An Evaluation of the Spatial Distribution of Fishes and Invertebrates off Central California in Relation to EPA Study Areas with Emphasis on Midwater Ichthyofauna.

Based on National Marine Fisheries Service and CalCOFI Survey Data

Report to U.S. EPA Region IX from:

James R. Bence, Dale Roberts and William H. Lenarz

National Marine Fisheries Service
Tiburon Laboratory, Southwest Fisheries Science Center
3150 Paradise Drive
Tiburon, California 94920

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Summary

In this report we evaluated the spatial distribution, in relation to the EPA study areas, of fish and invertebrates collected during NMFS research surveys and CalCOFI ichthyoplankton surveys. We also reviewed CalCOFI atlases that addressed the spatial distribution of zooplankton and phytoplankton, and California Department of Fish and Game publications on the spatial distribution of zooplankton in the study region.

There was no simple answer such as "the abundance of all organisms was higher in EPA study area 2". Some species and groups were more abundant near the inshore area, others at mid-depth, and still others offshore in deep water. The choice of a disposal site will need to be based on a judgment regarding the relative ecological and economic importance of the different groups, as well as the likelihood that a given group will be affected by dredge disposal. Overall, however, the abundance of adult fish of potential commercial or recreational value was highest at the shallower bottom depths associated with EPA study area 2 (Fig. 1) and the shallower portion of area 3. This was especially true for most bottom associated fish. Grenadiers, Dover sole, and sablefish, however, were found in relatively deep water. Although of potential commercial value, a substantial fishery has yet to develop for grenadiers. Presently, Dover sole caught below 800 meters are of little commercial value (see below). Sablefish are an important commercial species, and may be abundant in waters as deep as EPA study areas 4 and 5. Some juvenile fish, small pelagic adult fish and ichthyoplankton had peak abundance quite a distance from shore, and are abundant in and near areas 4 and 5. A variety of zooplankton and pelagic invertebrates are also abundant offshore.

The planktonic community in the study region is clearly very dynamic. The dynamic nature of the plankton makes it difficult to characterize the spatial distribution of the component species. Cruises done in different years, or at different times within the same year, found that both the onshore-offshore distribution and the north-south distribution of a species could change markedly. To some extent these patterns related to seasonal current and upwelling patterns. In the winter, when the Davidson current dominated, northern planktonic forms were rare in the Gulf of the Farallones and inshore species were found further from shore and mixed to a greater extent with offshore species than in the spring.

CalCOFI data indicated that both chlorophyll a and phaeo pigments had their highest concentrations in nearshore areas well up on the continental shelf, while plankton volume was somewhat higher in offshore areas. Although based on only one year of data, the result for chlorophyll a and phaeo pigments strongly suggested that standing stocks of phytoplankton were higher in nearshore areas, like EPA study area 2 and the inshore portion of area 3, than in offshore regions. The result for plankton volume needs to be interpreted cautiously because the CalCOFI sampling procedure was designed for collecting ichthyoplankton, and probably under-represented abundant but potentially evasive forms such as euphausiids. This is important for two main reasons. First, euphausiids are clearly of ecological importance, being an important grazer and a food source for many fish and invertebrate species. Second, CalCOFI atlases indicated that the two most abundant euphausiids in the area, Euphausia pacifica and Thysanoessa spinifera, were nearshore-oriented species with highest abundances on the continental shelf. Midwater trawls for juvenile rockfish sometimes collected substantial numbers of euphausiids, but the resulting data did not indicate clear-cut depth or latitudinal patterns. This last result was of limited utility because the large mesh of the trawl net may have selected for some (larger) species over others, and because sampling was done only in May-June.

Copepods are an abundant component of the zooplankton both in shallow inshore waters and farther from shore. Copepods are an important food source for many organisms including juvenile fish, such as rockfish (Sebastes). Acartia, the most common genus of copepods in the area, had different species common inshore and offshore, but overall had highest abundances inshore. However, other copepods were also abundant offshore, and inshore species were sometimes abundant at substantial distances from shore.

Many of the planktonic organisms identified as having an inshore orientation are meroplankton (i.e. adult stages are benthic). Crab larvae, especially the early stage zoeae, tended to be most abundant inshore. Among the brachyuran crabs, the most abundant stage I zoeae in waters deeper than 30 meters was Cancer magister, the Dungeness crab. Adults of this species are an important fishery resource in shallow water in the vicinity of EPA study area 2. Other inshore oriented meroplankton included porcellanid larvae, pinnotherid larvae, and Callianassa spp. (ghost shrimp) larvae.

Clearly, the planktonic forms of organisms that are benthic as adults must have a strong seasonal pattern related to the reproductive season of the adults. This has been well studied off central California for Dungeness crab. Peak abundances of early stage zoeae were present inshore during January. The planktonic period lasted about four months so that megalopa were most abundant in the spring. During development the larvae underwent an extensive onshore-offshore movement. Later stage zoeae of Dungeness crab and other

Cancer crabs tended to be found further from shore than the earlier stages; the later stage zoeae of Dungeness crab were rare in waters shallower than 915 meters. The extent of the offshore movement appeared to be less for other species. Dungeness crab megalopa tended to be found further inshore than late stage zoeae, and the inshore movement was progressive as they developed. Thus, planktonic stages of Dungeness crab will tend to be abundant in regions like EPA study area 2 at certain times and for certain developmental stages, but will be more abundant in deep areas like EPA study area 5 at other times. This is probably true to a lesser extent for some other Cancer crabs, and may also apply to other species of meroplankton.

CalCOFI atlases indicated that both thaliaceans (salps) and pelagic molluscs tended to be most abundant offshore. Results from trawls for juvenile rockfish provide additional evidence for the offshore/deep water distribution of salps. This group is likely to be most abundant in areas like area 5. Chaetognaths have both inshore and offshore distributed species. Trawls for juvenile rockfish captured highest numbers of jellyfish inshore and to the south.

The nonplanktonic pelagic squid and octopus were sampled by the trawls targeting on juvenile rockfish. Market squid, Loligo opalescens, was most abundant inshore at depths like those of EPA study area 2. Octopus were most abundant at intermediate bottom depths and other squid tended to be most abundant in deep water like that associated with area 5.

Total ichthyoplankton were most abundant in the winter, and most individual ichthyoplankton groups reached peak abundance in the winter or spring. At the time of their peak abundance, total ichthyoplankton were most abundant at shallow water stations, and this was also true of the most abundant ichthyoplankton group, rockfish (Sebastes). In addition to rockfish, both slender sole and other flatfish (excluding slender sole and sanddabs) were most abundant in shallow water. The larvae of a number of other species, however, tended to be more abundant in deep water like that of EPA study area 5. These included the myctophids, medusafish, popeye blacksmelt, and California smoothtongue. Larvae of northern anchovy, Pacific hake, and sanddabs tended to have lowest abundance at the shallowest stations (depths similar to area 2), but to have fairly uniform abundance elsewhere.

Not withstanding these general patterns, ichthyoplankton distributions, like those of zooplankton, could be quite dynamic. For example, an extensive single survey in February 1991 found high abundances of shortbelly rockfish, which numerically dominated larval collections, quite a distance offshore. In addition, during this survey Pacific hake were relatively and absolutely much more abundant in comparison with the long-term pattern from CalCOFI surveys.

Pelagic fish, especially pelagic juveniles, were sampled by midwater trawl cruises designed to capture juvenile rockfish. The spatial patterns seen for the pelagic fish sometimes were complex, rather than simple functions of latitude and bottom depth or distance from shore. Juvenile rockfish as a group were consistently abundant inshore, but were also abundant in some locations offshore. This same pattern was seen for the most abundant component of this group, shortbelly rockfish. Juvenile stripetail rockfish, squarespot rockfish and yellowtail rockfish were each patchily abundant, with abundance not clearly related to bottom depth or distance from shore. Juvenile Dover sole were patchily abundant, with an area of high abundance in the vicinity of EPA study area 2.

A suite of pelagic fish species/stages were clearly more abundant in shallower water. These included Pacific herring, Pacific butterfish, plainfin midshipman, juvenile northern anchovy, juvenile lingcod, and juvenile blue, brown and canary rockfish. Other species were clearly most abundant at the deepest stations. These included the myctophids, California smoothtongue, blacksmelt, juvenile rex sole, and juvenile bocaccio. Juvenile Pacific hake had low abundances at the shallowest stations but were of roughly equal abundances at other depths. Adult Pacific hake had an intermediate depth distribution suggesting they would be most abundant in the shallower areas of EPA study area 3. Juvenile sanddabs also had an intermediate spatial distribution. Locations where adult shortbelly rockfish have been caught are concentrated near the shelf break suggesting that they could be abundant in the offshore portion of area 2.

For some of the species collected as part of the midwater trawl surveys for juvenile rockfish it was possible to directly evaluate abundance within the EPA study areas. With a few exceptions there was general agreement between the overall depth and onshore/offshore patterns and results for the EPA study areas. California smoothtongue, myctophids as a group, and the myctophid, California headlightfish, each had low abundances within study area 2, relative to the other areas. The myctophid northern lampfish and Pacific argentine had relatively high abundance at area 5 and relatively low abundance at area 2. Rex sole had high abundance at area 5 relative to the other areas. In general, the species/groups that had low abundances at area 2 and/or high abundances at area 5 had been classified as offshore or deep-water distributed. Blacksmelt, another group associated with deep water, was most abundant at study area 4. Dover sole juveniles were identified as having higher abundances within area 2, although overall they were not especially abundant in shallow water. Blue rockfish had higher abundances at areas 2 and 5. The high abundance at area 5 appears to be a local feature overlaying the generally shallow water distribution of this species. Juvenile chilipepper had the highest abundance within EPA study area 3, and this species tended to have lowest abundance at the deepest stations and roughly equal abundance at other depths. Spiny dogfish, a shallow water species, had the highest abundance at area 2 and the lowest abundance at area 5. Adult Pacific hake, which were generally most abundant at intermediate depths, had low abundance at area 5 and higher abundances at areas 3 and 2.

In contrast with the results for pelagic fish, fish collected by bottom trawl had spatial distributions that were usually related to depth and latitude in simple ways. For these fish, bottom depth was generally an important variable for predicting abundance. A variety of species had quite shallow distributions as adults. Fish that were most abundant at depths of less than 180 meters included spiny dogfish, Pacific electric ray, petrale sole, curlfin sole, plainfin midshipman, American shad, pink seaperch, lingcod, white croaker, Pacific pompano and greenstriped rockfish. Since EPA study area 2 is within this depth range, we expect that these species are most abundant within that area. Rockfish, as a group, were most abundant from 180 to 270 meters. Chilipepper, shortbelly rockfish, stripetail rockfish and bocaccio were each individually most abundant in this depth range. These groups are probably most abundant in area 2, although their peak abundances occur between the depths of area 2 and the shallower parts of area 3. Slender sole and spotted ratfish both were abundant in the 270-360 meter depth range, suggesting they might be abundant in the shallowest portions of area 3. Other species/groups having their highest abundances between 100 and 500 meters of bottom depth were rex sole, eelpouts, Pacific hake and the Bering skate. These species are likely to be most abundant in the shallower parts of area 3.

Thornyhead were most abundant between 700 and 900 meters, cat sharks were most abundant at 550 meters, and tanner crabs were abundant between 550 and 900 meters. These species probably have their highest abundances within area 3 and in shallow parts of area 4.

Grenadiers and Pacific flatnose had their highest abundances at the deepest bottom depth sampled (1300 meters) and thus are likely to be most abundant in the deep portions of area 3 and in areas 4 and 5. Catches of Ca. slickhead peaked between 700-1100 meters, and thus this species is likely to be most abundant in areas 3 and 4. Maximum catches of sablefish biomass were made from 550 to 1300 meters so this species is likely to be abundant in areas 3 and 4, and perhaps 5, although substantial numbers were caught as shallow as 180 meters. Dover sole were caught in substantial numbers over a wide depth range from 180 to 1100 meters. However fish caught deeper than 800 meters have high water content and currently are of little value to commercial fishermen. Thus, given current market conditions and technology, Dover sole is likely to be an important fishery resource only in the shallow parts of area 3.

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Fig. 113. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of petrale sole for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 114. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of Dover sole for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 115. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of curlfin sole for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 116. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of English sole for each combination of depth and latitude categories, based on AFSC triennial bottom trawl surveys.

Fig. 117. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of sablefish for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 118. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of plainfin midshipman for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 119. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of American shad for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 120. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of pink seaperch for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 121. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of lingcod for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 122. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of white croaker for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 123. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of Pacific pompano for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 124. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of rockfish (all species) for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 125. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of greenstriped rockfish for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 126. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of chilipepper for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 127. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of shortbelly rockfish for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 128. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of stripetail rockfish for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 129. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of bocaccio for each combination of depth and latitude categories, based on AFSC triennial bottom trawl surveys.

Fig. 130. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of spotted ratfish for each combination of depth and latitude categories, based on AFSC triennial bottom trawl surveys.

Fig. 131. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of market squid for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys.

Fig. 132. Abundance of sablefish versus depth category as indicated by least-squares means of $\log_e$ catch per trap (biomass and numbers) from 1986 and 1988 sablefish trap surveys.

Fig. 133. Locations of positive catches of shortbelly rockfish from the RACE database and from Tiburon Laboratory data.

Fig. 134. Locations of positive catches of Pacific hake adults from the triennial hydroacoustic surveys (RACE data).

Introduction

The U.S. Environmental Protection Agency Region IX (EPA) is preparing an Environmental Impact Statement (EIS) to evaluate potential locations for the designation of an ocean dredge material disposal area. EPA, as lead agency for the Long-Term Management Strategy (LTMS) Ocean Studies, selected study areas 2, 3, 4, and 5 (Fig. 1) for further investigation and analysis in the EIS. The purpose of this document is to evaluate the spatial distribution, in relation to the study areas, of fish and invertebrates collected during NMFS research surveys and CalCOFI ichthyoplankton surveys. We also review: (1) relevant published information on the spatial distribution of organisms in the study region; and, (2) natural and life history literature on selected species and groups.

The California Cooperative Oceanic Fisheries Investigations (CalCOFI) is a consortium of marine research institutions engaged in studies of the ecology of the California Current. In support of these studies, systematic plankton sampling has been conducted since 1951. This sampling consisted of oblique tows through the top 140 m (prior to 1969) or 210 m (1969 and after) of the water column. Currently the standard sampler is a bongo net; in surveys done in 1975 and earlier the standard sampler was a one-meter plankton net. The volume of plankton is measured, and the samples are sorted to count and identify ichthyoplankton. The Southwest Fisheries Science Center maintains an electronic database with standardized plankton volume and ichthyoplankton counts. A variety of individual invertebrate groups have been counted for a subset of the samples by Scripps Institution of Oceanography, and CalCOFI atlases have been published. However, these data are not included in the electronic database. Invertebrates in plankton samples primarily from the Gulf of the Farallones region have been counted by California Department of Fish and Game as part of their studies on Dungeness Crab (Cancer magister) and are reported in Tasto et al. (1981) and Wild and Tasto (1983).

Five CalCOFI stations within the study region depicted in Fig. 1 have frequently been sampled over the period 1951-1978 (Fig. 2). In 1981 and 1984 more limited sampling was done, and since 1984 the CalCOFI surveys have not extended much further north than Pt. Conception. In addition to these five stations found within the study region we have also included three stations off Monterey in our analyses (Fig. 2). In all, our analysis considers 464 tows done in 15 years. We are able to analyze zooplankton volume (as an index of biomass) and 14 species/groups of ichthyoplankton (Table 1).

In February 1991, the NMFS Tiburon laboratory conducted an ichthyoplankton survey designed to capture larval shortbelly rockfish. Samples were collected using a bongo net, following the standard CalCOFI sampling procedures. Data from 120 stations within the study region (Fig. 3) on the abundance of shortbelly rockfish and Pacific hake larvae are available.

Since 1983, the NMFS Tiburon laboratory has conducted annual midwater trawl surveys for juvenile rockfish in May and June, with additional studies in March and April of several years. Throughout this period, during May and June, a total of 526 successful trawls have been done in a standard fashion within the region depicted in Fig. 1. The stations generally sampled on each survey and other stations occasionally sampled are indicated on Fig. 4. The resulting database contains information on midwater fish and invertebrates, vertically migrating species which are sometimes found in midwater, and some limited information on microplankton. We are able to analyze the spatial distribution of 31 species/groups of fish and eight invertebrate species/groups (Table 2); other taxa were too rarely captured.

The Resource Assessment and Conservation Engineering Division (RACE) of the Alaska Fisheries Science Center, NMFS, maintains an electronic database containing data on numbers and biomass of fish caught in bottom and midwater trawls and in traps (pots). Some of the data contained in this database are from cruises fielded by the Southwest Fisheries Science Center. There are four sets of data which are of special interest to this analysis.

First, the database contains data from a cruise fielded by the Southwest Fisheries Science Center in January-February 1987 (Butler et al. 1989) designed to estimate the abundance of demersal fish on the continental slope off central California. In this survey, 20 bottom trawls were done within the study region, with sampling done systematically from 183 (183 meters = 100 fathoms) to 1281 meters of bottom depth (Fig. 5). For this study we analyzed data from the 14 most common species/groups of fish and one invertebrate (Table 3).

A second set of relevant data come from triennial bottom trawl surveys designed to estimate the abundance of groundfish along the Pacific coast. Five cruises have been fielded from 1977 through 1989. A total of 189 trawls spread throughout the study region over depths ranging from 55 to 457 meters are available (Fig. 6). For this study we analyzed data for 25 species/groups of fish and one invertebrate (Table 4).

A third set of relevant data in the RACE database comes from sampling of sablefish using traps. Surveys were done in 1986 and 1988 using conical Korean-style traps. Within the study region there is a single sampling line with samples taken from 275 to more than 1300 meters. A total of 22 samples have been collected along this line in 1986 and 1988 (Fig. 7). In 1984 only two samples were taken using the same gear, and different methods were used in earlier years. Here we evaluate data on sablefish catches from the 1986 and 1988 surveys, which followed the current standardized method.

Finally, the database contains records of (mainly) midwater trawls set on hydroacoustic targets. These trawls cannot generally be considered quantitative because they are set on targets (thought to be Pacific hake or sometimes shortbelly rockfish) identified by hydroacoustic signature. Because of this, we have used these data (which have used several different trawl designs) simply to identify locations where Pacific hake or shortbelly rockfish have been successfully captured. For shortbelly rockfish we have combined the RACE data with data reported by Chess et al. (1988) and with some additional midwater and bottom trawls (using various gear types and not always fishing on the bottom) fielded mainly by the Tiburon lab.

Field and Laboratory Methods

CalCOFI Surveys

The following description of methods is based on the on-line notes available within the CalCOFI data system (SWFSC 1988), and on Kramer et al. (1972), and Smith and Richardson (1977).

A one-meter ring net was the standard CalCOFI plankton sampler from 1951 through 1975. The one-meter plankton net consisted of a 1" (2.54 cm) galvanized pipe ring, one-meter in diameter, to which an elongate (approximately four meters in length) net was attached. A short three-way towing bridle was connected to several meters of line which in turn was clamped to a towing cable suspended from a survey vessel. Silk gauze nets were used from 1951 through 1968; most of the net was approximately 0.55 mm square mesh, and the last 40 cm including the codend were approximately 0.25 mm square mesh. Starting in 1969 nylon nets were used, with 0.505 mm square mesh throughout. Plankton samples were obtained by retrieving the sampler at an oblique angle. A 45 kg weight was attached to the end of a towing cable 10 meters below the attachment of the net bridle. While the survey vessel was under way, a fixed amount of towing cable was paid out at 50 m/min. The net was held at depth for 30 seconds and then retrieved at 20 m/min. Vessel speed varied between 1-2 kns and was adjusted to maintain the towing cable at 45° (±3°) to the vertical. From 1951 through 1968, 200 m of cable were paid out, resulting in a maximum sampling depth of approximately 140 m. Beginning in 1969, 300 m of towing cable were paid out, increasing the maximum depth sampled to approximately 210 m. In shallow areas, the amount of towing cable paid out was adjusted so that the net fished to approximately 15 m off the bottom.

The bongo net became the standard CalCOFI sampler in 1978 (the next standard survey in the study region after 1975). The bongo net frame consisted of two aluminum circles, 0.71 m in diameter, connected by a central yoke to which a towing cable is attached. The nets were 3 meters in length, consisting of a 1.5 m cylindrical portion joined to a 1.5 m conical portion tapering to a cod end. The principal ichthyoplankton sampling net was made from 0.505 mm square nylon mesh. Plankton samples were obtained by retrieving the sampler at an oblique angle. A 22 kg weight was attached to the end of the towing cable, a few meters below the attachment to the yoke. While the vessel was underway at 1-2 kns, 300 m of cable were paid out at a rate of 50 m/min, resulting in a maximum depth sampled of approximately 210 m. The net was held at depth for 30 seconds and is then retrieved at a rate of 20 m/min. Vessel speed was adjusted to maintain a 45° (±6°) angle between the towing cable and the vertical. In shallow areas the amount of cable paid out was adjusted so that the net fished to 15 m off the bottom.

Within the study region there were two standard CalCOFI sampling lines perpendicular to the coast. On these, 5 locations were deemed to have been sampled frequently enough to include in the analysis. An additional three locations along a line off Monterey Bay were also included in the analysis to help disentangle effects of bottom depth and distance from shore. Analysis was restricted to years in which each of these stations were sampled at least twice. In total, 464 samples collected in 15 years from 1952 through

1978 were analyzed. Limited sampling has occurred in the study region since 1978, and no samples have been collected in the area since 1984.

For each sample collected, the volume of plankton was measured, large items (such as salps) were removed and the volume was remeasured. The plankton volume was then standardized to cc's per 1000 m^3 based on flow meter readings. In this report we used the volume of plankton excluding the large items such as salps. If necessary, the plankton sample was split and then sorted so that ichthyoplankton could be identified and counted. Ichthyoplankton counts were standardized to numbers per 10 m^2 of surface area.

Tiburon Laboratory 1991 Ichthyoplankton Survey

The survey was accomplished during February 8-17, 1991. Sampling was done following standard CalCOFI bongo sampling procedures. A systematic sampling grid was set up (Fig. 3), with higher densities of sampling points in areas where concentrations of adult shortbelly rockfish were known to be found during the spawning season. A total of 120 standard CalCOFI samples were successfully collected within the study region and were processed in time for inclusion in this report. Additional samples were also collected to evaluate depth distribution of larvae and to compare results using different mesh sizes. These additional samples are still being processed.

Tiburon Laboratory Midwater Trawl Survey for Juvenile Rockfish

Starting in 1983, the Groundfish Analysis Investigation has conducted annual midwater trawl surveys designed to yield estimates of the abundance and distribution of juvenile rockfish (Sebastes spp.) during their pelagic phase. The design of the survey has evolved over time, and details of the changes in survey design can be found in Wyllie Echeverria et al. (1990). During the 1983-1985 period there was one survey annually during June (14-25 ship-days), allowing a single sweep through the survey area. Starting in 1986 the total survey area was reduced and from 1986 through 1991 a cruise of at least 20 days has been conducted during May-June, allowing three "sweeps" through the study region. In 1987, 1988, and 1990 an additional one sweep survey was also conducted during a shorter March-April cruise.

Details of the sampling methods can be found in Wyllie Echeverria et al. (1990). A midwater trawl net, with a square mouth, 26-meter headrope, and a codend liner of 3/8" (0.95 cm) stretch mesh was used. The target depth for standard samples was 30 m. In water shallower than 91 meters the target depth was 6 meters. For each sample the net was towed at depth for 15 minutes. All organisms captured were identified (to species or broader taxonomic categories) and enumerated. Counts from trawls at a target depth of 6 meters were adjusted upward (by a factor of 1.375 based on net mensuration studies) to standardize for the fact that the area of the net opening was less when towing at shallower depths.

Sampling locations are given in Fig. 4. Over the nine years of sampling a total of 21 sweeps have been accomplished during the May-June cruises. Data from a total of 526 trawls at standard depths from the May-June cruises were available within the study region. We did not analyze the data from the few March-April sweeps because of the limited extent of the data.

Additional samples above and below the standard sampling depth have been collected as time and conditions permitted. These samples were too infrequent to allow depth of net to be included in this analysis as a third dimension. Recently Lenarz et al. (1991) analyzed these data to determine overall patterns of depth distribution of juvenile fish and how these patterns varied with season.

1987 Continental Slope Survey for Demersal Fish

Methods for this survey were described by Butler et al. (1989). Although Butler et al. restrict their analysis to data collected south of the study region (for consistency with their 1988 survey), 20 successful trawls were accomplished during January-February 1987 within the study region. Trawls were done systematically from 183 to 1280 meters at depth intervals of 183 meters (100 fathoms). Within the study region trawls were done on two "lines" extending off Pt. Ano Nuevo and off Half Moon Bay (Fig. 5).

Samples were collected using a 400-mesh Eastern bottom trawl. 4" (10.1 cm) mesh was used in the wings, square, and belly, 3.5" (8.9 cm) mesh in the intermediate and in the codend. Mean path width was 14.6 m, and mean vertical opening was 1.7 m. We express results on a per hour basis because the duration of trawl hauls varied substantially. Results could be converted to an approximate per hectare trawled basis by dividing presented catches/hr by 10.4. Caution should be used when quantitatively comparing such converted data with similar data from other surveys; the actual distance towed on the bottom is unknown (Butler et al. 1989), as is the selectivity of the gear for different taxa. Catch processing and subsampling procedures followed standard Northwest and Alaska Fisheries Center protocols (Smith and Bakkala, 1982).

Triennial Groundfish Surveys

The Alaska Fisheries Science Center has conducted triennial bottom trawl surveys along the Pacific coast from 1977 through 1989. These surveys were done in the summer. The design of these surveys has changed over time, with designs consisting of both systematic and stratified random components (see Gunderson and Sample 1980, Weinberg et al. 1984, Coleman 1986, Coleman 1988). In each survey, trawls have been spread out along shore within the study region. In 1977 trawls were done over the depth range 91-457 meters. In all other surveys, samples have been collected at bottom depths of 55-366 meters. A total of 189 trawls were accomplished within the study region during the five surveys. In our analyses we restricted attention to transects at bottom depths of 366 meters or less (182 of the 189 trawls).

During the 1977-1986 surveys a nylon Noreastern bottom trawl was used. Five-inch (12.7 cm) mesh was used in the body of the net, while 3.5" (8.9 cm) mesh was used in the intermediate and codend, and there was a 1.5" (3.8 cm) mesh liner in the codend. The mean path width was approximately 13.4 m and the mean vertical opening was 9.2 m. In 1989 a polyethylene Noreastern trawl was used, which had similar operating characteristics to and the same mesh size and liner as the net used on previous surveys. Both versions of the Noreastern trawl were four-seam, hard-bottom, high-rise rockfish trawls.

Standard trawl hauls were done for 30 minutes on bottom at a speed of approximately 3 kns. Catch was processed using the standard protocols (Smith and Bakkala, 1982). We standardized trawl catch to a 13.4 m trawl path width and a duration of 30 minutes, correcting for (relatively minor) variations in trawl duration and path width. The average standardized trawl covered an area of approximately 3.72 hectares, and this value could be used to convert our results to a per hectare basis. However, as mentioned above for the continental slope survey, quantitative comparison with data collected using different gears or methods should be done cautiously.

Sablefish Trap Surveys

Surveys of sablefish have been done using traps. We used data from the 1986 and 1988 surveys which used a standard methodology (Parks and Shaw 1989). Conical "Korean-style" traps, with a bottom ring 137 cm in outside diameter and a top ring 85 cm in outside diameter were used. These traps were 71 cm high, covered with 5.7 cm nylon webbing, and had a tunnel entrance on the side. Traps were baited with chopped herring and the tunnels were closed by a timing device approximately 24 h after being set. Each sample consisted of the catch from ten traps attached at 90 m intervals along a 1000 m groundline set parallel to selected isobaths. Generally a "replicate" sample was collected at each depth on the day following the first set, and it is known that the catch in the second sample tends to be less than in the first. Standard sampling was done at five isobaths ranging from 412 to 961 meters. Additional samples were collected at 275 and between 1127 and 1610 meters on most lines (including the line in the study region) in 1988.

Analytical and Statistical Methods

The overall goal of most of the analyses in this report was to determine spatial variation in abundance, especially in relation to the locations of the EPA study areas. However, none of the studies was designed to assess abundance within the EPA study areas. Many of the analyses addressed broader geographical patterns related to latitude and depth, and this information can be used to assess the likelihood that a particular EPA study area or portion of a study area is important for a given species. Based on prior experience and an extensive ecological literature (e.g. Stewart-Oaten et al. 1986, Underwood 1981), we expected that most spatial (and temporal) effects operated more nearly in a multiplicative than in an additive fashion, with population number or biomass in one area being typically a certain percentage of that in another area, rather than being a set number more or less. Furthermore, based on past experience and preliminary analyses, we expected skewed distributions of errors, with variances positively related to the mean (e.g. Green 1979). For these reasons we $\log_e(x+0.1)$ transformed data for most of our analyses.

CalCOFI Surveys

The CalCOFI data (ichthyoplankton counts and plankton volume) were $\log_e$-transformed and analyzed by Analysis of Variance (ANOVA) using sampling location, year, and season as fixed main effects (i.e., class variables), and allowing an interaction between location and season. In cases where the attained significance level (i.e., the p-value) for the test of the interaction between season and location was greater than 0.1, a model without the interactive term was used. Our goal here was to detect consistent or predictable spatial patterns, so we did not include interactions involving year in the model, which in effect included them as part of the error about the model (in any case, limited sampling within any given year prevented the estimation of interactions involving this term.)

After fitting the ANOVA model we calculated least-squares means (also called population marginal means - see Searle et al. 1980) on a $\log_e$ scale for each effect in the model. The least-squares mean is an estimate of the mean value at a given level of a factor (say the spring season) obtainable if all levels of other factors were equally represented (i.e., if the design were balanced). The resulting least-squares means for station value were then plotted against the bottom depth of the sampling location, and in cases where there was an interaction with season, similar results were presented for each season. Least-squares means were also presented for seasons, now averaged over stations.

Tiburon Laboratory Ichthyoplankton Survey

This survey was done only once, with data on larval Pacific hake and shortbelly rockfish from 120 processed samples within the study region available at the time of our analysis. We $\log_e(x+0.1)$ transformed the data, and contoured $\log_e$-abundance throughout the study region using the minimum curvature algorithm available within Surfer™ software, and presented these results in map form.

Similar contour maps were also made based on the Tiburon midwater trawl data (see below). On all these maps contour lines indicate isopleths of constant abundance. In general, only every other contour line was marked, with every contour line being separated an equal number of units. Thus, an unlabeled line between, say a -0.6 and -0.2 contour would be the -0.4 contour. Note that negative values were possible because the results were expressed on a $\log_e$-scale. In some places contour lines curved so rapidly that there was no room for labels. In cases where "islands" of such unlabeled contours occurred, pockets of low abundance were indicated by inward facing tick marks, to distinguish them from isolated areas of higher abundance.

In addition to the contour maps, we also tested for depth and latitude effects using ANOVA. In this analysis we created depth categories of <183 m (100 fathoms), 183-549 m (100-300 fathoms), 549-915 m (300-500 fathoms), 915-1830 m (500-1000 fathoms), and >1830 m (1000 fathoms). We also created latitude categories of <37.267°N, 37.267°N - 37.633°N, and >37.633°N, roughly breaking the study area and sampling effort into thirds. The model we used included these as main (class) effects and allowed an interaction between the depth and latitude categories. Least-squares means were calculated and plotted. We caution that because one survey was done, there was no opportunity for time by location interactions to contribute to the errors about our ANOVA model.

Tiburon Laboratory Midwater Trawl Survey

In all these analyses we used a $\log_e(x+0.1)$ transformation. These data provided our most extensive spatial coverage of the study region extending over a number of years. Consequently, our analyses were most extensive for these data. One set of analyses used ANOVA models including sweep (i.e., time), latitude category (as defined above for the ichthyoplankton survey), and bottom depth category (<183 m, 183-915 m, 915-1830 m, and

>1830 m) as main (class) effects, and potentially allowed an interaction between depth and latitude categories (included if $p > 0.1$). Least-squares means were calculated and presented.

A second set of analyses was done to obtain contour maps of $\log_e$-abundance, and we use the contoured $\log_e$ abundances to test for variation among the EPA study areas. Although this is the most extensive data set at our disposal, these data were too sketchy to generate separate maps of abundance for each individual survey. In order to combine them we needed to adjust the data to account for among-sweep variation in mean and variance. Without such an adjustment we could easily confuse sweep and area effects. For example, during a sweep when abundances tended to be generally high, a sample might have been taken in area 5, resulting in a large catch. Unless this catch were adjusted for the sweep effect, the large catch in area 5 might lead us to over estimate the average abundance in area 5 relative to the others. We made this adjustment by calculating "Z-scores" for $\log_e$-abundance data as follows. For a given sweep we calculated the mean, M^*, and the standard deviation, s^*, using only the data from standard stations (i.e., the stations sampled on each sweep). Then,

$$Z = (\log_e(x + 0.1) - M^*)/s^*.$$

In these calculations the mean and standard deviations were calculated based on standard stations only, so that changes in survey design over time would not introduce artifactual effects into our adjustment. Z-scores calculated from surveys where the abundance was zero at all locations were not used because these surveys provide no information on multiplicative spatial variation.

We next calculated a grand mean, M, and grand standard deviation, s, which are the averages of the M^* and s^* over surveys. In the these calculations all surveys were used to calculate M^* but only surveys with at least one positive catch (for the species or group being analyzed) were used to calculate s. We then transformed our Z-scores back to a log-scale by calculating

$$x^* = s Z + M.$$

This is a simply a linear transformation and has no effect on our analyses other than allowing us to express our results as $\log_e$ abundance rather than in standard deviation units.

We then estimated $\log_e$ abundance throughout the study region using the minimum curvature algorithm within Surfer™. For a description of these contour maps see the "Tiburon Laboratory Ichthyoplankton Survey" subsection (above). As an alternative procedure for estimating a surface for $\log_e$-abundance over the study region we used the kriging algorithm within Surfer™. The general patterns in resulting contour maps were often similar for the two methods, although our kriged maps tended to show more fine-scale structure. In cases where the large-scale spatial pattern looked substantially different for the two procedures we presented no mapped results; in all other cases we presented contour maps of abundance using the minimum curvature algorithm only.

Our next task was to use the fitted surface (from the minimum curvature algorithm) of $\log_e$-abundance to estimate mean $\log_e$-abundance within each EPA study area and to test for variation among the areas. The mean was calculated simply as the mean of all the finely spaced grid points, for which the minimum curvature algorithm produced an estimate, within each of the areas. Tests for variation among areas and calculation of appropriate confidence intervals was substantially more involved. Clearly it is not appropriate to simply calculate the standard deviation of the fitted values within each study area, treating them as independent estimates. Instead we adopted a jackknife procedure in which the 21 sweeps were treated as independent samples. In this procedure, jackknife estimates of quantities of interest were generated by leaving out each sweep one at a time and repeating (21 times) the standardization and surface fitting procedure. Variation among these jackknife estimates was then used to construct confidence intervals and perform tests. More precisely, if q is our estimate of some quantity (say the difference in abundance between areas 2 and 5), then let q_i' be an estimate with the ith survey left out. Now define jackknife pseudovalues as

$$q_i^* = nq - (n-1)q_i'$$

These pseudovalues will then be independent and have an approximate normal distribution (see Miller 1974), and we therefore used them in normal-based tests and confidence intervals.

Correlation within a survey is also a potential problem. Therefore we did not simply calculate confidence intervals of $\log_e$-abundance and perform simple t-tests for differences between areas. Instead, our analysis was based on the vector of all possible <u>differences</u> between the areas. That is, q_i^* was now a vector with elements equal to the pairwise differences between the candidate areas. We then tested for significant variation among the areas by the multivariate Hotelling's T^2.

For graphical purposes we also calculated the difference between the means for each area and the average of the means over areas. For these quantities we also estimated confidence intervals based on jackknife pseudovalues, using standard methods for normally distributed variables. We presented these graphical results only when the pattern of differences among areas seen for minimum curvature was similar to that based on kriging.

Triennial Bottom Trawl Surveys

Our analysis was restricted to data collected at depths of 366 meters or less, and consequently the sampling encompasses only one of the EPA study areas. For this reason we did not develop contour maps of numbers (or biomass) or test for difference among EPA study areas. However, we did examine the data for depth and broad latitudinal patterns using ANOVA and least-squares means as described above. In this case we included survey, latitudinal category (defined as for the studies above) and depth category (<183 m, 183-274 m, and 275-366 m) as main effects (class variables), and included an interaction between depth and latitude categories when $p<0.1$ for the interaction. Again least-squares means were calculated and are presented. Numbers and biomass per standard tow were $\log(x+0.1)$ transformed.

Sablefish Trapping Survey

The sablefish trapping data consisted of data collected near the center of the study region in two different years. Duplicate samples were taken at each location within a survey, usually on two consecutive days. It is known that catches on the second day tended to be less than catches on the first sampling day for a given location. We again estimated least-squares means of $\log_e(x+0.1)$ data (both numbers and biomass per trap line) for depth categories after fitting an ANOVA model with year, order of sample, and depth category (< 550 m, 550-730 m, 731-915 m, and >915 m) as main effects.

Results

CalCOFI Surveys

The results indicated significant spatial variation in abundance in most cases. Table 5 presents a summary of the significance tests resulting from the ANOVA. In 13 of 15 cases there was a significant effect of station. An interaction between season and station was included in the ANOVA model in five cases because the test for the significance of the interaction resulted in a p-value less than 0.1.

Total fish larvae

Considering total fish larvae, averaged over seasons, highest abundances were seen over a broad range of intermediate depths along the on/off shore transects (Fig. 8). The greatest number of larvae was found in about 275 meters of water off Half Moon Bay. There is some indication that larval abundance peaked at a deeper depth off Monterey Bay than for the other lines. Averaged over stations, there was a strong seasonal pattern, with peak larval abundance in the winter (the months of Dec.-Feb.), falling steadily through fall (Fig. 8).

For total fish larvae there was a season by station interaction indicating that the spatial pattern depended upon the season. The highest abundance of larvae were found in the shallow stations in the winter, while the lowest abundance were at deep stations in the fall. During the summer upwelling season larval abundance was relatively low at the inshore stations (Fig. 9).

Taxa with season by station interactions

Other species/groups, in addition to total fish larvae, showing season by station interactions were rockfish, anchovy, northern lampfish, and slender sole. Averaged over seasons rockfish had their highest abundance at the shallower stations and their lowest abundance at the deepest stations. For this group there was no obvious latitudinal pattern (Fig. 10). Anchovy showed fairly uniform abundance as a function of depth, but abundance appeared to increase from the stations off Pt. Reyes in the north to the stations off Monterey in the south (Fig. 10). Northern lampfish had the lowest abundance at the shallowest station and there was some suggestion that abundance was somewhat higher at the deeper stations than at moderate depths. For this species there was no clear latitudinal pattern. Slender sole had low abundance at the shallowest station, otherwise the shallower stations tended to have higher abundances than the deep stations (Fig. 10). Abundance appeared to increase moving from south to north.

Averaging over stations, rockfish and northern lampfish had their peak abundance in the winter, anchovy had fairly uniform abundance from winter through summer and lower abundance in the fall (Fig. 11), and slender sole had their peak abundance in the summer (Fig. 11). The season by station interactions for these groups indicated that spatial patterns depended upon season. Rockfish (Fig. 12), anchovy (Fig. 13), and northern lampfish (Fig. 14) all showed a drop-off in abundance in shallower stations in the summer period of strong upwelling. The interaction for slender sole does not have such an obvious interpretation (Fig. 15). However the abundance at the shallowest station off Half Moon Bay dropped off in the spring and summer relative to other sampling stations.

Taxa without season by station interactions

Medusafish, popeye blacksmelt, and California smoothtongue all had their higher abundances at the deeper sampling stations (Fig. 16). Pacific hake showed some indication of lower abundance at the shallowest sampling stations (Fig. 16). Of these species, medusafish have their peak abundance in the summer and the other three had peak abundances in the winter and spring (Fig. 17).

Sanddabs had low abundance at the three shallowest stations and showed no other general pattern related to depth (Fig. 18). Other flatfish (excluding sanddabs and slender sole) had their highest abundance at the three shallowest stations, but no other easily interpreted pattern with bottom depth (Fig. 18). Both blue lanternfish and California flashlightfish had low abundances at the shallowest sampling stations with abundance increasing with depth (Fig. 18). None of these groups showed clear patterns with latitude.

Sanddabs and California flashlightfish had peak abundance in the fall and winter (Fig. 19). Other flatfish had peak abundance in the spring, and blue lanternfish had peak abundance in the summer and fall (Fig. 19).

Other myctophids had higher abundances at the deeper sampling stations, but no clear pattern with latitude (Fig. 20). There was a sharp peak in other myctophid abundance in the summer (Fig. 20). The volume of plankton collected did not vary as much in space (on a log scale) as did total ichthyoplankton numbers. There was, however, a tendency for somewhat higher volumes to be collected at the deepest stations (Fig. 20). The Monterey Bay line produced the lowest volumes, with volume increasing to the north. Plankton volume peaked in the spring and then declined steadily through winter (Fig. 20).

Review of CalCOFI Atlases on Zooplankton

The electronic CalCOFI database maintained by the Southwest Fisheries Science Center, NMFS, contains only data on ichthyoplankton and on plankton volume. However, based on work primarily contracted to Scripps Institute of Oceanography, a number of CalCOFI atlases have been produced on the distribution of invertebrates. Here we summarize the relevant results from CalCOFI atlases 2, 3, 5, 6, 7, 8, 18, 19, 20, and 24.

Calanoid copepods are an abundant component of the zooplankton in ocean waters, and maps of their distribution based on samples collected in 1949, 1950, 1958, and 1959 were reported in atlases 2, 7, and 19. Numerous species were found in central California waters; however, 11 species dominated. These species can be characterized as typically nearshore or typically offshore in their pattern of distribution. Acartia tonsa was identified as the most common copepod in the area and it was typically a nearshore species. Other abundant nearshore species were: Calanus helgolandicus, Clausocalanus pergens, Ctenocalanus vanus, Metridia luceus, and Toranus discaudatus. Some species of calanoid copepods were typically most abundant off the continental shelf and were sometimes abundant hundreds of miles offshore. The most abundant offshore species was Acartia danae, with abundances rivalling the abundances seen inshore for Acartia tonsa. The abundance of Acartia danae might have been underestimated because its small size could have allowed some individuals to pass through the net. Other abundant species of copepods in offshore waters were: Calanus gracilis, Clausocalanus arcuicornis, Gaidius pungens, and Plueromamma abdominalis.

The distribution of pelagic molluscs, based on data from six cruises during 1949, 1950, and 1952, are reported in Atlas 6. This group was typically an offshore group, with peak abundances hundreds of miles offshore. More species of pelagic molluscs occurred in southern California than in northern California. The most common species in central California was Carinaria japonica, which was found just offshore of the continental shelf. Other common species in central California included: Limacina helicina, Limacina inflata, Clio pyramidata, and Corolla spectabilis.

The distribution of thaliaceans (salps) was reported in Atlas 8 based on 26 cruises during six years from 1949 through 1958. Thaliaceans are a speciose class of invertebrates in central California waters. Of the common species, most had higher abundances in offshore waters well away from the edge of the continental shelf. The most common offshore thaliaceans in central California were: Thalia democratica, Ritteriella pecteti, and Doliolum denticulatum. Salpa fusiformis was an abundant offshore species but occasionally large concentrations were found inshore well up on the continental shelf. Dolioletta gegenbauri was the most abundant thaliacean in nearshore waters, typically being most abundant on the shelf and near the shelf break.

The distribution of Chaetognaths (arrow worms) was reported in Atlas 3 based on monthly cruises during 1954 and 1958. Many species were recorded in central California waters; however only six species were common. Three species of arrow worms were most abundant offshore: Sagitta bierii, Sagitta minima, and Eukrohnia hamata. Two species had nearly uniform distributions between nearshore and offshore areas: Sagitta scrippsae and

Sagitta euneritica. Sagitta enflata was most abundant in nearshore waters on the continental shelf.

Numerous species of euphausiids are found in Central California waters but only ten have been common and two of them made up the majority of all euphausiids in the area. The distribution of euphausiids was reported in Atlases 5 and 18 based on 24 cruises in nine years from 1939 through 1962. Euphausia pacifica and Thysanoessa spinifera were the most abundant species in central California and both of these species were most abundant on the continental shelf in nearshore waters. Nyctiphanes simplex was typically a more southern species, but concentrations were found in nearshore waters off central California in some years. Five species typically occurred offshore in central California waters: Euphausia gibboides, Euphausia mutica, Euphausia recurva, and Thysanoessa gregaria. In some years, and for some species, highest abundances were located several hundred miles offshore.

Maps of the concentration of chlorophyll a and phaeo pigments were reported in Atlas 20 based on monthly cruises during 1969. There was a distinct trend for highest concentrations to be found in the nearshore area, well up on the continental shelf.

Review of California Dept. of Fish and Game "Dungeness Crab" Zooplankton Studies

As part of their studies on Dungeness crab (Cancer magister), the California Dept. of Fish and Game (CDF&G) collected over 1600 ocean plankton samples from 1975-1980 and sorted more than 400 additional CalCOFI plankton samples collected from 1949-1975. The majority of the CDF&G samples were collected in the Gulf of the Farallones, inshore and/or north of the EPA study areas. However, sampling in 1979, and the CalCOFI samples they sorted, provide information on offshore areas. Results from these studies are reported by Wild and Tasto (1983) and by Tasto et al. (1981).

Wild and Tasto (1983) report on an intensive five-year study on Dungeness crab and the following summary for that species is based on their work. These crabs are an important fishery resource in depths of 90 meters and less. Females carry masses of one to two million eggs that hatch in late December through early January. Larvae go through five zoeal and one megalopal stage over a 105-125 day period before settling to the bottom in shallow water and molting and becoming juvenile crabs. In January, Dungeness crabs were generally the most abundant stage I zoeae of brachyuran crabs in plankton samples from stations of 30 m of depth or greater. Extensive plankton studies showed that in central California the larval zoeae were transported offshore because they spent a majority of their time in the upper 15 m of the water column, and there is net movement of this surface water offshore during the winter. No Dungeness crab zoeae were found in plankton sled tows on the bottom, although other Cancer zoeae were. Stage I zoeae were most abundant nearshore on the continental shelf in depths of 30 to 70 m. In contrast, relatively few stage III or later zoeae were collected inshore of the 915 meter isobath, and stage V zoeae were moderately abundant to 150 km from shore. Megalopal Dungeness crab were generally found further inshore than late stage zoeae. Intermolt staging indicated that the inshore movement was progressive as the megaplopae developed.

Hatfield (1983) and Tasto et al. (1981) also reported on zooplankton other than Dungeness crab. Hatfield (1983) analyzed data from oblique tows collected in spring 1976, winter and spring 1977, and March 1979. Except for the March 1979 samples, these data come from stations largely north or inshore of the EPA study areas. Notable in her results are substantial changes in the spatial distributions and abundance of a number of zooplankton species associated with seasonal current patterns, and localized current patterns and upwelling. In winter 1977, when the Davidson current dominated, northern planktonic forms were rare in the Gulf of the Farallones and typically inshore species were found further from shore and mixed with offshore forms, in comparison with what was seen in the spring. Based on the 1979 data, when sampling extended furthest offshore, Hatfield identified distinct inshore and offshore zooplankton groups. The inshore group consisted of a few holoplankton and many meroplankton species including the crabs Cancer antemarius zoeae, and Cancer gracilis zoeae stages I-III, Pinnotherid (small commensal crabs) zoeae and megalopa, pagurid (hermit crab) larvae, Callianassa spp. (ghost shrimp) larvae, the copepod Epilabidocera longipedata, grapsid crab zoeae stages IV-V, the Ctenophore Pleurobrachia bacheri, porcellanid (a family of Anomuran decapods) larvae, Upogebia pugettensis larvae, the euphausiid Thysanoessa spinifera, and the copepod Tortanus discaudatus. The offshore group was distributed predominantly beyond 30-50 km from shore in the Gulf of the Farallones transects and thus would likely be rare in EPA study area 2, but could be common in the other areas. Included in the offshore group were the copepods Candacia bipinnata, Euchaeta japonica, and Euchaeta acuta, the euphausiids Nematoscelis difficilis and Thysanoessa gregaria, the crabs Cancer productus zoeae IV-V and Cancer oregonensis zoeae IV-V, and a chaetognath Sagitta scrippsae. Other species did not show distinct onshore-offshore patterns in 1979. Several additional species were consistently classified as inshore species during the 1976 and 1977 cruises. These included the copepod Acartia clausi, Cancer productus zoeae I-III, Xanthid zoeae I-II and Majid zoeae I. Species that were consistently identified as offshore distributed in 1976 and 1977 were the copepods Eucalanus bungii and the combined group Neocalanus cristatus and N. plunchrus.

Tasto et al. (1981) reported station means and frequency of occurrence of zooplankton species for samples collected during the December to June period from 1975 through 1977 at their 34 standard stations in the Gulf of the Farallones. For the most part, these stations were north and/or inshore of the EPA study areas. However, some of the offshore stations were as far offshore as parts of area 3, and the results can be used to contrast expected zooplankton composition at area 2 with that expected further offshore. Tasto et al. (1981) also reported means and frequency of occurrence for transects done in March 1979 that extended further offshore than any of the EPA study areas. However, these results were given as averages for each transect so it was not possible to evaluate the onshore/offshore distribution of the zooplankton from this presentation. Two of the transects extended from the mouth of San Francisco Bay in the immediate region of the EPA study areas, and we use this information to further characterize the common zooplankton of the region. Tasto et al. (1981) used many of the data used by Hatfield (1983), but some data not used by Hatfield were included, and Hatfield did not present any station means or frequency of occurrence. However, Tasto et al. prepared their report before all the samples had been sorted. Thus, there is value to reviewing Tasto et al. as well as Hatfield (1983).

Based on Tasto et al. (1981) we identified the common zooplankton forms in the region and characterized their onshore/offshore distribution. Larvae of decapod crustaceans were generally more abundant inshore, suggesting that they have substantially higher abundances in study area 2 than in the other study areas. Callianassa spp. (ghost shrimp) larvae reached mean densities of over 600 (per 100 m^3) and were found in more than half the samples at some inshore stations. Callianassa was rare offshore. Porcellanid larvae were also most common inshore, reaching mean densities of over 200 and being present in more than half the samples at some stations. They were also uncommon offshore. Majid zoeae stage I reached mean densities of 50 and were present in more than half the samples at some inshore stations. Although they tended to be more abundant inshore, at some offshore stations they were common. Cancer antennarius zoeae stages I-III reached mean densities of over 1000 and were present in over 90% of the samples at some inshore stations. Zoeae stages IV-V had a more offshore distribution than stages I-III, but were still relatively more common inshore and were not very common at the furthest offshore stations. Cancer gracilis zoeae stages I-III were present in up to 60% of the samples at some inshore stations, reaching mean densities of over 350. Zoeal stages IV-V had a more offshore distribution, and were found in up to one third of the samples at some of the furthest offshore stations, but were still more common inshore. Cancer onegonensis zoeae I-III reached mean densities of over 200, and were present in over half the samples at some stations. Densities were generally below 50 at most stations. These zoeae were most common mid-distances from shore, and were relatively quite abundant at some offshore stations. Cancer spp. larvae (unidentified) reached mean densities of over 2500 and were present in over 85% of the samples at some stations. They were generally most abundant inshore. Grapsid zoeae stages I-III reached densities of over 500 and were present in about 80% of the samples at some inshore stations. These larvae were extremely rare at the furthest offshore stations.

The most abundant calanoid copepod was identified as Acartia clausi and reached mean densities of up to 15,000 (per 100 m^3) and was present in over 90% of the samples at some inshore stations. Although this group was most abundant inshore, it was also abundant at some offshore stations, being found more than half the time, and reaching mean densities of over 300. Acartia longiremis reached mean densities of up to 4000 and were present in about half the samples at some stations. There was no obvious onshore/offshore pattern for this species. Calanus pacificus reached mean densities of 4000 and were present in up to 90% of the samples at some stations. They tended to be more abundant inshore, but were also quite abundant at some offshore stations. Calanus tenuicornis was common, reaching mean density of about 1500 and being found in about 60% of the samples at some stations. There was no obvious onshore/offshore distribution for this species, and it had densities of over 100 at most stations. Epilabidocera longipedata was present in over 50% of the samples and reached a mean density of more than 800 inshore. This species was uncommon at the furthest offshore stations. Eucalanus bungii were present in up to 60% of the samples at some stations and sometimes exceeded mean densities of 400. There was no obvious onshore/offshore pattern for this species. Metridia lucens was an abundant species often exceeding a mean density of 500 and peaking at mean densities of over 3500. This species was found in over half the samples at some stations, but there was no obvious onshore/offshore pattern. Pseudocalanus sp. was present in over 60% of the samples at some stations, reached peak mean density of over 2500, and had mean density of over 100 at many stations. There was, however, no clear cut onshore/offshore pattern.

Pleurobrachia bachei (ctenophore) reached densities of over 100 (per 100 m^3) and were present in about half the samples at inshore stations. At the furthest offshore stations they were less frequently encountered, and mean densities were on the order of 5-20. Limacina helicina (pelagic mollusc) reached densities of 100 and were present in about half the samples at some stations. There was no obvious onshore/offshore pattern. Adult euphausiids were uncommon in the 1975-1977 samples, with no species occurring in close to half the samples at any station. The most common species of chaetognath was Sagitta euneritica, which reached peak mean density of nearly 400 and was present in more than 50% of the samples at some stations. This species appeared to be equally abundant inshore and offshore. A variety of other chaetognaths were encountered, but most were rare.

Many other taxa, in addition to those listed above, were identified in plankton samples from the region. However, most of these never approached a frequency of occurrence of 50% at any station. Among the coelenterates, a number of species of hydroids, Chondrophora and Siphonophora were identified. Several species of polychaetes were encountered, as were Cladocera and Ostracoda. Many other species of copepods, in addition to the abundant ones mentioned above, were also encountered. Other taxa encountered included mysids, isopods, cumaceans, amphipods, and echinoderm larvae. Representatives of the chordate classes Thaliacia and Larvacea were also sometimes encountered.

Many of the species that were abundant on the two transects off San Francisco Bay in March 1979 were also abundant in 1975-1977. However, some additional species were also common. The most notable difference was that euphausiids were common in 1979. Euphausia pacifica had mean densities of 100-200 (per 100 m^3) and were present in about 70% of the samples. Other common euphausiids in 1979 were Nematoscelis difficilis and Thysanoessa gregaria. The thaliacian (salp) Dolioletta gegenbauri was found in more than 75% of the samples at mean density over 350. Two chaetognaths, Sagitta decipiens and Sagitta scrippsae, which were infrequent in the 1975-1977 samples, were each present in more than half the 1979 samples off San Francisco. Some of the differences could be due to the farther offshore sampling in 1979. T. gregaria, for example, appeared to have an offshore distribution. An explanation for the overall much higher catches of euphausiids in 1979 is not obvious. Acartia clausi, the most abundant copepod identified in 1975-1977, was infrequent in the 1979 samples. This, however, may have resulted from the 1 mm mesh used in 1979 (relative to 0.505 mm mesh in earlier sampling) not retaining all individuals of this species (Tasto et al. 1981).

The substantial differences in distributions between those reported in CalCOFI atlases and those reported by Hatfield (1983) for the CDF&G study highlight the dynamic nature of the plankton. Both studies evaluated onshore-offshore patterns for euphausiids, calanoid copepods, and Chaetognaths. In CalCOFI atlases the copepod Candacia bipinnata showed varied patterns sometimes being broadly distributed, sometimes being more abundant inshore, and at others being more abundant offshore. The atlases do not record the presence of the copepod Euchaeta japonica, and Euchaeta acuta was relatively rare and tended to be more abundant inshore. Each of these species was classified as an offshore species by Hatfield based on CDF&G surveys in 1979. The Chaetognath Sagitta scrippsae was classified as an offshore species based on the CDF&G survey, but appeared to have a more even distribution in the CalCOFI atlases.

Other apparent differences may be due to differences in methodology or identifications. An example is the striking difference between the two studies in the dominant species of Acartia copepods that were identified. The CalCOFI atlases indicate that the most abundant species were Acartia danae offshore and Acartia tonsa inshore. The CDF&G study indicated that Acartia clausi, a bay-associated species, was the most abundant inshore and Acartia longiremis had a broader inshore/offshore distribution. Acartia tonsa and Acartia danae are not recorded at all in Tasto et al.'s checklist, and Acartia clausi is only occasionally recorded in the CalCOFI atlases, while Acartia longiremis is not recorded at all. Although some of these difference could be due to real changes in relative abundance, part of the apparent change in species composition might be due to taxonomic uncertainties associated with Acartia. The taxonomy of shallow water Acartia off the central California coast needs further review (pers. comm. W. Kimmerer, BioSystems analysis, 3152 Paradise Drive, Tiburon, California 94920).

There were also areas of agreement between the two sets of results. Both classified Thyanoessa spinifera as an inshore euphausiid and Thysanoessa gregaria as an offshore species. Both also classified Tortanus discaudatus as an inshore species, and Epilabidocera longipedata was reported as inshore in the CDF&G study and had an inshore distribution on the one CalCOFI cruise on which it was recorded.

Tiburon Lab 1991 Ichthyoplankton Survey

Pacific hake larvae reached their highest abundance offshore, especially in the southern part of the study region (Fig. 21). Abundance increased with increasing bottom depth to about 600 m, and then remained fairly constant (Fig. 22). Within depth categories, highest abundances were to the south, and lowest ones to the north.

The contour map for shortbelly rockfish larvae indicated two areas of high abundance. The first was in an offshore area in the north central portion of the study region, and the second is a band running parallel to the shore, just offshore of area 2, extending from Pt. Reyes in the north to the southern edge of the study region (Fig. 23). Although there were some high values inside and just inshore of area 5, the high contoured values offshore of area 5 were extrapolated into a region with no data (see Fig. 3). Consequently we feel that the trend within and extending off of area 5 may be an artifact, but the moderately high average value for the entire area 5 is supported by the data. We found low abundances in depths under about 200 m; abundance then appeared to peak in the 200-600 m depth range, fell, and then increased again at about 1000 m (Fig. 24). Preliminary findings indicate that the high numbers in offshore samples generally consisted of larger (and older) fish. This pattern of relatively high numbers offshore was not consistent with the long-term pattern seen in CalCOFI ichthyoplankton samples for rockfish, which presumably consisted largely of shortbelly rockfish. Shortbelly rockfish larvae were most abundant, within depth categories, in the intermediate latitudes (Fig. 24).

Tiburon Laboratory Midwater Trawl Survey

Analyses included the construction of contour maps, testing for differences among areas based on the contoured abundances, and ANOVA's along and their corresponding least-squares means of log-transformed abundance. It was not always possible to produce contour maps or test difference among areas. The reasons for this are presented in detail in the Methods, and largely had to due with two different contouring methods producing qualitatively different results. When this was the case we concluded that we could not test for spatial differences on as fine a scale as the study areas.

In general, the analyses detected significant spatial variability. Table 6 summarizes the results of the ANOVA tests of depth and latitudinal effects. In 23 (of 37) cases we found significant ($p<0.05$) depth effects and in 16 cases we found significant latitudinal effects. In 15 cases an interaction between depth and latitude categories was included in the model because the p-values for the latitude effect were relatively low ($p<0.1$), and in all but two of these cases the interaction was significant ($p<0.05$). In only six cases were the p-values for main effects and the interaction all above 0.05.

Pacific herring had their highest abundances inshore in the Gulf of the Farallones region, as indicated by the contour map (Fig. 25). In agreement, abundance tended to be highest in shallow water and to the north as indicated by the least-squares means (Fig. 26).

Pacific butterfish had very low abundances and, as indicated by the contour map, their distribution was restricted to inshore areas (Fig. 27). Least-squares means showed a consistent pattern, indicating highest abundances in shallow water, and also suggested that this species was rare in the northern part of the study region (Fig. 28).

Plainfin midshipman were most abundant inshore, especially in the Gulf of the Farallones (Fig. 29), and in the southernmost part of the study region. Least-squares means showed highest abundances in shallow water and lower abundances in the north than in the south and central regions (Fig. 30). This latter pattern is not obvious from the contour plot.

California smoothtongue showed a clear pattern of higher abundances offshore, beyond the 1800 m bottom depth contour, and to the south (Fig. 31). In agreement with the contour map, least-squares means increased with bottom depth (Fig. 32). In contrast with the contour map, however, the least-square means did not indicate consistently higher abundances in the south (over all depths). The apparent discrepancy between Fig. 31 and Fig. 32 was likely caused by the lack of equivalence between offshore distance and bottom depth. In the southernmost portion of the study region deep bottom depths occur relatively closer to shore (Fig. 1). We found a significant difference among EPA study areas, which is consistent with the spatial and depth patterns described above. The inshore area 2 was found to have fewer fish of this species than the other areas (Fig. 33).

Blacksmelt (all species combined) showed a similar pattern to that seen for California smoothtongue. Their abundances were higher to the south and offshore beyond the 1800 m bottom depth contour (Fig. 34). Again, the least-squares means indicated higher abundances offshore, but not necessarily (for a given depth category) to the south (Fig. 35). Again, this apparent difference suggests that the higher abundances to the south in Fig. 34 were primarily a depth effect, related to the deeper water in this region. It was possible to test for differences among EPA study areas, and a significant result was found. These results suggest higher abundance at area 4 than at the other areas (Fig. 33). We recommend that this result be interpreted cautiously because the generally higher abundances in the region of area four indicated on Fig. 34 (and hence on Fig. 33) are probably an extrapolation from heavily sampled regions to the south that are in deeper water.

Overall, Pacific argentine juveniles were rare and patchily distributed, with the contour map indicating higher abundance offshore to the north and inshore to the extreme south (Fig. 36). This pattern was consistent with the high abundances in shallow water to the south and the high abundances in deep water to the north indicated by the plot of least-squares means (Fig. 37). It was possible to test for differences among EPA study areas, but no significant differences were found ($p=0.33$). There was a suggestion of higher abundances at area 5 and lower abundance at area 2 (Fig. 38), as one might expect from the contour map (Fig. 36).

Northern anchovy juveniles were more abundant inshore (Fig. 39). The analysis by depth and latitude category was consistent with the contour map, indicating declining abundance with increasing bottom depth and lower abundances to the north (Fig. 40). We were able to test for differences among study areas, and found no significant differences among areas (Fig. 41), perhaps because northern anchovy were scarce in the vicinity of all the EPA study areas.

Adult Pacific hake appeared to be most abundant moderately inshore, between the 55 and 180 m bottom depth contours (Fig. 42) The contour map also suggested that adult Pacific hake are scarce in the southernmost portion of the study region. The ANOVA indicated somewhat consistent results. Abundance (as indicated by least-squares means) was generally higher in the north and lower in the south, and there was a tendency for abundance to fall with increasing bottom depth (Fig. 43). However, no such decline was seen in the north. There was a highly significant difference among EPA study areas, with highest abundances at areas two and three and much lower abundances at area 5 (Fig. 41).

Juvenile Pacific hake had low abundances inshore of the 180 m bottom depth contour, and high abundances in the center of the study region between the 180 and 900 m bottom depth contours (Fig. 44). Analysis by depth and latitude indicated that very few juvenile Pacific hake were caught in less than 180 meters, but elsewhere abundance was fairly uniform as a function of depth and latitude, perhaps with a slight trend toward increasing abundance to the north (Fig. 45).

Spiny dogfish showed higher abundance between the 90 and 180 m bottom depth contours in several places near the center of the study region, and generally higher abundances to the north (Fig. 46). Analysis by depth and latitude indicated lower abundance at bottom depth of about 900 m or greater (900 meters is the upper bound of the 550 meter category), and lower abundances in the south (Fig. 47). There was significant variation among the EPA study areas, with highest abundance in area 2 and lowest abundance in area 5 (Fig. 48).

Juvenile rockfish (total) appeared to be generally abundant inshore and also were patchily abundant offshore as indicated by the contour plot (Fig. 49). The analysis by depth and latitude produced a similar pattern: abundance was high at all latitudes in water shallower than 180 meters, with abundance depending upon the particular latitude category for other depths (Fig. 50).

The abundance of chilipepper juveniles appeared to be highest inshore, in the vicinity of the inshore portion of area 3, and between the 900 and 2750 m bottom contours in the southern portion of the study region (Fig. 51). Analysis by depth and latitude indicated lower abundance in the deepest depth category and higher abundances in the south (Fig. 52). It was possible to test for a study area effect, which was not significant ($p=0.13$). The pattern suggested somewhat higher abundances at area 3 than at the other EPA study areas (Fig. 53), but this is due primarily to the higher abundance for the inshore (eastern) portion of the area.

Juvenile shortbelly rockfish appeared to be most abundant in the central area of the study region at distances slightly inshore and north from the inshore edge of area 3 (Fig. 54). The analysis by depth and latitude showed a quite irregular pattern (Fig. 55). Juvenile shortbelly were moderately abundant at all latitudes in water shallower than 180 meters. In the mid-latitudes abundance remained high, falling off only moderately in the deepest depth category. In both the north and south, abundance did not change smoothly with depth. In the north abundance fell sharply in the next to shallowest depth category, increased, and then fell again for the deepest category. For the south, abundance fell sharply at the next to deepest category and then increased sharply for the deepest category. This irregular pattern suggested that juvenile shortbelly abundance may have been as much related to proximity to specific spots (e.g., spawning grounds) as to graded effects of depth or latitude.

Juvenile blue rockfish appeared to be more abundant inshore of the 180 m isobath and in the northern portion of the study region (Fig. 56). The contour map also suggested localized areas of higher abundance near the eastern border of area 5, and moderately far offshore in the south. The analysis of depth and latitude effects indicated much higher abundances in bottom depths less than 180 meters (Fig. 57). Although abundance was higher in the north than at mid-latitude, abundance (within a given depth category) in the south was nearly as high. There was significant variation among EPA study areas, with areas 2 and 5 showing higher abundances than others (Fig. 58). The high abundance at area 5 appeared to be a local feature, while the high abundance at area 2 was associated with the generally shallow water orientation of this species.

Juvenile brown rockfish appeared to be most abundant inshore of the 180 m isobath and were scarce to the north (Fig. 59). There also appeared to be a localized pocket of abundance on Pioneer seamount just offshore of area 3 (Fig. 59). The analysis by depth and latitude suggested consistently high abundance in water shallower than 180 meters, and somewhat lower and more variable abundance in deeper water, with abundance being quite low in the north (Fig. 60). It was possible to test for a area effect, but no significant effect, nor suggestion of a pattern, was found (Fig. 58).

Juvenile canary rockfish appeared to have low abundances inshore of the 180 meter isobath with a number of pockets of higher abundance offshore (Fig. 61). Analysis by depth and latitude indicated a general pattern of increasing abundances offshore, but the intermediate latitude area was an exception, with lower abundances beyond 900 meters in bottom depth (Fig. 62).

No contour map is presented for bocaccio because the two contouring algorithms produced quite different patterns. However, there was a very distinct pattern of increasing abundance with bottom depth, and a slight indication of higher abundances in the mid-latitude areas in comparison to the north or south (Fig. 63).

The contour plot for juvenile yellowtail rockfish did not show much variation in abundance spatially with one local concentration at the southern edge of the study region, moderately far offshore (Fig. 64). The analysis by depth and latitude also indicated a fairly even distribution of abundance, except for very low abundances in the next to shallowest depth category (Fig. 65).

The contour map for juvenile squarespot rockfish, like that for yellowtail rockfish, indicated a fairly even distribution, although this species was less abundant than yellowtail rockfish (Fig. 66). There appeared to be localized areas of abundance in the middle of the study region and offshore at the southern edge of the study region. For this species there were no significant effects of depth or latitude.

Juveniles of stripetail rockfish were scarce throughout the study region with the exception of somewhat higher abundance offshore of the 1800 meter isobath at the southern edge of the study region (Fig. 67). The analysis of depth and latitude suggested that abundance declined somewhat from south to north, but indicated little effect of bottom depth (Fig. 68).

Data for juveniles of widow and pygmy rockfish were analyzed and, in both cases, different interpolation methods produced different patterns and there were no significant effects of depth or latitude. Pygmy rockfish were relatively scarce in the samples so our failure to detect a spatial pattern may reflect resulting low power rather than an even spatial distribution. Widow rockfish, however, were found in 33% of the samples (Table 2), and we detected quite clear depth related patterns for less frequently encountered species. Thus, juvenile widow rockfish appeared, on average, to be more evenly distributed by depth and latitude than juveniles of a number of other species.

Juvenile lingcod were restricted to inshore areas, having highest abundances inside the 55 meter bottom contour, and were most abundant in the Gulf of the Farallones (Fig. 69). The analysis of depth and latitude effects showed that abundance was extremely low except at depths shallower than 180 meters (Fig. 70). Abundance was lowest (within depth categories) in the mid-latitude portion of the study region (Fig. 70). It was not possible to test for effects of areas, but Figs. 69 and 70 suggested low abundances in all EPA study areas, with area 2 being the only one with reasonable probability of occasionally producing positive catches.

Juvenile Dover sole were generally scarce, with pockets of abundance offshore of Pt. Reyes and fairly inshore in the vicinity of area 2 (Fig. 71). Outside the region near area 3, few juvenile Dover sole were captured over bottom depths of less than 180 meters as was indicated by the LSM's, but otherwise there was essentially no relationship with depth or latitude (Fig. 72). There was a nearly significant effect of EPA study area ($p=0.051$), suggesting higher abundances at area 2 (Fig. 73). This results from atypically high abundances in the vicinity of this area, rather than some more general effect of bottom depth or latitude; note that abundance at area 3 was nominally lower than any of the other areas.

Juvenile rex sole tended to be most abundant offshore of the 900 meter isobath, toward the central part of the study region, and along the southern edge as indicated on the contour map (Fig. 74). The analysis of depth and latitude effects indicated a general increase in abundance with increasing bottom depth, but in the north abundance fell off substantially for the deepest depth category (Fig. 75). Abundance tended to be lower in the north, but did not differ between mid-latitude and southern categories in a consistent way for all depth categories. There was a significant effect of EPA study area, with the highest abundance being found at area 5. Abundance seemed to be higher at area 3 than at areas 2 or 4.

For speckled and Pacific sanddabs we used data from 1989-1991 only, because (a) the consistency with which these species were distinguished increased over time, and (b) speckled sanddabs (which are translucent) were often missed in sorting samples from earlier years. Speckled sanddabs were apparently most abundant in the central portion of the study region offshore of area 2 and near the inshore portion of area 3 (Fig. 76), and Pacific sanddab showed a similar pattern (Fig. 77). The ANOVA by depth and latitude category could not be done for these species because of missing depth x latitude combinations.

Myctophids are known to be an offshore group, and this is apparent in the contour map (Fig. 78). The analysis by depth and latitude indicated that abundance increased with depth (Fig. 79). Looking across depth categories, the within-a-depth ordering of abundance among latitude categories was not consistent (Fig. 79). There was significant variation among areas, with abundance at EPA study area 2 being less than at the other areas (Fig. 80).

Like total myctophids, California headlight fish were generally more abundant offshore, as is indicated in the contour map (Fig. 81). There was a general pattern of increasing abundance with depth, with consistently low abundance in the shallowest depth category (Fig. 82). The only consistent effect of latitude across depth categories seemed to be generally lower abundances in the north. There was significant variation among EPA study areas, and like total myctophids, abundance was lower at area 2 than at other areas (Fig. 80).

The contour plot for blue lanternfish suggested an area of higher abundance in the center of the study region in the vicinity of area 3, and another very high area of abundance to the south and offshore (Fig. 83). This latter result was not an artifact caused by extrapolation; several extremely large catches were made in that region. Abundance was consistently lower in the shallowest depth category, and variable (among latitude categories) in deeper water (Fig. 84). The intermediate latitudes had highest abundances for the middle two depth categories, and the southern area had very high abundance for the deepest category, as we might expect from the contour map. Although there was a significant effect of area, no EPA study area appeared very different than the others (Fig. 85). The lower mean for area 4 is accompanied by a wide confidence interval. We suspect, based on the depth analysis, that the abundance of this species was low at area 2, and that this did not show up because the contouring procedure extrapolated from nearby but deeper areas.

Northern lampfish showed a very clear trend toward higher abundances offshore (Fig. 86) and in deeper water (Fig. 87), with little variation in abundance with latitude. There was a significant effect of EPA study area, with the lowest abundance at area 2 and the highest abundance at area 5 (Fig. 85).

For octopus, the contour plot suggested higher abundances between the 180 and 1800 meter isobaths, with pockets of higher abundance in the center of the study region and generally higher abundances to the south (Fig. 88). Analysis by depth and latitude categories also indicated that abundances were highest between 180 and 1800 meters of bottom depth, and there was a tendency for abundance to decrease from south to north (Fig. 89).

Market squid appeared to be more abundant inshore of the 180 isobath, especially in the southern portion of the study region (Fig. 90). The analysis by depth and latitude indicated higher abundances in shallower water, and this effect was most extreme in the south (Fig. 91).

In contrast with market squid, other squid were most abundant offshore, although the contour map indicated some patches of lower abundance in the offshore region (Fig. 92). There was a clear pattern of increasing abundance with depth, although the degree to which this increase occurred varied somewhat irregularly among the latitude categories, with the extent of the increase being greatest in the north (Fig. 93).

Siphonophores appeared to have a fairly irregular spatial distribution with areas of low and high abundance appearing over a range of latitudes, and both inshore and offshore (Fig. 94). The irregular distribution was apparent in the analysis of depth and latitude. In the north, abundance was consistently high, except in the deepest category where it fell sharply. In the south, there appears to be a gradual increase in abundance with increasing depth. In the intermediate latitude category, abundance was lowest in shallow water and highest in the next-to-shallowest depth category. There was significant variation among EPA study areas, with siphonophores appearing most abundant at area 4 (Fig. 96).

Jellyfish were generally more abundant near to shore (Fig. 97). Jellyfish were more abundant in shallow water, and the extent of this depth effect appeared to be greatest in the south (Fig. 98). We believe that the abundance of jellyfish in the southern part of the study region was underestimated. On a number of occasions, so many jellyfish were captured that the tow had to be aborted because the net could not be brought aboard ship. We found no significant variation among study areas ($p=0.08$) and roughly equal abundances at the different areas (Fig. 96).

Ctenophores were present in 63% of the samples (Table 2) with Pleurobrachia being the dominant taxa. The different interpolation methods produced different patterns and there were no significant effects of depth or latitude.

We present no contour map for salps (thaliacians) because the two interpolation methods produced markedly different spatial patterns. There was, however, a marked pattern of increasing abundance with increasing bottom depth (Fig. 99).

The contour map for euphausiids showed no marked patterns of inshore-offshore or latitudinal distribution (Fig. 100). There were areas of high abundance offshore both to the north and south, but also a band of higher abundances fairly inshore. There was no significant variation with either bottom depth or latitude.

Rex sole were caught at depths of 180 to 370 meters, with peak catches in biomass and numbers being made at the shallowest depth (Fig. 101, top panel).

Dover sole were caught in quite variable numbers between 180 and 1100 meters. Off Half Moon Bay peak numbers were caught in three trawls at depths of 180 to 370 meters, while the peak catch off Pt. Ano Nuevo was at a depth of about 900 meters (Fig. 101, bottom panel). High counts and low biomass sometimes occurred in shallower water because the Dover sole caught there tended to be relatively small.

Peak biomass of thornyhead (shortspine and longspine) was caught at depths of 700 to 900 meters (Fig 102). A very high number of shortspine thornyhead were caught in a trawl at about 370 meters; otherwise numbers followed the same pattern seen for biomass. Almost no longspine thornyhead were caught at 550 meters or shallower, while substantial numbers of shortspines were caught at bottom depths of 200 to 550 meters.

Eelpouts were caught from 370 to nearly 1300 meters, but the highest catches both in biomass and numbers were made at depths of 550 meters and shallower (Fig. 103, top panel).

Substantial numbers and biomass of Pacific hake were caught at depths of 180 to 370 meters, with almost no fish caught at deeper depths (Fig. 103, bottom panel). Substantially more fish were caught off Half Moon Bay than off Pt. Ano Nuevo.

Grenadier were not caught at depths less than 700 meters (Fig. 104). Giant grenadier were caught in increasing numbers and biomass up to nearly 1300 meters, the maximum depth sampled. A similar pattern is seen for Pacific grenadier, except that few fish were caught in the 1281 meter trawl off Pt. Ano Nuevo.

Blacktail snailfish were caught in peak numbers and biomass at about 700 meters. Few fish were caught below 550 meters or at depths exceeding about 900 meters (Fig. 105, top panel).

Few Pacific flatnose were caught in water shallower than about 900 meters and catches tended to be highest at the deepest sampling stations (Fig. 105, bottom panel).

Sablefish were caught over the entire depth range sampled, but the results were quite variable. High catches in numbers and biomass were made at 180 meters, but high catches in biomass (but not in numbers) were made at bottom depths of 1100 meters and deeper (Fig. 106, top panel). These results probably reflect, in part, the tendency for sablefish at shallower depths to be smaller than sablefish at deeper depths.

Few California slickhead were caught in water shallower than 700 meters, and catches peaked between 730 and 1100 meters (Fig. 106, bottom panel). Biomass did not fall off as much as numbers at the deepest depth sampled (near 1300 meters).

Substantial numbers and biomass of fish identified as Bering skate were collected at depths of 100 to 550 meters, with few individuals of this species caught at deeper depths (Fig 107, top panel). (These fish may be the same species as sandpaper skate [Raja kincaiddii]; see Literature Review below.)

While cat sharks were captured at all depths sampled, they showed a distinct peak in numbers and biomass caught at 550 meters (Fig. 107, bottom panel). Relatively few cat sharks were caught at 370 meters or shallower, or beyond about 700 meters.

Tanner crab were generally most abundant both in numbers and biomass for depths ranging from about 550 to about 900 meters, with very few caught in substantially shallower or deeper waters.

Triennial Bottom Trawl Survey

In at least 23 of 28 cases the statistical analyses (ANOVA) provided reasonable evidence that some of the variation in abundance was related to depth and/or latitude: for only five groups were the p-values for main effects (latitude and depth) and the interaction of main effects (either for biomass or counts) all above 0.1 (Table 7). In 22 (of 28) cases we found significant ($p<0.05$) depth effects for either counts or biomass, and in nine cases we found significant latitudinal effects for either counts or biomass. For only three species/groups did we include a depth-by-latitude interaction in the model ($p<0.1$), and in each of these cases the effect was significant for both counts and biomass.

Spiny dogfish generally tended to be more abundant in shallower water, although the effect of depth was not significant, and were more abundant toward the northern portion of the study region (Fig. 109). Pacific electric rays tended to be more abundant in shallower water, but were relatively scarce in the north (Fig. 110).

Flatfish showed a range of different depth and latitudinal patterns. Pacific sanddabs were much more abundant in the shallowest depth category, and showed little variation with latitude (Fig 111). Slender sole were most abundant in the deepest depth category sampled and were somewhat more abundant in the north than in other latitude categories (Fig. 112). Like Pacific sanddabs, petrale sole were more abundant in shallow water and showed little variation with latitude (Fig. 113). Dover sole showed higher abundances in the deeper two depth categories, and somewhat higher abundance in the intermediate latitude category (Fig. 114). Curlfin sole tended to be more abundant in shallow water and in the north (Fig. 115), but the effect of depth was not significant. English sole was the only flatfish to show a depth-by-latitude interaction. While they were generally most abundant in shallow water and scarcest in the deepest depth category, in the south they were slightly more abundant in the mid-depth category than in shallow water (Fig. 116), and this contributed to the statistical interaction. Rex sole occurred in 87% of the samples, but since there was no significant effect of depth or latitude no figure is presented.

Numbers of sablefish were about equal in the two deeper depth categories, and were less abundant in shallow water (Fig. 117); biomass appeared to be somewhat higher in the deepest depth category than at intermediate depths. Sablefish appeared to be somewhat more abundant in the central part of the study region (Fig. 117).

A taxonomically diverse group of fishes had higher abundances nearshore. Plainfin midshipman were markedly more abundant in the shallowest depth category and showed little variation with latitude (Fig. 118). Like midshipman, American shad are much more abundant in shallow water, but did show higher abundances to the north (Fig. 119). Results for pink seaperch were similar to those for American shad, but pink seaperch showed a steady increase in abundance to the north (Fig. 120). Lingcod were most abundant in the shallower two depth categories and much more abundant to the north than at other latitudes (Fig. 121). White croaker were much more abundant in the shallowest depth category than in deeper water, and there was some suggestion of declining abundance from south to north

(Fig. 122). Pacific pompano were also most abundant in shallow water, but had higher abundances at intermediate latitudes (Fig. 123).

As a group, rockfish had their peak abundance at intermediate depths, and there is a suggestion of slightly lower abundances in the north (Fig. 124). There was, however, substantial variation in the patterns exhibited by individual species. Greenstriped rockfish were most abundant in the shallowest two depth categories and were less abundant to the north (Fig. 125). Chilipepper were most abundant at intermediate depths, and their abundance fell off some to the north (Fig. 126). Shortbelly rockfish showed a similar pattern to that seen for chilipepper (Fig. 127). Stripetail rockfish were most abundant at intermediate depths and showed little variation with latitude (Fig. 128). Among the rockfish, bocaccio was the only one to show a depth-by-latitude interaction. While they were generally more abundant at intermediate depths, the extent of the drop off in abundance from the intermediate to the deepest depth category was greatest in the south and least in the north (Fig. 129).

Spotted ratfish had a depth-by-latitude interaction, because in the north they were common in deep water, but they were relatively scarce in deep water at intermediate latitudes (Fig. 130).

We analyzed data for two other species of fish: Pacific herring and Pacific hake. Like rex sole, Pacific hake were found in many samples (76%), but we detected no significant effects of depth or latitude. Pacific herring were the least frequently encountered species we analyzed for the triennial survey (22%), and we could detect no pattern related to depth or latitude.

Market squid were generally most abundant in water shallower than 180 meters, and to the south (Fig. 131). Counts increased, while biomass did not change between the intermediate and deepest depth categories, presumably because the market squid captured in deep water tended to be smaller. Counts decreased, but biomass did not change between the south and the intermediate latitude categories, presumably because larger squid occurred in the intermediate latitudes.

Sablefish Trap Surveys

Numbers of sablefish caught varied significantly among depths ($p < 0.05$), showing a trend toward lower numbers at deeper depths (Fig. 132). The biomass caught did not vary significantly among depths, and the estimated least-squares mean was actually higher at the deepest depth than at intermediate depths. The different patterns shown by biomass and numbers probably reflected a tendency for smaller sablefish to be found at shallower depths.

Positive Catches of Shortbelly Rockfish and Pacific Hake

Figures 133 and 134 indicate the locations of hauls that caught one or more shortbelly or Pacific hake. As explained in the methods almost all these hauls were done on hydroacoustic targets, not at fixed locations and almost all hauls done on targets yielded fish. However, not all targets were trawled, and essentially no areas without targets were sampled. Consequently, Figures 133 and 134 only provide some general qualitative information on where these species are known to be found. Locations without positive catches could simply mean no trawling was done there, or it could mean that targets were not seen there.

Positive catches of shortbelly rockfish in the combined RACE (hydroacoustic survey tows, mainly midwater tows) and Tiburon laboratory data (mainly midwater tows) indicated that successful catches have mainly been confined to the area near the 180 m isobath (Fig. 133). Few tows have been done in very shallow water so we cannot rule out the possibility that substantial concentrations sometimes occur in shallower water. We can be fairly sure that if substantial hydroacoustic targets had been seen in deeper water some trawling would have been done on them.

Positive catches of Pacific hake (from midwater trawls of the triennial survey for Pacific hake) were spread more widely in the onshore-offshore direction, being found throughout the area that was commonly surveyed (Fig. 134).

Life-history summaries for selected species and groups

Catsharks

Catsharks, family Scyliorhinidae, are a common member of the deepwater community. Several species are found in the waters off California. They reach a length of nearly one meter and are reported to inhabit depths from 150 to 650 meters (Miller and Lea 1972). They are found over both hard and soft substrates. There is no commercial or sport fishery for this group. Preliminary studies suggest they spawn year round (Cross 1988), and eggs hatch within one year. Juveniles are found in the water column within 200 - 300 meters of the bottom along the continental slope. The diet of adults consists primarily of crustaceans, myctophids, and molluscs. Little else is known about this group.

Spiny Dogfish

Spiny dogfish, Squalus acanthias, are a common shark species in the nearshore and estuarine environment. In the eastern Pacific they are found from Baja California to Alaska in depths from the surface to 400 meters (Miller and Lea 1972). This species reaches a maximum length of approximately 2 meters. In California, a small quantity of spiny dogfish are caught both commercially and recreationally.

Spiny dogfish are viviparous with a gestation period of approximately 2 years (Hart 1973). Young sharks may feed on plankton, while older fish tend to feed on a large variety of prey including both fish and invertebrates. Adults are often encountered in large schools. Studies of the migration of spiny dogfish in California have shown that some schools remain in the same area, while others will make somewhat random movements, and still other schools will make extended seasonal migrations (Hart 1973).

Bering Skate

There is virtually no information on the life history of the Bering skate, Bathyraja interrupta. Most of the problem seems to be that the taxonomy is very confused. The best evidence suggests that the Bering skate is the same species as the sandpaper skate, Raja kincaiddii (Smith and Allen 1988). If this is the case, then the range for this species is southern California to Alaska in depths of 60 to 1500 meters. The maximum length is believed to be approximately 80 cm. No other data are available for this species.

Northern Anchovy

Northern anchovy, Engraulis mordax, are a commercially important species in California waters. They have a geographic range from Baja California to Canada (Miller and Lea 1972). They reach a maximum length of approximately 20 cm. In 1990, approximately 3,500 tons were landed in California.

Spawning occurs both offshore and in inlets and estuaries in the upper water column (Hart 1973). Anchovy spawn more than once during the year. Fertilization is external. The pelagic eggs are typically found in the top 50 meters of the water column and hatch within 4 days (Ahlstrom 1959). Larvae are typically found in the upper water column and are most abundant near the edge of the continental shelf (Richardson and Pearcy 1977). Adults are found offshore in the winter and move inshore during the summer. Anchovy tend to be found on the bottom during the day and move up into the water column at night. Anchovies feed on euphausiids, copepods and decapod larvae (Hart 1973).

Pacific Herring

Pacific herring, Clupea pallasii (=harengus), supports one of the most lucrative fisheries in California. In 1990, 7,400 tons were landed by commercial fishermen and there was also a small sport fishery for this species. Pacific herring have a range from Baja California to the Arctic, typically in shallow nearshore areas (Miller and Lea 1972).

In California, spawning typically occurs from December through March (Lassuy 1989). Spawning occurs in shallow nearshore areas, particularly in estuaries. The sticky eggs are laid on the bottom where they adhere to the substrate until they hatch after approximately 10 days. The juveniles typically leave the shallower areas where they were spawned after approximately 3 months. While most herring still remain nearshore, schools occasionally will move offshore during the summer, and feed on a variety of plankton, including euphausiids.

Myctophids

Myctophids, family Myctophidae, are an extremely abundant and diverse group of fishes found in all oceans. This species has been studied extensively in some areas, but little information is available for the west coast of the United States. They are classified as mesopelagic, can be found in up to 5,000 meters of water, and reach a maximum length of approximately 20 cm (Miller and Lea 1972).

Little is known about reproduction for myctophids off the west coast of the United States. Larvae are typically found in the upper mixed layer above the thermocline (Ahlstrom 1959). Typically larvae are found offshore beyond the edge of the continental shelf and are abundant from December through May (Ahlstrom 1972), suggesting a prolonged spawning period. Myctophids feed on euphausiids, and copepods (Hart 1973). Myctophids are a food source for albacore, salmon, and rockfish (Hart 1973).

Popeye Blacksmelt

Popeye blacksmelt, Bathylagus ochotensis, are found from Baja California to the Bering sea in depths of 50 to 1,000 meters (Miller and Lea 1972). There is no commercial fishery for this species. Another common name for this species is the eared blacksmelt (Hart 1973). This species is bathypelagic and reaches a maximum length of approximately 19 cm (Miller and Lea 1972). Richardson and Pearcy (1977) found the larvae of popeye blacksmelt to be most abundant offshore near the shelf break from March through August. This suggests a protracted spawning season, but little is known about reproduction and feeding for this species. It is likely that this species is a food item for several species, but this has not been confirmed.

California Smoothtongue

California smoothtongue, Leuroglossus stilbius, are found from South America to the Bering sea from the surface down to 750 meters in the water column (Miller and Lea 1972). They reach a maximum length of approximately 15 cm. Another common name for this species is the northern smoothtongue (Hart 1973). There is no commercial fishery for this species. This species is one of the most abundant midwater species in California waters (Cailliet and Ebeling 1990).

Little is known about the reproduction of this species; however, larvae are abundant near the shelf break from January through June (Richardson and Pearcy 1977) suggesting a protracted spawning period. Larvae are most abundant in the upper 20 meters of the water column (Ahlstrom 1959). Adults feed on euphausiids, copepods, larvaceans, and salps (Cailliet and Ebeling 1990). Smoothtongues are prey for Pacific herring, eulachons, and salmon (Hart 1973).

Blacktail Snailfish

The blacktail snailfish, Careproctus melanurus, is common from San Diego, California to Canada, and is reported to inhabit depths of 100 to 1,800 meters (Miller and Lea 1972). Their maximum length is approximately 30 cm. Taxonomic studies have indicated that four different species may be commonly identified as blacktailed snailfish (Smith and Allen 1988). Adults are benthic and prefer soft muddy substrates where they are known to feed on polychaetes, crustaceans, and small molluscs (Fitch and Lavenburg 1968).

Little is known about the reproduction of this species, however larvae are most abundant in nearshore waters on the shelf (Richardson and Pearcy 1977). This species is of minor importance as prey for Pacific hake and rockfish (Fitch and Lavenberg 1968).

Eelpouts

Eelpouts, family Zooarcidae, are a speciose midwater and epibenthic group found in all oceans. There is no commercial fishery for any of the eelpouts caught off the west coast of the United States. The twoline eelpout (Bothrocara brunneum) is abundant from Southern California to Alaska to depths of 1800 meters (Miller and Lea 1972). The maximum length is approximately 70 cm. Typically they are found on sandy mud substrates where they feed on a large variety of foods, including dead animals (Fitch and Lavenberg 1968). Nothing is known about the reproduction of eelpouts on the west coast of the U.S.

California Slickhead

The California slickhead, Alepocephalus tenebrosus, is found throughout the eastern Pacific (Miller and Lea 1972). It is found in depths from 50 to 6,000 meters and reaches a maximum length of 60 cm. There is no commercial fishery for this species. This species is primarily benthic although juveniles are often caught in the midwater (Fitch and Lavenberg 1968). Small crustaceans are the primary food for this species. It is not likely that this species is an important prey item for any species (Fitch and Lavenberg 1968).

Pacific Flatnose

The Pacific flatnose, Antimora microlepis, is also known as the finescale codling (Miller and Lea 1972) and the flatnose codling (Fithch and Lavenberg 1968). They are found throughout the world in 400 to 3,500 meters. They reach at least 67 cm in total length. There is no commercial fishery for this species. The species is classified as benthic and probably feeds on molluscs and crustaceans (Fitch and Lavenberg 1968). Nothing is known about their reproduction but sexes are known to segregate in different areas (Iwamoto 1975).

Grenadiers and Rattails

Grenadiers, family Macrouridae, are among the most diverse and numerous of all fishes in the ocean. They are found in nearly all ocean waters to depths in excess of 2000 meters (Phleger 1971). In many parts of the world they are commercially valuable; however, on the west coast of the United States very few are caught commercially due to the difficulties associated with deepwater trawling and to a lack of market demand. With the declines in the Alaskan fisheries for pollock, there is a potential for development of a commercial fishery, most likely concentrated on the Pacific grenadier (Coryphaenoides acrolepis) off California (Matsui et al. 1990).

Most of the biological knowledge about this group is based on data from other areas where they are commercially valuable. Spawning is thought to occur from February through May. Fertilization is external for this group. The eggs and larvae are found in the water column below 200 meters typically off the continental shelf. For some species including the Pacific grenadier, juveniles have been found near the surface until they reach a length of about 8 cm, at which time they move down to the bottom (Matsui et al. 1990). Grenadiers feed on pelagic crustaceans, squid, fish, and dead animals (Pearcy and Ambler 1974).

Pacific Hake

Pacific hake, Merluccius productus, also called Pacific whiting, is the single most important commercial groundfish in landings on the west coast of the United States and Canada. In 1990, 184,000 tons were landed in the U.S. (PFMC 1991), with more than 6,000 tons landed in California. There is no sport fishery for this species and much of the product is exported. Pacific hake are found from the surface to depths of 1000 meters. Geographically, they are found from Baja California to Alaska (Miller and Lea 1972). They reach a maximum length of 1 meter. One important characteristic of this species is their extensive annual migrations (Bailey et al. 1982). In the fall most adults migrate south to spawning grounds in southern California and Baja California. During the spring, they migrate northward to Washington and British Columbia. Juveniles do not migrate and spend their first year of life off central and northern California.

Peak spawning occurs from January to February in the midwater, at depths of 150 - 500 m over the continental slope (Bailey et al. 1982). Eggs hatch in 4 - 6 days. The eggs are found at depths of 40 - 60 m in the water column. Juveniles move inshore to depths of less than 400 m for the first year of life. Adults feed on euphausiids, shrimp, herring and juvenile Pacific hake. Juveniles feed on copepods and euphausiids. Pacific hake are an important part of the diet of sea lions, sharks, rockfish, and lingcod.

Sablefish

Sablefish, Anoplopoma fimbria, are an important commercial species on the west coast. In 1989, more than 3,700 tons were landed in California. Sablefish occur from Baja

California to the Bering sea and to Japan. They are reported to inhabit depths to 1,800 meters (Miller and Lea 1972), but commercial fisheries rarely exist deeper than 1,000 meters. Most of the commercial fishery for sablefish is located north of Fort Bragg, California (PFMC 1990). They reach a maximum length of approximately 1 meter. Studies in Monterey Bay indicate that larger fish are found deeper (Cailliet et al. 1988).

Spawning occurs at depths greater than 300 meters (McFarlane and Beamish 1983). Peak spawning occurs from January through March. Fertilization is external and the eggs are bathypelagic and are most abundant below 400 meters (Mason et al 1983). Some larvae ascend to the surface, but most are deeper than 400 meters. Larvae develop to the juvenile stage within several weeks (Mason et al. 1983). Juveniles can often be found at or near the surface. Young fish feed on pelagic fish and cephalopods while adults tend to feed on demersal fish and crustaceans (Cailliet et al. 1988).

Lingcod

Lingcod, Ophiodon elongatus, is an important sport and commercial fish which occurs from Baja California to Alaska, and is reported from depths of 3 to 400 meters (Miller and Lea 1972). They reach a maximum length of 150 cm. Most of the commercial fishery is located to the north of California, but it is an important sportfish in California. In 1990, approximately 1,200 tons were landed by the commercial fishery in California, and sport landings have typically been about half the magnitude of commercial landings. This species is demersal and tends to be found in rocky substrates (Adams 1992).

Peak spawning occurs in January and February. Eggs are laid in a nest on the bottom in shallow nearshore areas (less than 30 meters deep) (Adams 1992). The eggs hatch within 7 weeks. Larvae and juveniles are pelagic until the end of June when they become benthic. Larval fish feed primarily on copepods. Adults feed on rockfish, Pacific hake, and Pacific herring.

Thornyheads

The longspine thornyhead, Sebastolobus altivelis, is found from Baja California to the Aleutian Islands and has been reported from depths of 370 to 1,600 meters (Miller and Lea 1972). They reach a maximum length of approximately 40 cm. The shortspine thornyhead, Sebastolobus alascanus, has a similar geographic distribution but is found in somewhat shallower water as well (Miller and Lea 1972). Maximum length of the shortspine thornyhead is approximately 75 cm. Both species are classified as bathybenthal (Miller and Lea 1972). In recent years, thornyheads (both longspine and shortspine) have become important commercial species with landings in California of approximately 6,300 tons in 1990 (PFMC 1991), and approximately 2/3 of the landings are shortspine thornyhead. Most of the fishery occurs from central California to northern Oregon. Together with Dover sole and sablefish, the thornyheads make up the deepwater complex, a group of fishes regulated by the Pacific Fisheries Management Council (PFMC).

These species are oviparous. Spawning probably occurs from January through May in most years (Moser 1974). The eggs float near the surface in masses of various sizes and shapes (Hart 1973). The eggs hatch after more than 10 days and the larvae are found near the surface (Richardson and Pearcy 1977). The larvae are most abundant offshore near the continental shelf break. Larvae and juveniles are undoubtedly eaten by numerous species of fish.

Rockfish

Rockfish, Sebastes, comprise a speciose genus (approximately 55 species in California). Rockfish are important in both commercial and sport fisheries. In 1990, an estimated 13,500 tons of rockfish were landed in California (NMFS unpublished data). In California, 38 species of rockfish are caught commercially, with approximately 15 of those making up more than 95% of the rockfish landings. All of the economically important species are found shallower than 600 meters and most commercial fishing takes place in less than 300 meters of water. Most sportfishing occurs in less than 150 meters of water. Shortbelly rockfish (S. jordani) are the most abundant rockfish species with an estimated biomass of more than 200,000 metric tons between the Farallon Islands, California and Santa Cruz, California (Pearson et al. 1991). This species has experienced only limited commercial fishing to date, but there is some potential for a valuable fishery to develop. Most species are found over rocky or hard substrate; however, some species, such as shortbelly rockfish, are more common over soft substrates. Most species of rockfish are benthic, but many species move up into the water column to feed; including widow rockfish, S. entomelas), yellowtail rockfish, S. flavidus, and shortbelly rockfish.

Rockfish are viviparous and many species are capable of spawning more than once during the year including bocaccio, S. paucispinis (Wyllie Echeverria 1987). Two general patterns of seasonal spawning are known: winter (November-March) and spring (April-July). Winter spawners include: widow rockfish, chilipepper rockfish, S. goodei, and canary rockfish, S. pinniger. Spring spawners include: brown rockfish, S. auriculatus, splitnose rockfish, S. diploproa, and greenspotted rockfish, S. chlorostictus (Wyllie Echeverria 1987). Larval rockfish tend to be found mostly in the mixed upper layer and thermocline (Ahlstrom 1959). Juveniles are, for the most part, uniformly distributed in the top 150 meters of the water column; however, bocaccio are more abundant near the surface, and blue rockfish S. mystinus, and yellowtail rockfish tend to be found somewhat deeper in the water column (Lenarz et al. 1991). Based on the disappearance of juveniles from the midwater and their ages at that time, it can be inferred that many species of juvenile rockfish tend to settle to the bottom within 6 months of parturition (Woodbury and Ralston 1991). Juveniles feed on various types of plankton including copepods and young stages of euphausiids (Reilly et al. 1992). Adults feed on a variety of fish and invertebrates.

Plainfin Midshipman

The plainfin midshipman, Porichthys notatus, is common from Baja California to southern Alaska (Miller and Lea 1972). They are found from the intertidal zone to depths of at least 300 meters. They reach a maximum length of 38 cm. There is no commercial fishery for this species.

Spawning takes place during the spring intertidally in coastal and estuarine environments, where eggs are deposited under rocks and shells (Hart 1973). The eggs hatch within 20 days. Typically, juveniles and adults are benthic, but adults make vertical migrations at night. Food of the adults is primarily fish and crustaceans. Midshipman are eaten by birds and other fish, but it is not known how important they are to diet of any given species.

Medusafish

The medusafish, Icichthys lockingtoni, are common from Baja California to Alaska in depths from the surface down to about 100 meters (Miller and Lea 1972). They reach a maximum length of approximately 40 cm. There is no commercial or sportfishery for this species. This species is typically commensal with jellyfish, and they are thought to be immune to the poison of their host (Hart 1973).

Little is known about reproduction in this species. Richardson and Pearcy (1977) found larvae were most abundant offshore near the continental shelf break. Juveniles are abundant year round (Fitch and Lavenberg 1968), suggesting spawning occurs year round. Food of adults and juveniles probably consists of "crumbs" from their jellyfish hosts, but they are also known to consume parts of their hosts (Fitch and Lavenberg 1968).

Dover sole

Dover sole, Microstomus pacificus, is the most important flatfish in west coast groundfish landings. In 1990, there were nearly 7,000 tons landed in California. Dover sole range from Baja California to the Bering sea in depths of 30 to 1000 m on soft muddy substrates (Miller and Lea 1972). Commercial fisheries for Dover sole exist throughout most of its range, however most commercial fishing is done in depths less than 800 m due to the high water content of the flesh associated with increased depth of capture.

Dover sole spawn from November through March in deep water (Allen and Mearns 1976). After hatching, the planktonic larvae remain in the upper 50 meters of the water column for as long as a year before metamorphosing to juveniles (Pearcy et al. 1977). Benthic juveniles are most often found inshore of the 200 meter isobath (Hart 1973). Adults feed on polychaetes, ophiuroids, and molluscs (Gabriel and Pearcy 1981). Larvae are an important component in the diet of albacore, while the chief predator on adults and benthic juveniles are sharks of various species (Allen and Mearns 1976).

Sanddabs

Two common species of sanddabs are found in the central California area; the speckled sanddab (Citharichthys stigmaeus), and the Pacific sanddab (Citharichthys sordidus). The speckled sanddab is one of the most abundant flatfish species at bottom depths less than 40 meters, although it can be found at depths from 3 meters to 365 meters (Kramer 1990, Miller and Lea 1976). It ranges from Montague Island, Alaska to Magdalena Bay, Baja California and is most abundant off the coast of central California (Kramer 1990, Rackowski and Pikitch 1989). The Pacific sanddab ranges from the Bering Sea to Cabo San Lucas at the tip of Baja California (Miller and Lea 1976). It is most abundant off the central California coast from Eureka to San Francisco (Rackowski and Pikitch 1989). The depth range of the Pacific sanddab is from 9 to greater than 500 meters, but it is found in greatest abundance between 35 and 95 meters (Miller and Lea 1976, Rackowski and Pikitch

1989). Speckled sanddabs reach a maximum length of 17 cm (Ford 1965, Rackowski and Pikitch 1989), and spawning usually commences after the second year (Feder et al. 1974). The Pacific sanddab reaches a maximum length of approximately 40 cm. Females become mature at 3 years of age and can reach spawning condition by 17 to 18 cm in length (Arora 1951). Because of its larger size, a commercial fishery has developed for the Pacific sanddab. In 1990, approximately 700 tons were landed in California, with most being landed in Eureka.

Pacific sanddabs have a predominantly summer spawning season (Arora 1951) and speckled sanddabs have an extended spawning season from March through October (Ford 1965, Goldberg and Pham 1987). Multiple spawning within a year is a possibility for both species (Arora 1951, Ford 1965, Pham 1987). Larvae of both species hatch in the plankton at about 2 mm in length and metamorphosis occurs at lengths between 2 and 4 cm (Ahlstrom et al. 1984).

Rex Sole

Rex sole, Glyptocephalus zachirus, is a commercially valuable species, ranging from San Diego, California to the Bering sea in depths from 20 to 700 meters (Miller and Lea 1972). The maximum length for this species is approximately 60 cm. Landings for rex sole in California in 1990 were in excess of 600 tons (PacFIN data).

Based on the timing of larval abundance, peak spawning probably occurs between January and March (Richardson and Pearcy 1977). The pelagic larval stage is protracted and may last for as long as one year (Pearcy et al. 1977). The larvae are typically found offshore near the edge of the continental slope and are most commonly found in the top 30 meters of the water column (Pearcy et al. 1977). Juveniles are most often found on the bottom in the 60 to 140 meter depth range (Demory 1971). Adults favor sandy silt substrate where they feed primarily on amphipods and polychaetes (Kravitz et al. 1977).

Slender Sole

Slender sole, Lyopsetta exilis, is a common flatfish on the continental shelf and slope. This species has a range from Baja California to Alaska in depths from 25 to 600 meters (Miller and Lea 1972). Its small size (maximum length approximately 35 cm) preclude it from being an important part of commercial landings. Based on time of peak larval abundance (March through August) it is suspected that peak spawning occurs between January and April (Richardson and Pearcy 1977). Larvae are most commonly collected near the edge of the continental shelf in the upper 30 meters of the water column (Richardson and Pearcy 1977, Boehlert et al. 1985). Young fish are found commonly on the bottom in 100 - 180 meters of water. Adults typically are found on soft mud substrate where they feed on pelagic crustaceans; including euphausiids, shrimp, and amphipods (Pearcy and Hancock 1978).

Petrale sole

Petrale sole, Eopsetta jordani, is a common inhabitant of the continental shelf off California. Petrale sole are found from Baja California to Alaska in depths of 20 to 400 meters (Miller and Lea 1972). In 1990, nearly 800 tons were landed in California (PFMC 1991). Typically, petrale sole are caught in conjunction with a variety of other species.

They command a higher price than other flatfish, and thus are considered a valuable resource. Few petrale sole are taken by sport fishermen.

Petrale sole spawn in 300 to 400 meters of water during the winter and move inshore during the spring and summer (Frey 1972). The pelagic eggs hatch in approximately 9 days. There is evidence that the juveniles are most abundant inshore in less than 60 meters of water (Hart 1973), which would indicate that the larvae are advected toward shore prior to metamorphosis. Petrale sole are active predators and feed on a variety of prey including shrimp, herring, and euphausiids.

English sole

English sole, Parophrys vetulus, is a common flatfish on the continental shelf. This species has a range from Baja California to northwest Alaska in depths of 1 to 900 meters (Miller and Lea 1972). It is an important part of the commercial groundfish landings in California, where it is typically the second most abundant flatfish (Pearson and Owen 1992). In 1990, nearly 1,000 tons were landed in California, with most of the landings occurring in the Eureka and San Francisco areas. There is no sport fishery for this species.

Adults are most often found on sandy substrates in depths of 40 to 300 meters where they feed on a variety of benthic invertebrates (Pearson and Owen 1992). Spawning occurs typically from December through February in depths of 70 to 90 meters. The eggs float near the surface and hatch within 2 weeks. The larvae typically are found in the middle of the water column until they undergo metamorphosis after 6 to 10 weeks. While they are in the midwater, currents transport them towards the coast. After metamorphosis, the benthic juveniles are found in shallow nearshore areas and particularly in estuaries. There is some evidence that estuaries are the favored habitat. At between 9 to 12 months, the juveniles migrate into deeper ocean waters.

Euphausiids

Euphausiids, also known as krill, are an important component of the food chain along the California coast. This group serves as a primary food source for many animals; including baleen whales, birds, fish of numerous important species, and invertebrates (squid and octopus). Euphausiids often migrate vertically. Euphausia pacifica is found between 200-400 meters below the surface during the day, and at the surface at night (Brinton 1976). Euphausiids feed on phytoplankton. This group is known to form dense swarms, which may be associated with reproduction (Smith and Adams 1988).

Squid

Squid are a valuable commercial resource in California. In 1990, a total of more than 26,000 tons were landed in California, most of which was landed in Santa Barbara. Most squid marketed in California is of the species Loligo opalescens (market squid). This species is common in the eastern Pacific ocean between Latitudes 25 and 50 degrees (Roper et al. 1984). This species most often is found in the midwater at depths of 20 - 60 meters. Spawning occurs from March through December, peaking in June (Roper et al. 1984). Eggs are deposited on the bottom to a maximum depth of 180 meters. This species feeds primarily on euphausiids (Roper et al. 1984).

Octopus

Octopus are not an important part of the commercial or sport fisheries of California (typically less than 14 tons annually). Most octopuses are benthic although they can be found high up into the water column. Eggs are laid on the bottom, typically in nests which are tended by the female (Roper et al. 1984). In some species, larval octopuses have a pelagic stage. Octopuses eat a wide variety of invertebrates and fishes (Roper et al. 1984).

Salps

Salps, subphylum Tunicata, class Thaliacea, are pelagic tunicates which are common throughout the world. There is no sport or commercial value for this group. This group exhibits complex types of reproductive strategies including both sexual and asexual reproduction depending on the species (Russel-Hunter 1969). Locomotion in this species is accomplished primarily by water being propelled through the gut cavity. Salps feed on plankton. Salps are a food source to many organisms including fish.

Tanner Crab

Tanner crabs, Chionoectes tanneri, are common inhabitants of the continental slope in depths of 450 to 2000 meters (Pereyra 1966). They are most abundant in depths of 500 to 750 meters. They are widely distributed along the coast from California to Alaska. There is no sport or directed commercial fishery for this species in California waters at this time. As commercial fishermen begin to look for new fisheries in deeper waters, it is likely that a commercial fishery will develop for this species since they are quite good to eat.

Tanner crabs probably spawn throughout the year, but there is evidence that peak spawning occurs during the winter. It is suspected that as the crabs mature, they move into somewhat shallower water (Pereyra 1966). There is no information on the early life history of Tanner crabs.

Discussion

We have analyzed a variety of different types of NMFS and CalCOFI data. None of the programs that produced these data was designed to evaluate the EPA study areas in particular and for the most part we have taken a more regional approach, evaluating general patterns with respect to distance from shore, bottom depth, and latitude. For the Tiburon Laboratory midwater trawl database we attempted to test for differences among the EPA study areas, but were able to conduct such tests for only 17 of the 37 groups we examined. We did not do tests in the other cases because different methods of interpolation led to different results. This suggests that, for many of these groups, important spatial features occurred on a scale less than the typical distance between sample locations. Nevertheless, we feel that general patterns related to bottom depth, distance from shore, and latitude provide useful information on their likely abundance in the EPA study areas.

For those species for which we did test for differences among areas (from midwater trawl data) there was general agreement with what would be expected based on broader patterns related to bottom depth, distance from shore, or latitude. Myctophids had lowest abundance at area 2, which has the shallowest bottom depth, and this group was identified as being associated with deep water. Both rex sole and Pacific argentine had higher abundance at area 5, the deepest area, as might be expected from their depth distributions. Adult Pacific hake had highest abundance at areas 2 and 3 and lower abundances in the deeper areas 4 and 5 as would be expected from their intermediate depth distribution. There were some surprising results, however. For example, juvenile Dover sole were abundant at the shallowest area 2 and juvenile blue rockfish were abundant at the deepest area 5 as well as at the shallowest area 2. The result for Dover sole is surprising because it is generally thought of as a deep water species, however, the high abundance at area 2 is actually consistent with the somewhat patchy distribution identified for pelagic juveniles and the known shallow water distribution of benthic juveniles. The high abundance at area 5 is clearly not typical of the more generally inshore distribution we saw for juvenile blue rockfish.

CalCOFI plankton data, Tiburon Laboratory midwater trawl data, and AFSC bottom trawl data were collected over a number of years. Temporal variation in the relative abundance of a group in one area relative to another contributes to the uncertainty of our estimates. This is proper, because the observed differences among areas will be used as a prediction of future conditions, and temporal variability will certainly play a role. As an example, in 1991 the Tiburon laboratory conducted an extensive ichthyoplankton survey with 120 sample locations distributed throughout the study region. It is tempting to view this as a much better dataset for evaluating the EPA study areas than the data from the eight CalCOFI stations we analyzed. This would be an error. The long-term data from CalCOFI indicate that in the winter rockfish larvae (in this area mostly shortbelly larvae) are most abundant at shallow stations and that their abundance falls off with bottom depth. Over the long term, rockfish larvae have also been about two orders of magnitude more abundant than Pacific hake larvae. If we were to base conclusions on the February 1991 Tiburon Laboratory survey alone, we might falsely conclude that high numbers of shortbelly larvae are typically found offshore, or that Pacific hake larvae are typically about as abundant as shortbelly rockfish larvae in this area. We did analyze data from a single 1987 bottom trawl survey on the continental shelf, and from a sablefish trapping survey using just two years of data. We suspect that spatial patterns of adult demersal fish are generally more static than the patterns seen in the plankton and among pelagic fish, especially the juveniles. Note, however, that some adult demersal fish are known to alter their spatial distribution seasonally and in response to other factors (e.g., oceanographic events like El Nino), so the observed distribution at one point in time may not always be representative of the typical distribution of a species.

The only data that allow us to directly evaluate seasonality are those from the CalCOFI surveys of ichthyoplankton. In the majority of cases we did not find interactions between location and seasonal effects. However, we did find some seasonal changes in spatial distribution, and an abundant and recreationally and commercially important group, the rockfish, had such an interaction. We suspect that the season by location interactions we saw for some groups of larvae are due to strong upwelling in the summer months tending to shunt larvae offshore from the shallowest stations. Similarly, Hatfield (1983) found substantial seasonality in zooplankton distributions related to current patterns and upwelling. Although we cannot evaluate seasonality for the midwater trawl data, we know that many of the juvenile fish species we analyzed are in their season of peak abundance during the May-June surveys. Although these groups may show different spatial patterns in other seasons, their overall abundance will be lower at those times. It is possible that the spatial distributions of pelagic adult fish and the invertebrates may show different patterns at other times of the year. This could come about because of strong upwelling during the summer, or be due to seasonal changes in spatial distributions associated with spawning. We cannot evaluate these possibilities based on our data. We suspect that the spatial distribution of demersal adult fish will tend to be more stable within a year than ichthyoplankton, or pelagic juveniles and adults. However, seasonal changes in spatial distribution, perhaps associated with spawning, feeding, or other factors cannot be ruled out.

One striking feature of the AFSC triennial bottom trawl results is that abundance could often be explained by bottom depth (together with latitude) in a simple way. For only three cases was there a significant interaction between bottom depth and latitude, and in 21 of 26 cases the main effect of depth was significant. In contrast we found 13 groups with significant bottom depth-by-latitude interactions for the Tiburon Laboratory midwater trawl data. For the ichthyoplankton analyses we treated individual stations as a main effect so there was no opportunity to evaluate depth by latitude interactions. It was clear, however, that there were often individual stations that did not follow an overall pattern with bottom depth. It is interesting, although perhaps not very surprising, that life-stages and groups more closely associated with the bottom environment show spatial distributions more tightly linked to bottom depth.

The AFSC triennial bottom trawls generally indicated that many of the commercially and recreationally important species as well as others of potential ecological importance were most abundant in relatively shallow bottom depths. Spiny dogfish, Pacific electric ray, petrale sole, curlfin sole, English sole, plainfin midshipman, American shad, pink seaperch, lingcod, white croaker, Pacific pompano, greenstriped rockfish, and market squid were all generally more abundant at bottom depths shallower than 183 meters (note that 183 meters = 100 fathoms). Rockfish as a whole, as well as chilipepper, shortbelly rockfish, stripedtail rockfish, and bocaccio were most abundant between 183 and 275 meters, with lower abundances in deeper and shallower water. Only slender sole and spotted ratfish were clearly more abundant in water deeper than 275 meters than in shallower water.

Although done only once, the 1987 slope survey for demersal fish extended to much deeper depths (nearly 1300 meters) than the triennial survey and indicated that a number of species had peak abundances beyond 275 meters. Many of these species were so infrequently captured in the triennial cruise that their spatial distribution was not analyzed in that case. However, only two groups/species had peak abundance at 1300 meters (the deepest depth sampled) and most groups had peak abundances at 900 meters or below. The grenadiers, which are a potentially important (but relatively unexploited) fishery resource, and Pacific flatnose both had peak abundance at near 1300 meters. Other groups with relatively high abundance in deep water were tanner crab (peak abundance 550-900 meters), thornyhead (700-900 meters), and California slickhead (700-1100 meters). Catsharks had a peak abundance in 550 meters, eelpouts at 370 to 550 meters, Bering skate at 180-550 meters, while Pacific hake and rex sole tended to be most abundant in the shallower waters that were sampled.

Dover sole and sablefish are two species that together with thornyhead form the so-called "deep-water complex", a commercially important fishery resource. The abundance of sablefish and Dover sole were evaluated in both the triennial and 1987 slope surveys, and sablefish were evaluated in a separate survey using traps. In the slope survey both sablefish and Dover sole had variable abundance and sometimes high abundance from 180 to 1100 meters. While numbers fell at the deeper depths, biomass of sablefish was highest from

1100 to 1300 meters. These results are consistent with the results from the triennial survey, where these two species were about equally abundant at depths from 180 to 275 meters and from 275 to 366 meters. The sablefish trapping survey indicates that biomass remained relatively constant from below 550 meters to deeper than 910 meters of bottom depth; numbers, however, fell a moderate amount over this depth range. Together, these results suggest that substantial resources of sablefish might occur in waters deeper than 1300 meters. The results for Dover sole suggest that abundance peaked at or before 1100 meters. Furthermore, the commercial value of Dover sole from deeper water is substantially lower because of a "jellied" condition, in which the water content of the fillets is substantially higher. As a consequence, few Dover sole are currently landed by commercial fishermen from waters exceeding 800 meters. The clear relationship with depth seen for adult Dover sole was not seen for juveniles collected by midwater trawl. At this stage, their distribution was more patchy, and they can be relatively abundant in shallow water.

Overall, larval fish were most abundant in winter and fell in abundance through fall. Most individual groups were also most abundant during the winter or spring. Notable exceptions include northern anchovy, which were abundant in all seasons but fall, and several of the myctophids, which tended to be most abundant in summer and fall. Rockfish were the most abundant group of fish larvae and they were most abundant in shallow water during the winter. Slender sole and "other flat fish" (excluding slender sole and sanddabs) larvae were also most abundant in shallow water. Most other groups had relatively low abundance in shallow water, and a number of groups had their highest abundance in deeper water. These included medusafish, popeye blacksmelt, California smoothtongue, and all the myctophids, as well as plankton volume.

For midwater trawls, we found that adult myctophids, like their larvae, were generally found in fairly deep water. We also found high abundances of blacksmelt (all species) and California smoothtongue in deep water, matching the larval distribution. Pacific hake juveniles tended to be scarce in shallow water and uniformly abundant beyond 183 meters, roughly matching their larval distribution. Adult Pacific hake (caught in midwater trawls) appear to have a more confined depth distribution, being caught in relatively few numbers beyond 1800 meters, except in the northern part of the study region. In bottom trawls few adult Pacific hake were caught deeper than 370 meters.

Juvenile rockfish, as a group, did not show the pronounced shallow water distribution seen for their larvae. While being consistently abundant in shallow water, they were also abundant in some locations in deeper water. A similar pattern was seen for the most abundant component, juvenile shortbelly rockfish. Juveniles of three other species of rockfish, brown, blue and canary rockfish, showed a decidedly shallow water distribution, and one, bocaccio, was generally more abundant in deeper water. The depth distribution of juvenile anchovy also did not match that of their larvae, being abundant in shallow water where the larvae were scarce.

Juvenile lingcod, (adult) Pacific herring, Pacific butterfish, and plainfin midshipman each showed a markedly inshore/shallow water distribution. The distribution of juvenile lingcod matched the distribution of adult lingcod from the triennial trawl data well. The distribution of midwater-trawl-caught plainfin midshipman also matched the distribution of bottom-trawl-caught midshipman.

The squids and octopus showed an interesting depth segregation. Market squid were found in greatest abundance inshore in shallow water, in sharp contrast to the offshore distribution of other squid, and the intermediate depth distribution of octopus.

The variety of different groups and life stages we evaluated showed a wide range of spatial patterns. There is no simple answer such as "fish are more abundant inshore." Some species or groups were abundant offshore, others abundant inshore, and others were abundant in particular subsets of the area. Clearly judgements based on the ecological, recreational, and commercial importance of the various species as well as on other grounds will need to be made in selecting the "best" dredge disposal area. A preponderance of the commercially and recreationally important fish caught on the bottom were most abundant in depths shallower than those of EPA study areas 4 and 5, but there were some notable exceptions, and many larval and pelagic juvenile fish were quite abundant in deep water. Zooplankton as a whole were somewhat more abundant in deeper water and a review of CalCOFI atlases and a CDF&G study (Tasto et al. 1981, Hatfield 1983) indicates a diversity of patterns with both inshore and offshore plankton species, even within a single family such the euphausiids. A review of the CalCOFI atlases does suggest that phytoplankton were generally more abundant in shallow water well off the shelf break, and this is probably generally true although the result is based on data from a single year.

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Table 1. Frequency of occurrence (percent of 464 samples), common names, and scientific names for categories analyzed from CalCOFI database.

Common Name	Scientific Name	Frequency (%)
Total fish larvae	Pisces	100
Rockfish	Sebastes sp.	87
Northern anchovy	Engraulis mordax	35
Northern lampfish	Stenobrachius leucopsarus	55
Slender sole	Lyopsetta exilis	22
Medusafish	Icichthys lockingtoni	22
Popeye blacksmelt	Bathylagus ochotensis	41
Calif. smoothtongue	Leuroglossus stilbius	32
Pacific hake	Merluccius productus	17
Sanddabs	Citharichthys sp.	38
Other flatfish	Pleuronectiformes	25
Blue lanternfish	Tarletonbeania crenularis	57
Calif. flashlightfish	Protomyctophum crockeri	24
Other myctophids	Myctophidae	27
Plankton volume	---	100

Table 2. Frequency of occurrence (percent of 526 samples), common names and scientific names for species analyzed from Tiburon midwater trawl survey for juvenile rockfish.

Common name	Scientific name	Frequency (%)
Pacific herring	Clupea harengus	10
Pacific butterfish	Peprilus simillimus	6
Plainfin midshipman	Porichthys notatus	25
Calif. smoothtongue.	Leuroglossus stilbius	14
Blacksmelt spp.	Bathylagidae	10
Pacific argentine (juv)	Argentina sialis	7
Northern anchovy (juv)	Engraulis mordax	13
Pacific hake (ad)	Merluccius productus	62
Pacific hake (juv)	Merluccius productus	60
Spiny dogfish	Squalus acanthias	17
Juvenile rockfish (total)	Sebastes sp.	76
Chilipepper (juv)	Sebastes goodei	19
Shortbelly rockfish (juv)	Sebastes jordani	58
Blue rockfish (juv)	Sebastes mystinus	27
Brown rockfish (juv)	Sebastes auriculatus	12
Canary rockfish (juv)	Sebastes pinniger	34
Bocaccio (juv)	Sebastes paucispinis	23
Yellowtail rockfish (juv)	Sebastes flavidus	27
Squarespot rockfish (juv)	Sebastes hopkinsi	16
Stripetail rockfish (juv)	Sebastes saxicola	14
Widow rockfish (juv)	Sebastes entomelas	33
Pygmy rockfish (juv)	Sebastes wilsoni	6
Lingcod (juv)	Ophiodon elongatus	11
Dover sole (juv)	Microstomus pacificus	9
Rex sole (juv)	Glyptocephalus zachirus	25
Speckled sanddab (juv)	Citharichthys stigmaeus	34
Pacific sanddab (juv)	Citharichthys sordidus	31
Total myctophids	Myctophidae	24
Calif. headlightfish	Diaphus theta	13
Blue lanternfish	Tarletonbeania crenularis	9
Northern lampfish	Stenobrachius leucopsarus	8
Octopus	Octopoda	25
Market squid	Loligo opalescens	27
Other squid	Teuthoidea	43
Siphonophores	Siphonophores	29
Jellyfish	Scyphozoa	41
Ctenophores	Ctenophores	63
Salps	Thaliacians	46
Euphausiid	Euphausiacea	73

Table 3. Frequency of occurrence (percent of 20 samples), common names and scientific names for 1987 continental slope bottom trawl survey for demersal fish.

Common Name	Scientific Name	Frequency (%)
Rex sole	Glyptocephalus zachirus	45
Dover sole	Microstomus pacificus	100
Longspine thornyhead	Sebastolobus alascanus	70
Shortspine thornyhead	Sebastolobus altivelis	85
Eelpout	Zoarcidae	85
Pacific hake	Merluccius productus	60
Giant grenadier	Albatrossia pectoralis	55
Pacific grenadier	Coryphaenoides acrolepis	50
Blacktail snailfish	Careproctus melanurus	70
Pacific flatnose	Antimora microlepis	45
Sablefish	Anoplopoma fimbria	100
Calif. slickhead	Alepocephalus tenebrosus	60
Bering skate	Bathyraja interrupta	45
Cat sharks	Scylinorhinidae	90
Tanner crab	Chionoecetes tanneri	30

Table 4. Frequency of occurrence (percent of 192 samples), common names, and scientific names for taxa analyzed from triennial bottom trawl survey.

Common Name	Scientific Name	Frequency (%)
Spiny dogfish	Squalus acanthias	48
Pacific electric ray	Torpedo californica	26
Pacific sanddab	Citharichthys sordidus	76
Slender sole	Lyopsetta exilis	40
Petrale sole	Eopsetta jordani	61
Dover sole	Microstomus pacificus	99
Curlfin sole	Pleuronichthys decurrens	26
English sole	Parophrys vetulus	69
Sablefish	Anaplopoma fimbria	60
Plainfin midshipman	Porichthys notatus	60
American shad	Alosa sapidissima	27
Pink seaperch	Zalembius rosaceus	50
Lingcod	Ophiodon elongatus	44
White croaker	Genyonemus lineatus	30
Pacific pompano	Peprilus simillimus	21
Total rockfish	Sebastes sp.	89
Greenstriped rockfish	Sebastes elongatus	47
Chilipepper	Sebastes goodei	57
Shortbelly rockfish	Sebastes jordani	52
Stripetail rockfish	Sebastes saxicola	52
Bocaccio	Sebastes paucispinis	53
Spotted ratfish	Hydrolagus colliei	25
Market squid	Loligo opalescens	30

Table 5. Summary of Analysis of Variance results for CalCOFI database. Shown are significance levels for tests of main effect of season and station, and the interaction between station and season. Interactions were not included in the model when the significance level for the interaction in a preliminary analysis was greater than 0.1.

Common Name	Season	Station	Station x Season
Total fish larvae	0.0001	0.0001	0.0001
Rockfish	0.0001	0.0001	0.0001
Northern anchovy	0.07	0.01	0.048
Northern lampfish	0.0001	0.0005	0.049
Slender sole	0.0001	0.006	0.04
Medusafish	0.0004	0.0001	-
Popeye blacksmelt	0.0001	0.0001	-
Calif. smoothtongue	0.0001	0.0001	-
Pacific hake	0.0001	0.24	-
Sanddabs	0.0001	0.07	-
Other flatfish	0.01	0.0001	-
Blue lanternfish	0.007	0.0001	-
Calif. flashlightfish	0.07	0.0001	-
Other myctophids	0.0001	0.001	-
Plankton volume	0.0001	0.02	-

Table 6. Summary of Analysis of Variance results for Tiburon midwater trawl survey for juvenile rockfish. Shown are significance levels for tests of main effect of depth category (Depth) and latitude category (Lat), and the interaction between depth and latitude categories (Depth x Lat). An interaction term was not included when the significance level of the interaction was greater than 0.1 in a preliminary analysis.

Common name	Depth	Lat	Depth x Lat
Pacific herring	0.0004	0.004	-
Pacific butterfish	0.003	0.003	-
Plainfin midshipman	0.0001	0.0001	-
Calif. smoothtongue	0.0001	0.0001	0.0001
Blacksmelt spp.	0.0001	0.0001	0.0001
Pacific argentine (juv)	0.10	0.32	0.004
Northern anchovy (juv)	0.23	0.04	-
Pacific hake (ad)	0.009	0.0001	0.0001
Pacific hake (juv)	0.0001	0.17	-
Spiny dogfish	0.07	0.02	-
Juvenile rockfish (total)	0.48	0.27	0.002
Chilipepper (juv)	0.29	0.004	-
Shortbelly rockfish (juv)	0.70	0.20	0.006
Blue rockfish (juv)	0.004	0.46	-
Brown rockfish (juv)	0.70	0.0001	-
Canary rockfish (juv)	0.44	0.17	0.06
Bocaccio (juv)	0.0001	0.51	-
Yellowtail rockfish (juv)	0.04	0.86	-
Squarespot rockfish (juv)	0.34	0.15	-
Stripetail rockfish (juv)	0.55	0.02	-
Widow rockfish (juv)	0.10	0.83	-
Pygmy rockfish (juv)	0.83	0.79	-
Lingcod (juv)	0.0002	0.25	-
Dover sole (juv)	0.03	0.94	-
Rex sole (juv)	0.0001	0.06	0.03
Total myctophids	0.0001	0.0001	0.0001
Calif. headlightfish	0.0001	0.0001	0.0001
Blue lanternfish	0.0001	0.003	0.0001
Northern lampfish	0.0001	0.61	-
Octopus	0.0001	0.04	-
Market squid	0.0001	0.04	0.14
Other squid	0.0001	0.40	0.02
Siphonophores	0.004	0.30	0.046
Jellyfish	0.0001	0.14	0.09
Ctenophores	0.74	0.28	-
Salps	0.0001	0.43	-
Euphausiid	0.60	0.47	-

Table 7. Summary of Analysis of Variance results for triennial bottom trawl survey data. Shown are significance levels for tests of main effects of latitude category (Lat) and depth category (Depth), and the interaction between depth category and latitude category (Depth x Lat). Interaction terms were not included in model when the significance level of the interaction was greater than 0.1 in a preliminary test.

	Biomass			Count		
Common Name	Lat	Depth	Depth x Lat	Lat	Depth	Depth x Lat
Spiny dogfish	0.047	0.13	-	0.052	0.26	-
Pacific electric ray	0.01	0.02	-	0.005	0.02	-
Pacific sanddab	0.88	0.0001	-	0.94	0.0001	-
Slender sole	0.07	0.006	-	0.14	0.01	-
Petrale sole	0.30	0.0001	-	0.42	0.0001	-
Dover sole	0.12	0.0001	-	0.07	0.0001	-
Curlfin sole	0.005	0.51	-	0.001	0.33	-
English sole	0.09	0.0001	0.01	0.12	0.0001	0.2
Sablefish	0.21	0.0002	-	0.19	0.005	-
Plainfin midshipman	0.34	0.0001	-	0.25	0.0001	-
American shad	0.17	0.04	-	0.10	0.04	-
Pink seaperch	0.008	0.002	-	0.002	0.0001	-
Lingcod	0.0007	0.02	-	0.001	0.01	-
White croaker	0.68	0.03	-	0.62	0.03	-
Pacific pompano	0.0002	0.0503	-	0.001	0.03	-
Total rockfish	0.62	0.0001	-	0.15	0.0001	-
Greenstriped rockfish	0.12	0.007	-	0.09	0.01	-
Chilipepper	0.17	0.0001	-	0.055	0.0001	-
Shortbelly rockfish	0.38	0.0002	-	0.52	0.002	-
Stripetail rockfish	0.78	0.0001	-	0.95	0.0001	-
Bocaccio	0.005	0.0001	0.01	0.03	0.0001	0.03
Spotted ratfish	0.01	0.001	0.048	0.001	0.005	0.002
Market squid	0.0002	0.02	-	0.006	0.006	-
Rex sole	0.63	0.099	-	0.55	0.16	-
Pacific herring	0.35	0.06	-	0.45	0.13	-
Pacific hake	0.48	0.78	-	0.54	0.73	-

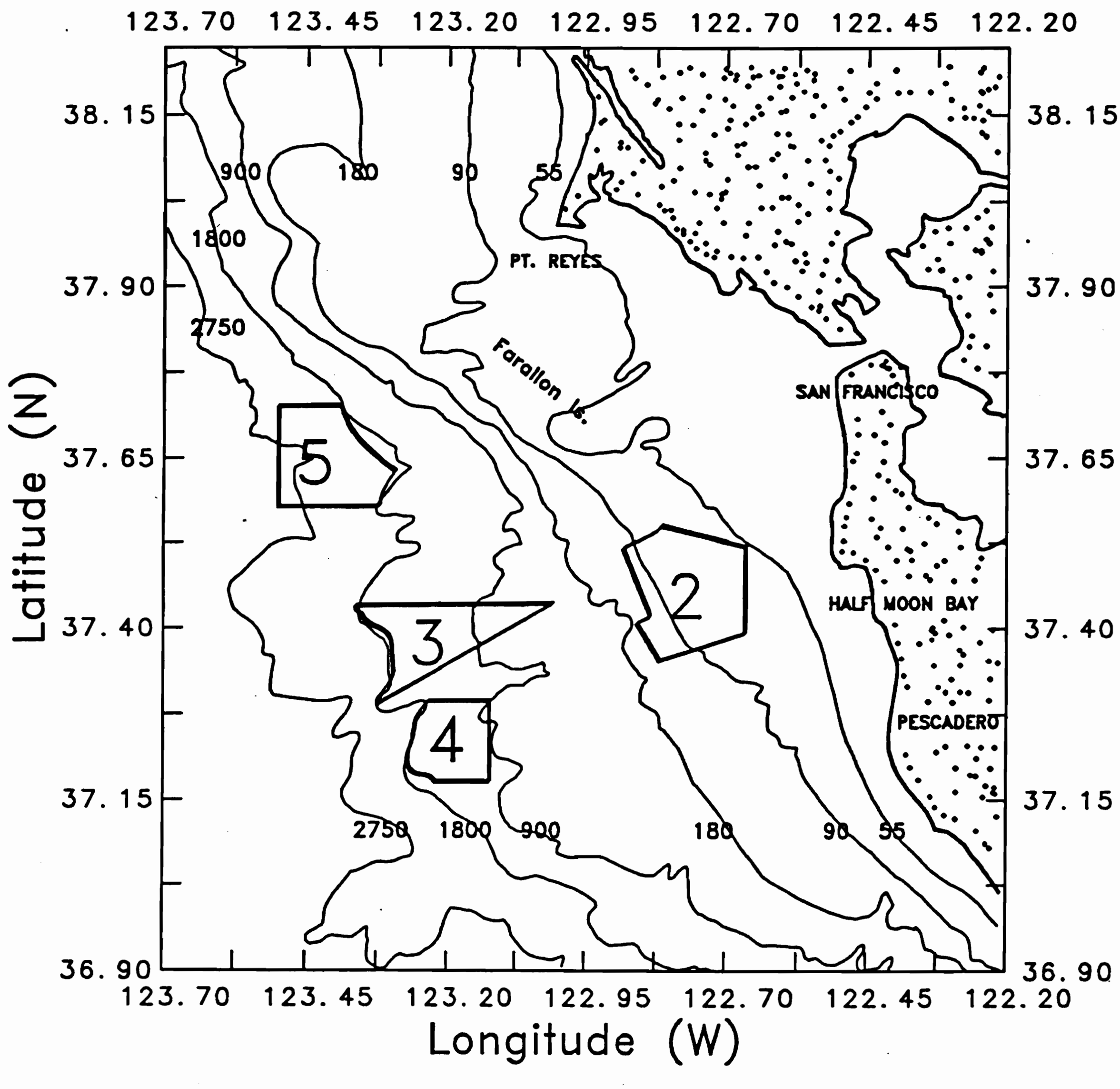


Fig. 1. Map of study region with locations of EPA study areas 2-5 and depth contours (meters). Depth contours were digitized from NOAA chart 18010 (Monterey Bay to Coos Bay) recorded in fathoms and depths in meters are based on converting these values (1.83 m = 1 fathom) and rounding them.

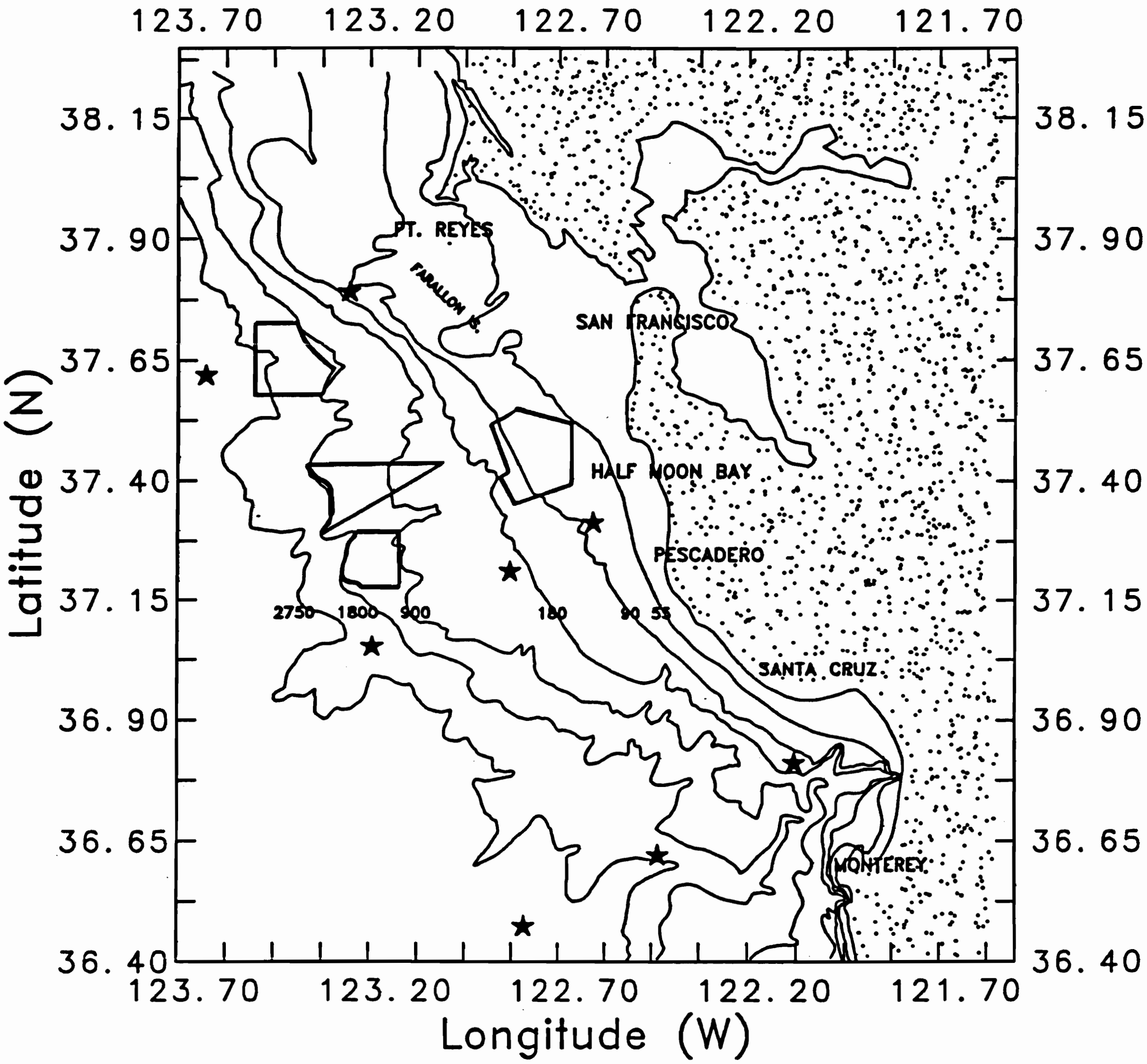


Fig. 2. Location of CalCOFI sampling stations (stars) used in analyses in this report. EPA study areas, and depth contours (meters) are also included.

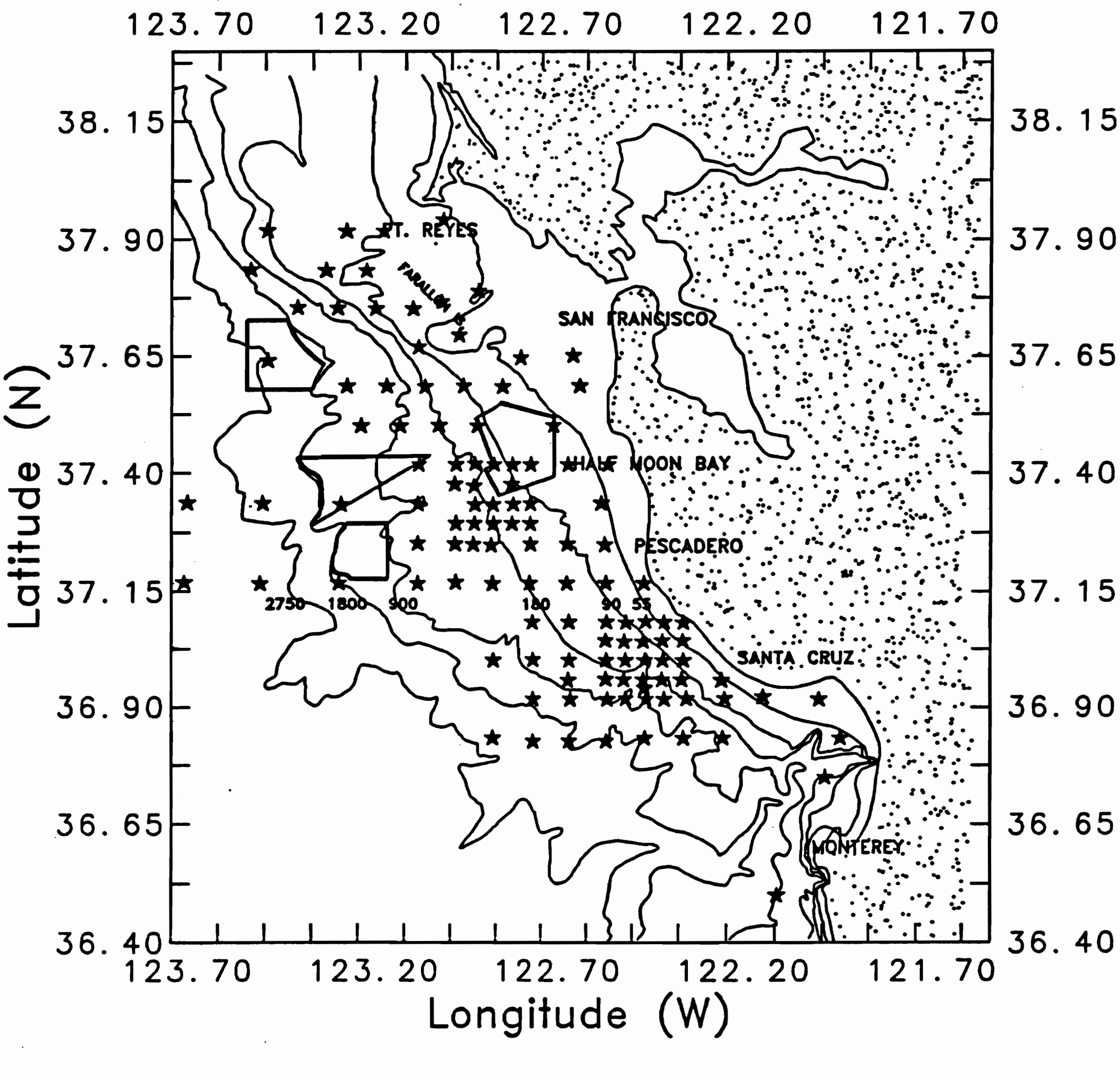


Fig. 3. Location of sampling stations (stars) for Feb. 1991 Tiburon Laboratory ichthyoplankton survey. EPA study areas, and depth contours (meters) are also included.

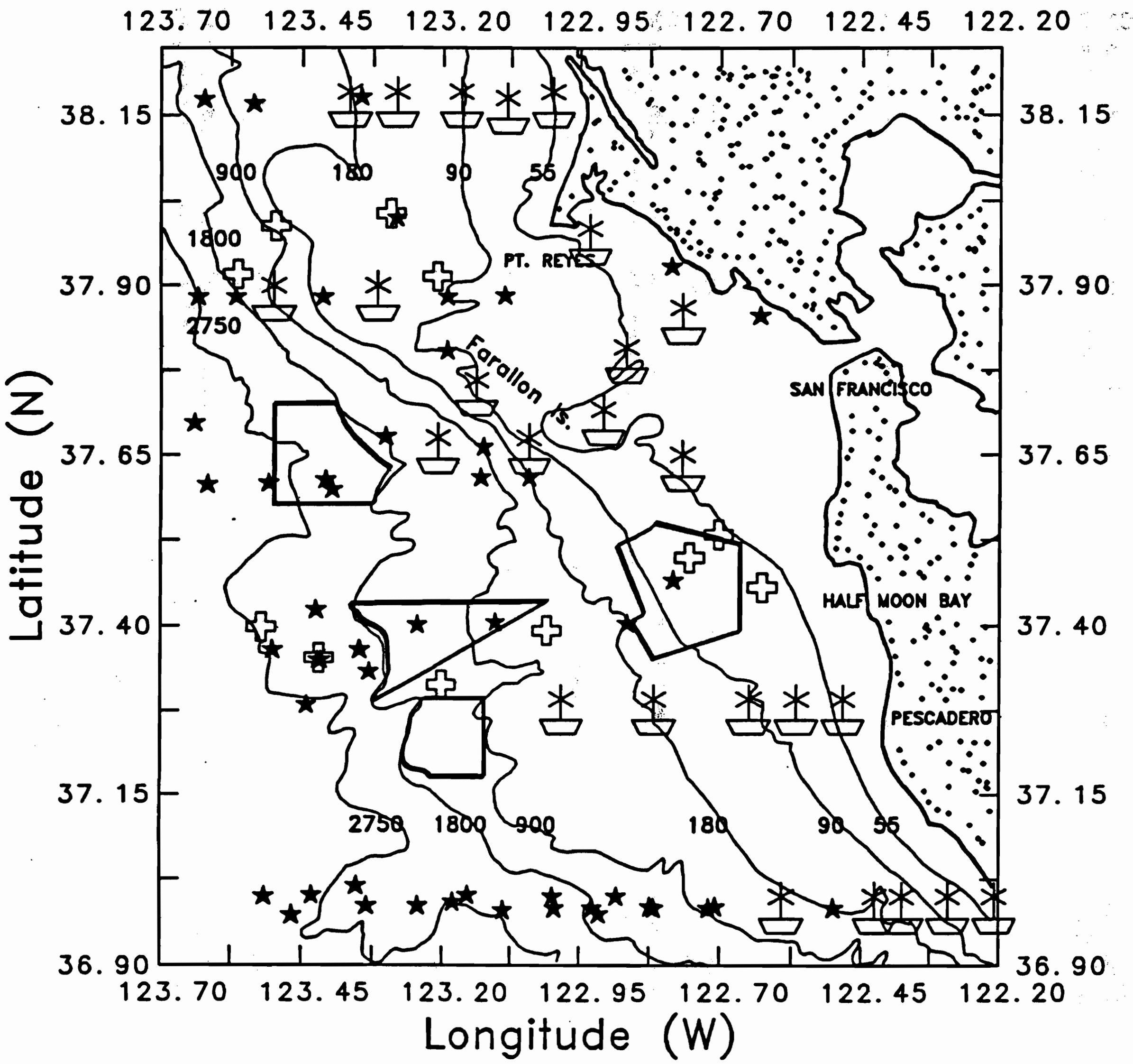


Fig. 4. Tiburon Laboratory midwater trawl survey sampling locations within the study region, with EPA study areas and depth contours (meters). "Boats" indicate standard sampling locations (generally sampled on all sweeps), stars indicate stations sampled one or more times, but not regularly on each survey, and crosses indicate locations of stations sampled only during the March-April cruises (and not used in the analysis).

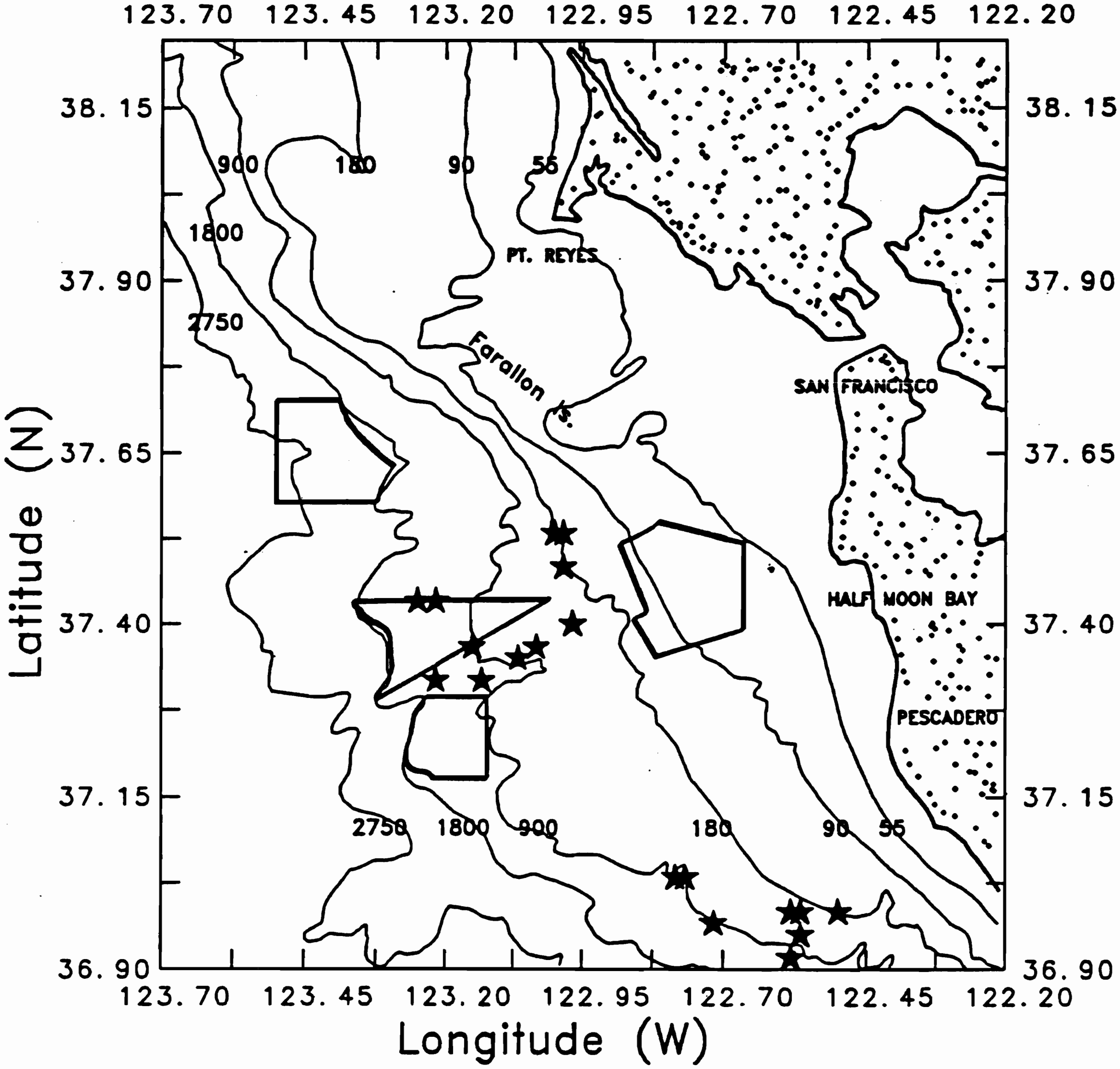


Fig. 5. Location of sampling stations (stars) for Southwest Fisheries Science Center survey of demersal fish on the continental slope. EPA study areas, and depth contours (meters) are also included.

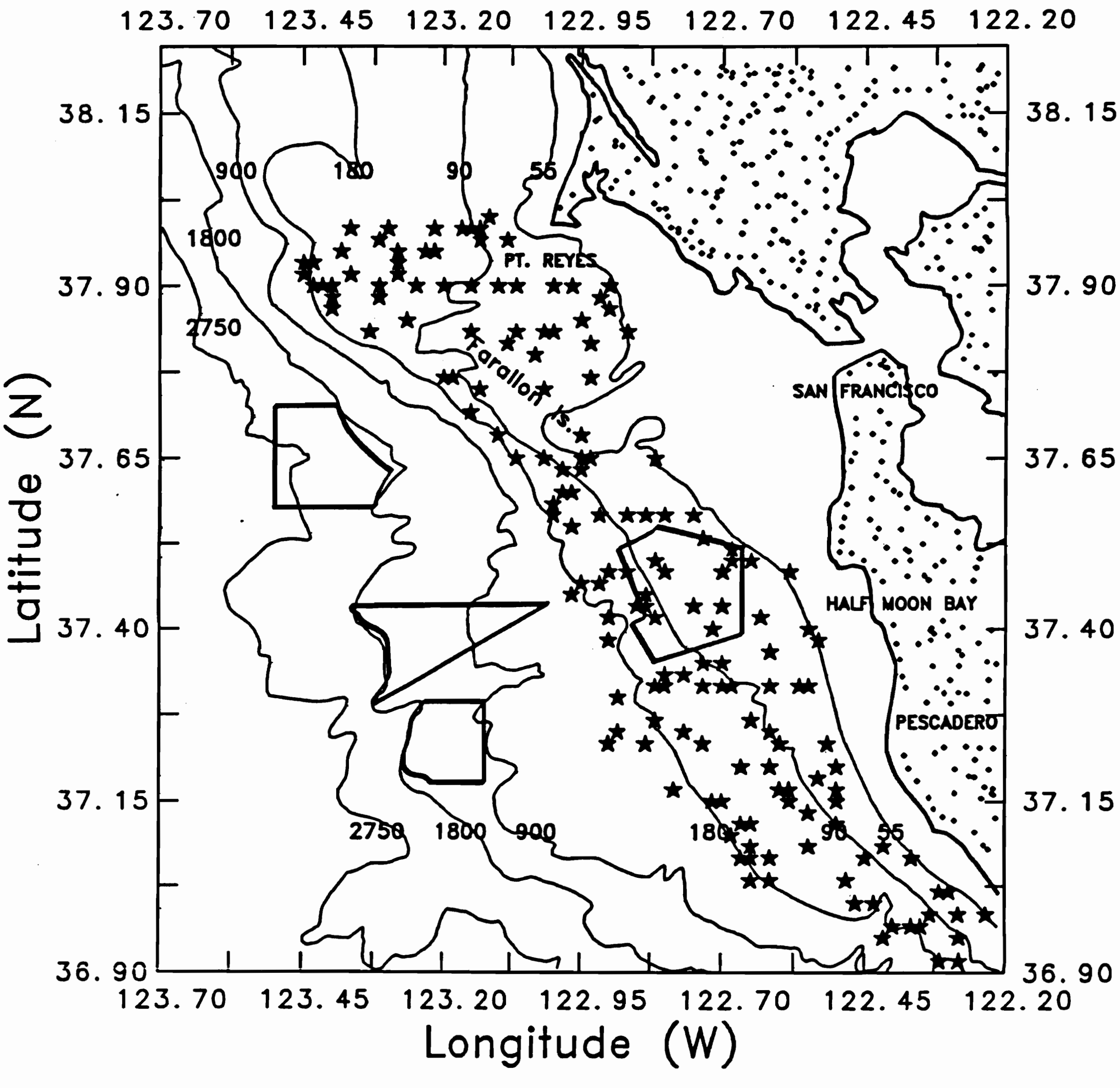


Fig. 6. Alaska Fisheries Science Center's triennial bottom trawl survey sampling locations (stars). EPA study areas, and depth contours (meters) are also included.

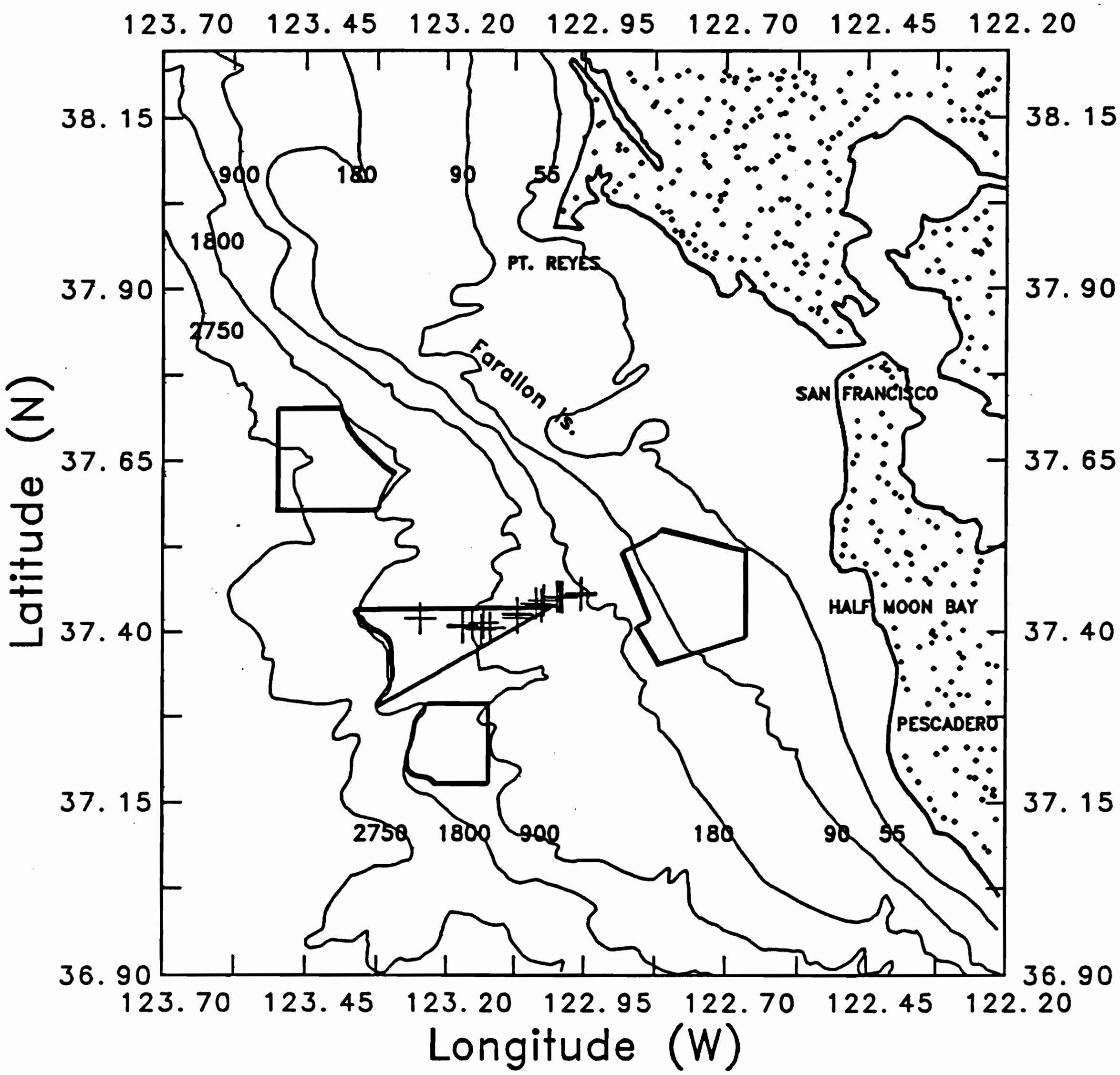


Fig. 7. Alaska Fisheries Science Center's sablefish trapping survey sampling locations (crosses). Darker symbols represent repeated sampling in same location. EPA study areas, and depth contours (meters) are also included.

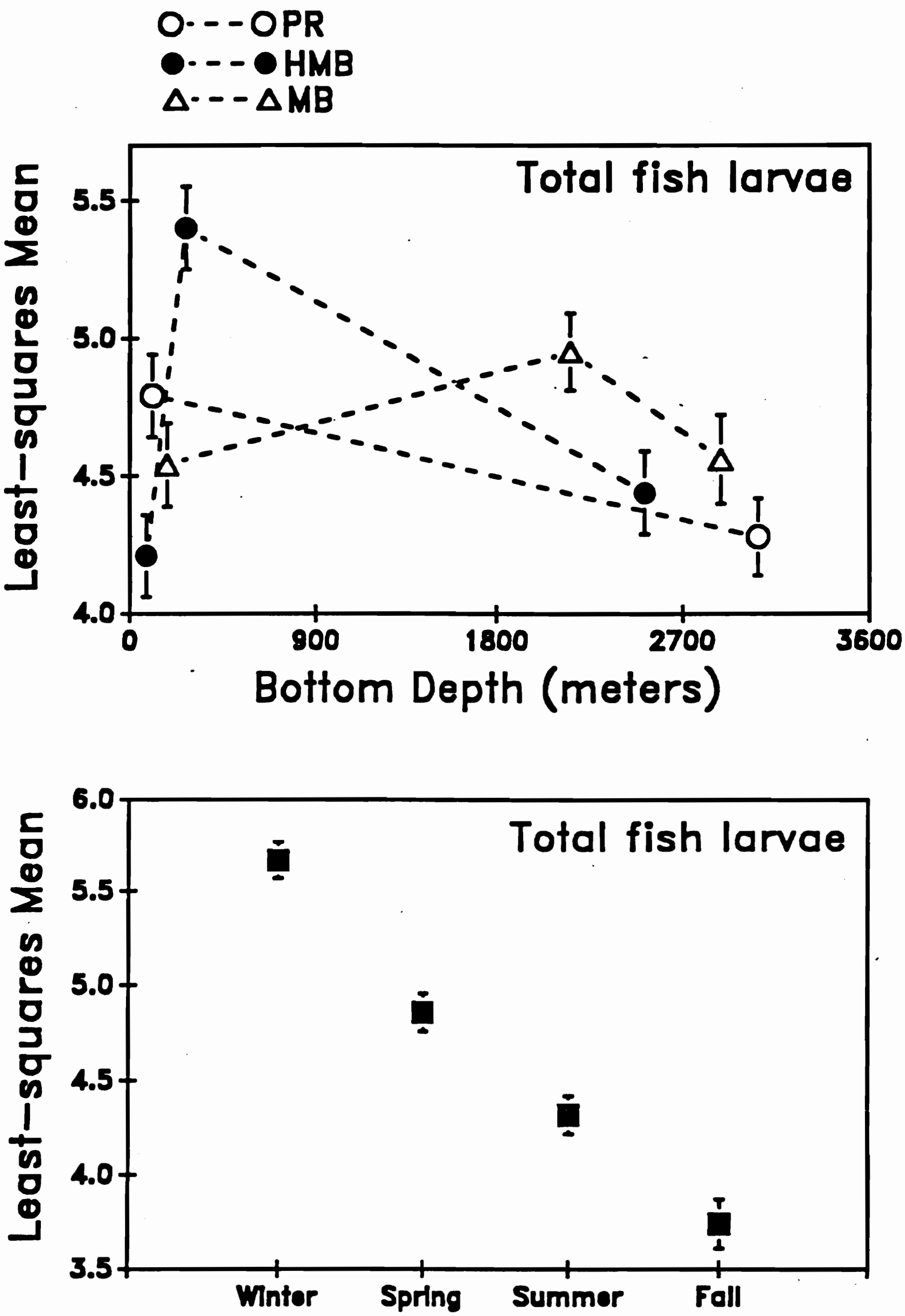


Fig. 8. Abundance of total fish larvae versus bottom depth (top panel) and by season (bottom panel). Shown are least-squares means (LSM's) for $\log_e$-transformed abundance for individual sampling stations (top panels) or by season (bottom panels). PR = Point Reyes line, HMB = Half Moon Bay line, MB = Monterey Bay line. Seasons are winter = Dec.-Feb., spring = March-May, summer = June-Aug., fall = Sept.-Nov. Standard errors of LSM's are indicated by vertical bars.

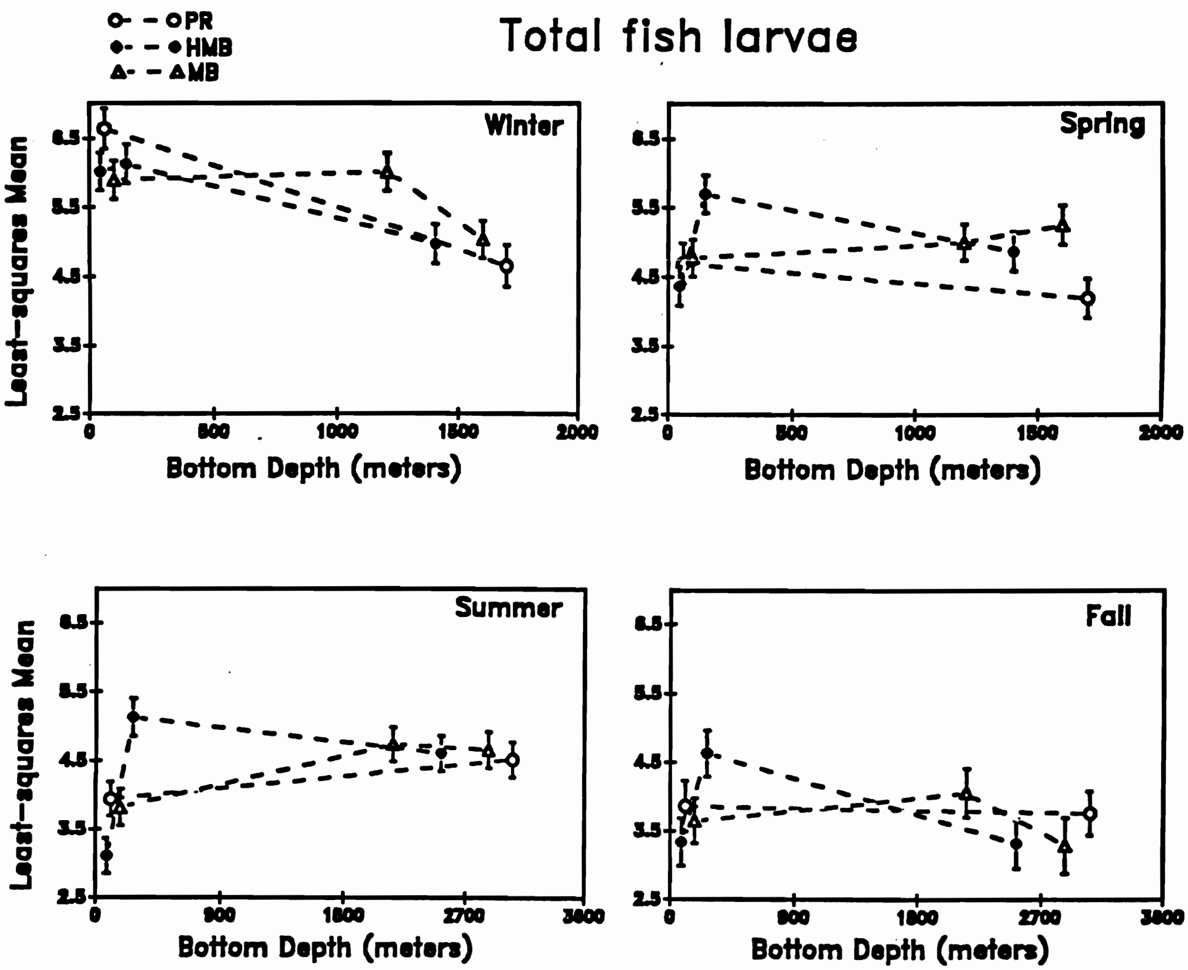


Fig. 9. Abundance of total fish larvae versus bottom depth. Shown are least-squares means (LSM's) for $\log_e$-transformed abundance from CalCOFI surveys for each combination of season and station plotted against bottom depth. PR = Point Reyes line, HMB = Half Moon Bay line, MB = Monterey Bay line. Standard errors of LSM's are indicated by vertical bars.

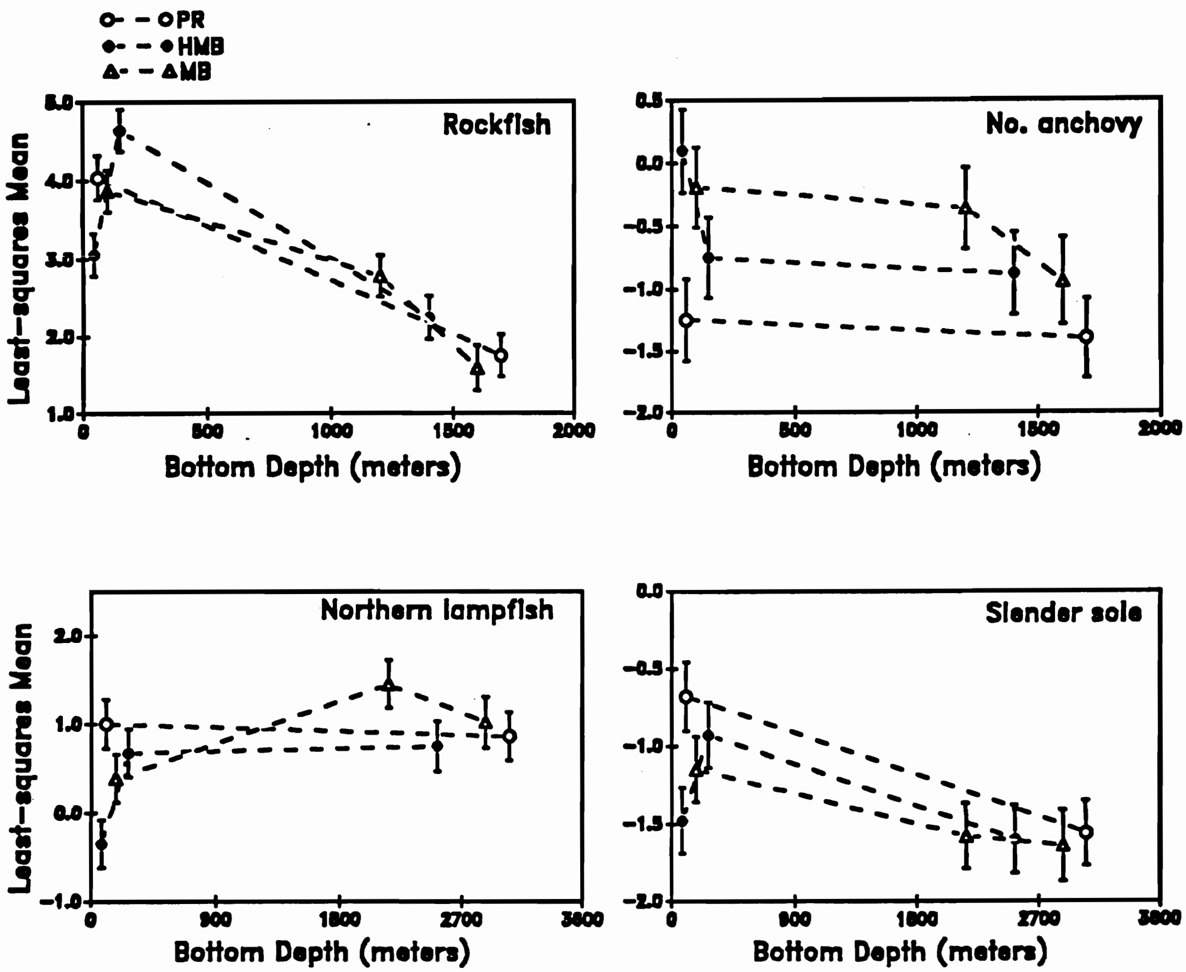


Fig. 10. Abundance versus bottom depth for four categories of larval fish. Shown are least-squares means (LSM's) for $\log_e$-transformed abundance collected during CalCOFI surveys for individual sampling stations. PR=Point Reyes line, HMB=Half Moon Bay line, MB=Monterey Bay line. Standard errors of LSM's are indicated by vertical bars.

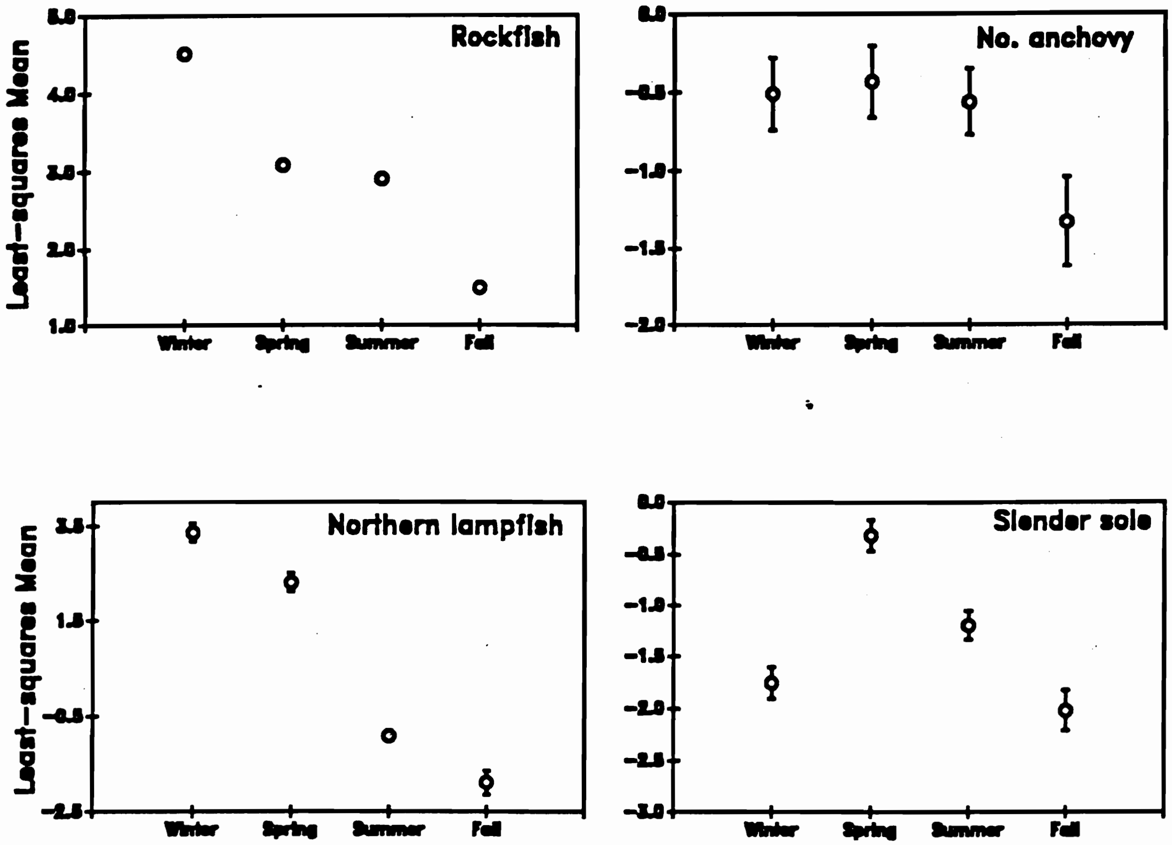


Fig. 11. Abundance by season for four categories of larval fish collected during CalCOFI surveys. Shown are least-square means by seasons (winter=Dec.-Feb., spring=March-May, summer=June-Aug., fall=Sept.-Nov.) of $\log_e$ transformed abundance. Standard errors of LSM's are indicated by vertical bars.

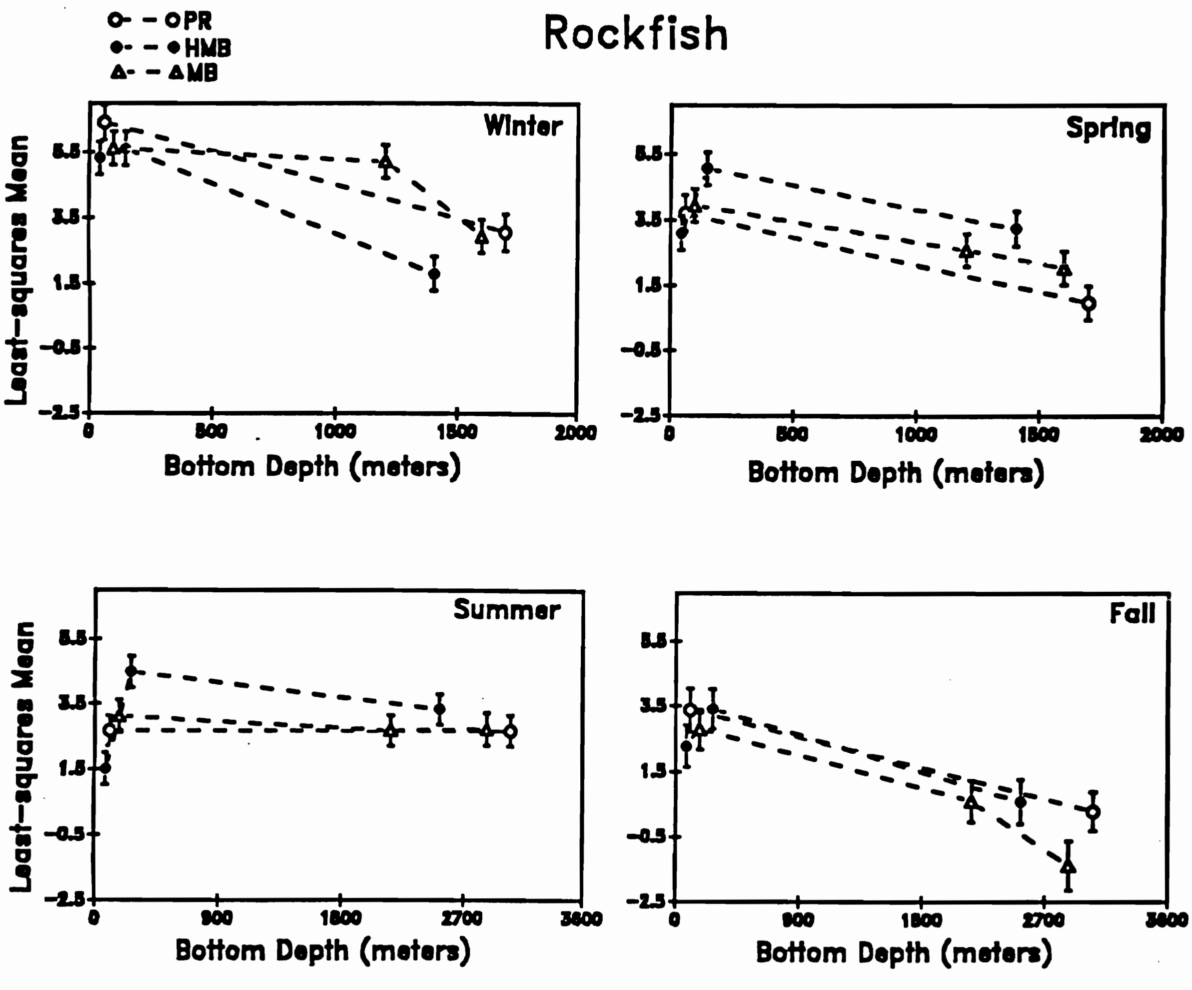


Fig. 12. Abundance of rockfish larvae versus bottom depth for CalCOFI surveys. Shown are least-squares means (LSM's) for $\log_e$-transformed abundance for each combination of station and season. PR = Point Reyes line, HMB = Half Moon Bay line, MB = Monterey Bay line. Standard errors of LSM's are indicated by vertical bars.

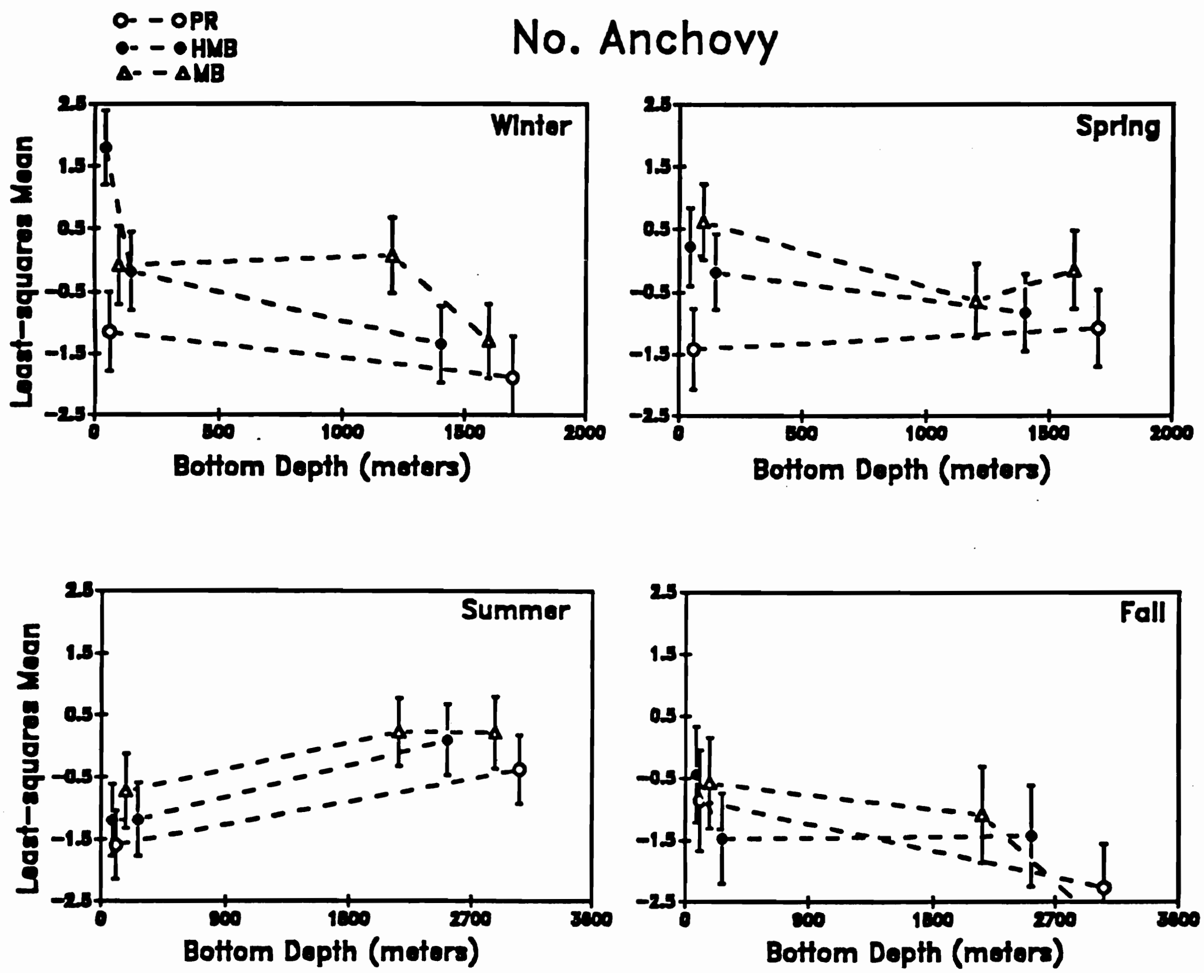


Fig. 13. Abundance of northern anchovy larvae versus bottom depth for CalCOFI surveys. Shown are least-squares means (LSM's) for $\log_e$-transformed abundance for each combination of station and season. PR = Point Reyes line, HMB = Half Moon Bay line, MB = Monterey Bay line. Standard errors of LSM's are indicated by vertical bars.

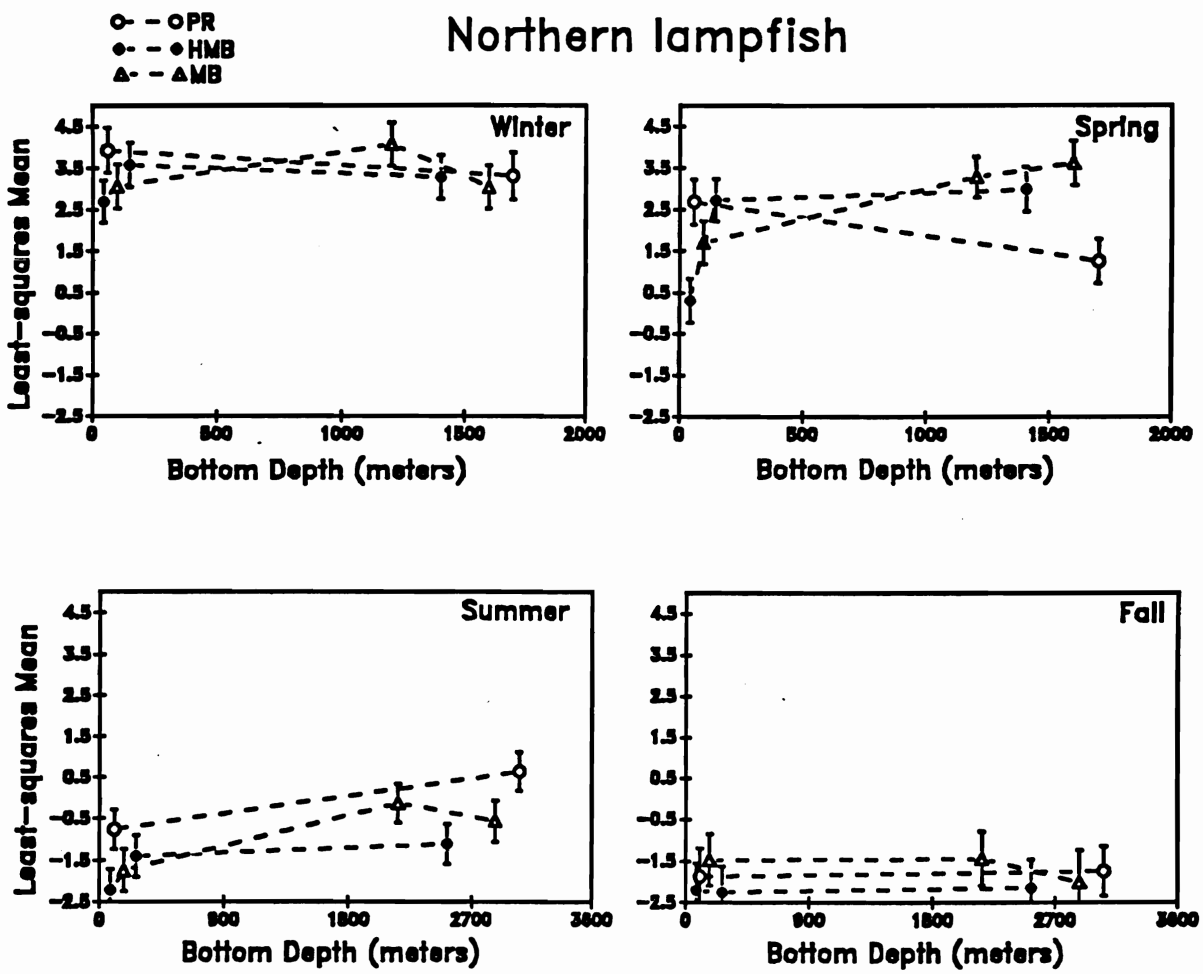


Fig. 14. Abundance of northern lampfish larvae versus bottom depth for CalCOFI surveys. Shown are least-squares means (LSM's) for $\log_e$-transformed abundance for each combination of station and season. PR = Point Reyes line, HMB = Half Moon Bay line, MB = Monterey Bay line. Standard errors of LSM's are indicated by vertical bars.

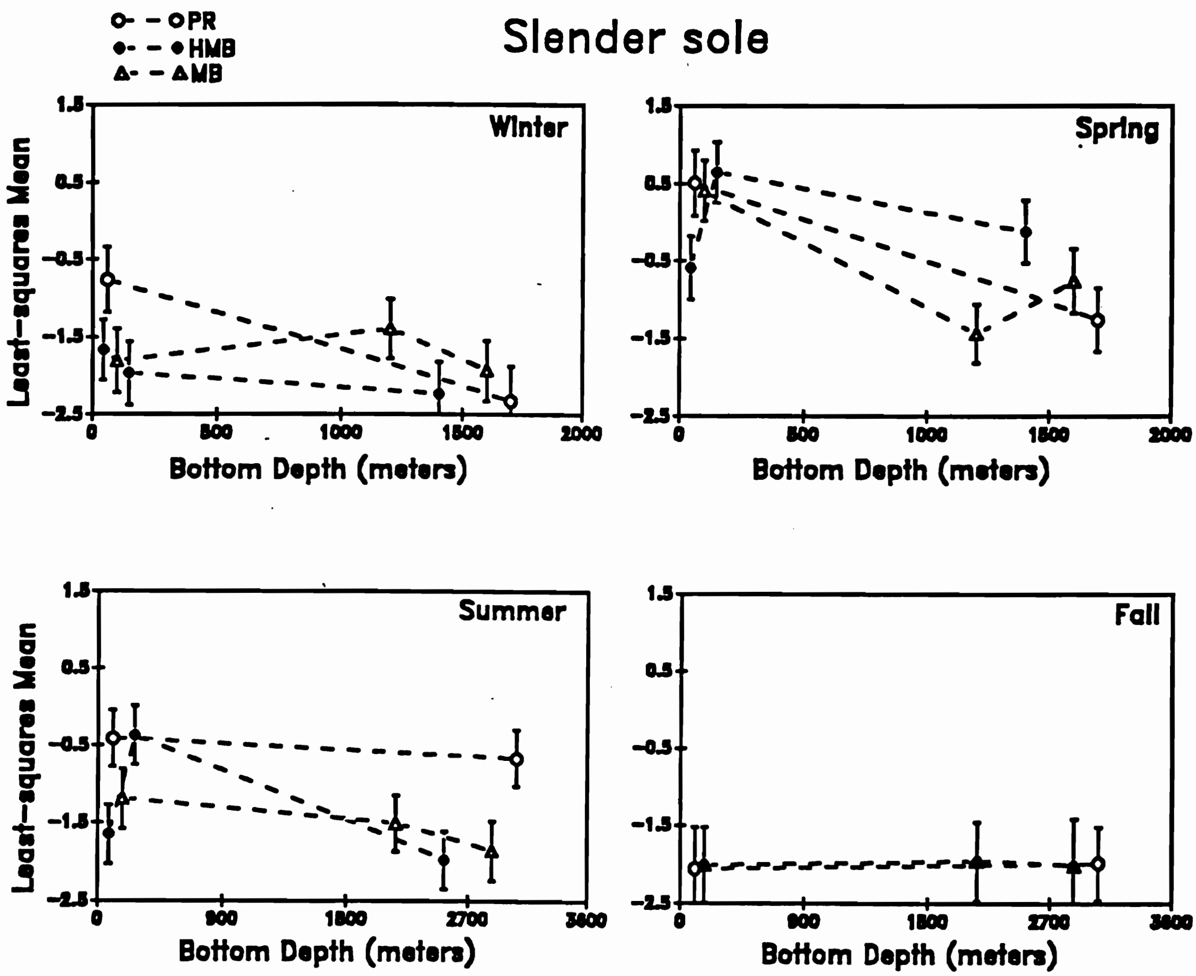


Fig. 15. Abundance of slender sole larvae versus bottom depth for CalCOFI surveys. Shown are least-squares means (LSM's) for $\log_e$-transformed abundance for each combination of season and station. PR=Point Reyes line, HMB=Half Moon Bay line, MB=Monterey Bay line. Standard errors of LSM's are indicated by vertical bars.

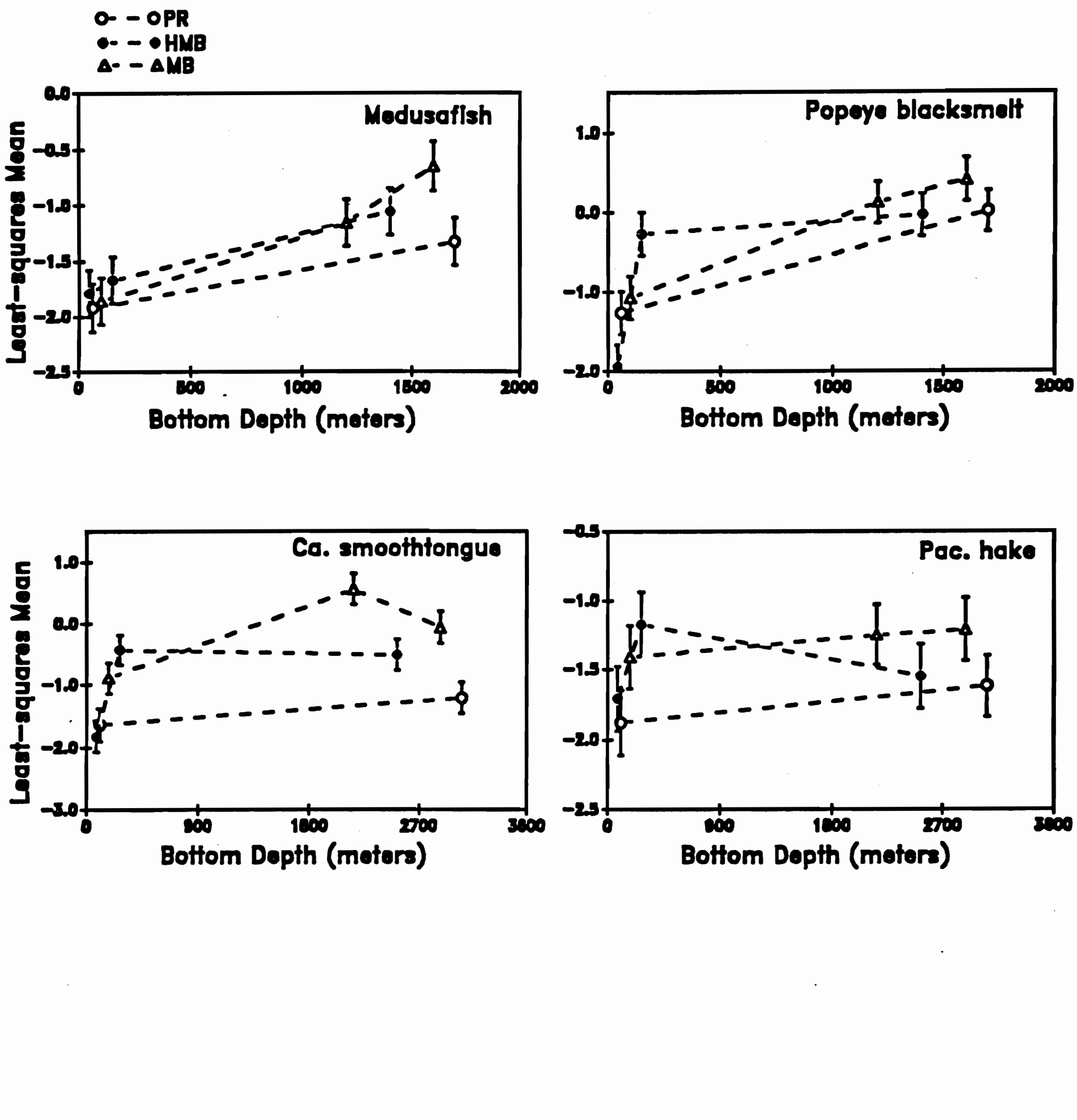


Fig. 16. Abundance versus bottom depth for four categories of larval fish collected during CalCOFI surveys. Shown are least-squares means (LSM's) for $\log_e$-transformed abundance for individual sampling stations. PR=Point Reyes line, HMB=Half Moon Bay line, MB=Monterey Bay line. Standard errors of LSM's are indicated by vertical bars.

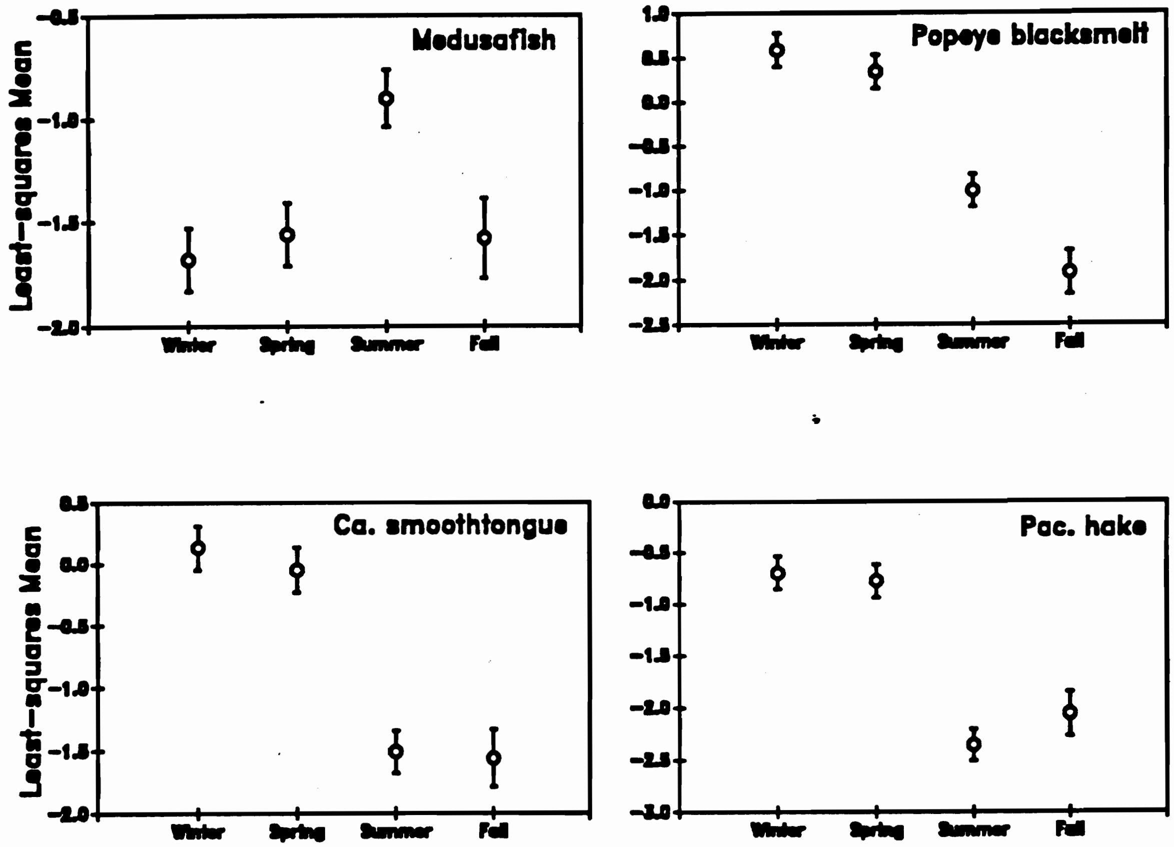


Fig. 17. Abundance by seasons (winter=Dec.-Feb., spring=March-May, summer=June-Aug., fall=Sept.-Nov.) for four categories of larval fish collected during CalCOFI surveys. Shown are least-squares means of $\log_e$ transformed abundance.

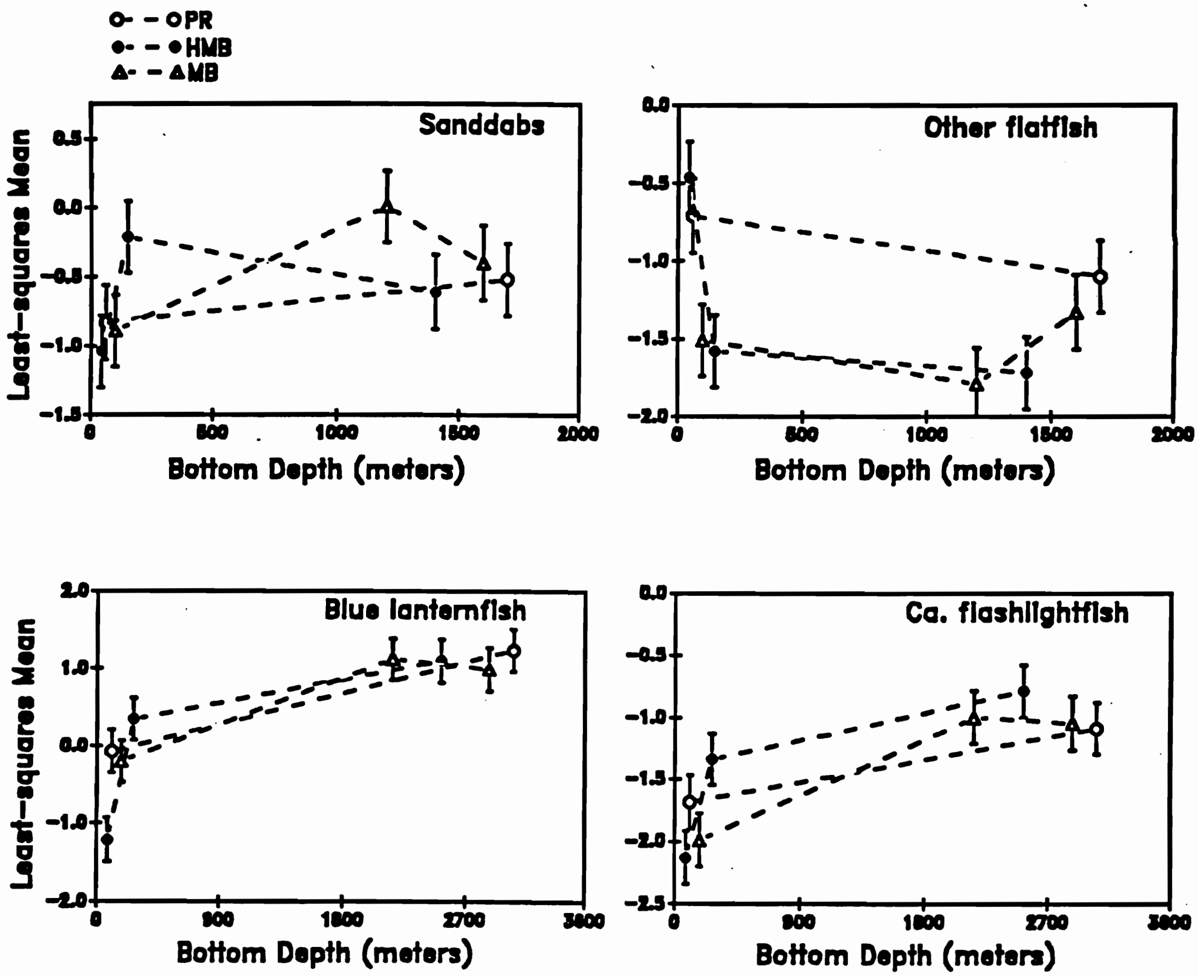


Fig. 18. Abundance versus bottom depth for four categories of larval fish collected during CalCOFI surveys. Shown are least-squares means (LSM's) for $\log_e$-transformed abundance for individual sampling stations. PR=Point Reyes line, HMB=Half Moon Bay line, MB=Monterey Bay line. Standard errors of LSM's are indicated by vertical bars.

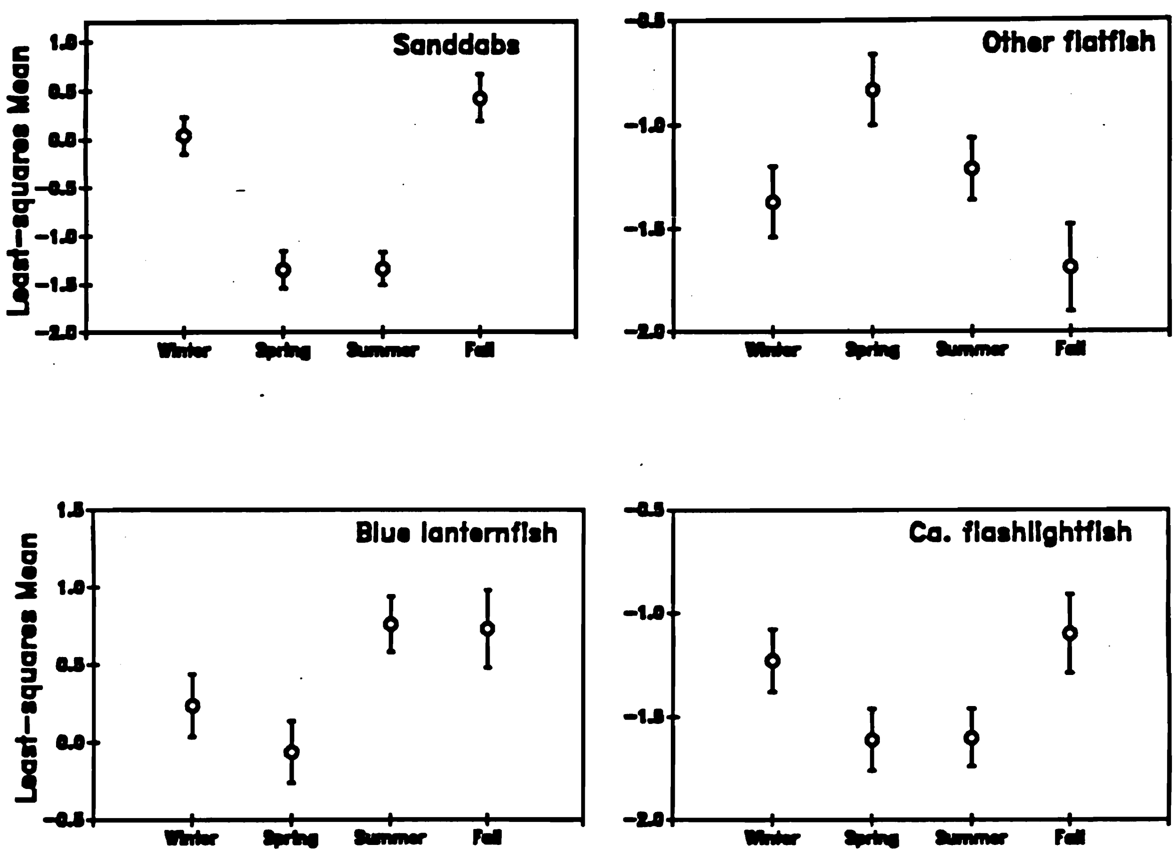


Fig. 19. Abundance by seasons (winter=Dec.-Feb., spring=March-May, summer=June-Aug., fall=Sept.-Nov.) for four categories of larval fish collected during CalCOFI surveys. Shown are least-squares means of $\log_e$ transformed abundance.

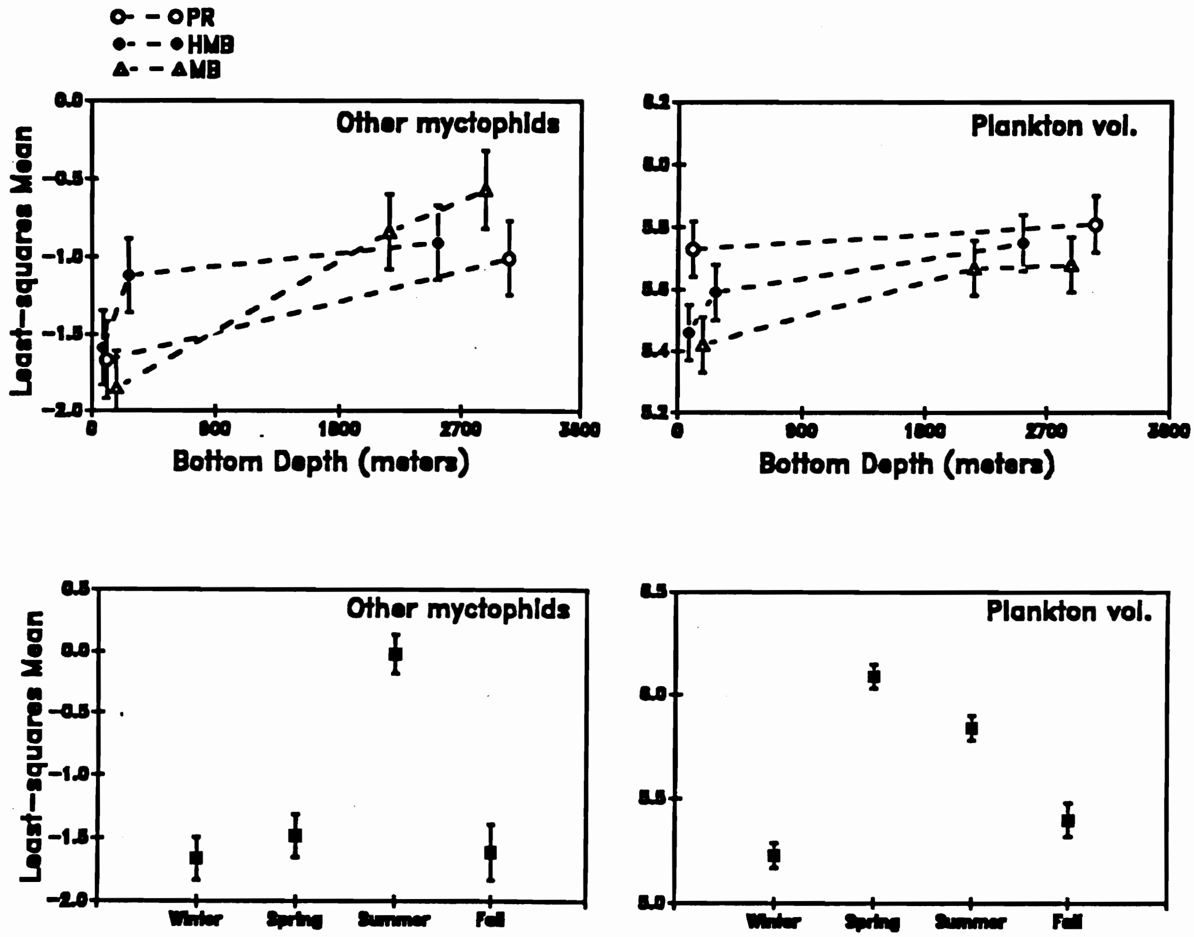


Fig. 20. Abundance of other myctophids and plankton volume versus bottom depth (top panels) and by season (bottom panels) for CalCOFI surveys. Shown are least-squares means (LSM's) for $\log_e$-transformed abundance and volume for individual sampling stations (top panels) and by season (bottom panels). PR = Point Reyes line, HMB = Half Moon Bay line, MB = Monterey Bay line. Seasons are winter = Dec.-Feb., spring = March-May, summer = June-Aug., fall = Sept.-Nov. Standard errors of LSM's are indicated by vertical bars.

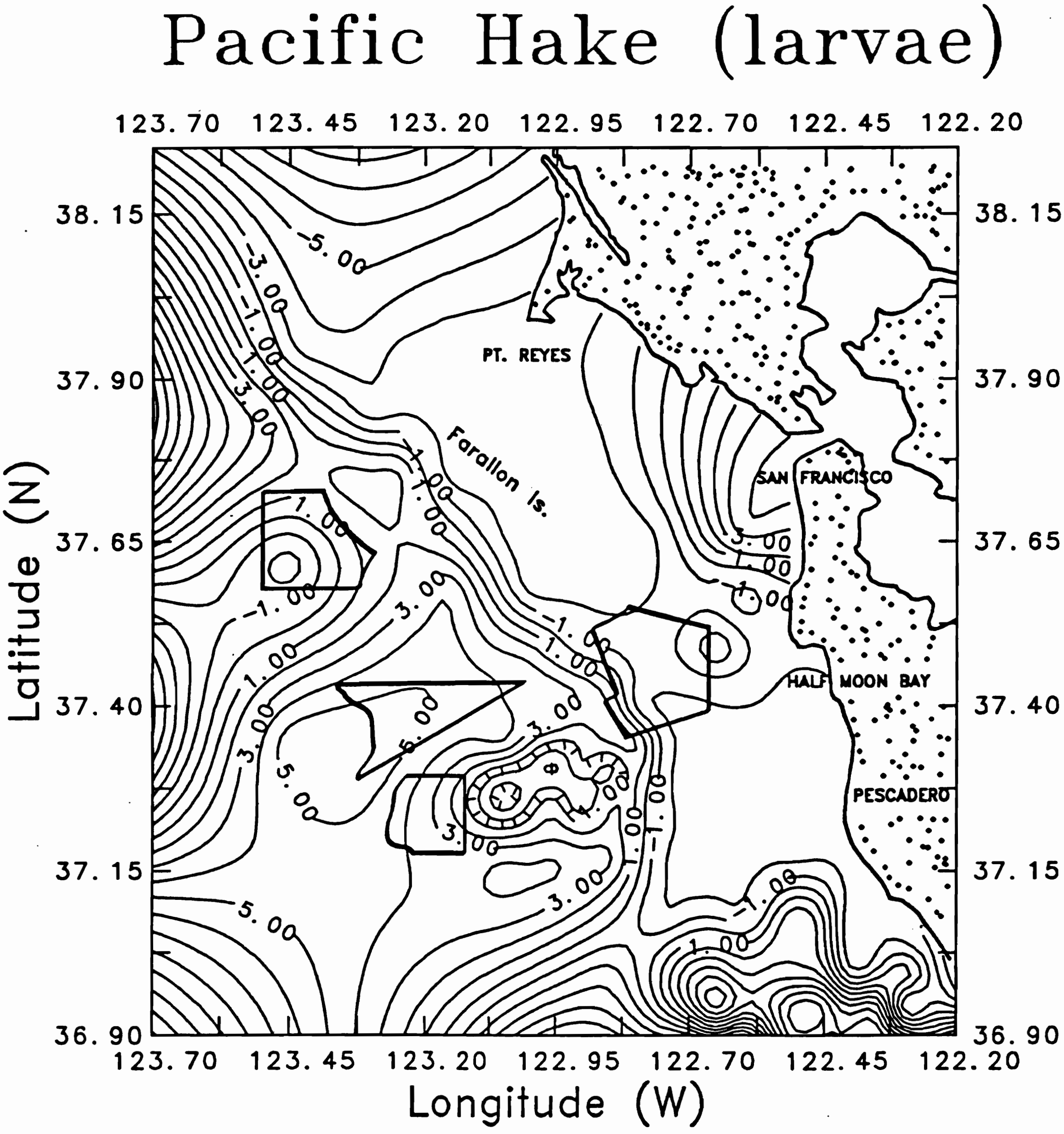


Fig. 21. Contour plot of $\log_e$-transformed abundance of Pacific hake larvae, based on samples taken during the Feb. 1991 survey by the Tiburon Laboratory (NMFS).

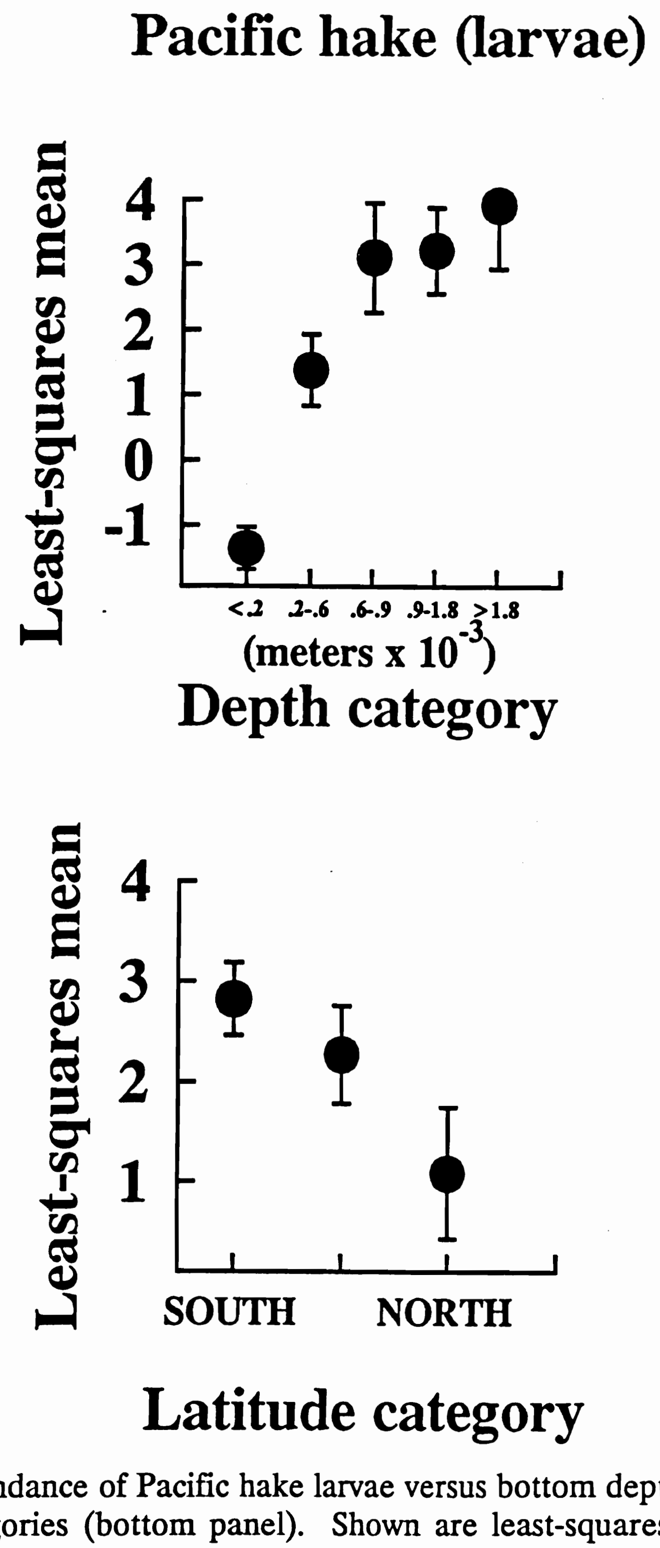


Fig. 22. Abundance of Pacific hake larvae versus bottom depth categories (top panel) and latitude categories (bottom panel). Shown are least-squares means of $\log_e$-transformed abundance. Data are from the Feb. 1991 survey by the Tiburon laboratory (NMFS). Standard errors of LSM's are indicated by vertical bars.

Shortbelly rockfish (larvae)

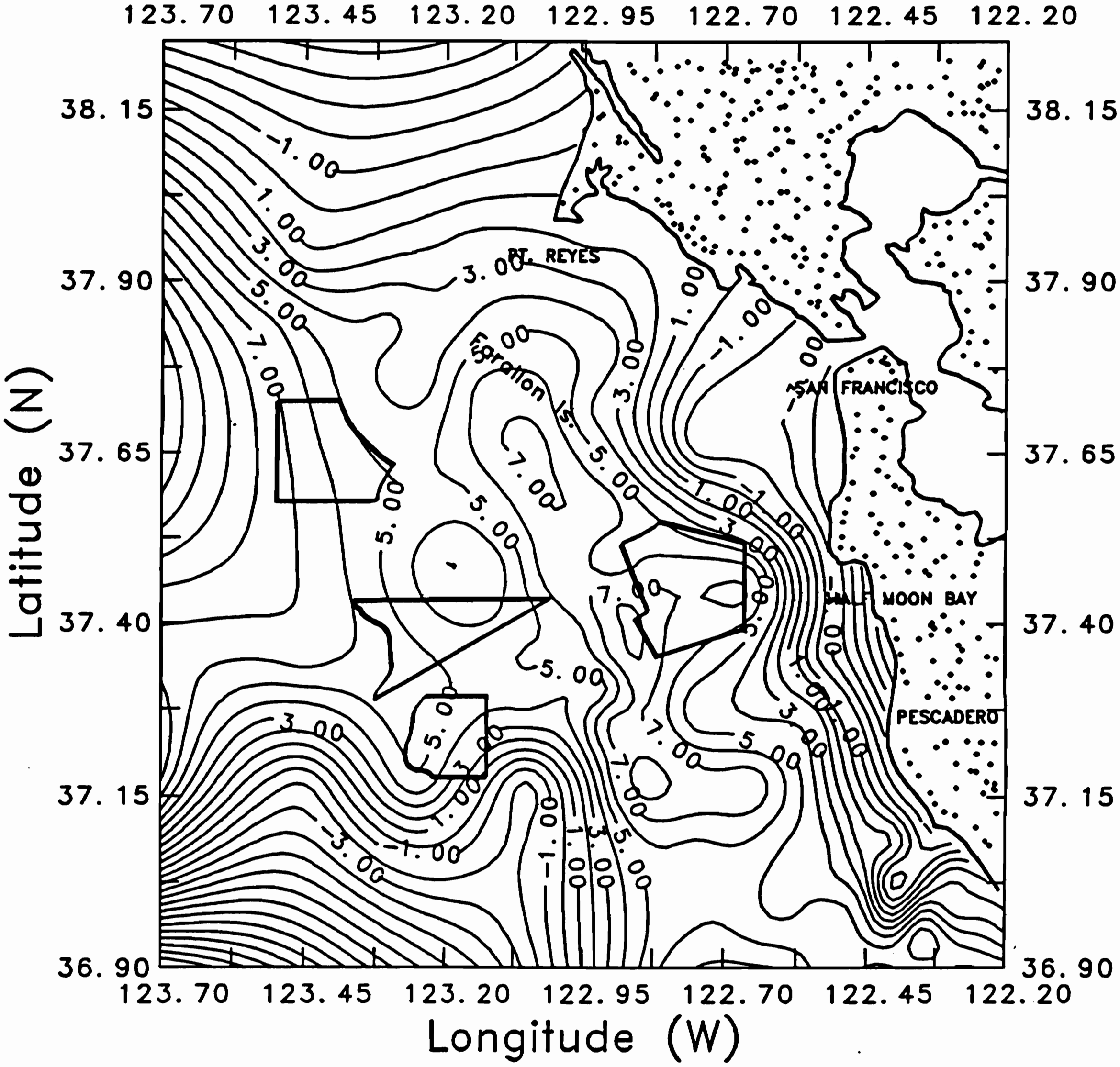


Fig. 23. Contour plot of $\log_e$-transformed abundance of shortbelly rockfish larvae, based on samples taken during the Feb. 1991 survey by the Tiburon Laboratory (NMFS).

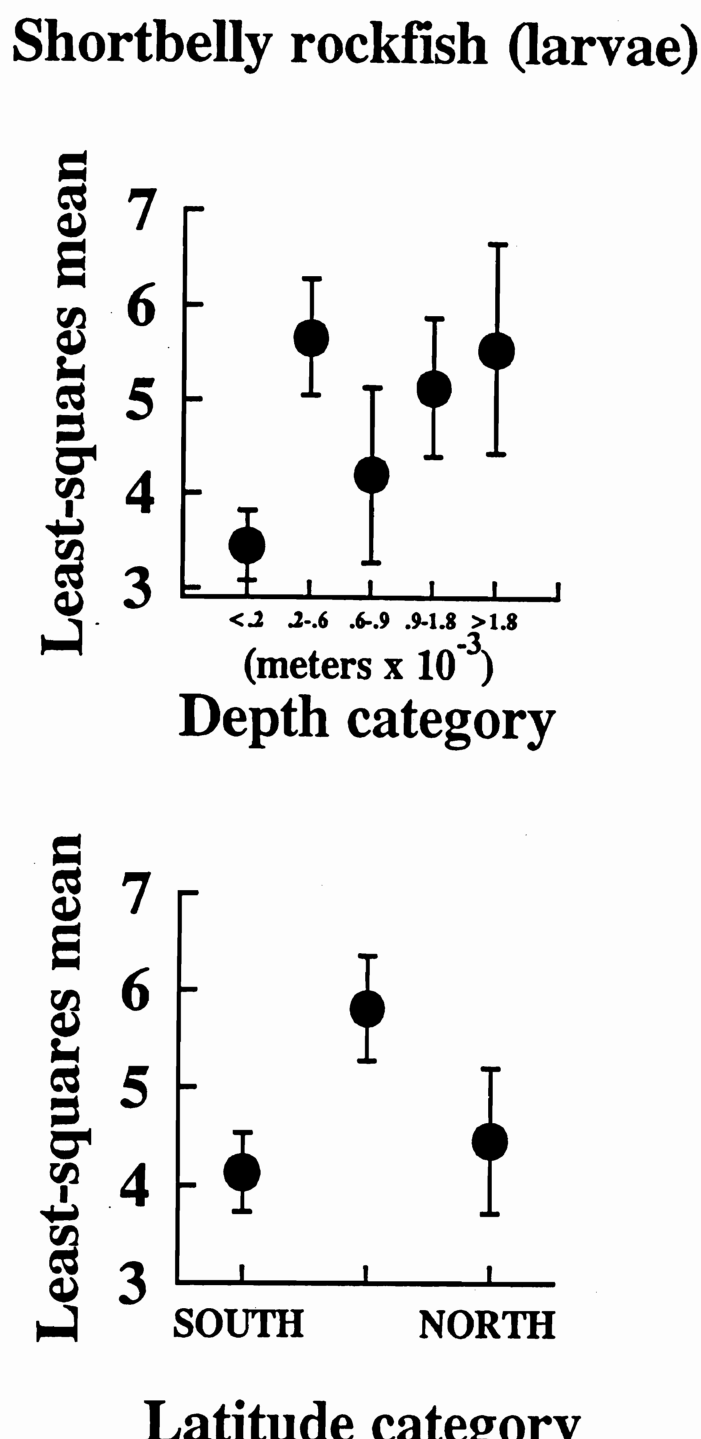


Fig. 24. Abundance of shortbelly rockfish larvae versus bottom depth categories (top panel) and latitude categories (bottom panels). Shown are least-squares means of $\log_e$-transformed abundance. Data are from the Feb. 1991 survey by Tiburon laboratory (NMFS). Standard errors of LSM's are indicated by vertical bars.

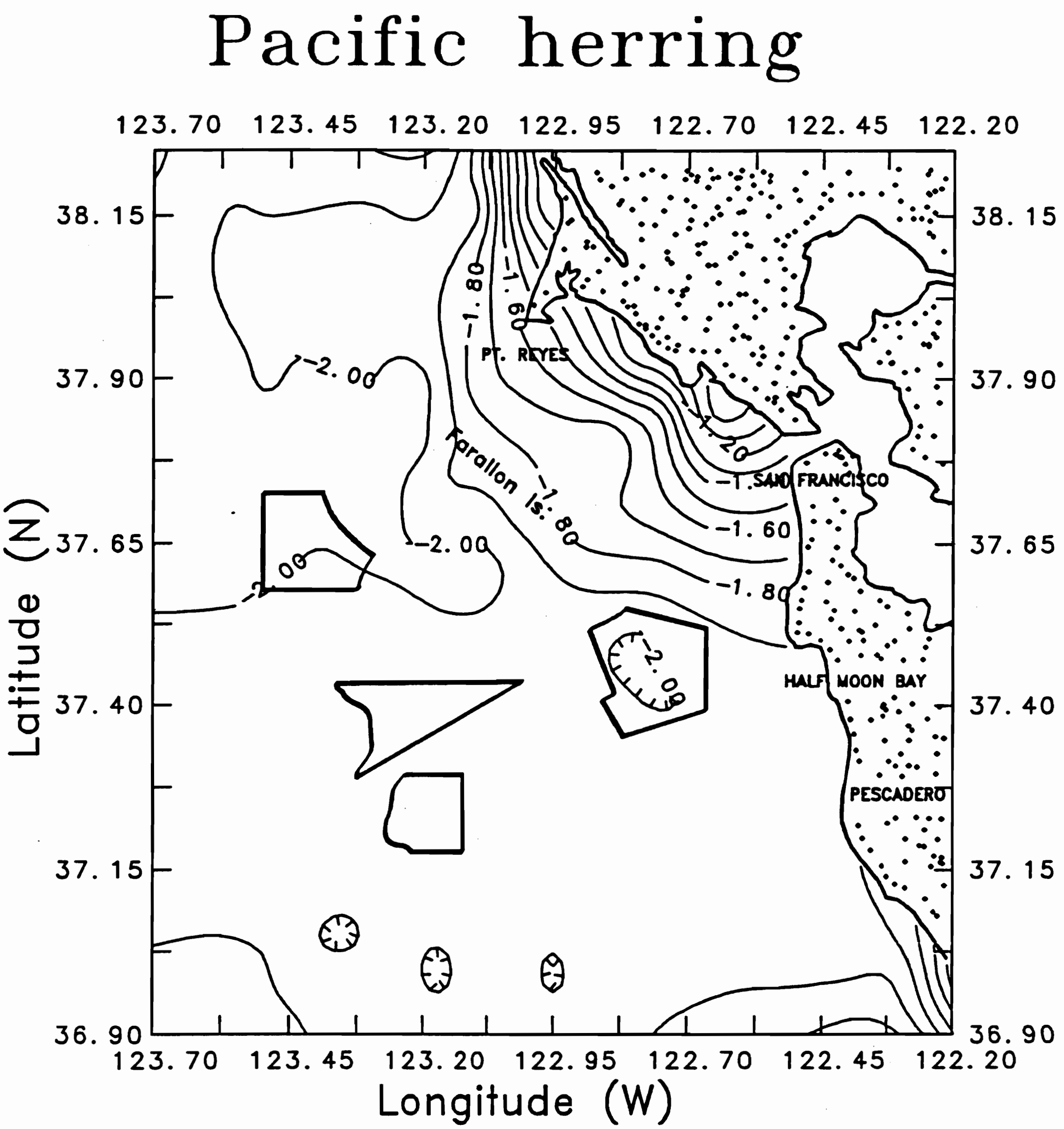


Fig. 25. Contour plot of $\log_e$-transformed abundance of Pacific herring based on the Tiburon laboratory midwater trawl surveys.

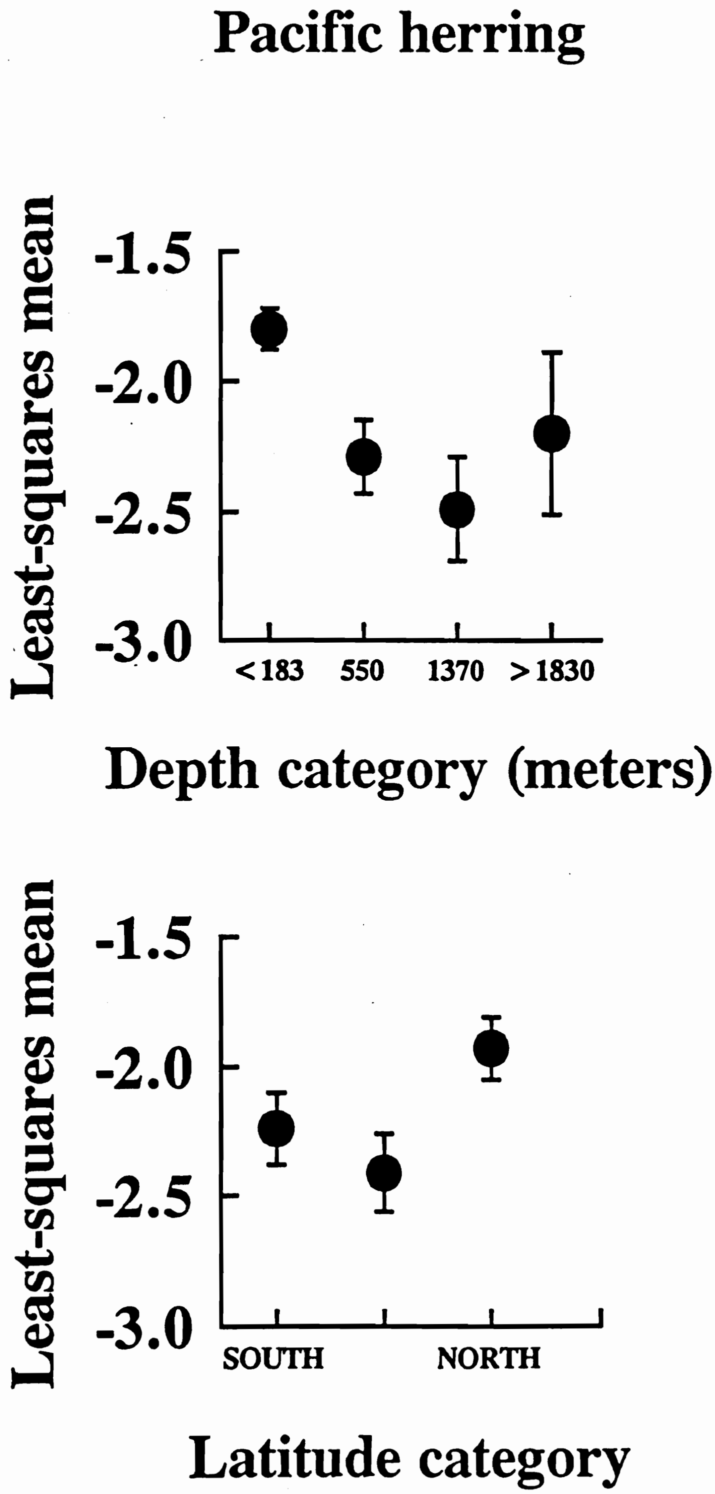


Fig. 26. Abundance of Pacific herring for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints on the graph. Standard errors of LSM's are indicated by vertical bars.

Pacific butterfish

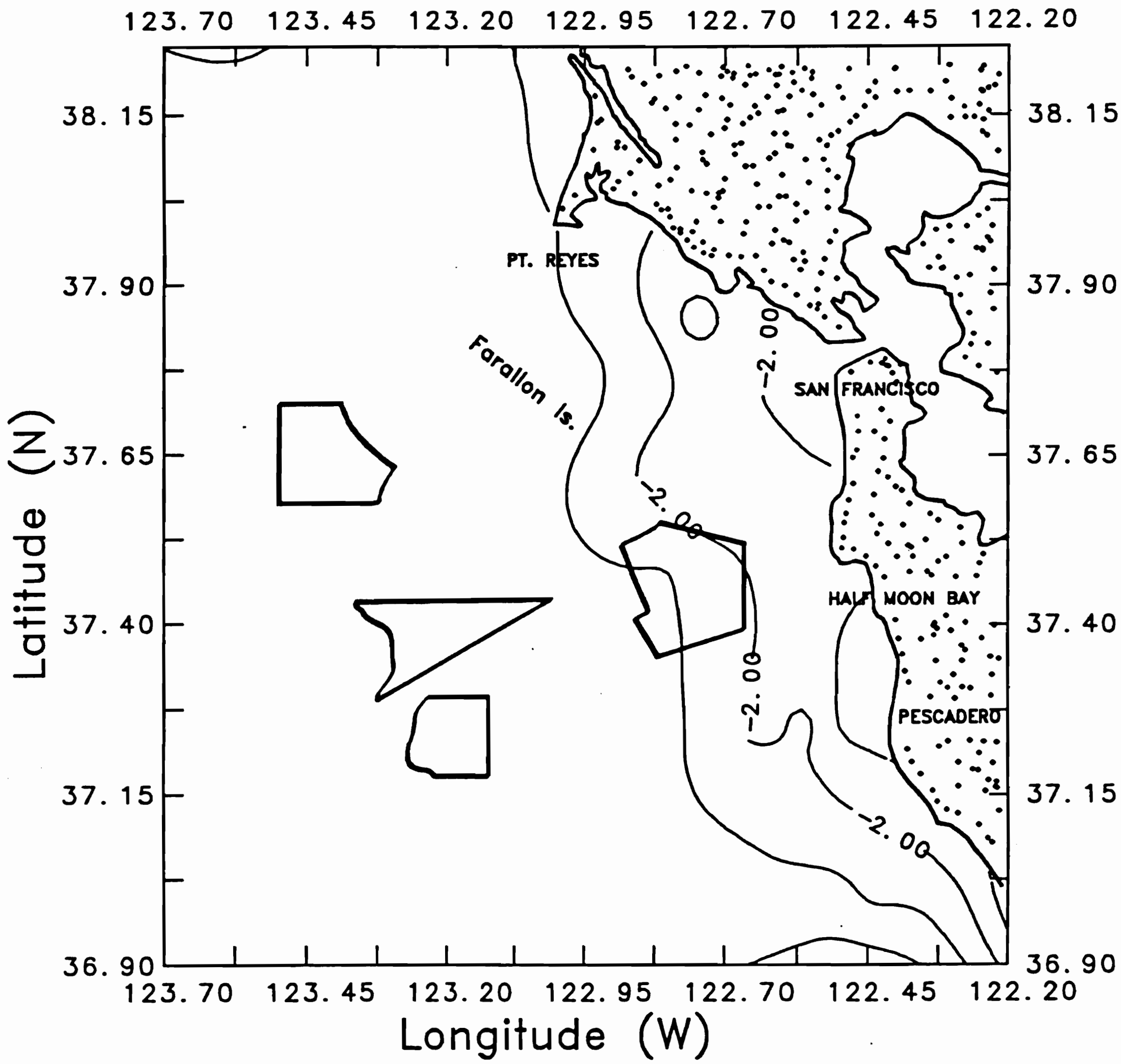


Fig. 27. Contour plot of $\log_e$-transformed abundance of Pacific butterfish based on the Tiburon laboratory midwater trawl surveys.

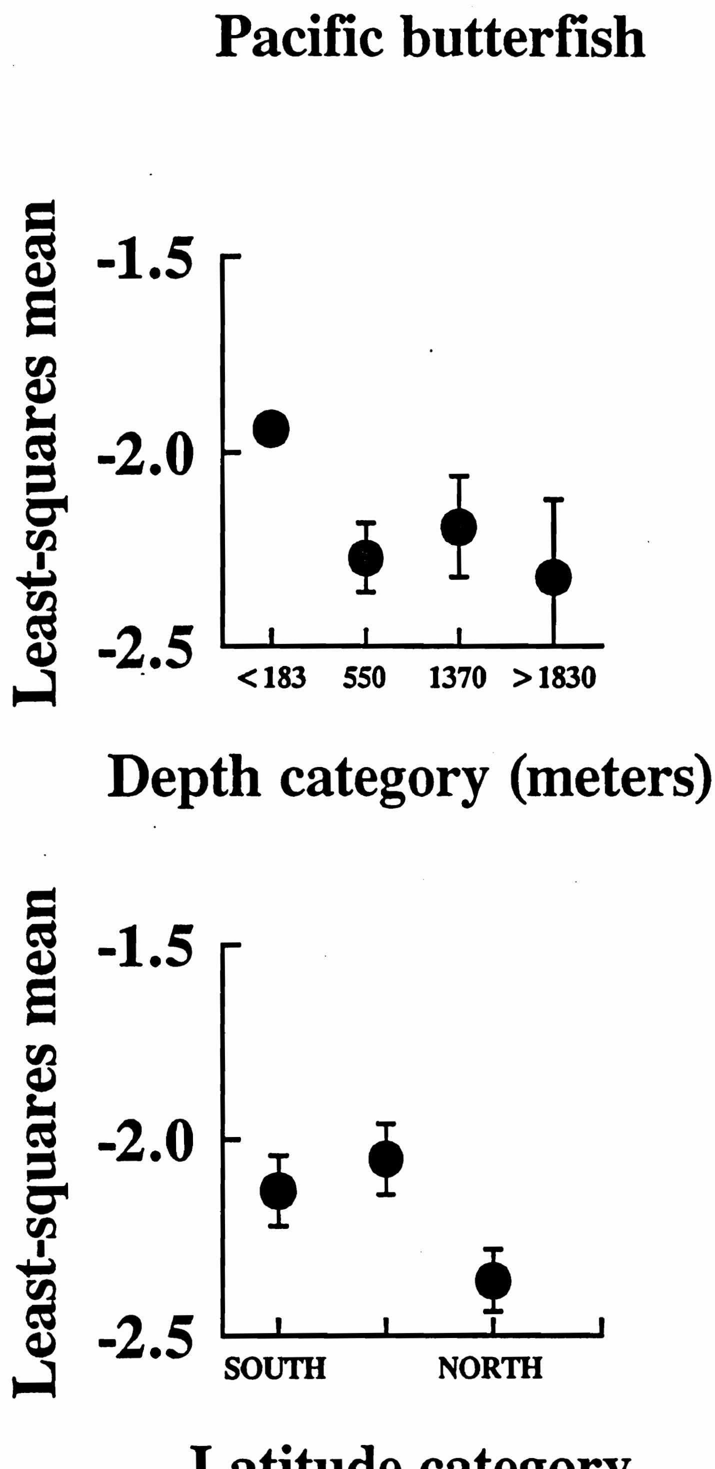


Fig. 28. Abundance of Pacific butterfish for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints on the graph. Standard errors of LSM's are indicated by vertical bars.

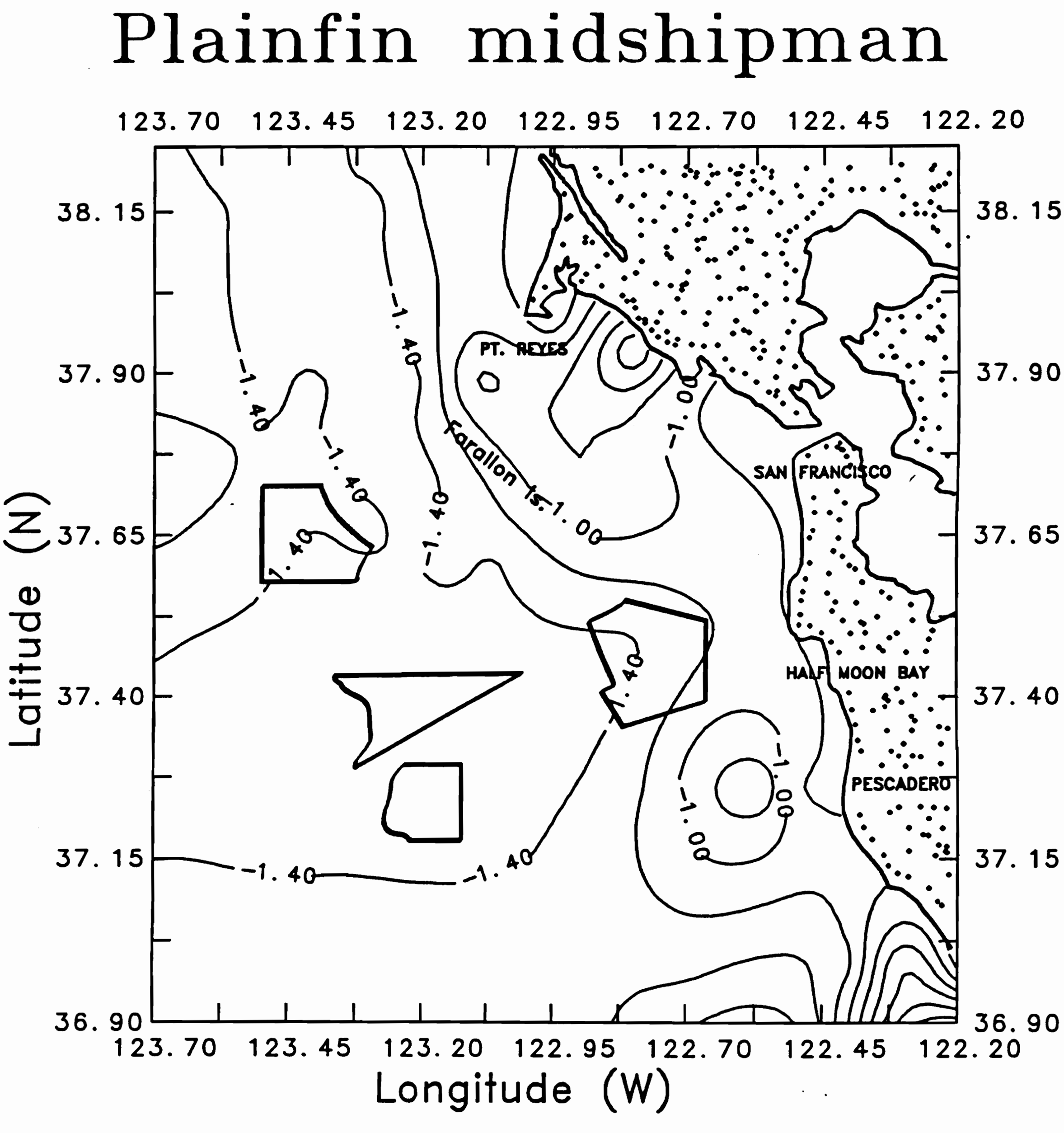


Fig. 29. Contour plot of $\log_e$-transformed abundance of plainfin midshipman based on the Tiburon laboratory midwater trawl surveys.

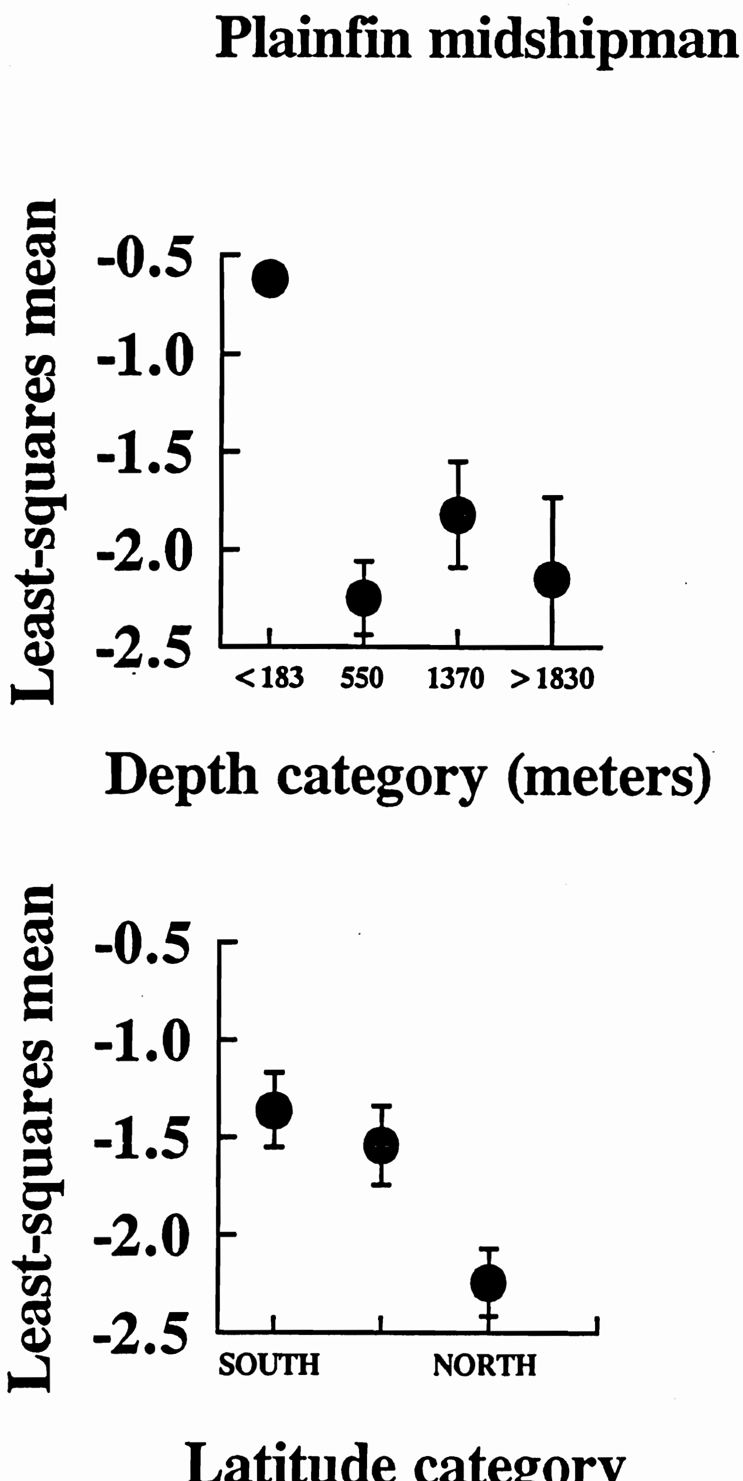


Fig. 30. Abundance of plainfin midshipman for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

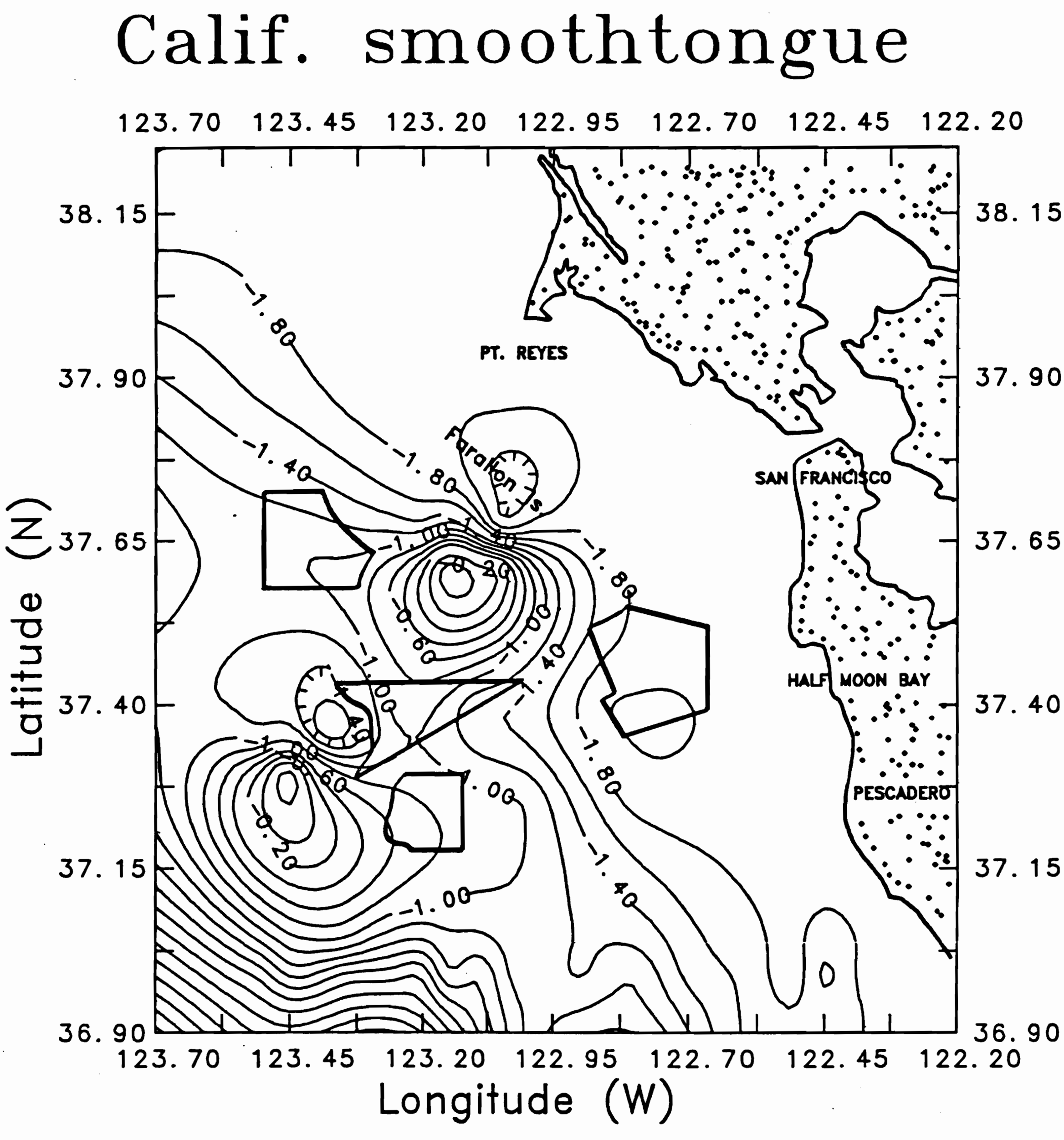


Fig. 31. Contour plot of log_e-transformed abundance of California smoothtongue based on the Tiburon laboratory midwater trawl surveys.

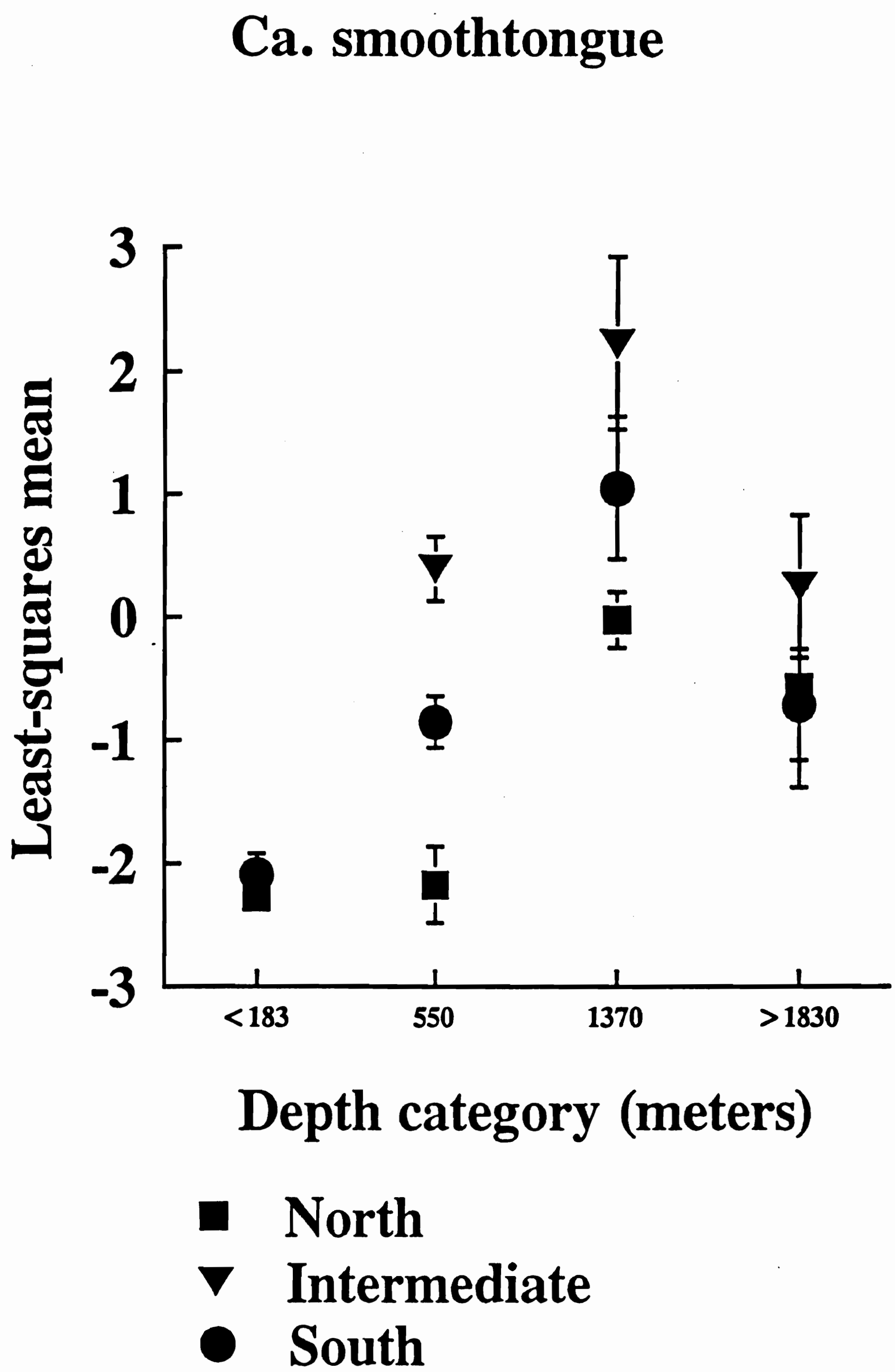
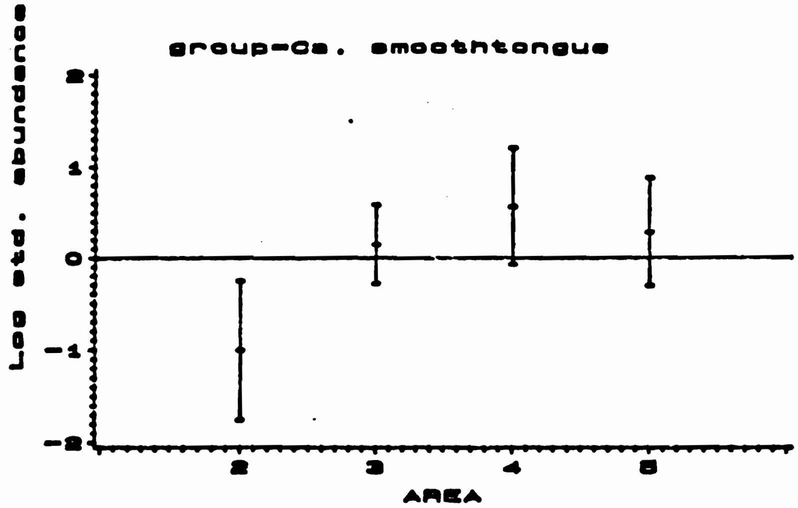


Fig. 32. Abundance of California smoothtongue for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.



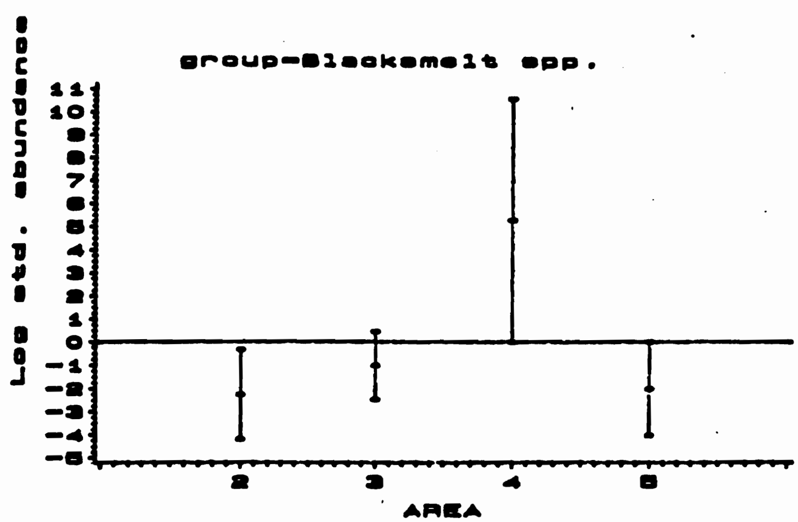


Fig. 33. Standardized mean $\log_e$-transformed abundance of California smoothtongue and blacksmelt (all species) for the EPA study areas with jackknifed 95% confidence intervals (vertical lines). Values are standardized by subtracting the mean over areas, so a value of zero is "average".

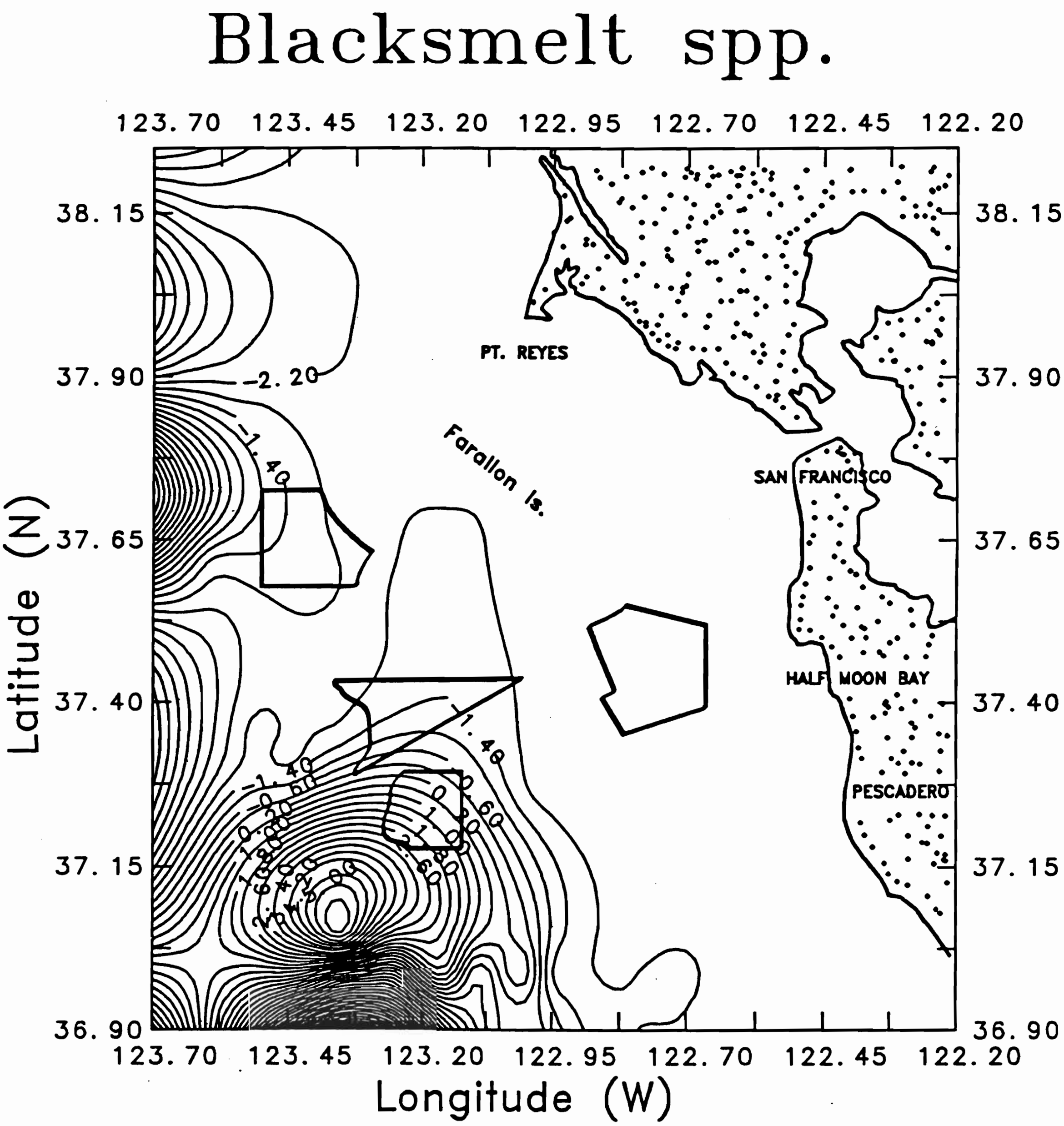


Fig. 34. Contour plot of $\log_e$-transformed abundance of blacksmelt (all species) based on the Tiburon laboratory midwater trawl surveys.

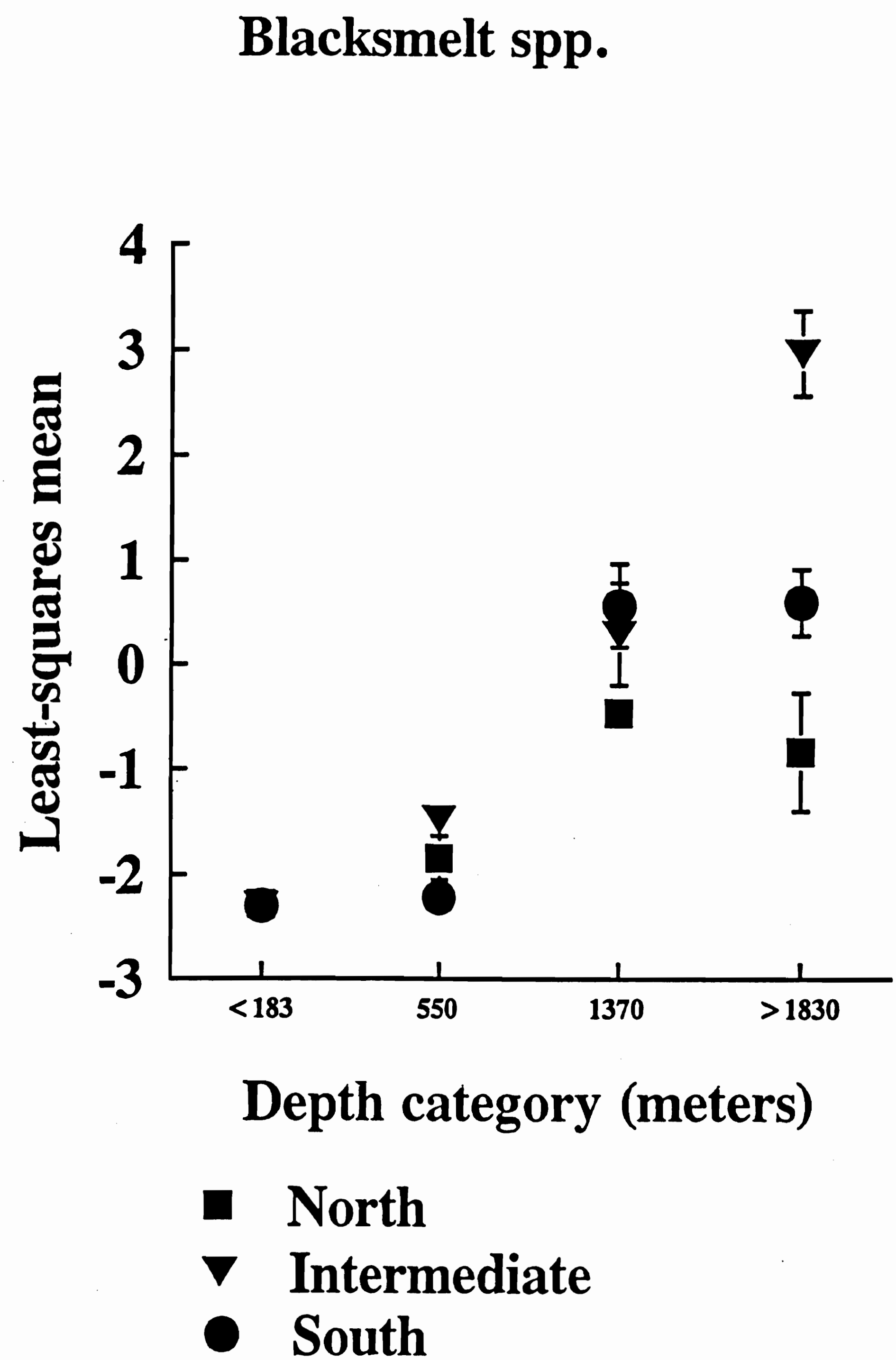


Fig. 35. Abundance of blacksmelt (all species) for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

Pacific argentine (juv)

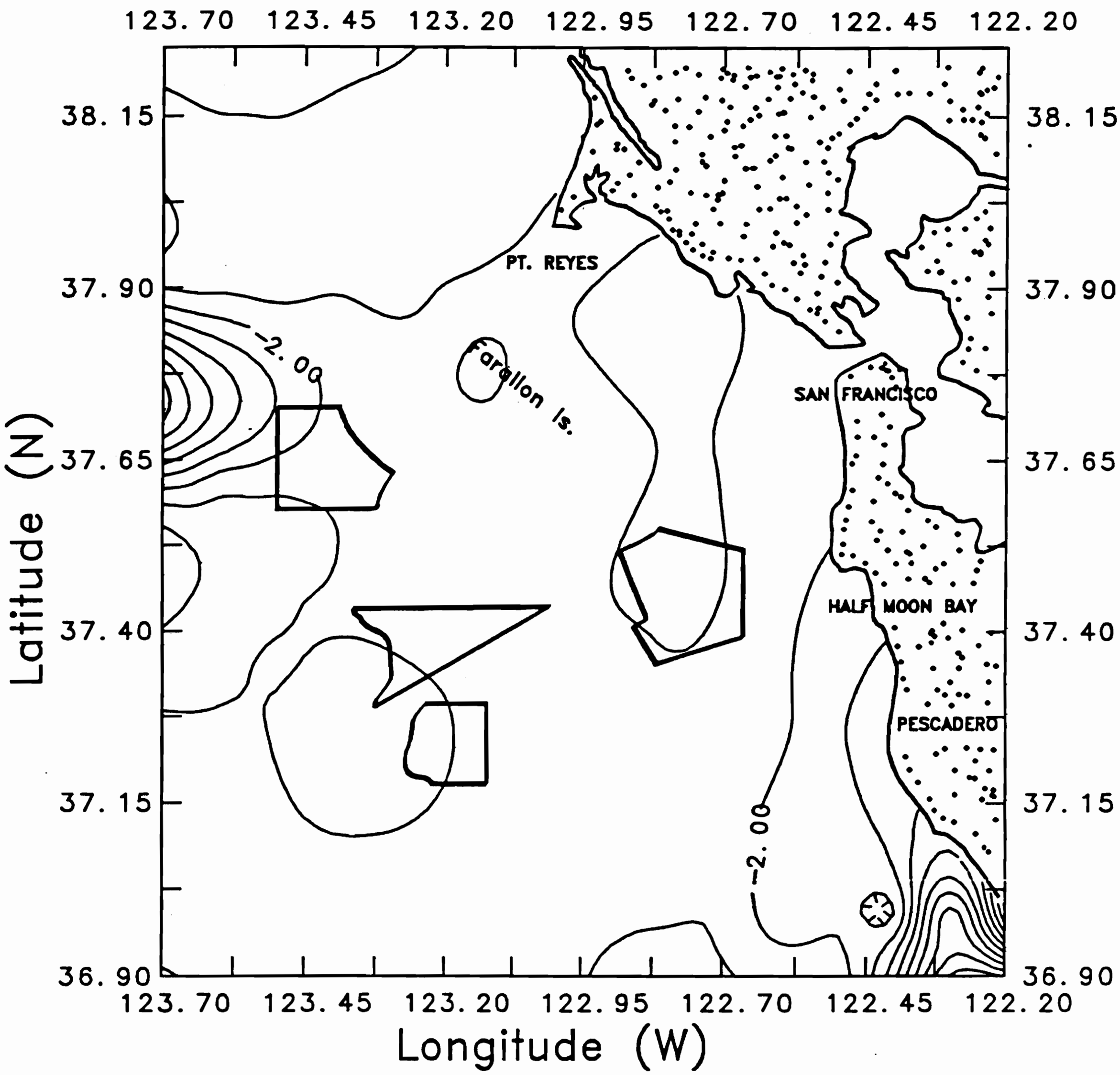


Fig. 36. Contour plot of $\log_e$-transformed abundance of Pacific argentine (juveniles) based on the Tiburon laboratory midwater trawl surveys.

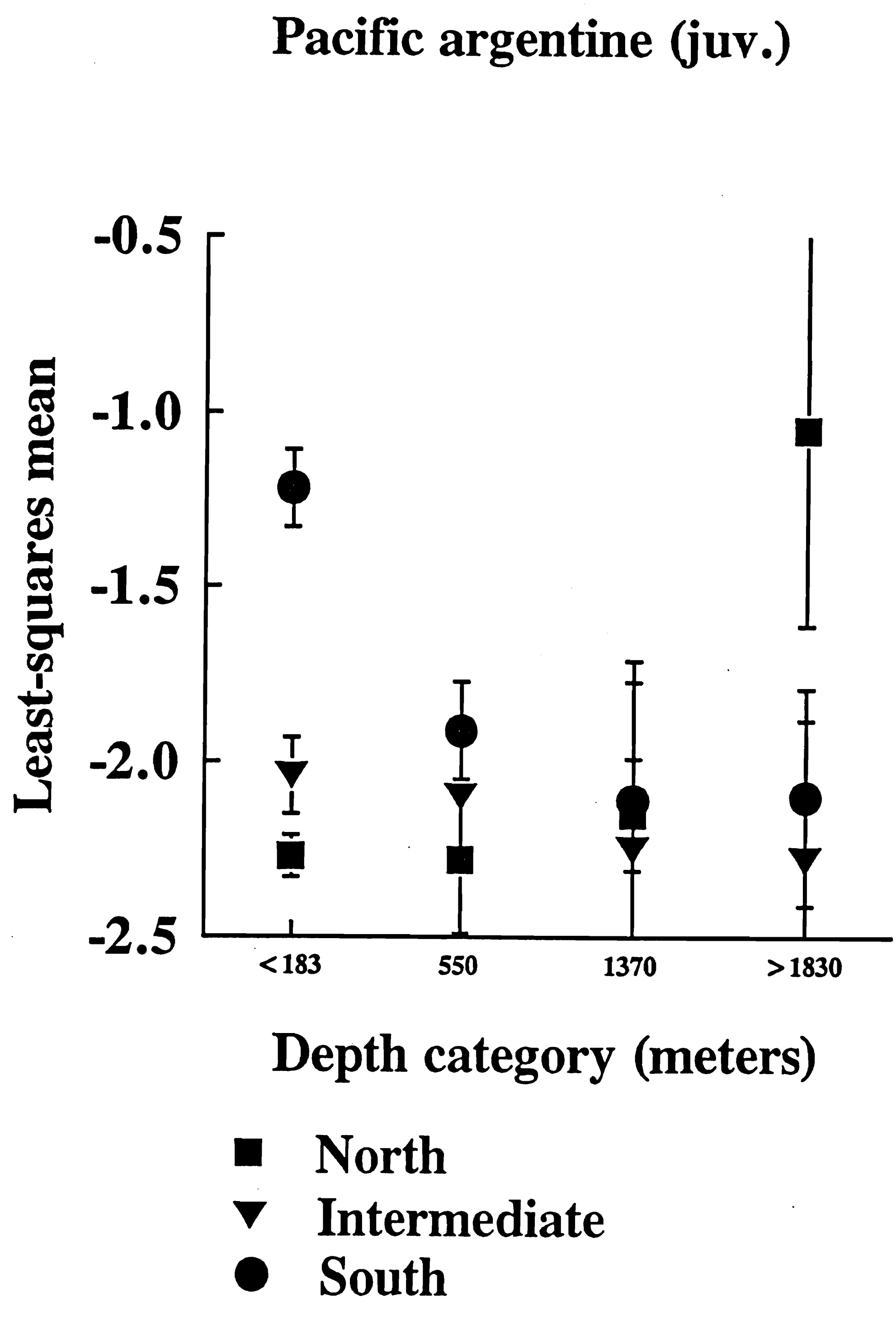


Fig. 37. Abundance of Pacific argentine (juveniles) for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

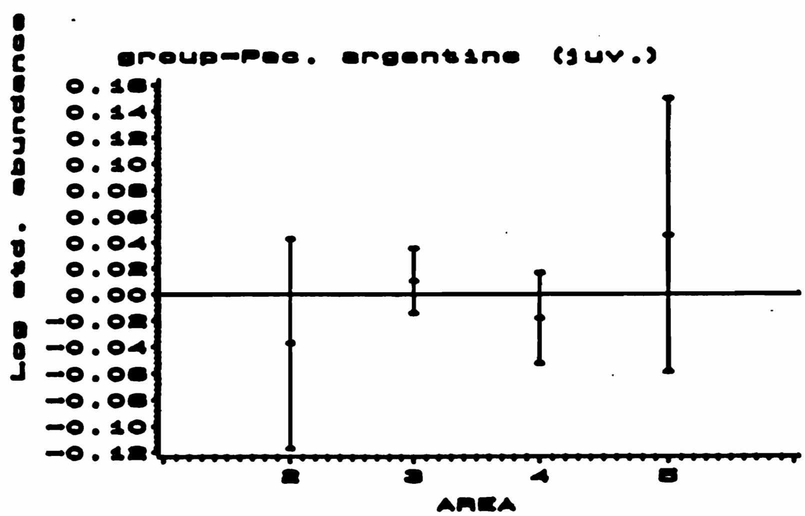


Fig. 38. Standardized mean $\log_e$-transformed abundance of Pacific argentine (juveniles) for the EPA study areas with jackknifed 95% confidence intervals (vertical lines). Values are standardized by subtracting the mean over areas, so a value of zero is "average".

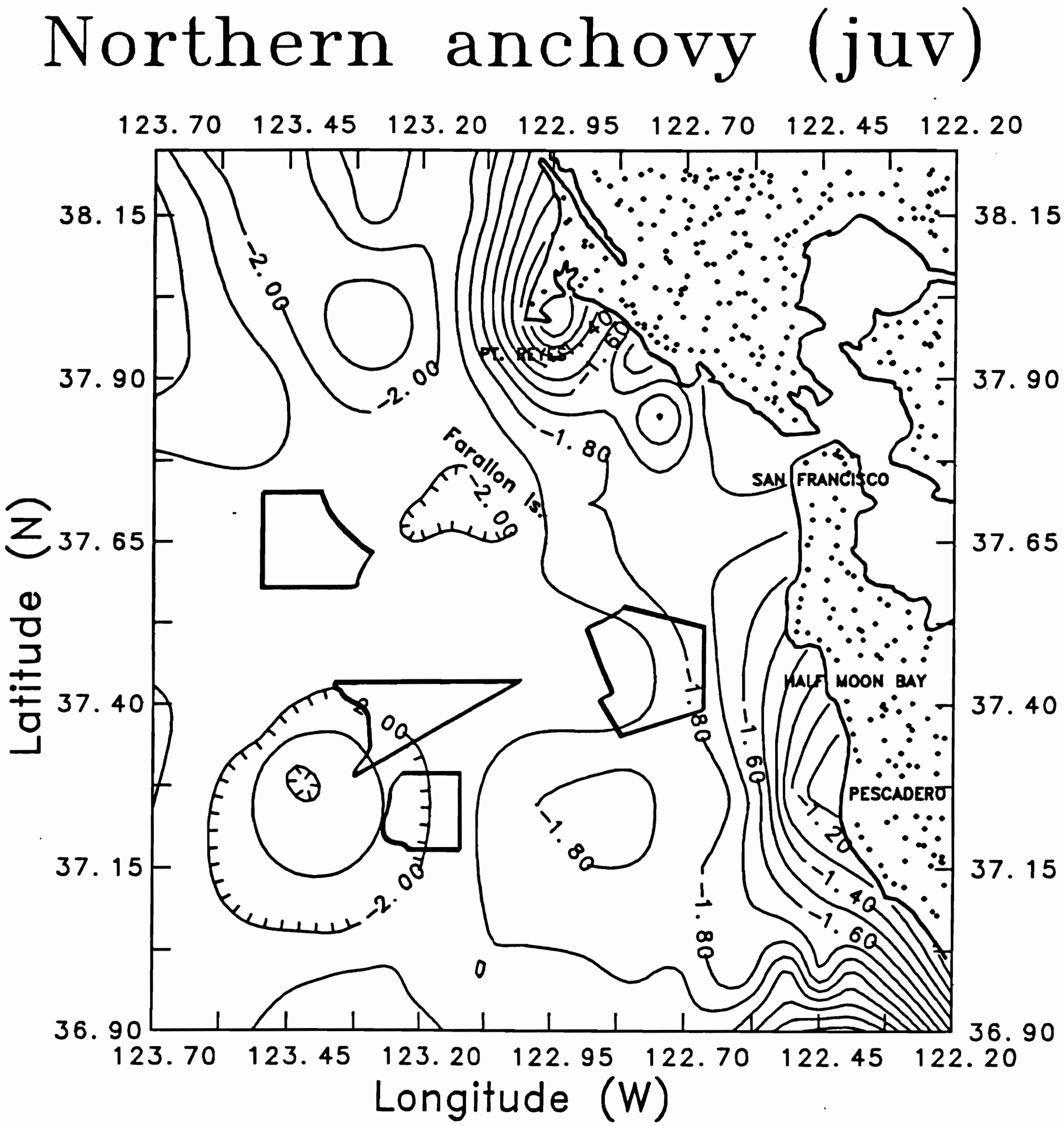


Fig. 39. Contour plot of $\log_e$-transformed abundance of northern anchovy (juveniles) based on the Tiburon laboratory midwater trawl surveys.

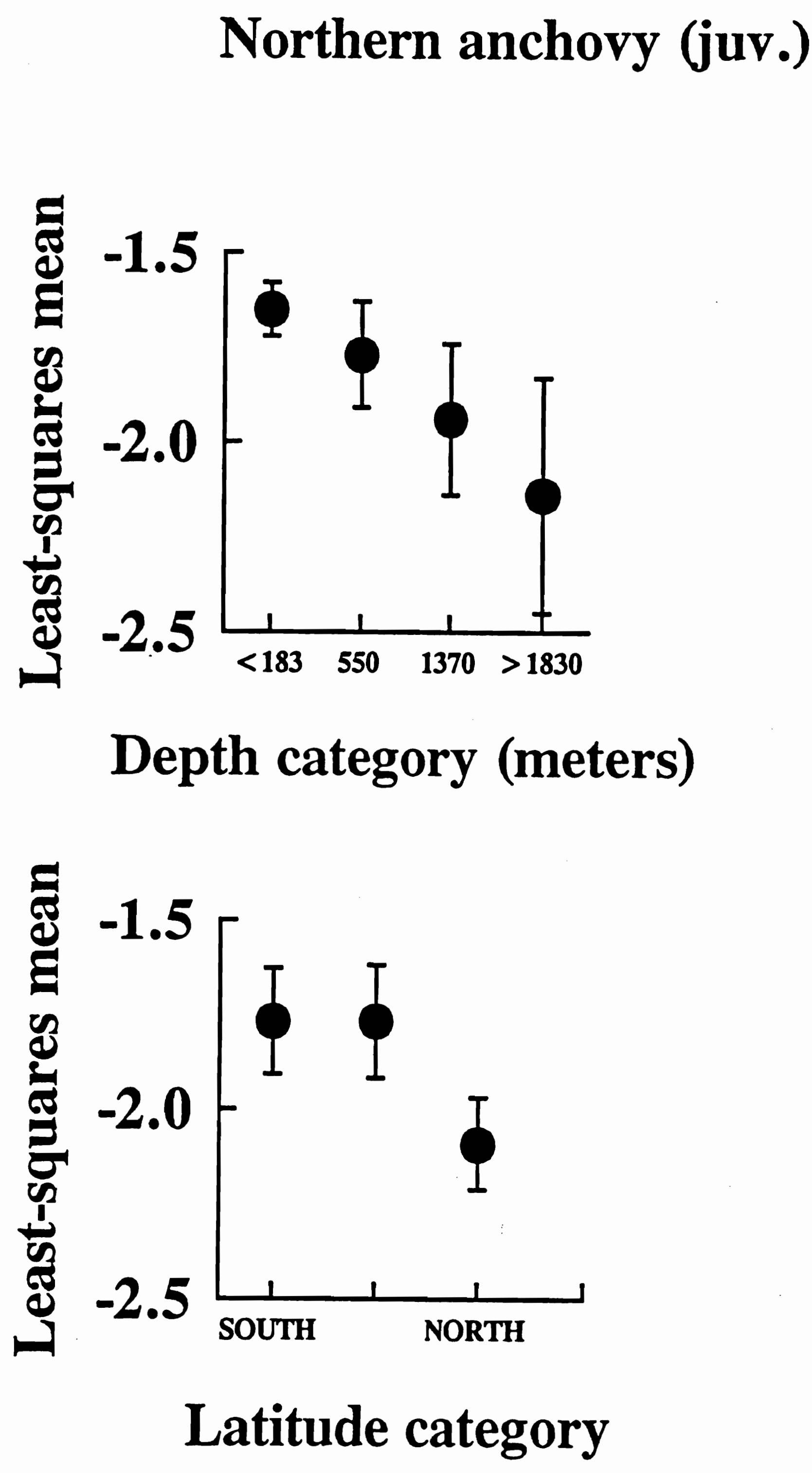
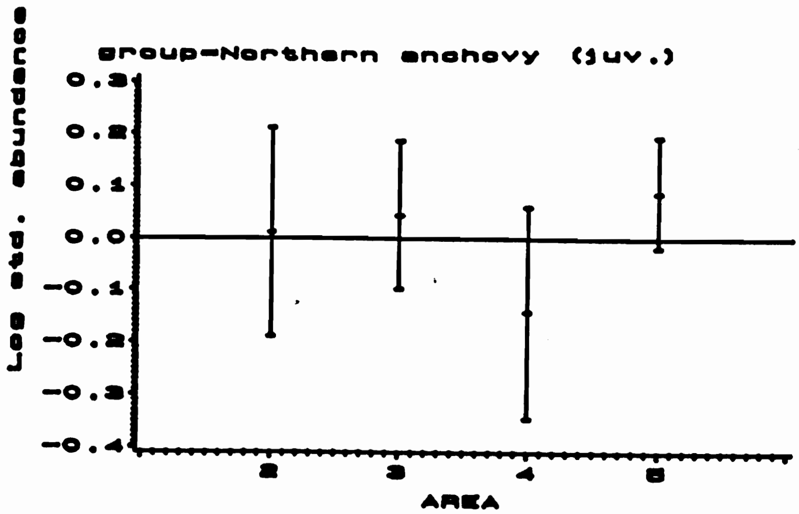


Fig. 40. Abundance of northern anchovy for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints on the graph. Standard errors of LSM's are indicated by vertical bars.



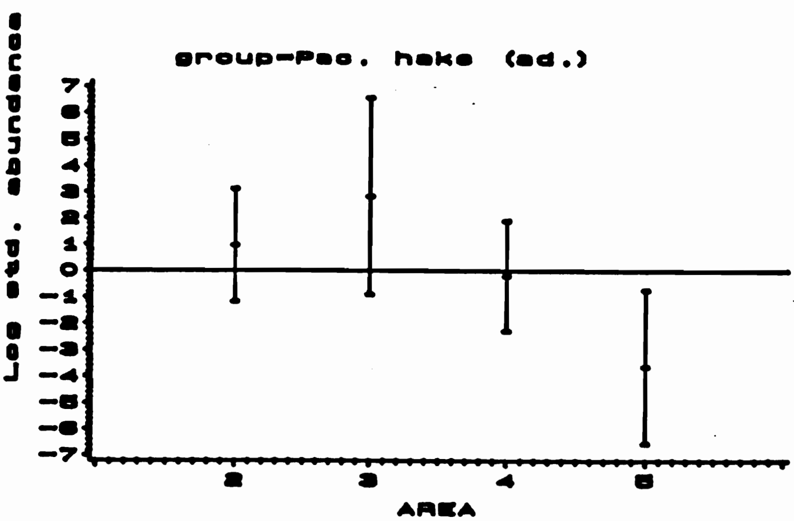


Fig. 41. Standardized mean $\log_e$-transformed abundance of northern anchovy juveniles and Pacific hake adults for the EPA study areas with jackknifed 95% confidence intervals (vertical lines). Values are standardized by subtracting the mean over areas, so a value of zero is "average".

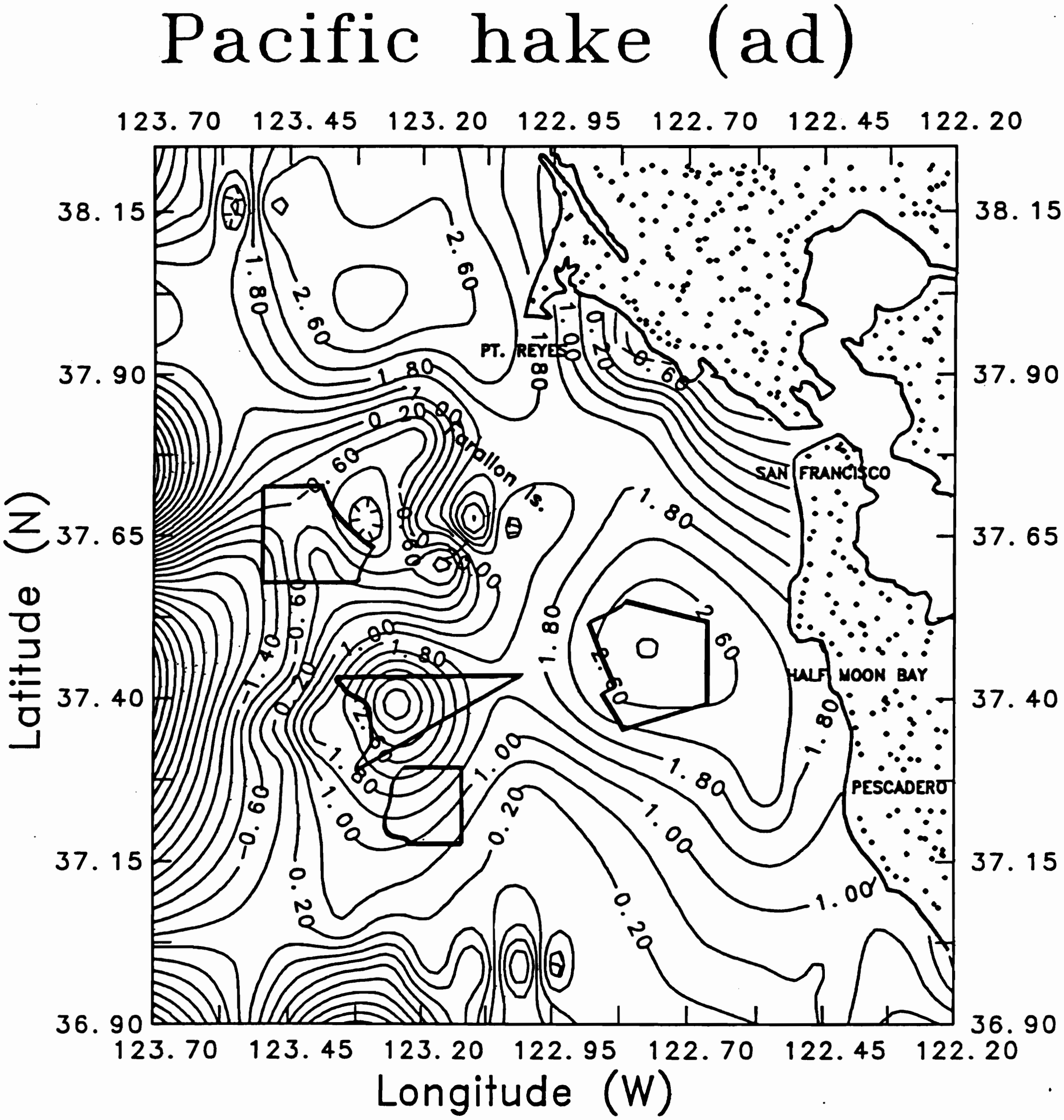


Fig. 42. Contour plot of $\log_e$-transformed abundance of Pacific hake (adults) based on the Tiburon laboratory midwater trawl surveys.

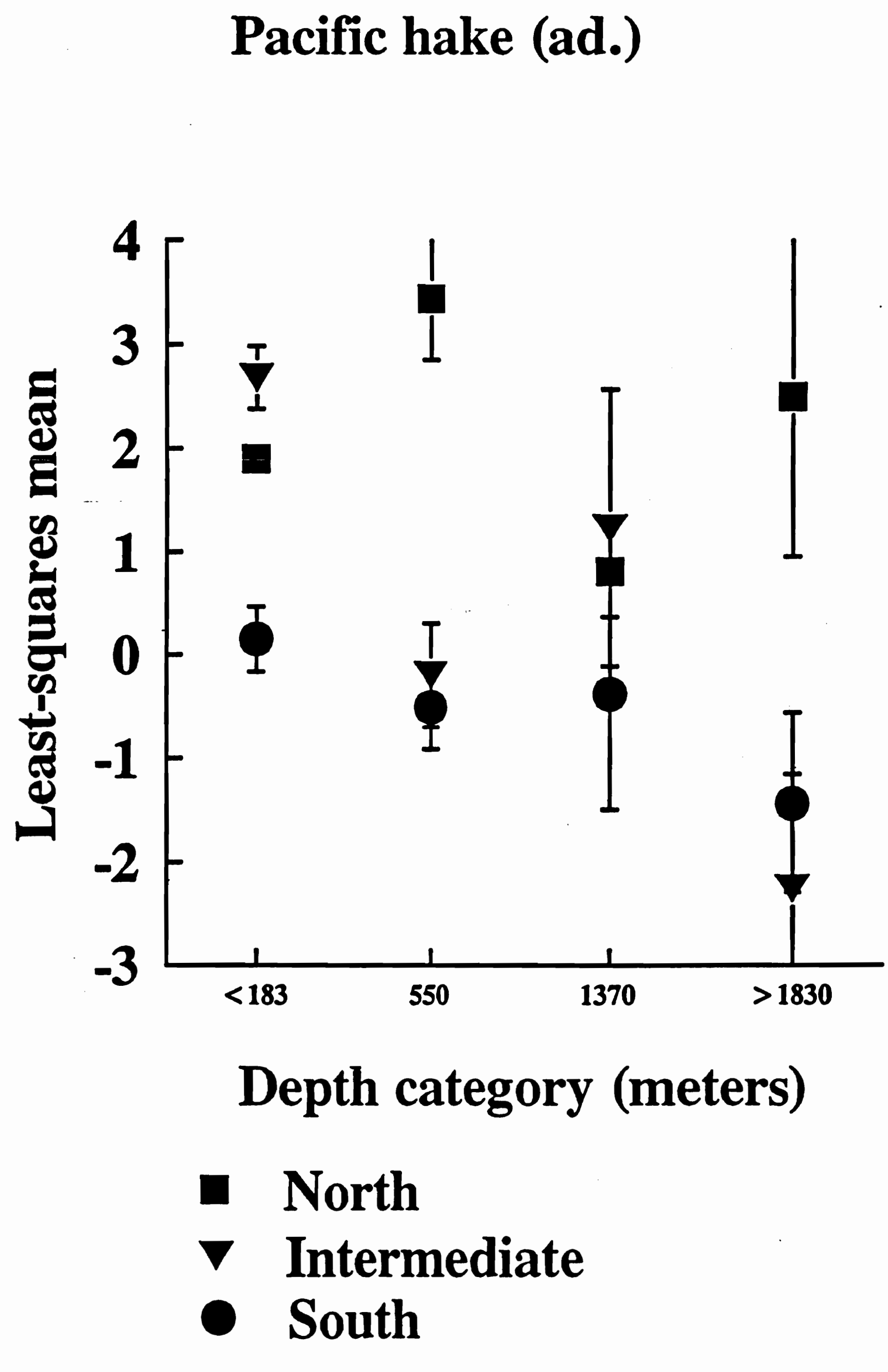


Fig. 43. Abundance of Pacific hake (adults) for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

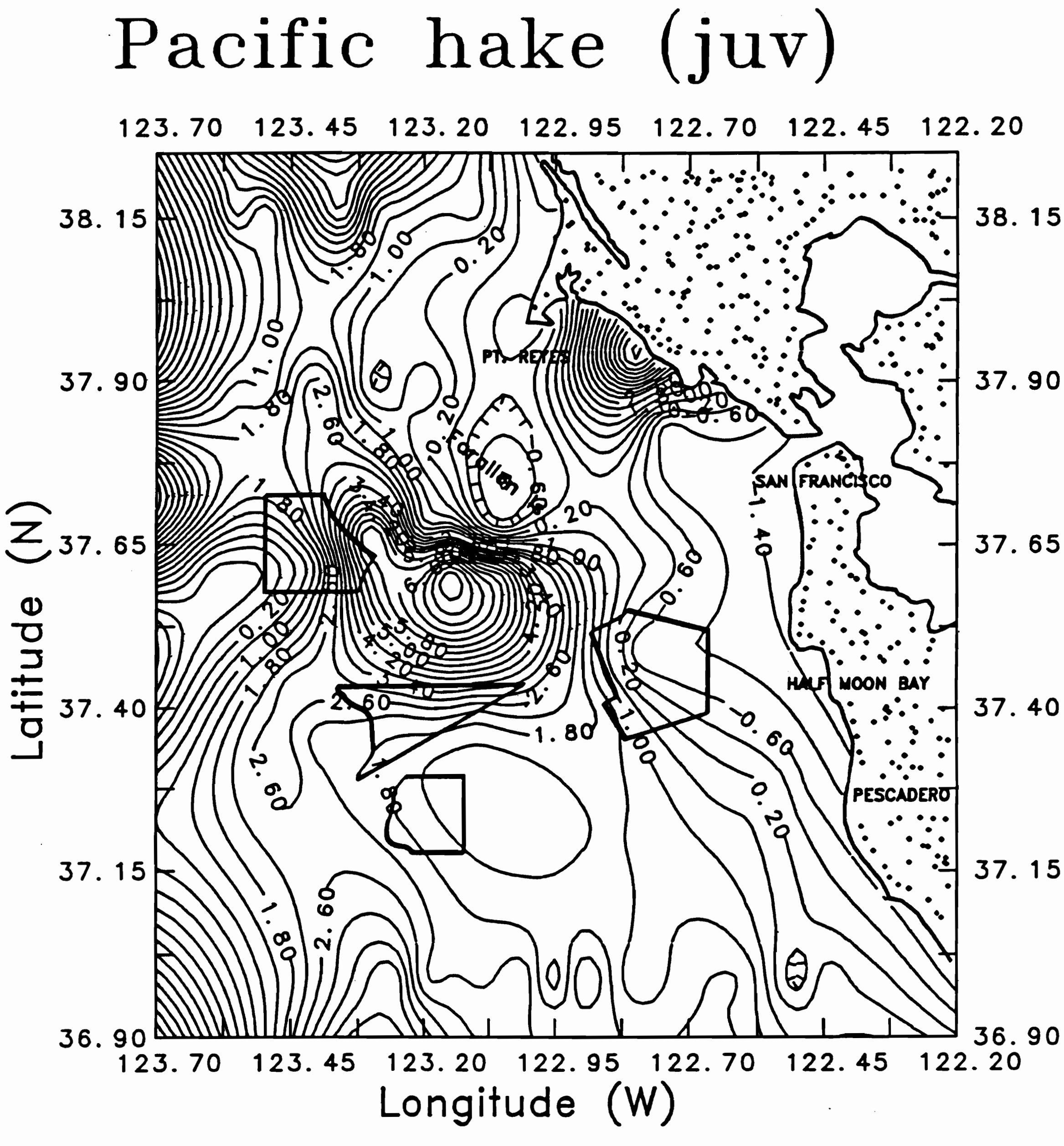
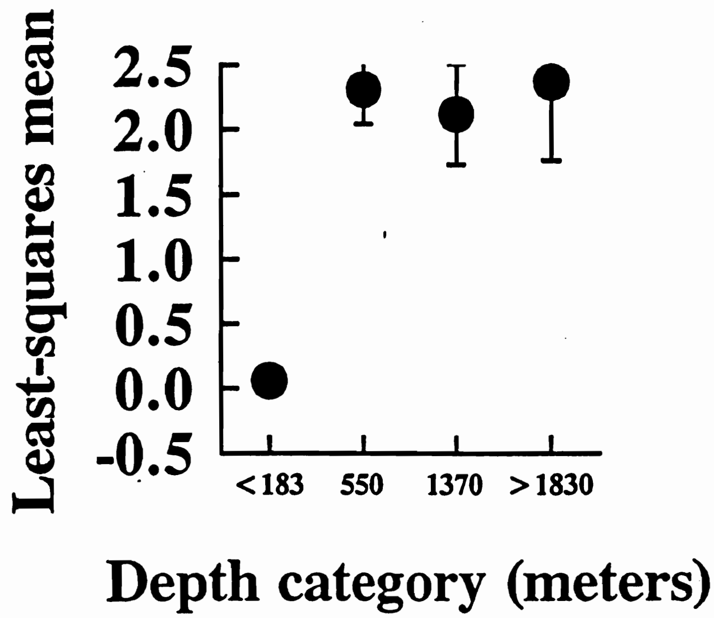


Fig. 44. Contour plot of $\log_e$-transformed abundance of Pacific hake (juveniles) based on the Tiburon laboratory midwater trawl surveys.

Pacific hake (juv.)



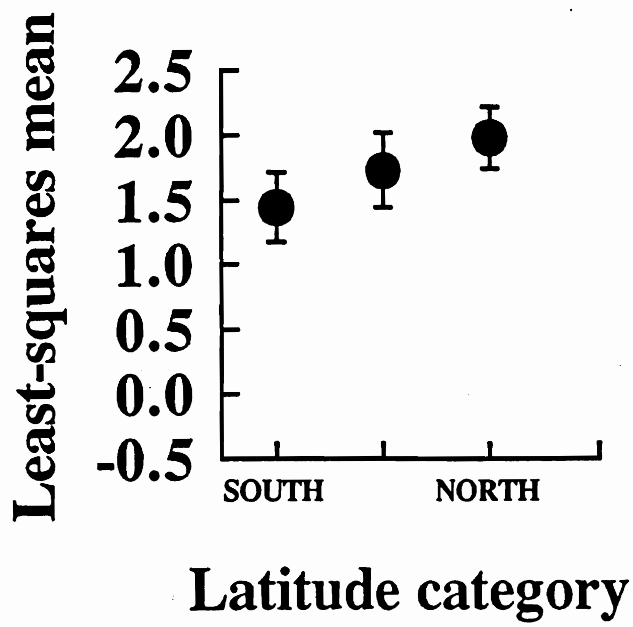


Fig. 45. Abundance of Pacific hake (juveniles) for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

Spiny dogfish

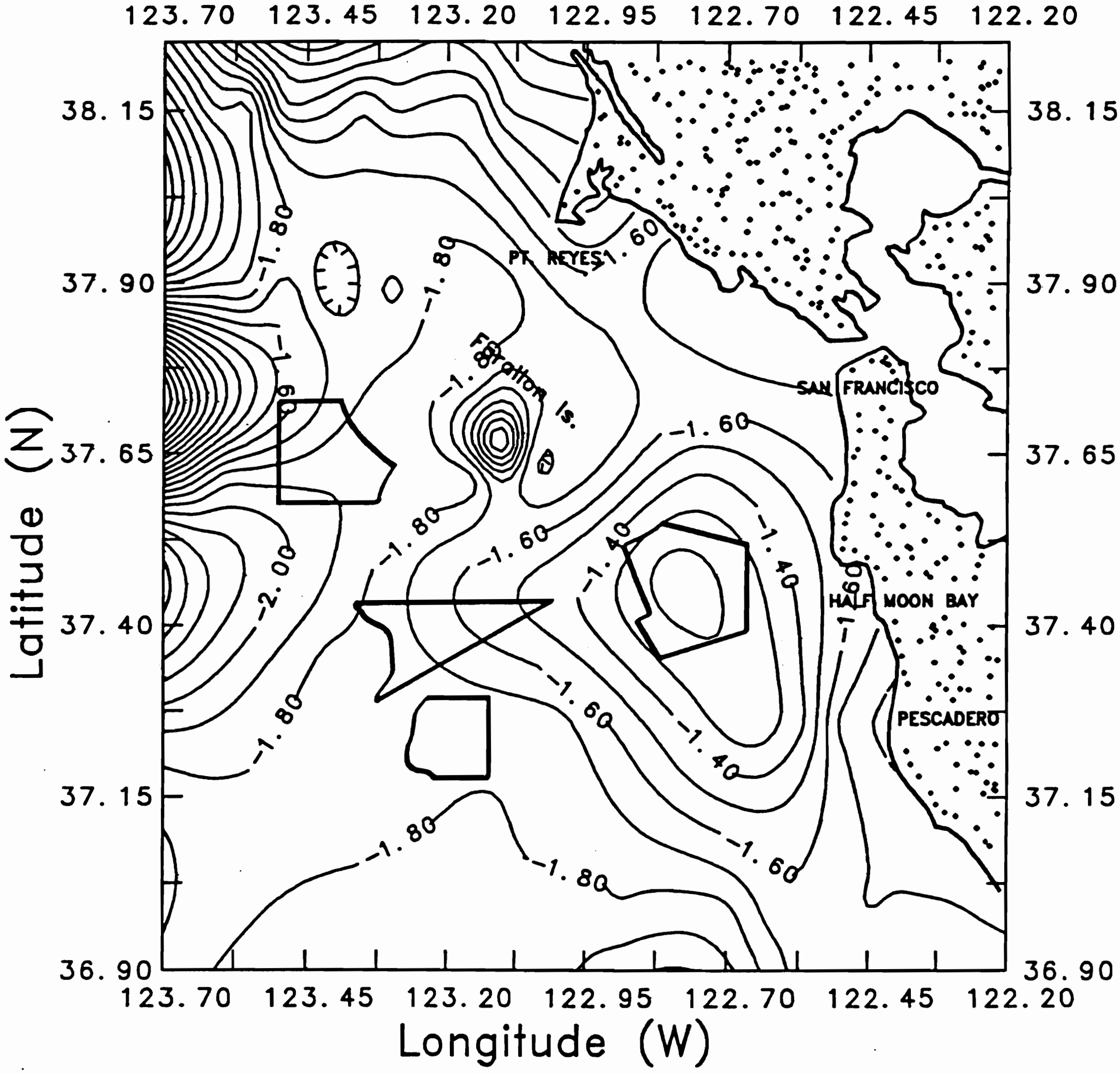


Fig. 46. Contour plot of $\log_e$-transformed abundance of spiny dogfish based on the Tiburon laboratory midwater trawl surveys.

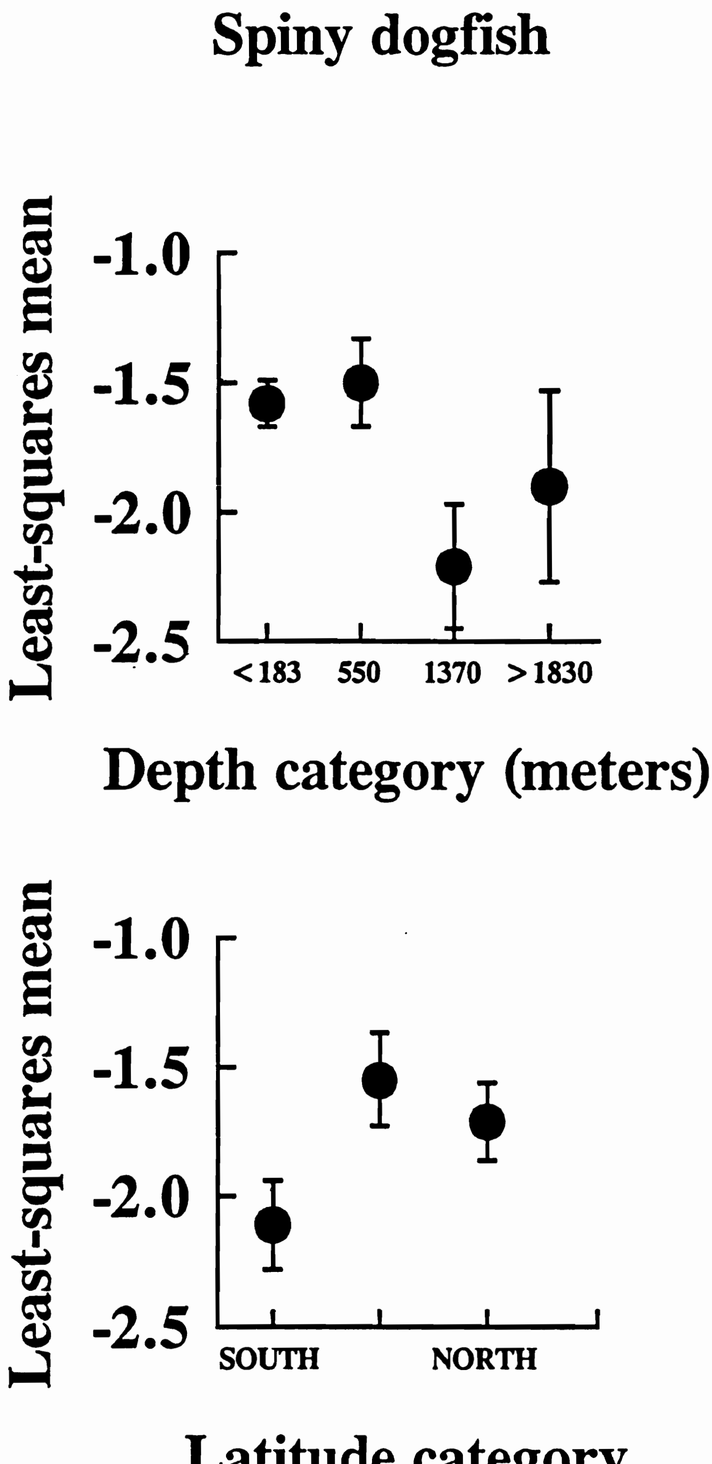


Fig. 47. Abundance of spiny dogfish for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints on the graph. Standard errors of LSM's are indicated by vertical bars.

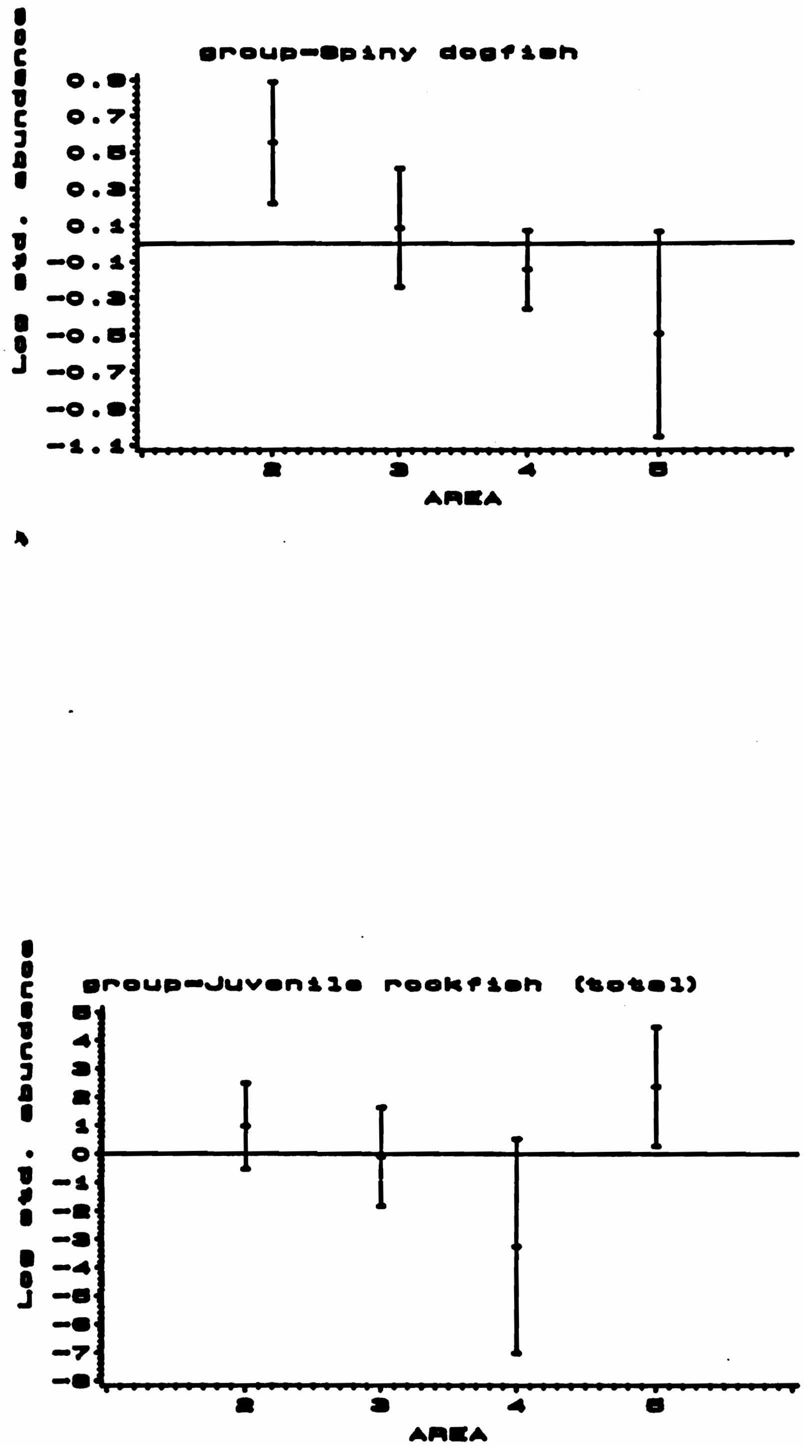


Fig. 48. Standardized mean $\log_e$-transformed abundance of spiny dogfish and total juvenile rockfish for the EPA study areas with jackknifed 95% confidence intervals (vertical lines). Values are standardized by subtracting the mean over areas, so a value of zero is "average".

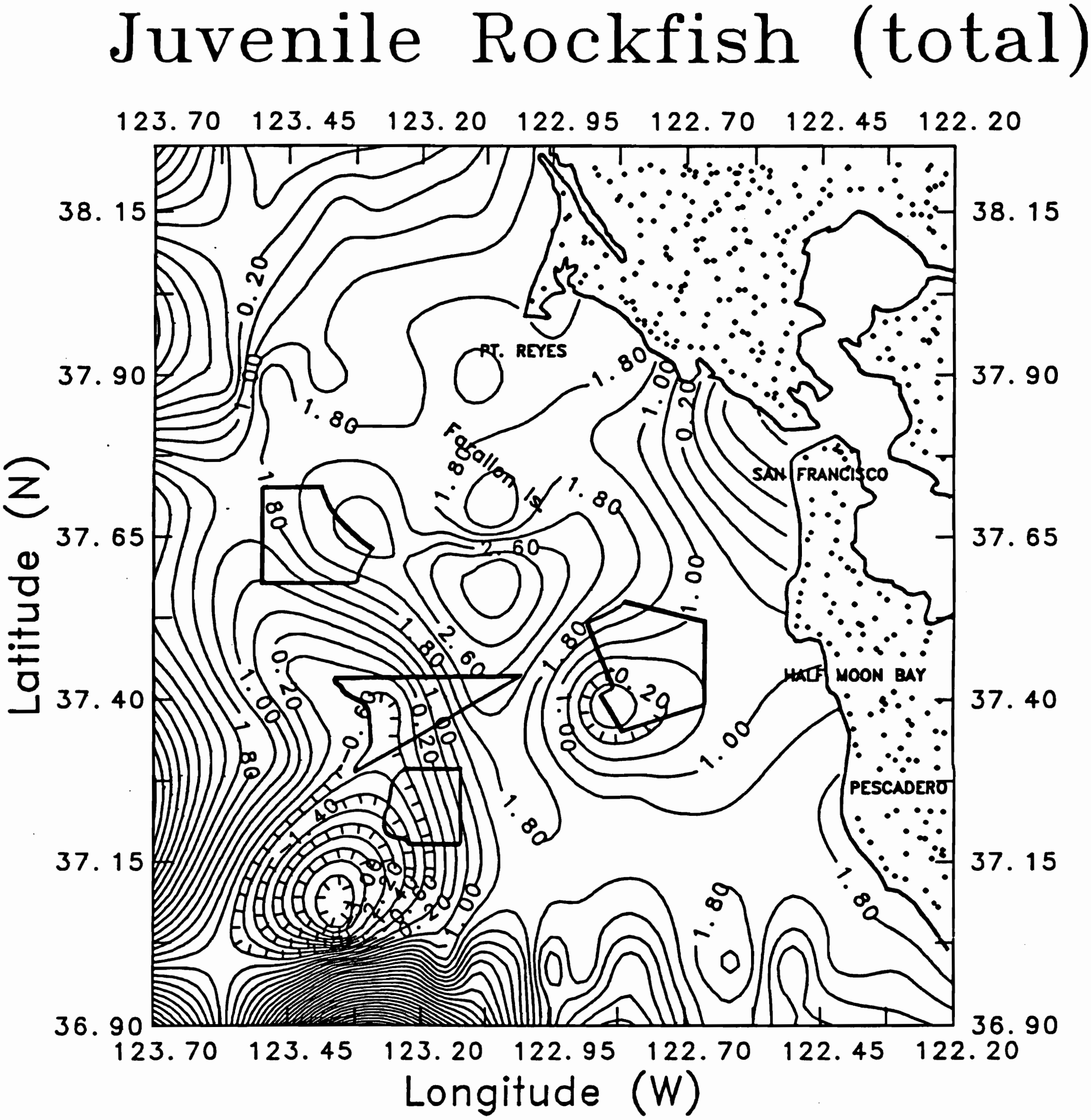


Fig. 49. Contour plot of $\log_e$-transformed abundance of juvenile rockfish (total) based on the Tiburon laboratory midwater trawl surveys.

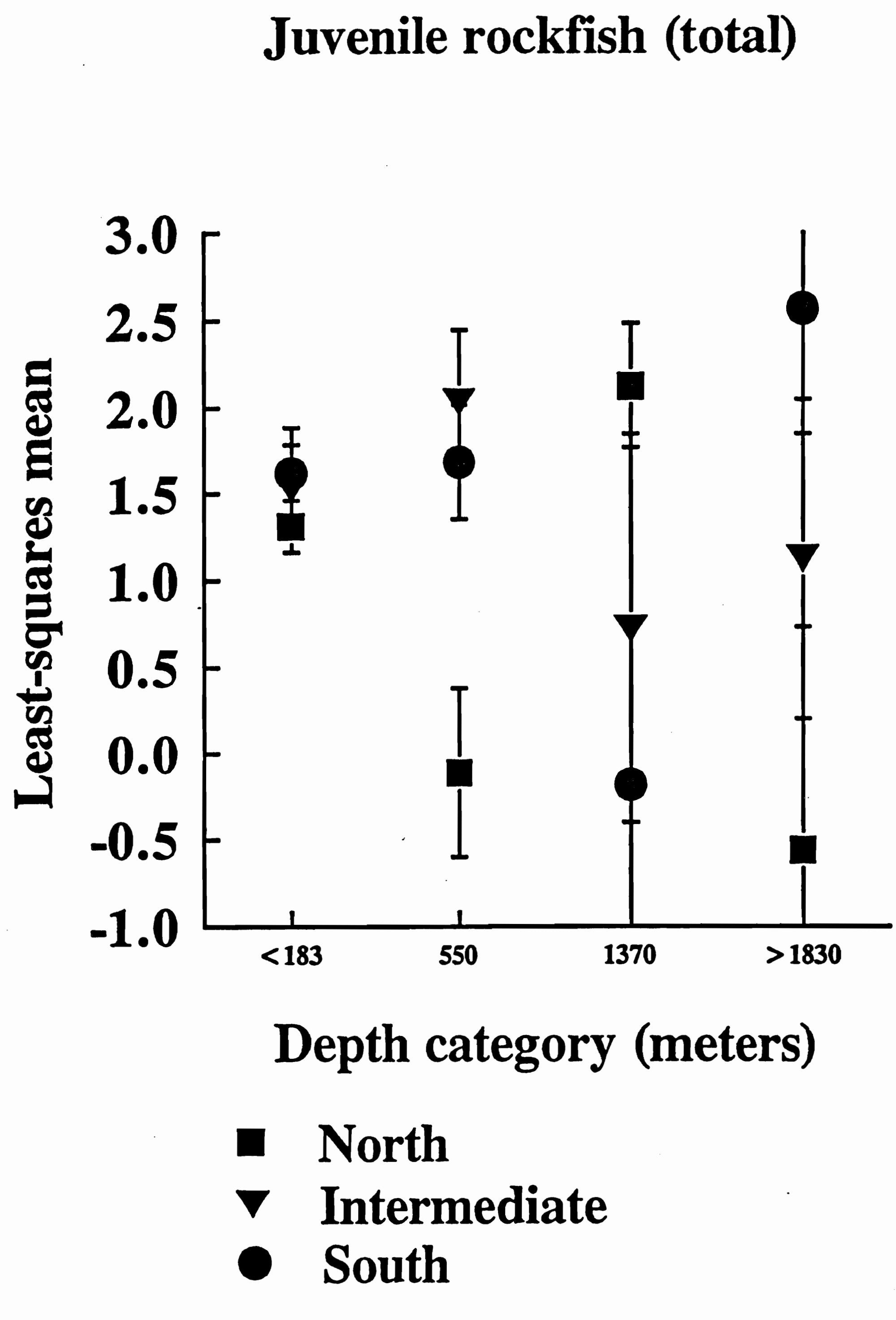


Fig. 50. Abundance of juvenile rockfish (all species) for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

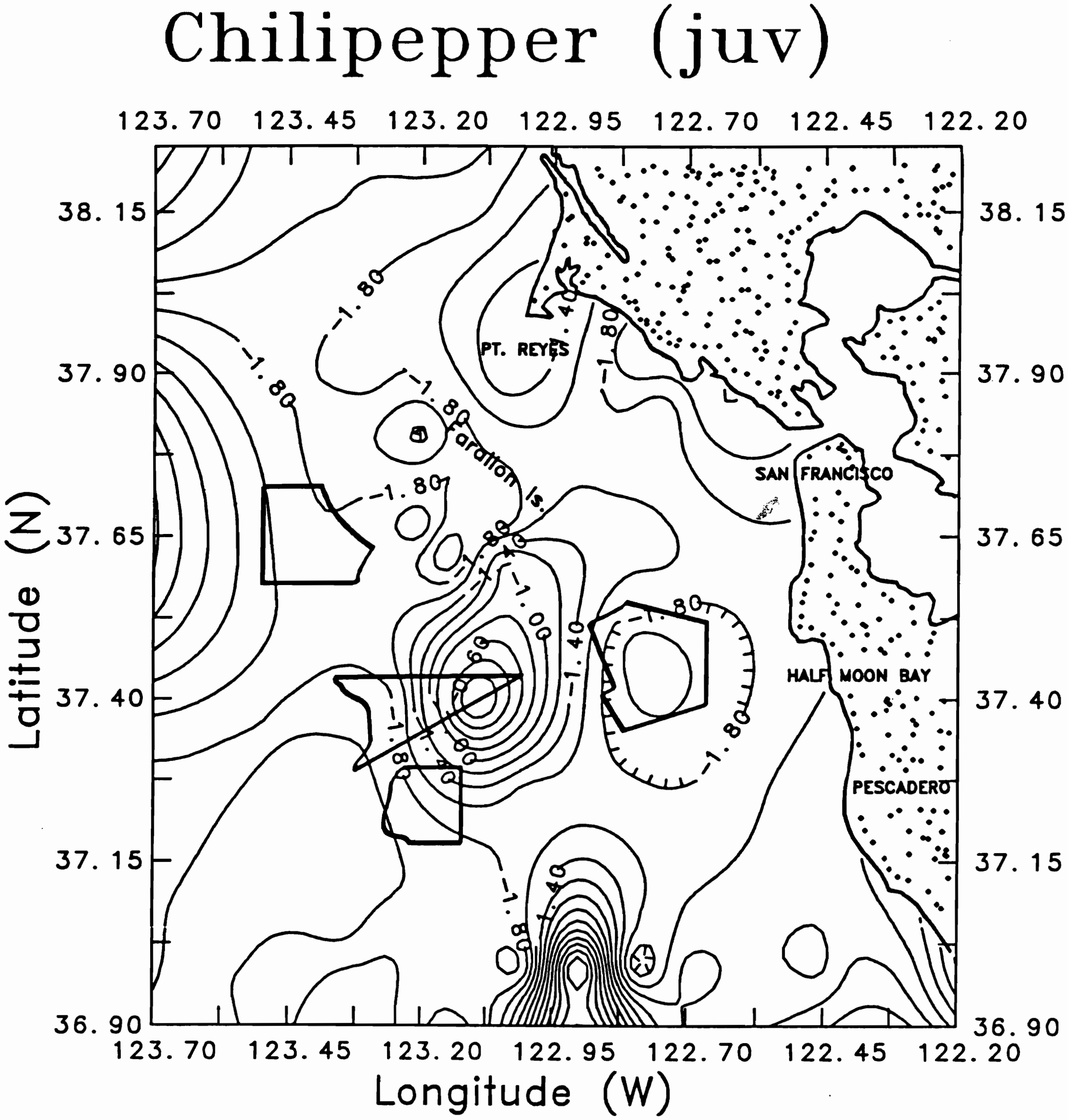


Fig. 51. Contour plot of $\log_e$-transformed abundance of chilipepper based on the Tiburon laboratory midwater trawl surveys.

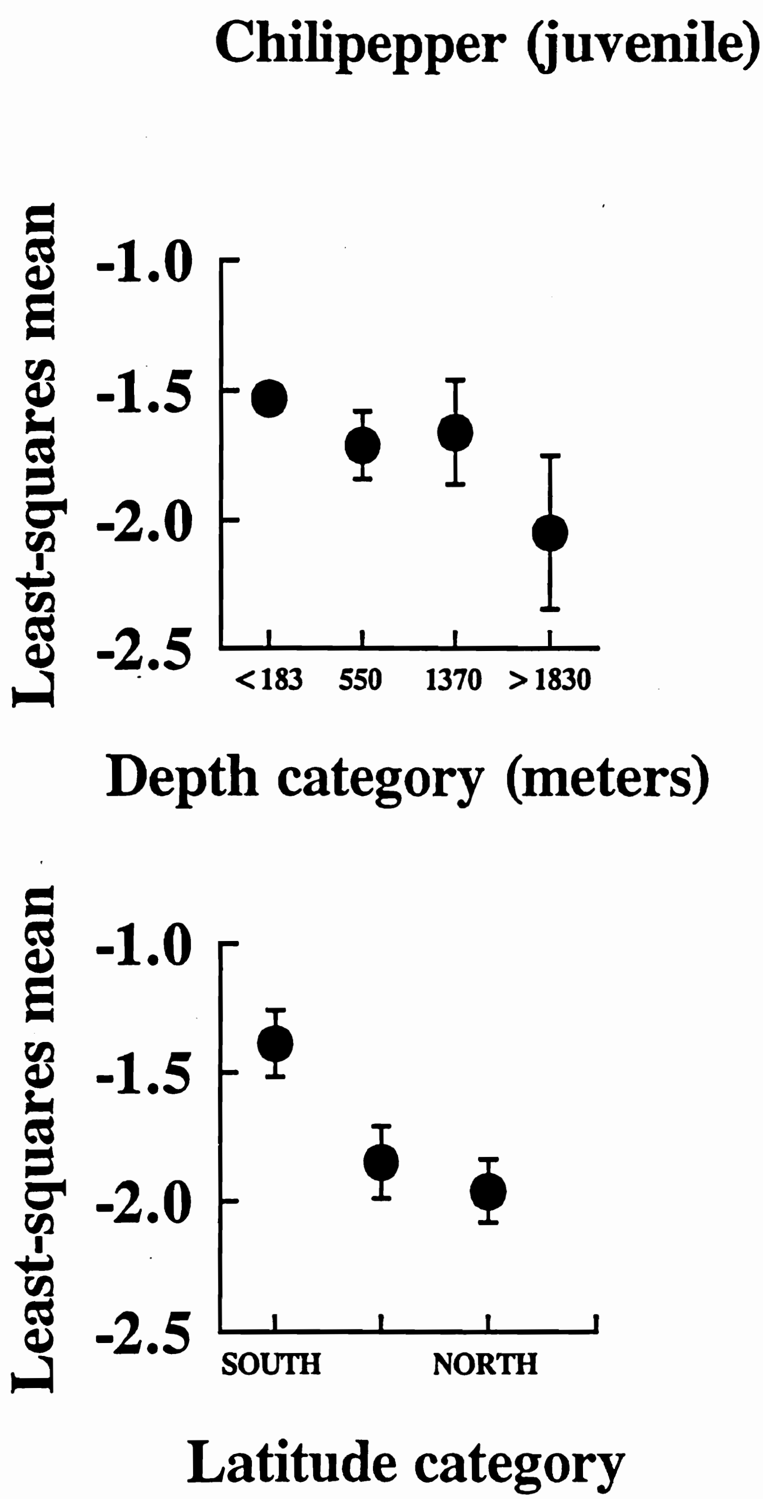
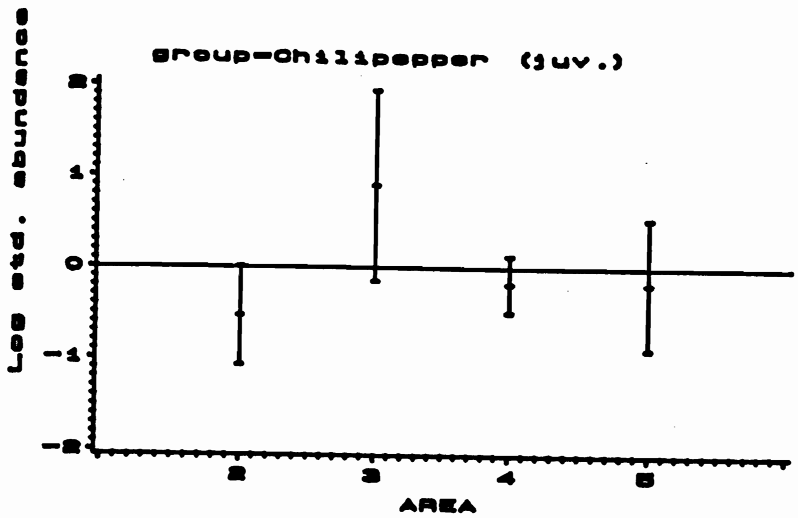


Fig. 52. Abundance of chilipepper (juveniles) for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.



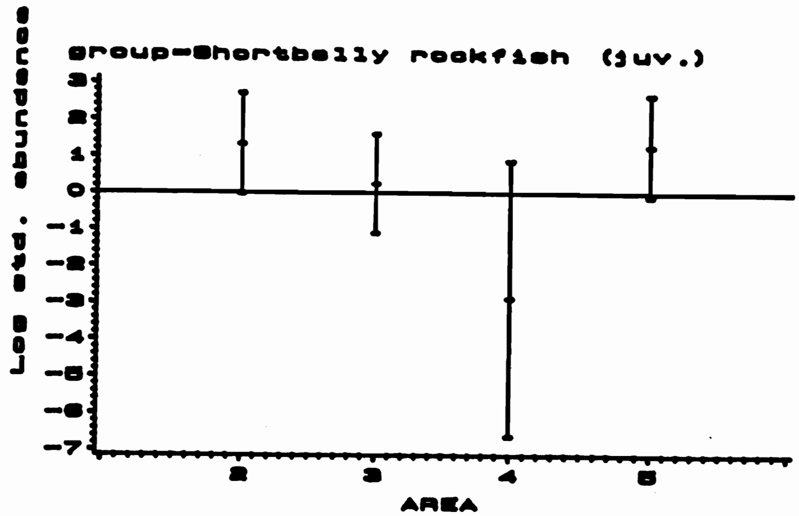


Fig. 53. Standardized mean $\log_e$-transformed abundance of chilipepper juveniles and shortbelly rockfish juveniles for the EPA study areas with 95% confidence intervals (vertical lines). Values are standardized by subtracting the mean over areas, so a value of zero is "average".

Shortbelly rockfish (juv)

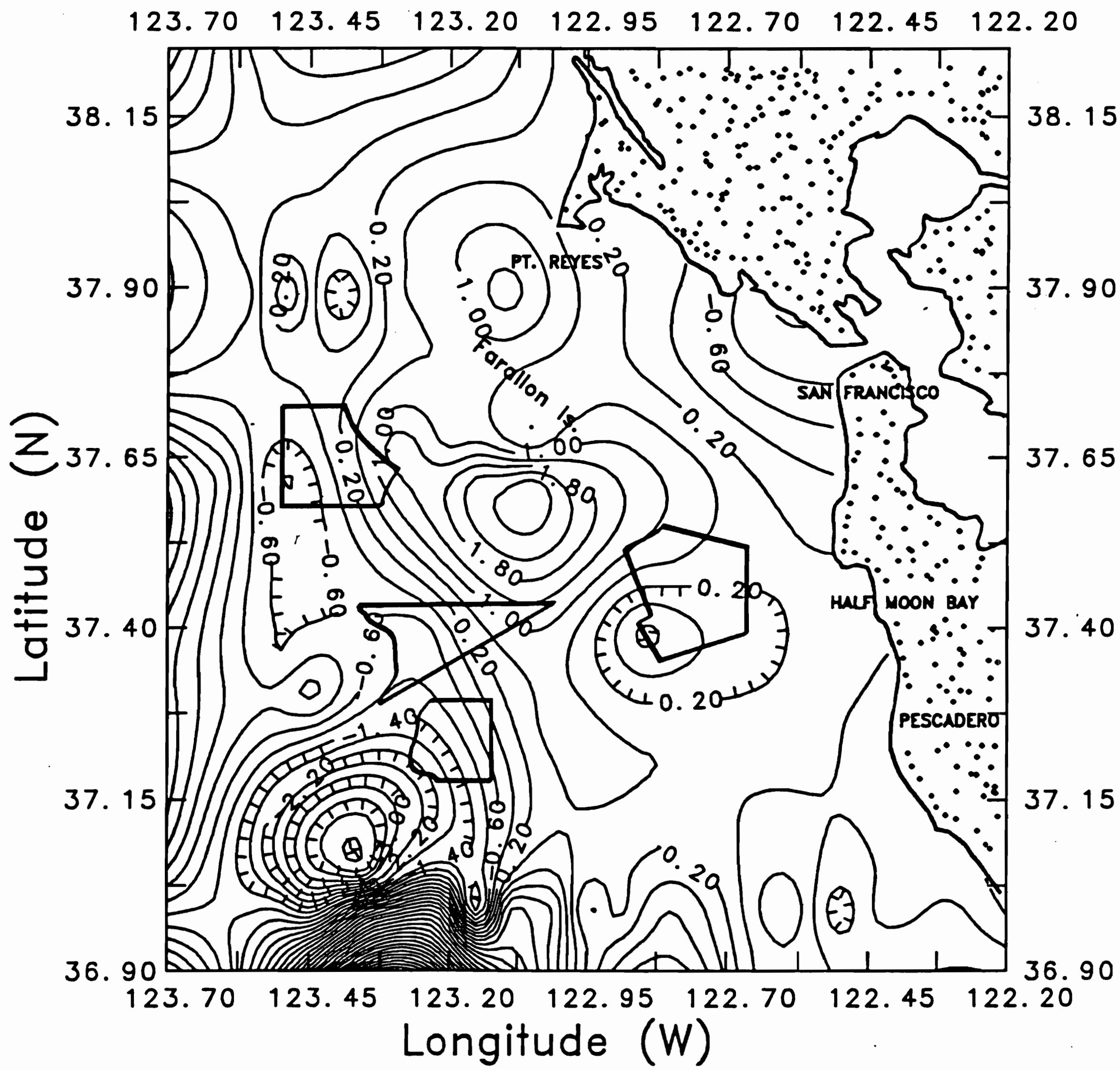


Fig. 54. Contour plot of $\log_e$-transformed abundance of shortbelly rockfish (juveniles) based on the Tiburon laboratory midwater trawl surveys.

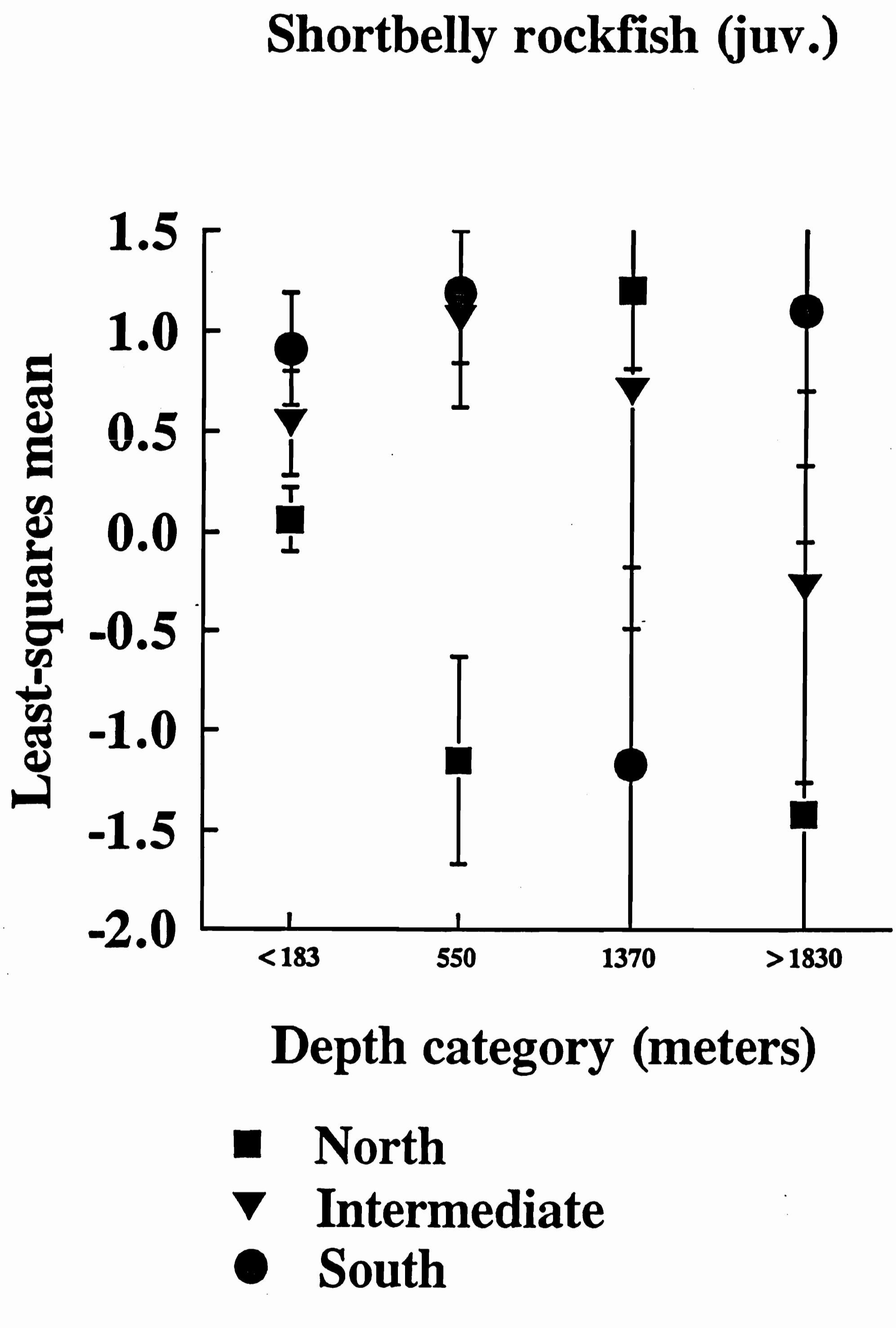


Fig. 55. Abundance of shortbelly rockfish (juveniles) for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

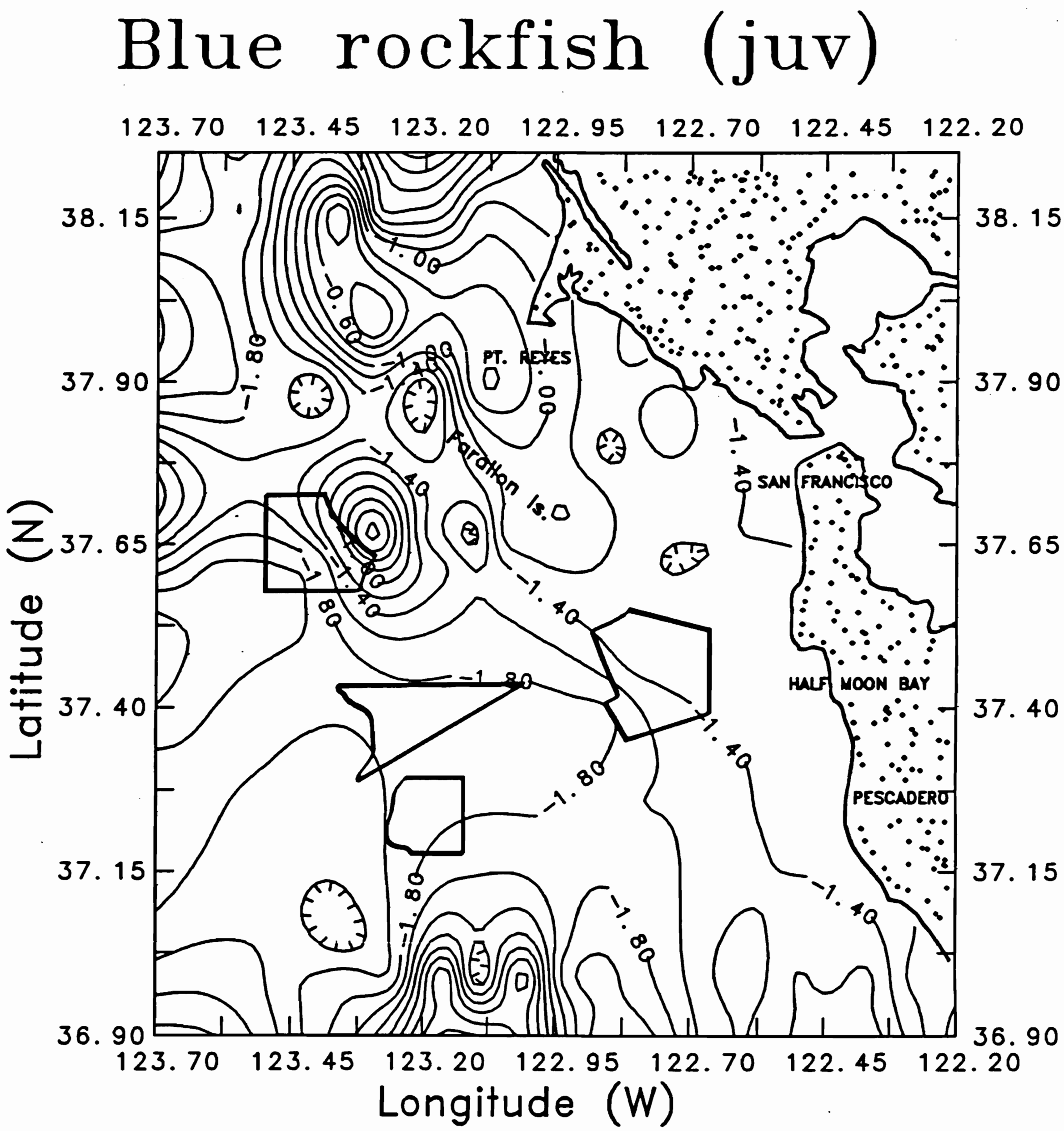


Fig. 56. Contour plot of $\log_e$-transformed abundance of blue rockfish (juveniles) based on the Tiburon laboratory midwater trawl surveys.

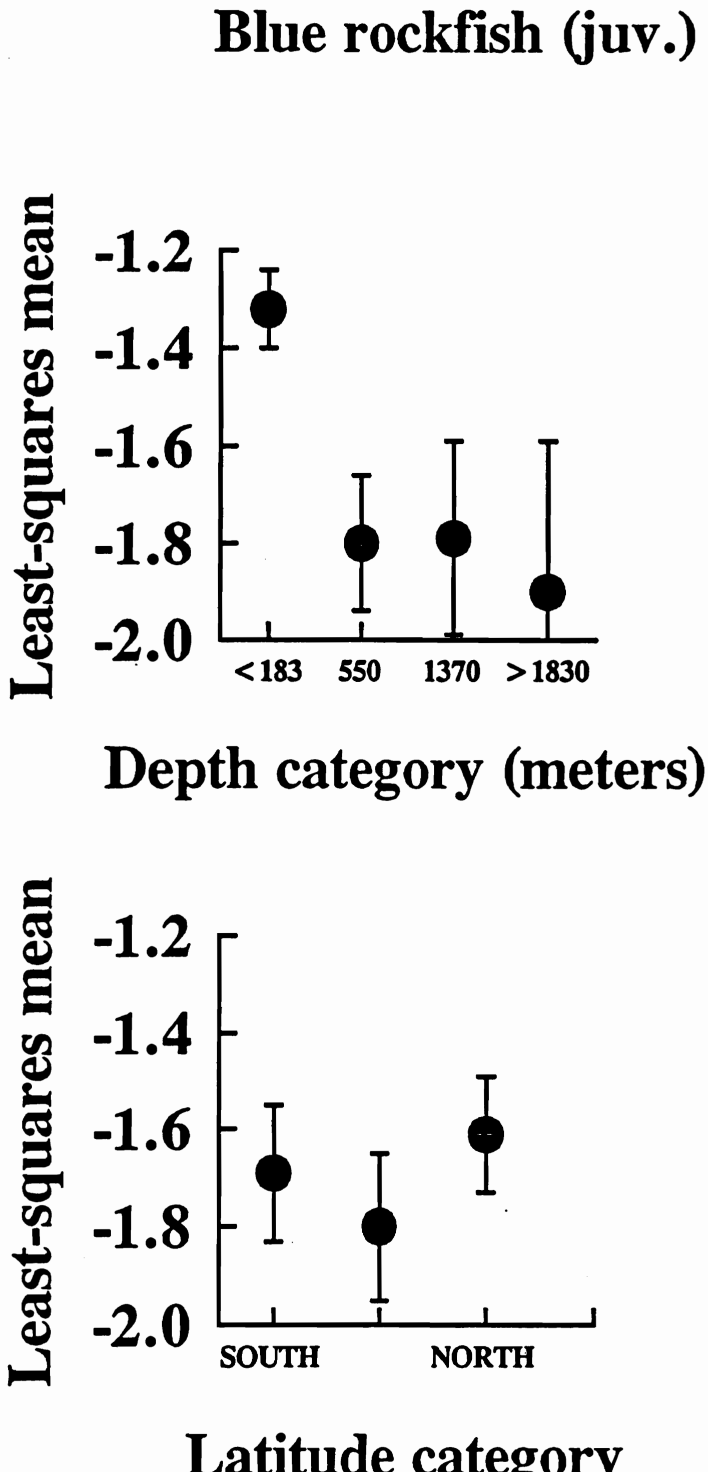
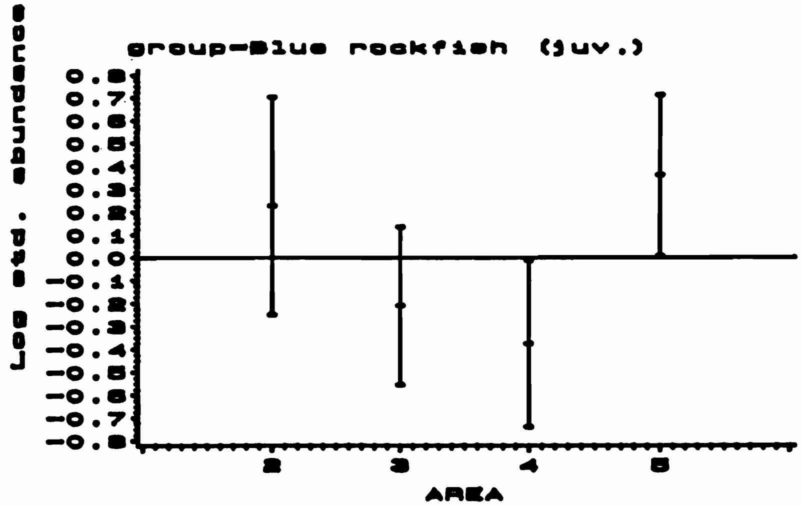


Fig. 57. Abundance of blue rockfish (juveniles) for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.



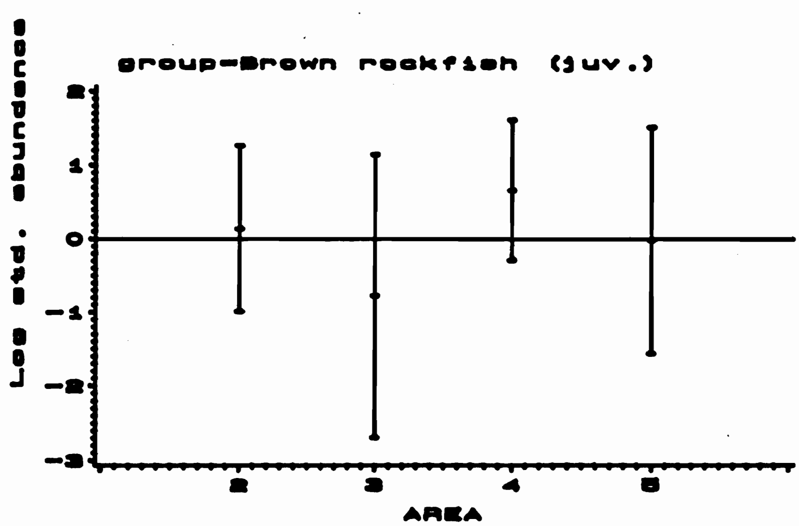


Fig. 58. Standardized mean $\log_e$-transformed abundance of blue rockfish juveniles and brown rockfish juveniles for the EPA study areas with jackknifed 95% confidence intervals (vertical lines). Values are standardized by subtracting the mean over areas, so a value of zero is "average".

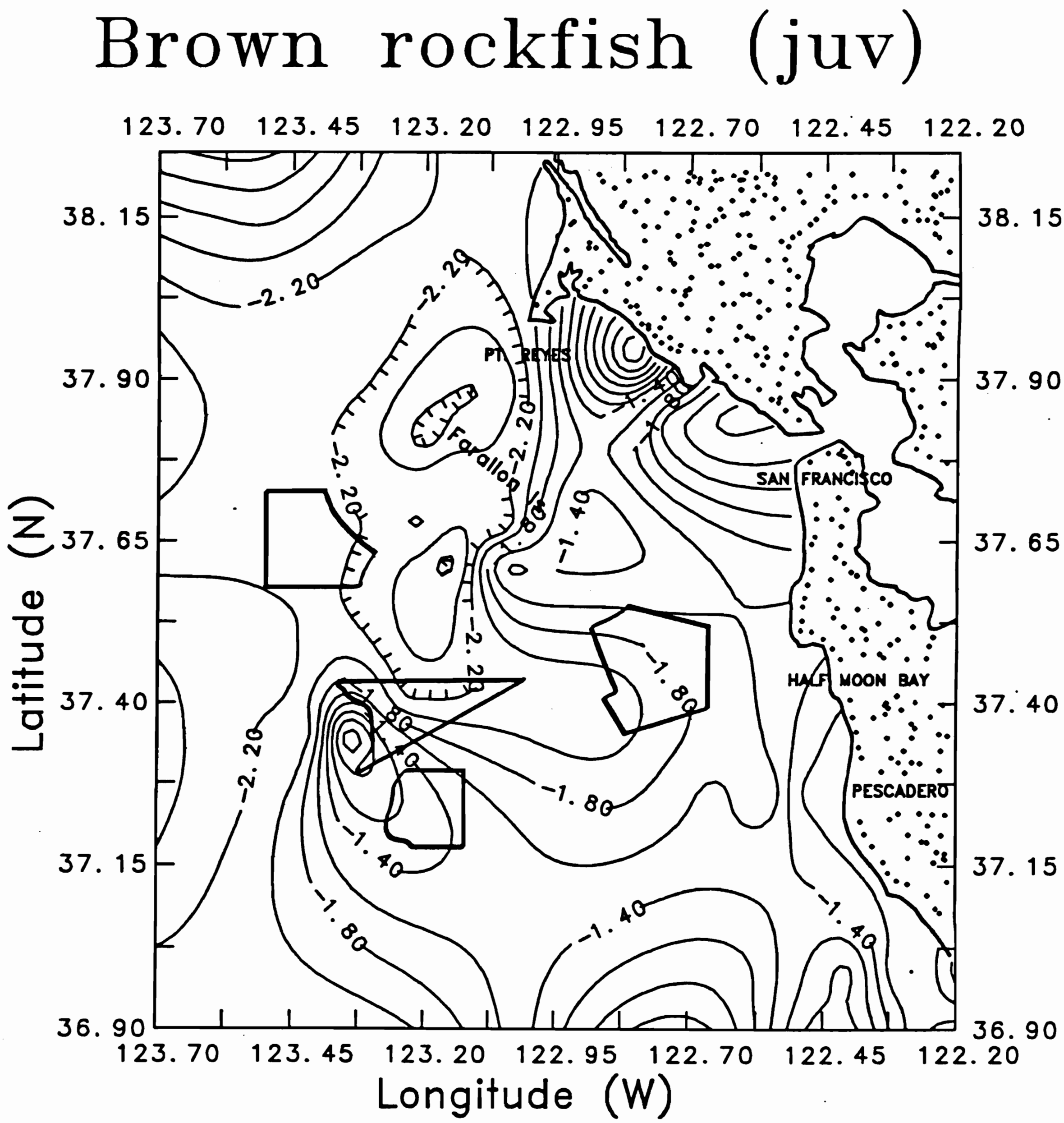


Fig. 59. Contour plot of log$_e$-transformed abundance of brown rockfish (juveniles) based on the Tiburon laboratory midwater trawl surveys.

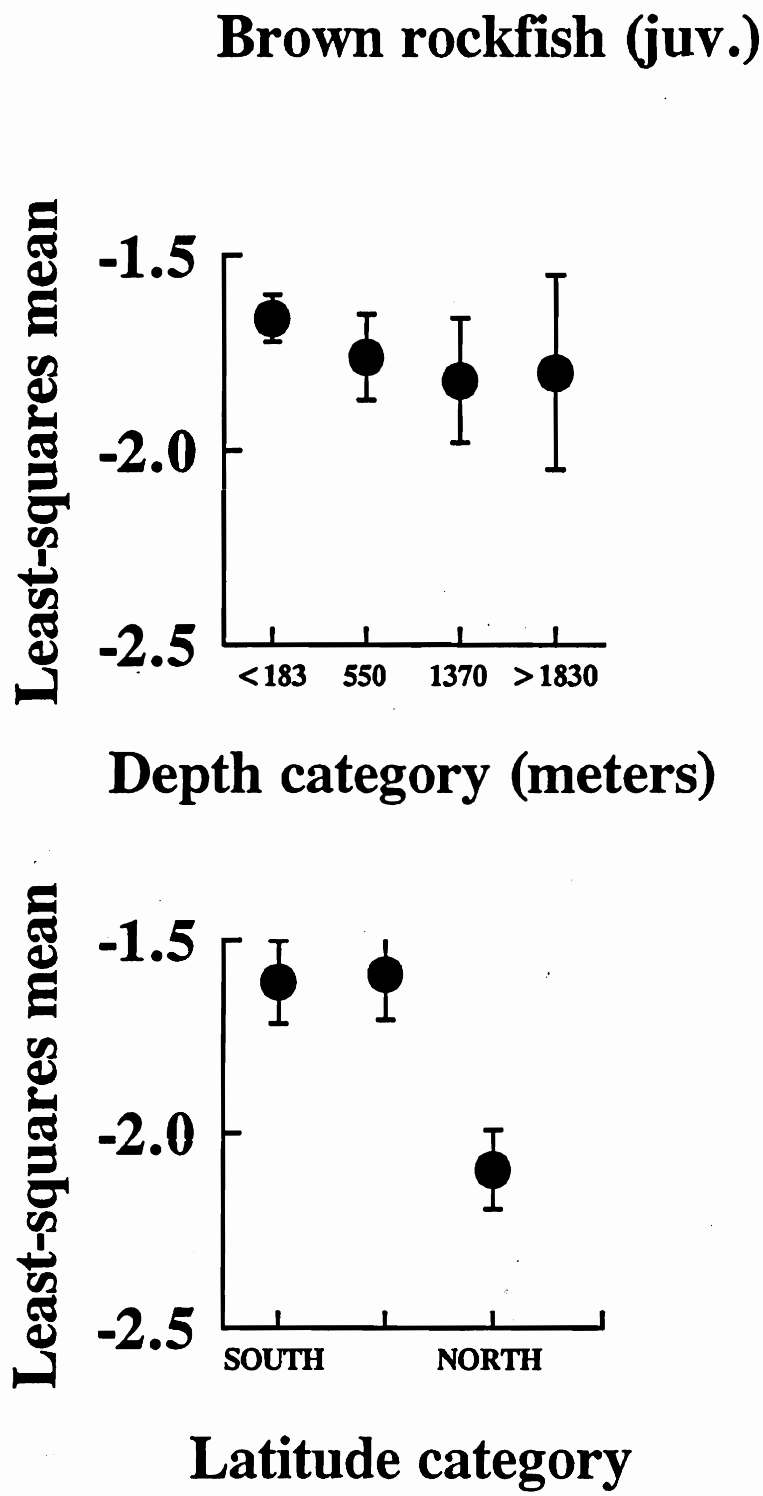


Fig. 60. Abundance of brown rockfish (juveniles) for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

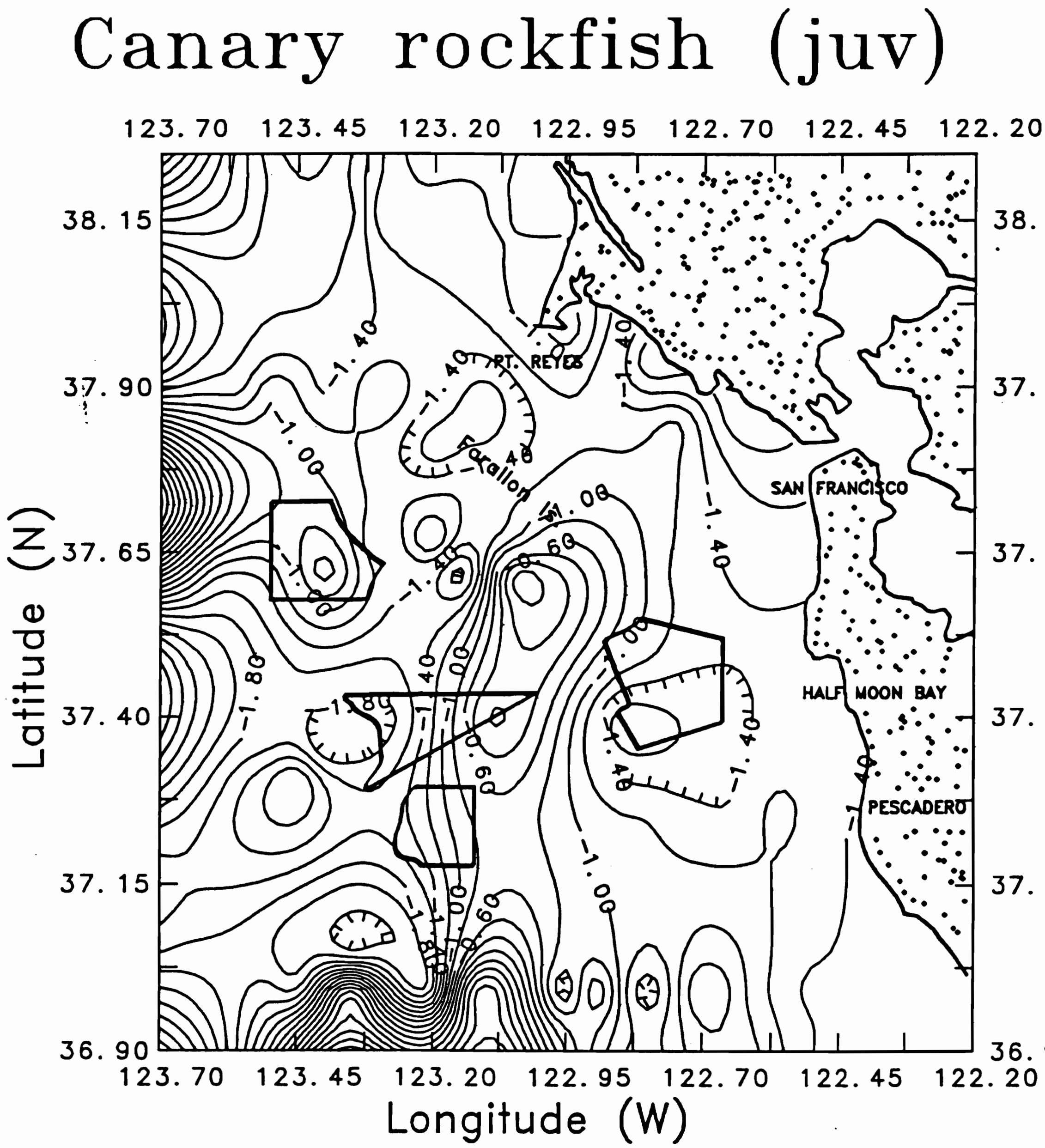


Fig. 61. Contour plot of $\log_e$-transformed abundance of canary rockfish (juveniles) based on the Tiburon laboratory midwater trawl surveys.

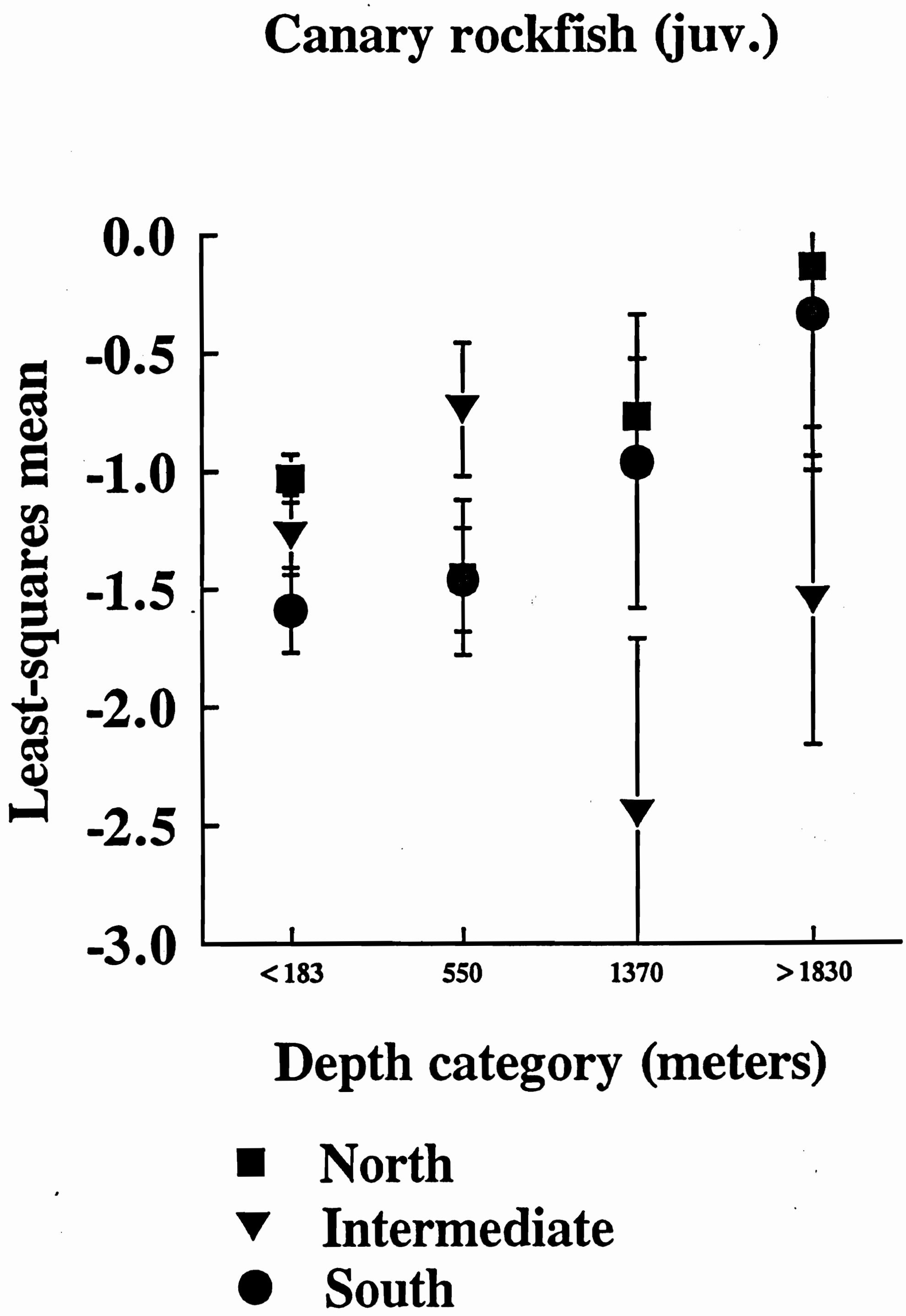


Fig. 62. Abundance of canary rockfish (juveniles) for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

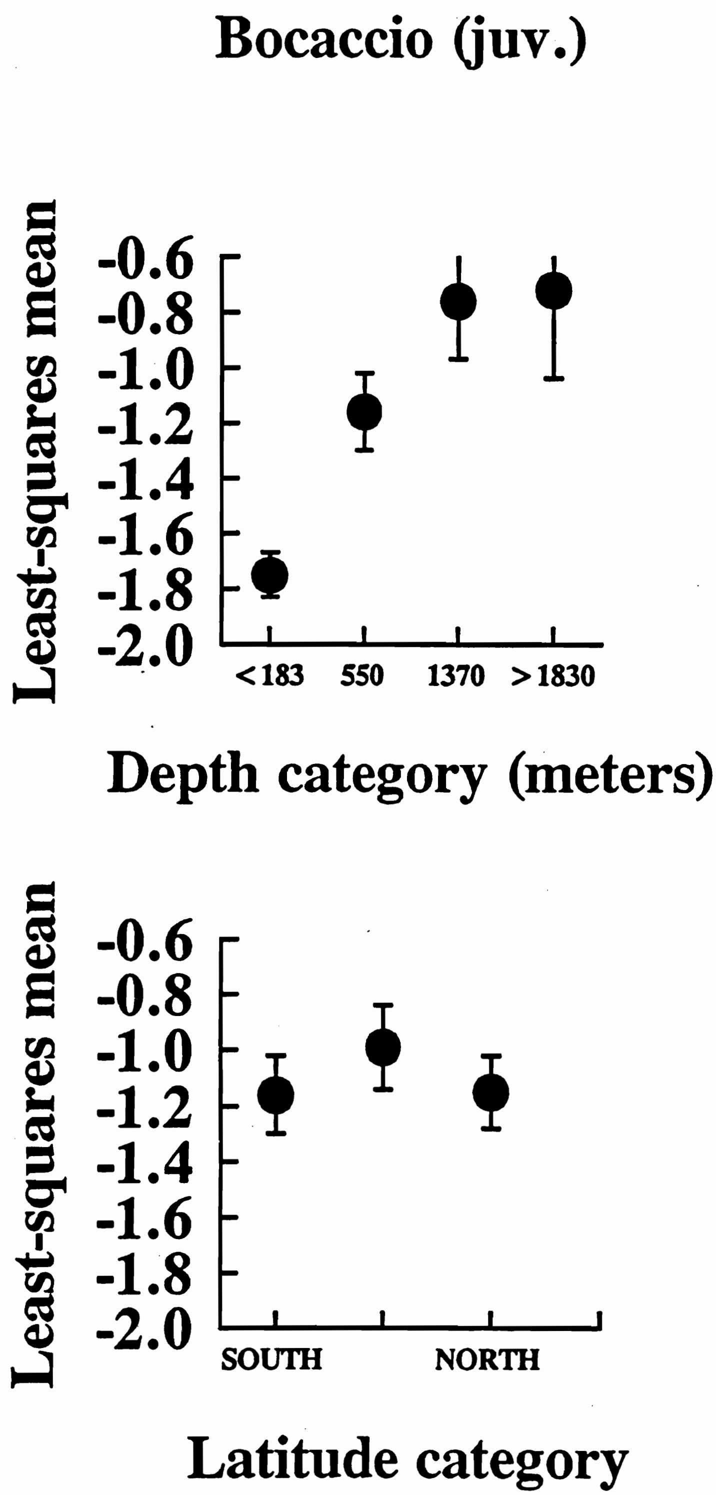


Fig. 63. Abundance of bocaccio for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints on the graph. Standard errors of LSM's are indicated by vertical bars.

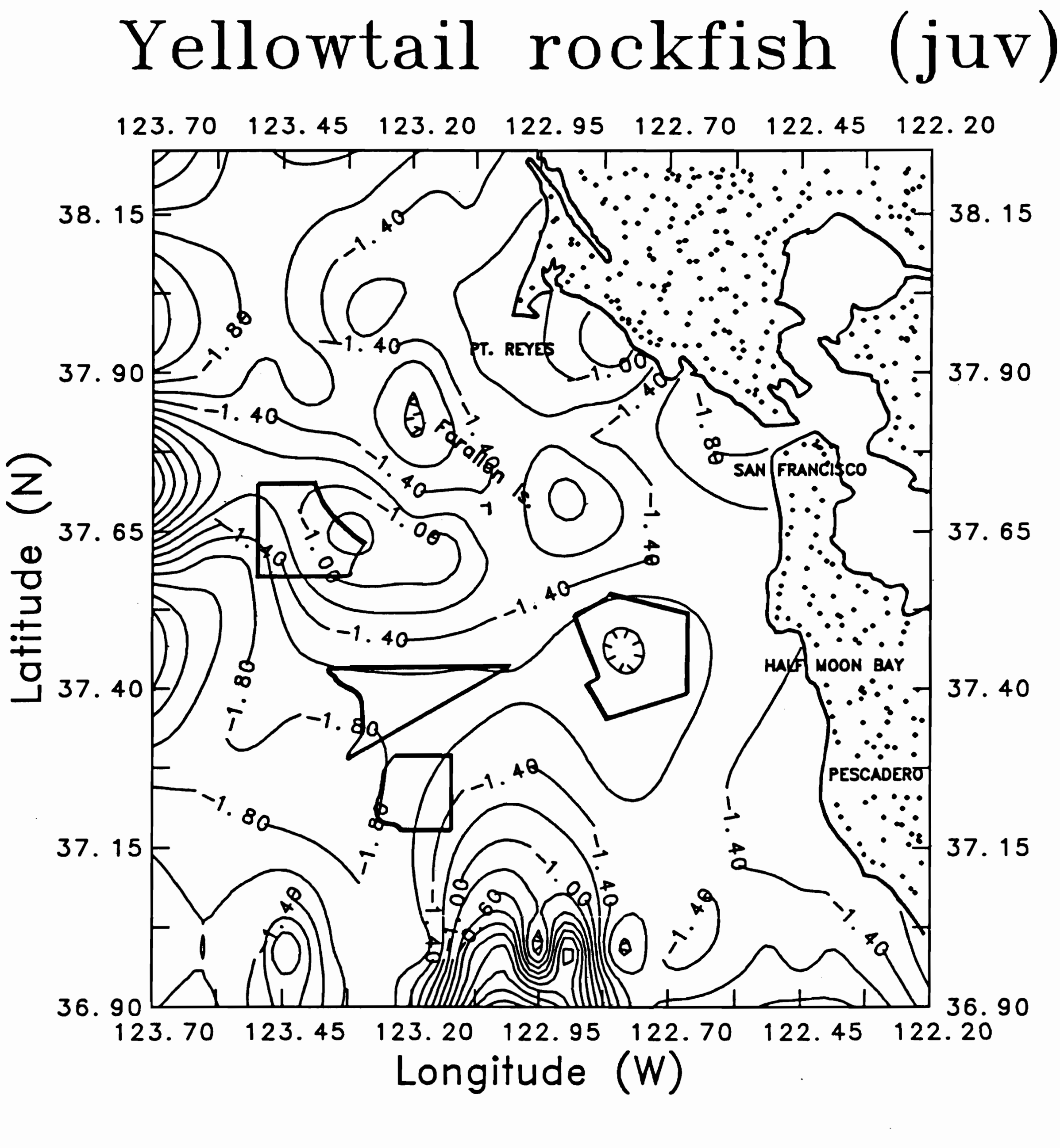


Fig. 64. Contour plot of log_e-transformed abundance of yellowtail rockfish (juveniles) based on the Tiburon laboratory midwater trawl surveys.

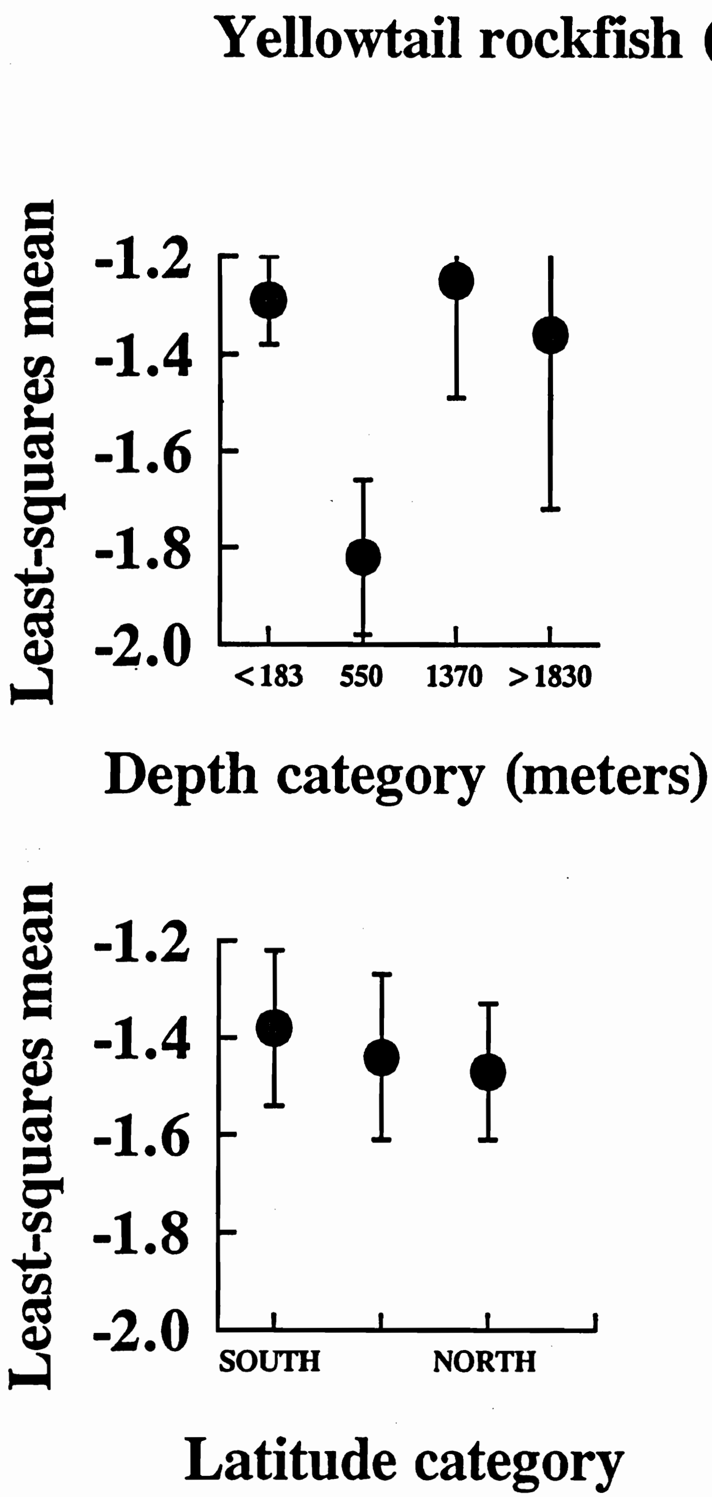


Fig. 65. Abundance of yellowtail rockfish (juveniles) for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints on the graph. Standard errors of LSM's are indicated by vertical bars.

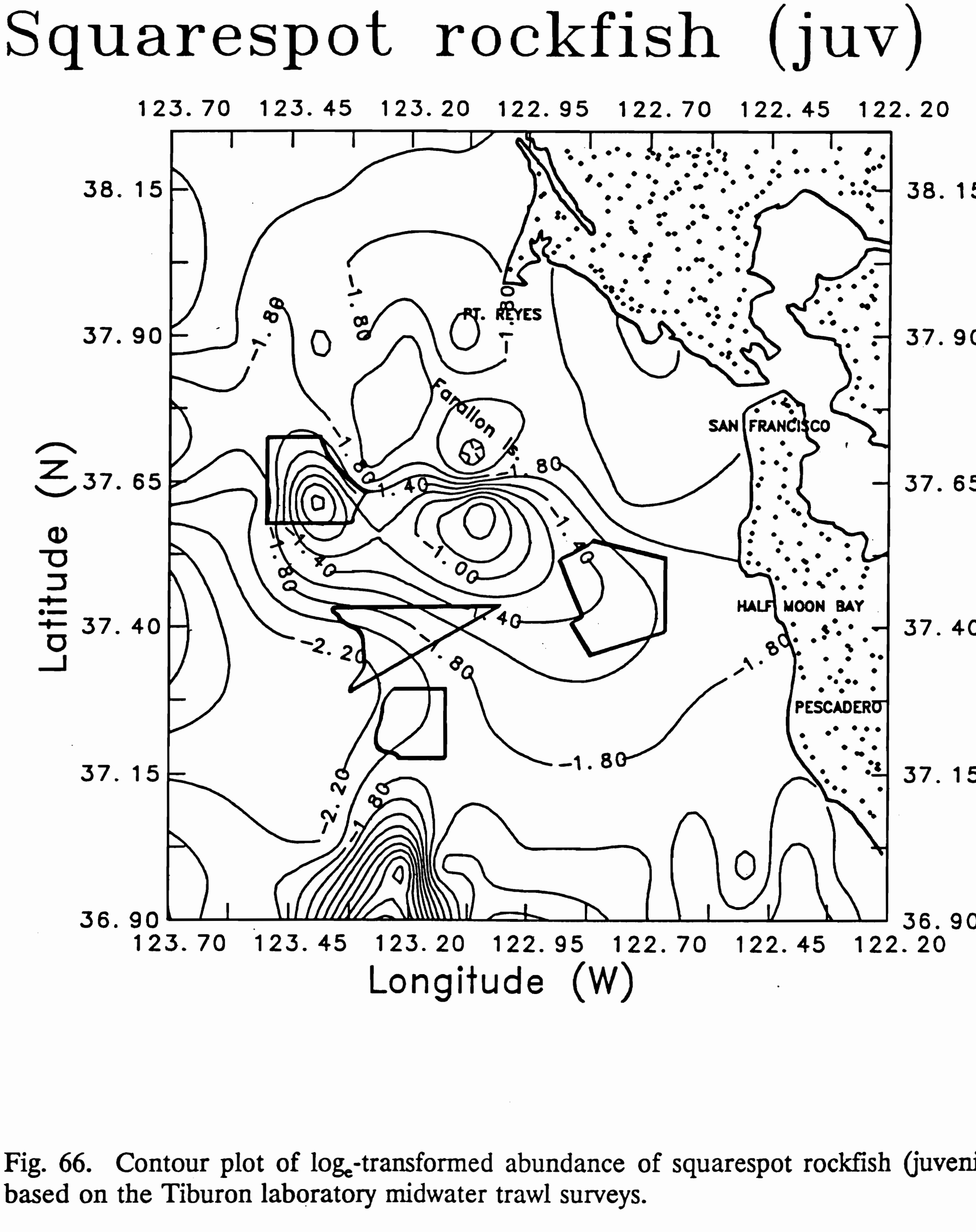


Fig. 66. Contour plot of $\log_e$-transformed abundance of squarespot rockfish (juveniles) based on the Tiburon laboratory midwater trawl surveys.

Stripetail rockfish (juv)

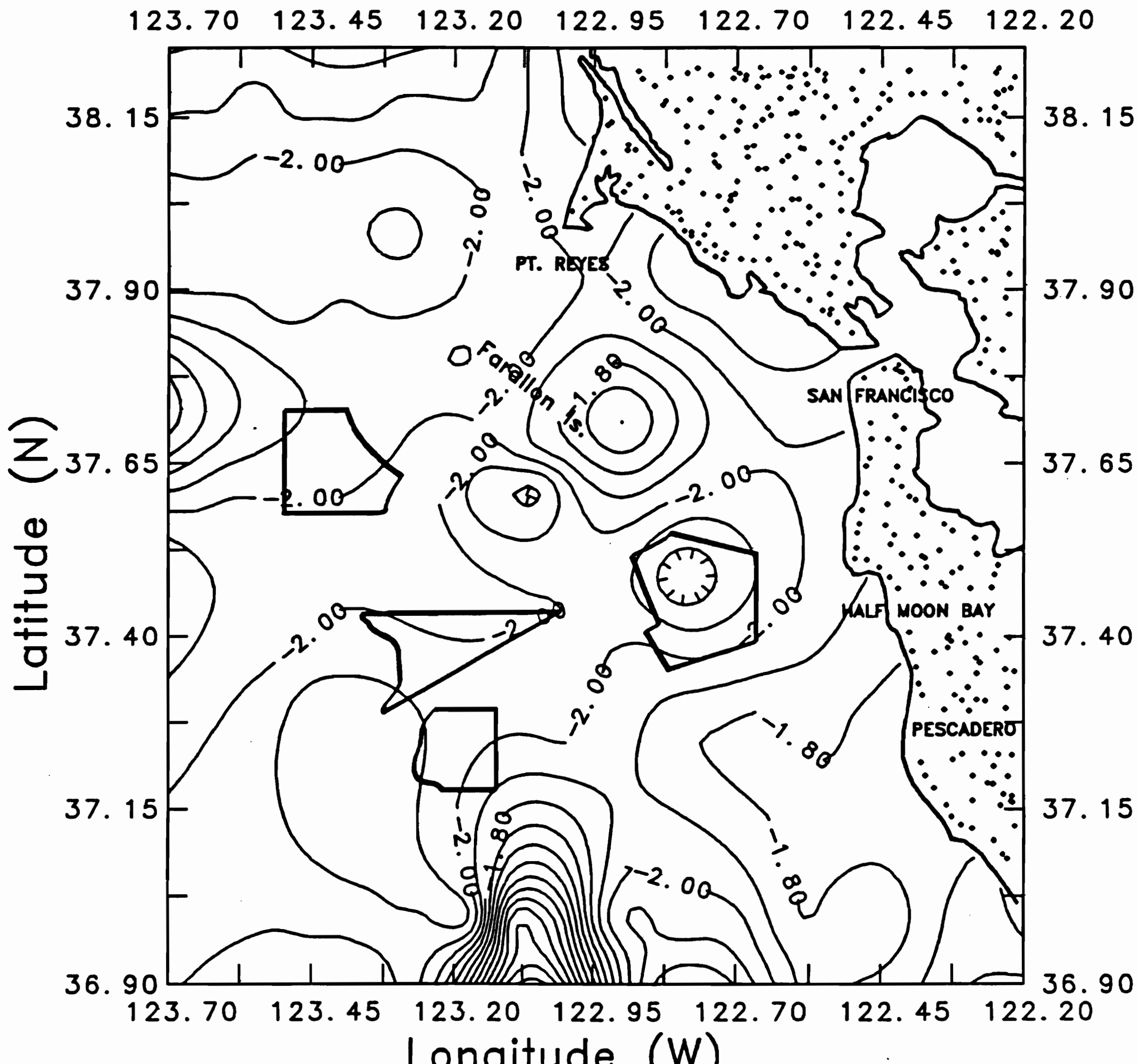


Fig. 67. Contour plot of $\log_e$-transformed abundance of stripetail rockfish (juveniles) based on the Tiburon laboratory midwater trawl surveys.

Stripetail rockfish (juv.)

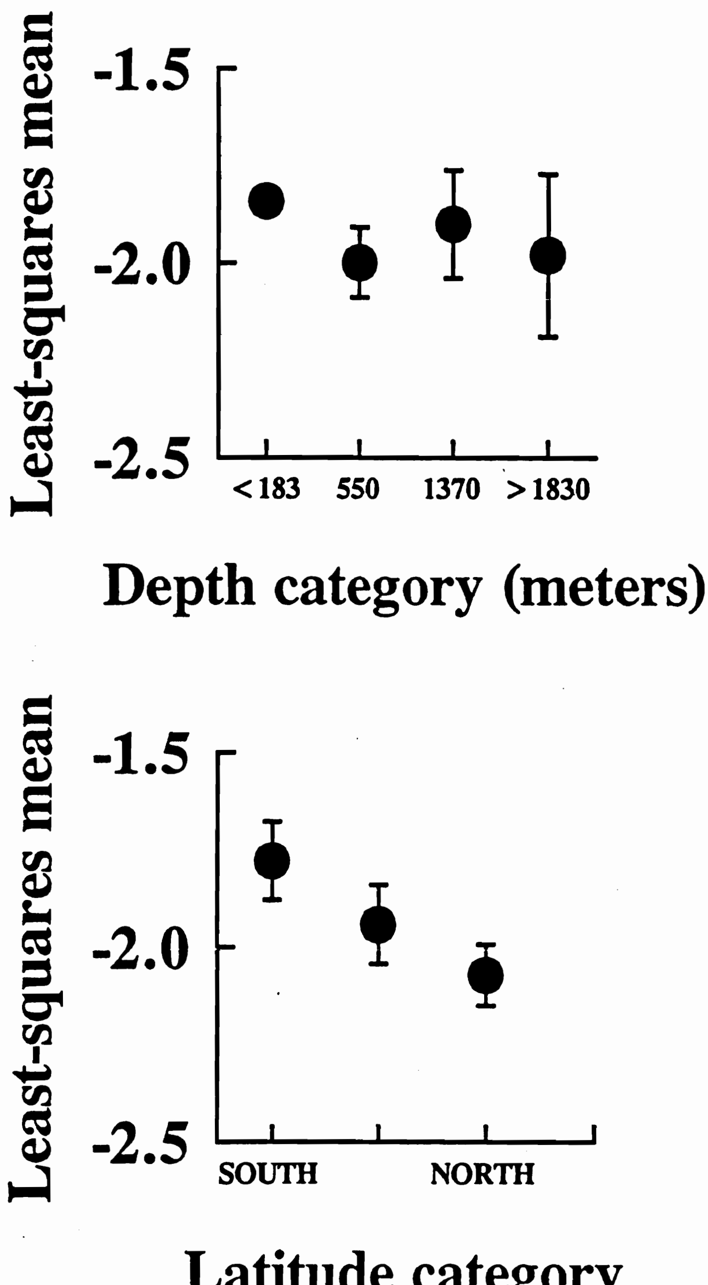


Fig. 68. Abundance of stripetail rockfish (juveniles) for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints on the graph. Standard errors of LSM's are indicated by vertical bars.

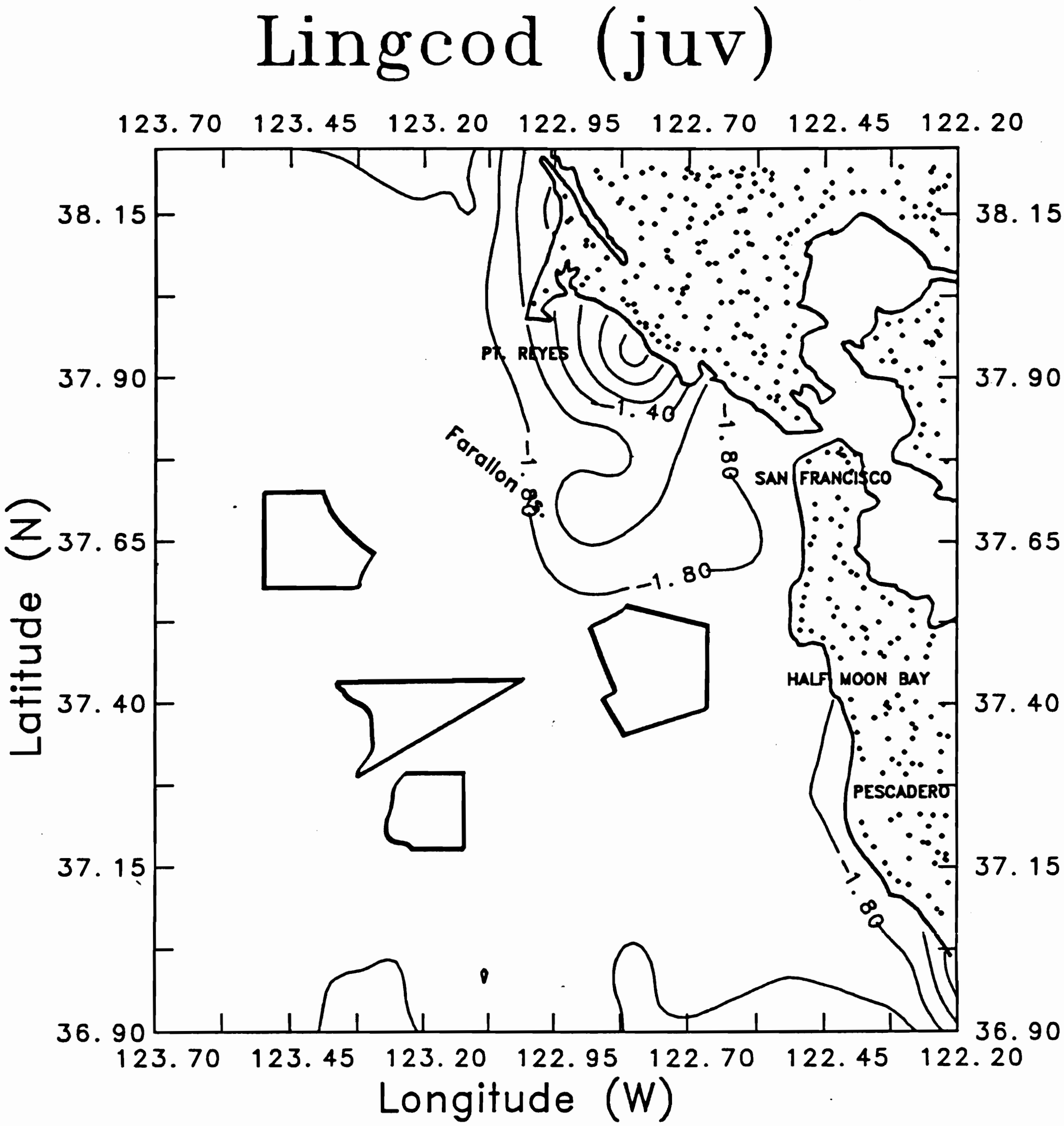


Fig. 69. Contour plot of $\log_e$-transformed abundance of lingcod (juveniles) based on the Tiburon laboratory midwater trawl surveys.

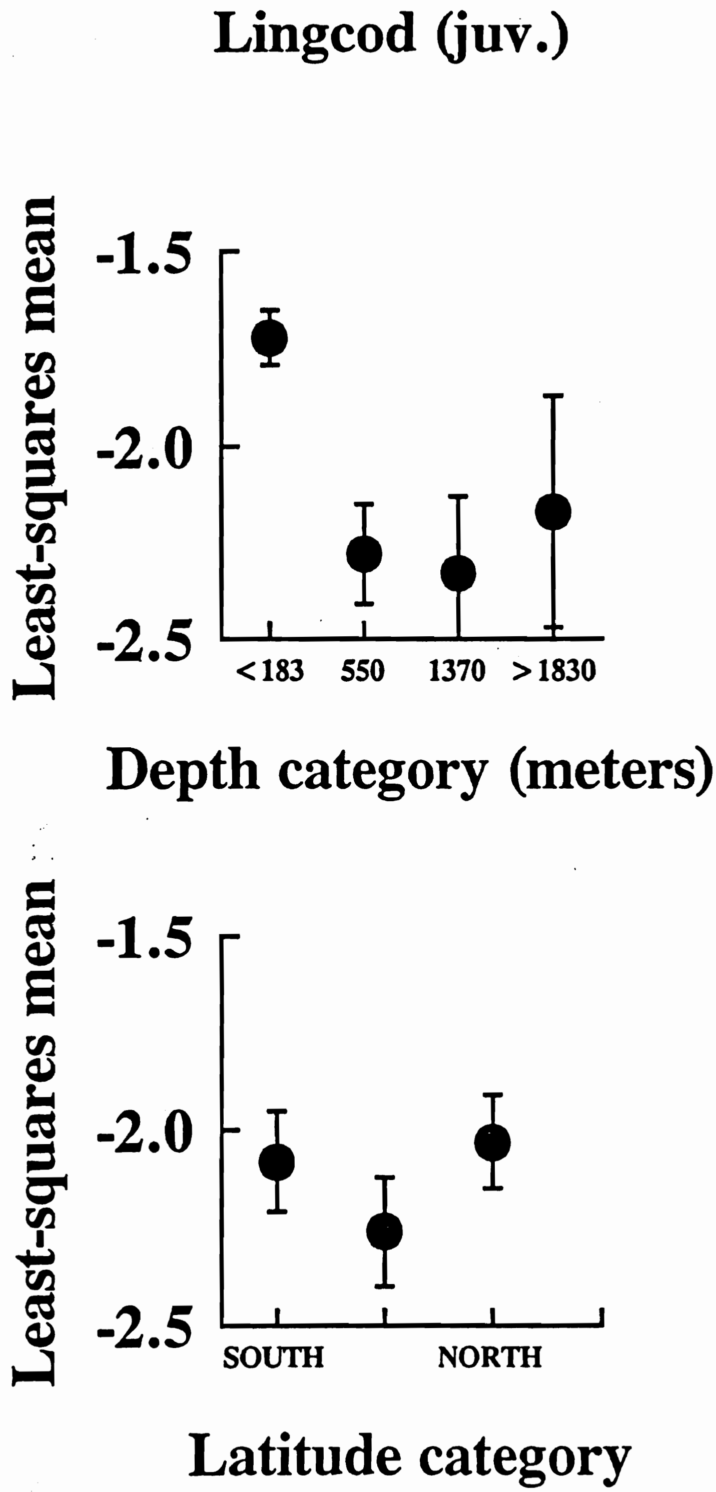


Fig. 70. Abundance of lingcod (juveniles) for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints on the graph. Standard errors of LSM's are indicated by vertical bars.

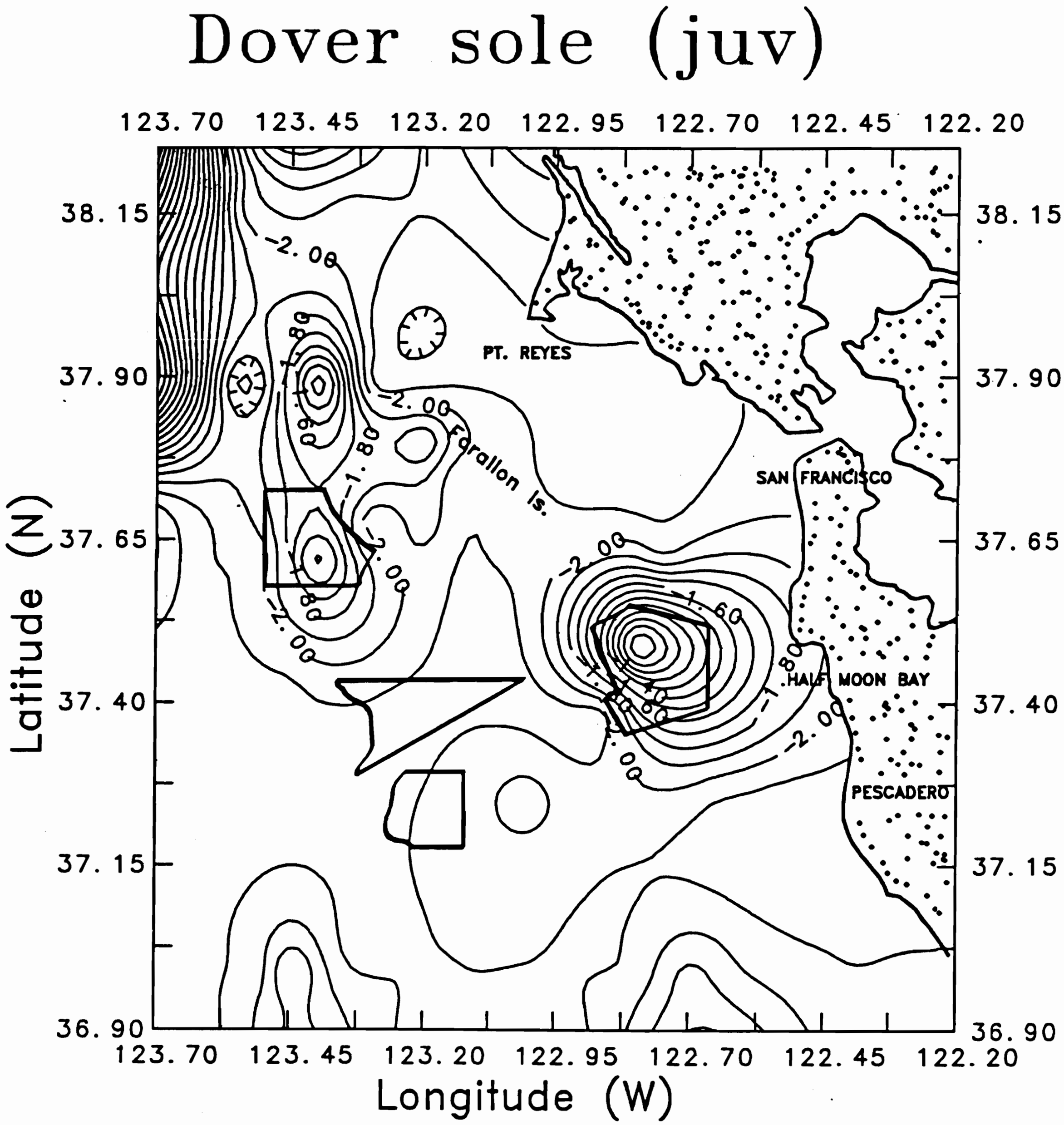


Fig. 71. Contour plot of $\log_e$-transformed abundance of Dover sole (juveniles) based on the Tiburon laboratory midwater trawl surveys.

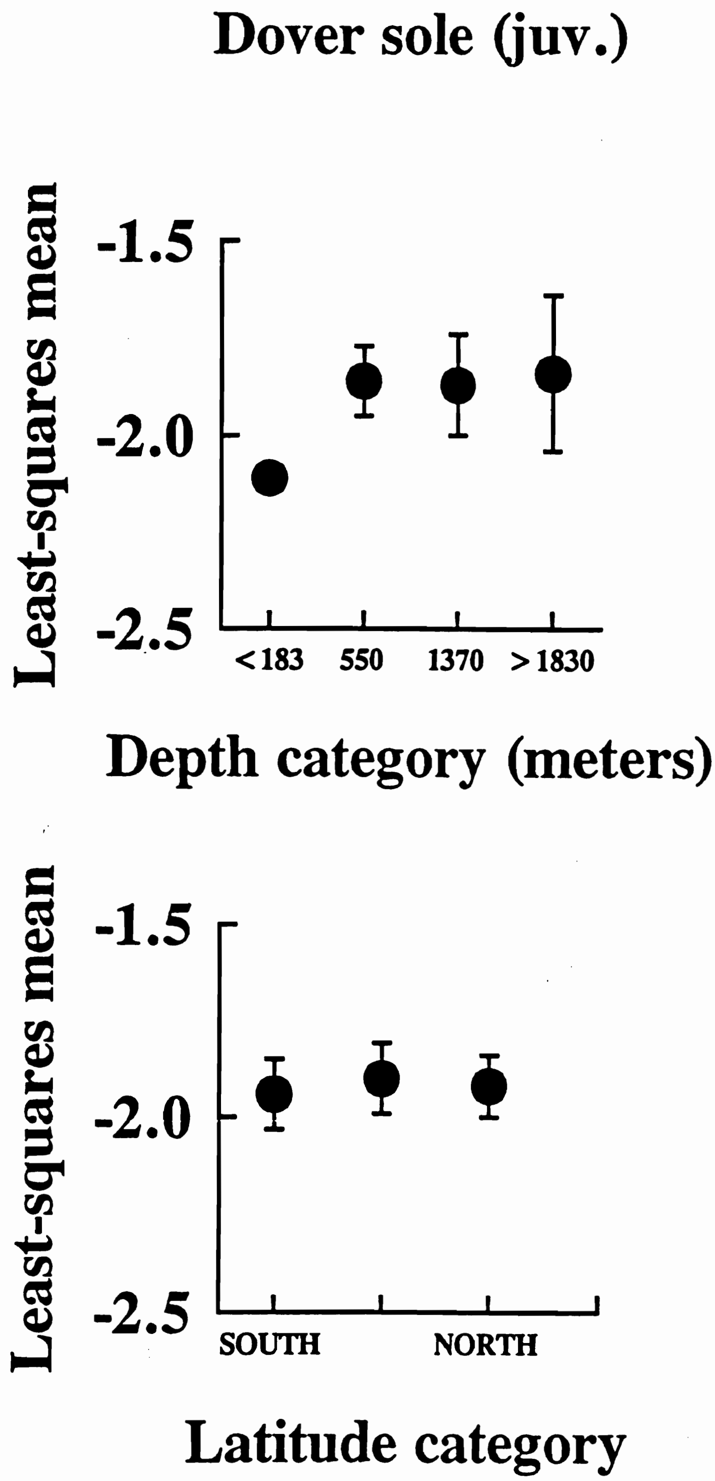
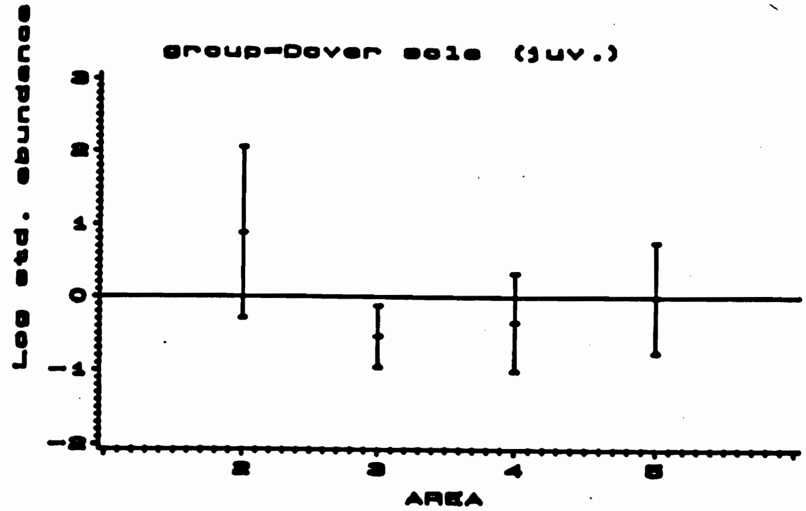


Fig. 72. Abundance of Dover sole (juveniles) for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.



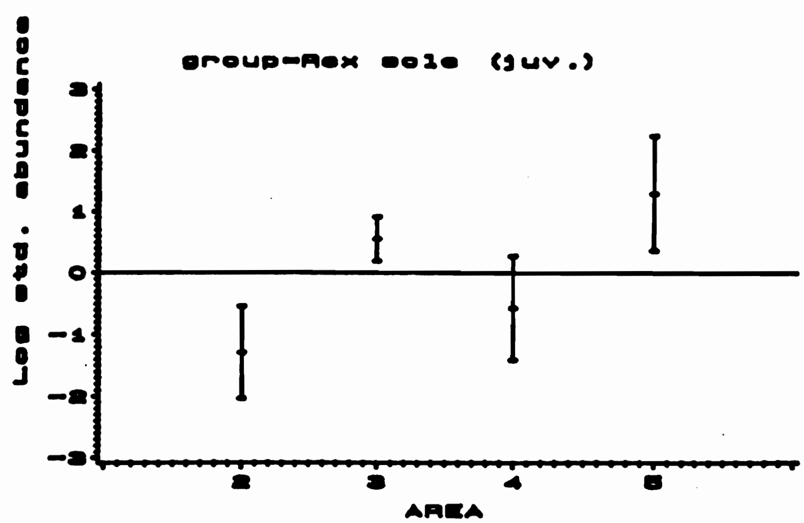


Fig. 73. Standardized mean $\log_e$-transformed abundance of Dover sole juveniles and rex sole juveniles for the EPA study areas with jackknifed 95% confidence intervals (vertical lines). Values are standardized by subtracting the mean over areas, so a value of zero is "average".

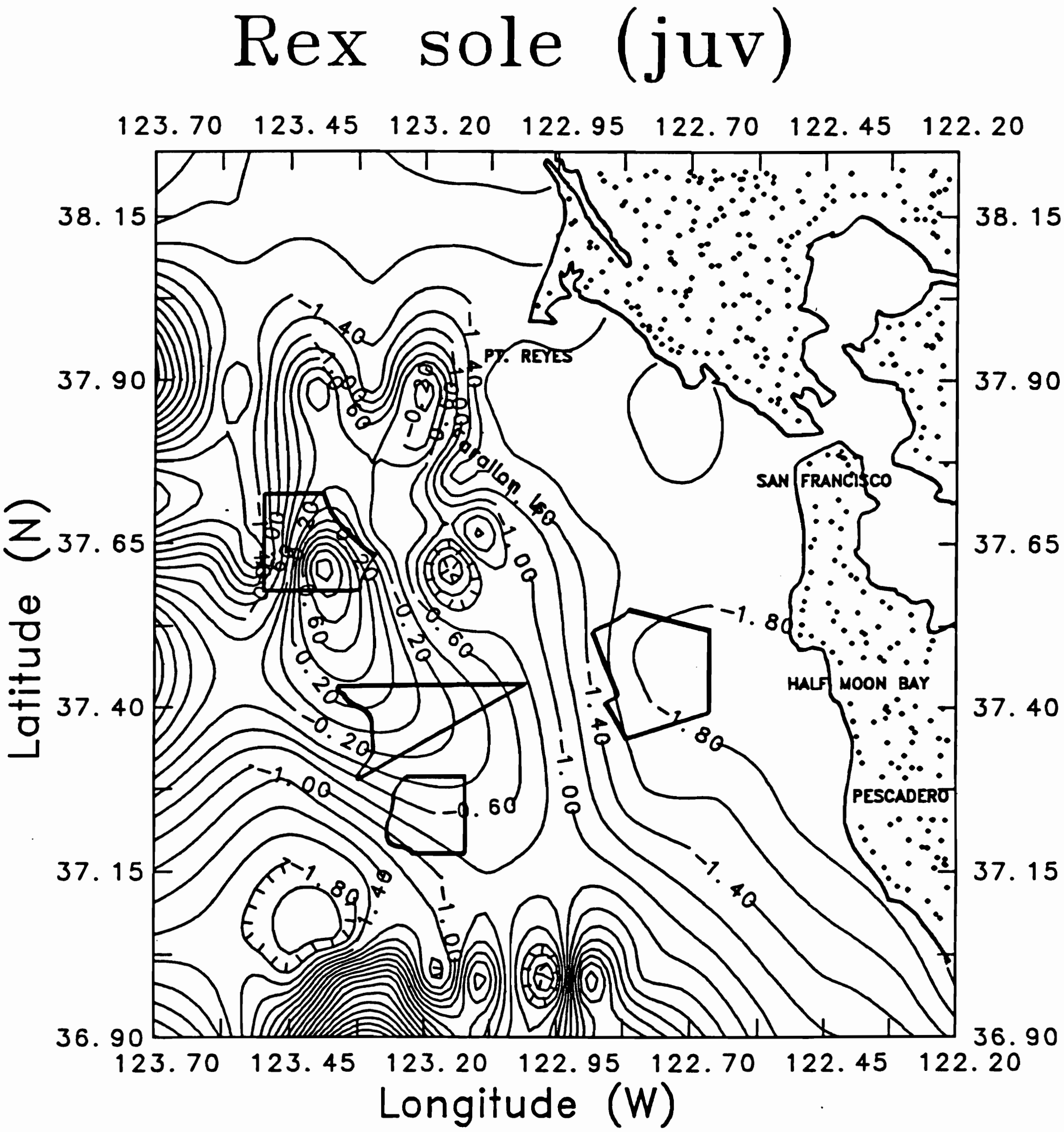


Fig. 74. Contour plot of $\log_e$-transformed abundance of rex sole (juveniles) based on the Tiburon laboratory midwater trawl surveys.

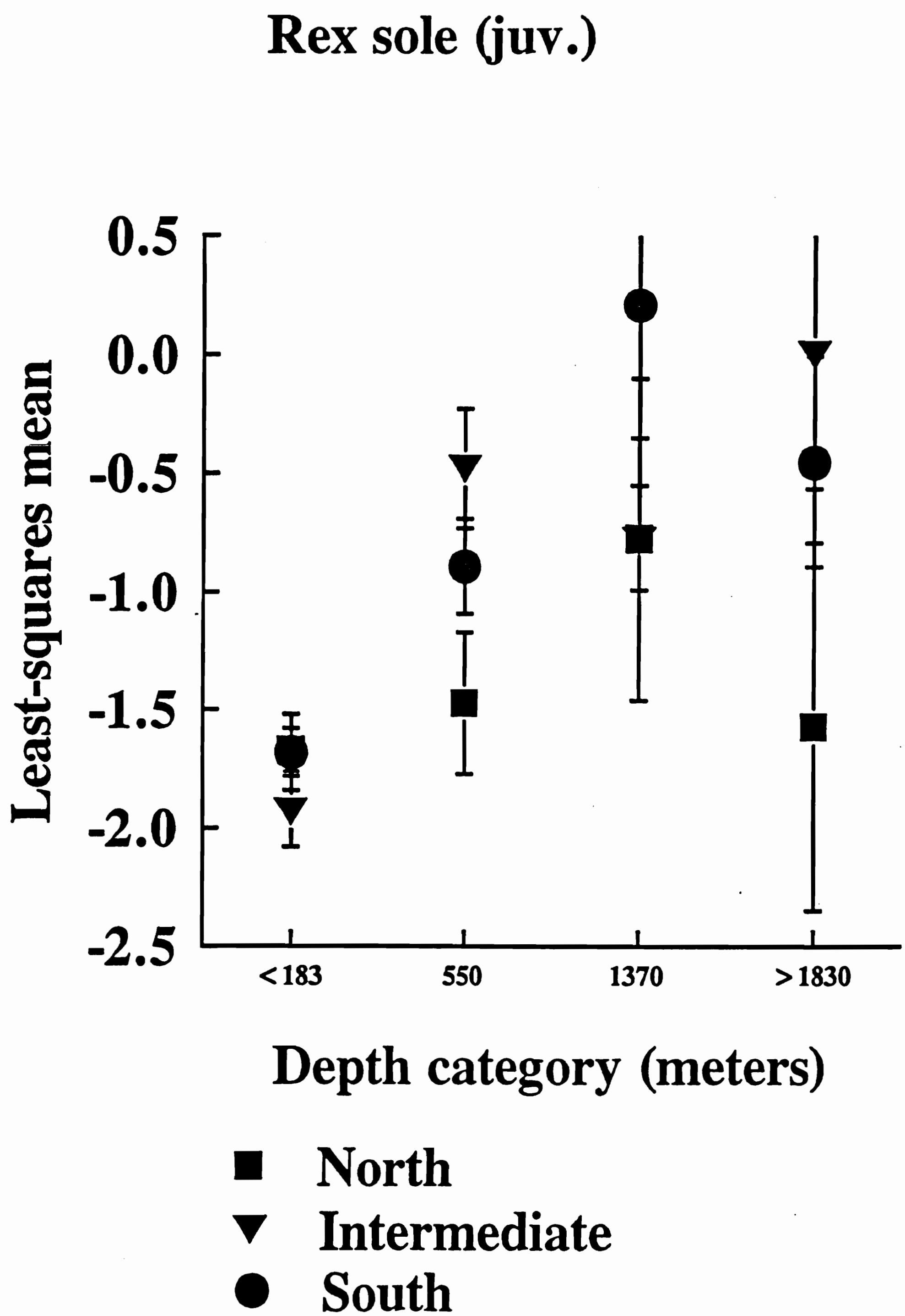


Fig. 75. Abundance of rex sole (juveniles) for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

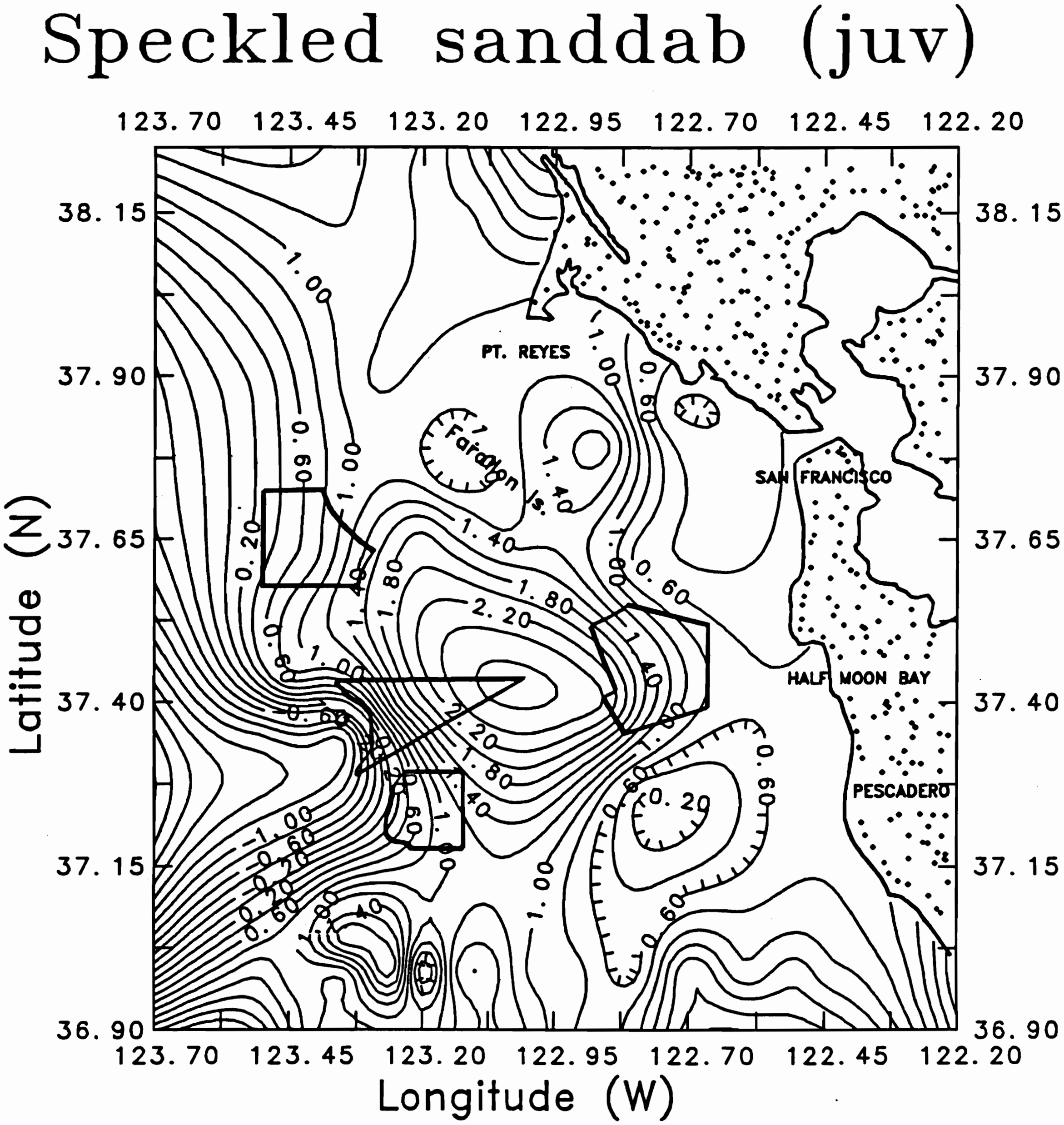


Fig. 76. Contour plot of $\log_e$-transformed abundance of speckled sanddab (juveniles) based on the Tiburon laboratory midwater trawl surveys.

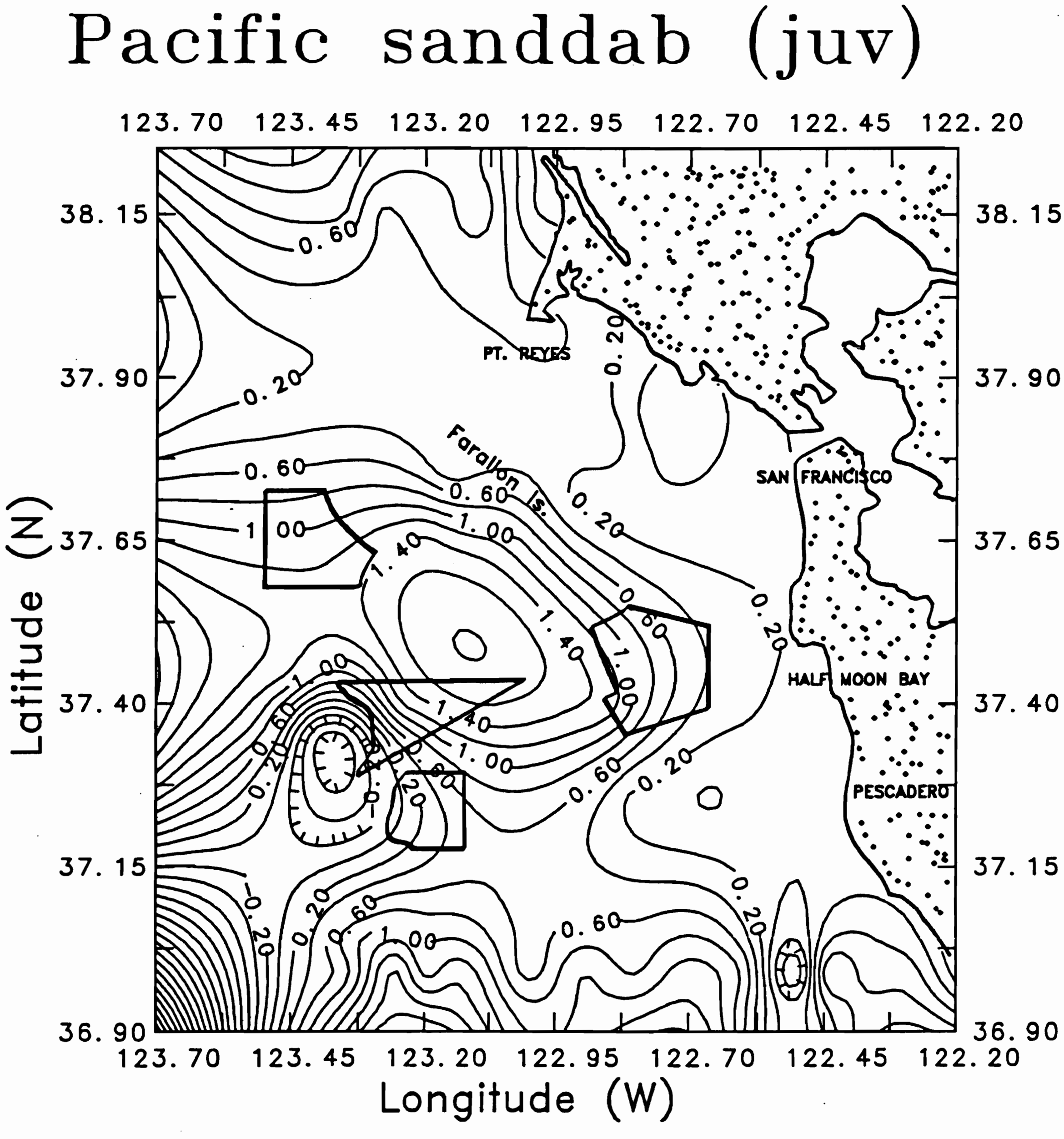


Fig. 77. Contour plot of $\log_e$-transformed abundance of Pacific sanddab (juveniles) based on the Tiburon laboratory midwater trawl surveys.

Myctophid

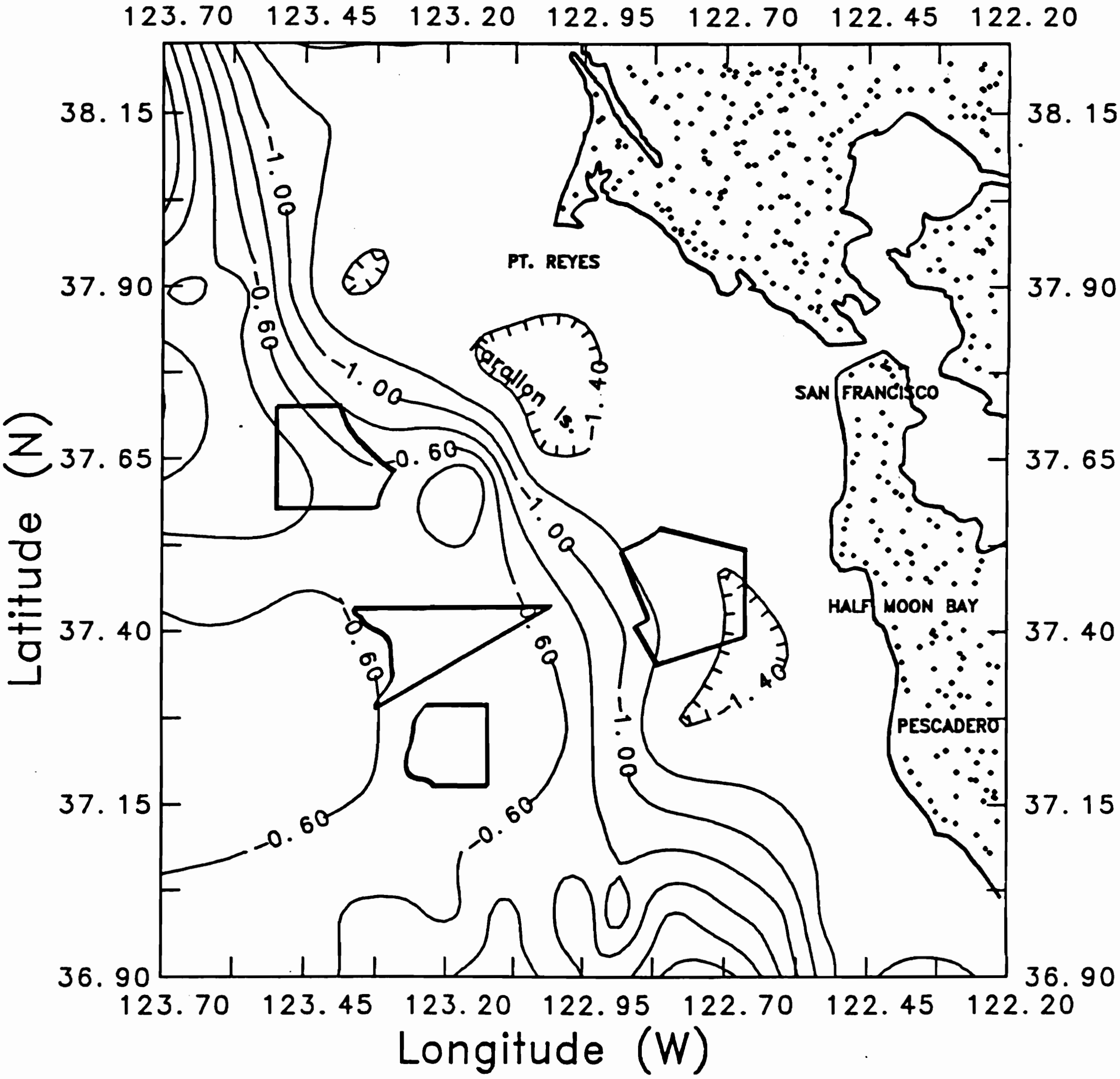


Fig. 78. Contour plot of $\log_e$-transformed abundance of myctophids (all species) based on the Tiburon laboratory midwater trawl surveys.

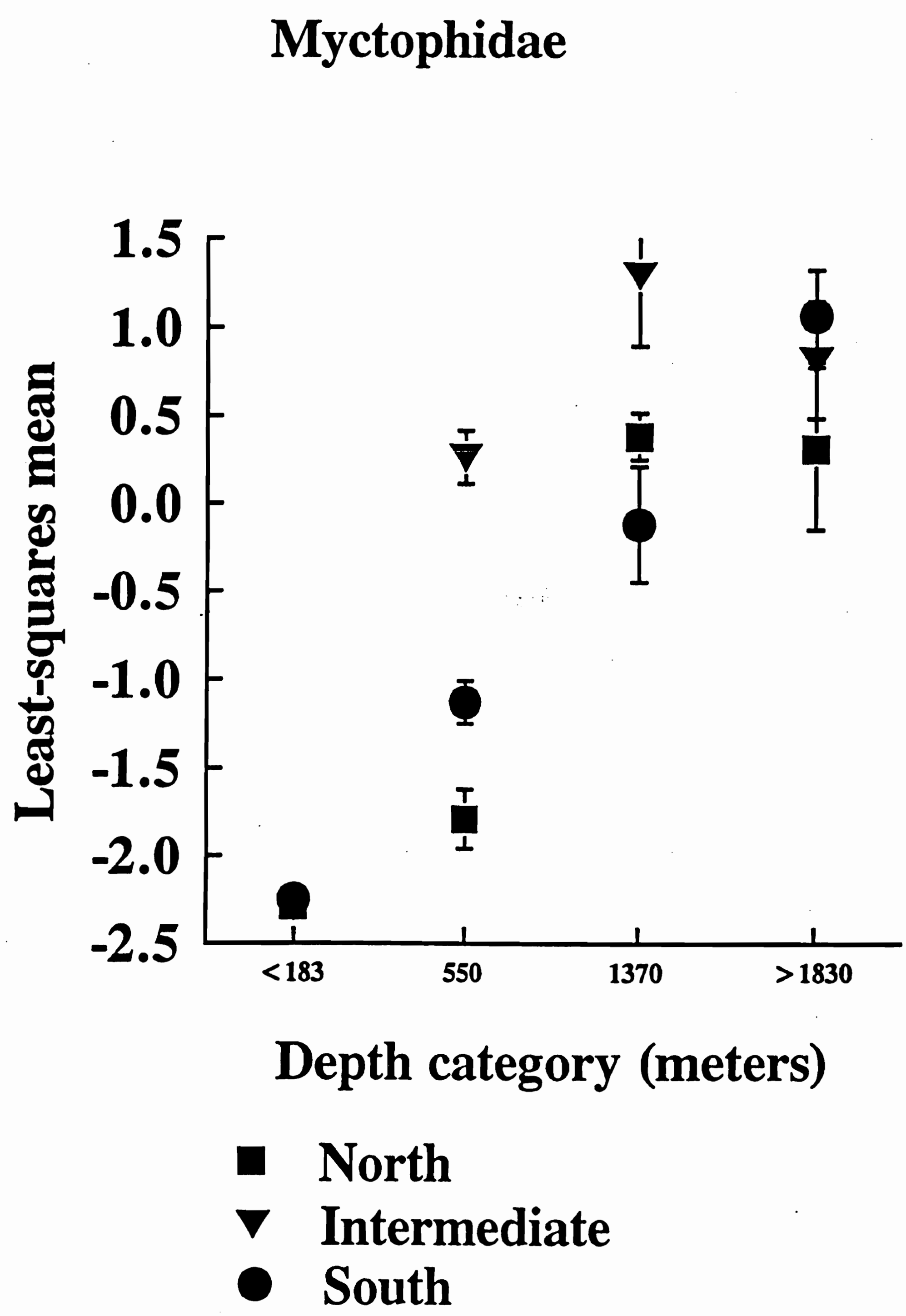
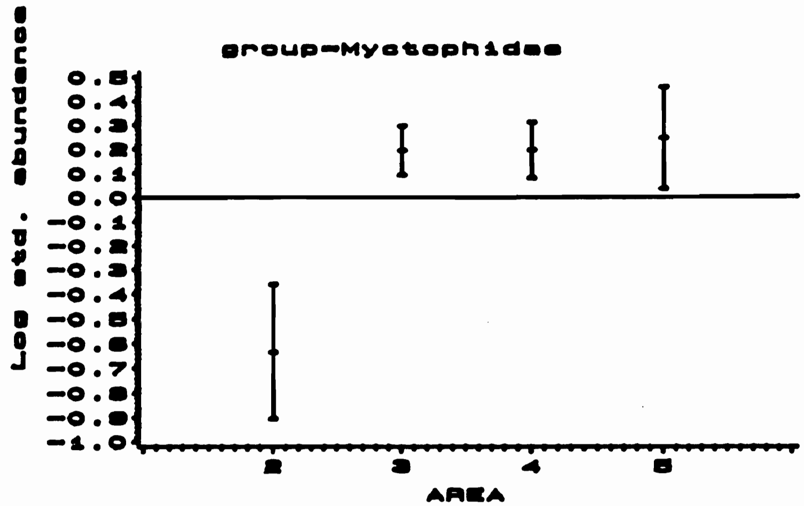


Fig. 79. Abundance of myctophids (all species) for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.



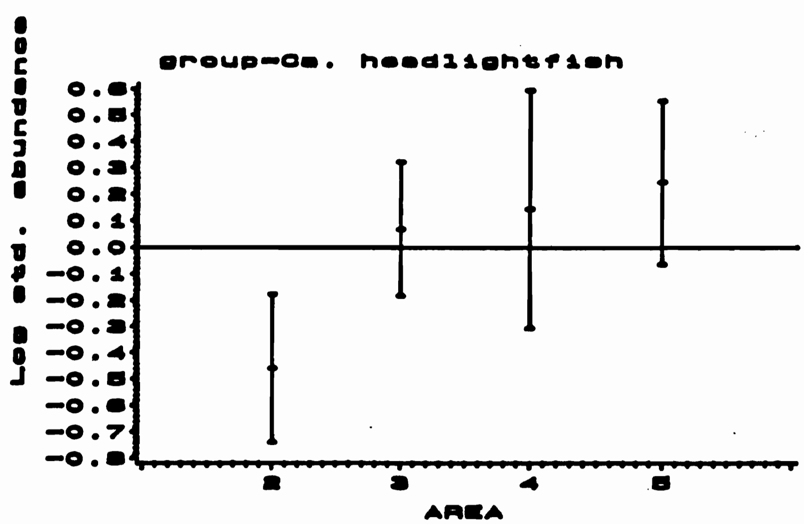


Fig. 80. Standardized mean $\log_e$-transformed abundance of all myctophids and California headlightfish for the EPA study areas with jackknifed 95% confidence intervals (vertical lines). Values are standardized by subtracting the mean over areas, so a value of zero is "average".

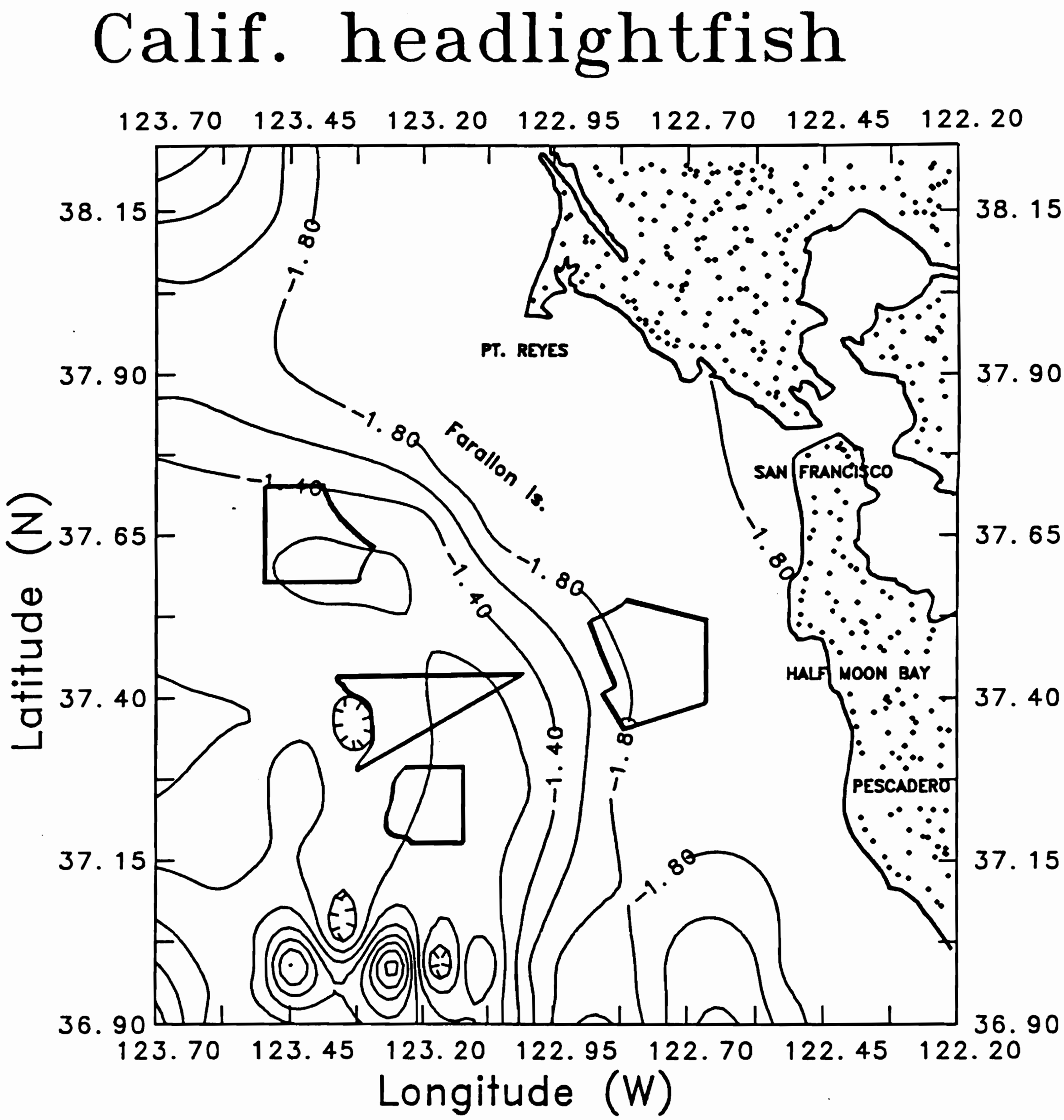


Fig. 81. Contour plot of $\log_e$-transformed abundance of California headlightfish based on the Tiburon laboratory midwater trawl surveys.

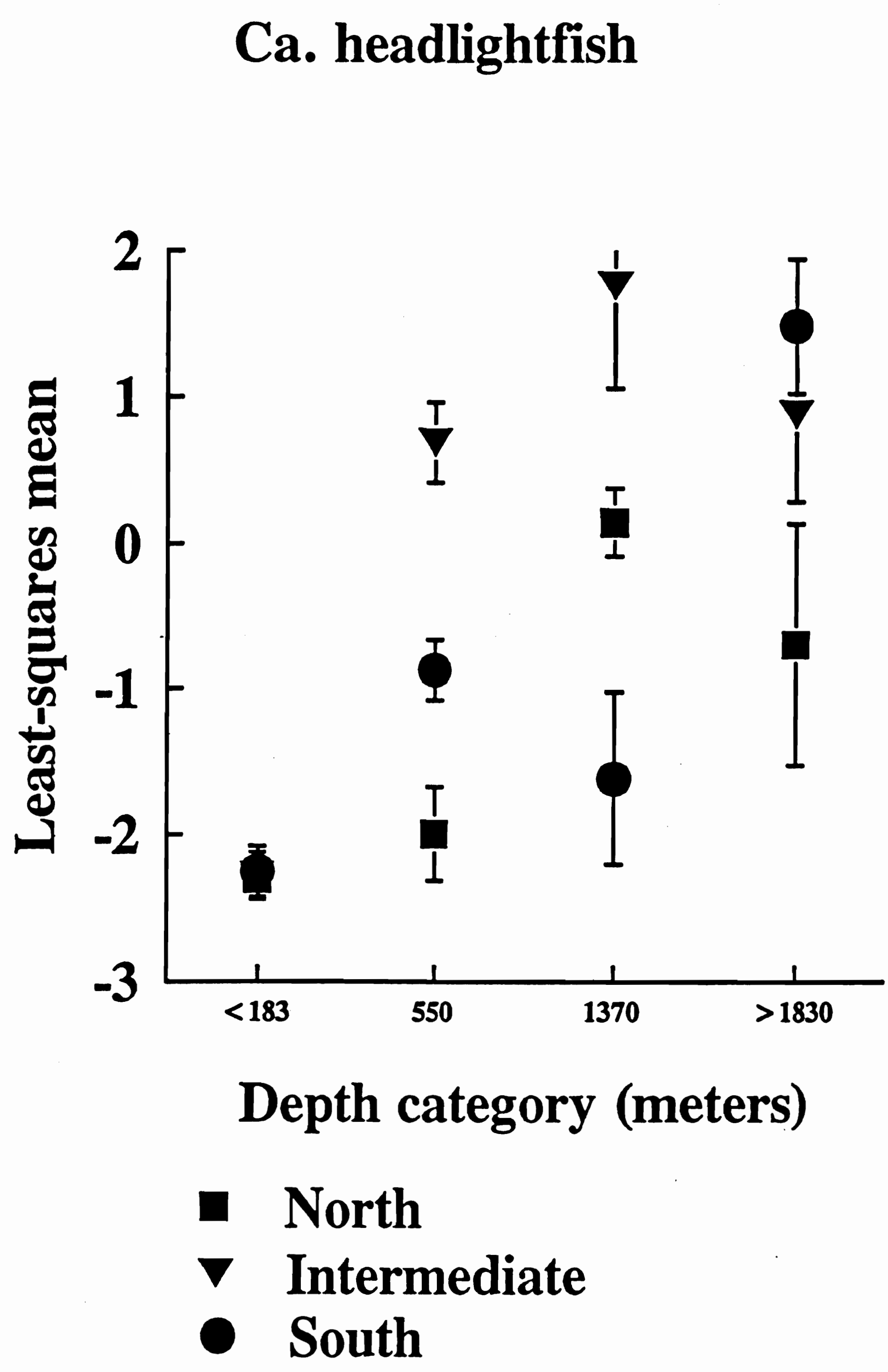


Fig. 82. Abundance of California headlightfish for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

Blue lanternfish

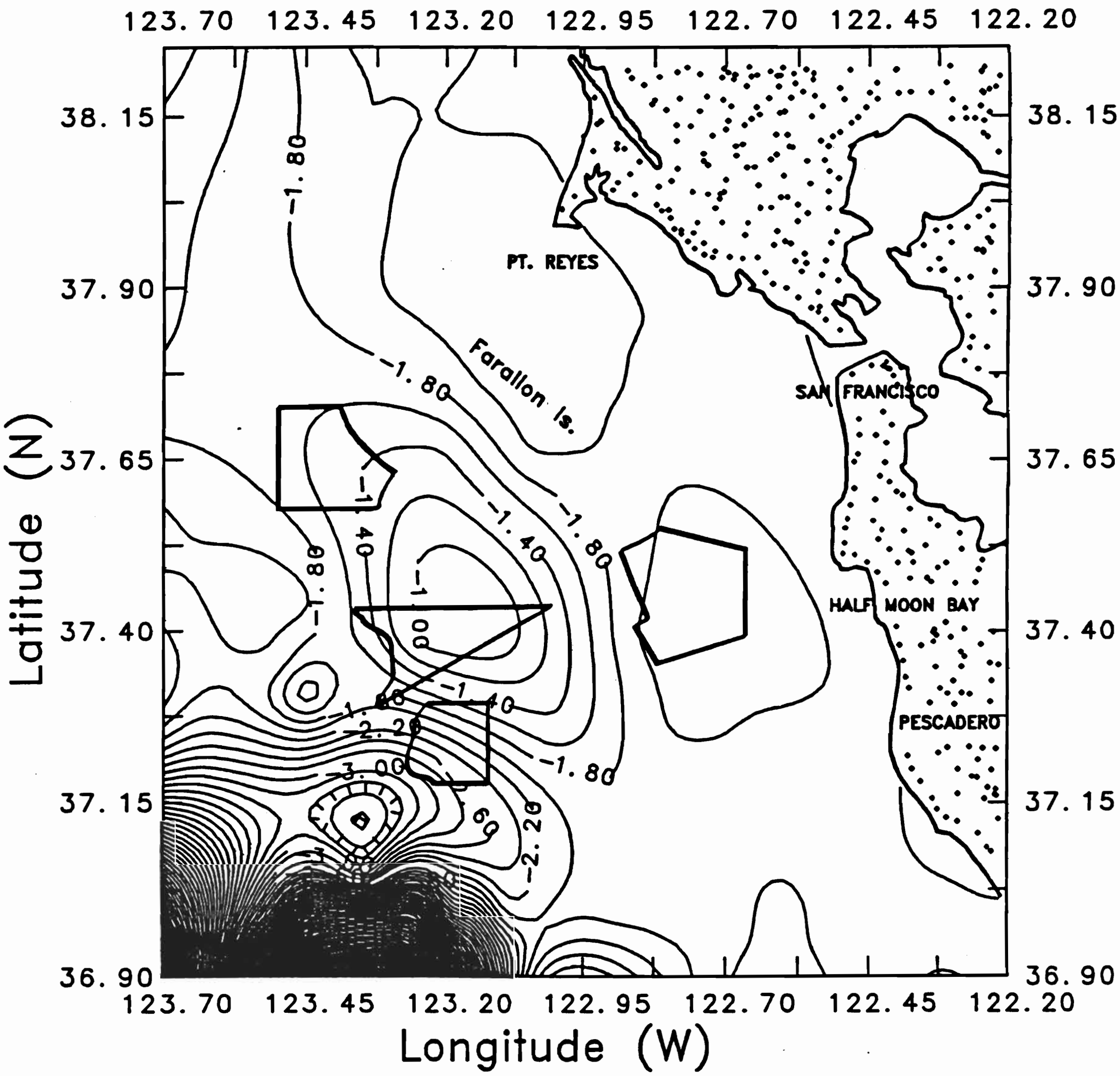


Fig. 83. Contour plot of $\log_e$-transformed abundance of blue lanternfish based on the Tiburon laboratory midwater trawl surveys.

Blue lanternfish

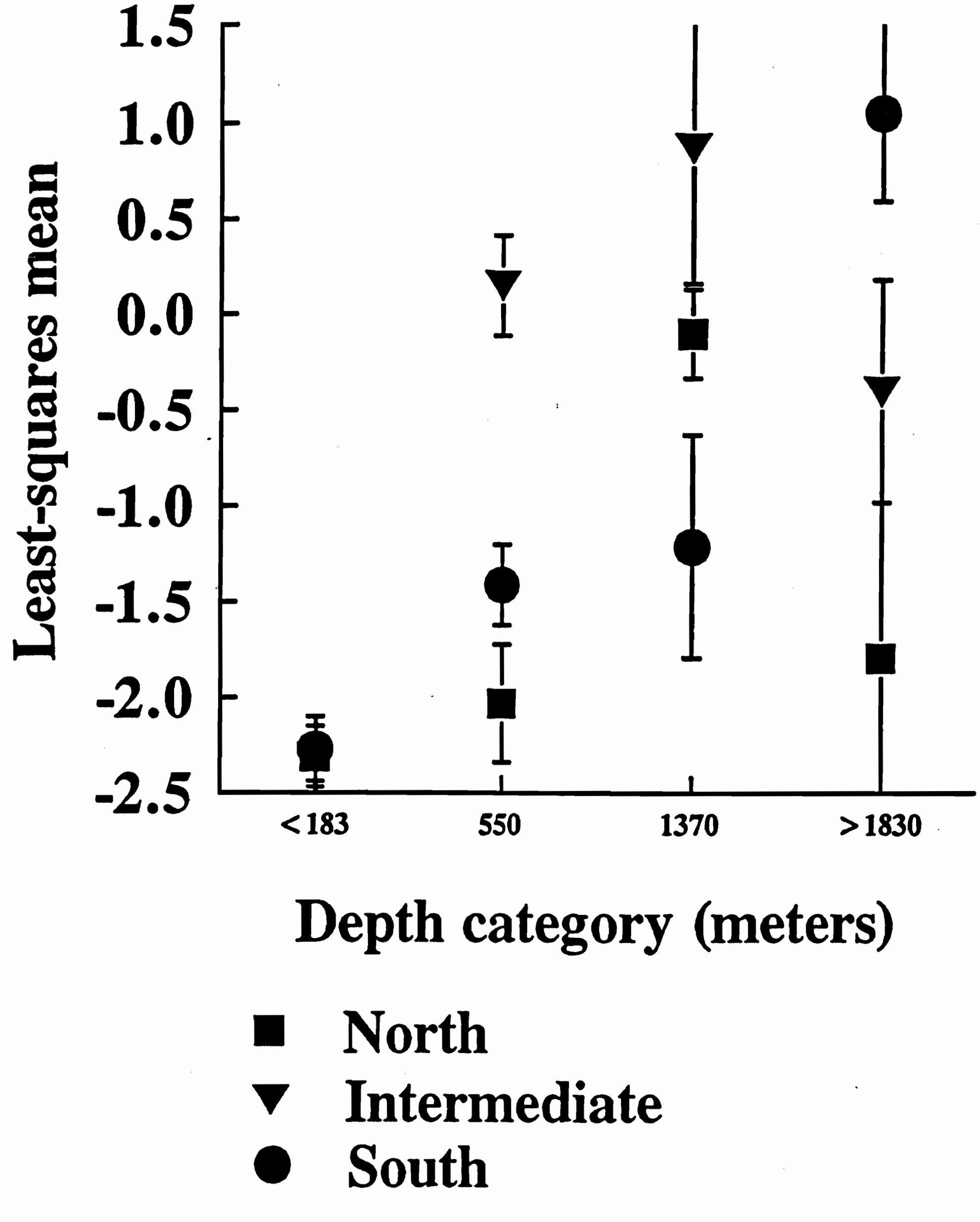
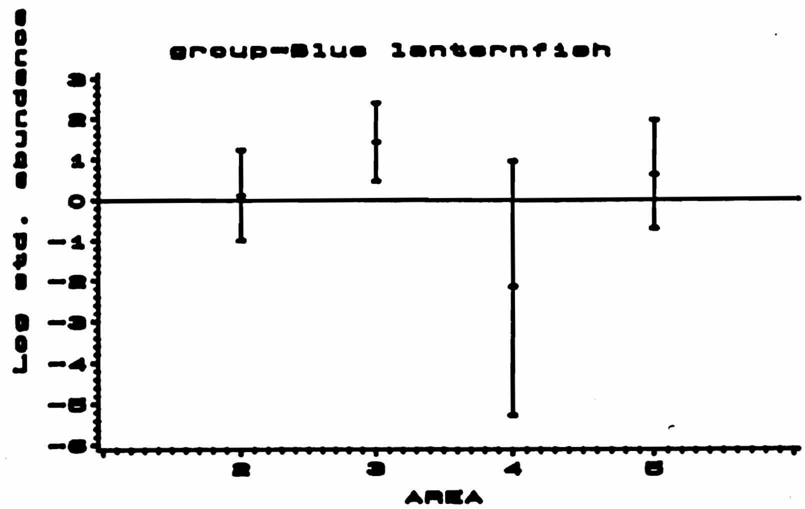


Fig. 84. Abundance of blue lanternfish for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.



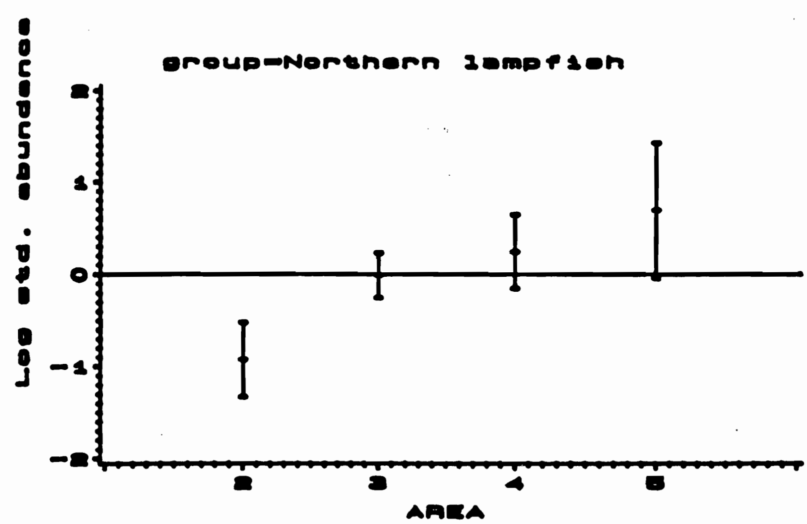


Fig. 85. Standardized mean $\log_e$-transformed abundance of blue lanternfish and northern lampfish for the EPA study areas with jackknifed 95% confidence intervals (vertical lines). Values are standardized by subtracting the mean over areas, so a value of zero is "average".

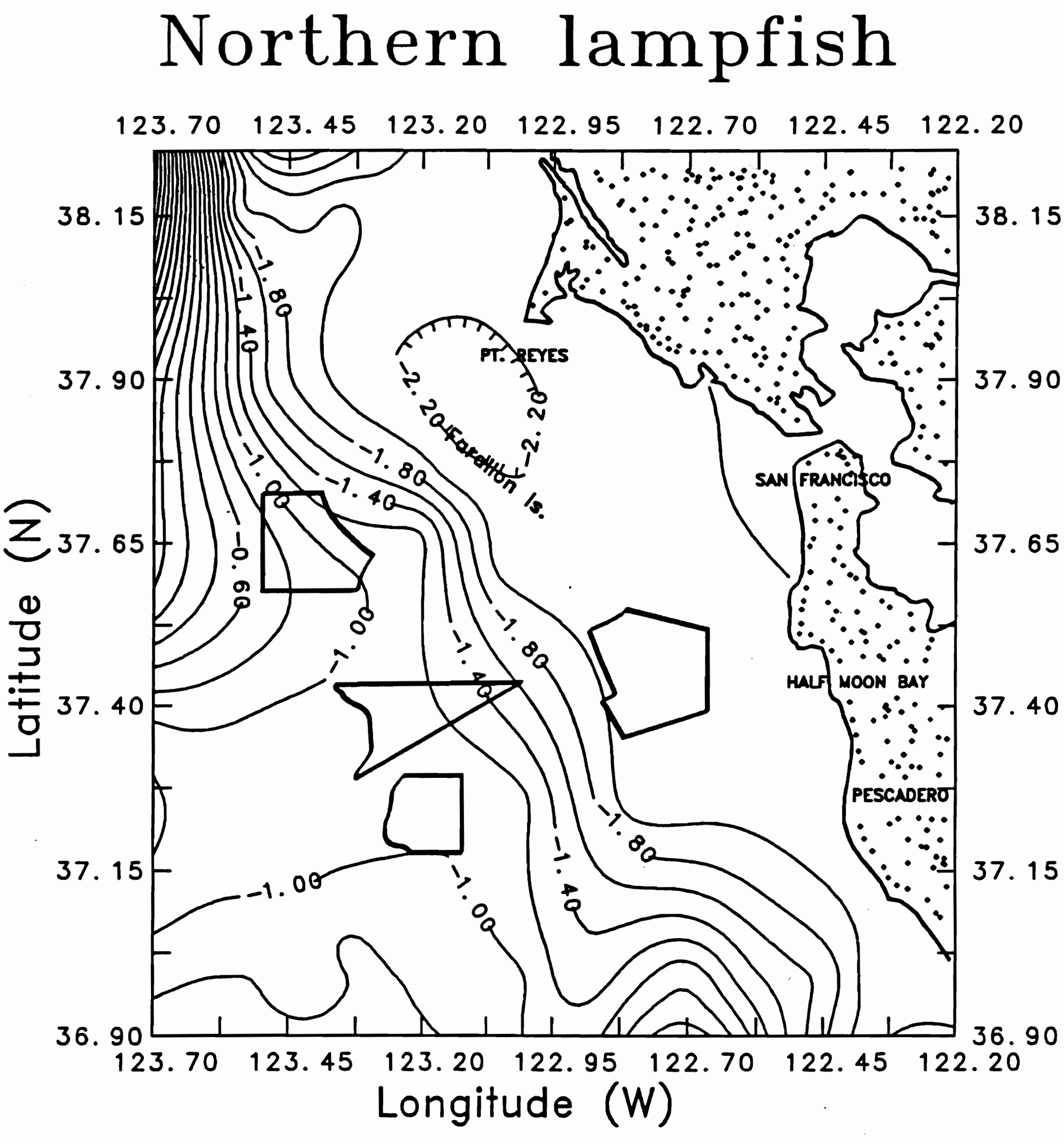


Fig. 86. Contour plot of $\log_e$-transformed abundance of northern lampfish based on the Tiburon laboratory midwater trawl surveys.

Northern lampfish

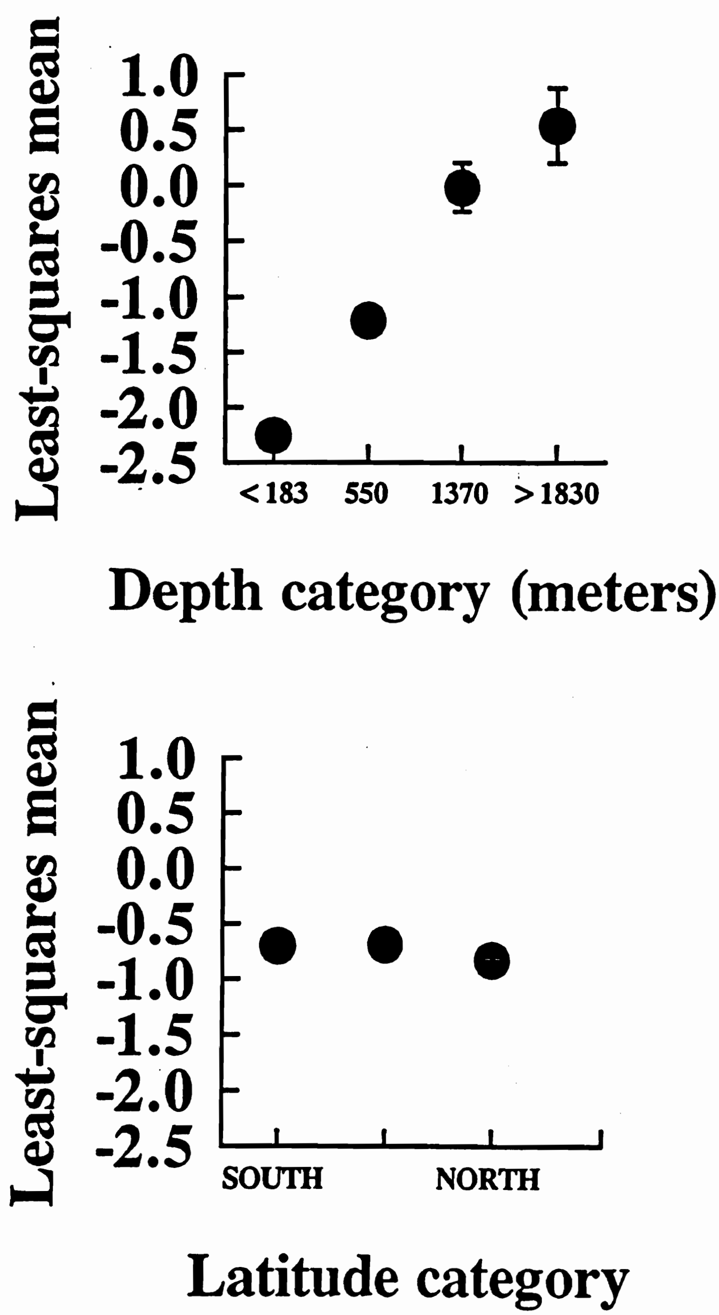


Fig. 87. Abundance of northern lampfish for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints on the graph. Standard errors of LSM's are indicated by vertical bars.

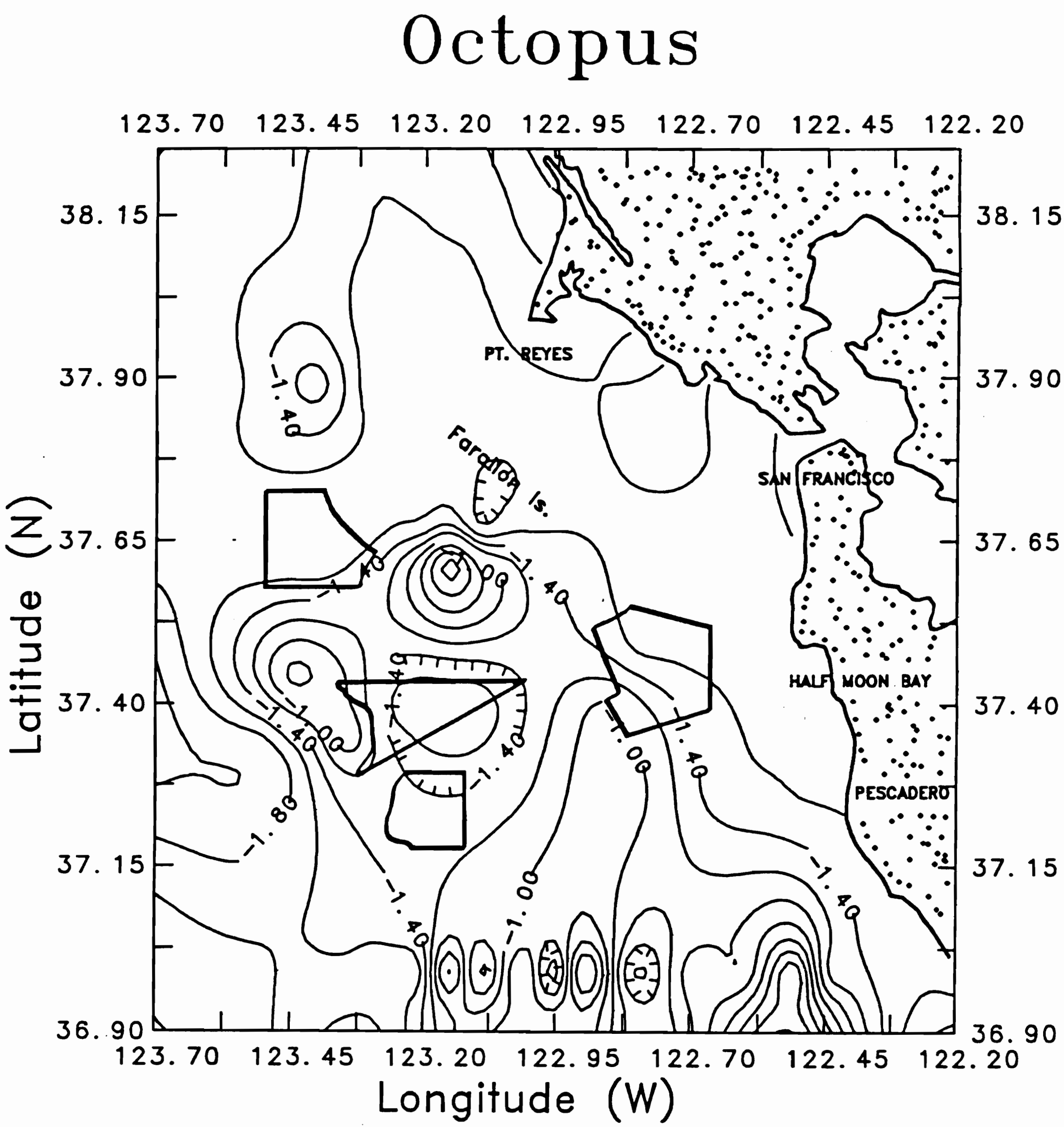


Fig. 88. Contour plot of $\log_e$-transformed abundance of octopus (all species) based on the Tiburon laboratory midwater trawl surveys.

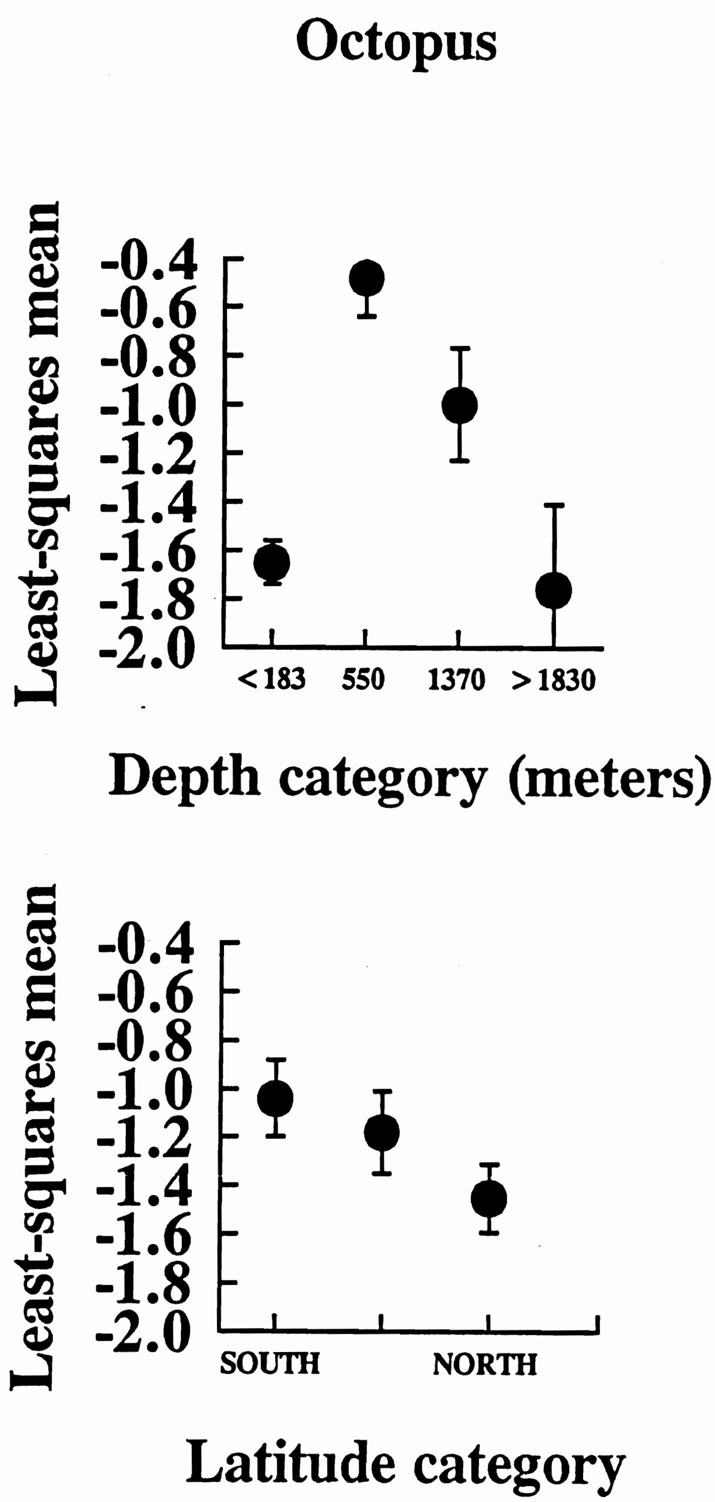


Fig. 89. Abundance of octopus for depth (top panel) and latitude (bottom panel) categories based on Tiburon Laboratory midwater trawl survey. Shown are Least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints on the graph. Standard errors of LSM's are indicated by vertical bars.

Market Squid

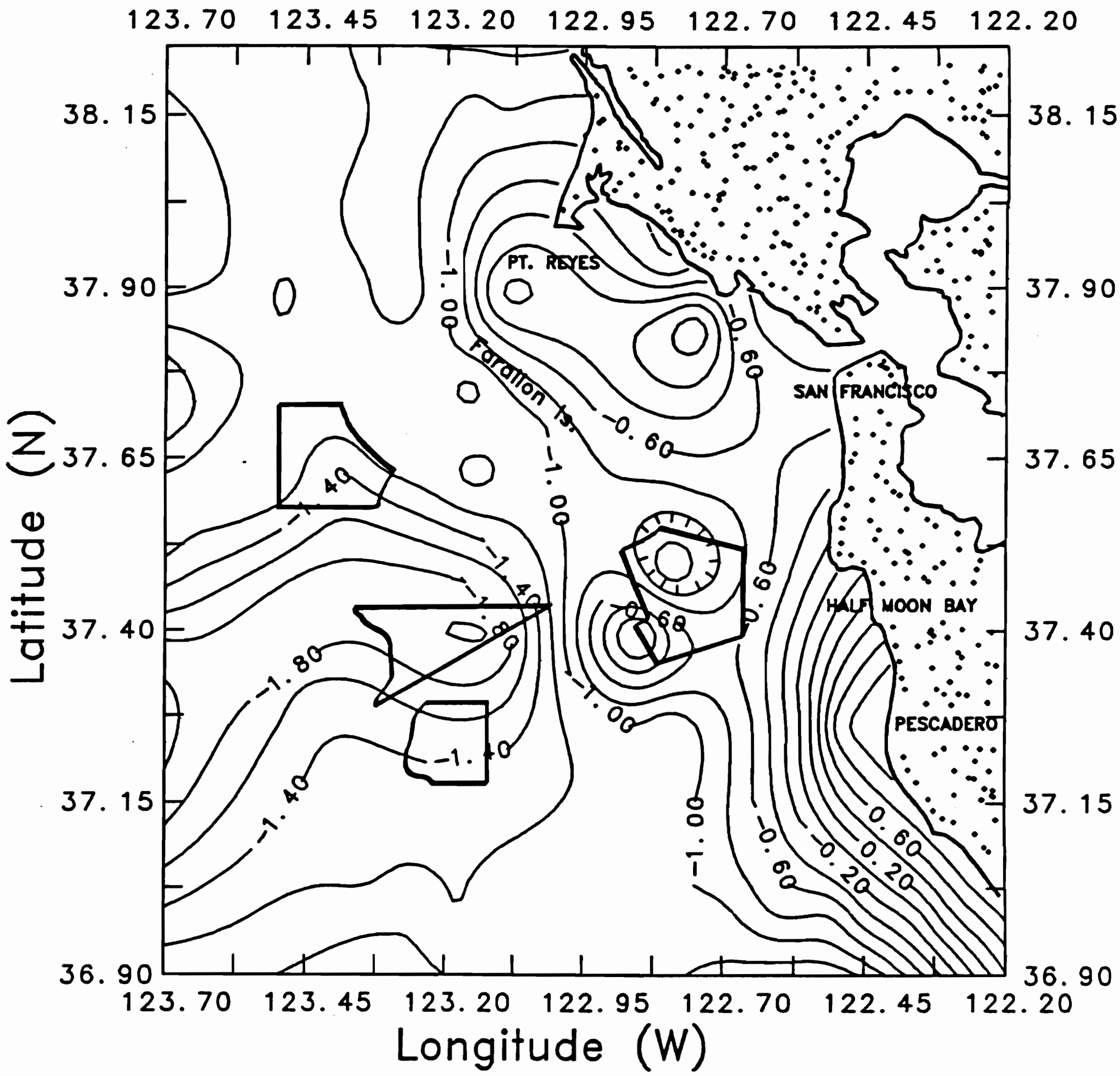


Fig. 90. Contour plot of $\log_e$-transformed abundance of market squid based on the Tiburon laboratory midwater trawl surveys.

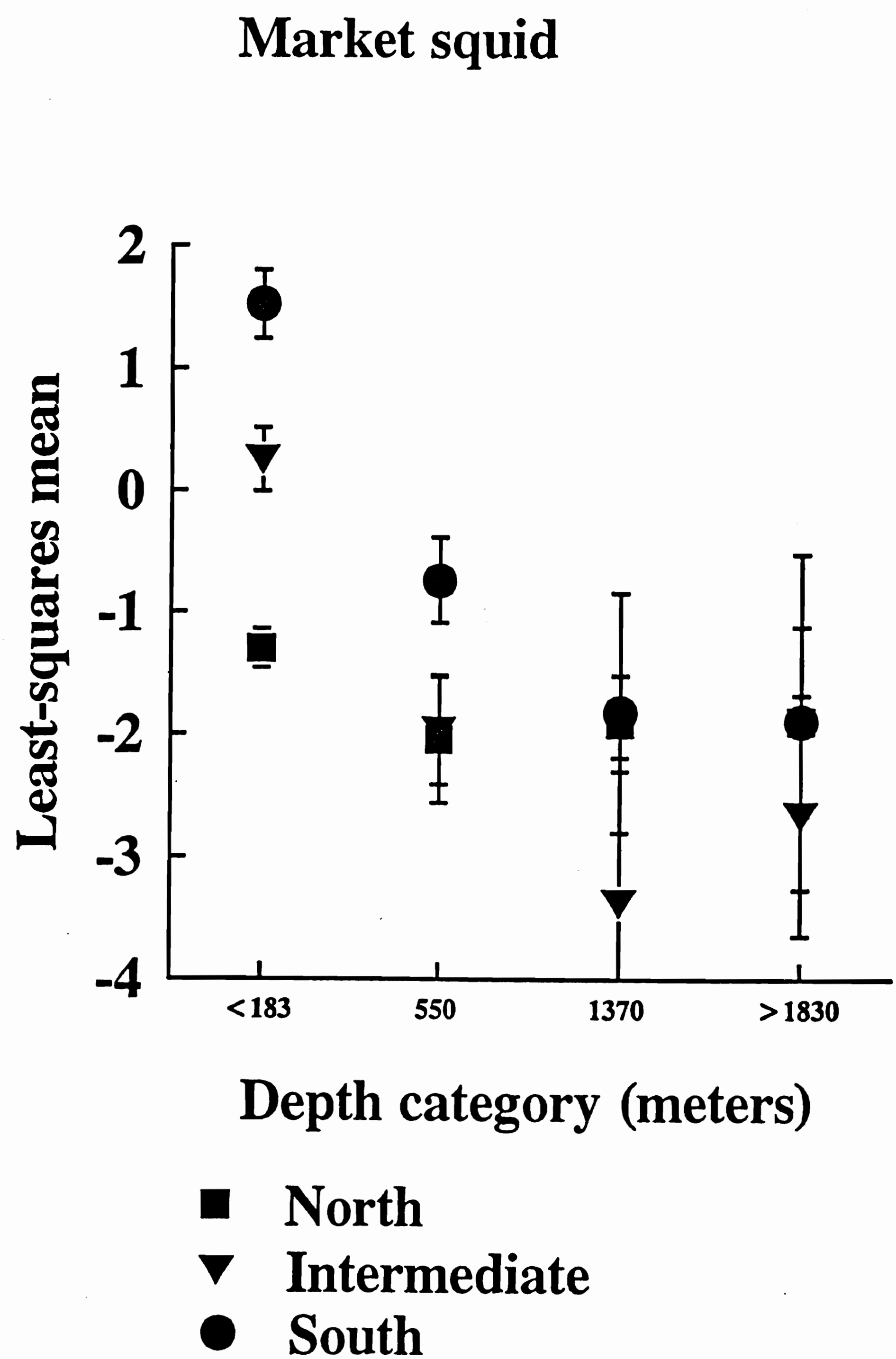


Fig. 91. Abundance of market squid for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

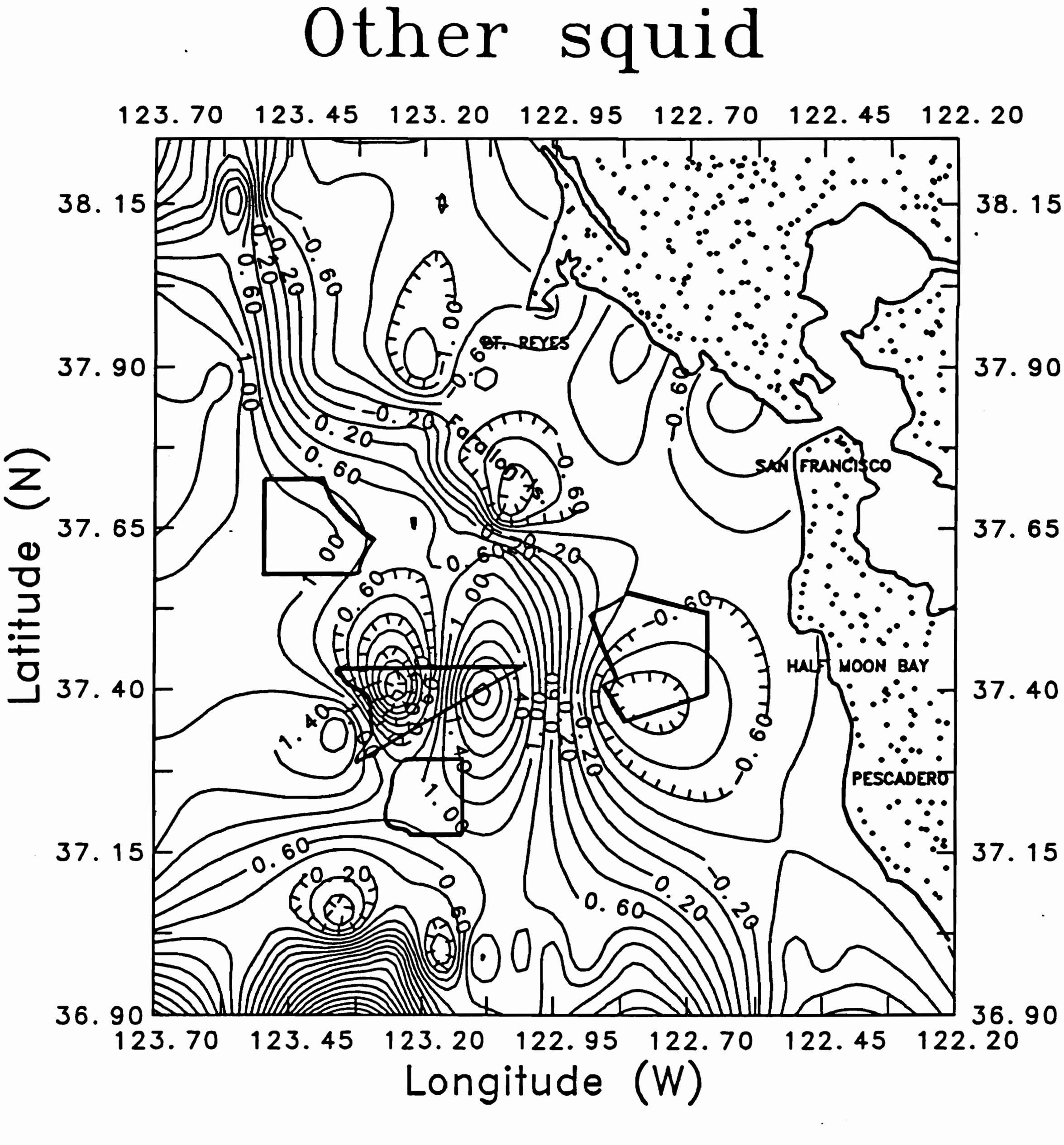


Fig. 92. Contour plot of $\log_e$-transformed abundance of squid (other than market squid) based on the Tiburon laboratory midwater trawl surveys.

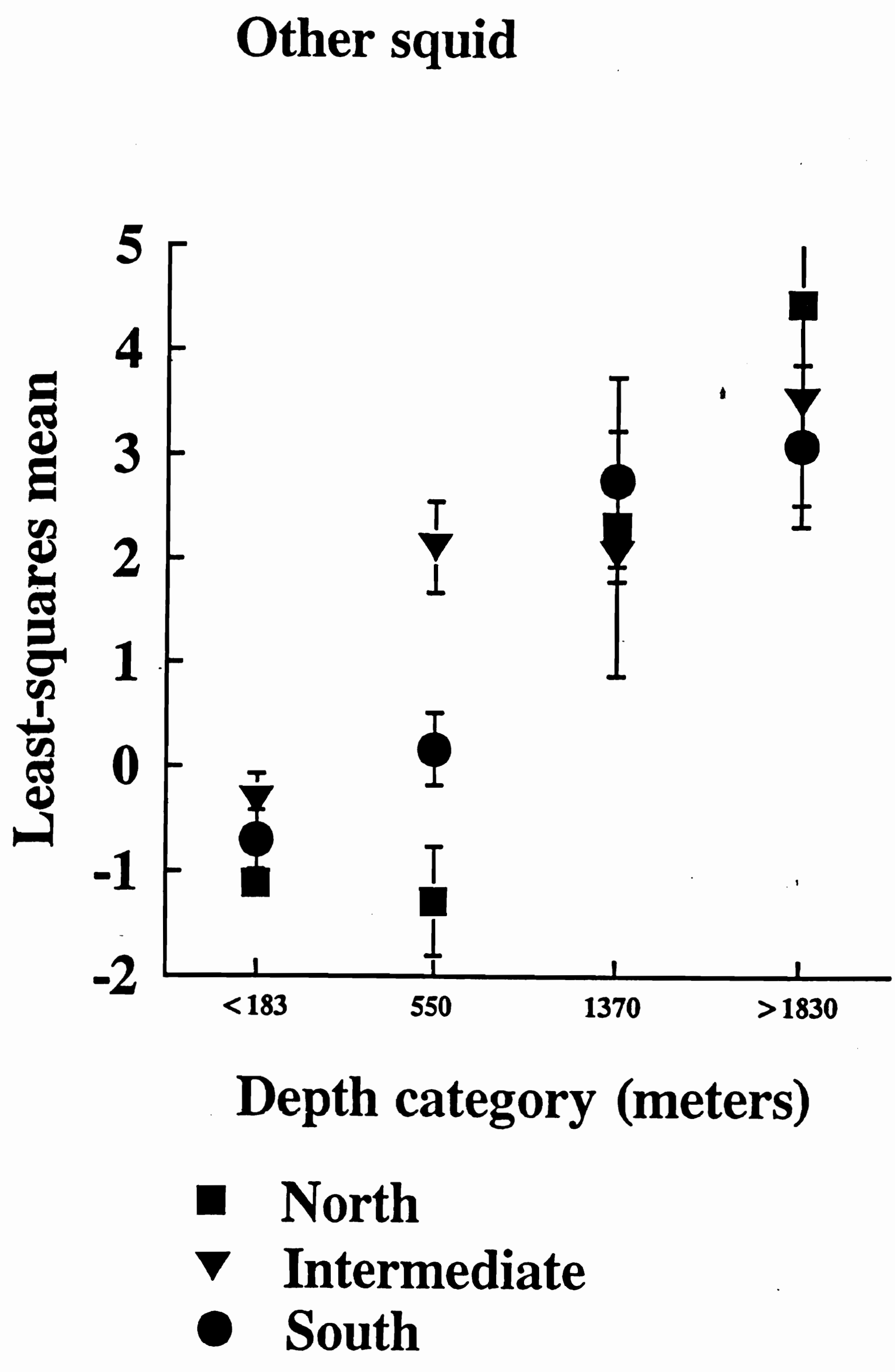


Fig. 93. Abundance of squid (other than market squid) for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

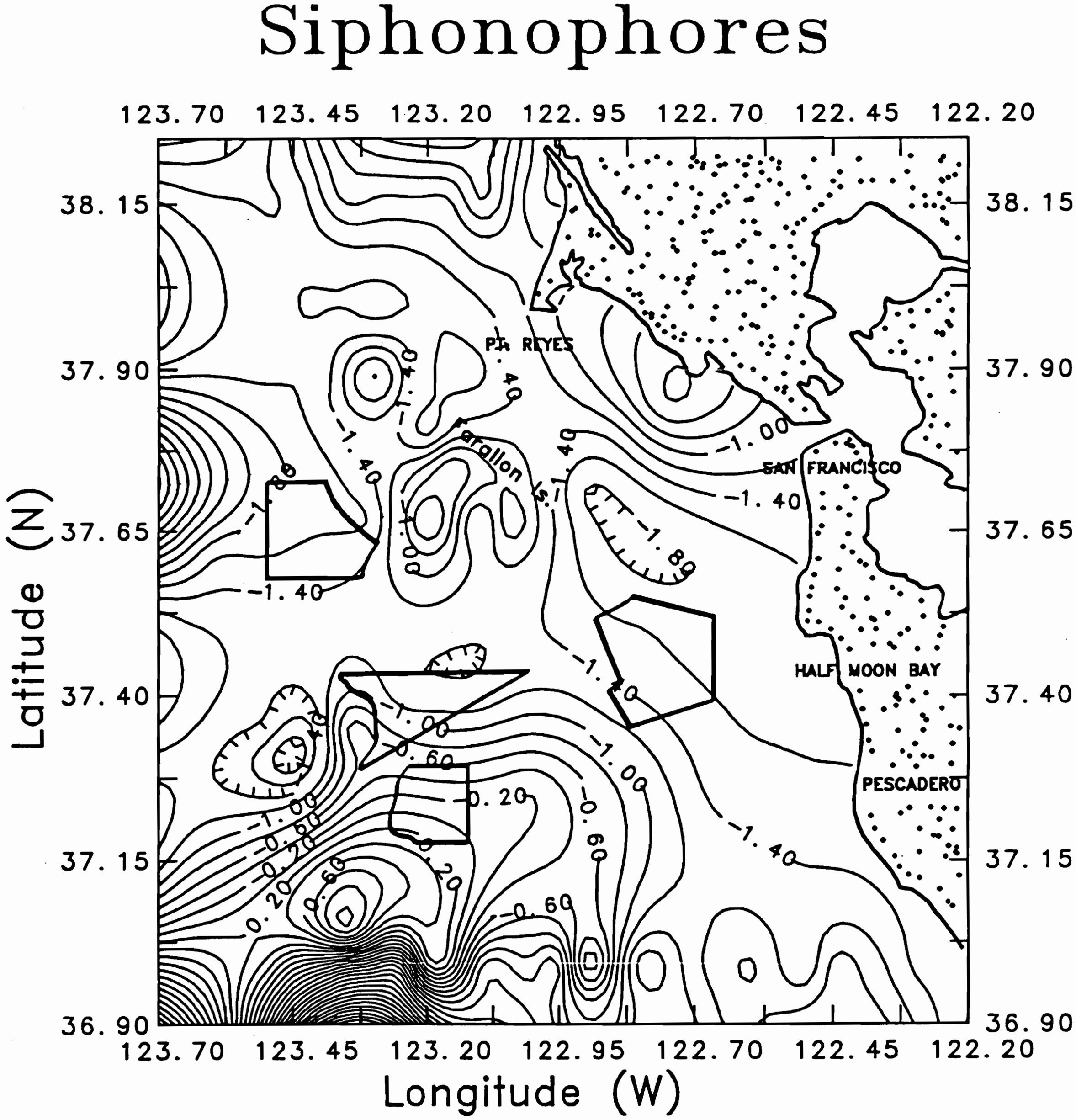


Fig. 94. Contour plot of $\log_e$-transformed abundance of siphonophores based on the Tiburon laboratory midwater trawl surveys.

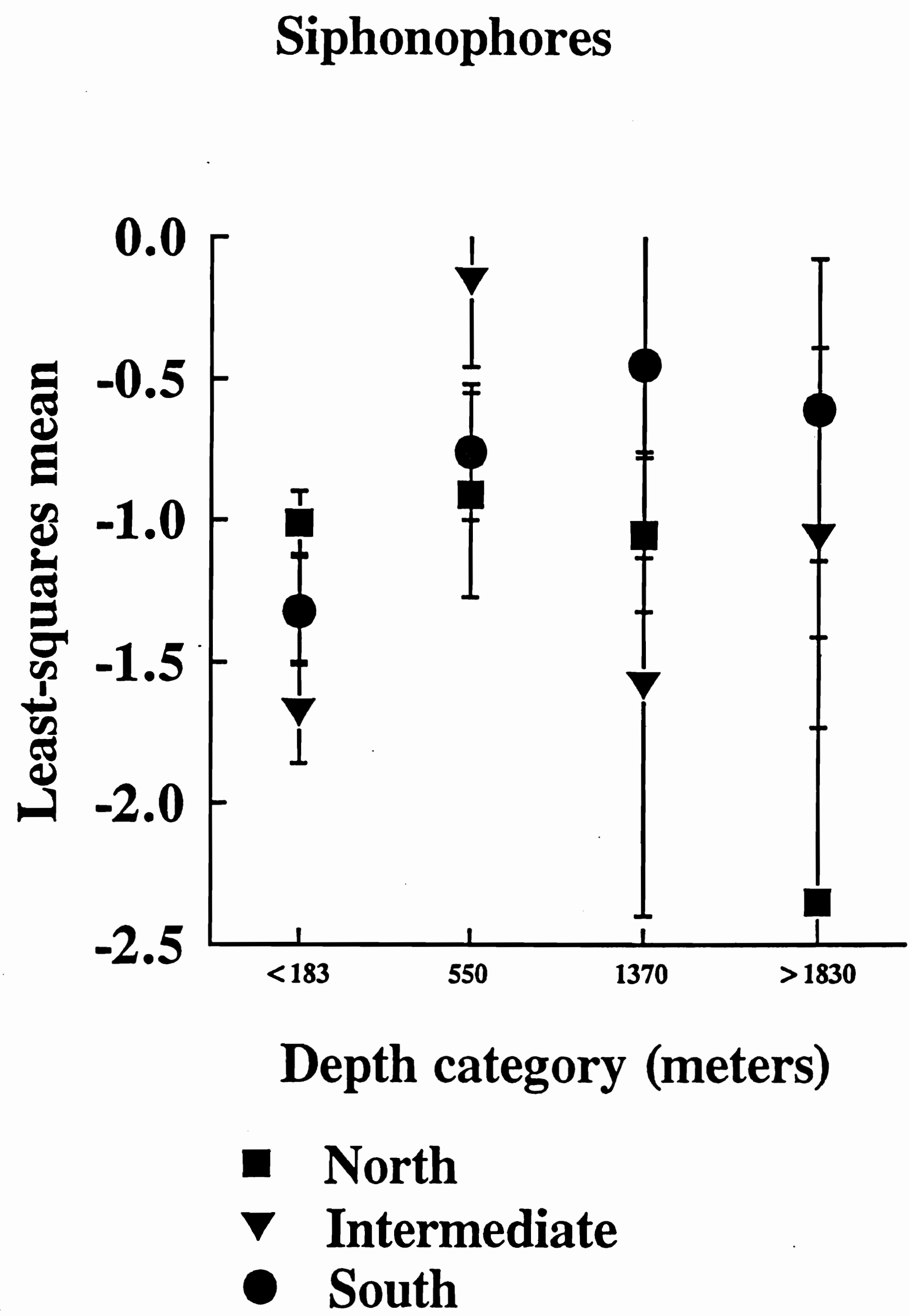
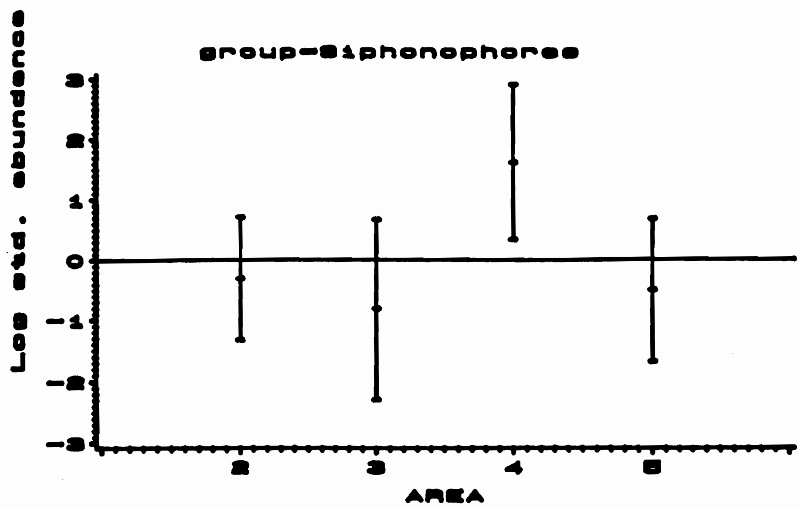


Fig. 95. Abundance of siphonophores for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of log_e-transformed abundance. The central two depth categories are indicated by their midpoints on the graph. Standard errors of LSM's are indicated by vertical bars.



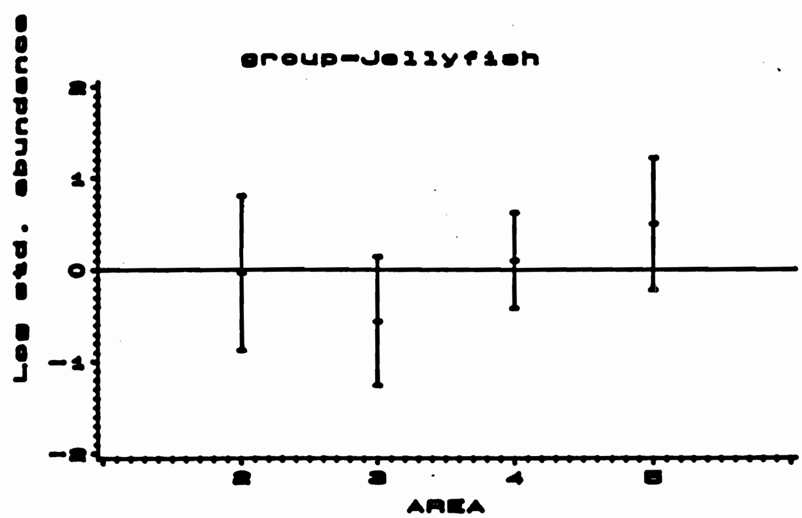


Fig. 96. Standardized mean $\log_e$-transformed abundance of siphonophores and all jellyfish for the EPA study areas with jackknifed 95% confidence intervals (vertical lines). Values are standardized by subtracting the mean over areas, so a value of zero is "average".

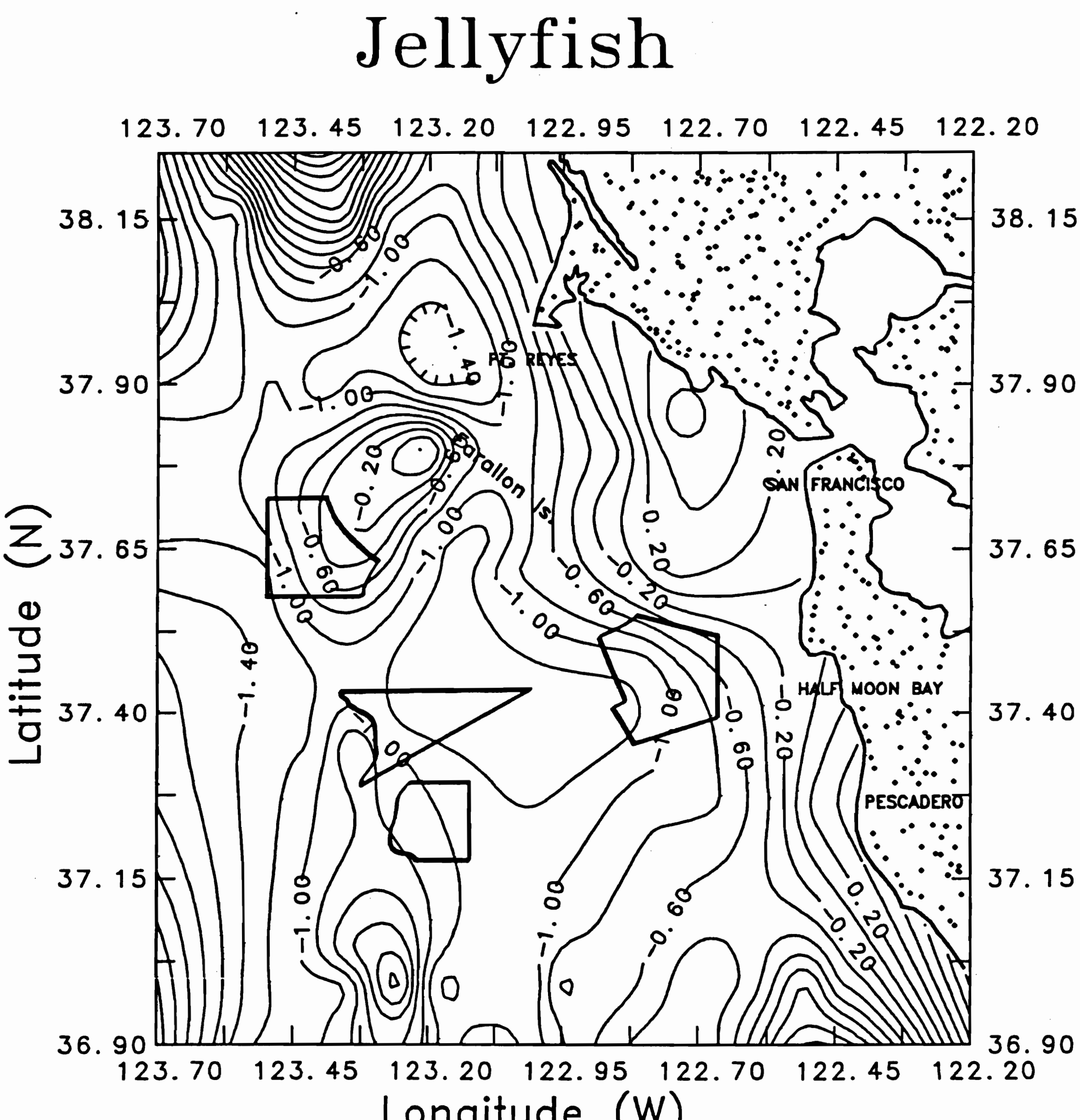


Fig. 97. Contour plot of $\log_e$-transformed abundance of jellyfish based on the Tiburon laboratory midwater trawl surveys.

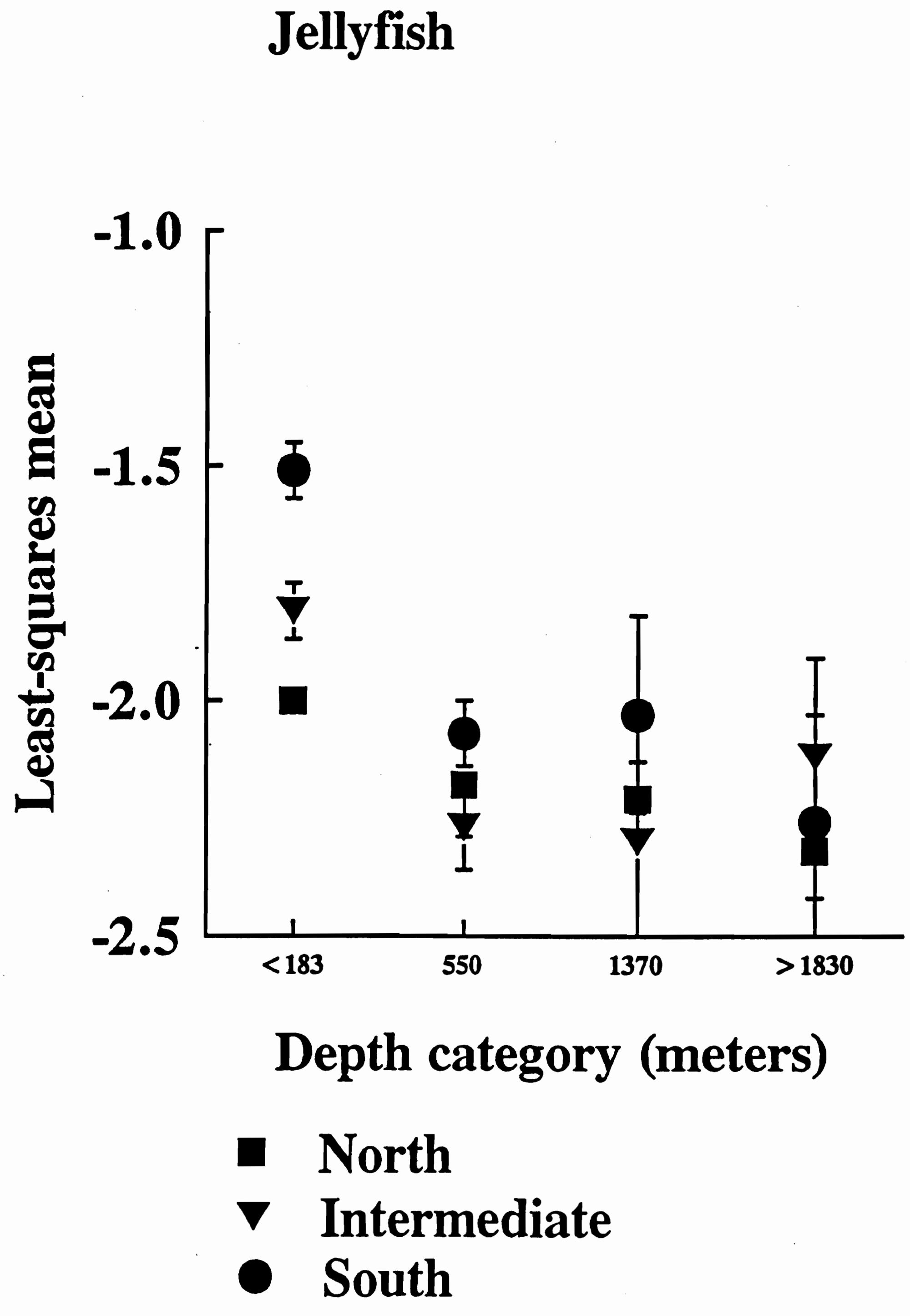


Fig. 98. Abundance of jellyfish for each combination of bottom depth and latitude based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two bottom depth categories are indicated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

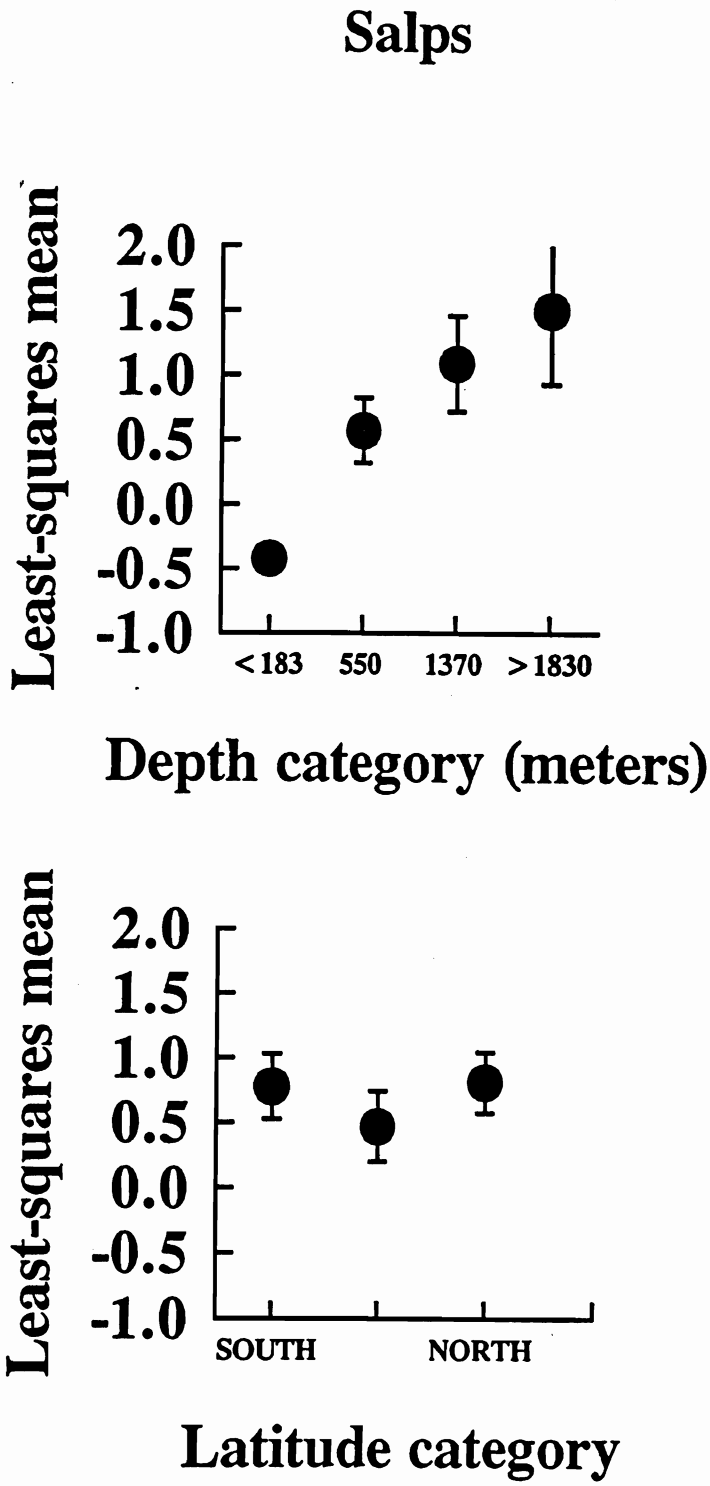


Fig. 99. Abundance of salps (all species) for depth (top panel) and latitude (bottom panel) categories based on the Tiburon Laboratory midwater trawl surveys. Shown are least-squares means of $\log_e$-transformed abundance. The central two depth categories are indicated by their midpoints on the graph. Standard errors of LSM's are indicated by vertical bars.

Euphausiid

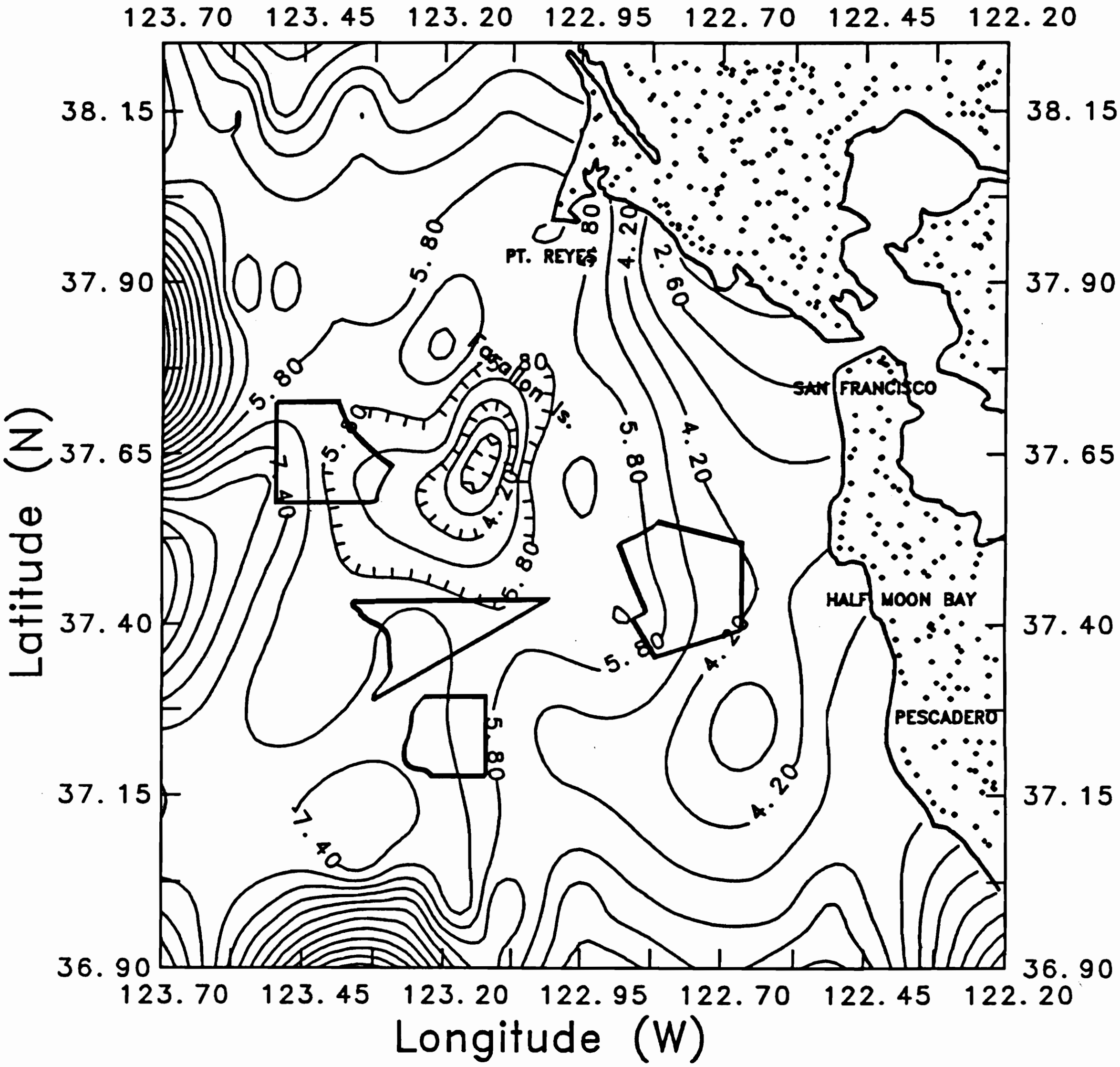


Fig. 100. Contour plot of $\log_e$-transformed abundance of euphausiids (all species) based on the Tiburon laboratory midwater trawl surveys.

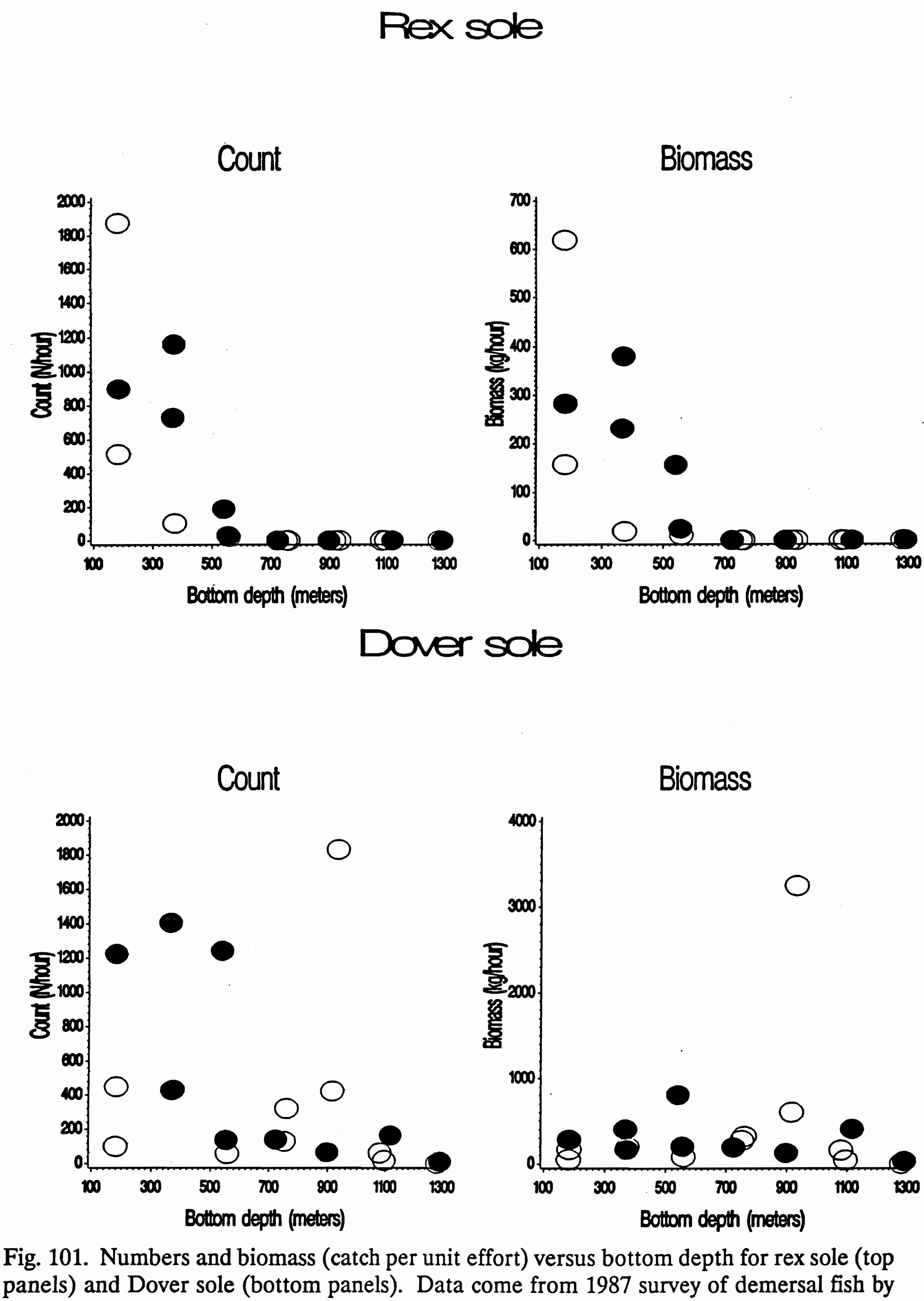


Fig. 101. Numbers and biomass (catch per unit effort) versus bottom depth for rex sole (top panels) and Dover sole (bottom panels). Data come from 1987 survey of demersal fish by SWFSC. Line off Half Moon Bay=solid circles and line off Pt. Ano Nuevo=open circles.

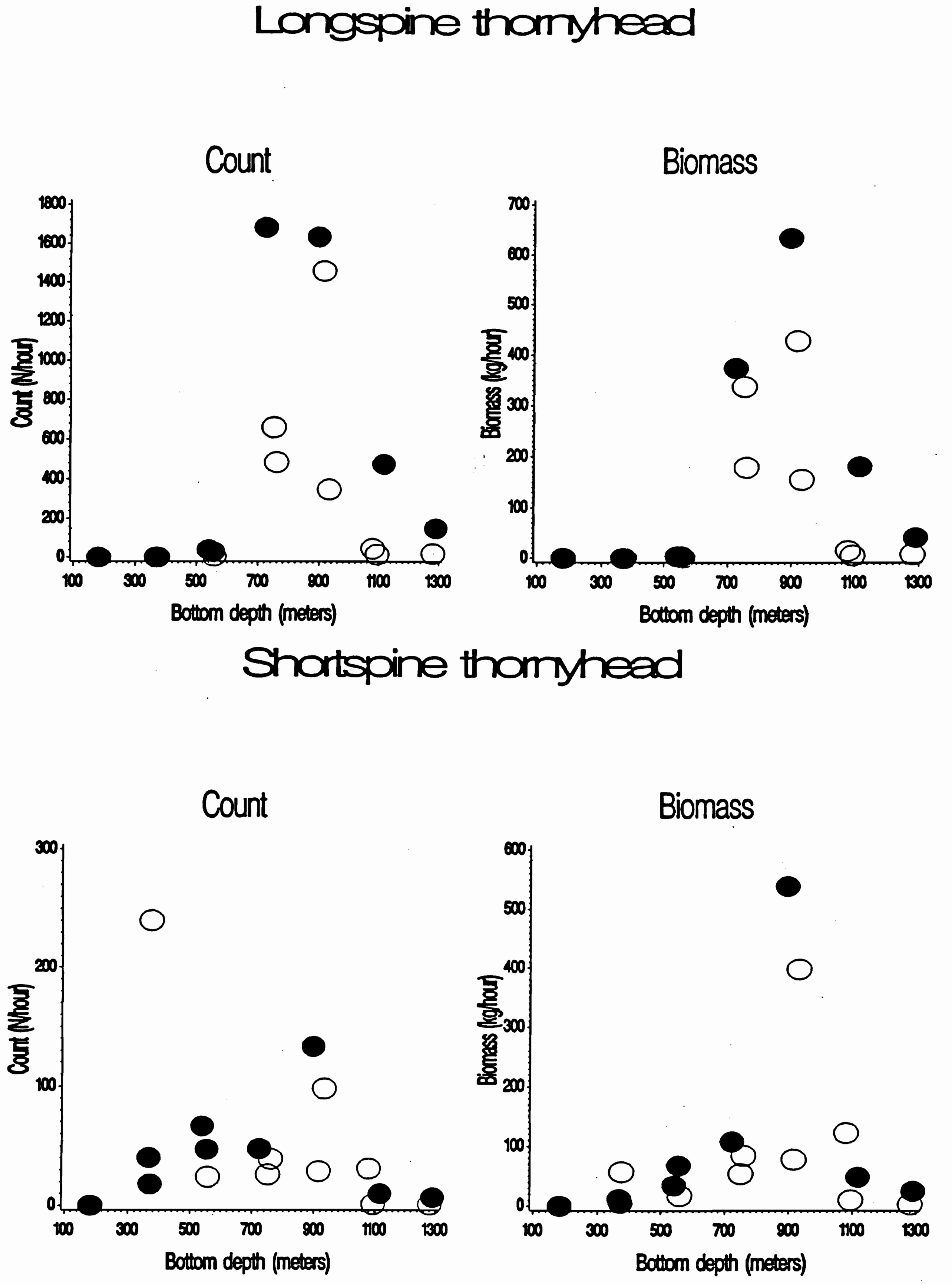


Fig. 102. Numbers and biomass (catch per unit effort) versus bottom depth for thornyheads (longspine - top panels; shortspine - bottom panels). Data come from 1987 survey of demersal fish by SWFSC. Line off Half Moon Bay=solid circles and line off Pt. Ano Nuevo=open circles.

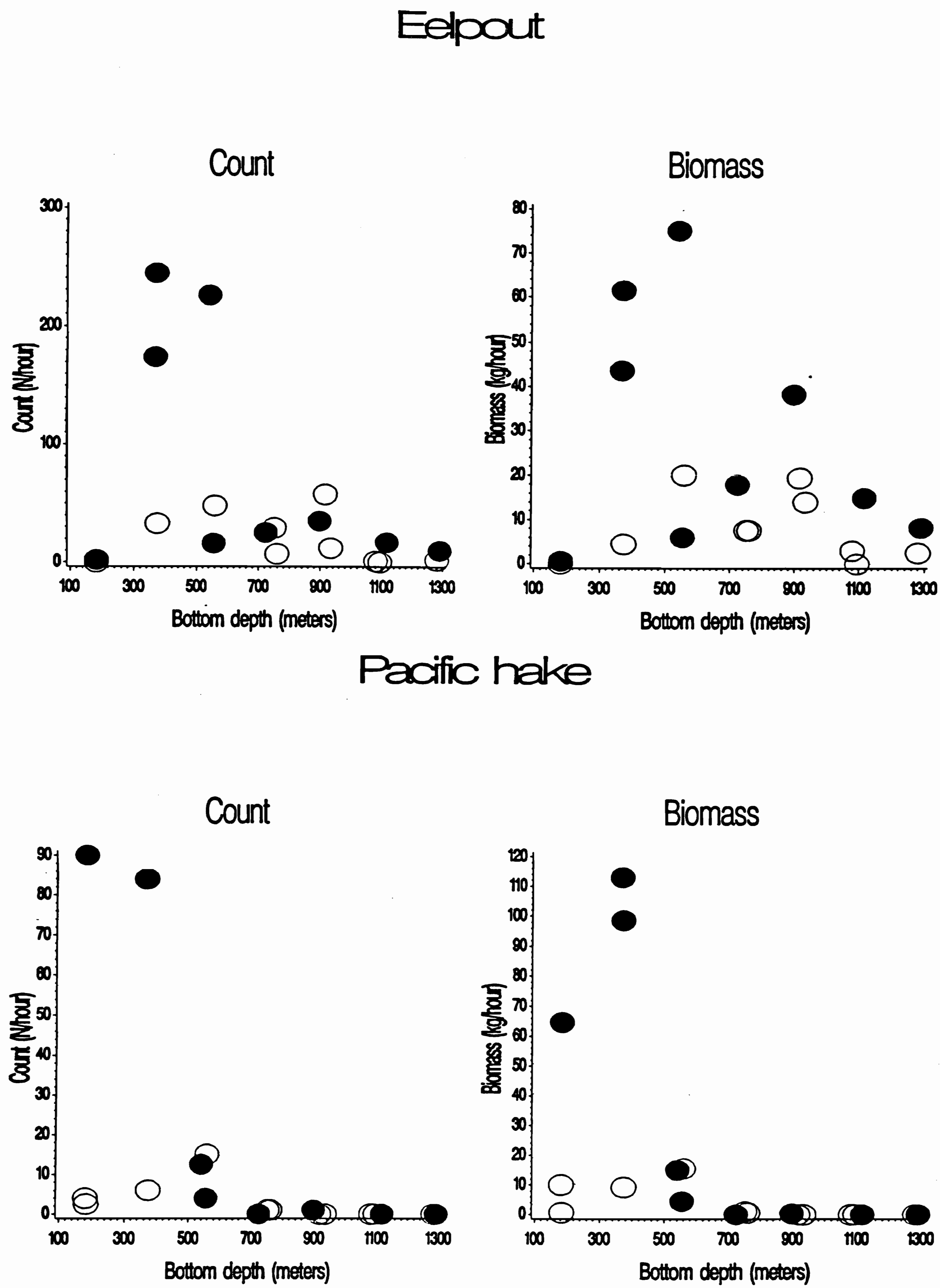


Fig. 103. Numbers and biomass (catch per unit effort) versus bottom depth for total eelpouts (top panels) and Pacific hake (bottom panels). Data come from 1987 survey of demersal fish by SWFSC. Line off Half Moon Bay=solid circles and line off Pt. Ano Nuevo=open circles.

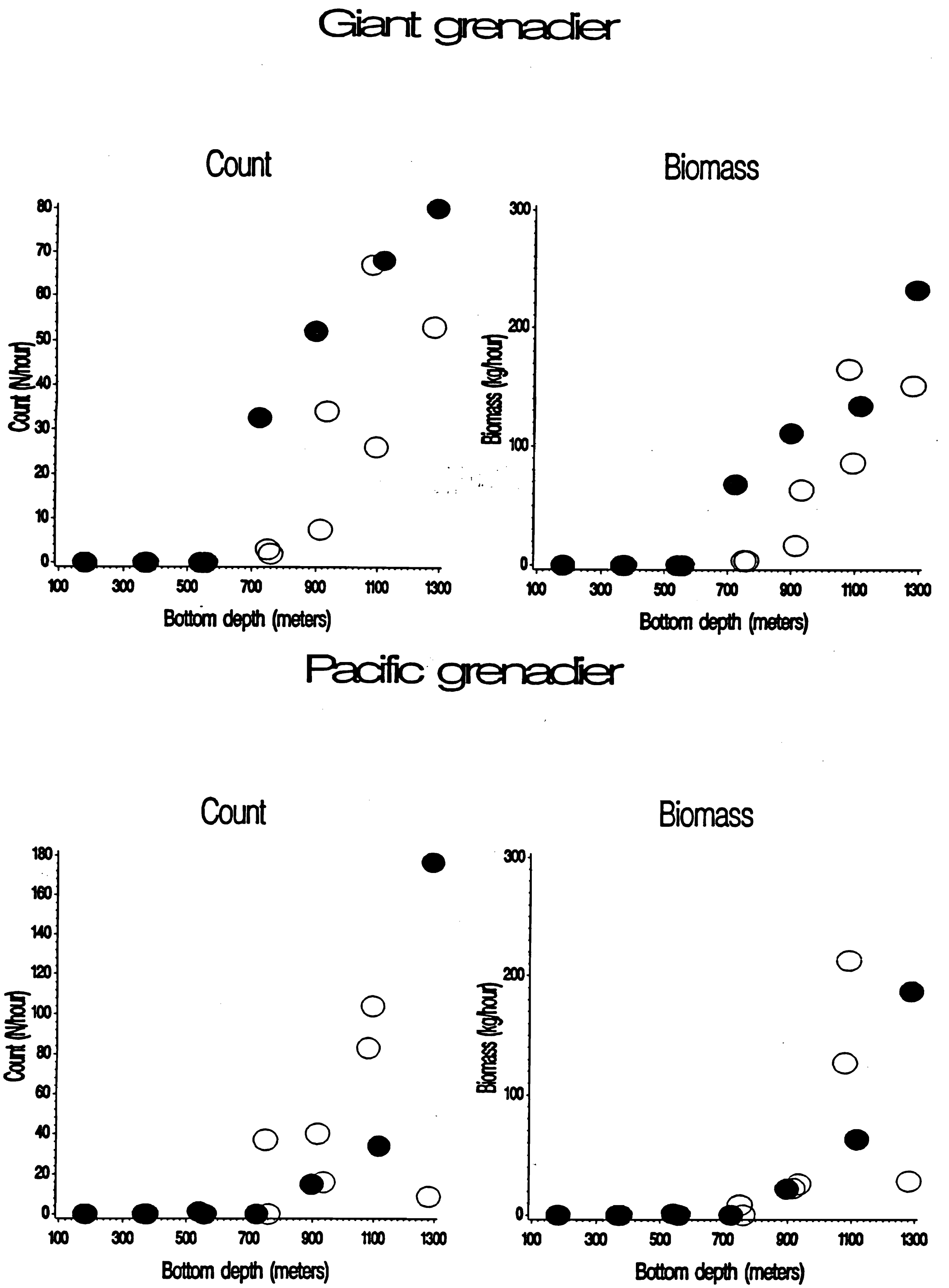


Fig. 104. Numbers and biomass (catch per unit effort) versus bottom depth for giant grenadier (top panels) and Pacific grenadier (bottom panels). Data come from 1987 survey of demersal fish by SWFSC. Line off Half Moon Bay=solid circles and line off Pt. Ano Nuevo=open circles.

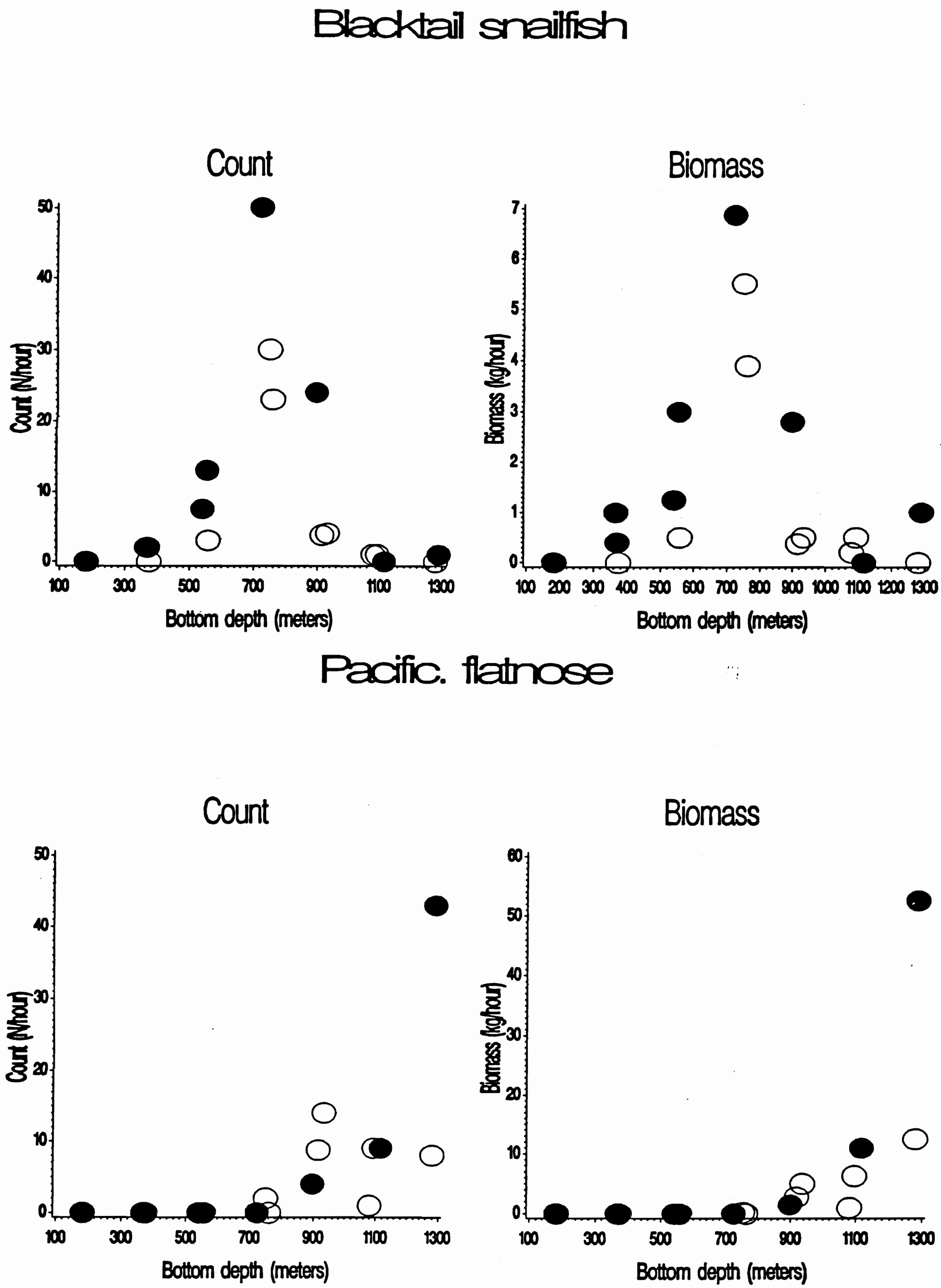


Fig. 105. Numbers and biomass (catch per unit effort) versus bottom depth for blacktail snailfish (top panels) and Pacific flatnose (bottom panels). Data come from 1987 survey of demersal fish by SWFSC. Line off Half Moon Bay=solid circles and line off Pt. Ano Nuevo=open circles.

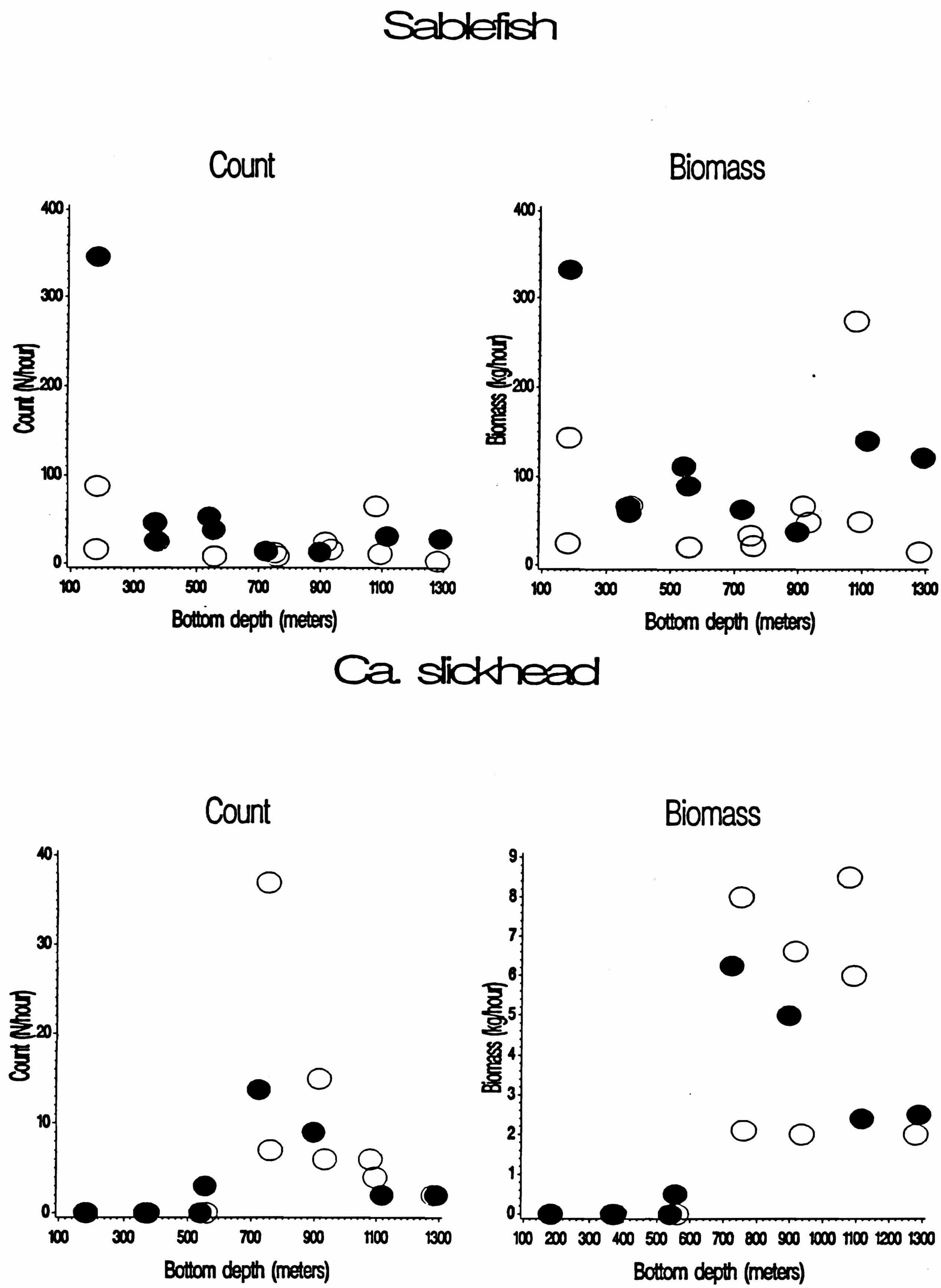


Fig. 106. Numbers and biomass (catch per unit effort) versus bottom depth for sablefish (top panel) and California slickhead (bottom panel). Data come from 1987 survey of demersal fish by SWFSC. Line off Half Moon Bay=solid circles and line off Pt. Ano Nuevo=open circles.

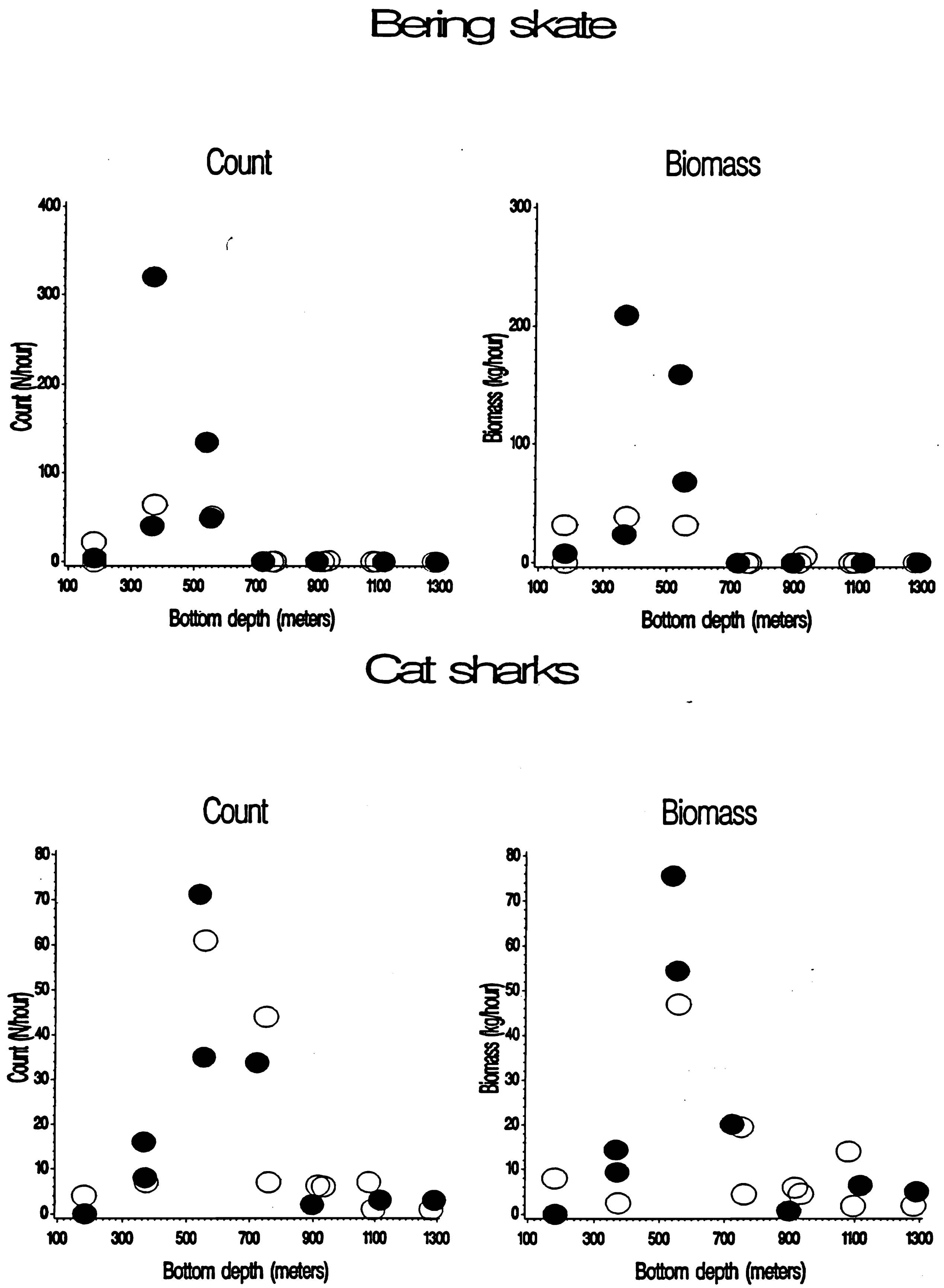


Fig. 107. Numbers and biomass (catch per unit effort) versus bottom depth for Bering skate (top panels) and all species of cat sharks (bottom panels). Data come from 1987 survey of demersal fish by SWFSC. Line off Half Moon Bay=solid circles and line off Pt. Ano Nuevo=open circles.

Tanner crab

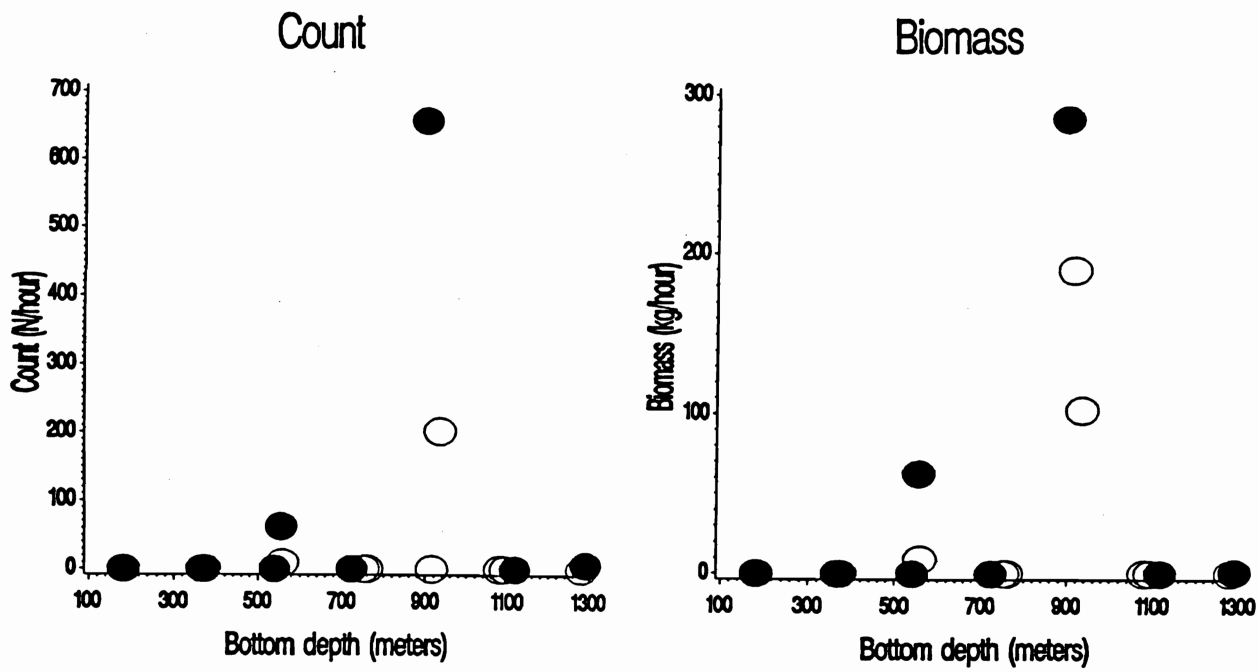


Fig. 108. Numbers and biomass (catch per unit effort) versus bottom depth for tanner crab. Data come from 1987 survey of demersal fish by SWFSC. Line off Half Moon Bay=solid circles and line off Pt. Ano Nuevo=open circles.

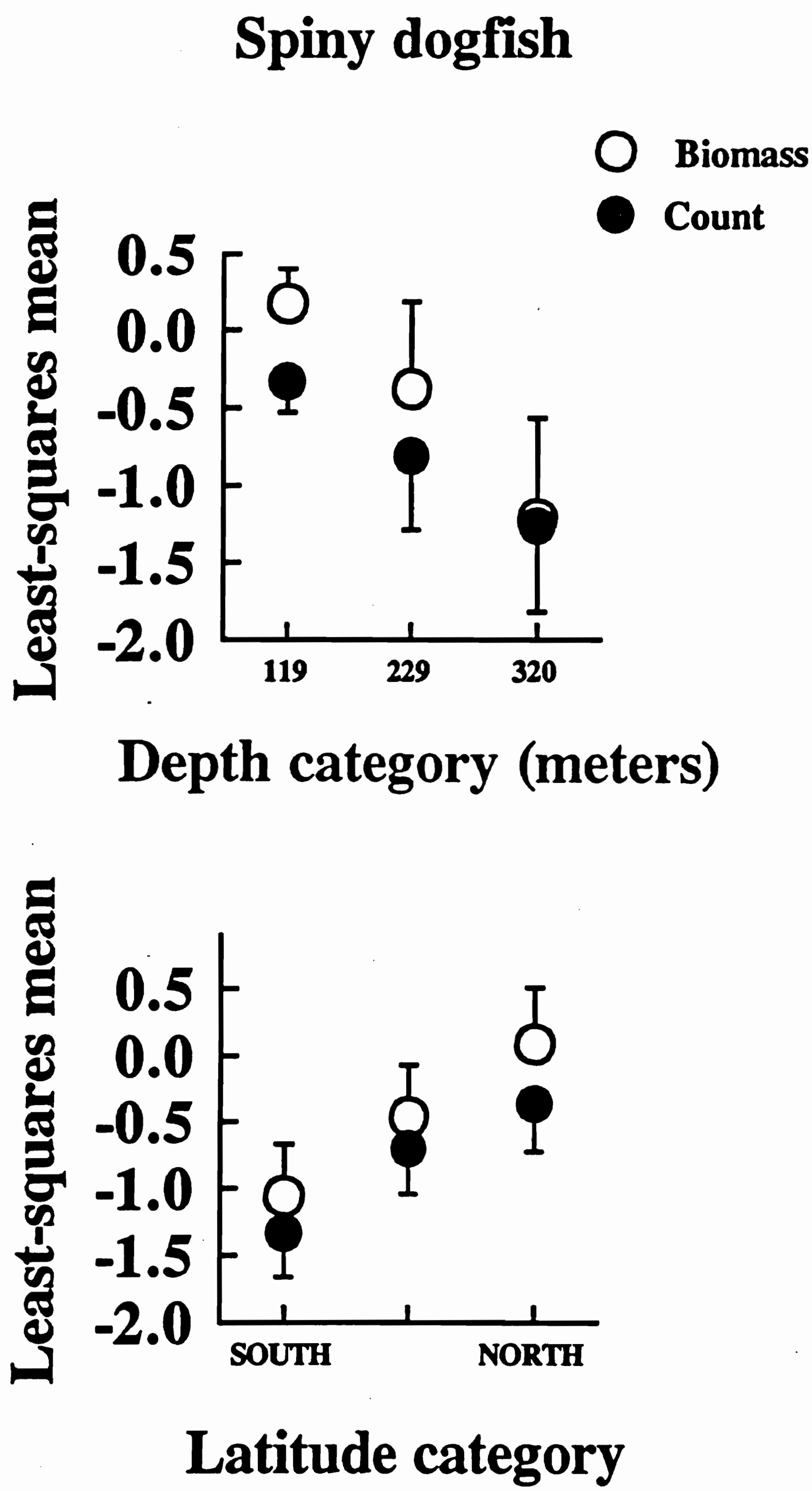


Fig. 109. Abundance (least-squares means of $\log_e$ transformed counts and biomass (catch per unit effort) of spiny dogfish for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

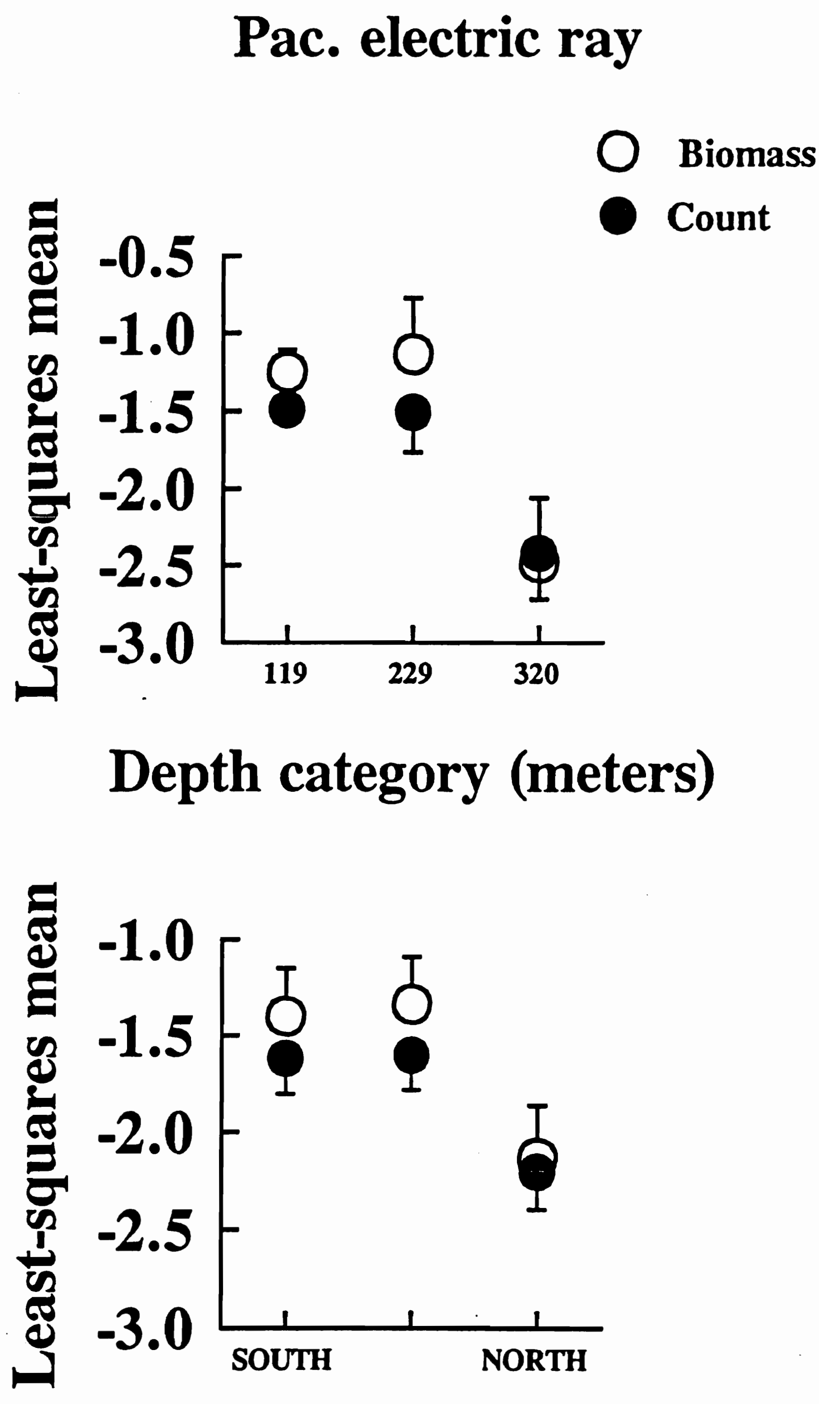


Fig. 110. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of Pacific electric ray for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

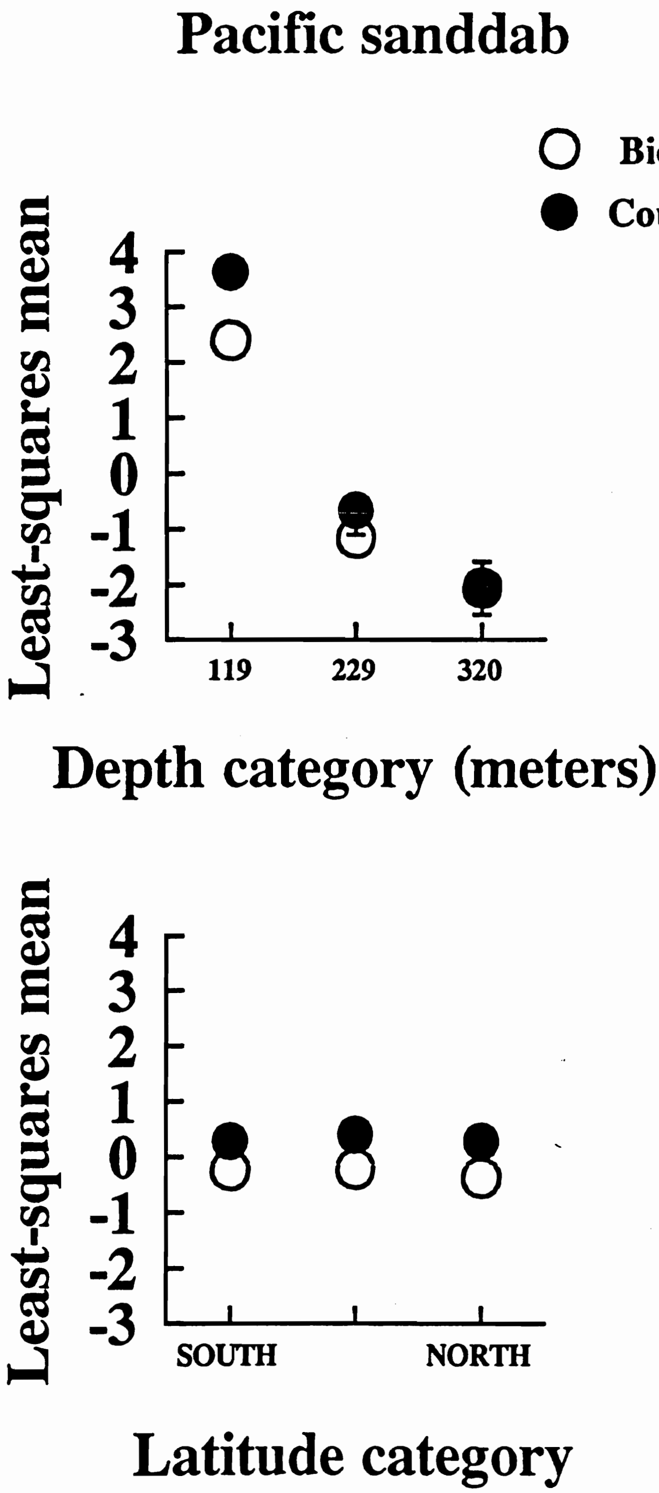


Fig. 111. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of Pacific sanddab for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

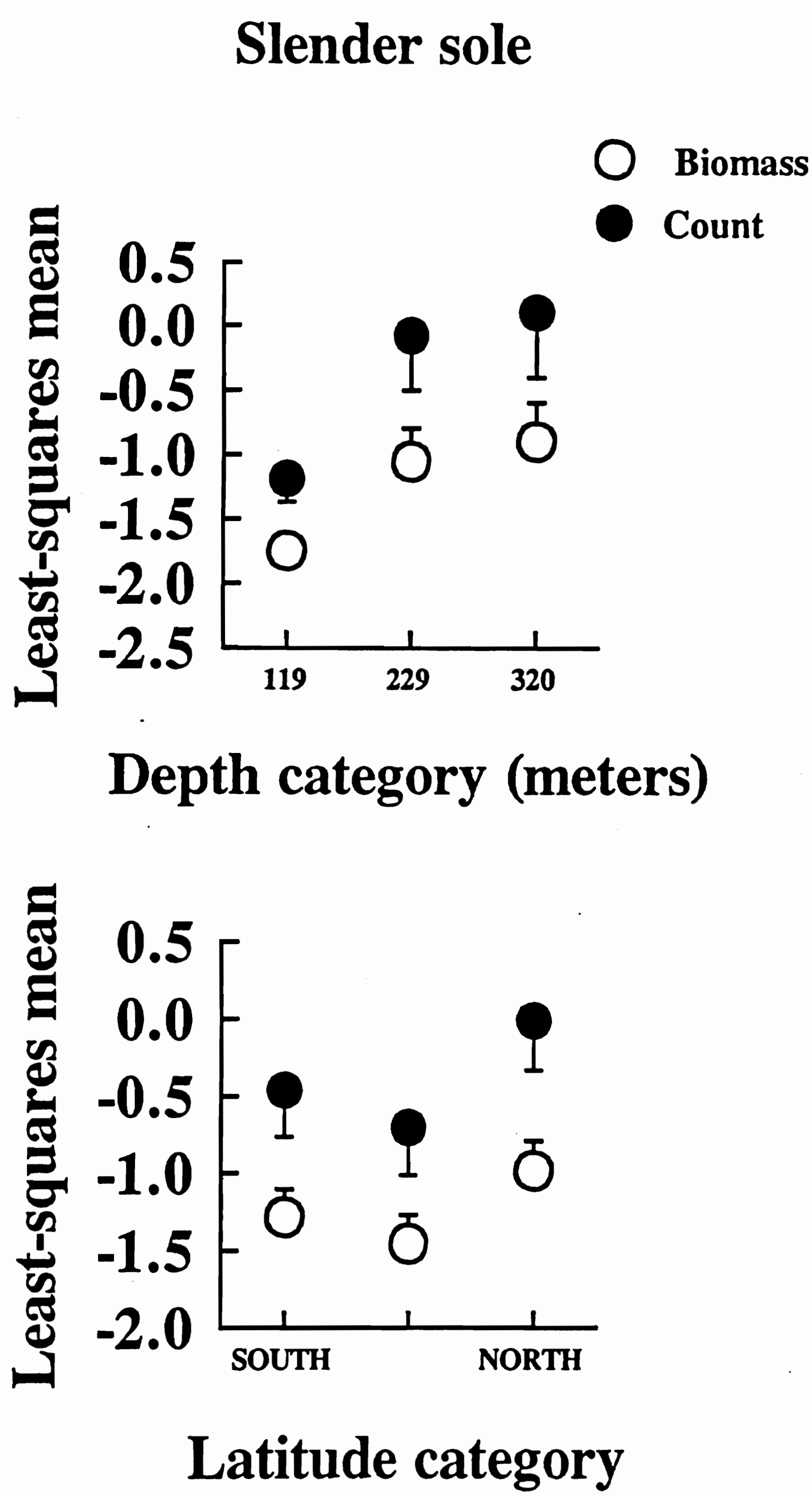


Fig. 112. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of slender sole for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

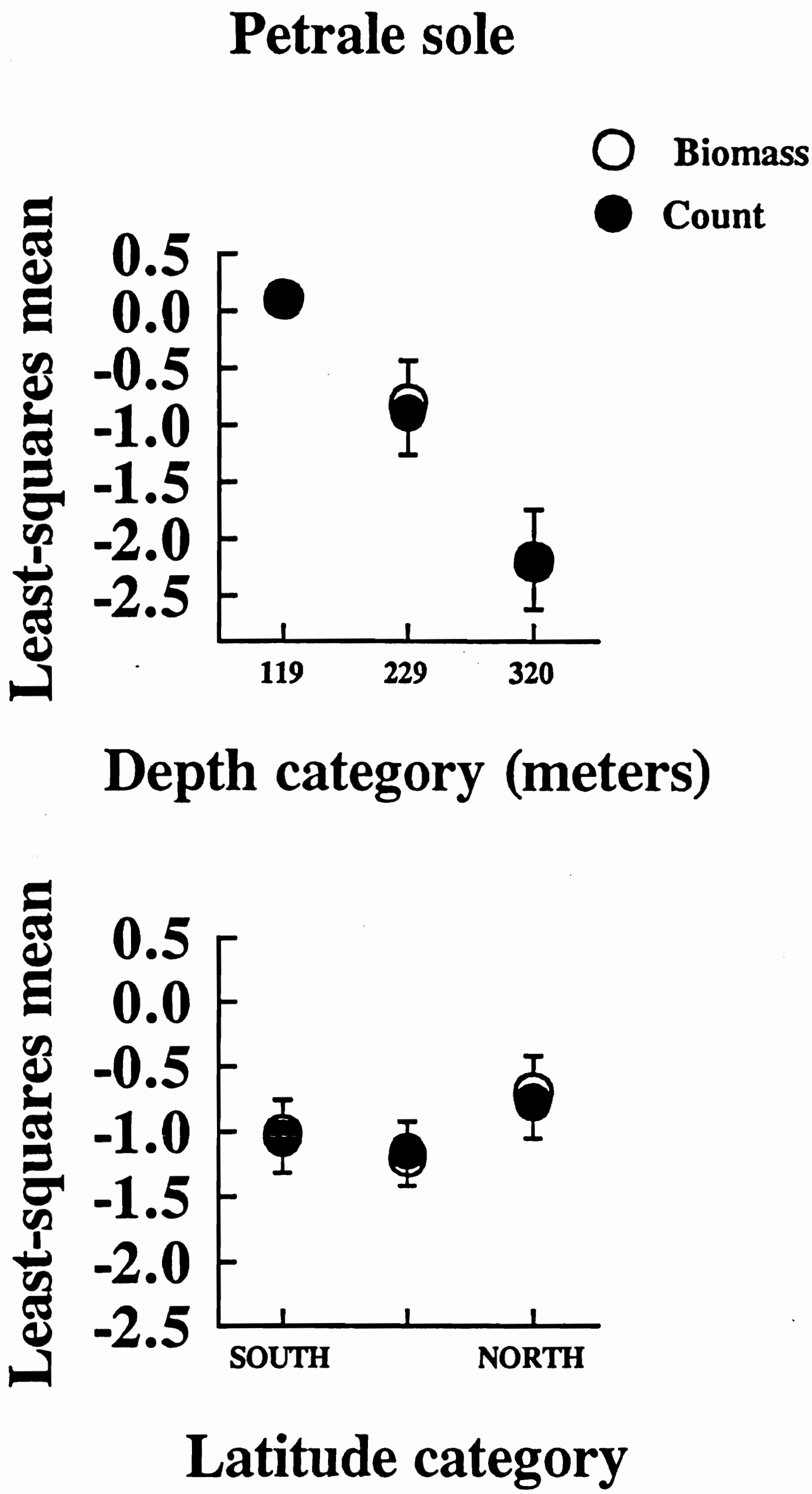


Fig. 113. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of petrale sole for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

Dover sole

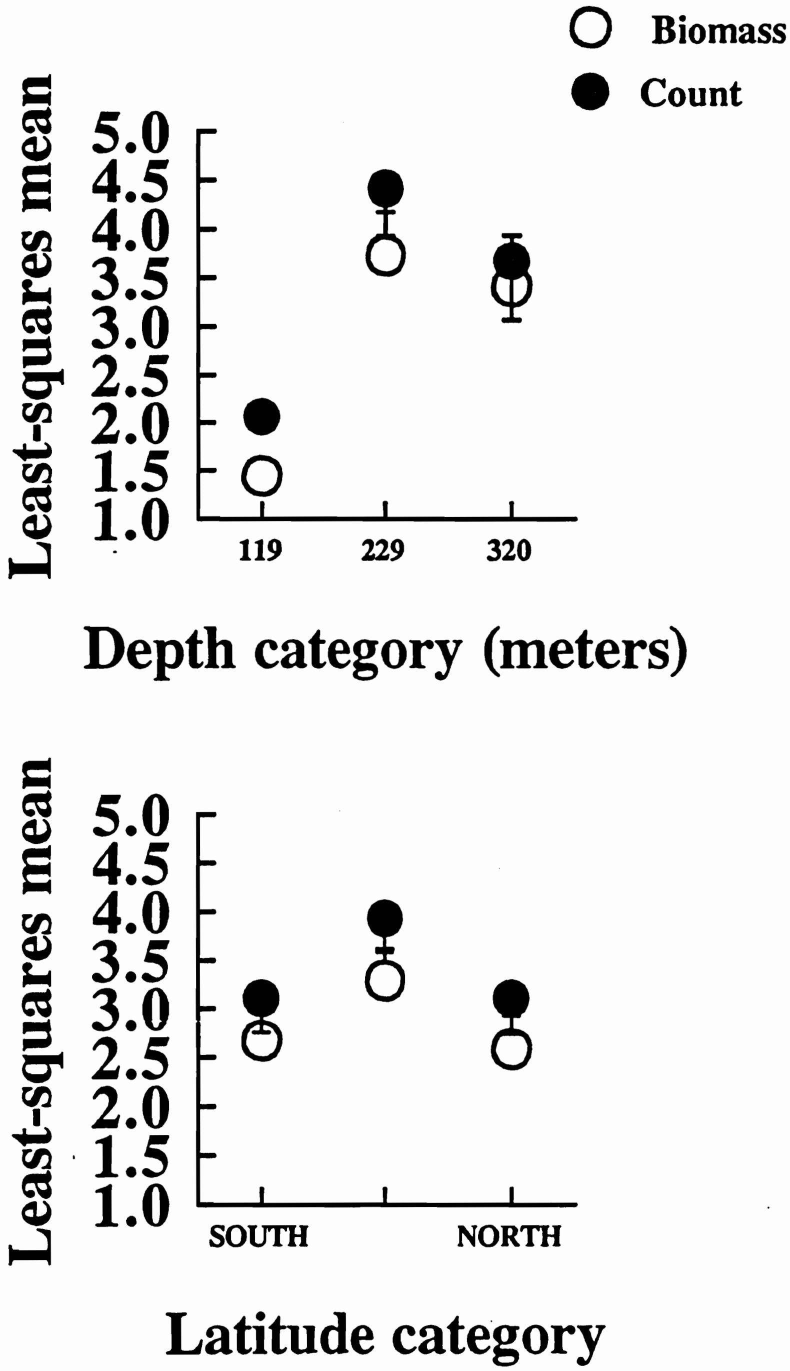


Fig. 114. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of Dover sole for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

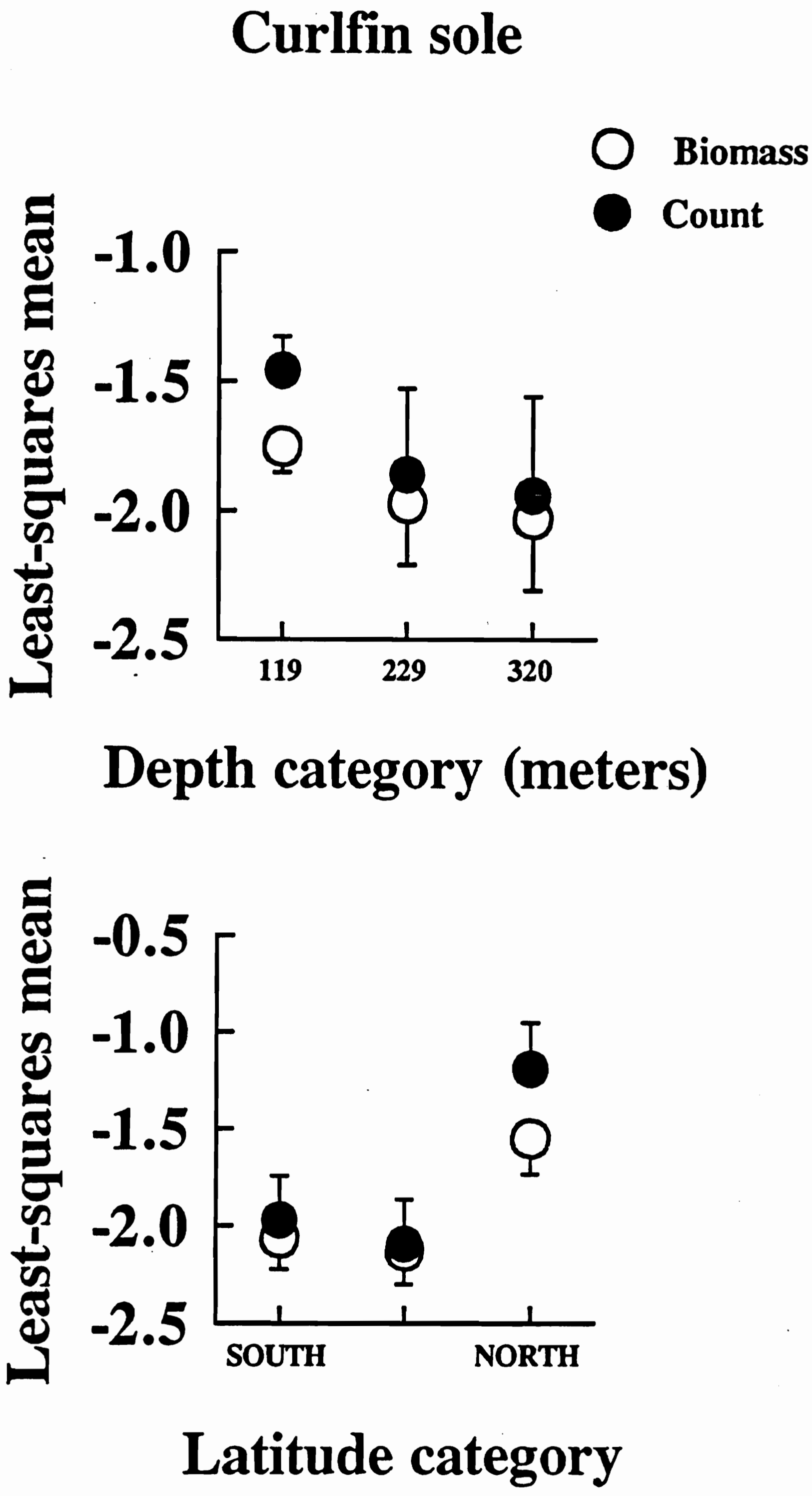


Fig. 115. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of curlfin sole for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

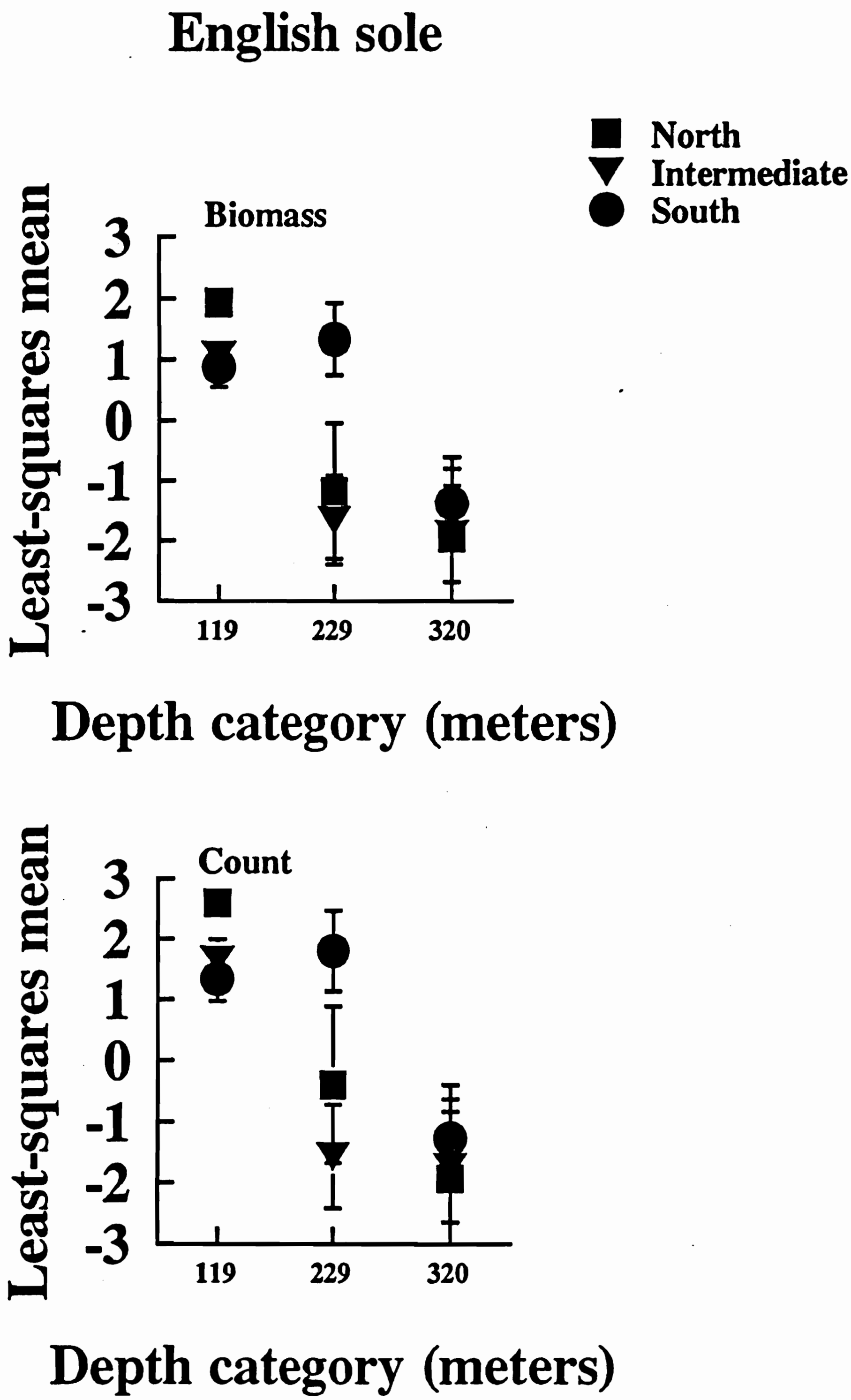


Fig. 116. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of English sole for each combination of depth and latitude categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

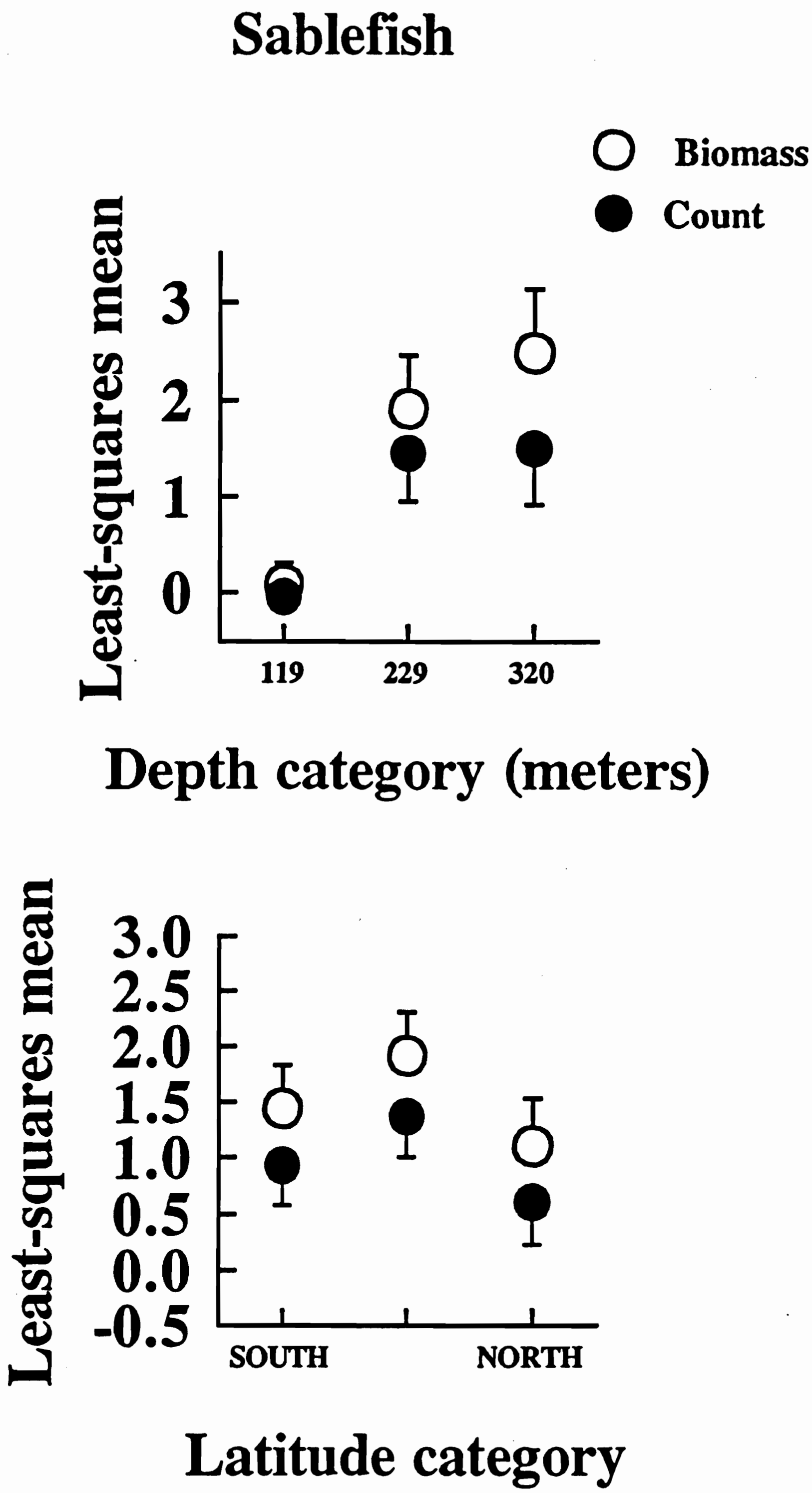


Fig. 117. Abundance (least-squares means of log_e transformed counts and biomass) of sablefish for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

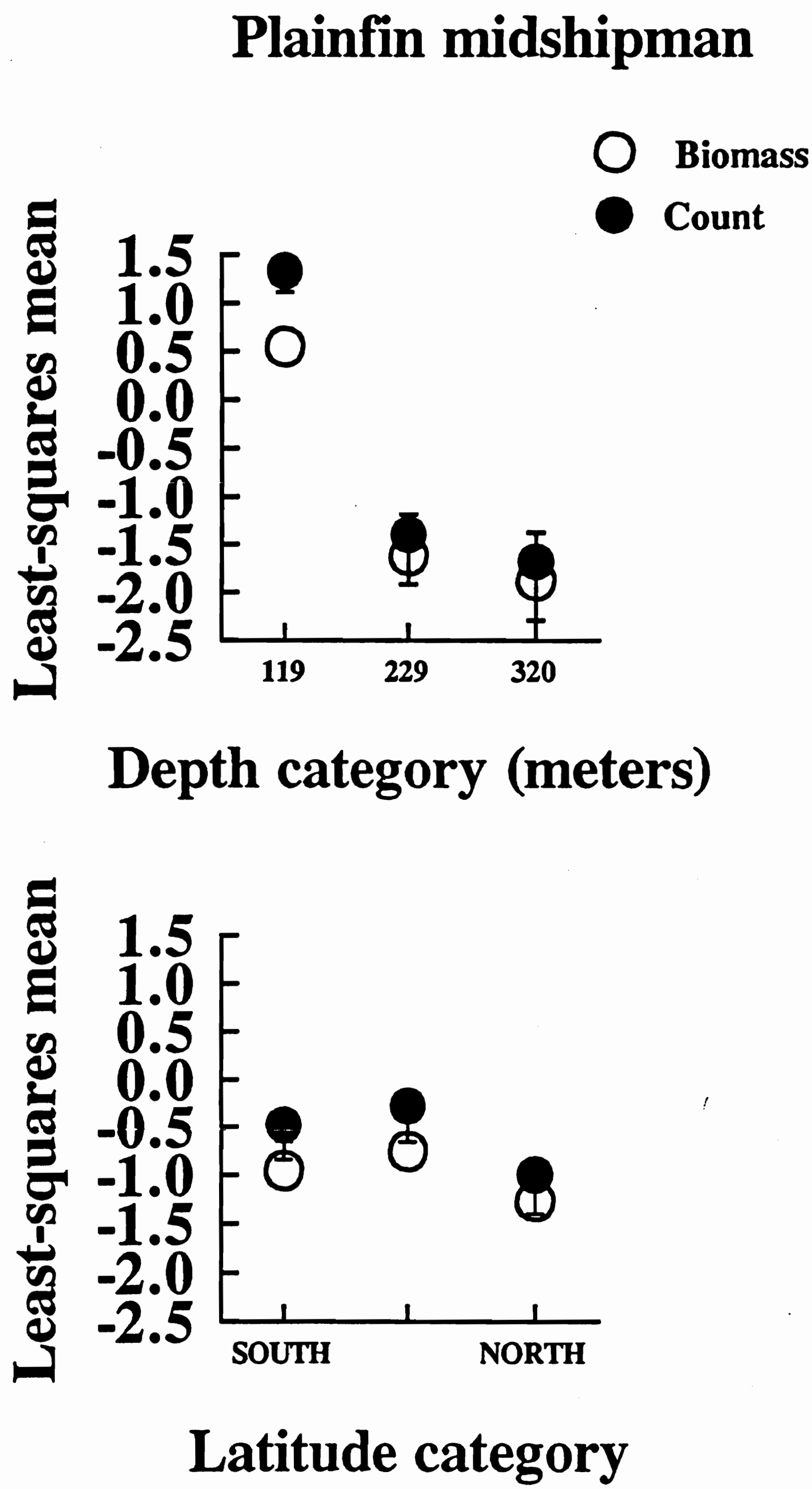


Fig. 118. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of plainfin midshipman for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

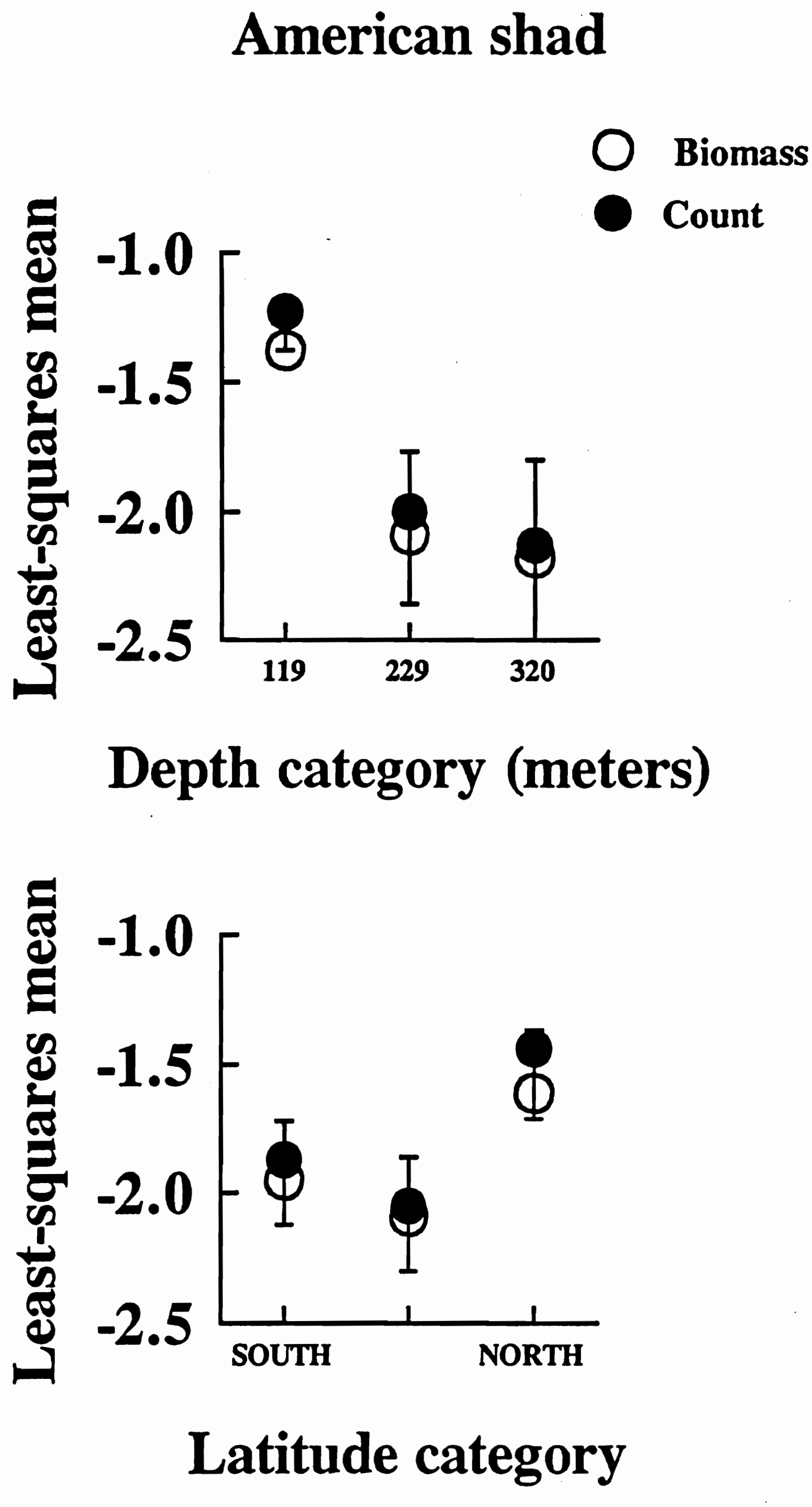


Fig. 119. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of American shad for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

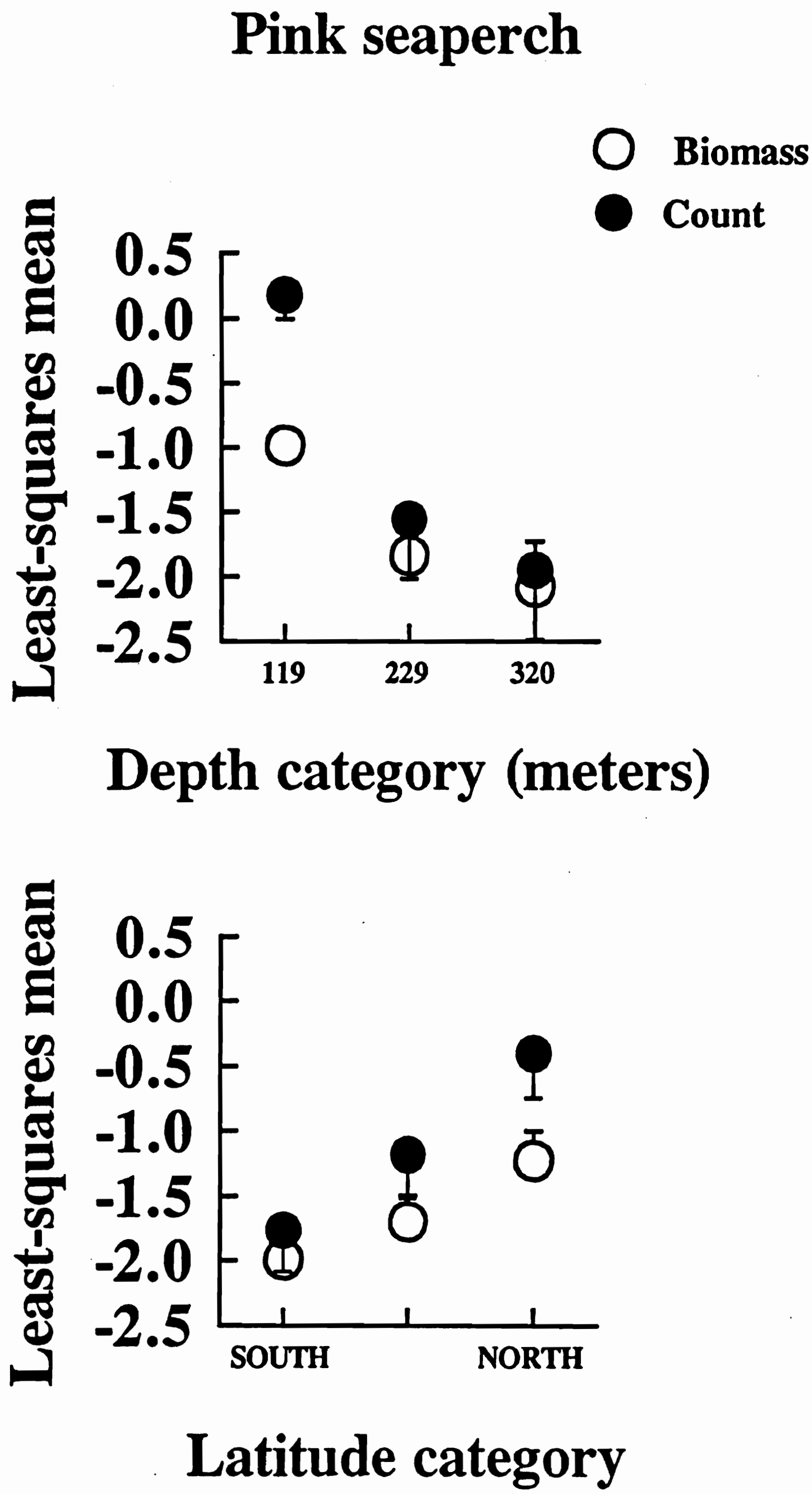


Fig. 120. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of pink seaperch for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

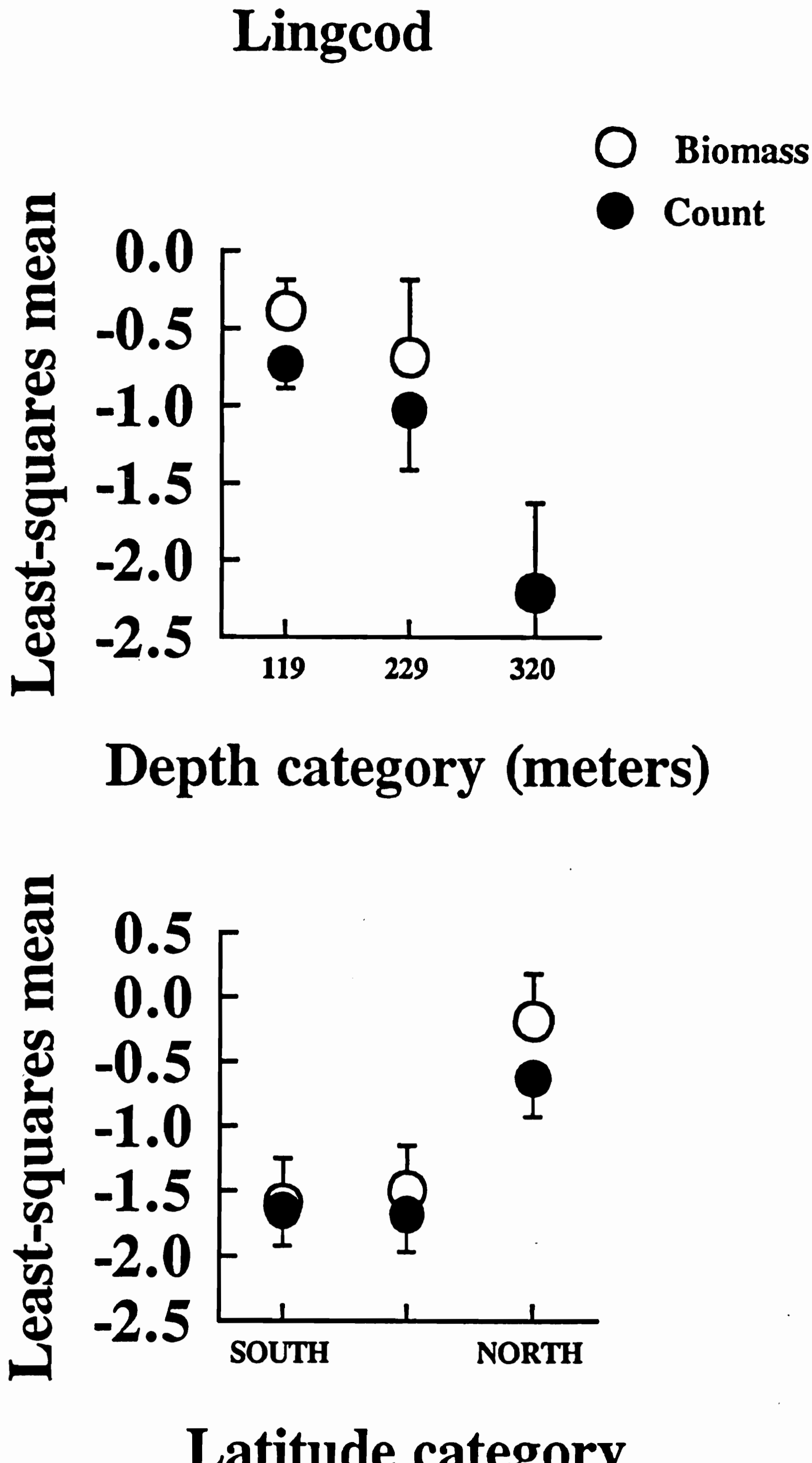


Fig. 121. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of lingcod for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

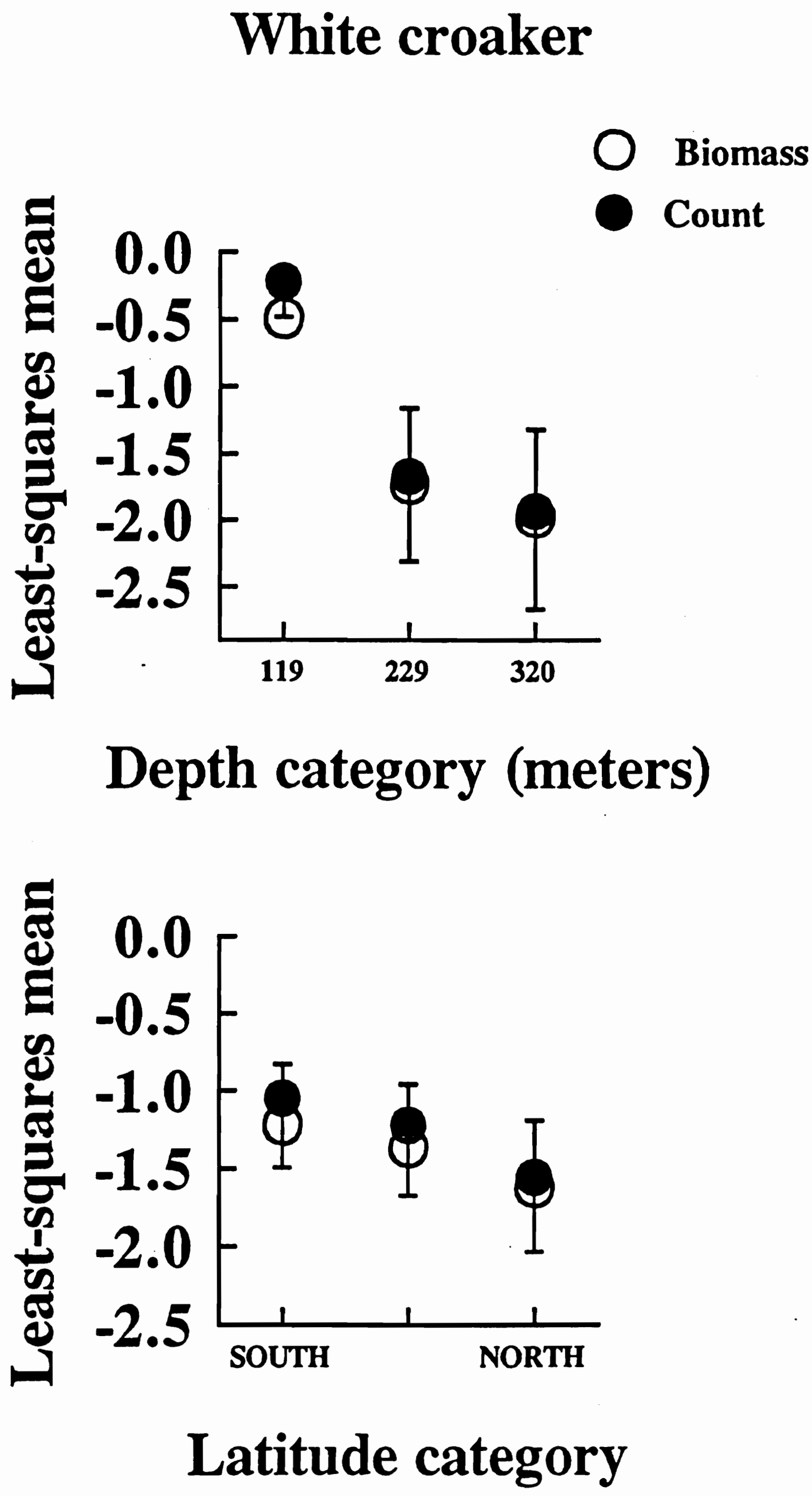


Fig. 122. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of white croaker for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

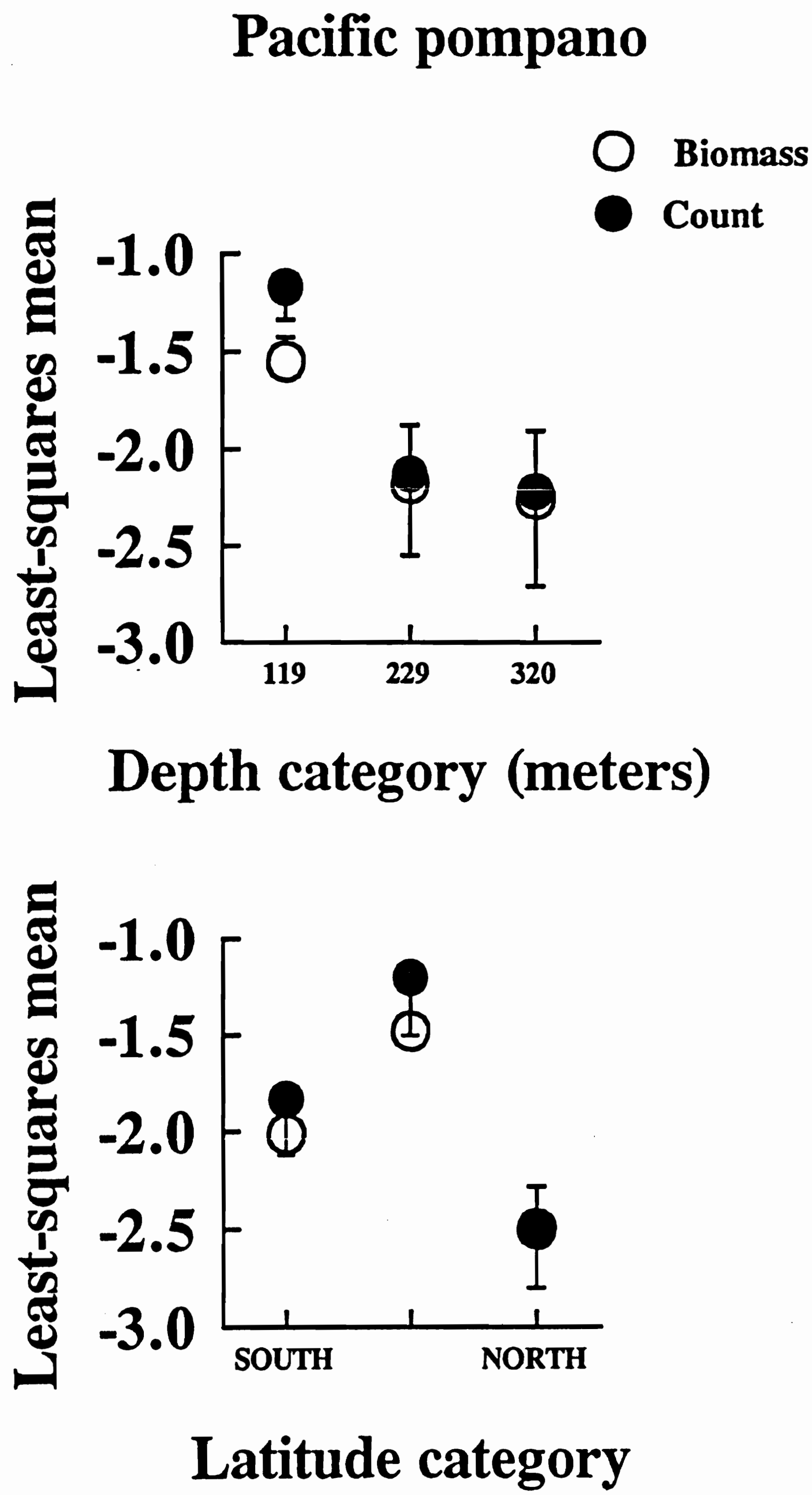


Fig. 123. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of Pacific pompano for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

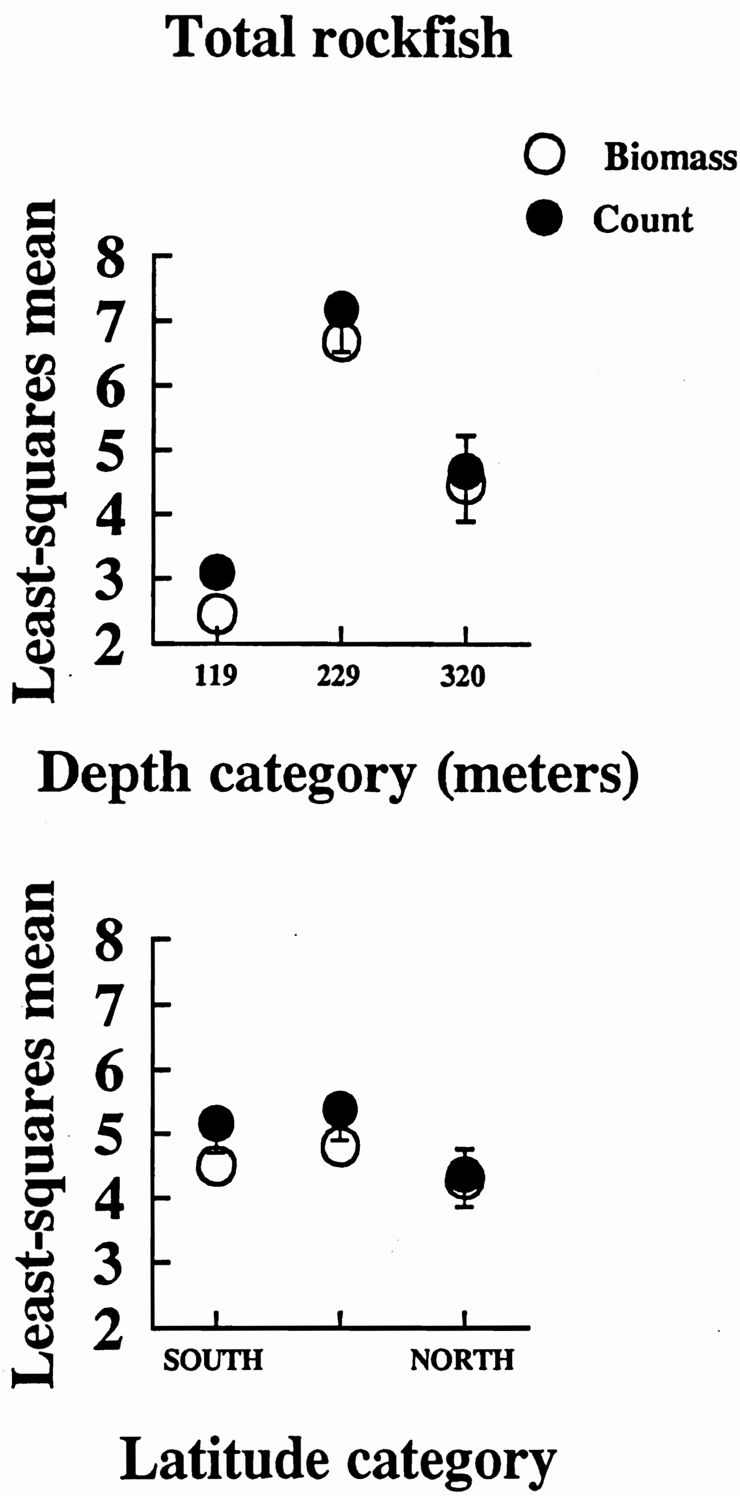


Fig. 124. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of rockfish (all species) for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

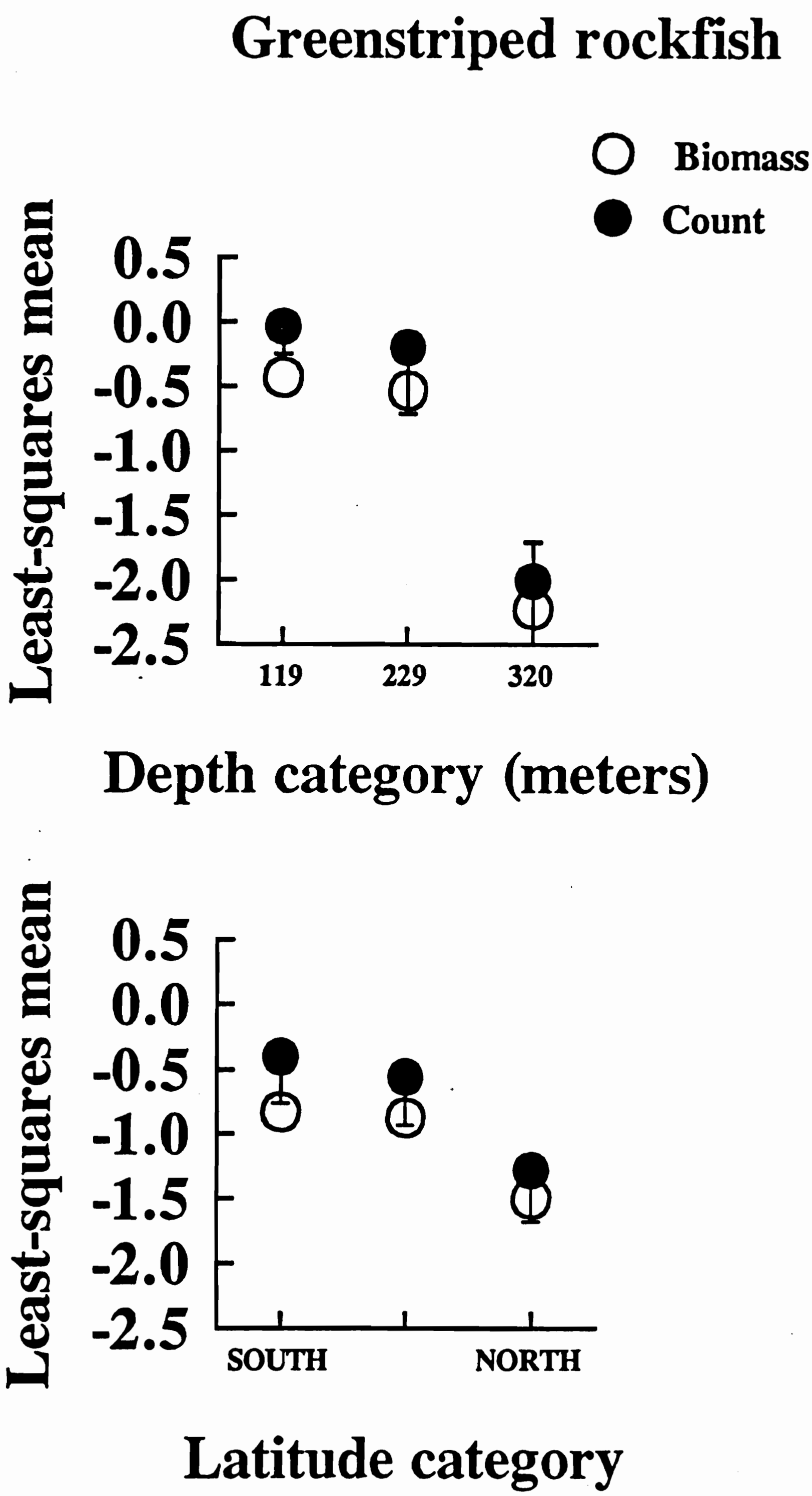


Fig. 125. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of greenstriped rockfish for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

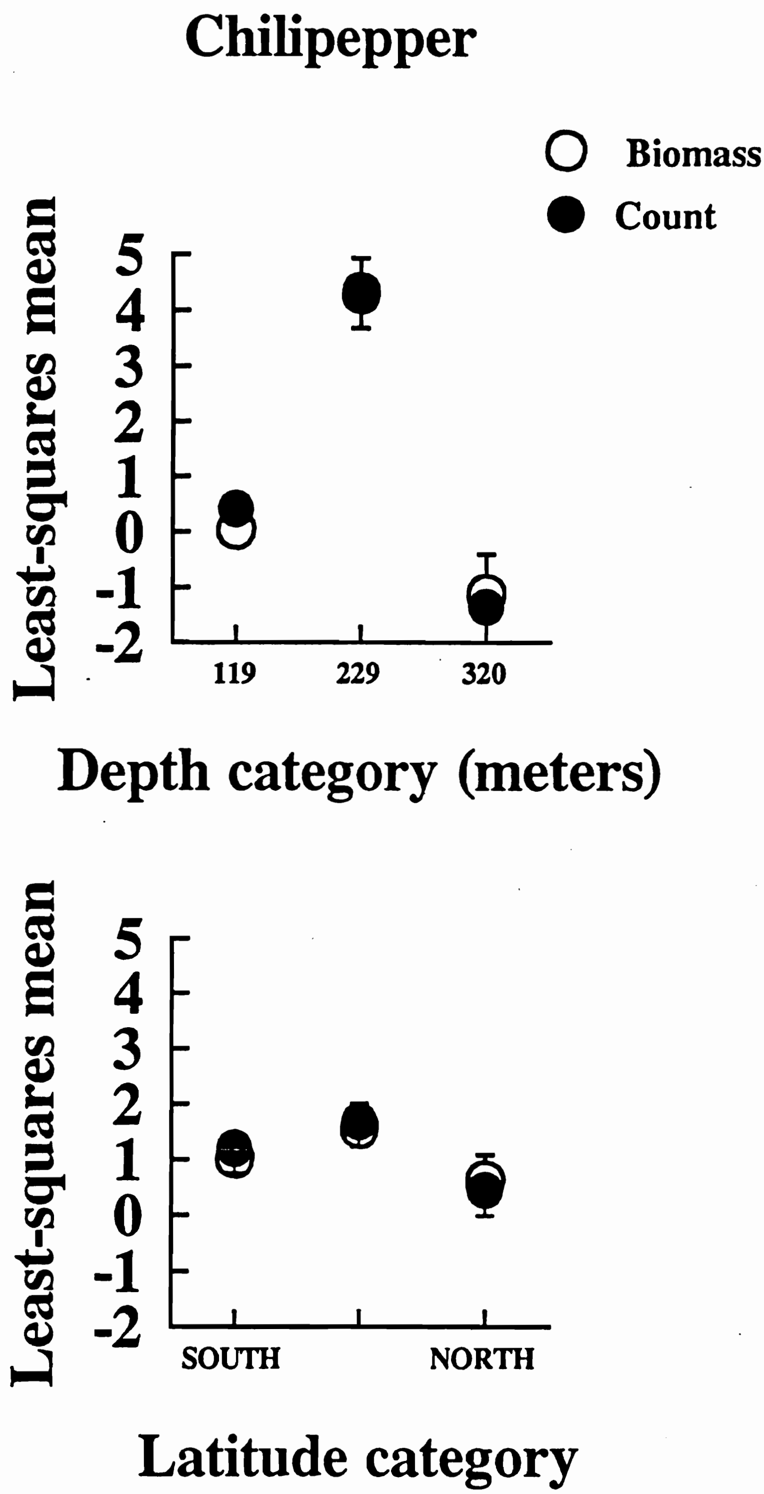


Fig. 126. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of chilipepper for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

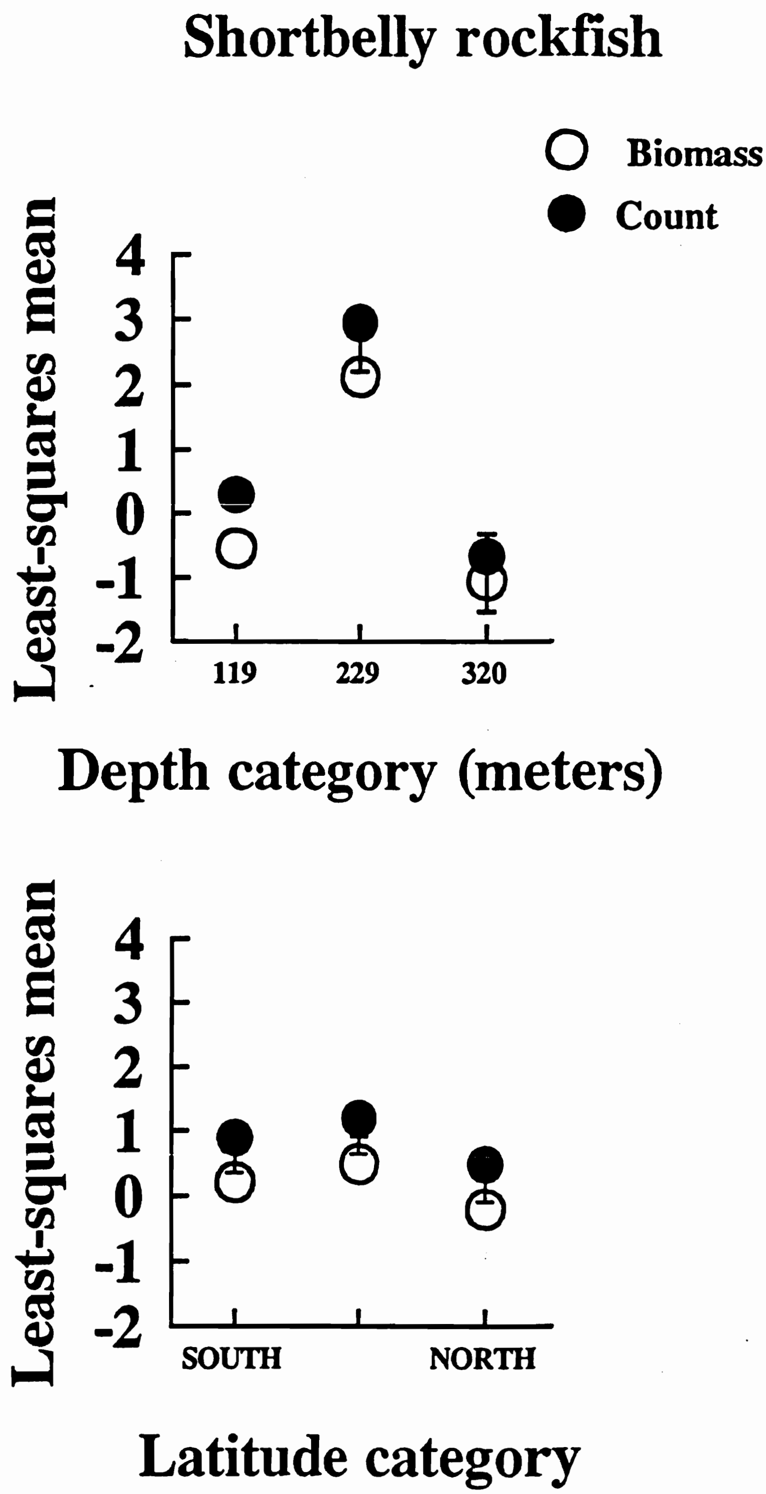


Fig. 127. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of shortbelly rockfish for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

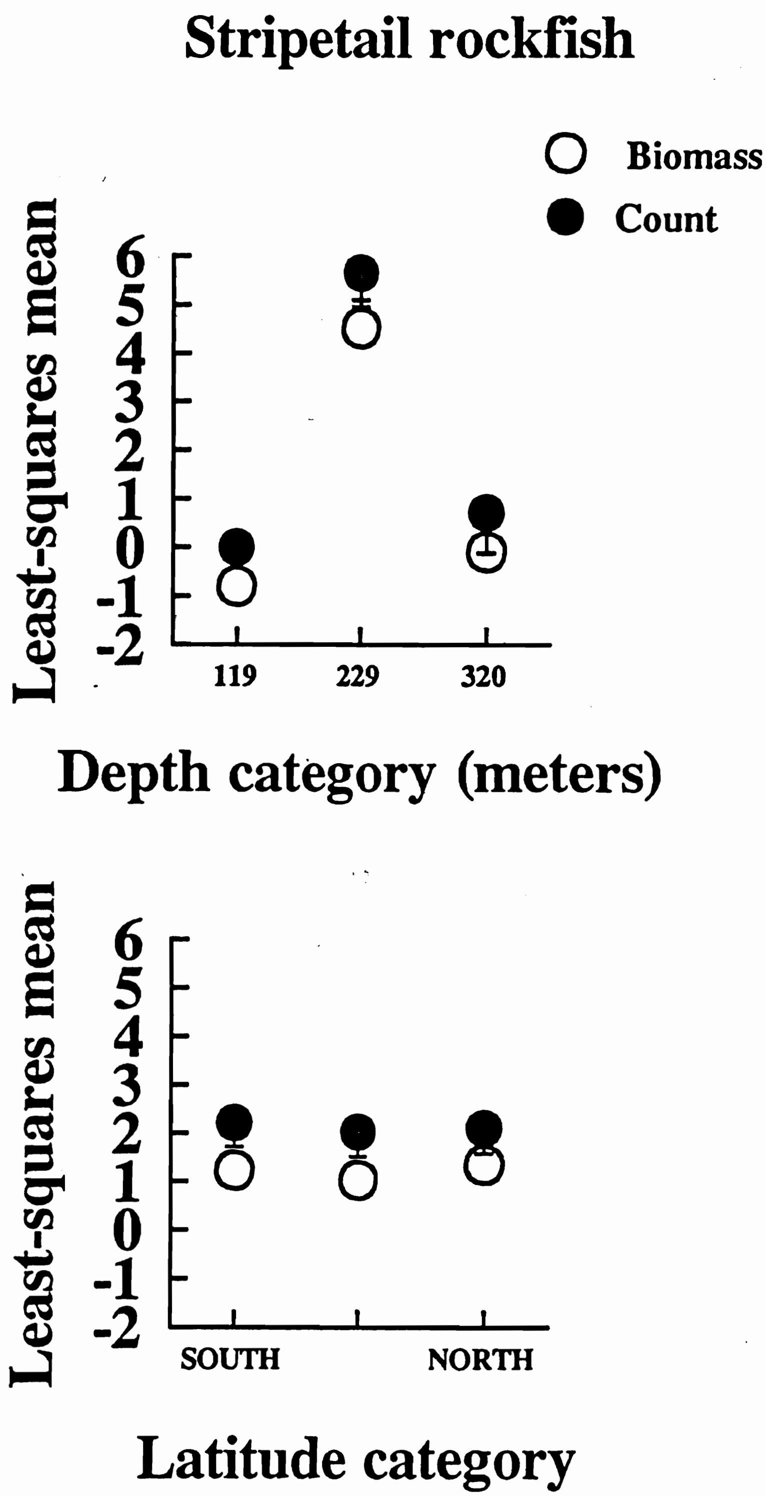


Fig. 128. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of stripetail rockfish for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

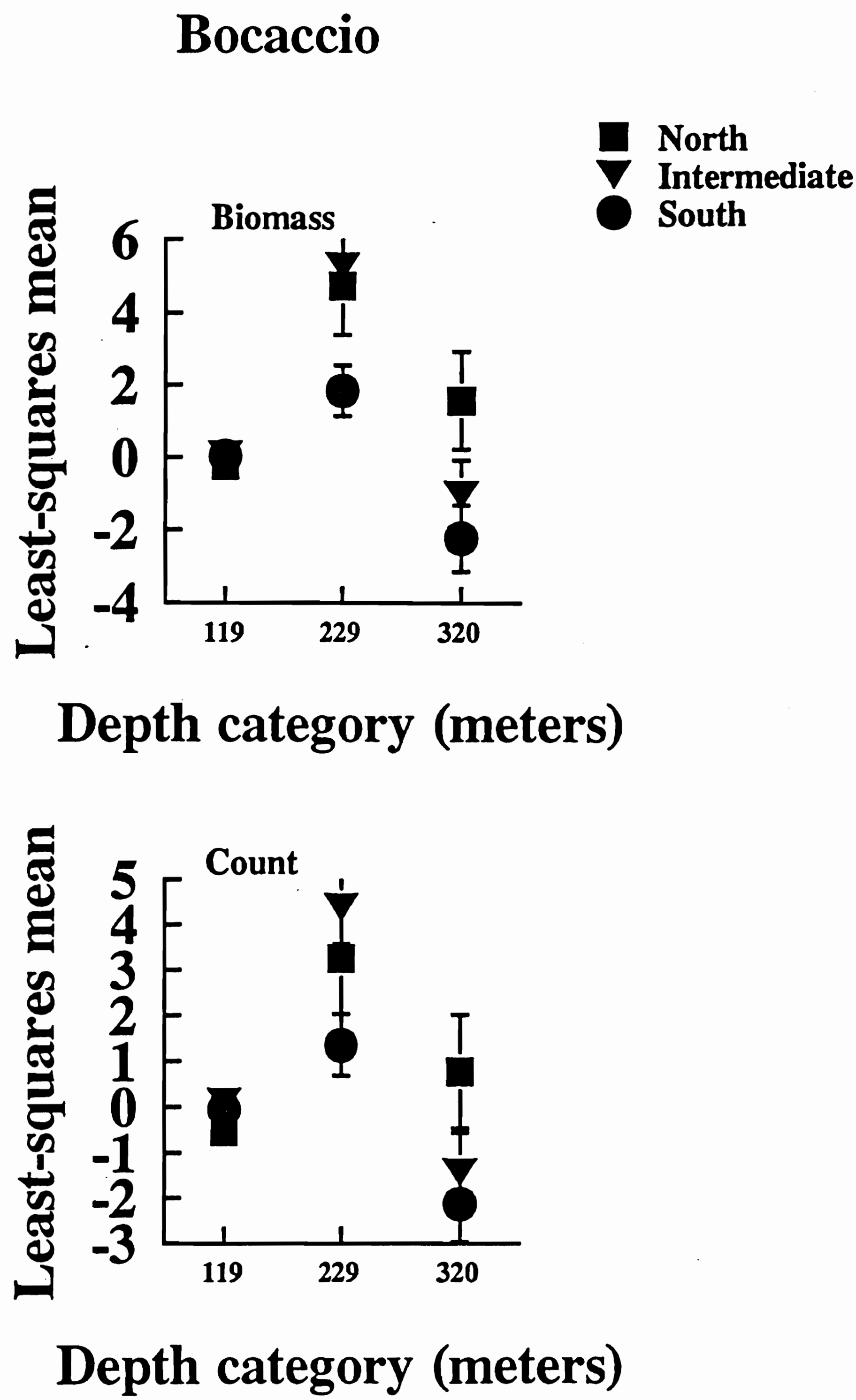
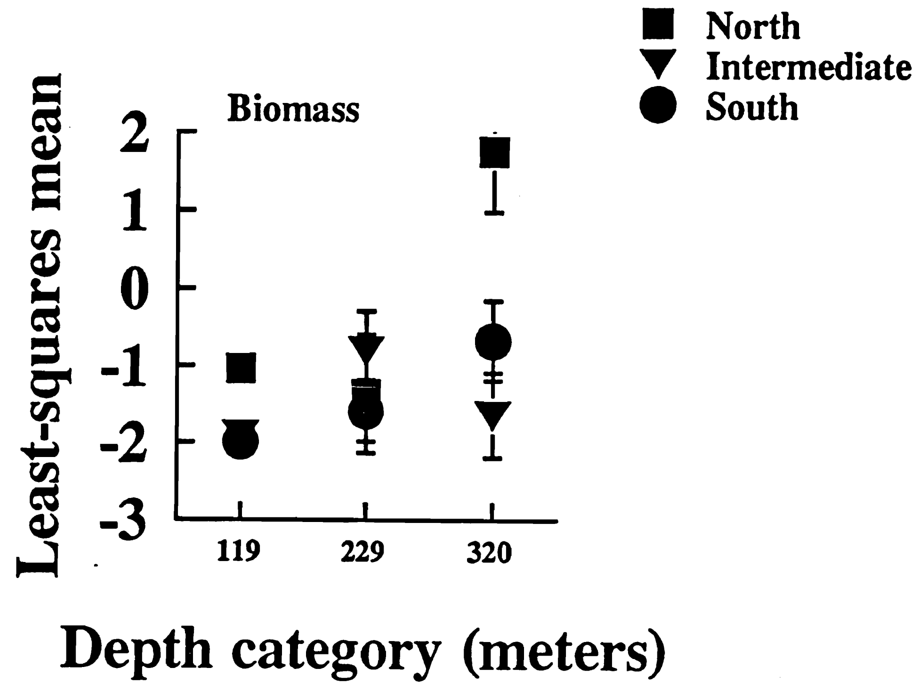


Fig. 129. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of bocaccio for each combination of depth and latitude categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

Spotted ratfish



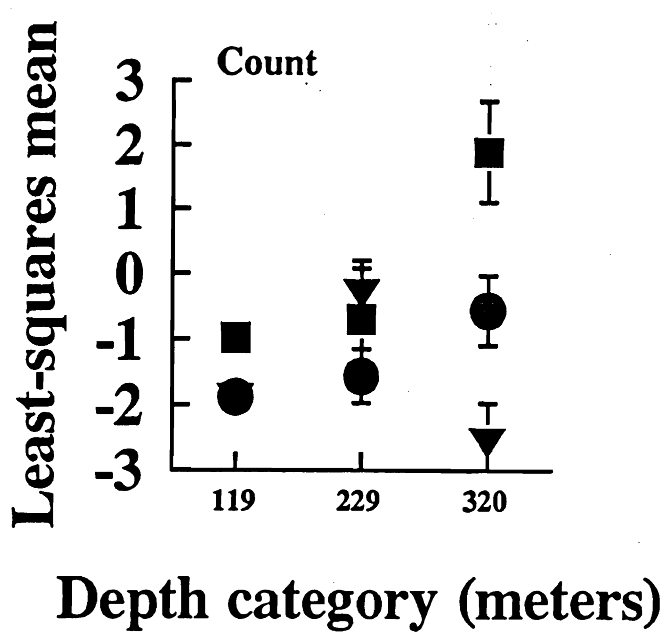


Fig. 130. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of spotted ratfish for each combination of depth and latitude categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

Market squid

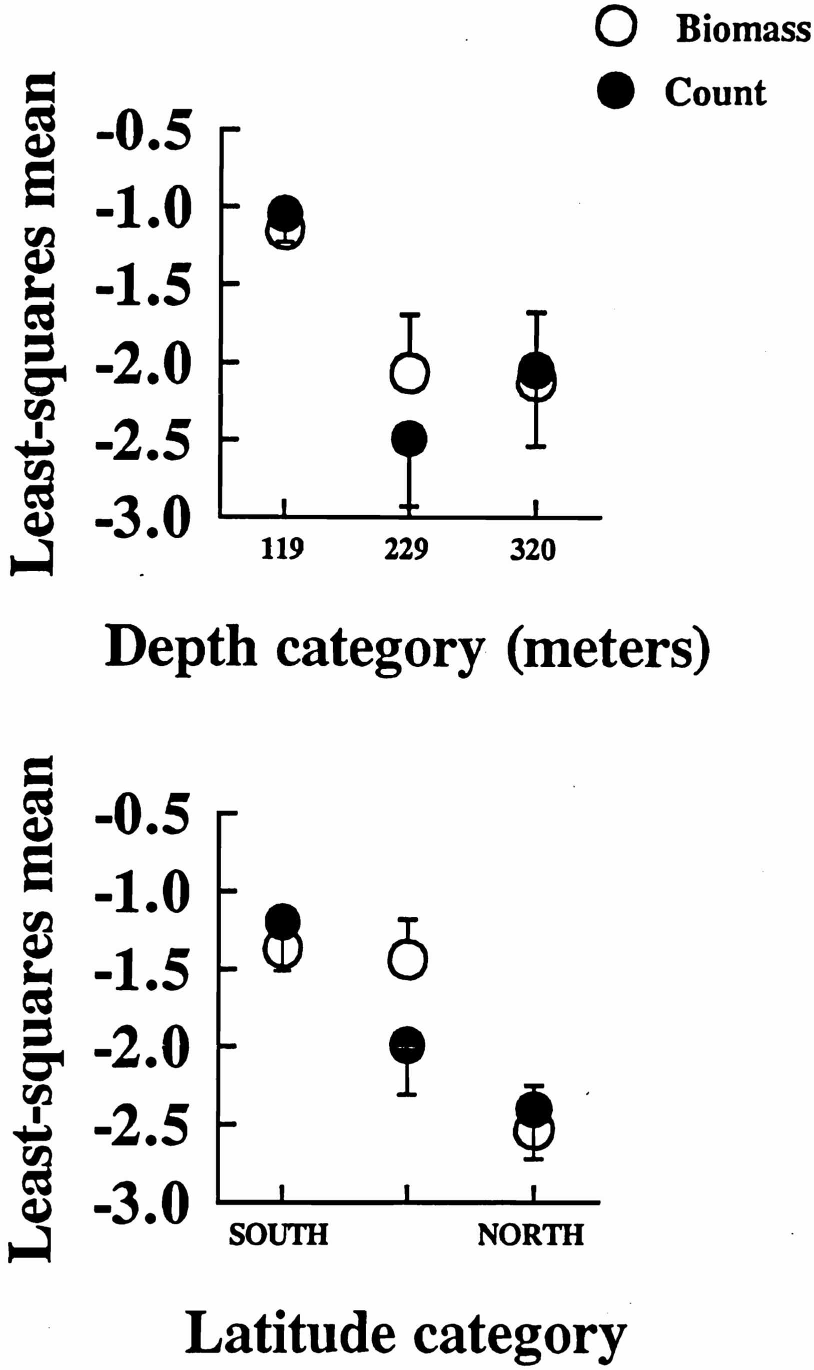


Fig. 131. Abundance (least-squares means of $\log_e$ transformed counts and biomass) of market squid for depth (top panel) and latitude (bottom panel) categories, based on AFSC triennial bottom trawl surveys. Depth categories are designated by their midpoints. Standard errors of LSM's are indicated by vertical bars.

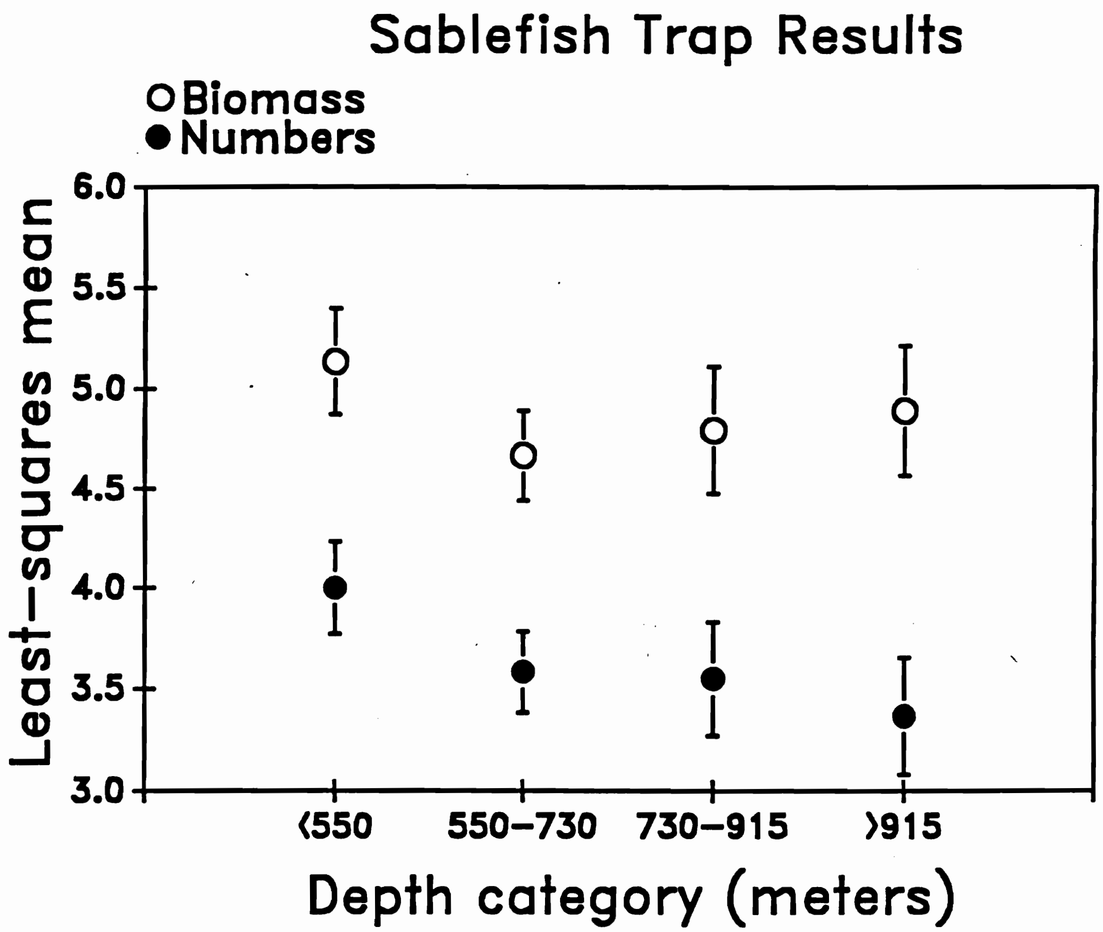


Fig. 132. Abundance of sablefish versus depth category as indicated by least-squares means of $\log_e$ catch per trap (biomass and numbers) from 1986 and 1988 sablefish trap surveys. Standard errors are indicated by vertical bars.

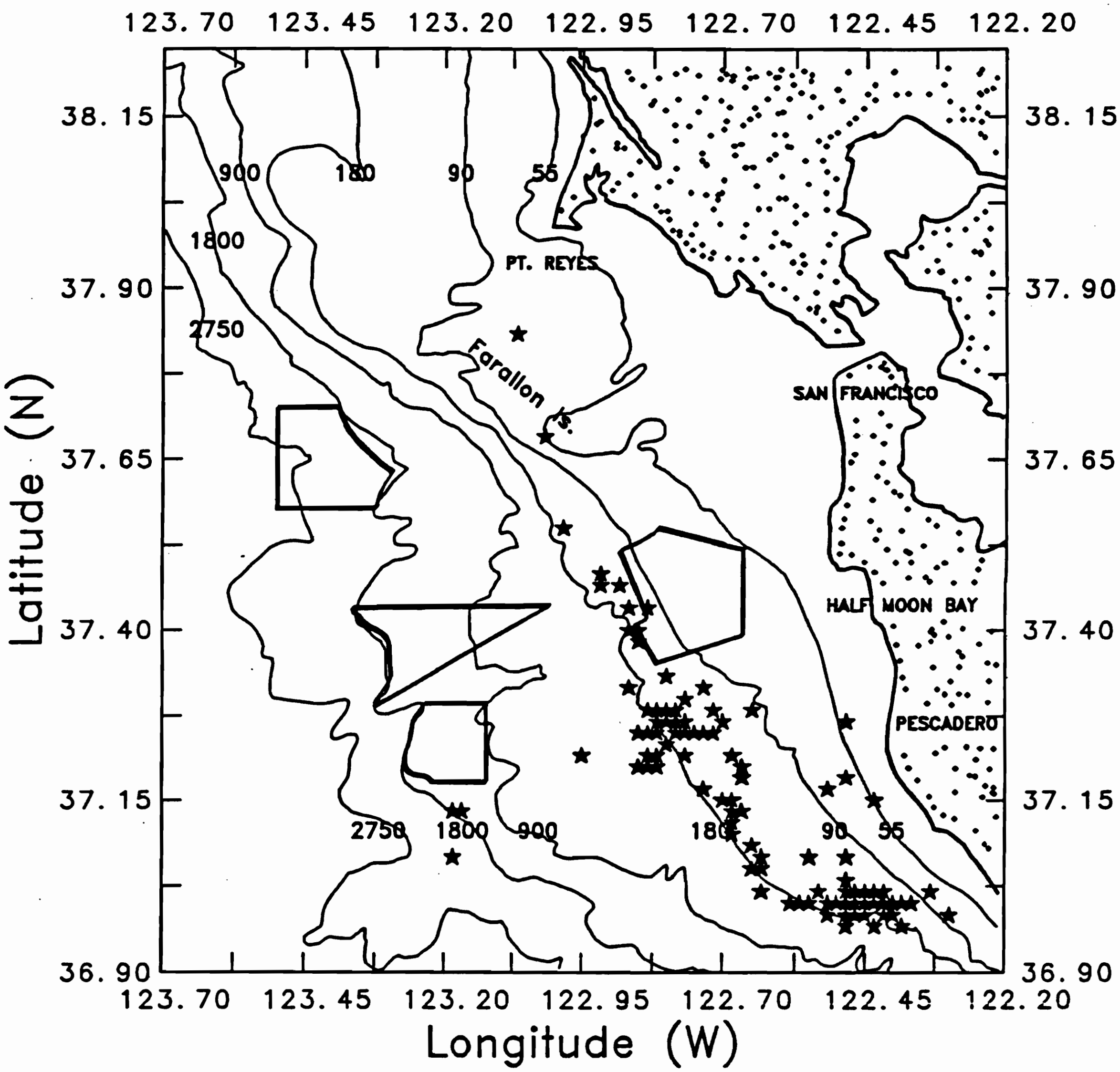


Fig. 133. Locations of positive catches of shortbelly rockfish from the RACE database and from Tiburon Laboratory data.

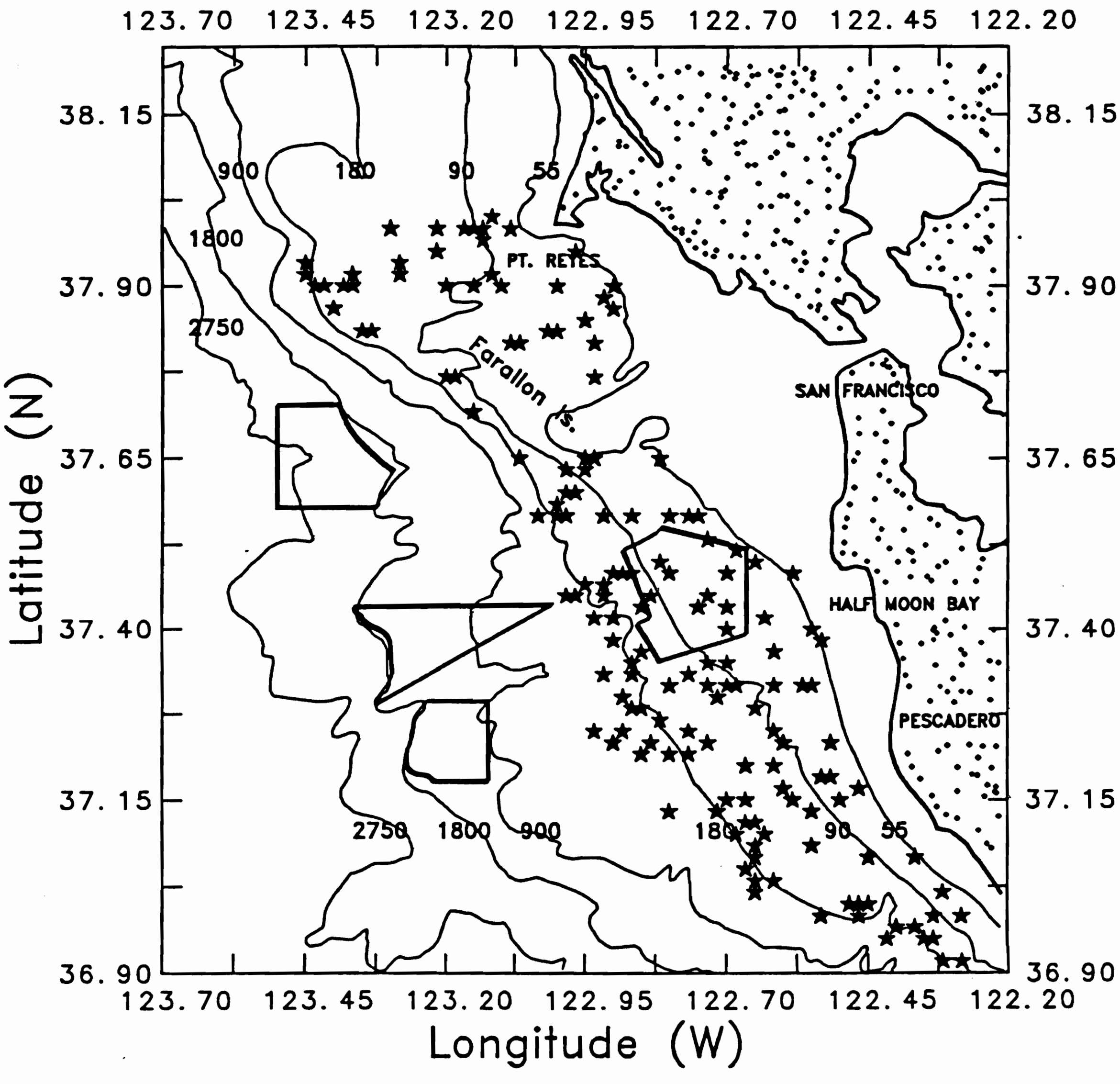


Fig. 134. Locations of positive catches of Pacific hake adults from the triennial hydroacoustic surveys (RACE data).