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ASSESSMENT OF SWORDFISH IN THE EASTERN PACIFIC OCEAN

by

Michael G. Hinton, William H. Bayliff, and Jenny M. Suter

CONTENTS

The stock structure of swordfish, *Xiphias gladius*, is not well known in the Pacific. There are indications that there is only limited exchange of swordfish between the eastern Pacific Ocean (EPO) and the central and western Pacific Ocean, so it is considered herein that examinations of local depletions and independent assessments of the swordfish of the EPO are meaningful. Accordingly, most of the data presented in this report are for the EPO. Nevertheless, for various reasons, some data for the central and western Pacific Ocean are also presented.

1. EXECUTIVE SUMMARY

Swordfish occur throughout the Pacific Ocean between about 50°N and 50°S. They are caught mostly by the longline fisheries of Far East and Western Hemisphere nations. Lesser amounts are caught by gillnet and harpoon fisheries. They are seldom caught by recreational fishermen. During recent years the greatest catches in the EPO have been taken by vessels of Chile, Japan, Mexico, and the United States.

Swordfish reach maturity at about 5 to 6 years of age, when they are about 150 to 170 cm in length. They probably spawn more than once per season. Unequal sex ratios occur frequently in the catches. For fish greater than 170 cm in length, the proportion of females increases with increasing length.

Only fragmentary data are available on the movements of swordfish. They tend to inhabit waters further below the surface during the day than at night.

Swordfish tend to inhabit frontal zones. Several of these occur in the EPO, including areas off California and Baja California, off Ecuador, Peru, and Chile, and in the equatorial Pacific. Swordfish tolerate temperatures of about 5° to 27°C, but their optimum range is about 18° to 22°C. Swordfish larvae have been found only at temperatures exceeding 24°C.

There may be two stocks of swordfish in the EPO. If there are, one has its center of distribution in the southeastern Pacific Ocean, and the other its center off California and Baja California. As well, there may be movement of a northwestern Pacific stock of swordfish into the EPO at various times.

Production modeling indicates that the catches per unit of effort (CPUEs) of swordfish, although they have declined and then increased recently, are still greater than the CPUEs that correspond to the average maximum sustainable yield. This conclusion is tentative, due particularly to the current uncertainty regarding stock structure.

2. DATA

2.1. Definitions of the fisheries

2.1.1. Longline fisheries

Longlining for tunas and billfishes takes place in the Pacific Ocean from the Americas to Asia between about 50°N and 50°S.

2.1.1.1. Far East nations

Vessels of Chinese Taipei, Indonesia, Japan, the Philippines, and the Republic of Korea have fished for tunas and billfishes in the Pacific Ocean (Sakagawa, 1989; Skillman, 1998; Ueyanagi *et al*., 1989; Caton *et al*., 1998; Uozumi and Uosaki, 1998; Okamoto and Bayliff, 2003). Those of Chinese Taipei, Japan, and the Republic of Korea collectively fish in nearly all of the range of swordfish in the Pacific Ocean.

2.1.1.2. South Pacific nations

Small amounts of swordfish are caught in the South Pacific by longline vessels of Australia, the Cook Islands, Fiji, French Polynesia, New Caledonia, New Zealand, Tonga, and Vanuatu (Caton *et al*., 1998; Williams, 1998).

2.1.1.3. Western Hemisphere nations

Longline vessels of Western Hemisphere nations, most notably Chile (Barría 2003, Barbieri *et al*., 1998), Mexico (Holts and Sosa-Nishikawa, 1998), and the United States (Holts and Sosa-Nishikawa, 1998; Ito *et al*., 1998; Vojkovich and Barsky, 1998; Ito and Coan, 2004), fish for tunas and billfishes in the eastern and central Pacific Ocean.

2.1.2. Gillnet fisheries

Until the end of 1992 there was a high-seas fishery for tunas and billfishes with large-meshed gillnets carried out by vessels of Chinese Taipei, Japan, and the Republic of Korea (McKinnell and Waddell, 1993; Nakano *et al*., 1993; Uosaki, 1998). Vessels of Chile (Barbieri *et al*., 1998), Mexico (Holts and Sosa-Nishikawa, 1998), and the United States (Hanan *et al*., 1993; Holts and Sosa-Nishikawa, 1998) fish or have fished for tunas, billfishes, and sharks with gillnets in the eastern Pacific Ocean (EPO). These latter fisheries generally operate in the coastal waters and Exclusive Economic Zones (EEZs) of the respective nations.

2.1.3. Harpoon fisheries

Harpoon fisheries, which take swordfish and other billfishes, operate in coastal waters of Chile (Barbieri *et al*., 1998), Chinese Taipei (Sakagawa 1889), Japan (Ueyanagi *et al*., 1989: Uozumi and Uosaki, 1998), and the mainland of the United States (Coan *et al*., 1998). Striped marlin, blue marlin, black marlin, and sailfish are also taken by the harpoon fisheries of Chinese Taipei and Japan, and several species of sharks are also taken by the harpoon fishery of the United States.

2.1.4. Purse-seine fishery

Small amounts of swordfish are caught by tuna purse-seiners in the eastern Pacific Ocean (Anonymous, 1999: Table 39). These are bycatches, and they are discarded at sea or kept by the vessel crews for their personal use.

2.1.5. Recreational fisheries

The recreational fisheries for swordfish are insignificant, or nearly so (de Sylva, 1974; Caton *et al*., 1998; Holts and Sosa-Nishizaki, 1998).

2.2. Catch and effort data

2.2.1. Commercial fisheries

Most of the commercially-caught swordfish are taken by the longline fisheries of Far East and Western Hemisphere nations. Lesser amounts of swordfish are or have been caught by the other fisheries described in Section 2.1. Data on the commercial catches of swordfish in the eastern Pacific Ocean are shown in Tables 2.2.1a-c.

The distributions of fishing effort by major fleets have varied over the decades as a result of varying target species for the fisheries. Summary information on the distribution of fishing effort for these major fleets is given by Uozumi and Uosaki (1998) for Japan, and by Skillman (1998) for Chinese Taipei and the Republic of Korea. Information on the longline, gillnet, and harpoon fisheries of the United States is given by Ito and Coan (2004), Ito *et al.* (1998), Sakagawa (1989) and Coan *et al.* (1998). Information on the longline fishery of Spain in the eastern Pacific is given by Mejuto and Garcia (1998). Variation in the historical distribution of fishing effort by longline fisheries by subarea in the EPO is given by Hinton and Bayliff (2002, Figures 2.2.1a – 2.2.1f). Total nominal fishing effort by longline fisheries for the northern and southern regions of the EPO (Figure 2.2.1a) are shown in Figure 2.2.1b..

2.2.2. Recreational fisheries

No comprehensive data on the recreational fishing effort or the recreational catches of swordfish are available.

2.3. Size-composition data

2.3.1. Longline fisheries

Length-frequency data for swordfish caught by longline gear in the EPO are given by Miyabe and Bayliff (1987: Figure 59), Nakano and Bayliff (1992: Figures 66-68), Vojkovich and Barsky (1998), Uosaki and Bayliff (1999: Figures 68-70), Hinton and Bayliff (2002, Figures 2.3.1a-e), and Okamoto and Bayliff (2003: Figures 80-82) and in the western Pacific Ocean by Williams (1998). Length-frequency histograms for swordfish caught by longline gear in the areas north and south of 5°S in the EPO are shown in Figures 2.3.1a-b.

2.3.2. Other commercial fisheries

Length-frequency data for swordfish taken by the gillnet and harpoon fisheries of the northern EPO are shown by Hanan *et al*. (1993) and Coan *et al*. (1998), respectively, and weight-frequency data for swordfish taken by artisanal gear (harpoons and gillnets) are shown by Barbieri *et al*. (1998). Length-frequency histograms for swordfish caught by purse-seine gear of the EPO are shown in Figure 2.3.1c.

2.3.3. Recreational fisheries

No comprehensive data on the sizes of recreationally-caught swordfish are available.

3. ASSUMPTIONS AND PARAMETERS

3.1. Biological and demographic information

3.1.1. Growth

The parameters of the von Bertalanffy growth equation of swordfish in the Pacific Ocean estimated by various researchers, and estimated lengths of swordfish at ages 1 through 10 calculated from those data, are summarized in Hinton and Bayliff (2002, Table 3.1.1a-b). Data on the weight-length relationships of swordfish are summarized by Hinton and Bayliff (2002, Table 3.1.1c).

3.1.2. Reproduction

According to Yabe *et al.* (1959), swordfish first reach maturity at 5 to 6 years of age, when they are 150 to 170 cm in length. The smallest mature fish encountered by Kume and Joseph (1969) was 139 cm long, but Nakano and Bayliff (1992) observed one mature swordfish in the 101- to 110-cm length class.

DeMartini *et al.* (2000) used microscopic morphological evidence to estimate the median body (eye-fork length; EFL) at sexual maturity to be about 102 cm for males and 144 cm for females captured in the longline fisheries operating from Hawaii. The smallest reproductively-active female in their samples had a length of 134 cm. They found that more than 95 percent of the females greater than 173 cm EFL, and males greater than 123 cm, were mature. DeMartini *et al*. noted that their finding of a female:male ratio of median lengths at sexual maturity of 2.9 is consistent with values found for swordfish in the Atlantic Ocean.

Information on the reproduction of swordfish in the Pacific Ocean is given by Nishikawa *et al*. (1985), Miyabe and Bayliff (1987), Nakano and Bayliff (1992), Uosaki and Bayliff (1999), Okamoto and Bayliff (2003), and Young *et al.* (2003). Swordfish larvae appear to be more abundant west of 140°W than east of that longitude (Nishikawa *et al*. 1985), but this could be an artifact of sampling. Hinton and Deriso (1998), using a validated index of reproductive activity for swordfish (Hinton *et al.* 1997), determined that swordfish were reproductively active in the vicinity of Baja California during May–August. They also determined that “regions of the EPO with individuals in spawning condition were clearly separated throughout the year,” with all occurrences either in or adjacent to identified regions of high relative abundance. A summary of reproductive activity by subarea of the EPO as proportion of sampled females that were reproductively active (Hinton *et al.* 1997) is presented by Hinton and Bayliff (2002, Table 3.1.2).

An ovary of a swordfish contains hundreds of millions of ova, portions of which mature throughout the life of the fish after it reaches maturity. Uchiyama and Shomura (1974) obtained estimates of 2.24 to 9.38 million ova of the most advanced group from fish weighing 83 to 204 kg. Swordfish probably spawn at frequent intervals, in which case their annual fecundities would be much greater.

According to Sakagawa (1989), female swordfish tend to inhabit higher latitudes than male swordfish, in which case unequal sex ratios should occur frequently. Kume and Joseph (1969) found the sex ratio to be about equal for fish between 130 and 170 cm in length in all areas of the EPO except that bounded by 10°N, 100°W, 5°S, and the coastline of the Americas. In this area females were more abundant than males, especially during the first quarter. For fish greater than 170 cm in length, the proportion of females to males increased with increasing length. Weber and Goldberg (1986) found that 26 percent of 90 swordfish collected off Southern California were males, and the rest were females. DeMartini *et al.* (2000) found increasing body size with latitude, and increasing male:female ratios only during peak spawning periods. Young *et al.* (2003) found that size of fish and season were the main factors affecting the sex ratio of swordfish found off eastern Australia, with females always outnumbering males.

3.1.3. Movement

According to Kume and Joseph (1969), "catch records tend to show a movement of fish from off the tip of Baja California during the spring towards the north during the summer and fall." Bedford and Hagerman (1983) report that "a coastwide movement of fish between Baja California and California is evidenced by limited tagging data and Japanese longline hooks in fish taken off southern California. This hypothesis is further supported by the ... [fact that] ... the Japanese longline fishery peaks off Baja California in December and January, followed by the southern California season, running from summer through fall." The fish "move offshore for spawning" (Dewees, 1992). Hinton and Deriso (1998) stated that a tagged swordfish released northeast of the Hawaiian Islands (28°20’N-149°08’W) on May 1, 1993, was recaptured off San Clemente Island, California (32°03’N-118°29’W) on January 1, 1995. They hypothesized that there is “mingling of swordfish stocks in the EPO,” and stated that “larger individuals might migrate into [the] northern and westerly region of the EPO” from the north, the west, Baja California, or “the equatorial zone of high abundance.” de Sylva (1962) reported an apparent northward migration of swordfish off northern Chile in April and May. Caton *et al*. (1998) reported that a small juvenile swordfish tagged and released off Bermagui, New South Wales (ca. 37°S-150°E) was recaptured 200 km to the north, off Jervis Bay, New South Wales (ca. 35°S-151°E) 3 months later.

Carey and Robison (1981) reported on the daily activity patterns of swordfish monitored with acoustic telemetry. Two fish tagged near the tip of the Baja California peninsula occupied an inshore bank during the daytime, and moved offshore at night. During the daytime they remained near the bottom at a depth of about 90 m, where they may have been feeding on demersal fish, and at night they stayed close to the surface, where they are believed to have been feeding on squid and other fauna that concentrate near the surface at night. Two others tagged in the same general area, which were in water 400 to 800 m deep when they were tagged, moved westward until they were over a submarine canyon, at which time they changed course and moved southward along the length of the canyon. Fishermen suggested that the first two fish were part of a resident population, while the other two were transients. Carey and Robison noted that swordfish frequently bask at the surface off Baja California during the daytime, and postulated that they do this to repay oxygen debts that they accumulate in deeper water.

Holts *et al*. (1994) reported on the daily activities of a swordfish monitored by acoustic telemetry off Southern California. Its horizontal speed ranged from 0.7 to 2.5 knots. The fish spent virtually all of its time below 10 m and about 75 percent of its time between 10 and 50 m in or just below the upper mixed layer, where the temperature was about 14°C. It made two dives to about 300 m, where the temperature was about 8°C. Both dives were made during daylight, but during other periods the depths during daylight were only slightly greater than those during darkness. During the second dive the fish was over 14-mile Bank (33°24'N-118°00'W), where "it may have been foraging at or very close to the bottom."

3.1.4. Natural mortality

Boggs (1989) used the method of Murphy and Sakagawa (1977) and the growth parameter estimates of Yabe *et al*. (1959) to estimate the natural mortality of swordfish. For this report the method of Pauly (1980) was used with the growth parameter estimates of Yabe *et al*. (1959), Barbieri *et al*. (1998), and Uchiyama *et al*. (1998) and a mean temperature estimate of 20°C (see Section 3.2) to calculate estimates of the natural mortality for this species. These estimates appear in Table 3.1.1a. In their stock assessment of swordfish in the EPO, Hinton and Deriso (1998) used annual survival rates in the absence of fishing mortality of 0.62 and 0.81, which are equivalent to coefficients of natural mortality of 0.48 and 0.21, respectively.

3.2. Environmental influences

Swordfish are most abundant in "zones of high production of food organisms and where major ocean currents meet" (Sakagawa, 1989).

"In the Pacific Ocean, there are five frontal zones ... where swordfish are found in fishable concentrations ...: (1) in the northwestern Pacific ..., where the warm Kuroshio Current meets the coastal waters of Taiwan and Japan, and where the Kuroshio Extension Current meets the Oyashio Current to the north; (2) off southeastern Australia ..., where the warm East Australian Current meets intrusions of the cold Southern West Wind Drift Current; (3) off northern New Zealand ..., where the warm South Equatorial Current intersects with intrusions of the cold Southern West Wind Drift Current; (4) in the eastern tropical Pacific ..., where the warm Equatorial Counter Current intersects with the colder Peru Current; and (5) along Baja California, Mexico, and California, U.S.A. ..., where the cool offshore California Current intersects with intrusions along the coast of warmer water from the south" (Sakagawa, 1989). These are shown in Figure 3.2.

Nakamura (1985) stated that adult swordfish tolerate temperatures of 5° to 27°C, and that their optimum temperature range in the northwestern Pacific Ocean is 18° to 22°C. They avoid water with low concentrations of dissolved oxygen. Swordfish larvae have been found only at temperatures exceeding 24°C.

Carey and Robison (1981) described the movements of two swordfish that were tagged with acoustic tags in water 400 to 800 m deep. They moved westward until they were over a submarine canyon, at which time they changed course and moved southward along the length of the canyon. They said that "commercial fishermen feel that the submarine canyons and hummocky areas along the continental shelf are good places to find swordfish... Currents flowing over rough bottom produce eddies and flow separation features which may extend to the surface... The concentration of organisms as a result of turbulence generated by the rough bottom may be the feature that attracts swordfish to the waters over submarine canyons."

de Sylva (1962) reported that during April and May of 1956, in the vicinity of Iquique, Chile [about 20°15'S], there was "an influx of a thin warm-water layer from the north containing dinoflagellate populations; an admixture of nutrients, derived at least in part from upwelled coastal water from the south, caused growth of the dinoflagellate population, which resulted in a concentration of the zooplankton crop. Subsequently, anchovies concentrated and fed in these plankton patches and they in turn attracted squid and bonito. Swordfish and striped marlin moved into this region apparently attracted by the concentrations of squids as well as of anchovies. However, they were also probably affected by decreasing water temperatures, as this concentration seemed to be part of a northerly migration toward the onset of winter, following the northward-retreating warm front. It was reported that by late May, most swordfish were being taken well north of the Iquique area toward Arica [about 18°30'S]. This exodus may have been further prompted by the growth in area (to 60 miles offshore) of reported red-water conditions unfavorable to swordfish."

3.3. Stock structure

Hinton and Deriso (1998) discussed the various hypotheses which have been made concerning the stock structure of swordfish in the EPO and concluded that there is a stock with its center of distribution in the southeastern Pacific Ocean, and possibly another one with its center of distribution in the northeastern Pacific Ocean. Studies of swordfish genetics in the Atlantic Ocean and the Mediterranean Sea using mitochondrial DNA indicate distinct stocks in these oceans, and also differentiation between swordfish in the Atlantic and the Pacific (discussion in Hinton and Deriso, 1998). Alvarado Bremer *et al.* (2004) reviewed the published genetic studies of swordfish populations in the Pacific Ocean. They noted that in general, levels of population structuring in the Pacific Ocean are extremely low, compared to other basins, with two studies reporting significant heterogeneity in the Pacific, while four others found no significant differences. The contrasting views and hypotheses of population structure derived from different kinds of data are given. It is concluded that additional analyses with larger samples sizes and additional genetic markers are needed to resolve the population structure of swordfish in the Pacific Ocean. Hinton (2003) concluded that there are northern and southern stocks of swordfish in the EPO, with the boundary between the stock distributions occuring at 5°S, and that there may at times be some mixing of stocks from the central Pacific with the northeastern stock.

4. STOCK ASSESSMENT

4.1. Indices of abundance

Indices of abundance of swordfish in the EPO have previously been calculated as catch per unit of nominal effort (CPUE, *e.g.* Okamoto and Bayliff 2003), and by using general linear models (GLMs) (*e.g.* Nakano 1998; Hinton and Bayliff 2002) or other effort standardization approaches (*e.g.* Hinton and Deriso 1998) to estimate standardized effort and from that obtain catch per unit of standardized effort (CPUSE).

The results of standardizing fishing effort of the longline fishery in the EPO, which principally targets tunas, using GLMs are presented below. The standardization model used was of the form:

$$F(CPUE) = Year + Month + Latitude + Longitude + Environmental\ Index + Gear + interactions$$

Observations of CPUE at 5° latitude by 5° longitude by month resolution for the 1955-2002 period were included in the analysis. Gear included factors for flag-state (Flag), use of light sticks (Light), and hooks-per-basket (HPB) or categories of HPB (Hcode). When categorized, effort was grouped into four levels based on HPB: Level 1: HPB < 8; Level 2: 8 ≤ HPB < 12; Level 3: 12 ≤ HPB < 16; and Level 4: HPB ≥ 16. For the period prior to 1975, which brought the introduction of deep longlines to the EPO, all effort was considered to be Level 1.

Environmental indices considered were sea-surface temperature (SST), the temperature differences between the sea surface and that at 200 and at 400 meters (D200 and D400) (for rationale c.f. Hinton 2003 and Takahashi *et al.* 2003), and the monthly observations of the Southern Oscillation Index (SOI), and the Northern and Southern Extratropical Oscillation Indices (NOIx and SOIx, Schwing *et al.*, 2002).

Interaction terms were considered in the fitting of the models only for significant main effects. Year was not included in interaction terms, its coefficients thus providing a direct measure of relative annual abundance.

The models were fit in in S-PLUS 6.1 Release 1 (MathSoft, Inc., Cambridge, MA, USA) by first fitting to the mean using the procedure "glm," and then using function "step" to perform a stepwise fitting procedure for main effects, followed by fittings for interaction terms if indicated. Final model selection was made considering both AIC and likelihood ratio tests. Variables are shown in order of entry into the model during the fitting procedure.The model selected for the northern region was:

ln(CPUE) ~ Light + Flag + Lon5 + D400 + year + D200 + Lat5 + Month + Hcode + SOI + Lat5:Lon5.

The model selected for the southern region was:

ln(CPUE) ~ Flag + Lon5 + Month + Lat5 + Year + SOI + Hcode + D200 + SST + Lat5:Lon5.

Trends in annual abundance for the northern and southern stocks are shown in Figure 4.1.1. Comparisons of standardized to nominal trends in CPUE are shown in Figure 4.1.2.

4.2. Assessment models

Three general types of models, age-structured models, spawner-recruit models, and production models, all of which are described by Anonymous (1999: 35-49), are used to assess the condition of stocks of fish. All three types of models require that the analyses be done with a discrete stock of fish. As stated in Section 3.3, the swordfish of the EPO appear to belong to two stocks.

Production models, using data from the Japanese longline fishery for 1952 through 1980, have been applied to swordfish in the Pacific Ocean by Sakagawa and Bell (1980), Bartoo and Coan (1989), and Skillman (1989). Their results were only tentative, for at least two reasons. First, due to lack of data on tag returns, meristic and morphometric characteristics, genetic characteristics, *etc*., the investigators had to make assumptions regarding stock structure based on the distribution of catches of the fish. Second, due to lack of data which could be used to make adjustments for differences in the vulnerability of the fish to capture, they had to assume that swordfish were equally vulnerable to capture by longline gear in all years, seasons, and areas. They concluded that the swordfish were capable of supporting greater catches than those which were taken during that period. The fisheries have changed since then, however. By 1992, the swordfish catch in the Pacific Ocean had reached about 34,700 metric tons, a 69-percent increase since 1986.

The Deriso-Schnute delay-difference population model (Quinn and Deriso, 1999) was used with catch and effort data for 1962-1987 by Hinton and Deriso (1998) to investigate the dynamics of swordfish in the EPO. They investigated the status of stocks, assuming that this area was inhabited by a single stock of swordfish and that the area was open to movement of swordfish across the boundaries of the EPO. The standardized catch rates and data that were available at the time of the analysis, which showed declining standardized CPUEs with increasing fishing effort, provided a minimal amount of information with which to model the dynamics of the population. Preliminary examination of catch and effort data for 1988-1992 indicated that the CPUEs had continued to decline, but were still greater than the CPUEs that correspond to the average maximum sustainable yield (AMSY), so it was considered that swordfish were not overfished in the EPO.

Hinton (2003) concluded that a failure of attempts to fit the Deriso-Schnute delay-difference population model to the standardized catch and effort estimates for northern and southern stocks in the EPO obtained from fitted GLM models resulted from the lack of contrast in the indices of relative abundance over time in the standardized data series. Further, it was concluded that the trends in relative abundance obtained in the GLM standardizations give no indication of declining abundances of swordfish in the EPO, and that nominal longline fishing effort in the region has been steady to declining over the past decade. It was also noted that catches in the region have been fairly stable during the period since 1989, averaging about 13,000 mt annually.

Essential results related to stock status obtained in this assessment are similar to those of Hinton (2003), as discussed above. The indication in both the northern and the southern areas is that populations have not responded, in terms of decreasing standardized CPUE, to observed levels of fishing effort and catches of swordfish. Average annual catch for the 5-year period 1998 to 2002 for the northern region has been about 4,800 metric tons (t), and for the southern region about 9,100 t. It should be noted, however, that catches in the southern region have doubled during this period, reaching 13,300 t in 2002, which exceeded the previously recorded high catch of 12,400 t reported in 1991. At some point it would be a normal expectation that high levels of catch over a period of time will result in reductions in CPUE.

5. STOCK STATUS

As indicated in Section 4.2, the CPUEs previously obtained have been found to be greater than those that correspond to the AMSY, and trends in relative abundance obtained in the standardizations of CPUE of longline fisheries in the region do not indicate declining abundances. The lack of contrast in the standardized catch and effort series in the northern and southern regions of the EPO suggests that the fisheries that have been taking swordfish in these regions have not been of a magnitude sufficient to cause significant responses in the populations. As well, catches in the region have been fairly stable since 1989, averaging about 3,700 t in the northern region and 8,400 t in the southern region annually. Based on these considerations, it appears that swordfish are not overfished in the northern and southern regions of the EPO. However, given the changing nature of the fisheries for swordfish in these regions, particularly those gillnet and longline fisheries which are increasingly targeting swordfish, the stocks should be monitored closely for changes in these trends.

6. FUTURE DIRECTIONS

The two items indicated in this section at the last assessment were:

1) The investigation of the distribution of swordfish stocks in the EPO using results from mitochondrial and nuclear DNA sequencing, which had a projected time of completion of August, 2001. Current status: Completion date for draft report of results: May, 2004. Reason for delay: lack of funding.

2) The development of an integrated standardization and dynamics model to be fitted using AD-Model Builder, which will be able to incorporate information on the biology, environment, and multiple fisheries harvesting swordfish in the EPO. Current status: Operational with continuing development of increased capabilities.

Recommendations from last meeting:

Conduct assessment on Pacific-wide stock. Current status: unable to establish collaboration as of this date.

Items for future work:

1) Complete data compilation and perform assessment using integrated statistical habitat modeling.
2) Structure assessment models, using results from genetic studies, and compare results.
3) Develop collaboration to investigate and model movement of stock(s) across boundary of 150°W.
4) Develop improved model of swordfish habitat utilization using tag data which has been provided by the National Research Institute of Far Seas Fisheries of Japan [M. Takahashi] and the U.S. National Marine Fisheries Service [D. Holts].

6.1. Collection of new and/or updated information

As more data become available these analyses should be updated to ensure that if there develop indications that the condition of the stock of swordfish has deteriorated, then action could be considered and taken in a timely manner.

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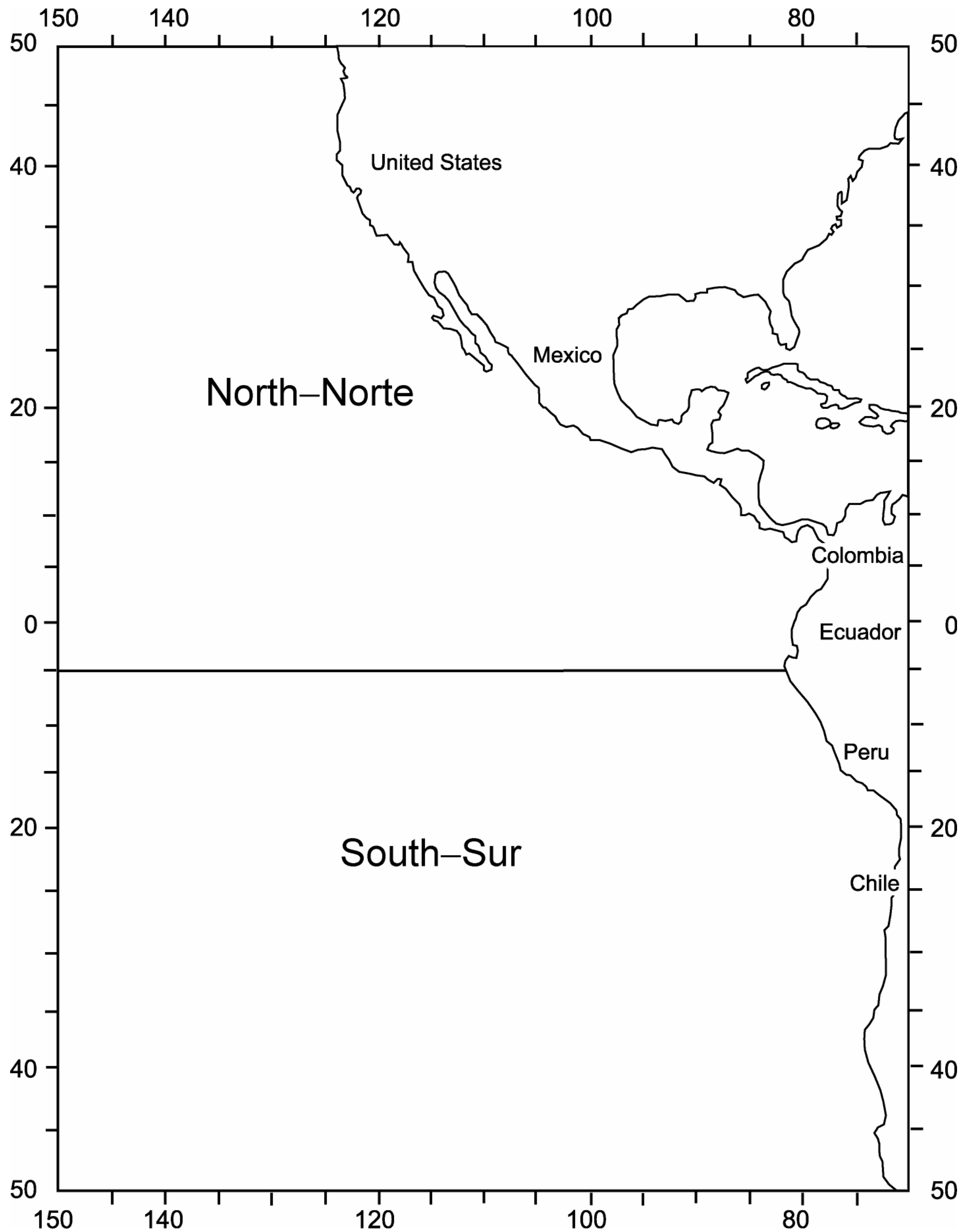

FIGURE 2.2.1a. Area stratification for analysis of swordfish stocks in the eastern Pacific Ocean.
FIGURA 2.2.1a. Estratificación del Océano Pacífico oriental para el análisis de los stocks de pez espada.

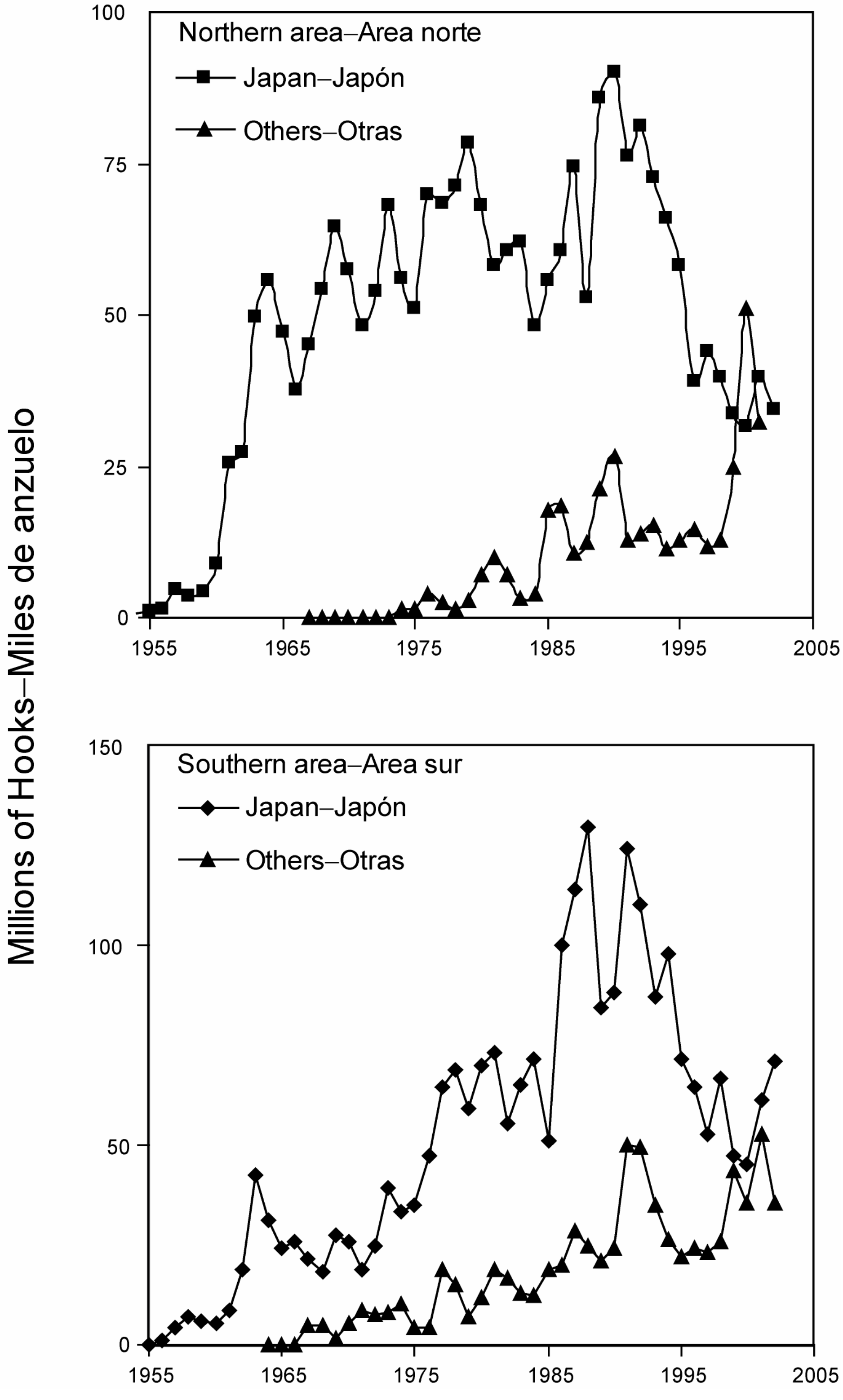

FIGURE 2.2.1b. Distributions of total nominal effort by fishery by area of the EPO.
FIGURA 2.2.1b. Distribución del esfuerzo nominal total por pesquería por áreas del OPO.

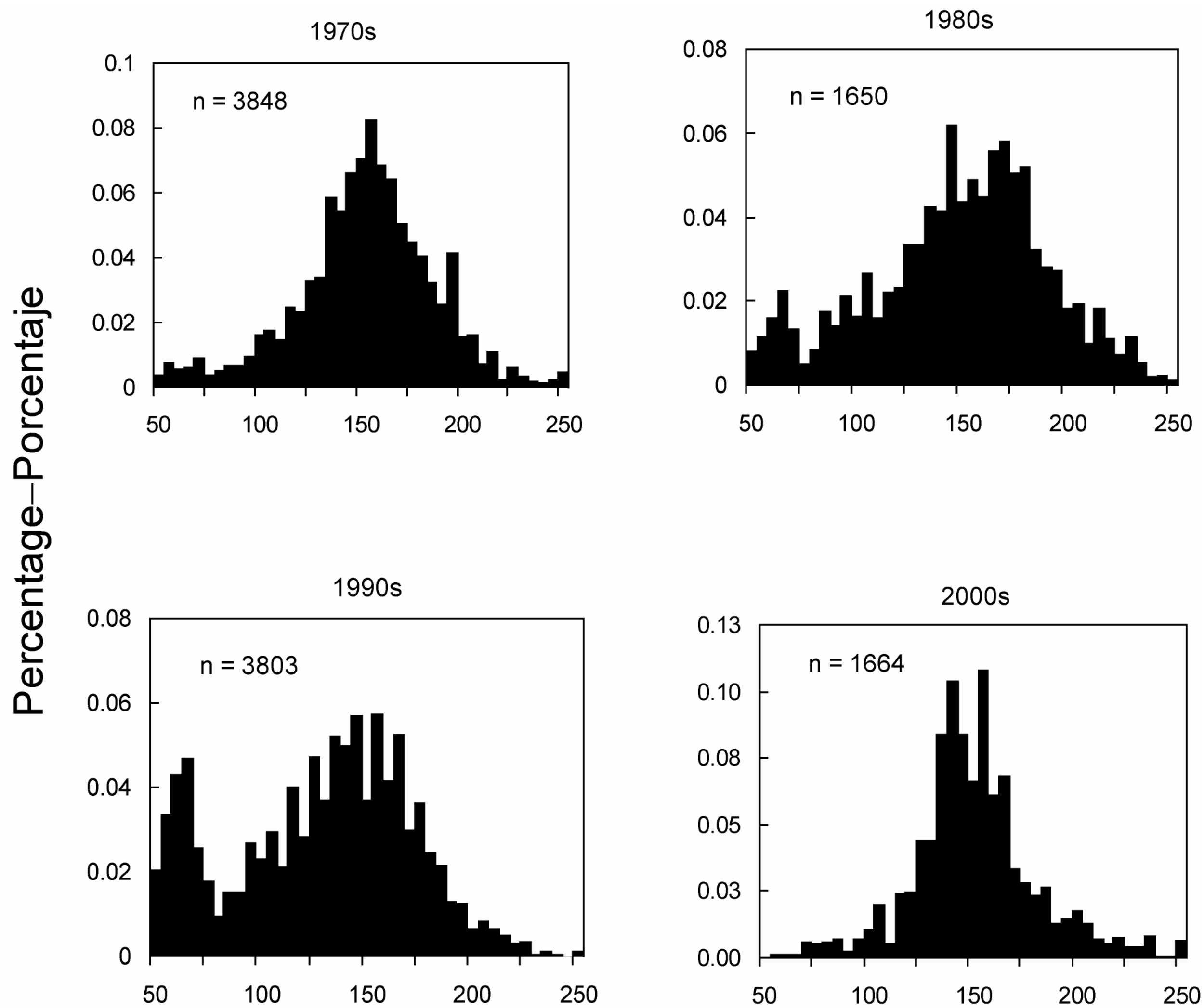

FIGURE 2.3.1a. Length-frequency distributions for swordfish taken by longline fisheries in the northern EPO by decade.

FIGURA 2.3.1a. Distribuciones de frecuencia de talla para pez espada capturado por pesquerías palangreras en [the northern] el OPO [by decade].

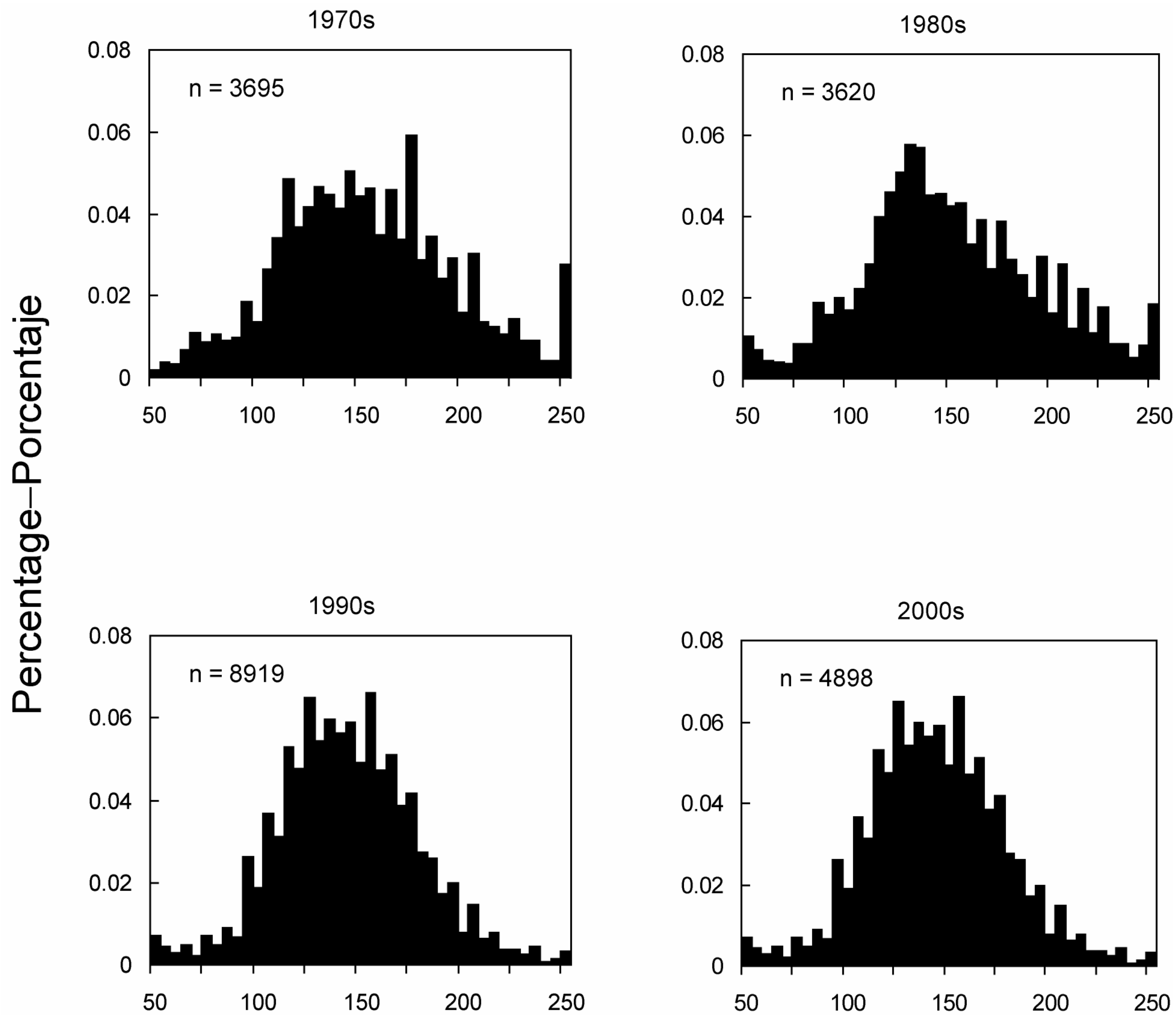

FIGURE 2.3.1b. Length-frequency distributions for swordfish taken by longline fisheries in the southern EPO by decade.
FIGURA 2.3.1b. Distribuciones de frecuencia de talla de pez espada capturado por pesquerías palangreras en el [southern] OPO [by decade].

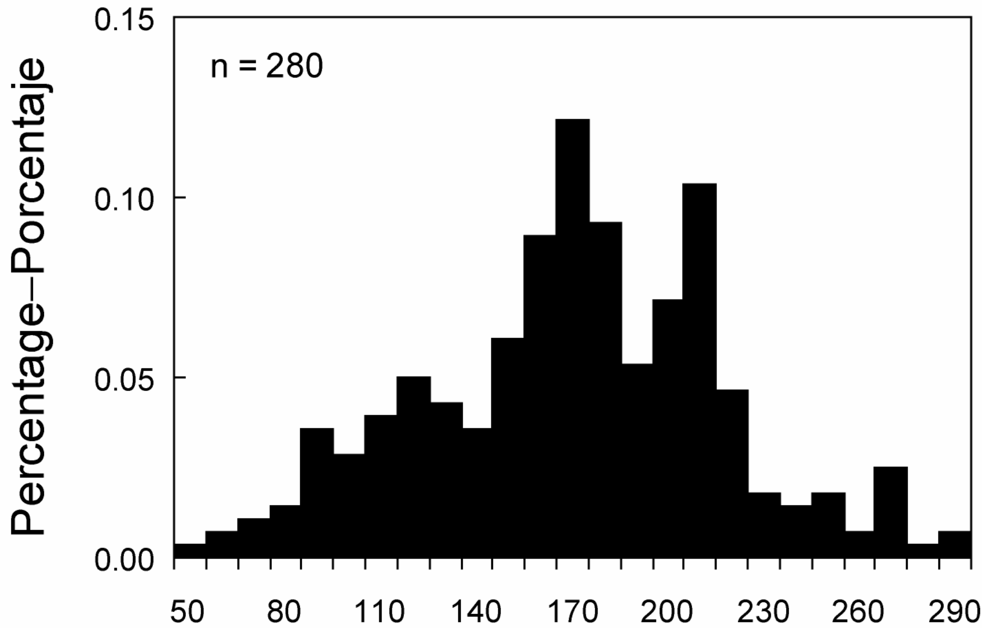

FIGURE 2.3.1c. Length-frequency distribution (eye-fork length in cm) for swordfish taken by purse seine fisheries in the EPO during 1991-2003.
FIGURA 2.3.1c. Distribucion de frecuencia de talla de pez espada (/) capturado por pesquerías cerqueros en el OPO durante 1991-2003.

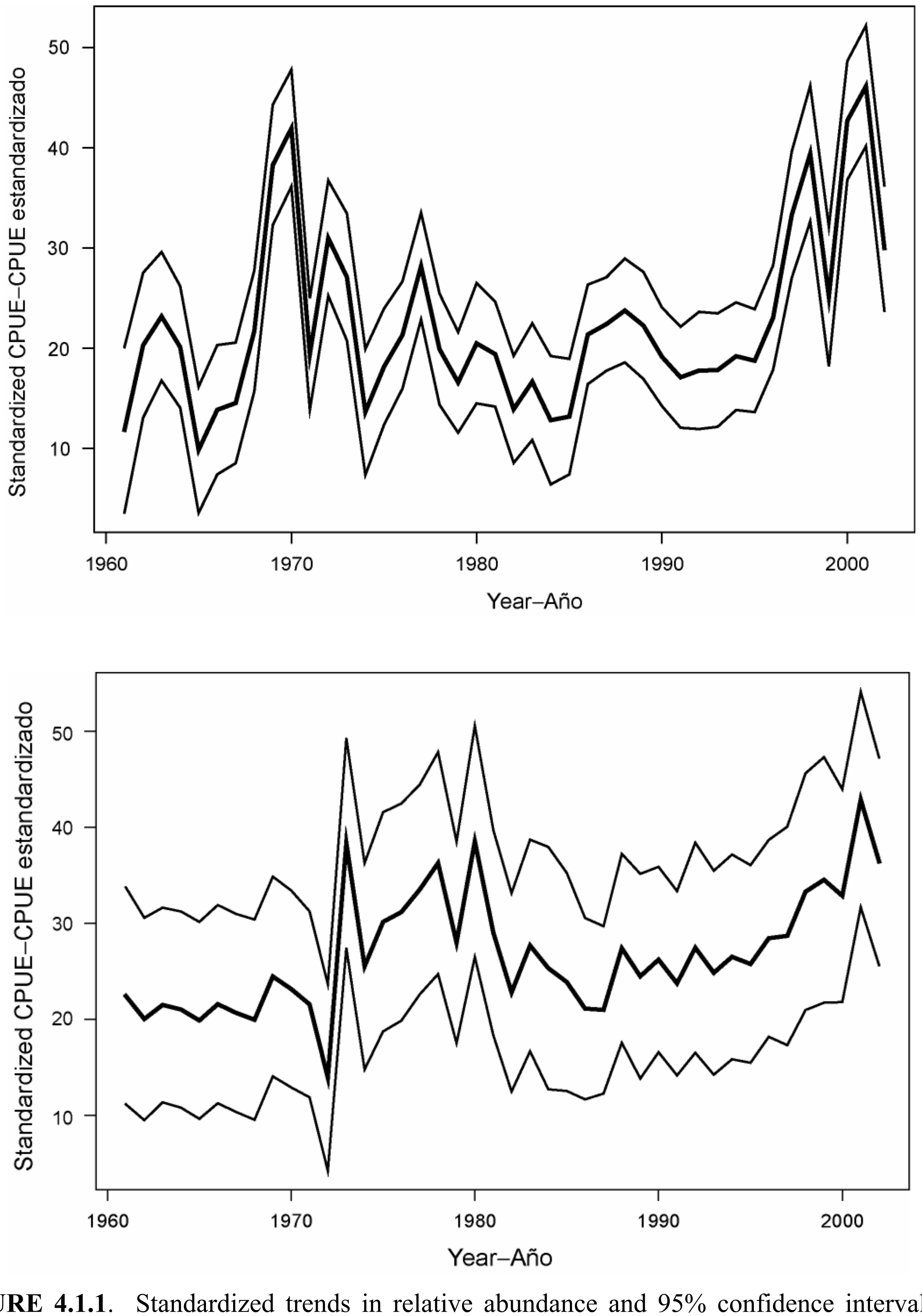

FIGURE 4.1.1. Standardized trends in relative abundance and 95% confidence intervals for northern (upper panel) and southern (lower panel) areas of the EPO.
FIGURA 4.1.1. Tendencias estandarizadas en la abundancia relativa e intervalos de confianza de 95% para áreas norte (/) y sur (/) del OPO.

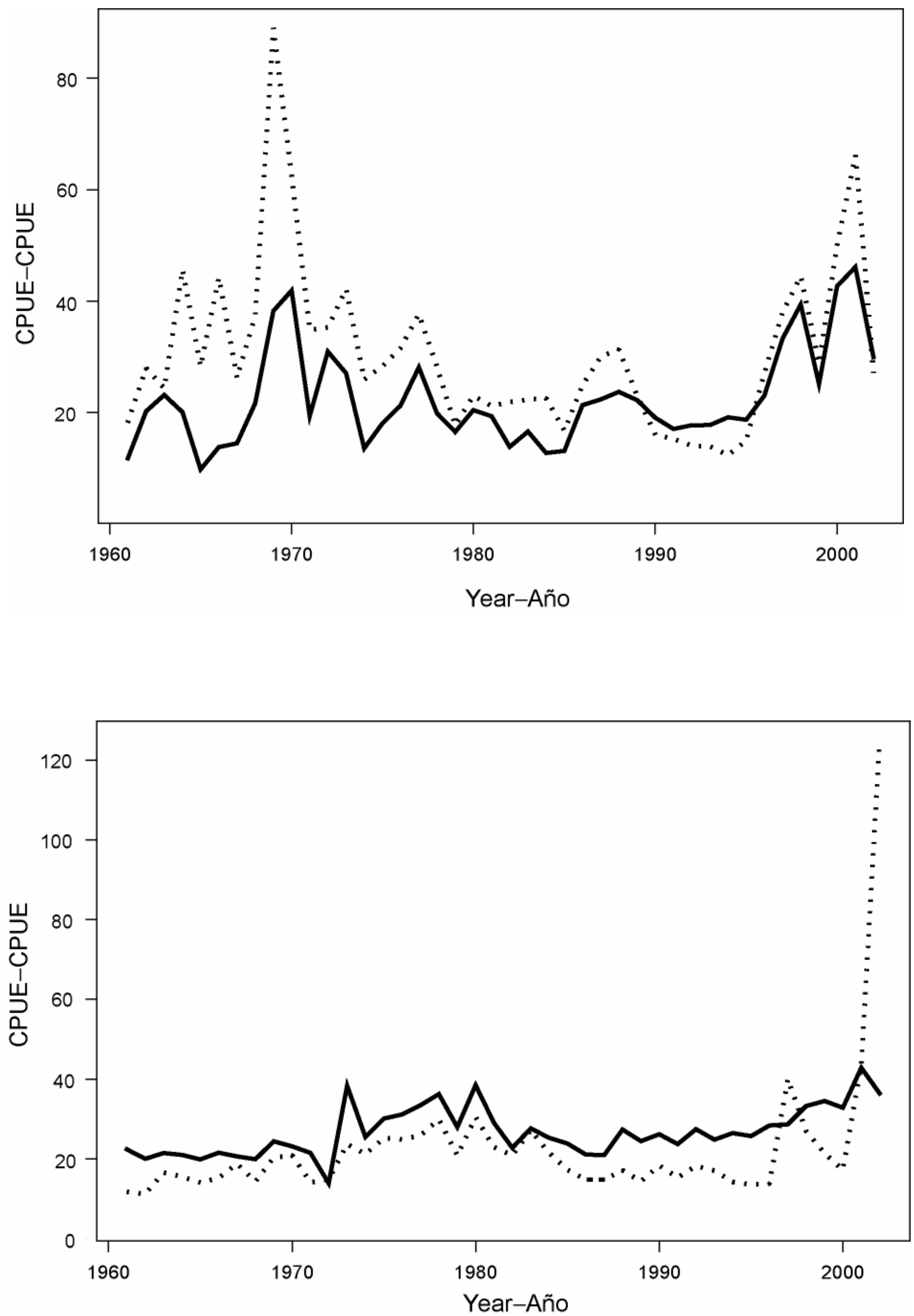

FIGURE 4.1.2. Standardized (solid line) and nominal (dashed line) trends in relative abundance for northern (upper panel) and southern (lower panel) areas of the EPO.

FIGURE 4.1.2. [spanish]

TABLE 2.2.1a. Catches of swordfish, in metric tons, in the eastern Pacific Ocean. The abbreviations for the countries are as follows: CHL, Chile; CHN, China; COL, Colombia; CRI, Costa Rica; ECU, Ecuador; ESP, Spain; GTM, Guatemala; JPN, Japan; KOR, Republic of Korea; MEX, Mexico; NIC, Nicaragua; PAN, Panama; PER, Peru; PYF, French Polynesia; SLV, El Salvador; TWN, Chinese Taipei; United States of America.

Year	CHL	CHN	COL	CRI	ECU	ESP	GTM	JPN	KOR	MEX	NIC	PAN	PER	PYF	SLV	TWN	USA	Total
1945	1,455																	1,455
1946	2,166																	2,166
1947	1,701																	1,701
1948	1,209																	1,209
1949	690																	690
1950	786												6,900					7,686
1951	870												2,400					3,270
1952	570												1,900				175	2,645
1953	416												900				94	1,410
1954	334							17					700				15	1,067
1955	237							14					400				89	739
1956	386							13					600				181	1,180
1957	357							120					600				247	1,324
1958	392							97					400				310	1,199
1959	555							71					400				295	1,321
1960	456							137					400				214	1,206
1961	394							568					300				243	1,504
1962	297							971					400				26	1,694
1963	94							1,886					200				65	2,245
1964	312							3,017					900			0	120	4,350
1965	151							1,682					300			0	215	2,349
1966	175							2,061					200			0	308	2,745
1967	203							1,569					1,300			31	201	3,303
1968	175							2,285					800			18	131	3,409
1969	314							6,327					1,200			6	678	8,526
1970	243							4,125					2,396			26	621	7,411
1971	181							1,939					185			18	102	2,424
1972	141							2,266					550			38	175	3,170
1973	410							3,779					1,941			30	404	6,563

TABLE 2.2.1a. (continued)

Year	CHL	CHN	COL	CRI	ECU	ESP	GTM	JPN	KOR	MEX	NIC	PAN	PER	PYF	SLV	TWN	USA	Total
1974	218							2,143					470			34	427	3,292
1975	137							2,303	9				158			9	569	3,185
1976	13							3,424	29				295			34	55	3,850
1977	32							4,234	33				420			31	336	5,087
1978	56							4,060	35				436			8	1,713	6,308
1979	40							2,610	18				188			30	386	3,273
1980	104							3,667	62				216			17	787	4,853
1981	294							2,882	153				91			35	749	4,205
1982	285							2,475	97				154			32	1,112	4,155
1983	342							3,147	65				238			9	1,758	5,559
1984	103							2,625	65				343			15	2,890	6,041
1985	342							1,764	91				55			12	3,418	5,681
1986	764							2,637	198	23			21			12	2,530	6,184
1987	2,059							3,573	205	14			73			30	1,803	7,757
1988	4,455							3,619	111	19			54			38	1,634	9,931
1989	5,824							3,158	108	2			3			111	1,357	10,563
1990	4,955					1,007		3,015	432				1			39	1,236	10,685
1991	7,255		29	107		2,794		3,053	588				3			40	1,035	14,905
1992	6,379			27		2,435		3,135	272				16	5		32	1,741	14,042
1993	4,712			20		928	22	2,513	289	4			76	38		19	2,085	10,705
1994	3,801			27		575		2,464	261	12			310	51		44	1,939	9,486
1995	2,594			29		698		1,992	291	19			7	38		8	1,896	7,572
1996	3,145			315		772	2	1,968	366	6			1,013	64		35	1,678	9,365
1997	4,040			1,072		2,018	3	2,576	423	1	1		24	38		29	2,058	12,283
1998	4,492		6	419		1,302		3,178	453	168	4		98	44		34	2,420	12,618
1999	2,925			99	203	1,121		1,790	358	237	3		15	46		97	3,621	10,516
2000	2,973			407	374	1,306	1	2,104	417	965	1	21	2	42	2	648	3,432	12,695
2001	3,262	316		653	106	3,427	2	4,207	872	424	7	433		69	2	1,711	2,275	17,765
2002	3,523	830		481	135	5,629		3,439	561	102	11	431	14	60	20		987	16,224

TABLE 2.2.1b. Catches of swordfish, in metric tons, in the eastern Pacific Ocean north of 5°S. The abbreviations for the countries are as follows: CHN, China; COL, Colombia; ESP, Spain; GTM, Guatemala; JPN, Japan; KOR, Republic of Korea; MEX, Mexico; NIC, Nicaragua; PAN, Panama; SLV. El Salvador; TWN, Chinese Taipei; USA, United States of America.

Year	CHN	COL	ESP	GTM	JPN	KOR	MEX	NIC	PAN	SLV	TWN	USA	Total
1952												175	175
1953												94	94
1954					17							15	33
1955					13							89	102
1956					10							181	191
1957					66							247	313
1958					33							310	344
1959					39							295	334
1960					101							214	314
1961					464							243	707
1962					760							26	785
1963					1,210							65	1,275
1964					2,546						0	120	2,666
1965					1,338						0	215	1,553
1966					1,660						0	308	1,968
1967					1,179						0	201	1,380
1968					2,024						0	131	2,155
1969					5,758						0	678	6,436
1970					3,583						0	621	4,204
1971					1,677						0	102	1,779
1972					1,898						0	175	2,073
1973					2,867						0	404	3,270
1974					1,449						0	427	1,876
1975					1,421	6					0	569	1,996
1976					2,215	14					0	55	2,284

TABLE 2.2.1b. (continued)

Year	CHN	COL	ESP	GTM	JPN	KOR	MEX	NIC	PAN	SLV	TWN	USA	Total
1977					2,580	17					0	336	2,933
1978					2,016	6					0	1,713	3,734
1979					1,384	6					0	386	1,775
1980					1,564	30					0	787	2,381
1981					1,229	74					2	749	2,054
1982					1,332	71					1	1,112	2,515
1983					1,376	37					0	1,758	3,171
1984					1,087	28					0	2,890	4,004
1985					896	20					0	3,418	4,334
1986					1,164	138	23				0	2,530	3,854
1987					1,912	110	14				2	1,803	3,840
1988					1,386	35	19				0	1,634	3,074
1989					1,942	80	2				38	1,357	3,418
1990					1,420	326					13	1,236	2,993
1991		29	0		1,157	250					18	1,035	2,489
1992			0		1,114	90					3	1,741	2,949
1993			0	22	1,008	94	4				0	2,085	3,213
1994			0		837	140	12				0	1,939	2,929
1995			0		779	76	19				3	1,896	2,773
1996			0	2	783	139	6				21	1,678	2,628
1997			0	3	1,408	277	1	1			0	2,058	3,747
1998		6	64		1,173	206	168	4			0	2,420	4,042
1999			29	0	533	93	237	*3*			20	3,621	4,537
2000			0	1	939	227	965	1	19	2	436	3,432	6,021
2001	209		0	2	1,792	605	424	7	2	2	1,289	2,275	6,607
2002	517		0		940	360	102	11	0	20		987	2,937

TABLE 2.2.1c. Catches of swordfish, in metric tons, in the eastern Pacific Ocean south of 5°S. The abbreviations for the countries are as follows: CHL, Chile; CHN, China; COL, Colombia; CRI, Costa Rica; ECU, Ecuador; ESP, Spain; JPN, Japan; KOR, Republic of Korea; PAN, Panama; PER, Peru; PYF, French Polynesia; TWN, Chinese Taipei.

Year	CHL	CHN	COL	CRI	ECU	ESP	JPN	KOR	PAN	PER	PYF	TWN	Total
1945	1,455												1,455
1946	2,166												2,166
1947	1,701												1,701
1948	1,209												1,209
1949	690												690
1950	786									6,900			7,686
1951	870									2,400			3,270
1952	570									1,900			2,470
1953	416									900			1,316
1954	334									700			1,034
1955	237						1			400			638
1956	386						4			600			990
1957	357						54			600			1,011
1958	392						64			400			856
1959	555						32			400			987
1960	456						36			400			892
1961	394						104			300			798
1962	297						211			400			908
1963	94						676			200			970
1964	312						471			900		0	1,684
1965	151						344			300		0	795
1966	175						402			200		0	777
1967	203						390			1,300		31	1,924
1968	175						261			800		17	1,253
1969	314						570			1,200		6	2,090
1970	243						542			2,396		26	3,206
1971	181						261			185		18	645
1972	141						368			550		38	1,097
1973	410						912			1,941		30	3,293

TABLE 2.2.1c. (continued)

Year	CHL	CHN	COL	CRI	ECU	ESP	JPN	KOR	PAN	PER	PYF	TWN	Total
1974	218						694			470		34	1,416
1975	137						882	3		158		9	1,189
1976	13						1,210	15		295		34	1,567
1977	32						1,654	16		420		31	2,154
1978	56						2,045	29		436		8	2,574
1979	40						1,226	13		188		30	1,497
1980	104						2,103	32		216		17	2,472
1981	294						1,653	79		91		33	2,150
1982	285						1,144	26		154		31	1,640
1983	342						1,771	28		238		9	2,388
1984	103						1,538	37		343		15	2,036
1985	342						868	70		55		12	1,347
1986	764						1,473	60		21		12	2,330
1987	2,059						1,661	96		73		28	3,917
1988	4,455						2,233	77		54		38	6,857
1989	5,824						1,216	28		3		73	7,144
1990	4,955					1,007	1,596	106		1		26	7,692
1991	7,255		29	107		2,794	1,896	338		3		22	12,445
1992	6,379			27		2,435	2,020	181		16	5	29	11,093
1993	4,712			20		928	1,505	195		76	38	19	7,492
1994	3,801			27		575	1,627	121		310	51	44	6,557
1995	2,594			29		698	1,213	216		7	38	4	4,800
1996	3,145			315		772	1,186	227		1,013	64	14	6,736
1997	4,040			1,072		2,018	1,169	146		24	38	29	8,536
1998	4,492		6	419		1,238	2,004	246		98	44	34	8,582
1999	2,925			99	203	1,092	1,257	264		15	46	77	5,979
2000	2,973			407	374	1,306	1,164	191	2	2	42	212	6,673
2001	3,262	107		653	106	3,427	2,414	267	431		69	422	11,158
2002	3,523	313		481	135	5,629	2,500	201	431	14	60	0	13,287