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REPORT ON THE 2018 CALIFORNIA CURRENT ECOSYSTEM (CCE) SURVEY (1807RL), 26 JUNE TO 23 SEPTEMBER 2018, CONDUCTED ABOARD NOAA SHIP *REUBEN LASKER*

Kevin L. Stierhoff, Juan P. Zwolinski, Danial G. Palance, Josiah S. Renfree, Scott A. Mau, David W. Murfin, Thomas S. Sessions, and David A. Demer

NOAA Fisheries
SWFSC Fisheries Resources Division
8901 La Jolla Shores Drive
La Jolla, CA 92037

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1 Introduction

The 2018 California Current Ecosystem (CCE) Survey (1807RL) was conducted by the Fisheries Resources Division (FRD) of the Southwest Fisheries Science Center (SWFSC) aboard NOAA Ship *Reuben Lasker* (hereafter, *Lasker*; **Fig. 1**), 26 June to 23 September 2018. The Acoustic-Trawl Method (ATM) was used to assess coastal pelagic fish species (CPS) and krill within the CCE. Data were collected using multi-frequency echosounders, surface trawls, vertically and obliquely integrating net tows, a continuous underway fish-egg sampler (CUFES), and conductivity-temperature-depth probes (CTDs).

The objectives for the survey were to: 1) acoustically map the distributions and estimate the abundances of CPS, i.e., Pacific Sardine *Sardinops sagax*, Northern Anchovy *Engraulis mordax*, Pacific Herring *Clupea pallasii*, Pacific Mackerel *Scomber japonicus*, and Jack Mackerel *Trachurus symmetricus*; and krill (euphausiid spp.); 2) characterize their biotic and abiotic environments, and investigate linkages; 3) gather information regarding their life histories; and 4) evaluate the use of Saildrones to augment the ship-based sampling. Reported elsewhere, the Marine Mammal and Turtle Division (MMTD) of the SWFSC concurrently surveyed the abundances and distributions of whales, dolphins, and seabirds in the survey area; characterized their pelagic ecosystem; and identified certain cetacean species using biopsies and photographs.

The survey domain encompassed the anticipated distributions of the northern sub-population (stock) of Pacific Sardine and the central and northern stocks of Northern Anchovy off the west coasts of the U.S. and Canada from approximately San Diego, CA, to Cape Scott, British Columbia, but also encompassed a large portion of the anticipated distributions of Pacific Mackerel, Jack Mackerel, and Pacific Herring. The survey domain was defined by the modeled distribution of Pacific Sardine potential habitat (Zwolinski *et al.*, 2011), and information recently gathered from other research projects (e.g., California Cooperative Oceanic Fisheries Investigations [CalCOFI] samples) or the fishing industry (e.g., bycatch of Pacific Sardine).

This report provides an overview of the survey objectives and a summary of the survey equipment, acoustic-system calibration, sampling and analysis methods, and preliminary results. This report does not include estimates of the distributions and biomasses of CPS, krill, marine mammals, or seabirds; and does not elaborate on the evaluation of Saildrone technology. Advantages and disadvantages to the combination of CPS and marine mammal and seabird sampling are discussed from the ATM perspective.

Figure 1: NOAA Ship *Lasker*.

1.1 Scientific Personnel

As elaborated below, the collection and analysis of the survey data was conducted by the SWFSC. Superscripts denote affiliations and roles of the other cruise participants: 1-Fisheries Resources Division, 2-Marine Mammal and Turtle Division, 3-Chief Scientist, 4-Cruise Leader, and 5-Volunteer.

Project Leads:

- D. Demer[1,3]
- J. Moore[2,3]

Acoustic Data Collection and Processing:

- Leg I: D. Demer[1,3] and D. Palance[1]
- Leg II: D. Palance[1] and J. Zwolinski[1,4]
- Leg III: J. Renfree[1] and T. Sessions[1]
- Leg IV: M. Mayorga[1,5] and D. Murfin[1]

Trawl Sampling:

- Leg I: A. Friere[1], D. Griffith[1], M. Human[1], K. Runge[1,5], L. Vasquez de Mercado[1]
- Leg II: E. Gardner[1], A. Hays[1], R. Pound[1,5], L. Vasquez de Mercado[1], W. Watson[1]
- Leg III: S. Charter[1], E. Gardner[1], T. Mowatt-Larssen[1,5], B. Overcash[1], J. Renfree[1], D. Winters[1,5]
- Leg IV: A. Hays[1,4], S. Manion[1], S. Mau[1], A. Mische[1,5], B. Overcash[1], L. Vasquez de Mercado[1]

Echosounder Calibration:

- J. Renfree[1], T. Sessions[1], D. Murfin[1], and D. Palance[1]

2 Methods

2.1 Survey region and design

During spring, Pacific Sardine typically aggregate offshore of central and southern California to spawn (Demer *et al.*, 2012, and reference therein). During summer, if the stock is large enough, adults will migrate north, compress along the coast, and feed in the upwelled regions (**Fig. 2**).

During summer 2018, the west coast of the United States was surveyed using *Lasker*. Compulsory transects were nearly perpendicular to the coast with separations of 10 to 20 nmi. The survey began off Cape Scott, British Columbia, and progressed southwards toward San Diego, CA.

The planned transects (**Fig. 3**) spanned the latitudinal extent of the potential habitat of the northern stock of Pacific Sardine[1] at the time of the survey (**Fig. 4**). Transect positions, lengths, and spaces were adaptively adjusted during the survey according to the observed distribution of putative CPS backscatter in the echosounders, CPS eggs in CUFES, or CPS landed in trawls.

[1]http://swfscdata.nmfs.noaa.gov/AST/sardineHabitat/habitat.asp

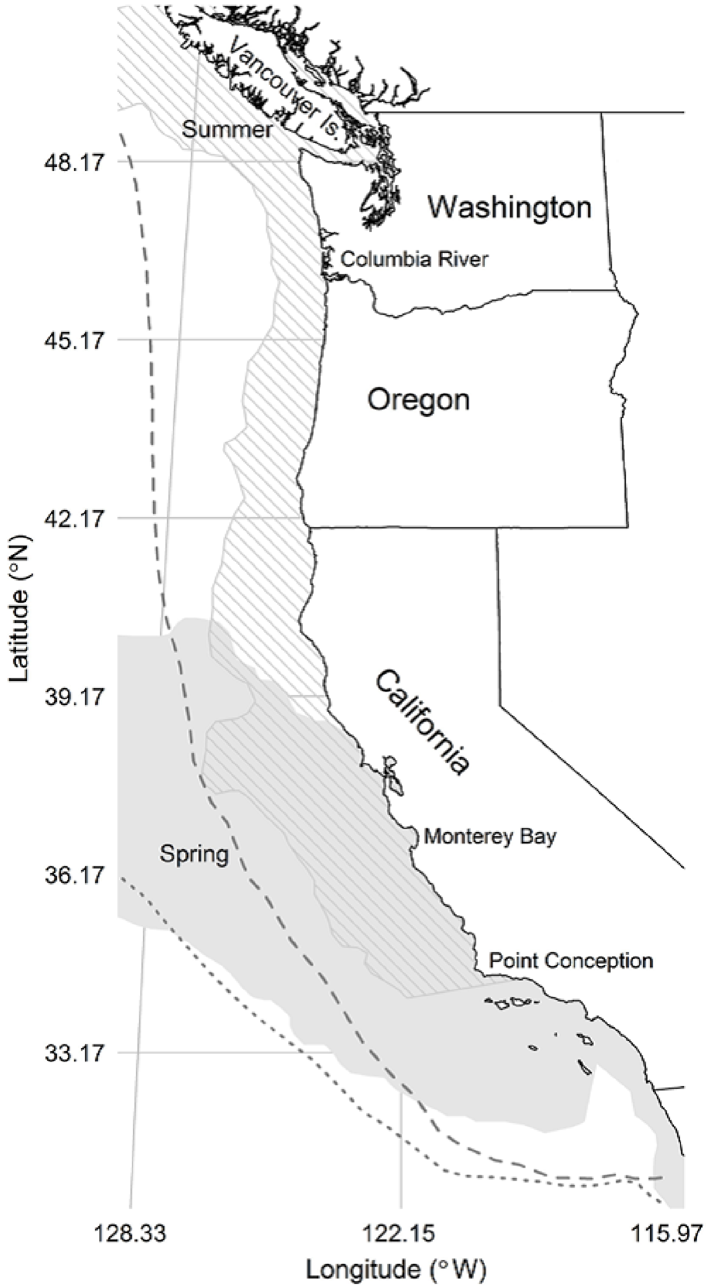

Figure 2: Conceptual spring (shaded region) and summer (hashed region) distributions of potential habitat for the northern stock of Pacific Sardine along the west coasts of Mexico, the United States, and Canada. The dashed and dotted lines represent, respectively, the approximate summer and the spring position of the 0.2 mg m^{-3} isoline of chlorophyll-a concentration. This isoline appears to oscillate in synchrony with the transition zone chlorophyll front (TZCF, Polovina *et al.*, 2001) and the offshore limit of the Pacific Sardine potential habitat (Zwolinski *et al.*, 2014). 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.

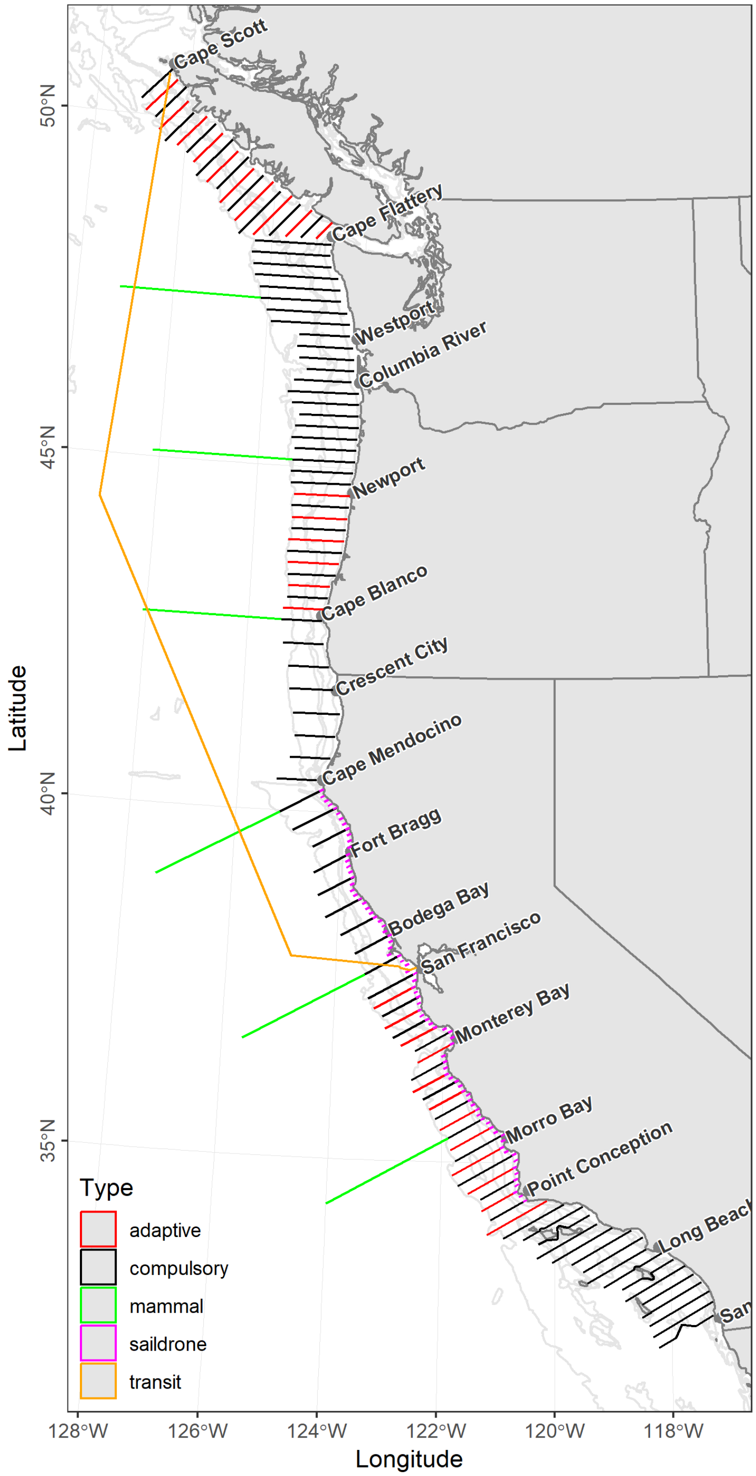

Figure 3: Planned pre-survey transit (orange line); compulsory (black lines) and adaptive (red lines) acoustic transect lines; offshore extensions to acoustic transects for marine mammal and CPS sampling (green lines); and Saildrone transects for nearshore CPS (magenta lines). Isobaths (light gray lines) are placed at 50, 200, 500, and 2,000 m (or approximately ~1,000 fathoms).

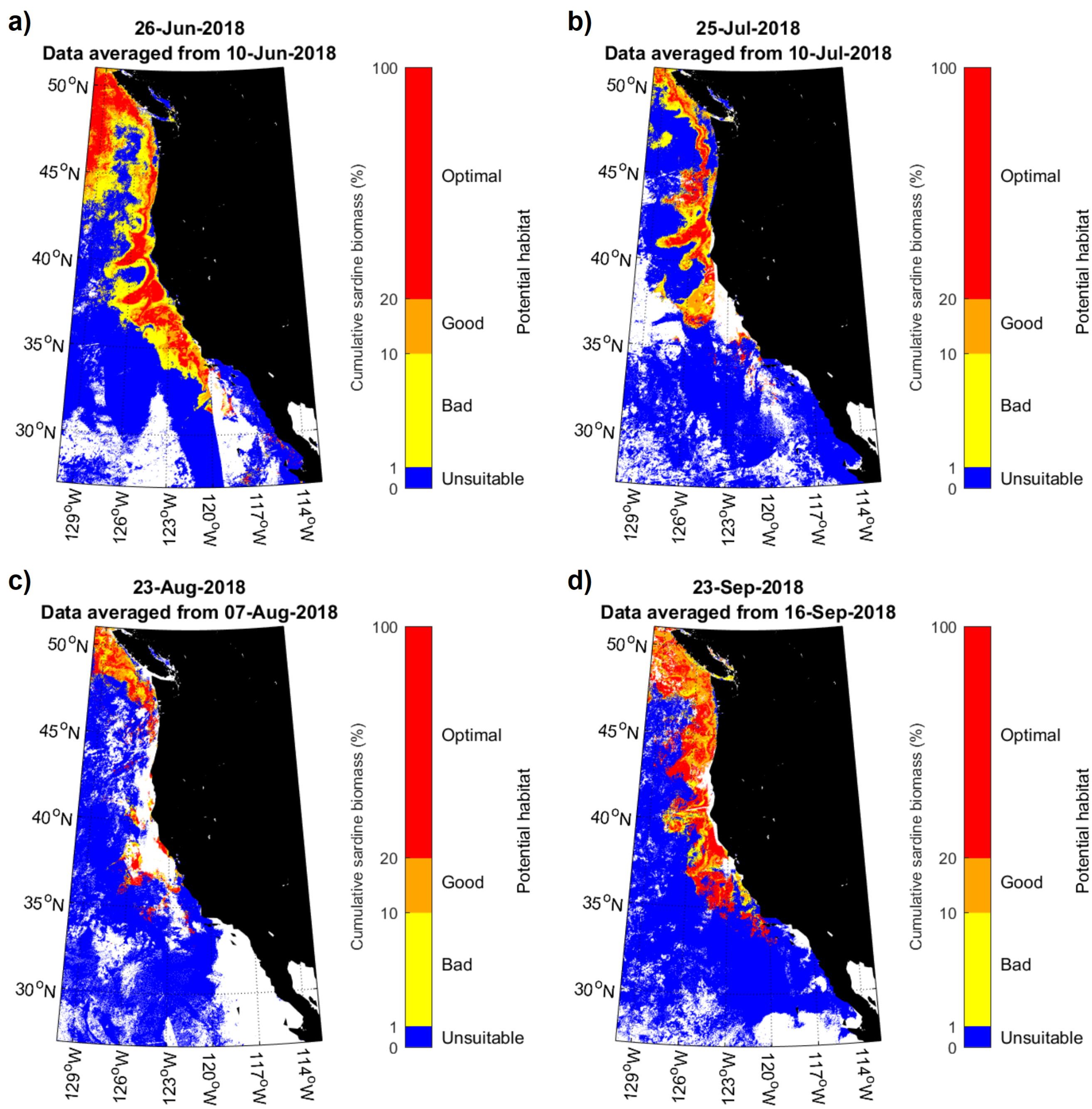

Figure 4: Distribution of potential habitat for the northern stock of Pacific Sardine (a) before, (b,c), during, and (d) at the end of the summer 2018 survey. Areas in white correspond to no available data, e.g., cloud coverage preventing satellite-sensed observations.

2.2 Acoustic sampling

2.2.1 Echosounders

Multi-frequency (18, 38, 70, 120, 200, and 333 kHz) General Purpose Transceivers (EK60 GPTs, Simrad) and Wideband Transceivers (EK80 WBTs, Simrad) were configured with split-beam transducers (ES18-11, ES38B, ES70-7C, ES120-7C, ES200-7C, and ES333-7C, respectively; Simrad). 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**).

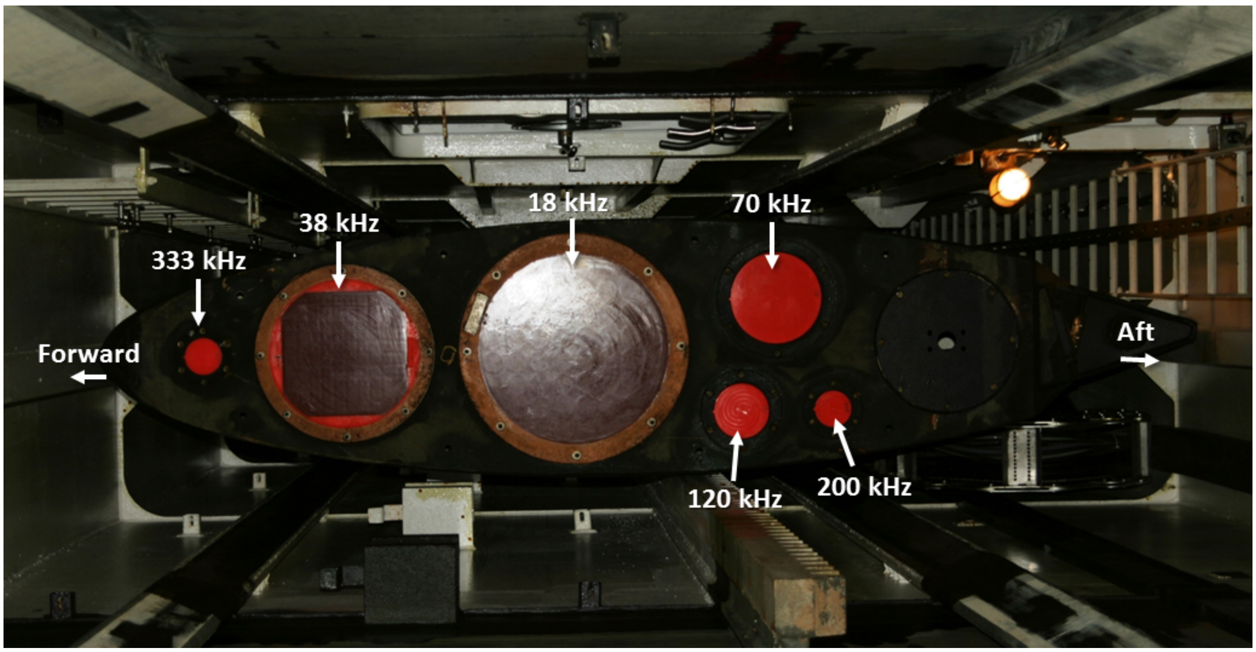

Figure 5: Transducer locations on the bottom of the centerboard aboard *Lasker*.

2.2.2 Calibration

Prior to calibration, the integrity of each transducer was verified through impedance measurements of each transducer in water and air using an LCR meter (Agilent E4980A) and custom Matlab software. For each transducer, impedance magnitude ($|Z|$,), phase (θ, °), conductance (G, S), susceptance (B, S), resistance (R,), and reactance (X,) were measured at the operational frequencies with the transducer quadrants connected in parallel (**Appendix B**). The echosounders were calibrated using the standard sphere technique (Demer *et al.*, 2015; Foote *et al.*, 1987). The reference target was a 38.1-mm diameter sphere made from tungsten carbide (WC) with 6% cobalt binder material (*Lasker* sphere #1). The GPTs were configured, via the ER60 software, using the calibration results (see **Section 3.1**).

2.2.3 Data collection

Computer clocks were synchronized with the GPS clock (GMT) using synchronization software (NetTime[2]). Echosounder pulses were transmitted simultaneously at all frequencies, at variable intervals, as controlled by the ER60 Adaptive Logger (EAL, Renfree and Demer, 2016). The EAL optimizes the pulse interval, based on the seabed depth, while minimizing aliased seabed echoes. Acoustic sampling for CPS-density estimation along the pre-determined transects was limited to daylight hours (approximately between sunrise and sunset).

[2] http://timesynctool.com

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 600 m and stored in Simrad .raw format with a 50-MB maximum file size. For each acoustic instrument, the prefix for the file names is a concatenation of the survey name (e.g., CCE 2018), the acoustic system (e.g., EK60, EK80, ME70), and the logging commencement date and time from the GPT-control software. For example, an EK60 file generated by the Simrad ER60 software (V2.4.3) is named `1807RL-D20180723-T125901.raw`.

To minimize acoustic interference, transmit pulses from the ME70, the MS70, the SX90, and the acoustic Doppler current profiler (Ocean Surveyor Model OS75, Teledyne RD Instruments) were triggered using the K-Sync synchronization system (Simrad). All other instruments that produce sound within the echosounder bandwidths were secured during daytime survey operations. Exceptions were made during stations (e.g., plankton sampling and fish trawling) or in shallow water when the vessel's command occasionally operated the bridge's 50- and 200-kHz echosounders (Furuno), the Doppler velocity log (Sperry Marine Model SRD-500A), or both.

2.2.4 Data processing

Echoes from schooling CPS were identified using a semi-automated data processing algorithm implemented using Echoview software (V9.0.279.33861). 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**). The filter includes the following steps:

- Estimate and subtract background noise using the built-in Echoview background noise removal function (De Robertis and Higginbottom, 2007, **Fig. 6b,e**);
- Average the noise-free S_v echograms using non-overlapping 11-sample by 3-ping bins;
- Expand the averaged, noise-reduced S_v echograms with a 7 pixel x 7 pixel dilation;
- 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 $S_{v,70\text{kHz}} - S_{v,38\text{kHz}}$;
- Create a Boolean echogram for S_v differences in the CPS range: $-13.85 < S_{v,70\text{kHz}} - S_{v,38\text{kHz}} < 9.89 \wedge -135.5 < S_{v,120\text{kHz}} - S_{v,38\text{kHz}} < 9.37 \wedge -13.51 < S_{v,200\text{kHz}} - S_{v,38\text{kHz}} < 12.53$;
- Compute the standard deviation (SD) of $S_{v,120\text{kHz}}$ and $S_{v,200\text{kHz}}$ using non-overlapping 11-sample by 3-ping bins;
- Expand the SD($S_{v,120\text{kHz}}$) and SD($S_{v,200\text{kHz}}$) echograms with a 7 pixel x 7 pixel dilation;
- Create a Boolean echogram based on the SDs in the CPS range: SD($S_{v,200\text{kHz}}$) > -65 dB $\wedge$ SD($S_{v,120\text{kHz}}$) > -65 dB. Diffuse backscattering layers (Zwolinski *et al.*, 2010) have low standard deviations whereas fish schools have high standard deviations (Demer *et al.*, 2009);
- Intersect the two Boolean echograms. The resulting echogram has samples with "TRUE" for candidate CPS schools and "FALSE" elsewhere;
- Mask the noise-reduced echograms using the CPS Boolean echogram (**Fig. 6c,f**);
- Create an integration-start line at a range of 5 m from the transducer (~10 m depth);
- 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;
- Set the minimum S_v threshold to -60 dB (corresponding to a density of approximately three fish per 100 m^3 in the case of 20-cm-long Pacific Sardine);
- Integrate the volume backscattering coefficients (s_V, m^2 m^{-3}) attributed to CPS over 5-m depths and averaged over 100-m distances;
- 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.

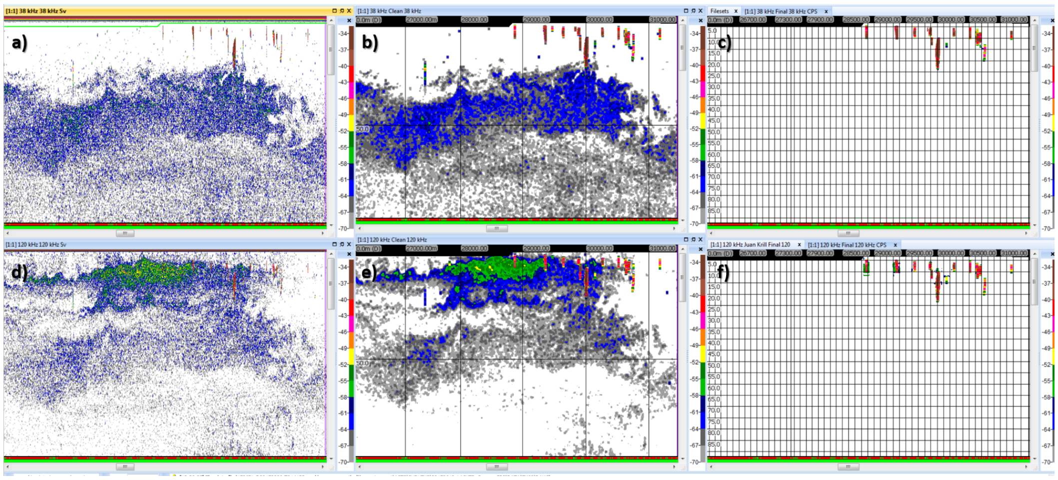

Figure 6: Echogram depicting CPS schools (red) and plankton aggregations (blue and green) at 38 kHz (top row) and 120 kHz (bottom row). Example data processing steps include the original echogram (left column), after noise subtraction and bin-averaging (middle column), and filtering to retain only putative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

2.3 Trawl sampling

During the day, CPS form schools in the upper mixed layer (to 70-m depth in the spring; Kim *et al.*, 2005), and 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), 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 headrope is lined with floats so the trawl tows at the surface.

Up to three nighttime (i.e., 30 min after sunset to 30 min before sunrise) surface trawls, typically spaced 10-nmi apart, were conducted in areas where putative echoes from CPS schools were observed 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. 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 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 CPS habitat.

Trawls were towed at ~4 kn for 45 min. The total catch from each trawl was weighed and sorted by species or groups. From the catches with CPS, up to 50 fish were selected randomly for each of the target species. Those were weighed (g) 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 all species; ovaries were preserved for Pacific Mackerel if active, hydrated, or both. Fin clips were removed from Pacific Sardine and Northern Anchovy and preserved in ethanol for genetic analysis. Otoliths were removed from all 50 Pacific Sardine in the subsample; for other CPS species, 25 otoliths were removed “as equally as possible” from the range of sizes present. Regional species composition was estimated from the nearest trawl cluster, i.e., the combined catches of up to three trawls per night, separated by ~10 nmi.

2.4 Ichthyoplankton and oceanographic sampling

2.4.1 Egg and larva sampling

During the day, fish eggs were collected using CUFES (Checkley *et al.*, 1997), 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. 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 were identified to species, counted, and logged. Eggs from other species (e.g., 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 initial stages of the egg phase is short for most fish species, the egg distributions inferred from CUFES indicate the nearby presence of actively spawning fish.

A CalCOFI bongo oblique net (or bongo; a paired, bridleless, 71-cm diameter net with 505-μm mesh; Smith and Richardson, 1977) was used to sample ichthyoplankton and krill at one station each day soon after sunset. 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°. Bongo samples were stored in 5% buffered formalin.

2.4.2 Conductivity and temperature versus depth (CTD) sampling

Day and night, conductivity and temperature versus depth to 350 m were measured with calibrated sensors on a CTD rosette or underway probe (UCTD) cast from the vessel. 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 also provided indication of the depth of the upper-mixed layer, where most epipelagic CPS reside during the day, which is later used to determine the integration depth during acoustic data processing.

3 Results

3.1 EK60 echosounder calibration

The EK60s were calibrated on 30 May to 4 June 2018 while the vessel was at anchor near 10th Avenue Marine Terminal, San Diego Bay (32.6956 °N, -117.15278 °W). Measurements of sea-surface temperature (t_w = 18.5 °C) and salinity (s_w = 33.7 psu) to a depth of 10 m were measured using a handheld probe (Pro2030, YSI) and input to the GPT-control software (ER60 V2.4.3, Simrad), which derived estimates of sound speed (c_w = 1515.7 m s^{-1}) and absorption coefficients (see **Table 1**). Varying with tide, the seabed was approximately 8 to 12 m beneath the transducers. The calibration sphere was positioned nominally 5-8 m below the transducers.

GPT information, configuration settings, and beam model results following calibration are presented in **Table 1**. Measurements of uncompensated sphere target strength (TS_u, dB re 1 m^2) are plotted in **Fig. 7** and beam-compensated sphere target strength (TS_{rel}, dB re 1 m^2), relative to the theoretical target strength, are plotted in **Fig. 8**. A time-series of calibration results for *Lasker*, including on-axis gain (G_0), S_a correction ($S_a$corr), beamwidths (α_{-3dB} and β_{-3dB}), offset angles (α_0 and β_0), and RMS, are plotted in **Fig. 9**.

Table 1: Simrad EK60 general purpose transceiver (GPT) 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 and angle offsets, and S_a Correction ($S_a$corr) values from calibration results were entered into the GPT-control software (Simrad ER60).

		Frequency (kHz)					
	Units	18	38	70	120	200	333
Model		ES18-11	ES38B	ES70-7C	ES120-7C	ES200-7C	ES333-7C
Serial Number		2116	31206	233	783	513	124
Transmit Power (p_{et})	W	2000	2000	750	250	110	40
Pulse Duration (τ)	ms	1.024	1.024	1.024	1.024	1.024	1.024
On-axis Gain (G_0)	dB re 1	21.31	24.95	27.07	26.65	27.23	24.83
S_a Correction ($S_a$corr)	dB re 1	-0.84	-0.65	-0.41	-0.24	-0.22	-0.15
Bandwidth (W_f)	Hz	1570	2430	2860	3030	3090	3110
Sample Interval	m	0.194	0.194	0.194	0.194	0.194	0.194
Eq. Two-way Beam Angle ( )	dB re 1 sr	-17.1	-20.4	-20.3	-20.2	-20.2	-19.6
Absorption Coefficient (α_f)	dB km^{-1}	2	7.7	21.6	43.7	69.5	97.8
Angle Sensitivity Along. (Λ_α)	Elec.°/Geom.°	13.9	21.9	23	23	23	23
Angle Sensitivity Athw. (Λ_β)	Elec.°/Geom.°	13.9	21.9	23	23	23	23
3-dB Beamwidth Along. (α_{-3dB})	deg	12.15	6.79	6.42	6.4	6.52	6.35
3-dB Beamwidth Athw. (β_{-3dB})	deg	11.95	6.93	6.47	6.49	6.79	6.84
Angle Offset Along. (α_0)	deg	0	0.05	-0.01	-0.03	-0.01	-0.03
Angle Offset Athw. (β_0)	deg	-0.24	-0.02	-0.03	0.04	0.02	0
Theoretical TS (TS_{theory})	dB re 1 m^2	-42.36	-42.44	-41.45	-39.47	-39.22	-36.43
Ambient Noise	dB re 1 W	-129	-142	-153	-151	-153	-138
On-axis Gain (G_0)	dB re 1	22.5	24.84	27	25.69	27.46	24.05
S_a Correction ($S_a$corr)	dB re 1	-0.6	-0.61	-0.25	-0.21	-0.14	-0.22
RMS	dB	0.42	0.24	0.21	0.25	0.4	0.5
3-dB Beamwidth Along. (α_{-3dB})	deg	11.07	6.95	6.52	6.54	6.45	6.77
3-dB Beamwidth Athw. (β_{-3dB})	deg	11.05	6.87	6.49	6.49	6.45	6.74
Angle Offset Along. (α_0)	deg	-0.05	0.06	0.05	-0.04	-0.03	-0.03
Angle Offset Athw. (β_0)	deg	0	0.02	-0.03	0.14	0.11	0.02

Figure 7: Uncompensated sphere target strength (TS_u, dB re 1 m^2) measurements of a 38.1-mm diameter sphere made from tungsten carbide (WC) with 6% cobalt binder material, at 18, 38, 70, 120, 200, and 333 kHz. Crosses indicate measurements marked as outliers after viewing the beam model results.

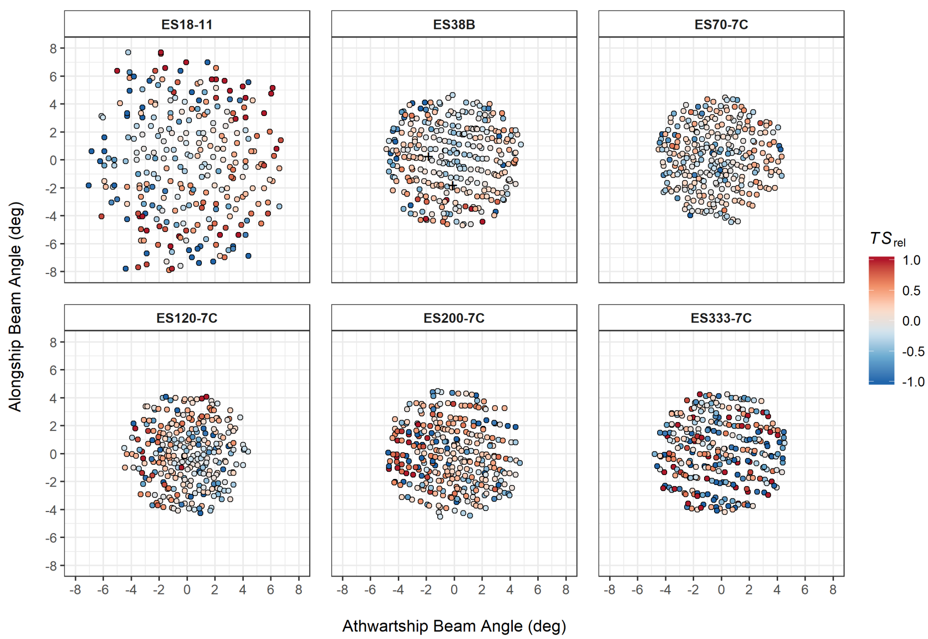

Figure 8: Relative beam-compensated sphere target strength (TS_{rel}, dB re 1 m^2) measurements of a 38.1-mm diameter sphere made from tungsten carbide (WC) with 6% cobalt binder material, at 18, 38, 70, 120, 200, and 333 kHz. TS_{rel} is calculated as the difference between the beam-compensated target strength (TS_c) and the theoretical target strength (TS_{theory}, see **Table 1**). Crosses indicate measurements marked as outliers after viewing the beam model results.

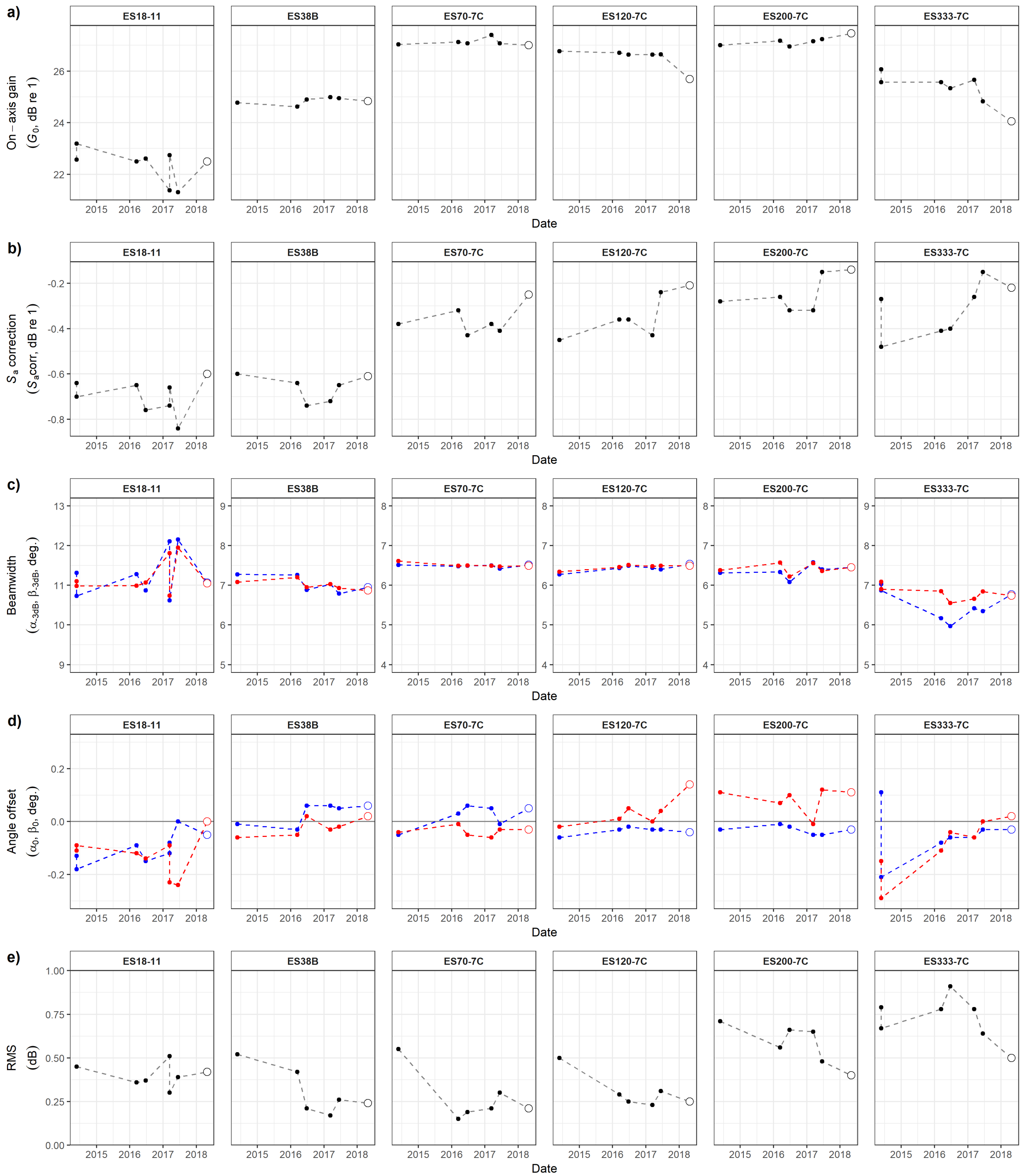

Figure 9: Time series of beam model results of a) on-axis gain (G_0, dB); b) S_a correction ($S_a corr$, dB re 1); c) alongship ($\alpha_{-3\text{dB}}$, blue) and athwartship ($\beta_{-3\text{dB}}$, red) beamwidths (deg); d) alongship (α_0, blue) and athwartship (β_0, red) offset angles (deg); and e) RMS (dB) for 18, 38, 70, 120, 200, and 333 kHz. Unfilled circles indicate results from the current survey.

3.2 Data collection

3.2.1 Acoustic and trawl sampling

The survey spanned an area from approximately Cape Scott, British Columbia, to San Diego, CA (**Fig. 10**), with 127 east-west transects totaling 6104 nmi, and 169 Nordic trawls.

Leg I
On 26 June, *Lasker* departed from the Exploratorium (Pier 15) in San Francisco at ~2130 (all times GMT) and began the offshore transit to northern Vancouver Island. Throughout the transit, sampling was conducted during the day with CUFES, EK60s, ME70, MS70 and SX90. The EK80 was run at night only. On 1 July, *Lasker* arrived at the first nearshore station off Cape Scott at 1250 to begin acoustic sampling along transect 126. On 26 June, at the start of the transit, the MS70 was inoperable due to a damaged power supply. On 30 June, the supply was replaced and the MS70 was fully operational. Acoustic sampling ceased after the completion of transect 90 off Tillamook Bay. On 16 July, *Lasker* arrived at the Marine Operations-Pacific (MOC-P) Pier in Newport, OR, at ~1700 to complete Leg I.

Leg II
On 21 July, *Lasker* departed from MOC-P Pier in Newport at 0200, and arrived at transect 90 off Tillamook Bay at 1240 on 21 July to resume survey operations. On 6 August, the GPS data to EK60 was lost at ~0930 and then restored at 0220 on 7 July. On 8 August, acoustic sampling ceased after the completion of transect 58 off Cape Mendocino. On 9 August, *Lasker* arrived at the Exploratorium (Pier 15) in San Francisco at ~1300 to complete Leg II.

Leg III
On 13 August, *Lasker* departed from the Exploratorium (Pier 15) in San Francisco at 2200, and arrived at transect 58 off Cape Mendocino at 1750 on 14 August to resume survey operations. On 17 August, the ER60 software crashed and had to be restarted. On 18 August, the ER60 again crashed, and it was discovered the ER60 software was not correctly receiving motion data, which was resolved by changing the baud rate. On 25 August, transect 34 was interrupted to put an injured scientist ashore at Monterey Bay. On 28 August, the final day of acoustic transects, transect 29 was not completed before sunset, and needed to be resampled during Leg 4. On 29 August, at the end of the offshore marine mammal line, a planned trawl was not feasible due to a chaffed line that required repair. On 31 August, *Lasker* arrived at the 10th Avenue Marine Terminal in San Diego to complete Leg III.

Leg IV On 05 September, *Lasker* departed from the fuel dock of 10th Avenue Marine Terminal in San Diego at 2345. During the transit, a lander was successfully deployed near Pt. Conception (34.43875 °N, 120.5472833 °W) equipped with a WBAT and AURAL. At 0200 on 07 September, *Lasker* resumed survey operations at the first station south of Big Sur, near the inshore segment of transects 28/29. On 19 September, the UCTD winch failed and was not used for the remainder of the survey. For the remainder of the survey, the CTD rosette was cast up to two times per transect. On 23 September, survey operations concluded with *Lasker*'s arrival to the 10th Avenue Marine Terminal in San Diego at 0230.

3.2.2 Ichthyoplankton and oceanographic sampling

A total of 59 CTD casts and 55 bongo tows were conducted throughout the survey. In addition, 239 UCTD casts were conducted and 1848 CUFES samples were collected underway. The locations of CTD and UCTD stations are shown in **Fig. 11** and **Appendix C**.

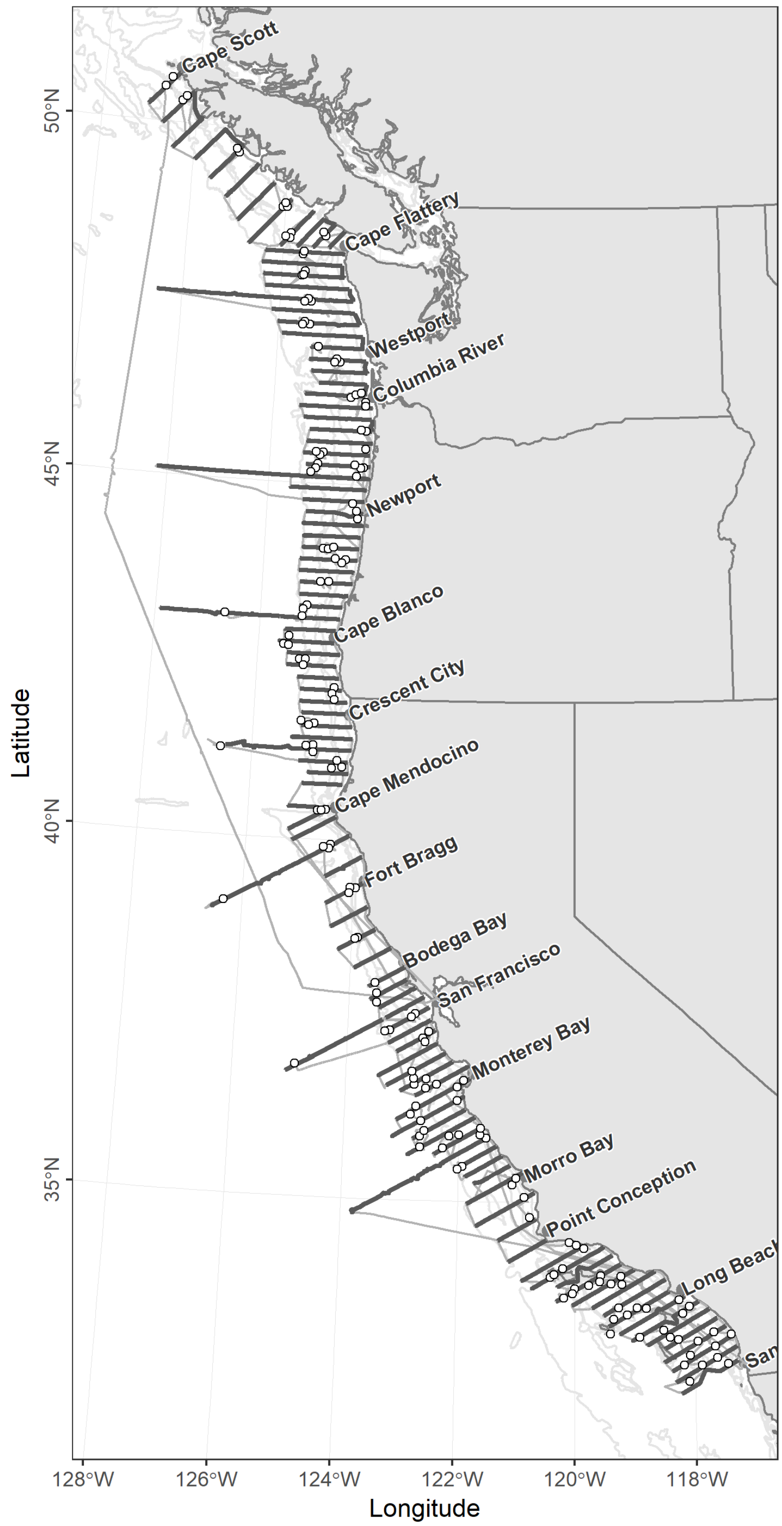

Figure 10: Cruise track of *Lasker* (gray line), east-west acoustic transects (black lines), and locations of surface trawls (white points).

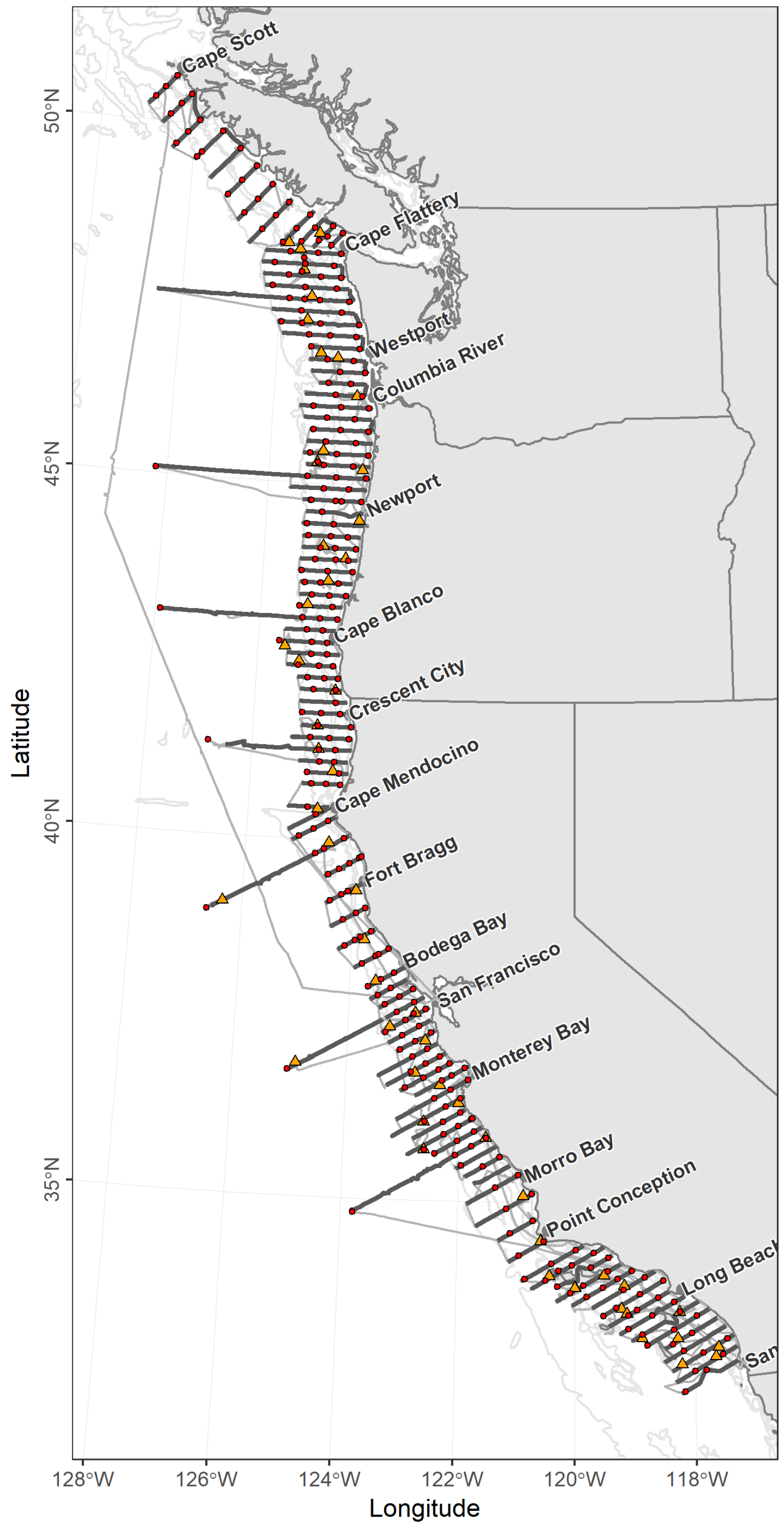

Figure 11: Locations of CTD and UCTD casts (red circles) and bongo net samples (orange triangles) relative to the acoustic transects (black lines) and vessel track (light gray line).

3.3 Distribution of CPS

Acoustic backscatter ascribed to CPS (**Fig. 12a**) was observed throughout the survey area, but was most prevalent off Cape Flattery, between the Columbia River and Cape Blanco, inshore between Bodega Bay and Morro Bay, CA, and throughout the Southern California Bight.

Jack Mackerel eggs were the most abundant of any CPS species (**Fig. 12b**) and were present in the CUFES throughout most of the survey area, found predominately in the offshore portion of transects between Cape Scott and approximately Newport. Northern Anchovy eggs were present in the CUFES samples nearshore off the Columbia River; nearshore between Bodega Bay and Morro Bay; and to a lesser extent in the Santa Barbara Basin south of Pt. Conception. Pacific Sardine eggs, overall small in density, were observed in the CUFES offshore of the Columbia River (obscured by dense Jack Mackerel eggs in the same area); between Cape Blanco and San Francisco; south of Pt. Conception; and near San Diego.

Jack Mackerel comprised the greatest proportion of catch in trawl samples (**Fig. 12c**) between Cape Flattery and San Francisco, and offshore in the Southern CA Bight. Pacific Herring comprised the greatest proportion of catch in trawl samples in Canadian waters, and to a lesser extent in nearshore waters off Newport. Anchovy were predominantly collected in trawls conducted between Westport, WA, and Newport; and between San Francisco and San Diego. Sardine were collected in trawls conducted between the Columbia River and Newport; between Pt. Conception and Long Beach, CA; and to a lesser extent offshore between Crescent City, CA, and Cape Mendocino. Overall, the 169 trawls captured a combined 16460 kg of CPS (533 kg Pacific Sardine, 7217 kg Northern Anchovy, 6361 kg Jack Mackerel, 841 kg Pacific Mackerel, and 1508 kg Pacific Herring; **Appendix D**).

4 Discussion

The combination of A-T methods used to survey CPS and line-transect methods used to survey marine mammals and seabirds identified several advantages (pros) and disadvantages (cons) to this combined approach, which are elaborated below from the perspective of the A-T group.

4.1 Pros:

- Acoustic transects extended farther offshore than normal, which allowed estimations of population biomasses in offshore strata;
- Combined sampling provided coincident predator and prey observations, which may be used to estimate predator consumption requirements and foraging areas;
- Combined sampling slowed the daytime sampling progress, which resulted in higher trawl density in some cases.

4.2 Cons:

- Acoustic transects extended farther offshore than normal, which reduced the transect densities on the shelf, and caused the survey to progress down the coast faster and with fewer trawls in some higher-density areas;
- Combined sampling slowed daytime sampling progress, which made the sampling less synoptic;
- The additional personnel required to conduct the marine mammal and seabird sampling necessarily limited the number of berths available to trawl staff, which made the processing of large trawl catches more difficult.

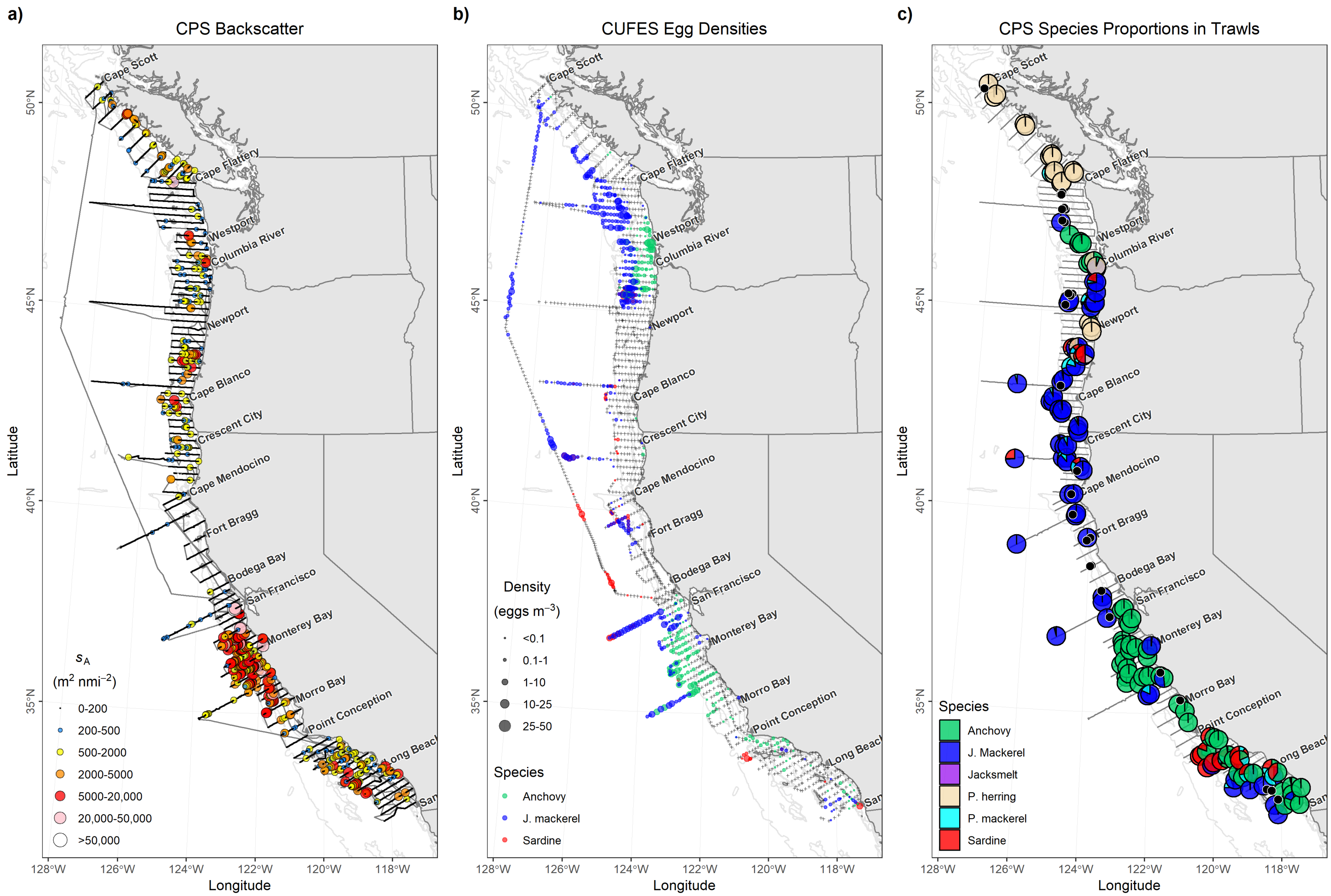

Figure 12: Survey transects overlaid with (a) the distribution of 38-kHz integrated backscattering coefficients (s_A, m^2 nmi^{-2}; averaged over 2000-m distance intervals and from 5- to 70-m deep) ascribed to CPS; (b) Northern Anchovy-, Jack Mackerel-, and Pacific Sardine-egg densities (eggs m^{-3}) from the CUFES; and (c) proportions of CPS species in trawl clusters (black points indicate trawls with no CPS).

5 Disposition of Data

Approximately 437G of raw EK60 data, 8.74T of raw EK80 data, 887G of raw ME70 data, 2.69T of raw MS70 data, and 4.8T of raw SX90 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).

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Appendix

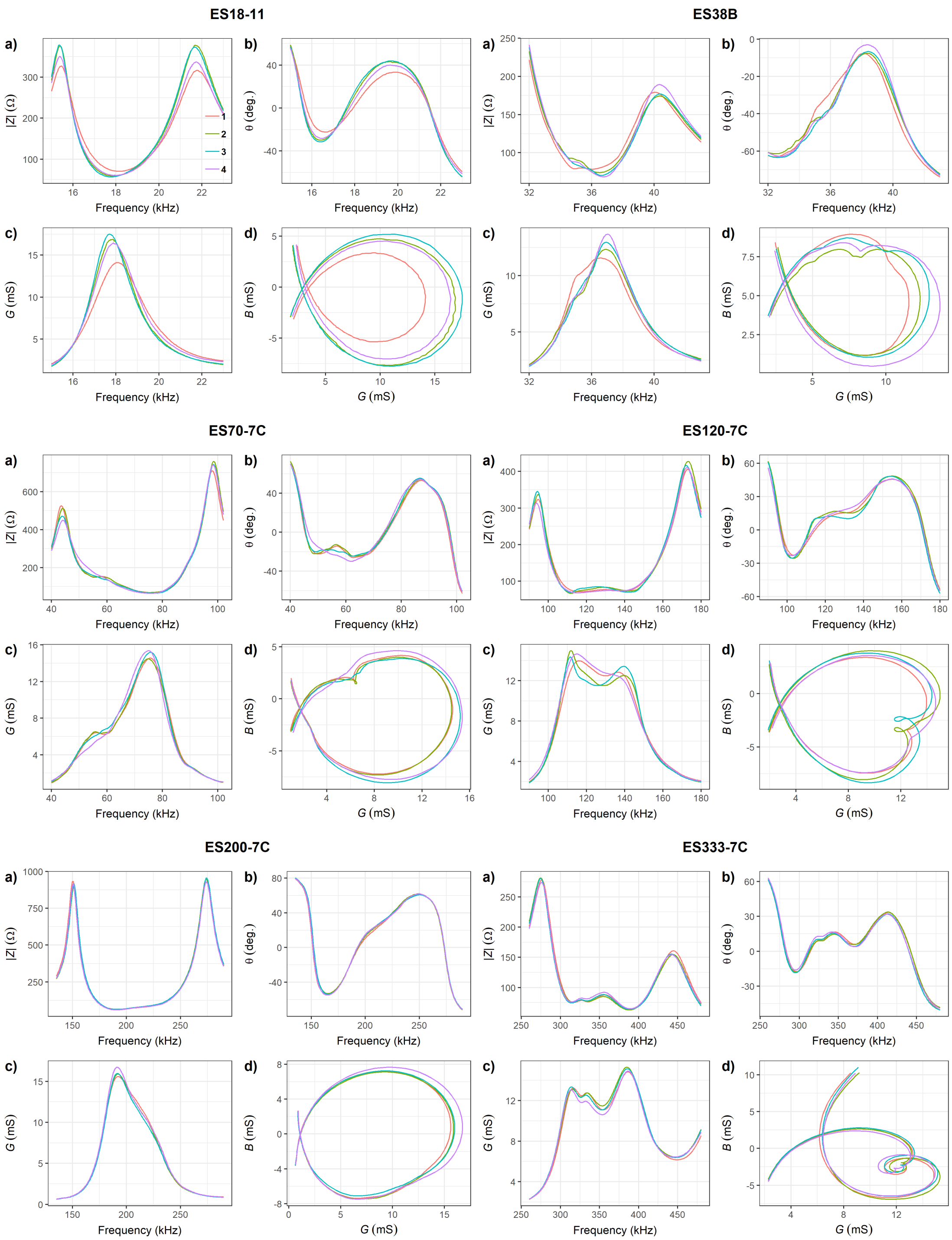
A Centerboard positions

Date, time, and location associated with changes to the position of the centerboard and transducer depth (retracted ~5-m, intermediate ~7-m, extended ~9-m).

Date Time	Position (depth)	Latitude (deg)	Longitude (deg)
07/21/2018 03:09	Intermediate (7 m)	44.6575	-124.1397
08/09/2018 02:08	Retracted (5 m)	38.8512	-123.9195
08/14/2018 00:00	Intermediate (7 m)	37.8013	-122.7428
08/31/2018 13:15	Retracted (5 m)	32.6820	-117.2298
09/06/2018 00:25	Intermediate (7 m)	32.6377	-117.2695
09/23/2018 09:02	Retracted (5 m)	32.6760	-117.3963

B Echosounder transducer impedance measurements

The magnitude of impedance ($|Z|$, ; panel a), phase (θ, °; panel b), and conductance (G, S; panel c) versus frequency, and susceptance (B, S) versus G (admittance circle; panel d), for each transducer quadrant (various colors).



C CTD and UCTD sampling locations

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

Date Time	Cast Type	Latitude (deg)	Longitude (deg)
07/01/2018 13:11	UCTD	50.6558	-128.4757
07/01/2018 15:16	UCTD	50.4850	-128.7000
07/01/2018 16:28	UCTD	50.3423	-128.8908
07/01/2018 20:38	UCTD	50.1002	-128.5417
07/01/2018 22:02	UCTD	50.2600	-128.3310
07/01/2018 23:18	UCTD	50.4133	-128.1292
07/02/2018 02:02	UCTD	50.0410	-127.9162
07/02/2018 04:00	UCTD	49.8630	-128.1482
07/02/2018 16:03	UCTD	49.6830	-128.3810
07/02/2018 18:30	UCTD	49.5170	-127.9230
07/02/2018 19:09	UCTD	49.5923	-127.8260
07/02/2018 21:47	UCTD	49.9113	-127.4100
07/03/2018 00:01	UCTD	49.6872	-127.0248
07/03/2018 13:05	UCTD	49.4540	-126.6530
07/03/2018 15:12	UCTD	49.2315	-126.9370
07/03/2018 17:50	UCTD	49.0167	-127.2112
07/03/2018 21:05	UCTD	48.7733	-126.8460
07/04/2018 00:18	UCTD	48.9790	-126.5807
07/04/2018 02:05	UCTD	49.2040	-126.2960
07/04/2018 13:19	UCTD	48.9630	-125.9335
07/04/2018 14:56	UCTD	48.7602	-126.1935
07/04/2018 17:06	UCTD	48.5552	-126.4532
07/04/2018 23:18	UCTD	48.3845	-126.0098
07/05/2018 01:04	UCTD	48.5937	-125.7445
07/05/2018 02:41	UCTD	48.8000	-125.4810
07/05/2018 14:57	UCTD	48.4378	-125.2678
07/05/2018 16:42	UCTD	48.6520	-124.9942
07/05/2018 19:13	UCTD	48.6155	-125.3693
07/05/2018 20:51	UCTD	48.4092	-125.6310
07/06/2018 01:25	UCTD	48.3822	-125.0103
07/06/2018 02:56	UCTD	48.5615	-124.7822
07/06/2018 05:07	CTD	48.5047	-125.0922
07/06/2018 13:39	UCTD	48.2615	-124.8023
07/06/2018 15:33	UCTD	48.2603	-125.2685
07/06/2018 17:50	UCTD	48.2605	-125.8422
07/06/2018 22:55	UCTD	48.0942	-126.1540
07/07/2018 02:34	UCTD	48.0945	-125.5237
07/07/2018 10:33	CTD	48.1805	-125.5477
07/07/2018 14:24	UCTD	48.0903	-124.9255
07/07/2018 16:36	UCTD	47.9252	-124.7700
07/07/2018 18:17	UCTD	47.9263	-125.1875
07/07/2018 22:53	UCTD	47.9272	-125.8465
07/08/2018 02:32	UCTD	47.7635	-126.1577
07/08/2018 12:08	CTD	47.9843	-125.5807

(continued)

Date Time	Cast Type	Latitude (deg)	Longitude (deg)
07/08/2018 16:32	UCTD	47.7635	-125.4998
07/08/2018 19:38	UCTD	47.7627	-124.8525
07/08/2018 22:24	UCTD	47.5903	-124.5785
07/09/2018 01:05	UCTD	47.5920	-125.1775
07/09/2018 04:08	CTD	47.5925	-125.4925
07/09/2018 15:12	UCTD	47.5920	-125.7993
07/10/2018 15:13	UCTD	47.4253	-125.5410
07/10/2018 20:25	UCTD	47.4257	-124.7285
07/10/2018 22:59	UCTD	47.2588	-124.3577
07/11/2018 02:17	UCTD	47.2580	-125.1448
07/11/2018 04:05	CTD	47.2475	-125.5208
07/11/2018 14:44	UCTD	47.2582	-125.9373
07/11/2018 18:23	UCTD	47.0957	-125.3588
07/11/2018 20:08	UCTD	47.0952	-124.9340
07/11/2018 22:22	UCTD	47.0938	-124.4032
07/12/2018 00:21	UCTD	46.9225	-124.3303
07/12/2018 04:24	CTD	46.9232	-125.3058
07/12/2018 14:05	UCTD	46.7500	-124.9633
07/12/2018 16:38	UCTD	46.7497	-124.4353
07/12/2018 19:21	UCTD	46.5828	-124.1987
07/12/2018 21:29	UCTD	46.5817	-124.7045
07/13/2018 02:00	CTD	46.4225	-124.9130
07/13/2018 16:32	UCTD	46.4208	-124.4717
07/13/2018 19:45	UCTD	46.2538	-124.2323
07/13/2018 22:07	UCTD	46.2547	-124.7605
07/14/2018 13:35	UCTD	46.0867	-124.0862
07/14/2018 16:42	UCTD	46.0860	-124.6425
07/14/2018 19:04	UCTD	46.0862	-125.1958
07/15/2018 00:03	UCTD	45.9247	-124.9150
07/15/2018 03:11	UCTD	45.9260	-124.3610
07/15/2018 16:52	UCTD	45.7582	-124.0790
07/15/2018 19:20	UCTD	45.7580	-124.6327
07/15/2018 21:38	UCTD	45.7580	-125.1768
07/16/2018 00:20	UCTD	45.5887	-124.9228
07/16/2018 03:03	UCTD	45.5878	-124.3172
07/21/2018 14:31	UCTD	45.5875	-124.3168
07/21/2018 18:08	UCTD	45.5882	-124.9093
07/21/2018 23:39	UCTD	45.4203	-125.2148
07/22/2018 02:16	CTD	45.4195	-124.6853
07/22/2018 17:01	UCTD	45.4198	-124.0613
07/22/2018 19:51	UCTD	45.2570	-124.3528
07/22/2018 22:16	UCTD	45.2575	-124.9350
07/23/2018 01:32	UCTD	45.0898	-124.6740
07/23/2018 04:34	CTD	45.0915	-124.0832
07/23/2018 15:14	UCTD	44.9282	-124.4155
07/23/2018 17:21	UCTD	44.9272	-124.9057

(continued)

Date Time	Cast Type	Latitude (deg)	Longitude (deg)
07/24/2018 00:32	UCTD	45.0893	-125.2345
07/24/2018 04:01	CTD	45.2965	-125.0523
07/25/2018 01:58	CTD	45.0793	-128.2242
07/25/2018 13:57	UCTD	44.7595	-125.1523
07/25/2018 14:02	UCTD	44.7593	-125.1363
07/25/2018 17:05	UCTD	44.7597	-124.6612
07/25/2018 17:36	UCTD	44.7592	-124.5477
07/25/2018 19:19	UCTD	44.7605	-124.1623
07/26/2018 01:07	UCTD	44.4260	-124.6795
07/26/2018 14:04	UCTD	44.5948	-124.9158
07/26/2018 17:26	UCTD	44.4263	-125.2013
07/26/2018 23:01	UCTD	44.0900	-124.2280
07/27/2018 00:45	UCTD	44.0897	-124.6240
07/27/2018 03:38	CTD	44.0903	-124.9080
07/27/2018 15:55	UCTD	44.2550	-125.1498
07/27/2018 20:33	UCTD	44.2568	-124.7255
07/27/2018 21:58	UCTD	44.2565	-124.3978
07/28/2018 02:29	UCTD	43.9265	-124.3653
07/28/2018 03:50	CTD	43.9290	-124.6090
07/28/2018 14:48	UCTD	43.9260	-124.9995
07/28/2018 17:28	UCTD	43.7610	-125.2522
07/28/2018 20:04	UCTD	43.7617	-124.7523
07/28/2018 22:15	UCTD	43.7627	-124.2677
07/29/2018 02:09	UCTD	43.5982	-124.5322
07/29/2018 03:49	CTD	43.6008	-124.8757
07/29/2018 15:04	UCTD	43.5987	-125.1783
07/29/2018 18:05	UCTD	43.4257	-125.0328
07/29/2018 19:41	UCTD	43.4257	-124.6925
07/29/2018 21:20	UCTD	43.4255	-124.3713
07/30/2018 00:54	UCTD	43.2607	-124.6207
07/30/2018 03:48	CTD	43.2632	-125.2593
07/31/2018 02:10	CTD	43.0947	-127.9073
07/31/2018 16:08	UCTD	43.0942	-125.1877
07/31/2018 18:17	UCTD	43.0940	-124.8503
07/31/2018 19:45	UCTD	43.0942	-124.5195
07/31/2018 22:29	UCTD	42.9275	-124.7903
08/01/2018 00:03	UCTD	42.9282	-125.0903
08/01/2018 03:46	CTD	42.7553	-125.5998
08/01/2018 15:43	UCTD	42.7557	-124.9857
08/01/2018 17:04	UCTD	42.7548	-124.6968
08/01/2018 20:43	UCTD	42.5943	-124.6857
08/01/2018 22:01	UCTD	42.5945	-124.9813
08/02/2018 03:44	CTD	42.4313	-125.2168
08/02/2018 16:03	UCTD	42.4267	-124.8292
08/02/2018 17:31	UCTD	42.4273	-124.5533
08/02/2018 19:08	UCTD	42.2610	-124.4602

(continued)

Date Time	Cast Type	Latitude (deg)	Longitude (deg)
08/02/2018 20:55	UCTD	42.2602	-124.7155
08/02/2018 22:18	UCTD	42.2612	-125.0288
08/03/2018 01:20	UCTD	42.0932	-124.9092
08/03/2018 04:20	CTD	42.0940	-124.4875
08/03/2018 14:30	UCTD	41.9250	-124.4748
08/03/2018 18:39	UCTD	41.7643	-125.0955
08/03/2018 20:14	UCTD	41.7660	-124.7417
08/03/2018 21:54	UCTD	41.7653	-124.3817
08/04/2018 00:07	UCTD	41.5850	-124.1742
08/04/2018 03:43	CTD	41.5873	-124.7918
08/04/2018 18:50	UCTD	41.4190	-124.9227
08/04/2018 20:50	UCTD	41.4197	-124.5618
08/04/2018 22:51	UCTD	41.4202	-124.1962
08/05/2018 02:00	UCTD	41.2567	-124.4413
08/05/2018 03:36	CTD	41.2573	-124.7502
08/06/2018 02:37	CTD	41.3043	-126.8153
08/06/2018 15:16	UCTD	41.0887	-124.7272
08/06/2018 16:53	UCTD	41.0888	-124.4523
08/06/2018 22:47	UCTD	40.9317	-124.3553
08/07/2018 02:31	CTD	40.9338	-124.9493
08/07/2018 13:57	UCTD	40.7750	-124.3197
08/07/2018 17:59	UCTD	40.7753	-124.5855
08/07/2018 19:12	UCTD	40.7743	-124.8542
08/07/2018 23:53	UCTD	40.4483	-124.9037
08/08/2018 03:33	CTD	40.3467	-124.7433
08/14/2018 18:37	UCTD	40.0342	-125.0328
08/14/2018 20:05	UCTD	40.1485	-124.7722
08/14/2018 21:26	UCTD	40.2640	-124.5150
08/15/2018 01:08	UCTD	40.0280	-124.2093
08/15/2018 03:05	CTD	39.8732	-124.5647
08/16/2018 03:08	CTD	38.9518	-126.6267
08/16/2018 15:09	UCTD	39.8022	-124.7172
08/16/2018 18:49	UCTD	39.5172	-124.4620
08/16/2018 19:50	UCTD	39.6000	-124.2750
08/16/2018 22:01	UCTD	39.6845	-124.0868
08/16/2018 22:56	UCTD	39.7607	-123.9190
08/16/2018 23:08	UCTD	39.7767	-123.8800
08/16/2018 23:11	UCTD	39.7790	-123.8745
08/17/2018 03:18	CTD	39.2930	-124.1012
08/17/2018 14:04	UCTD	39.2417	-124.2160
08/17/2018 16:01	UCTD	39.1507	-124.4178
08/17/2018 20:09	UCTD	38.8898	-124.1647
08/17/2018 21:27	UCTD	38.9920	-123.9355
08/17/2018 22:24	UCTD	39.0693	-123.7682
08/18/2018 01:21	UCTD	38.7402	-123.6523
08/18/2018 02:22	UCTD	38.6570	-123.8393
08/18/2018 03:21	CTD	38.6142	-123.9390

(continued)

Date Time	Cast Type	Latitude (deg)	Longitude (deg)
08/18/2018 14:28	UCTD	38.5323	-124.1147
08/18/2018 18:08	UCTD	38.2910	-123.7957
08/18/2018 19:33	UCTD	38.3995	-123.5538
08/18/2018 19:55	UCTD	38.4262	-123.4947
08/18/2018 20:56	UCTD	38.5058	-123.3215
08/19/2018 00:59	UCTD	38.1748	-123.2142
08/19/2018 02:10	UCTD	38.0733	-123.4388
08/19/2018 03:34	CTD	37.9708	-123.6670
08/19/2018 15:15	UCTD	37.8577	-123.4862
08/19/2018 16:28	UCTD	37.9585	-123.2645
08/19/2018 20:44	UCTD	37.9518	-122.8687
08/19/2018 22:04	UCTD	37.8452	-123.1063
08/19/2018 23:57	UCTD	37.7320	-123.3548
08/20/2018 03:24	CTD	37.3432	-123.3290
08/20/2018 15:42	UCTD	37.5185	-122.9800
08/20/2018 17:37	UCTD	37.6783	-122.6318
08/20/2018 20:31	UCTD	37.7698	-122.8405
08/20/2018 22:24	UCTD	37.6307	-123.1450
08/21/2018 02:56	CTD	37.6113	-122.8465
08/22/2018 02:34	CTD	36.7667	-125.0297
08/22/2018 14:54	UCTD	37.3003	-123.0373
08/22/2018 16:34	UCTD	37.4377	-122.7442
08/22/2018 19:29	UCTD	37.3532	-122.5253
08/22/2018 21:08	UCTD	37.2272	-122.8007
08/22/2018 23:09	UCTD	37.1045	-123.0672
08/23/2018 02:07	UCTD	37.0063	-122.8445
08/23/2018 14:36	UCTD	37.1253	-122.5845
08/23/2018 17:55	UCTD	36.7972	-122.8605
08/23/2018 19:20	UCTD	36.9130	-122.6090
08/23/2018 20:43	UCTD	37.0242	-122.3678
08/23/2018 22:46	UCTD	36.9277	-122.1867
08/23/2018 23:52	UCTD	36.8402	-122.3738
08/24/2018 01:20	UCTD	36.7188	-122.6405
08/24/2018 03:09	CTD	36.5708	-122.9530
08/25/2018 02:52	CTD	36.6850	-122.3135
08/25/2018 14:30	UCTD	36.7603	-122.1465
08/25/2018 20:05	UCTD	36.8660	-121.9188
08/25/2018 22:00	UCTD	36.7035	-121.8592
08/25/2018 23:47	UCTD	36.5632	-122.1607
08/26/2018 02:47	CTD	36.4403	-121.9883
08/26/2018 14:44	UCTD	36.4332	-122.4427
08/27/2018 03:26	CTD	36.1067	-122.6010
08/27/2018 15:48	UCTD	36.3253	-122.2360
08/27/2018 18:13	UCTD	36.2455	-121.9840
08/27/2018 20:19	UCTD	36.1075	-122.2793
08/28/2018 03:13	CTD	35.7100	-122.5980
08/28/2018 16:12	UCTD	35.9320	-122.2613

(continued)

Date Time	Cast Type	Latitude (deg)	Longitude (deg)
08/28/2018 18:07	UCTD	36.0482	-122.0147
08/28/2018 19:25	UCTD	36.1508	-121.7937
08/28/2018 19:33	UCTD	36.1602	-121.7748
08/28/2018 21:45	UCTD	35.9780	-121.7420
08/28/2018 23:23	UCTD	35.8437	-122.0305
08/29/2018 03:04	CTD	35.6608	-122.4125
08/30/2018 03:07	CTD	34.8085	-123.7847
09/07/2018 03:41	CTD	35.8935	-121.5320
09/07/2018 14:41	UCTD	35.9783	-121.7412
09/07/2018 16:21	UCTD	35.8433	-122.0302
09/07/2018 18:53	UCTD	35.6450	-122.0583
09/07/2018 20:28	UCTD	35.7748	-121.7788
09/07/2018 21:53	UCTD	35.8910	-121.5317
09/08/2018 04:12	CTD	35.5012	-121.9542
09/08/2018 15:36	CTD	35.4962	-121.5747
09/08/2018 17:41	UCTD	35.6280	-121.2868
09/09/2018 14:26	UCTD	35.3817	-120.9662
09/09/2018 16:40	CTD	35.1990	-121.3565
09/10/2018 00:40	UCTD	34.9065	-121.1672
09/10/2018 03:39	CTD	35.1118	-120.7358
09/10/2018 14:42	UCTD	34.7392	-120.7130
09/10/2018 16:50	UCTD	34.5577	-121.0958
09/10/2018 21:46	UCTD	34.2485	-120.9443
09/11/2018 00:39	UCTD	34.4497	-120.5243
09/11/2018 15:04	UCTD	34.3318	-119.9833
09/11/2018 17:30	UCTD	34.1347	-120.3970
09/11/2018 20:01	UCTD	33.9225	-120.8400
09/12/2018 00:58	UCTD	33.8997	-120.4967
09/12/2018 02:40	CTD	34.0415	-120.2722
09/12/2018 15:08	UCTD	34.1168	-120.0425
09/12/2018 17:16	UCTD	34.2910	-119.6788
09/12/2018 20:08	UCTD	34.2242	-119.4330
09/12/2018 21:52	UCTD	34.0828	-119.7278
09/13/2018 02:32	CTD	33.8138	-120.2960
09/13/2018 15:05	UCTD	33.7253	-120.0732
09/13/2018 17:12	UCTD	33.8317	-119.8537
09/13/2018 20:45	UCTD	34.0287	-119.4423
09/13/2018 23:53	UCTD	34.0368	-119.0327
09/14/2018 02:05	CTD	33.9240	-119.2757
09/14/2018 15:18	UCTD	33.8025	-119.5255
09/14/2018 16:56	UCTD	33.6703	-119.7978
09/15/2018 01:03	UCTD	33.7720	-119.1778
09/15/2018 15:35	UCTD	33.9435	-118.8193
09/15/2018 20:03	UCTD	33.8925	-118.5105
09/15/2018 22:25	UCTD	33.7058	-118.9013
09/16/2018 00:44	UCTD	33.5160	-119.2970

(continued)

Date Time	Cast Type	Latitude (deg)	Longitude (deg)
09/16/2018 02:09	CTD	33.4077	-119.5180
09/16/2018 17:24	UCTD	33.4837	-118.9540
09/16/2018 19:47	UCTD	33.6575	-118.5950
09/16/2018 23:59	UCTD	33.5913	-118.3258
09/17/2018 04:13	CTD	33.4122	-119.1013
09/17/2018 14:48	UCTD	33.4092	-118.7018
09/17/2018 17:04	UCTD	33.2157	-119.1027
09/17/2018 21:14	UCTD	33.1370	-118.8638
09/18/2018 02:33	CTD	33.4525	-118.2368
09/18/2018 19:07	UCTD	33.3918	-117.9473
09/18/2018 21:27	UCTD	33.2023	-118.3400
09/19/2018 02:27	CTD	32.9882	-118.7883
09/19/2018 14:43	UCTD	32.9995	-118.3588
09/19/2018 16:40	UCTD	33.1552	-118.0417
09/20/2018 02:23	CTD	32.9043	-118.1837
09/20/2018 22:58	CTD	32.8697	-117.8585
09/21/2018 02:07	CTD	33.0628	-117.4537
09/21/2018 17:39	CTD	32.8455	-117.5353
09/21/2018 23:09	CTD	32.6147	-117.9998
09/22/2018 15:52	CTD	32.3307	-118.1715
09/22/2018 19:18	CTD	32.6303	-117.8052
09/22/2018 20:13	CTD	32.6307	-117.8070

D Trawl sample summary

Date, time, location at the start of trawling (i.e., at net equilibrium), and biomasses (kg) of CPS collected for each trawl haul.

Haul	Date Time	Latitude (deg)	Longitude (deg)	J. Mackerel	N. Anchovy	P. Herring	P. Mackerel	P. Sardine	All CPS
1	06/30/2018 23:01	50.5003	-128.7005						
2	07/01/2018 02:07	50.6367	-128.5650			5.28			5.28
3	07/01/2018 23:30	50.3082	-128.3135			1.56			1.56
4	07/02/2018 02:27	50.3793	-128.2310			12.40			12.40
5	07/02/2018 23:18	49.6278	-127.0378			5.67			5.67
6	07/03/2018 01:25	49.6817	-127.0865			0.82			0.82
7	07/03/2018 22:07	48.8960	-126.0597			34.02			34.02
8	07/04/2018 00:11	48.8970	-125.9605			7.76			7.76
9	07/04/2018 02:14	48.9530	-126.0050			1.42			1.42
10	07/04/2018 22:07	48.5302	-125.8573		0.03	64.34			64.36
11	07/05/2018 00:14	48.4585	-125.8635			8.65			8.65
12	07/05/2018 02:27	48.4725	-125.9565			0.56	0.31	0.17	1.04
13	07/05/2018 22:20	48.5097	-125.1265			69.77			69.77
14	07/06/2018 01:15	48.5628	-125.1753			22.07			22.07
15	07/06/2018 21:34	48.2353	-125.5855	1.38		529.72			531.10
16	07/07/2018 00:16	48.2747	-125.5588			637.09			637.09
17	07/07/2018 21:40	47.9323	-125.5805						
18	07/08/2018 00:17	47.9958	-125.5130						
19	07/08/2018 02:33	47.9373	-125.5415						
20	07/08/2018 21:43	47.5667	-125.3542						
21	07/09/2018 00:16	47.6060	-125.4137						
22	07/09/2018 02:08	47.5660	-125.4895						
23	07/10/2018 21:43	47.2403	-125.3642						
24	07/11/2018 00:16	47.2762	-125.4622						
25	07/11/2018 02:39	47.2350	-125.5052	3.42					3.42
26	07/11/2018 22:11	46.9312	-125.1693		2.97				2.97
27	07/12/2018 21:11	46.7255	-124.7100		26.36	0.39			26.75
28	07/12/2018 23:41	46.7678	-124.7835		106.37	0.07			106.43
29	07/13/2018 02:28	46.7202	-124.8168		3.15				3.15
30	07/13/2018 22:14	46.2307	-124.4560		16.51	1.24	0.29	0.05	18.08

(continued)

Haul	Date Time	Latitude (deg)	Longitude (deg)	J. Mackerel	N. Anchovy	P. Herring	P. Mackerel	P. Sardine	All CPS
31	07/14/2018 00:40	46.2757	-124.3642		144.88	0.13	0.75		145.75
32	07/14/2018 22:00	46.2975	-124.2568		21.54	12.24			33.79
33	07/15/2018 00:18	46.1688	-124.1570		0.20	3.38			3.58
34	07/15/2018 02:27	46.1167	-124.1592	140.12		5.20			145.32
35	07/15/2018 22:13	45.7647	-124.1305	119.32		1.23	10.09	33.99	164.64
36	07/16/2018 01:44	45.7777	-124.2190	110.75	1.15	1.01	4.20	6.95	124.06
37	07/20/2018 23:12	45.2495	-124.1462	255.70	0.16	0.27			256.13
38	07/21/2018 02:22	45.5075	-124.1200	94.96		0.19			95.15
39	07/21/2018 21:57	45.4382	-124.9588						
40	07/22/2018 00:32	45.3967	-125.0202						
41	07/22/2018 02:50	45.4412	-125.0978						
42	07/22/2018 22:39	45.2390	-124.1970	46.58	0.06	13.97			60.61
43	07/23/2018 00:48	45.2760	-124.3175	172.08	2.31	3.77	40.53	24.05	242.75
44	07/23/2018 02:47	45.1188	-124.2758	38.89	0.13	1.98	5.17	1.38	47.54
45	07/23/2018 21:43	45.2785	-125.0512	45.81					45.81
46	07/24/2018 00:07	45.2118	-125.0845	2.35					2.35
47	07/24/2018 02:48	45.1552	-125.1840						
48	07/25/2018 21:29	44.5192	-124.2175			0.14			0.14
49	07/25/2018 23:44	44.6247	-124.2462			0.43			0.43
50	07/26/2018 01:46	44.7302	-124.3323		0.02	0.14			0.16
51	07/26/2018 21:31	44.0845	-124.8535	22.22	1.12	2.56		12.38	38.28
52	07/27/2018 00:22	44.0830	-124.7583	12.21	0.07	0.88		1.64	14.80
53	07/27/2018 02:50	44.1097	-124.6552	20.10		7.97			28.08
54	07/27/2018 22:10	43.9412	-124.4188	71.78	1.58	37.03		113.71	224.10
55	07/28/2018 00:37	43.8922	-124.4818	38.33	0.20	0.02	5.08	20.00	63.64
56	07/28/2018 02:50	43.9452	-124.6183	2.95	0.04	12.06	2.44	2.34	19.83
57	07/28/2018 22:09	43.6173	-124.7183	956.65			200.11	49.56	1206.32
58	07/29/2018 02:03	43.6130	-124.8728	770.15			306.99	4.21	1081.34
59	07/29/2018 22:04	43.2738	-125.1155	43.82			0.30	0.83	44.95
60	07/30/2018 00:38	43.2160	-125.1800	5.33			0.34		5.67
61	07/30/2018 02:27	43.1190	-125.1980						
62	07/30/2018 23:53	43.1017	-126.6710	46.71			2.02		48.73
63	07/31/2018 22:08	42.7133	-125.5110	178.87			27.50	2.96	209.33

(continued)

Haul	Date Time	Latitude (deg)	Longitude (deg)	J. Mackerel	N. Anchovy	P. Herring	P. Mackerel	P. Sardine	All CPS
64	08/01/2018 00:50	42.8338	-125.4248	283.95			14.26	6.20	304.42
65	08/01/2018 03:02	42.7013	-125.4207	291.64		0.41	37.02	0.88	329.95
66	08/01/2018 21:39	42.5152	-125.2003	208.36			8.86	2.36	219.58
67	08/01/2018 23:55	42.5145	-125.0938	263.96			4.65	1.87	270.48
68	08/02/2018 02:15	42.4298	-125.1203	128.25			8.40	0.73	137.37
69	08/02/2018 21:34	42.1345	-124.5208	339.35			14.54	14.09	367.97
70	08/03/2018 01:10	42.0448	-124.5517	86.45			4.44	0.19	91.08
71	08/03/2018 02:58	41.9628	-124.5112	735.27			29.43	0.71	765.40
72	08/03/2018 21:22	41.6223	-124.8620	19.90			1.52		21.43
73	08/04/2018 00:06	41.6542	-125.1135	75.59			2.34	1.33	79.27
74	08/04/2018 02:39	41.5997	-124.9662	103.46			7.78	2.51	113.74
75	08/04/2018 21:25	41.3172	-124.8613	68.07			12.45	5.23	85.75
76	08/04/2018 23:40	41.3090	-124.9927	103.29			4.89		108.18
77	08/05/2018 01:44	41.2215	-124.8538	82.95			10.05	0.86	93.86
78	08/05/2018 21:08	41.2232	-126.5768	71.20			0.71	24.41	96.32
79	08/06/2018 22:16	41.0015	-124.4970						
80	08/07/2018 00:55	41.1098	-124.4077	171.86			39.43	38.03	249.32
81	08/07/2018 03:09	41.0233	-124.3083	29.54			0.29		29.83
82	08/07/2018 21:46	40.4075	-124.7188	14.43					14.43
83	08/08/2018 00:27	40.4233	-124.5720	23.08					23.08
84	08/08/2018 02:48	40.4075	-124.6520						
85	08/14/2018 22:18	39.9348	-124.4540	14.54					14.54
86	08/14/2018 23:37	39.8812	-124.4772	0.44					0.44
87	08/15/2018 01:41	39.8988	-124.5745						
88	08/15/2018 22:20	39.0913	-126.3307	1.26					1.26
89	08/16/2018 21:47	39.3397	-123.9627						
90	08/17/2018 00:13	39.3453	-124.0657	0.33					0.33
91	08/17/2018 02:18	39.2705	-124.0743						
93	08/17/2018 23:54	38.6512	-123.8918						
94	08/18/2018 02:50	38.6328	-123.9363						
95	08/18/2018 21:51	38.0275	-123.5468						
96	08/19/2018 00:00	37.8843	-123.5098	2.02					2.02
97	08/19/2018 02:09	37.7520	-123.4995	6.65					6.65

(continued)

Haul	Date Time	Latitude (deg)	Longitude (deg)	J. Mackerel	N. Anchovy	P. Herring	P. Mackerel	P. Sardine	All CPS
99	08/19/2018 23:48	37.3757	-123.2575						
100	08/20/2018 02:05	37.3522	-123.3452	0.01					0.01
101	08/20/2018 20:36	37.6152	-122.8148		1238.70				1238.70
102	08/21/2018 00:32	37.5687	-122.8842		14.96				14.96
103	08/21/2018 20:59	36.8512	-124.9010	14.90			0.41	0.24	15.55
104	08/22/2018 20:26	37.2707	-122.6727		886.94				886.94
105	08/22/2018 23:59	37.3640	-122.5648		7.30				7.30
106	08/23/2018 02:36	37.2223	-122.6318		125.58				125.58
107	08/23/2018 21:00	36.6225	-122.8005		2415.37				2415.37
108	08/24/2018 00:18	36.7083	-122.8142		720.25			0.06	720.32
109	08/24/2018 03:15	36.8048	-122.8378		9.78				9.78
110	08/24/2018 20:57	36.6342	-122.4063	0.01	13.16				13.17
111	08/24/2018 23:12	36.7035	-122.5882	0.01	61.41			0.08	61.50
112	08/25/2018 02:23	36.5752	-122.5955		0.02				0.02
113	08/25/2018 20:42	36.4058	-122.0378		204.40			0.12	204.52
114	08/25/2018 23:31	36.6013	-122.0425		0.05				0.05
115	08/26/2018 02:35	36.6910	-121.9345	0.56	0.01				0.57
116	08/26/2018 21:05	36.1172	-122.6615	0.09	94.62			0.12	94.83
117	08/26/2018 23:33	36.2043	-122.8517	0.03	5.01				5.04
118	08/27/2018 01:59	36.3167	-122.7530		19.37			0.03	19.39
119	08/27/2018 21:04	35.7463	-122.6718		14.20			0.03	14.23
120	08/27/2018 23:38	35.8992	-122.6807		20.04			0.05	20.10
121	08/28/2018 03:01	35.9808	-122.6027		258.20			0.36	258.56
122	08/28/2018 21:07	35.7385	-122.2762	0.01	213.62			2.98	216.62
123	08/29/2018 00:06	35.9110	-122.1663		1.72		0.02	0.02	1.76
124	08/29/2018 03:12	35.9278	-122.0025		0.03				0.03
125	09/06/2018 21:21	35.8912	-121.5283	2.84	2.68			0.04	5.56
126	09/06/2018 23:23	35.9373	-121.6353		26.88			0.03	26.91
127	09/07/2018 02:25	36.0247	-121.6293						
128	09/07/2018 21:36	35.4847	-121.9365	4.57			1.03		5.60
129	09/08/2018 00:13	35.4452	-122.0192	0.06					0.06
131	09/09/2018 00:52	35.2412	-121.0713		83.86				83.86
132	09/09/2018 03:33	35.3343	-121.0092						

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Haul	Date Time	Latitude (deg)	Longitude (deg)	J. Mackerel	N. Anchovy	P. Herring	P. Mackerel	P. Sardine	All CPS
133	09/09/2018 21:33	35.0683	-120.8657		0.01				0.01
135	09/10/2018 03:58	34.7878	-120.7633		0.02				0.02
138	09/10/2018 23:42	34.4330	-120.0915		0.03			0.02	0.05
139	09/11/2018 01:34	34.4017	-119.9712		0.02				0.02
140	09/11/2018 03:35	34.3543	-119.8437		0.05				0.05
141	09/11/2018 20:53	33.9465	-120.4090	0.53	0.08		0.09	2.50	3.20
142	09/11/2018 23:22	33.9828	-120.3443		0.05			0.12	0.18
143	09/12/2018 02:26	34.0695	-120.1988	0.01	1.11			0.26	1.38
144	09/12/2018 21:42	33.7842	-119.9973	0.51	0.03		0.22	6.06	6.81
145	09/13/2018 00:23	33.7217	-120.0385	0.63			0.09		0.72
146	09/13/2018 03:08	33.6595	-120.1857	0.46			1.20	9.46	11.13
147	09/13/2018 20:54	33.9707	-119.5593	0.06	2.43				2.49
148	09/13/2018 23:37	33.8325	-119.7578	0.72	0.78		0.08	5.48	7.06
149	09/14/2018 02:44	33.8875	-119.5783	0.20	3.84		1.02	1.10	6.15
150	09/14/2018 20:27	33.8468	-119.2027	0.29	14.04		16.73	45.80	76.87
151	09/14/2018 22:33	33.8568	-119.3857	0.92	230.92		2.79	10.04	244.66
152	09/15/2018 02:16	33.9580	-119.2230	0.53	0.03		8.42	72.88	81.87
153	09/15/2018 21:15	33.5180	-119.2590	0.04	0.72			0.03	0.78
154	09/16/2018 00:14	33.3543	-119.3452	0.36	0.02				0.38
155	09/16/2018 03:33	33.1543	-119.3967	3.75			0.96	0.25	4.96
156	09/16/2018 21:49	33.4135	-119.1155	0.13	9.66		0.02	0.20	10.00
157	09/17/2018 00:27	33.5122	-118.9473	0.09			0.04	0.05	0.18
158	09/17/2018 02:50	33.5023	-118.8008	1.14	155.30		0.15	0.52	157.10
159	09/17/2018 21:10	33.6190	-118.2487	0.01	0.16		0.20	0.11	0.48
160	09/18/2018 00:17	33.5252	-118.0805		0.62			0.42	1.05
161	09/18/2018 02:58	33.4315	-118.1910	0.14			0.16		0.30
162	09/18/2018 20:40	33.1010	-118.9090	0.78	0.01				0.79
163	09/19/2018 00:41	33.1953	-118.5080	0.06					0.06
164	09/19/2018 03:09	33.0945	-118.4052						
165	09/19/2018 20:53	33.0665	-118.2653						
166	09/19/2018 23:50	33.0360	-117.9390		0.01				0.01
167	09/20/2018 02:53	32.8408	-118.0742						
168	09/20/2018 20:28	32.9638	-117.6558	0.00	0.11				0.11

(continued)

Haul	Date Time	Latitude (deg)	Longitude (deg)	J. Mackerel	N. Anchovy	P. Herring	P. Mackerel	P. Sardine	All CPS
169	09/20/2018 23:11	33.1615	-117.6725	0.02	5.11		0.09	0.06	5.29
170	09/21/2018 02:24	33.1215	-117.3908		24.80		0.10	0.18	25.08
171	09/21/2018 20:41	32.7053	-118.1772	0.07					0.07
172	09/21/2018 23:25	32.6957	-117.8810		0.17				0.17
173	09/22/2018 02:44	32.4682	-118.0880	0.01					0.01
174	09/22/2018 20:27	32.7988	-117.6200	0.01	0.03				0.04
175	09/22/2018 22:48	32.7107	-117.4427		0.03				0.03