



Northwest Fisheries Science Center

National Marine Fisheries Service

U.S. DEPARTMENT OF COMMERCE

NWFSC CRUISE REPORT, CRUISE NO. MF2009-03

The 2009 Integrated Acoustic and Trawl Survey of
Pacific Hake (*Merluccius productus*) in U.S. Waters
off the Pacific Coast

February 2010

INTRODUCTION

Pacific hake (*Merluccius productus*) is an important commercial marine fish off the west coast of North America, with annual harvests totaling between 176,000 and 361,000 metric tons from 1986 through 2009. Because of the economic and ecological value of coastal Pacific hake, integrated acoustic and trawl (IAT) surveys have been conducted since 1977 to assess the distribution, abundance, and biology of coastal Pacific hake along the Pacific coasts of the United States and Canada.

The results presented here are from the U.S. portion of the summer 2009 IAT survey of Pacific hake. This report provides a brief description of the methods used in the survey and summarizes the primary objective of observing the distribution, biological composition, and biomass of Pacific hake in U.S. waters off the Pacific coast. It also summarizes results of acoustic system calibrations and secondary survey objectives. Results from the Canadian portion of the summer 2009 IAT survey are not included in this report and are presented elsewhere.

MATERIALS AND METHODS

Scientists from the Fishery Resource Analysis and Monitoring (FRAM) division at the Northwest Fisheries Science Center and the Pacific Biological Station (PBS) of the Department of Fisheries and Oceans Canada conducted an IAT survey (science cruise number MF2009-03) between 30 June and 22 August 2009 (Table 1) from 35.7°N to 48.4°N aboard the NOAA Ship *Miller Freeman*, a 66-m stern trawler equipped for fisheries and oceanographic research.

The Pacific hake population was surveyed along a series of parallel line transects that were oriented east-west, spaced at a 10-nmi interval, and traversed sequentially in alternating directions (Figure 1). The survey began just north of Point Piedras Blancas, California and proceeded north toward the northwest tip of Washington state while targeting aggregations of Pacific hake along the continental shelf and upper slope. Sea depth at the nearshore end of individual transects was typically 50 m, although a few transects ended in waters deeper than 50 m because of restricted areas, navigation hazards, or boat traffic. Offshore extent of individual transects was typically at a depth of 1,500 m.

Acoustic Sampling

Equipment

All acoustic data were collected with a Simrad EK60 scientific echo sounder system coupled with an ER60 software system. Simrad 18-kHz, 38-kHz, 120-kHz, and 200-kHz split-beam transducers were mounted on the bottom of the *Miller Freeman's* centerboard which, when fully extended, held the transducers at a nominal depth of 9.15 m below the water surface.

Calibration

The acoustic system was calibrated in the field three times, twice before (May 2 and June 29) and once after the survey (August 23). Calibration locations 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, Simrad 2004). A 38.1-mm tungsten carbide sphere was used for the 38-kHz, 120-kHz, and 200-

kHz transducers, and a 64-mm copper sphere was used for the 18-kHz transducer. Target strength and echo integration data were collected to calculate echo sounder gain parameters to ensure the quality of system performance. On-axis measurements were taken during the first and third calibrations in Elliott Bay, Seattle but not during the second calibration in Monterey Bay, California due to a combination of current and wind; beam pattern measurements were taken during all three calibrations. This IAT survey marked the first time that an automated system was employed to conduct beam pattern measurements (Tomich et al 2009).

Operation

Acoustic data were collected from 14 m below the surface (about 5 m below the centerboard-mounted transducer face) to a maximum depth of 600 m to ensure a ping rate of approximately one ping per second. Raw acoustic backscatter (EK 60) and Myriax Echolog 500 data files were logged from all four frequencies; the Echolog 500 data files were used for live viewing in Echoview v.4.60 software. Event log markers and other marks, including at-sea judgments of Pacific 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.

Vessel speed was maintained at approximately 6.1 m/sec (12 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 50 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 Pacific hake formed identifiable midwater layers.

Noise background 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. This was done to ensure the quality of the acoustic data and the consistency of system performance throughout the survey.

Biological Sampling

Equipment

Biological sampling was performed with an Aleutian wing trawl 24/20 (AWT). This net had a vertical opening that averaged 24 m (range: 13–40 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-m² “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 WESMAR TCS 770 third-wire scanning sonar system or a Furuno wireless net sounder system was attached to the AWT headrope to monitor and guide the fishing process for all tows.

To provide additional biological ground truthing, a separate AWT was optionally deployed with a video camera system mounted inside the net with the codend left open. The video camera system included a low-light underwater video camera, an LED light array, and two paired scaling lasers for fish length measurement. Video was recorded to tape using a SONY camcorder mounted in an underwater housing equipped with a pressure switch that automatically switched the camcorder on when deeper than a preset depth and switched it off when shallower

than this depth. This alternative and new method provided non-extractive sampling and information on biological composition of multiple scattering layers in the water column.

An electronic, 60-kg capacity Marel M1100 motion-compensating scale was used to weigh sorted portions of the catch to the nearest 0.05 kg. Large trawl catches (e.g., >1,500 kg) were weighed to the nearest 2 kg with an Eilon Engineering RON 2150 H-05 hook type load cell. A 15-kg capacity Marel M1100 motion-compensating scale was used to determine all weights of individual fish specimens to either the nearest 0.02 or 0.002 kg. Individual fish lengths (fork length) were determined to the nearest centimeter using a Scantrol FM100 FishMeter board.

To obtain high-resolution optical images of plankton in the water column, a SeaScan, Inc. video plankton recorder (VPR) was mounted on the conductivity-temperature-depth (CTD) rosette. Sampling for plankton and larval fish was conducted for Oregon State University with a Hydro-Bios Midi type MultiNet Multiple Plankton Sampler multi-opening net. The mouth opening of this net was 0.25 m² (0.5 m × 0.5 m) and it was equipped with five nets measuring 250 cm long with a mesh of 333 μm. Samples for a harmful algal bloom (HAB) analysis conducted by scientists at the Environmental Conservation (EC) Division at the Northwest Fisheries Science Center were collected along survey transect lines to obtain a spatial ‘snapshot’ of the presence of HAB species and the toxins they produce. Seawater particulates, collected by filtering 1 liter of seawater onto a 0.45-μm pore size membrane filter, will be later analyzed by EC scientists for marine toxins such as domoic acid and saxitoxin.

Operation

Trawl samples were used to classify observed backscatter layers to species and size composition and to collect specimens of Pacific 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 were dependent on the occurrence and pattern of backscattering layers observed at the time of the survey. Coverage by trawling was not systematic, but adaptive, and individual tows did not require a standardized effort. Distinct layers of intense backscatter that were indicative of high densities of Pacific hake were the highest priority for trawl sample assignments, but other types of backscattering features, both in terms of areas of low fish density and putative aggregations of species other than Pacific hake, were also sampled. Attention was given to perform tows at several locations along any single, extensive, and continuous aggregation of Pacific 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 either the WESMAR or Furuno 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 less than roughly 1,500 kg were sorted and weighed completely; seven trawl catches between roughly 1,500 kg and 5,000 kg were weighed with a load cell for total weight before being subsampled. One trawl catch of roughly 18,000 kg was volumetrically

estimated. Total weights and numbers were determined for most species; gelatinous invertebrates such as jellyfish and salps often could not be counted. Pacific hake were subsampled to determine length composition by sex (about 300 samples per trawl), to collect otoliths for subsequent age determination (about 50 samples per trawl), and to collect individual weight measurements and gonad condition. When fewer than roughly 300 to 400 Pacific hake were caught, they were sampled completely. Pacific hake 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 from Pacific hake were collected and preserved in 10% neutral-buffered formalin (about 10 samples per trawl). Additional, ad hoc biological sampling consisted of measuring the dimensions of swim bladders from Pacific hake, lanternfish (Myctophidae), yellowtail rockfish (*Sebastes flavidus*), widow rockfish (*S. entomelas*), and canary rockfish (*S. pinniger*), and recording the weight, mantle length, and stomach contents of Humboldt squid (*Dosidicus gigas*).

The VPR was deployed with each CTD cast (except for CTD casts conducted during calibration of the vessel's acoustic system). An Oregon State University graduate student deployed the Multiple Plankton Sampler only at night during just the third leg of the survey.

Oceanographic Sampling

Equipment

Vertical profiles of temperature and salinity data were collected using a Sea-Bird Electronics, Inc. SBE 911*plus* 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 CTD. Additional temperature and depth profile data were collected by attaching a Sea-

Bird SBE 39 temperature and pressure recorder to the trawl headrope during trawl hauls and by launching expendable bathythermographs (XBTs). Ocean current velocity profile data were obtained using a Teledyne RD Instruments Ocean Surveyor 75-kHz Acoustic Doppler Current Profiler (ADCP) system. Sea surface temperature and salinity data were collected using a Sea-Bird SBE 21 probe located approximately 5 m below the vessel's waterline and stored on the *Miller Freeman's* Scientific Computing System (SCS). Brightwaters Instrument Corp. Model 115 GPS drifters (with Argos telemetry and set up in the Davis/CODE configuration for surface water tracking) were used to show the path that potential HABs would take if present at the location of the drifter deployment.

Operation

Physical oceanographic sampling was conducted at day and at night. CTD and XBT casts were made at selected locations along designated acoustic transects. CTD casts were performed primarily at night after collection of acoustic echosounder data had ceased, but they also were conducted during daytime to determine sound speed during all three acoustic calibrations. XBTs were performed 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. An EC scientist deployed GPS drifters during the day, off survey transect, off the coast of Washington State in the Juan de Fuca eddy region, an area known to be an initiation site for HABs.

RESULTS AND DISCUSSION

Acoustic System Calibration

Three calibrations of the *Miller Freeman* acoustic system were conducted, the first on 2 May in Elliott Bay, Washington, the second on 29 June, in Monterey Bay, California, and the third on 23 August, in Elliott Bay. Results of the two calibrations conducted in Elliott Bay were within expected levels based on factory settings and results from previous calibrations. However, results from the partial calibration conducted at Monterey Bay were of marginal value because of biological organisms present in the water column.

Biological Sampling

A total of 91 midwater trawls—of which 16 were video camera tows—were successfully conducted during the course of the survey (Figure 2). Four trawls were aborted because marine mammals were in the area and ten were unsuccessful due to either mechanical malfunctions or operational errors. Catch weights ranged from 0.02 kg to 18,000 kg (mean = 692.9 kg). By weight, Pacific hake and Humboldt squid were the two dominant species caught, accounting for 50.5% and 46.7%, respectively, of catch composition. By number, Pacific hake was caught far more commonly than other species, accounting for 75.5% of catch composition. Lanternfish and Humboldt squid, at 17.4% and 2.5%, respectively, were the second- and third-most commonly caught species. During the survey, 13,375 Pacific hake were lengthed and 2,500 pairs of Pacific hake otoliths were collected. Over 575 Pacific hake stomachs were collected. The dimensions of over 100 lanternfish swimbladders were measured, and the stomach contents of over 110 Humboldt squid were examined and recorded.

Although a poly Nor' eastern trawl 89/121 (PNE) was aboard the vessel and available for use, no bottom trawling was performed during the survey. It was decided at the start of the survey to use both available net reels aboard the ship for the two AWT nets (one with the closed codend, the other with the video camera system and open codend), with an option of swapping out an AWT for a PNE in case it was decided to do a bottom trawl. As the survey progressed, though, in contrast to previous IAT surveys, the observed Pacific hake echosign was never so strongly associated with the bottom (i.e., "hugging the bottom") that it could not be sampled with an AWT flown 5 m to 10 m off bottom. Also, using the video camera-mounted AWT helped with sampling close to bottom in areas where potential bycatch was a concern.

A total of 319 HAB samples were collected. Analysis of samples by EC staff is ongoing.

Oceanographic Sampling

A total of 227 CTD temperature and salinity profiles were collected at selected locations along the line transects and at acoustic system calibration sites (Figure 3). Additional temperature profiles were collected from 122 XBT casts (Figure 3) and from 94 SBE casts that were collected at most trawl stations. A total of three GPS drifters were deployed. Analysis of oceanographic data is ongoing.

Pacific Hake Distribution and Abundance Estimates

Acoustic data were collected from 77 line transects that covered a distance of 4,752 km (2,566 nmi). Aggregations of Pacific hake were detected along the continental shelf break from just north of Monterey Bay (37° N) to the most northerly survey transect off Washington state (Figure 4). Highest concentrations of Pacific hake were observed forming almost a continuous band off the Oregon and Washington coast from approximately 43°N to 47°N. Concentrations

of Pacific hake off the California coast were either absent (i.e., the first nine transects of the survey) or relatively sparse.

The estimate of Pacific hake biomass off the U.S. coast totaled 1.127 million metric tons and the estimate of Pacific hake numbers totaled 2.766 billion fish. Over half of the observed biomass and numbers (roughly 54% of survey total) was in the South Columbia INPFC area. Pacific hake biomass and numbers in the Vancouver-North Columbia area accounted for just under one third (roughly 32%) of survey total, while the Monterey and Eureka areas combined accounted for only about 12% of survey total.

ACKNOWLEDGEMENTS

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Table 1. Itinerary and scientific personnel for the 2009 integrated acoustic and trawl (IAT) survey of Pacific hake in U.S. waters off the Pacific coast.

Pre-Survey

May 2 Conduct acoustic system calibration with standard targets in Elliott Bay, Washington.

<u>Scientific Personnel</u>	<u>Position</u>	<u>Organization</u>	<u>Nation</u>
Dezhang Chu	Chief Scientist	NWFSC	USA
Lisa Bonacci	Acoustic Scientist	NWFSC	USA
Stephen de Blois	Acoustic Scientist	NWFSC	USA
Larry Hufnagle	Acoustic Scientist	NWFSC	USA
Stan Tomich	Engineer	NWFSC	USA

Leg 1

June 28 Embark personnel in San Francisco, California.
 June 29 Transit south; conduct partial acoustic system calibration in Monterey Bay, California; continue transit south to start of survey area.
 June 30 Begin survey.
 July 12–14 Inport Eureka, California. Exchange personnel.

<u>Scientific Personnel</u>	<u>Position</u>	<u>Organization</u>	<u>Nation</u>
Dezhang Chu	Chief Scientist	NWFSC	USA
Lisa Bonacci	Acoustic Scientist	NWFSC	USA
Chris Grandin	Acoustic Scientist	DFO	Canada
Melanie Johnson	Fishery Biologist	NWFSC	USA
John Pohl	Fishery Biologist	NWFSC	USA
Stan Tomich	Engineer	NWFSC	USA
Anthony Odell	Biologist	NWFSC	USA
Stephen Pierce	Oceanographer	OSU	USA
Stephen Anderson	Teacher at Sea	AES	USA

Table 1 continued. Itinerary and scientific personnel for the 2009 integrated acoustic and trawl (IAT) survey of Pacific hake in U.S. waters off the Pacific coast.

Leg 2

July 15 Resume survey.
 July 29– Inport Newport, Oregon. Exchange personnel.
 August 2

<u>Scientific Personnel</u>	<u>Position</u>	<u>Organization</u>	<u>Nation</u>
Lisa Bonacci	Chief Scientist	NWFSC	USA
Dezhang Chu	Acoustic Scientist	NWFSC	USA
Stephen de Blois	Acoustic Scientist	NWFSC	USA
Chris Grandin	Acoustic Scientist	DFO	Canada
Melanie Johnson	Fishery Biologist	NWFSC	USA
John Pohl	Fishery Biologist	NWFSC	USA
Julia Clemons	Fishery Biologist	NWFSC	USA
Stephen Pierce	Oceanographer	OSU	USA
Jennifer Fry	Teacher at Sea	MES	USA

Leg 3

August 3 Resume survey.
 August 15–18 Inport Port Angeles, Washington. Exchange personnel.

<u>Scientific Personnel</u>	<u>Position</u>	<u>Organization</u>	<u>Nation</u>
Stephen de Blois	Chief Scientist	NWFSC	USA
Dezhang Chu	Acoustic Scientist	NWFSC	USA
Larry Hufnagle	Acoustic Scientist	NWFSC	USA
Melanie Johnson	Fishery Biologist	NWFSC	USA
John Pohl	Fishery Biologist	NWFSC	USA
Nick Adams	Biologist	NWFSC	USA
Stephen Pierce	Oceanographer	OSU	USA
Angie Johnson	Graduate Student	OSU	USA
Jeremiah Minich	Undergraduate Student	PLNU	USA
Bryan Hirschman	Teacher at Sea	SHC	USA

Table 1 continued. Itinerary and scientific personnel for the 2009 integrated acoustic and trawl (IAT) survey of Pacific hake in U.S. waters off the Pacific coast.

Leg 4

August 19 Resume survey.
 August 22 Finish survey.
 August 23 Conduct acoustic system calibration with standard targets in Elliott Bay, Washington; disembark personnel; end of cruise.

<u>Scientific Personnel</u>	<u>Position</u>	<u>Organization</u>	<u>Nation</u>
Larry Hufnagle	Chief Scientist	NWFSC	USA
Dezhang Chu	Acoustic Scientist	NWFSC	USA
Melanie Johnson	Fishery Biologist	NWFSC	USA
John Pohl	Fishery Biologist	NWFSC	USA
Julia Clemons	Fishery Biologist	NWFSC	USA
Patty Burke	Program Manager	NWFSC	USA
Motoki Wu	Graduate Student	UW	USA
Patricia Schromen	Teacher at Sea	DCE	USA

AES – Amerman Elementary School, Northville, Michigan
 DCE – Dry Creek Elementary School, Port Angeles, Washington
 DFO – Department of Fisheries and Oceans Canada, Nanaimo, British Columbia
 MES – Meadows Elementary School, Valencia, California
 NWFSC – Northwest Fisheries Science Center, Seattle, Washington
 OSU – Oregon State University, Corvallis, Oregon
 PLNU – Point Loma Nazarene University, San Diego, California
 SHC – Spaulding High School, Barre, Vermont
 UW – University of Washington, Seattle, Washington

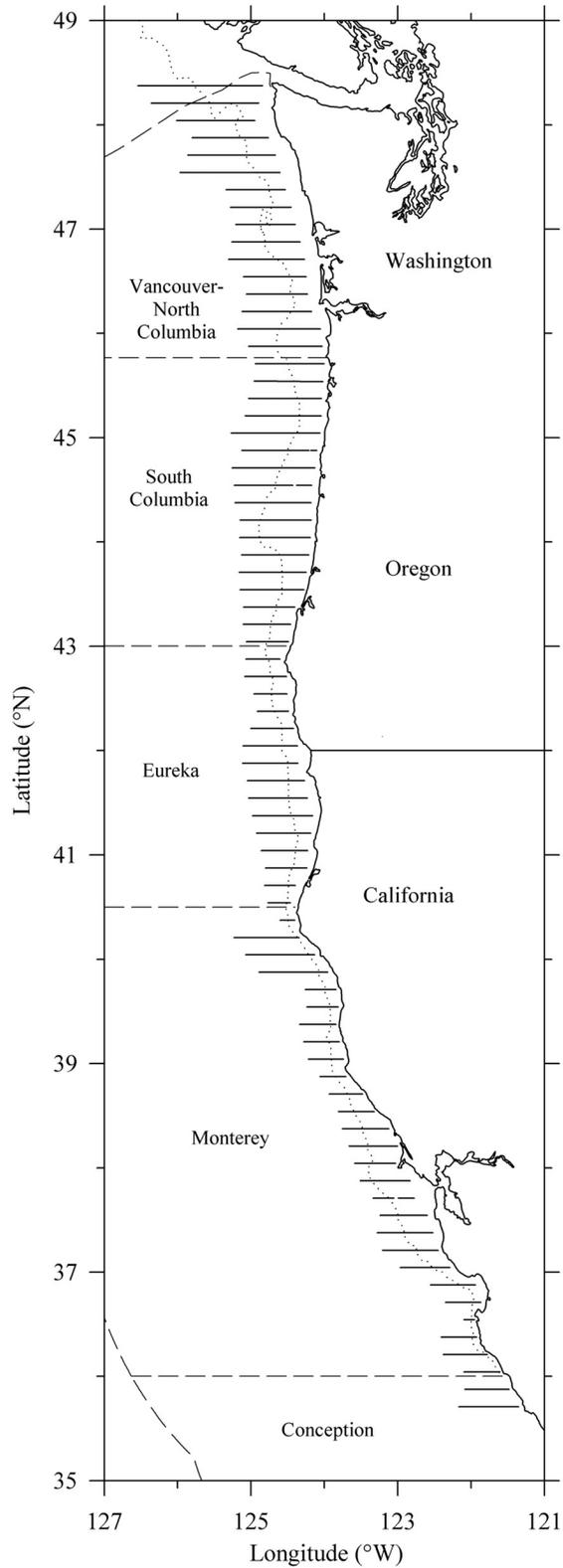


Figure 1. Survey track design used during the 2009 integrated acoustic and trawl (IAT) survey of Pacific hake in U.S. waters off the Pacific coast. International North Pacific Fisheries Commission (INPFC) statistical areas are outlined for reference. 200-m depth contour is designated by a dotted line.

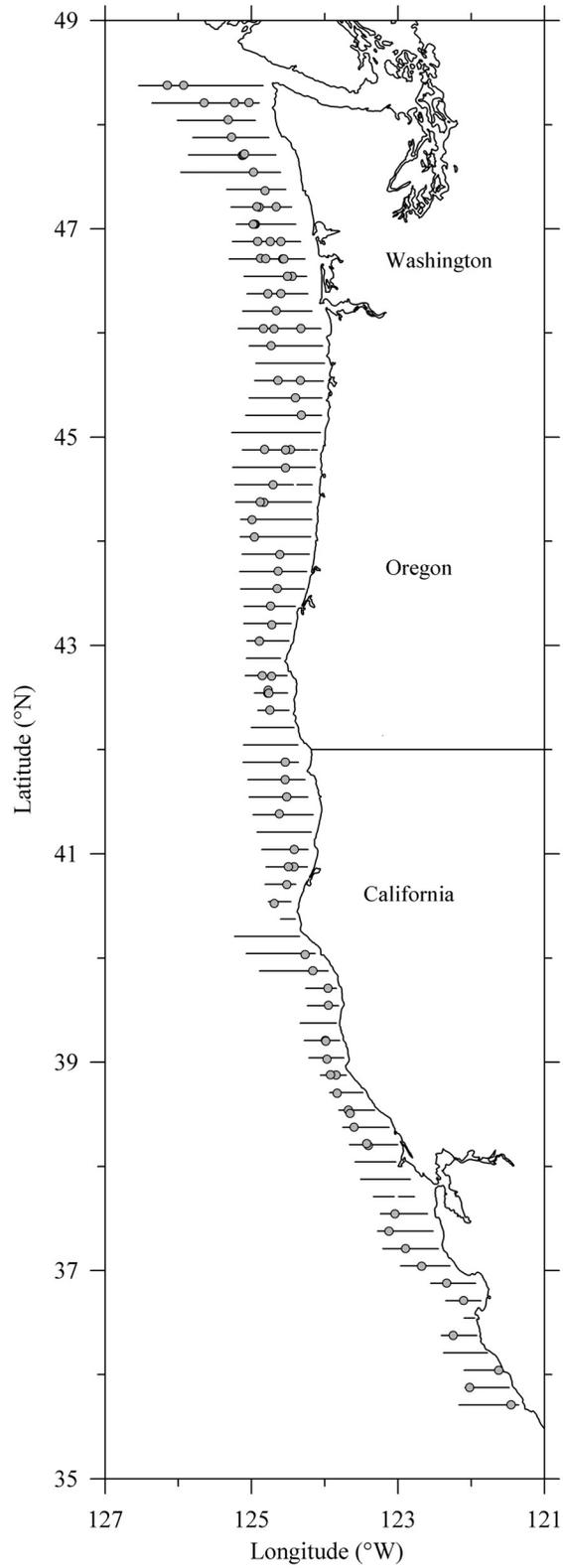


Figure 2. Details of acoustic transect lines and locations of midwater trawls during the 2009 integrated acoustic and trawl (IAT) survey of Pacific hake in U.S. waters off the Pacific coast.

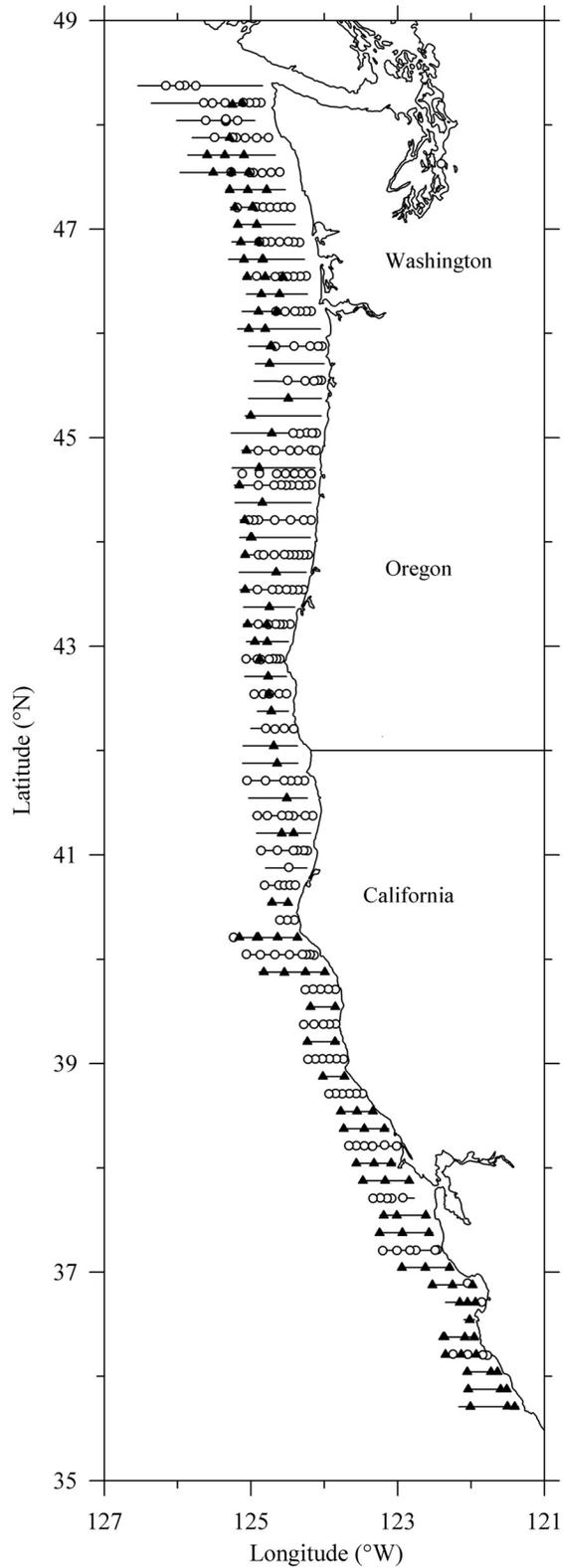


Figure 3. Survey track design with locations of expendable bathythermograph (▲) and conductivity-temperature-depth (○) profile measurements taken during the 2009 integrated acoustic and trawl (IAT) survey of Pacific hake in U.S. waters off the Pacific coast.

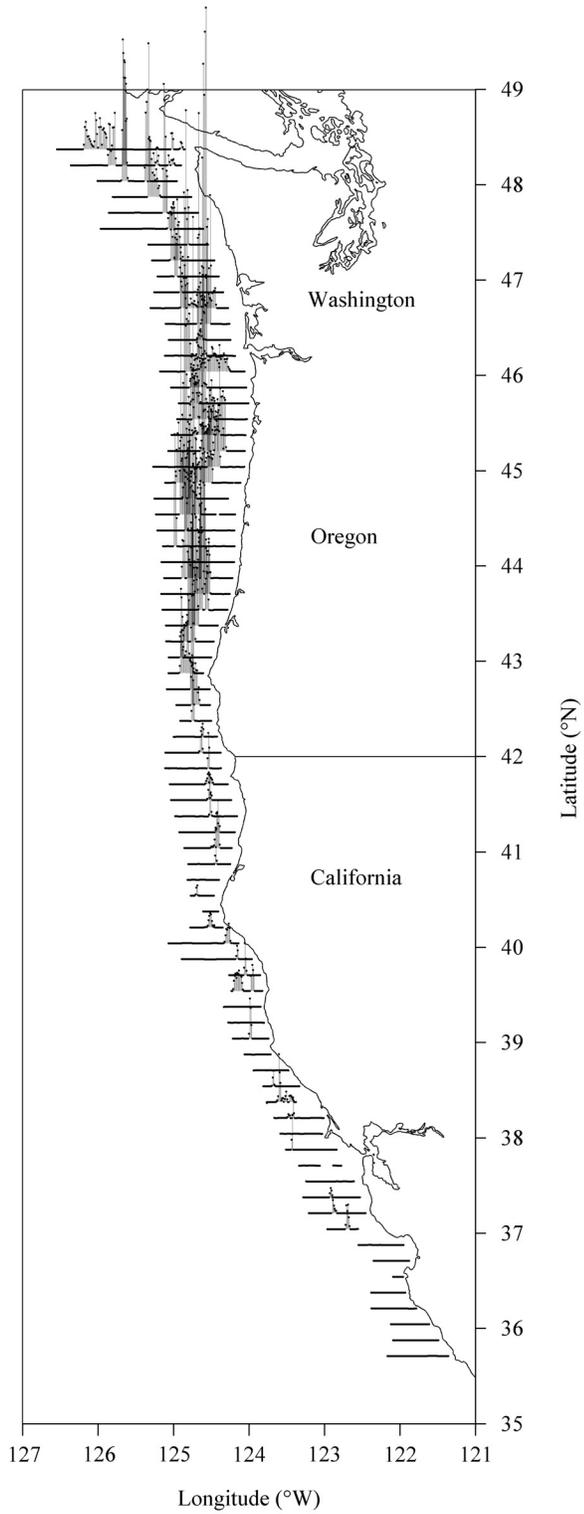


Figure 4. Acoustic area backscattering attributed to Pacific hake along transects completed during the 2009 integrated acoustic and trawl (IAT) survey of Pacific hake in U.S. waters off the Pacific coast.