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REPORT OF THE SWORDFISH ASSESSMENT WORKSHOP

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SUMMARY

The Northwest Atlantic Swordfish Resource was assessed in April, 1985, at a National Marine Fisheries Service-sponsored Stock Assessment Workshop in Miami, Florida USA. Attendees included fisheries scientists from the Gulf, South Atlantic, and Mid-Atlantic Fishery Management Councils, the University of Miami, and the Miami and Woods Hole NMFS Laboratories. Other Workshop scientists included the ICCAT Assistant Executive Secretary, Peter Miyake; John Pope of the Directorate of Fisheries Research in Lowestoft, England, and the USA ICCAT Advisory Panel Chairman, Gordon Broadhead. All findings represent a general consensus of opinion by participating scientists.

The population dynamics were estimated by least-squares procedures that employ all available data. The results indicate that the adult stock (number of fish that are 130 lb and larger dressed weight, age 5 and older) decreased about 40 percent from 1978 to 1984, then increased from 1984 to 1986. The January 1, 1986, adult stock is estimated to be within 75 percent of the 1978 level. Juvenile abundance is estimated to have remained relatively stable from 1978 to 1982 and is estimated to have increased each year since. Stock biomass (total live weight) decreased about 30 percent from 1978 to 1982 and then increased to about the 1978 level by 1985. Catches exceeded stock growth (surplus production) during 1978-80, but the 1981 stock growth was approximately equal to the catch. Stock growth apparently exceeded yields since 1982, so the biomass has increased every year since then and seems to be continuing to increase under current fishing mortality levels. Theoretical simulations show that the maximum equilibrium yield per recruit is about 20 percent higher than that obtainable with the 1985 fishing mortality rate; the current rate is estimated at 0.37 and the theoretical maximum occurs at a fishing mortality rate of 0.14. These theoretical yield-per-recruit simulations do not model the current state of the stock. Fishing mortality rates and recruitment abundances have not been constant through time therefore, the yield per recruit currently realized in the fishery is not known.

RESUME

Les ressources en espadon de l'Atlantique nord-ouest ont été évaluées en avril 1985 lors de journées d'étude sur l'évaluation des stocks organisées à Miami par le "National Marine Fisheries Service. Les participants comprenaient des scientifiques des conseils de gestion des pêches du golfe du Mexique, de l'Atlantique sud et de l'Atlantique central, de l'université de Miami et des laboratoires de Miami et Woods Hole du NMFS. Assistaient également le Secrétaire exécutif adjoint de l'ICCAT, P.M. Miyake, J. Pope du "Directorate of Fisheries Research" de Lowestoft, Royaume-Uni, et G. Broadhead, président du "USA ICCAT Advisory Panel". Les conclusion illustrent toutes un concensus général d'opinions de la part des scientifiques présents.

La dynamique des populations a été estimée par la méthode des moindres carrés qui utilise toutes les données disponibles. Les résultats indiquent que le stock adulte (nombre de poisson d'un poids manipulé de 130 livres ou plus, d'âge 5 et au-dessus) a baissé d'environ 40 % entre 1978 et 1984, puis s'est accru entre 1984 et 1986. Au 1er janvier 1986, le stock est estimé être environ 75 % du niveau de 1978. L'abondance en juvéniles est estimée être demeurée relativement stable de 1978 à 1982, puis s'être accrue par la suite jusqu'à des niveaux considérablement supérieurs à celui de 1978. L'abondance des cohortes recrutées a été stable de 1978 à 1982, et est estimée s'être accrue depuis d'année en année. La biomasse du stock (poids vif total) a diminué d'environ 30 % entre 1978 et 1982, mais était remontée en 1985 presque au niveau de 1978. Les prises ont dépassé la croissance du stock (production excédentaire) en 1978-80, mais cette croissance était en 1981 à peu près égale à la prise. La croissance du stock dépasse apparemment la production depuis 1982, si bien que la biomasse s'accroît depuis lors d'année en année et semble poursuivre cet accroissement avec les niveaux actuels de mortalité par pêche. Des simulations théoriques montrent que la production maximale équilibrée est d'environ 20 % supérieure à celle qui peut être obtenue avec le taux de mortalité par pêche de 1985; le taux actuel est estimé à 0.37, et le maximum théorique se situe à un taux de mortalité par pêche de 0.14. Ces simulations théoriques de la production par recrue n'illustrent pas l'état actuel du stock. Le taux de mortalité par pêche et l'abondance du recrutement n'ont pas été constants dans le temps, et la production par recue actuelle de la pêcherie n'est donc pas connue.

RESUMEN

El Recurso de Pez espada en el Atlántico Noroeste fue evaluado en abril de 1985, en unas Jornadas de Evaluación de las Poblaciones, en Miami, Florida, EE.UU., patrocinadas por el "National Marine Fisheries Service". Entre los asistentes se contaban científicos de los Consejos de Ordenación de Pesquerías del Golfo, Atlántico Sur y Atlántico Central, Universidad de Miami y los Laboratorios de la NMFS de Miami y Woods Hole. Asistieron a las Jornadas, entre otros científicos, el Secretario Ejecutivo Adjunto de ICCAT, Peter Miyake, John Pope, del "Directorate of Fisheries Research in Lowestoft", Inglaterra, y el presidente del Comité de Asesoramiento de ICCAT, Gordon Broadhead, de Estados Unidos. Todos los logros reseñados representan un acuerdo general de opinión entre los científicos participantes.

La dinámica de poblaciones se calculó por procedimientos de cuadrados mínimos, que emplean todos los datos disponibles. Los resultados indican que la población adulta (número de peces de 130 lb y mayores, peso eviscerado, edades 5 y más) han disminuído en un 40% desde 1978 a 1984, aumentando desde ese año hasta 1986. Al primero de enero de 1986, se calculó que la población estaba comprendida en el 75% del nivel de 1978. Se estima que la abundancia de juveniles ha permanecido relativamente estable desde 1978 a 1982 y haber aumentado a partir de ahí a niveles considerablemente más altos que el nivel de 1978. La abundancia de cohortes reclutadas fue estable desde 1978 a 1982 y se calcula que ha aumentado cada año desde entonces. La biomassa de la población (peso en vivo total) descendió aproximadamente un 30% desde 1978 a 1982 y aumentó a aproximadamente el nivel de 1978 antes de 1985. Las capturas sobrepasaron el crecimiento de la población (producción excedente) durante 1978-80, pero en 1981 el crecimiento de la población fue aproximadamente igual a la captura. El crecimiento de la población, aparentemente, excedió los rendimientos desde 1982, y por tanto, la biomasa se ha incrementado cada año desde entonces, y parece continuar incrementándse bajo los niveles actuales de mortalidad por pesca.

Las simulaciones teóricas muestran que el equilibrio máximo de rendimiento por recluta es aproximadamente el 20% más alto que el que se obtendría con la tasa de mortalidad por pesca de 1985; la tasa actual se calcula en un 0.37 y el máximo teórico tiene lugar con una tasa de mortalidad por pesca de 0.14. Estas simulaciones teóricas de rendimiento por recluta no constituyen una pauta de la situación actual de la población. Las tasas de mortalidd por pesca y abundancia del reclutamiento no han sido constantes a lo largo del tiempo, y, por tanto, se desconoce el rendimiento por recluta que tiene lugar actualmente en la pesquería.

1. OPENING OF THE MEETING

The Miami Laboratory Swordfish Workshop was held by the National Marine Fisheries Service at the Miami Laboratory during April 16-26, 1986. Mike Parrack served as Chairman. Walter Nelson, Miami Laboratory Director, welcomed the participants (Appendix 1). The Chairman discussed guidelines for the Workshop and the Agenda. The primary objective of the Workshop was to assess the status of the Northwest Atlantic swordfish resource. It was stated by the Chairman that all calculations required in the assessment would be carried out by the participants during the meeting. Two computer mainframes would be available to the participants, a Burroughs 7800 and a 6800, as well as two IBM PC's. The participant suggesting that a particular calculation was needed would be responsible for generating the calculation. The participants adopted the Agenda that was circulated in advance, with the addition of one item, a history of the Northwest Atlantic fishery.

2. HISTORY OF THE SWORDFISH FISHERY IN THE NORTHWEST ATLANTIC

Cuba, Tiawan, and Korea report Northwest Atlantic swordfish catches as well as Japan, the USA, and Canada. Tiawanese longline vessels fished in the Atlantic since 1962, however, the species composition of that billfish catch is not reported before 1973. Korean longline vessels entered the Atlantic in 1962 but did not report swordfish catches until 1975.

North American Fleet Prior to 1962, swordfish were harvested by a seasonal Canadian and United States harpoon fishery off New England and Nova Scotia. In the early 1960's, longlining quickly became the dominant harvesting method. Landings increased dramatically from 1960 to 1963, declined, and then stabilized through 1970. During this period, the fishery expanded both to the south and to the east so that by 1969 a year-round fishery exploited most one degree squares along the edge of the shelf and the north wall of the Gulf Stream from Cape Hatteras (35°N, 74°W) to the Grand Banks and Flemish Cap (46°N, 45°W).

In 1970, the United States Food and Drug Administration (FDA) instituted regulations prohibiting the interstate transportation and importation of swordfish which contained mercury in excess of 0.5 ppm. These restrictions went into place as commercial fishing expanded into the Gulf of Mexico. Although the regulations substantially reduced the US and Canadian effort, an "underground" fishery developed and a portion of the catch was not reported. By the mid-1970's a new fishery had developed, primarily in southern Florida.

In 1978, the FDA increased the allowable level of mercury to 1.0 ppm. This occurred with the exploitation of a high concentration of swordfish off the Atlantic coast of Florida. A dramatic increase in the number of vessels participating in the U.S fishery followed. Many of those vessels were based in southern states, especially Florida, Texas, and South Carolina. The fishermen experimented with extensive gear modifications adapting some Cuban creole drift line techniques Major changes included a switch from tarred nylon mainlines and branch lines to complete monofilament construction, increased hook spacing, increased gangion and float line lengths, and the use of chemical light sticks ("Cyalume"* lights) with each bait.

Most of the reported landings were caught with traditional New England-style gear from the late 1970's to 1979. Florida-style gear replaced Cuban gear in the Florida Straits by 1979, and its use then spread throughout the Gulf of Mexico, Florida, east coast and the South Atlantic Bight. In 1980-82, the southern vessels extended their fishing range northward into the traditional New England fishing areas beyond Cape Hatteras. Gear experimentation accelerated and the traditional New England gear was replaced by Florida gear. Florida gear has accounted for most of the landings since 1980. Florida gear has been shown to be two to three times as effective as New England gear in a sample of logbooks from vessels fishing in the Florida Straits (Berkeley et al 1981). There are no gear comparison results from north of Cape Hatteras where the water is cooler. It is believed that additional gear changes occurred since 1982, due to increased availability and consequent use of advanced technology and electronics (thermograph and weather fax instrumentation). These changes are not well documented and are not believed to have been dramatic after 1980 as before. They occurred in consort with the expansion of the fishing areas east of the Flemish Cap and the concentration of fishing operations around the time of the full moon.

Until 1980, most of the catch came from northern areas, however, from 1980 on, more than 50% came from southern waters. In the winter of 1984-85, thirteen vessels expanded operations into the Caribbean, and that fleet increased to 35-40 vessels by the following winter. The number of different vessels targeting swordfish that occurred in comprehensive samples of bills of sale decreased after 1983, however, the decrease could be due to a drop in sampling efficiency rather than fleet size.

Japanese Fleet The Japanese longline fishery began in the tropical central Atlantic in 1956. By 1965, the fishery had expanded into the entire Atlantic between 40°N and 40°S latitudes. In the early 1970's the Japanese fleet abandoned the central areas of the north and south Atlantic, concentrating their fishing effort in those regions of the ocean with prominent oceanic currents. These geographic changes probably resulted from targeting bluefin.

3. STOCK STRUCTURE

The workshop addressed stock structure by reviewing mark-recapture data, geographic distribution of swordfish bycatch in the Japanese longline fishery, and geographic distribution of swordfish larvae. Stock structure was addressed from the standpoint of defining a manageable resource, not from the standpoint of establishing absolute geographic bounds on movements of individuals or from the standpoint of genetic isolation.

* Registered trademark, American Cyanimid Company

Mark-Recapture Data Data were examined from 2058 swordfish marked and released in the Northwest Atlantic over a twenty year period (1965-1985) by Canada and the United States. Most marks were applied since 1978 by USA observers aboard Japanese longline vessels and scientists aboard USA research cruises. The tag return rate was about 5% with commercial fishermen reporting all returns. Few fish were tagged in the Gulf of Mexico and the Caribbean Sea. All returns (Figure 1) were from the Northwest Atlantic north of the Caribbean Sea. No tags were returned from the Caribbean Sea, the Brazilian coastal fishery, or East Atlantic coastal Spanish fishery. Although the Japanese longline fleet fished extensively in the central and eastern Atlantic during the past two decades, they did not fish these areas extensively during the period when marked swordfish were available (1978 to present). In contrast, blue sharks marked in the Northwest Atlantic have been routinely recovered from the Eastern Atlantic. This indicates that swordfish in the Northwest Atlantic do not extensively migrate to the east and movement seems to be north-south. Significant fishing effort in the Caribbean did not begin until 1984, thus movement between the Caribbean and the Northwest Atlantic can not be ruled out. The Workshop concluded that the mark-recapture data provides evidence of a distinct Northwestern Atlantic stock.

Longline CPUE The Workshop considered 1957-83 Japanese tuna longline fishery swordfish bycatch as indicative of possible geographical discreteness (Doc 86/3). These plots (Appendix 2) indicate there is not a distinct delineation between stocks in the Atlantic. No clear boundary is evident; these CPUE data are continuous from east to west and north to south. (There is slight indication of separation at 10°N latitude in the West Atlantic). Concentrations of swordfish, however, do occur in some areas. CPUE data from the North American longline fleet indicates that fish are concentrated along the west wall of the Gulf Stream, along the edge of the continental shelf (200M-3000M) near mid-ocean islands, and on sea mounts. Japanese longline swordfish bycatch data indicate that although concentrations occur in continental shelf waters, swordfish are distributed throughout the Atlantic. Therefore, a continuous emmigration from the open Atlantic into areas of concentration is considered possible.

Larval Distribution The Workshop considered the geographical distribution and abundance of swordfish larvae in plankton samples as an indicator of spawning concentrations. Larvae are reported in the Gulf Stream south of Cape Hatteras, the Gulf of Mexico, and the Caribbean Sea (Markle 1974). It was recognized that currents would carry larvae spawned in the Caribbean into the Gulf Stream off the southern USA coast. Concentrations, however, were found at the equator and in the southern hemisphere off Brazil and in the Caribben Sea in an area bounded from 70°W to 85°W longitude and 15°N to 20°N latitude (Nishikawa et al. 1978). Larvae were found throughout all months although peak abundance was observed in February (Grall et al. 1983). Apparently a spawning area also exists in the Mediterranean Sea in July, August, and September (Sella 1911, Dicenta 1977, Taning 1955). The Workshop concluded that these data indicate the existence of two separate spawning areas in the North Atlantic, one in the Mediterranean Sea and one in the Caribbean Sea.

Workshop Consensus Available information indicates that: 1) fish are continuously distributed across the Atlantic, 2) trans-Atlantic movement in the North Atlantic probably negligible, 3) north-south movement in the North Atlantic is extensive, and 4) separate spawning areas exist in the Northwest and Northeast Atlantic. The consensus was that these findings support the working hypothesis of a separate Northwest Atlantic stock north of 10°N latitude and west of 35°W longitude that spawns during winter in the Caribbean Sea. The Workshop, however, recognized that the existence of a single Atlantic wide stock was possible.

4. GROWTH

The Workshop considered three sources of information: 1) direct observations of growth from mark-recapture data, 2) age interpreted from growth marks on anal spine cross sections ("hardparts"), and 3) modes in size-frequency samples from catches. After considering the characteristics and usefulness of the three data sources, the participants sought a method of calculating age from size to establish the age distribution of catches. Here, the Workshop concluded that since frequency samples from the catches were in dressed weight (not length) and the length-weight conversions varied appreciable, growth in terms of dressed weight was most germane rather than growth in length.

Mark-Recapture Observations The Workshop Document 86/2 reviewed mark-recapture observations where both weight at release and recapture were recorded as well as both release and recapture dates (Table 1). The Workshop noted that these data would support least square fits of various growth models (Doc. 86/2). There were only sixty-six observations available, and these came from three sources: 1) NMFS Miami Laboratory, 2) NMFS Narragansett Laboratory (courtesy of Jack Casey), and 3) Canadian Department of Fisheries and Oceans, St. Andrews, New Brunswick. Sex was not recorded. Release and recapture size was recorded in terms of total weight and converted to dressed weight using the ratio 0.755:1.0. Release weights were visual estimates made while the fish were in the water; the fish were not actually weighted. These visual estimates might have over-estimated release size, in some cases perhaps to a large degree due to refraction (Williams 1970). It was pointed out, however, that most estimates were made by experienced observers, fishermen, and scientists, hence the average bias may be small. The simple annual growth rate ranged from -398 to 1251 pounds dress weight per year. Fish were at large from a few days to 15 years.

The Workshop discussed 1) which observations to exclude from the analysis and 2) which growth model was most appropriate. The uncertainty in these data suggests that some of these observations were likely unreliable enough to warrant exclusion. The exact criteria for identifying which points to exclude was subject of considerable discussion. A plot of the growth increment on time at large (Figure 2) identified five specific data points for possible exclusion; several other graphic displays of growth rates indicated the same five points were outliers. The Workshop noted that excluding these observations resulted in marked changes in the least squares estimate of the von Bertalanffy growth parameters and reductions in mean square error. Other schemes were considered that excluded short times at large. These approaches resulted in parameter estimates and mean square errors that were similar to those obtained by eliminating the 5 points identified. The Workshop agreed that the best procedure was to exclude the five identified points.

The Workshop then considered the growth of small fish that were at large for short periods. The observed growth of small fish was noted to be slower than for larger fish, hence it was agreed that the Gompertz model was the most appropriate equation. Consideration was also given to the statistical form of the model. Here, concern was expressed as to the nature of the error distribution. First, since it was recognized that the measures of release size were likely biased, an estimate of the magnitude of bias in release size was made via least squares techniques (i.e., a bias term was simply included within the model). These estimates indicated that the magnitude of bias was small, 10 percent or less, and thus need not be considered further. Second, since the error distribution was unknown, it was decided that multiplicative log normal error should be assumed. The resulting model contained three parameters but only two could be estimated from mark-recapture data. The third parameter was calculated directly after defining fish of three pounds dressed weight to be zero age (birth). The other two parameters were estimated via least squares (Figure 3).

Hardpart Observations The Workshop reviewed the data collected by Berkeley and Houde (1983). Steve Berkeley provided the original data for Workshop review. These data included the date the sample was taken (i.e., when the fish was killed), the fork length and sex of the fish, and the distance from the center of the anal spine to each major circuli and to the edge. Marginal increment ratios calculated from these data did not indicate that the major circuli were annual (Doc. 86/5). Plots of marginal increments by month sampled (Doc. 86/4) showed a random time of major circuli formation and did not support the assumption that the formation of marks is an annual phenomena. That was corroborated by the original investigation (Berkeley and Houde 1983). Thus, there was no evidence that these hardpart readings could be used to determine the age of Northwest Atlantic swordfish. Some participants, however, felt that until it could be proven beyond doubt that these major circuli were not annual marks, they should be given further consideration because they indicated a growth rate similiar to that from the mark-recapture data which is also weak data. With this in mind, sexual dimorphic growth was examined. Plots of growth from the hardpart data for each sex separately (Doc. 86/4) were overlayed and compared. They did not show evidence of a difference between sexes. Size specific samples, by sex, however, show that fish greater than 150 pounds (dressed weight) tended to be females and that males greater than 230 pounds are very rare (Doc. 86/10). The Workshop noted that this was either the result of differential mortality or differential growth between sexes and that the latter seemed more likely. The Workshop concluded that a growth curve for the sexes combined was sufficient since: 1) evidence of sexual dimorphoric growth was not demonstrated, 2) most of the catch was of fish less than 150 pounds where both sexes seemed to occur equally, and 3) that larger fish tended to be almost all females so that a single growth function fit to a random sample of combined sexes would correctly describe the growth of the entire population and thus could estimate the age structure of the catch acceptably well.

With all of the above decisions in mind, it was agreed to first convert the hardpart observations from length to dressed weight via conversions defined in Document 86/11, then fit the Gompertz equation to those data combined over sex. The resulting model is:

dressed weight (lbs) =450 * .035 ** (.85 ** t).

Modal Analysis of Size Frequency Samples The method of Shepherd (1985) was applied to weight frequency samples. The method employs a non-least squares goodnes of fit measure to establish an asymptotic size by K surface for the von Bertalanffy function. The measure is designed to take account of data in proportion to its quantity and likely reliability without pre-processing, and not to be unduly sensitive to possible spurious modes created by sampling noise. The technique maps this measure over the feasible range of parameter values thus allowing the investigator to choose the most appropriate parameter set in light of this surface of goodness of fit measures. The method did not yield usable information when applied to available size frequency samples in that it did not indicate which of numerous parameter sets were superior.

Consensus The possibility that the mark-recapture data and the hardpart data reflected the same growth rate was considered. This hypothesis was investigated by establishing .999 approximate joint confidence contours on the two parameters that establish the shape of the Gompertz curve for each data set. The confidence regions did not overlap, thus at the approximate .999 probability level the two data sets reflected different growth rates. In summary: 1) the mark-recapture data contained observation and transcription errors, however, it provided direct observations of growth; 2) major circuli on hardparts could not be validated as annuli either from marginal increment analysis or from compatability with mark-recapture observations. The workshop consensus was that the mark-recapture data provided the best basis for estimating growth and establishing the age distribution of catches with the information available at this time. It is a consensus that the current level of knowledge of swordfish growth, particularly of larger fish, is very meager and thus places an additional degree of uncertainty on analysis results.

5. CATCHES AND SIZE FREQUENCY SAMPLES

Historic swordfish landings, by area and date of capture, and size frequency samples are fragmented and of variable quality. The participants recognized these limitations and applied a variety of techniques (adjustments, substitutions, and additions) in an attempt to construct a useful catch-at-age table for the period 1978-85. The group agreed that the final products were an improvement over previous attempts, however, the resulting quality is not such that analysis results are without significant uncertainty; further work to improve these basic data is needed.

Reported Landings Catches of swordfish north of 10°N and west of 35°W are taken by USA longline, gillnet, and harpoon vessels, Canadian longline and harpoon vessels, and Japanese, Taiwanese, Korea, and Cuban longline fleets (Table 2).

USA landings for 1978-85 were obtained from NMFS Southeast Fisheries Center and from the National Fishery Statistics Program, Washington, DC. These landings were obtained by interviewing all known fish brokers monthly or annually. Brokers are asked for either total monthly landings or total weight landed on each fishing trip. Recorded USA landings during the period 1971-1977 are believed to be extremely inaccurate due to federal laws dealing with the mercury content of the flesh. Landings from Virginia to Maine are incomplete until the summer after the close of the calendar year; landings from North Carolina to Texas are available by the February after the close of the year. Puerto Rico landings began in the winter of 1984, and a comprehensive system to census these landings by the usual procedures did not exist in 1984-85.

A second source of USA domestic landings data was available at the NMFS Miami Laboratory. On a voluntary basis, concerned fish brokers and fishermen sent copies of the actual tally of each fish sold on separate fishing trips to NMFS scientists for research purposes. In some cases these "trip sheets" record the major part, if not the entire, landings at a port-month. This was the only source for Puerto Rican landings for 1984 and 1985.

The Workshop focused on the accuracy of the reported USA landings. In some months reported harpoon landings for New York and Massachusetts were several fold larger than longline landings and this was considered unlikely; these were believed to be miscoded data. In many month-gear-state categories the weight totaled from the trip sheets exceeded the reported landings by rather large amounts. Of the 896 month-gear-state partitions considered, the landings from trip sheets exceeded the reported landings in 103 cases (12%). These differences ranged from 103 to 484,118 pounds dressed weight with an average difference of 23,513 pounds. This comparison underestimated the magnitude of the errors in the reported landings, however, the consensus was that replacement of reported landings by the sum of trip tickets in cases where the latter was larger than the former generally improved the accuracy of the landings data.

The Workshop considered Canadian landings from three sources: ICCAT official statistics, those reported by the Statistics Branch of the Department of Fisheries and Oceans, and those obtained through personal communication with Mr. Peacock* (1978-82) and Mr. Forbes* (1983-85). These sources differed considerably in some years (below). Information was not available to judge the accuracy of the three sources. The major problem was assumed to pertain to the possibility that a portion of the catch may have been double reported in two ways: 1) once reported when caught by the Canadian fishermen and again at the time of importation to the United States, and 2) the possibility that Canadian reported landings included the quantity caught by Canadian vessels and then illegally transferred at sea to U.S. vessels. After considerable discussion, the Workshop decided that if either occurred the net effect on reported landings was small, therefore, ICCAT statistics were used and corrections for transshipments were not made. The month of landing is not known except for 1985 (below), thus these percentages were applied to all years.

Canadian Landings, Mt Whole Weight

	ICCAT		Statistics Dept.		Pers. Comm.
Year	LL	Harp	LL	Harp	Total
1978	2314	0	3053	0	1000
1979	2970	0	2963	7	1000
1980	1794	91	1276	32	1200
1981	542	19	402	41	1000
1982	542	12	869	36	1000
1983	960	128	785	107	960
1984	465	34	465	34	499
1985	-	-	-	-	515

*Employees of the Canadian Dept, of Fisheries and Oceans

June	July	August	September	October	November
1,3%	5.3%	33.1%	32.1%	27.8%	0.4%

Other landings from west of 35°W and north of 10°N taken by Japan, Taiwan, Korea and Cuban longline fleets were obtained from ICCAT statistics. The area and month for these catches were estimated from a sample of log books; the samples range from 30% to 100% for 1978-84. The 1985 catch was assumed to be the same as 1984. Foreign vessels fishing in US waters are required by law to cut off all swordfish. Estimates of these amounts were made from reports of US observers on foreign longline vessels and from vessel logbooks. These estimates were added to the catch obtained from ICCAT.

Magnitude of Discarding at Sea The occurrence of swordfish being discarded at sea was discussed. This activity has never been reported by fishermen nor by observers aboard USA vessels. Those familiar with the USA fishery indicated that, due to the value of all swordfish regardless of size, discarding was very limited. The consensus was that discarding was not occurring on North American vessels.

Size Samples From Catches The Workshop reviewed the number of fish measured by each nation each year from catches taken north of 1ØºN and west of 35ºW (below). Only USA catches were sufficiently sampled; most catches of other

			Numbers of Fish Measured			
Year	USA	Canada	Japan	Taiwan	Korea	Cuba
1978	8727	-	65	-	-	-
1979	26227		65	-	-	-
198Ø	413Ø4	-	192	49	-	-
1981	34759	-	59	19	-	-
1982	511ØØ	-	145	-	-	-
1983	5328Ø	-	142	38	-	-
1984	55353	111	-	-	-	297
1985	4823Ø	-	-	-	-	-

countries were not sampled at all. The USA size samples were bills of sale and these contain the dressed weight of each swordfish landed on a fishing trip. The gear used, port of landing, fishing location, and month is also included.

Availability of Sex Ratio Samples The Workshop reviewed all observations of size-sex-date-location of swordfish in the Northwest Atlantic (Doc. 86/1Ø) and concluded these data indicated no difference from a 1.1 sex ratio throughout the Northwest Atlantic. As mentioned previously sex ratios do seem to change with size in that fish greater than 15Ø pounds dressed weight are predominantly females.

Weight-Length Conversions Algorithms for converting three length measurements (lower jaw fork length, eye-orbit fork length, total length) to dressed weight and visa-versa (Doc. 86/11) was reviewed by the Workshop. The consensus was that estimators for both sexes combined would be the best to use should such conversions need be made.

6. ESTIMATION OF NUMBERS CAUGHT AT SIZE

The numbers caught within one pound dressed weight catagories (Appendix 3) were based on yields and catches, and USA size-frequency samples from west of 35ºW longitude and north of 1ØºN latitude. Samples and catches were combined into gear and area strata (offloading sites and fishing areas) on the basis of observed similarity of size distributions. Gear partitions were longline harpoon, and gillnet. If the combined samples within strata contained at least 2ØØ fish, they were applied to the corresponding landings, otherwise similar size frequencies from other strata were substituted. Substitutions were based on visual comparisons of the modal size and the range of sizes in size-frequency histograms from different month, areas and gears within each year.

USA Monthly landings and samples from Virginia to Maine were divided into four offloading areas and three fishing areas (Appendix 4). Landings and samples for northeast ports were low during winter months, however, the available size samples were similar over these months. January through April and November through December samples were thus combined within gear and area. May through October samples were kept separate. If samples of the same gear were not adequate, substitutions were made between offloading and fishing areas, from adjacent months for the same fishing area, and from adjacent fishing areas. Almost all longline landings were matched by these combinations. Otherwise, samples from the closest months and area were used. Substitutions were made so that winter and spring samples were separated from summer and fall. For 1978, only George's Bank catches were adequately sampled, thus these samples were applied to all Northeast Atlantic longline catches by month.

Size samples were not available or were inadequate for harpoon catches. There were no systematic differences in the size distributions among areas, months or years. The sizes were much larger than for longline so harpoon samples were combined over month and area and somtimes over years.

Very few gillnet samples were available and these were similar to harpoon and longline samples combined. Thus, combined harpoon and longline samples were used for gillnet catches.

Samples and landings from Texas to North Carolina and Puerto Rico were matched on the basis of month and offloading area because fishing area was not recorded in the landings data. Gear was not recorded for Florida landings, so it was assumed to be longline. Substitutions were made in the following hierarchy: (a) adjacent offloading areas in the same month, (b) adjacent months in the same area, (c) fishing areas adjacent to the southeast offloading area.

Canada Samples of Canadian landings were not adequate. During 1978-1985, Canadian and USA vessels fished in the same or nearby areas, thus, it was assumed that the sizes of fish were similar and USA samples were used. Matching of catches and samples was by fishing area and gear. Fishing area was assumed to be George's Bank in early summer and Grand Banks, Scotian Shelf, and Flemish Cap in late summer and fall (John Hoey, pers. comm.). Thus, the corresponding USA longline and harpoon samples were substituted.

Japan, Taiwan, Korea, and Cuba Japanese size samples were compared to USA samples and although the number of fish in the Japanese samples were too few to clearly determine the size distribution, they were not radically different from USA samples (although they were assuredly not identical). Participants decided to apply USA samples to catches of Japan, Taiwan, Korea, and Cuba because samples from those nations catches were too samll. These longline catches are reported by 5 degree squares and these were combined to correspond as much as possible to the fishing areas used for the USA landings (Appendix 4). Georges Bank to Mid Atlantic Bight and Grand Banks to Scotian Shelf samples were used for the corresponding catches. Texas to Key West, Florida Atlantic coast, Georgia, South Carolina and North Carolina samples were combined and applied to Gulf of Mexico and South Atlantic Bight catches. There were no USA samples from Caribbean Sea catches until December 1984 and these were dissimilar to all others; the fish were much larger. Thus 1984 and 1985 Caribbean Sea samples were used for all such catches regardless of year. When necessary, samples were combined within quarter or half years or over adjacent areas or else samples from the preceeding quarter were used.

Calculation Methods Since discarding is very limited or non-existent, it was assumed that reported landings were the entire catch. Samples deemed applicable to each separate catch were combined into a single frequency distribution then the percent of numbers at each one pound dressed weight interval computed to the hundredths to minimize roundoff error. This was redone for each catch since a different combination of samples was used each time. The percent at weight was multiplied by the total numbers caught to compute the catch at weight. If catch was reported in weight rather than numbers (i.e. yield) then the total numbers caught was computed as the quotient of yield to average weight in the sample.

7. ESTIMATION OF CATCH AT AGE FROM CATCH AT SIZE

Estimators Participants agreed that the best method of partitioning the numbers caught at size into numbers at age was to use monthly or quarterly (or at worst annual) age-size keys. Such keys do not exist for Northwest Atlantic swordfish, hence the Workshop was forced to consider other methods. Three methods of splitting size frequencies (numbers caught at dressed weight) into age frequencies (numbers caught at age) based on growth estimates were considered: 1) inverting a growth equation to an expression of age as a deterministic function of size, 2) the linear least squares method (see Bartoo 1983), and 3) a non-linear least squares method (Shepherd 1985).

Methods 2 and 3 account for the variation in size of individuals of the same age, and method 1 does not. However, these stochastic estimators require knowledge of the frequency distribution of size given age. It was noted that method 1 is commonly used when age-size keys are not available, however it is recognized to be deficient in that it tends to smooth out or equalize cohort strengths. Workshop participants, however, did not identify other sources of bias. Since populations of large pelagic fishes are not thought to exhibit large differences in abundances of adjoining cohorts (e.g., groundfish stocks are known to exhibit differences of 20 fold or more), it was felt that this deficiency may not seriously impact the assessment for swordfish. Methods 2 and 3 were recognized to be superior, however, estimates of the variance of size at age were not available; these are usually developed from hardpart data. Since the available hardpart data did not encompass large fish and was not shown to be an accurate measure of age, such variances were not estimatable. Therefore, an inverted Gompertz equation was employed to calculate age from dressed weight. Here fish of each cohort were assumed to be three pounds dressed weight between July 1 of the preceeding year and June 30 of that year.

Results Gompertz growth function parameters were used to calculate the catch at age from the estimated catch at weight and month. Workshop participants expressed a desire to view two catch-at-age tables, one based on mark-recapture data and one based on the hardpart data (Table 3). Most participants felt that the table based on hardpart growth data was not appropriate because this method of estimating age and growth could not be validated. The possibility of generating a third table using the Gompertz function for small fish and linear growth for larger fish in order to include more ages in the catch table was also considered, however, there was not enough time to properly develop an agreed upon procedure. After comparing the two age tables, the Workshop pointed out that the mark-recapture generated catch-at-age appeared to be typical of that seen in tuna fisheries, the only large pelagic resources where age tables exist. In such fisheries it is unusual to encounter 5 or 6 year classes contributing to the catch on a near equal basis as was exhibited in the hardpart generated catch-at-age. Two or three significant year classes was thought to be typical as shown by the mark-recapture generated table. In concern for the amount of work to be done in the remaining time, the Workshop considered the strengths and weaknesses of the two age tables and decided to use the mark-recapture based table.

8. INDICES OF ABUNDANCE

The Workshop reviewed three studies (Docs. 86/1, 86/8 and 86/9) which estimated indices of swordfish abundance indices based on catch-per-unit-of-effort (CPUE) samples from the USA and Japanese fleets.

USA Logbook Records Indices of catch (number of fish) per unit of effort (1000 hooks) based on data extracted from logbook records of three USA domestic swordfish longline vessels covering the years 1974-82 (Doc. 86/9) were reviewed. The generalized linear model (GLM) procedure was employed to generate CPUE, including year, month, vessel and month-vessel interaction terms assuming multiplicative effects. One analysis included zero observations by adding 1 to the observed CPUEs, and another eliminated all observations of zero CPUE. Another series was generated excluding data from the Gulf of Mexico and February, March, and April, and not using observations of zero CPUE. The three series thus generated indicated similar trends.

The Workshop noted the large amount of effort required and difficulties that were overcome in collecting logbook information and computerizing it. However, the Workshop expressed concern regarding the data coverage in terms of the total

US fleet since log records from a limited number of boats were used in this study.

Catch Per Trip Analysis The Workshop reviewed indices of abundance established by analyzing swordfish catch (in number of fish) per trip, based on data obtained from commercial bills of sale (trip tickets) during 1978 through 1985 (Doc. 86/8). The GLM procedure was applied that included year, month, area, gear, vessel and interaction terms; these effects were assumed multiplicative. Trip tickets which were believed to represent more than one trip were not included as well as those of vessels which were found to possess multiple identifications. CPUE indices of abundance were calculated for juveniles (less than 130 lb) and adults (greater or equal to 130 lb dressed weight). This size partition was used because probit analysis of histological sections of swordfish gonads have shown that the average size of first spawning females is 130 lb dressed weight. The analysis shows no definite trend for juvenile swordfish and a downward trend for adults during 1978-81 and then stabilization.

The value of these CPUE indices in estimating abundance of swordfish was questioned by the participants. As previously described (Section 2. History of the Fishery), the USA longline fleet is believed to have made major changes in their gear since 1978 that probably increased catching efficiency. In addition, trip length may have lengthened in the regions off the southern USA coast. The Workshop participants expressed concern that since these factors could not be quantified from the trip ticket information, catch-per-trip abundances indices probably underestimated the degree of any decrease in abundance that might have occurred. Although various hypotheses of gear efficiency were discussed there were no quantitative measures of increasing gear efficiency available thus adjustments could not be made. Since the data was not available to the participants, increases in the number of sets made during a trip and the number of hooks used per set could not be quantified. Those familiar with the fishery believe such changes occurred so the Workshop felt it is important to improve this index. The Workshop decided that the index will be improved considerably with the collection and inclusion of additional data on gear efficiency changes, but that the catch-per-trip could be used as a preliminary estimate of population abundance with the qualifications listed above.

Japanese Longline Observer Data Data recorded by USA observers while aboard Japanese longline vessels fishing within the US FCZ during 1978-85 were reviewed (Doc 86/1). Records consisted of the number of swordfish caught and released (dead or alive) and the number of hooks on each longline set. The GLM technique was applied to the data assuming multiplicative effects. Zero catch records were included in the analysis by adding 0.5 to the CPUE. Year, area, target species (as reported by observers) and month interactions were accounted for in the model. Two analyses were carried out, one on data from the entire area and one on data from the area north of Cape Hatteras. Both series showed similar overall downward trends except during 1979 and 1980 where an increase occurred. The Gulf of Mexico has been closed to the Japanese fleet by bluefin regulations since 1982. Thus, the series which excluded the Gulf data was deemed most relevant by the Workshop. Some concern was expressed regarding the usefulness of these data as an indicator of swordfish abundance because this fishery does not target on swordfish, in fact it is illegal for them to land these fish in the US FCZ.

Japanese Longline High-Seas CPUE The catch (in number of fish) and effort (number of hooks) summarized by month and 5 degree square (longitude and latitude) as archived by ICCAT was also analyzed to derive an abundance index (Doc. 86/1). Since all the billfish caught within US FCZ were released, these data did not include swordfish caught in that zone. The USA observer records and Japanese reports were therefore added to the original data. Only data from north of 10°N and west of 35°W were used. Zero values were included by adding 0.5 to each point. Three indices were developed: 1) 1958-83 for all the areas including FCZ, 2) 1958-83 excluding the USA FCZ, and 3) 1978-83 all areas including the USA FCZ. The two CPUE indices which include FCZ data show increases from 1957 through early 1970's, and fluctuations thereafter. The Workshop recognized that there had been major changes in fishing strategy by the Japanese fleet through the period, with the shift of target species from albacore and yellowfin to bigeye and bluefin tuna. Therefore, it was decided to review the trends in the CPUE indices only for the recent years, 1978-83. All data sets showed a sharp decline between 1978 and 79 and some stability with variations thereafter.

9. VIRTUAL POPULATION ANALYSIS

VPA was employed by the Workshop to establish estimates of the numbers of each cohort alive on January 1 each year and annual age specific instantaneous fishing mortality rates. These estimates were the basis for establishing the recent history (1978-85) of annual stock abundance, stock biomass, exploitation rates, stock growth (surplus production), and for yield-per-recruit simulations. The Workshop considered the accuracy of the estimated catch-at-age for older fish regarding its use in VPA. After considerable discussion it was concluded that estimates of catch for age 10 and older were very uncertain and, because they contributed very little to the total numbers caught, would contribute very little to the results. Therefore, the consensus was to use only catches for ages 0-10, for the VPA.

Calibration The Workshop decided to calibrate VPA estimates of abundance to indices of abundance developed from the standardized CPUE sets considered previously (Section 8). The least squares procedure the Workshop used minimizes the sum of squared difference between an observed abundance index and VPA estimates of absolute abundance with respect to a parameter vector containing F in the last year of catch (1985 in this case), a constant loss rate factor due to all causes other than the recorded catch, and a proportionally constant between the abundance index and absolute abundance. The technique also provides criteria for judging the adequacy of trial abundance indices to reflect stock abundance trajectories resident within the catch-at-age table (Parrack 1986). The Workshop pointed out that in this case this method was not the best to use because the available abundance index was CPUE from the fishery rather than one based on fisheries-independent data; in such a case catches appear on both terms of the sum of squares, hence theoretically an auto-correlation exists. The Workshop pointed out that in such cases where fisheries-independent indices of abundance were not available, techniques which calibrate partial F's estimated by VPA to observed partial fishing effort are theoretically most appropriate. However, lacking an established computer algorithm for such a calibration, and considering that the CPUE was standardized via a multiplicative fishing power model, the Workshop decided that the former procedure would suffice.

The Workshop noted that the CPUE's were somewhat dissimiliar and hence tended to reflect different stock abundance trajectories. It was then concluded that some should be better indicators of stock abundance than others, hence tests were carried out as provided by the calibration method. In order to make such calibrations, it is necessary to define the ages that each of the CPUE's indexed. The Workshop used the available weight-length conversions (Doc. 86/11) and the Gompertz weight-age model developed previously (Section 4. Growth) to define the age bounds for CPUE's which applied to specific size fish. In these tests each CPUE series was calibrated separately and two of the diagnostics compared, the sample correlation coefficient (rho) between estimated abundance and CPUE and the distribution of residuals (below). The CPUE indices based on

CPUE	ages	rho	distribution of residuals
Japan longline			
Yellowbooks, 1985-83			
w/o FCZ	Ø-1Ø	.29	very strong time trend
with FCZ	Ø-1Ø	.3Ø	acceptable
Yellowbooks, 1978-83	Ø-1Ø	.22	acceptable
Observer, 1978-85	Ø-1Ø	.83	acceptable
USA logbook data			
no zero	Ø-1Ø	.Ø4	OK
CPUE+1.Ø	Ø-1Ø	-.Ø1	OK
USA catch per trip			
juveniles	Ø- 4	.44	poor; U-shaped
adults	5-1Ø	.93	acceptable

Japanese high-seas longline data (by month and 5 degree square) were found to be poorly correlated with stock abundance and thus were excluded. The CPUE developed from the logbooks of three USA longline vessels were likewise excluded for the same reason. The index based on the catch-per-trip of fish less than 13Ø pounds (juveniles) was excluded because the correlation was low and the distribution of residuals was unacceptable. Two indices were found to be of possible use: the catch-per-trip of fish greater than or equal to 13Ø pounds dressed weight (adults) and the CPUE based on catch-per-hook recorded by observers on Japanese longline vessels fishing in the USA FCZ. In both cases the indices were highly correlated with stock abundance (i.e., probability that positive correlation exists is .99) and time trends in residuals were not present (Figure 4). The sum of squares surface for the index based on observer data was extremely flat with respect to 1985 F thus the index is of little value in estimating trajectories of stock size and F levels. The sum of squares surface of the adult catch-per-trip did exhibit reasonable relief thus providing an estimate of 1985 F. The Workshop therefore chose to use only the catch-per-trip of ages 5-1Ø (adults) in calibration, thus providing estimates of those ages for 1978-86. Since the calibration system estimated 1985 F on fully exploited ages (full-F), 1985 F on younger ages was calculated from a partial F (or partial recruitment) vector.

Partial Recruitment The Workshop reviewed two methods of establishing partial recruitment vectors: 1) the separable VPA method (Pope and Shepherd 1982) and 2) the newly developed Historical Averaging Method (Doc. 86/7). Both methods assume that year specific partial recruitment (fishing pattern) is constant through time and that the level of natural mortality (M) is known.

Separable VPA is a least squares procedure that analyzes a table of log catch ratios (log[C(1,j)/C(i-1,j-1)] where i=year and j=age) to estimate the partial recruitment vector (S). The technique minimizes the sum of the squared differences between the observed and predicted log catch ratios with respect to S and full-F in each year of catch. The Workshop noted that the technique has defined statistical properties and that it does allow for S(j) less than one for ages older than the first age of full recruitment, but that it might be somewhat sensitive to outlying points.

The historical averaging method employs average F's from VPA iterations to calculate successive partial recruitment vectors until there is no change between successive iterations. In each iteration, relative F's for each age are calculated using the yearly average F of fully recruited ages as a divisor, and a new partial recruitment vector is calculated from the average of the relative age specific F's. Iterations are continued until the change between successive iterations in all partial recruitment values is less than .ØØ5. Prior to each iteration, the fishing mortality rate on the oldest age in each year is reestimated. The method is insensitive to the starting values of F and the age at full recruitment. The procedure's diagnostics include plots of observed versus predicted log catch ratios, log catch ratio residuals, residuals against age by year, and yearly relative F's against the final partial recruitment vector.

Both methods were employed to estimate a partial recruitment vector for swordfish and both estimated the same selection factors to the second decimal point (below). The Workshop noted that the resulting vectors were not

	partial recruitment factors				
M	age Ø	age 1	age 2	age 3	age 4
.1	.Ø5	.34	.77	.98	1.ØØ
.2	.Ø5	.33	.77	.98	1.ØØ
final vector used	.Ø5	.34	Ø.77	1.ØØ	1.ØØ

dependent on M in this case.

VPA and Surplus Production: The Workshop used the above partial recruitment vector to establish 1985 F for the ages Ø to 3 from 1985 full-F. VPA abundance estimates were calibrated to adult catch-per-trip thus estimating 1985 full-F, a loss rate due to causes other than the reported catch (i.e. immigration, emigration, unreported catch, over reported catch, and natural mortality), and the proportionality constant between the catch-per-trip and adult (age 5+) stock size. The resulting VPA estimates of age 5+ stock sizes accounted for 83% of the variation in standardized catch-per-trip. Full-F in 1985 was estimated to be .46 and the change rate due to causes other than the reported catch to be -.Ø5 (thus indicating a possible net immigration). Eighty percent confidence belts (approximate) included 1985 full-F levels from .ØØØØØ1 to 1.7 and change rate levels due to causes other than the reported catch from -1.4 to Ø.6 (Figure 5). The participants recognized that the resulting confidence intervals on stocksize and F estimates reflected the degree of uncertainty inherent in the estimates. Participants decided to ignore change rates due to factors other than F (the reported catch) and M (natural mortality). This required that a level of M be chosen; F was thus estimated by the least squares procedure (calibration).

The Workshop considered the likely range of levels of M at length. It was pointed out in these discussions that in almost all studies of exploited fisheries stocks, the parameter is as yet not truly estimable from available data with state of the art techniques; usually sensible levels are assumed rather then relying upon analytical estimates. For example, scientists working with North Atlantic stocks (cod, haddock, flounders, etc.) believe that M on post recruit fish is low. In this regard the Workshop discussed what level is sensible in the case of Northwest Atlantic swordfish. After these discussions the Workshop consensus was that sensible levels of M were Ø.1 to Ø.2 and that both levels would be used in estimations; almost all of the Workshop participants who voiced an opinion believed that Ø.1 was a more reasonable level than Ø.2.

The Workshop first performed two VPA's one assuming M=Ø.2 and one for M=Ø.1 (Table 5), however, concern was expressed that confidence level calculations were needed. After some discussion, it was concluded that .9Ø confidence intervals would be established on the estimate of 1985 full-F in each case (M=.2 and M=.1) and used to derive VPA's representing the confidence limits. These calculations, however (below), produced very narrow confidence intervals on 1985

	M = Ø.1	M = Ø.2
RMS	Ø.14Ø9 E -3	Ø.1495 E -3
1985 full -F	Ø.37	Ø.31
-statistic, Pr(.9Ø)	1.64	1.64
Ø.9Ø confidence interval	Ø.35 to Ø.39	Ø.29 to Ø.33

full-F and thus would create extremely narrow intervals on abundance trends. The Workshop pointed out that this was likely the result of the auto-correlation mentioned previously, therefore, these confidence interval calculations are not very meaningful.

Stock biomass and surplus production estimates were based on the weight at age calculated from the Gompertz growth equation developed previously (section 4. Growth) and stock size estimates from the two VPA's, one for M=Ø.1 and one for M=Ø.2. The Workshop decided not to calculate the 1986 surplus because of the uncertainty of 1986 cohort abundance (no data was available from the cohort at the time the Workshop was held) and because it is currently not the basis of regulations (a quota management regulation is not currently in place). The computerized algorithm of Rivard (1982) was employed to make these calculations for 1978-1985 for both levels of M (Table 6).

Status of the Resource The fishing mortality rate on adult fish (ages 5+) increased from 1978 to 1979, then decreased through 1982. The 1983 level was the highest in the series. Fishing mortality then decreased in 1984, and in 1985 decreased further to the 1978 level. The fishing mortality rate of juvenile fish (ages Ø-4) increased from 1978 to 198Ø and decreased since to a little more than half the 1978 level in 1985.

Adult (ages 5+) stock abundance (numbers) was stable from 1978 to 1979, then decreased 4Ø% from 1979 to 1984. The adult stock increased in 1985 to within 75% of the 1978 level by 1986 (Figure 6). Juvenile (ages Ø-4) abundance remained relatively constant from 1978 to 1982 and then increased every year thereafter to a level 5Ø-7Ø% higher than the 1978 level. The 1978-81 cohorts were of approximately the same abundance however, a consistent increase in cohort strength has occurred since; the 1985 cohort appears to be quite abundant.

Stock biomass calculations (Table 6) indicate that the resource decreased by 3Ø% from 1978-1982 and then increased steadily since; the 1985 total stock weight is approximately at the 1978 level. Comparisons of annual yields (catch in weight) to annual surplus productions (the total amount of stock growth in weight) show that fishing removals were in excess of stock production from 1978 to 198Ø (Figure 7) thus the stock was decreased by heavy fishing during those years. The 1981 yield was equal to stock production, thus fishing did not further decrease the stock biomass that year. Annual removals have been less than stock production since, thus allowing stock biomass to rapidly increase. The 1985 yield was less then half of the total stock production thus allowing for the 2Ø% increase in stock biomass from 1984 to 1985.

Yield-Per-Recruit Considerations Participants recognized that there is always a major difference between the theoretical yield-per-recruit calculations and that which can actually be achieved. Thompson and Bell yield-per-recruit simulations were calculated using the partial recruitment vector from the VPA, the two levels of M (Ø.1 and Ø.2), and the Gompertz growth function described previously. The Workshop was concerned that this growth function might be biased enough at older ages to seriously bias yield-per-recruit calculations.

The asymptotic size in the growth equation is 269 pounds dressed weight, but fish over 860 pounds have been observed and the largest fish sampled in each year's catch exceeded 550 pounds. It was noted that there was high variation in the observed growth rates of the older fish in the mark-recapture data. The Workshop examind the growth rates of fish larger than 200 pounds at recapture and concluded that the data did not show curvilinear growth with a reasonable degree of certainty and that fish of that size were growing about 35 pounds per year. The Workshop decided to use the Gompertz function to estimate mid-year weights for ages 0-7 (fish 215 pounds or less) and assume linear growth of 25, 35, and 45 pounds per year for older ages with an 850 pound maximum size limit (age 25). The resulting calculations showed very little difference between the 25, 35, and 45 pounds per year assumptions, therefore the Workshop chose to restrict reference to the simulation assuming 35 pounds per year (Table 7).

The Workshop discussed which F level would be the most appropriate reference point for current conditions when considering yield-per-recruit implications. It was noted that the average of 1978-85 full-F levels provide a measure reflective of the entire time period and that the 1985 full-F from the VPA does measure the recent condition. The resulting simulations (Figure 8) show F-max is 0.14 as compared to the 1985 level of 0.37 for M=0.1; F-max is 0.28 for M=0.2 as compared to the current (1985) level of 0.31. Therefore, if the level of natural mortality is assumed to be 0.1, current F levels are about two and one-half to three times F-max and the theoretical equilibrum yield-per-recruit could be increased about 20%; yield per recruit at F=0.37 is approximately 67 pounds and is 82 pounds at (F-max). If M is assumed to be 0.2, the current level is approximately that of F-max. Whether the current fishing mortality rate is in excess of F-max depends on the level of natural mortality rate assumed. It was recognized by the Workshop that 1) since the stock was definitely not in steady-state as evidenced by pronounced trendwise changes in recruitment abundances and F's, these yield-per-recruit results do not describe the current stock conditions; 2) these calculated yield-per-recruit levels would not be fully realized unless full-F and the assumed partial recruitment vector remained constant for 15 to 20 years (maximum age in the simulation is 25 years).

10. ADJOURNMENT

On the evening of June 25, the Workshop completed the assessment agreeing that the report would be concluded through correspondence and that suggested changes would be circulated to other participants at the discretion of the author of the changes. The Chairman thanked the other participants for their contribution to the Workshop and adjourned the meeting.

Literature Cited

Amorim, A.F. and C.A. Arfelli. 1984. Estudo brologico-pesquerio de espadarte. Xiphias gladius Linnaeus, 1958, no Sudeste e Sul de Brasil (1971 a 1981). B. Inst. Pesca 11 (unico):35-62.

Bartoo, N.W. and K.R. Parker. 1983. Stochastic age-frequency estimation using the Von Bertalanffy growth equation. Fishery Bulletin 81(1):91-96.

Berkeley, S.A. and E.D. Houde. 1983. Age determination of broadbill swordfish, Xiphias gladius, from the Straits of Florida, using anal fin spine sections. NOAA Tech. Rept. NMFS 8:137-143.

Berkeley, S.A., E.W. Irby, Jr, and J.W. Jolley, Jr. 1983. Florida's commercial swordfish fishery: Longline gear and methods. Marine Advisory Bulletin MAR-14, Florida Sea Grant.

Caveriviere, A. and P. Cayre. 1986. Premieres peches plangrieres de surface a R'espadon (Xiphias gladius) an Sengal (1983-1984): prises, rendements et structure entaille de captures. ICCAT Col. Vol. Sci. Pap. XXV:185-196.

Dicenta, A. 1977. Zonas de puesta del atun (Thunnus thynnus L.) y otros tunidos del Mediterraneo occidental y primer intento de evaluacion del "stock" de reproductores de atun. Boletin del Instituto Espanol de Oceanografia 234:109-135.

Gonzalez-Garces, A. 1986. Analisis de la pesqeria espanola de pez espada, Xiphias gladius, del Atlantico, 1984 ICCAT Col. Vol. Sci Pap. XXV:197-201.

Grall, C., D.P. de Sylva, and E.D. Houde. 1983. Distribution, relative abundance and seasonality of swordfish larvae. Transactions of the American Fisheries Society 112:235-246.

ICCAT. 1972. Statistical Bulletin Vol 2. ICCAT; Madrid, Spain

ICCAT. 1982. Historical Statistical Bulletin Vol. 1 (1950-59). ICCAT; Madrid, Spain 79 p.

Markle, G.E. 1974. Distribution of larval swordfish in the northwest Atlantic Ocean. NOAA (National Oceanic and Atmospheric Administration) Technical Report, NMFS (National Marine Fisheries Service) SSRF (Special Scientific Report Fisheries) 675:252-260.

Nishikawa, Y., S. Kikawa, M. Honma, and S. Ueyanagi. 1978. Distribution atlas of larval tunas, billfishes, and related species--results of larval surveys by R/V Shunyo Maru and Shoyo Maru 1956-1975. Far Sea Fisheries Research Laboratory S Series 9:1-99. (In Japanese, English summary).

Parrack, M.L. 1986. A method of analyzing catches and abundance indices from a fishery. ICCAT Col. Vol. Sci. Pap. XXIV:209-221.

Pope, J.G. and J.G. Shepherd. 1982. A simple method for the consistent interpretation of catch-at-age data. J. Cons. Int. Explor. Mer. 40:176-184.

Rivard, D. 1982. APL program for stock assessment (revised). Can. Tec. Rept. of Fish. Agnat. Sci 1091: 146p.

Sella, M. 1911. Contributo alla conoscenza della riproduzione e dello sviluppo del pesce-spada (Xiphias gladius L.) Memorie del Reale Comitato Talassografico Italiano 2.

Shepherd J.G. 1985. A weakly parametric method for the analysis of length composition data. Mimeographed 18p. Fisheries Laboratory, Lowestoft, Suffolk NR330HT, England.

Shepherd J.G. 1985. Deconvolution of length compositions ICES methods WG 1985: Working Paper. 7p.

Taning, A.V. 1955. On the breeding areas of the swordfish (Xiphias). Deep Sea Research 3(supplement):438-50.

Williams, J. 1970. Optical properties of the sea. United States Naval Institute. Annapolis, Maryland. 123p.

Table 1. Swordfish mark and recapture data.

Release Weight*	Recovery Weight*	Time at Large	Weight Change	Weight Change per Year
359.81	356.00	3.86	-3.81	-0.99
22.73	39.00	1.05	16.28	15.43
22.73	189.38	5.87	166.65	28.37
30.30	108.00	3.07	77.70	25.28
37.88	68.00	1.24	30.13	24.22
56.81	140.00	1.76	83.19	47.22
98.47	212.10	1.88	113.63	60.54
7.58	71.96	1.82	64.39	35.29
45.45	75.75	0.29	30.30	103.36
22.73	94.69	2.02	71.96	35.59
24.24	41.66	0.70	17.42	24.94
75.15**	573.20	1.95	498.05	254.96
41.75	189.38	3.86	147.63	38.21
83.50	203.00	0.76	119.50	156.90
22.73	66.66	1.36	43.94	32.33
5.30	25.00	0.96	19.69	20.42
265.13**	161.35	1.54	-103.78	-67.28
60.60	150.00	2.90	89.40	30.84
66.80	220.00	1.96	153.20	77.99
56.81	106.05	1.55	49.24	31.75
83.50	175.00	0.74	91.50	123.69
66.80	68.18	1.05	1.38	1.31
33.40	75.00	0.32	41.60	130.90
121.20	212.00	2.59	90.80	35.11
151.50**	445.00	1.08	293.50	270.52
167.00	200.00	2.98	33.00	11.08
217.10	185.00	2.62	-32.10	-12.24
58.45	106.05	0.40	47.60	118.19
90.90	110.00	2.66	19.10	7.19
30.30	50.00	1.85	19.70	10.64
151.50	113.63	0.76	-37.88	-49.55
303.00**	150.00	2.72	-153.00	-56.30
267.20	215.00	0.36	-52.20	-146.56
150.30	170.44	1.11	20.14	18.10
217.10	196.95	2.95	-20.15	-6.83
41.75	83.33	4.44	41.58	9.37
100.20	132.56	0.73	32.36	44.24
125.25	225.00	0.76	99.75	130.97
50.10	166.65	1.38	116.55	84.74
50.10	85.00	1.99	34.90	17.50
208.75	140.14	0.17	-68.61	-397.52
170.44	350.00	4.05	179.56	44.31
7.58	43.94	1.66	36.36	21.90
90.00	188.00	1.76	98.00	55.80
90.18	267.20	10.94	177.02	16.18
302.27	399.13	1.29	96.86	74.90
151.97	317.30	5.17	165.33	31.98

Table 1. (cont.)

Release Weight*	Recovery Weight*	Time at Large	Weight Change	Weight Change per Year
350.00**	590.00	1.18	240.00	203.25
121.91	150.30	0.18	28.39	154.66
121.91	210.42	2.09	88.51	42.29
151.97	217.10	3.96	65.13	16.43
170.34	233.80	2.07	63.46	30.64
56.78	222.11	5.32	165.33	31.07
151.97	312.29	6.13	160.32	26.16
120.00	145.00	0.19	25.00	132.25
170.00	172.00	0.02	2.00	121.67
150.00	185.00	0.16	35.00	212.92
173.68	267.20	8.12	93.52	11.52
128.59	262.19	4.14	133.60	32.27
75.15	75.15	0.25	0.00	0.00
180.00	228.00	0.04	48.00	1251.43
143.62	223.78	5.14	80.16	15.60
136.94	250.50	2.93	113.56	38.74
35.07	359.05	15.07	323.98	21.50
188.71	240.48	2.91	51.77	17.81
150.00	155.00	0.01	5.00	912.50

*Weights converted to dressed weights
**Observations deleted from the analysis

Table 2. Estimates of swordfish removals

Country	Gear	Units of Measure*	1978	1979	1980	1981	1982	1983	1984	1985
USA	Longline	MTRW	2675	3288	4321	3341	4299	4099	3910	3950
	Harpoon	MTRW	619	642	458	388	100	263	56	65
	Gillnet	MTRW	0	0	15	35	0	**	15	18
Canada	Longline	MTRW	2314	2970	1794	542	542	960	465	480
	Harpoon	MTRW	0	0	91	19	12	128	34	35
Japan	Longline	Numbers	10845	5796	12703	17684	7262	3720	4705	4703
Taiwan	Longline	Numbers	995	1462	2261	3551	4019	2173	2493	2493
Korea	Longline	MTRW	37	259	38	40	15	12	0	18
Cuba	Longline	Numbers	57	12	6	32	207	207	207	207

* MTRW = metric tons, round weight
** Less than one metric ton

Table 3a. Northwest Atlantic swordfish catch at age based on mark-recapture data.

AGE	1978	1979	1980	1981	1982	1983	1984	1985
0	1125	1743	5508	3231	7650	6282	6938	8030
1	9970	11696	29315	14160	20882	27504	28253	24217
2	28077	21578	35608	27589	29117	25125	30718	30040
3	25126	21143	25402	18343	21200	18995	17477	19433
4	14744	15847	15577	10499	10297	11451	9107	9612
5	7166	9177	8069	6091	5546	6673	4817	4555
6	3445	5163	4446	3626	2673	3332	2354	2472
7	1985	3336	2686	1994	1739	1845	1217	1262
8	1017	1981	1440	1197	1009	1269	691	739
9	616	1241	744	802	577	653	353	357
10	507	902	606	537	409	513	308	386
11	138	408	284	378	239	276	128	151
12	212	293	254	200	148	209	100	114
13	24	291	123	178	107	156	61	97
14	141	219	97	78	79	71	51	71
15	9	71	64	53	50	68	32	26
16	0	11	4	18	12	9	4	7
17	73	204	136	53	30	26	28	24
18	0	4	1	4	3	3	0	5
19	0	0	0	0	0	0	0	0
20+	3403	7740	4471	4777	3638	3966	2352	2443

Table 3b. Northwest Atlantic swordfish catch at age based on anal spine readings.

AGE	1978	1979	1980	1981	1982	1983	1984	1985
0	4952	6173	20219	9368	18267	20724	19668	20506
1	6658	9455	16886	10473	11858	15876	18065	14012
2	13042	10636	20015	15160	15713	13629	17552	16425
3	18226	12298	17617	13681	15757	12474	14305	15880
4	15760	12390	15766	11050	13119	11698	10589	11836
5	12862	12164	13099	8792	9107	8914	7732	8070
6	8830	9720	9408	6497	6349	7451	5573	5571
7	6020	7525	6635	5040	4414	5446	3868	3648
8	3487	3535	4711	3718	2821	3408	2437	2519
9	2419	4143	3269	2579	2195	2466	1562	1579
10	1747	3242	2084	2076	1471	1801	936	1136
11	1118	2865	1585	1294	1042	1304	665	694
12	710	1504	860	1058	723	796	448	559
13	539	1272	794	764	562	575	344	373
14	416	839	445	461	403	504	255	241
15	216	591	376	372	246	205	219	196
16	148	335	222	383	239	181	105	132
17	129	118	129	222	130	200	104	90
18	112	311	131	144	111	158	76	74
19	18	139	93	77	106	43	54	21
20	269	774	471	599	572	573	392	359

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Table 4. Standardized CPUE abundance indices.

	Year							
	78	79	80	81	82	83	84	85
Japanese longline data								
Yellowbooks, 1985-83								
with FCZ	.6719	.3100	.4482	.4722	.4848	.3941		
No FCZ	.7684	.4325	.4847	.4927	.5474	.4739		
Yellowbooks, 1978-83	.6173	.2556	.4122	.4198	.4245	.3621		
Observers, 1978-85	.6050	.3657	.6671	.4465	.2662	.1393	.1849	.1173
USA logbook data								
No zeros	.2034	.1341	.1693	.1106	.1401			
CPUE+1.0	.1665	.1001	.1315	.1067	.1214			
Northern area	.2440	.1278	.1922	.1242	.1939			
USA catch per trip								
Juveniles	.5277	.5660	.4434	.2672	.3164	.3244	.4864	.5801
Adults	.1247	.1413	.948	.739	.813	.682	.760	.835

Table 5.1 VPA stock size estimates (number of fish) with M=0.1.

Final Estimates

AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986
0	126848	142469	125936	133035	168083	194650	245976	498288	
1	104493	113707	127254	108717	117303	144817	170155	215973	443236
2	93454	85077	91776	87334	84924	86319	104932	127141	172418
3	68258	57948	56516	49331	52878	49259	54287	65827	86547
4	39055	37968	32410	27111	27266	27779	26587	32560	41142
5	21572	21378	19358	14599	14591	14921	14298	15430	20350
6	12172	12730	10660	9880	7446	7951	7190	8374	9644
7	7246	7748	6632	5438	5506	4206	4041	4275	5234
8	4304	4674	3854	3458	3033	3334	2060	2503	2672
9	3054	2929	2355	2124	1995	1788	1815	1209	1565
10	1696	2179	1476	1426	1162	1258	999	1308	756

AGES	1978	1979	1980	1981	1982	1983	1984	1985	1986
0-10	482152	488807	478228	442453	484187	536282	632341	972889	
3-10	157358	147554	133261	113367	113877	110496	111278	131486	
0- 4	432107	437169	433892	405527	450454	502823	601937	939790	167908
5-10	50045	51638	44336	36926	33733	33459	30404	33098	40219

Lower Bound of CI

AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986
0	127260	143199	127150	135345	172304	202346	258794	526524	
1	104735	114080	127915	109815	119393	148636	177119	227572	468784
2	93571	85296	92114	87931	85917	88209	108386	133441	182912
3	68385	58054	56714	49636	53417	50156	55996	68949	92243
4	39114	38062	32505	27289	27542	28266	27397	34104	43964
5	21611	21431	19462	14686	14752	15170	14738	16161	21746
6	12193	12765	10708	9973	7524	8097	7414	8771	10305
7	7260	7766	6663	5482	5590	4276	4173	4478	5592
8	4311	4687	3871	3487	3072	3410	2123	2622	2855
9	3060	2936	2367	2139	2021	1823	1884	1267	1672
10	1699	2184	1483	1436	1176	1282	1031	1370	808

AGES	1978	1979	1980	1981	1982	1983	1984	1985	1986
0-10	483199	490481	480950	447218	492707	551671	659055	1025257	
3-10	157633	147906	133772	114128	115094	112479	114756	137721	
0- 4	433065	438712	436397	410015	458573	517613	627692	990589	179185
5-10	50135	51770	44553	37203	34135	34058	31363	34668	42978

Upper Bound on CI

AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986
0	126477	141815	124849	130964	164300	187747	234474	472949	
1	104275	113372	126662	107733	115429	141394	163909	205566	420308
2	93348	84881	91473	86799	84033	84624	101836	121492	163003
3	68145	57852	56338	49057	52394	48454	52755	63029	81438
4	39002	37866	32324	26951	27019	27342	25861	31176	38613
5	21538	21330	19266	14522	14446	14698	13904	14774	19099
6	12154	12698	10617	9797	7376	7821	6988	8018	9051
7	7233	7731	6603	5400	5431	4143	3924	4093	4912
8	4297	4663	3839	3433	2997	3266	2003	2397	2506
9	3049	2923	2345	2110	1972	1756	1754	1158	1468
10	1694	2174	1471	1417	1150	1238	971	1252	709

AGES	1978	1979	1980	1981	1982	1983	1984	1985	1986
0-10	481212	487306	475787	438181	476549	522483	608379	925903	
3-10	157111	147238	132803	112686	112786	108718	108160	125896	
0- 4	431248	435786	431646	401503	443176	489561	578835	894211	157799
5-10	49964	51520	44142	36678	33373	32921	29544	31691	37747

Table 5.2 VPA estimates of fishing mortality rates (F) with M=0.1

FINAL ESTIMATE

Fishing Mortalities (F's)

AGE	1978	1979	1980	1981	1982	1983	1984	1985
0	0.0094	0.0129	0.0470	0.0258	0.0490	0.0345	0.0301	0.0171
1	0.1056	0.1143	0.2764	0.1470	0.2067	0.2222	0.1914	0.1252
2	0.3779	0.3090	0.5208	0.4018	0.4447	0.3638	0.3663	0.2846
3	0.4866	0.4811	0.6346	0.4929	0.5437	0.5167	0.4112	0.3700
4	0.5026	0.5736	0.6975	0.5195	0.5028	0.5642	0.4441	0.3700
5	0.4275	0.5958	0.5726	0.5733	0.5071	0.6302	0.4350	0.3700
6	0.3517	0.5521	0.5730	0.4847	0.4712	0.5767	0.4199	0.3700
7	0.3384	0.5982	0.5511	0.4841	0.4016	0.6137	0.3790	0.3700
8	0.2847	0.5855	0.4959	0.4500	0.4283	0.5080	0.4327	0.3700
9	0.2377	0.5852	0.4018	0.5028	0.3609	0.4817	0.2281	0.3700
10	0.3756	0.5674	0.5609	0.5010	0.4594	0.5559	0.3898	0.3700

Average F's Weighted by Catches

AGES	1978	1979	1980	1981	1982	1983	1984	1985
0-10	0.3933	0.4264	0.4938	0.3994	0.3951	0.3883	0.3144	0.2580
3-10	0.4616	0.5439	0.6272	0.5087	0.5133	0.5539	0.4206	0.3700
0- 4	0.3961	0.3790	0.4837	0.3758	0.3852	0.3552	0.3038	0.2460
5-10	0.3782	0.5831	0.5559	0.5212	0.4684	0.5953	0.4153	0.3700

Average F's Weighted by Stocksizes

AGES	1978	1979	1980	1981	1982	1983	1984	1985
0-10	0.2466	0.2473	0.3595	0.2532	0.2651	0.2447	0.1977	0.1237
3-10	0.4536	0.5404	0.6229	0.5075	0.5105	0.5516	0.4187	0.3700
0- 4	0.2323	0.2077	0.3396	0.2291	0.2502	0.2216	0.1870	0.1151
5-10	0.3705	0.5827	0.5534	0.5181	0.4646	0.5925	0.4100	0.3700

LOWER BOUND OF CI

Fishing Mortalities (F's)

AGE	1978	1979	1980	1981	1982	1983	1984	1985
0	0.0093	0.0129	0.0466	0.0254	0.0478	0.0332	0.0286	0.0162
1	0.1053	0.1139	0.2748	0.1454	0.2027	0.2158	0.1832	0.1185
2	0.3774	0.3081	0.5183	0.3984	0.4382	0.3544	0.3523	0.2692
3	0.4854	0.4800	0.6315	0.4890	0.5365	0.5047	0.3959	0.3500
4	0.5016	0.5713	0.6945	0.5151	0.4964	0.5513	0.4278	0.3500
5	0.4265	0.5938	0.5685	0.5688	0.4999	0.6160	0.4190	0.3500
6	0.3510	0.5501	0.5696	0.4789	0.4650	0.5629	0.4043	0.3500
7	0.3376	0.5963	0.5476	0.4792	0.3943	0.6000	0.3646	0.3500
8	0.2841	0.5834	0.4932	0.4454	0.4216	0.4934	0.4167	0.3500
9	0.2371	0.5833	0.3994	0.4982	0.3555	0.4698	0.2188	0.3500
10	0.3748	0.5655	0.5578	0.4964	0.4527	0.5426	0.3752	0.3500

Table 5.2 (cont.)

Average F's Weighted by Catches

AGES	1978	1979	1980	1981	1982	1983	1984	1985
0-10	0.3925	0.4250	0.4912	0.3959	0.3893	0.3787	0.3023	0.2440
3-10	0.4606	0.5421	0.6240	0.5044	0.5064	0.5411	0.4049	0.3500
0- 4	0.3953	0.3778	0.4814	0.3727	0.3796	0.3463	0.2920	0.2327
5-10	0.3774	0.5811	0.5523	0.5163	0.4616	0.5813	0.3998	0.3500

Average F's Weighted by Stocksizes

AGES	1978	1979	1980	1981	1982	1983	1984	1985
0-10	0.2460	0.2463	0.3570	0.2501	0.2599	0.2368	0.1886	0.1166
3-10	0.4526	0.5387	0.6196	0.5031	0.5035	0.5387	0.4032	0.3500
0- 4	0.2317	0.2068	0.3373	0.2263	0.2451	0.2143	0.1783	0.1085
5-10	0.3697	0.5807	0.5498	0.5131	0.4577	0.5785	0.3946	0.3500

UPPER BOUND OF CI

Fishing Mortalities (F's)

AGE	1978	1979	1980	1981	1982	1983	1984	1985
0	0.0094	0.0130	0.0474	0.0263	0.0501	0.0358	0.0316	0.0180
1	0.1058	0.1146	0.2779	0.1484	0.2104	0.2282	0.1995	0.1320
2	0.3784	0.3099	0.5231	0.4048	0.4506	0.3726	0.3798	0.3000
3	0.4876	0.4821	0.6374	0.4964	0.5504	0.5279	0.4260	0.3900
4	0.5035	0.5757	0.7001	0.5236	0.5088	0.5763	0.4599	0.3900
5	0.4283	0.5976	0.5763	0.5774	0.5137	0.6435	0.4505	0.3900
6	0.3524	0.5539	0.5762	0.4900	0.4769	0.5897	0.4349	0.3900
7	0.3391	0.6000	0.5542	0.4886	0.4085	0.6266	0.3929	0.3900
8	0.2852	0.5875	0.4984	0.4542	0.4346	0.5218	0.4481	0.3900
9	0.2382	0.5869	0.4039	0.5069	0.3660	0.4929	0.2371	0.3900
10	0.3763	0.5691	0.5638	0.5053	0.4656	0.5684	0.4039	0.3900

Average F's Weighted by Catches

AGES	1978	1979	1980	1981	1982	1983	1984	1985
0-10	0.3940	0.4277	0.4961	0.4025	0.4004	0.3973	0.3262	0.2719
3-10	0.4626	0.5455	0.6301	0.5127	0.5197	0.5660	0.4356	0.3900
0- 4	0.3968	0.3800	0.4859	0.3787	0.3904	0.3636	0.3152	0.2593
5-10	0.3789	0.5849	0.5592	0.5257	0.4747	0.6084	0.4302	0.3900

Average F's Weighted by Stocksizes

AGES	1978	1979	1980	1981	1982	1983	1984	1985
0-10	0.2472	0.2482	0.3617	0.2561	0.2701	0.2522	0.2066	0.1309
3-10	0.4545	0.5420	0.6258	0.5114	0.5169	0.5636	0.4338	0.3900
0- 4	0.2328	0.2084	0.3417	0.2317	0.2549	0.2285	0.1955	0.1217
5-10	0.3712	0.5845	0.5566	0.5226	0.4709	0.6057	0.4248	0.3900

Table 5.3 VPA stock sizes estimates (number of fish) with M=0.2

Final Estimates

AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986
0	186422	204832	183904	195822	241523	277040	334722	623522	
1	142581	151613	166128	145595	157408	190836	221149	267782	503244
2	117163	107741	113581	109626	106436	110060	131469	155603	197404
3	84926	70691	68798	61050	64966	60995	67522	80025	100369
4	48220	46982	38903	33576	33523	34179	32898	39582	48055
5	27192	26250	24259	17913	18072	18208	17717	18758	23769
6	15430	15826	13268	12627	9206	9820	8930	10180	11264
7	9299	9535	8328	6877	7083	5138	5053	5197	6113
8	5507	5828	4817	4409	3840	4237	2554	3043	3121
9	3961	3593	2996	2652	2535	2238	2330	1470	1827
10	2144	2688	1830	1784	1451	1557	1246	1590	583

AGES	1978	1979	1980	1981	1982	1983	1984	1985	1986
0-10	642844	645580	626811	591932	646044	714308	825590	1206751	
3-10	196678	181393	163198	140888	140676	136371	138250	159844	195400
0- 4	579313	581859	571314	545670	603856	673111	787760	1166514	
5-10	63532	63721	55497	46262	42187	41196	37830	40237	46977

Lower Bound of CI

AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986
0	187688	206855	186945	201056	250173	291289	356156	666226	
1	143324	152650	167784	148085	161693	197918	232815	285331	538208
2	117524	108349	114429	110982	108474	113567	137264	165151	211769
3	85314	70985	69295	61742	66073	62660	70390	84763	106179
4	48400	47298	39144	33981	34088	35083	34258	41926	51928
5	27310	26397	24518	18109	18402	18669	18455	19868	25685
6	15492	15923	13388	12838	9366	10090	9307	10782	12172
7	9342	9586	8406	6975	7256	5268	5273	5505	6606
8	5530	5864	4859	4474	3921	4377	2660	3223	3372
9	3979	3612	3025	2686	2588	2303	2445	1557	1975
10	2153	2703	1845	1808	1479	1600	1300	1684	954

AGES	1978	1979	1980	1981	1982	1983	1984	1985	1986
0-10	646057	650224	633638	602736	663513	742825	870321	1286017	
3-10	197521	182369	164480	142613	143173	140051	144087	169309	210870
0- 4	582250	586138	577597	555847	620502	700517	830882	1243398	
5-10	63807	64086	56041	46889	43011	42308	39439	42619	50763

Upper Bound of CI

AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986
0	185310	203055	181234	191226	233928	264525	315887	585993	
1	141927	150703	164673	143409	153645	184618	210903	252362	472519
2	116846	107206	112835	108436	104646	106980	126380	147218	184781
3	84585	70432	68361	60441	63993	59533	65004	75865	93510
4	48061	46703	38691	33220	33026	33385	31705	37525	44655
5	27088	26120	24032	17741	17781	17802	17069	17782	22087
6	15375	15741	13162	12442	9065	9583	8599	9651	10467
7	9262	9490	8258	6790	6932	5023	4859	4927	5680
8	5486	5798	4781	4353	3770	4113	2460	2885	2900
9	3944	3576	2971	2622	2489	2180	2229	1394	1698
10	2136	2675	1816	1764	1427	1519	1199	1507	820

AGES	1978	1979	1980	1981	1982	1983	1984	1985	1986
0-10	640020	641499	620814	582443	630702	689261	786295	1137108	
3-10	195937	180535	162072	139373	138483	133138	133125	151535	181817
0- 4	576729	578098	565794	536732	589238	649041	749879	1098962	
5-10	63290	63401	55020	45711	41464	40220	36416	38145	43653

Table 5.4 VPA estimates of fishing mortality rates (F) with M=0.2.

FINAL ESTIMATE

Fishing Mortalities (F's)

AGE	1978	1979	1980	1981	1982	1983	1984	1985
0	0.0067	0.0094	0.0336	0.0184	0.0356	0.0253	0.0231	0.0143
1	0.0802	0.0888	0.2157	0.1133	0.1578	0.1726	0.1515	0.1049
2	0.3053	0.2486	0.4208	0.3232	0.3567	0.2886	0.2964	0.2385
3	0.3920	0.3972	0.5174	0.3995	0.4423	0.4174	0.3341	0.3100
4	0.4081	0.4610	0.5755	0.4195	0.4104	0.4571	0.3618	0.3100
5	0.3413	0.4823	0.4529	0.4657	0.4099	0.5124	0.3541	0.3100
6	0.2813	0.4421	0.4572	0.3781	0.3832	0.4644	0.3414	0.3100
7	0.2672	0.4828	0.4359	0.3826	0.3140	0.4991	0.3071	0.3100
8	0.2269	0.4654	0.3970	0.3535	0.3400	0.3980	0.3521	0.3100
9	0.1876	0.4750	0.3182	0.4027	0.2876	0.3855	0.1823	0.3100
10	0.3006	0.4580	0.4506	0.4002	0.3696	0.4477	0.3165	0.3100

Average F's Weighted by Catches

AGES	1978	1979	1980	1981	1982	1983	1984	1985
0-10	0.3166	0.3450	0.3983	0.3207	0.3171	0.3106	0.2540	0.2161
3-10	0.3720	0.4414	0.5095	0.4099	0.4167	0.4479	0.3420	0.3100
0- 4	0.3194	0.3072	0.3913	0.3022	0.3091	0.2834	0.2452	0.2061
5-10	0.3015	0.4699	0.4413	0.4163	0.3768	0.4812	0.3376	0.3100

Average F's Weighted by Stocksizes

AGES	1978	1979	1980	1981	1982	1983	1984	1985
0-10	0.1869	0.1887	0.2747	0.1910	0.2006	0.1855	0.1542	0.1025
3-10	0.3646	0.4391	0.5046	0.4085	0.4139	0.4457	0.3404	0.3100
0- 4	0.1751	0.1580	0.2587	0.1723	0.1886	0.1676	0.1456	0.0953
5-10	0.2750	0.4694	0.4392	0.4126	0.3729	0.4782	0.3329	0.3100

LOWER BOUND OF CI

Fishing Mortalities (F's)

AGE	1978	1979	1980	1981	1982	1983	1984	1985
0	0.0066	0.0093	0.0330	0.0179	0.0343	0.0241	0.0217	0.0134
1	0.0797	0.0882	0.2133	0.1113	0.1533	0.1659	0.1434	0.0982
2	0.3042	0.2470	0.4170	0.3186	0.3488	0.2784	0.2820	0.2231
3	0.3899	0.3952	0.5126	0.3940	0.4331	0.4038	0.3181	0.2900
4	0.4062	0.4571	0.5708	0.4133	0.4021	0.4424	0.3448	0.2900
5	0.3395	0.4789	0.4470	0.4593	0.4009	0.4962	0.3374	0.2900
6	0.2800	0.4388	0.4520	0.3707	0.3753	0.4489	0.3251	0.2900
7	0.2658	0.4795	0.4308	0.3761	0.3053	0.4834	0.2922	0.2900
8	0.2259	0.4619	0.3929	0.3475	0.3318	0.3825	0.3355	0.2900
9	0.1867	0.4718	0.3147	0.3965	0.2809	0.3723	0.1730	0.2900
10	0.2991	0.4547	0.4458	0.3939	0.3613	0.4328	0.3013	0.2900

Table 5.4 (cont.)

Average F's Weighted by Catches

AGES	1978	1979	1980	1981	1982	1983	1984	1985
0-10	0.3151	0.3427	0.3944	0.3160	0.3100	0.3000	0.2416	0.2022
3-10	0.3700	0.4384	0.5046	0.4039	0.4079	0.4334	0.3257	0.2900
0- 4	0.3179	0.3052	0.3877	0.2979	0.3022	0.2736	0.2332	0.1928
5-10	0.3000	0.4665	0.4360	0.4097	0.3683	0.4654	0.3216	0.2900

Average F's Weighted by Stocksizes

AGES	1978	1979	1980	1981	1982	1983	1984	1985
0-10	0.1859	0.1872	0.2712	0.1872	0.1947	0.1775	0.1454	0.0955
3-10	0.3628	0.4362	0.4996	0.4025	0.4050	0.4312	0.3242	0.2900
0- 4	0.1741	0.1567	0.2554	0.1688	0.1830	0.1603	0.1372	0.0889
5-10	0.2935	0.4660	0.4339	0.4059	0.3644	0.4624	0.3170	0.2900

UPPER BOUND OF CI

Fishing Mortalities (F's)

AGE	1978	1979	1980	1981	1982	1983	1984	1985
0	0.0067	0.0095	0.0341	0.0188	0.0367	0.0265	0.0245	0.0152
1	0.0806	0.0894	0.2178	0.1151	0.1620	0.1790	0.1595	0.1117
2	0.3062	0.2499	0.4243	0.3274	0.3641	0.2982	0.3103	0.2538
3	0.3939	0.3990	0.5216	0.4044	0.4507	0.4301	0.3495	0.3300
4	0.4098	0.4644	0.5798	0.4250	0.4180	0.4708	0.3783	0.3300
5	0.3428	0.4854	0.4583	0.4714	0.4182	0.5276	0.3703	0.3300
6	0.2824	0.4451	0.4618	0.3849	0.3904	0.4790	0.3570	0.3300
7	0.2684	0.4857	0.4404	0.3885	0.3220	0.5139	0.3214	0.3300
8	0.2279	0.4685	0.4007	0.3590	0.3476	0.4127	0.3682	0.3300
9	0.1885	0.4778	0.3214	0.4083	0.2938	0.3979	0.1914	0.3300
10	0.3020	0.4609	0.4549	0.4059	0.3772	0.4617	0.3311	0.3300

Average F's Weighted by Catches

AGES	1978	1979	1980	1981	1982	1983	1984	1985
0-10	0.3179	0.3471	0.4018	0.3250	0.3236	0.3206	0.2661	0.2301
3-10	0.3736	0.4441	0.5140	0.4153	0.4248	0.4616	0.3576	0.3300
0- 4	0.3207	0.3090	0.3946	0.3062	0.3155	0.2926	0.2569	0.2194
5-10	0.3029	0.4729	0.4461	0.4223	0.3846	0.4960	0.3531	0.3300

Average F's Weighted by Stocksizes

AGES	1978	1979	1980	1981	1982	1983	1984	1985
0-10	0.1879	0.1901	0.2778	0.1945	0.2061	0.1931	0.1628	0.1095
3-10	0.3663	0.4417	0.5091	0.4140	0.4219	0.4593	0.3560	0.3300
0- 4	0.1759	0.1591	0.2616	0.1754	0.1938	0.1745	0.1538	0.1018
5-10	0.2963	0.4724	0.4440	0.4187	0.3807	0.4930	0.3482	0.3300

Table 6.1 Stock biomass and surplus production for northwest Atlantic swordfish assuming natural mortality (M) of 0.1.

MEAN POPULATION BIOMASS (KG)

	1978	1979	1980	1981	1982	1983	1984	1985
0	841104	943026	819812	875026	1093127	1274942	1614914	3287135
1	2172386	2354056	2439027	2215619	2323467	2847527	3395056	4448810
2	3863186	3630912	3555324	3570915	3404985	3591612	4361023	5488686
3	4596062	3911456	3562603	3312115	3470221	3272106	3782659	4674424
4	3754743	3536188	2858659	2586701	2621119	2598107	2624633	3325232
5	2749309	2526007	2311097	1742378	1793700	1736630	1815962	2018973
6	1890274	1804858	1497427	1443881	1094767	1115053	1082061	1289449
7	1261355	1198922	1047886	885594	930884	646352	690407	733324
8	828875	784954	673654	617109	546523	579590	370521	463373
9	629801	515325	450018	387622	388445	329426	376057	234462
10	340160	400606	272262	270108	224354	232553	199117	262897
0+	22927255	21606309	19487769	17907069	17891592	18223897	20312411	26226765

CATCH BIOMASS

	1978	1979	1980	1981	1982	1983	1984	1985
0	7875	12201	38556	22617	53550	43974	48566	56210
1	229310	269008	674245	325680	480286	632592	649819	556991
2	1460004	1122056	1851616	1434628	1514084	1306500	1597336	1562080
3	2236214	1881727	2260778	1632527	1886800	1690555	1555453	1729537
4	1887232	2028416	1993856	1343872	1318016	1465728	1165696	1230336
5	1175224	1505028	1323316	998924	909544	1094372	789988	747020
6	664885	996459	858078	699818	515889	643076	454322	477096
7	426775	717240	577490	428710	373885	396675	261655	271330
8	235944	459592	334080	277704	234088	294408	160312	171448
9	149688	301563	180792	194886	140211	158679	85779	86751
10	127764	227304	152712	135324	103068	129276	77616	97272
0+	8600915	9520594	10245519	7494690	7529421	7855835	6846542	6906071

WEIGHTS AT THE BEGINNING OF THE YEAR

	1978	1979	1980	1981	1982	1983	1984	1985	1986
0	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	.00
1	15.30	12.69	12.69	12.69	12.69	12.69	12.69	12.69	12.69
2	39.75	34.58	34.58	34.58	34.58	34.58	34.58	34.58	41.69
3	74.21	68.03	68.03	68.03	68.03	68.03	68.03	68.03	78.19
4	113.08	106.73	106.73	106.73	106.73	106.73	106.73	106.73	116.43
5	151.18	144.89	144.89	144.89	144.89	144.89	144.89	144.89	153.50
6	182.86	177.91	177.91	177.91	177.91	177.91	177.91	177.91	185.64
7	206.97	203.70	203.70	203.70	203.70	203.70	203.70	203.70	209.37
8	226.69	223.34	223.34	223.34	223.34	223.34	223.34	223.34	226.92
9	238.62	237.44	237.44	237.44	237.44	237.44	237.44	237.44	241.00
10	247.46	247.46	247.46	247.46	247.46	247.46	247.46	247.46	248.69
11	.00	256.62	256.62	256.62	256.62	256.62	256.62	256.62	255.35

Table 6.1 (cont.)

POPULATION BIOMASS AT BEGINNING OF YEAR

I	1978	1979	1980	1981	1982	1983	1984	1985
0	489854	550177	486335	513744	649092	751714	950109	1921686
1	1598346	1442781	1614669	1379465	1488408	1837518	2159104	2741026
2	3714562	2942214	3173912	3020301	2936943	2985189	3628893	4397158
3	5065661	3942145	3844734	3355951	3597262	3351045	3693111	4478205
4	4416422	4052470	3459194	2893629	2910226	2964925	2837736	3475212
5	3261227	3097322	2804770	2115246	2114024	2161925	2071579	2235542
6	2225830	2264751	1896577	1757794	1324701	1414596	1279097	1489761
7	1499777	1578282	1350870	1107829	1121610	856706	823249	870813
8	975625	1044010	860810	772342	677281	744638	460080	559082
9	728736	695580	559213	504296	473727	424526	431017	287133
10	419735	539156	365366	352881	287647	311382	247308	323563
0+	24395775	22148887	20416450	17773478	17580921	17804164	18581285	22779179

PRODUCTION

SOURCE	1978	1979	1980	1981	1982
RECRUITMENT BIOMASS	489854	550177	486335	513744	649092
GROWTH	8367108	9749307	9233237	8644385	8960603
TOTAL PRODUCTION	8856962	10299484	9719572	9158130	9609696
LOSS THROUGH FISHING	8600915	9520594	10245519	7494690	7529421
SURPLUS PRODUCTION	6564236	8138853	7770795	7367423	7820536
NET PRODUCTION	¯2036679	¯1381741	¯2474724	¯127267	291115

SOURCE	1983	1984	1985
RECRUITMENT BIOMASS	751714	950109	1921686
GROWTH	9672821	11311142	18583605
TOTAL PRODUCTION	10424535	12261252	20505291
LOSS THROUGH FISHING	7855835	6846542	6986071
SURPLUS PRODUCTION	8602145	10230010	17882615
NET PRODUCTION	746310	3383468	10896544

Table 6.2 Stock biomass and surplus production of northwest Atlantic swordfish assuming a natural mortality rate (M) of 0.2.

MEAN POPULATION BIOMASS (KG)

	1978	1979	1980	1981	1982	1983	1984	1985
0	1178932	1293628	1148036	1231415	1506294	1736106	2100491	2930769
1	2859988	3028712	3126286	2874896	3043484	3664196	4288005	5309733
2	4782893	4514556	4399981	4438626	4244169	4527453	5388633	6549602
3	5704264	4736939	4369864	4086839	4266300	4050443	4656005	5579157
4	4624386	4400358	3464291	3203667	3211662	3206788	3221681	3968826
5	3443850	3120269	2921601	2145116	2218731	2135725	2230752	2409742
6	2363690	2253943	1876827	1850787	1346233	1384646	1330913	1539019
7	1597299	1485650	1324863	1120534	1190772	794720	852153	875258
8	1039789	987497	841588	785569	688391	739777	455243	553058
9	797828	634910	568206	484002	487521	411582	470481	279842
10	425030	496297	338908	338141	278864	288756	245232	313781
0+	28817949	26952757	24380451	22559591	22482421	22940192	25239589	31308781

CATCH BIOMASS

	1978	1979	1980	1981	1982	1983	1984	1985
0	7875	12201	38536	22617	53550	43974	48566	56210
1	229310	269008	674245	325680	480286	632592	649819	556991
2	1460004	1122056	1851616	1434628	1514084	1306500	1597336	1562080
3	2236214	1881727	2260778	1632527	1886800	1690555	1555453	1729537
4	1887232	2028416	1993856	1343872	1318016	1465728	1165696	1230336
5	1175224	1505028	1323316	998924	909544	1094372	789988	747020
6	664885	996459	858078	699818	515889	643076	454322	477096
7	426775	717240	577490	428710	373885	396675	261655	271330
8	235944	459592	334080	277704	234088	294408	160312	171448
9	149688	301563	180792	194886	140211	158679	85779	86751
10	127764	227304	152712	135324	103060	129276	77616	97272
0+	8600915	9520594	10245519	7494690	7529421	7855835	6846542	6986071

WEIGHTS AT THE BEGINNING OF THE YEAR

	1978	1979	1980	1981	1982	1983	1984	1985	1986
0	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	.00
1	15.30	12.69	12.69	12.69	12.69	12.69	12.69	12.69	12.69
2	39.75	34.58	34.58	34.58	34.58	34.58	34.58	34.58	41.69
3	74.21	68.03	68.03	68.03	68.03	68.03	68.03	68.03	78.19
4	113.08	106.73	106.73	106.73	106.73	106.73	106.73	106.73	116.43
5	151.18	144.89	144.89	144.89	144.89	144.89	144.89	144.89	153.50
6	182.86	177.91	177.91	177.91	177.91	177.91	177.91	177.91	185.64
7	206.97	203.70	203.70	203.70	203.70	203.70	203.70	203.70	209.37
8	226.69	223.34	223.34	223.34	223.34	223.34	223.34	223.34	226.92
9	238.62	237.44	237.44	237.44	237.44	237.44	237.44	237.44	241.80
10	247.46	247.46	247.46	247.46	247.46	247.46	247.46	247.46	248.69
11	.00	256.62	256.62	256.62	256.62	256.62	256.62	256.62	255.35

Table 6.2 (cont.)

POPULATION BIOMASS AT BEGINNING OF YEAR

	1978	1979	1980	1981	1982	1983	1984	1985
0	719915	791004	710192	756214	932697	1069726	1292872	2409165
1	2180956	1923760	2107916	1847402	1997280	2421431	2805712	3398483
2	4656963	3725996	3927996	3791254	3680921	3806252	4546619	5380496
3	6302649	4809047	4680305	4153190	4419618	4149494	4593504	5444066
4	5452745	5014504	4152235	3583715	3578023	3648015	3511363	6224746
5	4110847	3803212	3514803	2595338	2618327	2638039	2566974	2717704
6	2821484	2815661	2360414	2246495	1637831	1747038	1588760	1811073
7	1924719	1942388	1696364	1400776	1442875	1046598	1029295	1058630
8	1248236	1301728	1075906	904742	857663	946177	570313	679664
9	945078	853115	711410	629652	601896	531322	553174	949062
10	530519	665152	452718	641604	359192	385225	308333	393349
0+	30894111	27645567	25390259	22430381	22126324	22389317	23366920	27866438

PRODUCTION

SOURCE	1978	1979	1980	1981	1982
RECRUITMENT BIOMASS	719915	791004	710192	756214	932697
GROWTH	10658451	12302876	11650464	11021138	11429912
TOTAL PRODUCTION	11378366	13093879	12360656	11777352	12362609
LOSS THROUGH FISHING	8600915	9520594	10245519	7494690	7529421
SURPLUS PRODUCTION	5614776	7703328	7484566	7265433	7866125
NET PRODUCTION	-2986139	-1817266	-2760953	-229257	336704

SOURCE	1983	1984	1985
RECRUITMENT BIOMASS	1069726	1292872	2409165
GROWTH	12337637	14175579	22074937
TOTAL PRODUCTION	13407363	15468451	24484102
LOSS THROUGH FISHING	7855835	6846542	6986071
SURPLUS PRODUCTION	8819325	10420534	18222346
NET PRODUCTION	963490	3573992	11236275

Table 7.1 Yield per recruit simulation with M=0.1.

	FISHING MORTALITY	CATCH (NUMBER)	YIELD (KG)	AVG. WEIGHT (KG)	YIELD PER UNIT EFFORT
F0.1—	.0858	.382	77.475	202.663	1.000
	.1000	.415	79.926	192.367	.885
FMAX—	.1370	.483	81.989	169.710	.663
	.2000	.560	79.243	141.567	.439
	.3000	.632	71.728	113.492	.265
	.4000	.676	64.968	96.095	.180
	.5000	.706	59.466	84.212	.132
	.6000	.729	54.988	75.514	.101
	.7000	.745	51.291	68.833	.081
	.8000	.759	48.193	63.516	.067
	.9000	.770	45.560	59.173	.056
	1.0000	.779	43.295	55.551	.048
	1.1000	.787	41.326	52.480	.042
	1.2000	.795	39.598	49.839	.037
	1.3000	.801	38.069	47.542	.032
	1.4000	.806	36.706	45.523	.029
	1.5000	.811	35.482	43.734	.026

Table 7.2 Yiel per recruit simulation with M=0.2.

	FISHING MORTALITY	CATCH (NUMBER)	YIELD (KG)	AVG. WEIGHT (KG)	YIELD PER UNIT EFFORT
	.1000	.235	33.025	140.346	1.287
F0.1—	.1463	.299	37.553	125.481	1.000
	.2000	.355	39.902	112.290	.777
FMAX—	.2782	.415	40.754	98.113	.571
	.3000	.429	40.711	94.917	.525
	.4000	.479	39.802	83.061	.388
	.5000	.516	38.394	74.391	.295
	.6000	.545	36.890	67.738	.240
	.7000	.567	35.437	62.450	.197
	.8000	.586	34.085	58.135	.166
	.9000	.602	32.846	54.541	.142
	1.0000	.616	31.717	51.497	.124
	1.1000	.628	30.691	48.882	.109
	1.2000	.638	29.757	46.610	.097
	1.3000	.648	28.906	44.616	.087
	1.4000	.656	28.126	42.850	.078
	1.5000	.664	27.411	41.273	.071

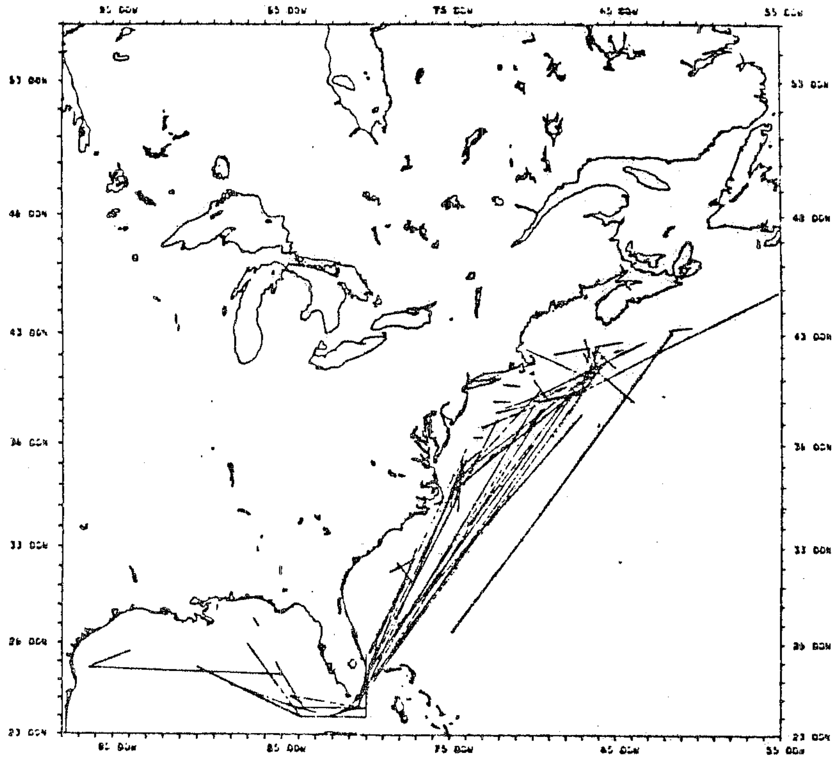

Figure 1. Swordfish mark and recaptures (United States and Canadian data).

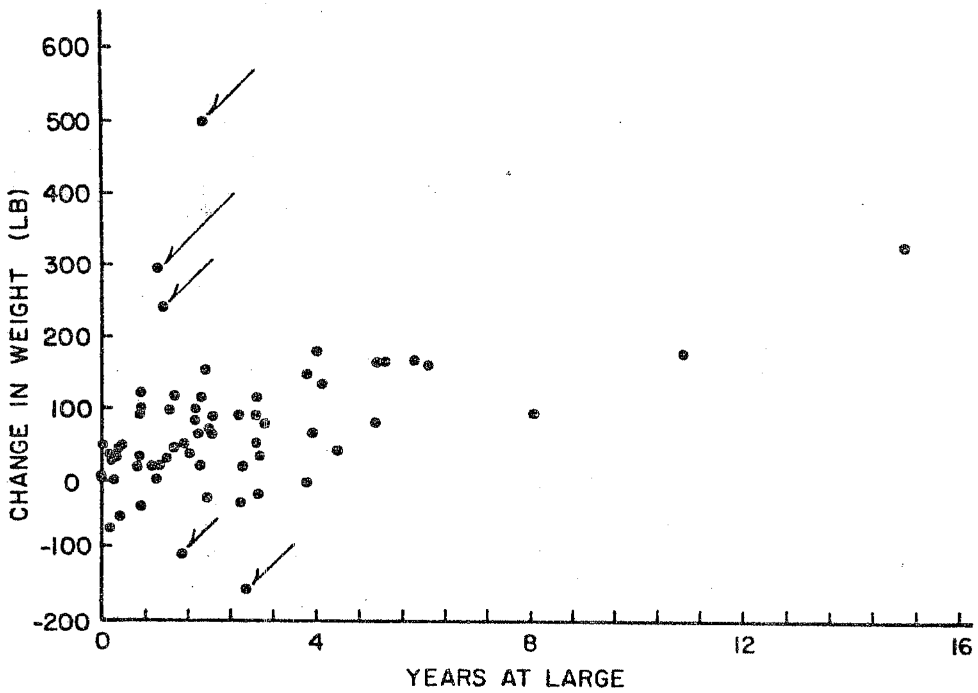

Figure 2. Change in swordfish weight as indicated from mark-recapture data. Arrows indicate points deleted in this analysis.

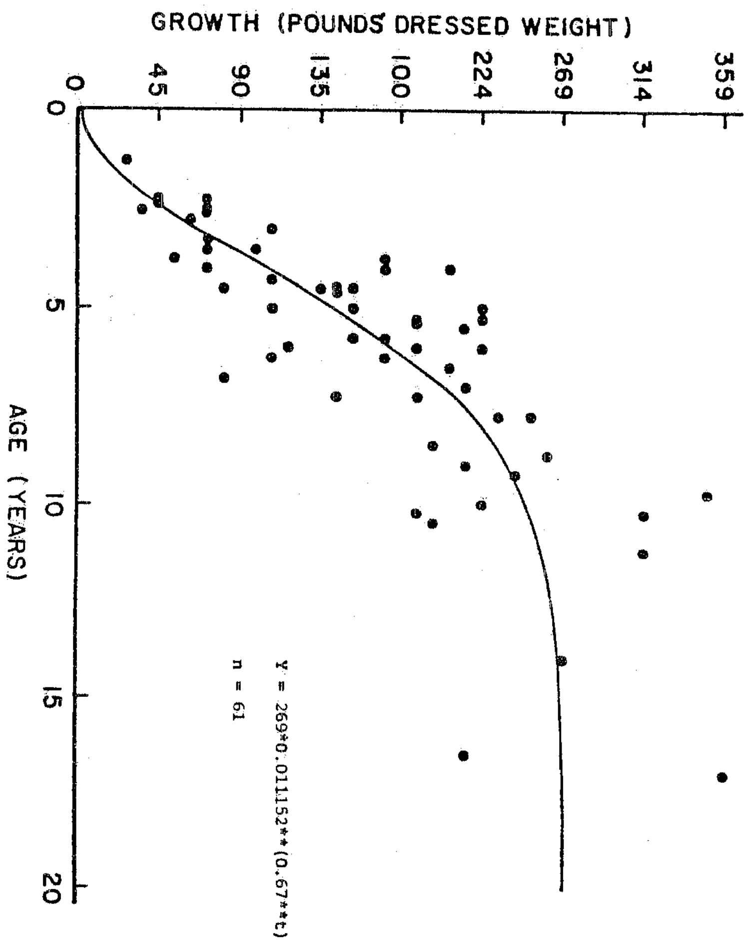

Figure 3 The Gompertz growth model fitted to swordfish mark-recapture data in dressed weight

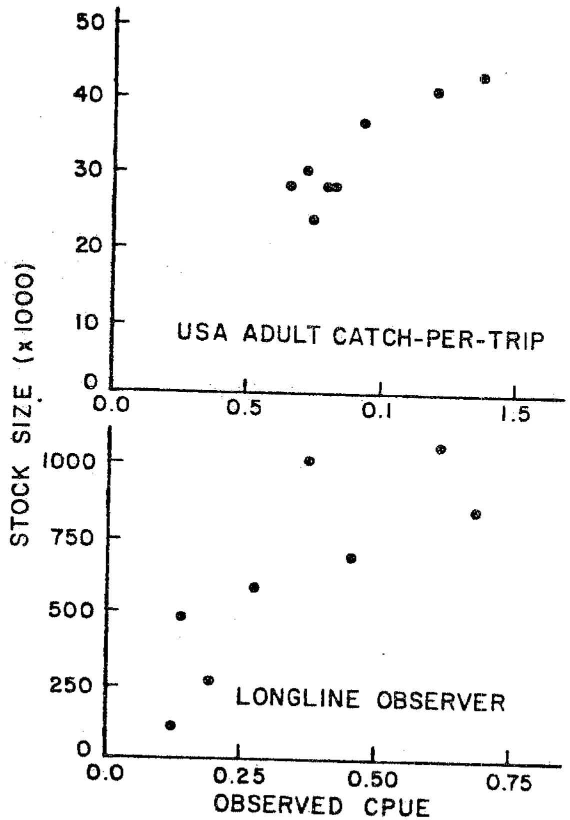

Figure 4. Estimated swordfish stocksize on observed CPUE for USA adult catch-per-trip and longline observer data.

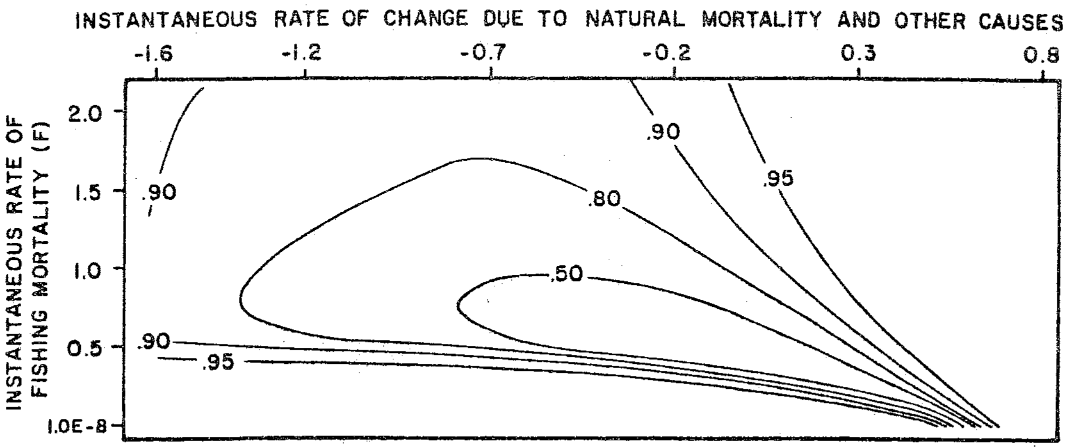

Figure 5. Confidence belts (approximate) for northwest Atlantic swordfish mortality rates.

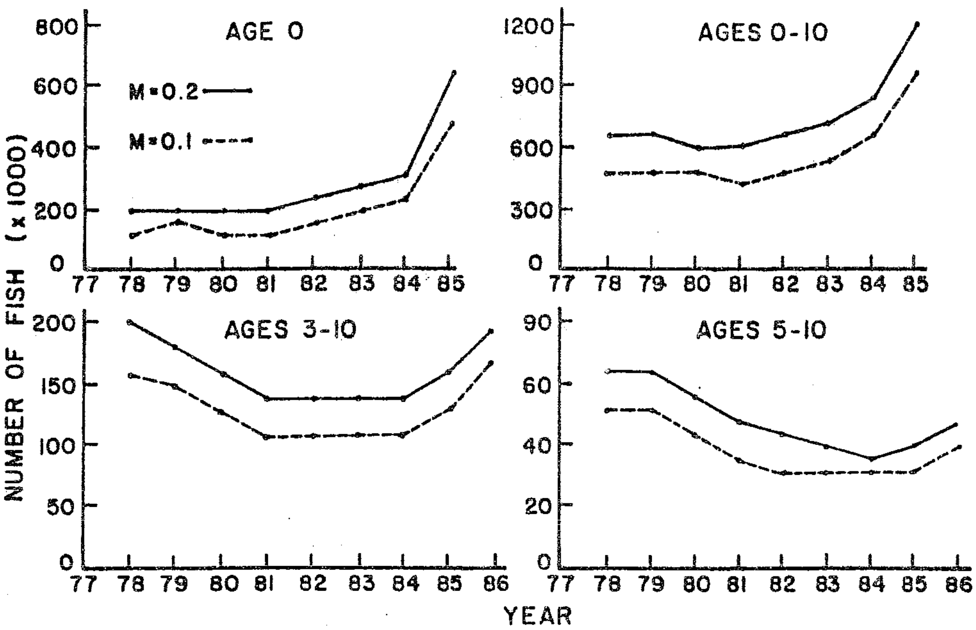

Figure 6. Stock size estimates.

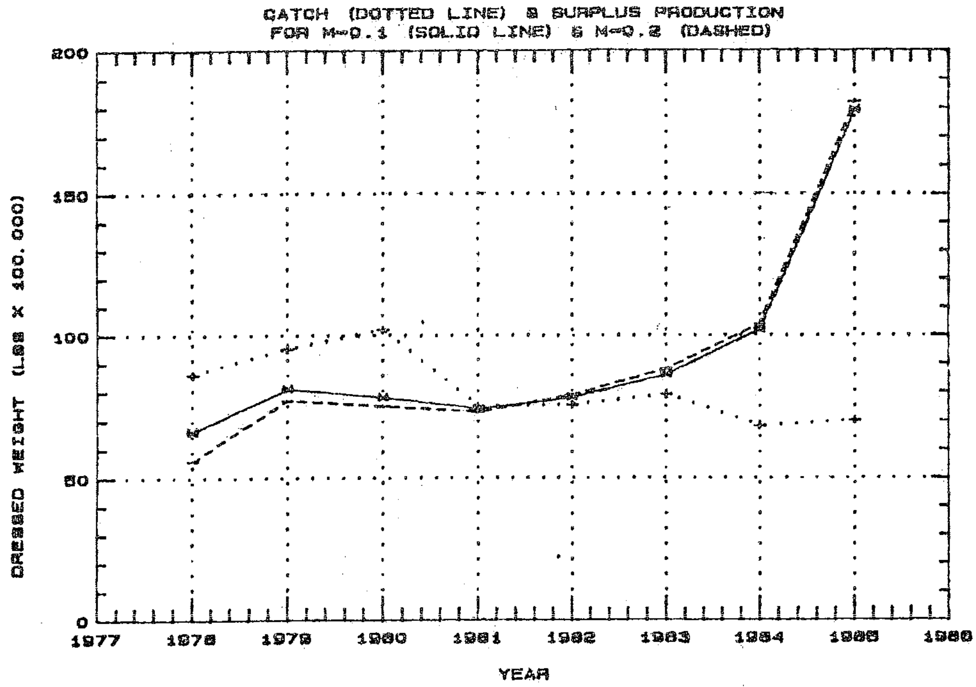

Figure 7. Yield and surplus production of Northwest Atlantic swordfish.

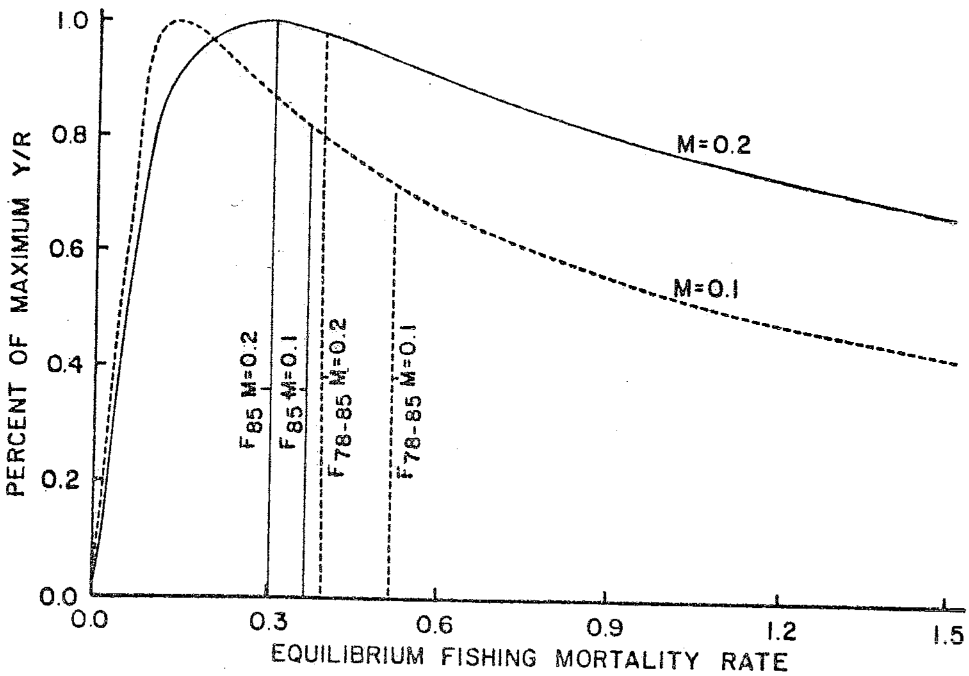

Figure 8. Relative yield-per-recruit for swordfish using natural mortality rates (M) of 0.1 and 0.2 and assuming the partial recruitment vector used in the VPA and a growth rate for large fish (over 205 lb) of 35 lb per year.

Appendix 1

SWORDFISH WORKSHOP PARTICIPANTS

APRIL 16-25, 1986

Dates	Participants
16-25	John Pope, Fisheries Laboratory, Lowestoft Suffolk, United Kingdom
21-24	Gordon Broadhead, Living Marine Resources, San Diego, CA
21-25	Tim Smith, Northeast Fisheries Center, Woods Hole, MA
21-25	Peter Miyake, ICCAT, Madrid, Spain
16-18	Nelson Ehrhart, University of Miami, Miami, FL
16-18	Mike Sissenwine, Northeast Fisheries Center, Woods Hole, MA
16-25	Steve Berkeley, South Atlantic Fishery Management Council, Charleston, SC
16	Bruce Freeman, Mid-Atlantic Fishery Management Council, Dover, DE
16	Thomas Hoff, Mid-Atlantic Fishery Management Council, Dover, DE
16-25	Doug Gregory, Gulf of Mexico Fishery Management Council, Tampa, FL
16-18	Darryl Christensen, Northeast Fisheries Center, Woods Hole, MA
16-17	Miguel Rolon, Caribbean Fishery Management Council, St. Thomas, U.S. Virgin Islands
16-17	Ileana Clavijo, Caribbean Fishery Management Council, St. Thomas, U.S. Virgin Islands
16-25	Mike Parrack, Southeast Fisheries Center, Miami, FL
16-25	Ray Conser, Southeast Fisheries Center, Miami, FL
*	Walter Nelson, Southeast Fisheries Center, Miami, FL
17-23	Patty Phares, Southeast Fisheries Center, Miami, FL
16-25	George Darcy, Southeast Fisheries Center, Miami, FL
*	Brad Brown, Southeast Fisheries Center, Miami, FL
16-25	Ed Gaw, Southeast Fisheries Center, Miami, FL
16-22	Ed Scott, Southeast Fisheries Center, Miami, FL
17-24	Dennis Lee, Southeast Fisheries Center, Miami, FL
16	Wayne Witzell, Southeast Fisheries Center, Miami, FL
*	Joe Powers, Southeast Fisheries Center, Miami, FL
23-24	Eric Prince, Southeast Fisheries Center, Miami, FL
16-25	Steve Turner, Southeast Fisheries Center, Miami, FL
16-25	John Hoey, Southeast Fisheries Center, Miami, FL
23-24	Nancie Cummings, Southeast Fisheries Center, Miami, FL
16-23	Mark Farber, Southeast Fisheries Center, Miami, FL
16-25	Larry L. Massey, Southeast Fisheries Center, Miami, FL

* Intermittent

Appendix 1 (cont.)

Workshop Participants

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Trenton, NJ 08625

AGENDA

USA National Marine Fisheries Service Swordfish Workshop
April 16-25, 1986
Miami Laboratory, 75 Virginia Beach Drive
Miami, Florida

1. Opening of the Meeting
2. Adoption of Agenda
3. Stock Structure
   a. mark-recapture data
   b. geographical distribution of longline CPUE
4. Growth as it Pertains to Estimation of Age Compositions of Catches
   a. a review of mark-recapture data
   b. a review of hard part ageing studies
   c. methods of establishing age from size
      1) consideration of sexual dimorphism
      2) form of the age-size relationships
      3) method of parameter estimation
5. Catches and Size-sex Frequency Samples
   a. review of reported landings
   b. magnitude of discarding at sea
   c. review of the availibility of size samples
   d. review of the available sex ratio samples (if pertinent)
   e. review of length-weight conversions
6. Estimation of Numbers Caught at Size (and Sex if Appropriate)
   a. substitutions
   b. calculation methods
7. Procedure for Estimation of Age Distribution of Catches
8. Indicies of Abundance
   a. CPUE from U.S.A. vessel logbooks
   b. CPUE from U.S.A. trip sheets
   c. CPUE from Japanese longline observer data in the U.S.A. FCZ
   d. CPUE from the highseas Japanese longline fishery
   e. Other possible indices including use of mark-recapture data
9. Virtual Population Analysis
   a. partial recruitment vector estimation
   b. calibration of stocksize and F calculations
   c. trends in stocksize and spawning stock biomass
   d. estimation of 1986 surplus production (if appropriate)
   e. yield per recruit considerations
10. Review of Workshop Report
11. Adjournment

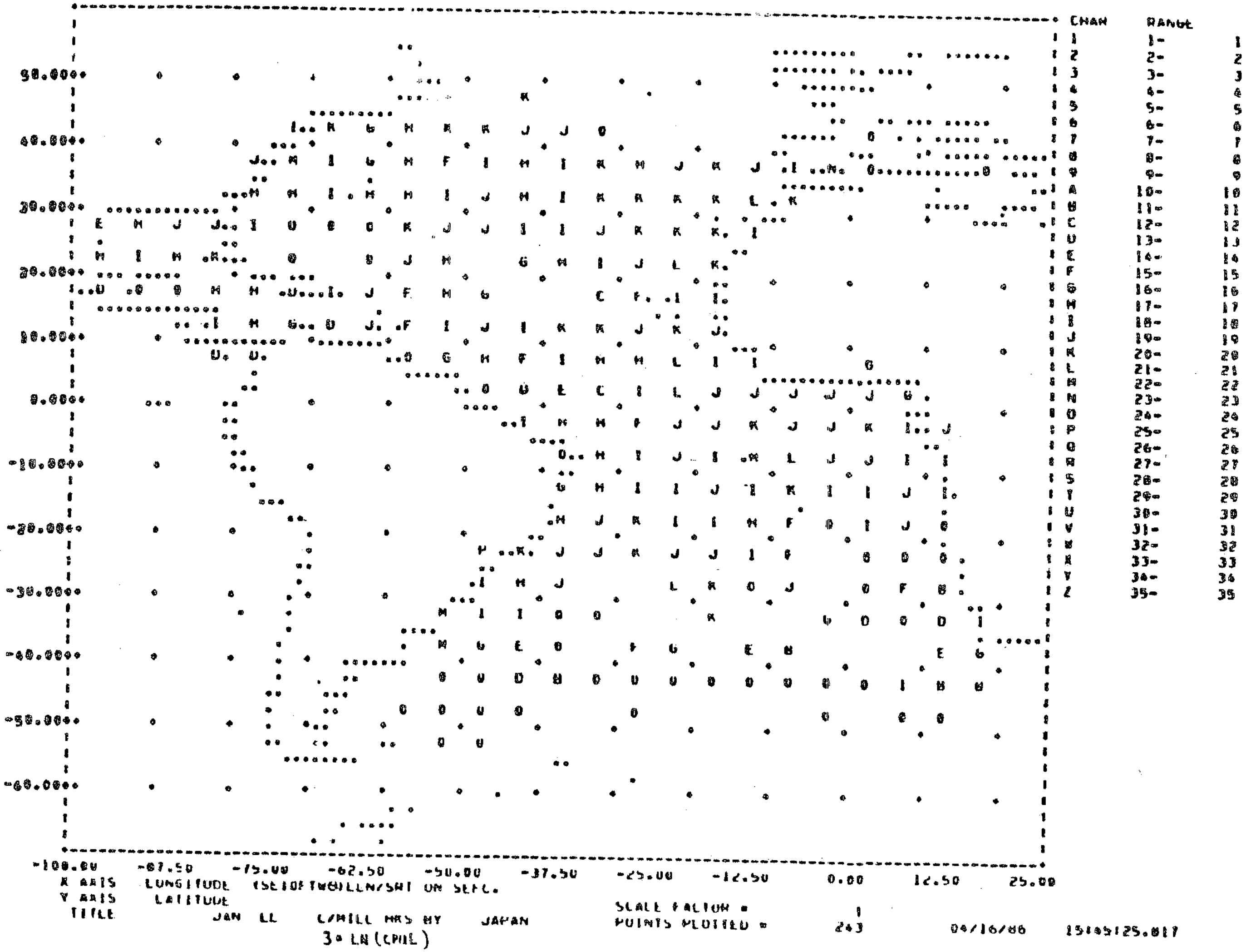
APPENDIX 1 (cont.)

DOCUMENT NUMBER	TITLE	AUTHOR
86/1	Swordfish Catch Per Unit Effort (CPUE) Trends in the Northwest Atlantic Based on Japanese Longline Data	Mark I. Farber
86/2	Swordfish Growth Analysis From Mark-Recapture Observations	Michael L. Parrack
86/3	Distribution Plots of Japanese Longline Data, 1957-1983, for Swordfish	Mark I. Farber
86/4	Further Examination of the Marginal Increments Observed by Berkeley and Houde in Cross Sections of Anal Spines From Swordfish	Stephen Turner
86/5	Determination of Marginal Increment Ratios from Berkeley and Houde Swordfish Ageing Data Using Anal Fin Spine Sections	Mark I. Farber
86/6	User's Guide for Running the Canadian APL Programs for Stock Assessment on the SEFC IBM PC's	Ray Conser Thomas Chewning
86/7	Estimating Partial Recruitment from Catch at Age Data	Ray Conser
86/8	Catch Per Trip Indices of Abundance for West Atlantic Swordfish	Michael L. Parrack
86/9	CPUE Trends from Set Records of United States Directed Swordfish Effort	John J. Hoey
86/10	A Review of Sex-Ratio Size Data for Western North Atlantic Swordfish	John J. Hoey
86/11	Length to Weight and Weight to Length Conversions for Swordfish in the Western North Atlantic and Gulf of Mexico	Stephen Turner

APPENDIX 2

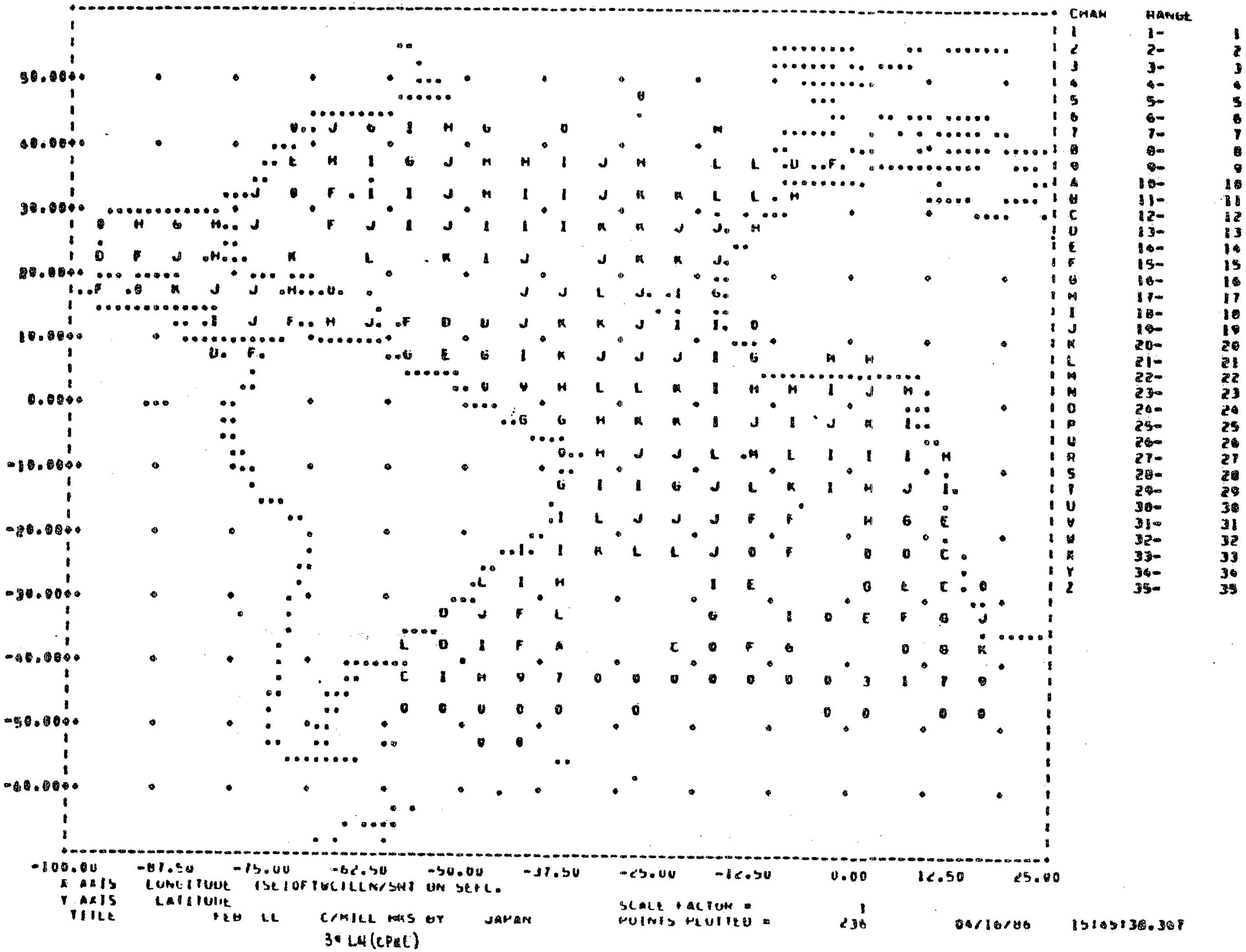
Japanese longline swordfish CPUE, 1957-58 combined

January



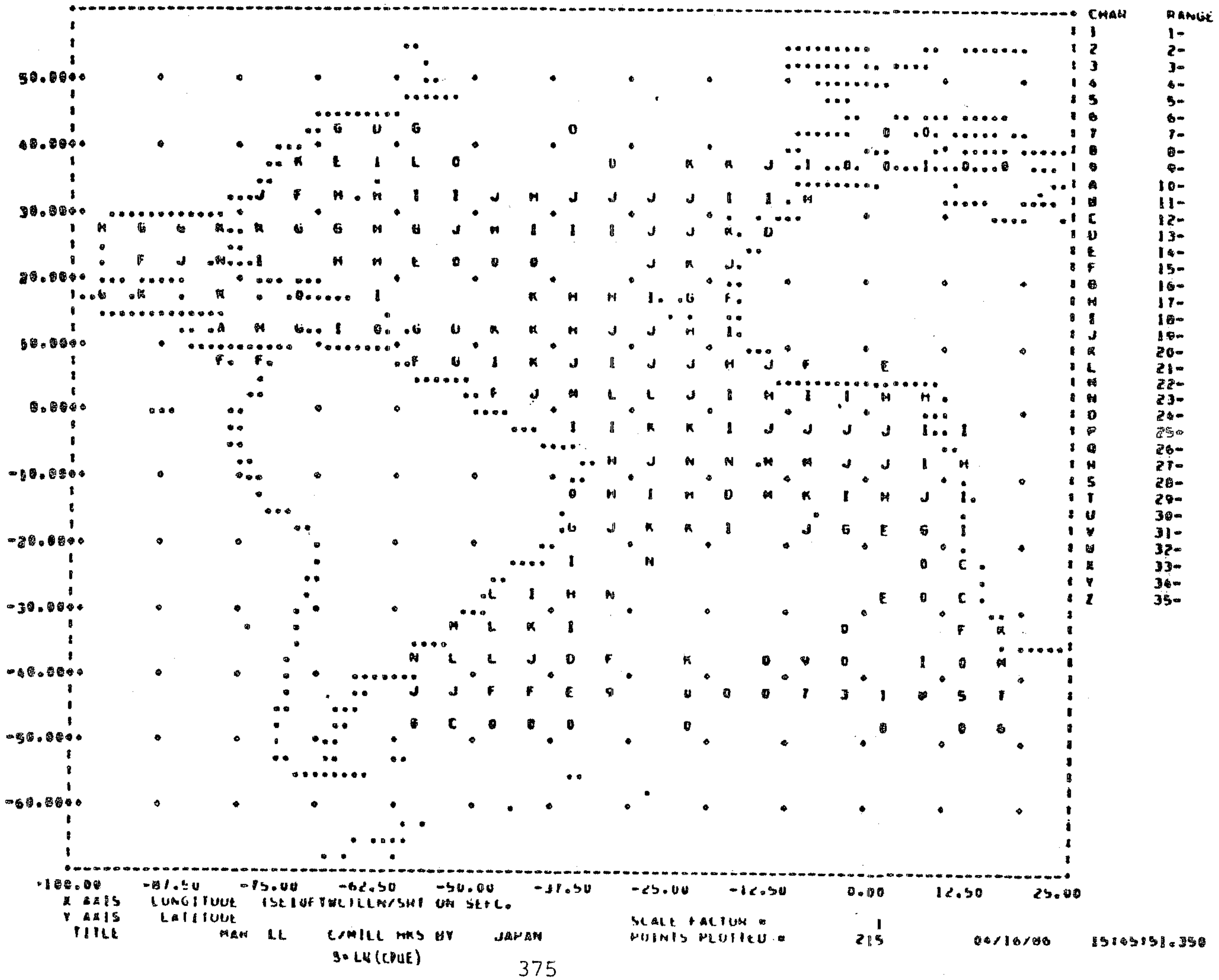
APPENDIX 2 (cont.)

February



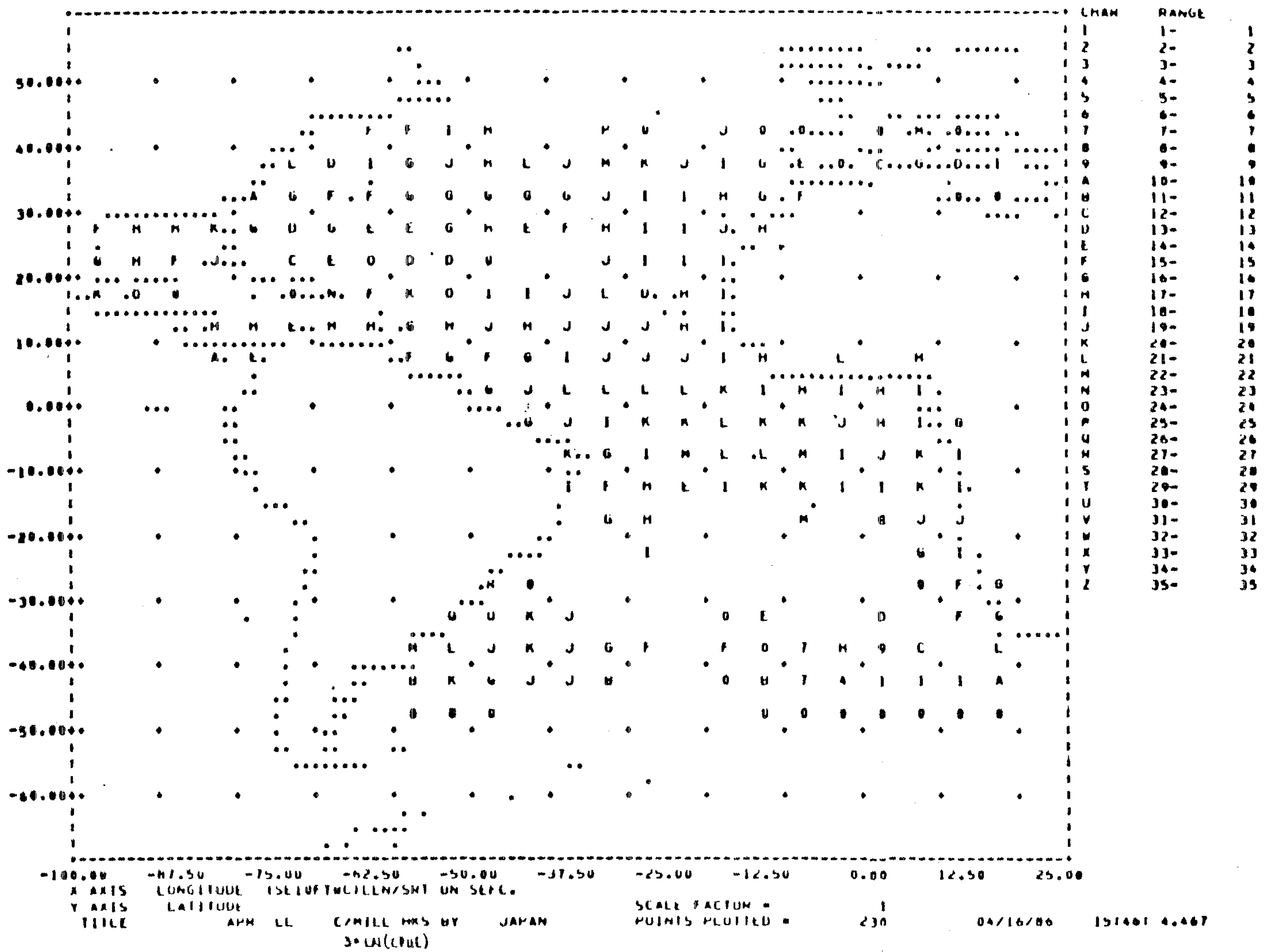
APPENDIX 2 (cont.)

March

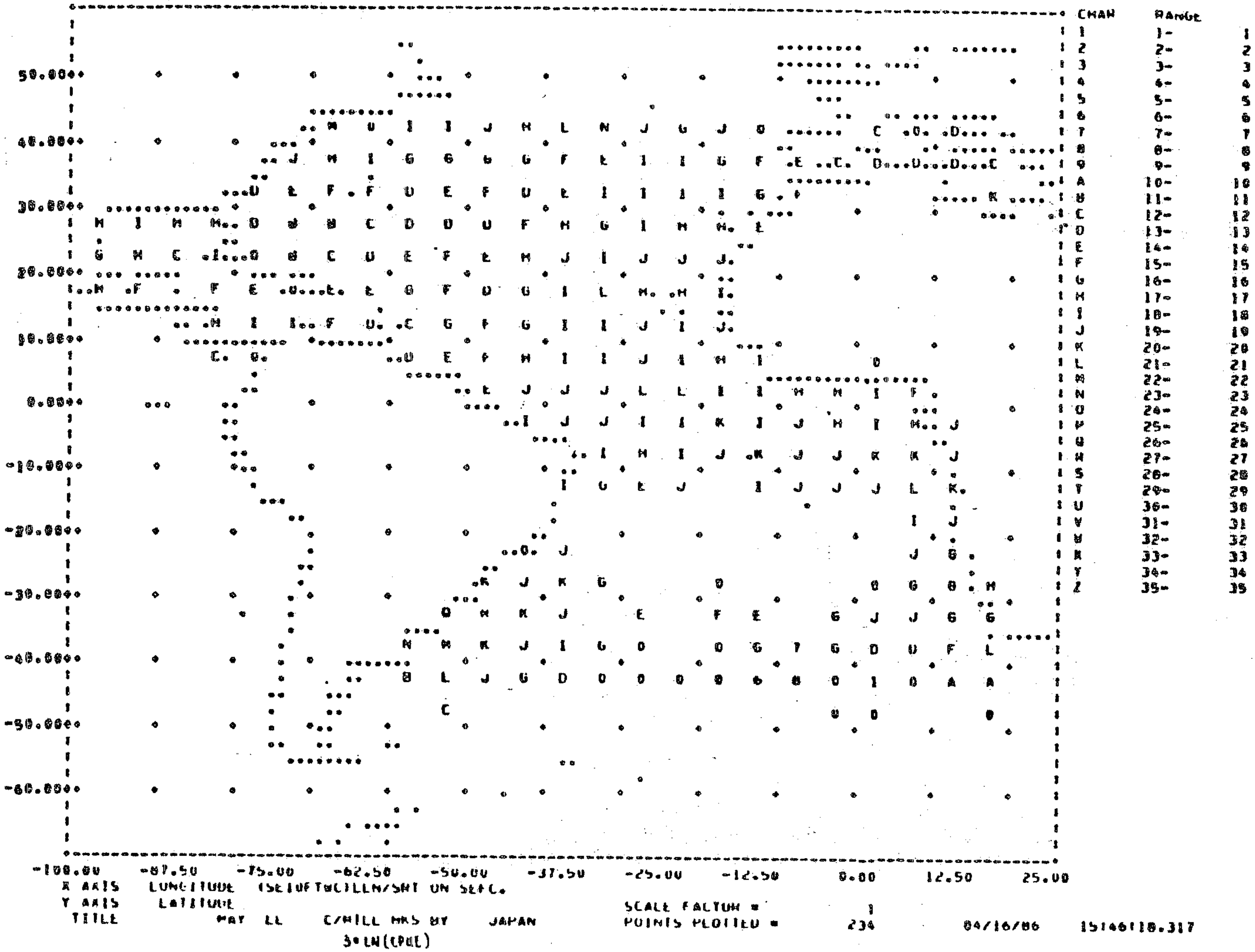


APPENDIX 2 (cont.)

April



May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30.00
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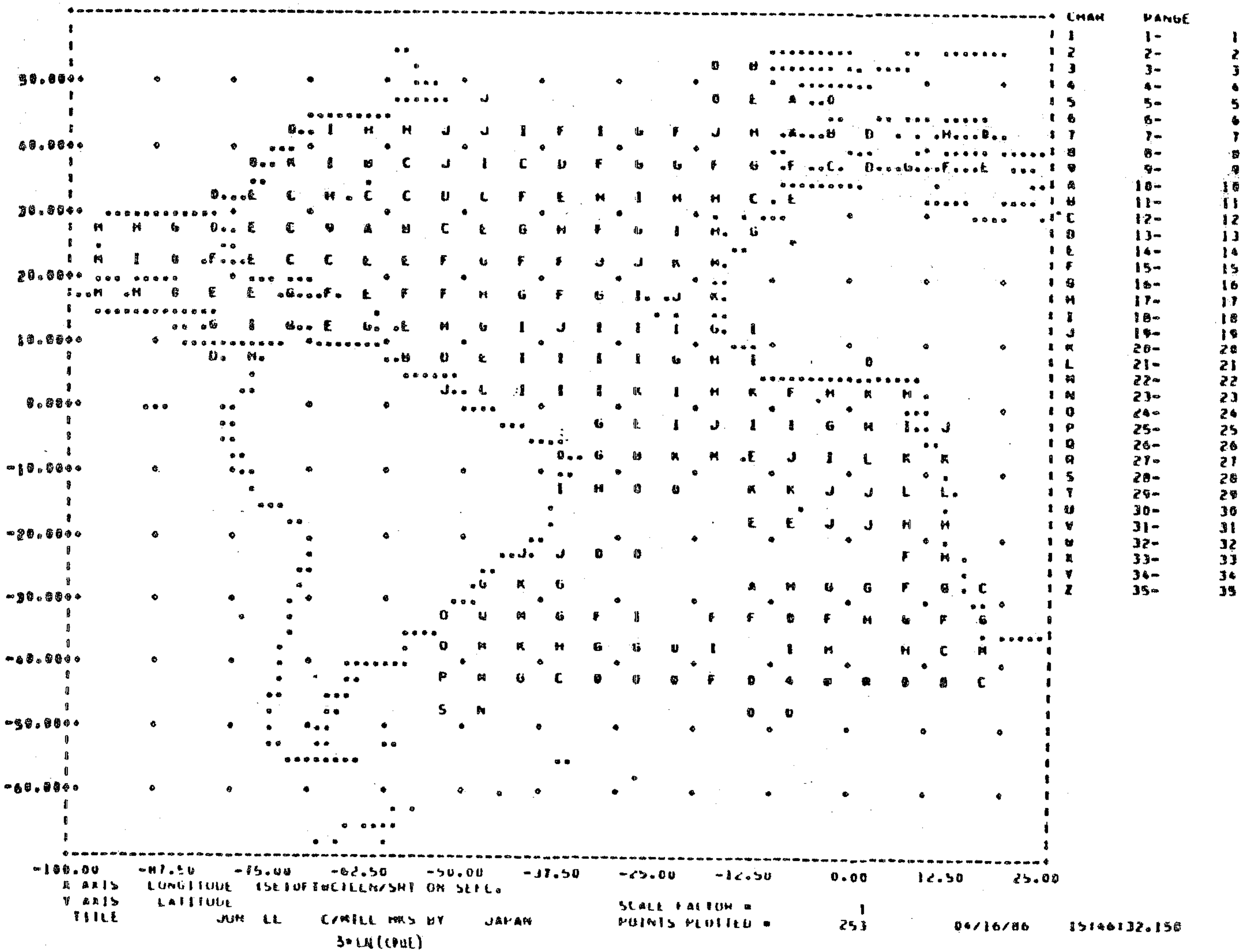
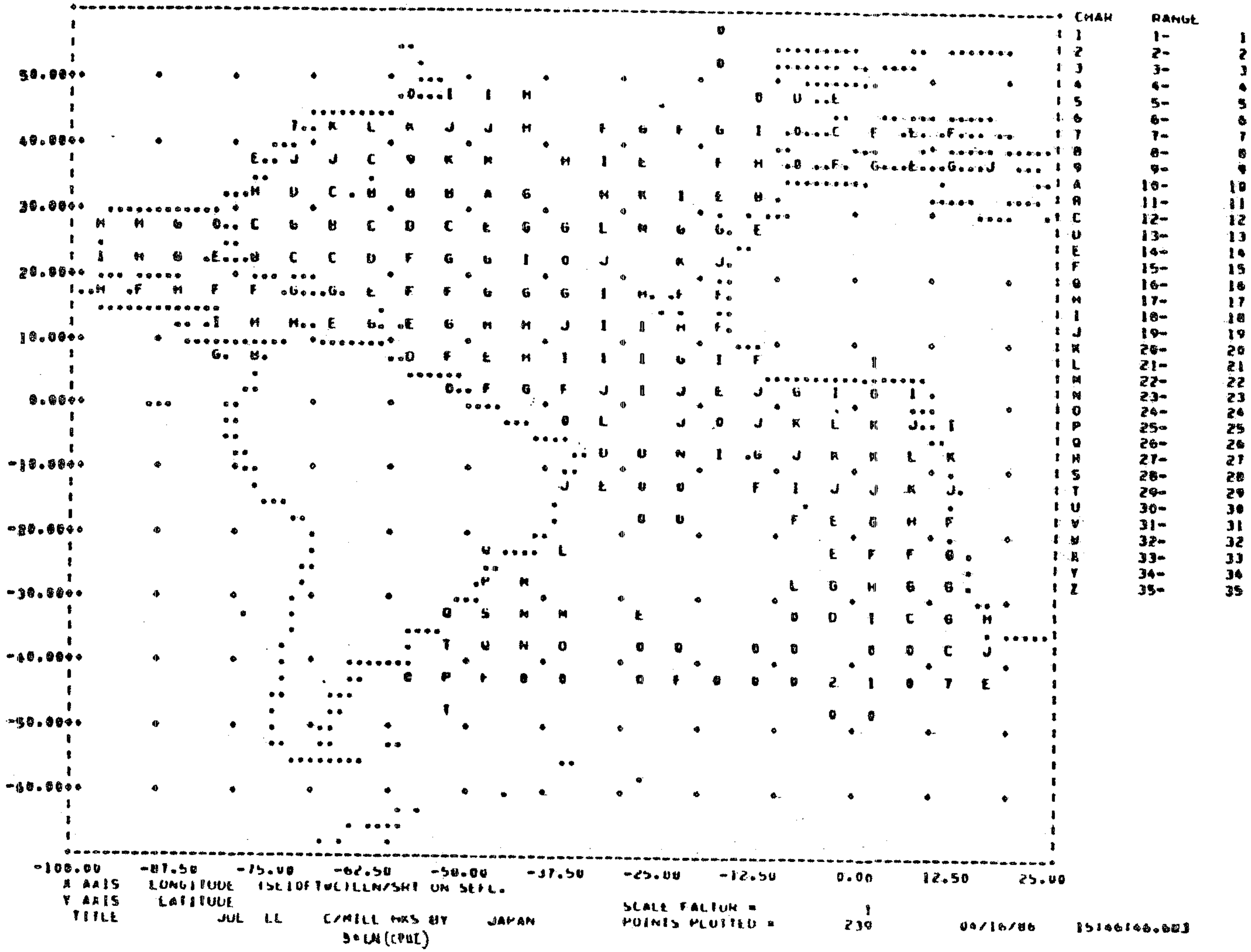
-75.00
-62.50
-50.00
-37.50
-25.00
-12.50
0.00
12.50
25.00
X AXIS LONGITUDE
Y AXIS LATITUDE
TITLE MAY LL C/HILL HRS BY JAPAN
3*LN(CPUE)
SCALE FACTOR = 1
POINTS PLOTTED = 234
04/16/86

APPENDIX 2 (cont.)

June



July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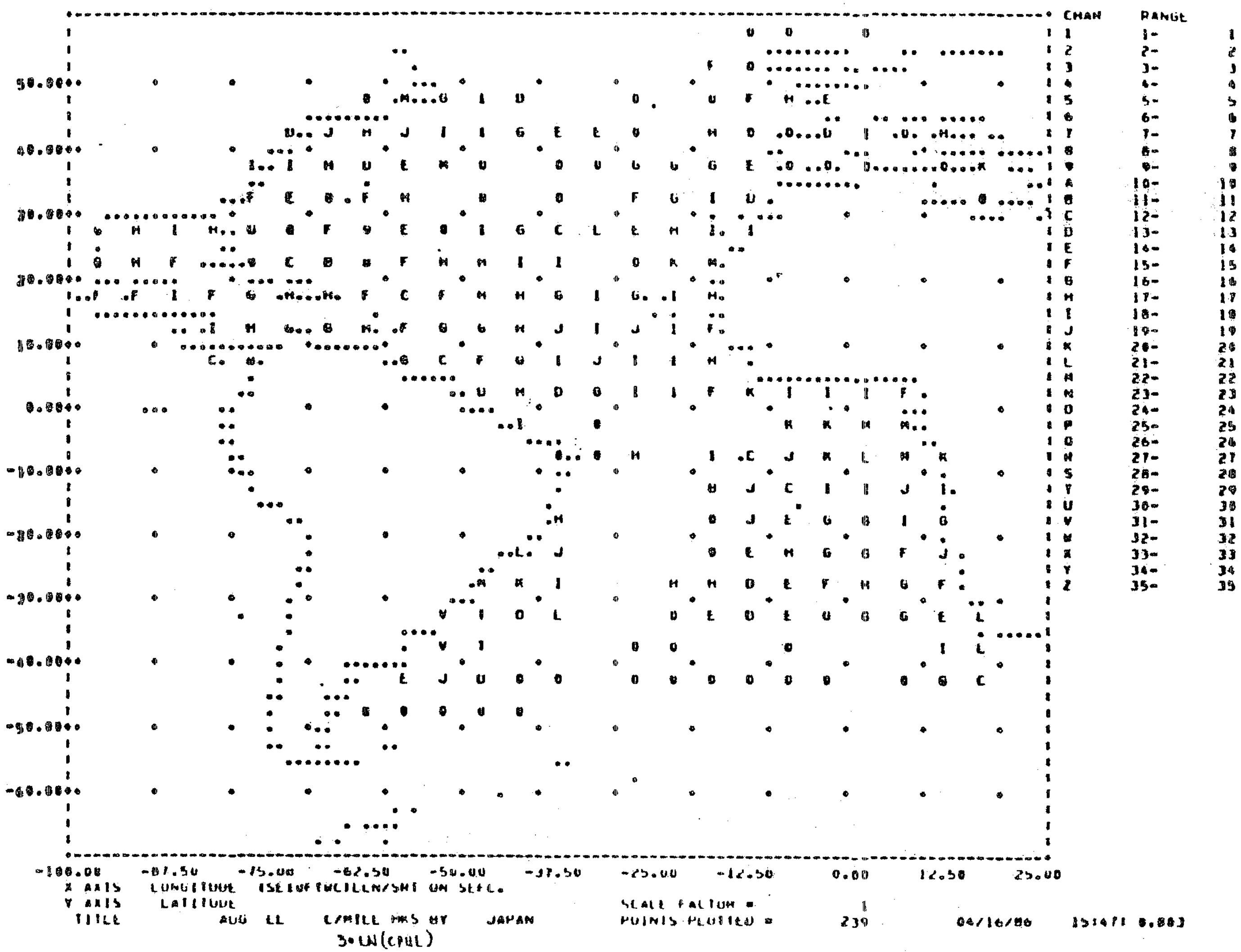
X AXIS LONGITUDE
Y AXIS LATITUDE
TITLE JUL
JAPAN
SCALE FACTOR = 1
POINTS PLOTTED = 239
04/16/86

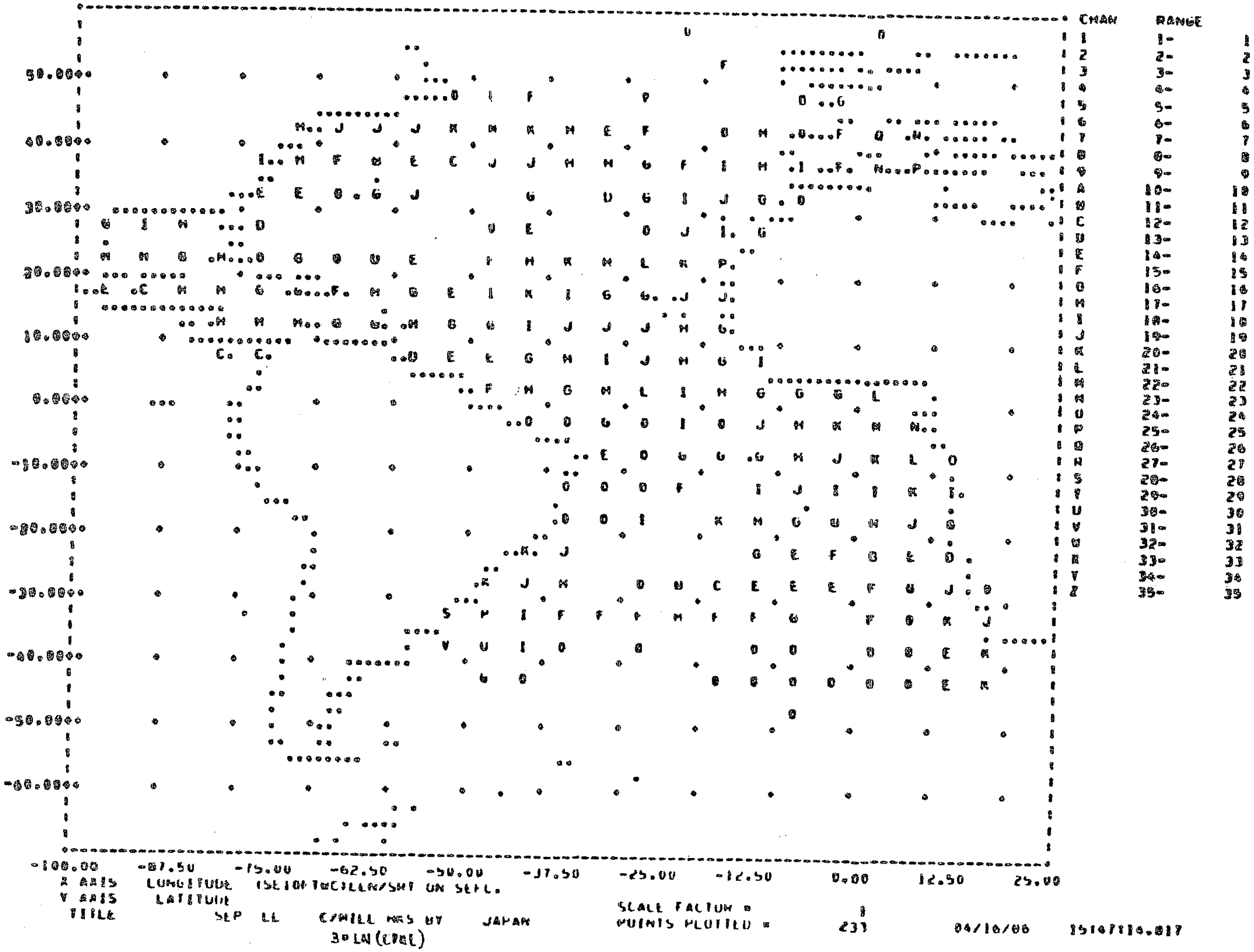
APPENDIX 2 (cont.)

August



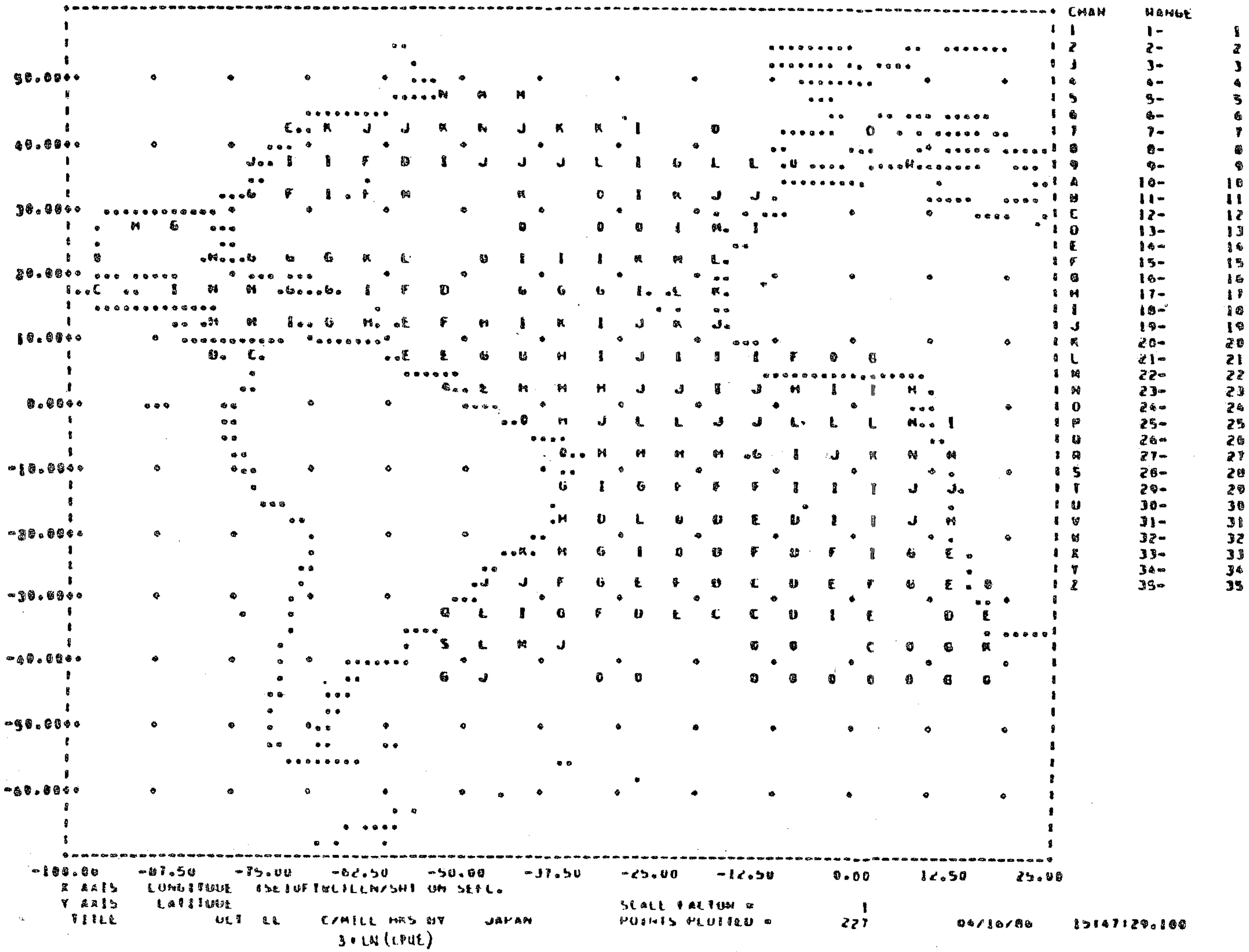
APPENDIX 2 (cont.)

September

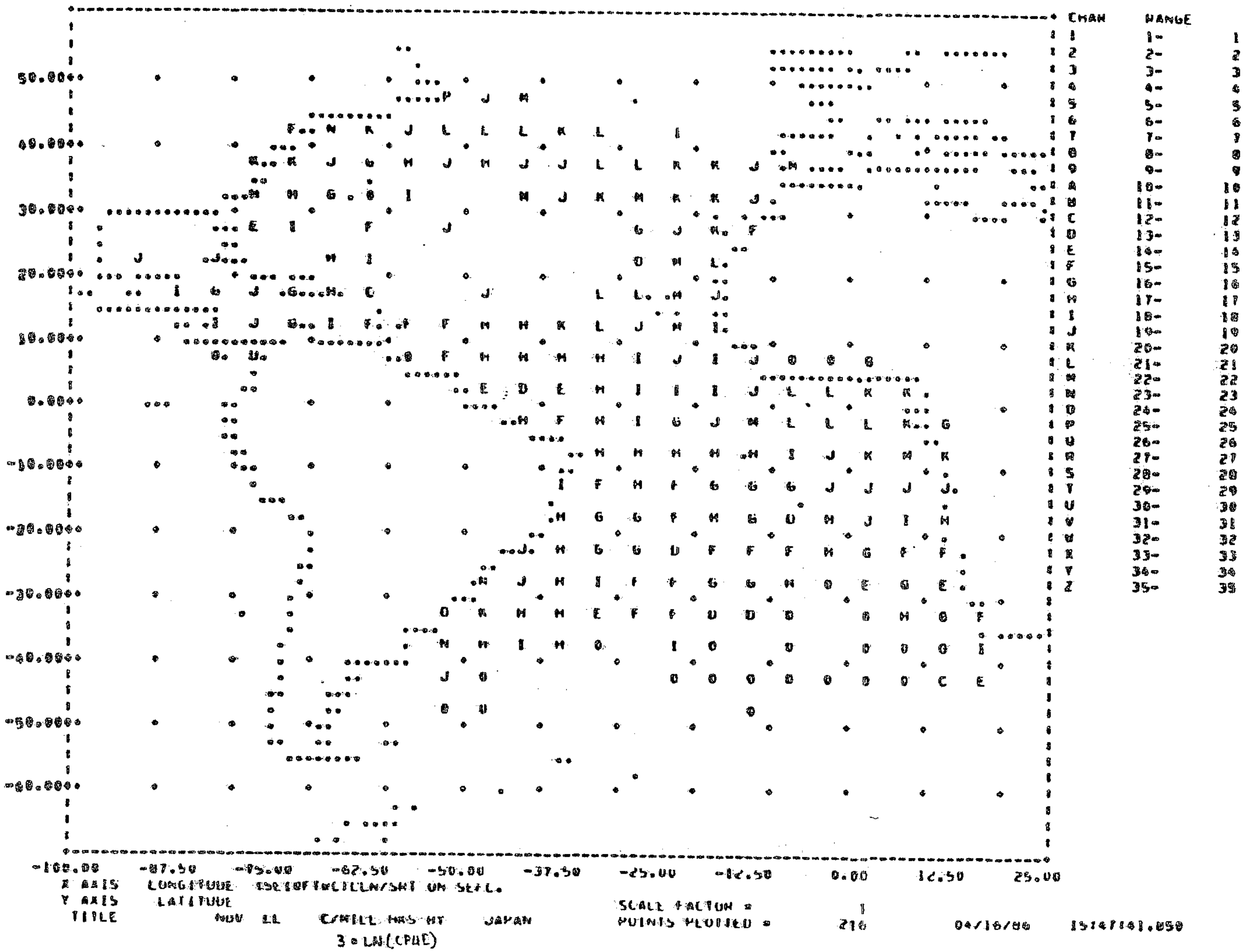


APPENDIX 2 (cont.)

October



November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-50.00
-37.50
-25.00
-12.50
0.00
12.50
25.00
X AXIS LONGITUDE
Y AXIS LATITUDE
TITLE
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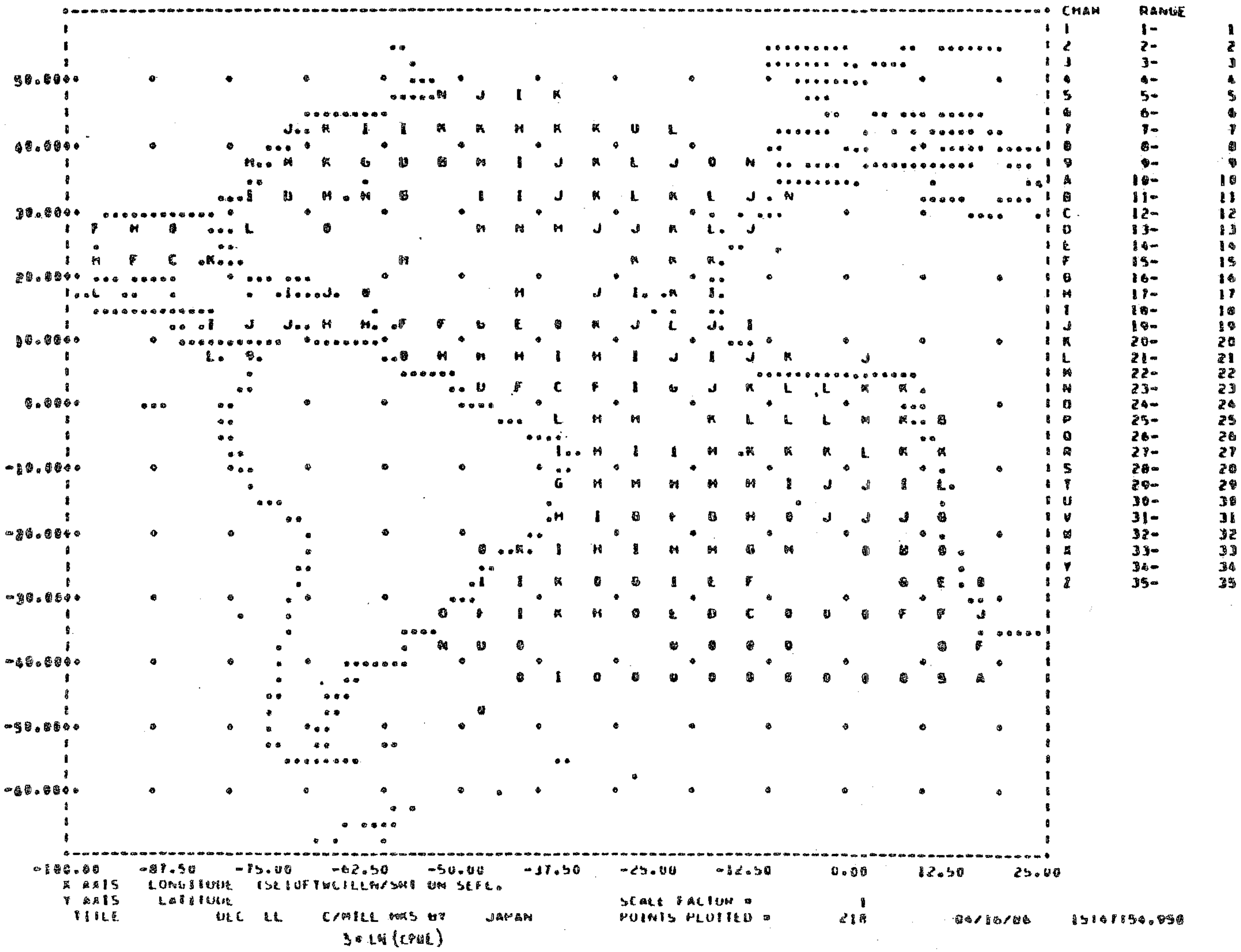
SCALE FACTOR = 1
POINTS PLOTTED = 216
3 = LN(CPUE)

APPENDIX 2 (cont.)

December



Appendix 3. Estimated numbers caught annually by intervals of one lb dressed weight.

WT	78	79	80	81	82	83	84	85
3	0	3	4	0	19	0	9	3
4	0	16	23	10	21	28	29	16
5	0	31	54	17	87	48	102	72
6	2	119	134	58	148	115	149	117
7	18	32	189	112	219	125	160	176
8	15	62	165	156	191	254	205	338
9	23	60	276	243	312	253	245	354
10	30	104	388	278	403	569	388	592
11	19	98	428	323	444	495	464	428
12	9	111	539	390	531	671	495	785
13	61	142	723	420	561	748	576	691
14	74	185	815	522	753	988	716	698
15	141	229	728	468	642	1175	855	905
16	273	274	932	538	836	1331	844	993
17	119	268	1021	498	1048	1153	1071	1073
18	176	349	1079	553	1132	1395	1134	1085
19	318	350	1254	485	1082	1260	1119	1244
20	462	453	1167	571	1245	1362	1184	1396
21	333	378	1236	598	1197	1278	1288	1347
22	314	425	1300	546	1193	1174	1282	1390
23	361	415	1358	585	1100	1251	1344	1356
24	335	478	1377	550	1034	1251	1367	1299
25	480	669	1468	672	1136	1426	1307	1293
26	417	602	1349	641	1143	1376	1591	1303
27	368	627	1189	698	1064	1210	1288	1130
28	413	584	1237	616	995	1260	1276	1246
29	329	739	1358	684	943	1279	1499	1104
30	579	804	1382	757	1023	1202	1411	1179
31	316	846	1252	724	939	1494	1403	1195
32	387	647	1158	626	852	1244	1179	1014
33	417	722	1189	763	932	1187	1236	943
34	406	688	1359	771	875	1078	1280	1104
35	513	798	1229	851	862	1116	1325	951
36	531	716	1261	809	866	1232	1313	1028
37	669	541	1237	776	748	1024	1147	1013
38	419	588	1150	898	798	1051	1126	1072
39	409	564	1196	942	847	968	1261	940
40	572	691	1276	948	879	965	1381	965
41	478	601	1159	759	836	957	1188	927
42	686	693	1231	826	851	1002	1176	966
43	497	629	1260	846	951	826	1108	879
44	581	565	1230	788	845	778	1083	1076
45	499	585	1315	851	942	865	1009	908
46	597	545	1243	894	866	733	1065	931
47	503	501	982	878	944	657	1044	913
48	696	693	1158	914	969	808	992	1043
49	741	376	1074	764	736	862	921	858
50	829	952	1871	1160	1027	936	1240	1008
51	743	559	1053	743	761	735	937	892
52	838	651	1011	880	861	696	958	934
53	863	559	1063	738	770	715	938	913
54	882	602	947	782	892	742	942	881
55	832	527	1091	780	879	768	830	876
56	701	545	898	684	783	570	934	843
57	714	469	750	743	872	635	764	810
58	571	647	1130	746	976	654	903	875
59	730	568	729	610	807	665	787	854
60	1067	622	950	848	970	616	905	880

Appendix 3. (cont.)

61	1270	658	786	572	837	617	799	854
62	795	578	832	702	850	550	717	863
63	730	601	899	705	809	644	847	779
64	923	570	832	643	763	681	746	960
65	997	573	1011	642	845	513	717	942
66	867	539	869	629	790	602	788	828
67	585	440	777	717	719	505	723	824
68	865	620	950	612	782	699	639	772
69	960	475	738	678	776	570	655	704
70	1139	754	985	740	765	625	785	900
71	602	604	769	516	706	485	652	693
72	910	454	758	603	690	407	558	666
73	900	626	807	562	645	578	661	700
74	856	612	906	654	743	546	610	714
75	799	485	917	632	674	446	646	642
76	940	469	751	546	579	483	680	585
77	915	331	606	624	735	493	576	608
78	760	685	836	658	648	679	529	632
79	718	549	548	530	652	504	574	623
80	961	574	934	525	725	652	538	633
81	726	667	706	599	674	575	560	556
82	706	579	734	595	628	451	539	502
83	711	621	691	487	605	507	547	490
84	760	390	713	512	611	548	556	624
85	828	548	825	501	630	482	534	568
86	605	540	529	513	497	487	466	618
87	598	316	537	441	590	419	488	548
88	592	470	683	477	708	493	415	534
89	746	498	703	360	503	438	441	461
90	609	598	761	448	556	560	462	497
91	830	425	662	358	560	404	419	512
92	515	439	631	503	567	446	487	491
93	428	455	649	552	531	543	420	542
94	577	576	677	425	462	550	424	468
95	807	592	693	423	597	518	467	407
96	711	367	521	578	537	526	384	448
97	684	589	566	446	558	578	376	449
98	738	521	567	427	484	457	327	424
99	561	248	299	231	268	162	250	380
100	905	1233	1389	721	997	830	663	547
101	545	558	603	351	393	512	370	436
102	459	457	566	310	405	302	326	402
103	564	404	681	398	505	468	374	468
104	681	268	570	396	363	420	374	430
105	936	406	645	395	455	399	373	406
106	499	585	600	361	411	300	387	354
107	405	487	495	302	448	364	253	431
108	366	448	527	374	378	495	390	397
109	498	420	555	400	603	401	363	374
110	646	507	701	626	418	273	418	394
111	690	426	453	367	406	266	301	411
112	422	578	633	410	478	529	293	288
113	437	270	502	363	434	398	274	293
114	422	498	525	345	359	344	324	341
115	631	642	569	366	410	399	357	305
116	516	415	507	340	323	313	351	349
117	303	594	528	342	366	284	273	296
118	501	396	476	361	296	407	288	288
119	500	468	373	268	290	440	301	263
120	596	468	625	378	406	311	292	282
121	476	503	424	333	313	303	313	253
122	427	536	510	406	392	239	211	272
123	482	494	419	263	271	306	254	308

Appendix 3. (cont.)

124	482	599	415	263	305	328	218	251
125	552	481	471	390	373	194	251	236
126	392	465	487	284	338	377	307	235
127	475	444	471	293	284	355	318	301
128	414	432	449	333	308	244	287	315
129	654	520	420	245	297	345	285	193
130	515	662	537	258	336	311	270	267
131	411	539	399	311	280	353	214	282
132	519	679	483	324	290	352	263	245
133	416	351	372	298	249	248	271	312
134	271	377	324	190	233	249	255	212
135	453	412	392	346	265	373	273	281
136	366	256	338	221	257	302	215	282
137	367	438	467	171	246	415	222	191
138	331	410	297	265	258	300	256	195
139	500	290	334	206	238	236	216	250
140	343	462	560	310	262	344	257	272
141	339	208	298	228	263	313	232	211
142	352	367	329	270	233	276	220	212
143	426	413	411	291	270	310	201	219
144	269	426	467	237	213	261	169	186
145	206	494	266	292	243	257	226	223
146	243	303	253	279	267	323	222	192
147	293	360	425	211	239	243	203	269
148	392	201	280	176	174	199	207	161
149	304	379	273	236	260	247	240	196
150	400	237	457	260	235	196	#198	157
151	206	231	331	245	255	290	132	125
152	327	376	248	224	179	151	186	161
153	321	298	306	174	179	254	164	129
154	429	513	318	156	189	237	185	135
155	416	419	277	250	220	235	188	250
156	221	484	279	184	178	274	164	122
157	268	293	257	194	220	120	149	125
158	162	234	261	168	234	250	183	224
159	325	324	282	139	165	178	204	146
160	239	299	381	259	246	293	188	135
161	320	222	227	165	159	163	144	116
162	251	256	219	243	186	313	157	152
163	302	316	231	192	170	289	157	111
164	228	301	267	174	190	197	127	109
165	360	382	322	206	177	253	152	151
166	182	377	218	301	194	184	161	285
167	173	398	247	213	152	185	124	115
168	218	223	255	199	172	210	155	149
169	201	243	226	194	175	234	150	137
170	151	320	208	190	186	189	111	118
171	162	287	248	206	123	210	159	146
172	220	239	250	148	108	215	129	96
173	226	245	235	199	130	196	187	124
174	169	178	338	256	112	97	116	115
175	259	432	251	188	211	271	157	140
176	213	238	178	187	173	140	147	113
177	299	230	244	146	133	148	99	102
178	243	187	247	199	132	140	152	168
179	100	177	177	115	138	167	165	86
180	186	264	280	135	187	244	160	200
181	137	239	208	134	160	170	139	88
182	275	227	155	106	97	225	125	108
183	103	203	247	141	103	165	117	165
184	177	315	284	203	169	96	110	101
185	251	200	277	174	136	238	110	146
186	192	223	270	153	167	204	84	68

Appendix 3. (cont.)

187	148	161	182	171	112	245	91	98
188	115	222	126	162	93	120	105	109
189	192	307	174	164	100	114	112	65
190	232	251	213	183	129	124	143	95
191	154	248	93	119	95	124	93	139
192	136	191	196	85	108	67	95	87
193	126	281	143	135	104	202	137	111
194	27	157	188	137	112	186	103	62
195	205	323	185	137	90	97	99	128
196	165	134	194	118	100	138	115	105
197	160	391	245	124	86	138	78	53
198	248	195	162	138	107	97	90	119
199	93	154	97	121	77	86	107	118
200	232	161	267	205	171	150	119	131
201	59	179	123	113	67	140	42	85
202	152	235	135	175	101	104	83	43
203	83	156	164	102	131	178	58	64
204	56	124	115	167	64	74	45	99
205	104	207	189	146	99	136	71	95
206	38	105	189	144	74	105	50	74
207	44	119	155	134	98	127	60	137
208	120	205	124	110	101	147	97	95
209	108	185	142	110	114	93	46	42
210	165	365	177	132	125	145	80	60
211	64	108	201	122	83	79	99	30
212	53	216	129	126	114	74	76	60
213	119	152	93	150	75	114	66	51
214	184	165	120	60	97	133	36	78
215	172	108	211	117	111	177	60	47
216	141	124	120	111	60	77	65	57
217	122	242	170	99	73	52	75	47
218	148	205	142	86	70	108	70	61
219	122	129	116	114	98	76	60	54
220	254	183	181	98	119	82	71	68
221	140	232	116	118	104	162	71	53
222	46	262	168	87	109	61	43	89
223	76	294	146	89	120	73	56	81
224	75	149	160	85	91	84	54	93
225	121	148	94	116	70	66	74	31
226	97	219	141	77	67	64	79	44
227	53	85	138	84	81	111	89	99
228	73	148	93	104	47	66	69	86
229	34	156	86	121	91	130	69	55
230	49	108	115	96	83	153	59	81
231	2	115	70	116	96	79	48	41
232	88	160	102	112	68	122	41	53
233	69	168	81	62	74	48	55	43
234	85	97	90	89	78	74	31	32
235	42	106	117	82	81	54	65	55
236	77	62	98	85	69	175	39	42
237	77	278	155	53	67	94	48	34
238	81	191	134	89	80	27	39	37
239	136	128	69	91	68	60	34	46
240	129	154	158	83	102	82	73	95
241	98	198	71	84	38	99	38	81
242	82	127	93	102	48	53	50	38
243	83	190	104	78	48	124	59	22
244	23	58	57	60	63	129	28	25
245	118	225	146	115	74	66	38	38
246	66	179	54	97	65	73	29	38
247	85	109	106	94	65	84	43	27
248	40	85	64	44	44	36	34	47
249	62	27	31	72	48	92	16	35

Appendix 3. (cont.)

250	85	250	97	86	51	62	55	51
251	43	67	114	59	61	61	55	82
252	62	103	109	104	73	105	54	30
253	119	206	96	109	65	94	20	92
254	38	77	80	76	71	55	66	74
255	143	175	88	89	71	60	64	48
256	33	178	91	100	62	63	25	38
257	35	183	32	62	37	81	39	36
258	21	83	72	71	56	50	29	27
259	16	37	53	53	55	62	21	17
260	168	118	146	139	64	36	26	35
261	86	133	79	45	26	64	46	21
262	11	31	78	58	41	66	41	58
263	15	84	38	50	73	164	25	24
264	2	140	71	82	42	43	25	36
265	34	189	68	116	57	33	32	88
266	135	137	53	41	68	54	33	33
267	4	72	61	67	37	69	28	20
268	74	208	137	57	33	31	28	29
269	31	183	73	49	36	48	15	10
270	49	235	113	78	68	49	31	26
271	51	182	45	49	44	90	51	55
272	5	89	52	53	64	118	22	36
273	73	117	92	70	35	51	24	18
274	41	241	75	75	32	23	20	10
275	113	77	88	38	54	81	28	19
276	14	70	34	56	31	24	16	18
277	126	84	37	54	35	102	23	38
278	29	87	58	40	26	53	13	20
279	14	59	52	28	39	47	37	21
280	87	204	107	45	48	35	33	66
281	84	77	98	70	57	31	27	31
282	44	133	62	73	37	19	8	10
283	26	100	18	57	53	36	20	24
284	1	131	37	46	32	64	24	27
285	52	91	44	40	24	40	21	26
286	23	97	31	42	43	18	33	11
287	70	118	83	50	17	51	21	16
288	40	59	47	65	56	21	6	0
289	52	47	27	69	44	15	27	33
290	39	71	40	30	35	41	15	20
291	19	90	44	66	43	29	23	10
292	0	20	24	36	32	56	18	92
293	15	49	25	35	26	25	27	28
294	8	41	41	62	23	90	13	21
295	27	113	31	33	59	42	20	13
296	21	49	39	95	52	14	28	8
297	31	42	62	59	28	94	19	21
298	68	20	29	44	28	23	38	24
299	16	58	14	25	31	25	18	12
300	96	133	86	30	38	56	42	33
301	46	72	60	56	26	12	11	8
302	28	77	41	41	35	107	14	20
303	65	88	24	29	23	43	34	72
304	0	52	31	24	20	41	18	17
305	0	99	37	55	21	50	15	15
306	38	68	56	46	42	50	32	50
307	27	132	44	24	17	32	11	57
308	5	108	37	36	37	18	19	12
309	91	84	62	60	50	56	33	11
310	56	74	80	67	41	49	33	33
311	3	19	41	55	26	18	7	6
312	0	21	24	67	29	43	29	20

Appendix 3. (cont.)

313	0	37	42	42	20	11	7	17
314	45	61	72	17	41	21	22	7
315	43	135	38	27	21	25	16	24
316	70	43	29	21	21	19	22	13
317	14	20	35	35	22	15	8	20
318	2	48	31	27	29	9	30	16
319	20	17	30	29	16	28	14	12
320	59	69	54	40	46	31	7	37
321	35	90	60	62	27	19	25	15
322	42	158	44	31	30	79	16	9
323	15	7	8	32	29	40	13	13
324	24	38	17	55	29	23	11	6
325	43	107	35	46	28	19	21	56
326	32	46	51	45	23	19	9	4
327	22	47	33	13	15	20	17	5
328	36	11	19	20	23	7	9	11
329	15	59	34	17	31	27	16	9
330	0	91	24	48	31	39	14	13
331	53	53	39	10	17	44	11	9
332	0	47	30	10	26	47	15	3
333	15	16	31	12	22	19	20	49
334	3	12	8	49	17	13	11	3
335	11	17	24	14	10	27	16	9
336	17	68	26	27	21	14	10	1
337	81	70	16	27	21	51	36	46
338	5	11	20	17	13	30	31	54
339	24	81	25	24	23	17	17	25
340	24	13	20	21	7	20	20	47
341	0	10	13	39	18	18	11	46
342	1	11	41	21	17	6	3	6
343	8	11	3	44	18	22	14	7
344	16	11	26	6	8	10	28	12
345	64	77	30	47	33	20	19	6
346	0	14	12	25	32	10	13	16
347	30	54	43	5	15	6	4	6
348	18	24	25	47	16	15	18	7
349	15	61	33	18	17	7	4	4
350	15	79	42	16	21	6	25	7
351	20	47	7	22	17	22	8	8
352	0	49	25	14	20	8	7	9
353	3	45	9	17	26	15	9	3
354	33	80	56	25	9	13	7	19
355	13	10	13	23	11	8	5	19
356	12	49	7	42	10	9	7	3
357	11	20	11	26	30	32	9	6
358	16	20	14	13	16	24	8	22
359	0	5	17	19	7	12	5	14
360	0	16	17	42	18	12	17	7
361	0	45	14	37	19	14	6	3
362	15	23	21	46	16	8	4	6
363	0	7	7	21	17	5	7	20
364	6	10	2	4	12	10	5	6
365	11	58	5	21	4	26	10	12
366	57	29	32	7	12	8	11	7
367	5	11	12	53	25	4	6	1
368	15	5	19	25	13	59	3	6
369	14	10	0	7	11	7	9	1
370	11	10	12	16	9	7	12	3
371	5	9	13	11	11	11	6	5
372	56	26	16	23	14	4	17	3
373	12	8	5	25	7	21	9	0
374	3	0	17	11	4	12	8	4
375	0	9	21	45	2	6	9	14

Appendix 3. (cont.)

376	2	19	12	8	20	51	13	11
377	0	5	8	19	22	7	5	8
378	0	8	19	21	11	9	11	3
379	1	43	17	27	9	24	21	46
380	23	42	14	21	22	31	9	8
381	5	12	11	40	12	6	2	5
382	1	48	10	10	17	10	4	8
383	0	76	15	9	2	3	0	6
384	21	10	17	6	12	36	0	3
385	5	15	11	23	22	10	9	2
386	44	15	10	8	8	34	7	2
387	14	44	8	9	21	1	7	2
388	5	11	1	6	8	5	5	3
389	0	6	14	5	13	4	17	2
390	0	6	10	12	4	5	12	2
391	0	9	8	12	8	5	1	0
392	0	0	13	11	3	6	5	1
393	1	4	1	7	9	3	4	5
394	0	43	25	6	13	6	3	3
395	5	46	5	3	9	6	3	4
396	14	12	14	14	10	6	14	3
397	11	9	7	5	11	2	10	14
398	0	0	6	11	5	4	1	0
399	18	72	1	2	4	4	1	4
400	26	51	5	10	16	4	1	10
401	0	3	17	23	10	4	4	2
402	1	2	0	8	10	6	2	5
403	0	8	7	12	26	7	6	4
404	0	0	6	7	18	12	1	3
405	15	7	14	6	2	36	5	5
406	16	2	5	17	4	1	8	1
407	0	3	2	11	5	5	11	7
408	0	0	13	0	6	10	2	3
409	0	0	0	5	7	3	10	3
410	14	3	9	8	3	16	21	2
411	0	0	3	3	4	4	6	1
412	1	48	17	7	12	20	7	4
413	0	3	5	16	6	28	10	2
414	0	0	4	3	8	16	2	7
415	12	5	0	12	6	3	5	4
416	0	6	1	9	3	4	18	2
417	22	40	9	6	9	4	1	1
418	0	6	7	13	5	3	1	3
419	0	3	0	1	3	5	4	3
420	0	3	1	3	3	5	0	4
421	0	1	3	2	6	7	13	9
422	0	2	7	18	10	2	1	1
423	0	0	19	0	4	0	7	2
424	0	3	6	3	6	2	1	1
425	1	33	7	1	5	8	2	3
426	0	7	3	9	8	6	6	4
427	3	11	3	8	3	29	3	6
428	0	0	2	1	6	4	3	2
429	0	0	5	7	7	2	2	4
430	0	5	4	5	9	2	2	34
431	14	0	0	14	5	2	1	2
432	26	2	4	1	10	26	5	4
433	0	5	4	2	7	1	1	0
434	0	0	0	5	8	1	3	4
435	0	0	13	2	1	6	4	6
436	0	0	0	2	2	3	2	1
437	0	2	1	1	2	2	3	3
438	0	0	0	1	6	1	0	4

Appendix 3. (cont.)

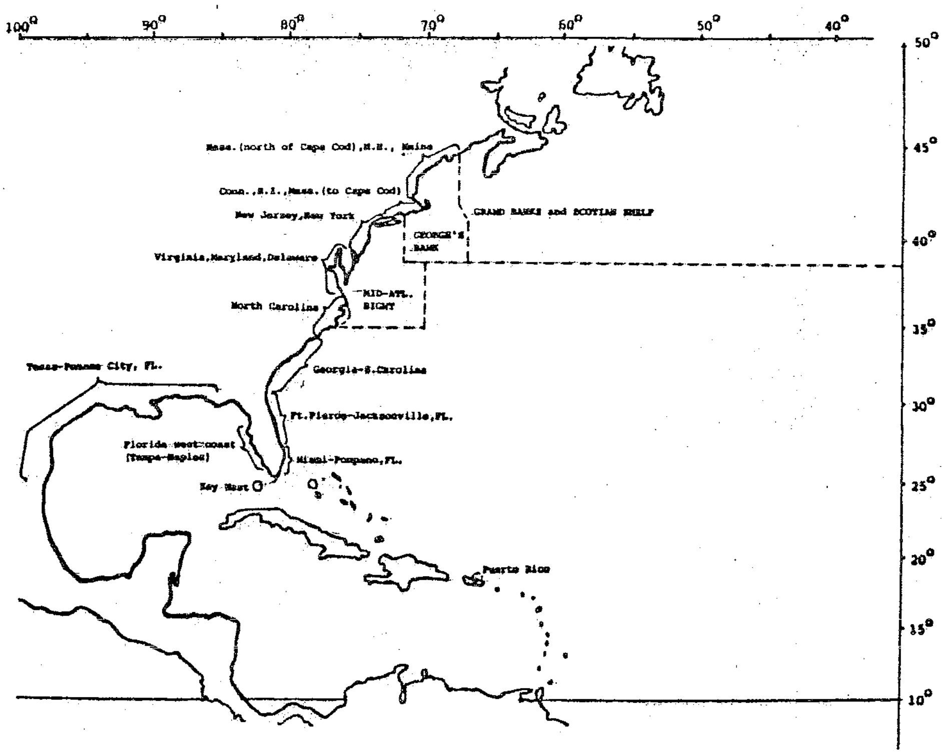
439	0	0	0	0	0	0	4	1
440	0	0	15	6	2	1	0	1
441	0	1	0	1	6	0	3	6
442	0	0	13	3	0	3	4	3
443	0	64	1	2	4	0	0	4
444	0	1	5	6	4	1	6	3
445	0	0	0	3	9	4	1	7
446	0	1	3	0	9	0	1	2
447	0	6	0	19	5	6	8	0
448	0	32	0	0	2	2	6	0
449	0	0	0	5	4	4	0	3
450	15	59	15	10	3	2	1	3
451	11	0	4	0	0	3	2	10
452	0	0	0	12	22	2	1	1
453	0	5	0	3	4	1	0	3
454	0	3	2	5	11	4	2	4
455	0	3	14	0	0	4	1	0
456	0	3	20	6	1	3	1	1
457	0	26	0	1	10	9	2	0
458	0	0	0	4	20	0	1	3
459	0	2	1	3	2	5	11	1
460	0	0	0	17	5	24	6	5
461	0	0	0	20	5	1	1	0
462	15	18	20	0	0	1	14	2
463	0	0	0	2	5	0	1	1
464	0	1	1	1	1	1	1	1
465	0	0	3	8	3	4	0	1
466	0	1	0	0	0	5	13	1
467	0	2	1	2	0	0	0	0
468	0	7	0	4	3	2	3	0
469	0	3	5	5	0	1	1	6
470	0	0	2	2	8	1	0	0
471	0	0	0	2	1	3	12	3
472	44	0	0	0	6	36	3	2
473	0	0	0	0	1	1	0	0
474	0	0	3	1	2	1	0	3
475	18	0	5	8	1	1	1	0
476	0	3	7	0	2	1	4	1
477	17	24	24	6	5	5	6	5
478	0	0	0	0	2	1	2	7
479	11	3	2	0	2	0	2	2
480	0	0	1	2	3	2	7	2
481	0	5	1	0	0	2	1	0
482	15	18	15	0	10	0	6	0
483	0	0	0	1	3	1	4	1
484	0	0	0	0	6	1	0	1
485	0	0	1	4	0	0	1	3
486	0	0	0	0	7	12	0	9
487	0	0	8	2	0	1	0	1
488	0	3	0	2	0	2	0	4
489	0	0	1	2	4	0	0	0
490	14	2	0	1	1	1	0	0
491	0	0	0	0	1	3	0	1
492	0	0	7	2	0	0	2	1
493	0	1	7	3	0	1	0	0
494	0	0	0	2	1	0	1	0
495	0	0	0	1	6	1	0	1
497	14	36	0	0	4	1	1	0
498	0	0	7	4	1	0	2	6
499	0	0	0	1	1	0	2	1
500	0	4	0	1	1	0	0	4
501	0	0	0	3	0	1	0	0
502	0	2	0	4	3	0	0	0

Appendix 3. (cont.)

503	0	0	0	0	1	0	0	0
504	0	0	1	3	0	13	0	0
505	0	2	2	6	0	0	6	0
506	0	0	0	2	0	0	0	2
507	0	0	3	0	3	0	0	3
508	0	4	1	5	2	2	0	2
509	0	3	0	2	0	0	0	0
510	0	0	0	1	2	1	2	1
511	0	0	0	2	0	0	0	0
512	0	3	0	2	6	0	0	0
513	0	0	0	0	6	0	0	0
514	0	1	0	0	0	13	0	0
515	0	0	0	0	0	1	0	0
516	0	0	1	3	1	0	1	1
517	1	8	3	11	6	3	4	5
518	0	0	0	0	0	0	1	1
519	0	0	0	0	16	0	1	0
520	0	0	3	0	0	0	0	1
521	0	0	0	0	1	7	0	0
522	0	0	0	0	0	0	1	0
523	0	0	0	4	1	0	1	1
524	0	0	0	0	0	2	0	0
525	14	0	0	0	0	0	1	0
526	0	3	0	0	0	0	0	1
527	0	0	0	0	1	0	1	0
528	0	0	0	0	3	0	0	2
529	0	0	0	3	0	0	0	0
530	0	0	1	0	3	11	0	0
532	0	0	0	0	0	7	0	0
533	0	0	0	0	0	1	0	0
534	0	0	0	0	0	0	0	1
535	0	0	0	0	0	1	0	1
536	0	0	0	1	0	0	1	0
537	0	3	0	0	3	0	0	0
538	0	0	0	10	0	0	0	0
539	0	0	0	3	0	0	0	0
540	0	0	0	0	0	1	1	0
541	0	0	0	15	1	1	0	0
542	0	0	0	0	0	0	1	0
544	0	0	0	0	0	0	0	2
545	0	0	0	0	0	0	0	3
547	0	0	0	0	1	0	1	1
548	0	2	3	1	0	0	0	0
549	0	0	0	0	0	1	0	0
550	0	0	0	0	0	1	1	1
551	0	0	0	0	0	0	0	1
553	0	0	0	0	0	0	0	1
554	0	0	0	0	0	0	1	0
555	0	0	0	8	0	0	0	1
557	0	0	0	0	0	0	0	1
559	0	0	0	0	0	0	1	0
560	0	0	3	2	4	1	1	0
561	0	0	0	0	0	1	0	0
562	0	35	0	0	1	0	1	0
563	3	4	3	1	2	1	1	1
565	0	0	3	0	0	0	0	0
566	0	0	1	0	0	2	0	0
569	0	0	0	0	0	1	3	0
572	0	0	0	0	6	0	0	0
573	0	0	0	0	5	0	0	0
574	0	0	0	0	0	0	0	1
575	0	0	0	0	0	1	1	1
576	0	0	2	0	2	0	0	0

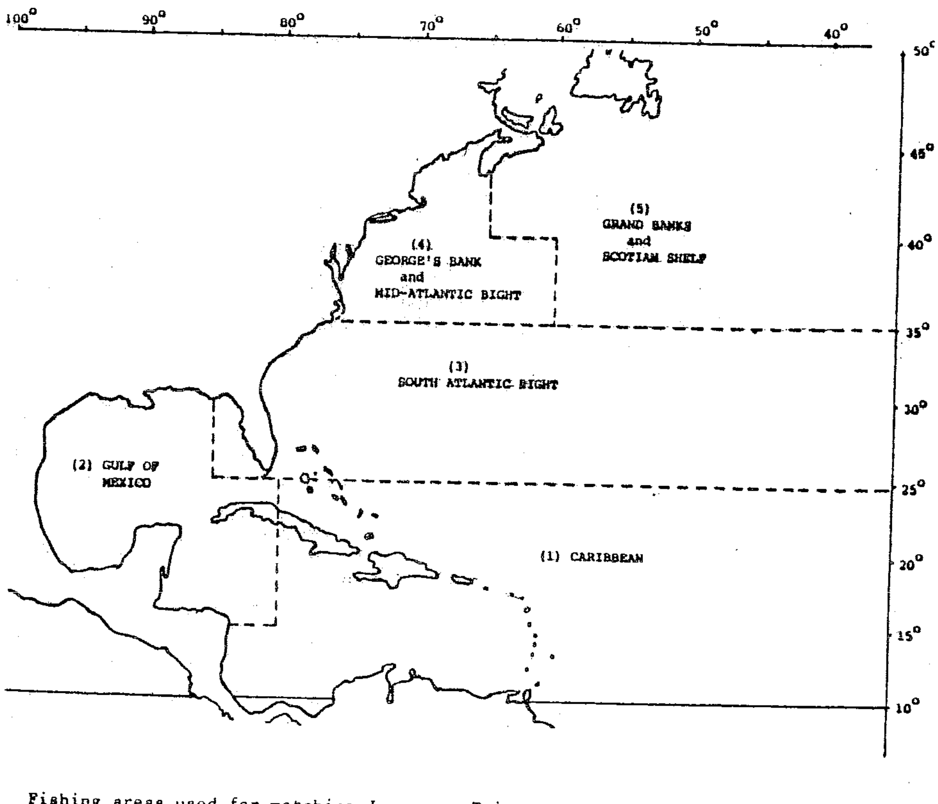
Appendix 3. (cont.)

577	0	0	0	0	0	1	0	0
578	0	0	0	0	0	1	0	0
579	1	7	3	4	5	4	4	6
580	0	0	0	0	0	0	0	2
581	0	0	0	0	2	0	0	0
582	0	0	0	0	1	0	0	0
585	0	0	0	0	0	0	3	0
586	0	0	0	1	0	0	0	0
589	0	0	0	15	1	0	0	0
590	0	0	0	0	0	0	1	0
598	0	0	0	0	0	0	2	0
600	0	0	0	0	0	0	0	1
601	0	0	0	0	0	3	0	0
605	0	0	3	0	0	0	0	0
608	0	0	0	0	1	0	0	0
611	0	0	0	0	1	0	0	0
617	0	0	0	0	0	0	0	1
623	0	0	0	0	0	1	0	0
625	0	0	0	2	0	0	0	0
629	0	0	0	0	0	1	0	0
630	0	0	0	0	0	0	0	2
642	0	0	0	0	0	0	2	0
645	0	0	0	0	0	0	0	1
654	0	0	0	2	0	0	0	0
656	0	0	0	0	0	1	0	1
662	0	0	0	0	2	0	0	0
680	0	0	0	1	0	0	0	0
692	0	0	3	0	0	0	0	0
699	0	0	0	0	0	0	3	0
702	0	0	0	0	0	0	1	0
800	0	0	0	0	0	0	0	3
868	0	0	0	1	0	0	0	0
TABLE								
SUM OF N	97929	103045	134675	93794	105491	108486	105054	104071
SUM OF WT	10572062	12835434	12535112	9591430	9389205	9718312	8198096	8256897
ACTUAL								
SUM OF N	97923	103041	134866	93791	105469	108486	105055	104085
SUM OF WT	10571280	12834877	12540605	9590709	9388290	9720298	8198692	8260443



Offloading areas and fishing areas (inside broken lines) used for matching US and Canadian landings to US size-frequency data.

Appendix 4 (cont.)



Fishing areas used for matching Japanese, Taiwanese, Korean and Cuban catches to US size frequency data.