L. Georges Bank/Gulf of Maine white hake

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1.0 Background

The white hake, *Urophycis tenuis*, occurs from Newfoundland to Southern New England and is common on muddy bottom throughout the Gulf of Maine (Bigelow and Schroeder 1953; Klein-MacPhee 2002). Depth distribution of white hake varies by age and season; juveniles typically occupy shallower areas than adults, but individuals of all ages tend to move inshore or shoalward in summer, dispersing to deeper areas in winter (Musick 1974; Markel et al. 1982). Small white hake are difficult to distinguish from red hake, *Urophycis chuss*, resulting in a small degree of bias in reported nominal catches (NEFSC 2005).

Larval distributions indicate the presence of two spawning groups in the Gulf of Maine, Georges Bank and Scotian Shelf region, one which spawns in deep water on the continental slope in late winter and early spring, and a second which spawns on the Scotian Shelf in the summer (Fahay and Able 1989; Lang et al. 1994). The population found in U.S. waters appears to be supported by both spawning events, but individuals are not distinguishable in commercial landings. The stock is currently assessed as a single unit in United States waters, although Canadian catch from Georges Bank is included (Figure L1).

This stock was last assessed and reviewed at the Groundfish Assessment Review Committee meeting in 2005 (NEFSC 2005). The AIM method was used to assess the status of the stock relative to reference points developed by the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish (NEFSC 2002). Landings and discards of fish greater than 60 cm were used in the model as well as autumn survey indices of biomass. Fishing mortality in 2004 was estimated to be more than twice the value for F_{rel}. Biomass estimates were less than 1/2 B_{MSY}.

The assessment for this stock has evolved over time from index-based in the early 1990s, to Collie-Sissenwine in 1994, finally to VPA in 1998. However, the addition of years to the VPA model created a marked retrospective pattern in the assessment in 2001. The assessment then became based upon a surplus production model which was itself unstable and rejected in 2002. The AIM method is currently used to assess the status of the stock relative to biological reference points. The GARM III Models Panel (O'Boyle et al. 2008a) recommended examining forward projecting length or age-based models to include all portions of the stock. The GARM III Biological Reference Points Panel (O'Boyle et al. 2008b) accepted a forward projecting age-based model, but suggested some more exploration of the model formulation to mitigate some of the problems encountered in the model.

2.0 The Fishery

Commercial Landings

United States commercial landings of white hake increased from a low of 2,225 mt in 1997 to 4,435 mt in 2003 (Table L1; Figure L2). Landings subsequently declined to 1,532 mt. Canadian landings declined to 46 mt. Historical landings of white hake from the United States were discovered in ICNAF (1952) (Table L2). These landings ranged from almost 22,000 mt in 1898 to 5,500 mt in 1950 with many years more than double the largest landings seen since 1964.

The primary gear type used to catch white hake is the otter trawl (Table L3). Historically, line trawls were also important, but from 1980 to 1991, this gear accounted for less than 5% of the total. Line trawls again increased in importance and, in 1997, accounted for 18% of the total landings. However, in recent years they have averaged less than one percent. Sink gill nets historically (1960s) accounted for less than 10% of total landings, but the share enlarged in the 1970s to between 20 and 40% of the total and currently account for about 25% of the total landings.

Discards

Commercial discards were re-estimated for white hake for 1989-2007 using the SBRM (Wigley et al. 2006) method of white hake discard/all kept (Table L4). In recent years, discards in both the otter trawl and the sink gill net fisheries have been very low.

Commercial Catch

The GARM III Models Meeting (O'Boyle et al. 2008a) recommended using the ratio of white hake to red hake in the survey to split out white hake discards. This involved estimating red and white hake landings-at-length as well as red and white hake discards-at-length.

Sampling intensity for white hake landings was good and the coverage adequate, except for unclassified (Table L5). These were prorated at the end for 1998-2007. Sampling for red hake was sufficient for most years but was the intensity was low for some years (Table L6). For example, the same length samples were used for both halves of the year in 1996.

Red hake discards were estimated in the same fashion as white hake discards (Table L7). There were sufficient length samples for both species to estimate only otter trawl discards-at-length (Tables L8-L11).

The four components were added together by half year and then the ratio of white hake to red hake at length from the appropriate survey was used to split out white hake (Table L12; Figure L3). The ratio between the old data and the new data was used to estimate landings back to 1964. Age-length keys combining survey and observer age data by half year were used to derive the catch-at-age from 1989-2000 (Table L13, Figure L4). A pooled age-length key by half year was used to derive the catch-at-age from 2001-2007. Mean weights-at-age at the start of the year as well as spawning stock biomass weights-at-age were derived using the Rivard equation (Table L14).

3.0 Research Vessel Surveys

NEFSC has conducted research vessel bottom trawl surveys off the northeast coast of the United States since 1963 (autumn) and 1968 (spring). The NOAA research vessels Albatross IV and Delaware II have been used exclusively during these surveys. Gear and door changes have occurred during the survey period. Calibration coefficients for all changes were not significant for white hake.

The NEFSC autumn bottom trawl survey biomass index fluctuated about a relatively high level during the 1970s and 1980s but declined during the 1990s, falling to a near record low in 1999 (Figure L5; Table L15). The biomass index increased between 2000 and 2002 because of the recruitment of a good 1998 year class (NEFSC 2001), but has since declined to a very low level. The 2007 index is higher and may indicate another year class, although it also may be a year effect. The NEFSC spring survey biomass indices are more variable than the autumn, but declined during the 1990s, increased in the early 2000s, but have since declined.

Maturity information was not updated. The single maturity ogive used in the last VPA assessment was carried forward for this assessment (NEFSC 1999). Natural mortality was assumed to be 0.2 as in the last several assessments.

4.0 Assessment

Input data and Model Formulation

The catch data used for the assessments considered cover the period 1963-2007 (Table L12). Catch-at-age information is provided for the commercial catches during the 1989 to 2007 period (Table L13). Table L14 lists weight-at-age data input, and Table L15 provides annual mean catch per tow information for the NEFSC surveys. Catch-at-age information for these surveys is available for the years 1982 to 2003/2002 (for the spring and autumn surveys respectively) (Tables L16 and L17; see also Figure L6), with survey catch-at-length data being available for the remaining years. The plus-group for the age data fitted by the assessment model is 7+, though within the model itself, the age structure is taken to age 9+.

An SCAA/ASPM assessment method was applied. Table L18 provides a list of symbols used for this assessment approach and the results evaluated there from. Further details of the method are specified in Appendix 2 of Butterworth and Rademeyer (2008a), augmented by the procedure to incorporate catch-at-length data in the likelihood that is detailed in Butterworth and Rademeyer (2008b). This last procedure requires a value for the parameter β which relates to the width of the distribution of length at age about its expected value (see equation 3 of Butterworth and Rademeyer, 2008b). Since there appeared to be insufficient information in the data to be able to satisfactorily treat this as an estimable parameter when fitting the assessment model, β was fixed to 0.15 for all computations. For years for which catch-at-age data are included in the likelihood, the corresponding catch-at-length data were omitted.

Because the assessments commence in 1963, either specification on input or estimation is required of the parameters that determine the starting numbers-at-age, namely θ which is the ratio of the starting spawning biomass B^{sp} to that for the pristine resource K^{sp}, and ϕ which effectively specifies the extent to which the mean Z reflected by the starting age-structure of the population exceeds M (for full details, see Butterworth and Rademeyer (2008a), equations A.2.13 and 14). Table L19 shows results for assessment "A1" (which assumes a Ricker stock-recruitment function and fits to both catch-at-age and catch-at-length data) for three fixed values of each of θ and ϕ, as well at the best estimate of θ for each of these ϕ values. From these results it was judged that it is reasonable to estimate θ, but that ϕ is somewhat less well determined, though the highest value of 0.4 considered does show some deterioration in fits to the data. The decision was made to fix $\phi = 0.2$, noting that any bias introduced by this choice would tend to err on the conservative side in terms of the current status of the resource relative to its spawning biomass at MSY.

Model Selection Process and Sensitivity Runs

The assessments considered focused on two factors found to be particularly influential in relation to key results:

a) the shape of the stock-recruitment relationship (specifically here Ricker *vs* Beverton-Holt: "A" vs "B");

b) whether the survey catch-at-length data for years for which survey catch-at-age data are not available are included in the likelihood or not("1" vs "2").

The selection basis (for assessments based upon the same data) was AIC. This indicated a slight preference for "A" assessments. Sensitivity to forcing the q parameter (see Table L18) for the autumn survey not to exceed 1 (corresponding to no herding of fish by the survey fishing gear) was investigated but rejected because of markedly inferior AIC values. Estimation of the ϕ parameter was justified in AIC terms and indicated slightly better resource status, but this was not pursued to avoid a possible undue dependence of results on some minor feature of the initial years' data from the survey series. AIC values indicated a clear preference for domed rather than flat survey selectivity, but none for increasing M above 0.2 at larger ages.

Assessment results and Diagnostics

Results for four assessments A1, A2, B1 and B2, corresponding to the four possible combinations of the two factors in a) and b) above, are presented in Table L20. These results include Bayesian posterior medians and CVs which are based on wide uniform priors for all estimable parameters except recruitment residuals which are taken to be lognormally distributed with a standard deviation of the associated normal distribution of 0.5.

Figure L7 compares spawning biomass trends over time across the different assessments, while Figures L8 and L9 show diagnostics for the A1 and A2 assessments respectively. Although better precision is evident for the "1" assessments which incorporate catch-at-length data, the serious lack of fit for the residuals for fit to the autumn survey catch-at-length data (see Figure L8) led to the "2" assessments (which do not fit to these data) being preferred.

Further diagnostics for the consequently preferred A2 assessment's fit to the data are shown in Figures L10 and L11. Overall the model provides reasonable fits to the various sets of input data. There is a mild retrospective pattern as illustrated in Figures L12 to L14, and summarized in Table L21. Tables L22 and L23 provide the fishing mortality and numbers-at-age matrices estimated for this A2 assessment.

The results for the final choice of the A2 assessment are summarized in Figure L15 in terms of estimated spawning biomass, fishing mortality and recruitment trends. These reflect a resource whose size grew from the early 1960s to peak in the late 1970s, and then decline sharply under increased catches until the turn of the century, following which a slow recovery trend is indicated, together with improved recruitment for the last three years. Figure 16 provides posterior distribution plots for the 2007 fishing mortality and spawning biomass; point estimates for these two quantities are 0.15 and 19,800 mt respectively.

5.0 Biological Reference Points

Figure L17 shows the Ricker curve estimated for the chosen A2 assessment and the associated estimated stock-recruitment data points. Although the Ricker relationship is marginally preferred over the Beverton-Holt, estimates of biological reference points related to fishing mortality and spawning biomass differ markedly between the two (see Table L20). However estimates of mean recruitment are very similar across the four assessments, so that for a robust basis for BRP estimation, the approach finally chosen is to use the F40% proxy basis, coupled to the average recruitment for assessment A2, for computation.
The resultant estimates for biological reference points are:

F_{msy} = 0.125 (on age 6)
SSB_{MSY} = 56,300 mt
MSY = 5,800 mt

The resultant status for the resource is that it is overfished and that overfishing took place in 2007 (see Figure L18 which compares these results to those which would follow from the Ricker stock-recruitment curve estimated in assessment A2 for which the estimated F_{msy} is somewhat higher).

6.0 Projections

Projections were conducted with a stochastic model for recruitment using a five-year average for mean catch and stock weights and the life history and selectivity parameters from the A2 assessment (Table L24). Starting population vectors were provided by the joint Bayesian posterior distribution computed using MCMC, and future recruitment was generated from a lognormal distribution with parameters estimated from the set of recruitments estimated in the A2 assessment. Catch in 2008 was assumed to be the same as catch in 2007 (2163 mt). Three scenarios for 2009 were evaluated: 1) F_{MSY}; 2) $F_{STATUS\ QUO}$; and 3) the F required to rebuild the stock by 2014 (see Table L18). The results are reported in Table L20. The F associated with the rebuilding in 3) was estimated to be 0.078, with an associated 2009 projected catch of 2,200 mt.

7.0 Summary

Fishing mortality in 2007 is estimated to be 0.150 and current spawning stock biomass in 2007 is estimated to be 19,800 mt. The stock is overfished and overfishing is occurring (Figure L19). The assessment has changed since GARM II and the reference points and biomass estimates are not comparable. Two sources of uncertainty in the assessment are the use of survey ages to age the commercial fishery, and the unavailability of age information for the earlier years of the surveys. The latter is of consequence because estimates of the current status of the resource are closely linked to its status in the early 1960s, which is in turn difficult to estimate given the limited information for that period.

8.0 Panel Discussion /Comments:

Conclusions

Following from the recommendations of earlier GARM III reviews, the Panel considered two SCAA formulations, one by Sosebee (working paper 1.L.a), and the other by Butterworth and Rademeyer (working paper 1.L.b). Both models used age composition data for the 1989-2000 commercial fishery and for 1982 - 2003/2002 for the spring and autumn surveys respectively. A pooled age-length key was created from these observations and was used, in concert with year-specific length frequency samples, to derive age compositions for commercial catches for 2001-2007. The Sosebee model used this combined age-length key to estimate survey age compositions for 1963-1988. The Butterworth and Rademeyer model used survey catch at length data for 1963-1981 and 2004/3 – 2007 in some model formulations, but these were considered inferior to the Final model.

The two models produced similar trends in stock size but differed in scale with the Sosebee model generally producing lower estimates than the Butterworth and Rademeyer model. Both models produced a dome shaped selectivity in the fishery and the survey. Both models indicated that younger and older fish had higher selectivity in the fishery than in the survey.

The Panel had reservations about the use of a common age-length key in this assessment as this would not follow recruitment variability very well. However, it was recognized that it was important to have age composition estimates for the most recent years, since these would be used in catch projections. The Panel accepted the Butterworth and Rademeyer model as Final and the best available to provide management advice on stock status and from which to base stock and rebuilding plan projections. This model made less use of the common age-length key and had a more realistic method of deriving the population age composition in the initial year of the analysis (1963). It also made more use of the historical data.

A number of formulations of the Butterworth and Rademeyer model were also considered. One used length composition data for years that did not have age compositions. However, this formulation had poor model fit for younger ages, and thus these data were not incorporated in the Final model. Two Stock - Recruitment relationships were examined (Ricker and Beverton / Holt). There was little difference in estimates between the two, and the Panel selected the model with the Ricker relationship. Residual plots and retrospective diagnostics indicated a small retrospective pattern and no adjustment was required.

The Panel recommended that the catch forecasts include $F_{40\%MSP}$ instead of the estimated F_{MSY}. The Panel accepted that the catch forecasts use recruitment modeled as lognormal variation about the average historical recruitment with a standard deviation equal to the historical pattern.

Research Recommendations

The Panel had no specific research recommendations for this stock.

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Table L1. Total nominal landings (mt, live) of white hake by country from the Gulf of Maine to Cape Hatteras (NAFO Subareas 5 and 6), 1964-2007.

	Canada	USA	Other	Grand Total
1964	29	3016	0	3045
1965	0	2617	0	2617
1966	0	1563	0	1563
1967	16	1126	0	1142
1968	85	1210	0	1295
1969	34	1343	6	1383
1970	46	1807	280	2133
1971	100	2583	214	2897
1972	40	2946	159	3145
1973	117	3279	5	3401
1974	232	3773	0	4005
1975	146	3672	0	3818
1976	195	4104	0	4299
1977	170	4976	338	5484
1978	155	4869	29	5053
1979	251	4044	4	4299
1980	305	4746	2	5053
1981	454	5969	0	6423
1982	764	6179	2	6945
1983	810	6408	0	7218
1984	1013	6757	0	7770
1985	953	7353	0	8306
1986	956	6109	0	7065
1987	555	5818	0	6373
1988	534	4783	0	5317
1989	583	4548	0	5131
1990	547	4927	0	5474
1991	552	5607	0	6159
1992	1138	8444	0	9582
1993	1681	7466	0	9147
1994	955	4737	0	5692
1995	481	4333	0	4814
1996	372	3287	0	3659
1997	290	2225	0	2515
1998	228	2367	0	2595
1999	174	2621	0	2795
2000	224	2984	0	3208
2001	203	3482	0	3685
2002	158	3266	0	3424
2003	128	4435	0	4563
2004	85	3510	0	3595
2005	85	2670	0	2755
2006	89	1700	0	1789
2007	46	1532	0	1578

Table L2. Total United States nominal landings (mt, live) of white hake from the Gulf of Maine to Cape Hatteras (NAFO Subareas 5 and 6), 1893-1950.

Year	Landings	Year	Landings
1893	17424	1922	10894
1894	17121	1923	11222
1895	16227	1924	11214
1896	14332	1925	10462
1897	14239	1926	11177
1898	21669	1927	10392
1899	15275	1928	7798
1900	11977	1929	10840
1901	14090	1930	13976
1902	19198	1931	6678
1903	14927	1932	6991
1904	17525	1933	6021
1905	19039	1934	6214
1906	14910	1935	10225
1907	17134	1936	8947
1908	19170	1937	9399
1909	16177	1938	9384
1910	17603	1939	8222
1911	15548	1940	5982
1912	14745	1941	5001
1913	15788	1942	4985
1914	13068	1943	7426
1915	14623	1944	6155
1916	14469	1945	5876
1917	11003	1946	7398
1918	10048	1947	6159
1919	11862	1948	6660
1920	9615	1949	6123
1921	9787	1950	5492

Table L3. US nominal commercial landings (mt,live) and the annual percentage of total landings of white hake by gear type, 1964-2007.

	Landings (mt,live)					Percentage of Annual Landings				
Year	Line Trawl	Bottom Otter Trawl	Sink Gill Net	Other Gear	Total	Line Trawl	Bottom Otter Trawl	Sink Gill Net	Other Gear	Total
1964	1228	1681	99	8	3016	40.7	55.7	3.3	0.3	100
1965	1513	1034	64	4	2617	57.8	39.5	2.5	0.2	100
1966	704	755	99	5	1563	45.0	48.3	6.3	0.3	100
1967	326	730	67	4	1126	28.9	64.8	5.9	0.4	100
1968	265	825	116	3	1210	21.9	68.2	9.6	0.2	100
1969	228	1005	108	2	1343	17.0	74.8	8.0	0.1	100
1970	201	1474	129	4	1807	11.1	81.5	7.1	0.2	100
1971	532	1925	118	9	2583	20.6	74.5	4.6	0.3	100
1972	834	1717	384	11	2946	28.3	58.3	13.0	0.4	100
1973	840	1941	491	6	3279	25.6	59.2	15.0	0.2	100
1974	638	1852	1274	9	3773	16.9	49.1	33.8	0.2	100
1975	993	1356	1320	4	3672	27.0	36.9	35.9	0.1	100
1976	546	1606	1943	9	4104	13.3	39.1	47.3	0.2	100
1977	391	2316	2257	12	4976	7.9	46.5	45.4	0.2	100
1978	321	2183	2341	23	4869	6.6	44.8	48.1	0.5	100
1979	206	2058	1752	28	4044	5.1	50.9	43.3	0.7	100
1980	90	2656	1967	33	4746	1.9	56.0	41.4	0.7	100
1981	108	3473	2376	13	5970	1.8	58.2	39.8	0.2	100
1982	97	3860	2202	20	6179	1.6	62.5	35.6	0.3	100
1983	79	4868	1395	66	6408	1.2	76.0	21.8	1.0	100
1984	22	5158	1486	90	6757	0.3	76.3	22.0	1.3	100
1985	315	5508	1418	112	7353	4.3	74.9	19.3	1.5	100
1986	231	4671	1163	44	6109	3.8	76.5	19.0	0.7	100
1987	86	4798	911	24	5819	1.5	82.5	15.7	0.4	100
1988	85	3655	1008	35	4783	1.8	76.4	21.1	0.7	100
1989	15	2552	1892	88	4548	0.3	56.1	41.6	1.9	100
1990	78	3286	1508	54	4927	1.6	66.7	30.6	1.1	100
1991	249	3553	1616	189	5607	4.4	63.4	28.8	3.4	100
1992	948	5195	2262	40	8444	11.2	61.5	26.8	0.5	100
1993	1203	4656	1590	16	7466	16.1	62.4	21.3	0.2	100
1994	1186	2479	1065	7	4737	25.0	52.3	22.5	0.1	100
1995	764	2407	1123	39	4333	17.6	55.6	25.9	0.9	100
1996	307	2036	926	19	3287	9.3	61.9	28.2	0.6	100
1997	394	1284	543	5	2225	17.7	57.7	24.4	0.2	100
1998	326	1370	662	9	2367	13.8	57.9	28.0	0.4	100
1999	140	1535	922	23	2621	5.4	58.6	35.2	0.9	100
2000	95	1832	1042	15	2984	3.2	61.4	34.9	0.5	100
2001	48	2484	931	18	3482	1.4	71.3	26.8	0.5	100
2002	19	2445	776	25	3266	0.6	74.9	23.8	0.8	100
2003	93	2993	1341	7	4435	2.1	67.5	30.2	0.2	100
2004	49	2514	850	98	3510	1.4	71.6	24.2	2.8	100
2005	89	1730	660	191	2670	3.3	64.8	24.7	7.1	100
2006	7	1290	318	85	1700	0.4	75.9	18.7	5.0	100
2007	12	1019	384	117	1532	0.8	66.5	25.0	7.7	100

Table L4. Number of trips sampled and the resulting discards of white hake from sink gill net and otter trawl trips by the Domestic Observer Program, 1989-2007.

	SGN						OT					
	Half 1		Half 2		Total		Half 1		Half 2		Total	
YEAR	trips	discards	trips	discards	trips	discards	trips	discards	trips	discards	trips	discards
1989	1	2.3	106	21.8	107	24.1	72	171.6	104	509.7	176	681.3
1990	75	10.2	78	78.4	153	88.6	67	661.0	71	634.3	138	1295.3
1991	194	25.5	763	54.7	957	80.2	92	12.3	164	231.4	256	243.7
1992	497	37.3	690	84.0	1187	121.3	116	242.5	70	273.4	186	515.9
1993	348	56.4	422	153.7	770	210.0	37	70.1	29	564.8	66	634.9
1994	188	0.5	216	11.5	404	12.0	28	155.0	35	64.3	63	219.3
1995	298	1.2	239	27.2	537	28.4	81	50.1	144	116.0	225	166.1
1996	254	2.8	168	48.1	422	50.9	69	102.6	125	12.1	194	114.7
1997	257	4.8	132	27.3	389	32.1	72	76.9	40	91.1	112	168.0
1998	267	2.2	136	2.0	403	4.1	42	27.5	28	30.6	70	58.0
1999	88	12.7	101	5.4	189	18.2	42	3.4	66	556.5	108	559.9
2000	118	6.2	108	11.1	226	17.3	108	90.9	79	86.6	187	177.5
2001	98	1.4	69	47.2	167	48.6	110	131.1	172	164.4	282	295.5
2002	67	6.6	106	2.6	173	9.2	76	45.6	290	60.2	366	105.8
2003	162	6.4	330	7.7	492	14.2	267	34.5	290	216.3	557	250.8
2004	289	1.0	800	10.6	1089	11.5	371	26.9	688	65.4	1059	92.3
2005	260	3.9	744	14.2	1004	18.0	855	15.8	1013	50.9	1868	66.7
2006	136	2.0	115	13.0	251	14.9	542	19.9	382	24.4	924	44.4
2007	100	2.3	234	2.2	334	4.6	453	14.1	616	10.7	1069	24.8

Table L5. Summary of US Commercial white hake landings (mt), number of length samples (n), and number of fish measured (len) by market category and quarter from the Gulf of Maine to the Mid-Atlantic for all gear types, 1985-2006.

		small					medium					large					unclassified					All	Samplin
		Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Total	tensity
1985	mt	129	162	235	167	694	63	78	181	124	446	237	433	1135	623	2428	367	737	1690	988	3782	7349	272
	N		2	4	3	9					0		5	5	3	13		1	3	1	5	27	
	# fish		233	323	317	873					0		632	519	271	1422		101	293	104	498	2793	
1986	mt	59	134	105	100	398	86	89	55	54	284	274	422	835	417	1948	455	752	1578	694	3478	6107	235
	N	1	3	2	1	7	1	1		2	4	1	3	2	1	7	2	2	3	1	8	26	
	# fish	102	263	215	101	681	94	122		229	445	122	315	248	96	781	215	206	292	106	819	2726	
1987	mt	98	300	641	576	1616	13	49	122	123	306	171	326	943	372	1813	262	482	1035	301	2080	5814	194
	N		2	4	5	11		2	1	1	4		1	6	3	10	2	1	1	1	5	30	
	# fish		240	291	507	1038		203	91	109	403		111	518	236	865	218	140	112	125	595	2901	
1988	mt	181	549	893	397	2020	26	82	262	120	489	136	330	695	325	1486	73	137	437	134	782	4776	165
	N	5	6	3	5	19	1	1	1		3	1	1	2	1	5		1		1	2	29	
	# fish	558	764	240	478	2040	100	92	105		297	112	121	214	85	532		100		41	141	3010	
1989	mt	149	221	404	358	1132	41	54	124	68	287	188	473	904	470	2035	33	190	774	96	1092	4547	350
	N	1	1	2	2	6			1		1			2	2	4	1		1		2	13	
	# fish	91	94	213	195	593			103		103			206	204	410	100		106		206	1312	
1990	mt	207	411	885	450	1953	43	108	303	171	625	167	300	596	320	1382	24	182	580	176	962	4922	234
	N	3	4	4	2	13			2	1	3	2		1	1	4				1	1	21	
	# fish	309	408	399	151	1267			202	99	301	214		101	103	418				101	101	2087	
1991	mt	150	366	1215	612	2342	88	160	381	129	758	126	241	533	338	1238	52	358	714	138	1262	5601	156
	N	2	5	6	4	17	1	1	3	1	6	4	1	1	4	10		2	1		3	36	
	# fish	151	471	485	244	1351	103	100	382	100	685	375	99	96	539	1109		207	94		301	3446	
1992	mt	424	626	1735	848	3633	102	202	766	358	1428	231	351	699	371	1651	60	280	1246	141	1727	8439	211
	N	4	4	8	3	19	1	4	3	3	11		2	3	2	7	1		2		3	40	
	# fish	329	432	655	240	1656	80	388	266	317	1051		194	325	297	816	97		237		334	3857	
1993	mt	331	502	453	214	1500	161	397	1117	461	2136	173	476	795	416	1860	94	463	975	433	1965	7462	191
	N	2	5	4	1	12	2	3	2	1	8	2	3	7	2	14		2	2	1	5	39	
	# fish	150	504	275	50	979	184	309	196	95	784	199	262	676	175	1312		214	196	97	507	3582	
1994	mt	63	82	116	56	317	154	374	593	265	1386	206	481	687	407	1782	193	352	457	251	1252	4737	144
	N		2	4	1	7		2	3	3	8		3	4	2	9		2	4	3	9	33	
	# fish		167	386	100	653		230	305	272	807		303	363	304	970		236	431	372	1039	3469	
1995	mt	39	43	98	66	245	140	238	616	399	1393	197	398	595	374	1564	134	225	504	268	1130	4333	361
	N		1	1	1	3		2	2	1	5		2		1	3		1			1	12	
	# fish		107	97	105	309		191	222	111	524		221		103	324		100			100	1257	

Table L5 cont. Summary of US Commercial white hake landings (mt), number of length samples (n), and number of fish measured (len) by market category and quarter from the Gulf of Maine to the Mid-Atlantic for all gear types, 1985-2007.

1996	mt	23	34	80	43	181	96	207	531	269	1103	208	331	416	280	1234	110	152	339	169	769	3287	122
	N					0	1		4	4	9		2	4	5	11	1	1	3	2	7	27	
	# fish					0	101		435	541	1077		202	451	759	1412	127	72	326	220	745	3234	
1997	mt	31	58	124	83	295	76	113	370	193	752	146	146	438	335	1066	34	28	26	26	113	2225	32
	N	4	2	4	2	12	3	7	6	13	29	5	7	7	9	28				1	1	70	
	# fis	458	206	430	261	1355	276	694	564	1200	2734	541	720	678	896	2835				58	58	6982	
1998	mt	31	54	128	105	318	55	77	218	152	502	159	311	571	407	1449	28	23	34	14	100	2370	74
	N	1	2	1	1	5	3		3	2	8	7	2	8	1	18			1		1	32	
	# fis	53	220	120	59	452	327		402	305	1034	684	213	1311	110	2318			118		118	3922	
1999	mt	50	76	103	87	317	85	110	236	149	580	303	468	633	257	1661	11	14	25	16	66	2624	119
	N			1		1	1	1	3	4	9	1	6	2	3	12					0	22	
	# fish			119		119	111	102	315	313	841	166	665	202	327	1360					0	2320	
2000	mt	55	70	81	81	286	118	202	289	201	811	293	497	596	446	1833	14	15	20	12	60	2990	120
	N	4			1	5	5	1	5	4	15	1	1		3	5					0	25	
	# fis	428			123	551	527	106	573	450	1656	103	126		336	565					0	2772	
2001	mt	59	122	167	177	525	131	155	219	310	815	413	497	697	434	2041	10	22	57	12	101	3482	97
	N	2	3	2	2	9	2	1	2	2	7	3	4	7	6	20					0	36	
	# fis	231	329	213	224	997	221	100	235	215	771	328	456	797	660	2241					0	4009	
2002	mt	125	58	51	31	264	330	186	234	163	912	454	378	640	576	2047	7	14	15	6	43	3266	58
	N		2	1	11	14	6	4	4	7	21	7	4	7	3	21					0	56	
	# fish		154	103	968	1225	626	391	417	629	2063	768	372	665	335	2140					0	5428	
2003	mt	35	20	42	32	129	153	92	158	134	537	918	997	1066	743	3724	6	5	26	9	46	4435	46
	N	3	6	6	4	19	4	8	4	8	24	6	14	17	17	54					0	97	
	# fis	249	424	306	208	1187	355	768	387	796	2306	576	1369	1620	1665	5230					0	8723	
2004	mt	17	17	44	38	116	113	87	180	122	503	869	632	721	420	2642	5	53	98	88	245	3505	42
	N	2	3		7	12	5	5	2	6	18	20	14	5	15	54					0	84	
	# fis	83	162		445	690	383	456	211	579	1629	2062	1474	524	1213	5273					0	7592	
2005	mt	23	24	32	24	103	78	83	167	120	449	445	352	414	250	1461	269	148	136	105	658	2671	30
	N	7	7	8	6	28	3	5	6	5	19	9	10	8	11	38	1	1	1		3	88	
	# fis	349	360	400	313	1422	161	494	554	493	1702	825	924	738	973	3460	28	111	61		200	6784	
2006	mt	26	10	14	17	67	66	48	78	76	268	327	161	299	225	1012	192	47	48	66	354	1700	18
	N	6	9	5	9	29	5	3	6	6	20	12	13	9	10	44					0	93	
	# fis	372	398	254	547	1571	434	263	534	601	1832	958	1013	776	972	3719					0	7122	
						67																	
2007	mt	12	16	31	42	102	39	53	75	76	244	207	221	338	198	964	75	58	59	31	223	1532	15
	N	12	6	7	10	35	5	5	7	7	24	9	8	10	11	38	1	1			2	99	
	# fis	478	264	325	388	1455	396	386	428	618	1828	753	716	667	922	3058	100	101			201	6542	

Table L6. Summary of US Commercial red hake landings (mt), number of length samples (n), and number of fish measured (len) by quarter from the Gulf of Maine to the Mid-Atlantic for all gear types, 1985-2007.

		unclassified					Sampling
		Q1	Q2	Q3	Q4	sum	Intensity
1985	mt	175	494	637	398	1705	61
	N	6	6	8	8	28	
	# fish	669	513	711	802	2695	
1986	mt	303	585	543	671	2102	68
	N	5	11	8	7	31	
	# fish	339	944	770	777	2830	
1987	mt	328	632	559	438	1956	89
	N	5	3	10	4	22	
	# fish	486	300	920	260	1966	
1988	mt	286	498	467	482	1733	62
	N	5	9	6	8	28	
	# fish	516	762	633	639	2550	
1989	mt	153	539	467	392	1550	155
	N	1	2	2	5	10	
	# fish	111	201	200	519	1031	
1990	mt	140	543	581	332	1595	100
	N	5	2	3	6	16	
	# fish	502	258	309	573	1642	
1991	mt	197	439	493	481	1611	81
	N	8	7	1	4	20	
	# fish	860	667	100	413	2040	
1992	mt	395	586	575	471	2027	225
	N	1	3	1	4	9	
	# fish	101	299	101	414	915	
1993	mt	242	382	511	407	1541	308
	N	1	2	2		5	
	# fish	103	200	195		498	
1994	mt	253	427	541	387	1608	201
	N	3	1	1	3	8	
	# fish	299	120	67	289	775	
1995	mt	300	369	500	430	1599	145
	N	6	4	1		11	
	# fish	701	366	62		1129	
1996	mt	173	322	326	274	1094	547
	N			1	1	2	
	# fish			72	121	193	
1997	mt	339	357	310	314	1319	55
	N	14	7	1	2	24	
	# fish	1162	679	99	147	2087	

Table L6. Cont.

		unclassified					Sampling Intensity
		Q1	Q2	Q3	Q4	sum	
1998	mt	295	326	402	304	1327	74
	N	5	6	3	4	18	
	# fish	392	512	227	220	1351	
1999	mt	397	423	388	349	1557	87
	N	3	6	4	5	18	
	# fish	234	514	364	478	1590	
2000	mt	374	466	442	307	1589	227
	N	3			4	7	
	# fish	250			388	638	
2001	mt	493	583	360	236	1672	80
	N	5	6	7	3	21	
	# fish	440	570	660	255	1925	
2002	mt	188	215	308	197	908	91
	N	5	1	2	2	10	
	# fish	448	70	213	193	924	
2003	mt	169	168	243	228	808	37
	N	5	7	7	3	22	
	# fish	389	679	746	257	2071	
2004	mt	145	175	236	118	674	28
	N	4	3	12	5	24	
	# fish	370	385	1134	431	2320	
2005	mt	102	116	157	54	430	19
	N	8	3	5	7	23	
	# fish	696	334	491	717	2238	
2006	mt	80	117	186	69	453	16
	N	8	6	5	10	29	
	# fish	688	567	496	743	2494	
2007	mt	83	109	169	88	449	8
	N	11	19	9	15	54	
	# fish	982	1837	843	1200	4862	

Table L7. Number of trips sampled and the resulting discards of red hake from otter trawl trips by the Domestic Observer Program, 1989-2007.

	OT					
	Half 1		Half 2		Total	
	trips	discards	trips	discards	trips	discards
1989	72	1867.7	104	2143.9	176	4011.6
1990	67	3996.3	71	1122.1	138	5118.4
1991	92	1676.6	164	1283.8	256	2960.4
1992	116	4118.5	70	1485.3	186	5603.9
1993	37	1461.7	29	1075.8	66	2537.5
1994	28	186.8	35	544.2	63	730.9
1995	81	519.1	144	529.3	225	1048.4
1996	69	997.9	125	1110.9	194	2108.8
1997	72	3116.0	40	987.4	112	4103.3
1998	42	1574.1	28	6678.7	70	8252.9
1999	42	3060.5	66	950.1	108	4010.7
2000	108	2167.1	79	133.0	187	2300.1
2001	110	2051.7	172	73.9	282	2125.6
2002	76	28.7	290	330.6	366	359.3
2003	267	80.2	290	141.5	557	221.7
2004	371	249.0	688	400.5	1059	649.5
2005	855	267.5	1013	555.1	1868	822.6
2006	542	598.9	382	760.9	924	1359.8
2007	453	1456.0	616	1004.4	1069	2460.4

Table L8. Number of length samples taken for white hake from sink gill net and otter trawl trips by the Domestic Observer Program, 1989-2007.

		SGN						OT						Grand	
		Half 1		Half 2		Total		Half 1		Half 2		Total		Total	
		Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc
1989	trips			14	1	14	1	4	10	3	19	7	29	21	30
	len			512	2	512	2	123	916	154	1734	277	2650	789	2652
1990	trips	6		8	1	14	1	3	4	1	5	4	9	18	10
	len	206		1197	32	1403	32	68	53	138	312	206	365	1609	397
1991	trips	20	1	89	7	109	8	2	1	3	2	5	3	114	11
	len	2526	134	9973	30	12499	164	53	180	413	45	466	225	12965	389
1992	trips	34	1	182	4	216	5	7	6	2	4	9	10	225	15
	len	1620	1	8473	4	10093	5	265	17	59	144	324	161	10417	166
1993	trips	26	1	129	10	155	11	8	20	5	2	13	22	168	33
	len	1276	1	4001	13	5277	14	681	333	658	44	1339	377	6616	391
1994	trips	10		81	3	91	3	12	37	8	7	20	44	111	47
	len	44		1835	12	1879	12	247	570	489	294	736	864	2615	876
1995	trips	9	1	117	7	126	8	12	49	9	10	21	59	147	67
	len	167	1	2638	30	2805	31	1111	1375	697	372	1808	1747	4613	1778
1996	trips	11	2	78	2	89	4	8	16	6	13	14	29	103	33
	len	70	13	826	3	896	16	284	526	331	381	615	907	1511	923
1997	trips	8		24	2	32	2	5	9	6	6	11	15	43	17
	len	85		427	4	512	4	117	93	110	64	227	157	739	161
1998	trips	8		31	1	39	1	3	2	1	1	4	3	43	4
	len	36		411	1	447	1	39	17	12	2	51	19	498	20
1999	trips	6		17	3	23	3	1		7	17	8	17	31	20
	len	79		218	20	297	20	23		113	287	136	287	433	307
2000	trips	7	2	5		12	2	7	5	15	10	22	15	34	17
	len	47	9	143		190	9	421	119	475	76	896	195	1086	204
2001	trips	1	1	6	1	7	2	1	1	4		5	1	12	3
	len	15	3	4501	2	4516	5	46	43	2217		2263	43	6779	48
2002	trips	1		10	1	11	1	4		35	15	39	15	50	16
	len	1		49	2	50	2	125		1050	189	1175	189	1225	191
2003	trips	8	2	38	6	46	8	55	14	57	16	112	30	158	38
	len	16	5	362	24	378	29	2353	83	2477	246	4830	329	5208	358
2004	trips	5	4	125	17	130	21	50	26	80	49	130	75	260	96
	len	28	6	1826	67	1854	73	1733	336	2147	733	3880	1069	5734	1142
2005	trips	6		155	10	161	10	158	61	131	72	289	133	450	143
	len	16		2225	21	2241	21	3442	597	3988	1075	7430	1672	9671	1693
2006	trips	10	2	24	1	34	3	81	35	54	25	135	60	169	63
	len	63	2	159	2	222	4	2231	535	1591	419	3822	954	4044	958
2007	trips	3	1	25	1	28	2	54	29	64	40	118	69	146	71
	len	40	6	177	5	217	11	740	292	1427	252	2167	544	2384	555

Table L9. Number of length samples taken for white hake from shrimp trawl and scallop dredge trips by the Domestic Observer Program, 1989-2007.

		ST						SD						Grand	
		Half 1		Half 2		Total		Half 1		Half 2		Total		Total	
		Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc
1989	trips		2				2								
	len		200				200								
1990	trips		1				1								
	len		37				37								
1991	trips	1				1									
	len	52				52									
1992	trips	1	6		3	1	9								
	len	37	17		58	37	75								
1993	trips		17				17		1	1		1	1	1	18
	len		282				282		1	1		1	1	1	283
1994	trips		30		4		34		1		3		4		38
	len		517		256		773		1		3		4		777
1995	trips		37				37		2	1	1	1	3	1	40
	len		958				958		51	1	73	1	124	1	1082
1996	trips		9		2		11				1		1		12
	len		325		15		340				1		1		341
1997	trips										1		1		1
	len										1		1		1
1998	trips							1	1		5	1	6	1	6
	len							1	5		63	1	68	1	68
1999	trips										3		3		3
	len										35		35		35
2000	trips								1				1		1
	len								2				2		2
2001	trips														
	len														
2002	trips														
	len														
2003	trips		1				1		1				1		2
	len		1				1		2				2		3
2004	trips			1		1			1		6		7		8
	len			111		111			6		212		218		329
2005	trips	2	5			2	5			1	5	1	5	3	10
	len	157	28			157	28			1	64	1	64	158	92
2006	trips		4				4			1	2	1	2	1	6
	len		131				131			1	5	1	5	1	136
2007	trips		3				3		1		1		2		5
	len		43				43		1		15		16		59

Table L10. Number of length samples taken for red hake from sink gill net and otter trawl trips by the Domestic Observer Program, 1989-2007.

		SGN						OT						Grand	
		Half 1		Half 2		Total		Half 1		Half 2		Total		Total	
		Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc
1989	trips				1		1		14	3	11	3	25	3	26
	len				1	512	1		1352	297	859	297	2211	297	2212
1990	trips					14	0		4	2	5	2	9	2	9
	len					1403	0		383	157	755	157	1138	157	1138
1991	trips	2	1	1	6	109	7		1	2	10	2	11	5	18
	len	2	2	21	7	12499	9		45	151	643	151	688	174	697
1992	trips	9	2	8	1	216	3	7	13	9	5	16	18	33	21
	len	12	4	16	1	10093	5	633	2190	624	536	1257	2726	1285	2731
1993	trips	2		2	1	155	1	3	4	2	6	5	10	9	11
	len	2		6	1	5277	1	228	741	250	680	478	1421	486	1422
1994	trips	2	1	5	1	91	2	1	4	1	3	2	7	9	9
	len	2	1	13	2	1879	3	42	136	3	27	45	163	60	166
1995	trips			6		126	0	2	4	12	4	14	8	20	8
	len			8		2805	0	80	102	972	42	1052	144	1060	144
1996	trips	1	2	3	2	89	4			1	15	1	15	5	19
	len	1	2	30	4	896	6			17	1187	17	1187	48	1193
1997	trips					32	0	1	4	1	7	2	11	2	11
	len					512	0	122	203	2	874	124	1077	124	1077
1998	trips	2				39	0		4		2	0	6	2	6
	len	2				447	0		442		251	0	693	2	693
1999	trips	1	1	2	3	23	4		2	1	7	1	9	4	13
	len	1	2	20	5	297	7		210	13	302	13	512	34	519
2000	trips		3		1	12	4		5		6	0	11	0	15
	len		22		1	190	23		540		158	0	698	0	721
2001	trips	1	1	2	1	7	2		3		1	0	4	3	6
	len	18	3	16	3	4516	6		21		99	0	120	34	126
2002	trips		1	3	2	11	3		1	19	25	19	26	22	29
	len		1	12	6	50	7		26	870	544	870	570	882	577
2003	trips	3	9		2	46	11	2	17	4	15	6	32	9	43
	len	5	12		5	378	17	114	232	57	442	171	674	176	691
2004	trips		9	4	16	130	25	4	14	9	58	13	72	17	97
	len		12	27	29	1854	41	96	460	366	2380	462	2840	489	2881
2005	trips		1	2	6	161	7	6	51	13	60	19	111	21	118
	len		1	3	10	2241	11	42	1021	655	2175	697	3196	700	3207
2006	trips				2	34	2	3	30	6	24	9	54	9	56
	len				2	222	2	5	530	614	1322	619	1852	619	1854
2007	trips					0	0	13	26	8	23	21	49	21	49
	len					0	0	641	1248	592	1366	1233	2614	1233	2614

Table L11. Number of length samples taken for red hake from shrimp trawl and scallop dredge trips by the Domestic Observer Program, 1989-2007.

		ST						SD						Grand	
		Half 1		Half 2		Total		Half 1		Half 2		Total		Total	
		Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc
1989	trips	1	11	1		2	11							2	11
	len	40	1815	135		175	1815							175	1815
1990	trips	1	2			1	2							1	2
	len	48	160			48	160							48	160
1991	trips	2				2								2	0
	len	98				98								98	0
1992	trips		7		2		9								9
	len		39		152		191								191
1993	trips		1				1		1				1		2
	len		2				2		4				4		6
1994	trips		1		3		4				3		3		7
	len		1		116		117				51		51		168
1995	trips		12		1		13		1				1		14
	len		136		3		139		2				2		141
1996	trips		7		1		8				2		2		10
	len		151		32		183				7		7		190
1997	trips		6				6		1		1		2		8
	len		104				104		184		7		191		295
1998	trips														0
	len														0
1999	trips								1		2		3		3
	len								1		36		37		37
2000	trips								4		2		6		6
	len								202		3		205		205
2001	trips														0
	len														0
2002	trips										3		3		3
	len										115		115		115
2003	trips		2				2		2		3		5		7
	len		7				7		3		207		210		217
2004	trips		3				3		2		10		12		15
	len		48				48		28		186		214		262
2005	trips		2				2				8		8		10
	len		82				82				219		219		301
2006	trips		1		1		2				7		7		9
	len		1		34		35				21		21		56
2007	trips		2				2								2
	len		30				30								30

Table L12. Catch (landings and discards) used in assessment from 1963-2007. The value for 1963 was estimated using a linear ramp down from 1950-1964.

Year	Landings	Year	Landings
1963	4100	1986	9270
1964	3995	1987	8362
1965	3434	1988	6976
1966	2051	1989	7955
1967	1498	1990	8154
1968	1699	1991	8215
1969	1815	1992	12602
1970	2799	1993	10342
1971	3801	1994	7108
1972	4127	1995	5791
1973	4462	1996	4108
1974	5255	1997	3391
1975	5010	1998	3724
1976	5641	1999	4462
1977	7196	2000	4375
1978	6630	2001	5998
1979	5641	2002	3763
1980	6630	2003	5081
1981	8428	2004	4229
1982	9112	2005	3136
1983	9471	2006	2256
1984	10195	2007	2163
1985	10898		

Table L13. Catch-at-age and mean weight-at-age for white hake from 1989-2007. Catches-at-age from 2001 are based on a pooled age-length key.

Year	1	2	3	4	5	6	7	8	9+
1989	493	2178	3150	932	542	243	30	32	12
1990	345	4840	3528	1289	316	97	43	12	19
1991	481	3540	2596	1322	358	116	37	11	18
1992	227	3651	4817	3067	423	204	127	26	12
1993	1322	2452	2326	2483	622	181	18	6	12
1994	116	915	1846	1270	500	231	42	24	8
1995	74	1928	2030	806	309	147	41	19	22
1996	388	635	724	510	389	237	68	22	8
1997	1326	946	881	260	294	162	93	33	11
1998	3349	1705	554	189	155	176	168	36	1
1999	376	1196	2112	281	236	151	97	75	45
2000	18	1800	1407	244	224	136	98	104	83
2001	3	155	1801	1257	274	178	90	47	25
2002	234	178	302	421	377	197	56	21	7
2003	44	372	481	224	241	298	183	78	34
2004	82	655	483	176	163	163	134	95	47
2005	255	408	276	183	166	133	63	54	45
2006	186	888	333	114	105	96	38	25	31
2007	109	717	425	175	108	86	35	16	21

Year	1	2	3	4	5	6	7	8	9+
1989	0.101	0.370	0.738	1.770	2.944	4.052	6.099	6.684	11.580
1990	0.142	0.287	0.713	1.731	3.072	4.203	5.536	7.977	13.671
1991	0.174	0.302	0.865	1.606	2.667	3.582	6.136	8.170	13.213
1992	0.192	0.271	0.696	1.547	3.318	5.017	5.426	7.571	14.041
1993	0.094	0.227	0.892	1.811	3.131	4.439	6.530	8.447	14.288
1994	0.103	0.400	0.759	1.804	2.912	4.340	6.347	8.385	12.904
1995	0.124	0.445	0.927	1.665	2.464	3.176	4.491	6.519	**11.676**
1996	0.083	0.304	0.781	1.746	2.696	3.585	4.330	7.126	10.448
1997	0.107	0.249	0.552	1.739	2.637	3.519	4.616	6.273	8.726
1998	0.105	0.216	0.708	1.752	2.806	3.912	5.138	7.765	10.132
1999	0.155	0.286	0.513	1.724	2.534	3.670	5.043	6.406	8.234
2000	0.175	0.287	0.449	1.710	2.594	3.321	4.602	6.606	7.716
2001	0.207	0.431	0.768	1.397	3.075	4.706	6.199	7.093	8.754
2002	0.127	0.398	0.958	1.970	3.137	4.292	5.689	6.559	7.683
2003	0.150	0.351	0.656	1.960	3.387	4.873	6.098	6.857	8.040
2004	0.156	0.329	0.670	1.936	3.436	4.843	6.491	7.541	8.613
2005	0.120	0.297	0.680	2.035	3.319	4.562	6.146	7.822	10.048
2006	0.149	0.255	0.590	1.842	3.548	4.672	5.959	7.556	11.737
2007	0.147	0.312	0.630	1.657	3.457	4.661	5.976	7.046	12.920

Table L14. Rivard Jan-1 weights-at-age for white hake from 1989-2007.

Year	1	2	3	4	5	6	7	8	9+
1989	0.060	0.267	0.482	1.344	2.464	3.467	5.333	6.385	11.580
1990	0.097	0.170	0.514	1.130	2.332	3.518	4.736	6.975	13.671
1991	0.139	0.207	0.498	1.070	2.149	3.317	5.078	6.725	13.213
1992	0.177	0.217	0.459	1.157	2.308	3.658	4.409	6.816	14.041
1993	0.046	0.209	0.492	1.123	2.201	3.838	5.724	6.770	14.288
1994	0.050	0.194	0.415	1.269	2.296	3.686	5.308	7.400	12.904
1995	0.079	0.214	0.609	1.124	2.108	3.041	4.415	6.432	11.676
1996	0.048	0.194	0.590	1.272	2.119	2.972	3.708	5.657	10.448
1997	0.075	0.144	0.410	1.165	2.146	3.080	4.068	5.212	8.726
1998	0.064	0.152	0.420	0.983	2.209	3.212	4.252	5.987	10.132
1999	0.114	0.173	0.333	1.105	2.107	3.209	4.442	5.737	8.234
2000	0.112	0.211	0.358	0.937	2.115	2.901	4.110	5.772	7.716
2001	0.149	0.275	0.470	0.792	2.293	3.494	4.537	5.713	8.754
2002	0.076	0.287	0.643	1.230	2.093	3.633	5.174	6.377	7.683
2003	0.101	0.211	0.511	1.370	2.583	3.910	5.116	6.246	8.040
2004	0.113	0.222	0.485	1.127	2.595	4.050	5.624	6.781	8.613
2005	0.082	0.215	0.473	1.168	2.535	3.959	5.456	7.126	10.048
2006	0.103	0.175	0.419	1.119	2.687	3.938	5.214	6.815	11.737
2007	0.100	0.216	0.401	0.991	2.524	4.067	5.284	6.480	12.921

Table L15. Stratified mean catch per tow in numbers and weight (kg) for white hake from NEFSC offshore spring and autumn research vessel bottom trawl surveys (strata 21-30,33-40), 1963-2008. The mean length shown is in cm.

	Spring			Autumn		
Year	No/Tow	Wt/Tow	Length	No/Tow	Wt/Tow	Length
1963				5.00	6.31	46.2
1964				1.77	4.14	56.3
1965				4.39	6.86	50.4
1966				6.79	7.67	45.1
1967				3.92	3.64	42.6
1968	1.60	1.74	44.1	4.24	4.54	44.9
1969	3.76	5.09	46.3	9.24	13.09	46.8
1970	5.84	11.86	52.9	8.05	12.82	51.3
1971	3.31	5.14	51.3	10.38	12.10	43.6
1972	10.18	12.66	47.3	12.52	13.10	45.2
1973	9.24	12.22	49.9	9.05	13.46	51.7
1974	8.08	13.99	55.0	5.35	11.00	54.5
1975	9.32	11.22	44.7	5.28	7.23	48.5
1976	9.98	17.01	52.7	6.04	10.56	54.7
1977	6.13	11.01	55.5	9.78	13.74	47.8
1978	3.22	6.14	51.8	7.87	12.54	50.2
1979	5.26	4.97	43.0	5.62	10.31	53.1
1980	10.38	13.96	49.7	10.86	16.66	48.8
1981	17.09	19.92	45.9	8.70	12.16	49.9
1982	6.06	8.91	51.0	1.96	2.11	46.7
1983	3.23	3.12	43.7	8.22	10.79	48.8
1984	2.75	4.17	51.4	5.32	8.23	51.9
1985	4.33	5.38	48.5	9.37	9.74	42.9
1986	8.24	5.61	40.0	14.42	11.56	41.9
1987	7.15	6.44	45.3	7.59	9.62	49.2
1988	4.52	3.69	41.9	8.12	9.88	46.1
1989	3.65	3.22	43.0	11.76	9.23	40.5
1990	11.11	18.37	53.3	13.09	10.58	41.5
1991	8.42	6.14	41.6	13.22	12.20	44.6
1992	7.59	7.11	45.1	10.16	11.24	47.7
1993	7.93	6.84	45.1	11.35	11.66	45.2
1994	4.59	3.17	40.1	8.44	7.02	42.3
1995	4.38	4.02	44.1	9.54	8.20	40.8
1996	2.87	3.07	45.9	4.52	6.35	51.2
1997	1.88	0.89	38.4	4.69	4.55	41.5
1998	2.25	1.09	37.7	4.41	4.27	44.5
1999	3.32	2.97	44.6	5.68	3.44	36.3
2000	5.19	3.33	40.4	7.57	6.72	43.8
2001	4.81	5.18	48.4	5.74	7.97	52.7
2002	5.13	6.32	49.0	6.91	6.73	42.0
2003	5.16	5.73	46.5	4.58	4.91	44.6
2004	4.91	5.19	46.0	3.55	3.72	44.8
2005	3.78	5.52	48.8	3.32	3.59	45.5
2006	2.56	1.46	36.8	4.69	4.18	43.1
2007	2.30	2.64	47.3	6.36	6.56	46.6
2008	6.33	3.77	39.3			

Table L16. Stratified mean number per tow at age of white hake in the NEFSC bottom trawl spring survey (Strata 21-30,33-40), 1982-2008. The years for which a pooled age-length key has been applied are indicated in bold.

	Age														
Year	0	1	2	3	4	5	6	7	8	9	10+	Total	9+	1+	1+ Abundance
1982	0.0000	0.0559	0.8951	2.7397	0.8080	1.1785	0.2447	0.0205	0.0341	0.0177	0.0618	6.0560	0.0795	6.0560	14007.204
1983	0.0000	0.0658	1.0135	1.2366	0.5966	0.1495	0.0854	0.0435	0.0339	0.0000	0.0000	3.2248	0.0000	3.2248	7458.790
1984	0.0000	0.0193	0.4363	1.0334	0.5940	0.4108	0.1602	0.0479	0.0352	0.0000	0.0156	2.7527	0.0156	2.7527	6366.848
1985	0.0000	0.0605	0.8190	1.7399	1.1089	0.4023	0.1100	0.0298	0.0189	0.0000	0.0388	4.3281	0.0388	4.3281	10010.663
1986	0.0000	0.1429	3.2192	3.1799	1.0404	0.4654	0.1794	0.0000	0.0153	0.0000	0.0000	8.2425	0.0000	8.2425	19064.461
1987	0.0000	0.0196	1.3290	4.1538	1.1008	0.3596	0.1181	0.0000	0.0313	0.0000	0.0326	7.1448	0.0326	7.1448	16525.540
1988	0.0000	0.1813	1.6423	1.2877	0.8169	0.3738	0.1099	0.0221	0.0697	0.0000	0.0139	4.5176	0.0139	4.5176	10448.967
1989	0.0000	0.0663	1.2371	1.5201	0.2697	0.3827	0.1540	0.0203	0.0000	0.0000	0.0000	3.6502	0.0000	3.6502	8442.717
1990	0.0000	0.0706	1.7355	2.3733	4.3770	1.8403	0.2864	0.1086	0.1417	0.0589	0.1178	11.1101	0.1767	11.1101	25697.066
1991	0.0000	0.2341	2.7823	2.4390	1.7550	0.8637	0.2549	0.0439	0.0153	0.0000	0.0276	8.4158	0.0276	8.4158	19465.295
1992	0.0000	0.0000	0.8169	2.5201	3.8107	0.3157	0.0879	0.0337	0.0084	0.0000	0.0000	7.5934	0.0000	7.5934	17563.127
1993	0.0000	0.0362	2.0586	3.1199	2.2549	0.4293	0.0276	0.0000	0.0000	0.0000	0.0000	7.9265	0.0000	7.9265	18333.570
1994	0.0000	0.0335	1.6935	1.8829	0.6658	0.1965	0.0831	0.0080	0.0224	0.0000	0.0000	4.5857	0.0000	4.5857	10606.478
1995	0.0000	0.1134	0.8956	2.1134	0.7609	0.2467	0.1499	0.0331	0.0638	0.0000	0.0000	4.3768	0.0000	4.3768	10123.304
1996	0.0000	0.2441	0.4780	1.0302	0.5293	0.4181	0.0978	0.0188	0.0298	0.0261	0.0000	2.8722	0.0261	2.8722	6643.245
1997	0.0000	0.0360	0.6734	0.8669	0.2508	0.0479	0.0000	0.0000	0.0000	0.0000	0.0000	1.8750	0.0000	1.8750	4336.775
1998	0.0000	0.0127	1.1398	0.8587	0.1591	0.0641	0.0126	0.0000	0.0000	0.0000	0.0000	2.2470	0.0000	2.2470	5197.191
1999	0.0000	0.0417	0.5923	1.5783	0.6007	0.3522	0.0832	0.0499	0.0084	0.0000	0.0000	3.3067	0.0000	3.3067	7648.210
2000	0.0000	0.1057	1.5878	2.4689	0.6951	0.2369	0.0790	0.0124	0.0000	0.0000	0.0000	5.1858	0.0000	5.1858	11994.478
2001	0.0000	0.0426	0.5178	2.0788	1.4451	0.4426	0.1839	0.0160	0.0317	0.0196	0.0310	4.8091	0.0506	4.8091	11123.191
2002	0.0000	0.0380	1.4163	0.9713	1.4177	1.0753	0.1328	0.0077	0.0347	0.0238	0.0114	5.1291	0.0352	5.1291	11863.255
2003	0.0000	0.0226	1.3396	1.6120	0.7166	0.7947	0.4727	0.0776	0.0196	0.0000	0.0103	5.0657	0.0103	5.0657	11716.693
2004	0.0000	0.0472	1.1934	1.9781	0.8486	0.5110	0.1617	0.0722	0.0853	0.0128	0.0010	4.9113	0.0138	4.9113	11359.605
2005	0.0000	0.1077	0.9615	1.0570	0.8013	0.4092	0.1250	0.0945	0.1582	0.0497	0.0150	3.7792	0.0647	3.7792	8741.013
2006	0.0000	0.1642	1.3036	0.6817	0.2006	0.1273	0.0471	0.0060	0.0249	0.0038	0.0000	2.5592	0.0038	2.5592	5919.239
2007	0.0000	0.0341	0.4589	0.9053	0.5339	0.1993	0.0937	0.0359	0.0152	0.0067	0.0135	2.2966	0.0203	2.2966	5311.811
2008	0.0000	0.3307	2.3368	2.1491	1.1832	0.2408	0.0722	0.0121	0.0050	0.0020	0.0015	6.3333	0.0035	6.3333	14648.653

Table L17. Stratified mean number per tow at age of white hake in the NEFSC bottom trawl autumn surveys (Strata 21-30,33-40), 1982-2007. The years for which a pooled age-length key has been applied are indicated in bold.

Year	0	1	2	3	4	5	6	7	8	9	10+	Total	9+	1+	1+ Abundance
1982	0.0043	0.3170	0.5152	0.7349	0.2107	0.1048	0.0577	0.0171	0.0000	0.0000	0.0000	1.9617	0.0000	1.9574	4527.361
1983	0.0000	0.5652	2.8285	2.6364	1.6096	0.2440	0.2413	0.0076	0.0000	0.0139	0.0696	8.2161	0.0835	8.2161	19003.399
1984	0.0000	0.3774	1.0913	2.1531	1.1271	0.3589	0.1357	0.0292	0.0107	0.0000	0.0346	5.3180	0.0346	5.3180	12300.249
1985	0.3101	2.9641	1.8769	2.0345	1.4613	0.4341	0.1397	0.0685	0.0245	0.0000	0.0517	9.3654	0.0517	9.0553	20944.424
1986	0.8543	1.1644	6.6635	4.0970	0.8765	0.4968	0.1413	0.0831	0.0000	0.0281	0.0153	14.4203	0.0434	13.5660	31377.431
1987	0.0633	0.5314	1.6312	3.7002	1.0633	0.2483	0.1572	0.0804	0.0452	0.0390	0.0314	7.5909	0.0704	7.5276	17410.936
1988	0.0000	0.5094	3.7547	2.0666	1.2842	0.3477	0.1104	0.0000	0.0000	0.0000	0.0448	8.1178	0.0448	8.1178	18776.037
1989	0.2911	3.0347	3.2924	3.4743	0.8438	0.4093	0.3410	0.0441	0.0196	0.0000	0.0057	11.7560	0.0057	11.4649	26517.700
1990	0.9693	1.8051	4.8687	3.6504	1.4762	0.2934	0.0222	0.0000	0.0000	0.0000	0.0000	13.0853	0.0000	12.1160	28023.659
1991	0.1897	1.1341	5.8094	4.3180	1.3777	0.3326	0.0431	0.0000	0.0196	0.0000	0.0000	13.2242	0.0000	13.0345	30148.100
1992	0.1454	0.4136	2.3525	5.5875	1.2894	0.1618	0.1287	0.0346	0.0299	0.0000	0.0196	10.1630	0.0196	10.0176	23170.172
1993	0.1559	1.4687	2.6703	4.1235	2.3872	0.4213	0.1202	0.0000	0.0000	0.0000	0.0000	11.3471	0.0000	11.1912	25884.646
1994	0.3556	0.9621	2.8374	2.9629	0.9868	0.2072	0.1024	0.0204	0.0000	0.0000	0.0000	8.4348	0.0000	8.0792	18686.757
1995	1.1788	0.5332	3.9421	2.8394	0.7083	0.1930	0.0124	0.1070	0.0000	0.0000	0.0302	9.5444	0.0302	8.3656	19349.185
1996	0.0239	0.2953	1.0225	1.5424	1.2022	0.3342	0.0276	0.0274	0.0248	0.0000	0.0160	4.5163	0.0160	4.4924	10390.681
1997	0.0000	1.6117	1.2346	0.9233	0.5920	0.1766	0.0640	0.0124	0.0196	0.0000	0.0558	4.6900	0.0558	4.6900	10847.719
1998	0.0356	0.3728	1.7562	1.4964	0.4728	0.1455	0.0797	0.0336	0.0159	0.0000	0.0000	4.4084	0.0000	4.3728	10114.052
1999	0.3428	2.2359	1.2231	1.1093	0.5024	0.1951	0.0643	0.0035	0.0000	0.0000	0.0000	5.6764	0.0000	5.3336	12336.331
2000	0.1158	0.5175	3.4850	2.2224	0.6976	0.3171	0.0874	0.0410	0.0430	0.0174	0.0224	7.5666	0.0398	7.4508	17233.301
2001	0.0080	0.1420	0.5833	3.1547	1.5129	0.2216	0.0698	0.0178	0.0112	0.0107	0.0068	5.7386	0.0175	5.7307	13254.724
2002	0.034	2.7951	1.1104	0.8529	1.315	0.3727	0.0718	0.0124	0.0000	0.0124	0.0000	6.5767	0.0124	6.5427	15132.915
2003	0.0283	1.1844	1.0789	1.1644	0.7103	0.2110	0.1448	0.0485	0.0054	0.0000	0.0000	4.5761	0.0000	4.5478	10518.743
2004	0.0248	0.3739	1.5348	0.9560	0.3892	0.1409	0.0606	0.0255	0.0132	0.0078	0.0208	3.5474	0.0286	3.5225	8147.446
2005	0.0316	0.6346	0.9799	0.8289	0.5011	0.2409	0.0573	0.0164	0.0123	0.0039	0.0078	3.3147	0.0117	3.2831	7593.536
2006	0.0107	0.5591	2.3562	1.0113	0.4753	0.1867	0.0583	0.0177	0.0000	0.0000	0.0164	4.6918	0.0164	4.6810	10826.970
2007	0.0684	0.5021	1.8013	2.8207	0.9616	0.1343	0.0339	0.0014	0.0010	0.0004	0.0359	6.3611	0.0363	6.2926	14554.474

Table L18. Definitions of symbols used in presenting results. Unless otherwise indicated biomasses are "deterministic", i.e. as estimated in the model fit, prior to any bias adjustment for recruitment variability.

'-lnL:overall	Total negative log-likelihood
-lnL:Survey/CAAcom/CAAsurv /CALsurv/RecRes	Contributed to -lnL from survey indices/survey catch-at-age proportions/survey catch-at-length proportions/commercial catch-at-age proportions/ recruitment residuals
h	Stock recruitment curve steepness
γ	Parameter of generalised Ricker S/R function (γ=1 for Ricker)
θ	B^{sp}/K^{sp} for starting year
ϕ	$Z_a \approx M_a + \phi$ for starting year
K^{sp}	Pristine spawning biomass
B^{sp}_{2007}	Spawning biomass in 2007
MSYL^{sp}	$B^{sp}_{\mathrm{MSY}}/K^{sp}$
B^{sp}_{MSY}	Spawning biomass at MSY
B^{*sp}_{MSY}	Spawning biomass at MSY adjusted for recruitment variability by multiplying by $\exp(\sigma_R \mathrm{out}^2/2)$
MSY	Maximum sustainable yield
$MSY*$	MSY adjusted for recruitment variability as above
F_{MSY}	Fishing mortality rate (F) at MSY (corresponds to F at the age at which commercial selectivity = 1, which here is age 6)
$F_{rebuild}$	F to achieve 50% probability that B^{sp} recovers to B^{*sp}_{MSY} by 2014
F_{2007}	F for year 2007
$F_{40\%}$	F at which B^{sp}/R (R = recruitment) equals 40% of its value when F=0
B^{*sp}_{MSY}_40%	Spawning biomass corresponding to $F_{40\%}$; evaluated as (B^{sp}/R for $F_{40\%}$)$\overline{R}$ where $\overline{R}$ is average of recruitment estimates
$MSY*$_40%	MSY corresponding to $F_{40\%}$; evaluated as (Y/R for $F_{40\%}$)$\overline{R}$; shown with * as based on average over fluctuations
K^{sp} (av. rec.)	Pristine biomass corresponding to recruitment constant at $\overline{R}$
MSYL^{sp} (av. rec.)	$B^{sp}_{\mathrm{MSY}}/K^{sp}$ (av. rec.)
$F_{rebuild}$ (av. rec.)	F to achieve 50% probability that B^{sp} recovers to B^{*sp}_{MSY}_40% by 2014
C_{2008}	Catch in 2008, assumed equal to 2007 catch
C_{2009} (F_{MSY})	Projected 2009 catch under F_{MSY}
C_{2009} ($F_{\text{status quo}}$)	Projected 2009 catch under F_{2009}=F_{2008}
C_{2009} (F_{rebuild})	Projected 2009 catch under $F_{rebuild}$
C_{2009} (F_{rebuild} (av. rec.))	Projected 2009 catch under $F_{rebuild}$ - av. rec.
q spring/autumn	Multiplicative bias for spring/autumn NEFSC survey swept-area-based biomass estimate relative to actual survey selectivity-at-age weighted biomass
Slope_com/surv 6/7	Selectivity slope given by $S_7 = e^{-Slope} S_6$
$\sigma_R$out	Standard deviation of distribution of logs of multiplicative recruitment residuals about estimated S/R relationship
$M1/M9+$	Natural mortality rate for age 1/9+

Table L19. Overall negative log-likelihood and current spawning biomass relative to B^{*sp}_{MSY} for a series of θ and ϕ values for assessment A1. For the final column, θ is estimated rather than fixed.

ϕ = 0.1	θ	0.15	0.25	0.35	0.40
	'-lnL:overall	15.5	10.0	6.8	6.5
	$B^{sp}_{2007}/B^{sp}_{MSY}$	0.18	0.34	0.48	0.53
ϕ = 0.2	θ	0.15	0.25	0.35	0.26
	'-lnL:overall	12.9	8.3	9.9	8.3
	$B^{sp}_{2007}/B^{sp}_{MSY}$	0.27	0.48	0.60	0.50
ϕ = 0.4	θ	0.15	0.25	0.35	0.16
	'-lnL:overall	14.4	19.4	28.8	14.3
	$B^{sp}_{2007}/B^{sp}_{MSY}$	0.46	0.67	0.82	0.49

Table L20. Estimates of management quantities for white hake. Values in bold are inputs. Values in parenthesis are CVs: Hessian-based for MLE's and for Bayes posteriors for the Bayesian MCMC computations. Mass units are '000 tons. Note that the MLE's are Bayesian posterior modes for the estimable parameters of the model.

	Run A1: Reference Case 1 Domed survey sel, with survey CAL				Run A2: Reference Case 2 Domed survey sel, without survey CAL			
	MLE and Hessian-based CVs		Posterior medians and CVs		MLE and Hessian-based CVs		Posterior medians and CVs	
'-lnL:overall	8.3				-100.8			
'-lnL:Survey	-30.0				-32.2			
'-lnL:CAAcom	-13.4				-10.8			
'-lnL:CAAsurv	-52.0				-66.2			
'-lnL:CALsurv	89.5				-			
'-lnL:RecRes	14.2				8.4			
h	2.28	(0.17)	2.00	(0.10)	1.24	(0.27)	1.23	(0.09)
γ	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**	-
θ	0.26	(0.16)	0.27	(0.10)	0.19	(0.23)	0.20	(0.11)
ϕ	**0.20**	-	**0.20**	-	**0.20**	-	**0.20**	-
K^{sp}	62.0	(0.16)	69.1	(0.08)	116.5	(0.32)	113.3	(0.11)
B^{sp}_{2007}	13.8	(0.26)	15.8	(0.22)	19.8	(0.31)	20.8	(0.22)
B^{sp}_{2007}/K^{sp}	0.22	(0.25)	0.23	(0.21)	0.17	(0.28)	0.18	(0.20)
MSYL^{sp}	0.41	(0.13)	0.41	(0.01)	0.42	(0.15)	0.42	(0.01)
B^{sp}_{MSY}	25.6	(0.18)	28.5	(0.08)	49.1	(0.23)	47.8	(0.11)
B^{*sp}_{MSY}	27.7	(0.18)	30.7	(0.08)	51.5	(0.23)	51.3	(0.11)
$B^{sp}_{2007}/B^{*sp}_{\mathrm{MSY}}$	0.50	(0.25)	0.51	(0.22)	0.38	(0.24)	0.40	(0.20)
MSY	8.1	(0.07)	7.9	(0.06)	8.1	(0.12)	7.8	(0.08)
MSY^*	8.8	(0.07)	8.6	(0.06)	8.5	(0.12)	8.4	(0.08)
F_{MSY}	0.24	(0.00)	0.24	(0.10)	0.19	(0.00)	0.19	(0.08)
$F_{rebuild}$	0.261	-	0.261	-	0.130	-	0.134	-
F_{2007}	0.15	(0.26)	0.14	(0.23)	0.15	(0.21)	0.15	(0.21)
$F_{2007}/F_{\mathrm{MSY}}$	0.61	(0.26)	0.61	(0.25)	0.82	(0.21)	0.79	(0.23)
$F_{40\%}$	0.10	(0.00)	0.11	(0.07)	0.13	(0.00)	0.13	(0.06)
B^{*sp}_{MSY}_40%	52.0	(0.13)	52.0	(0.04)	56.3	(0.15)	56.3	(0.06)
MSY^*_40%	6.9	(0.08)	6.5	(0.03)	5.8	(0.04)	5.8	(0.03)
$B^{sp}_{2007}/B^{*sp}_{\mathrm{MSY}}$_40%	0.27	(0.23)	0.30	(0.21)	0.35	(0.21)	0.37	(0.19)
$F_{2007}/F_{40\%}$	1.40	(0.25)	1.27	(0.22)	1.21	(0.21)	1.17	(0.21)
K^{sp} (av. rec.)	130.1	(0.05)	130.2	(0.04)	140.8	(0.08)	141.0	(0.06)
MSYL^{sp} (av. rec.)	0.40	(0.10)	0.40	(0.00)	0.40	(0.07)	0.40	(0.00)
$F_{rebuild}$ (av. rec.)	0.080	-	0.080	-	0.078	-	0.078	-
C_{2008}	**2.2**	-	**2.2**	-	**2.2**	-	**2.2**	-
C_{2009} (F_{MSY})	6.7	(0.25)	6.1	(0.23)	4.9	(0.22)	4.8	(0.24)
C_{2009} ($F_{\mathrm{status\ quo}}$)	2.8	(0.03)	2.7	(0.04)	2.7	(0.04)	2.7	(0.05)
C_{2009} (F_{rebuild})	7.3	(0.25)	6.7	(0.23)	3.6	(0.22)	3.5	(0.23)
C_{2009} (F_{rebuild} (av. rec.))	2.3	(0.23)	2.3	(0.23)	2.2	(0.23)	2.2	(0.23)
q spring	1.04	(0.09)	1.00	(0.06)	1.09	(0.10)	1.07	(0.08)
q autumn	1.73	(0.08)	1.63	(0.07)	1.98	(0.10)	1.91	(0.09)
Slope_com 6/7	0.01	(0.15^{+})	0.09	(0.64)	0.35	(0.50)	0.36	(0.28)
Slope_surv 6/7	0.42	(0.38)	0.43	(0.29)	0.69	(0.25)	0.71	(0.23)
σ_R out	0.40	(0.09)	0.39	(0.06)	0.31	(0.10)	0.38	(0.08)

Selectivity	WHSpr	WHAut	Comm	WHSpr	WHAut	Comm	WHSpr	WHAut	Comm	WHSpr	WHAut	Comm
1	0.03	0.22	0.19	0.03	0.22	0.20	0.03	0.26	0.23	0.03	0.27	0.23
2	0.41	0.51	0.57	0.42	0.52	0.57	0.43	0.58	0.66	0.44	0.60	0.65
3	0.96	1.00	0.88	0.94	1.00	0.89	1.00	1.00	1.00	0.99	1.00	0.99
4	1.00	0.89	0.90	1.00	0.89	0.87	1.00	0.75	0.96	1.00	0.75	0.92
5	0.92	0.58	0.84	0.89	0.58	0.79	0.74	0.36	0.84	0.73	0.36	0.82
6	0.68	0.58	1.00	0.64	0.59	1.00	0.44	0.25	1.00	0.45	0.27	1.00
7	0.45	0.35	0.99	0.41	0.32	0.91	0.22	0.13	0.71	0.22	0.14	0.70
8	0.29	0.21	0.98	0.27	0.17	0.83	0.11	0.07	0.50	0.11	0.07	0.49
9+	0.19	0.12	0.97	0.17	0.10	0.76	0.06	0.04	0.35	0.05	0.04	0.34

Table L20 continued

	Run B1: Beverton-Holt Domed survey sel, with survey CAL				Run B2: Beverton-Holt Domed survey sel, without survey CAL			
	MLE and Hessian-based CVs		Posterior medians and CVs		MLE and Hessian-based CVs		Posterior medians and CVs	
'-lnL:overall	9.0				-100.6			
'-lnL:Survey	-29.4				-32.1			
'-lnL:CAAcom	-13.4				-10.7			
'-lnL:CAAsurv	-51.9				-66.4			
'-lnL:CALsurv	88.9				-			
'-lnL:RecRes	14.8				8.5			
h	0.98*	-	0.98	(0.00)	0.76	(0.14)	0.76	(0.09)
γ	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**	-
θ	0.12	(0.20)	0.16	(0.15)	0.10	(0.33)	0.10	(0.15)
ϕ	**0.20**	-	**0.20**	-	**0.20**	-	**0.20**	-
K^{sp}	140.6	(0.09)	140.2	(0.08)	243.0	(0.35)	229.9	(0.17)
B^{sp}_{2007}	15.4	(0.24)	18.2	(0.22)	20.4	(0.30)	22.7	(0.28)
B^{sp}_{2007}/K^{sp}	0.11	(0.23)	0.13	(0.22)	0.08	(0.38)	0.10	(0.24)
MSYL^{sp}	0.27	(0.11)	0.26	(0.03)	0.31	(0.10)	0.31	(0.05)
B^{sp}_{MSY}	38.6	(0.17)	37.2	(0.08)	76.5	(0.30)	71.8	(0.21)
B^{*sp}_{MSY}	42.0	(0.17)	40.1	(0.08)	80.3	(0.30)	76.7	(0.21)
$B^{sp}_{2007}/B^{*sp}_{\text{MSY}}$	0.37	(0.23)	0.45	(0.22)	0.25	(0.32)	0.29	(0.25)
MSY	7.5	(0.09)	6.9	(0.07)	8.6	(0.22)	8.1	(0.09)
MSY^*	8.2	(0.09)	7.5	(0.07)	9.0	(0.22)	8.6	(0.09)
F_{MSY}	0.16	(0.00)	0.18	(0.10)	0.14	(0.00)	0.14	(0.10)
$F_{rebuild}$	0.183	-	0.183	-	0.034	-	0.034	-
F_{2007}	0.14	(0.22)	0.14	(0.23)	0.15	(0.21)	0.14	(0.22)
F_{2007}/F_{MSY}	0.86	(0.22)	0.77	(0.25)	1.09	(0.21)	1.02	(0.24)
$F_{40\%}$	0.11	(0.00)	0.12	(0.08)	0.13	(0.00)	0.13	(0.07)
B^{*sp}_{MSY}_40%	52.6	(0.12)	53.7	(0.04)	56.7	(0.14)	57.6	(0.07)
MSY^*_40%	6.8	(0.06)	6.3	(0.04)	5.8	(0.03)	5.8	(0.03)
$B^{sp}_{2007}/B^{*sp}_{\text{MSY}}$_40%	0.29	(0.21)	0.34	(0.21)	0.36	(0.21)	0.39	(0.22)
$F_{2007}/F_{40\%}$	1.31	(0.23)	1.15	(0.23)	1.21	(0.21)	1.12	(0.23)
K^{sp} (av. rec.)	131.7	(0.04)	134.5	(0.04)	141.9	(0.08)	144.1	(0.07)
MSYL^{sp} (av. rec.)	0.40	(0.09)	0.40	(0.00)	0.40	(0.07)	0.40	(0.00)
$F_{rebuild}$ (av. rec.)	0.082	-	0.082	-	0.082	-	0.082	-
C_{2008}	**2.2**	-	**2.2**	-	**2.2**	-	**2.2**	-
C_{2009} (F_{MSY})	4.9	(0.20)	5.0	(0.23)	3.7	(0.22)	3.8	(0.26)
C_{2009} ($F_{\text{status quo}}$)	2.8	(0.03)	2.7	(0.04)	2.7	(0.04)	2.7	(0.05)
C_{2009} (F_{rebuild})	5.4	(0.20)	5.0	(0.22)	0.9	(0.22)	1.0	(0.23)
C_{2009} (F_{rebuild} (av. rec.))	2.5	(0.22)	2.5	(0.22)	2.4	(0.23)	2.4	(0.23)
q spring	1.02	(0.08)	0.99	(0.07)	1.08	(0.10)	1.04	(0.09)
q autumn	1.70	(0.08)	1.58	(0.08)	1.97	(0.10)	1.87	(0.10)
Slope_com 6/7	0.07	(0.13^{+})	0.21	(0.42)	0.37	(0.45)	0.40	(0.34)
Slope_surv 6/7	0.43	(0.36)	0.52	(0.30)	0.69	(0.25)	0.73	(0.23)
$\sigma_R$out	0.41	(0.08)	0.39	(0.08)	0.31	(0.10)	0.37	(0.08)

Selectivity	WHSpr	WHAut	Comm	WHSpr	WHAut	Comm	WHSpr	WHAut	Comm	WHSpr	WHAut	Comm
1	0.03	0.22	0.19	0.03	0.22	0.20	0.03	0.26	0.23	0.03	0.27	0.23
2	0.41	0.50	0.56	0.41	0.51	0.57	0.43	0.59	0.66	0.44	0.60	0.66
3	0.96	1.00	0.88	0.95	1.00	0.88	1.00	1.00	1.00	0.99	1.00	0.99
4	1.00	0.89	0.89	1.00	0.88	0.88	1.00	0.74	0.96	1.00	0.74	0.92
5	0.93	0.59	0.83	0.88	0.58	0.82	0.73	0.35	0.84	0.73	0.36	0.82
6	0.68	0.58	1.00	0.67	0.60	1.00	0.43	0.25	1.00	0.44	0.26	1.00
7	0.44	0.35	0.93	0.40	0.32	0.81	0.22	0.13	0.69	0.21	0.13	0.67
8	0.29	0.21	0.87	0.23	0.17	0.66	0.11	0.07	0.48	0.10	0.07	0.45
9+	0.19	0.12	0.82	0.14	0.09	0.54	0.05	0.04	0.33	0.05	0.03	0.30

Table L21. Retrospective statistics (Mohn's Rho) for the ASPM run A2.

	RunA2		
	SSB	F	N1
2000	0.015	0.146	0.638
2001	0.209	-0.143	0.554
2002	0.264	-0.209	1.718
2003	0.237	-0.225	0.160
2004	0.096	-0.212	0.230
2005	0.153	-0.209	-0.121
2006	0.022	-0.005	-0.391
Average	0.142	-0.123	0.319

Table L22. Fishing mortality estimates from the ASPM run A2.

	1	2	3	4	5	6	7	8	9+
1963	0.066	0.189	0.287	0.275	0.242	0.287	0.203	0.143	0.101
1964	0.067	0.193	0.293	0.281	0.247	0.293	0.207	0.146	0.103
1965	0.059	0.170	0.258	0.248	0.218	0.258	0.182	0.129	0.091
1966	0.034	0.097	0.147	0.141	0.124	0.147	0.103	0.073	0.052
1967	0.022	0.063	0.095	0.091	0.080	0.095	0.067	0.047	0.033
1968	0.021	0.061	0.092	0.088	0.078	0.092	0.065	0.046	0.032
1969	0.019	0.053	0.081	0.078	0.068	0.081	0.057	0.040	0.029
1970	0.024	0.069	0.105	0.101	0.089	0.105	0.074	0.052	0.037
1971	0.028	0.082	0.124	0.119	0.105	0.124	0.088	0.062	0.044
1972	0.028	0.080	0.121	0.116	0.102	0.121	0.085	0.060	0.042
1973	0.028	0.080	0.122	0.117	0.103	0.122	0.086	0.061	0.043
1974	0.032	0.092	0.140	0.134	0.118	0.140	0.099	0.070	0.049
1975	0.030	0.087	0.132	0.126	0.111	0.132	0.093	0.066	0.046
1976	0.034	0.098	0.148	0.142	0.125	0.148	0.104	0.074	0.052
1977	0.044	0.128	0.193	0.186	0.163	0.193	0.137	0.096	0.068
1978	0.042	0.120	0.183	0.175	0.154	0.183	0.129	0.091	0.064
1979	0.036	0.102	0.155	0.149	0.131	0.155	0.110	0.077	0.055
1980	0.042	0.120	0.183	0.175	0.154	0.183	0.129	0.091	0.064
1981	0.055	0.159	0.241	0.231	0.203	0.241	0.170	0.120	0.085
1982	0.063	0.182	0.276	0.265	0.233	0.276	0.195	0.138	0.097
1983	0.070	0.200	0.303	0.291	0.256	0.303	0.214	0.151	0.107
1984	0.084	0.243	0.368	0.353	0.311	0.368	0.260	0.184	0.130
1985	0.103	0.295	0.448	0.430	0.378	0.448	0.316	0.223	0.158
1986	0.099	0.284	0.431	0.413	0.363	0.431	0.304	0.215	0.152
1987	0.095	0.272	0.413	0.396	0.348	0.413	0.291	0.206	0.145
1988	0.080	0.231	0.350	0.336	0.296	0.350	0.247	0.175	0.123
1989	0.090	0.259	0.393	0.377	0.332	0.393	0.278	0.196	0.138
1990	0.087	0.251	0.381	0.365	0.321	0.381	0.269	0.190	0.134
1991	0.088	0.254	0.384	0.369	0.324	0.384	0.271	0.192	0.135
1992	0.143	0.411	0.624	0.599	0.526	0.624	0.440	0.311	0.220
1993	0.135	0.388	0.588	0.564	0.496	0.588	0.415	0.293	0.207
1994	0.108	0.311	0.472	0.453	0.398	0.472	0.333	0.235	0.166
1995	0.108	0.312	0.472	0.453	0.398	0.472	0.333	0.235	0.166
1996	0.087	0.251	0.381	0.365	0.321	0.381	0.269	0.190	0.134
1997	0.082	0.235	0.356	0.341	0.300	0.356	0.251	0.177	0.125
1998	0.080	0.230	0.348	0.334	0.294	0.348	0.246	0.174	0.123
1999	0.099	0.284	0.431	0.414	0.364	0.431	0.304	0.215	0.152
2000	0.094	0.270	0.409	0.392	0.345	0.409	0.288	0.204	0.144
2001	0.107	0.307	0.465	0.447	0.393	0.465	0.329	0.232	0.164
2002	0.063	0.181	0.274	0.263	0.231	0.274	0.194	0.137	0.097
2003	0.089	0.255	0.387	0.371	0.326	0.387	0.273	0.193	0.136
2004	0.079	0.228	0.346	0.332	0.292	0.346	0.244	0.172	0.122
2005	0.064	0.183	0.277	0.266	0.234	0.277	0.196	0.138	0.097
2006	0.043	0.125	0.189	0.181	0.159	0.189	0.133	0.094	0.066
2007	0.035	0.100	0.152	0.146	0.128	0.152	0.107	0.076	0.053

Table L23. Abundance estimates from the ASPM run A2 (units are in 000's).

	1	2	3	4	5	6	7	8	9+	Total
1963	4359.1	3403.1	2418.3	1583.9	1047.6	713.0	467.0	328.5	1016.5	15336.9
1964	5753.6	3357.1	2316.3	1474.2	978.6	672.8	434.6	313.6	993.0	16293.7
1965	5255.2	4424.7	2274.4	1401.0	904.0	624.6	407.0	290.4	962.5	16543.7
1966	6148.1	4069.2	3064.3	1427.5	889.8	594.4	392.0	278.4	934.1	17797.8
1967	7430.2	4872.5	3028.5	2163.1	1014.0	643.8	419.6	289.8	940.4	20801.9
1968	8005.7	5957.3	3754.4	2258.4	1619.3	767.7	480.1	321.9	972.8	24137.6
1969	8304.9	6424.7	4602.9	2811.7	1697.6	1230.4	575.0	369.5	1025.2	27041.7
1970	8589.1	6680.1	4997.7	3483.8	2135.0	1301.3	931.2	445.7	1108.5	29672.4
1971	8508.1	6871.4	5113.8	3689.1	2582.7	1602.8	960.5	709.6	1223.5	31261.7
1972	8153.1	6775.9	5189.9	3695.5	2679.9	1905.1	1158.3	721.5	1507.9	31787.0
1973	8232.5	6494.9	5121.9	3755.2	2687.7	1978.9	1378.5	870.7	1741.2	32261.4
1974	8625.0	6555.6	4903.7	3699.2	2726.4	1981.7	1429.2	1035.0	2038.2	32993.9
1975	8662.7	6843.2	4895.6	3480.5	2641.4	1981.5	1406.5	1060.5	2382.8	33354.6
1976	8284.4	6886.9	5141.4	3508.4	2508.2	1935.0	1420.0	1050.5	2680.7	33415.5
1977	8618.6	6565.4	5125.3	3629.2	2492.0	1814.7	1365.9	1049.8	2890.5	33551.4
1978	10590.5	6769.0	4753.4	3461.0	2471.2	1738.6	1225.4	980.4	3006.8	34996.3
1979	6422.2	8336.8	4935.4	3246.6	2382.4	1740.2	1187.5	886.2	3056.2	32193.4
1980	10588.4	5083.5	6181.8	3463.5	2293.3	1715.4	1221.2	874.5	3051.7	34473.3
1981	9466.2	8334.3	3705.3	4220.1	2383.0	1614.3	1171.0	882.9	3010.8	34787.9
1982	10720.3	7366.7	5864.0	2387.6	2748.2	1600.4	1040.2	815.0	2928.5	35470.8
1983	7105.8	8285.8	5072.1	3644.6	1502.4	1792.7	994.7	707.2	2783.9	31889.1
1984	8883.8	5463.8	5611.0	3065.4	2233.4	958.3	1083.4	664.3	2575.0	30538.5
1985	14607.4	6753.6	3564.8	3180.8	1768.1	1353.9	543.2	695.0	2343.1	34809.7
1986	7836.7	10957.2	4212.4	1865.8	1701.8	1006.9	708.6	331.8	2144.3	30765.6
1987	12305.2	5894.4	6898.0	2241.9	1014.0	981.8	535.9	437.3	1765.9	32074.4
1988	9608.9	9283.2	3748.6	3738.2	1239.3	593.3	532.1	334.3	1573.4	30651.4
1989	13543.9	7326.6	6116.7	2161.7	2191.3	761.5	342.2	345.0	1389.0	34177.9
1990	14713.1	10251.4	4711.3	3380.4	1217.3	1302.0	420.9	216.1	1245.3	37457.7
1991	8940.0	11160.0	6638.7	2636.2	1925.9	730.4	728.5	267.8	1056.1	34083.6
1992	8071.9	6776.7	7211.6	3700.6	1496.6	1152.1	407.1	462.5	953.0	30232.0
1993	7616.4	5896.3	3848.5	3164.9	1679.3	745.5	505.6	224.5	945.6	24626.7
1994	5620.1	5591.8	3410.6	1750.3	1484.7	859.2	339.1	284.4	797.5	20137.6
1995	4543.7	4199.5	3441.9	1742.8	915.6	830.0	439.0	204.2	756.8	17073.5
1996	5674.8	3394.9	2584.1	1757.8	911.1	511.6	423.9	264.3	674.3	16196.8
1997	8998.6	4304.5	2198.7	1446.2	1001.7	546.8	286.3	269.7	673.6	19726.2
1998	10162.3	6855.5	2828.3	1261.8	843.8	613.1	313.8	185.1	682.1	23745.6
1999	11197.5	7752.2	4524.0	1635.3	741.5	519.6	354.5	203.8	630.7	27559.0
2000	3183.1	8423.1	4881.9	2409.0	889.2	428.0	276.7	218.8	591.3	21301.1
2001	3445.0	2403.5	5372.4	2659.4	1338.3	522.4	233.1	173.2	577.1	16724.4
2002	5896.6	2577.3	1485.6	2766.1	1401.0	752.5	269.0	141.0	527.0	15816.1
2003	3726.8	4559.6	1777.1	925.5	1744.6	915.7	468.8	183.2	497.3	14798.6
2004	3737.6	2824.7	2945.5	990.1	525.2	1043.2	510.1	297.5	488.0	13361.9
2005	7157.6	2853.0	1867.9	1709.1	583.8	324.3	605.3	332.0	567.4	16000.4
2006	7871.0	5531.9	1964.1	1160.7	1075.3	380.7	201.5	411.5	664.9	19261.6
2007	4865.5	6187.1	4015.7	1332.0	793.5	752.8	258.2	145.0	820.0	19169.8

Table L24. Input values for white hake BRP calculations and projections based on 2003-2007 average values from the ASPM run A2.

Age	S[PR]	Maturity	Mid-year catch weights	SSB weights	Jan1 Weights
1	0.232	0.058	0.144	0.100	0.100
2	0.660	0.268	0.309	0.208	0.208
3	1.000	0.683	0.645	0.458	0.458
4	0.961	0.927	1.887	1.155	1.155
5	0.844	0.987	3.430	2.585	2.585
6	1.000	0.998	4.722	3.985	3.985
7	0.704	1.000	6.134	5.339	5.339
8	0.495	1.000	7.364	6.689	6.689
9+	0.349	1.000	10.271	10.272	10.272

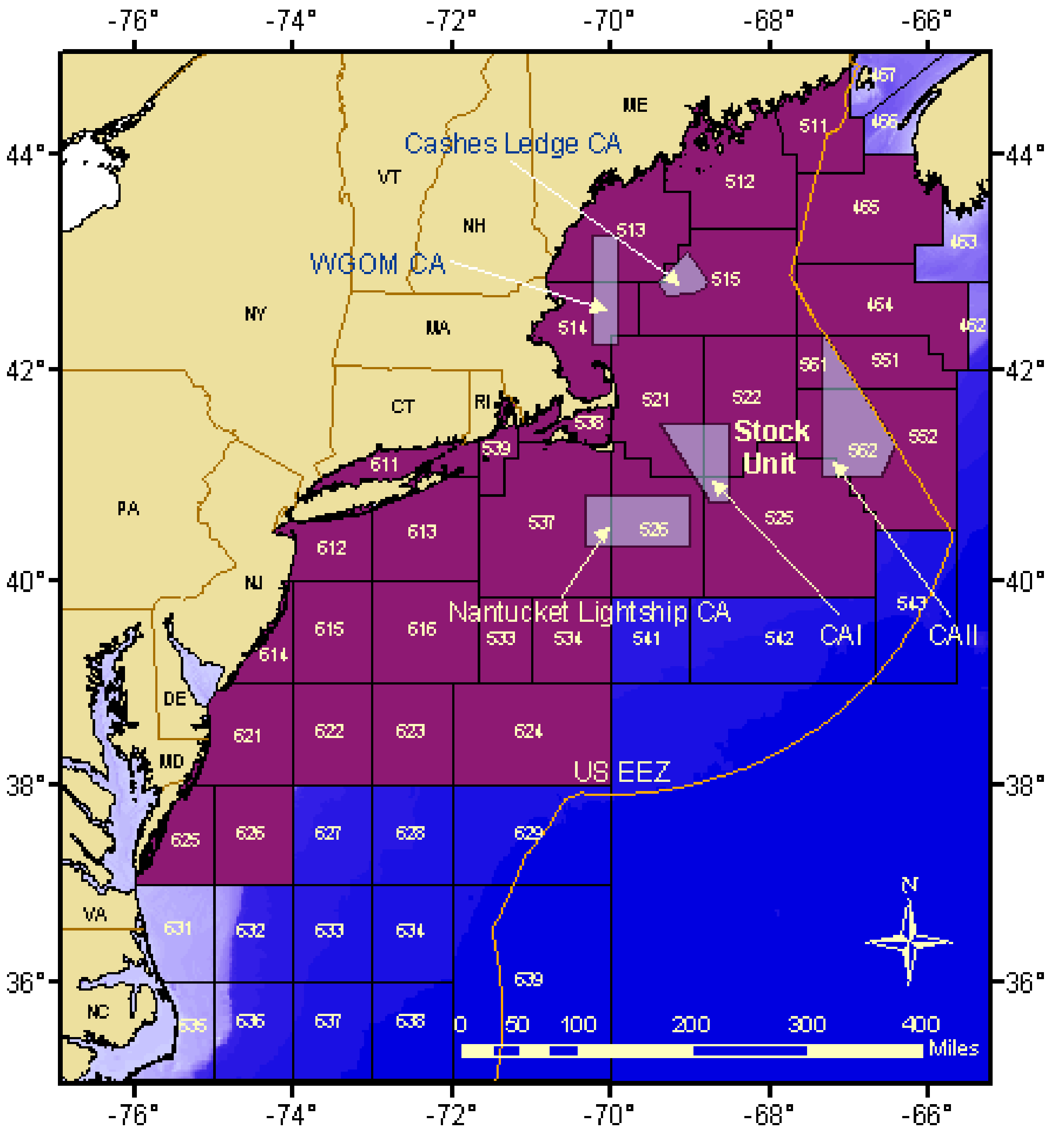


Figure L1. Map showing statistical areas used in the white hake stock unit.

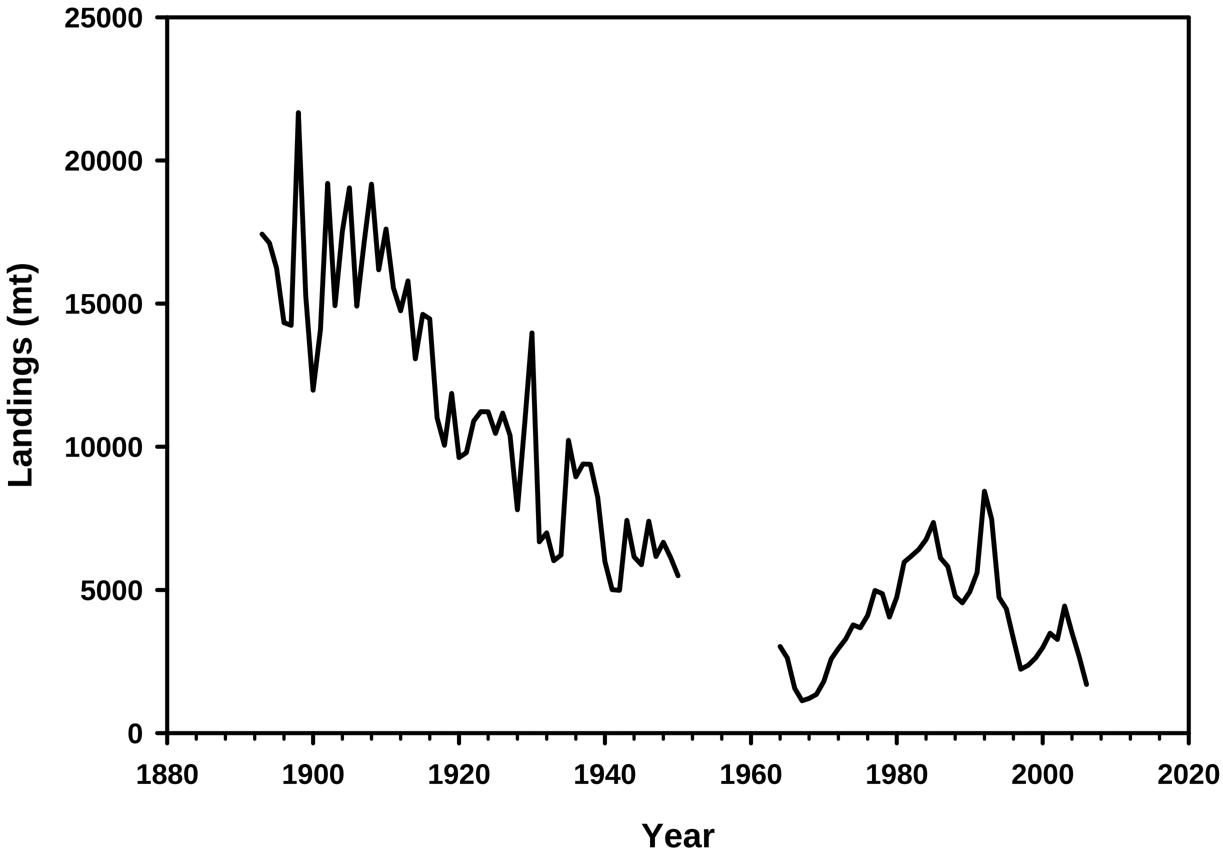


Figure L2. Reported total nominal landings of white hake (mt, live weight) from the Gulf of Maine to Mid-Atlantic region, 1893-2007.

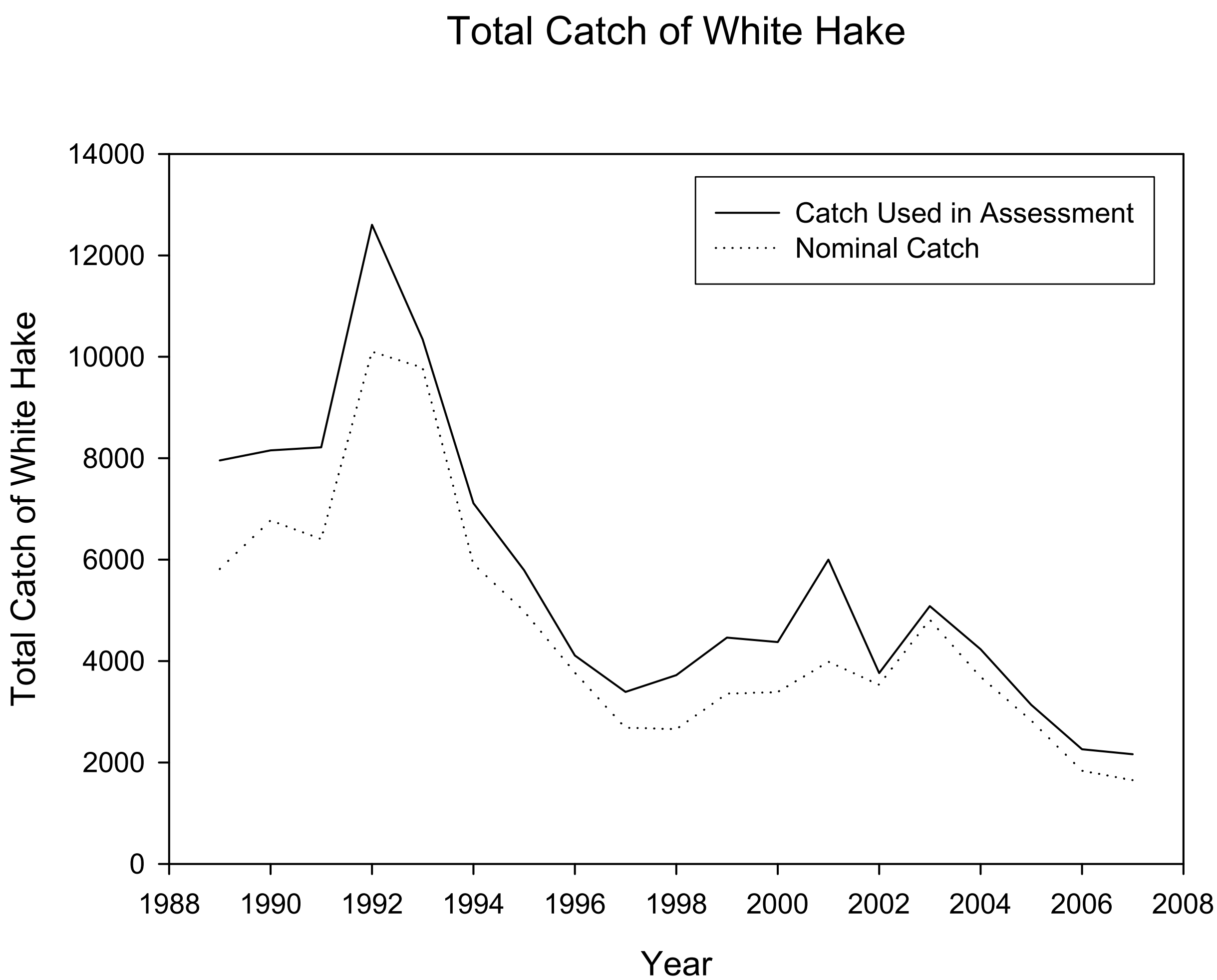


Figure L3. Total catch of white hake from 1989-2007 using just white hake data (Nominal Catch) and using survey data to split out combined red and white hake catches (Catch Used in Assessment).

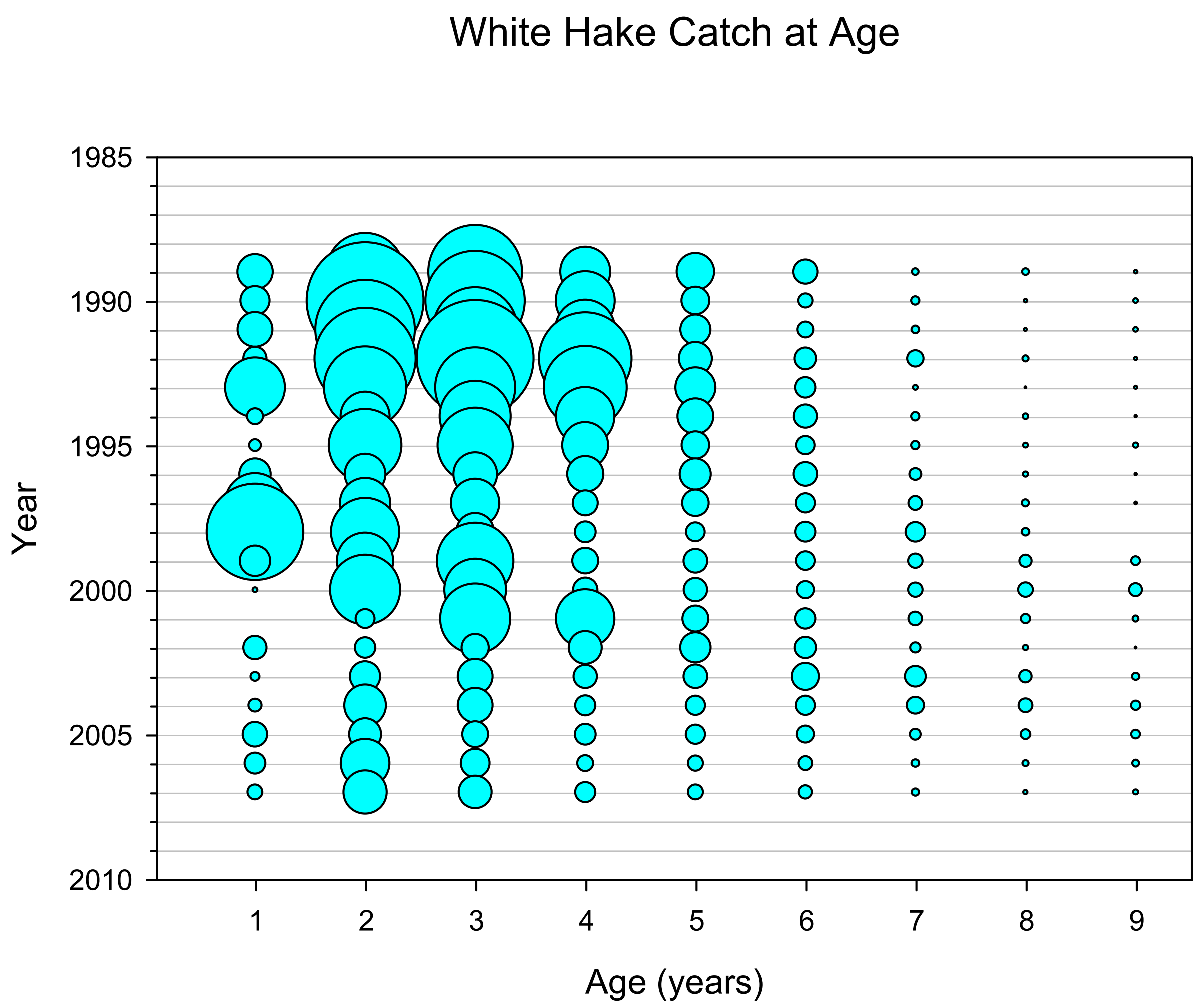


Figure L4. Catch at age (thousands of fish) of commercial landings for white hake, 1989-2007. Values from 2001 are based on a pooled age-length key.

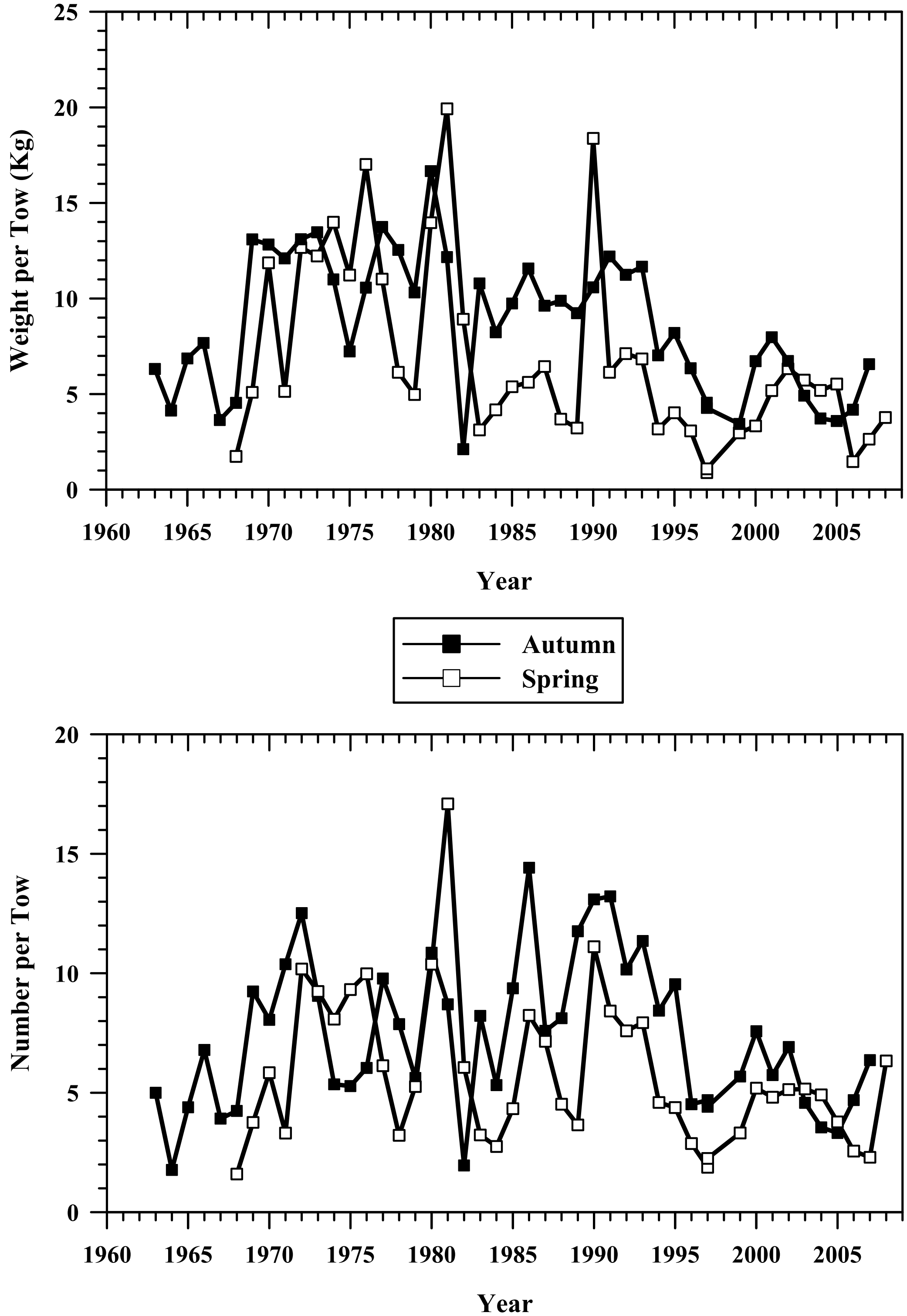
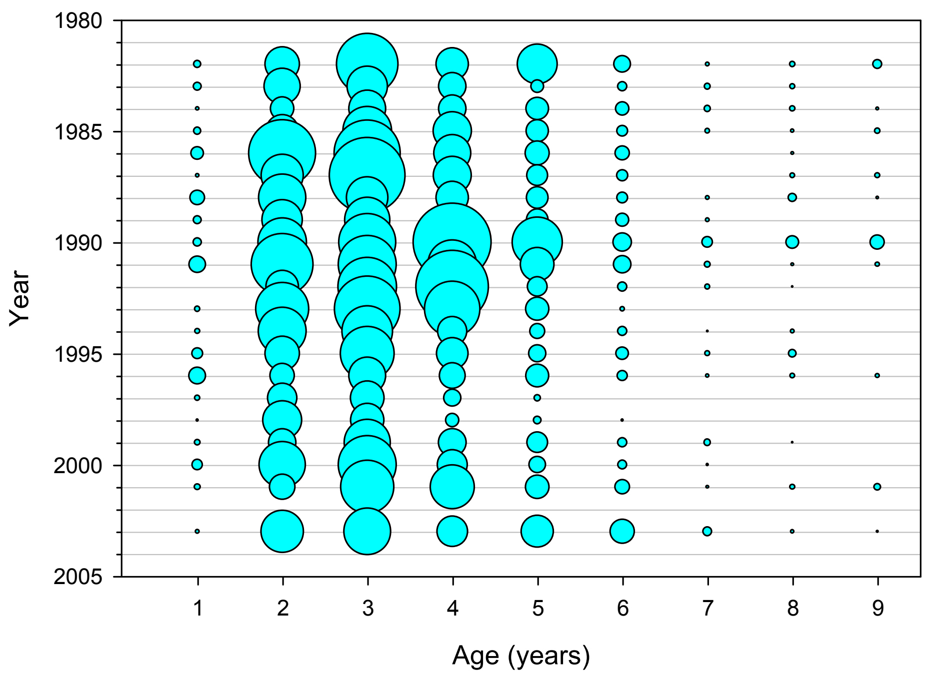


Figure L5. White hake indices of biomass (top panel) and abundance (bottom panel) from the NEFSC bottom trawl spring (open squares) and autumn (solid squares) surveys in the Gulf of Maine to Northern Georges Bank region (offshore strata 21-30, 33-40), 1963-2008.

White Hake Spring Survey Indices by Age



White Hake Autumn Survey Indices by Age

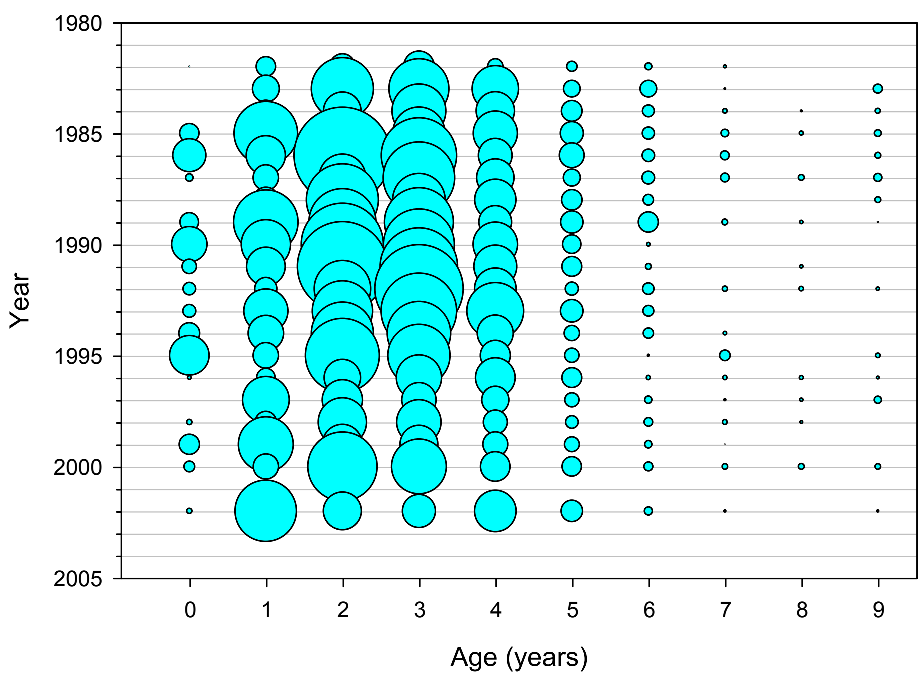


Figure L6. Age composition of white hake from the spring and autumn surveys from 1982-2003.

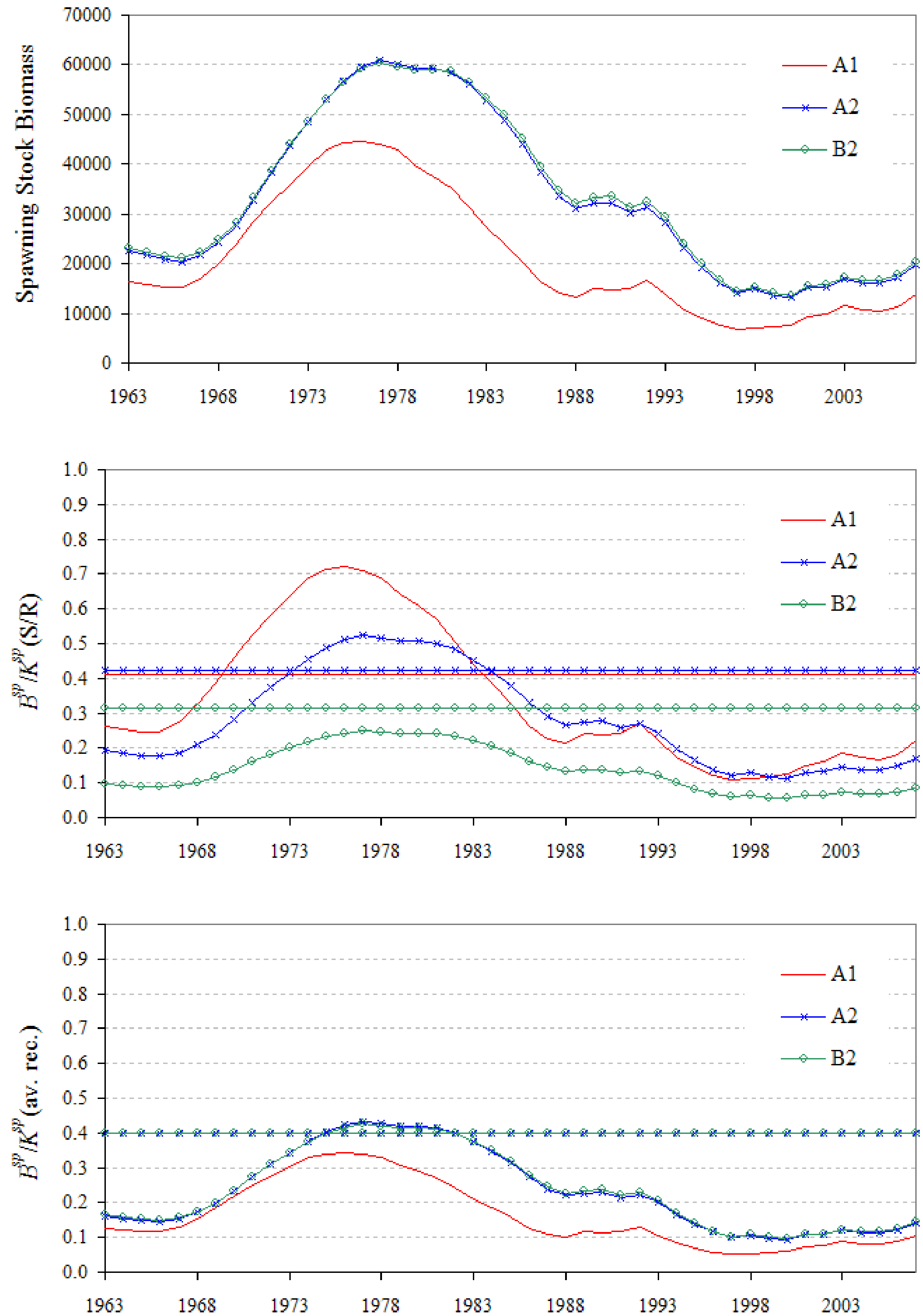


Figure L7. Spawning stock biomass trajectories for ASPM runs A1, A2 and B2. The flat horizontal lines shown are the corresponding MSYL target levels.

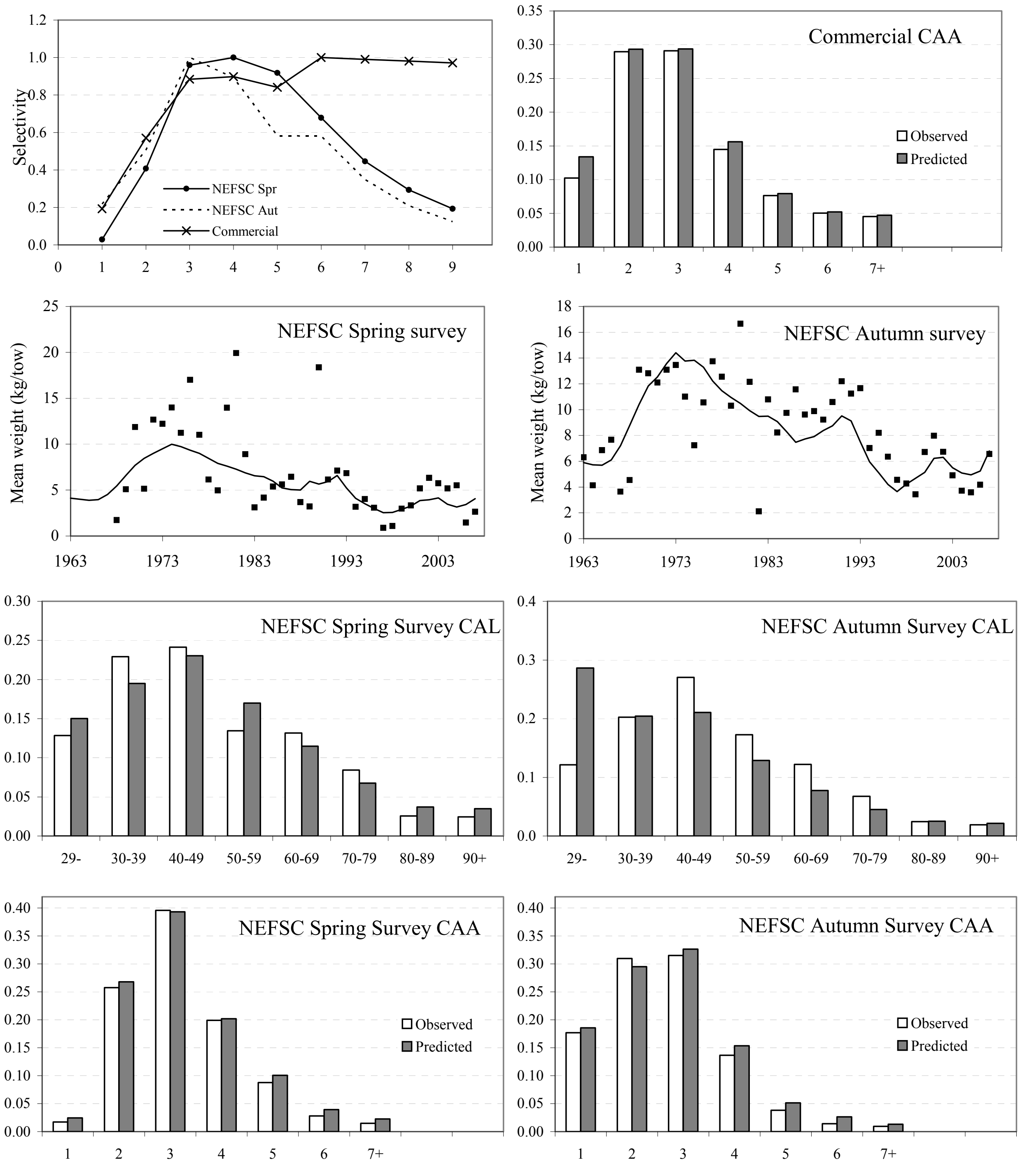


Figure L8. Estimates of selectivity-at-age and fits to the data input for ASPM run A1.

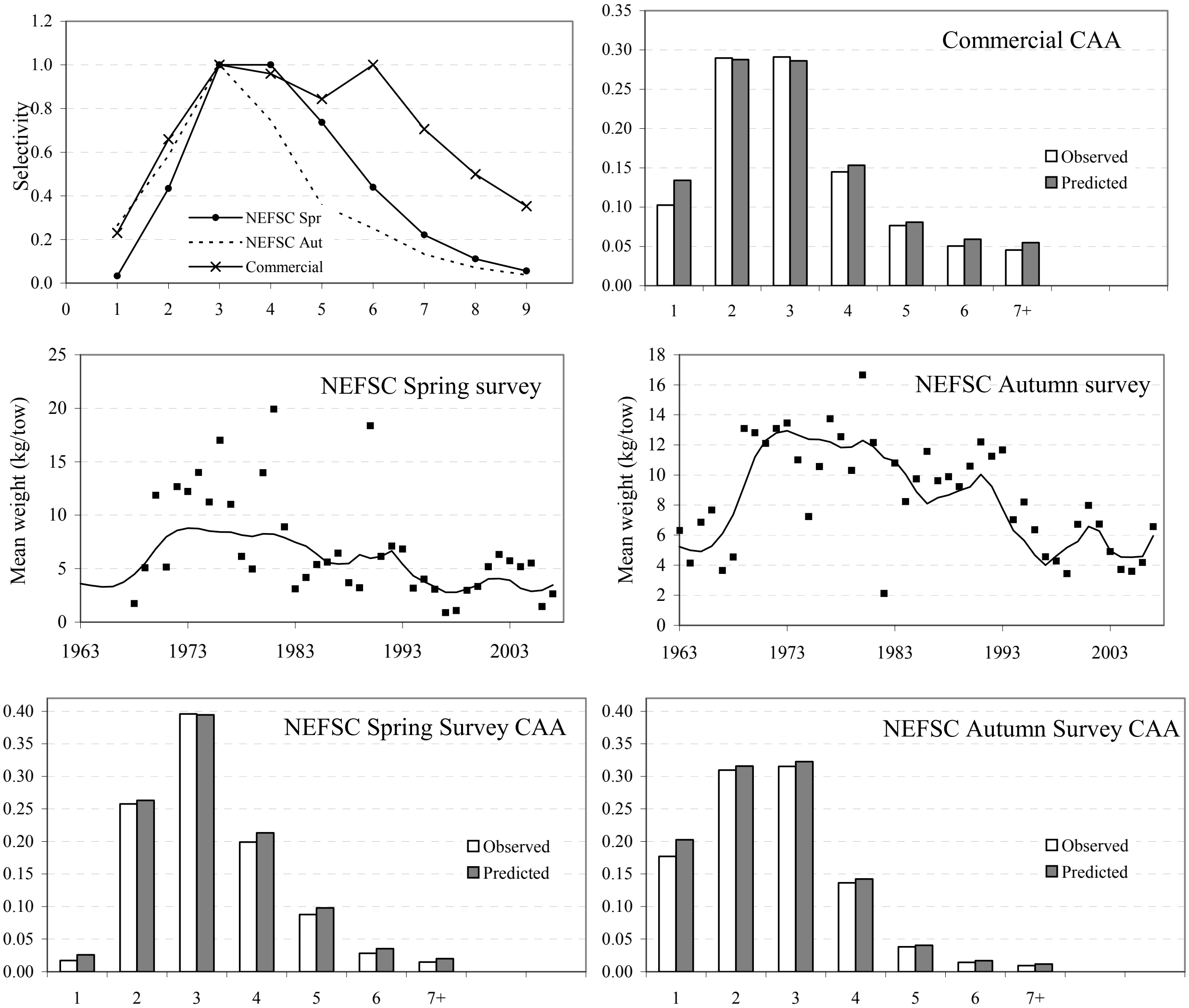


Figure L9. Estimates of selectivity-at-age and fits to the data input for ASPM run A2.

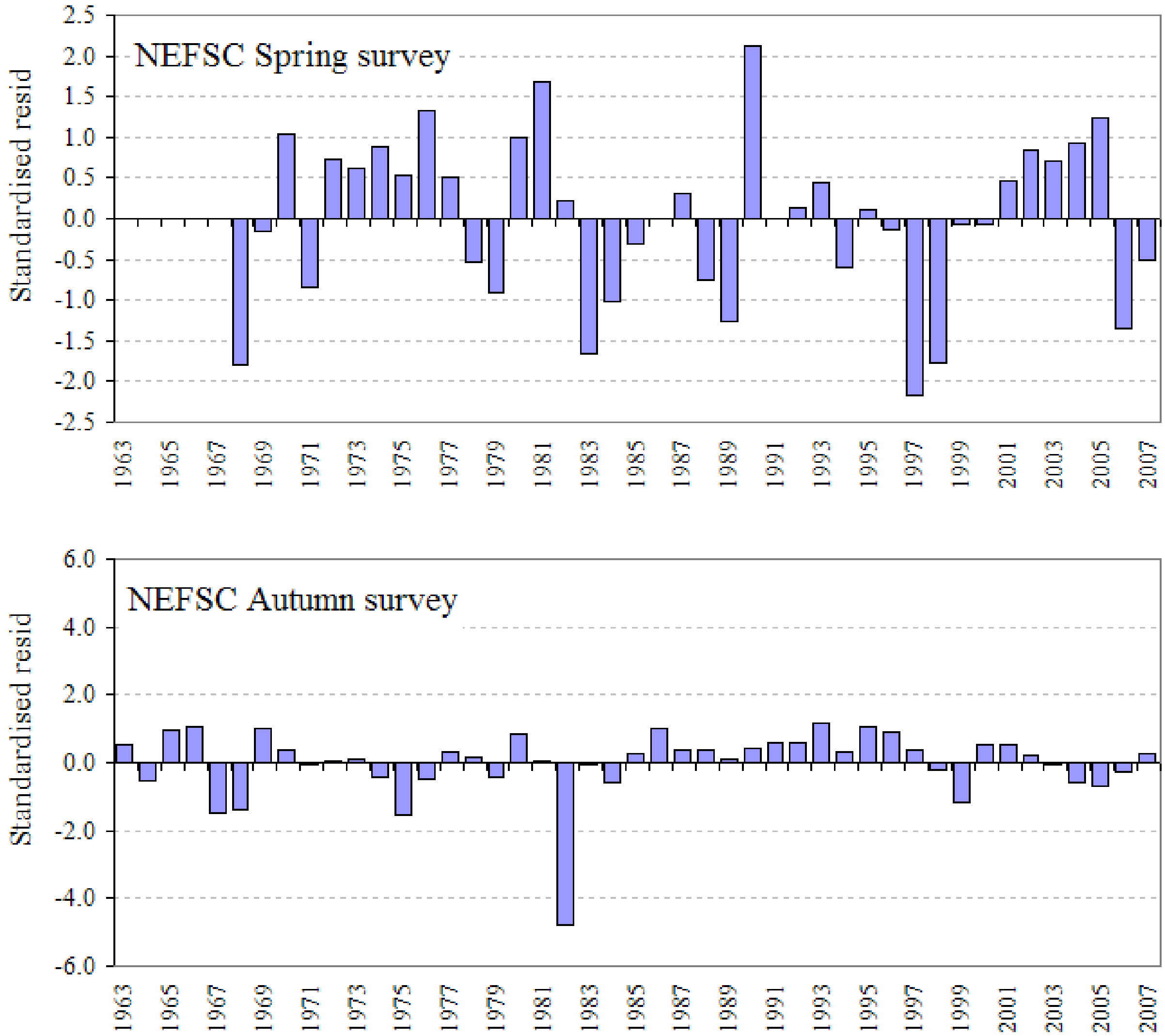


Figure L10. Standardised residuals for the fits to surveys for the ASPM run A2.

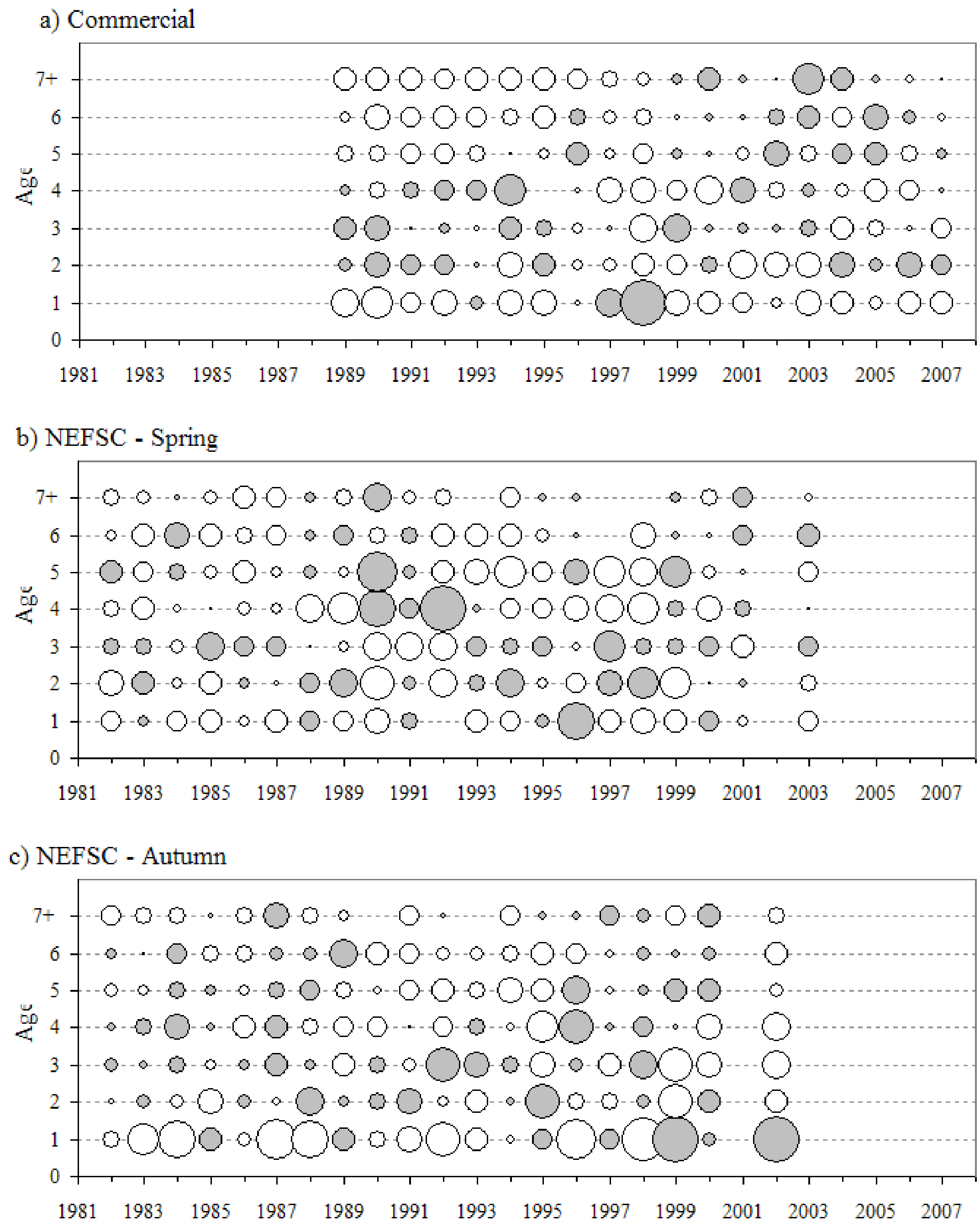


Figure L11. Bubble plots of the standardised residuals for the catch-at-age data for ASPM run A2. The size (area) of the bubbles represents the size of the residuals. Grey bubbles represent positive residuals and white bubbles represent negative residuals. Commercial catches-at-age post 2000 are based on a pooled age-length key.

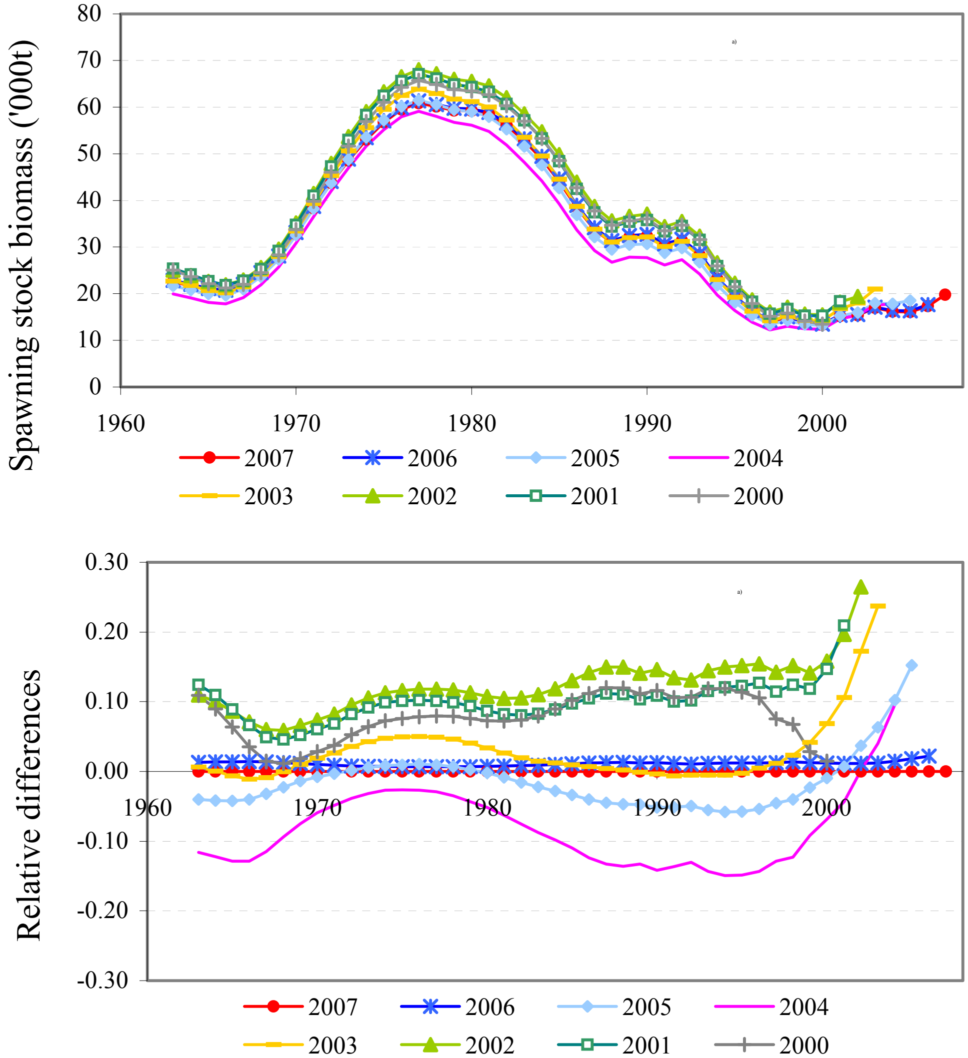
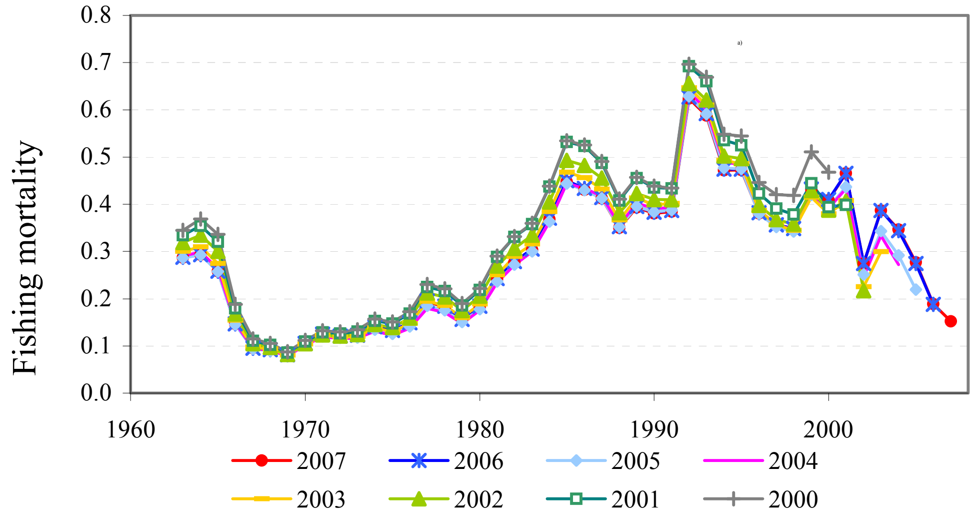


Figure L12. Retrospective plots for spawning biomass (SSB) from the ASPM run A2.



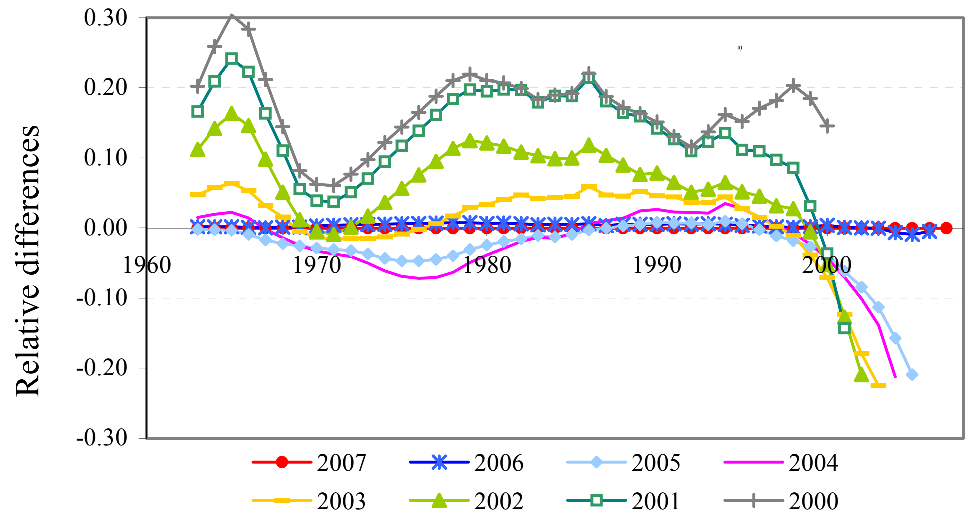


Figure L13. Retrospective plots for fully selected (age 6) fishing mortality from the ASPM run A2.

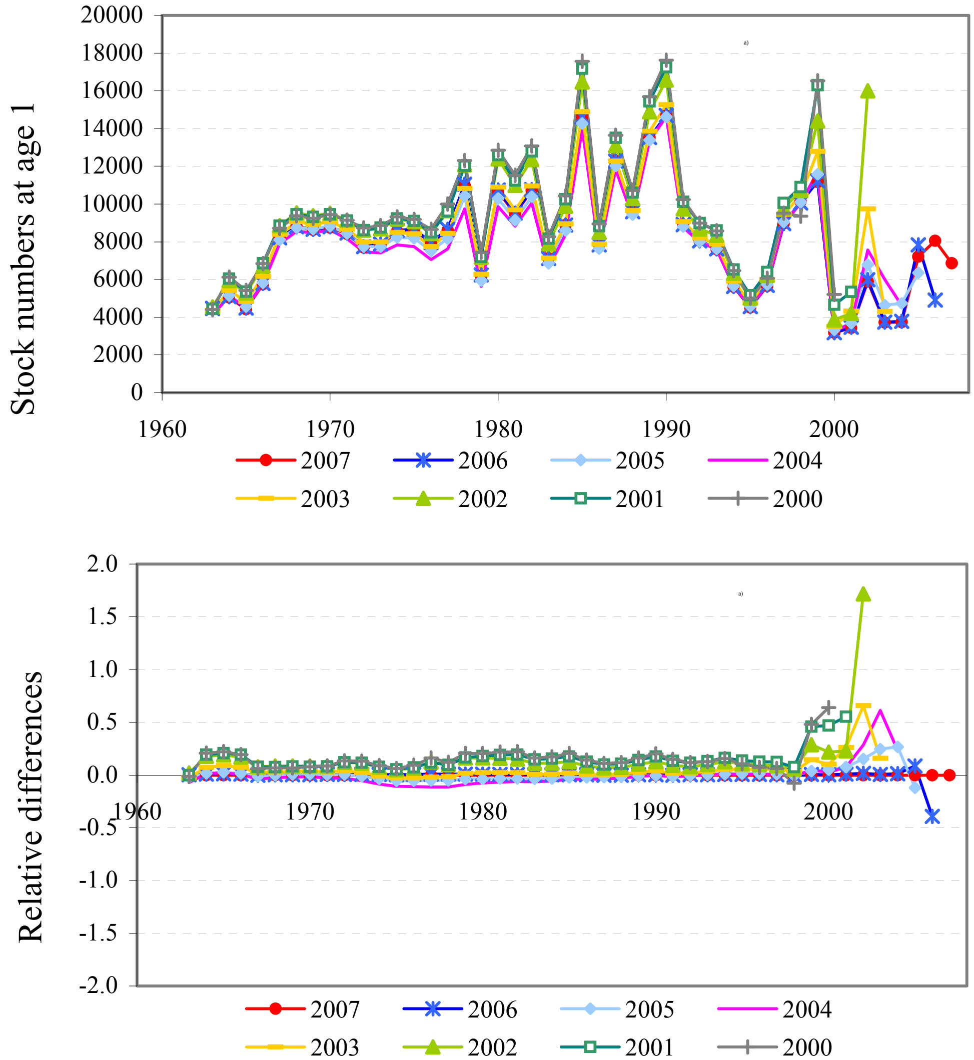


Figure L14. Retrospective plots for recruitment (numbers at age 1) from the ASPM run A2.

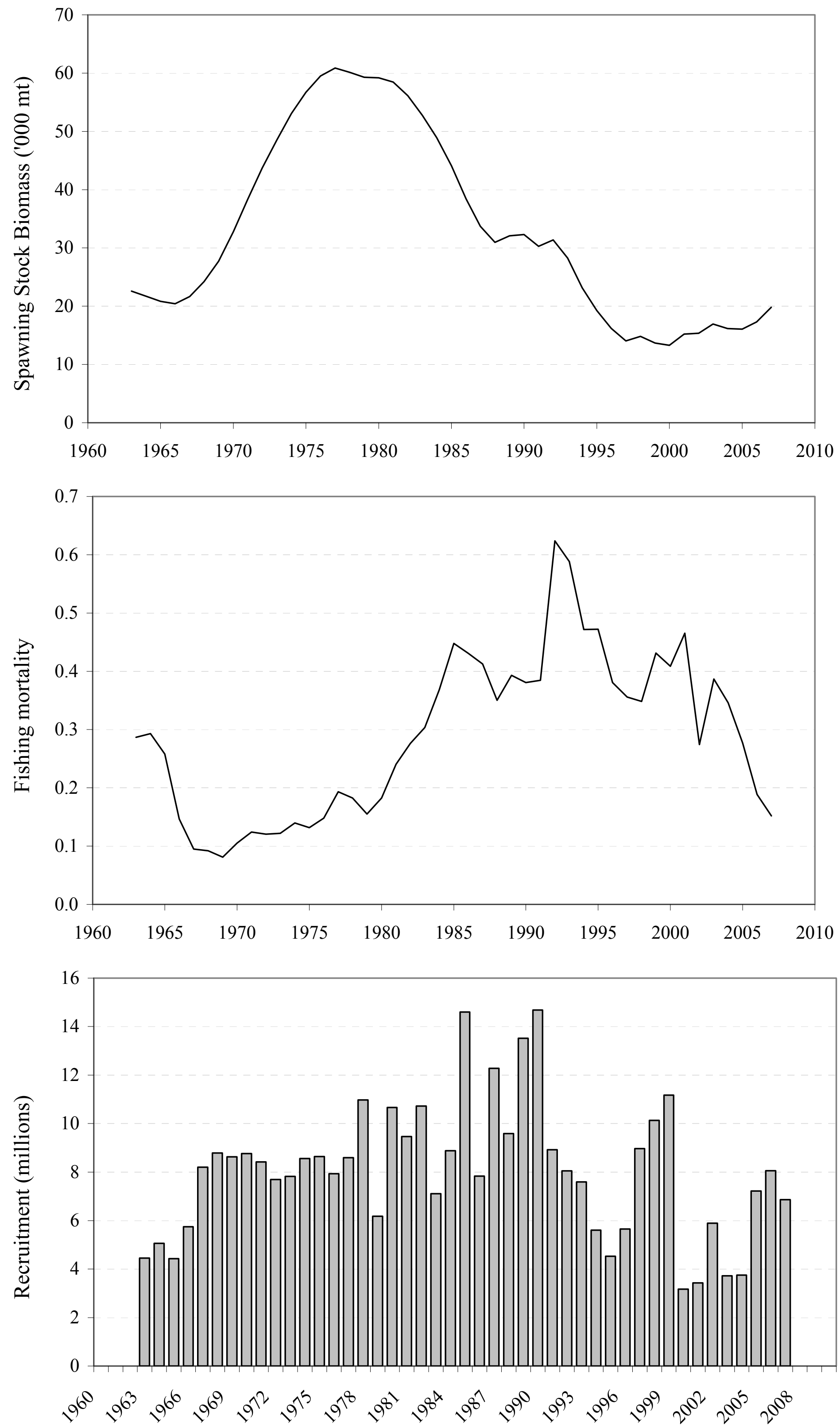


Figure L15. Results of the ASPM run A2. Top panel is spawning stock biomass, middle panel is fishing mortality (on age 6) and lower panel is recruitment.

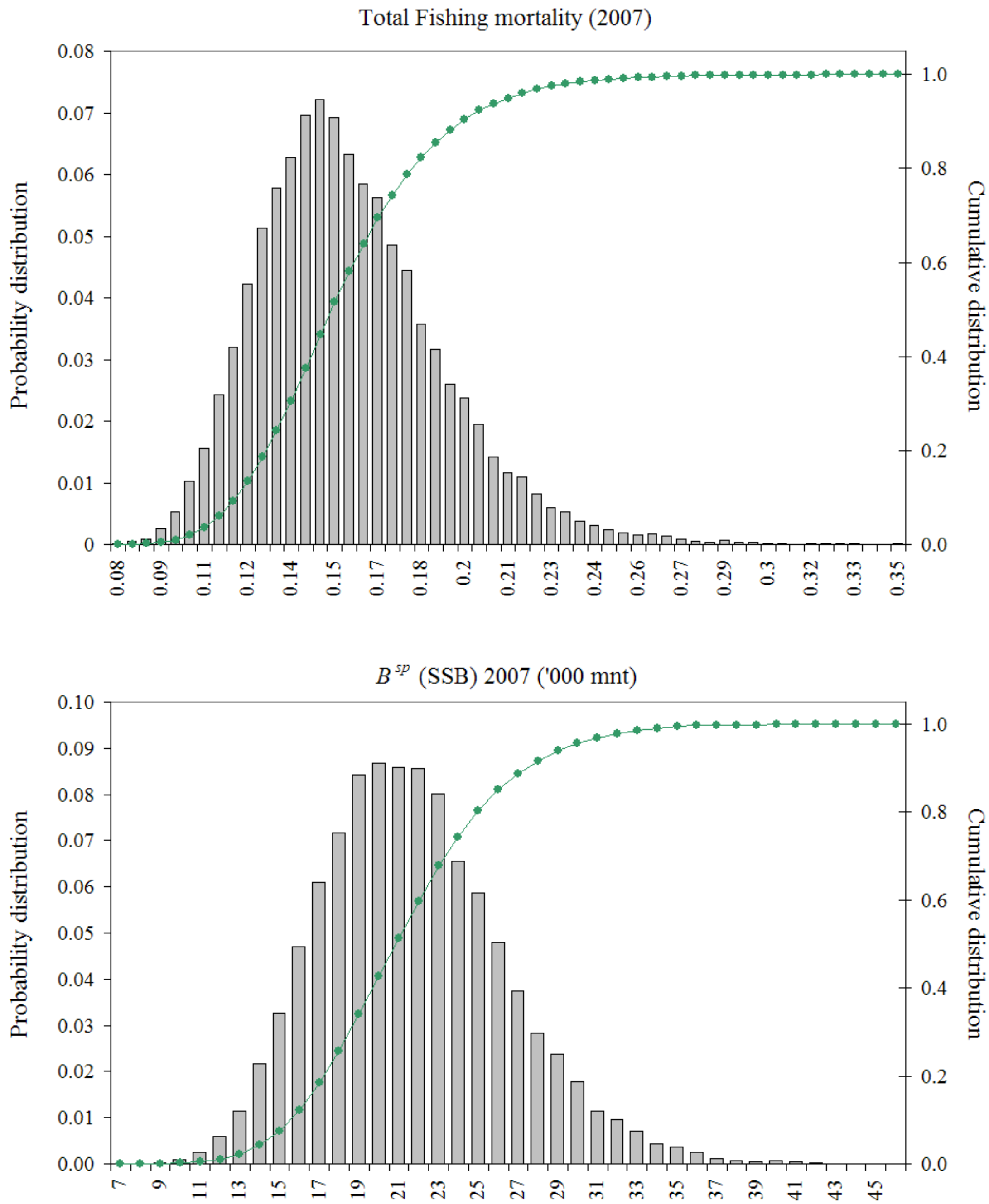


Figure L16. Uncertainty plots for fully selected fishing mortality and spawning stock biomass from the ASPM run A2 as indicated by the Bayesian posterior MCMC computations.

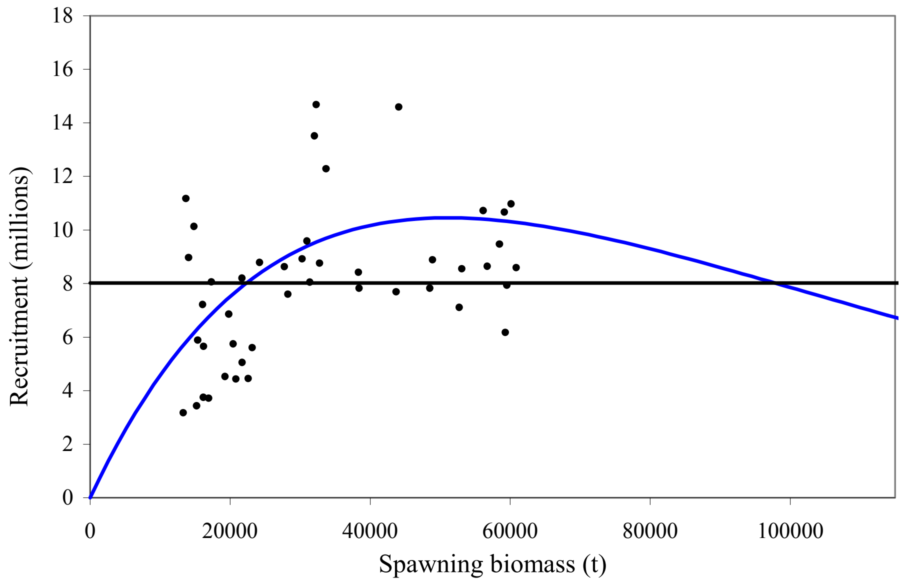


Figure L17. The estimated Ricker stock-recruitment curve and estimated recruitment and spawning biomass each year for ASPM run A2. The horizontal line represents the average recruitment over the whole period as used for the MSY proxy calculations.

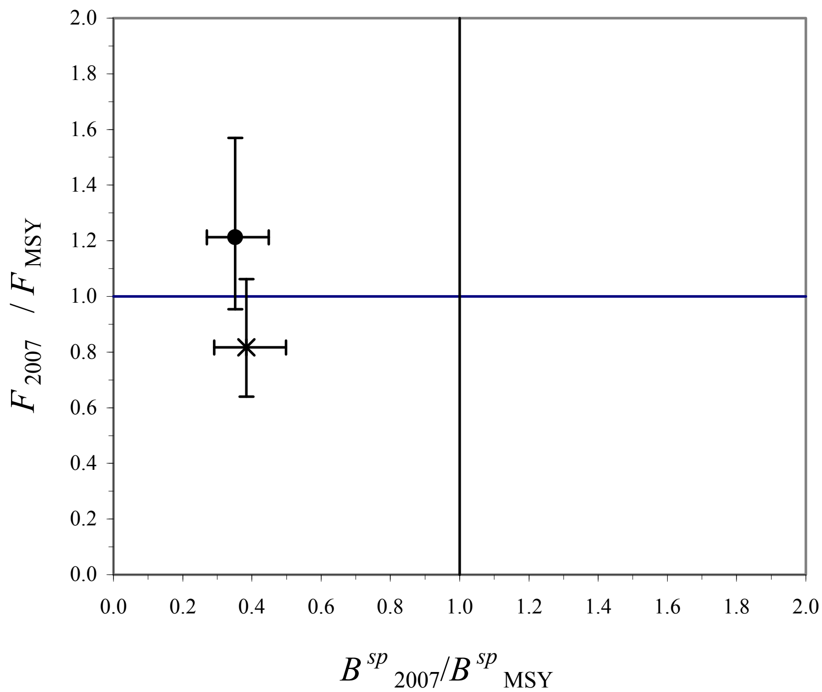


Figure L18. The current status of white hake with regard to the new biological reference points. The cross is for ASPM run A2 in terms of the estimated Ricker stock-recruitment function, while the full dot corresponds to BRPs computed for the F40% proxy and average recruitment. The point estimates are MLEs (corresponding to calculations from Bayesian posterior modes for the estimable parameters of the model) and the errors bars are 80% Bayesian posterior probability intervals.

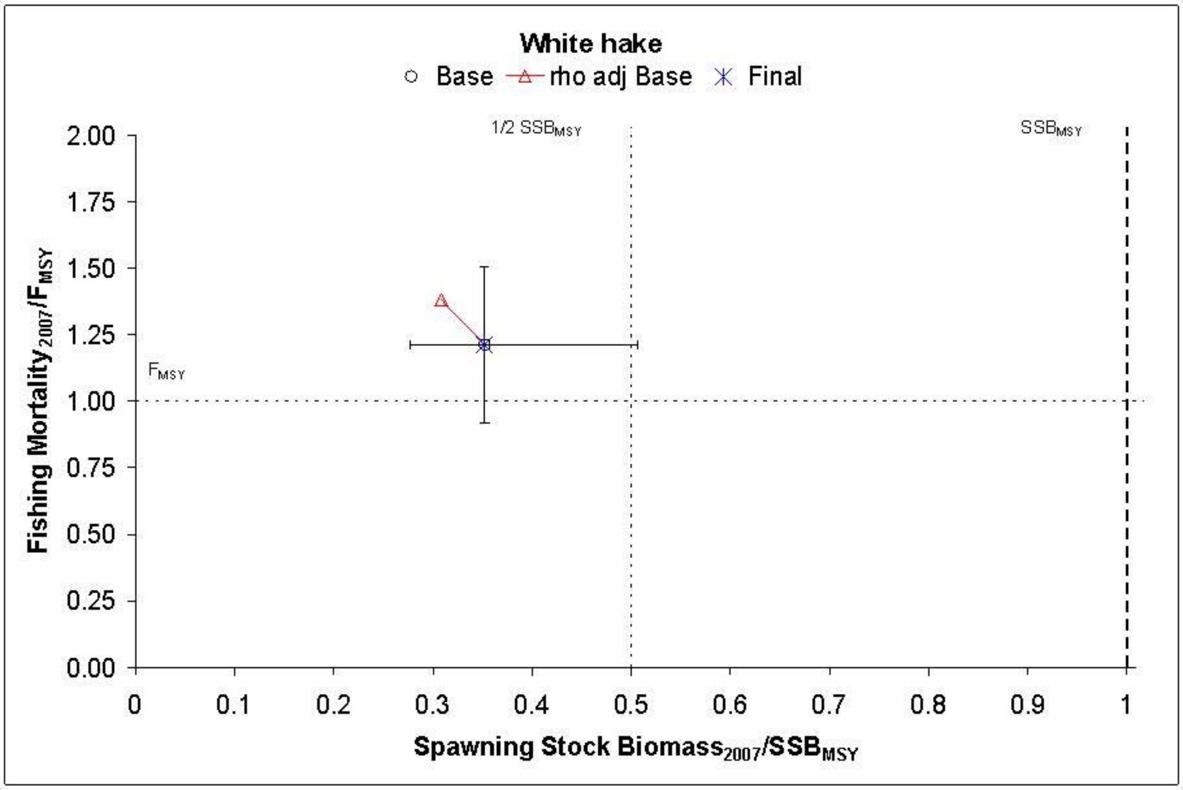


Figure L19. The current status of white hake with regard to the biological reference points as given by MLE's corresponding to F40% proxies for MSY and associated parameters.