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## STOCK STATUS INDICATORS (SSIs) FOR TROPICAL TUNAS IN THE EASTERN PACIFIC OCEAN

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**CONTENTS**



**Summary**

Stock status indicators (SSIs; time series of data used as supplements to, or in the absence of, stock assessments), based on both purse-seine and longline data, are presented for the three tropical tuna species (yellowfin - YFT, bigeye - BET, and skipjack - SKJ). Some SSIs based on the floating-object fishery suggest that the fishing mortality of all three species has increased, mainly due to the increase in the number of floating-object sets. The general increasing trend in the number of sets in the floating-object fishery, except in the first COVID-19 pandemic year of 2020, is reflected in increased catches for yellowfin and skipjack, reduced catch-per-set for bigeye, and reduced average length initially for all three species in the floating-object fishery, but the trends in average length have flattened off over the most recent decade. As the impact of the pandemic on the fishery operation began to diminish in 2021, the number of sets on floating objects resumed its general increasing trend and reached its maximum historical level in 2022, exceeding the *status quo*[1] by 12%. The increasing trend did not continue in 2023 but the number of floating-object sets remained above the *status quo* (8%). Trends in some other SSIs do not support the interpretation that fishing mortality has increased due to an increase in the number of floating-object sets. Identifying the reasons for the differences among the SSIs is difficult, even when SSIs are considered in aggregate.

Of all three tropical tuna species, the SSIs are particularly concerning for bigeye. Bigeye is caught mainly in the floating-object fishery for which the catch per set and the average length have shown a consistent decline over time, while the catch has been somewhat stable, except in recent years where catches reached low historical levels in 2022 and 2023. These all indicate that the fishing mortality has been increasing and the abundance has been decreasing. In 2022 and 2023, both the catch in weight (Figure 2a) and catch-per-set (Figure 3) for bigeye caught in floating-object sets were at the lowest levels since 2000, which may partly be a result of the introduction of the individual vessel threshold (IVT) scheme to provide incentives to reduce bigeye catches under Resolution C-21-04. An evaluation of the impact of the

[1] Defined as the average conditions in 2017-2019.

IVT scheme confirmed that it likely had a positive effect on reducing bigeye catches in 2022 and 2023 (SAC-15 INF-K).

## 1. BACKGROUND

One of the management objectives for tropical tunas in the eastern Pacific Ocean (EPO) established in the Antigua Convention is to maintain populations at levels of abundance that can produce the maximum sustainable yield (MSY). 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 the estimation of both reference points and quantities to which they can be compared. Various model-based reference points require different amounts and types of information, from biological information (*e.g*., natural mortality, growth, stock-recruitment relationship) and fisheries characteristics (*e.g.,* age-specific selectivity) to estimates of absolute biomass and exploitation rates, which in turn generally require a formal stock assessment. For many species and stocks, the information required to conduct such an assessment is not available, the assessments are unreliable, or cannot be conducted at the frequency that management may require, and thus, alternative approaches are needed.

One alternative is to compute stock status indicators (SSIs), which are simply time series of raw or lightly-processed data for a stock that may reflect trends in abundance or exploitation of that stock. SSIs include quantities such as fishing effort, catch, catch per unit effort (CPUE), and the size of fish in the catch. SSIs cannot be used directly for management approaches that depend on model-based quantities (*e.g*., MSY, $F_{MSY}$), but they can be used for historical comparisons and to identify trends and can provide information that may be useful for managing a stock. They can also be used in management strategies that do not rely on model-based harvest control rules, such as strategies that use empirical (data-based) harvest control rules for which performance can be formally evaluated using management strategy evaluation.

SSIs were initially developed for EPO skipjack because traditional stock assessments of that species were initially considered unreliable (*e.g*., Maunder and Deriso 2007), but they have also been used recently as a complementary component of the IATTC staff's management advice for yellowfin and bigeye in the EPO. Since 2018, SSIs have become particularly important as supplemental information to, or temporary replacement of, formal stock assessments for both bigeye (SAC-09-16) and yellowfin (SAC-10-08), because the staff considered that the results of the assessments at that time were not sufficiently reliable to be used as the basis for its management advice.

In 2024, the staff has completed bigeye (SAC-15-02), yellowfin (SAC-15-03) and skipjack (SAC-15-04) benchmark assessments, which are now conducted in a model ensemble risk-based framework. The new risk-based assessment framework was applied for all three species in 2024, before the start of the next multi-year management cycle in 2025. However, two sets of SSIs, one based on data from the purse-seine fishery and the other on data from the longline fishery, will continue to be reported as supplemental information to monitor the stocks during the management cycle between assessments, and to provide management advice as needed. We computed the same SSIs for all three species, whenever possible, and collated them into this report to facilitate comparisons among species.

The **purse-seine-based SSIs** reported by set type (NOA: unassociated; DEL: dolphin-associated; OBJ: floating-object associated) whenever possible are the following: **number of sets by set type** (Figure 1), **closure-adjusted capacity** (Figure 1), **catch by set type** (Figure 2), **catch-per-set by set type** (Figure 3), and **average length of the fish in the retained catch by set type** (Figure 4). For yellowfin, an additional SSI was developed based on spatiotemporal modeling of **catch-per-day-fished (CPDF)** and **average fish length** for the fishery associated with dolphins (Figure 5). The current SSIs start in 2000 because the IATTC port-sampling program began the species composition sampling in that year, and it is after the major offshore expansion of the floating-object fishery which started in the early- to mid-1990s. All SSIs are scaled (relative indicators) so that their average equals 1 during the 2000-2023 period. The 10% and 90% percentiles are used as reference levels because percentiles in the extremes of the distribution's tails are less reliable with fewer years of data.

Several indicators that use data from the **longline fishery** have also been developed. These include **catch and effort** (Figure 6), and **CPUE** (catch-per-hook) and **average length** of fish estimated from spatiotemporal models (Figure 7). To be consistent with the purse-seine SSIs, the longline SSIs start in 2000 and have been scaled so that their average equals 1 during the 2000-2023 period. Reference levels also are based on the 10% and 90% percentiles. Exceeding a reference level can have multiple interpretations, and these will depend on the SSI being considered and whether the upper or the lower reference level has been exceeded. To interpret trends in SSIs, it may be helpful to consider multiple SSIs simultaneously.

Further information about bigeye, yellowfin, and skipjack can be found in Documents SAC-15-02, SAC-15-03, and SAC-15-04, respectively, and information on the absolute catch and number of sets by set type can be found in SAC-15-01. The tables and R code we used to generate all figures in this report are available online at https://github.com/HaikunXu/Indicators/blob/main/2024.

## 2. RESULTS AND DISCUSSION

Care needs to be taken when interpreting the information content of indicators about increased fishing mortality. In general, increased effort implies increased fishing mortality, but changes in fishing strategy could cause fishing mortality to remain stable or even decrease when effort is increased. Similarly, increased fishing mortality typically reduces the population size and will be reflected in reduced CPUE. However, changes in fishing strategy could influence the relationship between CPUE and abundance. In addition, abundance may fluctuate due to environmental conditions, particularly given its impact on recruitment, which is more influential on fisheries that catch mainly juveniles like the OBJ fishery. Catch may increase due to the fishing mortality increasing faster than the stock is declining and/or the stock-recruitment relationship being weak in the case of fisheries that catch mainly juveniles, or decrease due to the fishing mortality increasing slower than the stock is declining. The mean size in the catch could decrease due to increased fishing mortality, but it could also decrease due to increasing recruitments (i.e., more smaller fish entering the fishery) or increase due to low recruitments. As indicated above, the age range of the fish caught by a fishery also needs to be taken into consideration when interpreting the indicators.

Many of the SSIs for recent years are near their 10% and 90% reference levels, with 2020 being an exception in that the number of sets in the floating-object fishery was substantially reduced due to the negative impact of the COVID-19 pandemic on fishery operations (Figure 1). Since then, the closure-adjusted fishing capacity and the number of sets in the floating-object fishery have recovered from the COVID-19 pandemic. The closure-adjusted fishing capacity for 2023 has recovered to about 1% below the *status quo* level. In 2022, the number of sets in the floating-object fishery increased to the highest level since 2000, exceeding the *status quo* level by 11%. This number slightly dropped by 4% from 2022 to 2023, but in 2023 it is still 8% above the *status quo* level. In 2022 and 2023, the number of sets in the floating-object fishery was above the 90% reference level while that in the unassociated fishery decreased to the lowest level since 2000 (about 50% of the average number between 2000 and 2023; Figure 1). In comparison, the number of sets in the dolphin-associated fishery for 2023 was near the historical mean level.

Some floating-object fishery SSIs suggest that the stocks for all three species have potentially been subject to increased fishing mortality, mainly due to the increase in the number of sets in the floating-object fishery as described above (see FAD-05 INF-D for details on the relationship between the number of floating-objects sets and the fishing mortality for juvenile bigeye). Overall, there have been increasing trends in catch for skipjack and yellowfin on floating-object sets since 2000 (Figure 2). In 2023, the catch for skipjack in floating-object sets was at the highest level since 2000 (Figure 2). The catch-per-set for yellowfin and skipjack in floating-object sets has not shown an obvious trend since 2010 while that for bigeye in floating-object sets kept declining since 2005 (Figure 3). The average length for the three tropical tunas on floating-object sets showed similar temporal trends: decreased between 2000 and 2015 and remained relatively stable thereafter (Figure 4).

Of all three tropical tuna species, the SSIs are particularly concerning for bigeye. Bigeye is caught mainly in the floating-object fishery for which the catch per set (Figure 3) and the average length (Figure 4) have shown a consistent decline over time, while the catch has been somewhat stable, except in recent years where catches reached low historical levels in 2022 and 2023 (Figure 2a). These all indicate that the fishing mortality has been increasing and the abundance has been decreasing. In 2023 and 2023, both the catch in weight (Figure 2a) and catch-per-set (Figure 3) for bigeye in floating-object sets were at the lowest levels since 2000, which may partly be a result of the introduction of the individual vessel threshold (IVT) scheme to provide incentives to reduce bigeye catches under Resolution C-21-04. An evaluation of the impact of the IVT scheme confirmed that it likely had a positive effect on reducing bigeye catches in 2022 and 2023 (SAC-15 INF-K).

On the other hand, trends in some of the other SSIs do not necessarily support the interpretation that increased fishing mortality is occurring due to the increase in the number of floating-object sets. Positive trends were observed in the catch-per-set for skipjack and yellowfin in unassociated and dolphin-associated sets, respectively (Figure 3). However, these may also be reflective of increased fishing efficiency due to improved technology. Both the dolphin-associated purse-seine (Figure 5) and longline (Figure 7) indices of abundance for yellowfin have been increasing since 2015. The longline index of abundance for bigeye has not shown a noticeable long-term trend since 2010 (Figure 7). It is worth noting that the longline indices of abundance for bigeye and yellowfin have wide confidence intervals in recent years due to a recent decrease in the spatial coverage and sample size (i.e., number of sets) of the Japanese longline catch and effort dataset (Figure 7). Therefore, the recent abundance trends informed by the longline indices are highly uncertain.

Identifying the causes of different trends in the SSIs for a stock is difficult, even when SSIs are considered in aggregate. The inconsistencies among SSIs for yellowfin may be due to an interaction between potential stock structure and differences in the spatial distribution of effort in the different set types and gears (see IATTC-95-05 Fig. B-4). In addition, catch-per-set may not be a reliable indicator of relative abundance, particularly for the target species (*i.e.*, skipjack in the floating-object fishery and yellowfin in the dolphin-associated fishery).

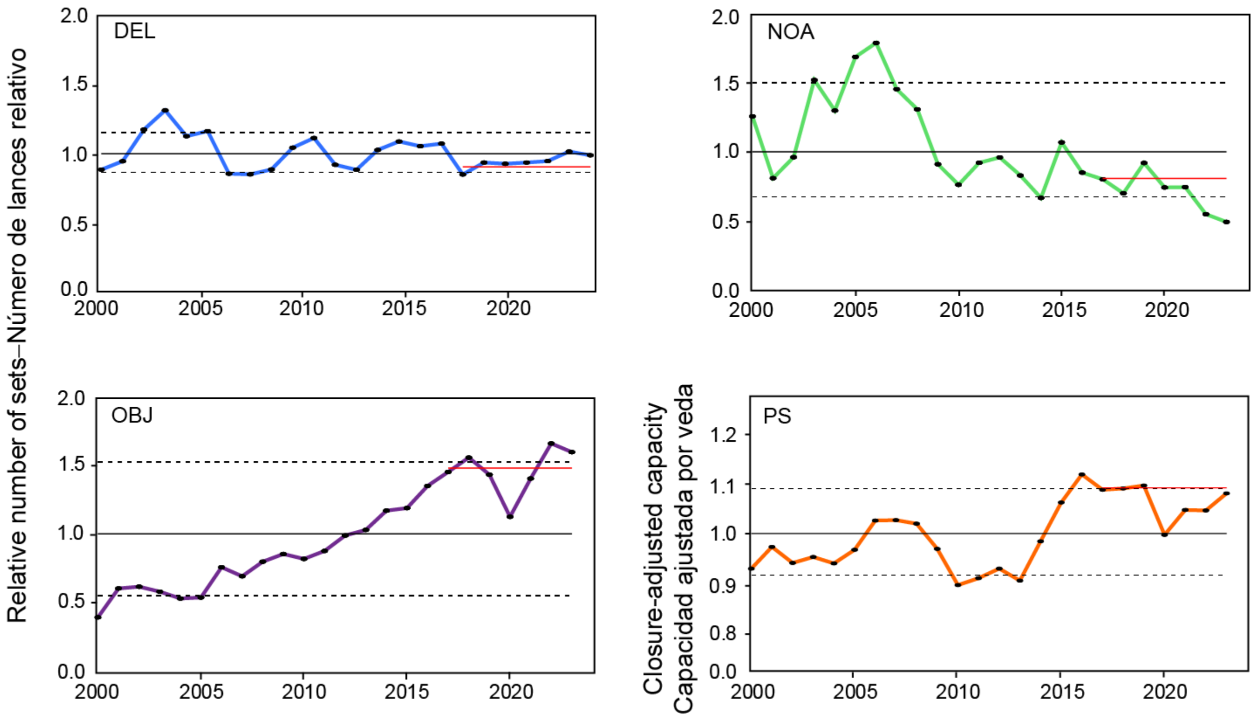


**FIGURE 1.** Indicators based on purse-seine fishing effort, 2000-2023. The red horizontal lines mark the *status quo* levels (average conditions in 2017-2019).

**FIGURA 1.** Indicadores basados en el esfuerzo de pesca de cerco, 2000-2023. Las líneas horizontales rojas marcan los niveles de *statu quo* (condiciones promedio en 2017-2019).

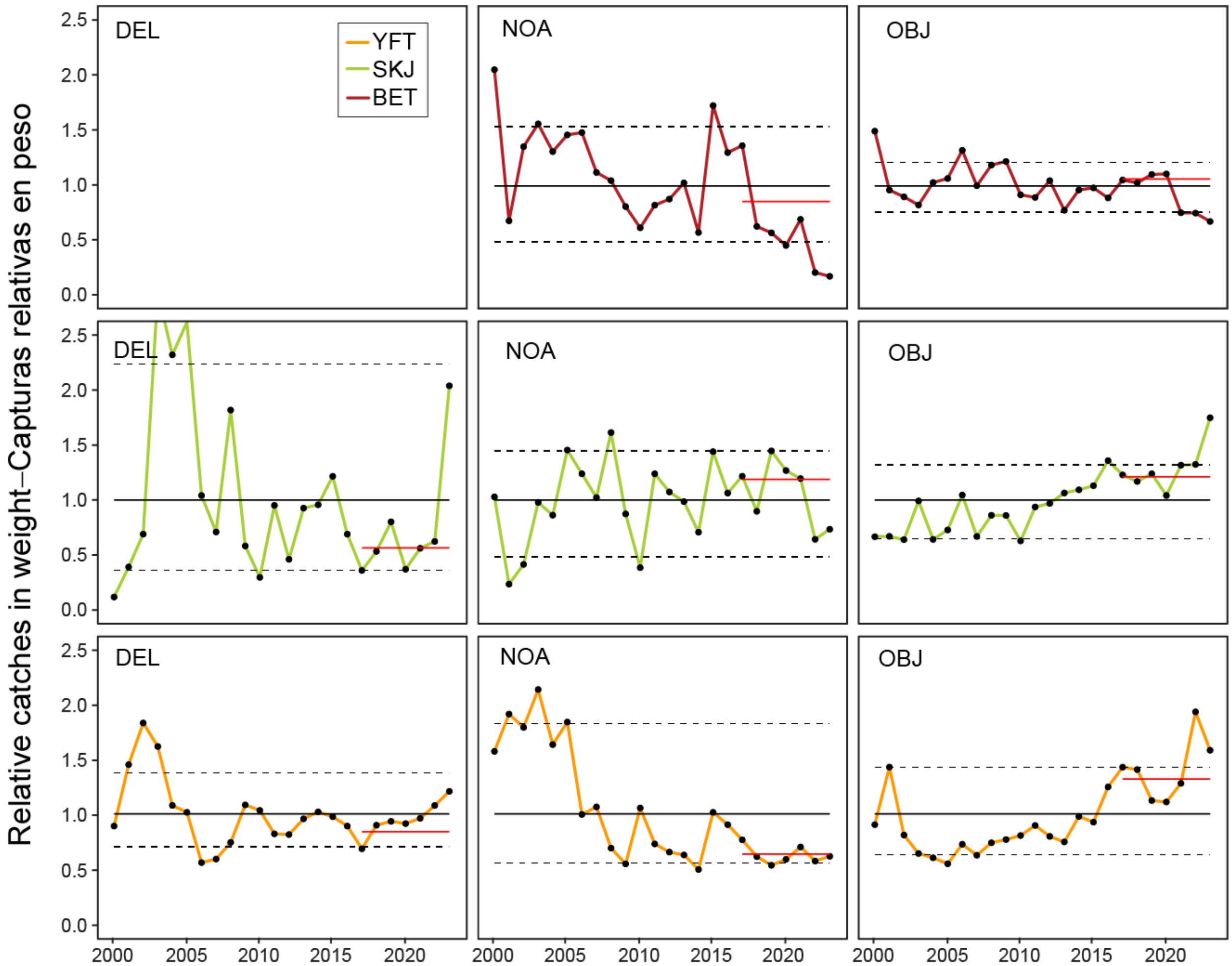


**FIGURE 2a.** Indicators based on purse-seine catch in weight, 2000-2023. The OBJ catches during 2020 and 2021 (COVID-19 years) are biased-adjusted according to SAC-14-INF-D. The red horizontal lines mark the *status quo* levels (average conditions in 2017-2019).

**FIGURA 2a.** Indicadores basados en la captura cerquera en peso, 2000-2023. La captura por lance OBJ durante 2020 y 2021 (años de COVID-19) es ajustada por sesgo acorde a SAC-14-INF-D. Las líneas horizontales rojas marcan los niveles de *statu quo* (condiciones promedio en 2017-2019).

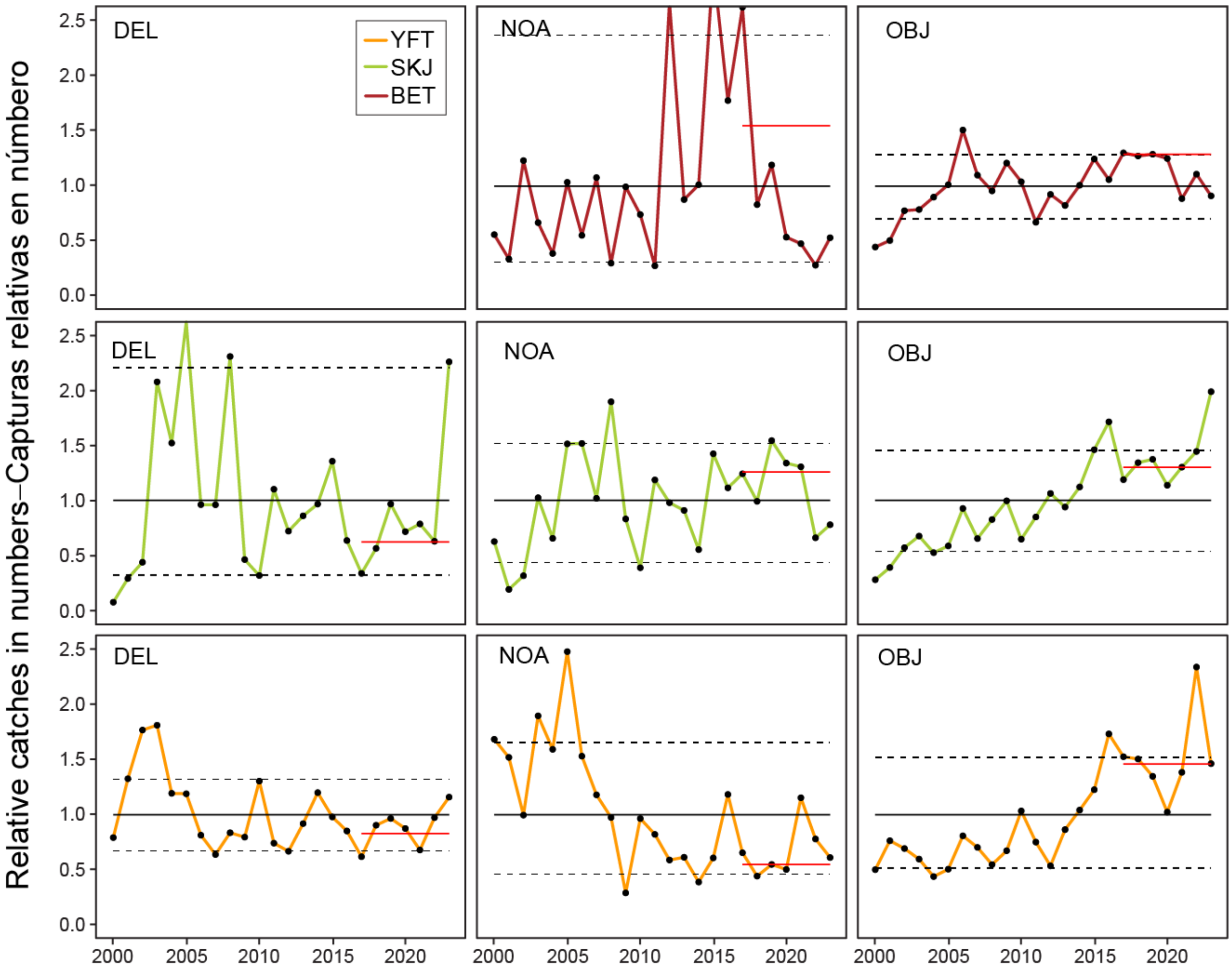


**FIGURE 2b.** Indicators based on purse-seine catch in number, 2000-2023. The OBJ catches during 2020 and 2021 (COVID-19 years) are biased-adjusted according to SAC-14-INF-D. Here we assume that the impact of COVID-19 on the port sampling did not influence the size composition of the catch. The red horizontal lines mark the *status quo* levels (average conditions in 2017-2019).

**FIGURA 2b.** Indicadores basados en la captura cerquera en número, 2000-2023.. La captura por lance OBJ durante 2020 y 2021 (años de COVID-19) es ajustada por sesgo acorde a SAC-14-INF-D. Aquí se supone que el impacto del COVID-19 en el muestreo en puerto no influyó en la composición por talla de la captura. Las líneas horizontales rojas marcan los niveles de *statu quo* (condiciones promedio en 2017-2019).


**FIGURE 3.** Indicators based on purse-seine catch-per-set, 2000-2023. The OBJ catch per set during 2020 and 2021 (COVID-19 years) are biased-adjusted according to SAC-14-INF-D. The red horizontal lines mark the *status quo* reference levels (average conditions in 2017-2019).

**FIGURA 3.** Indicadores basados en captura por lance cerquero, 2000-2023. La captura por lance OBJ durante 2020 y 2021 (años de COVID-19) es ajustada por sesgo acorde a SAC-14-INF-D. Las líneas horizontales rojas marcan los niveles de referencia de *statu quo* (condiciones promedio en 2017-2019).


**FIGURE 4.** Indicators based on the average length of fish in the purse-seine catch, 2000-2023. The y-axis limits differ from the figures for the other indicators to accentuate the changes because average length is less sensitive to fishing mortality.

**FIGURA 4.** Indicadores basados en la talla promedio de los peces en la captura cerquera, 2000-2023. Los límites del eje "y" difieren de las figuras de los otros indicadores para acentuar los cambios ya que la talla promedio es menos sensible a la mortalidad por pesca.

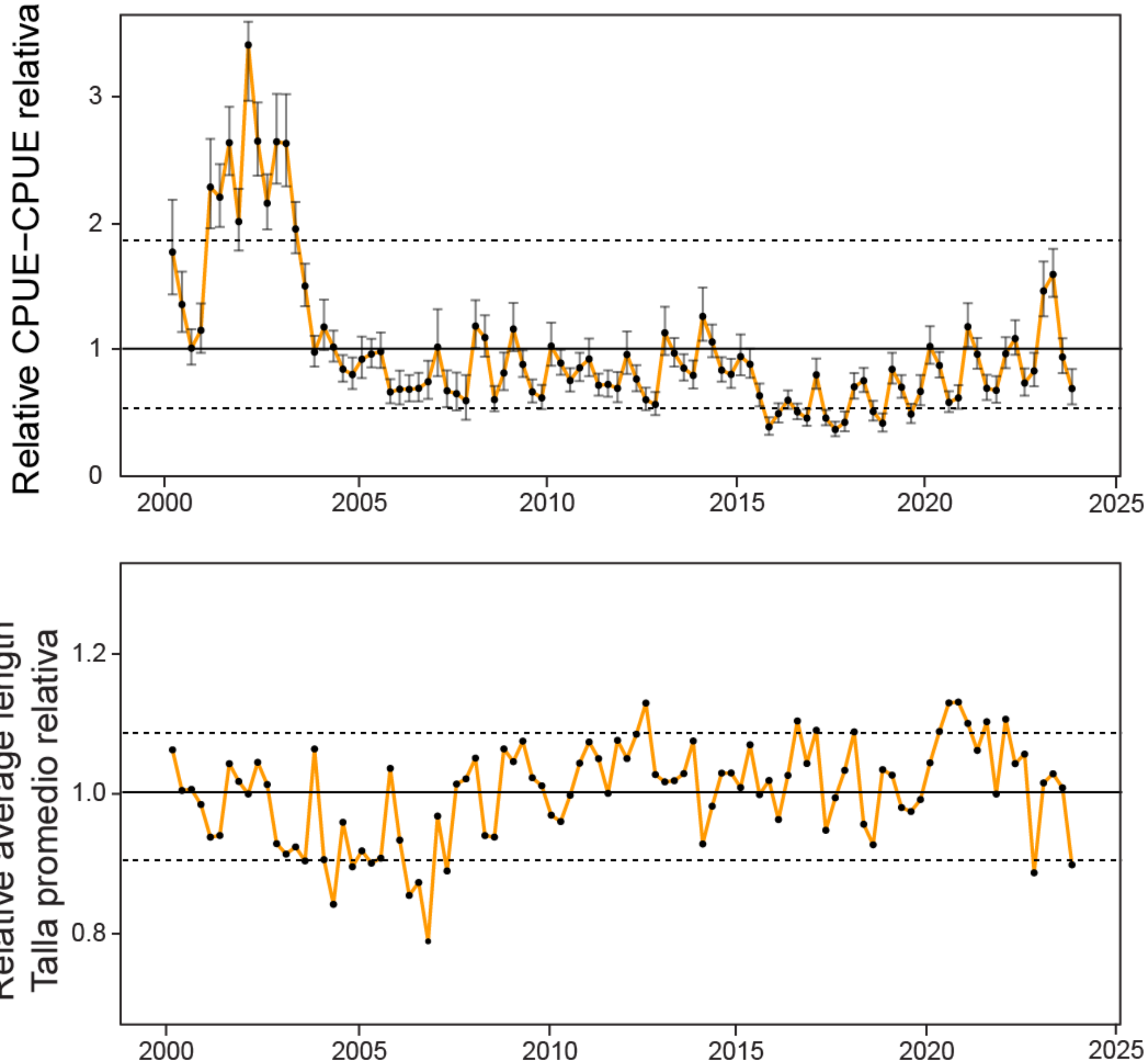


**FIGURE 5.** Quarterly indicators based on spatio-temporal modeling of catch-per-day-fished and length compositions for the purse-seine fishery on yellowfin associated with dolphins, 2000-2023. The error bars represent the 95% confidence intervals.

**FIGURA 5.** Indicadores trimestrales basados en el modelado espaciotemporal de la captura por día de pesca y composiciones por talla para la pesquería cerquera de aleta amarilla asociada a delfines, 2000-2023. Las barras de error representan los intervalos de confianza del 95%.

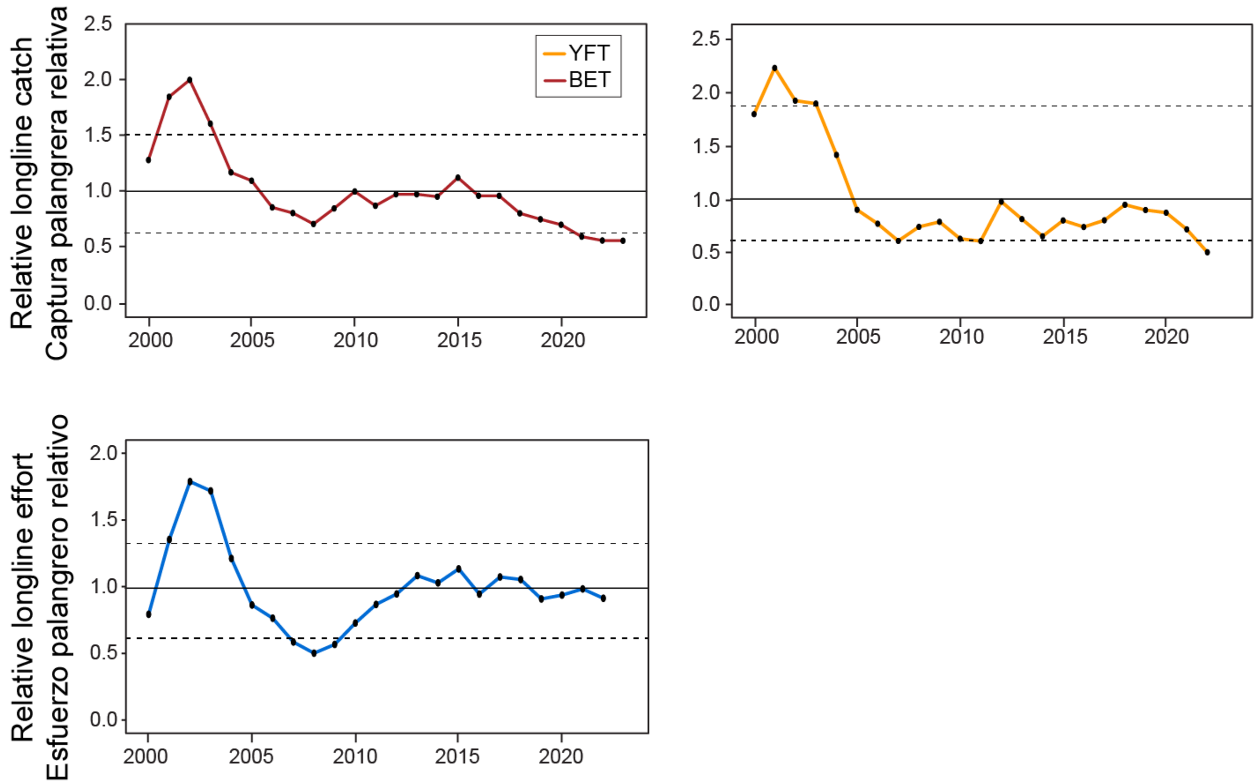


**FIGURE 6.** Indicators based on longline catch and effort data for all fleets combined, 2000-2023 (catch data for 2023 only included that for bigeye tuna from monthly reports).

**FIGURA 6.** Indicadores basados en datos de captura y esfuerzo de palangre para todas las flotas combinadas, 2000-2023 (los datos de captura para 2023 solo se incluyen para atún patudo, obtenidos de los informes mensuales).

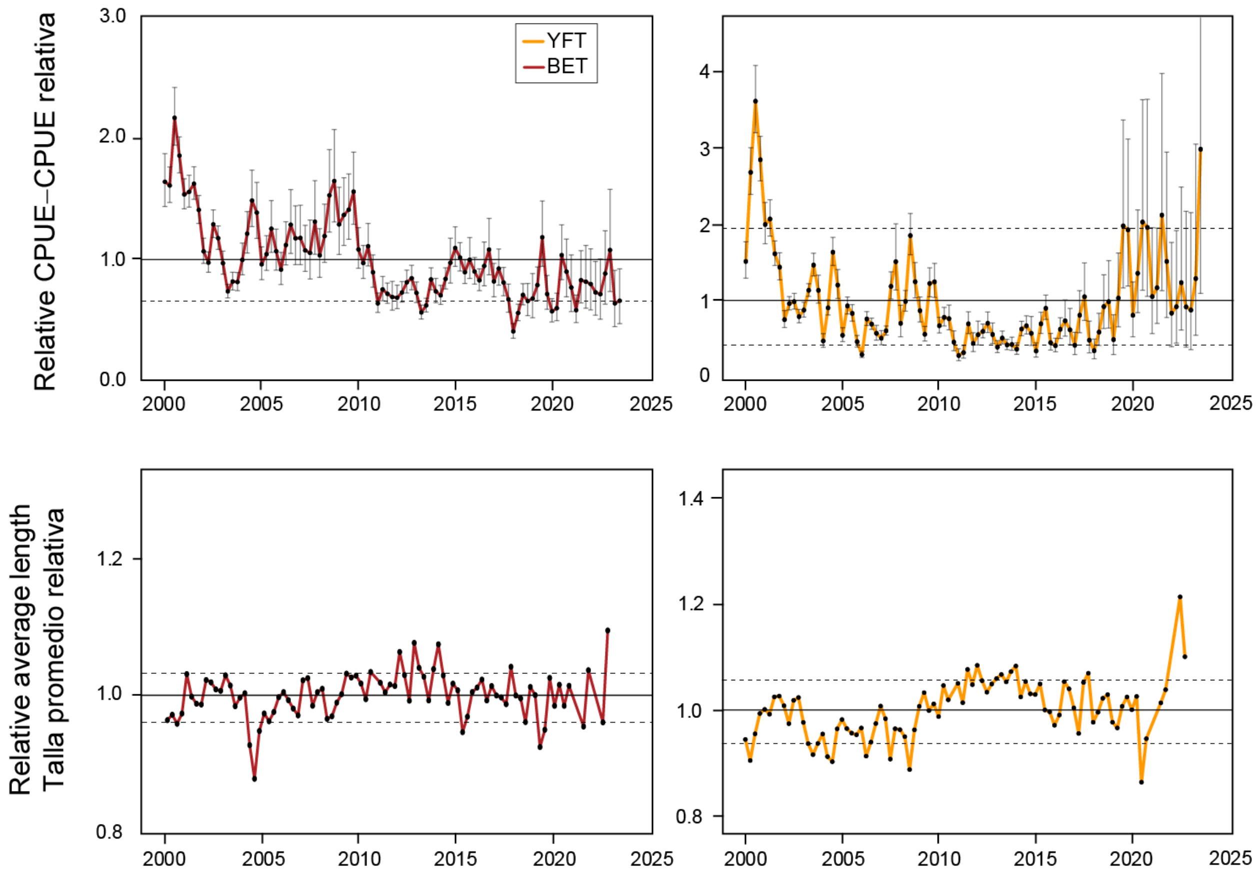


**FIGURE 7.** Quarterly indicators based on spatio-temporal modeling of Japaneselongline CPUE data (top row) and Japanese and Korean combined longline length compostion data (bottom row), 2000-2023. The error bars represent the 95% confidence intervals. The y-axis limits for average length differ from the figures for the other indicators to accentuate the changes because average length is less sensitive to fishing mortality.

**FIGURA 7.** Indicadores trimestrales basados en el modelado espaciotemporal de datos de CPUE de palangre de Japón (fila superior) y de los datos combinados de composición por talla de palangre de Japón y Corea (fila inferior), 2000-2023. Las barras de error representan los intervalos de confianza del 95%. Los límites del eje "y" para la talla promedio difieren de las figuras de los otros indicadores para acentuar los cambios ya que la talla promedio es menos sensible a la mortalidad por pesca.