Options for Whiting/Hake Biological Reference Points, MSY Proxies, And ABC

Whiting PDT

March 2011

1.0 Issue

The Magnuson Stevens Fishery Conservation and Management Act requires Councils and NOAA's National Marine Fisheries Service (NMFS) to establish annual catch limits (ACLs) for managed fish stocks, overfished stocks by 2010 and all stocks by 2011. As stocks with index based assessments, the small mesh multispecies stocks (silver, red, and offshore hake, collectively known as whiting in the fishery and the management plan) have never had total allowable catches (TACs) established and are managed by minimum mesh and possession limits by the Northeast Multispecies Fishery Management Plan (FMP). For simplicity, this report will refer to these species as 'hakes', as they are known in the scientific literature. A related species, white hake, managed by the Northeast Multispecies FMP as a large mesh species is not addressed here.

Now the Scientific and Statistical Committee (SSC) must approve an Acceptable Biological Catch (ABC) limit and the New England Fishery Management Council (Council) must set ACLs for the managed small mesh multispecies stocks based on new assessment data, coming from the recent benchmark assessment completed in December 2010 and published in January 2011.

The background and context of the issue is described in Section 3.0. A synopsis of the recent benchmark assessment is given in Section 4.0, but for more details, the reader is referred to the SAW 51 benchmark assessment reports (NEFSC 2011). And because important new data has been developed, indicating that consumption of silver hake is considerably higher than removals by the fishery, a brief description of the amount consumed by important predators (including cannibalism by larger silver hake) is presented in Section 5.0. The accepted assessment and biological reference points do not include the removals due to predation, so the OFL and ABC options only include the removals due to fishing, i.e. landings and dead discards.

Most important to the issue addressed in this report, a description of various sources of scientific and management uncertainty is given in Section 6.0. Some sources of uncertainty are common to all managed stocks, while some are more important or peculiar to silver, red, or offshore hake, or all three. Section 7.0 describes the proposed biological reference points that the NEFSC 2011 benchmark assessment proposes for the small mesh multispecies (silver, red, and offshore hake). Both catch and survey data were deemed unreliable for management of offshore hake, so the PDT in Section 8.4 recommends adding an allowance for the customary catches of offshore hake into the southern silver hake ABC. The PDT therefore recommends this approach rather than track offshore hake catches separately, which would require fishermen to separate mixed hake catches of silver and offshore hake, and monitor the fishery removals against a highly uncertain and almost meaningless offshore hake ABC.

Three potential methods for setting ABCs are applied to silver and red hake data and explored in Section 8.0 to estimate scientific uncertainty of the F_{msy} proxy (recommended by NEFSC 2011 for the index based hake assessments) and of the 2008-2010 mean biomass indexed by the spring (red hake) and fall (silver hake) survey. Method 1 is the same as the procedure adopted for many groundfish stocks and skates, i.e. choice of an ABC that is a fixed percentage of OFL. Method 3 is similar, but the fixed percentage varies by stock depending on the precision of the F_{msy} estimate. Method 2 is the most complex and requires an annual estimation of uncertainty of OFL to estimate ABC from a fixed percentage of the cumulative frequency distribution of OFL. A more detailed description of the three methods is given in Section 8.1.

Section 8.0 also includes a risk analysis that various levels of catch (i.e. mortality) will exceed the 25th, 50th, and 75th percentiles of the cumulative F_{msy} proxy distribution (CFD). Exceeding the 50th percentile of the F_{msy} proxy distribution is most often thought of as 'overfishing', but other percentiles of the cumulative frequency distributions provide a measure of precision. Each section also includes an analysis of how the three methods respond to changes in stock biomass, scenarios derived from adding or subtracting one standard deviation of the three year moving average biomass from the 2008-2010 values that are now available (converted to FSV Albatross units using peer reviewed calibration methods). Table 19 and Table 20 summarize the results and sensitivity analysis for the three methods, comparing the results to 2009 landings.

Lastly, the Whiting PDT summarizes the characteristics and provides some caveats about the three methods in Section 9.0.

2.0 Table of Contents

2.1 *Table of Tables*

2.2 Table of Figures

2.3 Table of Maps

3.0 Background

Amendment 19 to develop Annual Catch Limits (ACLs) for hakes was postponed until after the benchmark assessment results became available (NEFSC 2011) in January 2011. It was hoped that the benchmark would produce analytical assessments with estimates of maximum sustainable yield (MSY) based reference points and scientific uncertainty. Unfortunately, despite many attempts with different models, the analytical assessments ultimately could not resolve different signals coming from low catches (especially compared with those in the early part of the time series), increasing stock biomass, and an increasingly truncated age structure in survey catches (i.e. increasing absence of older fish, particularly silver hake).

Nonetheless, the benchmark assessment made progress on resolving stock structure, species identification in the survey and commercial catches, and in estimating consumption. Despite the inclusion of predatory consumption estimates which were almost an order of magnitude greater than catch (Section 5.0), the analytical models still did not perform well. Instead, the SAW accepted an index based assessment for both red and silver hake status determination, similar to previous assessments, with updated reference points. There was no reliable information about catch or trends in abundance and biomass to guide management of offshore hake.

The Whiting PDT is considering various MSY proxy approaches that may be used to determine red and silver hake ABCs. An allowance for a small percentage of offshore hake is being proposed for the southern silver hake ACL, to be managed jointly as one complex.

Using guidance from the SSC, the Whiting PDT will return with ABC specification recommendations for SSC approval in August. These will be incorporated into a developing Draft Amendment 19 for approval at the September Council meeting.

4.0 Benchmark assessment and biological reference points

4.1 Silver hake

4.1.1 Stock Distribution and Identification

Silver hake range from Newfoundland to South Carolina and are most abundant from Nova Scotia to New Jersey. Silver hake are found over a wide range of depths, from shallow waters to greater than 400 m (219 fathoms). Larger and older silver hake tend to be found further to the north and in deeper water. There are seasonal patterns with movement inshore during the spring and summer.

Management is based on two stocks (north and south) due to differences in morphology of silver hake in the two areas (Map 1), population trends, and fishery patterns. The northern stock is distributed in the Gulf of Maine-northern Georges Bank region. The southern stock extends from southern Georges Bank to Cape Hatteras. There was no strong biological evidence to support either a separate or combined silver hake assessment. The two management units were retained in this assessment.

4.1.2 Catches

Nominal (reported) annual landings from the northern area were high in the 1950s and 1960s averaging 52,200 mt, followed by a period of lower landings (30,850 mt) through 1975 (Table 1). After the industrial and distant water fleet fisheries ended in the late 1970s, landings averaged only 8,000 mt. From 2005-2009, annual landings declined to about 1000 mt. Nominal annual landings from the southern area averaged 14,700 mt in the 1950s, followed by a period of extremely high landings over 300,000 mt in 1965 (Table 1). Landings then averaged 61,000 mt during the 1970s. After the industrial and distant water fleet fisheries ended in the late 1970s, landings averaged only 12,000 mt through 1999. From 2001-2009, annual landings declined to about 7000 mt (Table 1).

Prior to 1991 landings of silver hake and offshore hake were not reported by species. Since 1991 reporting by species has occurred but to varying extents. This introduces a source of uncertainty in landings data particularly for the southern region where offshore hake are more abundant (Garcia-Vazquez et al., 2009). Therefore, two models (length-based and depth-based estimators) were developed to estimate the proportion of silver hake landed from the total hake landings (offshore and silver hake combined).

Estimated annual discards of silver hake in the north ranged from 38 mt (2006) to 2,900 mt (1982) and in the south discards ranged from 131 mt (2007) to 6,600 mt (1989) (Table 1). Silver hake discards from the longline and sink gill net fishery were minimal for both stock areas (Table 2 and Table 3). However, the otter trawl fisheries have been a significant source of discards for silver hake and the trends were variable.

4.1.3 Data and Assessment

Data available included fishery landings and discards by fleet, length compositions of landings and discards, age-based surveys indices from the NEFSC fall and spring surveys, and estimates of minimum consumption at age for a subset of fish predators sampled for stomach contents on the NEFSC surveys. The NEFSC bottom trawl survey switched from the FRV *Albatross IV* to the FSV *Bigelow* in spring 2009. Survey data given here are in "*Albatross IV*" units.

Two assessment models were attempted, An Age Structured Assessment Program (ASAP) and An Index Based Method (AIM). However, due to the difficulties reconciling the inconsistent interpretations from the age profiles in the fishery and survey data in the ASAP model, and the inadequate diagnostics from the AIM model, neither model formulations were considered for management. Thus, for the purpose of this report, the index method based on the three year survey biomass and relative exploitation (catch/index) was used. For additional details on the ASAP and AIM model analyses, please refer to Background Document 3.

The index method that is being used was based on an update of the previous index method in the 2003 Stock Assessment and Fishery Evaluation (SAFE Report) report. Relative abundance indices and associated reference points were previously based on the delta method estimator. For this new assessment, the "delta" estimators were replaced with arithmetic estimates (i.e. no log transform was applied). The delta transformation inflated the variance of the survey and it also was sensitive to treatment of tows with no catch. As a result, the arithmetic mean is recommended for deriving fall survey estimates. The same years (1973-1982) as used previously were used to define the biomass reference points for the fall survey index. Landings for the period (1973-1982) were used previously to characterize the relative exploitation reference points. However, discards since 1989 can be reliably estimated, so the relative exploitation index is now defined using catch over the relative biomass. Historical discarding, particularly in the distant water fleet (DWF), has likely been very small. Therefore, comparison of relative exploitation index based on catch/biomass with reference points based on landings over biomass is justified.

Trends in landings and discards by gear are giving in Table 2 and Table 3. Most of the landings are derived from commercial trips using trawls, while the discards are more or less evenly split in the north by large and small mesh, with a significant contribution from shrimp trawls, although the shrimp trawl discards have declined, probably due to the introduction of the Nordmore Grate (Table 3). In the south, most of the estimated discards come from vessels using small mesh. Trends in recruitment and age 3+ abundance are presented in Figure 1, showing a general decline in the abundance of older fish in both the northern and southern stock units. In both stocks, the exploitation ratio has declined from values prevalent during 1963-1974 and has remained well below the overfishing definition mortality thresholds (Figure 4).

Map 1. Statistical areas used to define the northern and southern silver hake stocks.

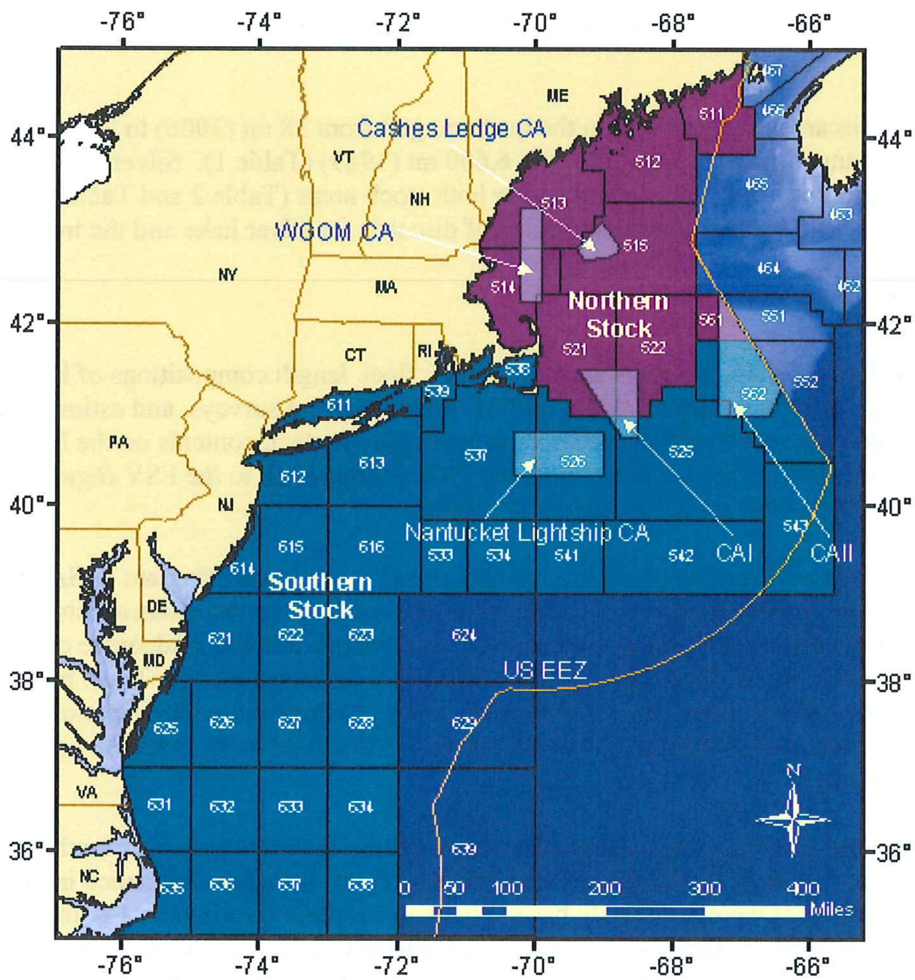


Table 1. Silver hake landings, catch, survey biomass, and exploitation trends for northern and southern stocks (Source: NEFSC 2011).

Northern stock

					NEFSC Survey		Replacement Ratio		Relative Fishing	
Year	Catch (mt)	Pct DWF landings	Pct discards	Pct recreational	Fall (kg/tow)	3-yr average	Fall (kg/tow)	3-yr average	Fall (mt/kg)	3-yr average
1955	53361									
1956	42150									
1957	62750									
1958	49903									
1959	50608									
1960	45543									
1961	39688									
1962	79002									
1963	73924				23.1				3.2	
1964	94462				4.34				21.77	
1965	45279				7.06	11.5			6.41	10.46
1966	47808				4.19	5.2			11.41	13.2
1967	33371				2.27	4.51			14.7	10.84
1968	41378.94				2.28	2.91			18.15	14.75
1969	24054.96				2.41	2.32			9.98	14.28
1970	27527.97				3.03	2.57			9.09	12.41
1971	36398.22				2.67	2.7			13.63	10.9
1972	25223.95				5.78	3.83			4.36	9.03
1973	32090.95	56%			4.12	4.19			7.79	8.6
1974	20682	67%			3.45	4.45			5.99	6.05
1975	39874	68%			8.09	5.22			4.93	6.24
1976	13634	1%			11.25	7.6			1.21	4.05
1977	12457	0%			6.72	8.69			1.85	2.66
1978	12609	0%			6.32	8.1			2	1.69
1979	3415	0%			6.18	6.41			0.55	1.47
1980	4730	0%			7.23	6.58			0.65	1.07
1981	7054	0%	37%		4.52	5.98			1.56	0.92
1982	7569	0%	38%		6.28	6.01			1.21	1.14
1983	7954	0%	33%		8.76	6.52			0.91	1.22
1984	10880	0%	24%		3.36	6.13			3.24	1.78
1985	10859	0%	24%		8.28	6.8			1.31	1.82
1986	10856	0%	22%		13.04	8.23			0.83	1.79
1987	7765	0%	27%		9.79	10.37			0.79	0.98
1988	8574	0%	21%		6.05	9.63			1.42	1.01
1989	6963	0%	33%		10.53	8.79			0.66	0.96
1990	8335	0%	23%		15.61	10.73			0.53	0.87
1991	7311	0%	17%		10.52	12.22			0.69	0.63
1992	6730	0%	21%		10.25	12.13			0.66	0.63
1993	5050	0%	14%		7.5	9.42			0.67	0.67
1994	4140	0%	6%		6.84	8.2			0.61	0.65
1995	3224	0%	20%		12.89	9.08			0.25	0.51
1996	4443	0%	19%		7.57	9.1			0.59	0.48
1997	3045	0%	8%		5.66	8.71			0.54	0.46
1998	2738	0%	25%		18.91	10.71			0.14	0.42
1999	4190	0%	18%		11.15	11.91			0.38	0.35
2000	2952	0%	12%		13.51	14.52			0.22	0.25
2001	3868	0%	12%		8.33	11			0.46	0.35
2002	3106	0%	17%		7.99	9.94			0.39	0.36
2003	2006	0%	10%		8.29	8.2			0.24	0.37
2004	1165	0%	10%		3.28	6.52			0.35	0.33
2005	890	0%	7%		1.72	4.43			0.52	0.37
2006	941	0%	4%		3.69	2.9			0.26	0.38
2007	1764	0%	43%		6.44	3.95			0.27	0.35
2008	788	0%	21%		5.27	5.13			0.15	0.23
2009	1232	0%	15%		6.89	6.2			0.18	0.2

Southern stock

Year	Catch (mt)	Pct DWF landings	Pct discards	Pct recreational	NEFSC Survey Fall (kg/tow)	NEFSC Survey 3-yr average	Replacement Ratio Fall	Replacement Ratio Spring	Relative Fishing Mortality Fall (mt/kg)	Relative Fishing Mortality 3-yr average
1955	13255									
1956	14241									
1957	16426									
1958	12902									
1959	16387									
1960	8816									
1961	12649									
1962	17939									
1963	89425				4.66				19.19	
1964	147048				4.06				36.22	
1965	294117				5.28	4.67			55.7	37.04
1966	202318				2.64	3.99			76.64	56.19
1967	87383				2.44	3.45			35.81	56.05
1968	58157				2.73	2.6			21.3	44.58
1969	74891				1.26	2.14			59.44	38.85
1970	26832				1.35	1.78			19.88	33.54
1971	70506				2.21	1.61			31.9	37.07
1972	88179				2.13	1.9			41.4	31.06
1973	102078	94%			1.7	2.01			60.05	44.45
1974	102396	93%			0.85	1.56			120.47	73.97
1975	72164	89%			1.79	1.45			40.32	73.61
1976	64608	85%			1.99	1.54			32.47	64.42
1977	57160	81%			1.68	1.82			34.02	35.6
1978	25834	53%			2.5	2.06			10.33	25.61
1979	16398	27%			1.68	1.95			9.76	18.04
1980	11684	13%			1.63	1.94			7.17	9.09
1981	16931	16%			1.12	1.48			15.12	10.68
1982	18806	12%			1.56	1.44			12.06	11.45
1983	16674	4%			2.57	1.75			6.49	11.22
1984	17838	2%			1.4	1.84			12.74	10.43
1985	16691	8%			3.55	2.51			4.7	7.98
1986	14029	4%			1.45	2.13			9.68	9.04
1987	13804	0%			1.95	2.32			7.08	7.15
1988	13447	0%			1.78	1.73			7.55	8.1
1989	19568	0%			1.87	1.87			10.46	8.37
1990	18992	0%			1.52	1.72			12.49	10.17
1991	12821	0%			0.85	1.41			15.08	12.68
1992	13977	0%			0.99	1.12			14.12	13.9
1993	17653	0%			1.28	1.04			13.79	14.33
1994	18118	0%			0.79	1.02			22.93	16.95
1995	13394	0%			1.59	1.22			8.42	15.05
1996	12613	0%			0.45	0.94			28.03	19.8
1997	13172	0%			0.83	0.96			15.87	17.44
1998	13084	0%			0.57	0.62			22.95	22.28
1999	13965	0%			0.82	0.74			17.03	18.62
2000	9800	0%			0.72	0.7			13.61	17.87
2001	9072	0%			2.04	1.19			4.45	11.7
2002	5298	0%			1.18	1.31			4.49	7.52
2003	6884	0%			1.42	1.55			4.85	4.6
2004	8168	0%			1.24	1.28			6.59	5.31
2005	7971	0%			0.94	1.2			8.48	6.64
2006	4745	0%			1.42	1.2			3.34	6.14
2007	5212	0%			0.87	1.08			5.99	5.94
2008	6616	0%			1.36	1.22			4.86	4.73
2009	7434	0%	11%		1.1	1.11			6.76	5.87

Table 2. Silver hake landings percent by gear type (Source: NEFSC 2011).

Northern stock

Year	Longline	Fish trawl	Shrimp trawl	Sink gillnet	Other	Total (mt)
1964	0%	100%	0%	0%	0%	37,222
1965	0%	100%	0%	0%	0%	29,512
1966	0%	100%	0%	0%	0%	33,569
1967	0%	100%	0%	0%	0%	26,489
1968	0%	100%	0%	0%	0%	30,873
1969	0%	100%	0%	0%	0%	16,008
1970	0%	100%	0%	0%	0%	15,223
1971	0%	100%	0%	0%	0%	11,158
1972	0%	100%	0%	0%	0%	6,440
1973	0%	100%	0%	0%	0%	14,005
1974	0%	100%	0%	0%	0%	6,907
1975	0%	98%	2%	0%	0%	12,566
1976	0%	99%	0%	0%	0%	13,483
1977	0%	99%	0%	0%	0%	12,455
1978	0%	99%	0%	1%	1%	12,609
1979	0%	99%	0%	1%	0%	3,415
1980	0%	99%	0%	1%	0%	4,730
1981	0%	95%	4%	1%	0%	4,416
1982	0%	97%	3%	1%	0%	4,664
1983	0%	94%	5%	1%	1%	5,312
1984	0%	97%	2%	0%	1%	8,289
1985	0%	93%	6%	0%	1%	8,297
1986	0%	89%	9%	1%	2%	8,502
1987	0%	89%	7%	1%	3%	5,658
1988	0%	91%	6%	0%	2%	6,789
1989	0%	93%	5%	1%	1%	4,648
1990	0%	95%	4%	1%	0%	6,377
1991	0%	95%	3%	1%	1%	6,055
1992	0%	96%	2%	1%	2%	5,306
1993	0%	96%	0%	1%	3%	4,364
1994	0%	95%	1%	2%	2%	3,899
1995	0%	87%	1%	2%	10%	2,594
1996	0%	97%	1%	2%	0%	3,619
1997	0%	93%	5%	2%	1%	2,802
1998	0%	98%	0%	1%	0%	2,045
1999	0%	98%	0%	1%	0%	3,444
2000	0%	95%	1%	2%	3%	2,592
2001	0%	97%	0%	1%	2%	3,391
2002	0%	99%	0%	1%	0%	2,593
2003	0%	97%	0%	1%	2%	1,808
2004	0%	92%	0%	2%	5%	1,049
2005	0%	89%	0%	4%	7%	827
2006	0%	98%	0%	2%	0%	903
2007	0%	99%	0%	1%	0%	1,014
2008	0%	93%	0%	7%	0%	620
2009	0%	79%	1%	19%	1%	1,038

Southern stock

Year	Longline	Fish trawl	Sink gillnet	Other	Total
1964	0%	100%	0%	0%	26,518
1965	0%	100%	0%	0%	23,765
1966	0%	100%	0%	0%	11,212
1967	0%	100%	0%	0%	9,500
1968	0%	100%	0%	0%	9,074
1969	0%	100%	0%	0%	8,165
1970	0%	100%	0%	0%	6,879
1971	0%	100%	0%	0%	5,546
1972	0%	98%	0%	2%	5,973
1973	0%	100%	0%	0%	6,604
1974	0%	100%	0%	0%	7,751
1975	0%	100%	0%	0%	8,441
1976	0%	100%	0%	0%	10,434
1977	0%	100%	0%	0%	11,458
1978	0%	100%	0%	0%	12,779
1979	0%	100%	0%	0%	13,498
1980	0%	100%	0%	0%	11,848
1981	0%	100%	0%	0%	11,783
1982	0%	100%	0%	0%	12,164
1983	0%	100%	0%	0%	11,520
1984	0%	100%	0%	0%	12,731
1985	0%	100%	0%	0%	11,843
1986	0%	100%	0%	0%	9,573
1987	0%	100%	0%	0%	10,121
1988	0%	100%	0%	0%	9,195
1989	0%	100%	0%	0%	13,428
1990	0%	100%	0%	0%	13,610
1991	0%	100%	0%	0%	10,492
1992	0%	100%	0%	0%	10,873
1993	0%	100%	0%	0%	12,942
1994	0%	93%	0%	7%	12,159
1995	0%	89%	0%	11%	12,102
1996	0%	100%	0%	0%	12,561
1997	0%	100%	0%	0%	12,763
1998	0%	100%	0%	0%	12,828
1999	0%	100%	0%	0%	10,577
2000	0%	100%	0%	0%	9,769
2001	0%	100%	0%	0%	9,517
2002	0%	100%	0%	0%	5,345
2003	0%	100%	0%	0%	6,835
2004	0%	96%	1%	3%	7,436
2005	1%	93%	0%	6%	6,671
2006	1%	92%	1%	6%	4,629
2007	0%	95%	1%	4%	5,345
2008	0%	89%	3%	9%	5,638
2009	0%	70%	3%	27%	6,720

Table 3. Silver hake discard percent by gear type (Source: NEFSC 2011). The discards from 1981-1988 (1991 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

Northern stock

Year	Longline	mesh trawl	mesh trawl	Sink gillnet	Scallop dredge	Shrimp trawl	Total (mt)
1981	0%	88%	0%	3%	1%	8%	2,638
1982	0%	87%	0%	2%	1%	10%	2,905
1983	0%	85%	0%	2%	1%	13%	2,642
1984	0%	78%	0%	2%	0%	19%	2,592
1985	0%	71%	0%	2%	0%	27%	2,562
1986	0%	62%	0%	2%	0%	36%	2,354
1987	0%	61%	0%	3%	1%	36%	2,107
1988	0%	68%	0%	3%	2%	28%	1,785
1989	0%	13%	51%	2%	1%	33%	2,342
1990	0%	35%	32%	4%	2%	28%	1,989
1991	0%	31%	41%	4%	0%	24%	1,251
1992	0%	26%	41%	3%	0%	30%	1,430
1993	0%	35%	26%	8%	8%	23%	740
1994	0%	19%	28%	18%	0%	35%	240
1995	0%	19%	3%	5%	1%	72%	634
1996	0%	8%	3%	7%	0%	83%	826
1997	0%	23%	6%	11%	3%	57%	249
1998	0%	20%	42%	1%	5%	31%	694
1999	0%	24%	58%	3%	3%	13%	719
2000	0%	52%	0%	7%	1%	39%	355
2001	0%	85%	4%	3%	1%	8%	477
2002	0%	75%	20%	2%	1%	2%	513
2003	0%	37%	45%	5%	2%	11%	202
2004	0%	59%	26%	3%	0%	12%	113
2005	0%	65%	15%	2%	1%	17%	62
2006	0%	55%	13%	3%	3%	26%	38
2007	0%	3%	95%	0%	0%	2%	749
2008	0%	27%	43%	4%	0%	26%	167
2009	0%	32%	44%	3%	1%	20%	216

Southern stock

Year	Longline	Large mesh trawl	Small mesh trawl	Sink gillnet	Scallop dredge	Total (mt)
1981	0%	97%	0%	0%	3%	3,603
1982	0%	99%	0%	0%	1%	4,788
1983	0%	99%	0%	0%	1%	4,952
1984	0%	99%	0%	0%	1%	5,023
1985	0%	99%	0%	0%	1%	3,982
1986	0%	99%	0%	0%	1%	4,456
1987	0%	98%	0%	0%	2%	4,374
1988	0%	98%	0%	0%	2%	4,626
1989	0%	2%	96%	0%	2%	6,642
1990	0%	45%	51%	0%	4%	6,193
1991	0%	37%	62%	0%	1%	3,234
1992	0%	19%	81%	0%	0%	3,480
1993	0%	5%	88%	0%	7%	5,245
1994	0%	9%	90%	0%	0%	5,992
1995	0%	10%	81%	0%	9%	1,439
1996	0%	4%	89%	0%	7%	491
1997	0%	58%	35%	0%	8%	639
1998	0%	1%	95%	0%	4%	354
1999	0%	1%	98%	0%	1%	3,552
2000	0%	3%	57%	2%	38%	333
2001	0%	2%	92%	0%	6%	192
2002	0%	3%	92%	0%	5%	280
2003	0%	2%	97%	0%	1%	676
2004	0%	7%	92%	0%	1%	1,244
2005	0%	3%	96%	0%	1%	1,574
2006	0%	15%	77%	0%	8%	160
2007	0%	16%	77%	0%	7%	132
2008	0%	2%	97%	0%	1%	1,045
2009	0%	7%	90%	0%	3%	828

Figure 1. Trends in fall survey abundance by age group for silver hake.

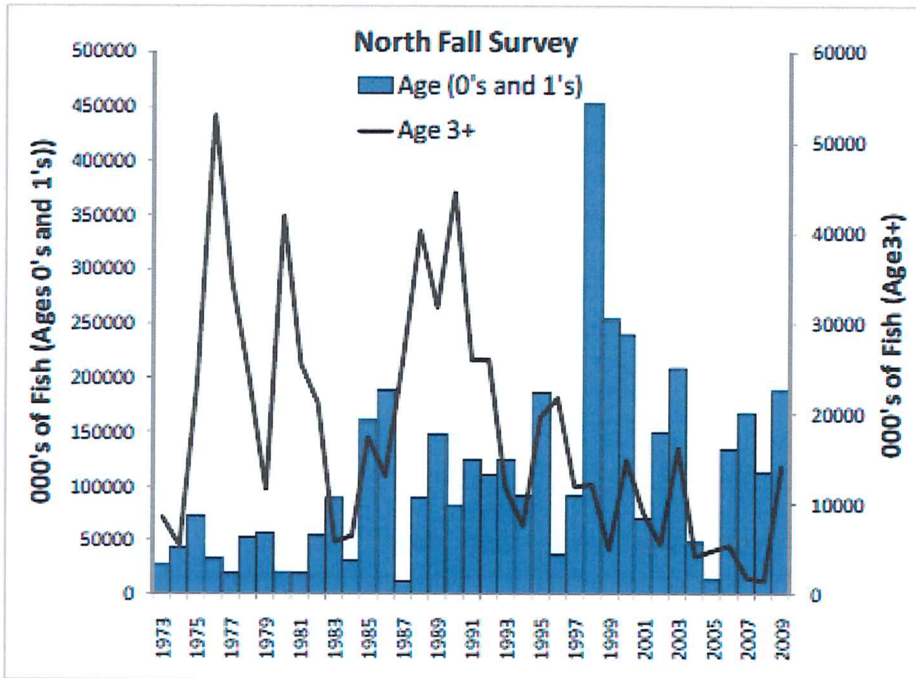
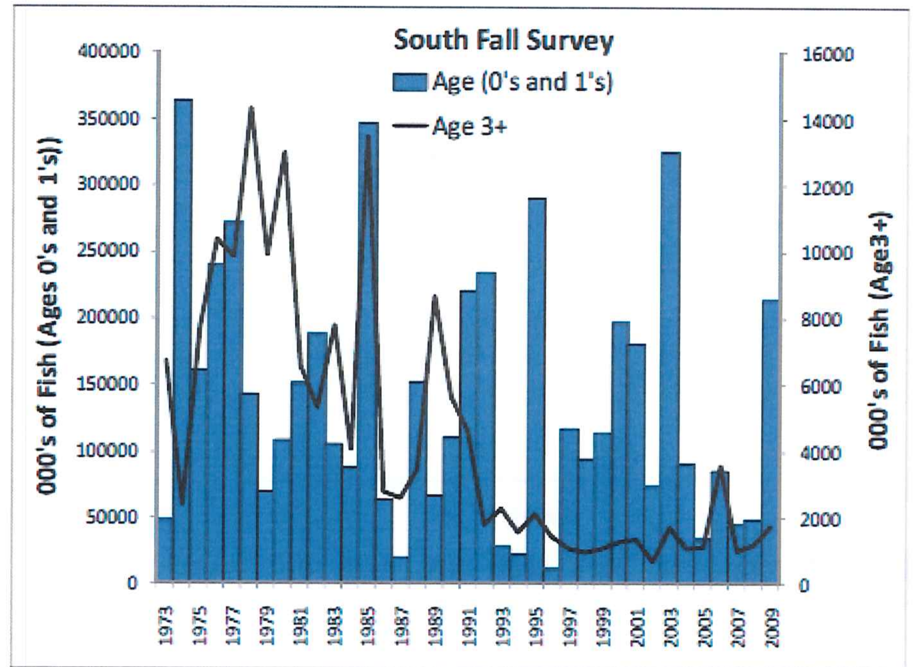
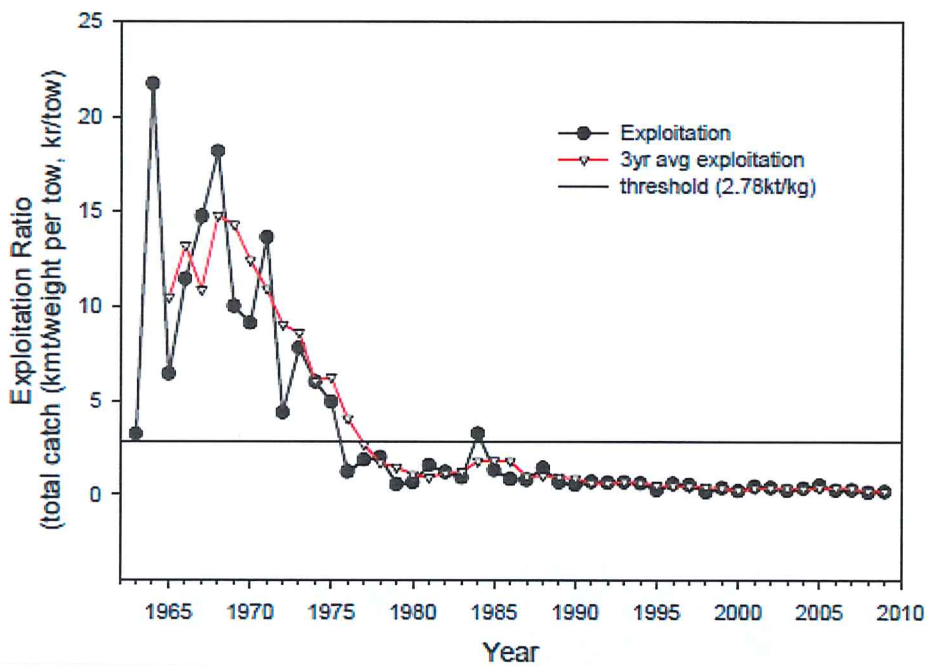
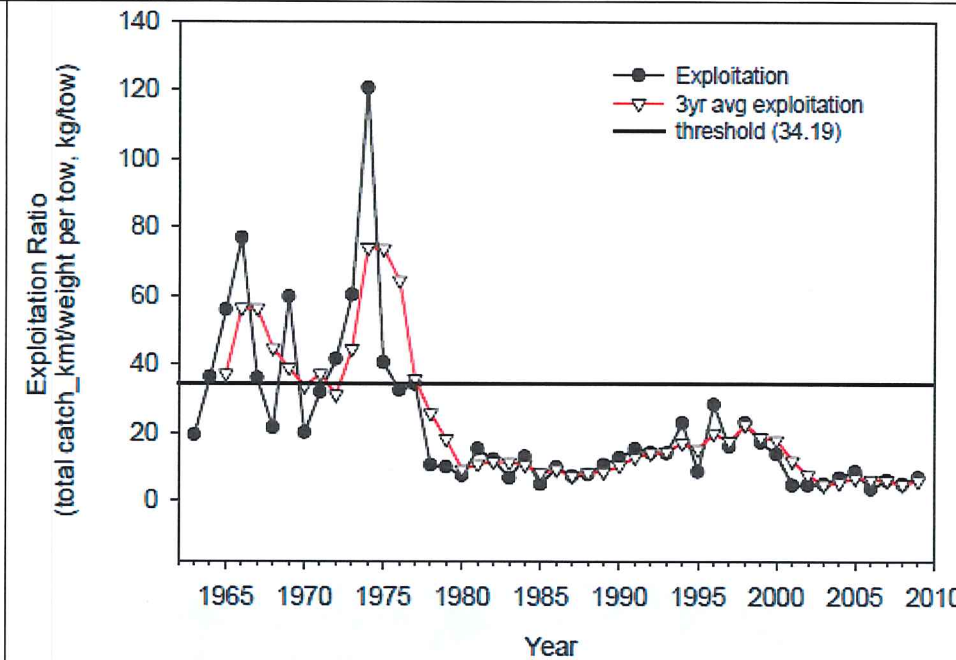
Northern stock	Southern stock
	

Figure 2. Exploitation indices (fall survey) and newly proposed overfishing threshold for silver hake.

Northern stock	Southern stock
	

4.2 Red hake

4.2.1 Stock Distribution and Identification

Red hake is a demersal gadoid species distributed from the Gulf of St. Lawrence to North Carolina, and is most abundant from the western Gulf of Maine through Southern New England waters (Bigelow and Schroeder 1953). Red hake are separated into northern and southern stocks for management purposes (Map 2). The northern stock extends from the Gulf of Maine to northern Georges Bank region, while the southern stock extends from the southern Georges Bank to Mid-Atlantic Bight region. Red hake stock structure was determined by considering distribution, homogeneous maturity, and differences in growth. There was no strong biological evidence to support either a separate or combined assessment. Analysis of otoliths from red hake captured in the northwestern and eastern part of the Bay of Fundy (Gulf of Maine) varied from the otolith morphology for red hake captured elsewhere and had intermediate characteristics with white hake, suggesting the possible existence of hybridization in that area (Penttila and Dery 1988).

4.2.2 Catches

Nominal red hake commercial landings in the northern stock peaked at 15,000 mt in 1972 and 1973, followed by a sharp decline in 1977 corresponding to the departure of the distant water fleets (Table 4). Landings then averaged 1,000 mt from 1977-1994, but declined to an average of only 100 mt through 2009. In the southern stock, nominal landings peaked at over 100,000 mt in 1965 with a second peak of 60,000 in 1972 (Table 4). Landings then averaged 2,000 mt from 1977-1994, but declined to average 900 mt through 2009. Discards from the northern stock averaged 1300 mt in the early 1980s, declined to about 250 mt from 1995-2000 and have averaged 100 mt through 2009 (Table 6). Discards from the southern stock averaged 4,000 mt in the 1980s, declined to about 1,000 mt from 1995-2000 and have averaged 700 mt through 2009 (Table 6). Recreational landings have been relatively small with averages of 300 mt in the south compared to less than 3 mt in the north (Table 4).

Catch data are a major source of uncertainty for this assessment because of mixed reporting of landings of red and white hake and uncertain identification to species by observers. Therefore, a length-based model was developed to estimate the proportion of red hake in the total hake catch (red and white hake combined). The model estimates for the northern stock area were generally lower than the nominal and the large peak in landings in the 1970s is eliminated. The landings for the southern stock area were also lower but the trend was similar. The complete change in trend in the north was not considered acceptable, so the length-based split was not used, and the nominal catch was used in the assessment. From 1994 to 2009, landings for bait in the north have averaged 50% of the reported landings (Table 4) and ranged from one percent of the reported landings early in the time series to five times the reported landings in more recent years. In some years, less than three vessels reported bait landings on VTRs. Therefore, bait landings cannot be tabulated separately.

4.2.3 Data and Assessment

Information used in the 2010 assessment include data from the NEFSC surveys, as well as commercial fishery data from vessel trip reports, dealer landings records and on-board fishery observers through 2009. The NEFSC bottom trawl survey switched from the FRV *Albatross IV* to the FSV *Bigelow* in spring 2009. Survey data given here are in "*Albatross IV*" units. Although some statistical catch at length models (SCALE and SS3) were applied, model diagnostics were not adequate for stock status determination or for the provision of fishery management advice. Therefore, the assessment is based on the spring survey indices and exploitation indices from each area. Examination of the effect of using the delta transformation on the variability of red hake survey indices indicated that the transformation did not reduce the variance. The delta transform and was very sensitive to the treatment of zero weight tows which occurred when the weight of fish was less than 0.1 kg prior to 2001. Therefore, the arithmetic mean is considered a better option for assessment purposes (Table 4).

Nearly all commercial landings for both the northern and southern red hake stocks come from trips using trawls (Table 5). The majority of estimated discards also come from trips using trawls (Table 6), more or less evenly split between large and small mesh in the north and predominately from trips using small mesh in the south. Average fish size in survey catches shows a general downward trend since the mid-1980s in both the northern and southern stocks (Figure 3). Exploitation, measured as catch/survey biomass, has declined from values prevalent during the 1970s and has fluctuated around the overfishing definition thresholds (Figure 4). The 2009 exploitation ratio was below the threshold and overfishing is therefore not occurring.

Map 2. Statistical areas used to define the northern and southern red hake stocks.

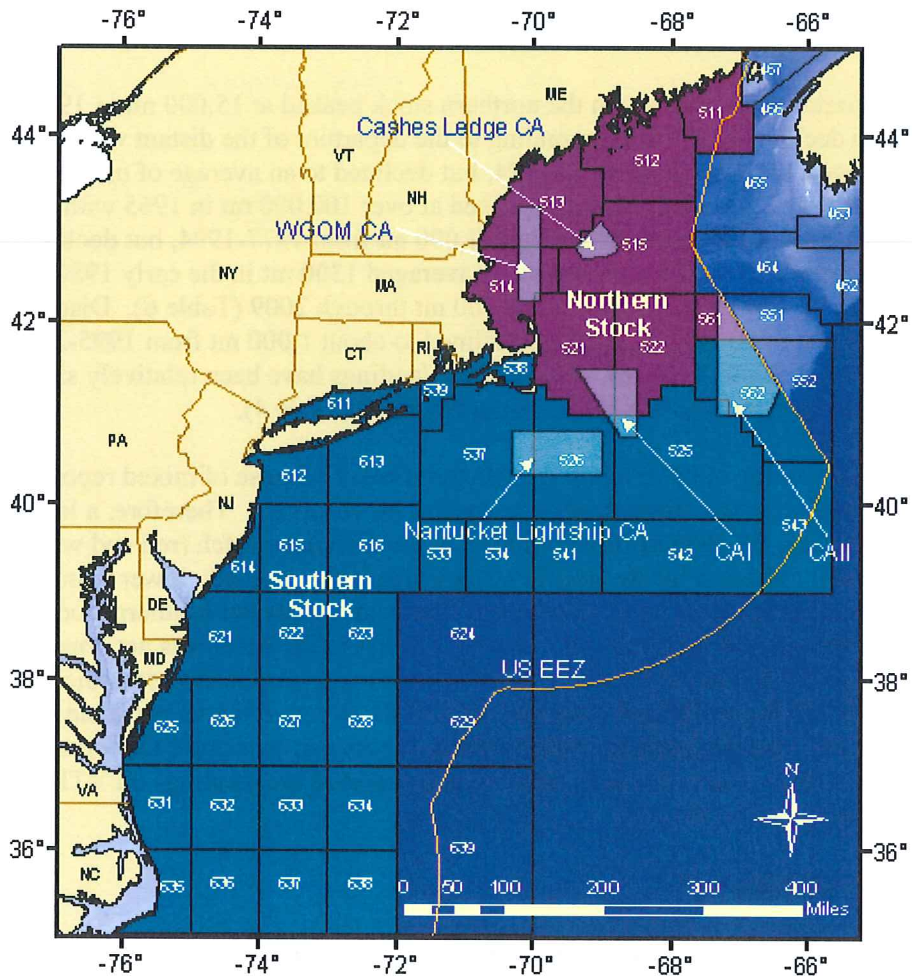


Table 4. Red hake landings, catch, survey biomass, and exploitation trends for northern and southern stocks (Source: NEFSC 2011).

Northern stock

					NEFSC Survey		*Replacement Ratio*		*Relative Fishing Mortality*	
Year	*Catch (mt)*	*Pct DWF landings*	*Pct discards*	*Pct recreational*	*Fall (kg/tow)*	*Spring (kg/tow)*	*Fall*	*Spring*	*Fall (mt/kg)*	*Spring (mt/kg)*
1963	3,281	63%		0%	4.85				676.5	
1964	1,409	80%		0%	1.31				1075.6	
1965	2,773	93%		0%	1.22				2273	
1966	5,575	84%		0%	0.92				6059.8	
1967	1,863	69%		0%	0.49				3802	
1968	2,627	79%		0%	0.26	1.14	0.148		10103.8	2304.4
1969	2,021	93%		0%	0.67	0.64	0.798		3016.4	3157.8
1970	1,032	75%		0%	0.6	0.54	0.843		1720	1911.1
1971	4,805	92%		0%	1.33	0.65	2.262		3612.8	7392.3
1972	15,026	96%		0%	2.34	1.56	3.493		6421.4	9632.1
1973	15,288	98%		0%	1.56	4.31	1.500	4.757	9800	3547.1
1974	7,223	88%		0%	0.68	2.43	0.523	1.578	10622.1	2972.4
1975	8,701	95%		0%	1.76	4.25	1.352	2.239	4943.8	2047.3
1976	6,337	90%		0%	1.7	3.37	1.108	1.277	3727.6	1880.4
1977	891	0%		0%	3.49	2.66	2.170	0.835	255.3	335
1978	1,223	0%		0%	3.06	2.57	1.665	0.755	399.7	475.9
1979	1,523	0%		0%	1.82	2.04	0.851	0.668	836.8	746.6
1980	1,033	0%		0%	3.76	3.88	1.589	1.303	274.7	266.2
1981	2,601	0%	51%	1%	2.81	6.35	1.016	2.187	925.8	409.7
1982	2,673	0%	55%	0%	1.67	2.13	0.559	0.609	1600.5	1254.8
1983	2,248	0%	60%	0%	4.11	3.7	1.566	1.090	547	607.6
1984	2,388	0%	56%	0%	3.54	2.98	1.249	0.823	674.5	801.2
1985	2,262	0%	56%	0%	4.73	3.91	1.488	1.027	478.3	578.6
1986	2,646	0%	45%	0%	2.84	3.26	0.842	0.855	931.8	811.8
1987	2,066	0%	51%	0%	2.25	2.94	0.666	0.920	918.2	702.7
1988	1,763	0%	51%	0%	2.54	2	0.727	0.596	694	881.4
1989	2,224	0%	65%	0%	4.67	1.65	1.469	0.547	476.1	1347.6
1990	1,425	0%	42%	0%	3.32	1.33	0.975	0.483	429.1	1071.2
1991	1,563	0%	52%	0%	2.56	1.62	0.820	0.725	610.6	964.8
1992	1,645	0%	44%	0%	2.29	2.5	0.746	1.310	718.2	657.8
1993	853	0%	10%	0%	1.99	2.82	0.647	1.550	428.4	302.3
1994	806	0%	10%	0%	3.69	1.59	1.244	0.801	218.4	506.9
1995	250	0%	25%	0%	3.28	1.97	1.184	0.999	76.2	126.9
1996	1,070	0%	61%	1%	2.53	1.79	0.916	0.852	423	597.8
1997	464	0%	27%	0%	2.92	1.81	1.060	0.848	158.8	256.2
1998	317	0%	41%	0%	4.84	2.52	1.679	1.263	65.5	125.8
1999	687	0%	68%	0%	3.32	2.32	0.962	1.198	207	296.2
2000	252	0%	22%	0%	5.66	3.19	1.676	1.532	44.5	78.9
2001	358	0%	38%	0%	4.89	3.58	1.269	1.539	73.1	99.9
2002	376	0%	27%	0%	5.37	4.46	1.241	1.662	70	84.3
2003	297	0%	30%	0%	3.55	1	0.737	0.311	83.7	297.2
2004	160	0%	36%	0%	1.56	1.77	0.342	0.608	102.6	90.4
2005	153	0%	37%	0%	1.16	1.1	0.276	0.393	132.1	139.3
2006	277	0%	65%	0%	2.19	0.91	0.662	0.382	126.4	304.3
2007	197	0%	65%	0%	2.42	2.06	0.875	1.115	81.3	95.5
2008	112	0%	53%	0%	1.91	3.49	0.878	2.551	58.5	32
2009	180	0%	53%	0%	12.46	1.75	6.742	0.938	14.5	103.1

Southern stock

Year	Catch (mt)	Pct DWF landings	Pct discards	Pct recreational	NEFSC Survey Fall (kg/tow)	NEFSC Survey Spring (kg/tow)	Replacement Ratio Fall	Replacement Ratio Spring	Relative Fishing Mortality Fall (mt/kg)	Relative Fishing Mortality Spring (mt/kg)
1963	31,901	7%		2%						
1964	43,373	25%		2%						
1965	92,990	73%		1%						
1966	107,922	96%		0%						
1967	58,783	88%		0%	1.69				34782.8	
1968	18,138	61%		3%	3.07	1.29			5908.1	14060.5
1969	52,928	90%		1%	3.55	1.08			14909.3	49007.4
1970	11,454	59%		4%	2.26	1.72			5068.1	6659.3
1971	35,134	91%		1%	2.57	3.49			13670.8	10067
1972	61,194	97%		0%	3.85	3.59	1.465		15894.5	17045.7
1973	51,362	93%		1%	2.35	3.99	0.768	1.786	21856.2	12872.7
1974	26,643	92%		1%	0.91	2.84	0.312	1.024	29278	9381.3
1975	19,976	90%		0%	4.88	3.18	2.044	1.017	4093.4	6281.8
1976	22,465	83%		3%	3.34	5.31	1.147	1.554	6726	4230.7
1977	7,062	64%		11%	2.51	2.3	0.819	0.608	2813.5	3070.4
1978	5,463	39%		18%	1.88	7.65	0.672	2.171	2905.9	714.1
1979	7,592	13%		3%	2.38	1.51	0.880	0.355	3189.9	5027.8
1980	4,226	4%		3%	3.13	2.38	1.044	0.597	1350.2	1775.6
1981	5,211	4%	52%	3%	2.32	4.61	0.876	1.204	2246	1130.3
1982	6,975	3%	54%	0%	3.1	3.34	1.268	0.905	2250.1	2088.4
1983	5,465	2%	71%	2%	6.04	2.21	2.358	0.567	904.8	2472.7
1984	5,730	1%	68%	10%	1.18	1.33	0.348	0.473	4855.5	4307.9
1985	3,901	2%	76%	1%	1.99	1.39	0.631	0.501	1960.2	2806.3
1986	4,288	1%	79%	5%	0.96	1.73	0.328	0.672	4466.7	2478.6
1987	4,728	0%	70%	10%	0.76	0.88	0.286	0.440	6221.6	5373.2
1988	4,584	0%	76%	5%	0.77	1.01	0.352	0.670	5952.6	4538.1
1989	6,372	0%	79%	7%	1.18	0.49	1.042	0.386	5400.3	13004.9
1990	6,060	0%	78%	8%	1.22	0.71	1.078	0.646	4967.2	8535.1
1991	3,822	0%	68%	7%	1.61	0.61	1.646	0.633	2373.6	6264.8
1992	7,782	0%	82%	2%	0.63	0.46	0.569	0.622	12352.9	16918.1
1993	6,321	0%	84%	1%	0.9	0.42	0.832	0.640	7023.5	15050.4
1994	2,772	0%	62%	2%	0.8	0.67	0.722	1.245	3464.7	4136.9
1995	2,801	0%	47%	2%	0.46	0.52	0.446	0.906	6090	5387.3
1996	1,099	0%	35%	2%	0.39	0.45	0.443	0.840	2817.4	2441.8
1997	3,595	0%	67%	5%	0.6	1.16	0.943	2.302	5991.5	3099
1998	1,948	0%	38%	3%	0.5	0.21	0.794	0.326	3895.1	9274
1999	2,465	0%	43%	2%	0.54	0.45	0.982	0.748	4564	5476.8
2000	1,712	0%	15%	3%	0.48	0.42	0.964	0.753	3565.8	4075.1
2001	1,630	0%	8%	1%	0.55	0.64	1.096	1.190	2964.1	2547.2
2002	1,000	0%	33%	1%	0.6	0.54	1.124	0.938	1667.2	1852.4
2003	986	0%	35%	2%	0.55	0.21	1.030	0.465	1792.1	4693.6
2004	1,214	0%	51%	1%	0.4	0.15	0.735	0.332	3035.9	8095.7
2005	1,419	0%	71%	4%	0.63	0.38	1.221	0.969	2251.6	3732.9
2006	1,103	0%	61%	5%	0.82	0.38	1.502	0.990	1344.7	2901.7
2007	2,035	0%	76%	1%	0.55	0.86	0.917	2.590	3699.3	2365.8
2008	1,467	0%	55%	5%	0.73	0.47	1.237	1.187	2009.8	3121.6
2009	1,543	0%	56%	6%	1.02	1.34	1.629	2.991	1513.1	1151.8

Table 5. Red hake landings percent by gear type (Source: NEFSC 2011).

Northern stock

Year	Longline	Fish trawl	Shrimp trawl	Sink gillnet	Other	Total (mt)
1964		100%	0%	0%		288
1965		100%	0%	0%		200
1966		100%	0%	0%	0%	885
1967		100%	0%	0%		577
1968		100%	0%	0%		552
1969	1%	99%	0%	0%		146
1970	0%	100%	0%	0%	0%	261
1971	0%	100%	0%	0%	0%	377
1972	0%	100%	0%	0%	0%	538
1973	0%	94%	0%	6%		362
1974		100%	0%	0%	0%	891
1975	2%	88%	8%	1%	1%	450
1976	6%	90%	1%	3%	0%	653
1977	3%	93%	2%	3%		889
1978	2%	97%	0%	0%	0%	1,223
1979		100%	0%	0%		1,523
1980	0%	99%	0%	0%	0%	1,029
1981	0%	91%	0%	8%	0%	1,246
1982		95%	2%	3%	0%	1,210
1983	0%	97%	2%	0%	0%	895
1984		98%	2%	0%	0%	1,059
1985	0%	93%	4%	2%		992
1986		81%	18%	0%	1%	1,457
1987	0%	80%	17%	0%	2%	1,013
1988	0%	92%	5%	1%	2%	862
1989	0%	89%	6%	4%	0%	776
1990	0%	87%	9%	3%	0%	826
1991	1%	86%	9%	4%	0%	743
1992	0%	94%	2%	3%	1%	918
1993	0%	95%		1%	4%	768
1994	0%	95%	0%	1%	4%	727
1995	1%	92%	0%	1%	6%	186
1996	0%	99%	0%	0%	0%	409
1997	1%	96%	0%	1%	3%	338
1998	1%	98%	0%	1%	1%	187
1999		98%	0%	2%	0%	220
2000		97%	0%	1%	2%	197
2001		94%	0%	1%	5%	222
2002		99%	0%	1%		275
2003		98%	0%	0%	1%	210
2004		97%	0%		3%	103
2005		99%	0%		1%	96
2006	0%	100%	0%			96
2007	0%	100%	0%			69
2008		100%	0%			52
2009	0%	100%	0%			85

Southern stock

Year	Longline	Fish trawl	Sink gillnet	Other	Total (mt)
1964	0%	100%	0%	0%	32,622
1965	0%	100%	0%	0%	25,246
1966	0%	100%	0%	0%	3,985
1967	0%	100%	0%	0%	6,764
1968	0%	100%	0%	0%	7,001
1969	0%	100%	0%	0%	5,539
1970	0%	100%	0%	0%	4,679
1971	0%	100%	0%	0%	3,227
1972	0%	99%	0%	1%	1,995
1973	0%	100%	0%	0%	3,603
1974	0%	100%	0%	0%	2,183
1975	0%	100%	0%	0%	2,065
1976	0%	100%	0%	0%	3,905
1977	0%	100%	0%	0%	2,522
1978	0%	98%	0%	2%	3,327
1979	0%	99%	0%	1%	6,624
1980	0%	99%	0%	1%	3,927
1981	0%	98%	0%	2%	2,124
1982	0%	98%	0%	2%	2,993
1983	0%	95%	0%	5%	1,334
1984	0%	91%	0%	9%	1,214
1985	0%	93%	0%	6%	827
1986	0%	93%	0%	7%	644
1987	0%	94%	0%	6%	943
1988	0%	92%	0%	8%	871
1989	0%	90%	0%	10%	931
1990	0%	93%	0%	7%	798
1991	0%	94%	0%	6%	925
1992	1%	95%	0%	4%	1,245
1993	0%	92%	0%	8%	924
1994	0%	87%	0%	13%	983
1995	0%	69%	0%	30%	1,428
1996	0%	99%	0%	1%	700
1997	0%	98%	0%	1%	999
1998	0%	99%	0%	1%	1,154
1999	0%	99%	0%	1%	1,351
2000	0%	99%	0%	1%	1,417
2001	0%	98%	1%	1%	1,469
2002	0%	99%	0%	1%	663
2003	0%	100%	0%	0%	623
2004	0%	98%	0%	2%	588
2005	0%	98%	0%	2%	356
2006	0%	98%	0%	2%	375
2007	0%	98%	0%	2%	470
2008	0%	98%	1%	1%	580
2009	0%	96%	0%	4%	575

Table 6. Red hake discard percent by gear type (Source: NEFSC 2011). The discards from 1981-1988 (1991 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

Northern stock

Year	Longline	Large mesh trawl	Small mesh trawl	Shrimp trawl	Sink gillnet	Other	Total (mt)
1981	0%	90%	0%	0%	1%	8%	1325
1982	0%	89%	0%	0%	1%	10%	1460
1983	0%	86%	0%	0%	1%	13%	1353
1984	0%	78%	0%	0%	0%	21%	1327
1985	0%	70%	0%	0%	0%	30%	1270
1986	0%	61%	0%	0%	0%	38%	1189
1987	1%	61%	0%	0%	1%	37%	1053
1988	1%	68%	0%	1%	1%	29%	897
1989	1%	27%	48%	1%	1%	23%	1447
1990	1%	24%	19%	1%	2%	53%	595
1991	6%	27%	40%	0%	0%	26%	818
1992	0%	20%	67%	0%	0%	12%	726
1993	0%	25%	39%	1%	29%	6%	83
1994	0%	12%	69%	5%	5%	10%	77
1995	13%	25%	41%	3%	2%	17%	63
1996	1%	2%	80%	1%	1%	16%	656
1997	6%	10%	3%	1%	5%	76%	125
1998	5%	6%	73%	1%	0%	14%	130
1999	1%	67%	29%	1%	1%	2%	468
2000	10%	49%	1%	7%	11%	22%	55
2001	4%	35%	48%	9%	4%	1%	135
2002	1%	35%	53%	3%	7%	0%	101
2003	0%	33%	32%	3%	33%	0%	88
2004	3%	46%	45%	3%	2%	1%	57
2005	5%	63%	19%	1%	12%	0%	57
2006	1%	23%	69%	5%	1%	2%	181
2007	1%	17%	61%	0%	16%	6%	127
2008	4%	58%	31%	4%	1%	2%	59
2009	1%	48%	47%	1%	2%	1%	95

Southern stock

Year	Longline	Large mesh trawl	Small mesh trawl	Sink gillnet	Other	Total (mt)
1981	0%	100%	0%	0%	0%	2,715
1982	0%	100%	0%	0%	0%	3,776
1983	0%	100%	0%	0%	0%	3,889
1984	0%	100%	0%	0%	0%	3,910
1985	0%	100%	0%	0%	0%	2,969
1986	0%	100%	0%	0%	0%	3,389
1987	0%	99%	0%	0%	1%	3,313
1988	0%	99%	0%	0%	1%	3,462
1989	0%	1%	98%	0%	0%	5,006
1990	0%	28%	71%	0%	1%	4,748
1991	0%	17%	82%	0%	1%	2,612
1992	0%	12%	88%	0%	0%	6,343
1993	0%	1%	99%	0%	0%	5,308
1994	0%	2%	95%	0%	3%	1,720
1995	0%	3%	95%	0%	2%	1,329
1996	0%	3%	91%	0%	5%	380
1997	0%	12%	85%	0%	3%	2,423
1998	0%	0%	99%	0%	1%	740
1999	0%	0%	93%	0%	6%	1,060
2000	0%	5%	47%	0%	47%	250
2001	1%	0%	72%	0%	27%	138
2002	0%	0%	92%	0%	8%	327
2003	0%	14%	83%	0%	3%	345
2004	0%	18%	77%	0%	5%	616
2005	0%	13%	81%	0%	6%	1,007
2006	0%	15%	70%	0%	15%	674
2007	0%	8%	90%	0%	1%	1,545
2008	1%	14%	78%	0%	7%	814
2009	1%	16%	76%	0%	0	869

Figure 3. Trends in length composition of red hake from the spring survey.

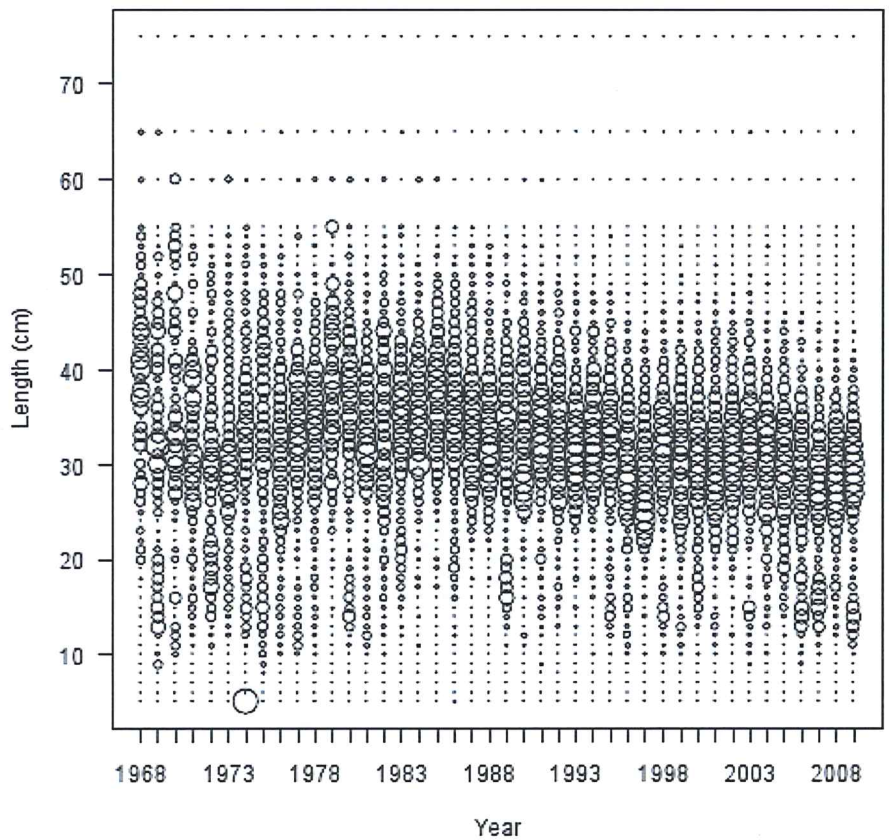
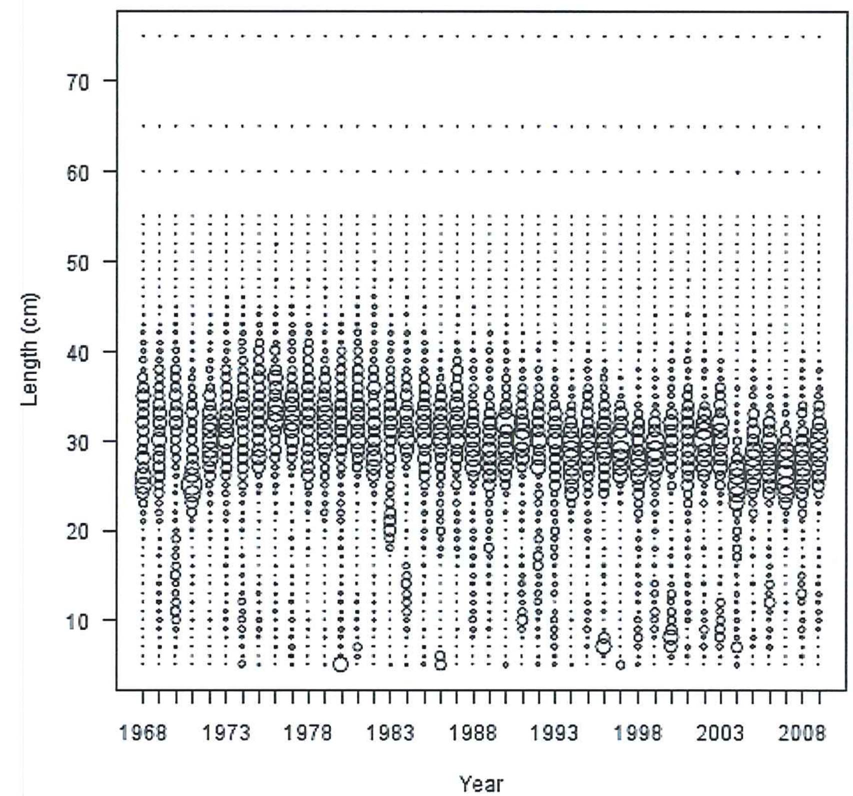
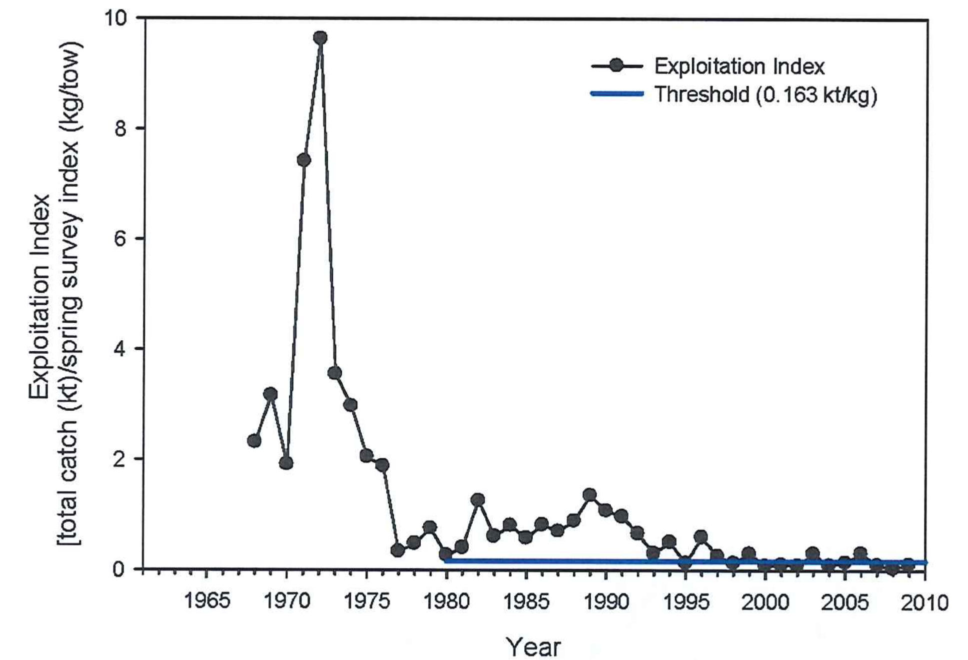
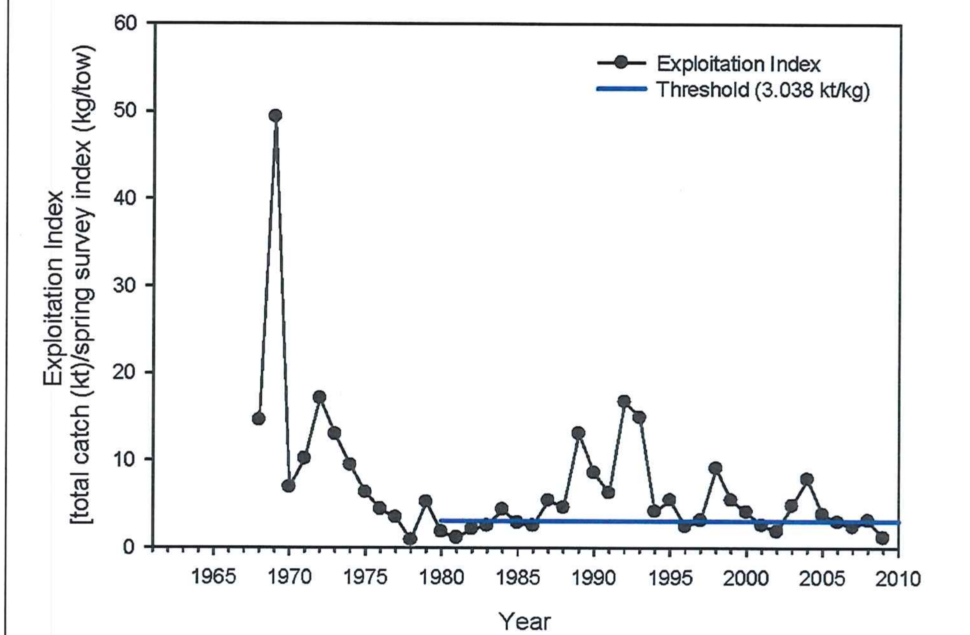
Northern stock	Southern stock
	

Figure 4. Exploitation indices (spring survey) and newly proposed overfishing threshold for red hake.

Northern stock	Southern stock
	

4.3 Offshore hake

4.3.1 Stock Distribution and Identification

Offshore hake are distributed off the continental slope of the northwest Atlantic and southward to the Caribbean and the Gulf of Mexico (Chang et al 1999). They are found from southern Georges Bank through the Mid-Atlantic Bight at depths ranging from 160-550 meters (Bigelow and Schroeder 1953, Klein-MacPhee 2002). Offshore hake and silver hake (*M. bilinearis*) are sympatric over a considerable range of the continental slope, but are often separated by depth (Helser 1996). Due to their similar morphology and spatial overlap, they have been misidentified for years. The fishing industry did not separate the commercial landings of the two species until 1991, and the extent to which they are still landed as a single species is uncertain (Helser 1996).

4.3.2 Catches

Nominal offshore hake commercial landings, which have only been reported since 1991, have varied from 120 mt in the early 1990s to less than 5 mt in 2001-2002, the lowest in the time series. Landings and catches data are uncertain because landings of hakes (silver, offshore and red hake) were not reported by species until 1991. Those that are reported may not be identified correctly (Garcia-Vazquez et al., 2009). Two models (length-based and a depth-based) were developed to estimate the proportion of offshore hake landed from the total mixed hake landings based on species composition in the NEFSC trawl surveys. The two model estimates were similar, both were much higher than the nominal landings, and the higher estimates were used in this assessment. Landings (Table 7) may have been as high as 25,000 mt in the 1960s and have averaged 300-600 mt over the last decade, which is much greater than the 13 mt indicated from nominal landings. Nearly all landings come from commercial trips on vessels using trawls (Table 8).

Discards from the longline and sink gill net fishery were minimal for silver and offshore hake (Table 8). Discards from the otter trawl fisheries have been significant and variable for silver hake. The same problem with species identification that exists with landings also exists with discards. There are discards of offshore hake estimated for the north but because the geographical distribution of offshore hake is limited to the southern stock of silver hake, any discards from the northern stock are assumed to be silver hake. The length-based estimator was used to separate hake discards by species for the southern region.

4.3.3 Data and Assessment

Data used in the assessment include survey indices from the NEFSC fall survey, landings and discards. Models were utilized to apportion the landings and discards into hake species. A length-based landings model used the catch-at-length for silver hake and the proportion of offshore hake at length from the survey to apportion catch. A depth-based landings model used VMS data and depth-based logistic functions from the survey to apportion landings. The NEFSC bottom trawl survey switched from the FRV *Albatross IV* to the FSV *Bigelow* in spring 2009. Survey data given here are in "*Albatross IV*" units.

Two assessment models were attempted, An Index Method (AIM) and Survival Estimation in Non-Equilibrium Situations Model (SEINE). Neither model was considered adequate for management. Trends in catch and the exploitation ratio are shown in Figure 5.

Table 7. Offshore hake landings, catch and survey biomass (Source: NEFSC 2011).

				NEFSC Survey	
Year	Catch (mt)	Pct DWF landings	Pct discards	Fall (kg/tow)	Spring (kg/tow)
1963	3956.8				
1964	6506.4				
1965	13013.8				
1966	8951.9				
1967	3866.4			0.11	
1968	339.4			0.19	0.06
1969	670.3			0.14	0.11
1970	680.2			0.11	0.28
1971	1383.7			0.06	0.16
1972	6175.7			0.69	0.45
1973	2514.8			0.1	0.81
1974	7467.5			0.22	1.06
1975	2088.7			0.27	0.65
1976	4132.8			0.61	0.94
1977	2148.1			0.35	0.71
1978	1298			0.54	1.38
1979	1976.9			0.23	1.73
1980	1862.4			0.33	4.61
1981	1497.6			1.41	0.85
1982	542.4			0.04	0.55
1983	417.7			0.14	0.33
1984	328.1			0.11	0.14
1985	455.2			0.48	0.51
1986	549.8			0.26	0.45
1987	692.4			0.19	0.53
1988	373.9			0.12	0.14
1989	502.8		0%	0.2	0.28
1990	811.2		0%	0.39	0.21
1991	936		0%	0.14	0.6
1992	494.1		0%	0.15	0.24
1993	631.1		0%	0.11	0.08
1994	147.8		0%	0.01	0.03
1995	218.7		0%	0.14	0.03
1996	506.2		0%	0.11	0.05
1997	256.1		1%	0.11	0.06
1998	276.8		63%	0.09	0.06
1999	172.5		1%	0.03	0.03
2000	307.6		0%	0.04	0.13
2001	649.1		2%	0.48	0.14
2002	479.2		31%	0.2	0.34
2003	639.2		0%	0.54	0.24
2004	540.4		1%	0.06	0.14
2005	293.1		2%	0.03	0.05
2006	85.4		5%	0.14	0.02
2007	296.3		7%	0.3	0.21
2008	97		1%	0.11	0.07
2009	156.4		16%	0.14	0.08

Table 8. Offshore hake catch percent by gear type for Southern Georges Bank, Southern New England, and the Mid-Atlantic region (Source: NEFSC 2011).

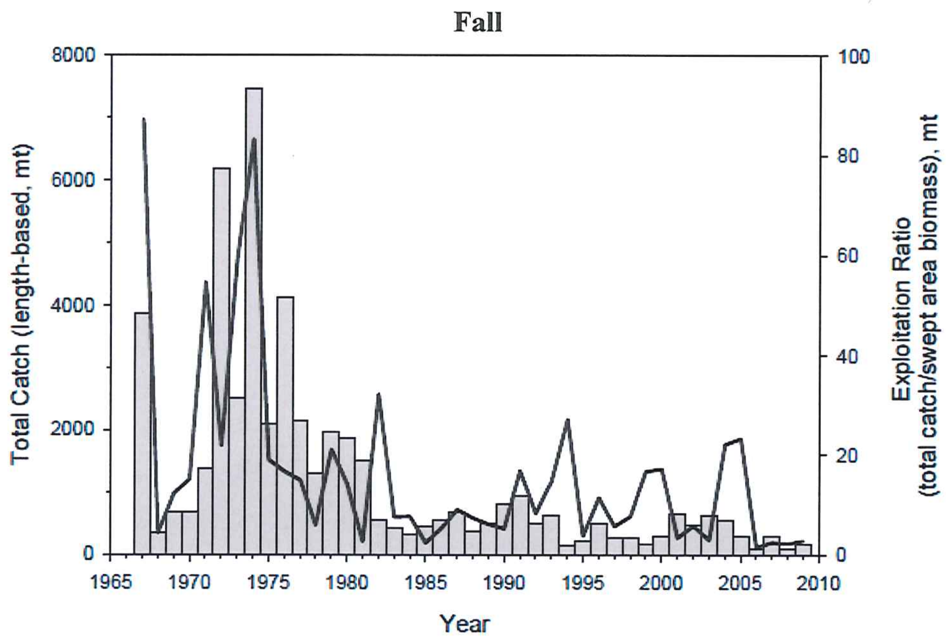
Landings

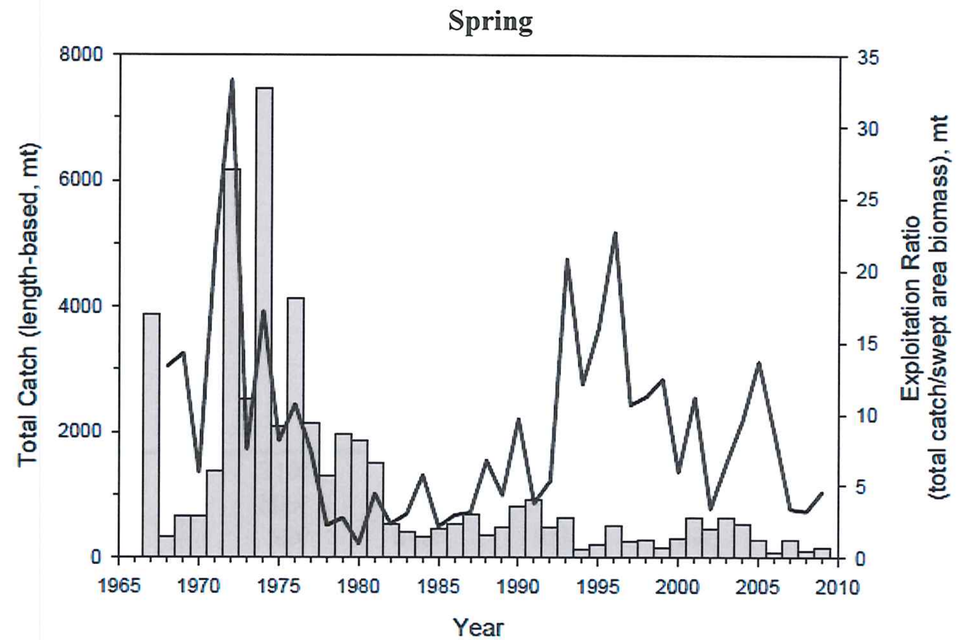
Year	*Longline*	*Fish trawl*	*Sink gillnet*	*Other*	*Total (mt)*
1991	0%	100%	0%	0%	30
1992	0%	100%	0%	0%	119
1993	0%	100%	0%	0%	98
1994	0%	100%	0%	0%	115
1995	0%	64%	0%	36%	71
1996	0%	100%	0%	0%	67
1997	0%	100%	0%	0%	22
1998	0%	100%	0%	0%	5
1999	0%	100%	0%	0%	7
2000	0%	100%	0%	0%	4
2001	0%	100%	0%	0%	2
2002	0%	100%	0%	0%	6
2003	0%	100%	0%	0%	10
2004	0%	99%	0%	1%	23
2005	0%	35%	0%	65%	12
2006	0%	97%	0%	3%	37
2007	2%	96%	0%	2%	12
2008	0%	95%	0%	5%	21
2009	1%	92%	0%	7%	17

Discards

Year	*Large mesh trawl*	*Small mesh trawl*	*Sink gillnet*	*Scallop dredge*	*Total (mt)*
1989					0
1990					0
1991					0
1992					0
1993					0
1994					0
1995	0%	0%	0%	100%	0
1996					0
1997	0%	55%	1%	44%	3
1998	0%	98%	0%	2%	174
1999	0%	67%	0%	33%	2
2000	56%	38%	0%	5%	1
2001	1%	99%	0%	0%	10
2002	0%	98%	0%	2%	146
2003	0%	0%	0%	100%	2
2004	1%	62%	0%	37%	5
2005	0%	100%	0%	0%	6
2006	9%	91%	0%	0%	5
2007	6%	94%	0%	0%	21
2008	96%	1%	0%	3%	1
2009	21%	79%	0%	0%	26

Figure 5. Exploitation ratios for total catch (total catch/swept area biomass) for offshore hake (Source: NEFSC 2011).





5.0 Special ecosystem considerations

5.1 Consumption of Hakes

Food habits were evaluated for a wide range (14) of fish predators that eat silver hake and commonly occur in NEFSC bottom trawl surveys. The amount of food eaten and the type of food eaten were the primary food habits data examined. From these data, per capita consumption, total consumption of silver hake, and an estimate of the amount of silver hake removed by these fish predators were calculated. Combined with abundance estimates of these predators, an amount of silver hake removed by these predators was then calculated. Consumption estimates of silver hake were presented as an estimate that is biased towards conservative values because consumption by birds, marine mammals, large pelagic fish and organisms outside of the survey area were not included. Moreover, swept-area biomass estimates for many of predators were based on bottom trawl survey data (without adjustments for bottom trawl catchability), although stock assessment results were used for some predators, such that predator abundance estimates and associated silver hake consumption would be mostly underestimates as well. Based upon length frequencies of silver hakes in the stomachs, these estimates of consumptive removals were then partitioned into size (age) classes (with age 0s being omitted) and used as an input matrix into the assessment model (ASAP).

Results suggest that even these conservative estimates of consumption by fish predators were relatively large compared to recent landings and discards. That is, estimated consumption of silver hake is on the same order of magnitude or one order or magnitude higher as estimates of silver hake stock catch. These estimates of consumption of silver hake also exhibit similar trends as landings estimates, until recent years. Estimates of predatory removal of silver hake via consumption are likely conservative given nature of these consumption estimates, but are at least 5-10x higher than catches. These consumption estimates should be useful to inform both the scaling of biomass estimates and the magnitude of mortalities for silver hake. These estimates are also likely to be quite informative to the dynamics of silver hake, as they represent a major source of removals and internal dynamics (cannibalism) that is being accounted for.

Similar efforts, but with less detailed analyses, were executed for red hake, but insufficient information was extant for offshore hake. Similar, but less pronounced results were observed for red hake landings and consumption.

- High consumption (M2) compared to catch increases uncertainty of natural mortality (M1)
- These consumption estimates are also likely to be quite informative to the dynamics of silver hake, as they represent a major source of removals and internal dynamics (cannibalism) that is being accounted for.
- These consumption estimates are conservative because other important predation by birds, marine mammals, etc. have not been estimated. Uncertainty in consumption estimates is not available, but it appears that consumption is higher than catch since 1980.
- The silver hake OFL and MSY estimates are based on fishery catch only and do not include removals due to consumption. Therefore the Council should not add further consideration of scientific uncertainty into the OFL due to uncertainty and annual variation in consumption estimates.

Table 9. Species of consistent silver hake predators. Whether abundances were estimated from recent stock assessments (SA) or swept area (SWA) from surveys are noted, as is the resolution of the diet data (all predators were presented as two year averages). *Pollock was ultimately excluded from the analyses due to an excessive degree of variability in diet composition comprised of silver hake.

Common Name	Species Name	Assessment or Swept Area	Diet Resolution
Spiny dogfish	*Squalusa canthias*	SWA	2yr
Little skate	*Raja ocellata*	SWA	2yr
Winter skate	*Raja erinacea*	SWA	2yr
Thorny skate	*Raja radiata*	SWA	2yr
Silver Hake	*Merluccius bilinearis*	SWA	2yr
Atlantic cod	*Gadus morhua*	SA	2yr
Pollock*	*Pollachius virens*	SA	2yr
Red hake	*Urophycis chuss*	SWA	2yr
White hake	*Urophycis tenuis*	SWA	2yr
Fourspot flounder	*Paralichthys oblongus*	SWA	2yr
Summer Flounder	*Paralichthys dentatus*	SA	2yr
Windowpane	*Scophthalmus aquosus*	SWA	2yr
Bluefish	*Pomatomuss altatrix*	SA	2yr
Goosefish	*Lophius americanus*	SA	2yr

Table 10. Proportion of all silver hake lengths in all predators of silver hake at size, in 5 cm size classes.

Year	<5	5-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
1973	0.053	0.263	0.316	0.211	0.053	0	0.105	0	0
1974	0	0.067	0.467	0.2	0.067	0.2	0	0	0
1975	0.667	0.333	0	0	0	0	0	0	0
1976	0.231	0.308	0.231	0.154	0	0.077	0	0	0
1977	0.759	0.034	0	0.034	0.103	0.034	0.034	0	0
1978	0.776	0.096	0.032	0.032	0.016	0.016	0.032	0	0
1979	0.053	0.105	0.316	0.263	0.105	0.053	0.053	0.053	0
1980	0	0.071	0.143	0.214	0.143	0.214	0	0.143	0.071
1981	0.143	0	0	0.143	0.571	0.143	0	0	0
1982	0.094	0.156	0.156	0.125	0.188	0.094	0.156	0.031	0
1983	0	0.054	0.405	0.189	0.216	0.081	0.054	0	0
1984	0.216	0.081	0.054	0.135	0.297	0.162	0.027	0.027	0
1985	0.106	0.187	0.211	0.154	0.203	0.098	0.024	0.008	0.008
1986	0.055	0.097	0.29	0.255	0.166	0.103	0.028	0.007	0
1987	0.06	0.048	0.048	0.145	0.434	0.241	0.024	0	0
1988	0.143	0.446	0.286	0.012	0.042	0.036	0.024	0.006	0
1989	0.08	0.492	0.174	0.148	0.061	0.035	0.01	0	0
1990	0.227	0.241	0.124	0.149	0.188	0.057	0.007	0.007	0
1991	0.157	0.442	0.235	0.078	0.041	0.046	0	0	0
1992	0.129	0.3	0.229	0.194	0.077	0.06	0.011	0	0
1993	0.176	0.127	0.337	0.173	0.15	0.037	0	0	0
1994	0.159	0.37	0.077	0.159	0.183	0.053	0	0	0
1995	0.056	0.222	0.268	0.193	0.18	0.072	0.007	0	0.003
1996	0.09	0.244	0.167	0.141	0.256	0.103	0	0	0
1997	0.183	0.639	0.063	0.042	0.037	0.021	0.005	0	0
1998	0.106	0.229	0.402	0.162	0.067	0.022	0.006	0	0.006
1999	0.047	0.253	0.24	0.197	0.219	0.039	0.004	0	0
2000	0.246	0.192	0.069	0.277	0.177	0.038	0	0	0
2001	0.099	0.441	0.053	0.138	0.211	0.039	0.007	0.013	0
2002	0.108	0.313	0.325	0.06	0.12	0.06	0	0	0
2003	0.095	0.23	0.459	0.135	0.041	0.034	0	0.007	0
2004	0.013	0.227	0.16	0.213	0.28	0.107	0	0	0
2005	0.133	0.167	0.1	0.3	0.267	0.033	0	0	0
2006	0.115	0.462	0.115	0.038	0.192	0.038	0.038	0	0
2007	0.186	0.116	0.209	0.163	0.186	0.093	0.047	0	0
2008	0.075	0.275	0.1	0.125	0.325	0.1	0	0	0
2009	0.036	0.384	0.268	0.08	0.125	0.08	0.027	0	0

Figure 6. Estimates of total silver hake biomass removed, as that consumed by major fish predators and total catch in the fishery.

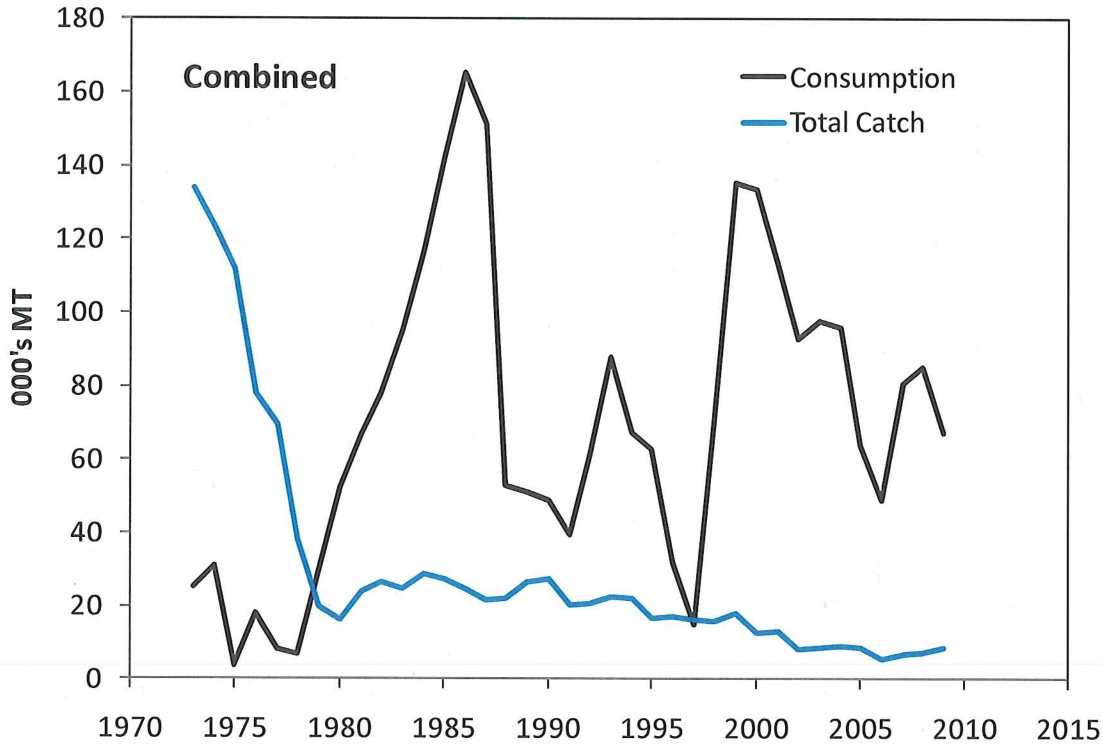


Figure 7. Estimates of total silver hake biomass removed, as that consumed by major fish predators and total catch in the fishery for the north (top) and south (bottom) stocks.

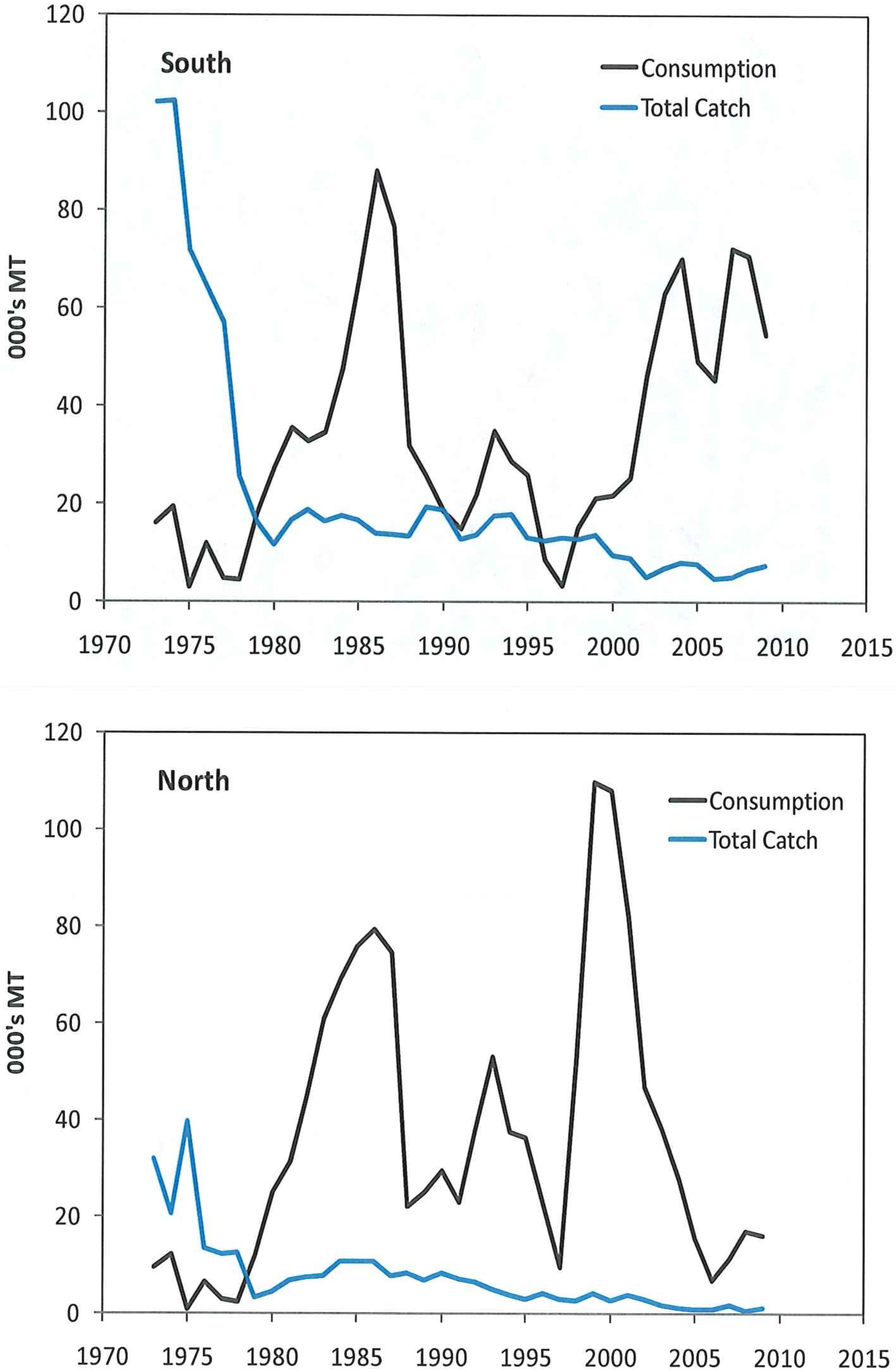


Figure 8. Proportion of total consumption by size classes of silver hake eaten by the predators in this study.

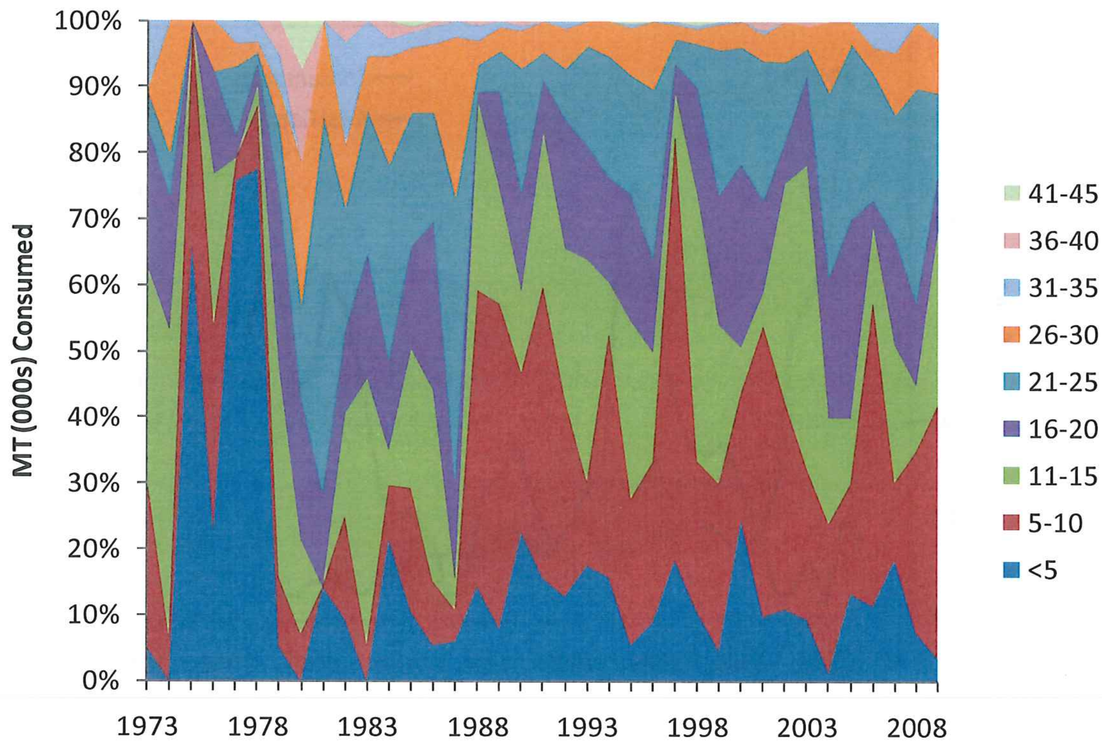
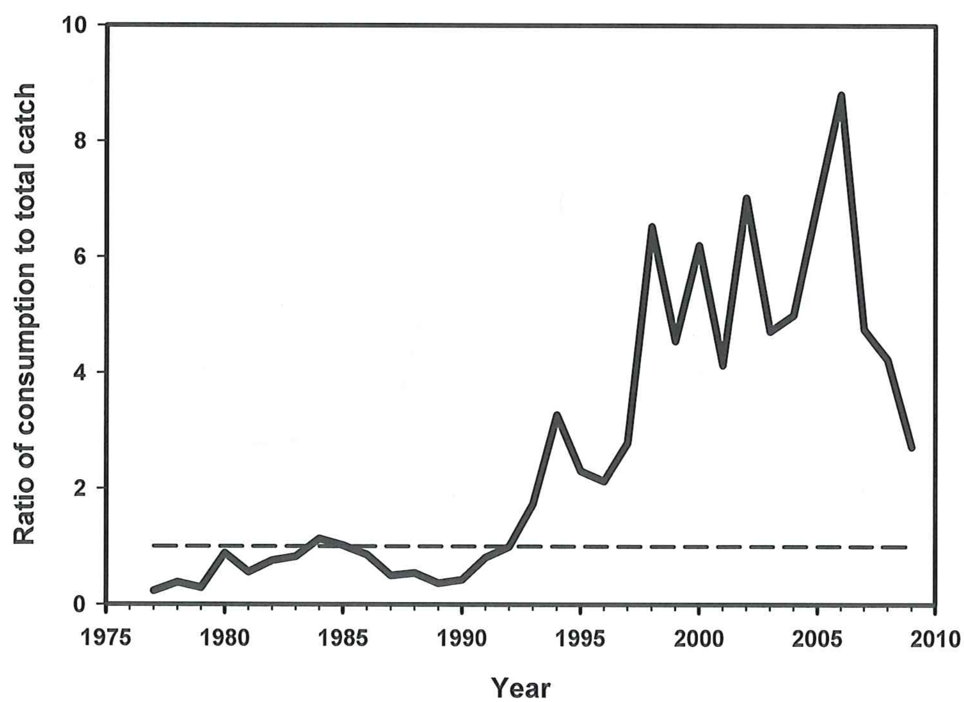


Figure 9. Ratio of consumption landings of red hake. Dashed line is at one.



6.0 Sources of uncertainty

6.1 Sources of scientific uncertainty

Common uncertainties about the stock and population size also apply to hakes. Because the lack of analytical model available for any of the hakes, the, scientific uncertainty for the hakes is on the higher end of the usual spectrum, and difficult to quantify..

In addition, scientific data (either commercial catch or survey catch) appear to be unreliable to manage offshore hake as a separate stock. Thus there is little to base conclusions about trends in population size and health.

The following sources of scientific uncertainty apply to hakes:

- Discards
- Unreported landings
- Inaccurate reporting of hake landings (i.e. mixed hake landings)
- Stock structure
- Annual variation/Environmental variability
- Survey sampling error
- Model error
- Retrospective pattern (No model to provide estimate)
- Consumption estimates
- Offshore hake distribution

6.2 Sources of Management Uncertainty

It is difficult to quantify management uncertainty except through several years of observation under a stable management system or through MSE models that accurately predict fishing behavior and response to regulation. Since neither of these factors exist for hakes, a qualitative assessment of management uncertainty and risk is necessary which the Council must balance against the long term cost of harvesting less than MSY. Population projections at various fishing levels are unavailable because no analytic assessment is available. To account for this and examine how the various ABC setting methods would perform, the PDT provided ABC estimates based on the historic variation in the survey biomass indices, represented by adding and subtracting one standard deviation of the three year moving average for survey biomass from the 2010 value.

The table below describes types of management uncertainty that apply to the Northeast US whiting fishery with respect to the potential for exceeding ACLs. These uncertainties range from unreported landings and unregulated (or lightly regulated fishing) to uncertainties about catch, with comments about how these uncertainties arise and how the Council might address them. Some may seem like scientific uncertainty, but the errors associated with the uncertainties arise from issues that can be addressed by management.

The Council should take these issues into account in setting an ACL buffer to account for management uncertainty.

Table 11. Sources and assessment of management uncertainty for hake stocks.

Type of Uncertainty	Degree of problem	Risk	Comments	Solution to reduce degree or risk of uncertainty
Unregulated and illegal fishing	Low	Low	1. No foreign or JV fishing exists in the EEZ. 2. Catch by state-registered vessels could be considered a form of unregulated fishing when there are no compatible regulations or limits. 3. Landings exceeding possession limits	1. Timely reports of state landings and discard estimation. 2. State water landings could be counted against the ACL, rather than being an assumed fraction.
Landings by Federally-permitted vessels	Very low	Very low	4. Landings may be mis-reported, particularly during directed fishery closures 5. No-sale fish which are landed, but not sold 6. Unreported bait sales 7. UFPC sales	3. Rely on easy to enforce measures.
Discard estimation error	Moderate	Low	8. Sub-sampled trips may be biased or are of insufficient sampling frequency	4. Risk can be reduced by incorporating estimated variance in estimates. 5. Error can be reduced by increasing frequency of observed trips.
Discard variability and estimation error	Moderate	Moderate	9. Assumed discards fail to adequately apply to future catches 10. Existing discard estimates have uncertainty due to subsampling the commercial catch	6. More frequent estimation and real-time monitoring of discards
Open access fishing	Moderate	High	11. Any vessel with a NE Multispecies FMP permit may fish for hakes, far too many for the current hake possession limits if more vessels begin targeting	7. Limit the type and number of vessels that may target hake in Federal waters

			hakes 12. Low prices and limited markets have kept a lid on landings since 2002 when the possession limits became effective.	
Species identification	Low	Low	13. Landings of offshore hake are often mis-identified as silver hake and small red hake are difficult to distinguish from white hake.	8. Subsampling landings to identify species, or other programs to encourage fishermen and processors to separate and report landings would reduce uncertainty.

7.0 Maximum Sustainable Yield (MSY) and Overfishing Level (OFL)

The benchmark assessment (NEFSC 2011) proposed new overfishing definitions based on MSY proxy estimates. The PDT assumes that the OFL is equivalent to applying the F_{msy} proxy to the current survey biomass using a three year moving average.

In the absence of an agreed ASAP model run, the proposed new overfishing definition for northern and southern silver hake stocks are:

> *Silver hake is overfished when the three-year moving average of the fall survey weight per tow (i.e. the biomass threshold) is less than one half the B_{MSY} proxy, where the B_{MSY} proxy is defined as the average observed from 1973-1982. The most recent estimates of the biomass thresholds are 3.21 kg/tow for the northern stock and 0.83 kg/tow for the southern stock.*
>
> *Overfishing occurs when the ratio between the catch and the arithmetic fall survey biomass index from the most recent three years exceeds the overfishing threshold. The most recent estimates of the overfishing threshold are 2.78 kt/kg for the northern stock and 34.19 kt/kg for the southern stock of silver hake.*

Overfishing threshold estimates are based on annual exploitation ratios (catch divided by arithmetic fall survey biomass) averaged from 1973-1982. Catch per tow is in "Albatross" units.

The proposed new overfishing definition for northern and southern red hake stocks are:

> *Red hake is overfished when the three-year moving arithmetic average of the spring survey weight per tow (i.e., the biomass threshold) is less than one half of the B_{MSY} proxy, where the B_{MSY} proxy is defined as the average observed from 1980 – 2010. The current estimates of $B_{THRESHOLD}$ for the northern and southern stocks are 1.27 kg/tow and 0.51 kg/tow, respectively.*
>
> *Overfishing occurs when the ratio between catch and spring survey biomass exceeds 0.163 kt/kg and 3.038 kt/kg, respectively, derived from AIM analyses from 1980-2009.*

To estimate MSY, the benchmark assessment applied the F_{MSY} proxy to the B_{MSY} proxy to estimate MSY equal to 412 mt for the northern stock and 3,086 mt for the southern stock. Catch per tow is in "Albatross" units.

The 80% confidence interval around the F_{MSY} proxy for the north is 0.062 - 0.240 kt/kg/tow and for the south is 2.240 - 3.700 kt/kg/tow.

For offshore hake, the benchmark assessment (NEFSC 2011) proposed no overfishing definition. So no OFL can therefore be estimated with currently available data.

8.0 Options for setting ABC for stocks with index based assessments

For red and silver hake, the Whiting PDT considered and developed three potential methods for setting hake ABCs, using data and analysis from the benchmark assessment (NEFSC 2011). Examples are given below for each stock based on the estimated uncertainty of F_{msy}-proxy and uncertainty about the survey biomass index. To demonstrate the effect that rising and falling stock biomass and possible assumptions about future stock biomass would have on ABC method results, the PDT also included ABC estimates assuming that the three year moving average was one standard deviation (of the time series of three year moving biomass averages) higher or lower than the 2010 estimate.

Amendment 19 is expected to become effective for the 2012 fishing year and by that time the spring 2011 biomass index will be available for setting the ABC based on 2009-2011 survey data for red hake. This information should also be available for the Draft Amendment slated for Council approval in September 2011. Since none of the stocks are overfished, the Whiting PDT anticipates that the Council will approve a three year specification cycle.

One approach to accommodate a three year specification is to assume that the next year's survey data biomass index will equal the last available year, while the first year in the series is dropped. So for 2012, the three year biomass index, OFL and ABC estimates would use 2009-2011 data, while for 2013 the specifications would use 2010 and two years of 2011 data (if available). The third year of specifications could be based on the 2011 index only, or be the same as the specifications for 2012. To represent the response of the three methods to changes in future stock biomass, the Whiting PDT estimated the associated ABCs assuming that the biomass changes by an amount equivalent to one standard deviation estimated from the entire survey biomass time series.

8.1 Description of method options

<u>Method 1 – 75% of F_{msy}</u>

Method 1 assumed a constant fraction of F_{msy} as a buffer to account for scientific uncertainty, for example 75% of F_{msy}. This buffer would apply across all hake stocks. In actuality, the buffer would account for various amounts of scientific uncertainty for each stock because the amount of scientific uncertainty is less for assessment with more precision, and vice versa. This approach would be the simplest approach for an index based stock with an exploitation ratio threshold that serves as a proxy for F_{msy}.

This method is currently used for groundfish and skate stocks in the absence of what an appropriate buffer should be between OFL and ABC. This approach however does not offer a robust statistical measure of uncertainty.

<u>Method 2 – constant percentile of OFL</u>

Method 2 was based on uncertainty in both the F_{msy} proxy and on stock biomass distributions. Sources of uncertainty for F_{msy} would include variation in estimation of fishery removals (landings and discards), whereas, precision of the survey biomass indices can vary over time due to the number of tows and the variation in catch. Scientific uncertainty would be reassessed during each specification cycle for which the ABC would be based on a 25^{th} percentile (or an alternative level) of the OFL distribution.

'Method 2' would be implemented by the following three steps:

1. SSC determines an appropriate level for ABC.

   - For example, the SSC determines that setting the ABC at the 25th percentile of the OFL as a precautionary approach, based on scientific uncertainty that is appropriate for hake stocks with an index based OFL.

2. The corresponding ABC will be based on the 25th percentile (or another percentile established by the SSC) of the current OFL (which itself accounts for uncertainty on F_{msy} proxy and the survey biomass estimate) derived from the cumulative frequency distribution. The ABC control rule would state that ABC is based equal to the value associated with the appropriate percentile on the cumulative frequency distribution of the estimated OFL.

   - In the above example, the 25th percentile for OFL (applying F_{msy} proxy to the 2008-2010 average survey biomass) corresponds to 2,435 mt for the southern red hake stock and 32,350 mt for the northern silver hake stock.

3. Each year, the cumulative frequency distribution for the OFL would be re-calculated based on the distribution of the mean and variance of the survey in the most recent three year period. The ABC would be set at the 25th percentile (or an alternative level approved by the SSC) of the OFL distribution (i.e., repeat step 2 at the 25th percentile.).

<u>Method 3 – constant fraction of OFL based on F_{msy} proxy uncertainty</u>

Similar to Method 2, the scientific uncertainty in the F_{msy} proxy was be estimated and an acceptable level of preventing overfishing (e.g. 75%) would be chosen. But instead of the process for Method 2 described above, the ABC would be expressed as a constant fraction of the OFL which itself would be specified on an annual basis using the three year average survey biomass. For stocks with more precise estimates of F_{msy} proxy, a higher than 75% of OFL could be set as the ABC, and vice versa. For future specifications, ABC as a fraction of OFL would not change unless a new reference point for overfishing was adopted.

'Method 3' in the table would be implemented by the following four steps:

1. SSC determines an appropriate risk level. For example, the SSC determines that a 25th percentile of the F_{msy} proxy is acceptable for hake stocks with an index based OFL. For each stock (each stock having a different level of estimated precision of F_{msy} proxy), an F/F_{msy} proxy is calculated which corresponds to this level of risk.

   - For example, the F/F_{msy} proxy fraction that corresponds to a 25th percentile on the cumulative frequency distribution of F_{msy} proxy, e.g. 70.7% for northern red hake and 87.5% for southern red hake.

2. ABC for each stock is determined as the product of F/F_{msy} proxy and the annual OFL. The ABC control rule would state that "ABC = xx% of OFL for yyy stock."

   - As an example for southern red hake, 88% of the OFL based on 2008-2010 survey data is 2,538 mt.

3. For each stock, subsequent specifications would simply calculate ABC as a constant fraction of OFL.

- For example, if it was determined that the 2012 OFL was 3,200 mt, the 2012 ABC would equal 2,800 mt (87.5% x 3,200 mt)

8.2 Application to silver hake

Estimating Uncertainty in Overfishing Levels

In the absence of an analytical model, multiyear projections for both stocks of silver hake were not feasible. However, the SARC 51 panel reviewers recommended the previous approach that uses the 3-yr moving average of the fall survey biomass and exploitation ratios to determine stock status for the northern and southern stock of silver hake. Additionally, reference points were updated such that the fall survey arithmetic mean weight per tow (kg/tow) was used rather than the previous delta stratified mean weights and the relative exploitation rates is now based on total catch (landings + discards) rather than landings only. The catch and survey indices for each stock are summarized in Tables 8.1-1and 8.1-2. Based on the new reference points and updated survey indices, the OFL for both stocks of silver hake were derived by applying the most recent 3-year average fall biomass survey from 2008-2010 to the F_{msy} proxy (OFL=F_{msy}*2010 fall survey biomass (2008-2010 moving average)). The implied 2010 OFL for the northern and southern stocks of silver hake were estimated at 23,600 mt and 60,120 mt respectively (Table 12 and Table 13; Figure 10).

Uncertainty in the OFLs for both the northern and southern stocks of silver hake were estimated as a joint product of the probability distribution between the F_{msy} proxy and the most recent 3-year moving average of the fall survey biomass (2008-2010) assuming a normal error structure for the fall survey. Variance for the fall survey index explicitly incorporates the Bigelow conversion coefficients and standard errors from the calibration experiment (Miller et al 2010) for 2009 and 2010 to approximate the Albatross variance equivalent based on the following relationship:

$$V_{3yravg} = \left[\frac{V\left[I_{ALB}^{2008}\right] + V\left[\frac{I_{HB}^{2009}}{\rho}\right] + V\left[\frac{I_{HB}^{2010}}{\rho}\right]}{3} \right]$$

The variance for the observed indices for each year and vessel was estimated from the expected values $E(I_{vessel}^{yr})$ of the stratified mean weight (kg/tow) and the observed coefficient of variance (CV) as:

$$V(I_{vessel}^{yr}) = (CV * E(I))^2$$

The variances for the 2009 and 2010 Henry B. Bigelow survey indices, calibrated to Albatross IV units (Miller et al 2010) by applying the conversion coefficient (ρ), were estimated using Taylor series expansion in the following relationship:

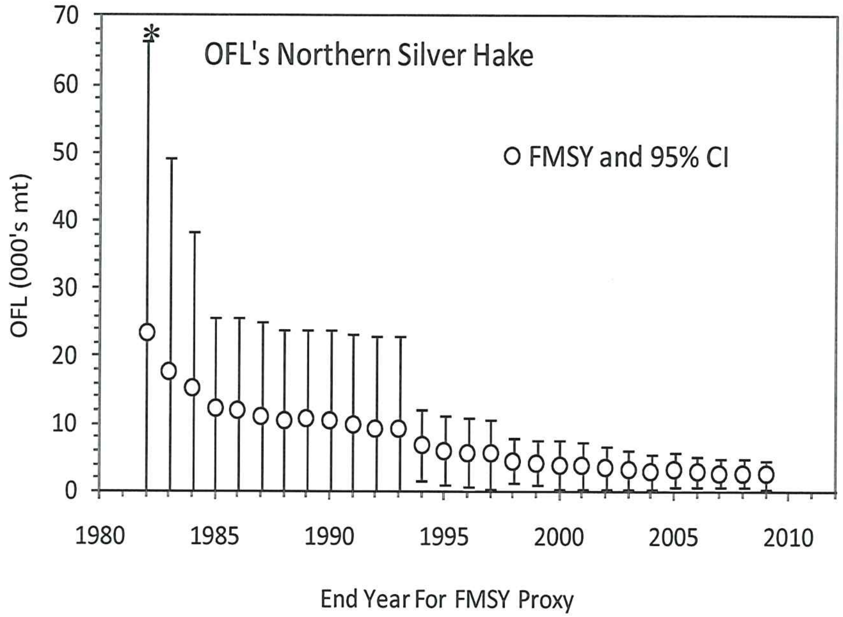
$$V\left[\frac{I_{HB}^{yr}}{\rho}\right] = \left(\frac{I_{HB}^{yr}}{\rho}\right)^2 \times \left[\frac{V(I_{HB}^{yr})}{(I_{HB}^{yr})^2} + \frac{V(\rho)}{\rho^2}\right]$$

Although survey mean weights were estimated from a length-based based model, the standard errors were derived from the constant model as a proxy for the length-based estimates due to unavailable variance estimates for the length-based calibration approach. A comparison of the aggregated survey mean weights between length-based and constant model approach suggested minimal differences, therefore, the application of the variance from the constant model was assumed to be a reasonable approximation for the length-based model.

Probability distributions for Relative F (F_{msy} proxy) were obtained from lognormal distribution of the mean and variance. The normal distribution of the mean and variance was attempted but deemed less desirable due to the large variances in the F_{msy} proxy and distribution of relative F estimates less than zero for the northern and southern stock areas. The large variances can be explained by the substantial decline in catches (i.e. low exploitation ratio) between the late 1970's and early 1980s when the departure of the foreign fleets occurred (Figure 10).

In recent years, exploitation has been low and relatively stable with the exception in the south during ht 1990's and 2000's when relative F increased briefly and then declined due to a decline in the survey biomass relative to silver hake catch. Although the transition from the 1970's to the 1980's highlight high and low productivity in the stock dynamics, this resulted in high estimates of OFLs with wide variances for both northern and southern stock of silver hake.

Figure 10. OFL estimates and 95% CI based on 10 moving averages in the FMSY and fall survey index from 2008-2010 for both the northern and southern stock of silver hake. The symbol * represents baseline OFL derived from the SARC 51 recommended $F_{threshold}$ (average 1973-1982).



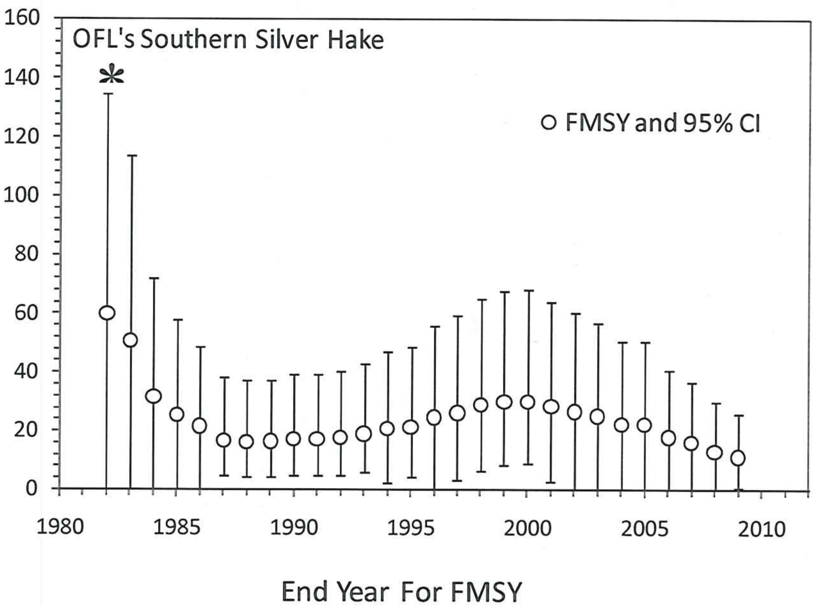


Table 12. Summary of catch and survey indices in Albatross units for northern silver hake, 1955-2010

Silver Hake northern Stock

Year	Northern Fall Survey (arithmetic kg/tow	Northern Fall Survey (3-year average)	Northern Landings (000'smt)	Northern Discards (000's mt)	Northern total catch (000 mt)	Northern Exploitation Index	Northern Exploitation Index (3 year avg)
1955			53.36		53.36		
1956			42.15		42.15	3-yr Survey (08-10) kg/tow	8.50
1957			62.75		62.75		
1958			49.90		49.90	FMSY Proxy (kt/kg)	2.77
1959			50.61		50.61		
1960			45.54		45.54	OFL (000's mt)	23.60
1961			39.69		39.69		
1962			79.00		79.00		
1963	23.10		73.92		73.92	3.20	
1964	4.34		94.46		94.46	21.77	
1965	7.06	11.50	45.28		45.28	6.41	10.46
1966	4.19	5.20	47.81		47.81	11.41	13.20
1967	2.27	4.51	33.37		33.37	14.70	10.84
1968	2.28	2.91	41.38		41.38	18.15	14.75
1969	2.41	2.32	24.06		24.06	9.98	14.28
1970	3.03	2.57	27.53		27.53	9.09	12.41
1971	2.67	2.70	36.40		36.40	13.63	10.90
1972	5.78	3.83	25.22		25.22	4.36	9.03
1973	4.12	4.19	32.09		32.09	7.79	8.60
1974	3.45	4.45	20.68		20.68	5.99	6.05
1975	8.09	5.22	39.87		39.87	4.93	6.24
1976	11.25	7.60	13.63		13.63	1.21	4.05
1977	6.72	8.69	12.46		12.46	1.85	2.66
1978	6.32	8.10	12.61		12.61	2.00	1.69
1979	6.18	6.41	3.42		3.42	0.55	1.47
1980	7.23	6.58	4.73		4.73	0.65	1.07
1981	4.52	5.98	4.42	2.64	7.05	1.56	0.92
1982	6.28	6.01	4.66	2.91	7.57	1.21	1.14
1983	8.76	6.52	5.31	2.64	7.95	0.91	1.22
1984	3.36	6.13	8.29	2.59	10.88	3.24	1.78
1985	8.28	6.80	8.30	2.56	10.86	1.31	1.82
1986	13.04	8.23	8.50	2.35	10.86	0.83	1.79
1987	9.79	10.37	5.66	2.11	7.77	0.79	0.98
1988	6.05	9.63	6.79	1.79	8.57	1.42	1.01
1989	10.53	8.79	4.65	2.32	6.96	0.66	0.96
1990	15.61	10.73	6.38	1.96	8.34	0.53	0.87
1991	10.52	12.22	6.06	1.26	7.31	0.69	0.63
1992	10.25	12.13	5.31	1.42	6.73	0.66	0.63
1993	7.50	9.42	4.36	0.69	5.05	0.67	0.67
1994	6.84	8.20	3.90	0.24	4.14	0.61	0.65
1995	12.89	9.08	2.59	0.63	3.22	0.25	0.51
1996	7.57	9.10	3.62	0.82	4.44	0.59	0.48
1997	5.66	8.71	2.80	0.24	3.05	0.54	0.46
1998	18.91	10.71	2.05	0.69	2.74	0.14	0.42
1999	11.15	11.91	3.45	0.74	4.19	0.38	0.35
2000	13.51	14.52	2.59	0.36	2.95	0.22	0.25
2001	8.33	11.00	3.39	0.48	3.87	0.46	0.35
2002	7.99	9.94	2.59	0.51	3.11	0.39	0.36
2003	8.29	8.20	1.81	0.20	2.01	0.24	0.37
2004	3.28	6.52	1.05	0.12	1.16	0.35	0.33
2005	1.72	4.43	0.83	0.06	0.89	0.52	0.37
2006	3.69	2.90	0.90	0.04	0.94	0.26	0.38
2007	6.44	3.95	1.01	0.75	1.76	0.27	0.35
2008	5.27	5.13	0.62	0.17	0.79	0.15	0.23
2009	6.89	6.20	1.04	0.19	1.23	0.18	0.20
2010	13.35	8.50					

Table 13. Summary of Catch and survey indices in Albatross units for southern silver hake, 1955-2010

Silver Hake Southern Stock

Year	Southern Fall Survey (arithmetic kg/tow)	Southern Fall Survey (3-year average)	Southern Landings (000'smt)	Southern Discards (000's mt)	Southern total catch (000 mt)	Southern Exploitation Index	Southern Exploitation Index (3 year avg)
1955			13.26		13.26		
1956			14.24		14.24		
1957			16.43		16.43		
1958			12.90		12.90		
1959			16.39		16.39		
1960			8.82		8.82		
1961			12.65		12.65		
1962			17.94		17.94		
1963	4.66		89.43		89.43	19.19	
1964	4.06		147.05		147.05	36.22	
1965	5.28	4.67	294.12		294.12	55.70	37.04
1966	2.64	3.99	202.32		202.32	76.64	56.19
1967	2.44	3.45	87.38		87.38	35.81	56.05
1968	2.73	2.60	58.16		58.16	21.30	44.58
1969	1.26	2.14	74.89		74.89	59.44	38.85
1970	1.35	1.78	26.83		26.83	19.88	33.54
1971	2.21	1.61	70.51		70.51	31.90	37.07
1972	2.13	1.90	88.18		88.18	41.40	31.06
1973	1.70	2.01	102.08		102.08	60.05	44.45
1974	0.85	1.56	102.40		102.40	120.47	73.97
1975	1.79	1.45	72.16		72.16	40.32	73.61
1976	1.99	1.54	64.61		64.61	32.47	64.42
1977	1.68	1.82	57.16		57.16	34.02	35.60
1978	2.50	2.06	25.83		25.83	10.33	25.61
1979	1.68	1.95	16.40		16.40	9.76	18.04
1980	1.63	1.94	11.68		11.68	7.17	9.09
1981	1.12	1.48	13.43	3.50	16.93	15.12	10.68
1982	1.56	1.44	14.15	4.65	18.81	12.06	11.45
1983	2.57	1.75	11.86	4.81	16.67	6.49	11.22
1984	1.40	1.84	12.96	4.88	17.84	12.74	10.43
1985	3.55	2.51	12.82	3.87	16.69	4.70	7.98
1986	1.45	2.13	9.70	4.33	14.03	9.68	9.04
1987	1.95	2.32	9.55	4.25	13.80	7.08	7.15
1988	1.78	1.73	8.95	4.50	13.45	7.55	8.10
1989	1.87	1.87	13.00	6.57	19.57	10.46	8.37
1990	1.52	1.72	13.02	5.97	18.99	12.49	10.17
1991	0.85	1.41	9.74	3.08	12.82	15.08	12.68
1992	0.99	1.12	10.53	3.45	13.98	14.12	13.90
1993	1.28	1.04	12.49	5.17	17.65	13.79	14.33
1994	0.79	1.02	12.18	5.94	18.12	22.93	16.95
1995	1.59	1.22	11.99	1.40	13.39	8.42	15.05
1996	0.45	0.94	12.13	0.48	12.61	28.03	19.80
1997	0.83	0.96	12.55	0.62	13.17	15.87	17.44
1998	0.57	0.62	12.56	0.53	13.08	22.95	22.28
1999	0.82	0.74	10.42	3.55	13.97	17.03	18.62
2000	0.72	0.70	9.47	0.33	9.80	13.61	17.87
2001	2.04	1.19	8.88	0.19	9.07	4.45	11.70
2002	1.18	1.31	4.89	0.41	5.30	4.49	7.52
2003	1.42	1.55	6.28	0.60	6.89	4.85	4.60
2004	1.24	1.28	6.97	1.20	8.17	6.59	5.31
2005	0.94	1.20	6.40	1.58	7.97	8.48	6.64
2006	1.42	1.20	4.58	0.16	4.74	3.34	6.14
2007	0.87	1.08	5.07	0.15	5.21	5.99	5.94
2008	1.36	1.22	5.58	1.03	6.62	4.86	4.73
2009	1.10	1.11	6.60	0.84	7.43	6.76	5.87
2010	2.82	1.76					

3-yr Survey (08-10) kg/tow	1.76
FMSY Proxy (kt/kg)	34.18
OFL (000's mt)	60.12

Risk Analyses (Probability of overfishing)

The probability of mortality exceeding the potential choices for F_{msy} from its cumulative distribution (25th, 50th, and 75th percentiles) was estimated (Table 14, Figure 11, and Figure 12). For each catch scenario, a relative exploitation was calculated at each realization of the survey biomass distribution from the cumulative probability distribution. The probability of F for a given catch exceeded a percentile of F_{msy} was estimated as the sum product of the probability of each relative F exceeding $F_{threshold}$ at given percentile (1 or 0) and the probability of each survey realization.

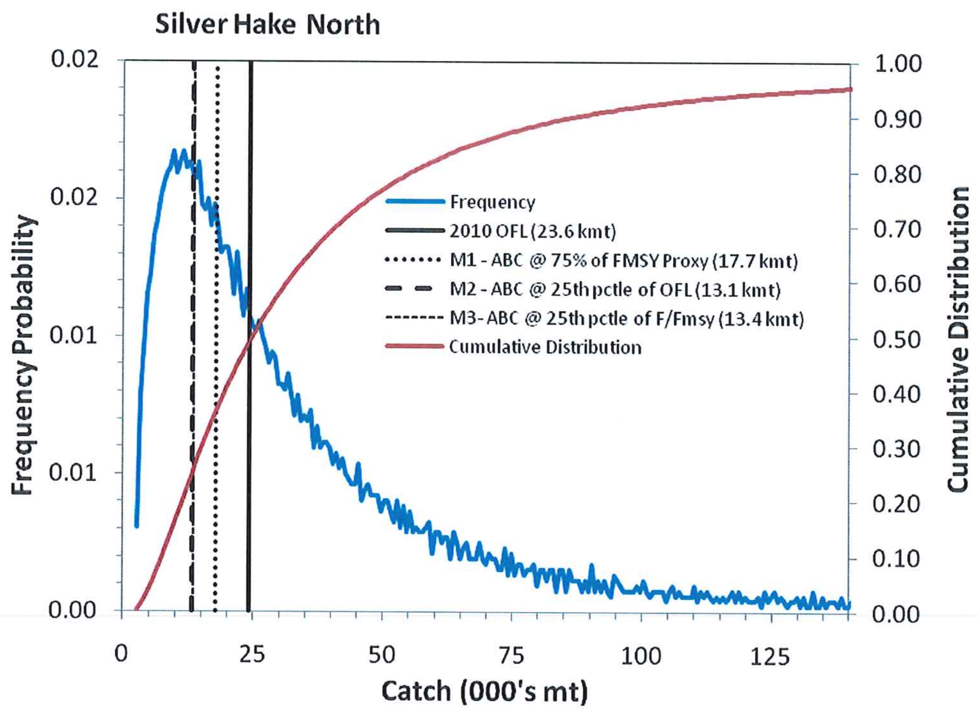
Application of proposed ABC's Methods for Silver hake

Method 1 (M1): Requires adjusting the F_{msy} proxy by a prescribed specification (e.g. 75% of $F_{threshold}$) and applying the adjustment to the three year moving average of the fall survey. For silver hake, this implies an ABC of 17,700 mt in the north and 45,100 mt in the south, which are all well above the recent catches in both management regions. Based on this method, the risk of mortality exceeding the 25^{th} percentile level of F_{msy} is 98% and zero at the 50^{th} and 75^{th} percentile (Table 14, Figure 11, and Figure 12). This approach is commonly used in groundfish stocks with index based assessments. However, it does not account for varying levels of scientific uncertainty and risk of exceeding the OFL.

Method2 (M2): The estimated ABC based on the corresponding 25^{th} percentile of the OFL is 13,100 mt for northern silver hake and 32,400 mt for southern silver hake. The corresponding relative F at the 25^{th} percentile of the 2010 OFL was approximately 1.56 kt/kg in the north and 19.1kt/kg in the south. Given the estimated ABCs for both management regions, the risk of exceeding the 25^{th} percentile of the F_{msy} proxy is about 38% in the north and 39% in the south. The risk at the 50^{th} and 75^{th} percentile of the F_{msy} proxy is zero in both the northern and southern management regions (Table 14, Figure 11, and Figure 12). For this approach, the 25^{th} percentile on OFL would be recalculated each year with new survey data.

Method3 (M3): The corresponding ABC is estimated as the constant ratio of a specified percentile of F_{masy} proxy to the estimated F_{msy} proxy from the overfishing definition and applied to the current year OFL. For example, the fraction that corresponds to the 25^{th} percentile F_{msy}/F_{msy} in the north is 57% and 56% in the south. Applying this ratio as a constant to the estimated 2010 OFL, results in ABC of 13,482 mt in the north and 33,518 mt in the south. Based on ABC estimates for this method, the risk of exceeding the 25^{th} percentile of the F_{msy} proxy is 48% in the north and 47% in the south (Table 14, Figure 11, and Figure 12). These ratios would be used each year to set ABC relative to updated estimates of OFL using the most recent survey data. The F/F_{msy} ratio as a function of the cumulative frequency distribution of F_{msy} proxy is illustrated in Figure 13.

Figure 11. OFL frequency distribution for the northern (TOP) and southern (BOTTOM) stock of silver hake derived as a product of the fall survey distribution from the most recent 3yr mean and variance and the distribution around the SARC 51 $F_{threshold}$ with an underlying lognormal error structure. M1, M2 and M3 refer to the three proposed methods for estimating ABC.



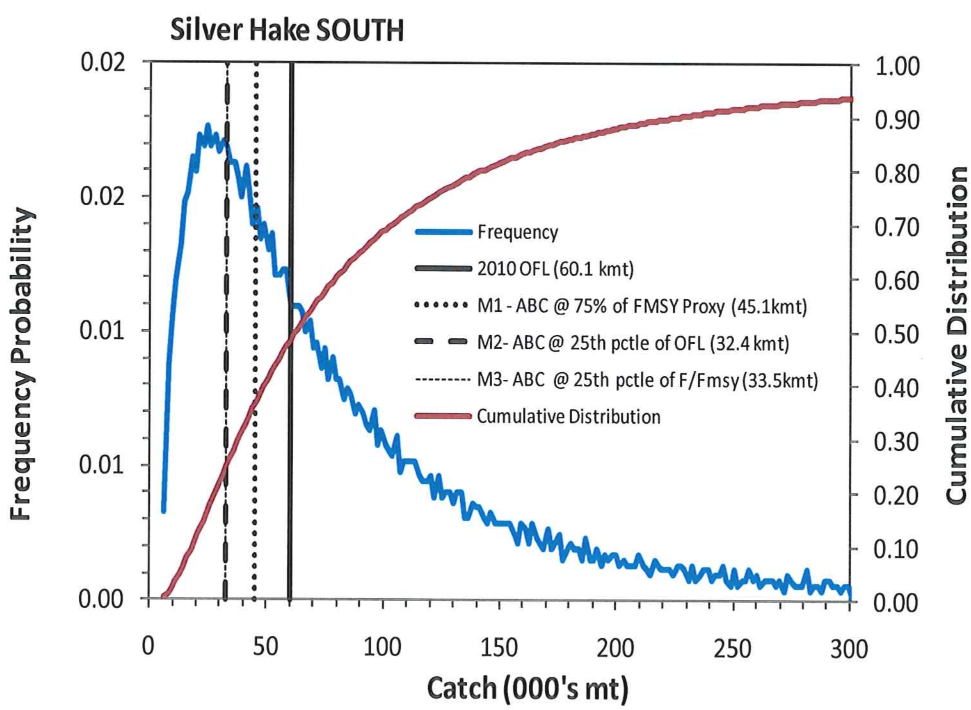
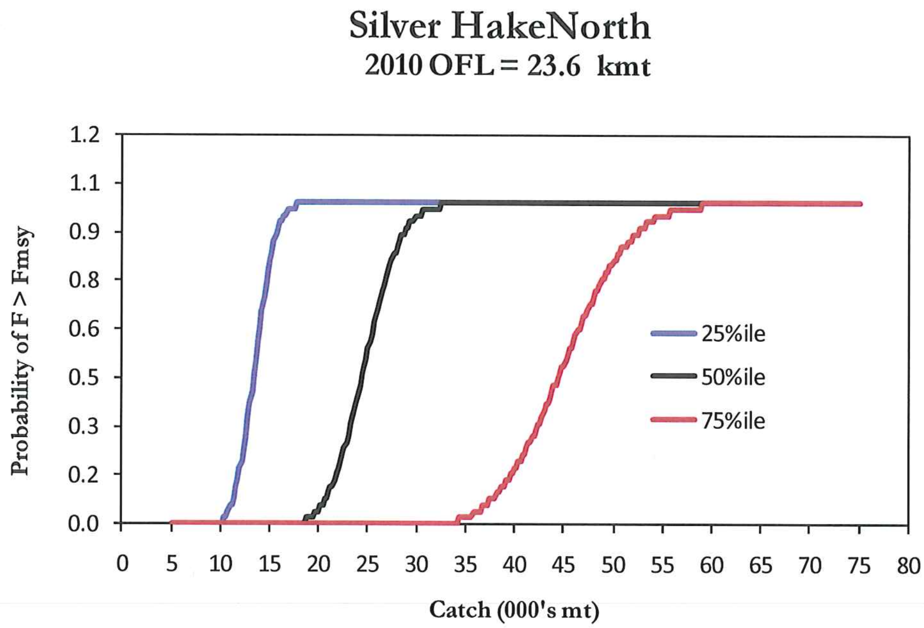


Figure 12. Probability of overfishing for northern (TOP) and southern (BOTTOM) silver hake based on 2010 OFL at the 25th, 50th and 75 percentile of F_{msy}. The probability of overfishing is a product of the probability of F > F_{msy} at each survey realization and the probabilities corresponding to the survey biomass distribution.



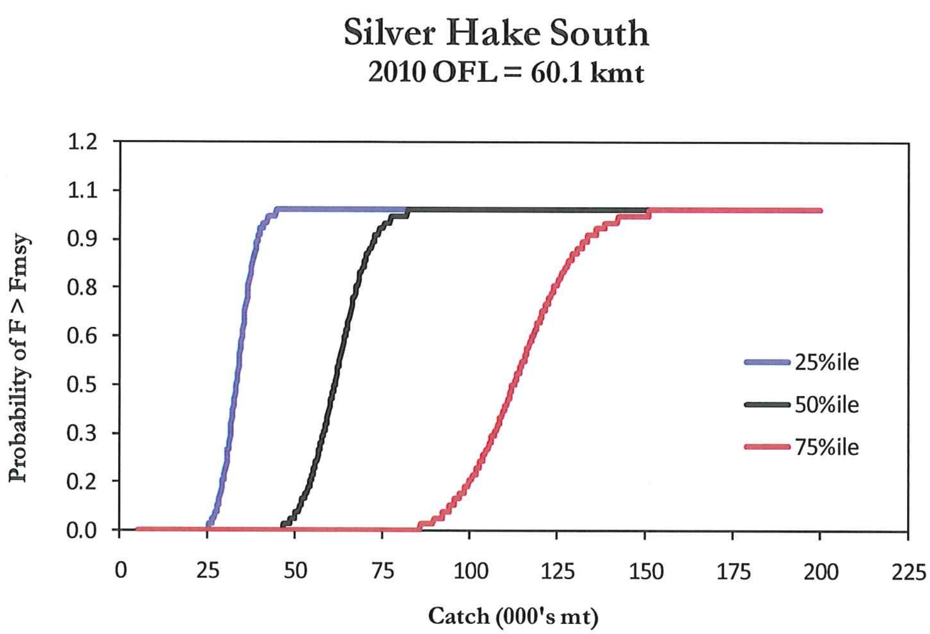


Figure 13. Example of 2010 ABC (2008-2010 biomass index) control rule for the northern stock (TOP) and southern stock (BOTTOM) of silver hake using Method 3. Instead of a fixed percent for all stocks (e.g. 75% of OFL), the ABC could be set at 85% of OFL, chosen based on the estimated uncertainty of F_{msy} proxy.

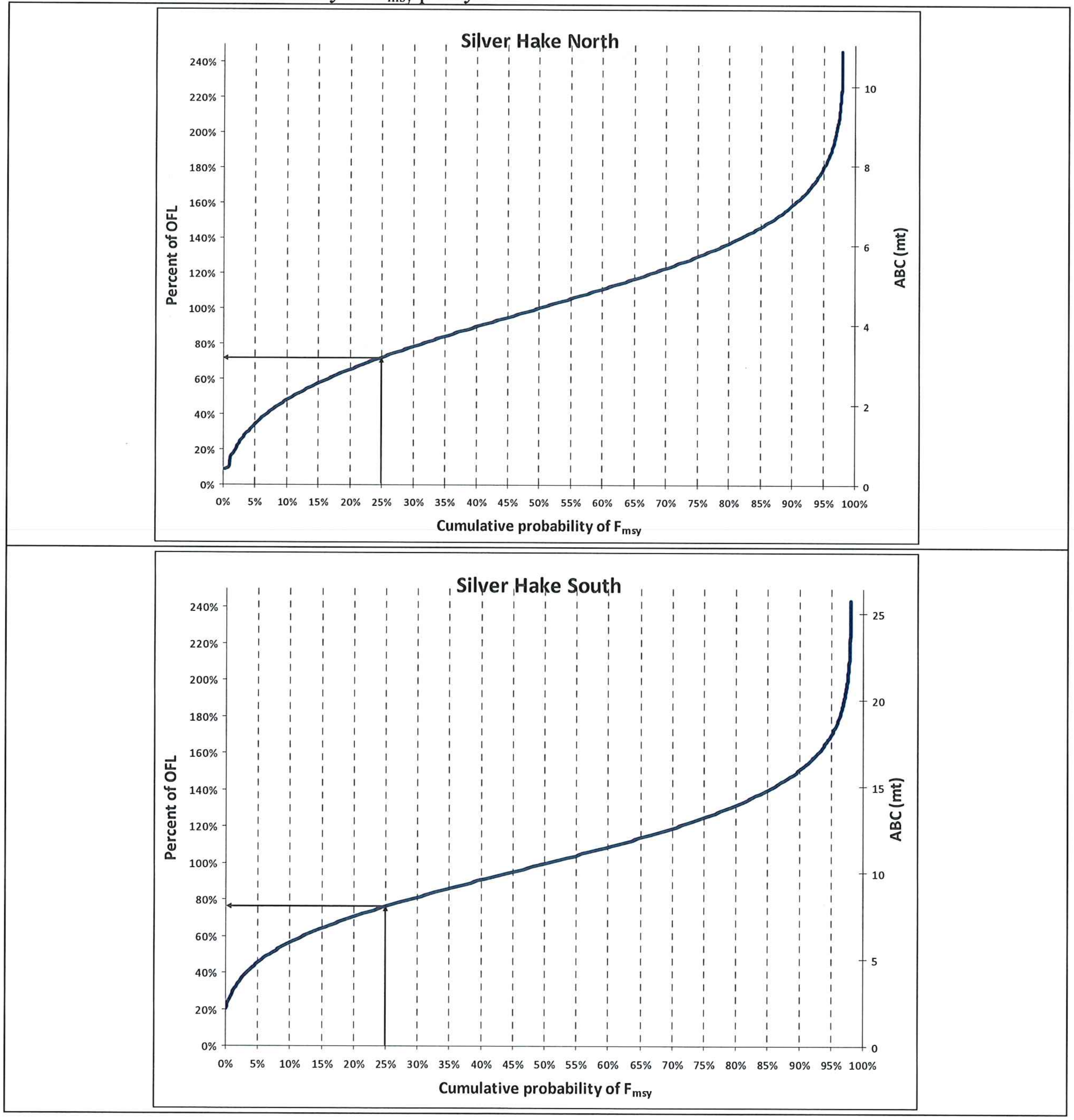


Table 14. Probability of mortality exceeding the 25th, 50th and 75 percentile of F_{msy} for northern (TOP) and Southern (BOTTOM) silver hake based on 2010 OFL.

Silver hake NORTH_2010 OFL = 23.6 kmt				
Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	17.7	98%	0%	0%
2	13.1	38%	0%	0%
3	13.5	48%	0%	0%

Silver Hake SOUTH_2010 OFL = 60.1 kmt				
Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	45.1	99%	0%	0%
2	32.4	39%	0%	0%
3	33.5	47%	0%	0%

Multiyear specifications

In the absence of an analytical model to conduct projections for silver hake, the following approaches were considered for setting multiyear specifications for both stocks of silver hake. These scenarios are intended to illustrate how the three models would respond to changes in stock biomass, estimated by the three year moving average for the fall survey biomass index. They are not to be intended to substitute for assumptions about future biomass, which could include multiyear specifications that assume that 2011 and 2012 survey values will equal the 2010 value.

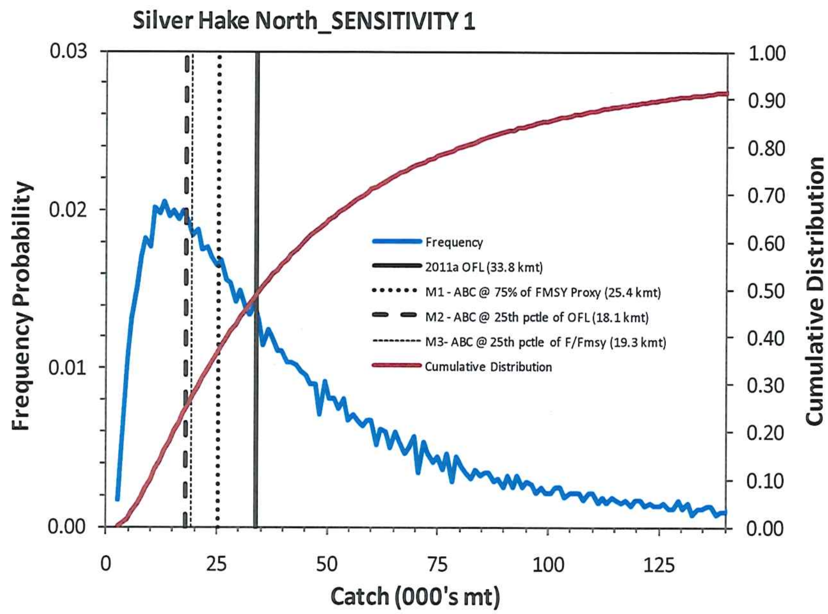
One approach to setting future specifications for two or three years could follow the procedure described below:

1) Set ABC at a constant level, using the most recent three year average. For example, update the three year average, dropping the first year of the three year period and adding a new year with the expectation that the new data will have the same value as the most recent survey. For example, the 2012 silver hake specifications could be based on the 2009-2011 average biomass from the fall survey. The 2013 specifications would then be based on the 2010 and 2011 biomass, plus an assumed 2012 survey biomass that is equal to the 2011 value.

   Sensitivity analyses are presented in Table 15that demonstrates using two current survey estimates (2009-2010) and assuming the 3rd estimate for 2011. The assumed 2011 survey estimate was derived from the 2010 survey estimate ± 1 standard deviation. The standard deviation was calculated from the times series of the annual survey biomass estimates. The probability distribution of OFL and candidate ABCs are presented in Figure 14 and Figure 16 and the probability of overfishing is presented in Figure 15 and Figure 17.

2) Alternatively, the Council could require annual automatic specifications when new survey data become available. This annual specification process would be easier to manage using Method 3

Figure 14. Sensitivity analyses on the Probability distribution of 2011OFL for northern silver hake and candidate ABCs based on 1 standard deviation above the 2010 fall survey estimate. Note that the 2011a survey (SENSITIVITY 1) is based on three year average (2009-2011) and standard deviations were derived using the entire fall survey time series from 1963-2010.



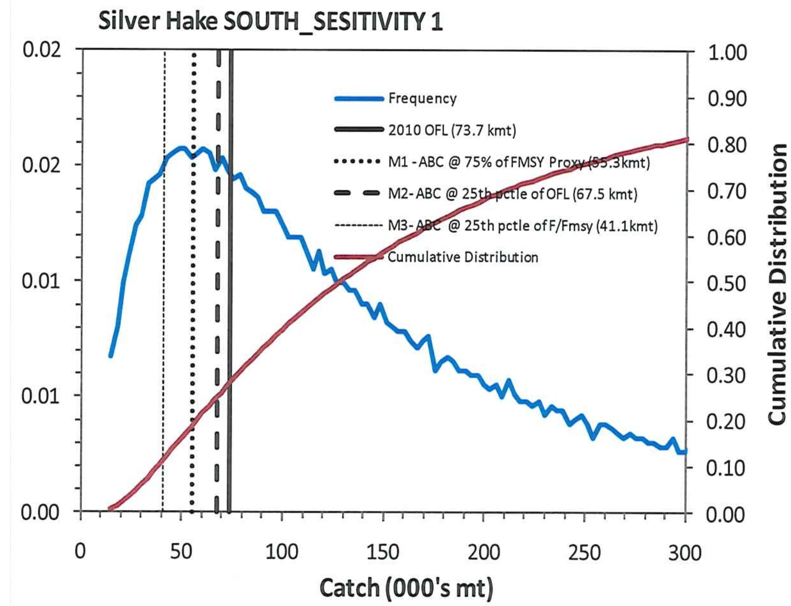
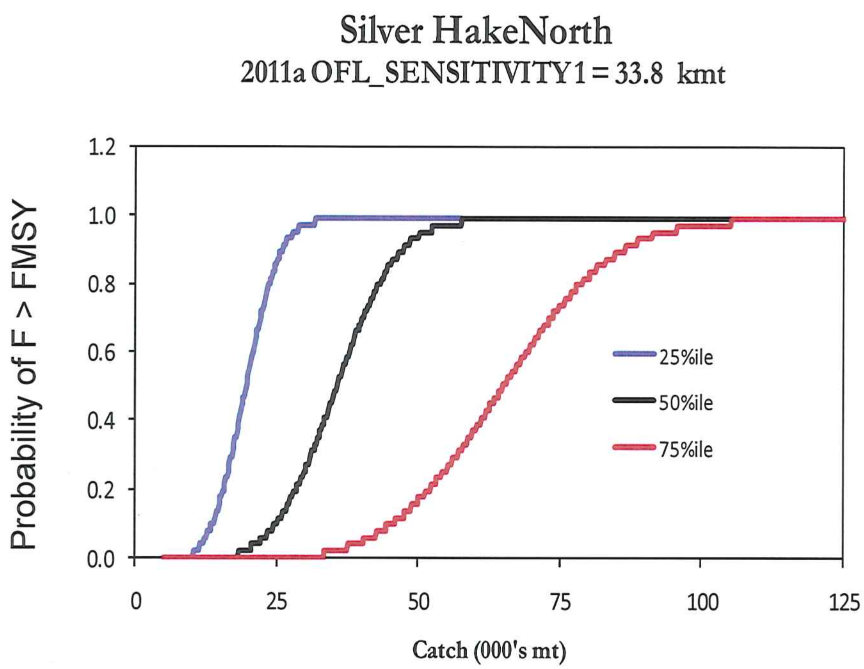


Figure 15. Sensitivity analyses on the Probability of overfishing in 2011 for $\mathbf{F_{msy}}$ at 25th, 50th and 75th percentile for Northern (LEFT) and southern silver hake (RIGHT) based on 1 standard deviation above the 2010 fall survey estimate



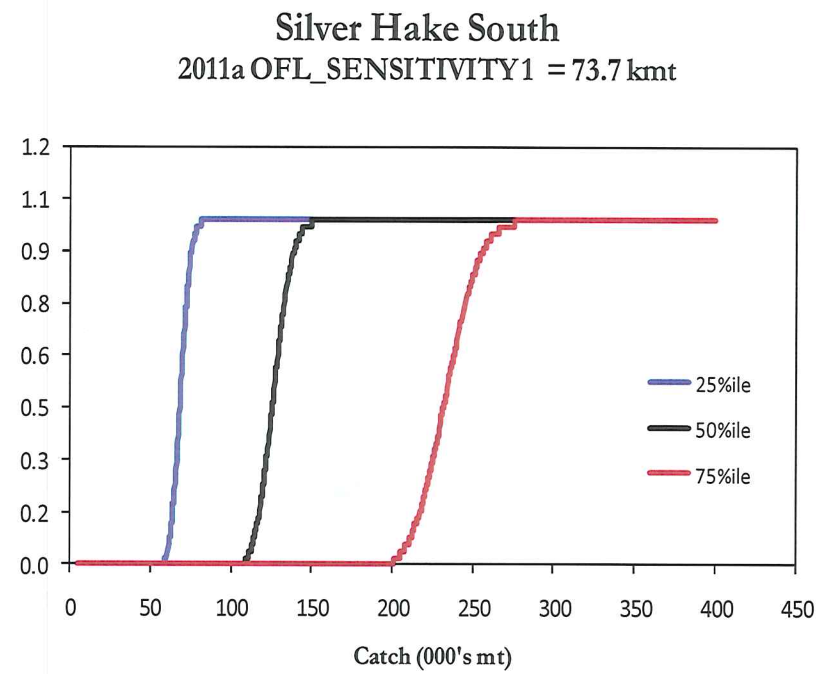
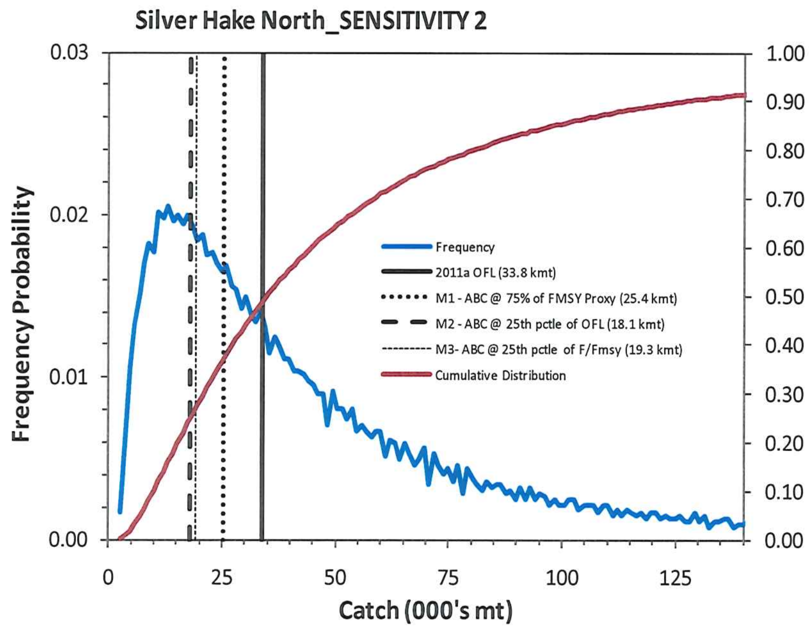


Figure 16. Sensitivity analyses on the Probability distribution of 2011OFL for northern silver hake and candidate ABCs based on 1 standard deviation below the 2010 fall survey estimate. Note that the 2011a survey (SENSITIVITY 2) is based on three year average (2009-2011) and standard deviations were derived using the entire fall survey time series from 1963-2010.



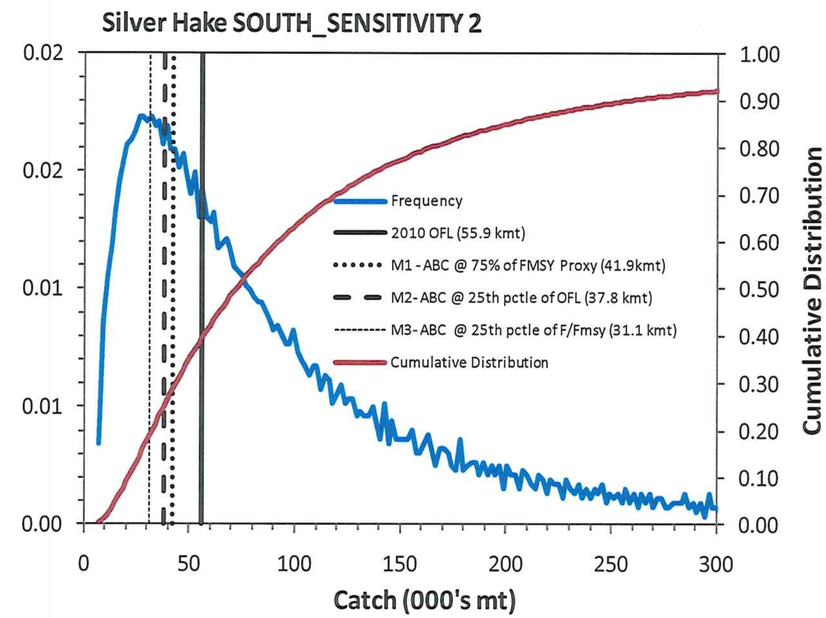
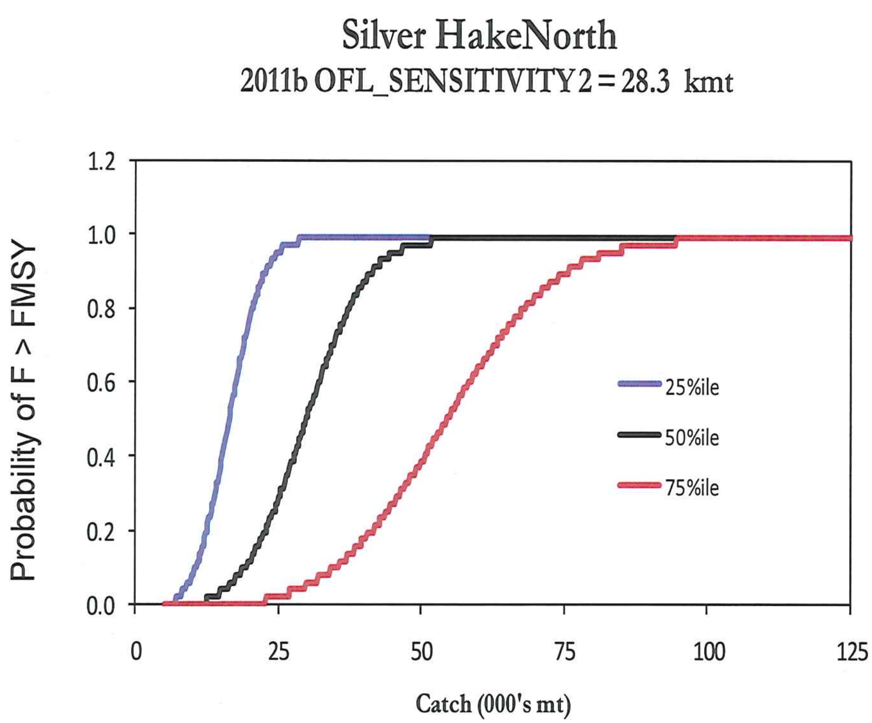


Figure 17. Sensitivity analyses on the Probability of overfishing in 2011 for $\mathbf{F_{msy}}$ at 25th, 50th and 75th percentile for Northern (LEFT) and southern silver hake (RIGHT) based on sensitivity based on 1 standard deviation below the 2010 fall survey estimate.



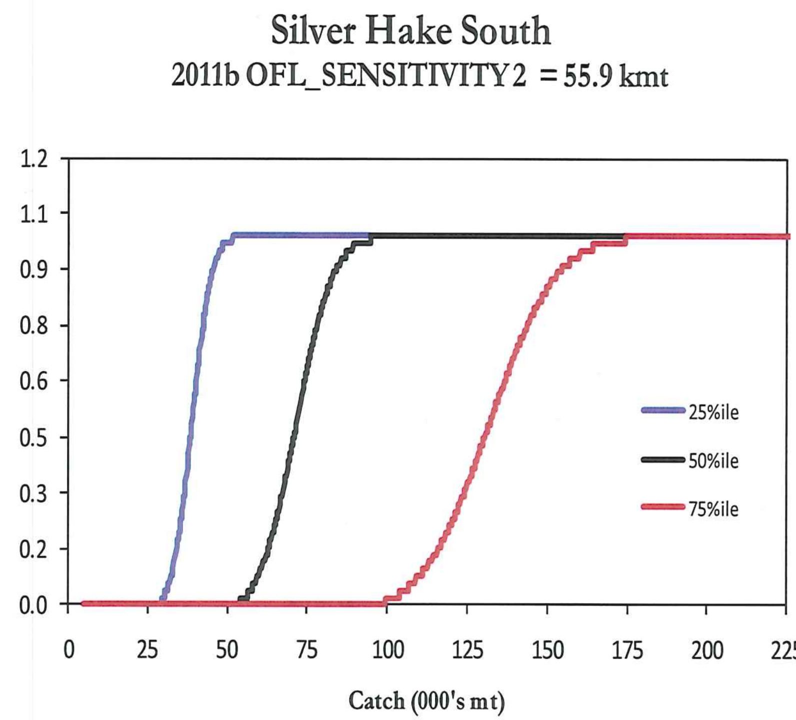


Table 15. Probability of F > F_{msy} for northern (LEFT) and southern (RIGHT) Silver hake for 2010 OFL and 2011 OFL assuming +1 SD (SENSITIVTY 1_2011a) and -1 SD (SENSITIVITY 2_2011b)

Silver hake NORTH_2010 OFL = 23.6 kmt

Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	17.7	98%	0%	0%
2	13.1	38%	0%	0%
3	13.5	48%	0%	0%

SENSITIVITY 1_2011a OFL = 33.8 kmt

Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	25.4	89%	12%	0%
2	18.1	39%	0%	0%
3	19.3	47%	2%	0%

SENSITIVITY 2_2011b OFL = 28.3 kmt

Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	21.2	83%	16%	0%
2	14.9	37%	4%	0%
3	16.2	49%	4%	0%

Silver Hake SOUTH_2010 OFL = 60.1 kmt

Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	45.1	99%	0%	0%
2	32.4	39%	0%	0%
3	33.5	47%	0%	0%

SENSITIVITY 1_2011a OFL = 73.7 kmt

Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	55.2	0%	0%	0%
2	67.5	39%	0%	0%
3	41.1	0%	0%	0%

SENSITIVITY 2_2011b OFL = 55.9 kmt

Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	41.9	72%	0%	0%
2	37.8	41%	0%	0%
3	31.1	4%	0%	0%

8.3 Application to red hake

Estimation of OFL uncertainty

Although SARC 51 did not accept a new assessment model, the SARC agreed to use the relative F (RelF) from the AIM analysis strictly as a proxy F_{msy}. In addition, the previous biological reference point's were revised such that the spring survey arithmetic stratified mean weight per tow (kg/tow) rather than a delta stratified mean would be used to calculate the three-year moving average of mean weight per tow for determination of stock status. The catch and survey indices for each stock are presented in Table 16 and Table 17. The 2010 overfishing limit (OFL= F_{msy} *2010 spring survey biomass (2008-2010 moving average)) for northern and southern red hake is estimated at 394 mt and 2,899 mt (Figure 18), respectively.

The uncertainty in the OFL estimate was estimated as the joint probability distribution of F_{msy} and the 3-year spring survey moving average of biomass. The probability distribution of RelF (proxy F_{msy}) was obtained from the AIM bootstrap distribution. For each bootstrap calculation, the saved predicted values of ln (replacement ratio) and random residuals from the initial regression of the replacement ratio and the RelF estimates are passed to a regression routine, and the α and β values saved to obtain 1,000 realizations of the replacement F ($-\alpha/\beta$). The probability distribution of the spring survey three-year (2008-2010) moving average of biomass was estimated from a normal distribution of the mean and variance. The variance of the spring survey 3-year moving average (V3yravg) was estimated as:

$$V_{3yravg} = \left[\frac{V\left[I_{ALB}^{2008}\right] + V\left[\frac{I_{HB}^{2009}}{\rho}\right] + V\left[\frac{I_{HB}^{2010}}{\rho}\right]}{3} \right]$$

The variance for the observed survey indices for each year and vessel was estimated from the expected values E(I) of the stratified mean weight (kg/tow) and the coefficient of variance (CV) as:

$$V(I_{vessel}^{yr}) = (CV * E(I))^2$$

The variances for the 2009 and 2010 Henry B. Bigelow survey indices, calibrated to Albatross IV units by applying length-based conversion coefficients (ρ) (Miller et al 2010), were estimated using Taylor series expansion :

$$V\left[\frac{I_{HB}^{yr}}{\rho}\right] = \left(\frac{I_{HB}^{yr}}{\rho}\right)^2 \times \left[\frac{V(I_{HB}^{yr})}{(I_{HB}^{yr})^2} + \frac{V(\rho)}{\rho^2}\right]$$

Although survey mean weights were estimated from a length-based model, the standard errors were derived from the constant model due to unavailable variance estimates from the length-based approach. A comparison of the calibrated survey mean weight between length-based and constant model approaches suggested minimal differences, therefore, the application of the standard error from the constant model was assumed to be a reasonable approximation for the length-based estimates.

Table 16. Catch and survey indices for northern red hake, 1962-2010, and threshold biological reference points.

Red Hake , Northern Stock

Year	Northern Spring Survey (arithmetic kg/tow)	Northern spring Survey (3-yr average)	Northern Landings (000 mt)	Northern Discards (000 mt)	Northern total catch (000 mt)	Northern Exploitation Index	Northern Exploitation Index (3 Yr avg)
1962			1.918	1.600	3.518		
1963			3.285	1.600	4.885		
1964			1.410	1.701	3.111		
1965			2.774	1.624	4.398		
1966			5.578	1.603	7.181		
1967			1.865	1.404	3.269		
1968	1.138		2.629	1.301	3.930	3.454	
1969	0.639		2.022	1.117	3.138	4.909	
1970	0.541	0.773	1.033	1.098	2.130	3.939	4.101
1971	0.648	0.609	4.806	1.162	5.969	9.211	6.020
1972	1.560	0.916	15.028	0.963	15.991	10.248	7.800
1973	4.311	2.173	15.289	0.909	16.199	3.757	7.739
1974	2.431	2.768	7.226	0.815	8.041	3.308	5.771
1975	4.254	3.665	8.703	1.199	9.902	2.328	3.131
1976	3.371	3.352	6.339	0.925	7.264	2.155	2.597
1977	2.656	3.427	0.894	1.081	1.976	0.744	1.742
1978	2.571	2.866	1.227	1.117	2.345	0.912	1.270
1979	2.041	2.422	1.529	1.223	2.751	1.348	1.001
1980	3.883	2.831	1.033	1.366	2.399	0.618	0.959
1981	6.353	4.092	1.277	1.324	2.601	0.409	0.792
1982	2.127	4.121	1.213	1.460	2.673	1.257	0.761
1983	3.698	4.059	0.895	1.353	2.248	0.608	0.758
1984	2.982	2.936	1.060	1.327	2.388	0.801	0.888
1985	3.913	3.531	0.992	1.270	2.262	0.578	0.662
1986	3.260	3.385	1.458	1.189	2.646	0.812	0.730
1987	2.941	3.371	1.013	1.052	2.066	0.702	0.697
1988	1.996	2.732	0.866	0.897	1.763	0.883	0.799
1989	1.651	2.196	0.777	1.447	2.224	1.347	0.977
1990	1.331	1.660	0.830	0.595	1.425	1.070	1.100
1991	1.621	1.535	0.745	0.818	1.563	0.964	1.127
1992	2.501	1.818	0.918	0.726	1.645	0.658	0.897
1993	2.824	2.315	0.769	0.083	0.853	0.302	0.641
1994	1.590	2.305	0.729	0.077	0.806	0.507	0.489
1995	1.973	2.129	0.187	0.063	0.250	0.127	0.312
1996	1.792	1.785	0.414	0.656	1.070	0.597	0.410
1997	1.811	1.859	0.339	0.125	0.464	0.256	0.327
1998	2.519	2.041	0.187	0.130	0.317	0.126	0.326
1999	2.322	2.217	0.220	0.468	0.687	0.296	0.226
2000	3.186	2.676	0.197	0.055	0.252	0.079	0.167
2001	3.579	3.029	0.223	0.135	0.358	0.100	0.158
2002	4.460	3.742	0.275	0.101	0.376	0.084	0.088
2003	0.996	3.012	0.210	0.088	0.297	0.298	0.161
2004	1.772	2.409	0.103	0.057	0.160	0.090	0.158
2005	1.097	1.288	0.096	0.057	0.153	0.140	0.176
2006	0.912	1.260	0.096	0.181	0.277	0.303	0.178
2007	2.056	1.355	0.069	0.127	0.197	0.096	0.180
2008	3.488	2.152	0.052	0.059	0.112	0.032	0.144
2009	1.748	2.431	0.085	0.095	0.180	0.103	0.077
2010	2.020	2.419					

Ref. Pt.	Threshold
Biomass	1.265
Exploitation	0.163

Table 17. Catch and survey indices for southern red hake, 1962-2010, and threshold biological reference points.

Red Hake Southern Stock

Year	Southern Spring Survey (arithmetic kg/tow)	Southern Spring Survey (3-year average)	Southern Landings (000 mt)	Southern Discards (000 mt)	Southern total catch (000 mt)	Southern Exploitation Index	Southern Exploitation Index (3 year avg)
1962			12.757	4.000	16.757	Ref. Pt	Threshold
1963			32.671	4.000	36.671	Biomass	0.51
1964			44.221	3.758	47.979		
1965			93.624	4.292	97.916	Exploitation	3.04
1966			108.016	3.773	111.789		
1967			58.948	3.660	62.608		
1968	1.285		18.713	3.715	22.428	17.450	
1969	1.082		53.417	3.623	57.040	52.707	
1970	1.723	1.364	11.864	3.141	15.005	8.708	26.288
1971	3.488	2.098	35.421	2.313	37.734	10.817	24.077
1972	3.590	2.934	61.371	2.098	63.469	17.680	12.402
1973	3.992	3.690	51.679	2.240	53.919	13.506	14.001
1974	2.838	3.473	26.834	2.158	28.992	10.217	13.801
1975	3.179	3.336	20.028	1.763	21.791	6.855	10.193
1976	5.314	3.777	23.110	1.827	24.937	4.693	7.255
1977	2.300	3.598	7.812	1.818	9.630	4.186	5.245
1978	7.648	5.087	6.434	2.436	8.870	1.160	3.346
1979	1.514	3.821	7.837	2.665	10.502	6.938	4.095
1980	2.380	3.847	4.226	2.702	6.928	2.911	3.670
1981	4.613	2.835	2.496	2.715	5.211	1.130	3.660
1982	3.342	3.445	3.199	3.776	6.975	2.087	2.043
1983	2.207	3.387	1.576	3.889	5.465	2.476	1.898
1984	1.331	2.293	1.819	3.910	5.729	4.305	2.956
1985	1.392	1.643	0.932	2.968	3.901	2.802	3.194
1986	1.734	1.486	0.899	3.389	4.288	2.473	3.193
1987	0.878	1.335	1.415	3.313	4.728	5.389	3.554
1988	1.006	1.206	1.122	3.462	4.584	4.557	4.139
1989	0.487	0.790	1.367	5.006	6.372	13.077	7.674
1990	0.707	0.733	1.312	4.748	6.060	8.573	8.735
1991	0.611	0.602	1.210	2.612	3.822	6.257	9.302
1992	0.465	0.594	1.439	6.343	7.782	16.743	10.524
1993	0.424	0.500	1.014	5.308	6.321	14.926	12.642
1994	0.675	0.521	1.052	1.720	2.772	4.108	11.926
1995	0.516	0.538	1.473	1.329	2.801	5.433	8.156
1996	0.453	0.548	0.719	0.380	1.099	2.426	3.989
1997	1.161	0.710	1.172	2.422	3.595	3.097	3.652
1998	0.214	0.609	1.207	0.740	1.948	9.118	4.880
1999	0.455	0.610	1.404	1.060	2.465	5.420	5.878
2000	0.423	0.364	1.462	0.250	1.712	4.047	6.195
2001	0.642	0.507	1.492	0.138	1.630	2.540	4.002
2002	0.542	0.536	0.673	0.327	1.000	1.846	2.811
2003	0.206	0.463	0.641	0.345	0.986	4.794	3.060
2004	0.154	0.301	0.599	0.616	1.214	7.865	4.835
2005	0.376	0.245	0.411	1.007	1.418	3.772	5.477
2006	0.380	0.304	0.429	0.674	1.103	2.902	4.846
2007	0.857	0.538	0.489	1.545	2.035	2.373	3.015
2008	0.473	0.570	0.653	0.814	1.467	3.099	2.791
2009	1.342	0.891	0.674	0.869	1.543	1.150	2.207
2010	1.045	0.954					

Risk Analyses (Probability of overfishing)

The probability of mortality exceeding F_{msy} was estimated for a range of 2011 catches for 3 scenarios of F_{msy} (25th, 50th, and 75th percentiles) for the northern and southern stock (Table 18, Figure 18, and Figure 19). For each catch scenario, a RelF was calculated at each realization of the survey biomass distribution (from the normal distribution as described above). The probability that a catch exceeded a percentile of F_{msy} was estimated as the sum of the products of the probability of each relative F exceeding that catch (1 or 0) and the probability of each survey realization.

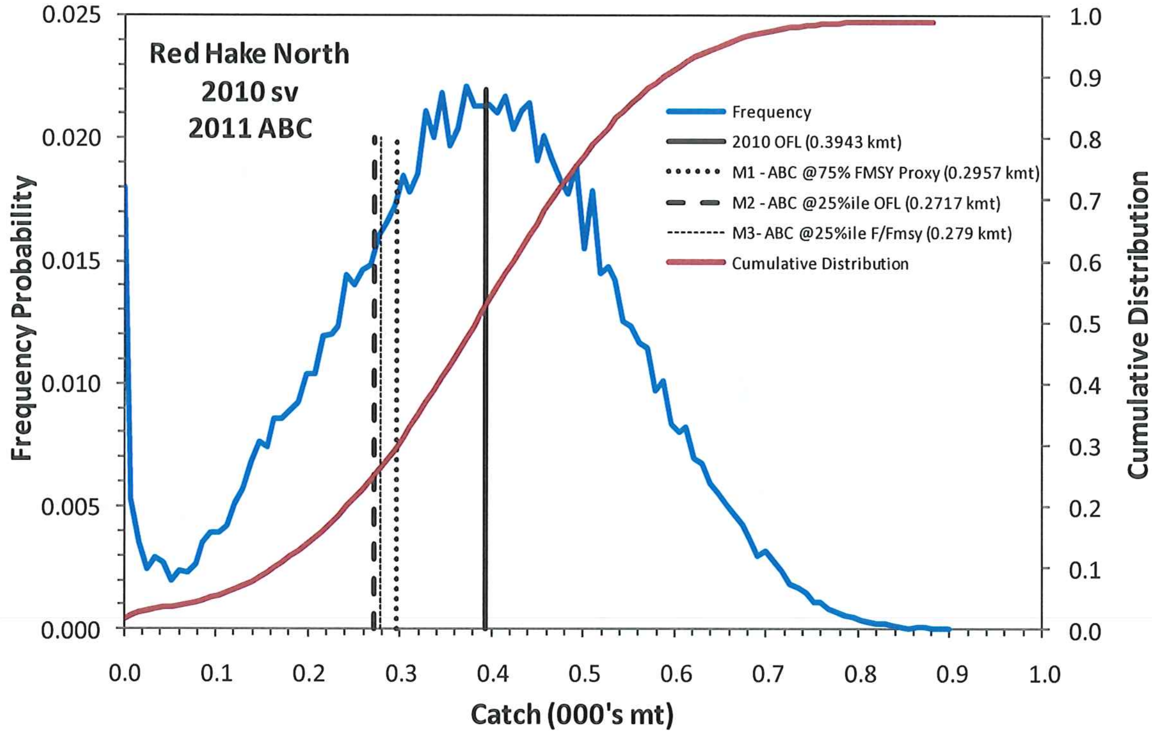
Application of proposed ABC's Methods for Red hake

Method 1: Requires adjusting the F_{msy} proxy by a prescribed specification (e.g. 75% of $F_{threshold}$) and applying the adjustment to the 3-year moving average of the spring survey. For red hake, this implies an ABC of 2,957 mt in the north and 2,174 mt in the south, which are well above the recent catches in both management regions (Table 18, Figure 18, and Figure 19). This approach is commonly used in groundfish stocks with index based assessments. However, it does not account for any scientific uncertainty or risk of exceeding the OFL.

Method 2: The estimated ABC based on the 25th percentile of the 2010 OFL is 271 mt for northern red hake and 2,435 mt for southern red hake (Figure 18; Table 20). The corresponding relative F at the 25th percentile of the 2010 OFL was 1.67 kt/kg in the north and 0.80 kt/kg in the south. Given the estimated ABCs for both management regions, the risk of exceeding the 25th percentile of the Fmsy proxy is about 39% in the north and 37% in the south. The risk at the 50th and 75th percentile of the Fmsy proxy is 0% in the north about 10% and 2%, respectively, in the south (Table 18). The 25th percentile on OFL would be recalculated each year with new survey data.

Method 3: The corresponding ABC is estimated as the constant ratio of a specified percentile of F_{msy} to the estimated F_{msy} proxy from the overfishing definition and applied to the current year OFL. For example, the 25^{th} percentile F_{msy} / F_{msy} in the north is 70.7% and 87.5% in the south. Applying these ratios to the estimated 2010 OFLs result in an ABC of 288 mt in the north and 2,537 mt in the south (Figure 18; Table 20). Based on ABC estimates for this method, the risk of exceeding the 25th percentile of the F_{msy} proxy is about 50% in the north and in the south (Table 18). These ratios would be used each year to set ABC relative to updated estimates of OFL estimated with the most recent survey data, as demonstrated in Table 18. The F/ F_{msy} ratio as a function of the cumulative frequency distribution of F_{msy} proxy is illustrated in Figure 20.

Figure 18. OFL frequency distribution for the northern (TOP) and southern (BOTTOM) stocks of red hake derived as a product of the fall survey distribution from the most recent 3yr mean and variance and the distribution around the recommended SARC 51 $F_{Threshold}$. M1, M2 and M3 refer to the three proposed methods for estimating ABC.



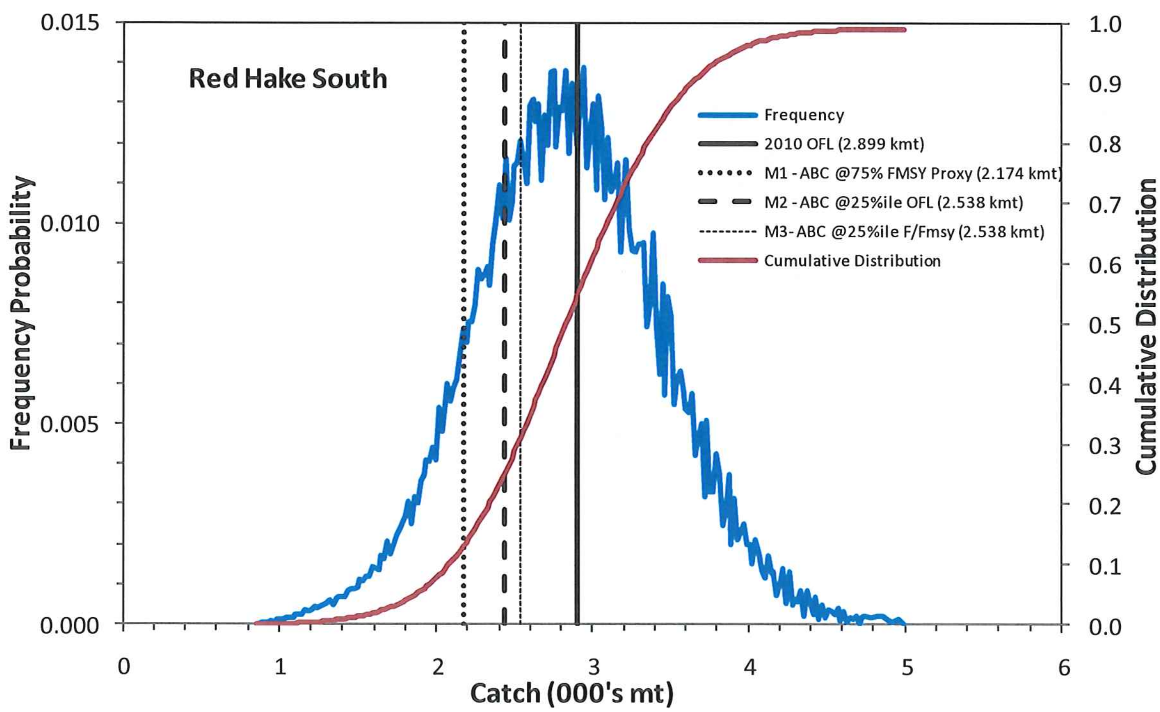


Figure 19. Probability of overfishing for northern (TOP) and southern (BOTTOM) red hake based on 2010 OFL at the 25th, 50th and 75 percentile of F_{msy}. Probability of overfishing for northern (TOP) and Southern (BOTTOM) red hake based on 2010 OFL at the 25th, 50th and 75 percentile of F_{msy}. The probability of overfishing is a product of the probabilities of $F > F_{msy}$ at each realization of the survey biomass distribution and the probabilities corresponding to the survey biomass distribution.

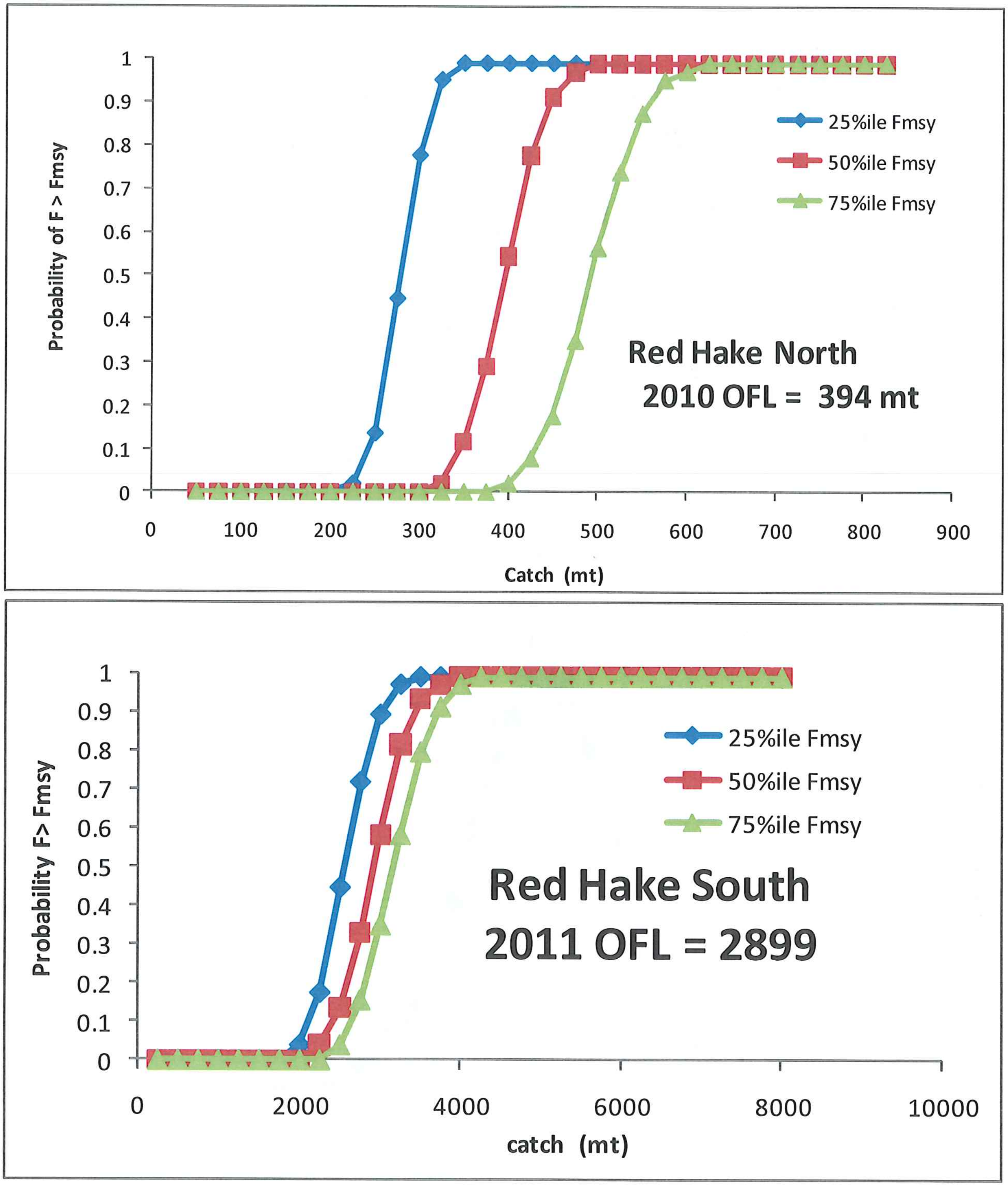
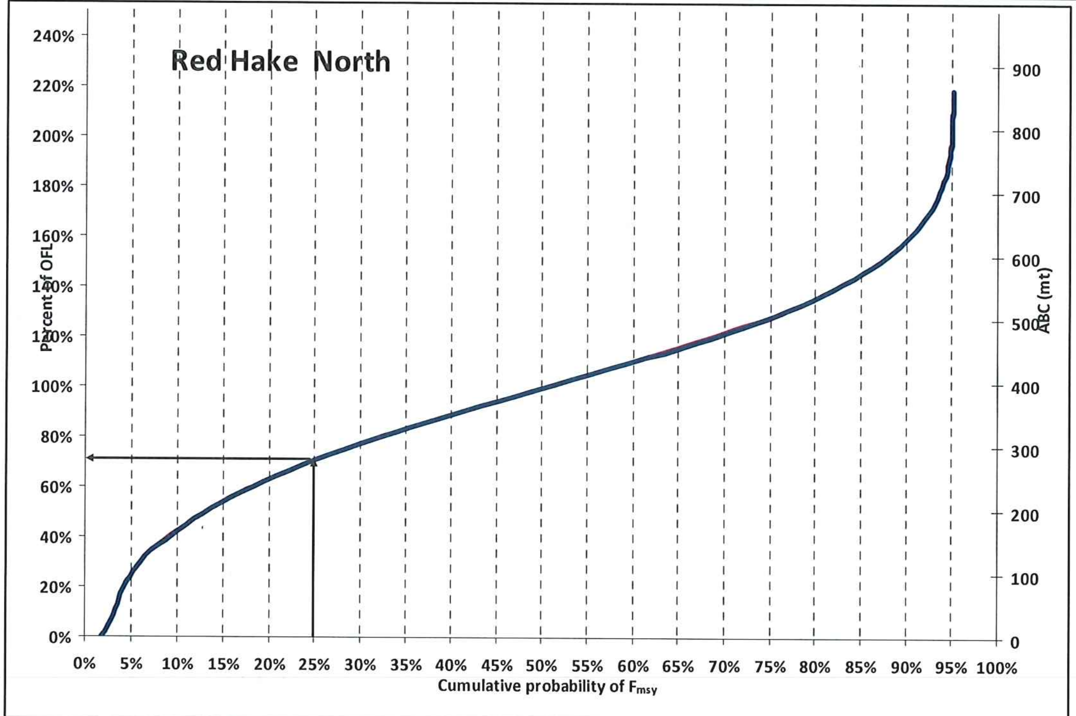


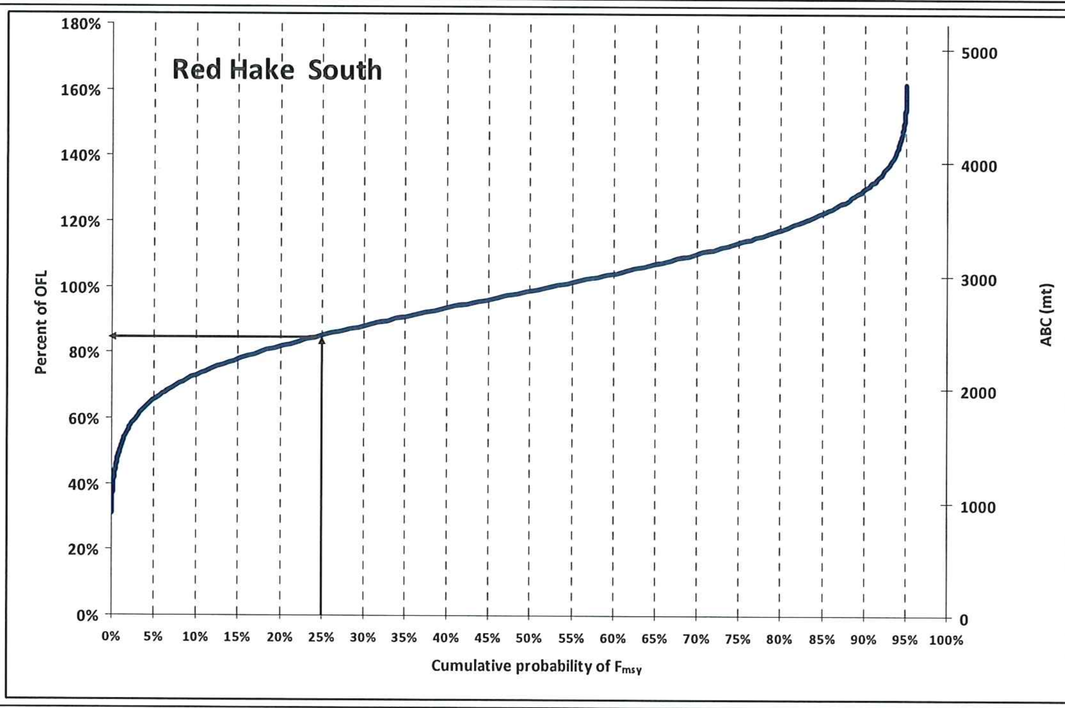
Table 18. Probability of overfishing for northern (LEFT) and southern (RIGHT) red hake based on 2010 OFL and sensitivity scenarios in 2011 at the 25th, 50th and 75 percentile of F_{mssy} for each of the 3 methods for ABC selection.

2010 OFL = 0.394 kmt				NORTH
Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	0.296	74%	0%	0%
2	0.272	39%	0%	0%
3	0.279	50%	0%	0%
SENSITIVITY 1_2011a OFL =0.364 kmt				
Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	0.273	74%	0%	0%
2	0.251	39%	0%	0%
3	0.257	49%	0%	0%
SENSITIVITY 2_2011b OFL = 0.265 kmt				
Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	0.199	68%	0%	0%
2	0.181	39%	0%	0%
3	0.188	50%	0%	0%

2010 OFL = 2.899 kmt				
Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	2.174	12%	2%	0%
2	2.435	37%	10%	2%
3	2.538	49%	16%	6%
SENSITIVITY 1_2011a OFL = 4.870 kmt				
Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	3.653	4%	0%	0%
2	4.185	41%	4%	0%
3	4.263	49%	6%	0%
SENSITIVITY 2_2011b OFL = 1.502 kmt				
Method	ABC (000's mt)	25th pctle FMSY	50th pctle FMSY	75th pctle FMSY
1	1.127	29%	17%	14%
2	1.129	29%	17%	14%
3	1.315	48%	31%	23%

Figure 20. Example of 2010 ABC (2008-2010 biomass index) control rule for the northern stock of red hake (TOP) and southern stock of red hake (BOTTOM) using Method 3. Instead of a fixed percent for all stocks (e.g. 75% of OFL), the ABC could be set at 85% of OFL (2899 mt), chosen based on the estimated uncertainty of F_{msy} proxy.





Multiyear specifications

No projection analyses were accepted from the AIM analysis for red hake. In the absence of such projections, the following approaches were considered for setting multiyear specifications for both stocks of red hake. The examples presented here are intended to illustrate how the three methods would respond to changes in stock biomass, estimated by the three year moving average for the spring survey biomass index. They are not to be intended to substitute for assumptions about future biomass, which could include multiyear specifications that assume that 2011 and 2012 survey values will equal the 2010 value.

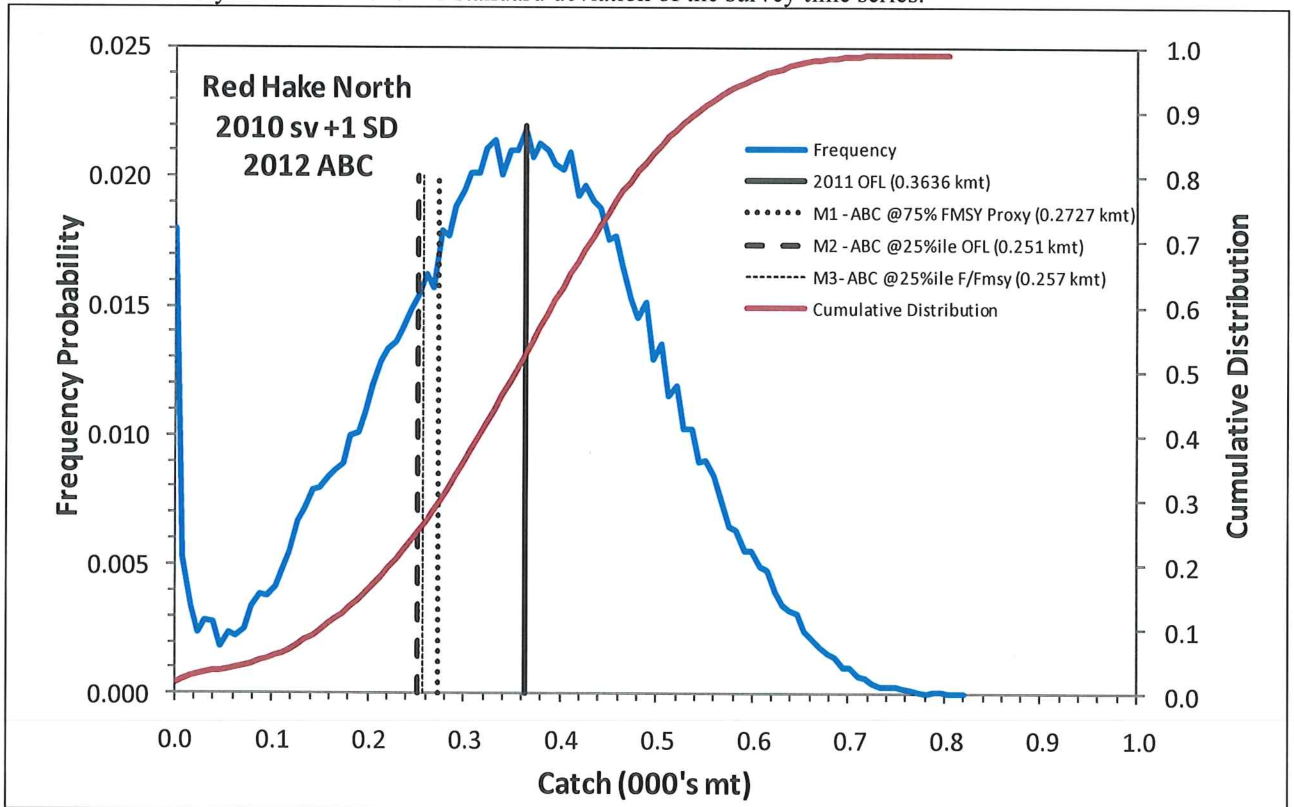
One approach to setting future specifications for two or three years could follow the procedure described below:

1) Set ABC at a constant level, using the most recent three year average. For example, update the three year average, dropping the first year of the three year period and adding a new year with the expectation that the new data will have the same value as the most recent survey. For example, the 2012 red hake specifications could be based on the 2009-2011 average biomass from the spring survey. The 2013 specifications would then be based on the 2010 and 2011 biomass, plus an assumed 2012 survey biomass that is equal to the 2011 value.

   Sensitivity analyses are presented in Table 18 and Table 20 that demonstrate using two current survey estimates (2009-2010) and assuming the 3rd estimate (2011). The assumed 2011 survey estimate was derived from the 2010 survey estimate ± 1 standard deviation. The standard deviation was calculated from the times series of the annual survey biomass estimates. The probability distribution of OFL and candidate ABCs are presented in Figure 21 and Figure 22 and the probability of overfishing is presented in Figure 23and Table 18.

2) Alternatively, the Council could require annual automatic specifications when new survey data becomes available. This annual specification process would be easier to manage using Method 3

Figure 21. Probability distribution of OFL for northern red hake and candidate ABCs based on sensitivity analyses on the 2011. The 2011 estimate is based on the three year average (2009-2011) by assuming 2011 survey estimate = 2010 + 1 standard deviation of the survey time series.



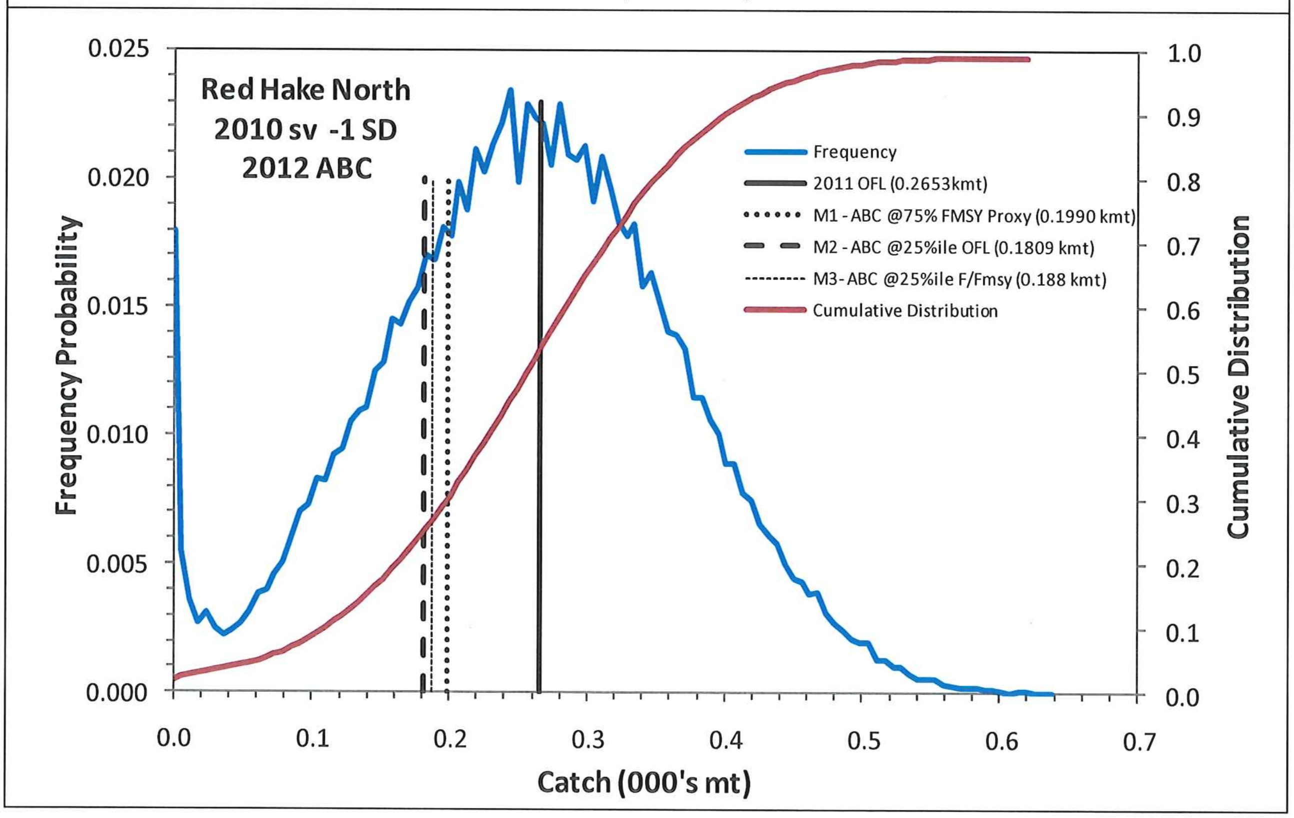
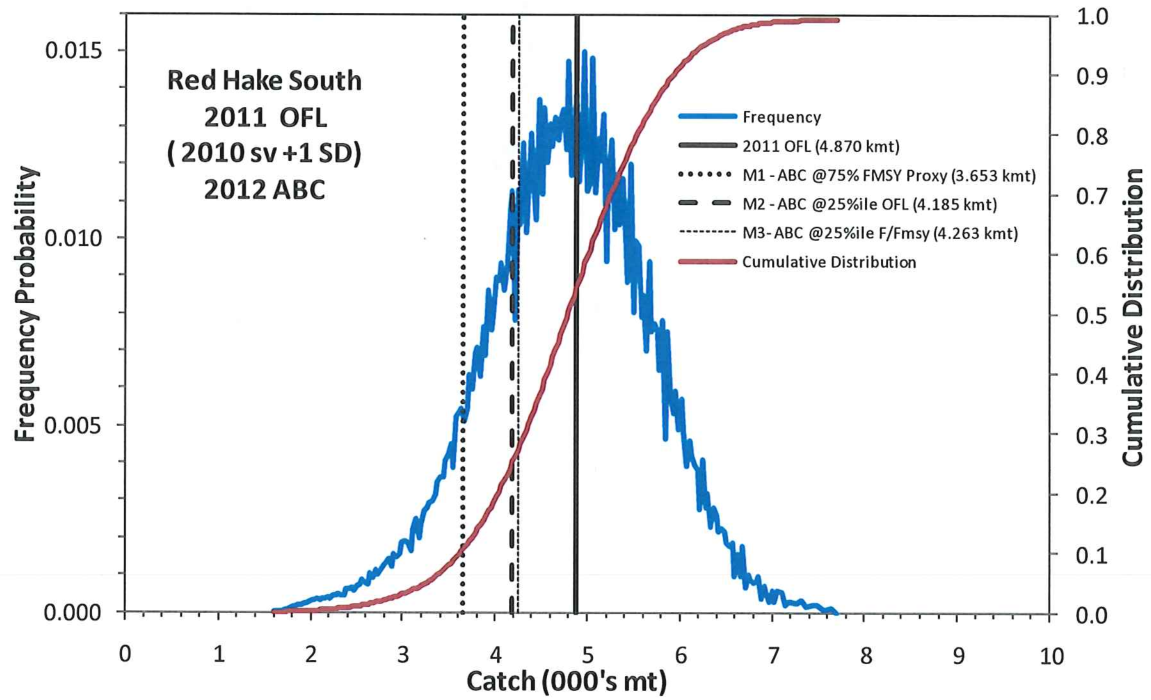


Figure 22. Probability distribution of OFL for southern red hake and candidate ABCs based on sensitivity analyses on the 2011. The 2011 estimate is based on the three year average (2009-2011) by assuming 2011 survey estimate = 2010 - 1 standard deviation of the survey time series.



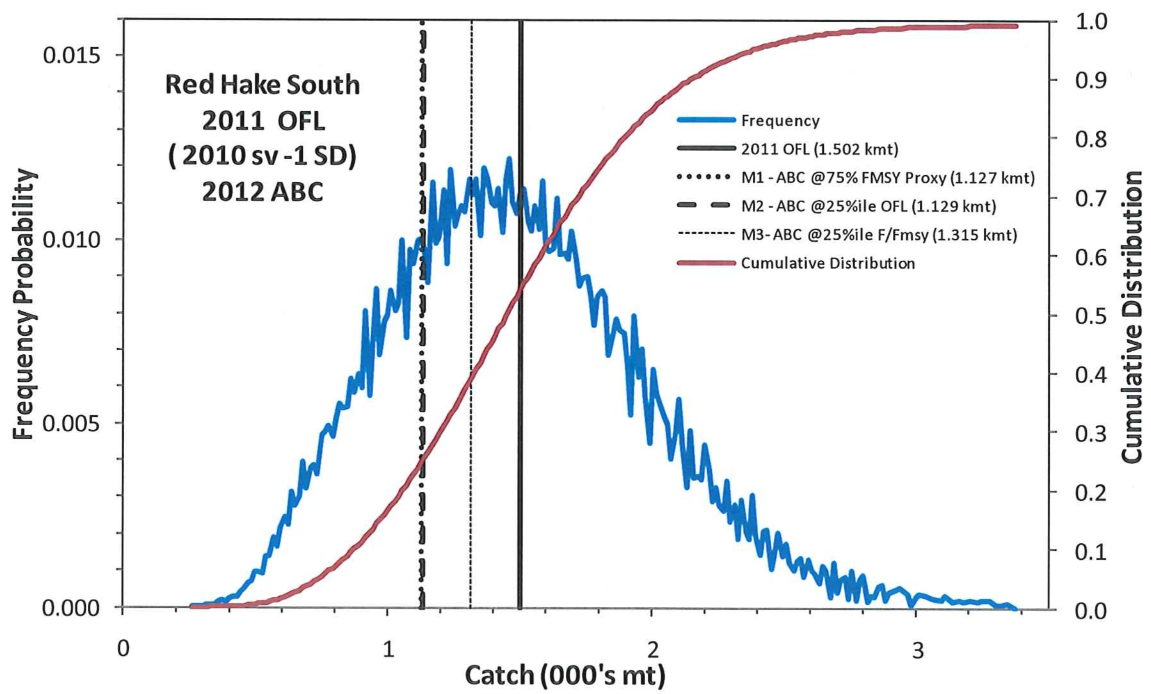


Figure 23, Probability of overfishing in 2011 for two sensitivity analyses (±1 standard deviation) for 3 scenarios of F_{msy} : 25th, 50th and 75th percentile for northern and southern red hake.

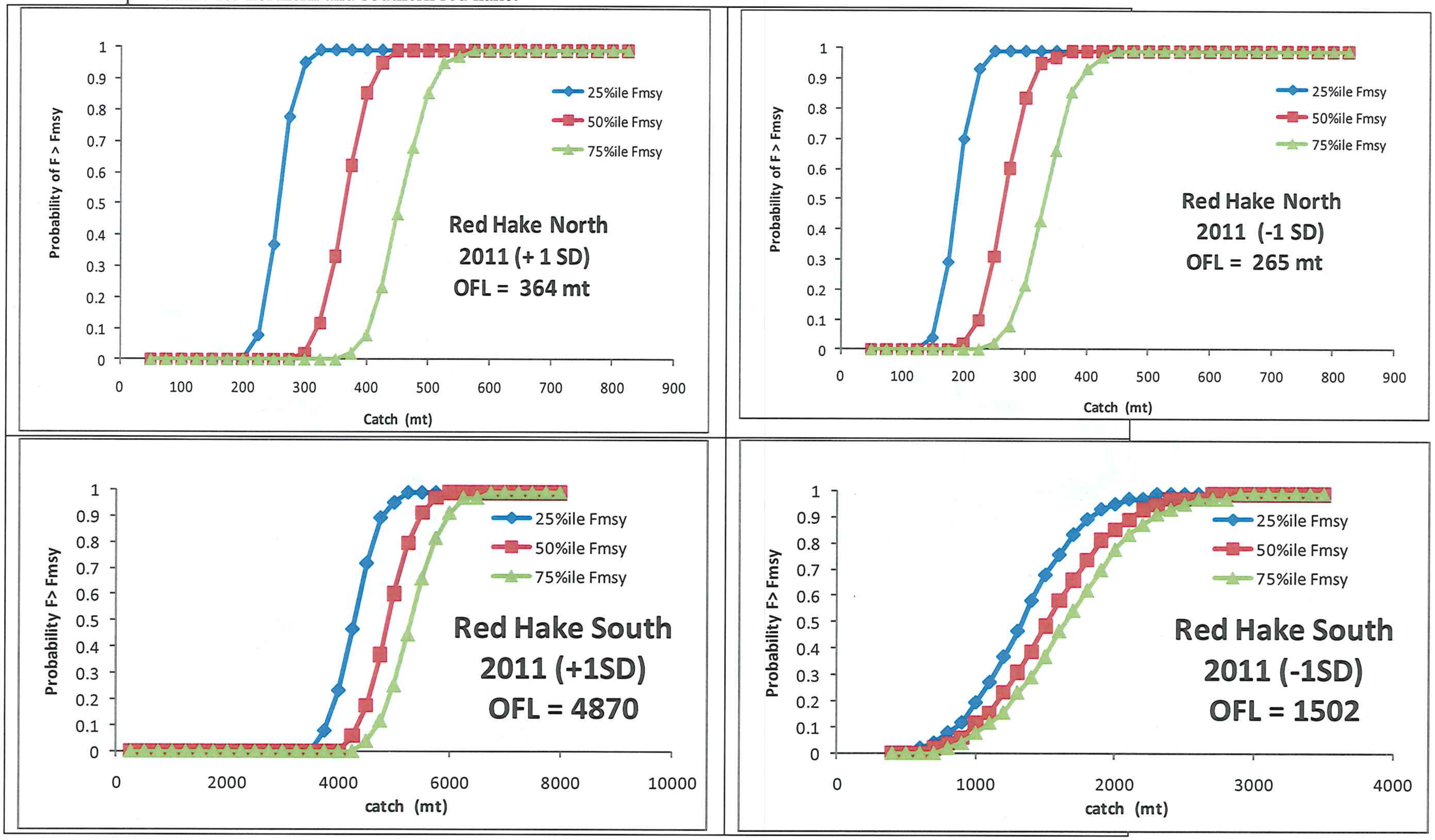


Table 19. Example relationship between **silver hake** OFL and candidate ABC three methods described in Section 8.1 to account for scientific uncertainty.

ACL fishing year / Survey years		2009 catch (mt)	OFL and ABC (mt)		
			2008-2010	+1 Standard Deviation	-1 Standard Deviation
Northern stock	Survey biomass (kg/tow)	1,232	8.50	12.19	10.20
	OFL F_{msy} = 2.78 kt/kg		23,596	33,834	28,308
	Method 1 75% F_{msy} = 2.08 kt/kg		17,697	25,357	21,231
	Method 2 25th percentile of OFL		13,140	18,091	14866
	Method 3 57% of F_{msy} = 1.59 kt/kg		13,482	19,331	16,174
Southern stock	Survey biomass (kg/tow)	7,434	1.76	2.16	1.63
	OFL F_{msy} = 34.18 kt/kg		60,124	73,704	55,868
	Method 1 75% F_{msy} = 25.63 kt/kg		45,093	55,278	41,901
	Method 2 25th percentile of OFL		32,350	67,541	37,790
	Method 3 56% of F_{msy} = 19.05 kt/kg		33,518	41,089	31,146

Table 20. Example relationship between **red hake** OFL and candidate ABC three methods described in Section 8.1 to account for scientific uncertainty.

ACL fishing year		2009 catch (mt)	OFL and ABC (mt)		
Survey years			**2008-2010**	**+1 Standard Deviation**	**-1 Standard Deviation**
Northern stock	Survey biomass (kg/tow)	180	2.419	2.231	1.628
	OFL F_{msy} = 0.163 kt/kg		394.3	363.6	265.3
	Method 1 75% F_{msy} = 0.122 kt/kg		295.7	272.7	199.0
	Method 2 25th percentile of OFL		271.7	251.1	180.9
	Method 3 70.5% of F_{msy} = 0.115 kt/kg		278.7	257.0	187.5
Southern stock	Survey biomass (kg/tow)	1,444	0.954	1.603	0.494
	OFL F_{msy} = 3.038 kt/kg		2,899	4,870	1,502
	Method 1 75% F_{msy} = 2.279 kt/kg		2,173	3,653	1,127
	Method 2 25th percentile of OFL		2,435	4,185	1,129
	Method 3 85.2% of F_{msy} = 2.588 kt/kg		2,538	4,263	1,315

8.4 Offshore hake

During the benchmark assessment (NEFSC 2011), it was determined that both estimated catch of offshore hake and the survey indices were unreliable indicators of trends for the purposes of managing the stock and fishery.

And since these indicators are unreliable and a model-based estimate of catch (averaging a percentage of total silver and offshore hake catches derived from the length or depth based model estimators in the benchmark assessment report), the PDT recommends including offshore hake into a combined offshore and silver hake southern stock ABC, the silver hake ABC increased by an appropriate amount to account for the average catches of offshore hake.

This procedure would a) not have a significant impact on silver hake status, b) account for the usual additional contribution of offshore hake in landings and discards, and c) would not require fishermen to separate offshore hake from large catches of silver hake, which is rarely done at present.

9.0 Summary

After reviewing the results and discussing the performance of the models, the Whiting PDT agreed on the following conclusions:

- Method 1 (75% of F_{msy}) accounts only for uncertainty in F_{msy}, but to varying degrees for each stock. Choosing a level may be somewhat arbitrary based on unquantified risk.

- Methods 2 and 3 use a robust statistical approach to assess of risk arising from scientific uncertainty. However Method 2 is more desirable because it considers variability in uncertainty about stock size. Method 3 may be easier to understand because the ABC would be a constant fraction of F_{msy}.

- Method 2 (setting ABC to continuously achieve a constant level of overfishing risk by accounting for estimated scientific uncertainty in both F_{msy} and survey biomass) would mean that ABC as a fraction of OFL would continuously vary with time. It would also require a continuous re-evaluation of scientific uncertainty for every specification cycle. This approach has some advantages, but is more complex and therefore may be difficult for the public to understand.

- Method 3 (setting ABC as a constant fraction of F_{msy}, accounting for uncertainty in F_{msy} but not for changes in variance of survey biomass) would vary by stock. The risk of causing overfishing may however change from initial estimates due to variation in the survey biomass indices, e.g. decreases in the precision of the mean biomass increases scientific uncertainty and the risk of overfishing, and vice versa.

- Offshore hake catch should be added to the ABC for the southern stock of silver hake and catches should be monitored with the total catch of both species.

- The sensitivity analyses estimate lower ABCs for the decreased biomass and higher ABCs for the higher biomass in contrast with the 2011 observed ABC, as expected. The variances of the +1 SD was equivalent to the -1 SD, however , the variance was from the observed Bigelow estimates, which are higher than have been observed in the Albatross surveys. These variances are thus informative, incorporating uncertainty that might be expected in the future.

- The risk analysis incorporates the uncertainty in both the FMSY and survey biomass estimates and thus provides a robust means for estimating the probability of overfishing for the various ABC estimates.

Table 21. Description of and comments on the potential approaches for setting hake stock ABCs.

Basis for ABC OFL = F_{msy}*B_t MSY = F_{msy}*B_{msy}	Relationship to OFL	Estimated value	Rationale	Advantages	Disadvantages
Silver hake – sources of scientific uncertainty derived from 10-year F_{msy} variance and interannual variability in survey biomass					
75% of $F_{threshold}$*3year ma survey	% of F_{msy} proxy = 2.78*75 north; 34.18*.75 south	23,596*0.75 mt north; 60,127*0.75 mt south	Constant buffer for unquantified scientific uncertainty	Consistent with groundfish stocks with index based assessments	Does not explicitly account for vary levels of uncertainty and risk
ABC variable fraction of OFL to account for interannual variation	Calculated probability level (e.g. 25th percentile of F_{msy} estimate)	Varies with 3 year moving average of survey biomass and uncertainty about stock size	Applies explicit estimate of scientific uncertainty, varies through time.	Incorporates level of acceptable risk, accounting for trends in scientific uncertainty and survey precision.	Requires annual re-estimation of uncertainty
Constant fraction of OFL based on relative estimates of scientific uncertainty	Constant for each stock (e.g. 25th percentile of OFL/median OFL).	Varies with 3 year moving average of survey biomass	Applies constant scientific uncertainty of F_{msy} by stock	Simpler to calculate and easier to understand that ABC is a constant fraction of OFL	Assumes that scientific uncertainty doesn't change, or there is no information about changes in scientific uncertainty
Red hake - sources of scientific uncertainty derived from AIM bootstrap distribution of F_{msy} and interannual variability in survey biomass					
75% of $F_{threshold}$*3year ma survey	% of F_{msy} proxy = 0.163*.75 north; 3.04*.75 south	394*0.75 mt north; 2,897*0.75 mt south	Constant buffer for unquantified scientific uncertainty	Consistent with groundfish stocks with index based assessments	Does not explicitly account for vary levels of uncertainty and risk
ABC variable fraction of OFL to account for interannual variation	Calculated probability level (e.g. 25th percentile of F_{msy} estimate)	Varies with 3 year moving average of survey biomass and uncertainty about stock size	Applies explicit estimate of scientific uncertainty, varies through time.	Incorporates level of acceptable risk, accounting for trends in scientific uncertainty and survey precision.	Requires annual re-estimation of uncertainty

Basis for ABC $OFL = F_{msy}*B_t$ $MSY = F_{msy}*B_{msy}$	Relationship to OFL	Estimated value	Rationale	Advantages	Disadvantages
Constant fraction of OFL based on relative estimates of scientific uncertainty	Constant for each stock (e.g. 25^{th} percentile of OFL/median OFL).	Varies with 3 year moving average of survey biomass	Applies constant scientific uncertainty of Fmsy by stock	Simpler to calculate and easier to understand that ABC is a constant fraction of OFL	Assumes that scientific uncertainty doesn't change, or there is no information about changes in scientific uncertainty
Offshore hake					
Recent catch	Unknown	Wasn't calculated – not preferred method	Maintain status quo until more information is available	Prevents offshore hake catches from escalating	Monitoring or reporting costs may be unrealistic
Added to combined silver/offshore ABC for southern stock	Unknown	~10% of southern hake catches	'Basket' ABC consistent with fishery practices	Basket ABC does not require separation of the catch	May not adequately protect offshore hake from overfishing

10.0 References

Bigelow HB, Schroeder WC. 1953. Fishes of the Gulf of Maine. Fish Bull. 53:577 p.

Chang, S., Berrien, P. L., Johnson, D.L., Zetlin, C. A. 1999. Offshore Hake, Merluccius albidus, Life History and Habitat Characteristics. US Dep Commer, Northeast Fish Sci Cent Tech Memo. NMFS NE 130. http://www.nefsc.noaa.gov/nefsc/publications/tm/tm130/

Garcia-Vazquez, E. , Horreo, J.L., Campo, D., Machado-Schiaffino, G., Bista, I. Triantafyllidis, A. and Juanes, F. 2009. Mislabeling of Two Commercial North American Hake Species Suggests Underreported Exploitation of Offshore Hake. Trans. Am. Fish. Soc. 138: 790-796.

Helser, T.E. 1996. Comparative Biology of Two Sympatric Species of the Genus, Merluccius, off the Northeastern Continental Shelf of the United States: Offshore Hake (M. albidus) and Silver Hake (M. bilinearis). Report submitted to the New England Fishery Management Council.

Klein-MacPhee, G. 2002. Silver Hake. Family Merlucciidae. *In*: Bigelow and Schroeder's fishes of the Gulf of Maine. 3rd Edition. B. B. Collette and G. Klein-MacPhee (eds.). Smithsonian Institution Press, Washington D.C., 748 p.

Miller TJ, Das C, Politis PJ, Miller AS, Lucey SM, Legault CM, Brown RW, Rago PJ. 2010. Estimation of Albatross IV to Henry B. Bigelow calibration factors. Northeast Fish Sci Cent Ref Doc. 10-05; 233 p.

Northeast Fisheries Science Center. 2011. 51st Northeast Regional Stock Assessment Workshop (51st SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 11-01; 70 p. http://www.nefsc.noaa.gov/publications/crd/crd1102/index.html.

Penttila J, Dery LM. 1988. Age Determination methods for Northwest Atlantic species. NOAA Tech. Rep. NMFS 72.