NOAA Technical Memorandum NMFS-AFSC-115

The 1999 Pacific West Coast Upper Continental Slope Trawl Survey of Groundfish Resources off Washington, Oregon, and California: Estimates of Distribution, Abundance, and Length Composition

by
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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

May 2000

NOAA Technical Memorandum NMFS

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This document should be cited as follows:

Lauth, R. R. 2000. The 1999 Pacific west coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-115, 287 p.

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May 2000

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ABSTRACT

The Alaska Fisheries Science Center's Resource Assessment and Conservation Engineering Division (RACE) conducted a groundfish bottom trawl survey of the West Coast upper continental slope (WCUCS) in 1999. The survey area stretched from the U.S.-Canada border (near Nitinat Canyon) to 34°30'N lat. (near Pt. Arguello) in waters from 183 to 1,280 m deep. This was the eleventh survey in an ongoing series to monitor long-term trends in the distribution and abundance of WCUCS groundfish populations. This was the second year that spatial coverage of the WCUCS groundfish trawl survey was expanded to include all of the International North Pacific Fisheries Commission (INPFC) statistical areas between Point Conception (34°30'N lat.) and the U.S./Canada border. Sampling was conducted aboard the NOAA ship *Miller Freeman*. We successfully sampled 199 of the 208 stations that we established during the 1997 and previous WCUCS surveys. Survey catches included 142 different species of fishes from 55 fish families and 246 different invertebrates representing 12 phyla and 24 classes. Only 146 of the invertebrates were identified to the species level. With all depth strata and INPFC areas combined, Dover sole (*Microstomus pacificus*), longspine thornyhead (*Sebastoblobus altivelis*), and spiny dogfish (*Squalus acanthias*) had the highest catch rates. Spiny dogfish were the most abundant in the U.S.-Vancouver and Columbia INPFC areas and Dover sole and longspine thornyhead had higher catch rates in the Eureka, Monterey, and Conception INPFC areas when all depths were combined. The biomass estimates for Dover sole, sablefish, longspine thornyhead, and shortspine thornyhead (*Sebastolobus alascanus*) varied by stratum and INPFC area. The total biomass estimates for all INPFC areas and strata combined were 105,520 metric tons (t), 46,230 t, 95,795 t, and 25,295 t for Dover sole, sablefish, longspine thornyhead, and shortspine thornyhead, respectively.

The survey design and the methods used are described, the data collected are summarized, and the results of analyses of distribution, abundance, and biological parameters are presented. Data on water temperature, catch composition, relative abundance, and geographic distribution are reported. Estimates of biomass, population abundance, and length composition are also presented. Appendices include position and catch listings for each haul and catch rates of fish and invertebrates.

CONTENTS

INTRODUCTION

Fishery-independent data obtained from the Alaska Fisheries Science Center's (AFSC) West Coast upper continental slope (WCUCS) groundfish trawl surveys are used by fishery managers to assess stock conditions and to establish annual harvest guidelines for the commercially valuable fish species inhabiting the WCUCS. These species, referred to as the deepwater complex (DWC), include sablefish (*Anoplopoma fimbria*), shortspine thornyhead (*Sebastolobus alascanus*), longspine thornyhead (*S. altivelis*), and Dover sole (*Microstomus pacificus*). The Resource Assessment and Conservation Engineering (RACE) Division conducted its first groundfish assessment survey of the WCUCS in 1984 and has done so annually since 1988. The WCUCS covers habitat 183-1,280 m deep from the U.S.-Canada border to 34°30'N lat. and is divided into five International North Pacific Fisheries Commission (INPFC) statistical areas including the U.S.-Vancouver, Columbia, Eureka, Monterey, and Conception areas (Fig. 1).

The spatial coverage of annual slope surveys has varied. Prior to 1997, WCUCS groundfish bottom trawl surveys were limited in their spatial coverage of INPFC areas because of limited vessel time and other logistic considerations. The 1996 survey was the most extensive and covered the U.S.-Vancouver and Columbia INPFC areas (Lauth 1997a). The U.S.-Vancouver INPFC area was surveyed once before in 1993 in addition to the northern portion of the Columbia INPFC area (Lauth et al. 1997). Central and/or southern sections of the Columbia INPFC area (45°30' to 43°00'N lat.) were also surveyed in 1984, 1988, 1989, and 1992 (Raymore et al. 1990, Parks et al. 1993, Lauth et al. 1997). The Eureka INPFC area was surveyed in 1990 (Lauth et al. 1997) and again in 1995 (Lauth 1997b), and the northern section of the Monterey INPFC area (38°20' to 40°30'N lat.) was surveyed in 1991 (Lauth et al. 1997). The Southwest Fisheries Science Center (SWFSC) conducted two other groundfish bottom trawl surveys in 1987 and 1988 which covered parts of the Conception and Monterey INPFC areas between 34°30' and 36°30' N lat. (Butler et al. 1989).

During the 1993 AFSC survey, concerns were raised about the performance of the slope survey trawl and, consequently, the validity of slope survey data. These concerns prompted an external review of the slope survey by a panel of fishery scientists in July 1995. The panel criticized the lack of synopticity in survey coverage and the performance of survey gear (Parma et al. 1995). Survey gear performance was investigated during an experimental gear cruise aboard the NOAA ship *Miller Freeman* in 1994. During that cruise, we experimented with ways to stabilize the sampling trawl, learned more about how to evaluate trawl performance, and investigated alternative methods of surveying groundfish resources using a video camera sled. Regular survey work resumed in 1995 after several changes were made to the sampling trawl and to towing protocol. The changes stabilized the slope trawl and resulted in more consistent trawl performance (Lauth et al., 1998).

The spatial coverage of WCUCS groundfish trawl surveys was expanded in 1997 (Lauth 1999) to include all of the INPFC areas between Point Conception (N. 34°30' lat.) and the U.S.-Canada border. Sampling density was reduced compared to previous surveys so that the expanded area could be surveyed within a 5-week period.

To extend the life of the NOAA ship *Miller Freeman,* it was necessary to make repairs and updates during the 1998 fall/winter period so the vessel was not available; hence, no WCUCS survey was done. During the same year, the Fisheries Resource Analysis and Monitoring (FRAM) Division of the Northwest Fisheries Science Center (NWFSC) initiated its own WCUCS bottom trawl survey using local West Coast fishing vessels. The new survey effort is the beginning of a new time series to augment fishery independent data on the DWC.

In 1999, we resumed the WCUCS survey aboard the NOAA ship *Miller Freeman*. The objective of this report is to document the survey design and field procedures, summarize the survey data, and present the results of the standard RACE analyses for the 1999 WCUCS survey for each of the INPFC statistical areas. Included are summaries of catches, distribution, abundance, and size composition for major components of the community, as well as analyses of length-weight relationships of selected species.

SURVEY METHODS

Survey Period and Sampling Area

The U.S.-Vancouver, Columbia, Eureka, Monterey, and Conception INPFC statistical areas (U.S.-Canada border to 34°30'N lat.) were surveyed between 14 October and 19 November. Survey sampling began near Cape Arguello (34°30'N lat.) and progressed northward to Nitinat Canyon (48°05'N lat., Fig. 1). Water depth at survey stations ranged between 183 and 1,280 m (100-700 fm).

Vessels and Sampling Gear

The NOAA ship *Miller Freeman* is a 65.5 m stern trawler powered by a 2,200 continuous horsepower engine. The ship is equipped with dual net reels, a Rapp-Hydema warp tensioning system, Wesmar Fish Eye net sonar system, Furuno netsonde, EQ-50 depth sounder, and global positioning system (GPS) navigational aids. A high-opening Poly Nor'Eastern trawl (Fig. 2) constructed of polyethylene mesh and equipped with mudsweep roller gear (Fig. 3) was used to collect all samples. This trawl, built and rigged to RACE Division gear standards, has a 27.2 m headrope and a 37.4 m footrope. The body is constructed of 127 mm stretched-mesh polyethylene netting, 89 mm stretched-mesh web in the codend, and a 32 mm stretched-mesh codend liner. Three 55 m dandylines made of 16 mm galvanized steel cable lead from each wing to a pair of

1.8 × 2.7 m steel V-doors weighing 1,000 kg each. Each door has a 4-point bridle on its backside made with 13-mm long-link chain having 33 links forward and 22 links aft in both the top and bottom. Instruments attached to the trawl gear to monitor gear performance included the SCANMAR equipment for measuring net dimensions, a Furuno wireless netsonde for real-time monitoring of the headrope height, and one bottom contact sensor on the footrope. A Wesmar net sonar was attached to the net headrope and used to ensure that the trawl gear was performing to engineering specifications during the wire marking procedure and during the initial gear calibration. A Richard Brancker XL-200 submersible data logger was attached to the trawl and used in conjunction with a Rockwell GPS unit to record data on the time, depth, water temperature, and geodetic position during each trawl. These data were combined with fishing dimensions of the net, producing a comprehensive set of haul data describing gear performance in space and time.

Trawl Station Allocation

There were 208 stations along 32 east-west tracklines spaced 50 km apart between the U.S.-Canada border and 34°30'N lat. near Cape Arguello. Stations were basically the same as those sampled during 1997 WCUCS survey (Lauth 1999). A combined systematic and random design was used for selecting the survey bottom trawl stations. Sampling was conducted between 183 and 1,280 m in six strata of 183 m (100 fm) depth intervals (183-365 m, 366-547 m, 548-730 m, 731-913 m, 914-1,095 m, and 1,096-1,280 m). The number of sampling stations within each depth stratum was allocated proportional to the trackline length across each depth interval at the rate of one station per 13.0 km of linear trackline length (e.g., a stratum with a trackline length of 30 km would be allocated 3 stations). Tracklines were positioned roughly perpendicular to the coastline. To ensure even depth coverage within a stratum, the depth range of each stratum was divided into a number of bins equal to the number of stations scheduled to be surveyed that year. Nominally, a bin was identified by its midpoint target depth. Stations were then randomly assigned to tracklines by picking target depths without replacement.

Trawling Procedures

Sampling was done on a 24-hour basis. Stations were located by GPS and echosounder and then surveyed prior to towing. If the terrain was determined to be too rough or too steep to allow the successful completion of a tow, we searched for an alternate site with a similar target depth within a 10 km radius of the original. If no favorable ground was located the station was declared untrawlable and abandoned. If the gear was damaged during the tow severely enough to affect catch composition, or if the gear performance was in any way judged to be unacceptable (e.g., mud, large trap entangled in the net), the haul was considered unsatisfactory and the station was either repeated or abandoned. Unsuccessful tows were not used in the analyses.

Scientists, officers, and deck crew worked together to standardize fishing procedures. A scientist familiar with trawling was always present in the trawl house during fishing operations to monitor adherence to standardized protocols. Also, AFSC gear experts participated in the cruise to ensure that the trawl gear and associated rigging were properly maintained. The scope ratio varied with depth and ranged from 2.5:1 at shallower depths to 1.6:1 at the deepest depths (Table 1). Vessel speed while the trawl was being set was between 5.5 and 6.5 km/hr. Vessel speed gradually decreased to 4.3 km/hr (2.3 knots) at brakeset and this speed was maintained as closely as possible throughout each haul. The target duration of a trawl sample was 30 minutes. A haul began when the ground-gear first touched bottom and ended when it lost contact with the bottom. The Furuno netsounder was used to monitor ground-gear contact during a haul, but actual bottom time was determined from the bottom contact sensor data upon completion of the tow. Position data were collected at 2-second intervals for each haul using a GPS receiver. The position data were used to monitor ground speed, track the trawl's path, and estimate distance fished. Average vessel speed over ground and distance fished were calculated from the position data and the trawl's actual bottom time.

Catch Sampling Procedures and Biological Data Collection

Standard RACE catch sampling procedures were followed as described by Smith and Bakkala (1982). All catches less than one metric ton (t) were dumped directly onto a sorting table and processed. Catches larger than 1 t were weighed by an electronic load cell and then dumped onto the sorting table in a series of splits. Large catches were made more manageable for processing by weighing and measuring a random subsample of the dominant fish species (e.g., Pacific whiting or spiny dogfish) and discarding the remainder of that species overboard. The estimated non-subsample catch weight for that species was the difference between the total catch weight measured by the electronic load cell and the sum of the subsample weight for that species and the catch weights for all other species. Fishes and invertebrates were identified to species as time and expertise permitted. After the catches were sorted by species, weighed, and enumerated, biological data and specimens were collected. Samples of all fish species were measured to characterize their size composition. Sex determination and fork length measurements were done for up to 200 specimens of each of the primary target species, rockfishes, and flatfishes from each haul. The same was done for grenadiers except they were measured from the tip of their snout to the insertion of the anal fin ray. Other non-target species were measured as unsexed. This was the first year that all skates and rays were measured using total length. Wingtip-to-wingtip measurements were made on a subsample of skates and rays so that comparisons could be made with measurements from prior years. Otoliths were collected for age determination from arrowtooth flounder (*Atheresthes stomias*), Dover sole, Pacific grenadier (*Coryphaenoides acrolepis*), sablefish, shortspine thornyhead, and longspine thornyhead. Otolith collections were depth-, area-, and size-stratified so that sampling effort was more evenly spread over the entire survey area. There were three depth zones (183-549 m, 550-914 m, and 915-1,280 m) and three geographical areas (southern [south of 38°30'N lat.], central [38°30'to 43°20'N lat.], and northern [north of 43°20'N lat.]). Otoliths were collected from size-stratified samples of 5 fish per sex/centimeter interval in each depth zone and geographical area.

Additional biological collections were made at the request of other scientists from a number of laboratories, agencies, and universities interested in West Coast fishery resources. These collections were taken for studies involving age and growth, genetics, and other fish life history parameters.

Oceanographic Data Collection

Sea surface temperatures were taken at all stations using a bucket thermometer. Bottom temperatures and water column temperature profiles were measured using a Richard Brancker XL-200 data logger mounted on the trawl headrope. Additional information on temperature profiles from this cruise is available on request from the author.

Data Analysis

Several analyses are performed routinely on RACE survey data. These include:

1) estimation of relative abundance,
2) estimation of population biomass,
3) estimation of population numbers, and
4) estimation of the population's size composition.

We used the area-swept method as described by Gunderson and Sample (1980) to estimate population biomass and numbers. Briefly, this method entails standardizing samples from each station into catch per unit of effort (CPUE) in terms of either kilograms or numbers per hectare (kg/ha, no./ha) and calculating the arithmetic mean CPUE for each sampling stratum. Length-frequency data were weighted by CPUE (no./ha) and expanded to the total estimated population abundance to estimate the population size composition for each species. No age data were available for this report so age composition analysis was not done.

RESULTS

Haul, Catch, and Biological Data

Several stations that were abandoned during the 1997 WCUCS survey were successfully surveyed and sampled during this year's survey. A new transect line in the U.S.-Vancouver INPFC area was also added to increase the sample size of trawl stations for each depth stratum. During the 1999 survey, 207 tows were attempted. Out of 208 possible stations, 199 stations were sampled successfully (Fig. 1). Nine stations were abandoned because they were too rough or steep to tow. The remainder of the attempted tows were unsuccessful due to trawl hang-ups, net rips, excessive mud in the tows, crossing into an adjacent depth stratum, or gear deployment problems. SCANMAR net mensuration data were obtained from 173 tows, submersible bathythermograph data from 201 tows, bottom contact sensor data from 201 tows, and GPS course and position data from 207 tows. Sampling densities ranged from 2.1 hauls/1,000 km^2 in the Conception INPFC area to 7.3 hauls/1,000 km^2 in the U.S-Vancouver INPFC area (Table 2).

Mean net widths were calculated for each trawl haul. The best predictor for tows with missing net width was inverse scope (Fig. 4). Inverse scope alone accounted for 34% of the variation. Additional variation was explained by the net height effect; however, it was not practical to use this in the final analysis because most of the 27 tows with missing net width measurements were deep tows where net height data was not collected either. The test statistic for zero slope for the straight line regression of inverse scope as a predictor for net width was rejected ($P < 0.001$). The range of mean net widths for these 173 tows was 13.8 to 18.4 m and the standard deviation was 0.81 m. For area-swept calculations, the predicted mean path width for hauls where actual width measurements were unavailable was calculated using the equation in Figure 4.

Table 3 summarizes the biological data collected from fish species. Specimen ages from collected otoliths will be determined by researchers from the Pacific States Marine Fisheries Commission and Oregon Department of Fish and Wildlife. Results from collected data and specimens for several special studies requested by colleagues in other agencies or institutions will be reported elsewhere.

A total of 149 fish species representing 55 fish families were identified over the course of the survey. Table 4 lists the frequencies of occurrence, depth range, and the latitudinal range for all fishes identified in trawl samples. Similarly, Table 5 shows ranges and frequencies of occurrence for invertebrates representing 12 phyla and 24 classes. Of the 247 invertebrates listed, 146 were identified to species. Appendix A presents detailed station information for each haul and catch weights of the major fish and invertebrate species caught in each haul. The number of individual fish length observations of each fish species are reported in Tables 6 to 11 by depth stratum and INPFC area.

Temperature Data

Sea surface temperatures ranged from 10.2° to 16.8°C and bottom temperatures ranged from 2.9° to 9.0°C (Fig. 5). Mean sea surface temperature was 12.6°C and mean bottom temperature was 4.8°C. Sea surface temperatures generally decreased and were more variable with increasing latitude. Bottom temperatures generally decreased with increasing depth within the survey area.

Relative Density and Distribution of Species

The 20 most abundant groundfish and selected crab species are presented with all depth strata combined by INPFC area (Table 12), with all INPFC areas combined by depth stratum (Table 13), and by INPFC area and depth stratum (Tables 14-18). Spiny dogfish (*Squalus acanthias*) had the highest catch rates in the U.S.-Vancouver and Columbia INPFC areas with all depth strata combined (Table 12). In the Eureka and Conception INPFC areas, longspine thornyhead had the highest catch rates when all depths were combined, as did Dover sole in the Monterey INPFC area and when all INPFC areas were combined (Table 12). With all INPFC areas combined, spiny dogfish had the highest catch rates in the shallowest stratum (Table 13), Dover sole the highest in Strata 2 and 3, longspine thornyhead in Strata 4 and 5, and Pacific grenadier in the deepest stratum.

Catch rates by depth stratum varied among the INPFC areas (Tables 14-18). In general, the fish at the top of the rank list varied most for Stratum 1. Spiny dogfish had the highest CPUE in the U.S.-Vancouver and Columbia INPFC areas and rex sole (*Glyptocephalus zachirus*), shortbelly rockfish (*Sebastes jordani*), and Pacific whiting (*Merluccius productus*) were highest in the Eureka, Monterey, and Conception INPFC areas, respectively. In contrast, the highest CPUEs for Strata 2 and 4 were consistent across all INPFC areas with Dover sole topping the list in Stratum 2 and longspine thornyhead in Stratum 4. Longspine thornyhead also topped the list in Stratum 5 for all INPFC areas except the Monterey area, where Dover sole was highest. In the Monterey INPFC area, Dover sole also ranked highest in Strata 3 and 6. One of four species had the highest catch rates in the deepest stratum, depending on the INPFC area. Longspine thornyhead was highest in the U.S-Vancouver and Eureka INPFC areas, Dover sole in the Monterey INPFC area, giant grenadier (*Albatrossia pectoralis*) in the INPFC Columbia area, and Pacific grenadier (*Coryphaenoides acrolepis*) in the Conception INPFC area.

One notable catch was a large number of a rare king crab, *Neolithodes diomedae* (Family Lithodidae), at a depth of 1,268 m (Stratum 6) in the Conception INPFC area at lat. 34°59'N. Ninety-eight percent of the 670 *N. diomedae* captured were females. Its range to date has only been reported as far north as lat. 23°39'N at a depth of 1,382 m (MacPherson 1988).

Complete listings of the relative abundance of all fish and invertebrate species ranked by mean CPUE, depth stratum, and INPFC area are presented in Appendix B.

Maps of the geographical distribution and relative catch rates of selected important groundfish species and true Tanner crab (*Chionoecetes tanneri*) are presented in Figures 6-19 in alphabetical order. These maps show the locations of hauls where these species were caught. Catch rates were categorized as: 1) greater than zero and less than or equal to the mean CPUE; 2) greater than the mean CPUE and less than or equal to one standard deviation from the mean; 3) between one and two standard deviations greater than the mean CPUE; and 4) over two standard deviations greater than the mean CPUE.

Biomass and Population Estimates

Abundance estimates of biomass in metric tons and associated coefficients of variation (CV) are presented for selected taxa by stratum and area in Tables 19 through 24. Similarly, estimates of population numbers with associated CVs are presented for important species groups in Tables 25 through 30. The total number of hauls and hauls with catch weight, catch number, and length data by stratum and area for the various taxa are represented in Tables 31 through 36.

The biomass and population estimates for the deepwater complex (DWC) varied by species, stratum, and INPFC area. The total biomass estimates for all INPFC areas and strata combined were 46,230 t, 105,520 t, 95,795 t, and 25,295 t for sablefish, Dover sole, longspine thornyhead, and shortspine thornyhead, respectively (Table 19). The stratum with the greatest estimated biomass for each DWC species was Stratum 3 for sablefish (23%), Stratum 2 for Dover sole (35%), Stratum 4 for longspine thornyhead (34%), and Stratum 2 for shortspine thornyhead (23%). The INPFC area with the highest proportion of total estimated biomass for each DWC species was the Columbia area for sablefish (34%), and the Monterey area for Dover sole (35%), longspine thornyhead (30%), and shortspine thornyhead (22%). The total population estimates for all INPFC areas and strata combined were 3.168×10^7 for sablefish, 2.436×10^8 for Dover sole, 1.026×10^9 for longspine thornyhead, and 7.708×10^7 for shortspine thornyhead (Table 25). The stratum with the greatest estimated population numbers for each DWC species was Stratum 1 for sablefish (33%), Stratum 2 for Dover sole (45%), Stratum 4 for longspine thornyhead (36%), and Stratum 2 for shortspine thornyhead (52%).

Readers should be aware that the biomass and population estimates presented here are not absolute estimates since herding by doors and bridles and escapement underneath the trawl's footrope, around the net's opening, and through the net's meshes can affect the bottom trawl catches (Gunderson 1993). For lack of data on species-by-species catchability, abundance calculations are based on the assumption that all fish in front of the trawl and between the wingtips are captured. The degree of bias introduced by this assumption probably varies among species. For instance, the ability of a fish to avoid the net will depend on the fish's shape, size, swimming speed, and its reaction to the part of the net encountered. Furthermore, the survey covers limited portions of the depth and geographic range of some of these species. As mentioned previously, this survey targets many species and provides general information where it lacks in specific information. These surveys are the only fishery-independent source of information on the abundance, distribution, and length and age-composition for many of these species. Stock assessment scientists utilize our survey results, along with commercial catch data, in order to estimate acceptable biological catch levels.

Size Composition

Estimated population length compositions for several groundfish species are presented in Figures 20-73 by species and by depth stratum. At the time this report was prepared, no age data was available for analyses.

Length-Weight Relationships

From the individual fish weight samples, we determined length-weight relationships for arrowtooth flounder, Dover sole, sablefish, shortspine thornyhead, longspine thornyhead, Pacific grenadier, and splitnose rockfish using a non-linear least squares regression model. Table 37 summarizes the length-weight relationships by sex and for all INPFC areas and sexes combined (including unsexed fish).

Requests for Other Data Analyses

To avoid unnecessary detail and excessive printing costs, appendices listing estimated length compositions for major species and abundance estimates for less commercially important species were not included in this report. However, if the reader requires these or other more detailed analyses, they can be obtained as either printed pages or as computer files upon request from Robert Lauth at (206) 526-4121 (phone) or bob.lauth@noaa.gov (email).

ACKNOWLEDGMENTS

I would like to thank all the cruise participants for their hard work during the 1999 West Coast upper continental slope groundfish survey. Participants included (in alphabetical order by last name) Lisa Appesland, Troy Buckley, Roger Clark, Bill Flerx, Robin Harrison, Allen Harvison, Jerry Hoff, Dan Kamikawa, Mike MacEwan, Scott McKellip, Bob Mikus, Frank Morado, Debbie Nebenzahl, Russ Nelson, Jay Orr, Katherine Pearson, Jim Smart, Paul Von Szalay, Mark Wilkins, and Janelle Zimmermann. I would also like to express my appreciation to the officers, the survey department, the electronics department, and the rest of the crew of the NOAA ship *Miller Freeman* for their valuable assistance during the 1999 West Coast continental slope groundfish trawl survey. Thanks especially to Commander Gary Petrae who raised the bar for completing the ambitious survey work in a competent and timely manner, and to Bill Floering and Richard Epton who are always extremely helpful. Thanks also to Gary Mundell for data editing and Bill Flerx, Ron Payne, Dave Roetcisoender, and Larry Haaga for gathering together all the equipment necessary for survey operations. Special thanks to Dave King and his net shed crew for all their help supplying and maintaining the trawl nets and accessories that we used for this survey. I am also grateful to Mark Wilkins, James Lee, and Gary Duker for carefully reviewing this manuscript.

Bottom trawling was conducted in the Olympic Coast, Gulf of the Farallones, Cordell Bank, and Monterey Bay National Marine Sanctuaries in accordance with permits OCNMS-07-99 and GFNMS/CBNMS/MBNMS-01-99.

TABLES

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FIGURES

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