Northwest Fisheries Science Center

National Marine Fisheries Service

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The 2012 Joint U.S.-Canada Integrated Acoustic and Trawl Survey of Pacific Hake (*Merluccius productus*) and Pacific Sardine (*Sardinops sagax*)

February 2013

INTRODUCTION

Pacific hake (*Merluccius productus*), hereafter hake, is an important commercial marine fish off the west coast of North America, with annual harvests totaling between 177,000 and 363,000 metric tons from 1986 through 2011 (Stewart et al. 2012). Because of the economic and ecological value of coastal hake, integrated acoustic and trawl (IAT) surveys have been conducted since 1977 to assess the distribution, abundance, and biology of coastal hake along the Pacific coasts of the United States and Canada. Pacific sardine (*Sardinops sagax*), hereafter sardine, an important biological component of the California Current Ecosystem (CCE), has returned in numbers during the latter part of the 20th century after the stock and fishery underwent an earlier collapse (Zwolinski et al. 2012a). IAT surveys have been conducted on sardine (and other pelagic fishes) in the CCE during 2006, 2008, and 2010. 2012 marked the first time that scientists from the Northwest Fisheries Science Center (NWFSC) and the Southwest Fisheries Science Center (SWFSC) combined efforts to survey both hake and sardine during one IAT survey.

The results presented here are from the summer 2012 joint U.S.-Canada IAT survey of hake and sardine. This report provides a brief description of the methods used in the survey and summarizes the distribution, biological composition, and biomass of hake in U.S. and Canadian waters off the Pacific coast. It also summarizes results of acoustic system calibrations and secondary survey objectives. Summary results regarding sardine are presented in a separate document (Zwolinski et al. 2012b).

MATERIALS AND METHODS

Scientists from the Fishery Resource Analysis and Monitoring (FRAM) division at the NWFSC, the Fishery Resources Division (FRD) at the SWFSC, and the Pacific Biological Station (PBS) of the Department of Fisheries and Oceans Canada (DFO) conducted the 2012 IAT survey aboard the NOAA Ship *Bell M. Shimada*, the Canadian Coast Guard Ship (CCGS) *W.E. Ricker*, and the industry-provided vessel the F/V *Forum Star*. All vessels were stern trawlers equipped for fisheries and oceanographic research. The *Shimada* surveyed an area from 35.8°N to 50.8°N between June 27 and August 23, and the *Ricker* surveyed an area from 48.8°N to 55.3°N between August 15 and September 6. Between June 28 and August 11 the *Forum Star* remained in the vicinity the *Shimada* and provided fishing support.

Hake and sardine populations were surveyed along a series of parallel line transects that in general were oriented east-west, spaced at an interval of 10-nmi apart, and traversed sequentially in alternating directions (Figure 1); some areas in Canadian waters were better covered with transects that ran in a zigzag or north-south orientation. The survey began northwest of Morro Bay, California, proceeded north toward Dixon Entrance, and finished along the west side of Haida Gwaii (formerly called the Queen Charlotte Islands). Hake aggregations were targeted along the continental shelf and upper slope of the entire survey area, whereas sardine aggregations were targeted only as far north as the northern tip of Vancouver Island. The *Shimada* was tasked with completing transects up to the north end of Vancouver Island, at which point the *Ricker* would complete the remaining transects north to Dixon Entrance and along the west coast of Haida Gwaii. Sea depth at the inshore end of individual transects was nominally 30 m, although a few transects ended in waters deeper than 30 m because of restricted areas,

navigation hazards, or boat traffic. Offshore extent of individual transects was typically at a depth of 1,500 m or at a point 35 nmi west of the inshore waypoint, whichever resulted in a longer transect.

Acoustic Sampling

Equipment

Acoustic data on the *Shimada* and the *Ricker* were collected with a Simrad EK60 scientific echo sounder system coupled with an ER60 software system (Simrad 2004). On the *Shimada*, Simrad 18-kHz, 38-kHz, 70-kHz, 120-kHz, and 200-kHz split-beam transducers were mounted on the bottom of the ship's centerboard which—extended partially for the duration of the survey—held the transducers at a nominal depth of 7.0 m below the water surface. On the *Ricker*, Simrad 18-kHz and 120-kHz split-beam transducers were located on a hydraulic ram that was extended 1.2 m below the keel to 5.2 m below the surface.

The *Forum Star* used a Simrad ES60 quantitative echo sounder system, operating at 38 kHz and 120 kHz, to collect acoustic data during daytime operations. Split-beam transducers were mounted on the vessel's hull.

After completion of the survey, the *Shimada* deployed an EdgeTech SB-0512i wideband FM sub-bottom profiler. This towed body, operating at a frequency range of 500 Hz–12 kHz, was deployed to a maximum depth of 200 m at a maximum tow speed of 3 knots.

Calibration

Locations for calibration were chosen where water depths were greater than 50 m in order to avoid echo contamination from seafloor reverberation. The calibration procedure involved anchoring the vessel, suspending two metal spheres with known backscattering cross sections below the transducers, and then measuring the acoustic returns following standard procedures (Foote et al. 1987, Simmonds and MacLennan 2005). On the *Shimada*, a 38.1-mm tungsten carbide sphere was used for the 38-kHz, 70-kHz, 120-kHz, and 200-kHz transducers, and a 64-mm copper sphere was used for the 18-kHz transducer. On the *Forum Star*, just the tungsten carbide sphere was used for the 38-kHz and 120-kHz transducers. Target strength and echo integration data were collected to calculate echo sounder gain parameters to ensure the quality of system performance. On-axis and beam pattern measurements were taken during the calibrations.

Operations

Acoustic data on the *Shimada* were collected from 14 m below the surface (about 7 m below the centerboard-mounted transducer face) to a maximum depth of 750 m to ensure a ping rate of one ping per 1.1 seconds (Acoustic data on the *Forum Star* were collected either to 500 m or to 750 m, depending on the depth.). Raw acoustic backscatter (ER 60 .raw) and Echolog 60 (Echoview .ek6) data files were logged from all five frequencies; in Myriax Echoview the latter were used for live viewing and the former were used for scrutinizing. Event log markers and other marks, including at-sea judgments of hake backscattering layers, were made on the live-viewed files. Data from the 38-kHz echo sounder (the primary frequency used for generating biomass estimates) were post-processed using Myriax Echoview software on a PC, and results presented in this document are based on these data.

The *Shimada* maintained a vessel speed of approximately 4.1 m/sec (8 knots) during acoustic sounding along each transect, resulting in an acoustic sample volume coverage of about 100% for a fish layer at a depth of about 35 m at an average ping rate of slightly slower than 1 Hz, which ensured that all observed hake layers were covered 100% without any gaps. Acoustic operations were run only between sunrise and sunset (i.e., roughly from 0600 to 2100 PDT, about 15 hours per day) when hake formed identifiable midwater layers.

Background noise was recorded in passive mode each day either before transects started in the morning or during cross-transects conducted offshore in deep water >1,500 m. These recordings were done to ensure the quality of the acoustic data and the consistency of system performance throughout the survey.

Biological Sampling

Equipment

Daytime trawling on fish sign observed by the *Shimada* was performed from the *Forum Star* with an Aleutian wing trawl 24/20 (AWT). This net had a vertical opening that averaged 21 m (range: 16–27 m) and a headrope and footrope of 101.8 m each. A 3.2-cm (1.25-inch) codend liner was used. The AWT was deployed with a pair of 4-m^2 "Fishbuster" trawl doors (884.5 kg), 82.3-m legs, and 113.4-kg (250-pound) or 226.8-kg (500-pound) chain ("Tom") weights on each side. A Simrad FS900 third-wire trawl sonar was attached to the AWT headrope to monitor and guide the fishing process for all tows.

To provide additional biological ground truthing (i.e., provide information on the biological composition of multiple scattering layers in the water column), the AWT was

deployed with a digital video camera system mounted inside the net. The system included a low-light camera connected to a Supercircuits MDVR16 high-capacity micro digital video recorder, an LED light array, and two paired scaling lasers for fish length measurement. The camera was mounted in an underwater pressure housing equipped with a pressure switch that automatically switched the camera on when deeper than a preset depth and switched it off when shallower than this depth.

In addition to the AWT, the *Forum Star* also had on board a poly Nor'eastern trawl 89/121 (PNE) for bottom trawling. This net was not used.

An electronic, 60-kg capacity Marel M1100 PL4200 motion-compensating scale was used to weigh sorted portions of the catch to the nearest 0.05 kg. A 15-kg capacity Marel M1100 PL2060 motion-compensating scale was used to determine weights of individual fish specimens to the nearest 0.005 kg. Individual fish lengths (fork length) were determined to the nearest centimeter using a Scantrol FM100 FishMeter board.

Operations

In contrast to previous hake IAT surveys in which one vessel both collected acoustic data and trawled, in 2012 the *Shimada* restricted daytime activities to just collecting acoustic data—the *Forum Star* was responsible for hake trawling. Survey time constraints did not allow the *Shimada* to conduct a traditional IAT survey given the number of days that had been allotted. In addition, trawl gear on the *Shimada* had been configured at the start of the survey for shallow-water sardine trawling only, and this configuration precluded hake fishing from also being conducted.

When the *Shimada* identified one or more locations of interest to fish, coordinates, target depth(s), and a description of the target sign were sent to the *Forum Star* via VHF radio or Iridium satellite. A goal for the *Forum Star* was to remain close to the *Shimada* so that fishing operations could commence relatively promptly, i.e., no more than a few hours after receiving coordinates from the *Shimada*. However, on occasion the *Forum Star* needed to wait until the following morning to trawl on the target fish sign because arriving at the target site before sundown was not possible.

Trawl samples were used to classify observed backscatter layers to species and size composition and to collect specimens of hake and other organisms. The number and locations of trawl sets were not pre-determined—other than an allowance for a total number of tows by area based on available survey time (about one-third of the survey time, according to Simmonds and MacLennan 2005)—but depended on the occurrence and pattern of backscattering layers observed at the time of the survey. Coverage by trawling was not systematic but adaptive; individual tows did not require a standardized effort. Distinct layers of intense backscatter that were indicative of high densities of hake were the highest priority for trawl sampling, but other types of backscattering features, both in terms of areas of low fish density and putative aggregations of species other than hake, were also sampled. When possible, tows were conducted at several locations along any single, extensive, and continuous aggregation of hake, or within the same area where vertically discrete backscattering layers appeared.

During trawl operations, trawling speed averaged about 1.5 m/s (3 knots). Fish and other organisms entering the net were observed on the Simrad net monitoring sonar system by

scientists and crew conducting the trawl operations. Haul duration lasted only as long as the scientist overseeing trawl operations deemed was necessary to ensure an adequate catch sample.

Trawl catches were sorted and weighed completely. Total weights and numbers were determined for most species; gelatinous invertebrates such as jellyfish and salps often could not be counted. Hake were subsampled to determine length composition by sex (about 300 samples per trawl) and to collect otoliths for subsequent age determination (about 50 samples per trawl, which also included collecting individual weights and lengths). When fewer than roughly 300 to 400 hake were caught, they were sampled completely. Hake sexual maturity was determined by visual inspection of gonads and classified by a 5-stage scale. Otoliths were preserved in 50% ethanol for subsequent age determination. Stomachs and ovaries from hake were collected and preserved in 10% neutral-buffered formalin (about 10 samples per trawl). Blood samples for a study of insulin-like growth factors (IGF) were collected and frozen (10 samples per trawl) during the first two legs of the survey.

Oceanographic Sampling

Equipment

Vertical profiles of temperature and salinity data were collected on the *Shimada* using a Sea-Bird Electronics, Inc. SBE 911*plus* conductivity-temperature-depth (CTD) system and an Oceanscience UnderwayCTD. In conjunction with the CTD casts, vertical profiles of dissolved oxygen (DO) were collected using a Sea-Bird SBE 43 DO sensor that was attached to the SBE 911*plus* CTD. Additional oceanographic data were collected on the *Forum Star* by attaching the following instruments to the AWT during tows: a Sea-Bird SBE 39 temperature and pressure recorder, a Sea-Bird SBE 19*plus* CTD, a Sea-Bird SBE 43 DO sensor, a Wet Labs FLNTU

chlorophyll/turbidity sensor, and an Aanderaa Optode 4330F DO sensor. Ocean current velocity profile data were obtained on the *Shimada* using a Teledyne RD Instruments Ocean Surveyor 75-kHz Acoustic Doppler Current Profiler (ADCP) system. Sea surface temperature and salinity data were collected by the *Shimada* using a Sea-Bird SBE probe located below the vessel's waterline and stored on the *Shimada*'s Scientific Computing System (SCS).

Operations

Physical oceanographic sampling was conducted day and night. CTD casts were made at selected locations along designated acoustic transects. CTD casts were performed primarily at night after collection of acoustic data had ceased, but they also were conducted during daytime when the acoustic system was calibrated. Underway CTD casts were conducted during daytime while the ship was collecting acoustic data and moving at survey speed. ADCP data were collected continuously day and night throughout the entire survey (except for acoustic calibrations) to provide current information at depths up to roughly 600 m. SCS sea surface data (e.g., temperature and salinity) were collected continuously day and night throughout the entire survey.

RESULTS

Acoustic System Calibration

Two calibrations of the *Shimada*'s acoustic system were conducted, the first on June 24 off Newport, Oregon, and the second on August 23, midway along the west coast of Vancouver Island. One calibration was conducted of the *Forum Star*'s acoustic system on June 19 in Elliott

Bay, Washington. Results of all calibrations were within expected levels based on factory settings and results from previous calibrations.

Biological Sampling

A total of 116 midwater trawls (73 by the *Forum Star* and 43 by the *Ricker*) were successfully conducted during the course of the survey (Figure 2). One bottom trawl was conducted by the *Ricker*. In U.S. waters off California, one attempt to trawl was aborted because there were marine mammals near the *Forum Star*. A trawl off Oregon was aborted after gear had been deployed because of confusion regarding coordinates of the target fish sign; after the gear was retrieved, the trawl was reset at the correct location and completed successfully.

Of the 73 trawls that the *Forum Star* conducted, 65 caught hake; total catch weights ranged from 0.34 kg to 1,270 kg (mean = 262.6 kg). By weight, hake was the dominant species caught, accounting for just under 91% of catch composition. Other species caught included yellowtail rockfish (*Sebastes flavidus*) at 3% and Pacific herring (*Clupea pallasii*) at 2%; the remaining 4% comprised 77 species. By number, hake accounted for over 74% of catch composition. Lanternfish, at 7%, was the second-most commonly caught fish species, followed by Pacific herring at 5% and eulachon (*Thaleichthys pacificus*) at 4%. Of the 44 trawls that the *Ricker* conducted, 32 caught hake; catch weights ranged from 0.0 kg to 3,198 kg (mean = 272.4 kg). By weight, hake accounted for one-third of catch composition, followed by Pacific ocean perch (*Sebastes alutus*) at 27%. Other species caught included yellowmouth rockfish (*Sebastes reedi*) at 10%, Pacific herring at 9%, walleye pollock (*Theragra chalcogramma*) at 9%, and yellowtail rockfish at 5%; the remaining 7% comprised 27 species.

During the survey, 19,332 hake were lengthed and 3,549 pairs of hake otoliths were collected on the *Forum Star* and *Ricker*. The coast-wide length-frequency distribution (Figure 3) showed a marked bimodality, with a larger mode at 32 cm and a smaller one around 40 cm. Raw age-length data from aged otoliths showed a strong 2010 year class, followed by the 2008 year class which was less than half as strong. A little over 1,100 (N=1,105) hake stomachs were either examined in the field or collected, and 199 ovaries were collected.

Oceanographic Sampling

Forty-nine CTD temperature and salinity profiles were collected at selected locations along the line transects and at acoustic system calibration sites; 111 underway CTD profiles were also collected. Additional temperature profiles were collected from 70 SBE casts that were collected at most trawl stations. Analysis of oceanographic data is ongoing.

Pacific Hake Distribution and Abundance Estimates

The *Shimada* and the *Ricker* collected acoustic data from 85 and 45 transects, respectively. Eleven transects off the west coast of Vancouver Island (79, 81, and 83–91) were surveyed twice, first by the *Ricker* and then by the *Shimada*. Because only the *Ricker* was able to trawl for hake while collecting acoustic data in this area (the *Forum Star* was no longer supporting the *Shimada*), only the *Ricker*'s acoustic data for these eleven duplicated transects were used for the hake biomass estimate. Another transect that the *Shimada* surveyed but was not used was transect 82, which was run out of sequence near the very end of the survey; the *Ricker* also did not run transect 82. Six transects in U.S. waters (27, 35, 42, 48, 67, and 70) had to be dropped randomly to make up for the days the *Shimada* and *Forum Star* sought shelter in

San Francisco, waiting for unacceptably rough sea conditions to pass. Ultimately, 118 transects covering a linear distance of 8,558 km (4,621 nmi) were used for the hake biomass estimate.

Aggregations of adult (age 2+) hake were detected on 94 transects from the start of the survey (halfway between Morro Bay and Monterey Bay), north along the U.S. and Canadian coast, in the Queen Charlotte Sound and Hecate Strait, through Dixon Entrance, and at the southwest tip of Haida Gwaii (Figure 4). Highest concentrations of hake were observed along the California coast from Monterey Bay to south of Cape Mendocino, from just south of Crescent City, California to the southern Oregon coast, in between Newport and Astoria, Oregon, and in the Dixon Entrance area. Hake concentrations were relatively moderate off Washington and Vancouver Island, minimal in Hecate Strait, and essentially absent in southeast Alaska and along the west coast of Haida Gwaii.

The estimate of adult hake biomass off the U.S. and Canada west coast totaled 1.381 million metric tons. Over 91% of the observed biomass was in U.S. waters. With over 51% of the survey-wide observed biomass, age-2 hake were the largest component (Figure 5), followed by age-4 hake at 21% (which, as three year olds during the 2011 hake EIT survey, had been the largest component at over 60%). Age-3 hake came in third at just under 12%.

ACKNOWLEDGEMENTS

Thanks go to the officers and crew of the *Shimada* and *Ricker* and the crew of the *Forum Star* for their contribution to the successful completion of this survey. Thanks also go to all others who supported and helped make this a successful survey, notably the personnel from the NWFSC FRAM and REUT Divisions, the SWFSC FRD, and the Fisheries and Oceans Canada Stock Assessment Division.

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Table 1. Itinerary for the 2012 joint U.S.-Canada integrated acoustic and trawl (IAT) survey of Pacific hake and Pacific sardine.

Pre-Survey

June 19	Personnel conduct an acoustic system calibration of the *Forum Star* with standard targets in Elliott Bay, Washington.

U.S. Leg 1

June 23	Personnel embark onto the *Forum Star* in Seattle, Washington; transit south starts.
June 24	Personnel embark onto the *Shimada* in Newport, Oregon and conduct an acoustic system calibration with standard targets off the entrance to Yaquina Bay, Oregon.
June 25	The *Shimada* returns to Newport to load gear.
June 26	Personnel disembark from the *Forum Star* in Eureka, California; transit south continues. The *Shimada* starts transiting south.
June 27	Survey begins.
July 1	The *Forum Star* pulls into San Francisco overnight to fill the fresh water tank.
July 2	The *Forum Star* seeks shelter in Drake's Bay and Bodega Bay.
July 3	The *Forum Star* conducts one tow and then returns to Bodega Bay for shelter.
July 6–9	Inport San Francisco; exchange personnel.

U.S. Leg 2

July 10	Survey resumes.
July 12–14	The *Forum Star* and *Shimada* seek shelter in San Francisco.
July 15	The *Forum Star* and *Shimada* leave San Francisco.
July 16	Survey resumes.
July 26–29	Inport Newport; exchange personnel.

U.S. Leg 3

July 30	Survey resumes.
August 12	While transiting to Seattle, the *Forum Star* runs aground temporarily near Dungeness Spit, suffering no apparent damage.
August 12–15	The *Shimada* inports in Port Angeles, Washington; personnel exchange.

Table 1 continued. Itinerary for the 2012 joint U.S.-Canada integrated acoustic and trawl (IAT) survey of Pacific hake and Pacific sardine.

U.S. Leg 4

August 16	The *Shimada* leaves Port Angeles.
August 17	Survey resumes without the *Forum Star*.
August 22	The *Shimada* finishes transect 91 and transits to a calibration site.
August 23	Personnel conduct an acoustic system calibration of the *Shimada* with standard targets midway off the west coast of Vancouver Island. The *Shimada* finishes transect 82.
August 24	The *Shimada* deploys the EdgeTech towed body; personnel disembark at Neah Bay, Washington.
August 25	The Shimada conducts a second deployment of the EdgeTech towed body.
August 26–27	Transit south.
August 28	Inport Newport. U.S. portion of cruise ends.

Canada Leg 1

August 15	The *Ricker* starts surveying off Vancouver Island with transect 79.
August 21	The *Ricker* inports in Port Hardy, British Columbia; personnel exchange.

Canada Leg 2

August 22	The *Ricker* resumes surveying.
August 28	The *Ricker* inports in Prince Rupert, British Columbia; personnel exchange.

Canada Leg 3

August 29	The *Ricker* resumes surveying.
September 6	The *Ricker* finishes surveying.
September 7	The *Ricker* transits to Nanaimo, British Columbia. Canadian portion of cruise ends.

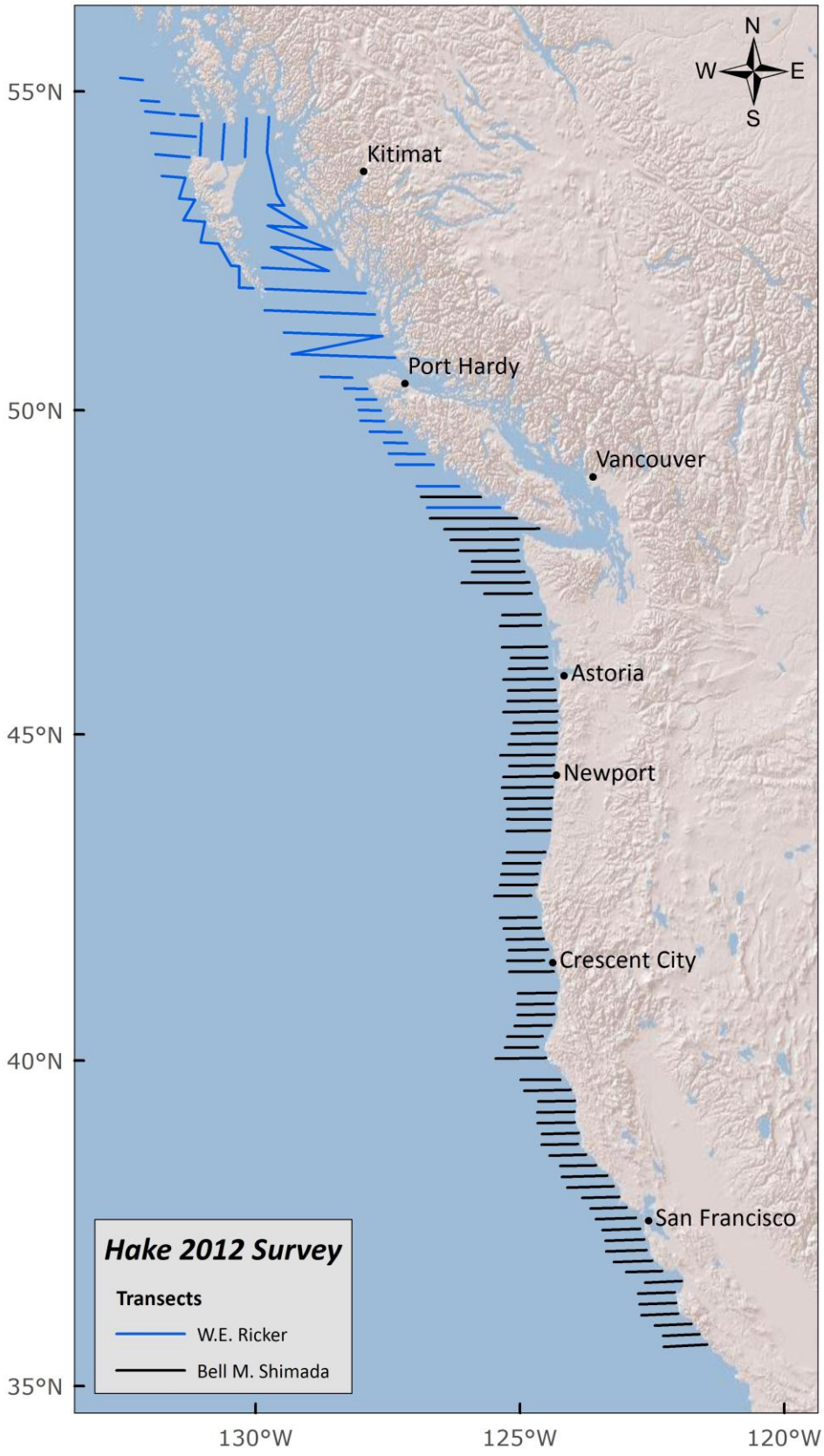

Figure 1. Survey track design used during the 2012 joint U.S.-Canada integrated acoustic and trawl (IAT) survey of Pacific hake and Pacific sardine.

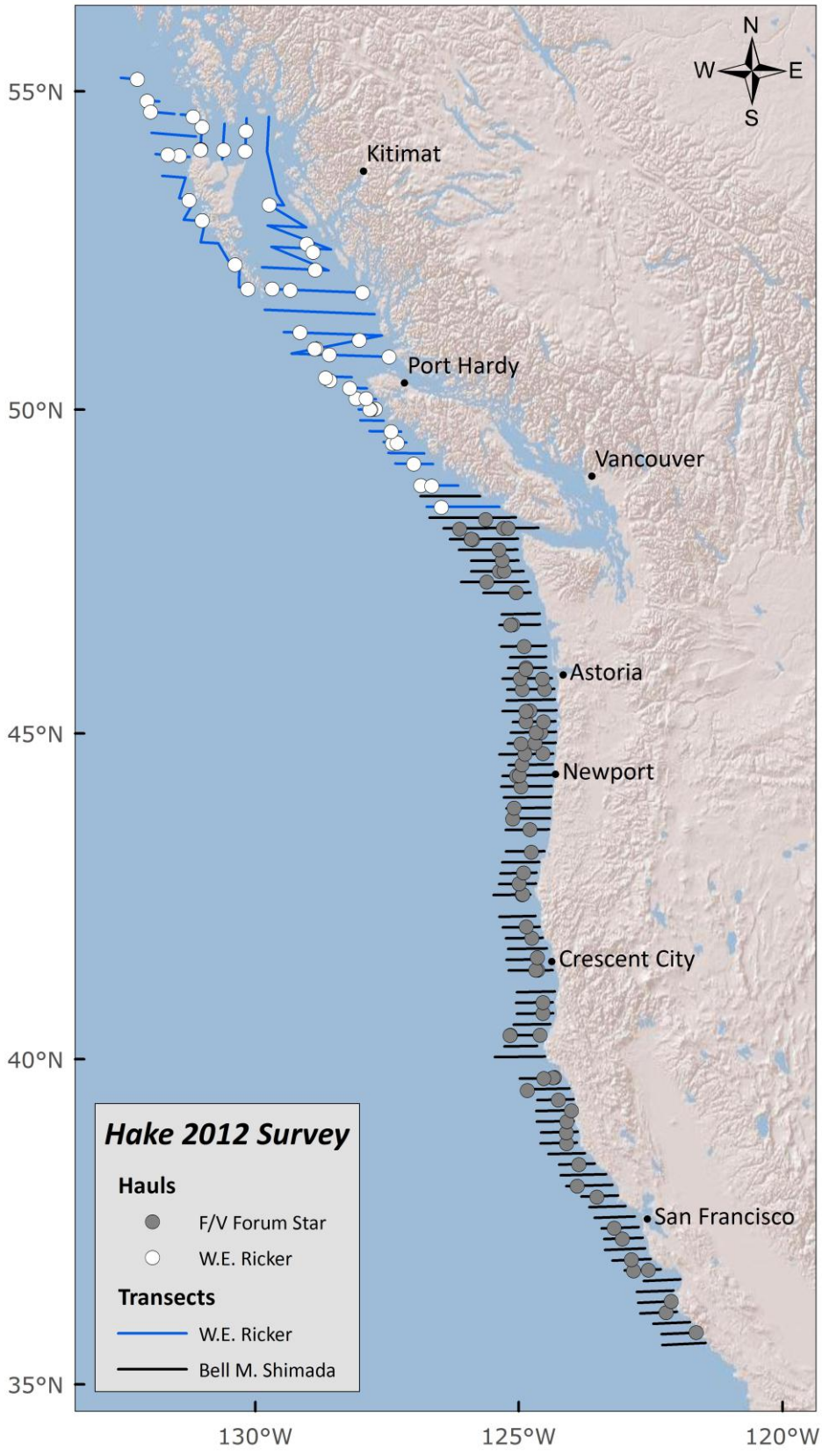

Figure 2. Acoustic transect lines and locations of midwater and bottom trawls during the 2012 joint U.S.-Canada integrated acoustic and trawl (IAT) survey of Pacific hake and Pacific sardine.

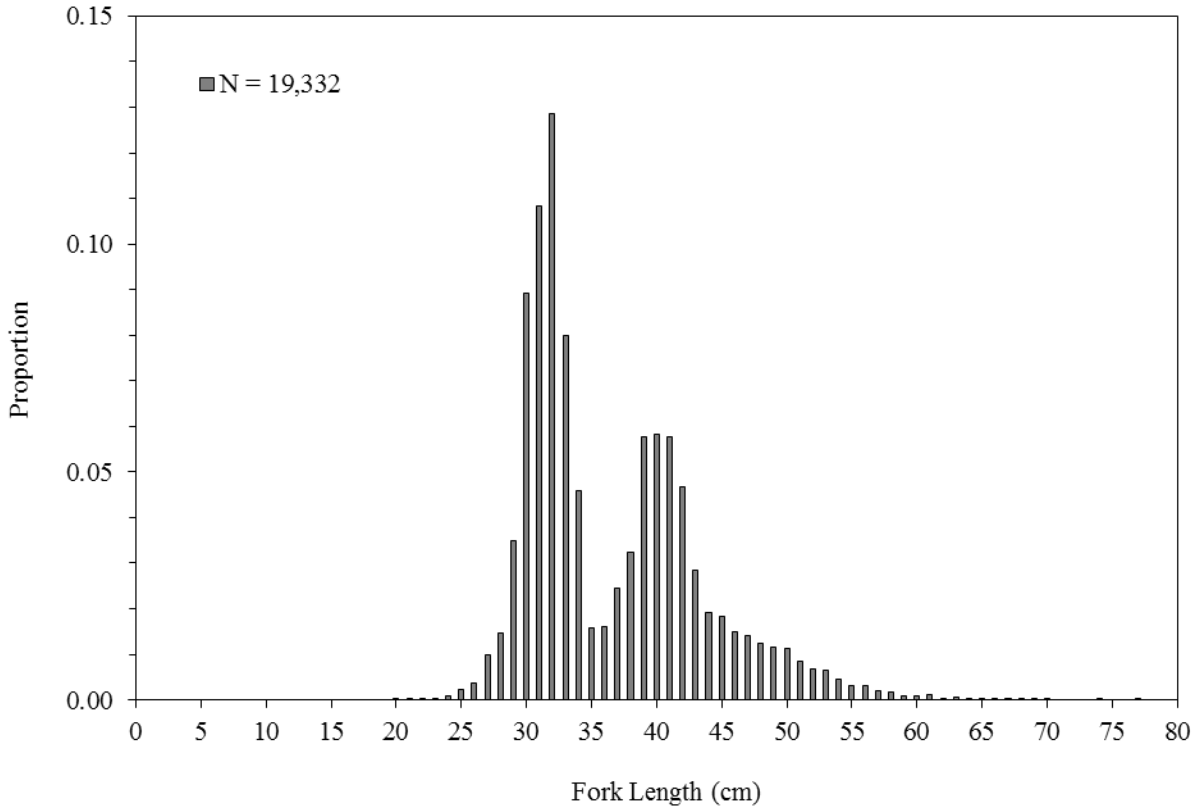

Figure 3. Coast-wide length-frequency distribution of Pacific hake from specimens measured during the 2012 joint U.S.-Canada integrated acoustic and trawl (IAT) survey of Pacific hake and Pacific sardine.

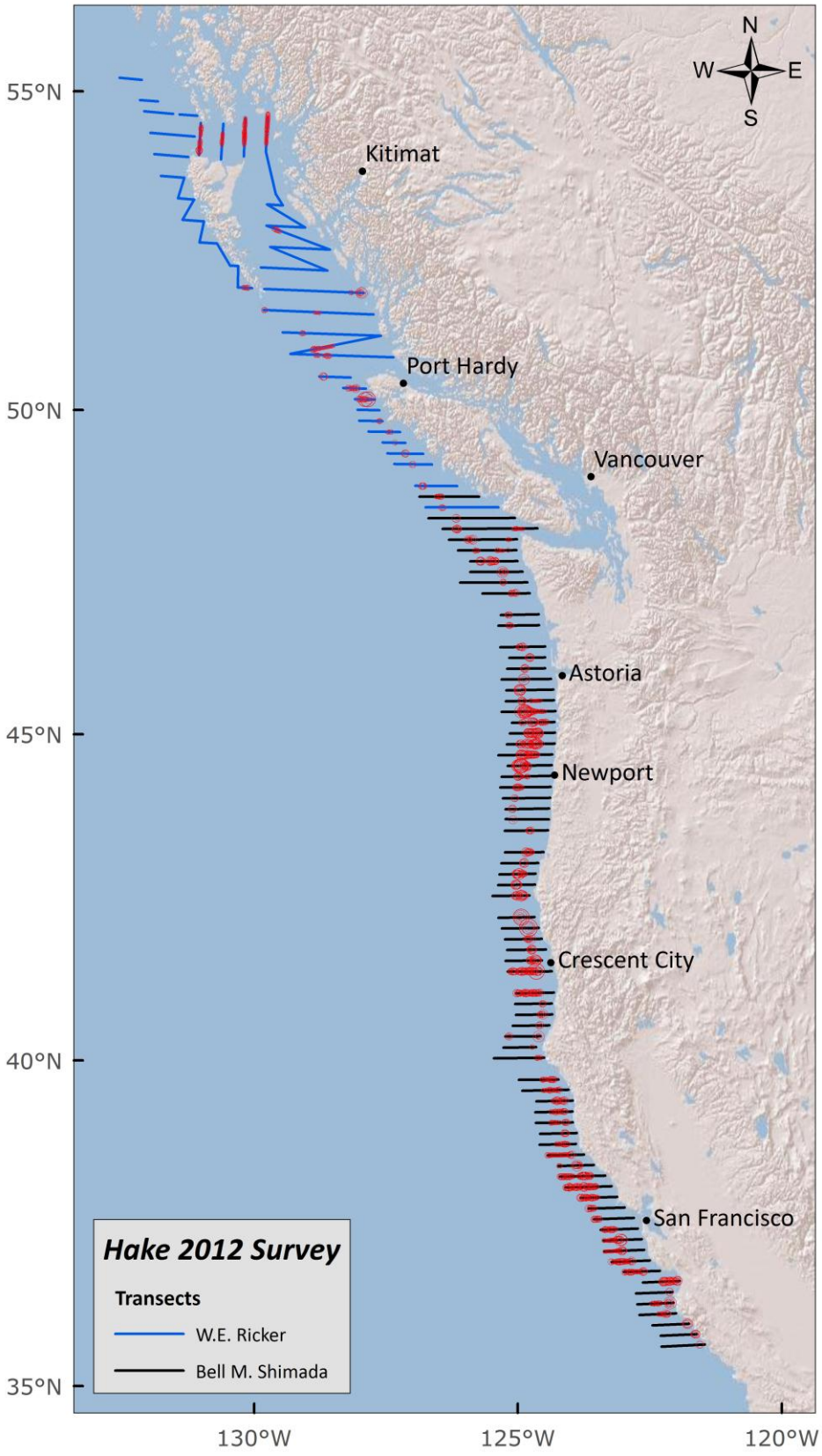

Figure 4. Acoustic area backscattering attributed to adult (age 2+) Pacific hake along transects completed during the 2012 joint U.S.-Canada integrated acoustic and trawl (IAT) survey of Pacific hake and Pacific sardine.

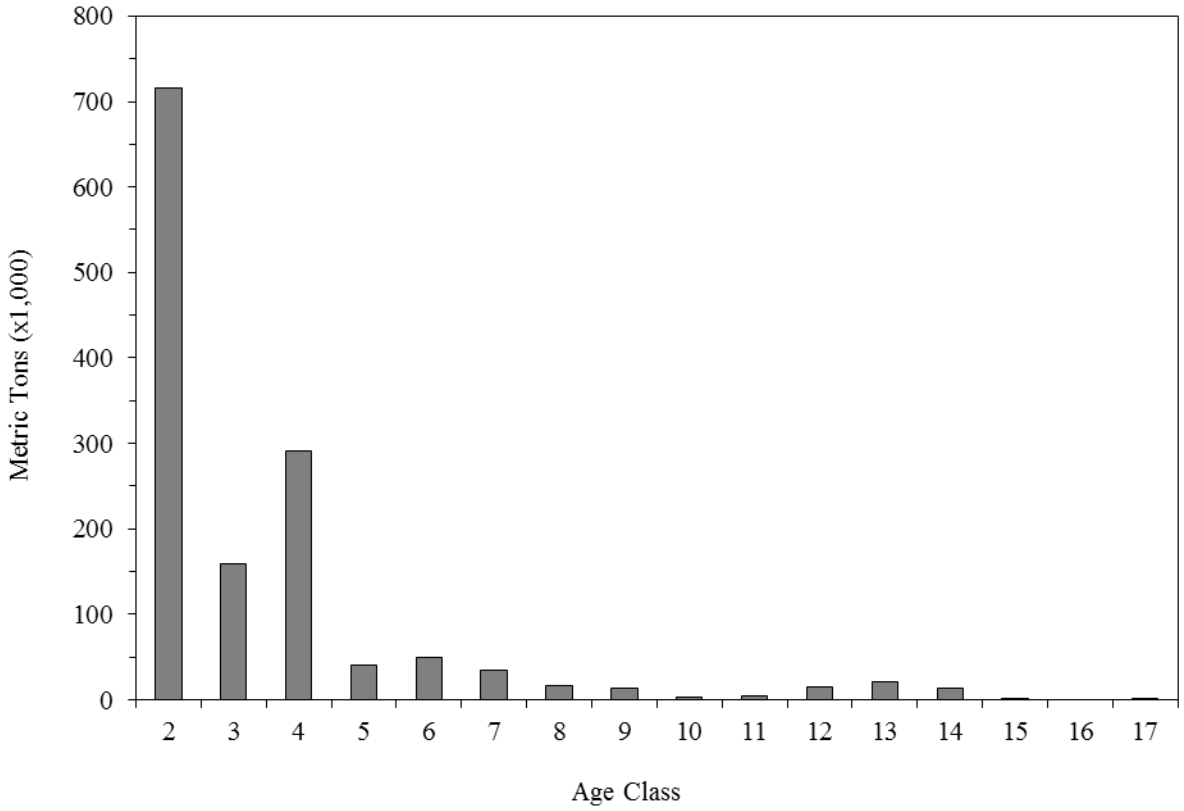

Figure 5. Estimated biomass (thousands of metric tons) of adult Pacific hake by age class for the 2012 joint U.S.-Canada integrated acoustic and trawl (IAT) survey of Pacific hake and Pacific sardine.