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REPORT ON THE SWFSC'S COLLECTION OF DATA DURING THE 2015 JOINT U.S.-CANADA INTEGRATED ACOUSTIC AND TRAWL SURVEY OF PACIFIC HAKE AND COASTAL PELAGIC SPECIES (SaKe 2015; 1507SH) WITHIN THE CALIFORNIA CURRENT ECOSYSTEM, 15 JUNE TO 10 SEPTEMBER 2015, CONDUCTED ABOARD FISHERIES SURVEY VESSEL *BELL M. SHIMADA*

Kevin L. Stierhoff, Juan P. Zwolinski, Josiah S. Renfree,
Scott A. Mau, David W. Murfin, and David A. Demer

Fisheries Resources Division
Southwest Fisheries Science Center
NOAA National Marine Fisheries Service
8901 La Jolla Shores Dr.
La Jolla, CA 92037, USA

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I. Introduction

The 2015 Joint U.S.-Canada Integrated Acoustic and Trawl Survey of Pacific Hake and Coastal Pelagic Species (SaKe 2015; 1507SH) was conducted aboard NOAA Fisheries Survey Vessel (FSV) *Bell M. Shimada* (hereafter, *Shimada*), 15 June to 10 September 2015. The Acoustic-Trawl Method (ATM) was used to assess coastal pelagic fish species (CPS) and krill within the California Current Ecosystem (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 SWFSC's 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; and 3) gather information regarding their life history parameters. Reported elsewhere, the Northwest Fisheries Science Center (NWFSC) concurrently surveyed hake (*Merluccius productus*). The survey domain encompassed the anticipated distributions of the northern sub-population of sardine and the central and northern sub-populations of anchovy off the west coasts of the U.S. and Canada from approximately San Diego, CA to Haida Gwaii, British Columbia. The survey domain was defined by the modeled distribution of sardine potential habitat (Zwolinski *et al.*, 2011), and information recently gathered from other research projects (e.g., California Cooperative Fisheries Investigations (CalCOFI) samples) or the fishing industry (e.g., sardine bycatch).

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. The biomass of the northern stock of Pacific sardine is presented in Zwolinski et al. (2016). This report does not include estimates of the distributions and biomasses for other CPS, krill, or hake.

I.1 Scientific Personnel

As elaborated below, the collection and analysis of the survey data was conducted by the SWFSC[1], and NWFSC[2]. Superscripts denote affiliations and roles of the other cruise participants: 1-SWFSC, 2-NWFSC, 3-Chief Scientist, 4-Field Party Chief, and 5-Lead Biologist.

Project Leads:

- D. Demer[1]
- L. Hufnagle[2]

Acoustic Data Collection and Processing:

- Leg I: J. Clemons[2,4], S. Parker-Stetter[2], J. Pohl[2], J. Renfree[1], and J. Zwolinski[1,3]
- Leg II: J. Clemons[2,3], S. Mau[1], and R. Thomas[2]
- Leg III: D. Chu[2], S. de Blois[2,3,4], V. Maynez[1], D. Murfin[1], and S. Parker-Stetter[2]
- Leg IV: J. Pohl[2,3], J. Renfree[1], and R. Thomas[2]

Trawl Sampling:

- Leg I: C. Colway[2], J. Evanilla[1], E. Gardner[1], B. Macewicz[1], S. Manion[1,3], K. Miller[1], T. Mitchell[2], A. Odell[2], H. Villalobos[1], C. Whiteside[2,5], and P. Y Chen[1]
- Leg II: A.L. Ahern[2], S. Manion[1,3], S. Deery-Schmitt[2], K. Gilmore[1], D. Griffith[1], M. Seibert[1], M. Ushido[2], W. Watson[1], and B. Whiteside[2,5]
- Leg III: S. Deery-Schmitt[2], A. Hays[1], D. Kamikawa[2,5], A. Kester[2], B. Macewicz[1], C. Purdy[1], M. Sedarat[1], A. Thompson[1], and E. Weber[1]
- Leg IV: A. Billings[2,5], E. Brasseur[2], K. Byers[1], S. Charter[1], S. Deery-Schmitt[2], B. Flores[1], D. Griffith[1,3], and A. Lowe[1]

Echosounder Calibration:

- D. Demer[1], J. Pohl[2], J. Renfree[1], J. Zwolinski[1]

II. Methods

II.1. Survey region and design

During spring, sardine typically aggregate offshore of central and southern California to spawn (Demer *et al.*, 2012, and references therein). During summer, if the stock is large enough, adults will migrate north, compress along the coast, and feed in the upwelled regions (**Figure II.1**).

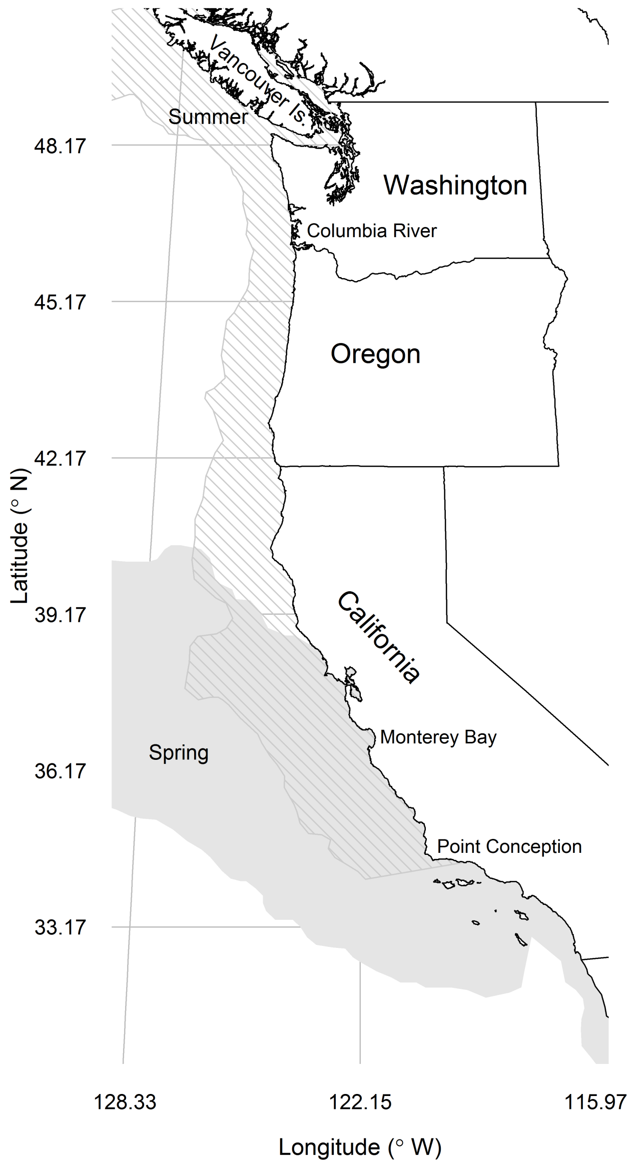

Figure II.1. Conceptual map showing the average spring and summer distributions of the northern sub-population of Pacific sardine potential habitat during spring and summer along the west coasts of Mexico, the United States, and Canada (Zwolinski *et al.*, 2014).

During summer 2015, the west coast of the United States was surveyed using *Shimada*. Compulsory transects were nearly perpendicular to the coast with separations of 10 to 20 nmi. The survey began off San Diego, CA and progressed northwards toward Haida Gwaii, British Columbia, first sampling the central sub-population of anchovy off southern and central California.

The planned transects (**Figure II.2**) spanned the latitudinal extent of the potential habitat of the northern sub-population of sardine at the time of the survey (**Figure II.3**; http://swfscdata.nmfs.noaa.gov/AST/sardineHabitat/habitat.asp). Transect positions, lengths, and spaces were adjusted according to the expected distributions of sardine and anchovy at the time of the survey.

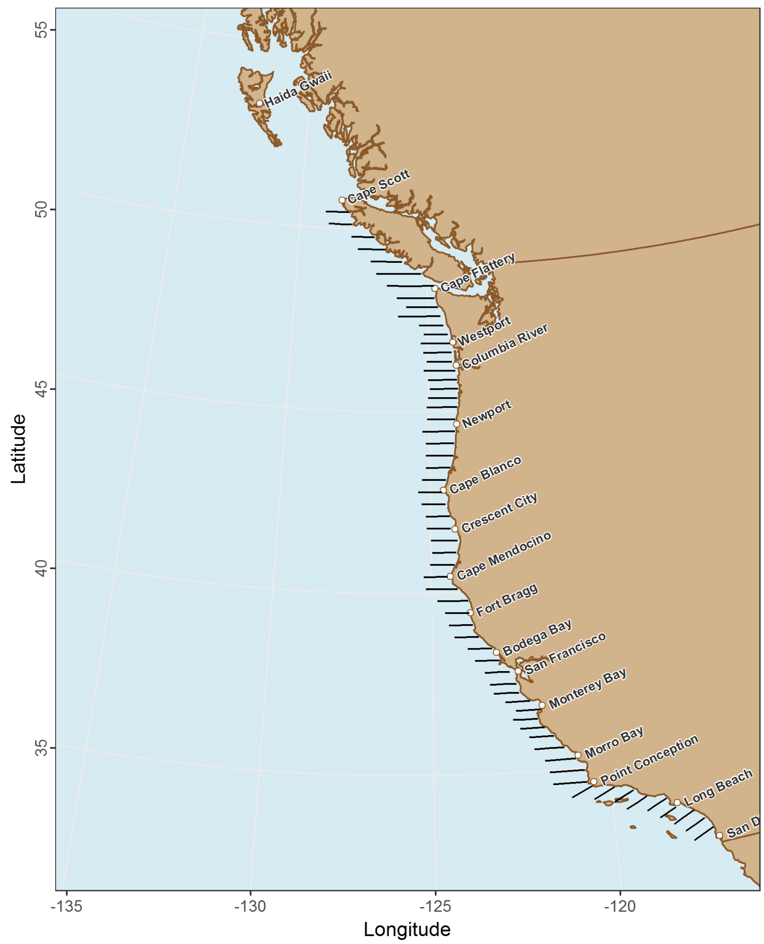

Figure II.2. Planned compulsory transect lines.

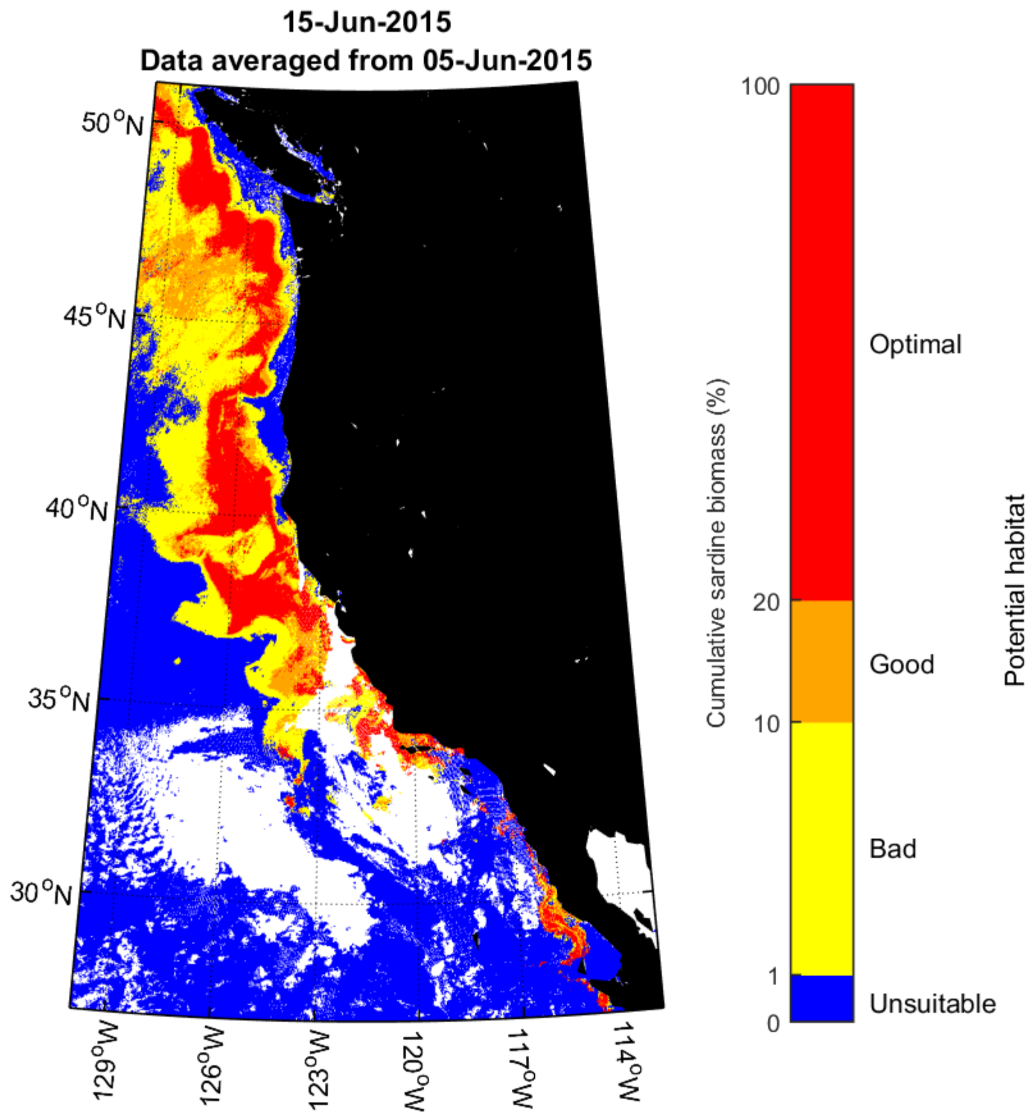

Figure II.3. Distribution of potential habitat for the northern stock of Pacific sardine on 15 June 2015 at the beginning of SaKe 2015.

II.2 Acoustic sampling

II.2.1. Echosounders

Multi-frequency (18, 38, 70, 120, and 200 kHz) General Purpose Transceivers (Simrad EK60 GPTs) and Wideband Transceivers (Simrad EK80 WBTs; 70 and 200 kHz only) were configured with split-beam transducers (Simrad ES18-11, ES38B, ES70-7C, ES120-7C, and ES200-7C, respectively). The transducers were mounted on the bottom of a retractable keel or "centerboard" (**Figure II.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**).

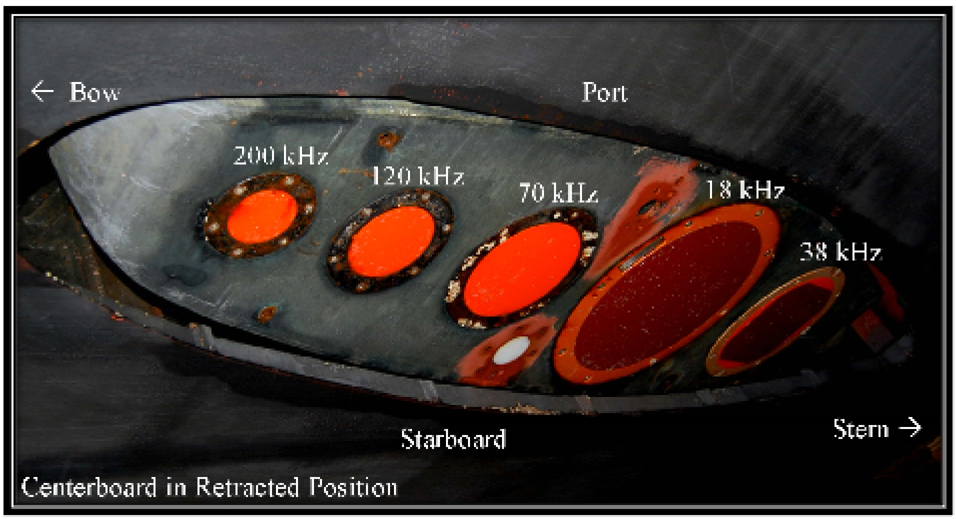

Figure II.4. Transducer locations on the bottom of the centerboard aboard *Shimada*.

II.2.2. Calibration

Prior to calibration (15 June 2015 at ~1900), the integrity of each transducer was verified through impedance measurements of each transducer using an LCR meter (Agilent Model E4980A) and custom Matlab software. For each transducer, impedance magnitude ($|Z|$), phase (θ), conductance (G), susceptance (B), resistance (R), and reactance (X) was measured at the operational frequencies with the transducer quadrants placed in parallel. 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 (NWFSC sphere; sphere number unknown). The GPTs were configured, via the ER60 software, using the parameters in **Table III.1** (below).

II.2.3. Data collection

The ER60-computer clock was set to Universal Coordinated Time (UTC) and synchronized with the GPS clock using SymmTime (Symmetricon, Inc.) every six hours. 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 (see **Section II.1**) 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 700-m range, and stored in Simrad .raw format (50-MB maximum file size; each filename begins with "1507SH_" and ends with the logging commencement date and time) using the GPT-control software (Simrad ER60 V2.4.3).

To minimize acoustic interference, transmit pulses were triggered using the EAL and TriggerJigger (Alaska Fisheries Science Center). All other instruments that produce sound within the echosounder bandwidths were secured during 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.

II.2.4. Data processing

The calibrated echosounder data were processed on a dedicated computer, using commercial software (Echoview V6.1.40.26321, Echoview Software Pty Ltd.) and the following procedure:

1. For each transect, the associated data files (.raw format) were loaded into an Echoview (.ev) file. Transducer depths were set to 0 m.
2. In each .ev file, values for the environment were set using Echoview calibration supplement (.ecs) files, including data from the closest CTD or UCTD cast. Since the CPS of interest reside in the upper mixed layer, environment data were averaged over 0- to 70-m depth.
3. For each frequency:
    - Echograms of S_v were displayed.
    - "Noise-reduced" echograms (**Figure II.5a**), generated by subtracting in the linear domain simulated background noise from the raw S_v, were smoothed by computing the median value in non-overlapping 11-sample by 3-ping cells (**Figure II.5b**).
    - The smoothed, noise-reduced echograms were used to calculate S_v-differences using the 38-kHz S_v (S_{v38kHz}) as a reference (i.e., S_{v70kHz} - S_{v38kHz}; $S_{v120kHz}$ - S_{v38kHz}; $S_{v200kHz}$ - S_{v38kHz}).
    - A CPS mask (**Figure II.5c**) was created for regions where S_v-differences were within the expected ranges for CPS (**Table II.1.**).
    - Data were provisionally ascribed to CPS if their S_v-differences (i.e., S_{v70kHz} - S_{v38kHz}; $S_{v120kHz}$ - S_{v38kHz}; $S_{v200kHz}$ - S_{v38kHz}) were within predicted ranges (**Table II.1.**).
    - Data collected when the ship approached or departed a sampling station, typically associated with a ship-speed less than 4 kn, were automatically marked as "bad data."
    - Provisional CPS regions created above were ascribed to CPS schools if the standard deviation of each 11-sample by 3-ping cell was > -50 dB at 120 and 200 kHz.
    - The 38-kHz CPS data with S_v < -60 dB (corresponding to a density of approximately three fish per 100 m^3 in the case of 20-cm-long sardine) were set to -999 dB (effectively zero; **Figure II.5d**).
    - An integration-start line was created at a range of 5 m from the transducers. When necessary, this line was manually modified to exclude reverberation due to bubbles.
    - The depth of the top of the dead-zone was estimated using the variance-to-mean ratio (Demer *et al.*, 2009).
    - An integration-stop line was created at 250-m depth or, when shallower, 3 m above the estimated depth of the top of the dead-zone.
    - Between the integration lines, to a maximum of 250 m, volume backscattering coefficients (s_v, m^2 m^{-3}) were integrated over 5-m depths and averaged over 100-m distances. The resulting integrated volume backscattering coefficients (s_A; m^2 nmi^{-2}), for each transect and frequency, were output to comma-delimited text (.csv) files.
    - The s_A values were summed over ranges from the integration start line to the approximate depth of the bottom of the upper mixed layer.
    - Data collected during daytime (i.e., not earlier than 30 min before sunrise to not later than 30 min after sunset) were averaged over 2-km distances, and mapped. Nighttime data, assumed to be negatively biased due to diel-vertical migration (DVM) and disaggregation of the target species' schools (Cutter and Demer, 2008; Demer and Hewitt, 1995) were omitted.

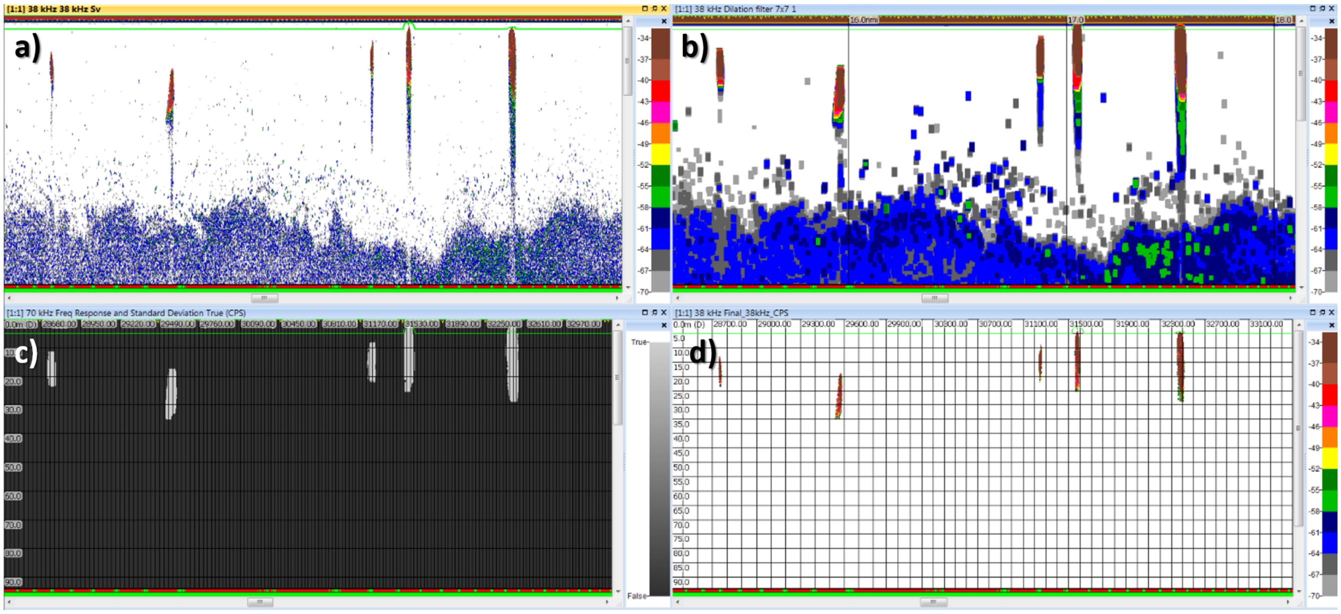

Figure II.5 Synchronized echograms of 38-kHz S_{v} after a) noise-subtraction, b) median smoothing, c) masking, and d) 38-kHz S_{v} thresholding at -60 dB (final, CPS-only).

Table II.1. S_{v}-differences (minimum, maximum; dB) for putative CPS.

$S_{\mathrm{v70kHz}} - S_{\mathrm{v38kHz}}$	$S_{\mathrm{v120kHz}} - S_{\mathrm{v38kHz}}$	$S_{\mathrm{v200kHz}} - S_{\mathrm{v38kHz}}$
-12.85, 9.89	-13.15, 9.37	-13.51, 12.53

II.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 much 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.

Nighttime trawl sampling was conducted where echoes from CPS schools were observed earlier that day. 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 75 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 sardine, anchovy, and herring, or fork length (L_{f}; mm) for jack mackerel and Pacific mackerel. In addition, otoliths were removed, sex and maturity recorded, and fin clips preserved in ethanol from up to 50 of the randomly selected individuals of each species. 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.

II.4. Ichthyoplankton and oceanographic sampling

II.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. Sardine, anchovy, jack mackerel, and hake eggs are identified to species, counted, and logged. 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 (or bongo) net (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% formalin. Paired vertical egg tow (PairoVET; Smith *et al.*, 1985) nets (25-cm diameter; 150-μm mesh) were used to sample fish eggs and larvae from a depth of 70 m to the sea surface at a rate of 70 m min^{-1} at the same locations where bongo nets were deployed. These PairoVET samples were preserved in 95% ethanol for future genetic analysis.

II.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 scatters (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.

III. Results

III.1. EK60 echosounder calibration

The EK60s were calibrated on 19 June 2015 (~2300 GMT) while the vessel was at anchor near Shelter Island, San Diego Bay (32.7135 °N, -117.2227 °W, **Figure III.1**). Thermosalinograph (Seabird Model SBE38) measurements of sea-surface temperature (t_{w} = 19.68 °C) and salinity (s_{w} = 33.57 psu) were input to the GPT-control software, which derived estimates of sound speed (c_{w} = 1519 m s^{-1}) and absorption coefficients (see **Table III.1**). Varying with tide, the seabed was approximately 8 to 12 m beneath the transducers. The calibration sphere was positioned 4.5 to 7 m below the transducers.

GPT information, configuration settings, and beam model results following calibration are presented in **Table III.1**. Measurements of beam-uncompensated sphere target strength (TS_{u}, dB re 1 m^2) are plotted in **Figure III.2** and relative beam-compensated sphere target strength (TS_{rel}, dB re 1 m^2) are plotted in **Figure III.3**. A time-series of calibration results for *Shimada*, 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 **Figure III.4**.

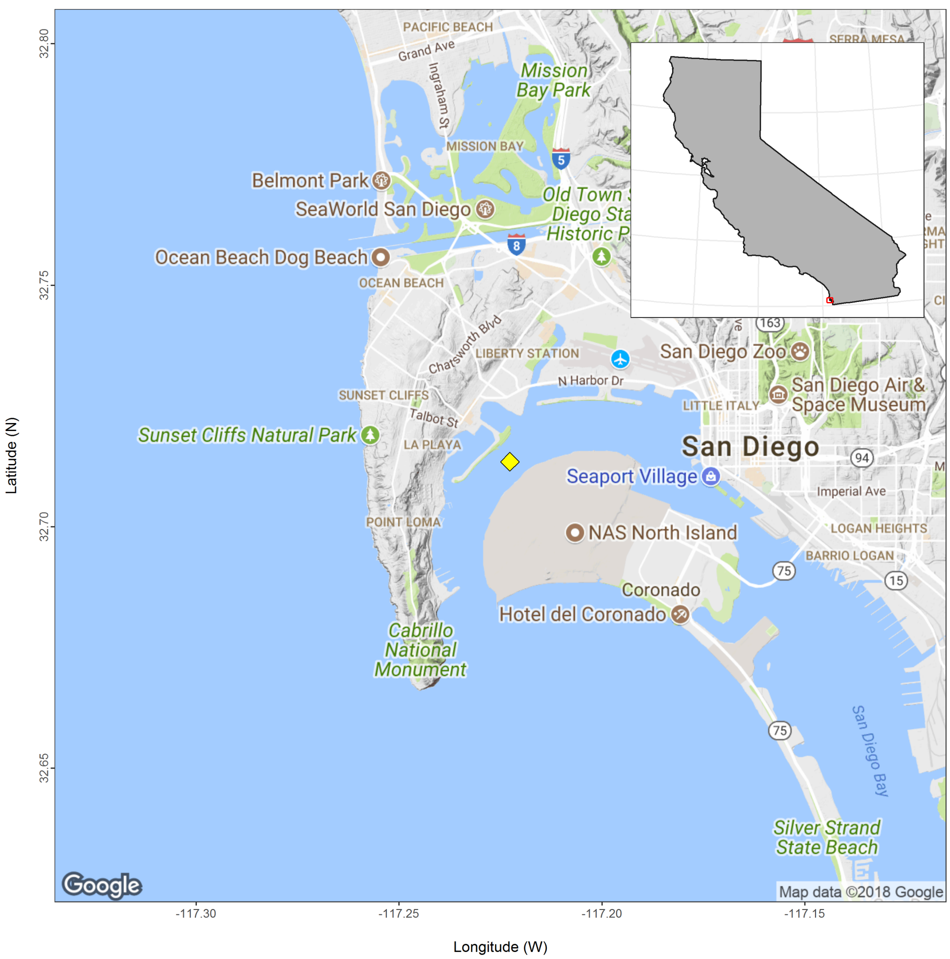

Figure III.1. Map of the calibration location (yellow diamond) near Shelter Island, San Diego Bay. The red box in the inset indicates the location and extent of the main map.

Table III.1 Simrad EK60 general purpose transceiver (GPT) information, pre-calibration settings, 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 (f, kHz)	Units	18	38	70	120	200
Model		ES18-11	ES38B	ES70-7C	ES120-7C	ES200-7C
Serial Number		2065	30715	168	573	339
Transmit Power (p_{et})	W	2000	2000	750	250	100
Pulse Duration (τ)	ms	1.024	1.024	1.024	1.024	1.024
On-axis Gain (G_0)	dB re 1	23.16	26.14	26.1	26.02	25.39
S_a Correction ($S_a$corr)	dB re 1	-0.74	-0.57	-0.34	-0.35	-0.36
Bandwidth (W_f)	Hz	1570	2430	2860	3030	3090
Sample Interval	m	0.194	0.194	0.194	0.194	0.194
Eq. Two-way Beam Angle ( )	dB re 1 sr	-18	-21.4	-21.5	-20.8	-20.8
Absorption Coefficient (α_f)	dB km^{-1}	1.9	7.5	21.2	44.2	71.4
Angle Sensitivity Along. (Λ_α)	Elec.°/Geom.°	13.68	21.62	22.64	22.78	22.69
Angle Sensitivity Athw. (Λ_β)	Elec.°/Geom.°	13.68	21.62	22.64	22.78	22.69
3-dB Beamwidth Along. (α_{-3dB})	deg	11.22	7.04	6.67	6.42	6.55
3-dB Beamwidth Athw. (β_{-3dB})	deg	11.28	7.1	6.73	6.45	6.49
Angle Offset Along. (α_0)	deg	-0.21	-0.01	-0.13	0.05	0.03
Angle Offset Athw. (β_0)	deg	0.22	-0.02	0.04	0.11	-0.08
Theoretical TS (TS_{theory})	dB re 1 m^2	-42.46	-42.39	-41.62	-39.73	-38.82
Ambient Noise	dB re 1 W					
On-axis Gain (G_0)	dB re 1	23.05	25.96	26.33	25.8	25.23
S_a Correction ($S_a$corr)	dB re 1	-0.78	-0.57	-0.34	-0.37	-0.22
RMS	dB	0.32	0.16	0.15	0.21	0.31
3-dB Beamwidth Along. (α_{-3dB})	deg	10.96	6.98	6.46	6.57	6.71
3-dB Beamwidth Athw. (β_{-3dB})	deg	11.1	6.94	6.51	6.63	6.68
Angle Offset Along. (α_0)	deg	-0.19	0.02	-0.09	0.03	0.02
Angle Offset Athw. (β_0)	deg	0.24	-0.01	0.05	0.1	-0.07

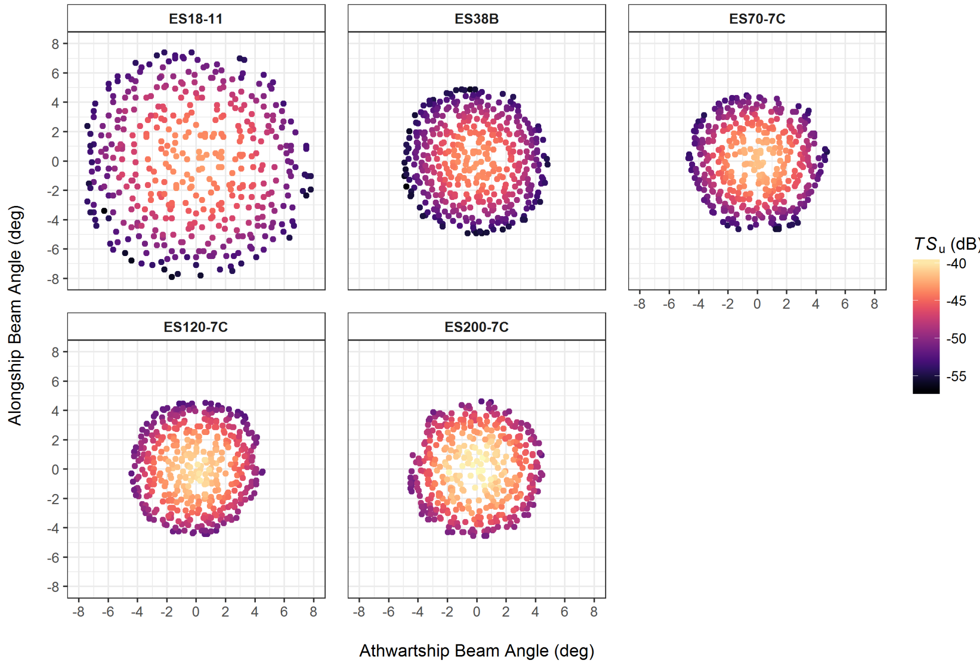

Figure III.2. Beam-uncompensated sphere target strength (TS_u, dB re 1 m^2) measurements of a 38.1-mm diameter sphere made from tungsten carbide (WC) with 6% cobalt binder material, at multiple EK60 frequencies (18, 38, 70, 120, and 200 kHz). Crosses indicate measurements marked as outliers after viewing the beam model results.

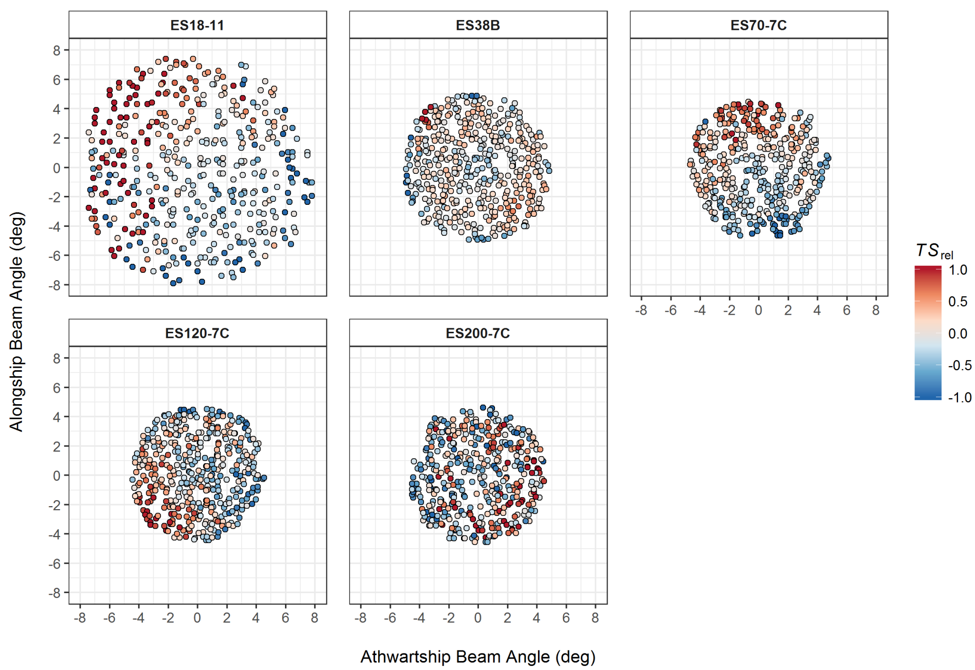

Figure III.3. Relative beam-compensated sphere target strength (TS_{rel}, dB re 1 m^2) measurements of a 38.1-mm diameter sphere made from tungsten carbide (WC) with 6% cobalt binder material, at multiple EK60 frequencies (18, 38, 70, 120, and 200 kHz). TS_{rel} is calculated as the difference between the beam-compensated target strength (TS_c) and the theoretical target strength (TS_{theory}, see **Table III.1**). Crosses indicate measurements marked as outliers after viewing the beam model results.

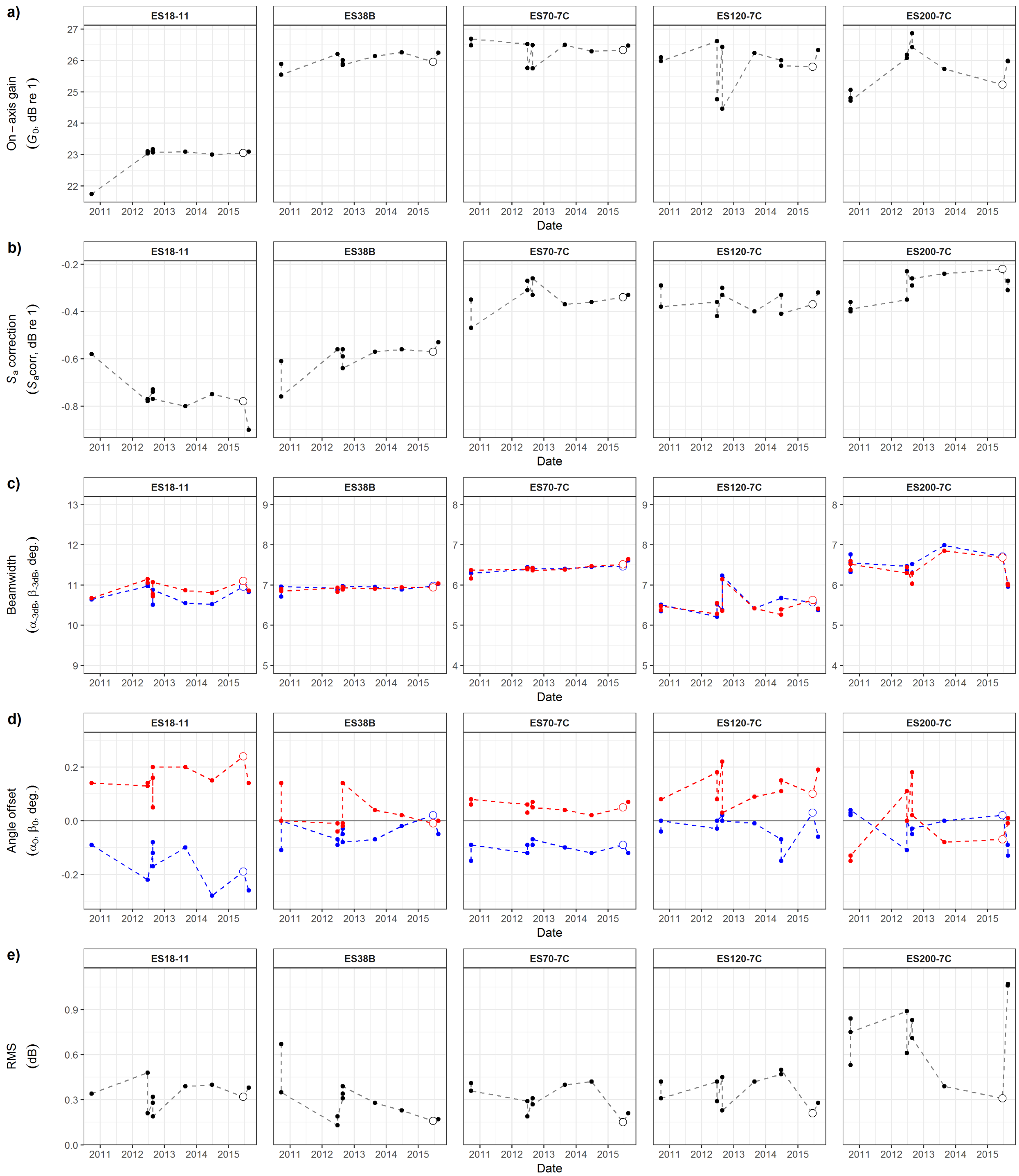

Figure III.4. Time series of beam model results of a) on-axis gain (G_0, dB); b) S_a correction ($S_a$corr, dB re 1); c) alongship (α_{-3dB}, blue) and athwartship (β_{-3dB}, red) beamwidths (deg); d) alongship (α_0, blue) and athwartship (β_0, red) offset angles (deg.); and e) RMS (dB) for each EK60 transducer frequency aboard *Shimada*. Unfilled circles indicate results from the current survey.

III.2. Data collection

III.2.1. Acoustic and trawl sampling

The survey spanned an area from approximately Haida Gwaii, British Columbia to San Diego, CA (**Figure III.5**), with 79 east-west transects totaling 3150 nmi, and 158 Nordic trawls.

Leg I
On 20 June, *Shimada* departed San Diego and began the first transect that day at ~1300 (all times UTC). On 3 July, *Shimada* arrived at Pier 15 in San Francisco, CA at ~2300 to end Leg I.

Leg II
On 8 July 2015, *Shimada* departed Pier 15 in San Francisco, CA at *ca.* 1700, and arrived at the first station (Station 18.1 on transect 18; 35 nmi. east of Santa Cruz, CA) at ~1800 on 8 July to resume survey operations. The ship's intercooler was leaking and repaired on 7 July, which delayed departure by one day. Foul weather made trawling difficult beginning on 15 July. Multiple CTD casts were made during the night shift on 15 July instead of trawling; due to foul weather, no trawling was conducted on 16 July. The hydraulic pump operating the ship's rudder malfunctioned for approximately one hour, after which the survey resumed using the backup pump. On 20 July, the ME70 ping rate became very slow. The laptop computer controlling the TriggerJigger fell from the rack and pulled the trigger cable from the EK60, which removed the trigger from the EK60 and caused the whole system to slow. On 22 July, transect 36 was briefly interrupted when the cooling line for the propeller shaft failed and required repair. At one point, the bridge ER60 was run in passive slave mode while trawling for hake, which caused the EAL to crash; disabling the EAL while operating the bridge ER60 in passive slave mode stopped the EAL from crashing. On 26 July, *Shimada* returned to the NOAA Pier, MOC-P in Newport, OR at ~1600 to end Leg II.

Leg III
On 5 August, *Shimada* departed from NOAA Pier, MOC-P in Newport OR, at ~1730, and arrived at the first station (transect 40 near Heceta Head) at ~2100 on 5 August to resume survey operations. On 5 August, upon sampling transect 40, communications to all EK60 GPTs except 200-kHz were lost and could not be reestablished via the ER60 software. All GPTs were disconnected from the Z-Mux junction box and communications were reestablished; no GPTs were connected to the Z-Mux for the remainder of Leg III. On 13 August, acoustic sampling was interrupted for ~45 min when *Shimada*'s main power transformer failed. On 15 August, the trawl gate began leaking hydraulic fluid and was secured by the ship's crew. With the trawl gate inoperable, it was difficult for the crew to manage the nets and damage occurred to both the hake and CPS trawl nets. Further, a joint SWFSC/NWFSC study was performed to inspect potential noise generated on the EK60s from *Shimada*'s propeller speed, connections to the Z-Mux, or both. On 19 August, a second calibration of the EK60 echosounders was conducted by the NWFSC in Shilshole Bay near Seattle, WA (37.7867 °N, -122.3843 °W; results not shown). On 20 August, *Shimada* returned to Pier 90 in Seattle, WA at ~2300to end Leg III.

During Leg III, aerial surveys of CPS were conducted by Frank Foode in coordination with *Shimada*. Analysis of those data are ongoing. On 18 August, acoustic data were collected using 70- and 200-kHz EK80 echosounders outside the straight of Juan de Fuca near Seattle, WA for comparison with EK60 data collected along transect 55.

Leg IV
On 23 August, *Shimada* departed from Pier 90 in Seattle, WA at ~1800 and arrived at the eastern end of transect 57 at ~1330 on 24 August to resume survey operations. On 25 August, transect 57 was extended westward due to presence of hake. On 26 August, transect 59 was also extended westward due to presence of hake. On 26 August, sardine eggs were collected in CUFES at ~2100 but there was no putative CPS backscatter in the EK60 echograms. On 27 August, acoustic sampling was interrupted between ~18:45 and 19:00 to troubleshoot the starboard power-steering pump. On 10 September, *Shimada* returned to MOC-P in Newport, OR at ~2030 to conclude survey operations.

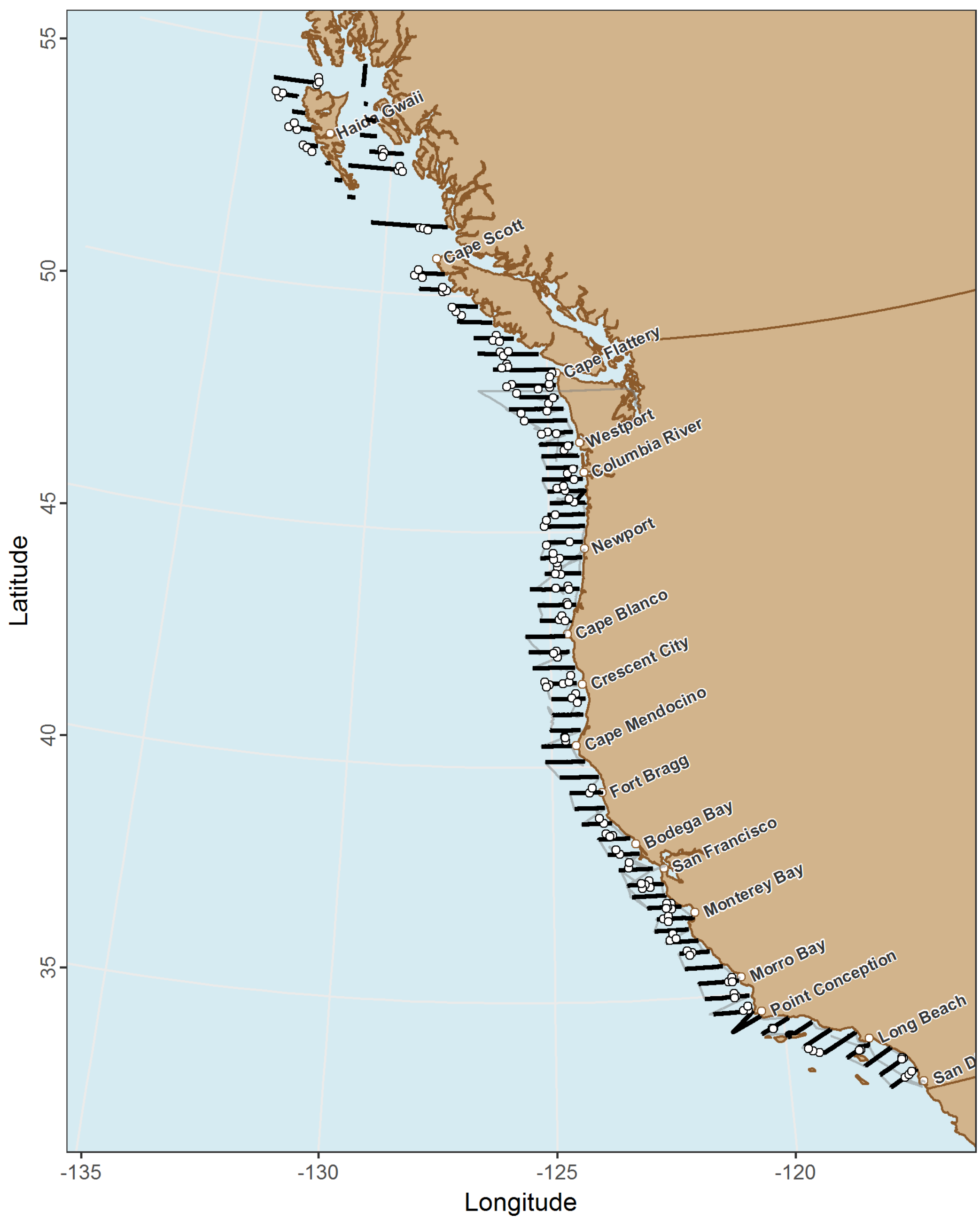

Figure III.5. Cruise track of *Shimada* (gray line), east-west acoustic transects (black lines), and locations of surface trawls (white points) superimposed on the vessel track (light gray lines). Transects north of Vancouver Island were planned *ad hoc* for investigating the northern extent of the hake distribution.

III.2.2 Ichthyoplankton and oceanographic sampling

A total of 126 CTD casts, 59 bongo tows, and 27 PairoVET tows were conducted throughout the survey. In addition, 166 UCTD casts were conducted and 941 CUFES samples were collected underway. The locations of CTD and UCTD stations are shown in Figure **III.6** and **Appendix C**.

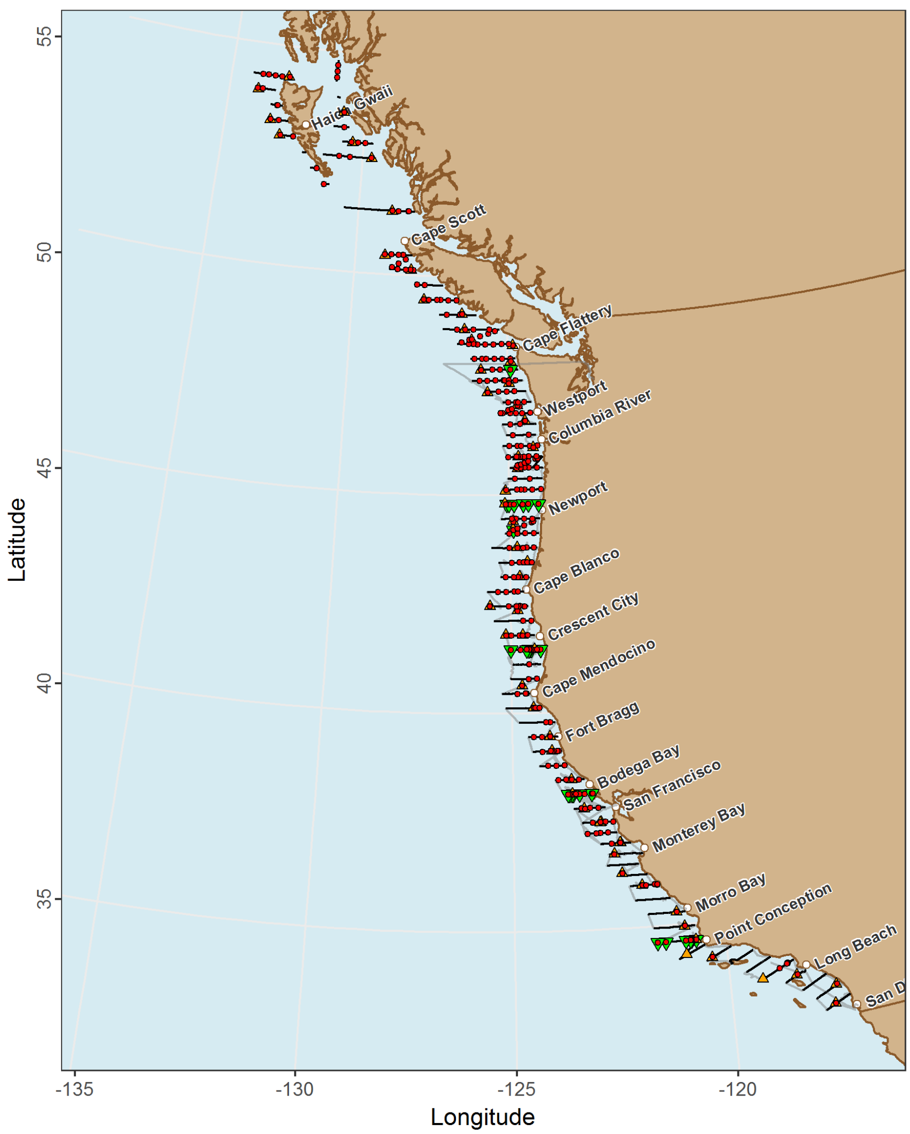

Figure III.6. Locations of CTD and UCTD casts (red circles) and plankton net samples (bongo net in orange triangles; PairoVET net in green triangles) relative to the vessel track (bold gray line), acoustic transects (black lines), and proposed transects (light gray lines).

III.3. Distribution of CPS

Acoustic backscatter ascribed to CPS was observed throughout the survey area, but was most prevalent between the Columbia River and Cape Blanco, inshore between Bodega Bay and Morro Bay, CA, and inshore of the northern Channel Islands in the Southern California Bight (**Figure III.7a**).

Jack mackerel eggs were the most abundant of any CPS species and were present in the CUFES throughout most of the survey area. Jack mackerel eggs were most abundant in the offshore portion of transects between the Columbia River and Bodega Bay and south of Monterey Bay (**Figure III.7b**). Sardine eggs were observed in the CUFES south of the Columbia River off Oregon; between Cape Blanco and Crescent City, CA; and between Point Arena (north of Bodega Bay) and Monterey Bay (**Figure III.7b**). Anchovy eggs were present in the CUFES samples off the Columbia River, nearshore between Point Conception and Long Beach, CA, and to a lesser extent in the Gulf of the Farallones near San Francisco (**Figure III.7b**).

Jack mackerel comprised the greatest proportion of catch in trawl samples between Cape Flattery and Cape Mendocino, and along the central CA coast between San Francisco and Big Sur (south of Monterey Bay) (**Figure III.7c**). Pacific herring comprised the greatest proportion of catch in trawl samples in trawl samples in Canadian waters, and to a lesser extent in nearshore trawls between the Cape Flattery and the Columbia River (**Figure III.7c**). Anchovy were predominantly found in trawls conducted between Fort Bragg and Monterey, between Morro Bay and Point Conception, and near San Diego (**Figure III.7c**). The only trawl samples that contained sardine were collected near Newport, OR, Monterey, and San Diego. Overall, the 158 trawls captured a combined 3512 kg of CPS (442 kg sardine, 88 kg anchovy, 1957 kg jack mackerel, 63 kg Pacific mackerel, and 961 kg Pacific herring; **Appendix D**).

IV. Disposition of Data

Archived on the SWFSC data server are approximately 328 GB of raw EK60 data and 0.479 TB of raw ME70 data. 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).

V. Acknowledgements

We thank the crew members of FSV *Shimada*, as well as the scientists and technicians that participated in the sampling operations at sea. CPS-catch data were compiled by Bev Macewicz and CPS-egg data were compiled by Ed Weber. Critical reviews by **Reviewer A** and Gerard Dinardo improved this report.

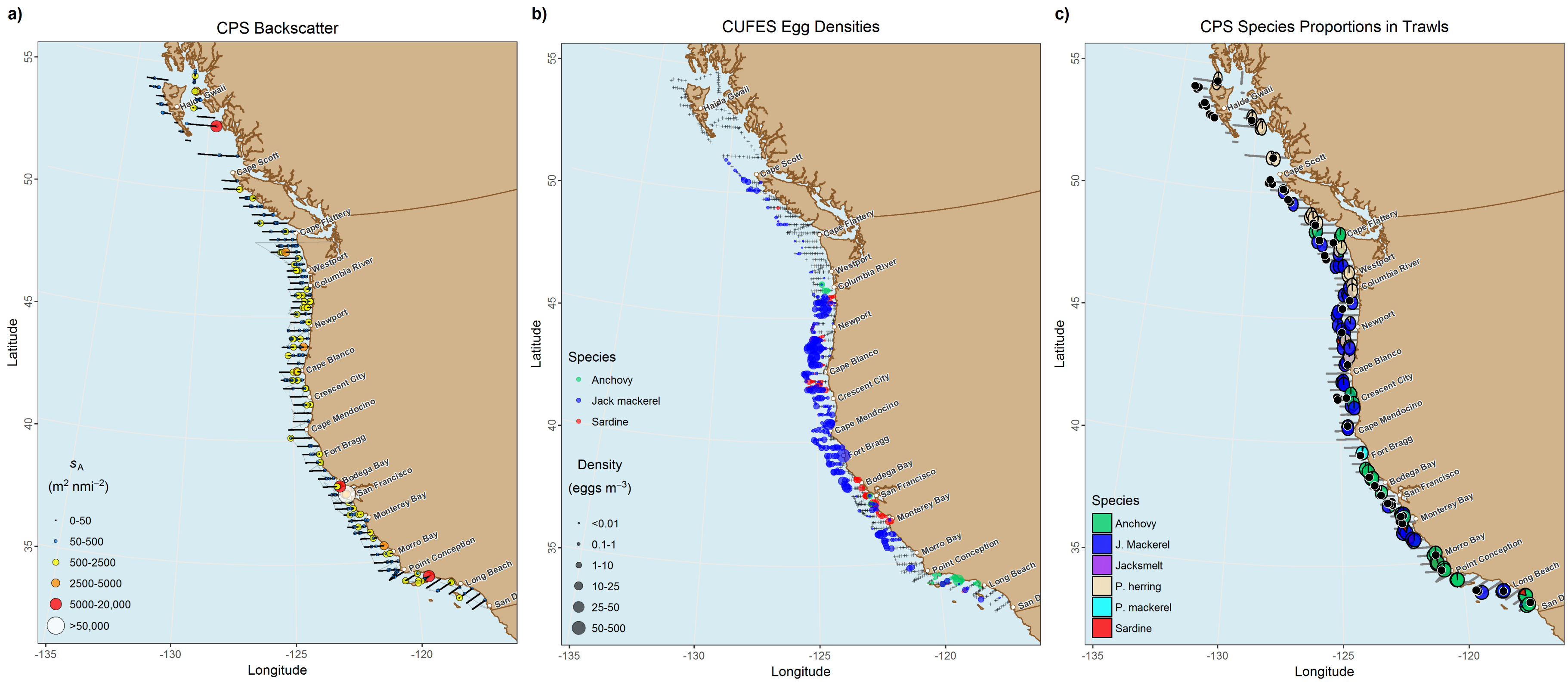

Figure III.7. Survey transects performed aboard *Shimada* overlaid with (a) the distribution of 38-kHz integrated backscattering coefficients (s_A, m^2 nmi^{-2}; averaged over 2000-m distance intervals and from 5- to 70-m deep) ascribed to CPS; (b) anchovy-, jack mackerel-, and sardine-egg densities (eggs m^{-3}) from the CUFES; and (c) proportions of CPS species in trawl clusters (black points indicate trawls with no CPS).

VI. Appendices

Appendix A. Centerboard positions

Transducer depths, associate with the centerboard position (retracted ~5-m, intermediate ~7-m, extended ~9-m) during the SaKe 2015 aboard *Shimada*.

Date	Position	Latitude	Longitude
06/20/2015 00:31	Intermediate (7 m)	32.63133	-117.2837
06/26/2015 22:06	Intermediate (7 m)	34.95050	-121.6900
07/08/2015 18:10	Intermediate (7 m)	37.75250	-122.6672
07/13/2015 16:13	Intermediate (7 m)	39.15967	-123.9762
07/16/2015 00:13	Extended (9 m)	40.45233	-125.2527
07/20/2015 02:56	Intermediate (7 m)	41.78183	-124.6800
08/05/2015 15:25	Retracted (5 m)	44.62633	-124.0483
08/05/2015 18:07	Intermediate (7 m)	44.59200	-124.1232
08/19/2015 12:34	Retracted (5 m)	47.62300	-122.3967
08/23/2015 15:15	Retracted (5 m)	47.62883	-122.3808
08/23/2015 19:33	Intermediate (7 m)	47.84433	-122.4570
08/28/2015 14:16	Extended (9 m)	49.78533	-127.8182
08/30/2015 20:42	Extended (9 m)	51.45283	-130.4925
08/31/2015 22:01	Intermediate (7 m)	51.43833	-128.2955

Appendix B. Impedance measurements

Transducer impedance magnitude ($|Z|$), phase (θ), conductance (G), susceptance (B), resistance (R), and reactance (X) measured at the operational frequencies with the transducer quadrants placed in parallel.

		Frequency (kHz)				
Measurement	Units	18	38	70	120	200
$\|Z\|$		17.66	18.19	23.92	20.65	24.72
θ	deg	-10.75	6.88	-1.03	14.21	-4.31
G	mS	55.64	54.59	41.75	46.94	40.35
B	mS	10.56	-6.59	0.71	-11.88	3.04
R		17.35	18.06	23.89	20.02	24.65
X		-3.29	2.18	-0.51	5.07	-1.86

Appendix C. CTD and UCTD sample summary

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

Date	Type	Latitude	Longitude
06/20/2015 03:19	CTD Cast	32.80517	-117.6333
06/21/2015 03:28	CTD Cast	33.24000	-117.5455
06/22/2015 03:28	CTD Cast	33.57367	-118.4302
06/22/2015 17:24	CTD Cast	33.86767	-118.6233
06/22/2015 18:09	CTD Cast	33.86033	-118.6337
06/22/2015 18:37	CTD Cast	33.86400	-118.6288
06/22/2015 19:17	CTD Cast	33.85483	-118.6488
06/23/2015 00:23	CTD Cast	33.76717	-118.8245
06/24/2015 03:21	CTD Cast	34.18700	-120.3518
06/25/2015 03:06	CTD Cast	34.61700	-120.7085
06/25/2015 13:49	CTD Cast	34.61717	-120.8127
06/25/2015 14:47	CTD Cast	34.61833	-120.8340
06/25/2015 16:16	CTD Cast	34.61833	-120.9513
06/25/2015 19:29	CTD Cast	34.62200	-121.4190
06/25/2015 21:24	CTD Cast	34.61867	-121.6188
06/26/2015 03:37	CTD Cast	34.95467	-120.9392
06/27/2015 03:38	CTD Cast	35.28533	-121.1072
06/28/2015 03:44	CTD Cast	35.95000	-121.8707
06/28/2015 04:57	CTD Cast	35.94933	-121.8913
06/28/2015 13:40	CTD Cast	35.94783	-121.7978
06/28/2015 15:19	CTD Cast	35.95567	-121.5945
06/28/2015 16:29	CTD Cast	35.94750	-121.5330
06/28/2015 17:05	CTD Cast	35.95200	-121.5238
06/29/2015 03:46	CTD Cast	36.25067	-122.3573
06/30/2015 03:48	CTD Cast	36.70183	-122.5233
07/01/2015 03:56	CTD Cast	36.95167	-122.3500
07/01/2015 14:04	CTD Cast	36.95167	-122.3740
07/01/2015 15:57	CTD Cast	36.95083	-122.5783
07/02/2015 03:46	CTD Cast	37.45017	-122.8038
07/02/2015 23:54	CTD Cast	38.11817	-123.0097
07/03/2015 01:49	CTD Cast	38.11817	-123.3238
07/03/2015 03:19	CTD Cast	38.11950	-123.4808
07/03/2015 13:35	CTD Cast	38.11800	-123.5135
07/03/2015 15:01	CTD Cast	38.11850	-123.5723
07/03/2015 15:58	CTD Cast	38.11883	-123.6050
07/09/2015 03:47	CTD Cast	36.95300	-122.3645
07/09/2015 19:33	UCTD Cast	37.20133	-122.6448
07/09/2015 21:50	UCTD Cast	37.20133	-122.8450
07/09/2015 22:20	UCTD Cast	37.20100	-122.9493
07/09/2015 23:22	UCTD Cast	37.20117	-123.1605
07/10/2015 02:25	UCTD Cast	37.44983	-123.0170
07/10/2015 04:04	CTD Cast	37.44817	-122.8350
07/10/2015 13:27	UCTD Cast	37.45083	-122.7032
07/10/2015 14:25	UCTD Cast	37.45067	-122.5133

(continued)

Date	Type	Latitude	Longitude
07/10/2015 22:09	UCTD Cast	37.78433	-123.2892
07/11/2015 01:14	UCTD Cast	37.78483	-123.0735
07/11/2015 02:13	UCTD Cast	37.78400	-122.8648
07/11/2015 05:48	CTD Cast	37.77767	-123.2010
07/11/2015 13:08	UCTD Cast	38.11767	-122.9853
07/11/2015 14:05	UCTD Cast	38.11750	-123.1983
07/11/2015 15:10	UCTD Cast	38.11683	-123.4162
07/11/2015 22:13	UCTD Cast	38.45083	-123.8468
07/11/2015 23:52	UCTD Cast	38.45167	-123.6395
07/12/2015 04:31	CTD Cast	38.45200	-123.4970
07/12/2015 13:15	UCTD Cast	38.45117	-123.3205
07/12/2015 17:43	UCTD Cast	38.78417	-123.6653
07/12/2015 17:43	UCTD Cast	38.78417	-123.6658
07/12/2015 18:43	UCTD Cast	38.78417	-123.8813
07/12/2015 19:45	UCTD Cast	38.78417	-124.0962
07/13/2015 02:26	UCTD Cast	39.11733	-123.8067
07/13/2015 02:39	UCTD Cast	39.11733	-123.8475
07/13/2015 03:20	CTD Cast	39.11850	-123.9363
07/13/2015 04:04	CTD Cast	39.11783	-123.9722
07/13/2015 13:47	CTD Cast	39.12017	-124.0185
07/13/2015 18:13	CTD Cast	39.10167	-124.2320
07/13/2015 22:37	UCTD Cast	39.45000	-124.4357
07/13/2015 23:37	UCTD Cast	39.44967	-124.2238
07/14/2015 05:18	CTD Cast	39.44950	-124.0125
07/14/2015 13:41	UCTD Cast	39.78333	-124.0092
07/14/2015 14:11	UCTD Cast	39.78383	-124.1170
07/15/2015 03:31	CTD Cast	40.11867	-124.4253
07/15/2015 13:15	UCTD Cast	40.11733	-124.3870
07/15/2015 13:47	UCTD Cast	40.11767	-124.2732
07/15/2015 17:56	CTD Cast	40.45017	-124.6088
07/15/2015 18:33	CTD Cast	40.45050	-124.6198
07/15/2015 19:15	CTD Cast	40.45167	-124.6292
07/15/2015 21:37	CTD Cast	40.44967	-124.8515
07/16/2015 04:09	CTD Cast	40.63017	-124.7198
07/16/2015 15:37	UCTD Cast	40.78333	-124.3238
07/16/2015 19:18	UCTD Cast	40.78483	-124.5395
07/17/2015 22:26	CTD Cast	41.11933	-124.5255
07/18/2015 02:14	CTD Cast	41.44950	-124.3687
07/18/2015 13:46	CTD Cast	41.45083	-124.2062
07/18/2015 14:25	UCTD Cast	41.45067	-124.3063
07/18/2015 15:33	CTD Cast	41.45567	-124.4617
07/18/2015 16:26	CTD Cast	41.45767	-124.5018
07/18/2015 16:26	CTD Cast	41.45783	-124.5018
07/18/2015 17:27	CTD Cast	41.45583	-124.5163
07/18/2015 19:21	CTD Cast	41.45883	-124.5838
07/18/2015 23:29	UCTD Cast	41.45017	-124.7472

(continued)

Date	Type	Latitude	Longitude
07/19/2015 01:13	CTD Cast	41.45183	-125.0148
07/19/2015 03:59	CTD Cast	41.78533	-125.1330
07/19/2015 13:44	UCTD Cast	41.78367	-124.9940
07/19/2015 18:02	UCTD Cast	41.78367	-124.7697
07/19/2015 19:08	UCTD Cast	41.78483	-124.5447
07/20/2015 03:10	CTD Cast	41.78067	-124.6832
07/20/2015 13:20	UCTD Cast	42.11800	-124.4347
07/20/2015 16:40	UCTD Cast	42.11683	-124.6603
07/21/2015 05:03	CTD Cast	42.34700	-124.8092
07/21/2015 14:08	UCTD Cast	42.45083	-124.6067
07/21/2015 14:57	CTD Cast	42.45483	-124.7417
07/21/2015 15:29	CTD Cast	42.45267	-124.7825
07/21/2015 16:09	CTD Cast	42.45350	-124.8328
07/22/2015 00:18	CTD Cast	42.45283	-125.0575
07/22/2015 03:12	CTD Cast	42.45183	-125.5720
07/22/2015 20:52	UCTD Cast	42.78400	-125.3458
07/22/2015 21:55	UCTD Cast	42.78383	-125.1230
07/22/2015 23:38	UCTD Cast	42.78450	-124.8932
07/22/2015 23:38	UCTD Cast	42.78450	-124.8927
07/23/2015 00:08	UCTD Cast	42.78400	-124.7837
07/23/2015 03:32	UCTD Cast	43.11750	-124.5527
07/23/2015 04:30	CTD Cast	43.11467	-124.7192
07/23/2015 13:45	UCTD Cast	43.11750	-124.7818
07/23/2015 16:21	UCTD Cast	43.11750	-124.9007
07/23/2015 17:25	UCTD Cast	43.11733	-125.1282
07/24/2015 01:50	UCTD Cast	43.44950	-124.9518
07/24/2015 02:52	UCTD Cast	43.45233	-124.7295
07/24/2015 03:22	UCTD Cast	43.45067	-124.6148
07/24/2015 04:04	CTD Cast	43.45350	-124.5098
07/24/2015 21:34	UCTD Cast	43.45050	-124.3803
07/25/2015 00:27	UCTD Cast	43.78300	-124.3200
07/25/2015 01:30	CTD Cast	43.78667	-124.5187
07/25/2015 02:22	CTD Cast	43.78500	-124.6203
07/25/2015 03:32	CTD Cast	43.78550	-124.7783
07/25/2015 18:54	CTD Cast	43.78500	-125.0133
08/05/2015 21:45	UCTD Cast	44.11783	-124.3140
08/05/2015 22:50	UCTD Cast	44.11750	-124.5627
08/05/2015 23:48	UCTD Cast	44.11733	-124.7758
08/06/2015 01:49	UCTD Cast	44.11700	-125.0058
08/06/2015 03:55	CTD Cast	44.19950	-124.8895
08/06/2015 18:14	UCTD Cast	44.23283	-124.7802
08/06/2015 19:18	UCTD Cast	44.29883	-124.5753
08/06/2015 20:19	UCTD Cast	44.36883	-124.3648
08/06/2015 20:34	UCTD Cast	44.38533	-124.3150
08/06/2015 22:32	UCTD Cast	44.45117	-124.3432
08/06/2015 23:37	UCTD Cast	44.45100	-124.5823

(continued)

Date	Type	Latitude	Longitude
08/07/2015 00:37	UCTD Cast	44.45050	-124.8112
08/07/2015 04:10	CTD Cast	44.38833	-124.8827
08/07/2015 13:26	UCTD Cast	44.45067	-124.9303
08/07/2015 17:37	CTD Cast	44.79000	-125.0795
08/07/2015 18:47	CTD Cast	44.78617	-125.0170
08/07/2015 19:45	UCTD Cast	44.78400	-124.9767
08/07/2015 20:48	CTD Cast	44.78500	-124.8725
08/08/2015 01:21	CTD Cast	44.78367	-124.6068
08/08/2015 06:58	CTD Cast	44.78033	-125.1080
08/08/2015 14:02	CTD Cast	44.78617	-124.4468
08/08/2015 15:59	CTD Cast	44.78283	-124.1542
08/08/2015 18:59	UCTD Cast	45.11767	-124.0725
08/08/2015 20:03	UCTD Cast	45.11767	-124.3182
08/09/2015 01:19	UCTD Cast	45.11750	-124.5397
08/09/2015 01:50	UCTD Cast	45.11733	-124.6553
08/09/2015 02:23	UCTD Cast	45.11767	-124.7743
08/09/2015 04:05	CTD Cast	45.11550	-125.0868
08/09/2015 14:16	UCTD Cast	45.36750	-124.8217
08/09/2015 18:40	UCTD Cast	45.36667	-124.3913
08/09/2015 22:42	UCTD Cast	45.61833	-124.1700
08/10/2015 01:52	UCTD Cast	45.61733	-124.4035
08/10/2015 02:24	UCTD Cast	45.61767	-124.5257
08/10/2015 02:57	UCTD Cast	45.61783	-124.6488
08/10/2015 03:57	CTD Cast	45.61833	-124.7665
08/10/2015 15:07	UCTD Cast	45.67400	-124.7490
08/10/2015 18:03	UCTD Cast	45.69983	-124.6375
08/10/2015 18:34	UCTD Cast	45.73117	-124.5278
08/10/2015 19:02	UCTD Cast	45.75667	-124.4280
08/10/2015 20:04	UCTD Cast	45.81367	-124.2027
08/10/2015 20:18	UCTD Cast	45.82683	-124.1507
08/10/2015 21:43	UCTD Cast	45.86750	-124.1742
08/10/2015 22:56	CTD Cast	45.87617	-124.4038
08/10/2015 23:47	UCTD Cast	45.86800	-124.5322
08/11/2015 00:42	UCTD Cast	45.86800	-124.6558
08/11/2015 01:16	CTD Cast	45.86767	-124.7245
08/11/2015 13:41	CTD Cast	45.86950	-124.7728
08/11/2015 16:01	CTD Cast	45.86717	-125.0143
08/11/2015 18:59	UCTD Cast	46.11683	-124.9748
08/11/2015 20:01	UCTD Cast	46.11767	-124.7330
08/12/2015 00:34	UCTD Cast	46.11750	-124.6175
08/12/2015 01:37	UCTD Cast	46.11750	-124.3712
08/12/2015 02:37	UCTD Cast	46.11667	-124.1335
08/12/2015 04:09	CTD Cast	46.07217	-124.2565
08/12/2015 14:13	UCTD Cast	46.36733	-124.3817
08/12/2015 18:41	UCTD Cast	46.36733	-124.8628
08/12/2015 22:15	UCTD Cast	46.61650	-124.9413
08/12/2015 23:27	UCTD Cast	46.61683	-124.6483

(continued)

Date	Type	Latitude	Longitude
08/13/2015 05:09	CTD Cast	46.68533	-124.4877
08/13/2015 13:28	UCTD Cast	46.86750	-124.3245
08/13/2015 14:30	UCTD Cast	46.86650	-124.5698
08/13/2015 15:27	CTD Cast	46.86517	-124.7623
08/13/2015 18:49	UCTD Cast	46.86817	-124.9345
08/13/2015 20:57	CTD Cast	46.87083	-125.1698
08/13/2015 21:50	UCTD Cast	46.87733	-125.2277
08/13/2015 22:52	UCTD Cast	46.93683	-124.9927
08/14/2015 01:54	UCTD Cast	46.96600	-124.8838
08/14/2015 02:55	UCTD Cast	47.02317	-124.6552
08/14/2015 04:37	CTD Cast	47.03983	-124.7140
08/14/2015 14:06	UCTD Cast	47.11750	-124.9925
08/14/2015 15:07	UCTD Cast	47.11800	-124.7492
08/14/2015 15:21	UCTD Cast	47.11717	-124.6927
08/14/2015 18:22	UCTD Cast	47.11800	-124.5035
08/14/2015 22:19	UCTD Cast	47.36717	-124.7923
08/15/2015 01:13	UCTD Cast	47.36750	-125.0380
08/15/2015 02:12	UCTD Cast	47.36717	-125.2812
08/15/2015 03:58	CTD Cast	47.34200	-125.6118
08/15/2015 14:19	UCTD Cast	47.61733	-125.8703
08/15/2015 15:20	UCTD Cast	47.61733	-125.6250
08/15/2015 16:42	CTD Cast	47.62183	-125.3822
08/15/2015 18:21	CTD Cast	47.62117	-125.1302
08/15/2015 19:04	CTD Cast	47.61833	-125.0913
08/16/2015 01:26	CTD Cast	47.61850	-124.9637
08/16/2015 02:29	UCTD Cast	47.61800	-124.7548
08/16/2015 05:25	CTD Cast	47.54650	-124.9617
08/16/2015 14:55	CTD Cast	47.86583	-124.9138
08/16/2015 18:21	UCTD Cast	47.86767	-125.2253
08/17/2015 01:16	UCTD Cast	47.86750	-125.4715
08/17/2015 02:55	CTD Cast	47.86500	-125.8177
08/17/2015 13:57	UCTD Cast	48.11733	-126.0315
08/17/2015 14:58	UCTD Cast	48.11600	-125.7823
08/17/2015 17:54	UCTD Cast	48.11733	-125.6562
08/17/2015 19:16	UCTD Cast	48.11800	-125.4083
08/17/2015 20:16	UCTD Cast	48.11817	-125.1573
08/17/2015 21:17	UCTD Cast	48.11717	-124.9097
08/18/2015 04:04	CTD Cast	48.05033	-124.8952
08/24/2015 05:44	CTD Cast	48.41833	-124.8175
08/24/2015 14:18	UCTD Cast	48.45067	-124.9480
08/24/2015 15:13	UCTD Cast	48.45117	-125.1822
08/24/2015 18:18	UCTD Cast	48.45083	-125.4363
08/24/2015 19:19	UCTD Cast	48.45100	-125.6908
08/24/2015 20:19	UCTD Cast	48.45083	-125.9427
08/24/2015 20:49	UCTD Cast	48.45100	-126.0692
08/24/2015 23:45	UCTD Cast	48.45117	-126.2058
08/25/2015 02:03	UCTD Cast	48.48733	-126.4357

(continued)

Date	Type	Latitude	Longitude
08/25/2015 03:03	UCTD Cast	48.54617	-126.1955
08/25/2015 03:47	CTD Cast	48.56200	-126.1102
08/25/2015 17:46	UCTD Cast	48.63250	-125.8517
08/25/2015 18:56	UCTD Cast	48.69433	-125.5915
08/25/2015 22:20	UCTD Cast	48.74750	-125.3800
08/26/2015 00:18	UCTD Cast	48.78350	-125.5692
08/26/2015 02:17	UCTD Cast	48.78383	-126.0705
08/26/2015 03:40	CTD Cast	48.78417	-126.3278
08/26/2015 14:47	UCTD Cast	48.78400	-126.5905
08/26/2015 22:27	UCTD Cast	49.11767	-126.9217
08/27/2015 01:59	UCTD Cast	49.11800	-126.4898
08/27/2015 04:41	CTD Cast	49.13250	-126.4353
08/27/2015 18:28	UCTD Cast	49.45117	-126.6123
08/27/2015 19:49	UCTD Cast	49.45117	-126.8822
08/27/2015 21:07	CTD Cast	49.45200	-127.1247
08/27/2015 22:49	CTD Cast	49.45233	-127.2515
08/28/2015 02:12	CTD Cast	49.44983	-127.5148
08/28/2015 03:29	CTD Cast	49.45550	-127.6865
08/28/2015 13:53	UCTD Cast	49.78467	-127.9147
08/28/2015 14:53	UCTD Cast	49.78417	-127.6590
08/28/2015 23:28	UCTD Cast	50.11800	-128.0463
08/29/2015 03:51	CTD Cast	50.12150	-128.1455
08/29/2015 15:23	UCTD Cast	50.11767	-128.3058
08/29/2015 16:23	UCTD Cast	50.11800	-128.5657
08/29/2015 16:25	UCTD Cast	50.11817	-128.5728
08/29/2015 18:03	UCTD Cast	50.16100	-128.7613
08/29/2015 19:04	UCTD Cast	50.25583	-128.5427
08/29/2015 20:07	UCTD Cast	50.35167	-128.3180
08/30/2015 00:49	UCTD Cast	50.45083	-128.4162
08/30/2015 01:22	UCTD Cast	50.45050	-128.5557
08/30/2015 02:19	UCTD Cast	50.45017	-128.8023
08/30/2015 03:39	CTD Cast	50.44617	-129.0135
08/31/2015 03:41	CTD Cast	51.44917	-128.8407
08/31/2015 17:04	UCTD Cast	51.45100	-128.6360
08/31/2015 18:19	UCTD Cast	51.45300	-128.2950
08/31/2015 18:21	UCTD Cast	51.45300	-128.2863
09/01/2015 05:31	CTD Cast	52.62533	-129.6703
09/01/2015 19:32	UCTD Cast	52.61750	-130.4367
09/01/2015 21:10	UCTD Cast	52.61850	-130.8220
09/02/2015 03:42	CTD Cast	52.95017	-130.4167
09/02/2015 14:47	UCTD Cast	52.95167	-130.1940
09/02/2015 17:52	UCTD Cast	52.95150	-129.9282
09/02/2015 22:49	UCTD Cast	53.28350	-130.7207
09/03/2015 04:12	CTD Cast	53.61550	-130.7632
09/03/2015 17:14	UCTD Cast	54.39950	-131.1478
09/03/2015 20:23	UCTD Cast	54.53933	-131.1473

(continued)

Date	Type	Latitude	Longitude
09/03/2015 21:16	UCTD Cast	54.68317	-131.1483
09/04/2015 04:18	CTD Cast	54.28750	-132.8650
09/04/2015 15:04	UCTD Cast	54.28433	-133.1537
09/04/2015 17:45	UCTD Cast	54.28417	-133.3888
09/04/2015 21:22	UCTD Cast	54.28417	-133.6498
09/04/2015 22:04	UCTD Cast	54.28350	-133.8488
09/05/2015 04:17	CTD Cast	53.95267	-133.9878
09/05/2015 15:07	UCTD Cast	53.95083	-133.8012
09/05/2015 19:58	CTD Cast	53.61800	-133.1940
09/05/2015 20:19	CTD Cast	53.61817	-133.1913
09/06/2015 04:08	CTD Cast	53.28067	-133.3682
09/06/2015 15:40	CTD Cast	53.28533	-133.0753
09/06/2015 23:14	CTD Cast	52.94717	-132.5023
09/07/2015 03:36	CTD Cast	52.95217	-132.9615
09/07/2015 18:13	CTD Cast	52.28550	-131.5523
09/08/2015 00:03	CTD Cast	51.94500	-131.2625

Appendix D. Trawl sample summary

Date, time, and location at the start of trawling (i.e., at net equilibrium), and biomasses (kg) of CPS species collected in each trawl. The duration of each trawl set was nominally 45 min.

Haul	Date	Latitude	Longitude	Anchovy	Sardine	P. mackerel	J. mackerel	P. herring	All CPS
1	06/19/2015 21:56	32.847	-117.553	0.157			0.058		0.214
2	06/20/2015 00:35	32.893	-117.465	0.010					0.010
3	06/20/2015 02:49	32.945	-117.392						
4	06/20/2015 21:25	33.249	-117.531	0.036	0.008				0.044
5	06/20/2015 23:24	33.272	-117.558	2.906			0.007		2.913
6	06/21/2015 01:32	33.240	-117.569	9.057					9.057
7	06/21/2015 21:10	33.580	-118.407				0.048		0.048
8	06/21/2015 23:31	33.546	-118.408						
9	06/22/2015 01:34	33.544	-118.445	0.006					0.006
10	06/22/2015 20:48	33.600	-119.303				0.071		0.071
11	06/22/2015 22:56	33.650	-119.444						
12	06/23/2015 01:21	33.710	-119.522						
13	06/23/2015 21:13	34.215	-120.274	2.366					2.366
14	06/23/2015 23:40	34.211	-120.237	0.459	0.003				0.462
15	06/24/2015 02:04	34.197	-120.251	20.552	0.004				20.555
16	06/24/2015 20:27	34.644	-120.746	0.000					0.000
17	06/24/2015 22:43	34.649	-120.861						
18	06/25/2015 01:20	34.732	-120.760	0.122					0.122
19	06/25/2015 21:13	34.961	-120.996	30.669	1.280				31.950
20	06/25/2015 23:29	35.022	-121.040	0.065					0.065
21	06/26/2015 01:54	34.926	-121.034		0.021				0.021
22	06/26/2015 21:10	35.280	-121.142	0.122	0.014				0.136
23	06/26/2015 23:25	35.362	-121.058	0.001					0.001
24	06/27/2015 01:42	35.273	-121.052						
25	06/27/2015 21:18	35.954	-121.904				133.400		133.400
26	06/27/2015 23:38	35.999	-122.009				0.006		0.006
27	06/28/2015 01:54	35.894	-121.951	0.014	0.008		0.002		0.026
28	06/28/2015 21:26	36.245	-122.377	0.002			1.443		1.446
29	06/28/2015 23:55	36.382	-122.316	0.109			0.122		0.231
30	06/29/2015 02:13	36.275	-122.236	0.001	0.002		0.020		0.024

(continued)

Haul	Date	Latitude	Longitude	Anchovy	Sardine	P. mackerel	J. mackerel	P. herring	All CPS
31	06/29/2015 21:07	36.710	-122.509						
32	06/29/2015 23:33	36.763	-122.388	0.004			0.198		0.202
33	06/30/2015 01:57	36.639	-122.389						
34	06/30/2015 21:35	36.953	-122.326						
35	06/30/2015 23:58	37.022	-122.312	0.000			0.122		0.122
36	07/01/2015 02:21	36.906	-122.295	0.004					0.004
37	07/01/2015 21:02	37.443	-122.823						
38	07/01/2015 23:23	37.535	-122.784						
39	07/02/2015 02:03	37.395	-122.774						
40	07/02/2015 21:09	38.124	-123.445						
41	07/02/2015 23:28	38.218	-123.522						
42	07/08/2015 21:52	36.959	-122.389	3.043	0.030		0.020		3.093
43	07/09/2015 00:23	37.032	-122.413	17.800	0.377		1.162		19.340
44	07/09/2015 03:00	36.922	-122.428						
45	07/09/2015 21:44	37.450	-122.879						
46	07/10/2015 00:14	37.373	-122.945	0.016	0.005		0.014		0.034
47	07/10/2015 02:40	37.479	-122.969						
48	07/10/2015 23:23	37.817	-123.248						
49	07/11/2015 01:37	37.934	-123.230	0.020	0.001				0.022
50	07/11/2015 22:11	38.526	-123.595	0.057	0.002				0.059
51	07/12/2015 00:19	38.564	-123.748						
52	07/12/2015 02:18	38.506	-123.660	0.051					0.051
53	07/12/2015 23:40	38.796	-123.784	0.004					0.004
54	07/13/2015 01:53	38.903	-123.896	0.003					0.003
55	07/13/2015 23:06	39.447	-124.113						
56	07/14/2015 01:22	39.553	-124.035	0.001		1.153	0.035		1.189
57	07/15/2015 22:02	40.555	-124.663				49.700		49.700
58	07/16/2015 00:20	40.652	-124.678						
59	07/16/2015 02:36	40.630	-124.669				2.783		2.783
60	07/17/2015 20:52	41.564	-124.380	0.000					0.000
61	07/17/2015 23:32	41.466	-124.490				46.959		46.959
62	07/18/2015 02:21	41.372	-124.346				16.380		16.380
63	07/18/2015 22:00	41.762	-125.043						

(continued)

Haul	Date	Latitude	Longitude	Anchovy	Sardine	P. mackerel	J. mackerel	P. herring	All CPS
64	07/19/2015 00:03	41.816	-125.161						
65	07/19/2015 03:21	41.711	-125.117						
66	07/19/2015 21:00	41.776	-124.704						
67	07/19/2015 23:08	41.812	-124.545				32.750		32.750
68	07/20/2015 01:50	41.946	-124.497	0.001					0.001
69	07/20/2015 22:31	42.347	-124.832		1.051	14.014	746.871		761.936
70	07/21/2015 02:25	42.339	-124.829				119.219		119.219
71	07/21/2015 23:43	42.471	-124.856				30.673		30.673
72	07/22/2015 02:23	42.428	-124.927				1.562		1.562
73	07/22/2015 22:12	43.135	-124.766		1.470		18.050		19.519
74	07/23/2015 00:48	43.218	-124.690	0.002	2.031		95.908		97.941
75	07/23/2015 03:12	43.116	-124.609						
76	07/23/2015 21:40	43.459	-124.554	0.002	0.457		4.826		5.285
77	07/24/2015 00:03	43.503	-124.558	0.004			8.400	1.400	9.805
78	07/24/2015 02:27	43.451	-124.529	0.002				0.100	0.102
79	07/24/2015 21:27	43.805	-124.842				9.714		9.714
80	07/25/2015 00:37	43.848	-124.524		2.410	15.452	6.367	157.550	181.779
81	07/25/2015 03:07	43.786	-124.496				10.600	0.098	10.698
82	07/25/2015 23:04	44.259	-124.787		4.782	6.449	62.180		73.411
83	07/26/2015 00:21	44.352	-124.801	0.002					0.002
85	08/06/2015 00:57	44.097	-124.703					6.300	6.300
86	08/06/2015 03:16	44.110	-124.856		428.091	24.047	9.887	26.700	488.726
87	08/06/2015 22:28	44.439	-124.719	0.136		0.102	158.486	2.500	161.224
88	08/07/2015 01:03	44.423	-124.885						
89	08/07/2015 03:02	44.547	-124.897				3.400		3.400
90	08/07/2015 21:40	44.725	-125.078				14.300		14.300
91	08/08/2015 03:27	44.786	-124.446				1.500	0.150	1.650
92	08/08/2015 21:46	45.127	-125.135				67.600		67.600
93	08/09/2015 00:16	45.257	-125.069				25.850		25.850
94	08/09/2015 03:09	45.368	-124.823						
95	08/09/2015 23:07	45.625	-124.307	0.032		1.730	43.579	0.187	45.528
96	08/10/2015 01:47	45.698	-124.443						
97	08/10/2015 21:43	45.933	-124.764				64.850		64.850

(continued)

Haul	Date	Latitude	Longitude	Anchovy	Sardine	P. mackerel	J. mackerel	P. herring	All CPS
98	08/11/2015 00:48	45.878	-124.533				52.050	7.850	59.900
99	08/11/2015 03:08	45.976	-124.581				3.450	0.430	3.880
100	08/11/2015 21:23	46.105	-124.290					1.900	1.900
101	08/11/2015 23:27	46.246	-124.474		0.066		13.029	1.750	14.844
102	08/12/2015 01:51	46.334	-124.307	0.026				19.500	19.526
103	08/12/2015 22:34	46.741	-124.541	0.140				14.900	15.040
104	08/13/2015 01:17	46.833	-124.435	0.026				8.400	8.426
105	08/13/2015 22:02	47.088	-124.754				3.462	0.100	3.562
106	08/14/2015 00:29	47.127	-125.013				0.882		0.882
107	08/14/2015 03:11	47.084	-125.173				2.293		2.293
108	08/14/2015 21:31	47.366	-125.664						
109	08/14/2015 23:44	47.528	-125.754						
111	08/15/2015 22:59	47.574	-125.007				0.004		0.004
112	08/16/2015 01:09	47.742	-124.965	0.201				0.200	0.401
113	08/16/2015 03:16	47.857	-124.830					0.450	0.450
114	08/16/2015 20:50	47.957	-125.888				0.198		0.198
115	08/16/2015 23:11	48.139	-126.033						
116	08/17/2015 01:39	48.093	-126.177				48.550		48.550
117	08/17/2015 21:17	48.082	-124.928					1.750	1.750
118	08/17/2015 23:09	48.145	-124.936					15.550	15.550
119	08/18/2015 01:48	48.042	-125.269						
120	08/24/2015 00:02	48.379	-124.862	0.036					0.036
121	08/24/2015 02:38	48.296	-124.926	0.212				0.044	0.257
122	08/24/2015 21:30	48.570	-126.175				16.100	13.200	29.300
123	08/25/2015 00:05	48.519	-126.148	0.001					0.001
124	08/25/2015 02:33	48.485	-126.327	0.000					0.000
125	08/25/2015 21:25	48.836	-126.384						
126	08/25/2015 23:44	48.752	-126.274						
127	08/26/2015 03:02	48.845	-126.133	0.001				0.065	0.066
128	08/26/2015 22:02	49.182	-126.501					31.850	31.850
129	08/27/2015 00:18	49.069	-126.602				0.100	561.350	561.450
130	08/27/2015 02:50	49.047	-126.404					6.400	6.400
131	08/27/2015 21:43	49.581	-127.545				25.910		25.910

(continued)

Haul	Date	Latitude	Longitude	Anchovy	Sardine	P. mackerel	J. mackerel	P. herring	All CPS
132	08/28/2015 00:49	49.663	-127.730						
133	08/28/2015 03:13	49.759	-127.852						
134	08/28/2015 21:11	50.079	-128.156				1.700		1.700
135	08/28/2015 23:30	50.102	-128.023						
136	08/29/2015 01:58	50.164	-128.148						
137	08/29/2015 21:07	50.393	-129.026						
138	08/30/2015 00:14	50.362	-128.797						
139	08/30/2015 03:15	50.516	-128.923						
140	08/30/2015 21:09	51.409	-128.966					0.600	0.600
141	08/30/2015 23:26	51.403	-128.837						
142	08/31/2015 01:43	51.371	-128.691					0.350	0.350
143	08/31/2015 22:56	52.593	-129.768					2.200	2.200
144	09/01/2015 01:16	52.680	-129.716					8.750	8.750
145	09/01/2015 03:22	52.583	-129.618					18.550	18.550
146	09/01/2015 21:08	53.015	-130.335					0.250	0.250
147	09/01/2015 23:12	52.944	-130.261					0.092	0.092
148	09/02/2015 01:23	52.867	-130.301						
149	09/03/2015 22:23	54.241	-132.730					48.550	48.550
150	09/04/2015 01:14	54.400	-132.698					1.350	1.350
151	09/04/2015 03:26	54.310	-132.667						
152	09/04/2015 21:43	53.886	-133.942						
153	09/04/2015 23:58	53.970	-133.839						
154	09/05/2015 02:36	54.004	-134.079						
155	09/05/2015 21:41	53.278	-133.473						
156	09/06/2015 00:40	53.249	-133.193						
157	09/06/2015 03:08	53.378	-133.325						
158	09/06/2015 21:20	52.939	-132.943						
159	09/06/2015 23:31	52.895	-132.795						
160	09/07/2015 01:48	52.824	-132.617						

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