Pacific sardine (*Sardinops sagax*) nearshore aerial biomass estimates in 2024 for the 2025 update and other stock assessments

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Background

The California Coastal Pelagic Species Survey (CCPSS) is an aerial survey of California nearshore waters that has been conducted since 2012 (Lynn et al. 2022, 2023). The aerial survey was formally reviewed in 2017 and data from the survey have been part of recent CPS stock assessments, including the Pacific sardine (*Sardinops sagax*, sardine) assessment time series since the 2020 benchmark, including the 2024 benchmark. Since 2020, a stratified sampling design with three transects per stratum (Dorval et al. 2024) has been implemented. During each seasonal survey, the spotter plane conducts replicated flights on each transect within predesignated strata covering waters out to 3,600 m (Dorval et al. 2024). Survey regions are always in Northern California (NCA) between Point Arena and Port San Luis, and Southern California (SCA) between Point Conception and San Diego (Figure 1). For each survey season and region, the ability to survey strata is determined by availability of survey personnel and aircraft, airspace restrictions, and weather conditions. We summarize below the data collected and biomass estimates for sardine from 2024 spring and summer survey flights by season and region.

Survey Methods and Data

Aerial survey data collection and biomass computation in each region and season since 2020 have followed methods described in Dorval et al. (2024). Biomass estimates were calculated in flown strata, and then average regional density from surveyed strata was used to expand into intervening unflown strata to derive regional biomass estimates (Figure 1).

Scheduling of survey flights was designed to coincide in space and time as closely as possible with offshore acoustic-trawl (AT) surveys by NOAA Ship *Reuben Lasker* (Dorval et al. 2024). Aerial survey flight dates were planned ahead of time based on the AT survey schedule. However, weather conditions and changes in AT survey plans can affect coordination with CCPSS flights. For some strata, this resulted in temporal discrepancies (< 7 days) between *Reuben Lasker* and aerial survey coverage of the same latitudinal water areas.

Aerial Survey: 2024

The spring 2024 CCPSS season in SCA progressed from north to south, and flew the following strata (in order) from March 25 to 28: S1, S2, S3, S5, S6, and S4 (Figure 2, Table 1). Biomass observed in each of these strata are shown in Table 1. All six core strata in SCA were flown and collected data were used to

calculate regional biomass and variance. Total nearshore biomass in the SCA region for this season was estimated to be 14,002 metric tons (mt, Table 2).

In summer 2024, strata were attempted from south to north (Figure 3). Due to unsuitable weather conditions, only two SCA strata were flown, S1 and S2 (July 10), in the limited time available for survey flights. Nearshore biomass estimated in these two strata (486 mt and 1,211 mt, respectively) are presented in Table 1. Expansion was not performed because of the small number of surveyed strata. Thus, for the summer 2024 SCA season, only observed biomass estimates are provided, representing a minimum estimate for the region. In the NCA region, four strata were flown synoptically with *Reuben Lasker* from August 2 to August 13: N5, N7, N4, and N3 (Figure 4, Table 1). Regional biomass only covered the area within the bounds of the three northernmost of these strata (N3 through N5) as these were adjacent to each other, and sardine were observed in each of these strata (Figure 4). Sardine length data from nearshore acoustic survey vessels *Long Beach Carnage* and *Lisa Marie* are shown in Figure 5. Total calculated nearshore biomass for NCA for the area comprising strata N3 through N5 (including two expansion strata, N3E and N4E) was estimated to be 53,897 mt (Table 2).

For summer 2024, the habitat for the northern subpopulation (NSP) of sardine off California has been determined to be waters north of Point Conception (Stierhoff et al., in prep). A comparison of all CPS survey areas covered (Figure 6, Table 3) shows temporal overlap between aerial and offshore AT surveys ranging from 1-6 days, and between aerial and nearshore acoustic surveys (conducted by *Lisa Marie* and *Long Beach Carnage*) ranging from 0-5 days. For strata N5 and N7, aerial surveys preceded acoustic surveys, whereas for strata N4 and N3, aerial surveys followed acoustic surveys. For summer 2024, weather conditions grounded survey flights in the days after 8/3, and additional days were added to the survey season to attempt more surveys that season. This resulted in one additional survey on 8/13.

Sardine from the NSP were observed by each of the aerial and acoustics surveys between Point Conception and just south of Bodega Bay (Figure 7). In the nearshore areas between Monterey Bay and Bodega Bay, both aerial and nearshore acoustic surveys detected sardine schools. As with previous aerial surveys, every effort was made to align flights with the offshore AT survey to best provide nearshore biomass estimates to calculate the total biomass of the sardine stock. Because aerial surveys face challenging and unpredictable weather conditions during the NCA summer months, integrating these data with ship-based surveys are not always easily done. However, the availability of alternate sources of data for stock assessments presents opportunities for innovation and improvement in data collection methodologies, enhancing the overall effectiveness and accuracy of surveys, stock assessments, and fishery management measures.

Table 1. Observed biomass (metric tons) of Pacific sardine estimated from 2024 spring and summer CCPSS flights per region and stratum. Two replicated flights were conducted on each transect within a given stratum.

Date	Region	Season	Stratum	Biomass (mt)
3/25/24	SCA	Spring	S1	8
3/27/24	SCA	Spring	S2	3,743
3/27/24	SCA	Spring	S3	0
3/28/24	SCA	Spring	S5	5,762
3/28/24	SCA	Spring	S6	1,018
3/29/24	SCA	Spring	S4	110
7/10/24	SCA	Summer	S1	486
7/10/24	SCA	Summer	S2	1,211
8/2/24	NCA	Summer	N5	23,824
8/3/24	NCA	Summer	N7	0
8/13/24	NCA	Summer	N4	8,051
8/13/24	NCA	Summer	N3	8,446

Table 2. Total SCA and NCA regional biomass estimates in metric tons.

Dates	Region	Year	Season	Area_Region (km^2)	Density_Region (mt/km^2)	Biomass_Region (mt)	SD_Biomass	CV_Biomass
3/25-3/28	SCA	2024	Spring	1,515	9.24	14,002	1,671	0.12
8/2-8/13	NCA	2024	Summer	786	68.61	53,897	5,050	0.09

Table 3. Survey coverage of NCA aerial strata flown in summer 2024. Survey dates are shown for aerial, offshore AT (RL – *Reuben Lasker*), and nearshore acoustic (LM – *Lisa Marie*, LBC - *Long Beach Carnage)* survey transects. At right are days of separation between aerial and acoustic surveys, where aerial surveys preceded (positive green values) and followed (negative red values) other surveys.

Aerial		Acoustic			Separation (days)		
Stratum	Flights	Offshore	Nearshore		Offshore	Nearshore	
		RL	LM	LBC	A-RL	A-LM	A-LBC
N5	8/2	8/8	8/7	-	6	5	-
N7	8/3	8/4, 8/5	-	8/3	1-2	-	0
N4	8/13	8/9, 8/10	8/8	-	-3-4	-5	-
N3	8/13	8/10, 8/11	8/9	-	-2-3	-4	-

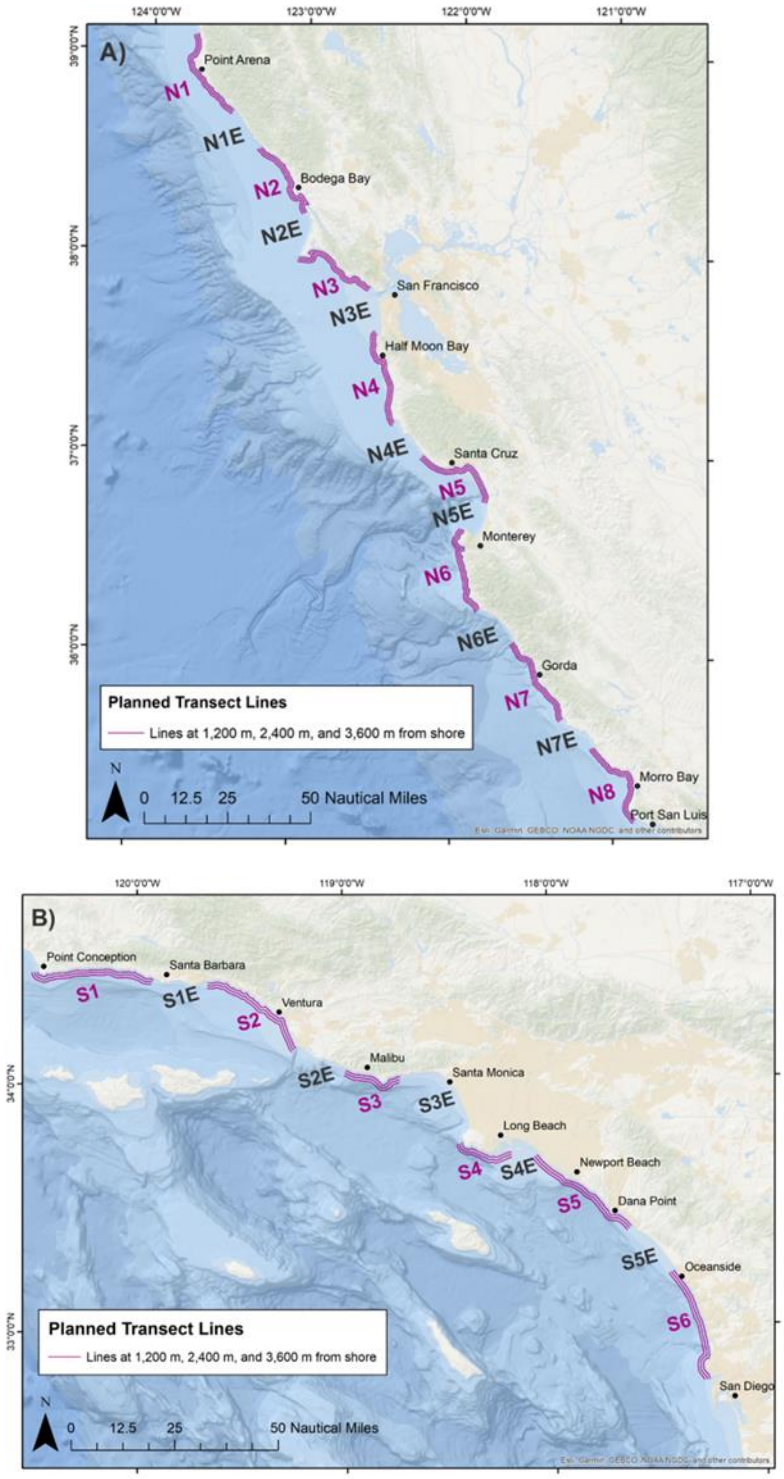

Figure 1. Spatial distribution of strata (Panels A and B) off northern California (NCA) and southern California (SCA) for 2024 surveys. Planned survey strata are in pink; strata for expansion of biomass are in black and labeled with an "E". Note strata S3 and S4 are smaller to circumvent airspace restrictions near the Los Angeles Airport.

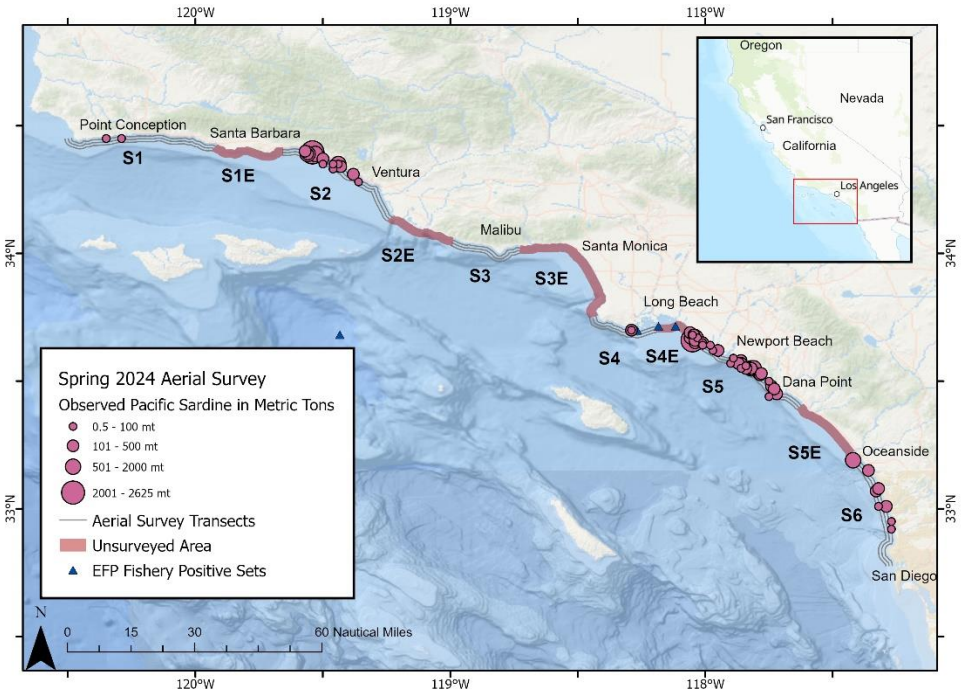

Figure 2. Spring 2024 observations in SCA (March 25-29). Also shown are locations of directed fishery Exempted Fishing Permit samples.

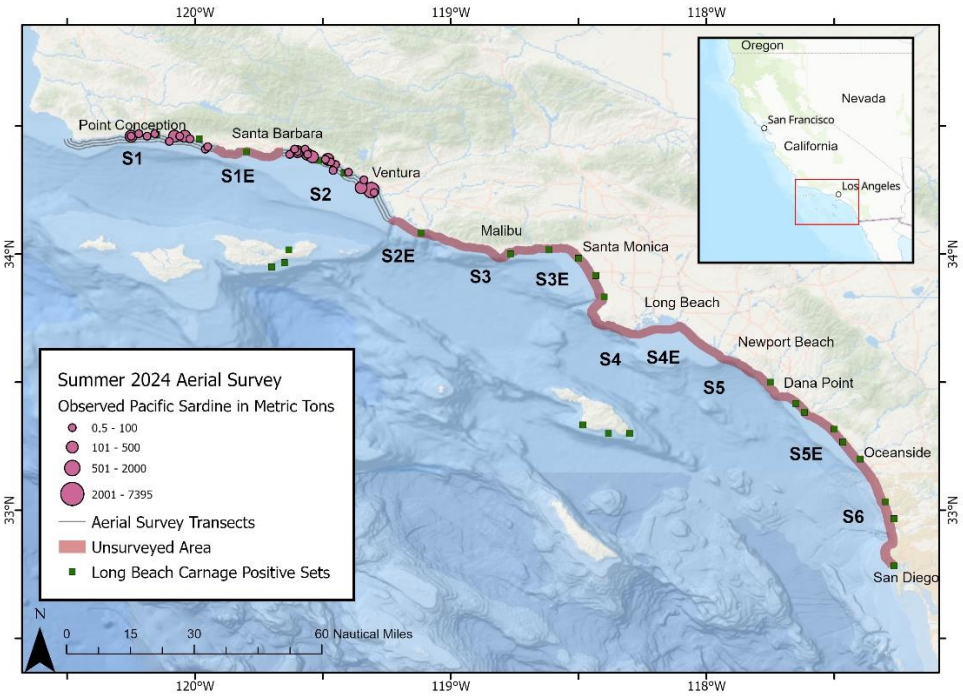

Figure 3. Summer 2024 observations in SCA (July 10-31). Locations of positive fishing sets and where samples taken by nearshore acoustic survey vessel *Long Beach Carnage* are also shown.

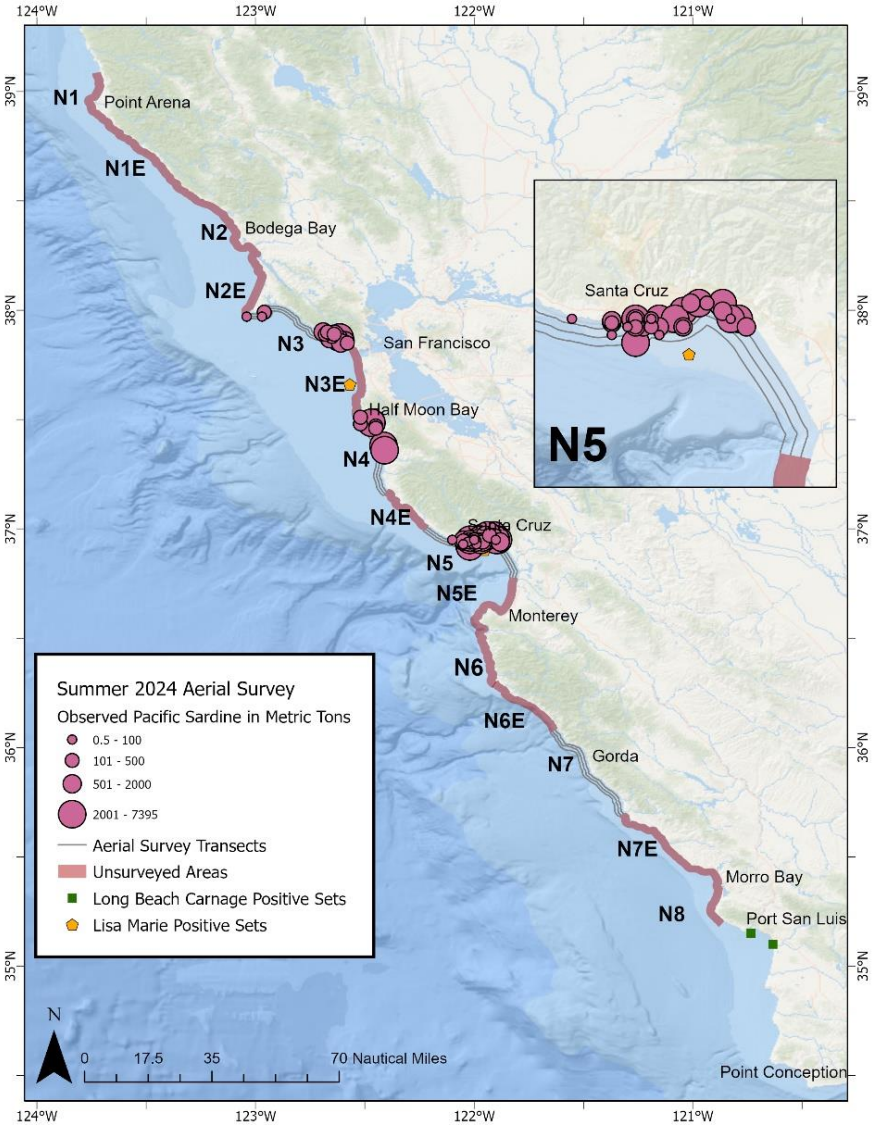

Figure 4. Summer 2024 observations in NCA (August 2-13). Locations of positive fishing sets and where samples taken by nearshore acoustic survey vessels *Long Beach Carnage* and *Lisa Marie* are also shown.

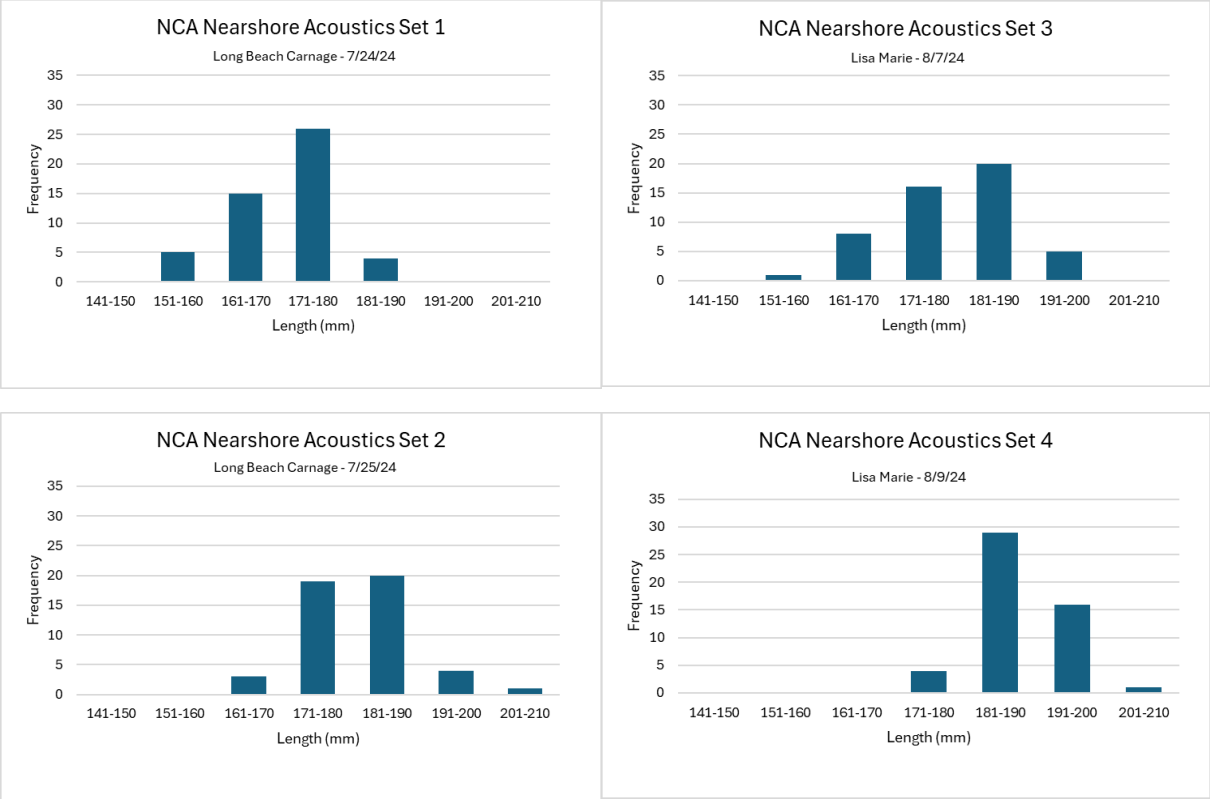

Figure 5. Pacific sardine length frequencies from *Long Beach Carnage* (left) and *Lisa Marie* (right) samples collected during the summer 2024 acoustic survey within the NCA aerial survey region.

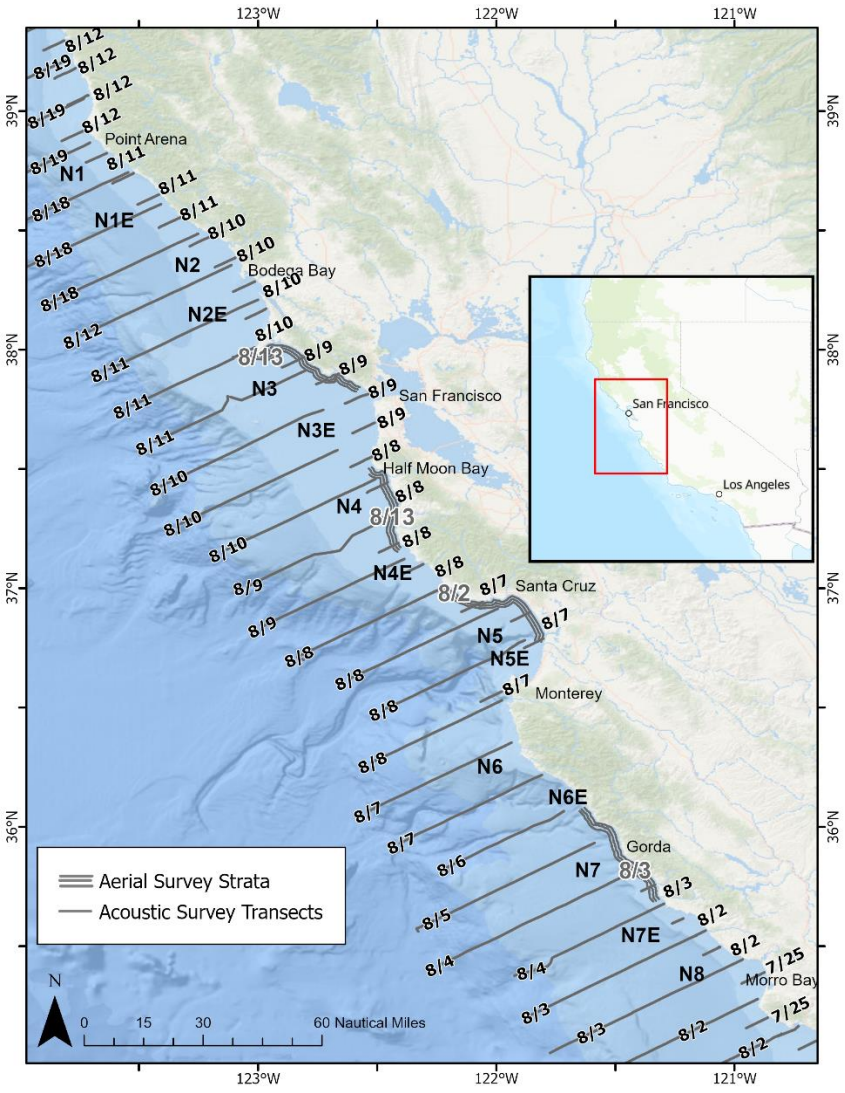

Figure 6. Summer 2024 NCA transect lines for acoustic surveys (single lines) and CCPSS aerial surveys (triple lines). Acoustic survey dates per transect are labeled. Aerial survey flight dates are labeled in larger dark grey text adjacent to strata.

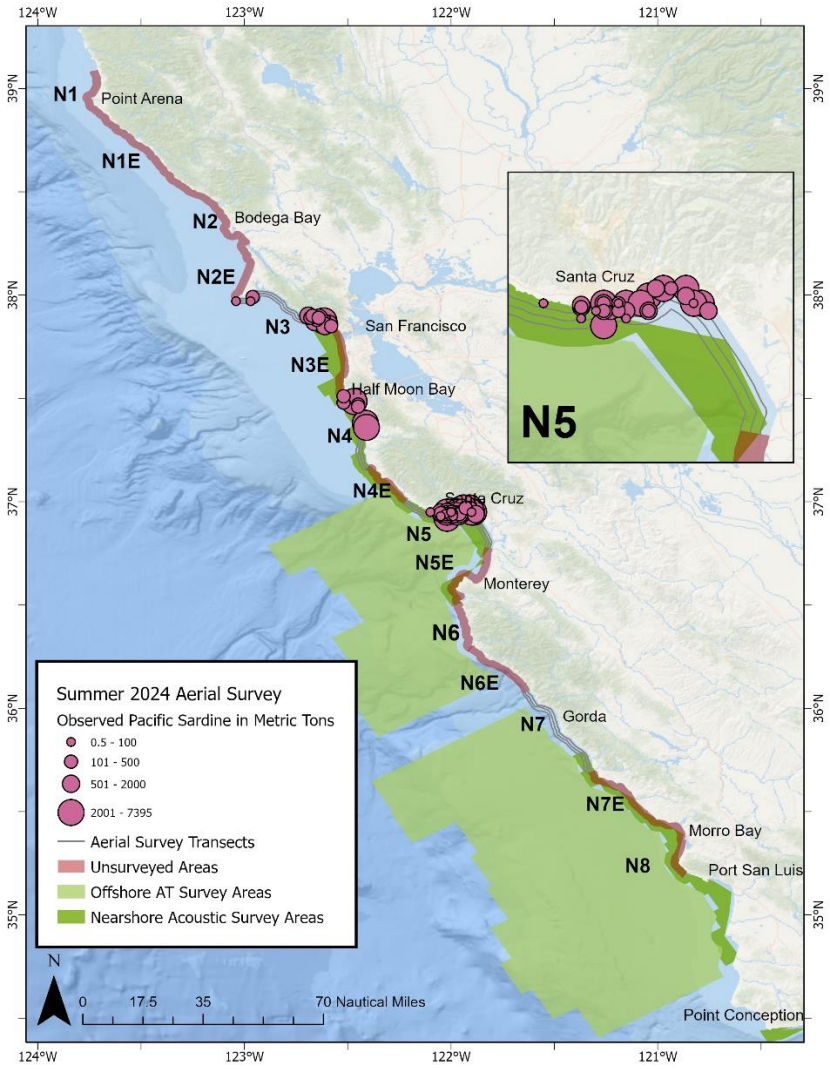

Figure 7. Pacific sardine school biomass observed by the CCPSS aerial survey (red circles) within the NCA region during summer 2024, and sampling areas covered by aerial and acoustic surveys. Survey areas where sardine were observed by the offshore AT survey are shown as light green polygons, and those for the nearshore acoustic survey as dark green polygons. Unsurveyed aerial survey strata and transects are delimited by red lines.

References

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