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DISTRIBUTION, BIOMASS, AND DEMOGRAPHICS OF COASTAL PELAGIC FISHES IN THE CALIFORNIA CURRENT ECOSYSTEM DURING SUMMER 2025 BASED ON ACOUSTIC-TRAWL SAMPLING

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Executive Summary

This report provides: 1) a detailed description of the acoustic-trawl method (ATM) used by NOAA's Southwest Fisheries Science Center for direct assessments of the dominant coastal pelagic species (CPS; i.e.: Pacific Sardine *Sardinops sagax*, Northern Anchovy *Engraulis mordax*, Pacific Mackerel *Scomber japonicus*, Jack Mackerel *Trachurus symmetricus*, and Pacific Herring *Clupea pallasii*) in the California Current Ecosystem off the west coast of the United States (U.S.), including changes related to the inaugural Integrated West Coast Pelagics Survey (IWCPS), which combined ATM surveys for Pacific Hake (*Merluccius productus*) and CPS on the same ship; and 2) estimates of the biomasses, distributions, and demographics of those CPS encountered in the survey area between 3 June and 13 September 2025.

The core survey region, which was sampled by NOAA ship *Bell M. Shimada* (hereafter, *Shimada*), spanned most of the continental shelf between San Diego, CA and Cape Flattery, WA. Planned transects were oriented approximately perpendicular to the coast in the Southern CA Bight (SCB), and east-to-west north of Pt. Conception, from the shallowest navigable depth (~30 m) to a distance of 35 nmi offshore or, if farther, to the 1,000 ftm (~1830 m) isobath. In the SCB, transects in the core region were extended to approximately 100 nmi.

Because navigation by *Shimada* in water shallower than ~30 m was deemed inefficient, unsafe, or both, fishing vessels *Long Beach Carnage* and *Lisa Marie* sampled CPS in the nearshore region, along 5 nmi-long transects spaced 7 nmi-apart off the mainland coast of the U.S., between San Diego and Cape Flattery, and along 2 nmi-long transects spaced ~3-nmi apart around Santa Cruz and Santa Catalina Islands in the SCB. In the nearshore region, and due to sparse purse-seine sampling along portions of the coast, the acoustically-sampled CPS were apportioned using the species compositions and length distributions from either daytime purse-seine sets by *Long Beach Carnage* or *Lisa Marie* or individual nighttime trawl hauls from *Shimada*, whichever was closest in space.

The biomasses (metric tons, t), distributions, and demographics for each species and subpopulation are for the survey area and period, and therefore may not represent their entire population or subpopulation. For example, no surveys for CPS were conducted off Baja California in the summer of 2025 by the SWFSC or the Instituto Mexicano de Investigación en Pesca y Acuacultura Sustentables (IMIPAS, formerly INAPESCA).

The estimated biomass of the northern subpopulation of Northern Anchovy was 4,178 t ($CI_{95\%}$ = 99 - 11,164 t, CV = 73%). In the core region, the biomass was 4,103 t ($CI_{95\%}$ = 88 - 11,013 t, CV = 74%), and in the nearshore region the biomass was 74.5 t ($CI_{95\%}$ = 10 - 151 t, CV = 47%), or 1.8% of the total CPS biomass. The northern subpopulation was sparsely distributed between Cape Blanco, OR and Westport, WA, and the distribution of standard lengths (L_S) ranged from 4 to 16 cm with modes at 4 and 15 cm in the core region and at 5 and 11 cm in the nearshore region.

The estimated biomass of the central subpopulation of Northern Anchovy was 1,238,065 t ($CI_{95\%}$ = 453,248 - 1,749,878 t, CV = 25%). In the core region, the biomass was 1,108,875 t ($CI_{95\%}$ = 402,851 - 1,531,551 t, CV = 27%), and in the nearshore region the biomass was 129,190 t ($CI_{95\%}$ = 50,396 - 218,326 t, CV = 35%), or 10% of the total biomass. The central subpopulation ranged from approximately San Diego to Fort Bragg, CA, and the distribution of L_S ranged from 6 to 16 cm with a mode at 12 cm in both regions. The estimated biomass of the central subpopulation of Northern Anchovy, which has comprised the majority of CPS biomass since 2015, increased by 79% from the 689,785 t estimated in summer 2024 (Stierhoff *et al.*, 2025).

The estimated biomass of the northern subpopulation of Pacific Sardine was 66,640 t ($CI_{95\%}$ = 11,478 - 169,859 t, CV = 56%). In the core region, the biomass was 40,799 t ($CI_{95\%}$ = 215 - 124,265 t, CV = 89%) and in the nearshore region the biomass was 25,841 t ($CI_{95\%}$ = 11,263 - 45,594 t, CV = 34%), or 38.8% of the total biomass. The northern subpopulation (as designated by the habitat model, Zwolinski and Demer, 2024) was observed between Pt. Conception and Newport, OR, but was most abundant in the core region near Fort Bragg and, in the nearshore region, along the Big Sur coast and between Fort Bragg and Cape Mendocino. The distribution of L_S ranged from 13 to 24 cm with a mode at 20 cm in the core region and at 17 cm in the nearshore region. Japanese Sardine (*Sardinops melanosticta*) were present in the survey area during the survey period (Longo *et al.*, 2026). However, due to their phenotypic resemblance and lack of

genetic identification at the time biomasses were estimated, all sardine were considered Pacific Sardine (*S. sagax*).

The estimated biomass of the southern subpopulation of Pacific Sardine in the surveyed area was 20,049 t ($CI_{95\%}$ = 8,869 - 33,605 t, CV = 29%). In the core region, the biomass was 833 t ($CI_{95\%}$ = 1.17 - 2,215 t, CV = 71%), and in the nearshore region the biomass was 19,216 t ($CI_{95\%}$ = 8,868 - 31,390 t, CV = 30%), or 96% of the total biomass. The southern subpopulation in the survey area was observed predominantly in the nearshore area of the SCB, but was most abundant near San Diego, Long Beach, and Santa Barbara. The distribution of L_S ranged from 10 to 24 cm with a mode at 19 cm in the core region and a mode at 16 cm in the nearshore region.

The estimated biomass of all Pacific Sardine in U.S. waters, including both the northern and southern subpopulations in the core and nearshore areas, was 86,689 t ($CI_{95\%}$ = 20,347 - 203,464 t, CV = 44%).

The estimated biomass of Pacific Mackerel was 10,586 t ($CI_{95\%}$ = 4,169 - 18,555 t, CV = 25%). In the core region, the biomass was 4,088 t ($CI_{95\%}$ = 855 - 8,791 t, CV = 50%), and in the nearshore region the biomass was 6,498 t ($CI_{95\%}$ = 3,314 - 9,764 t, CV = 25%), or 61% of the total biomass. Pacific Mackerel were sparsely distributed in the core and nearshore regions throughout the survey area. The distribution of fork lengths (L_F) ranged from 14 to 43 cm with modes at 27 and 42 cm in the core region and at 23, 27, and 41 cm in the nearshore region.

The estimated biomass of Jack Mackerel was 741,276 t ($CI_{95\%}$ = 421,184 - 1,095,509 t, CV = 21%). In the core region, the biomass was 668,518 t ($CI_{95\%}$ = 384,221 - 979,963 t, CV = 23%), and in the nearshore region the biomass was 72,759 t ($CI_{95\%}$ = 36,964 - 115,545 t, CV = 28%), or 9.8% of the total biomass. Jack Mackerel were observed throughout the core and nearshore survey areas, but were most abundant north of Bodega Bay, CA in the core region and between Cape Mendocino and Astoria, OR in the nearshore region. The distribution of L_F ranged from 4 to 55 cm with modes at 11, 25, and 45 cm in the core region and at 14, 30, and 41 cm in the nearshore region.

The total estimated biomass of Pacific Herring was 111,843 t ($CI_{95\%}$ = 42,030 - 223,110 t, CV = 30%). In the core region, the biomass was 76,299 t ($CI_{95\%}$ = 31,632 - 126,692 t, CV = 33%), and in the nearshore region the biomass was 35,544 t ($CI_{95\%}$ = 10,398 - 96,418 t, CV = 65%), or 32% of the total biomass. Pacific Herring were observed from San Francisco to Cape Flattery in the core and nearshore regions, but was most abundant north of Newport. The distribution of L_F ranged from 9 to 25 cm, with a mode at 15 cm in the core region and with modes at 9 and 13 cm in the nearshore region.

The total estimated biomass of eight populations or subpopulations of six coastal pelagic species within the survey area was 2,192,643 t. Of this, 56% (1,238,065 t) was from the central subpopulation of Northern Anchovy and 34% (741,276 t) was from Jack Mackerel. Proportions of other subpopulations, in decreasing order, were: Pacific Herring (5.1%), northern subpopulation of Pacific Sardine (3%), southern subpopulation of Pacific Sardine (1%), Pacific Mackerel (0.5%), and the northern subpopulation of Northern Anchovy (0.19%).

For additional information about the survey objectives, equipment, sampling and analysis methods used to estimate the distribution, size structure, and biomass of hake in U.S. and Canadian waters off the Pacific coast during the 2025 Summer IWCPS, see the detailed survey report by Clemons et al. (In prep.).

All analyses presented here were performed using R software (R Core Team, 2025), including functions contained in the {atm} package (Stierhoff and Zwolinski, 2026)[1] and scripts contained in the *estimATM* repository (Stierhoff *et al.*, 2026)[2], both of which are available on GitHub.

[1] https://github.com/SWFSC/atm
[2] https://github.com/SWFSC/estimATM

1 Introduction

In the California Current Ecosystem (CCE), multiple coastal pelagic fish species (CPS; i.e.: Pacific Sardine *Sardinops sagax*, Northern Anchovy *Engraulis mordax*, Jack Mackerel *Trachurus symmetricus*, Pacific Mackerel *Scomber japonicus*, and Pacific Herring *Clupea pallasii*) comprise the bulk of the forage fish assemblage. The term CPS is used here to refer to any of the above-mentioned species, which are a subset of the CPS assemblage listed in the Pacific Fishery Management Council's CPS Fishery Management Plan[3]. These populations, which can change by an order of magnitude within a few years, represent important prey for marine mammals, birds, and larger migratory fishes (Field *et al.*, 2001), and some are targets of commercial fisheries.

The current assumption is that, during summer and fall, the northern subpopulation of Pacific Sardine typically migrates north to feed in the productive coastal upwelling off OR, WA, and Vancouver Island (Zwolinski *et al.*, 2012, and references therein, **Fig. 1**). In synchrony, but separately, the southern subpopulation of Pacific Sardine migrates from Northern Baja CA, Mexico to the Southern CA Bight (SCB) (Smith, 2005). The predominantly piscivorous adult Pacific and Jack Mackerels also migrate north in summer, but go farther offshore to feed (Zwolinski *et al.*, 2014 and references therein). In the winter and spring, the northern subpopulation of Pacific Sardine typically migrates south to its spawning grounds, generally off Central and Southern CA (Demer *et al.*, 2012) and occasionally off OR and WA (Lo *et al.*, 2011). These migrations vary in extent with population size, fish age and length, and oceanographic conditions (Zwolinski *et al.*, 2012). The transition zone chlorophyll front (TZCF, Polovina *et al.*, 2001) may delineate the offshore and southern limit of both northern subpopulation Pacific Sardine and Pacific Mackerel habitat (e.g., Demer *et al.*, 2012; Zwolinski *et al.*, 2012), and juveniles may have nursery areas in the SCB, downstream of upwelling regions. In contrast, Northern Anchovy spawn predominantly during winter and closer to the coast where seasonal down-welling increases retention of their eggs and larvae (Bakun and Parrish, 1982). Pacific Herring spawn during spring and early summer in intertidal beach areas (Love, 1996). The northern subpopulation of Northern Anchovy is located off WA and OR and the central subpopulation is located off Central and Southern CA and northern Baja CA. Whether a species migrates or remains in an area depends on its reproductive and feeding behaviors, affinity to certain oceanographic or seabed habitats, and its population size.

Acoustic-trawl method (ATM) surveys, which combine information collected with echosounders and nets, were introduced to the CCE more than 50 years ago to survey CPS off the west coast of the United States (U.S.) (Mais, 1974, 1977; Smith, 1978). Following a two-decade hiatus, the ATM was reintroduced in the CCE in spring 2006 to sample the then-abundant Pacific Sardine population (Cutter and Demer, 2008). Since then, this sampling effort has continued and expanded through annual or semi-annual surveys (Demer *et al.*, 2012; Zwolinski *et al.*, 2014). Beginning in 2011, the ATM estimates of Pacific Sardine abundance, age structure, and distribution have been incorporated in the annual assessments of the northern subpopulation (Hill *et al.*, 2017; Kuriyama *et al.*, 2020, 2022a). ATM estimates are also used in assessments of Pacific Mackerel (Crone *et al.*, 2019; Crone and Hill, 2015; Kuriyama *et al.*, 2023) and the central subpopulation of Northern Anchovy (Kuriyama *et al.*, 2022b). Additionally, ATM survey results have yielded estimated abundances, demographics, and distributions of epipelagic and semi-demersal fishes (e.g., Swartzman, 1997; Williams *et al.*, 2013; Zwolinski *et al.*, 2014) and zooplankton (Hewitt and Demer, 2000).

This document, and references herein, describes in detail the ATM as presently used by NOAA's Southwest Fisheries Science Center (SWFSC) to survey the distributions, abundances, biomasses, and demographics of CPS and their oceanographic environments (e.g., Cutter and Demer, 2008; Demer *et al.*, 2012; Zwolinski *et al.*, 2014). In general terms, the contemporary ATM combines information from satellite-sensed oceanographic conditions, multifrequency echosounders, probe-sampled oceanographic conditions, trawl-net catches of juvenile and adult CPS, and sometimes pumped samples of fish eggs. The summer survey area spans the continental shelf and adjacent waters to the 1000-fathom (ftm) isobath off the west coast of the U.S., is expected to encompass the potential habitat of the northern subpopulation of Pacific Sardine (**Fig. 1**), and as time and resources permit, can be further expanded to encompass as much of the potential habitat as possible for other CPS present over the shelf along the west coasts of Canada and Baja CA.

[3]https://www.pcouncil.org/documents/2023/06/coastal-pelagic-species-fishery-management-plan.pdf/

Along transects in the survey area, multi-frequency split-beam echosounders transmit sound pulses downward beneath the ship and receive echoes from animals and the seabed in the path of the sound waves. Measurements of sound speed and absorption from conductivity-temperature-depth (CTD) probes allow accurate compensation of these echoes for propagation losses. The calibrated echo intensities, normalized to the range-dependent observational volume, provide indications of the target type and behavior (e.g., Demer *et al.*, 2009b).

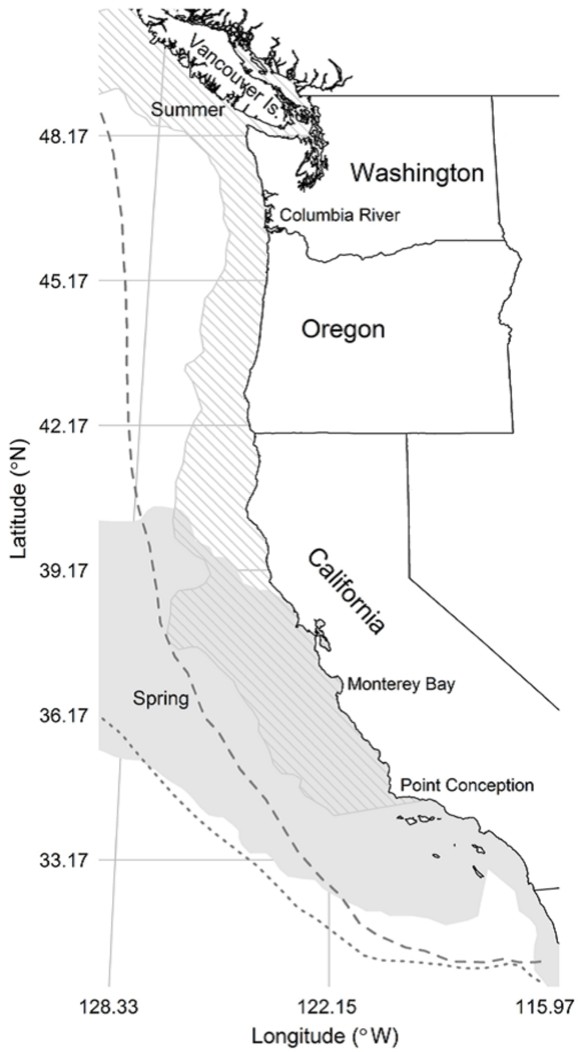

Figure 1: Conceptual spring (shaded region) and summer (hashed region) distributions of potential habitat for the northern subpopulation of Pacific Sardine along the west coasts of Mexico, the United States, and Canada. The dashed and dotted lines represent, respectively, the approximate summer and spring positions of the 0.2 mg m^{-3} chlorophyll-a concentration isoline. This isoline appears to oscillate in synchrony with the transition zone chlorophyll front (TZCF, Polovina *et al.*, 2001) and the offshore limit of the northern subpopulation Pacific Sardine potential habitat (Zwolinski and Demer, 2024). Mackerels are found within and on the edge of the same oceanographic habitat (e.g., Demer *et al.*, 2012; Zwolinski *et al.*, 2012). The TZCF may delineate the offshore and southern limit of both northern subpopulation Pacific Sardine and Pacific Mackerel distributions, and juveniles may have nursery areas in the SCB, downstream of upwelling regions.

Echoes from marine organisms are a function of their body composition, shape, and size relative to the sensing-sound wavelength, and their orientation relative to the incident sound waves (Cutter *et al.*, 2009; Demer *et al.*, 2009b; Renfree *et al.*, 2009). Variations in echo intensity across frequencies, known as echo spectra, indicate the taxonomic groups contributing to the echoes. The CPS, with highly reflective swim bladders, create high intensity echoes of sound pulses at all echosounder frequencies (e.g., Conti and Demer, 2003). In contrast, krill, with acoustic properties closer to those of the surrounding seawater, produce lower intensity echoes, particularly at lower frequencies (e.g., Demer *et al.*, 2003). The echo energy attributed to CPS, based on empirical echo spectra (Demer *et al.*, 2012), are apportioned to species using trawl-catch proportions (Zwolinski *et al.*, 2014).

Animal densities are estimated by dividing the vertically summed area-backscattering coefficients attributed to a species by their average echo intensity, i.e., the mean backscattering cross-section, from animals of that species (e.g., Demer *et al.*, 2012). Transects with similar densities and transect spacings are grouped into post-sampling strata that mimic the natural patchiness of the target species (e.g., Zwolinski *et al.*, 2014). Estimates of abundance are obtained by multiplying the mean densities in the stratum by the respective stratum areas (Demer *et al.*, 2012). The associated sampling variance is calculated using non-parametric bootstrap of the mean transect densities. The total abundance estimate in the survey area is the sum of abundances in all strata. Similarly, the total variance estimate is the sum of the variance in each stratum.

The primary objectives of the SWFSC's ATM surveys are to survey the distributions, abundances, and demographics of CPS and their abiotic environments in the CCE. Typically, summer surveys are conducted during 50-90 days-at-sea (DAS) between June and October. In summer, the ATM surveys also include the northern subpopulation of Northern Anchovy and Pacific Herring. When they occur, spring surveys are conducted during 25-40 DAS between March and May and focus primarily on the northern subpopulation of Pacific Sardine and the central subpopulation of Northern Anchovy; spring surveys have not occurred since 2021. During spring and summer, biomasses are also estimated for other CPS (e.g., Pacific Mackerel, Jack Mackerel, and sometimes Round Herring) present in the survey area. In summer 2025, the ATM surveys for CPS and Pacific Hake (*Merluccius productus*) were combined on the same ship and named the Integrated West Coast Pelagics Survey (IWCPS), similar to the sardine-hake (SaKe) surveys conducted in 2012, 2013, and 2015 (JTC, 2014; Stierhoff *et al.*, 2018, 2021a; Taylor *et al.*, 2015)

In summer 2025, the ATM survey was conducted in the core area by *Shimada*, and in the nearshore region by fishing vessels *Lisa Marie* and *Long Beach Carnage*, from San Diego, CA to Cape Flattery, WA.

Presented here are: 1) a detailed description of the ATM used to survey CPS in the California Current Ecosystem (CCE) off the west coast of the U.S., including changes related to the IWCPS; and 2) estimates of the abundances, biomasses, spatial distributions, and demographics of CPS, specifically the northern and southern subpopulations of Pacific Sardine, the central and northern subpopulations of Northern Anchovy, Pacific Mackerel, Jack Mackerel, and Pacific Herring for the core and nearshore survey regions in which they were sampled. Japanese Sardine (*Sardinops melanosticta*) were present in the survey area during the survey period (Longo *et al.*, 2026). However, due to their phenotypic resemblance and lack of genetic identification at the time biomasses were estimated, all sardine were considered Pacific Sardine (*S. sagax*). For additional information about the survey objectives, equipment, sampling and analysis methods used to estimate the distribution, size structure, and biomass of hake in U.S. and Canadian waters off the Pacific coast during the 2025 Summer IWCPS, see the detailed survey report by Clemons et al. (In prep.).

2 Methods

2.1 Sampling

2.1.1 Design

The summer 2025 survey was conducted principally using *Shimada*, but was augmented with nearshore acoustic and purse-seine sampling by two fishing vessels, *Long Beach Carnage* and *Lisa Marie*. The sampling domain between San Diego, CA and Cape Flattery, WA encompassed the U.S. west coast latitudinally and the expected distributions of CPS from onshore to offshore (**Fig. 1**). The longitudinal sampling domain extended from the coast to at least the 1,000 fathom (ftm, or ~1830 m) isobath (**Fig. 2**). Considering the expected distribution of the target species and the available ship time for the ATM survey (81 days at sea, DAS), the primary objective was to estimate the biomasses, spatial distributions, and demographics of the northern subpopulation of Pacific Sardine and the northern subpopulation of Northern Anchovy, whose expected distributions were encompassed by the survey region. Secondary objectives were to estimate the biomasses, spatial distributions, and demographics of the southern subpopulation of Pacific Sardine, central subpopulation of Northern Anchovy, Pacific Mackerel, Jack Mackerel, and Pacific Herring, since their full populations likely extend beyond the planned survey region.

The planned core region transects were perpendicular to the coast, extending from the shallowest navigable depth (~20 m) to either a distance of 35 nmi or to the 1,000 ftm isobath, whichever is farther offshore (**Fig. 2**). Compulsory transects were spaced 20 nmi apart in the Southern CA Bight (SCB) and 15 nmi apart between Pt. Conception and Cape Flattery. When CPS were observed within the westernmost 3 nmi of a transect, that transect and the next one to the north were extended in 5-nmi increments until no CPS were observed in the last 3 nmi of the extension, to a maximum extension of 50 nmi. In summer 2025, transects were sampled south-to-north to coordinate sampling with the hake survey conducted by the Department of Fisheries and Oceans Canada (DFO) aboard Canadian Coast Guard Ship (CCGS) *Sir John Franklin*.

To estimate the abundances and biomasses of CPS in the nearshore region between San Diego and Cape Flattery where *Shimada* could not efficiently nor safely navigate or trawl, two fishing vessels were used to conduct acoustic and purse-seine sampling (magenta lines, **Fig. 2**). *Long Beach Carnage* sampled as close to shore as possible, typically to the 5-m isobath, along 5-nmi-long transects spaced 7 nmi apart between San Diego and Half Moon Bay, CA, and 2.5-nmi-long transects spaced 2-2.5 nmi apart around Santa Cruz and Santa Catalina Islands in the SCB. *Lisa Marie* sampled transects as close to shore as possible, typically to the 5-m isobath, spaced 7 nmi apart between Half Moon Bay and Cape Flattery (**Fig. 2**).

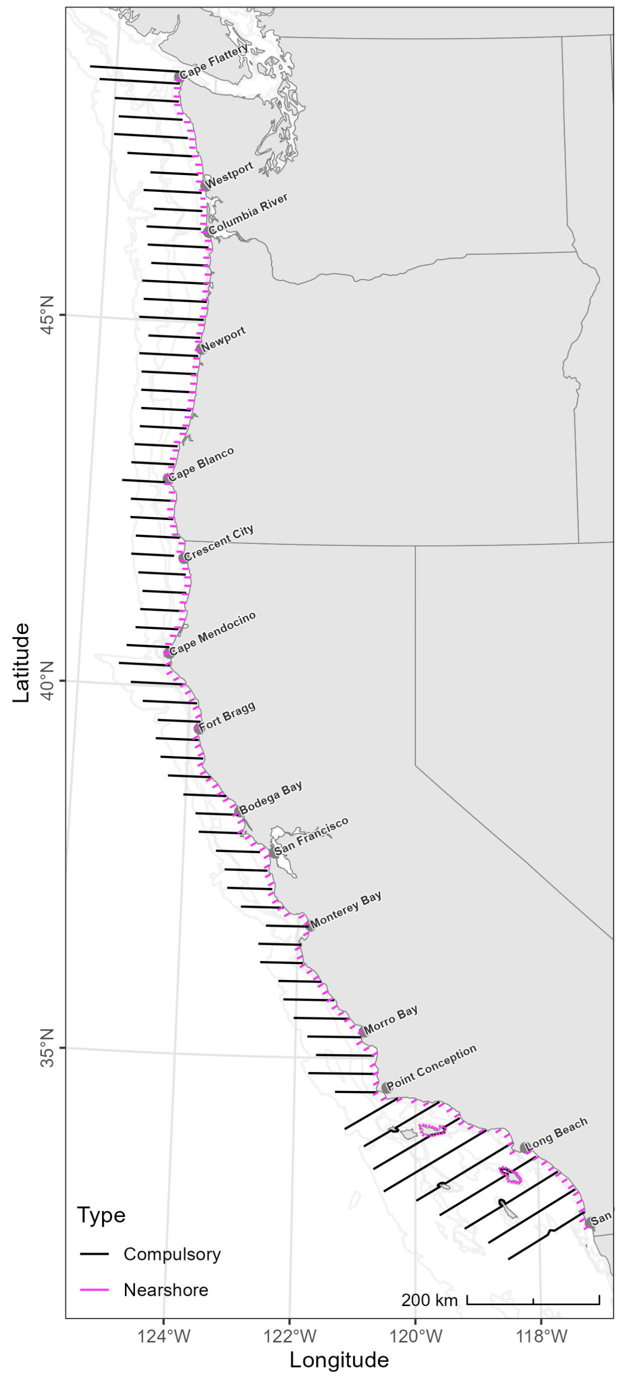

Figure 2: Planned compulsory transects sampled by NOAA Ship *Shimada* (black lines) and nearshore transects sampled by *Lisa Marie* and *Long Beach Carnage* (magenta lines). Isobaths (light gray lines) are 50, 200, 500, and 2,000 m.

2.1.2 Acoustic

2.1.2.1 Acoustic equipment

2.1.2.1.1 ***Shimada*** Multi-frequency Wide-Bandwidth Transceivers (18-, 38-, 70-, 120-, and 200-kHz Simrad EK80 WBTs; Kongsberg) were configured with split-beam transducers (Simrad ES18-11, ES38B, ES70-7C, ES120-7C, and ES200-7C, respectively; Kongsberg). The transducers were mounted on the bottom of a retractable keel or "centerboard" (**Fig. 3**). The keel was retracted (transducers at ~5-m depth) during calibration, and extended to the intermediate position (transducers at ~7-m depth) during the survey. Exceptions were made during shallow water operations, when the keel was retracted; or during times of heavy weather, when the keel was extended (transducers at ~9-m depth) to provide extra stability and reduce the effect of weather-generated noise. In addition, acoustic data were also collected using a multibeam echosounder (Simrad ME70; Kongsberg) and an ADCP (Ocean Surveyor OS75; Teledyne RD Instruments). Transducer position and motion were measured at 5 Hz using an inertial motion unit (Applanix POS-MV; Trimble).

2.1.2.1.2 ***Long Beach Carnage*** On *Long Beach Carnage*, the SWFSC's multi-frequency Wideband Transceivers (38-, 70-, 120-, and 200-kHz Simrad EK80 WBTs; Kongsberg) were configured with the SWFSC's split-beam transducers (Simrad ES38-12, ES70-7C, ES120-7C and ES200-7C; Kongsberg) mounted in a multi-frequency transducer array (MTA4) on the bottom of a retractable pole (**Fig. 4**). The transducers were at a water depth of approximately 2 m.

2.1.2.1.3 ***Lisa Marie*** On *Lisa Marie*, multi-frequency Wideband Transceivers (38-, 70-, 120-, and 200-kHz Simrad EK80 WBTs; Kongsberg) were connected to the vessel's hull-mounted split-beam transducers (Simrad ES38-7, ES70-7C, ES120-7C and ES200-7C; Kongsberg). The transducers were mounted in a blister on the hull at a water depth of ~4 m (**Fig. 5**).

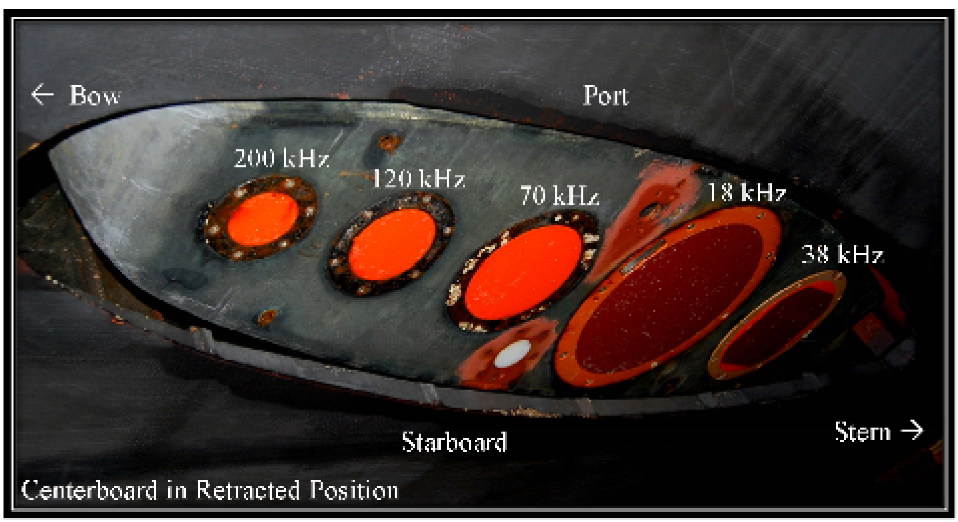

Figure 3: Echosounder transducers mounted on the bottom of the retractable centerboard on *Shimada*. During the survey, the centerboard was typically positioned in the intermediate position, placing the transducers ~2 m below the keel at a water depth of ~7 m.

Figure 4: Transducers (Top-bottom: Simrad ES200-7C, ES120-7C, ES38-12, and ES70-7C, Kongsberg) in a pole-mounted multi-transducer array (MTA4) installed on *Long Beach Carnage*.

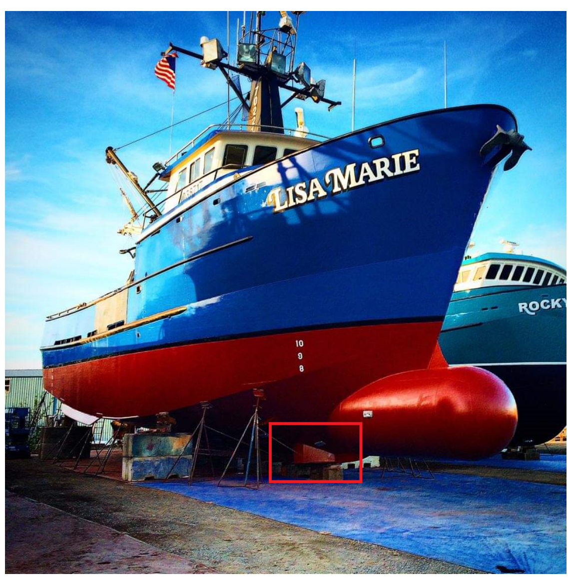

Figure 5: Transducers (Simrad ES38-7, ES70-7C, ES120-7C and ES200-7C; Kongsberg, not visible) mounted in a blister on the hull of *Lisa Marie*.

2.1.2.2 Echosounder calibrations

2.1.2.2.1 ***Shimada*** The echosounder systems aboard *Shimada* were calibrated on 9 June, 2025 while the vessel was docked at 10th Avenue Marine Terminal, San Diego Bay (32.6936 °N, -117.1503 °W) using the standard sphere technique (Demer *et al.*, 2015; Foote *et al.*, 1987). Each WBT was calibrated in CW mode (i.e., continuous wave or narrowband mode), FM mode (i.e., frequency modulation or broadband mode), or both. For both CW and FM mode calibrations, the reference target was a 38.1-mm diameter sphere made from tungsten carbide (WC) with 6% cobalt binder material (WC38.1); for FM mode, additional calibrations were conducted for the 70, 120, and 200 kHz echosounders using a 25-mm WC sphere (WC25). Prior to the calibrations, temperature and salinity were measured to a depth of 10 m using a handheld probe (Pro2030, YSI) to estimate sound speeds at the transducer and sphere depths, and the time-averaged sound speed and absorption coefficients for the range between them. The theoretical target strength (TS; dB re 1 m^2) of the sphere was calculated using values for the sphere, sound-pulse, and seawater properties. The sphere was positioned throughout the main lobe of each of the transducer beams using three motorized downriggers, two on the port side of the vessel and one on the starboard side. The calibration parameters for all vessels were derived in Echoview. For each echosounder, the calibrated Equivalent Two-Way Beam Angle (EBA) was derived by compensating the factory-measured EBA by the change in local sound speed (Bodholt, 2002; Demer *et al.*, 2015); when processing the survey transects, the calibrated measures of transducer gain, beamwidths, and EBA were then also compensated by the changes in local sound speed. Calibration results for *Shimada* are presented in **Table 1**, and were used to process the acoustic data used to estimate biomasses. Calibration plots for WBTs in CW and FM mode are presented in **Appendix A.1.1** and **Appendix A.1.2**, respectively.

Table 1: Wide-Bandwidth Transceiver (Simrad EK80 WBT; Kongsberg) information, pre-calibration settings, and post-calibration beam model results (below the horizontal line) estimated from calibration of the echosounders aboard *Shimada* using a WC38.1 standard sphere.

		Frequency (kHz)				
	Units	18	38	70	120	200
Model		ES18	ES38B	ES70-7C	ES120-7C	ES200-7C
Serial Number		2065	30715	168	573	339
Transmit Power (p_{et})	W	1000	2000	600	200	90
Pulse Duration (τ)	ms	1.024	1.024	1.024	1.024	1.024
Temperature	C	19.3	19.3	19.3	19.3	19.3
Salinity	ppt	33.5	33.5	33.5	33.5	33.5
Sound speed	m s^{-1}	1518.0	1518.0	1518.0	1518.0	1518.0
On-axis Gain (G_0)	dB re 1	23.06	26.19	27.62	26.53	26.73
S_{a} Correction (S_{a}corr)	dB re 1	0.02	-0.07	-0.07	-0.06	-0.05
3-dB Beamwidth Along. ($\alpha_{-3\mathrm{dB}}$)	deg	10.42	7.03	6.70	6.62	6.65
3-dB Beamwidth Athw. ($\beta_{-3\mathrm{dB}}$)	deg	10.59	7.07	6.76	6.58	6.63
Angle Offset Along. (α_0)	deg	-0.11	-0.16	0.00	-0.01	-0.09
Angle Offset Athw. (β_0)	deg	-0.07	-0.12	0.00	0.11	-0.08
Equivalent Two-way Beam Angle (Ψ)	dB re 1 sr	-17.18	-20.70	-20.56	-20.23	-19.99
RMS	dB	0.18	0.05	0.06	0.13	0.13

2.1.2.2.2 *Long Beach Carnage* The WBTs installed on *Long Beach Carnage* were calibrated on 15 April, 2025, using the standard sphere technique (Demer *et al.*, 2015; Foote *et al.*, 1987) in a tank at the SWFSC (Demer *et al.*, 2015). Calibration results for *Long Beach Carnage* are presented in **Table 2**, and were used to process the acoustic data used to estimate biomasses. Calibration plots for WBTs in CW mode are presented in **Appendix A.3**.

Table 2: Wideband Transceiver (Simrad EK80 WBT; Kongsberg) and transducer information (above horizontal line) and beam model results (below horizontal line) estimated from a tank calibration, using a WC38.1 standard sphere, of the echosounders later installed and used aboard *Long Beach Carnage*.

		Frequency (kHz)			
	Units	38	70	120	200
Model		ES38-12	ES70-7C	ES120-7C	ES200-7C
Serial Number		28075	234	813	616
Transmit Power (p_{et})	W	1000	600	200	90
Pulse Duration (τ)	ms	1.024	0.512	0.256	0.256
Temperature	C	18.8	18.8	18.8	18.8
Salinity	ppt	34.4	34.4	34.4	34.4
Sound speed	m s^{-1}	1517.5	1517.5	1517.5	1517.5
On-axis Gain (G_0)	dB re 1	21.60	27.64	26.65	26.45
S_{a} Correction (S_{a}corr)	dB re 1	-0.10	-0.08	-0.13	-0.28
3-dB Beamwidth Along. ($\alpha_{-3\mathrm{dB}}$)	deg	13.41	6.57	6.66	6.92
3-dB Beamwidth Athw. ($\beta_{-3\mathrm{dB}}$)	deg	13.18	6.68	6.58	6.93
Angle Offset Along. (α_0)	deg	-0.01	-0.05	0.08	-0.07
Angle Offset Athw. (β_0)	deg	-0.01	0.06	0.00	-0.03
Equivalent Two-way Beam Angle (Ψ)	dB re 1 sr	-15.66	-20.25	-20.15	-20.07
RMS	dB	0.09	0.08	0.21	0.18

2.1.2.2.3 ***Lisa Marie*** The WBTs aboard *Lisa Marie* were calibrated prior to the survey on 3 July, 2025 using the standard sphere technique (Demer *et al.*, 2015; Foote *et al.*, 1987) while the vessel was anchored off Sunrise Beach near Gig Harbor, WA (47.3552 °N, -122.5512 °W). Calibration results for *Lisa Marie* are presented in **Table 3**, and were used to process the acoustic data used to estimate biomasses. Calibration plots for WBTs in CW mode are presented in **Appendix A.2**.

Table 3: Wideband Transceiver (Simrad EK80 WBT; Kongsberg) and transducer information (above horizontal line) and beam model results (below horizontal line) estimated from calibration of the echosounders aboard *Lisa Marie* using a WC38.1 standard sphere.

		Frequency (kHz)			
	Units	38	70	120	200
Model		ES38-7	ES70-7C	ES120-7C	ES200-7C
Serial Number		448	761	2355	899
Transmit Power (p_{et})	W	2000	600	200	90
Pulse Duration (τ)	ms	1.024	1.024	1.024	1.024
Temperature	C	11.6	11.6	11.6	11.6
Salinity	ppt	29.9	29.9	29.9	29.9
Sound speed	m s^{-1}	1489.5	1489.5	1489.5	1489.5
On-axis Gain (G_0)	dB re 1	26.64	27.95	26.59	26.72
S_{a} Correction (S_{a}corr)	dB re 1	-0.03	-0.08	-0.07	-0.14
3-dB Beamwidth Along. ($\alpha_{-3\mathrm{dB}}$)	deg	6.53	6.83	6.76	6.46
3-dB Beamwidth Athw. ($\beta_{-3\mathrm{dB}}$)	deg	6.54	6.92	6.86	6.44
Angle Offset Along. (α_0)	deg	-0.07	-0.12	-0.02	-0.03
Angle Offset Athw. (β_0)	deg	0.14	0.00	-0.00	-0.06
Equivalent Two-way Beam Angle (Ψ)	dB re 1 sr	-20.37	-20.48	-20.48	-20.47
RMS	dB	0.16	0.14	0.10	0.12

2.1.2.3 Data collection

On *Shimada*, the computer clocks were synchronized with the GPS clock (UTC) using synchronization software (NetTime[4]). The echosounders were controlled by the EK80 Adaptive Logger (EAL[5], Renfree and Demer, 2016). The EAL optimizes the pulse interval based on the seabed depth, while avoiding aliased seabed echoes, and can be programmed to periodically record pings in passive mode, for obtaining estimates of the background noise level. Acoustic sampling for CPS-density estimation along the pre-determined transects was limited to daylight hours (approximately between sunrise and sunset).

To accommodate the goals of the IWCPS, the EK80 data were collected in varying configurations to optimize sampling for either Pacific Hake or CPS. In regions where Pacific Hake were expected to be observed (~50 to 750-m seabed depth), the goal was to record enough data beyond the initial seabed echo in order to accurately estimate the background noise level and characterize the seabed for classification of rockfish (*Sebastes* spp.) habitat. Due to potentially slow ping rates from extended logging ranges, the ship reduced its survey speed in these regions from ~9 to 7.5 knots (kn) in order to obtain an adequate spatial sampling resolution of CPS schools. Outside of the 50–350-m range, in which Pacific Hake were not expected to be observed, the goal was to minimize the logging range needed for CPS in order to maximize the sampling resolution. To accomplish this, the logging ranges were continually adjusted via the EAL according to the scheme in **Table 4**, with maximum logging ranges for the 18-, 38-, 70-, 120-, and 200-kHz echosounders set to 750, 750, 750, 600, and 300 m, respectively.

Table 4: EK80 logging range as a function of seabed depth, in order to accommodate desired sampling for both Pacific Hake and CPS in their expected habitats.

Depth	Logging range
<50 m	Depth + 50 m
50-350 m	2*Depth + 75 m
350-750 m	Depth + 150 m
750-1,500 m	650 m
>1,500 m	500 m

During daytime aboard *Shimada*, measurements of volume backscattering strength (S_v; dB re 1 m^2 m^{-3}), indexed by time and geographic positions provided by GPS receivers were stored with a 1-GB maximum file size, in Simrad-EK80 .raw format. The prefix for the file names was a concatenation of the survey name (e.g., 2506SH), the operational mode (CW or FM), and the logging commencement date and time from the EK80 software. For example, a file generated by the EK80 software (v24.6.1.0) for a WBT operated in CW mode is named `2506SH-CW-D20250801-T125901.raw`.

To minimize acoustic interference, transmit pulses from all echosounders and sonars (i.e., EK80, ME70, and ADCP) were triggered using a synchronization system (Simrad K-Sync; Kongsberg). The K-Sync trigger rate, and thus echosounder ping interval, was modulated by the EAL using the seabed depth either measured directly or estimated from a database and using the ship's location. During both day and night, the ME70 and ADCP were operated and recorded continuously whenever possible. All other instruments that produce sound within the echosounder bandwidths were secured during daytime survey operations. Exceptions were made during stations (e.g., plankton sampling and fish trawling) or in shallow water when the vessel's command occasionally operated the bridge's 50- and 200-kHz echosounders (Furuno), the Doppler velocity log (SRD-500A; Sperry Marine), or both. Analyses of data from the ADCP and ME70 are not presented in this report.

On *Lisa Marie* and *Long Beach Carnage*, the EK80 was set to "auto-range" mode to adjust the maximum ping rate and recording range. Because transmit pulses from the echosounders and fishing sonars were not synchronized, the latter were secured during daytime acoustic transects to avoid interference.

[4] http://timesynctool.com
[5] https://www.fisheries.noaa.gov/west-coast/science-data/ek80-adaptive-logger/

2.1.3 Oceanographic

2.1.3.1 Conductivity and temperature versus depth (CTD)

Conductivity and temperature were measured versus depth using calibrated sensors on a CTD rosette (Model SBE911+; Seabird) or underway CTD (UCTD) probe (RapidPro Plus; Valeport) cast from the vessel. Cast depths were 500 m or 320 m (or to within ~10 m of the seabed if shallower than the cast depth) for CTDs and UCTDs, respectively. Cast locations are available in **Appendix B**. These data were used to calculate the harmonic mean sound speed (Demer *et al.*, 2015) for estimating ranges to the sound scatterers, and frequency-specific sound absorption coefficients for compensating signal attenuation of the sound pulse between the transducer and scatterers (Simmonds and MacLennan, 2005) (see **Section 2.2.2**).

2.1.3.2 Scientific Computer System

While underway, information about the position and direction (e.g., latitude, longitude, speed, course over ground, and heading), weather (air temperature, humidity, wind speed and direction, and barometric pressure), and sea-surface oceanography (e.g., temperature, salinity, and fluorescence) were measured continuously and logged using the ship's Scientific Computer System (SCS). The data from a subset of these sensors, logged with a standardized format at 1-min resolution, are available on NOAA's ERDDAP data server[6].

2.1.4 Species Composition and Demographics

The net catches provide information about the regional species composition, lengths, weights and ages of CPS. After sunset, schools of CPS and other fish tend to ascend and disperse and are less likely to avoid a trawl net (Mais, 1977). Nighttime trawls conducted from *Shimada* sampled fish dispersed in the upper ~20-30 m of the sea surface. A Multifunction Trawl Net System (MFT; Swan Nets, Seattle, WA; **Figs. 6** and **7**) was used to trawl at night (Shaughnessy, 2025). Daytime purse-seine nets were set nearshore by *Long Beach Carnage* and *Lisa Marie* to sample CPS schools where their depth is constrained by the seabed and their vision is obscured by turbidity due to primary production and suspended particulates.

2.1.4.1 Trawl gear Aboard *Shimada*, the MFT was towed at the surface for 30 min at a speed of ~3.5 kn. The net has an elliptical opening with an area of approximately 648 m^2 (~18-m tall x 36-m wide, Shaughnessy, 2025), a throat with variable-sized mesh, and a marine mammal excluder device (MMED) designed to prevent the capture of large animals, such as dolphins, turtles, or sharks while retaining target species (Dotson *et al.*, 2010), and an 8-mm square-mesh cod-end liner (to retain a large range of animal sizes, **Figs. 6** and **7**). The trawl doors (Type 22 VK 4m2; Thyboron) have adjustable attachment points and flaps to modulate the depth of the doors, and the trawl headrope was configured with mesh pockets to allow for the addition of up to ten A4 floats to adjust the depth of the net. Temperature-depth recorders (TDRs; RBRduet[3] T.D., RBR) were attached to the kite and footrope to measure the headrope depth and vertical net opening, and net mensuration sensors (Simrad PX MultiSensors; Kongsberg) were installed on the doors to provide real-time measurements of door pitch, roll, depth, and spread for monitoring net performance (**Fig. 8**).

2.1.4.2 Purse-seine gear *Lisa Marie* used an approximately 440-m-long and 40-m-deep purse-seine net with 17-mm-wide mesh (A. Blair, pers. comm.). *Long Beach Carnage* used an approximately 283-m-long and 27-m-deep purse-seine net with 17-mm-wide mesh; a small section on the back end of the net had 25-mm-wide mesh (R. Ashley, pers. comm.). Specimens collected by *Lisa Marie* were processed aboard the vessel by the WA Department of Fish and Wildlife (WDFW; see **Section 2.1.4.4.2**), and specimens collected aboard *Long Beach Carnage* were processed ashore by the CA Department of Fish and Wildlife (CDFW; see **Section 2.1.4.4.3**).

[6] http://coastwatch.pfeg.noaa.gov/erddap/tabledap/fsuNoaaShipWTED.html

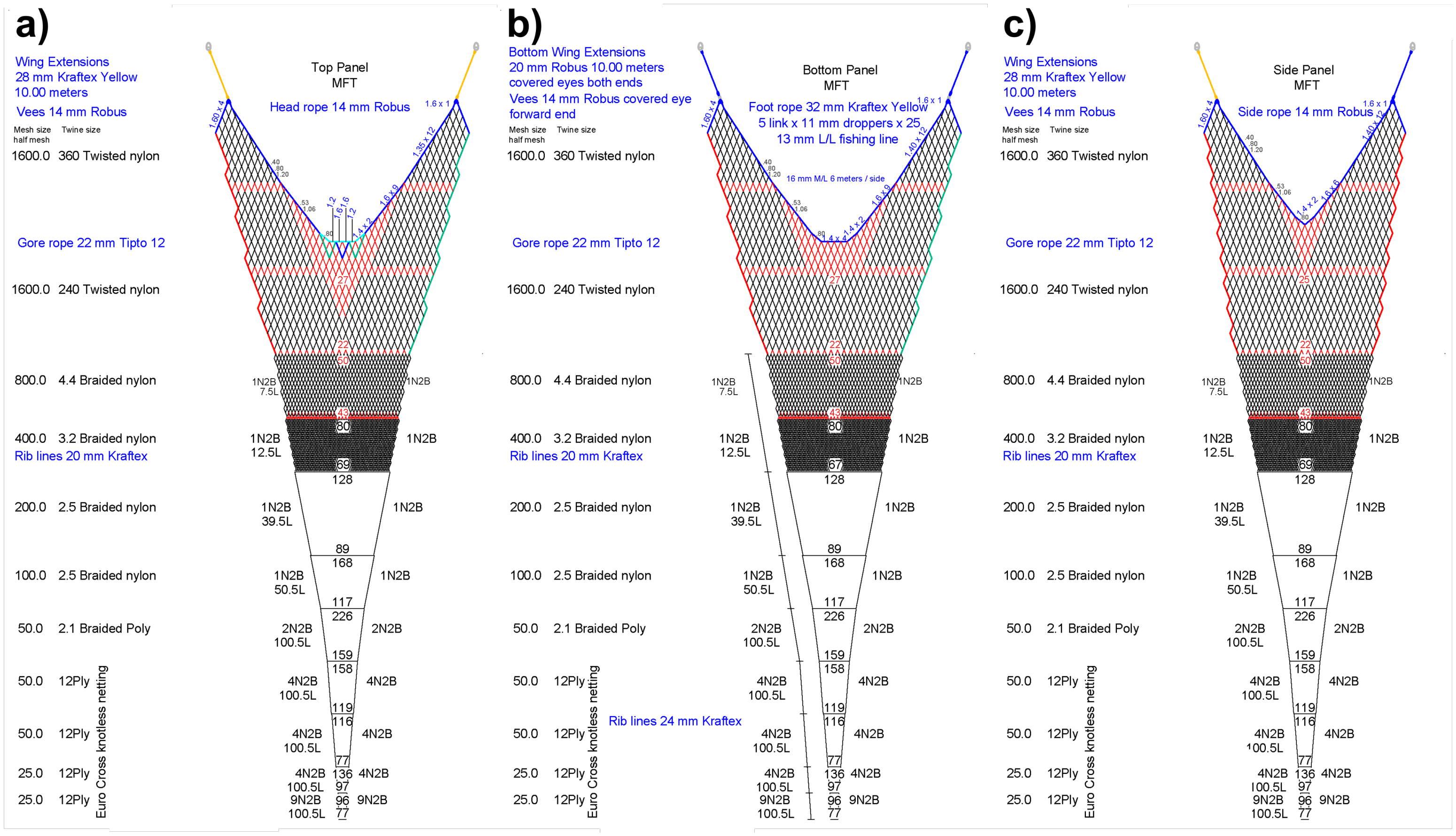

Figure 6: Schematics of the Multifunction Trawl Net System panels as viewed from the a) top, b) bottom, and c) side.

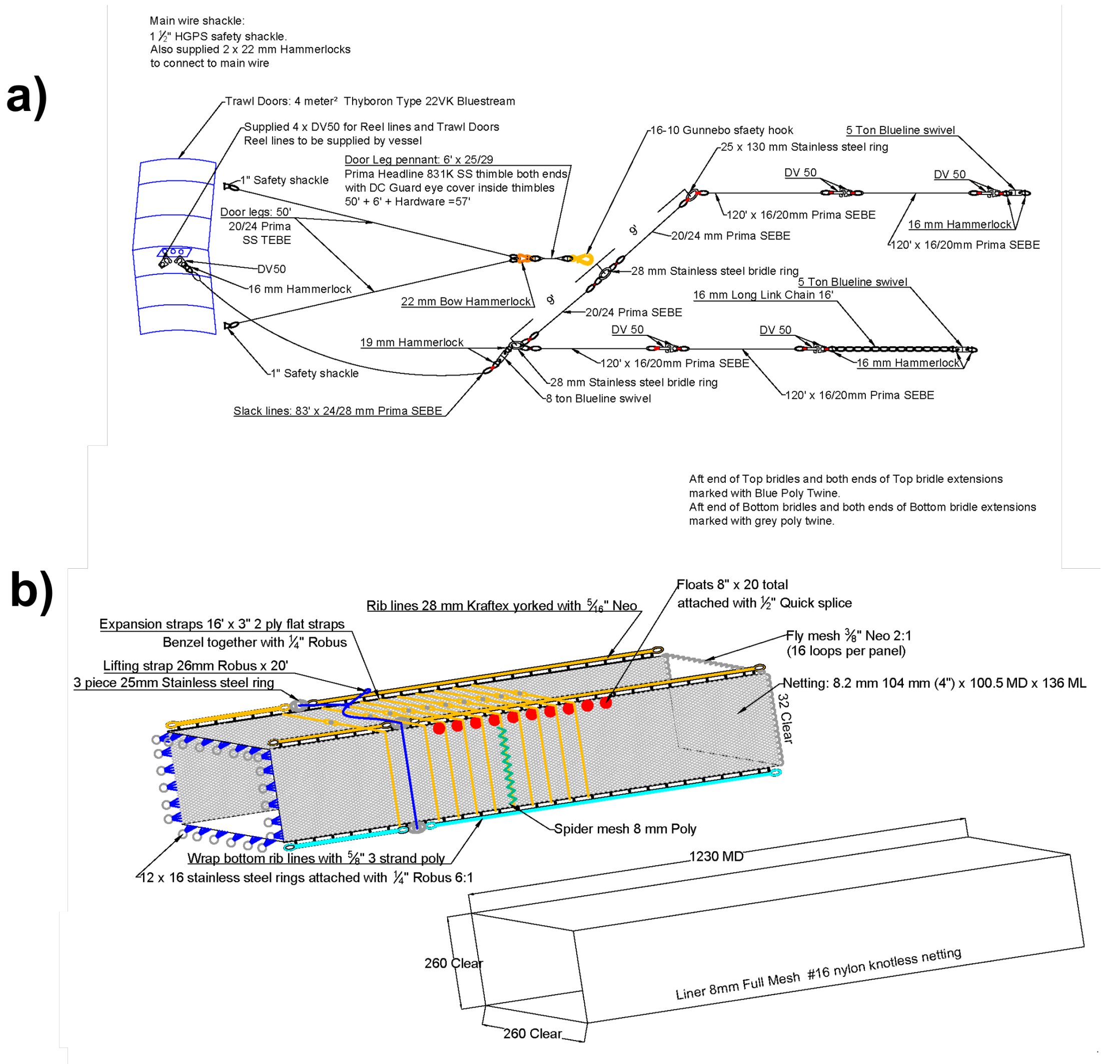

Figure 7: Schematics of the Multifunction Trawl Net System a) rigging and b) cod-end.

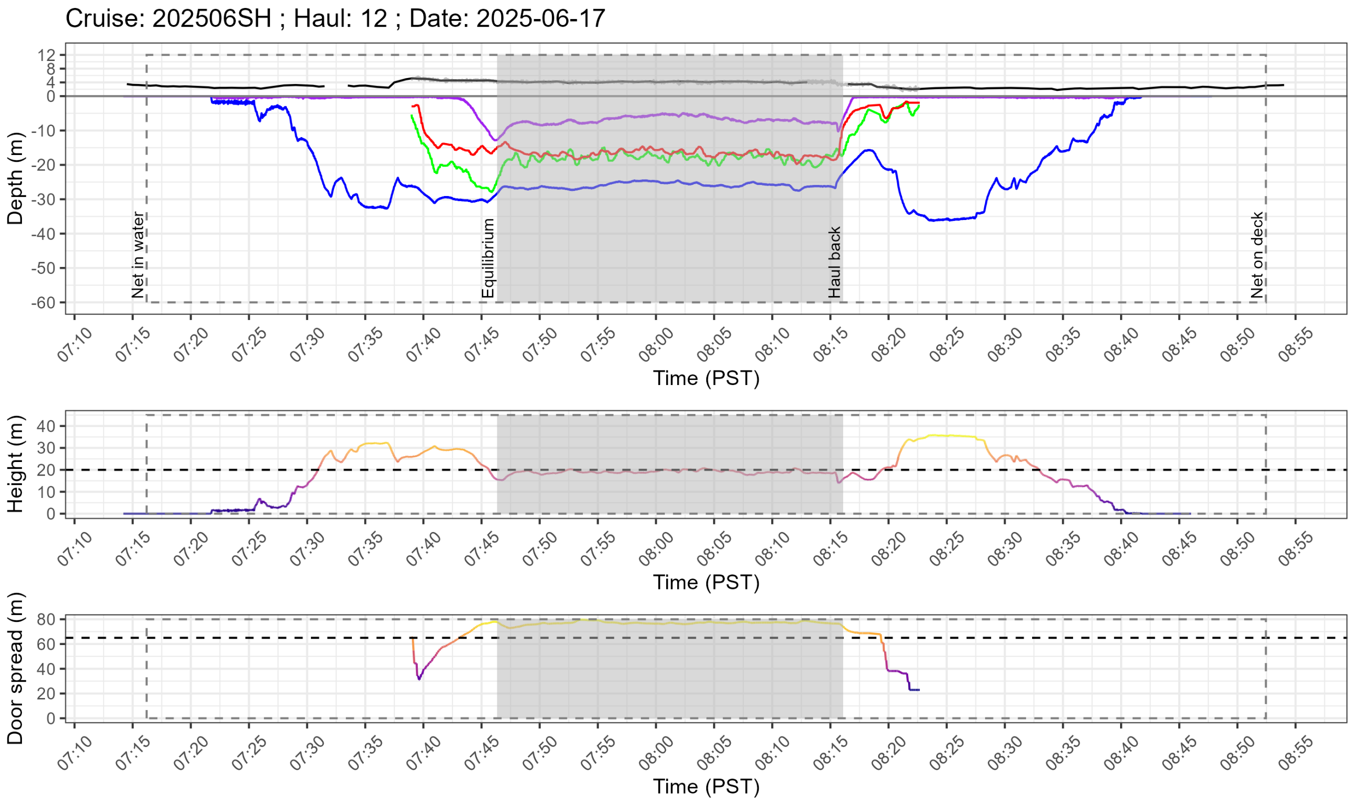

Figure 8: Example plot illustrating net performance during the net deployment (dashed box) and when actively fishing (shaded region) by combining outputs from the SCS, temperature-depth recorders (TDR), and Simrad PX MultiSensors (Top). Shown are the vessel speed over ground (kn, black line), measured using the ship's GPS, depths of the trawl kite (purple line) and footrope (blue line) measured using TDRs, and the port (green line) and starboard doors (red line), measured using the PX MultiSensors. (Middle) Height of the net opening measured as the difference between the kite and footrope depths. (Bottom) The spread of the doors measured by the PX MultiSensors.

2.1.4.3 Sampling locations

2.1.4.3.1 *Shimada* Up to three nighttime (i.e., 30 min after sunset to 30 min before sunrise) surface trawls, typically spaced at least 10-nmi apart, were conducted in locations where putative CPS schools were observed by an acoustician in echograms earlier that day. If no CPS echoes were observed along a transect that day, the trawls were alternately placed nearshore that night and offshore the next night, with consideration given to the seabed depth and the modeled distribution of CPS habitat. The locations were provided to the watch officers who charted the proposed trawl sites. Each morning, after the last trawl or no earlier than 30 min prior to sunrise, *Shimada* resumed sampling at the location where the acoustic sampling stopped the previous day.

2.1.4.3.2 *Lisa Marie* and *Long Beach Carnage* On *Lisa Marie* and *Long Beach Carnage*, as many as three purse-seine sets were conducted each day where CPS schools were observed at the surface or in echograms. For each set, three dip-net samples were collected from within the pursed net that were spatially separated as much as possible.

2.1.4.4 Sample processing

2.1.4.4.1 *Shimada* If the total volume of the trawl catch was less than or equal to five 35-l baskets (~175 l), all target species were separated from the catch, and all target species were sorted by species, weighed, and enumerated. If the volume of the entire catch was more than five baskets, a random five-basket subsample that included non-target species was collected, sorted by species, weighed, and enumerated; the remainder of the total catch was weighed. In these cases, the weight of the total catch (C_T) was calculated as: $C_T = C_S + C_R$, where C_S is the subsampled catch weight, and C_R is the remainder catch weight. The weight of species e in the total catch ($C_{T,e}$) was obtained by summing the catch weight of the respective species in the subsample ($C_{S,e}$) and the corresponding catch in the remainder ($C_{R,e}$), which was calculated as:

$$C_{R,e} = C_R * P_{w,e}, \tag{1}$$

where $P_{w,e} = C_{S,e}/C_S$, is the proportion in weight of species e in the subsample. The number of specimens of species e in the total catch ($N_{T,e}$) was estimated by:

$$N_{T,e} = \frac{C_{T,e}}{\overline{w}_e}, \tag{2}$$

where $\overline{w}_e$ is the mean specimen weight of species e in the subsample. For Pacific Sardine and Northern Anchovy, individual measurements of standard length (L_S, mm) and weight (w, g) were recorded for up to 75 specimens. For Jack Mackerel, Pacific Mackerel, and Pacific Herring, individual measurements of fork length (L_F) and w were recorded for up to 50 specimens. In addition, sex and visual maturity were recorded for all Pacific Sardine processed for lengths. Ovaries were only preserved for Pacific Sardine that were considered active and spawning (i.e., hydrated). Fin clips were removed from all Pacific Sardine processed for lengths and up to 50 Northern Anchovy per trawl from seven geographic zones (with boundaries at the Columbia River, Cape Mendocino, San Francisco Bay, Point Conception, San Diego, and San Quentin, Baja CA) and preserved in ethanol for genetic analysis. Otoliths were removed from all Pacific Sardine in the subsample; for Northern Anchovy, Pacific Mackerel, and Jack Mackerel, up to 25 otoliths were removed from the available specimens from the range of sizes present, and more information can be found in Dorval et al. (2022). The combined catches in each nighttime trawl cluster (i.e., up to three trawls per night) were used to estimate the proportions of species contributing to the nearest samples of acoustic backscatter.

2.1.4.4.2 ***Lisa Marie*** For each dip-net sample, all specimens were sorted, weighed, and counted to provide a combined weight and count for each species. Next, all three dip-net samples were combined and up to 50 specimens of each CPS species were randomly sampled to provide individual measures of weight and length (L_S for Pacific Sardine and Northern Anchovy and L_F for all others) for each set. Otoliths were extracted for aging later and macroscopic maturity stage was determined visually for CPS. For Pacific Sardine, tissue samples were collected and stored in ethanol for later genetic analysis.

2.1.4.4.3 ***Long Beach Carnage*** For each dip-net sample, all specimens were sorted, weighed, and counted to provide a combined weight and count for each species. Then all dip net samples were combined and as many as 50 specimens of each CPS species present were chosen randomly throughout the sample and frozen for later analysis by CDFW biologists, yielding individual measures of weight, length (L_S for Pacific Sardine and Northern Anchovy and L_F for all others), sex, and visual maturity. No female gonad samples were collected for later histological analysis. Otoliths were collected for aging later. For Pacific Sardine, fin clips were collected in the laboratory from specimens that were frozen at sea, and those samples were stored in ethanol for later genetic analysis.

2.1.4.5 Quality Assurance and Quality Control At sea on *Shimada*, trawl data were entered into an Oracle database using the Catch Logger for Acoustic Midwater Surveys software (CLAMS, NOAA/NMFS/AFSC[7]). During and following the survey, data were exported to an SQLite database, further checked, and verified or corrected as needed. Missing length (L_{miss}) and weight (W_{miss}) measurements were estimated as $W_{miss} = \beta_0 L^{\beta_1}$ and $L_{miss} = (W/\beta_0)^{(1/\beta_1)}$, respectively, where values for β_0 and β_1 are species- and season-specific parameters of the length-versus-weight relationships described in Palance et al. (2019). To identify measurement or data-entry errors, length and weight data were graphically compared to measurements from previous surveys and models of season-specific length-versus-weight from previous surveys from Palance et al. (2019, **Fig.** 9). Outliers were flagged, reviewed, and corrected if errors were identified. Catch data from aborted trawl hauls were not included.

[7] https://github.com/noaa-afsc-mace/CLAMS

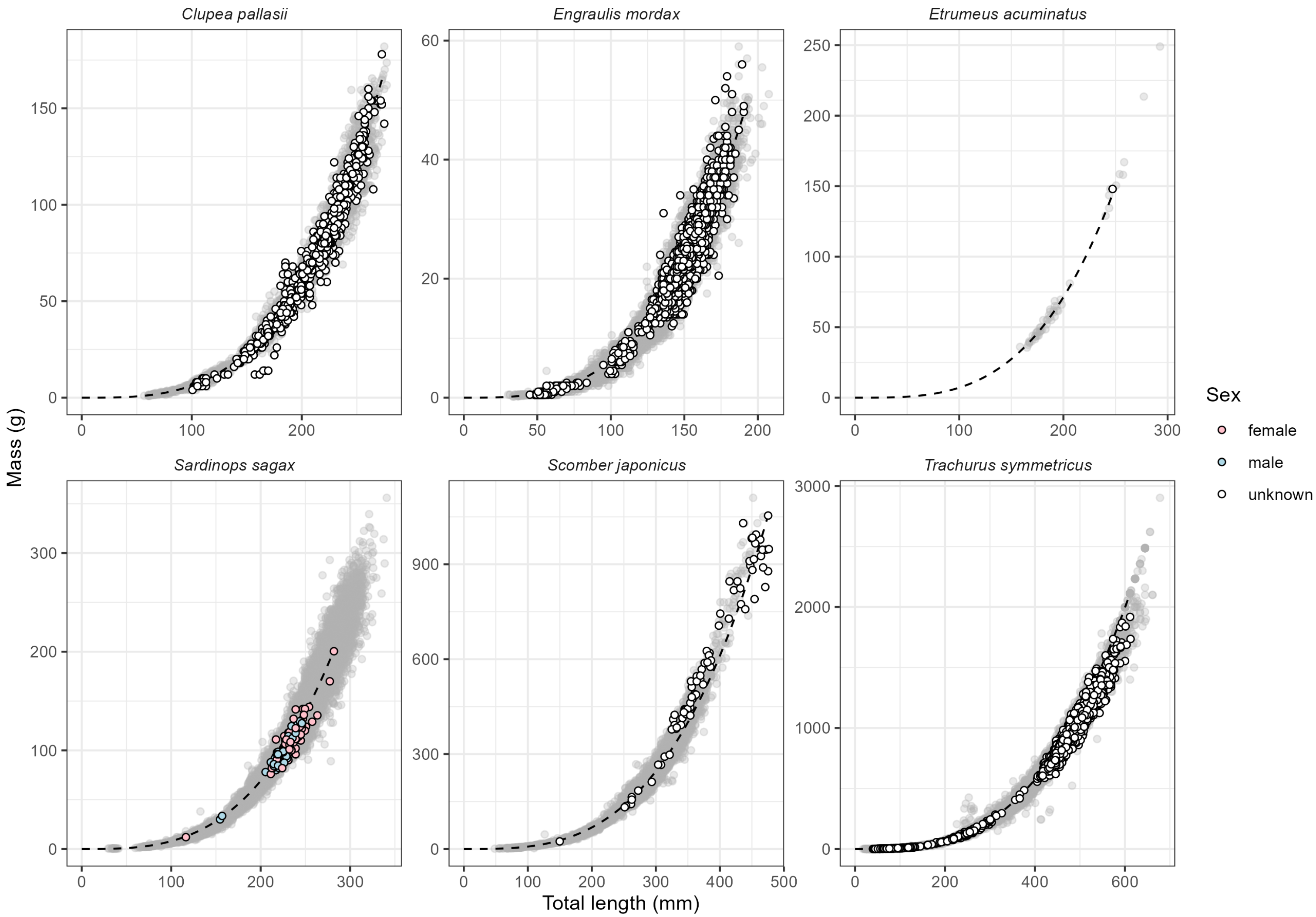

Figure 9: Specimen weight versus length from the current survey (colored points, by sex) compared to those from previous SWFSC surveys during the same season (gray points) and length-weight models from Palance et al. (2019) (dashed lines).

2.2 Acoustic data processing

2.2.1 Acoustic and oceanographic data

The calibrated echosounder data from each transect were processed using commercial software (Echoview v15.1; Echoview Software Pty Ltd.) and estimates of the sound speed and absorption coefficient calculated with contemporaneous data from CTD probes cast while stationary or underway (see **Section 2.1.3.1**). Data collected along the daytime transects at speeds $\geq$ 5 kn were used to estimate CPS densities. Nighttime acoustic data were not used for biomass estimations because they are assumed to be negatively biased due to diel-vertical migration and disaggregation of the target species' schools (Cutter and Demer, 2008).

2.2.2 Sound speed and absorption compensation

CTD casts provide measures of pressure, conductivity, and temperature, from which depth, salinity, and sound speed (c_w, m s^{-1}) are derived. On *Shimada*, CTD or UCTD probes provided pre-processed data containing temperature and derived measures of depth, salinity, and c_w. On *Lisa Marie*, the CTD probe (SBE19plus; Seabird) provided raw measures of pressure, conductivity, and temperature, for which post-processing software (SBEDataProcessing; Seabird) was used to filter the data, derive depth, average into 1-m bins, then derive salinity and c_w for each bin. For both probes, values of depth and c_w for the downcast were defined in transect-specific Echoview Calibration Supplement (ECS) files utilized for the Echoview data processing. The c_w profile is used to estimate ranges to the sound scatterers and to compensate the echo signal for spherical spreading and attenuation during propagation of the sound pulse from the transducer to the scatterer range and back (Simmonds and MacLennan, 2005). Similarly, the average temperature, salinity, and depth, along with the harmonic mean of c_w, were computed over the entire downcast and defined in the ECS file. These averaged values are used by Echoview to calculate absorption coefficients which account for frequency-dependent absorption losses. Lastly, the calibration parameters were updated to compensate for changes in local c_w relative to that at the time of the calibration (Bodholt, 2002):

$$G_0 = G_0^{'} + 20log_{10} \left(\frac{c_w^{'}}{c_w} \right) , \tag{3}$$

$$\Psi = \Psi^{'} + 20log_{10} \left(\frac{c_w}{c_w^{'}} \right) , \tag{4}$$

$$\alpha_{-3\mathrm{dB}} = \alpha_{-3\mathrm{dB}}^{'} * \left(\frac{c_w}{c_w^{'}} \right) , \tag{5}$$

$$\beta_{-3\mathrm{dB}} = \beta_{-3\mathrm{dB}}^{'} * \left(\frac{c_w}{c_w^{'}} \right) , \tag{6}$$

where the prime symbol denotes values from the calibration and c_w is at the depth of the transducer. The CTD rosette, when cast, also provides measures of fluorescence and dissolved oxygen concentration versus depth, which may be used to estimate the vertical dimension of Pacific Sardine potential habitat (Zwolinski and Demer, 2024), particularly the depth of the upper-mixed layer where most epipelagic CPS reside. The latter information is used to inform echo classification (see **Section 2.2.3**).

Long Beach Carnage did not have a CTD probe on the vessel during their survey. Therefore, the oceanographic data used for generating the ECS files was obtained from the nearest CTD or UCTD cast collected by *Shimada*.

2.2.3 Echo classification

Echoes from schooling CPS (**Figs. 10a, d**) were identified using the semi-automated data processing algorithm described below and implemented using Echoview software (v15.1; Echoview Software Pty Ltd). The filters and thresholds were based on a subsample of echoes from randomly selected CPS schools. The aim of the filter criteria is to retain at least 95% of the noise-free backscatter from CPS while rejecting at least 95% of the non-CPS backscatter (**Fig. 10**). Data from *Shimada*, *Lisa Marie*, and *Long Beach Carnage* were processed using the following steps:

1. Match geometry of all S_v variables to the 38-kHz S_v;
2. Remove passive-mode pings;
3. Estimate and subtract background noise using the background noise removal function (De Robertis and Higginbottom, 2007) in Echoview (**Figs. 10b, e**);
4. Smooth the noise-free S_v echograms using an 11-sample by 3-ping averaging window;
5. Expand the averaged, noise-reduced S_v echograms with a 7 pixel x 7 pixel dilation;
6. For each pixel, compute: $S_{v,200\text{kHz}} - S_{v,38\text{kHz}}$, $S_{v,120\text{kHz}} - S_{v,38\text{kHz}}$, and $S_{v,70\text{kHz}} - S_{v,38\text{kHz}}$;
7. Create a Boolean echogram for S_v differences in the CPS range: $-13.85 < S_{v,70\text{kHz}} - S_{v,38\text{kHz}} < 9.89$ and $-13.5 < S_{v,120\text{kHz}} - S_{v,38\text{kHz}} < 9.37$ and $-13.51 < S_{v,200\text{kHz}} - S_{v,38\text{kHz}} < 12.53$;
8. For 120 and 200 kHz, compute the squared difference between the noise-filtered S_v (Step 3) and averaged S_v (Step 4), average the results using an 11-sample by 3-ping window to derive variance, then compute the square root to derive the 120- and 200-kHz standard deviations ($\sigma_{120\text{kHz}}$ and $\sigma_{200\text{kHz}}$, respectively);
9. Expand the standard deviation echograms with a 7 pixel x 7 pixel dilation;
10. Create a Boolean echogram based on the standard deviations in the CPS range: $\sigma_{120\text{kHz}} >$ -65 dB and $\sigma_{200\text{kHz}} >$ -65 dB. Diffuse backscattering layers have low σ (Zwolinski *et al.*, 2010) whereas fish schools have high σ;
11. Intersect the two Boolean echograms to create an echogram with "TRUE" samples for candidate CPS schools and "FALSE" elsewhere;
12. Mask the noise-reduced echograms using the CPS Boolean echogram (**Figs. 10c, f**);
13. Create an integration-start line 5 m below the transducer (~10 m depth);
14. Create an integration-stop line 3 m above the estimated seabed (Demer *et al.*, 2009a), or to the maximum logging range (e.g., 350 m), whichever is shallowest;
15. Set the minimum S_v threshold to -70 dB (corresponding to a density of approximately three 20-cm-long Pacific Sardine per 100 m^3);
16. Integrate the volume backscattering coefficients (s_V, m^2 m^{-3}) attributed to CPS over 5-m depths and averaged over 100-m distances;
17. Output the resulting nautical area scattering coefficients (s_A; m^2 nmi^{-2}) and associated information from each transect and frequency to comma-delimited text (.csv) files.

When necessary, the start and stop integration lines were manually edited to exclude reverberation due to bubbles, include the entirety of shallow CPS aggregations, and exclude seabed echoes.

2.2.4 Removal of non-CPS backscatter

In addition to echoes from target CPS, echoes classified as CPS (**Section 2.2.3**) may also be from other pelagic fish species (e.g., Pacific Saury, *Cololabis saira*) or semi-demersal fish such as Pacific Hake and rockfishes. When analyzing the acoustic-survey data, it was therefore necessary to filter "acoustic by-catch," i.e., backscatter not from the target species. To exclude these echoes, echograms were visually examined using R and integration depths were edited to exclude echoes where the seabed was hard and rugose, or where diffuse schools were observed either near the surface or deeper than ~250 m (**Fig. 11**). In areas dominated by Pacific Herring, for example off Vancouver Island, backscatter was integrated to a maximum depth of 75 m.

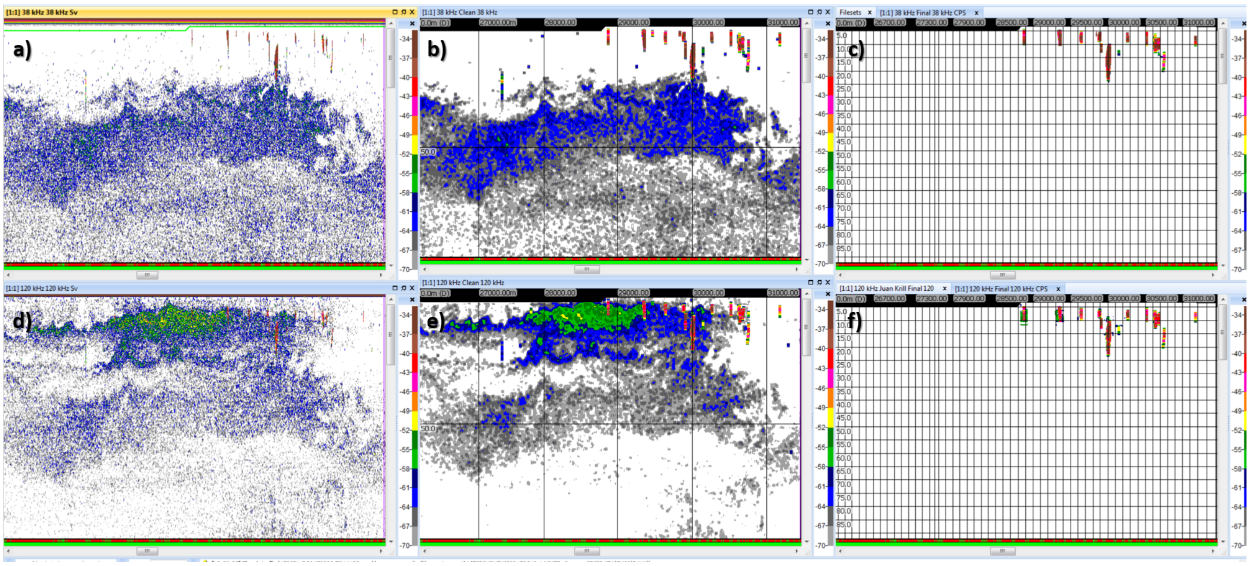

Figure 10: Two examples of echograms depicting CPS schools (red) and plankton aggregations (blue and green) at 38 kHz (top) and 120 kHz (bottom). Example data processing steps include the original echogram (a, d), after noise subtraction and bin-averaging (b, e), and after filtering to retain only putative CPS echoes (c, f).

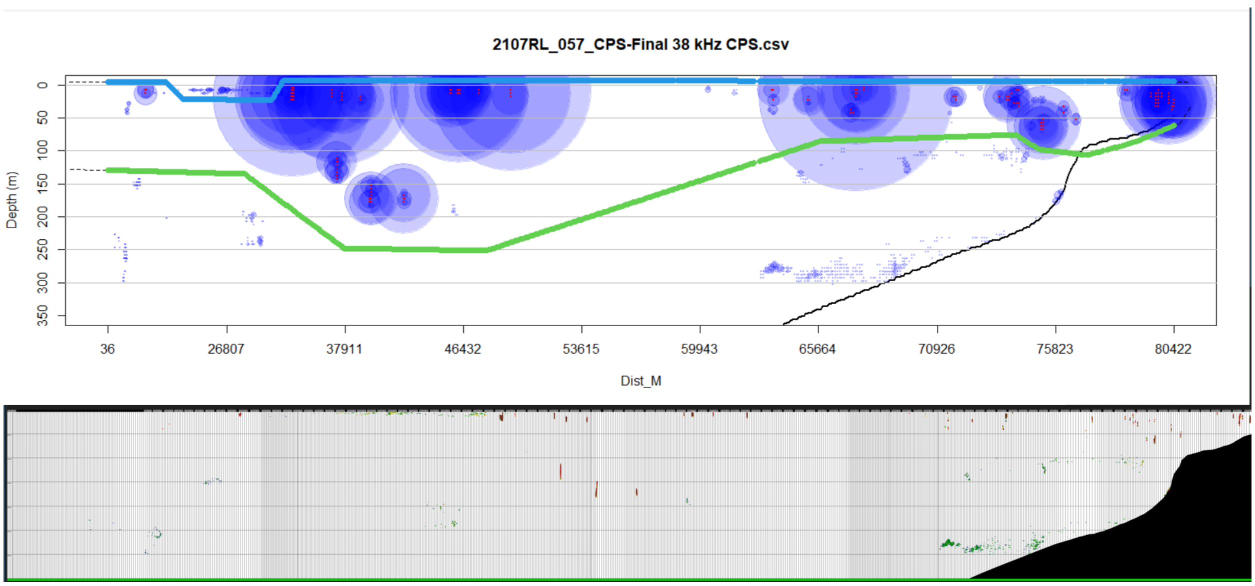

Figure 11: Echoes from fishes with swimbladders (blue points, scaled by backscatter intensity) along an example acoustic transect (top) and the corresponding echogram image (bottom). In this example, the upper (blue) and lower lines (green) indicate boundaries within which echoes were retained. Where the lower boundary was deeper than the seabed (black line), echoes above the seabed were retained. Echoes from deep, bottom-dwelling schools of non-CPS fishes with swimbladders, and from diffuse scatterers near the surface were excluded.

2.2.5 Quality Assurance and Quality Control

The largest 38-kHz vertically integrated backscattering coefficients (s_A, m^2 nmi^{-2}) were graphically examined to identify potential errors in the integrated data (e.g., when a portion of the seabed was accidentally integrated). Additionally, for each survey vessel and transect, one acoustician would process the transect, another acoustician would conduct an initial review of the transect and flag for further review if needed, then the broader acoustics group would convene to go through each flagged transect and decide on a course of action. If found, errors were corrected and data were re-integrated prior to use for biomass estimation.

2.2.6 Echo integral partitioning and acoustic inversion

For fishes with swimbladders, the acoustic backscattering cross-section of an individual (σ_{bs}, m^2) depends on many factors but mostly on the acoustic wavelength and the swimbladder size and orientation relative to the incident sound pulse. For echosounder sampling conducted in this survey, σ_{bs} is primarily a function of the dorsal-surface area of the swimbladder and was approximated by a function of fish length (L), i.e.:

$$\sigma_{bs} = 10^{\frac{m\ \log_{10}(L)+b}{10}}, \tag{7}$$

where m and b are frequency and species-specific parameters that are obtained theoretically or experimentally (see references below). TS, a logarithmic representation of σ_{bs}, is defined as:

$$TS = 10\ \log_{10}(\sigma_{bs}) = m\ \log_{10}(L) + b. \tag{8}$$

TS has units of dB re 1 m^2 if defined for an individual, or dB re 1 m^2 kg^{-1} if defined by weight. The following equations for $TS_{38\text{kHz}}$ were used in this analysis:

$$TS_{38\text{kHz}} = -14.90 \times \log_{10}(L_T) - 13.21, \text{ for Pacific Sardine;} \tag{9}$$

$$TS_{38\text{kHz}} = -11.97 \times \log_{10}(L_T) - 11.58561, \text{ for Pacific Herring;} \tag{10}$$

$$TS_{38\text{kHz}} = -13.87 \times \log_{10}(L_T) - 11.797, \text{ for Northern Anchovy; and} \tag{11}$$

$$TS_{38\text{kHz}} = -15.44 \times \log_{10}(L_T) - 7.75, \text{ for Pacific and Jack Mackerels,} \tag{12}$$

where the units for total length (L_T) is cm and TS is dB re 1 m^2 kg^{-1}.

Equations (9) and (12) were derived from echosounder measurements of σ_{bs} for in situ fish and measures of L_T and W from concomitant catches of South American Pilchard (*Sardinops ocellatus*) and Horse Mackerel (*Trachurus trachurus*) off South Africa (Barange *et al.*, 1996). Because mackerels have similar TS (Peña, 2008), Equation (12) is used for both Pacific and Jack Mackerels. For Pacific Herring, Equation (10) was derived from that of Thomas et al. (2002) measured at 120 kHz with the following modifications: 1) the intercept used here was calculated as the average intercept of Thomas et al.'s spring and fall regressions; 2) the intercept was compensated for swimbladder compression after Zhao et al. (2008) using the average depth for Pacific Herring of 44 m; and 3) the intercept was increased by 2.98 dB to account for the change of frequency from 120 to 38 kHz (Saunders *et al.*, 2012). For Northern Anchovy, Equation (11) was derived from that of Kang et al. (2009), after compensation of the swimbladder volume (Ona, 2003; Zhao *et al.*, 2008) for the average depth of Northern Anchovy observed in summer 2016 (19 m, Zwolinski *et al.*, 2017).

To calculate $TS_{38\text{kHz}}$, L_T was estimated from measurements of L_S or L_F using linear relationships between length and weight derived from specimens collected in the CCE (Palance *et al.*, 2019): for Pacific Sardine,

$L_T = 1.157L_S + 0.724$; for Northern Anchovy, $L_T = 1.137L_S + 5.100$; for Pacific Mackerel, $L_T = 1.115L_F + 4.114$; for Jack Mackerel, $L_T = 1.100L_F + 0.896$; and for Pacific Herring, $L_T = 1.110L_F - 0.323$.

The proportions of species in a trawl cluster were considered representative of the proportions of species in the vicinity of the cluster. Therefore, the proportion of the echo-integral from the e-th species (P_e) in an ensemble of s species can be calculated from the species catches $N_1, N_2, ..., N_s$ and the respective average backscattering cross-sections $\sigma_{bs_1}, \sigma_{bs_2}, ..., \sigma_{bs_s}$ (Nakken and Dommasnes, 1975). The proportion of acoustic backscatter for the e-th species in the a-th trawl (P_{ae}) is:

$$P_{ae} = \frac{N_{ae} \times \overline{w}_{ae} \times \overline{\sigma}_{bs,ae}}{\sum_{e=1}^{s_a} (N_{ae} \times \overline{w}_{ae} \times \overline{\sigma}_{bs,ae})}, \tag{13}$$

where $\overline{\sigma}_{bs,ae}$ is the arithmetic counterpart of the average target strength ($\overline{TS}_{ae}$) for all n_{ae} individuals of species e in the random sample of trawl a:

$$\overline{\sigma}_{bs,ae} = \frac{\sum_{i=1}^{n_{ae}} 10^{(TS_i/10)}}{n_{ae}}, \tag{14}$$

and $\overline{w}_{ae}$ is the average weight: $\overline{w}_{ae} = \sum_{i=1}^{n_{ae}} w_{aei}/n_{ae}$. The total number of individuals of species e in a trawl a (N_{ae}) is obtained by: $N_{ae} = \frac{n_{ae}}{w_{s,ae}} \times w_{t,ae}$, where $w_{s,ae}$ is the weight of the n_{ae} individuals sampled randomly, and $w_{t,ae}$ is the total weight of the respective species' catch.

The trawls within a cluster were combined to reduce sampling variability (see **Section 2.2.7**), and the number of individuals caught from the e-th species in a cluster g (N_{ge}) was obtained by summing the catches across the h trawls in the cluster: $N_{ge} = \sum_{a=1}^{h_g} N_{ae}$. The backscattering cross-section for species e in the g-th cluster with a trawls is then given by:

$$\overline{\sigma}_{bs,ge} = \frac{\sum_{a=1}^{h_g} N_{ae} \times \overline{w}_{ae} \times \overline{\sigma}_{bs,ae}}{\sum_{a=1}^{s_g} N_{ae} \times \overline{w}_{ae}}, \tag{15}$$

where:

$$\overline{w}_{ge} = \frac{\sum_{a=1}^{h_g} N_{ae} \times \overline{w}_{ae}}{\sum_{a=1}^{h_g} N_{ae}}, \tag{16}$$

and the proportion (P_{ge}) is;

$$P_{ge} = \frac{N_{ge} \times \overline{w}_{ge} \times \overline{\sigma}_{bs,ae}}{\sum_{e=1}^{s} (N_{ge} \times \overline{w}_{ge} \times \overline{\sigma}_{bs,ge})}. \tag{17}$$

2.2.7 Trawl clustering and species proportion

Nighttime trawl and daytime purse-seine samples were used to apportion backscatter in the core and nearshore areas, respectively. Trawls that occurred on the same night were assigned to a trawl cluster. Biomass densities (ρ; t nmi^{-2}) were calculated for 100-m transect intervals by dividing the integrated area-backscatter coefficients for each CPS species by the mean backscattering cross-sectional area (MacLennan *et al.*, 2002) estimated in the trawl cluster or purse-seine nearest in space. Acoustic transects were post-stratified to account for spatial heterogeneity in sampling effort and biomass density in a similar way to that performed for Pacific Sardine (PFMC, 2018; Zwolinski *et al.*, 2016).

For a generic 100-m long acoustic interval, the vertically summed area-backscattering coefficient for species e was computed as: $s_{A,e} = s_{A,cps} \times P_{ge}$, where $s_{A,cps}$ is the vertically summed area-backscattering coefficient for all CPS and P_{ge} (Equation (17)) is the proportion of acoustic backscatter from species e in the nearest trawl cluster or purse-seine (**Fig. 12**). Then, $s_{A,e}$ was used to estimate the biomass density ($\rho_{w,e}$) (MacLennan *et al.*, 2002; Simmonds and MacLennan, 2005) for every 100-m interval:

$$\rho_{w,e} = \frac{s_{A,e}}{4\pi\overline{\sigma}_{bs,e}}. \tag{18}$$

In 2025, purse-seine sampling was sparse in some areas where CPS backscatter was observed, so the nearest purse-seine sample or individual trawl haul were used to apportion backscatter, whichever was closest in space (**Fig. 12, b**). In one instance, dense backscatter along a nearshore transect was originally apportioned using a distant purse-seine sample with a species composition that was believed to not represent the observed backscatter, so that sample was removed and the nearest trawl was used instead (see **Section 4.2**).

The biomass densities were converted to numerical densities using: $\rho_{n,e} = \rho_{w,e}/\overline{w}_e$, where $\overline{w}_e$ is the corresponding mean weight. Also, for each acoustic interval, the biomass or numeric densities are partitioned into length classes according to the species' length distribution in the respective trawl cluster or purse-seine.

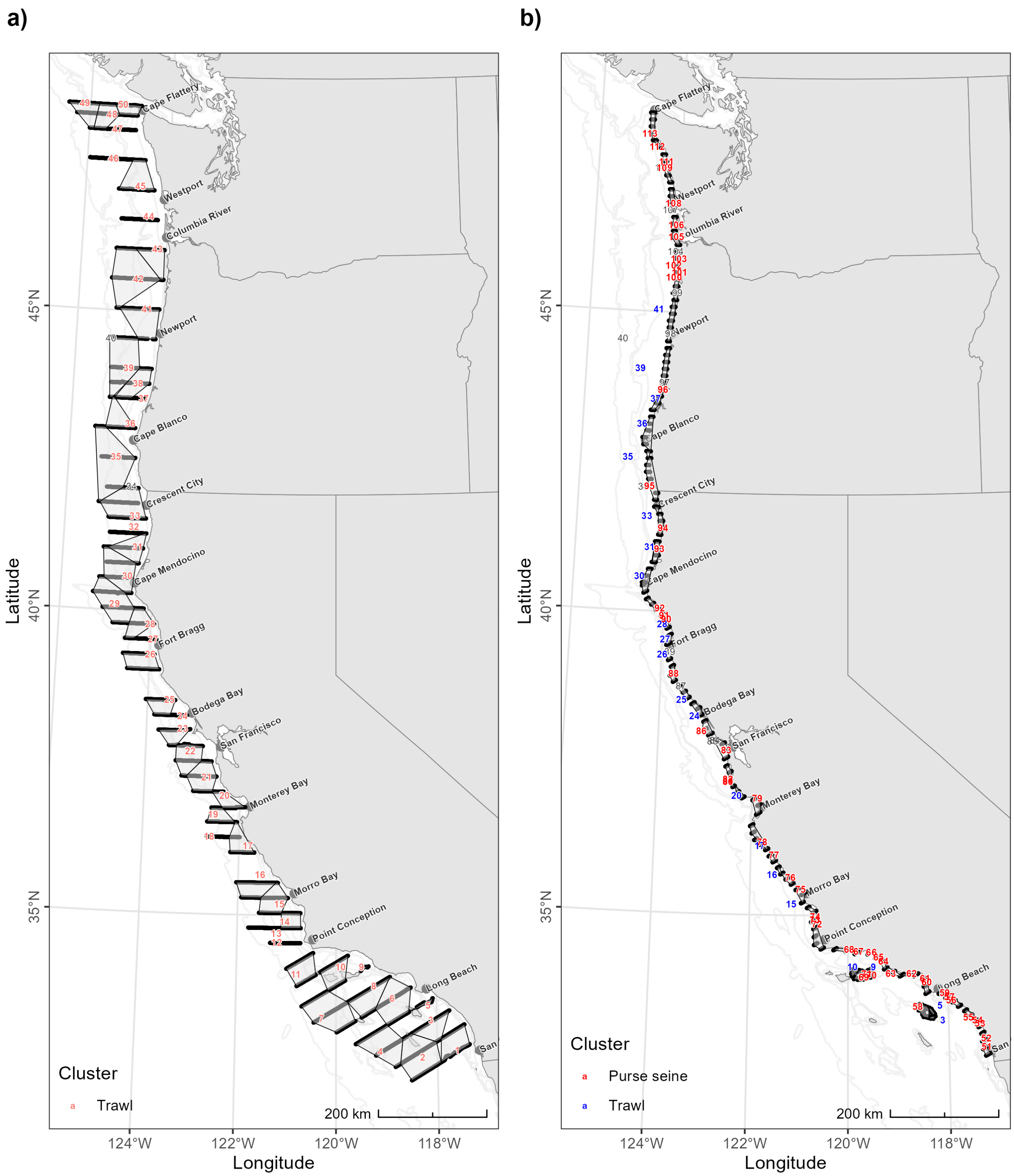

Figure 12: Polygons enclosing 100 m-long acoustic transect intervals sampled by a) *Shimada* in the core region (pink for trawls) and b) *Long Beach Carnage* and *Lisa Marie* in the nearshore region relative to the nearest trawl or purse-seine sample used to apportion acoustic backscatter. The colored numbers inside each polygon indicate the sample number and gear type (red for purse-seine, blue for trawl). Dark gray numbers in both panels indicate purse-seine or trawl samples with no CPS present in the catch.

2.3 Data analysis

2.3.1 Post-stratification

The transects were the sampling units (Simmonds and Fryer, 1996). Because most species do not generally span the entire survey area (Demer and Zwolinski, 2017; Zwolinski *et al.*, 2014), the sampling domain was post-stratified for each species and subpopulation (PFMC, 2018; Zwolinski *et al.*, 2016). Strata were defined by uniform transect spacing (i.e., sampling intensity) and either the presence (i.e., positive densities and potentially structural zeros) or absence (i.e., real zeros) of biomass for each species. Each stratum has: 1) at least three transects, with approximately equal spacing, 2) fewer than three consecutive transects with zero-biomass density, and 3) bounding transects with zero-biomass density (**Fig. 13**). This approach tracks patchiness and creates statistically-independent, stationary, post-sampling strata (Johannesson and Mitson, 1983; Simmonds *et al.*, 1992). For Northern Anchovy, we define the separation between the northern and central subpopulations at Cape Mendocino (40.8 °N) (McHugh, 1951; Vrooman *et al.*, 1981). For Pacific Sardine, the northern subpopulation biomass present in the survey area (Felix-Uraga *et al.*, 2004; Felix-Uraga *et al.*, 2005; Garcia-Morales *et al.*, 2012; Hill *et al.*, 2014) was separated using the revised model of Pacific Sardine potential habitat (Zwolinski and Demer, 2024) during the survey (**Fig. 14**), with all other Pacific Sardine biomass considered to belong to the southern subpopulation. This break between northern and southern subpopulation coincided geographically with Pt. Conception where there was a break in the distribution of Pacific sardine biomass (34.5 °N, **Fig. 13**).

2.3.2 Classification of echoes in the nearshore region

In some areas of the nearshore region, dense backscatter was observed toward the western end of the transects and at depths below the upper mixed layer (approximately 30 m). Pacific Sardine, which typically occur above the thermocline (J. Zwolinski, pers. comm.), were captured primarily in purse-seine samples collected in waters closer to shore, at depths largely above the net's maximum depth of 27 m. Therefore, the deeper offshore acoustic backscatter, likely associated with Northern Anchovy or Pacific Herring, was not adequately represented by the shallow purse-seine sets and should not be used to estimate epipelagic CPS biomass through apportionment of backscatter to the nearest purse-seine sample. Biomass estimation in the nearshore region was therefore limited to CPS backscatter within the upper 30 m, which was apportioned to species using the species- and length-composition from the nearest purse-seine or trawl haul from Shimada and used to estimate biomass densities. Because CPS backscatter below 30 m was not included, the nearshore biomass estimates exclude an unknown portion of Northern Anchovy and Pacific Herring biomass (see **Section 4.2**). Methods to incorporate biomass and length composition associated with deeper backscatter are currently under development and will be included in future estimates and reports.

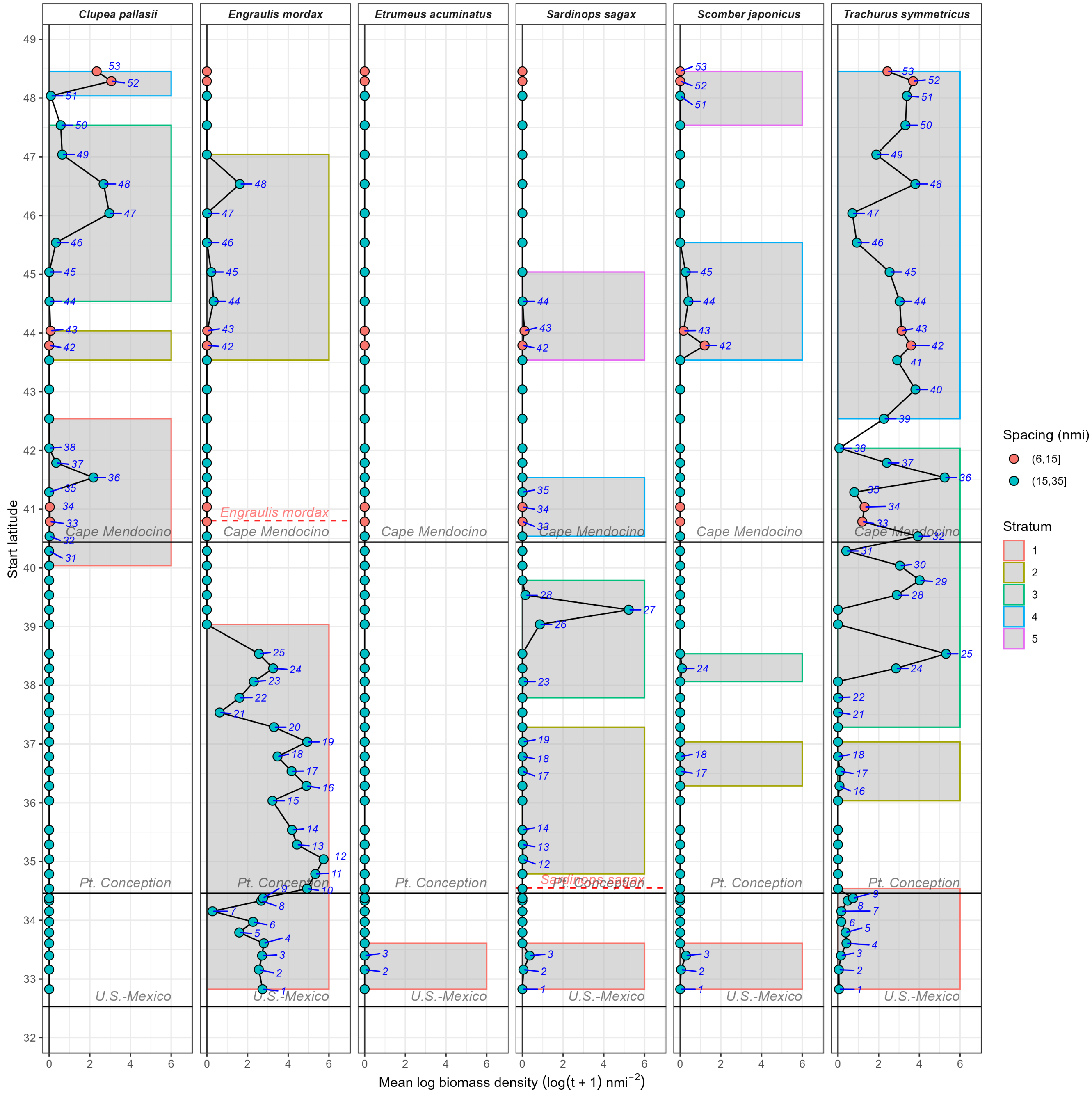

Figure 13: Log-transformed biomass density ($t\,\mathrm{nmi}^{-2}$) by transect versus latitude (easternmost portion of each transect) and strata (shaded regions; outline indicates stratum number) used to estimate biomass and abundance for each species in the core region surveyed by *Shimada*. Data labels (blue numbers) correspond to transects with positive biomass ($\log_e(t+1) > 0$). Transect spacing (nmi; point color), and subpopulation breaks for Northern Anchovy and Pacific Sardine (red dashed lines and text) are indicated.

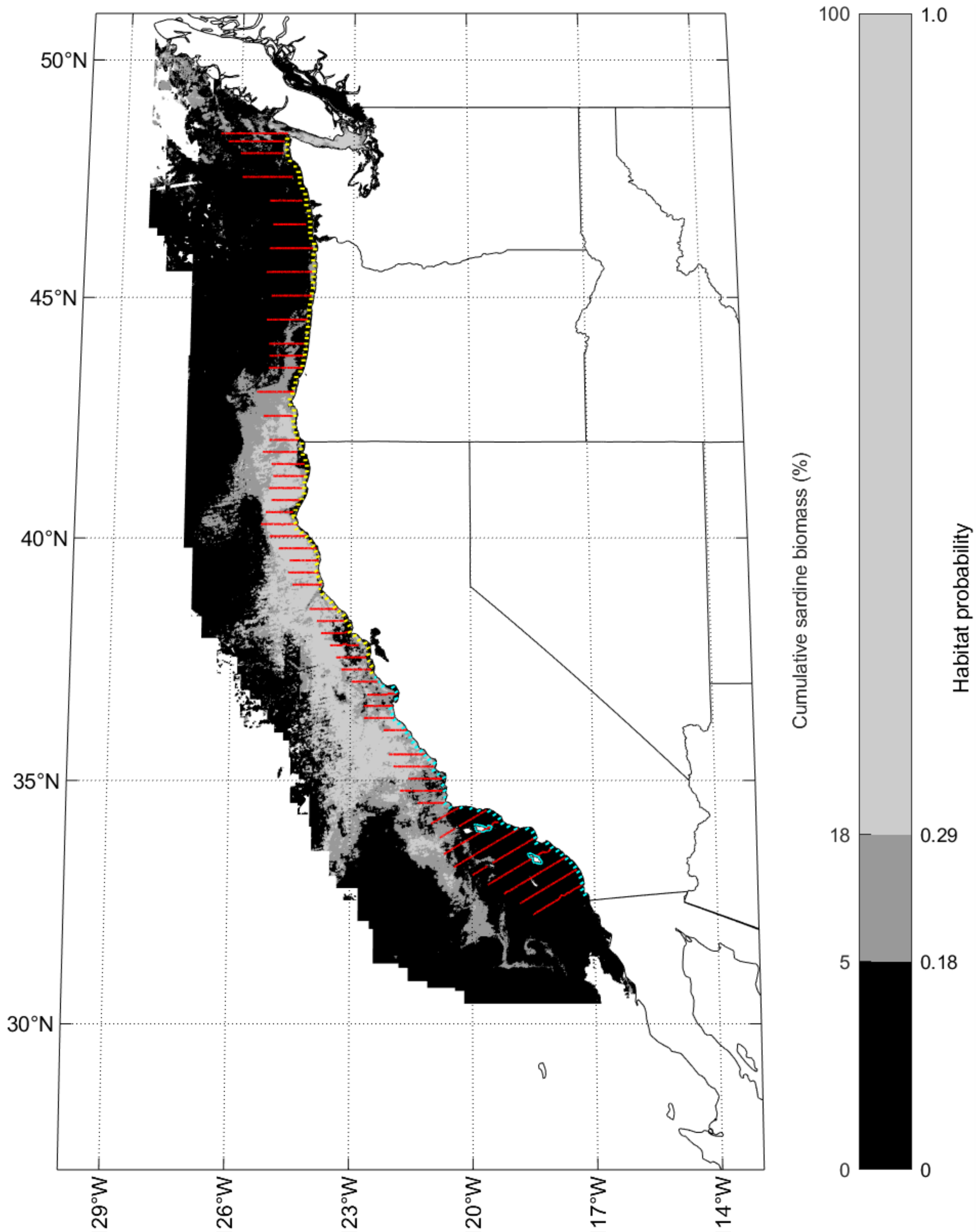

Figure 14: Summary of all core- and nearshore-region transects, in relation to the potential habitat for the northern subpopulation of Pacific Sardine, as sampled by *Shimada* (red), *Long Beach Carnage* (cyan), and *Lisa Marie* (yellow). The habitat is temporally aggregated using an average of the habitat centered ±2° around each vessel during the survey. Areas in white correspond to no available data (e.g., when cloud coverage prevented satellite-sensed observations).

2.3.3 Biomass and sampling precision estimation

For each stratum and subpopulation, the biomass ($\hat{B}$; kg) of each species was estimated by:

$$\hat{B} = A \times \hat{D}, \tag{19}$$

where A is the stratum area (nmi^2) and $\hat{D}$ is the estimated mean biomass density (kg nmi^{-2}):

$$\hat{D} = \frac{\sum_{l=1}^{k} \overline{\rho}_{w,l} c_l}{\sum_{l=1}^{k} c_l}, \tag{20}$$

where $\overline{\rho}_{w,l}$ is the mean biomass density of the species on transect l, c_l is the transect length, and k is the total number of transects. The variance of $\hat{B}$ is a function of the variability of the transect-mean densities and associated lengths. Treating transects as replicate samples of the underlying population (Simmonds and Fryer, 1996), the variance was calculated using bootstrap resampling (Efron, 1981) based on transects as sampling units. Provided that each stratum has independent and identically-distributed transect means (i.e., densities on nearby transects are not correlated, and they share the same statistical distribution), bootstrap or other random-sampling estimators provide asymptotically unbiased estimates of variance.

The 95% confidence intervals ($\text{CI}_{95\%}$) for the mean biomass densities ($\hat{D}$) were estimated as the 0.025 and 0.975 percentiles of the distribution of 1,000 bootstrap survey-mean biomass densities. Coefficient of variation (CV, %) values were obtained by dividing the bootstrapped standard error by the mean estimate (Efron, 1981). Total biomass in the survey area was estimated as the sum of the biomasses in each stratum, and the associated sampling variance was calculated as the sum of the variances across strata.

2.3.4 Abundance- and biomass-at-length estimation

The numerical densities by length class (**Section 2.2.7**) were averaged for each stratum in a similar way for that used for biomass (Equation (20)), and multiplied by the stratum area to obtain abundance per length class.

2.3.5 Percent biomass per cluster contribution

The percent contribution of each cluster to the estimated abundance in a stratum (**Appendix C**) was calculated as:

$$\frac{\Sigma_{i=1}^{l} \overline{\rho}_{ci}}{\Sigma_{c=1}^{C} \Sigma_{i=1}^{l} \overline{\rho}_{ci}}, \tag{21}$$

where $\overline{\rho}_{ci}$ is the numerical density in interval i represented by the nearest trawl cluster c.

2.3.6 Software and code

All analyses presented here were performed using R software (R Core Team, 2025), including functions contained in the {atm} package (Stierhoff and Zwolinski, 2026)[8] and scripts contained in the *estimATM* repository (Stierhoff *et al.*, 2026)[9], both of which are available on GitHub.

[8] https://github.com/SWFSC/atm
[9] https://github.com/SWFSC/estimATM

3 Results

3.1 Sampling effort and allocation

The core region of the summer 2025 survey spanned the continental shelf from San Diego to Cape Flattery, between 03 June and 14 September 2025, and included most of the potential habitat for the northern subpopulation of Pacific Sardine at the time of the survey[10]. In this region, *Shimada* sampled 53 east-west transects totaling 2,461 nmi during 63 DAS (**Fig. 15**). Catches from a total of 104 nighttime surface trawls were combined into 50 trawl clusters. In the core region, one to five post-survey strata were defined by their transect spacing and the densities of biomass attributed to each species.

The nearshore region spanned an area from 5-m depth to approximately 5 nmi from the continental coast, or 2.5 nmi from the Santa Cruz and Santa Catalina Islands, between San Diego and Cape Flattery. *Long Beach Carnage* surveyed from approximately San Diego to Half Moon Bay, CA and around the Santa Cruz and Santa Catalina Islands, with 93 east-west transects totaling 296 nmi and 29 purse-seine sets during 18 DAS (**Fig. 17**). *Lisa Marie* surveyed from Half Moon Bay to Cape Flattery, WA with 100 east-west transects totaling 371 nmi and 34 purse-seine sets during 27 DAS (**Fig. 18**). In the nearshore region, one to twelve post-survey strata were defined by their transect spacing and the densities of biomass attributed to each species.

Biomasses and abundances were estimated for each species and subpopulation in both the core and nearshore survey regions. The total biomass for each subpopulation within the survey region was estimated as the sum of its biomasses in the core and nearshore regions.

3.2 Core area survey aboard *Shimada*

Leg I

On 11 June, *Shimada* departed from 10th Avenue Terminal in San Diego, CA at ~2100 (all times UTC), then remained outside San Diego Bay to allow a RAPP Hydema technician to test and evaluate the trawl winch system as part of regular maintenance. At 1447 on 12 June, sampling was initiated on transect 002; at 1809 *Shimada* broke transect to transit back toward San Diego Bay where a small boat transfer was conducted to bring aboard a 2nd cook. Surface trawl sampling was then conducted that evening and acoustic sampling resumed on transect 002 at 1259 on 13 June. At 1259 on 17 June, *Shimada* anchored near Long Beach, CA to recalibrate the EK80 echosounders as requested by the NWFSC for hake analyses; at 1759, after an unsuccessful attempt, the anchor was retrieved and acoustic sampling resumed on transect 006. On 20 June, a bearing on the trawl gate broke during the first nighttime surface trawl, precluding further trawl operations. Acoustic sampling resumed as normal on the morning of 21 June while the ship's crew investigated a repair; at 2300 that evening the trawl gate was fixed and trawling could commence. At 1749 on 24 June, in support of an unrelated SWFSC project, *Shimada* retrieved a bottom lander near Point Conception and deployed a new one before resuming acoustic sampling on transect 011. Acoustic sampling ceased after completion of transect 011 at 0409 on 25 June, followed by two nighttime surface trawls before beginning transit to San Francisco. On 25 June, *Shimada* arrived in San Francisco, CA at ~1700 to complete Leg I.

Leg II

On 2 July, following a three-day delay, *Shimada* departed from Pier 30/32 in San Francisco at ~0800 and transited south toward Pt. Conception. The delay, which was due to medical issues with the ship's crew, resulted in a shortage of experienced deck crew, so the decision was made to limit trawl operations to 12 instead of 24 h. At ~1300 on 3 July, acoustic sampling was resumed along transect 011 near Lompoc, CA. In an effort to mitigate the lost days at sea, transect 016 was randomly selected to be skipped. On 10 July, a member of the science party was put ashore in Monterey, CA after experiencing a medical emergency. Following a brief interruption of survey operations, and thanks to the prompt and strategic response by the ship's personnel and medical officers, sampling resumed soon afterward. On 15 July, acoustic sampling

[10] https://coastwatch.pfeg.noaa.gov/erddap/griddap/sardine_habitat_modis.html

ceased after the completion of transect 024 off San Francisco. On 15 July, after a night of surface trawling, *Shimada* arrived at Pier 30/32 in San Francisco at ~1500 to complete Leg II.

Leg III

On 19 July, *Shimada* departed from Pier 30/32 at ~1600 and resumed sampling along transect 025 just north of San Francisco Bay. To regain additional time lost during Legs 1 and 2, transect 028 was randomly skipped. At ~0200 on 30 July, *Shimada* completed sampling transect 040 near Crescent City before transiting ~18 h to Newport for a medical emergency among the ship's crew. At ~1800 on 31 July, the affected crew member was put ashore via small craft. Rather than transiting back to transect 041, or ending the leg early, the decision was made to conduct only CTD and eDNA sampling along transects 051, 053, and 055 just north of Newport, OR. On 2 August, *Shimada* arrived at MOC-P in Newport at ~1600 to complete Leg III.

Leg IV

On 11 August, *Shimada* departed from Newport, OR at ~1500 and transited southward. On 12 August, *Shimada* resumed acoustic sampling at ~0715 along transect 041 near Brookings, OR. On 13 August the fog signal failed, and *Shimada* returned to Newport for repair, arriving at MOC-P at ~0700 on August 14. On 18 August at ~1630, *Shimada* departed from Newport, after repairing the fog signal and other personnel-related delays. On 19 August at ~0715, *Shimada* resumed acoustic sampling along transect 043 near Gold Beach, OR. On 21 August, acoustic sampling ceased after the completion of transect 048 off Reedsport, OR and *Shimada* transited to Newport, OR for a personnel exchange. On 22 August, after a failed personnel exchange attempt, *Shimada* departed Newport and resumed acoustic sampling along transect 048 near Reedsport on 22 August at ~1930. At ~2300, trawl sampling ceased on transect 048. On 23 August, *Shimada* arrived at MOC-P in Newport ~1430 to complete Leg IV.

Leg V

On 28 August, *Shimada* departed from MOC-P in Newport at 2302 and began the transit to Reedsport. On 29 August, *Shimada* resumed acoustic sampling along transect 049. Due to lost survey time during prior legs, acoustic sampling proceeded along odd-numbered transects for the remainder of the leg. On 30 August, the MFT used for surface trawling was damaged and replaced by a spare net on board. On 31 August, fishing was stopped after the second surface trawl due to a hydraulic leak in the crane, which was repaired while underway the following day and available to resume trawling. On 7 September, using time regained throughout Leg V, acoustic sampling was conducted along transect 066, which was planned to be skipped due to previously lost DAS. On 9 September, acoustic sampling ceased after the completion of transect 067 in the Strait of Juan de Fuca, after which *Shimada* transited to Elliott Bay near Seattle, WA to conduct a post-survey acoustic calibration. On 13 September, *Shimada* arrived at MOC-P in Newport at ~1600 to complete Leg IV.

3.3 Nearshore survey aboard industry fishing vessels

3.3.1 *Long Beach Carnage*

On 16 June, *Long Beach Carnage* was mobilized with EK80 echosounders at Point Loma Sportfishing in San Diego, CA. From 17 to 19 June, *Long Beach Carnage* sampled nearshore transects 1 to 11, between San Diego and Newport Beach, before transiting offshore to sample transects 327 to 347 around Santa Catalina Island. From 20 to 26 June, *Long Beach Carnage* sampled nearshore transects 12 to 25, between Newport Beach and Point Conception before transiting offshore to sample transects 284-303 around Santa Cruz Island. Finally, from 27 June to 2 July, Long Beach Carnage sampled nearshore transects 26 to 52, between Point Conception and Half Moon Bay, before completing nearshore sampling at 2000 on 2 July to conclude their portion of the nearshore survey.

3.3.2 *Lisa Marie*

From 22 July to 3 August, *Lisa Marie* sampled nearshore transects 53 to 109, between Half Moon Bay and Coos Bay, where they called port to end the first half of their survey, reprovision the vessel, and exchange crew. On 13 August, *Lisa Marie* resumed sampling nearshore sampling along transects 110 to 139 before calling port in Westport, WA on 24 August to refuel. On 25 August, *Lisa Marie* resumed sampling transects 140 to 152, between Westport and Cape Flattery, before completing acoustic sampling and concluding the nearshore survey at 1600 on 28 August.

3.4 Acoustic backscatter

Acoustic backscatter ascribed to CPS was observed throughout the latitudinal range of the core survey area (**Fig. 15a**), but was greatest between Point Conception and Crescent City. Acoustic backscatter was present from the shore to the shelf break, but was generally greater closer to shore. Zero-biomass intervals were observed at the offshore end of each transect in the core region. Greater than 90% of the biomass for each species was apportioned using catch data from trawl clusters collected within ~20 nmi (**Fig. 16**).

Acoustic backscatter ascribed to CPS was also observed throughout the nearshore survey area, but was most prevalent along transects sampled by *Long Beach Carnage* near Long Beach, Los Angeles, and between Point Conception and Santa Cruz (**Fig. 17a**), and along transects sampled by *Lisa Marie* between Half Moon Bay and Bodega Bay, and north of Cape Mendocino (**Fig. 18a**).

3.5 Trawl catch

Trawl catches from *Shimada* were composed of mostly Northern Anchovy between San Diego and Bodega Bay, Jack Mackerel between Fort Bragg and Newport, and Pacific Herring between Newport and Cape Flattery (**Fig. 15b**). Some Pacific Sardine were present in trawl clusters near Fort Bragg, while Pacific Mackerel were scarce throughout the survey area. Overall, the 104 trawls captured a combined 29,495 kg of CPS (15,926 kg of Northern Anchovy, 10,110 kg of Jack Mackerel, 3,325 kg of Pacific Herring, 87.5 kg of Pacific Mackerel, and 46.5 kg of Pacific Sardine (**Appendix D**).

3.6 Purse-seine catch

3.6.1 *Long Beach Carnage*

Purse-seine catches from *Long Beach Carnage* in the nearshore region were composed mostly of Pacific Sardine and Northern Anchovy collected along the mainland coast (**Fig. 17b**). Relatively few Pacific Mackerel, and Jack Mackerel were present in purse-seine samples collected by *Long Beach Carnage* (**Fig. 17b**). Overall, dip-net samples from 29 seines totaled 88.7 kg of CPS (55.8 kg of Pacific Sardine, 18.1 kg of Pacific Mackerel, 9.9 kg of Northern Anchovy, and 4.8 kg of Jack Mackerel, **Appendix E.1**).

3.6.2 *Lisa Marie*

Purse-seine catches from *Lisa Marie* in the nearshore were composed mostly of Pacific Herring, except Northern Anchovy collected between Half Moon Bay and Bodega Bay, several catches of Pacific Sardine between Pt. Arena and Eureka, CA, and a few catches of Jack Mackerel near Crescent City and north of Tillamook, OR (**Fig. 18b**). Purse-seine sampling between Cape Mendocino and Tillamook was sparse due to few CPS targets, the presence of marine mammals that did not permit the deployment of the purse-seine gear, or both. Many of the purse-seine sets north of Cape Mendocino contained no CPS (**Fig. 18b**). Overall, the dip-net samples from 34 purse-seine sets totaled 106 kg of CPS (80.3 kg of Jack Mackerel, 12.1 kg of Pacific Sardine, 10.3 kg of Pacific Herring, and 3.54 kg of Northern Anchovy, **Appendix E.2**).

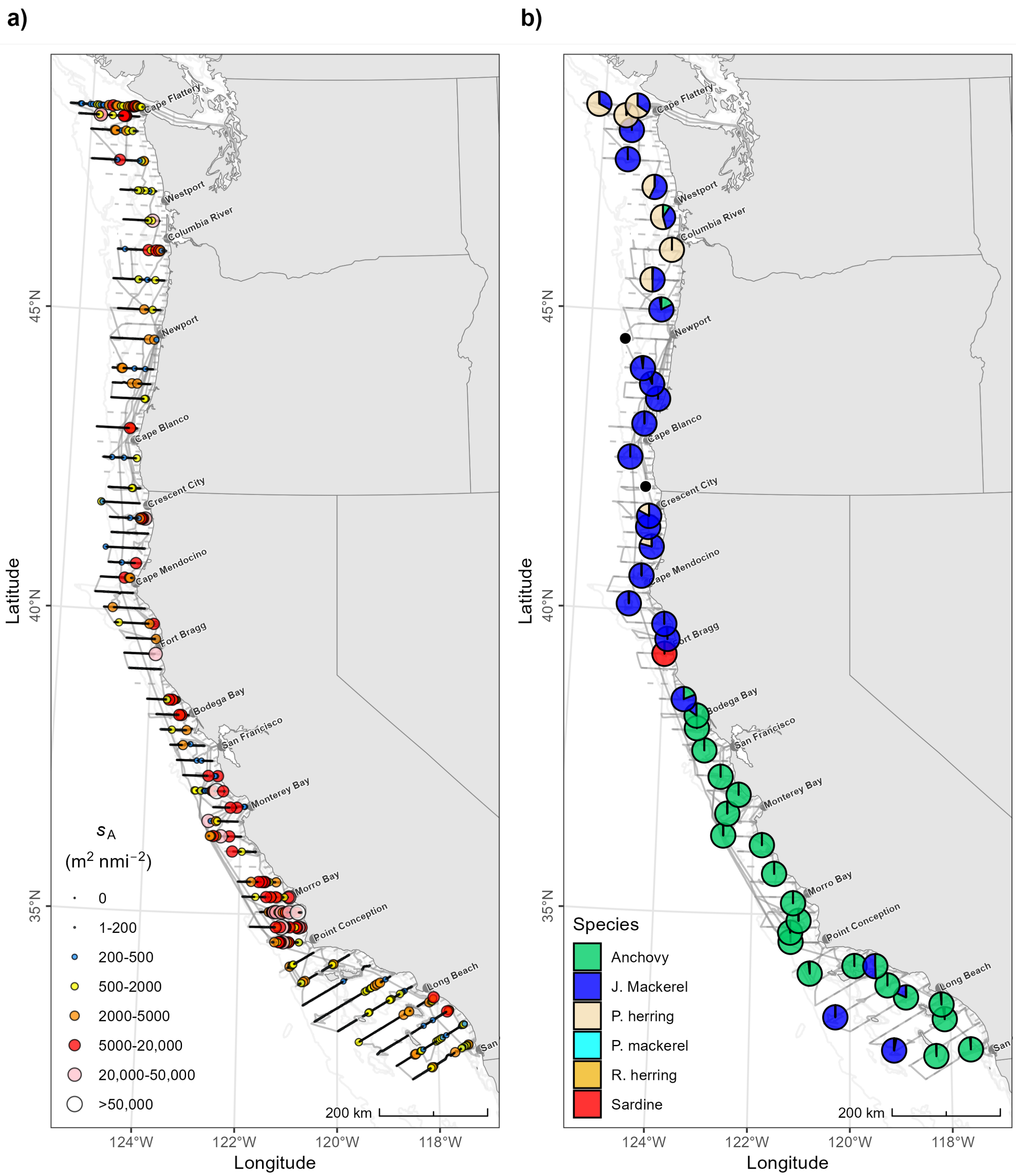

Figure 15: Spatial distributions sampled by *Shimada* of: a) 38-kHz vertically integrated backscattering coefficients (s_A, m^2 nmi^{-2}; averaged over 2000-m distance intervals) ascribed to CPS and b) proportion of acoustic backscatter from CPS in trawl clusters.

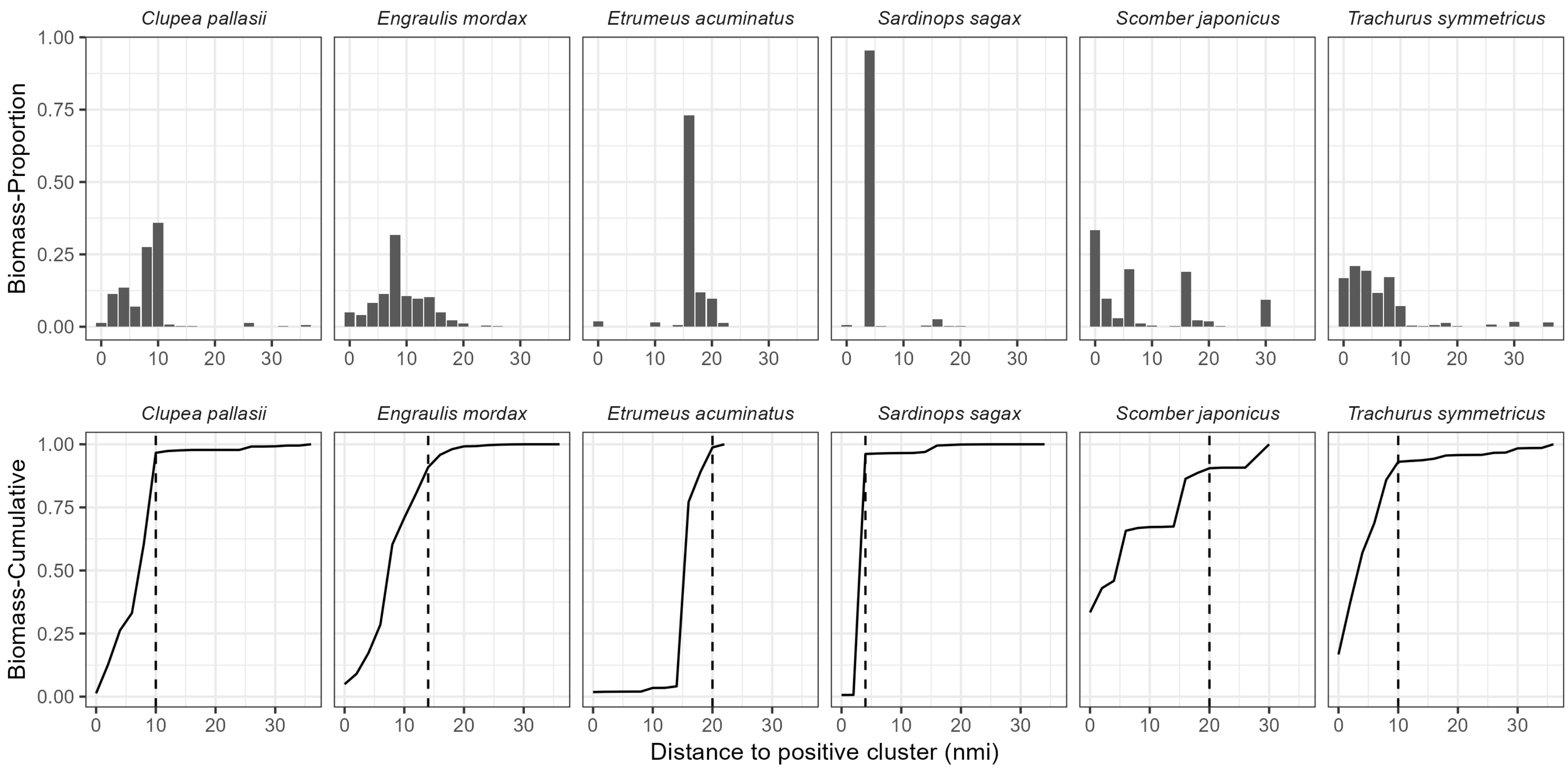

Figure 16: Proportion (top) and cumulative proportion (bottom) of biomass of each CPS species versus distance to the nearest positive trawl cluster sampled by *Shimada*. Dashed vertical lines (bottom) represent the cluster distance where cumulative biomass equals 90%. Note: these results are not separated by subpopulation.

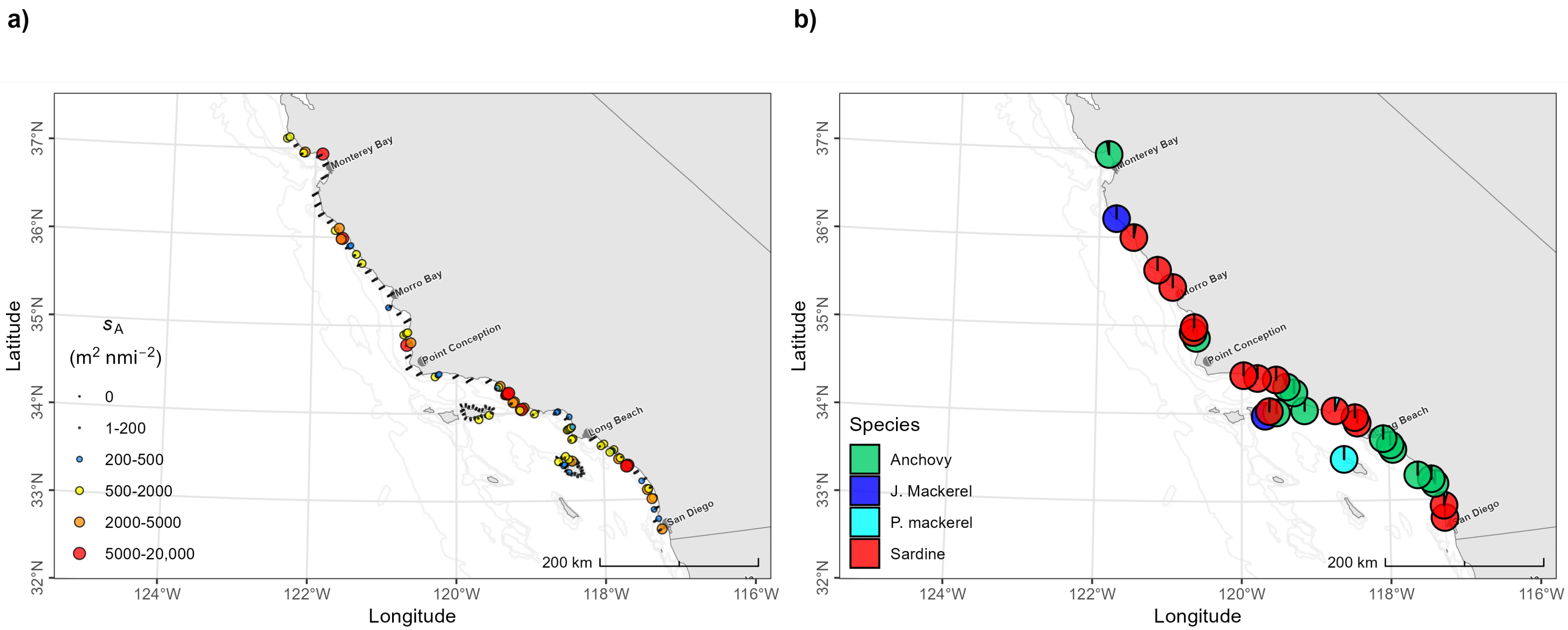

Figure 17: Nearshore transects sampled by *Long Beach Carnage* overlaid with the distributions of: a) 38-kHz vertically integrated backscattering coefficients (s_A, m^2 nmi^{-2}; averaged over 2000-m distance intervals) ascribed to CPS; and b) the proportions of acoustic backscatter from CPS in each purse-seine catch. Black points indicate purse-seine sets with no CPS present. Species with low catch weights may not be visible at this scale.

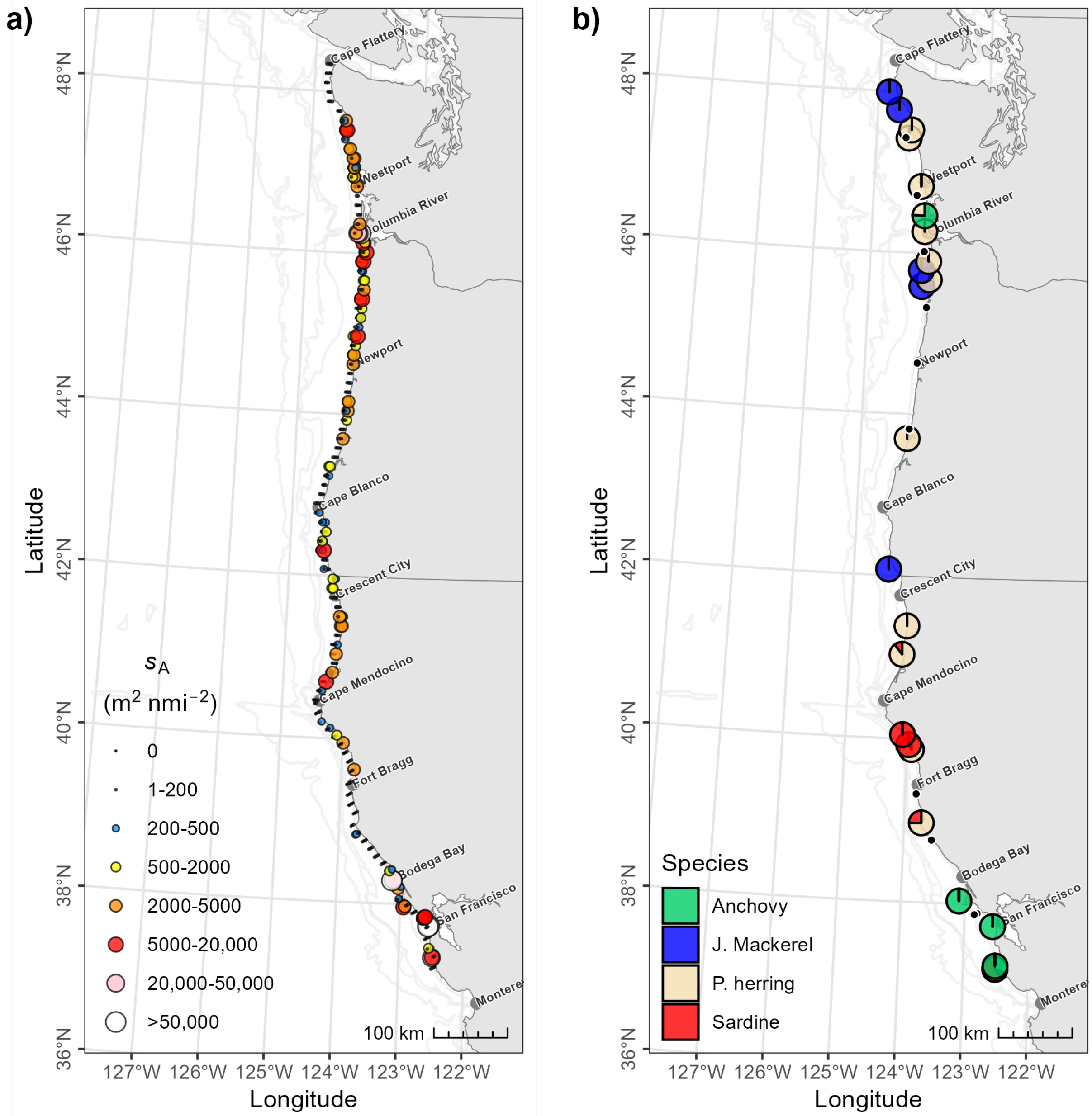

Figure 18: Nearshore survey transects sampled by *Lisa Marie* overlaid with the distributions of: a) 38-kHz vertically integrated backscattering coefficients (s_A, m^2 nmi^{-2}; averaged over 2000-m distance intervals) ascribed to CPS; and b) the proportion of acoustic backscatter from CPS in each purse-seine catch. Black points indicate purse-seine sets with no CPS present. Species with low catch weights may not be visible at this scale.

3.7 Biomass distribution and demographics

The biomasses, distributions, and demographics for each species and subpopulation are for the survey area and period and therefore may not represent the entire population. All biomass estimates are in metric tons (t).

3.7.1 Northern Anchovy

3.7.1.1 Northern subpopulation

The total estimated biomass of the northern subpopulation of Northern Anchovy was 4,178 t ($CI_{95\%}$ = 98.7 - 11,164 t, CV = 73%; **Table 5**). In the core region, biomass was 4,103 t ($CI_{95\%}$ = 88.4 - 11,013 t, CV = 74%; **Table 5**). L_S ranged from 4 to 16 cm with modes at 4 and 15 cm (**Table 6**, **Fig. 20**). In the nearshore region, biomass was 74.5 t ($CI_{95\%}$ = 10.3 - 151 t, CV = 47%; **Table 5**), comprising 1.8% of the total biomass. Lengths in the nearshore region had two modes at 5 and 11 cm (**Table 6**; **Fig. 20**). In both the core and nearshore regions, the subpopulation was sparsely distributed between Cape Blanco and Cape Flattery (**Fig. 19a, b**).

Table 5: Biomass estimates (metric tons, t) and their precisions (upper and lower 95% confidence intervals, $CI_{95\%}$; and coefficients of variation, CVs) for the northern subpopulation of Northern Anchovy (*Engraulis mordax*) in the core and nearshore survey regions. Stratum areas are nmi^2 and distance covered by transects is in nmi.

Stratum					Trawl		Biomass			
Region	Number	Area	Transects	Distance	Clusters	Individuals	$\hat{B}$	$CI_{L,95\%}$	$CI_{U,95\%}$	CV
Core	2	10,346	9	366	5	5,426	4,103	88	11,013	74
	All	10,346	9	366	5	5,426	4,103	88	11,013	74
Nearshore	7	132	5	18	1	4	63	1	136	54
	8	91	4	12	1	4	11	0	25	57
	All	224	9	30	2	8	75	10	151	47
All	**-**	**10,570**	**18**	**396**	**7**	**5,434**	**4,178**	**99**	**11,164**	**73**

Table 6: Abundance estimates (total number of individuals) versus standard length (L_S, cm) for the northern subpopulation of Northern Anchovy (*Engraulis mordax*) in the core and nearshore survey regions.

	Region	
L_S	Core	Nearshore
1	0	0
2	0	0
3	0	0
4	126,677,398	0
5	172,523,393	1,444,438
6	216,656,676	0
7	0	0
8	0	0
9	0	0
10	0	0
11	1,254,116	4,333,313
12	5,016,466	0
13	5,016,466	0
14	11,287,048	0
15	57,689,357	223,167
16	13,795,281	74,389
17	0	0
18	0	0
19	0	0
20	0	0

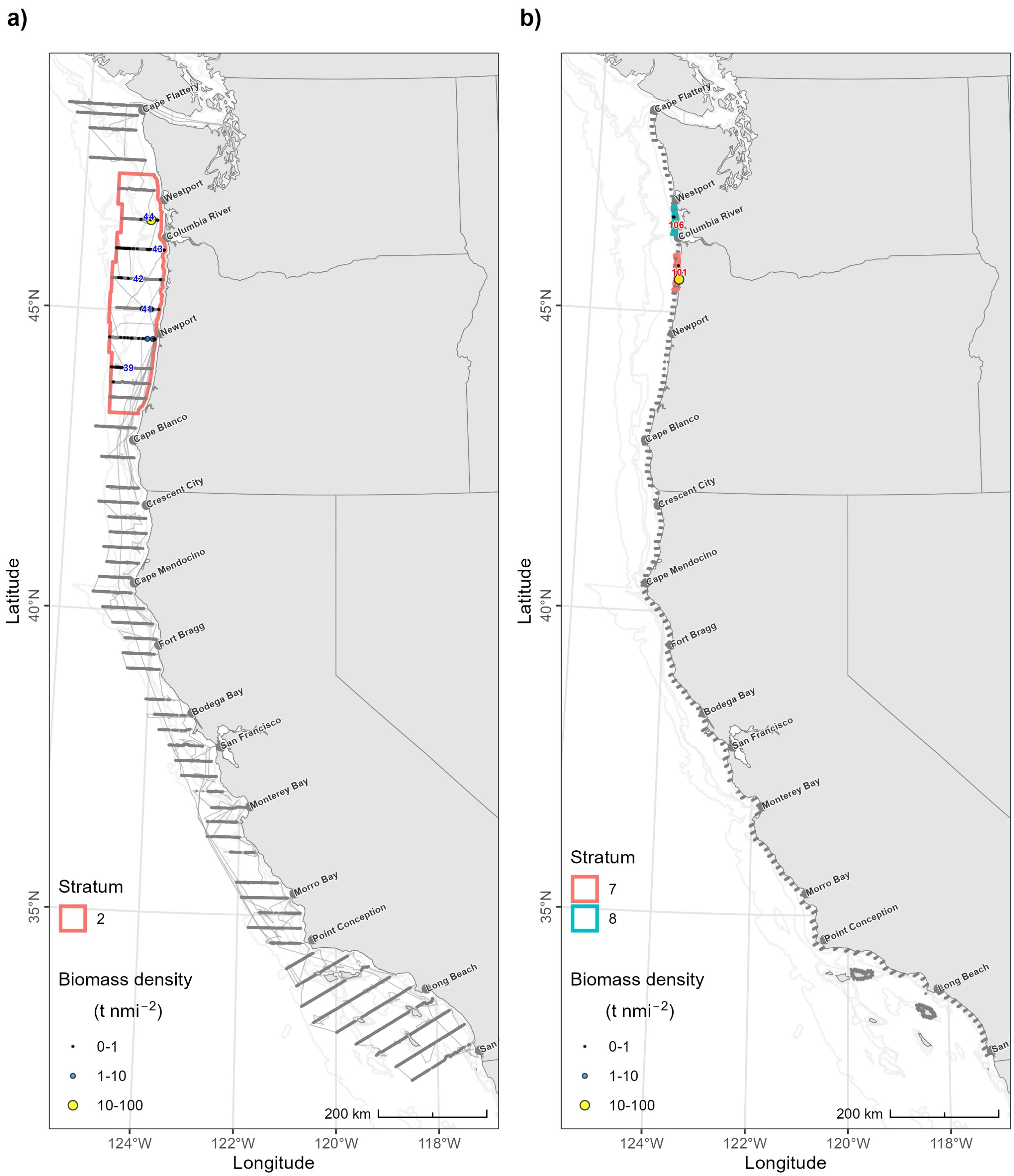

Figure 19: Biomass densities (colored points) of the northern subpopulation of Northern Anchovy (*Engraulis mordax*), per stratum, in the a) core and b) nearshore survey regions. Overlaid are the locations of trawl clusters (blue numbers) or purse-seine samples (red numbers) with at least one Northern Anchovy in each stratum (colored polygons). Thick gray lines represent acoustic transects.

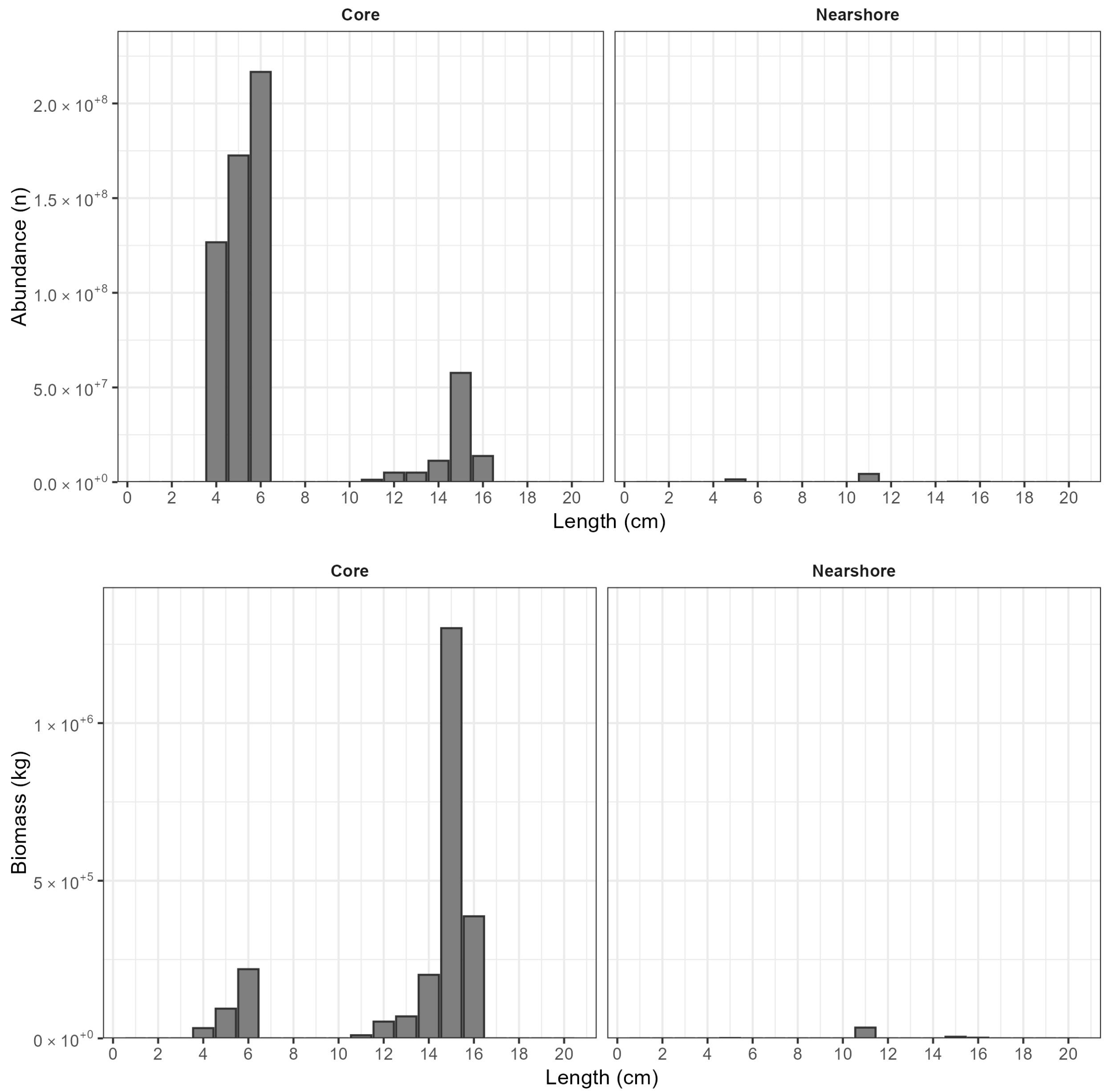

Figure 20: Abundance estimates (n) versus standard length (L_S, in cm, upper panels) and biomass (t) versus L_S (lower panels) for the northern subpopulation of Northern Anchovy (*Engraulis mordax*) in the core and nearshore survey regions.

3.7.1.2 Central subpopulation

The total estimated biomass of the central subpopulation of Northern Anchovy was 1,238,065 t ($CI_{95\%}$ = 453,248 - 1,749,878 t, CV = 25%; **Table 7**). In the core region, biomass was 1,108,875 t ($CI_{95\%}$ = 402,851 - 1,531,551 t, CV = 27%; **Table 7**). The subpopulation was distributed throughout most of the survey area from San Diego to Fort Bragg, but was most abundant north of Pt. Conception (**Fig. 21a**). L_S ranged from 6 to 16 cm with a mode at 12 cm (**Table 8**, **Fig. 22**). In the nearshore region, biomass was 129,190 t ($CI_{95\%}$ = 50,396 - 218,326 t, CV = 35%; **Table 7**), comprising 10% of the total biomass. The biomass was sparsely distributed between San Diego and Bodega Bay, but was greatest between San Diego and Long Beach, and between Santa Cruz and San Francisco, CA (**Fig. 21b**). The nearshore length distribution had a mode at 12 cm (**Table 8**, **Fig. 22**).

Table 7: Biomass estimates (metric tons, t) and their precisions (upper and lower 95% confidence intervals, $CI_{95\%}$; and coefficients of variation, CVs) for the central subpopulation of Northern Anchovy (*Engraulis mordax*) in the core and nearshore survey regions. Stratum areas are nmi^2 and distance covered by transects is in nmi.

Stratum					Trawl		Biomass			
Region	Number	Area	Transects	Distance	Clusters	Individuals	$\hat{B}$	$CI_{L,95\%}$	$CI_{U,95\%}$	CV
Core	1	24,062	26	1,237	24	783,764	1,108,875	402,851	1,531,551	27
	All	24,062	26	1,237	24	783,764	1,108,875	402,851	1,531,551	27
Nearshore	1	395	13	54	7	272	8,581	1,742	16,109	44
	2	251	7	32	3	150	14,178	2,873	25,415	42
	3	220	6	25	1	50	2,818	3	8,227	88
	4	128	4	15	1	48,753	95	0	279	85
	5	929	29	113	10	102,547	102,598	27,487	192,143	43
	6	81	3	11	1	2,197	24	0	72	82
	9	32	4	8	1	3,011	8	0	21	71
	10	41	6	12	2	73	79	5	221	72
	11	20	3	6	1	3,011	1	0	1	42
	12	73	13	26	2	89,889	809	5	2,282	86
	All	2,169	88	303	28	249,953	129,190	50,396	218,326	35
All	**-**	**26,231**	**114**	**1,539**	**52**	**1,033,717**	**1,238,065**	**453,248**	**1,749,878**	**25**

Table 8: Abundance estimates (total number of individuals) versus standard length (L_S, cm) for the central subpopulation of Northern Anchovy (*Engraulis mordax*) in the core and nearshore survey regions.

	Region	
L_S	Core	Nearshore
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	301,898	0
7	6,117,263	0
8	42,193,284	8,569,744
9	216,617,973	293,395,836
10	89,250,131	541,064,646
11	4,488,256,551	840,142,286
12	27,473,489,297	2,050,481,466
13	15,175,112,883	1,424,093,664
14	5,124,064,712	978,966,713
15	770,733,875	156,979,287
16	18,554,500	151,452
17	0	0
18	0	0
19	0	0
20	0	0

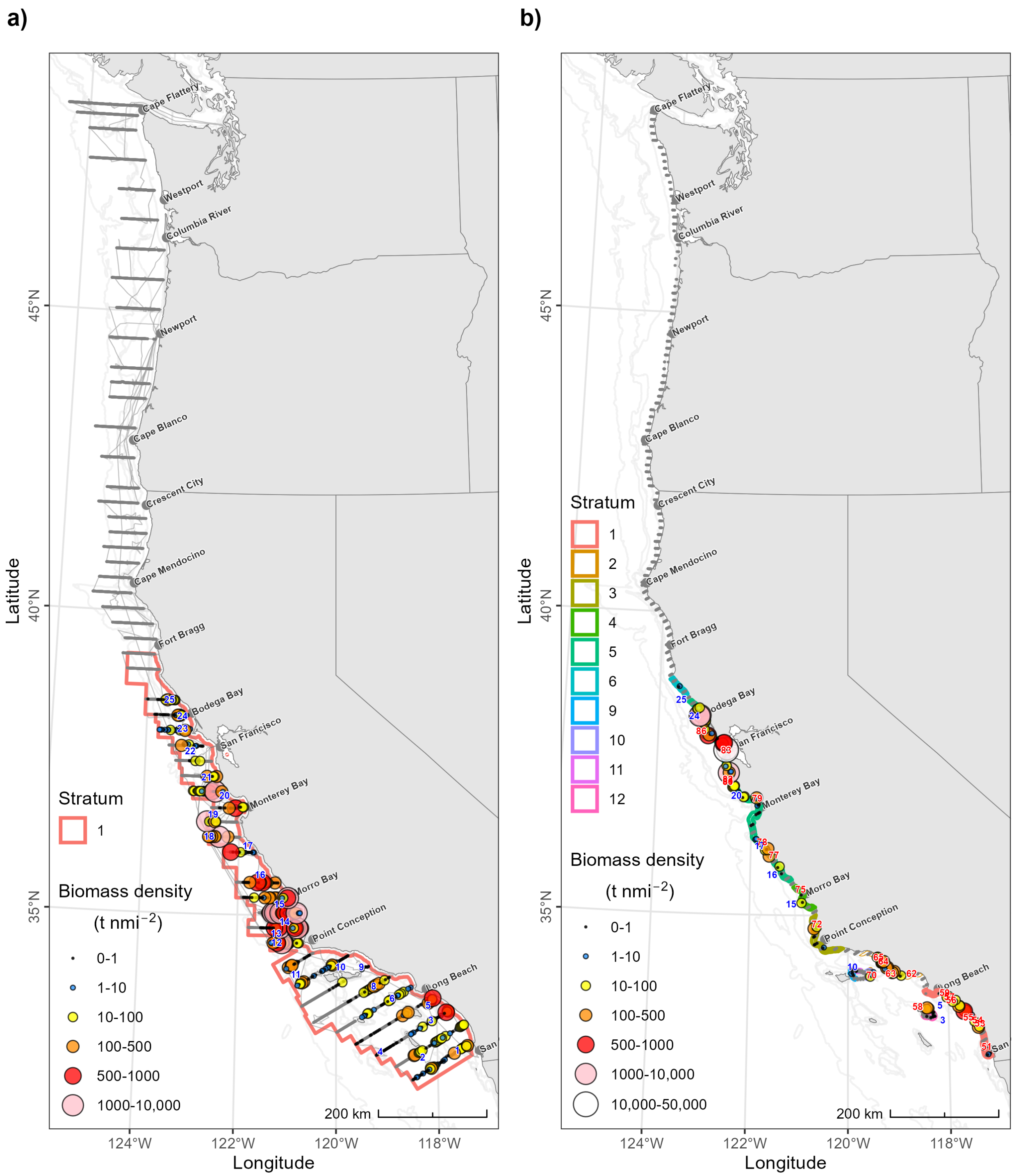

Figure 21: Biomass densities (colored points) of central subpopulation of Northern Anchovy (*Engraulis mordax*), per stratum, in the a) core and b) nearshore survey regions. Overlaid are the locations of trawl clusters (blue numbers) or purse-seine samples (red numbers) with at least one Northern Anchovy in each stratum (colored polygons). Thick gray lines represent acoustic transects.

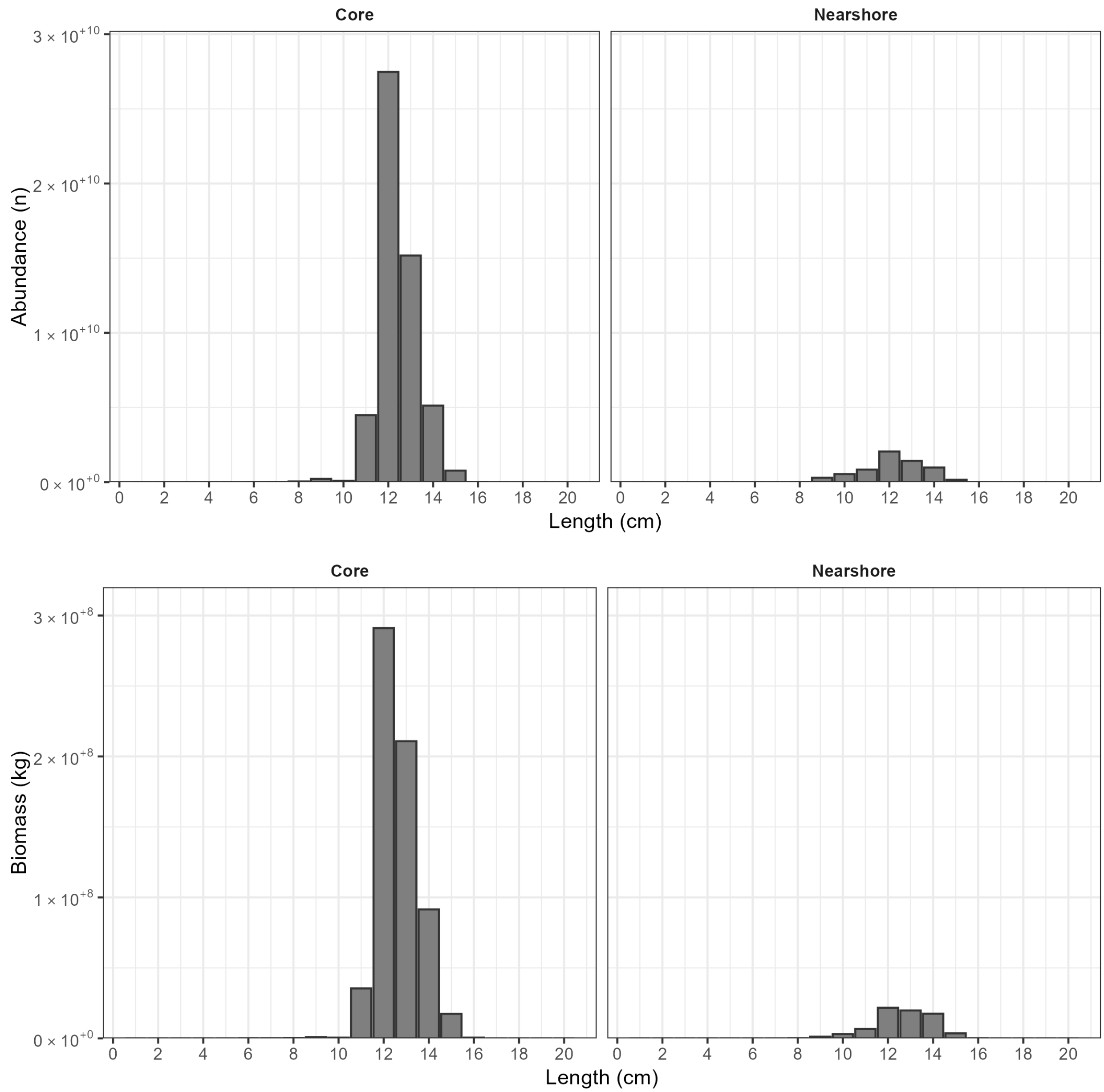

Figure 22: Abundance estimates (n) versus standard length (L_S, in cm, upper panels) and biomass (t) versus L_S (lower panels) for the central subpopulation of Northern Anchovy (*Engraulis mordax*) in the core and nearshore survey regions.

3.7.2 Pacific Sardine

3.7.2.1 Northern subpopulation

The total estimated biomass of the northern subpopulation of Pacific Sardine was 66,640 t ($CI_{95\%}$ = 11,478 - 169,859 t, CV = 56%; **Table 9**). In the core region, biomass was 40,799 t ($CI_{95\%}$ = 215 - 124,265 t, CV = 89%; **Table 9**), and was observed between Pt. Conception and Newport (**Fig. 23a**). L_S ranged from 13 to 24 cm with a mode at 20 cm (**Table 10**, **Fig. 24**). In the nearshore region, biomass was 25,841 t ($CI_{95\%}$ = 11,263 - 45,594 t, CV = 34%; **Table 9**), comprising 38.8% of the total biomass. Biomass was distributed between Pt. Conception and Cape Mendocino, but was most abundant along the Big Sur Coast and between Fort Bragg and Cape Mendocino (**Fig. 23b**). Lengths in the nearshore region had a mode at 18 cm (**Table 10**, **Fig. 24**).

Table 9: Biomass estimates (metric tons, t) and their precisions (upper and lower 95% confidence intervals, $CI_{95\%}$; and coefficients of variation, CVs) for the northern subpopulation of Pacific Sardine (*Sardinops sagax*) in the core and nearshore survey regions. Stratum areas are nmi^2 and distance covered by transects is in nmi.

Stratum					Trawl		Biomass			
Region	Number	Area	Transects	Distance	Clusters	Individuals	$\hat{B}$	$CI_{L,95\%}$	$CI_{U,95\%}$	CV
Core	2	6,111	10	372	3	12	51	12	99	44
	3	4,490	8	271	3	66	40,622	68	124,051	89
	4	2,561	5	179	1	1	0	0	1	54
	5	5,128	5	198	1	1	126	0	364	84
	All	18,290	28	1,021	8	80	40,799	215	124,265	89
Nearshore	4	415	14	54	6	256	10,232	1,311	24,269	59
	5	324	9	34	3	9	2,745	10	9,684	99
	6	432	15	57	6	142	12,797	2,021	27,219	49
	7	169	6	24	2	3	66	11	158	65
	All	1,340	44	170	17	410	25,841	11,263	45,594	34
All	**-**	**19,630**	**72**	**1,191**	**25**	**490**	**66,640**	**11,478**	**169,859**	**56**

Table 10: Abundance estimates (total number of individuals) versus standard length (L_S, cm) for the northern subpopulation of Pacific Sardine (*Sardinops sagax*) in the core and nearshore survey regions.

	Region	
L_S	Core	Nearshore
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	1,039,445	0
14	650,230	251
15	0	0
16	0	22,970,455
17	0	87,372,735
18	0	73,869,857
19	95,485,434	12,423,784
20	206,754,211	40,646,475
21	84,705,761	34,240,265
22	9,388,342	14,780,205
23	3,036	1,089,546
24	221,450	16,522,844
25	0	0
26	0	1,025,319
27	0	0
28	0	0
29	0	0
30	0	0

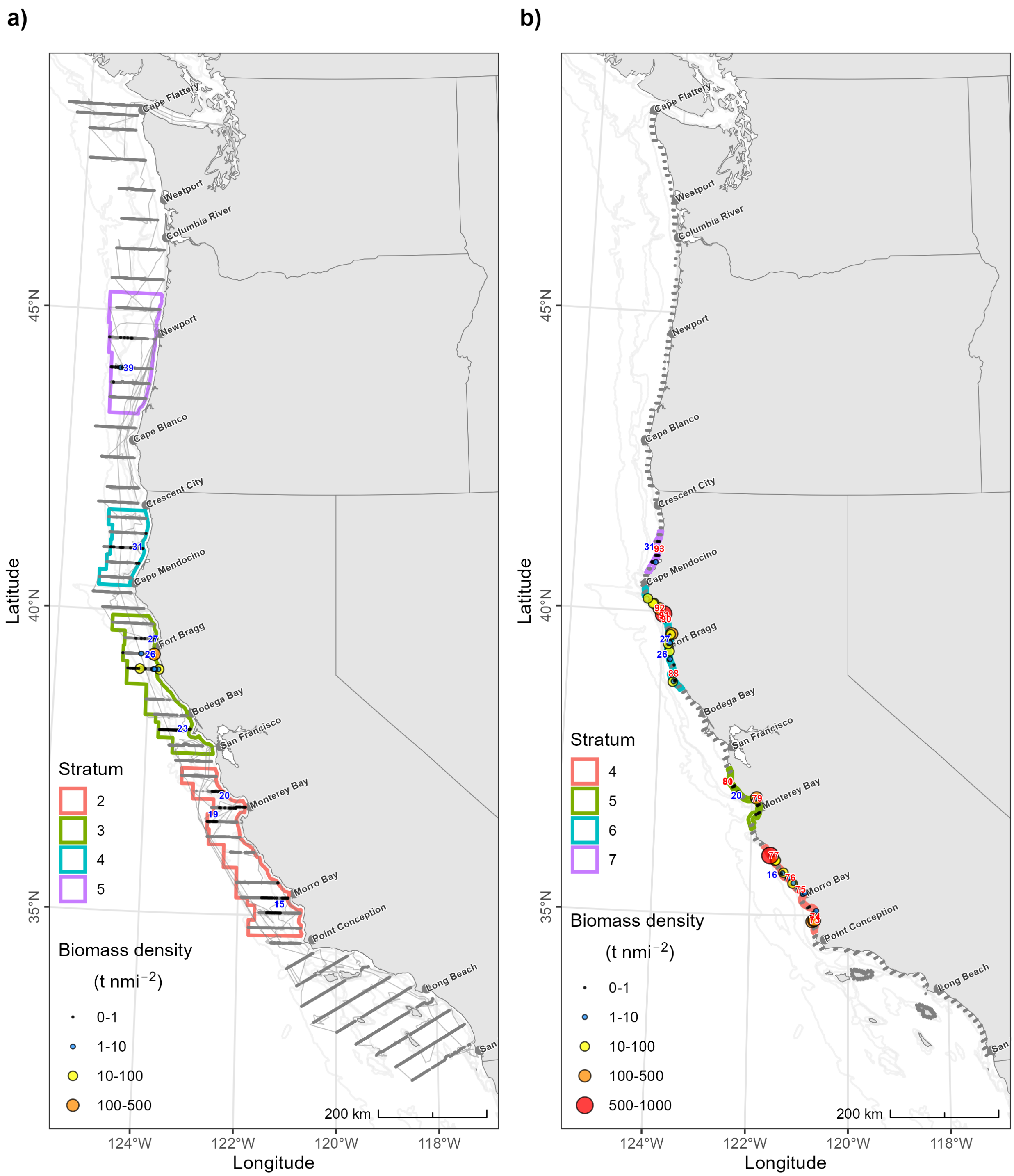

Figure 23: Biomass densities (colored points) of the northern subpopulation of Pacific Sardine (*Sardinops sagax*), per stratum, in the a) core and b) nearshore survey regions. Overlaid are the locations of trawl clusters (blue numbers) or purse-seine samples (red numbers) with at least one Pacific Sardine in each stratum (colored polygons). Thick gray lines represent acoustic transects.

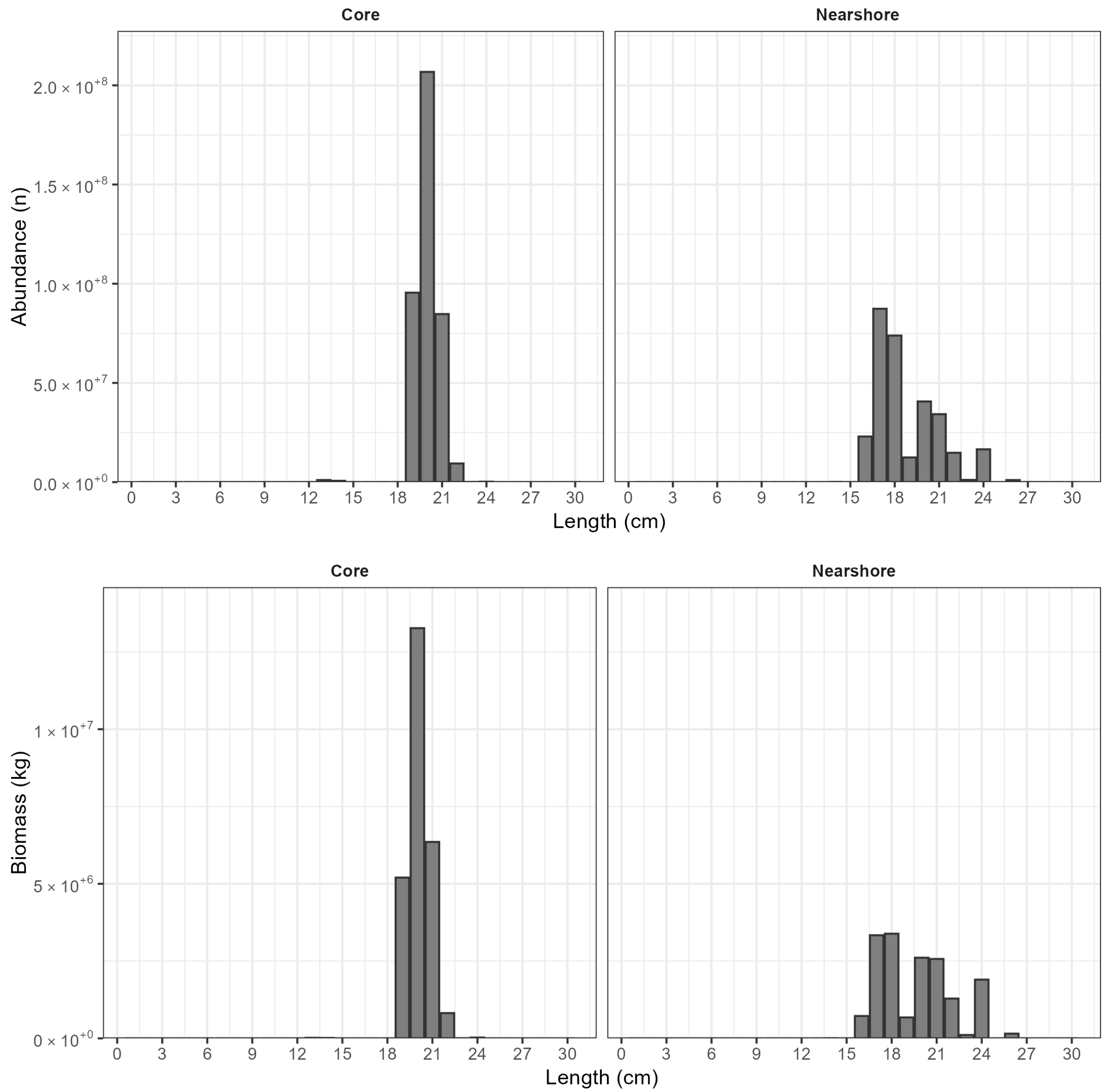

Figure 24: Abundance estimates (n) versus standard length (L_S, in cm, upper panels) and biomass (t) versus L_S (lower panels) for the northern subpopulation of Pacific Sardine (*Sardinops sagax*) in the core and nearshore survey regions.

3.7.2.2 Southern subpopulation

The total estimated biomass of the southern subpopulation of Pacific Sardine was 20,049 t ($CI_{95\%}$ = 8,869 - 33,605 t, CV = 29%; **Table 11**). In the core region, biomass was 833 t ($CI_{95\%}$ = 1.17 - 2,215 t, CV = 71%; **Table 11**), and was distributed between San Diego and Long Beach (**Fig. 25a**). L_S ranged from 10 to 24 cm with a mode at 19 cm (**Table 12**, **Fig. 26**). In the nearshore region, biomass was 19,216 t ($CI_{95\%}$ = 8,868 - 31,390 t, CV = 30%; **Table 11**), comprising 96% of the total biomass. The nearshore biomass was distributed throughout the survey area, but was most abundant near San Diego, Long Beach, and Santa Barbara. Lengths in the nearshore region had a mode at 16 cm (**Table 12**, **Fig. 26**).

Table 11: Biomass estimates (metric tons, t) and their precisions (upper and lower 95% confidence intervals, $CI_{95\%}$; and coefficients of variation, CVs) for the southern subpopulation of Pacific Sardine (*Sardinops sagax*) in the core and nearshore survey regions. Stratum areas are nmi^2 and distance covered by transects is in nmi.

Stratum					Trawl		Biomass			
Region	Number	Area	Transects	Distance	Clusters	Individuals	$\hat{B}$	$CI_{L,95\%}$	$CI_{U,95\%}$	CV
Core	1	6,491	4	316	2	399	833	1	2,215	71
	All	6,491	4	316	2	399	833	1	2,215	71
Nearshore	1	173	6	26	3	101	7,563	1,018	15,615	51
	2	268	7	34	3	150	7,440	1,047	15,510	51
	3	267	7	29	4	168	3,956	150	8,757	59
	8	56	8	15	2	51	20	1	46	61
	9	47	7	15	2	51	65	0	193	85
	10	41	7	14	1	398	172	50	327	41
	All	852	42	133	13	919	19,216	8,868	31,390	30
All	**-**	**7,344**	**46**	**448**	**15**	**1,317**	**20,049**	**8,869**	**33,605**	**29**

Table 12: Abundance estimates (total number of individuals) versus standard length (L_S, cm) for the southern subpopulation of Pacific Sardine (*Sardinops sagax*) in the core and nearshore survey regions.

	Region	
L_S	Core	Nearshore
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	67,329	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	30,051,389
16	0	148,076,856
17	0	114,325,688
18	693,864	40,111,881
19	3,816,498	4,573,271
20	3,030,320	2,065,681
21	1,018,084	116,487
22	92,606	10,596
23	0	0
24	23,152	2,649
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0
30	0	0

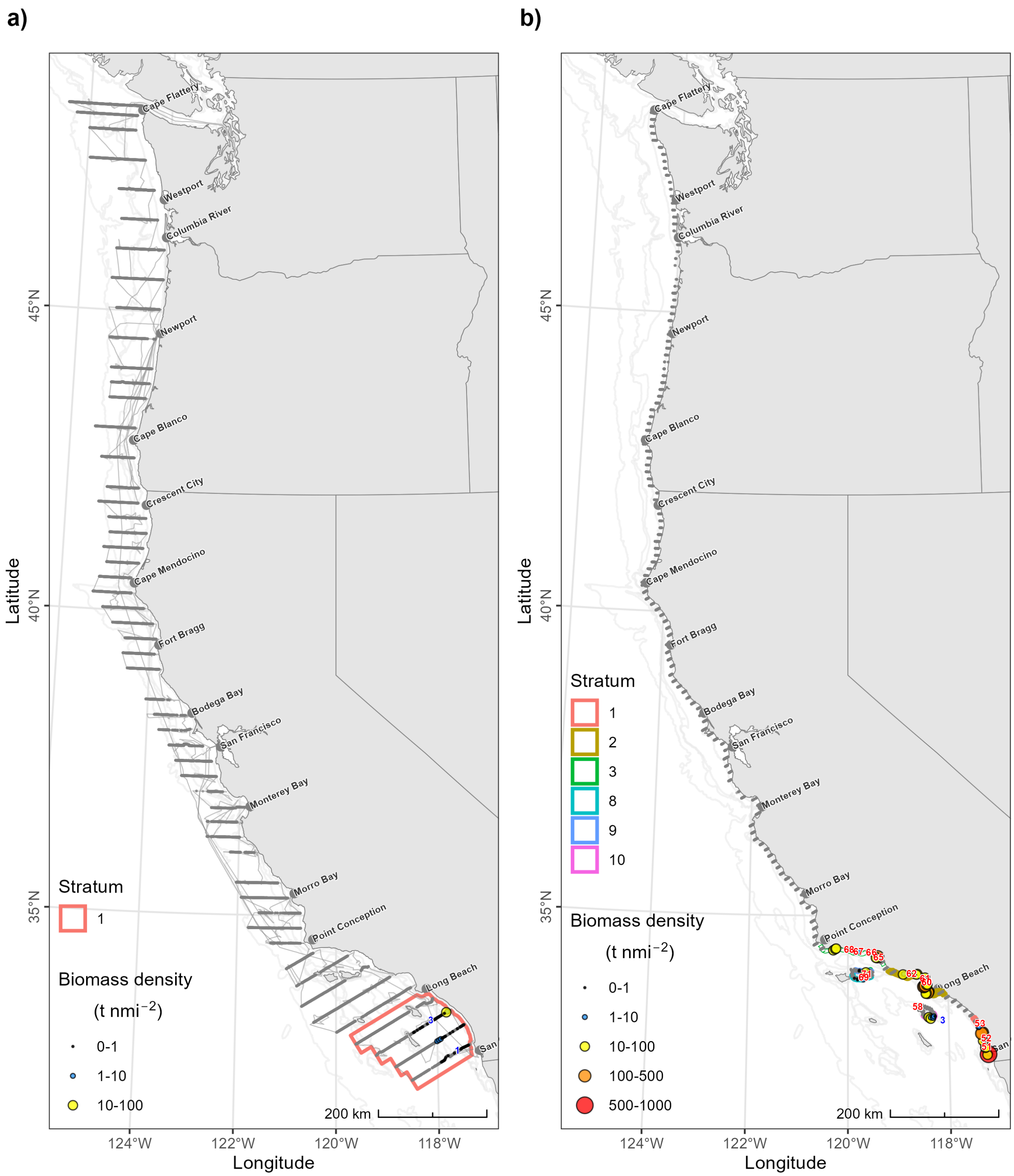

Figure 25: Biomass densities (colored points) of the southern subpopulation of Pacific Sardine (*Sardinops sagax*), per stratum, in the a) core and b) nearshore survey regions. Overlaid are the locations of trawl clusters (blue numbers) or purse-seine samples (red numbers) with at least one Pacific Sardine in each stratum (colored polygons). Thick gray lines represent acoustic transects.

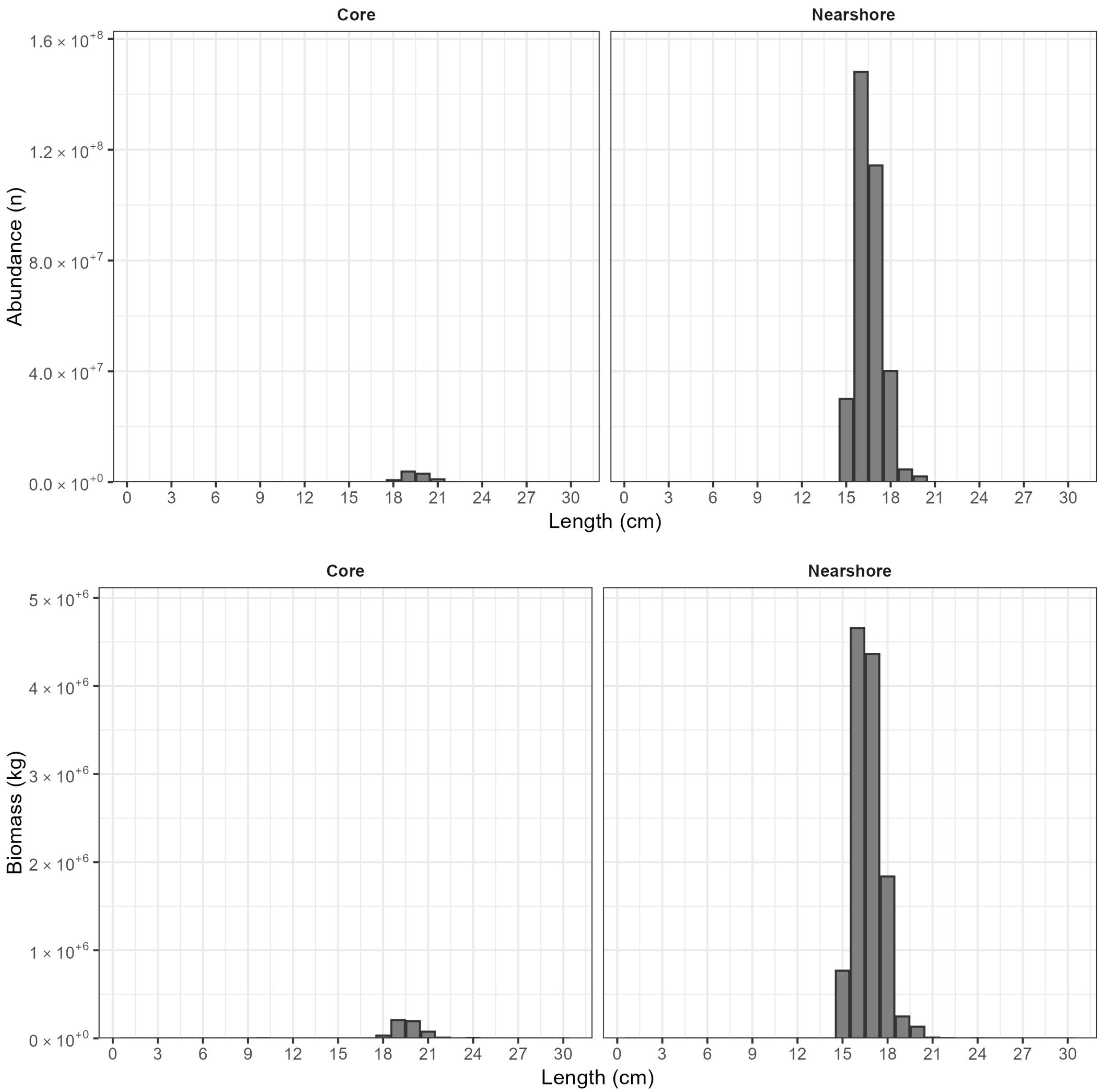

Figure 26: Abundance estimates (n) versus standard length (L_S, in cm, upper panels) and biomass (t) versus L_S (lower panels) for the southern subpopulation of Pacific Sardine (*Sardinops sagax*) in the core and nearshore survey regions.

3.7.2.3 All Pacific Sardines in U.S. waters

The estimated biomass of all Pacific Sardines in U.S. waters, including both the northern and southern subpopulations in the core and nearshore areas, was 86,689 t ($CI_{95\%}$ = 20,347 - 203,464 t, CV = 44%).

3.7.3 Pacific Mackerel

The total estimated biomass of Pacific Mackerel was 10,586 t ($CI_{95\%}$ = 4,169 - 18,555 t, CV = 25%; **Table 13**). In the core region, biomass was 4,088 t ($CI_{95\%}$ = 855 - 8,791 t, CV = 50%) and was sparsely distributed between San Diego and Cape Flattery (**Fig. 27a**). The distribution of L_F ranged from 14 to 43 cm with modes at 27 and 42 cm (**Table 14**, **Fig. 28**). In the nearshore region, biomass was 6,498 t ($CI_{95\%}$ = 3,314 - 9,764 t, CV = 25%; **Table 13**, **Fig. 27b**), comprising 61.4% of the total biomass, and was mostly present in along the mainland coast in the SCB and around Santa Cruz and Santa Catalina Islands. Lengths in the nearshore region had modes at 23, 27, and 41 cm.

Table 13: Biomass estimates (metric tons, t) and their precisions (upper and lower 95% confidence intervals, $CI_{95\%}$; and coefficients of variation, CVs) for Pacific Mackerel (*Scomber japonicus*) in nearshore survey region. Stratum areas are nmi^2 and distance covered by transects is in nmi.

Stratum					Trawl		Biomass			
Region	Number	Area	Transects	Distance	Clusters	Individuals	$\hat{B}$	$CI_{L,95\%}$	$CI_{U,95\%}$	CV
Core	1	6,491	4	316	2	81	643	3	1,705	71
	2	1,849	4	128	1	1	2	0	7	86
	3	1,676	3	96	1	1	60	0	175	79
	4	6,638	6	250	2	51	3,380	523	8,071	59
	5	4,769	4	231	1	4	4	0	9	60
	All	21,423	21	1,021	7	139	4,088	855	8,791	50
Nearshore	1	140	5	21	2	10	2,016	81	4,424	55
	2	268	7	34	2	10	654	193	1,161	39
	3	106	4	15	1	3	1,198	0	3,155	76
	4	315	12	44	1	7	719	307	1,162	31
	5	57	9	18	1	50	689	74	1,455	52
	6	19	3	6	1	80	14	0	30	83
	7	22	3	6	1	50	1,207	0	2,324	49
	All	926	43	145	8	210	6,498	3,314	9,764	25
All	**-**	**22,350**	**64**	**1,165**	**15**	**349**	**10,586**	**4,169**	**18,555**	**25**

Table 14: Abundance estimates (total number of individuals) versus fork length (L_F, cm) for Pacific Mackerel (*Scomber japonicus*) in the core and nearshore survey regions.

	Region	
L_F	Core	Nearshore
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	67,329	0
15	0	0
16	0	0
17	0	0
18	0	0
19	0	0
20	0	0
21	0	0
22	0	741,253
23	69,902	2,581,775
24	104,853	1,386,652
25	13,157	593,391
26	0	3,448,630
27	34,951	7,578,284
28	293,337	7,480,457
29	69,902	3,646,821
30	209,705	4,482
31	174,754	3,735
32	314,558	6,723
33	174,754	3,735
34	209,705	4,482
35	174,754	3,735
36	69,902	1,494
37	0	0
38	480,888	747
39	398,581	92,728
40	398,581	92,728
41	1,236,652	367,924
42	891,875	0
43	1,032,536	91,981
44	0	0
45	0	0
46	0	0
47	0	0

Table 14: Abundance estimates (total number of individuals) versus fork length (L_F, cm) for Pacific Mackerel (*Scomber japonicus*) in the core and nearshore survey regions. *(continued)*

L_F	Core	Nearshore
48	0	0
49	0	0
50	0	0

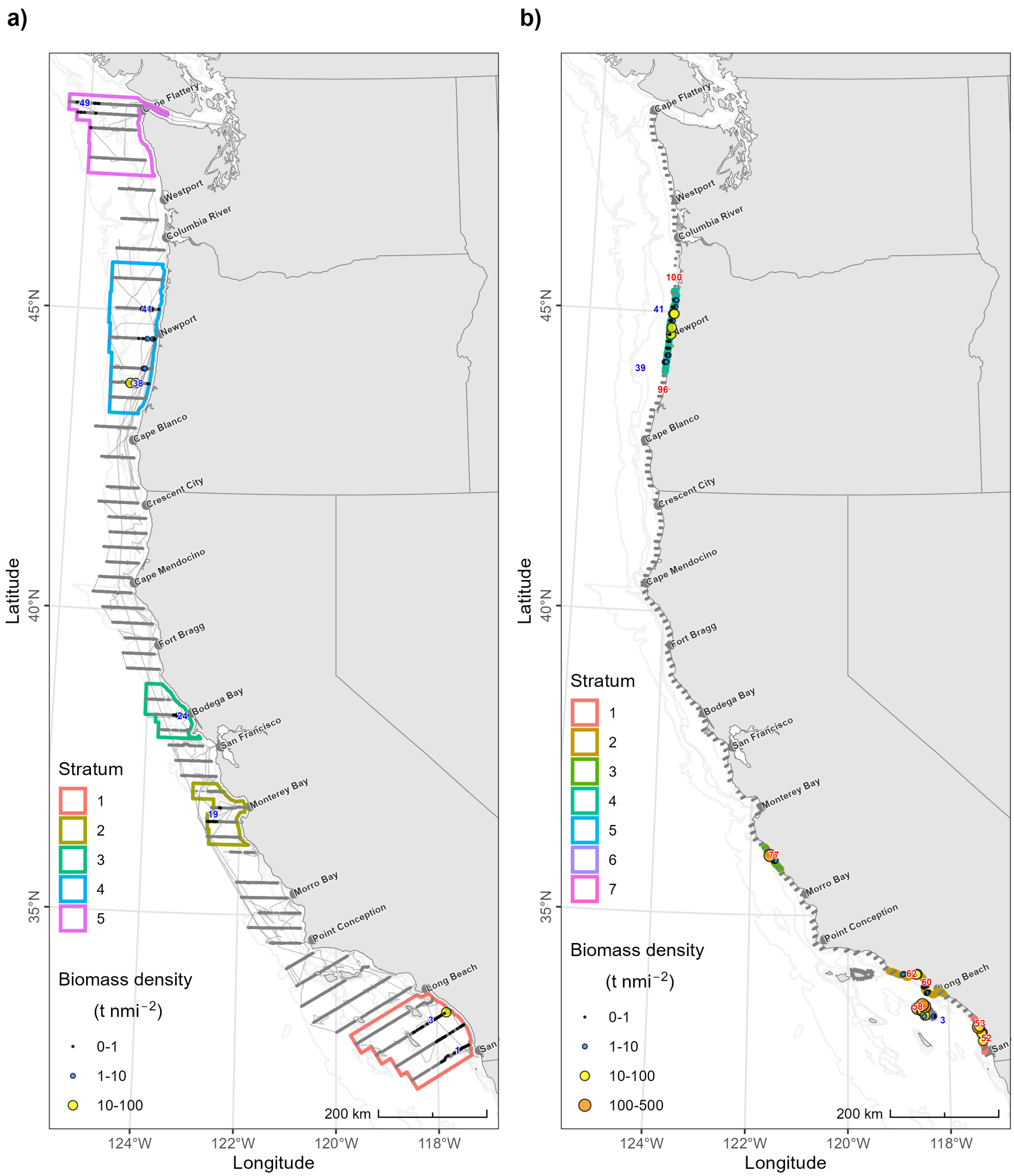

Figure 27: Biomass densities (colored points) of Pacific Mackerel (*Scomber japonicus*), per stratum, in the a) core and b) nearshore survey regions. Overlaid are the locations of trawl clusters (blue numbers) or purse-seine samples (red numbers) with at least one Pacific Mackerel in each stratum (colored polygons). Thick gray lines represent acoustic transects.

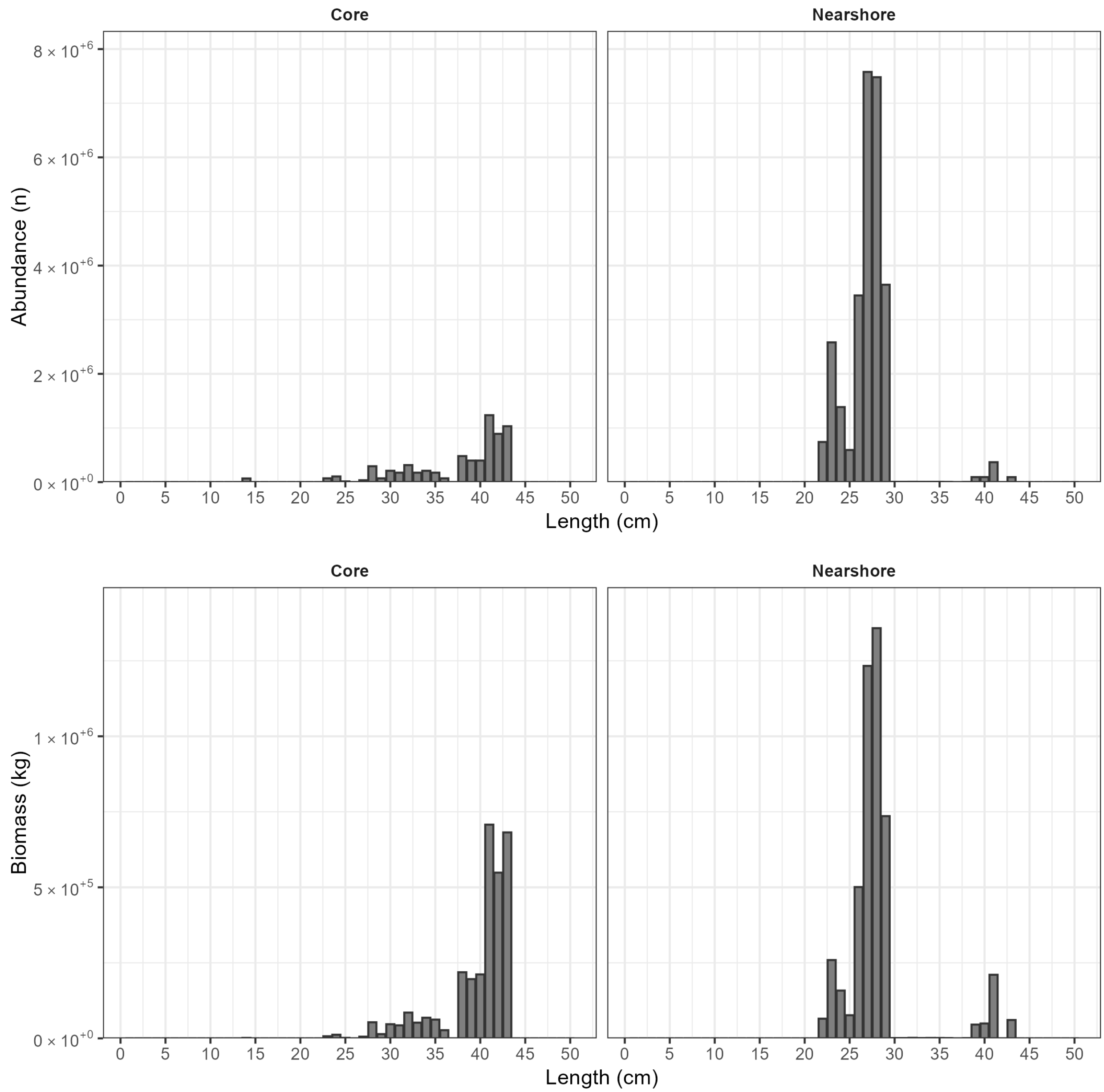

Figure 28: Abundance estimates (n) versus fork length (L_F, in cm, upper panels) and biomass (t) versus L_S (lower panels) for Pacific Mackerel (*Scomber japonicus*) in the core and nearshore survey regions.

3.7.4 Jack Mackerel

The total estimated biomass of Jack Mackerel was 741,276 t ($CI_{95\%}$ = 421,184 - 1,095,509 t, CV = 21%; **Table 15**). In the core region, the biomass was 668,518 t ($CI_{95\%}$ = 384,221 - 979,963 t, CV = 23%; **Table 15**), was distributed throughout the entire survey area, but was greatest north of Bodega Bay (**Fig. 29a**). L_F ranged from 4 to 55 cm, with modes at 11, 25, and 41 cm. (**Table 16**, **Fig. 30**). In the nearshore region, the biomass was 72,759 t ($CI_{95\%}$ = 36,964 - 115,545 t, CV = 28%; **Table 15**), comprising 9.8% of the total biomass. Biomass was present throughout the nearshore survey area, but was greatest between Cape Mendocino and Astoria (**Fig. 29b**). Lengths in the nearshore region had modes at 14, 30, and 41 cm (**Table 16**, **Fig. 30**).

Table 15: Biomass estimates (metric tons, t) and their precisions (upper and lower 95% confidence intervals, $CI_{95\%}$; and coefficients of variation, CVs) for Jack Mackerel (*Trachurus symmetricus*) in the core and nearshore survey regions. Stratum areas are nmi^2 and distance covered by transects is in nmi.

Stratum					Trawl		Biomass			
Region	Number	Area	Transects	Distance	Clusters	Individuals	$\hat{B}$	$CI_{L,95\%}$	$CI_{U,95\%}$	CV
Core	1	14,323	10	663	11	1,608	4,206	2,120	5,971	23
	2	2,608	5	153	2	57	103	0	216	54
	3	10,523	19	675	11	3,603	326,810	87,283	634,948	43
	4	16,952	15	671	14	6,775	337,398	211,824	443,575	18
	All	44,406	49	2,161	37	12,044	668,518	384,221	979,963	23
Nearshore	1	85	3	12	-	-	0	0	1	86
	2	85	3	10	1	1	1	0	3	82
	3	266	9	35	2	819	19,154	554	54,530	82
	4	108	4	15	2	107	24	0	61	65
	5	231	9	34	2	2,387	4,576	616	11,768	69
	6	554	20	76	5	1,183	16,186	8,547	28,001	31
	7	445	17	63	4	284	32,220	14,240	55,239	34
	8	201	7	24	2	53	201	42	423	49
	9	72	10	19	3	57	319	13	851	76
	10	52	8	17	4	65	16	0	46	84
	11	73	13	26	2	362	62	11	142	60
	All	2,174	103	330	24	5,318	72,759	36,964	115,545	28
All	**-**	**46,580**	**152**	**2,491**	**61**	**17,361**	**741,276**	**421,184**	**1,095,509**	**21**

Table 16: Abundance estimates (total number of individuals) versus fork length (L_F, cm) for Jack Mackerel (*Trachurus symmetricus*) in the core and nearshore survey regions.

	Region	
L_F	Core	Nearshore
1	0	0
2	0	0
3	0	0
4	19,777,288	0
5	11,247,255	0
6	31,354,555	0
7	29,725,893	0
8	14,997,367	5,870
9	18,815,680	20,593
10	19,173,981	80,375
11	42,836,274	341,797
12	19,599,807	152,345
13	1,209,205	196,408
14	41,565	99,552
15	166,260	107,639
16	166,260	228,869
17	497,447	791,022
18	1,457,576	1,364,118
19	1,326,351	785,310
20	1,538,534	694,990
21	1,122,547	412,593
22	4,406,504	123,648
23	5,173,347	17,608
24	4,675,757	13,428
25	71,890	1,634
26	4,688,411	4,930
27	5,336,730	3,709
28	2,342,554	2,440
29	1,171,277	1,220
30	0	30,492,346
31	0	0
32	202,005	0
33	248,915	0
34	202,005	0
35	0	0
36	275,305	176
37	1,712,585	255,495
38	10,540,521	566,408
39	18,722,070	3,169,881
40	60,321,815	4,939,058
41	68,757,221	9,787,102
42	54,804,719	7,392,142
43	73,168,443	7,869,416
44	76,494,833	6,734,162
45	71,449,008	3,353,980
46	55,911,492	4,057,618
47	20,481,417	6,584,823

Table 16: Abundance estimates (total number of individuals) versus fork length (L_F, cm) for Jack Mackerel (*Trachurus symmetricus*) in the core and nearshore survey regions. *(continued)*

L_F	Core	Nearshore
48	62,413,799	1,247,462
49	23,773,326	2,968,266
50	20,754,148	645,602
51	18,938,361	498,221
52	11,123,662	514,042
53	3,361,304	715,659
54	959,927	49
55	298,289	0
56	0	0
57	0	0
58	0	0
59	0	0
60	0	0

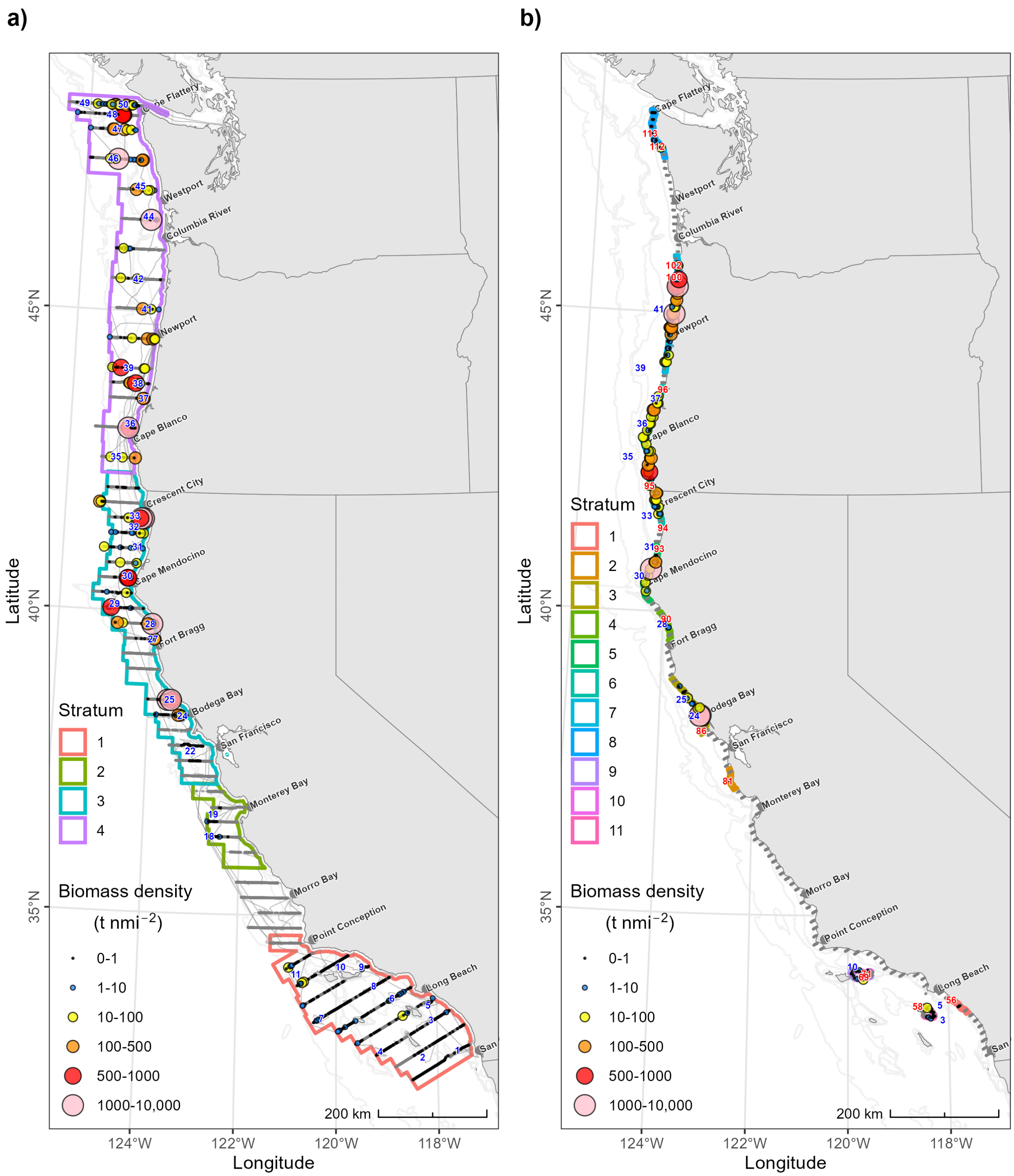

Figure 29: Biomass densities (colored points) of Jack Mackerel (*Trachurus symmetricus*), per stratum, in the a) core and b) nearshore survey regions. Overlaid are the locations of trawl clusters (blue numbers) or purse-seine samples (red numbers) with at least one Jack Mackerel in each stratum (colored polygons). Thick gray lines represent acoustic transects.

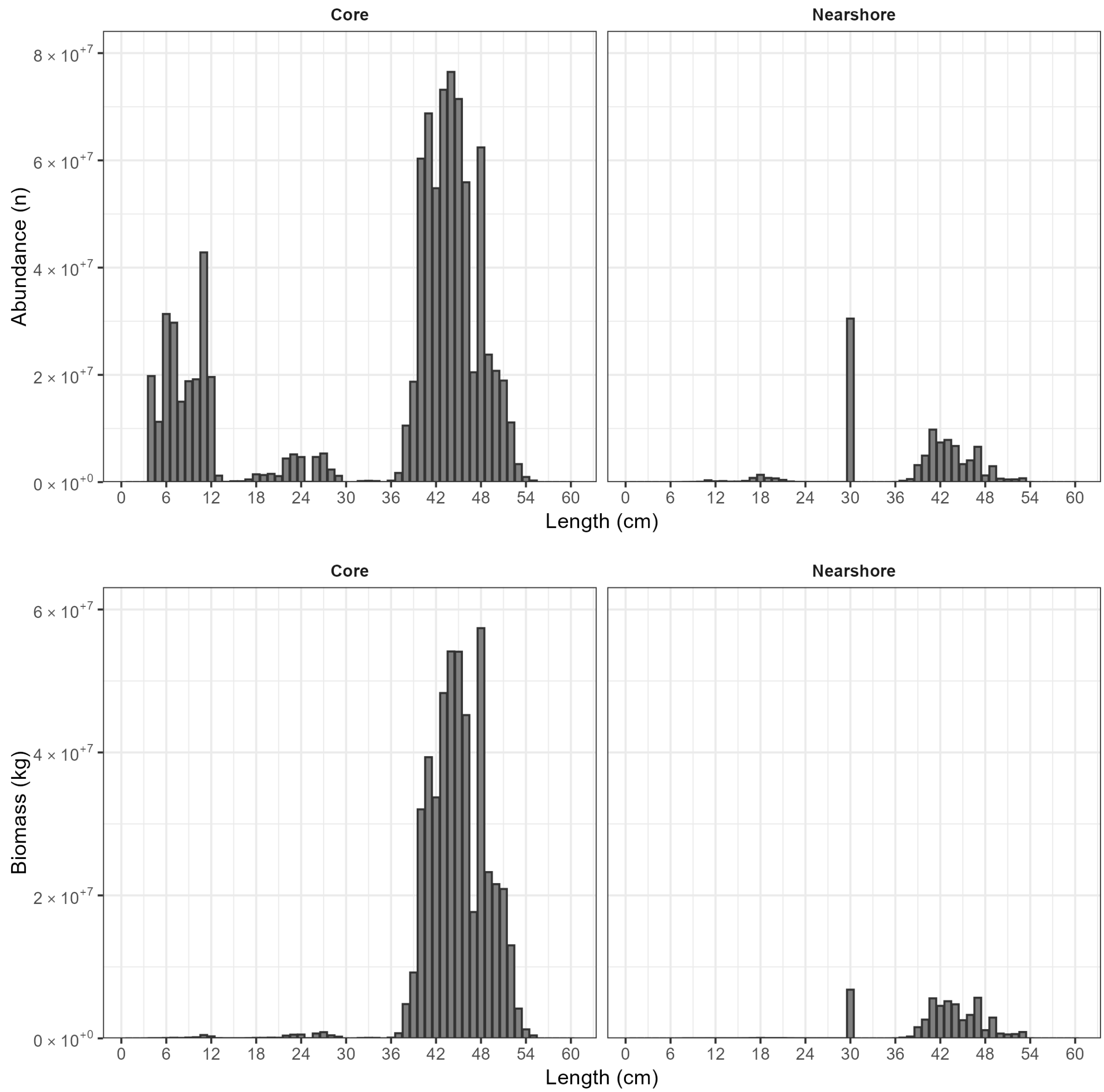

Figure 30: Abundance estimates (n) versus fork length (L_F, in cm, upper panels) and biomass (t) versus L_S (lower panels) for Jack Mackerel (*Trachurus symmetricus*) in the core and nearshore survey regions.

3.7.5 Pacific Herring

The total estimated biomass of Pacific Herring was 111,843 t ($CI_{95\%}$ = 42,030 - 223,110 t, CV = 30%; **Table 17**). In the core region, biomass was 76,299 t ($CI_{95\%}$ = 31,632 - 126,692 t, CV = 33%; **Table 17**), and was distributed from approximately Cape Mendocino to Cape Flattery (**Fig. 31a**). L_F in the core region ranged from 9 to 25 cm, with a mode at 15 cm (**Table 18**, **Fig. 32**). In the nearshore region, biomass was 35,544 t ($CI_{95\%}$ = 10,398 - 96,418 t, CV = 65%; **Table 17**, **Fig. 31b**), or 32% of the total biomass, was distributed from San Francisco to Cape Flattery (**Fig. 32**), but was most abundant north of Newport. Lengths in the nearshore region had modes at 9 and 13 cm (**Table 18**, **Fig. 32**).

Table 17: Biomass estimates (metric tons, t) and their precisions (upper and lower 95% confidence intervals, $CI_{95\%}$; and coefficients of variation, CVs) for Pacific Herring (*Clupea pallasii*) in the core and nearshore survey regions. Stratum areas are nmi^2 and distance covered by transects is in nmi.

Stratum					Trawl		Biomass			
Region	Number	Area	Transects	Distance	Clusters	Individuals	$\hat{B}$	$CI_{L,95\%}$	$CI_{U,95\%}$	CV
Core	1	5,971	10	366	3	279	5,855	41	16,927	86
	2	2,271	3	115	1	1	63	0	180	76
	3	9,976	7	305	6	6,893	38,315	3,259	84,718	54
	4	2,938	3	177	4	28,692	32,066	12,713	60,366	38
	All	21,156	23	963	13	35,865	76,299	31,632	126,692	33
Nearshore	1	200	6	25	1	2	416	0	959	66
	2	146	5	18	1	50	235	3	610	70
	3	79	3	11	1	50	16	0	50	84
	4	420	16	60	5	363	2,085	572	3,973	40
	5	979	38	134	10	280	32,791	7,914	93,251	70
	6	58	2	8	-	-	1	0	2	66
	All	1,883	70	257	18	745	35,544	10,398	96,418	65
All	**-**	**23,039**	**93**	**1,219**	**31**	**36,609**	**111,843**	**42,030**	**223,110**	**30**

Table 18: Abundance estimates (total number of individuals) versus fork length (L_F, cm) for Pacific Herring (*Clupea pallasii*) in the core and nearshore survey regions.

	Region	
L_F	Core	Nearshore
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	60,553,893
7	0	362,997,553
8	0	898,321,557
9	3,597,411	1,559,063,361
10	10,837,595	521,865,450
11	453,151	3,304,791
12	2,210,965	1,058,423
13	77,309,561	341,988,721
14	220,056,554	210,985,590
15	339,118,299	20,175,012
16	198,143,292	6,975,555
17	87,511,155	3,799,800
18	98,530,116	1,625,860
19	55,869,859	947,442
20	78,438,096	495,138
21	68,641,603	433,731
22	65,061,210	3,209
23	67,023,836	0
24	10,692,274	0
25	1,289,048	0
26	0	0
27	0	0
28	0	0
29	0	0
30	0	0

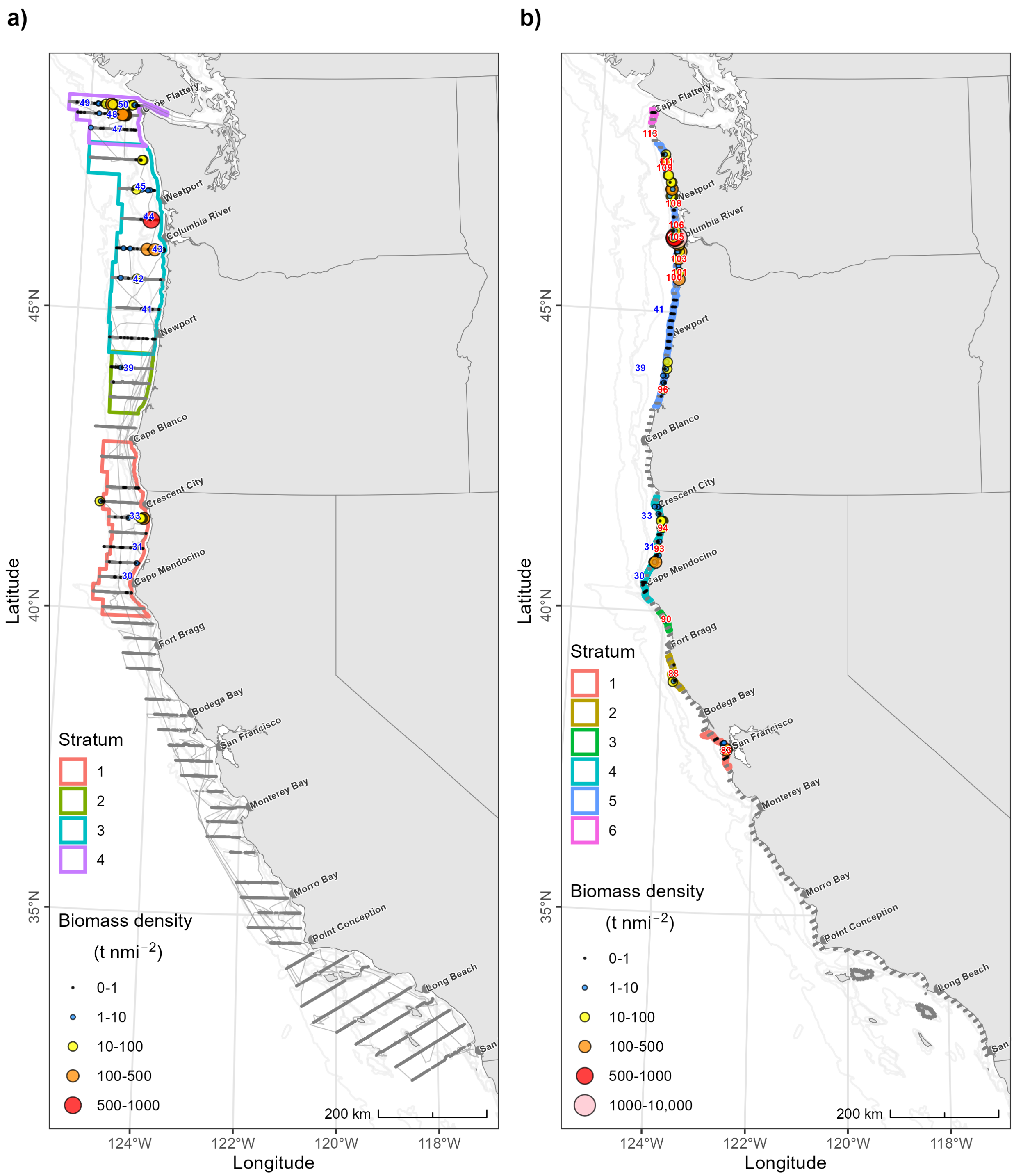

Figure 31: Biomass densities (colored points) of Pacific Herring (*Clupea pallasii*), per stratum, in the a) core and b) nearshore survey regions. Overlaid are the locations of trawl clusters (blue numbers) or purse-seine samples (red numbers) with at least one Pacific Herring in each stratum (colored polygons). Thick gray lines represent acoustic transects.

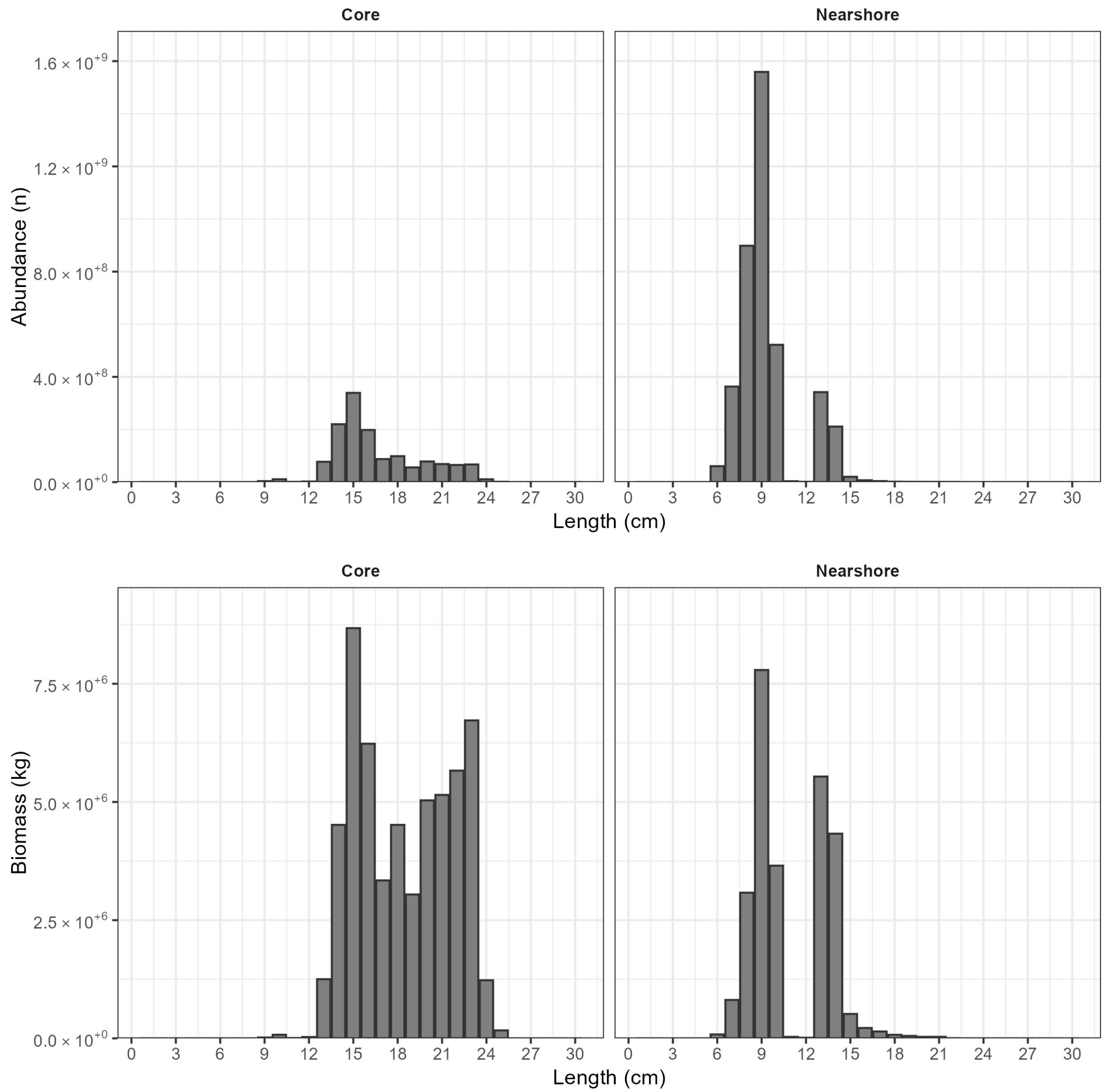

Figure 32: Abundance estimates (n) versus fork length (L_F, in cm, upper panels) and biomass (t) versus L_S (lower panels) for Pacific Herring (*Clupea pallasii*) in the core and nearshore survey regions.

4 Discussion

The primary objective of the ATM surveys is to estimate the biomasses, distributions, and demographics of CPS within the survey area at the time of the survey. The 2025 IWCPS allocated 81 DAS for the survey aboard *Shimada*. Due to inclement weather and personnel and mechanical issues with the ship and her crew, respectively, the ship was underway for only 69 DAS (or ~85%) and only 56 DAS (or ~69%) were available to conduct ATM sampling. The sampling of the nearshore region by F/Vs *Long Beach Carnage* and *Lisa Marie* was accomplished with minimal loss of survey days, all of which were testament to the planning, preparation, and skill of all parties involved. Coordination between the core and nearshore survey platforms had minimal spatial or temporal separation, except for when *Shimada* was not at sea for long and unanticipated periods of time.

Despite the losses of DAS, the summer 2025 survey area spanned the expected distribution of the northern subpopulation of Pacific Sardine and northern subpopulation of Northern Anchovy in U.S. waters, but also portions of the expected distribution of the southern subpopulation of Pacific Sardine, central subpopulation of Northern Anchovy, Pacific Mackerel, Jack Mackerel, and Pacific Herring. However, due to the loss of DAS, several acoustic transects were randomly dropped between Pt. Conception and Cape Mendocino, and every other transect was dropped between Brookings, OR and Cape Flattery, resulting in 30-nmi transect spacing and reduced trawl sampling effort for the latter, with an unknown effect on the precision of biomass estimates in those areas.

4.1 Biomass and abundance

4.1.1 Northern Anchovy

4.1.1.1 Northern subpopulation The estimated biomass of the northern subpopulation of Northern Anchovy in the survey region north of Astoria was 4,178 t ($CI_{95\%}$ = 99 - 11,164 t) in summer 2025. The northern subpopulation biomass has comprised a small fraction (0 to 5.4%) of the total CPS biomass in the CCE since at least 2015 (Stierhoff *et al.*, 2021a), and the 2025 point estimate is higher than the 164.38 t observed in summer 2024 (Stierhoff *et al.*, 2025).

4.1.1.2 Central subpopulation The estimated biomass of the central subpopulation of Northern Anchovy in the survey region was 1,238,065 t ($CI_{95\%}$ = 453,248 - 1,749,878 t), making up 56% of the total CPS biomass in summer 2025, and has comprised a substantial portion of the CPS biomass in the CCE since approximately 2016. The biomass point estimate in 2025 increased 79% from the 689,785 t estimated in summer 2024 (Stierhoff *et al.*, 2025). This estimate excludes an unquantified but relatively small amount of biomass attributed to deep (i.e., $\geq$ 30 m) Northern Anchovy schools in the nearshore region. This is an ongoing area of research to investigate how to better incorporate this biomass in any future revisions.

4.1.2 Pacific Sardine

4.1.2.1 Northern subpopulation The southern extent of northern subpopulation Pacific Sardine habitat was Pt. Conception based on the potential habitat model (Zwolinski and Demer, 2024). The northern extent based on the biological samples is southern Oregon. Unlike previous years, there was not a clear separation in the biomass density (**Fig. 13**) or length composition around the habitat break (**Fig. 13**) and visual differences in length compositions (**Fig. 34**). The estimated biomass of 66,640 t ($CI_{95\%}$ = 11,478 - 169,859 t) in the survey region was a decrease from the 77,703 t estimated in summer 2024 (Stierhoff *et al.*, 2025). However, unlike in 2024 when 99.7% of the biomass was in the nearshore region, the 2025 biomass attributed to the northern subpopulation was greater in the core survey regions. Since 2014, the ATM biomass of the northern subpopulation of Pacific Sardine has remained less than the 150,000 t rebuilding target adopted by the Pacific Fishery Management Council in 2020[11] (**Figs. 37**). Japanese Sardine (*S. melanosticta*) have been present in the survey area since 2022 (Longo *et al.*, 2024, 2025), but have not been separated out from Pacific Sardine biomass estimates. Since 2024, the length composition of the sardine complex in the NSP habitat has shown a decrease in the proportion of large sardine (200 mm and over) that were common in the Pacific Northwest (PNW) even after the closure of the fishery, but before the appearance of Japanese Sardine (see Stierhoff *et al.*, 2025, and references therein).

4.1.2.2 Southern subpopulation The estimated biomass of the southern subpopulation of Pacific Sardine was 20,049 t ($CI_{95\%}$ = 8,868.8 - 33,605 t), of which 19,216 t (96%) occurred in the nearshore region in the SCB. The southern subpopulation was first observed in U.S. waters by the SWFSC's ATM surveys in 2016 (323 t, Stierhoff *et al.*, 2021b). Since then, the southern subpopulation biomass in U.S. waters has persisted. The biomass estimated in 2025 is within the range of biomasses from 14,890 t estimated in summer 2019 (Stierhoff *et al.*, 2020) to 196,609 t in summer 2021 (Stierhoff *et al.*, 2023). In 2017, the summer survey did not extend into the SCB (Zwolinski *et al.*, 2019), and no summer survey was conducted in 2020 due to the COVID-19 pandemic. Unlike prior years, no contemporaneous survey of CPS was conducted by Mexico off Baja CA in summer 2025.

4.1.2.3 All Pacific Sardines in U.S. waters The estimated biomass of all Pacific Sardines in U.S. waters (i.e., excluding any biomass observed in Mexico or Canada), derived by combining the northern and southern subpopulation estimates, was 86,689 t ($CI_{95\%}$ = 20,347 - 203,464 t, CV = 44%, **Fig. 33**). The biomass of the southern subpopulation was first estimated in the summer of 2016, prior to which all biomass was attributed to the northern subpopulation. The combined biomass peaked in summer 2022, and has remained lower since.

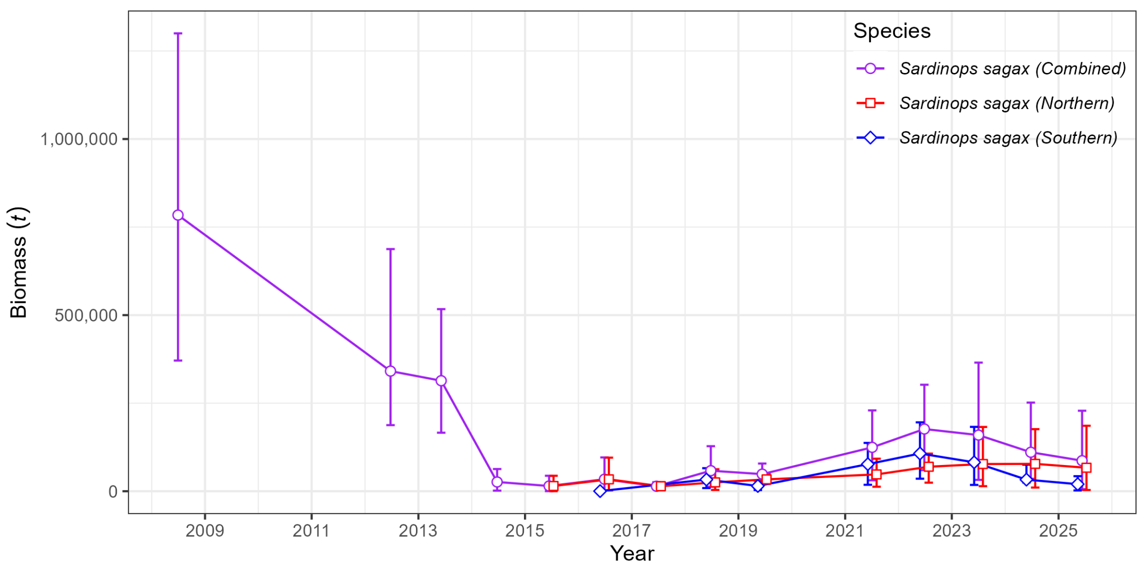

Figure 33: Estimated biomasses (t) of the northern, southern, and combined subpopulations of Pacific Sardine (*Sardinops sagax*) in U.S. waters since 2008. Error bars are approximate 95% confidence intervals based on 1,000 bootstrap estimates.

[11] https://www.pcouncil.org/documents/2020/08/g-1-attachment-1-pacific-sardine-rebuilding-plan-preliminary-environmental-analysis.pdf/

4.1.3 Pacific Mackerel

In summer 2025, the estimated biomass of Pacific Mackerel in the survey region was 10,586 t ($CI_{95\%}$ = 4,169 - 18,555 t), which is within the range of recent estimates (7,289 - 42,423) between 2016 and 2024, and comprised less than 1% of the total CPS biomass in the survey area.

4.1.4 Jack Mackerel

In summer 2025, the estimated biomass of Jack Mackerel in the survey region was 741,276 t ($CI_{95\%}$ = 421,184 - 1,095,509 t), with 9.8% of the total biomass in the nearshore region. The 2025 estimate was an increase from the 698,736 t estimated in summer 2024 (Stierhoff *et al.*, 2025), and comprised 34% of the total CPS biomass in the survey area.

4.1.5 Pacific Herring

In summer 2025, the estimated biomass of Pacific Herring in the survey region was 111,843 t ($CI_{95\%}$ = 42,030 - 223,110 t), with 32% of the total biomass in the nearshore region. The 2025 estimate was an increase from the 83,967 t estimated in summer 2024 (Stierhoff *et al.*, 2025), but similar to the estimate from 2023 (106,723 t), and comprised 5% of the total CPS biomass in the survey area.

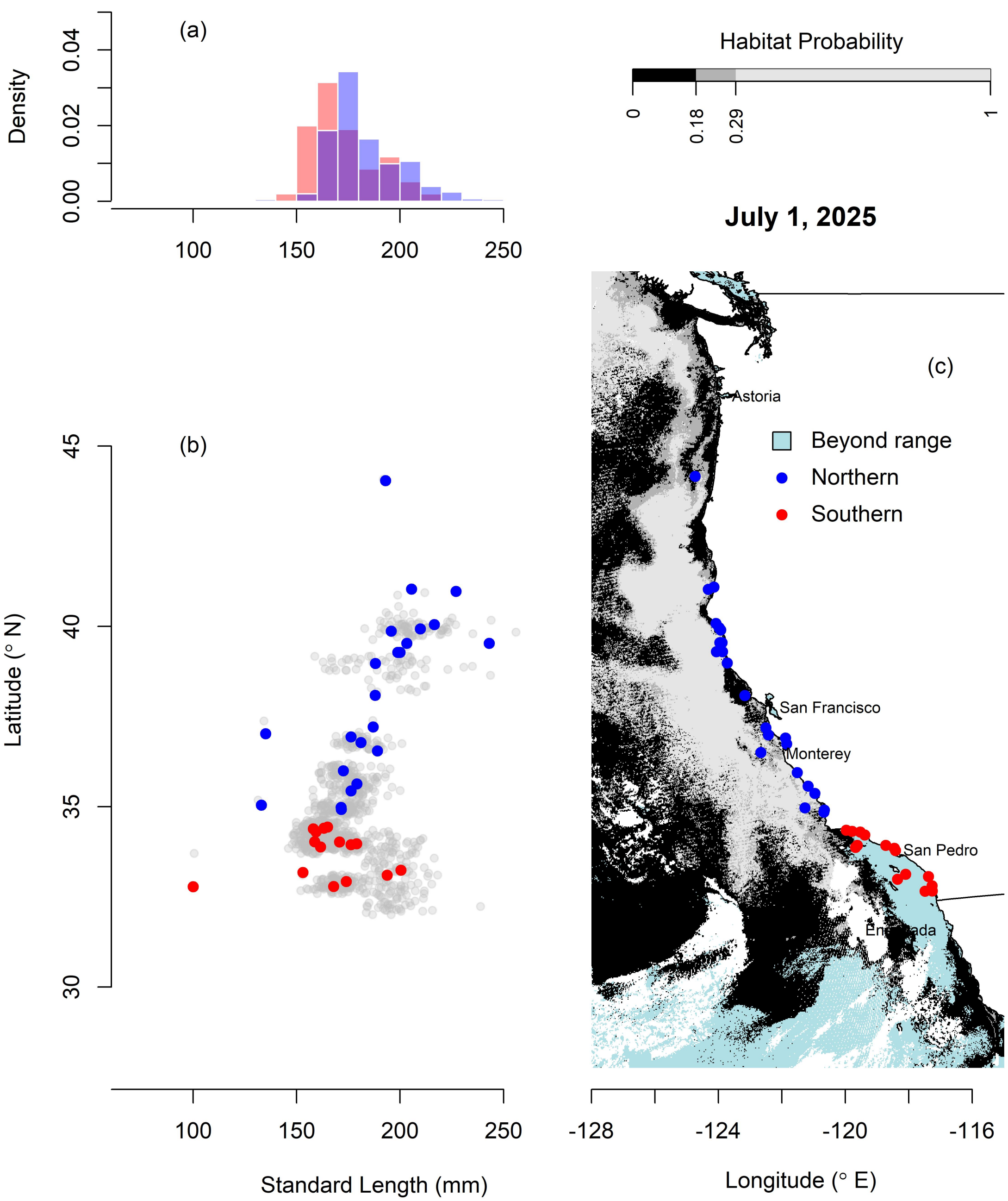

Figure 34: Summary of lengths for Pacific Sardine sampled during the summer 2025 survey: a) relative length distribution of individuals classified as northern (blue) and southern (red) subpopulations (NSP and SSP, respectively); b) individual length measurements (grey points) and mean lengths (blue and red points for NSP and SSP, respectively) for each trawl cluster versus latitude; and c) locations of trawls clusters with Pacific Sardine assigned to each subpopulation (blue and red points) based on the predicted potential habitat for the NSP (Zwolinski and Demer, 2024) at the time the survey passed Pt. Conception (July 1, 2025).

4.2 Uncertainty in the nearshore estimates

Accurate assignment of acoustic echoes to species is necessary for unbiased estimates of CPS biomass using the ATM. Acousticians often classify echoes based on visual similarities to those of representative echoes ground-truthed by daytime trawling. This "expert-classification" method is adequate in areas of gradually varying species composition and when different species have distinctive acoustic features. However, in regions with high species diversity, such as the California Current Ecosystem, CPS that co-occur in the epipelagic habitat can be difficult to differentiate. Instead of performing *ad hoc* classification of individual schools using the expert classification approach, SWFSC applies a nearest neighbor allocation of species composition from a cluster of proximal nighttime trawls. This method takes advantage of the typical dispersal of CPS in the upper water column during the night, allowing for the determination of the regional species composition and their lengths. The nighttime species proportions, weighted by their mean acoustic backscattering cross-sections, are used to apportion the backscatter of acoustically-identified epipelagic fish schools observed during the day. While the latter allows for an objective, repeatable, user-independent procedure that puts the burden of classification in judiciously placed trawls, its application to the nearshore daytime acoustic-seine survey requires additional consideration.

The use of nighttime trawl clusters for apportioning backscatter by species was devised under the working hypothesis that all CPS identified acoustically during the day migrate to and disperse in the upper mixed layer at night. Contrary to nighttime trawling, which targets randomly dispersed fishes, daytime purse-seining relies on the targeted sampling of individual schools, or portions of them. Therefore, each purse-seine sample is representative of a single school, whereas the nighttime trawl clusters can be composed of multiple schools. It then follows that daytime purse-seine sampling would require multiple sets randomly located along the transects to provide the same efficiency as a cluster of nighttime trawls. Purse-seining is further limited to capturing schools that are shallower than the depth of the net, which is approximately 27 m on *Long Beach Carnage* and 40 m on *Lisa Marie*. Additionally, the success of the capture is greater when the schools are closer to the surface or when the bottom is shallow enough to prevent fish escaping by diving below the net. These constraints are evident in the nearshore sampling off California where most of the nearshore purse-seine sampling occurs within 1 nmi from the coast (**Fig. 35**), despite the presence of CPS further offshore (**Fig. 17a**).

Figure 35: The nearshore survey track executed by *Long Beach Carnage* (continuous black line) and the location of purse-seine sets (white-filled circles). Of the 16 purse-seine sets performed in the mainland portion of this region, only one occurred in the offshore part of the transect, highlighting the preference for inshore sampling.

During the day, Pacific Sardine and Northern Anchovy form well-defined epipelagic schools. From 2008-2013, when Pacific Sardine dominated the CPS community, the majority of echosounder-detected CPS schools occurred in the upper mixed layer. As the central subpopulation of Northern Anchovy rebounded and began to dominate the CPS community off California, their schools were observed over a wider range of depths and often closer to the bottom than Pacific Sardine. Based on our experience and conversations with the operators of the purse-seine vessels, Northern Anchovy schools are often more well-defined, denser, and deeper than those of Pacific Sardine, making them more likely to escape the purse-seine sets in clear, deep water. That understanding led us to adapt a nearest-neighbor approach for using catches from the nearest purse-seine or trawl to apportion nearshore backscatter from the upper mixed layer, which is approximately between the surface and 30 m depth. Below the thermocline, echoes from CPS schools are considered to be Northern Anchovy or Pacific Herring, depending on latitude.

Unbiased classification of CPS in the epipelagic region still requires random or representative sampling of all schools observed along the transects. In the presence of a strong inshore-offshore gradient of the species distribution (**Fig. 35**), the preferential sampling in the nearshore region (**Fig. 35**) introduces an unquantified bias. Specifically, the preferential sampling of the Pacific Sardine-dominated region very close to the shore (i.e., less than 1 nmi in most cases; **Fig. 35**), is unlikely to capture well the transition to areas inhabited by Northern Anchovy. Using our standard approach, dense, unsampled CPS schools observed up to 5 nmi from the coast of central California were classified as Pacific Sardine based on purse-seine sets conducted very close to shore (**Figs. 35** and **36**). As a result, estimates of Pacific Sardine biomass would be positively biased by the inclusion of backscatter deeper and farther from shore that is more likely to be Northern Anchovy. In 2026, we plan to shift the timing of purse-seine sampling for the nearshore survey towards the evening, which is expected to allow for more representative biological sampling of CPS community.

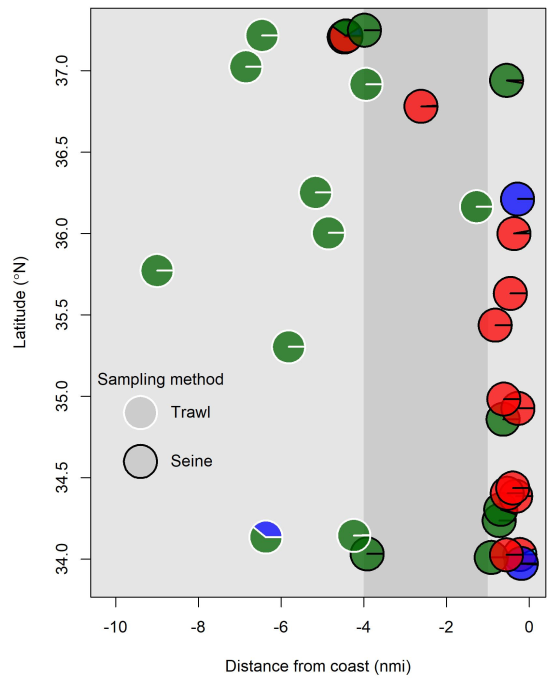

Figure 36: Relative species composition (by weight) of Northern Anchovy (green), Pacific Sardine (red) and Jack Mackerel (blue) in purse-seine (black border) and trawl (white border) samples collected off the central coast of California. The region between 1 to 4 nmi from the coast (gray-shaded region) has the least amount of biological sampling.

4.3 Ecosystem dynamics: Forage fish community

The acoustic-trawl method (ATM) has been used to monitor the biomasses and distributions of pelagic and mid-water fish stocks worldwide (e.g., Coetzee *et al.*, 2008; Karp and Walters, 1994; Simmonds *et al.*, 2009). In 2006, the SWFSC's ATM survey in the CCE focused on Pacific Sardine (Cutter and Demer, 2008), but evolved to assess the five most abundant CPS (Zwolinski *et al.*, 2014): Pacific Sardine, Northern Anchovy, Jack Mackerel, Pacific Mackerel, and Pacific Herring. In the CCE, ATM surveys have been used to directly assess Pacific Hake (Edwards *et al.*, 2018; JTC, 2014); northern subpopulation of Pacific Sardine (Hill *et al.*, 2017; Kuriyama *et al.*, 2020, 2022a); northern (Mais, 1974, 1977) and central subpopulations (Kuriyama *et al.*, 2022b) of Northern Anchovy; and Pacific Mackerel (Crone *et al.*, 2019; Crone and Hill, 2015; Kuriyama *et al.*, 2023). The proportions of these subpopulations that are in water too shallow to be sampled by NOAA ships are estimated using samples collected from fishing vessels. Also, concurrent satellite- and ship-based measures of their biotic and abiotic habitats are used to provide an ecosystem perspective.

Collectively, these annual or bi-annual ATM surveys provide a unique insight into the dynamics of forage fishes in the CCE, including their distributions, abundances, interactions, and environments. For example, results from 2006 through 2013 indicate that Pacific Sardine dominated the CPS assemblage, but their biomass was declining (Demer and Zwolinski, 2012; Zwolinski and Demer, 2012) and their seasonal migration was contracting (Zwolinski *et al.*, 2014). Meanwhile, harvest rates for the declining subpopulation increased (Demer and Zwolinski, 2017), and the total forage-fish biomass decreased to less than 200,000 t in 2014 and 2015 (**Figs. 37a,b**). The U.S. fishery for Pacific Sardine was closed in 2015 (National Marine Fisheries Service, 2015), and there were reports of mass strandings, deaths, and reproductive failures in Brown Pelicans

(*Pelecanus occidentalis*[12]), Common Murres (*Uria aalge*), Brandt's Cormorants (*Phalacrocorax penicillatus*), and California sea lions (*Zalophus californianus*[13]) (McClatchie *et al.*, 2016), all of which depend on forage species. NOAA deemed the northern subpopulation of Pacific Sardine overfished in 2019.

The survey-estimated CPS biomasses since 2008 were dominated by northern subpopulation Pacific Sardine until 2013, Jack Mackerel in 2014 and 2015, and then central subpopulation of Northern Anchovy since 2015, when it was resurgent. The biomass of the central subpopulation of Northern Anchovy, which had been increasing rapidly since 2015 and grew to ~2.75 million metric tons by 2021 (Stierhoff *et al.*, 2023), began decreasing after 2023 but still comprises the majority of CPS biomass in the CCE. Meanwhile, the northern and southern subpopulations of Pacific Sardine, delineated at Point Conception in 2025, were distributed approximately equally between the core and nearshore regions, with very little biomass north of Cape Mendocino. Comparatively, in 2023, the subpopulations of Pacific Sardine were delineated at Bodega Bay, with the northern subpopulation observed predominantly off Washington and central Oregon (Stierhoff *et al.*, 2024). However, because the change in distribution largely follows the geographical change in potential habitat, there is no indication that the biomasses of the northern or southern subpopulations of Pacific Sardine have changed significantly since summer 2023. The southern subpopulation of Pacific Sardine has been present in U.S. waters since at least 2015, located mostly nearshore, south of Monterey Bay; the biomass of the northern subpopulation has been fluctuating below 100,000 t mostly off Oregon and Washington. Meanwhile, the biomass of Pacific Mackerel remained the lowest in the assemblage, and the biomass of Jack Mackerel trended up from 2017 through 2022. In 2023, the delayed and smaller survey in the northern area created uncertainty about the decrease in Jack Mackerel biomass (**Fig. 37**), perhaps corroborated by the 2024 biomass being between the 2021 and 2022 biomasses (**Fig. 37b**). In 2024, the biomass of Jack Mackerel was roughly equal to the biomass of the central subpopulation of Northern Anchovy, with each contributing to 41% and 45% of the total CPS biomass, respectively.

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[12] https://e360.yale.edu/features/brown_pelicans_a_test_case_for_the_endangered_species_act

[13] https://www.fisheries.noaa.gov/national/marine-life-distress/2013-2017-california-sea-lion-unusual-mortality-event-california

a)

b)

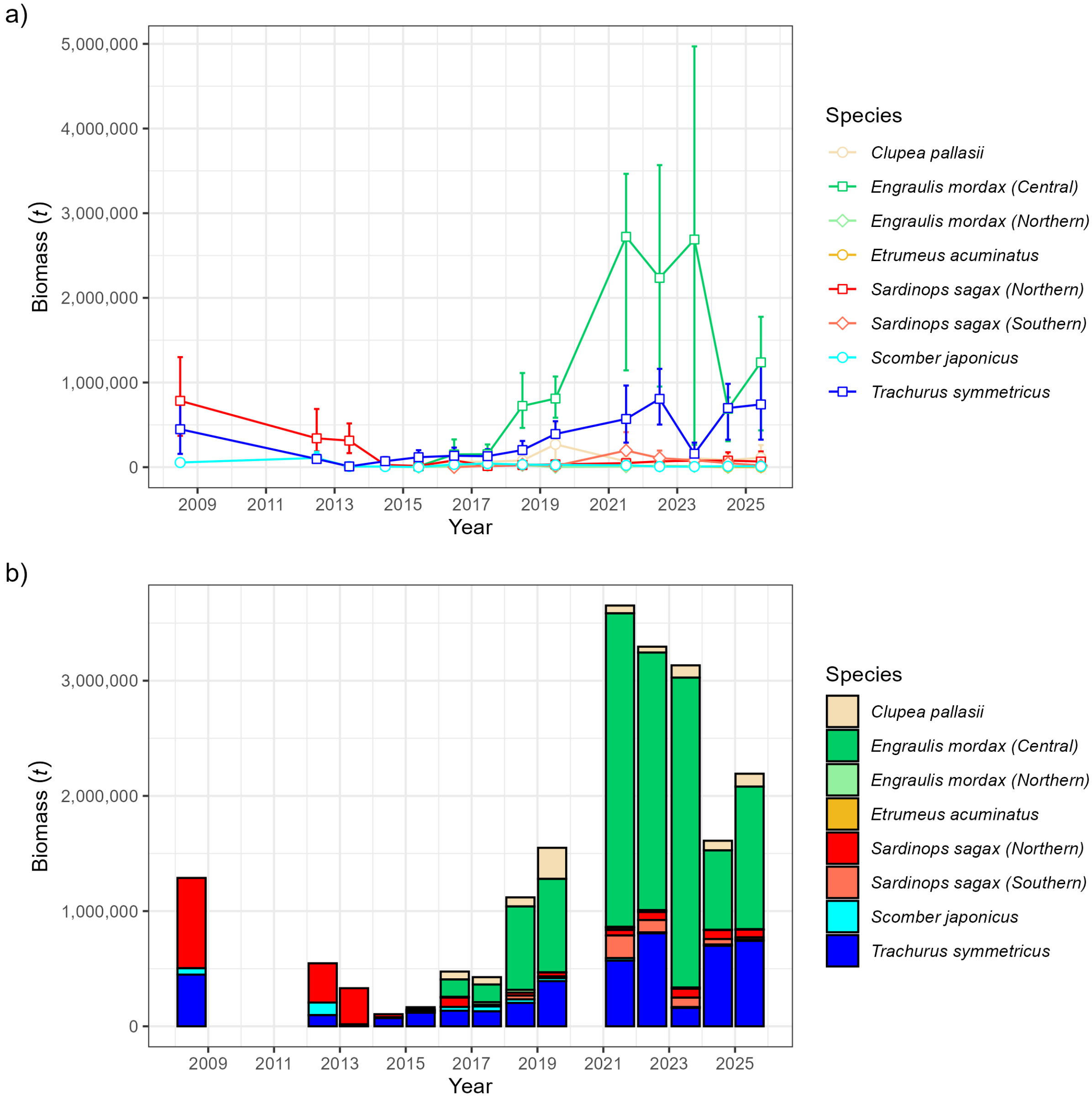

Figure 37: a) Estimated and b) cumulative estimated biomasses (t) of the eight most abundant CPS populations or subpopulations of six species in the CCE during summer since 2008. Error bars in panel a) are approximate 95% confidence intervals based on 1,000 bootstrap estimates. Surveys typically span the area between Cape Flattery and San Diego, but in some years also include Vancouver Island, Canada (2015-2019, 2024) and portions of Baja CA (2021-2022, 2024).

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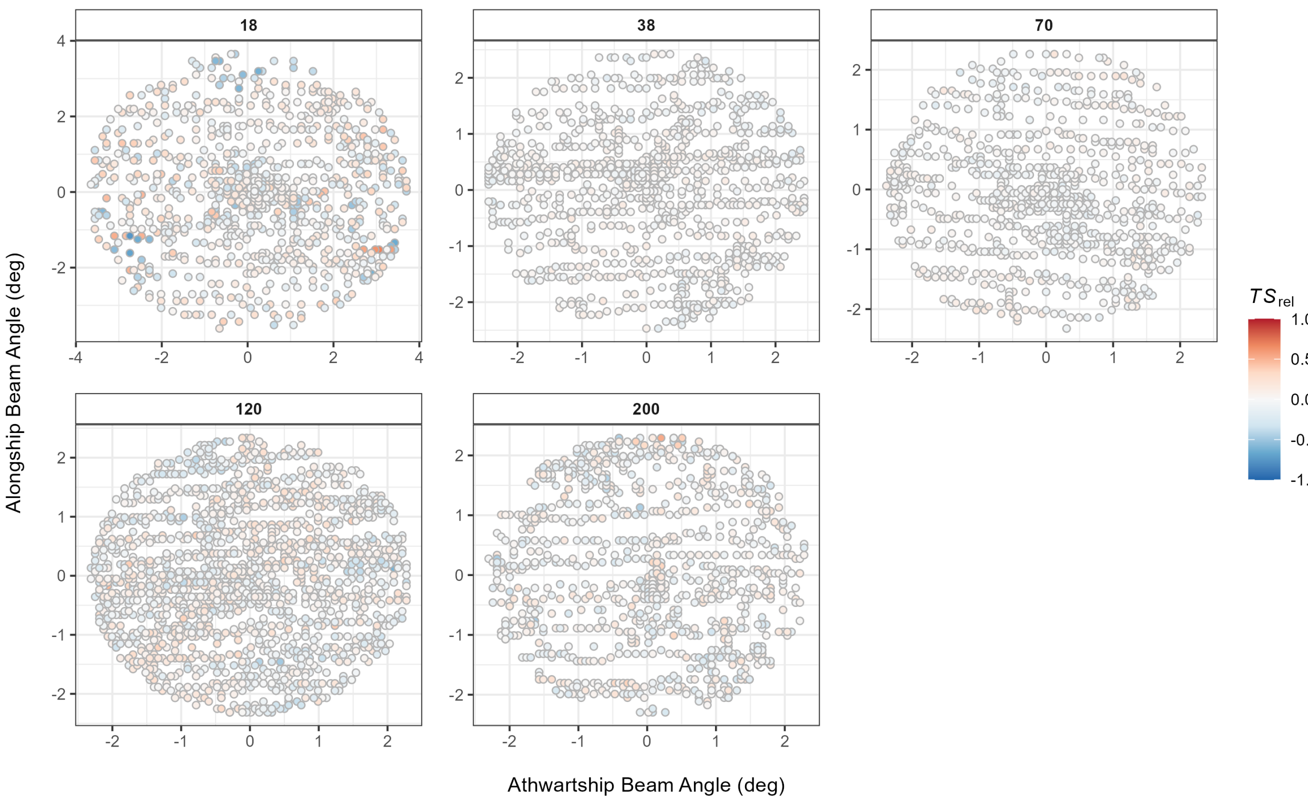
Appendices

A Calibration plots

A.1 *Shimada*

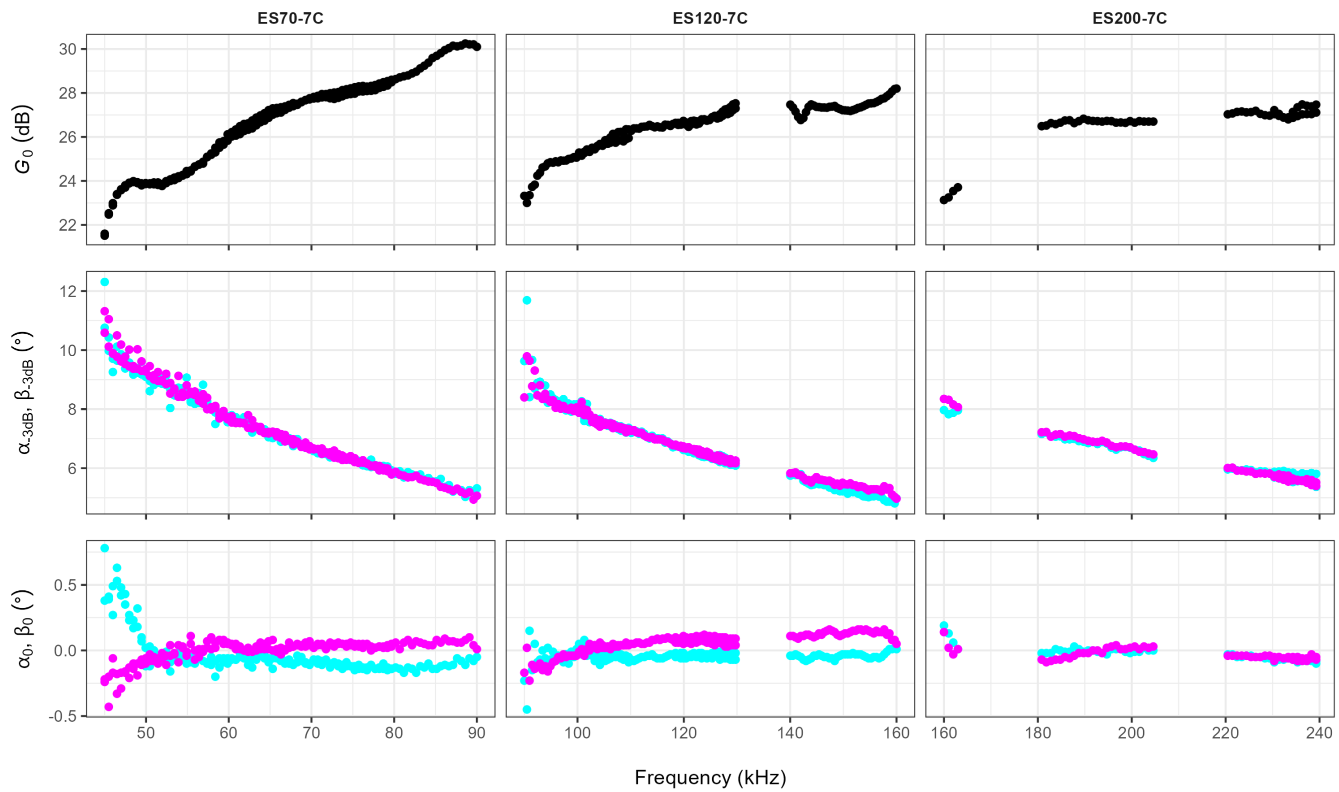
A.1.1 CW Mode

Relative beam-compensated target strength (TS_{rel}, dB re 1 m^2) measurements of a WC38.1 sphere at 18, 38, 70, 120, and 200 kHz for echosounders aboard *Shimada*. TS_{rel} is calculated as the difference between the beam-compensated target strength (TS_c) and the theoretical target strength (TS_{theory}).



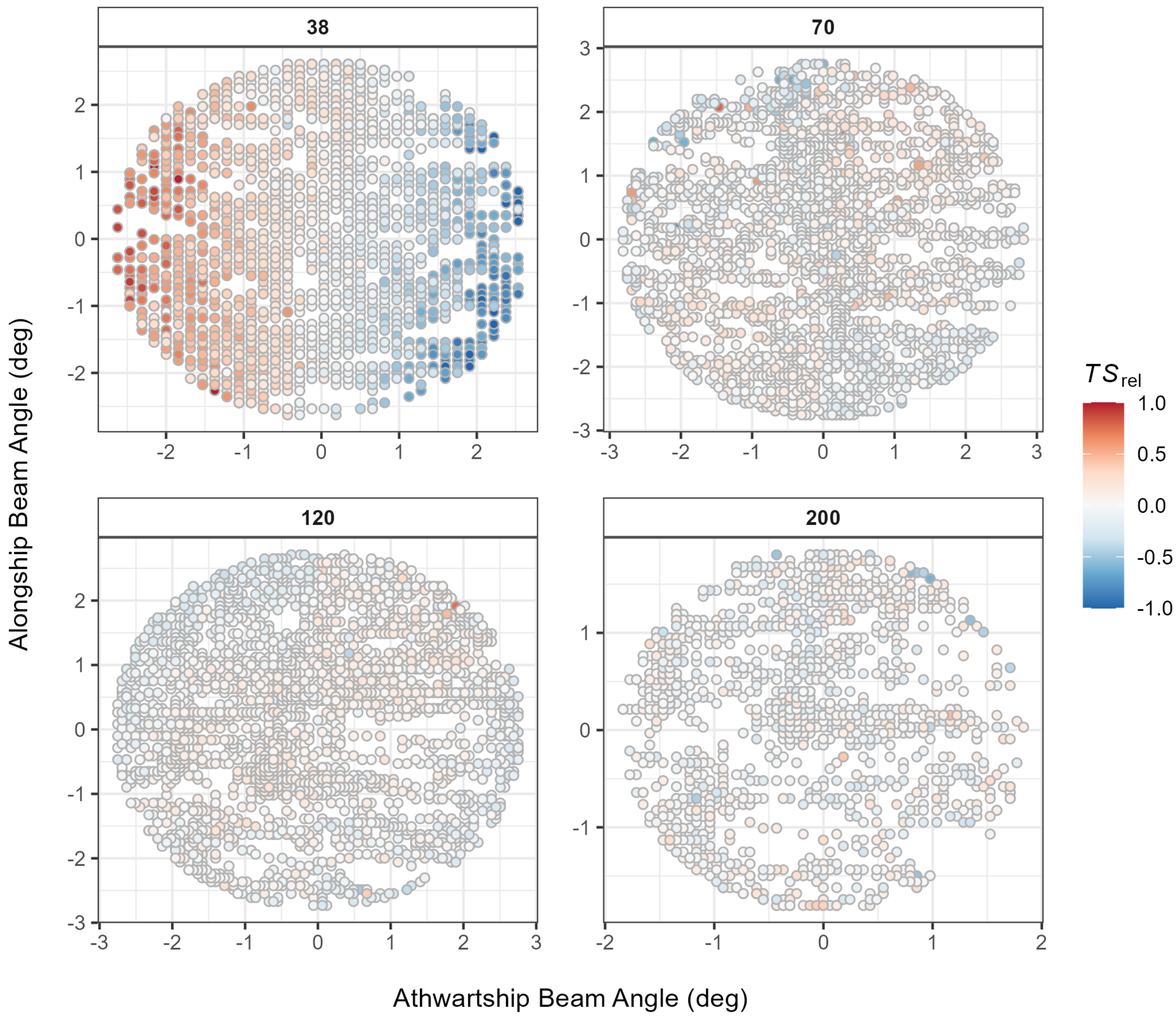
A.1.2 FM Mode

Measurements of on-axis gain (G_0, dB); alongship ($\alpha_{-3\mathrm{dB}}$, cyan) and athwartship ($\beta_{-3\mathrm{dB}}$, magenta) beamwidths (deg); and alongship (α_0, cyan) and athwartship (β_0, magenta) offset angles (deg) measured during calibrations of EK80 wideband transceivers aboard *Shimada* (WBT; 70, 120, and 200 kHz) in frequency modulation (FM, or broadband) mode.



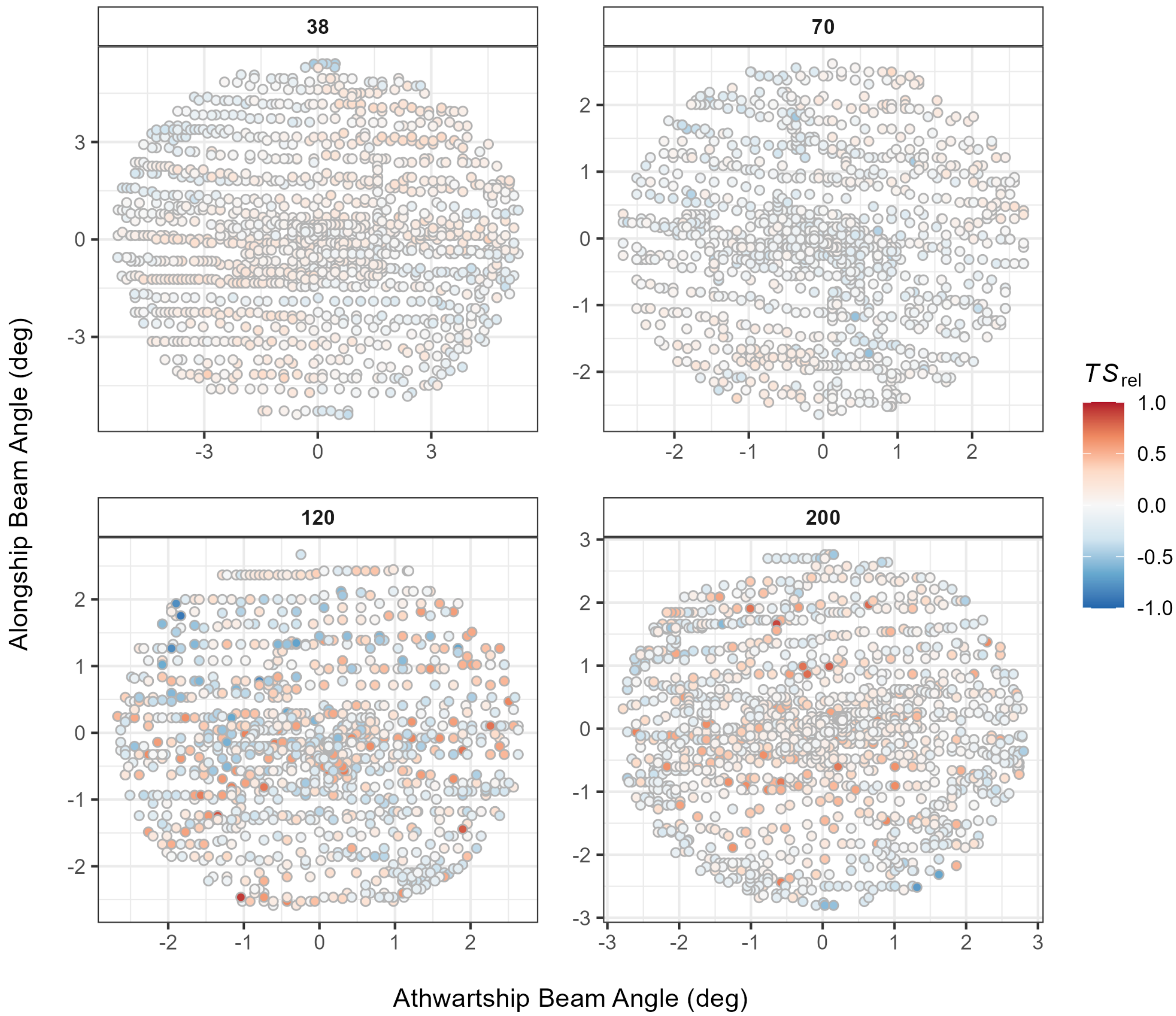
A.2 *Lisa Marie*

Relative beam-compensated target strength (TS_{rel}, dB re 1 m^2) measurements of a WC38.1 sphere at 38, 70, 120, and 200 kHz for echosounders aboard *Lisa Marie*. TS_{rel} is calculated as the difference between the beam-compensated target strength (TS_c) and the theoretical target strength (TS_{theory}). The results shown here are for the post-survey calibration conducted off Sunrise Beach near Gig Harbor, WA.



A.3 *Long Beach Carnage*

Relative beam-compensated target strength (TS_{rel}, dB re 1 m^2) measurements of a WC38.1 sphere at 38, 70, 120, and 200 kHz for echosounders aboard *Long Beach Carnage*. TS_{rel} is calculated as the difference between the beam-compensated target strength (TS_c) and the theoretical target strength (TS_{theory}).



B CTD and UCTD sampling locations

Times and locations of conductivity and temperature versus depth casts while on station (CTD) and underway (UCTD) from *Shimada* (SH).

Date time	Type	Latitude	Longitude
06/13/2025 22:56:46	UCTD	32.6548	-118.4656
06/14/2025 03:12:13	UCTD	32.6517	-118.1209
06/14/2025 21:34:10	UCTD	33.1553	-117.5740
06/15/2025 15:50:34	UCTD	33.1961	-118.1573
06/15/2025 21:12:06	UCTD	32.9039	-118.7376
06/16/2025 17:19:35	UCTD	33.1203	-119.0813
06/16/2025 20:25:10	UCTD	33.3481	-118.6259
06/17/2025 00:22:26	UCTD	33.5196	-118.2807
06/18/2025 14:56:57	UCTD	33.5919	-118.9116
06/18/2025 19:02:41	UCTD	33.3537	-119.3895
06/18/2025 22:46:40	UCTD	33.1137	-119.8700
06/19/2025 17:11:11	UCTD	33.4592	-119.9595
06/20/2025 01:56:52	UCTD	33.7489	-119.3792
06/20/2025 21:09:13	UCTD	34.1315	-119.4654
06/21/2025 14:44:28	UCTD	34.2489	-119.9276
06/22/2025 19:13:38	UCTD	33.9365	-120.5605
06/23/2025 21:20:36	UCTD	33.7444	-120.1654
06/24/2025 16:45:14	UCTD	34.3088	-120.5937
06/24/2025 21:30:32	CTD	34.5362	-120.6526
06/24/2025 22:24:10	CTD	34.5379	-120.7106
06/24/2025 23:24:55	CTD	34.5385	-120.8000
06/25/2025 01:25:29	CTD	34.5385	-120.9900
07/04/2025 12:28:54	CTD	34.7876	-120.7037
07/04/2025 13:47:17	UCTD	34.7878	-120.8519
07/04/2025 15:25:24	UCTD	34.7881	-121.0994
07/04/2025 16:28:22	UCTD	34.7866	-121.2483
07/04/2025 19:48:22	UCTD	34.7873	-121.7806
07/04/2025 22:29:04	CTD	35.0349	-121.5449
07/05/2025 16:04:02	CTD	35.0397	-120.9452
07/06/2025 00:50:53	CTD	35.0342	-120.7252
07/06/2025 01:38:31	CTD	35.0368	-120.8132
07/07/2025 14:15:08	CTD	35.5363	-121.1264
07/07/2025 15:00:16	CTD	35.5408	-121.1731
07/07/2025 15:58:00	CTD	35.5388	-121.2444
07/08/2025 05:58:41	CTD	35.5397	-121.5228
07/08/2025 14:19:59	CTD	36.0420	-121.6169
07/08/2025 14:59:54	CTD	36.0366	-121.6058
07/10/2025 17:11:00	CTD	36.5361	-122.0514
07/10/2025 18:44:15	CTD	36.5384	-121.9442
07/10/2025 19:13:37	CTD	36.5368	-121.9605
07/11/2025 23:03:39	CTD	37.0374	-122.7562
07/12/2025 00:29:52	CTD	37.0378	-122.6464
07/12/2025 03:57:52	CTD	37.0371	-122.2809
07/12/2025 04:57:10	CTD	37.0355	-122.3917

(continued)

Date time	Type	Latitude	Longitude
07/13/2025 18:21:34	CTD	37.5360	-123.0724
07/13/2025 23:35:36	CTD	37.5370	-123.0129
07/14/2025 00:45:39	CTD	37.5373	-122.8928
07/14/2025 02:53:50	CTD	37.5360	-122.5858
07/15/2025 04:09:03	CTD	37.7961	-123.2558
07/19/2025 21:26:14	CTD	38.0661	-123.0264
07/19/2025 22:33:31	CTD	38.0371	-123.1888
07/20/2025 01:17:18	CTD	38.0381	-123.5375
07/20/2025 16:27:13	UCTD	38.2876	-123.4445
07/21/2025 14:41:27	CTD	38.5347	-123.3340
07/21/2025 15:28:40	CTD	38.5354	-123.4122
07/21/2025 18:34:22	CTD	38.5373	-123.6732
07/21/2025 20:06:00	CTD	38.5370	-123.7340
07/22/2025 01:29:46	CTD	38.5334	-123.5454
07/22/2025 13:39:42	CTD	39.0388	-123.7283
07/22/2025 14:34:30	CTD	39.0364	-123.8359
07/22/2025 16:15:23	CTD	39.0364	-123.9566
07/22/2025 20:15:14	CTD	39.0367	-124.0978
07/23/2025 02:22:45	UCTD	39.2878	-124.2034
07/23/2025 18:08:11	CTD	39.5347	-123.8502
07/23/2025 18:49:40	CTD	39.5388	-123.8114
07/23/2025 19:56:05	CTD	39.5354	-123.9685
07/23/2025 20:45:57	CTD	39.5365	-124.0148
07/24/2025 19:18:04	UCTD	39.7878	-124.3543
07/25/2025 13:02:52	CTD	40.0416	-124.4092
07/25/2025 15:28:21	CTD	40.0393	-124.1293
07/25/2025 15:52:53	CTD	40.0407	-124.1398
07/25/2025 16:16:20	CTD	40.0383	-124.1494
07/26/2025 14:34:37	UCTD	40.2879	-124.8408
07/26/2025 20:45:11	CTD	40.5379	-124.7123
07/27/2025 00:38:05	CTD	40.5364	-124.6813
07/27/2025 02:13:06	CTD	40.5380	-124.5559
07/27/2025 03:15:13	CTD	40.5401	-124.4653
07/27/2025 19:07:49	UCTD	40.7875	-124.6442
07/28/2025 01:33:06	CTD	41.0377	-124.7007
07/28/2025 12:41:46	CTD	41.0395	-124.4014
07/28/2025 14:23:14	CTD	41.0376	-124.2903
07/28/2025 16:19:24	CTD	41.0376	-124.2251
07/29/2025 00:43:15	UCTD	41.2877	-124.5439
07/29/2025 12:36:20	CTD	41.5375	-124.3673
07/29/2025 13:37:12	CTD	41.5378	-124.2227
07/29/2025 15:32:12	CTD	41.5370	-124.5067
07/29/2025 20:44:37	CTD	41.5364	-124.5965
07/31/2025 22:34:32	CTD	45.0383	-124.0688
07/31/2025 23:15:39	CTD	45.0389	-124.1514
08/01/2025 00:52:09	CTD	45.0344	-124.4282
08/01/2025 03:32:54	CTD	45.0349	-124.8911

(continued)

Date time	Type	Latitude	Longitude
08/01/2025 13:10:56	CTD	46.0371	-124.0467
08/01/2025 14:31:26	CTD	46.0373	-124.2684
08/01/2025 16:40:03	CTD	46.0361	-124.7200
08/01/2025 17:52:25	CTD	46.0369	-124.8720
08/01/2025 21:20:48	CTD	45.5378	-124.8036
08/02/2025 00:16:18	CTD	45.5385	-124.5010
08/02/2025 02:29:22	CTD	45.5366	-124.1421
08/02/2025 03:24:57	CTD	45.5376	-124.0268
08/12/2025 13:43:36	CTD	42.0372	-124.3685
08/12/2025 14:44:51	CTD	42.0378	-124.4489
08/12/2025 16:10:23	CTD	42.0387	-124.5935
08/13/2025 00:11:34	CTD	42.0386	-124.8365
08/18/2025 20:30:32	CTD	44.0367	-124.3293
08/19/2025 00:07:46	CTD	43.5392	-124.6275
08/19/2025 03:56:00	CTD	43.0377	-124.8723
08/19/2025 07:43:32	CTD	42.5357	-124.8576
08/19/2025 09:04:41	CTD	42.5364	-124.7390
08/19/2025 10:15:51	CTD	42.5361	-124.6599
08/19/2025 11:01:50	CTD	42.5357	-124.6147
08/19/2025 11:58:00	CTD	42.5365	-124.5067
08/20/2025 01:39:52	CTD	42.5340	-124.9650
08/20/2025 14:00:21	CTD	43.0372	-124.4913
08/20/2025 14:55:45	CTD	43.0352	-124.5793
08/20/2025 17:37:17	CTD	43.0389	-124.9368
08/21/2025 13:10:14	CTD	43.5365	-124.2800
08/21/2025 14:03:22	CTD	43.5368	-124.3472
08/21/2025 18:05:02	CTD	43.5361	-124.9394
08/23/2025 14:35:22	CTD	44.5374	-124.5034
08/23/2025 16:57:47	CTD	44.5381	-124.1698
08/29/2025 03:06:40	CTD	44.0345	-124.1884
08/29/2025 06:25:58	CTD	44.0384	-124.9125
08/29/2025 07:16:16	CTD	44.0394	-124.9416
08/29/2025 08:22:11	CTD	44.0391	-124.9893
08/30/2025 15:14:45	CTD	44.5386	-124.9616
08/30/2025 18:08:59	CTD	44.5385	-124.6645
09/03/2025 13:27:29	CTD	46.5374	-124.2402
09/03/2025 14:51:31	CTD	46.5356	-124.4259
09/03/2025 15:53:43	CTD	46.5385	-124.5250
09/03/2025 20:43:38	CTD	46.5365	-124.7506
09/03/2025 23:37:28	CTD	46.5350	-125.1074
09/04/2025 13:58:15	CTD	47.0372	-124.3556
09/04/2025 16:29:13	CTD	47.0362	-124.6558
09/04/2025 18:58:52	CTD	47.0336	-125.0023
09/05/2025 00:11:39	CTD	47.0366	-125.2120
09/05/2025 14:34:53	CTD	47.5362	-124.5959
09/05/2025 15:50:10	CTD	47.5374	-124.7754
09/05/2025 17:25:25	CTD	47.5378	-124.9969
09/05/2025 22:50:46	CTD	47.5387	-125.2672

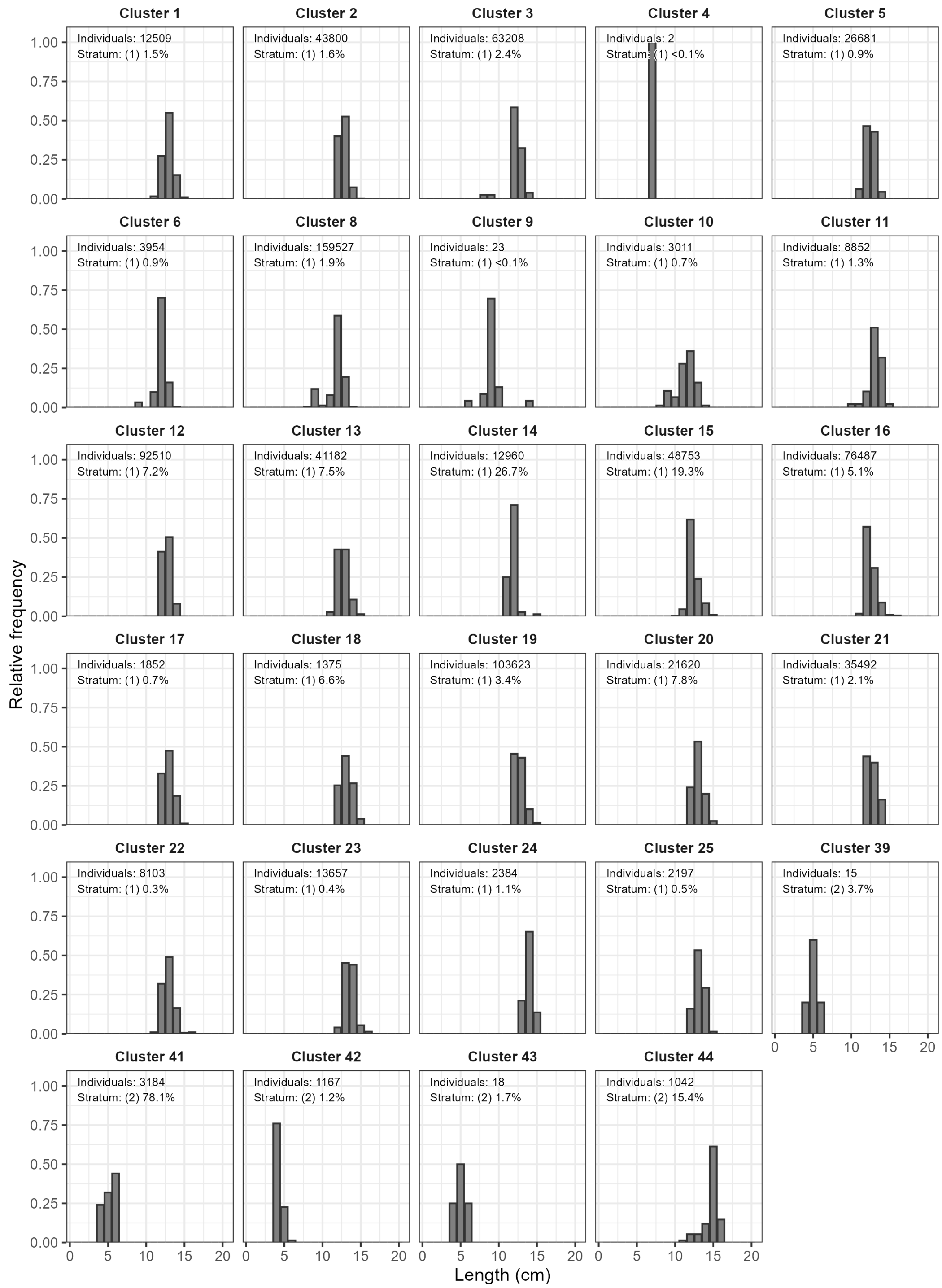
(continued)

Date time	Type	Latitude	Longitude
09/06/2025 15:10:35	CTD	48.0376	-125.7095
09/06/2025 21:52:29	CTD	48.0364	-125.3134
09/07/2025 03:47:39	CTD	48.0356	-124.9629
09/08/2025 17:08:16	CTD	48.4560	-126.2983
09/08/2025 21:07:19	CTD	48.4544	-126.1525
09/08/2025 23:01:39	CTD	48.4554	-125.9325
09/09/2025 14:33:45	CTD	48.4539	-125.5610
09/09/2025 17:16:56	CTD	48.4512	-125.1579
09/09/2025 21:43:43	CTD	48.4550	-124.7379
09/11/2025 12:50:31	CTD	47.6213	-122.3768
09/11/2025 22:42:26	CTD	47.6212	-122.3766

C Length distributions and percent biomass by cluster

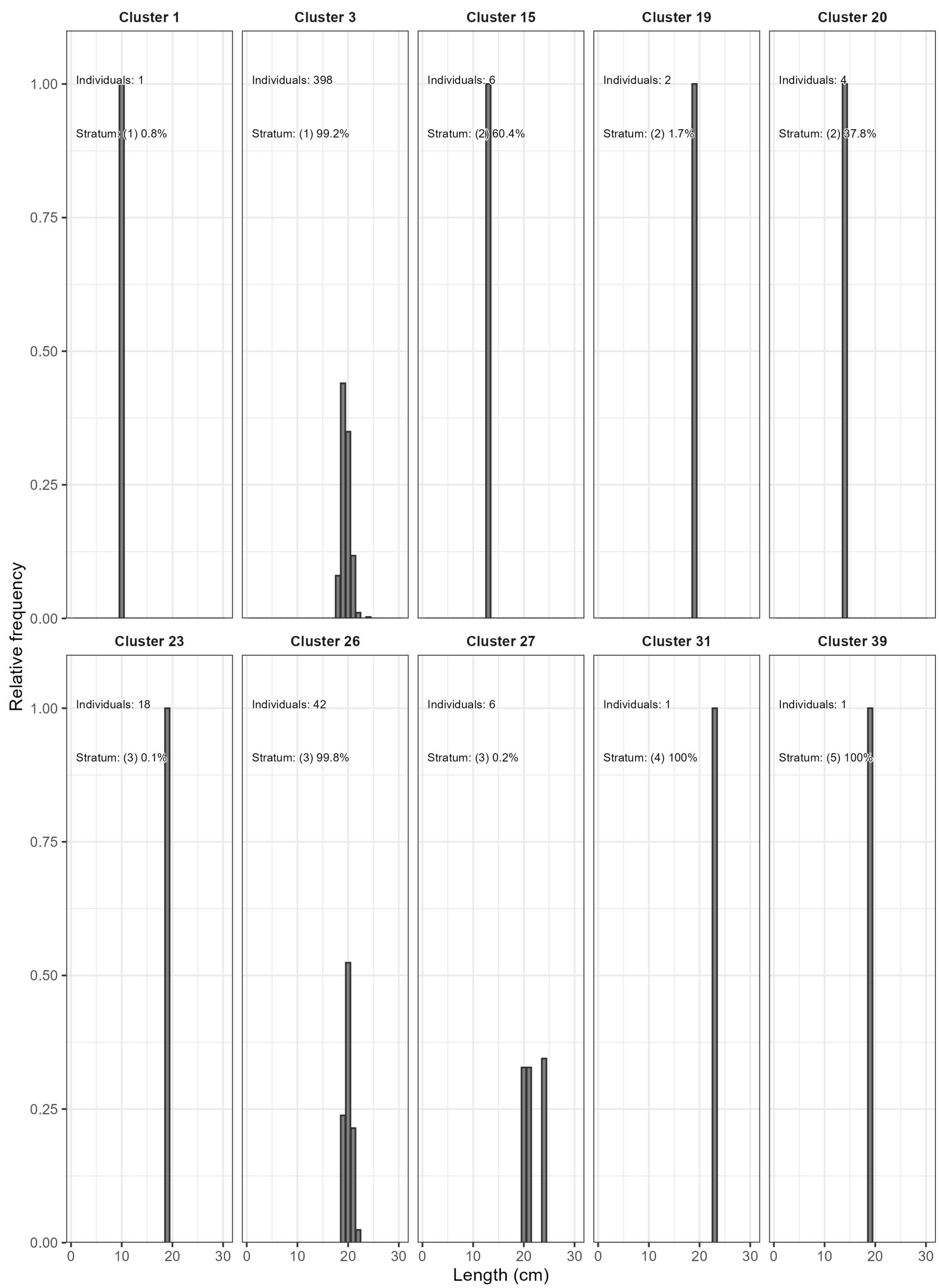
C.1 Northern Anchovy

Standard length (L_S) relative frequency distributions of Northern Anchovy (*Engraulis mordax*) per nighttime trawl cluster, annotated with the number of individuals caught and their percentage contributions to the abundance in each stratum.



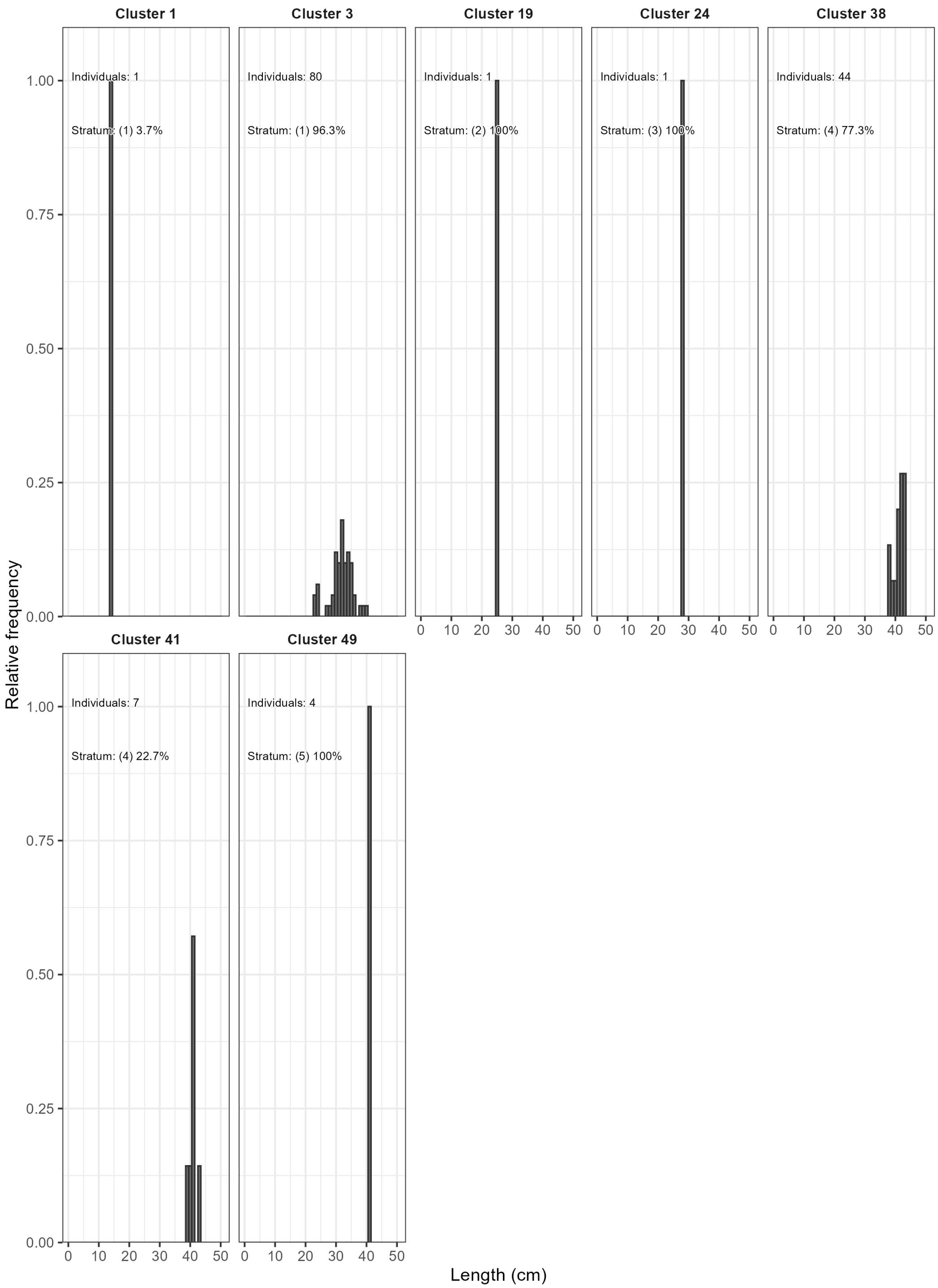
C.2 Pacific Sardine

Standard length (L_S) relative frequency distributions of Pacific Sardine (*Sardinops sagax*) per nighttime trawl cluster, annotated with the number of individuals caught and their percentage contributions to the abundance in each stratum. The southern subpopulation was sampled in stratum 1 and the northern subpopulation was sampled in strata 2 through 6.



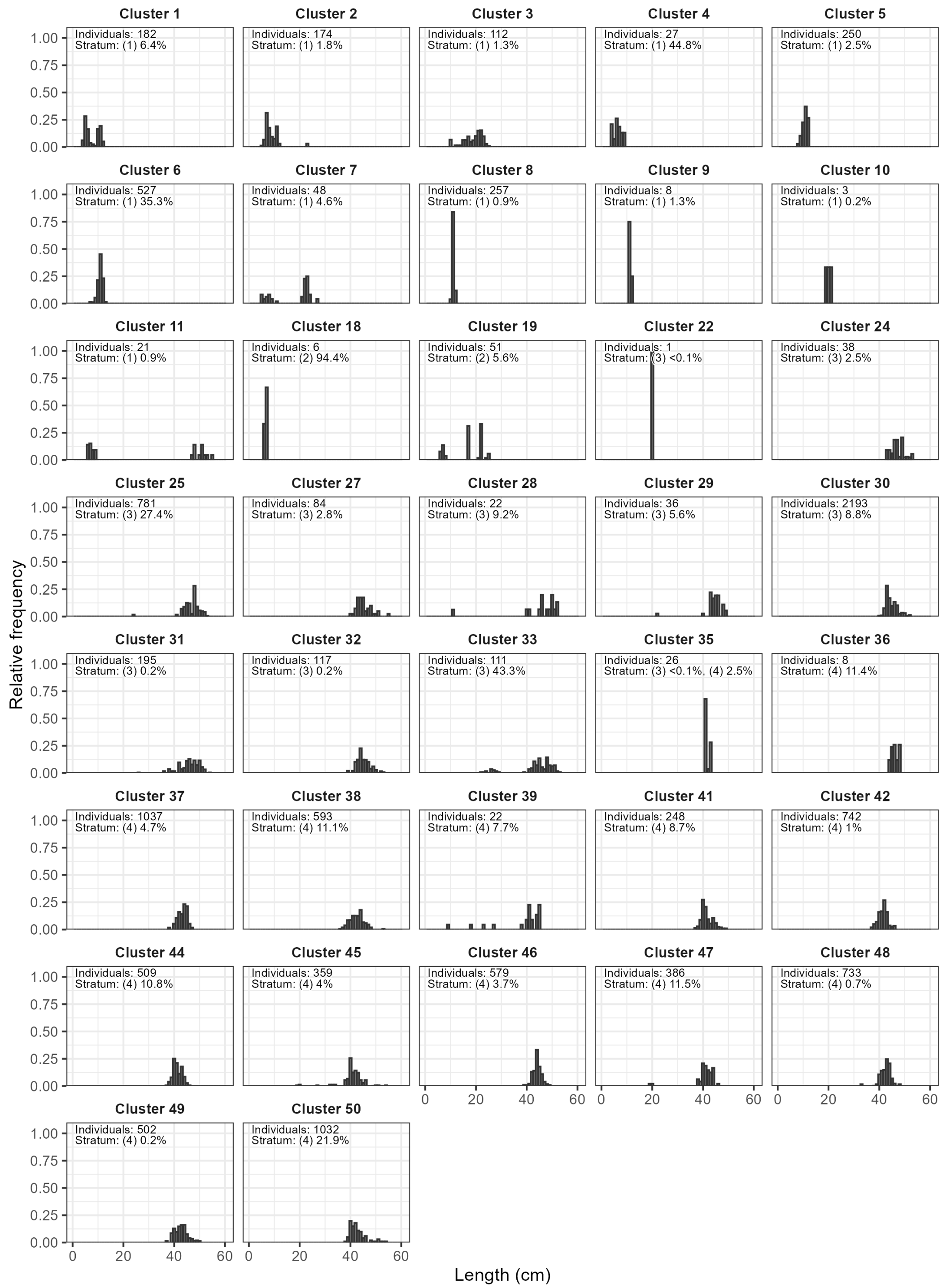
C.3 Pacific Mackerel

Fork length (L_F) relative frequency distributions of Pacific Mackerel (*Scomber japonicus*) per nighttime trawl cluster, annotated with the number of individuals caught and their percentage contributions to the abundance in each stratum.



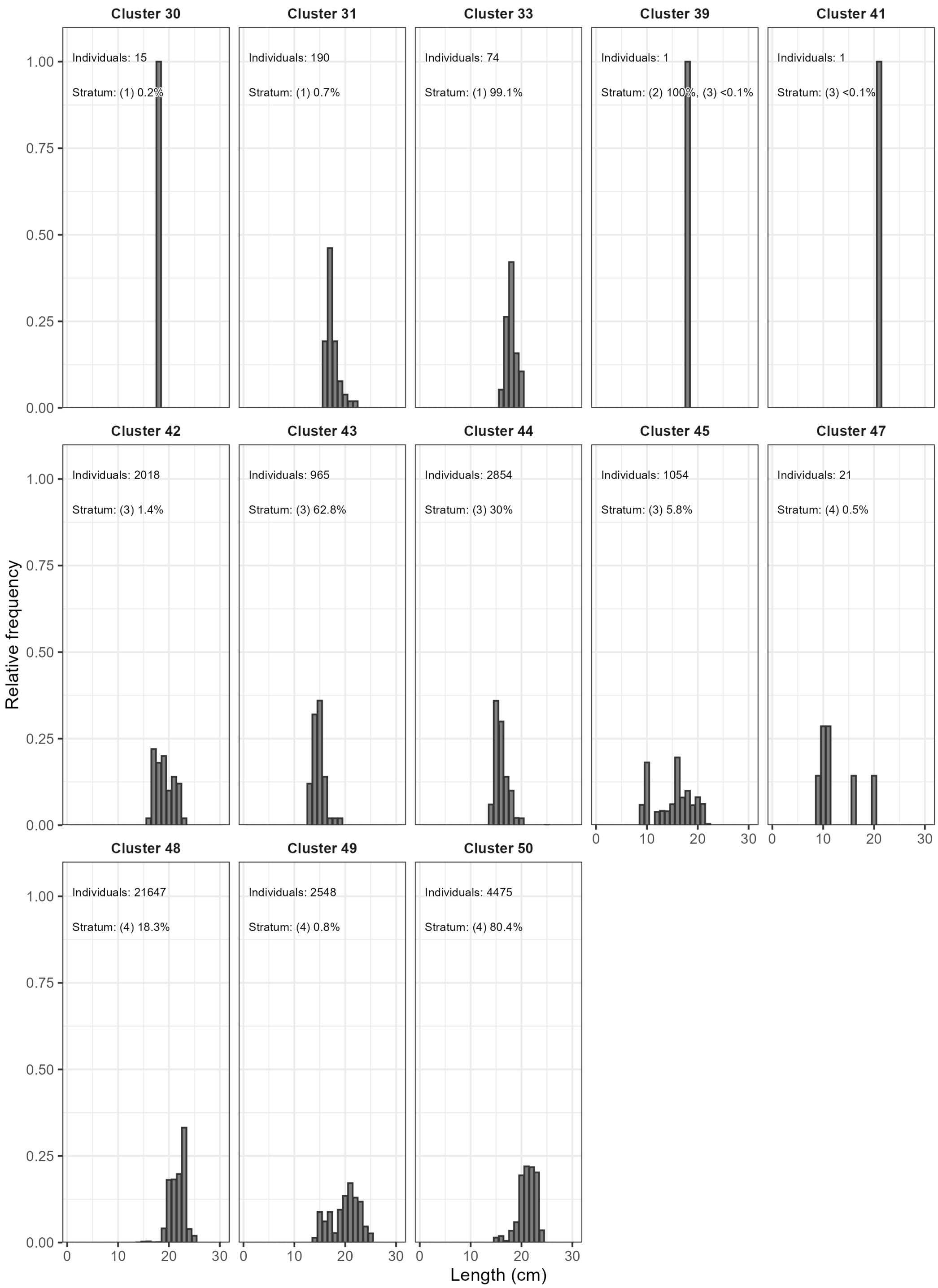
C.4 Jack Mackerel

Fork length (L_F) frequency distributions of Jack Mackerel (*Trachurus symmetricus*) per nighttime trawl cluster, annotated with the number of individuals caught or estimated and their percentage contributions to the abundance in each stratum.



C.5 Pacific Herring

Fork length (L_F) frequency distributions of Pacific Herring (*Clupea pallasii*) per nighttime trawl cluster, annotated with the number of individuals caught or estimated and their percentage contributions to the abundance in each stratum.



D Trawl sample summary

Date, time, and location at the start of trawling (i.e., at net equilibrium, when the net is fully deployed and begins fishing), and biomasses (kg) of CPS collected for each trawl haul aboard *Shimada*. A total of 107 trawls were conducted but three were aborted and are not included here.

Haul	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Herring	P. Mackerel	P. Sardine	R. Herring	All CPS
2	06/13/2025 07:42	32.7827	-117.4902	1.02	98.13	-	0.02	0.01	-	99.18
3	06/13/2025 10:50	32.6773	-117.6895	0.15	164.59	-	-	-	-	164.73
4	06/14/2025 04:37	32.5580	-118.1810	0.54	83.21	-	-	-	-	83.75
5	06/14/2025 07:56	32.7108	-118.3658	1.45	758.56	-	-	-	-	760.01
6	06/15/2025 04:29	33.3605	-117.8349	0.08	1032.66	-	-	-	-	1032.74
7	06/15/2025 07:54	33.2416	-118.0970	6.63	0.02	-	37.77	8.64	-	53.05
8	06/15/2025 11:05	33.1045	-118.3582	2.87	-	-	-	29.95	0.27	33.09
9	06/16/2025 05:02	32.6673	-119.0314	0.06	0.00	-	-	-	-	0.06
10	06/16/2025 08:17	32.7858	-119.1827	0.03	-	-	-	-	-	0.03
11	06/17/2025 04:27	33.4996	-118.0142	1.01	449.78	-	-	-	-	450.79
12	06/17/2025 07:46	33.4770	-118.2907	2.47	39.77	-	-	-	-	42.24
13	06/18/2025 04:31	33.7092	-118.8853	0.74	3.16	-	-	-	-	3.90
14	06/18/2025 07:37	33.5359	-118.9165	0.55	26.32	-	-	-	-	26.87
15	06/18/2025 11:50	33.6022	-118.7714	5.45	37.84	-	-	-	-	43.29
16	06/19/2025 04:58	33.2017	-120.2698	4.19	-	-	-	-	-	4.19
17	06/19/2025 08:22	33.3212	-120.1687	0.05	-	-	-	-	-	0.05
18	06/19/2025 11:25	33.3163	-120.3835	0.00	-	-	-	-	-	0.00
19	06/20/2025 04:46	33.8911	-119.0613	-	333.19	-	-	-	-	333.19
20	06/20/2025 08:37	33.8104	-119.2370	-	2119.37	-	-	-	-	2119.37
21	06/20/2025 12:02	33.7353	-119.3905	3.35	51.79	-	-	-	-	55.14
22	06/21/2025 04:56	34.1356	-119.4707	0.11	0.17	-	-	-	-	0.29
23	06/22/2025 04:52	34.1457	-119.8864	0.25	50.46	-	-	-	-	50.71
24	06/24/2025 04:53	33.8685	-120.6716	16.36	32.18	-	-	-	-	48.54
25	06/24/2025 08:45	34.1421	-120.9133	0.00	178.76	-	-	-	-	178.76
26	06/25/2025 05:21	34.5281	-121.2638	-	19.02	-	-	-	-	19.02
27	06/25/2025 08:31	34.5310	-121.1083	-	2072.00	-	-	-	-	2072.00
28	07/04/2025 06:19	34.6844	-121.1964	-	921.38	-	-	-	-	921.38
29	07/06/2025 09:19	34.8866	-121.0223	-	223.17	-	-	-	-	223.17
30	07/07/2025 05:52	35.0467	-121.2735	-	752.11	-	-	0.17	-	752.29
31	07/07/2025 11:15	35.3035	-121.0098	-	217.86	-	-	-	-	217.86

(continued)

Haul	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Herring	P. Mackerel	P. Sardine	R. Herring	All CPS
32	07/08/2025 07:30	35.5417	-121.5240	-	1003.88	-	-	-	-	1003.88
33	07/08/2025 11:18	35.7720	-121.5865	-	598.00	-	-	-	-	598.00
34	07/09/2025 05:47	36.0029	-121.6762	-	32.99	-	-	-	-	32.99
35	07/09/2025 08:58	36.1639	-121.7224	-	6.40	-	-	-	-	6.40
36	07/09/2025 11:51	36.2514	-121.9871	-	2.04	-	-	-	-	2.04
37	07/10/2025 05:35	36.2838	-122.6010	0.02	34.43	-	-	-	-	34.45
38	07/11/2025 06:06	36.5456	-122.6617	0.92	103.69	-	0.18	0.20	-	105.00
39	07/11/2025 10:55	36.7516	-122.3995	2.74	2369.03	-	-	-	-	2371.77
40	07/12/2025 08:52	36.9154	-122.1877	-	0.78	-	-	-	-	0.78
41	07/12/2025 12:10	37.0228	-122.4250	-	544.51	-	-	0.13	-	544.64
42	07/13/2025 06:22	37.2154	-122.5518	-	788.72	-	-	-	-	788.72
43	07/13/2025 10:17	37.3204	-122.8188	-	5.36	-	-	-	-	5.36
44	07/14/2025 05:19	37.5338	-122.8862	0.08	150.74	-	-	-	-	150.82
45	07/14/2025 12:16	37.8607	-123.2018	-	53.08	-	-	-	-	53.08
47	07/20/2025 06:22	38.0239	-123.2768	-	1.72	-	-	-	-	1.72
48	07/20/2025 10:53	38.0912	-123.1709	-	387.87	-	-	1.62	-	389.49
49	07/21/2025 07:18	38.2668	-123.3081	40.53	64.23	-	0.32	-	-	105.07
50	07/21/2025 11:29	38.2781	-123.1578	7.57	12.22	-	-	-	-	19.79
51	07/22/2025 04:44	38.5356	-123.4669	859.88	-	-	-	-	-	859.88
52	07/22/2025 08:58	38.5388	-123.5726	114.45	56.57	-	-	-	-	171.02
53	07/23/2025 05:09	39.2830	-123.8749	-	-	-	-	2.79	-	2.79
54	07/23/2025 09:30	39.2822	-124.0622	-	-	-	-	1.86	-	1.86
55	07/24/2025 05:00	39.5284	-123.9572	87.95	-	-	-	0.42	-	88.37
56	07/24/2025 08:28	39.5277	-123.8862	-	-	-	-	0.45	-	0.45
57	07/25/2025 05:04	39.7987	-124.0725	26.12	-	-	-	-	-	26.12
58	07/25/2025 08:38	39.7753	-123.9641	0.02	-	-	-	-	-	0.02
59	07/26/2025 05:36	40.0476	-124.8801	23.62	-	-	-	-	-	23.62
60	07/26/2025 08:32	40.0613	-124.7368	-	-	-	-	-	-	-
61	07/26/2025 11:21	40.1817	-124.7920	11.38	-	-	-	-	-	11.38
62	07/27/2025 04:40	40.5240	-124.5281	778.03	-	0.81	-	-	-	778.84
63	07/27/2025 08:36	40.5536	-124.6510	218.55	-	-	-	-	-	218.55
64	07/27/2025 11:24	40.6047	-124.5308	1346.59	-	-	-	-	-	1346.59
65	07/28/2025 05:07	40.9745	-124.3183	12.78	-	10.16	-	0.14	-	23.07

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Haul	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Herring	P. Mackerel	P. Sardine	R. Herring	All CPS
66	07/28/2025 07:47	41.0881	-124.2920	-	-	-	-	-	-	-
67	07/28/2025 10:34	41.1209	-124.4826	206.34	-	-	-	-	-	206.34
68	07/29/2025 05:17	41.2802	-124.6098	19.13	-	-	-	-	-	19.13
69	07/29/2025 08:06	41.3919	-124.4625	99.83	-	-	-	-	-	99.83
70	07/29/2025 10:42	41.4556	-124.3025	6.59	-	-	-	-	-	6.59
71	07/30/2025 04:56	41.5334	-124.3153	15.08	-	4.50	-	-	-	19.59
72	07/30/2025 07:51	41.5811	-124.4411	46.88	-	-	-	-	-	46.88
73	07/30/2025 10:18	41.5797	-124.5780	52.66	-	-	-	-	-	52.66
74	08/13/2025 06:51	42.0495	-124.5567	-	-	-	-	-	-	-
75	08/20/2025 04:27	42.5400	-124.7979	19.46	-	-	-	-	-	19.46
76	08/20/2025 08:15	42.5317	-125.0825	3.31	-	-	-	-	-	3.31
77	08/21/2025 04:33	43.0218	-124.6990	5.11	-	-	-	-	-	5.11
78	08/21/2025 07:42	43.1770	-124.6268	4.20	-	-	-	-	-	4.20
79	08/22/2025 05:02	43.5255	-124.3791	996.97	-	-	-	-	-	996.97
80	08/23/2025 05:03	43.7734	-124.6139	370.07	-	-	-	-	-	370.07
81	08/23/2025 08:14	43.7722	-124.4266	166.15	-	-	38.69	-	-	204.83
82	08/30/2025 05:42	44.0396	-124.7372	16.51	0.02	0.06	-	0.08	-	16.67
83	08/31/2025 06:04	44.5331	-125.2153	-	-	-	-	-	-	-
84	09/01/2025 04:15	45.0183	-124.2950	141.29	-	0.08	6.61	-	-	147.97
85	09/01/2025 08:07	45.0341	-124.4869	67.96	5.00	-	-	-	-	72.96
86	09/02/2025 04:13	45.5389	-124.2369	90.48	-	152.16	-	-	-	242.64
87	09/02/2025 07:30	45.5344	-124.6443	533.12	-	-	-	-	-	533.12
88	09/02/2025 10:42	45.5264	-124.9950	-	0.77	-	-	-	-	0.77
89	09/03/2025 04:54	46.0382	-124.2082	-	0.03	27.59	-	-	-	27.63
91	09/04/2025 04:08	46.5017	-124.4927	269.98	-	-	-	-	-	269.98
92	09/04/2025 07:19	46.5066	-124.4050	153.11	-	0.54	-	-	-	153.65
93	09/04/2025 10:23	46.7415	-124.4691	-	38.28	116.14	-	-	-	154.42
94	09/05/2025 04:08	47.0242	-124.7664	185.58	-	1.12	-	-	-	186.70
95	09/05/2025 07:46	47.0344	-124.6314	110.49	-	41.02	-	-	-	151.51
96	09/05/2025 10:51	47.2075	-124.6434	2.81	-	0.67	-	-	-	3.48
97	09/06/2025 05:08	47.5427	-125.4824	271.21	-	-	-	-	-	271.21
98	09/06/2025 08:14	47.5419	-125.2679	313.45	-	-	-	-	-	313.45
99	09/07/2025 05:23	48.0342	-125.1371	303.73	-	0.47	-	-	-	304.20

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Haul	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Herring	P. Mackerel	P. Sardine	R. Herring	All CPS
100	09/07/2025 08:54	48.0261	-125.4711	1.00	-	-	-	-	-	1.00
101	09/08/2025 05:08	48.2848	-125.1557	545.46	-	24.97	-	-	-	570.44
102	09/08/2025 08:00	48.2870	-125.4544	109.68	-	14.90	-	-	-	124.59
103	09/08/2025 10:47	48.2857	-125.7455	-	-	2260.62	-	-	-	2260.62
104	09/09/2025 04:47	48.4523	-126.2694	157.65	-	88.18	-	-	-	245.82
105	09/09/2025 08:16	48.4510	-126.0324	301.65	-	133.06	3.87	-	-	438.58
106	09/10/2025 04:04	48.4641	-124.9460	506.47	-	89.62	-	-	-	596.09
107	09/10/2025 08:46	48.4498	-125.4695	437.96	-	358.22	-	-	-	796.17

E Seine sample summary

E.1 *Long Beach Carnage*

Date, time (UTC), location, and biomasses (kg) of CPS collected for each purse-seine set by *Long Beach Carnage*. A total of 30 sets were conducted but one was excluded and not shown here.

Set	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Mackerel	P. Sardine	All CPS
1	06/17/2025 16:55	32.7866	-117.2614	-	0.04	-	96.62	96.65
2	06/17/2025 19:45	32.9262	-117.2688	-	-	1.26	29.94	31.20
3	06/18/2025 00:40	33.1778	-117.3834	-	14.74	1.05	0.06	15.85
4	06/18/2025 13:34	33.2320	-117.4307	-	25.40	-	-	25.40
5	06/18/2025 16:06	33.2803	-117.6132	-	29.94	-	-	29.94
6	06/18/2025 23:43	33.5773	-117.9437	-	0.37	-	-	0.37
7	06/19/2025 01:05	33.6286	-117.9790	-	18.60	-	-	18.60
8	06/19/2025 15:46	33.4740	-118.6092	-	-	28.58	-	28.58
9	06/20/2025 22:40	33.7024	-118.0732	-	16.78	-	-	16.78
10	06/21/2025 19:30	33.8851	-118.4230	-	-	0.10	26.76	26.87
11	06/21/2025 20:54	33.9477	-118.4538	-	-	-	32.66	32.66
12	06/22/2025 01:30	34.0284	-118.7240	-	-	1.58	25.85	27.44
13	06/22/2025 18:10	34.0323	-119.1407	-	19.96	-	-	19.96
14	06/22/2025 23:29	34.2373	-119.2841	-	23.13	-	-	23.13
15	06/23/2025 15:08	34.3055	-119.3855	-	22.23	-	1.12	23.35
16	06/23/2025 17:35	34.3863	-119.5280	-	-	-	21.32	21.32
17	06/23/2025 20:35	34.4043	-119.7835	-	-	-	24.95	24.95
18	06/23/2025 22:59	34.4366	-119.9742	-	-	-	32.66	32.66
19	06/24/2025 22:40	33.9738	-119.6802	5.90	-	-	0.07	5.97
20	06/25/2025 04:37	34.0104	-119.5246	-	19.50	-	-	19.50
21	06/26/2025 13:17	34.0266	-119.6219	0.08	-	-	21.77	21.85
22	06/27/2025 20:14	34.8590	-120.6272	-	22.68	-	-	22.68
23	06/27/2025 22:44	34.9258	-120.6732	-	-	-	24.49	24.49
24	06/27/2025 23:44	34.9827	-120.6605	-	-	-	28.12	28.12
25	06/29/2025 14:40	35.4368	-120.9627	-	-	-	27.22	27.22
26	06/29/2025 19:46	35.6313	-121.1764	-	-	-	19.05	19.05
27	06/30/2025 20:33	35.9990	-121.5157	-	-	0.77	26.31	27.08
28	07/01/2025 01:56	36.2107	-121.7628	5.44	-	-	-	5.44

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Set	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Mackerel	P. Sardine	All CPS
30	07/03/2025 19:06	36.9395	-121.8857	-	14.06	-	0.39	14.45

E.2 *Lisa Marie*

Date, time (UTC), location, and biomasses (kg) of CPS collected for each purse-seine set by *Lisa Marie*.

Set	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Herring	P. Sardine	All CPS
1	07/22/2025 18:54	37.2060	-122.5056	-	0.02	-	-	0.02
2	07/22/2025 19:24	37.2123	-122.5074	0.01	0.05	-	0.09	0.16
3	07/22/2025 20:26	37.2474	-122.5052	-	7.40	-	-	7.40
4	07/23/2025 14:36	37.7306	-122.5594	-	9.94	0.01	-	9.95
5	07/23/2025 18:58	37.8869	-122.8060	-	-	-	-	-
6	07/23/2025 20:07	37.8710	-122.8492	-	-	-	-	-
7	07/24/2025 15:03	38.0332	-123.0934	-	13.38	-	-	13.38
8	07/25/2025 17:53	38.7690	-123.5579	-	-	-	-	-
9	07/25/2025 23:11	38.9761	-123.7271	-	-	10.38	3.45	13.83
10	07/26/2025 18:00	39.3287	-123.8264	-	-	-	-	-
11	07/27/2025 17:36	39.8714	-123.9313	-	-	4.85	0.43	5.28
12	07/27/2025 19:06	39.9295	-123.9777	-	-	-	13.31	13.31
13	07/27/2025 23:17	40.0505	-124.0827	-	-	-	0.93	0.93
14	07/30/2025 19:15	41.0361	-124.1465	-	-	2.12	0.24	2.37
15	07/31/2025 15:43	41.3879	-124.0865	-	-	0.12	-	0.12
16	08/01/2025 15:13	42.0767	-124.4282	0.30	-	-	-	0.30
17	08/14/2025 18:30	43.6951	-124.2193	-	-	6.09	-	6.09
18	08/14/2025 21:53	43.8143	-124.1937	-	-	-	-	-
19	08/18/2025 14:18	44.6328	-124.1053	-	-	-	-	-
20	08/19/2025 14:06	45.3266	-123.9871	-	-	-	-	-
21	08/19/2025 20:08	45.5843	-124.0822	11.86	-	-	-	11.86
22	08/19/2025 22:10	45.6697	-123.9593	-	0.04	0.47	-	0.51
23	08/20/2025 15:19	45.7823	-124.1029	1.93	-	-	-	1.93
24	08/20/2025 17:35	45.8970	-123.9829	-	-	0.32	-	0.32
25	08/20/2025 20:07	46.0173	-124.0674	-	-	-	-	-
26	08/21/2025 15:49	46.2666	-124.0713	-	-	0.18	-	0.18
27	08/24/2025 15:57	46.4648	-124.0830	-	0.14	0.04	-	0.19
28	08/24/2025 20:49	46.7145	-124.2345	-	-	-	-	-
29	08/24/2025 22:51	46.8264	-124.1674	-	-	0.33	-	0.33
30	08/25/2025 21:34	47.4216	-124.4216	-	-	0.78	-	0.78
31	08/26/2025 18:54	47.4263	-124.4765	-	-	-	-	-

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Set	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Herring	P. Sardine	All CPS
32	08/26/2025 21:39	47.5250	-124.3819	-	-	4.15	-	4.15
33	08/27/2025 16:17	47.7696	-124.6193	46.26	-	-	-	46.26
34	08/27/2025 20:37	47.9873	-124.8129	20.98	-	-	-	20.98

F Scientific Personnel

The collection and analysis of the survey data used to estimate the biomasses of CPS were conducted by members of 1-NOAA, 2- CU Boulder/CIRES, 3-UCSC/CIMEAS, 4-NOAA Teacher at Sea, 5-OAI, 6-volunteer, 7-T&T, 8-AIS, 9-WDFW, 10-CWPA, 11-PSFMC, and 12-Knauss Fellow. For each leg, * denotes the Cruise Leader, and + the Acoustic and Trawl Leads from the SWFSC. The survey on *Shimada* was divided into five legs.

Principal Investigators:

J. Clemons[1] and * K. Stierhoff[1]

Acoustic Data Collection and Processing:

- Leg I: J. Clemons[1], J. Pohl[1], and J. Renfree[1*+]
- Leg II: S. de Blois[1], D. Murfin[1+], and R. Thomas[1]
- Leg III: J. Clemons[1], E. Phillips[1], and K. Stierhoff[1*+]
- Leg IV: S. de Blois[1], S. Sessions[1+], and R. Thomas[1]
- Leg V: S. de Blois[1], S. Mau[1+], and J. Pohl[1]

Trawl Sampling:

- Leg I: D. Bashford[2], E. Capriles[2], J. Cloninger[4], S. de Blois[1], K. James[1+], M. Liotta[1], B. Overcash[1], Z. Skelton[5], and A. Vitale[8]
- Leg II: S. Beyer[1], L. Chang[4], M. Liotta[1], M. Shak[7], Z. Skelton[5+], P. Vavoulis[1], A. Vitale[8], and C. Wilson[1]
- Leg III: J. Crofts[1], K. Davis[1], A. Ostrowski[1], B. Overcash[1], M. Rivera[1], Z. Skelton[5], B. Schwartzkopf[1+], S. Van Hofwegen[11], and A. Vitale[8]
- Leg IV: P. Bizzell[1], B. Erisman[1], J. Gonzalez[4], P. Kuriyama[1], M. Monneedy[12], D. Lowry[1], C. Sayre[1], L. Vasquez del Mercado[1+], and A. Vitale[8]
- Leg V: K. Alvstad[1], J. Dunigan[11], L. Kraatz[1], T. Mitchell[1], L. Ortiz[11], B. Overcash[1+], T. Rogers[1], C. Russ[12], and J. Stecher[6]

Purse-seine Sampling:

- *Lisa Marie*
  - A. Cravens [9] and K. Hinton[9]
- *Long Beach Carnage*
  - J. van Noord[10]

Echosounder Calibrations:

- *Bell M. Shimada*
  - D. Murfin, J. Renfree, S. Sessions, and J. Zwolinski
- *Long Beach Carnage*
  - D. Murfin, J. Renfree, and S. Sessions
- *Lisa Marie*
  - S. Sessions