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) Fisheries and Aquaculture Management Branch 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 DFO Summer Research Vessel (RV) Survey data from 1993-2011 was developed through the framework process, using a logistic biomass dynamic model. Biological reference points were calculated from model outputs and included a median estimate of Maximum Sustainable Yield (MSY), Biomass at MSY (B_{MSY}), and Fishing mortality at MSY (F_{MSY}). 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 2016 (DFO 2017).

This Science Response Report results from the Science Response Process of December 5, 2017, on the Stock Status Update for Scotian Shelf 4VWX Silver Hake.

Background

Biology

Silver Hake is a demersal member of the gadoid family occurring in the Northwest Atlantic Ocean from Cape Hatteras to the Grand Banks and the Gulf of St. Lawrence. Silver Hake are found in warmer water, with juvenile and mature hake associated with water temperatures between 5–12°C and 7-10°C, respectively. A population of Silver Hake occurs on the Scotian Shelf in NAFO Divisions 4VWX (Figure 1). This population aggregates in deepwater depressions on the Scotian Shelf (Emerald and LaHave basins) and in the warm slope water, except during the spawning period from July-September when large aggregations occur on the shelf in shallow waters surrounding Emerald and Sable Island banks. Young Silver Hake feed primarily on invertebrates, with euphausiids the predominant prey item. Older fish are piscivorous and exhibit a high degree of cannibalism. Silver Hake exhibit relatively rapid growth with females growing faster than males. Maximum reported age is 12 years. Maturity is relatively early, with the majority maturing at Age 2. Further detail on Silver Hake biology is available in Stone et al. (2013).

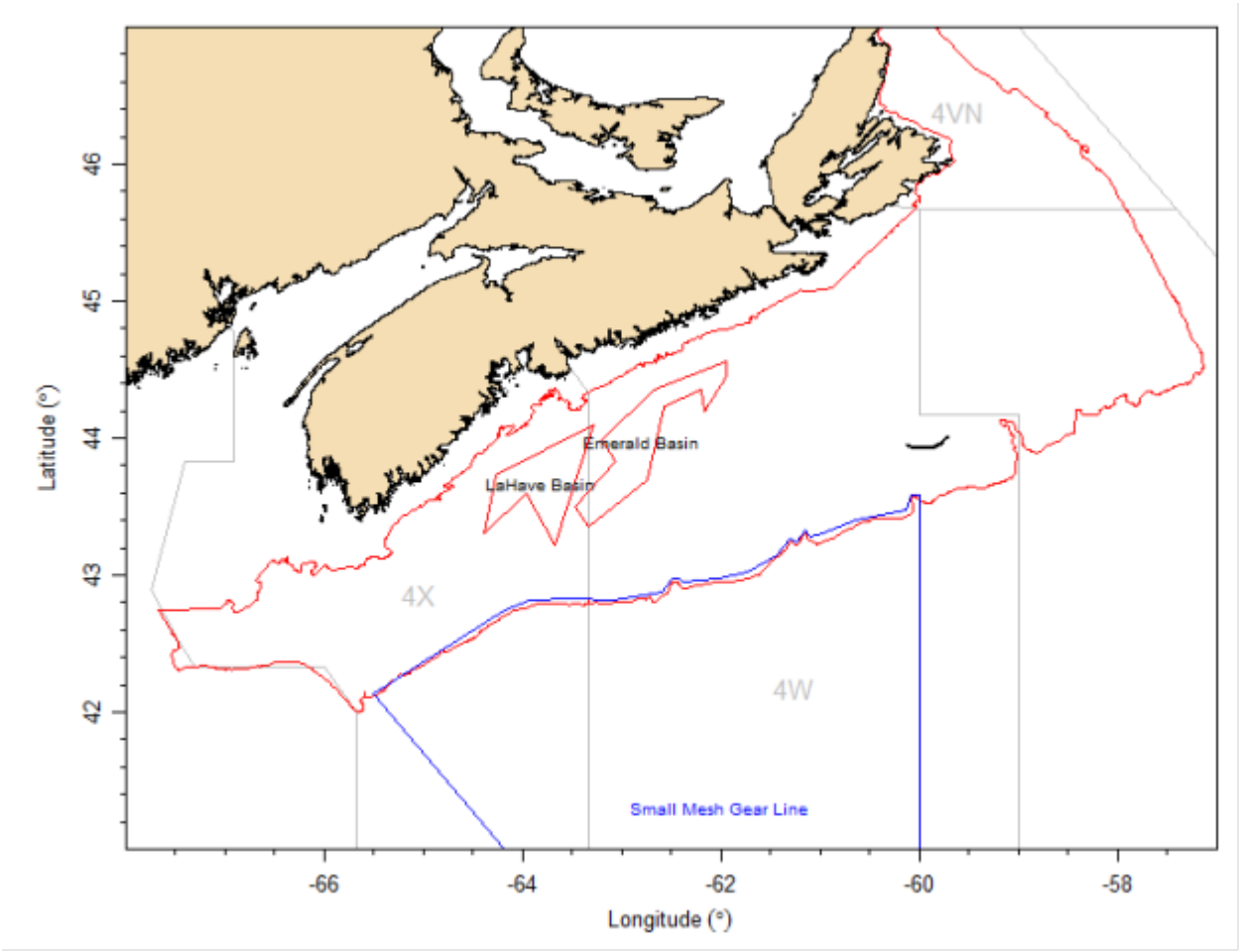

Figure 1. Northwest Atlantic Fisheries Organization Divisions 4VWX (grey lines) and associated DFO Summer Research Vessel survey strata (440-483) used to assess Scotian Shelf Silver Hake outlined in red.

Description of the Fishery

A significant fishery for Silver Hake across the Scotian Shelf (NAFO Divs. 4VWX) began in the early 1960s with the arrival of distant water fleets predominately from Russia, Japan, and Cuba. Foreign fleets dominated the Silver Hake fishery until the mid-1990s when participation by Canadian trawlers began (Showell and Cooper 1997). Since 2004, all catches have been from the Canadian mobile gear fleet using bottom trawls with 55 mm square mesh codends. Fishing is restricted to Emerald and LaHave basins, and the edge of the Scotian Shelf seaward of the Small Mesh Gear Line (Figure 1). Further details on the history of this fishery are available in Stone et al. (2013).

The TAC has been set at 15,000 tonnes (t) since 2003, but landings have been lower, averaging 7,600 t for the years 2012-2016. 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 of Silver Hake in the fishing years ending in 2015 and 2016 were 6,800 t and 7,600 t, respectively. (Table 1, Figure 2). In recent years, most catches have been from Emerald and LaHave basins. Annual total landings from the Scotian

Shelf outside of Emerald and LaHave basins were zero from 2005-2010 and averaged 0.7 t from 2012-2016 (Figure 2).

The 2017 fishing season is still ongoing, and landing statistics are incomplete.

Table 1. Landings and Total Allowable Catch (TAC) of Scotian Shelf Silver Hake in 4VWX ('x 1000 t)

Year	1970-79	1980-89	1990-99[3]	2000-09[4]	2010-14	2015	2016	2017
TAC	90.2[1]	98.5	53.3	16.5	15	15	15	15
Canada[2]	0	0	3.7	13.0	8.	6.8	7.6	-
Foreign	115.6	64.2	27.8	0	0	0	0	-
Total	115.6	64.2	31.5	13.0	8	6.8	7.6	-

[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.

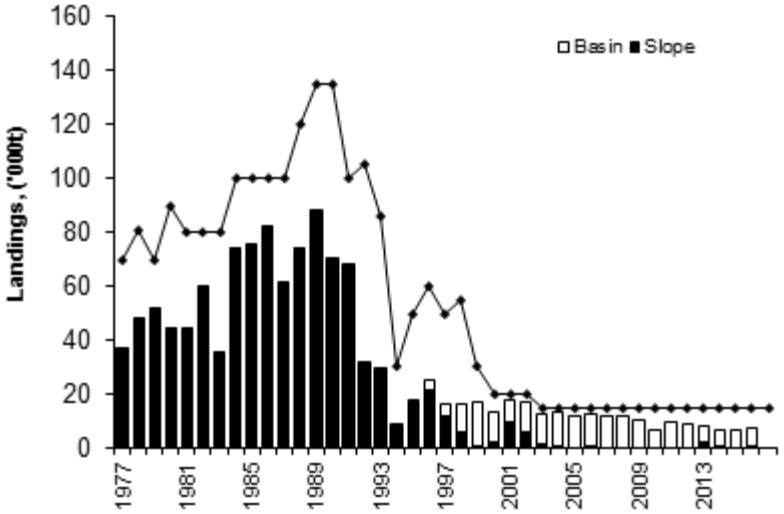

Figure 2. Silver Hake Total Allowable Catch (line) and landings (bars) (x 1000 t) by fishing area, 1977-2017. Basin: landings from Emerald and LaHave basins. Slope: landings from the shelf edge outside the basins. Landings for 2017 are incomplete.

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 to choose station locations. There were changes to the net used and the vessel conducting the survey in 1982 and 1983 and has been consistent since. This survey series covering the entire Silver Hake stock area is the DFO Summer RV Survey conducted in July. This survey provides information on Silver Hake numbers and biomass as well as estimates of year-class strength and recruitment.

Silver Hake biomass in the DFO Summer RV Survey (strata 440-483) was highest in the early 1980s, but showed a decreasing trend with a low period from 2002 to 2008 (Figure 3). Biomass then increased, and the biomass estimate for 2014 was the highest observed since the 1980s. Since 2014 biomass has decreased, but the 2017 estimate is still relatively high.

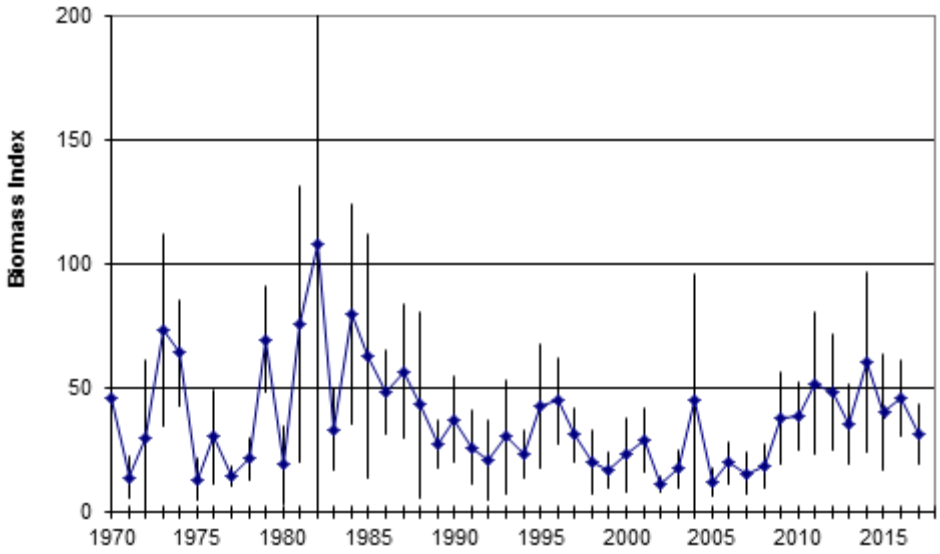

Figure 3. Stratified total biomass index estimates from the DFO Summer Research Vessel Survey (excludes Bay of Fundy strata), 1970-2016. The vertical bars indicate a confidence interval of two standard errors. 1970-1981 estimates are adjusted by 2.3 for vessel/gear effect (Fanning 1985).

Length frequency data are also available from the DFO Summer RV Survey (Figure 4). Catches of Silver Hake range from 10 cm to over 40 cm in length, with a mode of 17-19 cm seen in most years, representing Age 1 fish. Depending on year class strength, more diffuse modes are also seen between 22 and 35 cm, representing older fish.

The length distribution seen in 2016 (2015 year class) was very similar to that of the short term average. In 2017, the first mode representing the 2016 year class at age 1 was smaller, with a mode between 15 and 17 cm.

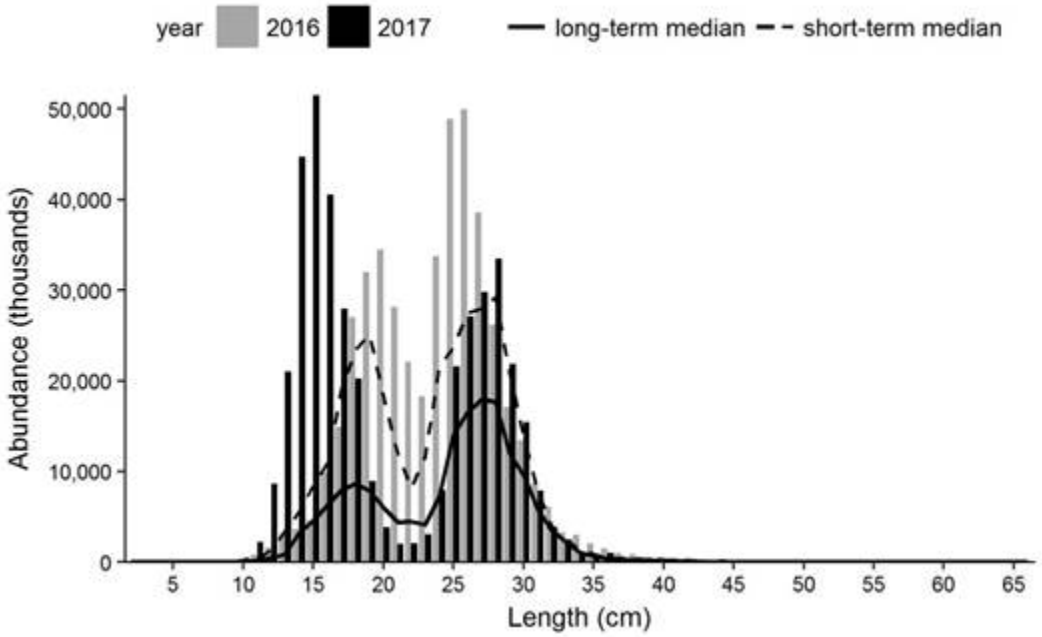

Figure 4. Length frequency indices for Scotian Shelf Silver Hake in 4VWX (strata 440-483) from the DFO Summer RV Survey. Black bars represent the number in thousands at length from the 2017 survey. Grey bars represent the number in thousands at length from the 2016 survey. The solid black line represents the median in thousands at length for the time period 1970-2015. The dashed black line represents the median in thousands at length for the time period 2006-2015 (DFO 2018).

Age data are not available from the 2015, 2016 and 2017 DFO Summer RV Surveys, but year classes are visible as distinct modes in the survey length frequency data. Total stratified number of fish < 23 cm provides a proxy for Age 1 numbers, and this has been 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 5). The 2014, 2015 and 2016 year classes (Age 1 in 2015, 2016 and 2017, respectively) have not been aged but appear to be above average based on length data.

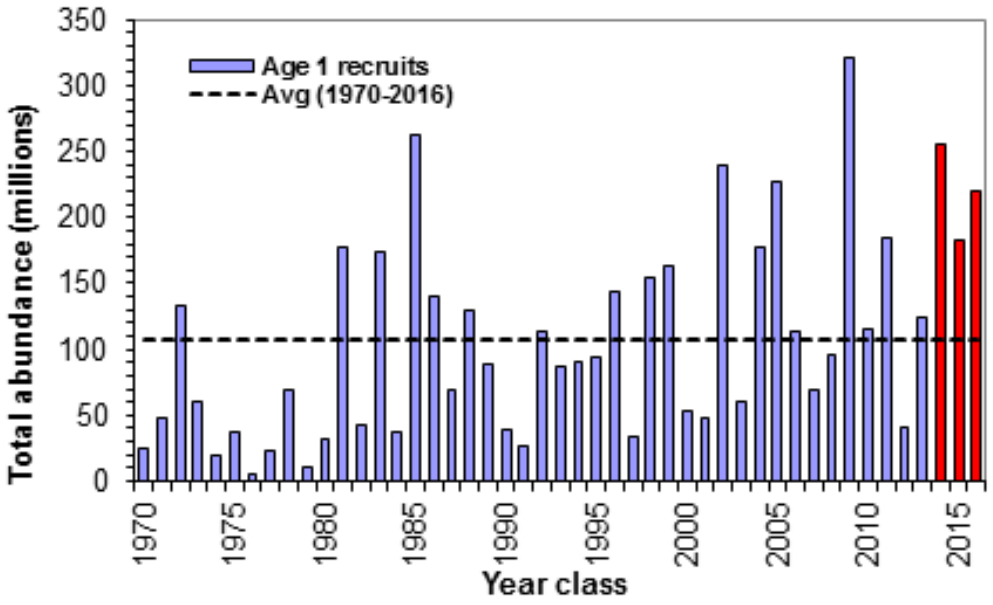

Figure 5. Age 1 abundance estimates for Scotian Shelf Silver Hake from the DFO Summer Research Vessel (RV) Survey. The long-term average (1970-2016) is indicated by the solid horizontal line. The 2014, 2015 and 2016 year classes (red bars) are estimated from the DFO Summer RV Survey length frequency data. 1970-1981 estimates are adjusted by 2.3 for vessel/gear effect (Fanning 1985).

Population Modelling and Stock Status

During the Silver Hake framework assessment, a logistic biomass dynamic model was accepted as a basis for estimating population biomass (Cook 2013). The catchability constant 'q' was used to scale the DFO summer RV 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.

Biological reference points for 4VWX Silver Hake stock estimated by the biomass model were accepted at the framework assessment (DFO 2013) as MSY: 16,000 t; B_{MSY}: 59,000 t; and F_{MSY}: 0.32. An Upper Stock Reference (USR) at 80% of B_{MSY} (47,200 t), and a Limit Reference Point (LRP) at 40% of B_{MSY} (23,600 t) were accepted. F_{MSY} was established as the Limit Removal Reference (0.32).

However, it should be recognized that these reference points are for the entire stock area, though the majority of the fishery is prosecuted within Emerald and LaHave basins. The restrictions on geographic extent of the fishery may preclude exploitation as high as F_{MSY}, since this may represent a higher proportion of the stock biomass than is present in Emerald and LaHave basins and available to be caught.

Biomass estimates from the population model have been above 100,000 t from 2011 to 2016, with the 2014 estimate the highest in the times series. Population biomass has declined since 2014. The biomass estimate for 2017 was 90,000 t (Figure 6).

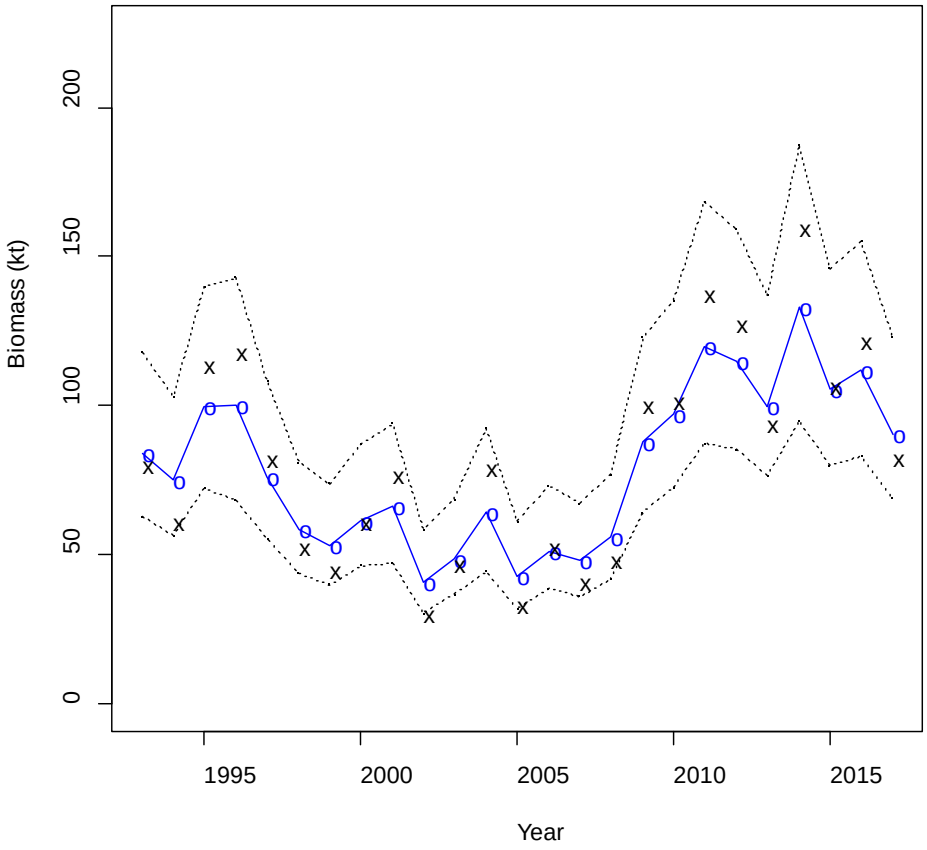

Figure 6. Model fits (blue line and points) to the q-corrected DFO Summer Research Vessel Survey biomass index (black X's) for Silver Hake (1993–2017). Dashed lines represent 50% credible intervals for model biomass estimates.

Updated model results incorporating recent landings to the end of the 2016 fishing year and the 2017 DFO Summer RV Survey are illustrated in Figure 7. The most recent stock status update projected a fishing mortality of 0.064 with an estimated catch of 7,000 t (DFO 2017). Actual catches for this period were approximately 7,600 t, for an estimated fishing mortality of 0.072.

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 7. For the period covered by the model (1993-2017), biomass has been mostly above 80% of B_{MSY} and fishing mortality has been below the reference level F_{MSY}. Population biomass in 2016 has decreased, as predicted in the 2016 stock status update (DFO 2017), but remains above B_{MSY}. Biomass in 2017 and 2018 is projected to change very little.

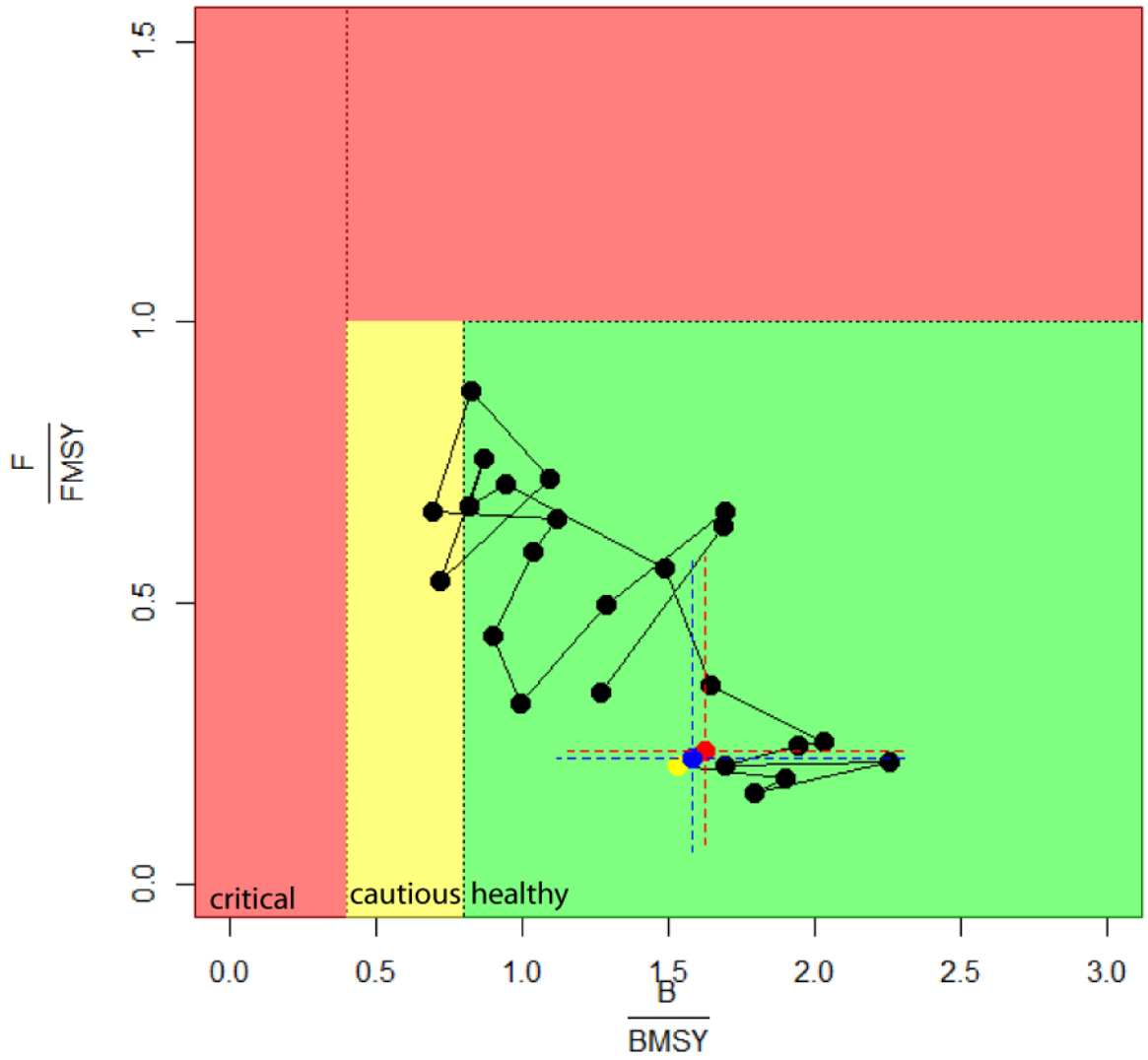

Figure 7. Phase plot of the ratio of fishing mortality (F) to fishing mortality at maximum sustainable yield (F_{MSY}), and biomass (B) to biomass at maximum sustainable yield (B_{MSY}). Colours represent stock status: red-critical, yellow-cautious and green-healthy. The yellow dot represents the 2017 biomass and fishing mortality from the population model. The red dot indicates projected biomass and exploitation with an assumed catch of 7,100 t for the July 2017 to June 2018 period. The blue dot represents projected biomass and exploitation at an assumed catch of 7,100 t (status quo) from July 2018 to June 2019). The dashed lines are the credible 50% intervals around the projected estimates.

Four landings scenarios were explored to provide one and two year projections for July 2017 to June 2018 and for July 2018 to June 2019. Biomass and exploitation rates were calculated for catch scenarios equal to the average landings for 2014-2016 (7,100 t), and also for TACs of 12,000, 15,000, and 18,000 t. Recruitment was assumed to be the mean of the model time series.

Figure 7 shows the projected population biomass and exploitation for the next two fishing years, for the first scenario (landings equal to the average landings for the 2014-2016 fishing years).

The biomass, exploitation and probabilities of the population declining below B_{MSY} are shown for five catch scenarios for 2017-2018 in Table 2, and 2018-2019 in Table 3.

Table 2. Impact of four catch scenarios on projected biomass (x10^3 t) and fishing mortality estimates, and probability of population declining below biomass at maximum sustainable yield (B_{MSY}), July 2017 to June 2018 (CI is Credible Interval).

Landings Used for Projections (x 10^3 t)	Fishing Mortality	Median Biomass 2017 (x 10^3 t)	50%CI Biomass 2016 (x 10^3 t)	Probability of 2017 Biomass Falling Below B_{MSY}	
				80% of B_{MSY}	40% of B_{MSY}
7.1[1]	0.071	104	70-143	0.040	0.001
12	0.129	99	63-136	0.061	0.002
15	0.167	96	58-131	0.077	0.003
18	0.215	93	54-125	0.094	0.003

[1] *7.1 x 10^3 t is the 2014 – 2016 average landings.*

Table 3. Impact of four catch scenarios on projected biomass (x10^3 t) and fishing mortality estimates and probability of population declining below biomass at maximum sustainable yield (B_{MSY}), July 2018 to June 2019 (CI – Credible Interval).

Landings Used for Projections (x 10^3 t)	Fishing Mortality	Median Biomass 2018 (x 10^3 t)	50%CI Biomass 2017 (x 10^3 t)	Probability of 2018 Biomass Falling Below B_{MSY}	
				80% of B_{MSY}	40% of B_{MSY}
7.1[1]	0.075	98	70-143	0.071	0.012
12	0.141	91	63-136	0.103	0.013
15	0.192	86	58-131	0.140	0.020
18	0.251	81	54-125	0.175	0.023

[1] *7.1 x 10^3 t is the 2014 – 2016 average landings*

In the 2016 update for this species, subsequent to the Science review, Industry requested that catch level corresponding to an F of 0.24 (i.e. 75% of F_{msy}) be identified. In 2017, fishing at $F_{0.24}$ would result in a catch of 19,500 t, which is very close to the 18,000 t scenario in Table 2.

Biomass is projected to decline and exploitation to remain about the same in 2017 assuming that landings remain similar to those of 2014-2016 and recruitment is average (1993-2016). Biomass is projected to decline further in 2018 for all catch scenarios. However, population biomass is predicted to remain above the reference level of 80% of B_{MSY} in all cases. The probability of falling below this threshold is less than 10% for catch scenarios up to 18,000 t in the 2017 projection, but is greater than 10% for all catch scenarios higher than the status quo in the 2018 projection (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 Removal Reference. Since that assessment of this resource, new information is available from two sources – commercial landings data and the results of the DFO Summer RV Survey. The current document updates the status of the resource, including 2016 landings data and the results of the 2017 DFO Summer RV Survey.

Exploitation in 2017 was slightly higher than projected in the 2016 update as actual landings were higher than those estimated for the projection in 2016 (7,600 t vs 7,000 t).

Based on the population model, the stock remains in a healthy zone, with biomass above the USR, and fishing mortality is likely below the Removal Reference.

The current TAC is consistent with a fishing mortality of 0.072 and a low probability of stock biomass dropping below B_{MSY} in 2017. Assuming an average recruitment for the projected years, biomass is expected to fall as the 2015 and 2016 year classes diminish over time. However, population biomass in 2017 and 2018 will continue to be above 80% B_{MSY}.

Sources of Uncertainty

Only the DFO Summer 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.

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).

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Sources of Information

Branton, R., J. Black, and M. Showell. 1997. 1997 Summer Groundfish Survey Update for Selected Scotia-Fundy Groundfish Stocks, Including a Revised Projection of Silver Hake Catch Using the Survey Estimate of the 1996 Year Class. DFO Atl. Fish. Res. Doc. 97/104.

Cook, A.M. 2013. Bayesian State Space Biomass Dynamic Modelling and Assessment of 4VWX Silver Hake 1993-2012. DFO Can. Stock Assess. Sec. Res. Doc. 2013/009.

DFO. 2013. 2012 Assessment of 4VWX Silver Hake. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/018.

DFO. 2017. Scotian Shelf Silver Hake (NAFO Divs. 4VWX) Stock Status Update for 2016-2017. DFO Can. Sci. Resp. 2017/010.

DFO. 2018. 2017 Maritimes Research Vessel Survey Trends on the Scotian Shelf and Bay of Fundy. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/021

Fanning, L.P. 1985. Intercalibration of Silver Hake abundance estimates from research vessel surveys by different vessels. NAFO Scr.Doc. 85/64 Serial No. N1016.

Showell, M.A., and C.G. Cooper. 1997. Development of the Canadian Silver Hake Fishery, 1987-96. NAFO Scr.Doc. 97/54 Serial No. N2888.

Stone, H.H., D. Themelis, A.M. Cook, D.S. Clark, M.A. Showell, G. Young, W.E. Gross, P.A. Comeau, and L.A. Alade. 2013. Silver Hake 2012 Framework Assessment: Data Inputs and Exploratory Modelling. DFO Can. Stock Assess. Sec. Res. Doc. 2013/008.

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