



## HARVEST ADVICE FOR PACIFIC SARDINE (*SARDINOPS SAGAX*) IN BRITISH COLUMBIA WATERS FOR 2021

### 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 2020.

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).

The 2021 assessment of the northern subpopulation of Pacific Sardine by NMFS occurred in April 2021. The coastal pelagics acoustic-trawl survey that was intended to be a main source of information in assessment efforts was cancelled in 2020 due to the coronavirus disease (COVID-19) pandemic. Recognizing the information gaps from not having survey information, a catch-only projection model was planned for generating results for use in 2021. However, due to complications associated with fitting a catch-only model with catch information for Mexico, the catch-only assessment method was not endorsed and results from the 2020 base assessment were recommended for use in 2021 instead (Kuriyama et al. 2020, Pacific Fishery Management Council 2021).

DFO Fisheries Management requested that Science Branch incorporate the most recent stock assessment estimate of age-1+ biomass for the northern subpopulation of Pacific Sardine into the DFO sardine harvest control rule.

The 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 2021 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 reports results from the Regional Science Response process of May 31, 2021 on the Harvest Advice for Pacific Sardine (*Sardinops sagax*) in British Columbia Waters for 2021.

## 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, incorporating recent science survey and fishery catch information. However due to recent sardine fishing restrictions in US and Canadian waters and the lack of a 2020 acoustic-trawl survey, the main source of new information available to update the 2020 stock assessment was from sardine landings in Mexican waters, which were approximately three times greater than preliminary expectations of catch. Although a catch-only projection assessment was conducted in 2021 (Kuriyama et al. 2021), it was not endorsed by the US Pacific Fishery Management Council process because it generated unrealistically high estimates of fishing mortality and past year recruitment and it did not accomplish the objective of informing stock abundance in the period following the previous assessment.

Results from the NMFS 2020 assessment model were recommended and endorsed during the US Pacific Fishery Management Council process as the preferred stock assessment option for providing 2021 sardine management advice. This is an alternative to the catch-only projection method and is considered an interim measure in the absence of other defensible stock assessment options. The methods, results, uncertainties and recommendations from the 2020 process were described in the 2020 harvest advice for Pacific Sardine in BC waters (DFO 2020).

For 2022, it is anticipated that new information will be available from the 2021 NMFS summer acoustic-trawl survey, 2020 and 2021 fishery independent nearshore surveys (collectively referred to as being part of a California Coastal Pelagic Species Survey, or CCPSS survey efforts); fishery landings, and fishery-dependent and independent biological samples. With the collection of new information, there is interest in having an updated stock assessment process in 2022, followed by a benchmark assessment in 2023, which would include evaluations of several assessment model assumptions.

### 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 of harvest rates ( $h$ ) of 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 Science Response provides the recommended 2021 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 2021 age-1+ biomass.

## Analysis and Response

### Biomass

Estimates of recent age-1+ Pacific Sardine biomass of the northern subpopulation from both the 2021 catch-age model projection estimates and the 2020 base assessment model are reported below, followed by a brief overview of trends in sardine observations made in BC waters.

From the 2021 catch-only projection model, the maximum likelihood estimate of age-1+ forecasted biomass in July 2021 was 14,0111 tonnes (Kuriyama et al. 2021). The coefficient of variation (CV) around this estimate was 0.58. Kuriyama et al. (2021) also conducted and reported on model sensitivities about recruitment and southern (MexCal) fishery fleet landing assumptions, which forecasted age 1+ biomass estimates of 14,456 tonnes (using recruitment averaged over 2010-2019), 32,647 tonnes (using recruitment averaged over 2005-2019) and 21,678 tonnes (using 2019-2020 fishing mortality approximately equal to 2018-2019 estimates from the 2020 base assessment).

From the 2020 base assessment model, the maximum likelihood estimate of age-1+ forecasted biomass in July 2020 was 28,276 tonnes. The CV around this estimate was 67%, demonstrating considerable uncertainty in the 2020 assessment process (Kuriyama et al. 2020).

DFO research trawl surveys, which are a source of sardine observations in BC waters, were cancelled in 2020 due to the COVID-19 pandemic and no sardine observations were reported in BC waters in 2020 from other sources. Prior to 2020, few or no sardines have been observed in BC waters from 2013 to 2019 in fisheries, surveys or from other sources, which is consistent with 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.

Although uncertainty associated with stock assessment results has increased given the absence of reliable information to update the assessment process in 2021, there is no evidence that the age-1+ Pacific Sardine stock biomass of the northern subpopulation has approached or

exceeded the cutoff of 150,000 tonnes in the last 5 years, nor is there evidence to show that sardine have been in BC waters in sufficient amounts since 2012 to support a fishery.

### 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 2020, with fishery closures from 2015 to 2020 (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  $\leq 1\%$  prior to 2009 to a peak in 2012 (between 5 and 6%), followed by 0% in 2013-2020 (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 fishery exploitation for years 2005-2020, where the 2020 estimate was a forecast. Total landings for 2002-2005 are from Hill et al. (2016) and total landings for 2006-2018 are from Kuriyama et al. (2020). Total landings in 2019 are from Kuriyama et al. (2021) and 2020 landing information is not available (hence NA). TAC, landings, and biomass values are in metric tonnes.*

Calendar 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	1,352,337	12.18%	0.24%
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%	0.11%
2008	12,491	10,435	112,959	1,313,490	6.77%	0.79%
2009	18,196	15,334	100,085	719,186	6.10%	2.13%
2010	23,166	22,223	97,876	506,747	5.98%	4.39%
2011	21,917	20,719	91,890	560,523	6.30%	3.70%
2012	27,279	19,129	121,950	365,815	8.83%	5.23%
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	33,834	35,186	19.03%	0.00%
2020	0	0	NA	28,276	67.03%	0.00%

**Uncertainties**

The absence of reliable information to update the assessment process for 2021 is a key uncertainty in the assessment. Related uncertainties associated with the 2020 and 2021 US NMFS assessment of the northern subpopulation of Pacific Sardine identified in Kuriyama et al. (2020, 2021), STAR (2020), and PFMC (2021) are:

1. A lack of 2020 acoustic-trawl survey information to estimate recent abundance and to obtain biological samples to represent size and age compositions;
2. Basing catch and biomass assignment between the northern and southern subpopulations of Pacific Sardine in California and Mexican waters on a surface water temperature (16.7°C) partitioning methodology;
3. Estimating catch near Ensenada and off the northwest coast of the Baja Peninsula in the terminal seasons of an assessment when actual catch data are not available in time to inform current stock assessment efforts;
4. Estimating catchability (Q) within and outside the acoustic-trawl survey area and assigning species identification and species target strength to acoustic trawl survey observations (when available);
5. A general lack of reliable age composition information to convert length composition data to age composition data in order to characterise spatial and temporal dynamics of the stock;
6. Nearshore CPSS survey methods and observations, such as: a) the use of purse seine point sets to ground truth visual estimates; b) limitations to the spatial and temporal range of the survey; c) the ability to collect biological samples to confirm species compositions;
7. The validity of CalCoFI temperature index to inform fishery management procedures; and
8. A lack of reliable methods to characterize or project recruitment abundance.

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

9. Unknown effects of setting harvest allowances independently of the US and Mexico;
10. Unknown effects of fisheries regionally targeting different age components of the population on stock structure and reproductive capacity;
11. Concerns about incidental capture of other species in the sardine fishery; and
12. Concerns about the effects of removing sardine from important foraging habitat of sardine predators.

**Harvest options**

At present, there is no evidence that the age-1+ Pacific Sardine stock biomass of the northern subpopulation has approached or exceeded the cutoff of 150,000 tonnes in the last 5 years, nor is there evidence to show that sardine have been in BC waters in sufficient amounts since 2012 to support a fishery.

**Conclusions**

Since the 150,000 tonne biomass cutoff value for age-1+ Pacific Sardine has not be reached, it is recommended that no allowable targeted harvest of Pacific Sardine occur in BC waters in 2021.

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