MIGRATION OF EASTERN BERING SEA HERRING, AS INFERRED FROM 1983-1988 JOINT VENTURE AND FOREIGN TRAWL BYCATCH RATES

by

Fritz Funk

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ACKNOWLEDGMENTS

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INTRODUCTION

Migration of Pacific herring (*Clupea harengus pallasi*) in the eastern Bering Sea was first described during Soviet research in support of the Soviet directed herring fisheries in the early 1960's (Dudnik and Usol'tsev 1964, Rumyantsev and Darda 1970). Subsequent records of the location of Japanese directed herring fisheries summarized in NPFMC (1983) and by Wespestad and Barton (1979) supported the two major migration patterns observed by the Soviets. During June and July, a southwestward movement of herring was observed in the northern Bering Sea, from Norton Sound to Nunivak Island (Figure 1). In Bristol Bay, Japanese vessels followed herring moving along the Alaska Peninsula during the summer months, heading offshore from Unimak Island along the continental shelf edge to the northwest in late summer. It was commonly hypothesized that stocks from both the northern and southern coasts of western Alaska shared a common wintering ground northwest of the Pribilof Islands (Wespestad and Barton 1979). Soviet and Japanese commercial vessels exploited large concentrations of herring during the 1960's near the continental shelf edge between the Pribilof Islands and St. Matthew Island from October through March. Foreign directed fishing for herring ended in 1980. After that time herring became a prohibited species and foreign fleets no longer tracked the movements of herring in the Bering Sea.

Stock identification studies were conducted to determine the origins of herring captured in a food/bait fishery near Dutch Harbor in July and August. These studies established that most of the herring in this area were Togiak spawning stocks (Rowell 1986, Rogers and Schnepf 1985, Rogers et al. 1984, Walker and Schnepf 1982).

Spawning locations of herring in the eastern Bering Sea have been generally well-documented since the beginning of the Bering Sea herring sac roe herring fisheries in 1978. Other than the limited stock identification studies of the Dutch Harbor food/bait fishery, information about the herring migration at other times of the year has not been available since the cessation of foreign directed fishing for herring.

Observer records of herring caught incidental to foreign and joint venture groundfish trawling provide another source of information about the timing and location of herring migration. The NPFMC has required a high level of observer sampling of foreign and joint venture groundfish harvests since 1983. This

paper examines the ratio of the weight of the herring catch to the total weight of the groundfish catch in observer records from Pacific cod (*Gadus macrocephalus*) and pollock (*Theregra chalcogramma*) bottom trawl tows, in order to define an index of herring abundance. The index is used to determine the timing and location of herring stocks during their annual migration. This index would be expected to fluctuate with groundfish density as well as with herring density. However, because the herring migration is a relatively distinct phenomenon, the index is sufficient to delineate the general movements of herring stocks during the annual migration. Also, over the 1983 through 1988 period, the abundance of both herring and groundfish stocks was relatively constant.

METHODS

The weights of herring bycatch and total groundfish catches were recorded by observers aboard joint venture and foreign groundfish vessels from 1983 through 1988. These data were summarized by month, 1/2° latitude by 1° longitude area, and target fishery category. Target fishery categories were arbitrarily assigned in the observer records based on the species composition of the catch, using criteria established by the NMFS observer program. The observer records used for this study were primarily from pollock and cod bottom trawls, using the NMFS-designated categories "pollock bottom trawl" and "other bottom trawl". Trawl tows in these target categories were defined as consisting of less than 20% Atka mackerel, less than 20% flatfish, and less than 95% pollock. Tows with greater than 95% pollock are assigned to a midwater trawl category by the NMFS criteria. Because preliminary analyses showed that midwater trawl bycatch rates were substantially less than bottom trawls, trawl tows from the midwater trawl category were not used. Because little difference in herring bycatch rates was found between the "pollock bottom trawl" and "other bottom trawl" categories, tows from both of these categories were combined.

A herring bycatch rate index was computed by dividing the observed herring catch for each month and 1/2° latitude by 1° longitude area from 1983 through 1988 by the total observed groundfish catch for the same area and period. The resulting bycatch rates by latitude, longitude and month comprised a grid that covered much of the Bering Sea in most months.

The area of study was restricted to 160° W. to 180° longitude and 51° N. to 61° N. latitude. Although some flatfish trawling occurs east of 160° W., little pollock and cod bottom trawling occurs east of this longitude. Little groundfish trawling effort occurred north of 61° in the winter months, although herring did appear to occur in this area. For each month, the grid of herring bycatch rates was smoothed by distance weighted least squares[1] to aid in the interpretation of migratory patterns. These data were plotted as a 3-

[1]The SYSTAT/SYGRAPH distance weighted least squares algorithm was used for smoothing, with a tension parameter (weighting) equal to the inverse of the number of 1/2° latitude by 1° longitude squares containing bycatch rates for a given month over the 1983-1988 period (SYSTAT 1988).

dimensional surface, with the vertical axis representing the bycatch rate. In order to better define the location of the herring migration with respect to the NPFMC's management areas (Fig. 2), the bycatch rate data were also plotted as a contour surface. Graphs of these surfaces for each month were used to delineate the average distribution of herring in the eastern Bering Sea over the 1983 through 1988 period.

In some months few tows were made in some 1/2° latitude by 1° longitude areas. Bycatch rates computed from areas and months with small sample size may not be representative of actual herring abundance. To depict the sample size on which the bycatch rates are based, the magnitude of the observed total groundfish catch in each square was indicated by shading.

RESULTS AND DISCUSSION

The pattern of observed herring bycatch rates in the southeastern Bering Sea strongly supported the clockwise migratory pattern inferred from earlier stock identification studies and Soviet and Japanese research. During January, herring bycatch was almost nonexistent (Fig 3). However, almost no data were available for the month of January from the herring wintering grounds northwest of the Pribilof Islands, as indicated by the shading in the bottom panel of Figure 3. The occurrence of substantial trawling effort along the Alaska Peninsula coupled with no herring bycatch strongly suggests that no herring overwinter in the southern Bering Sea. In February (Fig. 4) the observed fishing effort shifted northward. A few vessels fished southwest of St. Matthew Island and recorded high herring bycatch rates, consistent with the earlier reports of the herring wintering location in this area. Substantial bottom trawling effort along the continental shelf edge from the Pribilof Islands south to Unimak Pass resulted in almost no herring bycatch. In March and April (Figs. 5, 6), almost no herring bycatch was reported, although there was very little effort in the area of the herring wintering grounds. During the May herring spawning period herring bycatch rates were again very low (Fig. 7), except for some moderate bycatch just north of the Pribilofs. This could be due to immature juvenile herring that remain on the wintering grounds year round as suggested by Rumyantsev and Darda (1970). Peak herring spawning for the large Togiak stock occurred during early to mid-May. In June, high herring bycatch rates were reported along the Alaska Peninsula, southwest of Port Moller (Fig. 8). Fishing effort during June covered much of the Bering Sea, with little herring bycatch reported elsewhere. By July, most of the high herring bycatch rates shifted to the "horseshoe" area just north of Unimak Pass (Figure 9), where the 100 fathom contour creates a "horseshoe" shape. The distribution of bycatch rates indicates that offshore movement toward the Pribilofs has already begun in July, with moderate bycatch rates reported to the north of the Pribilof Islands. Again, the widespread distribution of fishing effort indicates that few herring are found in other areas. By August, herring bycatch was relatively high along the entire continental shelf edge (Fig. 10), with high bycatch rates continuing in the horseshoe area. By September, bycatch rates in the horseshoe area declined, and the area northwest of the Pribilofs became the dominant area of herring bycatch (Fig. 11). Sampling effort covers a wide area of the Bering

Sea, with good coverage along the entire continental shelf edge. In October, despite a large amount of effort in the horseshoe area, no herring bycatch was reported (Fig. 12). Herring bycatch was reported from the immediate vicinity of the Pribilof Islands and from the area southwest of St. Matthew Island. Sampling coverage is adequate along most of the continental shelf edge. In November, herring bycatch was low except for the area southwest of St. Matthew Island, with good sampling coverage over most of the continental shelf edge (Fig. 13). In December, some very high bycatch rates were reported southwest of St. Matthew Island (Fig. 14). Sample size was small however, so that the data are best interpreted as indicating the presence of herring. Further quantification of the herring bycatch rate may not be appropriate when sample sizes are small.

The herring migration in the southern Bering Sea appears to be a discrete phenomenon in time and space. The distribution of herring is unlike that of other prohibited species such as crab and halibut, which tend to have much broader distributions over a wider range of time. Because herring occupy areas along the migration route for only relatively short periods, herring should be easier for groundfish trawlers to avoid than other prohibited species.

The sporadic occurrence of high bycatch rates on the wintering grounds is consistent with the locations of the earlier Soviet and Japanese directed fisheries. Because sample sizes during the winter months in these areas were small, high herring bycatch rates only occur occasionally in the aggregated data.

These data provide little information on the migration of the northerly component of herring stocks which spawn from Norton Sound to Etolin Strait. Groundfish trawling effort in the area north and east of the herring wintering grounds that would intercept these stocks was very low from 1983 through 1988.

The movement of herring offshore from the horseshoe area occurred earlier than previously reported. It appears that this movement begins in July, and that substantial numbers of herring are in the area northwest of the Pribilof Islands by August.

CONCLUSIONS

1. Herring bycatch rates from 1983-88 joint venture and foreign bottom trawling for Pacific cod and pollock strongly support the previous Soviet and Japanese hypothesis of a clockwise migration of herring around the southern Bering Sea, with a wintering ground northwest of the Pribilof Islands.

2. Herring stocks migrate along the Alaska Peninsula during the summer months, appearing in the Port Moller area in early to mid-June.

3. Offshore movement from the Unimak Pass "horseshoe" area to the Pribilofs begins as early as July, and is complete by mid-September.

4. Bycatch rates were extremely low along the Alaska Peninsula except for the summer months, indicating that all herring stocks winter offshore.

5. The herring migration is a relatively discrete phenomenon. At any one time, herring stocks occupy only a small proportion of the Bering Sea.

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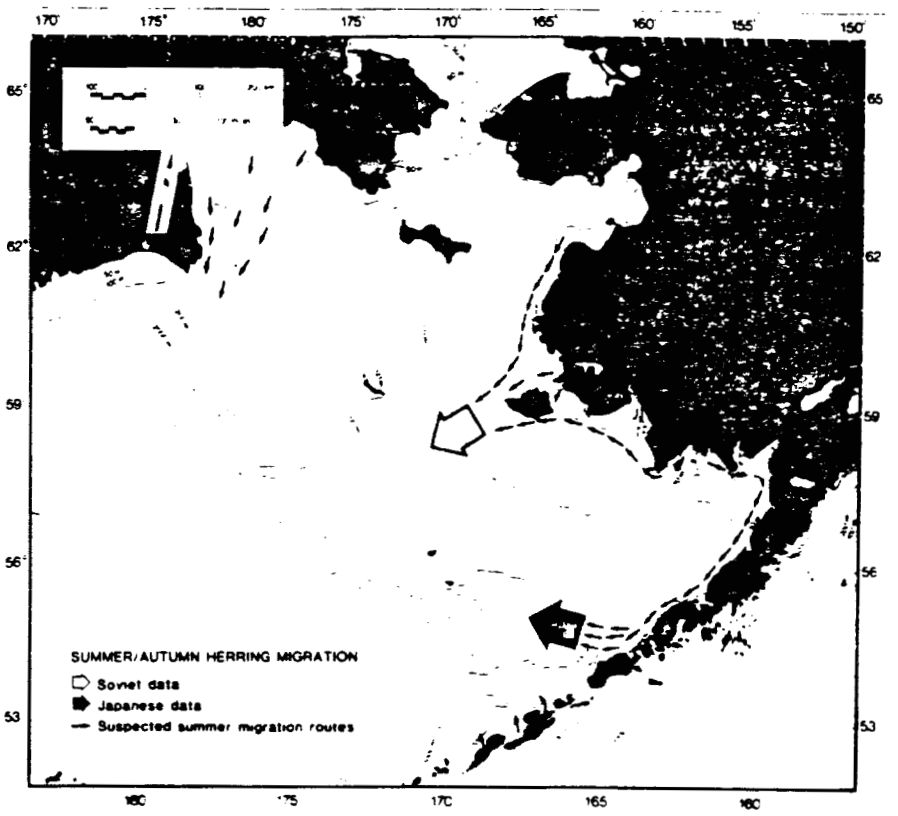

Figure 1. Summer and autumn migration routes to winter grounds. Large solid arrow: area of reappearance in offshore waters as determined by Soviet research and Japanese catches. Large open arrow: area of autumn reappearance in offshore waters reported from Soviet research. Small arrows: possible summer feeding routes and autumn migration routes (from Wespestad and Barton 1979).

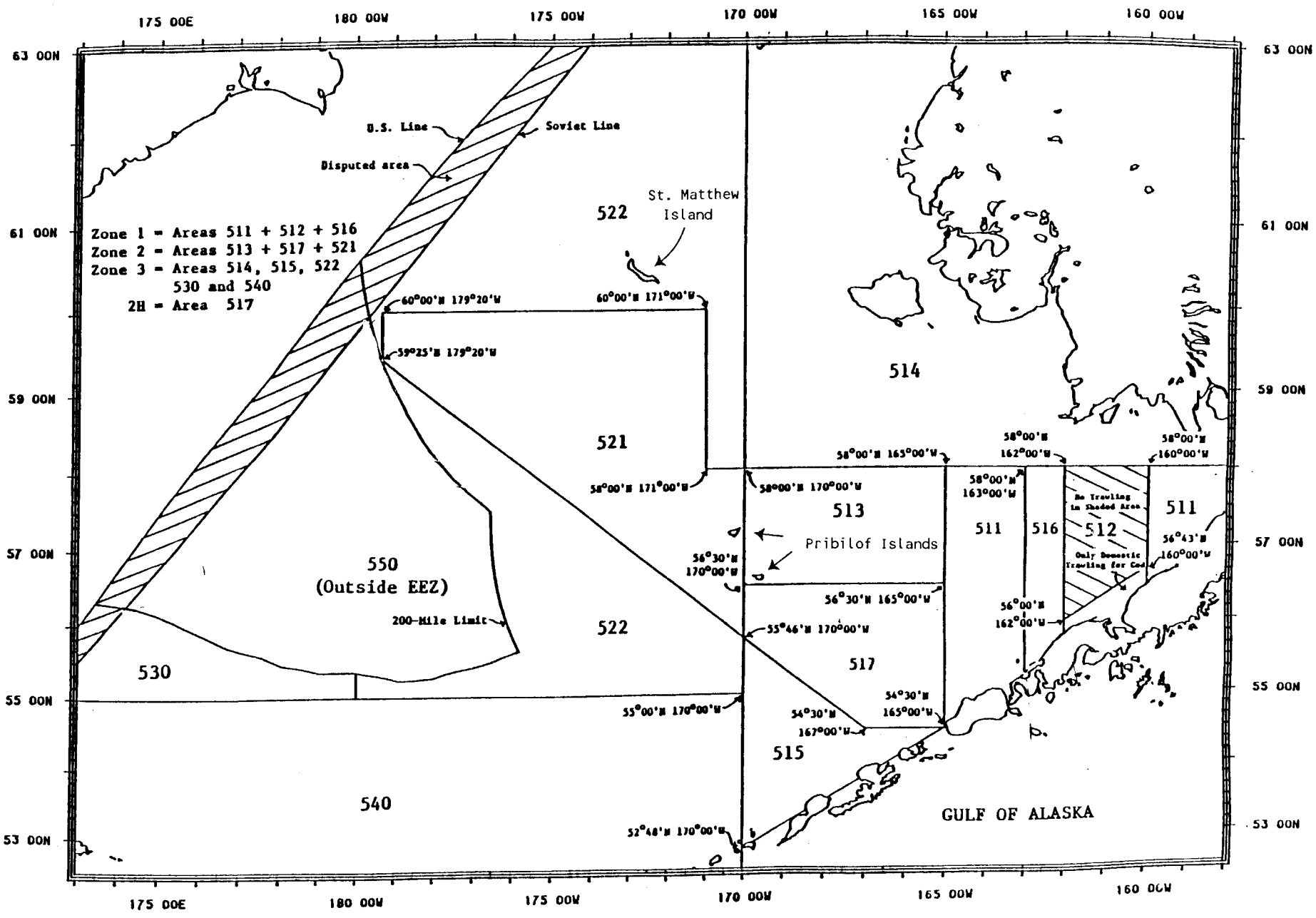

Figure 2. National Marine Fisheries Service regulatory reporting areas for the Bering Sea/Aleutians area.

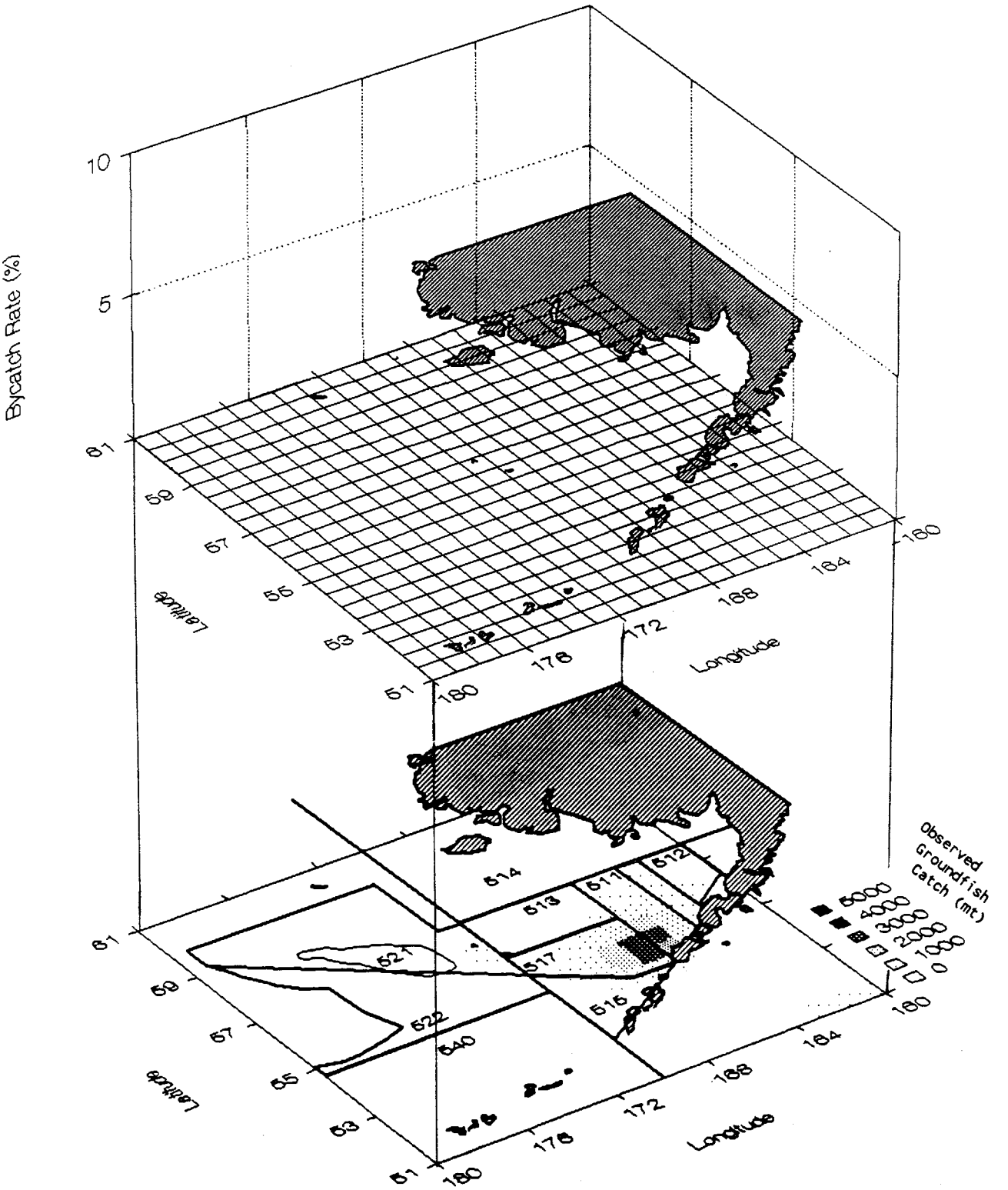

Figure 3. January herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

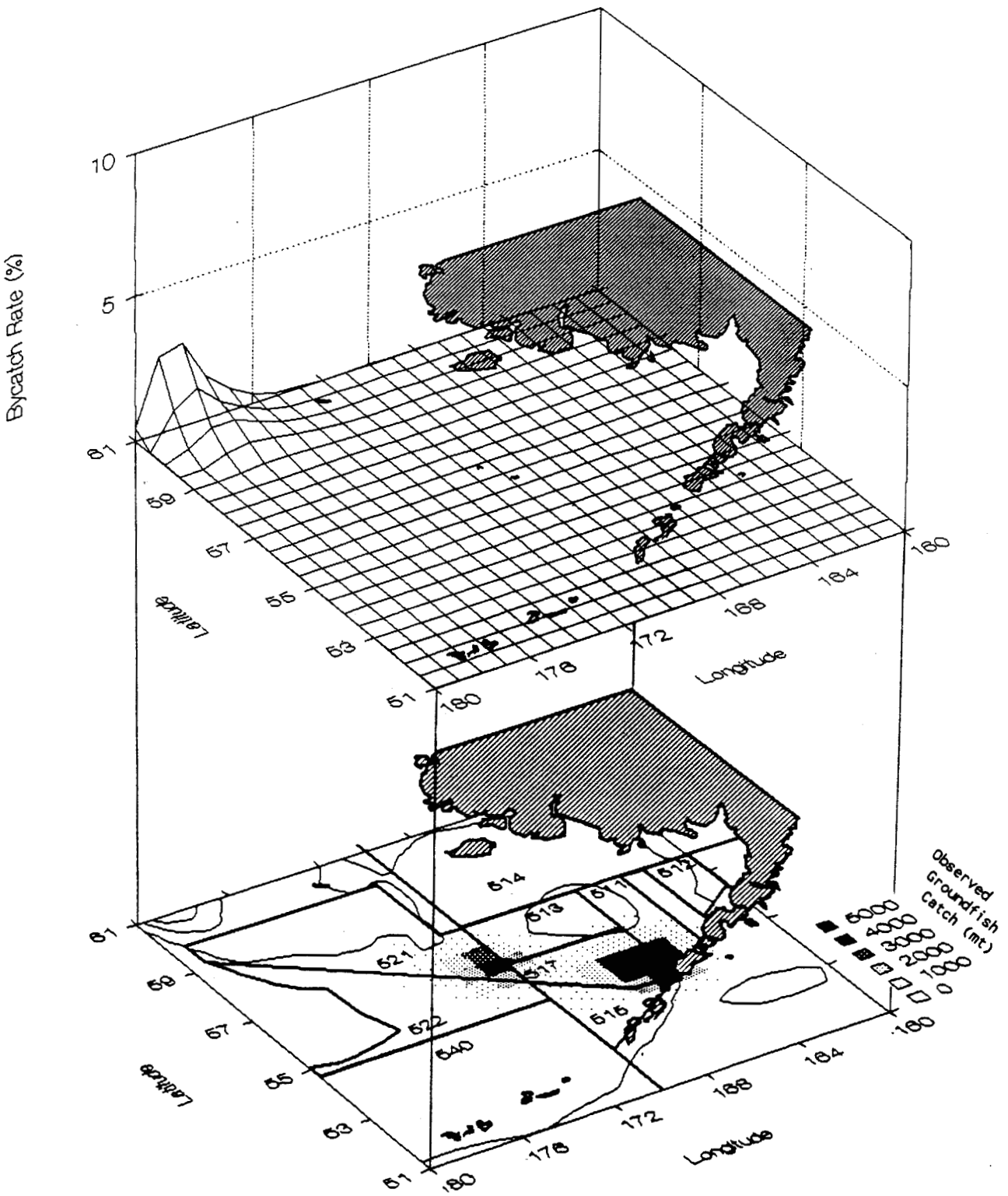

Figure 4. February herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

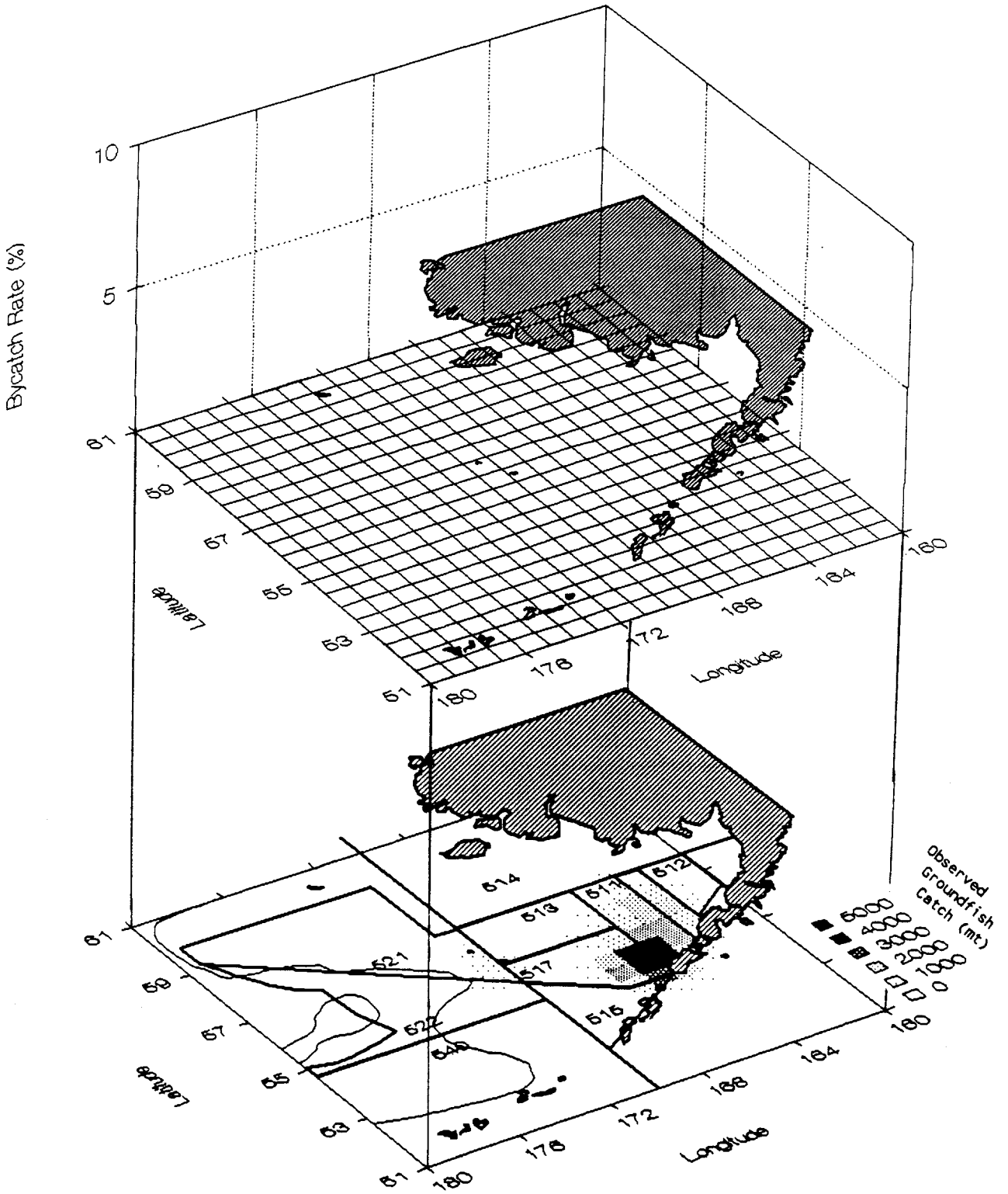

Figure 5. March herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

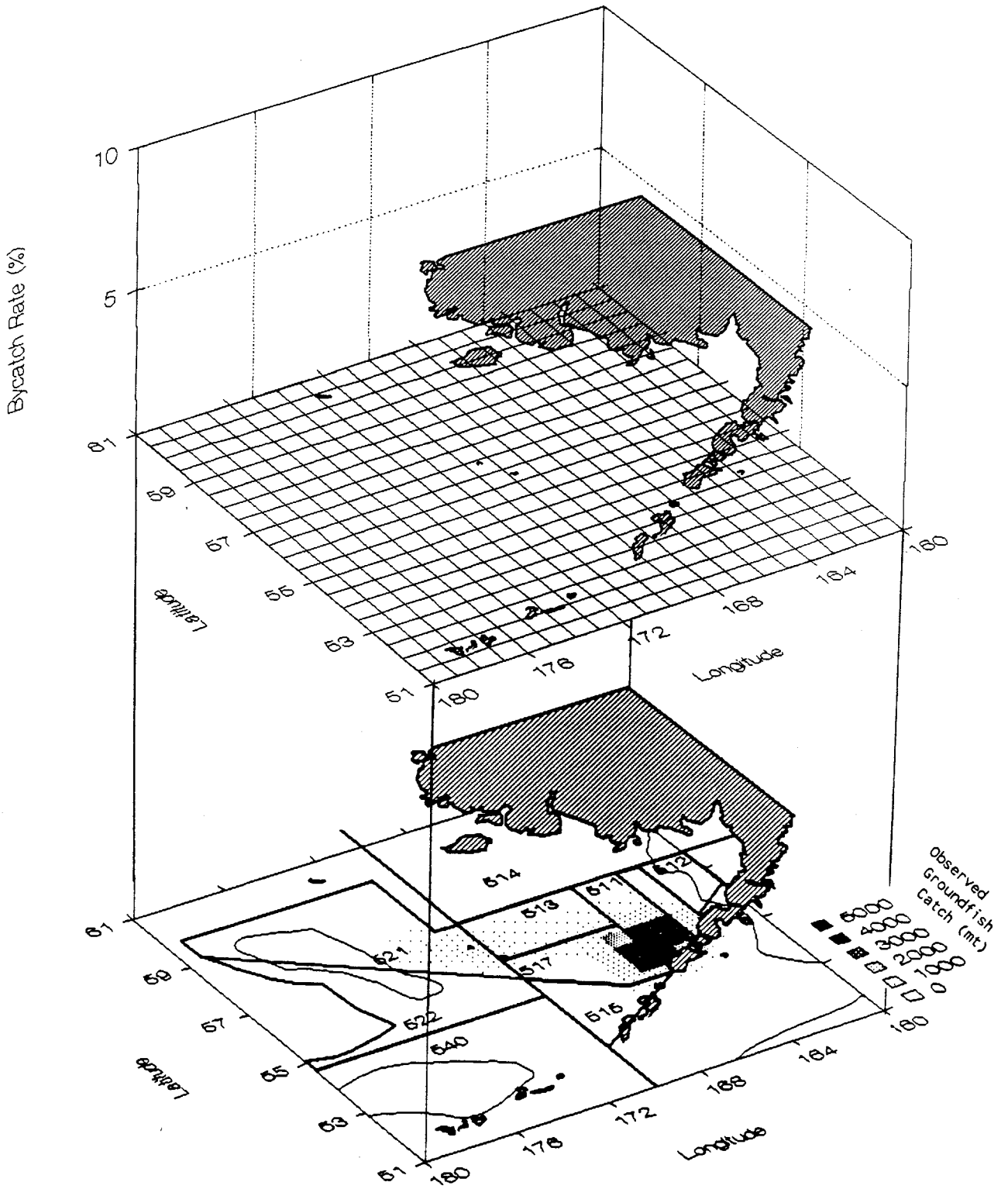

Figure 6. April herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

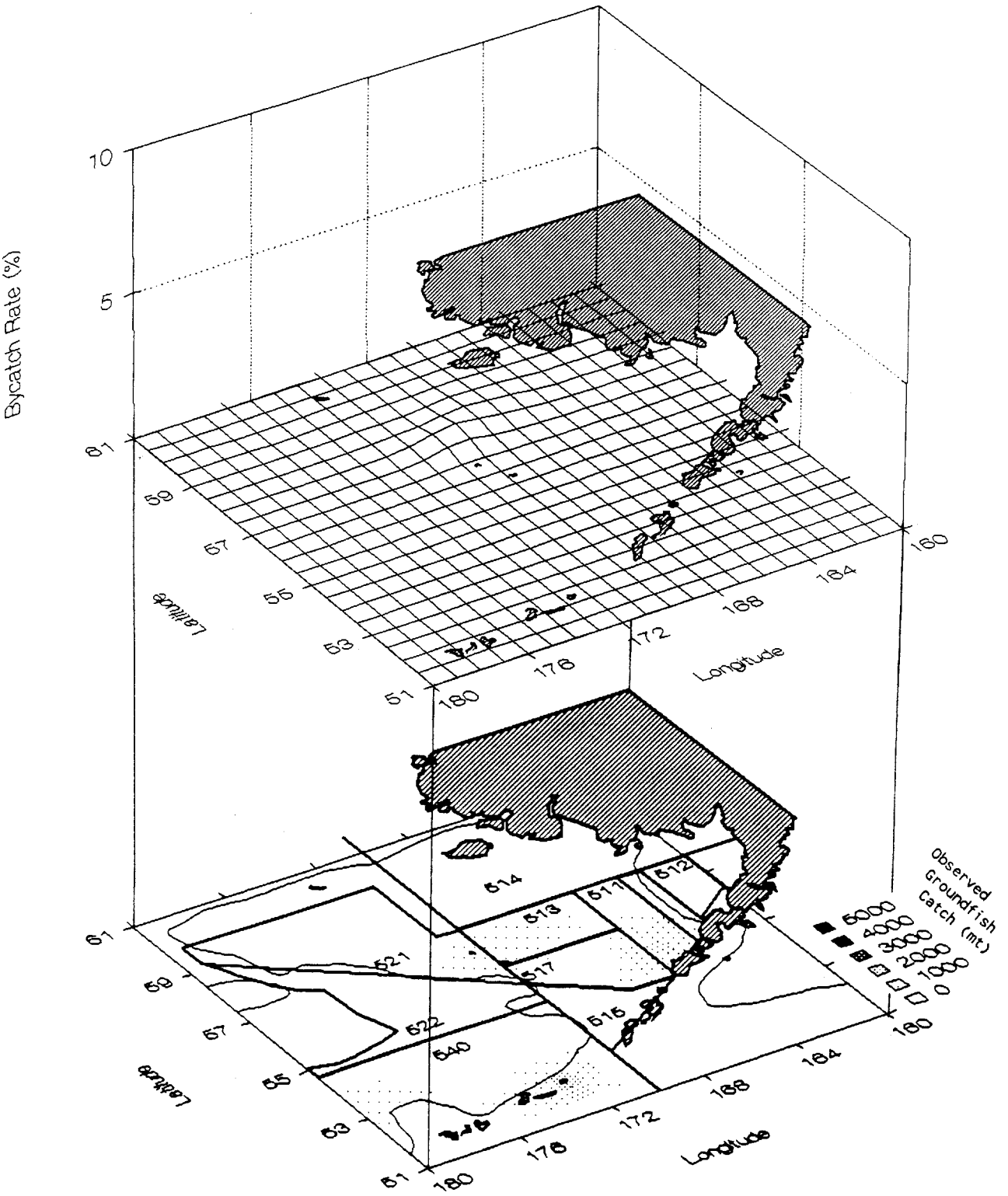

Figure 7. May herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

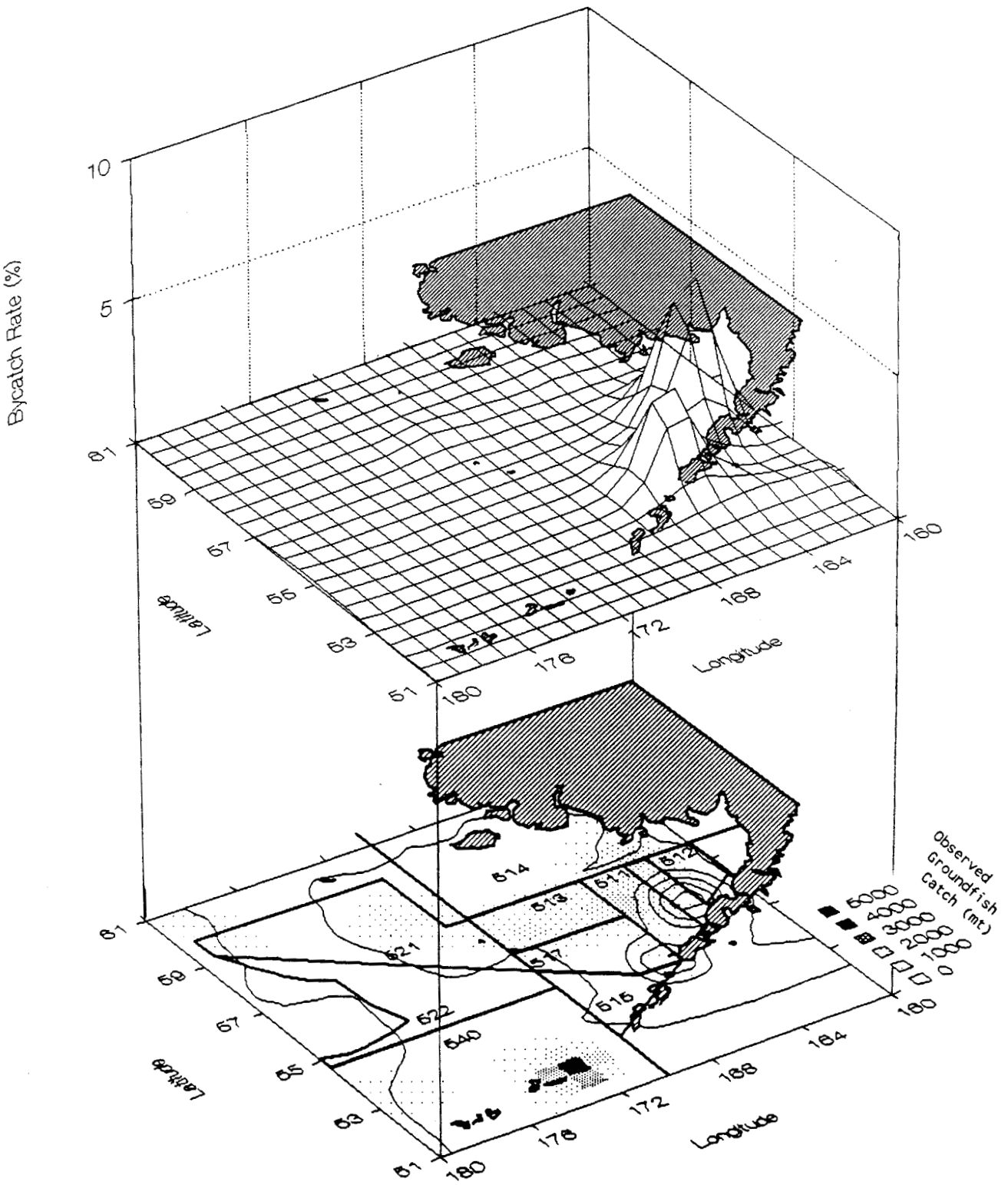

Figure 8. June herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

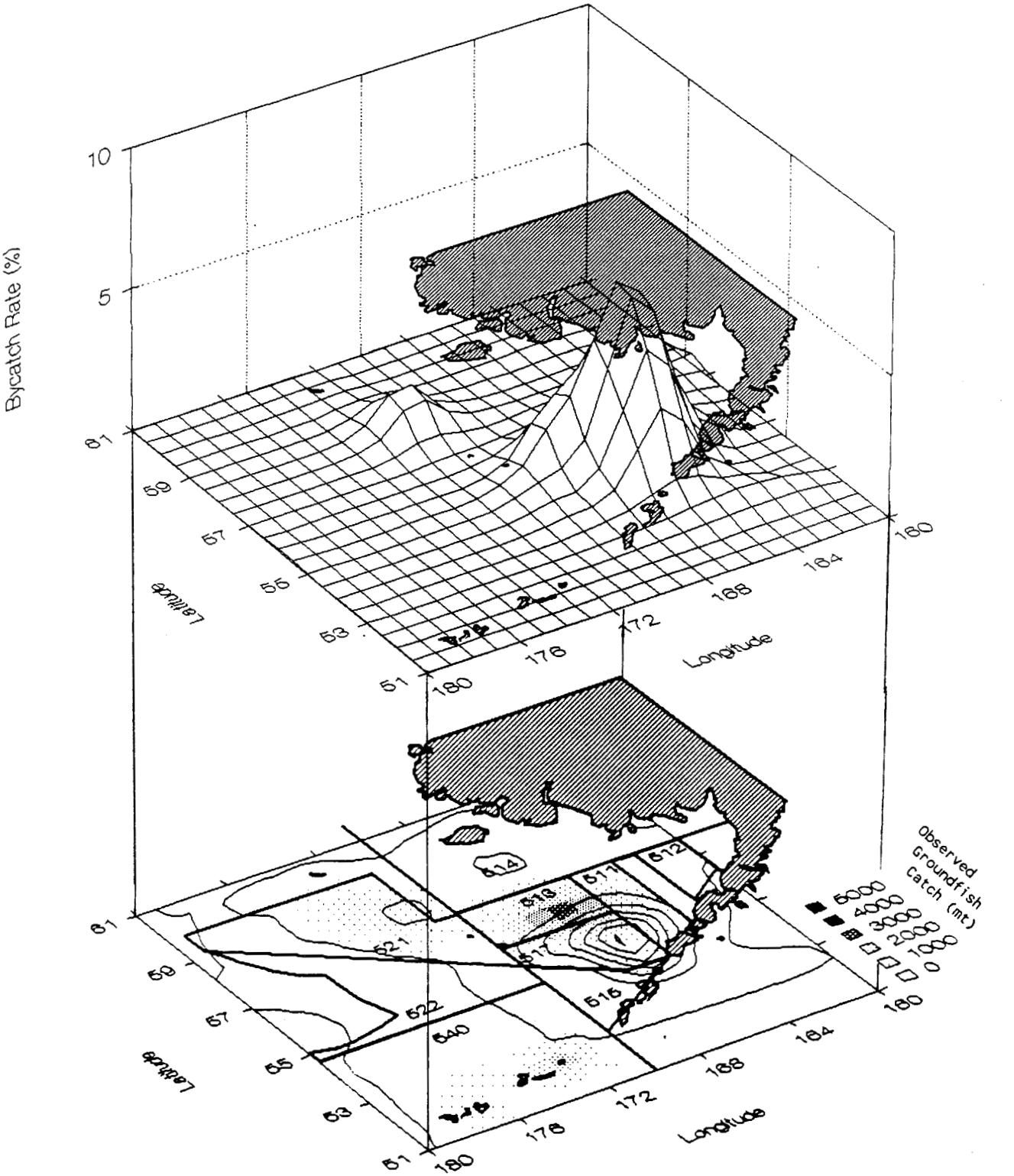

Figure 9. July herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

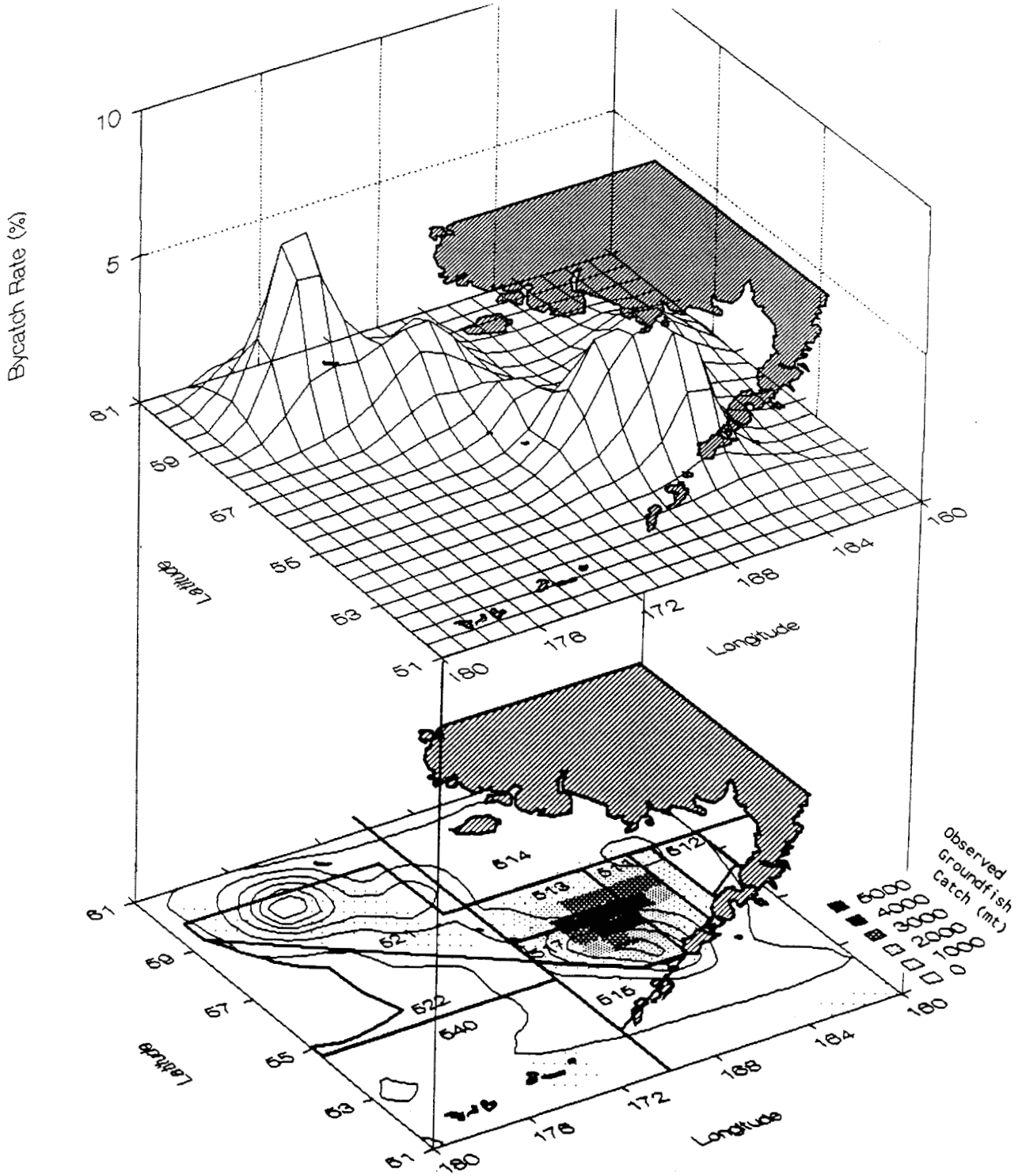

Figure 10 August herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

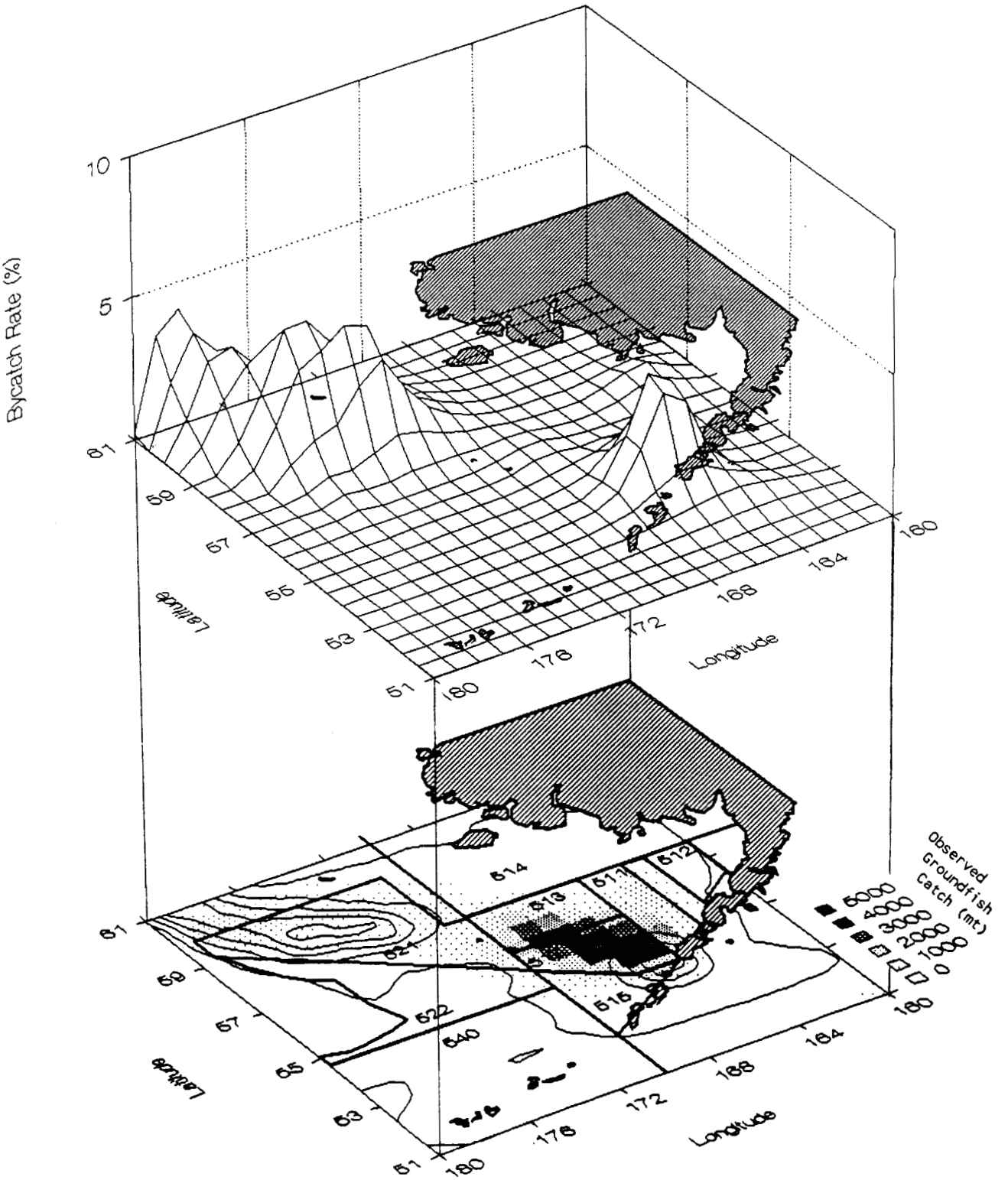

Figure 11. September herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

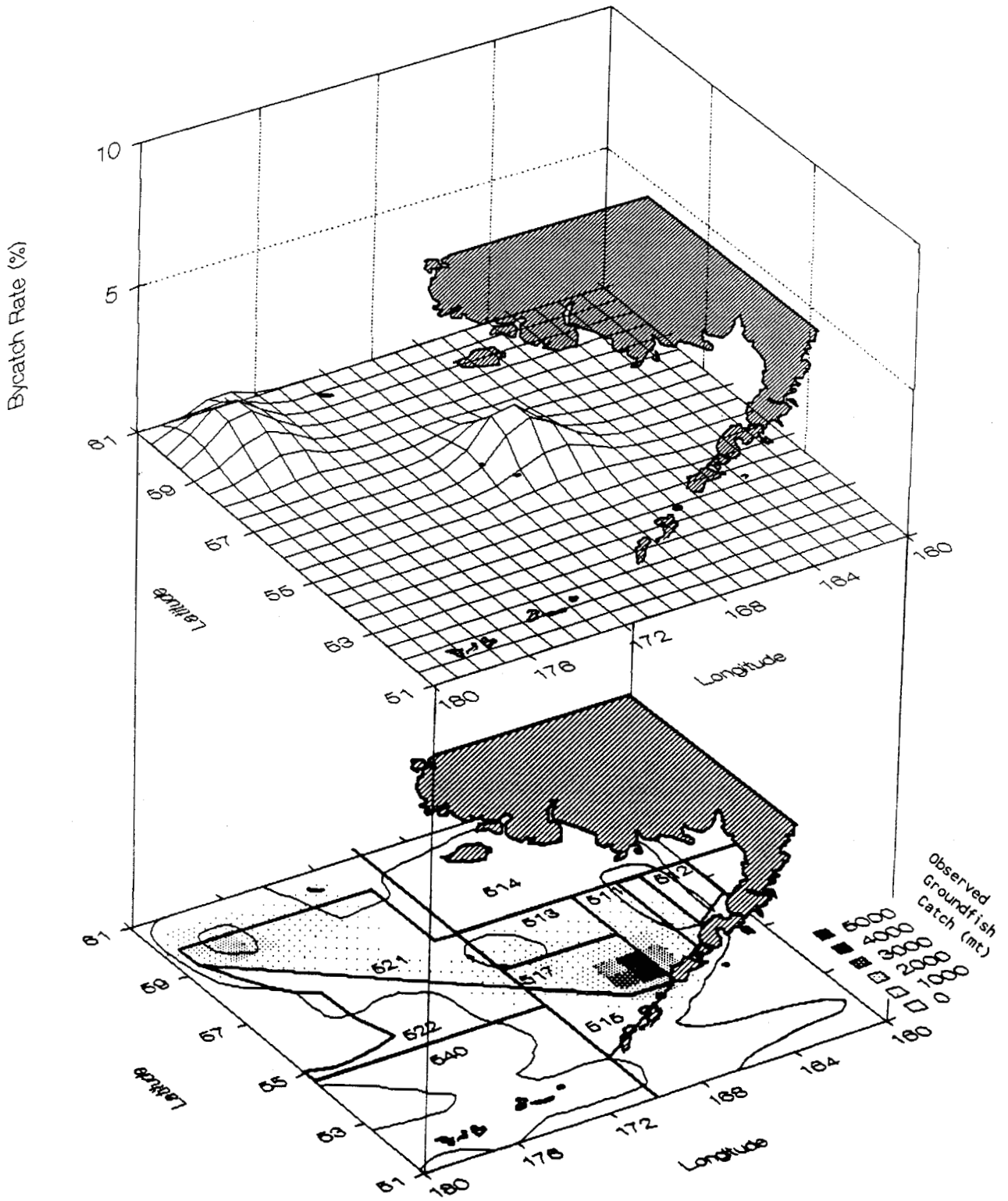

Figure 12. October herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).

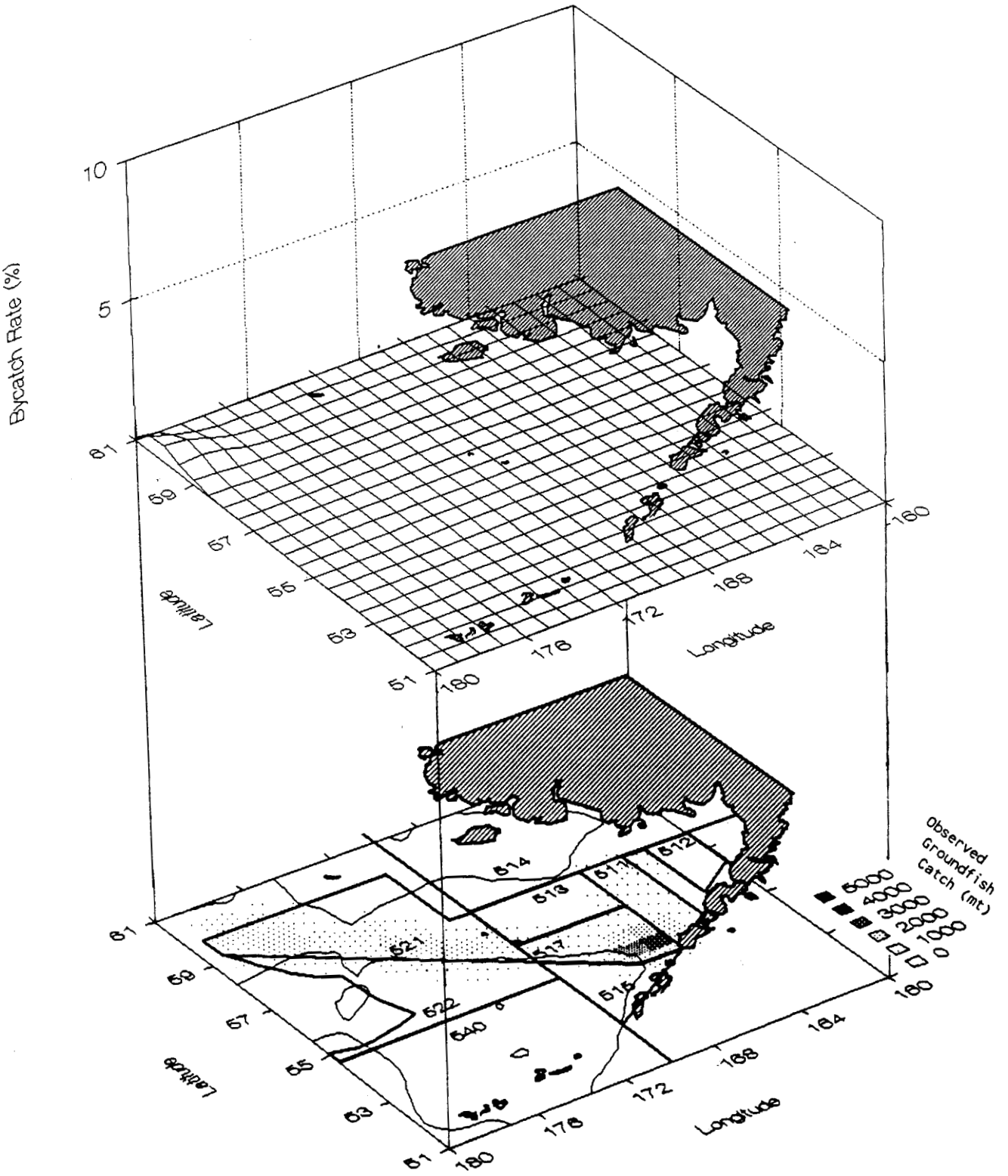

Figure 13. November herring and groundfish catch distributions. Upper panel: herring bycatch rate by foreign and joint venture pollock bottom trawl and "other" bottom trawl (primarily Pacific cod) gears, averaged from 1983 through 1988, by 1/2° latitude by 1° longitude area, smoothed by distance-weighted least squares. Lower panel: National Marine Fisheries Service regulatory reporting areas (511-540), contour lines of herring bycatch rates from the upper panel, and the distribution of observed foreign and joint venture observed catches for pollock and "other" bottom trawls from 1983-1988 (shaded areas).