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REPORT ON THE SPRING 2021 COASTAL PELAGIC SPECIES (CPS) SURVEY (2103RL), 20 MARCH TO 13 APRIL 2021, CONDUCTED ABOARD NOAA SHIP *REUBEN LASKER* AND FISHING VESSEL *LONG BEACH CARNAGE*

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1 Introduction

The Spring 2021 Coastal Pelagic Species (CPS) Survey (2103RL) was conducted by the Fisheries Resources Division (FRD) of the Southwest Fisheries Science Center (SWFSC) aboard NOAA ship *Reuben Lasker* (hereafter, *Lasker*) and fishing vessel *Long Beach Carnage* (**Fig. 1**), 20 March to 13 April 2021. The Acoustic-Trawl Method (ATM) was used to: 1) acoustically map the distributions and estimate the abundances of CPS, primarily Northern Anchovy *Engraulis mordax*, but also Pacific Sardine *Sardinops sagax*, Pacific Mackerel *Scomber japonicus*, and Jack Mackerel *Trachurus symmetricus*; and krill (euphausiid spp.) within the southern portion of the California Current Ecosystem (CCE); 2) characterize and investigate linkages to their biotic and abiotic environments; 3) gather information regarding their life histories; and 4) use a fishing vessel to sample in the nearshore areas where sampling from *Lasker* was deemed inefficient, unsafe, or both.

The sampling domain, between San Francisco, CA and San Diego, CA was defined by the expected distribution of the central stock of Northern Anchovy (**Fig. 2**), but it possibly included partial distributions of the northern and southern stocks of Pacific Sardine, Pacific Mackerel, and Jack Mackerel. Data were collected using multi-frequency echosounders, surface trawls, obliquely integrating plankton-net tows, a continuous underway fish-egg sampler (CUFES), and conductivity-temperature-depth probes (CTDs).

This report provides an overview of the survey objectives and summaries of the survey equipment, acoustic-system calibration, sampling and analysis methods, and collected data. This report does not include estimates of the animal distributions and biomasses, which are documented in Zwolinski et al. (2023).

Figure 1: NOAA ship *Lasker* and F/V *Long Beach Carnage* (inset).

1.1 Scientific Personnel

The survey data were collected and processed aboard *Lasker* by members of the Fisheries Resources Division at the SWFSC; and collected aboard *Long Beach Carnage* by a scientist from the California Wetfish Producers Association (CWPA) and processed ashore by scientists from the California Department of Fish and Wildlife (CDFW).

Project Lead:

- *Lasker*: J. Zwolinski
- *Long Beach Carnage*: D. Demer

Acoustic Data Collection and Processing:

- *Lasker*
  - Leg I: J. Zwolinski*
  - Leg II: G. Johnson and S. Mau*
- *Long Beach Carnage*
  - J. van Noord (CWPA)*

*Chief Scientists

Trawl Sampling:

- Leg I: N. Bowlin, B. Erisman, M. Human, B. Schwartzkopf, and A. Thompson
- Leg II: A. Freire, L. Giuseffi, V. Hermanson, K. James, O. Snodgrass, and W. Watson

Purse-seine Sampling:

- J. van Noord (CWPA, at-sea sampling)
- K. Kloos, T. Stocking, D. Aceituno, D. McDermott, K. Mooers, J. Mikkelsen, L. Laughlin, C. Protasio, M. Horeczko, and D. Porzio (CDFW, shore-side processing)

Echosounder Calibrations:

- *Lasker*
  - J. Renfree and T. Sessions
- *Long Beach Carnage*
  - J. Renfree and T. Sessions

2 Methods

2.1 Survey region and design

The SWFSC's ATM surveys of CPS in the CCE began in 2006 with a focus on the northern stock of Pacific Sardine. Since then, the surveys have expanded in scope and objectives to include the larger forage-fish assemblage and krill.

During spring 2021, the central stock Northern Anchovy was the priority, so the survey area was defined with consideration to its expected distribution (**Fig. 2**). This area was expanded, within the constraints of the allotted time, to include the potential habitats for other CPS stocks (e.g., Pacific Sardine; **Fig. 3**). The planned transects (**Fig. 4**) were nearly perpendicular to the coast, separated by 15 nmi south of Point Conception and 20 nmi north of Pt. Conception.

The survey began off San Diego. Sampling from *Lasker* progressed northwards and concluded near San Francisco. The offshore extents of the planned transects were adjusted during the survey according to the observed CPS distribution. To estimate CPS biomasses in areas south of Pt. Conception and around Santa Cruz and Santa Catalina Islands too shallow for *Lasker* to navigate safely, the core survey area was augmented with nearshore transects (**Fig. 4**) sampled by *Long Beach Carnage*.

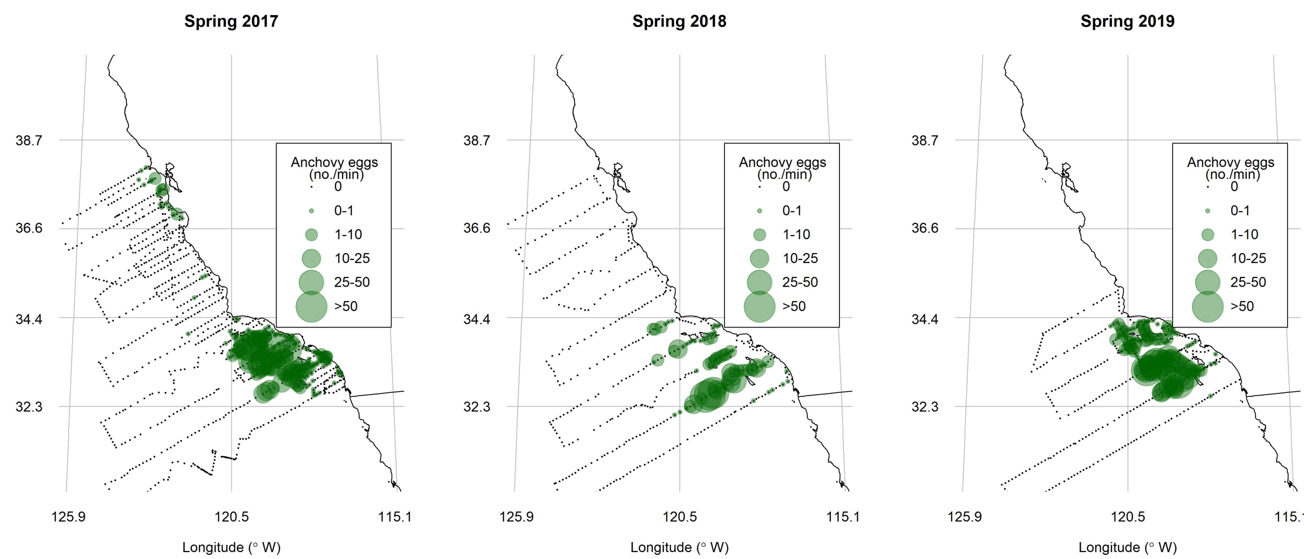

Figure 2: The distributions of Northern Anchovy eggs sampled by the CUFES during spring surveys from (left) 2017 through (right) 2019. Eggs indicate the presence of spawning Northern Anchovy and their distributions were used to delineate the spring 2021 survey area.

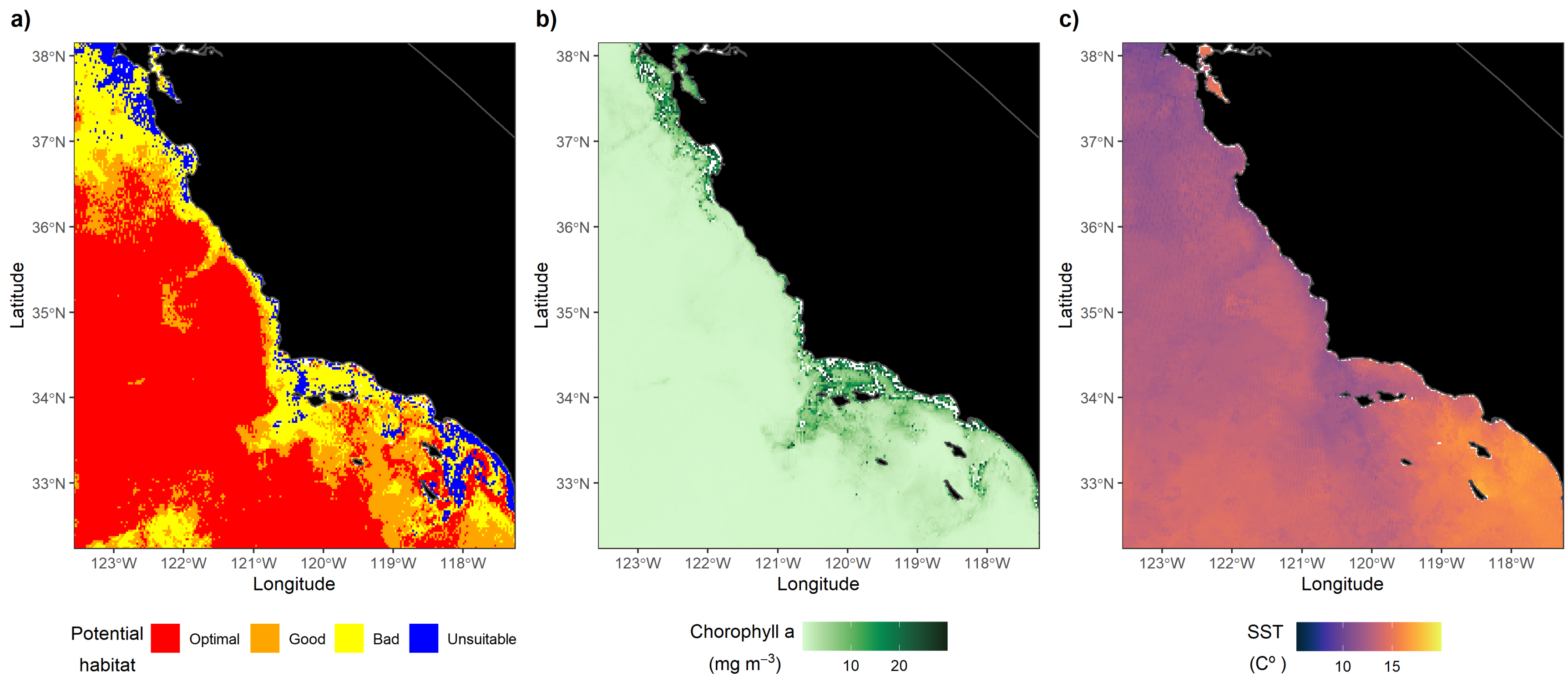

Figure 3: Distributions of (a) potential habitat for the northern stock of Pacific Sardine, which is a function of (b) chlorophyll-a concentration and (c) sea surface temperature (Zwolinski *et al.*, 2011). The images are composites of data from 8 days, 23 March to 1 April, 2021. The potential habitat categories are based on data from spring CalCOFI surveys between 1998 and 2009, and reflect the probabilities of finding at least one sardine egg in a standard CUFES sample. The “good” and “optimal” areas collectively include 90% of the sardine biomass, and the “bad” and “unsuitable” areas contain the remaining 10%.

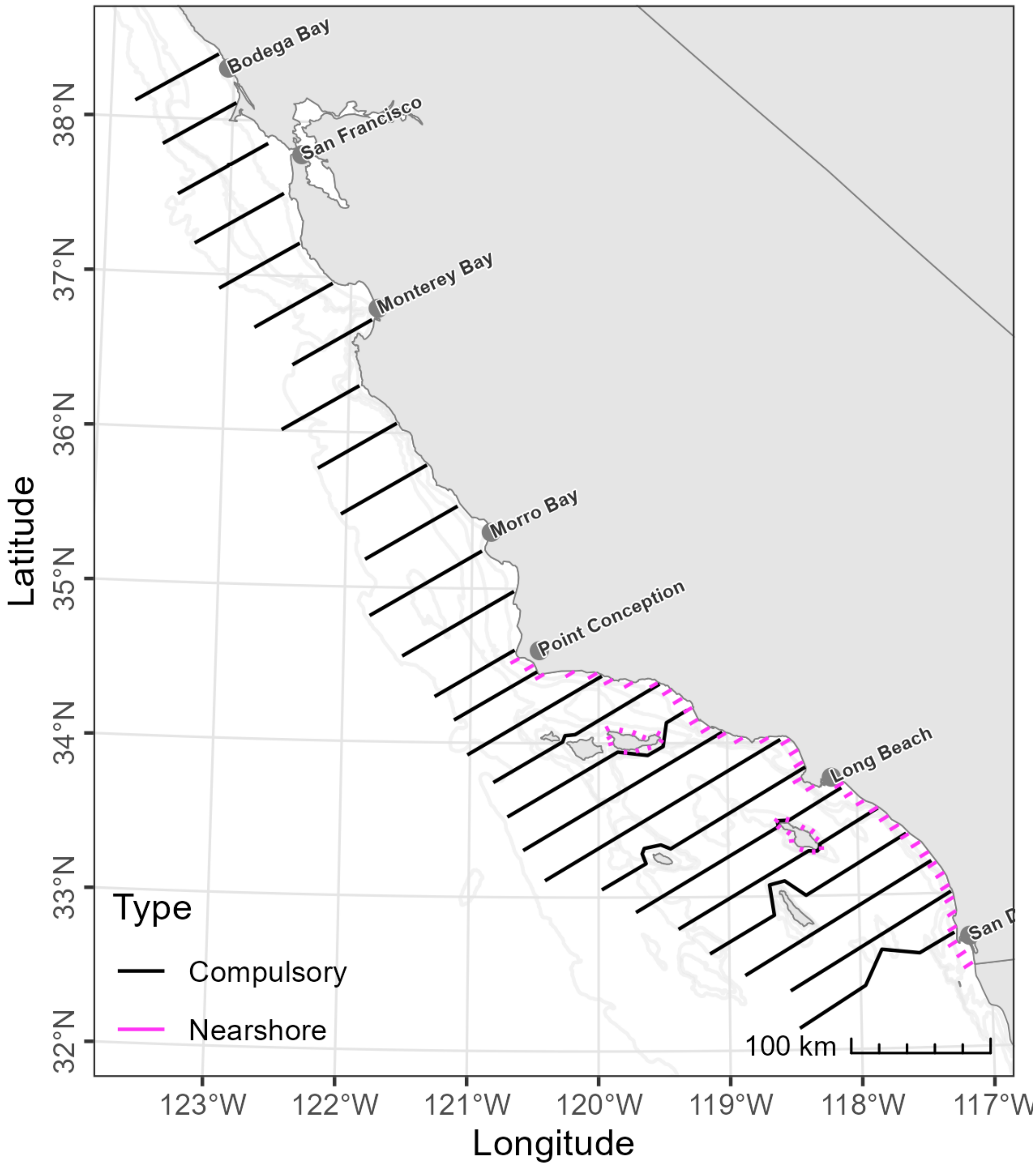

Figure 4: Planned core-area transect lines (solid black lines), sampled by *Lasker*, and nearshore transect lines (solid magenta lines) sampled by F/V *Long Beach Carnage*. Isobaths (light gray lines) indicate 50, 200, 500, and 2,000 m (or approximately 25, 100, 250, and 1,000 ftm) depths.

2.2 Acoustic sampling

2.2.1 Echosounders

On *Lasker*, multi-frequency Wide-Bandwidth Transceivers (18-, 38-, 70-, 120-, 200-, and 333-kHz Simrad EK80 WBTs; Kongsberg) were configured with split-beam transducers (Simrad ES18-11, ES38B, ES70-7C, ES120-7C, ES200-7C, and ES333-7C, respectively; Kongsberg). The transducers were mounted on the bottom of a retractable keel or "centerboard" (**Fig. 5**). The keel was retracted (transducers ~5-m depth) during calibration, and extended to the intermediate position (transducers ~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 ~9-m depth) to provide extra stability and reduce the effect of weather-generated noise (**Appendix A**). Transducer position and motion were measured at 5 Hz using an inertial motion unit (Applanix POS-MV, Trimble).

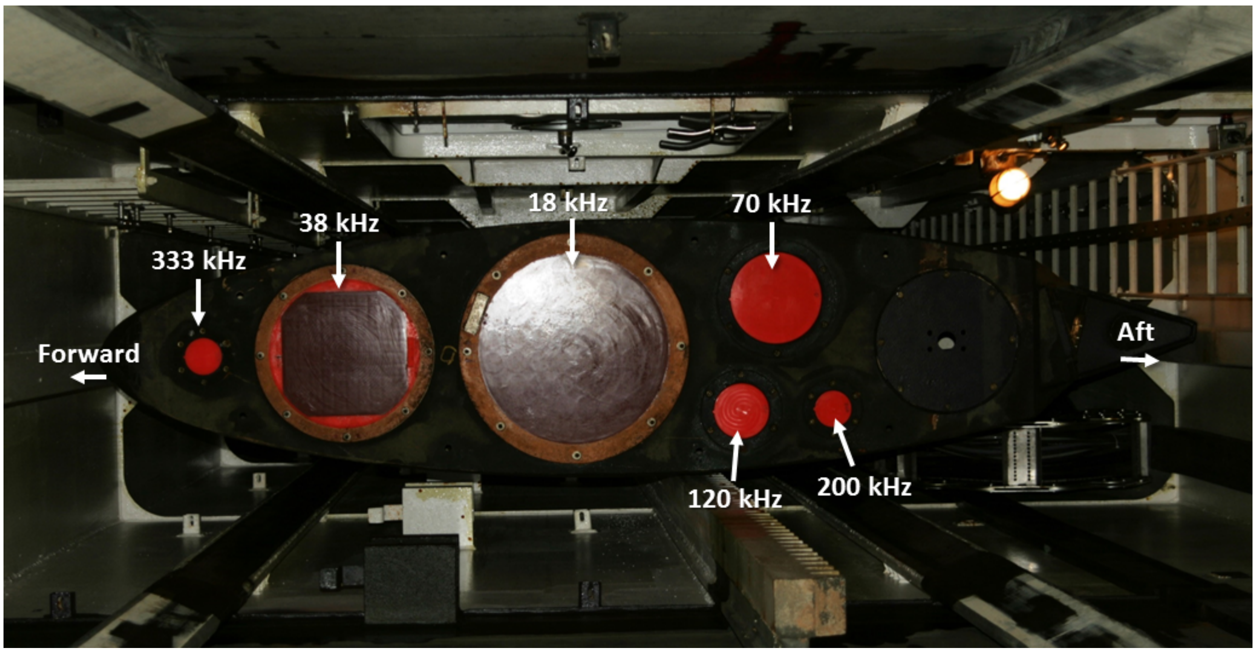

Figure 5: Transducer locations on the bottom of the centerboard aboard *Lasker*.

On *Long Beach Carnage*, the SWFSC's multi-frequency General Purpose Transceivers (38-, 70-, 120-, and 200-kHz Simrad EK60 GPTs; 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 pole (**Fig. 6**).

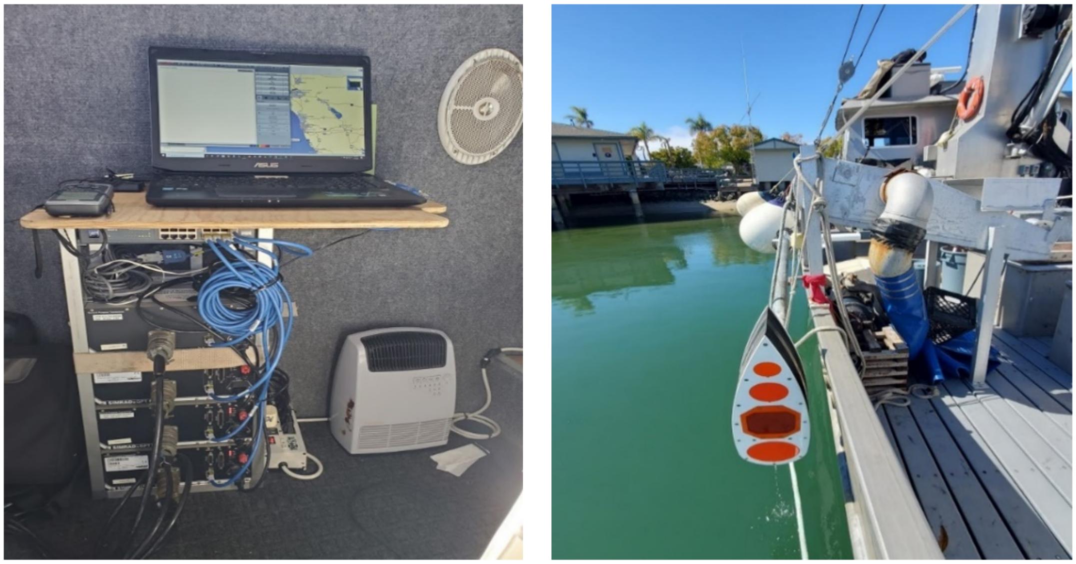

Figure 6: The four-frequency scientific echosounder system aboard F/V *Long Beach Carnage* included four Simrad EK60 GPTs (Kongsberg; left) and four split-beam transducers with center frequencies of 200, 120, 38 and 70 kHz (Kongsberg; top to bottom; right).

2.2.2 Calibrations

The echosounder systems on each vessel were calibrated using the standard sphere technique (Demer *et al.*, 2015; Foote *et al.*, 1987). On *Lasker*, each WBT was calibrated in both CW (i.e., continuous wave) and FM modes (i.e., frequency modulation, chirp, or broadband mode). For *Long Beach Carnage*, the GPTs were calibrated only in CW mode. For all CW calibrations, the reference target was a 38.1-mm diameter sphere made from tungsten carbide (WC) with 6% cobalt binder material (WC38.1; *Lasker* sphere #1); calibrations of WBTs in FM mode used both the WC38.1 and a smaller 25-mm WC sphere. On each vessel, GPTs and WBTs were configured using the calibration results via the control software (Simrad EK80 v1.12.2; Kongsberg; see **Section 3.1**). Impedance measurements were not made prior to the survey.

2.2.3 Data collection

2.2.3.1 *Lasker* Computer clocks were synchronized with the GPS clock (UTC) using synchronization software (NetTime[1]). The 18-kHz GPT, operated by a separate PC from the other echosounders, was programmed to track the seabed and output the detected depth to the ship's Scientific Computing System (SCS). The 38-, 70-, 120-, 200-, and 333-kHz echosounders were controlled by the ER60 Adaptive Logger (EAL[2], Renfree and Demer, 2016). The EAL optimizes the pulse interval based on the seabed depth, while avoiding aliased seabed echoes, and was programmed such that once an hour the echosounders would operate in passive mode and record three pings 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.

Measurements of volume backscattering strength (S_v; dB re 1 m^2 m^{-3}) and target strength (TS, dB re 1 m^2), indexed by time and geographic positions provided by GPS receivers, were logged to 60 m beyond the detected seabed range or to a maximum of 350 m and stored in Simrad .raw format with a 50-MB maximum file size. During daytime and nighttime, the echosounders were set to operate in CW and FM modes, respectively. For each acoustic instrument, the prefix for each file name is a concatenation of the

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

survey name (e.g., 2103RL), the operational mode (CW or FM), and the logging commencement date and time from the EK80 software. For example, a file generated by the Simrad EK80 software (v1.12.2) for a WBT operated in CW mode is named `2103RL-CW-D20210323-T125901.raw`.

To minimize acoustic interference, transmit pulses from the EK80s, multibeam echosounder (Simrad ME70; Kongsberg), imaging sonar (Simrad MS70; Kongsberg), scanning sonar (Simrad SX90; Kongsberg), and the acoustic Doppler current profiler (Ocean Surveyor Model OS75 ADCP; Teledyne RD Instruments) were triggered using a synchronization system (Simrad K-Sync; Kongsberg). The K-Sync trigger rate, and thus the echosounder ping interval, was modulated by the EAL using the 18-kHz seabed depth provided by *Lasker*'s Scientific Computing System (SCS). During daytime, the ME70, SX90, and ADCP were operated continuously, while the MS70 was only operated at times when CPS were present. At nighttime, only the EK80, and ADCP were operated. All other instruments that can produce sound within the EK80's CW 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 (Model SRD-500A DVL; Sperry Marine), or both.

2.2.3.2 ***Long Beach Carnage*** The EAL was used to control the EK80 software to modulate the echosounder recording ranges and ping intervals to avoid aliased seabed echoes. When the EAL was not utilized, the EK80 software recorded to 500 m and used the maximum ping rate. Transmit pulses from the EK60s and fishing sonars were not synchronized. Therefore, the latter was secured during daytime acoustic transects.

2.2.4 Data processing

Echoes from schooling CPS and krill (**Figs. 7a, d**) were identified using a semi-automated data processing algorithm implemented using Echoview software (v12.0; 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. 7**). Data from *Lasker* 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. 7b, e**);
4. Average the noise-free S_v echograms using non-overlapping 11-sample by 3-ping bins;
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. Compute the 120- and 200-kHz Variance-to-Mean Ratios ($VMR_{120\text{kHz}}$ and $VMR_{200\text{kHz}}$, respectively, Demer *et al.*, 2009) using the difference between noise-filtered S_v (Step 3) and averaged S_v (Step 4);
9. Expand the $VMR_{120\text{kHz}}$ and $VMR_{200\text{kHz}}$ echograms with a 7 pixel x 7 pixel dilation;
10. Create a Boolean echogram based on the VMRs in the CPS range: $VMR_{120\text{kHz}} >$ -65 dB and $VMR_{200\text{kHz}} >$ -65 dB. Diffuse backscattering layers have low VMR (Zwolinski *et al.*, 2010) whereas fish schools have high VMR (Demer *et al.*, 2009);
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. 7c, f**);
13. Create an integration-start line 5 m below the transducer (~12 m depth);
14. Create an integration-stop line 3 m above the estimated seabed (Demer *et al.*, 2009), or to the maximum logging range (e.g., 1000 m), whichever is shallowest;

15. Set the minimum S_v threshold to -60 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, to include the entirety of shallow CPS aggregations, or to exclude seabed echoes. Echoes suspected to be from rockfish schools were further excluded.

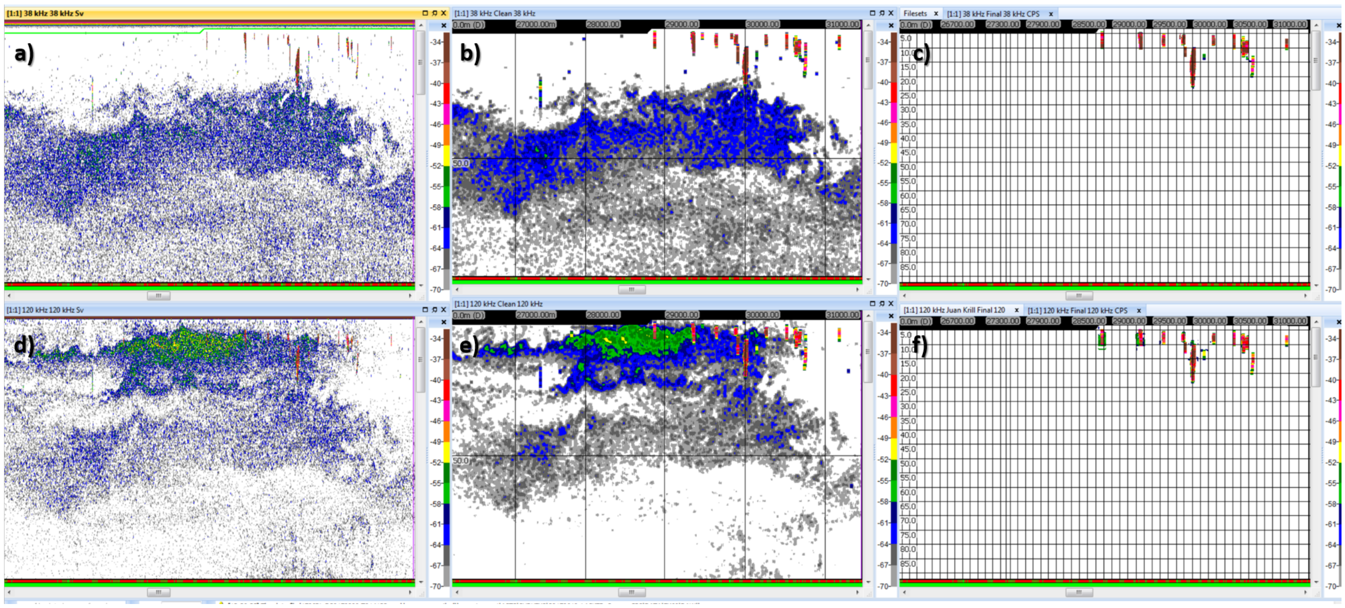

Figure 7: Echograms depicting CPS schools (red) and plankton aggregations (blue and green) at 38 kHz (top row) and 120 kHz (bottom row). Example data processing steps include the original echogram (left column), after noise subtraction and bin-averaging (middle column), and after filtering to retain only putative CPS echoes (right column). Different filtering was also used to retain only putative krill echoes (not shown).

2.3 Trawl sampling aboard *Lasker*

During the day, CPS form schools, typically in the upper mixed layer, e.g., to 70-m depth in the spring (Kim *et al.*, 2005), and generally shallower in summer. After sunset, CPS schools tend to ascend and disperse. At that time, with reduced visibility and no schooling behavior, they are less able to avoid a net (Mais, 1974). Therefore, trawl sampling, for identifying the species composition and length distributions of acoustic targets, was performed at night.

The net, a Nordic 264 rope trawl (NET Systems; Bainbridge Island, WA; **Figs. 8a, b**), has a rectangular opening in the fishing portion of the net with an area of approximately 300 m^2 (~15-m tall x 20-m wide), variable-sized mesh in the throat, an 8-mm square-mesh cod-end liner to retain a large range of animal sizes, and a "marine mammal excluder device" to prevent the capture of large animals, such as dolphins, turtles, or sharks (Dotson *et al.*, 2010). The trawl doors are foam-filled and the trawl head rope is lined with floats so the trawl tows at the surface.

Up to three nighttime (i.e., 60 min after sunset to 30 min before sunrise) surface trawls, typically spaced 5-10 nmi-apart, were conducted in areas where echoes from putative CPS schools were observed in echograms or eggs were observed in the Continuous Underway Fish Egg Sampler (CUFES, Checkley *et al.*, 1997) earlier that day. Each evening, trawl locations were selected by an acoustician who monitored CPS echoes and a member of the trawl group who measured the densities of CPS eggs in CUFES samples. The locations were provided to the watch officers who charted the proposed trawl sites. Trawl locations were selected using the following criteria, in descending priority: CPS schools in echograms that day, CPS eggs in CUFES samples that day, and the trawl locations and catches during the previous night. If no CPS echoes or CPS eggs were observed along the transect(s) that day, the trawls were alternatively placed nearshore one night and offshore the next night, with consideration given to the seabed depth and the modeled distribution of northern stock Pacific Sardine habitat.

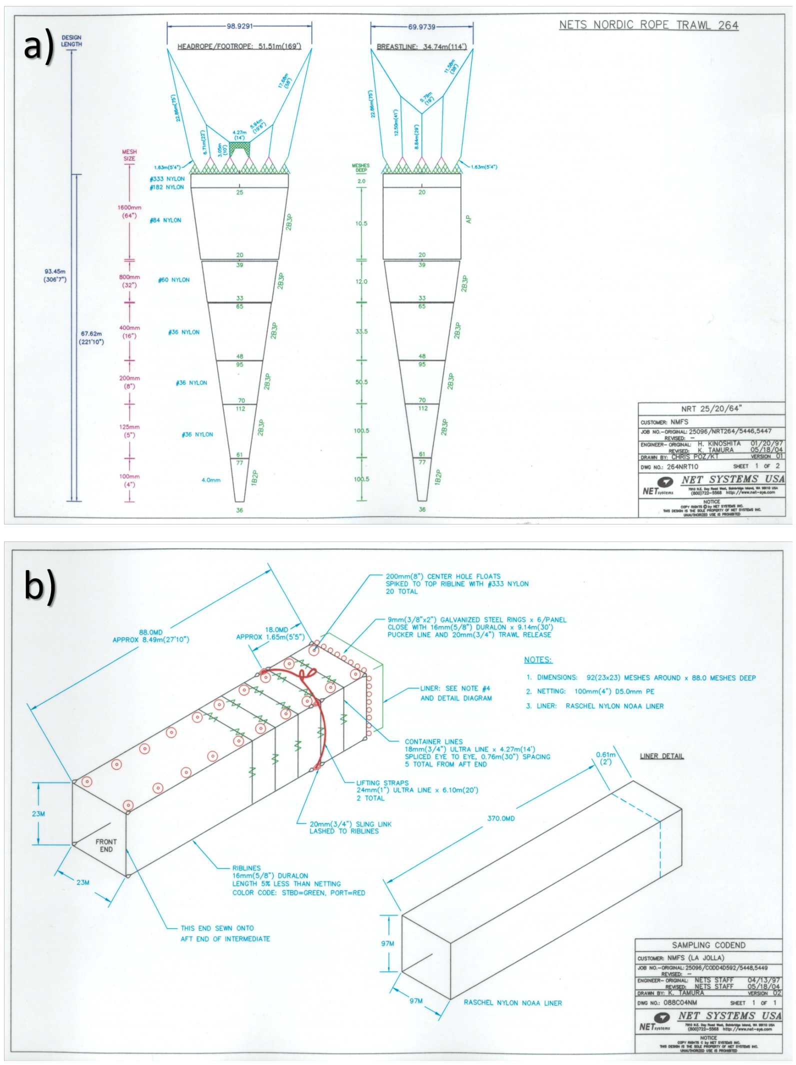

Figure 8: Schematic drawings of the Nordic 264 rope trawl net (a) and cod-end (b).

Trawls were towed at ~4 kn for 45 min. The total catch from each trawl was weighed and sorted by species or taxonomic groups. From the catches with CPS, specimens were selected randomly for each of the target species (up to 75 for Pacific Sardine and Northern Anchovy, and up to 50 for Pacific Mackerel, Jack Mackerel, and Pacific Herring). Those were weighed and measured to either their standard length (L_S; mm) for Pacific Sardine and Northern Anchovy, or fork length (L_F; mm) for Jack Mackerel, Pacific Mackerel, and Pacific Herring. In addition, sex and maturity were recorded for up to 75 specimens from Pacific Sardine and Northern Anchovy and up to 25 for Pacific and Jack Mackerels. Ovaries were preserved for up to 10 specimens of each CPS species except Pacific Herring, for which none were preserved, and for Northern Anchovy, for which up to 25 ovaries were preserved. From the random samples, otoliths were removed from up to 50 Pacific Sardine, from up to 25 Northern Anchovy, and from up to 10 Pacific Mackerel and 10 Jack Mackerel. The combined catches in up to three trawls per night (i.e., trawl cluster) were used to estimate the proportions of species contributing to the nearest samples of acoustic backscatter.

2.4 Purse seine sampling aboard *Long Beach Carnage*

Each day, after the transects had been surveyed, *Long Beach Carnage* collected CPS samples by fishing up to three times in the vicinity of randomly selected CPS schools observed in the echograms. The samples were set to provide information about size, age, and species composition of fishes observed in the nearshore region. The purse seine net was is 200-m-long and 27-m-deep net with mostly 17-mm-wide mesh. A small section on the back-end of the net had 25-mm-wide mesh.

For every set, three dip net samples were collected from the purse seine net. Each dip net sample was put in a bag and tagged with a date, time of capture, latitude and longitude, transect number, school and dip net numbers, and estimated tonnage of the entire school. Ashore, CDFW biologists processed the samples according to the following protocol:

- For each dip net sample, Pacific Sardine, Northern Anchovy, Pacific Mackerel, and Jack Mackerel were sorted and the number of fish and combined weight of each species were recorded.
- The contents of all dip nets in each set were combined, and as many as 50 fish of each species were selected randomly.
- From each random sample, the following statistics were measured:
  - total sample weight, to the nearest gram,
  - individual fish weight, to the nearest gram,
  - individual fish length, to the nearest mm, using L_S for Pacific Sardine and Northern Anchovy, and L_F for mackerels, and
  - maturity stage.

Otoliths were extracted from all randomly selected specimens.

2.5 Ichthyoplankton and oceanographic sampling aboard *Lasker*

2.5.1 Egg and larva sampling

During the day, fish eggs were collected using a CUFES, which collects water and particles at a rate of ~640 l min^{-1} from an intake on the hull of the ship at ~3-m depth. The particles in the sampled water were sieved by a 505-μm mesh. Pacific Sardine, Northern Anchovy, Jack Mackerel, and Pacific Hake (*Merluccius productus*) eggs among the particles were identified to species, counted, and logged. Eggs from other species (e.g., Pacific Mackerel and flatfishes) were also counted and logged as "other fish eggs". Typically, the duration of each CUFES sample was 30 min, corresponding to a distance of 5 nmi at a speed of 10 kn. Because the duration of the egg phase is less than three days for most CPS, the persistent presence of eggs is indicative of spawning activity within roughly 10 nmi, depending on the local advection and dispersion.

2.5.2 Conductivity and temperature versus depth (CTD) sampling

Aboard *Lasker*, conductivity and temperature were measured versus depth to 350 m using calibrated sensors on a probe cast from the vessel while on station (CTD), or cast from the vessel while underway (UnderwayCTD, or UCTD; Teledyne Oceanscience). These data were used to estimate the time-averaged sound speed (Demer, 2004), 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). These data indicate the depth of the surface mixed layer, above which most epipelagic CPS reside during the day, and are also used to determine the integration-stop depth during acoustic data processing.

3 Results

3.1 Echosounder calibrations

3.1.1 *Lasker*

The EK80s were calibrated on 1 March while the vessel was alongside the pier near 10th Avenue Marine Terminal (32.6956 °N, -117.15278 °W), San Diego Bay. Mean sea-surface temperature (t_w = 16.1 °C) and salinity (s_w = 33 psu) were measured to a depth of 10 m using a handheld probe (Pro2030, YSI) and input to the WBT-control software (Simrad EK80 v1.12.2, Kongsberg), which derived estimates of sound speed (c_w = 1507.9 m s^{-1}) and absorption coefficients (see **Table 1**). Varying with tide, the seabed was approximately 5 to 8 m beneath the transducers. The calibration spheres were positioned in the far-field of each transducer, at 3.5 to 7-m range. WBT information, settings, and calibration results are presented in **Table 1**. Measurements of beam-compensated sphere target strength relative to the theoretical target strength (TS_{rel}, dB re 1 m^2) are presented in **Fig. 9**. Measurements of gain, beamwidth, and offset angles from WBTs operated in FM mode are presented in **Fig. 10**.

Table 1: Wide-Bandwidth Transceiver (Simrad WBT; 18, 38, 70, 120, 200, and 333 kHz; Kongsberg) and transducer information; pre-calibration settings (above horizontal line); and beam model results following calibration (below horizontal line). Prior to the survey, on-axis gain (G_0), beam angles (α_{-3dB} and β_{-3dB}), angle offsets (α_0 and β_0), and S_a Correction ($S_a$corr) values from calibration results were entered into the control software (Simrad EK80 v1.12.2; Kongsberg).

		Frequency (kHz)					
	Units	18	38	70	120	200	333
Model		ES18	ES38-7	ES70-7C	ES120-7C	ES200-7C	ES333-7C
Serial Number		2106	337	233	783	513	124
Transmit Power (p_{et})	W	1000	1000	600	200	90	35
Pulse Duration (τ)	ms	1.024	1.024	1.024	1.024	1.024	1.024
Eq. Two-way Beam Angle (Ψ)	dB re 1 sr	-17	-20.7	-20.7	-20.7	-20.7	-20.7
On-axis Gain (G_0)	dB re 1	23.1	26.27	27.63	26.79	27.14	26.59
S_a Correction ($S_a$corr)	dB re 1	-0.0267	0.0471	-0.0081	-0.037	-0.0755	-0.1435
RMS	dB	0.039	0.047	0.04	0.032	0.079	0.11
3-dB Beamwidth Along. (α_{-3dB})	deg	10.37	6.41	6.73	6.6	6.57	6.55
3-dB Beamwidth Athw. (β_{-3dB})	deg	10.42	6.42	6.71	6.6	6.57	6.62
Angle Offset Along. (α_0)	deg	-0.06	0	-0.03	-0.02	-0.03	0.06
Angle Offset Athw. (β_0)	deg	-0.02	-0.04	-0.03	0.01	0	0.03

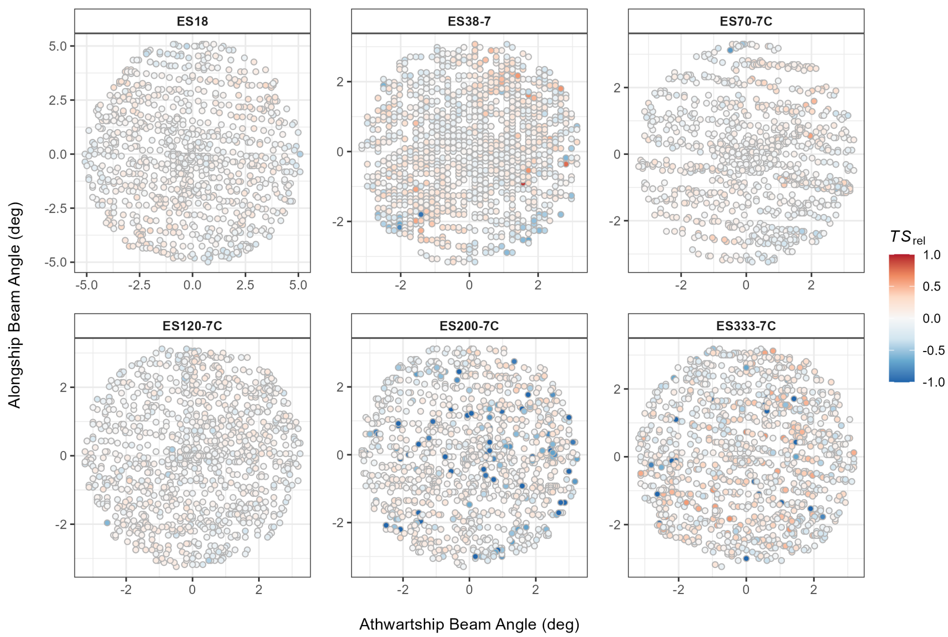

Figure 9: Relative beam-compensated target strength (TS_{rel}, dB re 1 m^2) measurements of a WC38.1 sphere at 18, 38, 70, 120, 200, and 333 kHz. TS_{rel} is calculated as the difference between the beam-compensated target strength (TS_c) and the theoretical target strength (TS_{theory}, see **Table 1**). Data for the 18-kHz transducer are from the last known good calibration prior to the 2018 Summer CCE survey. Crosses indicate measurements marked as outliers after viewing the beam model results.

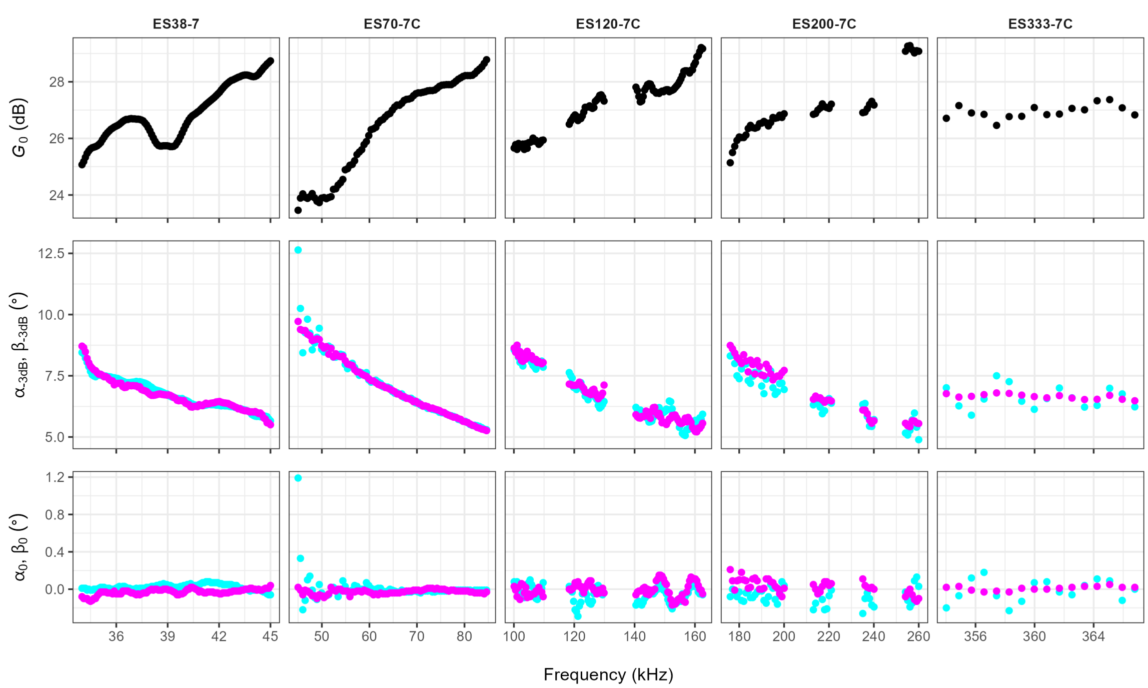

Figure 10: Measurements of on-axis gain (G_0, dB); alongship ($\alpha_{-3\text{dB}}$, cyan) and athwartship ($\beta_{-3\text{dB}}$, magenta) beamwidths (deg); and alongship (α_0, cyan) and athwartship (β_0, magenta) offset angles (deg) measured during calibrations of the 38, 70, 120, 200, and 333 kHz Simrad EK80 Wide-Bandwidth Transceivers (WBTs; Kongsberg) in frequency modulation (FM, or broadband) mode.

3.1.2 *Long Beach Carnage*

The echosounders were calibrated in a tank at the SWFSC. The beam model results were entered into the GPT-control software (Simrad EK80 v1.12.2; Kongsberg) and are presented in **Table 2**. The calibration parameters were adjusted for local environmental conditions using UCTD data collected from *Lasker*.

Table 2: General Purpose Transceiver (Simrad EK60 GPT; Kongsberg) calibrated beam model results. Prior to the survey, calibrated on-axis gain (G_0), beam angles and angle offsets, and S_a Correction ($S_\mathrm{a}$corr) values were entered into the GPT-control software (Simrad EK80; Kongsberg).

		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	1.024	1.024	1.024
Eq. Two-way Beam Angle (Ψ)	dB re 1 sr	-15.5	-20.7	-20.7	-20.7
On-axis Gain (G_0)	dB re 1	21.75	26.35	26.35	26.64
S_a Correction ($S_\mathrm{a}$corr)	dB re 1	-0.6298	-0.3434	-0.4141	-0.2052
RMS	dB	0.051	0.03	0.068	0.11
3-dB Beamwidth Along. ($\alpha_{-3\mathrm{dB}}$)	deg	12.66	6.76	6.82	6.83
3-dB Beamwidth Athw. ($\beta_{-3\mathrm{dB}}$)	deg	12.71	6.73	6.74	6.82
Angle Offset Along. (α_0)	deg	-0.03	0.06	0.15	-0.02
Angle Offset Athw. (β_0)	deg	0.07	0.02	0.06	0.1

3.2 Data collection

3.2.1 Acoustic and net sampling

The core survey region spanned an area from approximately San Francisco to San Diego (**Fig. 11**). *Lasker* sampled 27 east-west transects totaling 1,679 nmi, and conducted 49 nighttime trawls.

The nearshore region spanned an area from approximately Pt. Conception to San Diego, including around Santa Cruz and Santa Catalina Islands (**Fig. 13**). *Long Beach Carnage* sampled 61 east-west transects totaling 191 nmi, and completed 10 purse seine sets.

Leg I

On 20 March, *Lasker* departed from 10th Avenue Marine Terminal in San Diego at ~1400 (all times UTC). Acoustic sampling commenced along the southernmost transect, 002 (**Fig. 4**, **Appendix B**). On 1 April, acoustic sampling ceased in the middle of transect 010 off Pt. Mugu, CA, between Long Beach and Pt. Conception and due east of the northern Channel Islands, when *Lasker* transited to Dana Point to exchange scientific personnel before completing Leg I.

Leg II

On 1 April, *Lasker* resumed sampling along transect 012 (**Fig. 4**, **Appendix B**) near Santa Barbara, which is northeast of the northern Channel Islands. On 12 April, acoustic sampling ceased after the completion of transect 028 off Bodega Bay. At ~1700 on 16 April, *Lasker* arrived at Pier 30/32 in San Francisco Bay to complete Leg II.

During Legs I and II, *Lasker* coordinated with *Long Beach Carnage*, to sample the core and nearshore transects (**Fig. 4**, **Appendix C**), in the same areas, within less than three days of each other.

3.2.2 Ichthyoplankton and oceanographic sampling

A total of 11 CTD casts and 14 UCTD casts were conducted, and 430 CUFES samples were collected underway. The locations of CTD and UCTD stations are presented in **Fig. 11** and **Appendix D**.

3.3 Distribution of CPS

3.3.1 Core region

Acoustic backscatter sampled by *Lasker* and ascribed to CPS (**Fig. 12a**) was observed throughout the survey area, but was most prevalent south of San Francisco and in the offshore portion of transects south of Pt. Conception. Backscatter from CPS was conspicuously absent along the nearshore portions of the SCB, with the exception of the inner 2-3 nmi-wide strip sampled by *Long Beach Carnage* (**Fig. 13b**).

Northern Anchovy eggs were observed throughout the survey region south of Monterey Bay, but were most abundant in CUFES samples along the offshore portions of transects in the Southern CA Bight, coincident with backscatter ascribed to CPS (**Fig. 12b**). Few Pacific Sardine eggs were observed, mostly around the southeast coast of Santa Catalina Island (**Fig. 12b**). No Jack Mackerel eggs were observed.

Northern Anchovy catches were predominant, by weight, in trawl samples collected throughout the survey area (**Fig. 12c**). Jack Mackerel were present in the catches of several trawls offshore in the SCB, and one near Long Beach (**Fig. 12c**). Pacific Sardine were caught in nine trawls; however, catches were small and not visible in **Fig. 12c** except in the species proportions for one trawl haul offshore of the northern Channel Islands. Pacific Mackerel were caught in two hauls in the SCB, but are not visible at the map scale in **Fig. 12c**. Overall, the 49 trawls captured a combined 4,293 kg of CPS, including: 4,290 kg of Northern Anchovy, 1.32 kg of Pacific Sardine, 0.556 kg of Pacific Mackerel, 1.13 kg of Jack Mackerel, and no Pacific Herring (**Appendix E**).

3.3.2 Nearshore region

Acoustic backscatter sampled by *Long Beach Carnage* and ascribed to CPS was observed throughout the nearshore survey area, but was most prevalent between Santa Barbara and Malibu, between Costa Mesa and La Jolla, and around Santa Cruz Island (**Fig. 13a**).

Northern Anchovy and Pacific Sardine were the predominant CPS collected in purse seine sets by *Long Beach Carnage* (**Fig. 13b**). A few purse seine samples contained Pacific Mackerel south of Long Beach (**Fig. 13b**). Overall, the 10 seine sets captured a combined 15.7 kg of CPS, including: 2.5 kg of Northern Anchovy, 12.3 kg of Pacific Sardine, 0.94 kg of Pacific Mackerel, and no Jack Mackerel or Pacific Herring (**Appendix F**).

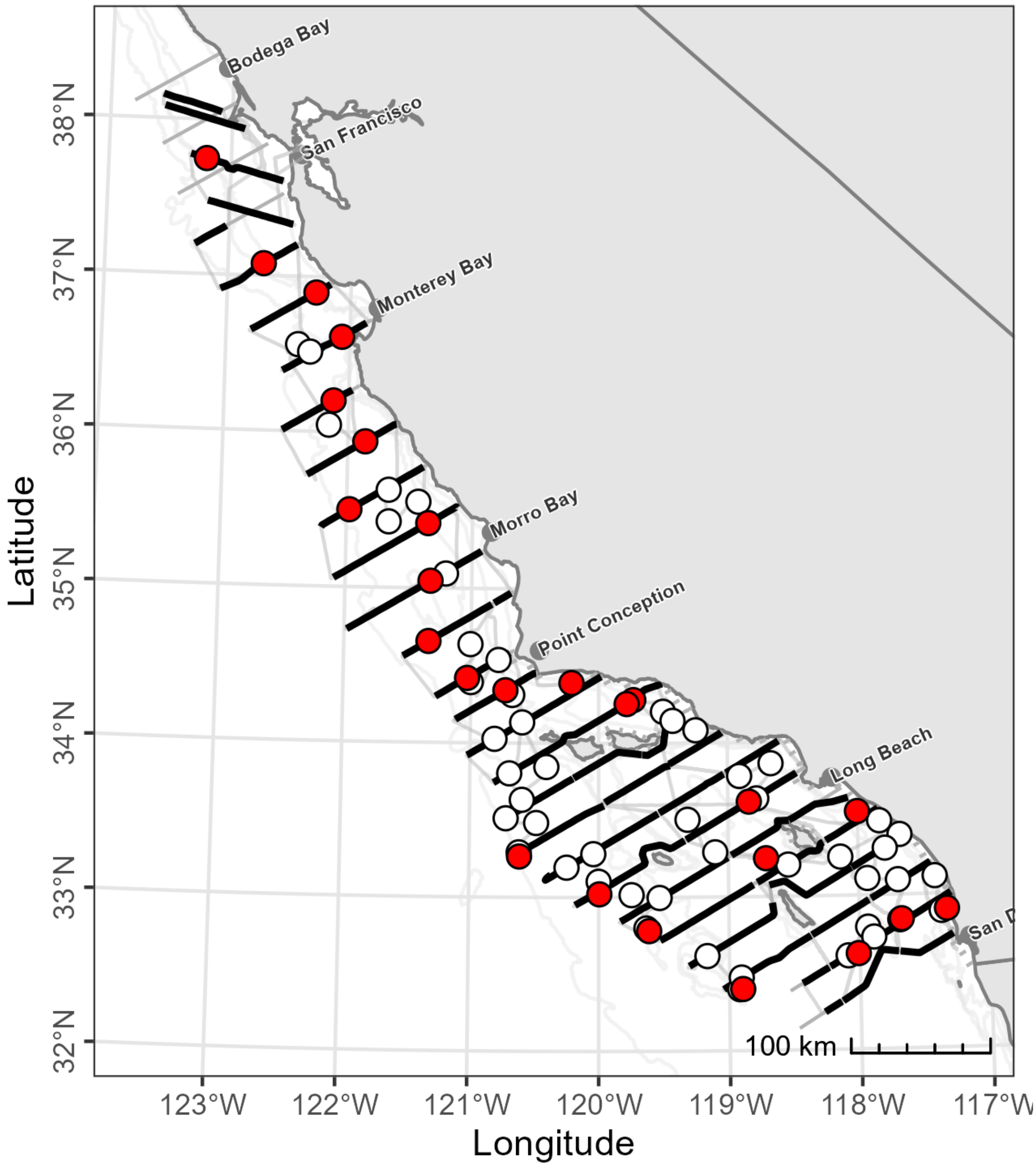

Figure 11: The locations of surface trawls (white points) and CTD and UCTD casts (red circles) relative to the east-west acoustic transects (black lines) and cruise track of *Lasker* (heavy gray line).

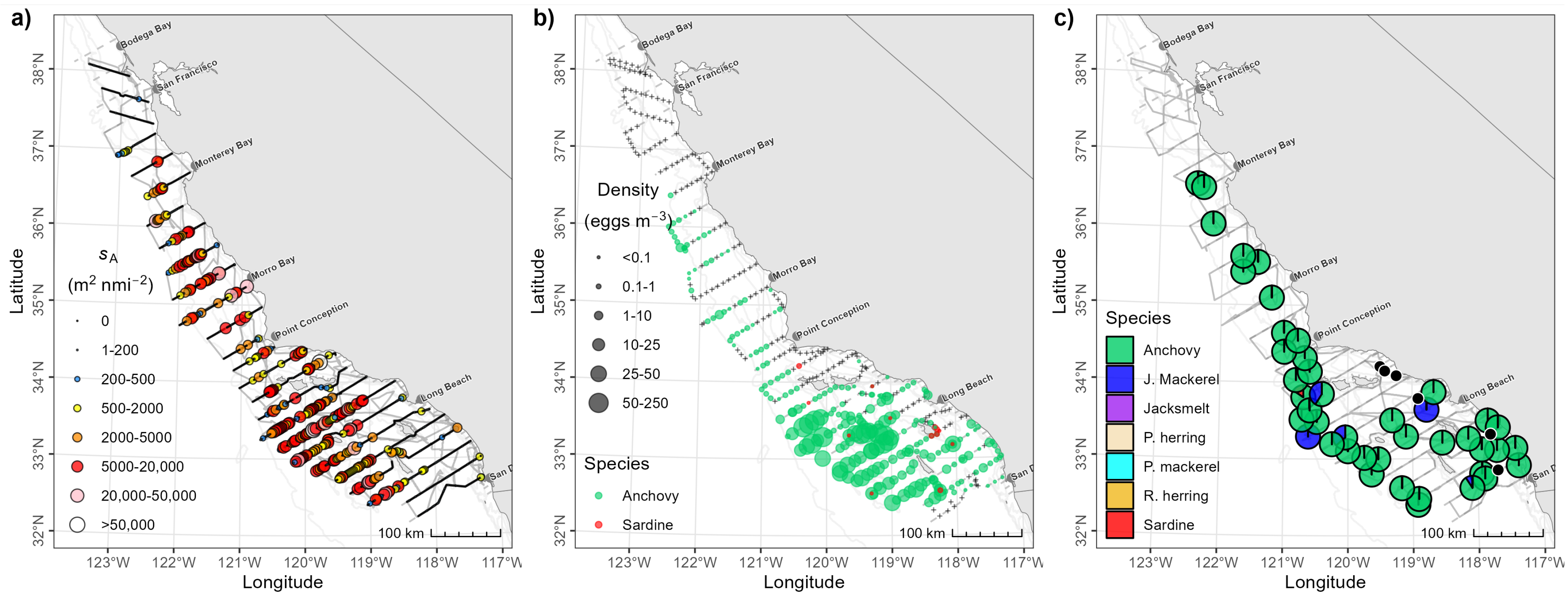

Figure 12: Survey transects overlaid with: (a) the distribution of 38-kHz integrated backscattering coefficients (s_A, m^2 nmi^{-2}; averaged over 2000-m distance intervals) ascribed to CPS; (b) egg densities (eggs m^{-3}) for Northern Anchovy, Jack Mackerel, and Pacific Sardine from the CUFES; and (c) proportions, by weight, of CPS species in each trawl sample (black points indicate trawls with no CPS). Species with low catch weights are not visible at this scale.

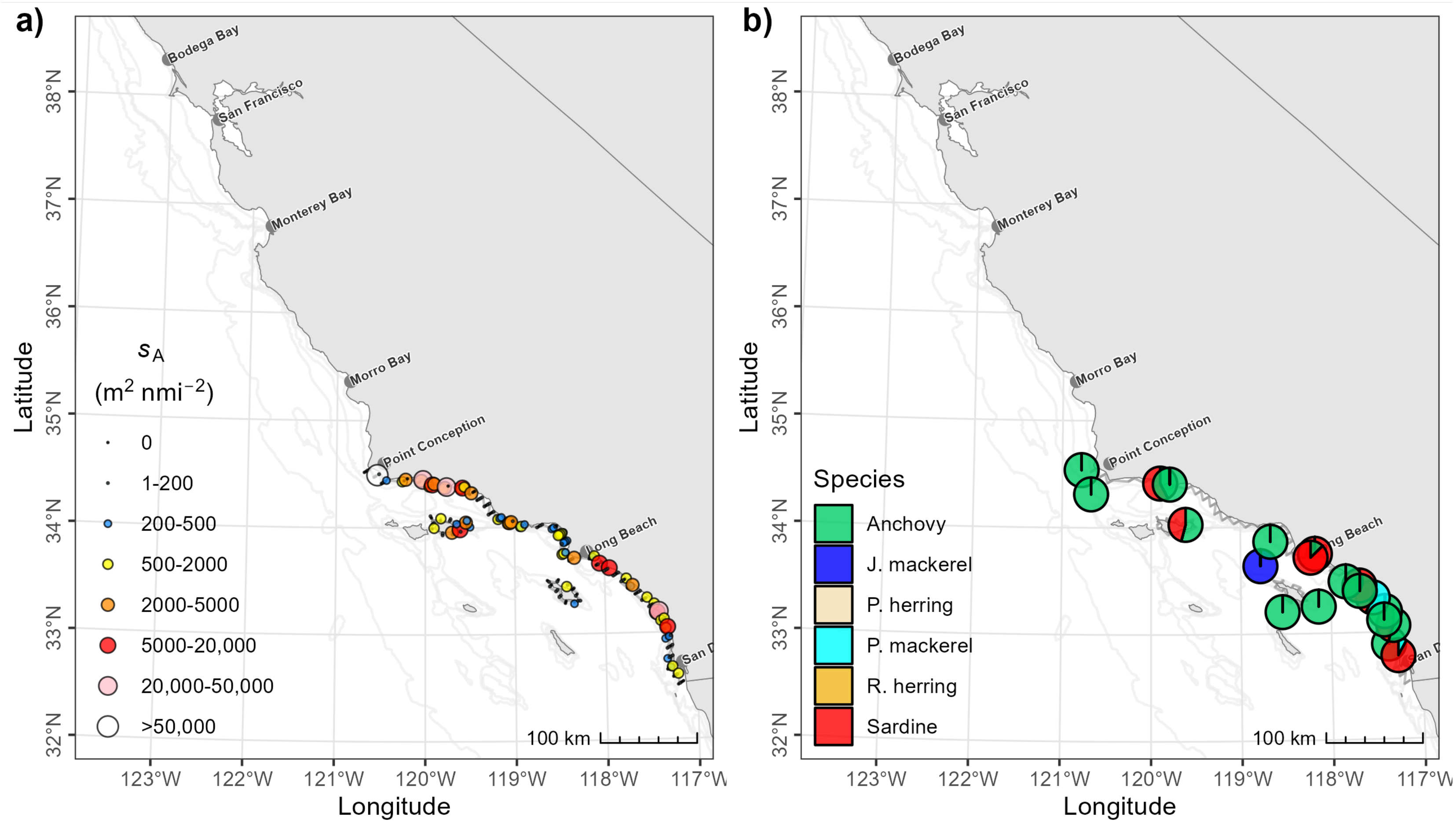

Figure 13: Nearshore survey transects conducted by *Long Beach Carnage* overlaid with: (a) the distribution of 38-kHz integrated backscattering coefficients (s_A, m^2 nmi^{-2}; averaged over 2000-m distance intervals) ascribed to CPS; and (b) the proportions, by weight, of CPS in the nearest purse seine set or trawl haul. Species with low catch weights are not visible at this scale.

4 Discussion

The principal objectives of the 25-day, Spring 2021 CCE Survey were to estimate the biomasses and distributions of the central stock of Northern Anchovy and, as possible, produce estimates for other CPS in the survey area. With the benefits of favorable weather and few technical problems, *Lasker* surveyed the entire planned area from San Francisco to San Diego, and *Long Beach Carnage* surveyed the nearshore region from Pt. Conception to San Diego, and around Santa Catalina and Santa Cruz Islands.

Northern Anchovy from the central stock dominated the egg samples and trawl catches in the core area. In addition to Northern Anchovy, the nearshore purse seine catches in the Southern California Bight and off Santa Cruz Island included mostly Pacific Sardine. Throughout the survey, catches of Jack and Pacific Mackerel were relatively scarce.

5 Disposition of Data

All raw EK60, EK80, ME70, MS70, and SX90 data, including the EK60 and EK80 calibration data, are archived on the SWFSC data server. For more information, contact: David Demer (Southwest Fisheries Science Center, 8901 La Jolla Shores Drive, La Jolla, California, 92037, U.S.A.; phone: 858-546-5603; email: david.demer@noaa.gov). A subset of acoustic data will also be available via NOAA's National Centers for Environmental Information (NCEI) Water Column Sonar Data portal[3]. Trawl catch[4] and specimen[5] data are available via ERDDAP. CUFES egg data[6] are also available via ERDDAP.

6 Acknowledgements

We thank the crew members of NOAA Ship *Lasker*, as well as the scientists that participated in the sampling operations at sea and the catch processing aboard. We thank Captains Rich Ashley and Tom Brinton, John Marcopolous, and William Hargrave (*Long Beach Carnage*) for their coordination and cooperation during the nearshore sampling. We thank Diane Pleschner-Steele for contracting *Long Beach Carnage* to conduct the nearshore survey. We thank Joel van Noord for conducting the biological sampling at sea aboard *Long Beach Carnage*. Critical reviews by Matthew Craig and Annie Yau improved this report.

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[5]https://coastwatch.pfeg.noaa.gov/erddap/tabledap/FRDCPSTrawlLHSpecimen.html
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Appendix

A Centerboard positions

Date, time, and location associated with each known change to the position of the centerboard and therefore the transducer depths. The information is obtained from event data generated by the ship's bridge, and may not be comprehensive.

Date Time	Position (depth)	Latitude	Longitude
04/01/2021 13:37	Retracted (5 m)	33.4448	-117.7483
04/01/2021 21:51	Intermediate (7 m)	33.3890	-117.8283
04/08/2021 18:15	Extended (9 m)	36.5485	-122.2160
04/11/2021 07:52	Retracted (5 m)	38.0098	-122.9495
04/11/2021 16:55	Extended (9 m)	37.9792	-122.8907
04/13/2021 03:37	Retracted (5 m)	37.6507	-122.6308

B Core transect waypoints

Planned transects in the core region sampled by *Lasker*.

Transect	Waypoint	Latitude	Longitude	Region	Depth (m)
2	002.1C	32.7427	-117.2745	S. CA Bight	-39
2	002.101C	32.6149	-117.5444	S. CA Bight	-1202
2	002.102C	32.6435	-117.8334	S. CA Bight	-665
2	002.103C	32.4114	-117.9631	S. CA Bight	-1754
2	002.2C	32.1406	-118.4695	S. CA Bight	-761
3	003.1C	33.0094	-117.2925	S. CA Bight	-25
3	003.2C	32.3844	-118.5352	S. CA Bight	-876
4	004.1C	33.2121	-117.4368	S. CA Bight	-24
4	004.2C	32.4881	-118.8804	S. CA Bight	-1296
5	005.1C	33.3927	-117.6262	S. CA Bight	-18
5	005.101C	33.0034	-118.4055	S. CA Bight	-838
5	005.102C	33.0993	-118.5691	S. CA Bight	-1274
5	005.103C	33.0740	-118.6857	S. CA Bight	-450
5	005.104C	32.8772	-118.6517	S. CA Bight	-682
5	005.2C	32.6305	-119.1484	S. CA Bight	-214
6	006.1C	33.5613	-117.8399	S. CA Bight	-49
6	006.101C	33.3356	-118.2932	S. CA Bight	-96
6	006.102C	33.3101	-118.2925	S. CA Bight	-71
6	006.103C	33.2895	-118.3145	S. CA Bight	-38
6	006.104C	33.2917	-118.3811	S. CA Bight	-79
6	006.2C	32.7922	-119.3881	S. CA Bight	-820
7	007.1C	33.6975	-118.1196	S. CA Bight	-18
7	007.101C	33.4925	-118.5284	S. CA Bight	-269
7	007.102C	33.4902	-118.6191	S. CA Bight	-248
7	007.103C	33.4502	-118.6129	S. CA Bight	-92
7	007.2C	32.9026	-119.7134	S. CA Bight	-1436
8	008.1C	33.8355	-118.3960	S. CA Bight	-6
8	008.101C	33.3146	-119.4446	S. CA Bight	-91
8	008.102C	33.3405	-119.5200	S. CA Bight	-94
8	008.103C	33.3179	-119.6482	S. CA Bight	-76
8	008.104C	33.2830	-119.6646	S. CA Bight	-62
8	008.105C	33.2190	-119.6343	S. CA Bight	-302
8	008.2C	33.0495	-119.9756	S. CA Bight	-934
9	009.1C	34.0167	-118.5865	S. CA Bight	-27
9	009.2C	33.1081	-120.4131	S. CA Bight	-925
10	010.1C	34.0690	-119.0377	S. CA Bight	0
10	010.2C	33.3036	-120.5824	S. CA Bight	-1447
11	011.1C	34.2139	-119.3082	S. CA Bight	-18
11	011.101C	34.1326	-119.4721	S. CA Bight	-239
11	011.102C	33.9785	-119.4989	S. CA Bight	-91
11	011.103C	33.9211	-119.6194	S. CA Bight	-603
11	011.104C	33.9433	-119.8517	S. CA Bight	-82
11	011.2C	33.5204	-120.7059	S. CA Bight	-1683
12	012.1C	34.3832	-119.5238	S. CA Bight	-15
12	012.101C	34.0563	-120.1839	S. CA Bight	-58

(continued)

Transect	Waypoint	Latitude	Longitude	Region	Depth (m)
12	012.102C	34.0495	-120.2618	S. CA Bight	-46
12	012.103C	34.0085	-120.2808	S. CA Bight	-32
12	012.2C	33.7434	-120.8169	S. CA Bight	-1705
13	013.1C	34.4357	-119.9749	S. CA Bight	-16
13	013.2C	33.9208	-121.0210	S. CA Bight	-2241
14	014.1C	34.4626	-120.4819	S. CA Bight	-16
14	014.2C	34.1461	-121.1280	S. CA Bight	-2083
15	015.1C	34.6023	-120.6584	S. CA Bight	-28
15	015.2C	34.2965	-121.2818	S. CA Bight	-2143
16	016.1C	34.9828	-120.6668	Central CA	-21
16	016.2C	34.5560	-121.5398	Central CA	-1681
17	017.1C	35.2426	-120.9223	Central CA	-65
17	017.2C	34.8143	-121.8011	Central CA	-1518
18	018.1C	35.5313	-121.1196	Central CA	-50
18	018.2C	35.1788	-121.8453	Central CA	-1812
19	019.1C	35.7958	-121.3675	Central CA	-24
19	019.2C	35.4684	-122.0439	Central CA	-1867
20	020.1C	36.0622	-121.6129	Central CA	-162
20	020.2C	35.7619	-122.2351	Central CA	-1735
21	021.1C	36.3006	-121.9174	Central CA	-42
21	021.2C	36.0053	-122.5313	Central CA	-3236
22	022.1C	36.7296	-121.8260	Central CA	-30
22	022.2C	36.4262	-122.4588	Central CA	-2130
23	023.1C	36.9595	-122.1500	Central CA	-50
23	023.2C	36.6620	-122.7727	Central CA	-2850
24	024.1C	37.2141	-122.4240	Central CA	-23
24	024.2C	36.9082	-123.0665	Central CA	-2945
25	025.1C	37.5331	-122.5637	Central CA	-42
25	025.2C	37.1948	-123.2766	Central CA	-1839
26	026.1C	37.8534	-122.7035	Central CA	-29
26	026.101C	37.7128	-123.0002	Central CA	-53
26	026.102C	37.7086	-123.0225	Central CA	-51
26	026.103C	37.7009	-123.0255	Central CA	-24
26	026.2C	37.5102	-123.4269	Central CA	-2355
27	027.1C	38.1103	-122.9732	Central CA	-11
27	027.2C	37.8316	-123.5649	Central CA	-2189
28	028.1C	38.4220	-123.1303	Central CA	-15
28	028.1C	38.1057	-123.8042	Central CA	-2978

C Nearshore transect waypoints

Planned transects in the nearshore region sampled by *Long Beach Carnage*.

Transect	Waypoint	Latitude	Longitude	Region	Depth (m)
1	001.1N	34.5167	-120.6904	S. CA Bight	-99
1	001.2N	34.5486	-120.6228	S. CA Bight	-19
2	002.1N	34.5065	-120.5098	S. CA Bight	-10
2	002.2N	34.4725	-120.5793	S. CA Bight	-79
3	003.1N	34.4151	-120.4956	S. CA Bight	-100
3	003.2N	34.4477	-120.4271	S. CA Bight	-3
4	004.1N	34.4317	-120.2592	S. CA Bight	-76
4	004.2N	34.4665	-120.1902	S. CA Bight	-7
5	005.1N	34.4555	-120.0128	S. CA Bight	69
5	005.2N	34.4210	-120.0827	S. CA Bight	-68
6	006.1N	34.3836	-119.9586	S. CA Bight	-127
6	006.2N	34.4147	-119.8914	S. CA Bight	-2
7	007.1N	34.3629	-119.8004	S. CA Bight	-76
7	007.2N	34.3953	-119.7333	S. CA Bight	-1
8	008.1N	34.3626	-119.6006	S. CA Bight	-43
8	008.2N	34.3911	-119.5401	S. CA Bight	-1
9	009.1N	34.3471	-119.4328	S. CA Bight	-4
9	009.2N	34.3127	-119.5023	S. CA Bight	-48
10	010.1N	34.2559	-119.4186	S. CA Bight	-36
10	010.2N	34.2897	-119.3491	S. CA Bight	-3
11	011.1N	34.2294	-119.2717	S. CA Bight	-4
11	011.2N	34.1981	-119.3374	S. CA Bight	-22
12	012.1N	34.1222	-119.2912	S. CA Bight	-22
12	012.2N	34.1532	-119.2272	S. CA Bight	-5
13	013.1N	34.1003	-119.1374	S. CA Bight	-5
13	013.2N	34.0670	-119.2037	S. CA Bight	-139
14	014.1N	34.0319	-119.0755	S. CA Bight	-522
14	014.2N	34.0626	-119.0106	S. CA Bight	-10
15	015.1N	34.0303	-118.8795	S. CA Bight	-9
15	015.2N	33.9988	-118.9448	S. CA Bight	-158
16	016.1N	33.9984	-118.7467	S. CA Bight	-50
16	016.2N	34.0295	-118.6789	S. CA Bight	-4
17	017.1N	34.0166	-118.5128	S. CA Bight	-8
17	017.2N	33.9825	-118.5823	S. CA Bight	-59
18	018.1N	33.9153	-118.5188	S. CA Bight	-57
18	018.2N	33.9487	-118.4502	S. CA Bight	-5
19	019.1N	33.8697	-118.4139	S. CA Bight	-6
19	019.2N	33.8357	-118.4830	S. CA Bight	-116
20	020.1N	33.7327	-118.4930	S. CA Bight	-723
20	020.2N	33.7631	-118.4278	S. CA Bight	-25
21	021.1N	33.7136	-118.3288	S. CA Bight	-12
21	021.2N	33.6825	-118.3944	S. CA Bight	-783
22	022.1N	33.6970	-118.1709	S. CA Bight	-22
22	022.2N	33.7308	-118.1027	S. CA Bight	-4
23	023.1N	33.6654	-118.0351	S. CA Bight	-10

(continued)

Transect	Waypoint	Latitude	Longitude	Region	Depth (m)
23	023.2N	33.6353	-118.0972	S. CA Bight	-28
24	024.1N	33.5823	-118.0076	S. CA Bight	-51
24	024.2N	33.6098	-117.9480	S. CA Bight	-10
25	025.1N	33.5681	-117.8399	S. CA Bight	3
25	025.2N	33.5346	-117.9073	S. CA Bight	-364
26	026.1N	33.4747	-117.8303	S. CA Bight	-586
26	026.2N	33.5095	-117.7603	S. CA Bight	-17
27	027.1N	33.4500	-117.6817	S. CA Bight	2
27	027.2N	33.4168	-117.7508	S. CA Bight	-498
28	028.1N	33.3590	-117.6702	S. CA Bight	-392
28	028.2N	33.3889	-117.6076	S. CA Bight	-12
29	029.1N	33.3346	-117.5224	S. CA Bight	-4
29	029.2N	33.3006	-117.5916	S. CA Bight	-73
30	030.1N	33.2364	-117.5249	S. CA Bight	-83
30	030.2N	33.2700	-117.4561	S. CA Bight	-7
31	031.1N	33.2005	-117.3997	S. CA Bight	-11
31	031.2N	33.1679	-117.4645	S. CA Bight	-190
32	032.1N	33.0989	-117.4069	S. CA Bight	-331
32	032.2N	33.1329	-117.3418	S. CA Bight	-3
33	033.1N	33.0530	-117.3053	S. CA Bight	-15
33	033.2N	33.0188	-117.3720	S. CA Bight	-406
34	034.1N	32.9369	-117.3424	S. CA Bight	-433
34	034.2N	32.9712	-117.2734	S. CA Bight	-17
35	035.1N	32.8814	-117.2592	S. CA Bight	-24
35	035.2N	32.8476	-117.3242	S. CA Bight	-87
36	036.1N	32.7502	-117.3239	S. CA Bight	-82
36	036.2N	32.7828	-117.2573	S. CA Bight	-13
37	037.1N	32.6848	-117.2578	S. CA Bight	-14
37	037.2N	32.6503	-117.3260	S. CA Bight	-105
38	038.1N	32.6181	-117.1924	S. CA Bight	-26
38	038.2N	32.5814	-117.2618	S. CA Bight	-59
39	039.1N	32.5443	-117.1423	S. CA Bight	-16
39	039.2N	32.5088	-117.2113	S. CA Bight	-45
101	101.1N	34.1112	-119.9422	Santa Cruz Island	-101
101	101.2N	34.0790	-119.9224	Santa Cruz Island	-55
102	102.1N	34.0467	-119.9003	Santa Cruz Island	-12
102	102.2N	34.0281	-119.9349	Santa Cruz Island	-38
103	103.1N	34.0007	-119.8868	Santa Cruz Island	-8
103	103.2N	33.9913	-119.9244	Santa Cruz Island	-51
104	104.1N	33.9267	-119.7923	Santa Cruz Island	-102
104	104.2N	33.9582	-119.7911	Santa Cruz Island	58
105	105.1N	33.9665	-119.7062	Santa Cruz Island	-18
105	105.2N	33.9373	-119.6932	Santa Cruz Island	-74
106	106.1N	33.9553	-119.6011	Santa Cruz Island	-78
106	106.2N	33.9862	-119.6107	Santa Cruz Island	281
107	107.1N	34.0234	-119.5313	Santa Cruz Island	38
107	107.2N	34.0062	-119.4968	Santa Cruz Island	-52

(continued)

Transect	Waypoint	Latitude	Longitude	Region	Depth (m)
108	108.1N	34.0783	-119.5246	Santa Cruz Island	-160
108	108.2N	34.0488	-119.5439	Santa Cruz Island	-70
109	109.1N	34.0540	-119.6397	Santa Cruz Island	-89
109	109.2N	34.0232	-119.6547	Santa Cruz Island	-79
110	110.1N	34.0508	-119.7326	Santa Cruz Island	-25
110	110.2N	34.0830	-119.7156	Santa Cruz Island	-88
111	111.1N	34.1010	-119.8215	Santa Cruz Island	-88
111	111.2N	34.0673	-119.8314	Santa Cruz Island	-54
201	201.1N	33.5122	-118.5341	Santa Catalina Island	-511
201	201.2N	33.4790	-118.5474	Santa Catalina Island	-108
202	202.1N	33.4805	-118.6097	Santa Catalina Island	-145
202	202.2N	33.5015	-118.6404	Santa Catalina Island	-354
203	203.1N	33.4619	-118.5940	Santa Catalina Island	-17
203	203.2N	33.4370	-118.6228	Santa Catalina Island	-131
204	204.1N	33.3979	-118.5438	Santa Catalina Island	-375
204	204.2N	33.4233	-118.5202	Santa Catalina Island	87
205	205.1N	33.3594	-118.4909	Santa Catalina Island	-71
205	205.2N	33.3556	-118.5310	Santa Catalina Island	-143
206	206.1N	33.2850	-118.4424	Santa Catalina Island	-144
206	206.2N	33.3165	-118.4305	Santa Catalina Island	343
207	207.1N	33.3014	-118.3422	Santa Catalina Island	127
207	207.2N	33.2679	-118.3415	Santa Catalina Island	-168
208	208.1N	33.3076	-118.3015	Santa Catalina Island	-71
208	208.2N	33.3081	-118.2615	Santa Catalina Island	-182
209	209.1N	33.3800	-118.3029	Santa Catalina Island	-366
209	209.2N	33.3536	-118.3273	Santa Catalina Island	-75
210	210.1N	33.4040	-118.3629	Santa Catalina Island	-191
210	210.2N	33.4322	-118.3351	Santa Catalina Island	-857
211	211.1N	33.4292	-118.4341	Santa Catalina Island	-59
211	211.2N	33.4590	-118.4127	Santa Catalina Island	-518

D CTD and UCTD sampling locations

Times and locations of conductivity and temperature versus depth casts while on station (CTD) and underway (UCTD; plotted in **Fig. 11**).

Date Time	Cast Type	Latitude	Longitude
03/21/2021 02:45	CTD	32.9028	-117.3270
03/22/2021 02:11	CTD	32.8418	-117.6757
03/23/2021 03:41	CTD	33.2480	-118.7098
03/24/2021 02:26	CTD	33.5437	-118.0020
03/25/2021 03:41	CTD	32.6218	-118.0105
03/26/2021 02:59	CTD	32.4008	-118.8977
03/27/2021 03:12	CTD	32.7815	-119.6130
03/28/2021 03:36	CTD	33.0208	-119.9948
03/29/2021 03:21	CTD	33.2648	-120.6140
03/30/2021 02:46	CTD	34.2805	-119.7297
03/31/2021 02:41	CTD	33.6165	-118.8375
04/02/2021 15:49	UCTD	34.2548	-119.7815
04/03/2021 20:37	UCTD	34.3908	-120.2125
04/04/2021 00:07	UCTD	34.3422	-120.7285
04/04/2021 18:30	UCTD	34.4198	-121.0292
04/04/2021 23:25	UCTD	34.6562	-121.3353
04/05/2021 22:42	UCTD	35.0467	-121.3258
04/06/2021 15:15	UCTD	35.4193	-121.3500
04/06/2021 23:07	UCTD	35.5003	-121.9773
04/07/2021 17:09	UCTD	35.9417	-121.8613
04/08/2021 01:40	UCTD	36.2020	-122.1220
04/08/2021 19:11	UCTD	36.6150	-122.0648
04/08/2021 23:37	UCTD	36.8975	-122.2797
04/09/2021 20:30	UCTD	37.0783	-122.7117
04/12/2021 16:55	UCTD	37.7467	-123.2003

E Trawl sample summary

Date, time, 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 (plotted in **Fig. 12c**).

Haul	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Mackerel	P. Sardine	All CPS
1	03/21/2021 04:28	32.8890	-117.3422		3.29			3.29
2	03/21/2021 07:59	33.1148	-117.3900		64.99			64.99
3	03/22/2021 03:49	32.8327	-117.6603					
4	03/22/2021 07:18	33.0940	-117.6710		10.20			10.20
5	03/22/2021 10:06	33.1048	-117.9197	0.05	52.38			52.43
6	03/23/2021 06:20	33.2155	-118.5158		0.86			0.86
7	03/23/2021 11:15	33.2418	-118.1397		0.07			0.07
8	03/24/2021 05:03	33.4802	-117.8028		29.36			29.36
9	03/24/2021 08:38	33.3888	-117.6473		0.80			0.80
10	03/24/2021 10:50	33.3052	-117.7538					
11	03/25/2021 04:43	32.6130	-118.0602	0.02	0.17			0.18
12	03/25/2021 09:45	32.7938	-117.9063		80.88			80.88
13	03/25/2021 12:00	32.7267	-117.8638		1.74			1.74
14	03/26/2021 04:07	32.3998	-118.8918		104.09	0.06		104.15
15	03/26/2021 07:24	32.4680	-118.8725		1056.16	0.49		1056.65
16	03/26/2021 11:01	32.6087	-119.1518		12.99			12.99
17	03/27/2021 04:30	32.7852	-119.6162		985.46			985.46
18	03/27/2021 07:47	32.9868	-119.5108		29.81		0.02	29.84
19	03/27/2021 10:51	33.0055	-119.7247	0.03	17.96		0.06	18.04
20	03/28/2021 06:08	33.0925	-119.9815		2.97			2.97
21	03/28/2021 09:00	33.2680	-120.0218	0.52	0.92			1.44
22	03/28/2021 11:43	33.1787	-120.2327		11.70			11.70
23	03/29/2021 04:35	33.2787	-120.5993	0.04				0.04
24	03/29/2021 07:53	33.4712	-120.4542		22.71			22.71
25	03/29/2021 10:42	33.4957	-120.7033		0.01			0.01
26	03/30/2021 06:02	34.2082	-119.4707					
27	03/30/2021 08:36	34.1525	-119.3990					
28	03/30/2021 11:46	34.0767	-119.2133					
29	03/31/2021 03:59	33.6415	-118.7535	0.02				0.02
30	03/31/2021 07:45	33.8690	-118.6375		0.01			0.01

(continued)

Haul	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Mackerel	P. Sardine	All CPS
31	03/31/2021 10:12	33.7907	-118.8787					
32	04/02/2021 04:54	33.2997	-119.0647		35.56		0.11	35.67
33	04/02/2021 08:17	33.5132	-119.2770	0.29	284.92		0.31	285.52
34	04/03/2021 04:53	33.7975	-120.6718		0.32		0.06	0.38
35	04/03/2021 08:30	33.6222	-120.5713		9.85		0.06	9.91
36	04/03/2021 11:51	33.8327	-120.3850	0.14	0.19			0.33
37	04/04/2021 04:41	34.0142	-120.7883		243.84			243.84
38	04/04/2021 08:14	34.1202	-120.5765		2.18		0.04	2.22
39	04/04/2021 11:27	34.3370	-120.6973		1033.37		0.63	1034.00
40	04/05/2021 04:41	34.6710	-121.0158		8.82			8.82
41	04/05/2021 07:35	34.4215	-121.0135	0.02	23.21		0.02	23.25
42	04/05/2021 11:32	34.5710	-120.8007		150.18			150.18
43	04/06/2021 08:07	35.1132	-121.2083		4.76			4.76
44	04/07/2021 04:25	35.5410	-121.4155		0.07			0.07
45	04/07/2021 07:47	35.4043	-121.6547		1.00			1.00
46	04/07/2021 10:50	35.6693	-121.7027		0.36			0.36
47	04/08/2021 10:55	36.0705	-122.1682		2.07			2.07
49	04/09/2021 08:12	36.5810	-122.4325		0.02			0.02
50	04/09/2021 11:51	36.5352	-122.3348		0.04			0.04

F Seine sample summary

Date, time, location for each set, and biomasses (kg) of CPS collected (plotted in **Fig. 13b**).

Set	Date Time	Latitude	Longitude	N. Anchovy	P. Sardine	P. Mackerel	All CPS
1	3/21/21 14:16	32.7786	-117.2680		1.54	0.05	1.59
2	3/21/21 20:42	33.0627	-117.3153	0.94	1.92		2.86
3	3/22/21 10:15	33.1946	-117.4039	0.34			0.34
4	3/22/21 14:20	33.3252	-117.5342	0.04	1.29	0.90	2.23
5	3/22/21 18:33	33.4390	-117.6794		1.76		1.76
6	3/27/21 20:06	34.0286	-119.6134	0.34	0.92		1.26
7	3/28/21 20:15	34.4149	-119.8977	0.37	1.68		2.06
8	3/28/21 22:00	34.4051	-119.7897	0.37			0.37
9	3/31/21 11:58	33.7092	-118.2180	0.09	1.56		1.65
10	3/31/21 14:50	33.7444	-118.1691		1.59		1.59