INTER-AMERICAN TROPICAL TUNA COMMISSION

SCIENTIFIC ADVISORY COMMITTEE

NINTH MEETING

La Jolla, California (USA)
14-18 May 2018

DOCUMENT SAC-09-13

UPDATED STOCK STATUS INDICATORS FOR SILKY SHARKS IN THE EASTERN PACIFIC OCEAN, 1994-2017

Cleridy E. Lennert-Cody, Alexandre Aires-da-Silva, Mark N. Maunder

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SUMMARY

The indices of relative abundance for the silky shark (*Carcharhinus falciformis*) in the eastern Pacific Ocean (EPO), developed from catch-per-set in purse-seine sets on floating objects, and presented at the 8th meeting of the Scientific Advisory Committee (SAC-08) in May 2017 (Document SAC-08-08a(i)), were updated with data from 2017. In both the north and south EPO, the indices for large silky sharks and for all silky sharks were similar, or increased slightly, relative to their 2016 values, while the indices for medium and small silky sharks were similar, or decreased slightly, relative to their 2016 values. Work subsequent to SAC-08 (Lennert-Cody *et al*. submitted) supported the previous conclusions (SAC-08-08a(i)) that the north EPO indices, particularly the small silky shark index, are influenced by inter-annual variability in ocean-climate forcing, and are therefore potentially biased as indicators of stock status. Future work (Project H.5.a) will attempt to adapt the current catch-per-set standardization methodology to develop indices that are less influenced by such variability, with emphasis on the indices for large silky sharks. In the meantime, the IATTC staff reiterates its previous recommendations (SAC-07-06b(i), SAC-07-06b(iii), SAC-08-11) regarding improving shark fishery data collection in the EPO. This will facilitate the development of other stock status indicators and/or conventional stock assessments to better inform the management of the silky shark and other co-occurring shark species. Spatio-temporal models that combine data from multiple gear types to improve spatial coverage should also be explored in the future, to facilitate modeling efforts once data from other sources become available.

1. BACKGROUND

An attempt by the IATTC staff in 2013 to assess the status of the silky shark in the EPO, using conventional stock assessment models, was severely hindered by major uncertainties in the fishery data, primarily total annual catch in the early years for all fisheries that caught silky sharks in the EPO (SAC-05 INF-F). Although the 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 by gaps in the available data. Since a conventional stock assessment was not possible, in 2014 the staff proposed a suite of possible stock status indicators (SSIs) that could be considered for managing the silky shark in the EPO (SAC-05-11a), including standardized catch-per-set (CPS) indices from the purse-seine fishery.

However, further investigations of the indices of relative abundance presented in 2017 (SAC-08-08a(i)) suggested that recent large changes in the indices, particularly in the north EPO index for small silky sharks, may be influenced by inter-annual variability in oceanographic conditions (*e.g.*, El Niño and La Niña events), and are thus potentially biased and compromised as indicators of stock status. The indices for large silky sharks may be least susceptible to such influences. These results are consistent with recent analyses of the relationship between indices for silky sharks, by subarea, across the Pacific and a different index of ocean-climate variability, the Pacific Decadal Oscillation. Those additional findings (Lennert-Cody *et al*. *submitted*) are presently under review for publication in the peer-reviewed journal *Fisheries Oceanography*; this document updates the purse-seine CPS indices with data for 2017, using previously developed methodology, and discusses future research directions.

2. DATA AND METHODS

Data on floating-object (OBJ) sets collected by IATTC observers aboard Class-6[1] purse-seine vessels were used to generate CPS-based indices of relative abundance for the silky shark. Observers record bycatches of silky sharks, which occur predominantly in floating-object sets (SAC-07-07b), by size category: small (<90 cm total length (TL)), medium (90-150 cm TL), and large (>150 cm TL). Annual summaries of the spatial distribution of bycatch rates for 1994-2017 are shown in Figures 1a-d.

CPS trends for OBJ sets were estimated using previously-developed generalized additive models (GAMs) (Minami *et al*. 2007). A zero-inflated negative binomial GAM was used to model the bycatch data from OBJ sets because of the large proportion of sets with zero bycatch, and also the existence of sets with large bycatches. Predictors used in this model were: year (factor); smooth terms for latitude, longitude, time of 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 bycatches of species other than silky sharks, natural logarithm of tuna catch, and two proxies for local floating-object density. Trends were computed by shark size category and for all sizes combined, using the method of partial dependence, which produces a data-weighted index. As in previous years, trends were computed for the EPO north and south of the equator.

3. RESULTS AND FUTURE WORK

Relative to 2016, the 2017 index values for the silky shark remain largely unchanged (Figures 2a-b). In both the north and south EPO, the indices for large silky sharks and all silky sharks were similar, or increased slightly, relative to their 2016 values, while those for medium and small sharks were similar or decreased slightly. In previous analyses (SAC-08-08a(i)), the indices for large silky sharks appeared to be the least susceptible to inter-annual change driven by variability in oceanographic conditions. No trend was computed for small silky sharks in the south EPO because of the low levels of small silky shark bycatch in that area (Figure 1a).

Future work (Project H.5.a) will attempt to adapt the current GAM CPS standardization methods to develop indices that are less influenced by inter-annual variability in ocean-climate forcing. Based on previous work (SAC-08-08a(i); Lennert-Cody *et al. submitted*), the emphasis of this work will be

[1] Carrying capacity > 363 t

development of a reliable index for large sharks. However, because it is by no means certain that this will be possible, obtaining reliable catch data for all fisheries catching silky sharks in the EPO, indices of relative abundance for other fisheries (especially longline fisheries, which take the majority of the catch), and composition data, by length/age and sex, continues to be vital.

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Minami, M. Lennert-Cody, C.E., Gao, W., Román-Verdesoto, M. 2007. Modeling shark bycatch: The zero-inflated negative binomial regression model with smoothing. Fisheries Research 845: 210-221.

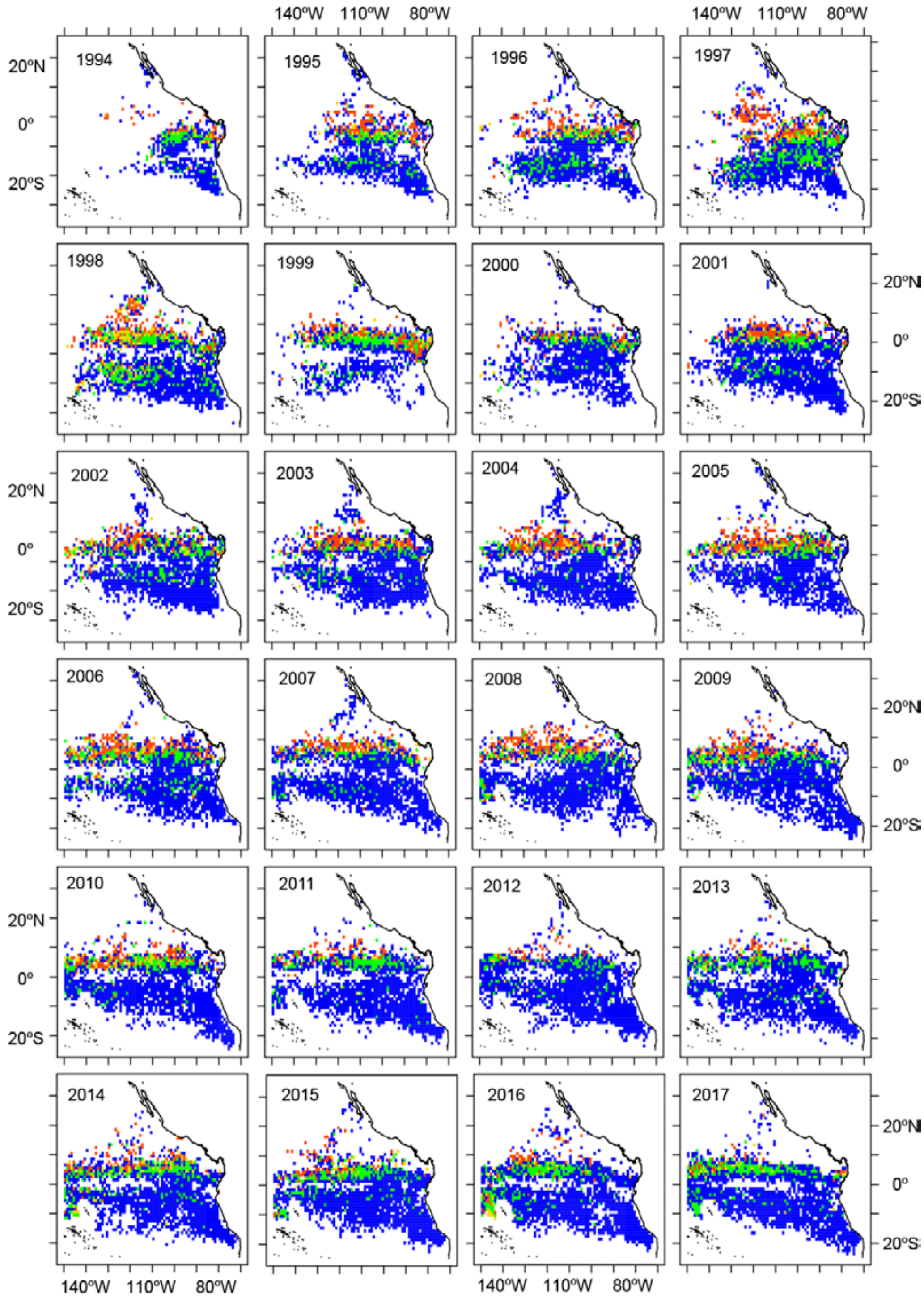

FIGURE 1a. Average bycatch per set in floating-object sets, in numbers, of small (< 90 cm total length) silky sharks, 1994-2017. Blue: 0 sharks per set, green: ≤ 1 shark per set; yellow: 1-2 sharks per set; red: > 2 sharks per set.

FIGURA 1a. Captura incidental media por lance en lances sobre objetos flotantes, en número, de tiburones sedosos pequeños (< 90 cm de talla total), 1994-2017. Azul: 0 tiburones por lance, verde: ≤ 1 tiburones por lance; amarillo: 1-2 tiburones por lance; rojo: > 2 tiburones por lance.

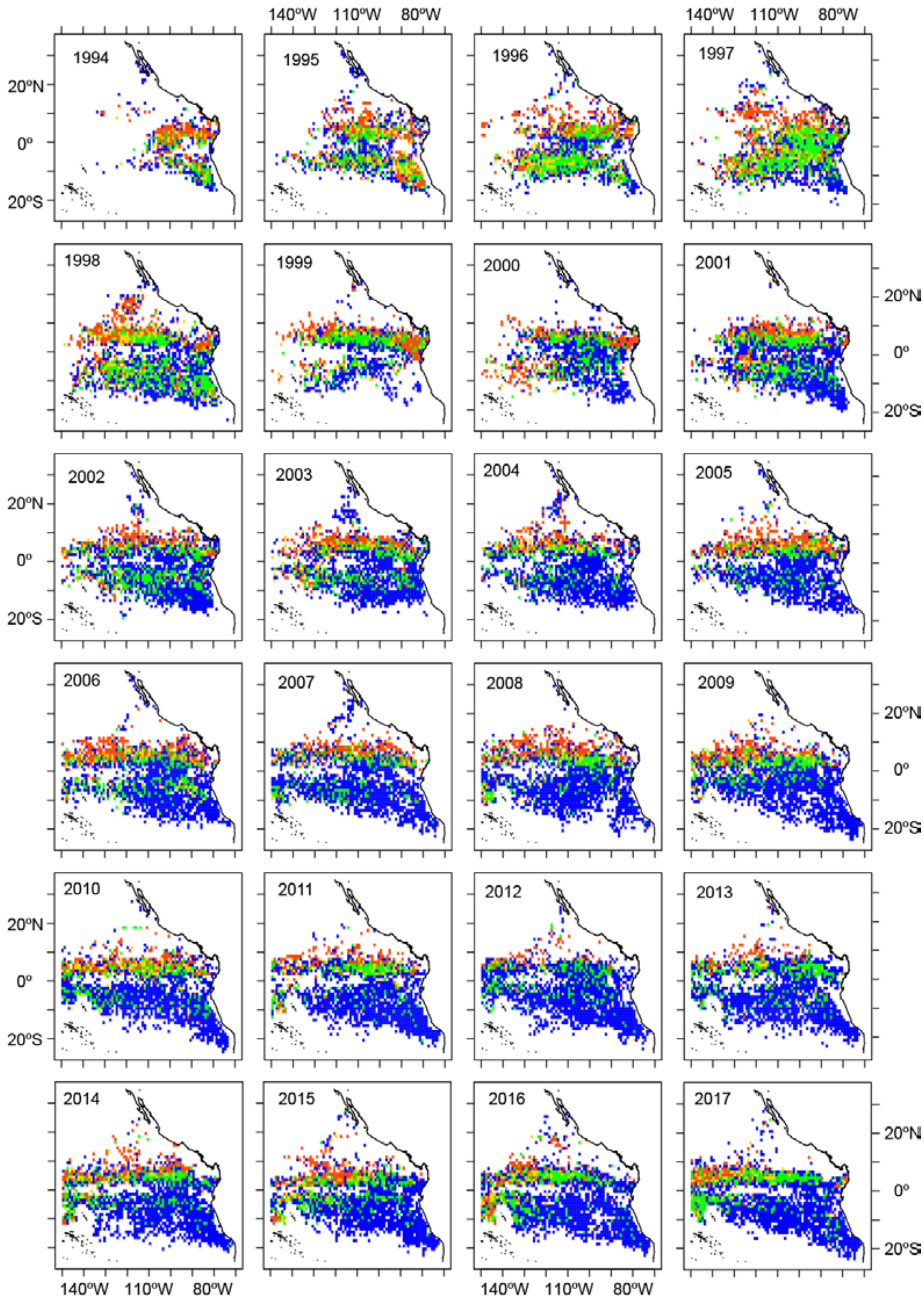

FIGURE 1b. Average bycatch per set in floating-object sets, in numbers, of medium (90-150 cm total length) silky sharks, 1994-2017. Blue: 0 sharks per set, green: ≤ 1 shark per set; yellow: 1-2 sharks per set; red: > 2 sharks per set.

FIGURA 1b. Captura incidental media por lance en lances sobre objetos flotantes, en número, de tiburones sedosos medianos (90-150 cm de talla total), 1994-2017. Azul: 0 tiburones por lance, verde: ≤ 1 tiburones por lance; amarillo: 1-2 tiburones por lance; rojo: > 2 tiburones por lance.

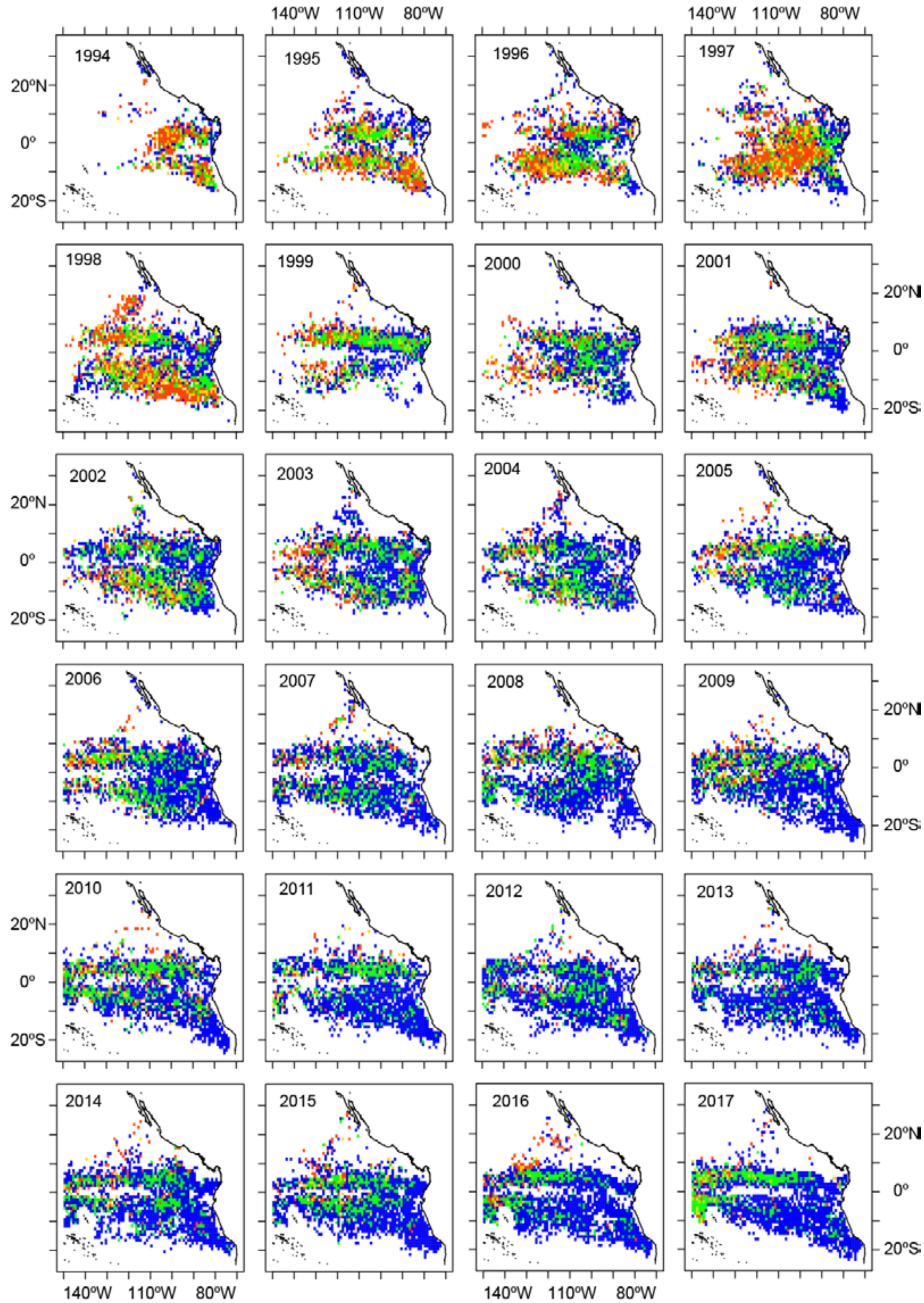

FIGURE 1c. Average bycatch per set in floating-object sets, in numbers, of large (> 150 cm total length) silky sharks, 1994-2017. Blue: 0 sharks per set, green: ≤ 1 shark per set; yellow: 1-2 sharks per set; red: > 2 sharks per set.

FIGURA 1c. Captura incidental media por lance en lances sobre objetos flotantes, en número, de tiburones sedosos grandes (> 150 cm de talla total), 1994-2017. Azul: 0 tiburones por lance, verde: ≤ 1 tiburones por lance; amarillo: 1-2 tiburones por lance; rojo: > 2 tiburones por lance.

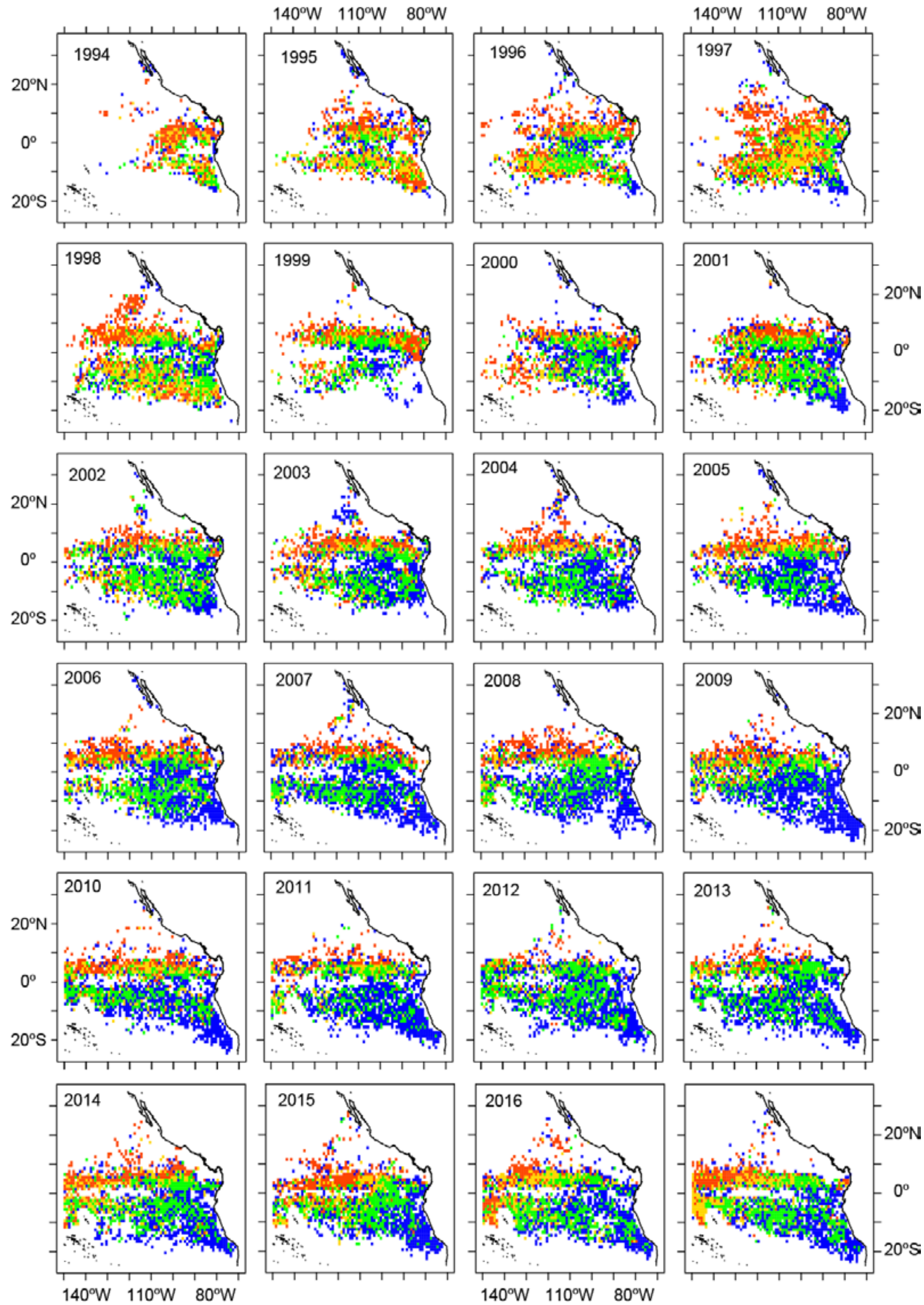

FIGURE 1d. Average bycatch per set in floating-object sets, in numbers, of all silky sharks, 1994-2017. Blue: 0 sharks per set, green: ≤2 shark per set; yellow: 2-5 sharks per set; red: >5 sharks per set.

FIGURA 1d. Captura incidental media por lance en lances sobre objetos flotantes, en número, de todos tiburones sedosos, 1994-2017. Azul: 0 tiburones por lance, verde: ≤ 2 tiburones por lance; amarillo: 2-5 tiburones por lance; rojo: > 5 tiburones por lance.

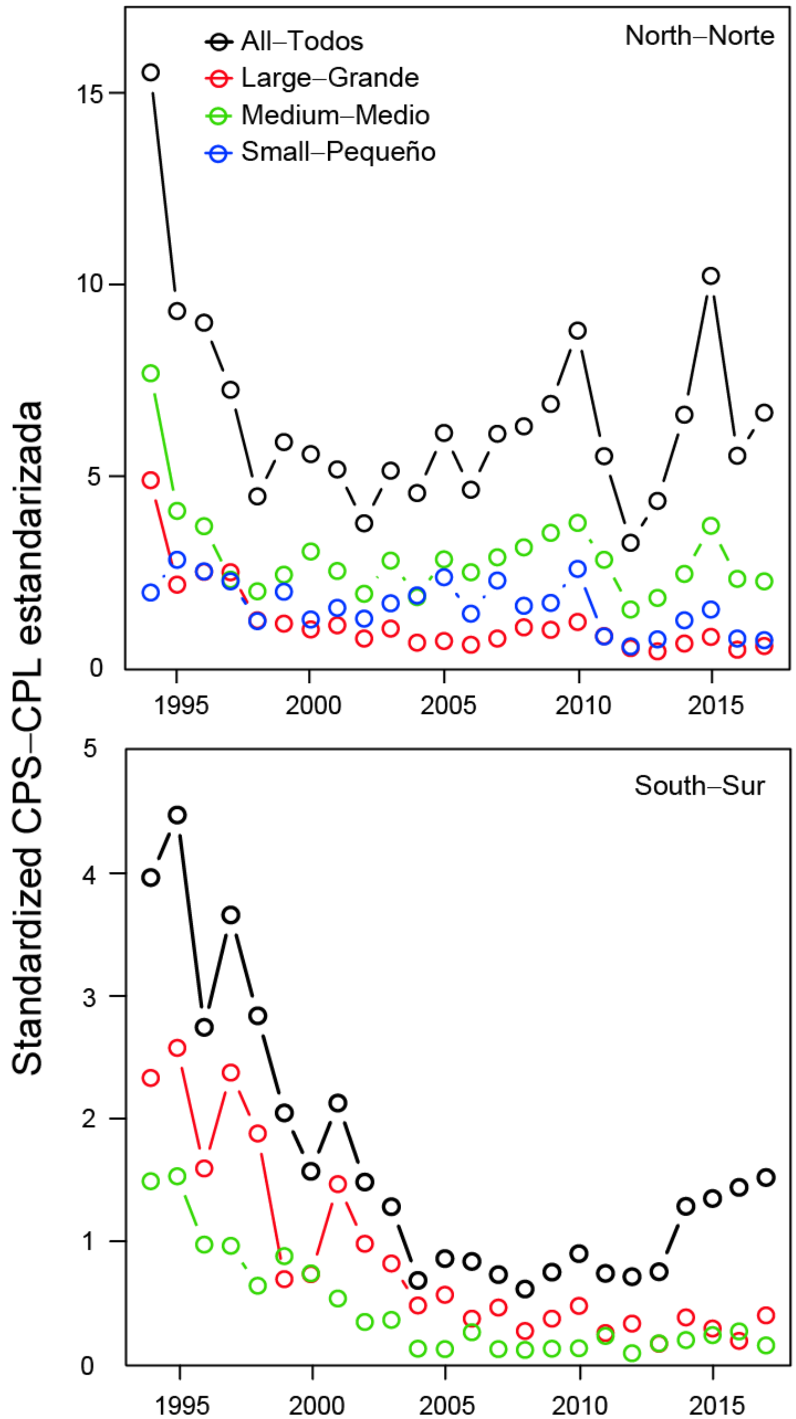

FIGURE 2a. Standardized silky shark catch-per-set (CPS; in numbers of sharks per set) in sets on floating objects for the three size categories (small, medium, large), and all sizes combined, in the north (top) and south (bottom) EPO.

FIGURA 2a. Captura por lance (CPL, en número de tiburones por lance) estandarizada en lances sobre objetos flotantes de tiburones sedosos de tres clases de talla (pequeño, mediano, grande) y todas las tallas combinadas, en el OPO norte (arriba) y sur (abajo).

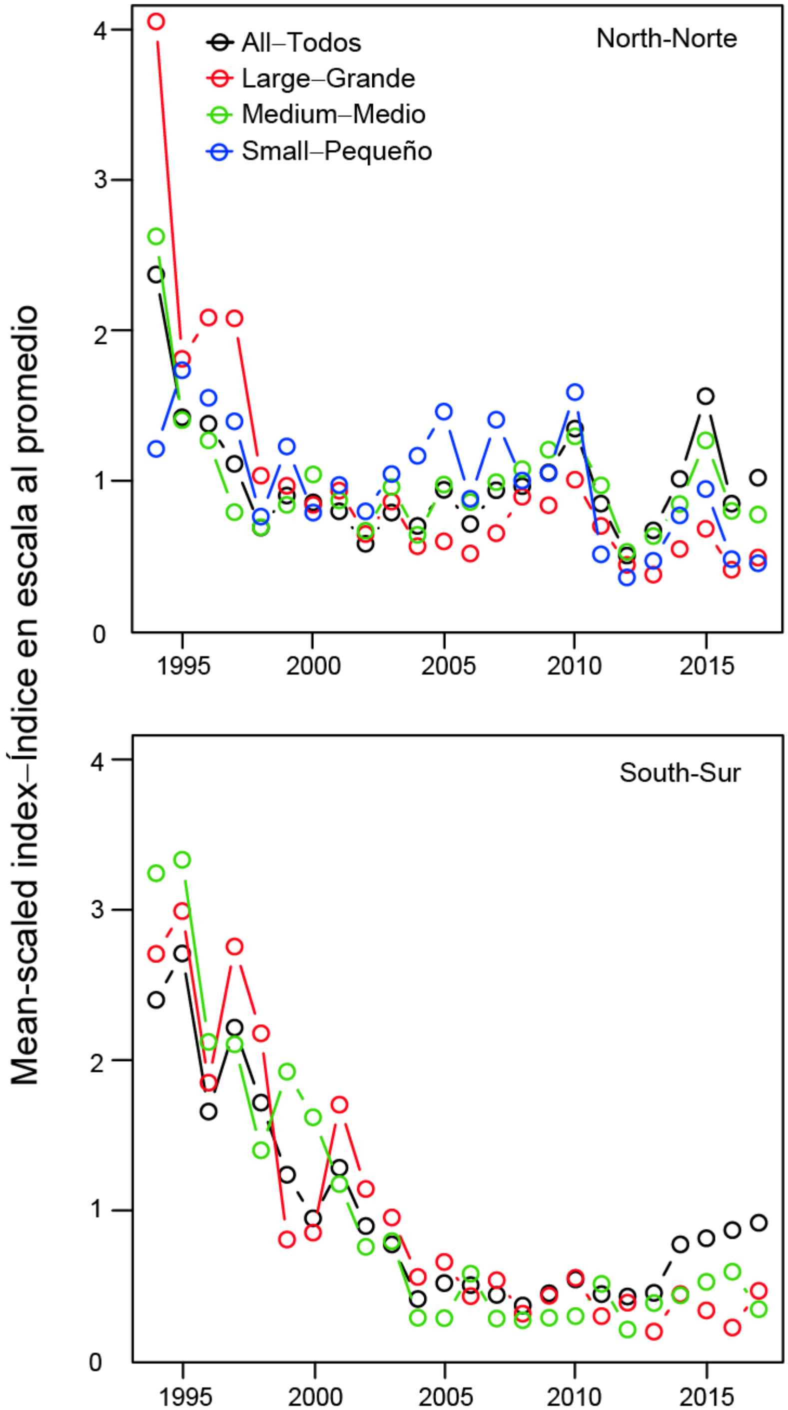

FIGURE 2b. Mean-scaled silky shark standardized catch-per-set in floating-object sets (from Figure 2a) for the three size classes (small, medium, large), and all sizes combined, for the north (top) and south (bottom) EPO.

FIGURA 2b. Captura por lance estandarizada en escala as promedio en lances sobre objetos flotantes (de la Figura 2a) de tiburones sedosos de tres clases de talla (pequeño, mediano, grande) y de todas tallas combinadas, en el OPO norte (arriba) y sur (abajo).