CORRECTION: The original publication of this report, released in January 2011, had some incorrect values in the silver hake, *Loligo* squid, and red hake chapters. On February 23, 2011 the report was corrected. The changes did not affect any conclusions about stock status that were given in the original report. For silver hake, the overfishing threshold for the southern area was changed from 52.30 kt/kg to 34.19 kt/kg. The wrong set of years was used in the calculation (1965 – 1974 instead of 1973 – 1982). For Loligo squid, the median biomass over the time series was changed from 25,578 mt to 27,578 mt, and the terminal year for that calculation was changed from 2009 to 2008. For red hake, the nominal discards in the southern area were corrected, which also required the catch and relative exploitation rate to be corrected in a table and figure.

A. SILVER HAKE ASSESSMENT SUMMARY FOR 2010

State of Stock
Stock status based on the current Biological Reference Points is described first, followed by description of results based on newly proposed BRPs.

Based on the current survey index method and current BRPs, silver hake is not overfished and overfishing is not occurring in the northern or southern management areas (Figure A1). For the northern area, the year delta mean biomass index (Figure A2) from the NEFSC fall bottom trawl survey during 2007-2009 (6.79 kg/tow) was above the biomass threshold (3.31 kg/tow) and slightly above the biomass target (6.63 kg/tow). The three year average exploitation index (landings divided by survey biomass index for 2007-2009 (0.13) in the north was less than the exploitation threshold and target (2.57, Figure A3). In the southern area, the three year survey biomass index (1.39 kg/tow) was greater than the biomass threshold (0.89 kg/tow) but below the biomass target (1.78 kg/tow, Figure A4). The three year exploitation index for 2007-2009 (4.33) in the south was below the overfishing threshold (34.39) and target (20.63) (Figure A5).

This year, an age-based analytical assessment (ASAP) for silver hake was attempted based on a "combined" (North + South) assessment area, and including estimates of fishery landings, discards, and predator consumption, by age class. The results were sensitive to model configurations indicating low biomass and high fishing mortality when selectivity was assumed to be flat topped, and high biomass and low fishing mortality when a dome was allowed to be fitted. The ASAP model was not accepted because the reasons for these inconsistencies are not understood. As a result, the existing survey index method was carried forward for this assessment, by management area, but with the fall survey arithmetic means and catch (landings + discards) rather than the previously used delta means and landings.

Based on newly proposed reference points which use arithmetic means, the northern stock of silver hake is not overfished and overfishing is not occurring. The three year average arithmetic mean biomass (Figure A6), based on the NEFSC fall bottom trawl survey data for 2007-2009 (6.20kg/tow), was above the proposed management threshold (3.21kg/tow) and below the target (6.42kg/tow). The three year average exploitation index (total catch divided by biomass index) (Figure A7) for 2007 – 2009 (0.20 kt/kg) was below the overfishing threshold (2.78 kt/kg).

Similarly under the newly proposed reference points, the southern stock of silver hake is not overfished and overfishing is not occurring. The three year average arithmetic mean biomass (Figure A8), also based on the NESFC fall bottom trawl survey data for 2007-2009 (1.11 kg/tow), was above the biomass threshold (0.83 kg/tow) and below the target (1.65 kg/tow). The three year average exploitation index, for 2007-2009 (5.87 kt/kg) (Figure A9) was below the overfishing threshold (34.19 kt/kg).

Projections
There is no accepted analytical assessment of the stock and it is not possible to carry out multiyear projections.

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 (Figure A10). 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 (Figure A12). 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.

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). Both methods rely on length-based or depth-dependent species compositions in the NEFSC trawl surveys. The two models provided similar estimates of proportion of silver hake, averaging 94-96% of nominal combined-species landings (Figure A11). The assessment is therefore insensitive to choice of model. The length-based landings estimates were used in the assessment because they were based on fewer assumptions.

Estimated annual discards of silver hake in the north ranged from 38 mt (2006) to 2,900 mt (1982) (Figure A11). Estimated annual discards of silver hake in the south ranged from 131 mt (2007) to 6,600 mt (1989) (Figure A13). Data on discards at age are available only from 1989, with age-aggregated estimates back to 1981.

Catch and Status Table (weights in mt): Silver Hake

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Max[1]	Min[1]	Mean[1]
Nominal Commercial Landings													
Northern Stock													
US	2592	3391	2593	1808	1049	827	903	1014	620	1038	62750	620	14952
DWF[2]											57240	2	18904
Total	2592	3391	2593	1808	1049	827	903	1014	620	1038	94462	620	20452
Southern Stock													
US	9769	9517	5344	6835	7436	6670	4629	5345	5638	6720	26518	4629	11132
DWF[2]											283366	2	56349
Total	9769	9517	5344	6835	7436	6670	4629	5345	5638	6720	307131	4629	37769
Combined Stock													
US	12361	12908	7937	8643	8485	7497	5532	6359	6258	7755	79903	5532	26084
DWF[2]											299159	2	67982
Total	12361	12908	7937	8643	8485	7497	5532	6359	6258	7758	352410	5532	58221
Length-Based Model Landings – Southern Stock													
US	9472	8884	4888	6281	6965	6395	4584	5067	5582	6595	25394	4584	10670
DWF[2]											271359	2	54064
Total	9472	8884	4888	6281	6965	6395	4584	5067	5582	6595	294117	4584	36228
Length-Based Model Landings – Combined Stock													
US	12064	12275	7481	8089	8014	7222	5487	6081	6202	7633	79176	5487	25623
DWF[2]											287152	2	65697
Total	12064	12275	7481	8089	8014	7222	5487	6081	6202	7633	339396	5487	56679
Nominal Discards													
Northern	362	477	514	203	115	62	39	750	167	221	2905	39	1159
Southern	333	192	280	676	1244	1574	160	132	1045	828	6642	132	2742
Combined	694	669	794	879	1359	1637	199	882	1213	1049	8984	199	3901
Length-Based Model Discards													
Southern	329	188	410	604	1203	1576	161	146	1033	839	6573	146	2691
Combined	690	665	924	806	1318	1638	200	895	1201	1060	8915	200	3850
Catch Used in Assessment[3]													
Northern	2954	3868	3107	2011	1164	889	942	1764	787	1259	94462	787	21063
Southern	9800	9072	5298	6884	8168	7971	4746	5212	6616	7434	294117	4746	37647
Combined	12754	12940	8405	8895	9332	8860	5687	6976	7403	8693	339396	5687	58709
Arithmetic Biomass (Fall Survey kg/tow)													
North	13.507	8.328	7.988	8.293	3.278	1.716	3.693	6.443	5.274	6.892	23.100	1.716	7.519
South	0.723	2.040	1.176	1.423	1.239	0.941	1.416	0.874	1.363	1.095	5.275	0.447	1.740
Arithmetic 3-year Average Biomass (Fall Survey kg/tow)													
North	14.521	10.994	9.941	8.203	6.519	4.429	2.896	3.951	5.137	6.203	14.521	2.317	7.337
South	0.705	1.195	1.313	1.546	1.279	1.201	1.198	1.077	1.218	1.111	4.667	0.617	1.692
Arithmetic Relative Exploitation (catch/Fall Survey Biomass)													
North	0.219	0.464	0.389	0.242	0.355	0.518	0.255	0.274	0.149	0.183	21.748	0.145	3.357
South	13.549	4.447	4.506	4.837	6.592	8.472	3.353	5.962	4.853	6.787	120.536	3.353	21.969
Arithmetic 3-year Average Relative Exploitation (catch/Fall Survey Biomass)													
North	0.246	0.352	0.357	0.365	0.329	0.372	0.376	0.349	0.226	0.202	14.769	0.202	3.294
South	17.829	11.674	7.501	4.597	5.312	6.634	6.139	5.929	4.722	5.867	74.009	4.597	22.257
Survey Recruitment Abundance[4] (000's)													
North	240420	69302	149828	208367	47123	12764	134985	168273	113613	187421	452389	10959	107972
South	196880	180877	74067	324662	90583	34474	85613	45174	49152	214301	363427	11023	138582

1Landings data based on 1955-2009 (mt). Commercial fishery discard means from 1981-2009.
2 DWF(Distant Water Fleet) landings are for NAFO Areas 5 and 6.
[3]Catch Used in Assessment is the Length-Based Model Estimated Catch.
[4]Survey recruitment abundance based on swept area estimates in thousands of fish from 1973-2009.

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 (Figure A1), 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.

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. In contrast to the index method, the ASAP model which was attempted used age structure, additional surveys, more comprehensive information on selectivity and accommodates uncertainty in the input data. These additional data might allow an assessment that can potentially accommodate changes in the silver hake fishery (gear, selectivity, targeting, and management), and the change to a new survey vessel (for which length-based calibration factors have been obtained). The ASAP model attempted to incorporate a measure of predatory consumption which informs the scaling of biomass and the magnitude of mortality estimates.

Catch curves from the NEFSC fall and spring trawl surveys, and from the commercial fishery landings, exhibit a very steep age profile that has become progressively steeper over time, suggesting high and increasing total mortality.

The index method that is being used was based on an update of the previous index method in the 2003 SAFE 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, 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.

The ASAP model, which was not accepted here, included catch by a directed fleet beginning in year 1973 when age information was available. Discards were included as a separate "fleet" in the model starting in 1981. Consumption was modeled as an additional fleet to represent removals from predation. The estimated mortality from the "fleet" of predators was then considered to be an additional source of natural mortality (termed "M2"). Total annual natural mortality at age from the Consumption models was calculated as M1+M2 where M1 is 0.15, and M2 varies by age and year. A wide range of sensitivity runs were explored varying the selectivity assumptions for the survey and directed fleet, numbers of blocks of years for fitting selectivity, varying the M1 value, and the use of a larger M1 whilst excluding the consumption fleet from the model (a value of M1 = 0.4 provided a similar cumulative survival to age 14 as given by the runs with 0.15+M2). All models included the NEFSC spring and fall bottom trawl surveys. Minimum swept area abundances, annual estimated CV, as well as the age composition for each survey were used in the model.

The ASAP results were sensitive to model configurations indicating low biomass and high fishing mortality when selectivity was assumed to be flat topped, and high biomass and low fishing mortality when a dome was allowed to be fitted. The model was not accepted because the causes of the instability could not be determined. As a result, the existing survey index method was carried forward for this assessment, using the fall survey arithmetic means and total catch rather than the delta means and landings for the northern and southern management areas.

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.

Biological Reference Points

The current overfishing definition as stated in the Fishery Management Plan (FMP) prior to SAW 51 (Nov. 29 – Dec 2) for silver hake is as follows:

> *Silver hake is overfished when the three-year moving average of the fall survey weight per tow is less than 3.31 kg/tow and 0.89 kg/tow for the northern and southern stocks respectively, one half of the B_{MSY} proxy (the average observed from 1973 – 1982). If an analytical assessment (e.g. VPA) for silver hake is available, the three-year moving average will be replaced with the terminal year biomass estimate and compared with the mean biomass estimated for 1973 – 1982.*
>
> *Overfishing occurs when fishing mortality, derived from the latest three years of survey data, exceeds F0.1 (0.41 and 0.39 for the northern and southern stocks of silver hake respectively). If an analytical assessment is available, then the terminal year fishing mortality rate will be compared to F0.1.*

Due to difficulties in estimating fishing mortality for silver hake in previous assessments, the New England Fishery Management Council's Whiting Monitoring Committee (WMC) developed a relative exploitation index (landings /survey using delta means) based reference in the interim to assess progress relative to Amendment 12 (SAFE 2002). The exploitation index approach was based on the original reference points to the extent possible (i.e. proxy for F_{MSY}). For the north, the WMC recommended an overfishing threshold and target of 2.57 (delta mean). For the southern area, a target set at 60% of F_{MSY} (20.63) and a threshold of 34.39 was

recommended by the WMC.

In the absence of an agreed ASAP model run, the new proposed BRPs at SAW 51 (2010) for both the northern and southern silver hake stocks are as follows:

> *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 (see Data and Assessment section).

There are indications from the ASAP assessment as well in the trends in age 3 and older silver hake in the NEFSC fall survey that total mortality is increasing (Figure A14). This suggests that the reference points described above may not be appropriate.

Fishing Mortality

The index-based proxy for fishing mortality (three-year average catches divided by fall survey biomass index) has declined substantially since the 1970s in both the northern and southern areas (Fig. A7 and A9) and is currently well below the management threshold/target.

Recruitment

The autumn surveys suggest possibly increasing recruitment in the recent years (Figure A15).

Recruitment trends from the ASAP model at age-1 were relatively insensitive to the model configuration choices, but the magnitude was sensitive to model configuration depending on whether consumption was included or not.

Stock Biomass or SSB

The fall survey biomass indices for the northern stock increased by more than a factor of two between 1970 and 1980, then declined sharply to values close to those recorded in the early 1970s (Fig. A2). In contrast, the spring survey biomass indices have been variable without any clear trend. The fall survey biomass indices for the southern stock declined sharply after the mid 1980s and increased again after 2000, whilst the spring survey showed a much larger decline of around 80% between the 1970s and the 2000s.

Ecosystem Considerations

Total consumptive minimum removals by all consistent silver hake predators, using swept area abundance and assessment estimates of the predators, were consistently around 15 thousand mt per year during the late 1970s and increased to average around 80 thousand mt through the

2000s. These estimates of silver hake consumed by the consistent fish predators in this study were compared to total catch. Estimates of consumption were lower than the catch at the beginning of the time series, but consumption estimates from 1979 onwards are the dominant source of removals with estimates from 2001-2009 averaging more than ten to twenty times the catch (Figures A16 and A17). Although predation focuses on ages 0-2 the modeled predation focused on age 1 and 2 while the fishery is mostly on 2+.

Special Comments

Stock structure of silver hake continues to be an important consideration for stock assessment. While two management areas are assumed to exist (Almeida, 1987), it is likely that the northern and southern stocks mix on Georges Bank. The extent of mixing remains uncertain. Survey trends indicate that biomass in the northern area is higher than in the southern stock area. The incoherence of the survey trends, especially in the spring relative to the removals in the southern area is likely attributed to movement of silver hake across the traditional stock boundaries, possibly resulting in disproportionate representation of silver hake density in the southern area. The empirical evidence about silver hake stock structure is equivocal. Data exist on morphometrics, tagging, egg distributions, larval distributions, and growth and maturity.

Silver hake are cannibalistic. Based on the NEFSC Food Habits Database, approximately 2% of the silver hake had consumed silver hake. By comparison, goosefish (*Lophius americanus*) only had 0.1% incidence of cannibalism. On average, silver hake comprised 12% of the silver hake diet composition (by weight), a significant, consistent and important prey item. This poses potential circularity in estimating silver hake abundance and silver hake cannibalism, which in turn can inform assessment models to estimate silver hake abundance. To accommodate this, we used swept area abundance estimates for silver hake as a predator of silver hake to help scale the total silver hake consumed by silver hake. The impact of cannibalism on stock-recruit relationships is being investigated.

The accepted catch and survey index-based BRPs do not incorporate age structure and do not include measures of uncertainty. No age-based analytical model formulations (ASAP) were accepted; nonetheless, the model results were informative. The most likely ASAP model (Run 6) did provide indications of trend that were in agreement with the declining age 3+ spawning numbers indicated in the fall NEFSC survey data.

Recent catches have been considerably less than historical ones. However, abundances of age 3+ silver hake in fall NEFSC surveys have been declining since the early 1990s under such catches, possibly for reasons other than only fishing. This suggests that the reference points may not be appropriate.

Research to address fishery selectivity and stock composition (mixing of northern and southern components) and the extent of stock distribution is needed to reconcile issues regarding selectivity in the current ASAP model formulation.

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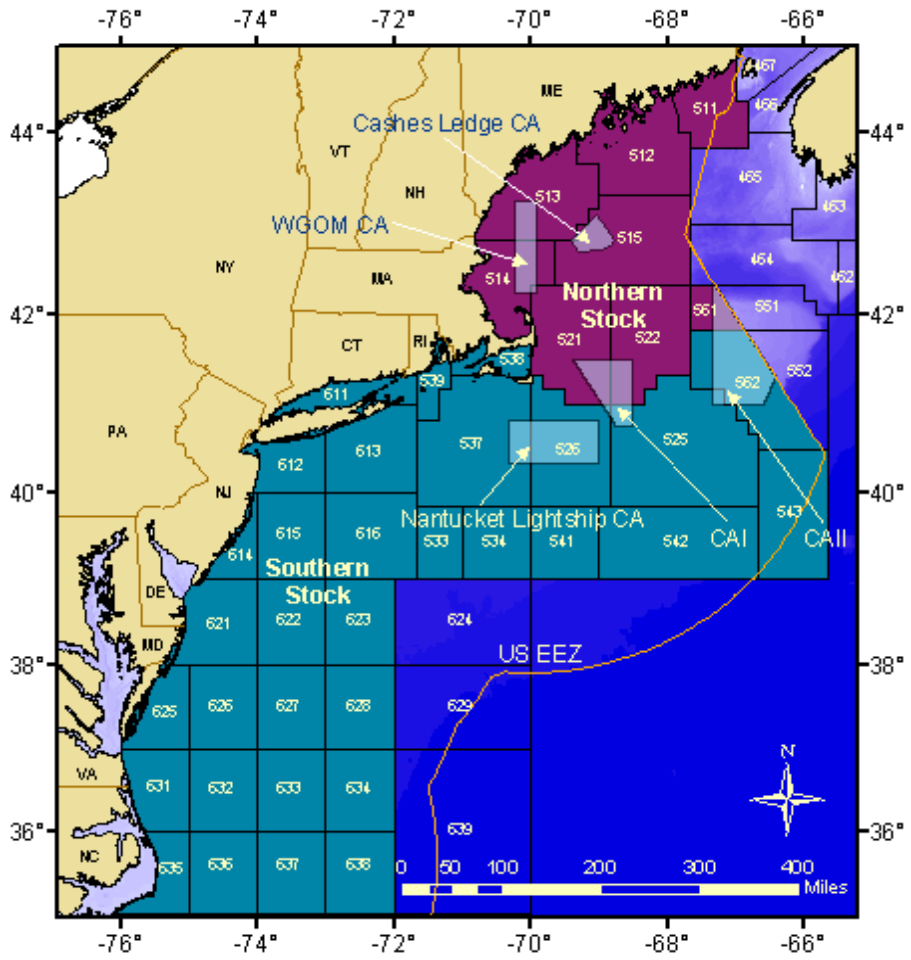
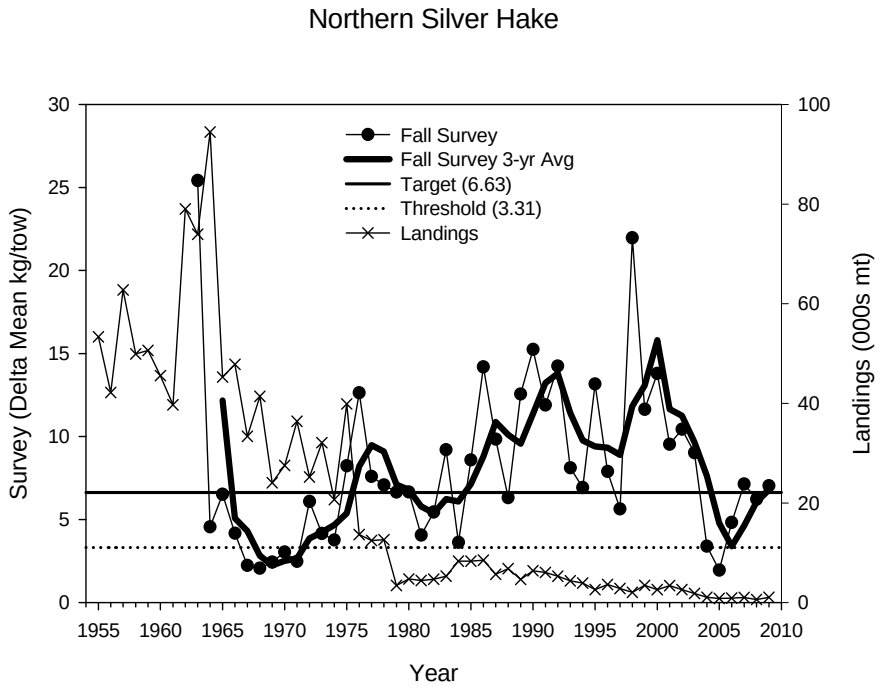
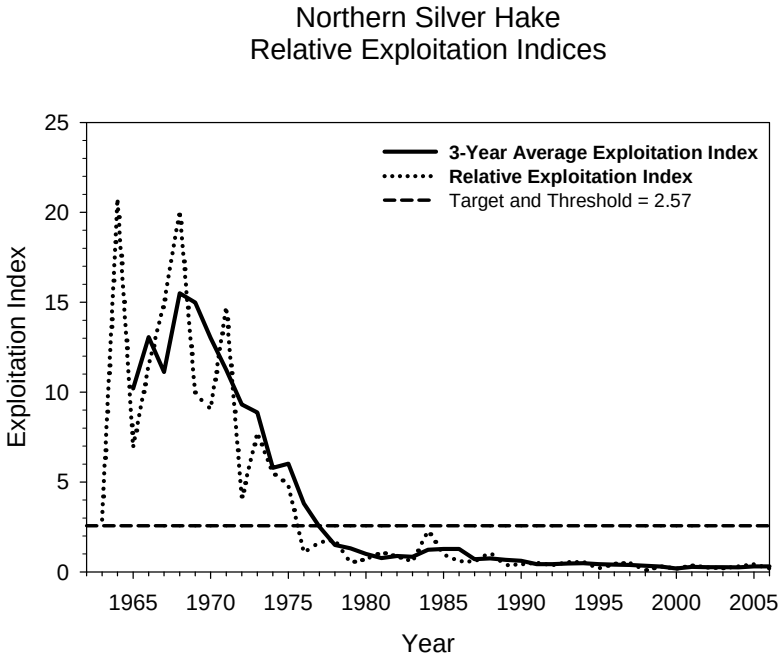


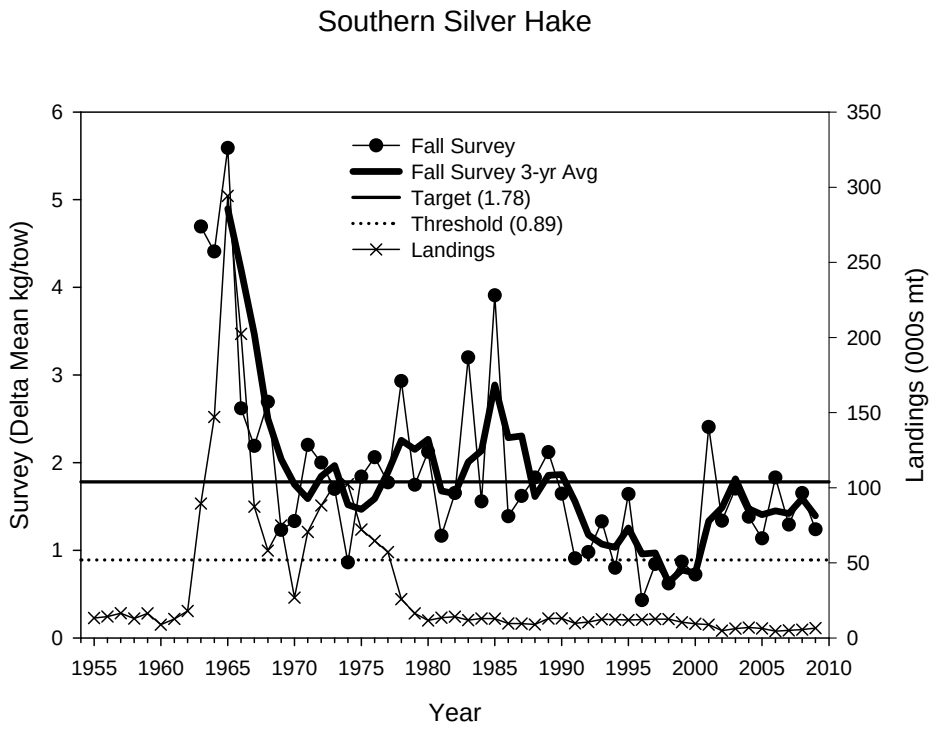
A1. Statistical areas used to define the northern and southern silver hake stocks.



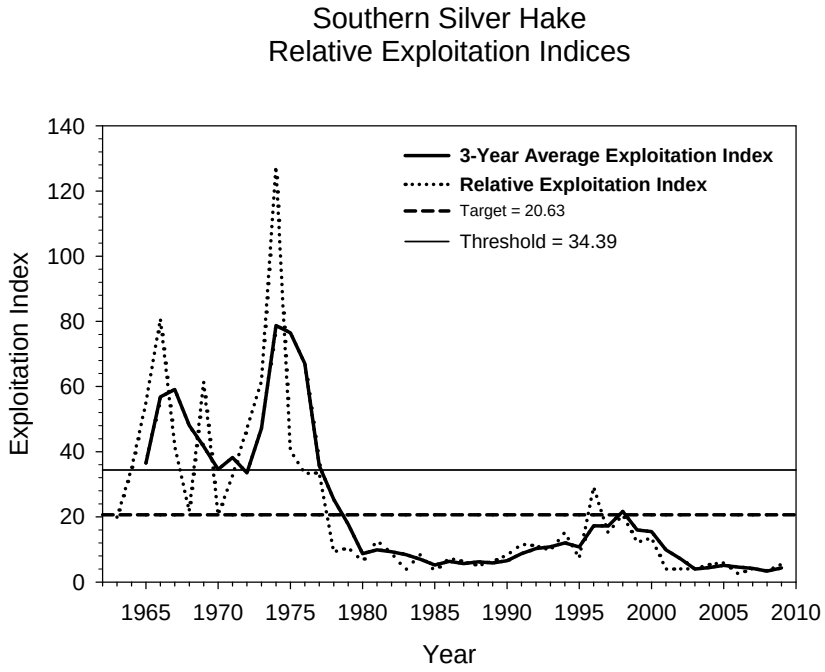
A2. Fall survey biomass (delta transformation) and current biomass reference points for the northern stock of silver hake.



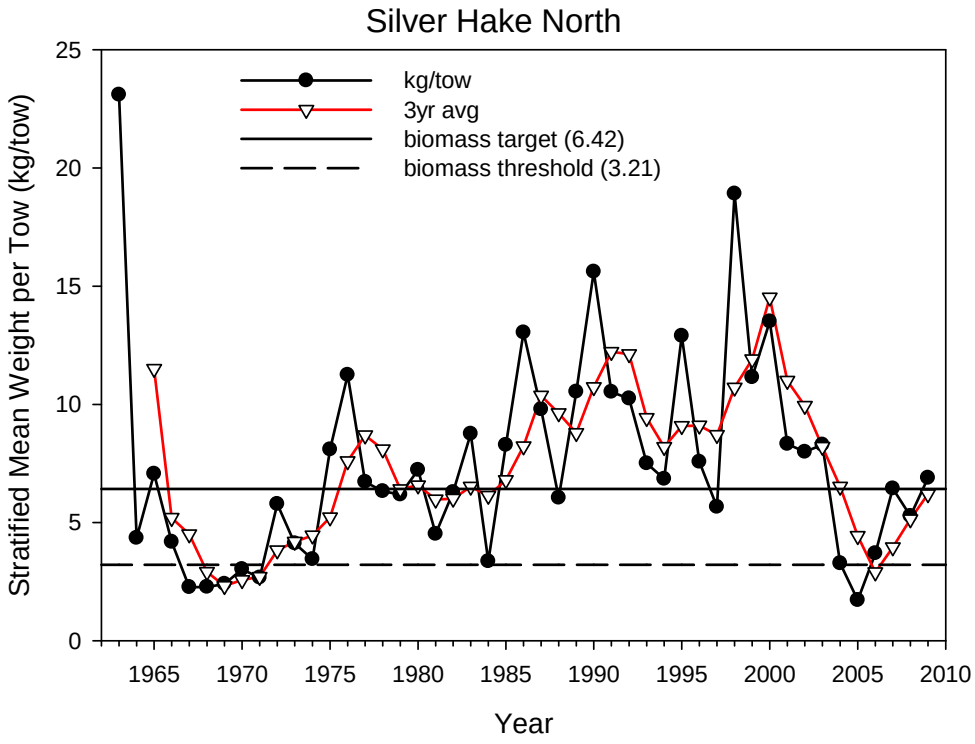
A3. Exploitation indices (delta transformation of fall survey) and current overfishing threshold for the northern stock of silver hake.



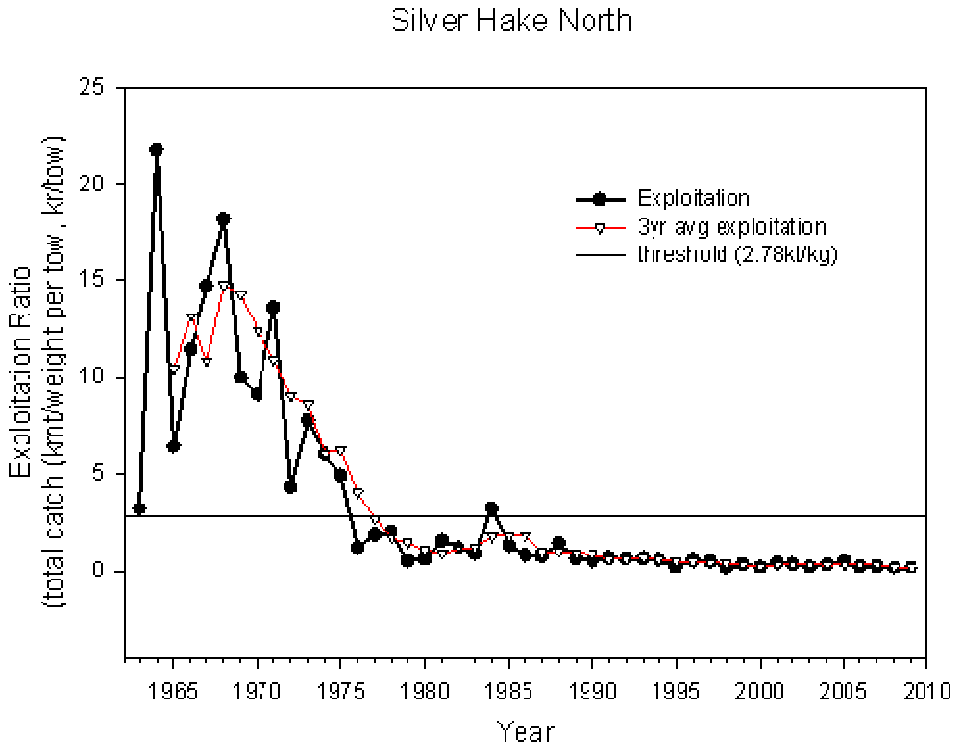
A4. Fall survey biomass (delta transformation) and current biomass reference points for the southern stock of silver hake.



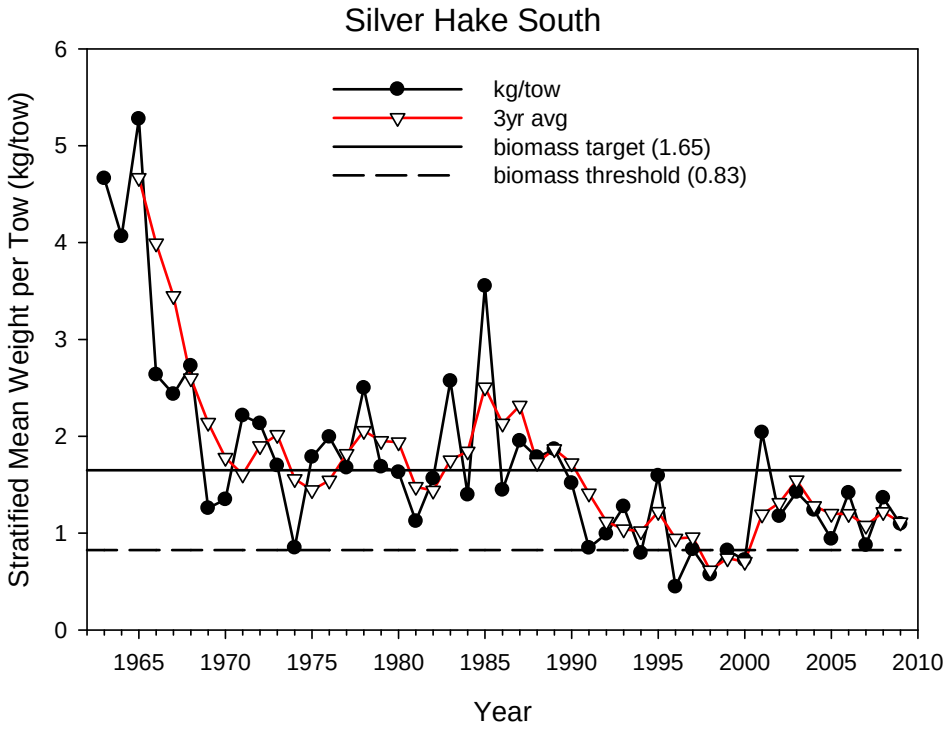
A5. Exploitation indices (delta transformation of fall survey) and current overfishing threshold (34.39) for the southern stock of silver hake.



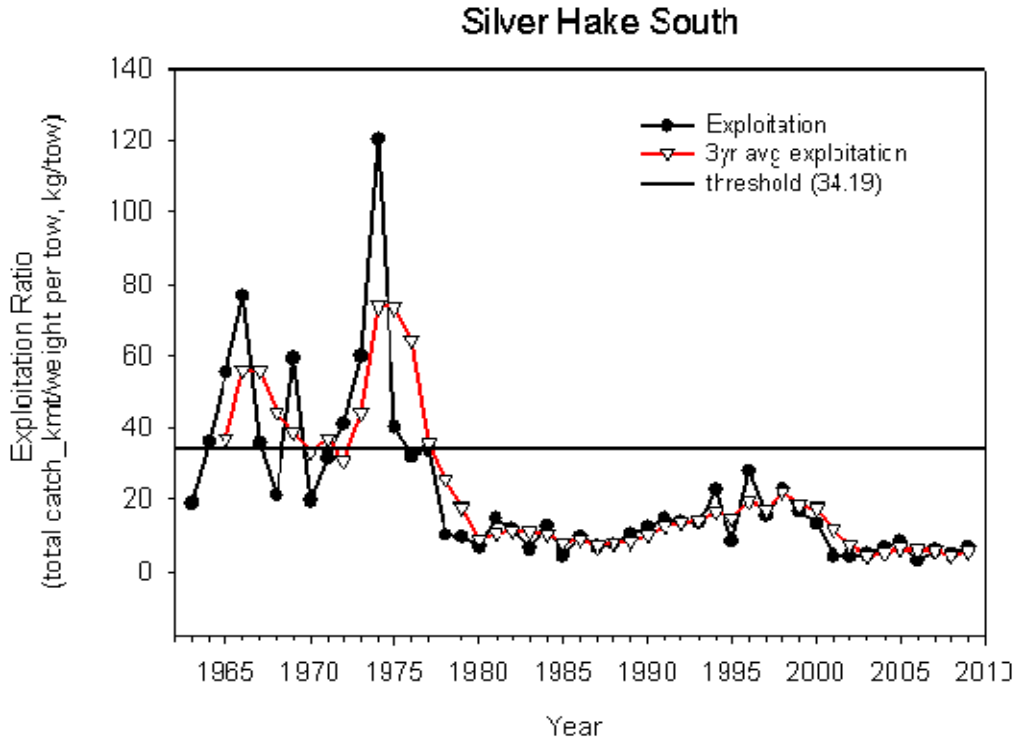
A6. Fall survey biomass (arithmetic mean) and the SARC 51 accepted biomass reference points for the northern stock of silver hake.



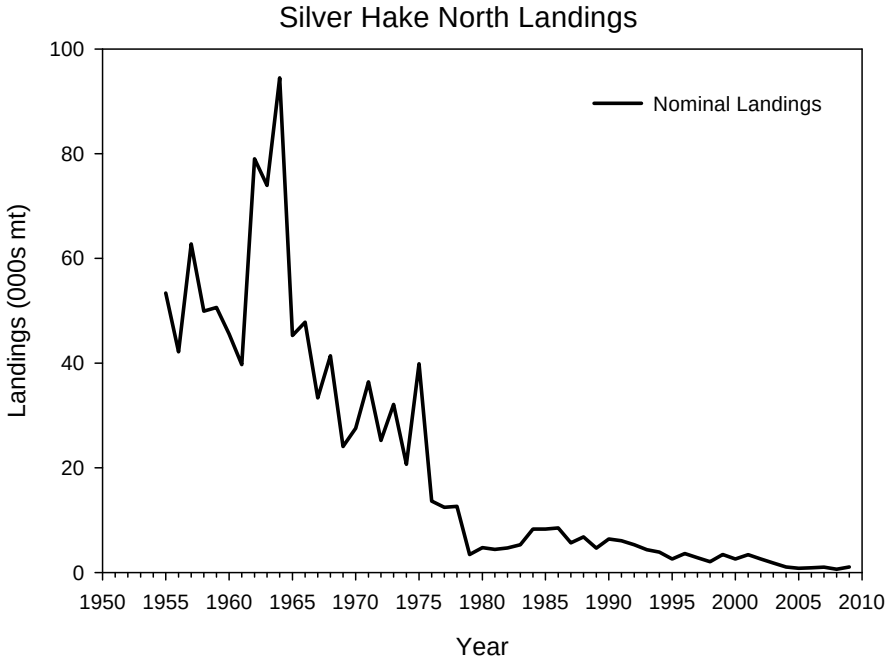
A7. Exploitation indices (ratio of catch to fall survey index) and the SARC 51 accepted overfishing threshold and target for the northern stock of silver hake.



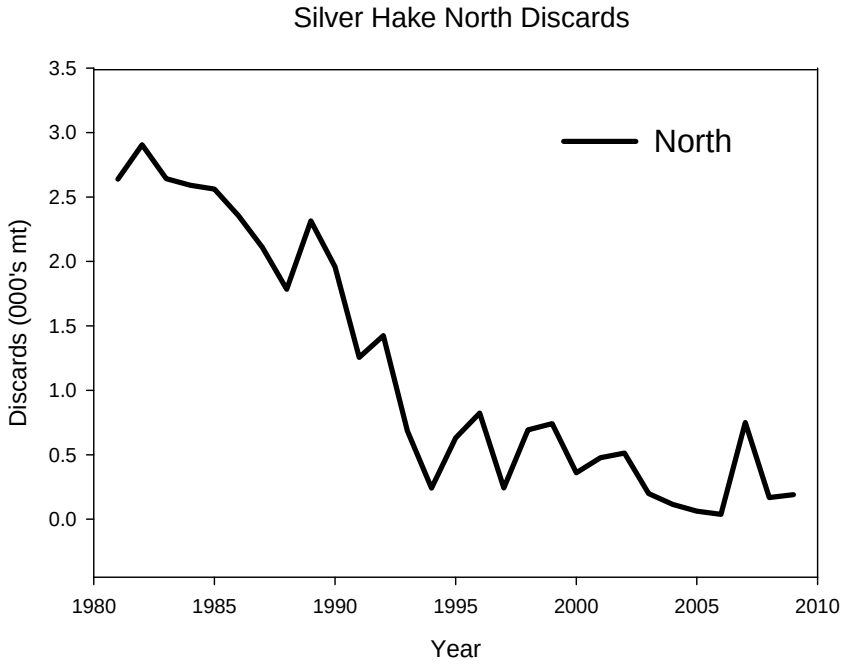
A8. Fall survey biomass (arithmetic mean) and the SARC 51 accepted biomass reference points for the southern stock of silver hake.



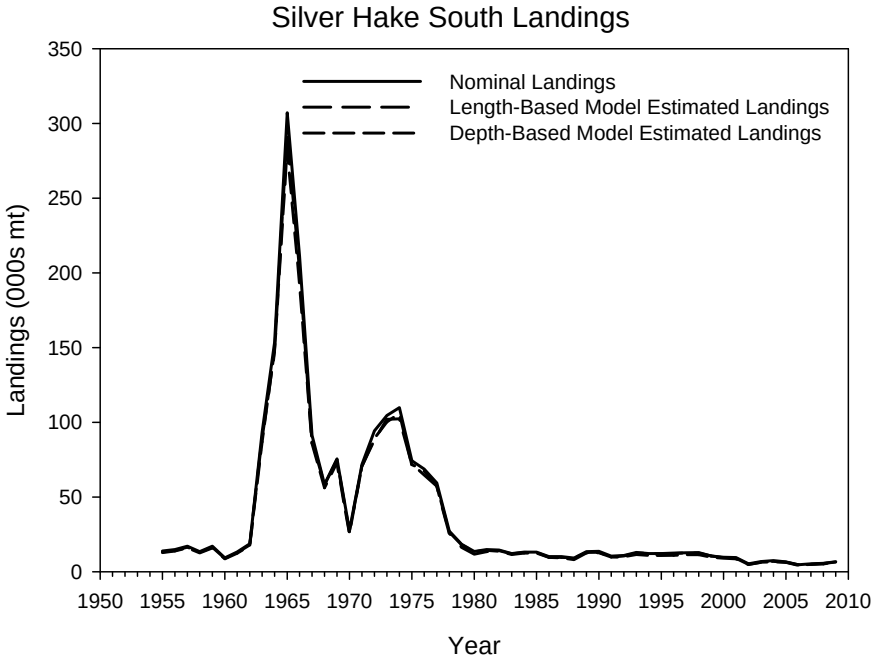
A9. Exploitation indices (ratio of catch to fall survey index) and the SARC 51 accepted overfishing threshold for the southern stock of silver hake.



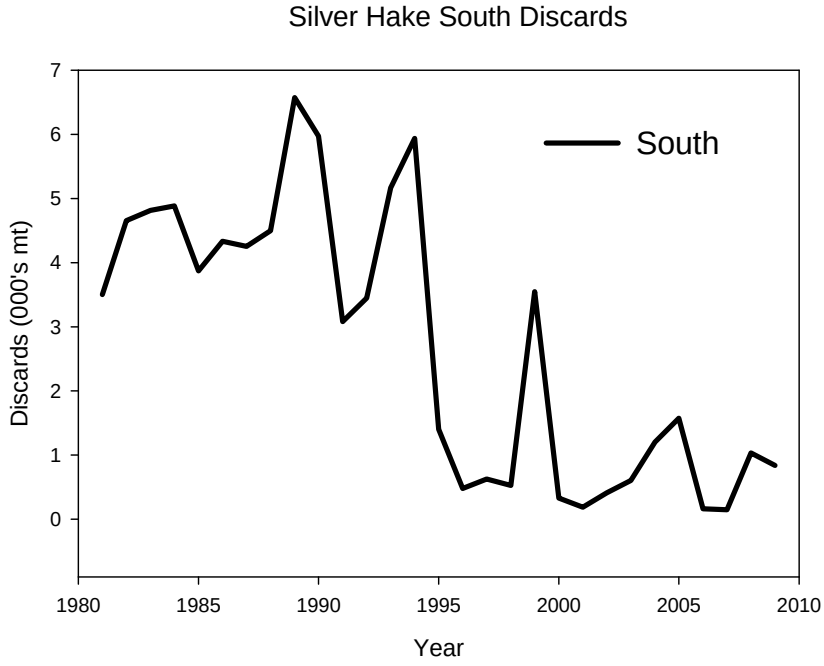
A10. Nominal landings of silver hake from the northern stock (000s mt).



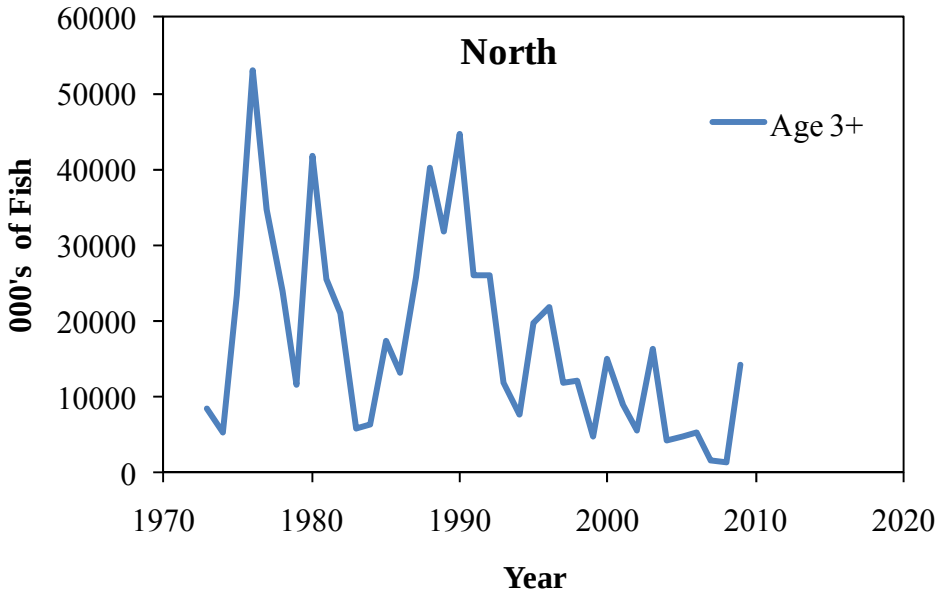
A11. Estimated discards if silver hake from the northern stock (000's mt).

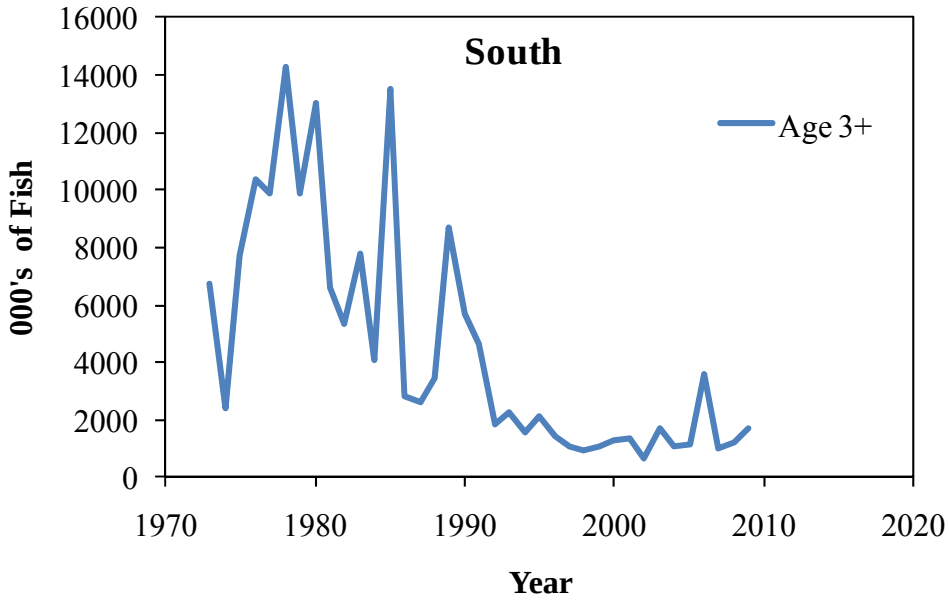


A12. Comparison of nominal landings of silver hake with length-based and depth-based model estimated landings (000s mt).

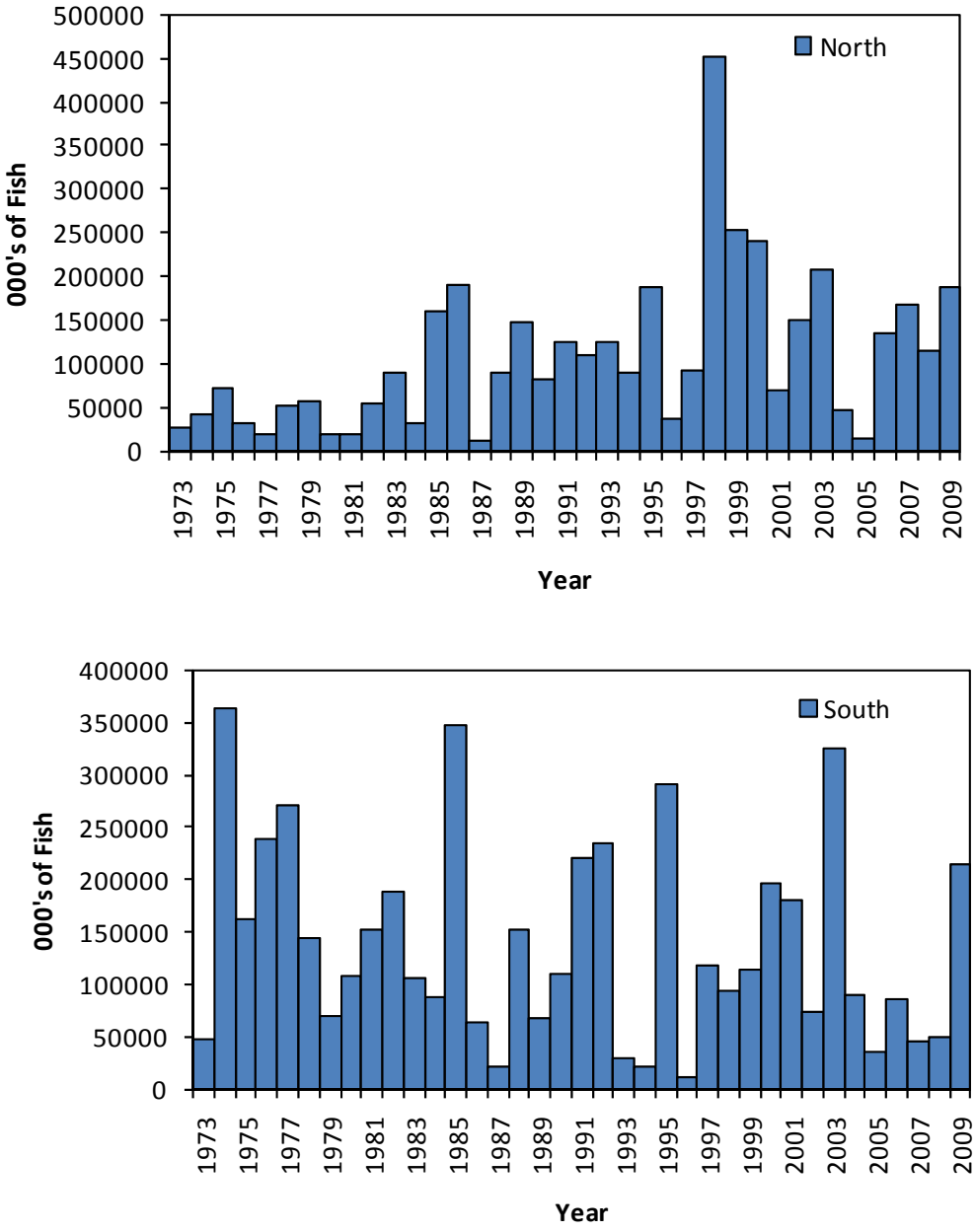


A13. Estimated discards of silver hake from the southern stock (000's mt).

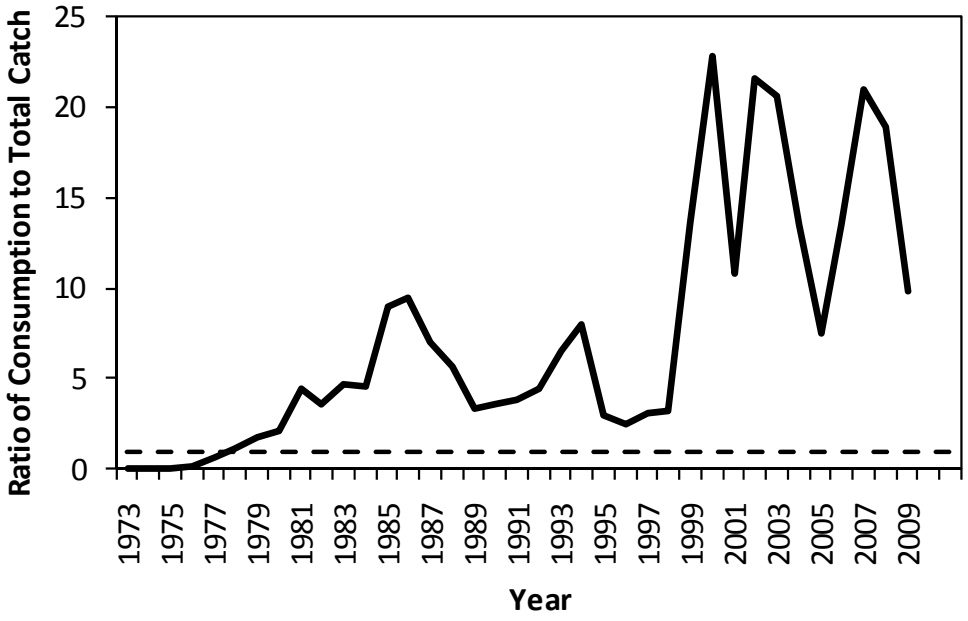




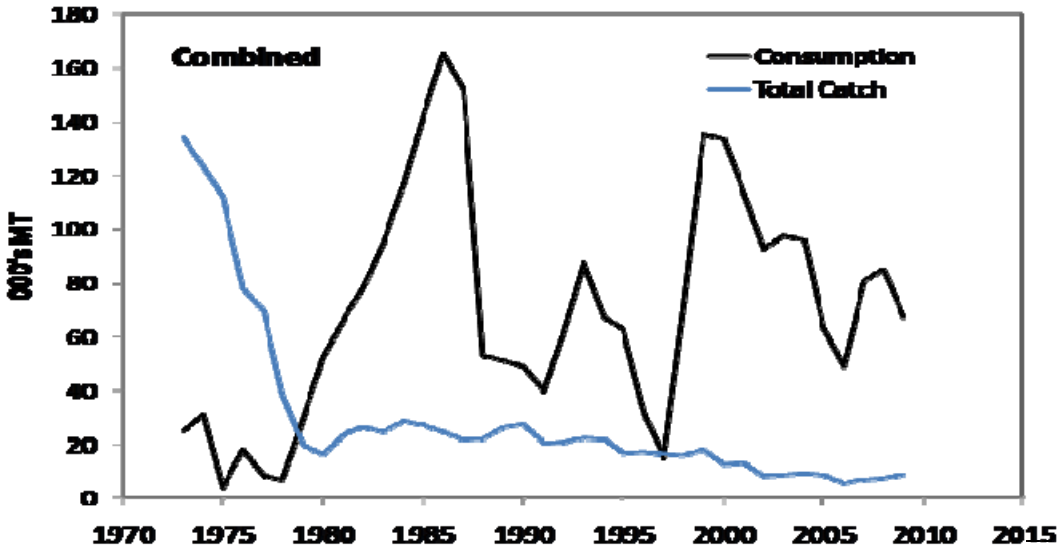
A14. NEFSC fall bottom trawl survey abundance of silver hake, based on swept area estimates in thousands of fish for age 3+ in the northern (top) and southern (bottom) management areas.



A15. Survey recruitment index (age 0's and 1's) in thousands of silver hake from the NEFSC fall bottom trawl survey for the northern (top) and southern (bottom) management areas.



A16. Ratio of silver hake consumption (by a subset of fish predators) to total catch of silver hake over time. Dashed line represents a ratio of one.



A17. Silver hake biomass consumed by major fish predators and total catch in the fishery for the north and south areas combined.