Scientific and Statistical Committee
Coastal Pelagic Species Subcommittee
Review of the draft update assessment of the Pacific sardine resource in 2025 for U.S. management in 2025-2026

Online
February 26, 2025

The Coastal Pelagic Species Subcommittee (CPSSC) of the Scientific and Statistical Committee (SSC) met via webinar on 26 February 2025 to review the 2025 stock assessment update for the Northern Subpopulation (NSP) of Pacific Sardine as well as additional analyses to support the assessments and application of harvest control rules for the NSP. SSC participants are listed in Appendix A and the report sections reference the meeting's agenda items.

1. CALIFORNIA COASTAL PELAGIC SPECIES SURVEY FOR 2024

Kirk Lynn (California Department of Fish and Wildlife) presented the biomass estimates from the 2024 aerial survey. These estimates were not included in the 2024 full assessment. Although the southern end of NSP distribution was extended southward to Point Conception based on the updated habitat model, the biomass in the NCA survey area was not used in this update assessment.

It was noted that the biomass estimate for the 2024 summer Northern California (NCA) area was much higher than those of the previous years (Table 1), which was also observed in the nearshore portion of the Acoustic Trawl (AT) survey. The 2024 NCA aerial survey estimate is precise (coefficient of variation, CV of 0.09). This may warrant a review of the biomass estimation procedure in the future.

2. CPS SURVEY METHODS AND RESULTS

Kevin Stierhoff (Southwest Fisheries Science Center [SWFSC]) summarized the 2024 AT survey for CPS, including the estimates of biomass for the NSP. Results are still considered preliminary but are not likely to change. The survey was conducted over 85 days at sea from Punta Eugenia (Baja California) to Vancouver Island (British Columbia) on the NOAA ship Reuben Lasker, with additional sampling in nearshore areas from the fishing vessels *Lisa Mari*e and *Long Beach Carnage*. There was good coordination among the various platforms with respect to timing of data collection. The survey observed most of the NSP biomass in the nearshore cooperative survey, with only 337 mt observed in the core area (surveyed by the Lasker) vs. 77,412 mt (~99.6%) nearshore.

This was the first year that the Multi-Function Trawl (MFT) was used on the Lasker for biological sampling within the core area, replacing the Nordic 264 net. This change precipitates the move from separate CPS and Pacific hake surveys to a joint coastwide survey, which will begin in 2025. Relative to the Nordic 264, the MFT is wider and taller, with a larger mouth opening that should reduce escapement of smaller fish in the large mesh sections (forward sections) of the net. Due to the greater size, the MFT takes longer to deploy, and so tow durations were reduced (from 45 to

30 minutes) in the 2024 survey to ensure that the target number of trawls could be deployed each night of sampling. For the AT survey, there have not been paired fishing trials to evaluate the relative catchability and selectivity of the two nets, although limited comparative trials were conducted for the Pacific hake survey. Given the potential differences between the nets and how they are deployed, there is a need for further research to compare the selectivity of the nets in terms of both size and species. However, this does not appear to be of great concern this year given that less than 0.5% of the biomass was found in the area surveyed by the Lasker in 2024. A review of the integrated survey that should include consideration of gear trials and selectivity differences is anticipated for early 2026.

As purse seine catches in the nearshore portion of the survey were sparse in some areas, nearshore sampling was occasionally augmented with the nearest trawl (core area) cluster when apportioning the nearshore biomass to species. To assign sardine biomass to NSP, the habitat model used in the past assessment (Zwolinski and Demer, 2024) was applied, and results indicated that the primary break between the NSP and the southern subpopulation (SSP) was approximately Point Conception. Differences in modal lengths between the two subpopulations were also noted in the 2024 data. For the purposes of this analysis, all sardines identified in NSP habitat (including those later determined to be Japanese sardine) were considered to be NSP.

3. JAPANESE SARDINE GENETICS RESULTS FROM THE 2024 SUMMER CPS SURVEY

Matthew Craig (SWFSC) provided a presentation of the presence of Japanese sardine in the California Current Large Marine Ecosystem in 2024, analyzed using genetic methods. A very distinct genetic group was identified in 2022 as Japanese sardine through genotyping using sequencing. The distribution of sampled Japanese sardine was found to extend coastwide during 2024. The percent of samples analyzed that were assigned to Japanese Sardine was 41.8% in 2022 and 40.5% in 2023 but has declined to 18.3% in 2024. Not all locations were sampled for genetics, including the nearshore Southern California Bight, where only 170 of 1,300 fish were sampled for genetic analysis. Although sampling was not synoptic, ageing indicates that a cohort of Japanese sardine is moving through the population, as the predominant age has increased over time from 2022-2024. That said, the lack of sampling in the Southern California Bight may have prevented identification of more recent recruitment.

Japanese sardine are being accounted for in the survey biomass estimate as Pacific sardine when located in the proper habitat for the NSP as designated by the Habitat Model, since they are not easily visually differentiated and not all sampled individuals are genotyped. No filters were applied to remove Japanese sardine from the weight-at-age or age-composition data included in the update assessment (consistent with how Japanese sardine were treated in the 2024 benchmark assessment).

A habitat model was applied using temperature thresholds for Japanese sardine, which shows that there was suitable habitat in the Arctic Pacific and Bering Sea providing a bridge that could have facilitated movement of Japanese sardine to the eastern Pacific during 2022 (Longo et al., 2024). Evidence from recent research in Russian trawl surveys showed that the prevalence of sardine increased from 50% to 75% in 2022, indicative of a recent migration event to the eastern Pacific during this period of suitable conditions (Longo et al., 2024). Strong recruitment in Washington

in bays in 2024 provided 800 samples, all of which were genotyped as Pacific sardine, which, together with other information provided in the briefing materials, may suggest that the recent introduction could dissipate over time. Concerns persist regarding whether hybridization would result in either outbreeding depression with fitness effects, neutral impact on productivity, or hybrid vigor (heterosis).

4. PACIFIC SARDINE STOCK ASSESSMENT UPDATE

Caitlin Allen Akselrud (SWFSC) presented the 2025 stock assessment update for the NSP on behalf of the Stock Assessment Team. Juan Zwolinski (University of California Santa Cruz) also participated in the discussion and answered questions about the assessment.

The stock assessment update that estimated projected 1+ biomass for 1 July 2025 was based upon the February 2024 benchmark assessment and the base model agreed upon at the end of the review meeting (model 2025.1d, Appendix A of the draft assessment report). It included:

- new Acoustic-Trawl (AT) survey index data and age-composition and weight-at-age data for summer 2024 (model year 2024-1);
- updated fishery age-composition and weight-at-age data for model year-semester 2023-1 (July-December 2023);
- new fishery age-composition and weight-at-age data for model year-semester 2023-2 (January-June 2024);
- new catch data for January-June 2024 (model year 2023-2; assumed projection value in last assessment) and July-December 2024 (model year 2024-1), along with an assumption about fishing mortality for model year-semester 2024-2;
- a corrected 2023 survey age-composition input sample size (17 rather than 9 in the 2024 assessment).

There was concern about the representativeness of the age and conditional weight-at-age samples from the 2024 survey (most of these data came from 98 aged individuals from two purse seine sets), as well as the inclusion of potentially substantial numbers of Japanese sardines contributing to these data, and thus the base model in the draft assessment presented to the CPSSC excluded these data. However, the result was a 2024 recruitment estimate coming from the spawner-recruit curve, which was higher than recent estimated recruitments; inclusion of the 2024 AT survey weight-at-age and age-composition data resulted in a recruitment estimate more in line with those recent recruitments. Inclusion of the 2024 AT survey age and weight-at-age data is the default approach for an update assessment. The stock assessment team (STAT) agreed to include those data in the base model, and the CPSSC reviewed this model (25.1d) as the proposed base model for the 2025 update assessment.

Forecast fishing mortality for model semester 2024-2 (January-June 2025) was $0.04yr^{-1}$, consistent with estimated fishing mortality for both previous semesters. AT survey catchability q was set to 1.0 for 2024, as it was for 2022 and 2023. Sensitivity models explored inclusion or exclusion of 2024 AT survey age and weight-at-age data as well as using recruitment time blocks.

The CPSSC endorses the 2025 update to the 2024 sardine assessment (Model 25.1d in the draft assessment report) as satisfying the Terms of Reference for update assessments. The results are

adequately consistent with the previous assessment given the new data and hence represent the best scientific information available for management of NSP Pacific Sardine. The CPSSC recommends that the assessment be designated as category 2(d) based on the uncertainties related to the presence of Japanese sardine co-occurring with NSP sardine, difficulties modeling weight-at-age, as well as uncertainties related to the magnitude of Mexican catch of NSP Pacific sardines (noted during the review of the 2024 benchmark assessment).

5. REVIEW OF CALCOFI TEMPERATURE - SARDINE POPULATION DYNAMICS CORRELATION

The STAT and CPSSC discussed updated analyses of the statistical relationship between the CalCOFI Sea Surface Temperature (SST) metric and (logged) recruits-per-spawner for Pacific sardine. It is important to note that this analysis is a key step in the evaluation and derivation of E_{MSY} for Pacific sardine, but E_{MSY} is not a direct output of this analysis. Rather, various methods for deriving temperature-dependent E_{MSY} values, or various static values, can have their expected relative performance evaluated using a Management Strategy Evaluation (MSE) whose operating model would include a statistically-informed model for the relationship between temperature and recruitment, accounting for the best estimate of how strong the predictive relationship is.

The updated analysis closely followed the methods used in the 2013 workshop, for example using age-2+ biomass as the metric of spawning biomass and considering the same set of linear models and GAMs with and without the temperature covariate and comparing linear versus nonlinear temperature effects. The updated analysis still finds the strongest support for a model including nonlinear effects of both spawning biomass and temperature. Therefore, the analysis demonstrates there is still valid statistical evidence for a relationship between CalCOFI SST and recruits-per-spawner. The predictive power does not appear as high as in the original analysis (adjusted R^2=0.74 for the original analysis based on input for 1984-2008 versus R^2=0.44 for the new analysis based on input for 1983-2023) To further understand how this change in the predictive power of the relationship may impact the E_{MSY} formula, at some point, an updated MSE using an operating model based on the latest estimates of the CalCOFI SST - recruits-per-spawner relationship should be performed to compare the expected performance of static versus temperature-dependent E_{MSY}. This further analysis could potentially derive a new E_{MSY} formula or value, if deemed necessary

The current analysis closely replicated the approach taken in 2013. The CPSSC noted a few statistical refinements that should be considered before using the results to inform an updated MSE. First, the choice to use age-2+ biomass rather than a direct estimate of spawning biomass reflected an initial desire to include spawning biomass estimates from early assessments that reached back to the 1930s, but only modeled ages 2 and older. For analyses restricted to 1984 or later, it would be preferable to use estimates of spawning biomass per se. Spawning biomass and recruitment estimates for 2005-2008 are available from two assessments that at times differed substantially. Rather than using only the results of the more recent assessment it could be useful to perform a sensitivity analysis to the choice of assessment or to use the mean of the assessments' estimates. It was noted that recent years have been characterized by warm temperatures, low biomass, and low recruitment; with concurrent trends in these metrics. This can confound statistical estimation of relationships, and there could be value in modeling a regime shift. There are also statistical challenges (e.g., non-independence) with using the outputs of assessment

models as "data" in relatively simple statistical models like these, and some guidance on addressing these can be found in Dichmont et al. (2003).

Although discussions mostly focused on the relationship between temperature and recruits-per-spawner, results were presented for the relationship between spawning biomass and recruits-per-spawner as well. For the more recent time period (2005-2023), there is little if any evidence for a density-dependent decline in recruits-per-spawner as spawning biomass increases, but there is also a lack of data at high spawning biomasses where density-dependence would be expected to be more apparent. However, the best-supported model for the longer (1984-2023) period showed a fairly modest effect over a wider range of spawning biomasses, which might have implications for the most plausible value of steepness.

References

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Zwolinski, J.P. and Demer, D.A., 2024. 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, 33(3), p.e12664. https://onlinelibrary.wiley.com/doi/abs/10.1111/fog.12664.

Table 1. Biomass estimates from the California aerial survey.

Year	Season	Area (km^2)	Sardine Biomass (mt)	
			SCA	NCA
2017	Spring	328	0	
	Summer	1,353		20,217
2018	Spring	1,054	2,697	
	Spring	1,055	2,283	
	Summer	996	553	
	Summer	239		15,034
2019	Spring	927	28,976	
	Summer	1,388		11,736
	Summer	1,044	25,475	
2020	Summer	2,259		8,699
	Summer	1,515	17,244	
2021	Spring	1,515	18,434	
	Summer	1,373		14,963
	Summer	1,515	13,159	
2022	Spring	1,515	1,326	
	Summer	381		1,728
	Summer	1,515	24,401	
2023	Spring	1,515	10,205	
	Summer	1,515	812	
	Summer	376		10,085
2024	Spring	1,515	14,002	
	Summer	312	1,697	
	Summer	786		53,897

APPENDIX A. SSC Member Participants

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