

## Supplemental Appendix to Pacific sardine benchmark stock assessment

March 29, 2024

The STAT realized that an index value from the AT survey was incorrectly included in the 2024 benchmark assessment. The AT survey biomass estimate from spring calendar year 2021 (model year-semester 2020-2) observed 1,409 mt of Pacific sardine in the core area and 24,960 mt in the nearshore area (Table 9.6 of [Agenda Item I.3, Attachment 1](#)) and when first included as a preliminary estimate in the 2022 Pacific sardine update assessment, these were considered northern subpopulation sardine. Thereafter Zwolinski *et al.* (2023) attributed these observations to the southern subpopulation based on the habitat model at the time. The updated habitat model (Zwolinski and Demer 2023) continues to attribute this biomass to the southern subpopulation as well.

The STAT has dropped the model year-semester 2020-2 biomass estimate from the base model (Table 1). Steepness remains fixed at 0.6, as the likelihood profile for steepness showed that a value of 0.6 is still within the 95% confidence interval (Figure 1). Summary biomass (age-1+; mt) estimates and recruitment estimates (and uncertainties) are shown in Table 2. Comparisons between previous base model (includes 2020-2 AT biomass) and current base model (drops 2020-2 AT biomass) for summary biomass are shown in Figure 2 and Table 3. Recruitment estimates from the two models are shown in Figure 3 and Table 4. Fits to the AT survey index are shown in untransformed and log space in Figures 4 and 5, respectively.

The current base model stock biomass forecast is 58,614 mt for July 1, 2024. The OFL for the base model in the Briefing Book was 8,002 mt (Table 5) and the OFL for the revised base model is 8,312 mt (Table 6).

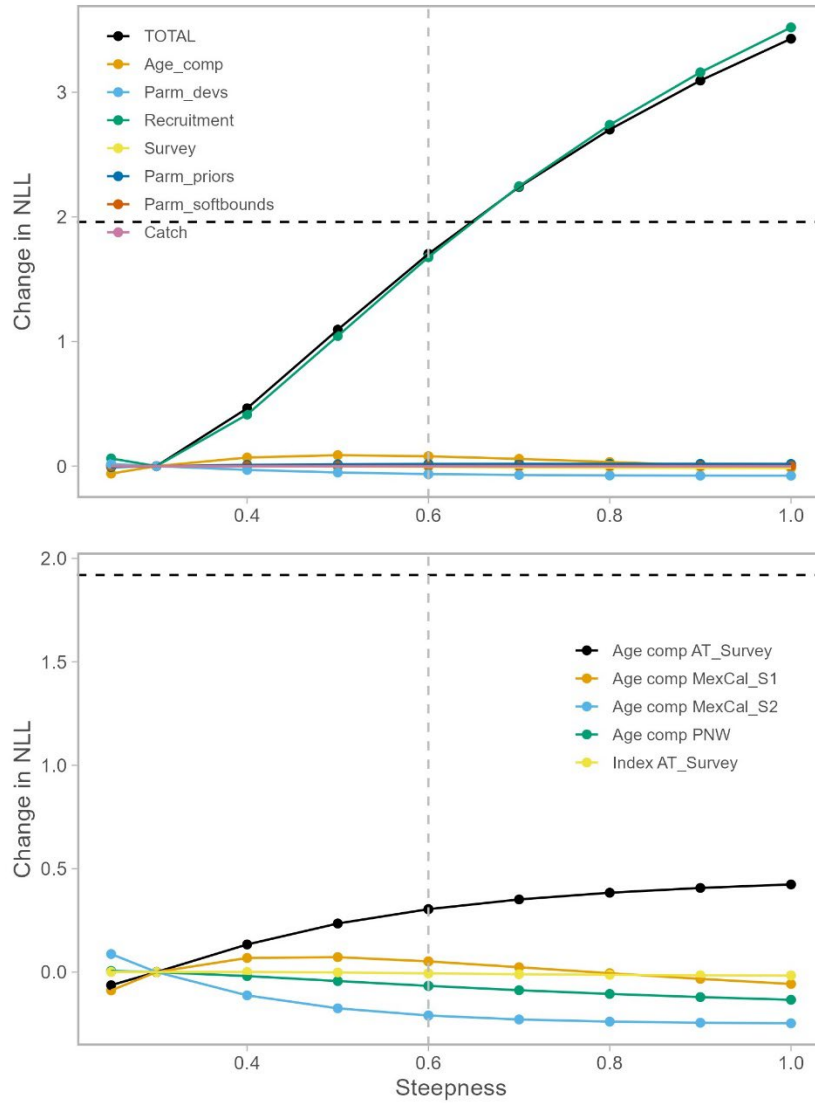


Figure 1: Likelihood profile across fixed values of steepness ( $h$ ) for likelihood components (top plot) and fleet-specific likelihood components (bottom) for the revised base model. Steepness was fixed at 0.6 in the 2024 base model (vertical dashed line). Values within 1.92 units of the MLE (dashed horizontal line) are within the 95% confidence interval.

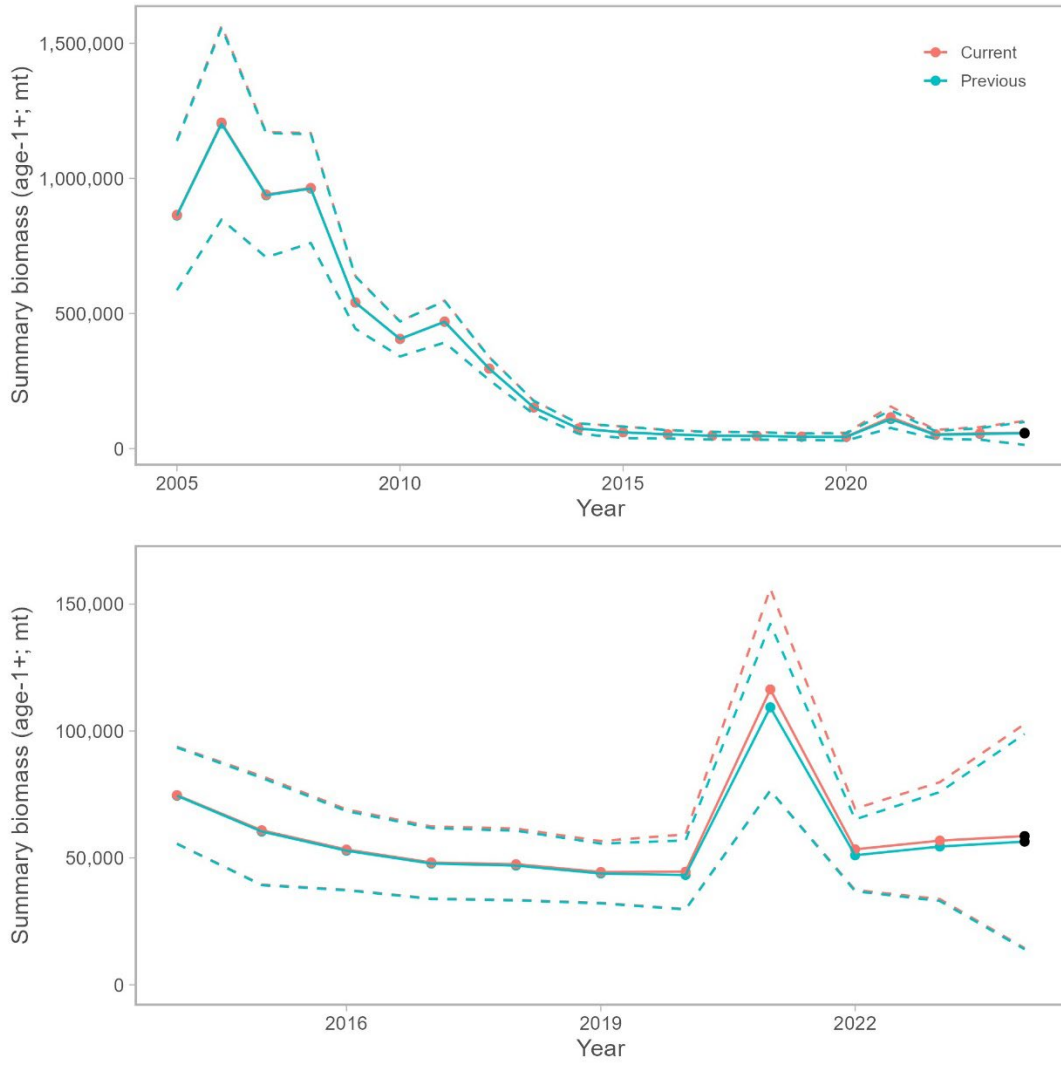


Figure 2: Summary biomass (age-1+; mt) estimates from the base model in the Briefing Book (includes 2020-2 AT biomass; blue) and the revised base model (drops 2020-2 AT biomass; red). Black points indicate values based on recruitment values from the stock-recruit relationship.

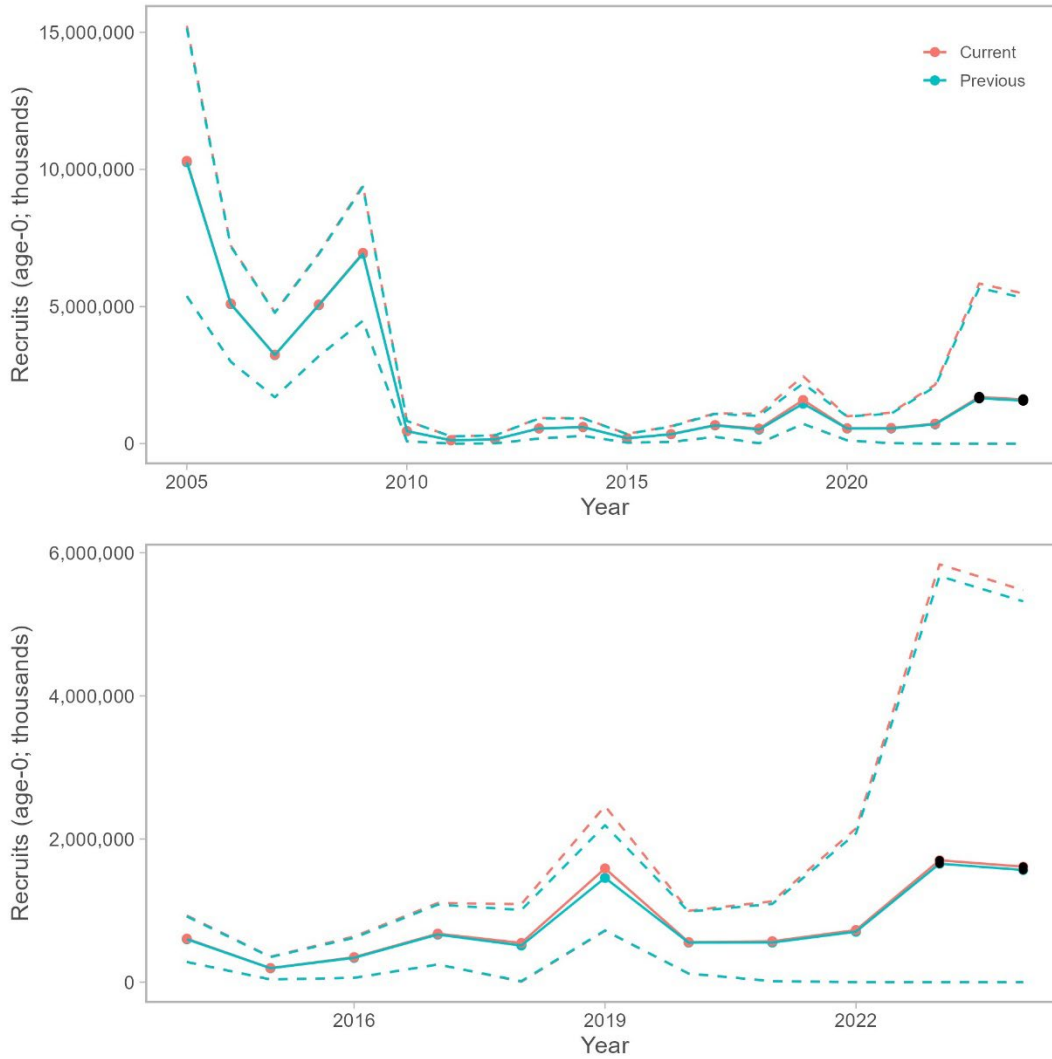


Figure 3: Recruitment (1000s fish) estimates from the base model in the Briefing Book (includes 2020-2 AT biomass; blue) and the revised base model (drops 2020-2 AT biomass; red). Black points indicate values based on recruitment values from the stock-recruit relationship.

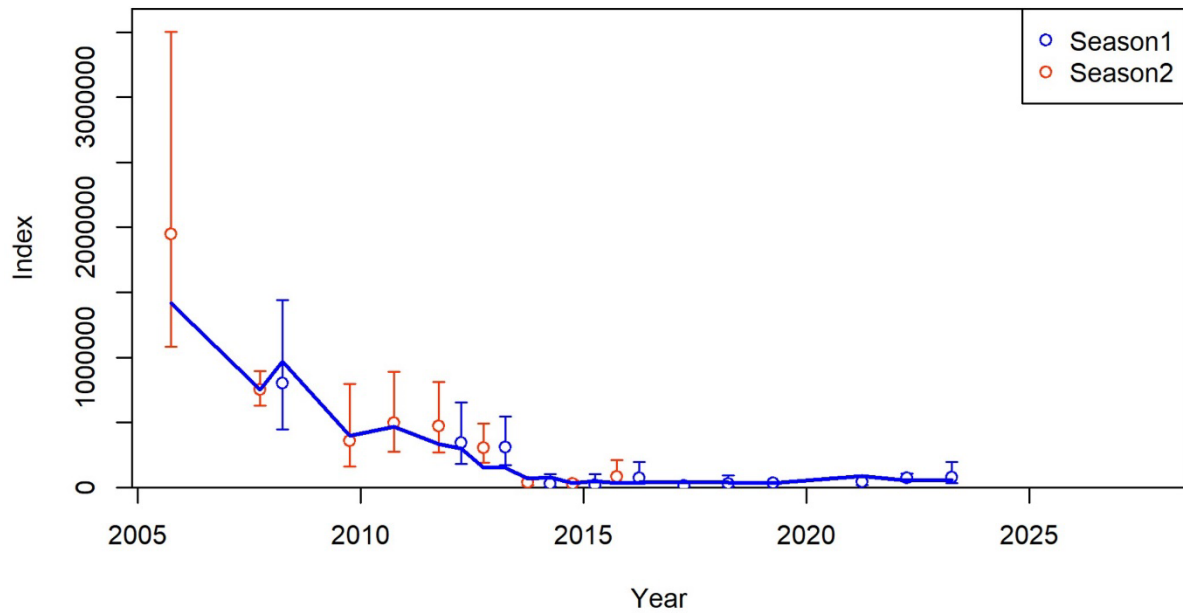
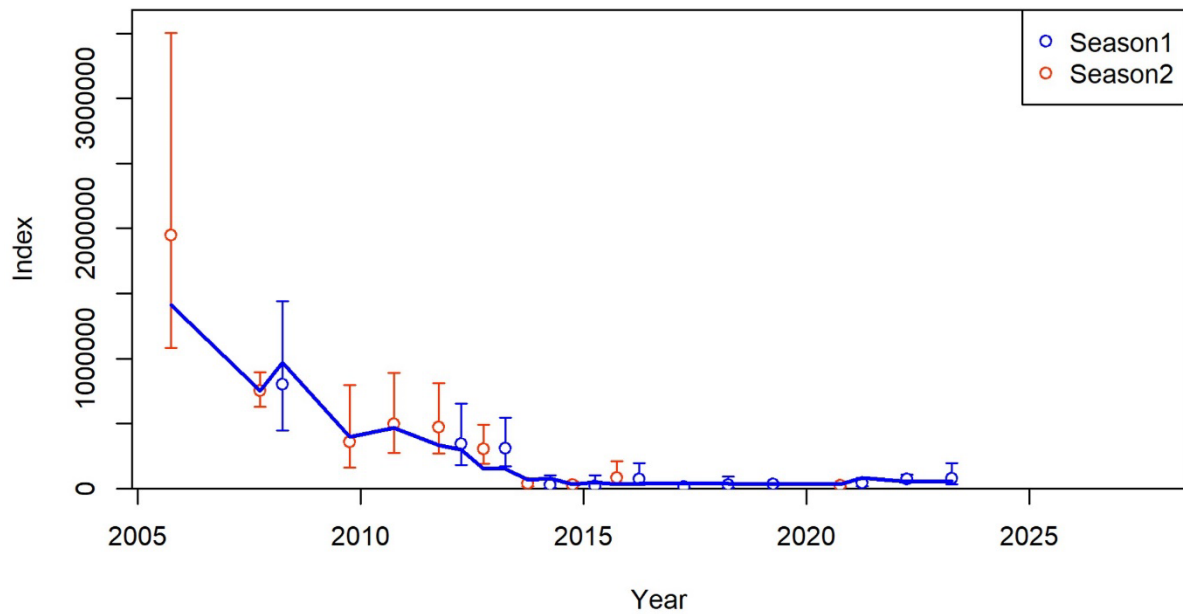


Figure 4: Fits to index data for AT survey for the base model in the Briefing Book (include 2020-2 AT biomass; top panel) and revised base model (drop 2020-2 AT biomass; bottom panel). Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error.

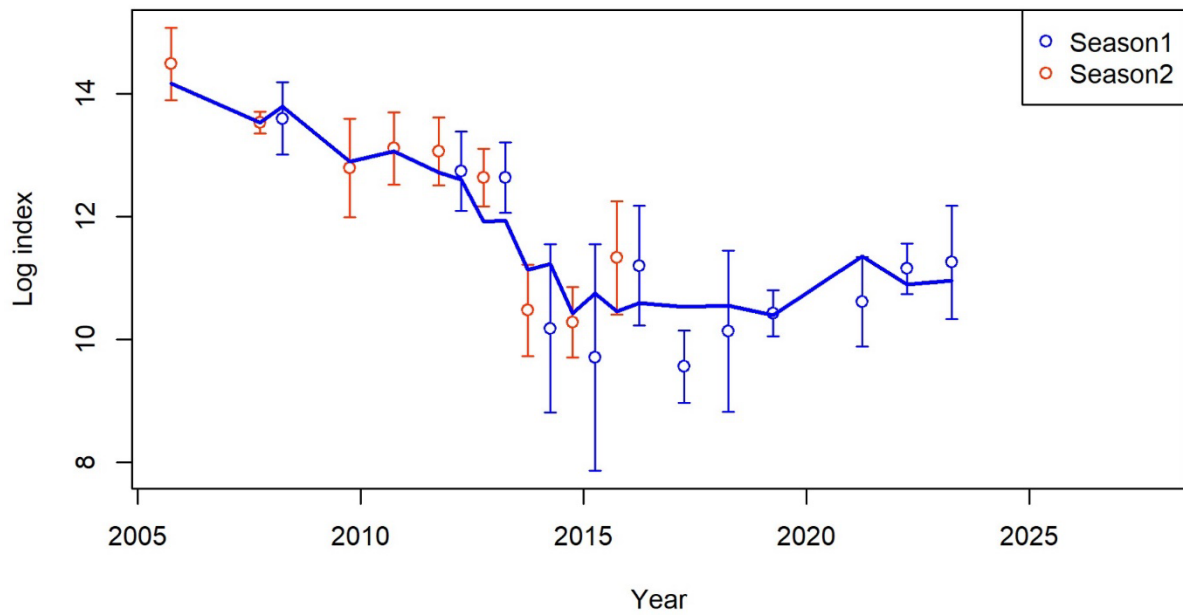
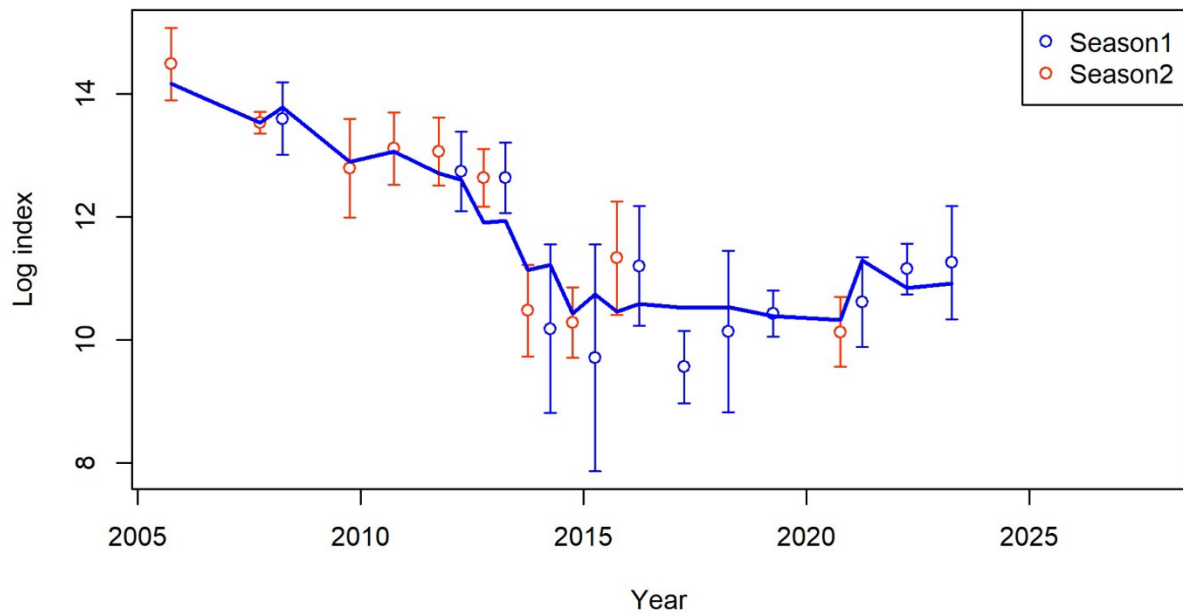


Figure 5: Fits to log index data for AT survey for the base model in the Briefing Book (include 2020-2 AT biomass; top panel) and revised base model (drop 2020-2 AT biomass; bottom panel). Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error.

Table 1: Fishery-independent indices of abundance for Pacific sardine from the AT survey, nearshore component of the AT survey, and aerial biomass estimates. The nearshore methods include model extrapolation (Ext), unmanned surface vehicles (USV), and fishing vessel acoustic purse-seine methods (F/V). Values in the first row of model year-semester 2022-1 values correspond to Lasker core, and the second row are from Lisa Marie core. The model year-semester 2023-1 survey values are preliminary. Values from the AT survey core and nearshore components (and nearshore method), and aerial survey are shown. The AT biomass, CVs, and Q values used as input in the base model are shown in the final three columns. Values associated with 2020-2 are dropped in the current base model.

Model Y-S	AT Core	AT CV	AT Nearshore	Near. CV	Method	Aerial	AT Input	CV	Qadj
2005-2	1,947,060	0.3	--	--	--	--	1,947,060	0.3	1
2006-1	--	--	--	--	--	--			--
2006-2	--	--	--	--	--	--			--
2007-1	--	--	--	--	--	--			--
2007-2	751,075	0.09	--	--	--	--	751,075	0.09	1
2008-1	801,000	0.3	--	--	--	--	801,000	0.3	1
2008-2	--	--	--	--	--	--			--
2009-1	--	--	--	--	--	--			--
2009-2	357,006	0.41	--	--	--	--	357,006	0.41	1
2010-1	--	--	--	--	--	--			--
2010-2	493,672	0.3	--	--	--	--	493,672	0.3	1
2011-1	--	--	--	--	--	--			--
2011-2	469,480	0.28	--	--	--	--	469,480	0.28	1
2012-1	340,831	0.33	--	--	--	--	340,831	0.33	1
2012-2	305,146	0.24	--	--	--	--	305,146	0.24	1
2013-1	306,191	0.293	--	--	--	--	306,191	0.29	1
2013-2	35,339	0.38	--	--	--	--	35,339	0.38	1
2014-1	26,279	0.697	--	--	--	--	26,279	0.7	1
2014-2	29,048	0.29	--	--	--	--	29,048	0.29	1
2015-1	16,375	0.94	452	0.32	Ext	--	16,375	0.94	0.733
2015-2	83,030	0.47	--	--	--	--	83,030	0.47	0.733
2016-1	72,867	0.497	1,403	0.42	Ext	--	72,867	0.5	0.733
2016-2	--	--	--	--	--	--			--
2017-1	14,103	0.3	146	0.57	Ext	--	14,103	0.3	0.733
2017-2	--	--	--	--	--	--			--
2018-1	25,148	0.67	308	0.86	USV/Ext	--	25,148	0.67	0.733
2018-2	--	--	--	--	--	--			--
2019-1	33,632	0.19	494	0.28	F/V	12,279	33,632	0.19	0.733
2019-2	--	--	--	--	--	--			--
2020-1	--	--	--	--	--	--			--
2020-2	--	--	--	--	--	18,409			--
2021-1	40,528	0.37	443	0.42	F/V	14,942	40,528	0.37	0.733
2021-2	--	--	--	--	--	--			--
2022-1	10,795	0.28	15,765	0.23	F/V	--	69,506	0.21	1
2022-1	42,946	0.32	--	--	--	--	--	--	--
2022-2	--	--	--	--	--	--			--
2023-1*	49,643	0.79	27,610	--	F/V	--	77,252	0.47	1

Table 2: Summary biomass (age-1+; mt) and recruitment (1000s fish) estimates and uncertainties from the revised base model (drops 2020-2 AT biomass).

Year	SummBio	SummBioSD	Recruitment	RecSD
2005	865,278	141,965	10,310,600	2,513,570
2006	1,206,690	182,485	5,104,020	1,079,660
2007	940,323	118,169	3,242,180	790,659
2008	964,881	103,663	5,071,680	956,872
2009	541,532	49,667	6,955,380	1,258,020
2010	406,551	33,159	458,216	190,657
2011	470,496	39,461	124,023	73,009
2012	296,612	21,594	156,313	74,869
2013	152,601	12,540	558,439	189,929
2014	74,737	9,726	607,810	165,156
2015	60,880	10,909	196,999	81,228
2016	53,302	8,066	348,990	147,353
2017	48,217	7,238	677,292	218,823
2018	47,524	7,170	547,956	276,593
2019	44,465	6,205	1,588,620	444,842
2020	44,581	7,507	559,253	223,672
2021	116,358	20,266	571,405	284,496
2022	53,391	8,164	727,951	724,397
2023	56,811	11,749	1,702,470	2,110,090
2024	58,614	22,511	1,613,080	1,971,300



Table 3: Summary biomass (age-1+; mt) estimates from the base model in the Briefing Book (includes 2020-2 AT biomass) and the revised base model (drops 2020-2 AT biomass). The difference between estimates is also shown.

Year	Previous	Current	Difference
2005	862,601	865,278	2,677
2006	1,202,530	1,206,690	4,160
2007	937,636	940,323	2,687
2008	962,485	964,881	2,396
2009	540,396	541,532	1,136
2010	405,766	406,551	785
2011	469,406	470,496	1,090
2012	295,977	296,612	635
2013	152,249	152,601	352
2014	74,489	74,737	248
2015	60,389	60,880	492
2016	52,841	53,302	461
2017	47,783	48,217	434
2018	46,988	47,524	536
2019	43,870	44,465	596
2020	43,279	44,581	1,302
2021	109,333	116,358	7,025
2022	51,055	53,391	2,336
2023	54,484	56,811	2,326
2024	56,428	58,614	2,186

Table 4: Recruitment (1000s fish) estimates from the base model in the Briefing Book (includes 2022-2 AT biomass) and the revised base model (drops 2020-2 AT biomass). The difference between estimates is shown as well.

Year	Previous	Current	Difference
2005	10,262,000	10,310,600	48,600
2006	5,084,250	5,104,020	19,770
2007	3,228,620	3,242,180	13,560
2008	5,051,120	5,071,680	20,560
2009	6,923,490	6,955,380	31,890
2010	455,723	458,216	2,493
2011	123,227	124,023	796
2012	155,321	156,313	992
2013	550,742	558,439	7,697
2014	599,672	607,810	8,138
2015	194,170	196,999	2,829
2016	339,649	348,990	9,341
2017	664,696	677,292	12,596
2018	511,669	547,956	36,287
2019	1,457,560	1,588,620	131,060
2020	552,397	559,253	6,856
2021	553,363	571,405	18,042
2022	705,235	727,951	22,716
2023	1,655,520	1,702,470	46,950
2024	1,567,400	1,613,080	45,680

Table 5: Pacific sardine harvest control rules for fishing year 2024-2025 for the base model in the Briefing Book that included the 2020-2 AT survey biomass ([Figure 1.4 of I.3, Attachment 1](#)).

<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>56,428</b>								
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC Buffer <sub>Tier1</sub>	0.9225	0.8499	0.7809	0.7142	0.6486	0.5827	0.5142	0.4393	0.3480
ABC Buffer <sub>Tier2</sub>	0.8510	0.7224	0.6098	0.5101	0.4208	0.3395	0.2644	0.1930	0.1211
ABC Buffer <sub>Tier3</sub>	0.7243	0.5219	0.3719	0.2602	0.1770	0.1153	0.0699	0.0373	0.0147
CalCOFI SST (2021-23)	15.597								
$E_{MSY}$	0.163								
FRACTION	0.163								
CUTOFF (mt)	150,000								
DISTRIBUTION (U.S.)	0.87								
<b>Harvest Control Rule Values (MT)</b>									
OFL =	<b>8,002</b>								
ABC <sub>Tier1</sub> =	7,382	6,801	6,249	5,715	5,190	4,663	4,115	3,515	2,785
ABC <sub>Tier2</sub> =	6,810	5,781	4,880	4,082	3,367	2,717	2,116	1,544	969
ABC <sub>Tier3</sub> =	5,796	4,176	2,976	2,082	1,416	923	559	298	118
HG =	<b>0</b>								

Table 6: Pacific sardine harvest control rules for fishing year 2024-2025 for the revised base model.

<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>58,614</b>								
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC Buffer <sub>Tier1</sub>	0.9225	0.8499	0.7809	0.7142	0.6487	0.5827	0.5142	0.4394	0.3480
ABC Buffer <sub>Tier2</sub>	0.8510	0.7224	0.6098	0.5101	0.4208	0.3395	0.2644	0.1930	0.1211
ABC Buffer <sub>Tier3</sub>	0.7243	0.5219	0.3719	0.2602	0.1770	0.1153	0.0699	0.0373	0.0147
CalCOFI SST (2021-23)	15.597								
$E_{MSY}$	0.163								
FRACTION	0.163								
CUTOFF (mt)	150,000								
DISTRIBUTION (U.S.)	0.87								
<b>Harvest Control Rule Values (MT)</b>									
OFL =	<b>8,312</b>								
ABC <sub>Tier1</sub> =	7,668	7,064	6,491	5,936	5,392	4,843	4,274	3,652	2,893
ABC <sub>Tier2</sub> =	7,074	6,005	5,069	4,240	3,498	2,822	2,198	1,604	1,007
ABC <sub>Tier3</sub> =	6,020	4,338	3,091	2,163	1,471	958	581	310	122
HG =	<b>0</b>								

## References

- Zwolinski, J. P., and Demer D. A. 2023. An updated model of potential habitat for northern stock Pacific Sardine (*Sardinops sagax*) and its use for attributing survey observations and fishery landings. Fisheries Oceanography. doi:[10.1111/fog.12664](https://doi.org/10.1111/fog.12664).
- Zwolinski, Juan P., Renfree J. S., Stierhoff K. L., and Demer, D.A. 2023. Distribution, biomass, and demographics of coastal pelagic fishes in the California Current Ecosystem during spring 2021 based on acoustic-trawl sampling. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-675. doi:[10.25923/zvzf-3306](https://doi.org/10.25923/zvzf-3306).