

CALIFORNIA COASTAL PELAGIC SPECIES AERIAL SURVEY – UPDATED METHODS AND PRELIMINARY 2020 RESULTS

The California Coastal Pelagic Species Survey (CCPSS) is an aerial survey of Pacific sardine (sardine) and northern anchovy (anchovy) in California nearshore waters conducted since 2012 by the California Department of Fish and Wildlife (CDFW) and the California Wetfish Producers Association (CWPA) (Lynn et al. 2019). Biomass data estimated from the CCPSS were used in the latest sardine stock assessment to inform National Oceanic and Atmospheric Administration (NOAA) acoustic-trawl (AT) survey catchability (PFMC 2020). The CCPSS continued in 2020 in both Northern California and Southern California. The methods were modified to address concerns raised during the stock assessment review over the lack of survey coverage and transect replication to compute variance of survey biomass estimates (PFMC 2020a). Research on validation of observer data is ongoing with the Nearshore Cooperative Survey (NCS) employing the same methods as used in previous work (Dorval and Lynn 2019). The total 2020 biomass estimate for nearshore sardine in Northern California is 9,876 mt and in Southern California is 20,083 mt. Based on average monthly sea surface temperature data and the sardine habitat model, 2020 fall Southern California sardine were from the southern subpopulation. For anchovy, the total nearshore Northern California biomass estimate is 65,209 mt and in Southern California is 5,402 mt. This document describes CCPSS design, methods, and preliminary results for fall 2020.

Aerial surveys were conducted within the Southern California Bight during the first five years, then extended north of Point Conception in August 2017. The 2017 summer survey was intended to sample nearshore coastal areas corresponding to offshore transects of the summer AT survey conducted at the same time. The survey period was scheduled to coincide with the southernmost extent of the AT survey as it proceeded south from Vancouver, British Columbia. Efforts to conduct the CCPSS off Northern California in summer 2018 were not successful due to logistical constraints. However, the CCPSS successfully coordinated with the AT survey in summer 2019.

The survey underwent a Pacific Fishery Management Council (PFMC) methodology review in April 2017 (PFMC 2017). The Scientific and Statistical Committee conditionally approved the survey protocol for use in management and recommended a focus on providing nearshore sardine and anchovy biomass estimates for areas shoreward of those represented by AT survey estimates.

The ongoing NCS project, which began in August 2018 (Dorval and Lynn 2019), was developed to address research recommendations from the 2017 review. Preliminary results from the NCS project were reviewed at a meeting for central subpopulation of northern anchovy (CSNA, anchovy) management in October 2019 (October 2019 meeting) hosted by PFMC (PFMC 2019). Although the October 2019 meeting focused on CSNA, recommendations were provided that could be applied to either sardine or anchovy data for CCPSS.

One of the key tasks of the October 2019 meeting was to evaluate and make recommendations for potential nearshore estimation methods to complement the offshore AT survey, since the nearshore area is not surveyed by NOAA ships. CCPSS survey methods and results from surveys since 2015

were presented and discussed (PFMC 2019). The most pertinent CCPSS surveys for the sardine stock assessment were those from summer 2017 and summer 2019. These two surveys were coordinated temporally and spatially (Northern California) with AT surveys, and covered areas where habitat of the PFMC-managed stock of sardine (northern subpopulation, NSP) was optimally located, as based on the model used by NOAA scientists (Hill et al. 2019, Zwolinski et al. 2011). The reviewers concluded that aerial surveys conducted in conjunction with AT surveys are preferable, to minimize overlap due to movement of fish schools between the two surveys. There was also a clear preference for biomass estimates from direct synchronous observations such as aerial survey or other field methods, rather than using an extrapolated biomass value based on AT transects (PFMC 2019). Aerial surveys were approved for nearshore biomass estimation if coordinated with AT surveys and with an appropriate variance estimator.

The meeting report concluded that NCS work on both the approach for assessing observer bias and the number of point sets completed for sardine are close to sufficient for consideration in stock assessments (PFMC 2019). Additional point sets will be attempted in 2021, with a focus on larger schools and wider geographic representation.

CCPSS biomass data are minimum estimates of abundance within the survey area. These surveys are limited to depths less than 10 m and conducted in daytime when many CPS are found in deeper waters. In addition, this survey covers only a fraction of the respective sardine and anchovy stock ranges. However, the aerial survey observed CPS that are likely exclusive of those observed by the AT survey conducted offshore, as the area surveyed was significantly shoreward of and shallower than the AT transects (PFMC 2017).

The execution of the 2020 CCPSS season was the initial effort using a new survey design that incorporated research results to complete a broader, replicated study covering nearshore waters over much of the California coast. Previous research led to specific design elements for 2020 that provided for data collection for biomass and variance estimation under limited budgetary and time resources. The strata/transect lengths and number of replicates (two) were chosen to allow the survey to be completed in the time needed to coordinate successfully with the AT survey and within the amount of time that survey aircraft and personnel were available.

2020 Aerial Survey

Survey flights were conducted in fall 2020 (September 5-20) off the Northern and Central California coast (“Northern California” region), from approximately Point Arena to Morro Bay, and in the Southern California Bight (“Southern California” region) from south of Point Conception to San Diego (Figures 1 and 2). The CCPSS surveyed areas inshore of NOAA AT survey tracklines, covering shallower waters that are not sampled by these research vessels. In the interest of providing estimates that can be expanded to unsampled nearshore waters, replicated transect lines were flown in 2020, a departure from the previous CCPSS survey design. Past CCPSS design flew inshore and offshore transects, with no replication of these flights. Strata locations and sizes were selected to cover the coastline while avoiding restricted flight zones, and to allocate sufficient time for completing each stratum in a single day. The survey design includes two types of strata: a) those selected to be surveyed (“survey strata”, or strata, N1-N12 and S1-S6, Figures 1 and 2), and b) those for which post-survey expansion of aerial biomass estimates are applied (“expansion strata”; N1E-N11E and S1E-S5E, Figures 1 and 2). Within each survey stratum, three transect lines are located at 1,200 meters (m, 0.65 nautical miles (nm)), 2,400 m (1.3 nm), and 3,600 m (1.9 nm) off the coastline. Each line delineates surveyed water areas 1,200 m

shoreward of the lines. Two daily replicates were conducted for each transect line. Here, a flight refers to a survey of a transect line.

In Northern California, a total of eight strata (N5-N12) were surveyed on September 5-16 (Figures 3 and 4). In Southern California, a total of six strata (S1-S6) were surveyed on September 18-20 (Figures 5 and 6). Airspace restrictions surrounding Los Angeles International Airport greatly limit survey areas in the vicinity. For this reason, there are two smaller selected strata, S3 and S4, to represent this area (Figure 2). Survey transects measure 56 kilometers (km, 30 nm) long, except for S3 and S4 at 28 km (15 nm) long. Expansion strata are 28 km (15 nm) long, except S2E (26 km (14 nm)), S3E (56 km (30 nm)) and S4E (13 km (7 nm)) (Figure 2).

For a given survey day, the determination of which strata are flown is contingent on local weather conditions, coordination with acoustic survey vessels (if any), and random selection within those constraints. For any specific area, acceptable conditions for conducting a survey are maximum wind speed of approximately 10-12 knots, and at least 90% clear of cloud cover. Transects were completed using a CDFW Cessna 185 aircraft flown by a CDFW Warden-Pilot with an experienced industry spotter serving as observer. Surveys were flown at 457 m (1,500 feet) altitude. Normally, strata would have been selected based on nearest proximity to the nearshore acoustic survey area that day in terms of location and time. Since no acoustic surveys were conducted in 2020 due to the COVID-19 pandemic, strata that met acceptable conditions were selected based on coordination with sampling by the fishing vessel (F/V) *Long Beach Carnage* (*LB Carnage*). For both the Northern and Southern California regions, efforts were made to fly as many strata as possible, with each stratum flown only once. For each stratum selected in a given day, the starting line (inner or outer) was randomly selected and maintained for the subsequent replicated flights for that stratum.

When sardine or anchovy were identified along a given transect, the aircraft diverted from the transect to more closely examine the sighting, confirm identification, and obtain species composition and tonnage estimates. These observations were recorded on field datasheets. For additional details on survey methods and data recorded, refer to Lynn et al. (2019).

The *LB Carnage* was not able to travel to the northernmost strata, so the aerial survey began with stratum N5 and continued south. Not all strata were surveyed in full because of weather conditions (stratum N8) and airspace restrictions due to firefighting efforts off the Central Coast (N10-N11). Aerial biomass estimates were expanded to those unsurveyed areas as well as the expansion strata using aerial survey data collected from surveyed strata (see Analytical Methods).

Biological Sampling

In 2020, the *LB Carnage* was available to support the CCPSS by collecting biological samples off the California coast from Bodega Bay south to San Diego. Sampling took place using the same survey strata area as the CCPSS aerial flight path, but occurred independently of aerial surveys, although attempts were made to sample as close in time as possible (no more than three days apart from aerial survey of those strata). The catch processing protocol for each set followed that used by the F/V *Lisa Marie* for acoustic survey research (PFMC 2020b). The *LB Carnage* began in the north with stratum N7 and proceeded southward, ending at stratum S6 (Figures 1 and 2).

The key objective of this sampling was to provide biological data for aerial spotter observations. Fall 2020 and spring and summer/fall 2021 length and age data together with aerial biomass

estimates can potentially be used for the CSNA assessment in late 2021. The collection of length composition data from adults can be used by stock assessment scientists to represent the stock observed by the survey. Data collected with this protocol can also be used to analyze length and age compositions of schools vs. distance from shore, to inform the structuring of future survey design.

Analytical Methods

To calculate the sampling error or within-flight variance, the total observed biomass per species for all flights are summed per line and the mean calculated. The sampling error is derived from this value. For variance of the total biomass per stratum, the mean biomass for each transect is calculated. A grand mean is then obtained by summing these means and dividing by the number of transects flown, from which a variance is derived. The total biomass for each stratum is the grand mean divided by the number of transects, for which the variance is the number of transects squared multiplied by the variance of the grand mean. Finally, stratum density is total stratum biomass divided by area flown by the aircraft. The mean daily density across all strata in the region is applied to all unsurveyed areas in the region, whether expansion strata or unflown portions of survey strata, to determine biomass for those areas, and then summed to get total regional biomass. In the future, regional variance will be obtained through resampling with replacement the flights within each stratum in the region to obtain 95% confidence intervals for mean regional density. Should any portions of survey strata not be flown (weather or airspace restrictions), those areas will be added to the nearest expansion strata area for use in calculating biomass when applying the regional mean density to unsurveyed areas.

At this time only regional biomass estimates for the 2020 survey are available, and both the survey design and analytical methods are yet to be reviewed. Such a review may take place at a potential anchovy data workshop in summer 2021 or at the CSNA stock assessment review meeting scheduled for December 2021.

Results

Total sardine and anchovy biomass were calculated from the eight survey strata (N5-N12) from Northern California and six survey strata (S1-S6) from Southern California that were surveyed (Tables 1 and 2). The total 2020 biomass estimate for nearshore sardine in Northern California is 9,876 mt and in Southern California is 20,083 mt. Based on average monthly sea surface temperature data and the sardine habitat model, 2020 fall Southern California sardine were from the southern subpopulation. For anchovy, the total nearshore Northern California biomass estimate is 65,209 mt and in Southern California is 5,402 mt. The 2020 results are in line with previous CCPSS surveys showing higher densities of sardine compared to anchovy in Southern California, and the reverse for Northern California (Table 3).

Sardine and anchovy were found generally in the same areas in Northern California, namely within the Monterey Bay, Big Sur and Morro Bay areas (Figures 3 and 4). In Southern California, sardine were observed in all surveyed areas, with heaviest concentrations off Santa Barbara and Orange County (Figure 5). Anchovy were primarily observed between Santa Barbara and Ventura, with smaller biomass near Malibu (Figure 6).

The calculation of biomass from unsurveyed areas used mean density of observed biomass from surveyed areas; the percentage of actual surveyed areas to unsurveyed areas by region was 69% to 31% in Northern California (Table 4) and 65% to 35% in Southern California (Table 5). These

proportions represent a relatively high ratio of surveyed areas to unsurveyed areas. The new CCPSS design expands biomass density into unsurveyed areas that are bounded on either side by surveyed areas, with surveyed and unsurveyed areas covering the same distance from shore (out to 3,600 m, 1.9 nm).

Replicating transects comes at the cost of surveying the entire coastline. With the need to align with offshore AT surveys, it is not logistically feasible to expect to be able to fly replicated transects out to the same distance offshore for the entire length of the coastline, given uncertain weather conditions and the availability of survey personnel and aircraft. A continuous survey of the coastline without the need for expansion of data into unsurveyed areas, as in CCPSS seasons prior to 2020, would be much more likely to occur if one replicate flown. This would be a more realistic and acceptable approach should data indicate a low or consistent variability in nearshore CPS biomass over time.

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Table 1. Preliminary sardine and anchovy biomass (mt) from 2020 CCPSS by region and area type. For each region, unsurveyed areas comprise expansion strata plus unsurveyed portions of survey strata, and biomass estimates for these areas are based on mean density from surveyed areas (see text). Note: Southern California sardine estimates are for the southern subpopulation.

		CCPSS Biomass (mt)		
		Surveyed	Unsurveyed	Total
Sardine	N CA	6,207	3,669	9,876
	S CA	13,821	6,262	20,083
Anchovy	N CA	40,975	24,234	65,209
	S CA	3,708	1,694	5,402

Table 2. 2020 CCPSS observed survey Pacific sardine and northern anchovy biomass by stratum for Northern California (left) and Southern California (right) strata. Note: Southern California sardine estimates are for the southern subpopulation.

Survey Date	Stratum	Stratum Biomass (mt)	
		<i>Sardine</i>	<i>Anchovy</i>
9/5	N12	898	646
9/6	N6	0	22
	N7	75	0
9/7	N5	133	28
9/14	N8	7	41
9/15	N9	5,021	40,238
	N10	67	0
9/16	N11	5	0
		6,207	40,975

Survey Date	Stratum	Stratum Biomass (mt)	
		<i>Sardine</i>	<i>Anchovy</i>
9/18	S1	1,194	0
	S2	1,816	3,634
9/19	S3	45	42
	S4	181	0
	S5	9,316	31
9/20	S6	1,270	0
		13,821	3,708

Table 3. 2015-2020 CCPSS survey biomass estimates by year, season, region. Northern California surveys highlighted in yellow. Note 2020 seasons used a new survey design with replicated transects within strata, and biomass estimates are preliminary. Replicate surveys are denoted with a (2). Note: summer/fall Southern California sardine estimates are considered to be for the southern subpopulation.

Year	Season	Region	Survey Range	Area Surveyed (km ²)	Sardine			Anchovy		
					Biomass (mt)	CV	Density (mt/km ²)	Biomass (mt)	CV	Density (mt/km ²)
2015	Summer	S	SCB; All Channel Islands	2,200	124	0.33	0.06	0	NA	0
	Summer (2)	S	SCB; All Channel Islands	2,209	395	1.07	0.18	0	NA	0
2016	Spring	S	SCB; Anacapa, SC, SR, SB, Cat	1,534	3,541	0.70	2.31	1,096	0.31	0.71
	Spring (2)	S	SCB	1,044	7,421	0.63	7.11	4,447	1.04	4.26
	Summer	S	SCB; All Channel Islands	2,188	7,808	1.29	3.57	30	1.41	0.01
2017	Summer *	N	Pt. Arena to Morro Bay	1,353	21,038	1.13	15.55	78,613	0.71	58.12
2018	Spring	S	SCB; Anacapa, SC, Cat	1,685	2,809	1.05	1.67	329	1.35	0.20
	Spring (2)	S	SCB	1,055	2,376	1.41	2.25	353	1.41	0.33
	Fall	S	SCB; Anacapa, SC, Cat	1,511	576	0.69	0.38	34	1.01	0.02
	Fall	N	Garrapata SP to Ragged Pt.	239	15,648	1.41	65.41	73,003	1.41	305.17
2019	Spring	S	SCB; Anacapa, SC, Cat	1,456	19,617	1.31	13.48	156	0.76	0.11
	Summer *	N	Cape Mendocino to Kirk Creek	1,388	12,861	1.34	9.27	50,733	1.37	36.55
	Summer	S	SCB; Anacapa, SC, Cat	1,560	26,634	0.55	17.08	10,208	0.18	6.54
2020	Fall	N	Strata N5-N12	2,261	9,876	NA	4.37	65,209	NA	28.84
	Fall	S	Strata S1-S6	1,515	20,083	NA	13.26	5,402	NA	3.57

* Survey coordinated with acoustic-trawl survey

Table 4. CCPSS sample (left) and expansion strata (right) in Northern California with area (km²) and proportions of total regional area.

Stratum	Area (km ²)	Stratum Area / Region Area
N1	199.12	0.06
N2	200.60	0.06
N3	199.68	0.06
N4	197.97	0.06
N5	200.11	0.06
N6	187.38	0.05
N7	196.11	0.06
N8	202.54	0.06
N9	193.65	0.06
N10	192.80	0.06
N11	197.78	0.06
N12	199.90	0.06
	2,367.64	0.69

Stratum	Area (km ²)	Stratum Area / Region Area
N1E	97.56	0.03
N2E	102.32	0.03
N3E	98.26	0.03
N4E	99.87	0.03
N5E	97.65	0.03
N6E	102.12	0.03
N7E	94.53	0.03
N8E	98.67	0.03
N9E	99.80	0.03
N10E	100.27	0.03
N11E	95.87	0.03
	1,086.92	0.31
N CA Region	3,454.56	

Table 5. CCPSS sample (left) and expansion strata (right) in Southern California with area (km²) and proportions of total regional area.

Stratum	Area (km ²)	Stratum Area / Region Area
S1	200.34	0.13
S2	194.99	0.13
S3	99.76	0.07
S4	95.09	0.06
S5	198.56	0.13
S6	196.84	0.13
	985.60	0.65

Stratum	Area (km ²)	Stratum Area / Region Area
S1E	99.84	0.07
S2E	93.28	0.06
S3E	190.96	0.13
S4E	44.27	0.03
S5E	100.75	0.07
	529.10	0.35
S CA Region	1,514.70	

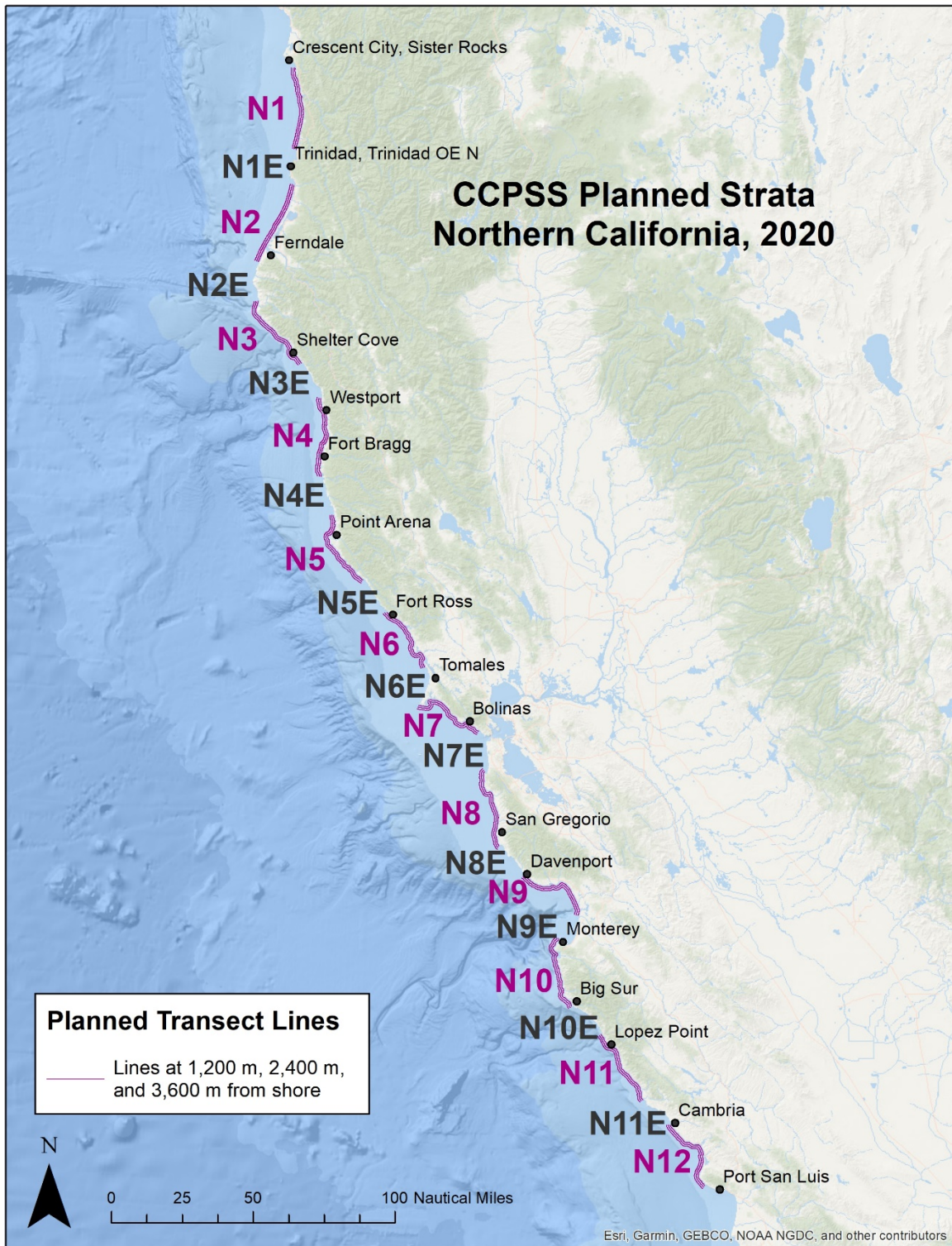


Figure 1. CCPSS strata for Northern and Central California. Sample strata are in purple, strata for expansion of data are in black and denoted with “E”. In Fall 2020, survey strata from N5 to N12 were surveyed. Portions of strata N8, N10, and N11 were unsurveyable due to weather conditions or airspace restrictions.

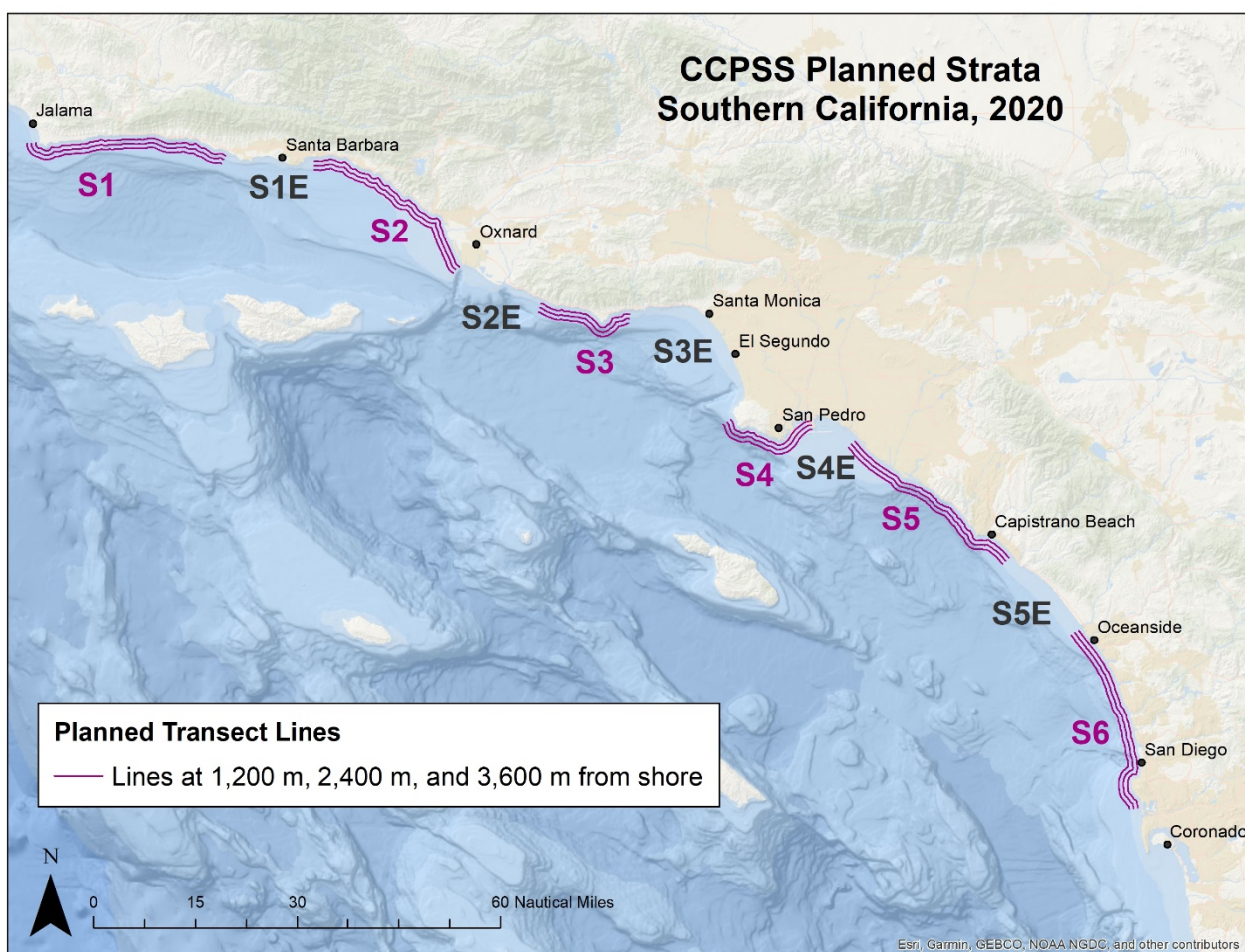


Figure 2. CCPSS strata for Southern California. Sample strata are in purple, strata for expansion of data are in black and denoted with “E”. Note strata S3 and S4 are smaller to circumvent airspace restrictions. In Fall 2020, all Southern California survey strata were surveyed.

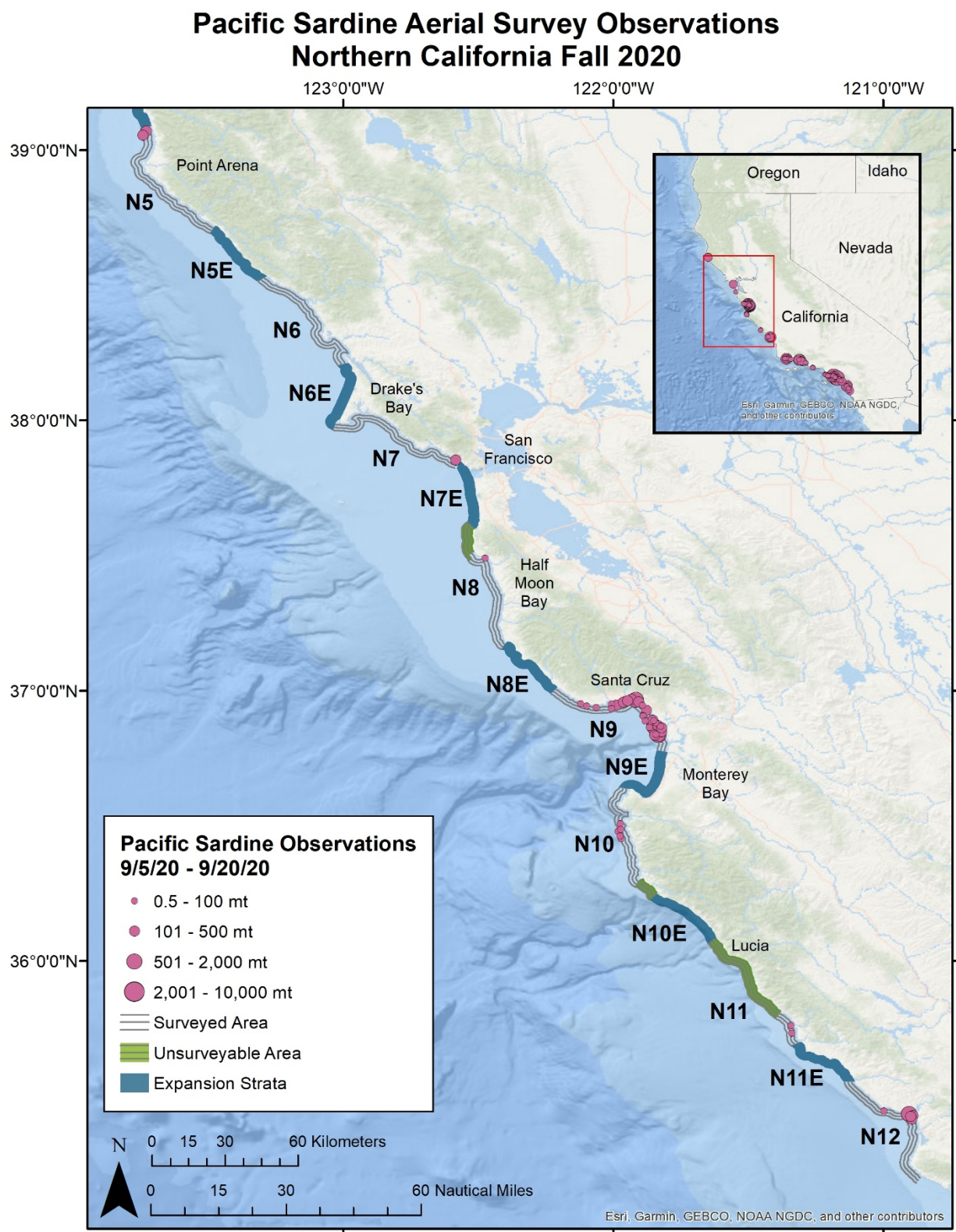


Figure 3. Pacific sardine observations from Fall 2020 for Northern California. Note unsurveyed portions of strata N8, N10, and N11.

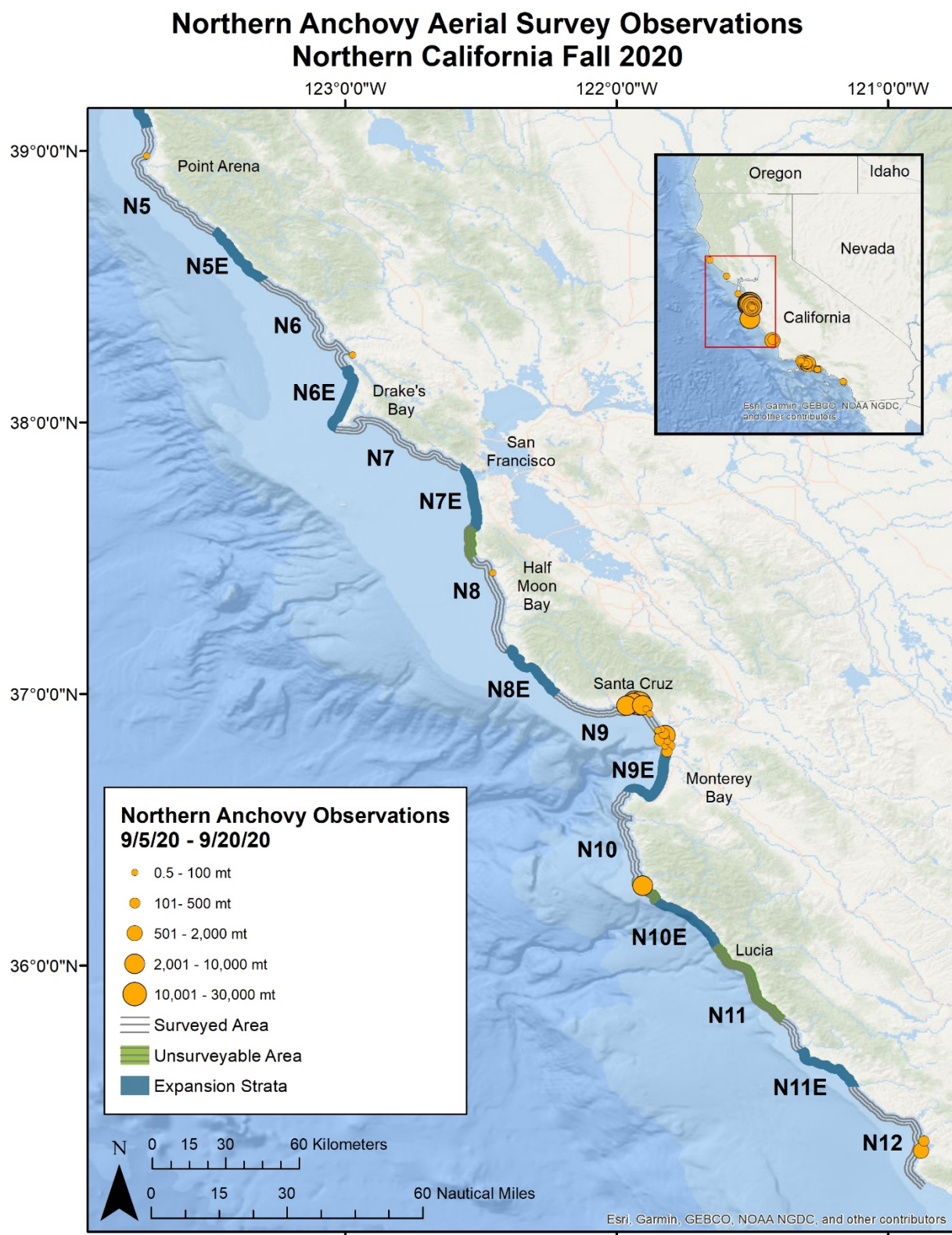


Figure 4. Northern anchovy observations from Fall 2020 for Northern California. Note unsurveyed portions of strata N8, N10, and N11.

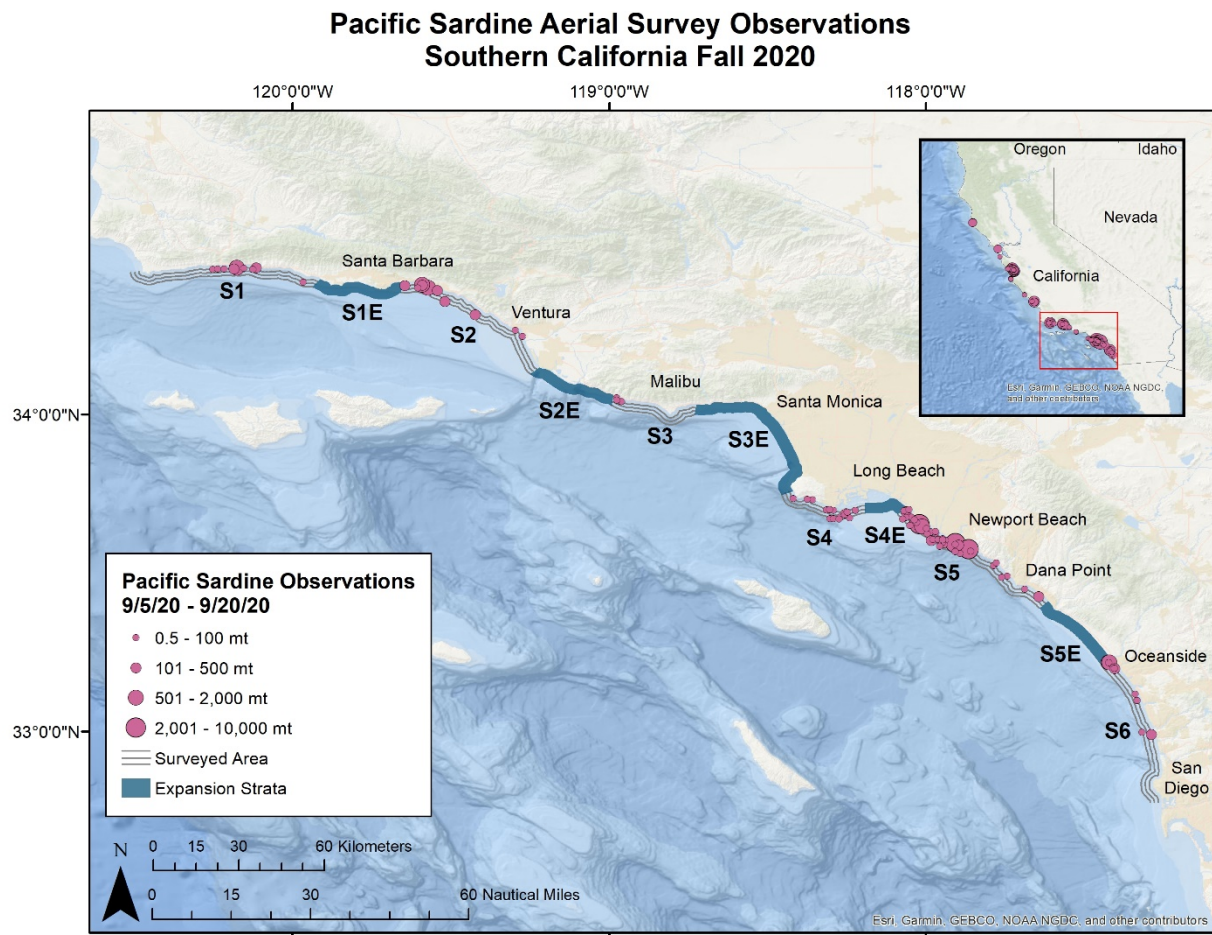


Figure 5. Pacific sardine observations from Fall 2020 for Southern California. Note: these observations are considered to be that of southern subpopulation sardine.



Figure 6. Northern anchovy observations from Fall 2020 for Southern California.