**INTER-AMERICAN TROPICAL TUNA COMMISSION**

**SCIENTIFIC ADVISORY COMMITTEE**

**SEVENTH MEETING**

**La Jolla, California (USA)**
**09-13 May 2016**

# DOCUMENT SAC-07-06b.i

## UPDATED STOCK STATUS INDICATORS FOR SILKY SHARKS IN THE EASTERN PACIFIC OCEAN (1994-2015)

Cleridy Lennert-Cody, Alexandre Aires-da-Silva, Mark N. Maunder, Marlon H. Román

**CONTENTS**



### 1. SUMMARY

Purse-seine indices for the silky shark have been updated with data from 2015. The index for all silky sharks in the northern area shows an increase in 2015 relative to 2014, but the index for all silky sharks in the southern area remains at the 2014 level. This increase in the index in the northern area may be in part the result of changes in availability, rather than abundance, due to strong El Niño conditions. Differences among trends computed for sub-areas in the north suggest that the overall recent increasing trend in the north may reflect an integration of spatially-distinct processes, including the effect of fishing pressure closer to the coast, and environmentally-mediated movement of individuals into the tropical eastern Pacific Ocean (EPO) from the west. The IATTC staff does not consider the more optimistic recent trends to be strong enough to offset the urgent need for precautionary management actions, and reiterates its previous recommendations. It is critical that improvements are made in shark fishery data collection in the EPO so that conventional stock assessments and/or other indicators of stock status can be developed and the results made available to better inform the management of silky and other shark species.

### 2. BACKGROUND

An attempt by the IATTC staff in 2013 to assess the status of the silky shark (*Carcharhinus falciformis*) in the EPO, using conventional stock assessment models, was severely handicapped by major uncertainties in the fishery data, mainly regarding total catch levels in the early years for all fisheries operating in the EPO that caught silky sharks (SAC-05 INF-F). Although this stock assessment attempt produced a substantial amount of new information about the silky shark in the EPO (*e.g.*, absolute and relative magnitude of the catch by different fisheries, and their selectivities), the absolute scale of population trends and the derived management quantities were compromised. Since a conventional stock assessment was not possible, in 2014 the staff proposed a suite of possible stock status (or stability) indicators (SSIs) which could be considered for managing the silky sharks in the EPO (SAC-05-11a), including standardized catch-per-unit-effort (CPUE) indices from the purse-seine fishery. This document updates the purse-seine CPUE indices with data for 2015.

## 3. DATA AND METHODS

Data collected by IATTC observers aboard Class-6[1] purse-seine vessels were used to generate CPUE-based indices of relative abundance for the silky shark. The observers recorded bycatch of silky sharks by size category: small (< 90 cm total length (TL), medium (90-150 cm TL), and large (>150 cm TL)). Bycatches of silky sharks occur predominantly in floating-object sets (SAC-07-07b Ecosystem considerations). Annual summaries of spatial data on bycatches of silky sharks in floating-object sets, by shark size category and for all silky sharks, are shown in Figure 1.

CPUE trends for floating-object sets (CPUE-OBJ) were estimated using generalized additive models (GAMs). A zero-inflated negative binomial GAM was used to model the bycatch data from floating-object sets because of the presence of many zeros and also large bycatch amounts. Predictors used in this model were: year (factor); smooth terms for latitude, longitude, time of the set, and day of the year (to capture seasonal patterns); and linear terms for depth of the purse-seine net, depth of the floating object, sea-surface temperature, natural logarithm of non-silky bycatch, natural logarithm of tuna catch, and two proxies for local floating-object density. Trends were computed by shark size category and for all silky sharks, using the method of partial dependence, which produces a data-weighted index. Approximate 95% pointwise confidence intervals were computed for the trends for all silky sharks by resampling from the posterior distribution of estimated GAM coefficients, assuming known smoothing and scale parameters. As in previous years, EPO trends were computed for two areas, north and south of the equator.

## 4. UPDATED TRENDS

For the northern area, the CPUE-OBJ index shows an initial sharp decline during 1994-1998, followed by a period of relative stability at a low level (1999-2009), then a sharp increase from 2009 to 2010, a sharp decrease from 2010 through 2012, and again a sharp increase from 2012 through 2015 (Figure 2). The increase in variability of the index in recent years may be in part the result of changes in availability, rather than abundance, due to environmental effects associated with El Niño events in 2010 and 2015, and La Niña events in 2011-2012. However, such events in previous years have not elicited a similar level of variability in the overall index; in particular, an increase in this index around 1998 is not apparent, despite strong El Niño conditions. In spite of this, the CPUE-OBJ trend in the northern area shows agreement with standardized presence/absence indices for all silky sharks in the northern area (obtained using logistic GAMs) for dolphin sets and unassociated sets (Figure 3).

The trends of the three size categories of silky sharks in the northern area (Figure 4a) are generally similar to the trend for all silky sharks in the northern area (Figure 2). Year-to-year changes in the index for small sharks have not always been the same as those of the indices for medium and large sharks (Figure 4b). This might be expected if the small shark category is a proxy for recruitment (ages 0 and 1). Since about 2009, however, the year-to-year changes in the small shark index more closely follow the trends for medium and large sharks (Figure 4b). Increases in a size category can only come from recruitment or from growth from one category to the next. Therefore, any increases in abundance should first occur in the smallest size category, as recruitment, and then propagate through into the larger categories. However, since all categories tend to increase at the same time, the increase in the index must be due to movement from outside the area or increases in catchability. Both of these could be related to environmental conditions, and could also be the cause of declines in the index.

[1] Carrying capacity > 363 t

Trends computed by sub-area within the northern EPO suggest that the recent overall increases (Figures 2 and 4) may be influenced by data from the more offshore equatorial region (Area 2, Figure 5). Updated indices show no increase in 2015 in the far northern area (Area 1, Figure 5) and there was no increase in 2015 in the index for small sharks in the nearshore area (Area 4, Figure 5). By contrast, in the more offshore equatorial areas (Areas 2-3, Figure 5), the updated indices show an increase for all size categories in 2015. Thus, the overall recent increasing trends in the northern EPO may reflect an integration of spatially-distinct processes, including the effect of fishing pressure closer to the coast, and the arrival of individuals from the west, perhaps as a result of recent environmental changes.

For the southern area, the CPUE-OBJ indicator shows a sharp decline during 1994-2004, followed by a period of stability at much lower levels until 2013, and then a small increase in 2014, with little change in 2015 (Figure 2). The trends for medium and large sharks show a generally similar pattern (Figure 4). The lack of increase in the index for all silky sharks in 2015 appears to be due at least in part to a decrease in the large shark index in 2015. Trends by sub-area and for other set types were not computed for the southern area because of the low levels of silky shark bycatch (Figure 1). In particular, there are very few small silky sharks in the bycatch in the southern area (Figure 1a). These very low levels of bycatch may be due to a lack of recruitment in the southern area. The source of recruits to the southern area is unclear; possible sources include movement of animals into that area from the north or the west.

## 5. FUTURE WORK

With respect to future research on SSIs for the silky shark in the EPO, priority should be given to improving the collection of shark fishery data in the EPO. As part of this effort, it is essential that data from other sources be collected to develop additional indicators. The purse-seine indicators alone are not sufficient to determine stock status for a species that may be impacted by different factors in different regions within the EPO. Obtaining reliable catch data for all fisheries catching silky sharks in the EPO, indices of abundance for other fisheries (*e.g.*, longline fisheries, which take the majority of the catch), and composition data, is vital. To date, no target or limit reference points or harvest control rules have been developed for the silky shark. While the current data shortcomings persist, management strategy evaluation (MSE) work to simulation-test and identify the reference points and harvest control rules that will achieve the conservation goals for the EPO should be conducted.

Given the spatial differences in the purse-seine indices noted above, and the possibility of environmental effects, future work on standardized trends from the purse-seine fishery data will include incorporating more environmental predictors into the GAMs used for standardization and development of an area-weighted index. Unconditional variance estimates for the indices will also be developed.

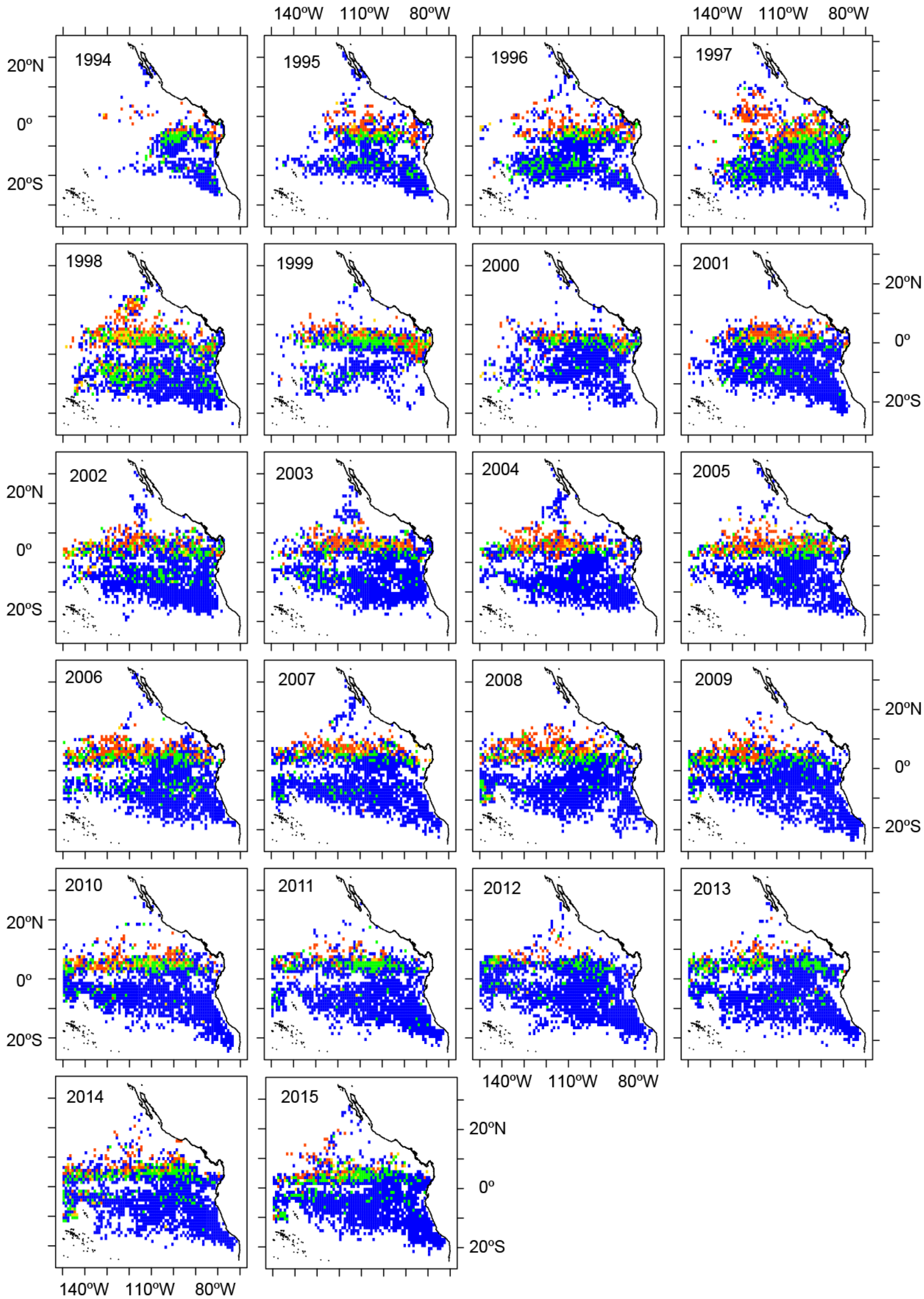


**FIGURE 1a.** Average bycatch per set in floating-object sets, in numbers, of small (< 90 cm total length) silky sharks, 1994-2015. Blue: 0 sharks per set, green: ≤ 1 shark per set; yellow: 1-2 sharks per set; red: > 2 sharks per set.

**FIGURA 1a.** Captura incidental media por lance en lances sobre objetos flotantes, en número, de tiburones sedosos pequeños (< 90 cm de talla total), 1994-2015. Azul: 0 tiburones por lance, verde: ≤ 1 tiburones por lance; amarillo: 1-2 tiburones por lance; rojo: > 2 tiburones por lance.

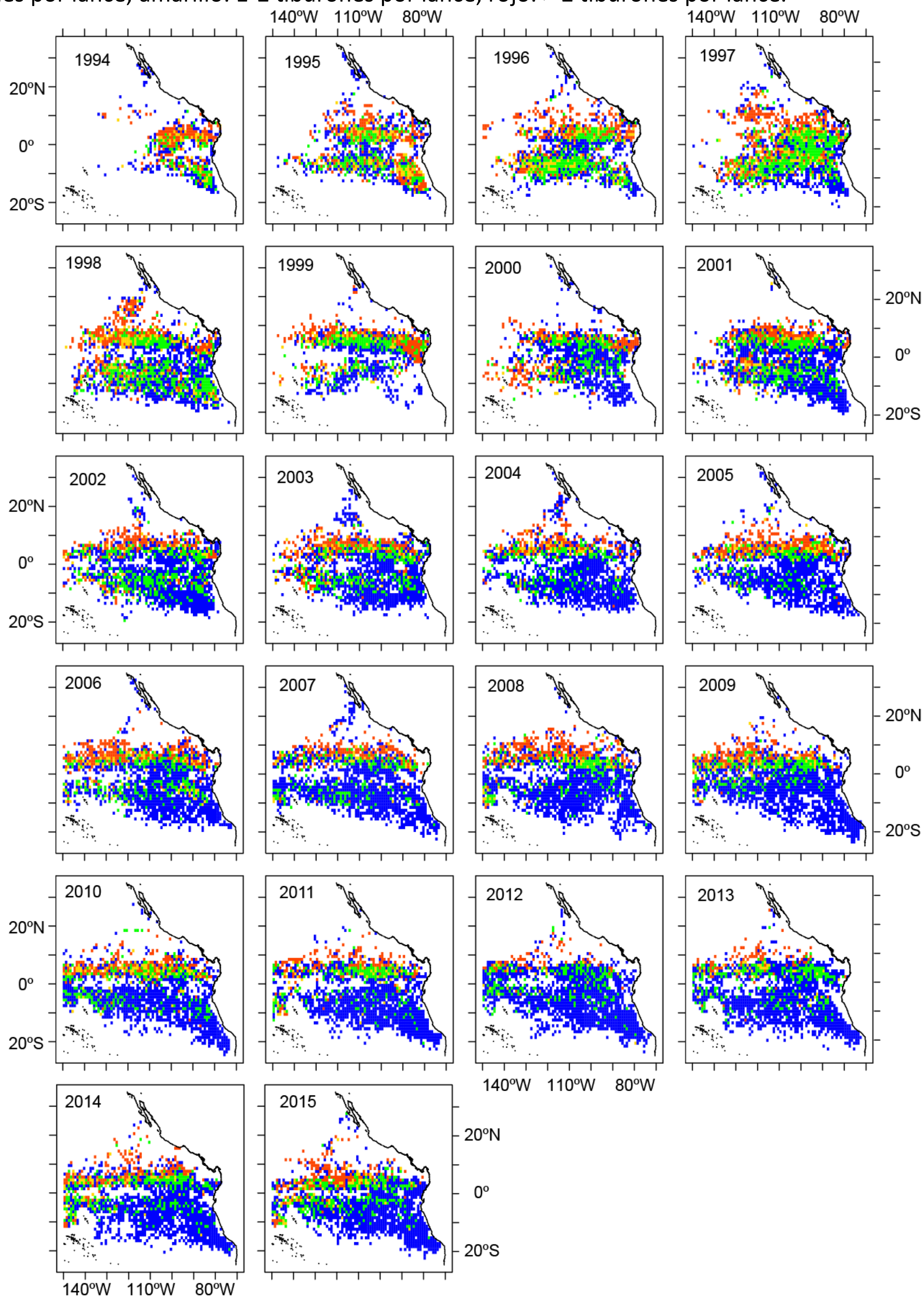


**FIGURE 1b.** Average bycatch per set in floating-object sets, in numbers, of medium (90-150 cm total length) silky sharks, 1994-2015. Blue: 0 sharks per set, green: ≤ 1 shark per set; yellow: 1-2 sharks per set; red: > 2 sharks per set.

**FIGURA 1b.** Captura incidental media por lance en lances sobre objetos flotantes, en número, de tiburones sedosos medianos (90-150 cm de talla total), 1994-2015. Azul: 0 tiburones por lance, verde: ≤

1 tiburones por lance; amarillo: 1-2 tiburones por lance; rojo: > 2 tiburones por lance.

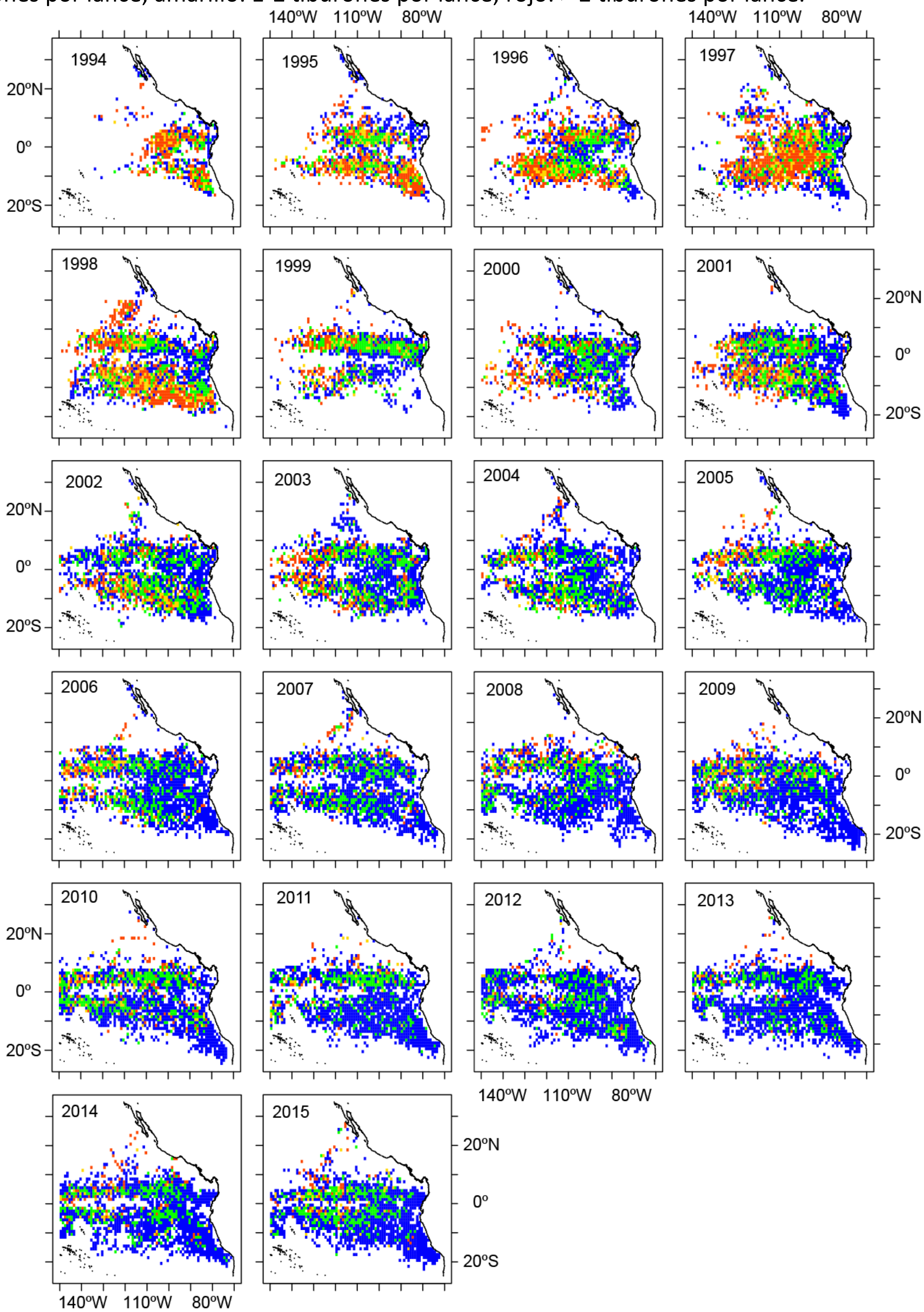


**FIGURE 1c.** Average bycatch per set in floating-object sets, in numbers, of large (> 150 cm total length) silky sharks, 1994-2015. Blue: 0 sharks per set, green: ≤ 1 shark per set; yellow: 1-2 sharks per set; red: > 2 sharks per set.

**FIGURA 1c.** Captura incidental media por lance en lances sobre objetos flotantes, en número, de tiburones sedosos grandes (> 150 cm de talla total), 1994-2015. Azul: 0 tiburones por lance, verde: ≤ 1 tiburones por lance; amarillo: 1-2 tiburones por lance; rojo: > 2 tiburones por lance.

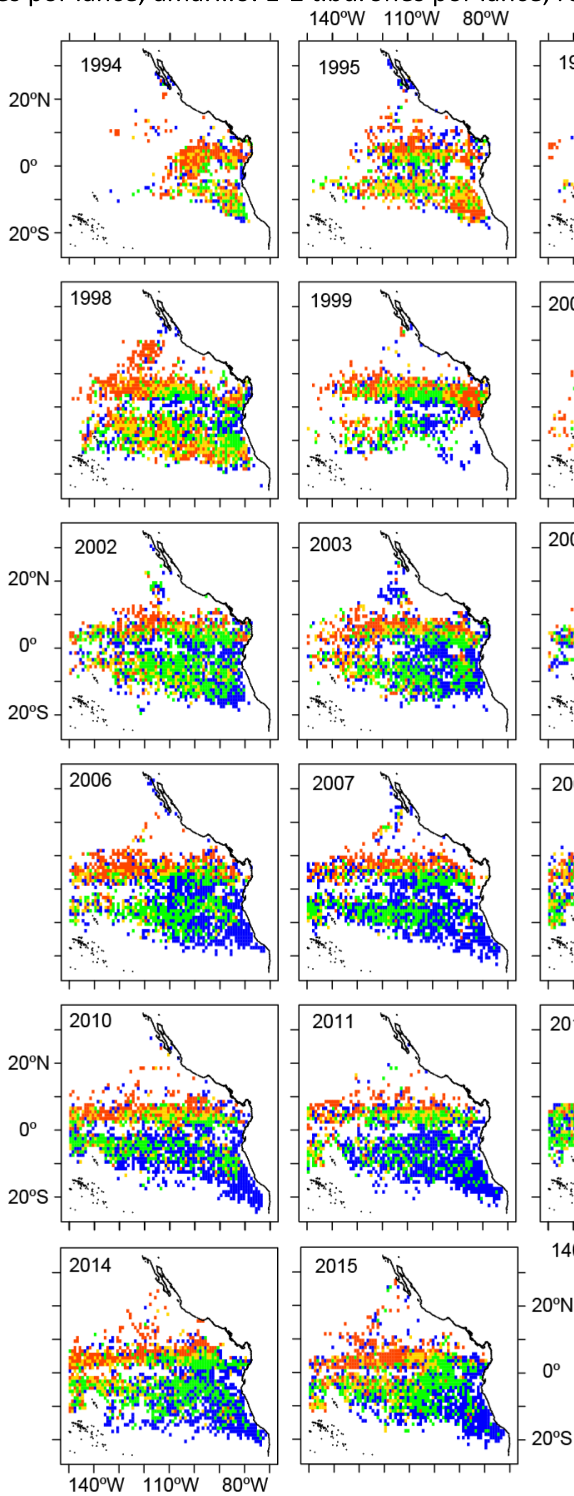


**FIGURE 1d.** Average bycatch per set in floating-object sets, in numbers, of all silky sharks, 1994-2015. Blue: 0 sharks per set, green: ≤2 shark per set; yellow: 2-5 sharks per set; red: >5 sharks per set.

**FIGURA 1d.** Captura incidental media por lance en lances sobre objetos flotantes, en número, de todos tiburones sedosos, 1994-2015. Azul: 0 tiburones por lance, verde: ≤ 2 tiburones por lance; amarillo: 2-5 tiburones por lance; rojo: > 5 tiburones por lance.

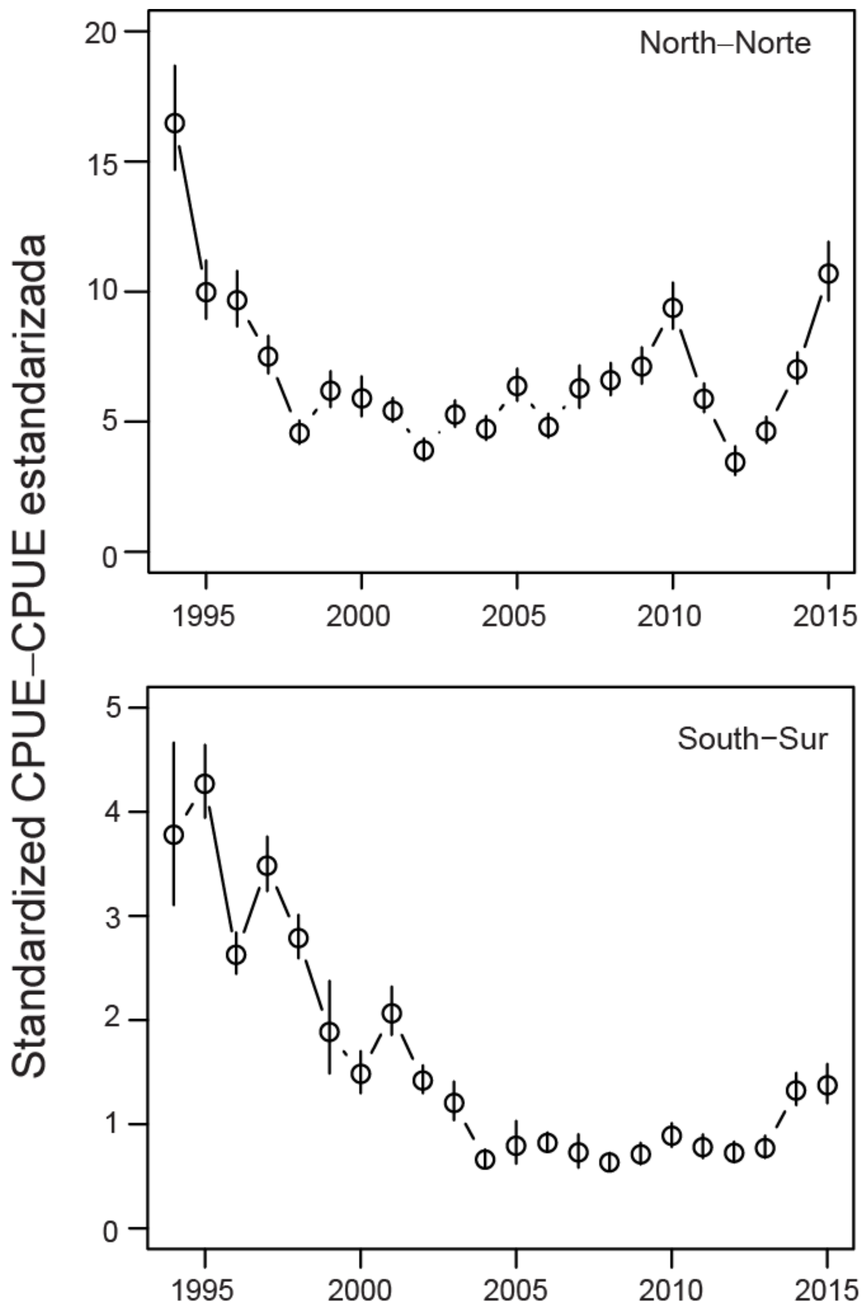


**FIGURE 2.** Standardized catch-per-unit-effort (CPUE, in number of sharks per set) of all silky sharks in floating-object sets for northern (top) and southern (bottom) EPO stocks.
**FIGURA 2.** Captura por unidad de esfuerzo (CPUE, en número de tiburones por lance) estandarizada de todos los tiburones en lances sobre objetos flotantes de las poblaciones del OPO del norte (arriba) y sur (abajo).

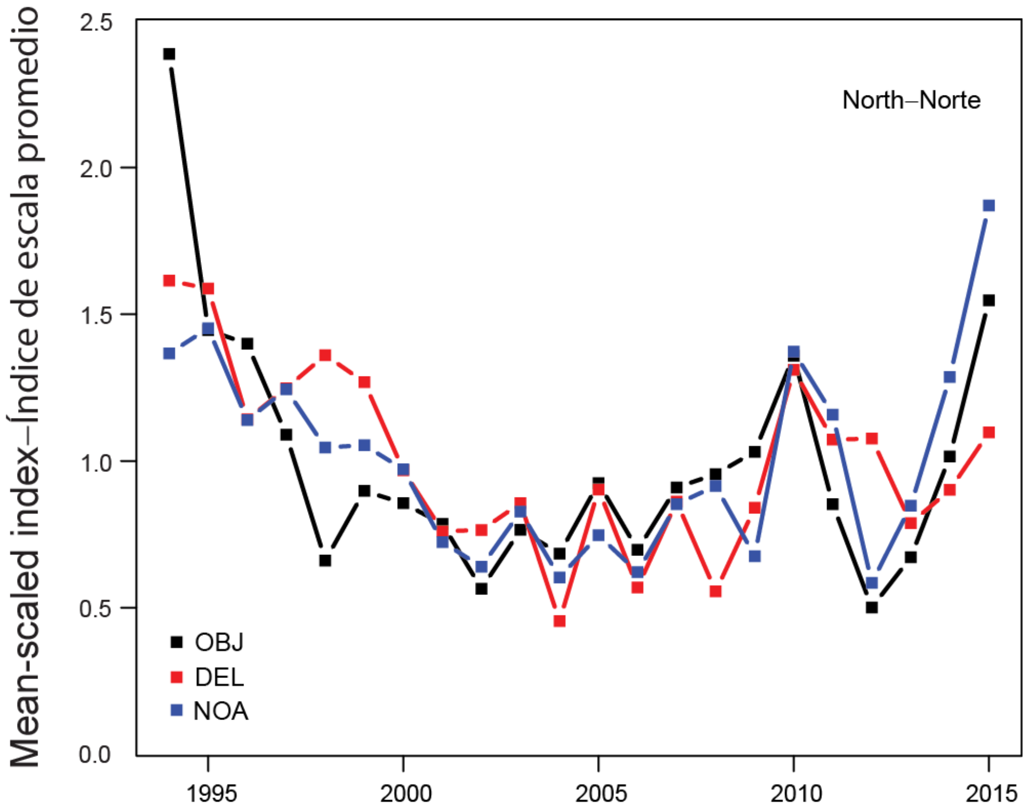


**FIGURE 3.** Comparison of stock status indicators (SSIs) for the northern silky shark produced for different purse-seine set types (floating-object (OBJ), dolphin (DEL), unassociated (NOA)).
**FIGURA 3.** Comparación de indicadores de condición de población (SSI) para el tiburón sedoso del norte producidos para distintos tipos de lance cerquero (objeto flotante (OBJ), delfín (DEL), no asociado (NOA)).

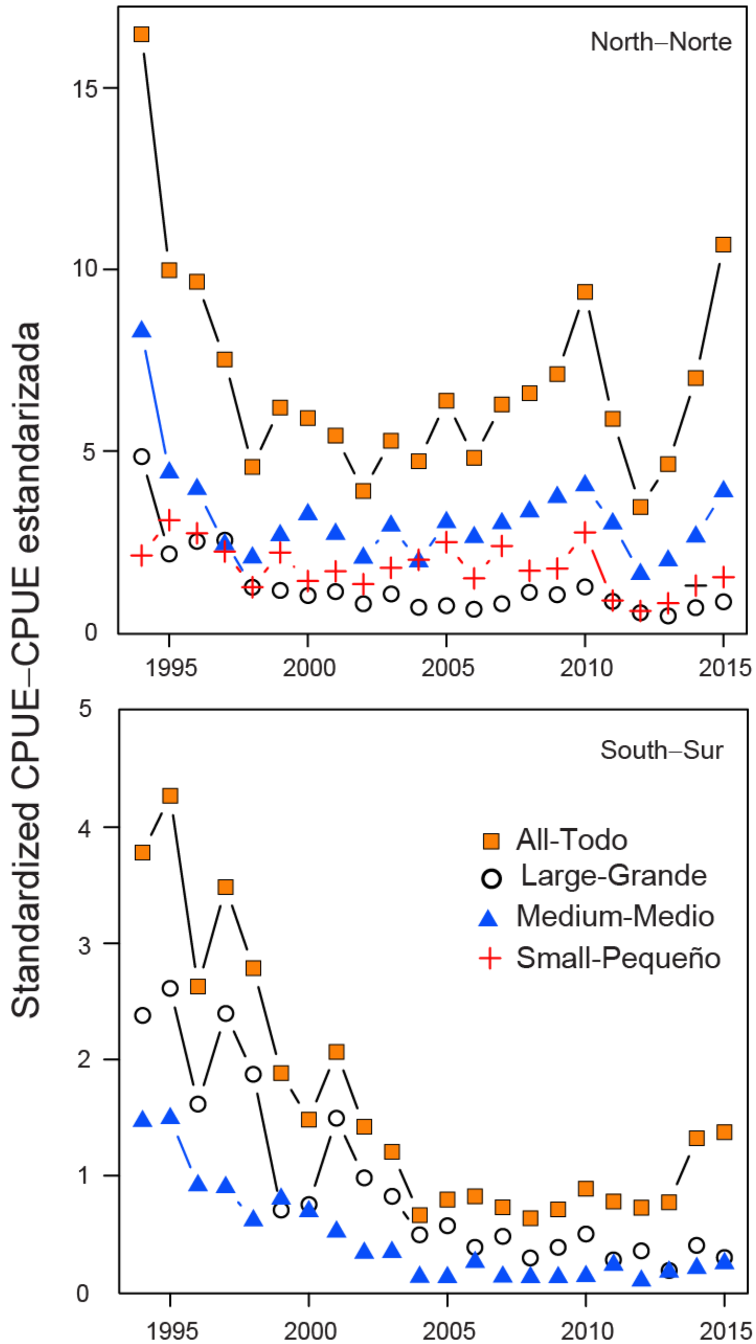


**FIGURE 4a**. Standardized catch-per-unit-effort (CPUE; in numbers of sharks per set) in sets on floating objects (OBJ) of silky sharks of different size classes (small, medium, large) and all silky sharks for northern (top) and southern (bottom) EPO stocks. No index was computed for small silky sharks in the south due to model instability caused by the low levels of bycatch in recent years; see Figure 1a.

**FIGURA** 4a. Captura por unidad de esfuerzo (CPUE, en número de tiburones por lance) estandarizada en lances sobre objetos flotantes (OBJ) de tiburones sedosos de distintas clases de talla (pequeño, mediano, grande) y todos los tiburones sedosos correspondiente a las poblaciones del norte (arriba) y sur (abajo) en el OPO. No se computó un índice para los tiburones sedosos pequeños en el sur debido a la inestabilidad del modelo causada por los bajos niveles de captura incidental en los años recientes (Figura 1a).

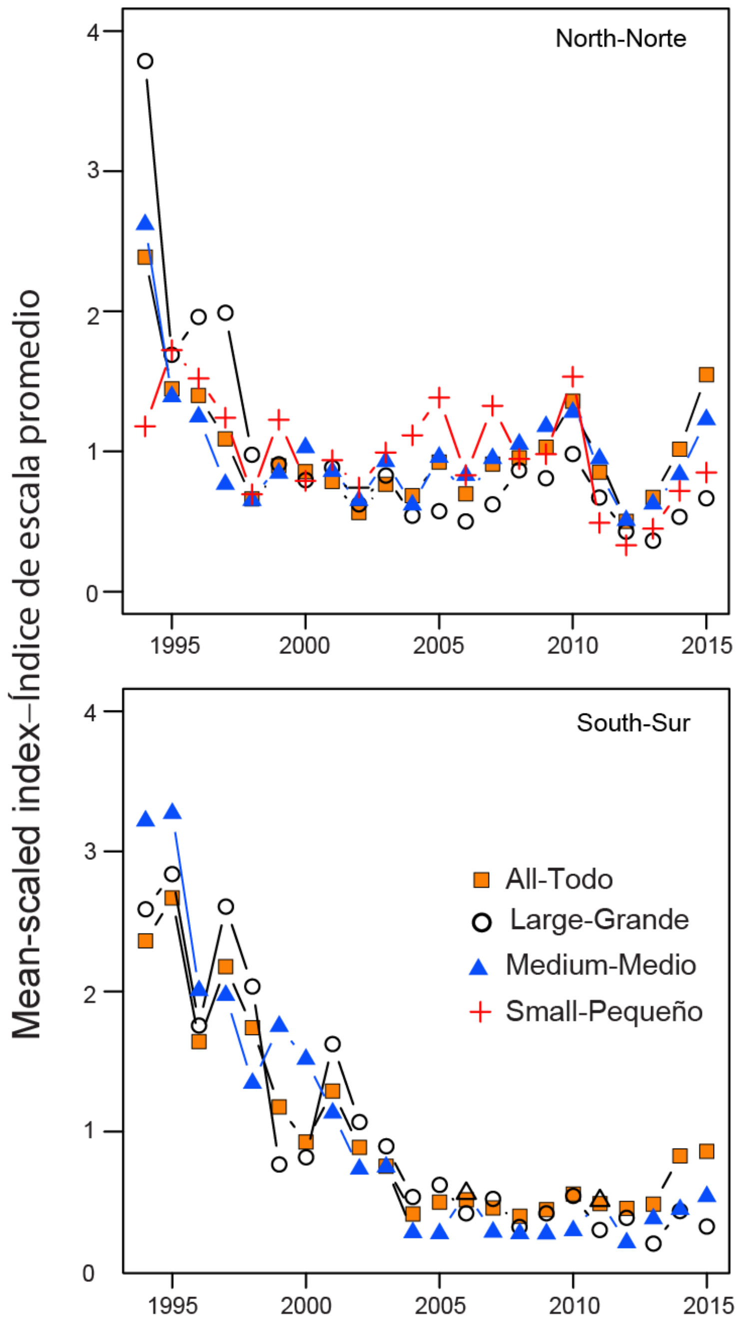


**FIGURE 4b.** Mean-scaled standardized catch-per-unit-effort in floating-object sets (CPUE-OBJ) (from Figure 3a) for silky sharks of different size classes (small, medium, large) and all silky sharks for the northern (top) and southern (bottom) EPO stocks. No index was computed for small silky sharks in the south due to model instability caused by the low levels of bycatch in recent years (Figure 1a).

**FIGURA 4b.** Captura por unidad de esfuerzo estandarizada en lances sobre objetos flotantes (CPUE-OBJ) en escala al promedio de tiburones sedosos de distintas clases de talla (pequeño, mediano, grande) y todos los tiburones sedosos correspondiente a las poblaciones del norte (arriba) y sur (abajo) en el OPO. No se computó un índice para los tiburones sedosos pequeños en el sur debido a la inestabilidad del modelo causada por los bajos niveles de captura incidental en los años recientes (Figura 1a).

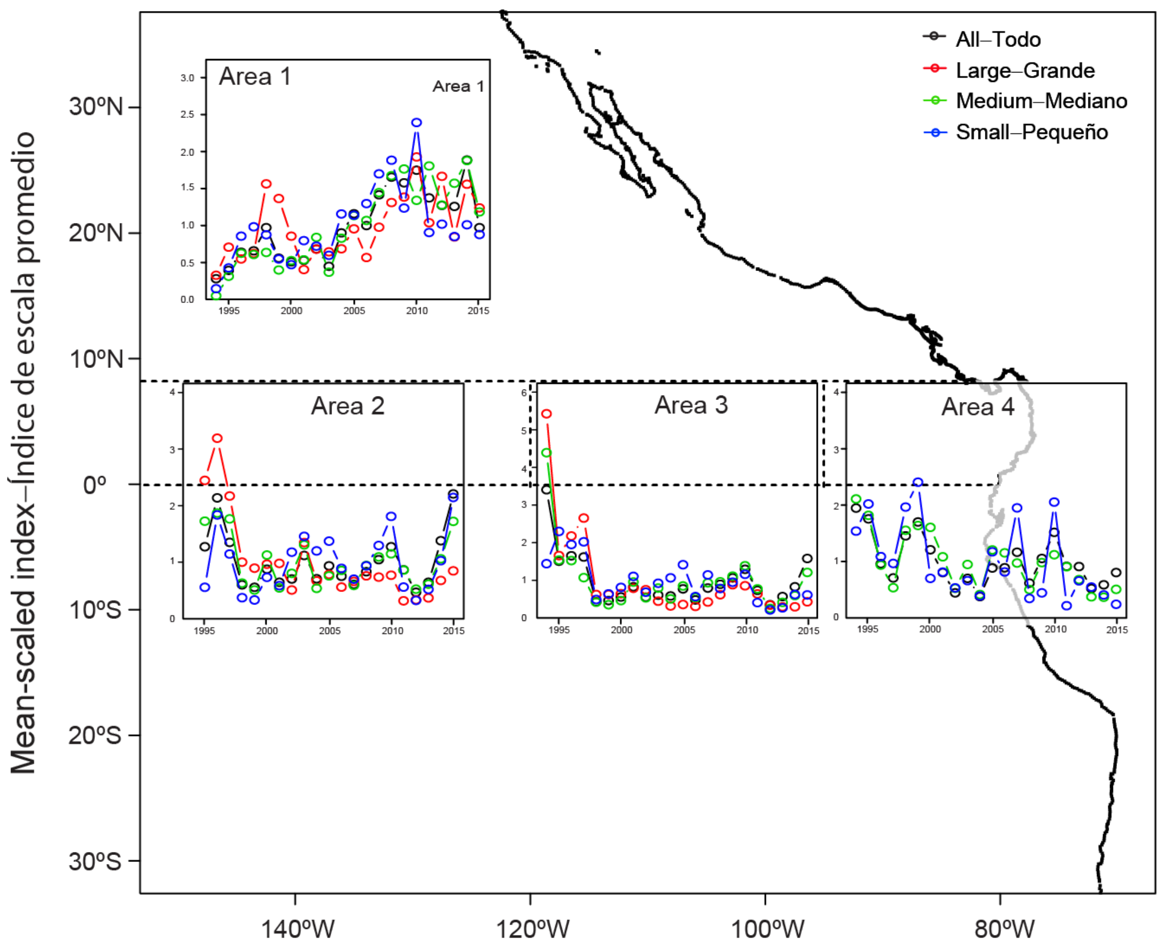


**FIGURE 5.** Mean-scaled standardized CPUE for silky sharks in the north, by sub-area. The black horizontal dashed lines show the locations of the four sub-areas: Area 1 (north of 8°N); Area 2 (0°-8°N and 120°-150°W); Area 3 (0°-8°N and 95°-130°W), and Area 4 (0°-8°N, from the coast to 95°W). A trend was not computed for large sharks in Area 4 because of model instability.

**FIGURA 5.** CPUE estandarizada en escala al promedio de tiburones sedosos en el norte, por subárea. Las líneas de trazos negras horizontales indican la posición de las cuatro subáreas: Área 1 (al norte de 8°N); Área 2 (0°-8°N y 120°-150°O); Área 3 (0°-8°N 95°-130°O), y Área 4 (0°-8°N, desde la costa hasta 95°O). No se computó una tendencia para los tiburones grandes en el Área 4 debido a inestabilidad en el modelo.