Appendix A5: Preliminary stock synthesis models for surfclams.

This appendix presents a preliminary evaluation of the Stock Synthesis Model (Version 3) for potential use in surfclam assessments. These materials are not to be used by managers in making decisions about the surfclam resource because the data and model are preliminary and may contain errors.

Although the KLAMZ model has performed well in recent assessments, it will not be used as the primary model in the next assessment due to expected changes in survey data. Further testing is required but the Invertebrate Subcommittee plans to replace KLAMZ with the Stock Synthesis model (Version 3). SS3 makes better use of available age and length data, is more flexible and better accommodates regional differences in biological parameters and surveys. A wider range of potential biological reference points are available with SS3. Moreover, SS3 can be configured to resemble the current KLAMZ model if required.

As shown below, biomass and exploitation rate estimates from SS3 and KLAMZ were similar when the two models were configured in approximately the same way with approximately the same data and number of parameters. Recruitment estimates from SS3 were more variable and probably more realistic than recruitment estimates from KLAMZ. The two models use measured fishing mortality using different metrics. The two mortality metrics were similar in trend but different in magnitude. Therefore, fishing mortality rates from the two models should not be compared. Simple exploitation rates (catch/biomass) from the SS3 and KLAMZ models are comparable and were quite similar.

Background

The current stock assessment model for surfclams and ocean quahogs (KLAMZ) is relatively simple, has proven stable, shows little or no retrospective patterns and projections from previous assessments have been similar to updated biomass estimates. However, it will be difficult to use in the next assessment if the current triennial synoptic NEFSC clam survey is replaced, as expected, with a cooperative clam survey using an industry vessel that would cover 1/3 of the stock each year. Anticipating these developments, the Invertebrate Subcommittee is developing a Stock Synthesis model (SS3) for surfclams. The most important potential benefits in using SS3 for surfclams stem from the ability to model regions independently using separate data streams and assuming different biological properties (growth, natural mortality, etc.).

The cooperative survey using a commercial vessel is expected to start in 2010 and will cover 1/3 of the stock each year. If a stock assessment were done in 2013, after cooperative surveys during 2010, 2011 and 2012, then the three regions will have survey data collected during different years and it would be difficult to combine the survey results to obtain a single index for the entire stock in a single year. It is possible, however, to use SS3 to estimate biomass for the area surveyed in 2010 based on survey and fishery data up to 2010, and project stock biomass forward based on fishery data up to 2012 precisely enough for use by managers (and so on for other regions). The estimation and projection calculations for each region would be carried out in a single model run. Whole stock biomass estimates for the terminal year, for example, would amount to the sum of the estimated and projected values for each region. The bookkeeping involved in combining regional estimates is handled automatically in SS3 and it is possible to use data for the whole stock, in addition to regional data. The community of users for SS3 is large relative to most other stock assessment models and a

variety of related tools (e.g. for graphical display of assessment results) are available and constantly being updated. In contrast, the KLAMZ model has a small pool of users and fewer available tools.

It would be possible but impractical to estimate stock biomass in 2012 by running three KLAMZ model runs for the three regions and using regional survey data. Whole stock biomass estimates could be produced for 2012 as in SS3 (by combining projection results and estimates from the regional models for each region). However, a substantial amount of programming effort would be required to avoid manual (and error prone) calculations, variance estimates might become unwieldy, and there are a number of potential sources of error to content with. SS3, in contrast, is widely used, well tested, appears suitable and is generally modified quickly when a user needs an additional feature.

Like all models (including SS3), KLAMZ has a number of shortcomings related to use of available data, realism of biological assumptions, and circumstances in the fishery. In particular, KLAMZ does not make full use of all the available shell length or age data from surveys or shell length data from the fishery, which contain useful information about recruitment. KLAMZ assumes knife edge selection (fish of the same age or size recruit to the fishery and the model at the beginning of the year). In reality, surfclams begin to recruit to the commercial fishery at roughly 10 cm and are almost fully recruited at about 15 cm, with variability among regions and over time. KLAMZ assumes that all individuals are the same size at each age even though growth data show considerable variability in size among surfclams of the same size. KLAMZ is divided up into two "age" groups (new and old recruits) with the latter representing survivors from previous years. In KLAMZ all of the old recruits have the same survey selectivity, even though the actual survey selectivity pattern is dome shaped for surfclams. KLAMZ is mathematically identical to an age structured model with knife edge recruitment and von Bertalanffy growth. It is expressed in terms of a single equation that is opaque and not easy to understand. Age structure details are implicit in the model but not available to the user. An age based model with conventional bookkeeping (numbers at age in each year) would be more useful to constituents. The KLAMZ model can be approximated in SS3, which is a very general modeling approach.

Methods

To facilitate comparison of results, the SS3 model was configured in a manner similar to the current KLAMZ model for comparison of results. Due to time limitations, the preliminary model described in this appendix does not make use of regional modeling features in SS3.

Model configuration

The entire stock of surfclams (age groups 0-40+ y) during 1965-2008 was modeled in SS3 as one sex in a single region. In contrast, the KLAMZ model (one sex and one region) was for the stock of surfclams 120+ mm SL (approximately age 5-7 y). Sexual dimorphism is not thought important for surfclams, although SS3 can model male and female dynamics after recruitment independently. The basecase KLAMZ model in this assessment was for 1982-2008 but it was rerun starting in 1965 for comparison to SS3 estimates in this appendix. As stated above, the KLAMZ model starting in 1965 is preliminary, for comparative purposes only and not for use by managers.

The SS3 model assumed a Beverton-Holt spawner-recruit relationship with the steepness parameter fixed at 0.95. In effect, the SS3 model assumed that recruitments were randomly distributed around a constant mean. Mean recruitment, recruit variance and annual deviations in recruitment were parameters estimated in the model. The KLAMZ model used an auto correlated random walk recruitment model with a specified variance for annual changes in recruitment.

The SS3 model for surfclam estimates initial age composition and abundance based on recruitment and a user supplied estimate of average historical catch (an equilibrium approach). Equilibrium estimates for young age groups in the first year can be replaced with direct estimates to the extent that age, size and other data contain information about recruitment prior to the first year in the model. For surfclams, the average catch during 1965-1969 (12,802 mt per year) was used as the historical catch level and the first year with an estimated recruitment parameter was 1975. The KLAMZ model estimates a parameter that defines the initial age structure (given other parameters, data and assumptions in the model) without making an equilibrium assumption.

The last year with an estimated recruitment pattern in the SS3 model was 2004 and average recruitment was assumed for 2005-2009. The data were insufficient to estimate recruitments during the latter period, probably because GBK was not sampled during the 2005 survey and survey age and length data for 2005 were not available for the stock as a whole.

SS3 assumed a single von Bertalanffy curve for growth in length and a single shell length-meat weight (SLMW) relationship. Due to time limitations, temporal variation in growth and SLMW parameters were ignored and relationships for different regions were combined using relatively crude procedures (e.g. by pooling all of the data). The KLAMZ model used time varying von Bertalanffy curves for growth in meat weight, which were carefully adjusted for the regional differences in growth and SHMW.

Variation in size at age is important in interpretation of shell length data, modeling mortality and in other SS3 calculations. The SS3 model for surfclams assumed variability in size at age with a constant CV at ages 0-1 y and a different constant CV at ages 30+ y. CVs for ages 1-36 y were interpolated. Survey age data show that CVs for shell length decline with age (Figure A5-1). Based on a regression model ($C_A = 0.1932 - 0.004190A$, where C_A is the CV at age A), the CV for size at age 1 was 0.189 and the CV for size age 30 was 0.0655. These estimates were used as initial parameter values in the SS3 model.

Surfclam survey age data were assumed to be unbiased and relatively precise in SS3 (Table A5-1 and Figure A5-1). One age reader carried out repeat age reading experiments to measure ageing precision following the 2005, 2007 and 2009 surveys. The total sample size (number of chondrophore sections read twice) was N=850. The best age for each chondrophore was the average of the two age readings and the data were binned by best age. Sample size declined with age but there were at least 10 chondrophores for most ages between 2 and 24 y (Figure A5-1). Exploratory analysis showed a slight but clear tendency for the standard deviation of age readings to increase with age (Figure A5-1). There were some young and old age groups with standard deviations of zero, although the sample size was usually less than 10 in these cases. A robust linear regression model was fit to the estimates for each age after excluding the zero cases ($S_A = 0.2919 + 0.0102A$, where S_A is the standard deviation for age A). Predicted values from the model were used as estimates of ageing precision for SS3 modeling. This procedure may bias estimates of ageing precision because ages with no

ageing imprecision in the experimental data were omitted. The KLAMZ model for surfclams does not require estimates of ageing precision because age data are not used.

Based on previous assessments, SS3 model runs assumed that 50% of age zero and 100% of older individuals were sexually mature. Common biological reference points based on egg production or mature spawning biomass are calculated in SS3 but not useful for surfclam at this time because of uncertainty about maturity and egg production as a function of shell length. The KLAMZ model does not estimate spawning biomass or related reference points so no assumptions about maturity are necessary.

SS3 was configured to estimate a one logistic size-selectivity curve for the commercial fishery during all years. The KLAMZ model assumes implicitly that all surfclams in the model are fully selected by the fishery. Age based fishery selectivity estimates were not required in SS3 because there were no age data available from the fishery.

Size- and age based selectivity curves were required in the SS3 model for surfclam because both shell length and age composition data are available from the NEFSC clam survey. The dome shaped size selectivity pattern for surfclams in NEFSC clam surveys was parameterized as the double normal selectivity function recommended for use in SS3 (Figure A5-2). An age based selectivity pattern for surfclams was estimated by converting shell lengths (0 to 160 mm in steps of 5 mm) to predicted ages based on the inverted von Bertalanffy growth curve. Selectivity was assumed to be zero at age zero. This resulted is an age based survey selectivity curve that was equivalent to the size based curve, but the ages were not integers. Selectivity values at integer ages 0-30 y were calculated by interpolation. Selectivity at 30-40 y was assumed constant. The result was a dome shaped curve with a right hand limb that declined starting at about age 9 y (Figure A5-2). Survey selectivity parameters were difficult to estimate for surfclam in SS3 so the size- and age based survey selectivity curves were fixed (not estimated) in the SS3 model. This is a topic for future research.

The SS3 model used Pope's approximation to calculate fishing mortality in order to speed up calculations. KLAMZ solves the catch equation exactly. However, at typical surfclam fishing mortality rates ($F < 0.05$), the approximation in SS3 is accurate.

Data

Data used in SS3 included commercial catch weights (landings plus discard with incidental mortality assumed to be 15% of landings).[20] Landings were assumed to be accurate in both models. NEFSC clam survey trends in abundance (mean numbers per tow for surfclams 30+ mm SL) were for all surveys during 1982-2008 without adjustment for survey dredge selectivity.[21] The KLAMZ model used survey biomass trends (mean kg per tow, adjusted for survey dredge selectivity prior to modeling) for surfclams 120+

[20] We initially modeled landings and stock abundance in SS3 as bushels (the units in which landings are reported). Later runs used meat weights instead to enhance comparison to KLAMZ model results and because predicted values for catch meat weight in SS3 account for the size of clams taken in the fishery (a bushel of large clams contains fewer individuals and represents less mortality than a bushel of small clams). The conversion from bushels to meat weight is based on a single crude conversion coefficient so bushels and meat weight of catch are proportional. This is an area for additional research. Additional port sampling to characterize annual mean numbers of surfclams per bushel may be desirable.

[21] Survey indices for all years with survey include holes (strata not sampled in some surveys) that are filled by borrowing from adjacent surveys (Table A8). Borrowing (or imputation of missing data) will be almost unnecessary when SS3 models are broken into regions because survey data for region/year combinations with substantial missing data will be simply omitted from the regional SS3 model.

SL to track trends in the stock as a whole and biomass trends for surfclams 120-128 mm SL as an index of recruitment. Both models assumed lognormal errors in survey trend data and both models used stratified random CVs in calculating the log likelihood. However, in SS3 the CV were "tuned" based on preliminary runs so that adjusted CVs and CVs implied by goodness of fit were similar.

Data for SS3 included efficiency corrected swept area survey abundance estimates (without adjustments for survey selectivity) for surfclams 30+ mm SL during 1997-2008, which are roughly analogous to the efficiency corrected swept area biomass estimates (adjusted for survey selectivity) for surfclams 120+ mm SL used in the KLAMZ model. The size selectivity pattern used in the SS3 model for efficiency corrected swept area abundance was the same as for NEFSC survey trend data. The data used in SS3 were not adjusted for selectivity *a priori* because the calculation is done in the model. SS3 used swept area abundance instead of biomass because the original survey data were collected in units of abundance and because the conversion from numbers at size to biomass is handled in the model.

The KLAMZ model for surfclams used swept area biomass data to estimate trend but not scale (the overall magnitude of stock biomass) to avoid "double dipping" (survey trend data for in the model for 1997-2005 is also used in calculating swept area biomass). Swept-area abundance data were used to estimate trends in SS3 because it was not possible to clearly separate the two types of information. In preliminary SS3 models, the likelihood weight for swept area biomass trends was reduced substantially but this approach seemed to degrade estimation of the catchability parameter for swept area abundance, which provides crucial information about scale (the overall biomass level).

SS3 was configured to use prior information about the catchability coefficient for efficiency corrected swept area abundance in a manner similar to the way KLAMZ uses prior information about the catchability coefficient for efficiency corrected swept area biomass. The prior information is important in scaling biomass estimates from both models. Unfortunately, selectivity and catchability are confounded to some extent in selectivity and capture efficiency estimates for surfclams. Based on estimates in this assessment, survey capture efficiency e=0.256 for surfclams 150+ mm SL. Size selectivity ranges 0.74 to 0.43 for surfclams 150 to 179 mm SL and is constant for larger sizes (Figure A5-3 and see below). For lack of a better approach, the average size selectivity for surfclams 150+ mm was assumed to be about 0.523 (the simple average of the selectivity values in the table below). Based on this assumption, capture efficiency for fully selected size groups in the NEFSC survey should be about 0.256/0.523=0.489. The efficiency corrected swept area abundance estimates used as data in the SS3 model were therefore calculated without adjustment for selectivity assuming a capture efficiency of 0.489 so that the catchability coefficient for swept area abundance estimated in the SS3 model would be about 1.0.

Middle of shell length bin	Survey dredge selectivity
155	0.74
165	0.48
175	0.44
185 to 245	0.43

In SS3, a lognormal distribution with a mean of one and CV=0.14 was used as a prior for the swept area abundance catchability parameter. The same distribution was used in KLAMZ for swept area biomass.

Survey shell length composition data (30-250 mm SL in 5 mm bins) was used in SS3 for all years with surveys. In addition, NEFSC clam survey age composition data (from age length keys) were included for years with age samples from each region (Table A20).[22,23] The KLAMZ model uses survey size or age data to distinguish new and old recruits only.

Results

Estimates from the final demonstration SS3 and KLAMZ models were similar but direct comparisons must be made with care because of differences between the models. In particular, KLAMZ calculates the biomass of surfclams 120+ mm SL while "summary biomass" output from SS3 was for surfclams age 5+.

The number of parameters estimated in the final preliminary demonstration models were similar for SS3 (42 parameters, Table A5-2) and KLAMZ (47 parameters, Table A5-3). Direct comparisons are difficult because, for example, SS3 estimates survey catchability values using two formal parameters while KLAMZ estimates catchability using closed form maximum likelihood estimates not counted as parameters. Similarly, the KLAMZ model constrains recruitment deviations to a greater extent than SS3 (using fewer degrees of freedom).

Annual recruitment parameters were the most difficult parameters to estimate in both models (note large CVs for some recruitment parameters in the SS3 output in Table A5-2). The KLAMZ model did not fully converge because the Hessian could not be inverted. Experience indicates that the problem was likely due to at least one weak recruitment parameter estimate.[24] Routine diagnostic plots (Figures A5-4 to A5-8a) indicate that the SS3 model fit the data for surfclam reasonably well. The estimated selectivity pattern from SS3 for the commercial fishery (Figure A5-8b) and estimated variance around the assumed growth curve were plausible (Figure A5-8c).

Biomass estimates from the two models were similar in scale and both suggest declining trends in recent years (Figure A5-9). Biomass trends for years prior to 1965 differed. The biomass estimates from KLAMZ were smoother because the lack of information about recruitment necessitated a very smooth recruitment pattern in KLAMZ compared to SS3 (Figure A5-10). The effects of more variable recruitment in the SS3 model are evident in estimates of numbers at age during each year, which suggest periodic pulses of strong recruitment over several years are important to the surfclam stock (Figure A5-11).

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[22] Once the SS3 model is broken into regions, age data for all regions/years with samples will be used because synoptic sampling across the entire stock is not required.

[23] "Conditional age at length" data (records of length and age) are the current preferred approach for using survey age data in SS3. However, the survey age data collection protocol is stratified based on stratum and shell length. The stratified approach precludes using conditional age at length data for the entire stock because unweighted samples are not representative of the stock as a whole. Weighting age by survey catch to obtain representative samples is an area for future research. Once the SS3 model is broken into regions, it should be easier to use conditional age at length data.

[24] If additional time were available, the weak recruitment estimates from the KLAMZ model could probably be identified and strengthen by minor changes to annual recruit parameter weights.

Based on delta method variance calculations for spawning biomass and recruitment estimates, population estimates from the SS3 model are relatively uncertain, as might be expected given data limitations that were exasperated by the one stock approach (Figures A5-12 and A5-13). CVs for the basecase KLAMZ model in this assessment were smaller due to the highly constrained recruitment estimates.

Simple exploitation rates (catch / estimated biomass) from the SS3 and KLAMZ models were similar in trend and magnitude. However, the most typical measures of fishing mortality (fully recruited *F* in SS3 and total *F* in KLAMZ) were similar in trend but different in magnitude (Figure A5-14). SS3 uses a number of metrics to measure fishing mortality that may be quite different than the metric used in KLAMZ. Trends may be comparable but the magnitude of fishing mortality estimates from SS3 and KLAMZ models should not be compared. Simpler exploitation rates (catch/biomass) are much easier to compare and interpret. For similar reasons, reference points computed in one model should never be compared to biomass or fishing estimates from the other model.

Table A5-1. Ageing precision data and estimates for surfclams from NEFSC clam surveys during 2005-2008.

Age bin	N	Minimum age	Maximum age	Standard deviation (mm)	CV	Fitted standard deviation (mm)
1	7	1	1	0.000	0.000	NA
2	55	1	3	0.354	0.177	0.312
3	145	3	3	0.000	0.000	NA
4	114	3	5	0.311	0.078	0.333
5	49	5	5	0.000	0.000	NA
6	56	4	8	0.484	0.081	0.353
7	21	6	8	0.312	0.045	0.363
8	41	7	9	0.458	0.057	0.374
9	26	9	9	0.000	0.000	NA
10	51	9	11	0.281	0.028	0.394
11	22	10	12	0.374	0.034	0.404
12	29	11	13	0.439	0.037	0.414
13	19	12	14	0.232	0.018	0.425
14	22	13	15	0.457	0.033	0.435
15	9	14	16	0.343	0.023	0.445
16	32	14	18	0.617	0.039	0.455
17	11	16	18	0.436	0.026	0.465
18	24	17	19	0.565	0.031	0.476
19	14	18	20	0.385	0.020	0.486
20	17	19	21	0.500	0.025	0.496
21	12	21	21	0.000	0.000	NA
22	27	21	23	0.532	0.024	0.516
23	11	22	24	0.309	0.013	0.527
24	21	23	26	0.656	0.027	0.537
25	1	25	25	0.000	0.000	NA
26	2	26	26	0.000	0.000	NA
27	2	27	27	0.000	0.000	NA
28	9	27	29	0.639	0.023	0.578
29	1	29	29	0.000	0.000	NA

Table A5-2. Descriptions, estimates, standard errors and CVs for parameters in the SS3 model.

Index	Description	Estimate	SD	CV
1	Predicted length at age 30	15.384	0.088	0.01
2	von Bertalanffy K	0.259	0.009	0.04
3	CV for size at age 1	0.145	0.011	0.08
4	CV for size at age 30	0.051	0.009	0.17
5	Beverton-Holt maximum recruitment	14.072	0.250	0.02
6	Recruitment standard deviation	0.569	0.074	0.13
7	Recruitment offset parameter	0.023	0.059	2.55
8	Recruitment deviation 1975	-0.663	0.409	0.62
9	Recruitment deviation 1976	0.147	0.392	2.67
10	Recruitment deviation 1977	1.390	0.310	0.22
11	Recruitment deviation 1978	1.307	0.272	0.21
12	Recruitment deviation 1979	-0.386	0.375	0.97
13	Recruitment deviation 1980	0.830	0.212	0.26
14	Recruitment deviation 1981	0.339	0.278	0.82
15	Recruitment deviation 1982	-0.084	0.258	3.07
16	Recruitment deviation 1983	-0.206	0.239	1.16
17	Recruitment deviation 1984	0.373	0.190	0.51
18	Recruitment deviation 1985	-0.556	0.302	0.54
19	Recruitment deviation 1986	-0.361	0.265	0.73
20	Recruitment deviation 1987	0.669	0.231	0.35
21	Recruitment deviation 1988	0.621	0.257	0.41
22	Recruitment deviation 1989	-0.013	0.269	21.46
23	Recruitment deviation 1990	0.300	0.253	0.84
24	Recruitment deviation 1991	0.027	0.324	11.93
25	Recruitment deviation 1992	1.445	0.142	0.10
26	Recruitment deviation 1993	0.335	0.279	0.83
27	Recruitment deviation 1994	-0.208	0.272	1.31
28	Recruitment deviation 1995	-0.436	0.247	0.57
29	Recruitment deviation 1996	-0.765	0.258	0.34
30	Recruitment deviation 1997	-0.593	0.267	0.45
31	Recruitment deviation 1998	-0.165	0.241	1.46
32	Recruitment deviation 1999	-0.042	0.209	4.94
33	Recruitment deviation 2000	-0.498	0.315	0.63
34	Recruitment deviation 2001	-0.675	0.393	0.58
35	Recruitment deviation 2002	-0.541	0.334	0.62
36	Recruitment deviation 2003	-0.758	0.330	0.44
37	Recruitment deviation 2004	-0.831	0.292	0.35
38	Fishing mortality rate prior to 1965	0.018	0.005	0.28
39	Catchability clam survey	-5.743	0.286	0.05
40	Catchability swept area abundance	0.458	0.312	0.68
41	Commercial size selectivity parameter	13.213	0.287	0.02
42	Commercial size selectivity parameter	3.830	0.384	0.10

Table A5-3. Descriptions and estimates for parameters in the KLAMZ model. Standard errors and CVs are not available because the model did not fully converge.

Index	Description	Estimate
1	Log old recruits 1965	6.66362
2	Log total biomass 1964	6.75012
3	Log mean recruitment	4.58878
4	Recruitment deviation 1965	0.00277
5	Recruitment deviation 1966	0.00270
6	Recruitment deviation 1967	0.00248
7	Recruitment deviation 1968	0.00277
8	Recruitment deviation 1969	0.00322
9	Recruitment deviation 1970	0.00296
10	Recruitment deviation 1971	0.00270
11	Recruitment deviation 1972	0.00291
12	Recruitment deviation 1973	0.00303
13	Recruitment deviation 1974	0.00296
14	Recruitment deviation 1975	0.00244
15	Recruitment deviation 1976	0.00245
16	Recruitment deviation 1977	0.00258
17	Recruitment deviation 1978	0.00405
18	Recruitment deviation 1979	0.00521
19	Recruitment deviation 1980	0.00482
20	Recruitment deviation 1981	0.00566
21	Recruitment deviation 1982	0.00631
22	Recruitment deviation 1983	0.00864
23	Recruitment deviation 1984	0.01000
24	Recruitment deviation 1985	0.01024
25	Recruitment deviation 1986	0.00909
26	Recruitment deviation 1987	0.01095
27	Recruitment deviation 1988	0.01058
28	Recruitment deviation 1989	0.01064
29	Recruitment deviation 1990	0.01119
30	Recruitment deviation 1991	0.01079
31	Recruitment deviation 1992	0.00966
32	Recruitment deviation 1993	0.00982
33	Recruitment deviation 1994	0.00877
34	Recruitment deviation 1995	0.00529
35	Recruitment deviation 1996	0.00355
36	Recruitment deviation 1997	0.00239
37	Recruitment deviation 1998	-0.00104
38	Recruitment deviation 1999	-0.00601
39	Recruitment deviation 2000	-0.00738
40	Recruitment deviation 2001	-0.01015
41	Recruitment deviation 2002	-0.01409
42	Recruitment deviation 2003	-0.01721
43	Recruitment deviation 2004	-0.01899
44	Recruitment deviation 2005	-0.02076
45	Recruitment deviation 2006	-0.02246
46	Recruitment deviation 2007	-0.02480
47	Recruitment deviation 2008	-0.02593

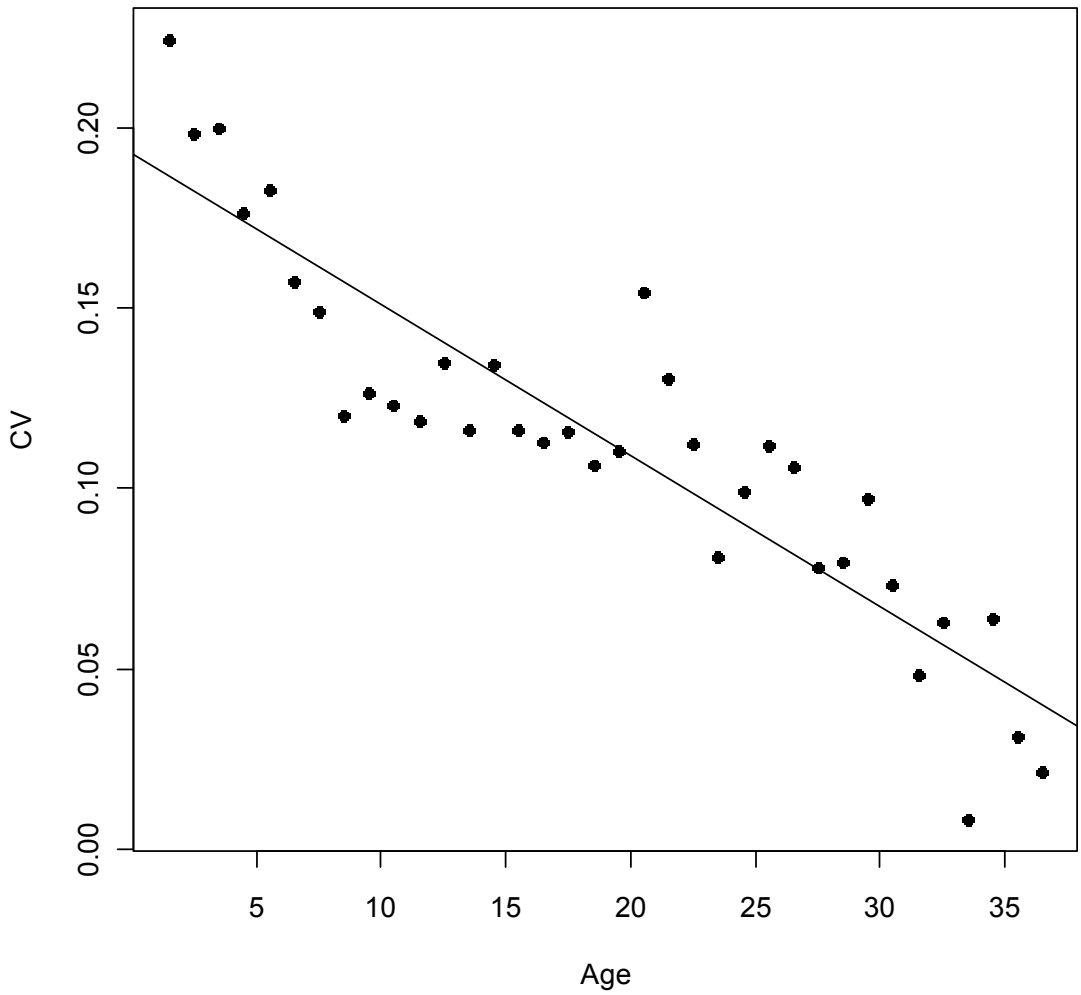

Figure A5-1. CVs for size at age 1-36 y for surfclams. The line was fit by linear regression using the sample size at each age as weights.

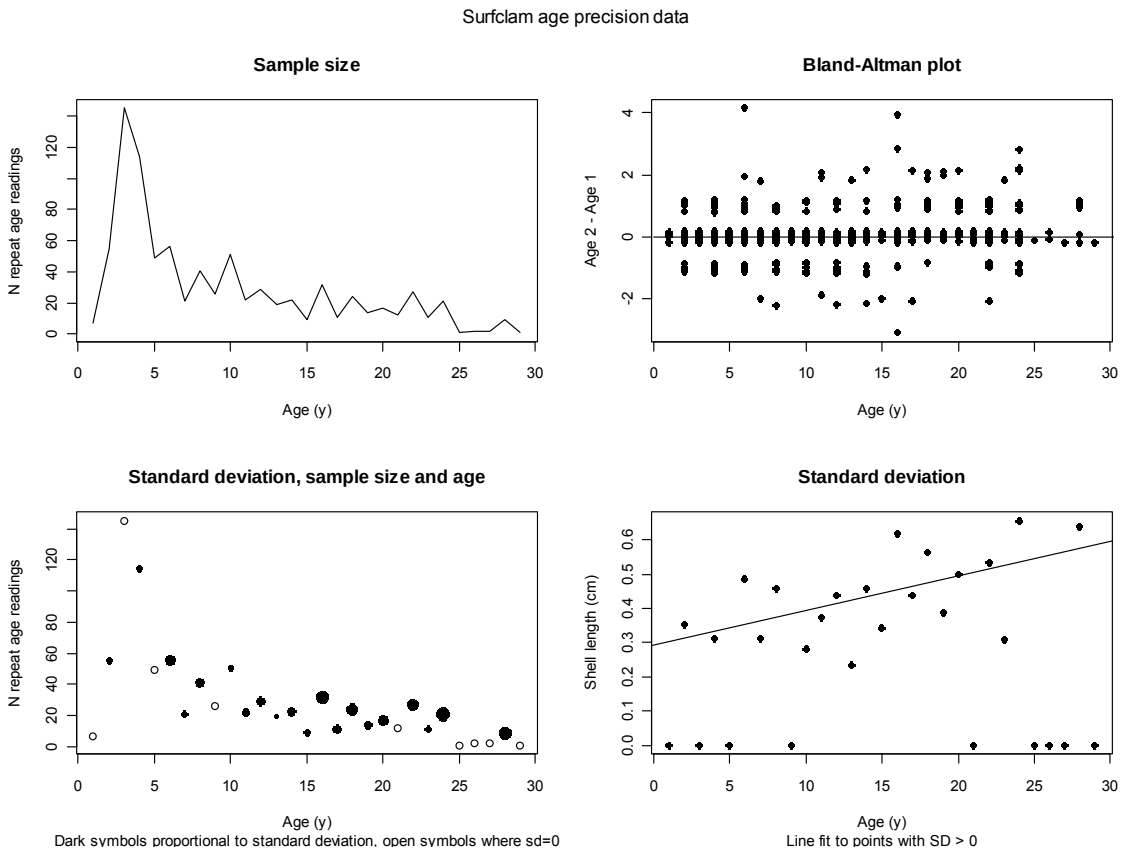

Figure A5-2. Surfclam age reader precision data from NEFSC clam surveys during 2005-2008. Data in the Bland-Altman plot (upper right) have been jittered to enhance visibility.

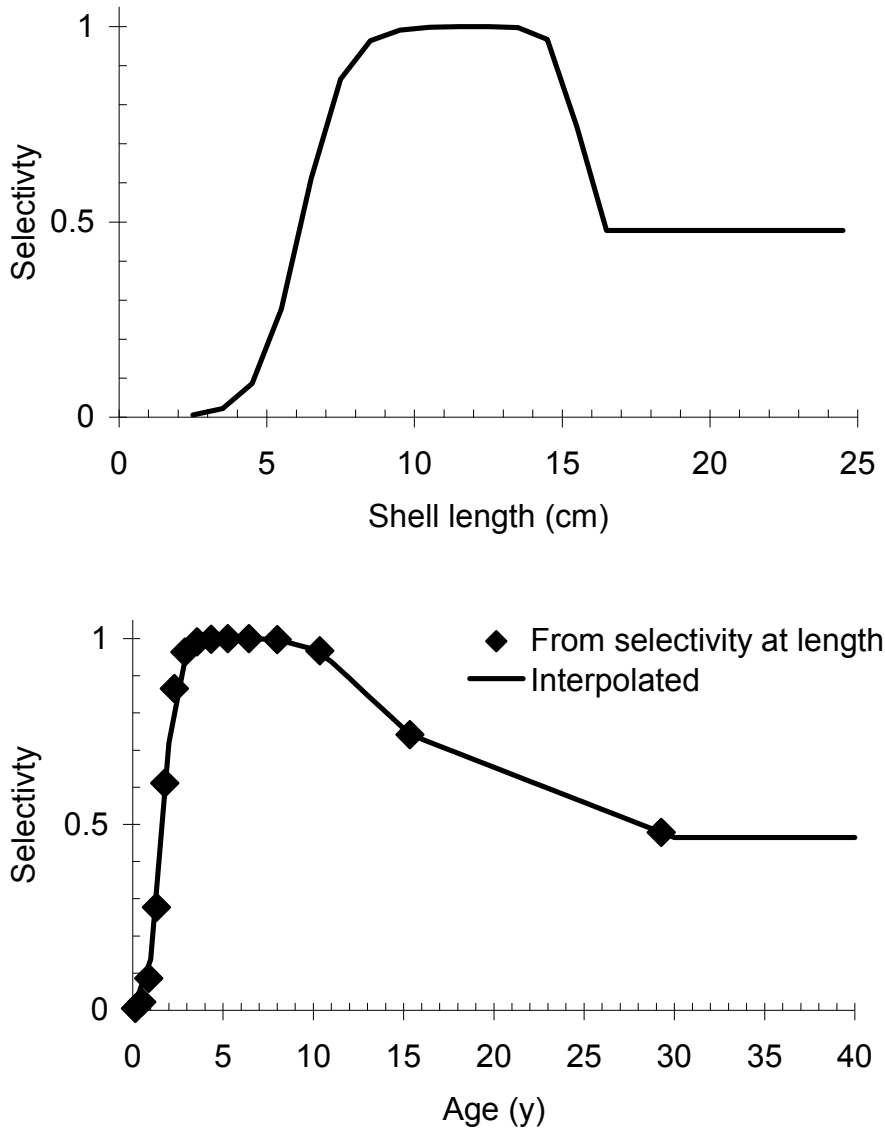

Figure A5-3. Selectivity at length and age for the NEFSC clam survey in preliminary SS3 models for surfclams.

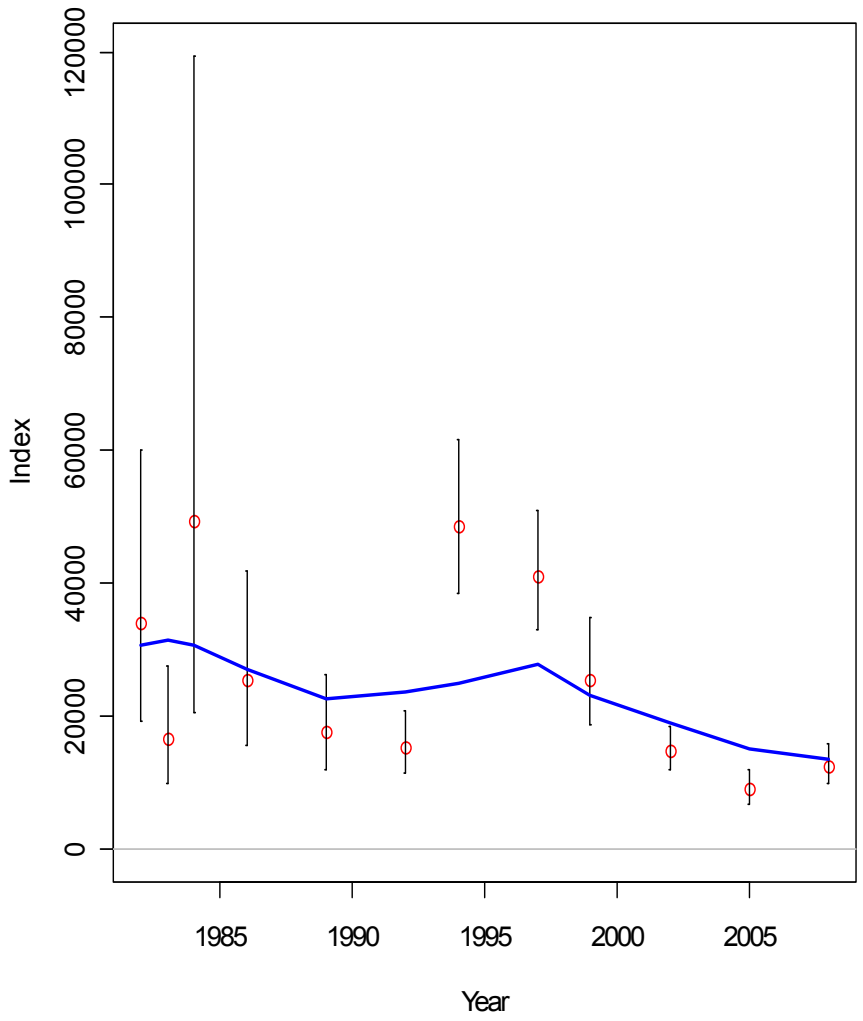

Figure A5-4. Observed and predicted values for NEFSC clam survey abundance data (mean number per tow) for surfclams 30+ mm SL from the SS3 model

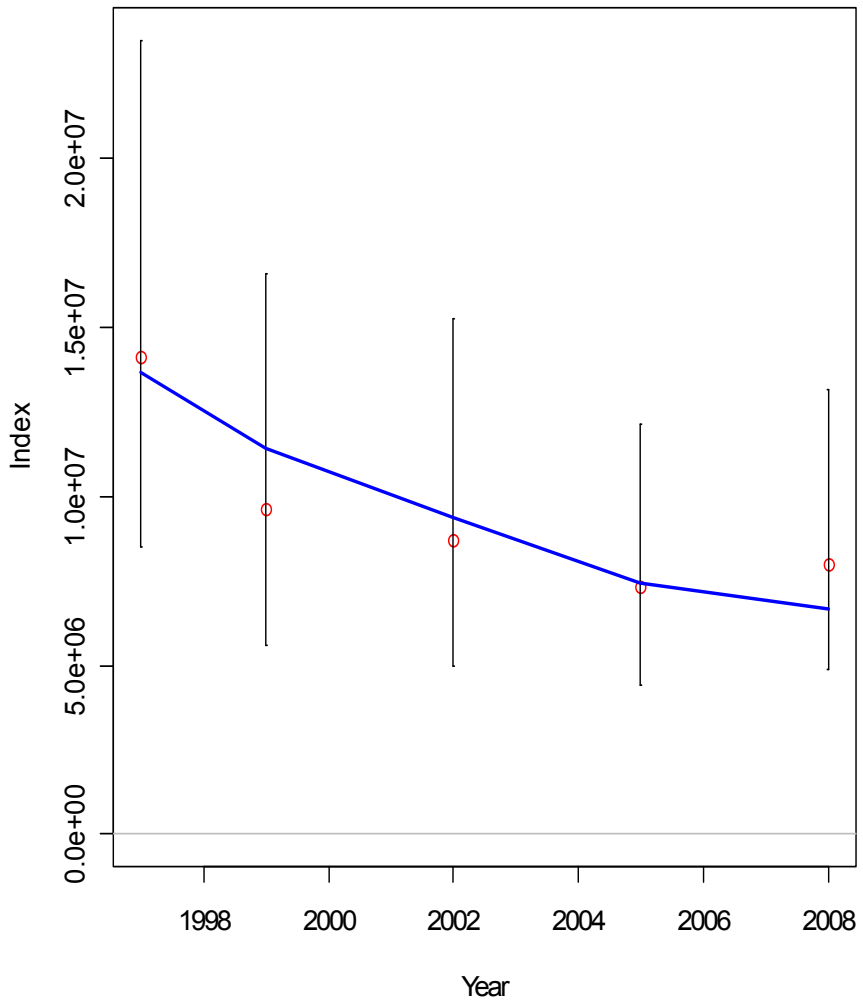

Figure A5-5. Observed and predicted values for efficiency corrected swept area abundance data for surfclams 30+ mm SL from the SS3 model.

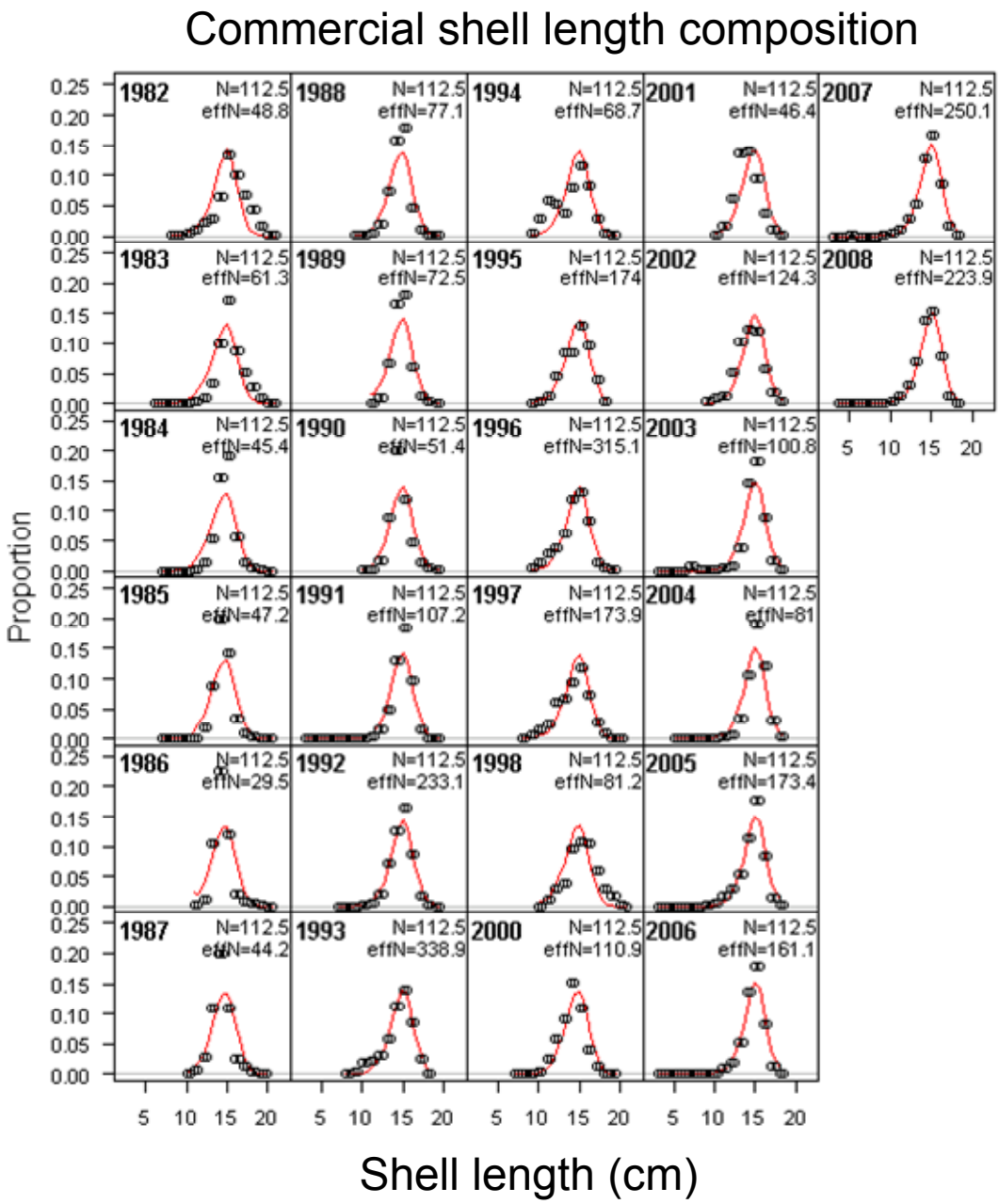

Figure A5-6. Observed and predicted fishery length composition data for surfclams from the SS3 model.

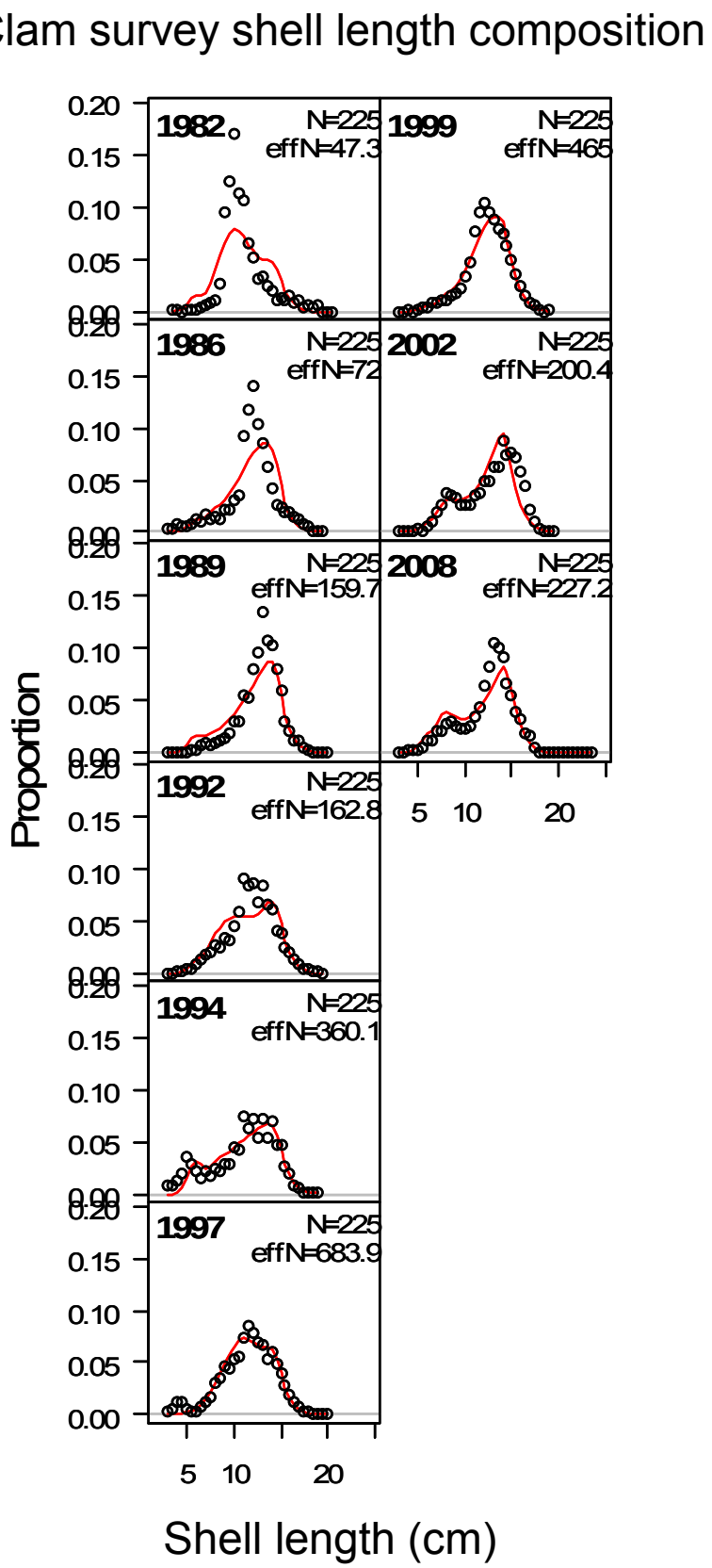

Figure A5-7. Observed and predicted NEFSC clam survey length composition data for surfclams from the SS3 model.

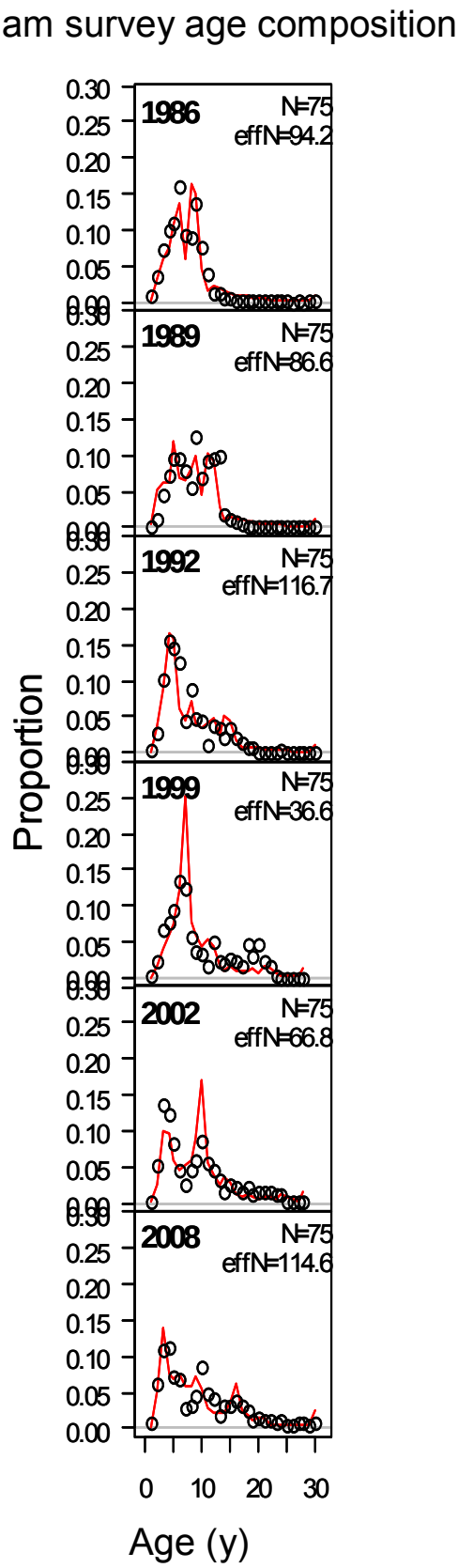

Figure A5-8a. Observed and predicted NEFSC clam survey age composition data for surfclams from the SS3 model.

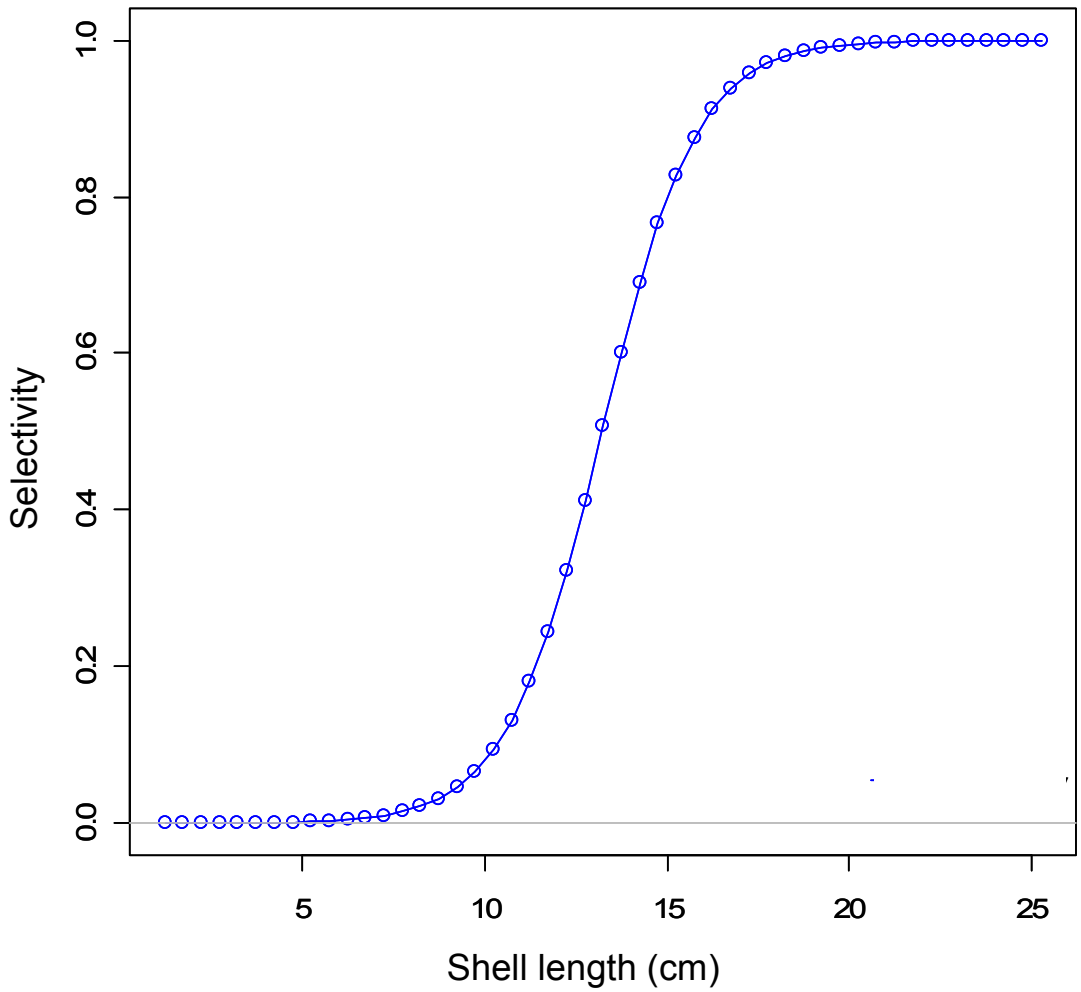

Figure A5-8b. Commercial fishery size selectivity curve for surfclams estimated in the SS3 model.

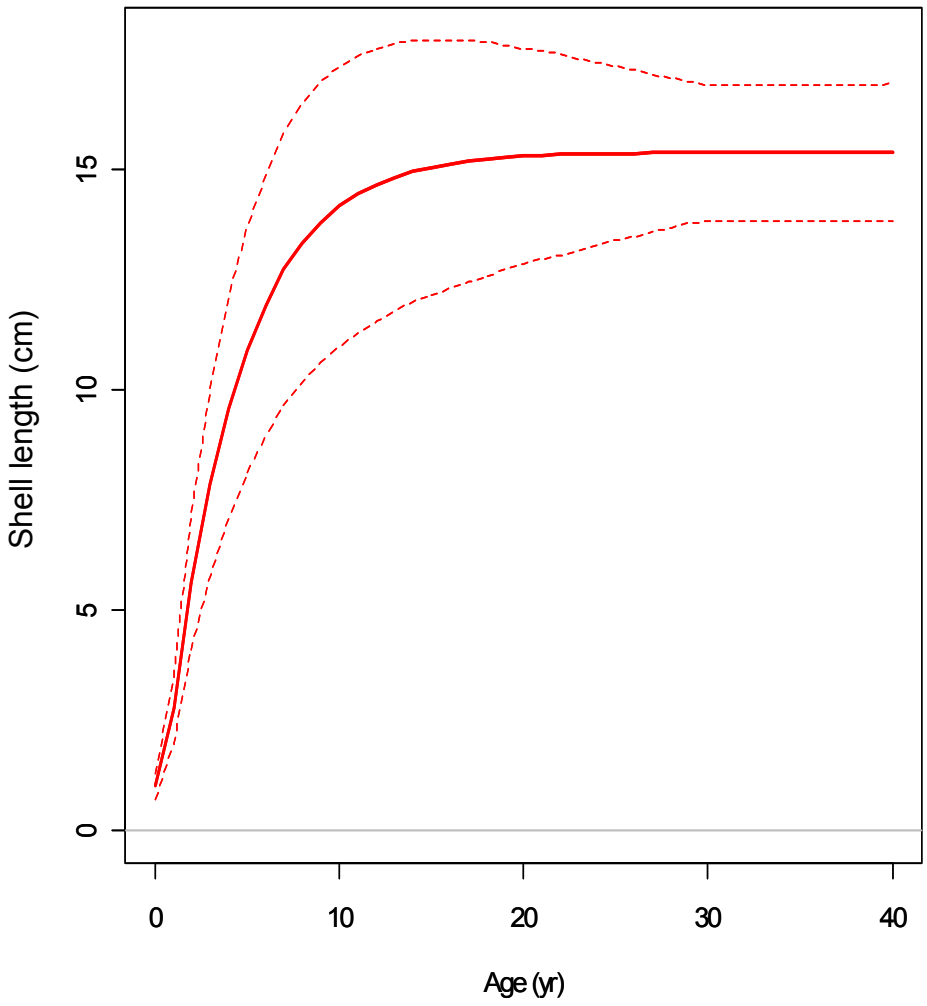

Figure A5-8c. The assumed growth curve and estimated distribution in size at age in the SS3 model for surfclams.

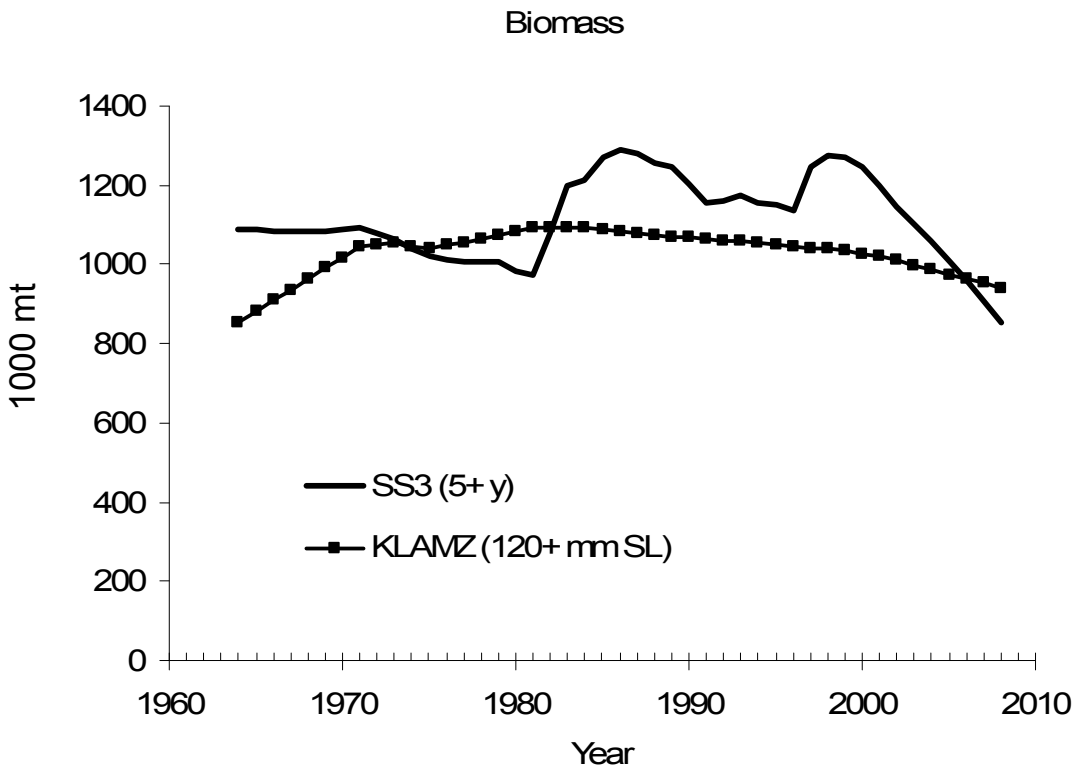

Figure A5-9. Biomass estimates from the SS3 and KLAMZ models. Note that estimates from SS3 are for surfclams ages 5+ while estimates from KLAMZ are for surfclams 120+ mm SL.

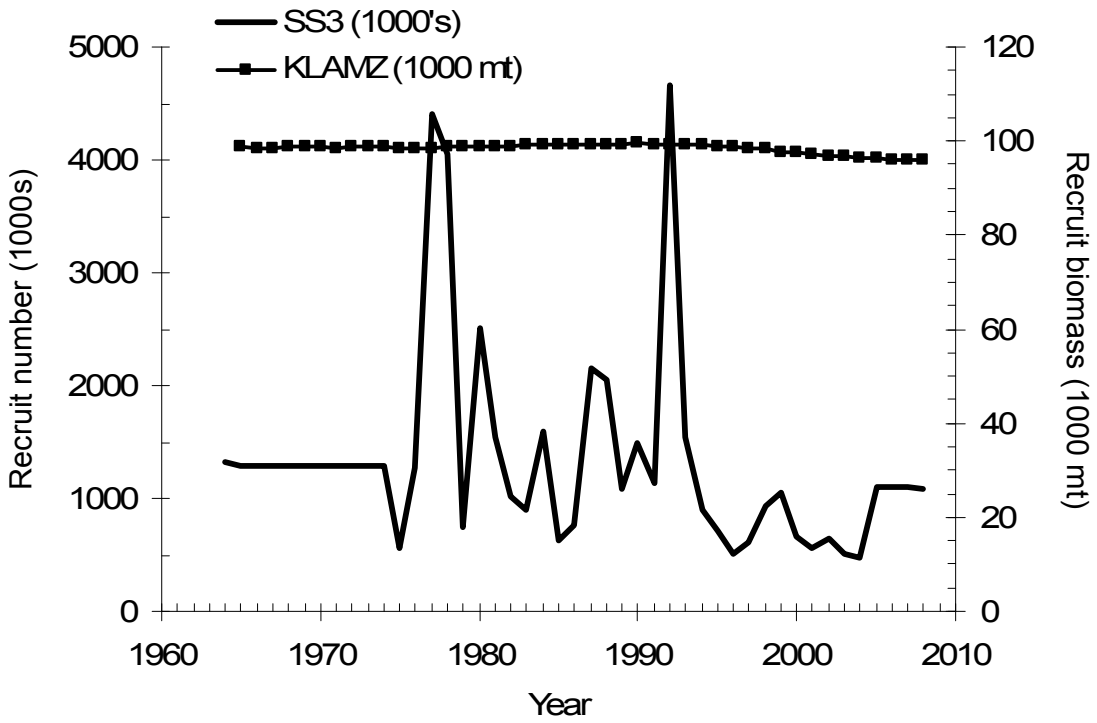

Figure A5-10. Recruitment estimates from the SS3 and KLAMZ models. Note that estimates from SS3 are for surfclams at age zero while estimates from KLAMZ are for surfclams approximately 120-128 mm SL and 5-7 y in age.

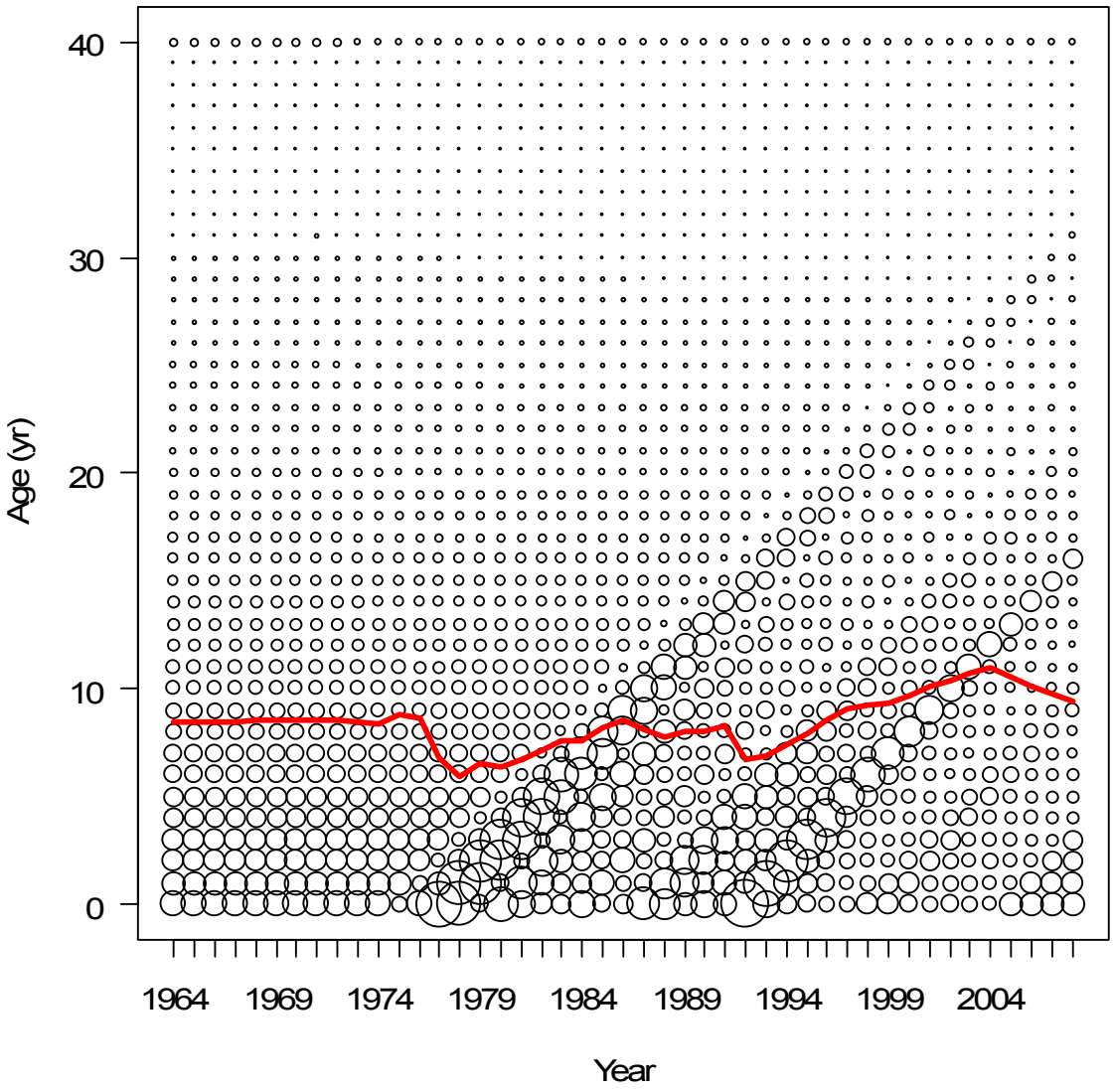

Figure A5-11. Surfclam stock number at age estimates from the SS3 model. The size of the circles is indicates the number of estimated clams at each age in each year.

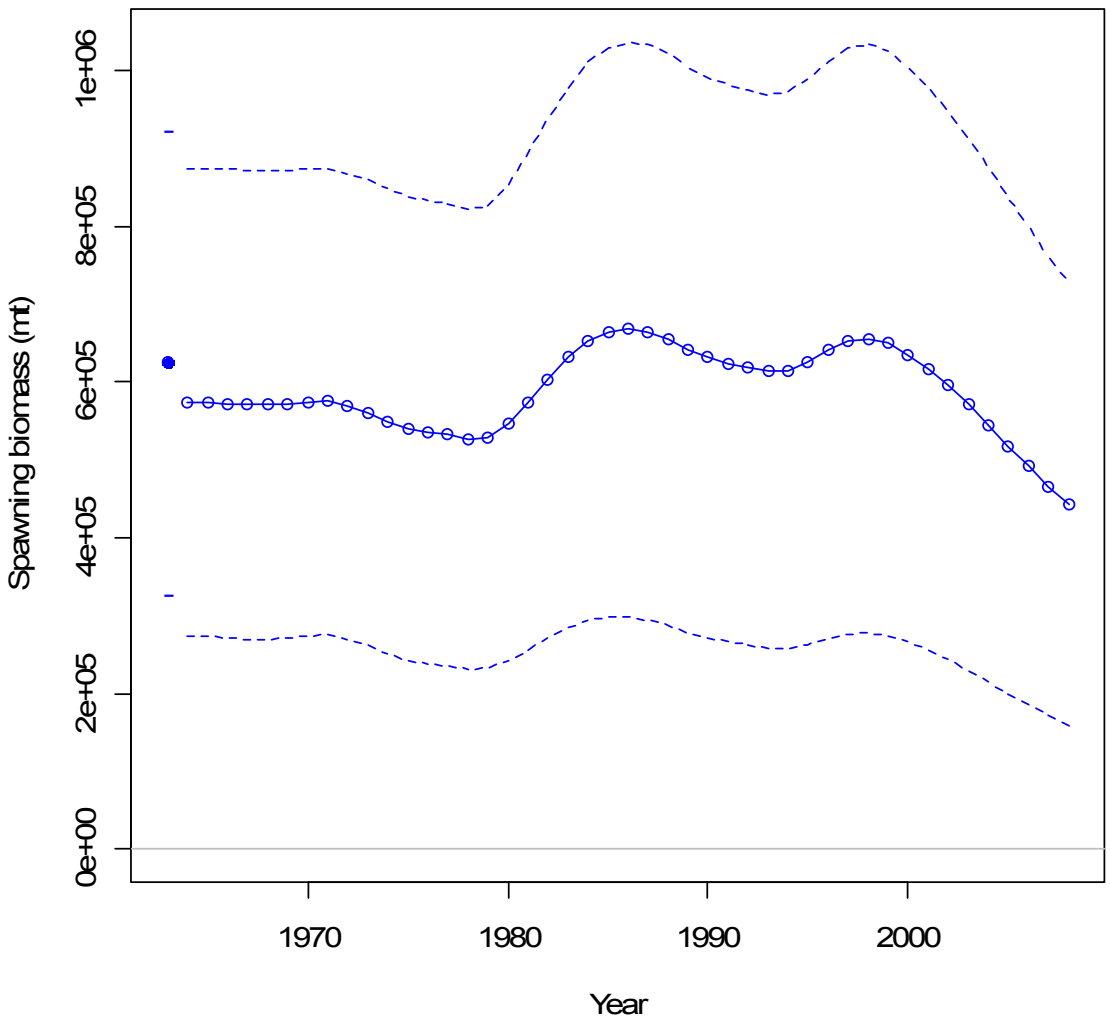

Figure A5-12. Surfclam spawning biomass estimates the SS3 model with approximate 95% confidence intervals. The figure is intended to demonstrate uncertainty. The absolute value of the estimates is not reliable due to lack of biological data for surfclams.

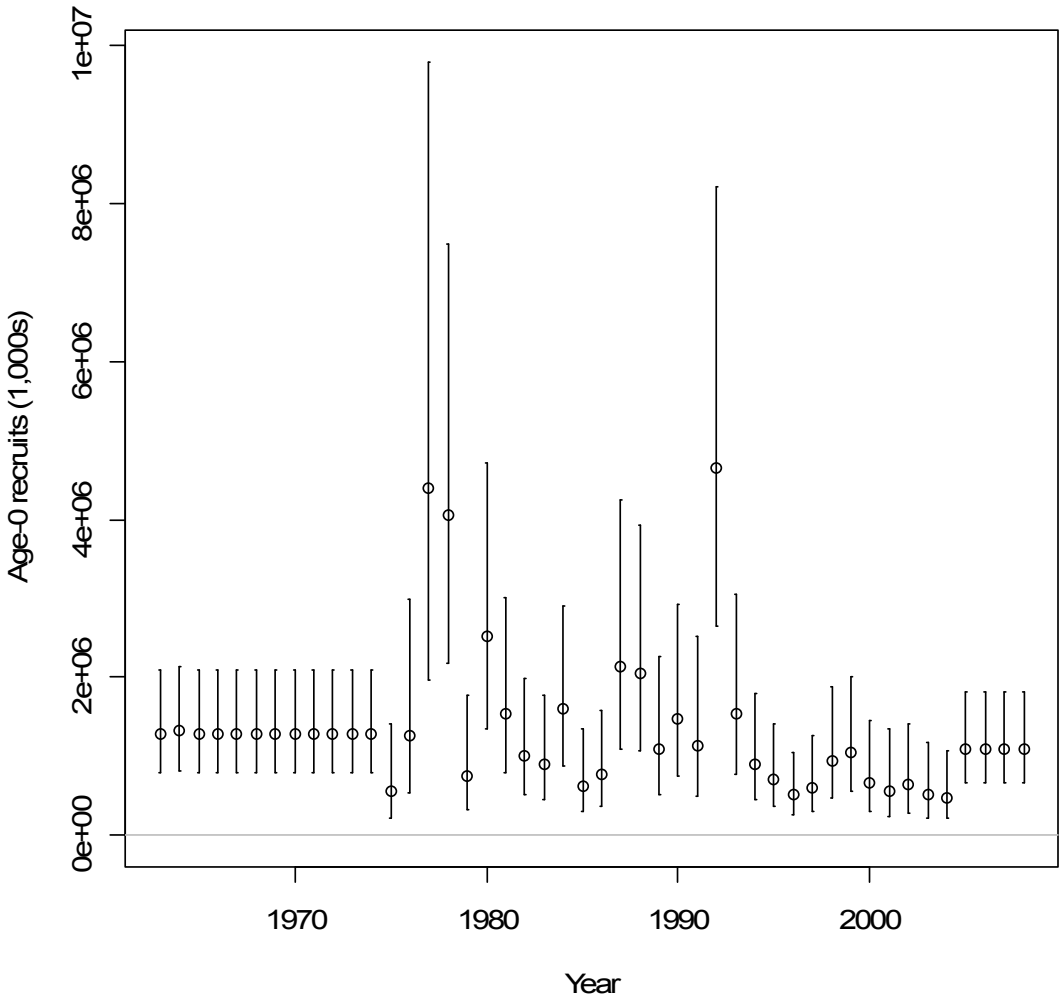

Figure A5-13. Surfclam recruitment estimates (age 0) from the SS3 model with approximate 95% confidence intervals. The figure is intended to demonstrate uncertainty.

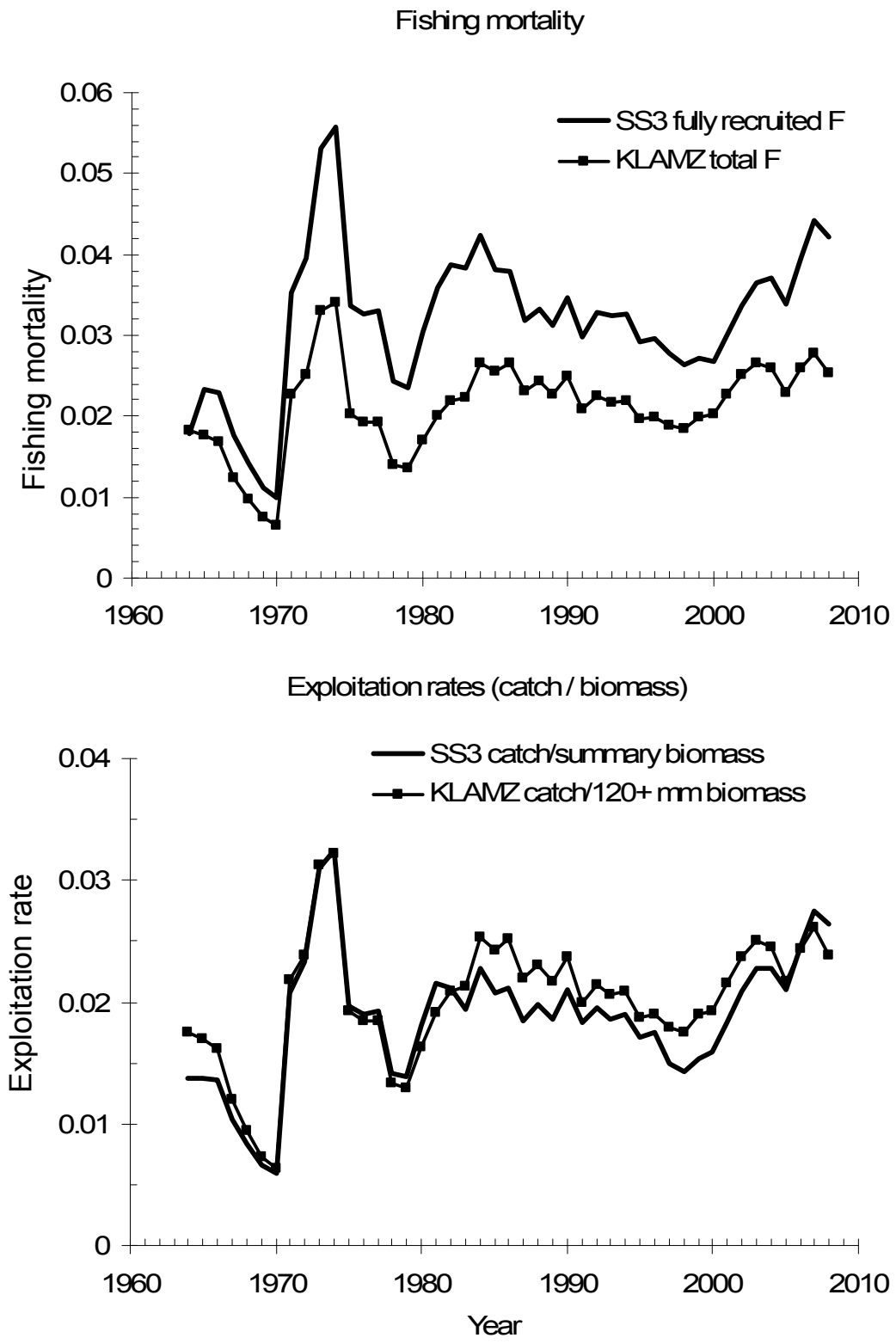

Figure A5-14. *Top:* Common measures of fishing mortality from the SS3 and KLAMZ models. *Bottom:* Simple exploitation rates estimates (catch / biomass) from the SS3 and KLAMZ models.