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Pacific Region

Canadian Science Advisory Secretariat
Science Response 2020/037

HARVEST ADVICE FOR PACIFIC SARDINE (*SARDINOPS SAGAX*) IN BRITISH COLUMBIA WATERS FOR 2020

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 2019.

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 acquired from the stock assessment conducted by the United States (US) National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA).

A 2020 stock assessment review process occurred in February 2020 to provide direction on the development of a revised base model for the northern subpopulation of Pacific Sardine by the US NMFS (STAR 2020). In addition to implementing some methodological changes, the resulting 2020 stock assessment base model is informed by data sets representing fishery landings, biological sample data and fishery independent survey findings to December 2019 and generates stock status results and forecasts of age 1+ sardine biomass (Kuriyama et al. 2020).

DFO Fisheries Management requested that Science Branch incorporate the updated 2020 US stock assessment results of the northern subpopulation of Pacific Sardine (based on Kuriyama et al. 2020) into the 2013 BC fishery harvest control rule and provide harvest advice for Pacific Sardine for the 2020 season. Specifically, this Science Response (SR) provides information on the northern subpopulation of Pacific Sardine (associated with the California Current Ecosystem) current estimates of biomass, exploitation rates, and commercial landings to inform harvest options for the 2020 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.
2. Identify uncertainties associated with this harvest advice.

A formal Canadian stock assessment was not conducted in 2020 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 of May 30, 2020 on Harvest Advice for Pacific Sardine (*Sardinops sagax*) in British Columbia Waters for 2020.

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; Kuriyama et al. 2020). Since 2014, the annual Pacific Sardine stock assessment process has been conducted and updated in the spring. The 2020 base model has many similar features found in the 2017-2019 base model as well as some differences (Hill et al. 2019; Kuriyama et al. 2020; STAR 2020). One notable difference of the 2020 base model is that the acoustic-trawl survey biomass estimation was partitioned into two time series, with catchability (Q) set to 1 for 2005-2014 and Q set to 0.733 for 2015-2019 (Kuriyama et al. 2020). The latter based on the ratio between the biomass estimates resulting from 2019 acoustic-trawl survey and the combined sum of the 2019 acoustic trawl survey and 2019 nearshore aerial and trawl survey efforts (where the nearshore aerial and trawl survey efforts are collectively referred to as being part of a California Coastal Pelagic Species Survey, or CCPSS) outside of the acoustic-trawl survey footprint. The adjusted Q was extrapolated over 2015-2018 based on evidence to suggest a recent increase in nearshore sardine distribution for these years. The 2020 stock assessment is informed by data collected from 2005 to December of 2019 from a fishery-independent acoustic-trawl survey; fishery independent nearshore CCPSS survey efforts; fishery landings, and fishery dependent and independent biological samples (Kuriyama et al. 2020).

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 (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 2020 BC Pacific Sardine fishery harvest options based on the use of this harvest control rule and the 2020 US NMFS forecast for the stock's July 2020 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 (Kuriyama et al. 2020). Declines in recruitment have also occurred since 2005-06, with the exception of a brief period of modest recruitment success from 2009-10 (Kuriyama et al. 2020). In particular, the 2011- 2018 year classes have been among the weakest in recent history. A small increase in recruitment for 2019 was estimated, albeit it is a highly uncertain estimate, with a coefficient of variation (CV) of 118%, and based on limited data (Kuriyama et al. 2020). The age-1+ biomass maximum likelihood estimate for the July 2020 forecast is 28,276 tonnes with a relatively large CV of approximately 67%, demonstrating considerable uncertainty in the estimation process corresponding to a 90% credible interval of approximately 10,708 to 74,668 tonnes (Kuriyama et al. 2020).

Few or no sardines have been observed in BC waters from 2013 to 2019 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 showed a decreasing trend from 2006 with no sardines observed in 2013 or 2014. During the summers of 2015, 2016, 2018 and 2019, 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), then increased considerably from 2007 to 2012 (up to a maximum of 22,223 tonnes in 2010) but were zero in 2013 through to 2019, with fishery closures from 2015 to 2019 (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. Annual BC fishery exploitation rates were estimated as the annual BC fishery landings (C_t) divided by the estimated age-1+ biomass in July of year *t*. These estimates show an increase from ≤ 1% prior to 2009 to a peak in 2012 (between 5 and 6%), followed by 0% in 2013-2019 (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 Kuriyama et al. (2020) estimates of July age-1+ population biomass ($B_{1+,\ July}$) and coefficients of variation (CV), and BC exploitation for years 2005-2019. Total landings for 2002-2005 are from Hill et al. (2016) and total landings for 2006-2019 are from Kuriyama et al 2020. Total landings in 2019 are preliminary (hence noted as *2019). 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	--	--	--

Year	BC TAC	BC Landings (C)	Total Landings	Biomass $B_{1+, July}$	CV ($B_{1+, July}$)	BC Exploitation ($C/B_{1+, July}$)
2005	15,200	3,266	94,149	1,352,337	12.18%	0.21%
2006	13,500	1,558	92,413	1,683,806	9.68%	0.09%
2007	19,800	1,507	134,365	1,342,647	8.09%	0.10%
2008	12,491	10,435	112,959	1,313,490	6.77%	0.95%
2009	18,196	15,334	100,085	719,186	6.10%	2.03%
2010	23,166	22,223	97,876	506,747	5.98%	3.74%
2011	21,917	20,719	91,890	560,523	6.30%	3.89%
2012	27,279	19,129	121,950	365,815	8.83%	5.61%
2013	25,477	0	73,595	195,396	13.08%	0.00%
2014	17,174	0	23,581	110,660	16.55%	0.00%
2015	0	0	2,994	68,147	15.04%	0.00%
2016	0	0	644	72,077	13.14%	0.00%
2017	0	0	7,252	55,289	14.88%	0.00%
2018	0	0	6,275	49,449	14.64%	0.00%
*2019	0	0	11,961	35,186	19.03%	0.00%

Uncertainties

Key uncertainties associated with the 2020 US NMFS assessment of the northern subpopulation of Pacific Sardine identified in STAR (2020) and Kuriyama et al. (2020) include information related to:

1. Acoustic-trawl survey catchability (Q) within and outside the survey area as well as acoustic species identification and target strength estimation.
2. Age-length keys to convert acoustic-trawl survey length compositions to age compositions and selectivity parameterization for the acoustic-trawl survey. There is a general lack of reliable age composition data for characterising spatial and temporal dynamics of the stock.
3. Nearshore CPSS survey limitations associated with ground truthing visual estimates with purse seine point sets; temporal and spatial replication schemes, and biological sampling, especially to confirm species compositions.
4. Assignment of catch and biomass between the northern and southern subpopulations of Pacific Sardine in California and Mexican waters based on a 16.7°C surface water temperature partitioning methodology.
5. In the absence of available data, landings from catches around Ensenada and off the northwest coast of the Baja Peninsula in the terminal seasons of an assessment have been assumed to be similar to earlier year catch levels, with varying bias effects on biomass estimates and forecasts.

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

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

Harvest options

The July 2020 forecasted age-1+ biomass for the Pacific Sardine northern subpopulation is 28,276 tonnes. Although the uncertainty associated with this estimate is considerably large (i.e. CV=67%), the 90% credibility interval associated with the July 2020 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 2020 fishing season.

Conclusions

It is recommended that there should be no allowable targeted harvest of Pacific Sardine in BC waters in 2020.

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May 25th, 2020

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This Report is Available from the

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ISSN 1919-3769

Correct Citation for this Publication:

DFO. 2020. Harvest Advice for Pacific Sardine (*Sardinops sagax*) in British Columbia Waters for 2020. DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/037.

Aussi disponible en français :

MPO. 2020. Avis sur les prélèvements de sardines du Pacifique (Sardinops sagax) dans les eaux de la Colombie-Britannique en 2020. Secr. can. de consult. sci. du MPO, Rép. des Sci. 2020/037.