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ASSESSMENT OF STRIPED MARLIN IN THE EASTERN PACIC OCEAN IN 2008 AND OUTLOOK FOR THE FUTURE

Michael G. Hinton

CONTENTS

1. SUMMARY

Striped marlin occur throughout the Pacific Ocean between about 45°N and 45°S. They are caught mostly by the longline fisheries of Far East and Western Hemisphere nations. Lesser amounts are caught by recreational, gillnet and other fisheries. During recent years the greatest catches in the eastern Pacific Ocean (EPO) have been taken by fisheries of Japan, Costa Rica and Korea.

Striped marlin reach maturity when they are about 140 cm long, and spawning occurs in widely-scattered areas of the Pacific Ocean.

Few tagging data are available on the movements of striped marlin. Tagged fish released off the tip of the Baja California peninsula generally have been recaptured in the same general area as where tagged, but some have been recaptured around the Revillagigedo Islands, a few around Hawaii, and one near Norfolk Island. Recently pop-up satellite tags have been placed on striped marlin in the Pacific (Domeier 2006), achieving times-at-liberty averaging about 2 to 3 months, with maximums of 4 to 9 months in each tagging region. These studies indicated that there was essentially no mixing of tagged fish among tagging areas, and that striped marlin maintained site fidelity.

The catch rates of striped marlin off California and Baja California tend to be greater when the sea-surface temperatures are higher and when the thermocline is shallow. The catch rates are greater on the shallower hooks of longlines, especially when the thermocline is shallow.

The stock structure of striped marlin is uncertain. Analyses of catch rates using generalized additive models (GAMs) suggest that in the north Pacific there appear to be at least two stocks, distributed principally east and west of about 145º-150ºW, with the distribution of the stock in the east extending as far south as 10°-15°S. Genetic studies provide a more detailed picture of stock structure. McDowell and Graves (2008) suggest that there are separate stocks in the northern, northeastern, and southeastern, and southwestern Pacific. Preliminary reports of more recent genetic studies (C. Purcell, University of Southern California, personal communication, May 2009) indicate that the striped marlin in the EPO off Mexico, Central America, and Ecuador are of a single stock and that there may be juveniles from an identified Hawaiian-stock present seasonally in regions of the northern EPO.

Analyses of stock status have been made using a number of population dynamics models. The results from these analyses indicated that striped marlin in the EPO were at or above the level expected to provide landings at the maximum sustainable yield (MSY), estimated at about 3300 to 3800 t, which is substantially greater than the annual catch in recent years and the new record low estimated catch of about 1,400 t in 2007. There is no indication of increasing fishing effort or catches in the EPO stock area. Based on the findings of Hinton and Maunder (2004), new information and recent observations of catch and fishing effort presented herein, it is considered that the striped marlin stocks in the EPO are in good condition, with current and near-term anticipated fishing effort less than F_{MSY}.

2. DATA

2.1. Effort, catch, and landing data

Landings of billfish are fairly well known, due to the value of these fish in commerce. However, there remain unreported landings from artisanal and recreational fisheries, and from components of the commercial longline fisheries operating in the region.

Most of the commercially-landed striped marlin are taken by the longline fisheries of Far East and Western Hemisphere nations. Lesser amounts of striped marlin are, or have been, landed by the other fisheries described in Hinton and Bayliff (2002, Section 2.1). Data on the distribution of effort and total hooks fished by the principal longline fisheries are shown in Figure 2.1.1a and 2.1.1b. Data on commercial landings of striped marlin in the EPO are shown in Table 2.1.1. The annual catch by commercial fleets peaked in the late 1960s to early 1970s at about 11,000 tons, dropped as targeting of billfish decreased, and by 1975 was on the order of 5,000 t. From 1975 to 1998 (the last year with annual catch greater than 3,000 t) the average annual catch was about 4,000 t. Since 1997 the catch of striped marlin from the EPO has been in a decreasing trend, with annual average catch at about 2,000 t, with catch in the most recent four years on the range of 1,400 to 1,500 t.

The principal recreational fisheries for striped marlin in the EPO operate within about 50 to 100 miles of the shores of Mexico, and they may be characterized as catch-and-release for all marlin species. Fleischer *et al*. (2009) reported sport-fishing trips increasing from about 32,500 trips in the early 1990s to about 55,500 trips in recent years, with annual catches of striped marlin increasing from about 13,300 fish to about 30,000 fish over this period. A record high catch of about 58,000 individuals was taken in 2007, the most recent year for which complete data are available, and the preliminary estimate for 2008 is of the same magnitude. Fleischer *et al.* (2009) report an average release rate (determined by the Instituto Nacional de Pesca and the Centro Regional de Investigación Pesquera of La Paz, Mexico) for the 1999-2007 period of about 77.4 percent (range: 72.4 to 82.5). Assuming (1) the average release rate for the 1990-2007 period, (2) 100 percent mortality of fish released, and (3) the reported (Fleischer *et al.* 2009) annual median weight of fish sampled, then the conservative estimate of average annual mortality resulting from the recreational fishery during 1990-2006 was about 195 t (range: 115 to 310), and the mortality associated with the record high catch in

2007 was about 545 t. At a mortality rate of about 25 percent (Domeier *et al.*, 2003), the mortality in 2007 was about 140 t.

A small number of striped marlin are captured in purse-seine fisheries targeting tuna in the EPO. During the 1998-2007 period, the average annual catch of striped marlin by the large (> 363 t carrying capacity) vessels in this fishery was about 370 fish (range: 161 to 566). This catch was orders of magnitude less than the catches made by either the commercial longline or the recreational fishery.

2.2. Size-frequency data

Size-frequency data for striped marlin taken by longline fisheries of Japan in the EPO north of 20ºS during the 1998-2007 period are shown in Figure 2.2.1a and 2.2.1b.

Size-frequency data for striped marlin taken by recreational fisheries of Mexico have been presented by Ortega-García *et al.* (2003) and Fleischer *et al.* (2009). Ortega-García *et al.* (2003) found significant differences in size frequencies of males and females. They found that during 1990-1996 there was a decreasing trend in average eye-fork length (EFL), from about 176 to 167 cm, followed by an increasing trend from 1996 to 1999 (Ortega-García *et al.* 2003, Figure 8), with EFL of sampled marlin ranging from about 113 to 217 cm over the period. Size-frequency data (lower-jaw-fork length – LJFL) for the 1985-2007 period were compiled by Fleischer *et al.* (2009). The annual median LJFL for the period averaged about 202 cm (range: 193 to 211). The general attributes of changes in EFL described by Ortega-García *et al.* (2003) were seen in LJFL (Figure 2.2.2). A gradual decline in median LJFL began in about 2000, followed by a leveling off in 2004 at about 194 cm. Some reduction in median length or average size might initially be expected as recruitment to the population increases due to decreased fishing mortality.

Plots of size frequency distributions of striped marlin taken by purse-seine vessels during the most recent 10-year period for which data are available are shown in Figure 2.2.3a and 2.2.3b.

3. ASSUMPTIONS AND PARAMETERS

3.1. Environmental influences

Information on the relationship of striped marlin to their environment is given by Squire (1974, 1985, and 1987), Hanamoto (1974, 1978 and 1979), Miyabe and Bayliff (1987), Holts and Bedford (1990), Nakano and Bayliff (1992), Brill *et al.* (1993) and Uosaki and Bayliff (1999).

Squire (1974) examined the catch rates for San Diego-based recreational fishing vessels, and found that the catch rates per half-month period were 40.5 fish per period when the sea-surface temperatures (SSTs) were less the 20°C, 99.2 fish per period when the SSTs were between 20° and 21.1°C, and 122.7 fish per period when the SSTs were greater than 21.1°C. When the 21.1°C isotherm was continuous, the catch rates were greater than when it was discontinuous. Squire (1985) found that the landings from off Southern California were greatest when there were continuous isotherms of 22.2°C. He stated that "it is reasonable to assume that the ocean temperatures … never attain values that would result in a maximum catch … because catches appear to be increasing at the peak continuous isotherm recorded (… 22.2°C)." Ortega-García *et al.* (2003) found significant intra-annual differences in seasonal catch rates and reported that “highest catch rates were recorded at [temperatures] between 22º and 24ºC.” Squire (1987) reported that the landings of striped marlin were distributed further to the north during the 1983 El Niño event than during "normal" years. Hanamoto (1974) reported that the catch rates of striped marlin for longliners are greater off Baja California when the thermocline is shallow, and attributed this to more abundant supplies of food during such conditions. Nakamura (1985) reported that the distribution of this species was generally bounded by the 20° and 25°C isotherms, at least in the western Pacific Ocean.

Holts and Bedford (1990) described the vertical movements of 11 striped marlin that were tracked with ultrasonic tags off Southern California. The fish spent most of their time in the upper mixed layer, at temperatures of 19° to 20°C, but sometimes descended to depths where the temperatures were less than 12°C. Four of the fish occupied greater depths at night than during the day. The maximum depth to which a fish descended was about 90 m. Brill *et al.* (1993) tracked six striped marlin in the vicinity of Hawaii. The fish spent about 80 percent of their time in waters with temperatures between 25° and 27°C, and never occupied water with temperatures less than 18°C. The maximum depth to which a fish descended was about 170 m. Abitia *et al*. (1998) stated that in the vicinity of Cape San Lucas, Baja California Sur, striped marlin feed on pelagic fishes during the day and "occasionally migrate to deeper waters to consume prey which live near or on the sandy bottoms."

3.2. Movement and stock structure

Data (catch and catch rates) from fisheries, tagging (conventional and electronic), and genetic studies are generally considered when developing stock-structure hypotheses. Striped marlin are distributed throughout the temperate and warmer waters of the Pacific (Nakamura, 1985). Shomura (1980) indicated hypotheses of either a single pan-Pacific stock, or two stocks, one north and one south of the equator, with mixing in the EPO. Hinton and Bayliff (2002, Section 3.3) considered that the predominance of the information available at the time supported a hypothesis of one stock in the EPO, and recommended study of the stock structure of striped marlin in the Pacific.

Domeirer (2006) reported results from pop-up satellite tags placed on striped marlin in the Pacific. His study achieved time-at-liberties averaging about 2 to 3 months, with maximums of 4 to 9 months in each tagging area. He concluded that "… striped marlin exhibited a degree of regional site fidelity with little to no mixing between fish tagged at different regions."

Genetic analyses by McDowell and Graves (2008) indicated that there were at least four discrete stocks of striped marlin in the Pacific, and identified them as occurring off Australia, in the northern Pacific (Japan/Taiwan/Hawaii/California), Mexico, and Ecuador. They associated these stocks with identified (by presence of larvae) spawning areas off Australia, Japan/Taiwan, Mexico and in the southeast Pacific at about 10ºS to 20ºS at 150ºW to 140ºW. They found temporal stability in samples from Japan and Australia.

More recent genetic analyses (C. Purcell, University of Southern California, personal communication, May 2009) utilizing large sample sizes and new markers for striped marlin, indicate that there are three discrete stocks in the northern Pacific, for which mature individuals were associated with identified spawning areas that were located off Hawaii (Hyde *et al.* 2006), Japan/Taiwan, and Mexico. Juveniles of the Japan group were found off Hawaii, and those of the Hawaii group were found seasonally off California (Catalina Islands), but they were not found further south. The eastern Pacific stock (México/Central America/Ecuador) was not found mixed with other stocks.

An analysis of stock structure of striped marlin in the northern and eastern Pacific was presented to the ISC billfish working group (M. G. Hinton, "Stock Assessment Modeling of Striped Marlin," Report, ISC/09/BILLWG-1/18, February 2009, 7 p.). The work was conducted in R (Ver. 2.8.1). Generalized ridge regression with optimal smoothing (GAM) models were fitted using function "gam" in package mgcv (Ver. 1.4-1.1). Modifications were made to code in function "vis.gam" to extract data for contour plots and to handle structure of the dependent variable as ln(catch rate + a constant). The fisheries data were from Japanese longline fisheries from 1965-1974, a period when the distribution of fishing effort extended through the principal known distribution areas of striped marlin, and preceded changes in longline gear configuration which may influence the catchability of striped marlin.

In the above analyses, multiple stocks and the intersections of their distributions were identified (Figures 3.2.1 and 3.2.2). In the north Pacific there appear to be at least two stocks, one with a geographical center at about 110°W and 23°N, and one at about 162°W-22°N. The model results separated these stocks at about 142.5°W, the center of the 5° longitude by 5° latitude data area with longitude of 140°W to 145°W. These two stocks appear separable for assessment purposes at about 145°W. The southern boundary of the northeastern stock follows at about 10°S from 165°W to the coast, though there appears a somewhat high catch rate region around the Galapagos Islands which may be bounded by the southern boundary of the northeastern stock and a line running from about 10°S and 110°W, thence to the coastline at about 20°N. It was found that the southern boundary for the western Pacific region may be set at the equator without loss of information.

4. STOCK ASSESSMENT

4.1. Previous assessments

The most recent stock assessment of striped marlin in the EPO is presented in Hinton and Maunder (2004), which also presents reviews of previous analyses of trends in catch rates and stock assessments of striped marlin.

Hinton and Maunder (2004) used updated data, new models and methods for standardizing catch rates, and two population dynamics models. Taking into account the time period (about 1964 to 1974) when billfish were targeted by longline fishing, they found that in one case the estimate of maximum sustainable yield was about 3,700 to 5,000 t, with a then current depletion ratio, or ratio of current biomass (B) to the estimated unfished population biomass (B_O), of about 0.47. The ratio of B to the biomass that may be expected to yield MSY (B_{MSY}) ranged from about 1.0 to 1.9. The results from the second analysis yielded estimates of MSY of 8,700 to 9,200 t, with then current depletion ratios of 0.68 to 0.70, and B to B_{MSY} ratios of about 1.2 to 1.6.

Their results were consistent with those presented in the previous (Hinton and Bayliff, 2002) assessment of striped marlin. Hinton and Maunder (2004) also noted that landings and standardized fishing effort for striped marlin in the EPO decreased from 1990-1991 through 1998, and this general decline has continued, reaching new lows in preliminary estimates of retained catch in 2000 and 2001 of about 1,500 t, which is well below estimated MSY harvest levels. They also noted that continuing low catches may result in a continued increase in the biomass of the stock in the EPO.

The following is from Hinton and Maunder (2004), Sec. 5 Stock Status:

> "The results cited indicate that striped marlin in the EPO are at or above the level expected to provide landings at MSY for the Pella-Tomlinson one q model when $B_{MSY}/B_O < 0.35$ and for the two q model for all values of B_{MSY}/B_O investigated. The current production is estimated at about 3300 to 3800, which is substantially more than the current catch. The results from the Deriso-Schnute model with two qs indicated that striped marlin in the EPO are above level expected to provide landings equivalent to MSY, and that the current depletion ratio is higher than indicated by the Pella-Tomlinson model."

4.2. Assessment

There is no indication of increasing fishing effort or catches of striped marlin in the EPO. During the period from 1965 to 2001, about 75 percent of the total longline fishing effort was north of 10ºS. Since then only about 65 percent has been north of 10ºS. A disproportionate amount of the overall drop in fishing effort has occurred in the principal portions of the stock distribution (Figure 2.1.1). Catch in the EPO region was about 1,400 t in 2007, again well below the estimated MSY of the stock. Fishing effort and catches have continued the decline noted in previous assessments. Based on these considerations, no additional stock assessment analysis was undertaken this year.

5. STOCK STATUS

The information and results presented indicate that striped marlin population levels in the EPO are at or above the level expected to provide landings at MSY levels, which are currently estimated at about 3,300 to 3,800 t, substantially more than the current catch. There has been an observed decreasing trend in standardized fishing effort since about 1990-1991, and nominal fishing effort and catch have continued to decline since about 2001. There are indications that for the next few years the nominal fishing effort will continue near or below levels observed in recent years. Based on the information, analyses and hypotheses discussed and shown herein, it is considered that the striped marlin stocks in the EPO are in good condition, with current and near-term anticipated fishing effort less than F_{MSY}.

6. FUTURE DIRECTIONS

6.1. Collection of new and/or updated information

In general, previous recommendations made concerning data and information on striped marlin remain true.

There remain questions about the stock structure of striped marlin in the EPO, particularly related to the temporal stability and distributions of stocks identified by genetic analyses. Publication of the most recent genetic analyses is expected in a few months, and they are expected to include additional information on stability and distribution. Once these results have been reviewed, more consideration should be given to the hypothesized stock structures to be considered in future assessments of striped marlin in the Pacific.

Assessment analyses would benefit significantly from improved information on the growth rates and natural mortality rates of striped marlin by stock region. Improved estimates of sex-specific size at age, with estimates of the landings by sex, would be expected to increase confidence in assessment results. These improvements would require increased on-board sampling for biological data, and improvements in techniques for aging of striped marlin.

Estimates of total removals of fish from a population are critical to stock assessment. There remain undocumented and unreported landings of striped marlin from the EPO, as well as uncertainty in estimates of population removals and cryptic mortalities from catch-and-release recreational fisheries. Efforts have been undertaken to increase reporting of landings made by artisanal and small-scale commercial fisheries, and attempts are being made to obtain estimates of landings of components of the large-scale longline fisheries for which data are not now available. Though there have been improvements in these areas during the intervening period, these efforts should be pursued with diligence.

6.2. Assessment model development

Efforts should be made to identify means by which stock status of striped marlin in the EPO may be estimated in an environment of limited or missing observations from what has been the key index of relative abundance, data from Japanese longline fisheries.

The collaborative effort examining the stock structure and status of striped marlin in the Pacific Ocean initiated during 2002 should be continued.

6.3. General

If there are observed significant increases in fishing effort or catch of striped marlin in the EPO, or as more data become available, assessment results presented here should be updated to ensure that, if there develop indications that the condition of the stock(s) of striped marlin has deteriorated, action could be considered and taken in a timely manner.

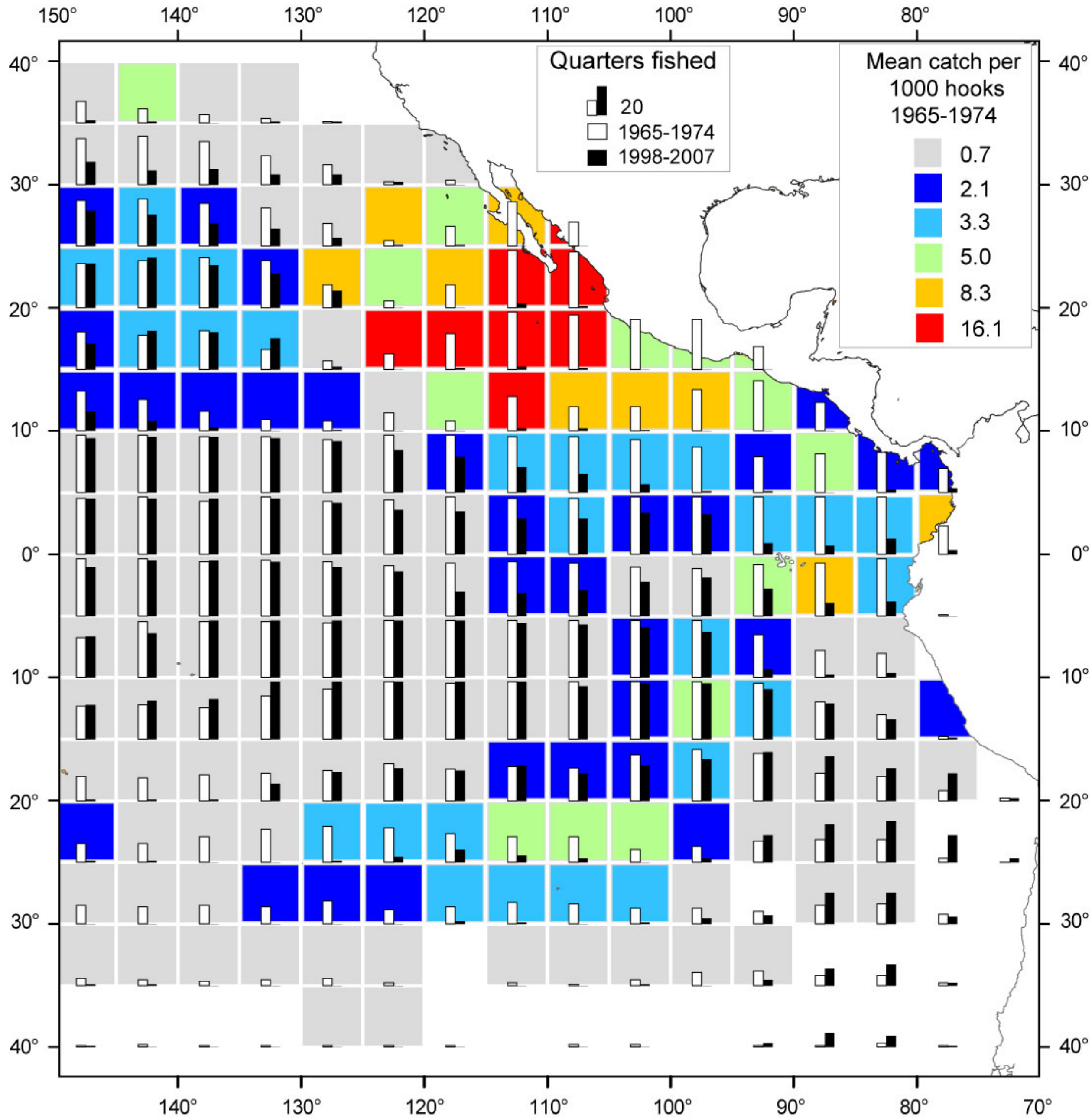

FIGURE 2.1.1a. Distribution of total quarters fished by Japanese-flag longline vessels by time periods. Data for the 1965-1974 period were used for stock structure analysis, and data for the 1998-2007 period are those for the most recent 10 years for which data are available.

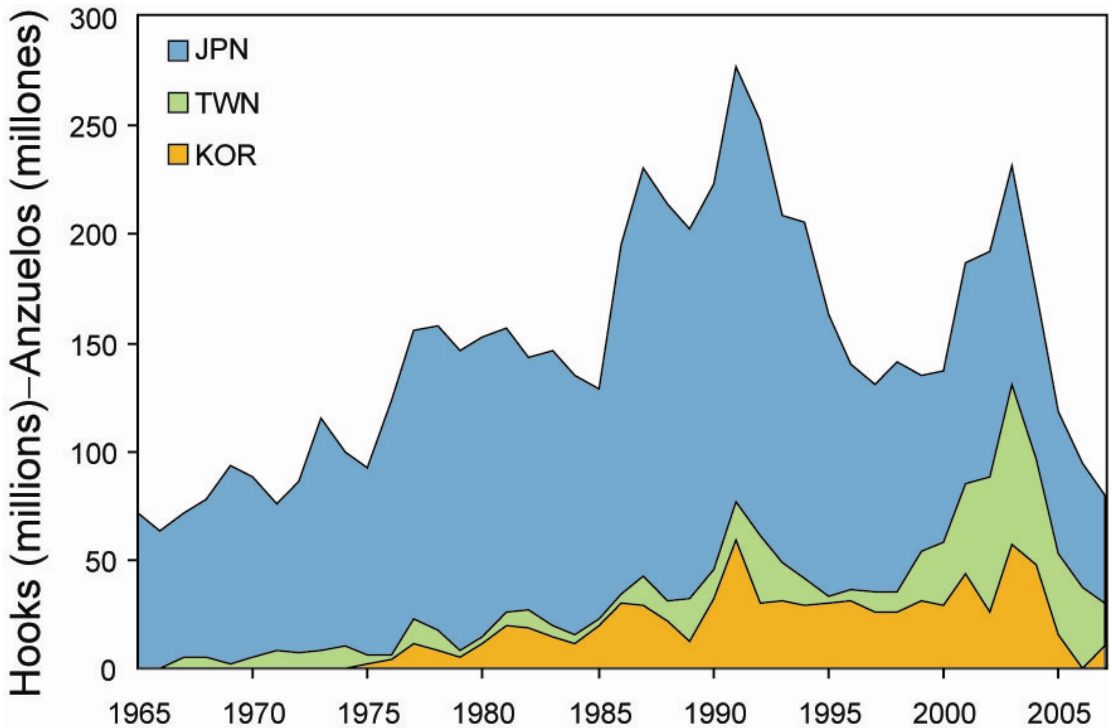

FIGURE 2.1.1b. Number of hooks fished by principal longline fleets operating in the EPO by flag of vessel by year.

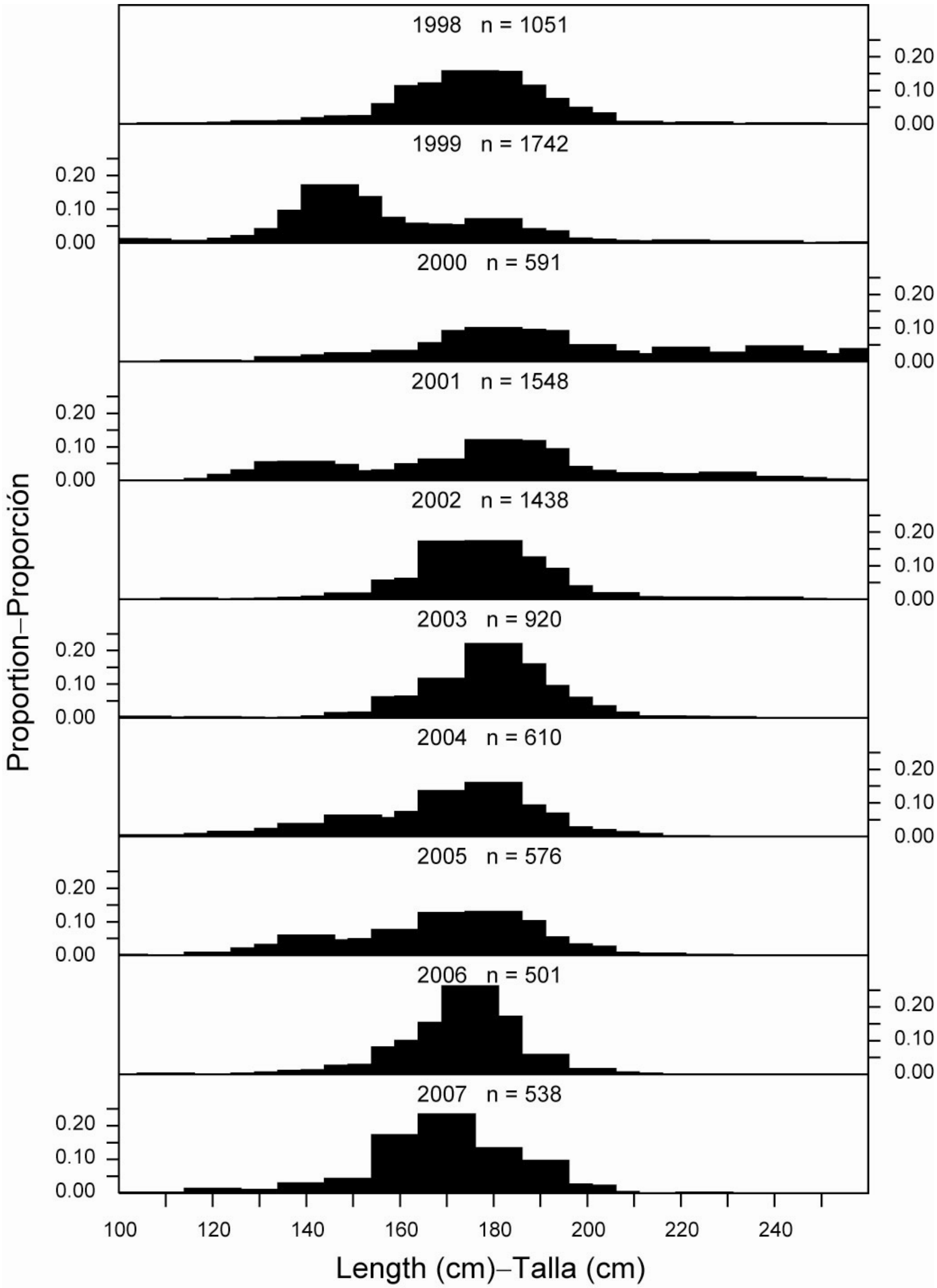

FIGURE 2.2.1a. Distribution of measurements of eye-fork length of striped marlin taken by Japanese longline fisheries in the EPO north of 20ºS, and the number (n) of measurements by year.

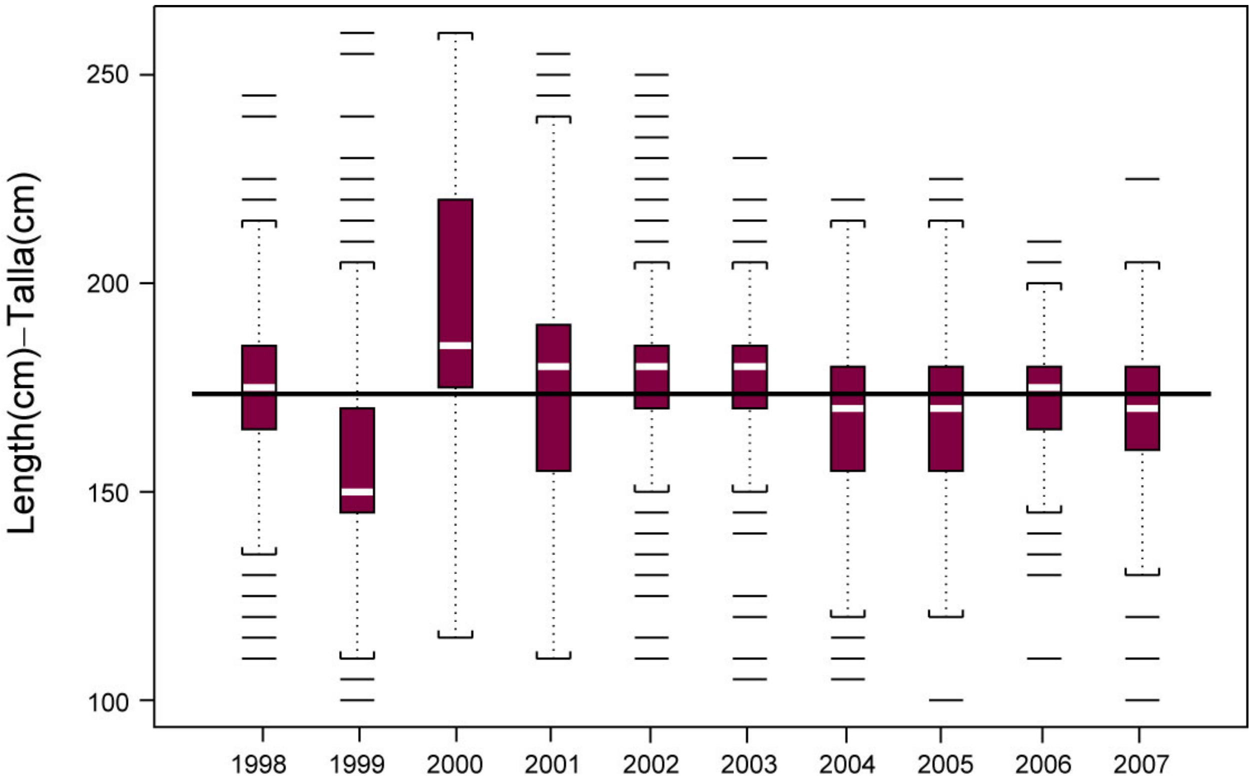

FIGURE 2.2.1b. Median and range of eye-fork length measurements of striped marlin taken by Japanese-flag longline fisheries in the EPO by year, and the 10-year average median (solid line).

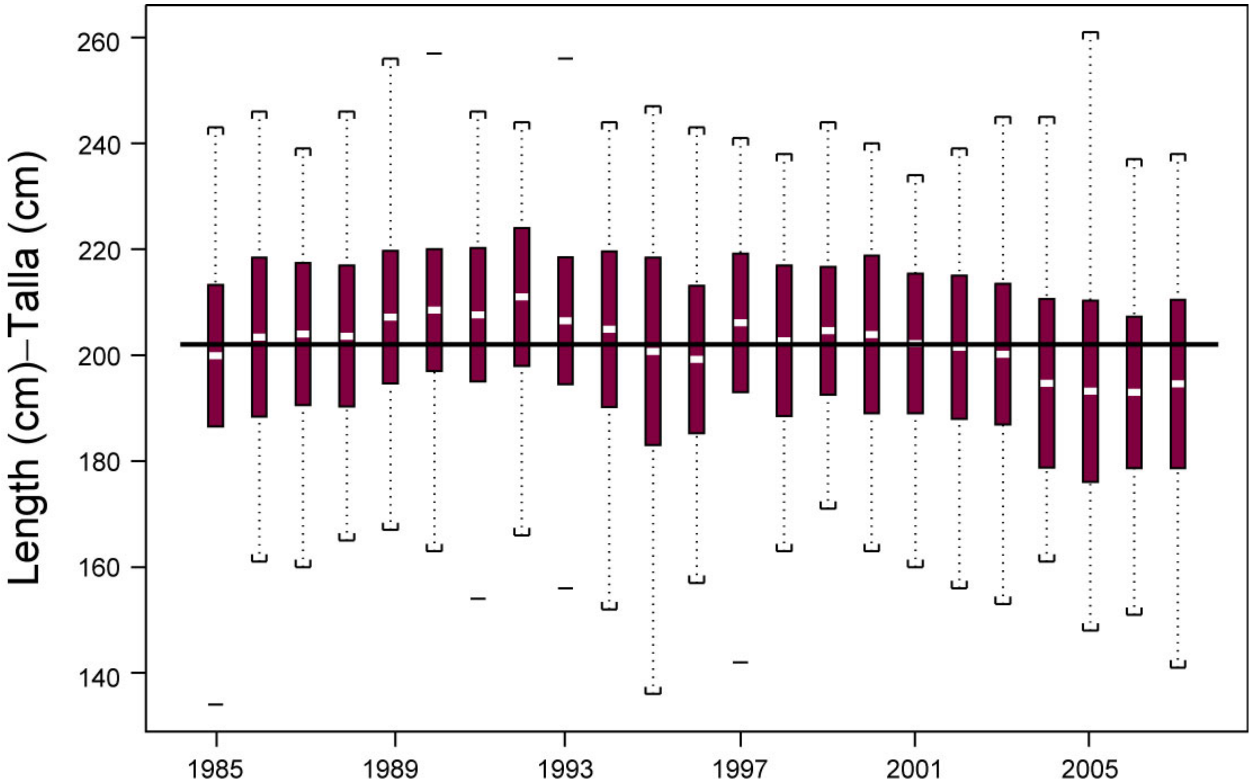

FIGURE 2.2.2. Distribution of measurements of lower-jaw-fork length of striped marlin taken by recreational fisheries of Mexico by year, and the average median (solid line). Boxes are median ± 1 se, and whiskers are range. Data are from Fleischer *et al*. (2009) Table 3.

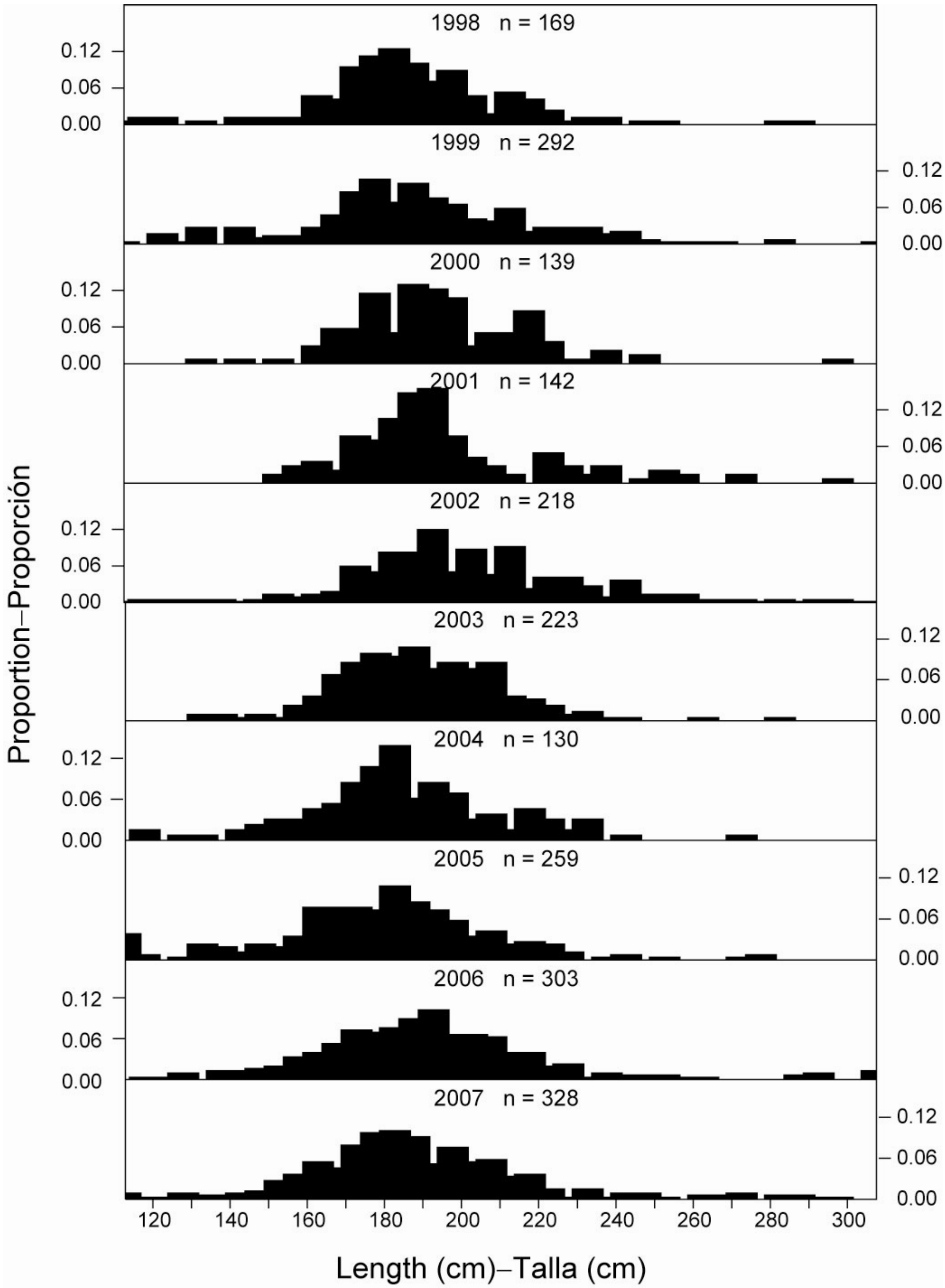

FIGURE 2.2.3a. Distribution of measurements of eye-fork length of striped marlin taken by purse-seine fisheries in the EPO, and the number (n) of measurements by year.

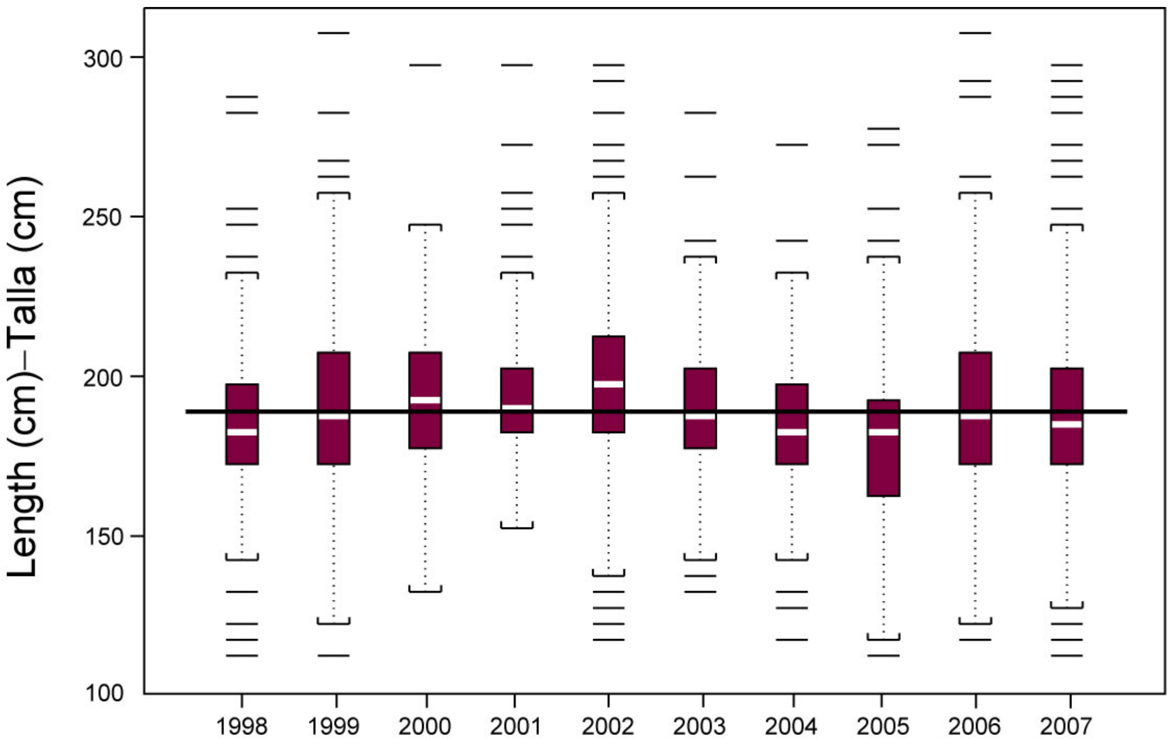

FIGURE 2.2.3b. Median and range of eye-fork length measurements of striped marlin taken by purse-seine fisheries in the EPO by year, and the 10-year average median (solid line).

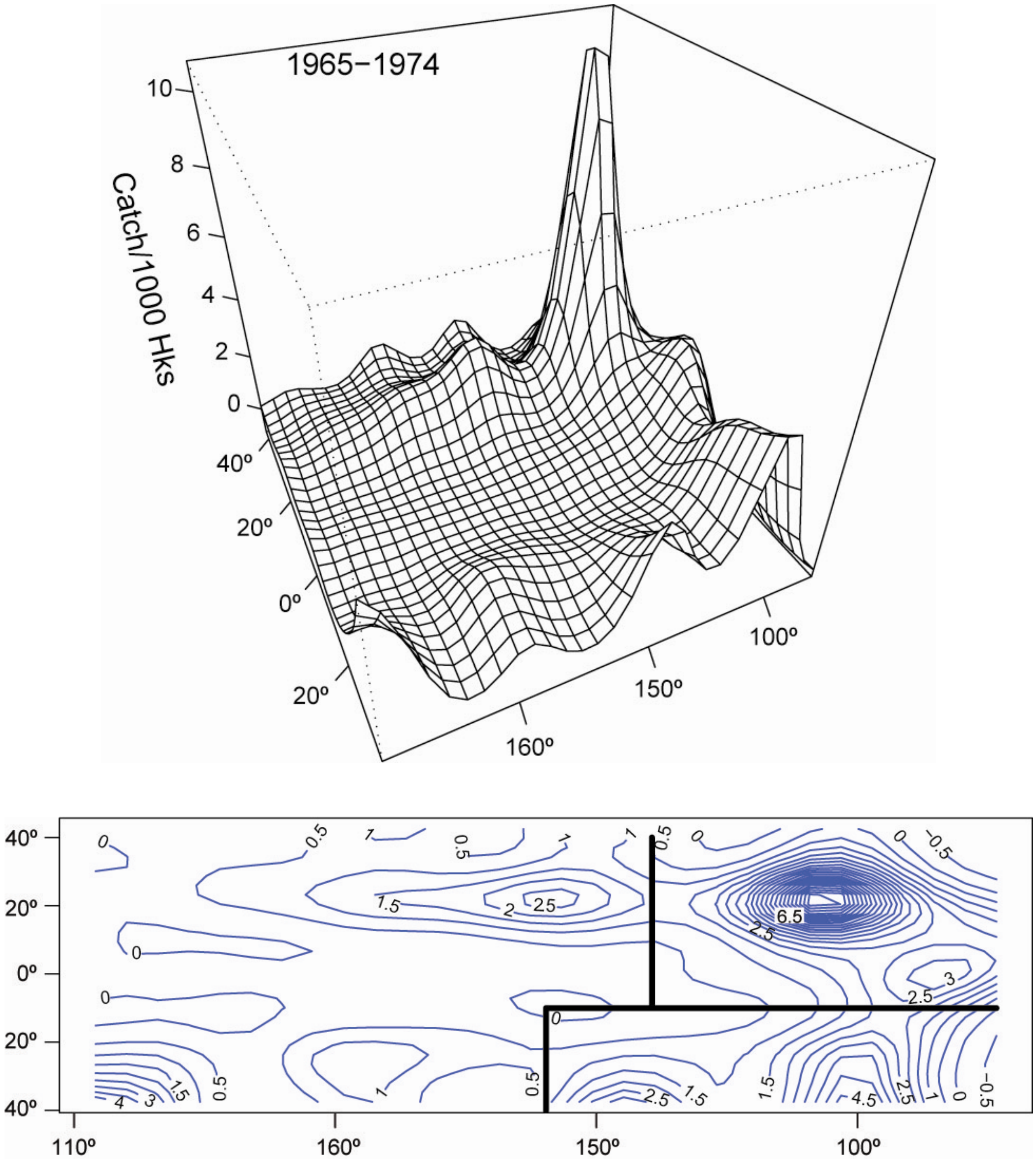

FIGURE 3.2.1 Average distribution of striped marlin relative abundance estimated by standardized (GAM) catch rates of Japanese longline fisheries for the 1965-1974 period. Solid lines demark areas in the EPO considered for stock assessment analysis.

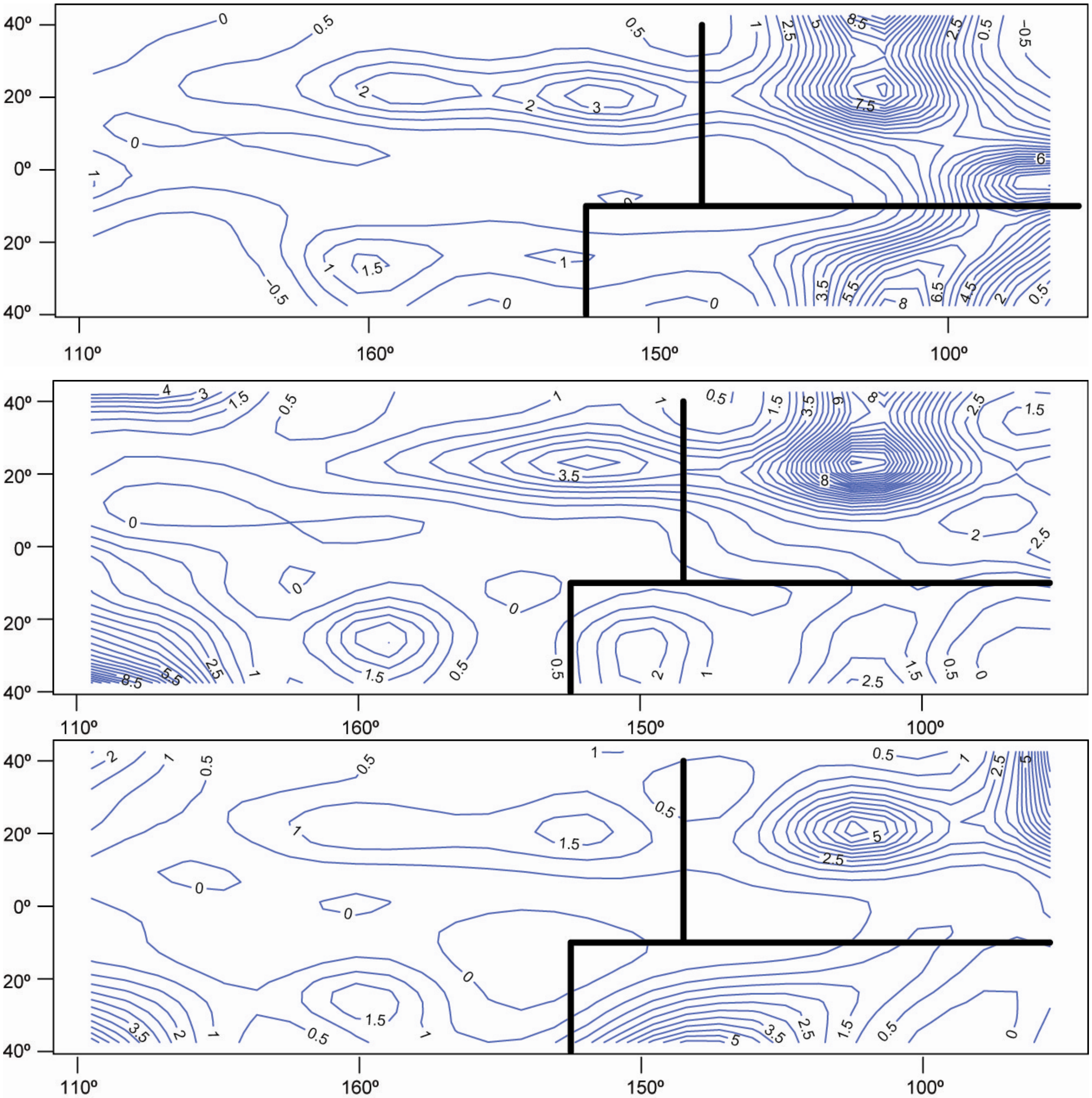

FIGURE 3.2.2. Representative annual distributions of relative abundance of striped marlin estimated by standardized (GAM) catch rates of Japanese longline fisheries for the 1965-1974 period. Solid lines demark areas in the EPO considered for stock assessment analysis. Top panel: 1965; middle panel: 1970; bottom panel: 1973.

TABLE 2.1.1. Preliminary estimates of retained catches (t) of striped marlin from the EPO. 0 means catch <0.5 t; * means data missing or not available.

Year	CRI	JPN	KOR	MEX	PYF	TWN	Other	Total
1965	*	9931	Figure	*	*	0	0	9931
1966	*	9060	*	*	*	2	0	9062
1967	*	10364	*	*	*	91	0	10455
1968	*	14130	*	*	*	83	0	14213
1969	*	9006	*	*	*	23	0	9029
1970	*	10949	*	*	*	57	0	11006
1971	*	10049	*	*	*	157	0	10206
1972	*	6981	*	*	*	116	0	7097
1973	*	5116	*	*	*	97	0	5213
1974	*	5229	*	*	*	124	0	5353
1975	*	5361	10	*	*	19	0	5390
1976	*	6410	14	*	*	8	0	6432
1977	*	3020	19	*	*	106	0	3145
1978	*	2170	292	*	*	33	0	2495
1979	*	4056	43	*	*	38	0	4137
1980	*	4771	23	0	*	33	0	4827
1981	*	4096	733	*	*	47	0	4876
1982	*	4162	482	*	*	67	0	4711
1983	*	3457	790	192	*	33	0	4472
1984	*	2306	339	*	*	17	0	2662
1985	*	1329	165	93	*	12	0	1599
1986	*	2535	0	969	*	36	0	3540
1987	*	5043	370	2171	*	63	0	7647
1988	*	3412	210	1631	*	30	0	5283
1989	*	3153	154	59	*	107	0	3473
1990	*	2812	429	*	*	19	0	3260
1991	188	2321	441	*	*	40	3	2993
1992	147	2006	713	*	6	173	9	3054
1993	243	2237	959	5	0	121	10	3575
1994	270	2379	606	10	35	94	2	3396
1995	306	2211	630	30	53	12	7	3249
1996	237	1961	928	21	49	19	3	3218
1997	272	2617	1480	*	46	56	2	4473
1998	281	2272	896	33	41	29	6	3558
1999	334	1284	861	4	60	68	10	2621
2000	190	860	657	21	79	79	3	1889
2001	274	1145	53	1	84	396	8	1961
2002	213	1142	191	0	7	564	43	2160
2003	133	975	167	1	80	530	26	1912
2004	234	650	319	7	82	213	43	1548
2005	328	708	72	0	53	339	21	1521
2006	137	742	*	*	95	521	5	1500
2007	273	588	48	*	110	207	180	1406

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