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An Analysis of the Stock Structure of Silver Hake,
Merluccius bilinearis, in NAFO Subareas 5 and 6

by

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ABSTRACT

The stock structure of silver hake is examined utilizing data from research vessel bottom trawl surveys, the commercial fishery, and morphometric data from research vessel surveys. The analyses indicate that silver hake inhabiting NAFO Subareas 5 and 6 comprise two stocks, although significant amounts of intermixture may occur between stocks. Proposed stock groupings include a northern group made up of silver hake found on northern Georges Bank and in the Gulf of Maine, and a southern group comprised of fish inhabiting southern Georges Bank south to Cape Hatteras.

INTRODUCTION

The silver hake, *Merluccius bilinearis*, a widely distributed, slender, swiftly swimming gadid, inhabits Northwest Atlantic waters between South Carolina and Newfoundland, but is most abundant from New Jersey to Nova Scotia. The abundance and availability of silver hake have made it important to United States (USA) commercial and recreational fisheries as well as to distant-water-fleet fisheries.

Silver hake in USA waters from Cape Hatteras, NC, to the Gulf of Maine have, since the early 1970's, been managed as three stocks using as boundaries the divisions and subdivisions of the Northwest Atlantic Fisheries Organization (NAFO). These stocks are the Gulf of Maine (Division 5Y), Georges Bank (Subdivision 5Ze), and Southern New England - Middle Atlantic (Subdivision 5Zw and Subarea 6) (Figure 1). The delineations were based on the scientific information available when management of silver hake

through ICNAF catch quotas began in 1973, but also conformed to the areas by which catch statistics were reported to ICNAF, thus facilitating the assessment and management of the fisheries in those areas.

Various studies have been conducted to distinguish between the stocks of silver hake in the Northwest Atlantic, however the results have not been conclusive or in total agreement. Tagging studies conducted by the USA (Fritz 1959, 1963) and the USSR (Noskov 1970) have proven inconclusive although almost 9,400 fish were tagged. Conover et al. (1961) examined morphometric characteristics of fish collected from the Gulf of Maine, both inshore and offshore, and south of Cape Cod to New Jersey. Based upon analysis of covariance and an examination of regression lines through T-tests, they suggested that two distinct stocks may populate the region, one in the Gulf of Maine and another from Southern New England to New Jersey, with Nantucket Shoals considered to be somewhat of a dividing line between the stocks (Figure 2). Nichy (1969) examined otoliths from immature silver hake from the Gulf of Maine and Southern New England waters and detected differences in zonal formation and lengths at age between fish in each area. He suggested using $41^{\circ}30'N$ latitude as the division line between the two stocks within these areas (Figure 2). On the basis of physiological characteristics, Konstantinov and Noskov (1969) reported separate stocks in the Georges Bank and Middle Atlantic areas. They also stated that in the Nantucket Shoals area, significant amounts of intermixture occurred (Figure 2). Anderson (1974) examined the seasonal distribution of silver hake from research vessel bottom trawl survey data and suggested a stock structure which placed fish on northern Georges Bank and in the Gulf of Maine in one group and fish on the southern part of Georges Bank south to Cape Hatteras in another (Figure 2).

In a recent study, an examination of tissue samples of spawning silver hake from commercial fishing vessels both south of Pt. Judith, RI and east of Gloucester, MA indicated that fish from

these two areas were genetically distinct (Schenk 1981). The samples, examined using an isoelectric focusing technique and the data analyzed using chi-square evaluation, showed highly significant chi-square values between areas when males and females were treated separately. Due to the limited sample area, it was not possible to indicate any stock boundaries associated with the groups analyzed.

In the present study, three sources of data were utilized to examine the stock structure of silver hake in NAFO Subareas 5 and 6: 1) morphometric data from fish collected during research vessel bottom trawl surveys, 2) research vessel survey catch data, and 3) commercial catch statistics, both USA and foreign where available.

METHODS AND MATERIALS

Discriminant Analysis Data

During the summer and autumn of 1978 and the spring of 1979, a total of 3,015 silver hake were collected from research vessel bottom trawl survey catches (Figure 3). Specimens were frozen and returned to the NMFS, Woods Hole Laboratory for analysis. Fork length was measured to the nearest millimeter and sex, age, and maturity were determined. A total of 13 morphometric characters were measured to the nearest 0.1 mm using vernier calipers, with all measurements made on the right side of each individual. Because silver hake do not possess distinctly separate second and third dorsal fins or ventral fins, at the time of analysis, two additional measurements were included which represented the combined second and third dorsal fins and ventral fins. Of the original number of specimens collected and measured, data from 1,112 males and 1,372 females (age 1 and older) were used in subsequent analysis; data from the remaining immature fish were not used.

The initial selection of parent groups required in the construction of the discriminant functions was based on an examination of composite plots of catches of silver hake from both

seasonal bottom trawl surveys and the commercial fishery. The plots indicated a clear separation of fish into components north and south of Georges Bank, with the shoal portions of the Bank and Nantucket Shoals generally devoid of fish. Hypothesizing that fish from these two components may constitute different stocks by virtue of their discontinuous distributional patterns, individuals from each of the sample periods were divided into northern and southern groups. The northern groups contained fish collected in the Gulf of Maine and on northern Georges Bank, while the southern groups were made up of fish collected on the southern portion of Georges Bank south to Cape Hatteras.

It was also decided to investigate whether fish separated at the time of spawning may represent separate stocks. Silver hake spawn generally in depths less than 90 m from May to November with peak spawning occurring in June-July along the continental shelf continuing into July-August in the Gulf of Maine (Bigelow and Schroeder 1953, Marak and Colton 1961, Sauskan and Serebryakov 1968, Colton and St. Onge 1974, Fahay 1974). Major spawning areas for silver hake include the coastal region of the Gulf of Maine from Cape Cod to Grand Manan Island, with the area on the eastern side of Cape Cod north to Cape Ann being the most important (Bigelow and Schroeder 1953, Colton and Byron 1977). On Georges Bank, the major spawning grounds are reported to be along the southern portion (Sauskan and Serebryakov 1968, Silverman 1982), although Sauskan and Serebryakov (1968) reported that in some years spawning did take place on the northwestern edge as well. In Southern New England - Middle Atlantic waters, spawning takes place in the area of Nantucket Shoals and south of Martha's Vineyard and as far south as Cape Hatteras (Fahay 1974). Fish from summer and autumn samples determined to be in spawning or post-spawning condition were assigned to two groups corresponding to the above areas for testing as possible separate stocks.

Since silver hake have been shown to be sexually dimorphic with respect to growth (Schaefer 1960, Nichy 1969), an analysis of covariance was performed on the morphometric measurements for males and females (all areas combined) using length as the

covariate, to test for differences in characters between sexes. Significant differences ($p=0.01$) were evident in 9 of the 13 characters (Table 1); therefore data were treated separately by sex throughout the discriminant function analysis. Strong linear relationships were also found between each character and fork length, with correlation coefficients averaging 0.906 for males (range=0.842 to 0.957) and 0.943 for females (range=0.858 to 0.979). Examination of residuals indicated the absence of any non-linear trends. To remove the linear effect, all characters were expressed as percentages of body length throughout the discriminant analysis.

After conversion to percentages of body length, the data from each survey were used in the SPSS Discriminant Analysis program (Klecka 1975). A stepwise analysis was performed to select which characters would best distinguish between the groups, construct the discriminant function, and finally assign individuals to either of the groups. Due to the migratory behavior of silver hake and the possibility of substantial amounts of intermixture between groups, prior probabilities of group membership were assigned such that the probability of classifying individuals into either of the groups was equal. Details of the statistical procedures used are described by Fisher (1936), Mahalanobis (1936), Rao (1952), Fukahara et al. (1962) and Amos et al. (1963).

Research vessel bottom trawl surveys

Seasonal bottom trawl surveys have been conducted by USA and foreign research vessels since the summer of 1963. The USA surveys initially covered the area extending from Nova Scotia to the Hudson Canyon in depths ranging from 27 to 366 m. In 1967, coverage was extended southward to include the area from New Jersey to Cape Hatteras, NC (Figure 4). In 1968, the survey program was expanded to include spring surveys; and inshore surveys, covering depths of 5 to 27 m, were added to the program in 1972.

Trawl stations were selected utilizing a stratified random

design and the number of stations allocated to strata were proportional to stratum areas. Within strata, stations were randomly assigned (Grosslein 1974). During USA offshore surveys conducted in the autumn, a No. 36 Yankee bottom trawl with a 1.3 cm stretched mesh cod end liner was towed at each station for 30 minutes at an average speed of 3.5 knots. Operations were conducted 24 hr/day. The No. 36 Yankee trawl used from 1968 to 1972 during the offshore spring surveys was replaced by a larger, high-opening No. 41 Yankee trawl during 1973-1981. Inshore surveys during 1972-1975 used either a modified 3/4 Yankee trawl or a No. 36 Yankee trawl. Since 1976, the No. 36 and No. 41 Yankee trawls have been used inshore in the autumn and spring, respectively. Research vessel surveys conducted in the winter and summer have utilized the No. 36 Yankee trawl throughout the series.

During 1967-1977, additional cooperative research vessel surveys were conducted periodically with the USSR, Poland, GDR, FRG and France. These surveys were also based on the USA stratified random design (except the R/V Walther Herwig survey in 1973), but sampled only selected strata between Nova Scotia and Cape Hatteras and utilized various types of commercial bottom trawls. Tow durations during these surveys were 30 minutes at speeds ranging from 3.5 to 5.0 knots. Sampling was conducted only during daylight hours, except during the R/V Khronometer survey in 1974 which sampled 24 hr/day. A summary of the research vessel survey cruises is presented in Table 4.

Silver hake catches (in numbers) from each survey were divided into prerecruits (age 0 for summer and autumn surveys and age 1 for winter and spring surveys) and adults (ages 1 and older for summer and autumn and 2 and older for winter and spring) based on age-length data from USA surveys. For each season/year, the maximum length for age 0 or 1 individuals was determined and fish above and below this length were designated adults or prerecruits, respectively. Numbers at length data for each group were then summed for each country/season/station by 10 minute square and divided by the total number of stations in each square

to obtain the mean catch (in numbers) per 10 minute square per country/season. All foreign research vessel surveys were grouped together and no attempt was made at standardizing the catches from the variety of gears utilized by the vessels in the series. The data were then plotted by 10 minute square to produce cumulative seasonal distribution maps of adult and prerecruit silver hake during the period for both USA and foreign surveys.

Commercial Fishery Catch Statistics

Detailed catch statistics for the USA silver hake fishery collected through a system of vessel captain interviews are available from New England ports since 1965 and from ports located in New Jersey since 1974. In order to elucidate the traditional fishing patterns of the USA fleet, landings from trips in all ports in which silver hake were the main species sought (ie. the silver hake catch made up at least 50% of the total catch during a trip) were summarized by 10 minute square for the period 1965-1980 and plotted by month (all years combined). The number of trips interviewed from which silver hake were designated the main species sought averaged approximately 38% of the total trips each year and were primarily from the New England fishing ports of Portland, ME, Gloucester, MA, Provincetown, MA, Pt. Judith, RI, and Newport, RI.

Commercial landings of silver hake sold in any USA port reported through a system of weighout reports on an individual trip basis with fishing locations to the nearest 30 minute square are available since 1975. The landings from individual vessel trips from all ports with silver hake determined to be the main species sought were summarized by 30 minute square for 1975-1980 and plotted by month (all years combined).

Summaries of foreign fishing activity beginning in 1963, primarily by the USSR, available through the ICNAF Redbook and Research Report series, were also examined to determine the fishing patterns of the largely offshore fleets with respect to silver hake.

RESULTS

Discriminant Analysis

The results of the stepwise discriminant analysis applied to the morphometric data collected during 1978-1979 are presented in Tables 1-3. The results indicated that 11 of the 13 characters contributed to the functions for males, and all characters contributed for females. For males, only one character, the length from the tip of the snout to the insertion of the pectoral fin, contributed to all three functions while five characters, length from snout to insertion of pectoral fin, second ventral fin length, snout to insertion of pelvic fin, snout length, and pelvic fin length, contributed to all three functions for females (Table 2). It was unclear why the significant characters differed between sexes and seasons. Preliminary analyses run using combined second and third dorsal and first and second ventral fins produced the same results as those using individual characteristics; therefore, only functions constructed using the individual characters were utilized in the following results.

The functions constructed by the stepwise discriminant analysis were in the form:

$$Z = \sum_{i=1}^k C_i X_i$$

where, from each fish; C_i = discriminant function coefficient for each characteristic, and X_i = the value of the characteristic. In order to assign group membership, estimated mean Z-values for each sex from the two areas were determined by substituting the respective X-values into the appropriate functions. Z-values for each sex are presented in Table 2. In discriminating between the groups, individuals with Z-values greater than the mean Z-value for each season were classified as southern fish, and those with Z-values less than the mean Z-value were classified as northern fish for each sex. Differences between the groups were significant during each season for both males ($F_{4,276} = 10.29$ for summer 1978, $F_{6,375} = 7.40$ for autumn 1978, and $F_{6,442} = 6.99$ for spring 1979) and females ($F_{7,235} = 10.33$ for summer, $F_{11,619} = 5.26$ for autumn, and $F_{9,486} = 10.55$ for spring) at the 0.005 level. The pro-

bability of correctly classifying individuals averaged 65.4% (range 65.2 - 65.6%) for males and 69.0% (range 64.5 - 72.0%) for females. The results of the analyses indicated the presence of two groups in the study area during all seasons but were not able to identify a clearcut separation between the groups. The percentages of fish classified as belonging to each of the groups is given in Table 3.

Stepwise discriminant analysis applied to data from Gulf of Maine and Southern New England - Middle Atlantic fish in spawning or post spawning condition from summer and autumn samples hypothesized to represent discrete parent stocks indicated only one character for males and two characters for females which contributed to the separation of the two groups. The probability of correctly classifying fish in this analysis was 56.8% and 58.6% for males and females, respectively. The number of characters and probabilities of correctly classifying individuals was considered insufficient to provide a basis for further analysis.

Seasonal Distribution Patterns

Adults

Adult silver hake inhabiting the continental shelf waters from Cape Hatteras, NC to Nova Scotia were found to occupy a variety of depths ranging from the shallow inshore areas to depths greater than 350 m (Figures 5-8). Silver hake occurred during bottom trawl surveys throughout their distributional range during all seasons with only the major concentrations of fish varying in response to hydrographic changes. In Subarea 5, they were found generally in the deep basins of the Gulf of Maine and along the outer continental shelf south of Georges Bank to eastern Long Island during the winter and early spring. As waters warm in the spring and summer, a general movement to the more shallow inshore waters of the Gulf of Maine and onto Georges Bank was evident. In Subarea 6, the seasonal pattern differed in that fish were present both inshore and offshore from eastern Long Island south to Cape Hatteras during late autumn to early spring, with a general northerly movement in the spring and summer.

The distribution of adult silver hake catches during both the USA and foreign winter surveys (6 Jan-8 Apr) (Figure 5) showed that although they were taken in many shallow strata, the major concentrations of fish (averaging greater than 100 fish/10 minute square in USA surveys) were located in the deep basins of the Gulf of Maine, along the continental slope from Georges Bank to Cape Hatteras and also in the nearshore waters from eastern Long Island to Cape Hatteras. Georges Bank was virtually devoid of all adults. Bottom temperatures at stations where silver hake were collected ranged from 1.5 to 12.9°C, but the preferred temperature range (defined as the range in bottom temperatures from which 60% or greater of the catches were taken) was 4.6 to 7.5°C.

During spring surveys (2 Mar-4 Jun), the major concentrations of fish were similar to those in the winter (Figure 6) except in the Gulf of Maine, where more fish were collected in the nearshore areas along the coasts of Maine and southwestern Nova Scotia. Again, the shallow areas of Georges Bank (strata 13, 16, 19, 20) were devoid of adults even though bottom temperatures averaged 5.8°C for those strata during the survey period. The range in bottom temperatures from stations collecting silver hake was from 1.9 to 18.4°C with preferred temperatures between 4.6 and 8.5°C.

The migration to shoaler waters of fish in Subarea 5 and the northern migration in Subarea 6 was clearly evident by the summer surveys (conducted during 23 Jun-1 Sep) (Figure 7). Major concentrations in the Gulf of Maine were located in the coastal areas between Cape Ann, MA and Grand Manan Island. On Georges Bank, concentrations were found on the northern and northwestern edges and again on the southern portion. In southern New England - Middle Atlantic waters, concentrations of fish were found in the area from south of Nantucket to eastern Long Island, and also in the Hudson Canyon area. Only small average catches (less than 10 fish/10 minute square) were indicated south of Hudson Canyon. Bottom temperatures ranged from 2.5 to 21.0°C while preferred temperatures ranged between 4.6 and 10.5°C.

By autumn, (surveys conducted during 3 Sep-16 Dec) the off-shore migration of fish in the Gulf of Maine was indicated by a shift in the concentrations from the coastal waters to the deeper areas of the Gulf (Figure 8). On Georges Bank, although small catches averaging less than 10 individuals/10 minute square were indicated on all parts, major concentrations were located on the northern and southern edges. Adults were distributed over the entire shelf from Nantucket Shoals to south of Hudson Canyon, but the southern migration of fish in this area was also indicated by concentrations of fish on the outer shelf and slope waters south to Cape Hatteras. A wider range of preferred temperatures was found in the autumn than in other seasons with temperatures ranging from 2.6 to 21.2°C, but with 5.6 to 12.5°C the preferred temperature range.

Prerecruits

The geographical distribution of prerecruit silver hake in the survey area was also very widespread and similar to that of adults with few major exceptions. These exceptions were; 1) while their overall distributional patterns were similar to those of adult fish, the maximum depths of major concentrations of prerecruits were generally less than those of adults, and 2) their preferred temperature range was usually narrower and cooler than the adults. The relationship between temperature and size was also reported by Edwards (1965).

During the winter and spring (Figures 9-10), prerecruits were taken in the deeper waters of the Gulf of Maine, along the southern edge of Georges Bank, and in Southern New England - Middle Atlantic waters, but the locations of their major concentrations generally abutted but did not overlap those for adults. On Georges Bank and in Southern New England - Middle Atlantic waters, they were taken in depths usually less than 100 m, while the largest concentrations of adults were found in depths between 100 and 200 m. In the Gulf of Maine, they were generally found in waters shallower and nearer shore than adults. During the winter, prerecruits were taken in waters with bottom

temperatures between 1.4 and 11.4°C with preferred temperatures between 2.8 and 6.5°C, while in the spring, the overall temperature range was 1.4-16.1°C with 3.6 to 7.5°C the preferred temperature range.

During the autumn (Figure 12), while adults were generally caught in very small numbers from the shoal waters of Georges Bank (strata 12, 16, 19, 20), large concentrations of prerecruits were found in these strata in bottom temperatures averaging 12.1°C. Major concentrations of prerecruits were also located south of Martha's Vineyard and Block Island out to depths of approximately 100 m, and in the inshore waters off central New Jersey and south of the Hudson Canyon. The overall temperature range was 3.6-21.2°C with a preferred temperature range of 6.6-12.5°C.

Distribution of Commercial Catches

USA Catches

The distribution of catches reported by the USA commercial fishing fleet reflected both the distribution of major concentrations of silver hake as indicated by research vessel bottom trawl surveys and also the composition of the fleet. The soft flesh of silver hake deteriorates rapidly if not frozen soon after it is caught. Because the USA fleet is comprised primarily of small vessels without freezing capabilities, the fishery has been one of day-trips or one in which the vessels' maximum trip length is approximately 5 days. These restrictions on trip length were indicated in the distribution of monthly catches in that very few landings were reported from the eastern or southern parts of Georges Bank and eastern Gulf of Maine, and only areas of consistently high concentrations of silver hake were fished.

The geographical distribution of monthly landings (Figures 13-18) indicated that during the winter there were three major areas where silver hake were taken 1) in the deep, nearshore waters of the western Gulf of Maine, 2) in the nearshore waters south of Block Island and 3) along the continental slope south of

Nantucket Island southward to Baltimore Canyon. There were consistent landings reported off the central and southern New Jersey coast as well.

These fishing areas persisted through the spring into summer when, because of shifts in distribution north in Subarea 6 and inshore and onto Georges Bank in Subarea 5, by July the major fishing areas were in the waters south and east of Block Island to Nantucket Shoals, the coastal area from Cape Cod to Casco Bay, ME, and on the northwestern slope of Georges Bank.

By October, fishing activity on Georges Bank was greatly reduced due to the migration of post-spawning adults off the Bank. Activity continued along the coastal areas from Cape Cod to Maine and also south of Block Island.

Landings continued to drop in November and December and were reported in the area south of Block Island where there appeared to be commercially exploitable concentrations year-round, and in the nearshore waters of western Gulf of Maine.

Foreign Catches

The distribution of landings by foreign vessels, primarily from the USSR, as indicated in the ICNAF Research Report and Research Document series, showed that effort was directed toward the offshore concentrations of silver hake, primarily along the slopes of the continental shelf.

During the first years of the USSR fishery, 1962-1964, the fleet located and fished concentrations of silver hake in Subarea 5. During December-January, overwintering concentrations in the deep basins of the Gulf of Maine were fished (at depths of 150-300m) before operations shifted to the southern portion of Georges Bank in March (Sauskan 1964, Noskov et al. 1976). The southwest slopes of Georges Bank were fished until about June-July when the fleet directed effort toward dense spawning concentrations on the southeastern slopes of the Bank. Effort was then shifted toward what were described as feeding concentrations on the northwest slopes of Georges Bank in late summer and into

autumn (Sarnits and Sauskan 1966).

During 1965-1976, as the stocks declined and restrictions were placed on the fishery, the major portions of the catch were taken from the slope areas of the shelf from the Hudson Canyon area to the southeastern part of Georges Bank primarily during the winter and spring months. During the summer and autumn, effort was concentrated on the northwest slope of Georges Bank and on Nantucket Shoal.

Since 1977, fishing operations have been further restricted to foreign fishing areas or "windows" located in the offshore waters from southern Georges Bank (west of 67°W latitude) to Cape Hatteras (north of 35° 13'N longitude), primarily during the winter months.

DISCUSSION

Seasonal distribution patterns of silver hake as indicated from bottom trawl survey catch and commercial fishery data show a separation of fish into northern and southern contingents with major concentrations found on the northern portion of Georges Bank and in the Gulf of Maine, and a virtually continuous distribution along the continental slope between the Hudson Canyon and southern Georges Bank (Figures 5-8). Anderson (1974) suggested that silver hake could possibly be divided into 'stocks' reflecting this pattern. Nichy (1969) also indicated that silver hake could be separated into two groups based on the otolith structure of young fish, with the shoal waters of Georges Bank representing the division between the groups. The results of the analysis of morphometric characters of silver hake collected in 1978-1979 from the Gulf of Maine to Cape Hatteras support the conclusions drawn by Nichy (1969) and Anderson (1974).

Although the discriminant analysis was able to define significantly different groups inhabiting the study area, the analysis however, did not show any clearcut separation between the two groups as indicated by the percentages of correctly clas-

sified fish in each of the seasons analyzed (Table 3). An average of 32.8% of the fish collected from either group during any season were classified as belonging to the opposite group, suggesting that fish inhabiting the waters of southern Georges Bank and the Southern New England - Middle Atlantic may migrate north onto the northern portion of the Bank or into the Gulf of Maine and fish inhabiting the northern areas may migrate south. This is generally consistent with the patterns indicated from bottom trawl survey catch data except that the discriminant analysis results showed mixing during all seasons.

The identification of Georges Bank as a mixing area for the two groups was demonstrated by an analysis of individuals collected from the northern and southern extremes of their distributional range. When samples from the Georges Bank area were removed from the data set and a stepwise discriminant analysis performed, while the functions changed very little with the most significant characters virtually the same in both analyses, the percentage of correctly classified fish increased to approximately 80% (79.5% for males and 80.8% for females). The results of the two analyses indicated that while there appeared to be intermixture between the groups, there were enough individuals from each of the groups present during each season to produce functions that showed significant differences between the groups. The analyses also indicated, through the calculation of Wilk's lambda (a statistic used to evaluate the discriminating power of the variables (Klecka 1975)), that there was an inherent weakness in the morphometric characteristics' ability to separate between groups, suggesting that while significantly different groups could be identified, the percentage of correctly classified individuals in each of the groups would not be high.

Further evidence to support the results of the discriminant analysis indicating two groups of silver hake inhabiting Subareas 5 and 6 was reported by Schenk (1981). The results of a biochemical analysis of tissue samples indicated significant differences in the enzyme systems of spawning silver hake collected

from the two areas. Discriminant analysis however, was unable to satisfactorily define separate spawning groups in the Gulf of Maine and Southern New England - Middle Atlantic areas based upon summer and autumn samples. The results are also in general agreement with Conover et al. (1961) in that both studies identified northern and southern groups, but while Conover recommended that Nantucket Shoals be the division between the two groups, the present analysis indicated that the division of groups be located in the shoal waters of Georges Bank.

In summary, the results of the analyses of research vessel bottom trawl survey catch data, commercial fishery catch data, and morphometric data collected during research vessel bottom trawl surveys, indicated that silver hake inhabiting NAFO Sub-areas 5 and 6 may be separated into two stocks, one comprised of fish from northern Georges Bank and the Gulf of Maine, and another with fish from southern Georges Bank south to Cape Hatteras. For assessment purposes, the northern stock of silver hake could include NAFO Division 5Y and sampling areas 521-523, while the southern stock could include sampling areas 524-526, Subdivision 5Zw and Subarea 6 (Figure 19). These divisions represent the same boundaries as proposed by Anderson (1974) (Figure 2).

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Table 1. Results of analysis of covariance of males versus females with all areas and all cruises combined. Values listed are the results of F test for equality of adjusted group means.

Source of Variance	F-value
Head length (X_1)	30.8204 **
Eye Diameter (X_2)	78.3902 **
Snout Length (X_3)	76.3027 **
Snout to Anal Opening (X_4)	17.2411 **
Snout to Insertion of Pelvic Fin (X_5)	53.1674 **
Snout to Insertion of Pectoral Fin (X_6)	71.1146 **
Pelvic Fin length (X_7)	15.0922 **
Pectoral Fin Length (X_8)	26.0644 **
First Dorsal Fin Length (X_9)	.2524
Second Dorsal Fin Length (X_{10})	1.8875
Third Dorsal Fin Length (X_{11})	2.5637
First Ventral Fin Length (X_{12})	10.7971 **
Second Ventral Fin Length (X_{13})	4.6207
Degrees of Freedom	.2482

**Significant at the 1 % level.

Table 2. Discriminant functions constructed by stepwise discriminant analysis utilizing data from samples collected during 1978-1979 and mean Z-values for each sex. For definitions of X-values, see Table 1.

Summer 1978

$$Z_{\text{males}} = 42.3066x_3 + 69.1059x_5 + 33.9835x_6 - 14.7353x_{12} - 22.9478$$

$$Z_{\text{females}} = 33.8833x_3 - 42.2224x_4 + 31.4400x_5 + 74.5822x_6 + 15.6988x_7 + 10.8359x_{12} + 29.5075x_{13} - 20.3722$$

$$\text{mean } Z_{\text{male}} = -0.0826$$

$$\text{mean } Z_{\text{female}} = -0.0296$$

Autumn 1978

$$Z_{\text{males}} = -65.2324x_1 + 156.3585x_2 + 56.6256x_6 + 48.5752x_7 - 29.5796x_8 - 12.1525x_{11} - 5.1823$$

$$Z_{\text{females}} = 56.2079x_1 - 59.5423x_2 + 28.2812x_3 + 23.1730x_5 - 60.5787x_6 - 35.9703x_7 + 26.2594x_9 + 14.8453x_{10} + 21.9684x_{11} - 18.8355x_{12} + 14.7318x_{13} - 1.3519$$

$$\text{mean } Z_{\text{males}} = -0.0325$$

$$\text{mean } Z_{\text{females}} = -0.1762$$

Spring 1979

$$Z_{\text{males}} = 67.1500x_3 - 74.0287x_5 + 35.2654x_6 + 59.4319x_7 - 18.9580x_{10} + 12.9367x_{13} - 3.2603$$

$$Z_{\text{females}} = 30.7580x_1 + 45.1670x_3 - 76.8818x_5 + 70.7100x_6 + 20.6504x_7 - 12.0073x_8 - 25.6993x_9 - 15.8943x_{10} + 22.6555x_{13} - 8.3345$$

$$\text{mean } Z_{\text{males}} = -0.1114$$

$$\text{mean } Z_{\text{females}} = -0.1100$$

Table 3. Summary results of discriminant analyses performed on data from samples collected in the summer and autumn of 1978 and the spring of 1979. Percentages represent the results of male and female data combined.

Season & Location of sample	Percentage of fish classified as belonging to the:		
	Gulf of Maine and Northern Georges Bank Group	Southern Georges Bank Southern New England - Middle Atlantic Group	Sample Size
<u>Summer 1978</u>			
Gulf of Maine and northern Georges Bank	65.8	34.2	298
Southern Georges Bank and Southern New England - Middle Atlantic	27.9	72.1	226
<u>Autumn 1978</u>			
Gulf of Maine and northern Georges Bank	64.3	35.7	401
Southern Georges Bank and Southern New England - Middle Atlantic	35.0	65.0	612
<u>Spring 1979</u>			
Gulf of Maine and northern Georges Bank	68.3	31.7	609
Southern Georges Bank and Southern New England - Middle Atlantic	32.4	67.6	336
<u>Combined Summer/Autumn 1978 & Spring 1979</u>			
Gulf of Maine and northern Georges Bank	66.5	33.5	1308
Southern Georges Bank and Southern New England - Middle Atlantic	32.9	67.1	1174

Table 4. Summary of USA and foreign research vessel bottom trawl surveys, both inshore and offshore, conducted between Cape Hatteras, N.C. and Nova Scotia during 1963-1981.

Season	Country	No. of Surveys	No. of Stations	Dates(inclusive)
Winter	USA	5	926	6 Jan - 8 Apr.
	Foreign	4	321	28 Jan - 15 Mar.
Spring	USA	23	4,760	2 Mar - 4 June
	Foreign	12	813	2 Mar - 16 Apr.
Summer	USA	14	2,388	23 Jun - 1 Sep
	Foreign	1	102	9-26 Aug.
Autumn	USA	27	5,918	3 Sep - 16 Dec
	Foreign	18	1,847	7 Sep - 11 Dec
Total		104	17,075	

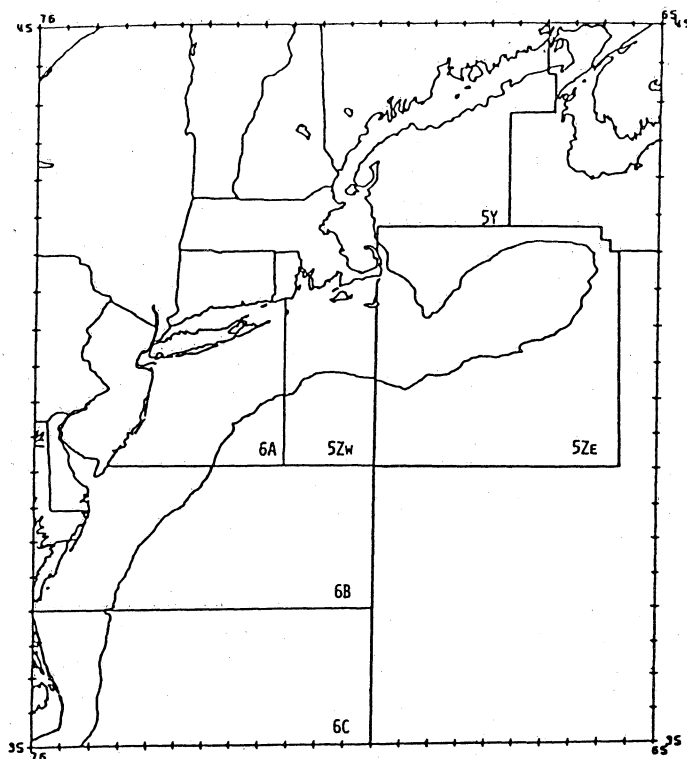


Figure 1. Current stock boundaries for silver hake based on NAFO divisions and subdivisions.

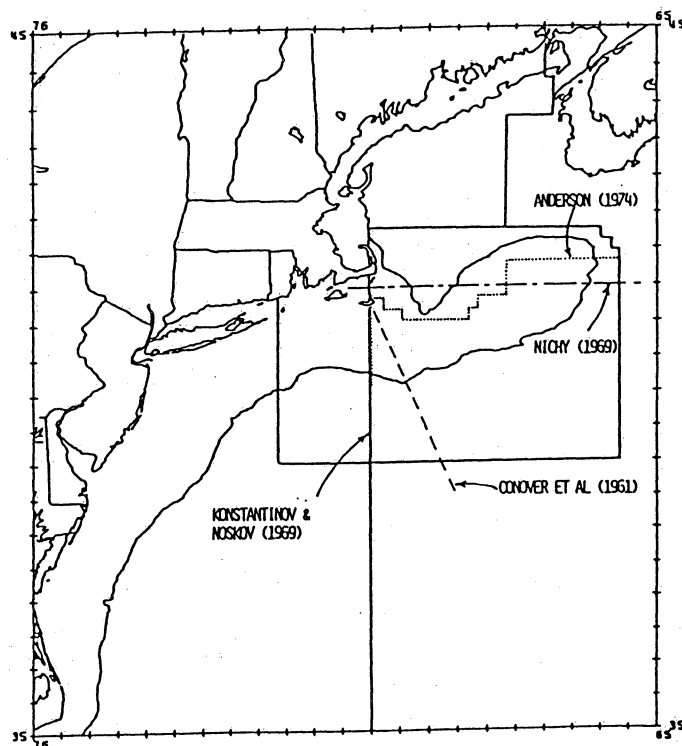


Figure 2. Stock boundaries proposed by the authors of previous studies.

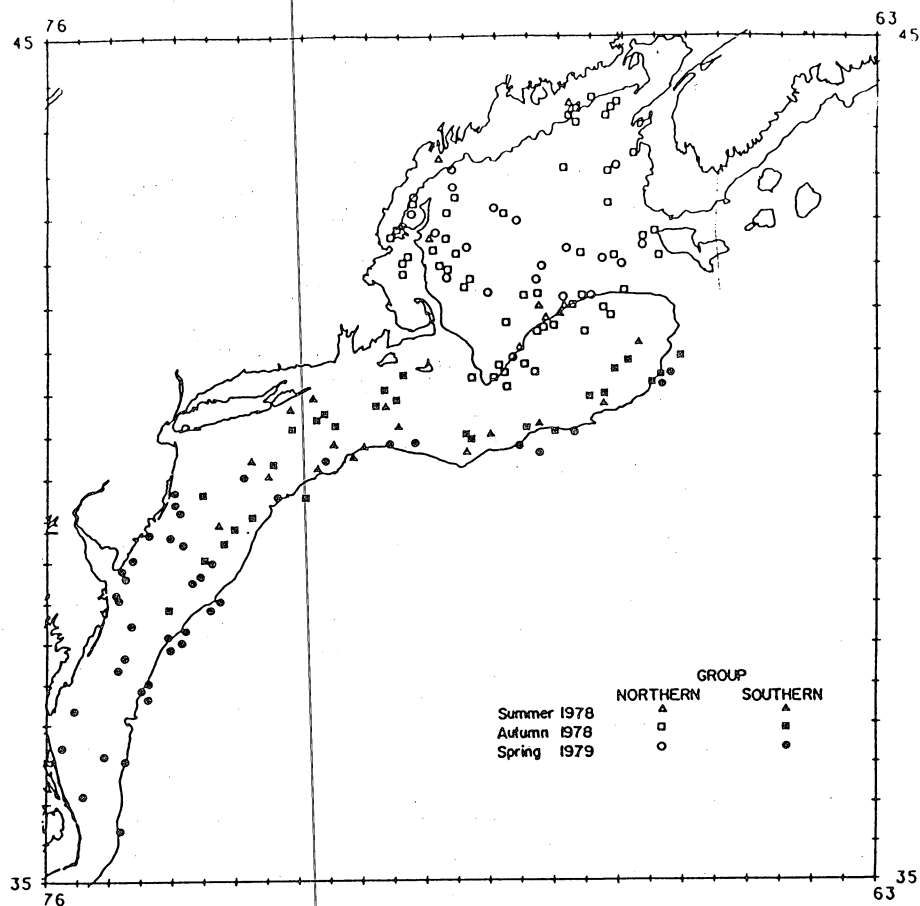


Figure 3. Location of samples collected during bottom trawl surveys used in the discriminant analysis of morphometric characters.

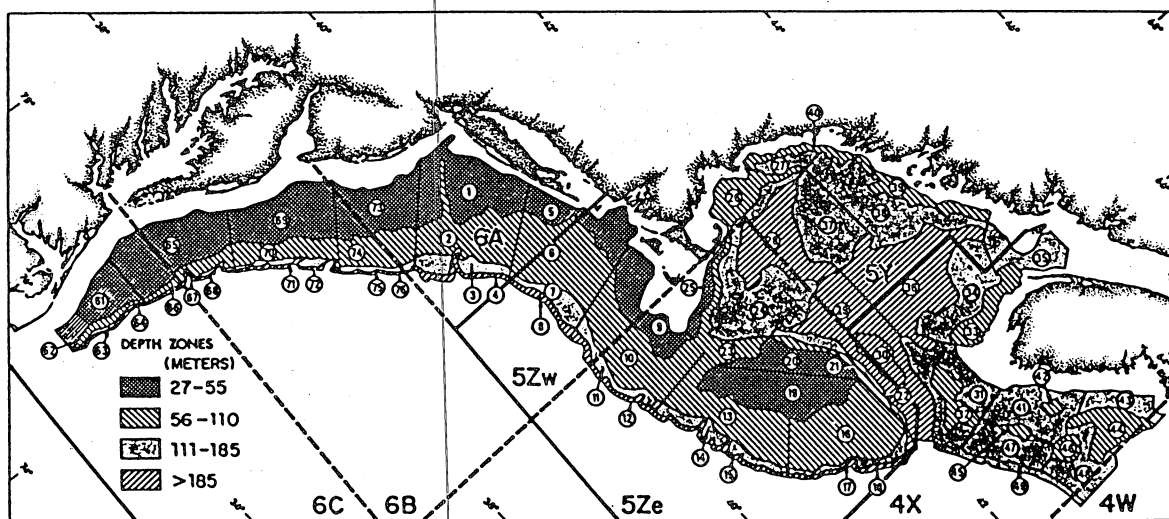


Figure 4. Bottom trawl survey sampling strata in NAFO Subareas 5 and 6.

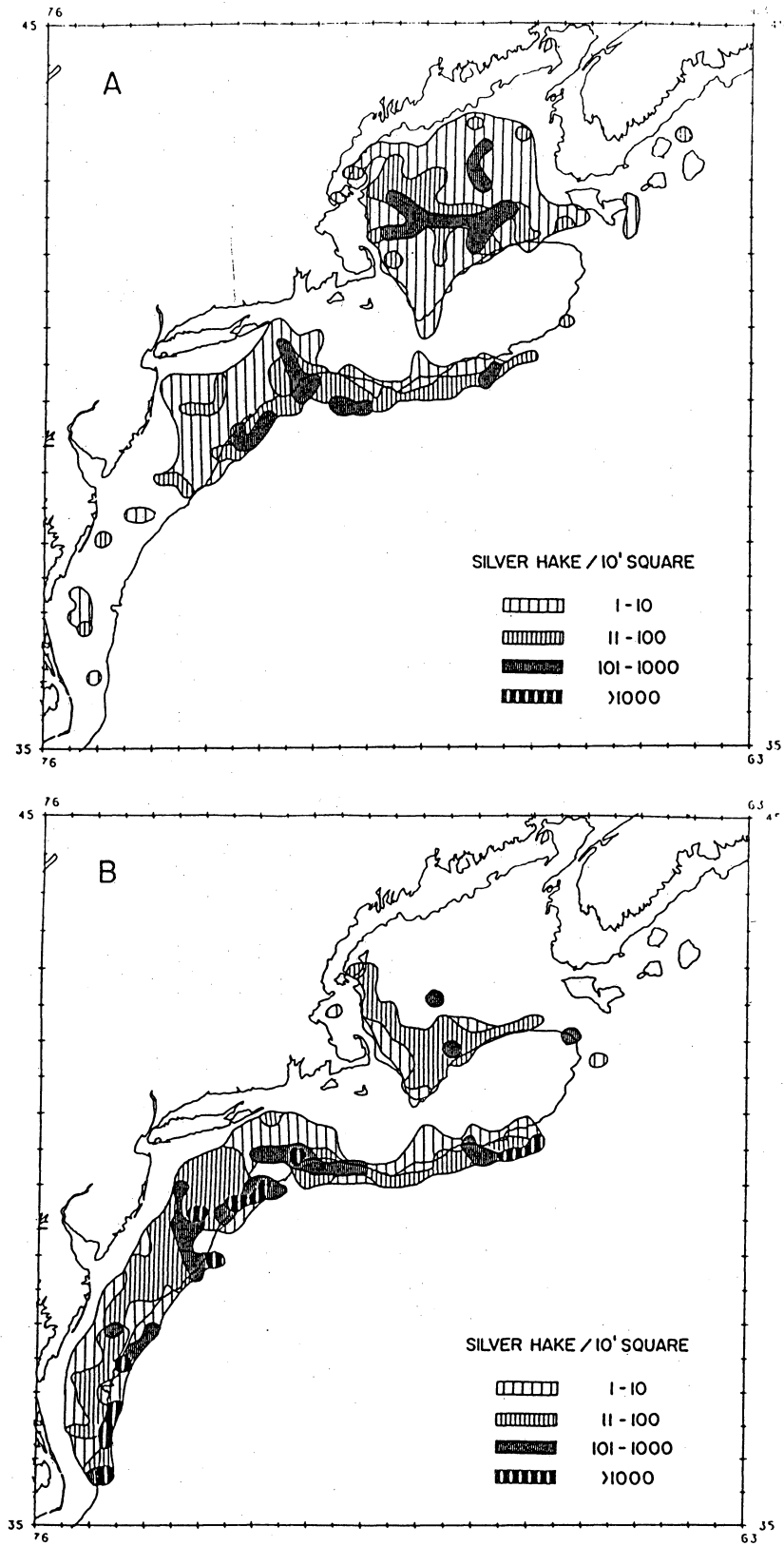


Figure 5. Distribution of adults silver hake (numbers) from USA (A) and foreign (B) bottom trawl surveys during the winter, 1964-1981.

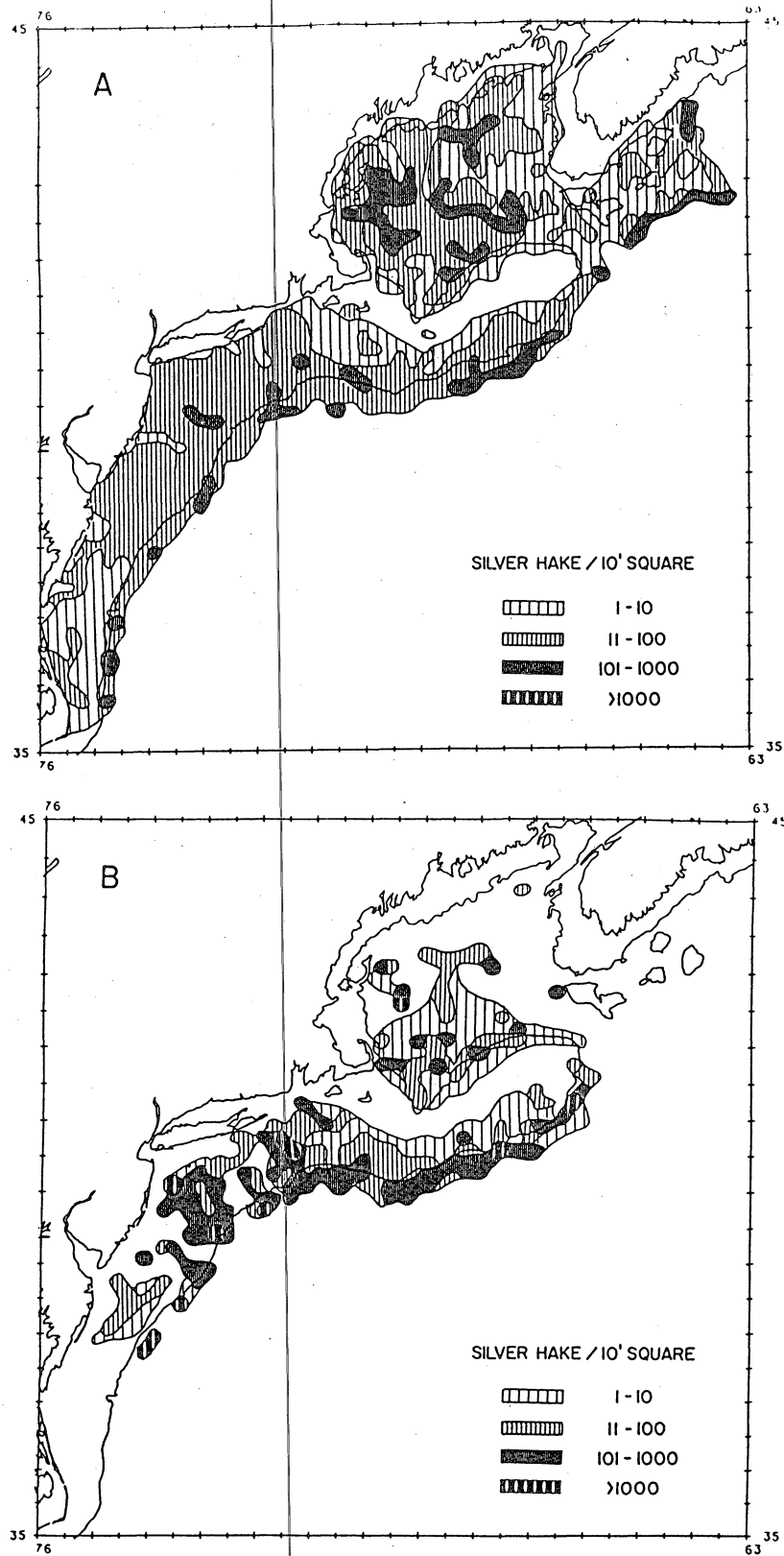


Figure 6. Distribution of adult silver hake (numbers) from USA (A) and foreign (B) bottom trawl surveys during the spring, 1968-1981.

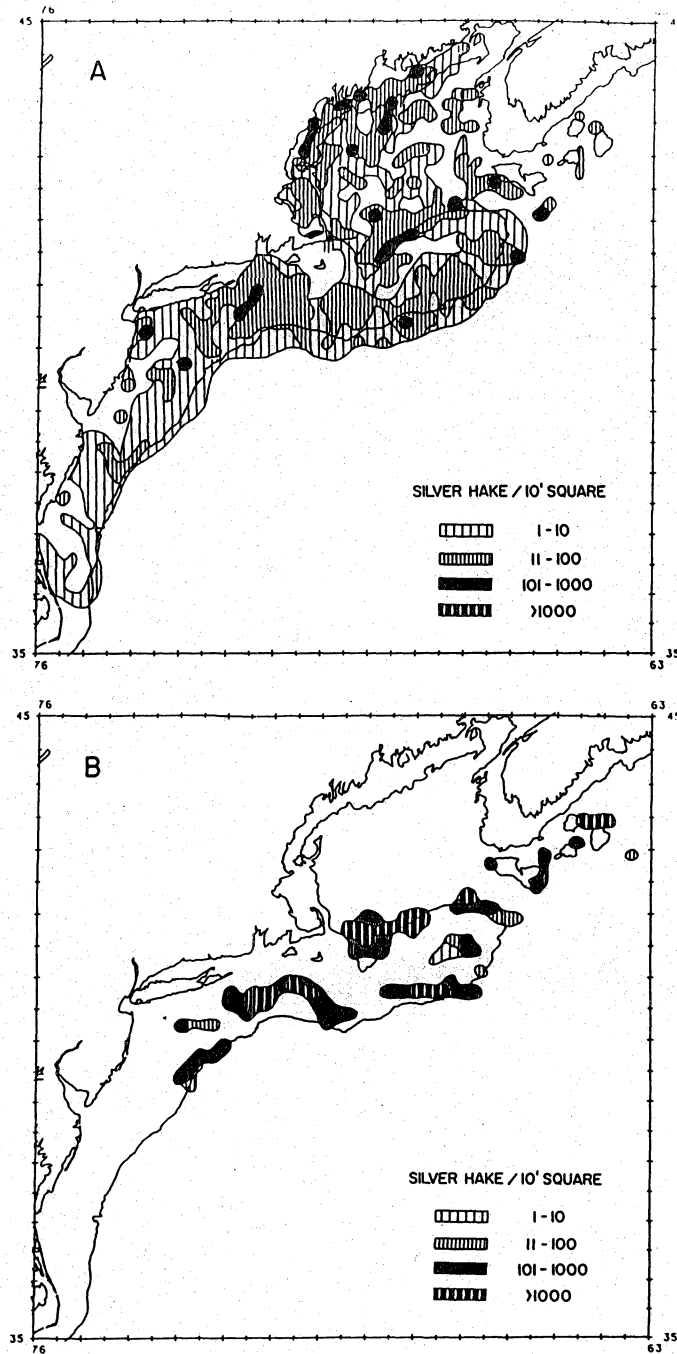


Figure 7. Distribution of adult silver hake (numbers) from USA (A) and foreign (B) bottom trawl surveys during the summer, 1963-1981.

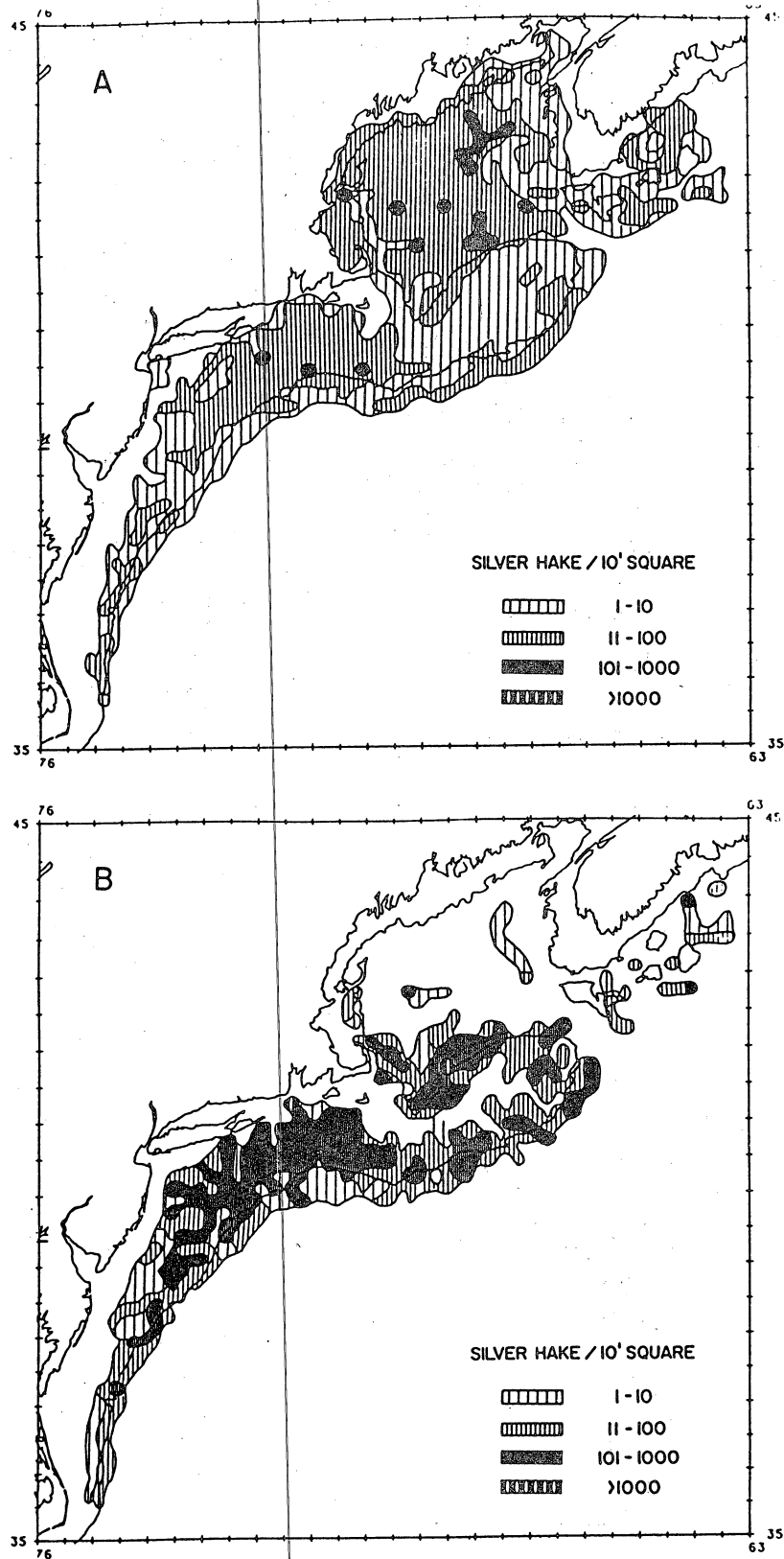


Figure 8. Distribution of adult silver hake (numbers) from USA (A) and foreign (B) bottom trawl surveys during the autumn, 1963-1980.

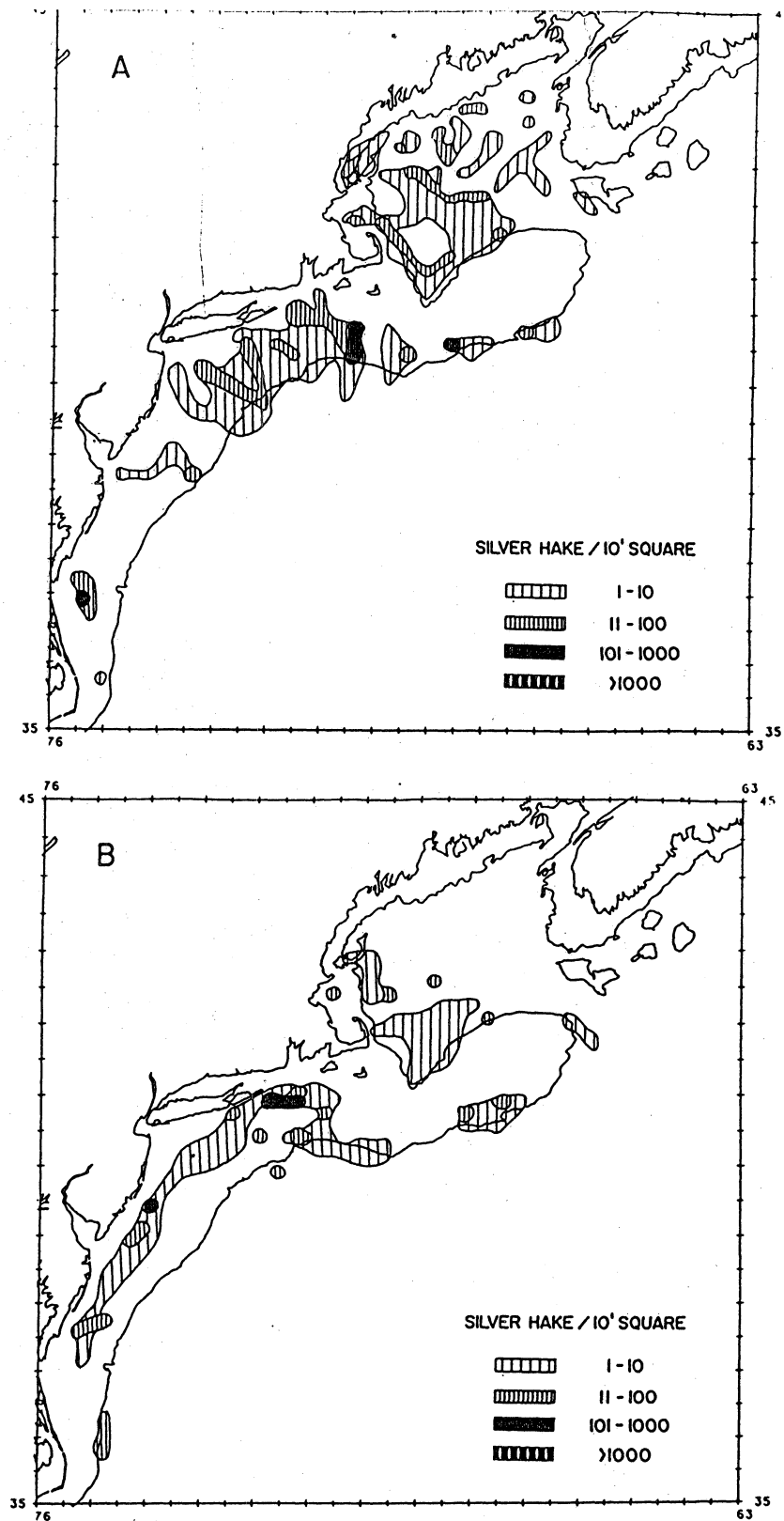


Figure 9. Distribution of prerecruit silver hake (numbers) from USA (A) and foreign (B) bottom trawl surveys during the winter, 1964-1981.

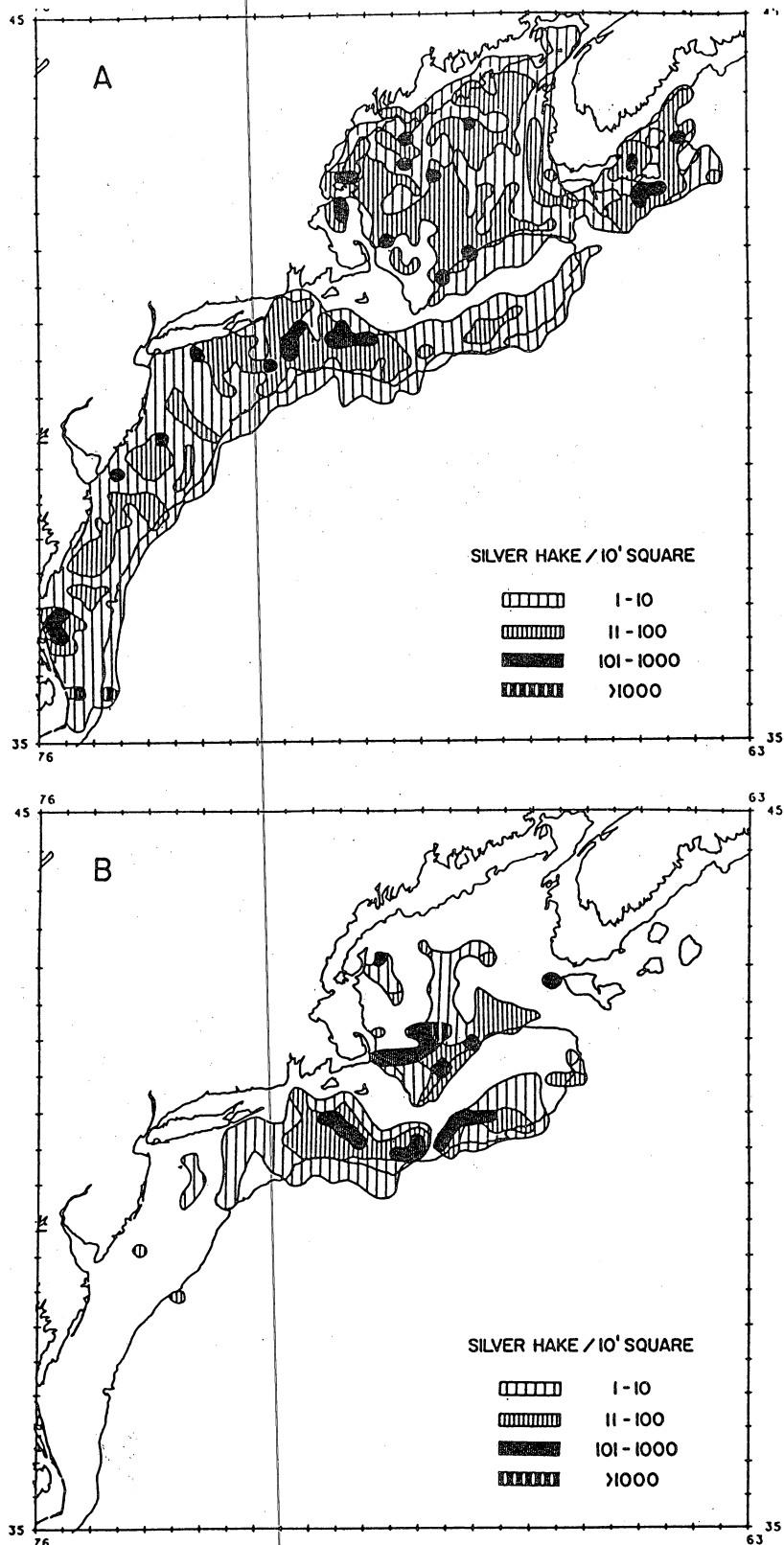


Figure 10. Distribution of prerecruit silver hake (numbers) from USA (A) and foreign (B) bottom trawl surveys during the spring, 1968-1981.

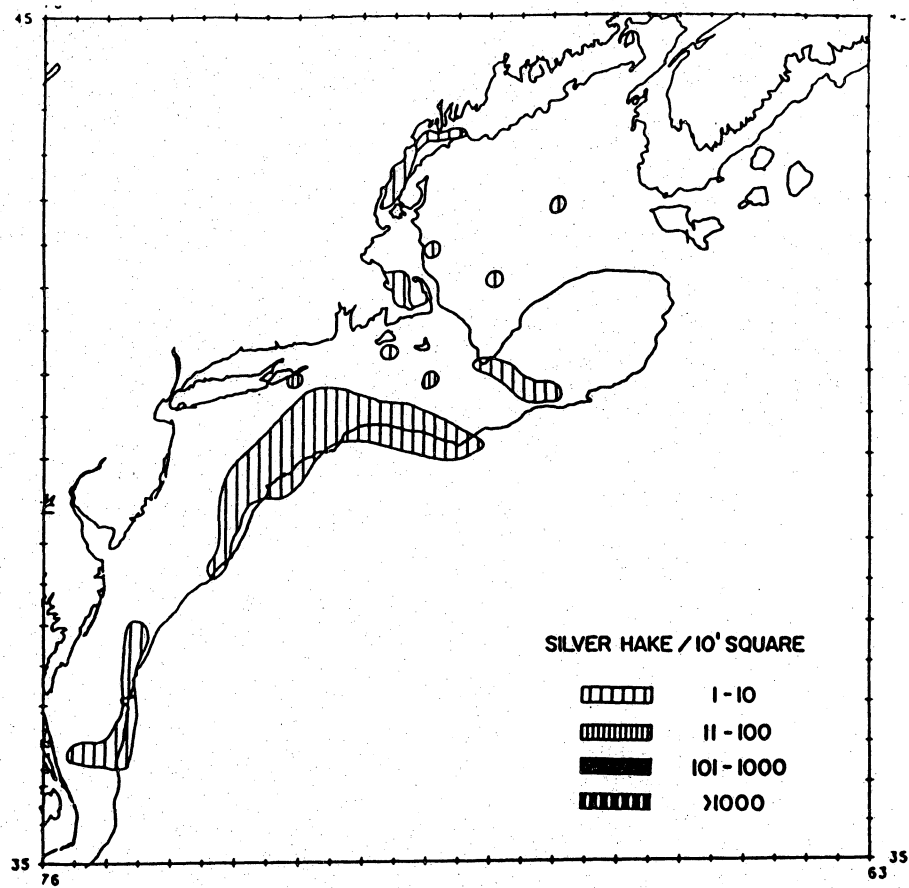


Figure 11. Distribution of prerecruit silver hake (numbers) from USA bottom trawl surveys during the summer, 1963-1981. Data from foreign surveys was not available.

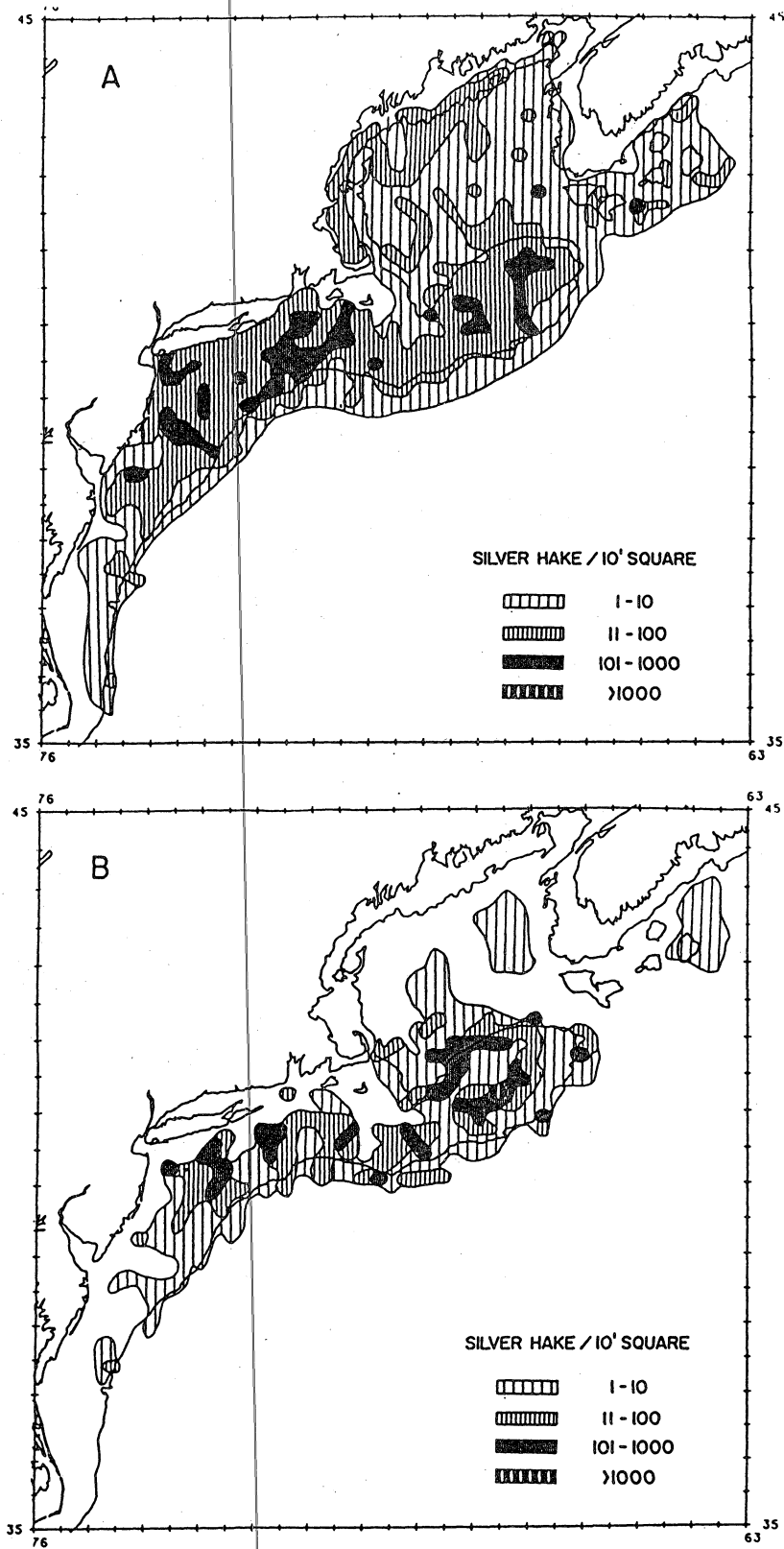


Figure 12. Distribution of prerecruit silver hake (numbers) from USA (A) and foreign (B) bottom trawl surveys during the autumn, 1963-1980.

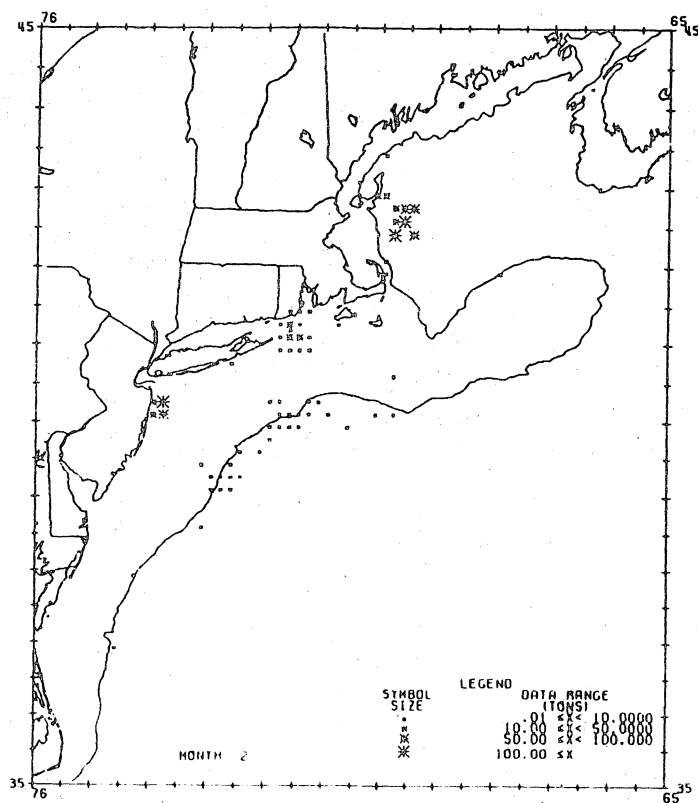
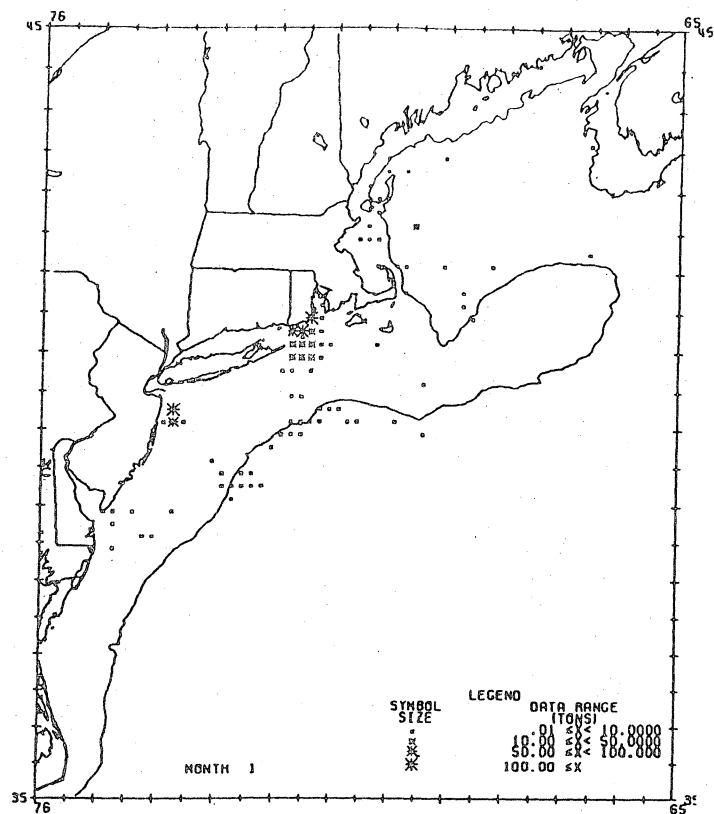


Figure 13. Distribution of silver hake catches (tons) from the USA commercial fishery during January-February, 1965-1980.

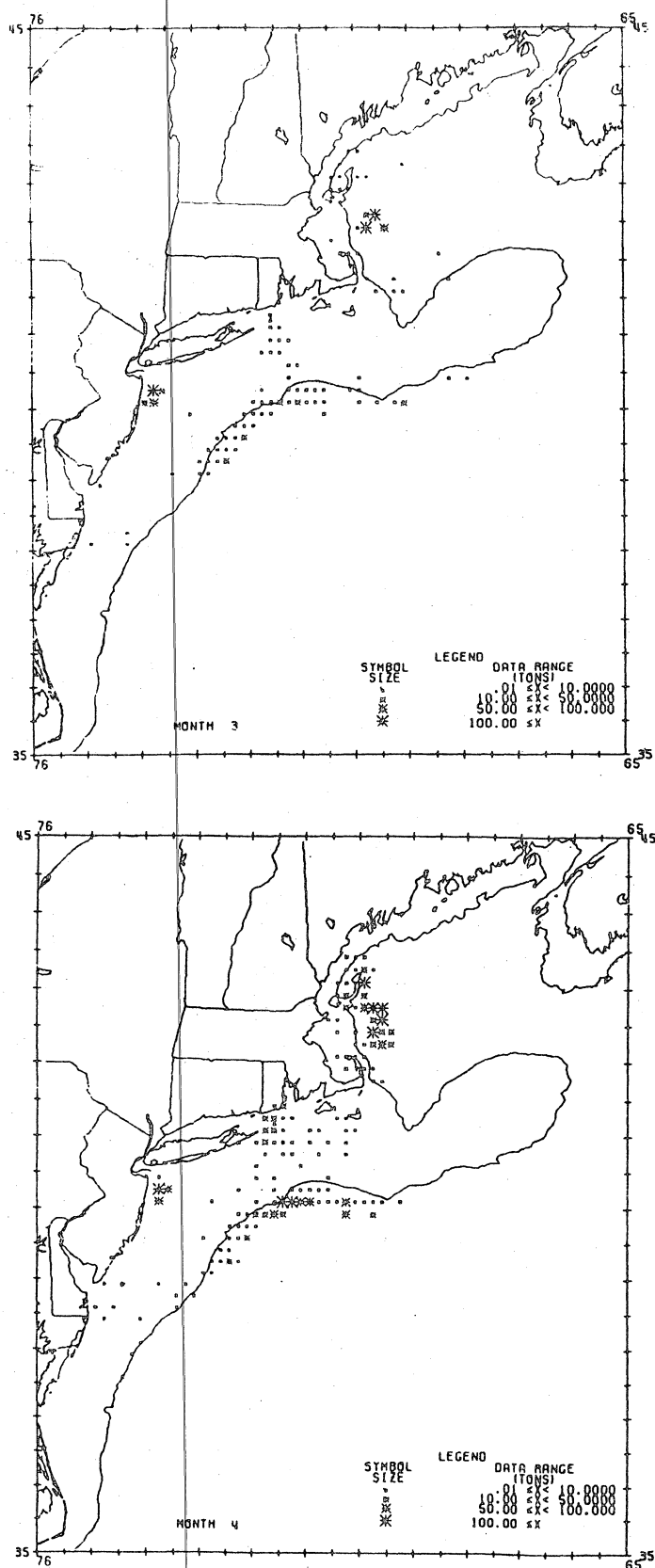


Figure 14. Distribution of silver hake catches (tons) from the USA commercial fishery during March-April, 1965-1980.

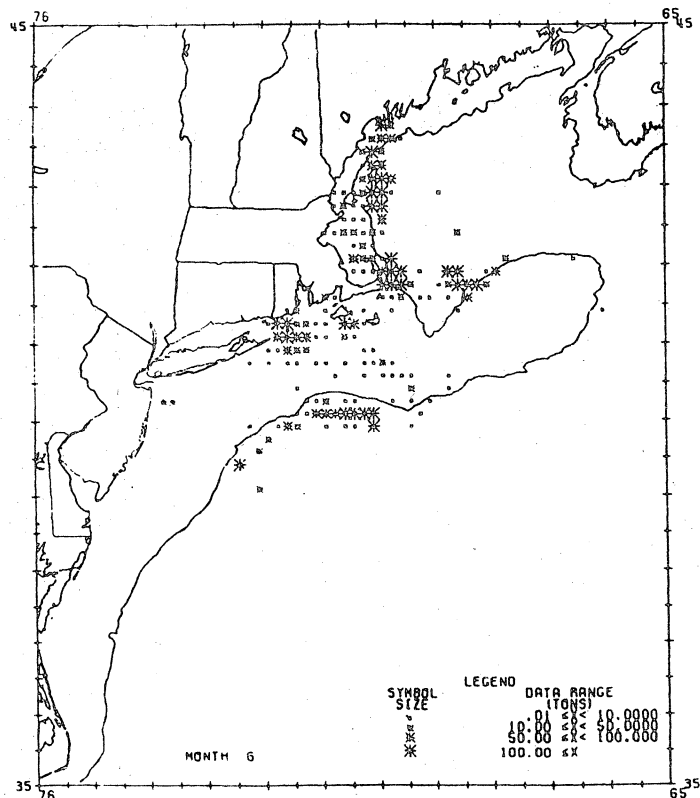
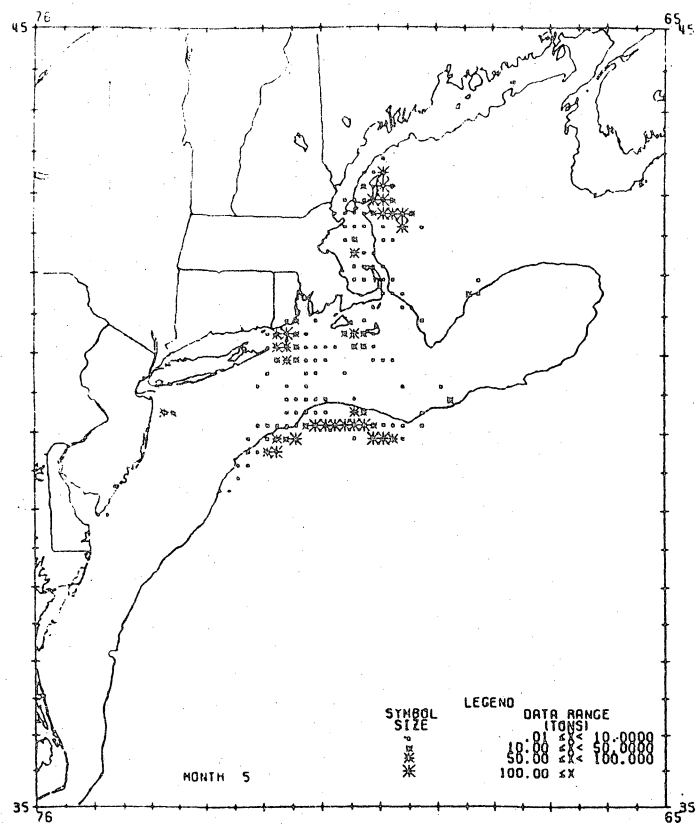


Figure 15. Distribution of silver hake catches (tons) from the USA commercial fishery during May-June, 1965-1980.

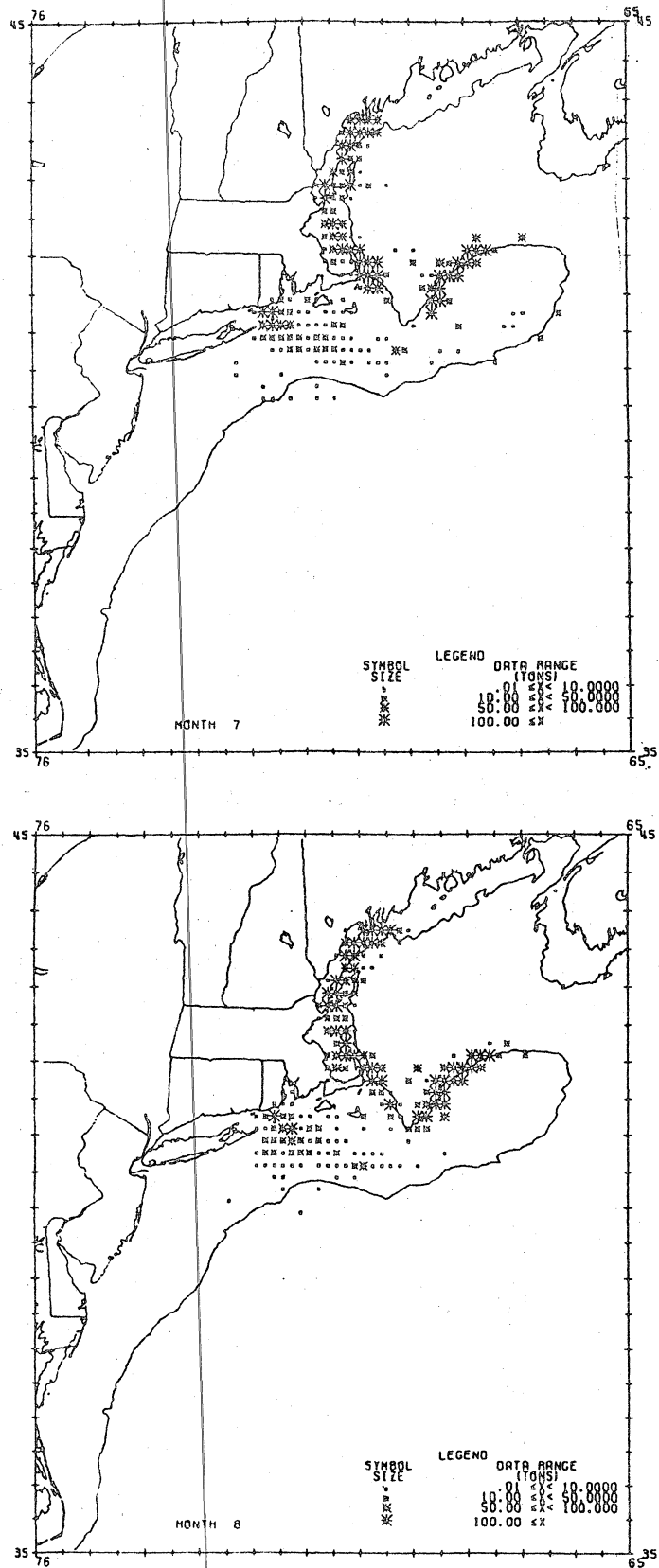


Figure 16. Distribution of silver hake catches (tons) from the USA commercial fishery during July-August, 1965-1980.

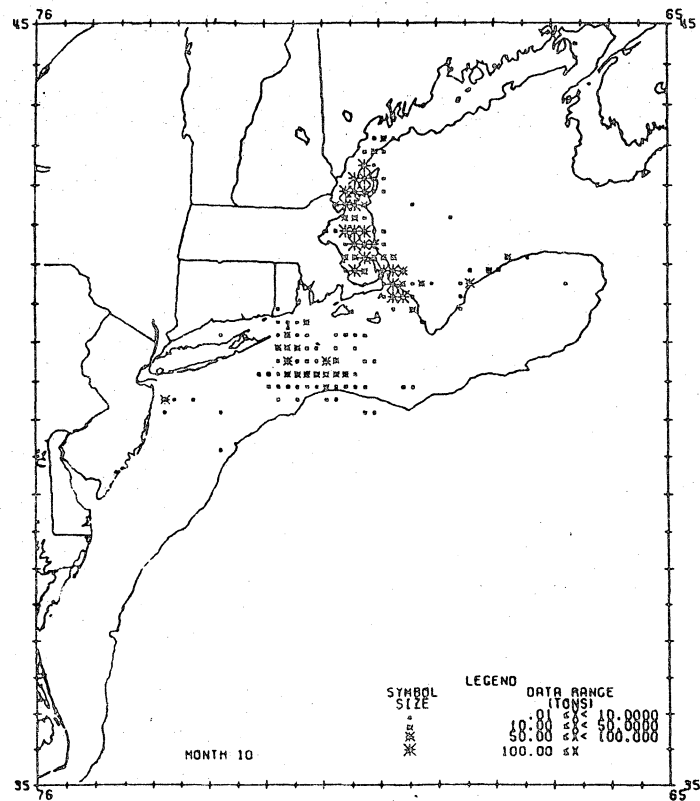
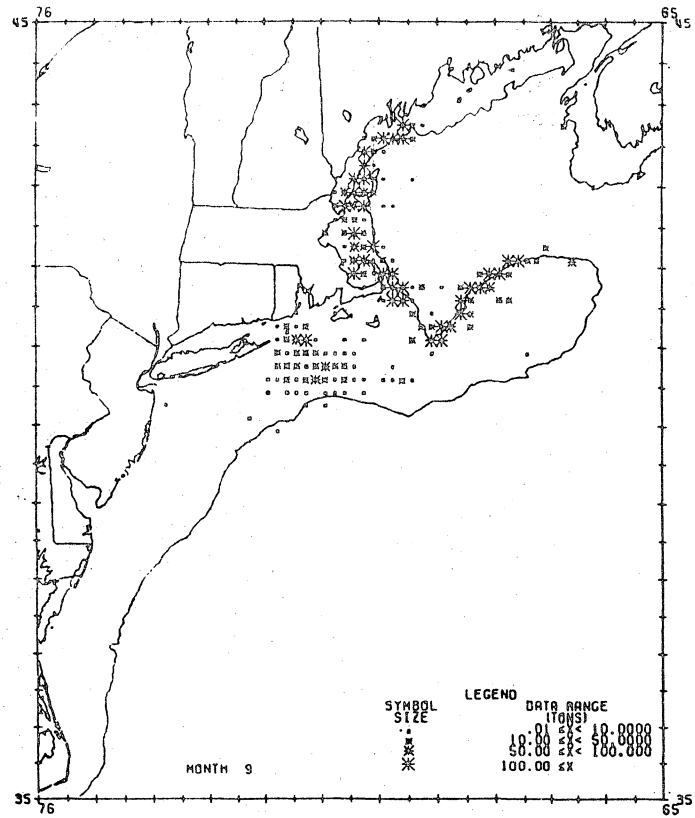


Figure 17. Distribution of silver hake catches (tons) from the USA commercial fishery during September-October, 1965-1980.

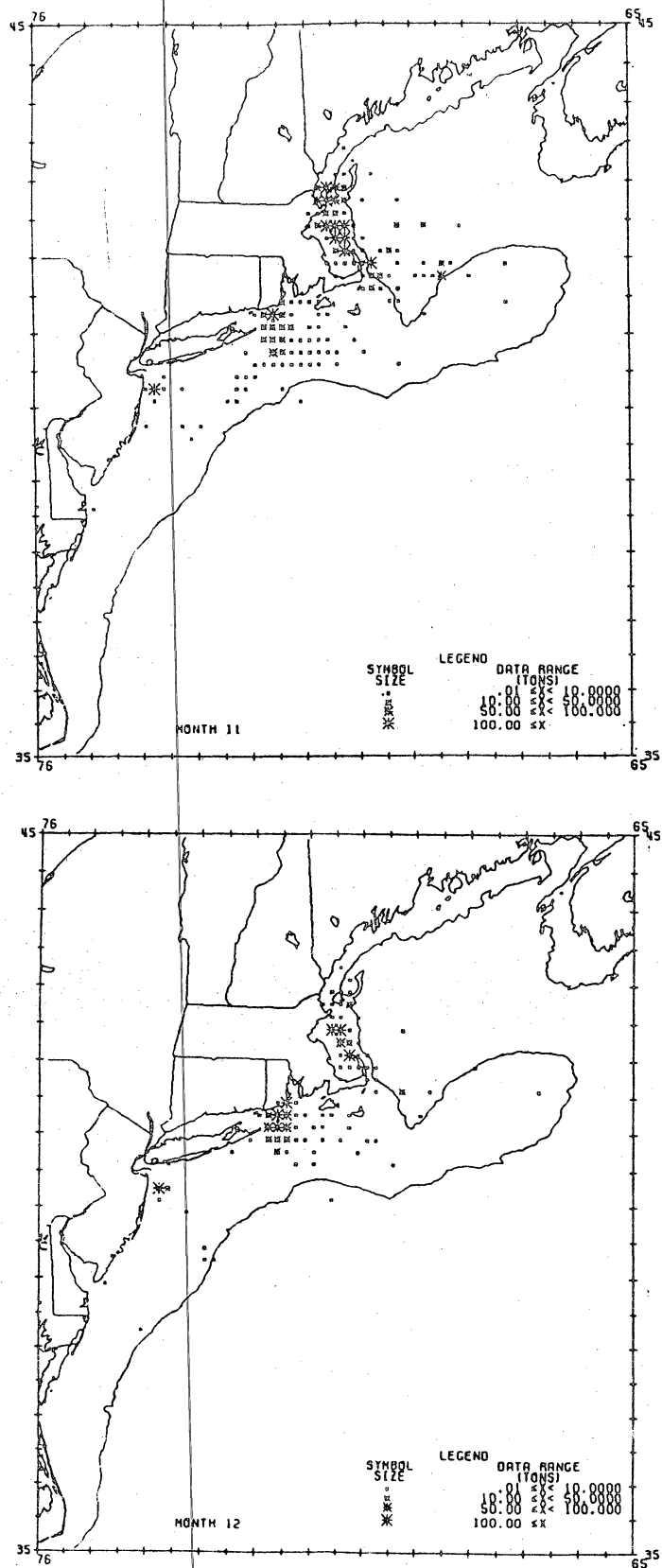


Figure 18. Distribution of silver hake catches (tons) from the USA commercial fishery during November-December, 1965-1980.

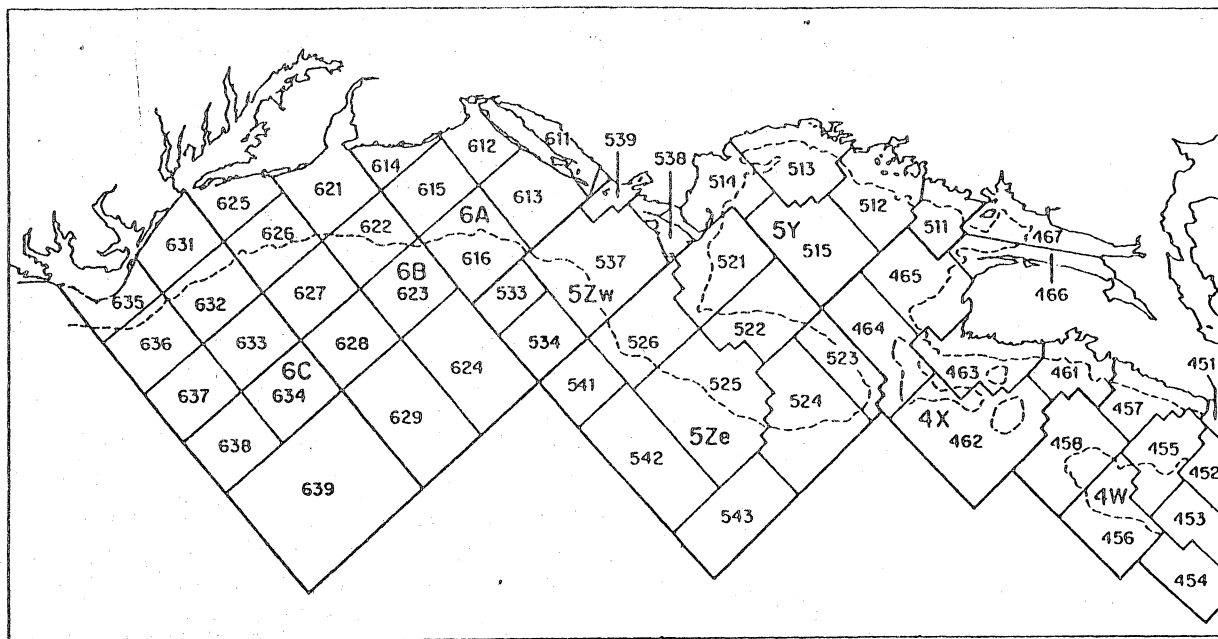


Figure 19. Sampling areas used in reporting silver hake catches in NAFO Subareas 5 and 6.