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VARIABILITY IN NEARSHORE AERIAL BIOMASS ESTIMATED FOR THE CENTRAL SUBPOPULATION OF NORTHERN ANCHOVY (ENGRAULIS MORDAX) OFF CALIFORNIA FROM 2020 TO 2024

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EXECUTIVE SUMMARY

The fishery for the central subpopulation of northern anchovy (*Engraulis mordax*) along the U.S. Pacific Coast has been federally managed since 1978 and under the Coastal Pelagic Species (CPS) Fishery Management Plan since 2000 by the Pacific Fishery Management Council and the National Marine Fisheries Service. Prior to 2020, relative abundance indices derived from research surveys did not fully reflect the distribution of CPS in nearshore waters of < 40 m depth, an area where the fishing industry takes most of its catches. Starting in 2020, stock assessments began to take into account nearshore biomass of Pacific sardine and northern anchovy off California estimated either from nearshore aerial surveys or from small boat acoustic nearshore surveys. This document describes the variability of nearshore biomass of northern anchovy computed from seasonal, transect-based, aerial surveys conducted from 2020 to 2024 off California and compares these estimates to offshore and nearshore acoustic survey biomass in seasons where all surveys occurred synoptically (i.e., usually within one week and the same latitudinal area). Aerial nearshore biomass of northern anchovy estimated off Southern California was in general smaller during spring surveys [363 mt (CV=18%) to 7,611 mt (CV= 4%)] than summer surveys [4,374 mt (CV= 28%) to 14,859 mt (CV= 6%)]. Further, aerial nearshore biomass estimates off Northern California in summer were much higher than those off Southern California, ranging from 19,796 mt (CV= 13%) to 106,551 mt (CV= 5%). Fish collected within the nearshore areas ranged from 55 mm to 142 mm standard length (SL) and from 0 to 6 years in age. Compared to offshore acoustic biomass estimated to be 2.6 million mt in summer 2021, aerial nearshore biomass estimates were relatively low at 19,796 mt (CV=13%), representing only 0.7% of the acoustic biomass. However, the nearshore aerial biomass estimate in summer 2024 made up a greater portion (16%) of offshore acoustic biomass, which was estimated to be 672,529 mt. Despite a limited number of synoptic surveys, these results support previous findings that the inclusion of nearshore biomass in stock assessments may become more important as northern anchovy abundance decreases and if a greater proportion of the biomass resides in nearshore waters.

1. INTRODUCTION

Northern anchovy, *Engraulis mordax*, is a small pelagic fish species that inhabits coastal waters of the northeastern Pacific Ocean from Queen Charlotte Islands (British Columbia, Canada) to Cape San Lucas (Baja California Sur, Mexico), and into the Gulf of California, Mexico (McHugh 1951, Miller and Lea 1972, Hart 1973). For management purposes, northern anchovy is assumed to be divided into three subpopulations: a northern subpopulation ranging from San Francisco to British Columbia; a central subpopulation (CSNA) occupying waters between San Francisco and Punta Baja, Mexico; and a southern subpopulation residing from Punta Baja to the Gulf of California, Mexico (MacCall and Methot 1983, Fielder et al. 1986, PFMC 2024). The CSNA has supported a major fishery in California since the 1940s, with historic peak landings dating from the late 1960s to the early 1980s (CDFW 2001). The CSNA fishery has been federally managed since 1978 under the Northern Anchovy Fishery Management Plan (FMP) that then became the Coastal Pelagic Species (CPS) FMP (PFMC 2024). After a period of low abundance in the 1990s through the mid-2010s when spawning stock biomass (SSB) declined to less than 100,000 mt (MacCall et al. 2016, Thayer et al. 2017), the CSNA rapidly rebounded in the late 2010s. By 2017, SSB was estimated to be 271,752 mt (CV= 43%) in the Southern California Bight (SCB, Dorval et al. 2018), whereas by 2021 age-1+ biomass was estimated to be 2,090,640 mt across the distributional range of the CSNA (Kuriyama et al. 2022b). Despite this rebound, annual landings have remained far below the catch limit of 25,000 mt recommended for managing the CSNA since the 2000s (PFMC 2024, CDFW 2024).

While the CSNA typically expands its populations in offshore habitats as population biomass increases, it is known to occupy nearshore habitats at both low and high population levels (Baxter 1967, Mais 1974, MacCall 1990). Further, tagging experiments have documented that northern anchovy move from Southern California to Monterey Bay in summer and from Northern to Southern California in the spring (Haugen et al. 1969). Previous studies have also consistently shown much higher spawning stock biomass in Southern California than in Northern California during the spring season (e.g., Picquelle and Hewitt 1983, Hewitt 1985, Dorval et al. 2018), whereas total biomass is typically higher off Northern California during summer and fall (Mais 1974, Kuriyama et al. 2022b, Stierhoff et al. 2023a, Zwolinski et al. 2023). These population dynamics also control the spatial and temporal distribution of the northern anchovy fishery, which is more productive in July to November and January to March off Monterey Bay (CDFW 2024). As a result, catches from Monterey Bay usually comprise larger and older fish than those from Southern California (Mais 1974, Mallicoate and Parrish 1981, Parrish et al. 1985).

Accordingly, whole population dynamics were assessed from either spring daily egg production method (DEPM) surveys in the 1980s or summer CPS Surveys, using the acoustic-trawl method (ATM) in the 2010s (Lasker 1985, Lo et 1985, Zwolinski et al. 2016, Dorval et al. 2022). In some intermittent years, spring stock biomass was estimated from both DEPM and ATM (e.g., 2017, Dorval et al. 2018, Stierhoff et al. 2017) or from ATM only (e.g., 2021, Zwolinski et al. 2023). However, since 2022 no DEPM or ATM surveys have been conducted in the spring while ATM survey effort has been concentrated mostly on studying the CSNA solely in the summer. Additionally, the California Coastal Pelagic Species Survey (CCPSS), an aerial survey conducted since 2012 (Lynn et al. 2022), has shown that substantial portions of the total biomass of northern anchovy and Pacific sardine (*Sardinops sagax*) can occupy nearshore habitats, particularly in a period of low abundance (Lynn et al. 2023, Kuriyama et al. 2020, Dorval et al.

2024). Beginning in 2021, the Southwest Fisheries Science Center (SWFSC) conducted whole population CPS summer surveys, using ATM and large NOAA fishery research vessels to survey offshore areas and small commercial fishing vessels to survey nearshore areas (Stierhoff et al. 2023a, 2023b, 2024, 2025, Zwolinski et al. 2023).

In an effort to continue monitoring seasonal variations in the nearshore biomass of CSNA (here and thereafter northern anchovy), the CCPSS conducted both spring and summer surveys off California from 2021 to 2024. Spring aerial surveys off Southern California were conducted from Point Conception to San Diego, whereas summer aerial surveys off Northern California ranged from Point Arena to Port San Luis (Figures 1 and 2). In the past, seasonal nearshore biomass estimates of northern anchovy were based on various aerial survey designs (Lynn et al. 2023) making it more difficult to compare spatial and temporal changes in biomass estimates. For this study, the primary objective was to describe the regional and seasonal variability in the nearshore aerial biomass of northern anchovy from 2020 to 2024, when more consistent design and statistical methods were implemented (Dorval et al. 2024). A secondary objective of this study was to compare nearshore acoustic and aerial biomass estimates when both surveys were conducted synoptically (i.e., usually within one week and the same latitudinal area) in the summer.

2. METHODS

2.1. Point set sampling and bias correction

From 2019 to 2023, experimental point set surveys of northern anchovy were conducted off California to collect data for computing bias correction factors for aerial biomass estimates by two professional spotters. Point set sampling was conducted following the same methods for Pacific Sardine schools as described in Dorval et al. (2024). During point set sampling, a Cessna 175 A aircraft was used to identify northern anchovy schools and their distribution ahead of purse seine fishing vessels equipped with echo-sounders (Furuno FCV 295/582, Furuno TZ 12/14) and/or SONAR (Furuno CH 37, 270 or 250, WESMAR HD 800). Then, the pilot ("Spotter 1") and an additional observer ("Spotter 2") communicated the location of observed schools and directed the fishing vessels to wrap selected individual schools. The spotters independently determined school species compositions and estimated the biomass and the proportion of each school that was effectively wrapped and caught by each purse seine set. After capture, catches from point sets were stored separately in different vessel holds. Upon landing, the total landed catch was weighed and the species composition of each captured school was determined. In addition, lengths and weights of individual fish from a 50-fish subsample were measured, and otoliths extracted from all fish in this subsample. However, based on the criteria to select point set data for analysis (> 90% wrapping), only 12 schools of northern anchovy collected in the SCB and in Monterey Bay were deemed adequate. Based on power analysis, this sample size was much smaller than the minimum number of point sets recommended to develop accurate calibration curves (PFMC 2018). Therefore, northern anchovy (n=12) and Pacific sardine (n=69) point sets were combined to derive a mixed-calibration curve for northern anchovy. Pacific sardine point sets included samples collected in 2010 (Jagielo et al. 2012) and from 2018 to 2023 (Dorval et al. 2024). For more information on school selection and wrapping, landed catch processing, and analysis, we refer the reader to Dorval et al. (2024).

2.2. Aerial Transect Survey

Following the aerial survey design described in Dorval et al. (2024), CCPSS flights were conducted in summer 2020-2024 within the Northern California (NCA) region, from approximately Point Arena to Morro Bay, and in spring 2021-2024 within the Southern California (NCA) region from south of Point Conception to San Diego (Figures 1 and 2). Based on assumed stock dynamics, spring surveys were conducted solely within the SCA region (Mais 1974, Picquelle and Hewitt 1983, Hewitt 1985, Dorval et al. 2018, Stierhoff et al. 2020, Kuriyama et al. 2022b). During each seasonal survey, aerial flights were conducted on predesignated strata covering waters out to 3,600 m, namely N1-N8 in NCA and S1-S6 in SCA. Then, post-survey expansions of aerial biomass estimates were computed for unsurveyed strata (expansion strata) identified as N1E-N7E in NCA and S1E-S5E in SCA (Figures 1 and 2). Airspace restrictions surrounding the Los Angeles International Airport greatly limited surveyable areas in the vicinity. For this reason, two smaller strata, S3 and S4, were delineated to represent the surveyable area from Malibu to Long Beach, CA. The expansion stratum S3E, which contained the restricted flight zone, was not surveyable. Survey strata measured 56 km long, except for S3 and S4, which were 28 km long. Expansion strata were 28 km long, except S2E (26 km), S3E (56 km) and S4E (13 km). Locations and sizes of strata were selected to maximize coastline coverage while avoiding restricted flight zones, and to allow sufficient time for completing each stratum in a single day. Additionally, in some seasons due to weather conditions and/or unexpected flight restrictions the total area of some predesignated survey strata may not have been flown. In these cases, unflown portions of these strata were considered as additional expansion areas. For example, Figures B7, B9, B11, and B12 in Appendix B show where small portions of both S1 and S6 strata were not surveyed, and thus considered as expansion areas. Within each stratum, three transects that follow the shore contours were located at 1,200 m, 2,400 m, and 3,600 m off the coastline. The transects were each flown twice during daily aerial surveys.

Whenever possible, summer aerial surveys were flown concurrently over areas inshore of the ATM survey and saildrone (unmanned surface vehicle) track lines (Stierhoff et al. 2025). Scheduling of survey flights was planned to coincide in space and time as closely as possible with offshore ATM surveys by NOAA Fishery Survey vessel (FSV *Reuben Lasker*) and/or the nearshore acoustic survey fishing vessel (FV *Long Beach Carnage*). Aerial survey flight dates were set ahead of time based on the ATM survey schedule. However, weather conditions and changes in ATM survey plans often affected coordination with CCPSS flights. For some strata, this resulted in temporal discrepancies (< 7 days) between FSV *Reuben Lasker* and aerial survey coverage of the same latitudinal water areas (Table A3, Appendix A). For example, in summer 2020 some NCA strata were inaccessible due to firefighting efforts that restricted flights over this region during the Dolan Fire (ArcGIS 2021), whereas in summer 2024 only two SCA strata (S1 and S2) were flown in July due to unsuitable weather conditions during the remaining time available in August for survey flights. As a result, spatial and temporal coverage of seasonal synoptic surveys varied from season to season as shown in Appendix C (Figures C1 to C5).

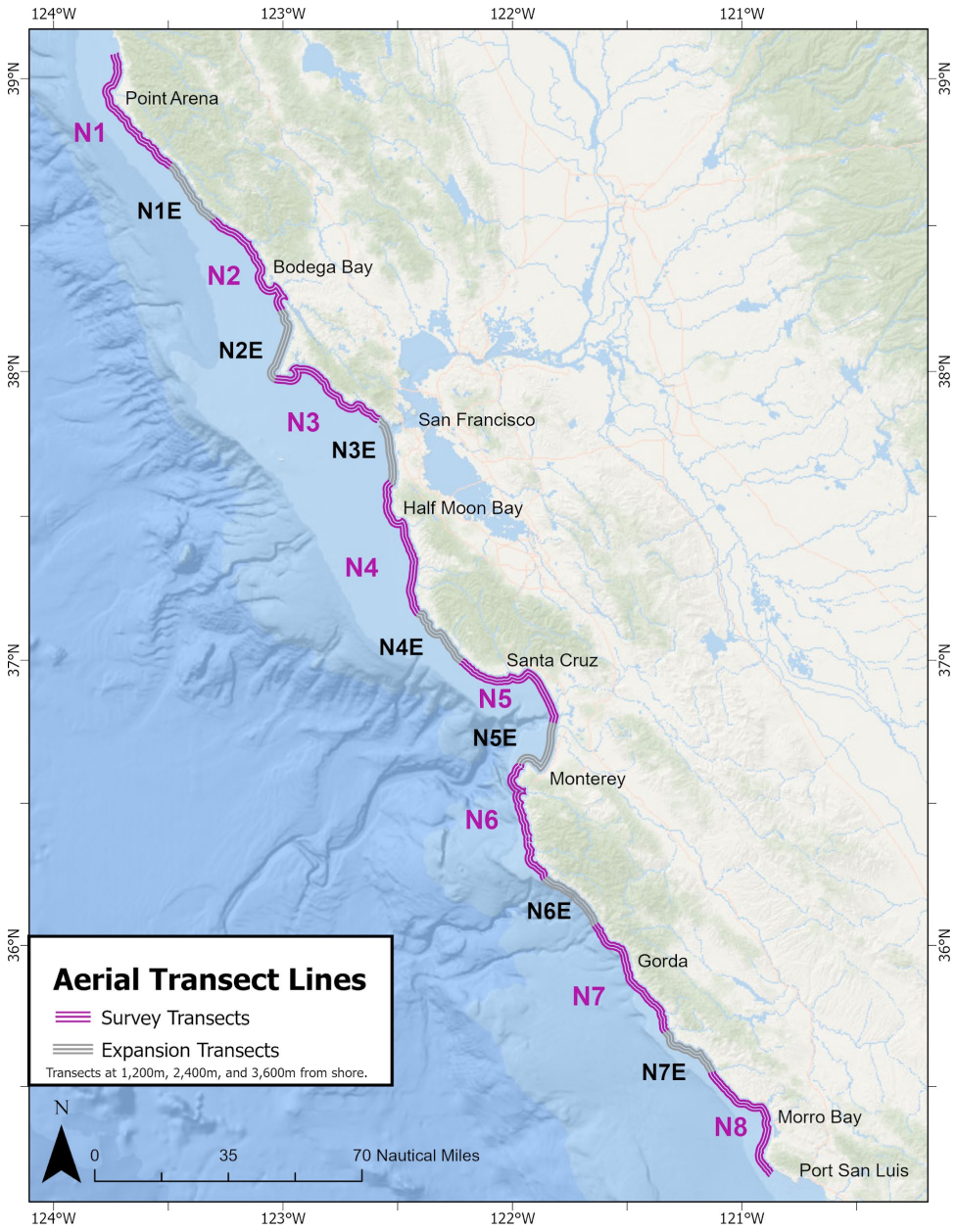

Figure 1. Strata of the California Coastal Pelagic Species Survey (CCPSS) in the Northern California (NCA) region. Predesignated survey strata (with 3 survey transects each) are shown in purple; strata for expansion (with 3 expansion transects each) of biomass are denoted with "E" label.

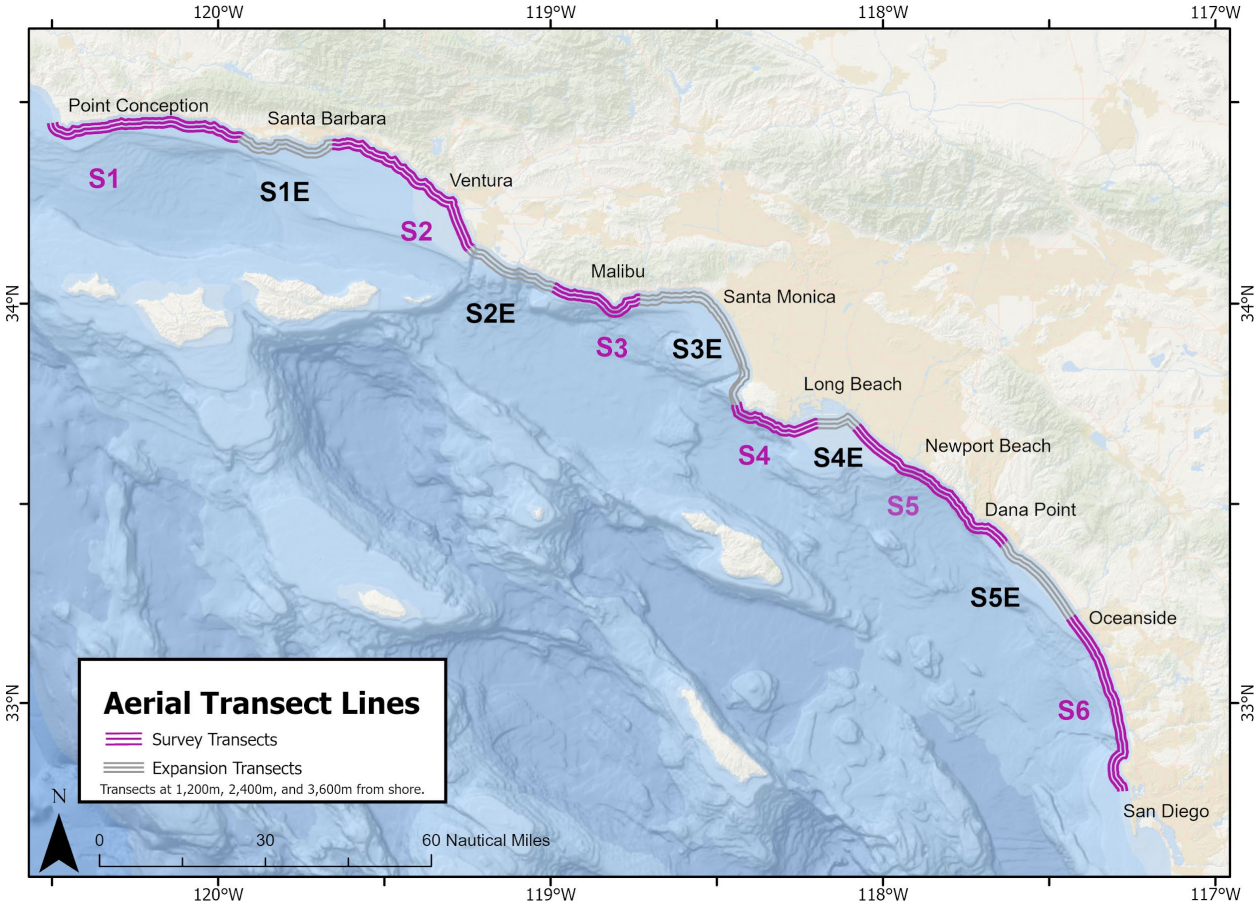

Figure 2. Strata of the California Coastal Pelagic Species Survey (CCPSS) in the Southern California (SCA) region. Predesignated survey strata (with 3 survey transects each) are shown in purple; strata for expansion (with 3 expansion transects each) of biomass are denoted with "E" label. Note strata S3 and S4 are smaller to circumvent airspace restrictions.

For a given flight day, the selection of which strata were flown was based on local weather conditions, coordination with acoustic survey vessels (if any), and random selection within those constraints. Acceptable conditions for conducting a survey flight were wind speed no more than approximately 10-12 knots, and at least 90% clear of cloud cover. In 2020, transects were completed using a Partenavia P68 (N28FG) equipped with a forward motion compensating (FMC, Aerial Imaging Solutions, LLC, Version 12.3.1) system, which automatically recorded geographic coordinates of flight paths while taking photographs of observed CPS schools (Dorval et al. 2024). However, from 2021 to 2024 a Cessna 185 or a Partenavia P68 (N37FG) was used, but an FMC system could not be installed in these aircraft. Consequently, from 2021 to 2023 school locations were recorded using the ArcGIS Quick Capture system as described in Dorval et al. (2024), whereas in 2024 the ForeFlight Application (version 16.10) was used. For the latter, when the observer spotted fish schools, he would mark the location on the ForeFlight application. The observer would then read off the GPS coordinates of those locations in the application to the biologist data recorder.

For all seasonal surveys conducted from summer 2020 to summer 2024, aircraft were flown by a California Department of Fish and Wildlife (CDFW) Warden-Pilot. Spotter 1 from the California Wetfish Producers Association (CWPA) served as observer, identifying schools of northern anchovy while providing single or aggregated school biomass estimates. Additionally, a CDFW biologist was onboard and recorded biomass, environmental, and distributional data on northern anchovy schools. It is important to note that in 2020 no offshore acoustic surveys were conducted due to COVID-19 restrictions, but the FV *Long Beach Carnage* conducted biological sampling synoptically with the aerial survey during the summer. Likewise, in summer 2020 surveyable strata closest in proximity to nearshore sampling by FV *Long Beach Carnage* were prioritized (see Figures B1 and B2, Appendix B).

2.3. Aerial Survey Biomass and Density Estimation

In 2020-2024, aerial survey biomass was estimated daily for each observed school on a given transect and stratum whenever possible. However, in many instances, the observer was not able to estimate individual school biomass, particularly with numerous schools moving and intermixing on the transect. In these cases, the biomass was "aggregated" for all fish schools observed on this portion of the transect line. Therefore, the sampling unit of the survey was considered the transect line surveyed by the spotter during a flight on a given day and stratum. The main objectives were to: a) estimate the daily total biomass measured on a given stratum; b) estimate the mean biomass density and its variance on a given stratum on a given day; and c) estimate the mean density, total biomass, and their variance for each region [Northern California (NCA) or Southern California (SCA)] during the survey period. Daily total biomass estimated on each transect were adjusted using the Spotter 1 bias correction factor, as they were the sole observer who participated in CCPSS aerial transect survey flights during the 2020-2024 period. Regional seasonal biomass was computed from mean density (mt/km^2) estimated across strata, while its variance was derived from resampling transect survey data within each stratum based on 10,000 iterations. Statistical methods and equations used to compute each one of these biomass components and their variance are provided in Dorval et al. (2024). Briefly, for each daily survey, spotter 1 data were used to compute aerial biomass for each of two replicated flights conducted on each transect *j* in a given stratum *s* ($N_{j,s}$). Thereafter, for each transect the daily mean biomass and its variance were computed, which were then used to estimate the grand mean of stratum biomass ($\overline{\boldsymbol{B}}_s$) and the total biomass of stratum using the following estimators:

$$B_s^{tot} = N_{j,s} \times \overline{\boldsymbol{B}}_s,$$

with variance equal to:

$$Var(B_S^{tot}) = (N_{j,s})^2 \times Var(\overline{\boldsymbol{B}}_s)$$

From the above equations, density in each stratum was estimated based on the area (A_s) flown by the pilot as:

$$D_s = \frac{B_S^{tot}}{A_s}$$

with variance equal to:

$$Var(D_s) = \frac{1}{(A_s)^2} \times Var(B_S^{tot})$$

Therefore, if $N_{s,r}$ strata were surveyed in region r during a seasonal survey, the total regional biomass (B_r^{tot}) was computed as:

$$B_r^{tot} = \sum_{s=1}^{N_{s,r}} \overline{D}_{s,r} \times A_{s,r},$$

where ($\overline{D}_{s.r}$) is the mean density over all strata of region r, and $A_{s,r}$ the area of stratum s in region r.

Finally, replicated flight (n = 6) biomass estimated for each stratum surveyed in a given region were bootstrapped, with each iteration repeating the steps above, leading to 10,000 estimates of mean density per region in a given season. These estimates were used to compute final variance of mean density and resulting regional total biomass and variance in a given season.

Note that aerial survey design and methods used in this study resulted from previous workshops and stock assessment review panels and were approved by the Statistical and Scientific Committee of the Pacific Fisheries Management Council (e.g., PFMC 2018, 2019, 2020, 2022). All biomass components of the CCPSS survey, including calibration curve parameters, can be estimated using the R package "*ccpss.aerial.biomass*" which is available upon request.

2.4. Sampling for Length and Age Compositions

Age and length compositions are important information for integrating survey biomass in age-structured stock assessment models (Chen et al. 2003, Hilborn and Walters 1992, Quinn and Deriso 1999). For example, these data allow the computation of selectivity- at-age or -at-length of the survey index (e.g., Quinn and Deriso 1999). These data have also helped in determining the range of ages and lengths that were suitable to adjust catchability of the ATM survey based on aerial biomass (Kuriyama et al. 2022a). As recommended by previous CPS stock assessment review panels (PFMC, 2020, 2021. 2022) understanding the ontogenetic distribution (*i.e.*, distribution of juveniles and adults) of CPS in nearshore and offshore waters is critical to accurately determine the ATM survey catchability. For this purpose, fish samples for CCPSS were collected from two main sources:

First, northern anchovy catches from 23 point sets conducted in 2019-2023 independently of aerial surveys were sampled for biological data. Fish samples were collected at the dock during offloading of each set. Each set was sampled four times at equal intervals throughout the pumping of the catch using 5-gallon buckets to collect fish samples. As catches often contained other species, the contents of each bucket were sorted by species and weighed in aggregate by species. All four subsamples were then pooled and mixed in a basket, and up to 50 fish per species and per set were randomly selected, stored in plastic bags and preserved on ice. All collected fish samples were measured and analyzed for biological characteristics (length, weight, sex, maturity, and age) at CDFW laboratories. The maturity stage of individual fish was determined from visual analysis

of gonad samples based on methods developed by Macewicz et al. (1996). Fish were aged from surface ageing of whole otoliths following similar procedures as described in Schwartzkopf et al. (2022) and Dorval et al. (2025), hence all ages were assigned assuming a June 1 birthday.

Second, FV *Long Beach Carnage* conducted biological sampling from purse seine catches during the aerial survey in 2020 and nearshore acoustic surveys off California in 2021-2024. In 2020, due to the COVID pandemic there were no CPS surveys, thus biological sampling for aerial surveys took place off the California coast from the Bodega Bay area south to San Diego, using the same survey strata as the CCPSS aerial flight path. Sampling from the FV *Long Beach Carnage* also occurred independently of aerial surveys although as close in time as possible (no more than three days apart from aerial survey of those strata). The goal was to have at least three samples taken per sample day, and a dip net was used to collect three subsamples in three separated points from each purse seine set.

In March 2021 and in summer 2021-2024, the FV *Long Beach Carnage* again sampled with the CCPSS nearshore areas from San Diego to Point Conception, in concert with the offshore NOAA ATM survey conducted by FSV *Reuben Lasker*. In 2020 three purse seine sets were made during daytime or nighttime within the same nearshore area as CCPSS. From 2021 to 2024, purse seine sampling was conducted following acoustic sampling on each odd-number transect and biological data were collected from a maximum of three samples per day (Table A4, Appendix A). From each catch, a maximum of three dip net samples were taken and then sorted by species. As many as 20 northern anchovy were then selected from each dip net and combined before randomly selecting a total of 50 fish from the set. After sampling, all fish were frozen and then delivered to CDFW laboratories for processing and collecting biological data as above (Stierhoff et al. 2025).

3. RESULTS

3.1. Point Set Sampling

Eighty-one point sets, including 12 for northern anchovy and 72 for Pacific sardine, were used to build the mixed calibration curve for correcting northern anchovy school biomass estimated during aerial surveys (Figure 3, Table A1). Prior to capture, schools observed from echo-sounders during the 2018-2023 point set surveys were distributed from a mean depth of 4.60 m to 23.80 m. In general, northern anchovy schools had a wider range of depth distribution than Pacific sardine in the water column, with only one school occupying a mean depth of 5.5 m. The remaining 11 northern anchovy schools were distributed from a mean depth of 11.00 m to 23.80 m (Figure 3). The largest northern anchovy school measured 111.40 mt and was observed at a mean depth of 18.30 m, spreading from 10.97 m (top) to 25.60 m (bottom) prior to capture (Figure 3). Ten northern anchovy point sets were from the Monterey Bay area and two were captured in Southern California. These point sets were all captured in ocean bottom depths ranging from 9.14 m to146 m. Of these, two were mixed with very small Pacific sardine schools of 0.34 mt and 0.54 mt (Figure 3). Nine-point sets of northern anchovy were sampled for biological data. In these catches, fish sizes ranged from a minimum of 79 mm to 142 mm (Figure 4). Northern anchovy sampled in these surveys ranged from 0 to 6 years old, but 95% of these catches comprised fish of < 4 years old (Figure 4).

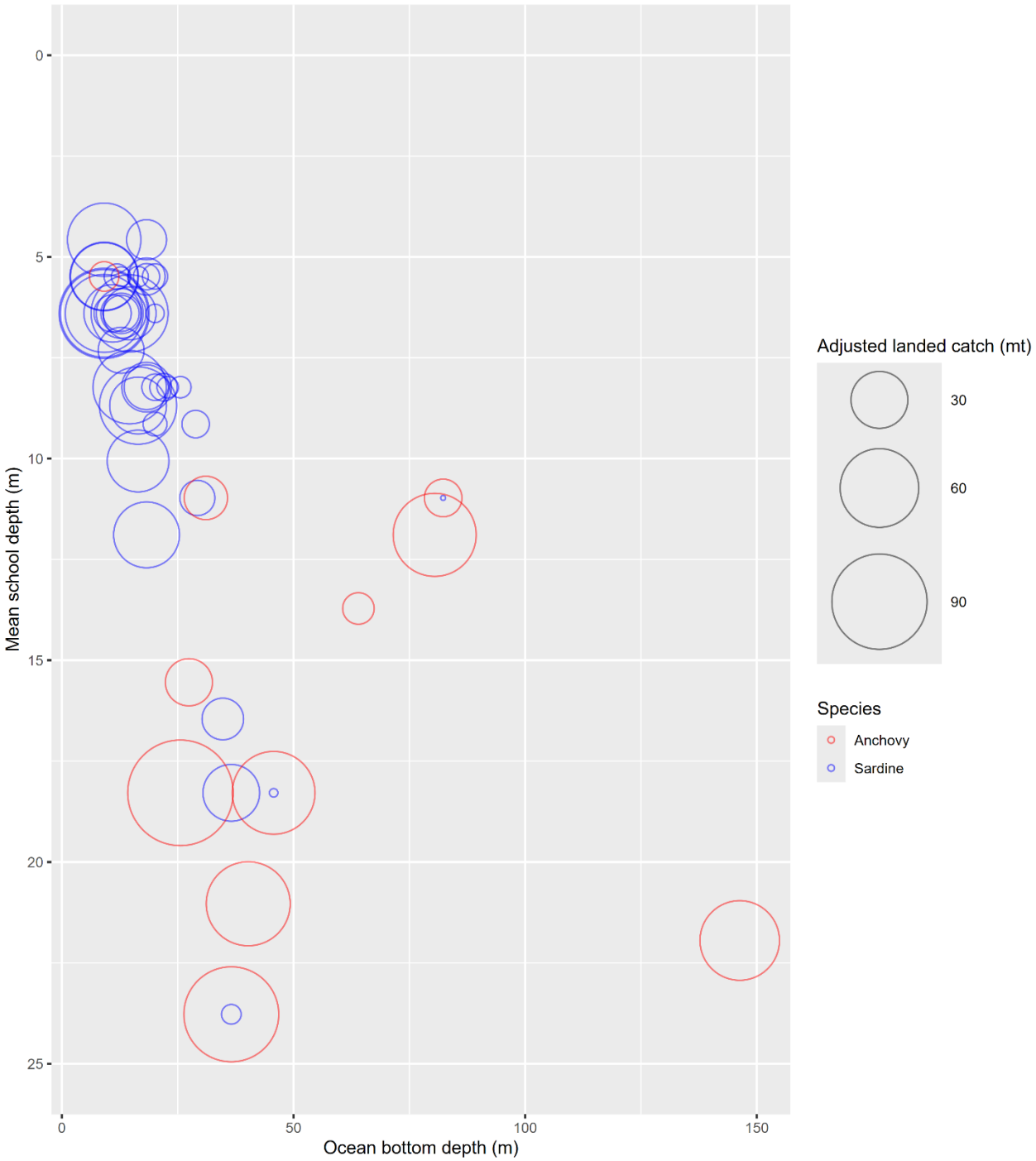

Figure 3. Northern anchovy (red circles) and Pacific sardine (blue circles) mean depth school distribution across ocean bottom depth, and adjusted biomass (size of circle in mt) estimated from chartered boat sonar observations during point set sampling off California from 2018 to 2023.

Finally, the largest Pacific sardine school observed in 2018-2023 weighed 80.08 mt, occupied a mean depth of 6.40 mt, and spread from 3.66 m (top) to 9.14 m (bottom) prior to capture. A total of 53 schools containing Pacific sardine were from Southern California, whereas 19 were captured in Northern California. All these schools except one were captured in ocean depths of < 46 m (Figure 3).

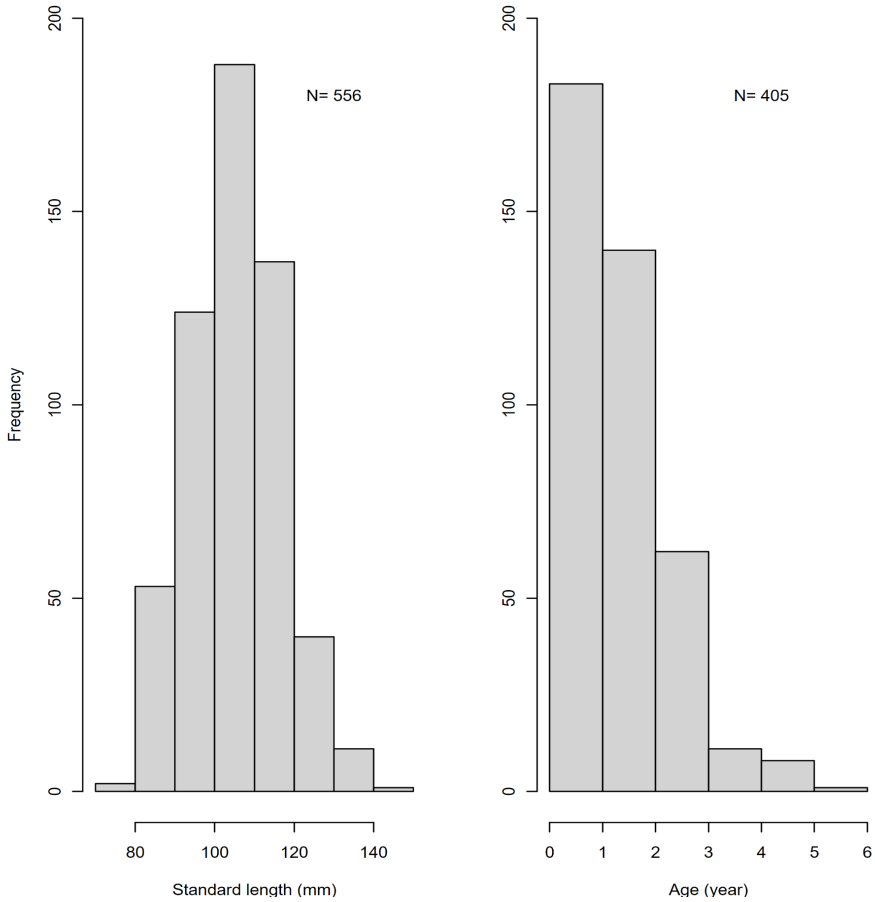

Figure 4. Length and age composition of northern anchovy collected during point set sampling in 2019-2023. Nine-point sets were sampled for biological data in Monterey Bay, and two in San Pedro, California. In both panels, N indicates the total number of northern anchovy collected (left panel) and aged (right panel) across all point sets.

3.2. Calibration factors

A comparison of the parameters estimated for the mixed calibration curves showed that both spotters underestimated the tonnage of northern anchovy and Pacific sardine schools during the point set surveys (Figure 5). Additionally, both calibration curves derived from the surveys explained ~ 97% of the variability in the data. Bias corrections estimated for Spotter 1 and 2 were similar, varying from 0.955 (SE= 0.020) to 0.959 (SE= 0.024). Therefore, both spotters underestimated northern anchovy landed tons by about 4%. The correction factor of Spotter 1 was applied to all field-estimated biomass of northern anchovy from the 2020-2024 seasonal surveys.

3.3. Aerial Biomass Estimates

From 2020 to 2024, summer surveys were conducted in both NCA and SCA, and spring surveys only in SCA (Table 1, Figures B1-B14). No fish were observed during summer 2023 in NCA (Figure B4, Appendix B). In summer 2022, only two NCA strata (N3 and N5) were successfully surveyed. However, northern anchovy were observed only in stratum N5 off Santa Cruz with biomass estimated at 4,445 mt (Table A3, Figure B3). Therefore, NCA regional biomass, density, and CV were computed only for summer 2020, 2021, and 2024. For those seasons, the regional biomass was estimated to be 53,853 mt (CV= 3%), 19,796 mt (CV= 13%), and 106,551 mt (CV= 5%), respectively. As a result, density in the NCA was estimated to be 22.80 mt/km^2, 11.00 mt/km^2, and 135 mt/km^2 in these three seasonal surveys, respectively. Despite the high density (135.35 mt/km^2) in summer 2024, only 33% of the predesignated survey area for the NCA was flown (Table 1). Thus, during this season northern anchovy schools were mostly aggregated in three strata, N3 off north of San Francisco, N4 off Half Moon Bay, and N5 off Santa Cruz (Figure B5, Appendix B). Further, mean biomass estimates from bootstrap resampling had a unimodal distribution in 2020, but exhibited a trimodal distribution in 2021 and 2024 (Figure 6).

Due to weather conditions, only two strata (S1 and S2) were flown in the SCA in summer 2024, with a minimum biomass of 315 mt of northern anchovy observed in S2 between Santa Barbara and Ventura [(Table A3, Appendix A); Figure B14, Appendix B)]. Thus, in SCA regional biomass was computed only for 2020 to 2023 summer surveys, which had adequate spatial coverage (Figures B6, B8, B9, Appendix B). For this period, 1,515 km^2 was consistently flown over the SCA with regional biomass increasing from 4,374 mt (CV= 28%) in 2020 to 14,859 mt (CV= 6%) in 2023 before decreasing to 4,870 mt (CV=17%) in 2023 (Table 1). As the SCA coverage remained the same in 2020-2023, mean density estimated in these summer surveys followed the same patterns as regional biomass, with the lowest density in 2020 (2.89 mt/km^2) and the highest in 2022 (9.81 mt/km^2). In addition, mean density estimated in 2020 had a trimodal distribution, while 2021-2022 mean densities showed unimodal distributions (Figure 7).

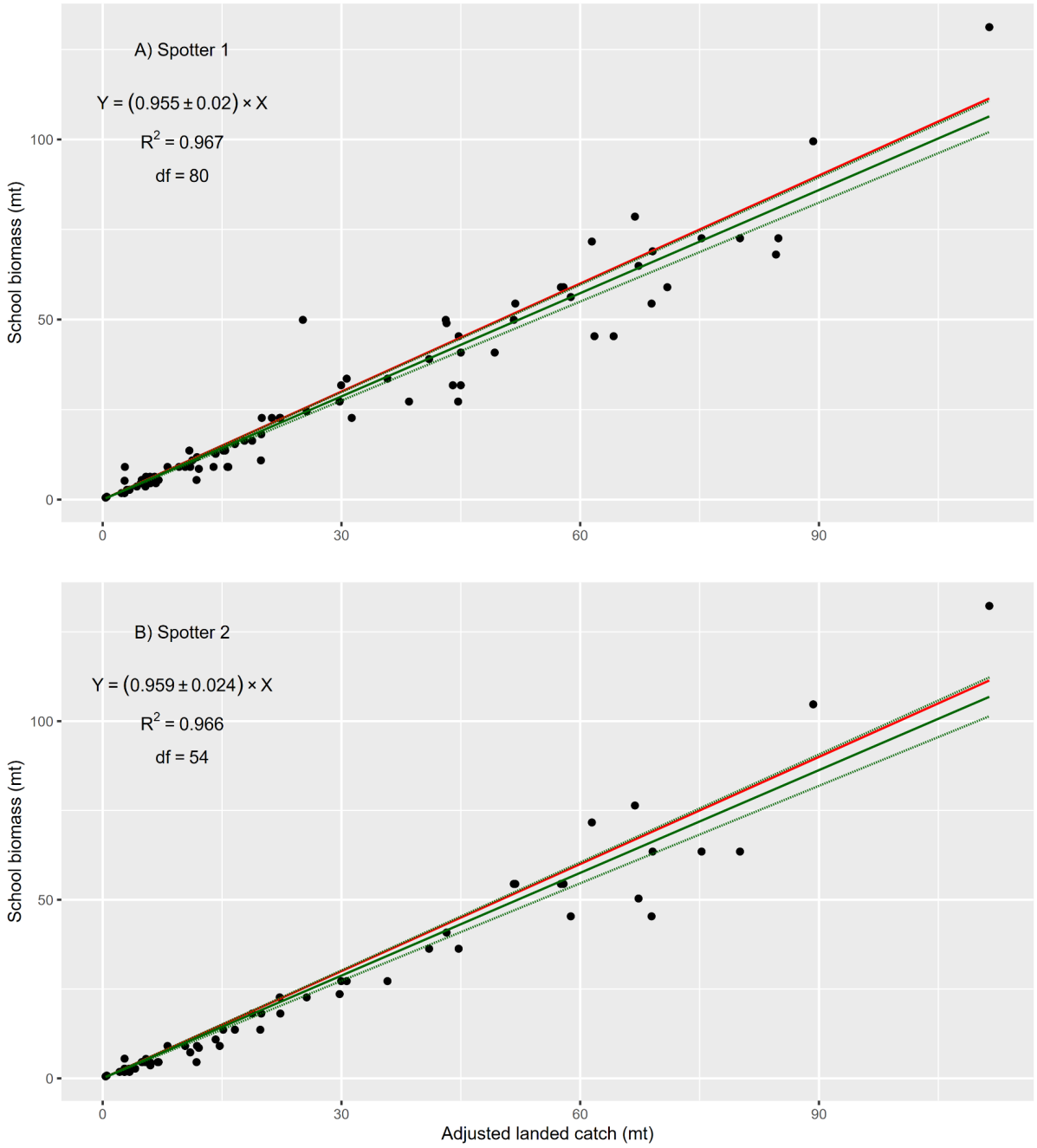

Figure 5. Mixed calibration curve developed for Spotter 1 (Panel A) and Spotter 2 (Panel B) from Pacific sardine and northern anchovy point set sampling conducted off California. Spotter-1 point sets were collected in 2010 and from 2018 to 2023 off California, whereas Spotter-2 observations covered only the 2018-2023 period. Estimated school biomass (Y-axis) is the aerial school biomass (black dots) observed by spotters, whereas adjusted landed catch (X-axis) is the corresponding landed biomass tonnage for observed schools, corrected for estimated percent capture by the fishing vessel. Lines on each panel represent the 1:1 relationship (red line), the predicted curve (solid green line), and the upper and lower 95% confidence intervals (dotted green lines) of the predicted curves.

By design, spring surveys were conducted only in SCA. Further, all 2021-2024 surveys were conducted with adequate coverage to generate consistent estimates of regional biomass (Figures B7, B9, B11, B13, Appendix B). Compared to summer, observations in the SCA, spring regional biomass estimates were in general smaller, ranging from 363 mt (CV= 18%) in 2024 to 7,611 mt (CV= 4%) in 2021 (Table 1). In spring 2021, most northern anchovy schools were observed from Point Conception to Malibu and from Oceanside to San Diego (Figure B7). No northern anchovy schools were observed on the predesignated survey strata (S1-S6) in spring 2022 (Figure B9, Appendix B). However, in spring 2023 northern anchovy schools were more locally aggregated, with most schools occurring on the predesignated strata S2 (Santa Barbara to Ventura) and S6 (Oceanside to San Diego) (Figure B11, Appendix B). Moreover, in spring 2024 school aggregations were observed only on S2 (Figure B13, Appendix B). The mean density distribution was trimodal in spring 2024, whereas in spring 2021 and 2023 it followed a unimodal distribution (Figure 7). Based on the aerial survey design, data collected in spring 2022 in SCA were not appropriate for computing mean density and regional biomass.

Table 1. Regional aerial survey density and biomass estimated by region and season from 2020 to 2021. Biomass variance was obtained from bootstrap resampling analysis.

Survey Dates	Region	Year	Season	Area (km^2)	Density (mt/km^2)	Biomass (mt)	SD	CV (%)
9/5 - 9/16	NCA	2020	Summer	2,259	23.84	53,853	1,431	3
9/18 - 9/20	SCA	2020	Summer	1,515	2.89	4,374	1,209	28
3/22 - 4/2	SCA	2021	Spring	1,515	5.02	7,611	272	4
8/6 - 8/11	NCA	2021	Summer	1,373	14.42	19,796	2,548	13
9/12 - 9/17	SCA	2021	Summer	1,515	6.29	9,522	567	6
8/28 - 9/2	SCA	2022	Summer	1,515	9.81	14,859	858	6
4/2 - 4/8	SCA	2023	Spring	1,515	4.47	6,771	300	4
7/10 - 7/14	SCA	2023	Summer	1,515	3.22	4,870	811	17
3/25 - 3/29	SCA	2024	Spring	1,515	0.24	363	66	18
8/2 - 8/13	NCA	2024	Summer	786	135.65	106,551	4,871	5

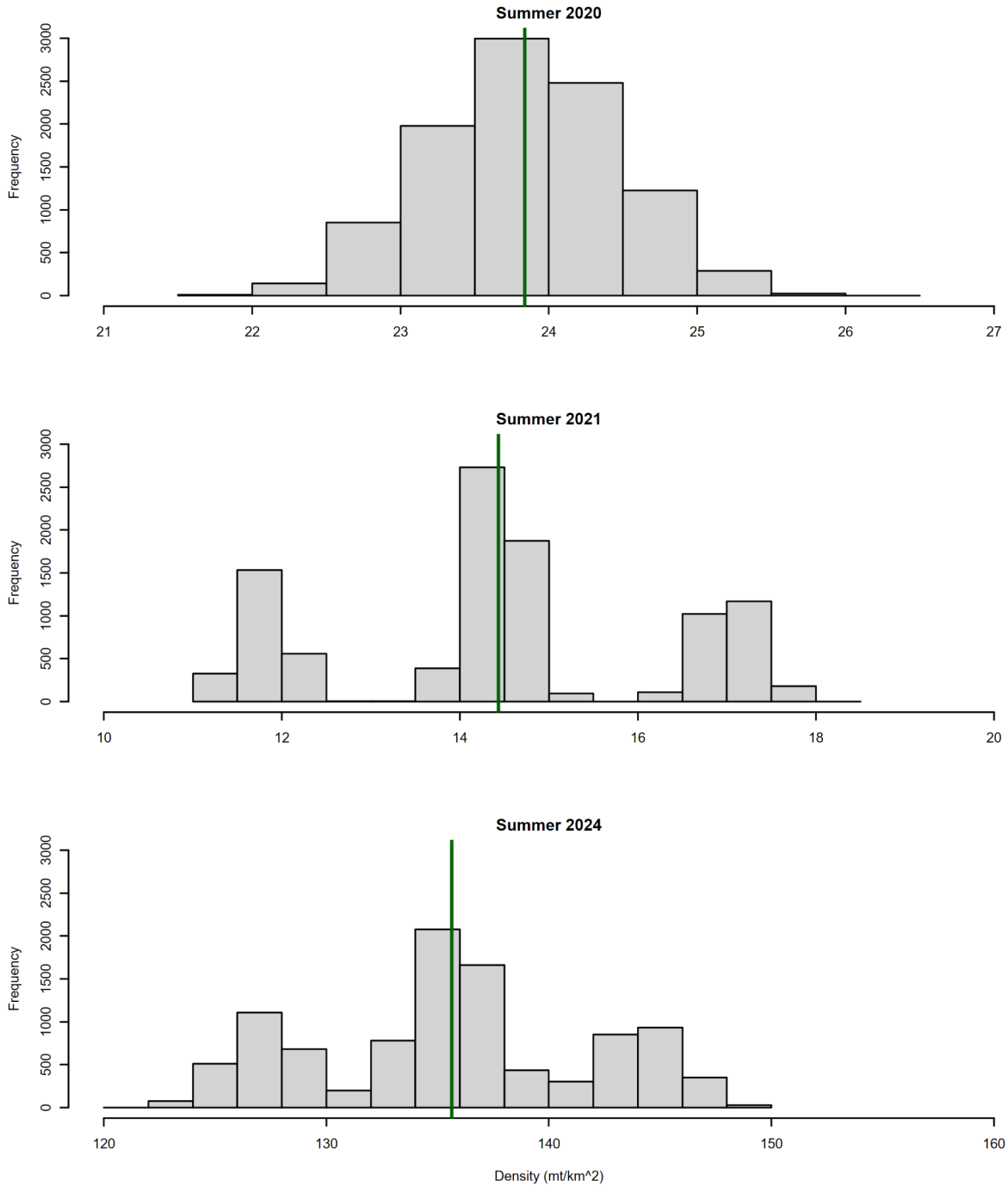

Figure 6. Distributions of northern anchovy mean densities (mt/km^2) estimated in the Northern California region (NCA) from bootstrap resampling analysis (n = 10,000 iterations) of 2020,2021 and 2024 summer aerial survey transect data. The bootstrap mean density is shown by the vertical green line.

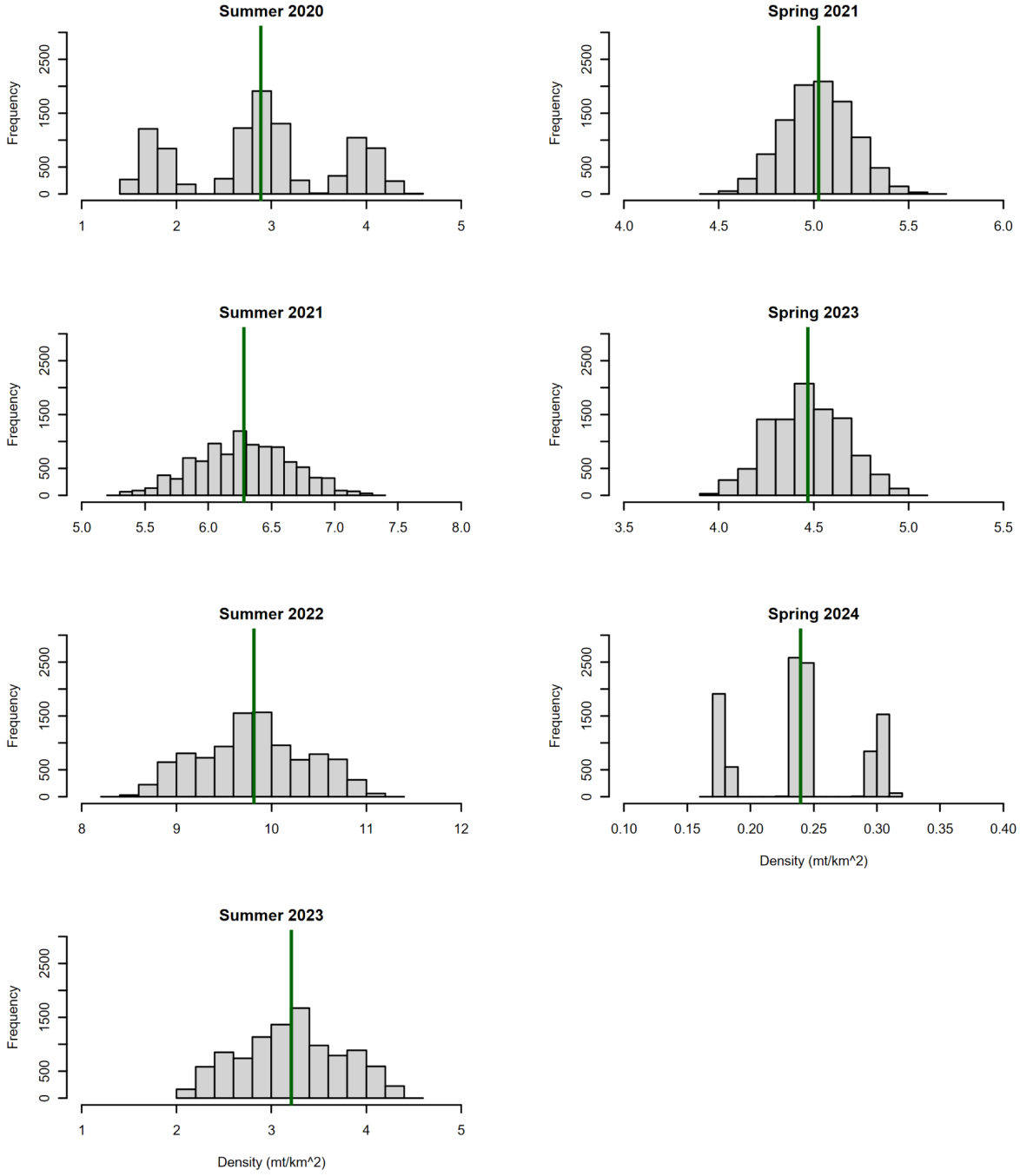

Figure 7. Distributions of mean densities (mt/km^2) of northern anchovy estimated in the Southern California region (SCA) from bootstrap resampling analysis (n = 10,000 iterations) of 2020-2022 and 2024 summer and spring aerial survey transect data. The bootstrap mean density is shown by the vertical green line.

3.4. CCPSS Length and Age Compositions

Northern anchovy caught by purse seine vessels within the CCPSS nearshore area in 2020-2024 ranged from 55 mm to 140 mm (SL) (Figures 8 and 9). The smallest fish (55 mm) was caught off SCA in August 2022 (Figure 9), whereas the largest fish (142 mm) was caught off NCA in August 2023 (Figure 8). Off Northern California, the 90-mm length class was the most frequent in summer 2021 and 2023, whereas the 110-mm length class was most frequent in summer 2022 and 2023. Off Southern California the most dominant length classes were 90 mm (SL) in summer 2020 and 2021, 80 mm (SL) in spring 2021, 100 mm (SL) in summer 2022 and 2023, and 70 mm (SL) in summer 2024 (Figure 9). Overall fish sizes caught off California in the nearshore areas were within the same length distribution as those caught during northern anchovy experimental point set surveys (Figure 4).

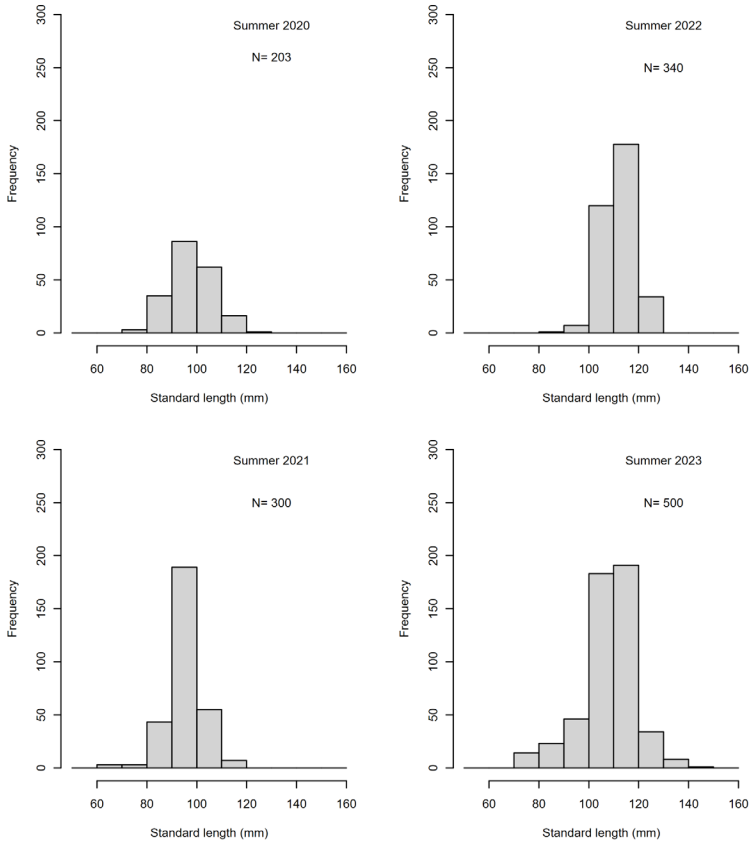

Figure 8. Length composition of northern anchovy collected off Northern California by the FV *Long Beach Carnage* during purse seine sampling within nearshore areas surveyed by CCPSS in 2020-2023.

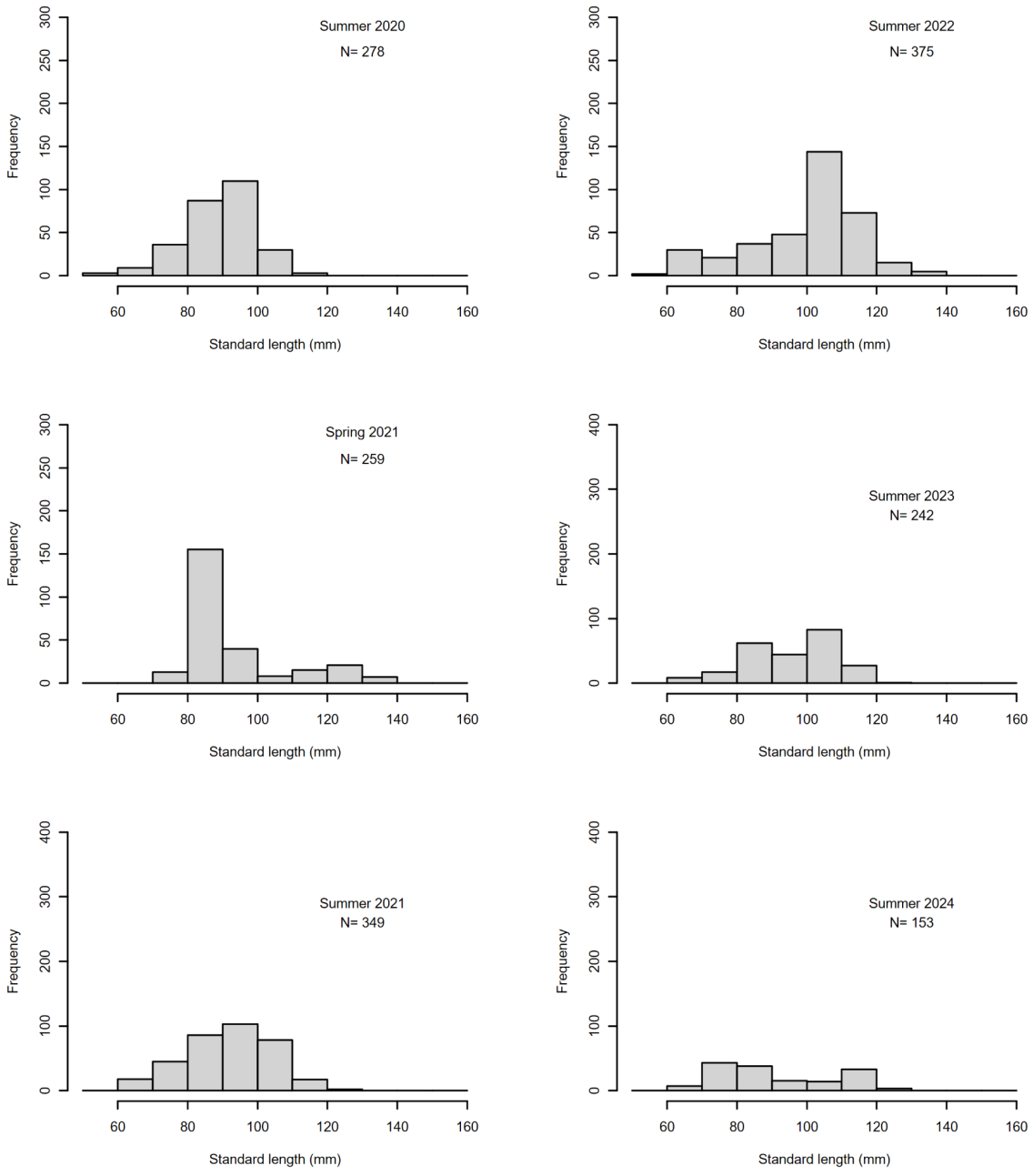

Figure 9. Length composition of northern anchovy collected off Southern California by the FV *Long Beach Carnage* during purse seine sampling within nearshore areas surveyed by CCPSS in 2020-2024.

Only northern anchovy samples (n = 894) collected from purse seine vessels during the 2021 spring and summer CCPSS surveys were aged in this study. These fish ranged from 0 to 6 years old, although only one individual collected in August in Northern California was found to be of age 6, and another collected during the same month off Southern California was of age 5 (Figure 10). In general, catches collected within the CCPSS nearshore area in spring and summer 2021 comprised mostly fish of age 0 and 1, with older age classes occurring less frequently. Northern anchovy age classes observed during these surveys were within the age composition of northern anchovy caught during the 2019-2023 point set surveys.

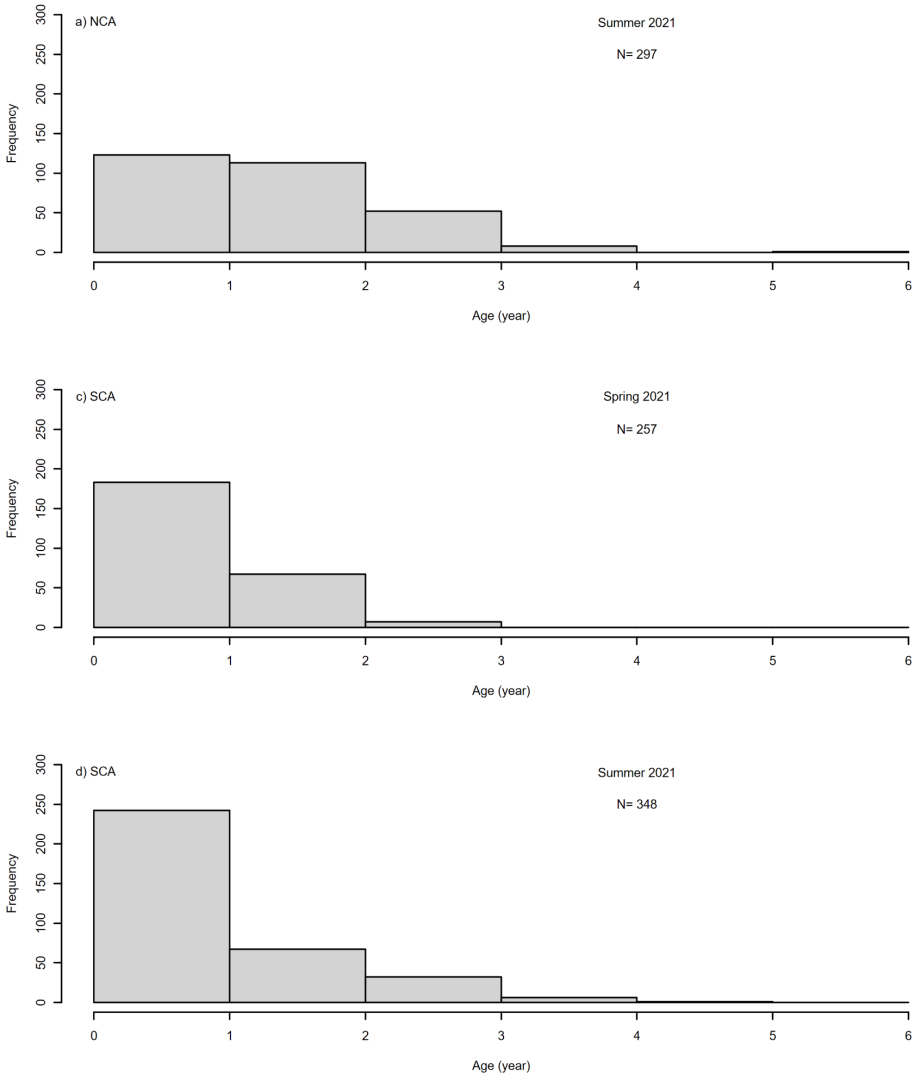

Figure 10. Age composition of northern anchovy collected by the FV *Long Beach Carnage* [Southern California (SCA) and northern California (NCA)] during purse seine sampling within nearshore areas surveyed by CCPSS in 2021.

3.5. Aerial versus Acoustic Biomass

Due to the Covid pandemic, summer weather conditions, and logistical issues, only five synoptic surveys were conducted during the 2020-2024 period. Further, out of these five surveys, only three (NCA summer 2021 and 2024, and SCA spring 2021) provided a regional biomass estimate of northern anchovy that were comparable to offshore and nearshore acoustic surveys conducted off Northern California (Table 2, Figures C1, C4, C5). The remaining two aerial surveys [summer 2022 (Figure C2) and summer 2023 (Figure C3)] did not have enough synoptic spatial coverage due to weather conditions, and thus could be used only to provide a minimal aerial biomass estimate in the nearshore areas off Northern California.

Nevertheless, in the three years with adequate spatial coverage, the data showed that aerial biomass estimates were more variable than biomass estimates from acoustic surveys. In spring 2021 for SCA, CCPSS biomass was equal to a small percentage (0.5%) of the offshore acoustic biomass, but 64% of the nearshore acoustic biomass. In summer 2021 for NCA, the CCPSS biomass increased, but still represented a small fraction (0.8%) of the offshore acoustic survey but a substantial percentage (19%) of the nearshore acoustic biomass. In 2024, CCPSS nearshore biomass for NCA continued to increase, representing 16% of the total offshore acoustic biomass and 617% of the nearshore acoustic biomass. As shown in Table 1, this large increase in estimated CCPSS nearshore regional biomass for NCA in summer 2024 was based on a much smaller surveyed area than in the summer 2021 synoptic survey.

Table 2. Comparison of northern anchovy seasonal survey biomass estimates during synoptic surveys between offshore acoustic-trawl survey method (ATM), the small boat nearshore acoustic survey, and aerial nearshore surveys (CCPSS) off Southern California (SCA) and Northern California (NCA) in 2021-2024. Nearshore aerial areas and offshore and nearshore polygons upon which seasonal biomass were computed are provided in Appendix C (Figures C1-C5).

Year	Season	Region	Biomass (mt)					
			Acoustic*				CCPSS	
			Offshore	CV (%)	Nearshore	CV (%)		CV (%)
2021	Spring	SCA	1,358,587	17	11,716	26	7,611	4
2021	Summer	NCA	2,619,046	20	102,642	22	19,796	13
2022	Summer	NCA	2,197,812	21	38,184	21	4,445**	-
2023	Summer	NCA	2,447,378	51	241,822	11	0**	-
2024	Summer	NCA	672,529	17	17,256	25	106,551	5

Notes: * Acoustic biomass estimates are from Zwolinski et al. (2023) and Stierhoff et al. (2023a, 2023b, 2024, 2025).
**indicates that CCPSS biomass was a minimum biomass estimate (based on 2 strata flown) rather than the total regional biomass.

4. DISCUSSION

Past studies have shown that professional spotter pilots were accurate at estimating school tonnage (Williams 1981, Squire 1993, Lo et al. 1992, Dorval et al. 2024) and identifying species (Taylor 2015, Dorval et al. 2024). The results of this study corroborate those findings by developing mixed calibration curves through northern anchovy and Pacific sardine point sets, for computing bias and precision of two spotters in estimating northern anchovy school biomass from aerial surveys off California. Despite the wide mean depth distribution of captured schools (5 m – 24 m), spotters accurately predicted school biomass, with an underestimation of about 4%. The application of the calibration curve from Spotter 1 to estimate aerial nearshore regional biomass and density from 2020 to 2024 surveys showed that seasonal variations in these estimates were consistent with migration patterns of northern anchovy in Northern and Southern California (Haugen et al. 1969). Consistently higher nearshore summer abundance and density of northern anchovy in Northern California aligned with summer migrations to northern waters, while in spring northern anchovy are concentrated in the SCB for spawning (Picquelle and Hewitt 1983, Hewitt 1985, Dorval et al. 2018).

Estimated regional CVs from bootstrap resampling of transect biomass were very low (< 10%) in some seasonal surveys but higher in others. This level of difference may reflect the spatial distributions (patchiness) of northern anchovy in nearshore waters. For example, the discrete patterns observed in NCA in summer 2021 and 2024 were likely due to known feeding dynamics of northern anchovy as related to the patchy food distribution in their preferred habitat (Nonacs et al. 1994). These differences might also be related to fish movements and the interplay with the timing of survey flights conducted during a given season. In some seasons, the strata within a region were surveyed in as few as three days (e.g., summer 2020 in SCA, 9/18 – 9/20), compared to other seasons where it took many more days to complete flights for a region (spring 2021 in SCA, 3/22 – 4/2). As the mean density distribution of northern anchovy showed exactly the same distributional patterns (i.e., three modes) as Pacific sardine caught in Southern California in summer 2020, it is likely these observed patterns were more related to the timing of the surveys than fish movement rates, particularly if observed schools of both species were highly mixed. Surveying relatively few strata within the available time window may have affected the resampling patterns that emerged from the bootstrap analysis of data from both species. These results may also indicate the need for more daily replicated flights in each stratum per region. Due to logistical constraints, only two replicated flights were conducted on each transect. As proposed by Dorval et al. (2024), future CCPSS surveys should consider increasing the number of replicated flights so that more of the temporal variability of biomass within strata can be captured.

Conversely, in other seasons the mean density of northern anchovy and Pacific sardine distributions showed completely different patterns. For example, in spring 2023, northern anchovy caught in Southern California had a unimodal distribution (this study), whereas Pacific sardine schools exhibited a trimodal distribution (Dorval et al. 2024). Additionally, in spring 2021 northern anchovy caught in Northern California had a trimodal distribution of mean density (this study), whereas mean density in Pacific sardine showed four to five peaks (Dorval et al. 2024). As both species were surveyed simultaneously, it is more likely that in both seasons these observed patterns were more likely due to fish behavior than to the timing of the surveys. From these patterns it can

also be inferred that in seasons where both species had a unimodal distribution their schools were highly mixed across the strata surveyed.

Due to the limited number of synoptic surveys, it is not yet possible to determine whether biomass estimates between CCPSS and ATM surveys are correlated. It remains difficult to successfully conduct synoptic surveys, as logistical constraints affect all surveys, and weather conditions and availability of spotters play a significant role in the timing of aerial surveys. Nevertheless, the available synoptic survey data showed that when northern anchovy abundance estimates in the ATM survey are lower, nearshore CCPSS aerial biomass may represent a more substantial proportion of total biomass. In these instances, catchability (q) computed from ATM data only may need to be adjusted. Likewise, the use and importance of aerial survey biomass in stock assessment may vary with stock abundance and whether synoptic survey temporal and spatial coverage was adequate in a given season. In that respect, northern anchovy aerial biomass estimated by Lynn et al. (2023) for spring 2017 was used in adjusting ATM survey catchability in the 2021 northern anchovy stock assessment (Kuriyama et al. 2022b). One caveat to consider is the relatively smaller latitudinal coverage of the CCPSS compared to the ATM survey. In contrast, the northern anchovy total stock was very high in 2021 (i.e., compared to 2017) and estimated at 2.09 million mt (Kuriyama et al. 2022b). Compared to the 2021 total population biomass, adjustments to the catchability of the ATM survey based on CCPSS biomass had no significant impacts on the estimated stock biomass.

CPS stock abundance can fluctuate unexpectedly (Baumgartner et al. 1992, McClatchie et al. 2017). As a recent example, off California in summer 2024 the estimated biomass of northern anchovy from the offshore acoustic survey decreased substantially to 26% of acoustic biomass in summer 2022 (Stierhoff 2025). Likewise, continued aerial surveys will likely be useful in the long-term to estimate nearshore abundance to inform CPS stock assessments especially when stock biomass declines. At lower stock biomass (as recently with Pacific sardine), there may be a greater proportion of biomass inshore of the ATM survey (MacCall 1990, MacCall et al. 2016, Thayer et al. 2017), and in such cases it is important to have a nearshore survey or else total stock biomass could be underestimated. Further analysis of the proportional volume of the nearshore waters inshore of the ATM survey sampled by acoustic vs aerial methods may provide insight into how to use these data, given the differing coverage in spatial sampling and the patchy/variable nature of the distribution of CPS.

Beyond adjusting catchability estimate of the acoustic survey, another potential use of aerial survey data would be as a stand-alone index, using a standardized measure of biomass such as density. As proposed by Lynn et al. (2023), CCPSS data could be segmented by region and season (spring vs. summer), possibly for comparison to other surveys and data as needed. These indices can document regional shifts in abundance possibly tied to seasonal spawning and feeding migrations (Mais 1974). Use of CCPSS data in this way would, however, require the collection of more length and age composition data. Spring and summer CCPSS data in SCA were collected on a consistent spatial frame and could be a good start for developing a regional biomass index. In contrast, in NCA both spatial and temporal coverage in summer would need to be more consistent

across years to increase the applicability of this index, given the variable proportion of the total biomass nearshore vs. offshore over time.

Data collected from 2018-2023 NCS point sets provided information on school depth distributions of Pacific sardine and northern anchovy as related to ocean depth and school size. During the daytime, at depths shallower than 50 m, it appeared that both Pacific sardine and northern anchovy schools extended to near the seafloor. This phenomenon may be useful in estimating school biomass from photogrammetric techniques in making assumptions on school density based on depth, although more information is needed at deeper depths for northern anchovy. This work can potentially lead to survey methods that will be more flexible, cost-effective, comprehensive, repeatable, and accurate. Using vessels to survey the extent of CPS abundance in the shallowest nearshore habitats remains a challenging task given constraints and limitations posed by the ship's draft (De Robertis and Handegard 2013, DuFour et al. 2018, 2019), which aerial platforms do not face. Fish avoidance of vessels, primarily due to noise and turbulence, can bias acoustics survey abundance estimates (De Robertis and Handegard 2013, DuFour et al. 2018, 2019). In addition, off California the distribution of lobster and crab pots in nearshore waters may limit access to saildrones, while the FV *Long Beach Carnage* cannot operate in waters shallower than 5 m depth. Regardless of the platform used, surveying CPS in nearshore areas will remain challenging, but using complementary methods will help reduce the risk of underestimating stock biomass, particularly in periods of low abundance.

A current research question concerns the proportion of adult and subadult ("pinhead") individuals within northern anchovy schools observed from both aerial and acoustic surveys. Age and length compositions shown in this study likely reflected more the selectivity of the purse seine gear than the natural distribution of northern anchovy in nearshore waters off California. Commercial purse seine nets used both during NCS and FV *Long Beach Carnage* sampling were designed and cast to systematically avoid capturing pinheads as catching them may lead to substantial loss of time and money due to cleaning and repairing of clogged purse seine nets. This lack of data on the proportion of pinhead in the population has important ramifications on assessments and management, as only adult biomass is applicable as total stock biomass (age-1+ biomass), which is the biomass metric of interest for stock assessment and management. As commercial fishery gears do not capture pinhead anchovy, collaborative efforts could use alternative gear types that may be able to provide more useful information. The authors have made efforts to procure the requisite gear and expertise to investigate this issue further. In addition, it is important to note that only two large schools were captured (90 mt and 111.40 mt) during this study. Thus, future point set surveys should focus on obtaining not only more data on northern anchovy schools, but also on capturing more schools that are within the 90 -110 mt size range.

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7. APPENDIX A (Tables A1- A5):

Table A1a. Estimated school biomass (ESB) and percent school wrapped by Spotter 1, landed catch (mt), and adjusted landed catch (ALC) for Pacific sardine and northern anchovy.

Date	Region	Species	Estimated school	Estimated %	Landed catch (mt)	Adjusted landed Catch
8/9/10	SCA	Sardine	4.54	100	4.80	4.80
8/12/10	SCA	Sardine	27.22	90	40.20	44.67
8/16/10	SCA	Sardine	27.22	100	38.50	38.50
8/17/10	SCA	Sardine	13.61	100	10.90	10.90
8/18/10	SCA	Sardine	13.61	100	15.40	15.40
8/18/10	SCA	Sardine	9.07	95	15.00	15.79
8/18/10	SCA	Sardine	4.54	100	6.70	6.70
8/18/10	SCA	Sardine	10.89	90	17.90	19.89
8/19/10	SCA	Sardine	9.07	100	2.80	2.80
8/19/10	SCA	Sardine	9.07	100	9.60	9.60
8/22/10	SCA	Sardine	9.07	95	14.90	15.68
8/23/10	SCA	Sardine	22.68	100	20.00	20.00
8/23/10	SCA	Sardine	10.89	95	10.70	11.26
8/31/10	SCA	Sardine	45.36	95	58.70	61.79
8/31/10	SCA	Sardine	22.68	100	31.30	31.30
8/31/10	SCA	Sardine	31.75	100	44.00	44.00
9/1/10	SCA	Sardine	58.97	95	67.40	70.95
9/1/10	SCA	Sardine	40.82	100	45.00	45.00
9/8/10	SCA	Sardine	49.90	90	38.80	43.11
9/8/10	SCA	Sardine	49.90	95	23.90	25.16
9/9/10	SCA	Sardine	40.82	95	46.80	49.26
9/10/10	SCA	Sardine	72.57	100	84.90	84.90
9/12/10	SCA	Sardine	68.04	100	84.60	84.60
9/13/10	SCA	Sardine	22.68	95	20.20	21.26
9/13/10	SCA	Sardine	45.36	100	64.20	64.20
9/13/10	SCA	Sardine	31.75	90	40.50	45.00
8/22/18	SCA	Sardine	3.63	100	5.38	5.38
8/22/18	SCA	Sardine	16.33	100	18.79	18.79
8/22/18	SCA	Sardine	9.07	100	11.01	11.01
8/22/18	SCA	Sardine	12.70	100	14.20	14.20
8/22/18	SCA	Sardine	11.79	100	11.86	11.86
8/27/18	SCA	Sardine	2.72	100	3.36	3.36
8/27/18	SCA	Sardine	6.35	100	5.45	5.45
8/27/18	SCA	Sardine	1.81	90	2.14	2.38
8/28/18	SCA	Sardine	1.81	100	2.76	2.76
8/28/18	SCA	Sardine	2.72	90	2.76	3.06
8/28/18	SCA	Sardine	5.44	100	4.91	4.91
3/26/19	SCA	Sardine	27.22	100	29.78	29.78
3/26/19	SCA	Sardine	39.01	100	41.02	41.02

3/26/19	SCA	Sardine	13.61	100	15.15	15.15
4/1/19	SCA	Sardine	58.97	100	57.91	57.91
4/1/19	SCA	Sardine	31.75	100	29.97	29.97
4/1/19	SCA	Sardine	49.90	100	51.66	51.66
4/2/19	SCA	Sardine	24.49	100	25.64	25.64
6/28/19	SCA	Sardine	72.57	95	71.49	75.26
8/13/19	Monterey	Sardine	6.35	90	5.88	6.53
8/14/19	Monterey	Anchovy	9.07	90	10.88	12.09
8/15/19	Monterey	Anchovy	66.22	100	67.33	67.33
8/21/19	Monterey	Sardine	5.44	95	11.21	11.80
8/21/19	Monterey	Sardine	33.57	90	27.60	30.67
8/21/19	Monterey	Sardine	9.07	95	13.24	13.93
9/12/19	Monterey	Anchovy	54.43	90	62.07	68.97
9/12/19	Monterey	Sardine	58.97	90	51.82	57.58
4/14/20	Monterey	Anchovy	68.95	100	69.10	69.10
4/22/20	SCA	Sardine	33.57	90	32.21	35.79
6/18/20	SCA	Anchovy	15.42	100	16.62	16.62
6/18/20	SCA	Anchovy	18.14	100	19.93	19.93
10/12/20	Monterey	Anchovy	48.99	100	43.21	43.21
10/12/20	Monterey	Sardine	5.44	100	7.03	7.03
10/13/20	Monterey	Sardine	16.33	100	17.83	17.83
10/13/20	Monterey	Sardine	22.68	100	22.25	22.25
10/14/20	Monterey	Sardine	9.07	100	10.37	10.37
10/14/20	Monterey	Sardine	6.35	100	5.96	5.96
10/15/20	Monterey	Sardine	22.68	100	22.33	22.33
10/15/20	Monterey	Sardine	45.36	100	44.73	44.73
10/15/20	Monterey	Sardine	54.43	100	51.85	51.85
10/21/20	Monterey	Sardine	56.25	100	58.82	58.82
10/21/20	Monterey	Sardine	72.57	100	80.08	80.08
10/5/21	Monterey	Anchovy	9.07	90	7.34	8.16
5/24/22	Monterey	Anchovy	107.96	100	111.40	111.40
5/30/23	Monterey	Anchovy	71.65	100	61.47	61.47
6/2/23	Monterey	Anchovy	99.48	100	89.28	89.28
6/2/23	Monterey	Sardine	5.24	100	2.76	2.76
6/5/23	Monterey	Anchovy	78.58	100	66.88	66.88

Table A1b. Estimated school biomass (ESB) and percent school wrapped by Spotter 2, landed catch (mt), and adjusted landed catch (ALC) for Pacific sardine and northern anchovy.

Date	Region	Species	Estimated school	Estimated %	Landed catch	Adjusted landed
8/22/18	SCA	Sardine	4.54	100	5.38	5.38
8/22/18	SCA	Sardine	18.14	100	18.79	18.79
8/22/18	SCA	Sardine	7.26	100	11.01	11.01
8/22/18	SCA	Sardine	10.89	100	14.20	14.20
8/22/18	SCA	Sardine	9.07	100	11.86	11.86
8/27/18	SCA	Sardine	2.72	100	3.36	3.36
8/27/18	SCA	Sardine	5.44	100	5.45	5.45
8/27/18	SCA	Sardine	1.81	100	2.14	2.14
8/28/18	SCA	Sardine	1.81	100	2.76	2.76
8/28/18	SCA	Sardine	2.72	100	2.76	2.76
8/28/18	SCA	Sardine	4.54	100	4.91	4.91
3/26/19	SCA	Sardine	23.59	100	29.78	29.78
3/26/19	SCA	Sardine	36.29	100	41.02	41.02
3/26/19	SCA	Sardine	13.61	100	15.15	15.15
4/1/19	SCA	Sardine	54.43	100	57.91	57.91
4/1/19	SCA	Sardine	27.22	100	29.97	29.97
4/1/19	SCA	Sardine	54.43	100	51.66	51.66
4/2/19	SCA	Sardine	22.68	100	25.64	25.64
6/28/19	SCA	Sardine	63.50	95	71.49	75.25
8/13/19	Monterey	Sardine	4.54	85	5.88	6.91
8/14/19	Monterey	Sardine	9.10	90	10.88	12.09
8/15/19	Monterey	Anchovy	54.40	100	67.33	67.33
8/21/19	Monterey	Anchovy	4.54	95	11.21	11.80
8/21/19	Monterey	Anchovy	27.22	90	27.60	30.67
8/21/19	Monterey	Sardine	9.07	90	13.24	14.71
9/12/19	Monterey	Anchovy	45.36	90	62.07	68.97
9/12/19	Monterey	Sardine	54.43	90	51.82	57.58
4/14/20	SCA	Sardine	63.50	100	69.10	69.10
4/22/20	Monterey	Sardine	27.22	90	32.21	35.79
6/18/20	SCA	Anchovy	13.60	100	16.62	16.62
6/18/20	SCA	Anchovy	18.10	100	19.93	19.93
10/12/20	Monterey	Anchovy	40.86	100	43.21	43.21
10/12/20	Monterey	Sardine	4.54	100	7.03	7.03
10/13/20	Monterey	Sardine	13.60	90	17.83	19.81
10/13/20	Monterey	Sardine	22.70	100	22.25	22.25
10/14/20	Monterey	Sardine	9.10	100	10.37	10.37
10/14/20	Monterey	Sardine	4.50	100	5.96	5.96
10/15/20	Monterey	Sardine	18.14	100	22.33	22.33
10/15/20	Monterey	Sardine	36.29	100	44.73	44.73
10/15/20	Monterey	Sardine	54.43	100	51.85	51.85
10/21/20	Monterey	Sardine	45.36	100	58.82	58.82

10/21/20	Monterey	Sardine	63.50	100	80.08	80.08
10/5/21	Monterey	Anchovy	9.07	90	7.34	8.16
5/24/22	Monterey	Anchovy	108.86	100	111.40	111.40
5/30/23	Monterey	Anchovy	66.14	100	61.47	61.47
6/2/23	Monterey	Anchovy	104.72	100	89.28	89.28
6/2/23	Monterey	Sardine	5.51	100	2.76	2.76
6/5/23	Monterey	Anchovy	77.16	100	66.88	66.88

Table A2. Northern anchovy biomass estimated daily during seasonal aerial surveys conducted from 2020 to 2024 in each stratum. Nearshore strata consisted of three transects covering waters from 0 to 3,600 m offshore. Each transect was flown twice during each daily aerial survey. Start and end locations provide the geographic coordinates of the two transects where daily aerial flights started and ended in each predesignated survey stratum.

Date	Region	Season	Stratum	Number of transects	Number of flights	Start Location		End Location		Area (km^2)	Biomass (mt)
						Latitude	Longitude	Latitude	Longitude		
9/5/2020	NCA	Summer	N8	3	2	35.555	-121.104	35.206	-120.857	200	582
9/6/2020			N2	3	2	38.535	-123.282	38.214	-122.981	187	20
9/6/2020			N3	3	2	37.996	-123.026	37.854	-122.57	196	0
9/7/2020			N1	3	2	39.09	-123.707	38.721	-123.473	200	26
9/14/2020			N4	3	2	37.498	-122.501	37.182	-122.393	148	37
9/15/2020			N6	3	2	37.014	-122.207	36.774	-121.798	165	0
9/15/2020			N5	3	2	36.637	-121.938	36.302	-121.896	194	36,271
9/16/2020			N7	3	2	35.815	-121.376	35.702	-121.305	51	0
9/18/2020	SCA	Summer	S1	3	2	34.45	-120.472	34.428	-119.913	200	0
9/18/2020			S2	3	2	34.417	-119.657	34.15	-119.219	195	3,277
9/19/2020			S3	3	2	34.061	-118.987	34.032	-118.725	100	38
9/19/2020			S4	3	2	33.758	-118.418	33.723	-118.193	95	0
9/19/2020			S5	3	2	33.706	-118.06	33.413	-117.614	199	28
9/20/2020			S6	3	2	33.212	-117.416	32.781	-117.255	197	0
3/22/2021	SCA	Spring	S5E	3	2	33.411	-117.614	33.226	-117.412	101	0
3/22/2021			S6	3	2	33.212	-117.416	32.828	-117.28	175	542
3/24/2021			S4E	3	2	33.722	-118.192	33.706	-118.06	44	0
3/24/2021			S5	3	2	33.706	-118.06	33.411	-117.614	199	43
4/1/2021			S2	3	2	34.417	-119.656	34.15	-119.219	195	3,856
4/1/2021			S2E	3	2	34.15	-119.219	34.061	-118.988	93	738
4/1/2021			S3	3	2	34.061	-118.988	34.032	-118.725	100	150
4/2/2021			S1	3	2	34.442	-120.453	34.428	-119.913	180	1,658
4/2/2021			S1E	3	2	34.428	-119.913	34.397	-119.707	81	693
4/2/2021			S4	3	2	33.736	-118.4	33.722	-118.192	78	0

8/6/2021	NCA	Summer	N1	3	2	38.921	-123.729	38.721	-123.473	122	15
8/10/2021			N2	3	2	38.535	-123.282	38.214	-122.981	187	47
8/10/2021			N4	3	2	37.6	-122.514	37.252	-122.418	164	0
8/11/2021			N5	3	2	37.014	-122.208	36.774	-121.798	194	11,098
9/12/2021	SCA	Summer	S1	3	2	34.442	-120.453	34.428	-119.913	179	0
9/12/2021			S1E	3	2	34.428	-119.913	34.417	-119.656	100	75
9/14/2021			S2	3	2	34.417	-119.656	34.15	-119.219	195	10,707
9/14/2021			S2E	3	2	34.15	-119.219	34.061	-118.987	93	15
9/14/2021			S3	3	2	34.061	-118.987	34.032	-118.725	100	0
9/16/2021			S4	3	2	33.758	-118.418	33.722	-118.192	95	2
9/16/2021			S4E	3	2	33.722	-118.192	33.706	-118.06	44	0
9/16/2021			S5	3	2	33.706	-118.06	33.411	-117.614	199	0
9/17/2021			S6	3	2	33.212	-117.416	32.838	-117.283	167	122
3/13/2022	SCA	Spring	S6	3	2	33.213	-117.448	32.798	-117.27	181	0
3/13/2022			S5E	3	2	33.411	-117.614	33.226	-117.412	101	236
3/14/2022			S5	3	2	33.706	-118.06	33.411	-117.614	199	0
3/14/2022			S4E	3	2	33.722	-118.192	33.706	-118.06	44	0
3/15/2022			S3	3	2	34.061	-118.988	34.032	-118.725	100	0
3/15/2022			S2E	3	2	34.15	-119.219	34.061	-118.988	93	372
3/21/2022			S4	3	2	33.758	-118.418	33.722	-118.192	95	0
3/21/2022			S2	3	2	34.417	-119.657	34.15	-119.219	195	0
3/22/2022			S1E	3	2	34.428	-119.913	34.417	-119.656	100	0
3/22/2022			S1	3	2	34.442	-120.444	34.404	-119.961	179	0
7/31/2022	NCA	Summer	N5	3	2	37.014	-122.208	36.774	-121.798	194	4,445
8/20/2022			N2	3	2	38.535	-123.282	38.214	-122.981	187	0
8/28/2022	SCA	Summer	S3	3	2	34.033	-118.998	34.022	-118.717	89	0
8/28/2022			S4	3	2	33.758	-118.418	33.722	-118.192	95	0
8/28/2022			S4E	3	2	33.722	-118.192	33.706	-118.06	44	0
8/31/2022			S1	3	2	34.418	-119.913	34.42	-120.398	152	165
8/31/2022			S1E	3	2	34.428	-119.913	34.417	-119.656	100	1,798
9/1/2022			S2	3	2	34.417	-119.657	34.15	-119.219	195	11,580

9/2/2022			S5	3	2	33.706	-118.06	33.413	-117.614	199	0
9/2/2022			S6	3	2	33.215	-117.42	32.812	-117.312	181	0
4/2/2023	SCA	Spring	S1	3	2	34.418	-119.917	34.439	-120.438	176	0
4/2/2023			S1E	3	2	34.428	-119.913	34.417	-119.656	100	0
4/4/2023			S2	3	2	34.417	-119.657	34.15	-119.219	195	388
4/4/2023			S2E	3	2	34.053	-118.991	34.129	-119.195	80	0
4/4/2023			S3	3	2	34.061	-118.988	34.032	-118.725	100	0
4/7/2023			S4	3	2	33.758	-118.418	33.723	-118.193	95	15
4/7/2023			S4E	3	2	33.722	-118.192	33.706	-118.06	44	1,248
4/7/2023			S5	3	2	33.706	-118.06	33.413	-117.614	199	0
4/8/2023			S6	3	2	33.226	-117.412	32.805	-117.279	185	1,829
7/10/2023	SCA	Summer	S6	3	2	33.226	-117.412	32.906	-117.27	136	0
7/12/2023			S4	3	2	33.758	-118.418	33.723	-118.193	95	0
7/12/2023			S4E	3	2	33.722	-118.192	33.706	-118.06	44	0
7/12/2023			S5	3	2	33.706	-118.06	33.413	-117.614	199	1,076
7/13/2023			S2	3	2	34.417	-119.657	34.15	-119.219	195	3,944
7/13/2023			S3	3	2	34.028	-118.989	34	-118.772	90	0
7/14/2023			S1	3	2	34.423	-119.93	34.423	-120.397	161	0
7/14/2023			S1E	3	2	34.428	-119.913	34.417	-119.656	100	8
7/28/2023	NCA	Summer	N8	3	2	35.555	-121.104	35.206	-120.857	200	0
7/31/2023			N3	3	2	37.824	-122.592	37.978	-123.035	176	0
3/25/2024	SCA	Spring	S1	3	2	34.45	-120.472	34.428	-119.913	200	0
3/27/2024			S2	3	2	34.417	-119.657	34.15	-119.219	195	281
3/27/2024			S3	3	2	34.061	-118.988	34.032	-118.725	100	0
3/28/2024			S5	3	2	33.706	-118.06	33.413	-117.614	199	0
3/28/2024			S6	3	2	33.212	-117.416	32.838	-117.283	168	0
3/29/2024			S4	3	2	33.758	-118.418	33.723	-118.193	95	0
7/10/2024	SCA	Summer	S1	3	2	34.399	-119.937	34.422	-120.408	158	0
7/10/2024			S2	3	2	34.406	-119.663	34.237	-119.277	153	315
8/2/2024	NCA	Summer	N5	3	2	37.014	-122.208	36.774	-121.798	194	67,780
8/3/2024			N7	3	2	36.087	-121.633	35.696	-121.308	153	0

8/13/2024			N4	3	2	37.171	-122.398	37.603	-122.51	203	836
8/13/2024			N3	3	2	37.996	-123.026	37.854	-122.57	196	10,666

Table A3. Northern Anchovy aerial biomass estimates by sampling date, region, season, and year, and difference in timing (days) between CCPSS aerial flights (A) and acoustic surveys conducted by FSV *Reuben Lasker* (RL) and FV *Long Beach Carnage* (LBC). Differences in timing are based on areas covered by the CCPSS on specific survey dates.

Aerial survey			Synoptic survey dates				Difference in sampling days among synoptic surveys			Aerial biomass (mt)
Year	Season	Region	Aerial	RL	LBC	LM	A-RL	A-LBC	A-LM	
2021	Spring	SCA	3/22	3/21, 3/22	3/21, 3/22	-	0-1	0-1	-	542
			3/24	3/23, 3/24	3/23	-	0-1	1	-	43
			4/1	3/29, 3/30, 3/31	3/29, 3/30	-	1-3	1-2	-	4,744
			4/2	3/23, 3/30	3/28, 3/31	-	3-10	2-5	-	2,350
2021	Summer	NCA	8/6	8/8, 8/9	NA	-	2-3	NA	-	15
			8/10	8/10, 8/11	8/12, 8/14	-	0-1	2-4	-	47
			8/11	8/11	8/14, 8/15	-	0	3-4	-	11,098
2021	Summer	SCA	9/12	9/10, 9/11	9/12	-	1-2	0	-	75
			9/14	9/11, 9/12, 9/13	9/14, 9/15	-	1-3	0-1	-	10,722
			9/16	9/14, 9/15, 9/16, 9/18, 9/19	9/17, 9/18	-	0-3	1-2	-	2
			9/17	9/17-9/21	9/18, 9/19	-	0-4	1-2	-	122
2022	Summer	NCA	7/31	8/3	8/1	-	3	1	-	4,445
			8/20	7/30	7/30	-	21	21	-	0
2022	Summer	SCA	8/28	9/18, 9/20	8/26, 8/27, 9/3	-	21-23	2-6	-	0
			8/31	9/16	8/22	-	16	22	-	1,963
			9/1	9/16	8/23, 8/26	-	15	6-9	-	11,580
			9/2	9/21, 9/23, 9/24	9/6, 9/7	-	19-22	4-5	-	0
2023	Summer	SCA	7/10	7/18	7/9	-	8	1	-	0
			7/12	7/20, 7/21	7/10, 7/11, 7/12, 7/13	-	8-9	0-2	-	1,076
			7/13	7/22, 7/25	7/14, 7/15, 7/17	-	9-12	1-4	-	3,944
			7/14	7/25	7/17, 7/18	-	11	3-4	-	8
2023	Summer	NCA	7/28	9/7	8/8, 8/9	-	41	11-12	-	0
			7/31	9/11	8/15, 8/16	-	42	15-16	-	0
2024	Summer	SCA	7/10	7/25, 7/29, 7/30	7/16, 7/17, 7/18	-	15-20	6-8	-	315
2024	Summer	NCA	8/2	8/8	-	8/7	6	-	5	67,780
			8/3	8/4, 8/5, 8/6	8/3	-	1-3	0	-	0
			8/13	8/9, 8/10, 8/11	-	8/8, 8/9, 8/10	2-4	-	3-5	11,503

Table A4. Dates, sample size, and sources of biological data collected for northern anchovy in Northern California (NCA) and Southern California (SCA) during seasonal surveys conducted by the nearshore cooperative survey (NCS) point set sampling and FV *Long Beach Carnage* (LBC) purse seine sampling in 2020-2024. N is the total number of positive sets taken by NCS or LBC in the nearshore area within 2 weeks before or after the completion of the CCPSS aerial survey in a given season. Bold numbers in parentheses indicate the number of positive sets taken by NCS or LBC and the number of daily aerial flights with positive observations of schools per season during the CCPSS survey. Only one positive set or school was observed in dates with no bold number in parenthesis.

Aerial survey date range	Year	Region	Survey	N	LBC or NCS collection dates and number of positive sets	Aerial survey dates of positive observations
9/5-9/16	2020	NCA	LBC	6	9/9 (**2**), 9/10 (**3**), 9/12	9/5 (**2**), 9/6, 9/7, 9/14, 9/15 (**17**)
			NCS	1	10/12	
9/18-9/20	2020	SCA	LBC	7	9/17, 9/18, 9/20, 9/21 (**3**), 9/22	9/18 (**14**), 9/19 (**9**)
3/22-4/2	2021	SCA	LBC	7	3/21, 3/22 (**2**), 3/27, 3/28 (**2**), 3/31	3/22 (**15**), 3/24, 4/1 (**45**), 4/2 (**21**)
8/6-8/11	2021	NCA	LBC	7	8/12, 8/13, 8/14, 8/15, 8/19, 8/20 (**2**)	8/6 (**2**), 8/10, 8/11 (**26**)
9/12-9/17	2021	SCA	LBC	6	9/13 (**2**), 9/15 (**2**), 9/17, 9/18	9/12 (**2**), 9/14 (**49**), 9/16, 9/17 (**7**)
3/13-3/22	2022	SCA	-	-	-	3/13 (**2**), 3/15 (8)
7/31-8/20	2022	NCA	LBC	9	7/30, 8/1 (**2**), 8/4 (**2**), 8/5 (**2**), 8/20, 8/21	7/31 (**11**)
8/28-9/2	2022	SCA	LBC	8	8/22, 8/23 (**2**), 8/24, 8/25, 8/26 (**2**), 8/27	8/31 (**11**), 9/1 (**46**)
4/2-4/8	2023	SCA	-	-	-	4/4 (**7**), 4/7 (**3**), 4/8 (**10**)
7/10-7/14	2023	SCA	LBC	4	7/10, 7/13, 7/14, 7/17	7/12 (**4**), 7/13 (**18**), 7/14
7/28-7/31	2023	NCA	NCS	2	6/2, 6/5	-
			LBC	11	8/7, 8/9 (**3**), 8/10, 8/12, 8/13 (**3**), 8/15 (**2**)	
3/25-3/29	2024	SCA	-	-	-	3/27 (**3**)
7/10	2024	SCA	LBC	4	7/9, 7/10, 7/12, 7/16	7/10 (**3**)
8/2-8/13	2024	NCA	-	-	-	8/2 (**25**), 8/13 (**8**)

8. Appendix B (Figures B1-B14)

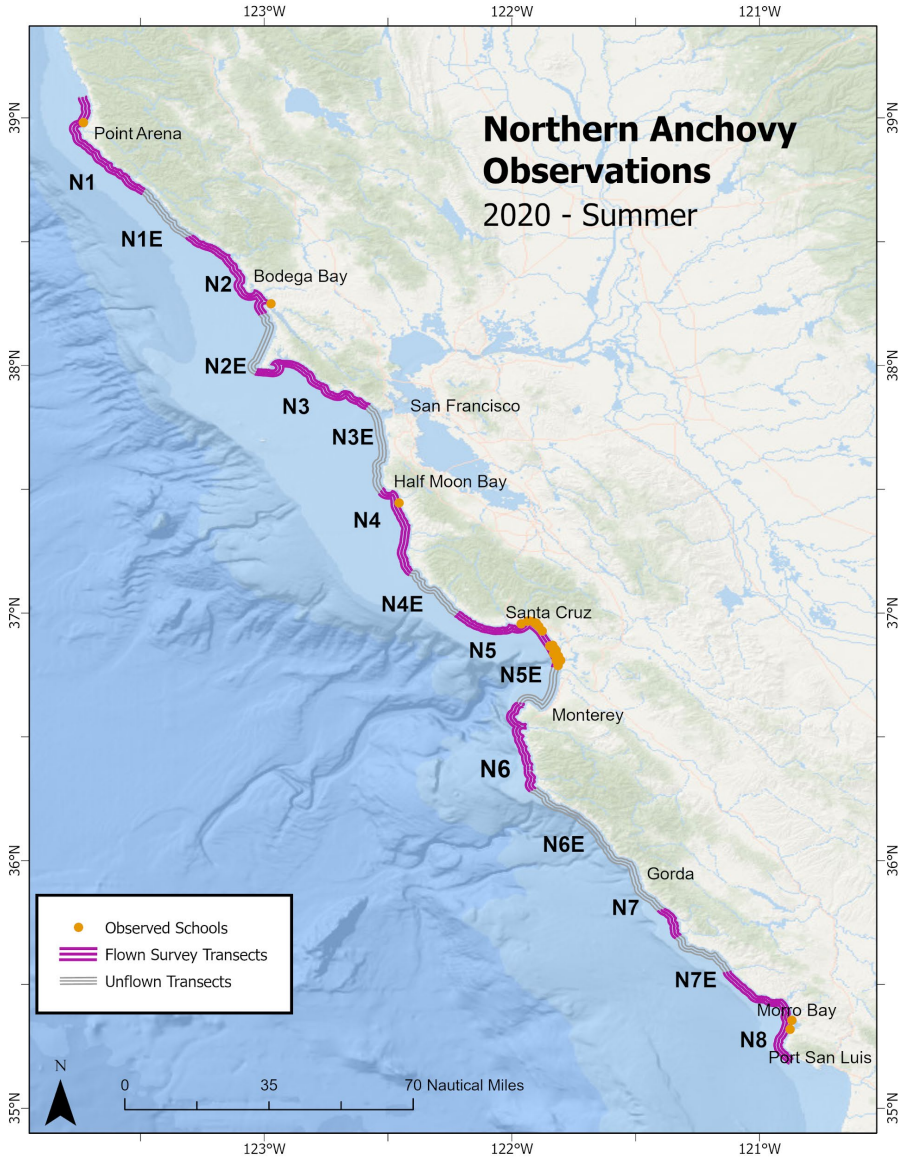

Figure B1. Spatial distribution of northern anchovy schools observed during summer 2020 CCPSS flights off Northern California. Predesignated survey strata (purple bold transect lines) and unflown strata (grey transect lines, including predesignated and expansion strata) between Port San Luis and Point Arena were used to compute regional biomass in this study.

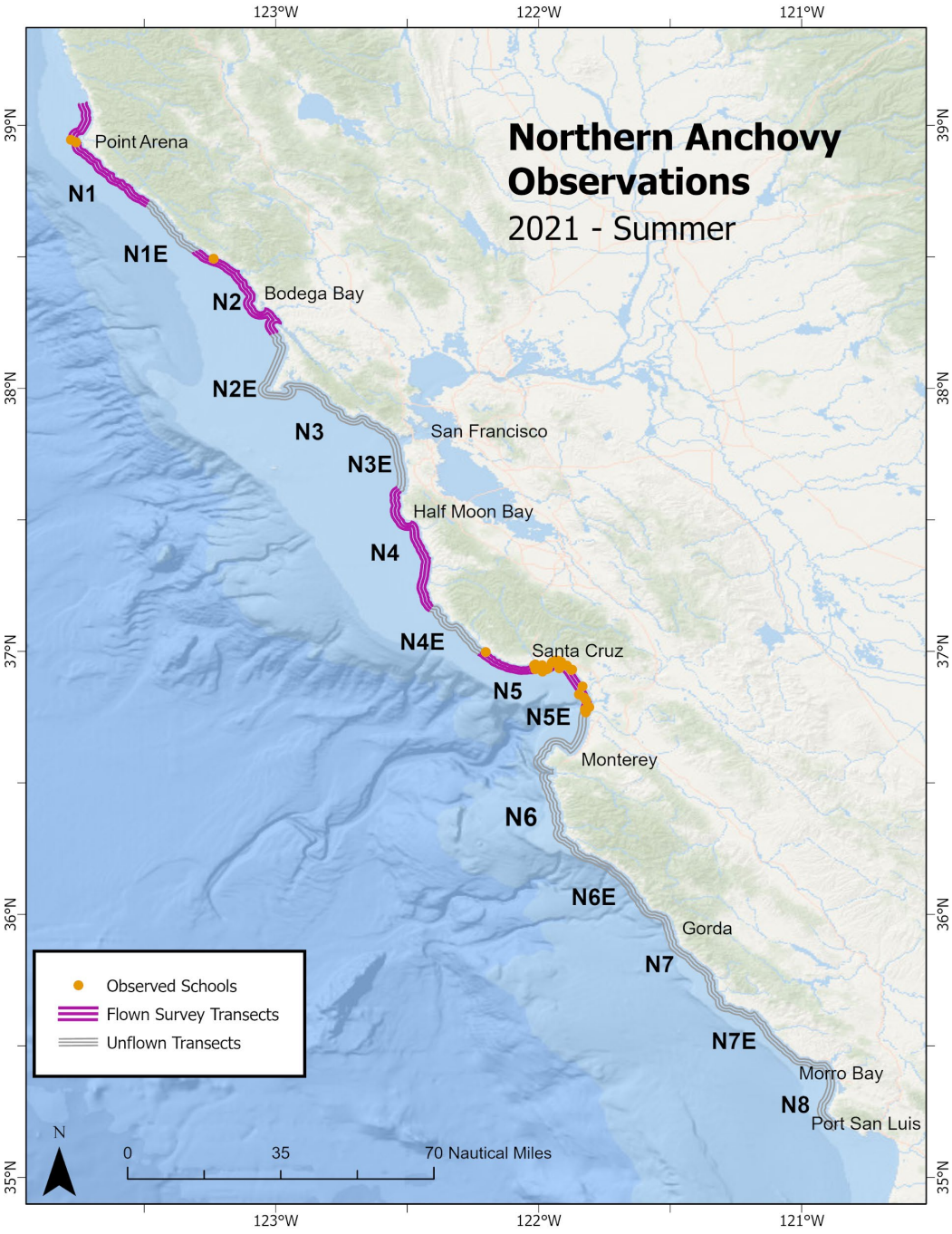

Figure B2. Spatial distribution of northern anchovy schools observed during summer 2021 CCPSS flights off Northern California. Only predesignated survey strata (purple transect lines) and strata (grey transect lines, including predesignated and expansion strata) between Monterey and Point Arena were used to compute regional biomass in this study.

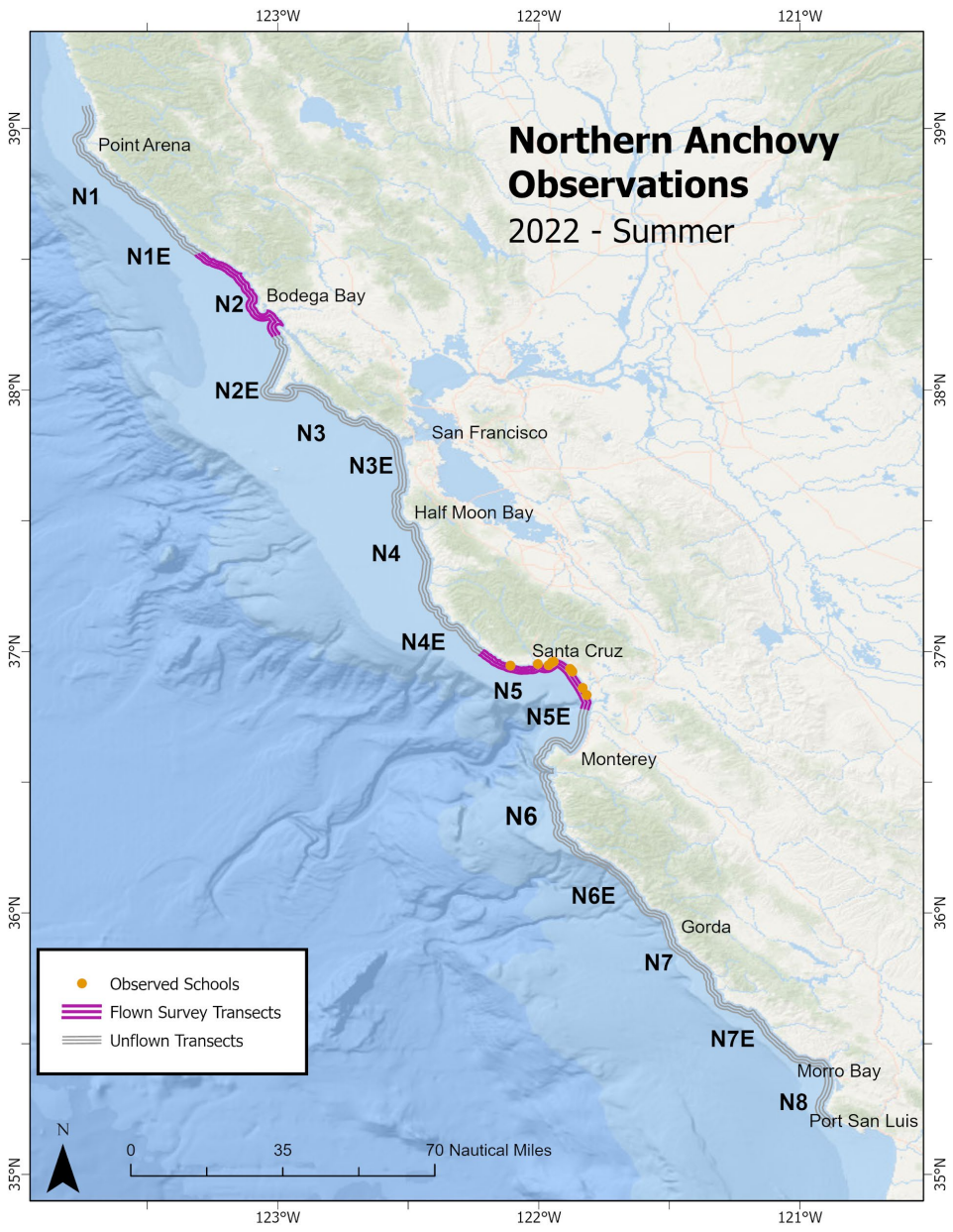

Figure B3. Spatial distribution of northern anchovy schools observed during summer 2022 CCPSS flights off Northern California. As only two predesignated survey strata (N2 and N5) were effectively surveyed in summer 2022 regional biomass was not computed for this season.

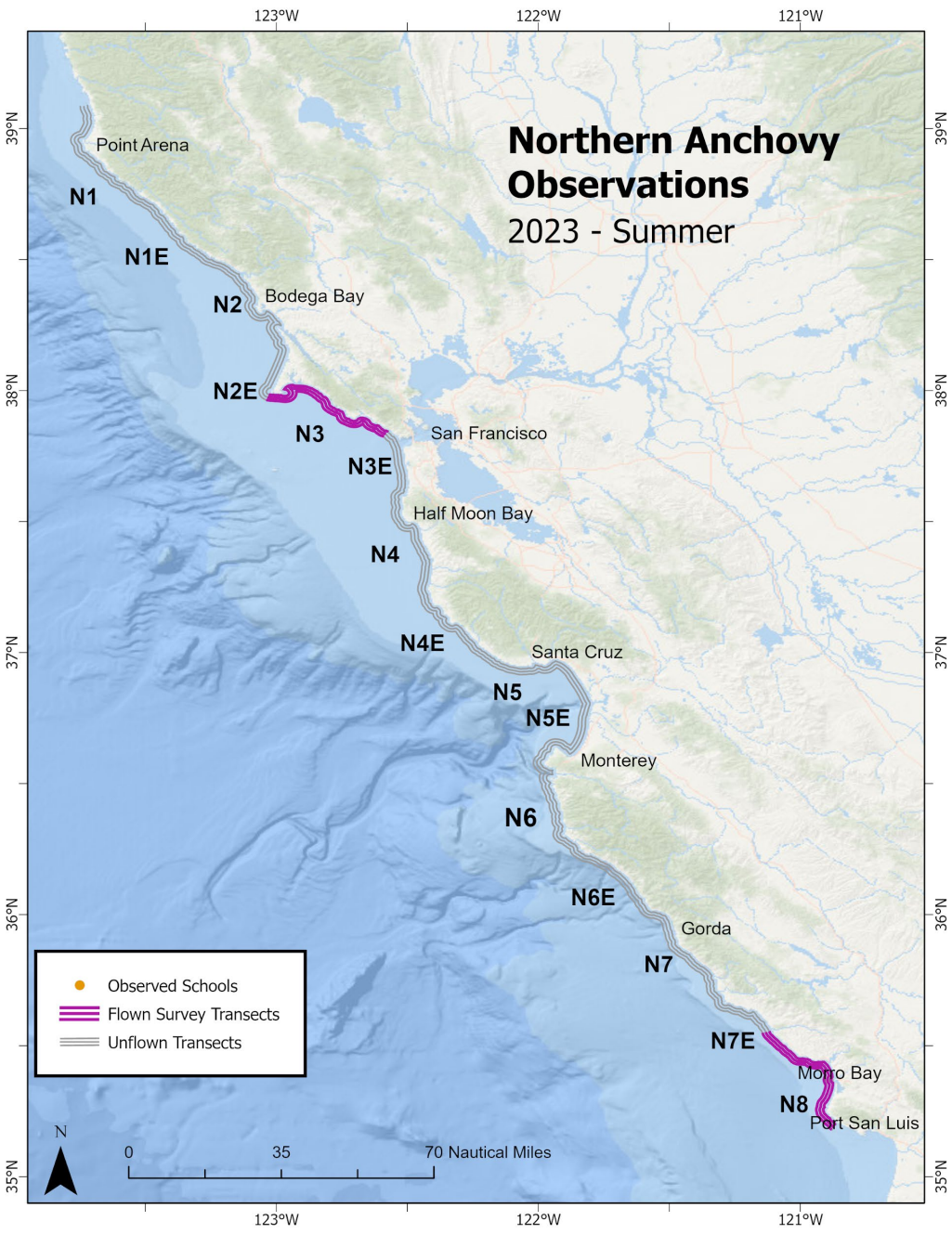

Figure B4. Spatial distribution of northern anchovy schools observed during summer 2023 CCPSS flights off Northern California. As only two predesignated survey strata (N3 and N8) were effectively surveyed in summer 2022 regional biomass was not computed for this season.

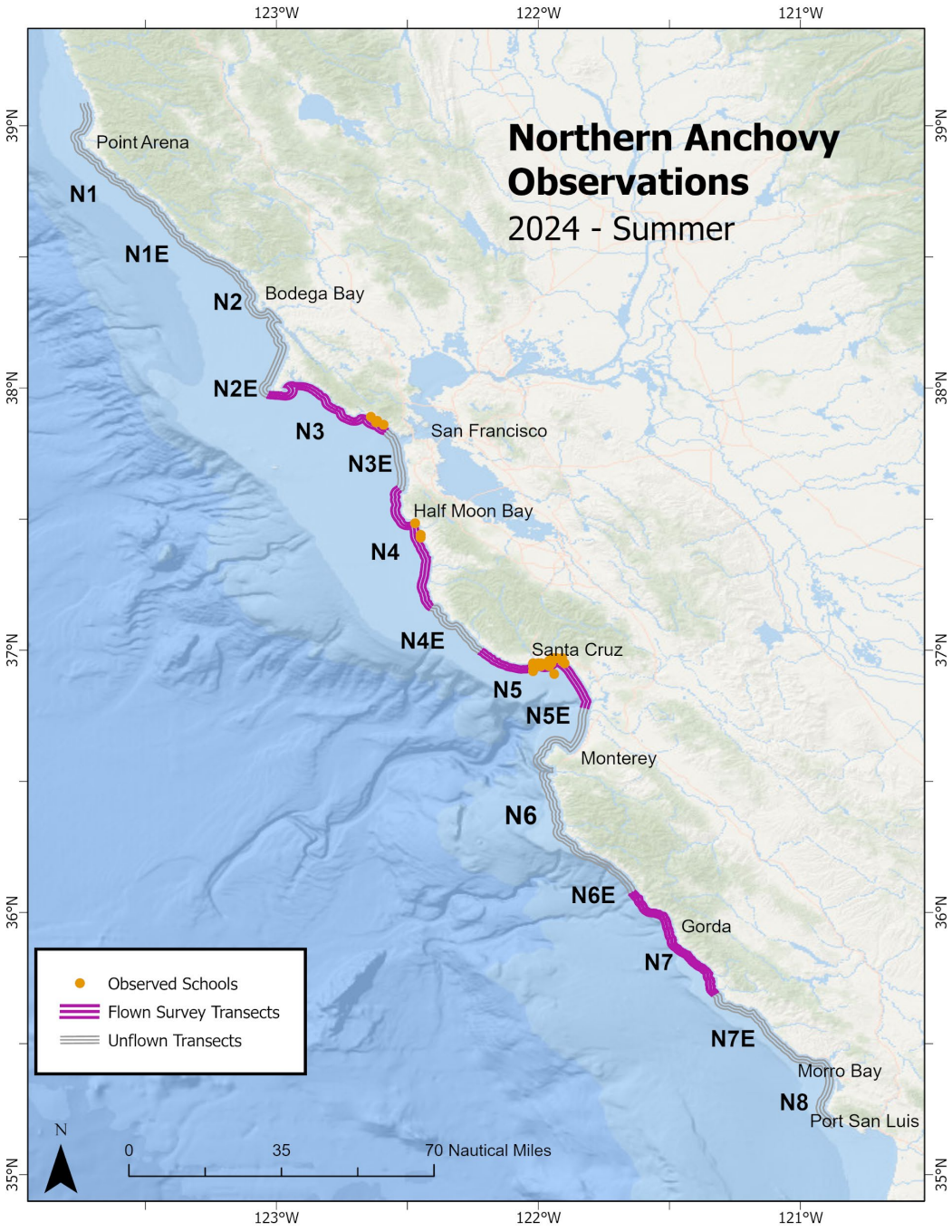

Figure B5. Spatial distribution of northern anchovy schools observed during summer 2024 CCPSS flights off Northern California. Only predesignated survey strata (purple transect lines) and strata (grey transect lines, including predesignated and expansion strata) between Monterey and Bodega Bay (N2E-N5E) were used to compute regional biomass in this study.

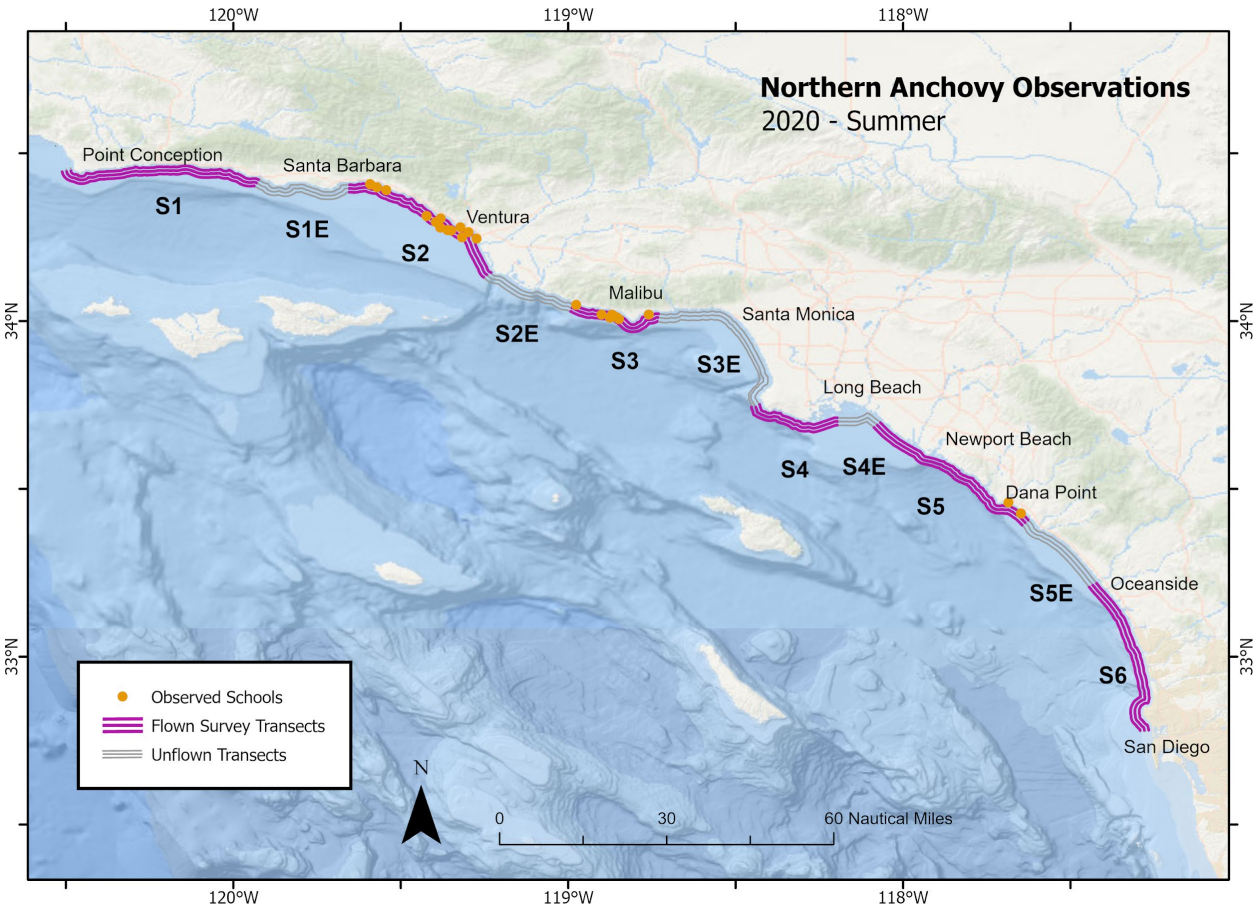

Figure B6. Spatial distribution of northern anchovy schools observed during summer 2020 CCPSS flights off Southern California. Predesignated survey strata (purple transect lines) and strata (grey transect lines, including predesignated and expansion strata) between Point Conception and San Diego (S1-S63) were used to compute regional biomass in this study.

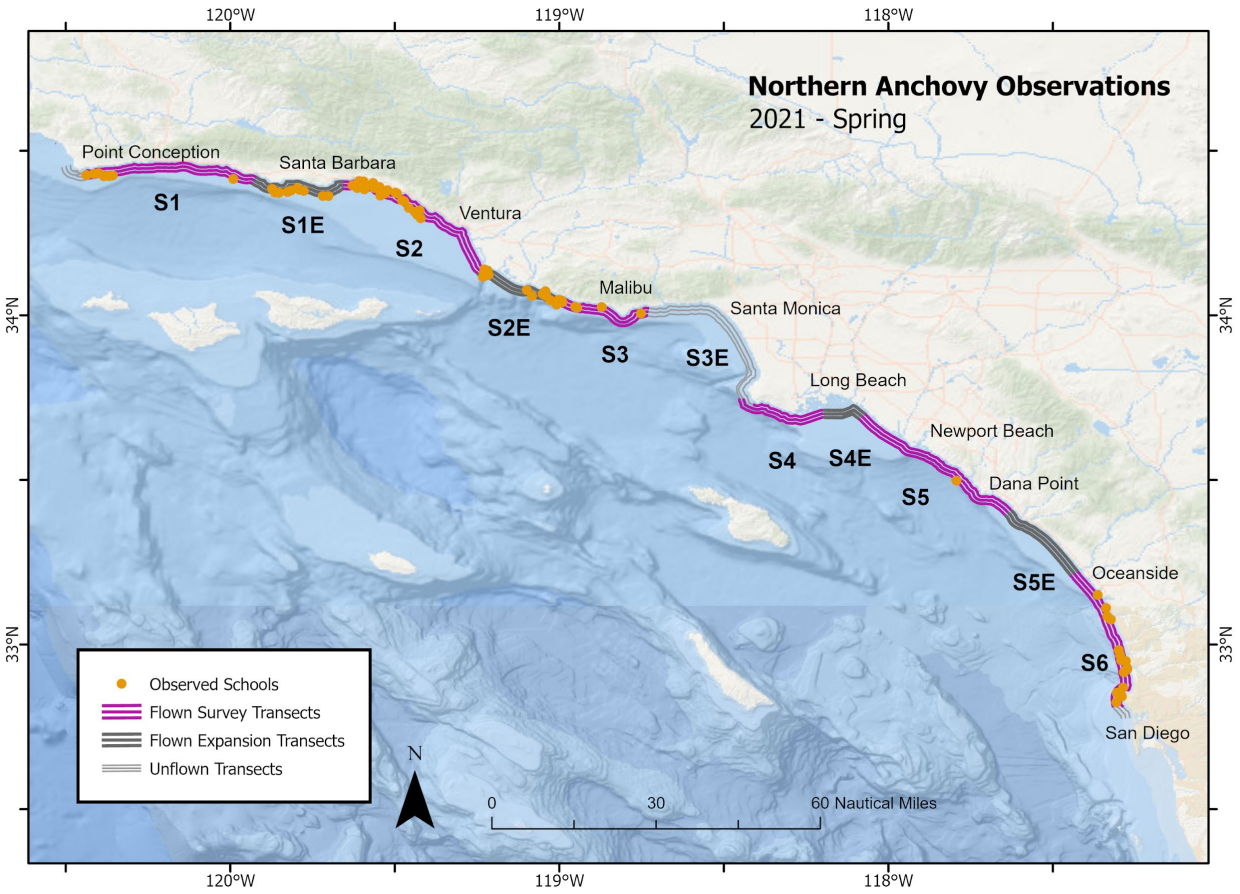

Figure B7. Spatial distribution of northern anchovy schools observed during spring 2021 CCPSS flights off Southern California. Expansion survey strata (black lines) that were flown in spring 2021 were parts of a special CDFW project, and thus following the design of this study data collected in these strata were not used in the computation of regional biomass for this season. Predesignated survey strata (purple transect lines) and design-based expansion strata between Point Conception and San Diego (S1-S6) were used to compute regional biomass in this study.

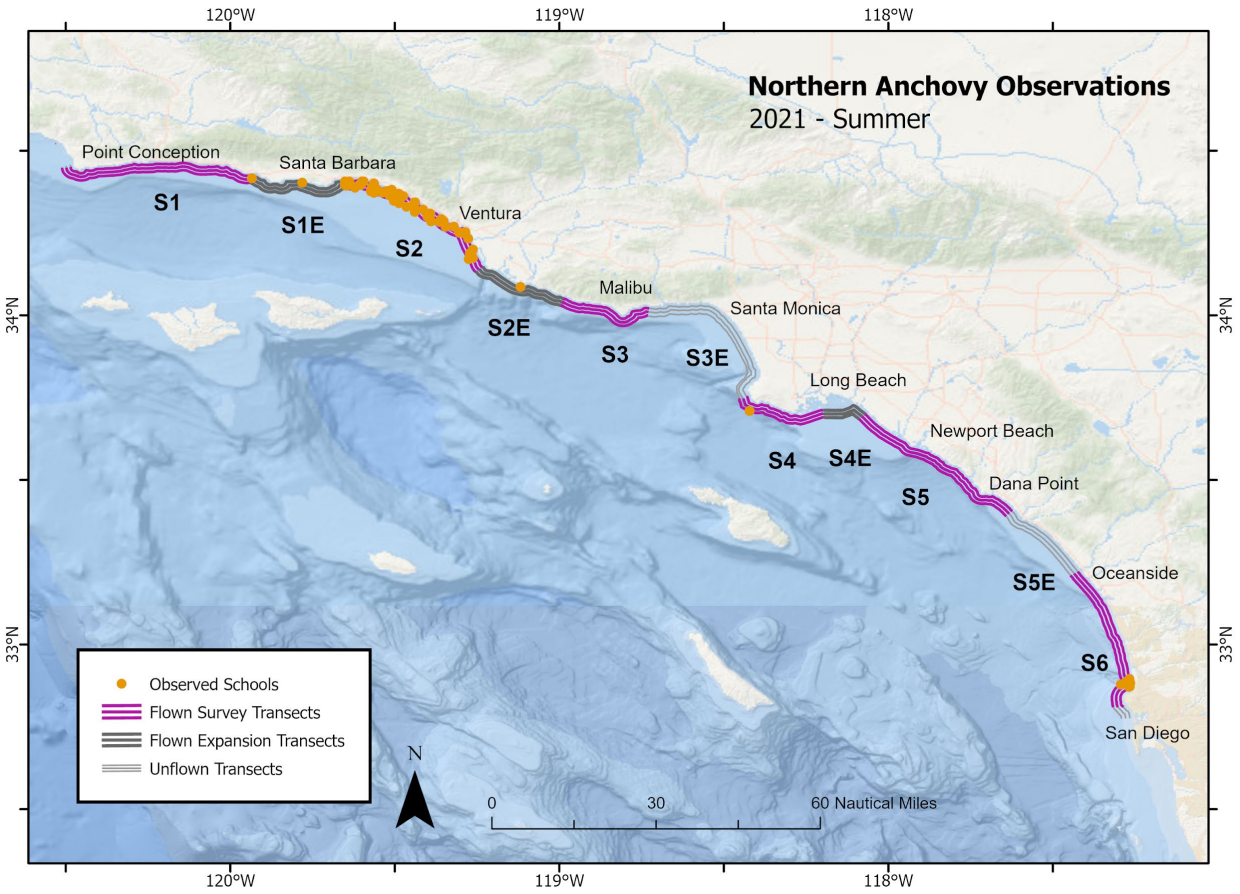

Figure B8. Spatial distribution of northern anchovy schools observed during summer 2021 CCPSS flights off Southern California. Expansion survey strata (black lines) that were flown in summer 2021 were parts of a special CDFW project, and thus following the design of this study data collected in these strata were not used in the computation of regional biomass. Predesignated survey strata (purple transect lines) and design-based expansion strata between Point Conception and San Diego (S1-S6) were used to compute regional biomass in this study. Note a small portion of S6 was not surveyed in this season and thus was considered as an expansion area.

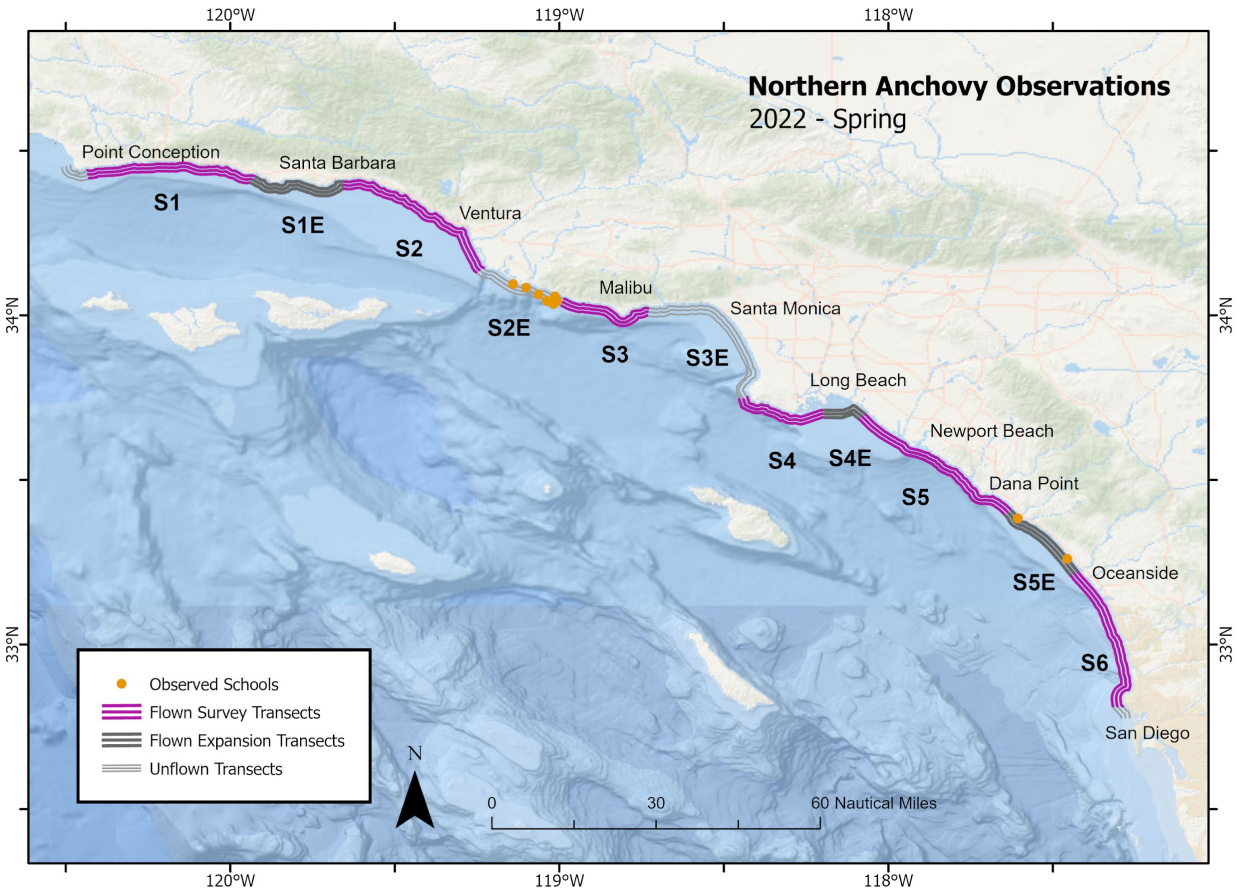

Figure B9. Spatial distribution of northern anchovy schools observed during spring 2022 CCPSS flights off Southern California. Expansion survey strata (black lines) that were flown in spring 2022 were parts of a special CDFW project, and thus following the design of this study data collected in these strata were not used in the computation of regional biomass for this season. Predesignated survey strata (purple transect lines) and design-based expansion strata between Point Conception and San Diego (S1-S6) were used to compute regional biomass in this study. Note a small portion of S6 was not surveyed in this season and thus was considered as an expansion area.

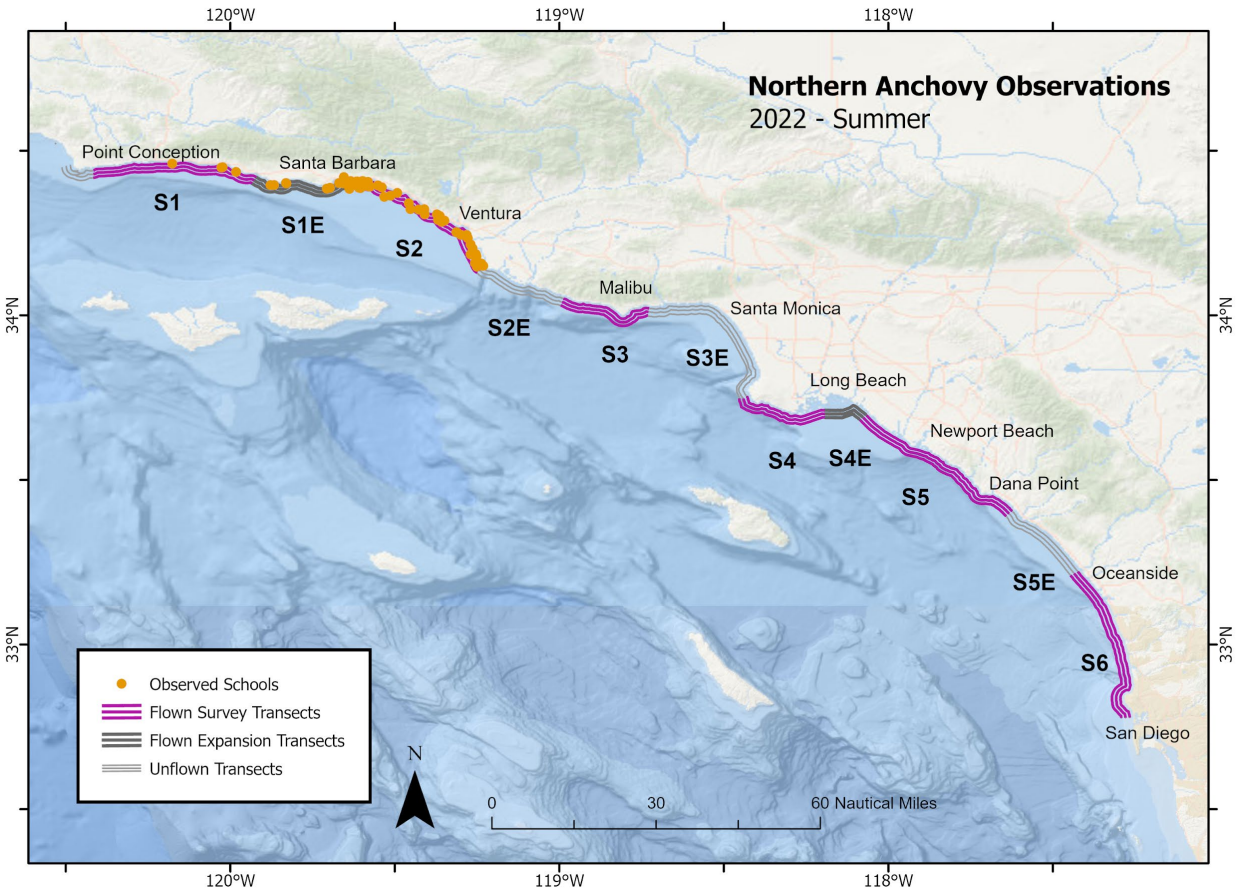

Figure B10. Spatial distribution of northern anchovy schools observed during summer 2022 CCPSS flights off Southern California. Expansion survey strata (black lines) that were flown in summer 2022 were parts of a special CDFW project, and thus following the design of this study data collected in these strata were not used in the computation of regional biomass for this season. Predesignated survey strata (purple transect lines) and design-based expansion strata between Point Conception and San Diego (S1-S6) were used to compute regional biomass in this study.

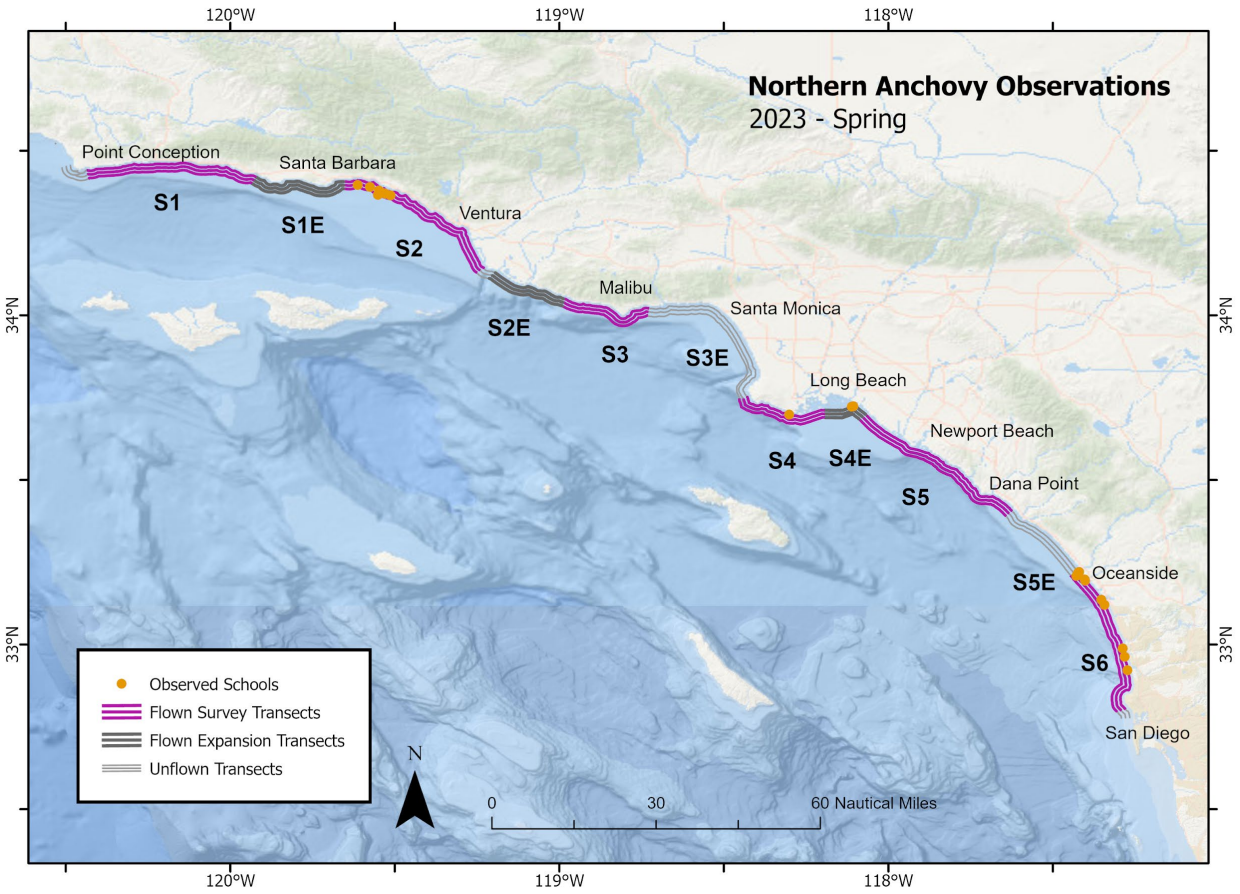

Figure B11. Spatial distribution of northern anchovy schools observed during spring 2023 CCPSS flights off Southern California. Expansion survey strata (black lines) that were flown in spring 2023 were parts of a special CDFW project, and thus following the design of this study data collected in these strata were not used in the computation of regional biomass for this season. Predesignated survey strata (purple transect lines) and design-based expansion strata between Point Conception and San Diego (S1-S6) were used to compute regional biomass in this study. Note a small portion of S6 was not surveyed in this season and thus was considered as an expansion area.

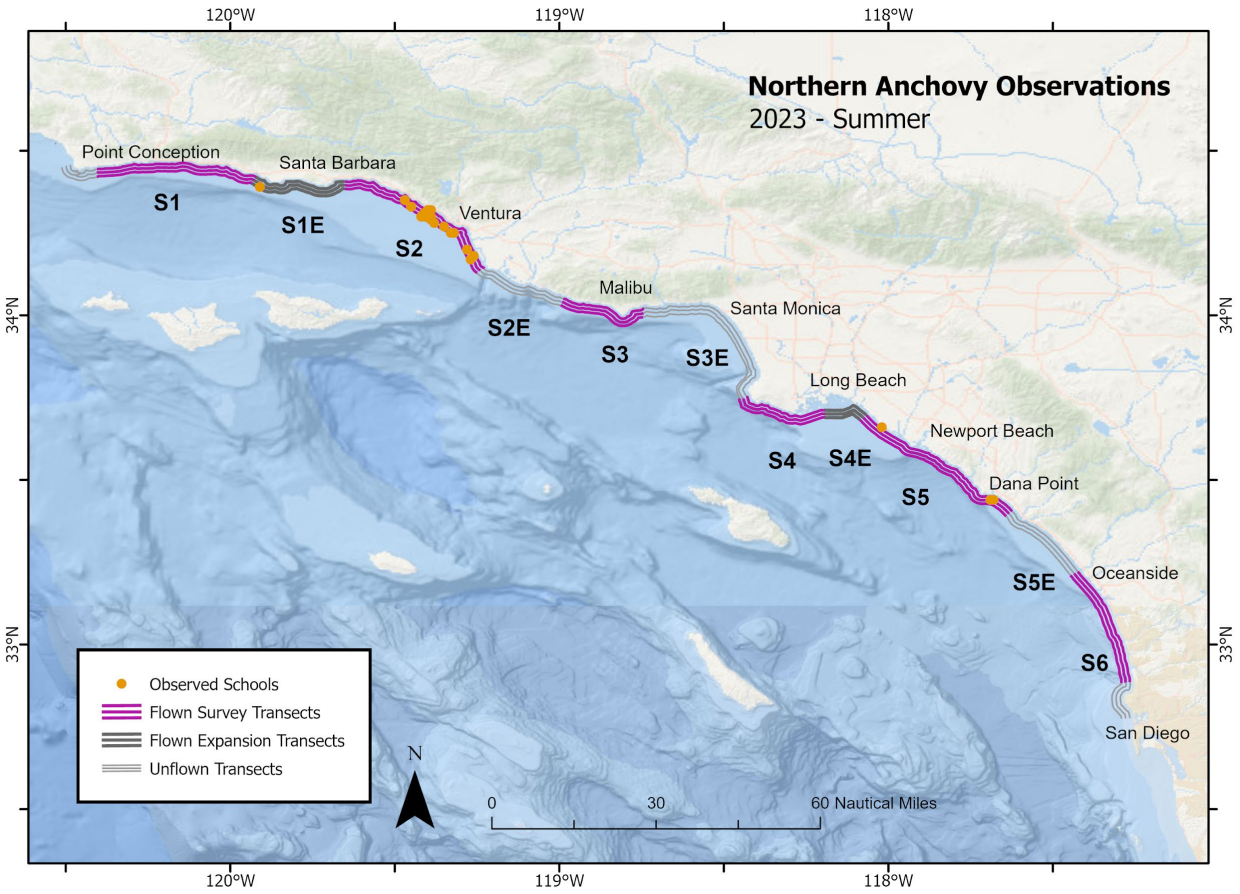

Figure B12. Spatial distribution of northern anchovy schools observed during summer 2023 CCPSS flights off Southern California. Expansion survey strata (black lines) that were flown in summer 2023 were parts of a special CDFW project, and thus following the design of this study data collected in these strata were not used in the computation of regional biomass for this season. Predesignated survey strata (purple transect lines) and design-based expansion strata between Point Conception and San Diego (S1-S6) were used to compute regional biomass in this study. Note a portion of S6 was not effectively surveyed in this season and thus was considered as an expansion area.

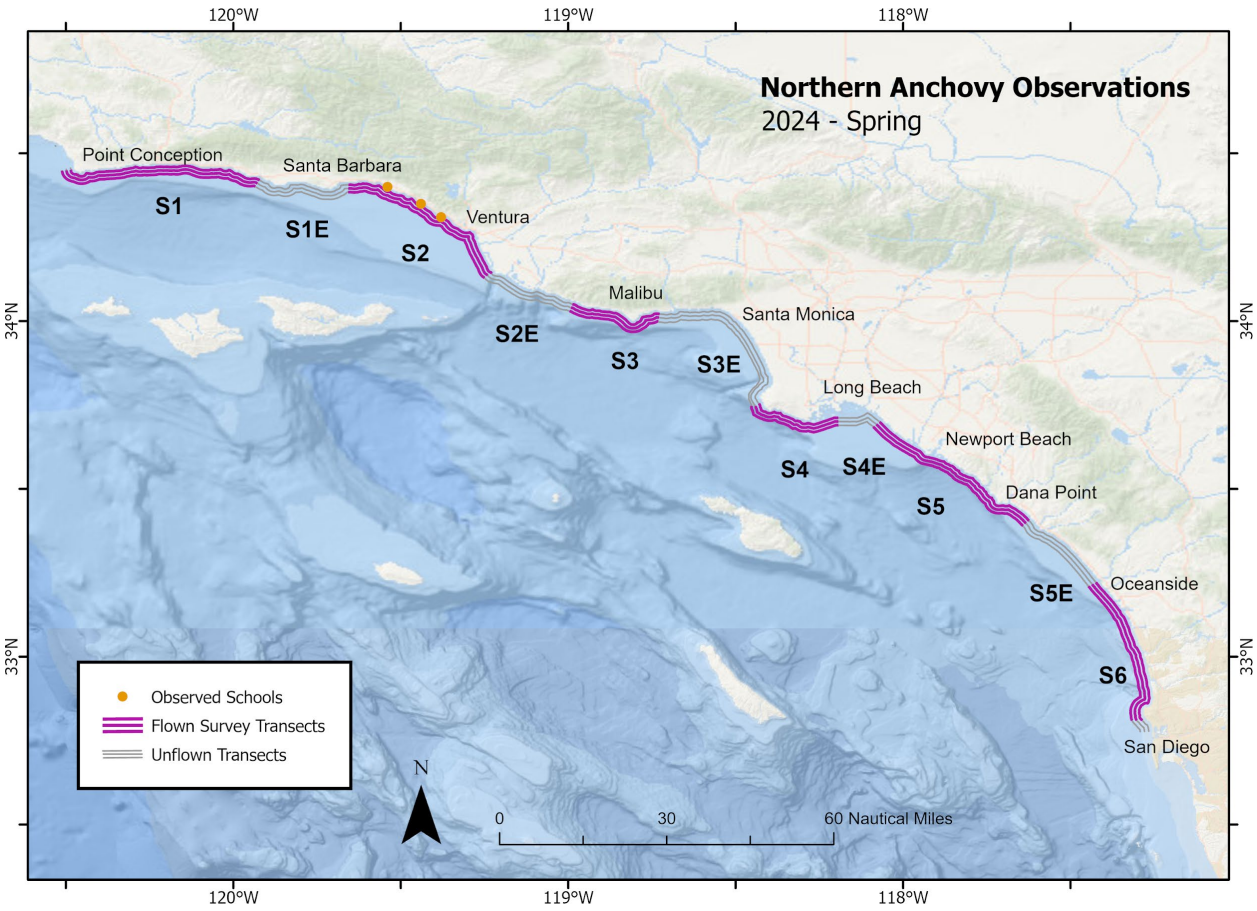

Figure B13. Spatial distribution of northern anchovy schools observed during spring 2024 CCPSS flights off Southern California. Predesignated survey strata (purple transect lines) and expansion strata (grey transects) between Point Conception and San Diego (S1-S6) were used to compute regional biomass in this study.

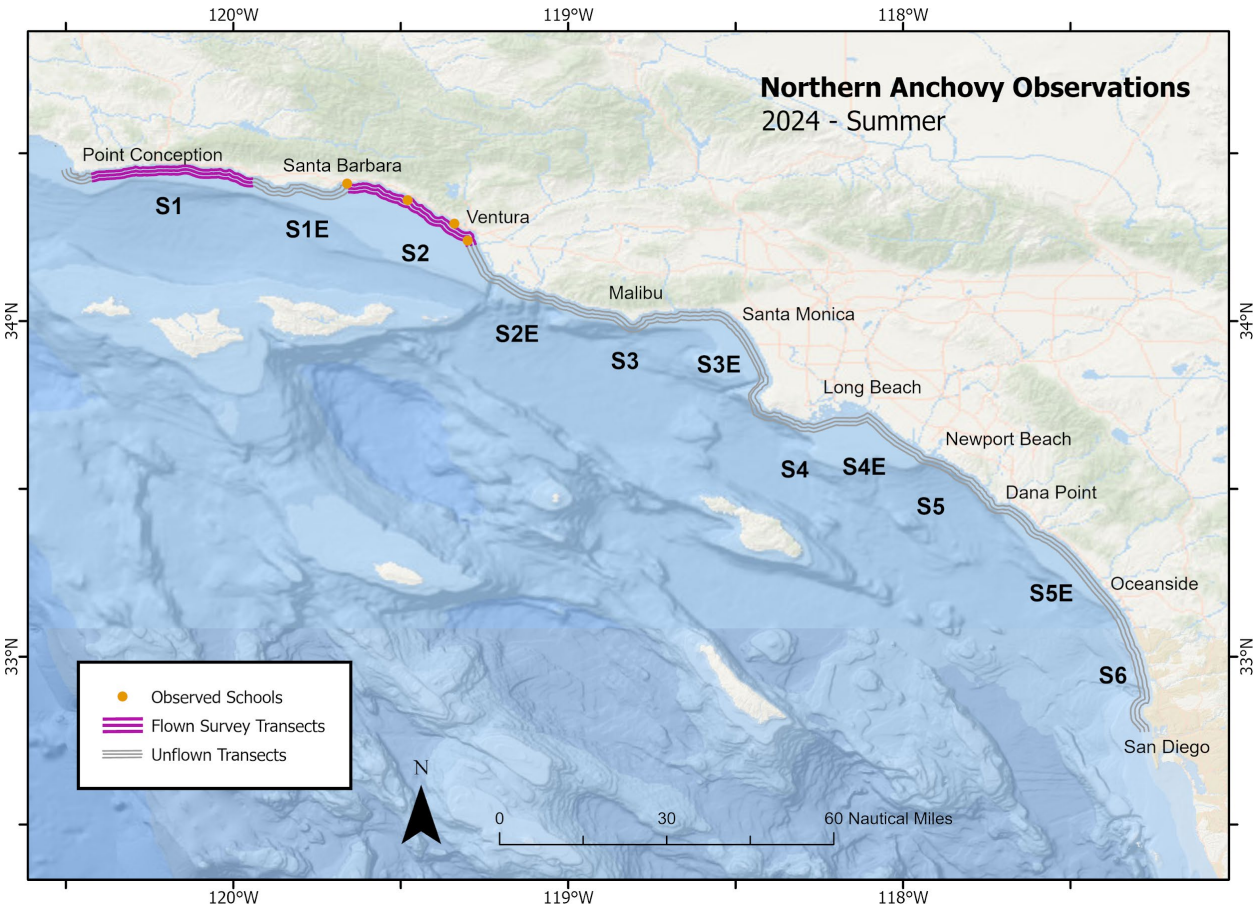

Figure B14. Spatial distribution of northern anchovy schools observed during summer 2024 CCPSS flights off Southern California. As only two predesignated survey strata were effectively surveyed in summer 2021 no regional biomass was computed for this season.

9. Appendix C (Figures C1-C5).

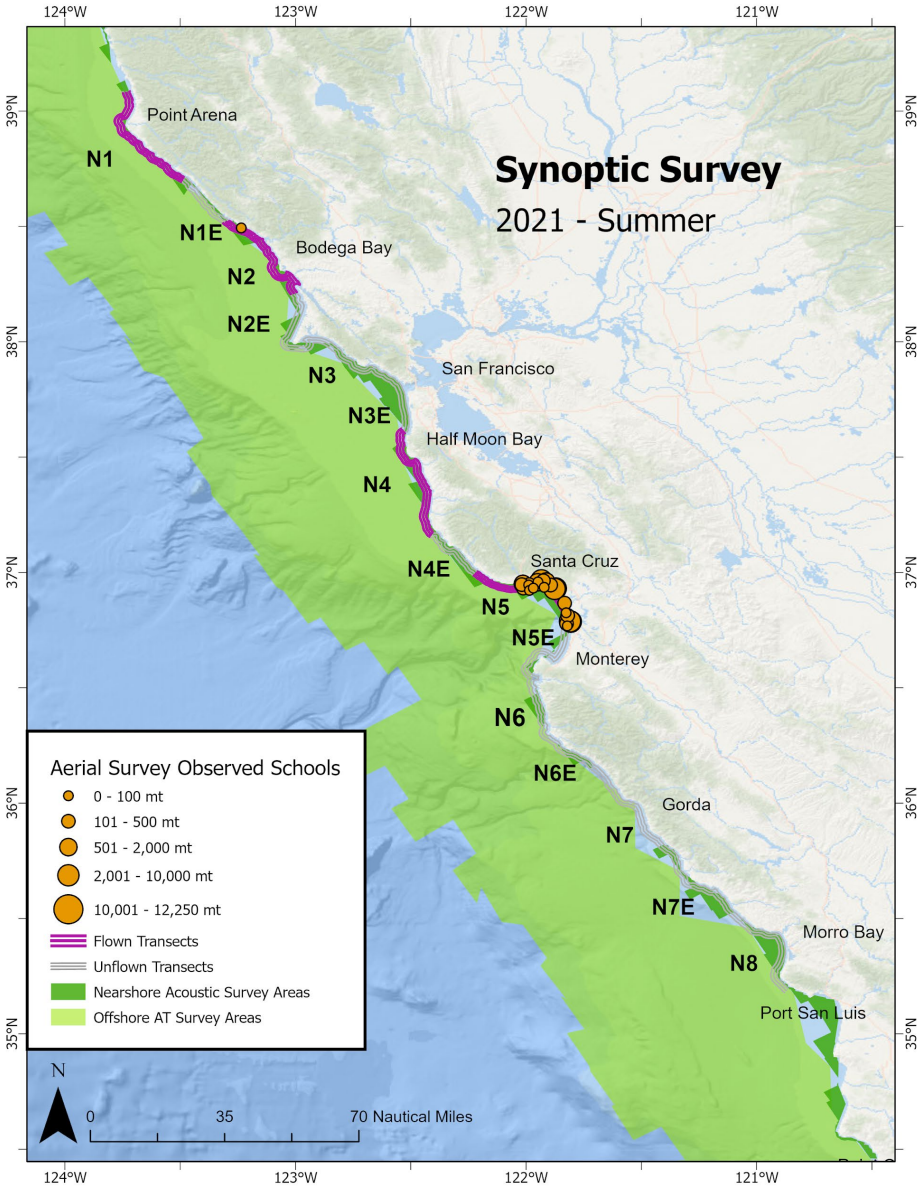

Figure C1. Northern anchovy school biomass observed by the CCPSS aerial survey (orange circles) during synoptic survey in summer 2021 off Northern California. Light green polygons show offshore areas surveyed FRV *Reuben Lasker* upon which northern anchovy core biomass was computed. Dark green polygons are nearshore areas surveyed by the FV *Long Beach Carnage* upon which northern anchovy acoustic nearshore biomass was computed. Aerial survey regional biomass was computed based on surveyed transect and expansion transects between Point Arena and Monterey Bay (N1-NE5).

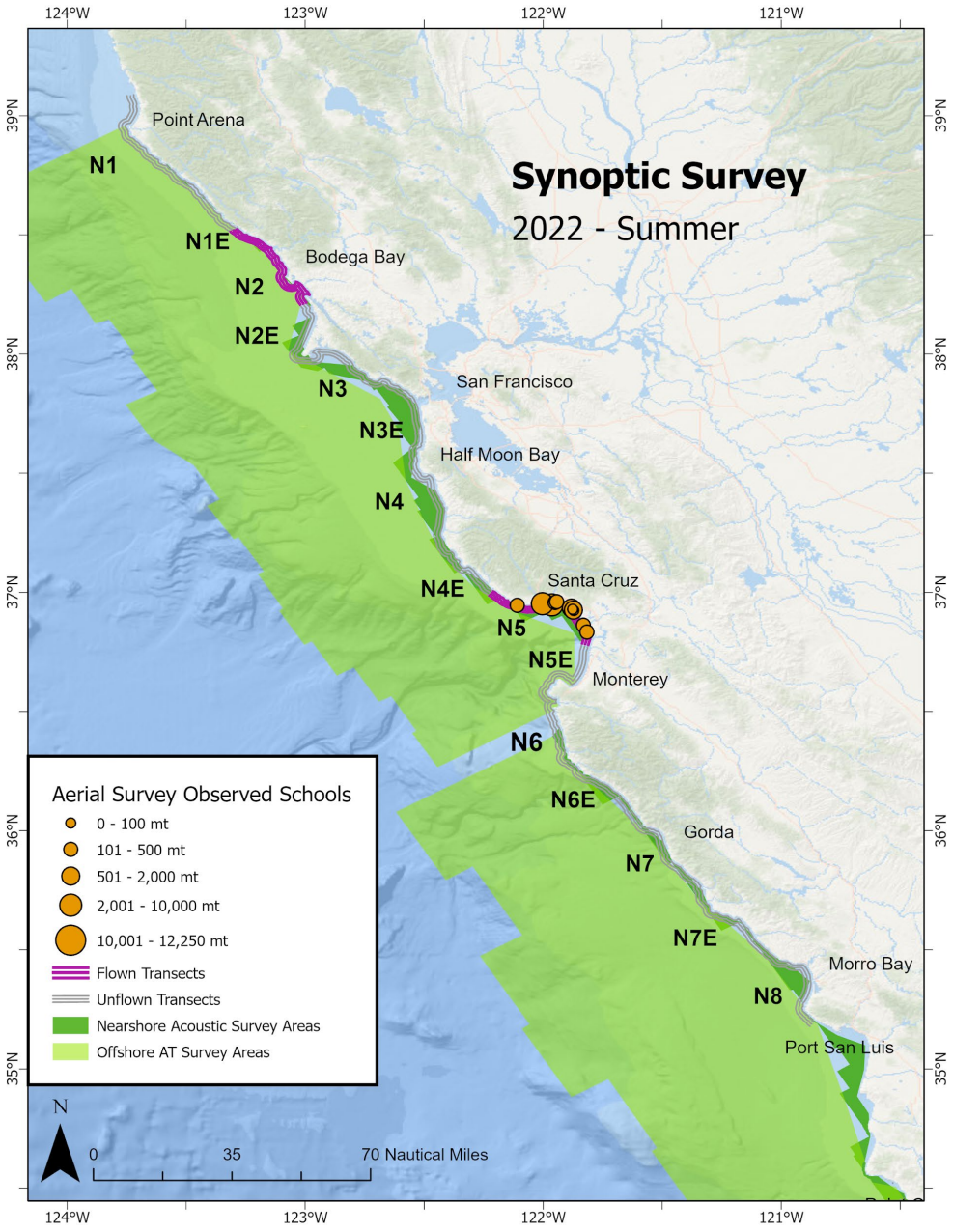

Figure C2. Northern anchovy school biomass observed by the CCPSS aerial survey (orange circles) during synoptic survey in summer 2022 off Northern California (NCA). Light green polygons show offshore areas surveyed FRV *Reuben Lasker* upon which northern anchovy core biomass was computed. Dark green polygons are nearshore areas surveyed by the FV *Long Beach Carnage* upon which northern anchovy acoustic nearshore biomass was computed. Aerial survey regional biomass was computed based on surveyed transect and expansion transects between Point Arena and Monterey Bay (N1-NE5).

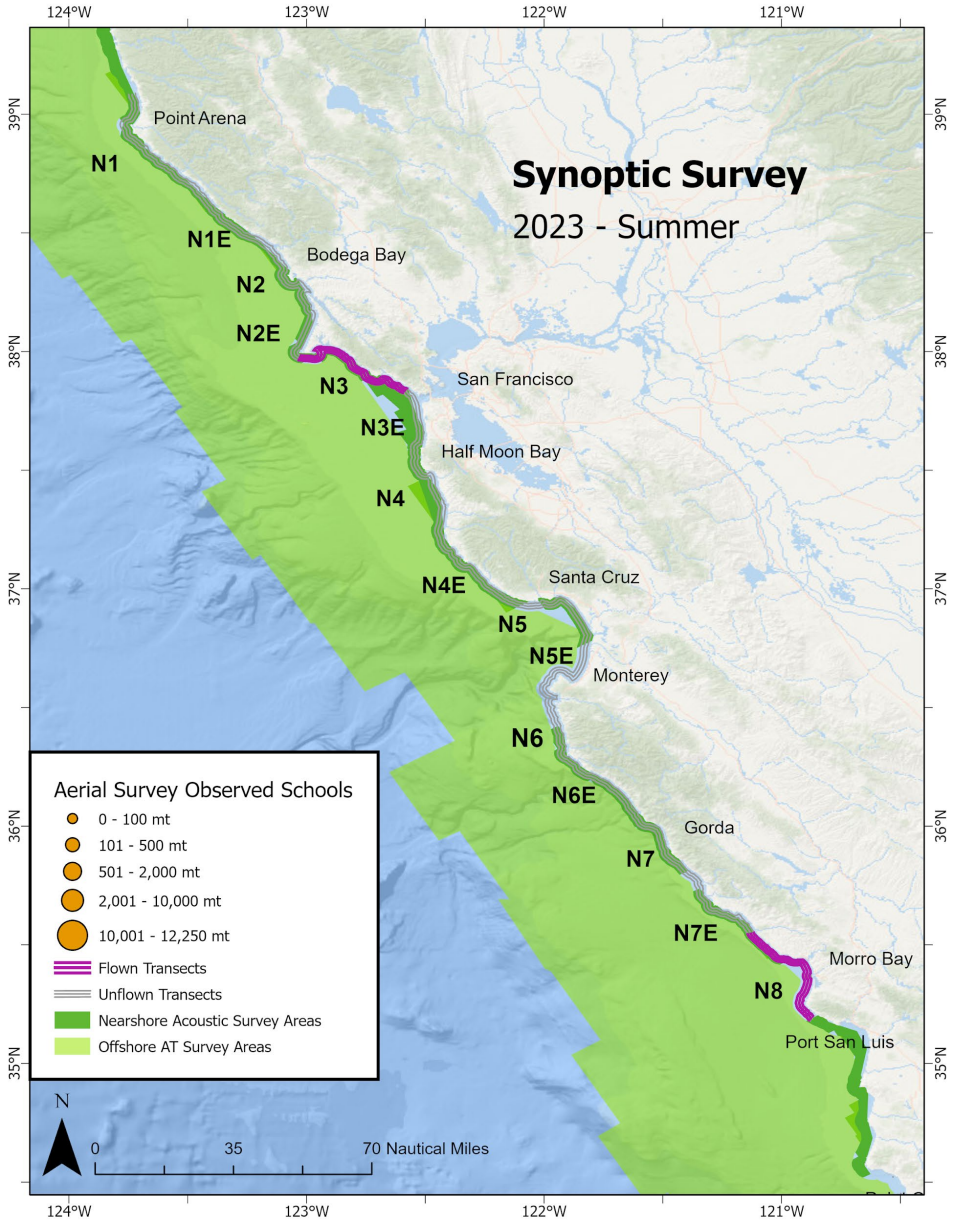

Figure C3. Northern anchovy school biomass observed by the CCPSS aerial survey (orange circles) during synoptic survey in summer 2023 off Northern California. Light green polygons show offshore areas surveyed FRV *Reuben Lasker* upon which northern anchovy core biomass was computed. Dark green polygons are nearshore areas surveyed by the FV *Long Beach Carnage* upon which northern anchovy acoustic nearshore biomass was computed. As only two strata were effectively surveyed (N3 and N8), aerial survey regional biomass was not computed for this season.

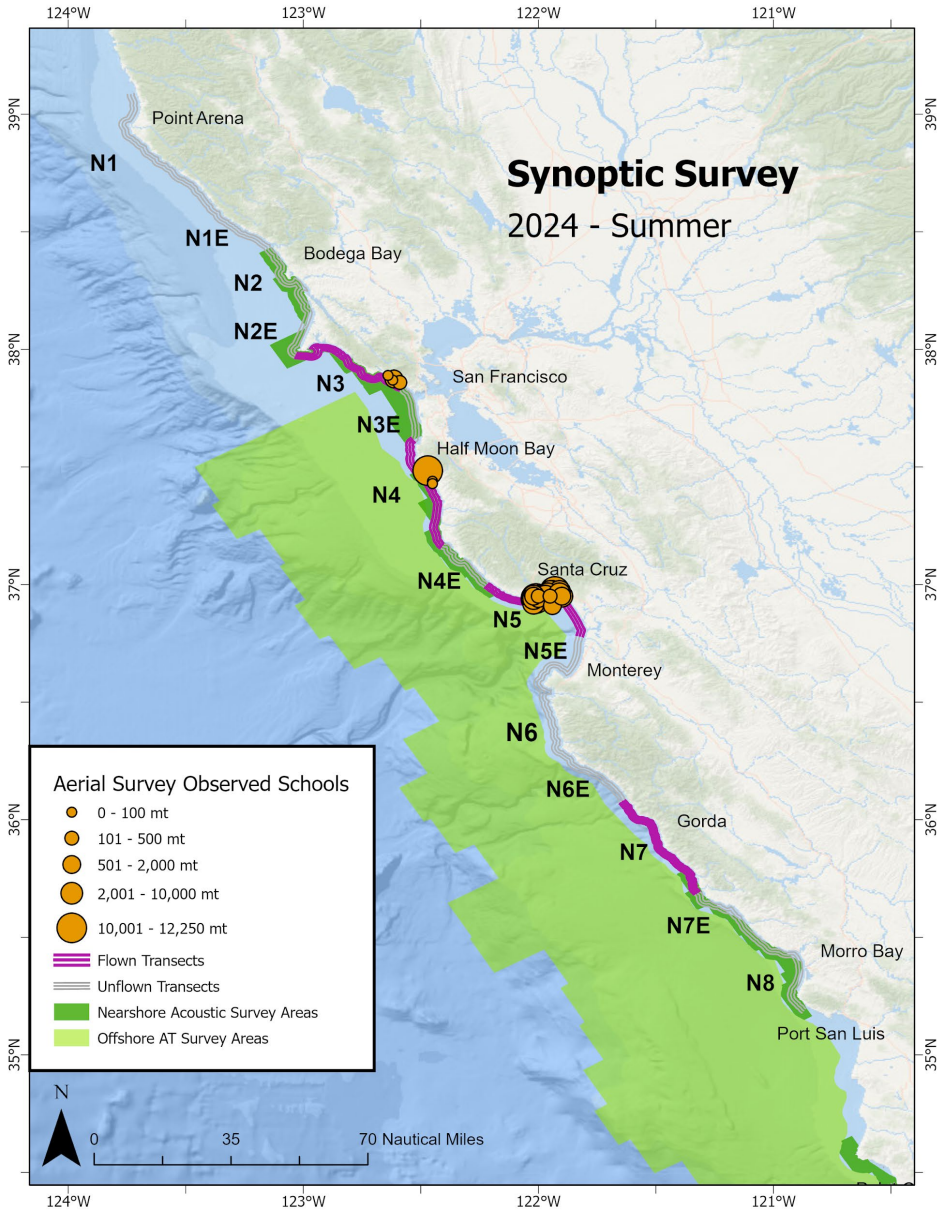

Figure C4. Northern anchovy school biomass observed by the CCPSS aerial survey (orange circles) during synoptic survey in summer 2024 off Northern California. Light green polygons show offshore areas surveyed FRV *Reuben Lasker* upon which northern anchovy core biomass was computed. Dark green polygons are nearshore areas surveyed by the FV *Long Beach Carnage* upon which northern anchovy acoustic nearshore biomass was computed. Aerial survey regional biomass was computed based on surveyed transect and expansion transects between Point Arena and Monterey Bay (N2E-NE5).

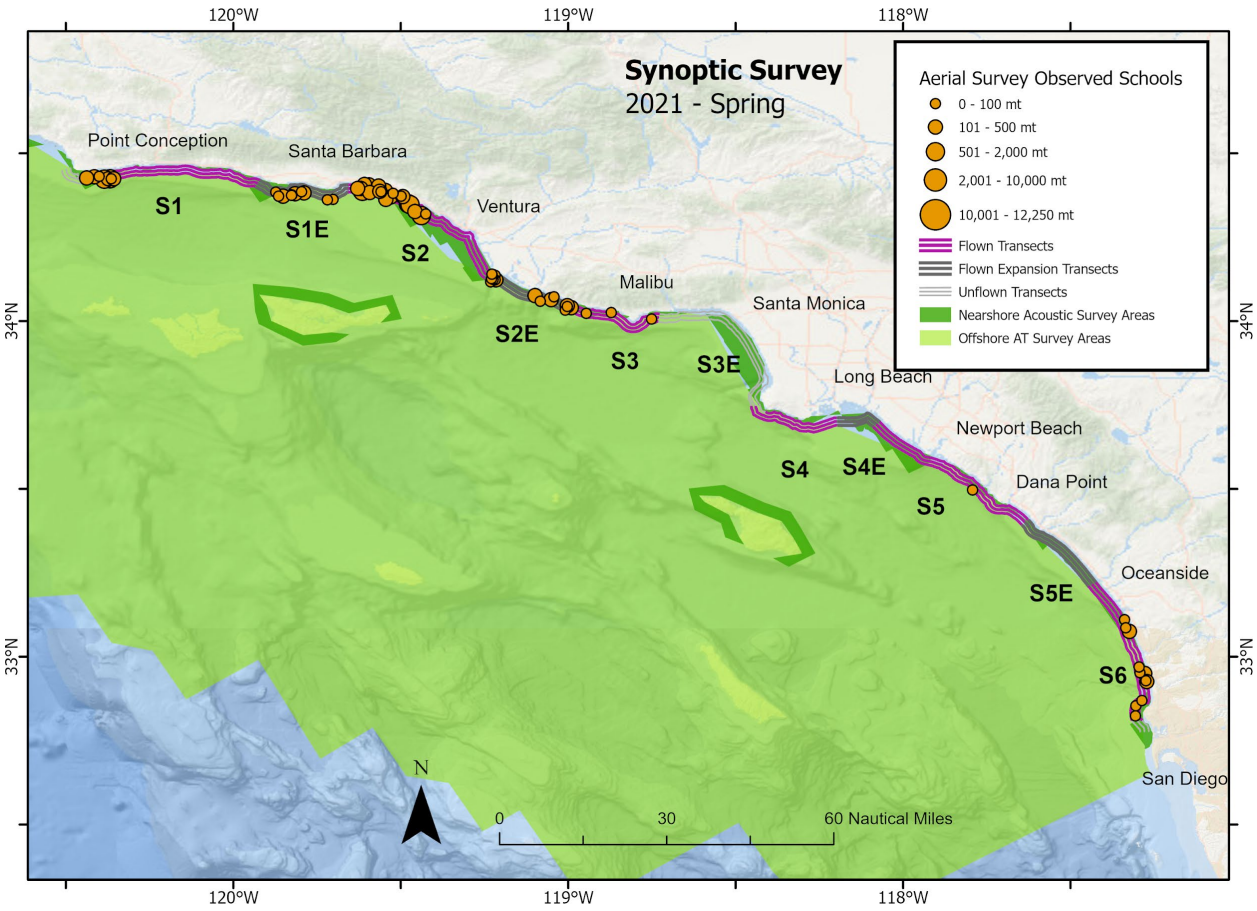

Figure C5. Northern anchovy school biomass observed by the CCPSS aerial survey (orange circles) during synoptic survey in summer 2024 off Southern California. Light green polygons show offshore areas surveyed FRV *Reuben Lasker* upon which northern anchovy core biomass was computed. Dark green polygons are nearshore areas surveyed by the FV *Long Beach Carnage* upon which northern anchovy acoustic nearshore biomass was computed. Expansion survey strata (black lines) that were flown in spring 2021 were parts of a special CDFW project, and thus following the design of this study data collected in these strata were not used in the computation of regional biomass for this season. Aerial survey regional biomass was computed based on surveyed transect and design-based expansion transects between Point Conception and San Diego (S1-S6).