Fisheries and Oceans Canada | Pêches et Océans Canada
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Canadian Science Advisory Secretariat
Maritimes Region **Science Response 2023/015**

STOCK STATUS UPDATE OF SCOTIAN SHELF SILVER HAKE (*MERLUCCIUS BILINEARIS*) IN NAFO DIVISIONS 4VWX

Context

Advice on the status of the Scotian Shelf portion of the Silver Hake (*Merluccius bilinearis*) stock in Northwest Atlantic Fisheries Organization (NAFO) Divisions 4VWX is requested annually by Fisheries and Oceans Canada (DFO) Resource Management to determine a Total Allowable Catch (TAC) consistent with the Integrated Fishery Management Plan (IFMP). The most recent framework and assessment of Silver Hake were conducted in 2012 (Cook 2013, Stone et al. 2013, DFO 2013). An analytical reconstruction of population trends based on commercial landings and Research Vessel (RV) survey data from 1993–2011 was developed through the framework process, using a logistic biomass dynamics model. The 2013 Framework also defined the Upper Stock Reference (USR) as 80% of Biomass at Maximum Sustainable Yield (B_{MSY}), the Limit Reference Point (LRP) was defined as 40% B_{MSY} and Fishing mortality at Maximum Sustainable Yield (F_{MSY}) was established as the Limit Removal Reference (RR) based on the median estimates of r and K (DFO 2013). The consequences and risk to productivity of the stock were evaluated under a number of harvest options (DFO 2013). Since the 2012 framework assessment, science advice has been provided annually as a stock status update and published as a Science Response. The objective of the interim update is to report new information from the DFO Summer RV Survey and commercial landings data. Recent trends in biomass and fishing mortality are evaluated against the values for B_{MSY} and F_{MSY} derived in the framework assessment. The most recent update occurred in December 2019 (DFO 2020). This Science Response Report results from the regional peer review of December 6–7, 2022 on the Stock Status Update of Silver Hake in 4VWX.

Background

Silver Hake are a widely distributed gadoid fish that range from Cape Hatteras to the Grand Banks including the Gulf of St. Lawrence. The distribution of these demersal-pelagic fish is closely associated with bottom water temperatures between 5–12 °C for juveniles, 7–10 °C for adults, and warmer (> 10 °C) waters for spawning. A self-reproducing population occurs on the Scotian Shelf with depth preferences over 120 m in the NAFO divisions 4VWX (Rikhter et al. 2001).

Historically, adult Silver Hake within these NAFO divisions predominantly aggregated along the warm slope waters of the shelf and inside the Emerald and LaHave basins (Figure 1). However, in recent years, landings from the fishery within the Emerald and LaHave basins have decreased which may be due to water temperatures within these areas reaching the upper limits of the species' preferred range for both juveniles and adults (Figure 2). From July to September, Silver Hake migrate to shallower (30–40 m), warmer (> 10 °C) waters surrounding the Emerald

and Sable Island banks for spawning (Rikhter et al. 2001). Silver Hake reach maturity by Age 2, with females growing faster than males, and can reach a maximum age of 12 years.

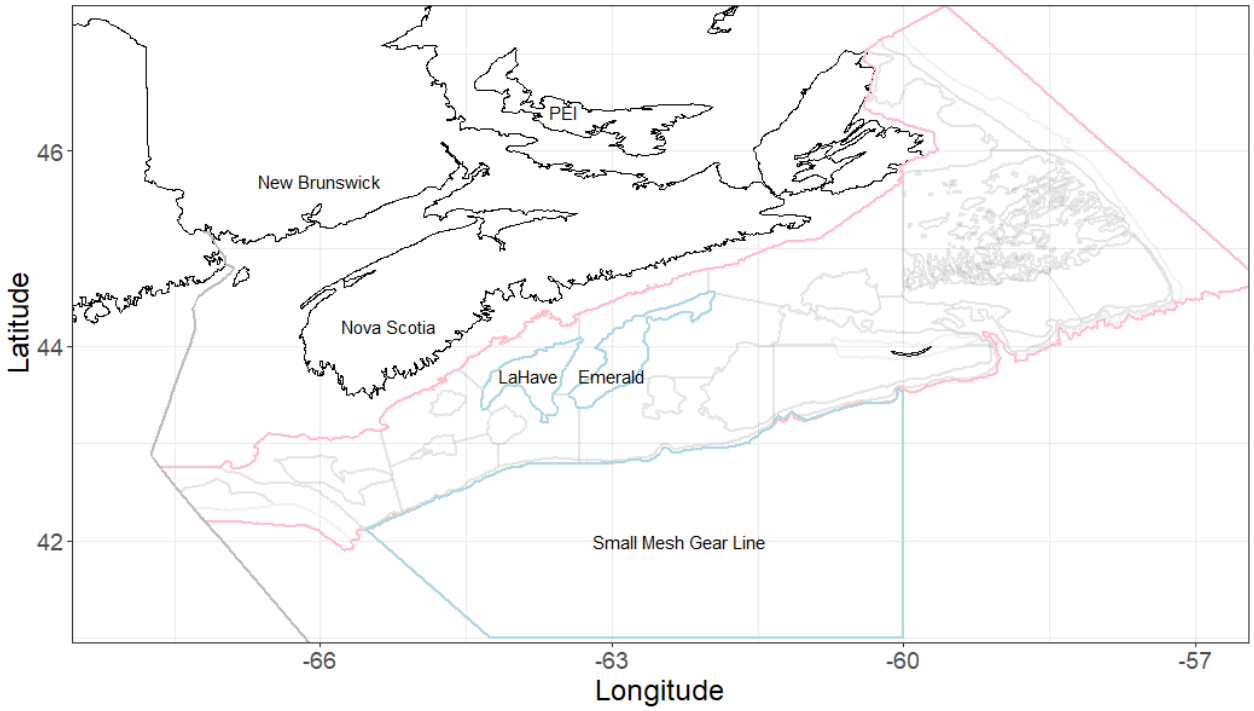

Figure 1. DFO Summer Research Vessel survey strata (440–483) used to assess 4VWX Silver Hake outlined in pink. Fishing is restricted to LaHave and Emerald Basins and the edge of the Scotian Shelf seaward of the Small Mesh Gear Line (blue).

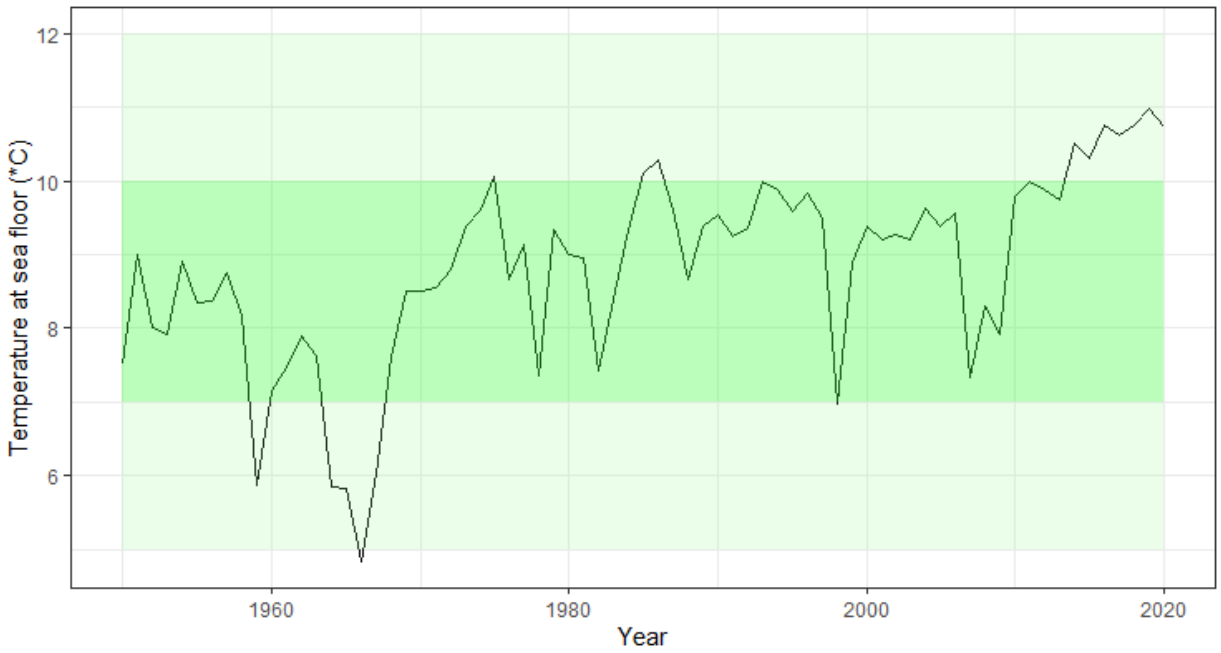

Figure 2. Yearly average sea floor temperature in Emerald Basin from 1950 to 2020. Light and dark green shaded areas denote the preferred temperatures for juvenile and adult Silver Hake, respectively. Data derived from annual broadscale data from Casault et al. (2018).

Description of the fishery

Foreign fleets (predominantly from Russia, Japan, and Cuba) dominated the Silver Hake fishery across the Scotian Shelf from the 1960s until the mid-1990s, when Canadian trawlers entered the commercial fishery in 1995 (Showell and Cooper 1997, Stone et al. 2013). Since 2004, all landings of Silver Hake in 4VWX have come from Canadian mobile gear fleets using bottom trawls with 55 to 65 mm square mesh codends to prevent over-harvesting of small fish. Fishing is restricted to Emerald and LaHave basins, and the edge of the Scotian Shelf seaward of the Small Mesh Gear Line (Figure 1). The age groups that the fishery has targeted have changed over time. Until the late 1980s, most of the catch was Ages 2–4. Since 1999, a high proportion of the catch has been Age 1 fish.

The TAC has been set at 15,000 tonnes (t) since 2003, but landings have consistently been lower, averaging about 3,467 t for the fishing years 2019/2020–2021/2022. Consistent landings below the TAC are thought to be a consequence of market conditions and the reduced effort directed at this species, rather than abundance (Stone et al. 2013). Landings in the fishing years 2020/2021 and 2021/2022 were 2,900 t and 3,900 t, respectively (Table 1, Figure 3). Since the early 2000s, catches of Silver Hake have come predominantly from LaHave and Emerald basins. In recent years, however, the contribution of the catch from the basins to the total catch has decreased substantially, accounting for only 27% of the catch from the 2020/2021 and 2021/2022 fishing seasons (Figure 3).

The 2022/2023 fishing season is still ongoing, and landing statistics for 2022/2023 are currently incomplete.

Table 1. Landings and Total Allowable Catch (TAC) of Scotian Shelf Silver Hake in 4VWX (thousands of tonnes).

Year	1970–79	1980–89	1990–99[3]	2000–09[4]	2010–16	2017	2018	2019	2020	2021
TAC	90.2[1]	98.5	53.3	16.5	15	15	15	15	15	15
Canada[2]	0	0	3.7	13	7.9	6.3	5.1	3.6	2.9	3.9
Foreign	115.6	64.2	27.8	0	0	0	0	0	0	0
Total	115.6	64.2	31.5	13	7.6	6.3	5.1	3.6	2.9	3.9

[1]Average TAC for 1974–79 period.
[2]Includes developmental allocations fished by foreign flagged vessels, ending in 2004.
[3]Fishing year, landings, and TAC refer to the 15-month period from January 1, 1999 to March 31, 2000.
[4]Commencing in 2000, fishing year, landings, and TAC refer to the period from April 1st of the current year to March 31st of the following year.

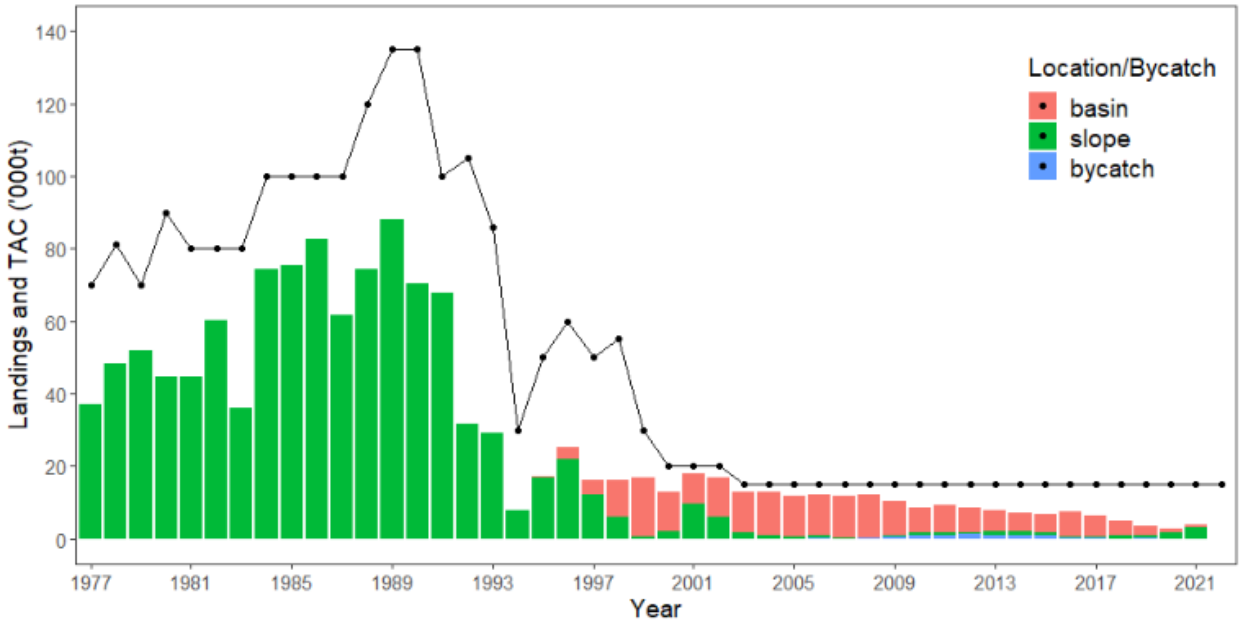

Figure 3. Silver Hake Total Allowable Catch (line) and landings (bars) (x1000 t) by fishing area, 1977–2021. Basin: landings from Emerald and LaHave basins. Slope: landings from the shelf edge. Bycatch: landings using mesh sizes above 65 mm or below 55 mm and mesh sizes with NA values outside of the basins or slope fishing areas.

Analysis and Response

DFO Summer Research Vessel Survey

Bottom trawl surveys of the Scotian Shelf have been conducted by DFO since 1970, using a stratified random sampling design. Silver Hake abundance, biomass, and estimates of year-class strength recruitment are derived from the summer RV survey. The Bay of Fundy strata (484–495) are excluded because Silver Hake from the Bay of Fundy were determined to be

more associated with the Georges Bank/Gulf of Maine stock rather than the Scotian Shelf stock (DFO 2013).

Silver Hake biomass index derived from the RV survey (strata 440–483) was highest in the early 1980s but showed decreasing trends from 1998 to 2008 (Figure 4). From 2009 to 2014, biomass indices increased to the highest observed level since the 1980s; however, biomass has decreased since 2014 and estimates have been below the long-term average since 2017 (Figure 4). It should be noted that due to incomplete coverage of the stock area by the summer RV surveys, biomass indices for 2018 and 2022 are not comparable to others in the time series and are excluded. Only 83 and 153 stations were sampled in 2018 and 2022, respectively, compared to 258 and 195 stations in 2019 and 2020, respectively, so these are not considered representative of the stock area (Figure 5). Similarly, the absence of conversion factors for the North East Science Trawl (NEST) net used in the 2021 summer survey precludes the use of the 2021 biomass index until reliable conversion factors can be developed.

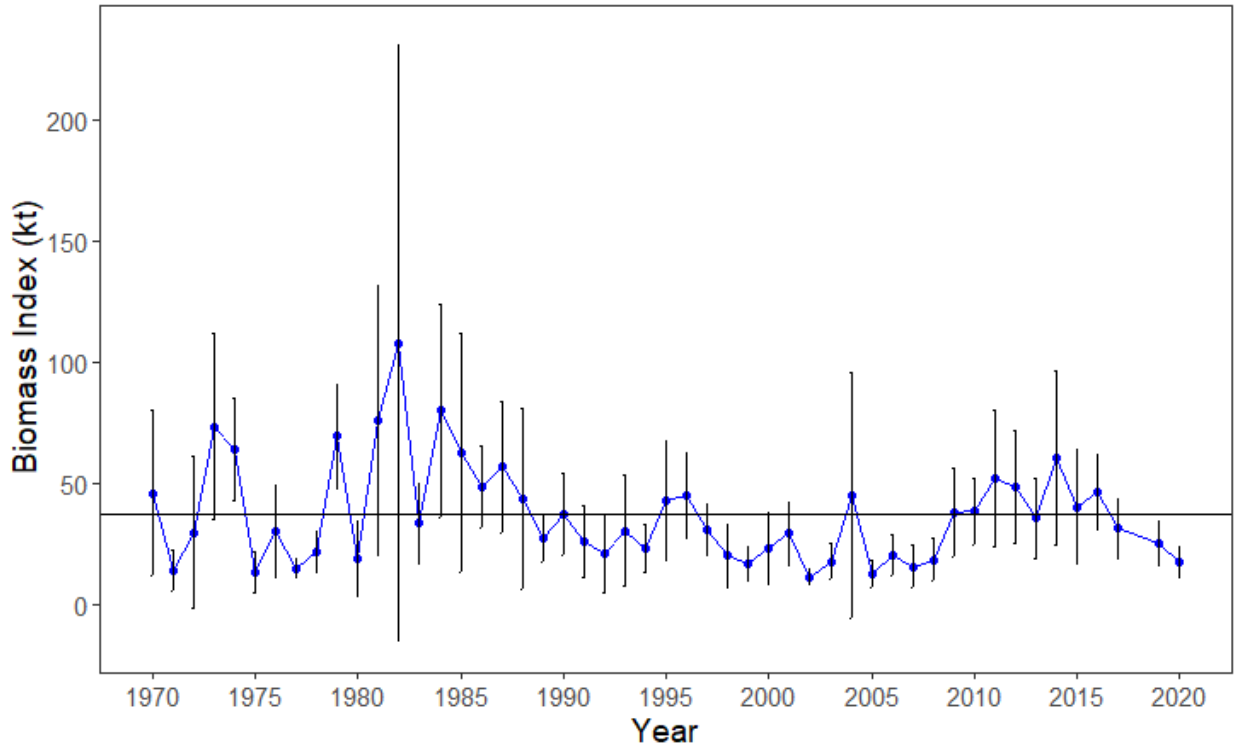

Figure 4. Stratified swept area total biomass index estimates from the DFO Summer Research Vessel Ecosystem Survey (excludes Bay of Fundy strata), 1970–2020. The 2018, 2021 and 2022 data are not included because of incomplete survey coverage or lack of conversion factors. The vertical bars indicate a 95% confidence interval (i.e., two times the standard error) and the horizontal line represents the long-term mean from 1970 to 2020. The 1970–1981 estimates are adjusted by 2.3 for vessel/gear effect (Fanning 1985).

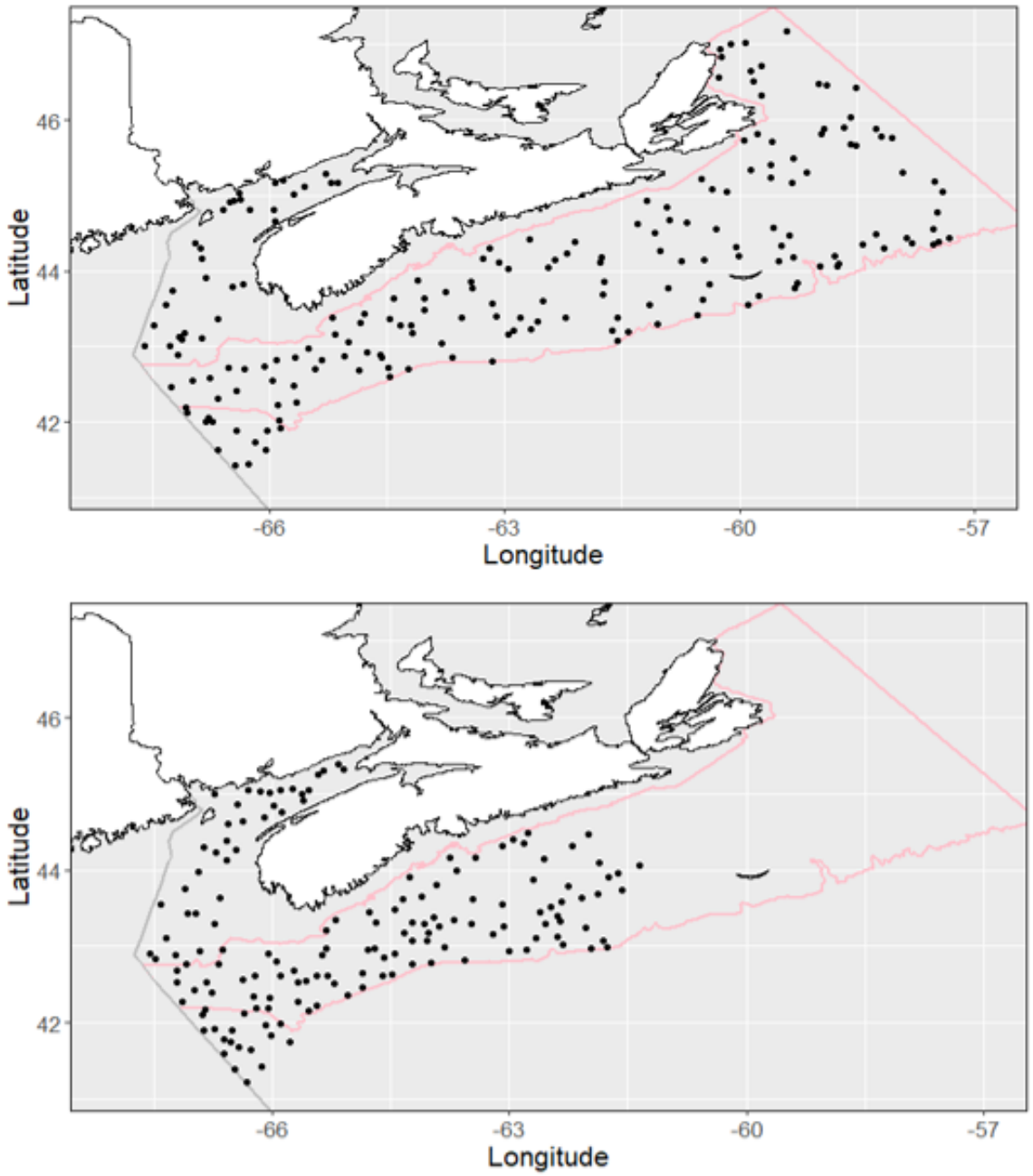

Figure 5. Stations sampled during the 2020 (top; complete coverage) and 2022 (bottom; incomplete) summer RV surveys. The area outlined in pink represents the stock area for 4VWX Silver Hake.

Length frequency data are available from the RV survey; however, due to lack of conversion factors in 2021 and incomplete survey coverage in 2022, the length frequencies are not directly comparable to previous years, resulting in the two terminal years for length frequency comparisons being 2019 and 2020 (Figure 6). Furthermore, age data from the RV survey has not been available since 2014, and therefore, age classes are estimated using long-term length frequency data where fish < 23 cm are used as a proxy for age 1 fish (Figure 6). The Age 1

modes in the two years are very similar, falling between 16 and 20 cm in both years. The Age 2 modes are much less pronounced compared to the short-term and long-term medians, falling somewhere around 25 cm (Figure 6).

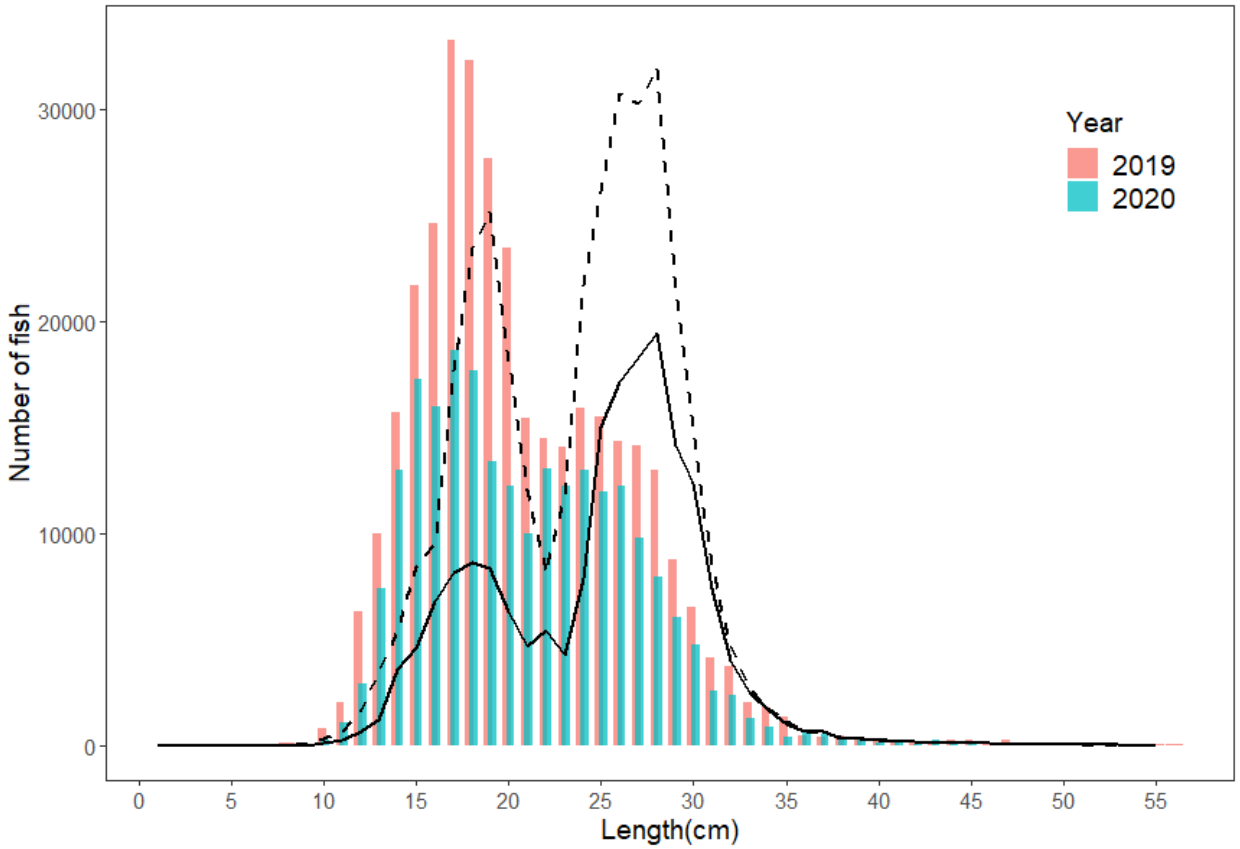

Figure 6. Length frequency indices for Scotian Shelf Silver Hake in 4VWX (strata 440–483) from the DFO Summer RV Survey. Bars represent the number in thousands-at-length from the 2020 survey (blue) and the 2019 survey (pink). The solid black line represents the long-term median (1970–2018) and the dashed line represents the short-term median (2009–2018).

Age data have not been available from the RV survey since 2014, but year classes are suggested by the distinct modes in the survey length frequency data. Total stratified number of fish < 23 cm provides a proxy for Age 1 numbers, and is used as a recruitment index (Branton et al. 1997, Stone et al. 2013). Based on aging data, recruitment over the time period is variable (Figure 7).

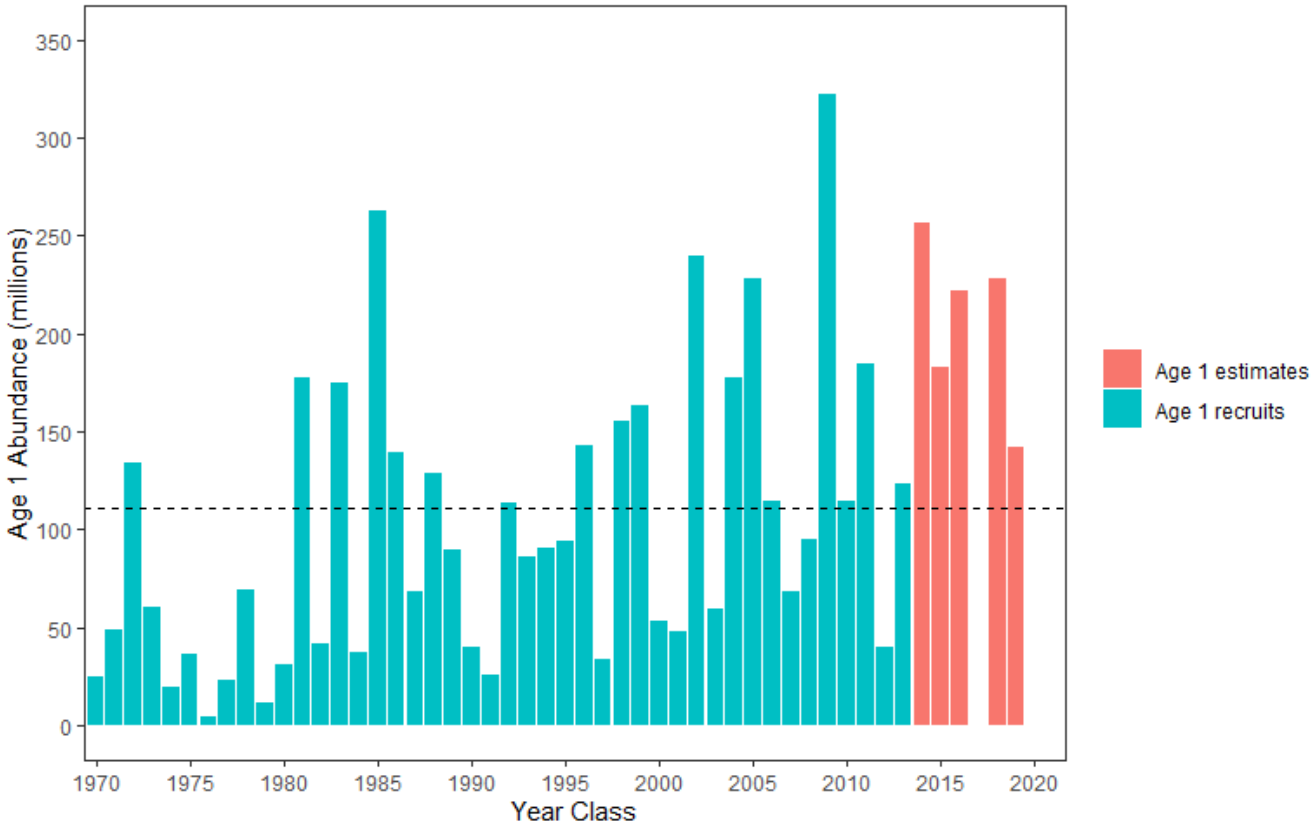

Figure 7. Age 1 abundance estimates from the Research Vessel (RV) Survey with long-term average estimates (1970–2020) indicated by the horizontal dashed line. Aged recruits are represented in blue while Age 1 abundances from 2014 (red) on are estimated from the RV Survey length frequency data. Year classes of 2017, 2020 and 2021 are missing due to incomplete RV Survey coverage or no conversion factors in 2018, 2021 and 2022. Abundance estimates from 1970–1981 are adjusted by 2.3 for vessel/gear effect (Fanning 1985).

Population Modelling

During the Silver Hake framework assessment, a logistic biomass dynamics model was accepted as a basis for estimating population biomass (Cook 2013). The catchability coefficient ‘q’ was used to scale the RV survey biomass index to estimate ‘true’ biomass. The model then used this survey biomass and commercial fishery landings to estimate trends in population biomass and fishing mortality.

At the 2013 Framework, the Upper Stock Reference (USR) was defined as 80% of B_{MSY}, the Limit Reference Point (LRP) was defined as 40% B_{MSY} and F_{MSY} was established as the Limit Removal Reference (RR) based on the median estimates of r and K (DFO 2013). Biomass estimates from the population model were above 100,000 t from 2009 to 2018, with the 2014 estimate the highest in the time series. Population biomass estimates have shown steady decline since 2014 to a low point in 2020, with some indication of a rebound since then to a value of 104,400 t in 2022 (Figure 8). Fishing mortality was estimated at 0.034 for 2022 which was the second lowest value in the time series; only 2020 had a lower fishing mortality estimate.

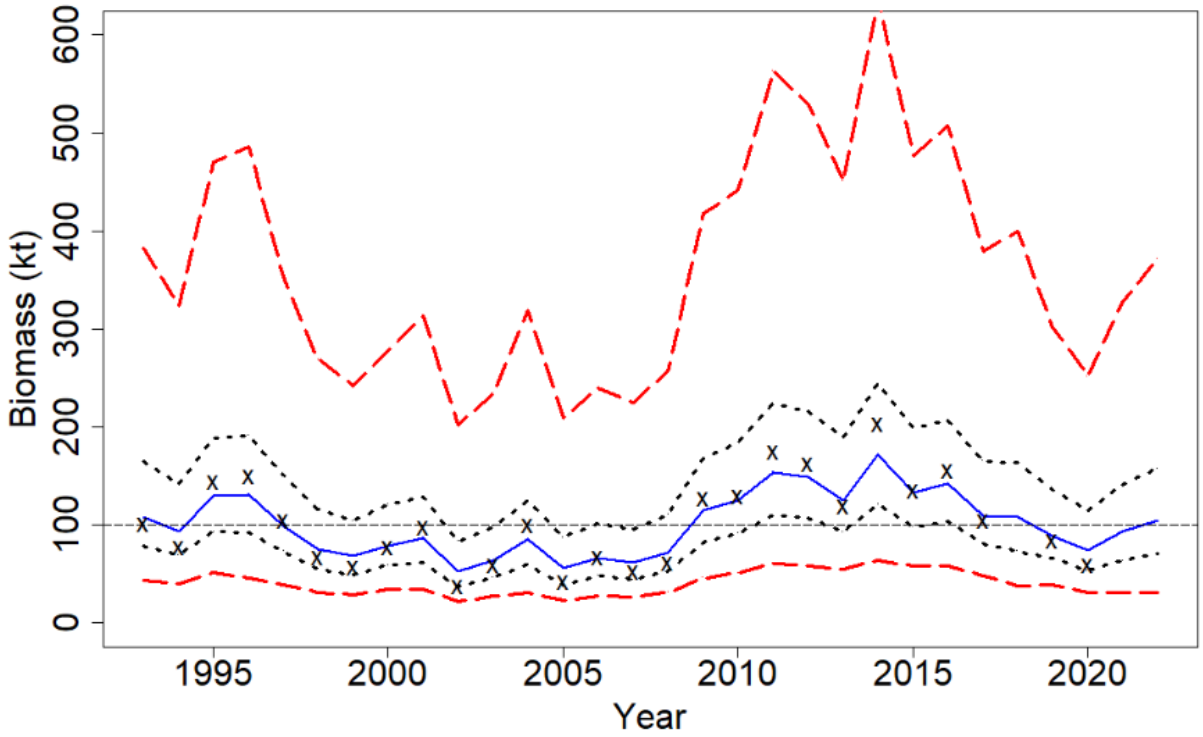

Figure 8. Model fits (blue line) to the q-corrected Research Vessel Survey biomass index (black x's; omitting years 2018, 2021 and 2022 due to lack of survey coverage or conversion factors) for Silver Hake (1993–2022). Dashed black lines represent the 25% and 75% credible intervals for model biomass estimates while the red dashed lines represent the 2.5% and 97.5% credible intervals.

The relationship between stock biomass and exploitation (expressed as ratios of biomass and fishing mortality to B_{MSY} and F_{MSY}, respectively) is presented in Figure 9. For the period covered by the model (1993–2022), biomass has been above 80% of B_{MSY} USR in the healthy zone and fishing mortality has been below the reference level F_{MSY}. Updated model results incorporate recent landings up to the end of the 2021/2022 fishing year and the 2020 summer RV survey.

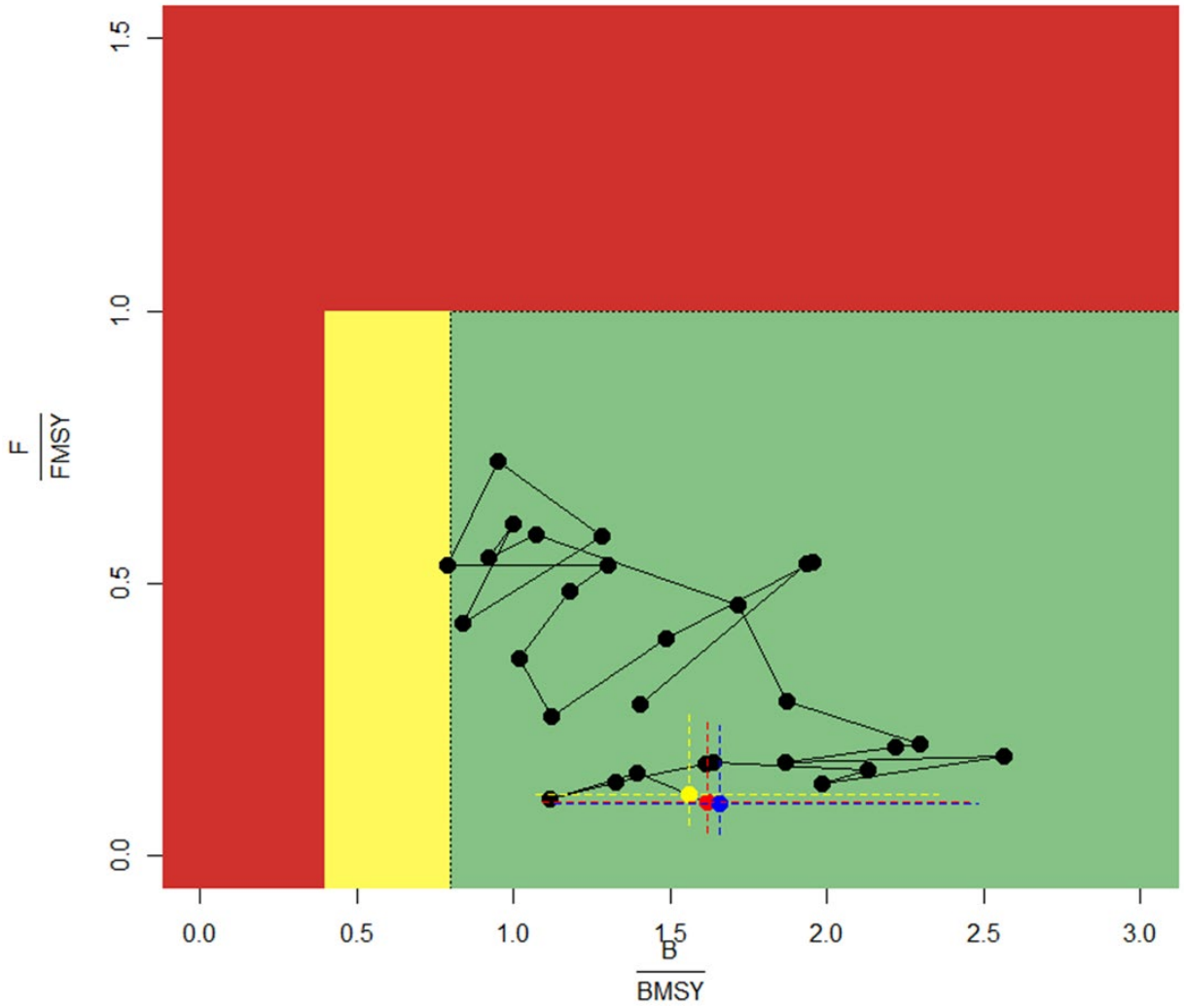

Figure 9. Phase plot of the ratio of fishing mortality (F) to fishing mortality at maximum sustainable yield (F_{MSY}), and biomass (B) to biomass at maximum sustainable yield (B_{MSY}). Colours reflect stock status: red = critical, yellow = cautious, and green = healthy. The yellow dot represents the 2022 biomass and fishing mortality from the population model. The red dot indicates projected biomass and exploitation with an assumed catch of 3,300 t for the July 2022 to June 2023 period. The blue dot represents projected biomass and exploitation at an assumed catch of 3,300 t (status quo) from July 2023 to June 2024. Dashed lines represent the 25% and 75% credible intervals around the projected estimates.

Four landings scenarios were explored to provide one- and two-year projections for July 2022 to June 2023 and for July 2023 to June 2024. Biomass and exploitation rates were calculated for catch scenarios equal to the average landings for 2019–2021 (3,300 t; based on landings of July to June the following year), and also for TACs of 12,000 t,15,000 t, and 18,000 t. Recruitment was assumed to be the mean of the model time series.

Figure 9 shows the projected population biomass and exploitation for the next two years, for the first scenario (landings equal to the average landings for the 2019–2021). The biomass,

exploitation and probabilities of the population declining below B_{MSY} are shown for four catch scenarios for 2022–2023 in Table 2, and 2023–2024 in Table 3.

Table 2. Impact of four catch scenarios on projected biomass (x1000 t) and fishing mortality estimates, and probability of population declining below biomass at maximum sustainable yield (B_{MSY}), July 2022 to June 2023. 50% CI is credible interval.

Landings for Projections	Fishing Mortality	Median Biomass 2022	50% CI Biomass 2022	Probability of 2022 Biomass Falling Below:	
				80% of B_{MSY}	40% of B_{MSY}
3.3[1]	0.031	107	74–164	0.120	0.024
12	0.129	99	65–155	0.163	0.033
15	0.170	96	63–150	0.178	0.041
18	0.218	92	60–148	0.199	0.045

[1] $3.3x10^3$ t is the 2019–2021 average landings.

Table 3. Impact of four catch scenarios on projected biomass (x1000 t) and fishing mortality estimates, and probability of population declining below biomass at maximum sustainable yield (B_{MSY}), July 2023 to June 2024. 50% CI is credible interval.

Landings for Projections	Fishing Mortality	Median Biomass 2023	50% CI Biomass 2023	Probability of 2023 Biomass Falling Below:	
				80% of B_{MSY}	40% of B_{MSY}
3.3[1]	0.030	110	74–168	0.116	0.027
12	0.132	97	63–154	0.184	0.051
15	0.178	92	57–148	0.229	0.064
18	0.232	87	53–142	0.256	0.076

[1] 3.3×10^3 t is the 2019–2021 average landings.

Biomass is projected to slightly increase and exploitation to decrease in 2022, assuming that landings remain similar to those of 2019–2021 and recruitment is average (1993–2021). Compared to 2022 projections, biomass is projected to increase again in 2023 while exploitation will remain similar (Tables 2 and 3). However, at higher catch scenarios, biomass is projected to decrease in 2023 in comparison to 2022 projections, although the trends in recent fishery removals make the high catch scenarios increasingly unlikely. In all catch scenarios for both projection years, however, the median biomass is expected to remain above the 80% B_{MSY}. The probability of falling below the 80% B_{MSY} ranges from 12.0% to 19.9% in 2022 projections and from 11.6 to 25.6% in 2023 projections (Tables 2 and 3).

Conclusions

At the 2012 framework and assessment, it was concluded that Scotian Shelf Silver Hake biomass was above the USR, and that fishing mortality was below the Limit RR. Since that assessment of this resource, new information is available from two sources: commercial landings data and the DFO Summer RV survey.

Landings of Silver Hake in the fishing year 2021/2022 were 3,900 t relative to a quota of 15,000 t. The Silver Hake fishery is reliant on Age 1 fish with landings maintained below quota

since 2000. Although landings have been constrained by market conditions, environmental factors may also be driving the distribution of Age 1 recruits.

Stratified swept area survey biomass for the most recent survey with complete coverage or conversion factors decreased in 2020 to the lowest level since 2014.

Based on the population model, the stock remains in the Healthy Zone, with biomass above the USR of 80% B_{MSY} and fishing mortality has remained below the Limit RR for the period covered by the model (1993–2021). Biomass is projected to be slightly higher in 2022 and 2023 compared to 2021, assuming catches remain similar to the 2019–2021 average and recruitment is similar to the time series average.

Based on model projections for each landings scenario, the probability of biomass falling below 80% B_{MSY} remains below 25.6% for 2022 and 2023.

The current TAC of 15,000 t is appropriate given stock status.

Sources of Uncertainty

Only the RV survey strata 440–483 were used, excluding data from the Bay of Fundy. The stock boundary between the Scotian Shelf and Bay of Fundy Silver Hake stocks is imprecise and may vary from year to year. In addition, the summer RV survey has missing points in the time series due to incomplete coverage (2018, 2022) and lack of conversion factors (2021). As a result, the 2018, 2021 and 2022 survey biomass estimates were not included in the updated model.

Dynamics of a logistic biomass model may not closely track the dynamics of the population. The model assumes mean recruitment and growth across the projected years and does not account for the variability in year-class strength. The ability of the model to describe future biomass more than one year ahead is uncertain given that Silver Hake have highly variable recruitment patterns, and the fishery is based on recruiting individuals (Age 1 fish).

Bycatch

Bycatch in the Silver Hake fishery is limited because the bottom trawls used in the Silver Hake fishery are equipped with a Nordmore Grate in the lengthening piece which serves to reduce the amount of bycatch by preventing larger fish from entering the cod end. Observer coverage in the Silver Hake fishery has averaged around 2.5% (54 out of 2,152 trips) since 2015. The most common bycatch species are squid and Alewives/Gaspereau (Tables 4 and 5).

Table 4. Retained catch (t) of Alewives/Gaspereau, Herring, Mackerel, Shad, and squid from the Silver Hake fishery using a 55–65 mm square mesh. Retained catch (t) are expressed as yearly averages from 2005 to 2016 and totals for years 2017 to 2021.

Common Name	2005–2016	2017	2018	2019	2020	2021
Alewives/Gaspereau	45.68	39.77	25.66	17.53	12.23	9.84
Herring	42.54	9.77	17.60	10.31	4.85	2.20
Mackerel	3.03	6.31	6.39	4.78	4.79	4.29
Shad	0.20	0.03	0.64	0.16	0.00	0.84
Squid	22.44	51.24	69.02	80.70	29.79	30.55

Table 5. Observed catch and bycatch of Silver Hake, Alewife, Herring, Mackerel, Shad, and squid from the Silver Hake fishery totaled from 2017 to 2021.

Species	Total Retained (t)	Total Discarded (t)	Total Observed (t)	Total weight caught (%)
Silver Hake	613.23	0.88	614.11	90.73
Atlantic Herring	0.73	0.00	0.73	0.11
Alewife	2.62	0.00	2.62	0.39
Squid	3.61	0.17	3.78	0.56
Atlantic Mackerel	0.41	0.00	0.41	0.06
American Shad	0.06	0.00	0.06	0.01

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