

Draft Working Paper for Pre-Dissemination Peer Review Only

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**GARMIII Biological Reference Point
Georges Bank/Gulf of Maine White Hake**

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A working paper in support of
GARM Biological Reference Points Meeting Term of Reference 4

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1.0 Background

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 2002b). 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 significant retrospective pattern in the assessment in 2001. The assessment then became 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 Meeting recommended examining forward projecting length or age-based models to include all portions of the stock.

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 L1). Landings subsequently declined to 1,789 mt. Canadian landings declined to a time-series low of 89 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.

Commercial Catch: The GARM III Models Meeting 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 L3). These were prorated at the end for 1998-2006. Sampling for red hake was sufficient for most years but was the intensity was low for some years (Table L4). For example, the same length samples were used for both halves of the year in 1996.

Commercial discards were re-estimated for white hake and estimated for red hake for 1989-2006 using the SBRM method of white/red hake discard/all kept. There were sufficient length samples for both species to estimate otter trawl discards-at-length (Tables L5-L8).

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

L9; Figure L2). The ratio between the old data and the new data was used to estimate landings back to 1964. Landings between 1951 and 1963 were imputed to ramp down the landings to the 1964 level (Table L9). Age-length keys combining survey and observer age data by half year were used to derive the catch-at-age from 1989-2000 (Table L10). A pooled age-length key by half year was used to derive the catch-at-age from 2001-2006.

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 near record low in 1999 (Figure L3; Table L11). 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. 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. Table L12 shows the survey numbers-at-age.

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

Two model formulations of ASAP were run for this stock. The first used the entire time series of catch while the second was restricted to the survey time series. Full selectivity in the fishery was set at age 5 and in the survey at age 4 while the other ages were allowed to be estimated. Both formulations required setting a low CV and lambda for catchability for runs to converge. Both runs have a residual pattern in the autumn survey with the last twenty years having positive residuals (Figures L4 and L5). The trends in SSB, fishing mortality, and recruitment are similar (Figure L6). The main difference between the two runs is that selectivity is highly domed in the shorter time series (Figure L7). This difference in selectivity will impact the estimates of reference points. Neither run exhibits much of a retrospective pattern in SSB or fishing mortality although the tendency for both models is to over-estimate SSB and under-estimate fishing mortality in the terminal year (Figures L8-L11).

5.0 Biological Reference Points

The existing biological reference points first developed by the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish (NEFSC 2002) from the AIM model are:

Bmsy 7.7 kg/tow (>60 cm fish)
Fmsy 0.55
MSY 4,300 mt

Since the catch was re-estimated, AIM was run on the new data and the new estimates are:

Bmsy 7.7 kg/tow (>60 cm fish)
Fmsy 0.616
MSY 4,743 mt

Parametric Approach

Biomass and F reference points were estimated under two scenarios. The first analysis was based on the conclusions of the Working Group on Re-estimation of Biological Reference Points for New England Groundfish (NEFSC 2002). In this formulation of the parametric approach, we performed the analysis using the Beverton-Holt S/R function without a prior on recruitment since the results were reasonable.

The spawning biomass and age 1 recruitment results obtained from the ASAP were included in a model (SRFIT) that also included life history and fishery parameters using the Sissenwine-Shepherd approach (See Brodziak and Legault 2005; Table L13). Catch and stock mean weights at age and the maturity at age schedule were averaged over the 2002-2006 time period. Partial recruitment at age was taken as the selectivity results from each model.

A stochastic age-based projection program (AGEPRO) was used to project 50 year scenarios to obtain equilibrium SSB_msy and MSY estimates based on the Beverton-Holt alpha and beta parameters and the estimated sigma squared from SRFIT as the variance term. The same mean weights, maturity schedule and partial recruitment parameters were used in the projection as in SRFIT analysis. A constant F strategy was employed setting F at the estimate of F_msy (0.21, long; 0.25, short) obtained from SRFIT. SSB_msy is estimated to be 89,900 mt from the long time series and 39,900 mt from the short time series (Table L14).

Non-Parametric Approach

In the non-parametric empirical approach, a yield and SSB per recruit analysis was conducted using the same life history and fishery parameters that were incorporated into the parametric Beverton-Holt model approach. A proxy for F_msy taken from this analysis is F40% MSP = 0.16 for the long series and 0.21 for the short series.

Again, a stochastic projection program (AGEPRO) was used to project 50 year scenarios to obtain equilibrium SSB_{MSY} and MSY estimates using the cumulative distribution function of the recruitment values from ASAP. For the long time series, it was necessary to attempt three scenarios because only 100 years of recruitment are allowed. These were: 1) the first 100 years; 2) the last 100 years; and 3) the last 43 years. The same mean weights, maturity schedule and partial recruitment parameters were used in the projection as in the YPR and SRFIT analyses. A constant F strategy was employed setting F at an F_{MSY} proxy F40% MSP obtained from the SSB per recruit analysis. SSB_{MSY} estimates range from 52,000 mt from the short time series to 59,900 with the long time series first hundred years of recruitment (Table L15).

6.0 Projections

Projections of future stock status should be conducted with a stochastic model for recruitment using the Beverton-Holt stock-recruitment relationship based on the long time series ASAP results and corresponding parametric BRPs (Table L14). Mean weights estimated for the most recent 5 years in the assessment (2002-2006) should be used in projections to reflect current conditions in the stock and fishery.

7.0 Summary

Fishing mortality in 2006 is estimated to be 0.22 and current spawning stock biomass in 2006 is estimated to be 11,751 mt.

NEFSC [Northeast Fisheries Science Center]. 2001. [Report of the] 33rd Northeast Regional Stock Assessment Workshop (33rd SAW). Northeast Fish. Sci. Cent. Ref. Doc. 01-18. 281 p.

NEFSC [Northeast Fisheries Science Center]. 1999. [Report of the] 28th Northeast Regional Stock Assessment Workshop (28th SAW). Northeast Fish. Sci. Cent. Ref. Doc. 99-08. 304 p.

NEFSC 2002. Report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish, NMFS, Northeast Fisheries Science Center Reference Document 02-04, 254 p.

NEFSC 2005. Assessment of 19 Northeast Groundfish Stocks Through 2004. 2005 Groundfish Assessment Review Meeting (2005 GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, 15-19 August, 2005. by R.K. Mayo and M Terceiro, editors. (NEFSC Reference Document 05-13).

North Atlantic Fishery Investigations, F& W Service. 1952. United States Landings of Groundfish from the Convention Area, 1893-1950. ICNAF Annual Meeting 1952 Index Doc. 7 (Vol. 4).

Table L1. Total Landings (mt,live) of white hake by country from the Gulf of Maine to Cape Hatteras (NAFO Subareas 5 and 6), 1964-2006.

	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	90	3505	0	3595
2005	85	2670	0	2755
2006	89	1700	0	1789

Table L2. Total United States 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. 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				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	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	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	2	4		1	1	1	2	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	1	21			
# fish	309	408	399	151	1267			202	99	301		214	101	103	418			101	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	1	1	12			
# fish	107	97	105	309		191	222	111	524		221	103	324		100			100	100	1257			

Table L3 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, 1985-2006.

	small					medium					large					unclassified					All					
	Q1		Q2		Q3	Q4		sum	Q1		Q2		Q3	Q4		sum	Q1		Q2		Q3	Q4		sum	Total	Sampling
	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	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	1	1	70					
# fish	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	1	1	32					
# fish	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	0	0	0	22					
# fish		119		119		111	102	315	313	841	166	665	202	327	1360					0	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	1	3	5		0	0	0	0	25					
# fish	428		123	551		527	106	573	450	1656	103	126		336	565					0	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	0	0	0	36					
# fish	231	329	213	224	997	221	100	235	215	771	328	456	797	660	2241					0	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	0	0	0	56					
# fish	154	103	968	1225		626	391	417	629	2063	768	372	665	335	2140					0	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	0	0	0	97					
# fish	249	424	306	208	1187	355	768	387	796	2306	576	1369	1620	1665	5230					0	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	0	0	0	84					
# fish	83	162		445	690	383	456	211	579	1629	2062	1474	524	1213	5273					0	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	1	3	88				
# fish	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	0	0	0	93					
# fish	372	398	254	547	1571	434	263	534	601	1832	958	1013	776	972	3719					0	0	7122				

Table L4. 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, 1985-2006.

	1985	mt	unclassified					Sampling Intensity
			Q1	Q2	Q3	Q4	sum	
		N	175	494	637	398	1705	61
		# fish	6	6	8	8	28	
			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 L4. Cont.

	1998	mt	unclassified					Sampling Intensity
			Q1	Q2	Q3	Q4	sum	
		N	295	326	402	304	1327	74
		# fish	5	6	3	4	18	
			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	

Table L5. Number of length samples taken for white hake from sink gill net and otter trawl trips by the Domestic Observer Program, 1989-2006.

		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

Table L6. Number of length samples taken for white hake from shrimp trawl and scallop dredge trips by the Domestic Observer Program, 1989-2006.

		ST				SD				Grand			
		Half 1		Half 2		Total Kept	Disc	Half 1		Half 2		Total 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	18
	len	282				282		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	40
	len	958				958		51	1	73		124	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
	len					1	5			63	1	68	1
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	3	10
	len	157	28			157	28			1	64	158	92
2006	trips	4				4				1	2	1	6
	len	131				131				1	5	1	136

Table L7. Number of length samples taken for red hake from sink gill net and otter trawl trips by the Domestic Observer Program, 1989-2006.

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

Table L8. Number of length samples taken for red hake from shrimp trawl and scallop dredge trips by the Domestic Observer Program, 1989-2006.

		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	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			51	168	
1995	trips	12		1		13		1						1	14	
	len	136		3		139		2						2	141	
1996	trips	7		1		8			2		2			2	10	
	len	151		32		183			7		7			7	190	
1997	trips		6			6		1		1		2			8	
	len	104				104		184		7		191			191	
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	

Table L9. Catch used in assessment from 1951-2006. The catch from 1951-1963 are imputed.

Year	Landings	Year	Landings
1951	5300	1980	6630
1952	5200	1981	8428
1953	5100	1982	9112
1954	5000	1983	9471
1955	4900	1984	10195
1956	4800	1985	10898
1957	4700	1986	9270
1958	4600	1987	8362
1959	4500	1988	6976
1960	4400	1989	7955
1961	4300	1990	8154
1962	4200	1991	8215
1963	4100	1992	12602
1964	3995	1993	10342
1965	3434	1994	7108
1966	2051	1995	5791
1967	1498	1996	4108
1968	1699	1997	3391
1969	1815	1998	3724
1970	2799	1999	4462
1971	3801	2000	4375
1972	4127	2001	5998
1973	4462	2002	3763
1974	5255	2003	5081
1975	5010	2004	4229
1976	5641	2005	3136
1977	7196	2006	2694
1978	6630		
1979	5641		

Table L10. Catch-at-age and mean length-at-age for white hake from 1989-2006.

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	185	781	659	295	111	97	38	25	31

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	7.512
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	0.261	0.686	1.365	3.469	4.664	5.959	7.556	11.734

Table L11. 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), 1963-2007.

Year	No/Tow	Spring		Autumn		
		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

Table L12. Stratified mean number per tow at age of white hake in the NEFSC bottom trawl spring and autumn surveys (Strata 21-30,33-40), 1982-2003.

Year	Age Group												Total	9+
	0	1	2	3	4	5	6	7	8	9	10+			
Spring														
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
2002	Not available											0.0000	0.0000	
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	
Autumn														
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
2001	Not available											0.0000	0.0000	
2002	0.034	2.7951	1.1104	0.8529	1.315	0.3727	0.0718	0.0124	0	0.0124	0	6.5767	0.0124	

Table L13. Input values for white hake BRP calculations based on 2002-2006 average values from the two ASAP runs.

Age	PR-long	PR-short	Maturity	Mid-Year Catch Weights	SSB Weights	Jan 1 Weights
1	0.08	0.08	0.04	0.140	0.010	0.010
2	0.22	0.27	0.26	0.327	0.222	0.222
3	0.57	0.55	0.70	0.730	0.513	0.513
4	1.00	0.77	0.89	1.853	1.717	1.717
5	1.00	1.00	0.98	3.350	2.493	2.493
6	1.00	0.97	0.98	4.647	3.897	3.897
7	1.00	0.74	1.00	6.077	5.314	5.314
8	1.00	0.55	1.00	7.267	6.669	6.669
9+	0.53	0.20	1.00	9.223	9.224	9.224

Table L14. Biological reference points and stock status for white hake from parametric stock-recruitment models.

Parametric BRPs

	Long	Short
MSY	16900	9700
FMSY	0.21	0.35
SSBMSY	89900	39900
Alpha	18.08	9.48
Beta	16.70	1.39
Sigma	0.296	0.406
steepness	0.81	0.97
SSBterm	11751	14708
Fterm	0.22	0.25
SSBterm/SSBMSY	13%	37%
Fterm/FMSY	105%	71%

Table L15. Biological reference points and stock status for white hake from non-parametric empirical approaches.

Empirical BRPs

	Long First 100	Long Last 100	Long Last 43	Short
F40%	0.16	0.16	0.16	0.21
MSY	8600	7500	7300	6500
SSBMSY	59900	51200	41300	52000
SSBterm	11751	11751	11751	14708
Fterm	0.22	0.22	0.22	0.25
SSBterm/SSBMSY	20%	23%	28%	28%
Fterm/FMSY	138%	138%	138%	119%

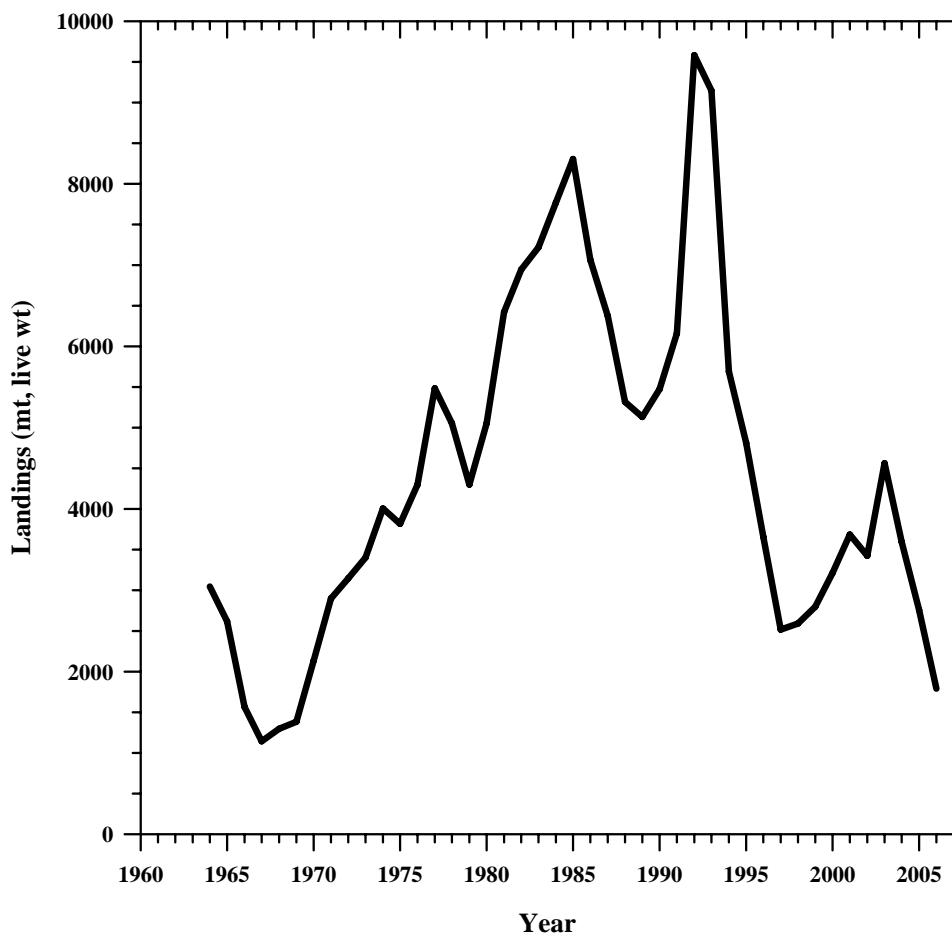


Figure L1. Reported total landings of white hake (mt, live weight) from the Gulf of Maine to Mid-Atlantic region, 1964-2006.

Total Catch of White Hake

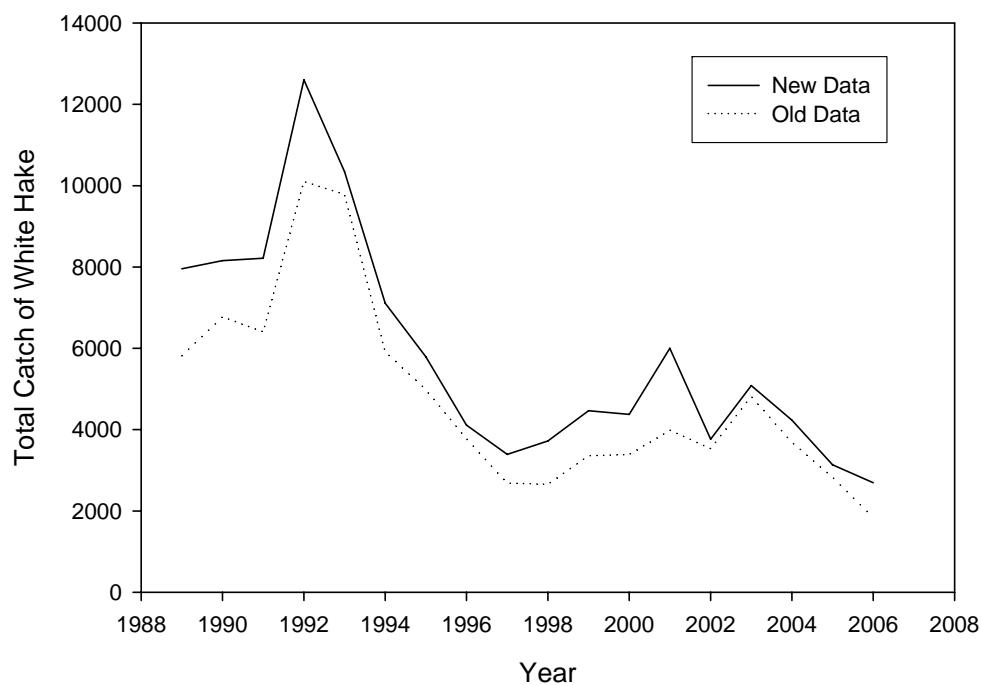


Figure L2. Total catch of white hake from 1989-2006 using just white hake data (Old Data) and using survey data to split out combined red and white hake catches (New Data).

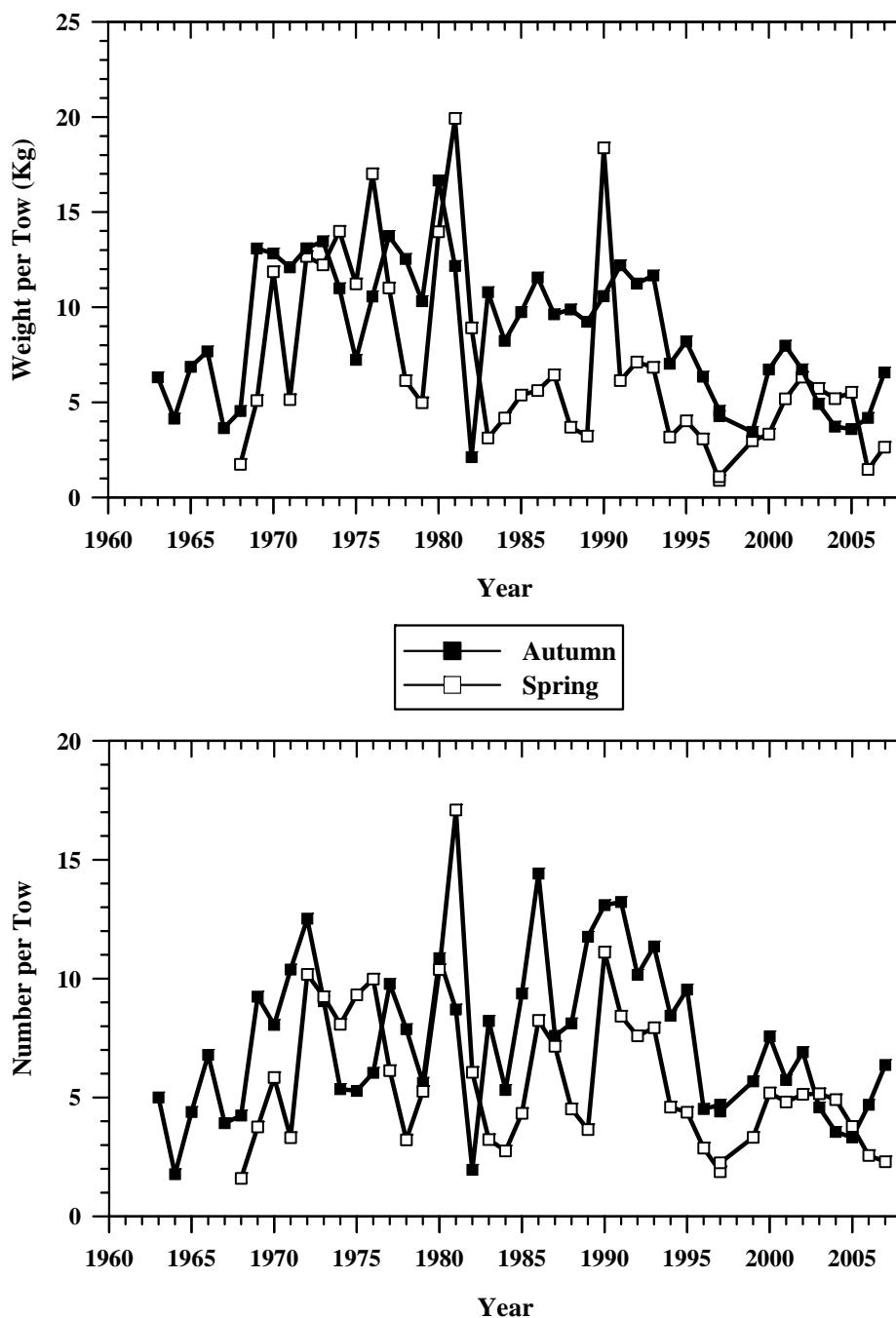


Figure L3. White hake indices of biomass (top panel) and abundance (bottom panel) from the NEFSC bottom trawl spring (open squares) and autumn (solid squares) surveys in the Gulf of Maine to Northern Georges Bank region (offshore strata 21-30, 33-40), 1963-2002.

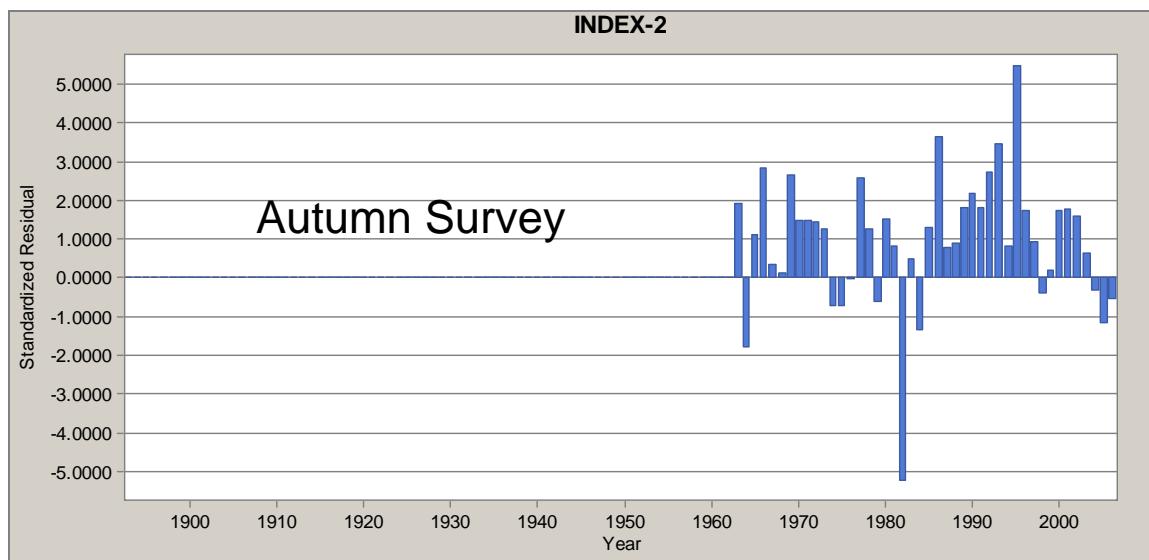
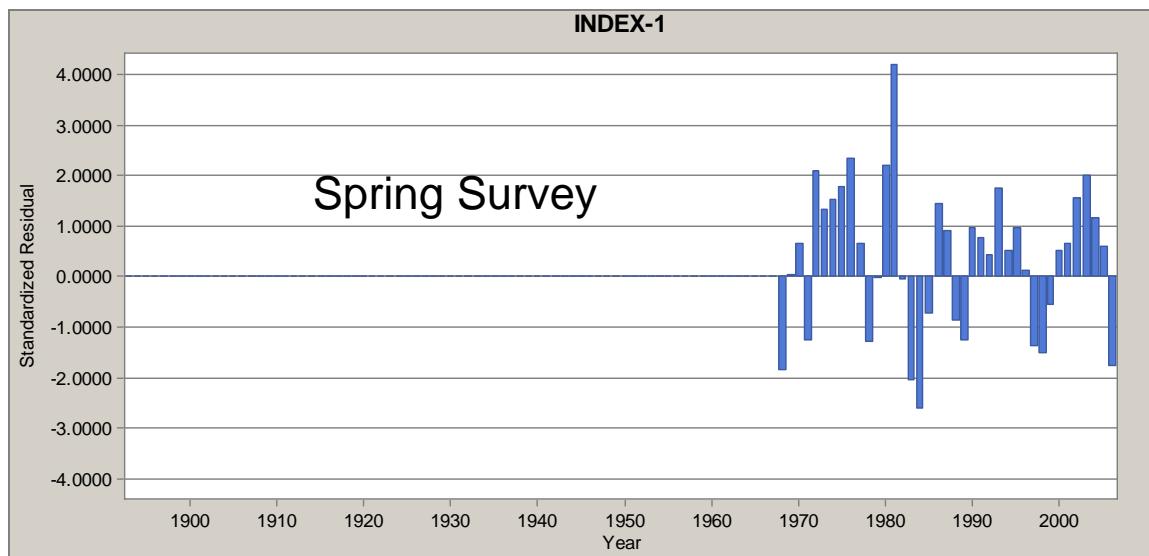


Figure L4. Residuals from the long time series ASAP formulation.

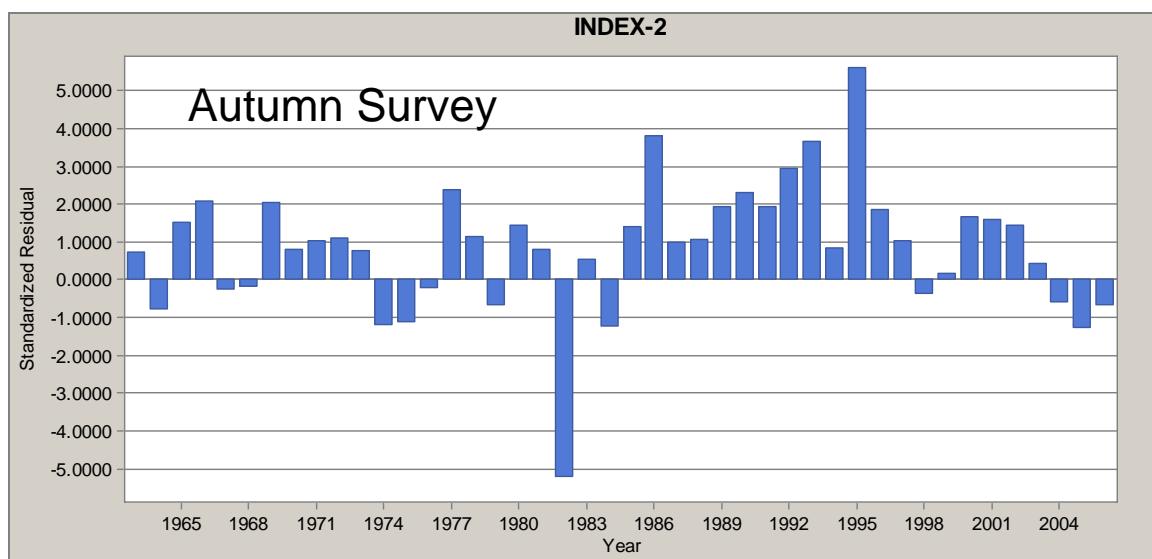
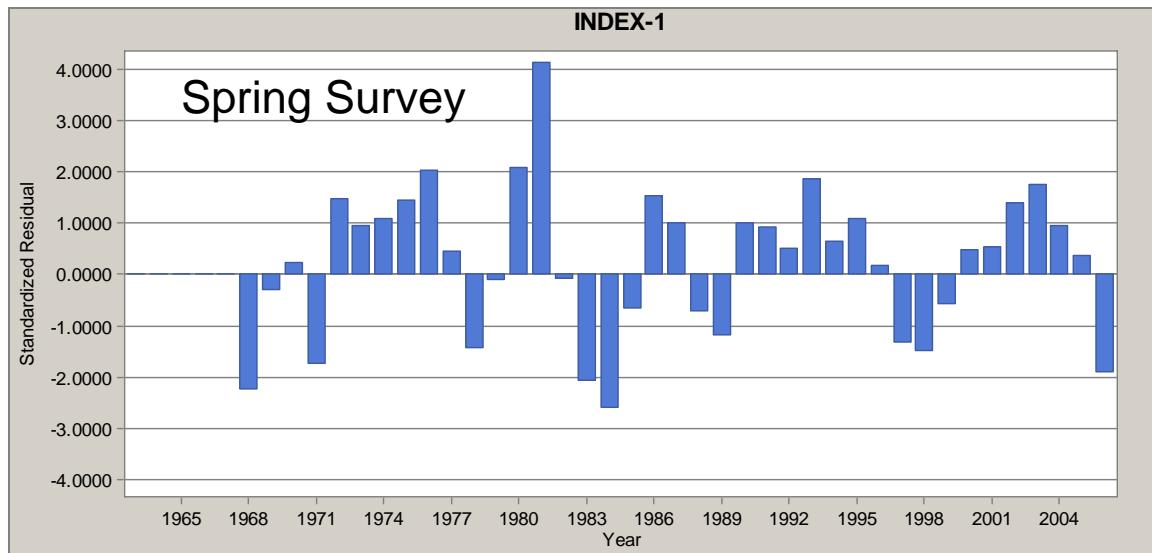


Figure L5. Residuals from the short time series ASAP formulation.

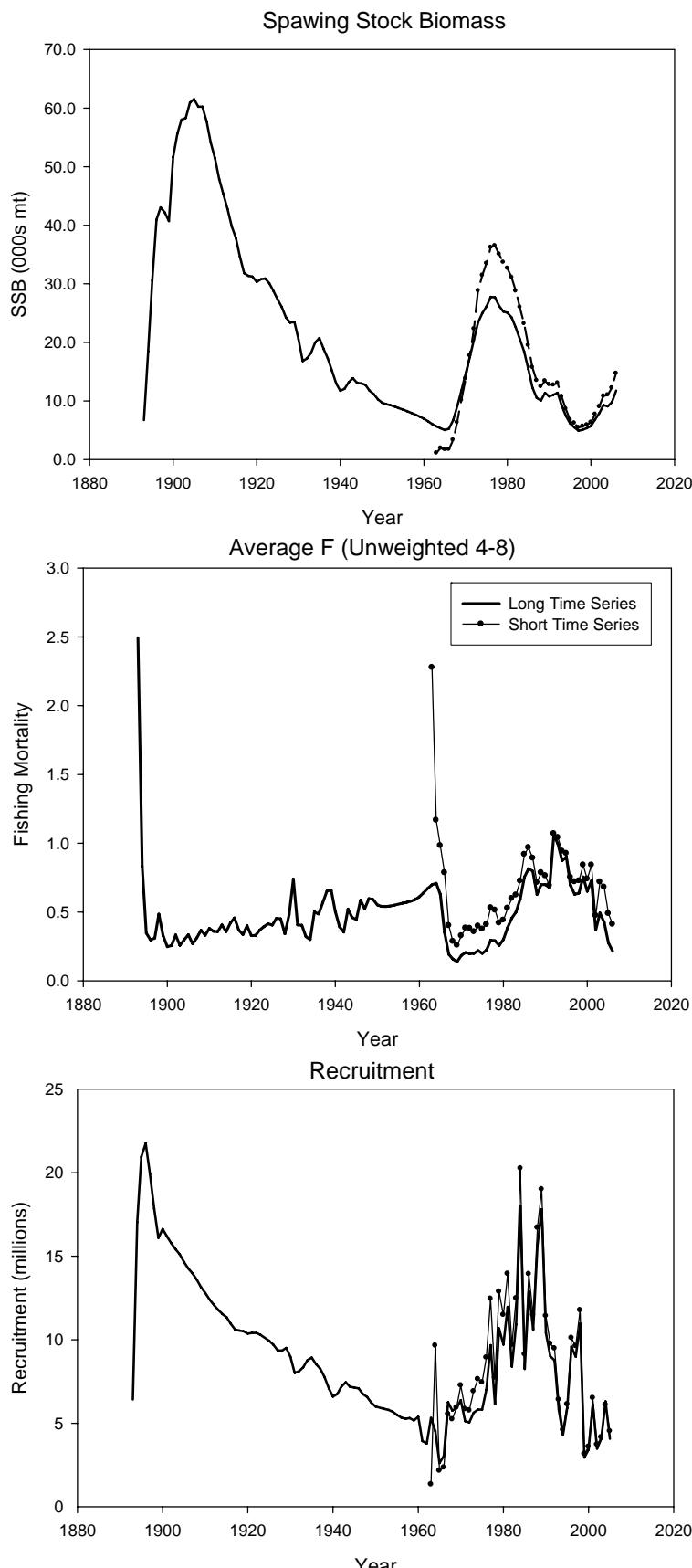


Figure L6. Results of both ASAP formulations. Top panel is spawning stock biomass, middle panel is fishing mortality and lower panel is recruitment.

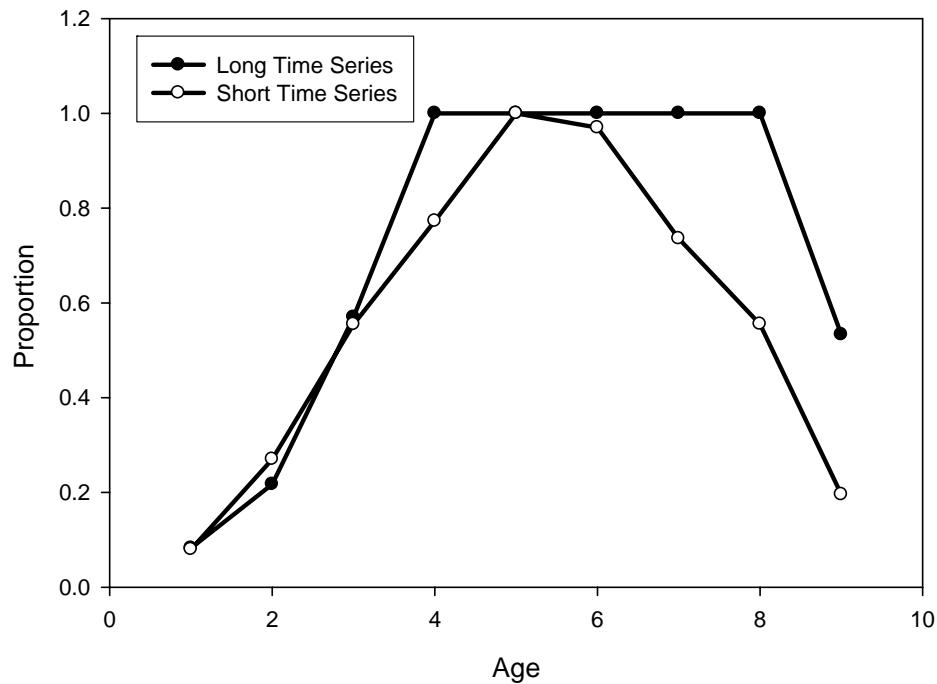


Figure L7. Selectivity of the commercial fishery estimated in the two formulations of ASAP. The closed circles are from the long time series run while the open circles are from the short time series run.

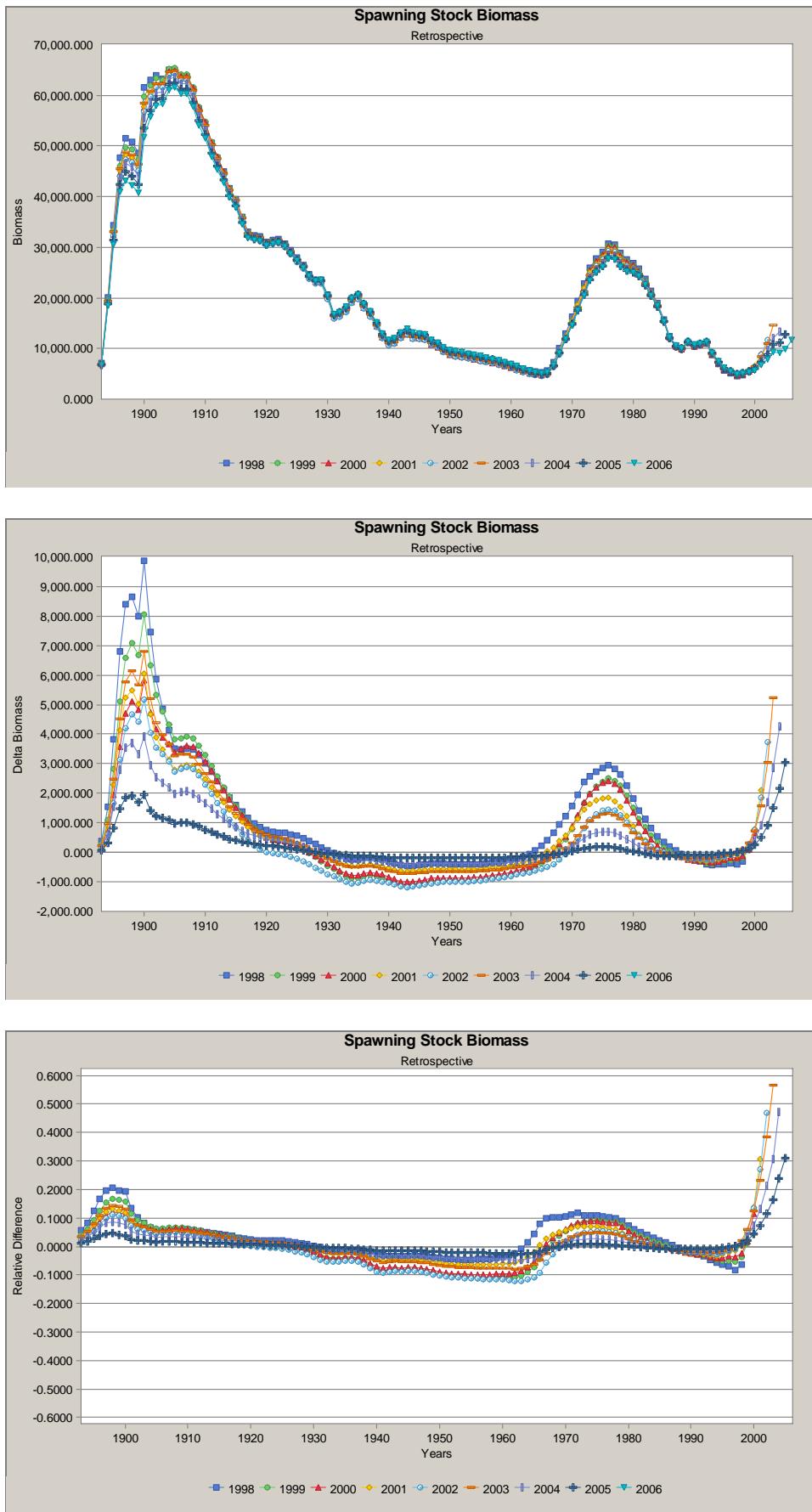


Figure L8. Retrospective plots for SSB from the long time series run.

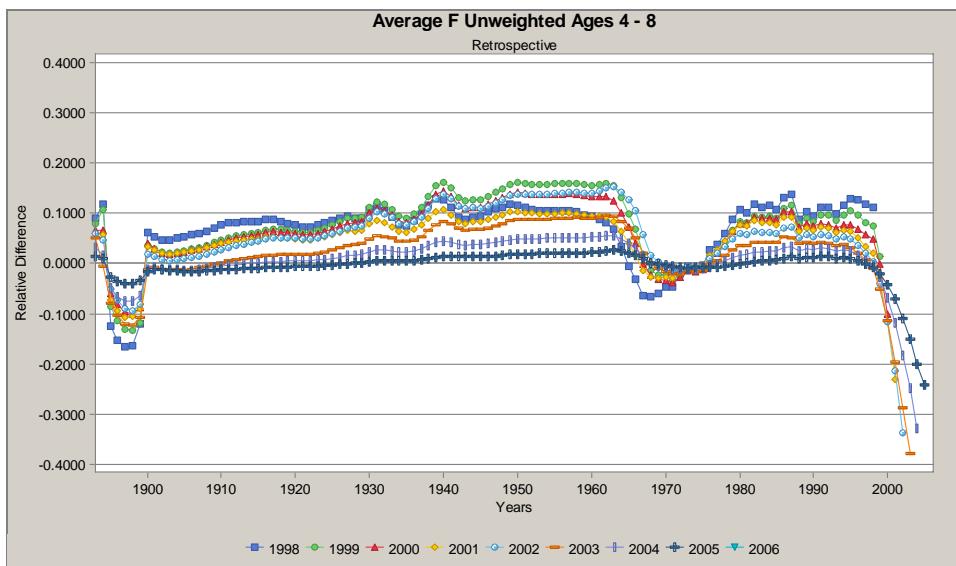
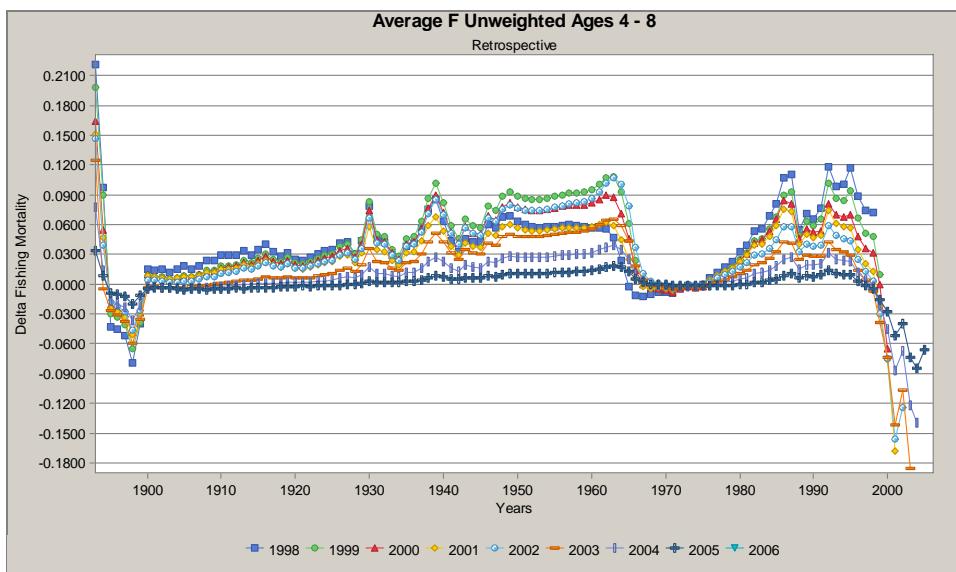
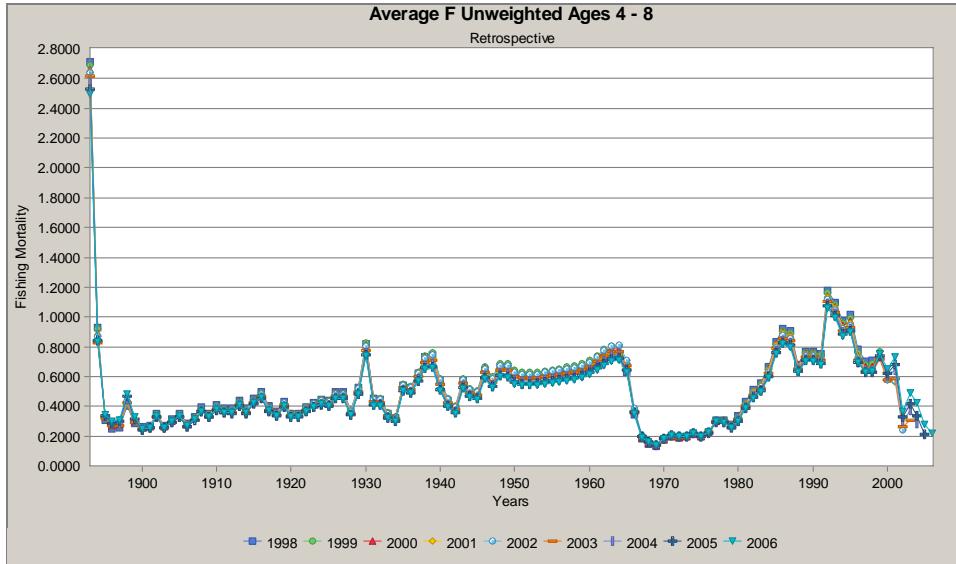


Figure L9. Retrospective plots for fishing mortality from the long time series run.

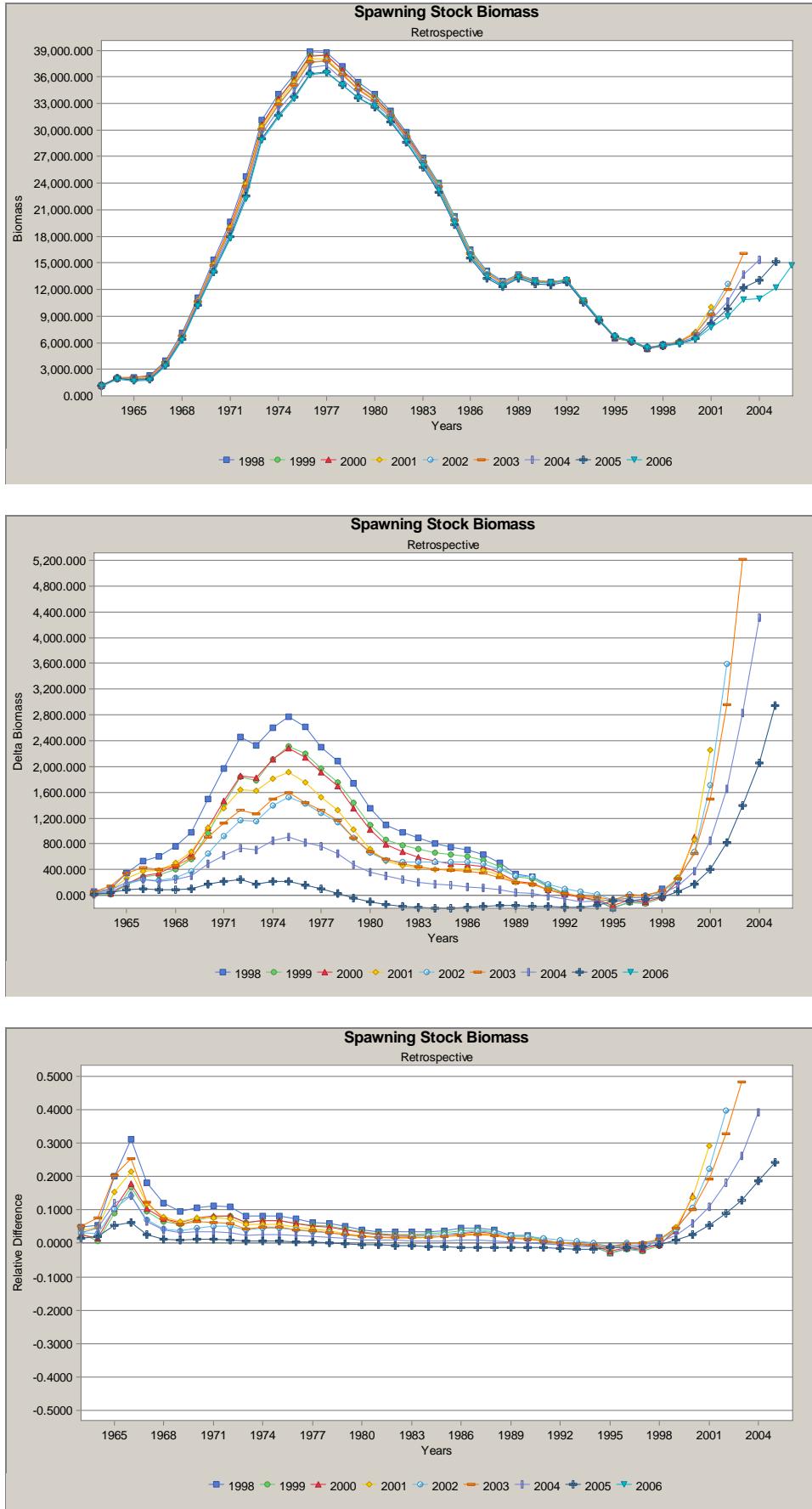


Figure L10. Retrospective plots for SSB from the short time series run.

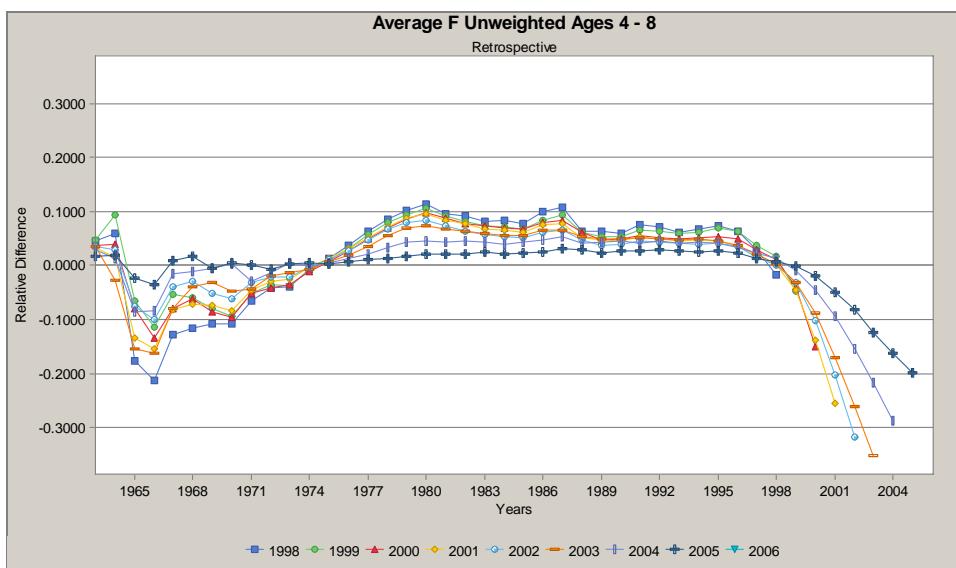
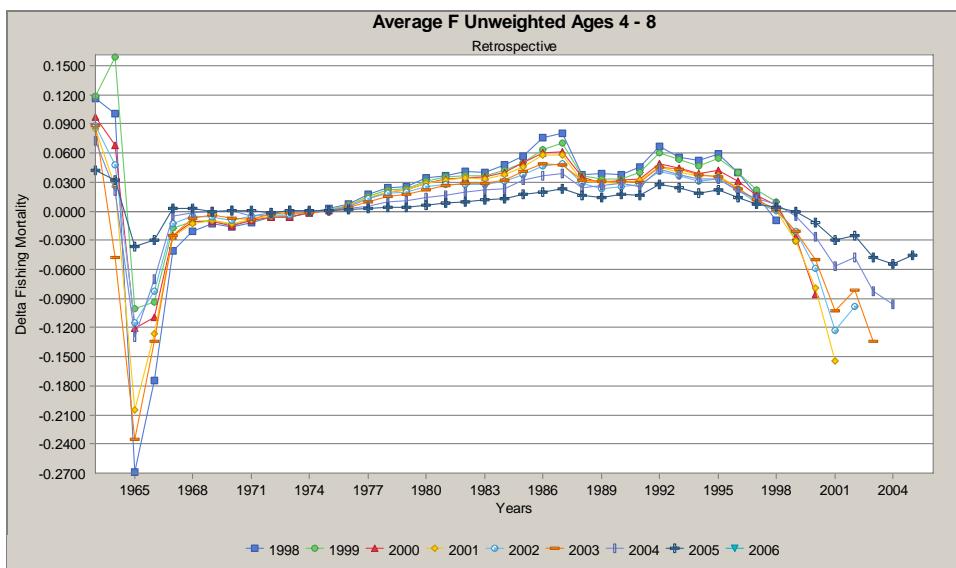
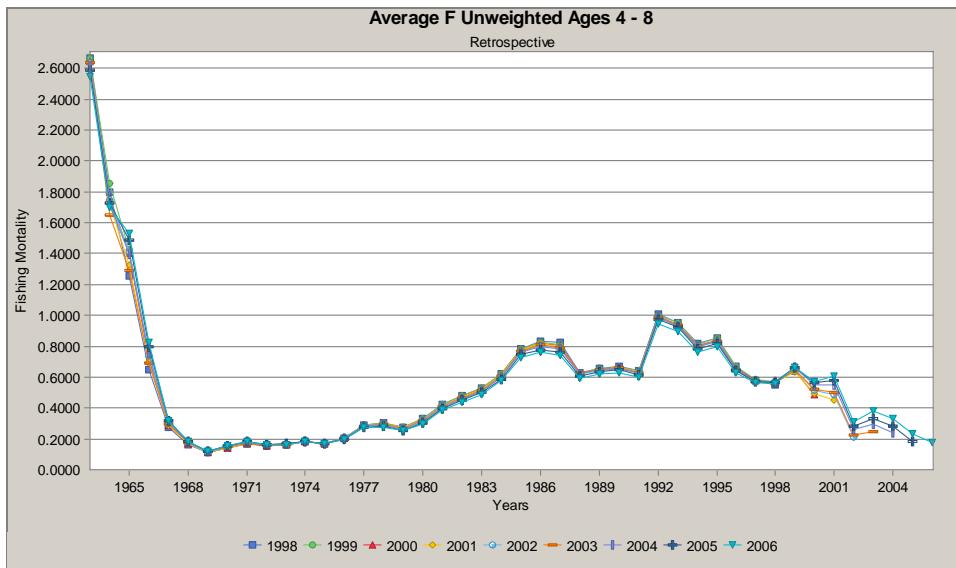


Figure L11. Retrospective plots for fishing mortality from the short time series run.