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The 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey: Cruise Report SH-21-06

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National Oceanic and Atmospheric Administration
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The 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey: Cruise Report SH-21-06

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Acknowledgments

Thanks go to the officers and crew of the NOAA Ship *Bell M. Shimada* and the Canadian FV *Nordic Pearl* for their contribution to the successful completion of the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey. Thanks go also to all others who supported and helped make this survey a success, notably the personnel from the Northwest Fisheries Science Center (Fishery Resource Analysis and Monitoring, Conservation Biology, and Environmental and Fisheries Sciences Divisions), Fisheries and Oceans Canada (Institute of Ocean Sciences), and volunteers.

This survey was conducted under the authority of the following permits:

- California Department of Fish and Wildlife Scientific Collecting Permit, Specific Use S-210270001-21034-001, and a Memorandum of Understanding for Incidental Take.
- Oregon Department of Fish and Wildlife 2021 – Scientific Taking Permit – Fish #25651.
- Alaska Department of Fish and Game Aquatic Resource Permit No. CF-21-046.
- NMFS Biological Opinion WCR-2016-5783.
- NMFS Determination of Take Authorization under a Biological Opinion 16335-4A.
- NMFS West Coast Region Scientific Research Permit SRP-09-2021.
- NOAA National Marine Sanctuary Research Permit MULTI-2021-008.

The *Shimada* also obtained clearance to enter Canadian waters.

Introduction

Pacific hake (*Merluccius productus*), hereafter hake, is a very important commercial marine fish found off the west coast of North America. Over the last ten years (2011–20), coastwide annual harvests averaged 325,105 metric tons (Johnson et al. 2021), with U.S. and Canadian catches averaging 258,306 metric tons and 66,799 metric tons, respectively. In 2020, the coastwide catch was 379,270 metric tons. Combined, the hake non-tribal at-sea and shoreside fishery for the U.S. West Coast supported 3,468 jobs and an income of $264 million in 2019 (J. Leonard, NWFSC, personal communication). In addition to its commercial importance, hake is also a key trophic species and the most abundant groundfish in the California Current Large Marine Ecosystem (Sherman 1991). Because coastal hake have a prominent economic and ecological value, integrated acoustic trawl (IAT) surveys have been used to assess the abundance, distribution, and biology of hake along the west coast of the United States and Canada (Fleischer et al. 2005). Beginning in 1977, the Alaska Fisheries Science Center (AFSC) conducted triennial IAT surveys in U.S. and Canadian waters, and in 1990, Fisheries and Oceans Canada (DFO) started conducting annual IAT surveys in Canadian waters. After the 2001 survey, responsibility for the U.S. portion of the IAT survey was transferred from AFSC to the Northwest Fisheries Science Center, and the survey frequency was increased from triennial to biennial. In addition, since 1995, the United States and Canada have collaborated in assessing hake: the triennial IAT surveys of 1995, 1998, and 2001 were conducted jointly by AFSC and DFO, and IAT surveys since 2003 have been conducted jointly by NWFSC and DFO.

The results presented here are from the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey. 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.

Materials and Methods

Scientists from the Fishery Resource Analysis and Monitoring (FRAM) Division at NWFSC and the Institute of Ocean Sciences at DFO led the 2021 IAT survey aboard the NOAA Ship *Bell M. Shimada*—a 209-foot acoustically quieted Fisheries Survey Vessel—and the *Nordic Pearl*, a chartered 115-foot Canadian fishing vessel. Both vessels are stern trawlers equipped for fisheries research, while the *Shimada* is also equipped for oceanographic research.

The survey began at Point Conception, California (the current southern extent of the survey area) and proceeded north along the west coast of the United States and Canada, surveying Queen Charlotte Sound, Hecate Strait, Dixon Entrance (the northern extent of the survey area), and the west side of Haida Gwaii, which was surveyed from north to south (Figure 1). The *Shimada* surveyed between 1 July and 21 September (Table 1), and the *Nordic Pearl* surveyed between 21 August and 11 September. Acoustic transects were oriented east–west (except for transects in Dixon Entrance, which had a north–south orientation), extended from the 50-m isobath (or as close to shore as was safely navigable) to the 1,500-m isobath, and were spaced 10 nautical miles (nmi) apart through Transect 100 (just north of Vancouver Island), after which spacing increased to 20 nmi. Transects were traversed sequentially, usually in alternating directions. If hake were observed on the first transect, the survey area was extended to the south; similarly, if hake were observed on the most northerly transect, the survey area was extended further north. If hake were detected at the offshore end of a transect, the vessel proceeded west to the end of the hake sign and then beyond for an additional 0.5 nmi to ensure that the end of the aggregation was located. This protocol was in place to ensure not only that the full extent of the hake coastal population was accounted for in the survey area, but also that the interpolation algorithm used for calculating hake biomass performed correctly at the offshore ends of transects.

Acoustic Sampling

Equipment

Five Simrad split-beam transducers, operating at 18, 38, 70, 120, and 200 kHz, were mounted on the bottom of the *Shimada*'s retractable centerboard. To reduce interference from bubbles, the centerboard was extended to its maximum depth during the survey, thereby positioning the transducers at a depth of 9.15 m below the water surface. Acoustic data from all five transducers were collected with a Simrad EK80 wideband transceiver (WBT) scientific echosounder system that operated with an EK80 software system (version 2.0.0) in either a CW (continuous wave or narrowband) or FM (broadband or wideband) pulse transmission mode. The *Nordic Pearl* also collected acoustic data with a Simrad EK80 system (version 2.0.1); two Simrad split-beam transducers, operating at 38 and 120 kHz, were mounted on a transducer pod located roughly 1.5 m starboard of the keel.

The *Shimada* was equipped with a Teledyne RD Instruments Ocean Surveyor 75-kHz Acoustic Doppler Current Profiler (ADCP) system and a Simrad ME70 scientific multibeam echosounder system, but the ME70 system was not used because of interference with the other acoustic systems. A Simrad K-Sync unit was used to synchronize pulse sequences from the EK80 and ADCP acoustic instruments.

Calibration

The *Shimada*'s acoustic system was calibrated in the field before and after the survey; the *Nordic Pearl*'s acoustic system was calibrated before the survey. Calibration locations were chosen based on past successful calibrations, survey logistics, and selecting sites where the water beneath the ship was sufficiently deep (to avoid echo contamination from multipath effects) and where the water column was, as much as possible, devoid of fish and other marine life. Both the *Shimada* and the *Nordic Pearl* anchored from the bow for calibration. The calibration procedure involved suspending a metal sphere with a known backscattering cross-section below the transducers and measuring the acoustic return following standard procedures (Simmonds and MacLennan 2005, Demer et al. 2015). On both the *Shimada* and the *Nordic Pearl*, a 38.1-mm tungsten carbide sphere with 6% cobalt binder was used for all transducers. Target strength and echo integration data were collected to calculate echosounder gain parameters to ensure the quality of system performance. On-axis and beam pattern data were recorded during the calibrations.

Operations

The *Shimada* maintained a vessel speed of up to approximately 11 knots (kn) during acoustic operations along each transect and cross-transect. The *Nordic Pearl* maintained a vessel speed of around 9 kn during survey operations. Running of acoustic transects occurred between sunrise and sunset (i.e., roughly from 0600 to 2100 PDT, about 15 hours per day) when hake formed identifiable midwater layers, although acoustic data were collected day and night. Likewise, ADCP data were also collected day and night.

Narrowband (CW) EK80 acoustic backscatter data were collected to a maximum depth of approximately 750 m for the 18-, 38-, and 70-kHz transducers, 600 m for the 120-kHz transducer, and 300 m for the 200-kHz transducer. Raw acoustic backscatter (EK80 .raw) data files were logged from all five frequencies. Acousticians used the raw files for live viewing and for scrutinizing on laptop PCs with Echoview (version 11.1.49; Echoview Software Pty Ltd.). Event log markers and other marks, including at-sea judgments of hake backscattering layers, were made on the live-viewed files. While all five EK80 frequencies could be used for at-sea judgements, data from only the 38-kHz echosounder (the primary frequency used for generating biomass estimates) were post-processed for hake using Echoview, and results presented in this document are based on these data. (Data from the 120-kHz echosounder are being post-processed for euphausiids [Euphausiacea].)

Background noise was recorded in passive mode at frequent intervals either before the surveying of transects started in the morning, or during cross-transects conducted offshore at depths greater than 1,500 m. These recordings were done to ensure the quality of the acoustic data and the consistency of system performance throughout the survey.

Analysis

Adult hake (age-2+) biomass and variability were estimated from survey data using kriging, one of several geostatistical numerical and mathematical techniques used to analyze observations that are correlated in space (Journel and Huijbregts 1978). Kriging—a local estimator used to interpolate a spatially distributed quantity in an unobserved location—has been considered suitable for estimating fish abundance and precision parameters (Rivoirard et al. 2000), and has been used to estimate the abundance and variance of fish stocks surveyed using acoustic techniques (Rivoirard et al. 2000, Simmonds and MacLenann 2005).

Biological Sampling

Equipment

The *Shimada* conducted daytime trawls with an Aleutian wing trawl 24/20 (AWT). This net had a vertical opening that averaged 26 m (range: 20–35 m) and a headrope and footrope of 101.7 m each. A 1.25-inch (32-mm) codend liner was used. The AWT was deployed with a pair of 4-m^2, 884.5-kg "Fishbuster" trawl doors, 82.3-m legs, and 750-lb chain ("Tom") weights on each side. Rigging between the trawl doors and the headrope and footrope consisted of synthetic 18-mm TS-II rope. A Simrad FS70 third-wire trawl sonar was attached to an AWT headrope kite to monitor depth, net opening, and water temperature; the trawl sonar also helped scientists to approximately gauge the catch quantity and to know when the AWT was in targeted sign. A Samsung Galaxy Tab A 9.7" (SM-T550), running an app created in-house with Android Developer, was used to record net mensuration details. On the *Nordic Pearl*, daytime trawling was performed with a midwater net that was made in 2021 and matched the specifications of the AWT.

To provide additional biological ground truthing (i.e., information on the biological composition of multiple scattering layers in the water column), the AWT was deployed with a SpyTec Mobius camera and light system mounted to the top panel of the intermediate approximately 20 m forward of the codend. The camera faced aft and along the net toward the codend. Three custom pressure housings (made by Sexton Corporation) were mounted to a rigid ultra-high-molecular-weight polyethylene (UHMWPE) board. Two of the pressure housings held LED lights while the third held the camera. The housings with enclosed batteries used a pressure switch to activate lights and camera. The camera was programmed to start recording when external power was applied. Video data stored on a 32GB micro SD card in the camera were transferred to external storage shortly after each trawl was completed. Time, temperature, and pressure information collected from a Sea-Bird Electronics, Inc. SBE 39plus temperature and pressure recorder clipped near the

camera was overlaid onto the video files using a program written in-house with Python. Files were spliced together and trimmed to remove video prior to the lights switching on underwater and directly after the lights switched off. Review of the video was completed soon after each trawl and notes were recorded onto a spreadsheet.

Similarly, the trawl on the *Nordic Pearl* was equipped with a digital video camera system mounted inside the net. This system consisted of a separate camera pressure housing and LED light pressure housing mounted in stainless steel frames tied directly to the inside of the net's top section. The lights were connected to an external battery pack housed in its own pressure cylinder. The frames were positioned at approximately 10 m ahead of the codend section (which was 9.7 m long). The camera was facing down and toward the aft of the net, at an angle of approximately 30°. The light source was placed 1.5 m aft of the camera and was aimed directly downward, toward the bottom of the net. The camera used was a GoPro HERO4, while the pressure housing and lights were manufactured by A.G.O. Environmental Electronics Ltd.

To verify the identity of acoustic targets suspected to be euphausiids and/or lanternfish (Myctophidae), and to obtain specimens for species identification and length, a Methot trawl was deployed during daytime hours. The Methot consisted of a square metal frame (inner dimensions of 2.4 m by 2.4 m) to which an outer protective net (2.4 m by 2.4 m by 44 ft, with a 2-inch mesh) and an inner net (1.4 m by 1.4 m by 43 feet, with a 1/8-inch mesh) were attached. Samples were collected in a two-piece PVC collection bucket attached to the tail end of the inner net. To stabilize the Methot trawl during fishing, a 2.5-m wide V-shaped metal net depressor fin with a 75-lb ballast weight was attached. A Simrad integrated trawl instrumentation (ITI) sensor was attached to the frame to monitor depth in real time while fishing, as well as an SBE 39plus recorder.

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 0.002 kg. Individual fish lengths (fork length) were determined to the nearest centimeter with a Scantrol FM100 FishMeter board.

The *Shimada*'s flow-through system was used to collect water for analysis of the presence, distribution, and identification of harmful algal bloom (HAB) species and the toxins they produce. Niskin bottle water collections were taken at conductivity–temperature–depth (CTD) stations; water extracted from the Niskin bottles was filtered in support of environmental DNA (eDNA) work. During Leg 1 on the *Shimada*, an eDNA autonomous sampler, "SADIE," developed in conjunction with the University of Washington Applied Physics Lab (APL), was attached to the CTD rosette and tested. During Leg 2, additional eDNA water samples were collected opportunistically from the flow-through system when marine mammals were sighted nearby; these samples were stored for later filtration.

Operations

Daytime trawling was 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 trawls were not predetermined—other than an allowance for an expected total number of trawls by area based on available survey time—but depended on the occurrence and pattern of backscattering layers observed at the time of the survey. Coverage by trawling was adaptive: highest priority was given to sampling distinct layers of intense backscatter that were indicative of high densities of hake. Hake aggregations were targeted for trawling along the entire survey area.

Prior to commencing trawl operations, NWFSC marine mammal protocols were followed on the *Shimada* to ascertain that no marine mammals were within 500 m of the vessel for ten minutes prior to deploying gear, and that no killer whales (*Orcinus orca*) were observed at any time, regardless of distance from the ship. During trawl operations, trawling speed averaged about 3 kn (up to 2 kn for the Methot trawl); observing for marine mammals and any seabird gear strike was maintained. Individual trawl durations varied, lasting only long enough to ensure that an adequate sample (i.e., a minimum of approximately 350 hake) was obtained. When targeted backscatter was light, however, trawl durations necessarily increased, lasting up to approximately 30 minutes. The scientist overseeing trawl operations on the bridge determined the trawl duration based on the quantity of fish and other organisms that the trawl sonar observed entering the net.

Trawl catches on the *Shimada* were sorted and weighed completely. CLAMS (Catch Logger for Acoustic Midwater Surveys), a program developed by AFSC and modified by the Fisheries Engineering and Acoustic Technologies (FEAT) team within FRAM, was used for recording catch parameters. Total weights and numbers were determined for most species; gelatinous invertebrates such as jellyfish and salps often could not be counted accurately because trawling frequently broke them apart. Hake were subsampled to determine length composition by sex (about 300 random samples per trawl) and to collect roughly 50 "enhanced" samples per trawl. When fewer than 350 hake were caught, they were sampled completely. The "enhanced" samples included collecting individual weights, lengths, sex, sexual maturity as determined by visual inspection of gonads, and otoliths for all hake in the sample. Otoliths were preserved in 50% ethanol for subsequent age determination. Additional measures for special projects were also taken on the "enhanced" sample fish. Hake ovaries were collected by size bins for histology and RNA analysis, with the ovaries preserved in 10% neutral-buffered formalin and the ovary RNA samples preserved in RNA*later*, an aqueous tissue storage reagent. The liver of the hake selected for ovary removal was also taken, with one piece frozen and another piece preserved in RNA*later*. Ten stomachs per trawl were taken, of which five were preserved in 10% neutral-buffered formalin for later analysis back on shore, while the contents of the other five were identified to the top three species and recorded without delay. With regards to non-hake species, lengths were taken from all rockfish, squid, and any species that was dominant in the catch composition. Lastly, a variety of species were frozen whole for a mix of special project requests.

Oceanographic Sampling

Equipment

Vertical profiles of temperature and salinity data were collected on the *Shimada* using a rosette-mounted Sea-Bird SBE 911plus CTD system. 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 911plus CTD. Additional oceanographic data were collected by attaching Sea-Bird SBE 39plus temperature and pressure recorders to the AWT headrope kite and underwater camera system during trawls, and by deploying an Oceanscience UnderwayCTD (UCTD) while the vessel was moving. Sea surface temperature and salinity data were collected using a Sea-Bird SBE probe located below the vessel's waterline in the *Shimada*'s flow-through system. On the *Nordic Pearl*, profiles of temperature, salinity, and DO were collected on all trawls from a net-mounted CTD (RBRconcerto3 standard logger) that was affixed to the starboard trawl ribline, adjacent to the trawl camera.

Operations

Physical oceanographic sampling was conducted day and night on the *Shimada*. CTD casts were performed at night at predetermined locations along acoustic transects, and also when the acoustic system was calibrated. UCTD casts were conducted at predetermined stations during daytime operations while the ship was underway and collecting acoustic data, but only if sea conditions were favorable for safely deploying and retrieving the UCTD probe (operations were cancelled when winds consistently exceeded 25 kn and/or seas were too rough). When deploying UCTDs, the *Shimada* slowed down to about 6 kn. The *Shimada*'s Scientific Computer System (SCS) collected sea surface data (e.g., temperature and salinity) continuously day and night throughout the entire survey.

Results

Acoustic System Calibration

Two calibrations of the *Shimada*'s EK80 acoustic system were conducted: the first on 30 June offshore of Monterey, California, and the second on 23 September in Elliott Bay, Washington. Results from both calibrations (Table 2) were within expected levels based on factory settings and results from previous calibrations. The *Nordic Pearl's* acoustic system was calibrated on 17 August in Saanich Inlet, Vancouver Island. Calibration results for the *Nordic Pearl* were also within expected levels

Acoustic Sampling and Pacific Hake Distribution

The *Shimada* collected acoustic data from 76 transects (Table 3) between lats 34°26.7′N (Transect 1) and 48°46.7′N (Transect 87), for a linear distance of 2,690 nmi. The *Nordic Pearl* collected acoustic data from 32 transects (Table 4) between lats 48°56.7′N (Transect 88) and 54°41.6′N (Transect 111), for a linear distance of 1,148 nmi. The *Shimada* dropped 11 transects, eight of which were dropped during the first half of Leg 2 off Northern California when the *Shimada* ran every other transect because of a potential survey time constraint; the *Nordic Pearl* dropped three transects, one of which (Transect 114) was dropped because it was fully in U.S. waters.

Six transects (22, 33, 39, 40, 41, and 62) were extended further west to map the offshore extent of hake sign; total linear distance of the extensions was slightly over 32 nmi. Two transects (46 and 52) were later determined to potentially have offshore hake, but were not extended at the time. The *Shimada*, at the discretion of the ship's commanding officer, adjusted the inshore waypoints of Transects 10 and 11 to the west for safety reasons, resulting in Transect 10 ending at a bottom depth of approximately 170 m and Transect 11 starting at a bottom depth of approximately 250 m. Transect 83 was shortened by 5 nmi based on bottom depth and having matched the position of the CTD station farthest offshore. The *Nordic Pearl* shortened four transects off Vancouver Island (88–91) and two off the northwest end of Haida Gwaii (115 and 116) to comply with a Canadian maritime requirement of staying within approximately 25 nmi of the shore, given crew staffing on the vessel.

Adult hake were observed on 61 transects, ranging from Transect 14, off Monterey (which was the northernmost start of observed adult hake sign since 2011), to the eastern side of Transect 104, off Price Island, British Columbia (Figure 2). Between Transects 14 and 87, the *Shimada* observed that only four transects (15, 22, 79, and 81) had no adult hake. Concentrations of adult hake south of lat 40°N were comparatively light, except for one area between Monterey Bay and San Francisco. North of lat 40°N through lat 47°N, aggregations of observed adult hake sign were more consistent and extensive; areas of strong adult hake sign were observed along Northern California from Humboldt Bay, all along the coast of Oregon, and into southwestern Washington. In Canadian waters, minimal adult hake sign was observed.

Biological sampling

The *Shimada* successfully conducted 64 midwater trawls during the survey and the *Nordic Pearl* conducted 18 (Figure 3, Table 5, Table 6). Average trawl duration on the *Shimada* was 13.4 minutes (range: 0.1–32.3); 80% of trawls (n = 51) lasted under 20 minutes. Only six trawls, which targeted weaker and more diffuse offshore sign, were longer than 30 minutes. Average trawl depth was 270 m (range: 110–513). Most trawls (73%, n = 47) were conducted between 150 and 350 m; only 9% of trawls (n = 6) were shallower than 150 m, and only 17% (n = 11) were deeper than 350 m. Over half of all trawls conducted on the *Shimada* (56%, n = 36) were within 50 m of the bottom. On the *Nordic Pearl*, average trawl duration and gear depth were 21.1 minutes (range: 8.0–38.3) and 248 m (range: 110–439), respectively; 50% of the trawls were between 100 and 200 m. On the *Shimada*, five trawls were aborted because marine mammals were within 500 m of the vessel; four other trawls were aborted because of gear issues. No trawls were aborted on the *Nordic Pearl*.

Of the 64 trawls that the *Shimada* conducted, 60 (94%) caught hake. Overall, hake catch weights ranged from <0.1 kg to 1,534.1 kg, with an average of 256 kg; non-hake catch weights ranged from <0.1 kg to 2,102.3 kg, with an average of 89 kg. Of the 18 trawls that the *Nordic Pearl* conducted, eight (44%) caught hake, although only two trawls (10 and 14) caught more than a small amount of hake. Hake catch weights ranged from 0.6 kg to over 3,600 kg. The *Shimada* also conducted two successful Methot trawls (Table 7), the first of which was an open-codend test trawl which still got clogged with pyrosomes (Pyrosomatidae) and krill (Euphausiidae).

Hake was the dominant species caught in the trawls that the *Shimada* conducted (Table 8), accounting for 73% of catch composition by weight. Shortbelly rockfish (*Sebastes jordani*), caught primarily in Trawl 44 (Transect 50), and sablefish (*Anoplopoma fimbria*), caught primarily in Trawl 33 (Transect 39), accounted for 10% and 7% of catch composition by weight, respectively. Previous IAT surveys have caught comparatively large quantities of shortbelly rockfish, but catching >1,300 kg of sablefish in one trawl (a trawl that was targeting near-bottom hake at a depth of approximately 125 m) was unprecedented. Pyrosomes accounted for only 3% of catch composition by weight, but were the most numerous species caught; they were especially abundant at the beginning of the survey. However, by the time the survey reached Monterey Bay (Transect 15), pyrosome abundance in trawls had decreased markedly. Across all trawls, relatively large numbers of northern anchovy (*Engraulis mordax*) and California headlightfish (*Diaphus theta*) were caught. On the *Nordic Pearl*, hake accounted for roughly 50% of overall catch composition by weight (Table 9), but 95% of these hake came from only one trawl (Trawl 10, Transect 102). Yellowtail rockfish (*Sebastes flavidus*), at roughly 16% of total catch composition by weight, was the most abundant species of rockfish caught. Relatively large numbers of Pacific herring (*Clupea pallasi*) and redstripe rockfish (*Sebastes proriger*) were also caught.

Between the *Shimada* and the *Nordic Pearl*, more than 14,200 hake were measured for length, and nearly 2,300 pairs of hake otoliths were collected (Table 10, Table 11). Hake stomachs were examined on both vessels, but only on the *Shimada* were hake stomachs, livers, and gonads sampled for future lab analysis; hake fin clips were collected only on the *Nordic Pearl*. Raw length–frequency distributions (Figure 4) were characterized by U.S. hake displaying a widely spaced bimodal distribution of age-1 hake (centered on 27 cm) and age-2+ hake, with a much smaller presence of age-0 hake at 4–14 cm. Hake in Canada consisted primarily of fish between 40 and 64 cm, with a mode at 49 cm. Hake specimens collected during the survey ranged in age from 1 to 18 years (Figure 5); age-1 hake (2020 year-class) were the most dominant age class observed, followed by age-5 hake (2016 year-class) and age-7 hake (2014 year-class). Age-4 and age-11 hake formed smaller modes.

Pacific hake abundance estimate

Due to non-linearity, the old EK60 system used in prior IAT surveys collected raw acoustic data (Nautical Area Scattering Coefficient, or NASC) that were consistently higher than those collected with the new EK80 system. Based on experiments conducted in 2018 that compared the EK60 with the EK80, as well as an analysis of EK60 data collected in 2019, it was found that EK60 NASC values were consistently larger than those of the EK80 by approximately 6%. To maintain a consistent biomass time series (1995–2021), total biomass estimates this year were multiplied by a factor of 1.06 so that they would compare favorably to biomass estimates had the old EK60 system still been used.

The 2021 biomass estimate of adult hake off the west coast of the United States and Canada totaled 1.525 million metric tons (mt, Figure 6), with approximately 95.7% (1.459 mt) of observed biomass located in U.S. waters. Although the 2021 estimate was slightly smaller than the 2019 biomass estimate (a decrease of 0.198 mt, or approximately 11.5%), it was close (4.9% larger) to the average biomass estimate for all surveys conducted since 1995 (1.525 vs. 1.453 mt). Age-5 and age-7 hake contributed most to the 2021 adult biomass estimate—combining for just under 50%—followed by age-4 (14.6%) and age-11 (10.9%) hake (Figure 7).

Oceanographic sampling

The *Shimada* collected 209 CTD temperature and salinity profiles at selected locations along the line transects and at acoustic system calibration sites (Figure 8); 93 UCTD profiles were successfully collected (two were tests). Additional temperature profiles were collected from 135 successful SBE 39plus casts (66 with the AWT headrope kite, 66 with the AWT camera system, two with the Methot trawl, and one test). Also collected were 92 HAB samples and 2,128 eDNA samples; SADIE collected 50 samples. The *Nordic Pearl* collected CTD profiles at the calibration site and at all trawl stations.

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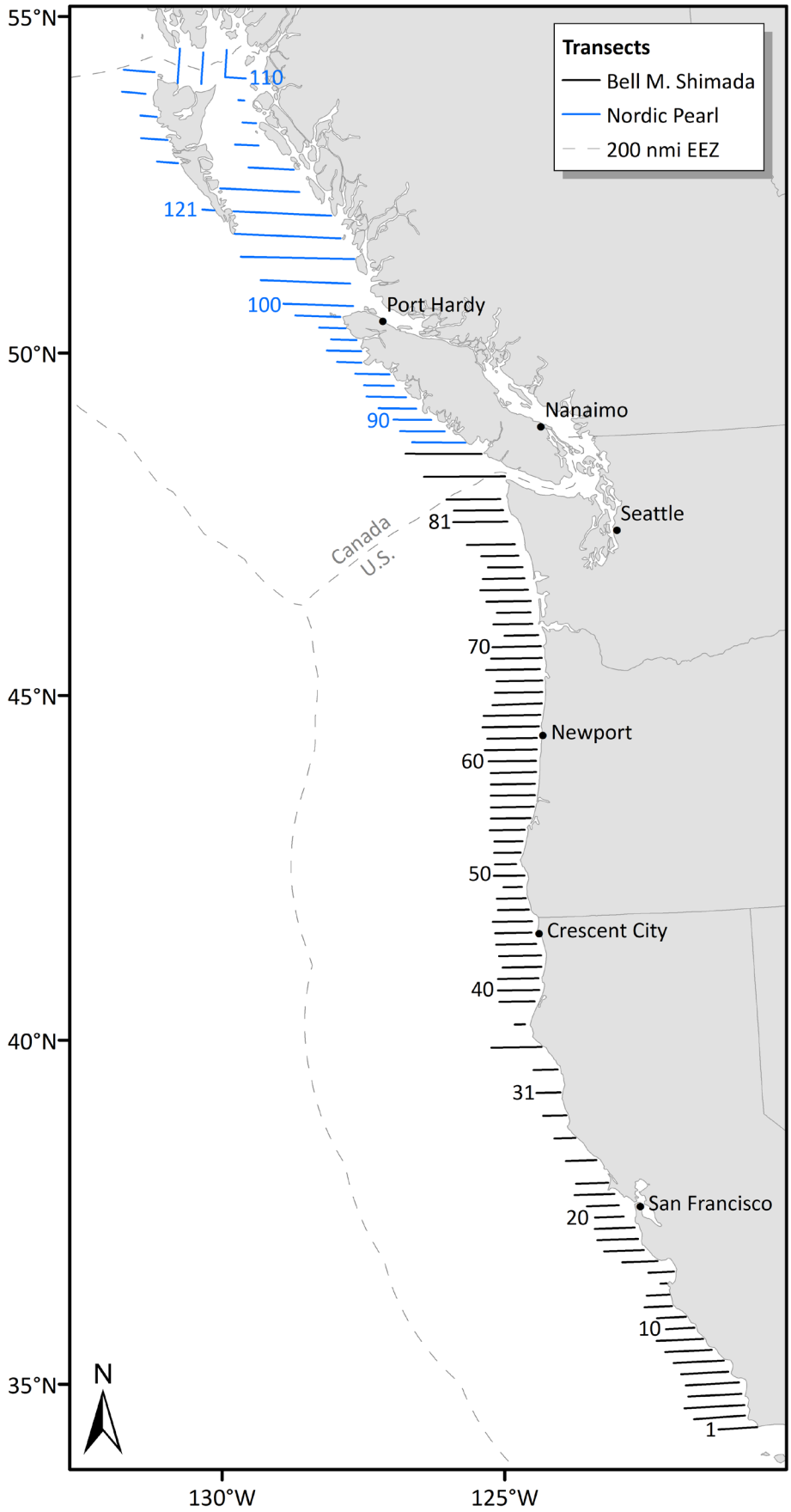

Figure 1. Survey track design used during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

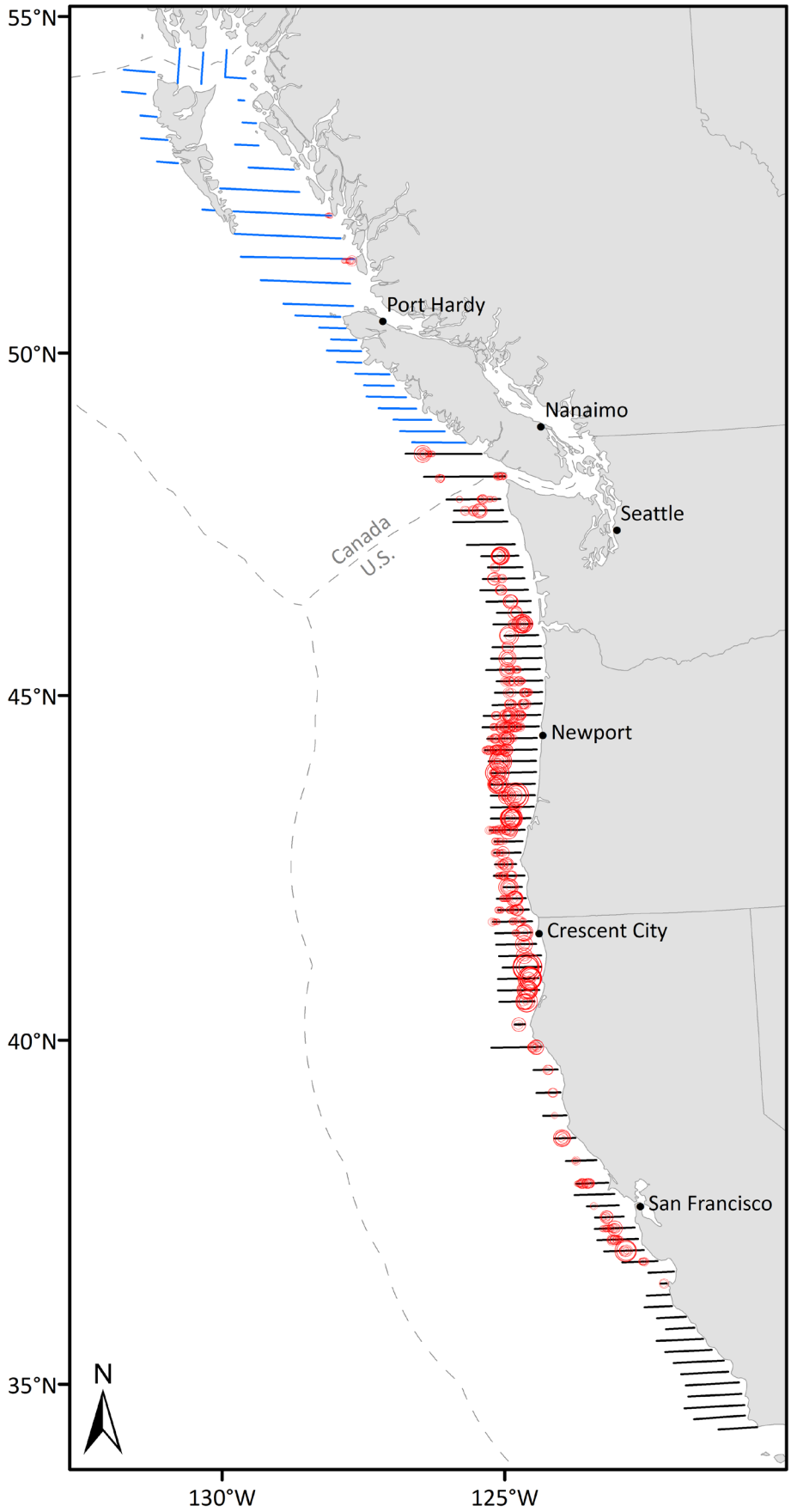

Figure 2. Acoustic area backscattering attributed to adult (age-2+) Pacific hake along transects completed during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

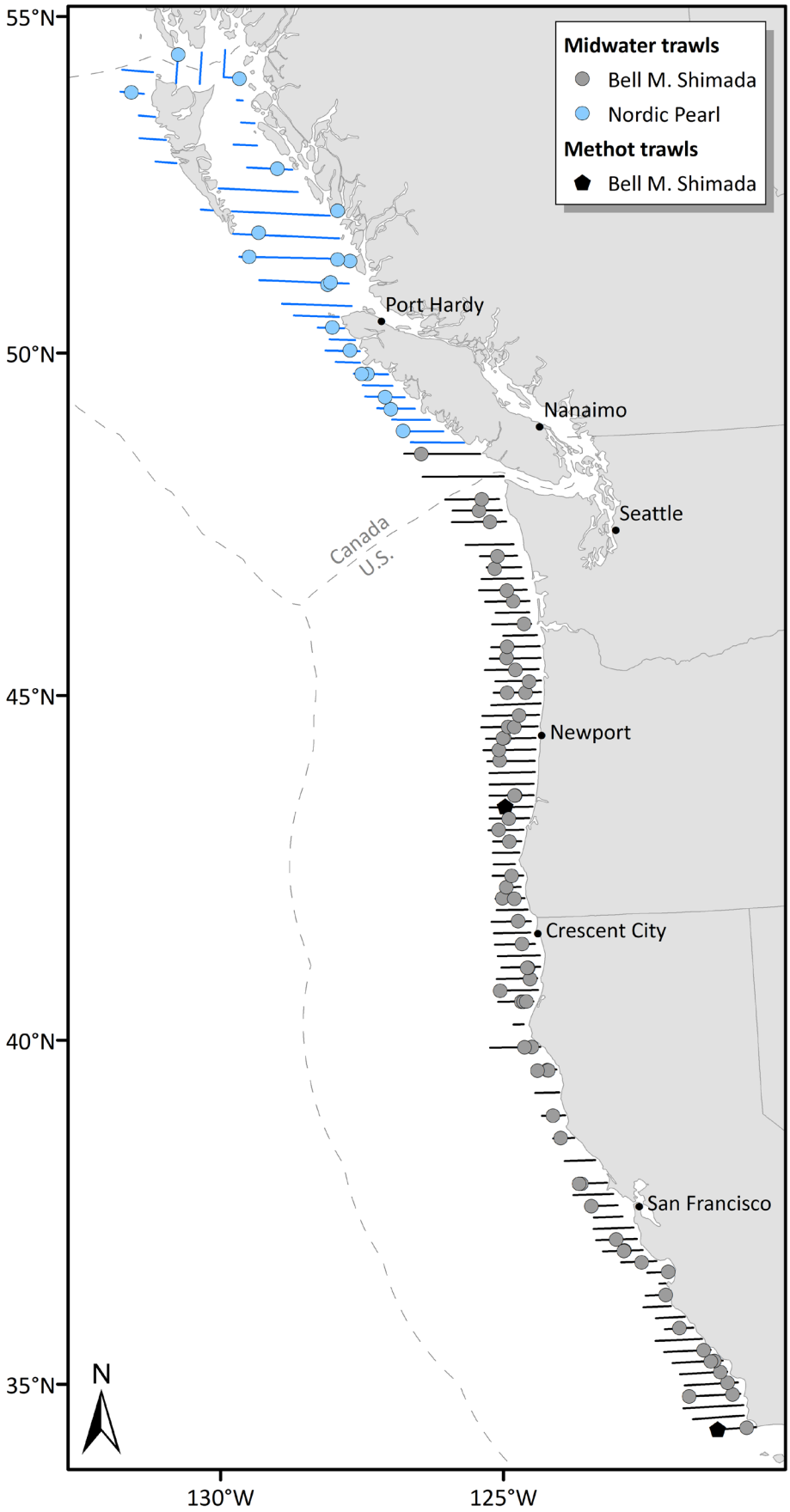

Figure 3. Acoustic transect lines and locations of midwater trawls and Methot trawls conducted during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

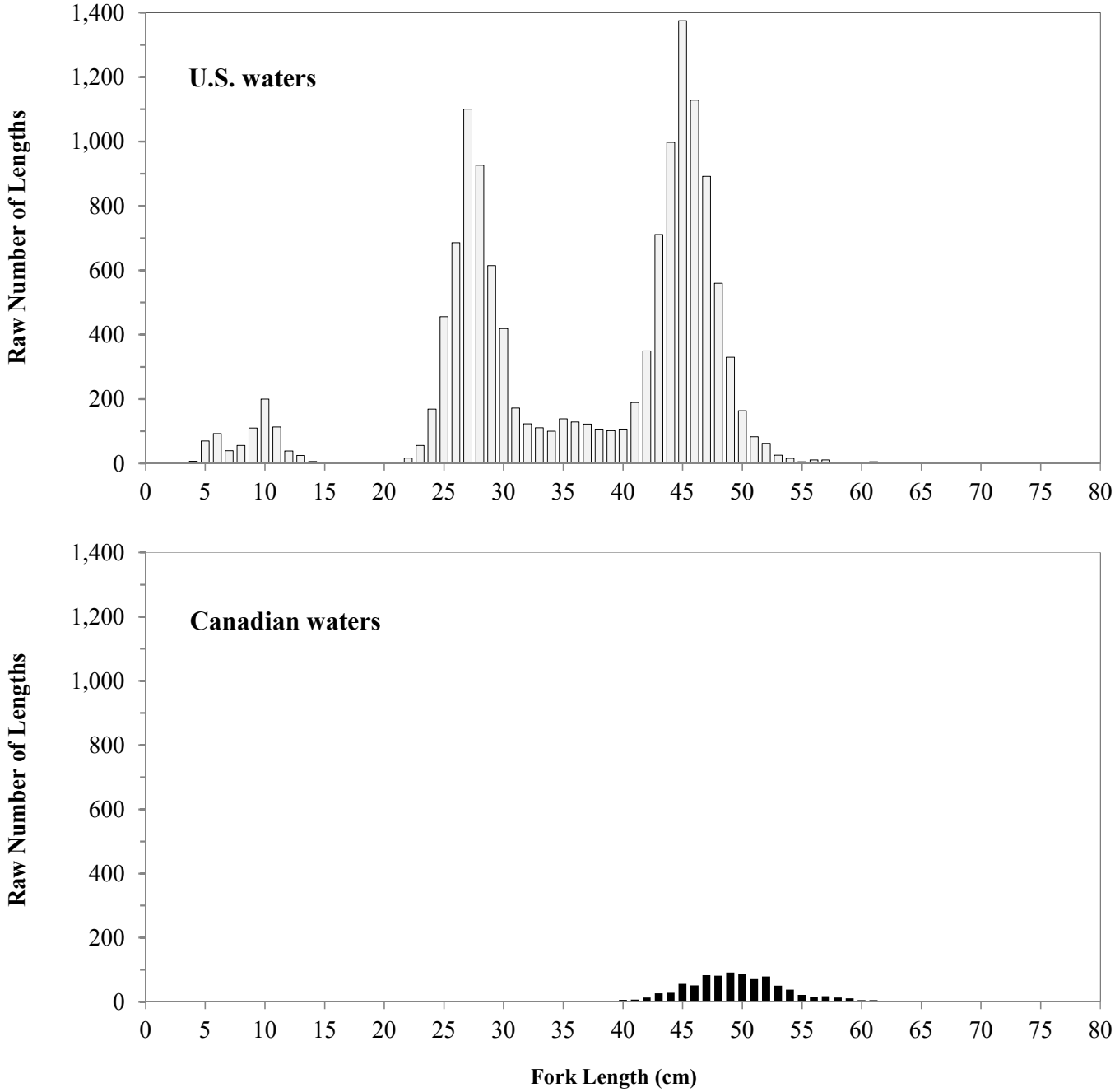

Figure 4. Raw length–frequency distributions of Pacific hake from specimens measured during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

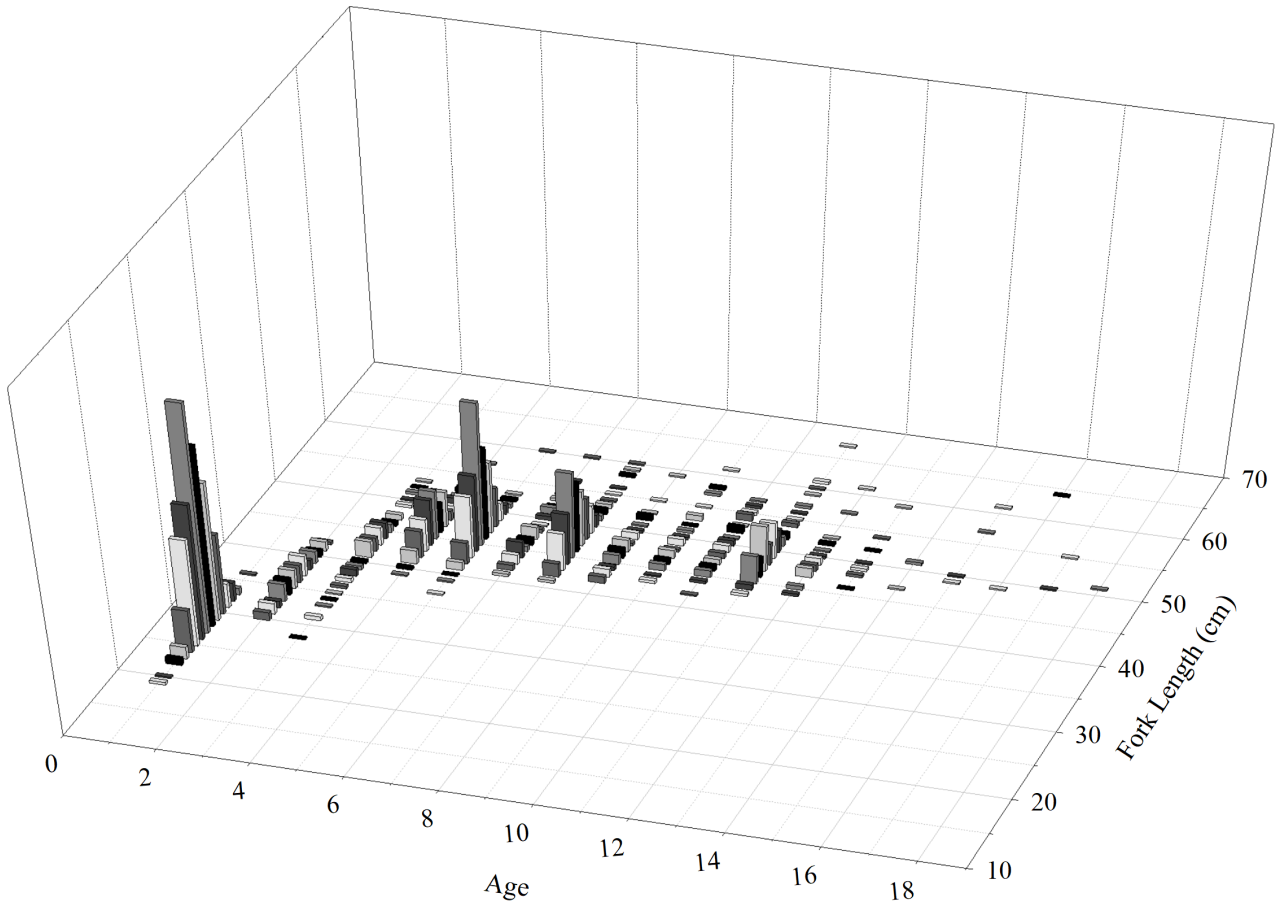

Figure 5. Age–length distribution of Pacific hake from specimens collected during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey. Ages are based on interpretation of otoliths.

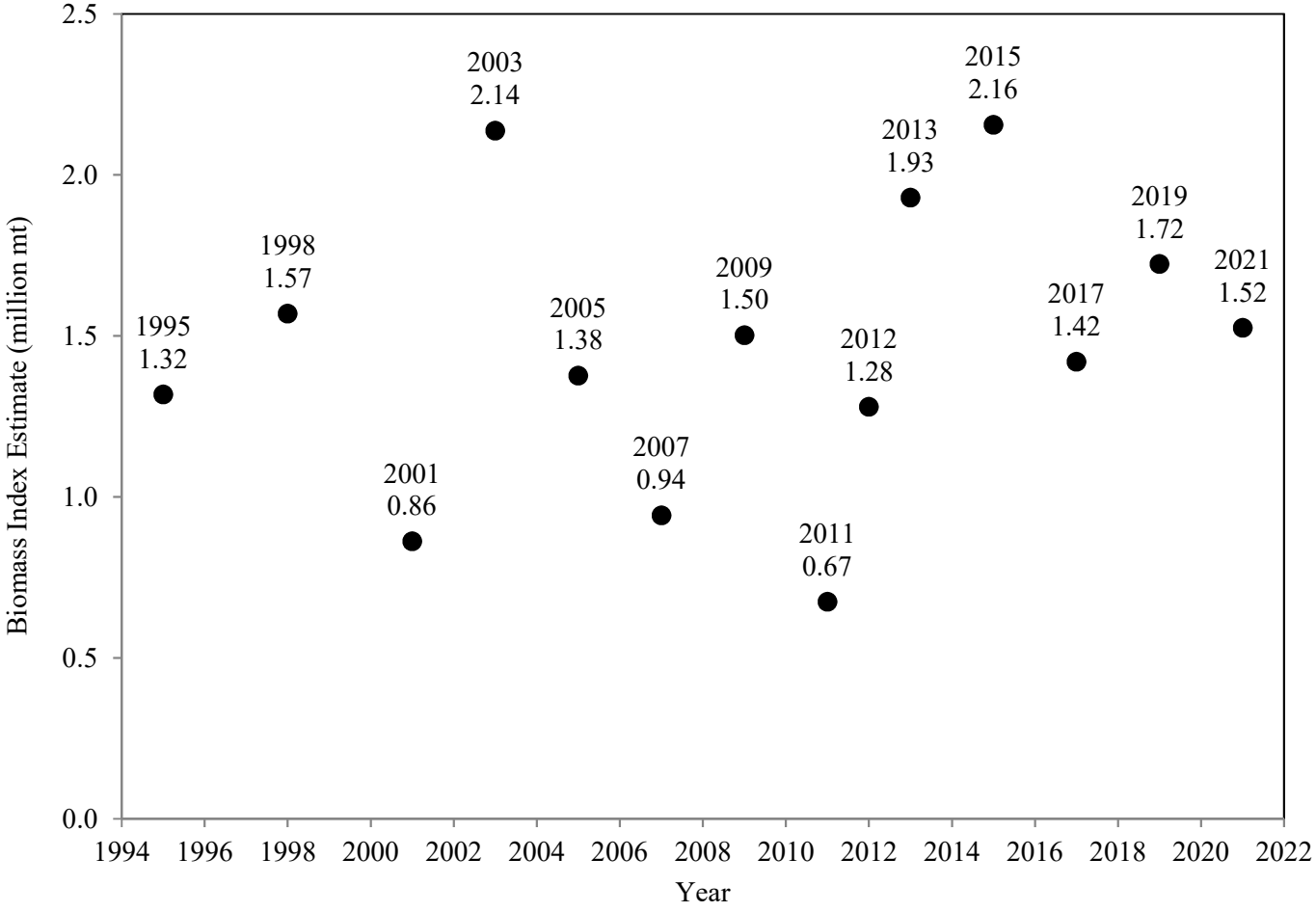

Figure 6. Coastwide biomass estimates (millions of metric tons) of adult Pacific hake (age-2+) from joint U.S.–Canada integrated acoustic trawl surveys, 1995 to 2021. Each symbol displays survey year and biomass estimate. *Note*: The 2021 biomass estimate was converted from one based on the EK80 acoustic system to one based on the EK60 system. Historical biomass estimates (1995–2013) were re-analyzed in 2015 and may be different from those in previous reports.

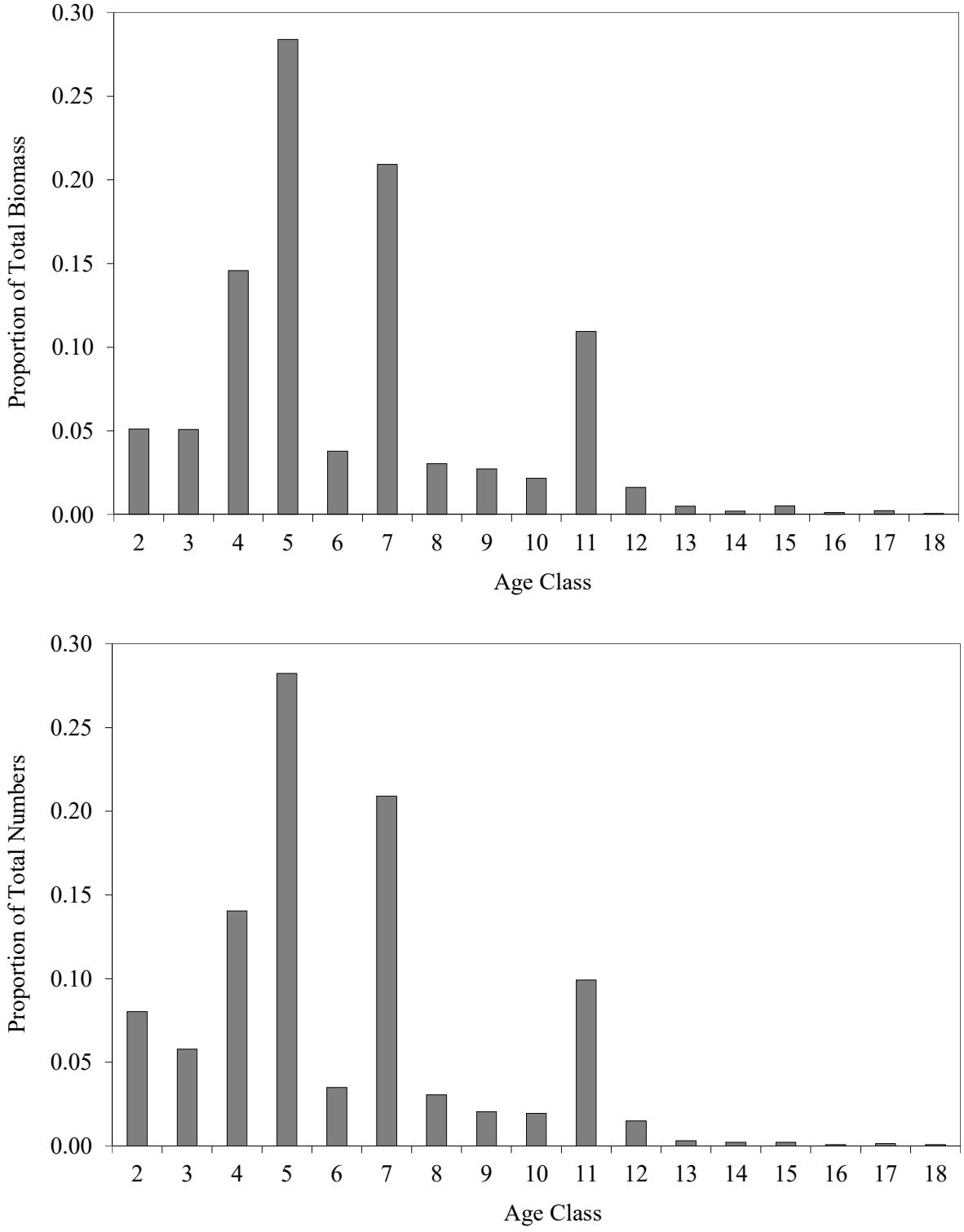

Figure 7. Acoustically weighted estimated proportions of total biomass and total numbers of adult (age-2+) Pacific hake, by age class, from the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

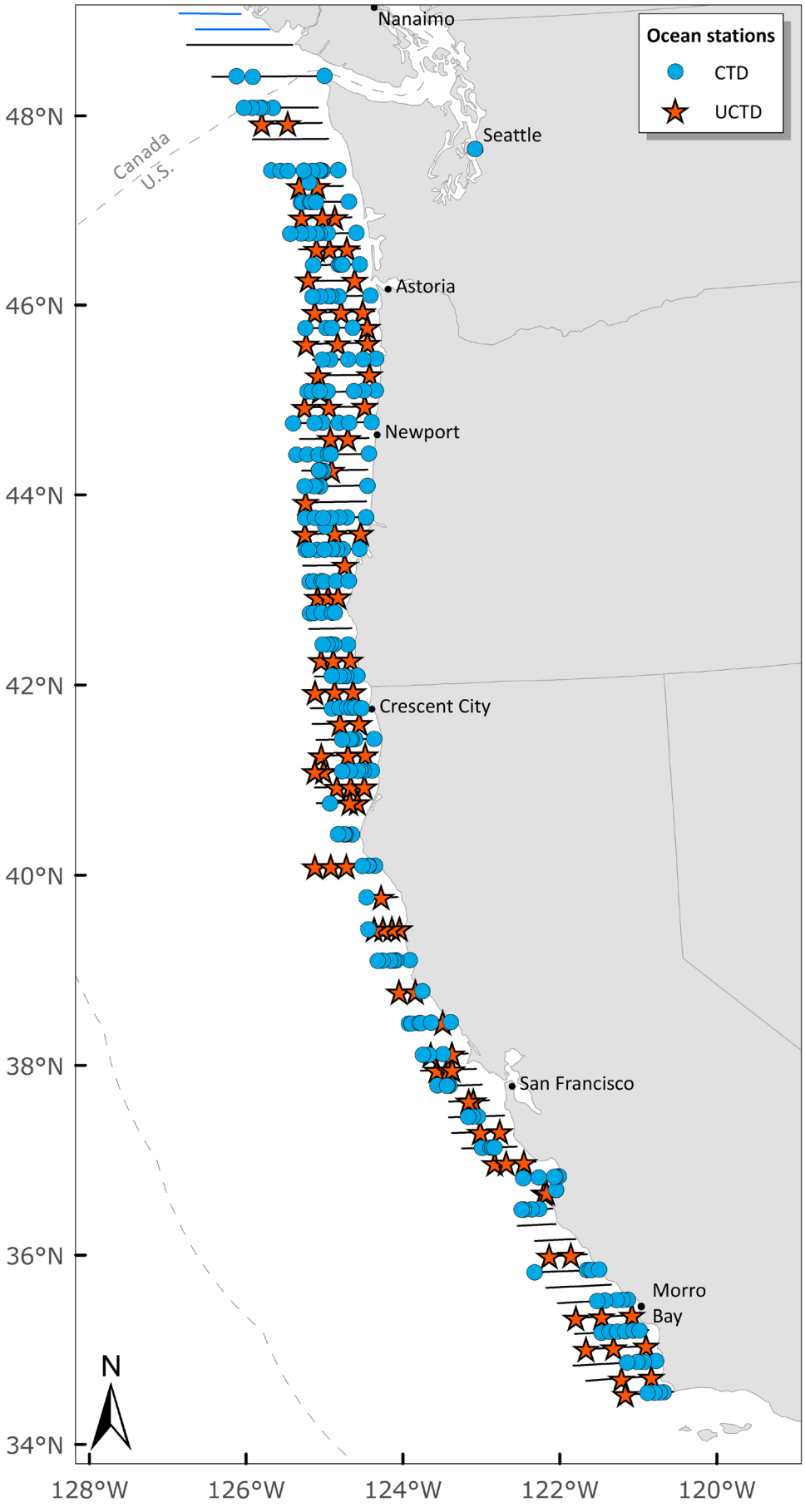

Figure 8. Acoustic transect lines with locations of conductivity–temperature–depth (CTD) rosette deployments and underway CTDs (UCTDs) conducted by the NOAA Ship *Bell M. Shimada* during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

Table 1. Itinerary for the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

Date(s)	Event(s)
U.S. Leg 1	
06/26	Personnel embark onto the NOAA Ship *Bell M. Shimada* in Newport (OR).
06/27	The *Shimada* leaves Newport and starts transiting south.
06/29	The *Shimada* retrieves a Drifting Autonomous Spar Buoy Recorder (DASBR) west of Monterey (CA).
06/30	Personnel conduct an acoustic system calibration of the *Shimada* with a standard target offshore of Monterey.
07/01	The survey starts with Transect 1 at Point Conception (CA).
07/10	Small-boat transfer southwest of San Francisco (CA) to offload personnel.
07/13	High winds and rough seas force the *Shimada* to find shelter in Drakes Bay (CA). The *Shimada* finishes Transect 22; starts transit north to Newport.
07/15	The *Shimada* conducts one Methot trawl operation.
07/16	The *Shimada* pulls into Newport one day ahead of schedule.
07/17–19	Inport Newport; exchange personnel.
U.S. Leg 2	
07/20	The *Shimada* leaves Newport; a leaking pipe in the engine room requires a return to port.
07/21	Piping repairs and testing are successfully completed.
07/22	The *Shimada* leaves Newport and starts transiting south.
07/24	The *Shimada* resumes the survey with Transect 23.
08/07	Fishing operations are suspended because of mechanical issues with the port winch. The *Shimada* finishes Transect 59. Issues with an electrical generator warrant a return to Newport, but fog precludes entering Yaquina Bay (OR).
08/08	The *Shimada* pulls into Newport one day ahead of schedule.
08/09–25	Inport Newport; exchange personnel.
U.S. Leg 3	
08/26–09/02	The planned departure is delayed eight days because of a ship's staffing shortage.
09/03	The *Shimada* leaves Newport.
09/04	The *Shimada* resumes the survey with Transect 60.
09/21	The *Shimada* finishes the survey with Transect 87; starts transit to Seattle (WA).
09/23	Personnel conduct an acoustic system calibration of the *Shimada* with a standard target in Elliott Bay (WA); Seattle personnel disembark. The *Shimada* starts transiting to Newport.
09/25	Inport Newport; personnel disembark.

Table 1 (continued). Itinerary for the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

Date(s)	Event(s)
Canada Leg 1	
08/17	Personnel embark onto the *Nordic Pearl* in Sidney (BC). The *Nordic Pearl* transits to Coles Bay, Saanich Inlet (BC); personnel conduct an acoustic system calibration of the *Nordic Pearl* with a standard target.
08/18	The *Nordic Pearl* conducts a test trawl in Saanich Inlet; starts transit to the west coast of Vancouver Island.
08/19	The *Nordic Pearl* conducts a CTD cast in Folger Passage, Barkley Sound (BC). Poor weather forces the *Nordic Pearl* to find shelter in Ucluelet (BC).
08/20	The *Nordic Pearl* participates in a Search and Rescue operation, then finds shelter in Ucluelet because of unfavorable weather.
08/21	The *Nordic Pearl* starts surveying with Transect 88.
08/24	The *Nordic Pearl* finishes Transect 95; starts transit to Port Hardy (BC).
08/25	Inport Port Hardy; exchange personnel and obtain fuel. The *Nordic Pearl* departs in the evening.
08/26	The *Nordic Pearl* resumes the survey with Transect 96.
08/30	The *Nordic Pearl* stops surveying while on Transect 102; starts transit to Port Hardy.
08/31	Inport Port Hardy; exchange personnel.
Canada Leg 2	
09/01	The *Nordic Pearl* resumes the survey with Transect 102.
09/04	A strong gale forces the *Nordic Pearl* to find shelter by Hotspring Island (BC).
09/07	The *Nordic Pearl* obtains fuel in Prince Rupert (BC) and stays sheltered because of gale-force winds in Dixon Entrance.
09/11	The *Nordic Pearl* finishes Transect 121; starts transit south.
09/12	The *Nordic Pearl* obtains fuel in Port Hardy.
09/13	Inport Sidney; personnel disembark.

Table 2. Simrad EK80 38-kHz acoustic system descriptions and settings used aboard the NOAA Ship *Bell M. Shimada* during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey, and results from acoustic system calibrations with a standard target. Key: $S_a = 10\log_{10}$ (area scattering coefficient), S_v = volume backscattering, *RMS* = root mean square.

	Calibrations		
	Survey system settings	**30 Jun Monterey, CA**	**23 Sep Elliott Bay, WA**
Transducer:	ES38B	—	—
Serial number:	30715	—	—
Transducer depth (m):	9.15	—	—
Pulse length (ms):	1.024	—	—
Transmitted power (W):	2,000	—	—
Two-way beam angle (dB):	–20.7	—	—
S_a correction (dB):	–0.10	–0.10	–0.10
System gain (dB):	26.37/26.56*	26.37	26.56
3-dB beam angle (deg.)			
Alongship (Minor):	7.10/6.93*	7.10	6.93
Athwartship (Major):	6.93/6.89*	6.93	6.89
Angle offset (deg.)			
Alongship (Minor):	–0.13	–0.13	–0.13
Athwartship (Major):	–0.17	–0.17	–0.17
Post-processing S_v threshold (dB):	–69	—	—
Sphere range from transducer (m):	—	25	23
Ambient sound speed (m/s):	1,480.0	1,493.5	1,495.25
Water temperature at transducer (°C):	—	12.4	13.3
Water temperature at sphere (°C):	—	10.5	12.8
Ambient water temperature (°C):	6.9	11.3	13.0
Ambient water salinity (ppt):	33.7	33.9	30.9
RMS error (dB):	—	0.06	0.05

*Values from the 30 June calibration were used for survey Legs 1 and 2, while values from the 23 September calibration were used for survey Leg 3.

Table 3. Coordinates and length of transects conducted by the NOAA Ship *Bell M. Shimada* during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

	Start		End		
Transect	Lat (N)	Long (W)	Lat (N)	Long (W)	Length (nmi)
1	34°26.70′	121°10.74′	34°26.66′	120°29.47′	34.0
2	34°37.42′	120°41.72′	34°36.68′	121°36.56′	45.1
3	34°46.70′	121°46.04′	34°46.69′	120°41.70′	52.8
4	34°56.64′	120°43.99′	34°56.70′	121°41.49′	47.1
5	35°06.72′	121°43.61′	35°06.70′	120°46.14′	47.0
6	35°16.70′	120°56.89′	35°16.71′	121°48.13′	41.8
7	35°26.67′	121°55.76′	35°26.70′	121°01.03′	44.6
8	35°36.65′	121°13.32′	35°36.69′	122°04.43′	41.6
9	35°46.53′	121°22.14′	35°46.70′	122°12.98′	41.2
10	35°56.65′	122°02.41′	35°56.70′	121°31.16′	25.3
11	36°06.69′	121°39.66′	36°06.68′	122°11.61′	25.8
12	36°16.70′	122°24.78′	36°16.71′	121°54.53′	24.4
13	36°26.71′	122°21.76′	36°26.71′	121°56.63′	20.2
14	36°36.71′	122°06.22′	36°36.70′	121°59.02′	5.8
15	36°46.73′	121°50.44′	36°46.72′	122°19.02′	22.9
16	36°56.68′	122°08.19′	36°56.71′	122°47.40′	31.3
17	37°06.72′	123°06.93′	37°06.69′	122°22.95′	35.1
18	37°16.77′	123°14.51′	37°16.63′	122°29.03′	36.2
19	37°26.65′	122°31.99′	37°26.71′	123°16.70′	35.5
20	37°36.68′	123°16.22′	37°36.72′	122°43.72′	25.7
21	37°46.71′	122°49.00′	37°46.69′	123°25.01′	28.5
22	37°56.75′	122°53.53′	37°56.69′	123°38.19′	35.2
23	38°06.69′	123°36.14′	38°06.67′	122°59.73′	28.6
24	dropped				
25	38°26.69′	123°12.42′	38°26.71′	123°46.96′	27.0
26	dropped				
27	38°46.71′	123°35.29′	38°46.69′	123°59.38′	18.8
28	dropped				
29	39°06.75′	124°11.51′	39°06.64′	123°45.03′	20.5
30	dropped				
31	39°26.68′	124°18.79′	39°26.70′	123°51.08′	21.4
32	dropped				
33	39°46.69′	123°53.72′	39°46.71′	124°21.90′	21.7
34	dropped				
35	40°06.72′	124°11.76′	40°06.71′	125°10.12′	44.6
36	dropped				
37	40°26.65′	124°42.53′	40°26.75′	124°30.72′	9.0
38	dropped				
39	40°46.70′	125°00.21′	40°46.68′	124°18.87′	31.3
40	40°56.65′	124°13.01′	40°56.71′	125°01.67′	36.8
41	41°06.69′	125°01.67′	41°06.73′	124°13.94′	36.0
42	41°16.70′	124°55.93′	41°16.70′	124°10.07′	34.5
43	41°26.67′	124°10.28′	41°26.66′	124°59.94′	37.2

Table 3 (continued). Coordinates and length of transects conducted by the NOAA Ship *Bell M. Shimada*.

	Start		End		
Transect	**Lat (N)**	**Long (W)**	**Lat (N)**	**Long (W)**	**Length (nmi)**
44	41°36.70′	124°15.88′	41°36.69′	125°03.19′	35.4
45	41°46.68′	125°04.47′	41°46.74′	124°21.01′	32.4
46	41°56.67′	124°20.18′	41°56.65′	125°07.08′	34.9
47	42°06.71′	125°00.48′	42°06.75′	124°23.72′	27.3
48	42°16.77′	124°27.09′	42°16.69′	125°01.70′	25.6
49	42°26.71′	124°31.40′	42°26.71′	124°53.88′	16.6
50	42°36.71′	124°28.22′	42°36.74′	125°05.16′	27.2
51	42°46.71′	125°03.84′	42°46.70′	124°37.99′	19.0
52	42°56.65′	124°32.24′	42°56.69′	125°04.43′	23.6
53	43°06.67′	124°29.99′	43°06.72′	125°04.18′	25.0
54	43°16.68′	125°09.81′	43°16.68′	124°27.00′	31.2
55	43°26.73′	124°19.96′	43°26.72′	125°07.99′	34.9
56	43°36.68′	125°07.95′	43°36.67′	124°15.39′	38.0
57	43°46.73′	124°13.67′	43°46.75′	125°08.17′	39.3
58	43°56.67′	125°07.62′	43°56.71′	124°13.40′	39.0
59	44°06.64′	125°07.78′	44°06.75′	124°11.75′	40.2
60	44°16.69′	124°11.67′	44°16.72′	125°10.07′	41.8
61	44°26.65′	125°14.84′	44°26.69′	124°10.29′	46.1
62	44°36.73′	124°09.86′	44°36.69′	125°11.79′	44.1
63	44°46.71′	125°17.44′	44°46.72′	124°07.03′	50.0
64	44°56.69′	124°04.96′	44°56.71′	125°15.79′	50.1
65	45°05.93′	125°04.73′	45°06.70′	124°02.80′	43.7
66	45°16.69′	124°02.03′	45°16.71′	125°01.64′	41.9
67	45°26.70′	124°59.17′	45°26.71′	124°01.66′	40.3
68	45°36.86′	124°04.44′	45°36.70′	125°12.30′	47.5
69	45°46.71′	125°05.93′	45°46.69′	124°01.54′	44.9
70	45°56.69′	125°03.96′	45°56.82′	124°02.46′	42.8
71	46°06.69′	124°05.72′	46°06.69′	124°48.55′	29.7
72	46°16.67′	124°12.65′	46°16.70′	125°02.62′	34.5
73	46°26.69′	124°58.00′	46°26.74′	124°14.91′	29.7
74	46°36.72′	125°11.14′	46°36.70′	124°14.47′	38.9
75	46°46.70′	124°17.68′	46°46.70′	125°18.98′	42.0
76	46°56.64′	125°15.61′	46°56.69′	124°21.70′	36.8
77	47°06.65′	124°23.97′	47°06.70′	125°08.79′	30.5
78	47°16.69′	125°17.38′	47°16.70′	124°29.08′	32.8
79	47°26.72′	124°33.44′	47°26.68′	125°35.94′	42.3
80	dropped				
81	47°46.73′	124°42.38′	47°46.71′	125°53.62′	47.9
82	47°56.72′	125°52.63′	47°56.88′	124°48.11′	43.2
83	48°06.72′	124°51.61′	48°06.69′	126°02.02′	47.0
84	dropped				
85	48°26.63′	126°32.26′	48°26.67′	124°45.09′	71.1
86	dropped				
87	48°46.70′	126°56.74′	48°46.70′	125°15.46′	66.7

Table 4. Coordinates and length of transects conducted by the Canadian chartered FV *Nordic Pearl* during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

	Start		End		
Transect	**Lat (N)**	**Long (W)**	**Lat (N)**	**Long (W)**	**Length (nmi)**
88	48°56.70′	125°37.44′	48°56.84′	126°48.35′	46.6
89	49°06.79′	127°04.51′	49°06.64′	126°04.99′	39.0
90	49°16.81′	126°22.90′	49°16.78′	127°13.61′	33.1
91	49°26.73′	127°33.45′	49°26.73′	126°42.96′	32.8
92	49°36.68′	126°56.96′	49°36.78′	127°50.14′	34.5
93	49°46.72′	127°53.95′	49°46.70′	127°13.62′	26.0
94	49°56.69′	127°19.87′	49°56.70′	128°06.00′	29.7
95	50°06.72′	127°57.87′	50°06.71′	128°30.83′	21.1
96	50°16.69′	127°58.43′	50°16.70′	128°45.33′	30.0
97	50°26.71′	128°40.43′	50°26.67′	128°05.38′	22.3
98	50°36.71′	128°20.77′	50°36.73′	128°56.92′	22.9
99	50°46.73′	129°30.18′	50°46.73′	128°28.29′	39.1
100	50°56.67′	128°11.28′	50°56.67′	129°47.38′	60.6
101	51°16.69′	130°19.96′	51°16.67′	128°16.17′	77.4
102	51°38.55′	128°10.97′	51°36.73′	130°49.29′	98.3
103	51°56.69′	130°59.62′	51°56.74′	128°31.02′	91.6
104	52°16.65′	128°45.03′	52°16.79′	131°03.20′	84.5
105	52°36.75′	131°23.75′	52°36.70′	129°31.48′	68.2
106	52°56.67′	129°40.39′	52°56.83′	130°44.95′	38.9
107	53°16.59′	131°06.00′	53°16.79′	130°32.39′	20.1
108	53°36.82′	130°37.86′	53°36.80′	130°57.00′	11.4
109	53°56.69′	130°56.31′	53°56.74′	131°05.04′	5.1
110	54°16.71′	131°26.31′	54°16.79′	130°55.86′	17.8
111	54°41.55′	131°26.34′	54°16.83′	131°26.13′	24.7
112	54°09.42′	132°00.51′	54°37.91′	132°00.65′	28.5
113	54°39.79′	132°35.30′	54°08.54′	132°35.01′	31.3
114	dropped				
115	54°16.71′	133°09.44′	54°16.61′	133°55.07′	26.6
116	53°56.82′	133°54.77′	53°56.67′	133°20.11′	20.4
117	53°36.76′	133°25.13′	53°36.75′	133°01.20′	14.2
118	53°16.71′	132°43.29′	53°16.68′	133°21.36′	22.8
119	52°56.74′	132°56.20′	52°56.72′	132°25.90′	18.3
120	dropped				
121	52°16.82′	131°47.12′	52°16.63′	131°29.89′	10.5
122	dropped				

Table 5. Station and catch data summary of midwater trawls conducted by the NOAA Ship *Bell M. Shimada* during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

											Catch		
					Start position		Depth (m)		Temp (°C)		Pacific hake		Other
Trawl	Transect	Date	Time (PDT)	Duration (min)[a]	Lat (N)	Long (W)	Gear[b]	Bottom	Gear[c]	Surface	kg	*n*	kg
1	1	1 Jul	15:53	3.5	34°26.60′	120°39.49′	211[d]	273	9.37	16.75	4.9	854	33.8
2	4	2 Jul	18:36	8.6	34°56.69′	120°52.54′	175	194	9.56	15.27	24.5	3,217	36.1
3	4	3 Jul				trawl aborted because of marine mammals							
4	4	3 Jul	11:47	29.7	34°56.75′	121°39.08′	271	1,368	8.21	15.41	—	—	13.2
5	5	3 Jul	18:44	20.0	35°07.06′	120°57.14′	250	272	8.70	15.25	30.4	321	10.7
6	6	4 Jul	10:08	19.8	35°16.80′	121°04.16′	110	316	9.59	15.49	<0.1	5	111.2
7	7	5 Jul	8:28	15.2	35°26.96′	121°10.13′	295	302	8.83	15.34	128.6	1,167	418.2
8	7	5 Jul	11:50	30.0	35°26.72′	121°13.87′	367	386	8.07	15.26	156.3	1,171	75.8
9	8	5 Jul	16:30	20.2	35°36.73′	121°21.04′	160	296	9.76	14.30	0.7	81	16.9
10	10	6 Jul	14:49	16.1	35°57.17′	121°46.14′	234	1,039	8.70	15.15	—	—	12.9
11	13	8 Jul				trawl aborted because of gear issues							
12	13	8 Jul	12:22	9.1	36°26.60′	121°59.30′	265	320	9.01	11.95	1.6	139	5.1
13	15	8 Jul	18:28	15.3	36°46.70′	121°55.43′	194	545	9.05	13.54	5.1	380	7.8
14	16	9 Jul				trawl aborted because of marine mammals							
15	16	9 Jul	13:51	30.2	36°56.09′	122°24.56′	321	397	8.14	14.36	35.0	243	1.6
16	17	10 Jul	14:58	5.3	37°09.96′	122°42.98′	285	363	8.38	13.76	663.0	1,834	6.6
17	17	10 Jul	17:19	23.7	37°06.68′	122°43.52′	351	443	7.82	13.97	60.0	297	224.1
18	18	11 Jul	10:05	10.2	37°16.76′	122°51.68′	182	251	9.07	13.72	194.2	934	2.5
19	21	12 Jul	16:19	30.1	37°46.71′	123°18.10′	299	610	8.35	12.09	9.8	58	5.7
20	23	24 Jul	8:17	4.4	38°06.62′	123°28.77′	162	220	8.98	11.37	176.9	869	4.0
21	23	24 Jul	9:59	5.6	38°06.51′	123°31.20′	183	452	9.13	11.36	319.3	1,636	8.9
22	27	25 Jul				trawl aborted because of marine mammals							
23	27	25 Jul	10:41	6.1	38°46.87′	123°50.68′	237	280	8.56	10.60	274.7	489	17.4
24	29	25 Jul	16:52	18.4	39°06.74′	123°58.79′	355	387	7.44	13.07	6.2	10	3.4
25	33	26 Jul	13:19	10.3	39°46.55′	124°04.13′	280	298	7.75	11.33	125.3	722	0.6
26	33	26 Jul				trawl aborted because of marine mammals							
27	33	26 Jul	16:29	1.1	39°46.29′	124°03.21′	208	220	8.33	11.38	766.8	6,092	4.6
28	33	26 Jul	20:07	10.1	39°46.34′	124°15.36′	191	1,244	8.31	10.91	0.6	4	1.8
29	35	27 Jul	8:42	23.0	40°06.87′	124°21.69′	418	449	7.17	10.82	31.0	64	1.2
30	35	27 Jul	11:26	15.7	40°06.81′	124°30.03′	149	699	8.43	11.26	—	—	1.4

Table 5 (continued). Station and catch data summary of midwater trawls conducted by the NOAA Ship *Bell M. Shimada*.

Trawl	Transect	Date	Time (PDT)	Duration (min)[a]	Start position		Depth (m)		Temp (°C)		Catch		
											Pacific hake		Other
					Lat (N)	Long (W)	Gear[b]	Bottom	Gear[c]	Surface	kg	*n*	kg
31	39	28 Jul	10:41	16.1	40°46.72′	124°32.86′	262	527	7.75	10.83	7.7	18	9.8
32	39	28 Jul	12:59	15.7	40°46.53′	124°30.28′	350	397	7.53	10.54	145.1	277	19.0
33	39	28 Jul	16:39	11.4	40°46.66′	124°27.14′	135	157	8.39	10.38	837.4	2,052	1,471.6
34	40	29 Jul	10:31	32.3	40°56.52′	124°57.56′	285	>3,000	7.62	10.91	1.1	2	2.0
35	41	29 Jul	18:46	7.5	41°06.28′	124°22.06′	213	228	8.20	11.06	394.5	694	9.6
36	42	30 Jul	9:57	0.4	41°16.08′	124°24.14′	145	190	8.31	10.75	1,297.5	8,232	1.7
37	42	30 Jul	12:24	7.5	41°16.08′	124°25.28′	245	264	8.11	10.56	178.5	392	1.6
38	44	31 Jul	9:10	21.6	41°36.91′	124°30.87′	398	427	6.91	10.43	128.7	229	14.1
39	45	31 Jul	trawl aborted because of gear issues										
40	46	1 Aug	9:34	21.5	41°56.91′	124°35.09′	304	318	7.84	11.07	181.5	315	6.8
41	48	2 Aug	9:44	31.5	42°17.14′	124°53.51′	336	917	6.20	12.85	5.6	9	10.0
42	48	2 Aug	13:35	12.7	42°16.68′	124°39.26′	349	351	7.56	12.15	140.2	353	26.4
43	49	2 Aug	18:18	16.5	42°26.66′	124°48.68′	229	395	7.83	11.59	481.9	807	1.7
44	50	3 Aug	8:58	0.1	42°36.64′	124°42.08′	193	198	8.01	9.80	21.8	>34	2,102.3
45	53	4 Aug	8:15	1.3	43°06.55′	124°44.18′	195	223	8.07	10.06	328.8	2,428	5.3
46	54	4 Aug	14:07	15.6	43°16.87′	124°56.98′	283	793	6.97	11.30	121.9	209	3.8
47	55	5 Aug	8:41	16.3	43°26.65′	121°44.45′	445	506	6.41	12.13	56.4	96	10.9
48[e]	57	6 Aug	8:13	—	43°46.75′	124°36.39′	—	266	—	—	121.9	187	27.2
49	57	6 Aug	trawl aborted because of marine mammals										
50	57	6 Aug	10:55	6.0	43°46.64′	124°37.13′	286	292	7.64	12.77	55.2	122	50.7
51	58	6 Aug	trawl aborted because of gear issues										
52	60	4 Sep	12:54	2.2	44°17.65′	124°54.79′	261[d]	376	7.23	14.67	1,099.1	1,671	123.3
53	61	5 Sep	8:29	6.1	44°26.73′	124°55.62′	267	541	7.23	11.36	1,112.3	1,748	0.7
54	62	6 Sep	10:22	15.1	44°37.00′	124°48.90′	328	342	6.82	12.05	170.2	270	29.4
55	62	6 Sep	~13:20	~6.0	44°36.69′	124°50.53′	288	364	6.31	10.79	339.8	534	74.3
56	63	7 Sep	8:45	9.6	44°46.80′	124°43.87′	273	295	7.36	14.75	9.1	13	28.9
57	63	7 Sep	11:40	8.2	44°46.49′	124°35.89′	223	271	7.61	14.60	1,287.3	2,041	101.4
58	64	7 Sep	19:23	5.1	44°56.62′	124°29.72′	336	366	6.97	15.68	147.4	231	9.8
59	66	8 Sep	8:56	13.3	45°16.30′	124°21.14′	245	264	7.47	16.18	224.8	318	17.7
60	66	9 Sep	14:21	13.3	45°16.73′	124°44.27′	513	551	5.76	17.44	281.7	456	19.9

Table 5 (continued). Station and catch data summary of midwater trawls conducted by the NOAA Ship *Bell M. Shimada*.

Trawl	Transect	Date	Time (PDT)	Duration (min)[a]	Start position		Depth (m)		Temp (°C)		Catch		
											Pacific hake		Other
					Lat (N)	Long (W)	Gear[b]	Bottom	Gear[c]	Surface	kg	*n*	kg
61	67	10 Sep	9:20	4.0	45°26.21′	124°16.60′	160	168	7.62	16.45	—	—	0.9
62	68	10 Sep	18:02	17.2	45°36.60′	124°33.74′	318	325	6.93	17.19	71.7	114	1.8
63	69	11 Sep	14:02	10.0	45°47.05′	124°44.47′	393	397	6.28	17.41	235.8	359	1.3
64	70	12 Sep	10:33	9.2	45°57.02′	124°43.53′	313	358	7.07	17.27	15.6	23	22.7
65	72	13 Sep	8:43	9.5	46°16.77′	124°21.56′	194	232	7.55	14.71	1,534.1	2,188	4.6
66	74	14 Sep	11:06	6.8	46°36.75′	124°35.04′	144	153	7.55	15.30	9.2	13	96.9
67	75	14 Sep	18:46	10.1	46°46.18′	124°42.88′	139	146	6.76	15.37	1.1	1	17.5
68	77	16 Sep	12:24	13.8	47°05.62′	124°58.32′	330	373	6.96	14.02	5.1	7	9.2
69	78	16 Sep	18:58	31.9	47°16.42′	124°54.58′	422	565	6.08	14.11	48.0	73	20.1
70	81	18 Sep	9:54	8.5	47°46.68′	125°03.81′	155[d]	216	7.43	12.89	—	—	<0.1
71	82	19 Sep	9:37	13.0	47°56.72′	125°17.82′	417	491	6.06	11.49	713.3	883	284.6
72	83	19 Sep	18:35	15.0	48°06.70′	125°13.99′	283	324	6.82	13.01	124.7	147	16.3
73	85	22 Sep	10:50	15.0	48°46.69′	126°34.02′	449	481	6.05	13.81	162.4	230	17.5

[a] Duration is the time during trawling between "Target Depth" and "Haul Back."
[b] Gear depths were measured at the foot rope.
[c] Gear temperatures were measured at the head rope.
[d] Vertical net openings were not recorded; thus, gear depths were calculated by using an average net opening of all other trawls.
[e] Trawl 48 was aborted because of gear issues, but still caught Pacific hake. Time, position, and bottom depth are from "Haul Back."

Table 6. Station and catch data summary of midwater trawls conducted by the Canadian chartered FV *Nordic Pearl* during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

									Catch		
					Start position		Depth (m)		Pacific hake		Other
Trawl	Transect	Date	Time (PDT)	Duration (min)[a]	Lat (N)	Long (W)	Gear[b]	Bottom	kg	*n*	kg
1	89	21 Aug	14:32	20.3	49°06.89′	126°58.40′	435	470	—	—	>1.8
2	91	22 Aug	13:58	24.8	49°25.91′	127°15.17′	278	300	5.6	6	>400.6
3	92	23 Aug	9:56	23.9	49°36.66′	127°23.07′	230[c]	360	—	—	>5.7
4	94	24 Aug	9:12	37.4	49°56.77′	127°47.46′	300[c]	550	1.4	2	1,007.1
5	94	24 Aug	11:59	12.0	49°56.65′	127°55.05′	245	370	—	—	>4.3
6	96	26 Aug	10:13	17.0	50°17.53′	128°11.67′	180	175	0.6	1	>10.8
7	98	27 Aug	9:12	10.0	50°37.27′	128°36.72′	181	179	—	—	1,024.8
8	101	29 Aug	12:36	20.7	51°15.21′	128°45.04′	150[c]	195	—	—	1.6
9	101	29 Aug	13:52	17.3	51°17.23′	128°40.91′	185	180	—	—	>50.7
10	102	30 Aug	8:19	38.3	51°36.84′	128°14.68′	144	130	3,609.9	3,793	235.8
11	102	30 Aug	12:11	25.5	51°37.76′	128°32.21′	152	140	29.4	28	371.6
12	102	1 Sep	11:47	25.5	51°37.03′	130°35.46′	439	1,263	—	—	>20.0
13	103	2 Sep	7:58	22.2	51°59.06′	130°24.05′	390	410	10.6	11	>22.2
14	104	3 Sep	7:31	20.5	52°21.34′	128°34.08′	230	245	145.1	198	21.8
15	106	5 Sep	17:30	20.5	52°56.88′	130°01.59′	184	210	—	—	354.8
16	110	6 Sep	18:42	15.9	54°16.34′	131°03.01′	110	115	—	—	20.9
17	113	8 Sep	17:26	8.0	54°34.44′	132°34.51′	199	285	2.2	1	202.6
18	116	9 Sep	13:32	20.1	53°57.12′	133°38.49′	430	555	—	—	>3.0

[a] Duration is the time during trawling between "FE_END_DEPLOYMENT_TIME" and "FE_BEGIN_RETRIEVAL_TIME."
[b] Gear depths were measured at the foot rope.
[c] Gear depths for Trawls 3, 4, and 8 are from "FE_MODAL_GEAR_DEPTH."

Table 7. Station data summary of Methot trawls conducted by the NOAA Ship *Bell M. Shimada* during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

Trawl	Transect	Date	Time (PDT)	Duration (min)[a]	Start position		Depth (m)		Temp (°C)	
					Lat (N)	Long (W)	Gear	Bottom	Gear[c]	Surface
501	1	1 Jul	9:32	5.1	34°26.88′	121°10.44′	113	1,479	9.40	14.82
502	56	15 Jul	17:24	15.1	43°37.39′	124°48.83′	331	697	7.01	13.17

[a] Duration is the time during trawling between "Target Depth" and "Haul Back."

Table 8. Catch by species from 64 midwater trawls conducted by the NOAA Ship *Bell M. Shimada* during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

Common name	Scientific name	Weight (kg)	Number
Pacific hake	*Merluccius productus*	15,112.2	>48,363
shortbelly rockfish	*Sebastes jordani*	2,107.5	9,727
sablefish	*Anoplopoma fimbria*	1,411.6	3,519
sea pickle, unidentified	*Pyrosomatidae*	641.1	>57,374
spiny dogfish	*Squalus suckleyi*	324.8	>516
northern anchovy	*Engraulis mordax*	209.8	10,115
jack mackerel	*Trachurus symmetricus*	166.9	325
widow rockfish	*Sebastes entomelas*	128.5	179
Chinook salmon	*Oncorhynchus tshawytscha*	108.1	81
splitnose rockfish	*Sebastes diploproa*	71.5	716
Pacific sardine	*Sardinops sagax*	70.1	396
brown cat shark	*Apristurus brunneus*	65.9	145
chub mackerel	*Scomber japonicus*	41.4	63
yellowtail rockfish	*Sebastes flavidus*	41.1	30
moon jellyfish	*Aurelia labiata*	38.3	72
big squid	*Moroteuthis robusta*	34.5	2
egg-yolk jellyfish	*Phacellophora camtschatica*	30.6	30
rougheye rockfish	*Sebastes aleutianus*	28.5	13
California headlightfish	*Diaphus theta*	20.4	4,002
opalescent inshore squid	*Doryteuthis opalescens*	18.2	613
eulachon	*Thaleichthys pacificus*	15.8	349
Pacific ocean perch	*Sebastes alutus*	15.0	22
salp, unidentified	*Thaliacea*	14.5	>290
chilipepper rockfish	*Sebastes goodei*	12.2	16
bocaccio	*Sebastes paucispinis*	8.9	3
pineapple benthic siphonophore	*Dromalia alexandri*	8.6	505
king-of-the-salmon	*Trachipterus altivelis*	8.4	17
rabbit-eared salp	*Thetys vagina*	5.3	>110
Pacific herring	*Clupea pallasii*	5.2	73
lanternfish, unidentified	*Myctophidae*	4.2	707
glass shrimp	*Pasiphaea pacifica*	3.8	1,716
boreal clubhook squid	*Onychoteuthis borealijaponicus*	3.7	>45
magistrate armhook squid	*Berryteuthis magister*	2.9	9
canary rockfish	*Sebastes pinniger*	2.8	2
silvergray rockfish	*Sebastes brevispinis*	2.7	1

Table 8 (continued). Catch by species from 64 midwater trawls conducted by the NOAA Ship *Bell M. Shimada*.

Common name	Scientific name	Weight (kg)	Number
American shad	*Alosa sapidissima*	2.7	4
pelagic hydrozoan, unidentified	*Aequorea* sp.	2.3	24
lampfish, unidentified	*Stenobrachius* sp.	2.0	>180
octopus squid	*Octopoteuthis deletron*	1.7	11
northern lampfish	*Stenobrachius leucopsarus*	1.7	280

Table 9. Catch by species from 18 midwater trawls conducted by the Canadian chartered FV *Nordic Pearl* during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

Common name	Scientific name	Weight (kg)	Number
Pacific hake	*Merluccius productus*	3,804.6	4,040
yellowtail rockfish	*Sebastes flavidus*	1,187.1	799
Pacific herring	*Clupea pallasi*	841.4	6,884
redstripe rockfish	*Sebastes proriger*	724.4	1,522
splitnose rockfish	*Sebastes diploproa*	310.9	433
walleye pollock	*Gadus chalcogrammus*	298.3	285
silvergray rockfish	*Sebastes brevispinis*	108.5	68
Pacific ocean perch	*Sebastes alutus*	91.5	87
widow rockfish	*Sebastes entomelas*	44.9	59
lion's mane jellyfish	*Cyanea capillata*	30.4	—
bocaccio	*Sebastes paucispinis*	23.2	14
Chinook salmon	*Oncorhynchus tshawytscha*	13.1	4
rougheye rockfish	*Sebastes aleutianus*	11.8	7
jellyfish, unidentified	*Scyphozoa*	8.6	—
arrowtooth flounder	*Atheresthes stomias*	8.0	7
unsorted shab	—	7.2	—
eulachon	*Thaleichthys pacificus*	6.9	134
pelagic hydrozoan, unidentified	*Aequorea* sp.	6.5	—
clawed armhook squid	*Gonatus onyx*	>5.8	>2
lanternfish, unidentified	*Myctophidae*	>4.6	>33
longfin dragonfish	*Tactostoma macropus*	3.8	—
California headlightfish	*Diaphus theta*	>3.7	>36
lanternfish genus, unidentified	*Tarletonbeania* sp.	2.6	—
lingcod	*Ophiodon elongatus*	2.4	1
Pacific viperfish	*Chauliodus macouni*	2.0	—
salp, unidentified	*Thaliacea*	2.0	—
spiny dogfish	*Squalus suckleyi*	1.8	4
dusky rockfish	*Sebastes variabilis*	1.6	1
glass shrimp	*Pasiphaea pacifica*	>1.5	>4
moon jellyfish	*Aurelia aurita*	1.0	—
squid, unidentified	*Teuthida*	>0.7	—
ribbon barracudina	*Arctozenus risso*	0.6	—
octopus squid	*Octopoteuthis deletron*	0.5	—
broadfin lanternfish	*Nannobrachium ritteri*	0.5	7

Table 9 (continued). Catch by species from 18 midwater trawls conducted by the Canadian chartered FV *Nordic Pearl*.

Common name	Scientific name	Weight (kg)	Number
jewel squid	*Histioteuthis heteropsis*	0.5	2
dinner plate jellyfish, unidentified	*Solmissus* sp.	0.4	—
prowfish	*Zaprora silenus*	0.3	2
sharpchin rockfish	*Sebastes zacentrus*	0.2	1
barracudina, unidentified	*Paralepididae*	0.2	—
shining loosejaw	*Aristostomias scintillans*	0.2	—

Table 10. Numbers of Pacific hake biological samples and measurements collected on the NOAA Ship *Bell M. Shimada* during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

Trawl	Length	Weight and maturity	Otoliths	Stomachs		Liver and gonad	Liver and gonad RNA
				Collected	Examined		
1	197	0	0	0	0	0	0
2	211	1	1	0	0	0	0
3	—	—	—	—	—	—	—
4	0	0	0	0	0	0	0
5	321	68	68	5	5	2	2
6	5	0	0	0	0	0	0
7	565	80	80	5	5	2	2
8	437	41	41	5	5	3	3
9	81	2	2	2	0	0	0
10	0	0	0	0	0	0	0
11	—	—	—	—	—	—	—
12	139	1	1	0	0	1	1
13	111	27	27	5	5	1	1
14	—	—	—	—	—	—	—
15	243	50	50	5	5	0	0
16	483	50	50	5	5	6	6
17	297	50	50	5	5	6	6
18	412	64	64	5	5	4	4
19	58	58*	58	4	5	2	2
20	377	26	26	5	5	5	5
21	411	60	60	5	5	6	6
22	—	—	—	—	—	—	—
23	248	47	47	5	5	4	4
24	10	10	10	5	4	2	2
25	479	62	62	5	5	3	3
26	—	—	—	—	—	—	—
27	576	61	61	5	5	0	0
28	4	4	4	4	0	0	0
29	55	55	55	5	5	2	2
30	0	0	0	0	0	0	0
31	18	13	13	5	5	0	0
32	277	43	43	5	5	3	3
33	377	51	51	5	5	1	1

Table 10 (continued). Numbers of Pacific hake biological samples and measurements collected on the NOAA Ship *Bell M. Shimada*.

Trawl	Length	Weight and maturity	Otoliths	Stomachs		Liver and gonad	Liver and gonad RNA
				Collected	Examined		
34	2	2	2	2	0	0	0
35	332	43	43	5	5	3	3
36	400	69	69	5	5	0	0
37	217	42	42	5	5	0	0
38	229	42	42	5	5	1	1
39	—	—	—	—	—	—	—
40	315	39	39	5	5	0	0
41	9	9	9	4	0	0	0
42	240	28	28	5	5	1	1
43	335	47	47	5	5	0	0
44	34	34	34	5	5	0	0
45	390	55	55	5	5	0	0
46	209	45	45	5	5	0	0
47	96	47	47	5	5	0	0
48	187	47	47	0	0	0	0
49	—	—	—	—	—	—	—
50	122	60	60	5	5	0	0
51	—	—	—	—	—	—	—
52	350	39	39	5	5	2	2
53	362	37	37	5	5	3	3
54	270	39	39	5	5	4	4
55	367	40	40	5	5	1	1
56	13	13	13	5	5	0	0
57	374	38	38	5	5	1	1
58	231	40	40	5	5	1	1
59	143	37	37	5	5	2	2
60	358	42	42	5	5	0	0
61	0	0	0	0	0	0	0
62	111	32	32	5	2	0	0
63	356	38	38	5	5	0	0
64	23	23	23	5	4	0	0
65	342	37	37	5	5	0	0
66	13	13	13	5	1	0	0
67	1	1	1	0	0	0	0
68	7	7	7	0	2	0	0
69	73	35	35	0	2	0	0
70	0	0	0	0	0	0	0
71	313	34	34	3	2	0	0
72	147	32	32	1	4	0	0
73	228	39	39	1	3	0	0
Totals	**13,591**	**2,148**	**2,149**	**241**	**229**	**72**	**72**

*58 maturities and 57 weights were recorded.

Table 11. Numbers of Pacific hake biological samples and measurements collected on the Canadian chartered FV *Nordic Pearl* during the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

Trawl	Length	Weight and maturity	Otoliths	Stomachs examined	Fin clips
1	0	0	0	0	0
2	6	6	6	6	0
3	0	0	0	0	0
4	2	2	2	2	0
5	0	0	0	0	0
6	1	1	1	1	0
7	0	0	0	0	0
8	0	0	0	0	0
9	0	0	0	0	0
10	391	49	49	25	20
11	28	28	28	25	20
12	0	0	0	0	0
13	11	11	11	11	0
14	198	51	51	25	20
15	0	0	0	0	0
16	0	0	0	0	0
17	1	1	1	1	0
18	0	0	0	0	0
Totals	**638**	**149**	**149**	**96**	**60**

U.S. Secretary of Commerce
Gina M. Raimondo

Under Secretary of Commerce for
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