

Catch-only projection of the Pacific sardine resource in 2021 for U.S. management in 2021-2022

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## **Introduction**

The Pacific sardine resource is assessed annually in support of the Pacific Fishery Management Council's (PFMC) process of specifying annual catch levels for the U.S. fishery. The following catch-only projection was conducted to provide a biomass estimate for harvest specifications during the 2021-2022 fishing year. The projection model included finalized catches for calendar year 2019 and updated catches for 2020, semester 1, but does not include other fishery or survey data collected over the past year (there are no new survey data available). New years of fishery and survey data will be incorporated in the next update assessment.

## **Methods**

The following catch-only projection for 2021 management is based on data and methods described by Kuriyama et al. (2020), as reviewed by a Stock Assessment Review Panel in February 2020 and the Scientific and Statistical Committee in April 2020. The assessment projection was conducted using Stock Synthesis (SS v.3.30.14).

The projection model included sardine landings (metric tons) from six major fishing regions: Ensenada (ENS), southern California (SCA), central California (CCA), Oregon (OR), Washington (WA), and British Columbia (BC). Catch data for the fisheries off ENS, SCA, and CCA were pooled into a single "MexCal" fleet, and catch data from OR, WA, and BC were combined and treated as a single "PacNW" fleet in the model. The sardine model is based on a July-June model year, with two semester-based seasons per year (S1-July to December and S2-January to June).

**Table 1:** Finalized catch values for fleet by model year-semester (bolded columns). Preliminary values used in the 2020 benchmark assessment are adjacent to the bolded columns. The values in bolded columns show updated and finalized catch values for model year 2019, and new finalized catch values for model-year semester 2020-1. These values are data and not assumed values based on previous fishing activity.

Calendar Y-S	Model Y-S	MexCal_S1	<b>MexCal_S1</b>	MexCal_S2	<b>MexCal_S2</b>	PNW	<b>PNW</b>
2018-2	2019-1	130.86	<b>223.61</b>	0	<b>0</b>	7.73	<b>8.198</b>
2019-1	2019-2	0	<b>0</b>	11819.4	<b>33070.23</b>	2.51	<b>0.06</b>
2019-2	2020-1	--	<b>764.00</b>	--	<b>0</b>	--	<b>0.418</b>

The 2020 benchmark assessment used F values ( $\text{yr}^{-1}$ ; as opposed to catch) to forecast for 2021. The 2021 catch-only projection used this approach, and used similar assumptions to forecast for 2022. The values for model year-semester 2020-1 were data (indicated by bolding in Table 2), and the values for 2020-2, 2021-1, and 2021-2 assumed F values estimated from the most recent observations from 2019-2 (see Table 1). For model year-semesters 2020-2 and 2021-2 the most recent observations were from 2019-2. For model year-semester 2021-1, the most recent observations were from 2020-1. The F values used in the forecast file were those associated with catch values. The catch-only projection assumed, as in the 2020 benchmark assessment, that fishing activity remained constant from the most recent observations. Note, the F values estimated from the MexCal\_S2 catch value (33,070 mt) were estimated to be 4.0, which is the upper bound in the model.

**Table 2:** Catch values and associated F values used in the forecast file for the 2021 catch-only projection. The values for model year-semester 2020-1 were data (indicated by bolding), and the values for 2020-2, 2021-1, and 2021-2 assumed F values estimated from the most recent years of observation. For model year-semesters 2020-2 and 2021-2 the most recent observations were from 2019-2. For model year-semester 2021-1, the most recent observations were from 2020-1.

Calendar Y-S	Model Y-S	MexCal_S1		MexCal_S2		PNW	
		Catch	F ( $\text{yr}^{-1}$ )	Catch	F ( $\text{yr}^{-1}$ )	Catch	F ( $\text{yr}^{-1}$ )
<b>2019-2</b>	<b>2020-1</b>	<b>764</b>	<b>0.345</b>	<b>0</b>	<b>0</b>	<b>0.42</b>	<b>0</b>
2020-1	2020-2	--	0	--	4	--	0
2020-2	2021-1	--	0.345	--	0	--	0
2021-1	2021-2	--	0	--	4	--	0

In summary, details regarding the projection estimate are as follows:

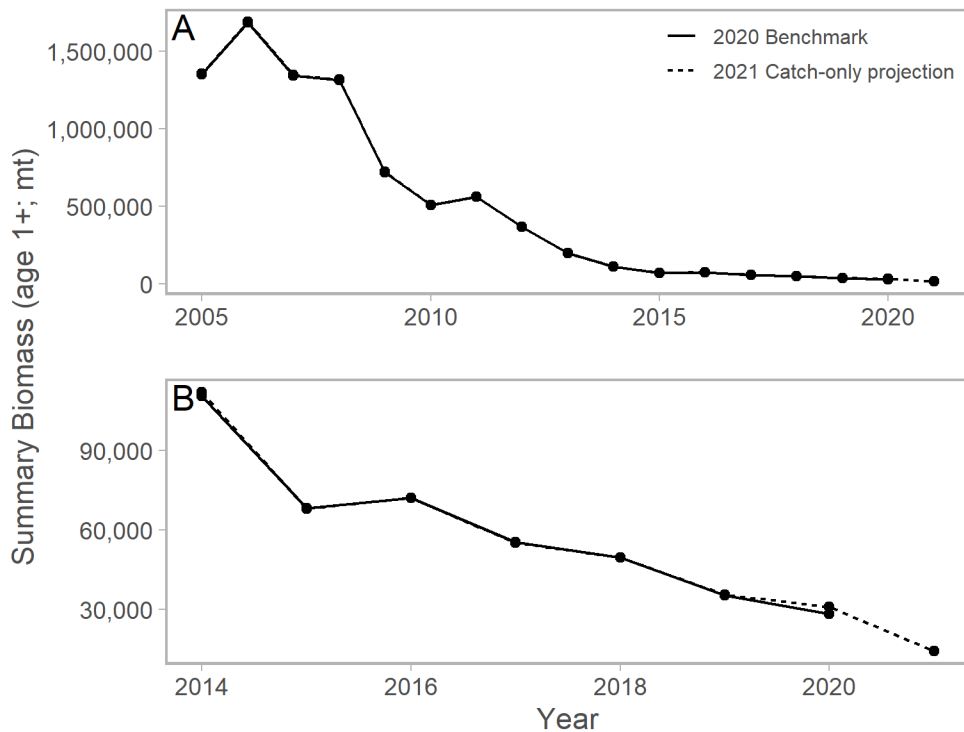
- Updated catch values associated with model year-semester 2019-1 and 2019-2 in the data file.
- Updated F values in the forecast file. F values for 2020-1 were calculated from an assessment run with catch values input in the forecast file. The 2020-1 calculated F values were then input to the forecast file. F values for 2020-2, 2021-1, and 2021-2 were

assumed to be the same as the F values from most recent data values (2019-2 for 2020-2 and 2021-2 and 2020-1 for 2021-1).

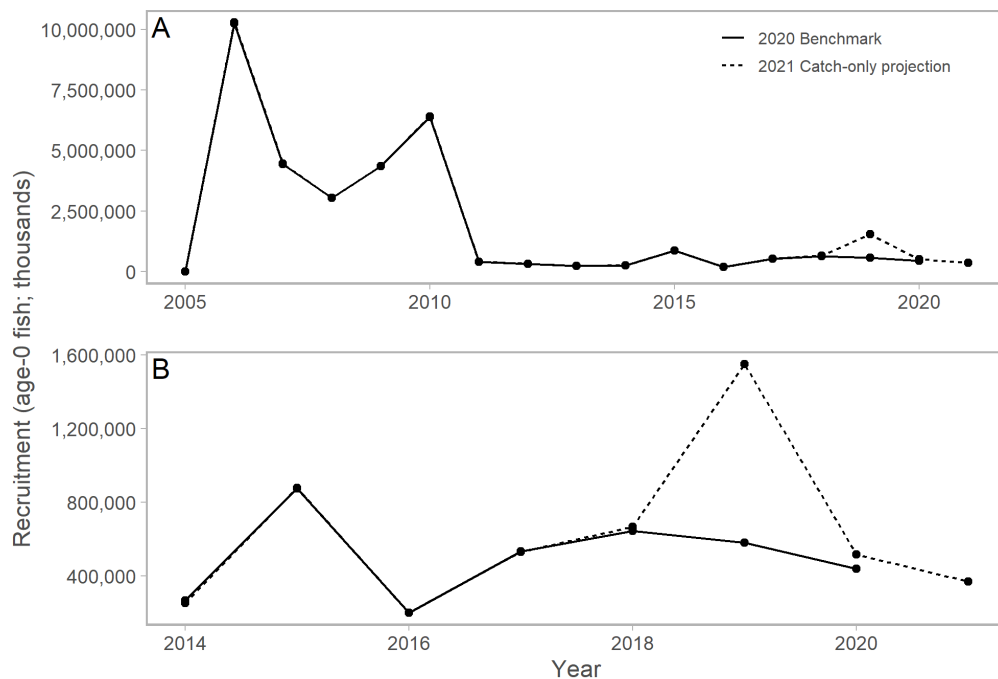
- No other data or parameterization changes were made to the assessment model.

## Results

Summary biomass (age 1+) for the 2021 fishing year is forecast to be 14,011 mt (Fig. 1), and recruitment is forecast to be 339 million age-0 fish (Fig. 2). The catch-only projection had a higher 2019 recruitment estimate than that from the 2020 benchmark assessment (Fig. 2), likely as a result of the finalized catch information from 2019. Specifically, the MexCal\_S2 catch amount was 33,070 mt, an increase over the preliminary value of 11,819 mt used in the 2020 benchmark assessment (Table 1). The 2021 forecast recruitment was estimated from the stock-recruit relationship (Fig. 2).



**Figure 1:** Time series of summary biomass (age 1+; mt) for the 2020 benchmark assessment (solid lines) and the 2021 catch-only projection (dashed lines). Panels are arranged by time series length (A: 2005-2021 and B: 2014-2021).



**Figure 2:** Time series of recruits entering the population (thousands of age-0 fish) for the 2020 benchmark assessment (solid lines) and the 2021 catch-only projection (dashed lines). Panels are arranged by time series length (A: 2005-2021 and B: 2014-2021).

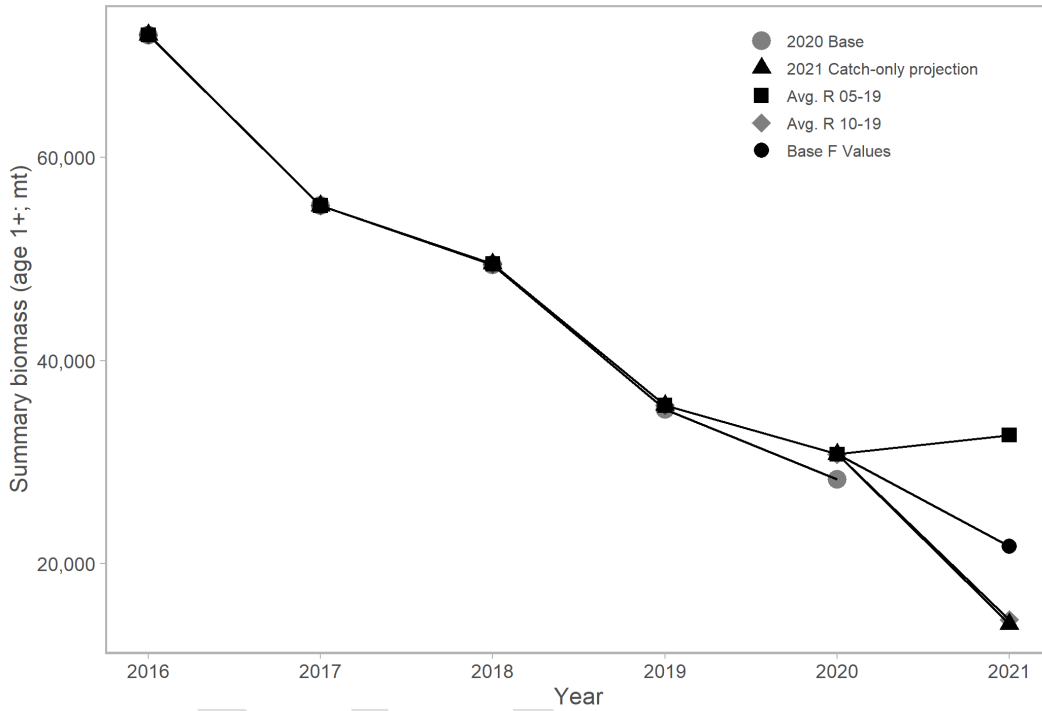
### Sensitivities

Sensitivities accounting for alternative assumptions about recruitment and uncertainties regarding MexCal catch values were evaluated. Two recruitment sensitivities assumed average recruitment from the years 2005-2019 (Avg. R 05-19) and from the years 2010-2019 (Avg. R 10-19). In the 2021 catch-only projection, recruitment was that calculated from the stock-recruit relationship. These recruitment scenarios represented the two recruitment scenarios evaluated in the sardine rebuilding plan (Hill et al. 2020). Another sensitivity run assumed that F values used in the forecast file were the same as those used in the 2020 benchmark (Base F). In this sensitivity, the primary change was that MexCal\_S2 F value was assumed to be 1.95 (value used for forecast in 2020 benchmark) instead of 4 (value calculated from updated data).

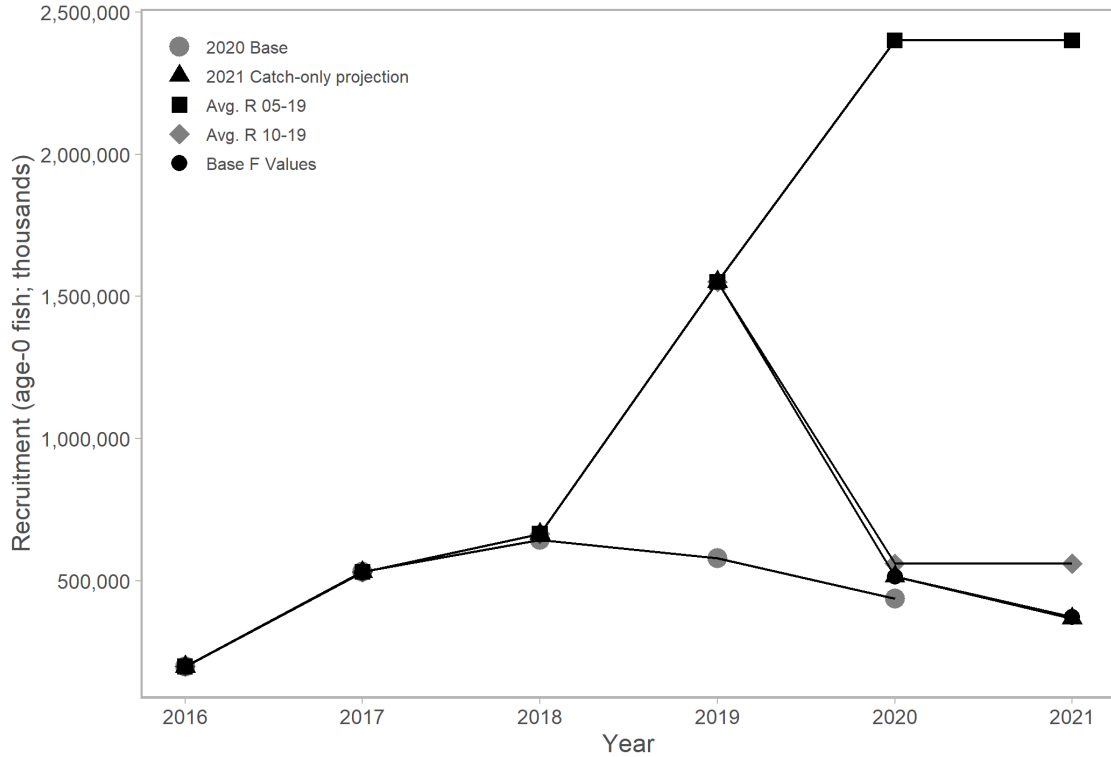
Summary biomass (age 1+) estimates were 32,647 mt for the Avg. R 05-19 scenario, 14,456 mt for the Avg. R 10-19 scenario, and 21,678 mt for the constant F scenario (Fig. 3). The summary biomass estimate from the 2021 catch-only projection was 14,011 mt.

The Avg. R 05-19 sensitivity is perhaps the least likely sensitivity scenario, as it calculates an average recruitment from a period that included high recruitment events in 2005-2010 (Fig. 2). Biomass levels are low, and it is likely that recruitment will continue to be low in the near term. The constant F scenario is more realistic, given potential uncertainties associated with recent

catches from the MexCal fleet. In prior assessments, the preliminary and final reported catch values have been comparatively close, and the recent difference (11,819 mt vs. 33,070 mt) is anomalous.



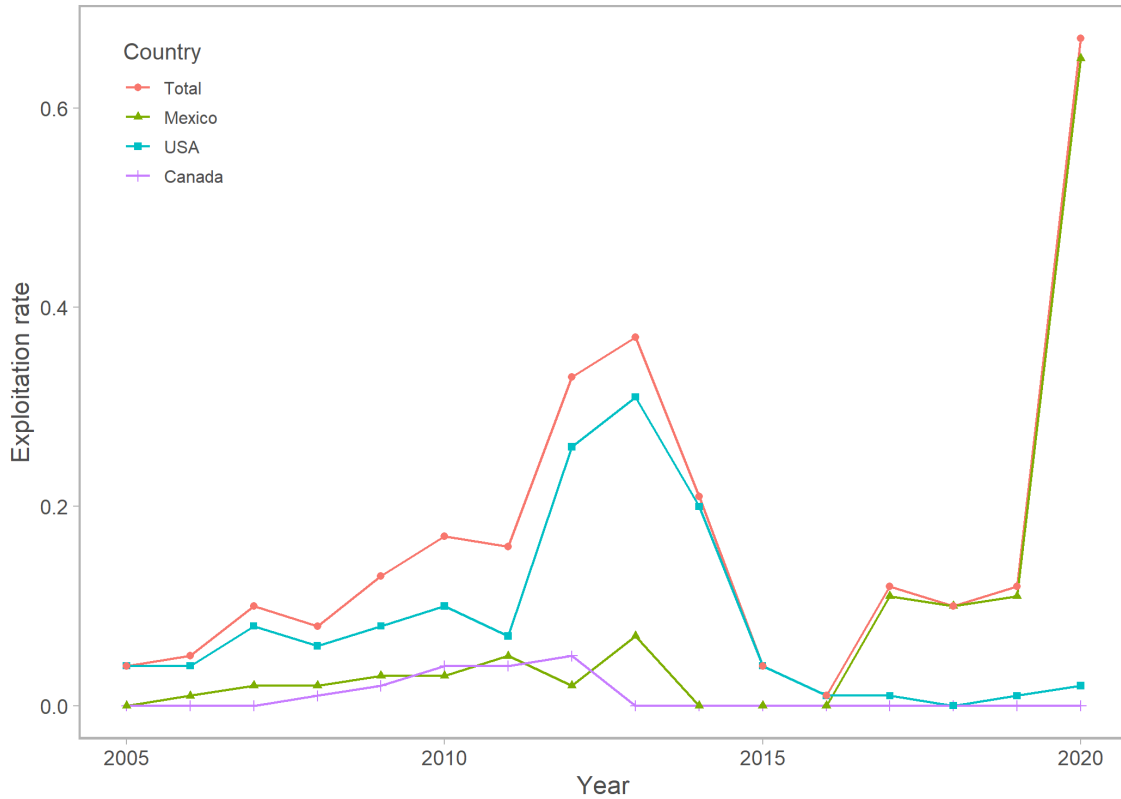
**Figure 3:** Time series of summary biomass (age 1+; mt) for the 2020 benchmark assessment (grey circles), 2021 catch-only projection (triangles), Avg. R 05-19 (squares), Avg. R 10-19 (grey diamonds), and Base F values (black circles). The 2021 catch-only projection and Avg. R 10-19 summary biomass values for 2021 are nearly identical and plotted on top of each other here.



**Figure 4:** Time series of recruits entering the population (thousands of age-0 fish) for the 2020 benchmark assessment (grey circles), 2021 catch-only projection (triangles), Avg. R 05-19 (squares), Avg. R 10-19 (grey diamonds), and Base F values (black circles).

### Exploitation status

Exploitation rate is defined as the calendar year catch divided by the total mid-year biomass (July-1, ages 0+). Based on the latest model and historic catches, the U.S. exploitation rate approached 2% and total exploitation (including Mexico and Canada landings) was about 67% during 2020. Catches from Mexico account for nearly all of the 2020 harvest, and have an exploitation rate of 65% (Fig. 5).



**Figure 5:** Plots of total exploitation rate (red) and exploitation rate by country. Countries shown are Mexico (green), U.S. (blue), and Canada (purple).

### Harvest control rules

The harvest guidelines are shown in the table below, based on the age 1+ biomass of 14,011 mt. The stock is below the 150,000 mt management threshold and the harvest guideline is 0 mt for the 2021 – 2022 fishing year. Acceptable biological catches for a range of P-star values are also shown in the table below (Tier 1  $\sigma=0.605$ ; Tier 2  $\sigma=1.0$ ).

<b>Harvest Control Rule Formulas</b>										
OFL = BIOMASS * $E_{MSY}$ * DISTRIBUTION; where $E_{MSY}$ is bounded 0.00 to 0.25										
ABC <sub>P-star</sub> = BIOMASS * BUFFER <sub>P-star</sub> * $E_{MSY}$ * DISTRIBUTION; where $E_{MSY}$ is bounded 0.00 to 0.25										
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION; where FRACTION is $E_{MSY}$ bounded 0.05 to 0.20										
<b>Harvest Formula Parameters</b>										
BIOMASS (ages 1+, mt)	<b>14,011</b>									
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05	
ABC Buffer(Sigma 0.582228)	0.93228	0.86817	0.80653	0.74631	0.68635	0.62523	0.56083	0.48914	0.39938	
ABC BufferTier 2	0.88191	0.77620	0.68023	0.59191	0.50942	0.43101	0.35472	0.27761	0.19304	
ABC BufferTier 3	0.77777	0.60248	0.46272	0.35036	0.25950	0.18577	0.12582	0.07707	0.03726	
CalCOFI SST (2018-2020)	16.0140									
EMSY	0.239680									
FRACTION	0.200000									
CUTOFF (mt)	150,000									
DISTRIBUTION (U.S.)	0.87									
<b>Harvest Control Rule Values (MT)</b>										
OFL =	<b>2,922</b>									
ABC(Sigma 0.607) =	2,724	2,537	2,356	2,180	2,005	1,827	1,639	1,429	1,167	
ABCTier 2 =	2,577	2,268	1,987	1,729	1,488	1,259	1,036	811	564	
ABCTier 3 =	2,272	1,760	1,352	1,024	758	543	368	225	109	
HG =	<b>0</b>									

### Recent management performance

US landings in the past years have remained below the annual catch limits (or annual catch targets, when applicable; Table 3). The 2020-2021 annual catch target for Pacific sardine, based on the 2020 benchmark assessment, was 4000 mt for Pacific sardine (Table 4). Landings-to-date of the northern subpopulation in the U.S. were 764 mt for 2020, 19% of the annual catch target. Note, March 2021 is still within the 2020-2021 fishing year.

**Table 3:** Summary biomass (age 1+), overfishing limit (OFL), allowable biological catch (ABC), annual catch limit (ACL), and annual catch target (ACT) values for recent fishing years. All units are in mt.

<b>Fishing-year</b>	<b>Summary Biomass</b>	<b>OFL</b>	<b>ABC</b>	<b>ACL</b>	<b>ACT</b>
2017-2018	86,586	16,957	15,497	8,000	
2018-2019	52,065	11,324	9,436	7,000	
2019-2020	27,547	5,816	4,514	4,514	4,000
2020-2021	28,276	5,525	4,288	4,288	4,000



**Table 4:** Annual catch limit (ACL), annual catch target (ACT) values, and catches from USA, Mexico, and Canada for recent fishing years. All units are in mt.

<b>Fishing-year</b>	<b>ACL</b>	<b>ACT</b>	<b>USA</b>	<b>Mexico</b>	<b>Canada</b>
2017-2018	8,000		372	6,032	0
2018-2019	7,000		655	11,210	0
2019-2020	4,514	4,000	705	32,589	0
2020-2021	4,288	4,000	764	0	0

## Uncertainties

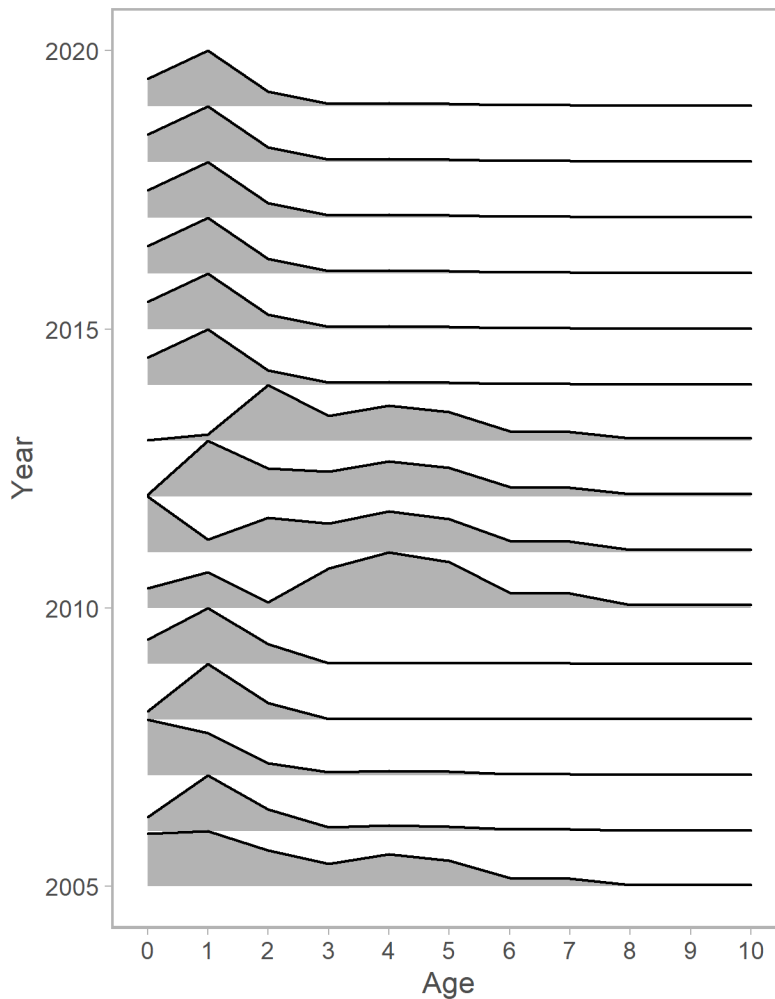
The high 2019 catch from Mexico and lack of 2020 biomass estimates due to cancellation of fishery-independent surveys in the past year contribute to the uncertainty of the catch-only projection. As a result, the uncertainties discussed in the 2020 benchmark assessment, such as the amount of nearshore biomass and proportion of northern subpopulation in Mexican waters remain. Specifically, the MexCal\_S2 F value of 4 is a major uncertainty, and the sensitivity assuming an F of 1.95 (also a very high number) provides a range of potential forecast biomass levels, both of which are below the 50,000 mt management threshold.

The 2021 summary biomass (age 1+) forecast from the 2020 benchmark assessment was 28,276 mt, and the MexCal\_S2 catches (applied to model year-semester 2019-2) were updated to be 33,070 mt. These numbers may seem to be biologically implausible but there are a number of factors to take into account. The 2021 catch-only projection estimated a larger recruitment event in 2019, and many of these recruits were then removed by the fishery.

The 2021 catch-only projection estimated a larger recruitment value for 2019 to fit to the updated catch values for 2019 (Table 5). The 2019-1 total biomass was estimated to be 103,697 mt in the 2021 catch-only projection instead of 60,689 mt as in the 2020 benchmark. Catch amounts were removed from the population according to the fleet-specific selectivity curves, which targeted primarily age-0 and age-1 fish (Fig. 6). The total biomass values for 2020-1 more similar than those from 2019-1, and the summary biomass values for 2019-1 and 2020-1 are also similar (Table 5).

**Table 5:** Total biomass (TB; age 0+) and summary biomass (SumB; age 1+) estimated from the 2020 benchmark assessment (2020bench) and 2021 catch-only projection (2021proj). All values are in mt.

Model Y-S	TB-2020bench	TB-2021proj	SumB-2020bench	SumB-2021proj
2018-1	62,012	62,516	49,449	49,528
2018-2	44,264	44,793	27,003	26,954
2019-1	60,689	103,697	35,186	35,591
2019-2	38,008	64,179	22,444	22,628
2020-1	47,548	53,428	28,276	30,758
2020-2	29,698	32,017	17,936	18,186
2021-1	NA	30,196	NA	14,011
2021-2	NA	18,626	NA	8,752



**Figure 6:** Time-varying age-based selectivity patterns for MexCal S2 fishing fleet in the 2020 benchmark assessment (Figure 24 in Kuriyama et al. 2020).

## **Research and data needs**

There have been no updates to the acoustic-trawl fishery data, thus uncertainty regarding nearshore biomass remains. There were no updates to the CCPSS aerial survey. The recommendations for the aerial survey included the need to coordinate visual estimates with randomly sampled purse-seine point sets, temporal rather than spatial replication, and sufficient biological sampling on mixed anchovy and sardine schools. The 2021 spring and summer acoustic-trawl surveys will make strides toward increasing nearshore coverage using acoustics in collaboration with the fishing industry.

## **References**

Hill, K.T., Kuriyama P. T., Crone, P.R. 2020. Pacific sardine rebuilding analysis based on the 2020 stock assessment. Pacific Fishery Management Council. Portland, OR.

Kuriyama, P.T., Zwolinski, J.P., Hill, K.T., Crone, P. R. 2020. Assessment of the Pacific sardine resource in 2020 for U.S. management in 2020-2021, U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-628.