HARVEST ADVICE FOR PACIFIC SARDINE (*SARDINOPS SAGAX*) IN BRITISH COLUMBIA WATERS FOR 2019 SEASON

Context

The northern subpopulation of Pacific Sardine (*Sardinops sagax*) in the eastern Pacific Ocean (California Current Ecosystem) has a distribution that can range between Baja California to southeast Alaska. In winter and spring months, most of this stock has the tendency to occur in waters off the California coast in association with spawning. Prior to, and during summer months, large aggregations of Pacific Sardine migrate from spawning habitat to more northern waters mainly to forage. Migratory patterns can be affected by age structure, population size and oceanographic conditions. Typically, most Pacific Sardines that migrate into British Columbia (BC) waters are the larger and older fish in the population. Pacific Sardine has not been fished in BC waters since 2012 due to reduced migration (a general absence of Pacific Sardine in BC waters) and formal fishery closures in 2015 to 2018.

Fisheries and Oceans Canada (DFO) adopted a harvest control rule in 2013 that applies a harvest rate to an estimate of age-1 year and older (age-1+) biomass that exceeds 150,000 t to calculate potential harvest options for the BC sardine fishery (DFO 2013). As described in the 2013 Science Advisory Report, a range in harvest rates from 3-5% was selected to calculate potential harvest options. The age-1+ biomass estimate used in the harvest control rule is based on stock assessment efforts conducted by the United States (US) National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA). Updates to the 2017 stock assessment model of the northern subpopulation of Pacific Sardine were conducted by the United States (US) National Marine Fisheries Service of the National Oceanic and Atmospheric Administration (NOAA) in 2018 and 2019. Results from the 2019 update include information on stock status and forecasts of age-1+ sardine biomass informed by data sets representing the most current information on fishery landings, biological sample data and fishery independent surveys until December 2018 (described in Hill et al. 2019).

DFO Fisheries Management requested that DFO Science Branch incorporate the updated 2019 US stock assessment results into the 2013 BC fishery harvest control rule and provide harvest advice for Pacific Sardine for the 2019 season. Specifically, this Science Response (SR) provides information on the northern subpopulation of Pacific Sardine (associated with the California Current Ecosystem) to report on its biomass status, exploitation rates, commercial landings, and harvest options for the 2019 BC Pacific Sardine fishing season. Objectives of this report are to:

1. Report the results of applying the harvest control rule for a range of harvest rates from 0.03 to 0.05 in increments of 0.01, if the expected stock biomass is above the escapement buffer of 150,000 tonnes; and
2. Identify uncertainties associated with this harvest advice.

A formal Canadian stock assessment was not conducted in 2019 so the following advice is based on the multi-year method approved in 2013 (DFO (2013). As such, for a full

understanding of Science recommendations, uncertainties, and future considerations, readers are referred to DFO (2013).

This Science Response results from the Science Response Process in May 2019 on Harvest Advice for Pacific Sardine (*Sardinops sagax*) in British Columbia Waters for 2019.

Background

Population assessment

The US NMFS assesses the status and population trends of the Pacific Sardine northern subpopulation in the eastern Pacific Ocean (also known as the California Current Ecosystem stock) using a statistical catch-at-age model on the Stock Synthesis platform (Methot and Wetzel 2013, Hill et al. 2018). Since 2014, the annual Pacific Sardine stock assessment process has been conducted and updated in the spring. An update to the 2017 model was conducted in March 2019. The model is informed by data from a fishery-independent acoustic-trawl survey, fishery landings, and biological samples collected from 2005 to December of 2018 (Hill et al 2019).

BC Pacific Sardine fishery harvest control rule

DFO Fisheries Management adopted a harvest control rule in 2013 that incorporates a July estimate (forecast) of the population's age-1+ biomass, a cutoff value of 150,000 tonnes, and a harvest rate. The cutoff value of 150,000 tonnes is consistent with the cutoff value used in the US harvest guideline. The harvest rate is applied to the difference between the estimated age-1+ biomass above the cutoff and the cutoff biomass. As described in the 2013 review (DFO 2013), a range in harvest rates (h) from 3-5% was selected in the calculation of potential harvest allowances. The equation for the calculation of a fishing season's potential total allowable catch (TAC_t, tonnes) for a season starting in year "t" is:

$TAC_t = h\ (B_{1+,t} - 150{,}000)$,

where

h = harvest rate

$B_{1+,t}$ = forecast age-1+ biomass (tonnes), July

150,000 = cutoff value (tonnes)

No harvest is recommended when the forecast of age-1+ biomass ($B_{1+,t}$) is less than 150,000 tonnes. This SR provides the recommended 2019 BC Pacific Sardine fishery harvest options based on the use of this harvest control rule and the 2019 US NMFS forecast for the stock's July 2019 age-1+ biomass.

Analysis and Response

Biomass

Estimates of the California Current Pacific Sardine age-1+ biomass showed a decreasing trend since 2006, reaching historically low levels in recent years (Hill et al. 2019). Declines in recruitment have also occurred since 2005-06, with the exception of a brief period of modest recruitment success from 2009-10 (Hill et al. 2019). In particular, the 2011- 2017 year classes have been among the weakest in recent history. A small increase in recruitment was estimated for 2018 for the 2017 year class, albeit it is a highly uncertain estimate (CV=77%) and based on

limited data (Hill et al. 2019). The age-1+ biomass maximum likelihood estimate for the July 2019 forecast is 27,547 tonnes with a relatively large CV of approximately 62%, demonstrating considerable uncertainty in the estimation process corresponding to a 90% credible interval of approximately 272 to 54,822 tonnes (Hill et al. 2019).

Few or no sardines have been observed in BC waters from 2013 to 2018 in fisheries, surveys or other sources, suggesting curtailed migration and/or stock size. Average estimates of Pacific Sardine trawl catch densities (a catch per unit effort index) from a west coast of Vancouver Island summer pelagic ecosystem night trawl survey in 2006, and 2008-2014 show a decreasing trend from 2006 with no sardines observed the last two years the survey was conducted (2013 and 2014). During the summers of 2015, 2016 and 2018, small amounts of sardine were detected off the west coast of Vancouver Island in trawl catches from other multi-species surveys (i.e. led by DFO or NOAA) and none were detected in 2017.

BC fishery exploitation

The commercial BC sardine fishery was reinitiated in 2002 following closure since 1947 (Ware 1999, DFO 2012). Most fishing occurred from July to October in association with seasonal sardine migratory behaviour (DFO 2012). During the 2002-2012 period, the annual total allowable catch (TAC), generally increased as a result of management decisions (DFO 2012). Prior to 2008, landings were relatively low (less than 5,000 tonnes), increased considerably from 2007 to 2012 (up to a maximum of 22,223 tonnes in 2010) but were zero in 2013 through to 2017, resulting in fishery closures from 2015 to 2018 (Table 1). Since 2002, total landings of the northern subpopulation (catches from BC, Washington, Oregon, California and Ensenada Mexico combined) were highest in 2007 and lowest in 2016. BC annual fishery exploitation rates were estimated as the annual fishery landings (C_t) divided by the estimated age-1+ biomass in July of year *t*. Exploitation rate estimates on the stock due to fishing in BC waters show an increase from ≤ 1% prior to 2009 to a peak in 2012 (between 5 and 6%), followed by 0% in 2013-2018 (Table 1).

*Table 1: A summary of recent Pacific Sardine fishery BC TAC, BC landings and total landings of the northern subpopulation for the west coast of North America (BC, Washington, Oregon, California and Ensenada Mexico). Also shown are Hill et al. (2019) estimates of July age-1+ population biomass ($B_{1+, July}$) and coefficients of variation (CV), and BC exploitation for years 2005-2018. Total landings for 2002-2005 are from Hill et al. (2016) and total landings for 2006-2018 are from Hill et al 2019. Total landings in 2018 are preliminary (hence noted as *2018). TAC, landings, and biomass values are in metric tonnes.*

Year	BC TAC	BC Landings (C)	Total Landings	Biomass $B_{1+, July}$	CV ($B_{1+, July}$)	BC Exploitation ($C/B_{1+, July}$)
2002	5,040	822	96,344	--	--	--
2003	9,000	1,006	84,311	--	--	--
2004	15,000	4,259	87,699	--	--	--
2005	15,200	3,266	94,149	1,522,803	7.10%	0.21%
2006	13,500	1,558	92,413	1,760,636	6.22%	0.09%
2007	19,800	1,507	134,365	1,459,081	6.13%	0.10%
2008	12,491	10,435	112,959	1,087,643	5.97%	0.95%
2009	18,196	15,334	100,085	747,755	6.00%	2.03%
2010	23,166	22,223	97,876	586,533	6.39%	3.74%
2011	21,917	20,719	91,890	521,084	7.46%	3.89%
2012	27,279	19,129	121,950	331,822	11.15%	5.61%
2013	25,477	0	73,595	164,200	16.36%	0.00%
2014	17,174	0	23,581	77,321	20.35%	0.00%

Year	BC TAC	BC Landings (C)	Total Landings	Biomass $B_{1+, July}$	CV ($B_{1+, July}$)	BC Exploitation ($C/B_{1+, July}$)
2015	0	0	2,994	61,869	19.83%	0.00%
2016	0	0	559	53,939	19.22%	0.00%
2017	0	0	9,536	37,197	23.21%	0.00%
*2018	0	0	11,485	25,642	32.77%	0.00%

Uncertainties

Key uncertainties associated with the 2019 US NMFS assessment of the northern subpopulation of Pacific Sardine identified in Hill et al. (2019) and STAR (2017) include information related to:

1. acoustic species identification, target strength estimation and spatial boundaries associated with the acoustic-trawl survey. Concern over poor near-shore survey coverage has also been expressed by representatives of the U.S and Canadian sardine fishing industry;
2. empirical weight-at-age data from the fishery and research survey samples and model characterization of population weight-at-age (e.g., time varying versus time-invariant);
3. age-length keys to convert acoustic-trawl survey length compositions to age compositions and selectivity parameterization for the acoustic-trawl survey; and
4. lack of empirical justification for increasing natural mortality from 0.4 to 0.6 yr-1.

Uncertainties and concerns identified in past DFO CSAS reviews related to BC Pacific Sardine fishery harvest advice (e.g. DFO 2013) include:

5. the effect of setting harvest allowances independently of the US and Mexico;
6. unknown effects on stock structure and reproductive capacity from fisheries in different regions targeting different age components of the population;
7. incidental capture of other species in the sardine fishery; and
8. the effects of removing sardine from important forage habitat of sardine predators.

Harvest options

The July 2019 forecasted age-1+ biomass for the Pacific Sardine northern subpopulation is 27,547 tonnes. Although the uncertainty associated with this estimate is considerably large (i.e. CV=62%), the 90% credibility interval associated with the July 2019 estimate of age 1+ biomass is well below the fishery cutoff of 150,000 tonnes. Based on the harvest control rule adopted in 2013, no allowable fishery harvest is recommended for the 2019 fishing season.

Conclusions

It is recommended that there should be no allowable targeted harvest of Pacific Sardine in BC waters in 2019.

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June 28, 2019

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This Report is Available from the:

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ISSN 1919-3769
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Correct Citation for this Publication:

DFO. 2019. Harvest Advice for Pacific Sardine (*Sardinops sagax*) in British Columbia Waters for 2019 Season. DFO Can. Sci. Advis. Sec. Sci. Resp. 2019/027.

Aussi disponible en français :

MPO. 2019. Avis sur les prélèvements de sardines du Pacifique (Sardinops sagax) dans les eaux de la Colombie-Britannique pour la saison 2019. Secr. can. de consult. sci. du MPO, Rép. des Sci. 2019/027.