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A PRELIMINARY METADATA ANALYSIS OF LARGE-SCALE TUNA LONGLINE FISHERY DATA IN THE EASTERN PACIFIC OCEAN: A PRECURSOR TO ECOLOGICAL RISK ASSESSMENT

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1. INTRODUCTION

The primary responsibility of the Inter-American Tropical Tuna Commission (IATTC), as mandated by the Antigua Convention, is to ensure the "*long-term conservation and sustainable use of the stocks of tunas and tuna-like species and other associated species of fish taken by vessels fishing for tunas and tuna-like species in the eastern Pacific Ocean (EPO)*". Although historically, management has focused on the principal target species of tunas and billfishes, the worldwide movement towards ecosystem-based fisheries management over the past two decades has led the IATTC to consider, and manage, the broader ecological impacts of its fisheries. This initiative is explicitly stated in Article VII of the Antigua Convention:

(1) "*adopt, as necessary, conservation and management measures and recommendations for species belonging to the same ecosystem and that are affected by fishing for, or dependent on or associated with, the fish stocks covered by this Convention, with a view to maintaining or restoring populations of such species above levels at which their reproduction may become seriously threatened*", and

(2) "*adopt appropriate measures to avoid, reduce and minimize waste, discards, catch by lost or discarded gear, catch of non-target species (both fish and non-fish species) and impacts on associated or dependent species, in particular endangered species*".

However, demonstrating the sustainability of all species impacted by EPO fisheries is difficult, owing to the lack of reliable biological, ecological and catch information required for robust single-species assessments for the many species of little or no economic value. Demonstrating sustainability is even more challenging in fisheries that use unselective passive gears such as longlines, where the diversity of bycatch can be high, especially in tropical regions. Therefore, data-limited assessment methods are required to assess such fisheries.

One approach that has been widely applied to various data-limited fisheries worldwide is ecological risk assessment (ERA). There are several types of ERA methods, ranging from qualitative expert-driven approaches (Fletcher 2005) to quantitative spatially-explicit assessment models (Zhou and Griffiths 2006). The semi-quantitative Productivity-Susceptibility Analysis (PSA) (Stobutzki *et al.* 2001) has proven to be a particularly useful method in data-limited fisheries due to its flexibility in data inputs and assessment criteria, and is now the preferred bycatch sustainability assessment method of the Marine Stewardship Council (MSC) for fishery certification (MSC, 2010). PSA estimates the relative vulnerability of each species to becoming unsustainable under current fishing levels by scoring a number of attributes relating to the species' susceptibility to being caught and its biological productivity, or resilience to fishing.

In recent years, the IATTC staff successfully applied a preliminary PSA to estimate the vulnerability of the suite of species caught in the EPO purse-seine fishery by Class-6[2] vessels (SAC-06-09). In response to recent requests by some IATTC Members to undertake ERA of other fisheries (IATTC 2015, pg. 26), the staff proposed a PSA for the EPO longline fishery. However, that fishery is difficult to define (see Aires-da-Silva *et al.* 2016; Siu and Aires-da-Silva 2016), because it encompasses a wide variety of vessels, flags, species, habitats, and fishing areas, from large industrial vessels (mainly from Asia) that target tuna and billfish on the high seas to smaller artisanal vessels targeting large pelagic species—mainly sharks, tunas, billfish and dorado (*Coryphaena hippurus*). The latter constitute the longline fleet of the EPO coastal CPCs[3] with a range of operation that can extend beyond coastal waters and national jurisdictions. For example, there is also a growing oceanic-artisanal fleet that fishes the high seas in small vessels, with assistance from motherships, targeting tuna, billfish, and sharks as far from land as 100°W (Andraka *et al.* 2013; Martínez-Ortiz *et al.* 2015).

In Resolution C-11-075, the IATTC classified longline vessels greater than 24 m length overall (LOA) as "large-scale tuna longline fishing vessels" (LSTLFVs), and vessels that fish for tuna and tuna-like species in the EPO are required to be included in both the IATTC's Regional Vessel Register and its "LSTLFV List". Also, Resolution C-11-08 requires that at least 5% of the fishing effort (defined as days fishing) by longline vessels over 20 m LOA carry a scientific observer, and that each CPC report annually to the IATTC the catch

[2] Carrying capacity >363 t

[3] Members and Cooperating Non-Members of the IATTC

and effort data for those vessels. Therefore, the analyses in this report are confined to these vessels, which we refer to as comprising the "large-scale tuna longline fishery" in the EPO. It is important to note that a project is currently underway to collect data for the artisanal fleet, which may eventually make it possible to conduct a cumulative ERA for all longline fisheries in the EPO (SAC-08-06(ii)).

Previously, application of an ERA to any longline fishery in the EPO was considered problematic due to the apparent spatial and/or temporal heterogeneity in the available catch and effort data. However, given the flexibility of the PSA method, it was determined that a preliminary assessment using currently available data would rapidly identify any major data deficiencies and potentially at-risk species, which could guide the Commission in developing measures to address sustainability concerns in the large-scale tuna longline fishery.

As a precursor to undertaking a PSA, it was decided to initiate a metadata analysis of the datasets held by the IATTC that could be used to parameterize a PSA for the large-scale tuna longline fishery. For general descriptions of the fishery—at least for the predominant Japanese longline fleet—see reviews by Kume and Joseph (1969) and Okamoto and Bayliff (2003). The primary objectives of this paper were to establish a list of species with which the fishery interacts, and define the catch and effort data that could fulfil the data requirements for the susceptibility attributes. In particular, these were the extent of geographic overlap of fishing effort with the distribution of the species in the EPO, gear encounterability relative to the depth distribution of a species, selectivity of the gear to capture a species once it encounters the gear, and post-release survival if the species is captured but discarded. Therefore, the specific aims were to:

i) Undertake a metadata analysis of the EPO large-scale tuna longline fishery data held by the IATTC that relate to the requirements of an ecological risk assessment of the fishery;

ii) Describe the general dynamics of the fishery, including the relative contribution by each CPC to the total longline fishing effort, and the spatial and temporal distribution of catch and effort;

iii) Describe the species composition of the catch reported by the fishery and the relative contribution of each species to the total catch (both retained and discarded);

iv) Analyze catch trends for principal tuna and billfish species and common shark and teleost bycatch species;

v) Identify key deficiencies and potential biases in the longline data held by the IATTC, and make recommendations for improving data quality, including assisting CPCs in meeting their obligations under the various applicable resolutions.

2. IATTC DATA REPORTING REQUIREMENTS FOR LONGLINE VESSELS

IATTC members have been required to report data on catches and effort, primarily for target species, to the Commission since around 1952. Since the entry into force of the Antigua Convention in 2010, CPCs are required to comply with Article XVIII, paragraph 2 of the Convention, which stipulates that: "*Each Party shall provide to the Commission all the information that may be required for the fulfillment of the objective of this Convention, including statistical and biological information and information concerning its fishing activities in the Convention Area, …*".

Aware of the need for improving the quality of data reported by CPCs, the Commission adopted Resolution C-03-05 on *data provision*, which requires catch and effort data to be reported as monthly aggregates at a minimum spatial resolution of 5°x5° (*i.e.* "Level 3" data), including information on gear configuration and target species, as well as length or weight of individual fish, if possible.

More explicit data reporting requirements for longline vessels were later adopted by the Commission via Resolution C-11-08 on *Scientific Observers for Longline Vessels*, which requires CPCs to have a minimum of 5% observer coverage of longline vessels of greater than 20 m length overall and report catch and effort data to the IATTC, by species. The resolution also mandates, among others, that scientific observers "… *record any available biological information, the catches of targeted fish species, species composition and any available biological information as well as any interactions with non-target species such as sea turtles, seabirds and sharks*."

3. FORMATS OF LONGLINE DATA HELD BY THE IATTC

The formats used to report longline catch and effort data to the IATTC vary considerably by CPC and through time. Most CPCs report catch and effort at the minimum required spatial resolution of 5°x5°, but some, including French Polynesia, Japan, Mexico, and the United States, report at 1°x1° resolution. As a result, the industrial longline fishery data—housed within the broader IATTC database framework—exist as two pairs of catch and effort data tables, to capture both data resolutions, although all 1°x1° data are also included within the appropriate grid in the 5°x5° tables. Therefore, for the purposes of broadly describing catch and effort in this report, only 5°x5° data were used. The specific data fields are described in Appendices 1 and 2.

At a minimum, individual data records for each CPC exist as a monthly aggregation of catch, by species or taxonomic group (*e.g.* "Elasmobranchii"), and effort for multiple sets and vessels in a particular grid. Very few of the records contain any data that are commonly used in the standardization of effort in longline fisheries, such as number of vessels, number of sets, hooks per basket/float (HPB) (except Japan), time of set, duration of set, length of the longline, and gear depth. As such, it is often impossible to verify whether the reported catch and effort in a record are raised totals or a sample of sets made in a particular month-grid-flag stratum. A small proportion of the records were accompanied by metadata descriptions stating that catch and effort were raised totals, and more detailed information was often included in the annual longline observer reports by individual CPCs at meetings of the Scientific Advisory Committee (SAC). However, it is generally not possible to apply this highly summarized information to the specific datasets held by the IATTC (SAC-08-03d). Consequently, this paper reports only the data available in the IATTC databases; therefore, the catch and effort data reported herein can be regarded as minimum estimates only.

Catch is generally reported to the IATTC in numbers of fish, to a lesser extent in weight (tons) only, and sometimes in both numbers and weight, although this varies by CPC. For example, Belize, the European Union, Vanuatu, and Chinese Taipei report in numbers and weight, whereas Japan and the United States report only numbers.

3.1. Preparation of data for reporting

To standardize the format of data described in this paper, only data reported in numbers were used, and expressed as either total numbers or catch-per-unit-of-effort (CPUE), calculated using nominal effort data. For the many records that included catch in weight only, a conversion factor was required for each taxon to estimate the catch in those records in number of fish. Reliable weight conversions factors are available for the purse-seine fishery, but not the longline fishery. This is because the required observer coverage is only 5%, and detailed length-frequency data, from which average weights could be estimated, are usually not reported to the IATTC, especially for low-value bycatch species. Mean weights for each taxon were therefore estimated by considering longline records where both numbers and weight were reported. For each taxon, the reported weight was divided by the reported number of fish caught to estimate a mean (± 1 SD) weight. This estimated mean weight was then applied to all records where only weight was reported in order to estimate number of individuals. The same process was applied to discard data; the resulting estimated numbers of discards, by taxon, were then added to the retained catch, and the sum included in our study as total catch.

It is important to note that these average weights, and the derived conversion factors, were estimated using data pooled across years, areas and flags, as there were insufficient data to estimate them at any finer spatial or temporal resolution.

Several taxa caught in the longline fishery are reported within highly aggregated taxonomic groups, such as "Elasmobranchii" for sharks and rays, "Thunnini" for tunas, and "Istiophoridae, Xiphiidae" for billfish. Unfortunately, the aggregated data cannot be used in the PSA ecological risk assessment approach, since these groups can contain species with different life histories. For the purposes of assessing trends in catches and CPUE over time, we disaggregated the grouped catches by first determining the percentage of each constituent species of a group in the annual data reports that were broken down by species. The reported catch for the group was then disaggregated by the same proportions as in the species-specific reported catch, and these catches were then added to the total catch of the relevant species.

4. METADATA ANALYSIS

4.1. Large-scale tuna longline fleet

As of 16 March 2017, the IATTC LSTLFV List included a total of 1 306 vessels from 17 CPCs (Table 1). The majority (82%) are from China (373 vessels), Japan (235), Korea (191), Chinese Taipei (153), and European Union (127).

The vessels range in size (in meters LOA) and fish hold capacity (in cubic meters (m^3)/metric tons (t)) from 24.0 to 91.5 m and 18 to 4 790 m^3/5 to 720 t, respectively. However, no capacity is listed for 265 vessels (20.3%) on the List. It is unknown which vessels on the List, or what percentage of vessels, overall or by CPC, are actually fishing or in service.

4.2. Description of data records

During 1954-2015, 10 CPCs provided a total of 82 053 records to the IATTC describing operations in the EPO by longline vessels over 24 m LOA (Table 2). Of these records, 54 765 (66.7%) reported catch in numbers only, 7 978 (9.7%) in weight only, 18 555 (22.6%) in both numbers and weight, and the remaining 755 (0.9%) contained no catch data. It is unknown whether reported total species weights are a sum of actual measurements of dressed weights of individuals, or estimates based on an average weight.

Each database record exists as a monthly aggregation of catch and effort, in number of sets, by 5°x5° and flag. The total number of hooks deployed for sets within each record was complete for all but 62 records. However, only 1 385 records (180 from United States and 1 205 from Vanuatu; 1.7%) included number of sets, and only 84 (all from French Polynesia; 0.1%) included operational-level data—only owing to the fact a single set was made within a specific grid in a particular month.

Only two CPCs, United States and Vanuatu, reported the number of vessels responsible for the catch and effort in individual records, in 37% and 100%, respectively, of the total number of records reported by each of these two CPCs.

None of the records specified the target species, and almost none contained fundamental operational data, including start or end time of set, mainline length, set duration, set direction, or hooks per basket (HPB). The sole exceptions were Japan, United States, and China, which provided HPB data for 41, 8 and 1 years, respectively.

5. ANALYSIS OF CATCH AND EFFORT DATA

5.1. Fishing effort

Longline fishing effort data are available in the IATTC database from 1954, when only Japan was fishing with longlines in the EPO, deploying an average of 28 million hooks per year. Japan was later joined by

Chinese Taipei (1964), Korea (1975), and Mexico (1980), and effort rapidly increased, to a peak of 277 million hooks in 1991, with Japan contributing 72% of the total effort (Figure 1). During the same period the average number of hooks per basket (HPB) in the Japanese fleet (presumed to be representative of the entire fleet) increased from 6 in 1975 to 11.6 in 1991. After 1991, effort rapidly declined, as vessels from Belize, China, the European Union (Spain), French Polynesia, United States and Vanuatu entered the fishery. Although Mexico withdrew from the fishery, some Mexican longline vessels continue to operate in the EPO, but target only sharks, and therefore are not currently required to report their activities to the IATTC. Interestingly, as effort declined, the average Japanese HPB increased sharply, to 15 HPB in 1995, and then continued to increase, to 16.7 in 2015 (Figure 1).

The trend of declining effort after 1991 ceased in 2001 with a dramatic increase in effort by Chinese Taipei and newly entered vessels from China, which peaked in 2003 at a total of 295 million hooks. A continued decline in effort by Japan, coupled with reduced effort by all CPCs other than Chinese Taipei, led to a precipitous decline to only 111 million hooks in 2008. Since 2008, effort has doubled, primarily due to an increase in effort by China, which accounted for 44% of the 223 million hooks deployed in 2015 (Figure 1).

5.1.1. Spatial distribution of effort

The spatial distribution of longline effort in the EPO has varied considerably during the history of the fishery (Figure 2). Originally only Japan fished with longlines, with the exception of nearshore areas in southern Peru and Chile. From 1967, the combined effort of Japan, Chinese Taipei and Korea expanded south of 30°S and east of 90°W into more coastal areas of Peru, Chile, Panama and Colombia. During the same period there was also an increase in effort in the area from 130 to 150°W between 25 and 35°N, which was primarily attributed to Japan and Korea expanding into the EPO from the Western Pacific. The two periods of 1987-1996 and 1997-2006 are similar in that predominant fishing grounds were south of the equator and the northwest portion of the Convention Area[4]. In the most recent period, 2006-2015, there has been a shift in effort to south of the equator.

5.1.2. Species distributions as determined from nominal catch data

An important component of ecological risk assessment is to understand the extent of the geographic overlap of a fishery with the distribution of each species impacted by that fishery. Figures 3-6 illustrate the distribution of catches for the most common species of tunas, billfishes, sharks, and large fishes caught in the longline fishery. Albacore, yellowfin, bigeye, and skipjack tunas were caught in nearly all 5°x5° grids across the EPO, as were swordfish and striped, blue, and black marlins. Indo-Pacific sailfish and shortbill spearfish were also caught across a wide spatial scale, but sailfish catches were more concentrated in the neritic region of Central America, while spearfish were caught offshore around 5°-20°S (Figure 4). Blue and mako sharks were both caught throughout most of the EPO, but particularly between the equator and 15°N and in the northwest of the Convention Area. Catches of silky, oceanic whitetip, and thresher sharks were more limited to equatorial latitudes, and particularly near the coasts for the latter two taxa (Figure 5). With respect to large fishes, almost all the catches of the six taxa examined were restricted to two regions west of 130°W: between 15° and 40°N, and between 10° and 25°S (Figure 6).

5.2. Species composition and catch trends

In total, 49 taxa were reported in the catch (retained or discarded) datasets submitted to the IATTC (Table 3). No records contained the capture, discard or live release of any taxa of seabird, sea turtle,

[4] In this document, as in other ecosystem work, a distinction is drawn between the IATTC Convention Area, with boundaries at 50°N/50°S, and the EPO, with no northern or southern limits.

or marine mammal.

The total number of taxa reported each year increased steadily from 10 (primarily target species) to 39 (Figure 7). This is primarily attributable to an increase in the number of taxa reported by the United States, although there was a slight increase in taxa reported by China and Korea after 2008. Some CPCs, such as Japan, which typically reports 10 or 11 species, apparently include data for commercially-important species only, while the European Union reported only catch of swordfish (Figure 7).

At the level of species, Figures 8-11 show the trends in nominal CPUE and total catch (retained catch and discards combined, in numbers) for the principal tuna and billfish species, and the six most important (in terms of number caught) species of sharks and large fishes. With regard to tunas, the nominal CPUE of bigeye and yellowfin declined in the early 2000s to levels similar to the 1960s, before the fishery was fully developed (Figure 5). In contrast, albacore CPUE and catch have steadily increased since around 2008. For billfishes, there have been dramatic declines in nominal CPUE and/or catch for striped, blue, and black marlins since the 1970s, and since 2000 for Indo-Pacific sailfish, while both have increased since 1994 for swordfish and shortbill spearfish (Figure 9). For sharks, nominal CPUE and catches of blue, mako, silky, oceanic whitetip, and thresher sharks have increased sharply since around 2008. Blue, mako, and thresher sharks have continued to maintain high CPUE and catch, whereas silky and oceanic whitetip sharks have experienced precipitous declines in recent years (Figure 10). The six large fish species represent epipelagic and mesopelagic assemblages, and have all showed a marked increase in nominal CPUE and catch since around 2005 (Figure 11).

Looking at the catch data more broadly, although the magnitude of the total catch has varied substantially over time, closely mirroring total effort (see Figure 1), the contribution of tunas has been consistent, and has generally exceeded 85% of the annual catches (Figure 12). However, since around 2008, this has declined to between 71 and 79%, while the contributions by billfishes (11% to 17%), sharks (2% to 7%), and large fishes (<1% to 3%) have all increased (Figure 12).

In terms of catch rates, there was a significant decline in the nominal CPUE of tuna species (combined) from around 47 fish per thousand hooks (FPTH) in the late 1950s to 13.8 FPTH in 1981; it then stabilized, and increased slightly to 18 FPTH in 1997, but declined again, to 12 FPTH by 2015 (Figure 13). The CPUE of swordfish increased nearly fourfold between 1995 and 2010, indicating an apparent change in targeting practices. This resulted in a concurrent increase of similar magnitude in the CPUE of bycatch species, particularly sharks, after 2003 (Figure 13).

The bycatch-to-target species ratio (B/T ratio)—based on numbers of fish—increased from 0.04 in 1997 to 0.16 in 2010 (Figure 14). However, in light of the increase in swordfish CPUE since 1995, examination of the ratio of bycatch-to-swordfish indicated a dramatic increase from 0.7 in 1995 to a peak of 2.4 in 2003, and has remained around 0.9 since 2006. The peak in B/T ratio closely mirrors a peak in the shark-to-swordfish ratio of 0.6 in 2009 (Figure 14).

6. DISCUSSION

The EPO large-scale tuna longline fishery represents an important component of the fishery for tunas and tuna-like species in the Pacific Ocean. Longlines are a passive gear, which means less control over interactions with non-target species, resulting in potentially greater ecological impacts than more selective or active gear types, such as purse seines. It is therefore important for researchers to have access to reliable and representative catch and effort data to undertake biological and ecological assessments that will contribute to ensuring the sustainability of impacted species and their supporting ecosystem.

This paper provided a general overview of the EPO longline data held by the IATTC, primarily as a precursor to undertaking an ecological risk assessment for the fishery to identify species that may be vulnerable of becoming unsustainable under current levels of fishing. In the process, we identified several shortcomings in the available data and the reporting process that hinder considerably the assessment of species caught in the longline fishery, and in particular, target species such as swordfish and bigeye and albacore tunas.

6.1. Spatial extent of the fishery for ecological risk assessment

The broad-scale analysis of the data on longline effort in the EPO illustrated that effort is highly dynamic in space and time, most likely owing to a number of factors, environmental (*e.g.* ocean current patterns), economic (*e.g.* value of catch, fuel costs), reporting, and political. Since 2007, the majority of longline effort has occurred south of the equator, and to a lesser degree in the northwest of the IATTC Convention Area. However, the significant spatial variability in effort over the preceding decades (Figure 2) suggests that effort distribution should be considered largely ergodic: that is, the distribution of effort has changed through time, but it cannot be presumed that current effort patterns will not change, or that historic patterns will not recur.

As such, it may be unwise to use the recent distribution of effort to define the spatial extent of the longline fishery for the purposes of ecological risk assessment, particularly for data-poor species. A precautionary approach would be to define the fishery as the maximum extent of historic fishing effort. This effectively means the fishery would extend to the boundaries of the IATTC Convention Area, since longline effort and, for several species, catch, was recorded in almost every 5°x5° grid over the fishery's history. This may positively bias the encounterability of the fishery by EPO bycatch species, and potentially identify a larger number of taxa that may be considered at risk of becoming unsustainable due to fishing. However, in accordance with Article IV of the Antigua Convention, such a precautionary approach must continue until more reliable fishery data—ideally operational-level data—are obtained.

6.2. Data reporting issues

The impetus for undertaking this data exploration was to determine the types and quality of bycatch data, particularly species composition of bycatch, in the IATTC database, and assess their suitability for inclusion in an ecological risk assessment. The reporting of bycatch by most CPCs has generally been poor, even for species of recent and serious conservation concern such as sharks. However, the diversity of finfish and shark bycatch reported by several CPCs improved from as early as 1990, and particularly since the early 2000s, coinciding with the adoption of the Antigua Convention in 2003 and the advent of regular seasonal closures of the purse-seine fishery and catch limits for the longline fishery. This suggests that CPCs are making a concerted effort to conform to IATTC mandates. However, both data reporting generally, and standardizing of reporting formats in particular, need further improvement, since the annual longline observer reports presented by CPCs at meetings of the SAC vary substantially in terms of the nature and quality of the data submitted. The most obvious example is the complete absence of any data on captures of, or interactions with, sea turtles, marine mammals or seabirds. However, several of these reports and various documents presented at IATTC meetings summarize detailed datasets on bycatch rates of these and other groups (*e.g*. Huang *et al.* 2008; Anderson 2009) that have contributed to the adoption of specific resolutions, such as C-07-03 and C-11-02 on mitigating the impact of tuna fishing on sea turtles and seabirds, respectively.

Furthermore, there are many instances where the diversity of bycatch species presented in the CPCs' reports to the SAC is significantly greater than in the datasets provided to the IATTC. For example, the European Union has reported catches of only one species (swordfish) since 1997 (Figure 7), yet its 2015 SAC report details the capture of at least 14 taxa (Table 5 in SAC-07 INF-A(a II)). Similarly, Japan has generally reported the catch of the ten or eleven most commonly caught taxa, whereas its 2015 SAC report details the capture of at least 23 taxa (Table 2 in SAC-07 INF A(f)). Clearly, therefore, not all the bycatch data specified in Resolution C-11-08 are being reported to the IATTC.

A major issue that emerged from the analysis of longline data was the taxonomic resolution of reported catches for some species groups, especially sharks and billfishes. For example, the generic taxonomic group "Elasmobranchii" constituted 26% of the total longline catch of sharks over the past five years. This is a particular concern given the vulnerability to overfishing of apex predators such as sharks and billfishes, which can also result in the disruption of ecosystem structure and function (Polovina *et al.* 2009; Ferretti *et al.* 2010). The lack of detailed species-specific catch data hinders the assessment of the status of potentially vulnerable species. Although there are some taxonomic difficulties in identifying some billfish and elasmobranch species (*e.g.* carcharhinids), particularly if they are dressed and/or frozen, the number of elasmobranch and billfish species caught by pelagic longlines is relatively low, and each specimen can typically be observed in a reasonably fresh state when brought aboard the vessel, when its prominent identifying features (*e.g.* fins, rostrum) are intact. Therefore, the quality of data reporting, to both the national programs and the IATTC, could be easily and cost-effectively improved—with the guidance of the IATTC staff—by enhancing the existing training of observers and fishers, through workshops and/or printed material to keep aboard vessels.

6.3. The need for operational-level data

It remains unclear whether the increase in the diversity and numbers in the bycatches of finfish and shark in the IATTC database over the past decade can be attributed to a true increase in abundance and/or landings of bycatch species, changes in gear configuration or targeting practices, increased level of reporting pursuant to recent resolutions, or a combination of the three. Unfortunately, the vast majority of records submitted to the IATTC do not contain the fundamental operational information required to disentangle such issues using standardized effort and abundance indices. An exception is Japan, which submitted hooks-per-basket (HPB) data for aggregated sets in monthly grid strata since 1975; also, the United States submitted HPB data for some sets during the 1991-2002 period. HPB can often be used as a proxy for maximum fishing depth, and therefore the likely target species and associated bycatch. For example, deep sets deploy a large number of HPB (typically 20-32) during daylight hours to primarily target bigeye tuna at depths of around 200–400 m (Bigelow *et al.* 2006), where these species are known to forage during the day in the EPO (Childers *et al.* 2011; Fuller *et al.* 2015). In contrast, shallow sets typically have far fewer HPB (2-6) and are deployed at night to target swordfish in the top ~100 m of the mixed layer, where swordfish are known to migrate diurnally to forage (Abascal *et al.* 2010; Sepulveda *et al.* 2010). Shallow sets typically have a higher diversity of bycatch, since the epipelagic species (*e.g.* wahoo, dorado, marlin) that continuously occupy the mixed layer (Sepulveda *et al.* 2011; Merten *et al.* 2014) are joined at night by vertically migrating mesopelagic species (*e.g.* opah, escolar, pomfret) that are distributed below the thermocline during the day (Kerstetter *et al.* 2008; Gray 2016).

After analyzing the available data, it appeared *prima facie* that, paradoxically, the increase in HPB—and thus presumed hook depth—since around 1995 coincided strongly with not only an increase in the CPUE of swordfish, but also an increase in the diversity and CPUE of epipelagic and mesopelagic bycatch species of finfish and sharks, at a bycatch-to-swordfish ratio of about 2:1. This suggests a substantial change in operational practices in the fishery towards shallow sets at night, possibly to target swordfish. If this is true, it has important implications not only for the development of standardized effort indices for target species, but also for ecological risk assessment, since shallow sets with a larger number of HPB significantly increase the potential for interactions with a larger number of bycatch species that would generally be avoided in deep daytime sets, in particular sharks, marlins, and sea turtles (Gilman *et al.* 2006). However, this hypothesis cannot be confirmed without operational-level data.

A similar, and roughly concurrent, shift in gear configuration was identified in the Indian Ocean longline fishery by Bach and Fonteneau (2005). They observed an abrupt increase in HPB, from 9-14 in 1992 to 20 from 1993 onwards, that coincided with a decline in CPUE of bigeye and an increase in CPUE of yellowfin, and suggested that shallow sets were being made with an increased number of HPB to target yellowfin in the mixed layer in response to market conditions. Such results led Bach *et al.* (2006) to argue that, with the widespread use of modern monofilament lines, HPB can no longer be used as a reliable proxy for maximum fishing depth or for CPUE standardization in the absence of other important operational data.

More importantly, the highly-aggregated data and lack of set-by-set operational information in the longline dataset hinders the ability of researchers to standardize CPUE, and thus to calculate reliable indices of abundance for both target species and important bycatch species such as silky and oceanic whitetip sharks, which have experienced declines in CPUE in recent years in both the purse-seine (Aires-da-Silva *et al.* 2014) and longline fisheries (Figure 10). This may be especially important in the EPO because of the great difficulty of standardizing purse-seine CPUE for tunas resulting from the differences among the three modes of fishing—on dolphins, unassociated tunas, and floating objects. Although per-set HPB data would be valuable for improving CPUE estimates, Bach *et al.* (2006) conclude that, in order to reliably describe the dynamics and effectiveness of the gear, observers and vessel logbooks should record, at a minimum, the time and position of the start and end of each set, total length of the mainline, total number of baskets, length of branchlines and floatlines, and the distance between floats.

6.4. Representativeness of data submissions to the IATTC

A final major issue identified in the EPO longline data held by the IATTC is the representativeness of the data submitted, which appears to vary significantly among and within CPCs. Specifically, the metadata descriptions submitted with the datasets are generally insufficient for the purposes of estimating total catch and/or effort. For example, the datasets from several CPCs comprise data from both logbooks and scientific observers, but the two sources cannot usually be identified. Furthermore, it is often unknown whether the data represent a sample of sets by the fleet, or expanded estimated totals. Even where data are identified as a sample of sets, catches cannot be expanded to total fleet effort, because the number of vessels by area-month stratum is typically not provided, and the total fleet size cannot be determined from the IATTC LSTLFV List.

7. RECOMMENDATIONS

The purpose of this report is to provide a general overview of the EPO large-scale tuna longline fishery and the types and quality of data held by the IATTC, primarily relating to bycatch, that can be used to develop an ecological risk assessment for the fishery. However, the analysis of the metadata and catch and effort data highlighted several issues relating to the variable quality and formats of the data supplied by CPCs to the IATTC that currently hinder the use of these data in tactical research undertaken to provide sound management advice to the Commission. The following recommendations are intended to address these issues, while also complying with the relevant provisions of the Antigua Convention and the various resolutions adopted by the Commission.

7.1. Operational data

It is highly recommended that CPCs collect and submit to the IATTC set-by-set operational-level data (*i.e.* "Level 1" data detailed in Resolution C-03-05) that will allow for the standardization of effort and abundance indices for target and non-target species. This includes information on gear configuration mandated under Resolution C-03-05. Specifically, the data fields recommended for inclusion in data reports include:

a. Principal target species;

b. Position of the start and end of each set;

c. Time at the start and end of each set;

d. Length of the mainline, floatlines and branchlines;
e. Duration of basket setting;
f. Line shooter speed;
g. Number of floats deployed;
h. Hooks per basket/float;
i. Vessel speed during setting;
j. Number of hooks deployed;
k. Bait type used.

If aggregated data are submitted, at the level of 1°x1° or 5°x5° by month, inclusion of the following data fields is recommended:

l. Total number of vessels contributing to the effort in each grid-month stratum;
m. Total number of sets made in each grid-month stratum;
n. Total number of hooks deployed.

7.2. Documentation of species interactions

The accurate documentation of the longline catch to the lowest possible taxonomic resolution is critical not only for single-species assessments, but also for monitoring the ecological sustainability of the supporting ecosystem through multispecies models or ecological risk assessment. It is recommended that CPCs, with the guidance of the IATTC staff: (i) enhance training of observers and fishers in species identification; (ii) require recording of all taxa caught in each set, whether as target or bycatch, in numbers and/or weights and as retained or discarded; and (iii) require that, whenever possible, all catches be recorded to the level of species.

Specifically, for seabirds, sea turtles, and marine mammals, the requirement to record all interactions, as specified in Resolutions C-11-02 and C-11-08, should be followed, and the data recorded should be reported to the IATTC in the relevant operational data.

Table 4 lists FAO and IATTC codes used to describe taxonomic groups rather than individual species. The use of these codes should be avoided whenever possible.

7.3. Length-frequency data

It is highly recommended that CPCs collect and submit to the IATTC "Level 1" length-frequency data (as per Resolution C-03-05) for all species, whether retained of discarded. Specifically, this should include the following:

a. **Position** at start and/or end of the set,
b. **Species** identified to the lowest possible taxonomic resolution (avoiding codes in Table 4),
c. **Length of individual animals**, using the most appropriate standard of measure for the relevant group:
    i. Finfish and sharks: fork length (FL), or total length (TL) for species with suitable body morphologies (*e.g.* Trichuridae);
    ii. Billfish: post-orbital fork length (EFL);
    iii. Rays: disk width (DW).

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TABLE 1. Number and characteristics of large-scale tuna longline fishing vessels over 24 m LOA included in the IATTC LSTLFV List.

TABLA 1. Número y características de los buques palangreros atuneros a gran escala de más de 24 m de eslora total incluidos en la lista de LSTLFV de la CIAT.

CPC	Number of vessels	Length (m)		Capacity (m^3)		Capacity (t)	
		Range	Mean	Range	Mean	Range	Mean
	Número de buques	Eslora (m)		Capacidad (m^3)		Capacidad (t)	
		Rango	Promedio	Rango	Promedio	Rango	Promedio
China	373	29.1-57.3	42.7	196-802	429.7	5-720	217.9
Japan-Japón	235	30.2-61.5	47.9	34-872	477.2	-	-
Korea-Corea	191	32.6-51.2	48.4	263-850	539.1	196-350	297.5
Chinese Taipei-Taipei Chino	153	25.1-63.2	43.8	62-3548	497.3	24-677	448.3
EU (Spain)-UE (España)	127	24.5-55.0	33.0	99-627	357.1	14-442	179.5
Panama-Panamá	65	24.0-91.5	29.5	79-446	203.7	40-360	206.8
Vanuatu	49	25.2-59.2	47.9	102-883	514.4	266-505	404.8
United States-Estados Unidos	38	24.1-29.9	25.7	18-4790	344.6	9-124	43.4
Ecuador	15	24.4-56.5	47.2	66-1003	485.1	186-242	214.0
Mexico-México	15	24.0-46.8	31.4	90-152	121.8	10-320	102.8
France-Francia	14	24.8-33.3	25.4	-	-	-	-
Costa Rica	12	24.0-30.0	25.1	78-78	78.0	72-72	72.0
EU (Portugal)-UE (Portugal)	10	28.6-50.8	39.8	351-546	448.5	180-180	180.0
Belize-Belice	4	26.5-27.6	27.0	30-75	50.8	30-75	41.3
Kiribati	3	49.2-49.2	49.2	487-493	491.0	-	-
Nicaragua	1	24.0	24.0	-	-	-	-
Peru-Perú	1	52.4	52.4	-	495.0	-	292.0

TABLE 2. Years of data for large-scale tuna longline fishing vessels over 24 m LOA reported by CPCs.
TABLA 2. Años de datos de buques palangreros atuneros a gran escala de más de 24 m de eslora total reportados por CPC.

CPC	**Years**	
	Range	**Number**
	Años	
	Rango	**Número**
Japan-Japón	1954–2015	62
Chinese Taipei-Taipei Chino	1964–2015	52
Korea-Corea	1975–2015	41
United States-Estados Unidos	1991–2015	25
French Polynesia-Polinesia Francesa	1992–2015	24
EU (Spain)-UE (España)	1997–2015	19
China	2001–2015	15
Mexico-México	1980–1989	10
Vanuatu	2007–2015	9
Belize-Belice	2009–2015	7

TABLE 3. Retained and discarded catches, in numbers, of taxa caught in the large-scale tuna longline fishery in the eastern Pacific Ocean, 2007-2015.

TABLA 3. Capturas retenidas y descartadas, en número, de taxones capturados en la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental, y 2007-2015.

Code	Scientific name	Common name	Retained	Discarded	Total	% of total (numbers)
Código	**Nombre científico**	**Nombre común**	**Retenido**	**Descartado**	**Total**	**% del total (números)**
		Tunas-Atunes				
SKJ	*Katsuwonus pelamis*	Skipjack tuna Atún barrilete	132,844	163	133,007	0.58
ALB	*Thunnus alalunga*	Albacore tuna Atún albacora	9,718,759	1,015	9,719,774	42.68
TUN	Thunnini	Undifferentiated tunas Atunes no diferenciados	23,883	14	23,897	0.10
BET	*Thunnus obesus*	Bigeye tuna Atún patudo	5,564,329	3,726	5,568,055	24.45
YFT	*Thunnus albacares*	Yellowfin tuna Atún aleta amarilla	1,713,935	78	1,714,013	7.53
SBF	*Thunnus maccoyii*	Southern bluefin tuna Atún aleta azul del sur	4	0	4	>0.001
PBF	*Thunnus orientalis*	Pacific bluefin tuna Atún aleta azul del Pacífico	75	0	75	>0.001
		Billfishes-Peces picudos				
BLM	*Istiompax indica*	Black marlin Marlín negro	28,978	0	28,978	0.13
BIL	*Istiophoridae, Xiphiidae*	Undifferentiated billfishes Peces picudos no diferenciados	5,775	9	5,784	0.03
SFA	*Istiophorus platypterus*	Indo-Pacific sailfish Pez vela del Indopacífico	5,427	13	5,440	0.02
MLS	*Kajikia audax*	Striped marlin Marlín rayado	219,095	153	219,248	0.96
BUM	*Makaira nigricans*	Blue marlin Marlín azul	281,529	75	281,604	1.24
SSP	*Tetrapturus angustirostris*	Shortbill spearfish Marlín trompa corta	230,160	231	230,391	1.01
SWO	*Xiphias gladius*	Swordfish Pez espada	2,535,228	3,770	2,538,998	11.15
		Elasmobranchs-Elasmobranquios				
THR	*Alopias* spp.	Thresher sharks Tiburones zorro	19,048	2,019	21,067	0.09
BTH	*Alopias superciliosus*	Bigeye thresher shark Tiburón zorro ojón	310	3,710	4,020	0.02
RSK	Carcharhinidae spp.	Requiem sharks Cazones, tintoreras, picudos	997	0	997	>0.001
FAL	*Carcharhinus falciformis*	Silky shark Tiburón sedoso	368,536	1,582	370,118	1.63
CCL	*Carcharhinus limbatus*	Blacktip shark Tiburón punta negra	4,016	0	4,016	0.02
OCS	*Carcharhinus longimanus*	Oceanic whitetip shark Tiburón oceánico punta blanca	9,642	2,293	11,935	0.05
SKX	Elasmobranchii	Sharks, rays, skates Tiburones, rayas	226,343	347	226,690	1.00
SMA	*Isurus oxyrinchus*	Shortfin mako shark Tiburón marrajo dientuso	53,437	0	53,437	0.23
LMA	*Isurus paucus*	Longfin mako shark Tiburón marrajo carite	0	1,819	1,819	0.01

Code	Scientific name	Common name	Retained	Discarded	Total	% of total (numbers)
Código	**Nombre científico**	**Nombre común**	**Retenido**	**Descartado**	**Total**	**% del total (números)**
MAK	*Isurus* spp.	Mako sharks Tiburones marrajos	5,216	6,112	11,328	0.05
POR	*Lamna nasus*	Porbeagle Marrajo sardinero	481	0	481	>0.001
BSH	*Prionace glauca*	Blue shark Tiburón azul	278,131	62,824	340,955	1.50
PLS	*Pteroplatytrygon violacea*	Pelagic stingray Raya-látigo violeta	30	38	68	>0.001
SPL	*Sphyrna lewini*	Scalloped hammerhead shark Cornuda común	0	186	186	>0.001
SPN	*Sphyrna* spp.	Hammerhead sharks Tiburones martillo/Cornudas	4,024	5	4,029	0.02
DGS	*Squalus acanthias*	Piked dogfish Mielga	235	0	235	>0.001
		Large fishes-Peces grandes				
WAH	*Acanthocybium solandri*	Wahoo Peto	79,903	37	79,940	0.35
ALX	*Alepisaurus ferox*	Long snouted lancetfish Lanzón picudo	599	1,706	2,305	0.01
BRZ	Bramidae spp.	Pomfrets Japutas	94,985	677	95,662	0.42
DOL	*Coryphaena hippurus*	Common dolphinfish Dorado	168,831	2,688	171,519	0.75
DOX	Coryphaenidae spp.	Dorados Dorados	51,211	0	51,211	0.22
RRU	*Elagatis bipinnulata*	Rainbow runner Salmón	0	3	3	>0.001
GEP	Gempylidae spp.	Snake mackerels, escolars Sierras, escolares	37,284	2,078	39,362	0.17
GES	*Gempylus serpens*	Snake mackerel Escolar de canal	400	531	931	>0.001
LAG	*Lampris guttatus*	Opah Opa	45,978	559	46,537	0.20
LAP	*Lampris* spp.	Moonfish & opah	48,501	353	48,854	0.21
LEC	*Lepidocybium flavobrunneum*	Escolar Escolar negro	23,865	0	23,865	0.10
MOP	*Mola* spp.	Sunfish	20	31	51	>0.001
THA	*Opisthonema oglinum*	Atlantic thread herring Machuelo hebra atlántico	0	0	0	>0.001
PEL	Osteichthyes	Pelagic fishes Peces pelágicos	693,639	26	693,665	3.05
BUR	*Pomadasys jubelini*	Sompat grunt Ronco sompat	0	0	0	>0.001
OIL	*Ruvettus pretiosus*	Oilfish Escolar clavo	0	0	0	>0.001
SAU	*Scomberesox saurus*	Atlantic saury Paparda del Atlántico	0	0	0	>0.001
GBA	*Sphyraena* spp.	Barracudas Barracudas	4	0	4	>0.001
SPR	*Sprattus sprattus*	European sprat Espadín	0	0	0	>0.001

TABLE 4. FAO and IATTC codes that should be avoided when recording catches.
TABLA 4. Códigos de FAO y la CIAT que no se deben usar al registrar capturas.

Group/species Grupo/especie	FAO FAO	Definition Definición	Species included Especies incluidas
Tunas Atunes	TUN	Unspecified tunas, mixed tunas, Thunnini Atunes no especificados, atunes mixtos, Thunnini	All tunas Todos atunes
Billfishes Peces picudos	BIL	Unidentified Istiophorids Istioféridos no identificados	Marlins, sailfish, swordfish Marlines, pez vela, pez espada
Elasmobranchs- Elasmobranquios			
Sharks Tiburones	SKX, SKH	Unidentified sharks Tiburones no identificados	All sharks Todos tiburones
Carcharhinid sharks Tiburones carcarínidos	CWZ	Unspecified carcharhinid sharks Tiburones carcarínidos no especificados	
Thresher sharks Tiburones zorro	THR	Unspecified alopiid sharks Tiburones Alopidae no especificados	*Alopias vulpinus*, *A. superciliosus*, *A. pelagicus*.
Hammerhead sharks Tiburones martillo/Cornudas	SPN		All *Sphyrna* species Todas especies de *Sphyrna*
Mako sharks Tiburones marrajo	MAK	Combines the two species of *Isurus* sharks Combina las dos especies de tiburones *Isurus*	*Isurus oxyrinchus*, *I. paucus*
Rays mantarrayas	MNT, SRX, STT, RMV,	Unidentified mobulid and dasyatid rays Rayas Mobulidae y Dasyatidae no identificadas	
Other fishes-Otros peces			
Large fishes Peces grandes	MZZ	Unidentified or aggregated teleosts	
Pomfrets Japutas	BRZ	Unspecified pomfrets Japutas no especificadas	All species of Bramidae Todas especies de Bramidae
Opah	LAP	Unspecified opahs Opas no especificadas	*Lampris guttatus*, *L. immaculatus*

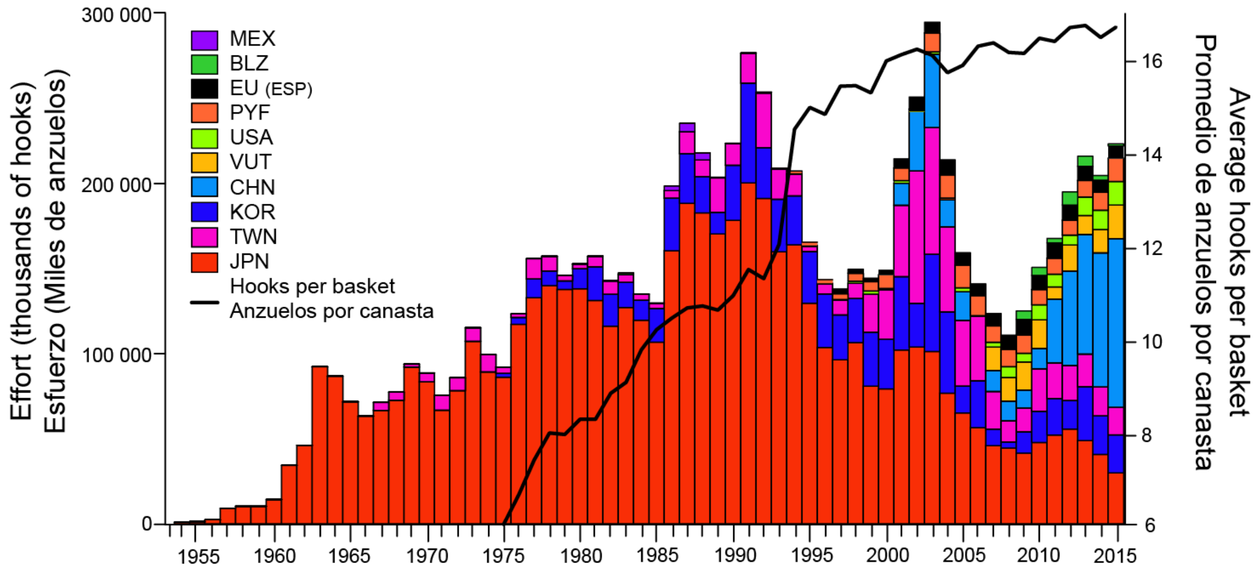

FIGURE 1. Annual fishing effort, in thousands of hooks, in the large-scale tuna longline fishery, by CPC (left y-axis), and annual average number of hooks per basket for the Japanese longline fleet (right y-axis), in the eastern Pacific Ocean, 1953-2015.

FIGURA 1. Esfuerzo de pesca anual, en miles de anzuelos, en la pesquería atunera palangrera a gran escala, por CPC (eje Y izquierdo), y número promedio de anzuelos por canasta para la flota palangrera japonesa (eje Y derecho) en el Océano Pacífico oriental, 1953-2015.

FIGURE 2. Distribution of total effort, in number of hooks by 5°x5° grid, by the large-scale tuna longline fishery in the eastern Pacific Ocean, 1954-2015, divided into time blocks of 13 years (a), 10 years (b-e), and the most recent nine-year period (f).

FIGURA 2. Distribución del esfuerzo total, en número de anzuelos por cuadrángulo de 5°x5°, de la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental, 1954-2015, dividido en bloques de tiempo de 13 años (a), 10 años (b-e), y el periodo de nueve años más reciente (f).

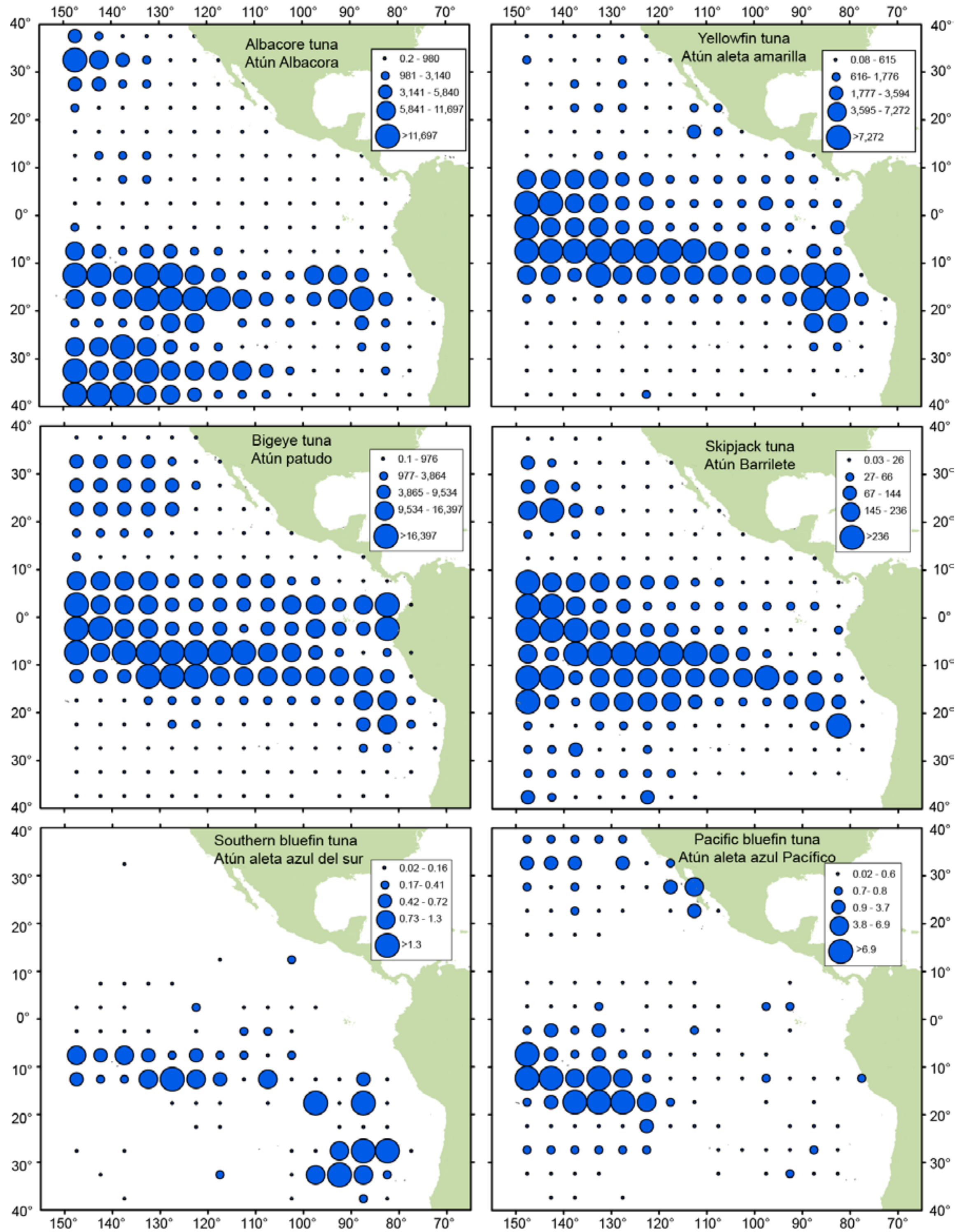

FIGURE 3. Nominal total catches (retained + discards), in numbers, of six species of tunas caught by the large-scale tuna longline fishery in the eastern Pacific Ocean, by 5° x 5° grid, 1954-2015.

FIGURA 3. Capturas nominales totales (retenida + descartes), en número, de seis especies de atunes capturados por la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental, por cuadrángulo de 5°x5°, 1954-2015.

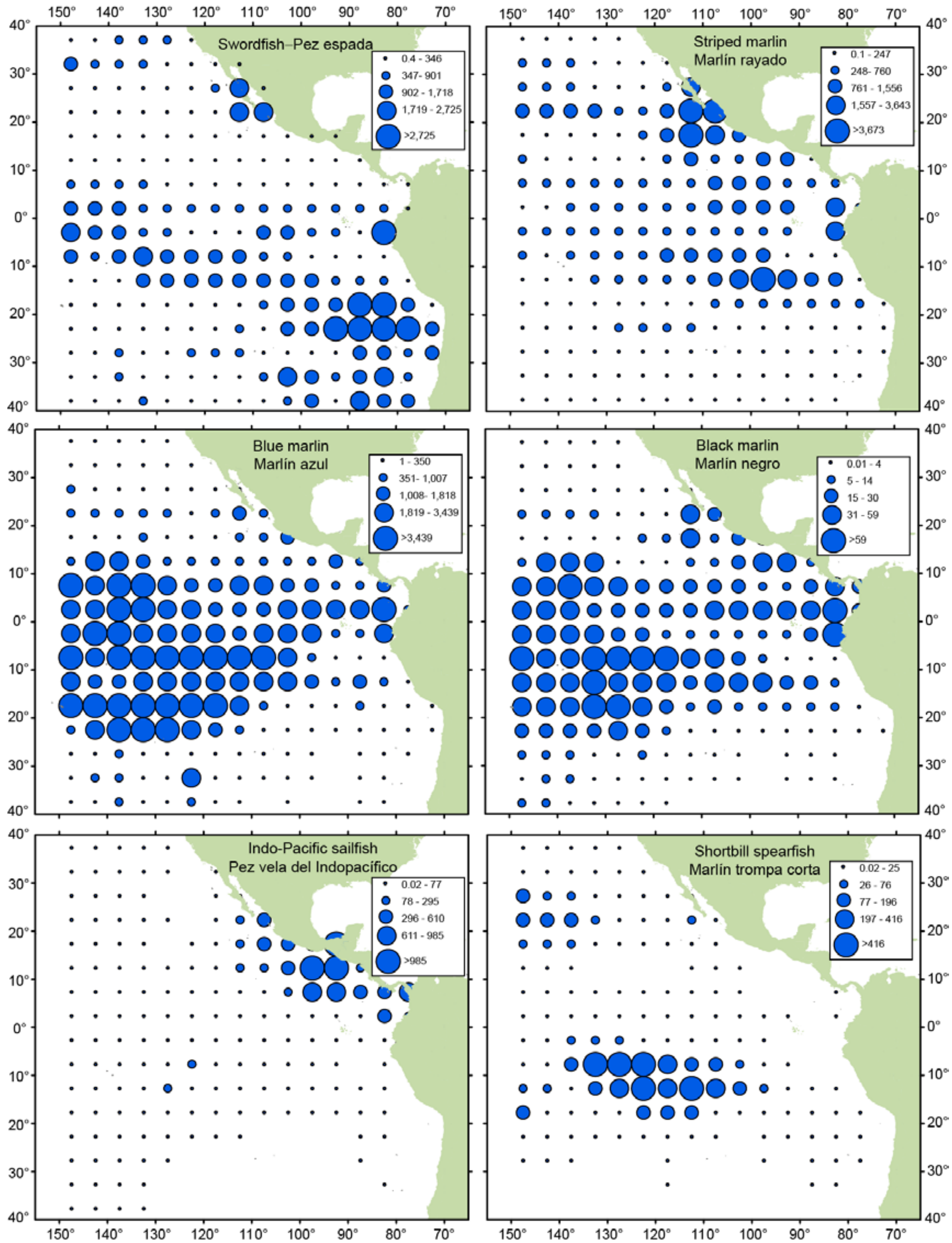

FIGURE 4. Nominal total catches (retained + discards), in numbers, of six species of billfishes caught by the large-scale tuna longline fishery in the eastern Pacific Ocean, by 5° x 5° grid, 1954-2015.

FIGURA 4. Capturas nominales totales (retenida + descartes), en número, de seis especies de peces picudos capturados por la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental, por cuadrángulo de 5°x5°, 1954-2015.

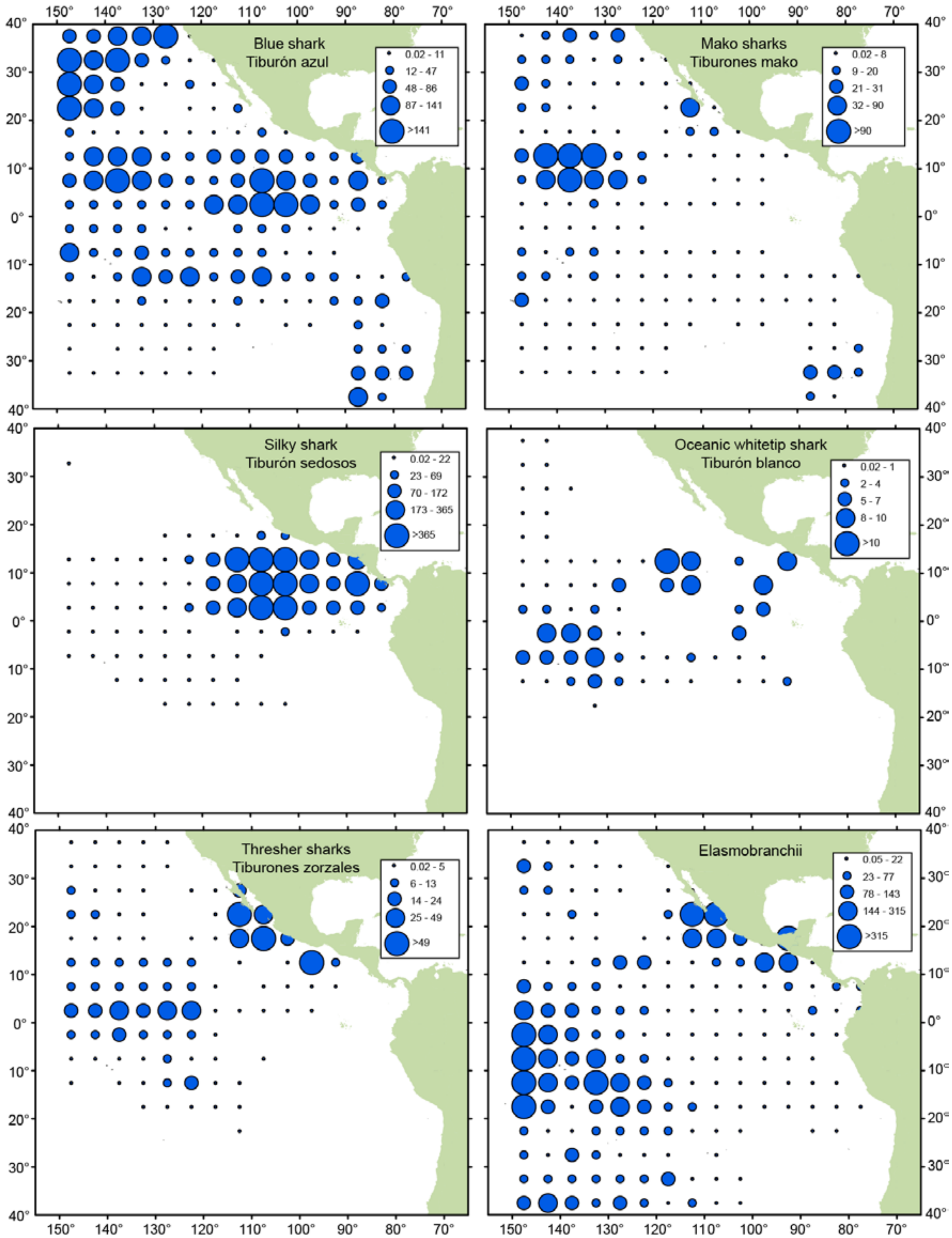

FIGURE 5. Nominal total catches (retained + discards), in numbers, of six taxa of sharks caught by the large-scale tuna longline fishery in the eastern Pacific Ocean, by 5° x 5° grid, 1954-2015.

FIGURA 5. Capturas nominales totales (retenida + descartes), en número, de seis taxones de tiburones capturados por la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental, por cuadrángulo de 5°x5°, 1954-2015.

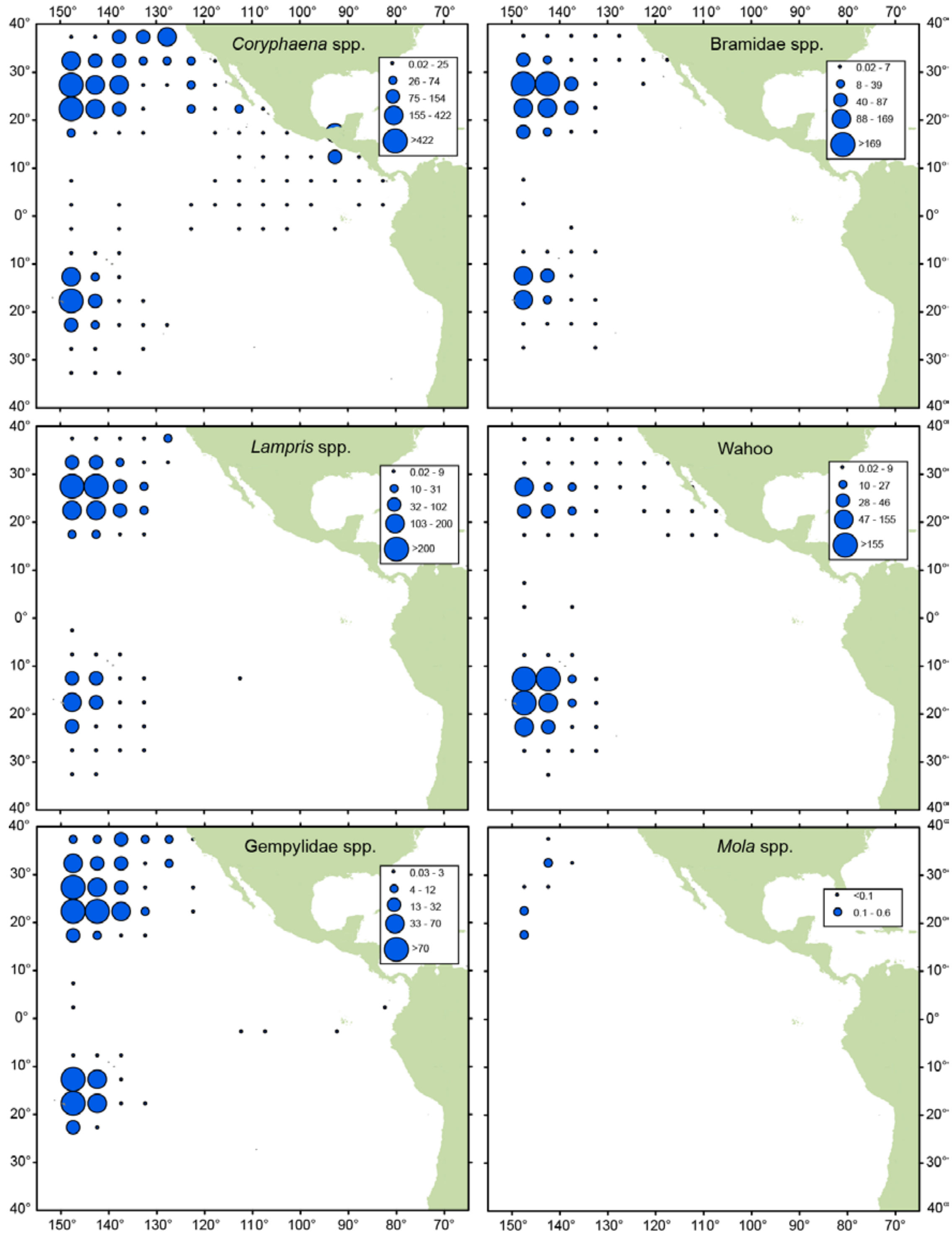

FIGURE 6. Nominal total catches (retained + discards), in numbers, of six taxa of large fish caught by the large-scale tuna longline fishery in the eastern Pacific Ocean, by 5° x 5° grid, 1954-2015.

FIGURA 6. Capturas nominales totales (retenida + descartes), en número, de seis taxones de peces grandes capturados por la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental, por cuadrángulo de 5°x5°, 1954-2015.

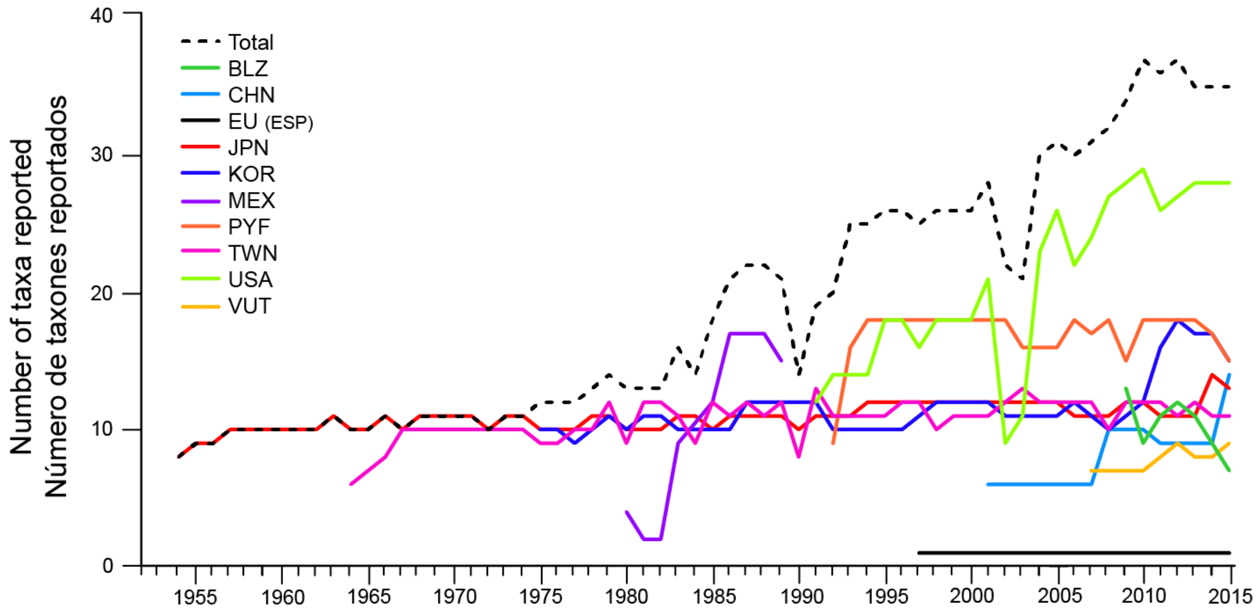

FIGURE 7. Annual number of taxa reported for the large-scale tuna longline fishery in the Eastern Pacific Ocean, by CPC, 1954-2015.
FIGURA 7. Número anual de taxones reportados para la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental, por CPC, 1954-2015.

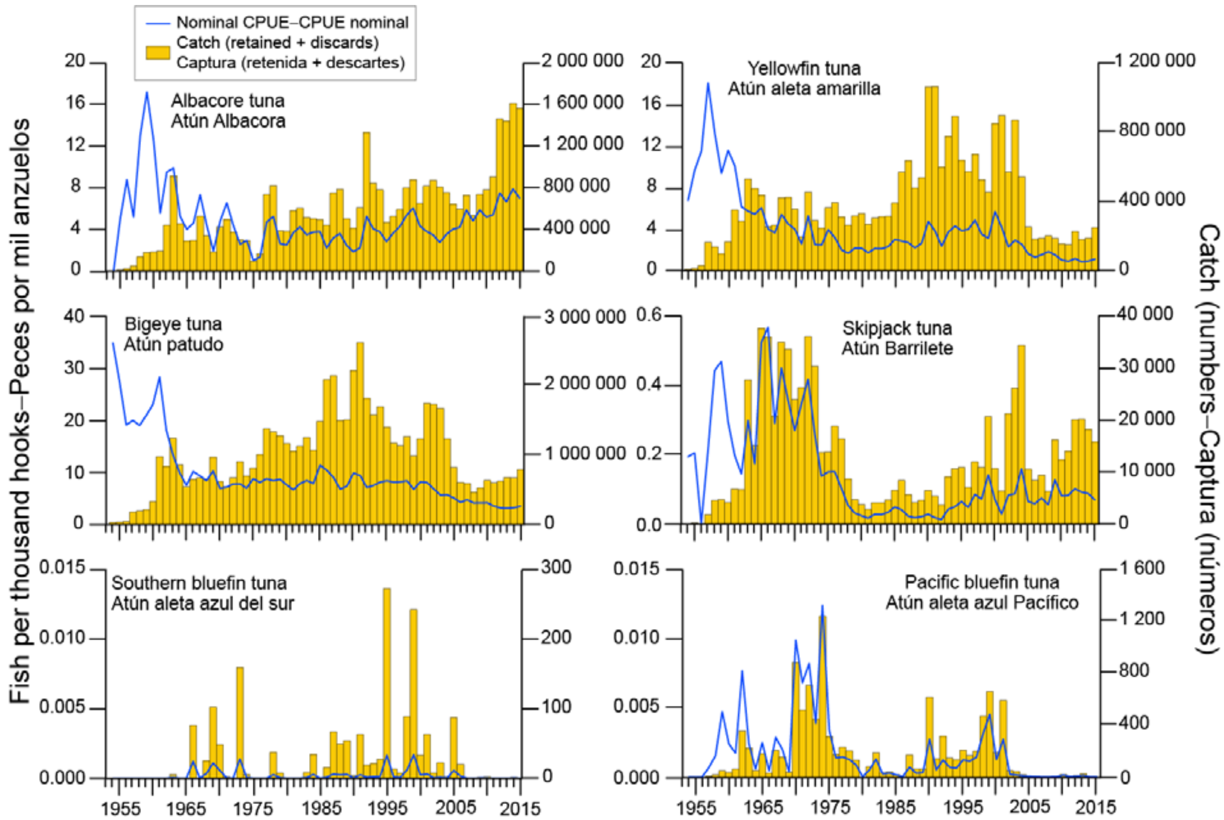

FIGURE 8. Nominal catch-per-unit-effort, in fish per 1000 hooks, and total catch (retained + discards), in numbers,) of six principal tuna species caught in the large-scale tuna longline fishery in the eastern Pacific Ocean.

FIGURA 8. Captura por unidad de esfuerzo nominal, en peces por 1000 anzuelos, y captura total (retenida + descartes), en números, de seis especies principales de atunes capturadas en la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental.

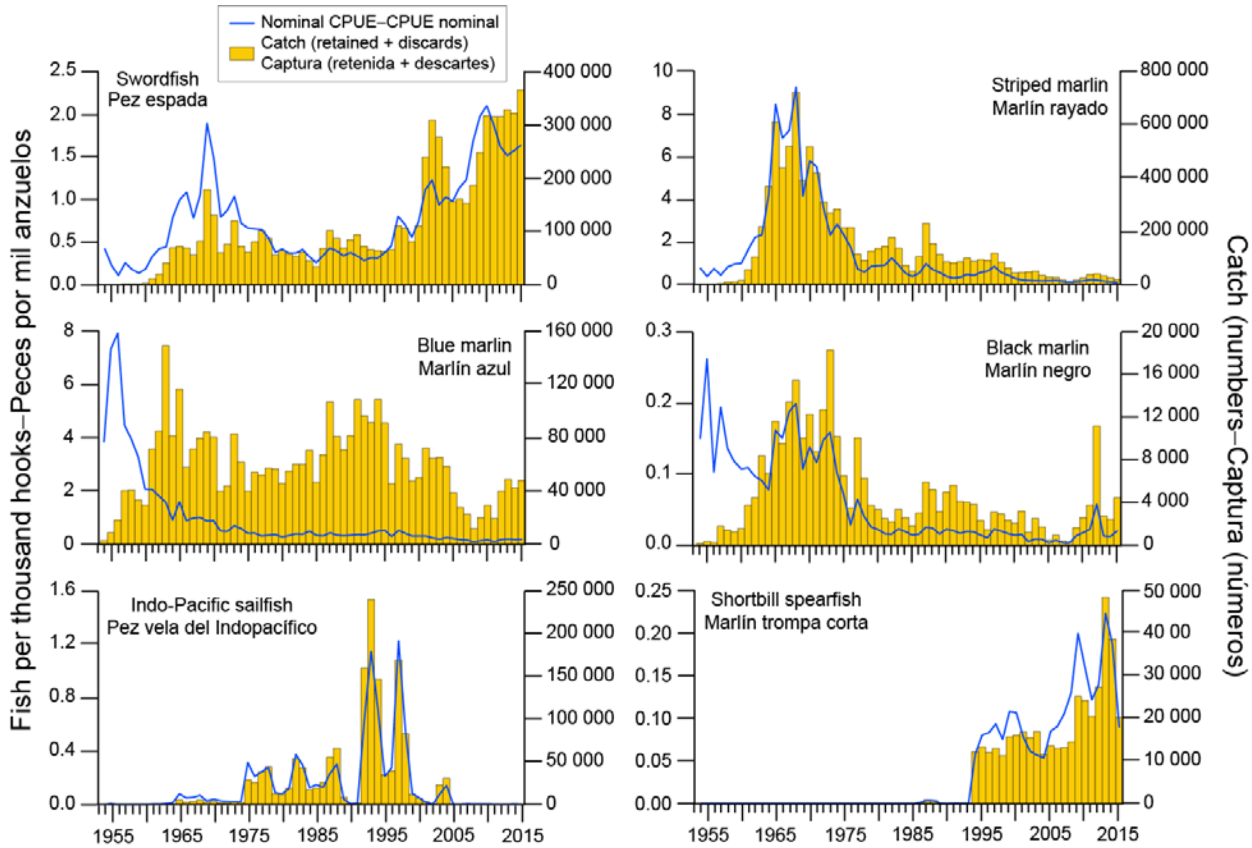

FIGURE 9. Nominal catch-per-unit-effort, in fish per 1000 hooks, and total catch (retained + discards), in numbers,) of six principal species of billfishes caught in the large-scale tuna longline fishery in the eastern Pacific Ocean.

FIGURA 9. Captura por unidad de esfuerzo nominal, en peces por 1000 anzuelos, y captura total (retenida + descartes), en números, de seis especies principales de peces picudos capturadas en la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental.

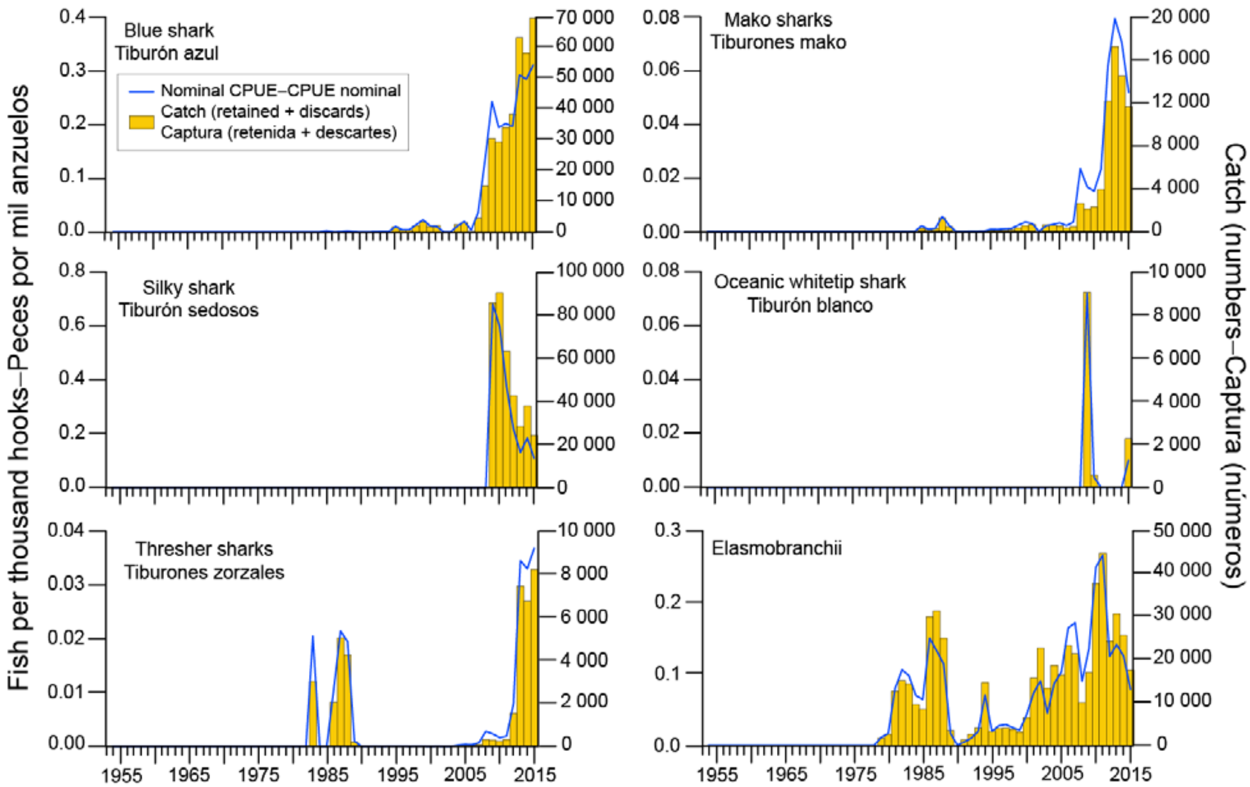

FIGURE 10. Nominal catch-per-unit-effort, in fish per 1 000 hooks, and total catch (retained + discards), in numbers,) of the six shark taxa most commonly caught in the large-scale tuna longline fishery in the eastern Pacific Ocean.

FIGURA 10. Captura por unidad de esfuerzo nominal, en peces por 1 000 anzuelos, y captura total (retenida + descartes), en números, de los seis taxones de tiburones capturados más comúnmente en la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental.

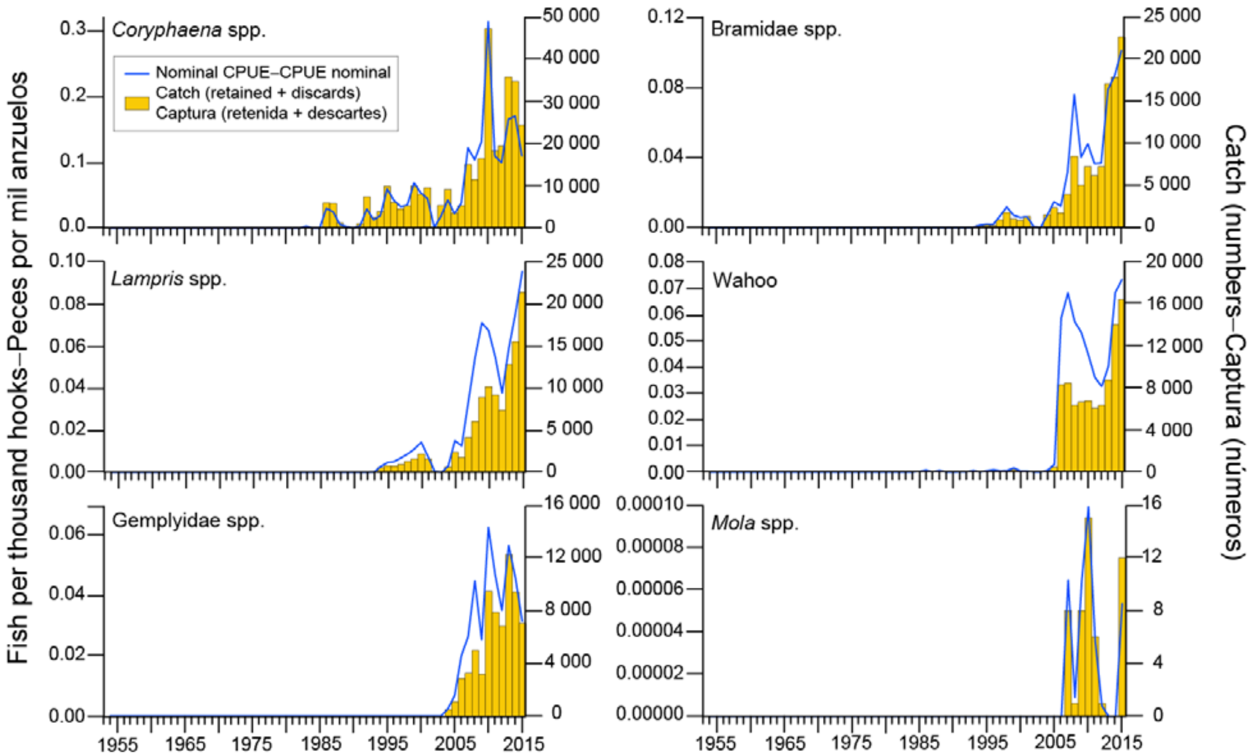

FIGURE 11. Nominal catch-per-unit-effort, in fish per 1 000 hooks, and total catch (retained + discards), in numbers,) of the six taxa of large fish most commonly reported as bycatch in the large-scale tuna longline fishery in the eastern Pacific Ocean.

FIGURA 11. Captura por unidad de esfuerzo nominal, en peces por 1 000 anzuelos, y captura total (retenida + descartes), en números, de los seis taxones de peces grandes reportados más comúnmente como captura incidental en la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental.

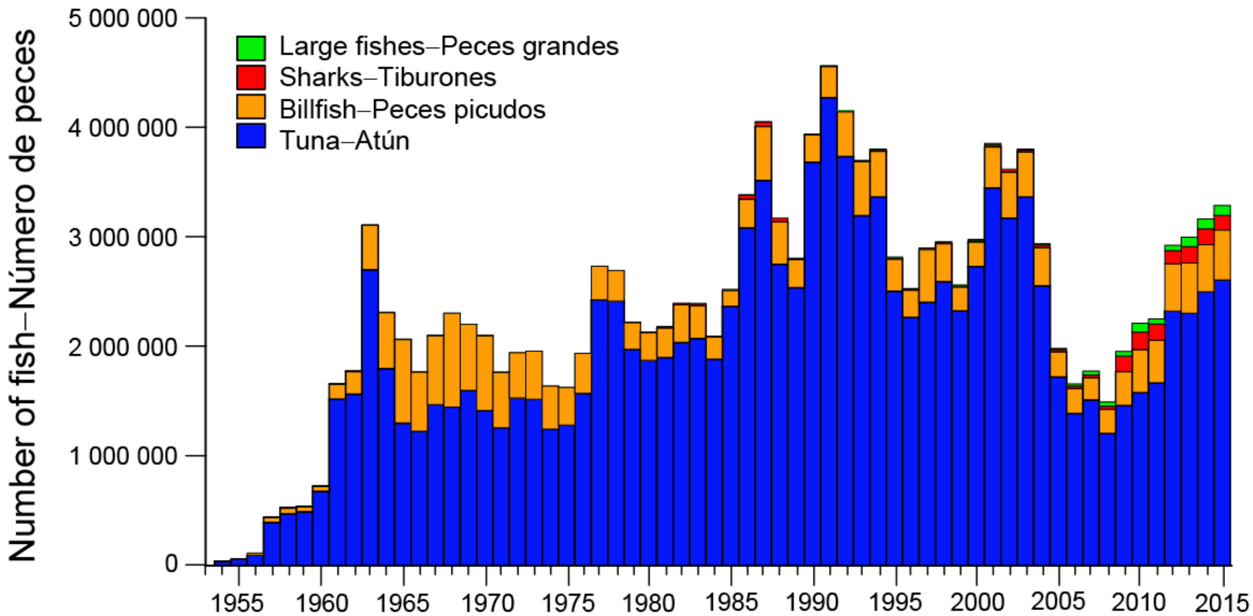

FIGURE 12. Annual reported catch (retained + discards), in numbers, of aggregated taxonomic groups of tunas, billfishes, sharks, and other large fishes by the large-scale tuna longline fishery in the eastern Pacific Ocean, 1954-2015.

FIGURA 12. Captura anual reportada (retenida + descartes), en números, de grupos taxonómicos conglomerados de atunes, peces picudos, tiburones, y otros peces grandes por la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental, 1954-2015.

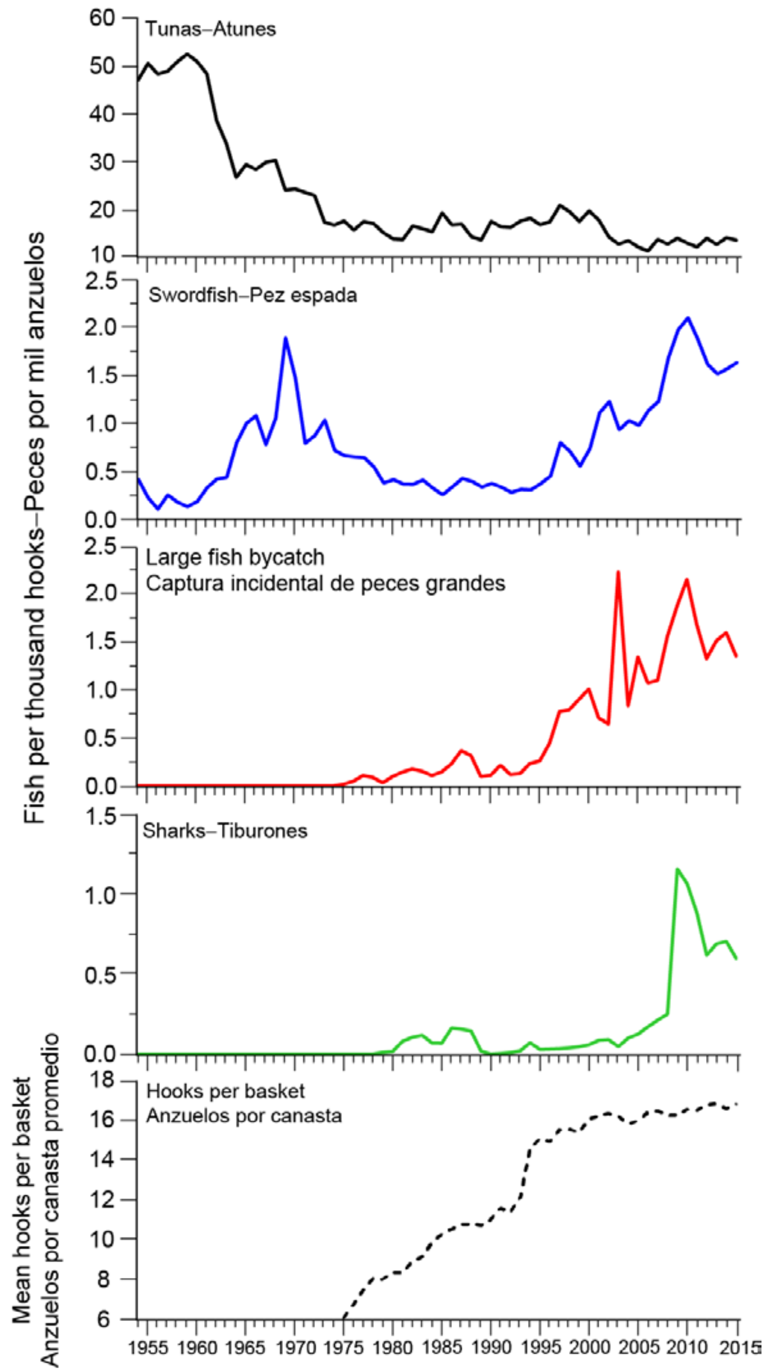

FIGURE 13. Annual nominal catch-per-unit-effort, in fish per 1 000 hooks, of: i) tuna species combined, ii) swordfish, iii) large fish bycatch species, and iv) sharks, reported in the catch (retained + discarded) data for the large-scale tuna longline fishery in the eastern Pacific Ocean, and the average number of hooks per basket reported for the Japanese longline fishery.

FIGURA 13. Captura por unidad de esfuerzo nominal anual, en peces por 1 000 anzuelos, de: i) especies de atunes combinadas, ii) pez espada, iii) especies de peces grandes de captura incidental, y iv) tiburones, reportada en los datos de captura (retenida + descartes) de la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental, y el número promedio de anzuelos por canasta reportado para la pesquería palangrera japonesa.

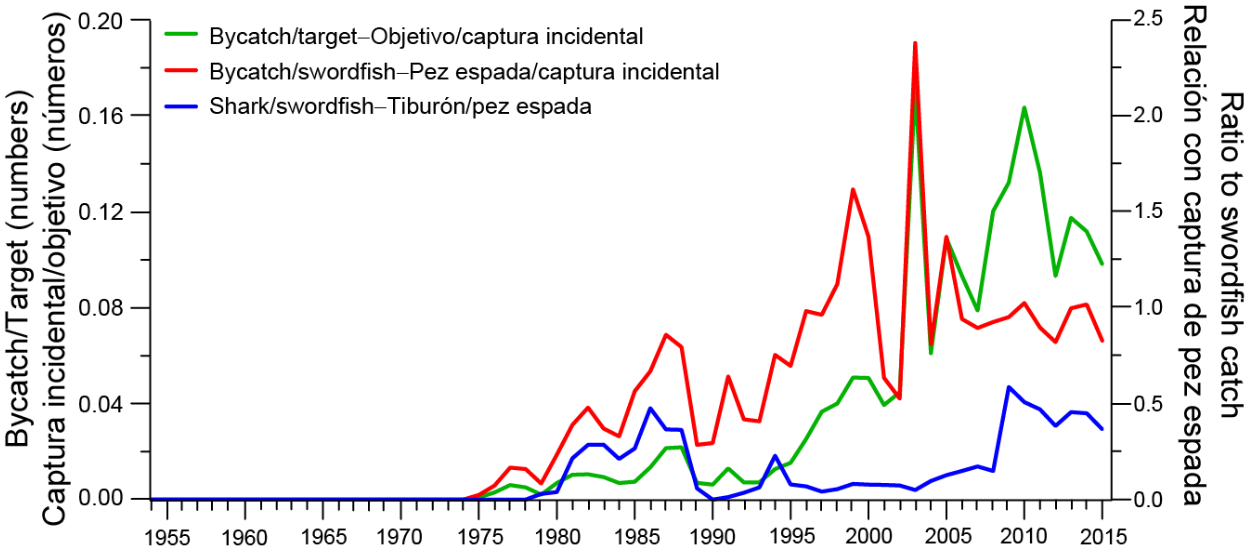

FIGURE 14. Annual ratios, based on numbers, of i) bycatch-to-target species catch, ii) bycatch-to-swordfish catch, and iii) shark-to-swordfish catch in the large-scale tuna longline fishery in the Eastern Pacific Ocean.
FIGURA 14. Razones anuales, basadas en números, de i) captura incidental a captura de especie objetivo, ii) captura incidental a captura de pez espada, y iii) tiburón a captura de pez espada en la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental.

APPENDICES

Appendix 1. Data fields and descriptions of the 5°x5° effort table contained in the IATTC database for large-scale tuna longline fishery in the eastern Pacific Ocean.

Data field	Description
Record	Unique numeric record identifier. Records contain effort and operational data for one or more vessels and one or more sets made within a specified 1°x1° or 5°x5° reporting grid.
Date	Date in which the set(s) for a record were made.
Date-Time Precision ID	Identifier of the precision in which date was reported for a record. Ranges from minute (=1) to year (=6). Most longline data is reported by month (=4).
Latitude	Latitude of the centroid of a grid, reported at either 0.1° or 0.5° resolution in each record.
Longitude	Longitude of the centroid of a grid, reported at either 0.1° or 0.5° resolution in each record.
Flag	The flag under which the set(s) comprising the record were made.
Hooks	The total number of hooks deployed, aggregated across all vessels and sets in a record.
Sets	The total number of sets made, aggregated across all vessels in a record.
Vessels	The total number of vessels contributing to sets contained within a record.
Estimated Position ID	An identifier of the estimated position of the set(s) within a record. Ranges from actual position of an individual set, to the entire EPO.
Metadata ID	An identifier of a metadata record that describes the source of data contained in a record.
Gear ID	An identifier of the gear type(s) used in a record. All longline data records are code 3.
HPB	Defines the hooks per basket, or hooks between floats, for the set(s) contained in a record.

Appendix 2. Data fields and descriptions of the 5°x5° catch table contained in the IATTC database for large-scale tuna longline fishery in the eastern Pacific Ocean.

Data field	Description
Record	Unique numeric record identifier. Linked to effort table that contains effort and operational data for one or more vessels and one or more sets made within a specified 1°x1° or 5°x5° reporting grid.
DType	Defines the data type reported within a record as either numbers, weights, or both numbers and weights.
Number	The total number of individual animals representing a specific taxonomic code that was caught and retained for a specific record.
DiscardNum	The total number of individual animals representing a specific taxonomic code that was caught and discarded for a specific record.
Weight	The total weight (in metric tons) of animals representing a specific taxonomic code that was caught and retained for a specific record.
DiscardNum	The total weight (in metric tons) of animals representing a specific taxonomic code that was caught and discarded for a specific record.
WeightConv	Identifier of the type of conversion factor used to convert the total number of individual animals representing a specific taxonomic code to a weight (in metric tons).