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STATUS OF SKIPJACK TUNA IN THE EASTERN PACIFIC OCEAN IN 2014

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CONTENTS

1. SUMMARY

This report presents the most current stock assessment of skipjack tuna (*Katsuwonus pelamis*) in the eastern Pacific Ocean (EPO). Several alternative methods have historically been used to assess the status of skipjack tuna: a) fishery and biological indicators; b) analysis of tag data; c) a length-structured stock assessment model; d) Age-Structured Catch-at-Length Analysis (A-SCALA); and e) a Spatial Ecosystem and Population Dynamic Model (SEAPODYM). The results of all five of these methods are compared when discussing the status of skipjack in the EPO. Only the indicator approach has been updated in this report.

Skipjack are distributed across the Pacific Ocean, and it is likely that there is a continuous stock throughout the Pacific Ocean, with exchange of individuals at a local level, although large-scale movements are thought to be rare. The bulk of the catches of skipjack are made in the eastern and western regions; the purse-seine catches are relatively low in the vicinity of the western boundary of the EPO at 150°W. The movements of tagged skipjack generally cover hundreds, rather than thousands, of kilometers, and exchange of fish between the eastern and western Pacific Ocean appears to be limited. Movement rates between the EPO and the western Pacific cannot be estimated with currently-available tagging data. In some analyses the EPO was divided into six independent sub-regions to accommodate spatial structure of the population and fishery dynamics.

Stock assessment requires substantial amounts of information and the information varies depending on the method used. The methods applied to skipjack require a variety of information, including data on retained catches, discards, indices of abundance, the size compositions of the catches of the various fisheries, tagging data, and oceanographic data. In addition, assumptions have to be made about processes such as growth, recruitment, movement, natural mortality, selectivity, and stock structure.

Biomass, recruitment, and fishing mortality are estimated to be highly variable over time. The estimates are uncertain and differ among the alternative assessment methods. A large recruitment appears to have entered the population in 1999, and led to increased biomass in that year, but the increase was temporary, due to the short-lived nature of skipjack. Biomass appears to have been above average in recent years, but this may differ among regions. SEAPODYM estimates annual biomass of skipjack 30cm or larger cycling between 1,800,000 t and 2,350,000 t from 1998 to 2008, but the quality of these estimates has yet to be determined. The average weight of skipjack started declining in 2000, but has stabilized in recent years. Previous assessments using a catch-at-length analysis (A-SCALA) to assess skipjack tuna in the EPO were considered preliminary because: 1) it was unknown if catch-per-day-fished for purse-seine fisheries is proportional to abundance; 2) it is possible that there is a population of large skipjack that is invulnerable to the fisheries; and 3) the structure of the EPO stock in relation to the western and central Pacific stocks is uncertain. These issues are also relevant to the other assessments.

Previous assessments estimated that maximum yields are achieved with infinite fishing mortality because the critical weight is less than the average weight at recruitment to the fishery. However, this is uncertain because of uncertainties in the estimates of natural mortality and growth. For this reason, no traditional reference points are available for skipjack tuna in the EPO. Consequently, indicators and reference levels have been used to evaluate the status of the stock. The main concern with the skipjack stock is the constantly increasing exploitation rate. However, exploitation rate appears to have leveled off in recent years. The data- and model-based indicators have yet to detect any adverse consequence of this increase. The average weight was below its lower reference level in 2009, which can be a consequence of overexploitation, but it can also be caused by recent recruitments being greater than past recruitments or expansion of the fishery into areas occupied by smaller skipjack. However, average weight has stabilized in recent years. The tagging analyses, length-structured model, A-SCALA, and the SEAPODYM analyses do not provide any information that indicates a credible risk to the skipjack stock(s).

Susceptibility and productivity analysis (PSA; see IATTC Fishery Status Report 12, p 149) shows that skipjack has substantially higher productivity than bigeye tuna. Biomass and fishing mortality corresponding to MSY are, respectively, negatively and positively related to productivity. Therefore, since skipjack and bigeye have about the same susceptibility, which is related to fishing mortality, the status of skipjack can be inferred from the status of bigeye. The current assessment of bigeye tuna estimates that the fishing mortality is less than F_{MSY}; therefore, the fishing mortality for skipjack should also be less than F_{MSY}. Since effort and skipjack biomass have been relatively constant over the past 10 years, this also implies that skipjack biomass is above B_{MSY}.

Key Results

1. There is uncertainty about the status of skipjack tuna in the EPO.
2. There may to be differences in the status of the stock among regions.
3. There is no evidence that indicates a credible risk to the skipjack stock(s).
4. No additional management action is needed above and beyond that implemented for the conservation of bigeye tuna.

2. INTRODUCTION

A major management objective for tunas in the eastern Pacific Ocean (EPO) is to keep stocks at levels capable of producing maximum sustainable yields (MSYs). Management objectives based on MSY or related reference points (*e.g.* fishing mortality that produces MSY (F_{MSY}); spawner-per-recruit proxies) are in use for many species and stocks worldwide. However, these objectives require that reference points and quantities to which they are compared be available. The various reference points require different amounts and types of information, ranging from biological information (*e.g.* natural mortality, growth, and stock-recruitment relationship) and fisheries characteristics (*e.g.* age-specific selectivity), to absolute estimates of biomass and exploitation rates. These absolute estimates generally require a formal stock assessment model. For many species, the information required to estimate these quantities is not available, and alternative approaches are needed. Even more data are required if catch quotas are to be used as the management tool.

Skipjack tuna is a notoriously difficult species to assess. Due to its high and variable productivity (*i.e.* annual recruitment is a large proportion of total biomass), it is difficult to detect the effect of fishing on the population with standard fisheries data and stock assessment methods. This is particularly true for the stock of the EPO, due to the lack of age-composition data and the limited tagging data. The continuous recruitment and rapid growth of skipjack mean that the temporal stratification needed to observe modes in length-frequency data make the current sample sizes inadequate. Previous assessments have had difficulty in estimating the absolute levels of biomass and exploitation rates, due to the possibility of a dome-shaped selectivity curve (Maunder 2002; Maunder and Harley 2005), which would mean that there is a cryptic biomass of large skipjack that cannot be estimated. The most recent comprehensive assessment of skipjack in the EPO (Maunder and Harley 2005) is considered preliminary because it is not known whether the catch per day fished for purse-seine fisheries is proportional to abundance. The results from that assessment are more consistent among sensitivity analyses than the earlier assessments, which suggests that they may be more reliable. Analysis of currently available tagging data is unlikely to improve the skipjack stock assessment (Maunder 2012a) and a fully length-structured model produced unrealistic estimates (Maunder 2012b). In addition to the problems listed above, the levels of age-specific natural mortality are uncertain, if not unknown, and current yield-per-recruit (YPR) calculations indicate that the YPR would be maximized by catching the youngest skipjack in the model (Maunder and Harley 2005). Therefore, neither the biomass- nor fishing mortality-based reference points, nor the indicators to which they are compared, are available for skipjack in the EPO.

One of the major problems mentioned above is the uncertainty as to whether the catch per unit of effort (CPUE) of the purse-seine fisheries is an appropriate index of abundance for skipjack, particularly when the fish are associated with fish-aggregating devices (FADs). Purse-seine CPUE data are particularly problematic, because it is difficult to identify the appropriate unit of effort. In the current assessment, effort is defined as the amount of searching time required to find a school of fish on which to set the purse seine, and this is approximated by number of days fished. Few skipjack are caught in the longline fisheries or dolphin-associated purse-seine fisheries, so these fisheries cannot be used to develop reliable indices of abundance for skipjack. Within a single trip, purse-seine sets on unassociated schools are generally intermingled with floating-object or dolphin-associated sets, complicating the CPUE calculations. Maunder and Hoyle (2007) developed a novel method to generate an index of abundance, using data from the floating-object fisheries. This method used the ratio of skipjack to bigeye in the catch and the "known" abundance of bigeye based on stock assessment results. Unfortunately, the method was of limited usefulness, and more research is needed to improve it. Currently, there is no reliable index of relative abundance for skipjack in the EPO. Therefore, other indicators of stock status, such as the average weight of the fish in the catch, should be investigated.

Since the stock assessments and reference points for skipjack in the EPO are so uncertain, developing alternative methods to assess and manage the species that are robust to these uncertainties would be beneficial. Full management strategy evaluation (MSE) for skipjack would be the most comprehensive method to develop and test alternative assessment methods and management strategies (Maunder 2007); however, developing MSE is time-consuming, and has not yet been conducted for skipjack. In addition, higher priority for MSE is given to yellowfin and bigeye tuna, as available data indicate that these species are more susceptible to overfishing than skipjack. Therefore, Maunder and Deriso (2007) investigated some simple indicators of stock status based on relative quantities. Rather than using reference points based on MSY, they compared current values of indicators to the distribution of indicators observed historically. They also developed a simple stock assessment model to generate indicators for biomass, recruitment, and exploitation rate. We update their results to include data up to 2014. To evaluate the current values of the indicators in comparison to historical values, we use reference levels based on the

5th and 95th percentiles, as the distributions of the indicators are somewhat asymmetric. The results are compared with historical assessments based on analysis of tag data, a length-structured stock assessment model, Age-Structured Catch-at-Length Analysis (A-SCALA), and a Spatial Ecosystem and Population Dynamic Model (SEAPODYM).

3. DATA

The data used differ among the five methods historically used to assess skipjack in the EPO. In general, Catch, effort, and size-composition data, plus biological data, were used to conduct the stock assessments.

Indices of abundance were derived from purse-seine catch and effort data. The catch per unit of effort (CPUE) for the purse-seine fisheries was calculated as catch divided by number of days fished. The number of days fished, by set type, was estimated from the number of sets, using a multiple regression of total days fished against number of sets by set type (Maunder and Watters 2001).

Tag release and recapture data from eight trips on pole-and-line vessels between 1973 and 1981 are available. Release information is available in summary form from printed records. Releases were coastal and north of the equator. The recapture information is available in an electronic data base. Detailed information such as length at release is not currently available in electronic form. Tag identification numbers are not available in electronic form for releases, so the recaptures can be matched only to the release trip, and not to the specific details of release (*e.g.* month). Tag release and recapture data from several trips by pole-and-line vessels between 2000 and 2006 are available in the IATTC database. Releases are limited in spatial extent to an area close to the equator.

4. BIOLOGICAL AND DEMOGRAPHIC INFORMATION

4.1. Growth

The IATTC staff has used a growth rate of 24 cm per year, from Forsbergh (1989), in its yield-per-recruit modeling of skipjack. Bayliff (1988) used tagging data to calculate the estimates for the parameters of the von Bertalanffy growth equation. However, the results of sensitivity analyses performed by Bayliff (1988) indicated that the estimates of the parameters were imprecise.

Maunder (2002a) estimated growth for the northern and southern coastal areas separately, using a version of the more flexible Richards growth curve, and also estimated the variation in growth, allowing the creation of growth transition matrices for use in a size-structured model.

The weight-length relationship of skipjack in the EPO is $W = (5.5293 \times 10^{-6})L^{3.336}$, where W = weight in kilograms and L = length in centimeters (Hennemuth, 1959).

4.2. Natural mortality

Attempts to estimate the natural mortality rate (M) of skipjack, and the many problems associated with these studies, are discussed by Wild and Hampton (1994). The IATTC staff has used a value of 1.5, on an annual basis, for M in yield-per-recruit analyses (Anonymous, 2000: 69). In contrast to yellowfin and bigeye tuna, skipjack do not show an increase in the proportion of males for older fish (Schaefer 2001). Hampton (2000), using tagging data, obtained estimates of natural mortality for skipjack in the western Pacific Ocean (WPO) that were higher for old and young individuals. The results showed much higher natural mortality rates for skipjack of sizes less than 40 cm and greater than 70 cm. Hampton's estimates of high natural mortality for old skipjack may be an artifact of the tagging data due to older fish moving out of the fishery. Hampton's estimates of high natural mortality for young skipjack may also be an artifact of the tagging data due to tagging mortality, and a lower natural mortality rate is used here.

4.3. Recruitment and reproduction

Information on the reproduction of skipjack in the EPO is given by Anonymous (1998: 26) and Schaefer (2001). Spawning is fairly widespread between about 15°N and 10°S from the coast of the Americas to about 130°W at sea-surface temperatures (SSTs) equal to or greater than 24°C. It is assumed that skipjack tuna can be recruited to the fishable population during every month of the year. No strong assumptions are made about the relationship between adult biomass (or abundance) and recruitment in the historical stock assessments of skipjack.

4.4. Movement

Information of the movements of skipjack in the EPO is given by Schaefer *et al*. (1961), Fink and Bayliff (1970), Hunter *et al*. (1986), and Schaefer (2009). The percentage of skipjack released in the western Pacific that were at liberty 0 to 30 days, 31 to 180 days, and more than 180 days that traveled more than 500 nautical miles are 0, about 5, and about 30, respectively. Twenty-seven tagged skipjack released in the EPO have been recaptured in the central or western Pacific (Bayliff, 1988: Appendix 2), but no tagged skipjack released in the central or western Pacific have been recaptured in the EPO. It should be recognized that the amounts of tagged fish recaptured at various locations are dependent on the amounts of fishing effort in those locations. If tagging experiments are initiated where the fishing effort is heavy the distances moved by the fish that are recaptured are likely to be less than they would have been if the tagged fish had been released in areas of both heavy and light fishing.

4.5. Stock structure

Skipjack occur throughout the tropical and subtropical waters of the Pacific Ocean, and it is known that there is considerable exchange of fish among areas. The stock structure of skipjack has been studied by various methods, including analyses of catch statistics, life history, tagging, biochemical genetic data, and data on the chemical composition of the otoliths of the fish. Research in these fields has been conducted by many organizations, including the IATTC, the South Pacific Commission (now the Secretariat of the Pacific Community; SPC), the U.S. National Marine Fisheries Service (NMFS), and various organizations in Japan. The research results pertinent to a solution to this problem were examined by Argue (1981), and the conclusions were discussed in detail by Anonymous (1984: 88-91). In summary, there were two principal hypotheses for skipjack in the Pacific Ocean. The separate-subpopulation hypothesis stated that there are two or more genetically-distinct subpopulations of skipjack in the Pacific Ocean, and the clinal hypothesis stated that separate subpopulations of skipjack do not exist in the Pacific Ocean, but that there is isolation by distance, i.e. the probability of any two fish interbreeding is an inverse function of their distance from one another. It was concluded by Argue (1981) that the available data did not favor either the separate-subpopulation or the clinal hypothesis. Subsequent studies, described by Anonymous (1995: 69-71) have not furnished information that would serve better as the basis for management decisions. (Those studies should not be considered as futile, however, as the information from them may eventually be combined with information to be gathered in the future to achieve a greater understanding of the stock structure of skipjack in the Pacific Ocean.) For the purposes of stock assessment and management, it is typically assumed that skipjack in the EPO do not interact with skipjack in the western and central Pacific. For the purposes of some historical analyses, it was assumed that there are six non-interacting sub-populations in the EPO.

4.6. Environmental influences

The influences of some environmental variables on the apparent abundance of skipjack in the EPO have been studied by Forsbergh (1989). The abundance of skipjack larvae in the central and western Pacific approximately doubles with each 1-degree increase in SST from 23°C to a maximum of 29°C. The catches of skipjack by surface gear tend to be reduced during El Niño episodes, however, due to the fact that during such times the depth of the thermocline increases, so that the fish spend less time at the surface than during anti-El Niño periods (Joseph and Miller, 1989).

A previous stock assessment (Maunder and Watters 2002a) included the assumption that oceanographic conditions might influence recruitment of skipjack tuna in the EPO. To incorporate the possibility of an environmental influence on recruitment of skipjack in the EPO, a temperature variable was incorporated into the previous stock assessment model to determine whether there is a statistically-significant relationship between this temperature variable and estimates of recruitment. Maunder (2002b) conducted the correlation outside the stock assessment model using SST and the Southern Oscillation Index and found no relationship between recruitment and the environmental variables.

The SEAPODYM assessment method (Senina *et al*. 2008, Lehodey *et al*. 2011) used environmental data to force productivity and movement.

5. STOCK ASSESSMENT

Several alternative methods have been used to assess the status of skipjack tuna in the EPO: a) fishery and biological indicators; b) analysis of tag data; c) length-structured stock assessment model; d) Age-Structured Catch-at-Length Analysis (ASCALA); and e) a Spatial Ecosystem and Population Dynamic Model (SEAPODYM). Only the indicator approach has been updated in this report.

5.1. Assessment methods

5.1.1. Indicators

Since the stock assessments and reference points for skipjack in the EPO are uncertain, developing alternative methods to assess and manage the species that are robust to these uncertainties would be beneficial. Maunder and Deriso (2007) investigated some simple indicators of stock status based on relative quantities. Rather than using reference points based on MSY, they compared current values of indicators to the distribution of indicators observed historically. They also developed a simple stock assessment model to generate indicators for biomass, recruitment, and exploitation rate. To evaluate the current values of the indicators in comparison to historical values, they use reference levels based on the 5th and 95th percentiles, as the distributions of the indicators are somewhat asymmetric. Eight data- and model-based indicators are evaluated: catch, catch-per-day-fished by floating object fisheries, catch-per-day-fished by unassociated fisheries, standardized effort, average weight, relative biomass, relative recruitment, and relative exploitation rate (Figure 1). These indicators are presented for the whole EPO stock.

5.1.2. Analysis of tag data

The IATTC carried out numerous tagging experiments during the 1950s to the early 1980s, and then resumed a limited amount of tuna tagging again beginning in 2000. These data have not been used in the stock assessments of skipjack tuna except to provide information on growth rates (Bayliff 1988; Maunder 2002a). Maunder (2012b) conducted a preliminary analysis of the tagging data to investigate its information content about exploitation rates. The tag data were analyzed using a tag attrition model comparing observed and predicted tag recoveries. The tag dynamics is modeled using a population dynamics model that is essentially the same as those used in stock assessments. The model differs in that recruitment is tag releases and factors such as tag loss, tagging related mortality, and reporting rate are modeled. Estimates are only available for two sub-regions. The estimates of exploitation rates are highly uncertain.

5.1.3. Length-structured stock assessment model

Maunder (2012c) developed a length-structured model for assessing skipjack tuna. This model differs from the standard age-structured model approach used for assessing yellowfin and bigeye tuna, implemented using Stock Synthesis. The ageing data for skipjack tuna is unreliable, and growth information is based on tagging length-increment data. Growth based on length-increment data is ideally suited for length-structured models, and is problematic for age-structured models. The EPO was divided into six stocks and each stock is analysed separately. The model was fitted to CPUE-based indices of relative abundance and length-composition data.

There is insufficient information in the CPUE and length-composition data to produce reliable estimates of skipjack stock size. In all but one region (off the coast of Ecuador) the estimates of abundance and exploitation rates were unrealistic.

5.1.4. Age-Structured Catch-At-Length Analysis (A-SCALA)

Maunder and Harley (2005) used an age-structured, catch-at-length analysis (A-SCALA) to assess skipjack tuna in the EPO. The analysis method and its technical details are described in IATTC Bulletin, Vol. 22, No. 5 (2003). The assessment was still considered preliminary because 1) it was unknown if catch-per-day-fished for purse-seine fisheries is proportional to abundance, 2) it is possible that there is a population of large skipjack that is invulnerable to the fisheries, 3) the structure of the EPO stock in relation to the western and central Pacific stocks is uncertain.

5.1.5. Spatial Ecosystem and Population Dynamic Model (SEAPODYM)

A Spatial Ecosystem and Population Dynamic Model (SEAPODYM) that fits to a variety of data sources (Senina *et al*. 2008) has been applied to skipjack tuna in the Pacific Ocean (see Lehodey *et al*. 2011 for details). The analysis differs from Lehodey et al. (2011) in that the analysis: 1) used the latest available SODA 2.1.6 variables; 2) switched to MFCL-2010 length-at-age estimates; 3) scaled the Western and Central Pacific Ocean (WCPO) stock to MFCL estimates via fixing recruitment and mortality coefficients; and 4) used asymmetric Gaussian functions for purse-seine selectivities instead of sigmoid selectivities.

The SEAPODYM model is a two-dimensional coupled physical–biological interaction model at the ocean basin scale, and contains environmental and spatial components used to constrain the movement and the recruitment of tuna. The model combines a forage (prey) production model with an age-structured population model of the fishery target (tuna predator) species. All the spatial dynamics are described with an advection– diffusion equation. Oceanographic Input data sets for the model are sea-surface temperature (SST), oceanic currents and primary production that can be predicted data from coupled physical–biogeochemical models, as well as satellite-derived data distributions. Recent improvements include rigorous parameter optimization using fisheries data (size composition and abundance indices), which are based on methods used for contemporary stock assessment models (Senina *et al*., 2008).

5.2. Assessment results

The results of each of the assessment methods are described below.

5.2.1. Fishing mortality

The fishing mortality estimates from the tagging analysis were highly variable over time. The maximum monthly fishing mortality was 0.65 for the historic data (1973-1981) and 0.20 for the recent data (2000-2006). The mean monthly (annual = monthly times 12) fishing mortality was estimated as 0.049 (0.588) and 0.025 (0.300), respectively. There is a large amount of uncertainty in the estimates of monthly fishing mortality with CVs around 40% to 140%. The estimates of approximate average and maximum monthly fishing mortality rates from the length-structured stock assessment are higher, 0.13 and 2.37, respectively. The fishing mortality was estimated to be high in the late 1970s and the early 1980, but considerably lower in later years (*e.g.* monthly (annual = monthly times 12) average of 0.06 (0.74) from 1998 to 2008). The average annual approximate fishing mortality during 1998-2008, calculated from the annual catch and the annual SEAPODYM biomass estimates, is 0.12. The standardized effort, a measure of exploitation rate, and the relative exploitation rate from the indicator analysis increased starting in 1985, but stabilized in the last 10-15 years (Figure 1).

5.2.2. Recruitment

The indicator analysis estimates that recruitment was much lower until 2002, except for a large recruitment in 1999 (Figure 1). The length-structured model estimated highly variable monthly recruitment with a very large recruitment in 1999, but did not estimate recent recruitment to be substantially higher than prior recruitment.

5.2.3. Biomass

The indicator analysis estimates that biomass was much lower until 2003, except for a large biomass in 1999 (Figure 1). The length-structured model estimated highly variable monthly biomass with a very large biomass in 1999 and generally increasing biomass since 1980. SEAPODYM estimated annual biomass of skipjack 30cm or larger cycling between 1,800,000 t and 2,350,000 t from 1998 to 2008 in the EPO.

5.2.4. Average weights of fish in the catch

The indicator analysis estimates that the average weight of skipjack had been declining since 2000, and in 2009 was below the lower reference level, but has stabilized in the last 5 years (Figure 1). The trend in average length is similar among regions and fisheries in recent years (Figure 3).

6. STOCK STATUS

Maintaining tuna stocks at levels that will permit the MSY is the management objective specified by the IATTC Convention. The IATTC has adopted interim target and limit reference points for the stocks that it manages. Previous assessments have found that yield per recruit is maximized by catching skipjack at the smallest size observed in the catch. In combination with the lack of evidence of a stock-recruitment relationship, this indicates that very high fishing mortality rates and very low biomass levels would be associated with MSY. The ASCALA assessment (Maunder and Harley 2004) estimated that maximum yields are achieved with infinite fishing mortality because the critical weight is less than the average weight at recruitment to the fishery. However, this is uncertain because of uncertainties in the estimates of natural mortality and growth. For this reason, reference points are not available for skipjack tuna in the EPO. Consequently, indicators and reference levels have been used to evaluate the status of the stock. However, susceptibility and productivity analysis shows that skipjack has substantially higher productivity than bigeye tuna. Biomass and fishing mortality corresponding to MSY are, respectively, negatively and positively related to productivity. Therefore, since skipjack and bigeye have about the same susceptibility, which is related to fishing mortality, the status of skipjack can be inferred from the status of bigeye. The current assessment for bigeye tuna estimates that the fishing mortality is less than F_{MSY}. Therefore, the fishing mortality rate for skipjack should also be less than F_{MSY}. Since effort and skipjack biomass has been relatively constant over the past 10 years, this also implies that skipjack biomass is above B_{MSY}.

Historically, the main concern with the skipjack stock was the constantly increasing exploitation rate. Exploitation rate appears to have leveled off in recent years. The data- and model-based indicators have yet to detect any adverse consequence of this increase. The average weight was below its lower reference level in 2009, which can be a consequence of overexploitation, but it can also be caused by recent recruitments being greater than past recruitments or expansion of the fishery into areas occupied by smaller skipjack. However, average weight has stabilized in recent years.

The historical assessments based on tagging analysis, length-structured model, A-SCALA, and the SEAPODYM analysis did not provide any information that indicated a credible risk to the skipjack stock(s).

7. MANAGEMENT

The fishery for skipjack tuna in the EPO is constrained by effort restrictions (e.g. temporal and spatial closures) implemented for the conservation of bigeye tuna. Due to the fact that skipjack tuna are much more productive than bigeye tuna and that there is no evidence for concern about the status of the skipjack stock, no additional action over and above the action adopted for bigeye tuna is needed. Further analysis and revised management action may be required if the fishery for skipjack develops methods to reduce the amount of bigeye in the catch.

8. FUTURE DIRECTIONS

8.1. Collection of new and updated information

Conducting a well-planned and executed comprehensive tagging study is probably the only way to provide an adequate stock assessment for skipjack tuna in the EPO.

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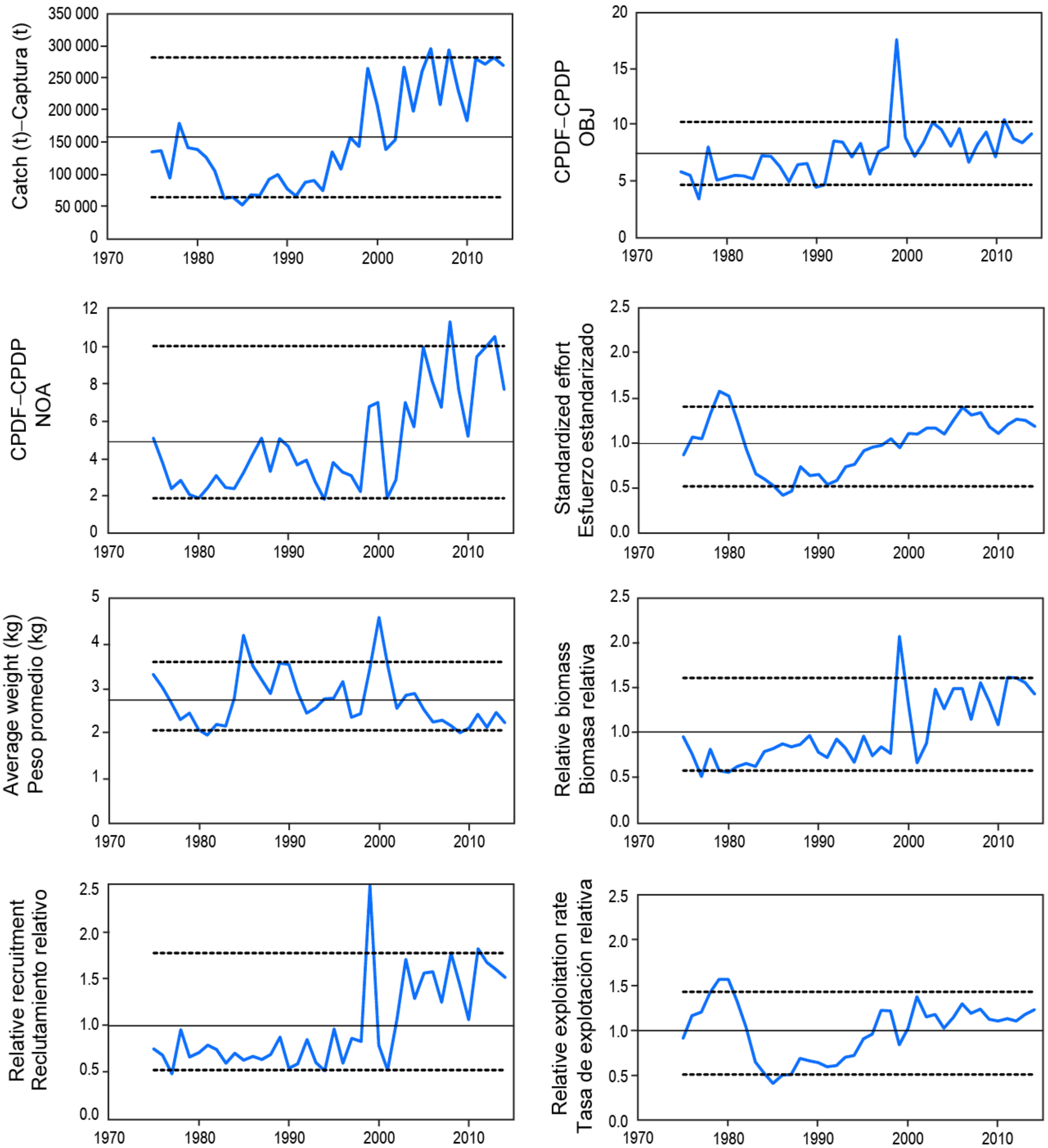

FIGURE 1. Indicators of stock status for skipjack tuna in the eastern Pacific Ocean. OBJ: floating-object fishery; NOA: unassociated fishery; CPDF: catch per day fished. All indicators are scaled so that their average equals one.

FIGURA 1. Indicadores del estatus de la población de atún barrilete en el Océano Pacífico oriental. OBJ: pesquería sobre objetos flotantes; NOA: pesquería no asociada; CPDP: captura por día de pesca. Se ajustó la escala de todos los indicadores para que su promedio equivalga a uno.

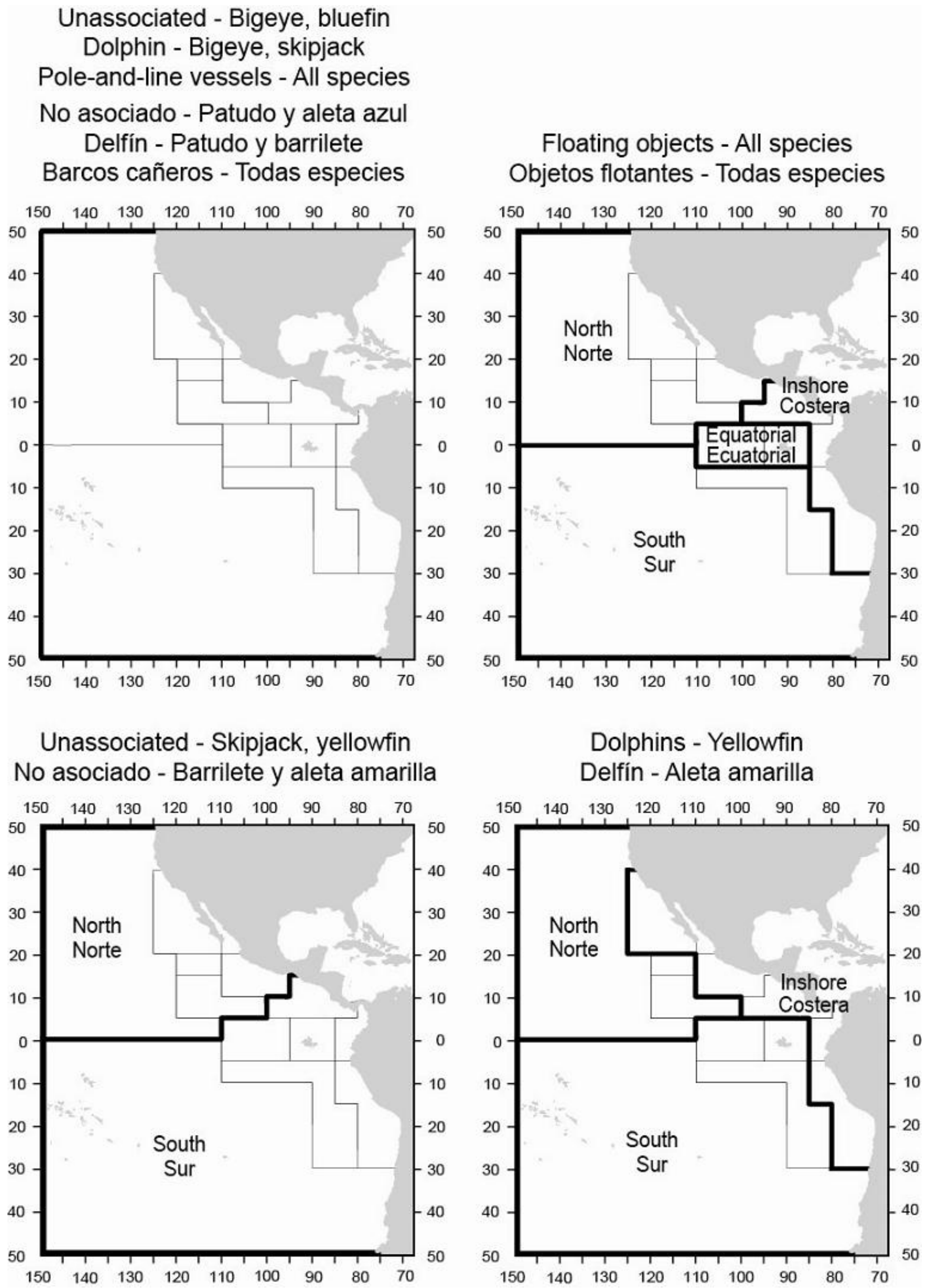

FIGURE 2. The fisheries defined by the IATTC staff for stock assessment of yellowfin, skipjack, and bigeye in the EPO. The thin lines indicate the boundaries of the 13 length-frequency sampling areas, and the bold lines the boundaries of the fisheries.

FIGURA 2. Las pesquerías definidas por el personal de la CIAT para la evaluación de las poblaciones de atún aleta amarilla, barrilete, y patudo en el OPO. Las líneas delgadas indican los límites de las 13 zonas de muestreo de frecuencia de tallas, y las líneas gruesas los límites de las pesquerías.

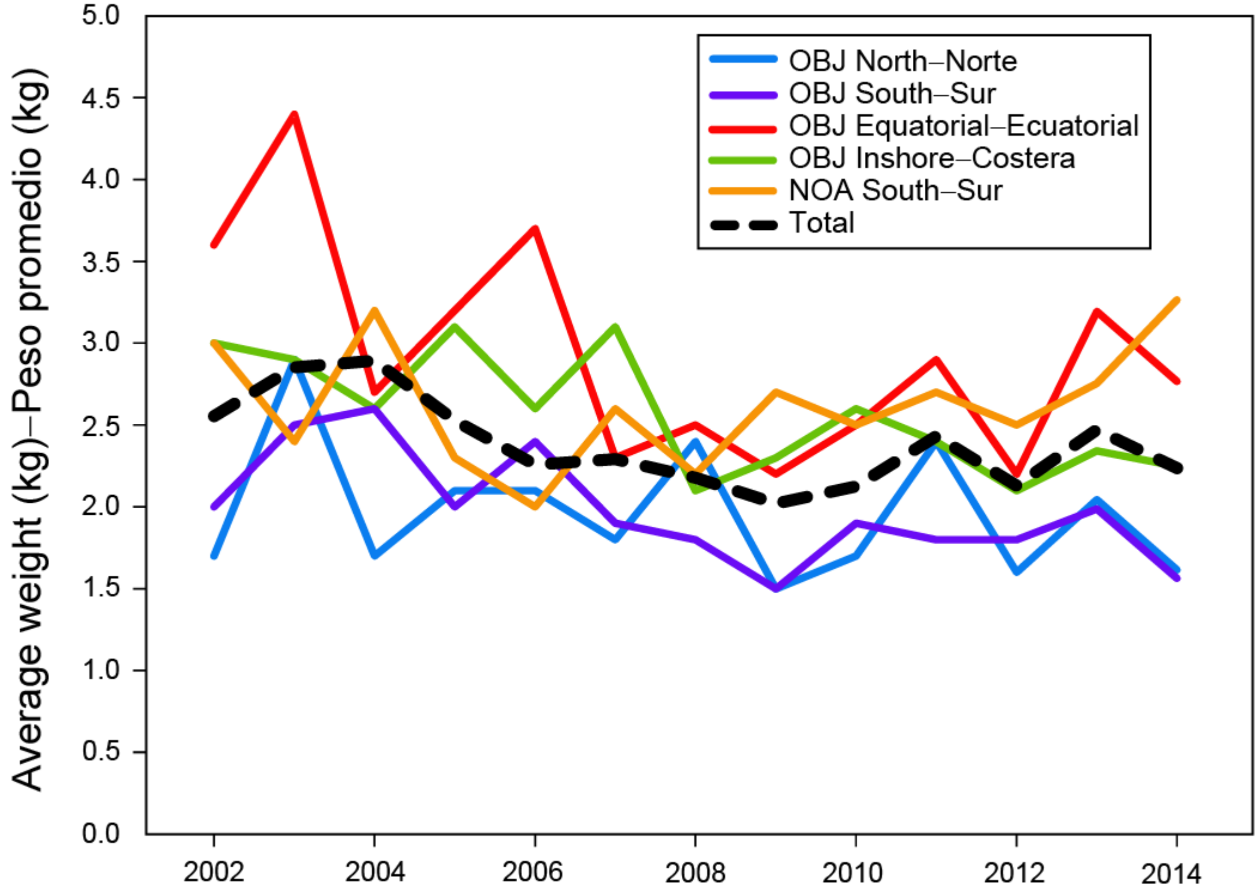

FIGURE 3. Average weight of skipjack caught in the floating-object purse-seine fisheries shown in Figure 2 and the southern unassociated fishery.
FIGURA 3. Peso promedio del barrilete capturado en las pesquerías cerqueras sobre objetos flotantes ilustradas in la Figura 2 y la pesquería no asociada del sur.