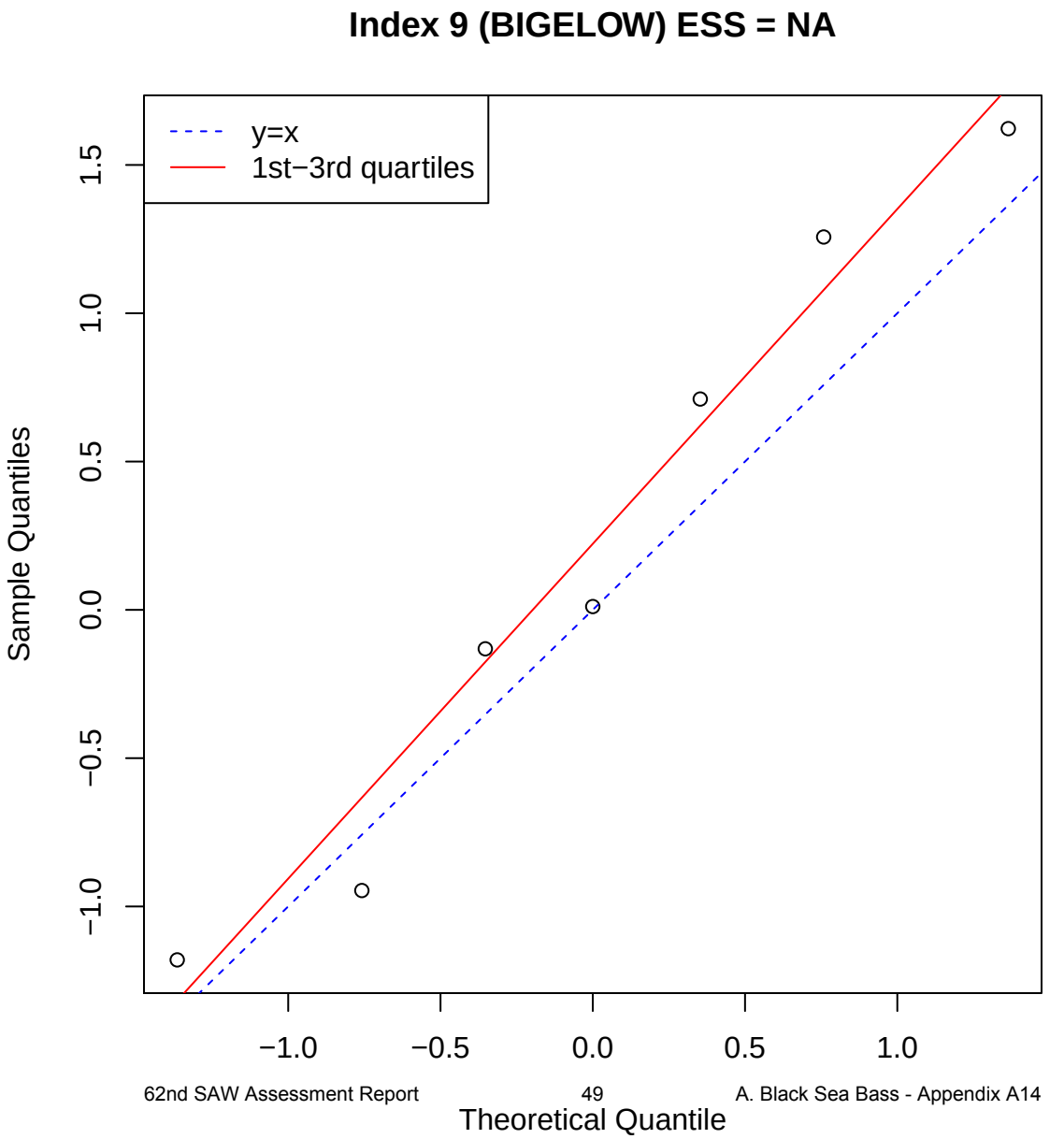

Index 8 (REC CPA) ESS = 50
Mean Age
0
2
4
6
8
10
1990
1995
2000
2005
2010
2015
Years

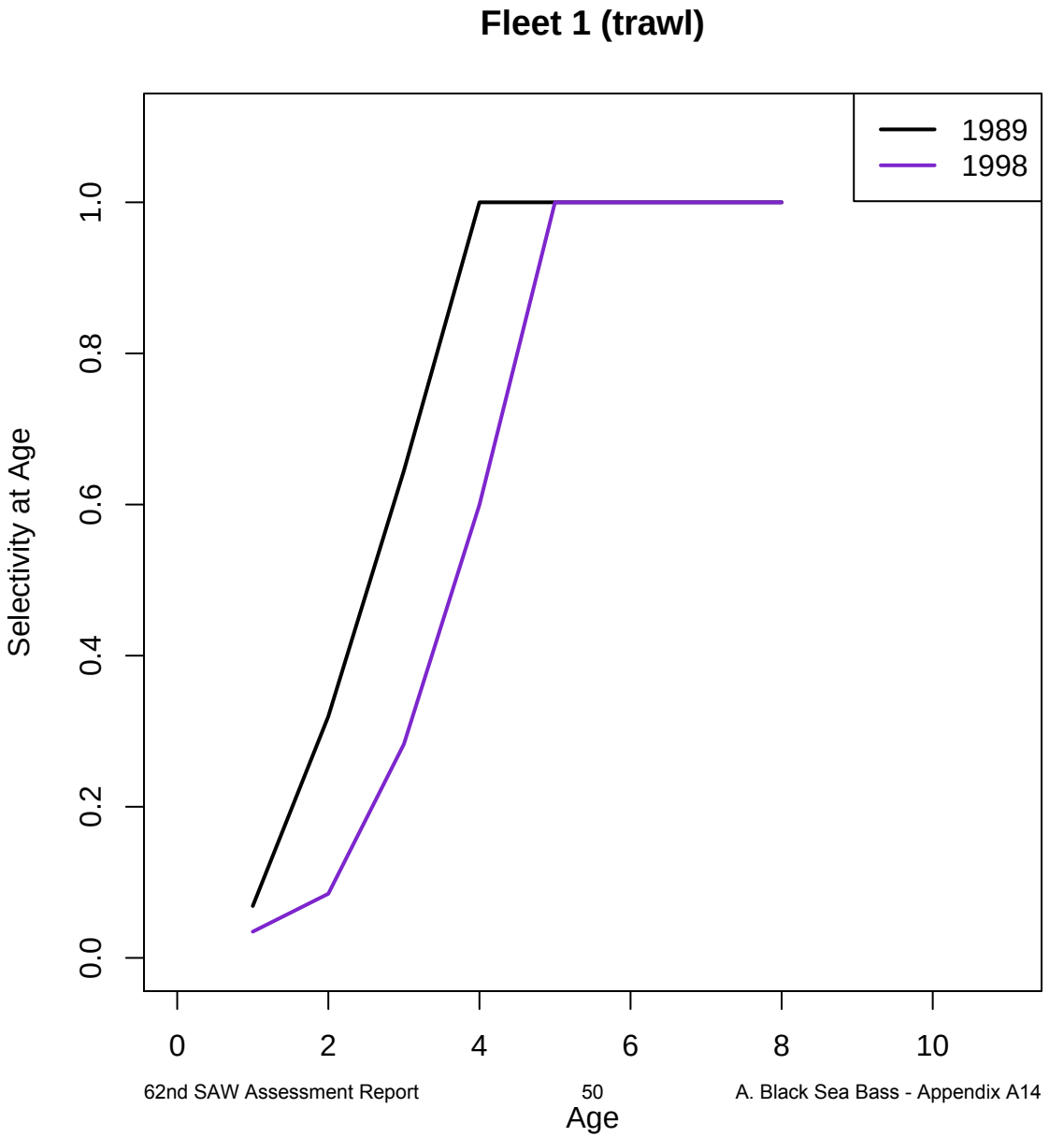

SDNR=1.33
RMSE=1.34
Std Resids
−2
−1
0
1
2
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year

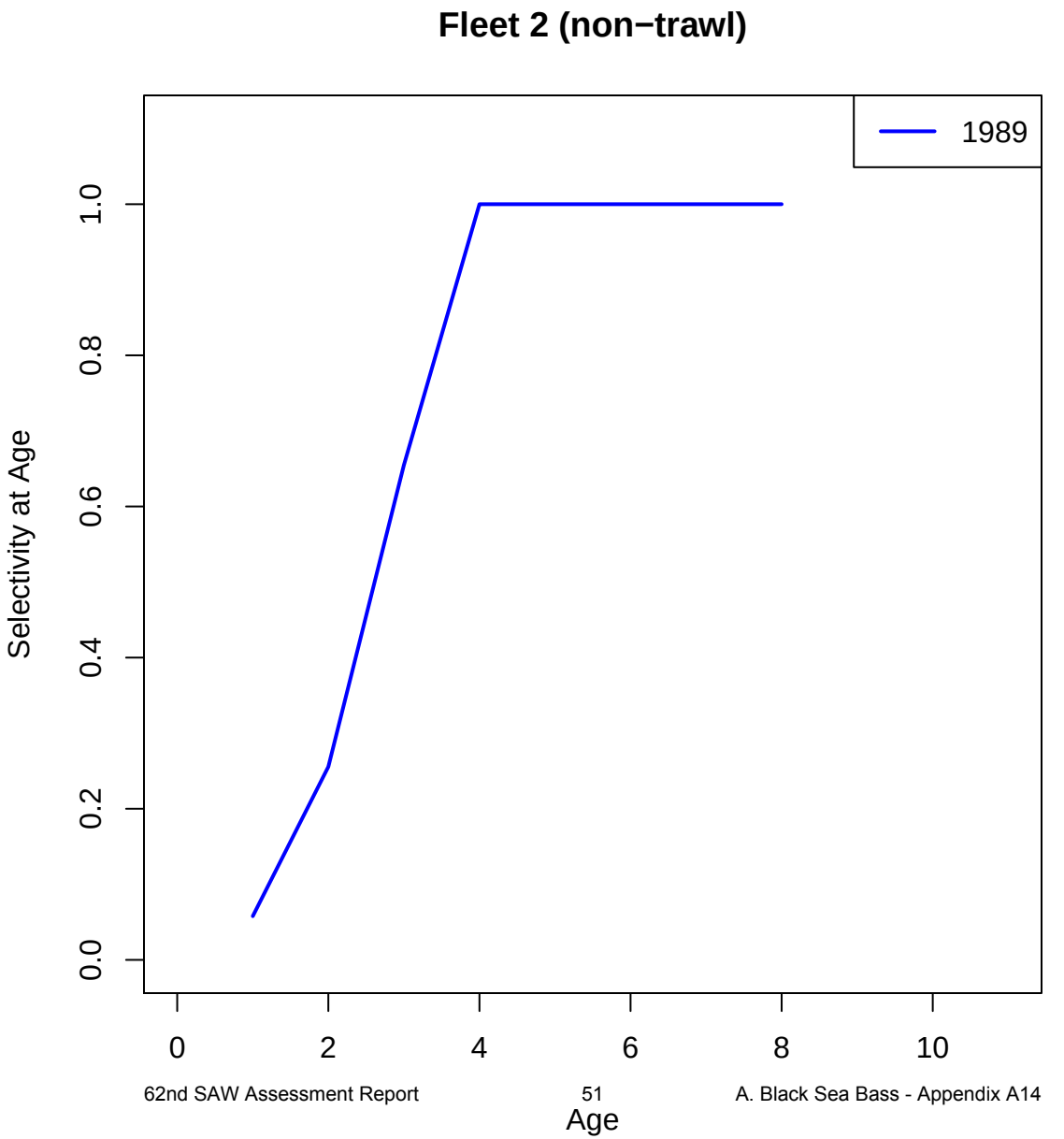

Index 8 (REC CPA) ESS = 50
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−2
−1
0
1
2

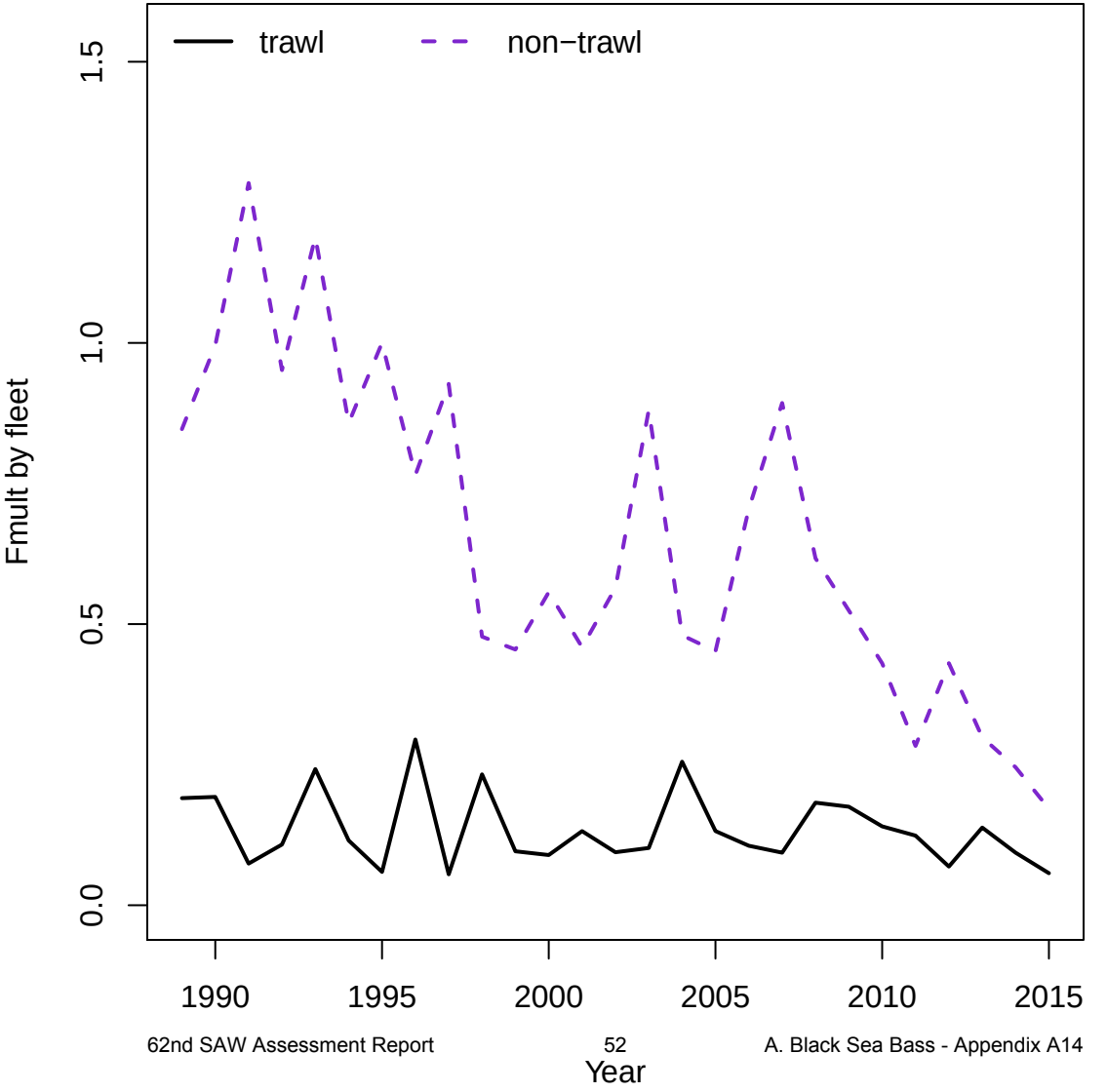

Index 9 (BIGELOW) ESS = NA
Mean Age
0
2
4
6
8
10
2009
2010
2011
2012
2013
2014
2015
Years

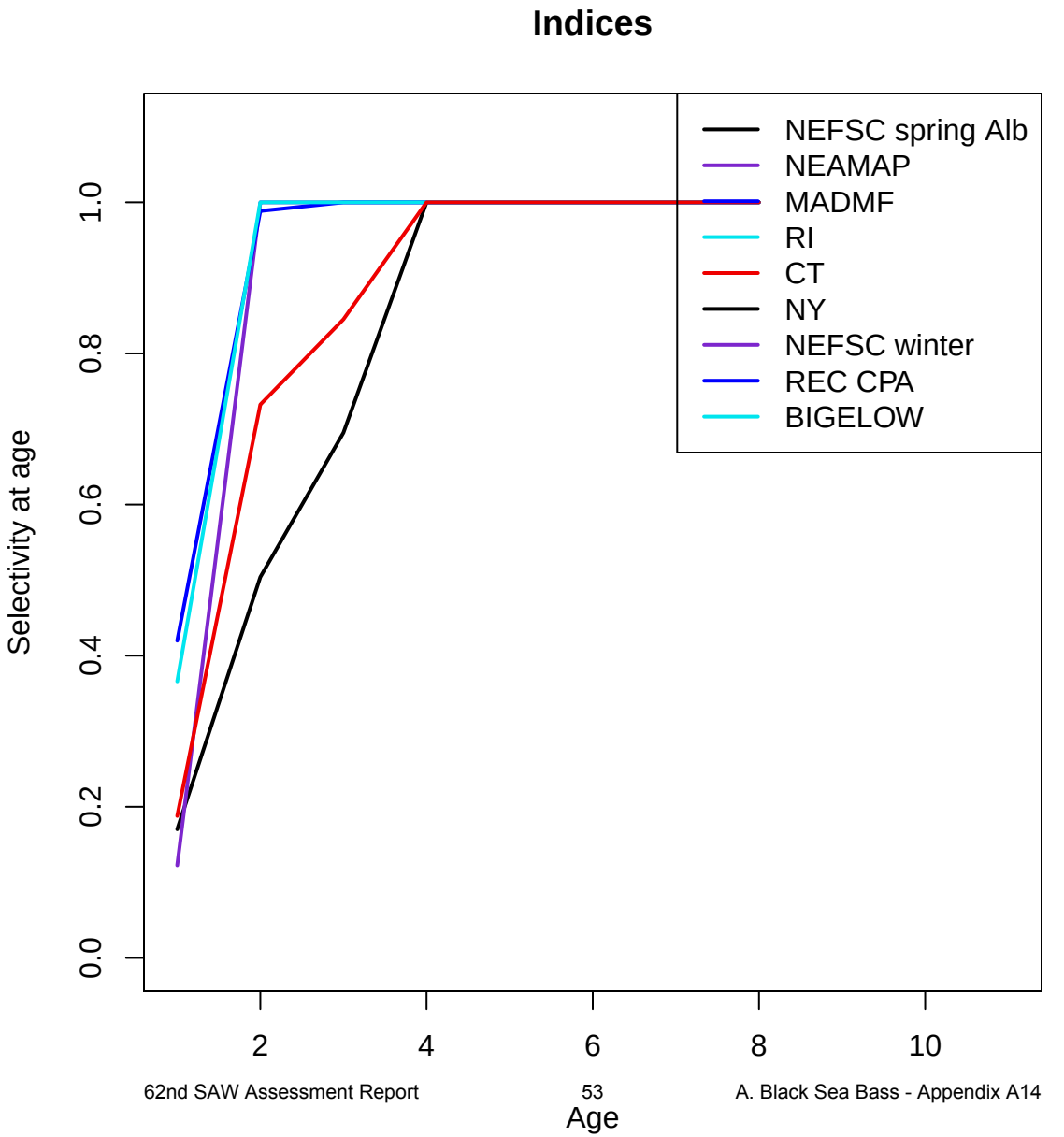

SDNR=1.06 RMSE=1
Std Resids
−1
0
0.5
1
1.5
2009
2010
2011
2012
2013
2014
2015
Year

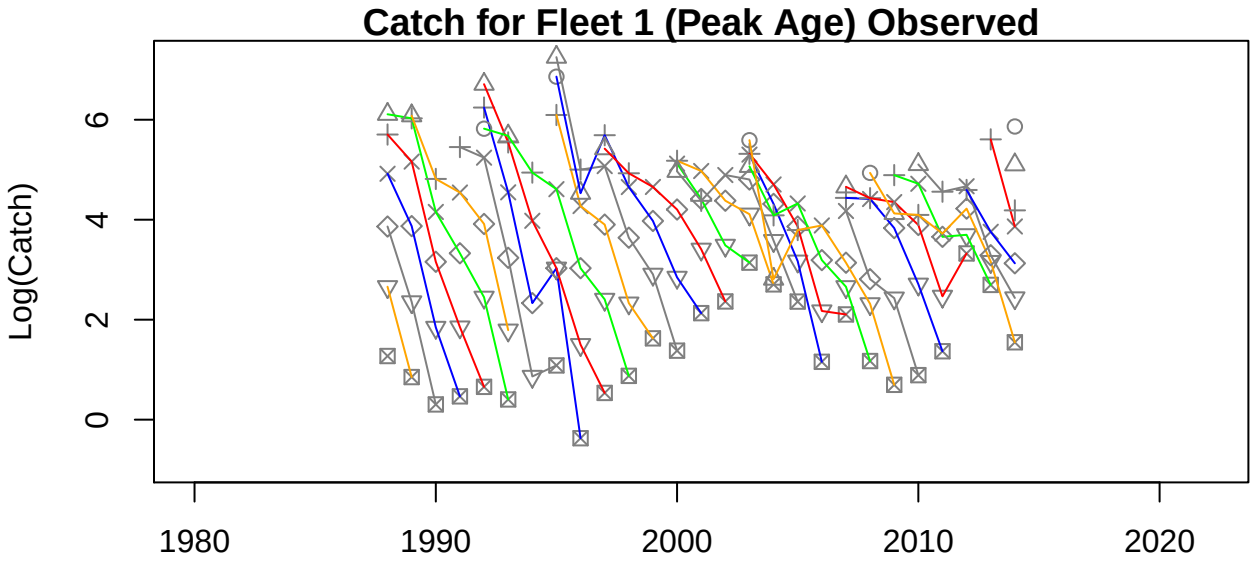

Index 9 (BIGELOW) ESS = NA
y=x
1st−3rd quartiles
Sample Quantiles
Theoretical Quantile
−1.0
−0.5
0.0
0.5
1.0
1.5

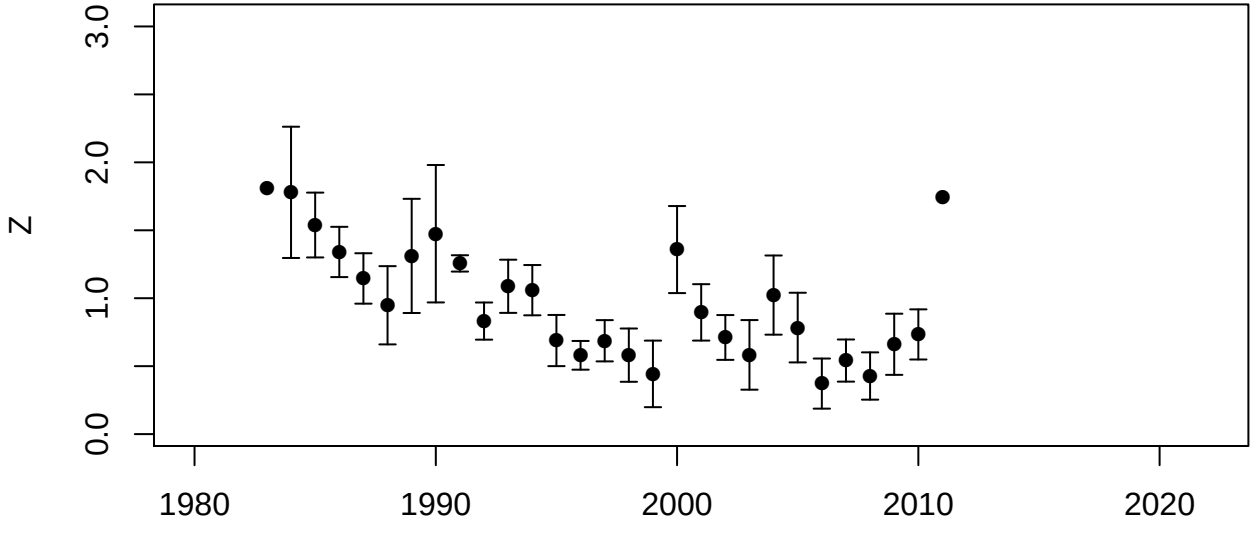

Fleet 1 (trawl)
1989
1998
Selectivity at Age
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
Age

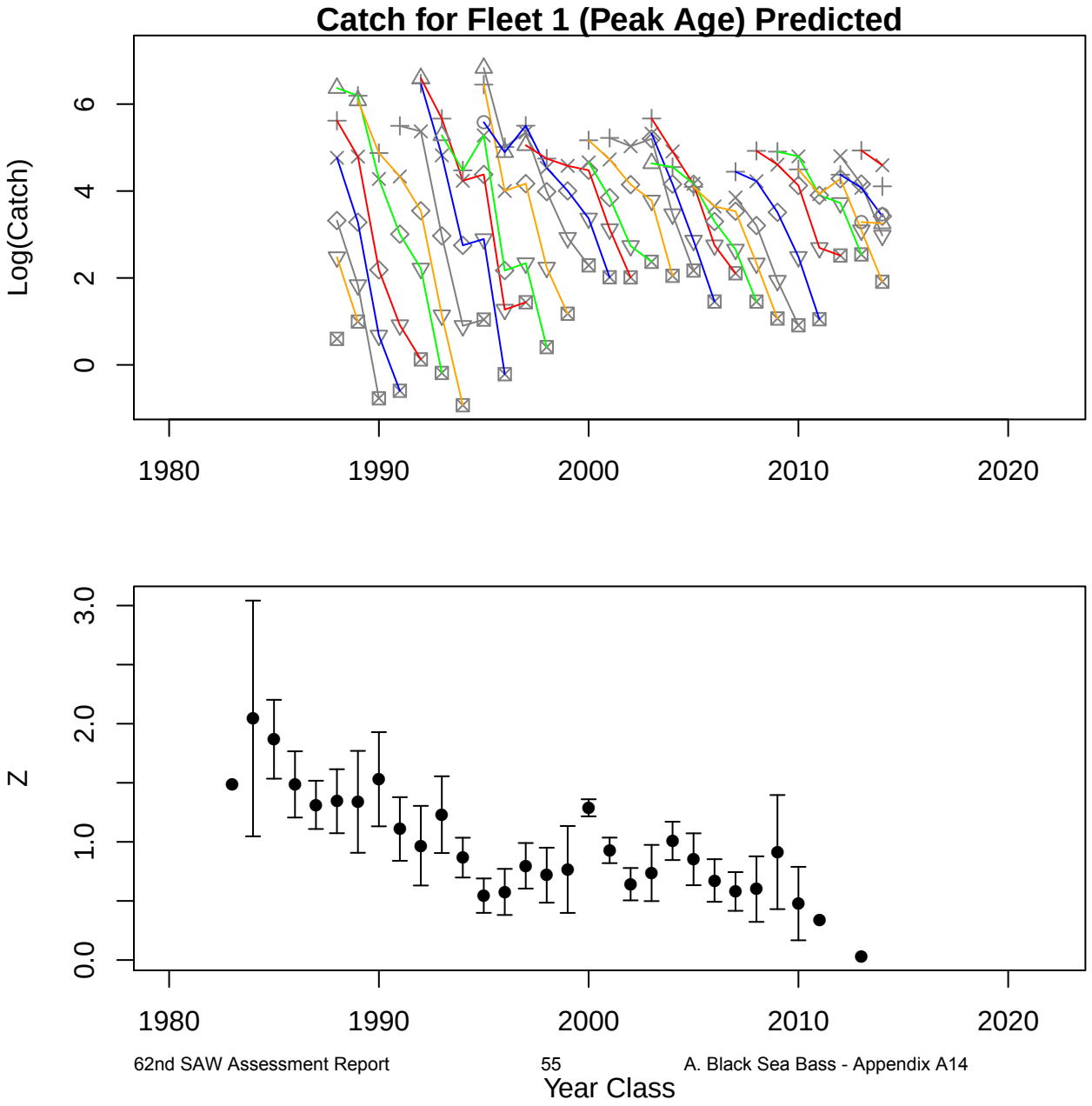

Fleet 2 (non−trawl)
1989
Selectivity at Age
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
Age

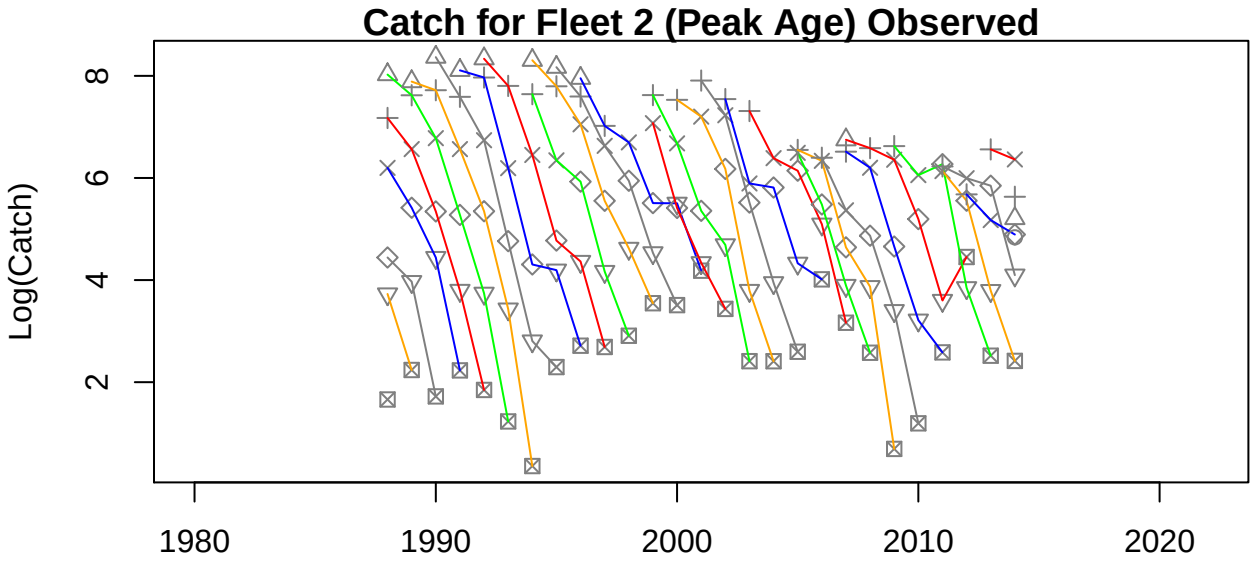

trawl
non−trawl
Fmult by fleet
0.0
0.5
1.0
1.5
1990
1995
2000
2005
2010
2015
Year

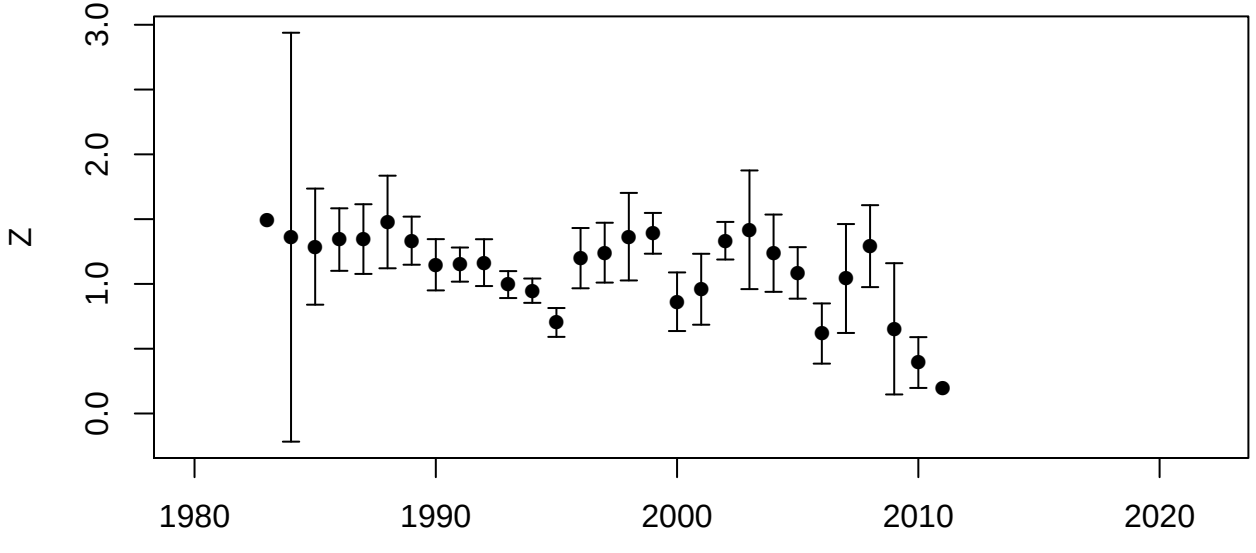

Indices
NEFSC spring Alb
NEAMAP
MADMF
RI
CT
NY
NEFSC winter
REC CPA
BIGELOW
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
10
Age

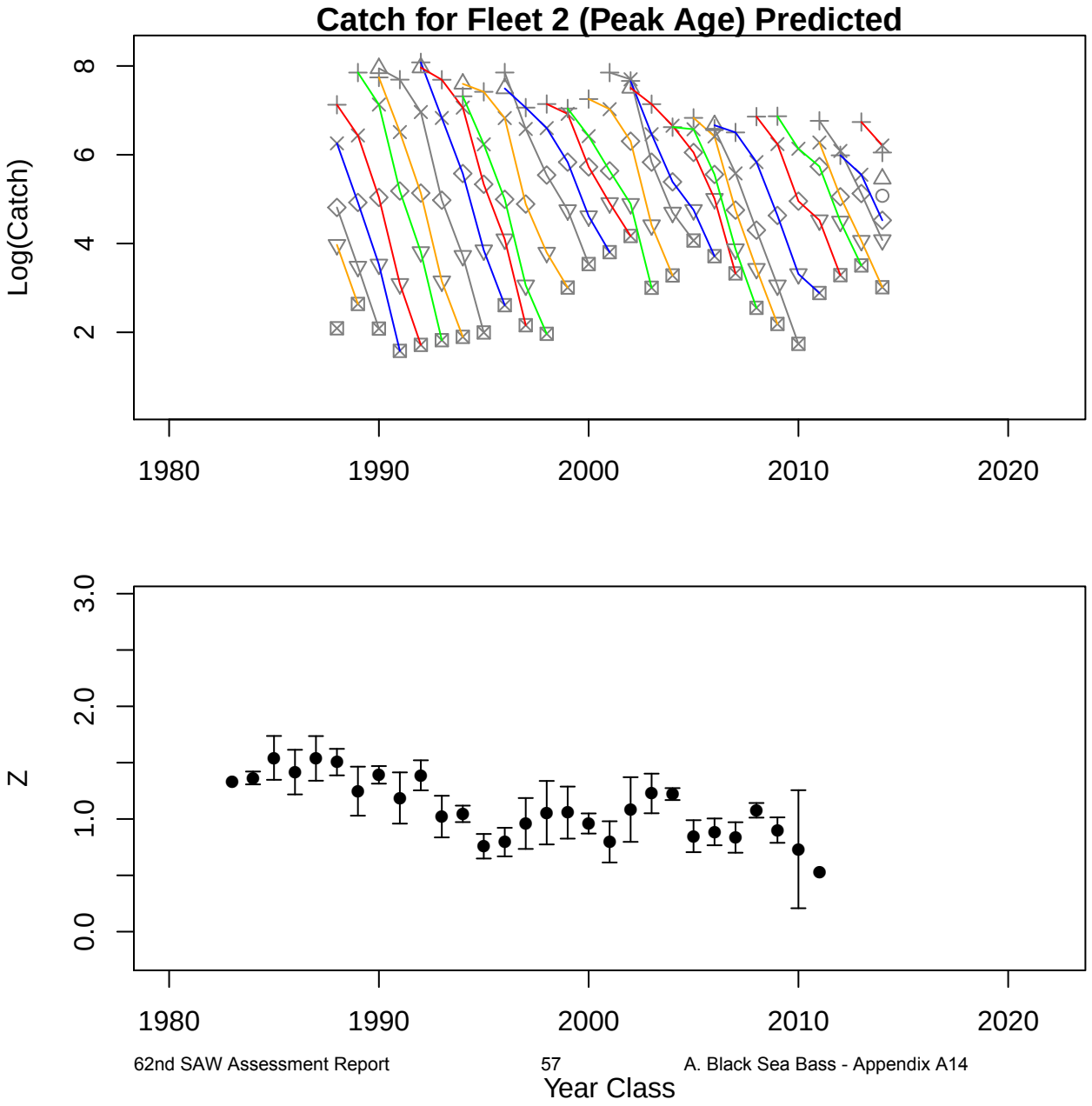

Catch for Fleet 1 (Peak Age) Observed
Log(Catch)
0
2
4
6
1980
1990
2000
2010
2020

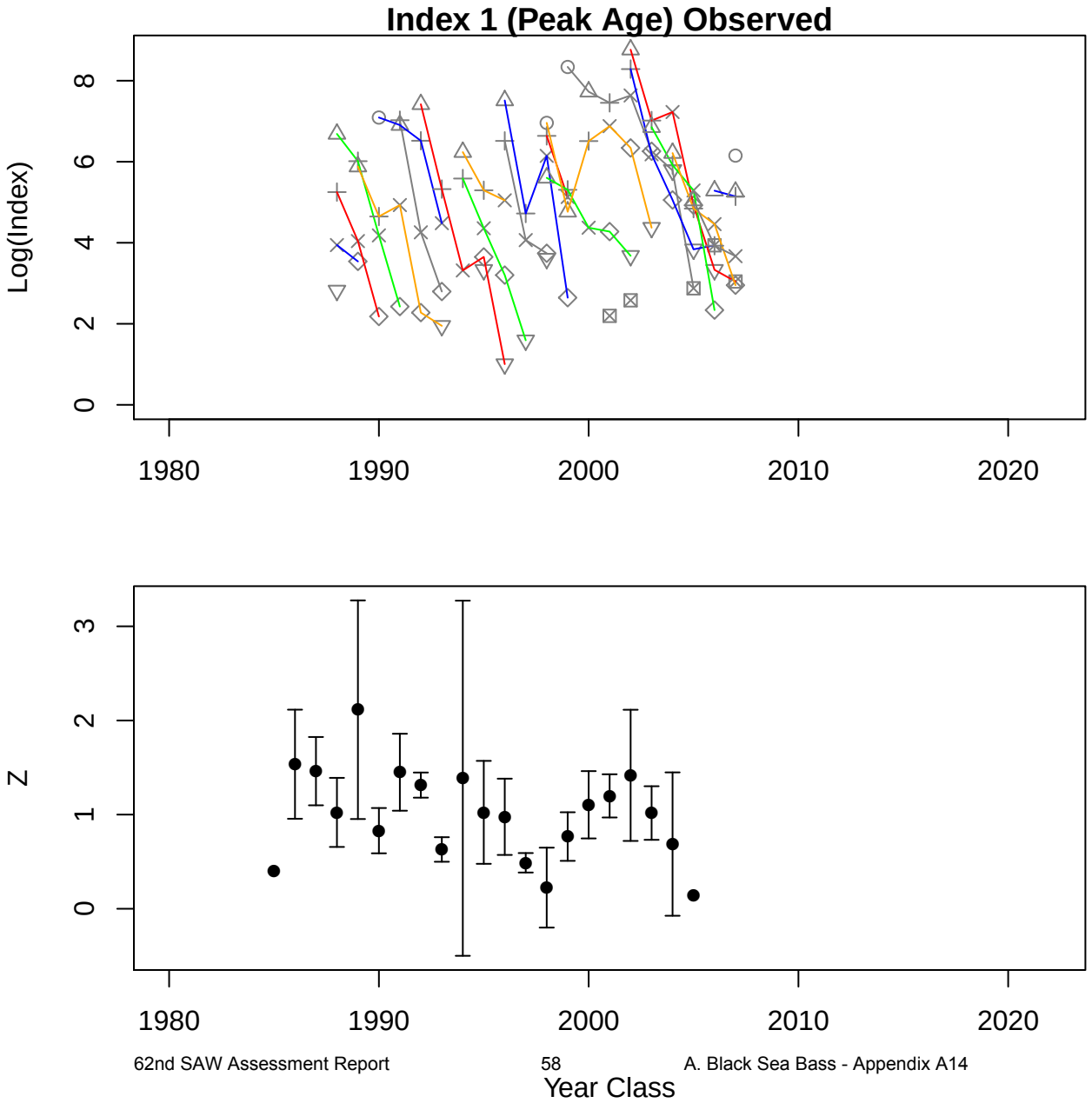

Z
0.0
1.0
2.0
3.0
1980
1990
2000
2010
2020
Year Class

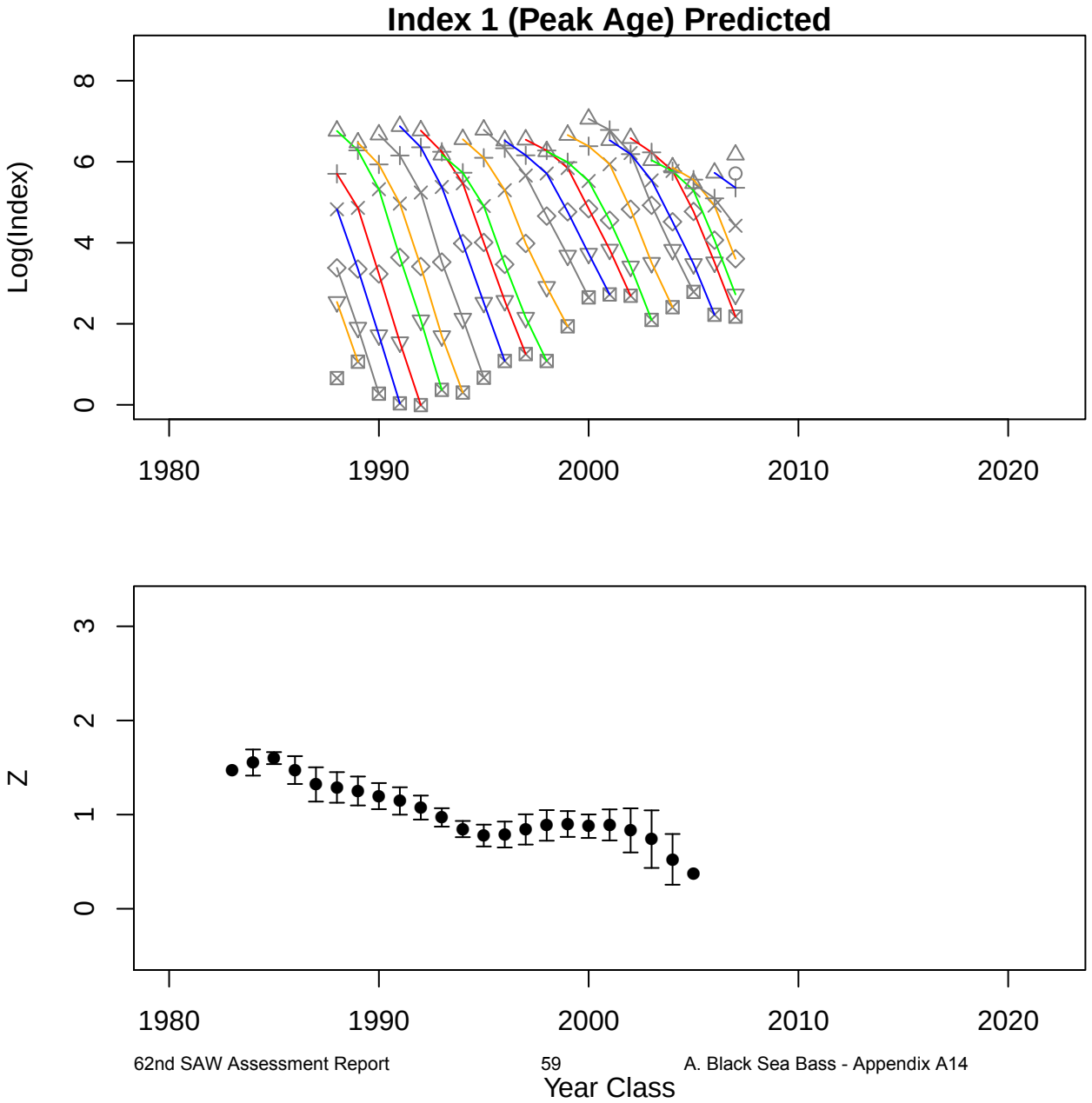

Catch for Fleet 1 (Peak Age) Predicted
Log(Catch)
0
2
4
6
1980
1990
2000
2010
2020
Z
0.0
1.0
2.0
3.0
1980
1990
2000
2010
2020
Year Class

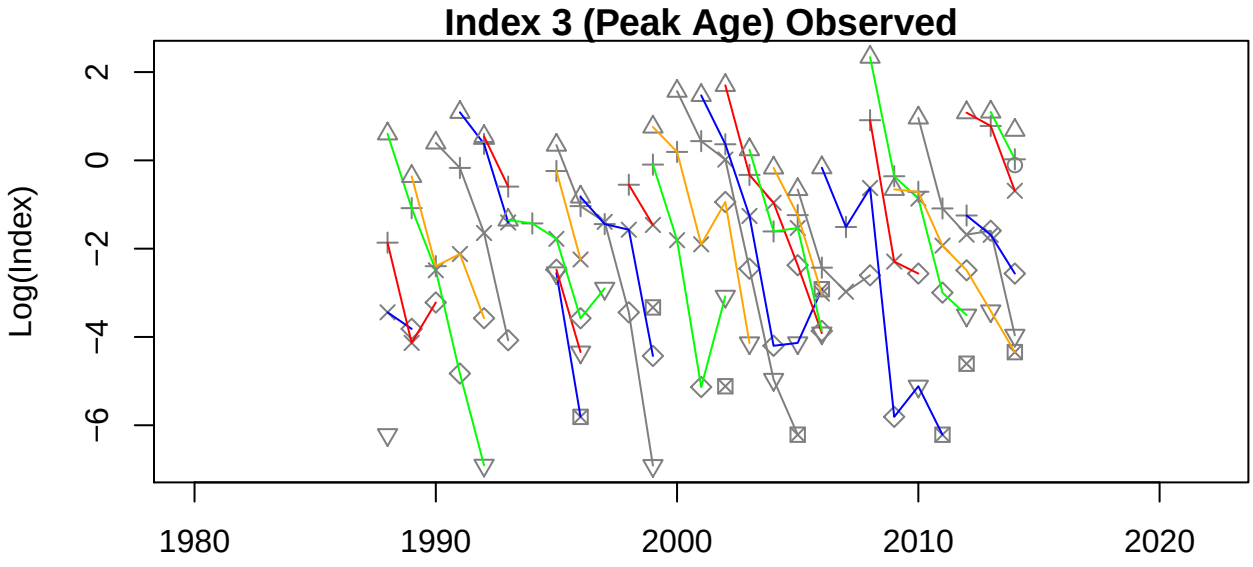

Catch for Fleet 2 (Peak Age) Observed
Log(Catch)
2
4
6
8
1980
1990
2000
2010
2020

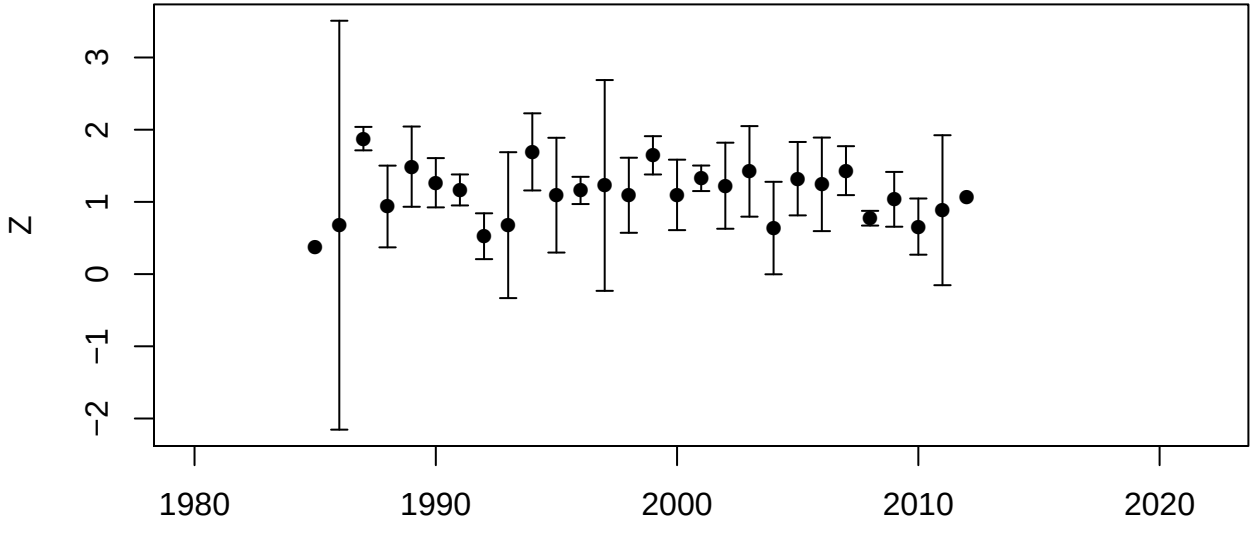

Z
0.0
1.0
2.0
3.0
1980
1990
2000
2010
2020
Year Class


Catch for Fleet 2 (Peak Age) Predicted
Log(Catch)
2
4
6
8
1980
1990
2000
2010
2020
Z
0.0
1.0
2.0
3.0
1980
1990
2000
2010
2020
Year Class

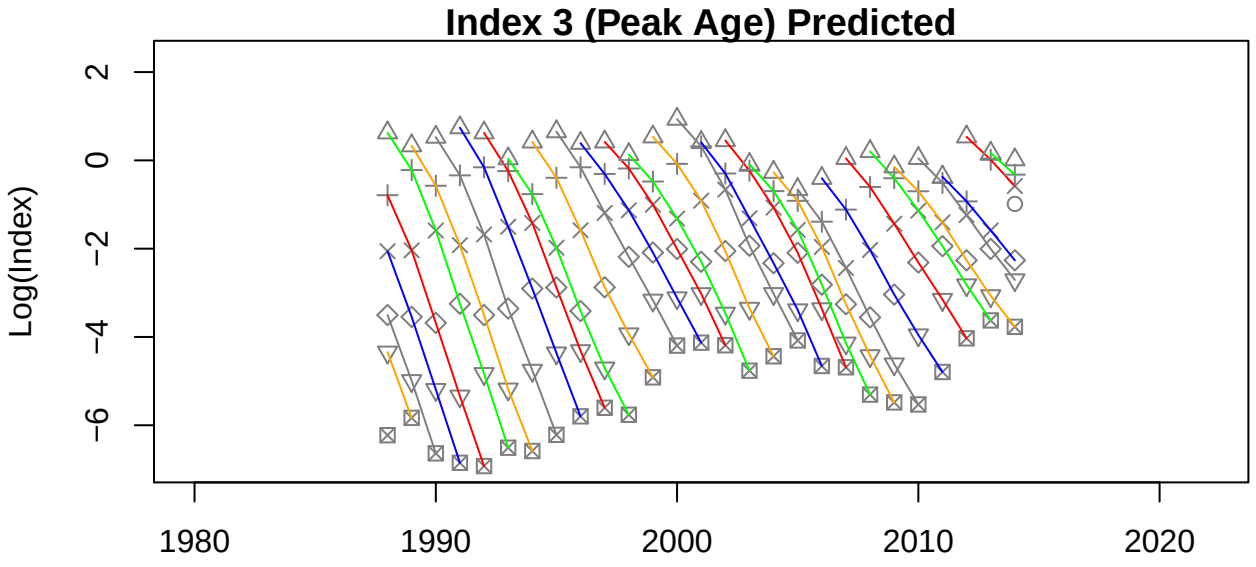

Index 1 (Peak Age) Observed
Log(Index)
0
2
4
6
8
1980
1990
2000
2010
2020
Z
0
1
2
3
1980
1990
2000
2010
2020
Year Class

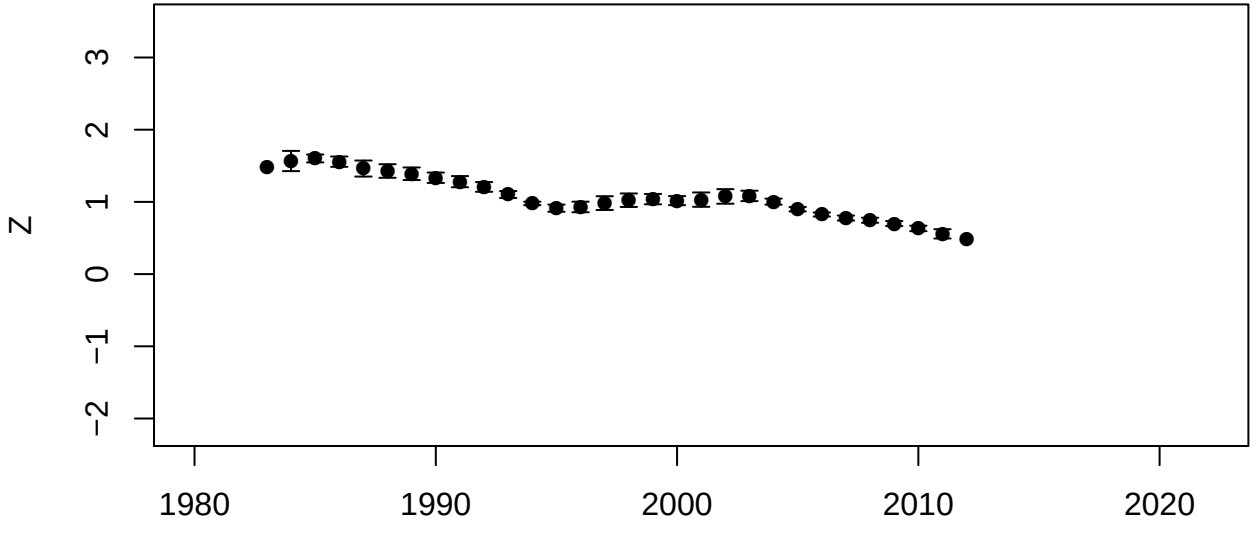

Index 1 (Peak Age) Predicted
Log(Index)
0
2
4
6
8
1980
1990
2000
2010
2020
Z
0
1
2
3
1980
1990
2000
2010
2020
Year Class

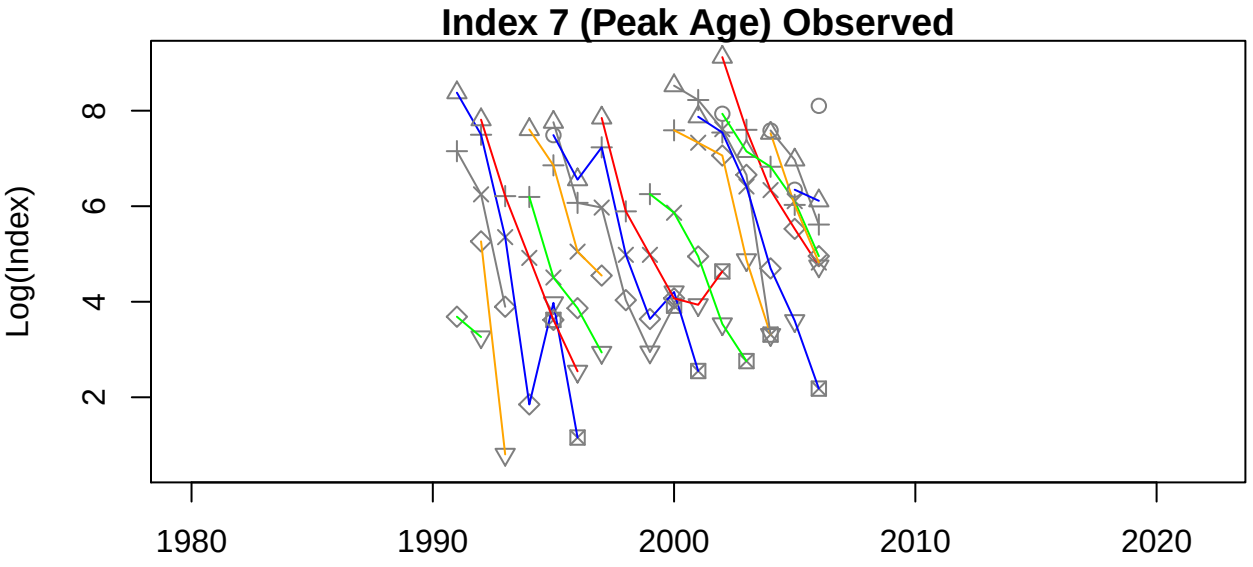

Index 3 (Peak Age) Observed
Log(Index)
2
0
−2
−4
−6
1980
1990
2000
2010
2020

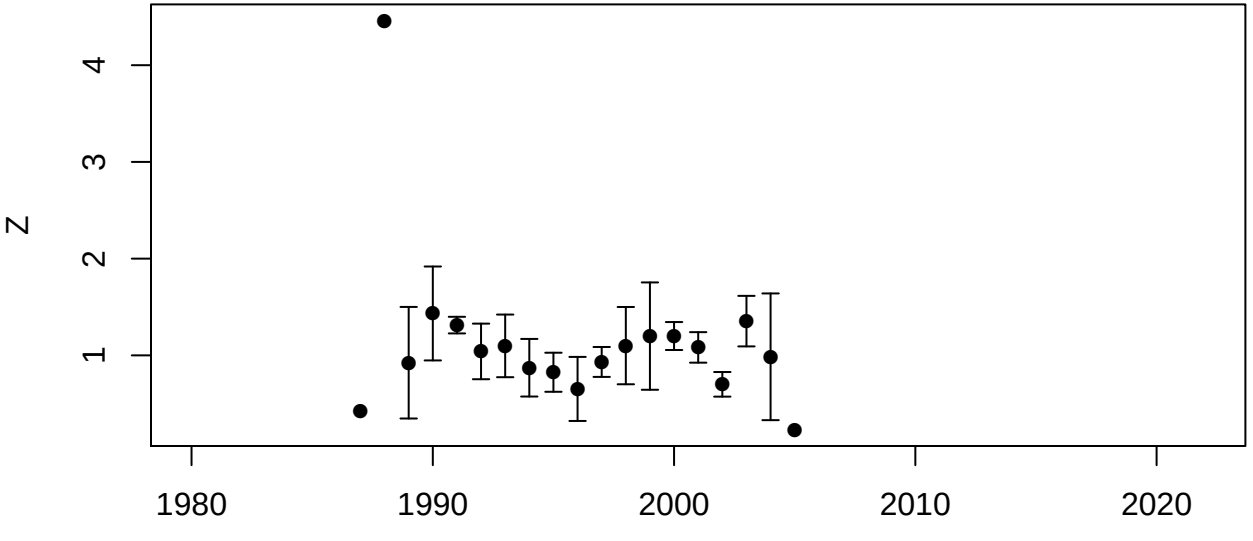

Z
3
2
1
0
−1
−2
1980
1990
2000
2010
2020

Year Class

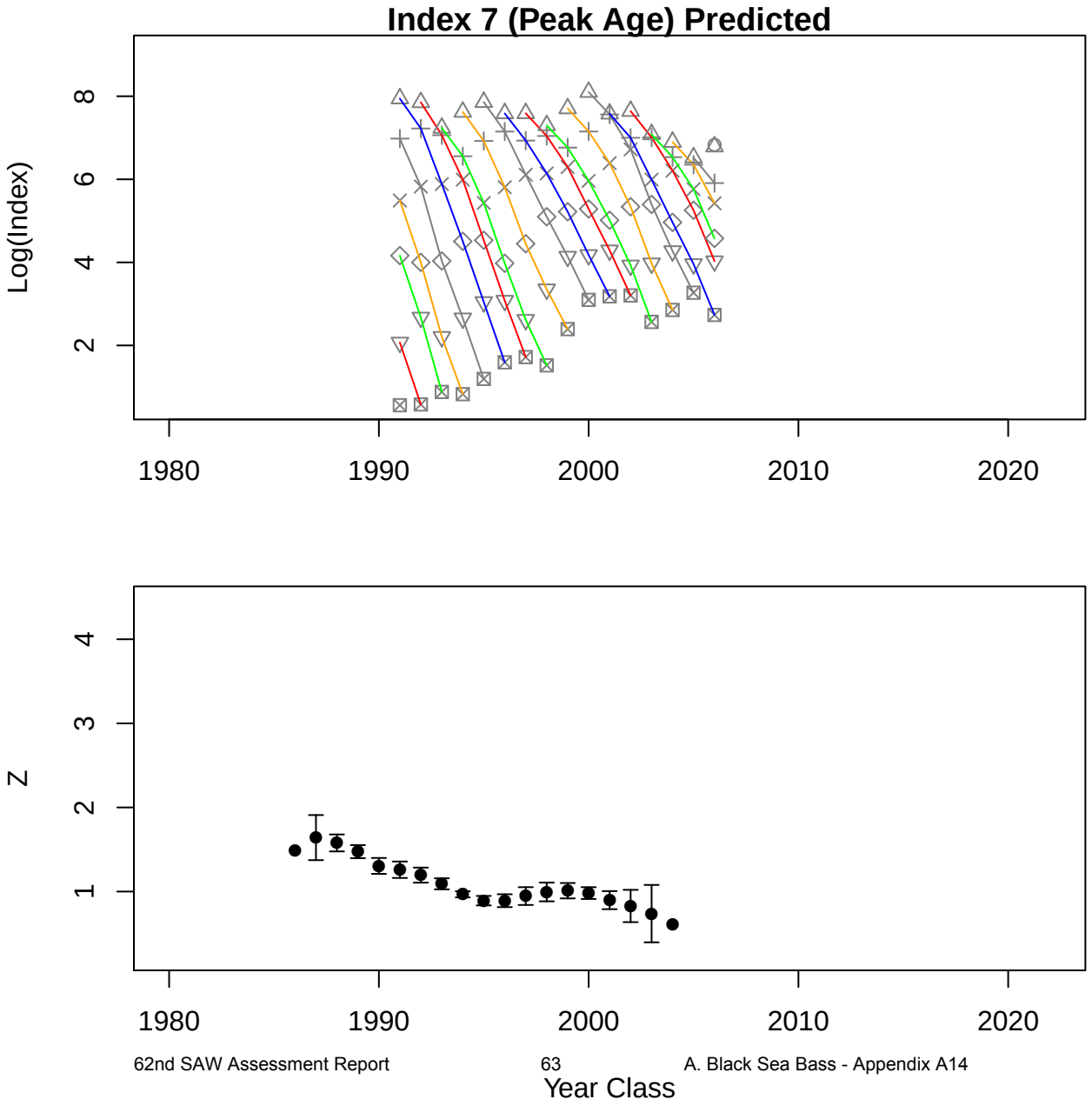

Index 3 (Peak Age) Predicted
Log(Index)
2
0
−2
−4
−6
1980
1990
2000
2010
2020

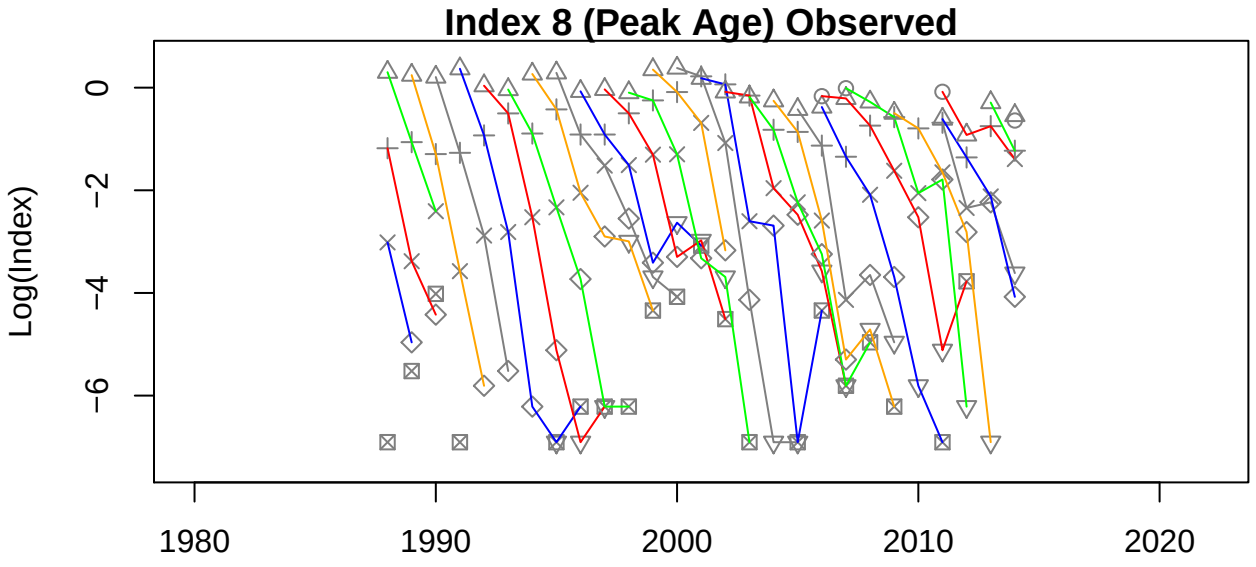

Z
3
2
1
0
−1
−2
1980
1990
2000
2010
2020
Year Class

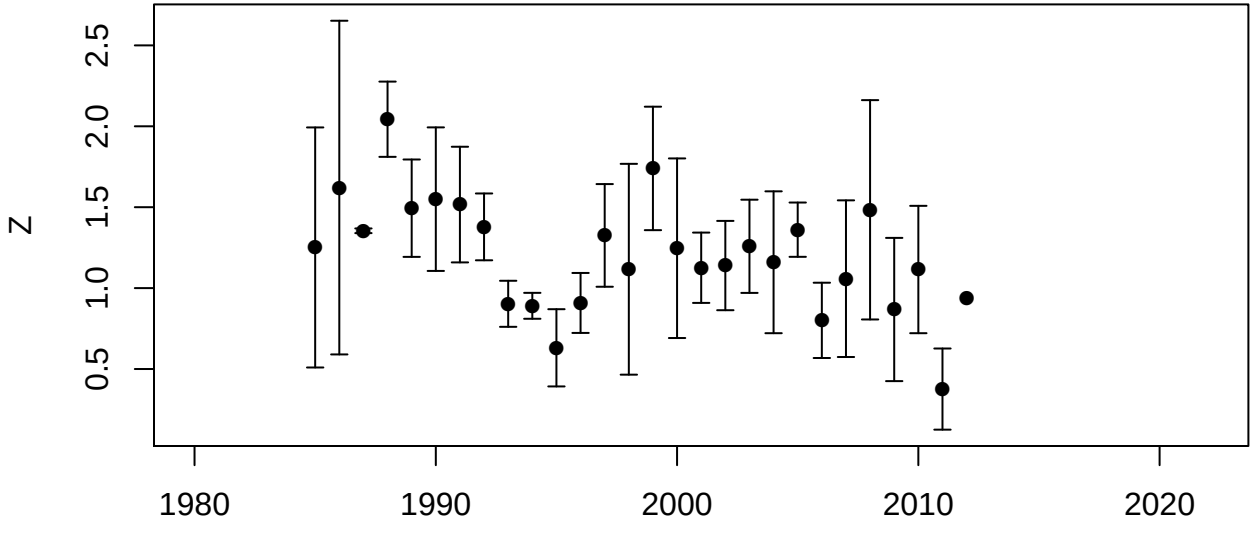

Index 7 (Peak Age) Observed
Log(Index)
2
4
6
8
1980
1990
2000
2010
2020


Z
1
2
3
4
1980
1990
2000
2010
2020

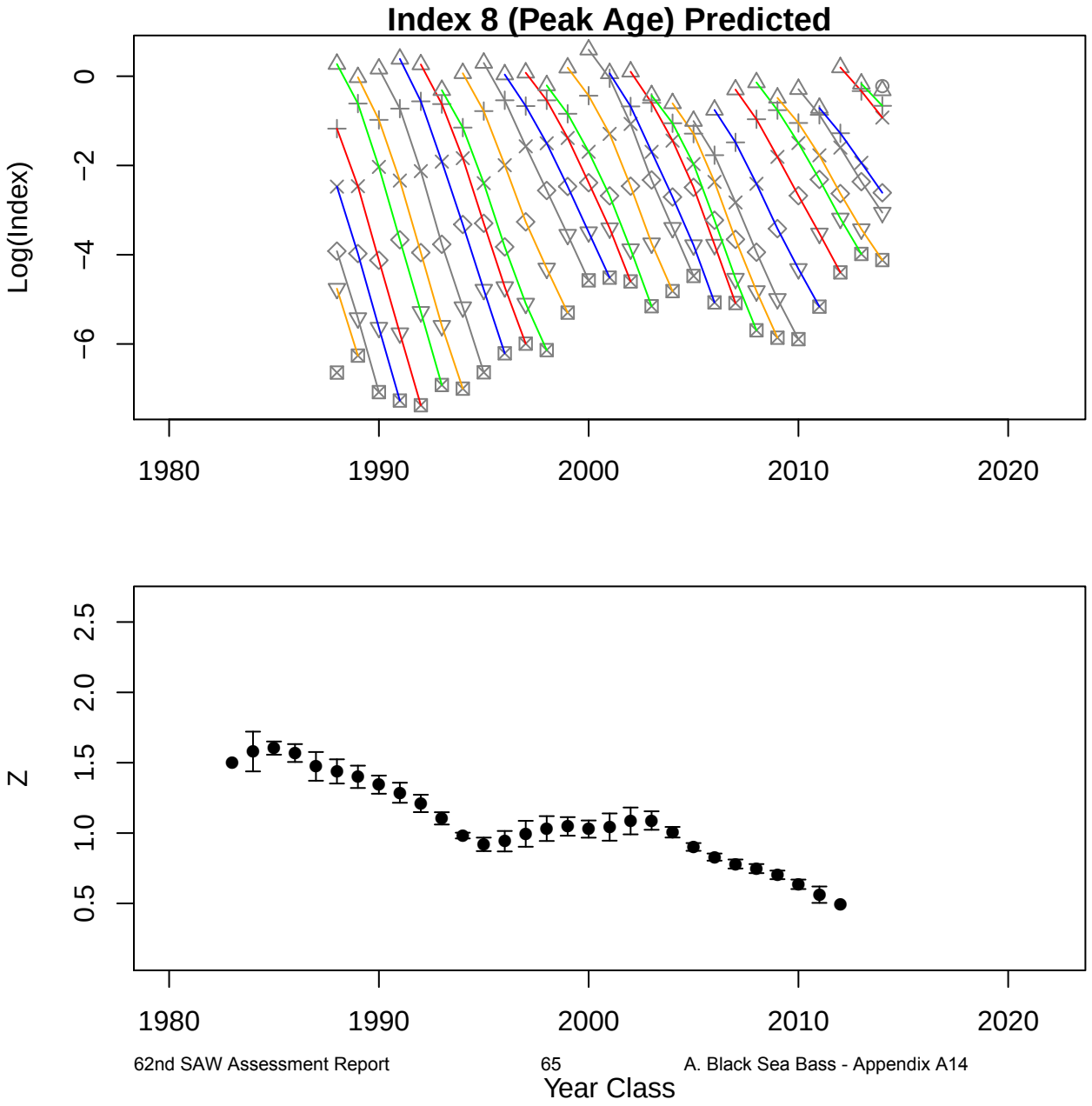
Year Class

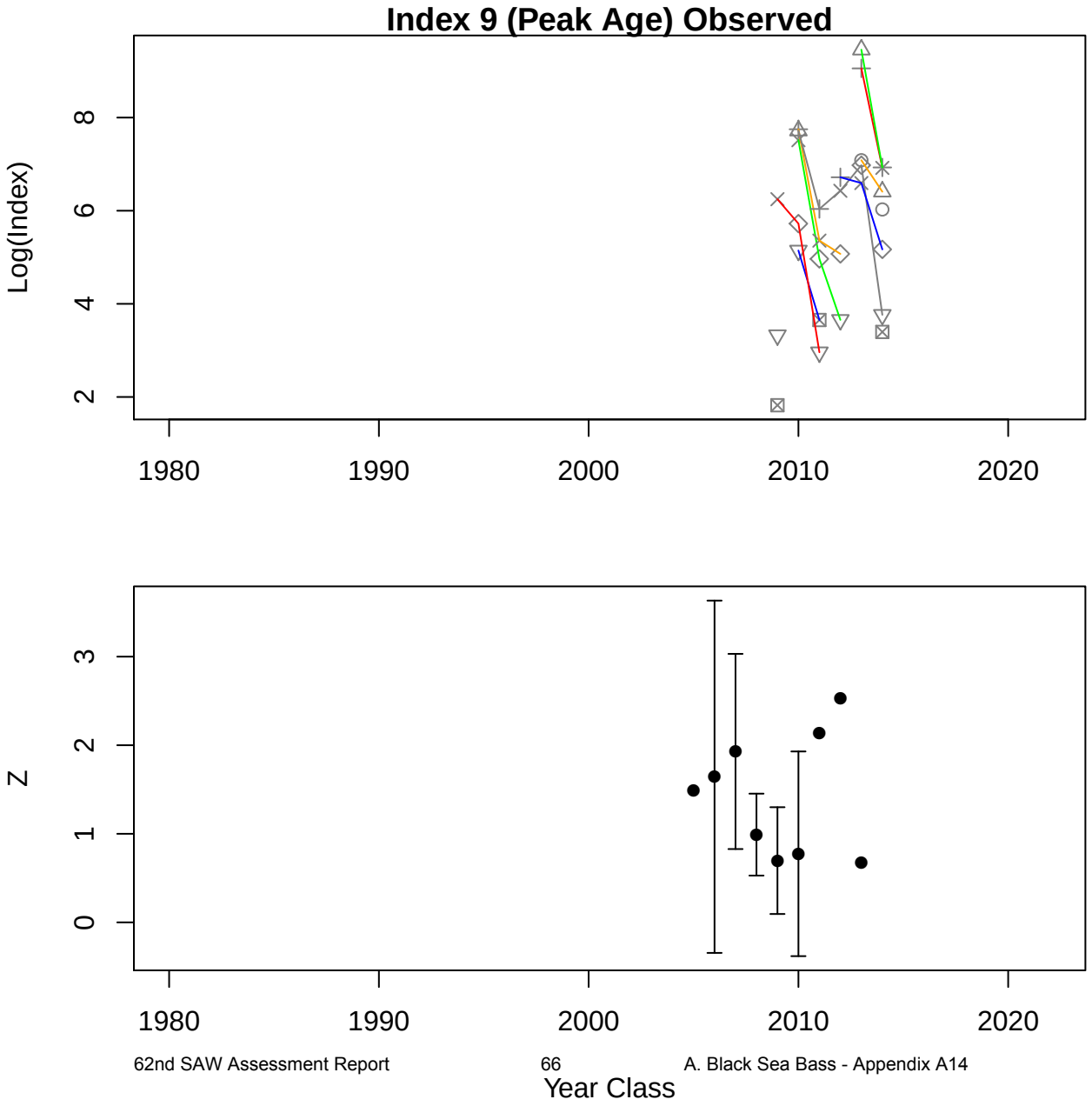

Index 7 (Peak Age) Predicted
Log(Index)
2
4
6
8
1980
1990
2000
2010
2020
Z
1
2
3
4
1980
1990
2000
2010
2020
Year Class

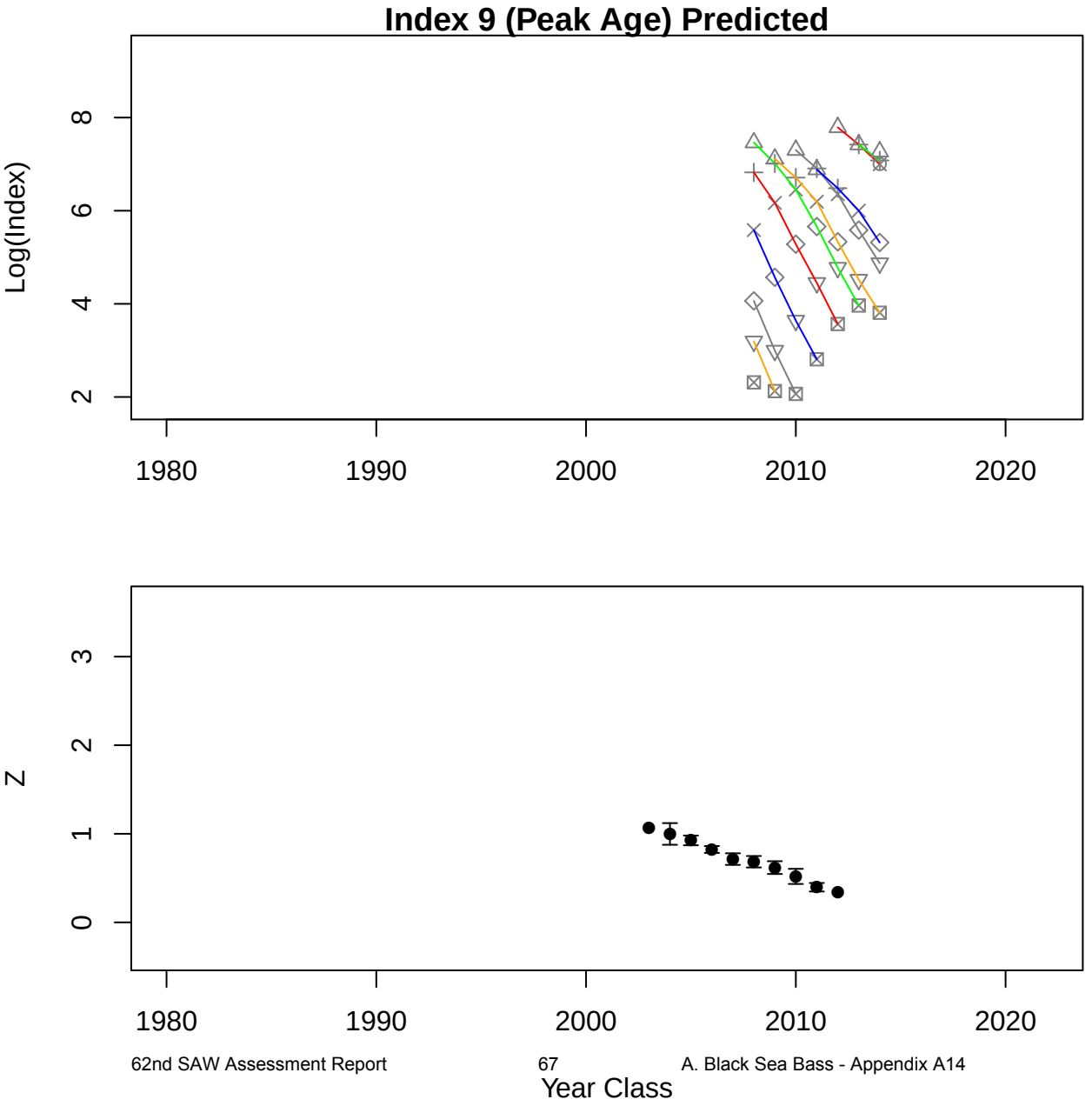

Index 8 (Peak Age) Observed
Log(Index)
0
−2
−4
−6
1980
1990
2000
2010
2020


Z
0.5
1.0
1.5
2.0
2.5
1980
1990
2000
2010
2020

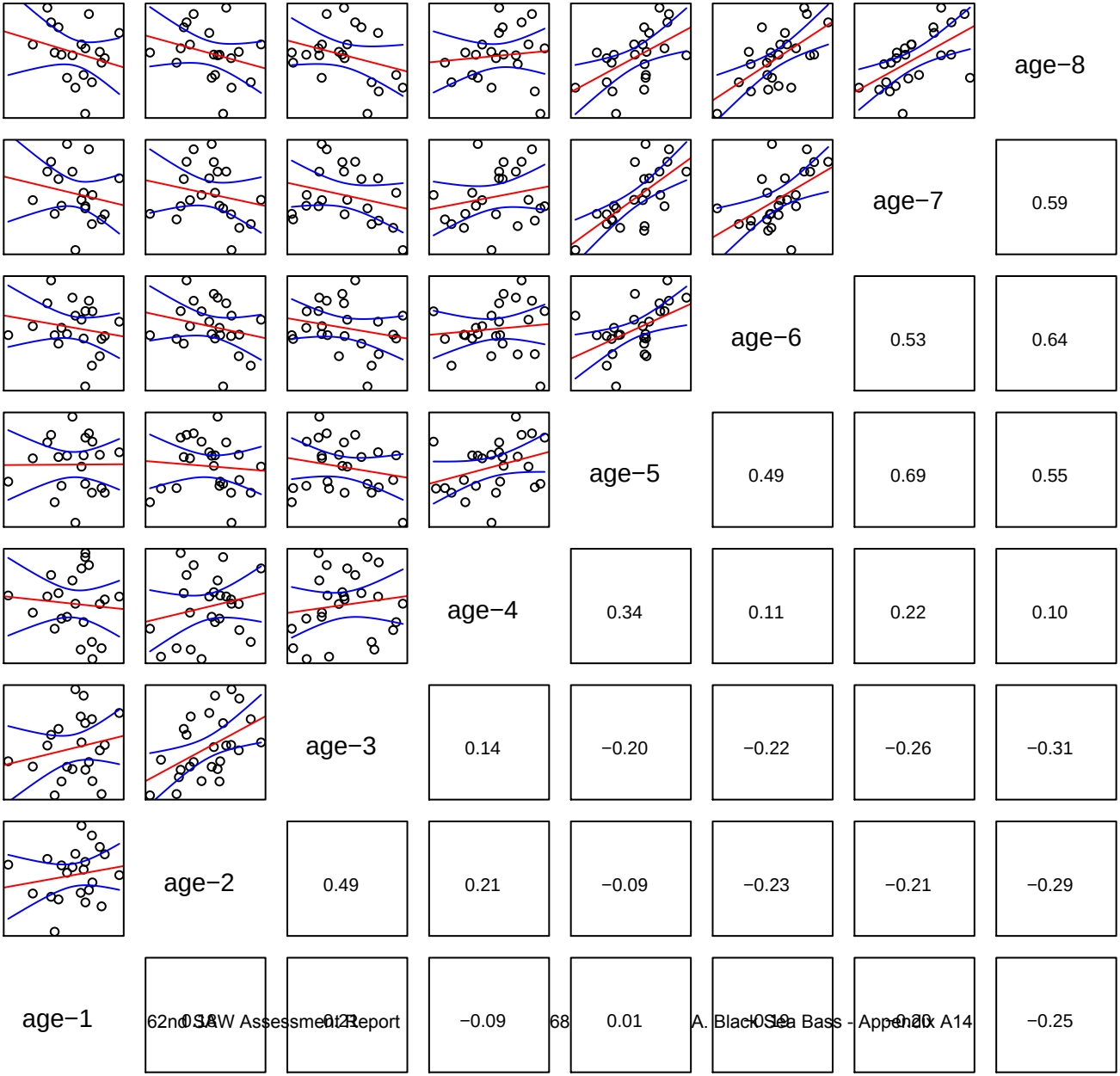
Year Class


Index 8 (Peak Age) Predicted
Log(Index)
0
−2
−4
−6
1980
1990
2000
2010
2020
Z
2.5
2.0
1.5
1.0
0.5
1980
1990
2000
2010
2020
Year Class

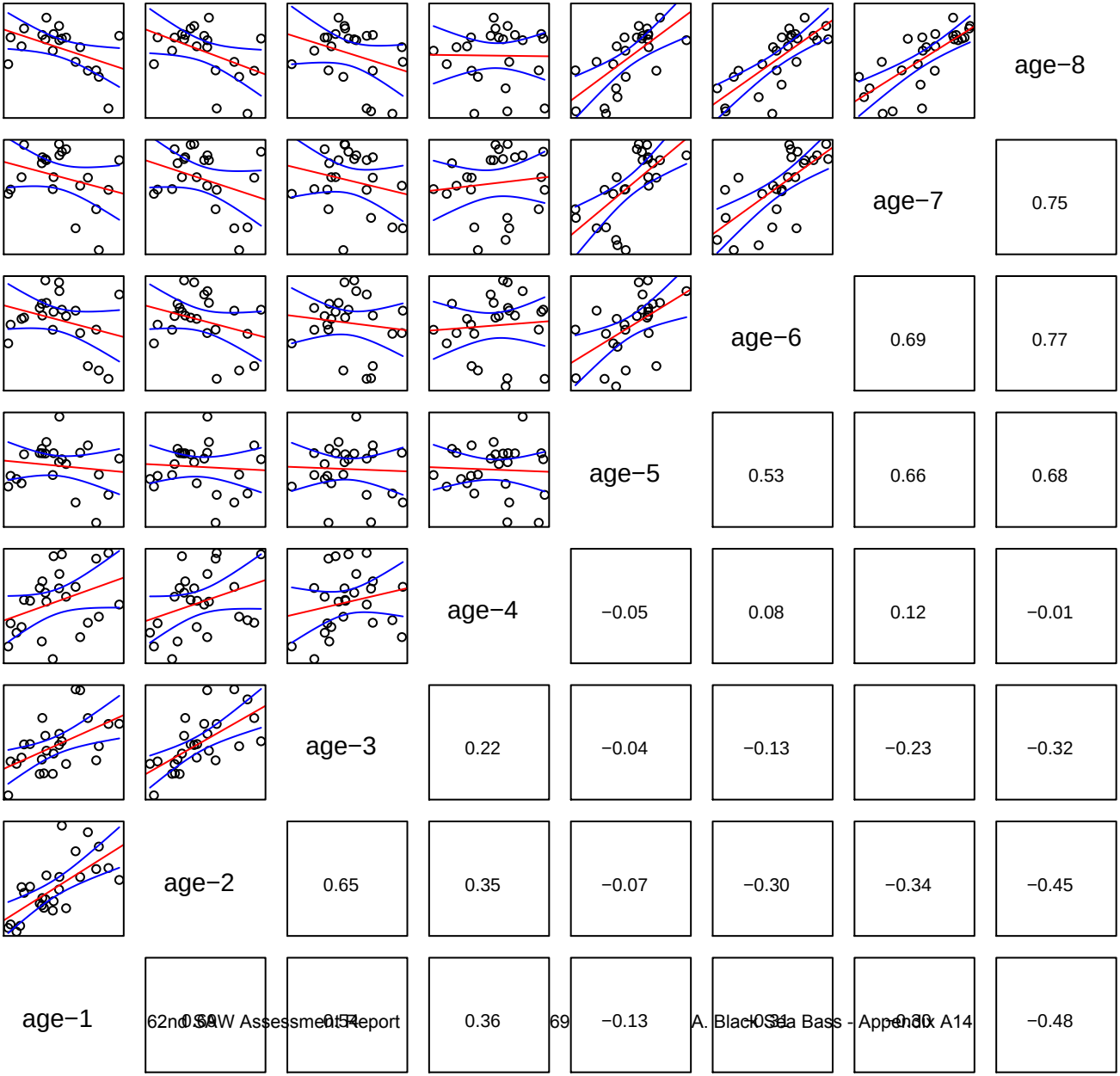

Index 9 (Peak Age) Observed
Log(Index)
2
4
6
8
1980
1990
2000
2010
2020
Z
0
1
2
3
1980
1990
2000
2010
2020
Year Class


Index 9 (Peak Age) Predicted
Log(Index)
8
6
4
2
1980
1990
2000
2010
2020
Z
3
2
1
0
1980
1990
2000
2010
2020
Year Class

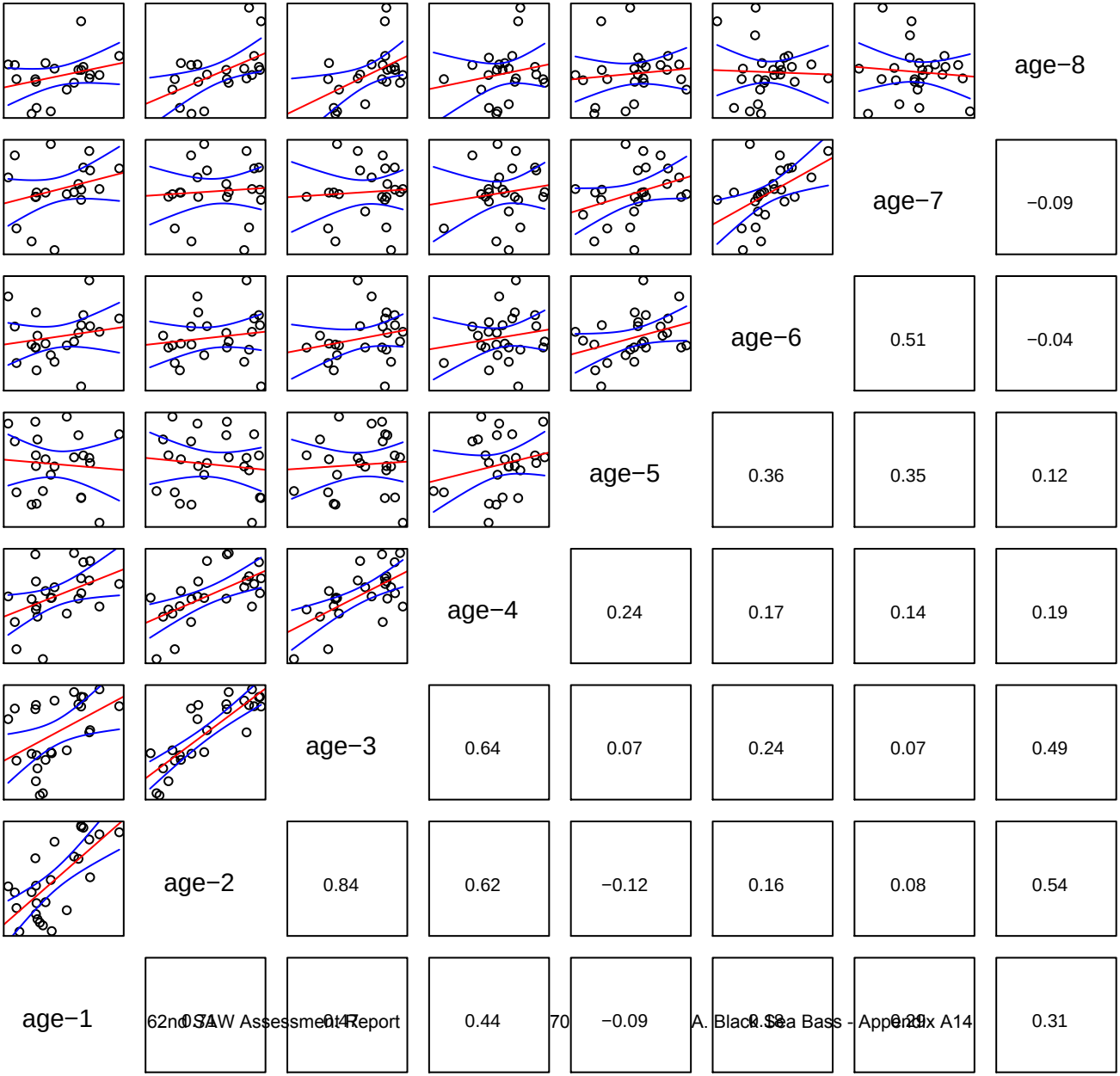
Catch for Fleet 1 Observed



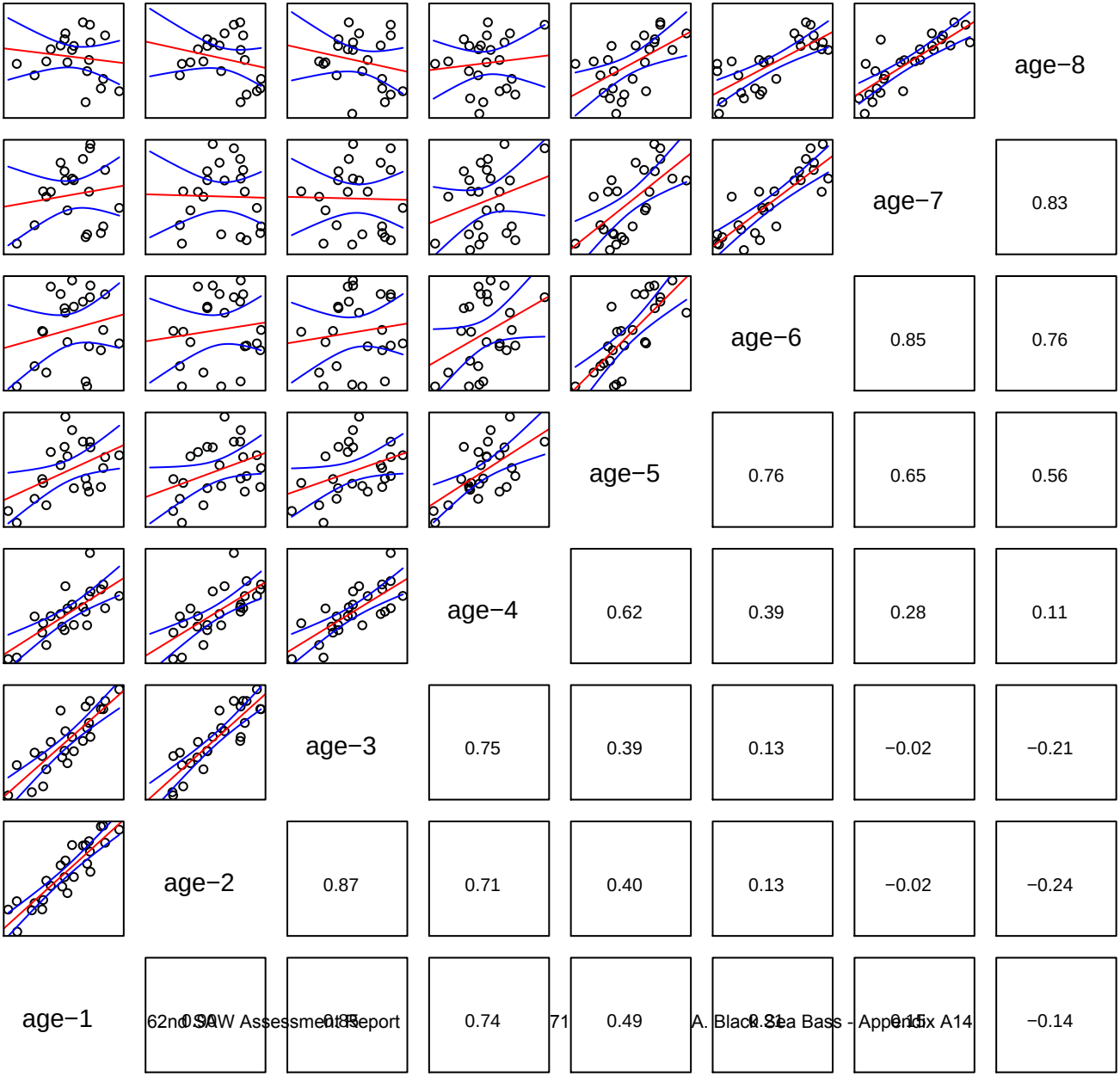
Catch for Fleet 1 Predicted



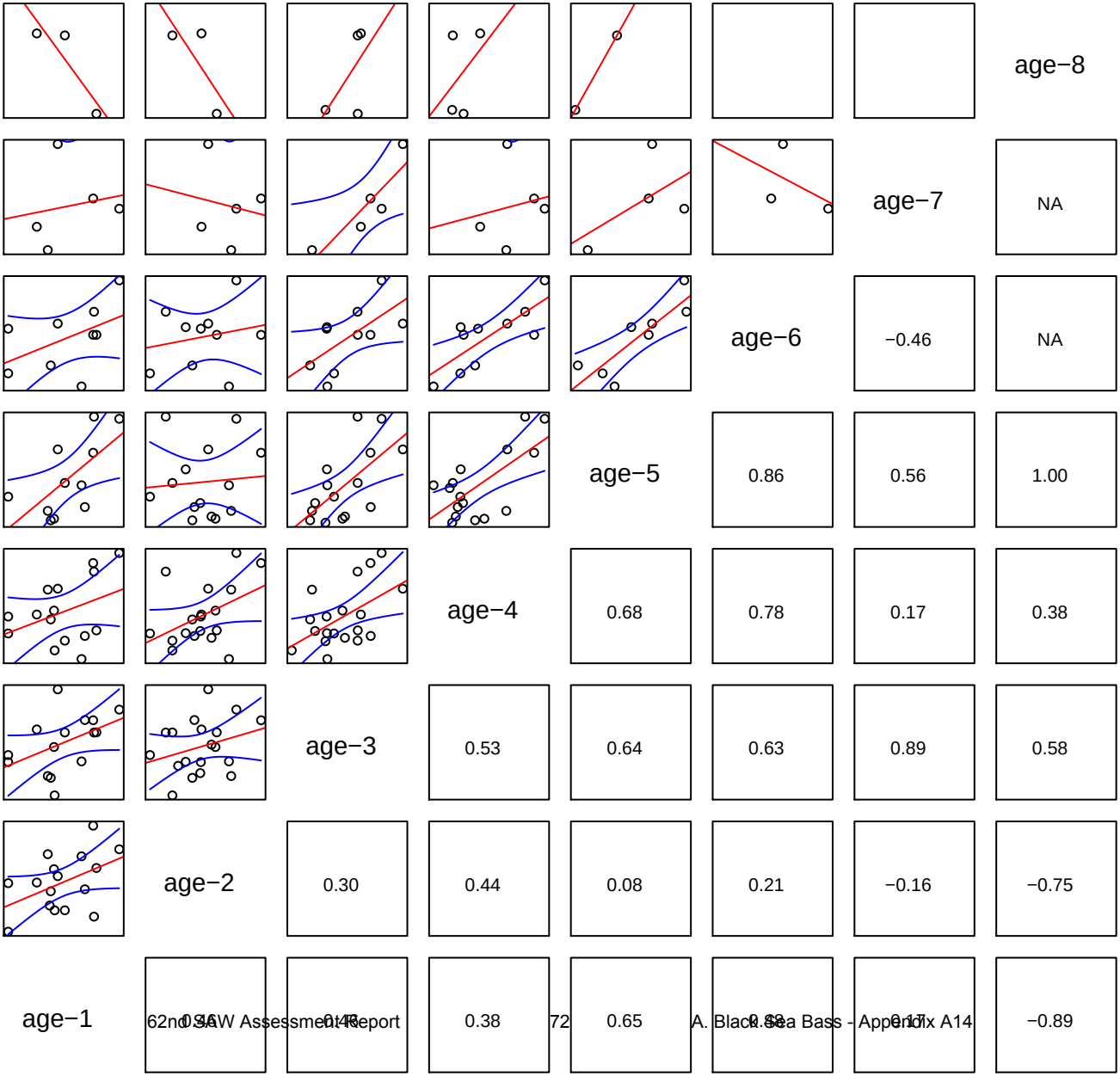
Catch for Fleet 2 Observed



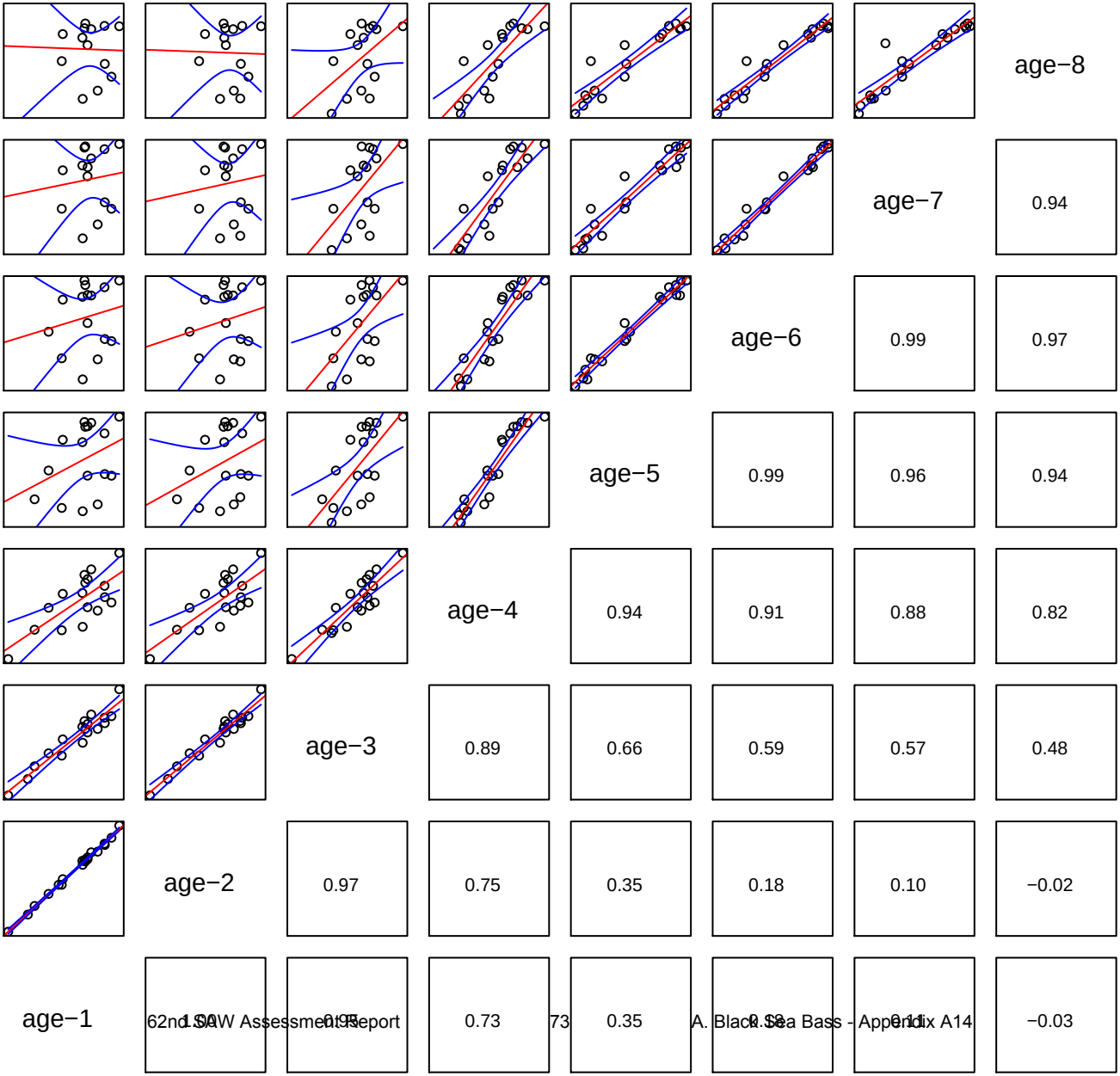
Catch for Fleet 2 Predicted



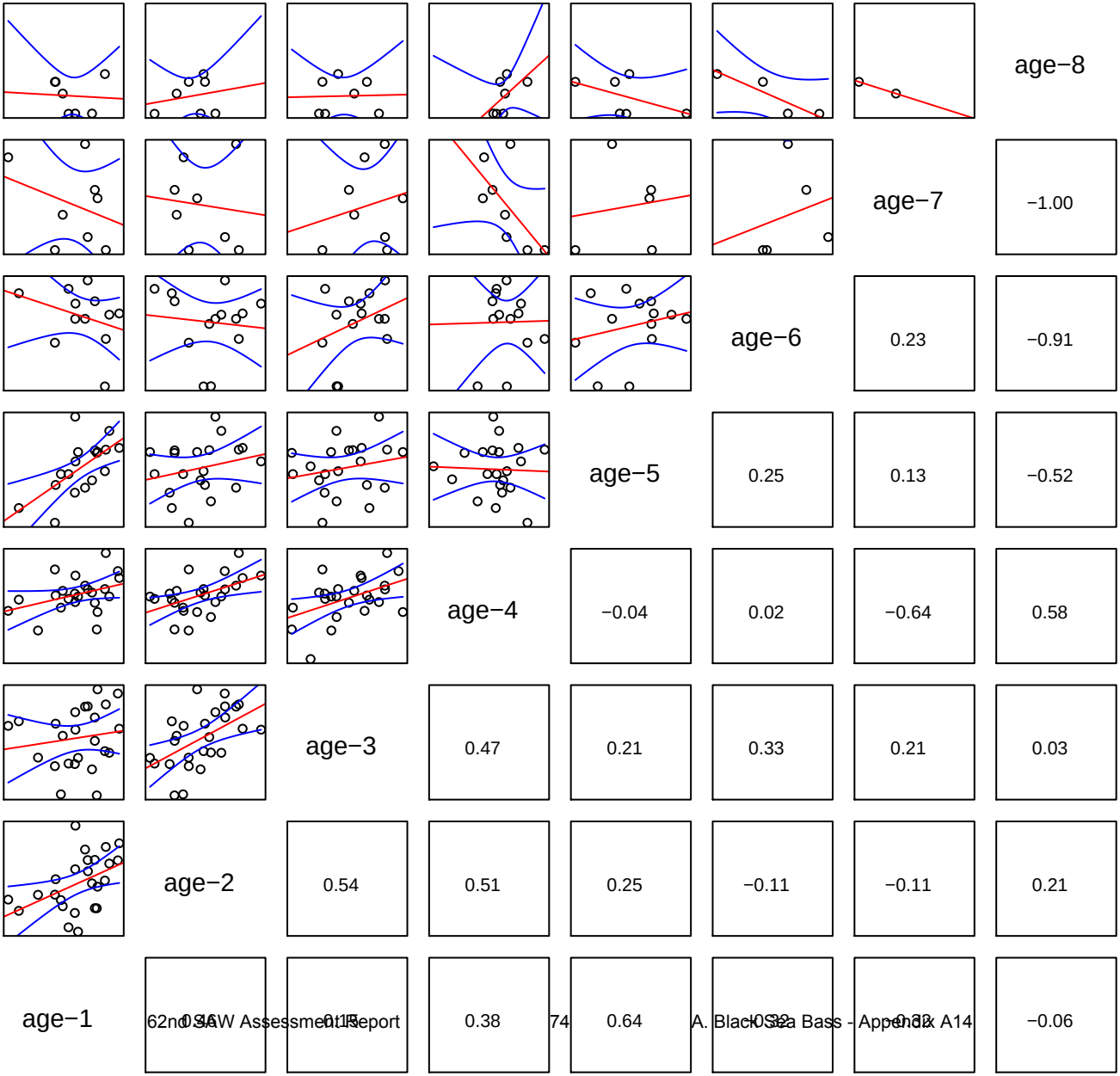
Index 1 Observed



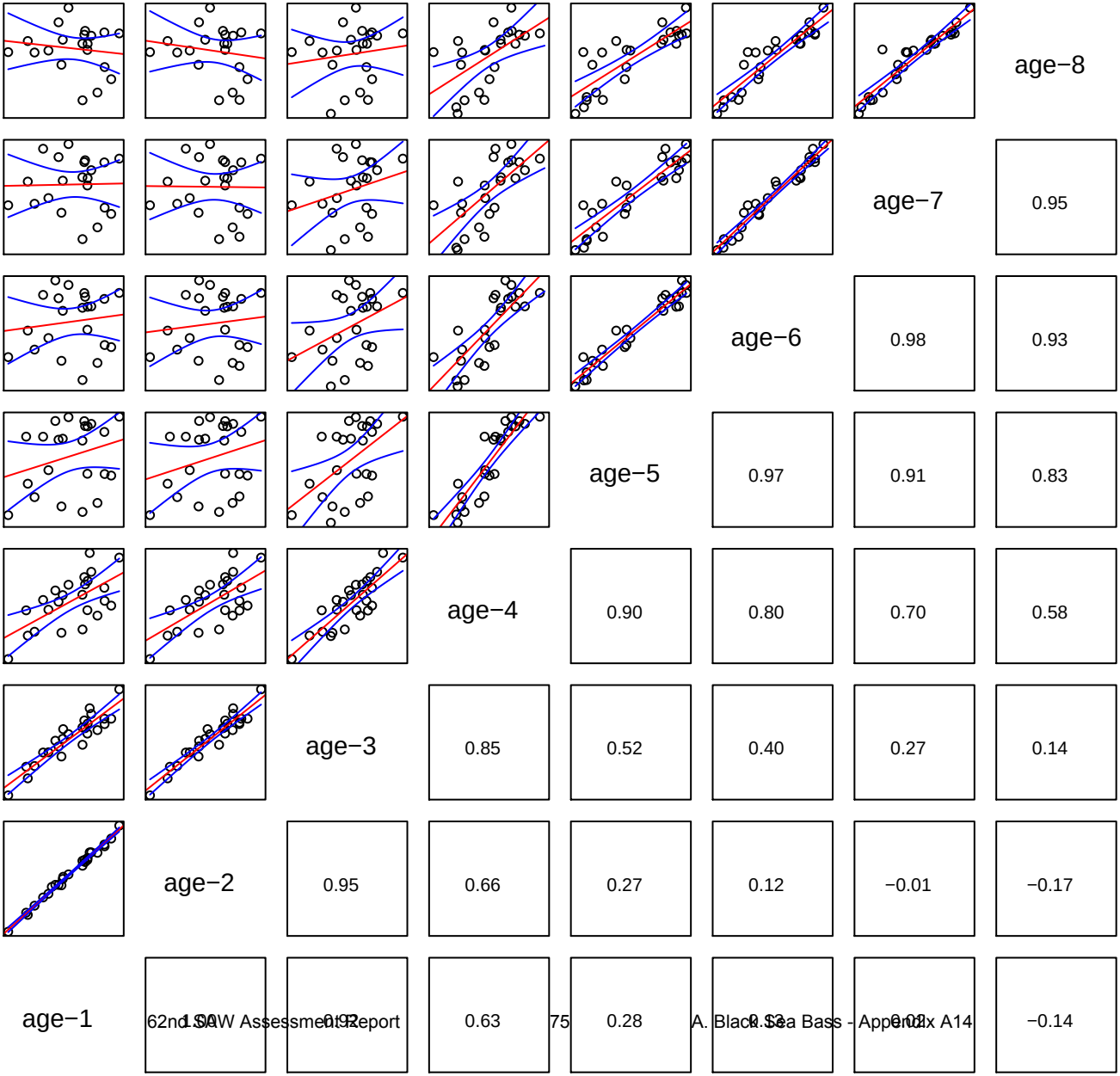
Index 1 Predicted



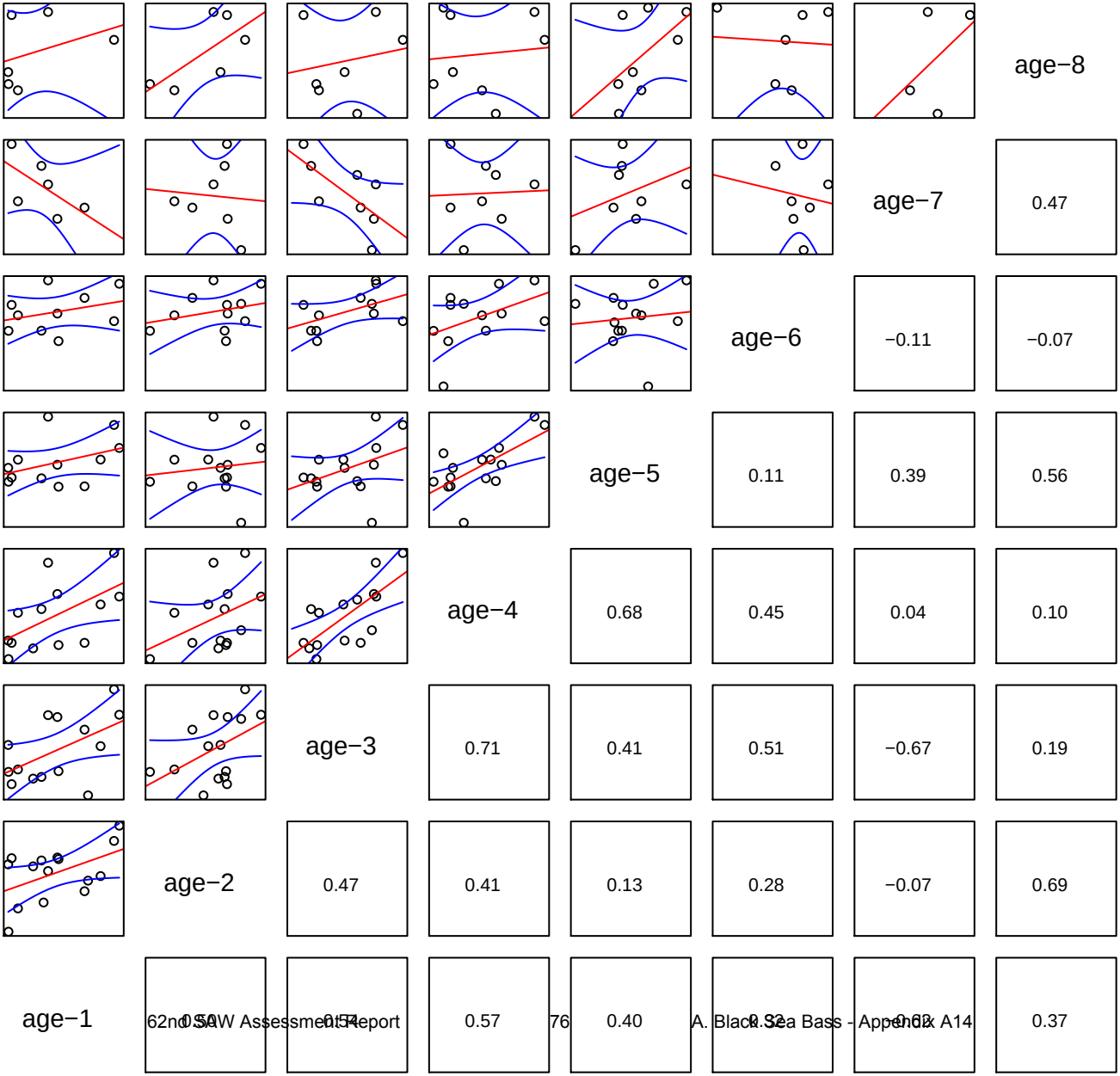
Index 3 Observed



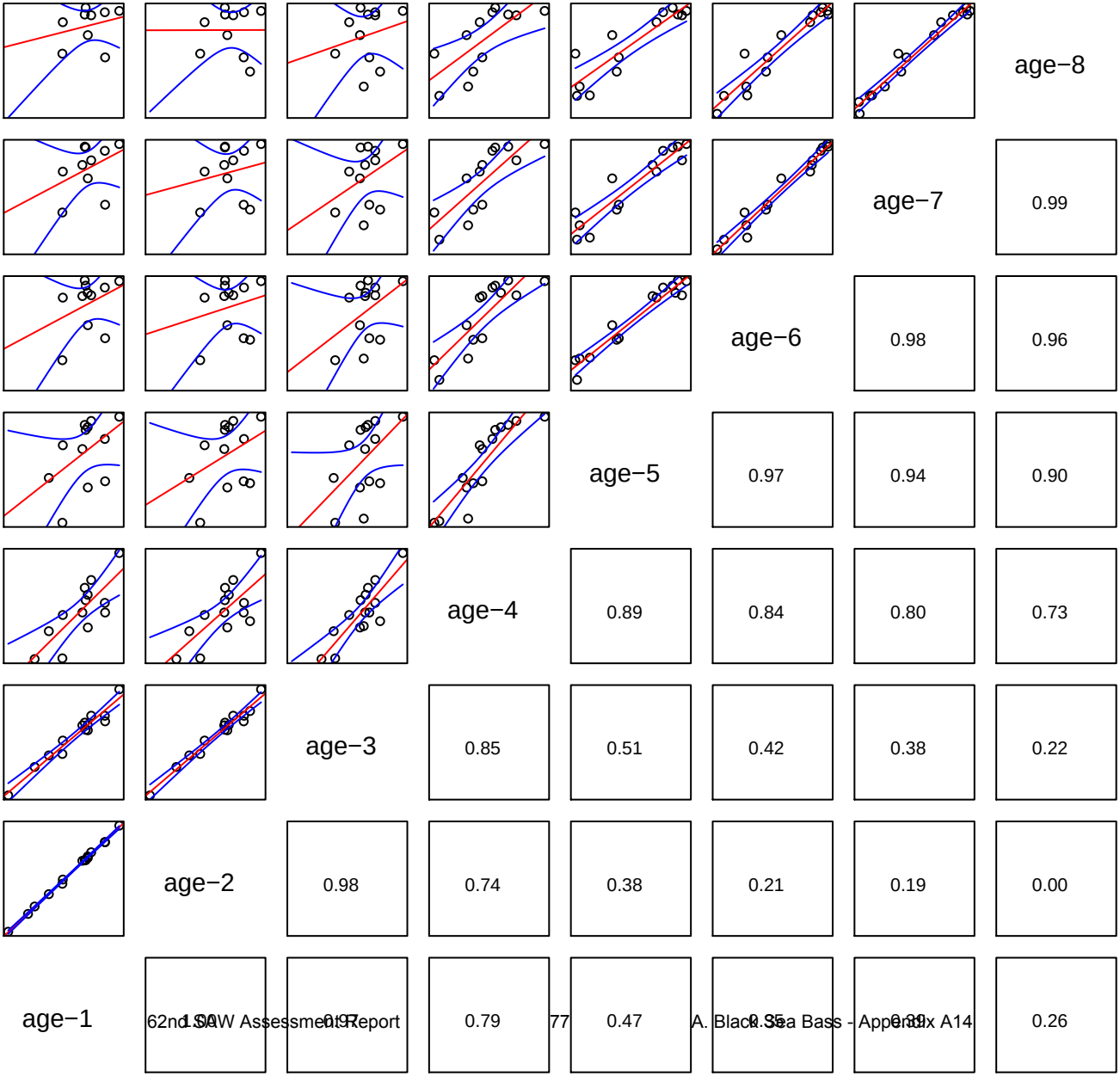
Index 3 Predicted



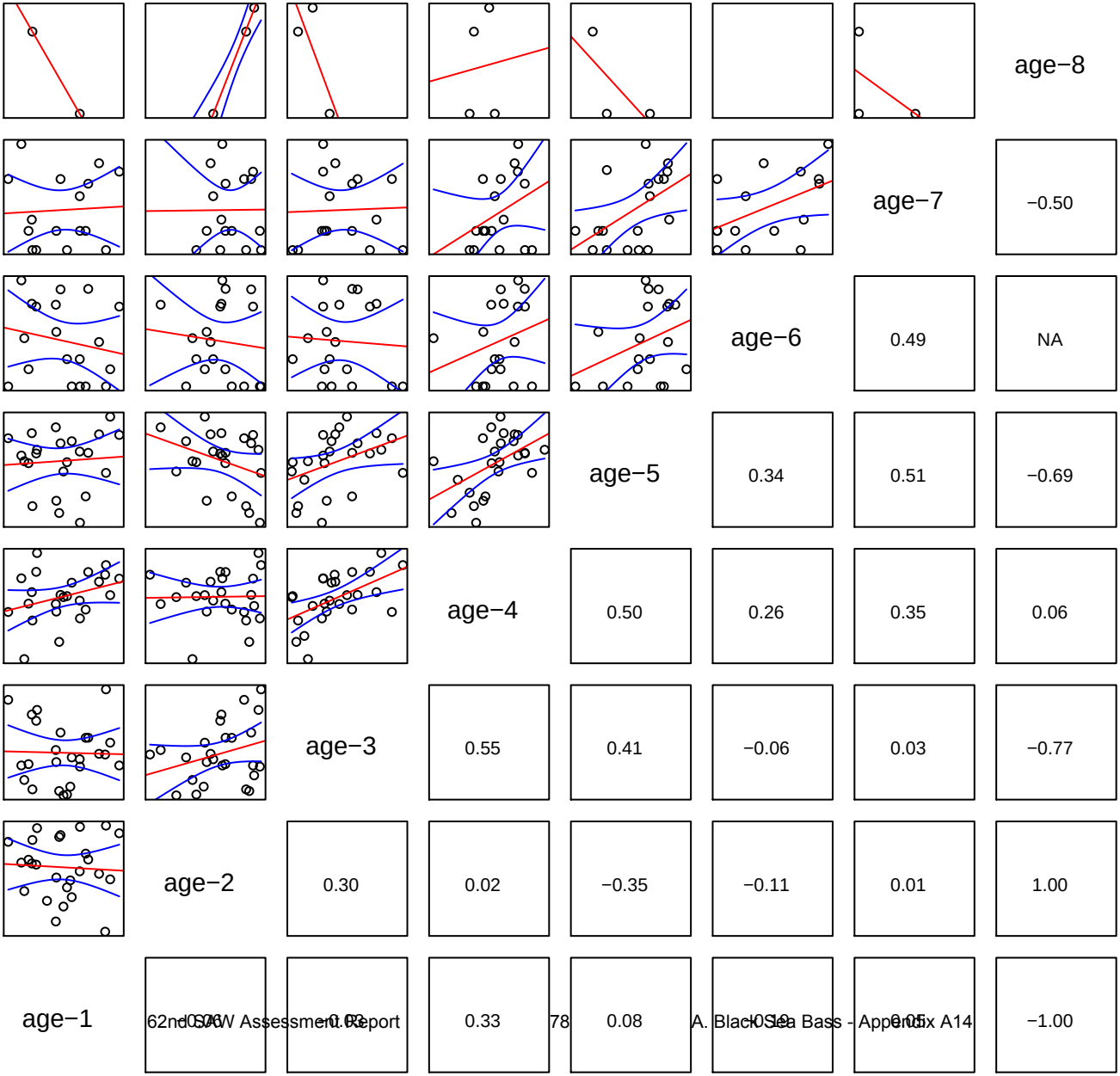
Index 7 Observed



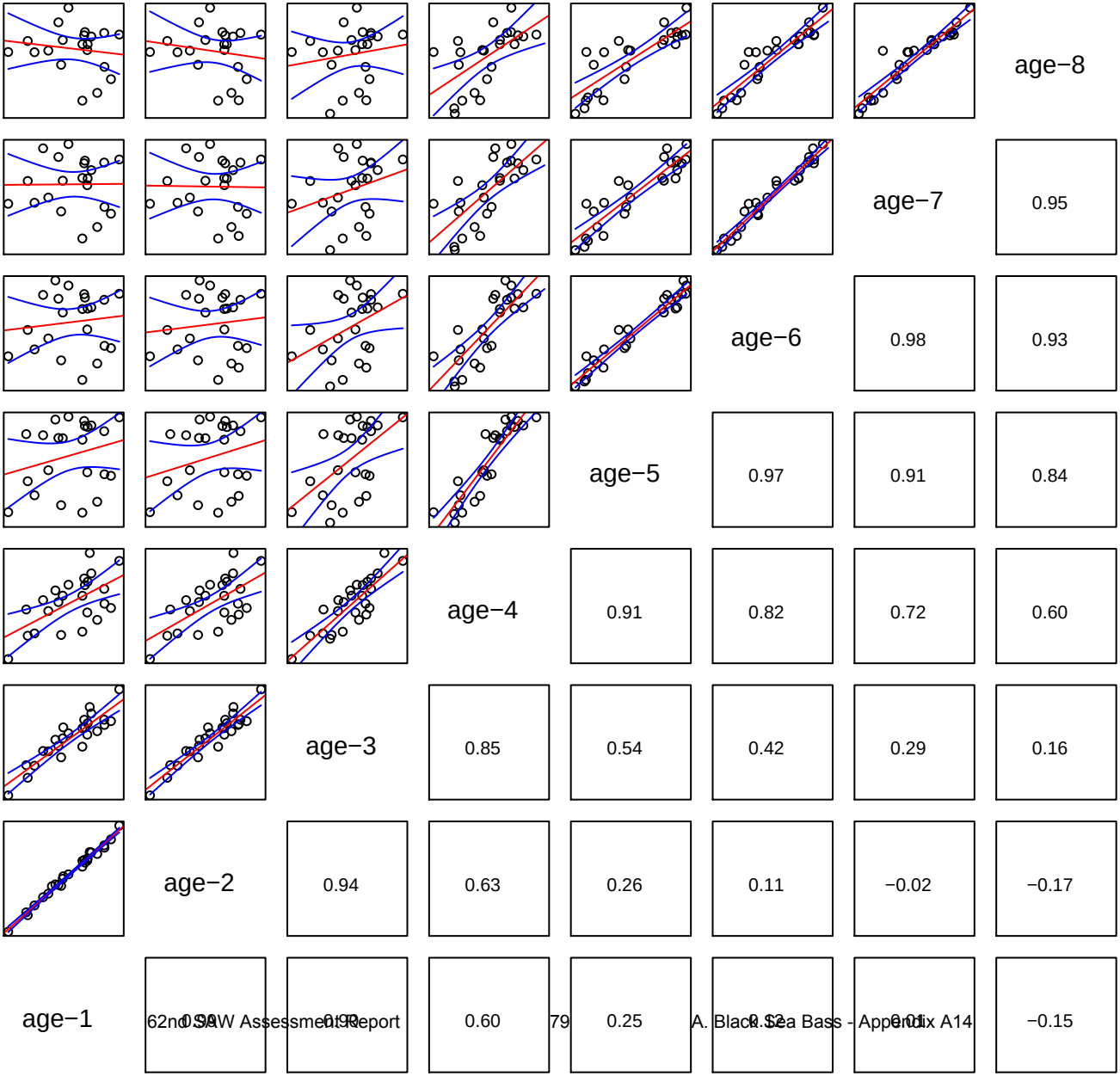
Index 7 Predicted



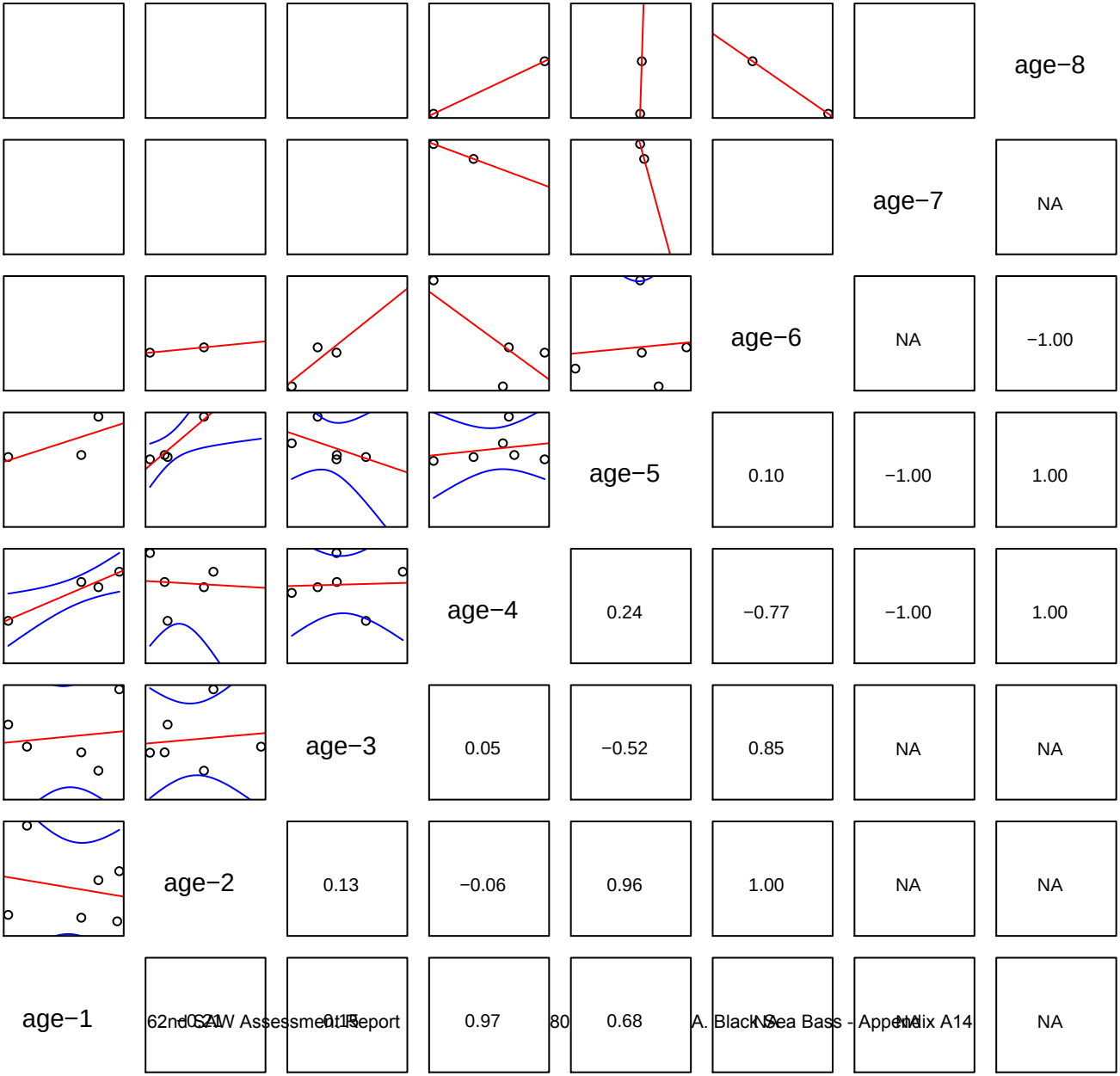
Index 8 Observed



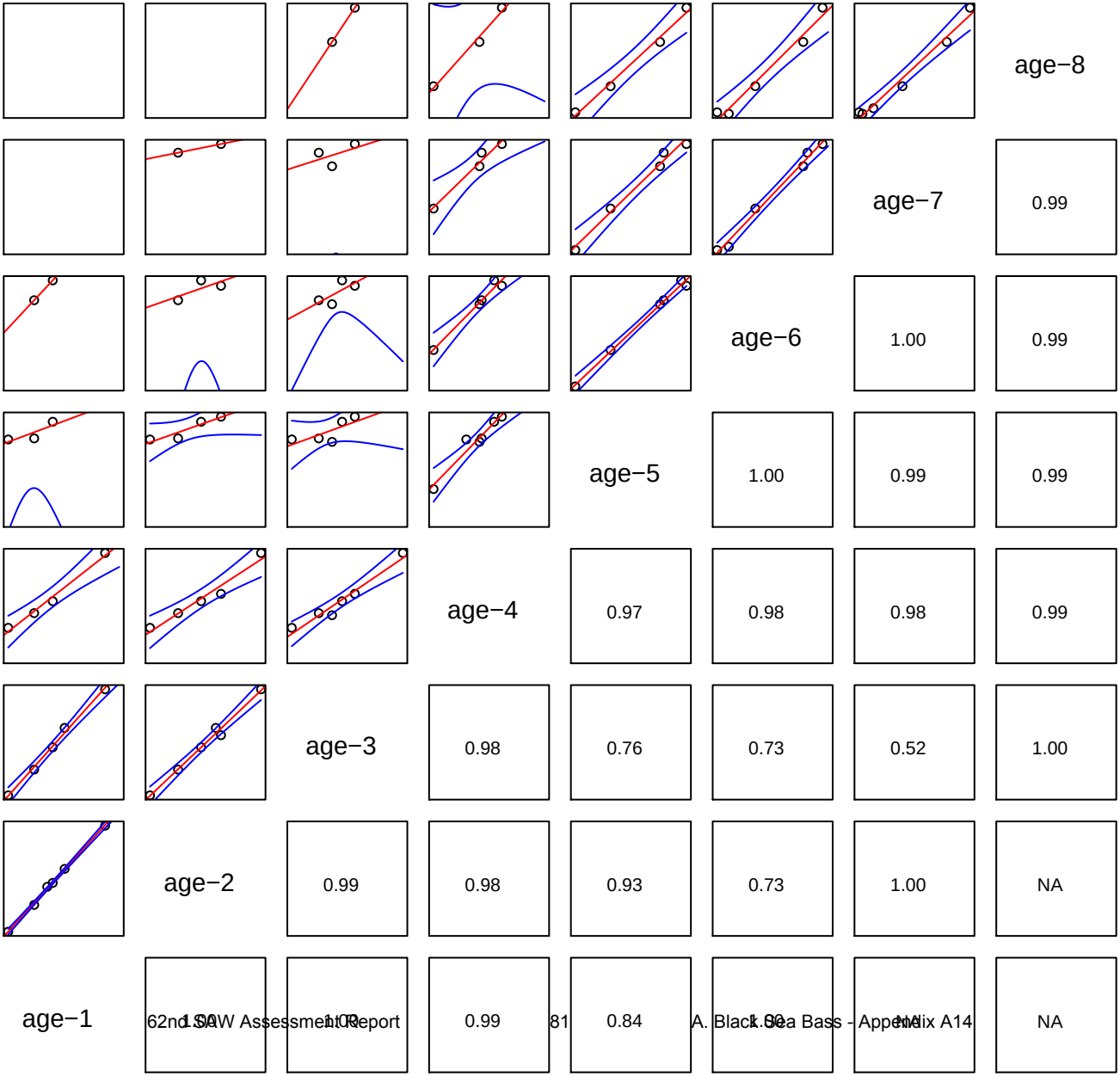
Index 8 Predicted

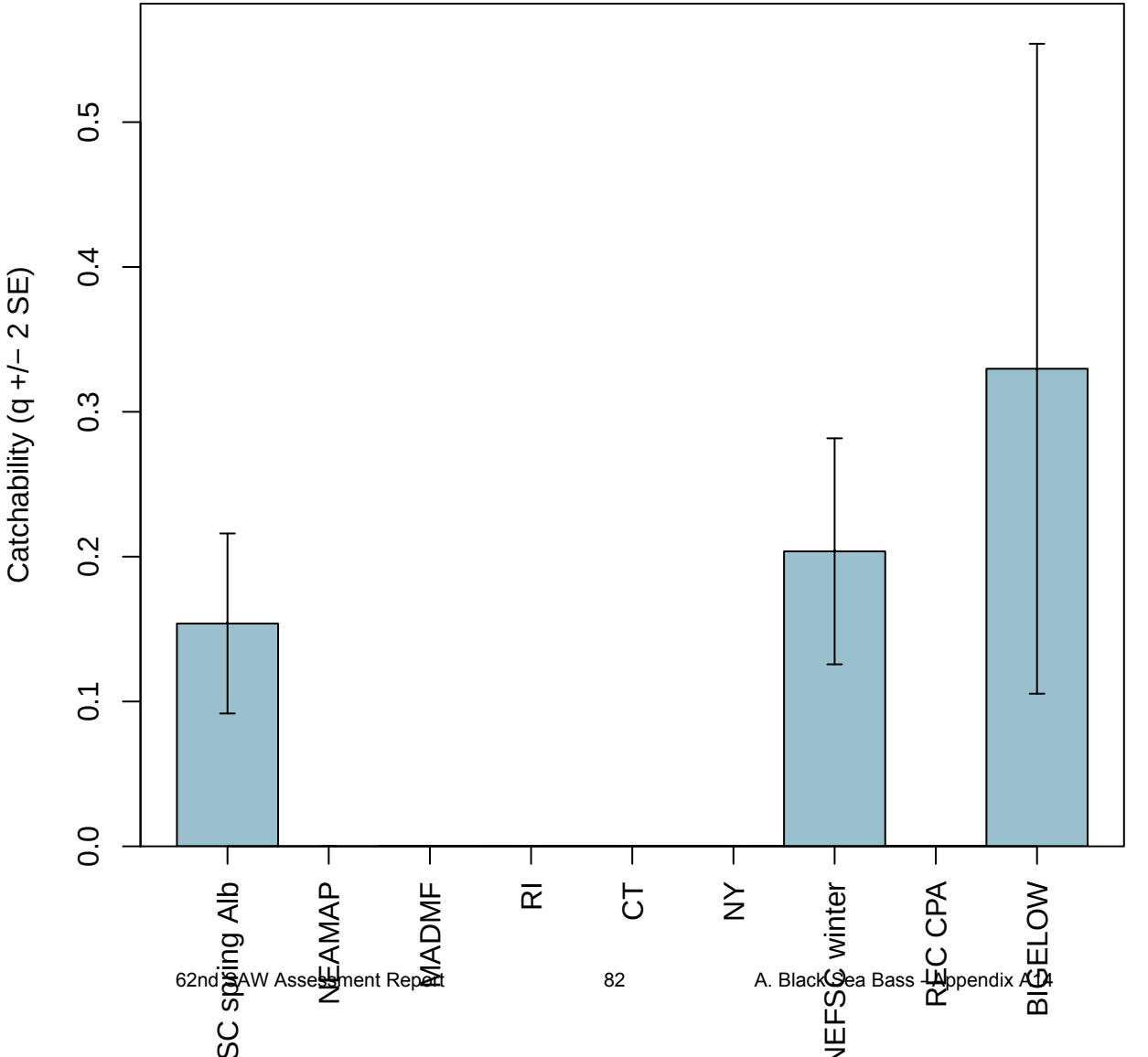


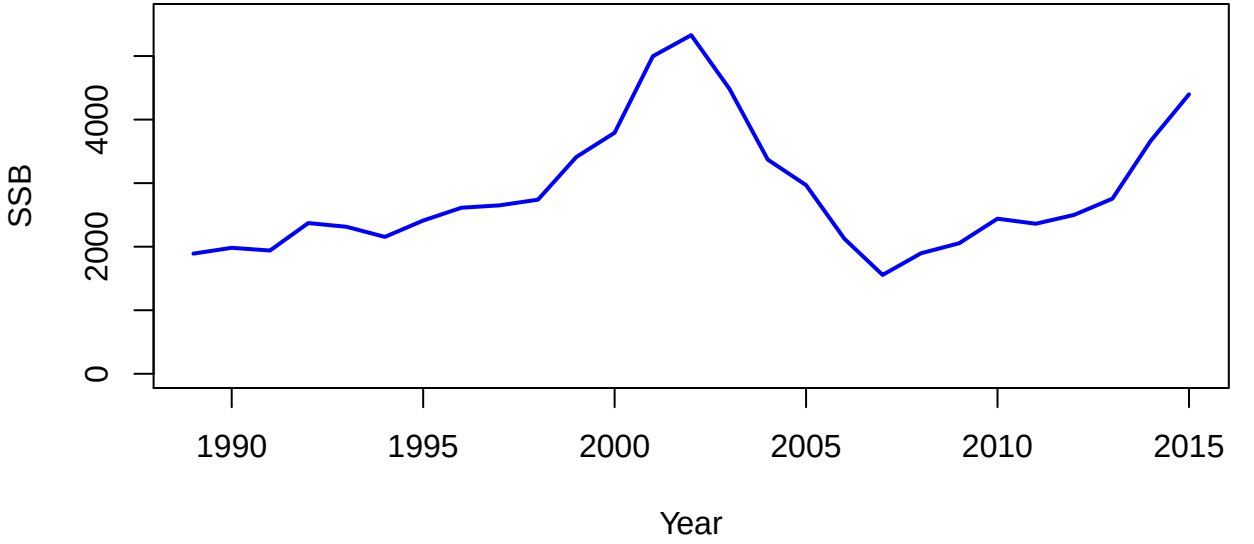
Index 9 Observed

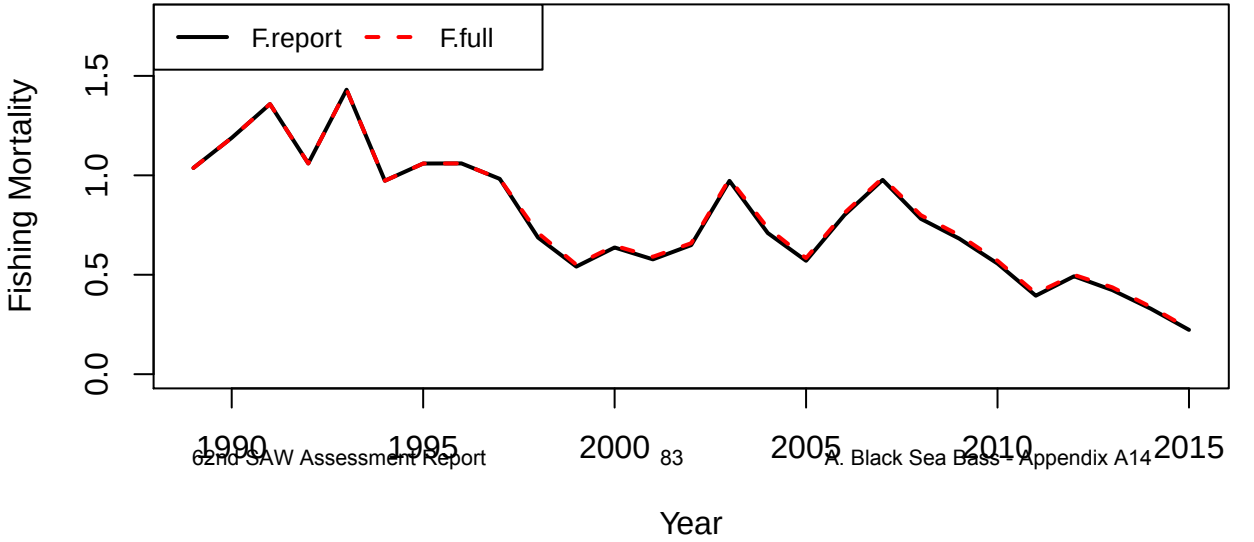


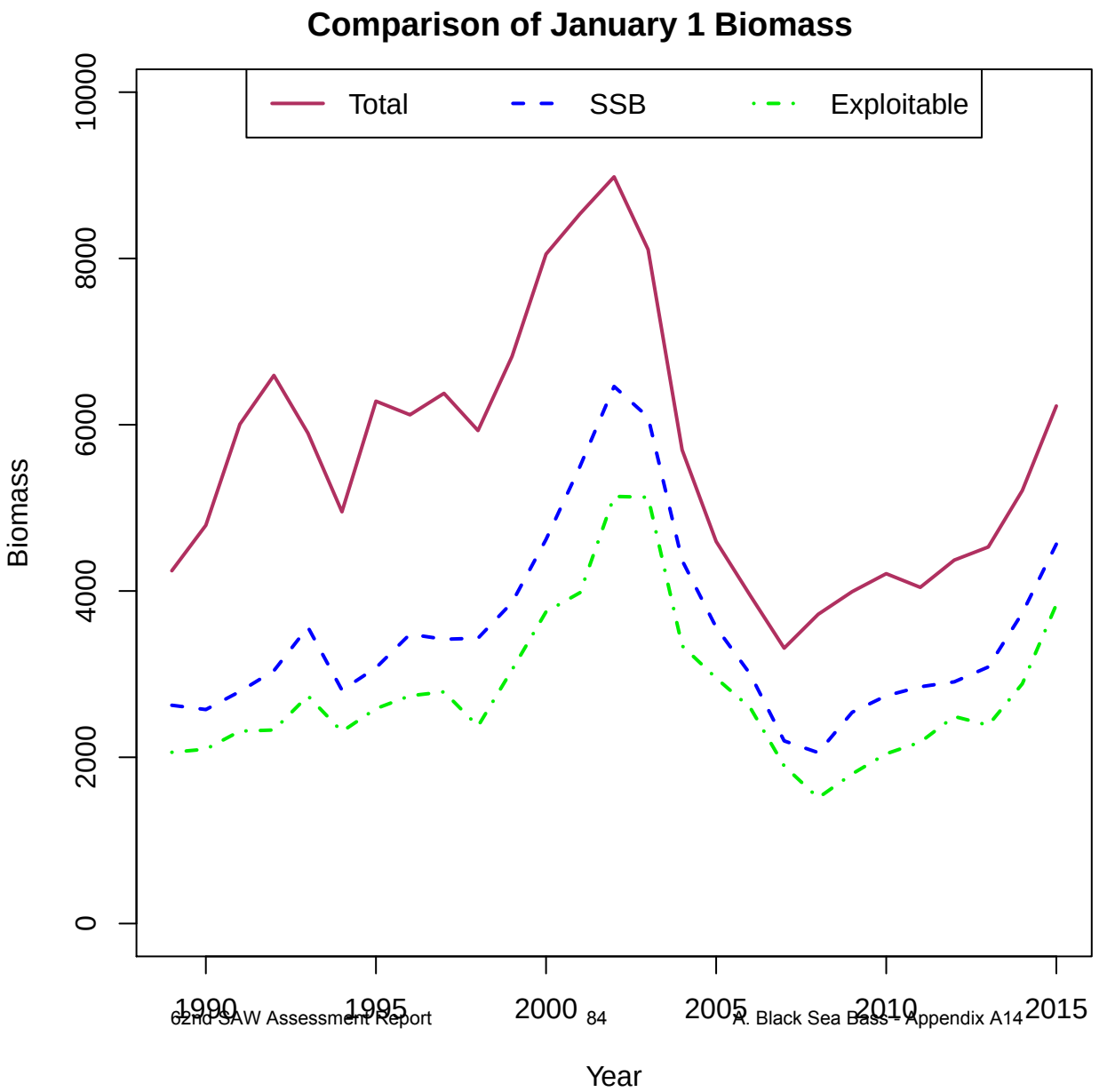
Index 9 Predicted

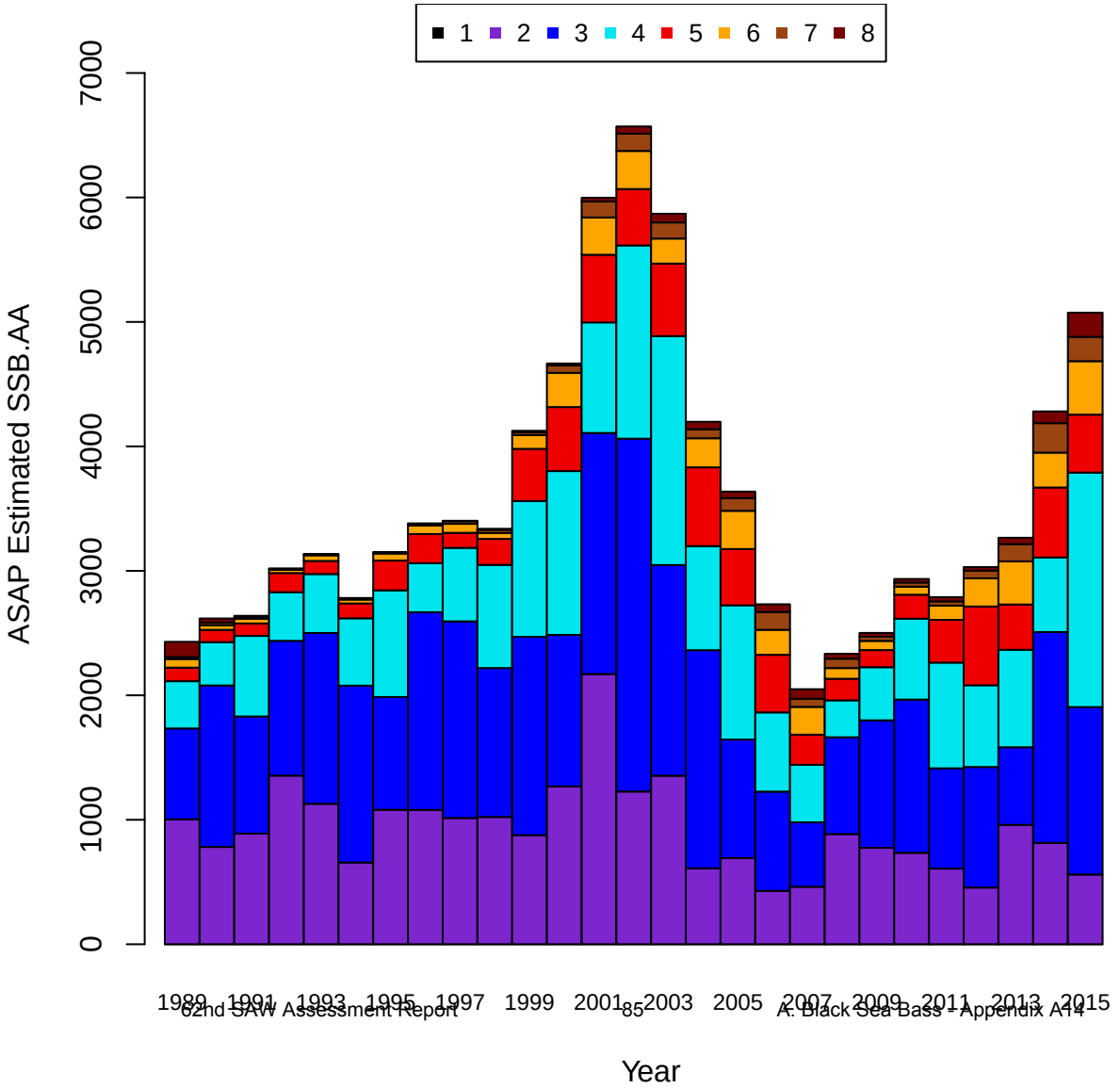


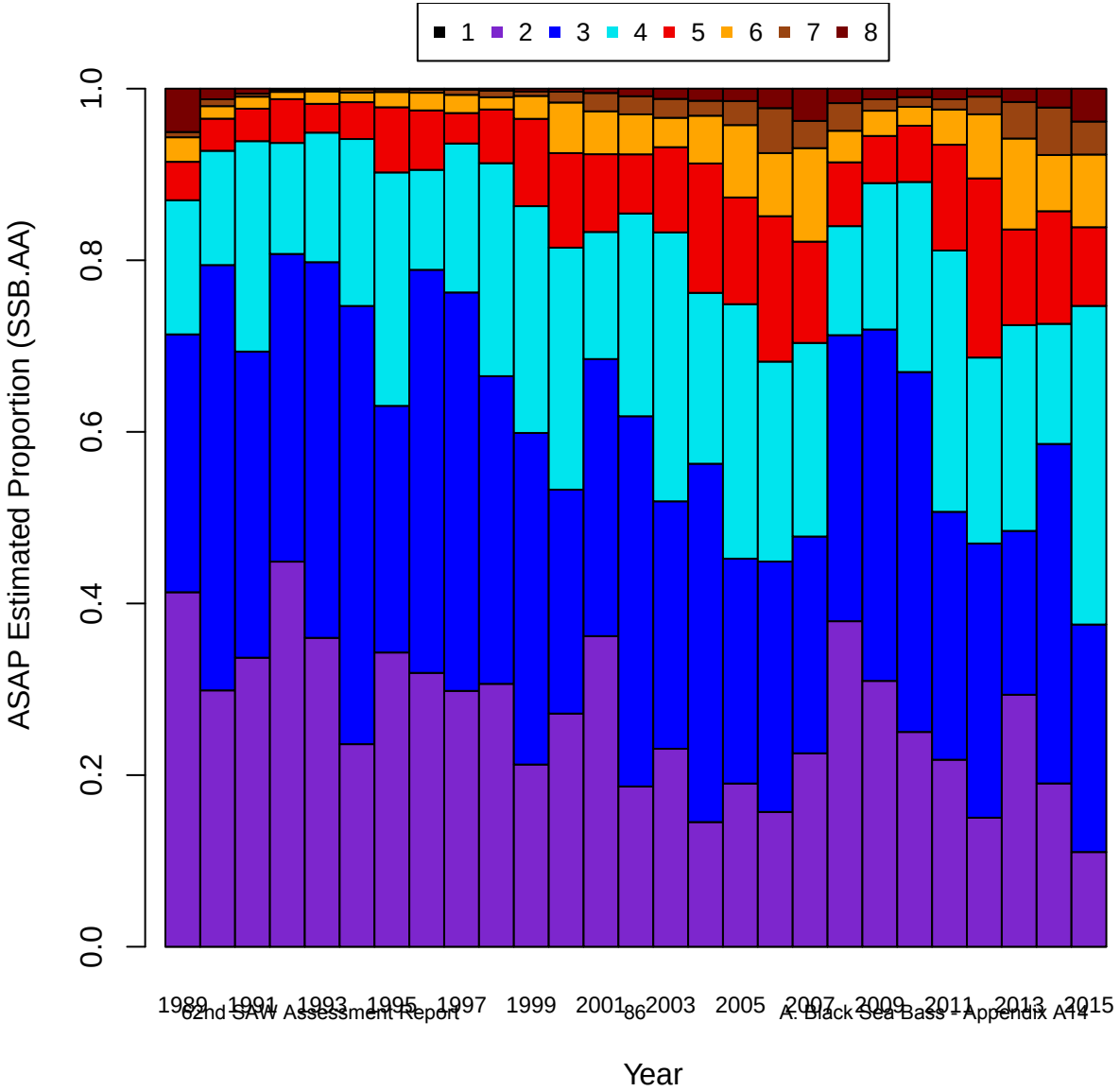

Catchability (q +/− 2 SE)
0.0
0.1
0.2
0.3
0.4
0.5
SC spring Alb
NEAMAP
MADMF
RI
CT
NY
NEFSC winter
RI EC CPA
BIGELOW

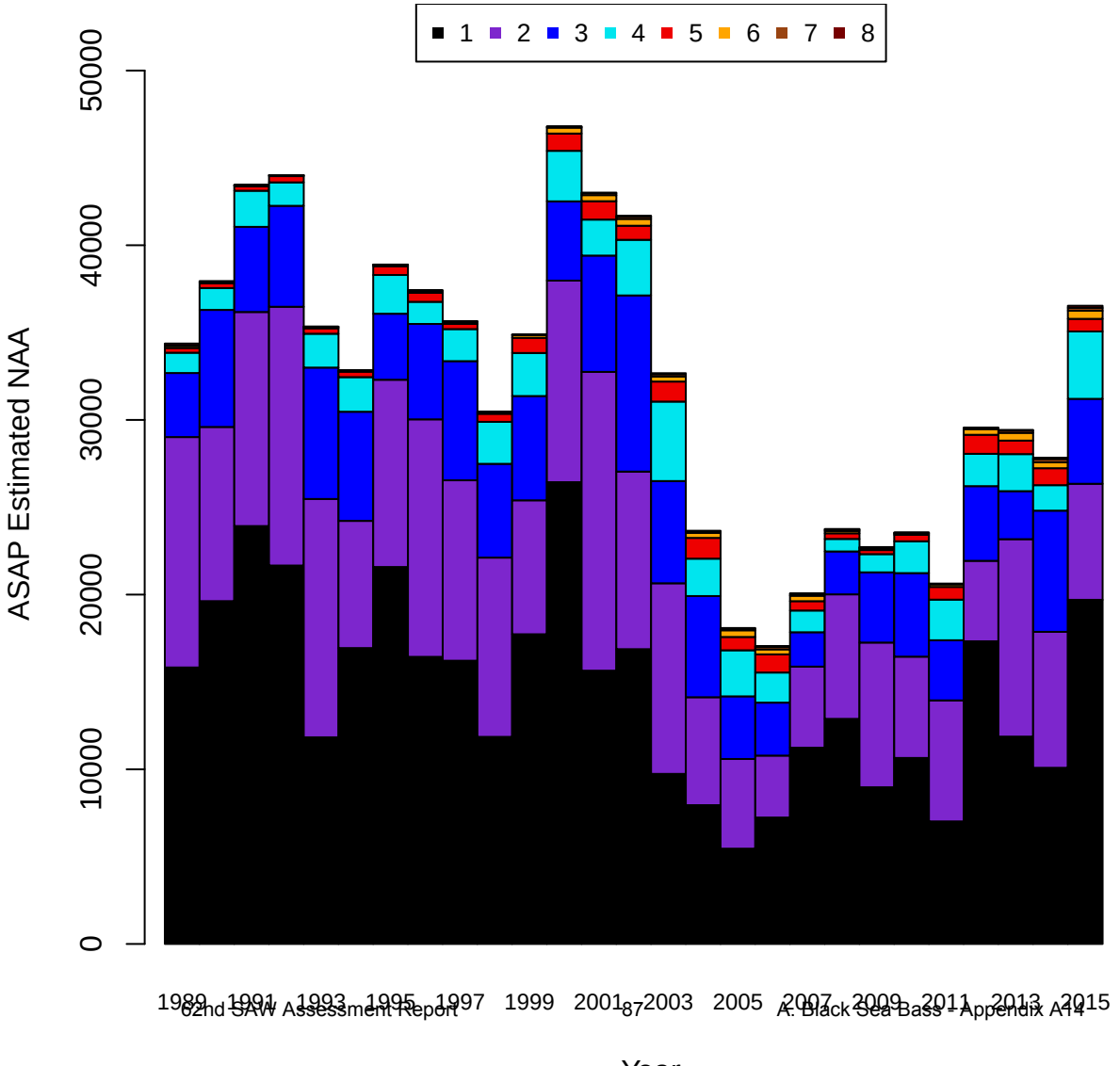

SSB
0
2000
4000
1990
1995
2000
2005
2010
2015
Year

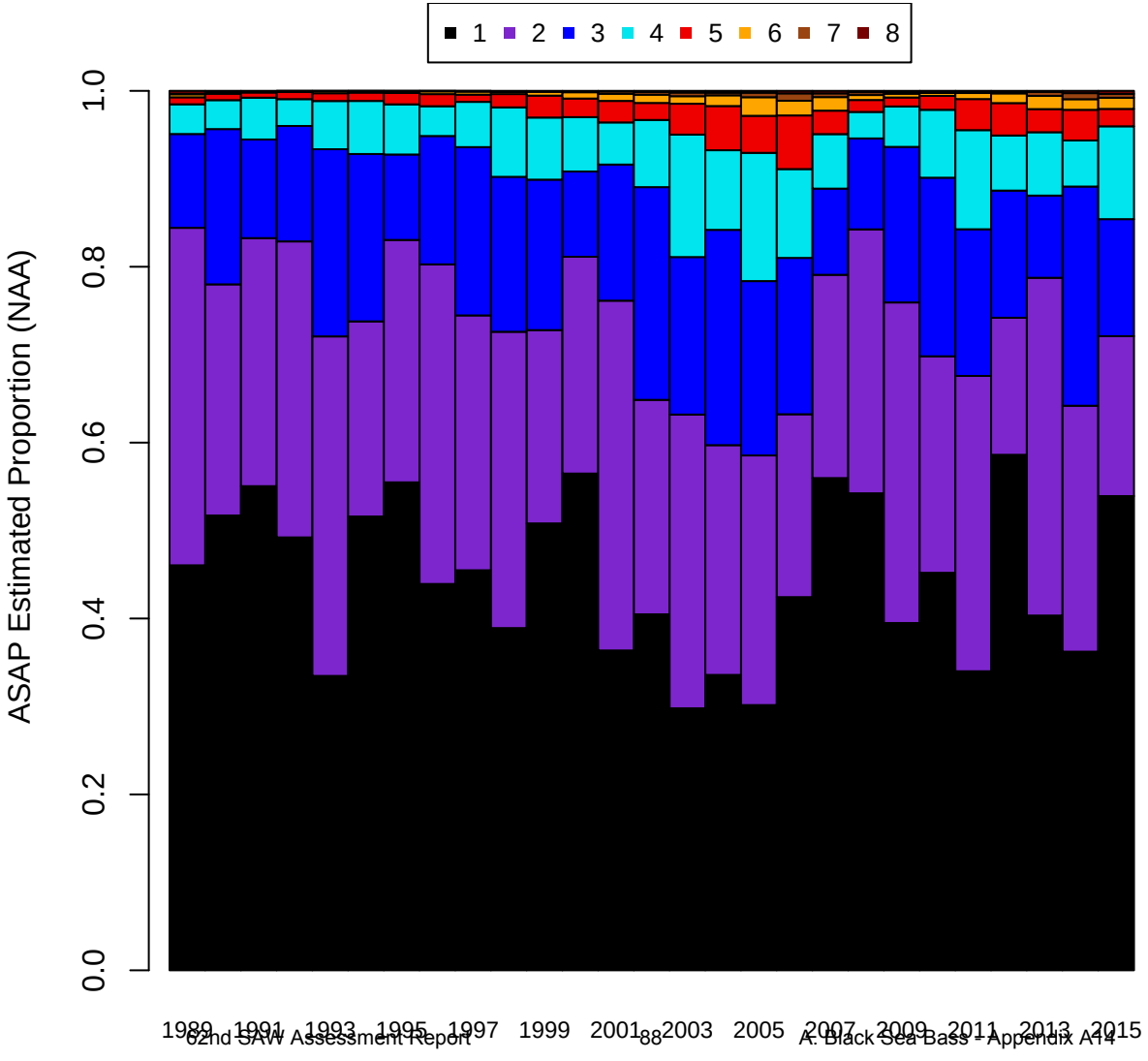

F.report
F.full
Fishing Mortality
0.0
0.5
1.0
1.5
1990
1995
2000
2005
2010
2015
Year

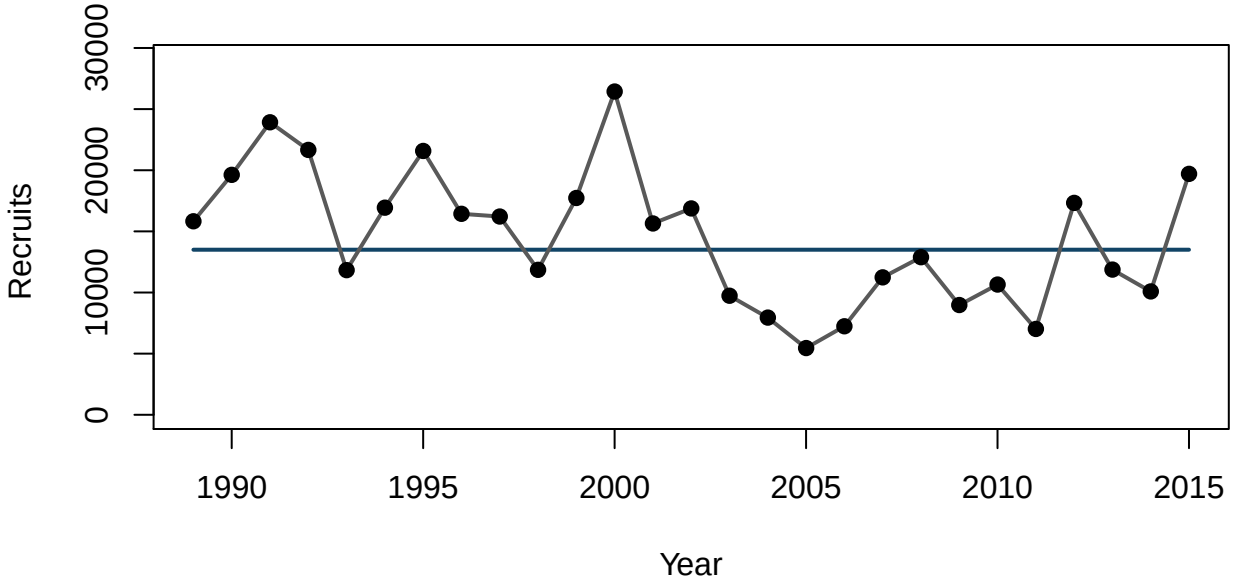

Comparison of January 1 Biomass
Total
SSB
Exploitable
Biomass
0
2000
4000
6000
8000
10000
1990
1995
2000
2005
2010
2015
Year

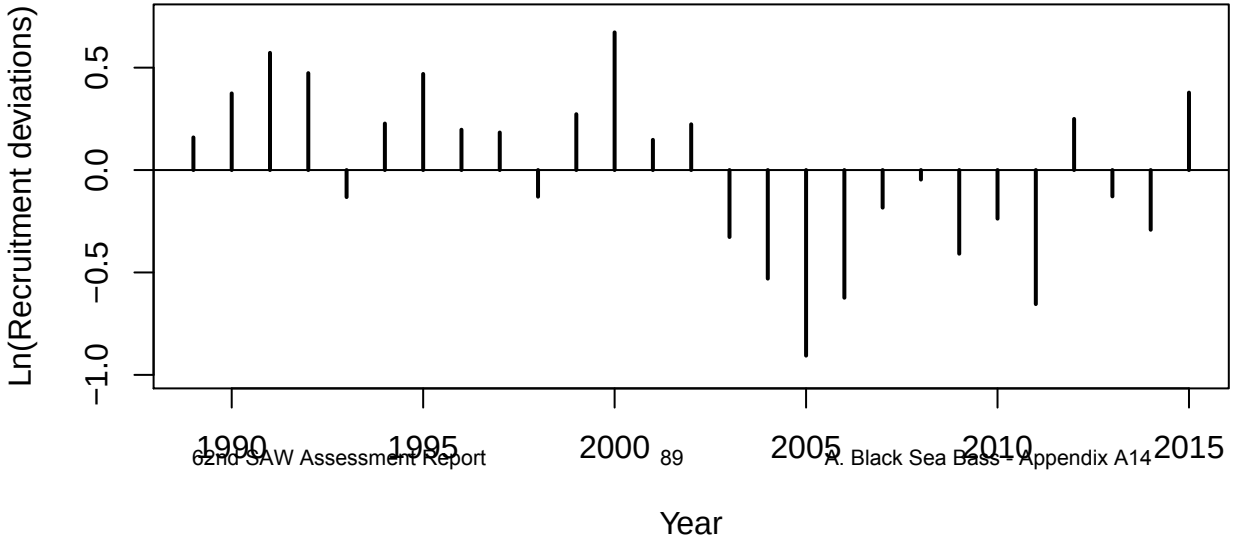

1 2 3 4 5 6 7 8
ASAP Estimated SSB.AA
0
1000
2000
3000
4000
5000
6000
7000
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

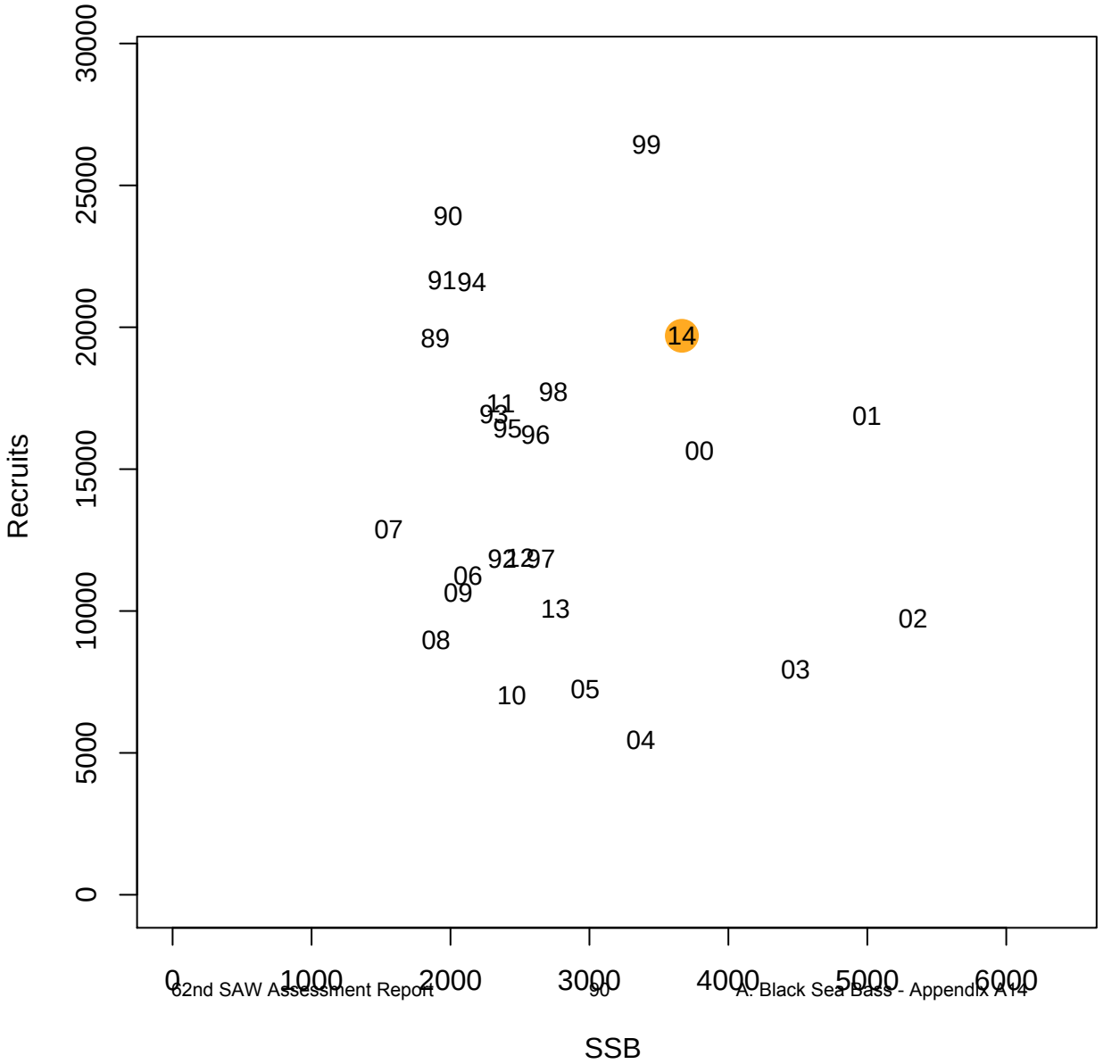

1 2 3 4 5 6 7 8
ASAP Estimated Proportion (SSB.AA)
0.0
0.2
0.4
0.6
0.8
1.0
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

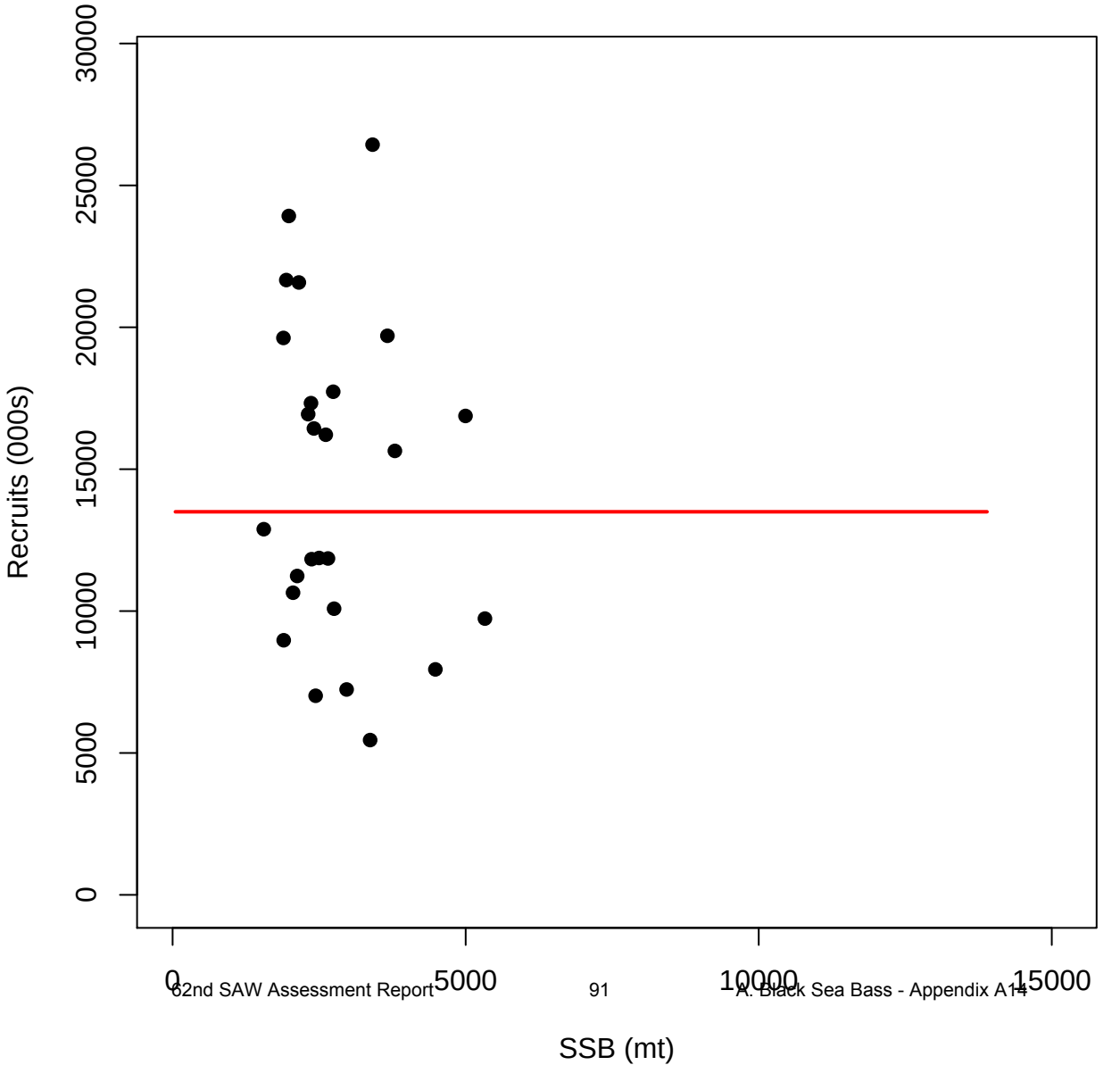

1 2 3 4 5 6 7 8
ASAP Estimated NAA
0
10000
20000
30000
40000
50000
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

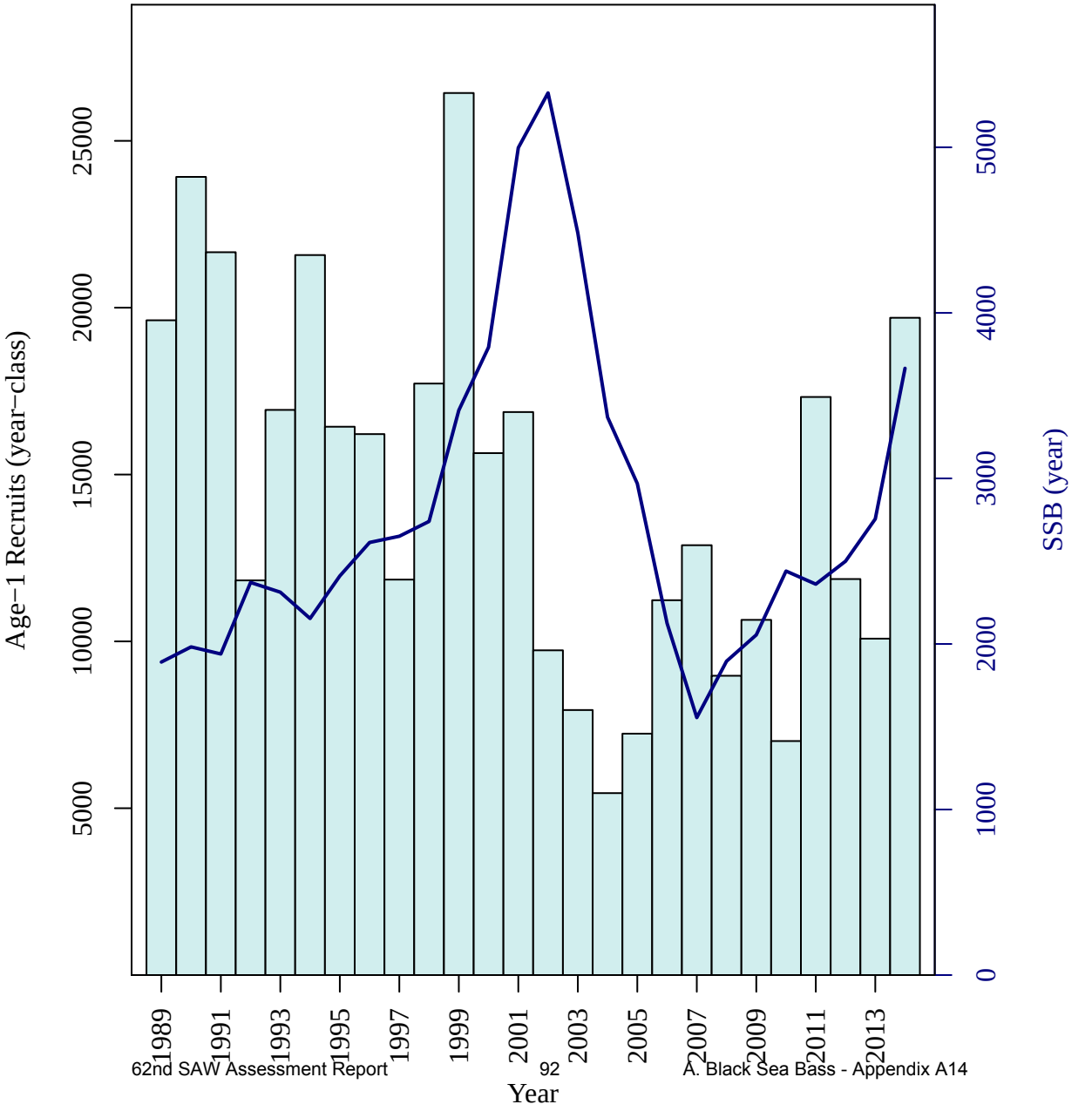

1 2 3 4 5 6 7 8
ASAP Estimated Proportion (NAA)
0.0
0.2
0.4
0.6
0.8
1.0
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Year

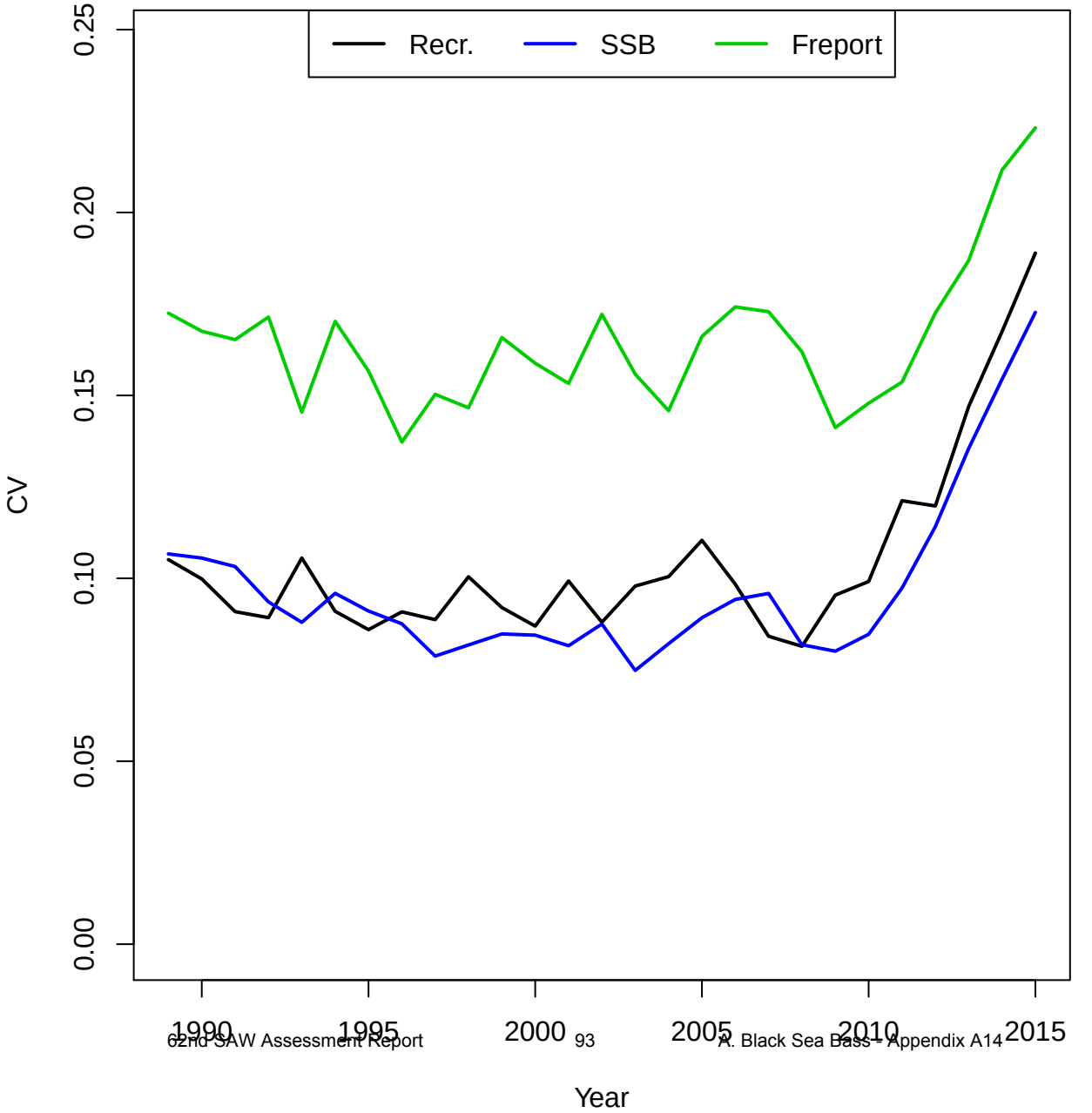

Recruits
0
10000
20000
30000
1990
1995
2000
2005
2010
2015
Year

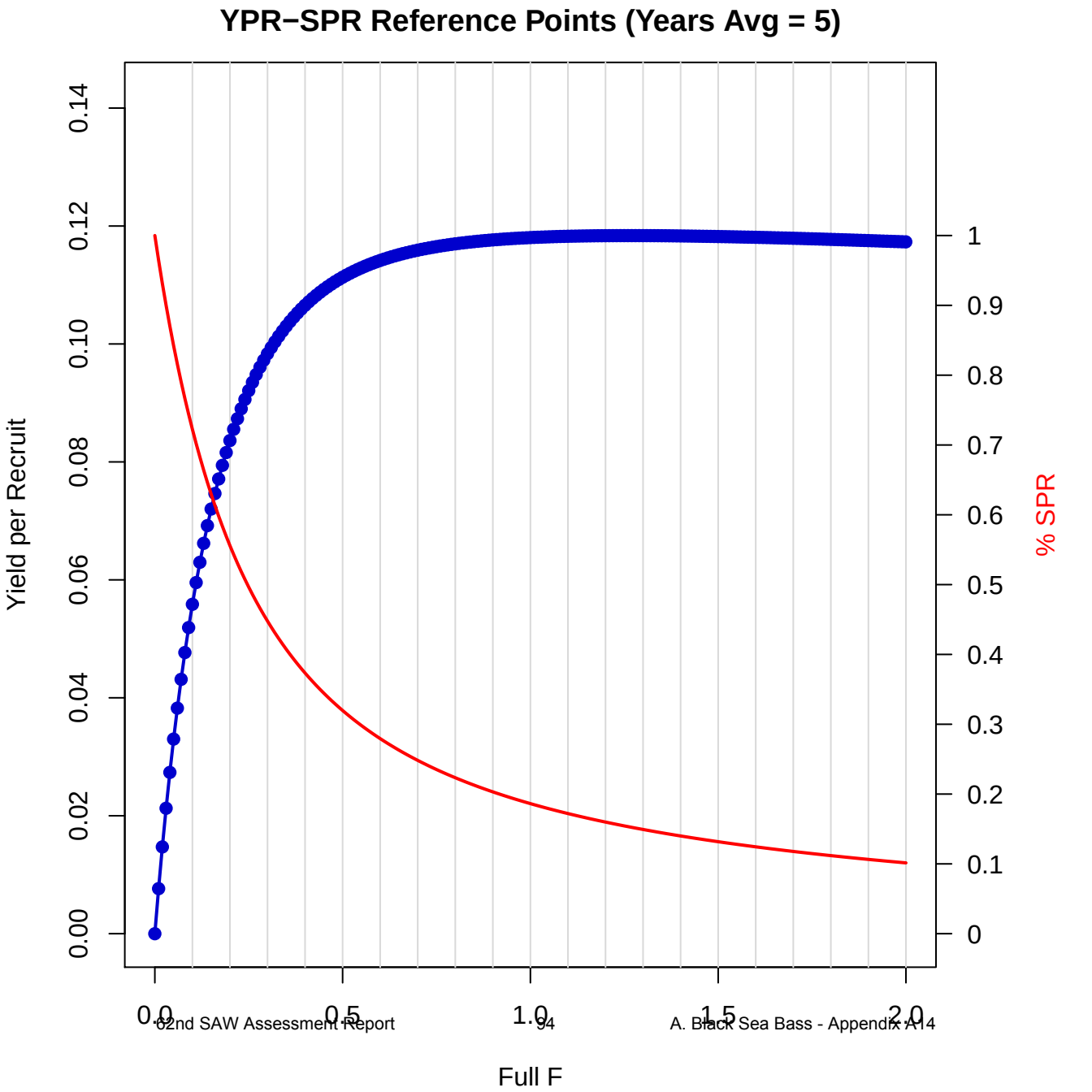

Ln(Recruitment deviations)
−1.0
−0.5
0.0
0.5
1990
1995
2000
2005
2010
2015
Year


Recruits
SSB
0
5000
10000
15000
20000
25000
30000
0
1000
2000
3000
4000
5000
6000
99
90
91
94
89
14
98
11
93
95
96
01
00
07
92
12
97
06
09
13
02
08
03
10
05
04


Recruits (000s)
0
5000
10000
15000
20000
25000
30000
0
5000
10000
15000
SSB (mt)

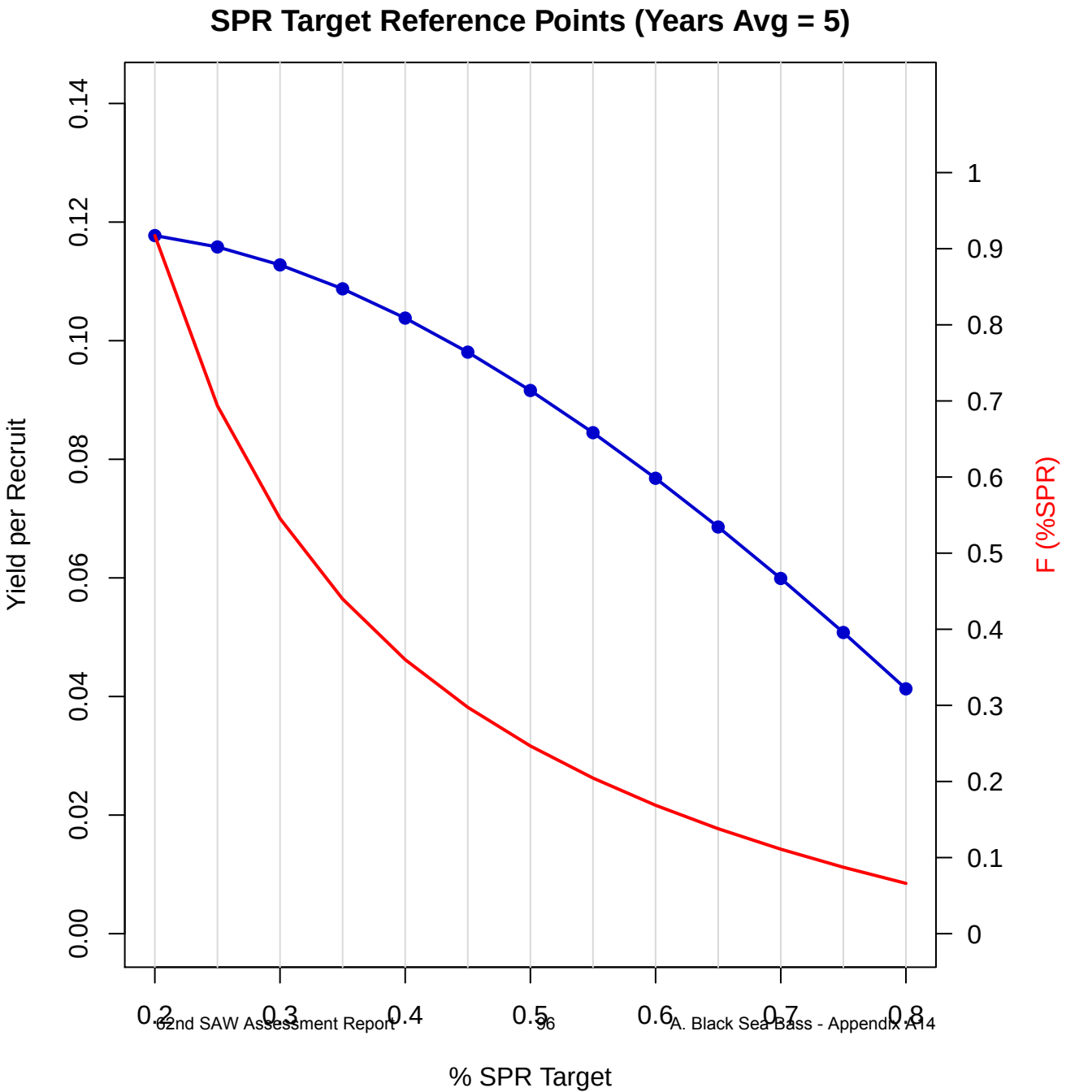

Age−1 Recruits (year−class)
5000
10000
15000
20000
25000
SSB (year)
0
1000
2000
3000
4000
5000
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Year


Recr.
SSB
Freport
CV
0.00
0.05
0.10
0.15
0.20
0.25
1990
1995
2000
2005
2010
2015
Year


YPR−SPR Reference Points (Years Avg = 5)
Yield per Recruit
% SPR
Full F
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.0
0.5
1.0
1.5
2.0

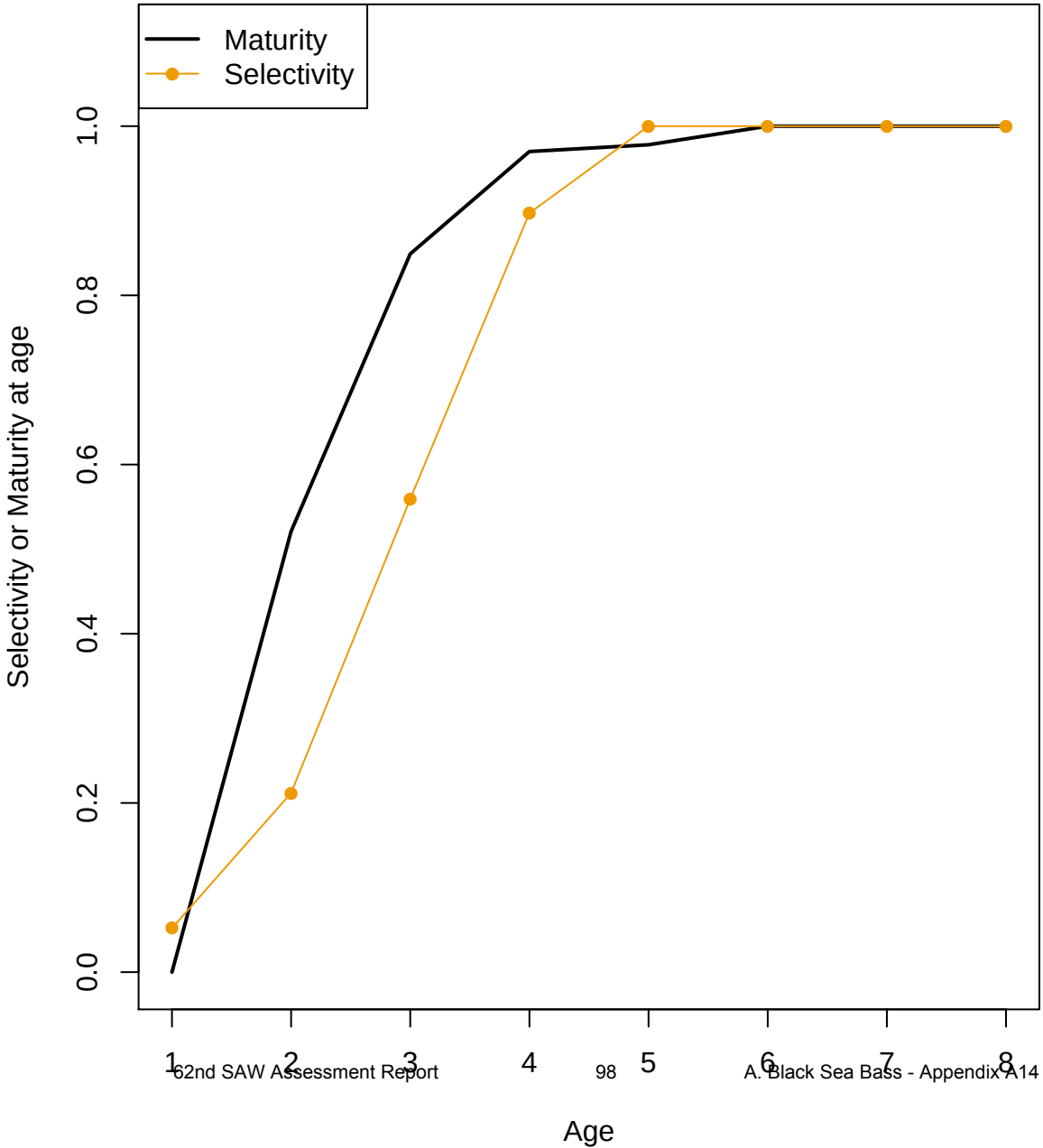
YPR−SPR Reference Points (Years Avg = 5)

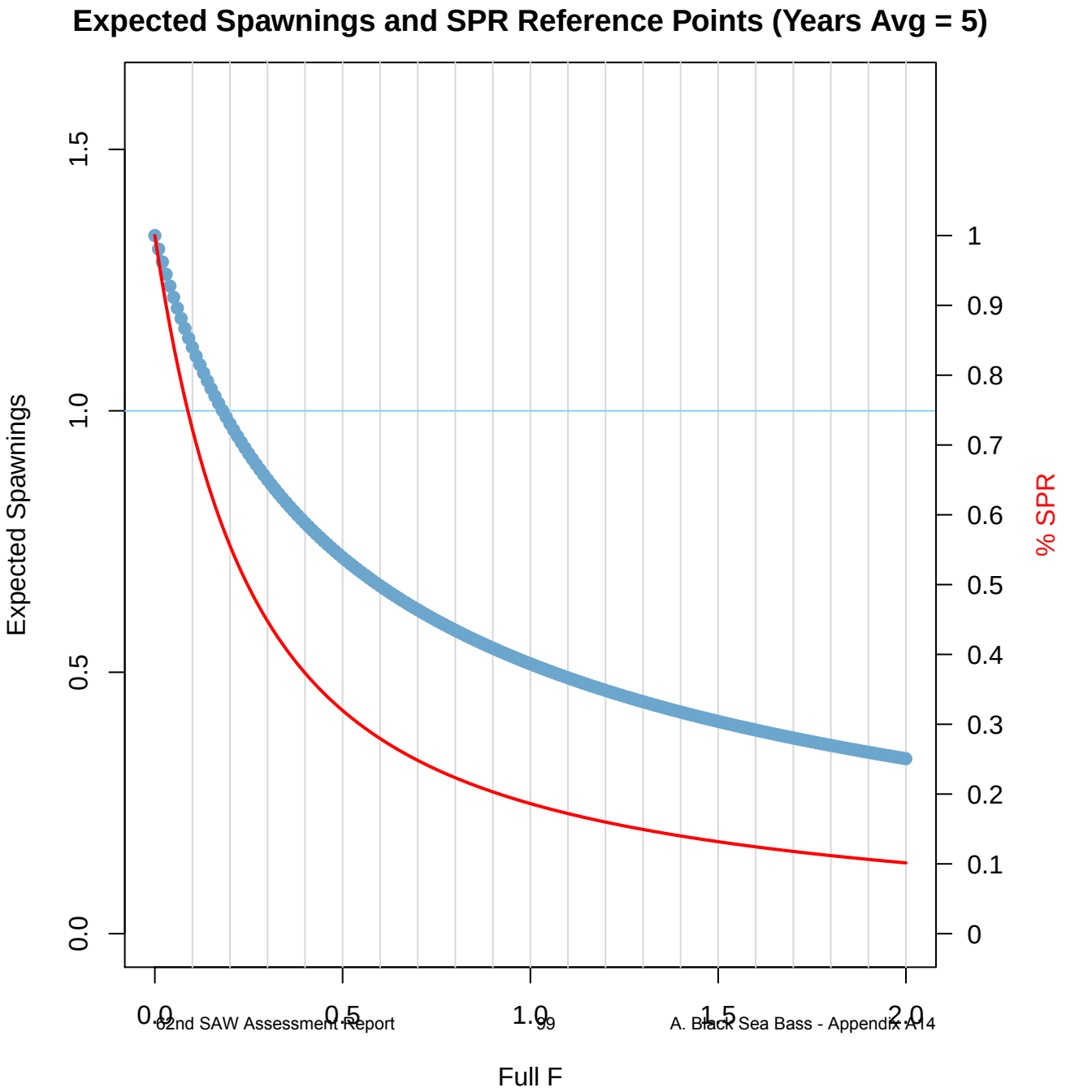
F	YPR	SPR	F	YPR	SPR	F	YPR	SPR
0	0	1	0.35	0.103	0.4073	0.7	0.1159	0.2482
0.01	0.0076	0.9646	0.36	0.1038	0.4001	0.71	0.116	0.2455
0.02	0.0147	0.9313	0.37	0.1045	0.393	0.72	0.1162	0.2428
0.03	0.0213	0.8999	0.38	0.1053	0.3863	0.73	0.1163	0.2402
0.04	0.0274	0.8702	0.39	0.1059	0.3797	0.74	0.1164	0.2376
0.05	0.033	0.8422	0.4	0.1065	0.3733	0.75	0.1165	0.2351
0.06	0.0382	0.8156	0.41	0.1071	0.3672	0.76	0.1166	0.2327
0.07	0.0431	0.7905	0.42	0.1077	0.3612	0.77	0.1167	0.2303
0.08	0.0477	0.7666	0.43	0.1082	0.3555	0.78	0.1168	0.2279
0.09	0.0519	0.744	0.44	0.1088	0.3499	0.79	0.1169	0.2256
0.1	0.0559	0.7225	0.45	0.1092	0.3445	0.8	0.117	0.2234
0.11	0.0595	0.702	0.46	0.1097	0.3392	0.81	0.1171	0.2212
0.12	0.063	0.6826	0.47	0.1101	0.3341	0.82	0.1171	0.219
0.13	0.0662	0.664	0.48	0.1105	0.3292	0.83	0.1172	0.2169
0.14	0.0692	0.6464	0.49	0.1109	0.3243	0.84	0.1173	0.2148
0.15	0.072	0.6295	0.5	0.1113	0.3197	0.85	0.1174	0.2128
0.16	0.0746	0.6134	0.51	0.1117	0.3151	0.86	0.1174	0.2108
0.17	0.0771	0.5981	0.52	0.112	0.3107	0.87	0.1175	0.2088
0.18	0.0794	0.5834	0.53	0.1123	0.3064	0.88	0.1175	0.2069
0.19	0.0816	0.5693	0.54	0.1126	0.3023	0.89	0.1176	0.205
0.2	0.0836	0.5558	0.55	0.1129	0.2982	0.9	0.1176	0.2031
0.21	0.0855	0.5429	0.56	0.1132	0.2942	0.91	0.1177	0.2013
0.22	0.0873	0.5306	0.57	0.1134	0.2904	0.92	0.1177	0.1995
0.23	0.089	0.5187	0.58	0.1137	0.2866	0.93	0.1178	0.1978
0.24	0.0906	0.5073	0.59	0.1139	0.283	0.94	0.1178	0.196
0.25	0.0921	0.4964	0.6	0.1142	0.2794	0.95	0.1179	0.1943
0.26	0.0935	0.4859	0.61	0.1144	0.2759	0.96	0.1179	0.1927
0.27	0.0948	0.4758	0.62	0.1146	0.2726	0.97	0.1179	0.191
0.28	0.0961	0.4661	0.63	0.1148	0.2693	0.98	0.118	0.1894
0.29	0.0972	0.4567	0.64	0.115	0.266	0.99	0.118	0.1879
0.3	0.0983	0.4477	0.65	0.1151	0.2629	1	0.118	0.1863
0.31	0.0994	0.4391	0.66	0.1153	0.2598	1.01	0.1181	0.1848
0.32	0.1004	0.4307	0.67	0.1155	0.2568	1.02	0.1181	0.1833
0.33	0.1013	0.4226	0.68	0.1156	0.2539	1.03	0.1181	0.1818
0.34	0.1022	0.4148	0.69	0.1158	0.251	1.04	0.1182	0.1803


SPR Target Reference Points (Years Avg = 5)
Yield per Recruit
F (%SPR)
% SPR Target
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

SPR Target Reference Points (Years Avg = 5)

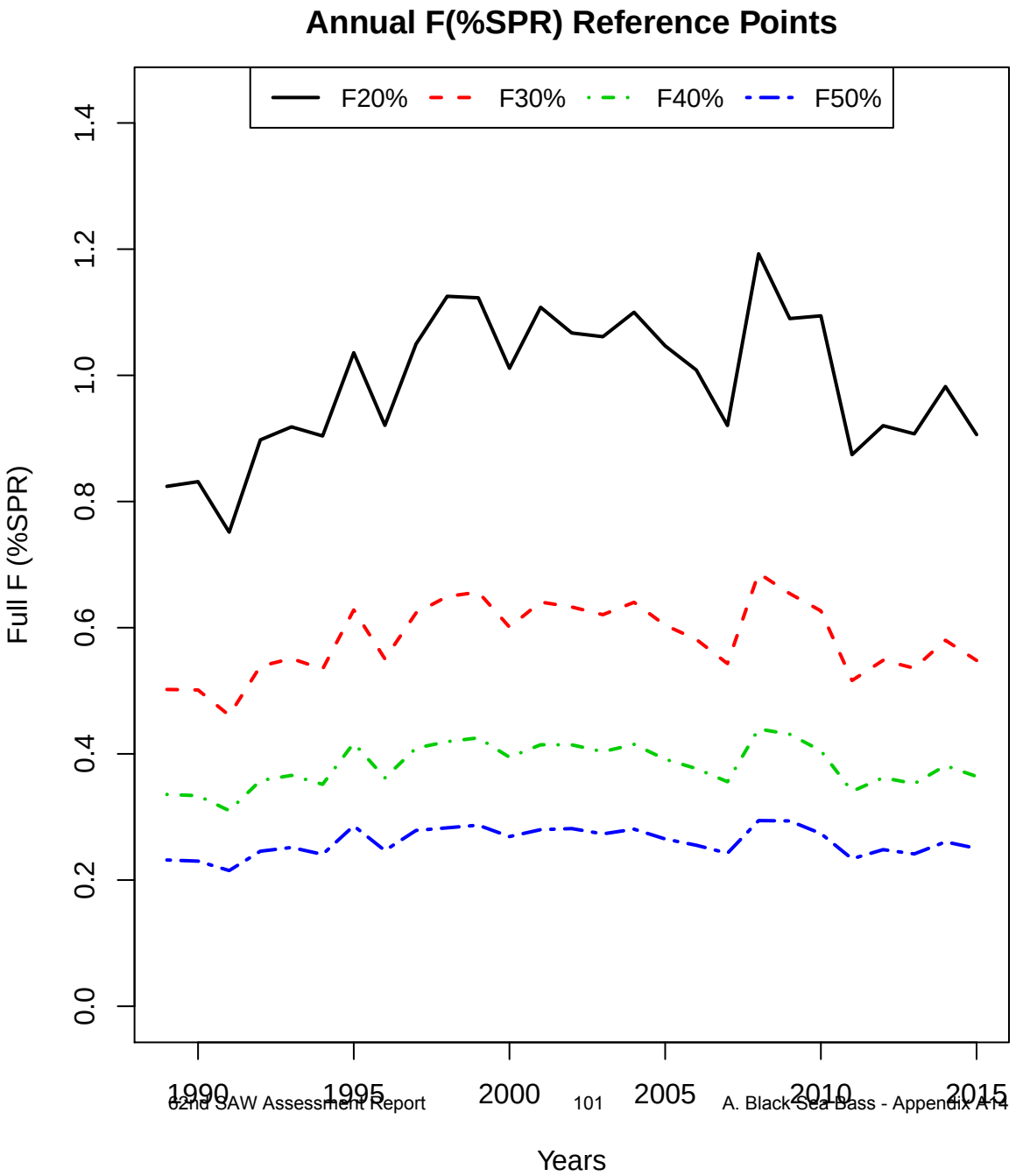
% SPR	F(%SPR)	YPR
0.2	0.9173	0.1177
0.25	0.6936	0.1158
0.3	0.5455	0.1128
0.35	0.4398	0.1087
0.4	0.3601	0.1038
0.45	0.2974	0.0981
0.5	0.2467	0.0916
0.55	0.2045	0.0845
0.6	0.1687	0.0768
0.65	0.1379	0.0686
0.7	0.111	0.0599
0.75	0.0873	0.0508
0.8	0.0662	0.0413

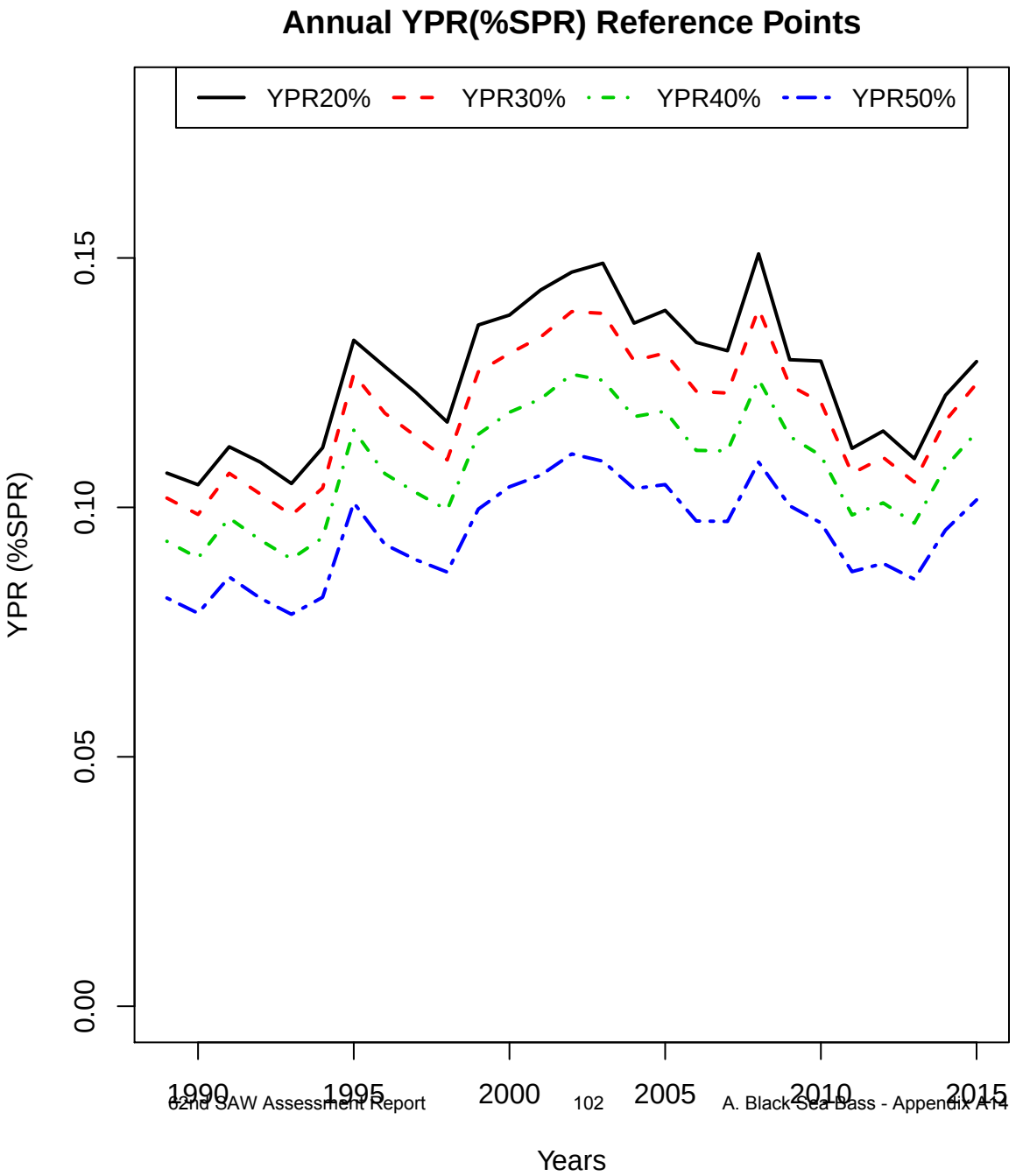

Maturity
Selectivity
Selectivity or Maturity at age
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
8
Age


Expected Spawnings and SPR Reference Points (Years Avg = 5)
Expected Spawnings
% SPR
Full F
0.0
0.5
1.0
1.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.0
0.5
1.0
1.5
2.0

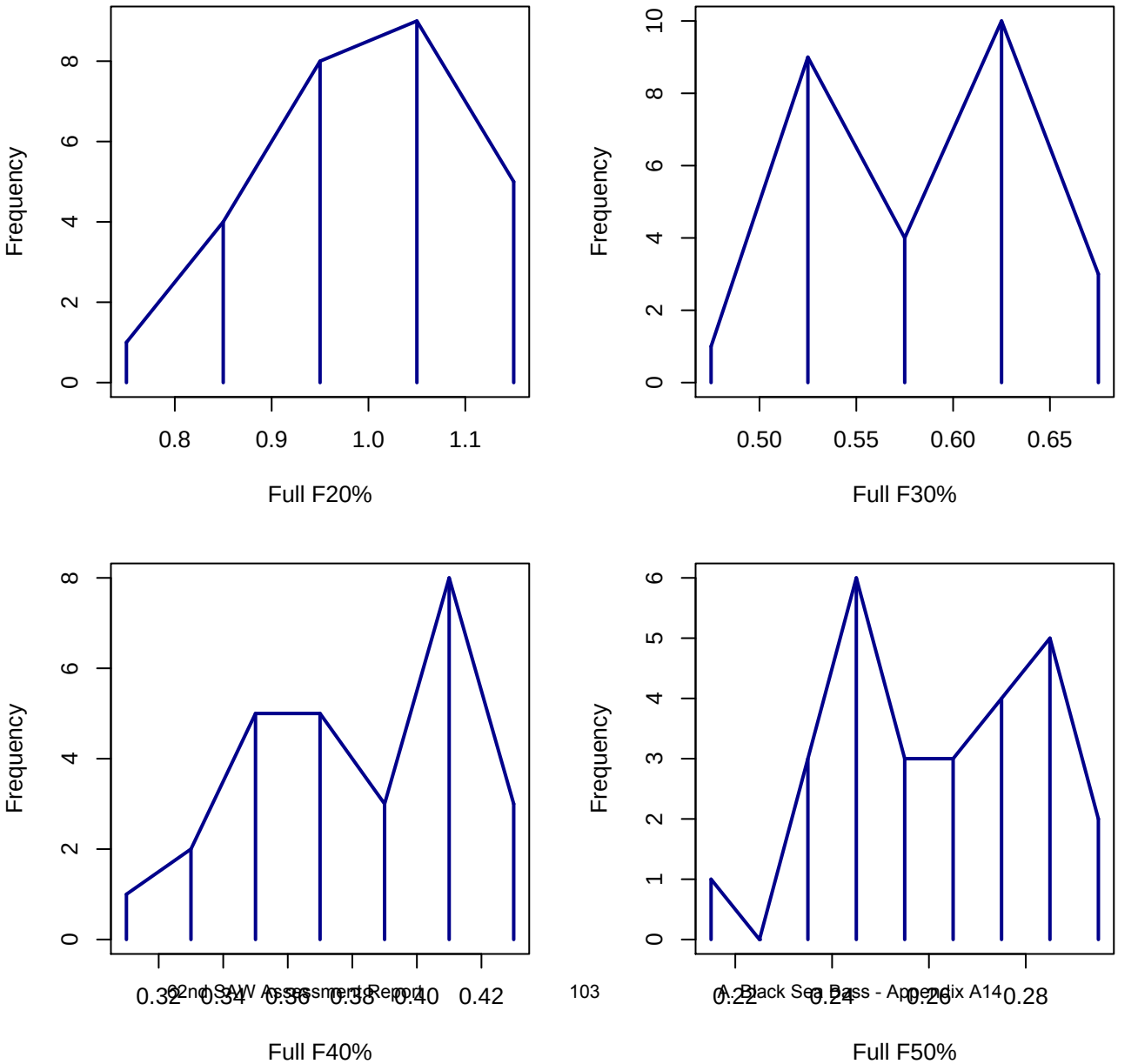
Expected Spawnings & SPR Reference Points (Years Avg = 5)

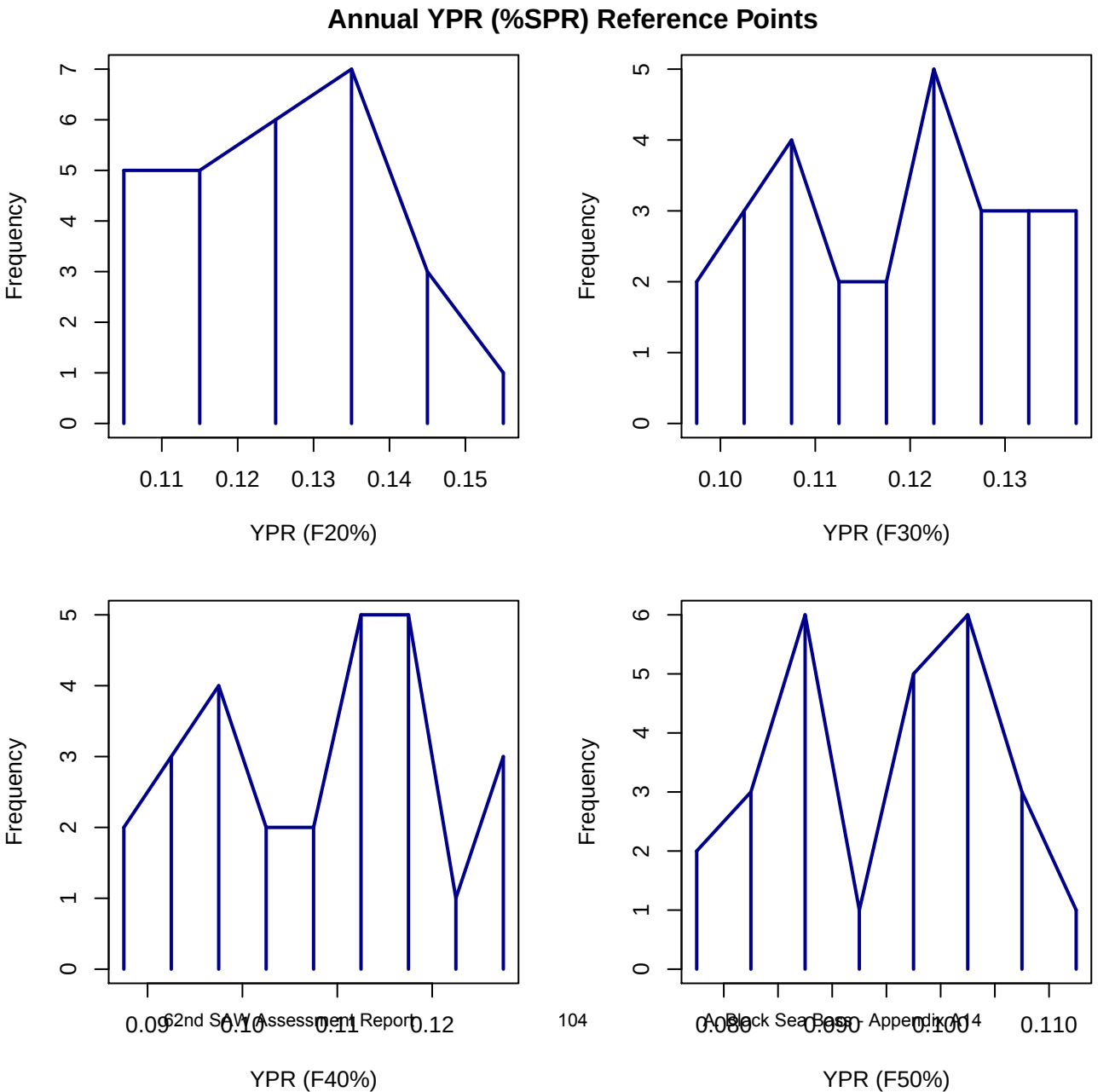
F	E[Sp]	SPR	F	E[Sp]	SPR	F	E[Sp]	SPR
0	1.3352	1	0.35	0.8245	0.4073	0.7	0.6194	0.2482
0.01	1.3094	0.9646	0.36	0.8163	0.4001	0.71	0.6152	0.2455
0.02	1.2848	0.9313	0.37	0.8084	0.393	0.72	0.6111	0.2428
0.03	1.2612	0.8999	0.38	0.8006	0.3863	0.73	0.607	0.2402
0.04	1.2387	0.8702	0.39	0.793	0.3797	0.74	0.603	0.2376
0.05	1.2171	0.8422	0.4	0.7856	0.3733	0.75	0.5991	0.2351
0.06	1.1964	0.8156	0.41	0.7784	0.3672	0.76	0.5952	0.2327
0.07	1.1765	0.7905	0.42	0.7713	0.3612	0.77	0.5914	0.2303
0.08	1.1575	0.7666	0.43	0.7643	0.3555	0.78	0.5876	0.2279
0.09	1.1391	0.744	0.44	0.7575	0.3499	0.79	0.5839	0.2256
0.1	1.1215	0.7225	0.45	0.7509	0.3445	0.8	0.5802	0.2234
0.11	1.1045	0.702	0.46	0.7443	0.3392	0.81	0.5766	0.2212
0.12	1.0881	0.6826	0.47	0.738	0.3341	0.82	0.573	0.219
0.13	1.0723	0.664	0.48	0.7317	0.3292	0.83	0.5695	0.2169
0.14	1.057	0.6464	0.49	0.7256	0.3243	0.84	0.566	0.2148
0.15	1.0422	0.6295	0.5	0.7195	0.3197	0.85	0.5626	0.2128
0.16	1.028	0.6134	0.51	0.7136	0.3151	0.86	0.5592	0.2108
0.17	1.0142	0.5981	0.52	0.7078	0.3107	0.87	0.5559	0.2088
0.18	1.0008	0.5834	0.53	0.7022	0.3064	0.88	0.5526	0.2069
0.19	0.9879	0.5693	0.54	0.6966	0.3023	0.89	0.5493	0.205
0.2	0.9754	0.5558	0.55	0.6911	0.2982	0.9	0.5461	0.2031
0.21	0.9632	0.5429	0.56	0.6857	0.2942	0.91	0.5429	0.2013
0.22	0.9514	0.5306	0.57	0.6804	0.2904	0.92	0.5398	0.1995
0.23	0.94	0.5187	0.58	0.6753	0.2866	0.93	0.5367	0.1978
0.24	0.9289	0.5073	0.59	0.6702	0.283	0.94	0.5337	0.196
0.25	0.918	0.4964	0.6	0.6652	0.2794	0.95	0.5307	0.1943
0.26	0.9075	0.4859	0.61	0.6602	0.2759	0.96	0.5277	0.1927
0.27	0.8973	0.4758	0.62	0.6554	0.2726	0.97	0.5247	0.191
0.28	0.8874	0.4661	0.63	0.6506	0.2693	0.98	0.5218	0.1894
0.29	0.8777	0.4567	0.64	0.6459	0.266	0.99	0.519	0.1879
0.3	0.8682	0.4477	0.65	0.6413	0.2629	1	0.5161	0.1863
0.31	0.859	0.4391	0.66	0.6368	0.2598	1.01	0.5133	0.1848
0.32	0.8501	0.4307	0.67	0.6324	0.2568	1.02	0.5105	0.1833
0.33	0.8413	0.4226	0.68	0.628	0.2539	1.03	0.5078	0.1818
0.34	0.8328	0.4148	0.69	0.6236	0.251	1.04	0.5051	0.1803

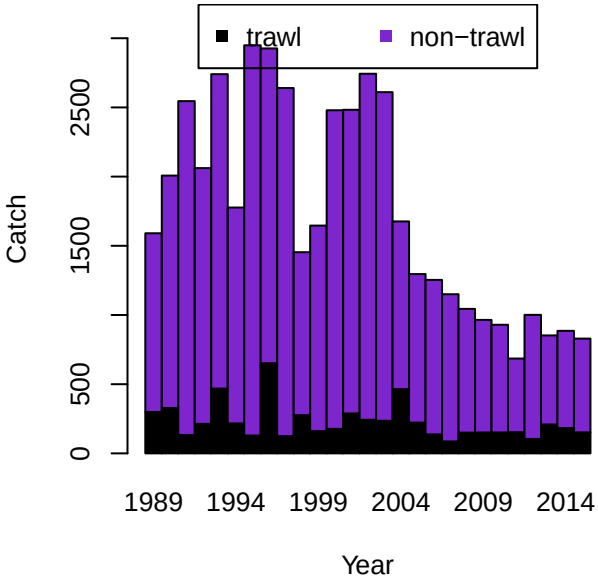

Annual F(%SPR) Reference Points
F20%
F30%
F40%
F50%
Full F (%SPR)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1990
1995
2000
2005
2010
2015
Years

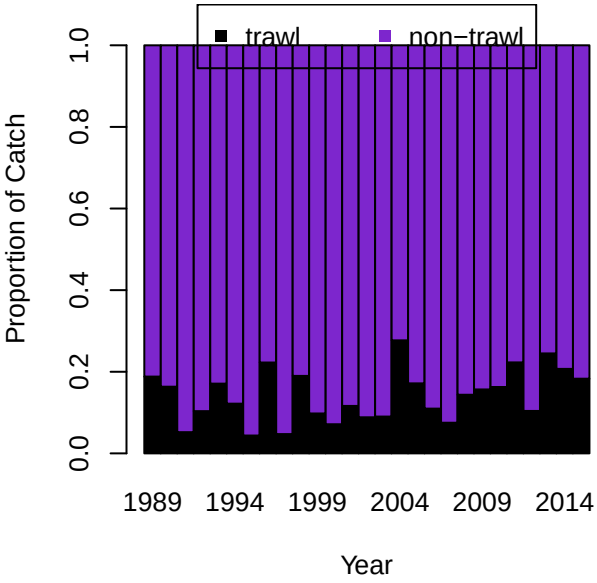

Annual YPR(%SPR) Reference Points
YPR20%
YPR30%
YPR40%
YPR50%
YPR (%SPR)
0.00
0.05
0.10
0.15
1990
1995
2000
2005
2010
2015
Years

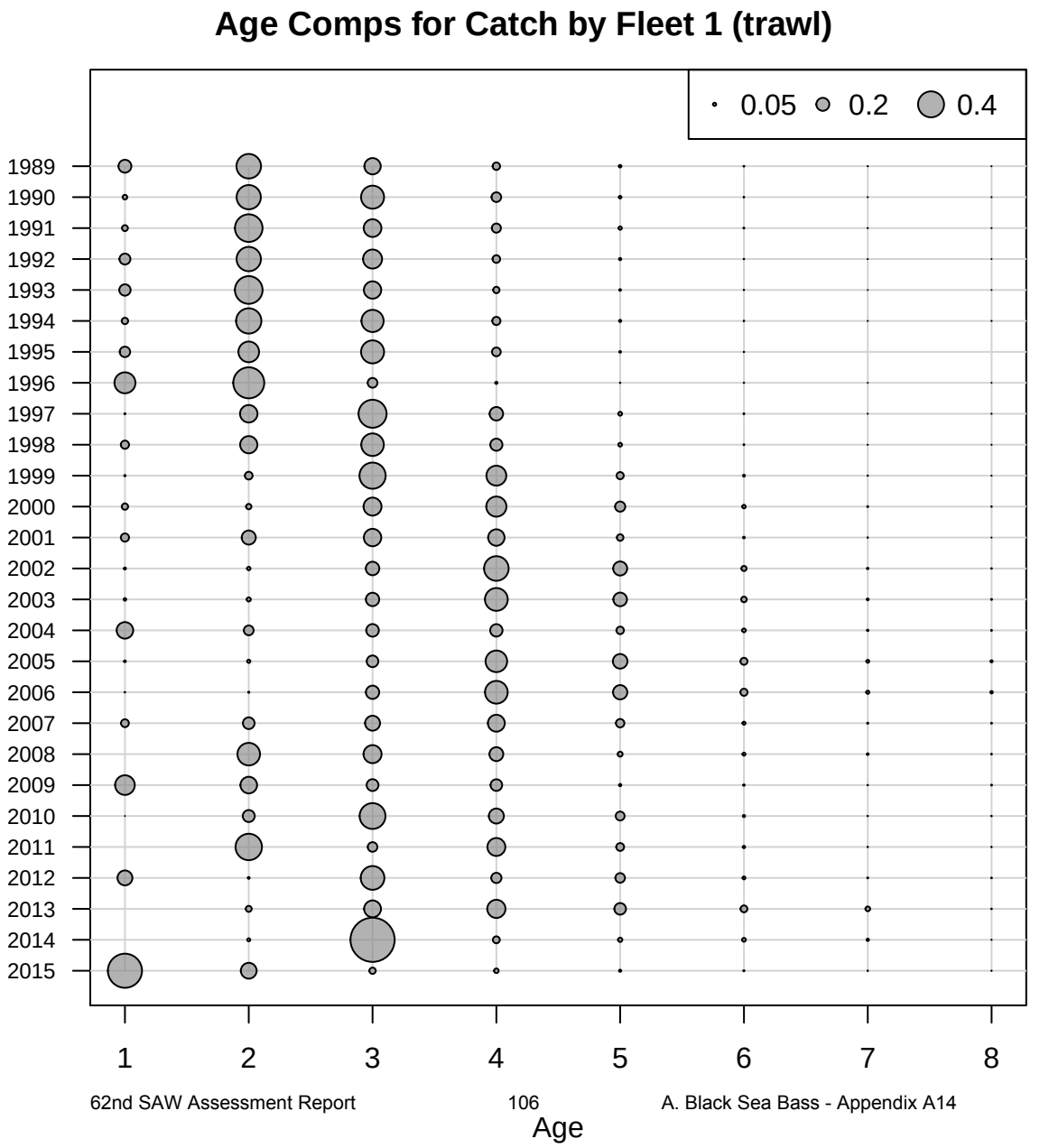
Annual F (%SPR) Reference Points



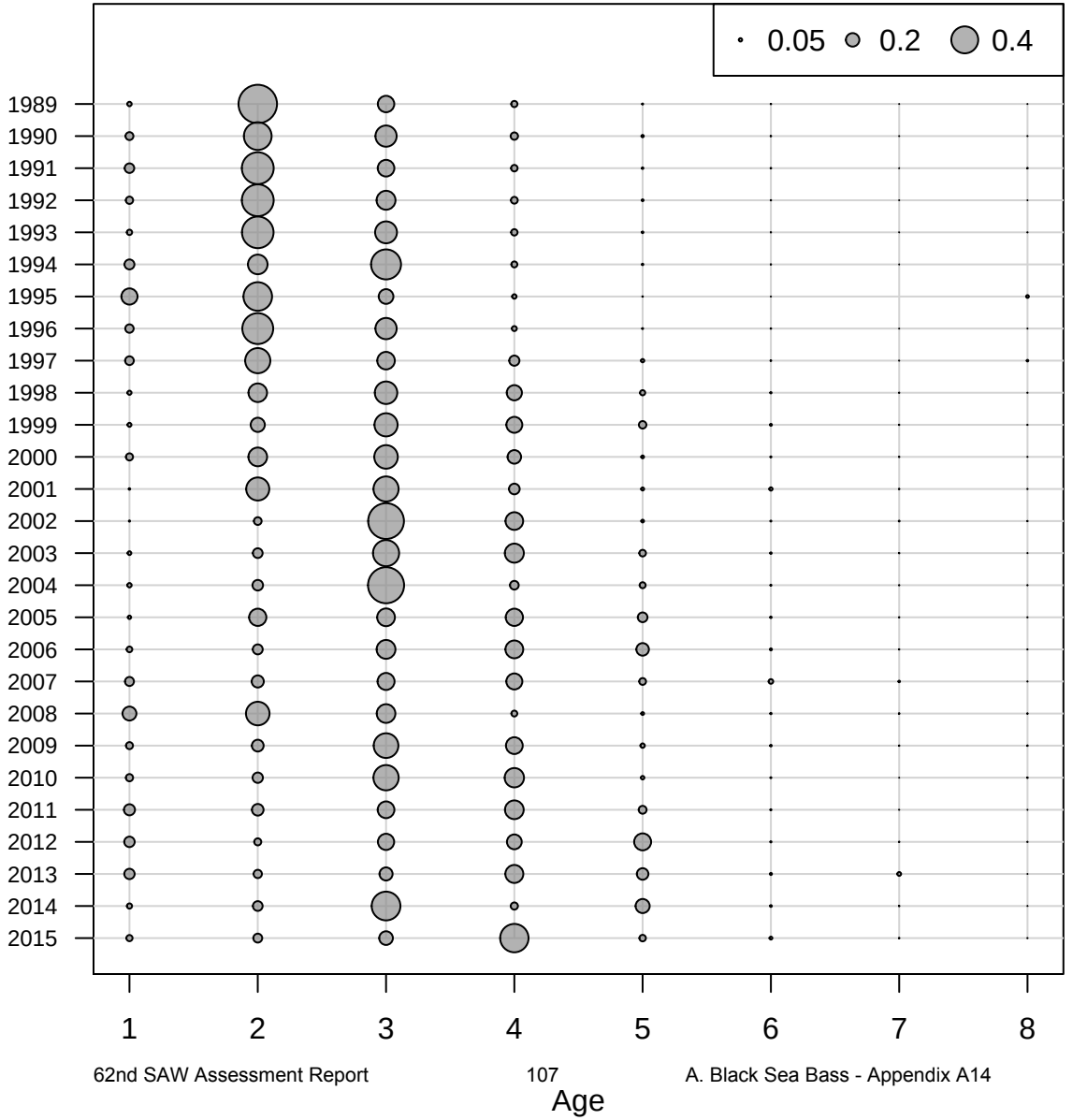

Annual YPR (%SPR) Reference Points
Frequency
YPR (F20%)
YPR (F30%)
YPR (F40%)
YPR (F50%)

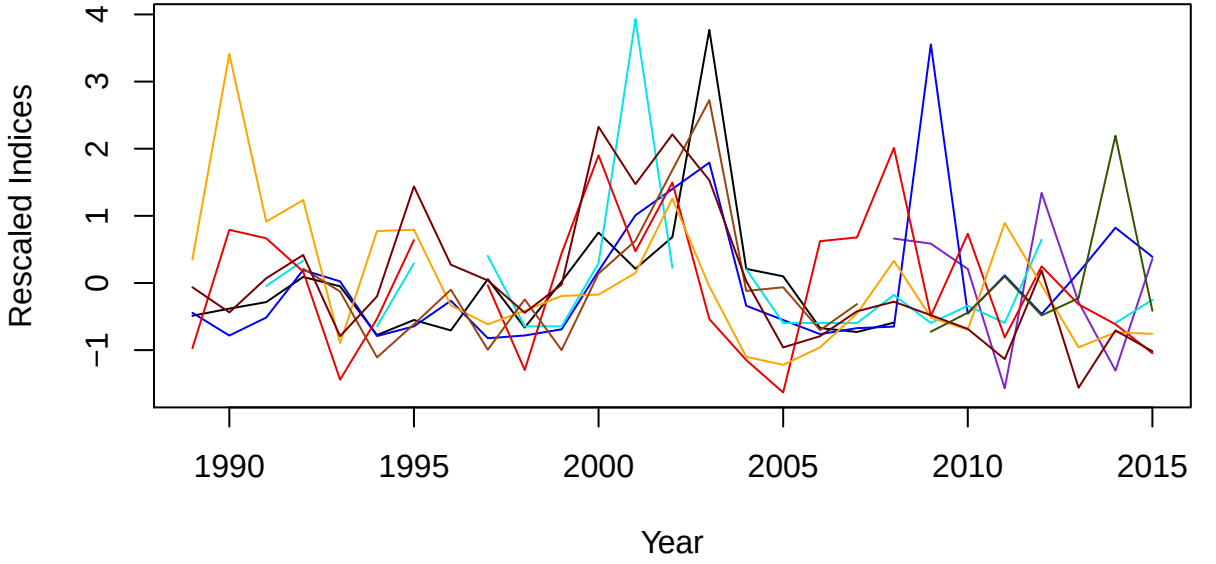

trawl
non−trawl
Catch
0
500
1500
2500
1989
1994
1999
2004
2009
2014
Year

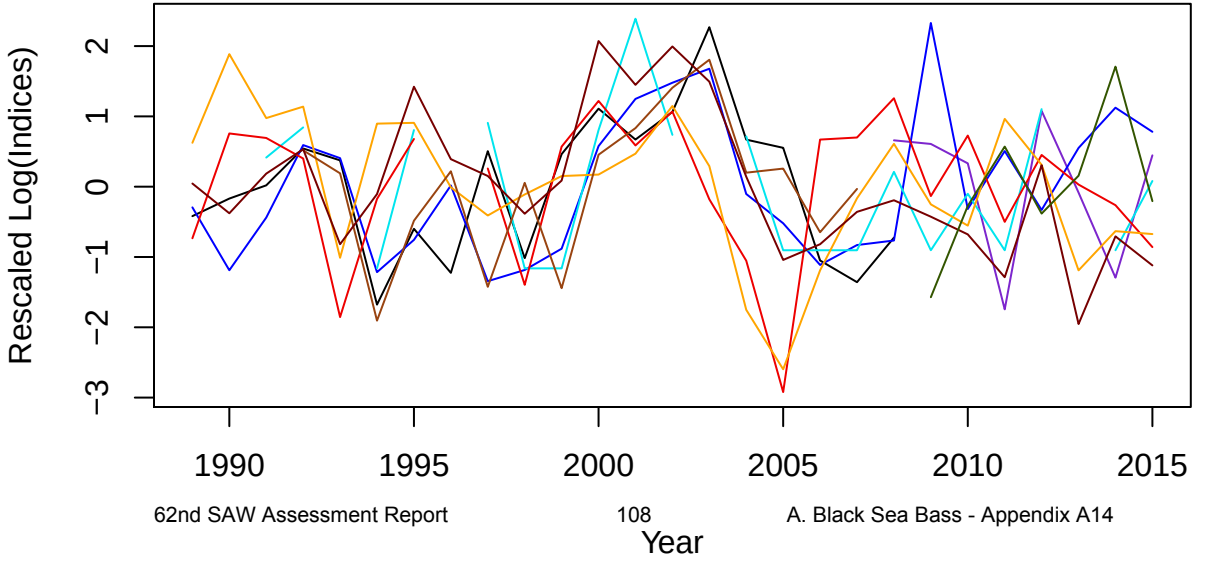

trawl
non−trawl
Proportion of Catch
0.0
0.2
0.4
0.6
0.8
1.0
1989
1994
1999
2004
2009
2014
Year

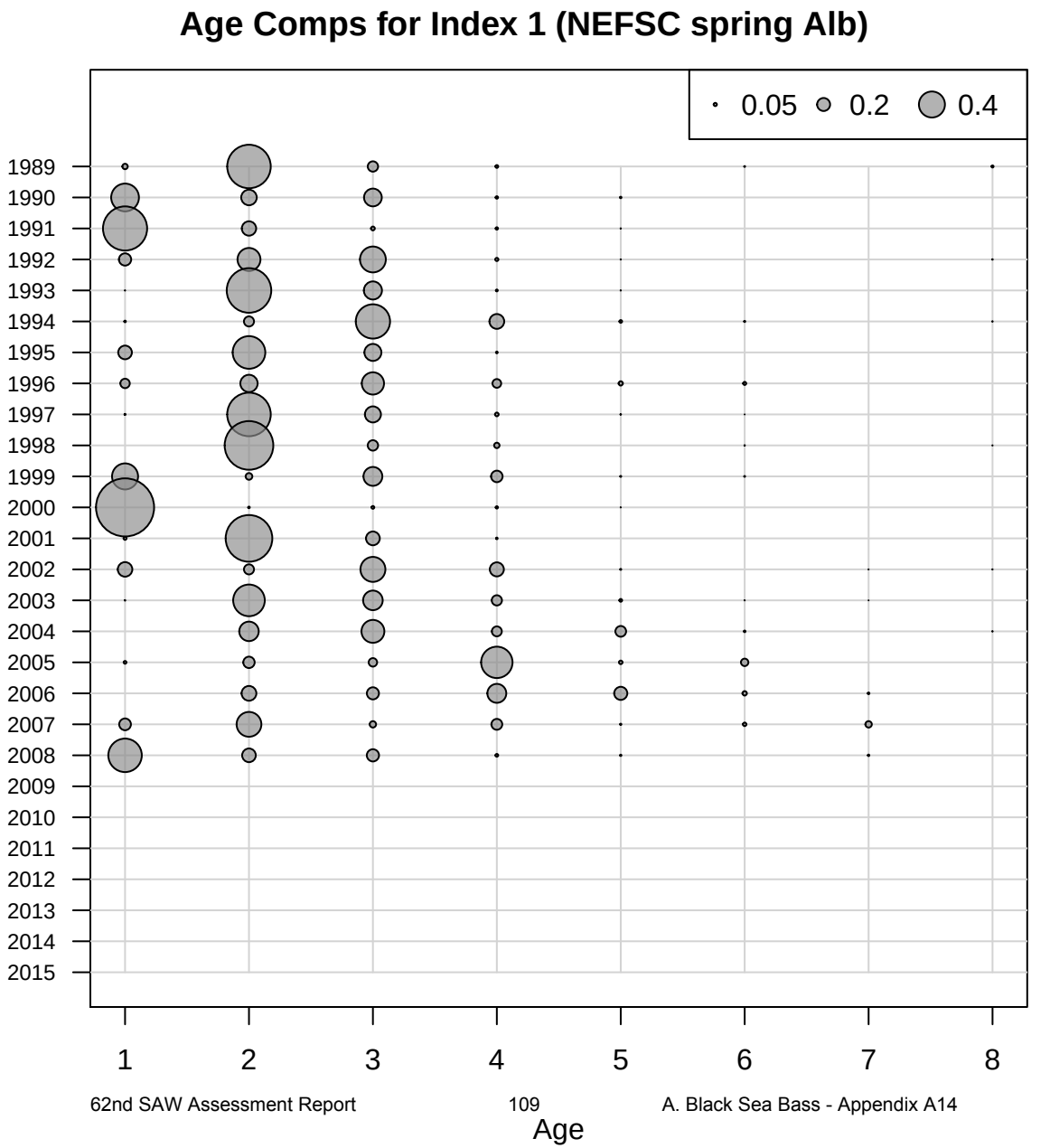

Age Comps for Catch by Fleet 1 (trawl)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

Age Comps for Catch by Fleet 2 (non−trawl)

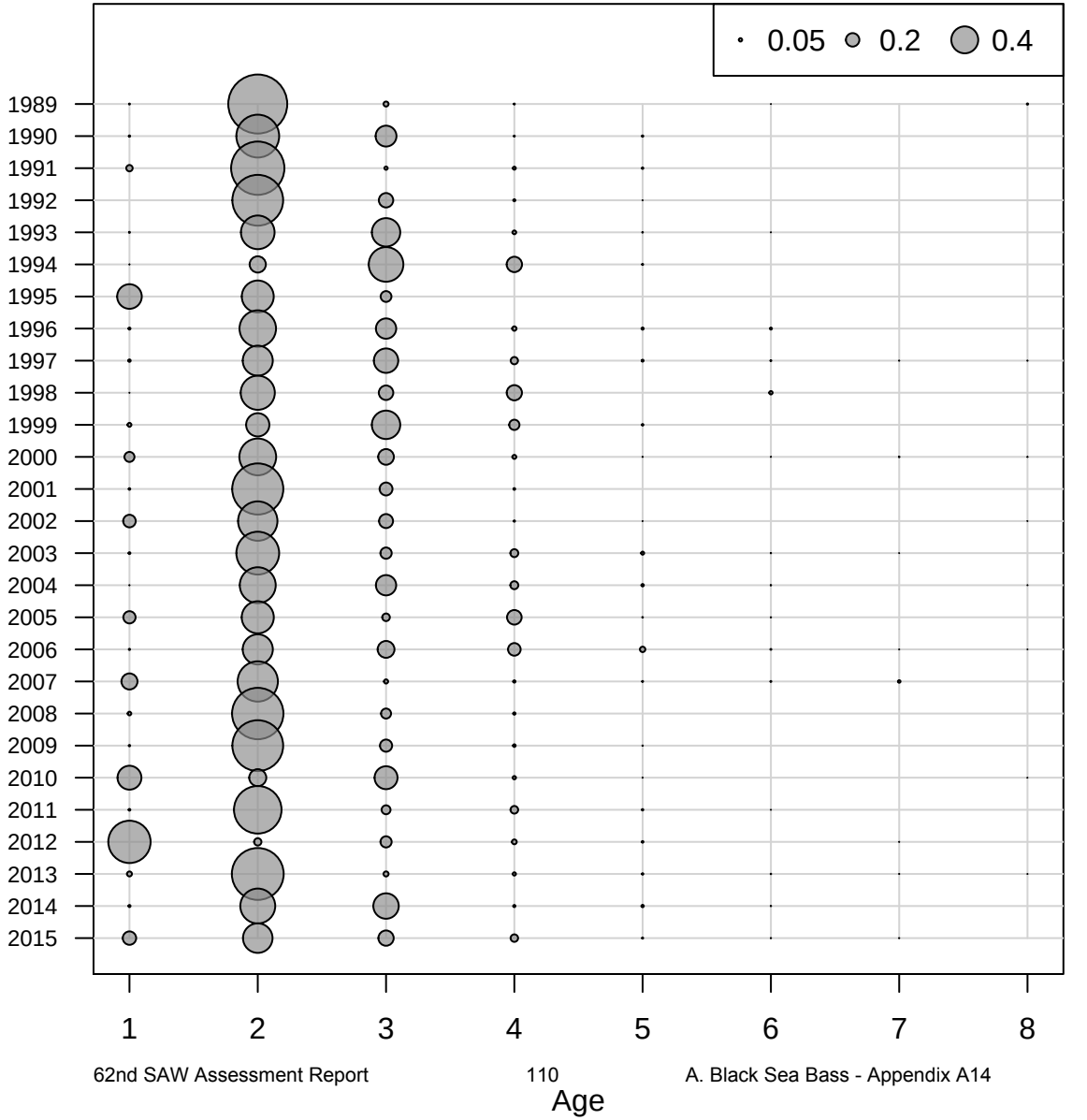


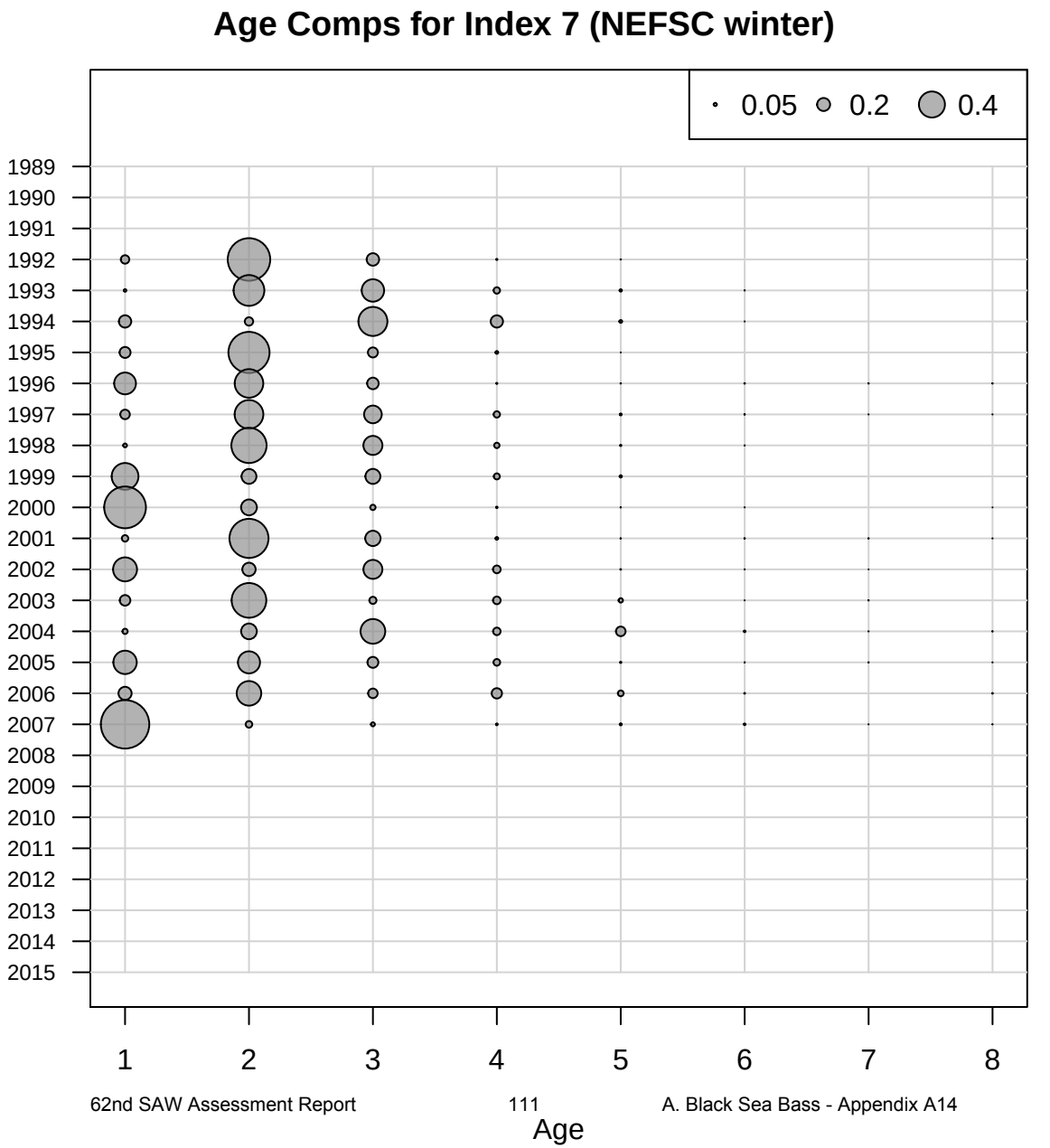

Rescaled Indices
4
3
2
1
0
−1
1990
1995
2000
2005
2010
2015
Year


Rescaled Log(Indices)
2
1
0
−1
−2
−3
1990
1995
2000
2005
2010
2015
Year

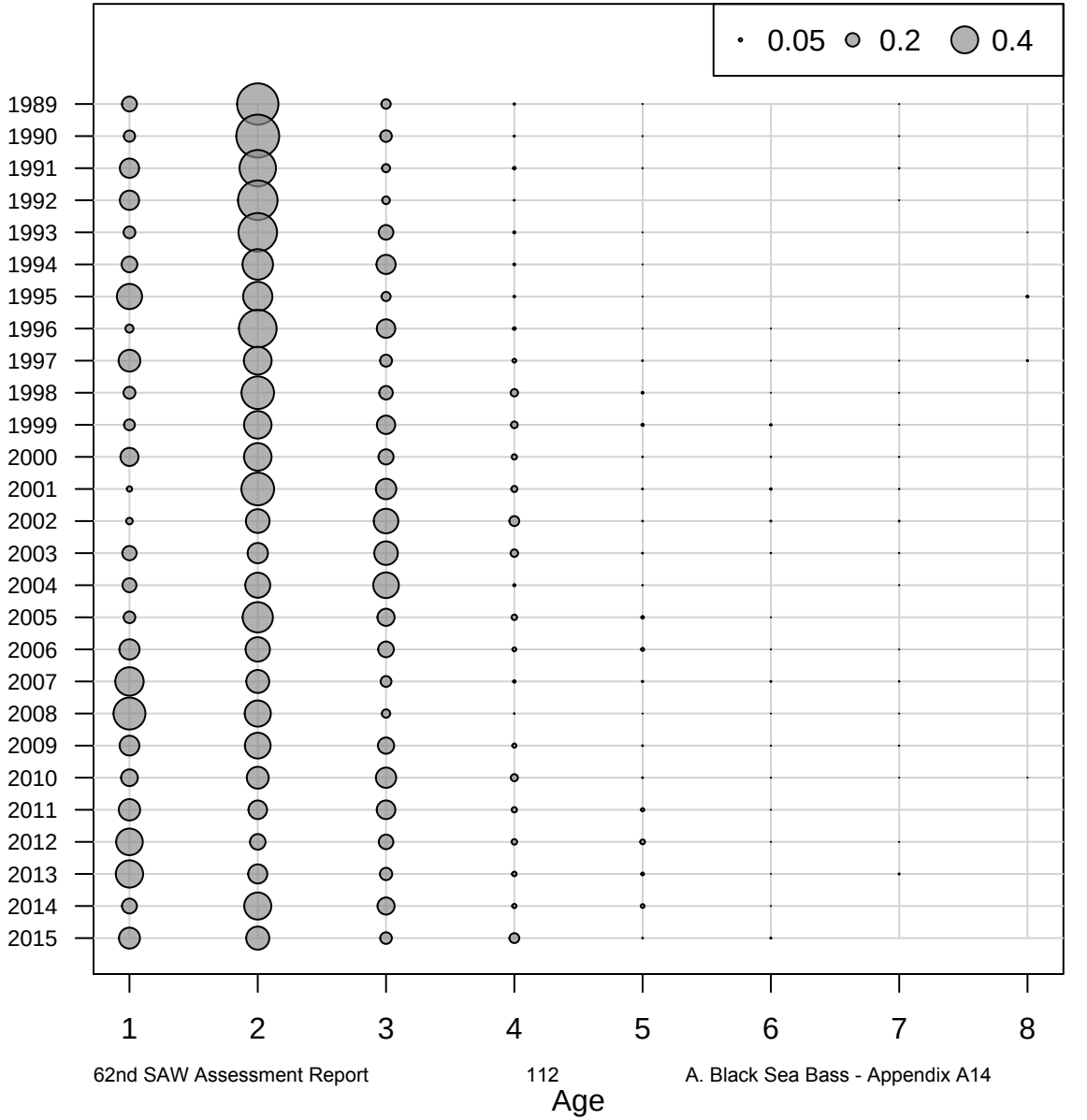

Age Comps for Index 1 (NEFSC spring Alb)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

Age Comps for Index 3 (MADMF)

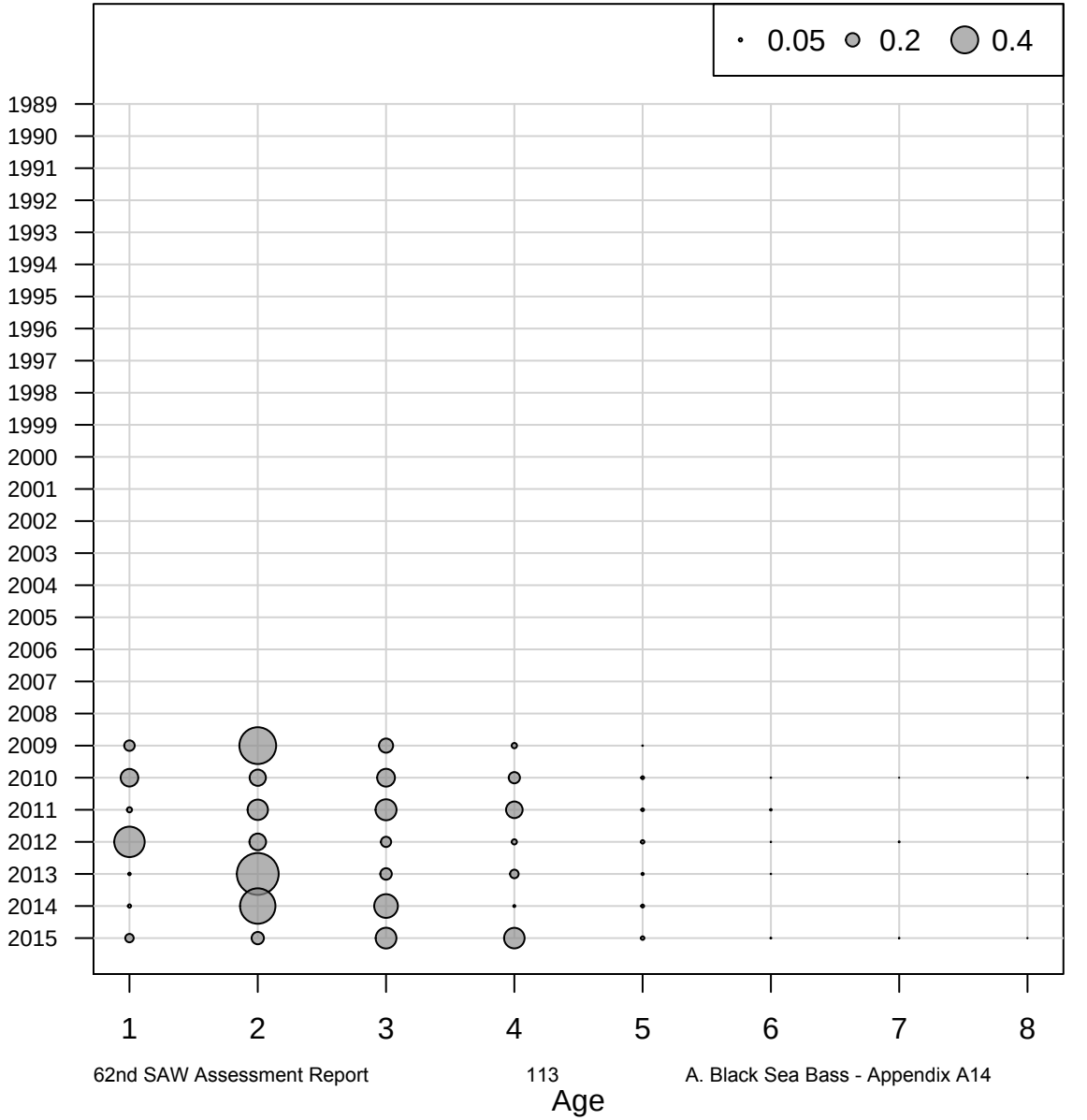


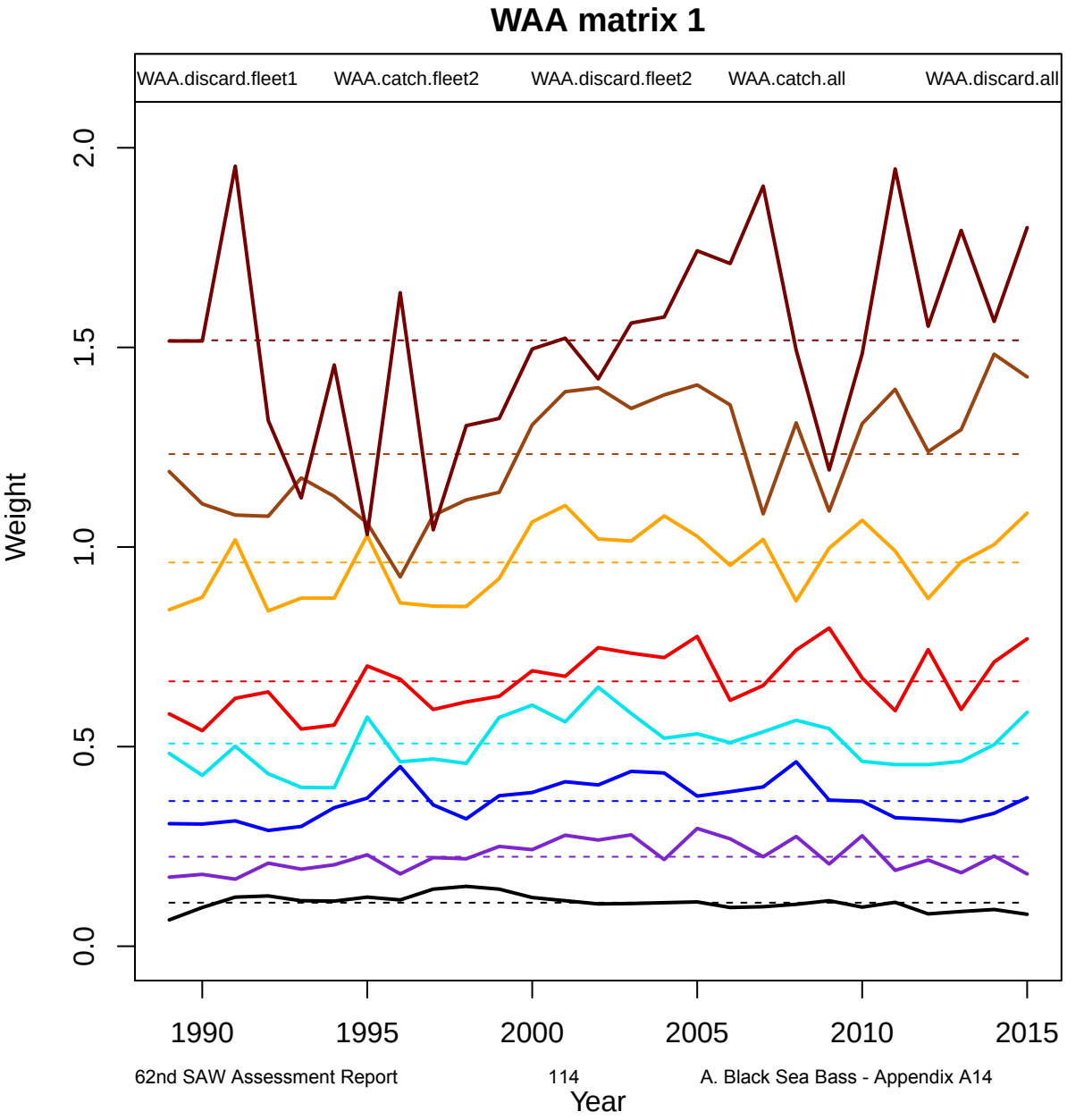

Age Comps for Index 7 (NEFSC winter)
0.05
0.2
0.4
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
1
2
3
4
5
6
7
8
Age

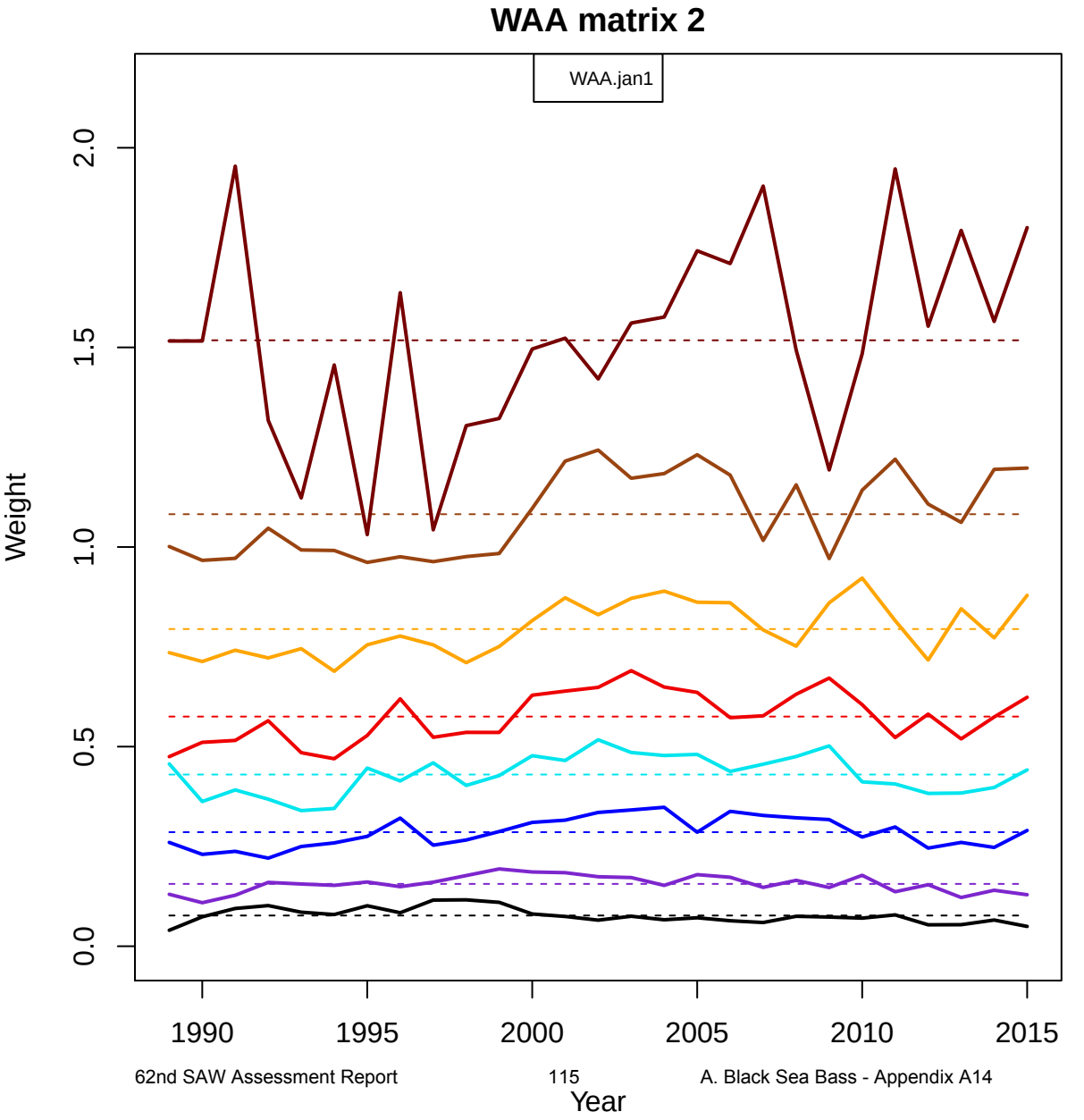
Age Comps for Index 8 (REC CPA)

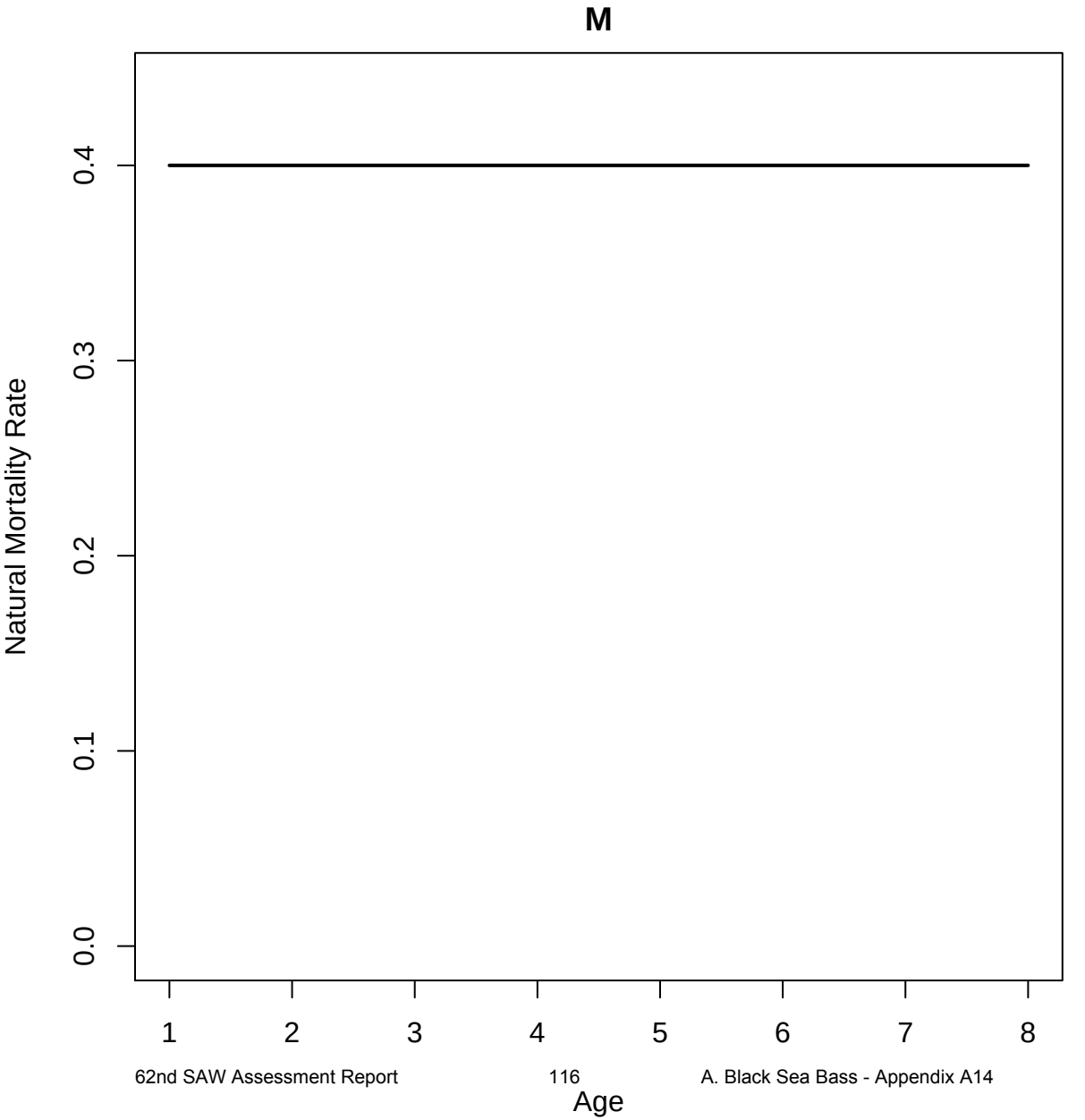


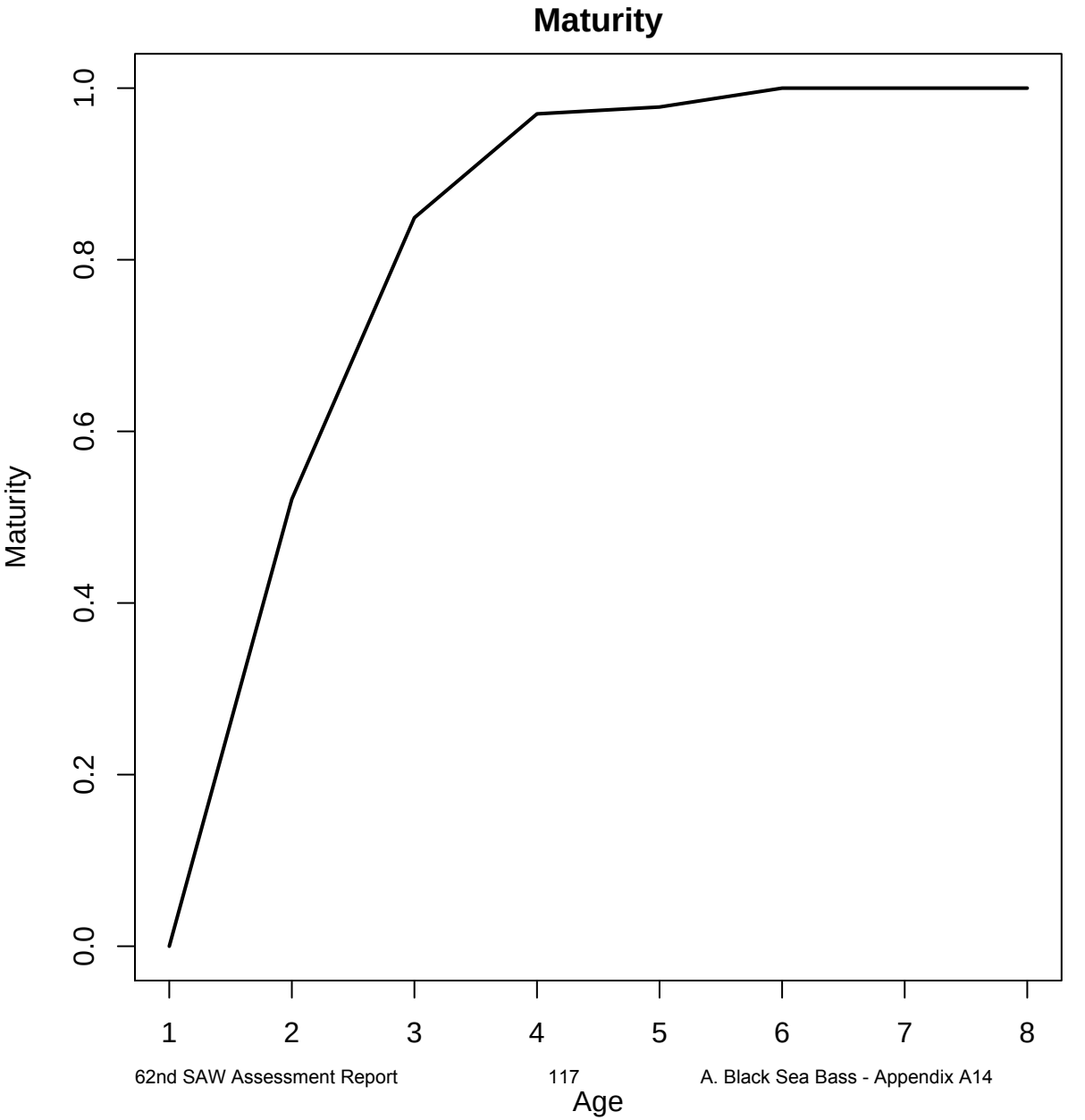
Age Comps for Index 9 (BIGELOW)




WAA matrix 1
WAA.discard.fleet1
WAA.catch.fleet2
WAA.discard.fleet2
WAA.catch.all
WAA.discard.all
Weight
0.0
0.5
1.0
1.5
2.0
1990
1995
2000
2005
2010
2015
Year


WAA matrix 2
WAA.jan1
Weight
0.0
0.5
1.0
1.5
2.0
1990
1995
2000
2005
2010
2015
Year


M
Natural Mortality Rate
0.0
0.1
0.2
0.3
0.4
1
2
3
4
5
6
7
8
Age


Maturity
Maturity
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
8
Age