HARVEST ADVICE FOR PACIFIC SARDINE (*SARDINOPS SAGAX*) IN BRITISH COLUMBIA WATERS FOR 2016 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 a formal fishery closure in 2015.

To calculate potential harvest options for the BC sardine fishery, 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 (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 April 2015 US stock assessment forecasted age 1+ sardine biomass to be below the 150, 000t cutoff (Hill et al. 2015), resulting in a recommendation of zero harvest in BC waters for 2015. An updated US stock assessment of the northern subpopulation of Pacific Sardine was conducted and reviewed in March 2016. Results from that assessment include information on stock status and forecasts of age-1+ biomass informed by data sets representing fishery landings, biological sample data and fishery independent surveys for the period of January 1993 to December 2015 (Hill et al 2016).

DFO Fisheries Management requested that Science Branch incorporate the updated March 2016 US stock assessment results into the 2013 BC fishery harvest control rule and provide harvest advice for Pacific Sardine for the 2016 season. Specifically, this Science Response 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 2016 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.
2. Identify uncertainties associated with harvest advice.

A formal Canadian stock assessment will not be undertaken in 2016 and the following advice is based on multi-year method approved in 2013. As such, for a full understanding of Science recommendations, uncertainties, and future considerations, readers are referred the 2013 Canadian Science Advisory Secretariat (CSAS) Science Advice Report (DFO 2013).

This Science Response Report results from the Science Response process of April 2016 on Harvest Advice for Pacific Sardine (*Sardinops sagax*) in British Columbia Waters for 2016.

Background

Population assessment

The United States (US) Fisheries Service of the National Oceanic and Atmospheric Administration (NOAA) assesses the status and population trend of the Pacific Sardine northern subpopulation of the eastern Pacific Ocean (also knowns as the California Current Ecosystem stock) using a Stock Synthesis model (Methot and Wetzel 2013, Hill et al. 2014, Hill et al. 2016). Since 2014, the annual Pacific Sardine stock assessment process has been conducted and updated in the spring. The most recent assessment was conducted in March 2016 and was informed by data from fishery landings, biological data and fishery independent abundance surveys updated until December 2015 (Hill et al. 2016).

BC Pacific Sardine fishery harvest control rule

In 2013, DFO Fisheries Management adopted a harvest control rule that incorporates a current estimate (forecast) of the population's age-1+ biomass $B_{1+,t}$, an escapement buffer, or cutoff value, of 150,000 tonnes, and a harvest rate, *h*. 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 and the cutoff. 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 (in tonnes):

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

where TAC_t is the potential total allowable catch for a fishing season starting in year "*t*". When the forecast of age-1+ biomass ($B_{1+,\,t}$) is less than 150,000 tonnes the recommendation is that there should be no harvest.

This Science Response (SR) provides 2016 BC fishery harvest options based on the March 2016 US forecast for July 2016 age-1+ biomass.

Analysis and Response

Biomass

Recent estimates of the California Current Pacific Sardine age-1+ biomass show a decreasing trend since 2007 (Hill et al. 2016), and the 2010 to 2014 year classes are estimated as having some of the lowest recruitment on record. There is a high degree of uncertainty associated with the 2015 year class but there is an indication that it may be relatively high compared with 2010-2014.

The age-1+ biomass maximum likelihood estimate for the July 2016 forecast is 106,137 tonnes (75,826 – 136,448 tonnes, 90% credible interval, Hill et al. 2016).

Few or no sardines have been observed in BC waters during 2013-2015 from fisheries, surveys or other sources, suggesting curtailed migration and/or stock size. Estimates of mean 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, 2008-2014 show a decreasing trend from 2006 with no sardines observed in 2014, and a survey was not conducted in 2015.

BC fishery exploitation

The commercial BC sardine fishery was reinitiated in 2002 following closure since 1947 (Ware 1999, DFO 2012). Most fishing has occurred from July to October in association with seasonal migratory behaviour (DFO 2012). From 2002-2012, the annual total allowable catch (TAC), generally increased as a result of management decisions (DFO 2012). Landings were relatively low prior to 2008 (less than 5,000 tonnes), increased considerably from 2007-2012 (up to 22,223 tonnes in 2010) but were 0 in 2013 to 2015 due to an apparent absence of Pacific Sardine in BC waters and a fishery closure in 2015 (Table 1). Total landings (BC, Washington, Oregon, California and Ensenada Mexico) of the northern subpopulation were highest in 2007 at 133,518 tonnes and lowest in 2015 at 2,994 tonnes.

BC exploitation rates were estimated as the annual fishery landings (C_t) divided by the estimated age-1+ biomass in July. The exploitation rate on the stock due to fishing in BC waters increased from ≤ 1% prior to 2008 to approximately 5% in 2012 and 0% in 2013-2015 (Table 1). Apical F is the instantaneous fishing mortality rate for fully-selected fish as characterized by the Hill et al. (2016) stock assessment. Apical F was highest in 2002 (43.00%) and 2013 (40.75%) and lowest in 2015 (0.12%).

Table 1: Pacific Sardine fishery TAC in BC, landings in BC and total landings for the west coast of North America (BC, Washington, Oregon, California and Ensenada Mexico (northern subpopulation only)), as reported in Hill et al. (2016). Also shown are age-1+ population biomass estimates, 2002-2015, biomass coefficient of variation (CV), BC exploitation rate, and Apical F for total landings in the population. Total landings (2002-2015) and all July age-1+ biomass numbers are from Hill et al. (2016). Apical F estimates from Hill (pers. comm., 2016). All 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 ($C/B_{1+,\ July}$)	Apical *F*
2002	5,040	822	96,344	519,727	9.94%	0.16%	43.00%
2003	9,000	1,006	84,311	354,144	10.74%	0.28%	18.86%
2004	15,000	4,259	87,699	567,408	12.37%	0.75%	25.70%
2005	15,200	3,266	94,149	717,624	10.18%	0.46%	20.49%
2006	13,500	1,558	91,695	940,145	8.36%	0.17%	10.97%
2007	19,800	1,507	133,518	949,526	6.56%	0.16%	19.51%
2008	12,491	10,435	112,195	876,103	5.97%	1.19%	21.67%
2009	18,196	15,334	99,352	725,189	5.63%	2.11%	17.39%
2010	23,166	22,223	96,827	664,184	5.72%	3.35%	15.58%
2011	21,917	20,719	91,268	545,295	5.64%	3.80%	29.06%
2012	27,279	19,129	121,401	380,531	6.12%	5.03%	38.87%
2013	25,477	0	73,345	212,865	8.75%	0.00%	40.75%
2014	17,174	0	23,438	111,285	13.22%	0.00%	22.04%
2015	0	0	2,994	75,476	16.72%	0.00%	0.12%

Uncertainties

Uncertainties identified by Hill et al. (2016) in the recent US Pacific Sardine assessment include:

1. The 2015 summer acoustic-trawl survey (led by NOAA) detected a relatively large proportion of small sardine (i.e. less than 9 cm) off central California, indicating that the recruitment from the 2015 year class may have improved relative to previous years (2010-2014); however, there is uncertainty about the absolute levels of recruitment. The 2015 survey estimate of sardine biomass was the lowest since 2006. Given this low biomass and the "systematic overestimation of terminal-year recruitments in the past several assessments", the projected biomass was based on average recruitment during 2012-2014 (Hill et al. 2016).
2. The summer acoustic-trawl survey (led by NOAA) length composition information was omitted from the assessment due to concerns over shifts in selectivity.

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

3. Uncertainty regarding the effect of setting harvest allowances independently of the US and Mexico.
4. Unknown effects on stock structure and reproductive capacity from fisheries in different regions targeting different age components of the population.
5. Incidental capture of other species in the sardine fishery.
6. Effects of removing sardine from important forage habitat of sardine predators.

Harvest options

The July 2016 forecasted age-1+ biomass is 106,137 tonnes, which is below the fishery cutoff of 150,000 tonnes. Based on the harvest control rule adopted in 2013, the current recommendation is that there should be no allowable fishery harvest, thus, a TAC of 0 tonnes is recommended for the fishing season starting in 2016.

Conclusions

It is recommended that there should be no allowable targeted harvest in 2016.

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Sources of information

DFO 2012. Pacific Region Integrated Fisheries Management Plan for Pacific Sardine (June 1, 2012 to February 9, 2015). (Accessed July 6, 2016)

DFO 2013. Review of harvest control rules for Pacific Sardine and seasonal biomass and migration in British Columbia for 2013. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/037. (Accessed July 6, 2016)

Hill, K.T., Crone, P., Lo, N.C.H., Demer, D.A., Zwolinski, J.P., Dorval, E. and Macewicz, B.J. 2014. Assessment of the Pacific sardine resource in 2014 for U.S.A. management in 2014-15. Pacific Fishery Management Council, April 2014 Briefing Book, Agenda Item H.1.b. 182 p.

Hill, K.T., Crone, P., Dorval, E. and Macewicz, B.J. 2015. Assessment of the Pacific sardine resource in 2015 for U.S.A. management in 2015-16. Pacific Fishery Management Council, April 2015 Briefing Book, Agenda Item G.1.a.

Hill, K.T., Crone, P., Dorval, E. and Macewicz, B.J. 2016. Assessment of the Pacific sardine resource in 2016 for U.S.A management in 2016-17. Pacific Fishery Management Council, April 2016 Briefing Book, Agenda Item H.1.a.

Methot, Jr. R.D. and C.R. Wetzel. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142:86-99

Ware, D.M. 1999. Life history of Pacific sardine and a suggested framework for determining a B.C. catch quota. DFO Can. Sci. Advis. Sec. Res. Doc. 1999/204. 19 p. (Accessed July 6, 2016).

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