https://doi.org/10.25923/66p9-hc28

NOAA Technical Memorandum NMFS

FEBRUARY 2023

REPORT ON THE SUMMER 2022 CALIFORNIA CURRENT ECOSYSTEM SURVEY (CCES) (2207RL), 27 JUNE TO 30 SEPTEMBER 2022, CONDUCTED ABOARD NOAA SHIP *REUBEN LASKER*, FISHING VESSELS *LISA MARIE* AND *LONG BEACH CARNAGE*, AND UNCREWED SURFACE VEHICLES

Josiah S. Renfree[1], Alice Beittel[2], Noelle M. Bowlin[1], Brad E. Erisman[1], Kelsey James[1], Scott A. Mau[1], David W. Murfin[1], Thomas S. Sessions[1], Kevin L. Stierhoff[1], Lanora Vasquez[1], William Watson[1], Juan P. Zwolinski[1,3], and David A. Demer[1]

[1] NOAA Fisheries, SWFSC Fisheries Resources Division, La Jolla, California

[2] NOAA Commissioned Officer Corps, Assigned to SWFSC

[3] University of California, Santa Cruz, The Cooperative Institute for Marine, Earth, and Atmospheric Systems (CIMEAS)

NOAA-TM-NMFS-SWFSC-678

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

About the NOAA Technical Memorandum series

The National Oceanic and Atmospheric Administration (NOAA), organized in 1970, has evolved into an agency which establishes national policies and manages and conserves our oceanic, coastal, and atmospheric resources. An organizational element within NOAA, the Office of Fisheries is responsible for fisheries policy and the direction of the National Marine Fisheries Service (NMFS).

In addition to its formal publications, the NMFS uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series, however, reflect sound professional work and may be referenced in the formal scientific and technical literature.

SWFSC Technical Memorandums are available online at the following websites:

SWFSC: https://swfsc-publications.fisheries.noaa.gov/

NOAA Repository: https://repository.library.noaa.gov/

Accessibility information

NOAA Fisheries Southwest Fisheries Science Center (SWFSC) is committed to making our publications and supporting electronic documents accessible to individuals of all abilities. The complexity of some of SWFSC's publications, information, data, and products may make access difficult for some. If you encounter material in this document that you cannot access or use, please contact us so that we may assist you.
Phone: 858-546-7000

Recommended citation

Renfree, Josiah S., Alice Beittel, Noelle M. Bowlin, Brad E. Erisman, Kelsey James, Scott A. Mau, David W. Murfin, Thomas S. Sessions, Kevin L. Stierhoff, Lanora Vasquez, William Watson, Juan P. Zwolinski, and David A. Demer. 2023. Report on the Summer 2022 California Current Ecosystem Survey (CCES) (2207RL), 27 June to 30 September 2022, conducted aboard NOAA ship *Reuben Lasker*, fishing vessels *Lisa Marie* and *Long Beach Carnage*, and uncrewed surface vehicles. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-678.
https://doi.org/10.25923/66p9-hc28

Report on the Summer 2022 California Current Ecosystem Survey (CCES) (2207RL), 27 June to 30 September 2022, conducted aboard NOAA ship *Reuben Lasker*, fishing vessels *Lisa Marie* and *Long Beach Carnage*, and uncrewed surface vehicles

Josiah S. Renfree[1], Alice Beittel[2], Noelle M. Bowlin[1], Brad E. Erisman[1], Kelsey James[1], Scott A. Mau[1], David W. Murfin[1], Thomas S. Sessions[1], Kevin L. Stierhoff[1], Lanora Vasquez[1], William Watson[1], Juan P. Zwolinski[1,3], and David A. Demer[1]

[1]Fisheries Resources Division
Southwest Fisheries Science Center (SWFSC)
NOAA-National Marine Fisheries Service
8901 La Jolla Shores Dr.
La Jolla, CA 92037, USA

[2]NOAA Commissioned Officer Corps, Assigned to SWFSC

[3]University of California, Santa Cruz
The Cooperative Institute for Marine, Earth and Atmospheric Systems (CIMEAS)
1156 High St Santa Cruz, CA 95064, USA

1 Introduction

The Summer 2022 California Current Ecosystem Survey (CCES) (2207RL) was conducted by the Fisheries Resources Division (FRD) of the Southwest Fisheries Science Center (SWFSC) aboard NOAA ship *Reuben Lasker* (hereafter *Lasker*) (**Fig.** 1), 27 June to 30 September 2022, and augmented by data collected from the fishing vessels *Lisa Marie* and *Long Beach Carnage* and uncrewed surface vehicles (USVs; Saildrone, Inc.). The Acoustic-Trawl Method (ATM) is routinely used to assess coastal pelagic fish species (CPS) within the California Current Ecosystem (CCE), typically between Vancouver Island, British Columbia and San Diego, CA. Starting in 2021, the survey has extended southward to include central Baja California, Mexico. Data were collected using multi-frequency echosounders, surface trawls, obliquely integrating net tows, a Continuous Underway Fish-Egg Sampler [CUFES; Checkley *et al.* (1997)], and conductivity-temperature-depth probes (CTDs).

The objectives for the survey were to: 1) acoustically map the distributions, measure the species compositions and size-frequency distributions, and estimate the abundances of CPS, e.g., Pacific Sardine *Sardinops sagax*, Northern Anchovy *Engraulis mordax*, Pacific Herring *Clupea pallasii*, Pacific Round Herring *Etrumeus acuminatus*, Pacific Mackerel *Scomber japonicus*, and Jack Mackerel *Trachurus symmetricus*; 2) characterize and investigate linkages to their biotic and abiotic environments; 3) gather information regarding their life histories; and 4) use fishing vessels and USVs to sample transects and nearshore areas (typically within 5 nmi of the coast) when and where sampling from NOAA ships was deemed inefficient, unsafe, or both (**Fig.** 1).

The survey domain, from Cape Flattery, WA to Central Baja California, Mexico, was defined primarily by the historically observed distribution of the northern subpopulation (stock) of Pacific Sardine (Zwolinski *et al.*, 2011), with a southern extension permitted by available sampling effort. This area was chosen to encompass the anticipated distributions of the northern stock of Pacific Sardine and the central and northern stocks of Northern Anchovy off the west coasts of the U.S., Canada, and Mexico, but it also spanned portions of the southern stock of Pacific Sardine, Pacific Mackerel, Jack Mackerel, Pacific Round Herring, and Pacific Herring.

This report provides an overview of the survey objectives and a summary of the survey equipment, sampling protocols, and data collections. This report does not include estimates of the animal distributions and biomasses, which are documented separately.

Figure 1: NOAA ship *Lasker* (top), F/V *Lisa Marie* (bottom left), F/V *Long Beach Carnage* (bottom middle), and an uncrewed surface vehicle (Saildrone USV, bottom right).

1.1 Scientific Personnel

The collection and analysis of the survey data were conducted by members of 1-NOAA, 2-UCSC/CIMEAS, 3-UCSD/SIO, 4-INAPESCA, 5-WDFW, 6-CWPA, 7-LBC crew, and 8-volunteers. Asterisks denote Chief Scientists.

Leg 1 of the survey on *Lasker* was cancelled due to OMAO staffing issues.

Project Lead:

- D. Demer[1]

Acoustic Data Collection and Processing:

- Leg II: S. Mau[1], S. Dolan[3], and D. Palance[2]
- Leg III: J. Zwolinski[1,2*] and S. Sessions[1]
- Leg IV: K. Stierhoff[1*] and A. Beittel[1]

Trawl Sampling:

- Leg II: K. James[1], E. Weber[1], A. Thompson[1], K. Walsh[3], and R. Backman[8]
- Leg III: J. Walker[1,2], N. Concha-Saiz[1], M. Illman[5], and J. Wood[8]
- Leg IV: B. Schwartzkopf[1], N. Concha-Saiz[1], O. Snodgrass[1], D. Lowry[1] , and D. Hernandez-Cruz[4]

CUFES Sampling:

- Leg II: W. Watson[1*] and E. Gardner[1]
- Leg III: A. Hays[1]
- Leg IV: B. Overcash[1] and S. Morales-Gutierrez[4]

Purse-seine Sampling:

- *Lisa Marie*
  - K. Hinton[5], E. Jaco[5], E. Seubert[5], and Z. Calef[5]
- *Long Beach Carnage*
  - J. van Noord[6], J. Marcopoulos[7], and W Hargrave[7]

Echosounder Calibrations:

- *Lasker*
  - D. Murfin[1], J. Renfree[1], and S. Sessions[1]
- *Lisa Marie*
  - J. Renfree[1]
- *Long Beach Carnage*
  - J. Renfree[1] and S. Sessions[1]
- *Saildrone*
  - Saildrone, Inc. and J. Renfree[1]

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, they have expanded in scope and objectives to include the larger forage-fish assemblage and krill. This evolution, and the migratory behavior of Pacific Sardine, serve to explain the present survey region and design.

Historically, in spring the northern stock of Pacific Sardine aggregates offshore of central and southern California to spawn (Demer *et al.*, 2012, and reference therein). During summer, adults migrate north, compress along the coast, and feed in the upwelled regions (**Fig. 2**). However, since 2012, when the population began to decline, the seasonal migration of the northern stock of Pacific Sardine diminished to the extent that it remains north of Cape Mendocino year-round.

During summer 2022, the west coasts of the United States and Baja California, Mexico were surveyed using *Lasker*, *Lisa Marie*, *Long Beach Carnage*, and USVs. Compulsory transects were nearly perpendicular to the coast and separated by 10 nmi. The survey began off Cape Flattery, WA and the combination of survey platforms progressed southwards toward Punta Baja, Baja CA Norte.

The planned transects (**Fig. 3**) spanned the latitudinal extent, based on historical observations, of the anticipated distributions of the northern stock of Pacific Sardine and the central and northern stocks of Northern Anchovy. For *Lasker*, the planned transects ranged from Cape Flattery, WA to Punta Baja, Baja CA Norte. To increase the spatial sampling resolution from *Lasker*, USVs were to conduct acoustic sampling interstitial to *Lasker* transects between Newport, OR and San Francisco, CA. To estimate CPS biomass near shore, typically within 5 nmi of the coast where it is too shallow to navigate NOAA ships safely, sampling from *Lasker* was to be augmented with echosounder and purse-seine sampling from *Lisa Marie* between Cape Flattery, WA to Bodega Bay, CA; and from *Long Beach Carnage* between Bodega Bay, CA to San Diego, CA, and around Santa Cruz and Santa Catalina Islands (**Fig. 3**). After Leg I on *Lasker* was cancelled due to OMAO staffing issues, the plan was modified for *Lisa Marie* to survey *Lasker*'s transects between Cape Flattery, WA to Bodega Bay, CA using 20 nmi spacing. *Lisa Marie* would continue to sample the nearshore portions of the transects, albeit at the 20-nmi spacing instead of 10 nmi as originally planned. Meanwhile the USVs would survey interstitial to *Lisa Marie* transects starting near Grays Harbor, WA and continuing as far south as time permitted. Further due to OMAO staffing issues, Leg III on *Lasker* was delayed by 16 days; the plan was then modified to use the remaining four days of the leg to survey northward from San Diego, CA into the Southern California Bight (SCB) using 20 nmi spacing. Leg IV on *Lasker* then resumed sampling southward from Monterey Bay, CA to Punta Baja, Baja CA Norte.

For *Lasker*, the offshore extent of the transects was extended by 5 nmi segments if CPS were observed in the echograms or CUFES samples during the last 3 nmi of the transect or additional segment, for up to a total extension of 50 nmi. If a transect was extended, the ensuing transect was extended by the same amount.

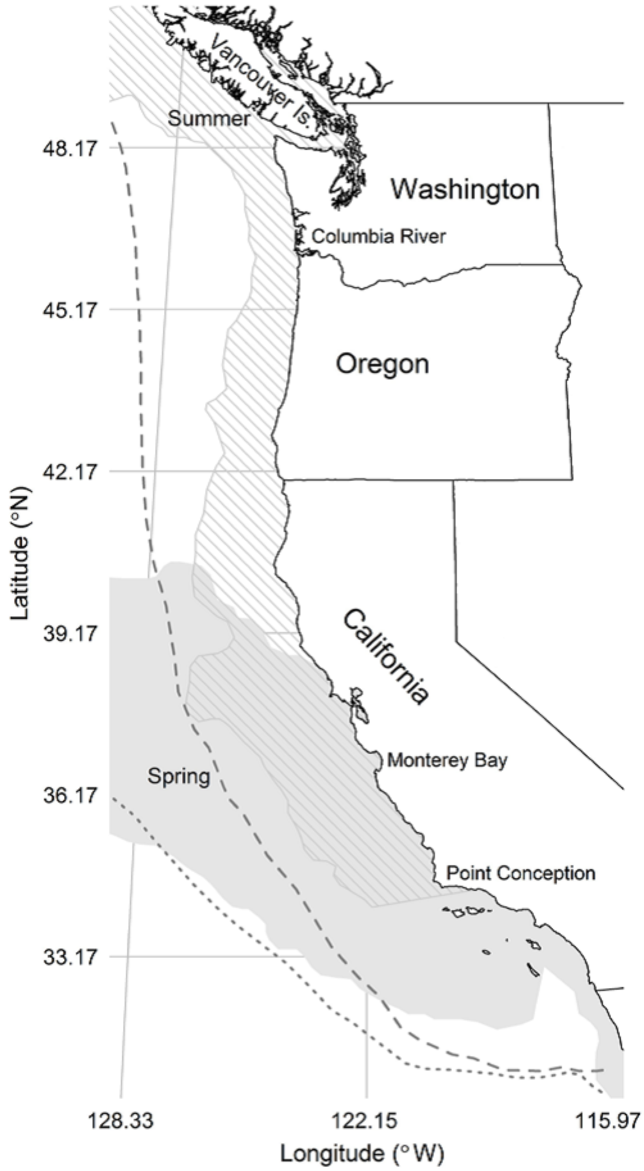

Figure 2: Conceptual spring (shaded region) and summer (hashed region) distributions of potential habitat for the northern stock of Pacific Sardine along the west coasts of Mexico, the United States, and Canada. The dashed and dotted lines represent, respectively, the approximate summer and spring positions 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 stock Pacific Sardine potential habitat (Zwolinski *et al.*, 2011). 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 Pacific Sardine and Pacific Mackerel distributions, and juveniles may have nursery areas in the Southern California Bight, downstream of upwelling regions.

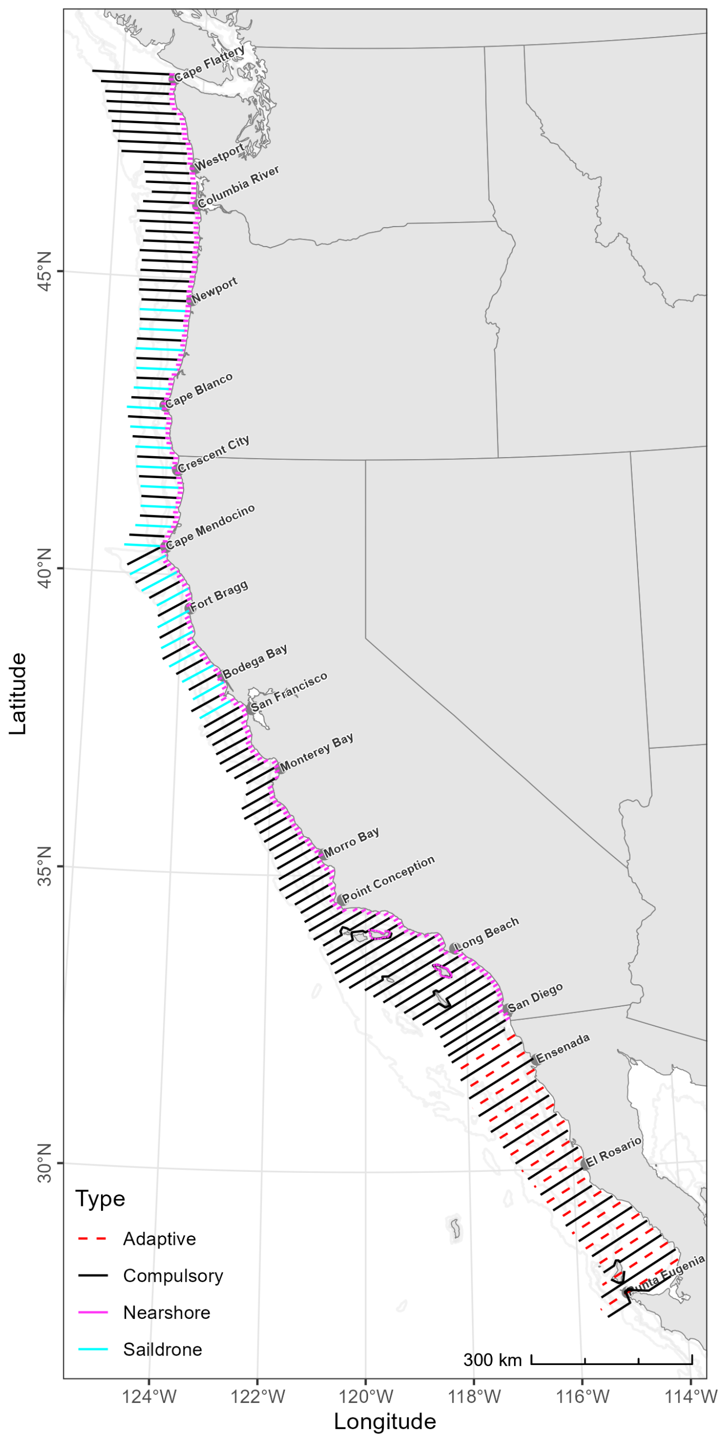

Figure 3: Planned core-area (solid black lines) and adaptive (dashed red lines) transect lines to be sampled by *Lasker*; interstitial transects to be sampled by USVs (solid cyan lines); and nearshore transect lines to be sampled by fishing vessels (solid magenta lines). Isobaths (light gray lines) are at 50, 200, 500, and 2,000 m (or approximately 25, 100, 250, and 1,000 ftm).

2.2 Acoustic sampling

2.2.1 Echosounders

On *Lasker*, multi-frequency Wideband Transceivers (18-, 38-, 70-, 120-, 200-, and 333-kHz Simrad-Kongsberg EK80 WBTs) were configured with split-beam transducers (Simrad-Kongsberg ES18-11, ES38B, ES70-7C, ES120-7C, ES200-7C, and ES333-7C). The transducers were mounted on the bottom of a retractable keel or "centerboard" (**Fig. 4**). 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).

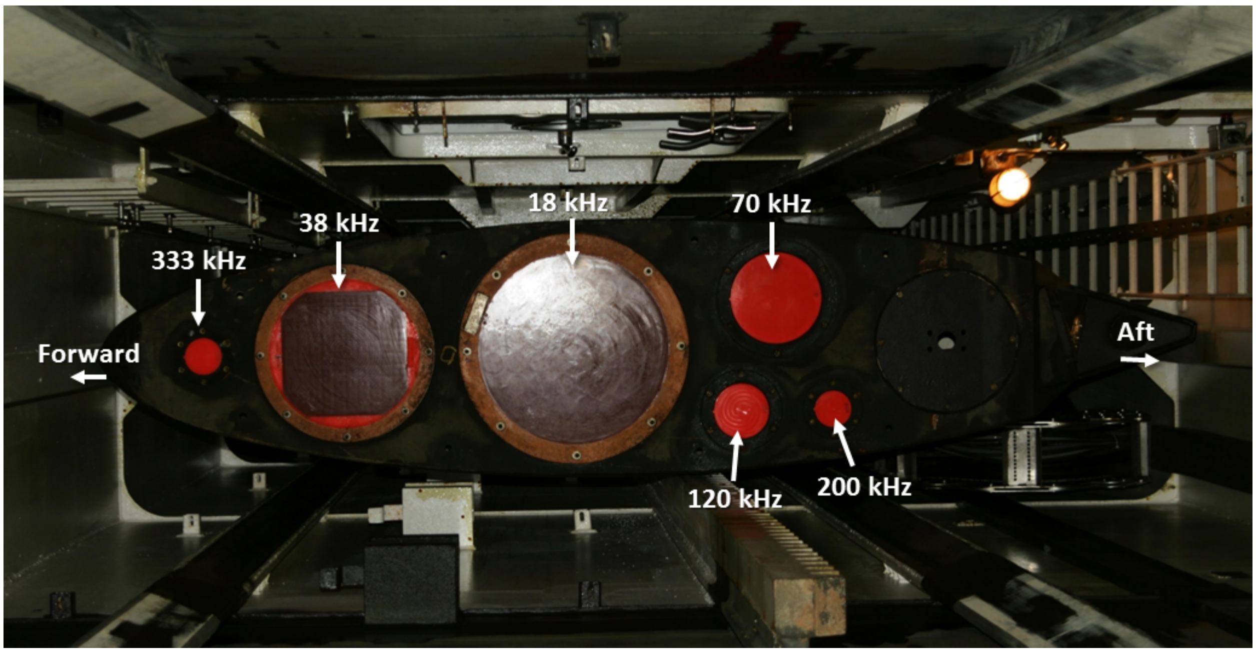

Figure 4: Transducer locations on the bottom of the centerboard aboard *Lasker*.

On *Lisa Marie*, multi-frequency Wideband Transceivers (38- and 200-kHz Simrad-Kongsberg EK80 WBTs) were connected to the vessel's hull-mounted split-beam transducers (Simrad-Kongsberg ES38-7 and ES200-7C).

On *Long Beach Carnage*, the SWFSC's multi-frequency General Purpose Transceivers (38-, 70-, 120-, and 200-kHz Simrad-Kongsberg EK60 GPTs) were configured with the SWFSC's split-beam transducers (Simrad-Kongsberg ES38-12, ES70-7C, ES120-7C and ES200-7C) mounted in a multi-frequency transducer array (MTA4) on the bottom of a pole (**Fig. 5**).

On the two USVs (SD-1076 and SD-1077), miniature Wideband Transceivers (Simrad-Kongsberg WBT Mini) were configured with gimbaled, keel-mounted, dual-frequency transducers (Simrad-Kongsberg ES38-18|200-18C) containing a split-beam 38-kHz transducer and single-beam 200-kHz transducer with nominally 18° beamwidths.

Figure 5: Transducer locations on the bottom of the pole-mounted multi-transducer array (MTA4) installed on the F/V *Long Beach Carnage*.

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 (continuous wave or narrowband mode) and FM modes (frequency modulation or broadband mode). For both modes, 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); For FM mode, additional calibrations were conducted for the 120, 200, and 333-kHz echosounders using a smaller 25-mm WC sphere. Calibrations for *Lisa Marie*, *Long Beach Carnage*, and the USVs were all conducted using a WC38.1. For each vessel, the calibration parameters were derived in Echoview and subsequently applied in the data processing (see **Section 3.1**).

2.2.3 Data collection

On *Lasker*, the computer clocks were synchronized with the GPS clock (UTC) using synchronization software (NetTime[1]). The 18-kHz WBT, 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 EK80 Adaptive Logger (EAL[2], Renfree

[1] http://timesynctool.com

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

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 record three 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).

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 range of 500, 500, 500, 300, and 150 m for 38, 70, 120, 200, and 333 kHz, respectively, and stored in Simrad-Kongsberg .raw format with a 50-GB 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 survey name (e.g., 2207RL), 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-Kongsberg EK80 software (v21.15.1) for a WBT operated in CW mode is named `2207RL_CW-D20220826-T155651.raw`.

To minimize acoustic interference, transmit pulses from the EK80s, acoustic Doppler current profiler and echosounder (Simrad-Kongsberg EC150-3C), multibeam echosounder (Simrad-Kongsberg ME70), imaging sonar (Simrad-Kongsberg MS70), scanning sonar (Simrad-Kongsberg SX90), and a separate acoustic Doppler current profiler (Teledyne RD Instruments OS75 ADCP) were triggered using a synchronization system (Simrad-Kongsberg K-Sync). 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 EC150-3C, ME70, SX90, and ADCP were operated continuously, while the MS70 was only operated at times when CPS were present. At nighttime, only the EK80, EC150-3C, 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, Sperry Marine), or both.

On *Lisa Marie* and *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 1000 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.

On the USVs, the echosounders were programmed to transmit CW pulses to a range dependent on the transect depth. For deeper seabed depths, the ping interval was 2 s and the 38 and 200-kHz echosounders recorded to 1000 and 400 m, respectively. For shallower depths, the ping interval was 1 s and both echosounders recorded to 250 m. Once an hour, the echosounders would operate in passive mode and record three pings to obtain estimates of the background noise level.

2.2.4 Data processing

Echoes from schooling CPS and plankton (**Figs. 6a, d**) were identified using a semi-automated data processing algorithm implemented using Echoview software (v12.1; 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. 6**). 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. 6b, 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. 6c, 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.*, 2009), or to the maximum logging range (e.g., 350 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.

Data from *Lisa Marie* and the USVs were processed using the following steps:

1. Match geometry of the $S_{v,200\text{kHz}}$ to the $S_{v,38\text{kHz}}$;
2. Remove passive-mode pings;
3. Perform Steps 3-5 from *Lasker* processing;
4. For each pixel, compute: $S_{v,200\text{kHz}} - S_{v,38\text{kHz}}$;
5. Create a Boolean echogram for S_v differences in the CPS range: $-13.51 < S_{v,200\text{kHz}} - S_{v,38\text{kHz}} < 12.53$
6. Perform Steps 8-9 from *Lasker* processing;
7. Create a Boolean echogram mask using $VMR >$ -57 dB;
8. Performs Steps 11-17 from *Lasker* processing.

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.

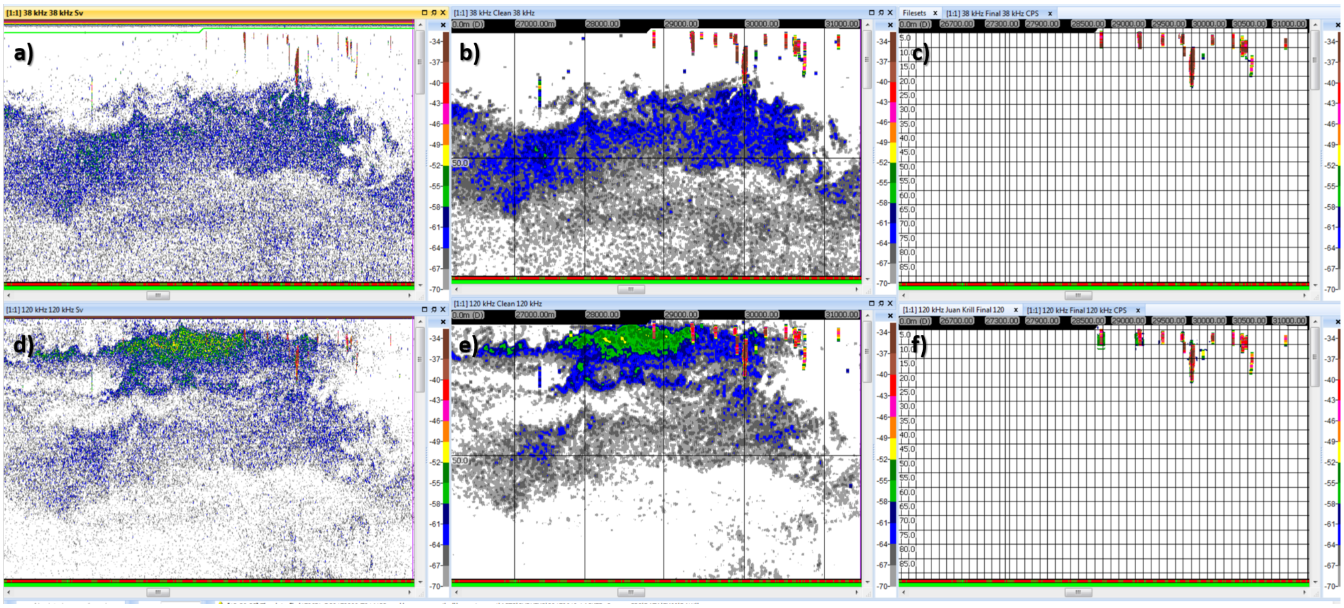

Figure 6: Echogram depicting CPS schools (red) and plankton aggregations (blue and green) at 38 kHz (top row) and 120 kHz (bottom row). Example data processing steps include the original echogram (left column; panels a and d), after noise subtraction and bin-averaging (middle column; panels b and e), and after filtering to retain only putative CPS echoes (right column; panels c and f).

2.3 Trawl sampling

During the day, CPS form schools, typically in the upper mixed layer (e.g., from the surface 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.

On *Lasker*, the net, a Nordic 264 rope trawl (NET Systems; Bainbridge Island, WA; **Figs. 7a, 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 larger animals, such as dolphins, turtles, or sharks (Dotson *et al.*, 2010). The trawl doors are foam-filled and the trawl headrope is lined with floats so the trawl opening spans from the surface to about 15-m depth.

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 CUFES earlier that day. Each evening, trawl locations were selected based on the acoustic and CUFES data 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, trawls were alternatively placed nearer to the coast one night and farther offshore the next night, with consideration given to the seabed depth and the modeled distribution of Pacific Sardine habitat.

Trawls were towed at ~4 kn for 45 min, excluding the deployment and haulback times. The total catch from each trawl was weighed and sorted by species or 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, Pacific Round Herring, 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, Pacific Round Herring, and Pacific Herring.

In addition, sex and maturity were visually determined and recorded for up to 50 specimens from Pacific Sardine and Northern Anchovy and up to 25 for Pacific and Jack Mackerels. Ovaries were preserved of each CPS, except Pacific Round Herring and Pacific Herring, for subsequent histological processing to validate maturity. For each CPS, ovaries (either whole or partial) were preserved for up to 10 specimens from each maturity code (immature specimens: maturity code 1; mature specimens: maturity codes 2-4), enabling an evaluation of accuracy for personnel who assessed maturity. Fin clips were removed from 50 Pacific Sardine and Northern Anchovy specimens each from seven different geographic zones (designated by J. Hyde and M. Craig, SWFSC) and preserved in ethanol for genetic analysis. Otoliths were removed from up to 50 Pacific Sardine in the subsample; for other CPS species (except Pacific Round Herring and Pacific Herring), 25 otoliths were removed from fish representing the range of lengths present, for age determination as described in Schwartzkopf *et al.* (2022) and Dorval *et al.* (2022). The combined catches of CPS 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.

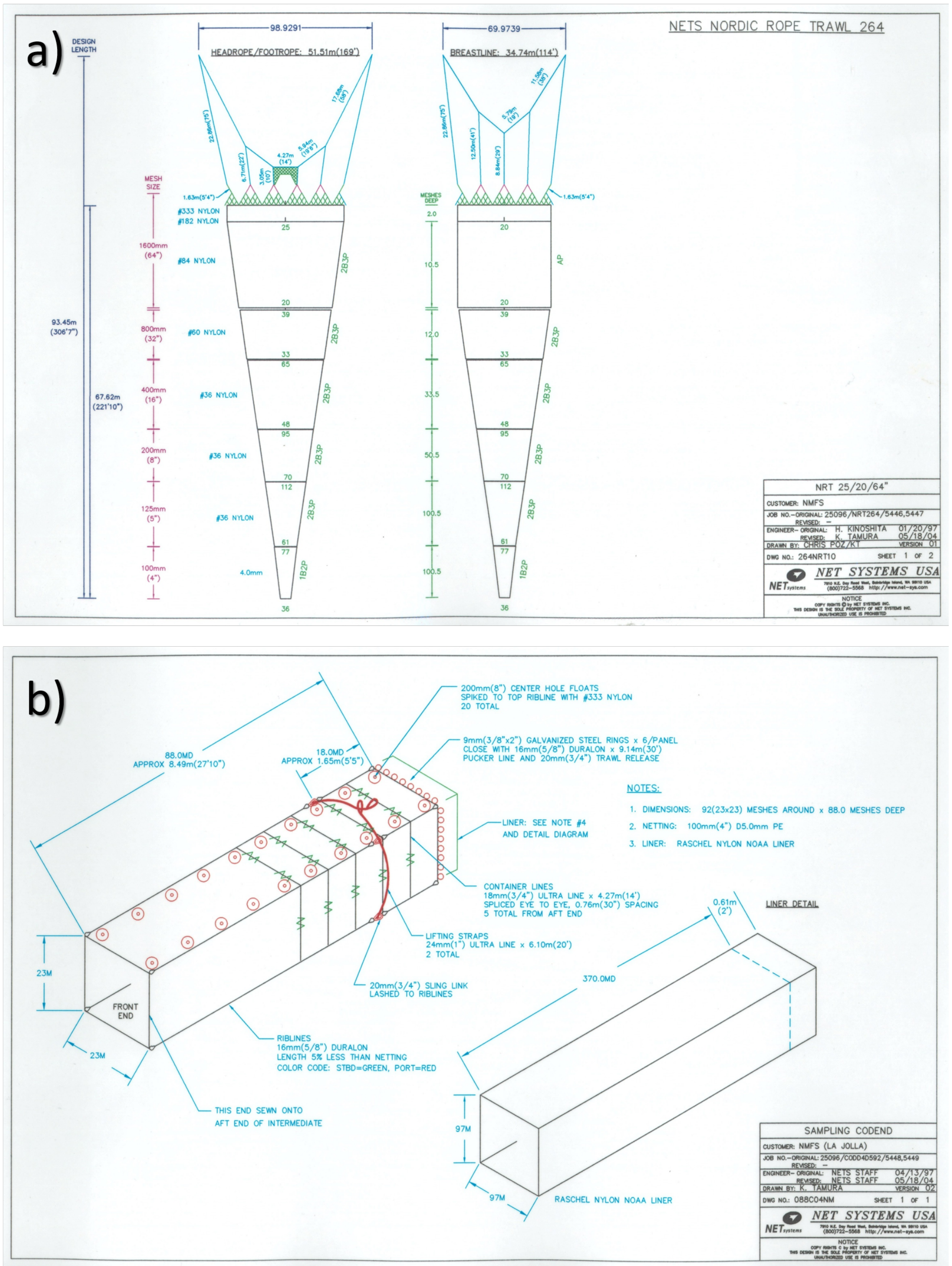

Figure 7: Schematic drawings of the Nordic 264 rope trawl net (a) and cod-end (b) on *Lasker*.

2.4 Purse seine sampling

Purse seine nets were set to provide information about size, age, and species composition of fishes observed in the echosounders mounted on the fishing vessels. *Lisa Marie* used an approximately 440-m-long and 40-m-deep net with 17-mm-wide mesh (A. Blair, pers. comm.). *Long Beach Carnage* used an approximately 200-m-long and 27-m-deep 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* and *Long Beach Carnage* were processed by the Washington Department of Fish and Wildlife (WDFW) and California Department of Fish and Wildlife (CDFW), respectively.

On *Lisa Marie*, as many as five purse seine sets were planned each day. Originally the vessel was assigned to sample nearshore transects, for which there would be one set per transect. However, after Leg I on *Lasker* was cancelled and *Lisa Marie* was redirected to survey *Lasker*'s transects, the plan was modified to allow *Lisa Marie* to randomly set on observed schools during a transect, for up to five sets per transect. For each set, three dip net samples, spatially separated as much as possible, were collected. For each dip net sample, all specimens were sorted, weighed, and counted to provide a combined weight and count for each. Next, all three dip net samples were combined and up to 50 specimens of each CPS species were randomly sampled to provide a combined weight for each set. The length (mm; L_S for Pacific Sardine and Northern Anchovy and L_F for all others) and weight was measured for up to 50 randomly selected specimens of each species. Otoliths were extracted, macroscopic maturity stage was determined visually, and gonads were collected and preserved from female specimens.

On *Long Beach Carnage*, as many as five purse seine sets were planned each day, including evenings, for an average of one set per transect. The vessel was to run each transect in its entirety, then randomly set on an observed school. The total weight (tons) of the school was estimated by the captain. For each set, three dip net samples, spatially separated as much as possible, were collected. For each dip net sample, all specimens were sorted, weighed, and counted to provide a combined weight and count for each. From each dip net sample, as many as 20 fish of each CPS species were chosen randomly throughout the sample, and combined for a random sample of 50 fish collected throughout the catch. The fish were then frozen for later analysis by CDFW biologists, yielding measures of total sample weight and individual fish weight, length (mm; L_S for Pacific Sardine and Northern Anchovy and L_F for all others), maturity, and otolith-derived ages. Because samples were frozen, no gonad samples from female specimens were analyzed.

2.5 Ichthyoplankton and oceanographic sampling

2.5.1 Egg and larva sampling

On *Lasker*, fish eggs were collected during the day using a CUFES, which collects water and plankton at a rate of ~640 l min^{-1} from an intake on the hull of the ship at ~3-m depth. For each vessel, the particles in the sampled water were sieved by a 505- and 500-μm mesh, respectively. Pacific Sardine, Northern Anchovy, Jack Mackerel, and Pacific Hake (*Merluccius productus*) eggs 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 durations of the initial egg stages is short for most CPS, the egg distributions inferred from CUFES samples indicate the nearby presence of actively spawning fish.

On *Lasker*, a CalCOFI bongo oblique net (a bridleless pair of 71-cm diameter nets with 505-μm mesh, Smith and Richardson, 1977) was used opportunistically to sample ichthyoplankton and krill after sunset, to contribute to the CalCOFI ichthyoplankton time series. Where there was adequate depth, 300 m of wire was deployed at a rate of 50 m min^{-1} and then retrieved at 20 m min^{-1}, at a nominal wire angle of 45°. Starboard-side samples were preserved in 5% sodium-borate buffered seawater formalin, and port-side samples were preserved in 100% Tris-buffered ethanol.

2.5.2 Conductivity and temperature versus depth (CTD) sampling

On *Lasker*, conductivity and temperature were measured versus depth to 350 and 500 m, respectively, using calibrated sensors on a probe cast from the vessel while on station (CTD), or a probe cast from the vessel while underway (UnderwayCTD, or UCTD; Teledyne Oceanscience). These data indicate the depth of the surface mixed layer, above which most epipelagic CPS reside during the day, which is later used to determine the integration-stop depth during acoustic data processing. These data were also 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).

Due to the cancellation of Leg I, *Lasker* did not survey north of Cape Mendocino, CA. Therefore, oceanographic data was obtained from CTD casts during the Northwest Fisheries Science Center's (NWFSC) 2022 Integrated Ecosystem and Pacific Hake Acoustic-Trawl Survey conducted from 22 July to 25 August, 2022 aboard NOAA ship *Shimada*, which spanned a region from Cape Flattery, WA to Coos Bay, OR. The nearest CTD data from either *Lasker* or *Shimada* was then used for processing acoustic data collected from *Lisa Marie* or the USVs.

3 Results

3.1 Echosounder calibrations

For *Lasker*, the EK80s were calibrated on 23 June while the vessel was alongside the pier near 10th Avenue Marine Terminal, San Diego Bay (32.6956 °N, -117.15278 °W). Measurements of sea-surface temperature (t_w = 23.42 °C) and salinity (s_w = 35 psu) were measured to a depth of 10 m using a handheld probe (Pro2030, YSI) and input to the WBT-control software (EK80 v21.15.1, Simrad-Kongsberg), which derived estimates of sound speed (c_w = 1530.6 m s^{-1}) and absorption coefficients. The centerboard was placed in the Retracted position, which resulted in the seabed being approximately 5 to 10 m beneath the transducers, depending on the tide. 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. 8**. Measurements of gains, beamwidths, and offset angles from WBTs operated in FM mode are presented in **Fig. 9**.

Table 1: Simrad-Kongsberg EK80 wideband transceiver (WBT; 18, 38, 70, 120, 200, and 333 kHz) and transducer information aboard *Lasker* (above horizontal line); and beam model results following calibration (below horizontal line).

	Units	Frequency (kHz) 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	2000	600	200	90	35
Pulse Duration (τ)	ms	1.024	1.024	1.024	1.024	1.024	1.024
Temperature	C	23.4	23.4	23.4	23.4	23.4	23.4
Salinity	ppt	35.0	35.0	35.0	35.0	35.0	35.0
Sound speed	m s^{-1}	1530.5	1530.5	1530.5	1530.5	1530.5	1530.5
On-axis Gain (G_0)	dB re 1	22.96	26.07	27.24	26.54	26.57	26.40
S_a Correction ($S_a$corr)	dB re 1	0.00	-0.37	-0.08	-0.07	-0.05	-0.15
3-dB Beamwidth Along. (α_{-3dB})	deg	10.29	6.55	6.82	6.59	6.46	6.47
3-dB Beamwidth Athw. (β_{-3dB})	deg	10.47	6.76	6.73	6.54	6.48	6.46
Angle Offset Along. (α_0)	deg	-0.01	0.03	-0.00	-0.00	0.01	-0.00
Angle Offset Athw. (β_0)	deg	-0.02	-0.06	-0.03	-0.01	-0.01	0.01
Equivalent Two-way Beam Angle (Ψ)	dB re 1 sr	-16.90	-20.19	-20.17	-20.09	-20.07	-19.55

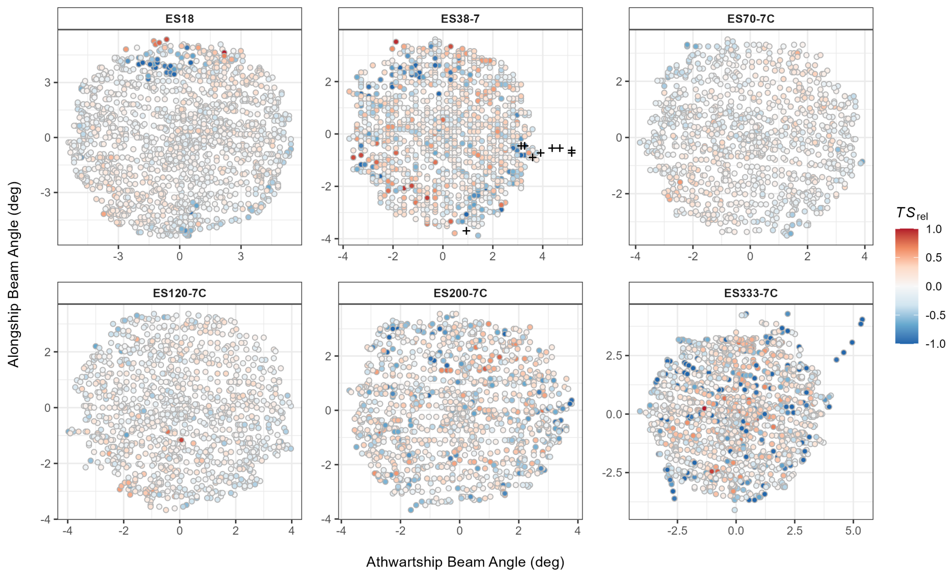

Figure 8: Relative beam-compensated target strength (TS_{rel}, dB re 1 m^2) measurements of a WC38.1 sphere at 18, 38, 70, 120, 200, and 333 kHz for echosounders aboard *Lasker*. TS_{rel} is calculated as the difference between the beam-compensated target strength (TS_c) and the theoretical target strength (TS_{theory}). Crosses indicate measurements marked as outliers after viewing the beam model results.

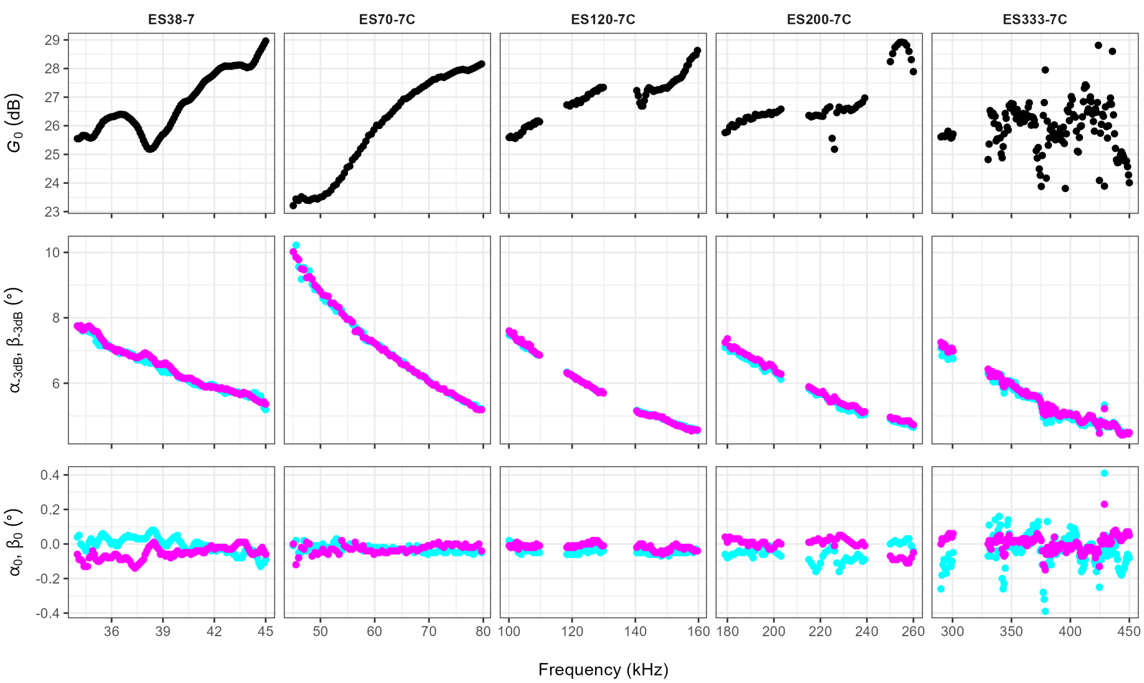

Figure 9: Measurements of on-axis gain (G_0, dB); alongship ($\alpha_{-3\mathrm{dB}}$, cyan) and athwartship ($\beta_{-3\mathrm{dB}}$, magenta) beamwidths (deg); and alongship (α_0, cyan) and athwartship (β_0, magenta) offset angles (deg) measured during calibrations of EK80 wideband transceivers aboard *Lasker* (WBT; 38, 70, 120, 200, and 333 kHz) in frequency modulation (FM, or broadband) mode.

For *Lisa Marie*, the 38- and 200-kHz WBTs were calibrated on 15 June, 2022 using the standard sphere technique with a WC38.1 while the vessel was anchored in Grays Harbor near Westport, WA (46.9202 N, 124.1090 W). Calibration results for *Lisa Marie* are presented in **Table 2**.

Table 2: Wideband Transceiver (Simrad-Kongsberg EK80 WBT) and transducer information (above horizontal line) and beam model results (below horizontal line) estimated from an in situ calibration of echosounders aboard *Lisa Marie* using a WC38.1.

		Frequency (kHz)	
	Units	38	200
Model		ES38-7	ES200-7C
Serial Number		448	899
Transmit Power (p_{et})	W	1000	90
Pulse Duration (τ)	ms	1.024	1.024
Temperature	C	13.1	13.1
Salinity	ppt	27.5	27.5
Sound speed	m s^{-1}	1491.6	1491.6
On-axis Gain (G_0)	dB re 1	26.76	26.48
S_{a} Correction (S_{a}corr)	dB re 1	-0.05	-0.05
3-dB Beamwidth Along. ($\alpha_{-3\mathrm{dB}}$)	deg	6.49	6.71
3-dB Beamwidth Athw. ($\beta_{-3\mathrm{dB}}$)	deg	6.40	7.25
Angle Offset Along. (α_0)	deg	-0.03	-0.16
Angle Offset Athw. (β_0)	deg	0.00	0.01
Equivalent Two-way Beam Angle (Ψ)	dB re 1 sr	-20.35	-20.46

For *Long Beach Carnage*, the echosounders were calibrated using the standard sphere technique with a WC38.1 on 7 July, 2022 in a tank at the SWFSC. Calibration results for *Long Beach Carnage* are presented in **Table 3**.

Table 3: General Purpose Transceiver (Simrad-Kongsberg EK60 GPT) and transducer information (above horizontal line) and beam model results (below horizontal line) estimated from a tank calibration of echosounders aboard *Long Beach Carnage* using a WC38.1.

		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
Temperature	C	19.1	19.1	19.1	19.1
Salinity	ppt	35.9	35.9	35.9	35.9
Sound speed	m s^{-1}	1520.1	1520.1	1520.1	1520.1
On-axis Gain (G_0)	dB re 1	21.77	26.21	26.03	26.70
S_{a} Correction (S_{a}corr)	dB re 1	-0.71	-0.29	-0.39	-0.24
3-dB Beamwidth Along. ($\alpha_{-3\mathrm{dB}}$)	deg	12.50	7.08	7.17	6.92
3-dB Beamwidth Athw. ($\beta_{-3\mathrm{dB}}$)	deg	12.49	7.10	7.33	6.96
Angle Offset Along. (α_0)	deg	-0.04	0.04	0.11	-0.05
Angle Offset Athw. (β_0)	deg	0.15	0.03	-0.01	0.02
Equivalent Two-way Beam Angle (Ψ)	dB re 1 sr	-15.64	-20.23	-20.13	-20.06

For the two USVs, the echosounders were calibrated while dockside by Saildrone, Inc. using the standard sphere technique with a WC38.1. The results were processed and derived by the SWFSC (Renfree *et al.*, 2019), and are presented in **Table 4**.

Table 4: Miniature Wideband Transceiver (Simrad-Kongsberg WBT Mini) beam model results estimated from calibrations of echosounders aboard USVs using a WC38.1.

	Units	Saildrone (Frequency)			
		1076 (38)	1076 (200)	1077 (38)	1077 (200)
Echosounder SN		266961-07	266961-08	268632-07	268632-08
Transducer SN		136	136	131	131
Temperature	C	20.2	20.2	20.1	20.1
Salinity	ppt	31.0	31.0	31.1	31.1
Sound speed	m s^{-1}	1517.5	1517.5	1517.5	1517.5
Eq. Two-way Beam Angle (Ψ)	dB re 1 sr	-12.9	-11.7	-12.4	-11.6
On-axis Gain (G_0)	dB re 1	19.18	19.45	18.87	19.00
S_a Correction ($S_a$corr)	dB re 1	0.08	0.08	0.02	0.09
3-dB Beamwidth Along. (α_{-3dB})	deg	17.3	19.4	18.2	20.1
3-dB Beamwidth Athw. (β_{-3dB})	deg	17.0	20.2	18.4	19.9
Angle Offset Along. (α_0)	deg	0.1	0.5	0.3	0.2
Angle Offset Athw. (β_0)	deg	-0.5	0.2	-0.6	-0.4
RMS	dB	0.27	0.46	0.32	0.41

3.2 Data collection

3.2.1 Acoustic and net sampling

The core survey region spanned an area from approximately Cape Flattery, WA to Punta Baja, Baja CA Norte (**Figs. 10 and 12**), predominantly including the potential habitat for the northern stock of Pacific Sardine at the time of the survey[3]. Due to the cancellation of Leg I on *Lasker*, *Lisa Marie* surveyed the northern region from Cape Flattery, WA to Bodega Bay, CA, while *Lasker* surveyed from Cape Mendocino, CA to Punta Baja, Baja CA Norte. The two USVs surveyed interstitial to the *Lisa Marie* and *Lasker* transects from Grays Harbor, WA to Cape Mendocino, CA. In total, *Lasker*, *Lisa Marie*, and the two USVs sampled 96 east-west transects totaling 4,281 nmi, and conducted 86 Nordic trawls and 41 purse seine sets.

The nearshore region was surveyed by *Long Beach Carnage* and spanned an area from approximately Bodega Bay, CA to San Diego, CA, including around Santa Cruz and Santa Catalina Islands, completing 129 east-west transects totaling 511 nmi and 53 purse seine sets (**Figs. 10 and 13**).

Leg I

Leg I on *Lasker* was canceled due to OMAO staffing issues. *Lisa Marie* was therefore directed to sample the Leg I *Lasker* transects in lieu of its nearshore transects. *Lisa Marie* sampled core-region compulsory Transects 178 to 143 between Cape Flattery, WA to Port Orford, OR, from 6 to 20 July. Two USVs (SD-1076 and SD-1077) sampled Transects 170 to 160, between Copalis Beach, WA to Tillamook Bay, OR, from 9 to 22 July.

Leg II

On 21 July, *Lasker* departed from the 10th Avenue Marine Terminal in San Diego, CA at ~1745 (all times GMT). Prior to the transit north, a calibration for the Simrad-Kongsberg EC150-3C ADCP and echosounder was attempted northwest of the sea buoy outside San Diego Bay (32.6598 N, 117.3833 W), but had to be abandoned due to GPS data-format incompatibilities. Due to departure delays, sampling North of Cape Mendocino was abandoned. Throughout the transit, sampling was conducted during the day with CUFES, EK80s, ME70, MS70 and SX90 while personnel continued to troubleshoot GPS issues and test equipment. On 25 July, *Lasker* arrived at the waypoint offshore of Cape Mendocino, CA at ~1930 and conducted one blind tow before initiating acoustic sampling on transect 129 at sunrise. Encountering CPS echoes on the first transect, adaptive sampling was initiated. On 26 July, Simrad-Kongsberg representative David Barbee resolved the issues with GPS and attitude data inputs to the EK80s. ADCP calibrations were successfully

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

completed on 27 July, taking advantage of good weather conditions, close proximity to the intended trawl locations, and the last couple hours of daylight. On 29 July, *Lasker* ceased adaptive transect sampling after completing transect 119. Small boat operations were conducted near Point Arena on 30 July at ~0230 to embark acoustician Scott Mau, a *Lasker*'s Junior Officer, and a trawl team member. On 4 August, *Lasker* completed transect 103 off Monterey, CA, ceased acoustic sampling, and transited to Point Conception, CA for lander recovery. The lander was recovered on 5 August at ~1400 before *Lasker* continued south to San Diego. On 6 August, *Lasker* arrived at the 10th Avenue Marine Terminal in San Diego, CA at ~1400 to complete Leg II.

Lisa Marie sampled core-region Transects 141 to 114, between Cape Sebastian, OR to Bodega Bay, CA, from 21 July to 1 August. On 2 August, on its transit north, *Lisa Marie* resampled Transect 133, which had previously been sampled during Leg II but did not record EK80 data. On 3 August, *Lisa Marie* returned to Wesport, WA to conclude its portion of the 2022 Summer CCE survey.

The two USVs (SD-1076 and SD-1077) sampled core-region Transects 158 to 146, between Neskowin, OR to Bandon, OR, from 23 July to 13 August.

Long Beach Carnage sampled nearshore Transects 227 to 186, between Bodega Bay, CA to Morro Bay, CA, from 30 July to 5 August.

Leg III

On 26 August, after a 16-day delay due to OMAO staffing issues, *Lasker* departed from the 10th Avenue Marine Terminal Pier in San Diego, CA at ~1400. Due to the limited survey time available on Leg III, the survey plan was adjusted northward from San Diego, CA, and acoustic sampling resumed along transect 72 at ~1930 on 26 August. A total of five transects were completed in the Southern California Bight. On 29 August, acoustic sampling ceased after the completion of transect 78 off of Long Beach, CA. On 30 August, after completing a compass calibration outside of the San Diego sea buoy, *Lasker* arrived at the 10th Avenue Marine Terminal in San Diego, CA at ~1900 to complete Leg III.

The two USVs (SD-1076 and SD-1077) sampled core-region Transects 144 to 122, between Cape Blanco, OR to Beaver Point, CA, from 9 to 31 August.

Long Beach Carnage sampled nearshore Transects 185 to 138, between Point Buchon, CA to the USA/Mexico border, and the Santa Cruz and Santa Catalina Islands, from 20 August to 8 September.

Leg IV

At ~1615 on 9 September, *Lasker* departed from 10th Avenue Marine Terminal in San Diego, CA. At ~1430 on 12 September, *Lasker* resumed acoustic sampling along transect 103 off Monterey, CA. At ~0330 on 16 September, an acoustic lander was deployed at 34.438635 N, 120.54667 W. The lander, consisting of an autonomous echosounder (WBAT; Simrad-Kongsberg) and passive-acoustic recorder (AURAL-M2; Multi-Electronique), is part of an ongoing project to utilize stationary platforms for monitoring the ecosystem off Point Conception, CA. At 0330 on 17 September, scientists Dayv Lowry and Daniel Hernandez Cruz were embarked via small craft in Santa Barbara Harbor, CA. At 0330 on 24 September, scientist Brittany Schwarzkopf disembarked and *Lasker*'s XO embarked via small craft in Mission Bay, CA. At 0200 on 29 September, acoustic sampling ceased at sunset along transect 54 off Punta Baja, Baja California. At 0700 on 30 September, *Lasker* arrived at the 10th Avenue Marine Terminal in San Diego, CA to conclude the 2022 Summer CCE survey.

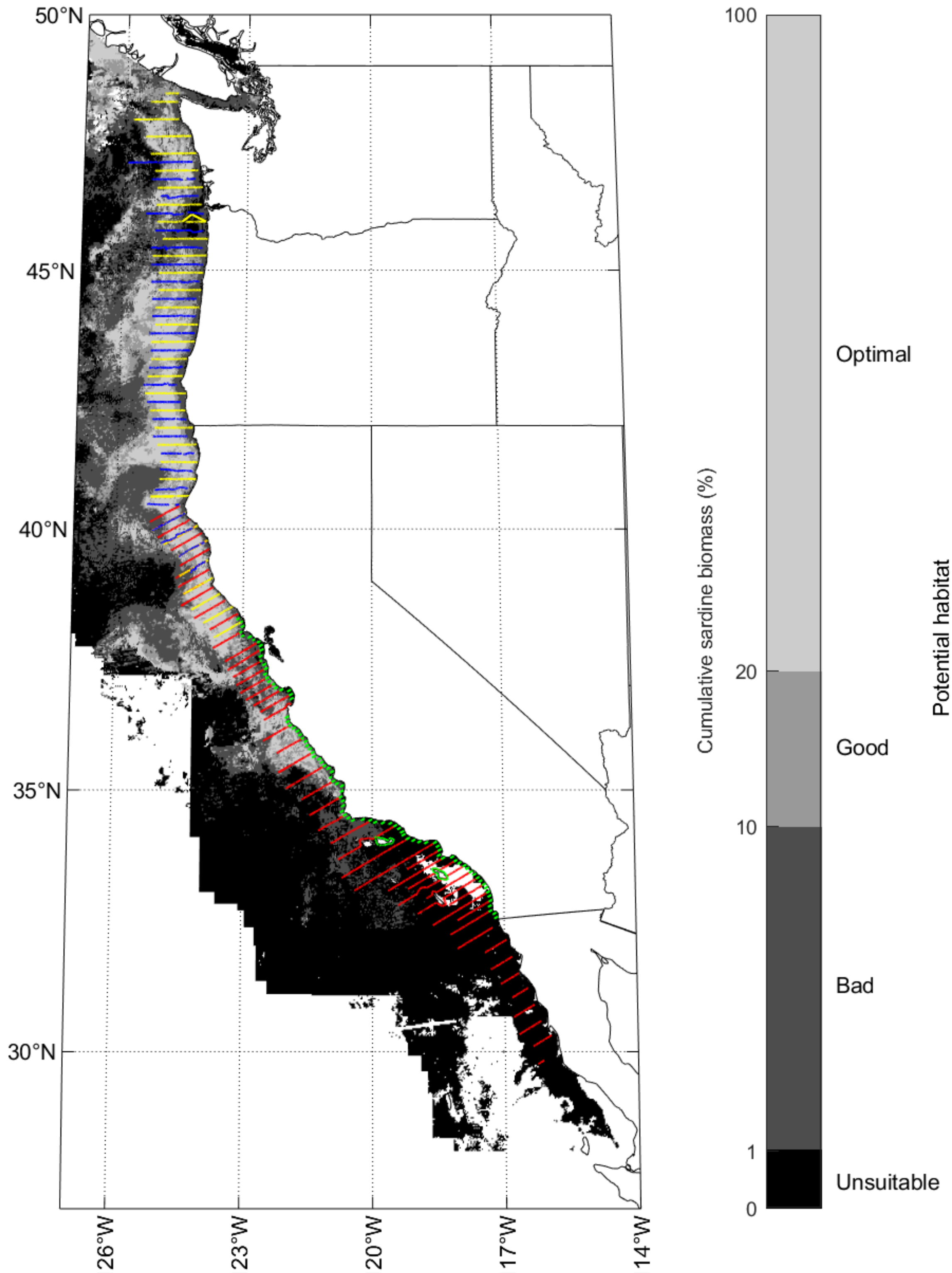

Figure 10: Summary of all transects sampled throughout the survey by *Lasker* (red), *Lisa Marie* (yellow), USVs (blue), and *Long Beach Carnage* (green), in relation to the potential habitat for the northern stock of Pacific Sardine. The habitat is temporally aggregated using an average of the habitat centered ±2° around each vessel during the survey. Areas in white correspond to no available data, e.g., cloud coverage preventing satellite-sensed observations.

3.2.2 Ichthyoplankton and oceanographic sampling

A total of 8 CTD casts and 89 UCTD casts were conducted from *Lasker* (**Fig. 11** and **Appendix B**), and 850 CUFES samples were collected underway. A total of 110 CTD casts were obtained from the NWFSC's 2022 Integrated Ecosystem and Pacific Hake Acoustic-Trawl Survey aboard *Shimada*, which were utilized for processing the *Lisa Marie* and USV transects off of Oregon and Washington.

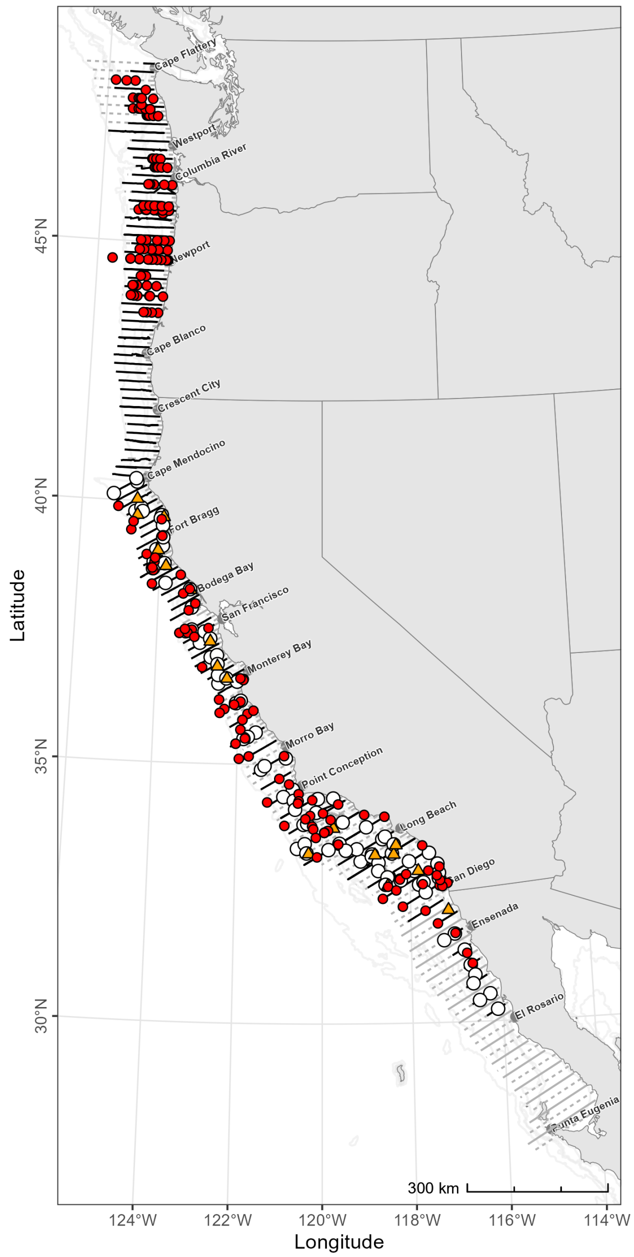

Figure 11: The locations of surface trawls (white points), CTD and UCTD casts (red circles), and bongo nets (orange triangles) relative to the planned east-west acoustic transects (solid and dashed grey lines) and cruise tracks (thick black line) of *Lasker*. The CTD casts off of Oregon and Washington were provided by the NWFSC from their 2022 Integrated Ecosystem and Pacific Hake Acoustic-Trawl Survey aboard *Shimada* from 22 July to 25 August, 2022.

3.3 Distribution of CPS

3.3.1 Core region

Acoustic backscatter ascribed to CPS (**Fig. 12a**), sampled by *Lasker*, *Lisa Marie*, and the USVs, was observed throughout the survey area, but was most prevalent off Cape Flattery, WA; between Willapa Bay, WA to Cape Blanco, OR; and south of Cape Mendocino, CA.

Purse seines, conducted by *Lisa Marie* north of Bodega Bay, CA, caught Pacific Herring predominantly off WA; Pacific Sardine mixed with Jack Mackerel between the WA/OR border to Fort Bragg, CA; and Northern Anchovy off of Bodega Bay, CA and near Cape Blanco, OR (**Fig. 12d**). The combined catches of the 41 purse seine sets included 147 kg of CPS (89 kg Pacific Sardine, 26 kg Northern Anchovy, 12 kg Jack Mackerel, 0 kg Pacific Mackerel, 20 kg Pacific Herring, and 0 kg Round Herring; **Appendix D.1**).

Surface trawls, conducted by *Lasker* south of Cape Mendocinco, CA, caught Jack Mackerel, generally mixed with Pacific Sardine, between Cape Mendocino, CA to Bodega Bay, CA and in the SCB; Northern Anchovy throughout the region south of Bodega Bay, CA; and Pacific Mackerel, which were only caught in nearshore trawls off San Clemente, CA and offshore of Punta Colonet, Baja California (**Fig. 12c**). The combined catches of the 86 trawls included 7,247 kg of CPS (134 kg Pacific Sardine, 6,887 kg Northern Anchovy, 208 kg Jack Mackerel, 18 kg Pacific Mackerel, 0 kg Pacific Herring, and 0 kg Round Herring; **Appendix C**).

The area between Cape Mendocino to Bodega Bay, CA was sampled by both *Lasker* and *Lisa Marie*, but had significant discrepancies in the species proportions of their catches. *Lasker*'s nighttime trawls mainly contained Jack Mackerels with a small amount of Pacific Sardine, whereas *Lisa Marie*'s daytime purse seines were composed primarily of Pacific Sardine. The two vessels both caught predominantly Northern Anchovy off of Bodega Bay, CA.

CUFES samples were dominated by Jack Mackerel eggs north of Monterey Bay, CA, and to the south by Northern Anchovy (**Fig. 12b**). Pacific Sardine eggs were observed offshore between San Francisco to Monterey Bay, CA, and throughout the SCB. The SCB contained a mixture of eggs from the three species, with Northern Anchovy and Pacific Sardine eggs found predominantly nearshore, Northern Anchovy and Jack Mackerel eggs offshore, and Pacific Sardine eggs nearshore off San Diego, CA. Note that due to the cancellation of Leg I on *Lasker*, no CUFES samples exist north of Cape Mendocino, CA.

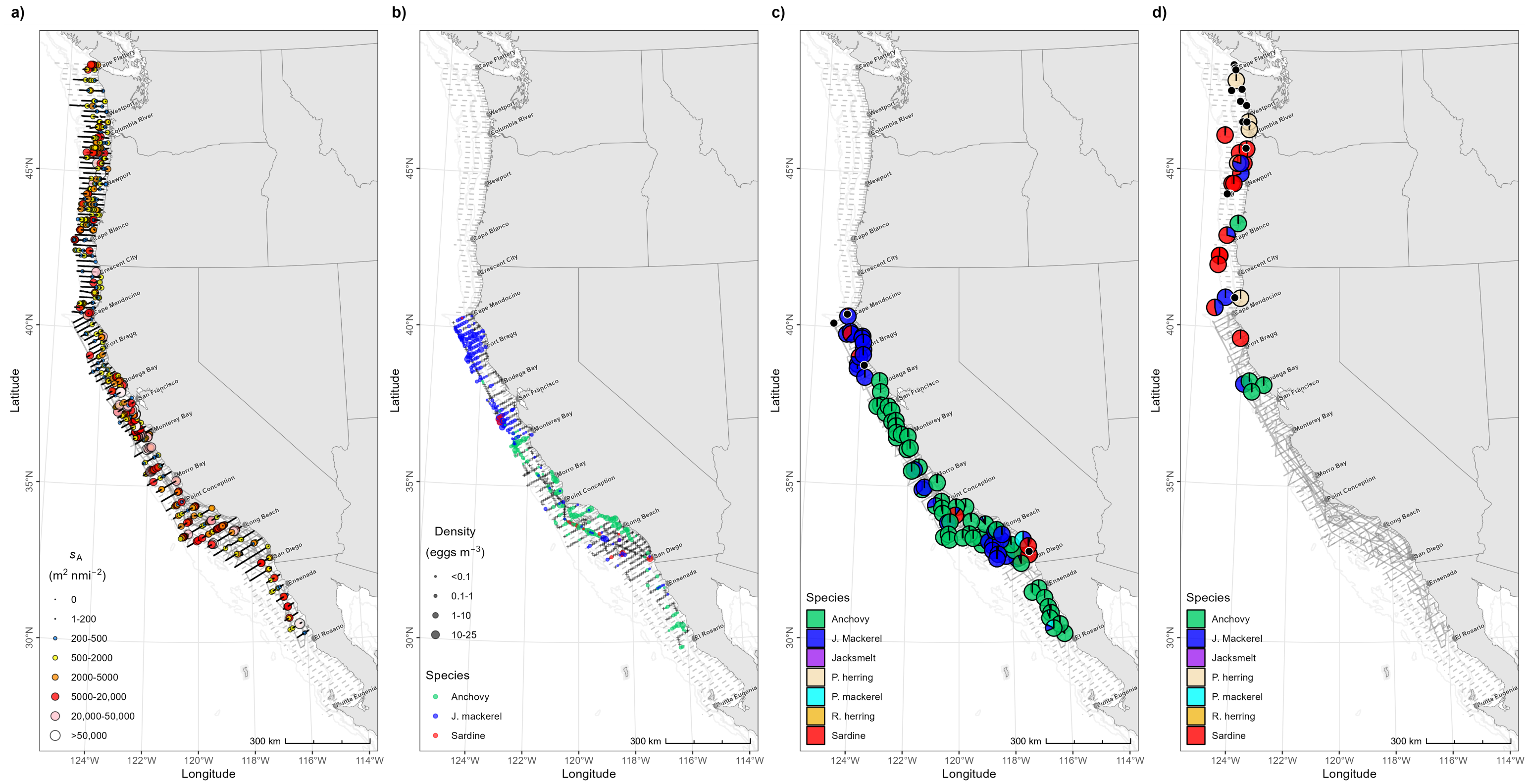

Figure 12: Survey transects overlaid with the distributions of: 38-kHz integrated backscattering coefficients (s_A, m^2 nmi^{-2}; averaged over 2000-m distance intervals and from 5- to 70-m deep) ascribed to CPS (a); egg densities (eggs m^{-3}) for Northern Anchovy, Jack Mackerel, and Pacific Sardine from the CUFES (b); and proportions, by weight, of CPS species in each nighttime *Lasker* trawl (c) or daytime *Lisa Marie* seine catch (d; black points indicate trawls with no CPS). Species with low catch weights are not visible at this scale.

3.3.2 Nearshore region

Acoustic backscatter sampled by *Long Beach Carnage* was observed throughout the nearshore survey area off California, but was most prevalent outside of Bodega Bay and San Francisco, between Monterey Bay and Point Conception, between Santa Barbara and Long Beach, and around Santa Cruz Island (**Fig. 13a**).

Purse seine catches by *Long Beach Carnage* included predominantly Northern Anchovy north of Point Conception, CA; Pacific Sardine south of Morro Bay, CA; and Pacific Mackerel near Santa Cruz Island (**Fig. 13b**). The combined catches of the 53 purse seine sets included 151 kg of CPS (87 kg Pacific Sardine, 10 kg Northern Anchovy, 7 kg Jack Mackerel, 46 kg Pacific Mackerel, 0 kg Pacific Herring, and 0 kg Round Herring; **Appendix D.2**)

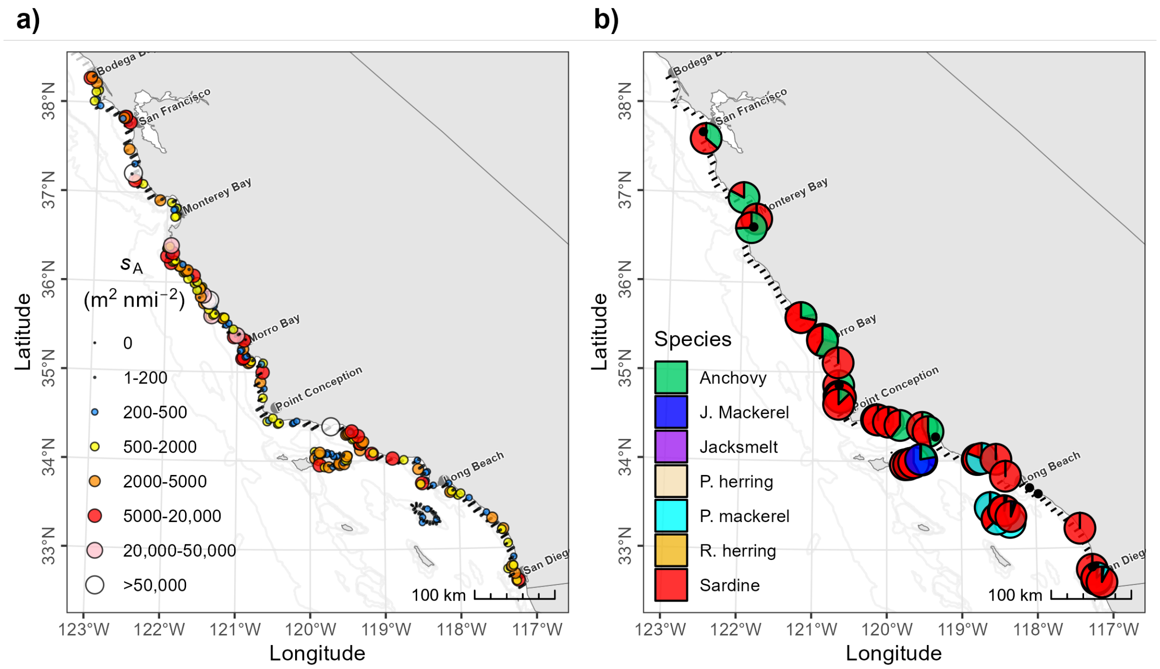

Figure 13: Nearshore survey transects conducted by *Long Beach Carnage* overlaid with the distributions of: 38-kHz integrated backscattering coefficients (s_A, m^2 nmi^{-2}; averaged over 2000-m distance intervals and from 5- to 70-m deep) ascribed to CPS (a); and the proportions, by weight, of CPS in each daytime purse seine catch (b). Species with low catch weights are not visible at this scale.

4 Discussion

The principal objectives of the 77-day Summer 2022 CCE Survey were to survey the northern stock of Pacific Sardine and the northern and central stocks of Northern Anchovy. Then, as possible, to survey the stocks of Pacific Mackerel, Jack Mackerel, Pacific Herring, Pacific Round Herring, and the southern stock of Pacific Sardine. Despite the original survey plan being substantially modified due to OMAO staffing issues on *Lasker*, the combined sampling from *Lasker*, *Lisa Marie*, *Long Beach Carnage*, and Saildrones spanned the offshore and nearshore areas from Cape Flattery, WA to Punta Baja, MX. This was made possible by the resilience and adaptability of all personnel from the various sampling platforms, particularly: *Lisa Marie*, which surveyed the *Lasker* transects north of Bodega Bay, CA; the *Long Beach Carnage* and Saildrone USVs, which repeatedly modified the timing of their surveys; and the scientists and crew on *Lasker*, who remained prepared and flexible throughout an uncertain survey schedule.

The forage fish assemblage was dominated by Northern Anchovy south of Bodega Bay, CA. To the north, trawl catches from *Lasker* were predominantly Jack Mackerel, while purse seine sets from *Lisa Marie* caught mainly Pacific Sardine between the WA/OR border to Fort Bragg, CA. Based on differences in the *Lasker* and *Lisa Marie* catches in the overlapping region in northern California, in addition to comparative historical results (Renfree *et al.*, 2022) and observations communicated by the *Lisa Marie* captain, it is hypothesized that purse seines are ineffective in capturing fast-moving Jack Mackerel, deep schools, and schools in clear water. Until further research can quantify the effectiveness of daytime purse seines in catching CPS, the species proportions and length distributions from such data should be analyzed with these discrepancies in mind.

5 Disposition of Data

All raw EK60, EK80, ME70, MS70, SX90, and EC150-3C 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).

6 Acknowledgements

We thank the crew members of the NOAA ship *Lasker* and all of the scientists who participated in the sampling operations at sea. We thank Captains Rick Blair (*Lisa Marie*) and Rich Ashley and Tom Brinton (*Long Beach Carnage*), along with all the F/V crew members, for their coordination and cooperation during the nearshore sampling. We thank Diane Pleschner-Steele for contracting the *Long Beach Carnage* to conduct the nearshore survey. We thank Trevor Stocking, Diego Aceituno, Dane McDermott, Angela Garelick, Trung Nguyen, Chelsea Protasio, and Michelle Horeczko (CDFW) for their efforts to coordinate with and process samples from *Long Beach Carnage*, and Dianna Porzio for coordinating the biological sampling and organizing, validating, and disseminating the resulting data. We thank Jennifer Topping (WDFW) for the ageing of biological samples from *Lisa Marie*. Andy Blair [President, West Coast Pelagic Conservation Group (WCPCG)], Mike Okoniewski (Secretary, WCPCG), and Greg Shaughnessy (Vice President of WCPCG and Chief Operating Officer of Ocean Gold Seafoods) were integral in the permitting and planning for *Lisa Marie*. Finally, we thank John Pohl and the NWFSC's Fisheries Engineering and Acoustic Technologies (FEAT) team for providing CTD data from their 2022 Pacific Hake survey. A critical review by Jarrod Santora improved this report.

References

Checkley, D. M., Ortner, P. B., Settle, L. R., and Cummings, S. R. 1997. A continuous, underway fish egg sampler. Fisheries Oceanography, 6: 58–73.

De Robertis, A., and Higginbottom, I. 2007. A post-processing technique to estimate the signal-to-noise ratio and remove echosounder background noise. ICES Journal of Marine Science, 64: 1282–1291.

Demer, D. A. 2004. An estimate of error for the CCAMLR 2000 survey estimate of krill biomass. Deep-Sea Research Part II-Topical Studies in Oceanography, 51: 1237–1251.

Demer, D. A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R., *et al.* 2015. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326: 133 pp.

Demer, D. A., Cutter, G. R., Renfree, J. S., and Butler, J. L. 2009. A statistical-spectral method for echo classification. ICES Journal of Marine Science, 66: 1081–1090.

Demer, D. A., Zwolinski, J. P., Byers, K. A., Cutter, G. R., Renfree, J. S., Sessions, T. S., and Macewicz, B. J. 2012. Prediction and confirmation of seasonal migration of Pacific sardine (*Sardinops sagax*) in the California Current Ecosystem. Fishery Bulletin, 110: 52–70.

Dorval, E., Schwartzkopf, B. D., James, K. C., Vasquez, L., and Erisman, B. E. 2022. Sampling methodology for estimating life history parameters of coastal pelagic species along the U.S. Pacific Coast. U.S. Dep. Commer., NOAA Tech. Memo., NMFS-SWFSC-660: 46 pp.

Dotson, R. C., Griffith, D. A., King, D. L., and Emmett, R. L. 2010. Evaluation of a marine mammal excluder device (MMED) for a Nordic 264 midwater rope trawl. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-SWFSC-455: 19.

Foote, K. G., Knudsen, H. P., Vestnes, G., MacLennan, D. N., and Simmonds. E., J. 1987. Calibration of acoustic instruments for fish density estimation: A practical guide. ICES Cooperative Research Report, 144: 69 pp.

Kim, H. J., Miller, A. J., Neilson, D. J., and McGowan, J. A. 2005. Decadal variations of Mixed Layer Depth and biological response in the southern California current. Sixth Conference on Coastal Atmospheric and Oceanic Prediction and Processes. San Diego.

Mais, K. F. 1974. Pelagic fish surveys in the California Current. State of California, Resources Agency, Dept. of Fish and Game, Sacramento, CA: 79 pp.

Polovina, J. J., Howell, E., Kobayashi, D. R., and Seki, M. P. 2001. The transition zone chlorophyll front, a dynamic global feature defining migration and forage habitat for marine resources. Progress in Oceanography, 49: 469–483.

Renfree, J. S., Bowlin, N. M., Erisman, B. E., Rojas-González, R. I., Johnson, G. E., Mau, S. A., Murfin, D. W., *et al.* 2022. Report on the 2021 California Current Ecosystem (CCE) Survey (2107RL), 6 July to 15 October 2021, conducted aboard NOAA Ship *Reuben Lasker*, Mexican Research Vessel *Dr. Jorge Carranza Fraser*, fishing vessels *Lisa Marie* and *Long Beach Carnage*, and uncrewed surface vehicles. U.S. Dep. Commer., NOAA Tech. Memo., NMFS-SWFSC-669: 50 pp.

Renfree, J. S., and Demer, D. A. 2016. Optimising transmit interval and logging range while avoiding aliased seabed echoes. ICES Journal of Marine Science, 73: 1955–1964.

Renfree, J. S., Sessions, T. S., Murfin, D. W., Palance, D., and Demer, D. A. 2019. Calibrations of Wide-Bandwidth Transceivers (WBT Mini) with Dual-frequency Transducers (ES38-18/200-18C) for Saildrone Surveys of the California Current Ecosystem During Summer 2018. U.S. Dep. Commer., NOAA Tech. Memo., NMFS-SWFSC-608: 29 pp.

Schwartzkopf, B. D., Dorval, E., James, K. C., Walker, J. M., Snodgrass, O. E., Porzio, D. L., and Erisman, B. E. 2022. A summary report on the life history information on the central subpopulation of Northern Anchovy *(Engraulis mordax)* for the 2021 stock assessment. U.S. Dep. Commer., NOAA Tech. Memo., NMFS-SWFSC-659: 76 pp.

Simmonds, E. J., and MacLennan, D. N. 2005. Fisheries Acoustics: Theory and Practice, 2nd Edition. Blackwell Publishing, Oxford.

Smith, P. E., and Richardson, S. L. 1977. Standard techniques for pelagic fish egg and larva surveys. FAO Fisheries Technical Paper No. 175: 108 pp.

Zwolinski, J. P., Demer, D. A., Byers, K. A., Cutter, G. R., Renfree, J. S., Sessions, T. S., and Macewicz, B. J. 2012. Distributions and abundances of Pacific sardine (*Sardinops sagax*) and other pelagic fishes in the California Current Ecosystem during spring 2006, 2008, and 2010, estimated from acoustic-trawl surveys. Fishery Bulletin, 110: 110–122.

Zwolinski, J. P., Emmett, R. L., and Demer, D. A. 2011. Predicting habitat to optimize sampling of Pacific sardine (*Sardinops sagax*). ICES Journal of Marine Science, 68: 867–879.

Zwolinski, J. P., Oliveira, P. B., Quintino, V., and Stratoudakis, Y. 2010. Sardine potential habitat and environmental forcing off western Portugal. ICES Journal of Marine Science, 67: 1553–1564.

Appendix

A Centerboard positions

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

Date Time	Position (depth)	Latitude	Longitude
08/06/2022 12:19	Retracted (5 m)	32.6095	-117.2392
08/26/2022 17:32	Intermediate (7 m)	32.6346	-117.2710
08/30/2022 13:36	Retracted (5 m)	32.6230	-117.2410
09/09/2022 17:32	Intermediate (7 m)	32.6337	-117.2740

B CTD and UCTD sampling locations

Times and locations of conductivity and temperature versus depth casts while on station (CTD) and underway (UCTD) from *Lasker* (RL). Also included are CTD casts conducted by *Shimada* (SH) during the NWFSC's 2022 Integrated Ecosystem and Pacific Hake Acoustic-Trawl Survey, used for processing acoustic data from *Lisa Marie* and the USVs.

Vessel	Date Time	Cast Type	Latitude	Longitude
RL	07/23/2022 12:04	UCTD	35.6644	-121.9323
RL	07/23/2022 16:33	UCTD	36.0547	-122.3230
RL	07/23/2022 18:40	UCTD	36.2331	-122.4528
RL	07/26/2022 03:49	CTD	34.6227	-120.7725
RL	07/27/2022 03:38	CTD	36.8465	-122.8788
RL	07/28/2022 04:37	CTD	39.4412	-124.7387
RL	07/28/2022 19:54	UCTD	38.9794	-124.3299
RL	07/29/2022 04:07	CTD	39.8776	-125.0894
RL	07/29/2022 12:29	UCTD	39.3407	-123.9604
RL	07/29/2022 14:57	UCTD	38.9166	-124.1176
RL	07/29/2022 20:12	UCTD	38.6758	-124.1467
RL	07/30/2022 04:27	CTD	39.5969	-124.6921
RL	07/30/2022 12:10	UCTD	38.7257	-124.1771
RL	07/30/2022 14:29	UCTD	38.4151	-124.1676
RL	07/30/2022 19:07	UCTD	38.6075	-123.4707
RL	07/30/2022 23:26	UCTD	38.2501	-123.3949
RL	07/31/2022 10:31	UCTD	38.3405	-123.2348
RL	07/31/2022 12:18	CTD	39.6599	-123.9957
RL	07/31/2022 14:35	UCTD	38.0657	-123.0903
RL	07/31/2022 16:07	UCTD	37.9297	-123.2472
RL	07/31/2022 21:22	UCTD	37.4909	-123.4526
RL	07/31/2022 21:22	UCTD	37.4909	-123.4526
RL	08/01/2022 11:11	UCTD	37.4991	-123.2568
RL	08/01/2022 12:51	UCTD	37.5705	-123.3227
RL	08/01/2022 16:17	UCTD	37.4247	-123.0880
RL	08/01/2022 18:14	UCTD	37.6011	-122.7537
RL	08/02/2022 12:24	CTD	38.8437	-124.1284
RL	08/04/2022 13:13	CTD	37.5610	-123.1542
RL	08/04/2022 17:44	UCTD	36.2030	-121.9410
RL	08/04/2022 19:39	UCTD	35.9710	-121.7703
RL	08/05/2022 12:33	UCTD	34.4377	-120.5486
RL	08/05/2022 14:43	UCTD	34.3008	-120.5449
RL	08/05/2022 18:52	UCTD	33.8150	-120.2338
RL	08/06/2022 11:31	UCTD	32.6505	-117.3321
RL	08/26/2022 14:50	UCTD	32.6955	-117.1532
RL	08/26/2022 17:33	UCTD	32.6346	-117.2710
RL	08/26/2022 22:02	UCTD	32.6824	-117.7133
RL	08/27/2022 12:06	UCTD	32.7796	-118.2326
RL	08/27/2022 14:30	UCTD	32.8816	-118.0883
RL	08/27/2022 20:20	UCTD	33.4291	-117.7070
RL	09/11/2022 13:57	UCTD	36.6355	-121.8774
RL	09/11/2022 20:03	UCTD	36.6354	-121.8771

(continued)

Vessel	Date Time	Cast Type	Latitude	Longitude
RL	09/11/2022 21:47	UCTD	36.6353	-121.8770
RL	09/12/2022 13:12	UCTD	36.6170	-121.8847
RL	09/12/2022 14:59	UCTD	36.6489	-121.9561
RL	09/12/2022 21:28	UCTD	35.9778	-122.4313
RL	09/12/2022 23:23	UCTD	36.1437	-122.0927
RL	09/13/2022 14:03	UCTD	36.0328	-121.6319
RL	09/13/2022 16:15	UCTD	35.8524	-121.8879
RL	09/13/2022 16:15	UCTD	35.8524	-121.8879
RL	09/13/2022 20:51	UCTD	35.3922	-122.0370
RL	09/13/2022 20:51	UCTD	35.3922	-122.0370
RL	09/13/2022 23:33	UCTD	35.4958	-121.8215
RL	09/14/2022 13:05	UCTD	35.1034	-121.9545
RL	09/14/2022 15:31	UCTD	35.1529	-121.7241
RL	09/14/2022 21:54	UCTD	35.1673	-120.8937
RL	09/15/2022 16:01	UCTD	34.7288	-121.0006
RL	09/15/2022 20:28	UCTD	34.2731	-121.2770
RL	09/16/2022 13:25	UCTD	34.2566	-120.5639
RL	09/16/2022 17:36	UCTD	34.3210	-120.2310
RL	09/16/2022 21:19	UCTD	34.0661	-119.9831
RL	09/16/2022 23:23	UCTD	34.2398	-119.6302
RL	09/17/2022 14:26	UCTD	34.0195	-120.2804
RL	09/17/2022 16:38	UCTD	33.9552	-120.3895
RL	09/17/2022 21:58	UCTD	33.8246	-120.8733
RL	09/18/2022 15:23	UCTD	33.7255	-119.8886
RL	09/18/2022 20:25	UCTD	34.0358	-119.0312
RL	09/18/2022 22:47	UCTD	33.9961	-118.5645
RL	09/19/2022 13:39	UCTD	33.7305	-119.8648
RL	09/19/2022 16:34	UCTD	33.7604	-120.2071
RL	09/19/2022 19:06	UCTD	33.9422	-119.8074
RL	09/19/2022 21:54	UCTD	33.6953	-119.9497
RL	09/19/2022 21:54	UCTD	33.6953	-119.9497
RL	09/19/2022 21:54	UCTD	33.6953	-119.9497
RL	09/19/2022 21:54	UCTD	33.6953	-119.9497
RL	09/19/2022 21:54	UCTD	33.6953	-119.9497
RL	09/19/2022 21:55	UCTD	33.6940	-119.9523
RL	09/19/2022 21:55	UCTD	33.6940	-119.9523
RL	09/19/2022 21:55	UCTD	33.6940	-119.9523
RL	09/19/2022 21:55	UCTD	33.6940	-119.9523
RL	09/19/2022 21:55	UCTD	33.6940	-119.9523
RL	09/19/2022 23:10	UCTD	33.5957	-120.1479
RL	09/20/2022 15:38	UCTD	33.2213	-120.1212
RL	09/20/2022 18:32	UCTD	33.4684	-119.6316
RL	09/24/2022 12:16	UCTD	32.6449	-118.5045
RL	09/24/2022 13:56	UCTD	32.4132	-118.6261
RL	09/24/2022 15:44	UCTD	32.5715	-118.3192
RL	09/24/2022 20:08	UCTD	32.9412	-117.5816
RL	09/24/2022 21:59	UCTD	33.0139	-117.3286
RL	09/24/2022 23:25	UCTD	32.7543	-117.3184

(continued)

Vessel	Date Time	Cast Type	Latitude	Longitude
RL	09/25/2022 13:02	UCTD	32.8472	-117.3900
RL	09/25/2022 18:51	UCTD	32.2555	-118.1765
RL	09/25/2022 23:28	UCTD	32.1685	-117.6661
RL	09/26/2022 16:37	UCTD	31.9177	-117.3945
RL	09/26/2022 21:08	UCTD	31.7244	-117.0060
RL	09/27/2022 13:15	UCTD	31.3321	-116.7600
RL	09/27/2022 18:52	UCTD	31.1303	-116.6433
SH	07/23/2022 05:29	CTD	43.9462	-124.5720
SH	07/23/2022 08:10	CTD	43.9394	-124.9792
SH	07/23/2022 09:20	CTD	43.9461	-125.0420
SH	07/24/2022 04:07	CTD	44.1393	-125.0274
SH	07/25/2022 03:40	CTD	44.1390	-125.0022
SH	07/25/2022 05:01	CTD	44.1413	-124.9736
SH	07/25/2022 08:09	CTD	44.1406	-124.3944
SH	07/25/2022 22:53	CTD	44.1413	-124.9113
SH	07/26/2022 00:47	CTD	44.1409	-125.0008
SH	07/26/2022 03:01	CTD	44.1414	-125.0250
SH	07/26/2022 06:22	CTD	44.1434	-124.6490
SH	07/27/2022 05:13	CTD	45.6103	-124.9716
SH	07/27/2022 07:29	CTD	45.6070	-124.7567
SH	07/27/2022 09:04	CTD	45.6113	-124.5596
SH	07/27/2022 10:37	CTD	45.6105	-124.3224
SH	07/27/2022 11:51	CTD	45.6114	-124.1530
SH	07/27/2022 22:39	CTD	45.6077	-124.4719
SH	07/28/2022 04:35	CTD	45.6113	-124.5570
SH	07/28/2022 06:44	CTD	45.6129	-124.3190
SH	07/28/2022 08:54	CTD	45.6109	-124.1588
SH	07/28/2022 10:29	CTD	45.6256	-124.2075
SH	07/28/2022 14:50	CTD	45.6249	-124.2075
SH	07/29/2022 04:11	CTD	45.5507	-124.3059
SH	07/29/2022 04:47	CTD	45.5519	-124.3105
SH	07/29/2022 05:45	CTD	45.5526	-124.3135
SH	07/29/2022 23:12	CTD	44.6501	-124.5563
SH	07/30/2022 02:17	CTD	44.6505	-124.5839
SH	07/30/2022 05:56	CTD	44.6534	-124.4122
SH	07/30/2022 07:11	CTD	44.6540	-124.5311
SH	07/30/2022 08:34	CTD	44.6491	-124.6492
SH	07/30/2022 10:49	CTD	44.6482	-124.8851
SH	07/30/2022 13:06	CTD	44.6501	-125.1240
SH	08/01/2022 04:22	CTD	45.6127	-124.1554
SH	08/01/2022 08:41	CTD	45.6124	-124.5580
SH	08/01/2022 11:49	CTD	45.6113	-124.7936
SH	08/03/2022 04:30	CTD	45.6117	-124.7637
SH	08/03/2022 09:12	CTD	45.6112	-124.3231
SH	08/04/2022 07:34	CTD	46.6101	-124.6708
SH	08/04/2022 08:22	CTD	46.6103	-124.6412
SH	08/04/2022 09:12	CTD	46.6129	-124.5570

(continued)

Vessel	Date Time	Cast Type	Latitude	Longitude
SH	08/04/2022 11:14	CTD	46.6107	-124.4464
SH	08/05/2022 04:23	CTD	47.4436	-124.8798
SH	08/05/2022 05:05	CTD	47.4453	-124.8515
SH	08/05/2022 05:45	CTD	47.4452	-124.8359
SH	08/05/2022 06:20	CTD	47.4453	-124.8075
SH	08/05/2022 07:10	CTD	47.4433	-124.7032
SH	08/05/2022 08:04	CTD	47.4430	-124.5666
SH	08/06/2022 03:18	CTD	47.5694	-125.2768
SH	08/06/2022 04:42	CTD	47.5704	-125.1182
SH	08/06/2022 05:40	CTD	47.5719	-125.0655
SH	08/06/2022 06:54	CTD	47.5721	-124.9315
SH	08/06/2022 07:49	CTD	47.5719	-124.7990
SH	08/06/2022 08:24	CTD	47.5696	-124.7983
SH	08/07/2022 02:45	CTD	47.6520	-125.0493
SH	08/13/2022 15:25	CTD	48.1144	-125.2503
SH	08/13/2022 17:15	CTD	48.1092	-125.4997
SH	08/13/2022 20:44	CTD	48.1108	-125.7980
SH	08/14/2022 01:32	CTD	47.9428	-124.9478
SH	08/14/2022 03:54	CTD	47.7778	-125.2943
SH	08/14/2022 05:08	CTD	47.7775	-125.1345
SH	08/14/2022 05:51	CTD	47.7775	-125.0887
SH	08/14/2022 06:31	CTD	47.7778	-125.0493
SH	08/14/2022 08:36	CTD	47.7768	-124.7292
SH	08/15/2022 03:41	CTD	46.4447	-124.5950
SH	08/15/2022 04:30	CTD	46.4445	-124.5725
SH	08/15/2022 05:17	CTD	46.4452	-124.5297
SH	08/15/2022 05:47	CTD	46.4443	-124.5025
SH	08/15/2022 06:35	CTD	46.4452	-124.4085
SH	08/15/2022 07:39	CTD	46.4452	-124.2477
SH	08/16/2022 15:34	CTD	44.6517	-124.1152
SH	08/16/2022 15:59	CTD	44.6518	-124.1305
SH	08/16/2022 16:39	CTD	44.6487	-124.1647
SH	08/16/2022 17:34	CTD	44.6510	-124.2973
SH	08/16/2022 18:24	CTD	44.6510	-124.4093
SH	08/16/2022 19:17	CTD	44.6525	-124.5275
SH	08/16/2022 20:08	CTD	44.6520	-124.6517
SH	08/16/2022 21:31	CTD	44.6520	-124.8848
SH	08/16/2022 23:18	CTD	44.6530	-125.1195
SH	08/17/2022 02:45	CTD	44.6517	-125.6020
SH	08/18/2022 06:05	CTD	46.1115	-124.0932
SH	08/18/2022 07:15	CTD	46.1127	-124.3107
SH	08/18/2022 08:42	CTD	46.1095	-124.5927
SH	08/18/2022 09:30	CTD	46.1113	-124.6992
SH	08/18/2022 10:16	CTD	46.1098	-124.7425
SH	08/19/2022 04:23	CTD	45.6890	-124.8458
SH	08/19/2022 05:28	CTD	45.6946	-124.6885
SH	08/19/2022 06:54	CTD	45.6952	-124.5493
SH	08/19/2022 08:29	CTD	45.6938	-124.3525

(continued)

Vessel	Date Time	Cast Type	Latitude	Longitude
SH	08/19/2022 10:03	CTD	45.6934	-124.1642
SH	08/20/2022 12:21	CTD	43.9437	-124.5553
SH	08/21/2022 06:05	CTD	43.9452	-124.2120
SH	08/21/2022 09:13	CTD	43.9380	-124.8897
SH	08/21/2022 09:57	CTD	43.9422	-124.9792
SH	08/21/2022 11:04	CTD	43.9473	-125.0607
SH	08/22/2022 06:55	CTD	43.6288	-124.3192
SH	08/22/2022 08:03	CTD	43.6286	-124.4860
SH	08/22/2022 09:07	CTD	43.6282	-124.6213
SH	08/22/2022 09:54	CTD	43.6288	-124.7022
SH	08/23/2022 05:37	CTD	44.3276	-124.6870
SH	08/23/2022 06:32	CTD	44.3279	-124.8210
SH	08/24/2022 06:28	CTD	45.0305	-124.0985
SH	08/24/2022 07:21	CTD	45.0288	-124.2417
SH	08/24/2022 08:26	CTD	45.0285	-124.4333
SH	08/24/2022 10:00	CTD	45.0282	-124.7213
SH	08/24/2022 11:09	CTD	45.0287	-124.8638
SH	08/25/2022 07:21	CTD	44.8440	-124.1408
SH	08/25/2022 08:48	CTD	44.8450	-124.3832
SH	08/25/2022 10:03	CTD	44.8446	-124.5708
SH	08/25/2022 11:21	CTD	44.8457	-124.7710
SH	08/25/2022 12:23	CTD	44.8445	-124.8875

C 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.

Haul	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Mackerel	P. Sardine	All CPS
1	07/25/2022 10:20	40.0933	-125.2093					
2	07/26/2022 07:37	40.4080	-124.6637					
3	07/26/2022 09:47	40.3787	-124.6742	2.46			0.14	2.59
4	07/27/2022 05:23	39.7872	-124.6383	8.71		1.09		9.80
5	07/27/2022 08:00	39.8878	-124.5312	1.22				1.22
6	07/27/2022 10:06	39.8202	-124.4963	13.81			8.69	22.51
7	07/28/2022 05:38	39.7207	-123.9662	21.64				21.64
8	07/28/2022 07:48	39.7010	-124.0413	53.41			0.12	53.52
9	07/28/2022 10:17	39.5660	-123.9770	9.77				9.77
10	07/29/2022 05:33	39.0730	-124.0788	0.65			0.21	0.86
11	07/29/2022 08:35	39.1323	-123.9275	2.82				2.82
12	07/29/2022 11:09	39.2957	-123.9267	17.10				17.10
13	07/30/2022 05:47	38.7962	-123.8687					
14	07/30/2022 08:32	38.8423	-124.1225	1.15				1.15
15	07/30/2022 11:12	38.7013	-124.1470	5.19				5.19
16	07/31/2022 05:25	38.4290	-123.8123	30.84				30.84
17	07/31/2022 10:13	38.3512	-123.2537		285.60			285.60
18	08/01/2022 04:45	37.9715	-123.1488		0.15			0.15
19	08/01/2022 09:02	37.5773	-123.1790		3.17			3.17
20	08/01/2022 11:32	37.5067	-123.2805		0.35			0.35
21	08/02/2022 04:55	37.2935	-122.9278		11.94			11.94
22	08/02/2022 08:14	37.5483	-122.8723		4.27			4.27
23	08/02/2022 10:30	37.4273	-122.7072		71.79		0.05	71.84
24	08/03/2022 05:00	37.0220	-122.6633	0.47	71.29		0.82	72.57
25	08/03/2022 07:43	37.1060	-122.5427		62.92		0.05	62.97
26	08/03/2022 09:59	36.9343	-122.5208		851.03		17.18	868.21
27	08/04/2022 04:52	36.5317	-122.4585		387.04		0.60	387.64
28	08/04/2022 08:01	36.7237	-122.5193		518.82		0.97	519.80
29	08/04/2022 10:21	36.6538	-122.3142		1397.58		1.18	1398.76
30	08/27/2022 04:22	32.6595	-117.7763	0.00				0.00

(continued)

Haul	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Mackerel	P. Sardine	All CPS
31	08/27/2022 07:15	32.6998	-117.6750	0.00			0.16	0.17
32	08/27/2022 11:19	32.7452	-118.1925	1.08				1.08
34	08/28/2022 06:30	32.9593	-117.9210	0.06	0.41			0.47
35	08/28/2022 09:39	33.1123	-117.9888	0.17	12.12	0.17	0.12	12.58
36	08/29/2022 04:31	33.2597	-118.8295	0.00	102.02		0.01	102.04
37	08/29/2022 07:59	33.1328	-119.0978		1.63			1.63
38	08/29/2022 11:20	33.3718	-119.1808	0.00	2.73			2.74
39	08/30/2022 03:46	33.3032	-117.5723	0.09		0.13		0.22
40	09/13/2022 03:39	36.5622	-122.0148		45.29		0.05	45.34
41	09/13/2022 08:04	36.1893	-122.0613	0.00	0.64			0.64
42	09/13/2022 10:47	36.2380	-121.9445		2.12			2.12
43	09/14/2022 03:54	35.6000	-121.5502		18.70		0.05	18.74
44	09/14/2022 06:50	35.5150	-121.7275	0.23				0.23
45	09/14/2022 09:09	35.4952	-121.8860	0.09	25.91			26.00
46	09/15/2022 03:47	34.8897	-121.4077	0.04	0.08			0.12
47	09/15/2022 06:36	34.9865	-121.3680	0.05				0.05
48	09/15/2022 11:26	35.1368	-120.8733		0.02			0.02
49	09/16/2022 04:43	34.5043	-120.6655		540.92			540.92
50	09/16/2022 08:09	34.4020	-120.9130	0.73	1.83			2.56
51	09/16/2022 11:15	34.3280	-120.6738	3.07	497.67	0.12		500.86
52	09/17/2022 04:18	34.3388	-119.7180		3.67			3.67
53	09/17/2022 08:10	34.3545	-120.1228	0.01	0.56			0.57
54	09/17/2022 11:45	34.0688	-120.1198	0.67	0.02		6.13	6.82
55	09/18/2022 04:37	34.1182	-120.6113	1.74	47.26			48.99
56	09/18/2022 08:42	33.8582	-120.4523	0.83				0.83
57	09/18/2022 11:21	33.8773	-120.3692	0.02	151.73		0.19	151.94
58	09/19/2022 03:23	33.7805	-118.9582	0.12	2.00	0.12	0.04	2.29
59	09/19/2022 07:08	33.8900	-119.4953	0.07	3.06		0.01	3.14
61	09/20/2022 03:29	33.3853	-120.6057	0.10	7.17			7.27
62	09/20/2022 06:02	33.4763	-120.4290	0.00	1.46			1.46
63	09/20/2022 08:38	33.3022	-120.3867		0.16			0.16
64	09/21/2022 04:22	33.4753	-119.5727	0.10	11.86	0.01		11.98
65	09/21/2022 07:33	33.3663	-119.8825		13.65			13.65

(continued)

Haul	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Mackerel	P. Sardine	All CPS
66	09/21/2022 10:49	33.3563	-119.4892		0.01			0.01
67	09/22/2022 04:35	33.2438	-118.8983	0.06				0.06
68	09/22/2022 06:58	33.1158	-118.7360	0.06				0.06
69	09/22/2022 10:25	33.2945	-118.4278	9.04	0.00	0.94	0.67	10.66
70	09/23/2022 04:07	33.5512	-118.5897	1.70	3.10	0.61	0.04	5.45
71	09/23/2022 06:36	33.6218	-118.5873	0.04	80.73		0.24	81.01
72	09/23/2022 09:24	33.4715	-118.3867	0.04				0.04
73	09/24/2022 04:34	32.9618	-118.7458	0.61				0.61
74	09/24/2022 07:14	32.8488	-118.5332	13.49		0.22	0.38	14.10
75	09/24/2022 09:39	32.6960	-118.5845	1.70				1.70
76	09/25/2022 04:43	32.7908	-117.3222	0.09	0.06	0.05	4.49	4.69
77	09/25/2022 08:01	33.0552	-117.3488	0.05		3.15	88.06	91.26
78	09/25/2022 11:24	32.8905	-117.3157					
79	09/26/2022 04:28	32.5100	-117.6250	0.04	0.82	0.01		0.87
80	09/27/2022 04:16	31.7003	-116.9987	0.00	146.30	0.03		146.33
81	09/27/2022 07:26	31.6062	-117.2832		0.31			0.31
82	09/27/2022 11:30	31.4158	-116.8303		659.46			659.46
83	09/28/2022 04:38	31.1165	-116.7182		95.40	0.10		95.50
84	09/28/2022 07:16	30.9222	-116.6153		122.11	2.18	2.07	126.36
85	09/28/2022 09:42	30.7575	-116.6635		38.66	2.46	0.05	41.17
86	09/29/2022 03:59	30.2130	-116.0988		5.05	0.50	0.22	5.77
87	09/29/2022 07:12	30.5173	-116.2528		563.86	3.50	0.94	568.30
88	09/29/2022 10:23	30.3952	-116.4938	2.17	10.54	2.63	0.02	15.37

D Seine sample summary

D.1 *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	07/06/2022 16:00	48.4607	-124.9466					
2	07/06/2022 18:31	48.3590	-124.8890					
3	07/06/2022 20:54	48.2969	-124.8526					
4	07/07/2022 17:58	47.9540	-124.8126			3.05		3.05
5	07/07/2022 21:36	47.6783	-124.5218					
6	07/08/2022 02:13	47.6201	-125.0047					
7	07/08/2022 21:25	47.2837	-124.5687					
8	07/09/2022 00:45	47.1566	-124.2733					
9	07/10/2022 00:52	46.6211	-124.4580					
10	07/10/2022 01:41	46.6217	-124.4174					
11	07/10/2022 03:31	46.6241	-124.2278					
12	07/10/2022 12:26	46.6253	-124.1513			9.80		9.80
13	07/10/2022 15:37	46.3872	-124.1044		0.16	7.07		7.23
14	07/11/2022 19:45	46.1670	-125.1954		0.16		10.86	11.01
15	07/13/2022 17:22	45.7749	-124.2152					
16	07/13/2022 18:11	45.7487	-124.1829				12.26	12.26
17	07/13/2022 23:41	45.6174	-124.4989				10.19	10.19
18	07/14/2022 18:00	45.2798	-124.5628				0.05	0.05
19	07/14/2022 18:42	45.2811	-124.5602			0.05		0.05
20	07/14/2022 20:09	45.2797	-124.4186	4.66			1.16	5.82
21	07/14/2022 21:32	45.2844	-124.2803				11.41	11.41
22	07/15/2022 13:45	44.9483	-124.3994	0.36			0.16	0.52
23	07/15/2022 23:54	44.6171	-124.7664				7.43	7.43
24	07/16/2022 00:57	44.6185	-124.6851				12.61	12.61
25	07/17/2022 17:09	44.2814	-124.8178					
26	07/17/2022 18:11	44.2773	-124.8820					
27	07/17/2022 19:20	44.2784	-124.9543					
28	07/19/2022 19:15	43.3439	-124.4098		0.01			0.01
29	07/20/2022 15:20	42.9521	-124.8704	0.20			0.46	0.66

(continued)

Set	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Herring	P. Sardine	All CPS
30	07/21/2022 17:45	42.2888	-125.1351				0.43	0.43
31	07/21/2022 18:24	42.2900	-125.1481				11.19	11.19
32	07/21/2022 22:11	42.0017	-125.1890				0.04	0.04
33	07/26/2022 23:14	40.9630	-124.8021	3.88				3.88
34	07/27/2022 02:34	40.9632	-124.4089					
35	07/27/2022 15:07	40.9536	-124.1690			0.26		0.26
36	07/28/2022 01:24	40.6206	-125.2271	0.69			0.80	1.48
37	07/29/2022 21:21	39.6754	-124.0920				9.55	9.55
38	07/31/2022 21:34	38.2196	-123.8819	2.45				2.45
39	07/31/2022 23:55	38.3184	-123.6596		8.31			8.31
40	08/01/2022 14:55	38.2057	-123.0704		10.30			10.30
41	08/01/2022 19:11	37.9789	-123.5454		7.23			7.23

D.2 *Long Beach Carnage*

Date, time (UTC), location, and biomasses (kg) of CPS collected for each purse seine set by *Long Beach Carnage*.

Set	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Herring	P. Sardine	All CPS
1	07/30/2022 19:00	37.6780	-122.6001					
2	07/31/2022 04:00	37.6027	-122.5582		0.79		1.38	2.18
3	08/01/2022 13:29	36.9485	-122.0037		0.73		0.15	0.88
4	08/01/2022 23:54	36.7108	-121.8203				2.13	2.13
5	08/02/2022 01:53	36.6212	-121.8580					
6	08/02/2022 02:27	36.6193	-121.8617					
7	08/02/2022 04:20	36.6123	-121.8910		0.77		0.26	1.03
8	08/05/2022 04:04	35.6102	-121.1840		0.76		2.77	3.52
9	08/05/2022 04:45	35.6100	-121.1832		0.86		2.21	3.07
10	08/06/2022 04:00	35.3693	-120.8840		0.89		2.18	3.07
11	08/06/2022 05:02	35.3517	-120.8835		0.89		0.67	1.56
12	08/20/2022 19:58	35.1047	-120.6665				1.75	1.75
13	08/21/2022 02:09	34.8510	-120.6500					
14	08/21/2022 03:50	34.8483	-120.6560		0.73		0.65	1.39
15	08/21/2022 16:11	34.7297	-120.6510				3.11	3.11
16	08/21/2022 17:07	34.7283	-120.6500				3.17	3.17
17	08/21/2022 18:07	34.7143	-120.6310				2.79	2.79
18	08/21/2022 19:50	34.6388	-120.6562		0.39		2.64	3.02
19	08/22/2022 18:05	34.4680	-120.1392				0.08	0.08
20	08/22/2022 18:47	34.4625	-120.1188				2.75	2.75
21	08/22/2022 21:01	34.4393	-119.9770				2.13	2.13
22	08/22/2022 23:26	34.4025	-119.8205		0.80		0.53	1.32
23	08/23/2022 16:24	34.3795	-119.5175		0.75		0.98	1.73
24	08/23/2022 18:40	34.3315	-119.4398		0.87		0.99	1.85
25	08/23/2022 20:51	34.2700	-119.3380					
26	08/25/2022 01:21	33.9598	-119.7482	1.61			2.82	4.60
27	08/25/2022 02:50	33.9733	-119.6815				2.46	2.46
28	08/25/2022 03:40	33.9757	-119.6702				1.81	2.11
29	08/25/2022 04:30	33.9625	-119.7055		0.03		1.51	1.66
30	08/25/2022 20:56	34.0118	-119.5268	3.87				11.86
31	08/26/2022 02:53	33.9822	-119.6365				2.30	3.99

(continued)

Set	Date Time	Latitude	Longitude	J. Mackerel	N. Anchovy	P. Herring	P. Sardine	All CPS
32	08/26/2022 04:33	34.0183	-119.5420	0.58	0.17			0.75
33	08/27/2022 02:47	34.0127	-118.7763		0.43		1.12	1.62
34	08/27/2022 03:48	34.0143	-118.7632		0.46		0.98	1.47
35	08/27/2022 15:55	34.0240	-118.7160		0.01		2.17	11.20
36	08/27/2022 18:13	34.0120	-118.5243				2.51	2.51
37	08/28/2022 19:00	33.6848	-118.0773					
38	09/03/2022 20:59	33.8198	-118.3992				2.77	2.77
39	09/04/2022 04:02	33.4545	-118.5907	0.03			3.11	3.38
40	09/04/2022 04:50	33.4700	-118.6103					9.78
41	09/04/2022 20:38	33.3418	-118.5207				3.29	3.77
42	09/05/2022 03:37	33.2988	-118.3468					8.86
43	09/05/2022 05:48	33.3390	-118.5213	1.14			3.12	8.38
44	09/06/2022 03:36	33.4317	-118.4345				3.20	5.71
45	09/06/2022 04:36	33.4302	-118.4205				3.18	3.26
46	09/06/2022 06:25	33.3642	-118.3347	0.13			3.65	3.86
47	09/06/2022 16:54	33.6153	-117.9627					
48	09/07/2022 13:57	33.2157	-117.4135				2.67	2.67
49	09/08/2022 00:09	32.7758	-117.2617					
50	09/08/2022 00:40	32.7490	-117.2635				3.22	3.22
51	09/08/2022 03:24	32.6325	-117.2103	0.03			3.26	3.28
52	09/08/2022 13:10	32.6518	-117.2083	0.03			1.56	1.79
53	09/08/2022 15:22	32.6023	-117.1407	0.06			2.97	3.23