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NOAA Technical Memorandum NMFS

JULY 2017

REPORT ON THE COLLECTION OF DATA DURING THE ACOUSTIC-TRAWL AND DAILY EGG PRODUCTION METHODS SURVEY OF COASTAL PELAGIC FISH SPECIES AND KRILL (1504SH) WITHIN THE CALIFORNIA CURRENT ECOSYSTEM, 28 MARCH TO 1 MAY 2015, CONDUCTED ABOARD FISHERIES SURVEY VESSEL *BELL M. SHIMADA*

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U.S. DEPARTMENT OF COMMERCE
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Southwest Fisheries Science Center

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U.S. DEPARTMENT OF COMMERCE
Wilbur L. Ross, Secretary of Commerce

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National Marine Fisheries Service
Chris Oliver, Assistant Administrator for Fisheries

I. Introduction

Coastal pelagic fish species (CPS), krill, and their environment within the California Current Ecosystem (CCE) were sampled using multi-frequency echosounders, surface trawls, vertically integrated net tows, continuous underway fish-egg samples (CUFES), and vertical CTD casts, and assessed using Acoustic-Trawl Method (ATM) and Daily Egg Production Method (DEPM) during the Spring CPS Survey (1504SH) aboard the Fisheries Survey Vessel (FSV) *Bell M. Shimada* (hereafter, *Shimada*), 28 March to 1 May 2015. The objectives of the survey were to: 1) acoustically map the distributions and estimate the abundances of CPS, including, but not limited to 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 the biotic and abiotic environments of these species, and investigate linkages; and 3) gather information regarding the animals' life history parameters.

This report provides an overview of the survey objectives and includes a summary of the survey equipment, acoustic-system calibration, sampling and analysis methods, and preliminary results. The acoustic-trawl estimate of the northern-stock Pacific sardine biomass from this survey was published by Zwolinski et al. (2016). Final biomass and abundance estimates for other CPS and krill will be reported separately.

I.1 Scientific Personnel

As elaborated below, the collection and analysis of acoustic data was conducted by the Advanced Survey Technologies Program (AST) at the Southwest Fisheries Science Center (SWFSC); and fish-egg and trawl data, provided by E. Weber and B. Macewicz (both from SWFSC), were collected by the SWFSC Trawl Sampling Group.

Project Leads:

- D. Demer (AST Leader)
- K. Stierhoff (Project Leader)

Acoustic Data Collection and Processing:

- K. Stierhoff (Leg I, Acoustician)
- J. Zwolinski (Leg II, Acoustician)

Echosounder Calibration:

- J. Renfree, K. Stierhoff, and J. Zwolinski

Trawl Sampling:

- C. Alvarez-Malo, K. Gilmore, D. Griffith, M. Human, B. Macewicz, S. McClatchie, B. Overcash, W. Watson, and E. Weber

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). During summer, the stock typically migrates north, compresses along the coast, and feeds in the upwelled regions (**Figure II.1**).

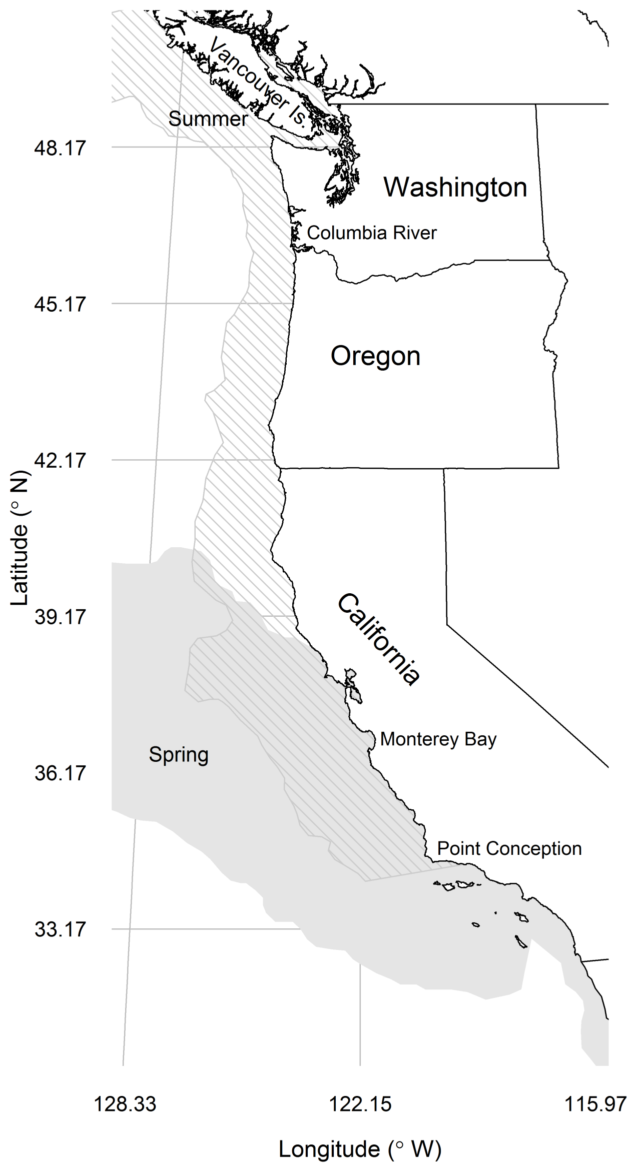

Figure II.1. Conceptual map showing the average seasonal distributions of Pacific sardine habitat during spring and summer along the west coasts of Mexico, the United States, and Canada (Zwolinski *et al.*, 2012). The distribution of potential habitat and catch information from the fishing industry are considered in the sampling design.

During spring 2015, part of the west coast of the United States was surveyed during the peak of the sardine spawning season, using *Shimada*. Transect spacings and lenghts were adjusted according to the distribution of potential habitat for the northern stock of sardine at the time of the survey (**Figure II.2**; http://swfscdata.nmfs.noaa.gov/AST/sardineHabitat/habitat.asp). Due to warm conditions in the northeast Pacific Ocean during spring 2015, the sardine potential habitat extended unseasonably farther north than usual so the survey area was extended accordingly. Transects were placed nearly perpindicular to the coast, between approximately Newport, OR and San Diego, CA, with nominal separations of 20 nmi and lengths of 80 nmi (**Figure II.3**). Compulsory acoustic sampling commenced along transects spaced 40-nmi apart, beginning along the transect ca. 40-nmi south of the northern extent of the potential sardine habitat. If CPS eggs were present in CUFES samples, CPS adults were present in trawl samples, or putative CPS targets were observed in echograms, adaptive sampling was initiated along transects spaced 20-nmi apart. Once initiated, a minimum of six consecutive adaptive transects were conducted to form a cluster until no indication of CPS were present in CUFES samples, trawl samples, or echograms, after which acoustic sampling resumed along compulsory transects spaced 40-nmi apart. Compulsory and adaptive transects were extended to ca. 120 nmi offshore in the event that CPS or their habitat was present near the offshore extent of the planned 80 nmi-long transects (**Figure II.3**).

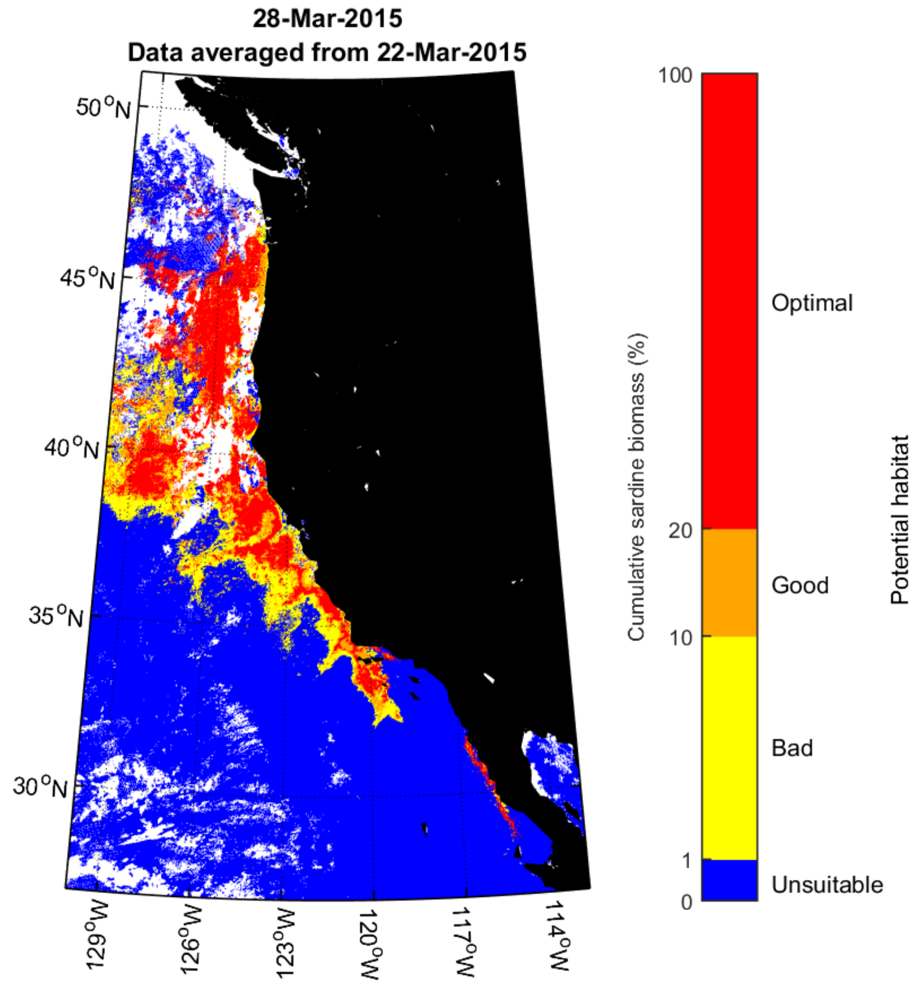

Figure II.2. Distribution of potential habitat for the northern stock of Pacific sardine on 28 March 2015 at the beginning of the Spring CPS Survey.

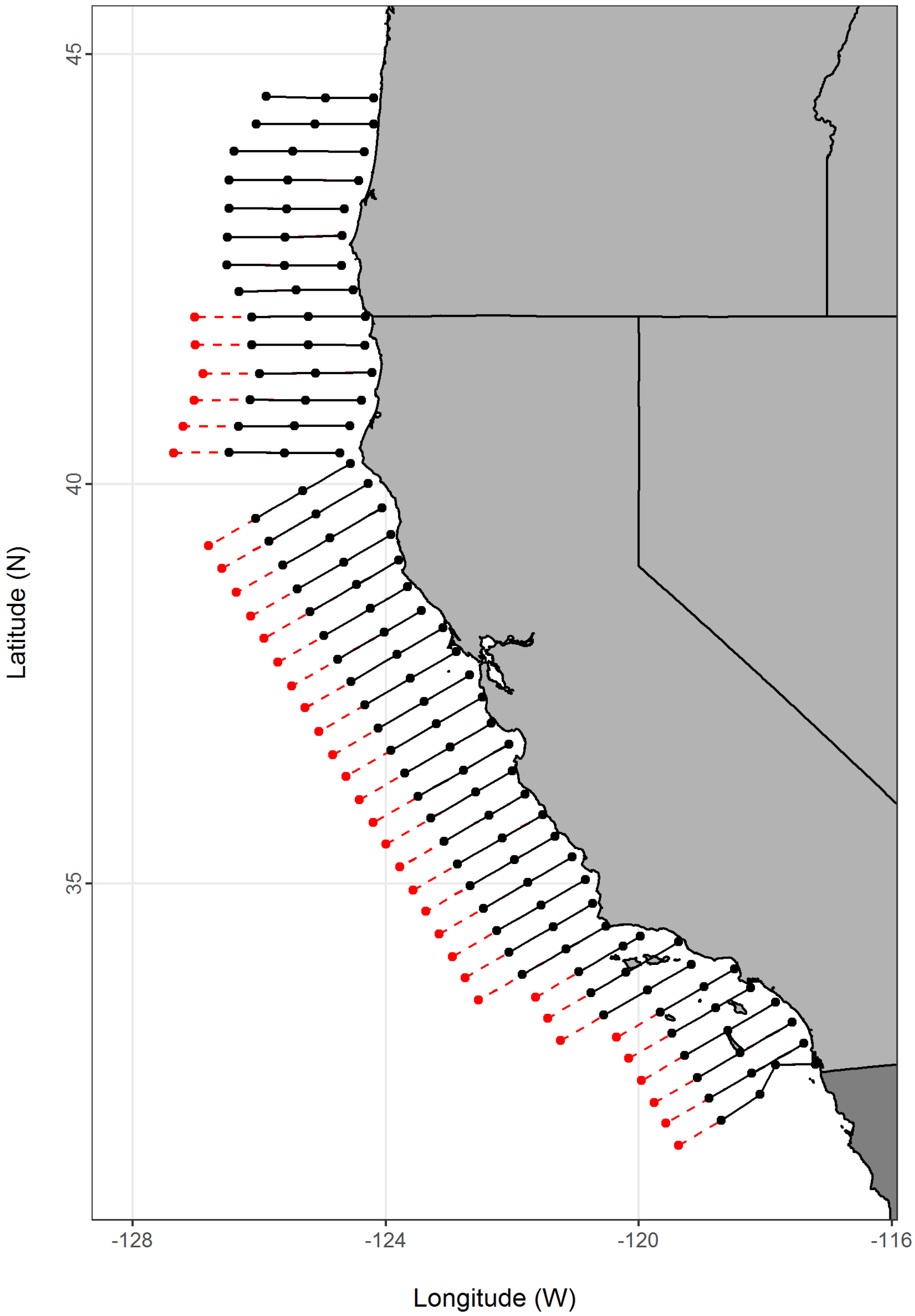

Figure II.3. Planned 80 nmi-long acoustic transects spaced 20-nmi apart (solid, black lines) between Newport, OR and San Diego, CA. Planned transects were extended to 120-nmi offshore (dashed, red line) in the event that CPS or their habitat was present near the offshore extent of the 80-nmi transects. Dots indicate the locations of fixed stationary sampling stations.

II.2 Acoustic sampling

II.2.1 Echosounders

Multi-frequency (18-, 38-, 70-, 120-, and 200-kHz) General Purpose Transceivers (Simrad EK60 GPTs), 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 (~ 5-m depth) during calibration, and extended to the intermediate position (~7-m depth) during the survey. Exceptions were made during shallow water operations, when the keel was retracted to ~ 5-m depth; or during times of heavy weather, when the keel was extended to ~9-m depth to provide extra stability and reduce the effect of weather-generated noise.

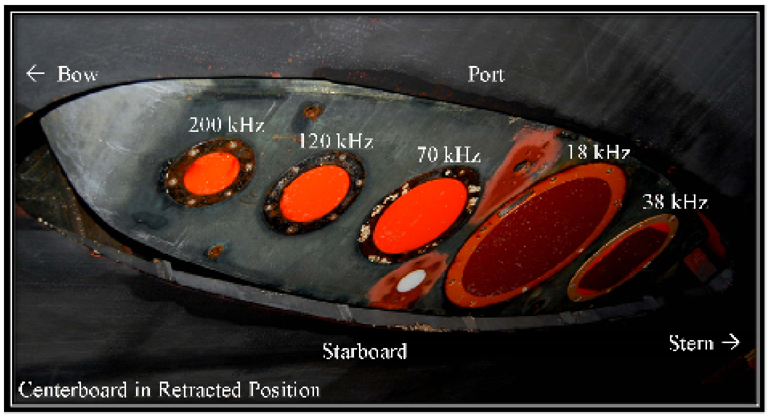

Figure II.4. Transducer locations on the bottom of the centerboard aboard *Shimada*.

II.2.2 Calibration

Prior to calibration, the integrity of the hardware was verified by impedance measurements of each transducer quadrant, individually and connected in parallel, using an Agilent 4294A Precision Impedance Analyzer and custom Matlab software. For each transducer, the magnitude (Z, Ω) and phase (θ, °) of the impedance, conductance (G, mS), susceptance (B, mS), and admittance circles (G vs. B) were plotted for each quadrant and for the quadrants in parallel. Also, the resonance frequency and quality factor were measured, and G, B, Z, and θ were measured at both the resonance and operational frequencies.

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 (AST sphere #6).

The GPTs were configured, via the ER60 software, using the parameters in **Appendix A**.

II.2.3. Data collection

The logging-computer clock was synchronized with the GPS clock (GMT) 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 avoiding 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^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 .raw format (50-MB maximum file size; each filename begins with "1504SH_" and ends with the logging commencement date and time) using the GPT-control software (Simrad ER60 V2.4.3). Changes to the nominal transducer depth (~5 m) are indicated in **Appendix B**. Using SyncBack Free (2BrightSparks Pte. Ltd.), backups of all raw and processed sampling data were archived to a laptop computer and external hard disk drive at least daily.

To minimize acoustic interference, transmit pulses from a multibeam sonar (Simrad ME70) were triggered by the echosounder. 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 captain occasionally operated the bridge echosounder (50- and 200-kHz Furuno), the Doppler velocity log, 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, Myriax) 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 simulated background noise from the raw S_v in the linear domain, were smoothed by computing the median value in non-overlapping 11-sample by 3-ping cell (**Figure II.5b**).
    - The smoothed, noise-reduced echograms were used to calculate S_v-differences using the 38-kHz echogram 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 was approaching or departing 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 (SD) 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 sardine 20 cm in length) 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 dead-zone height was estimated using the variance-to-mean ratio (VMR) (Demer *et al.*, 2009).
    - An "integration stop"" line was created at 250-m depth or, when shallower, 3 m above the estimated dead-zone height
    - 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.

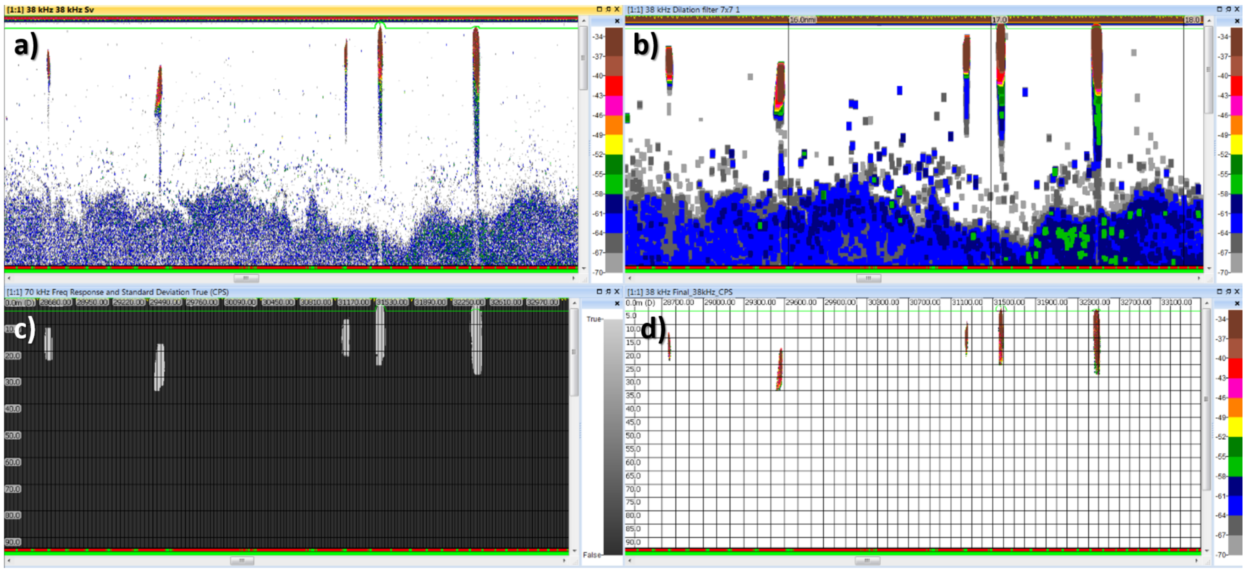

Figure II.5 Synchronized echograms of 38 kHz S_v after a) noise-subtraction, b) median smoothing, c) CPS masking, and d) final CPS-only 38 kHz S_v thresholding at -60 dB.

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 and McGowan, 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 species and their sizes was performed at night.

The net, a Nordic 264 rope trawl (NET Systems; Bainbridge Island, WA), has a square opening of 600 m^2, variable-size 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 where 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 from each of the target species were selected randomly. Those were weighed (g) and measured to either their standard length (L_s; mm) for sardine, northern anchovy, and herring, or fork length (L_f; mm) for jack mackerel and Pacific mackerel. 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 CUFES, CalBOBL, and Pairovet

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. All fish eggs were identified to lowest taxa, 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 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.

CalCOFI Bongo Oblique (CalBOBL, or bongo) nets (71-cm diameter; 505-μm mesh) were used to sample ichthyoplankton and krill at each station. Where there was adequate depth, 300 m of wire was deployed and then retrieved at 20 m min^{-1}, at a nominal wire angle of 45°.

Paired vertical egg tow (Pairovet; formerly CalCOFI vertical egg tow or CalVET, (Smith *et al.*, 1985)) nets (25-cm diameter; 150-μm mesh) were used to sample fish eggs from a depth of 70 m to the sea surface at a rate of 70 m min^{-1} in areas where their densities exceeded a threshold of $>$ 0.3 eggs min^{-1}.

II.4.2. Conductivity and temperature profiles

Day and night, conductivity and temperature versus depth to 200 m were measured with calibrated sensors on a CTD probe cast. 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 the echo signal for attenuation during propagation of the sound pulse from the transducer to the scatterer range and back (Simmonds and MacLennan, 2005). The CTD 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 echosounders were calibrated on 27 March 2015 (~23:00 GMT) while the vessel was docked at Pier 30/32, San Francisco Bay (37.7867 ∘N, -122.3843 ∘W, **Figure III.1**). Thermosalinograph (Seabird Model SBE38) measurements of sea-surface temperature (t_w = 15.97 °C) and salinity (s_w = 29.25 psu) were input to the GPT-control software, which derived estimates of sound speed (c_w = 1503 m s^{-1}) and absorption coefficients. Varying with tide, the seabed was 10.8 to 12.8 m from the transducers. The calibration sphere was positioned between 6.1 to 9 m below the transducers.

Measurements of beam-uncompensated sphere target strength (TS_u, dB) and the beam model are plotted in **Figure III.2**, beam-compensated sphere target strength (TS_c, dB) measurements are plotted in **Figure III.3**, and nautical area scattering coefficients (s_A, m^2 nmi^{-2}) are plotted in **Figure III.4**. GPT information, configuration settings, and beam model results following calibration are presented in **Appendix A**.

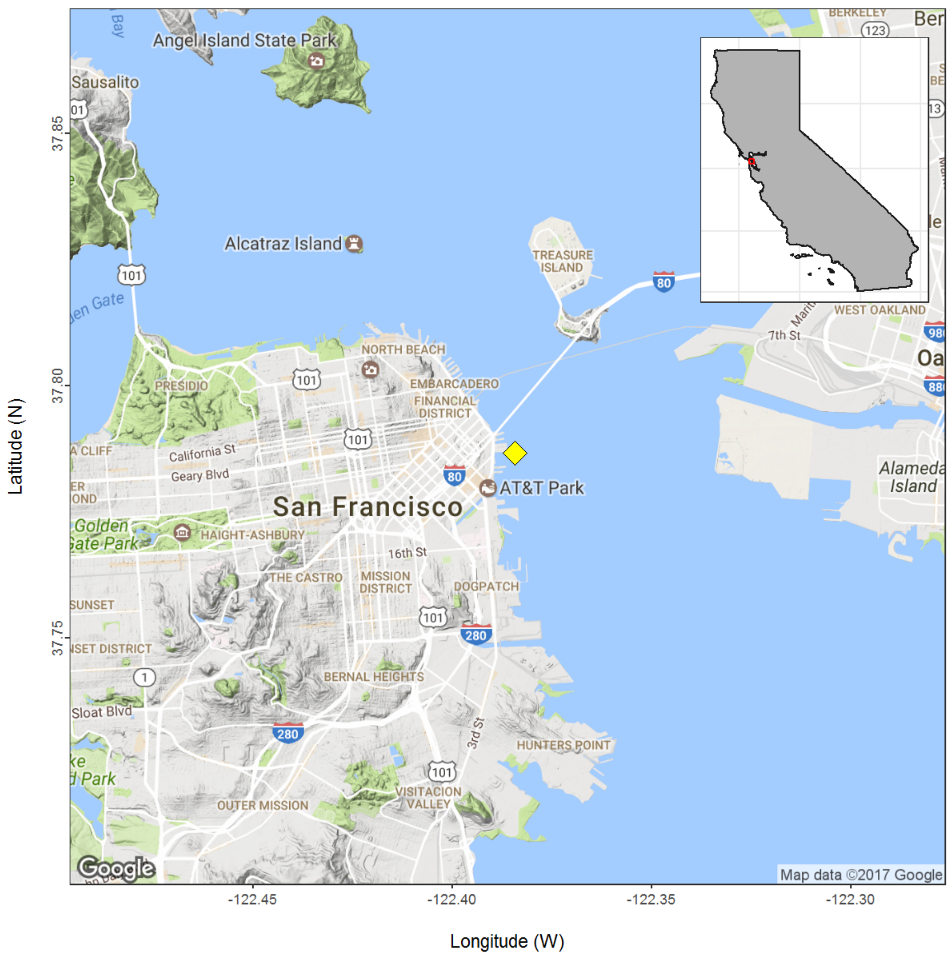

Figure III.1. Map of the calibration location (yellow diamond) near Pier 30/32, San Francisco Bay.

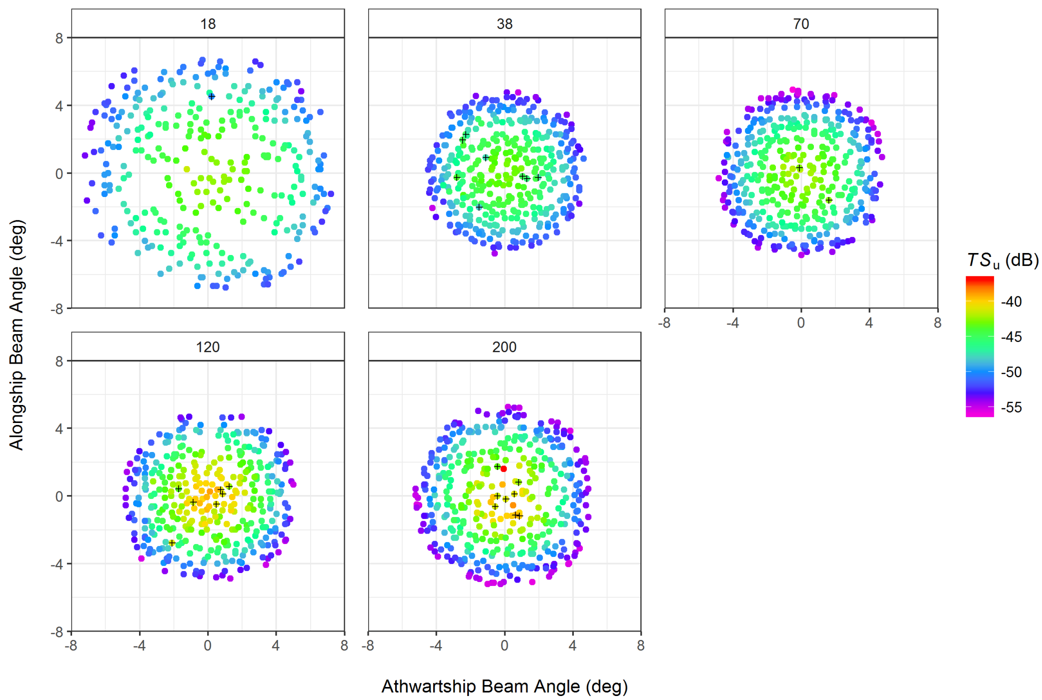

Figure III.2. Beam-uncompensated sphere target strength (TS_{u}, dB) measurements of a 38.1-mm diameter sphere made from tungsten carbide (WC) with 6% cobalt binder material, at multiple EK60 frequencies (18, 38, 70, 120, and 200kHz). Crosses indicate measurements marked as outliers after viewing the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

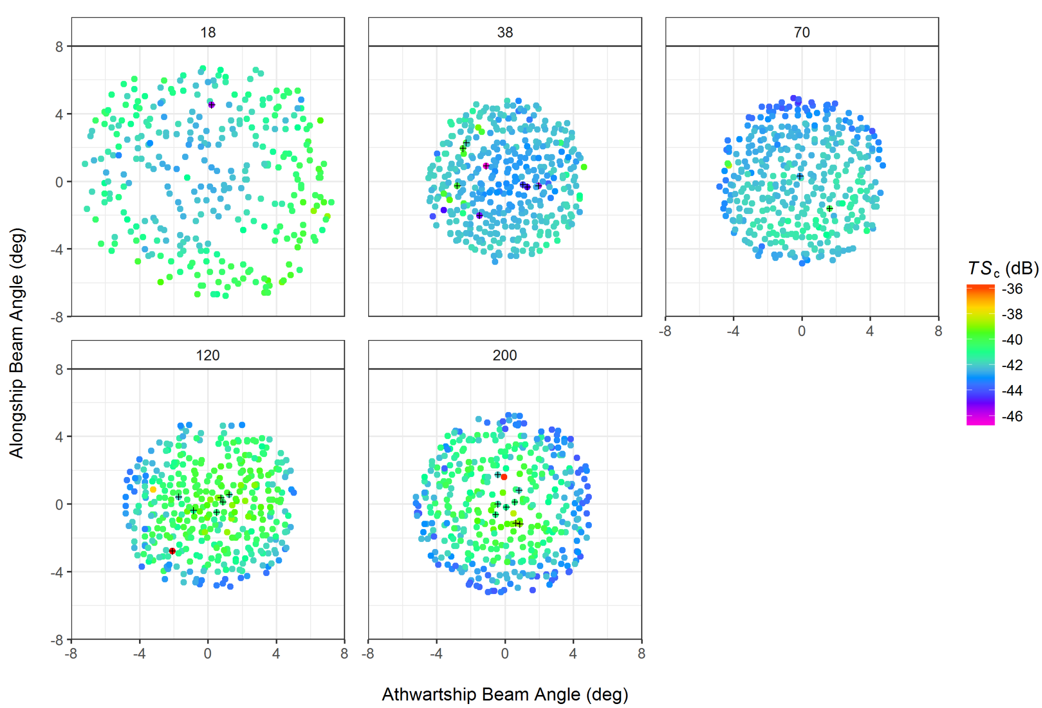

Figure III.3. Beam-compensated sphere target strength (TS_{c}, dB) measurements of a 38.1-mm diameter sphere made from tungsten carbide (WC) with 6% cobalt binder material, at multiple EK60 frequencies (18, 38, 70, 120, and 200kHz). Crosses indicate measurements marked as outliers after viewing the beam model results.

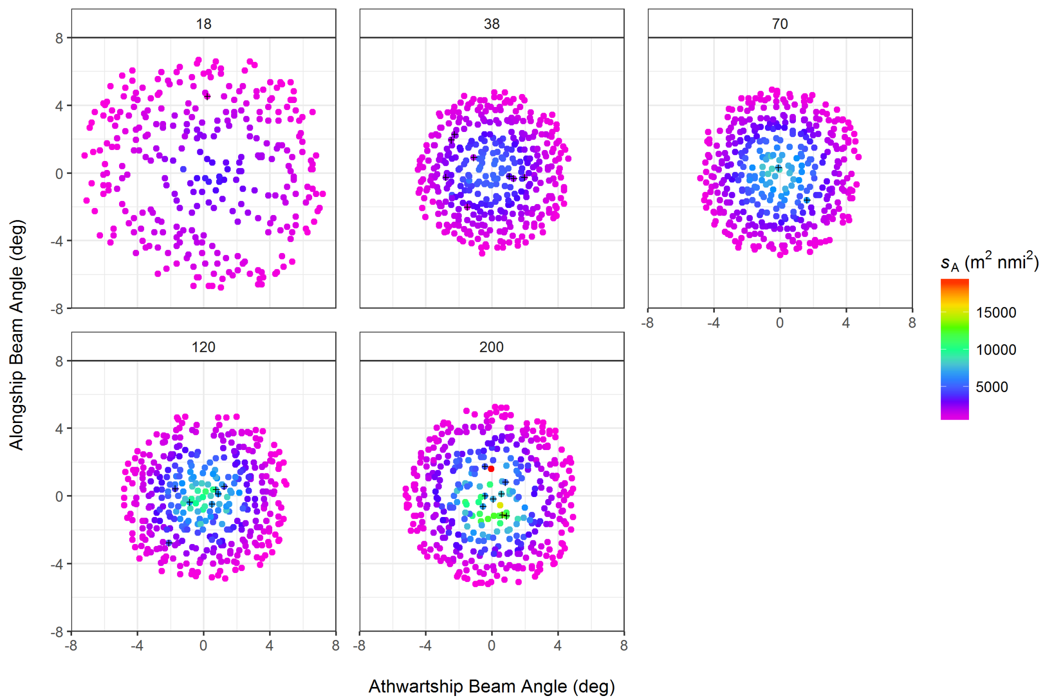

Figure III.4. Nautical area scattering coefficient (s_A, m^2 nmi^{-2}) measurements of a 38.1-mm diameter sphere made from tungsten carbide (WC) with 6% cobalt binder material, at multiple EK60 frequencies (18, 38, 70, 120, and 200kHz). Crosses indicate measurements marked as outliers after viewing the beam model results.

III.2. Data collection

III.2.1. Acoustic and trawl sampling

The survey comprised 23 east-west transects totaling 1843 nmi, and 51 Nordic trawls, which were used for acoustic-trawl biomass estimation. The survey spanned an area from approximately Newport, OR to Avila Beach, CA (**Figure III.5**). Inclement weather, and the concentration of adaptive samples with 20 nmi-spacing off Oregon and northern California precluded sampling south of Pt. Conception.

Leg I, *Shimada* departed from Pier 30/32 in San Francisco, CA, on 28 March 2015 at *ca.* 19:00, and arrived at the first station *ca.* 30 nmi north of Coos Bay, OR (Transect 3), at 15:52 on 30 March, to begin survey operations. The CUFES pump became inoperable while transiting north to begin the survey. Repair parts were received in Coos Bay, OR on 2 April at 21:30, the pump was repaired, and CUFES sampling resumed on 3 April at 13:50. Leg I of the survey concluded at 13:30 on 11 April at the end of Transect 11 near Trinidad Head, CA and *Shimada* returned to Pier 15 in San Francisco, CA on 12 April 2015 at *ca.* 17:00.

Leg II, *Shimada* departed from Pier 15 in San Francisco, CA on 15 April 2015 at *ca.* 17:30 and resumed acoustic sampling along Transect 12 at *ca.* 14:00 on 16 April. On 22 April, *Shimada* returned to San Francisco, CA after sampling Transect 17 to fix a mechanical problem with the ship. Sampling resumed on 25 April from south to north, beginning along Transect 75, near Avila Beach, CA. Survey operations for Leg II were concluded on 1 May at *ca.* 02:00 after sampling Transect 63 south of San Francisco, CA, and *Shimada* returned to San Francisco, CA on 1 May 2015 at *ca.* 08:00.

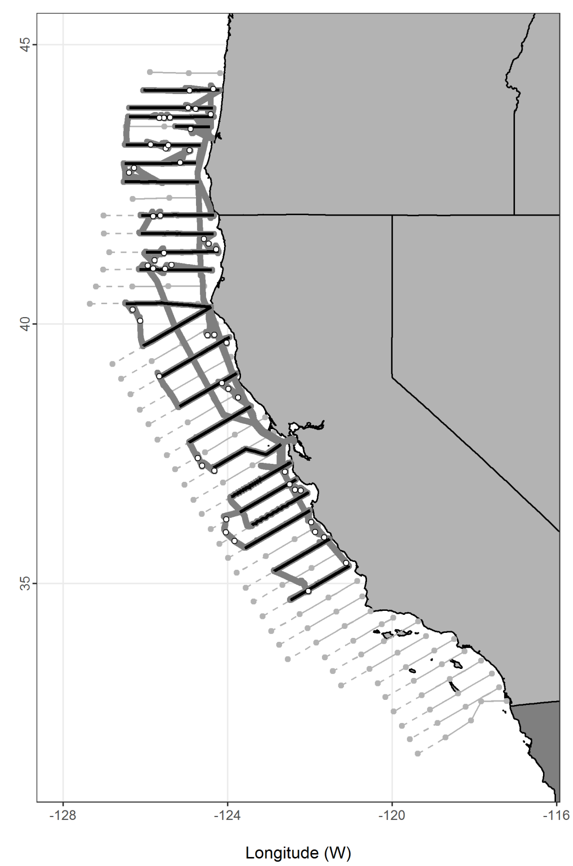

Figure III.5. Cruise track of *Shimada* (bold gray line), east-west acoustic transects (black lines), and locations of surface trawls (white points) superimposed on the proposed transects (light gray lines).

III.2.2 Ichthyoplankton and oceanographic sampling

A total of 54, 57, 67 CTD, bongo, and Pairovet samples were collected throughout the survey, respectively. In addition, 29 UCTD samples and 360 CUFES samples were collected underway. The locations of CTD and UCTD stations are shown in Figure **III.6** and **Appendix C**.

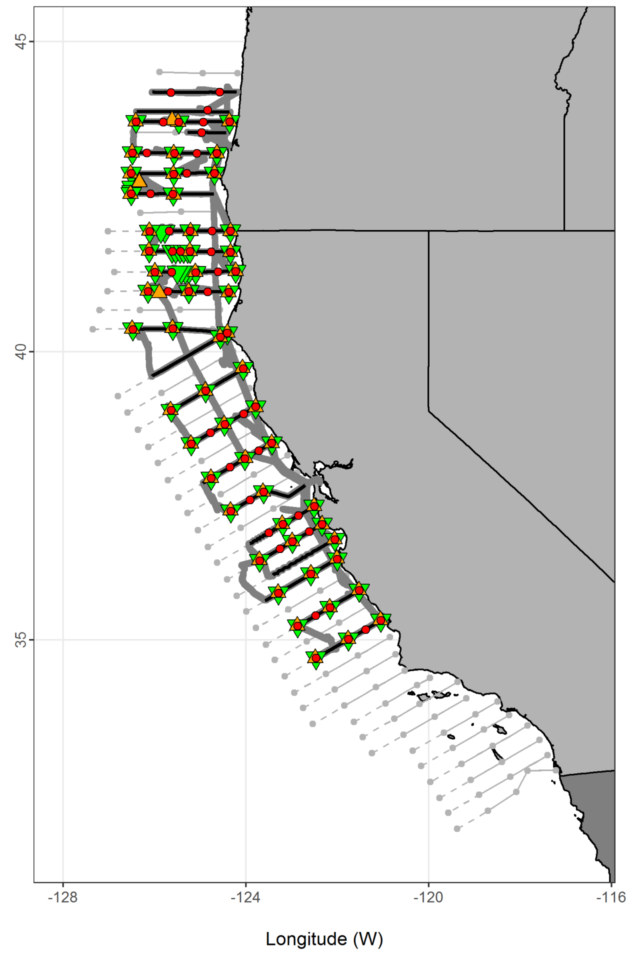

Figure III.6. CTD and UCTD locations (red circles) and plankton net samples (bongo net in orange triangles; Pairovet net in green triangles) relative to the vessel track (bold gray line), acoustic transects (black lines), and proposed transects (light gray lines).

III.3. Distribution of CPS

The majority of acoustic backscatter ascribed to CPS was observed between Newport and Coos Bay, OR; nearshore around Cape Mendocino; and to a lesser extent nearshore between San Francisco and Monterey, CA (**Figure III.7a**). Jack mackerel, sardine, and to a lesser extent Pacific mackerel, comprised the greatest proportion of catch in trawl samples north of Cape Mendocino, CA. Sardine were predominantly found in the northern region of their potential habitat, between Newport, OR and Cape Mendocino, CA, and no sardine were found south of Drake's Bay (38.00°N; **Figure III.7b**). Anchovy was the only species observed in trawl samples south of San Francisco, CA, and occurred only in trawl samples very close to shore. Overall, the 51 trawls captured 35.5 kg of sardine, anchovy and mackerels combined (**Appendix D**).

Sardine eggs were most abundant in CUFES samples in the offshore portion of transects conducted between Newport, OR and Eureka, CA (**Figure III.7c**). Small amounts of sardine eggs were observed inshore during the north-bound transit between San Francisco, CA and Pt. Arena during Leg I. No sardine eggs were observed south of San Francisco, CA, except for one single specimen sampled between San Francisco and Monterey, CA.

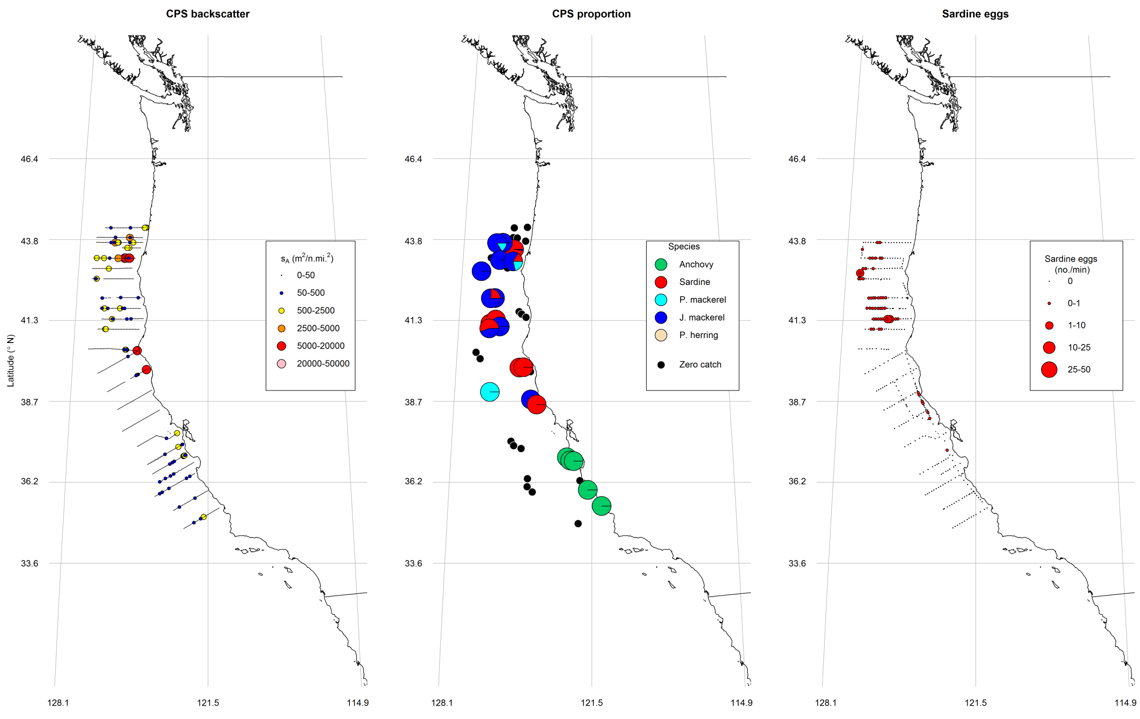

Figure III.7. Survey transects performed aboard *Shimada* overlaid with (a) the distribution of 38-kHz integrated backscattering coefficients (s_A, m^2 nmi^2) ascribed to CPS, averaged over 2000-m distance intervals and from 70-m deep to the integration start line (5 -m depth) superimposed on the distribution of potential sardine habitat defined at the mid-period of the survey; (b) proportions of CPS in trawl clusters used to apportion acoustic backscatter, including northern anchovy (*Engraulis mordax*), Pacific mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*), and Pacific herring (*Clupea pallasii*); and (c) sardine-egg densities from the CUFES.

IV. Problems and Suggestions

During calibration, one sphere, AST #7, was lost when the monofilament lines broke during deployment. Also, the starboard-aft downrigger lacked power to raise the sphere, and required manual assistance. The 512 kbps bandwidth of the satellite-Internet connection (V. Welton, Chief ET) was inadequate to telemeter echosounder data ashore, and made email sporadic and slow.

V. Disposition of Data

Archived on the SWFSC data server are approximately 144 GB of raw EK60 data and 435 GB 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).

VI. Acknowledgements

We thank the crew members of *Shimada* and the scientists and technicians that participated in the sampling operations at sea. Critical reviews by N. Bowlin and G. Dinardo improved this report.

Appendices

Appendix A. Echosounder settings and calibration results

Simrad EK60 general purpose transceiver (GPT) information, configuration settings (above the line), and beam model results following calibration (below the line). Prior to the survey, on-axis gain (G_0) and S_a Correction ($S_\mathrm{a}$corr) values were entered into the GPT-control software (Simrad ER60). Beam angles and offsets were set to their factory specifications.

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	26.26	26.26	26.01	25.8
S_a Correction ($S_\mathrm{a}$corr)	dB re 1	-0.75	-0.56	-0.29	-0.33	-0.35
Bandwidth (W_f)	Hz	1570	2430	2860	3030	3090
Sample Interval	m	0.193	0.193	0.193	0.193	0.193
Eq. Two-way Beam Angle (Ψ)	dB re 1 sr	-18	-21.4	-21.5	-20.8	-20.8
Absorption Coefficient (α_f)	dB km^{-1}	1.8	7.1	19.1	36.8	56.2
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. ($\alpha_{-3\mathrm{dB}}$)	deg	10.3	6.8	7	7.3	7.5
3-dB Beamwidth Athw. ($\beta_{-3\mathrm{dB}}$)	deg	10.3	6.8	6.9	7.2	7.4
Angle Offset Along. (α_0)	deg	0	0	0	0	0
Angle Offset Athw. (β_0)	deg	0	0	0	0	0
Theoretical TS (TS_theory)	dB re 1 m^2	-42.59	-42.41	-41.5	-39.55	-39.01
Ambient Noise	dB re 1 W	-135	-146	-156	-165	-158
On-axis Gain (G_0)	dB re 1	23.16	26.14	26.1	26.02	25.39
S_a Correction ($S_\mathrm{a}$corr)	dB re 1	-0.74	-0.57	-0.34	-0.35	-0.36
RMS	dB	0.25	0.26	0.21	0.35	0.38
3-dB Beamwidth Along. ($\alpha_{-3\mathrm{dB}}$)	deg	11.22	7.04	6.67	6.42	6.55
3-dB Beamwidth Athw. ($\beta_{-3\mathrm{dB}}$)	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

Appendix B. Centerboard positions

Transducer depths, associated with the centerboard position (retracted ~5-m, intermediate ~7-m, extended ~9-m) during the Spring CPS Survey aboard *Shimada*.

Date/Time	Position	Latitude	Longitude
03/28/2015 19:58	Retracted (5 m)	37.818167	-122.490167
03/28/2015 21:59	Intermediate (7 m)	37.872333	-122.909333
04/01/2015 21:30	Retracted (5 m)	43.368000	-124.410000
04/01/2015 22:57	Intermediate (7 m)	43.380167	-124.387167
04/07/2015 14:42	Intermediate (7 m)	41.996833	-124.386500
04/15/2015 15:35	Retracted (5 m)	37.802667	-122.396500
04/18/2015 18:41	Extended (9 m)	39.529500	-124.473667
04/20/2015 02:59	Intermediate (7 m)	38.902500	-124.106167
04/26/2015 15:09	Intermediate (7 m)	36.377667	-122.147667
04/27/2015 15:11	Intermediate (7 m)	36.377167	-122.150333
04/29/2015 14:49	Extended (9 m)	36.695167	-122.257500

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/Time	Event	Latitude	Longitude
03/31/2015 12:09	CTD Cast	43.9335	-124.8425
03/31/2015 17:12	UCTD Cast	44.2128	-124.5750
03/31/2015 21:52	UCTD Cast	44.2095	-125.6422
04/01/2015 18:22	UCTD Cast	43.5748	-124.9658
04/02/2015 12:00	CTD Cast	43.7462	-124.3560
04/02/2015 21:19	UCTD Cast	43.7445	-124.9323
04/02/2015 23:56	CTD Cast	43.7413	-125.4710
04/03/2015 02:30	UCTD Cast	43.7427	-125.8132
04/03/2015 16:41	CTD Cast	43.7502	-126.4033
04/03/2015 20:53	CTD Cast	43.2520	-126.4833
04/03/2015 23:11	UCTD Cast	43.2507	-126.1723
04/04/2015 02:13	CTD Cast	43.2473	-125.5685
04/04/2015 16:10	UCTD Cast	43.2483	-125.0783
04/04/2015 18:21	CTD Cast	43.2442	-124.6380
04/04/2015 21:15	CTD Cast	42.9292	-124.6928
04/05/2015 00:48	UCTD Cast	42.9257	-125.2913
04/05/2015 02:30	CTD Cast	42.9153	-125.5822
04/05/2015 18:26	CTD Cast	42.9242	-126.5088
04/05/2015 22:15	CTD Cast	42.5988	-126.5098
04/06/2015 01:09	UCTD Cast	42.5965	-126.0868
04/06/2015 14:54	CTD Cast	42.5922	-125.6027
04/07/2015 12:58	CTD Cast	41.9935	-124.3382
04/07/2015 16:31	UCTD Cast	41.9987	-124.7397
04/07/2015 19:00	CTD Cast	41.9987	-125.2237
04/07/2015 22:09	UCTD Cast	41.9932	-125.6805
04/08/2015 01:04	CTD Cast	41.9887	-126.1092
04/08/2015 11:51	CTD Cast	41.6680	-126.1152
04/08/2015 16:39	UCTD Cast	41.6620	-125.6057
04/08/2015 18:24	UCTD Cast	41.6608	-125.4382
04/08/2015 20:10	CTD Cast	41.6608	-125.2212
04/08/2015 23:12	UCTD Cast	41.6570	-124.7603
04/09/2015 01:23	CTD Cast	41.6535	-124.3385
04/09/2015 12:10	CTD Cast	41.3390	-124.2252
04/09/2015 15:44	UCTD Cast	41.3305	-124.6083
04/09/2015 18:14	CTD Cast	41.3188	-125.1015
04/09/2015 22:36	UCTD Cast	41.3232	-125.6270
04/10/2015 00:59	CTD Cast	41.3245	-125.9910
04/10/2015 12:54	CTD Cast	41.0070	-126.1430
04/10/2015 15:52	UCTD Cast	41.0035	-125.7013
04/10/2015 18:09	CTD Cast	41.0030	-125.2517
04/10/2015 20:56	UCTD Cast	40.9988	-124.8390
04/10/2015 23:20	CTD Cast	40.9938	-124.3732
04/16/2015 13:27	CTD Cast	40.3173	-124.4065
04/16/2015 20:45	CTD Cast	40.3907	-125.6018
04/17/2015 01:53	CTD Cast	40.3782	-126.4757
04/17/2015 22:56	CTD Cast	40.2493	-124.5543
04/18/2015 15:20	CTD Cast	39.7173	-124.0618
04/18/2015 21:38	CTD Cast	39.3450	-124.8842

04/19/2015 03:45	CTD Cast	39.0123	-125.6342
04/19/2015 13:53	CTD Cast	38.4385	-125.1945
04/19/2015 17:08	UCTD Cast	38.6315	-124.7753
04/19/2015 19:17	CTD Cast	38.7748	-124.4648
04/19/2015 22:33	UCTD Cast	38.9563	-124.0533
04/20/2015 00:21	CTD Cast	39.0728	-123.7858
04/20/2015 14:24	CTD Cast	38.4527	-123.4353
04/20/2015 16:35	UCTD Cast	38.3240	-123.7218
04/20/2015 18:33	CTD Cast	38.1872	-124.0247
04/20/2015 21:15	UCTD Cast	38.0397	-124.3473
04/20/2015 23:46	CTD Cast	37.8505	-124.7595
04/21/2015 12:33	CTD Cast	37.2797	-124.3327
04/21/2015 16:03	UCTD Cast	37.4752	-123.9112
04/21/2015 17:59	CTD Cast	37.6127	-123.6112
04/25/2015 12:58	CTD Cast	35.3522	-121.0508
04/25/2015 15:50	UCTD Cast	35.1933	-121.3822
04/25/2015 18:13	CTD Cast	35.0170	-121.7542
04/26/2015 00:12	CTD Cast	34.6788	-122.4672
04/26/2015 15:04	CTD Cast	35.2517	-122.8665
04/26/2015 18:13	UCTD Cast	35.4375	-122.4750
04/26/2015 20:23	CTD Cast	35.5835	-122.1612
04/27/2015 03:41	CTD Cast	35.8870	-121.5203
04/27/2015 13:14	CTD Cast	36.4427	-122.0057
04/27/2015 17:50	CTD Cast	36.1770	-122.5773
04/27/2015 23:08	CTD Cast	35.8410	-123.2905
04/28/2015 13:45	CTD Cast	36.4147	-123.7005
04/28/2015 17:13	UCTD Cast	36.6225	-123.2523
04/28/2015 18:57	CTD Cast	36.7492	-122.9813
04/28/2015 21:54	UCTD Cast	36.9220	-122.6107
04/28/2015 23:40	CTD Cast	37.0503	-122.3327
04/29/2015 12:38	CTD Cast	36.7808	-122.0557
04/30/2015 16:25	UCTD Cast	36.9005	-123.4975
04/30/2015 19:19	CTD Cast	37.0463	-123.1963
04/30/2015 22:13	UCTD Cast	37.2045	-122.8498
05/01/2015 00:50	CTD Cast	37.3620	-122.5050

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/Time	Lat (N)	Lon (W)	Anchovy	Sardine	P. mackerel	J. mackerel	All CPS
1	03/31/2015 05:53	43.900	-124.960					
2	03/31/2015 09:10	43.890	-124.780					
3	04/01/2015 03:40	44.210	-124.930					
4	04/01/2015 09:28	44.230	-124.350					
5	04/02/2015 03:53	43.530	-124.900		5.50		0.13	5.62
6	04/02/2015 08:21	43.790	-124.410					
7	04/03/2015 04:21	43.740	-125.400				0.41	0.41
8	04/03/2015 06:44	43.730	-125.550					
9	04/03/2015 09:34	43.730	-125.660			2.64	13.53	16.18
10	04/04/2015 03:37	43.260	-125.880					
11	04/04/2015 07:52	43.190	-125.500				0.07	0.07
12	04/04/2015 10:34	43.250	-125.440					
13	04/05/2015 06:00	43.150	-124.920		0.10	0.13	0.38	0.61
14	04/05/2015 09:26	42.940	-125.160					
15	04/06/2015 05:24	42.840	-126.270				0.22	0.22
16	04/06/2015 08:28	42.760	-126.390					
17	04/08/2015 03:44	41.990	-125.630				0.26	0.26
18	04/08/2015 06:19	41.980	-125.810		0.51		1.57	2.07
19	04/09/2015 02:25	41.560	-124.580					
20	04/09/2015 05:07	41.480	-124.470					
21	04/09/2015 08:24	41.380	-124.280					
22	04/10/2015 03:02	41.180	-125.780		4.02	0.15	3.77	7.93
23	04/10/2015 05:43	41.310	-125.550		0.50		0.36	0.86
24	04/10/2015 09:47	41.080	-125.940					
25	04/11/2015 03:50	41.090	-125.370				0.08	0.08
26	04/11/2015 06:04	41.020	-125.520					
27	04/11/2015 09:17	41.030	-125.810		0.16		0.13	0.30
28	04/17/2015 04:00	40.270	-126.310					
29	04/17/2015 07:50	40.070	-126.130					
30	04/18/2015 04:23	39.790	-124.490		0.21			0.21
31	04/18/2015 07:29	39.800	-124.320		0.00			0.00
32	04/18/2015 11:25	39.660	-124.030					
33	04/19/2015 04:18	39.020	-125.660			0.54		0.54
36	04/20/2015 03:17	38.890	-124.140					
37	04/21/2015 06:25	38.780	-123.980				0.09	0.09
38	04/20/2015 09:58	38.620	-123.740		0.00			0.00
39	04/21/2015 03:16	37.460	-124.730					
40	04/21/2015 06:38	37.320	-124.620					
41	04/21/2015 09:51	37.230	-124.320					
42	04/25/2015 09:32	35.410	-121.120	0.01				0.01
43	04/26/2015 03:28	34.850	-122.030					
45	04/27/2015 04:30	35.920	-121.660	0.00				0.00
46	04/27/2015 07:01	36.020	-121.870					
47	04/27/2015 09:24	36.210	-121.970					
48	04/28/2015 03:37	35.850	-123.830					
49	04/28/2015 06:26	36.020	-124.040					
50	04/28/2015 09:19	36.270	-124.030					
51	04/29/2015 03:12	36.950	-122.490	0.00				0.00

52	04/29/2015 06:21	36.850	-122.360	0.00	0.00
53	04/29/2015 09:06	36.830	-122.220	0.05	0.05

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