California Coastal Pelagic Species Survey Results from Summer 2017 and 2019 for Pacific Sardine (*Sardinops sagax*) - REVISED 3/11/20

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Introduction

Since 2012, the California Department of Fish and Wildlife (CDFW) and the California Wetfish Producers Association (CWPA) have jointly conducted the aerial California Coastal Pelagic Species Survey (CCPSS) to document Pacific Sardine (sardine, *Sardinops sagax*) and Northern Anchovy (anchovy, *Engraulis mordax*) in nearshore waters of the Southern California Bight (Lynn et al. 2019). The CCPSS expanded to cover nearshore waters off Northern California beginning in summer of 2017 (Lynn et al. 2017, Lynn et al. 2019). A 2017 Pacific Fishery Management Council (PFMC) methodology review recommended research to develop methods for estimating aerial survey biomass variance and quantifying observer bias to prepare CCPSS data for use in coastal pelagic species (CPS) stock assessments (PFMC 2017). An ongoing nearshore cooperative survey (NCS) project, which began in August 2018 (Dorval and Lynn 2019), was developed to address these recommendations. Preliminary results from the NCS project were reviewed at a meeting for central subpopulation of northern anchovy (CSNA) 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 National Oceanic and Atmospheric Administration (NOAA) acoustic-trawl (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, in order 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. Aerial surveys were approved for nearshore biomass estimation if coordinated with AT surveys and with an appropriate variance estimator.

Variance estimation and observer bias of biomass estimates were the primary topics of the aerial survey discussion during the October 2019 meeting (Dorval and Lynn 2019). Calculations of the CCPSS coefficient of variation (CV) are based on the two parallel transects within the current survey design. The reviewers agreed that mean biomass estimates from replicates, not maximum estimates, should be used for estimating nearshore biomass, unless information was available that showed these

would be underestimates. For observer bias, there are relatively fewer point sets for larger schools (> 80 metric tons); additional research is needed to account for schools larger than can be caught using purse seine vessels (> 120 metric tons). However, as concluded in the meeting report, 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 2020, with a focus on larger schools and wider geographic representation.

Daily CCPSS data from the summer 2017 and summer 2019 Northern California surveys were used to calculate seasonal sardine biomass estimates and their respective CVs and submitted to the sardine stock assessment team for use in the 2020 benchmark assessment. Length composition data from 2019 point sets were also provided. For the 2017 survey, length composition data were from non-directed fishery (NDF) samples from commercial fishing loads where sardine were present. This report summarizes CCPSS methods and results for calculating sardine biomass estimates from field observations, the CV for these estimates, and the sampled length compositions associated with these estimates.

Methods

CCPSS Field Methods and Surveys

Since 2015, the CCPSS survey design has been two daytime parallel coastal transects following the contours of the shoreline. These consist of an inner and outer transect line (“band”), each 1,200 meters (m, 0.65 nautical miles (nm)) wide. Survey coverage thus includes nearshore waters from the shoreline out to 2,400 m (1.3 nm). The observer is positioned on the right side of the aircraft and looks to the right. Direction of travel and plane flight path are chosen based on minimizing glare due to sun position at the time of the survey. Surveys are flown only when cloud cover and winds allow for observing CPS schools based on detectability and fish presence in the upper water column (within about 10 m (32.8 feet (ft)) depth). Additional details are available in Lynn et al. 2019.

A result of the 2017 and 2019 reviews was to focus on coordinating the CCPSS with AT surveys. NSP habitat is generally off northern California when the summer AT survey occurs. The survey was expanded to northern California in summer of 2017 to document CPS biomass, particularly NSP, synchronously with the AT survey as it proceeded south (Figure 1). 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 (Figure 2). Each survey date covered a different geographical portion of the total area for that season, with the exception of some overlap within Monterey Bay in 2019 (Figure 2). Biomass observed within overlap areas after initial surveys were not included in the survey biomass.

Biomass Estimates and Coefficient of Variation

Field CCPSS sardine biomass estimates were first adjusted for observer bias, based on results from NCS point set data (Dorval and Lynn 2019).

For each survey date, an inner and outer band were flown one time off a specific segment of coastline. Biomass estimated on each band was assumed independent. When few schools were observed, the spotter was able to estimate the biomass of each school. When too many schools were observed on a given transect for the spotter to be able to estimate single school biomass, an aggregated biomass estimate was provided.

Hence, it was not possible to develop a method to consistently estimate a variance for all individual bands. Therefore, only total biomass was estimated for each band in the analysis as follows:

$$B_{j,A} = \sum_{i=1}^{n(j)} b_{i,j,A} \tag{1}$$

where $b_{i,j,A}$, is the biomass estimated for each single (or aggregated) school *i* (total number of schools = *n*(*j*)) on band *j* in area A.

An estimate of number of schools was provided for each band. The estimate of inshore biomass is then

$$B_A^{tot} = \sum_{j=1}^{2} B_{j,A} \tag{2}$$

For daily biomass observed in a given area, the mean of total biomass across the two bands, can be estimated as follows:

$$\bar{B}_A = \frac{1}{2}\sum_{j=1}^{2} B_{j,A} \tag{3}$$

The variance of each daily biomass ($\bar{B}_A$) was estimated as follows:

$$V(\bar{B}_A) = \frac{1}{(2-1)}\sum_{j=1}^{2} (B_{j,A} - \bar{B}_A)^2 \tag{4}$$

Variance of a given season where x areas were surveyed was computed as:

$$\sum_{A=1}^{x} 4 \times V(\bar{B}_A) \quad (5)$$

Biological Information

Since the July 2015 closure of the directed sardine fishery, CDFW has collected NDF sardine biological samples. Data collected include weight, standard length, sex, maturity, and age. Sample ageing has been completed through 2016. The samples include two landings on July 14 and July 28, 2017. These landings were those closest in time to the summer 2017 CCPSS survey and associated length data were submitted for use in the 2020 sardine stock assessment.

A total of six successful NCS sardine point sets in Northern California were conducted in August and September 2019 and sampled by CDFW biologists. The catch from these point sets were landed and weighed, and biological information was recorded. Ageing has not been completed for these point sets.

Length compositions from both the 2017 NDF and 2019 NCS point set data were weighted by total weight of each landing.

Results

The CCPSS total sardine biomass estimates for the 2017 and 2019 summer surveys in Northern California are comparable across seasons (Table 1). The bias-corrected final total biomass for summer 2017 was 21,046 mt (CV = 1.13), and for summer 2019 was 12,279 mt (CV = 1.34). The vast majority (> 99% from 2017, > 96% from 2019) of sardine biomass was observed in Band 1, the inner band (Table 1). Both seasons saw heavy concentrations of sardine biomass between San Francisco and immediately north of Drake's Bay, in Half Moon Bay, and from one observation in Bodega Bay in 2017 (Figures 3 and 4).

Biological samples for 2017 and 2019 were all from Monterey Bay (Figures 3 and 5). There were additional NDF sardine sample data for 2019 in the approximate time period of the CCPSS, but these were not included in the final length composition for 2019 in favor of data from the directed sardine schools from the NCS point sets (Figure 5). The weighted length compositions for the two survey seasons are similar in range and peak, with a slight shift to smaller fish in 2019 (Figure 6). The 2017 NDF fish lengths (effective school n=2) range from 16.6 to 19.0 cm, while 2019 fish lengths (effective school n=6) range from 14.6 to 18.0 cm.

Discussion

The inability to survey nearshore CPS biomass is recognized as a shortcoming of the AT survey (PFMC 2018). The CCPSS provides an efficient and effective means to account for nearshore sardine biomass. Recent CCPSS data have shown relatively large portions of total NSP biomass are missed by the AT surveys and not included in sardine stock assessments and management. For example, the 2017 offshore (from Vancouver Island, Canada to Morro Bay, California; 1,722 km (930 nm)) NSP biomass estimate from the AT survey (Zwolinski et al. 2019) is 14,103 mt (CV = 0.30). The 2017 CCPSS estimate for nearshore NSP biomass off Northern California (from near Point Arena to north of Morro Bay, California; 569 km (307 nm)) is 21,046 mt (CV = 1.13).

The additional NSP biomass from alternate surveys can have important impacts to sardine fishery management. Although increases in estimated total NSP biomass may not result in resumption of a major directed fishery, it can still greatly affect allowances of sardine to be taken incidentally in other CPS fisheries or for live bait. Given recent economic challenges from the closure of the directed sardine fishery, and management measures and availability of other CPS stocks, accounting for the nearshore component of the NSP is essential.

Future CCPSS efforts will incorporate research recommendations to adopt a survey design similar to that used in the NCS, specifically, including additional replicates and/or parallel transects to obtain appropriate aerial survey biomass variance. Obtaining sufficient biological information for biomass estimates from surveys that are timely and proximate to AT survey areas is another research focus. Careful NCS point set survey planning and allocation of resources is needed to adequately represent population structure of the observed biomass. The difficulty lies in the often extreme distances that vessels may be required to travel to sample areas where biomass were observed from aircraft.

Tables and Figures

Table 1. Summer 2017 and summer 2019 CCPSS sardine biomass by date and band, with daily and seasonal variance, standard deviation (SD), and CV (see Methods). Note: Band 1 = inner (0-1,200 m from shore), Band 2 = outer (1,200-2,400 m from shore). *Bias-corrected biomass.

Survey Date	Band	Survey Area	Band Biomass* $B_{j,A}$	Daily Total Biomass B_{tot}	Daily Mean Biomass $\bar{B}_A$	Daily Biomass Variance $V(\bar{B}_A)$	Seasonal Variance	SD	Seasonal Total Biomass	CV
8/3/2017	1	Carmel to Half Moon Bay	4,807	4,876	2,438	11,224,322	562,622,252	23,720	21,046	1.13
	2		69							
8/4/2017	1	Half Moon Bay to Point Arena	16,089	16,089	8,045	129,427,961				
	2		0							
8/10/2017	1	Carmel to Morro Bay	81	81	41	3,281				
	2		0							
8/6/2019	1	Stewart's Point to Cape Mendocino	0	9	5	41	269,549,476	16,418	12,279	1.34
	2		9							
8/7/2019	1	Manresa Beach to Drake's Bay	11,851	12,093	6,047	67,384,441				
	2		242							
8/8/2019	1	Monterey to Limekiln SP (Kirk Creek)	51	178	89	2,888				
	2		127							

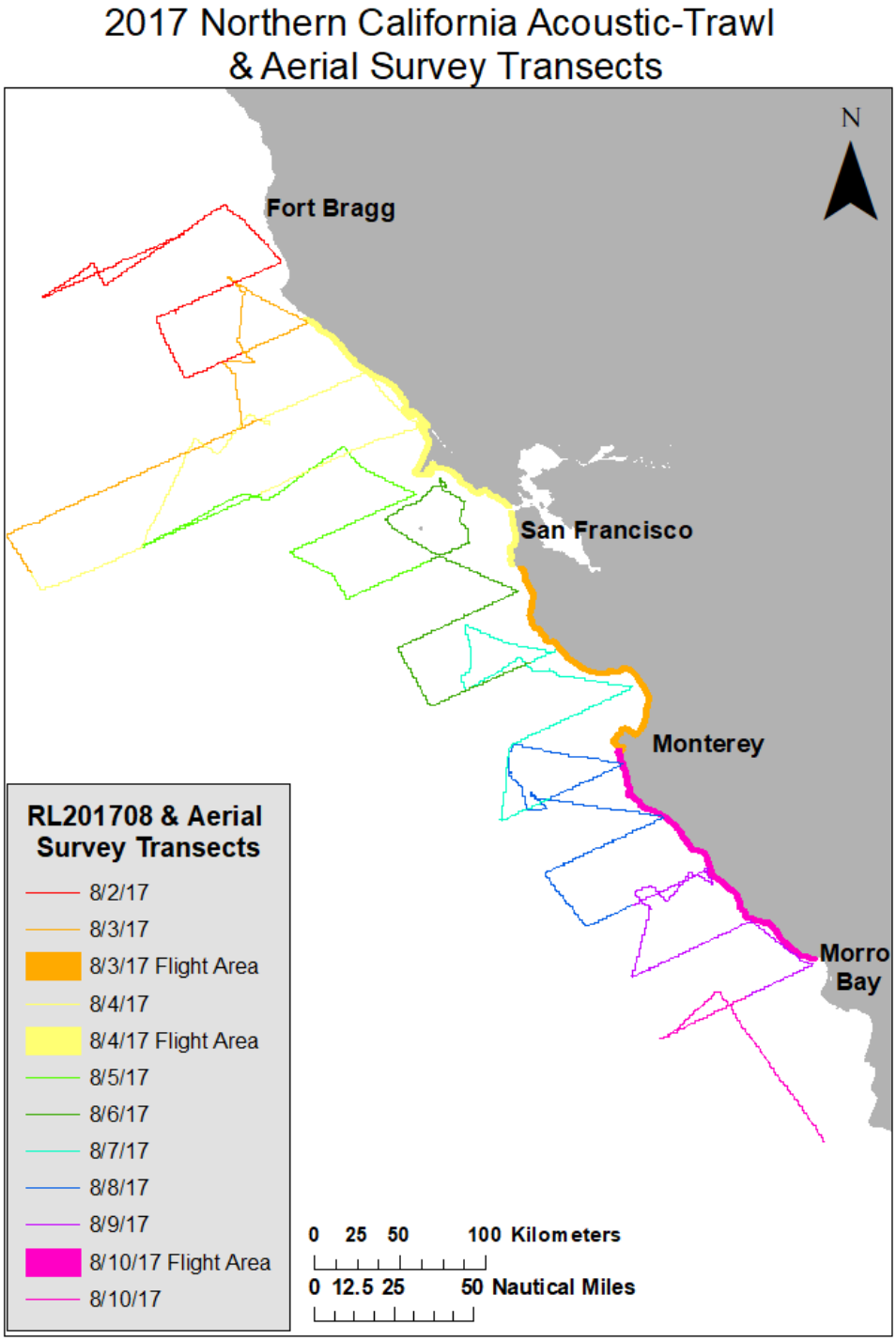

Figure 1. August 2017 NOAA Ship *Reuben Lasker* and CCPSS transect lines in northern California from near Point Arena to north of Morro Bay. Line colors denote daily *Reuben Lasker* and aerial transects. The August 4 aerial survey coincided with *Reuben Lasker* (yellow lines).

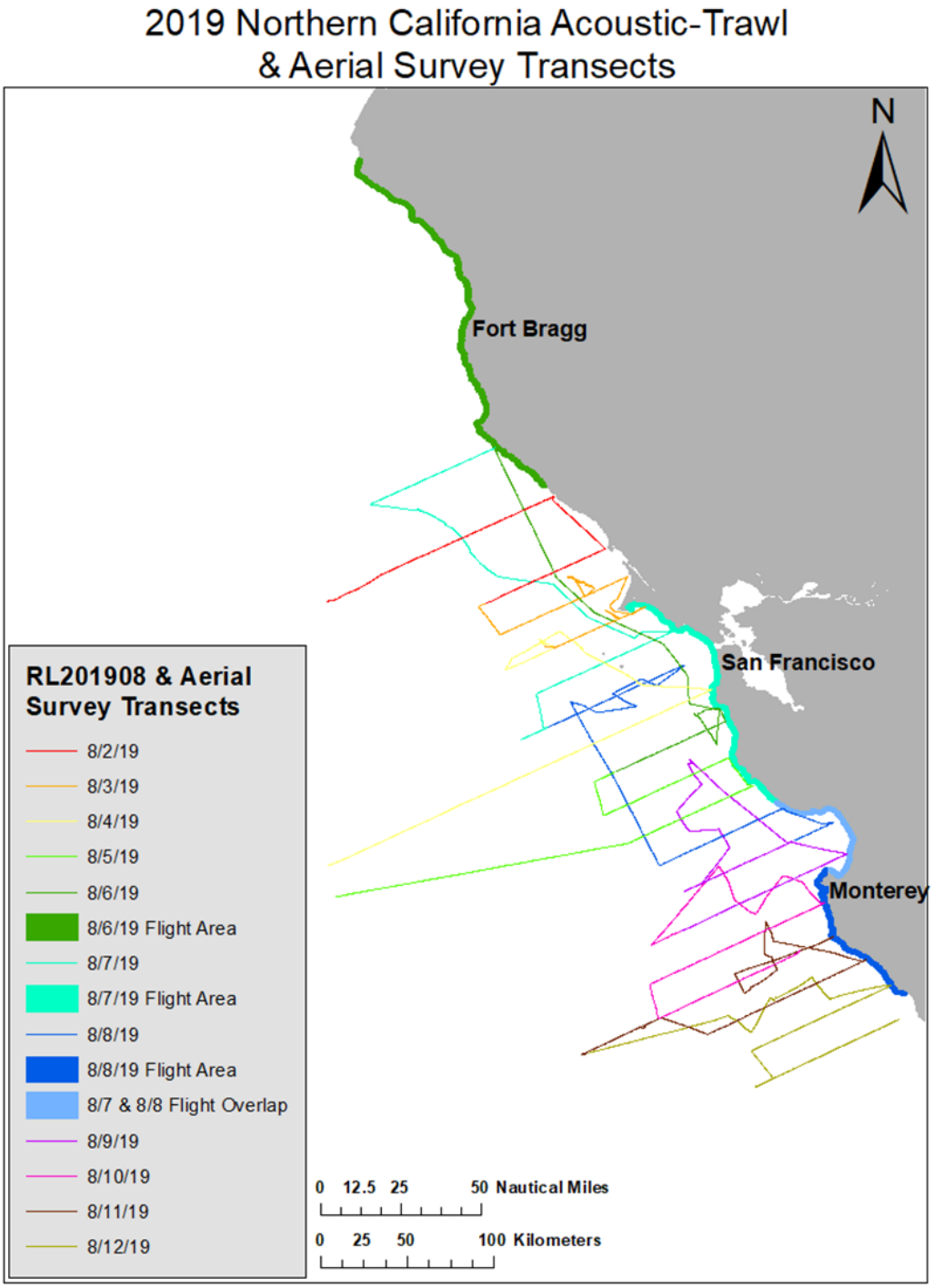

Figure 2. August 2019 NOAA Ship *Reuben Lasker* and CCPSS transect lines in Northern California from Cape Mendocino to the Big Sur coast. Line colors denote daily *Reuben Lasker* and aerial transects. August 7 and 8 aerial surveys coincided with *Reuben Lasker* (aqua and blue lines).

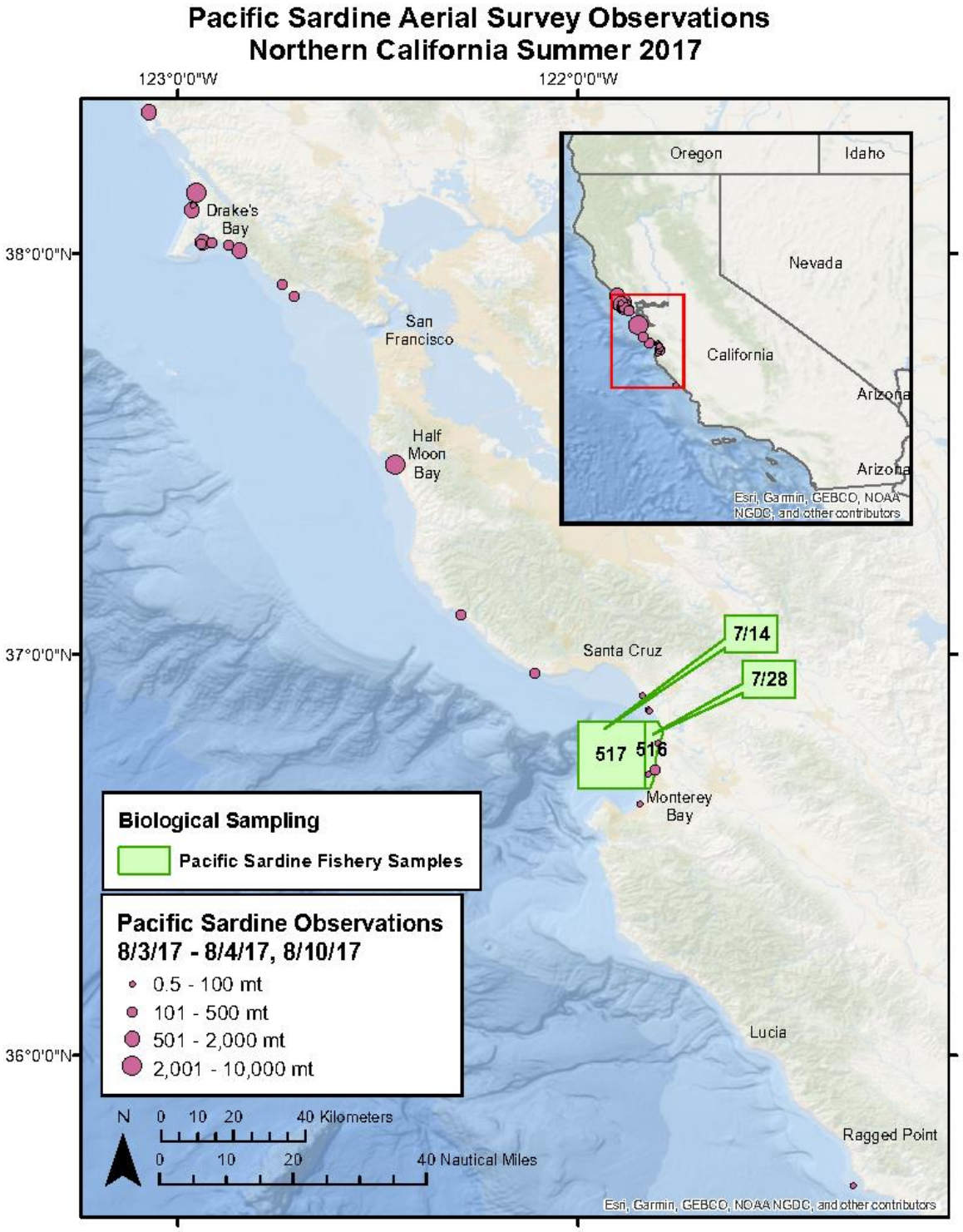

Figure 3. Locations of sardine samples from NDF samples and CCPSS sardine observations from summer 2017 in Northern California. There were single samples from 7/14 and 7/28. Samples were taken from CDFW fishing blocks 516 and 517.

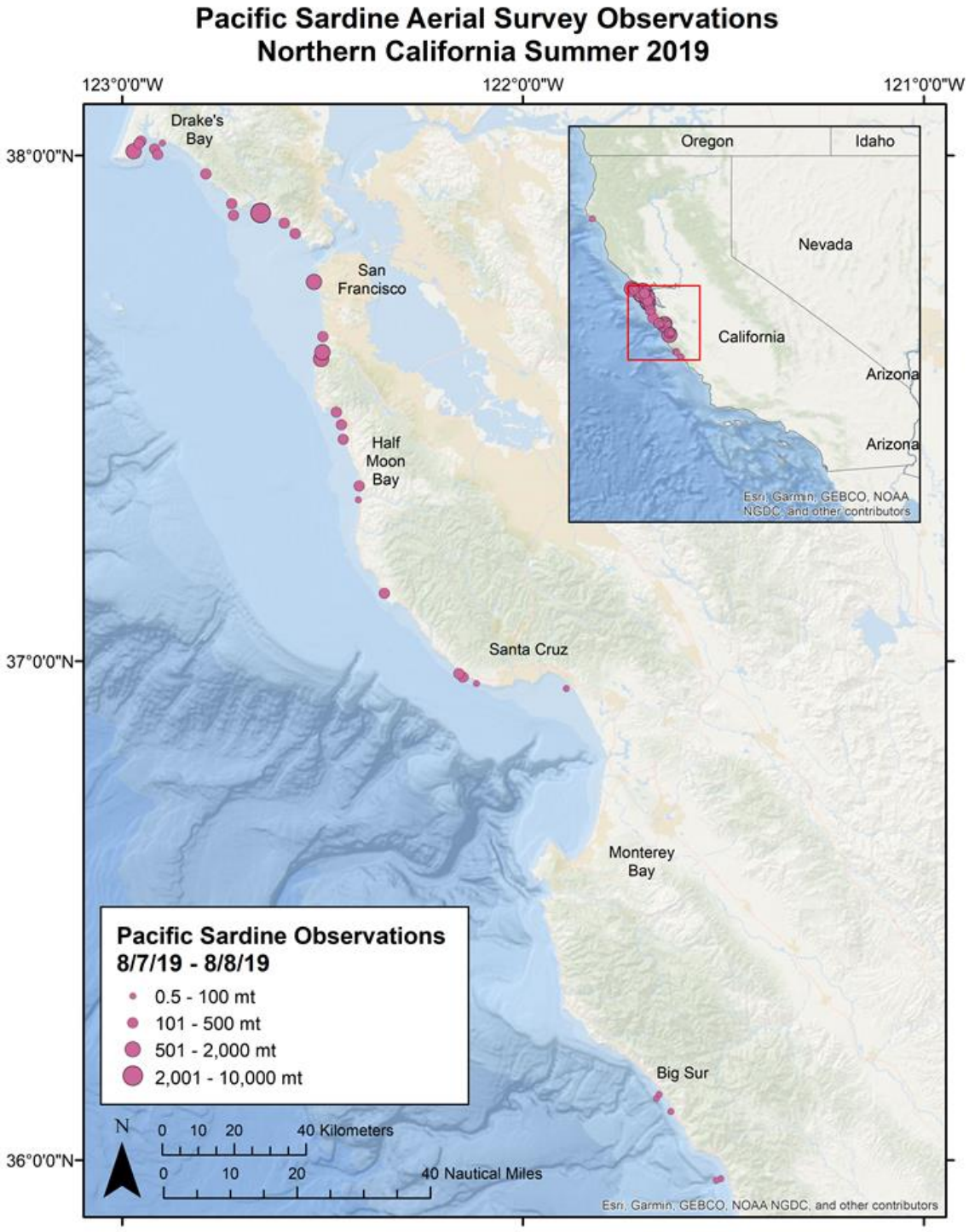

Figure 4. Distribution and biomass of sardine schools observed in Northern California during the August 2019 CCPSS. Note a single observation north of inset area, near Shelter Cove.

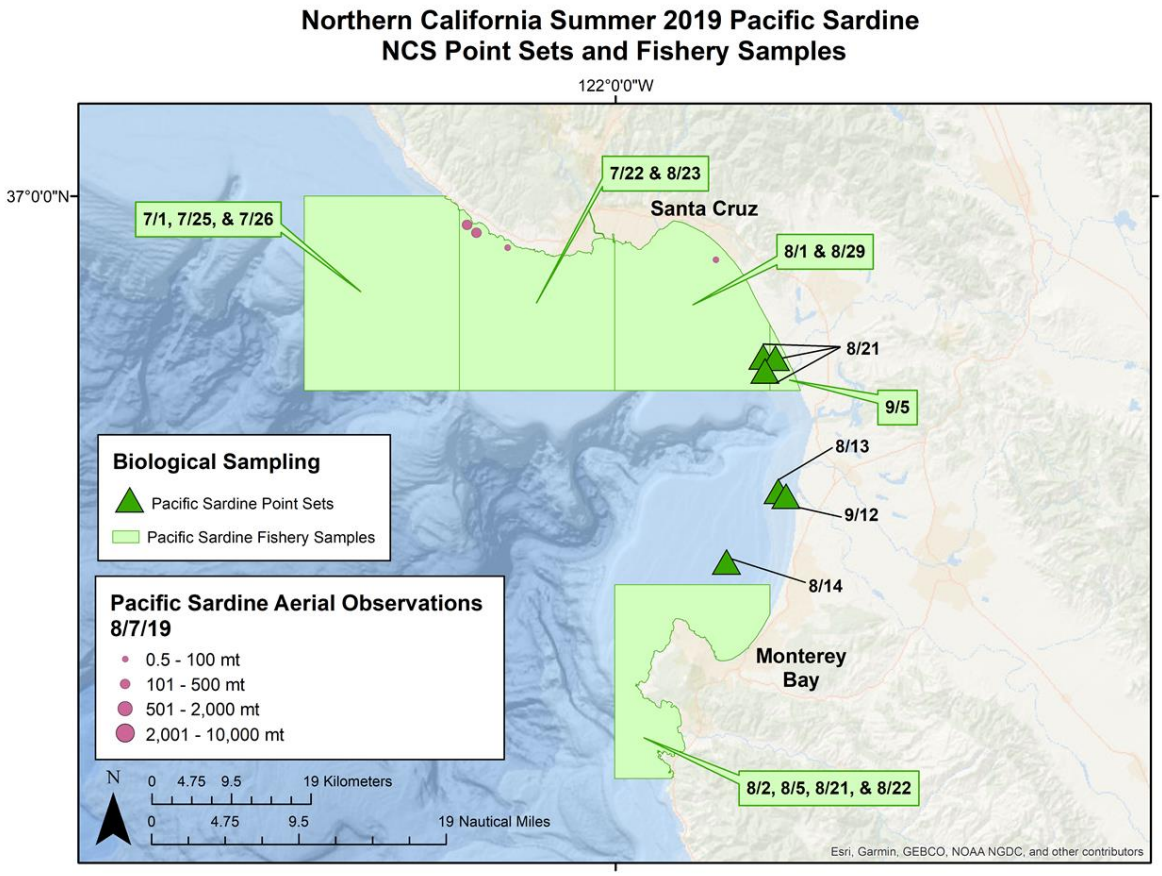

Figure 5. NCS sardine point set and NDF samples in Monterey Bay from summer 2019 shown with nearby CCPSS sardine observations. Sampling dates and CDFW fishing block numbers are shown. NCS point sets (n=6) were selected to represent CCPSS observations.

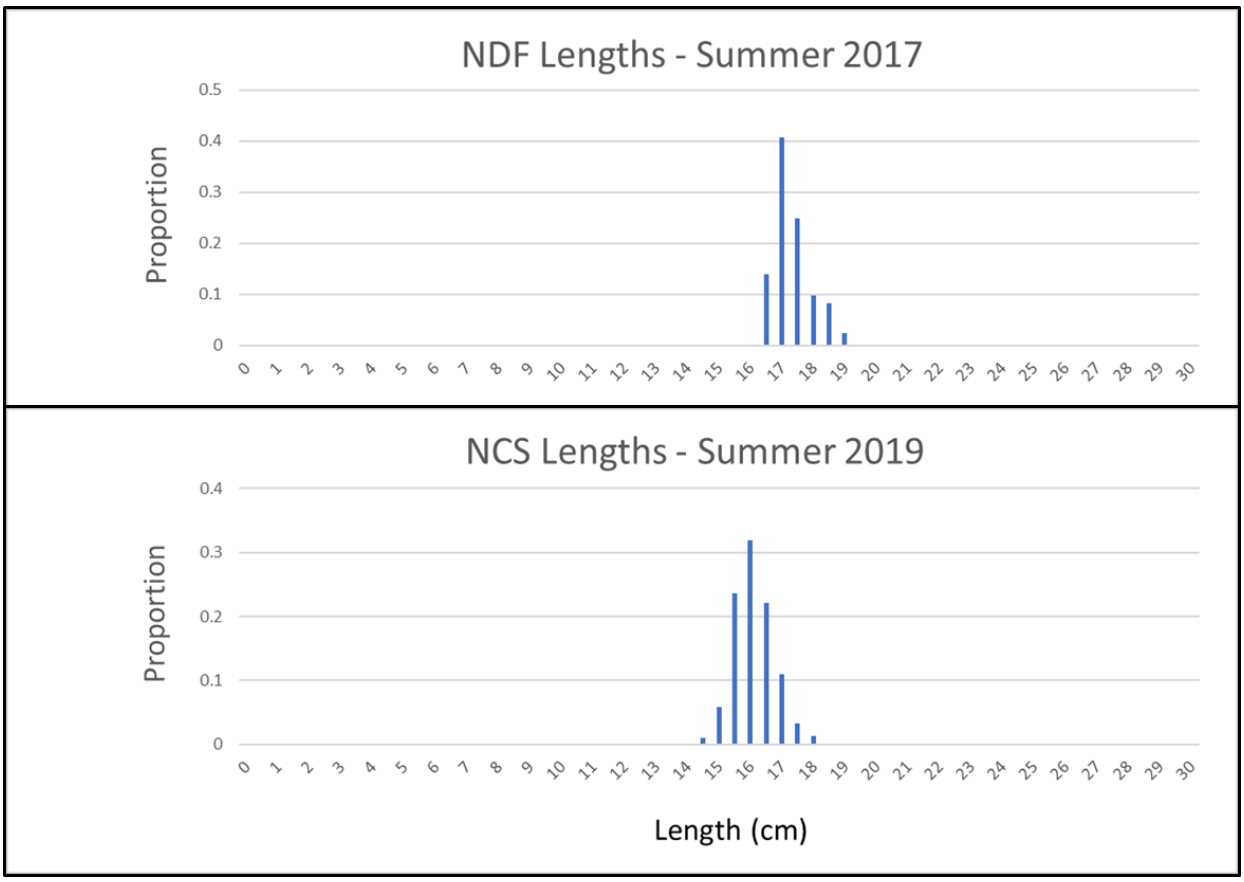

Figure 6. Sardine length composition from two NDF samples from August 2017 in Monterey Bay (top) and from six NCS point set samples from August 2019 in Monterey Bay (bottom).

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