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## ECOSYSTEM CONSIDERATIONS

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**CONTENTS**



### 1. INTRODUCTION

The 1995 FAO Code of Conduct for Responsible Fisheries stipulates that "States and users of living aquatic resources should conserve aquatic ecosystems" and that "management measures should not only ensure the conservation of target species, but also of species belonging to the same ecosystem or associated with or dependent upon the target species"[1]. In 2001, the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem elaborated these principles with a commitment to incorporate an ecosystem approach into fisheries management.

Consistent with these instruments, one of the functions of the IATTC under the 2003 Antigua Convention is to "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".

Consequently, the IATTC has recognized ecosystem issues in many of its management decisions since 2003. This report provides a brief summary of what is known about the direct and indirect impacts of tuna fisheries in the eastern Pacific Ocean (EPO) on the populations of species and ecological functional groups

[1] The Code also provides that management measures should ensure that "biodiversity of aquatic habitats and ecosystems is conserved and endangered species are protected", and that "States should assess the impacts of environmental factors on target stocks and species belonging to the same ecosystem or associated with or dependent upon the target stocks, and assess the relationship among the populations in the ecosystem."

and the structure of the ecosystem, as controlled by the strength of predator-prey interactions.

This report does not suggest objectives for the incorporation of ecosystem considerations into the management of fisheries for tunas or billfishes, nor any new management measures. Rather, its main purpose is to demonstrate that the Commission considers the ecological sustainability of the fisheries which it manages.

However, the view that we have of the ecosystem is based on the recent past; there is almost no information available about the ecosystem before exploitation began. Also, the environment is subject to change on a variety of time scales, including the well-known El Niño fluctuations and more recently recognized longer-term changes, such as the Pacific Decadal Oscillation (PDO) and other climate-related changes.

In addition to reporting the catches of the principal species of tunas and billfishes, the staff estimates catches (retained and discarded) of non-target species. In this report, data on those species are presented in the context of the effect of the fishery on the ecosystem. While relatively good information is available for catches of tunas and billfishes across the entire fishery, this is not the case for bycatch species. The information is comprehensive for large[2] purse-seine vessels that carry observers under the Agreement on the International Dolphin Conservation Program (AIDCP), and some information on retained catches is also reported for other purse-seine vessels, and much of the longline fleet (see SAC-08-07b). There is little information available on bycatches and discards by fishing vessels that use other gear types (*e.g.* gillnet, harpoon, and recreational gear (see SAC-07-INF-C(d))).

Detailed information on past ecosystem studies can be found in documents for previous meetings of the Scientific Advisory Committee (*e.g.* SAC-08-07a), and current and planned ecosystem-related work by the IATTC staff is summarized in the Strategic Science Plan (SAC-09-01) and the Staff Activities and Research report (SAC-09-02).

## 2. IMPACT OF CATCHES

### 2.1. Single-species assessments

This report presents current information on the effects of the tuna fisheries on the stocks of individual species in the EPO. An ecosystem perspective requires a focus on how the fishery may have altered various components of the ecosystem. Sections 2.2 and 2.3 of this report refer to information on the current biomass of each stock. The influences of predator and prey abundances are not explicitly described. Sections 2.4-2.7 include estimates of catch data by vessels of the large purse-seine and large-scale longline (herein 'longline fisheries') fisheries reported to the IATTC.

Observer data were used to provide estimates of total catches (retained catches and discards) during sets by large purse-seine vessels in the EPO on floating objects (OBJ), unassociated schools (NOA), and dolphins (DEL).

Complete data are not available for small purse-seine, longline, and other types of vessels. There is considerable variability in reporting formats of longline data by individual CPCs through time, thereby limiting application of catch and effort data (SAC-08-07b, SAC-08-07d, SAC-08-07e). Some catches of non-target species by the tuna longline fisheries in the EPO are reported to the IATTC, but often in a highly summarized form (*e.g.* monthly aggregation of catch by broad taxonomic group (*e.g.* "Elasmobranchii")), often without verification of whether the reported catch has been raised to total catch (SAC-08-07b). Because of data limitations, catch data for longline fisheries were obtained using IATTC's 5°x5° catch tables following methods described in SAC-08-07b and SAC-08-07d. Such estimates must be regarded as minimum estimates only. However, due to the paucity of catch data in the IATTC longline database,

[2] Carrying capacity greater than 363 t

a report on establishing minimum data standards and reporting requirements for longline observer programs was discussed at the Eighth Meeting of the SAC (SAC-08-07e). As data reporting improves, better estimations of catches by longline vessels will be available.

### 2.2. Tunas

Information on the effects of EPO fisheries on bigeye, yellowfin, and skipjack tunas is found in Documents SAC-09-05, 06, and 07, respectively. A report of the Bluefin Working Group of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) and outcomes of the Joint Tuna RFMO meeting of Pacific bluefin tuna will be presented at this meeting. The ISC Northern Albacore Working Group completed its stock assessment in 2017, and an update on management strategy evaluation (MSE) work on north Pacific albacore tuna will be presented at this meeting.

Preliminary estimates of the catches of tunas and bonitos in the EPO during 2017 are found in Table A-2a of Document SAC-09-03.

### 2.3. Billfishes

Information on the effects of the tuna fisheries on swordfish, blue marlin, striped marlin, and sailfish is presented in Sections G-J of IATTC Fishery Status Report 15. Stock assessments and/or stock structure analyses for swordfish (2007, structure), eastern Pacific striped marlin (2010, assessment and structure), northeast Pacific striped marlin (2011, assessment), southeast Pacific swordfish (2012, assessment), and eastern Pacific sailfish (2013, assessment) were completed by the IATTC staff. Stock assessments of striped marlin (2015), Pacific blue marlin (2016), and north Pacific swordfish (2017) were completed by the ISC Billfish Working Group.

No stock assessments have been conducted for black marlin and shortbill spearfish, although data published jointly by scientists of the National Research Institute of Far Seas Fisheries (NRIFSF) of Japan and the IATTC in the IATTC Bulletin series show trends in catches, effort, and catches per unit of effort (CPUEs).

Preliminary estimates of the catches of billfishes in the EPO during 2017 are found in Table A-2b of Document SAC-09-03.

### 2.4. Marine mammals

Marine mammals, especially spotted dolphins (*Stenella attenuata*), spinner dolphins (*S. longirostris*), and common dolphins (*Delphinus delphis*), are frequently found associated with yellowfin tuna in the EPO. Purse-seine fishermen commonly set their nets around herds of dolphins and the associated schools of yellowfin tuna, and then release the dolphins while retaining the tunas. Whilst the incidental mortality of dolphins in the fishery was high during the 1960s and 1970s, it decreased precipitously since the 1980s.

Preliminary estimates of the incidental mortality of marine mammals in the fishery in 2017 are shown in Table 1, and estimates during 1993-2017 are shown in Figure J-1. Dolphin mortality

**TABLE 1.** Mortality of dolphins and other marine mammals caused by the fishery in the EPO, 2017 (preliminary data).

| | Incidental mortality | |
|---|---|---|
| Species and stock | Numbers | t |
| Offshore spotted dolphin | | |
| Northeastern | 92 | 6.0 |
| Western-southern | 178 | 11.6 |
| Spinner dolphin | | |
| Eastern | 266 | 11.8 |
| Whitebelly | 98 | 5.9 |
| Common dolphin | | |
| Northern | 26 | 1.8 |
| Central | 9 | 0.6 |
| Southern | 16 | 1.1 |
| Other mammals* | 3 | 0.2 |
| **Total** | **688** | **39.1** |

*"Other mammals" includes the following species and stocks, whose observed mortalities were as follows: unidentified dolphins 2 (0.1 t) and striped dolphin (*Stenella coeruleoalba*) 1 (0.06 t).

rarely occurred in sets on unassociated tuna schools and on floating objects. Decreasing mortalities were observed for northeastern spotted dolphins, whitebelly spinner dolphins, western-southern spotted dolphins, central common dolphins, and other delphinidae. Numbers of mortalities were variable for northern common dolphins and eastern spinner dolphins, and those of southern common dolphins were generally less than 40 individuals, with the exception of peaks to 220 in 2004 and about 120 in 2008.

### 2.5. Sea turtles

Sea turtles are caught on longlines when they take the bait on hooks, are snagged accidentally by hooks, or are entangled in the lines. Estimates of incidental mortality of turtles due to longline and gillnet fishing are few. The mortality rates in the EPO industrial longline fishery are likely to be lowest in "deep" sets (around 200-300 m) targeting bigeye tuna, and highest in "shallow" sets (<150 m) for albacore and swordfish. In addition, there is a sizeable fleet of artisanal longline vessels that also impact sea turtles (see Section 9.2).

**TABLE 2**. Interactions and mortalities of sea turtles with large purse-seine vessels in the EPO, 2017 (preliminary data).

| | Interactions | | | | Mortalities | | | |
|---|---|---|---|---|---|---|---|---|
| | Set type | | | Total | Set type | | | Total |
| | OBJ | NOA | DEL | | OBJ | NOA | DEL | |
| Olive Ridley | 132 | 16 | 48 | 196 | 2 | - | 2 | 4 |
| Eastern Pacific green | 29 | 19 | 30 | 78 | - | - | - | - |
| Loggerhead | 9 | 19 | 1 | 29 | - | - | - | - |
| Hawksbill | 3 | 1 | 2 | 6 | - | - | - | - |
| Leatherback | 1 | - | 1 | 2 | - | - | - | - |
| Unidentified | 187 | 23 | 69 | 279 | - | - | - | - |

Sea turtles are occasionally caught in purse seines in the EPO tuna fishery, generally when the turtles associate with floating objects, and are captured when the object is encircled. Also, sets on unassociated tunas or tunas associated with dolphins may capture sea turtles that happen to be at those locations. Sea turtles sometimes become entangled in the webbing under fish-aggregating devices (FADs) and drown. In some cases, they are entangled by the fishing gear and may be injured or killed.

The olive Ridley turtle (*Lepidochelys olivacea*) is, by far, the species of sea turtle taken most often by purse seiners. It is followed by green sea turtles (*Chelonia mydas*) and, very occasionally, by loggerhead (*Caretta caretta*) and hawksbill (*Eretmochelys imbricata*) turtles (Figure J-2). Since 1990, when IATTC observers began recording this information, only three mortalities of leatherback (*Dermochelys coriacea*) turtles have been recorded. Some of the turtles are unidentified because they were too far from the vessel or it was too dark for the observer to identify them.

Preliminary estimates of the mortalities and interactions (in numbers) of turtles in sets by large purse-seine vessels on floating objects (OBJ), unassociated tunas (NOA), and dolphins (DEL) during 2017, based on IATTC observer data, are shown in Table 2, and for 1993-2017 in Figure J-2. Data on sea turtle interactions or mortality were deficient for the longline fisheries (SAC-08-07b).

The mortalities of sea turtles due to purse seining for tunas are probably less than those due to other human activities, which include exploitation of eggs and adults, beach development, pollution, entanglement in and ingestion of marine debris, and impacts of other fisheries.

### 2.6. Sharks and rays

Sharks are caught as bycatch or targeted catch in EPO tuna longline and purse-seine fisheries as well as multi-species and multi-gear fisheries of the coastal nations.

Stock assessments or stock status indicators (SSIs) are available for only five shark species in the EPO: silky

(*Carcharhinus falciformis*) (IATTC: SAC-05 INF-F, SAC-08-08a(i), SAC-09-13), blue (*Prionace glauca*) (ISC Shark Working Group), shortfin mako (*Isurus oxyrinchus*) (ISC Shark Working Group), common thresher (*Alopias vulpinus*) (NMFS), and bigeye thresher (*Alopias superciliosus*) (FAO Common Oceans Tuna Project). A Pacific-wide assessment of the porbeagle shark (*Lamna nasus*) in the southern hemisphere was completed in late 2017 as part of the FAO Common Oceans Tuna Project. Whale shark interactions with the tuna purse-seine fishery in the EPO are summarized in Document BYC-08 INF-A. The impacts of tuna fisheries on the stocks of other shark species in the EPO are unknown.

**TABLE 3**. Catches, in tons, of sharks and rays in the EPO by large purse-seine vessels, by set type, 2017, and by longline vessels, 2016 (preliminary data). Longline estimates are minimums

| | Purse-seine | | | | Long-line |
|---|---|---|---|---|---|
| | OBJ | NOA | DEL | Total | |
| Silky shark (*Carcharhinus falciformis)* | 678 | 7 | 26 | 711 | 452 |
| Oceanic whitetip shark (*C. longimanus)* | 4 | <1 | <1 | 5 | 65 |
| Hammerhead sharks (*Sphyrna* spp.) | 21 | 6 | 2 | 28 | 34 |
| Thresher sharks (*Alopias* spp.) | 2 | 3 | 2 | 7 | 107 |
| Mako sharks (*Isurus* spp.) | <1 | <1 | 0 | 2 | 340 |
| Other sharks | 89 | 3 | 3 | 95 | 841 |
| Blue sharks (*Prionace glauca*) | - | - | - | - | 1,816 |
| Manta rays (Mobulidae) | 10 | 30 | 9 | 49 | - |
| Pelagic sting rays (Dasyatidae) | <1 | <1 | <1 | <1 | - |

Preliminary estimates of the catches of sharks and rays reported by observers on large purse-seine vessels in the EPO during 2017 and minimum estimates of catches by longline vessels in 2016 are shown in Table 3.

Catches of sharks and rays in the purse-seine and longline fisheries during 1993-2017 are shown in Figure J-3. Silky sharks are the most commonly-caught species of shark in the purse-seine fishery. Shark catches were generally greatest in sets on floating objects (mainly silky, oceanic whitetip (*C. longimanus*), hammerhead (*Sphyrna* spp.) and mako (*Isurus* spp.) sharks), followed by unassociated sets and, at a much lower level, dolphin sets (Figure J-3). Until about 2007, thresher sharks (*Alopias* spp.) occurred mostly in unassociated sets (Figure J-3). Historically, oceanic whitetip sharks were commonly caught in sets on floating objects, but they became much less common after 2005. In general, the bycatch rates of manta rays (Mobulidae) and stingrays (Dasyatidae) are greatest in unassociated sets, followed by dolphin sets, and lowest in floating-object sets, although catches by set type can be variable (Figure J-3). The numbers of purse-seine sets of each type in the EPO during 2002-2017 are shown in Table A-7 of Document SAC-09-03.

The reported longline catches of sharks increased sharply after 2008 with catches of silky, oceanic whitetip, and hammerhead sharks declining thereafter. Catches of thresher, mako, and blue sharks increased through 2016. These data should be interpreted with caution due to limitations in data-reporting requirements for non-target species caught in the longline fishery resulting from Resolutions C-03-05 and C-11-08 and documented in SAC-08-07b.

The small-scale artisanal longline fisheries of the coastal CPCs target sharks, tunas, billfishes and dorado (*Coryphaena hippurus*), and some of these vessels operate in areas beyond coastal waters and national jurisdictions[3]. However, essential shark data from longline fisheries is lacking, and therefore conventional stock assessments and/or stock status indicators cannot be produced (see data challenges outlined in

[3] Martínez-Ortiz, J., Aires-da-Silva, A.M., Lennert-Cody, C.E., Maunder, M.N. 2015. The Ecuadorian artisanal fishery for large pelagics: species composition and spatio-temporal dynamics. PLoS ONE 10(8): e0135136.

SAC-07-06b(iii)). A project is underway to improve data collection on sharks, particularly for Central America, for the artisanal longline fleet through funding from the Food and Agriculture Organization of the United Nations (FAO) and the Global Environmental Facility (GEF) under the framework of the ABNJ Common Oceans program (SAC-07-06b(ii), SAC-07-06b(iii)). Data obtained from this project may be included in future iterations of the Ecosystem Considerations report to provide better estimates of sharks caught by the various longline fleets.

### 2.7. Other large fishes

Preliminary estimates of the catches of dorado (*Coryphaena* spp.) and other large fishes in the EPO by large purse-seine vessels during 2017 are shown in Table 4, along with minimum estimates from longline data in 2016. Catch trends for the most important species during 1993-2017, by set type and fishery, are shown in Figure J-4.

**TABLE 4**. Catches, in tons, of large fish species commonly caught in the EPO by large purse-seine vessels, by set type, 2017, and by longline vessels, 2016. Longline estimates are minimums (preliminary data).

| | Purse-seine | | | | Long-line |
|---|---|---|---|---|---|
| | OBJ | NOA | DEL | Total | |
| Dorado (*Coryphaena* spp.) | 1,865 | 12 | <1 | 1,877 | 184 |
| Wahoo (*Acanthocybium solandri*) | 368 | 1 | <1 | 368 | 243 |
| Rainbow runner (*Elagatis bipinnulata*) & yellowtail (*Seriola lalandi*) | 37 | 24 | - | 61 | - |
| Pomfrets (Bramidae) | - | - | - | - | 98 |
| Opahs (*Lampris* spp.) | - | - | - | - | 640 |

Dorado is the most commonly reported fish species caught incidentally in the EPO purse-seine tuna fishery. It is also one of the most important species caught in the artisanal fisheries of the coastal nations of the EPO, leading to an exploratory stock assessment (SAC-07-06a(i)) and management strategy evaluation (MSE) in the south EPO (SAC-07-06a(ii)).

Around 2006 sharp increases were observed in longline catches of dorado, wahoo, pomfrets and opahs, although this may be related to changes in data reporting. Purse-seine catches of dorado, wahoo, rainbow runner, and yellowtail were variable, and occurred primarily in sets on floating objects.

## 3. OTHER FAUNA

### 3.1. Seabirds

There are approximately 100 species of seabirds in the tropical EPO. Some of them associate with epipelagic predators, such as fishes (especially tunas) and marine mammals, near the ocean surface. Feeding opportunities for some seabird species are dependent on the presence of tuna schools feeding near the surface. Most species of seabirds take prey, mainly squid (primarily Ommastrephidae), within half a meter of the surface, or in the air (flyingfishes, Exocoetidae). Subsurface predators, such as tunas, often drive prey to the surface to trap it against the air-water interface, where it becomes available to the birds, which also feed on injured or disoriented prey, and on scraps of large prey.

Some seabirds, especially albatrosses (waved (*Phoebastria irrorata*), black-footed (*P. nigripes*), Laysan (*P. immutabilis*), and black-browed (*Thalassarche melanophrys*)) and petrels, are susceptible to being caught on baited hooks in pelagic longline fisheries. There is particular concern for the waved albatross, because it is endemic to the EPO and nests only in the Galapagos Islands. Observer data from artisanal vessels show no interactions with waved albatross during those vessels' fishing operations. Data from the US pelagic longline fishery in the north EPO indicate that bycatches of black-footed and Laysan albatrosses occur.

The IATTC has adopted two measures on seabirds (section 9.3); also, the Agreement on the Conservation of Albatrosses and Petrels (ACAP) and BirdLife International have updated their maps of seabird distribution in the EPO, and have recommended guidelines for seabird identification, reporting, handling, and mitigation measures (SAC-05 INF-E, SAC-07-INF-C(d), SAC-08-INF-D(a), SAC-08-INF-D(b), SAC-08-INF-D(d) ). Additionally, ACAP has reported on the conservation status for albatrosses and large petrels (SAC-08-INF-D(c)).

Data pertaining to interactions with seabirds is deficient in the IATTC longline database(SAC-08-07b).

### 3.2. Forage species

A large number of taxa occupying the middle trophic levels in the EPO ecosystem—generically referred to as "forage" species—play a key role in providing a trophic link between primary producers at the base of the food web and the upper-trophic-level predators, such as tunas and billfishes. Cephalopods, especially squids, play a central role in many marine pelagic food webs by linking the massive biomasses of micronekton, particularly myctophid fishes, to many oceanic predators. For example, the Humboldt squid (*Dosidicus gigas*) is a common prey for yellowfin and bigeye tunas and other predatory fishes, but is also a voracious predator of small fishes and cephalopods. Recent changes in the abundance and geographic range of Humboldt squid could affect the foraging behavior of the tunas and other predators, perhaps affecting their vulnerability to capture and the trophic structure of pelagic ecosystems. Given the high trophic flux passing through the squid community, concerted research on squids is important for understanding their role as key prey and predators.

Some small forage fishes are incidentally caught in the EPO by purse-seine vessels on the high seas, mostly in sets on floating objects, and by coastal artisanal fisheries, but are generally discarded at sea. Frigate and bullet tunas (*Auxis* spp.), for example, are a common prey of many high trophic level predators, and can comprise 10% or more of their diet biomass. Preliminary estimates of the catches of small fishes by large purse-seine vessels in the EPO during 2017 are shown in Table 5, and catches during 1993-2017 are shown in Figure J-5. Declines in catches of small teleost fishes over the 25-year period were observed.

**TABLE 5.** Catches of small fishes, in tons, by large purse-seine vessels in the EPO, 2017 (preliminary data).

| | Set type | | | Total |
|---|---|---|---|---|
| | OBJ | NOA | DEL | |
| Triggerfishes (Balistidae) and filefishes (Monacanthidae) | 86 | <1 | - | 87 |
| Other small fishes | 12 | <1 | - | 12 |
| Frigate and bullet tunas (*Auxis* spp.) | 153 | 103 | - | 256 |

### 3.3. Larval fishes and plankton

Larval fishes have been collected in surface net tows in the EPO for many years by personnel of the Southwest Fisheries Science Center of the US National Marine Fisheries Service (NMFS). Of the 314 taxonomic categories identified, 17 were found to be most likely to show the effects of environmental change; however, the occurrence, abundance, and distribution of these key taxa revealed no consistent temporal trends. Research[4] has shown a longitudinal gradient in community structure of the ichthyoplankton assemblages in the eastern Pacific warm pool, with abundance, species richness, and species diversity high in the east (where the thermocline is shallow and primary productivity is high) and low but variable in the west (where the thermocline is deep and primary productivity is low).

The phytoplankton and zooplankton populations in the tropical EPO are variable. For example, chlorophyll concentrations on the sea surface (an indicator of phytoplankton blooms) and the abundance of copepods were markedly reduced during the El Niño event of 1982-1983, especially west of 120°W. Similarly, surface concentrations of chlorophyll decreased during the 1986-1987 El Niño episode and increased during the 1988 La Niña event due to changes in nutrient availability.

The species and size composition of zooplankton is often more variable than the zooplankton biomass. When the water temperatures increase, warm-water species often replace cold-water species at particular locations. The relative abundance of small copepods off northern Chile, for example, increased during the 1997-1998 El Niño event, while the zooplankton biomass did not change.

## 4. TROPHIC INTERACTIONS

The following is a brief summary of current knowledge of trophic interactions. Proposed studies on trophic interactions are outlined in the IATTC's Strategic Science Plan (SAC-09-01) and the staff activities and research work plan (SAC-09-02).

Tunas and billfishes are wide-ranging, generalist predators with high energy requirements, and, as such, are key components of pelagic ecosystems. The ecological relationships among large pelagic predators, and between them and animals at lower trophic levels, are not well understood, but are required to develop models to assess fishery and climate impacts on the ecosystem. Knowledge of the trophic ecology of predatory fishes in the EPO has been derived from stomach contents analysis, and more recently from chemical indicators. Each species of tuna appears to have a generalized feeding strategy (high prey diversity and low abundance of individual prey types) that varies spatially and ontogenetically.

Stable isotope analysis can complement dietary data for delineating the trophic flows of marine food webs. While stomach contents represent a sample of the most-recent feeding events, stable carbon and nitrogen isotopes integrate all components of the entire diet into the animal's tissues, providing a history of recent trophic interactions. Finer-resolution information is provided by compound-specific isotope analysis of amino acids (AA-CSIA). For example, the trophic position of a predator in the food web can be determined from its tissues by relating "source" amino acids (*e.g.* phenylalanine) to "trophic" amino acids (*e.g.* glutamic acid), which describe the isotopic values for primary producers and the predator, respectively.

Trophic studies have revealed many of the key trophic connections in the tropical pelagic EPO, and have formed the basis for representing food-web interactions in an ecosystem model (IATTC Bulletin, Vol. 22, No. 3) to explore the ecological impacts of fishing and climate change. The staff aim to continue and improve trophic data collection for many components of the EPO ecosystem, such as small and large mesopelagic fishes, which will allow the ecosystem dynamics to be better understood, but also enable the development of an improved ecosystem model that represents the entire EPO.

[4] Vilchis, L.I., L.T. Ballance, and W. Watson. 2009. Temporal variability of neustonic ichthyoplankton assemblages of the eastern Pacific warm pool: Can community structure be linked to climate variability? Deep-Sea Research Part I-Oceanographic Research Papers 56(1): 125-140

## 5. PHYSICAL ENVIRONMENT[5]

Environmental conditions affect marine ecosystems, the dynamics and catchability of tunas and billfishes, and the activities of fishermen. Tunas and billfishes are pelagic during all stages of their lives, and the physical factors that affect the tropical and sub-tropical Pacific Ocean can have important effects on their distribution and abundance.

The ocean environment varies on a variety of time scales, from seasonal to inter-annual, decadal, and longer (*e.g.* climate phases or regimes). The dominant source of variability in the upper layers of the EPO is known as the El Niño-Southern Oscillation (ENSO), an irregular fluctuation involving the entire tropical Pacific Ocean and global atmosphere. El Niño events occur at 2- to 7-year intervals, and are characterized by weaker trade winds, deeper thermoclines, and abnormally high sea-surface temperatures (SSTs) in the equatorial EPO. El Niño's opposite phase, commonly called La Niña, is characterized by stronger trade winds, shallower thermoclines, and lower SSTs. The changes in the physical and chemical environment due to ENSO have a subsequent impact on the biological productivity, feeding, and reproduction of fishes, birds, and marine mammals.

With respect to commercially important tunas and billfishes, ENSO is thought to cause considerable variability in their recruitment and availability for capture. For example, a shallow thermocline in the EPO during La Niña events can contribute to increased success of purse-seine fishing for tunas, by compressing the preferred thermal habitat of small tunas near the sea surface. In contrast, during an El Niño event, when the thermocline is deep, tunas are apparently less vulnerable to capture, and catch rates can decline. Furthermore, warmer- or cooler-than-average SSTs can also cause these mobile fishes to move to more favorable habitats.

Climate-induced variability on a decadal scale (*i.e.* 10 to 30 years) also affects the EPO and has often been described in terms of "regimes" characterized by relatively stable means and patterns in the physical and biological variables. Decadal fluctuations in upwelling and water transport coincide with higher-frequency ENSO patterns, and have basin-wide effects on the SSTs and thermocline slope that are similar to those caused by ENSO, but on longer time scales. For example, analyses by the IATTC staff have indicated that yellowfin in the EPO have experienced regimes of lower (1975-1982) and higher (1983-2001) recruitment, thought to be due to a shift in the primary productivity regime in the Pacific Ocean.

Indices of variability in oceanographic conditions—from shorter-term, inter-annual ENSO events assessed in different regions of the EPO, to the longer-term interdecadal PDO index—are used to describe SST anomalies in the Pacific Ocean. Oceanographic indices can be used to explore the influence of environmental drivers on the vulnerability of non-target species impacted by fisheries (see, for example, SAC-08-08a(i)). Some of these indices include the Oceanic Niño Index (ONI), the Índice Costero El Niño (ICEN) and the PDO. The ONI is used by the US National Oceanic and Atmospheric Administration (NOAA), and is the primary indicator of warm El Niño (ONI ≥+0.5) and cool La Niña (ONI ≤-0.5) conditions within the Niño 3.4 region in the east-central tropical Pacific Ocean between 120° and 170°W[6]. The ICEN index is used by the Comité Multisectorial para el Estudio del Fenómeno El Niño (ENFEN) to monitor the occurrence and magnitude of El Niño in the Niño 1+2 region (the smallest of the El Niño regions, from 0° to 10°S between 90° and 80°W), corresponding to the highly dynamic region along the coast of Peru. The PDO—a long-lived El

[5] Some of the information in this section is from Fiedler, P.C. 2002. Environmental change in the eastern tropical Pacific Ocean: review of ENSO and decadal variability. Mar. Ecol. Prog. Ser. 244: 265-283.

[6] Dahlman, L. 2016. Climate Variability: Oceanic Niño Index. National Oceanic and Atmospheric Administration. https://www.climate.gov/news-features/understanding-climate/climate-variability-oceanic-ni%C3%B1o-index.

Niño-like pattern of Pacific climate variability—tracks large-scale interdecadal patterns of environmental and biotic changes, primarily in the North Pacific Ocean[7], with secondary signatures in the tropical Pacific[8]. Monthly ONI[9], ICEN[10] and PDO[11] data from 1993-2017 are shown in Figure J-6 to provide a general overview of variability in these indices over the past two decades.

ICEN values have been categorized from "strong cold" events (values <-1.4) to "extraordinary warm" events (values >3)[12]. ICEN values were >3 during the 1997-1998 El Niño; values peaked to a high of 2.23 in October 2015, indicating a "very strong" event. Similarly, ONI values were >2 during the 1997-1998 and 2015-2016 El Niño events, representing "very strong" events[13]. PDO values peaked at 2.79 in August 1997, and at 2.62 in April 2016.

Maps of mean SSTs across the EPO for each year during 1993-2017 were created using NOAA_OI_SST_V2 data[14] provided by the NOAA/OAR.ESRL PSD, Boulder, Colorado, USA. Figure J-7 shows the expansion of warmer waters during the extreme El Niño events of 1997-1998 and 2015-2016.

## 6. ECOLOGICAL INDICATORS

Over the past two decades, many fisheries worldwide have broadened the scope of management to consider fishery impacts on non-target species and the ecosystem more generally. This ecosystem approach to fisheries management is important for maintaining the integrity and productivity of ecosystems while maximizing the utilization of commercially important assets. However, demonstrating the ecological sustainability of EPO fisheries is a significant challenge, given the wide range of species with differing life histories with which those fisheries interact. While biological reference points have been used for single-species management of target species, alternative performance measures and reference points are required for the many non-target species for which reliable catch and/or biological data are lacking; for example, incidental mortality limits for dolphins have been set in the EPO purse-seine fishery under the AIDCP.

Another important aspect of assessing ecological sustainability is to ensure that the structure and function of the ecosystem is not negatively impacted by fishing activities. Several ecosystem metrics or indicators have been proposed to address this issue, such as community size structure, diversity indices, species richness and evenness, overlap indices, trophic spectra of catches, relative abundance of an indicator species or group, and numerous environmental indicators.

Given the complexity of marine ecosystems, no single indicator can completely represent their structure and internal dynamics. In order to monitor changes in these multidimensional systems and detect the potential impacts of fishing and the environment, a variety of indicators is required. Therefore, a range of indicators that can be calculated with the ecosystem modelling software *Ecopath with Ecosim* (EwE) are used in this report to describe the long-term changes in the EPO ecosystem. The analysis covers the 1970-2014 period, and the indicators included are: mean trophic level of the catch ($MTL_c$), the Marine Trophic

[7] Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society 78: 1069-1079.

[8] Hare, S.R., and N.J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography 47: 103-145.

[9] http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

[10] http://www.met.igp.gob.pe/variabclim/indices.html

[11] http://research.jisao.washington.edu/pdo/

[12] http://www.imarpe.pe/imarpe/archivos/informes/imarpe_comenf_not_tecni_enfen_09abr12.pdf

[13] http://ggweather.com/enso/oni.htm

[14] https://www.esrl.noaa.gov/psd/data/gridded/data.noaa.oisst.v2.html

Index (MTI), the Fishing in Balance index (FIB), Kempton's Q diversity index, and three indicators that describe the mean trophic level of three components, or 'communities' (TL 2.0-3.5, 3.5-4.0, and >4.0), after fisheries have extracted biomass as catches. These indicators, and the results derived from the ecosystem model of the pelagic Eastern Tropical Pacific Ocean (ETP)[15], are summarized below.

**Trophic structure of the EPO ecosystem.** Ecologically-based approaches to fisheries management require accurate depictions of trophic links and biomass flows through the food web. Trophic levels (TLs) are used in food-web ecology to characterize the functional role of organisms and to estimate energy flows through communities. A simplified food-web diagram, with approximate TLs, from the ETP model is shown in Figure J-8. Toothed whales (Odontoceti, average TL 5.2), large squid predators (large bigeye tuna and swordfish, average TL 5.2), and sharks (average TL 5.0) are top-level predators. Other tunas, large piscivores, dolphins (average TL 4.8), and seabirds (average TL 4.5) occupy slightly lower TLs. Smaller epipelagic fishes (*e.g. Auxis* spp. and flyingfishes, average TL 3.2), cephalopods (average TL 4.4), and mesopelagic fishes (average TL 3.4) are the principal forage of many of the upper-level predators in the ecosystem. Small fishes and crustaceans prey on two zooplankton groups, and the herbivorous micro-zooplankton (TL 2) feed on the producers, phytoplankton and bacteria (TL 1).

**Ecological indicators.** In exploited pelagic ecosystems, fisheries that target large piscivorous fishes act as the system's apex predators. Over time, fishing can cause the overall size composition of the catch to decrease, and, in general, the TLs of smaller organisms are lower than those of larger organisms. The mean trophic level of the catch ($MTL_c$) by fisheries can be a useful metric of ecosystem change and sustainability, because it integrates an array of biological information about the components of the system. $MTL_c$ is also an indicator of whether fisheries are changing their fishing or targeting practices in response to changes in the abundance or catchability of traditional target species. For example, declines in the abundance of large predatory fish by overfishing has resulted in fisheries progressively targeting species at lower trophic levels in order to remain profitable. Studies that have documented this phenomenon, referred to as 'fishing down the food web', have shown that the $MTL_c$ decreased by around 0.1 of a trophic level per decade.

The Marine Trophic Index (MTI) is essentially the same as $MTL_c$, but it includes only high trophic level species—generally TL>4.0—that are the first indicator of 'fishing down the food web'. Some ecosystems, however, have changed in the other direction, from lower to higher TL communities, sometimes as a result of improved technologies to allow exploitation of larger species—referred to as 'fishing up the food web'—but it can also result from improved catch reporting, as previously unreported catches of discarded predatory species, such as sharks, are recorded.

The Fishing in Balance (FIB) index indicates whether fisheries are balanced in ecological terms and not disrupting the functionality of the ecosystem (FIB = 0). A negative FIB indicates overexploitation, when catches do not increase as expected given the available productivity in the system, or if the effects of fishing are sufficient to compromise the functionality of the ecosystem, while a positive FIB indicates expansion of a fishery, either spatially, or through increased species richness of the catch.

Kempton's Q index measures the diversity and evenness in the ecosystem of species or functional groups with a trophic level greater than 3. Because the number of functional groups defined by an ecosystem model is fixed, a decrease in the index indicates that the relative contribution of each group to the overall biomass has changed relative to a reference year.

In contrast to $MTL_c$, the mean trophic level of the community essentially describes what the expected

[15] Olson, R.J., and G.M. Watters. 2003. A model of the pelagic ecosystem in the eastern tropical Pacific Ocean. Inter-American Tropical Tuna Commission, Bulletin 22(3): 133-218.

trophic level of components of the ecosystem is after fishing has extracted biomass as catches. There are three components—referred to as "communities"—that aggregate the biomass of functional groups in the model by trophic level: 2.0-3.5 ($MTL_{2.0}$), 3.5-4.0 ($MTL_{3.5}$), and >4.0 ($MTL_{4.0}$). These indicators can be used in unison to detect trophic cascades, whereby a decline in biomass of $MTL_{4.0}$ due to fishing would reduce predation pressure on $MTL_{3.5}$ and thus increase its biomass, which would in turn increase predation pressure on $MTL_{2.0}$ and reduce its biomass.

**Monitoring the EPO ecosystem using ecological indicators**. Given the potential utility of combining ecological indicators for describing the various structures and internal dynamics of the EPO ecosystem, annual indicator values were estimated from a 1970-2014 time series of annual catches and discards, by species, for three purse-seine fishing modes, the pole-and-line fishery, and the longline fishery in the EPO. The estimates were made by assigning the annual catch of each species from the IATTC tuna, bycatch, and discard databases to a relevant functional group defined in the ETP ecosystem model, and refitting the Ecosim model to the time series of catches to estimate $MTL_c$ and the other aforementioned ecological indicators.

Values for $MTL_c$ and MTI increased from 4.63 in 1970 to 4.66 in 1993, the year for which the ecosystem model was characterised, and coincidentally the year when the purse-seine fishing effort on FADs increased significantly (Figure J-9). After 1993, $MTL_c$ continued to increase, to a peak of 4.72 in 1997, due to the expansion of the FAD fishery, which increased bycatches of other high trophic level species that also aggregate around floating objects (*e.g.* sharks, billfishes, wahoo and dorado). This expansion is seen in the positive FIB index during the same period, and also a change in the composition of the community indicated by Kempton's Q index. After 1997, $MTL_c$, MTI, FIB and Kempton's Q index all show a gradual decline (Figure J-9). Since its peak in 1997, $MTL_c$ declined by 0.08 of a trophic level in the subsequent 18 years, or 0.044 trophic levels per decade.

The above indicators generally describe the change in the exploited components of the ecosystem, whereas community biomass indicators describe changes in the structure of the ecosystem once biomass has been removed due to fishing. The biomass of the $MTL_{4.0}$ community peaked at 4.444 in 1993, but has continued to decline, to 4.439 in 2014 (Figure J-9). As a result of changes in predation pressure on lower trophic levels, between 1993 and 2014 the biomass of the $MTL_{3.0}$ community increased from 3.799 to 3.800, while that of the $MTL_{2.0}$ community decreased from 3.306 to 3.305.

Together, these indicators show that the ecosystem structure has likely changed over the 44-year analysis period. However, these changes, even if they are a direct result of fishing, are not considered ecologically detrimental, but the patterns of changes, particularly in the mean trophic level of the communities, certainly warrant the continuation, and possible expansion, of monitoring programs for fisheries in the EPO.

## 7. ECOLOGICAL RISK ASSESSMENT

The primary goal of ecosystem-based fisheries management is to ensure the long-term sustainability of all species impacted—directly or indirectly—by fishing. However, this is a significant challenge for fisheries that interact with many non-target species with diverse life histories, for which sufficiently reliable catch and biological data for single-species assessments are lacking. An alternative approach for such data-limited situations is Ecological Risk Assessment (ERA), a tool for prioritizing management action or further data collection and research for potentially vulnerable species.

'Vulnerability' is defined here as the potential for the productivity of a stock to be diminished by direct and indirect fishing pressure. The IATTC staff has applied an ERA approach called 'productivity-susceptibility analysis' (PSA) to estimate the vulnerability of data-poor, non-target species caught in the EPO purse-seine fishery by large (Class-6) vessels in 2010 and in the longline fishery in 2017. PSA considers a stock's vulnerability as a combination of its susceptibility to being captured by, and incur mortality from, a fishery and its capacity to recover, given its biological productivity.

**Purse-seine fishery**. A preliminary evaluation of three purse-seine "fisheries" in the EPO was made in 2014, using 32 species (3 target tunas, 4 billfishes, 3 dolphins, 7 large fishes, 3 rays, 9 sharks, 2 small fishes and 1 turtle) that comprised the majority of the biomass removed by the purse-seine fleet during 2005-2013 (Table J-1). The overall productivity (*p*) and susceptibility (*s*) values that contributed to the overall vulnerability score (*v*) are shown in Table J-1. Vulnerability was highest for shortfin mako shark (*Isurus oxyrinchus*), bigeye thresher shark (*Alopias superciliosus*), pelagic thresher shark (*A. pelagicus*), giant manta ray (*Manta birostris*), hammerhead sharks (*Sphyrna mokarran*, *S. lewini*, and *S. zygaena*), and silky shark (*Carcharhinus falciformis*). Billfishes, dolphins, rays, and turtles were all moderately vulnerable, while small fishes, most large fishes, and two of the three target tuna species had the lowest vulnerability scores (Table J-1; Figure J-10a).

**Large-scale tuna longline fishery**. A preliminary assessment of the longline fishery in the EPO was undertaken for 2016 for 68 species that had some level of interaction (captured, discarded, or impacted) with the fishery. There were 12, 38, and 18 species classified as having low, moderate, and high vulnerability, respectively (Figure J-10b; Table J-2). Of the 18 highly vulnerable species, 13 were elasmobranchs—with the bigeye thresher, tiger, porbeagle and blue sharks identified as most vulnerable—, and 5 were commercially important tunas and billfishes (albacore, Pacific bluefin, and yellowfin tunas, swordfish, and striped marlin). Other tuna-like and mesopelagic species were classified as either having moderate or low vulnerability in the fishery, although four species—wahoo, snake mackerel, and the two species of dorado—had *v* scores close to 2.0, in close vicinity to being highly vulnerable (Figure J-10b; Table J-2).

In response to requests by participants at SAC-07 in 2016 to expand the ERA to other fisheries operating in the EPO, the IATTC staff produced three documents for SAC-08, covering (1) methodological improvements to PSA by resolving redundancy in productivity attributes (SAC-08-07c), (2) a metadata review for the large-scale longline fishery in the EPO (SAC-08-07b) to establish a list of impacted species and susceptibility parameters required for PSAs, and (3) a preliminary PSA for the large-scale longline fishery in the EPO (SAC-08-07d). Responding to requests for more quantitative cumulative ecological assessments for the EPO has been a priority for IATTC staff, and has led to the development of a new flexible spatially-explicit approach that quantifies the cumulative impacts of multiple fisheries on data-poor species (SAC-09-12). A demonstration of a preliminary form of the method will be presented at SAC-09.

## 8. ECOSYSTEM MODELING

Although ERA approaches can be useful for assessing the ecological impacts of fishing, they generally do not consider changes in the structure and internal dynamics of an ecosystem. As data collection programs improve and ecological studies (*e.g.* on diet) are conducted on components of the ecosystem, more data-rich ecosystem models can be employed that quantitatively represent ecological interactions among species or ecological 'functional groups'. These models are most useful as descriptive devices for exploring the potential impacts of fishing and/or environmental perturbations on components of the system, or the ecosystem structure as a whole.

The IATTC staff has developed a model of the pelagic ecosystem in the tropical EPO (IATTC Bulletin, Vol. 22, No. 3) to explore how fishing and climate variation might affect the animals at middle and upper trophic levels. The ecosystem model has 38 components, including the principal exploited species (*e.g.* tunas), functional groups (*e.g.* sharks and flyingfishes), and species of conservation importance (*e.g.* sea turtles). Fisheries landings and discards are included as five fishing "gears": pole-and-line, longline, and purse-seine sets on tunas associated with dolphins, with floating objects, and in unassociated schools. The model focuses on the pelagic regions; localized, coastal ecosystems are not included.

The model has been calibrated to time series of biomass and catch data for a number of target and non-target species for 1961-1998. There have been significant improvements in data collection programs in the EPO since 1998, and these new data may allow the model to be calibrated to the most recent data.

One shortcoming of the model is that it describes only the tropical component of the EPO ecosystem, and results cannot be reliably extrapolated to other regions of the EPO. Therefore, future work may aim to update the model to a spatially-explicit model that covers the entire EPO. This is a significant undertaking, but it would allow for an improved representation of the ecosystem and the potential fishery and climate impact scenarios that may be modelled to guide ecosystem-based fisheries management.

## 9. ACTIONS BY THE IATTC AND THE AIDCP ADDRESSING ECOSYSTEM CONSIDERATIONS

Both the IATTC's Antigua Convention and the AIDCP have objectives that involve the incorporation of ecosystem considerations into the management of the tuna fisheries in the EPO. Actions taken in the past include:

### 9.1. Dolphins

a. For many years, the impact of the fishery on the dolphin populations has been assessed, and programs to reduce or eliminate that impact have met with considerable success.

b. The incidental mortalities of all stocks of dolphins have been limited to levels that are insignificant relative to stock sizes.

### 9.2. Sea turtles

a. A database on all sea turtle sightings, captures, and mortalities reported by observers has been compiled.

b. Resolution C-04-07 on a three-year program to mitigate the impact of tuna fishing on sea turtles was adopted by the IATTC in June 2004; it includes requirements for data collection, mitigation measures, industry education, capacity building, and reporting.

c. Resolution C-04-05 REV 2, adopted by the IATTC in June 2006, contains provisions on releasing and handling of sea turtles captured in purse seines. The resolution also prohibits vessels from disposing of plastic containers and other debris at sea, and instructs the Director to study and formulate recommendations regarding the design of FADs, particularly the use of netting attached underwater to FADs.

d. Resolution C-07-03, adopted by the IATTC in June 2007, contains provisions on implementing observer programs for fisheries under the purview of the Commission that may have impacts on sea turtles and are not currently being observed. The resolution requires fishermen to foster recovery and resuscitation of comatose or inactive hard-shell sea turtles before returning them to the water. CPCs with purse-seine and longline vessels fishing for species covered by the IATTC Convention in the EPO are directed to avoid encounters with sea turtles, to reduce mortalities using a variety of techniques, and to conduct research on modifications of FAD designs and longline gear and fishing practices.

### 9.3. Seabirds

a. Recommendation C-10-02, adopted by the IATTC in October 2010, reaffirmed the importance that IATTC Parties and cooperating non-Parties, fishing entities, and regional economic integration organizations implement, if appropriate, the FAO International Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries ("IPOA-Seabirds").

b. Resolution C-11-02, adopted by the IATTC in July 2011, reaffirmed the importance of implementing the IPOA-Seabirds (see 9.3.a) and provides that Members and Cooperating non-Members (CPCs) shall require their longline vessels of more than 20 meters length overall and that fish for species covered by the IATTC in the EPO to use at least two of the specified mitigation measures, and establishes minimum technical standards for the measures.

### 9.4. Other species

a. Resolution C-00-08, adopted in June 2000, establishes guidelines on live release of sharks, rays, billfishes, dorado, wahoo, and other non-target species.

b. Resolution C-04-05, adopted in June 2006, instructs the Director to seek funds for reduction of incidental mortality of juvenile tunas, for developing techniques and equipment to facilitate release of billfishes, sharks, and rays from the deck or the net, and to carry out experiments to estimate the survival rates of released billfishes, sharks, and rays.

c. Resolution C-11-10, adopted in July 2011, prohibits retaining onboard, transhipping, landing, storing, selling, or offering for sale any part or whole carcass of oceanic whitetip sharks in the fisheries covered by the Antigua Convention, and to promptly release unharmed, to the extent practicable, oceanic whitetip sharks when brought alongside the vessel.

d. Resolution C-15-04, adopted in July 2015, prohibits retaining onboard, transhipping, landing, storing, selling, or offering for sale any part or whole carcass of manta rays (Mobulidae) (which includes *Manta birostris* and *Mobula* spp.) and requires vessels to release all mobulid rays alive wherever possible.

e. Resolution C-16-05, adopted in July 2016, states that the IATTC scientific staff shall develop a workplan for completing full stock assessments for the silky shark (*Carcharhinus falciformis*) and hammerhead sharks (*i.e.*, *Sphyrna lewini*, *S. zygaena* and *S. mokarran*). CPCs shall require their fishers to collect and submit catch data for silky and hammerhead sharks, and shall submit the data to the IATTC in accordance with IATTC data reporting requirements.

f. Resolution C-16-06, adopted in July 2016, prohibits retaining on board, transshipping, landing, or storing, in part or whole, carcasses of silky sharks caught by purse-seine vessels in the IATTC Convention Area.

### 9.5. Fish-aggregating devices (FADs)

a. Resolution C-16-01, adopted in July 2016, amends and replaces Resolution C-15-03, adopted by the IATTC in July 2015. It requires all purse-seine vessels, when fishing on FADs in the IATTC Convention Area, to collect and report FAD information including an inventory of the FADs present on the vessel, specifying, for each FAD, identification, type, and design characteristics. To reduce entanglement of sharks, sea turtles, or any other species, principles for the design and deployment of FADs are specified. Setting a purse seine on tuna associated with a live whale shark is prohibited, if the animal is sighted prior to the set. A working group on FADs is established and its objectives are to collect and compile information on FADs, review data collection requirements, compile information regarding developments in other tuna-RFMOs on FADs, compile information regarding developments on the latest scientific information on FADs, including information on non-entangling FADs, prepare annual reports for the SAC, and identify and review possible management measures.

b. Resolution C-17-02, adopted in July 2017, specifies measures for the fishery on FADs, including the number of allowable active FADs.

### 9.6. All species

a. Data on the bycatches of large purse-seine vessels are being collected, and governments are urged to provide bycatch information for other vessels.

b. Data on the spatial distributions of the bycatches and the bycatch/catch ratios have been collected for analyses of policy options to reduce bycatches.

c. Information to evaluate measures to reduce the bycatches, such as closures, effort limits, *etc*., has been collected.

d. Assessments of habitat preferences and the effect of environmental changes have been made.

e. Requirements have been adopted for the CPCs to ensure that, from 1 January 2013, at least 5% of the fishing effort made by its longline vessels greater than 20 m length overall carry a scientific observer.

## 10. FUTURE DEVELOPMENTS

It is unlikely, in the near future at least, that there will be stock assessments for most of the bycatch species. The IATTC staff's experience with dolphins suggests that the task is not trivial if relatively high precision is required. In lieu of formal assessments, it may be possible to develop indices to assess trends in the populations of these species, which is currently undertaken for silky sharks.

An ecosystem-based approach to fisheries management may be best facilitated through a multi-faceted approach involving the development and monitoring of biologically and ecologically meaningful indicators for key indicator species and ecosystem integrity. Ecological indicators may be aggregate indices describing the structure of the entire ecosystem (*e.g.* diversity), or specific components (*e.g.* trophic level of the catch). Biological indicators may generally relate to single species—perhaps those of key ecological importance or 'keystone' species—and be in the form of commonly-used fishery reference points (*e.g.* $F_{MSY}$), CPUE, or other simple measures such as changes in size spectra. However, the indicator(s) used depend heavily on the reliability of the information available at the species to ecosystem level.

The distributions of the fisheries for tunas and billfishes in the EPO are such that several regions with different ecological characteristics may be included. Within them, water masses, oceanographic or topographic features, influences from the continent, *etc*., may generate heterogeneity that affects the distributions of the different species and their relative abundances in the catches. It would be desirable to increase our understanding of these ecological strata so that they can be used in the analyses.

It is important to continue studies of the ecosystems in the EPO. The power to resolve issues related to fisheries and the ecosystem will increase with the number of habitat variables, taxa, and trophic levels studied and with longer time series of data.

Future ecosystem work is described in the IATTC Strategic Science Plan (SAC-09-01) and staff activities report (SAC-09-02). Briefly, this work will include improving ERAs, developing and maintaining databases of key biological and ecological parameters (*e.g.* growth parameters), developing research proposals for biological sampling, ecosystem monitoring and field-based research on consumption and evacuation experiments, development of a spatially-explicit ecosystem model of the EPO and ecological indicators, and continued reporting of bycatch estimates.

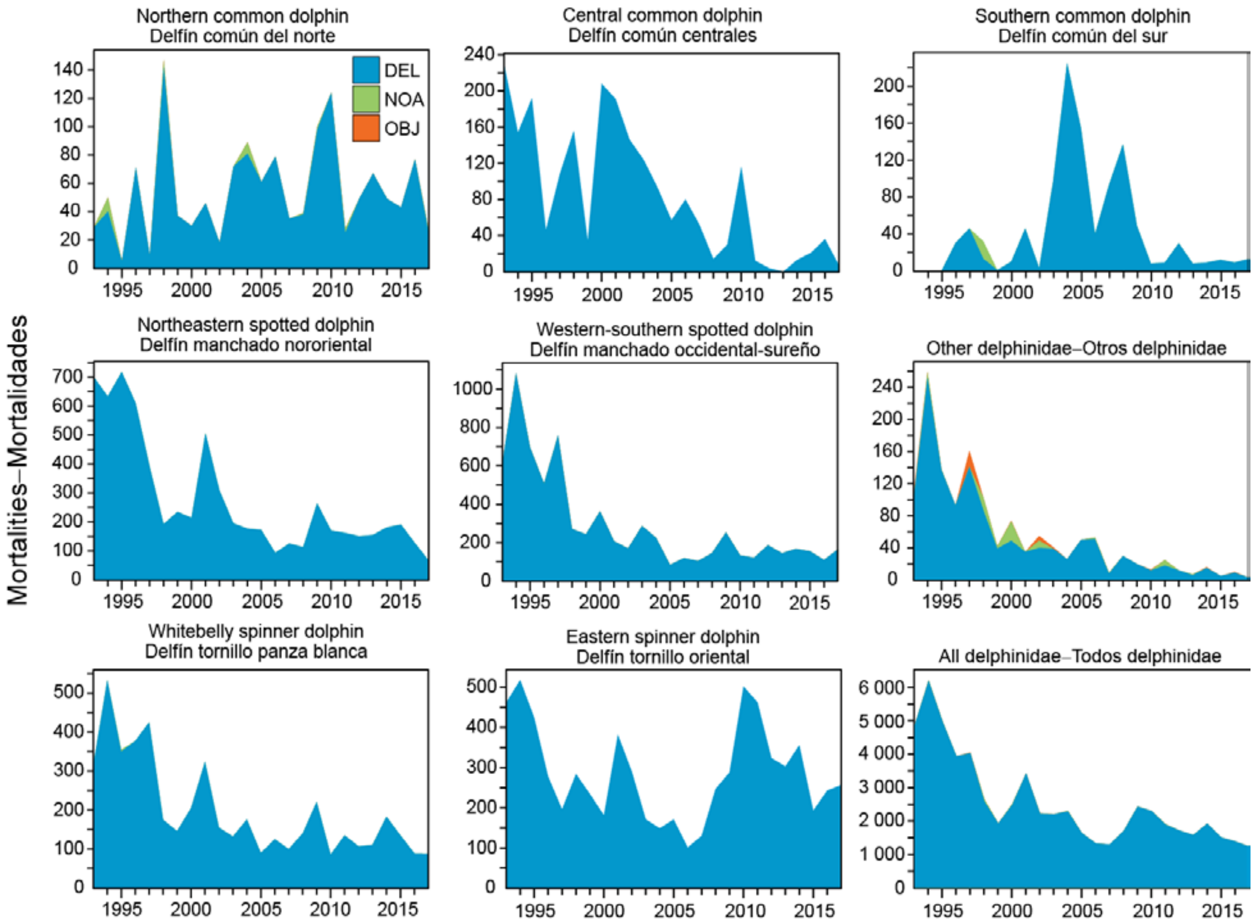


**FIGURE J-1**. Incidental dolphin mortalities, in numbers of animals, reported by observers aboard large purse-seine vessels, 1993-2017, by set type (dolphin (DEL), unassociated (NOA), floating object (OBJ)). Data for 2017 are preliminary.

**FIGURA J-1**. Mortalidades incidentales de delfines, en número de animales, reportadas por observadores a bordo de buques cerqueros grandes, 1993-2017, por tipo de lance (delfín (DEL), no asociado (NOA), objeto flotante (OBJ)). Los datos de 2017 son preliminares.

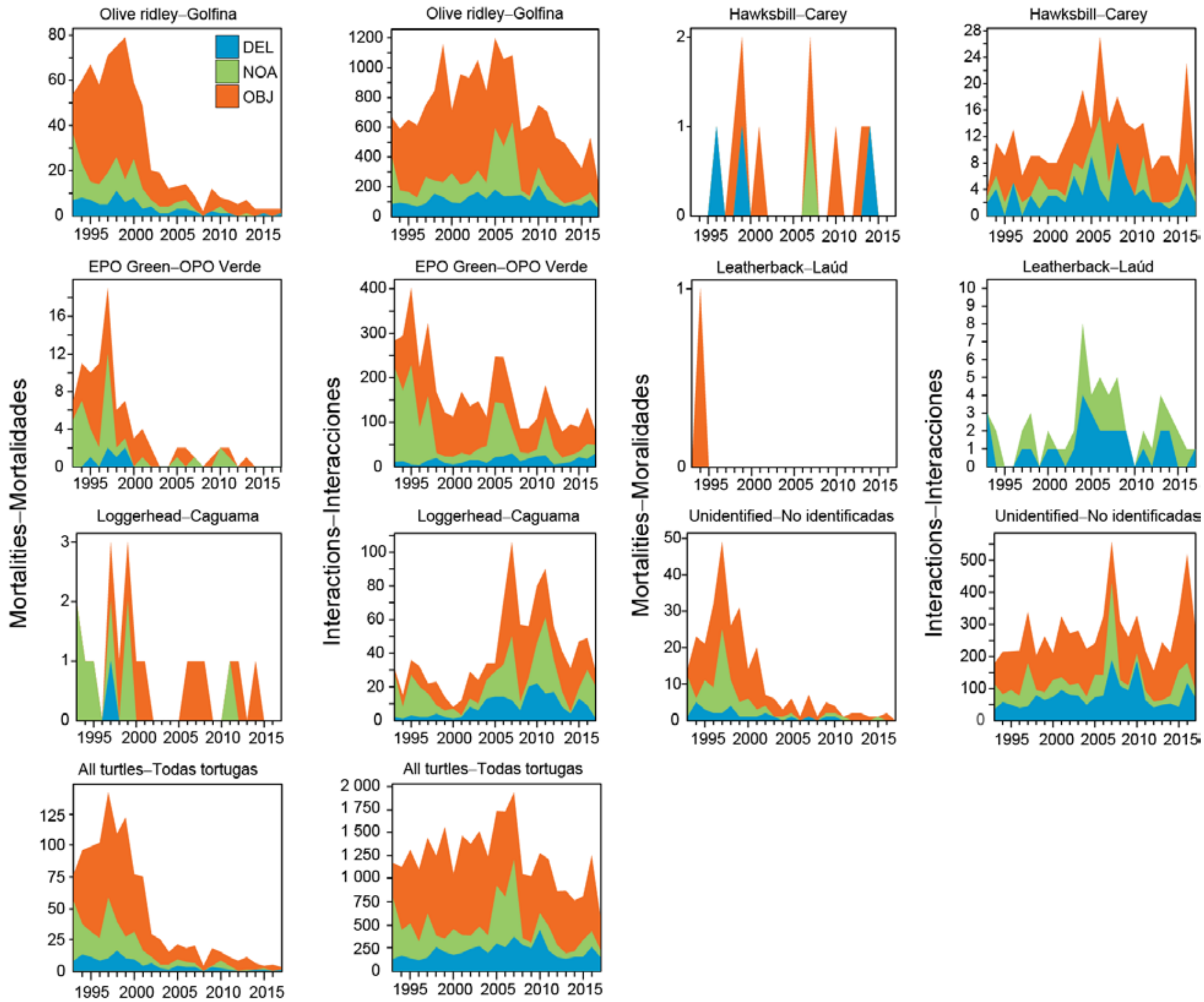


**FIGURE J-2**. Sea turtle interactions and mortalities, in numbers of animals, reported by observers aboard large purse-seine vessels, 1993-2017, by set type (dolphin (DEL), unassociated (NOA), floating object (OBJ)). Data for 2017 are preliminary.

**FIGURA J-2**. Interacciones y mortalidades incidentales de tortugas marinas, en número de animales, reportadas por observadores a bordo de buques cerqueros grandes, 1993-2017, por tipo de lance (delfín (DEL), no asociado (NOA), objeto flotante (OBJ)). Los datos de 2017 son preliminares.

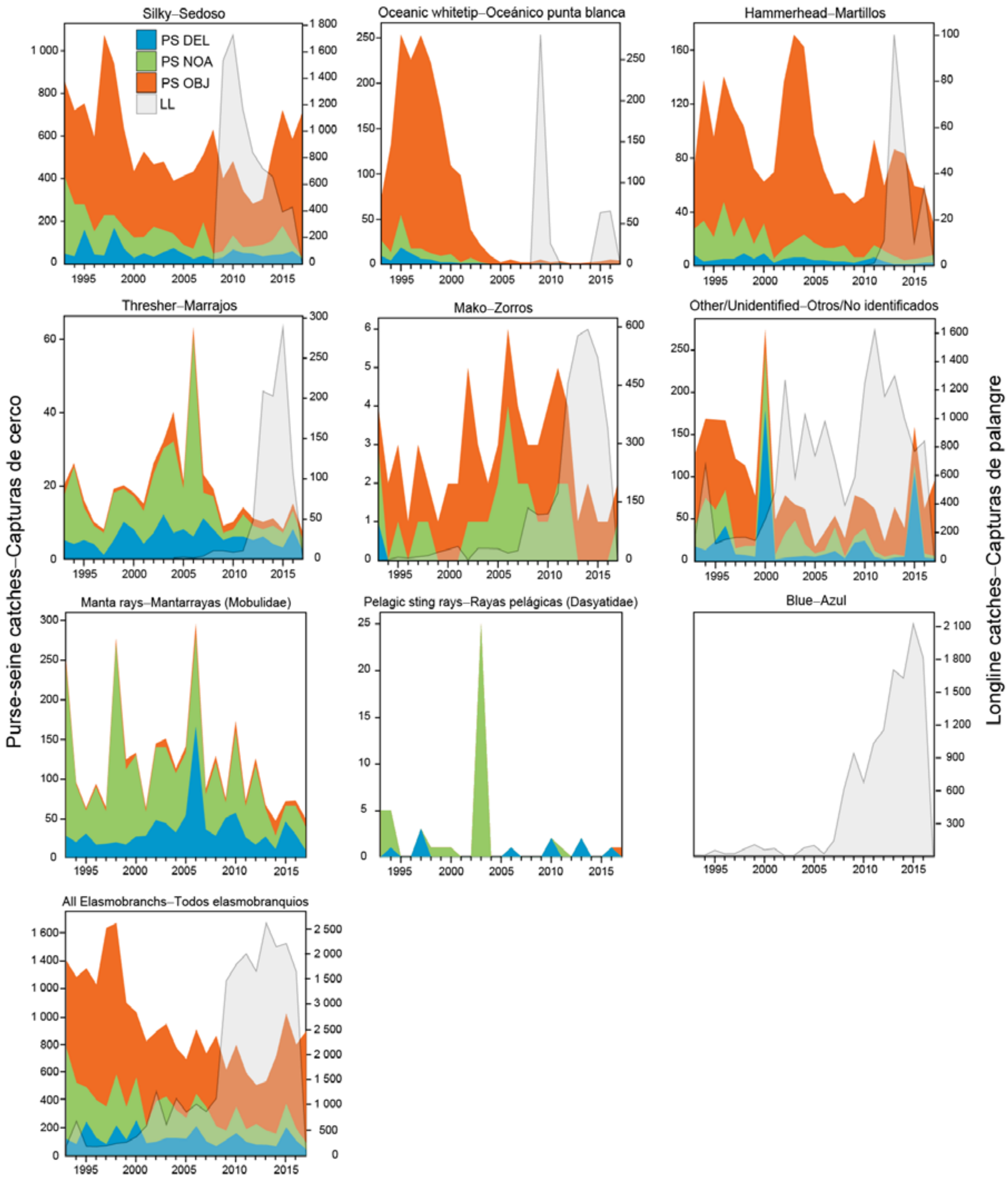


**FIGURE J-3.** Catches, in tons, of sharks and rays by large purse-seine vessels, 1993-2017, by set type (dolphin (DEL), unassociated (NOA), floating object (OBJ)) (left y-axis) and by longline vessels (LL), 1993-2016 (right y-axis). Purse-seine data for 2017 are preliminary; longline data for 2017 not available. See section 2.1 and SAC-08-07b for limitations associated with longline data.

**FIGURA J-3**. Capturas, en toneladas, de tiburones y rayas por buques cerqueros grandes, 1993-2017, por tipo de lance (delfín (DEL), no asociado (NOA), objeto flotante (OBJ)) (eje *y* izquierdo) y por buques palangreros (LL) 1993-2016 (eje *y* derecho). Los datos de cerco de 2017 son preliminares; datos de palangre para 2017 no disponibles. Ver sección 2.1 y SAC-08-07b para limitaciones asociadas a los datos de palangre.

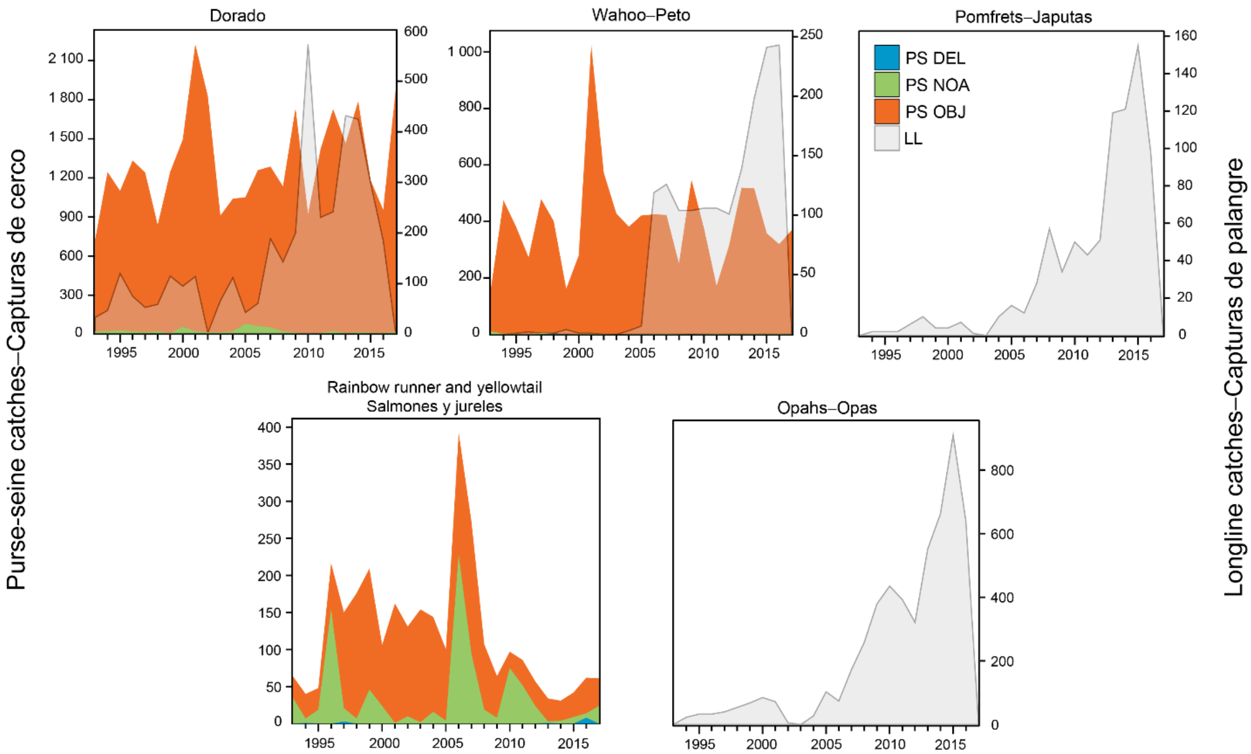


**FIGURE J-4.** Catches, in tons, of commonly-caught fishes by large purse-seine vessels, 1993-2017, by set type (dolphin (DEL), unassociated (NOA), floating object (OBJ)) (left y-axis) and by longline vessels (LL), 1993-2016 (right y-axis). Purse-seine data for 2017 are preliminary; longline data for 2017 not available. See section 2.1 and SAC-08-07b for limitations associated with longline data.

**FIGURA J-4**. Capturas, en toneladas, de peces capturados comúnmente por buques cerqueros grandes, 1993-2017, por tipo de lance (delfín (DEL), no asociado (NOA), objeto flotante (OBJ)) (eje *y* izquierdo) y por buques palangreros (LL) 1993-2016 (eje *y* derecho). Los datos de cerco de 2017 son preliminares; datos de palangre para 2017 no disponibles. Ver sección 2.1 y SAC-08-07b para limitaciones asociadas a los datos de palangre.

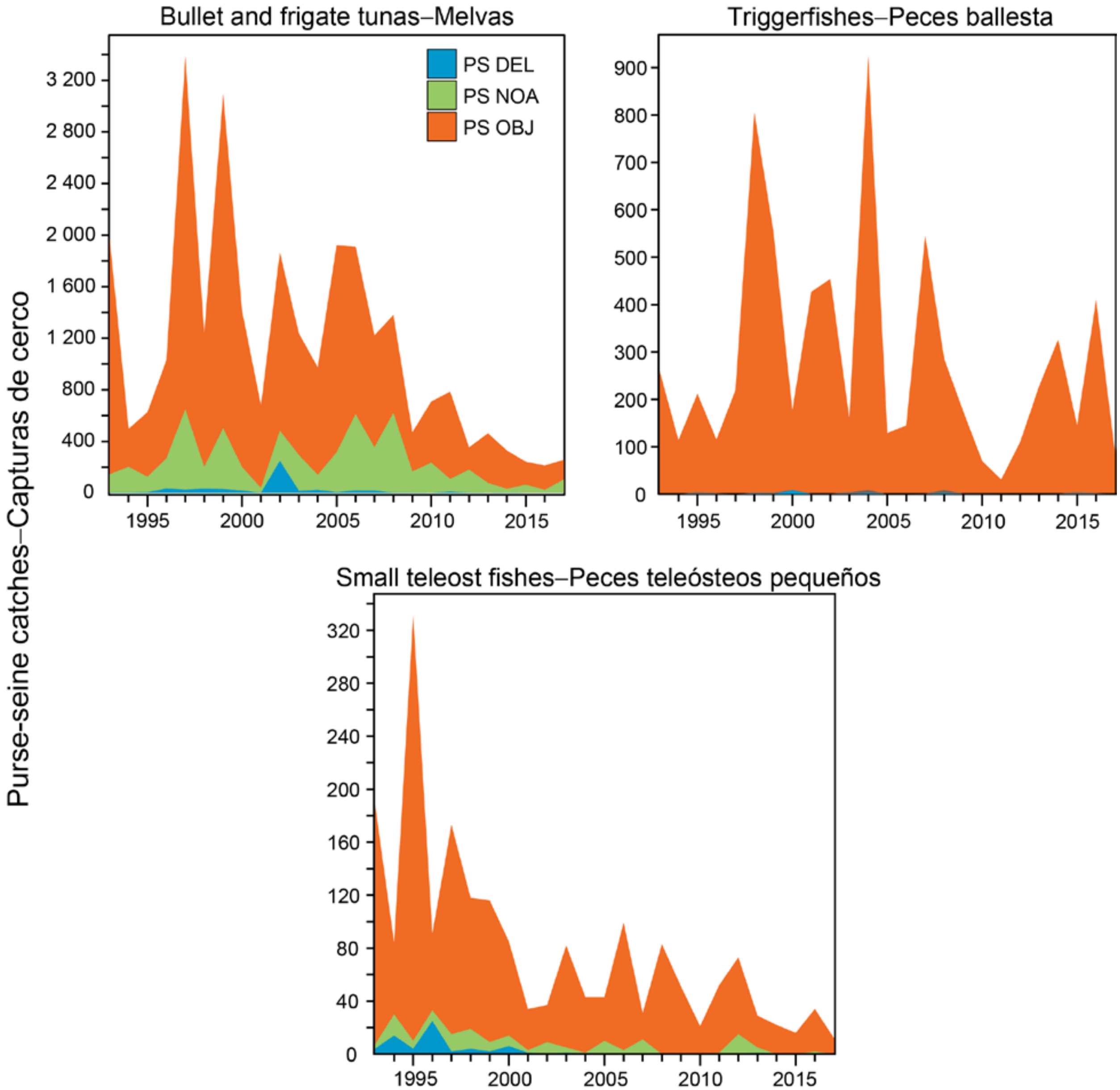


**FIGURE J-5.** Catches, in tons, of forage fishes by large purse-seine vessels, 1993-2017, by set type (dolphin (DEL), unassociated (NOA), floating object (OBJ)). Data for 2017 are preliminary.

**FIGURA J-5**. Capturas, en toneladas, de peces de alimento por buques cerqueros grandes, 1993-2017, por tipo de lance (delfín (DEL), no asociado (NOA), objeto flotante (OBJ)). Los datos de 2017 son preliminares.

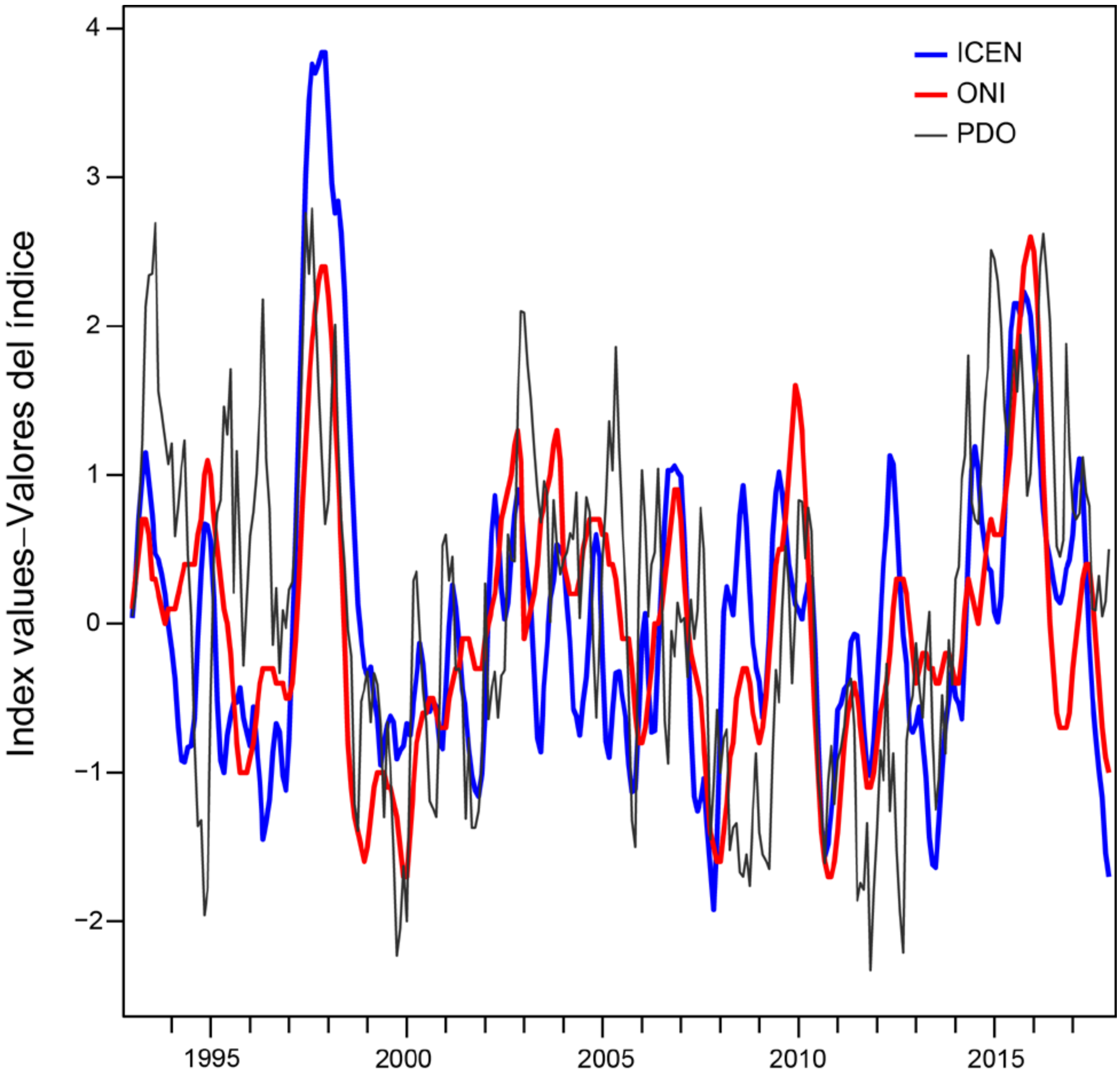


**FIGURE J-6.** Oceanographic indices used to characterize SST anomalies and El Niño-Southern Oscillation (ENSO) events in the Pacific Ocean, 1993-2017. ICEN: Índice Costero El Niño; ONI: Oceanic Niño Index; PDO: Pacific Decadal Oscillation. See section 5 of text for details.

**FIGURA J-6.** Índices oceanográficos usados para caracterizar las anomalías de las TSM y los eventos de El Niño-Oscilación del Sur (ENOS) en el Océano Pacífico, 1993-2017. ICEN: Índice Costero El Niño; ONI: Índice Oceánico del Niño; PDO: Oscilación Decadal del Pacífico. Ver detalles en la sección 5 del texto.

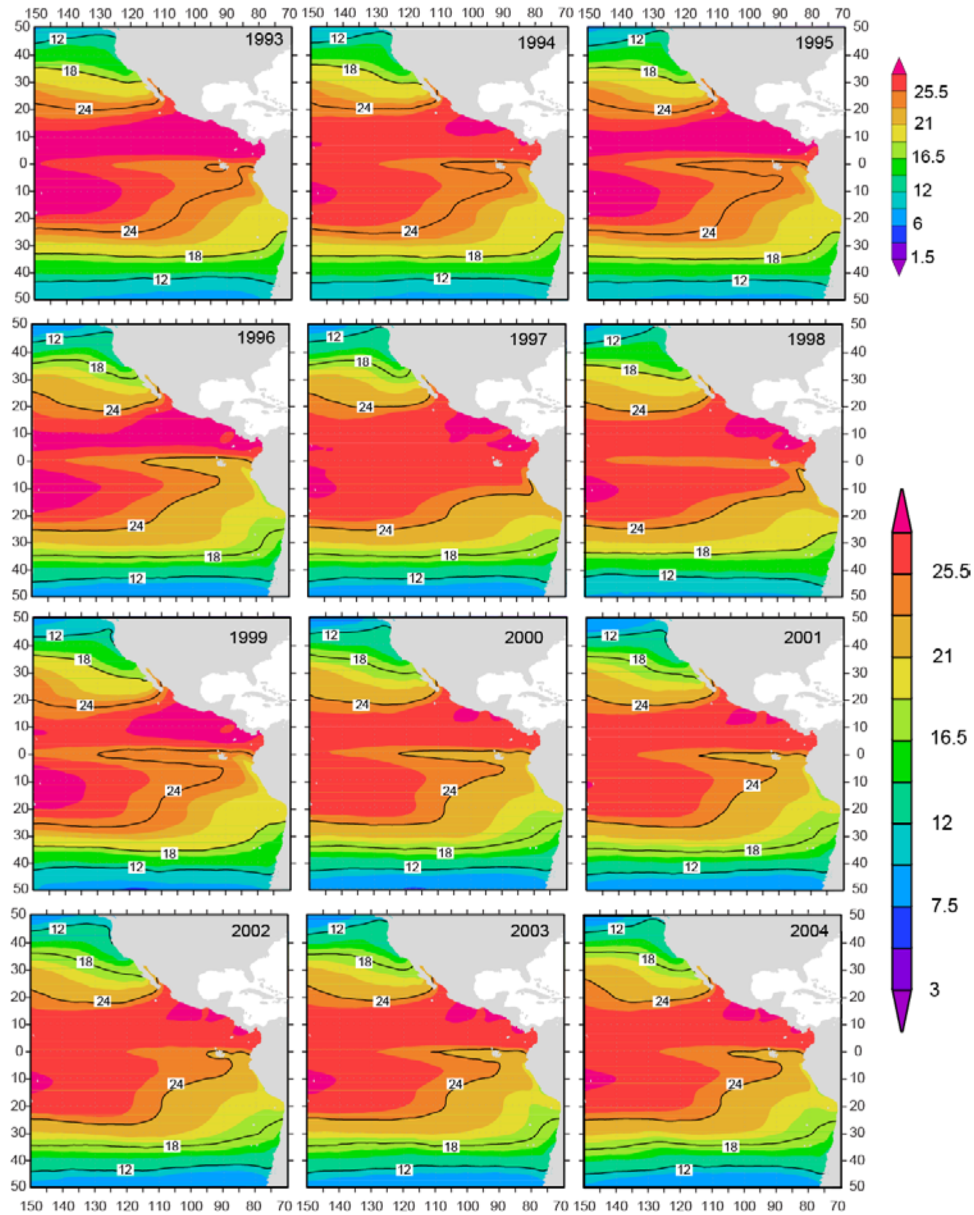


**FIGURE J-7a.** Mean annual SSTs in the EPO, 1993-2004. See section 5 of text for details.
**FIGURA J-7a.** TSM anuales medias en el OPO, 1993-2004. Ver detalles en la sección 5 del texto.

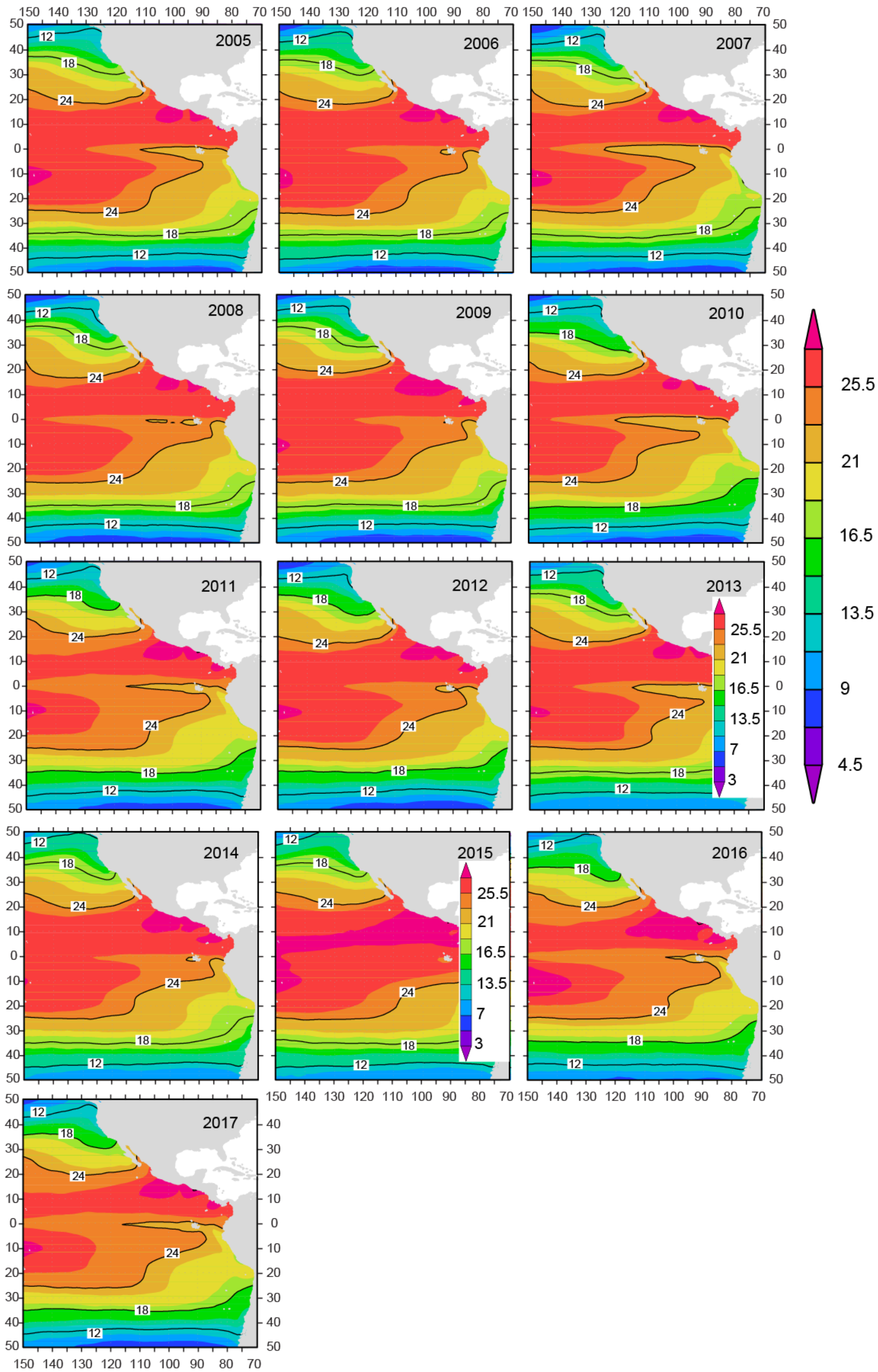


**FIGURE J-7b.** Mean annual SSTs in the EPO, 2005-2017. See section 5 of text for details.
**FIGURA J-7b.** TSM anuales medias en el OPO, 2005-2017. Ver detalles en la sección 5 del texto.

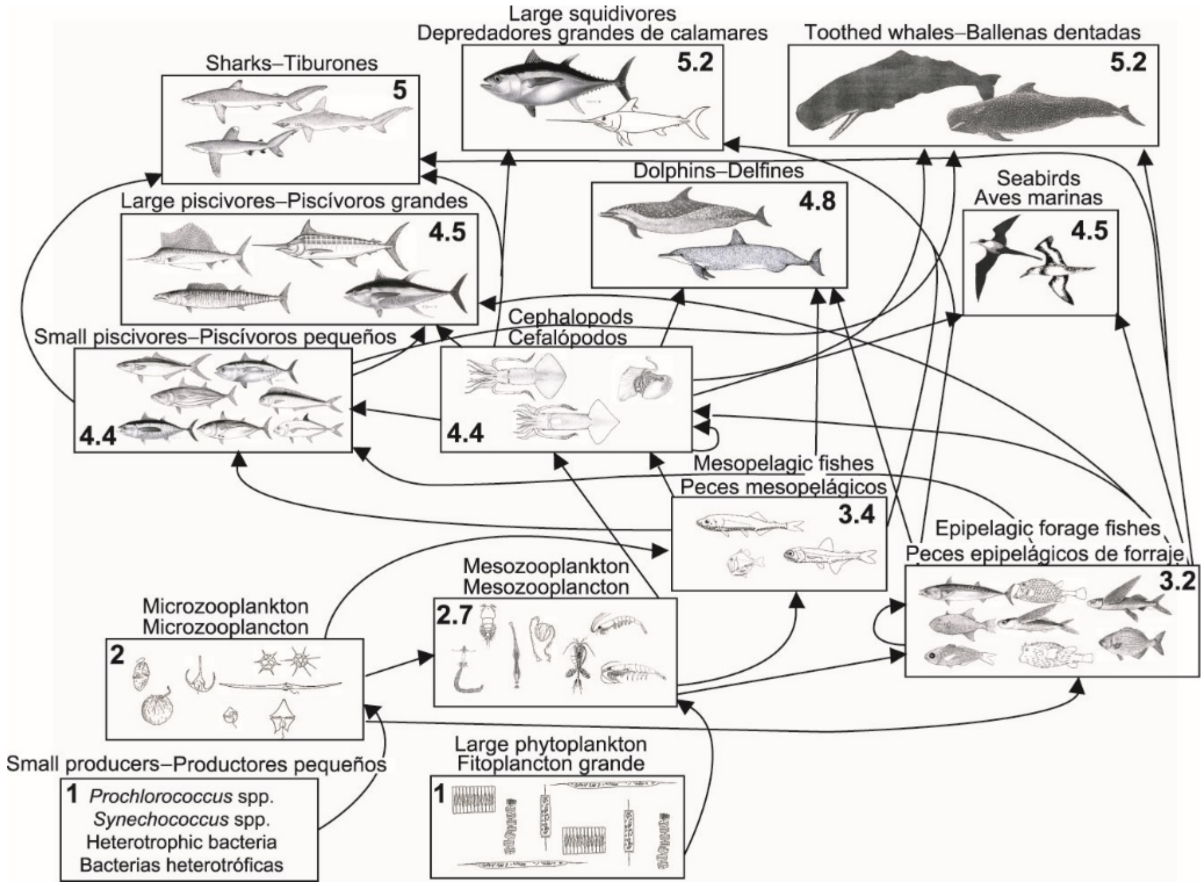


**FIGURE J-8.** Simplified food-web diagram of the pelagic ecosystem in the tropical EPO. The numbers inside the boxes indicate the approximate trophic level of each group.

**FIGURA J-8.** Diagrama simplificado de la red trófica del ecosistema pelágico en el OPO tropical. Los números en los recuadros indican el nivel trófico aproximado de cada grupo.

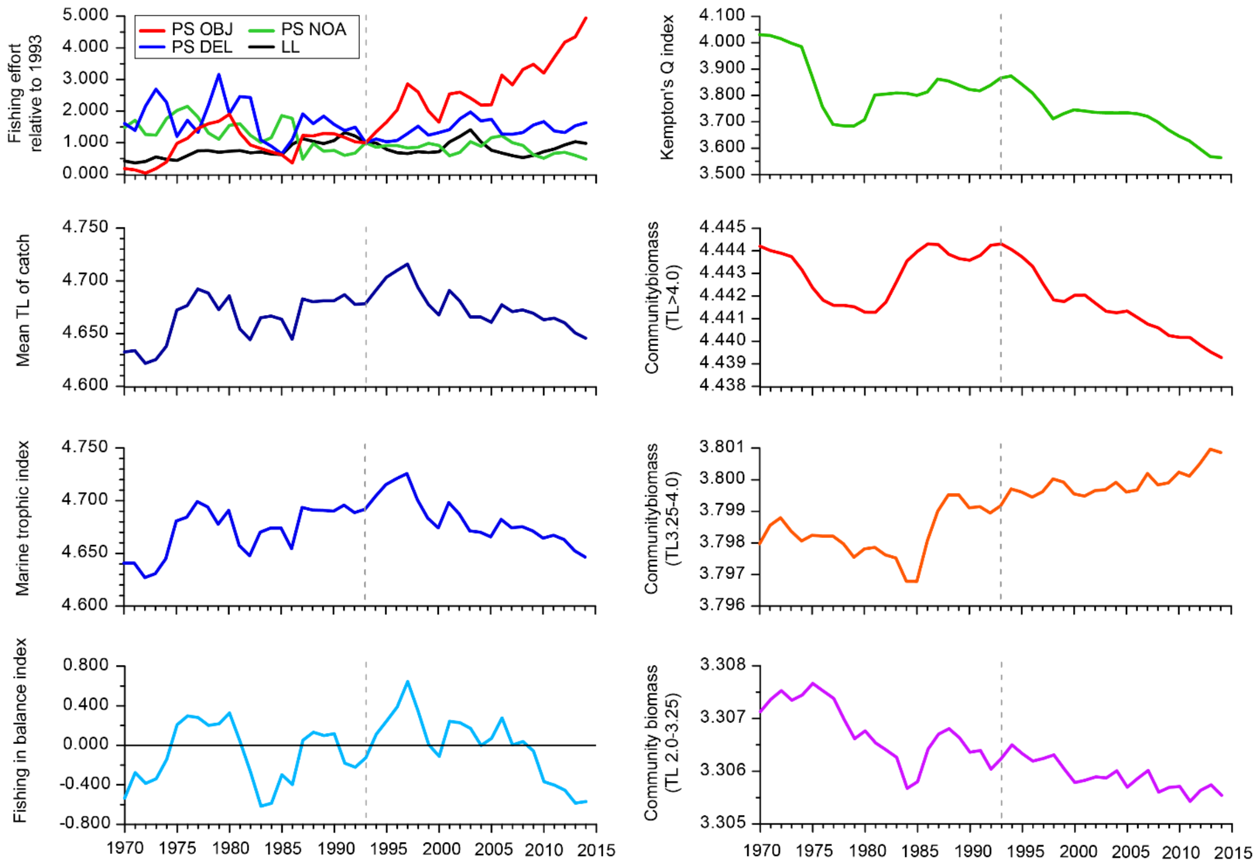


**FIGURE J-9.** Annual values for seven ecological indicators of changes in different components of the tropical EPO ecosystem, 1970-2014 (see Section 6 of text for details), and an index of longline (LL) and purse-seine (PS) fishing effort, by set type (dolphin (DEL), unassociated (NOA), floating object (OBJ)), relative to the model start year of 1993 (vertical dashed line), when the expansion of the purse-seine fishery on FADs began.

**FIGURA J-9.** Valores anuales de siete indicadores ecológicos de cambios en diferentes componentes del ecosistema tropical del OPO, 1970-2014 (ver detalles en la sección 6 del texto), y un índice de esfuerzo palangrero (LL) y cerquero (PS), por tipo de lance (delfín (DEL), no asociado (NOA), objeto flotante (OBJ)) relativo al año de inicio del modelo de 1993 (línea de trazos vertical), cuando comenzó la expansión de la pesquería cerquera sobre plantados.

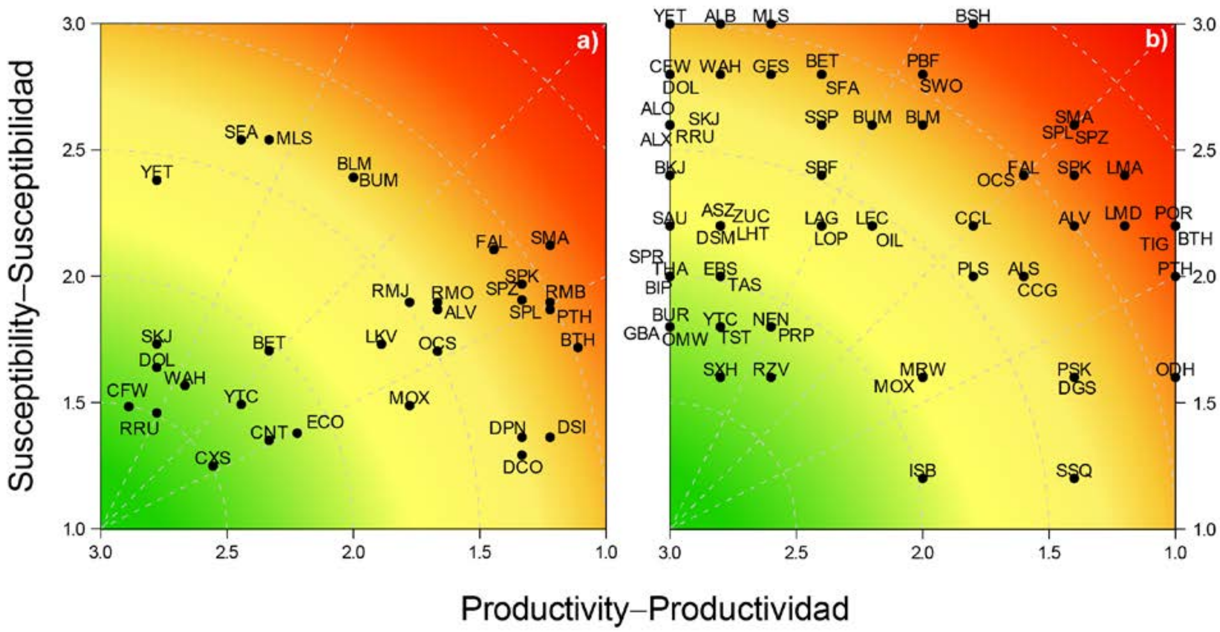


**FIGURE J-10.** Productivity and susceptibility x-y plot for target and bycatch species caught by the purse-seine fishery (a) and the longline fishery (b) in the EPO during 2005-2013 and 2017, respectively. See Tables J-1 and J-2 for species codes for each fishery.

**FIGURA J-10.** Gráfica x-y de productividad y susceptibilidad de especies objetivo y de captura incidental capturadas por la pesquería cerquera (a) y la pesquería palangrera (b) en el OPO durante 2005-2000 y 2017, respectivamente. Ver códigos de especies para cada pesquería en las Tablas J-1 y J-2.

**TABLE J-1.** Productivity (*p*) and susceptibility (*s*) scores used to compute the overall vulnerability measure *v*. Susceptibility (*s*) scores are shown for each fishery (dolphin (DEL), unassociated (NOA), floating object (OBJ)) and as a weighted combination of the individual fishery values. Vulnerability scores rated as low (green), medium (yellow), and high (red)

**TABLA J-1.** Puntuaciones de productividad (*p*) y susceptibilidad (*s*) usadas para computar la medida general de vulnerabilidad *v*. D. Se señalan las puntuaciones de susceptibilidad para cada pesquería (DEL: delfín; NOA: no asociada; OBJ: objeto flotante) y como combinación ponderada de los valores de las pesquerías individuales. Puntuaciones de vulnerabilidad clasificadas de baja (verde), mediana (amarillo), y alta (rojo).

| Group | Scientific name | Common name | Nombre común | Code | *s* by fishery *s* por pesquería | | | *p* | *s* | *v* |
|---|---|---|---|---|---|---|---|---|---|---|
| Grupo | Nombre científico | | | Código | DEL | NOA | OBJ | | | |
| Tunas | *Thunnus albacares* | Yellowfin tuna | Atún aleta amarilla | YFT | 2.38 | 2.38 | 2.38 | 2.78 | 2.38 | 1.4 |
| Atunes | *Thunnus obesus* | Bigeye tuna | Atún patudo | BET | 1 | 2.23 | 2.38 | 2.33 | 1.7 | 0.97 |
| | *Katsuwonus pelamis* | Skipjack tuna | Atún barrilete | SKJ | 1 | 2.38 | 2.38 | 2.78 | 1.73 | 0.76 |
| Billfishes | *Makaira nigricans* | Blue marlin | Marlín azul | BUM | 2.23 | 2.23 | 2.69 | 2 | 2.39 | 1.71 |
| Peces picudos | *Istiompax indica* | Black marlin | Marlín negro | BLM | 2.23 | 2.23 | 2.69 | 2 | 2.39 | 1.71 |
| | *Kajikia audax* | Striped marlin | Marlín rayado | MLS | 2.54 | 2.54 | 2.54 | 2.33 | 2.54 | 1.68 |
| | *Istiophorus platypterus* | Indo-Pacific sailfish | Pez vela indopacífico | SFA | 2.54 | 2.54 | 2.54 | 2.44 | 2.54 | 1.64 |
| Dolphins | *Stenella longirostris* | Unidentified spinner dolphin | Delfín tornillo no identificado | DSI | 1.77 | 1 | 1 | 1.22 | 1.36 | 1.82 |
| Delfines | *Stenella attenuata* | Unidentified spotted dolphin | Delfín manchado no identificado | DPN | 1.77 | 1 | 1 | 1.33 | 1.36 | 1.71 |
| | *Delphinus delphis* | Common dolphin | Delfín común | DCO | 1.62 | 1 | 1 | 1.33 | 1.29 | 1.7 |
| Large fishes | *Coryphaena hippurus* | Common dolphinfish | Dorado | DOL | 1 | 2 | 2.31 | 2.78 | 1.64 | 0.68 |
| Peces grandes | *Coryphaena equiselis* | Pompano dolphinfish | Dorado pompano | CFW | 1 | 1 | 2.38 | 2.89 | 1.48 | 0.5 |
| | *Acanthocybium solandri* | Wahoo | Peto | WAH | 1 | 1 | 2.62 | 2.67 | 1.57 | 0.66 |
| | *Elagatis bipinnulata* | Rainbow runner | Salmón | RRU | 1 | 1 | 2.31 | 2.78 | 1.46 | 0.51 |
| | *Mola mola* | Ocean sunfish, Mola | Pez luna | MOX | 1 | 1.92 | 1.92 | 1.78 | 1.49 | 1.31 |
| | *Caranx sexfasciatus* | Bigeye trevally | Jurel voráz | CXS | 1 | 2.38 | 1 | 2.56 | 1.25 | 0.51 |
| | *Seriola lalandi* | Yellowtail amberjack | Medregal rabo amarillo | YTC | 1 | 2.08 | 1.85 | 2.44 | 1.49 | 0.75 |
| Rays | *Manta birostris* | Giant manta | Mantarraya gigante | RMB | 1.92 | 2.08 | 1.77 | 1.22 | 1.9 | 1.99 |
| Rayas | *Mobula japanica* | Spinetail manta | | RMJ | 1.92 | 2.08 | 1.77 | 1.78 | 1.9 | 1.51 |
| | *Mobula thurstoni* | Smoothtail manta | | RMO | 1.92 | 2.08 | 1.77 | 1.67 | 1.9 | 1.6 |
| Sharks | *Carcharhinus falciformis* | Silky shark | Tiburón sedoso | FAL | 2.08 | 2.08 | 2.15 | 1.44 | 2.1 | 1.91 |
| Tiburones | *Carcharhinus longimanus* | Oceanic whitetip shark | Tiburón oceánico punta blanca | OCS | 1.69 | 1 | 2.08 | 1.67 | 1.7 | 1.5 |
| | *Sphyrna zygaena* | Smooth hammerhead shark | Cornuda común | SPZ | 1.77 | 1.92 | 2.08 | 1.33 | 1.91 | 1.9 |
| | *Sphyrna lewini* | Scalloped hammerhead shark | Cornuda gigante | SPL | 1.77 | 1.92 | 2.08 | 1.33 | 1.91 | 1.9 |
| | *Sphyrna mokarran* | Great hammerhead shark | Cornuda cruz | SPK | 2.08 | 1.77 | 1.92 | 1.33 | 1.97 | 1.93 |
| | *Alopias pelagicus* | Pelagic thresher shark | Tiburón zorro pelágico | PTH | 1.92 | 1.92 | 1.77 | 1.22 | 1.87 | 1.98 |
| | *Alopias superciliosus* | Bigeye thresher shark | Tiburón zorro ojón | BTH | 1.77 | 2.08 | 1.46 | 1.11 | 1.72 | 2.02 |
| | *Alopias vulpinus* | Common thresher shark | Tiburón zorro | ALV | 1.92 | 1.92 | 1.77 | 1.67 | 1.87 | 1.59 |

| Group | Scientific name | Common name | Nombre común | Code | *s* by fishery / *s* por pesquería | | | *p* | *s* | *v* |
|---|---|---|---|---|---|---|---|---|---|---|
| Grupo | Nombre científico | | | Código | DEL | NOA | OBJ | | | |
| | *Isurus oxyrinchus* | Short fin mako shark | Tiburón marrajo dientuso | SMA | 2.23 | 2.23 | 1.92 | 1.22 | 2.12 | 2.1 |
| Small fishes | *Canthidermis maculatus* | Ocean triggerfish | Pez ballesta oceánico | CNT | 1 | 1 | 2 | 2.33 | 1.35 | 0.76 |
| Peces pequeños | *Sectator ocyurus* | Bluestriped chub | Chopa | ECO | 1 | 1 | 2.08 | 2.22 | 1.38 | 0.87 |
| Turtles-Tortugas | *Lepidochelys olivacea* | Olive ridley turtle | Tortuga golfina | LKV | 1.62 | 2.23 | 1.62 | 1.89 | 1.73 | 1.33 |

**TABLE J-2.** Species included in the productivity-susceptibility analysis for the large-scale tuna longline fishery in the eastern Pacific Ocean, showing average productivity (*p*) and susceptibility (*s*) scores used to compute the overall vulnerability score (*v*) for each species, rated as low (green), medium (yellow), and high (red).

**TABLA J-2.** Especies incluidas en el análisis de productividad-susceptibilidad de la pesquería atunera palangrera a gran escala en el Océano Pacífico oriental. indicado las puntuaciones promedio de productividad (*p*) y susceptibilidad (*s*) usadas para calcular la puntuación general de vulnerabilidad (*v*) para cada especie, clasificada como baja (verde), mediana (amarillo), y alta (rojo).

| Group | Scientific name | Common name | Nombre común | Code | *p* | *s* | *v* |
|---|---|---|---|---|---|---|---|
| Grupo | Nombre científico | | | Código | | | |
| Billfishes | *Istiompax indica* | Black marlin | Marlín negro | BLM | 2.00 | 2.60 | 1.89 |
| Peces picudos | *Istiophorus platypterus* | Indo-Pacific sailfish | Pez vela indopacífico | SFA | 2.40 | 2.80 | 1.90 |
| | *Kajikia audax* | Striped marlin | Marlín rayado | MLS | 2.60 | 3.00 | 2.04 |
| | *Makaira nigricans* | Blue marlin | Marlín azul | BUM | 2.20 | 2.60 | 1.79 |
| | *Tetrapturus angustirostris* | Shortbill spearfish | Marlín trompa corta | SSP | 2.40 | 2.60 | 1.71 |
| | *Xiphias gladius* | Swordfish | Pez espada | SWO | 2.00 | 2.80 | 2.06 |
| Tunas | *Katsuwonus pelamis* | Skipjack | Barrilete | SKJ | 3.00 | 2.60 | 1.60 |
| Atunes | *Thunnus alalunga* | Albacore | Albacora | ALB | 2.80 | 3.00 | 2.01 |
| | *Thunnus albacares* | Yellowfin | Aleta amarilla | YFT | 3.00 | 3.00 | 2.00 |
| | *Thunnus maccoyii* | Southern bluefin | Aleta azul del sur | SBF | 2.40 | 2.40 | 1.52 |
| | *Thunnus obesus* | Bigeye | Patudo | BET | 2.40 | 2.80 | 1.90 |
| | *Thunnus orientalis* | Pacific bluefin | Aleta azul del Pacífico | PBF | 2.00 | 2.80 | 2.06 |
| Elasmobranchs | *Alopias pelagicus* | Pelagic thresher shark | Zorro pelágico | PTH | 1.00 | 2.00 | 2.24 |
| Elasmobranquios | *Alopias superciliosus* | Bigeye thresher shark | Zorro ojón | BTH | 1.00 | 2.20 | 2.33 |
| | *Alopias vulpinus* | Common thresher shark | Zorro | ALV | 1.40 | 2.20 | 2.00 |
| | *Carcharhinus albimarginatus* | Silvertip shark | Tiburón de puntas blancas | ALS | 1.60 | 2.00 | 1.72 |
| | *Carcharhinus falciformis* | Silky shark | Tiburón sedoso | FAL | 1.60 | 2.40 | 1.98 |
| | *Carcharhinus galapagensis* | Galapagos shark | Tiburón de Galápagos | CCG | 1.60 | 2.00 | 1.72 |
| | *Carcharhinus limbatus* | Blacktip shark | Tiburón macuira | CCL | 1.80 | 2.20 | 1.70 |

| Group<br>Grupo | Scientific name<br>Nombre científico | Common name | Nombre común | Code<br>Código | *p* | *s* | *v* |
|---|---|---|---|---|---|---|---|
| | *Carcharhinus longimanus* | Oceanic whitetip shark | Tiburón oceánico punta blanca | OCS | 1.60 | 2.40 | 1.98 |
| | *Galeocerdo cuvier* | Tiger shark | Tintorera tigre | TIG | 1.00 | 2.20 | 2.33 |
| | *Prionace glauca* | Blue shark | Tiburón azul | BSH | 1.80 | 3.00 | 2.33 |
| | *Pteroplatytrygon violacea* | Pelagic stingray | | PLS | 1.80 | 2.00 | 1.56 |
| | *Isurus oxyrinchus* | Shortfin mako shark | Marrajo dientuso | SMA | 1.40 | 2.60 | 2.26 |
| | *Isurus paucus* | Longfin mako shark | Marrajo carite | LMA | 1.20 | 2.40 | 2.28 |
| | *Lamna ditropis* | Salmon shark | Marrajo salmón | LMD | 1.20 | 2.20 | 2.16 |
| | *Lamna nasus* | Porbeagle shark | Marrajo sardinero | POR | 1.00 | 2.20 | 2.33 |
| | *Odontaspis noronhai* | Bigeye sand tiger shark | Solrayo ojigrande | ODH | 1.00 | 1.60 | 2.09 |
| | *Pseudocarcharias kamoharai* | Crocodile shark | Tiburón cocodrilo | PSK | 1.40 | 1.60 | 1.71 |
| | *Sphyrna lewini* | Scalloped hammerhead shark | Cornuda común | SPL | 1.40 | 2.60 | 2.26 |
| | *Sphyrna mokarran* | Great hammerhead | Cornuda gigante | SPK | 1.40 | 2.40 | 2.13 |
| | *Sphyrna zygaena* | Smooth hammerhead | Cornuda cruz | SPZ | 1.40 | 2.60 | 2.26 |
| | *Isistius brasiliensis* | Cookie cutter shark | Tollo cigarro | ISB | 2.00 | 1.20 | 1.02 |
| | *Squalus acanthias* | Picked dogfish, Spiny dogfish | Mielga | DGS | 1.40 | 1.60 | 1.71 |
| | *Zameus squamulosus* | Velvet dogfish | | SSQ | 1.40 | 1.20 | 1.61 |
| Mesopelagic fishes Peces mesopelágicos | *Alepisaurus brevirostris* | Short snouted lancetfish | | ALO | 3.00 | 2.60 | 1.60 |
| | *Alepisaurus ferox* | Long snouted lancetfish | Lanzón picudo | ALX | 3.00 | 2.60 | 1.60 |
| | *Eumegistus illustris* | Brilliant pomfret | | EBS | 2.80 | 2.00 | 1.02 |
| | *Taractes asper* | Rough pomfret | | TAS | 2.80 | 2.00 | 1.02 |
| | *Taractichthys steindchneri* | Sickle Pomfret | Tristón segador | TST | 2.80 | 1.80 | 0.82 |
| | *Gempylus serpens* | Snake mackerel | Escolar de canal | GES | 2.60 | 2.80 | 1.84 |
| | *Lepidocybium flavobrunneum* | Escolar | Escolar negro | LEC | 2.20 | 2.20 | 1.44 |
| | *Nesiarchus nasutus* | Black gemfish | Escolar narigudo | NEN | 2.60 | 1.80 | 0.89 |
| | *Promethichthys prometheus* | Roudi escolar | Escolar prometeo | PRP | 2.60 | 1.80 | 0.89 |
| | *Ruvettus pretiosus* | Oilfish | Escolar clavo | OIL | 2.20 | 2.20 | 1.44 |
| | *Lampris guttatus* | Opah | Opa | LAG | 2.40 | 2.20 | 1.34 |
| | *Lophotus capellei* | Crestfish | | LOP | 2.40 | 2.20 | 1.34 |
| | *Masturus lanceolatus* | Sharptail mola | | MRW | 2.00 | 1.60 | 1.17 |
| | *Mola mola* | Sunfish | Pez luna | MOX | 2.00 | 1.60 | 1.17 |
| | *Ranzania laevis* | Slender sunfish | | RZV | 2.60 | 1.60 | 0.72 |
| | *Omosudis lowii* | Omosudid (Hammerjaw) | | OMW | 3.00 | 1.80 | 0.80 |
| | *Scombrolabrax heterolepis* | Longfin escolar | | SXH | 2.80 | 1.60 | 0.63 |

| Group<br>Grupo | Scientific name<br>Nombre científico | Common name | Nombre común | Code<br>Código | *p* | *s* | *v* |
|---|---|---|---|---|---|---|---|
| | *Desmodema polystictum* | Polka-dot ribbonfish | | DSM | 2.80 | 2.20 | 1.22 |
| | *Zu cristatus* | Scalloped ribbonfish | | ZUC | 2.80 | 2.20 | 1.22 |
| | *Assurger anzac* | Razorback scabbardfish | Sable aserrado | ASZ | 2.80 | 2.20 | 1.22 |
| | *Trachipterus fukuzakii* | Tapertail ribbonfish | | LHT | 2.80 | 2.20 | 1.22 |
| Tuna-like species<br>Especies afines a los atunes | *Elagatis bipinnulata* | Rainbow runner | Salmón | RRU | 3.00 | 2.60 | 1.60 |
| | *Seriola lalandi* | Yellowtail amberjack | Medregal rabo amarillo | YTC | 2.80 | 1.80 | 0.82 |
| | *Opisthonema oglinum* | Atlantic thread herring | Machuelo hebra atlántico | THA | 3.00 | 2.00 | 1.00 |
| | *Sprattus sprattus* | European sprat | Espadín | SPR | 3.00 | 2.00 | 1.00 |
| | *Coryphaena equiselis* | Pompano dolphinfish | Dorado pompano | CFW | 3.00 | 2.80 | 1.80 |
| | *Coryphaena hippurus* | Common dolphinfish | Dorado | DOL | 3.00 | 2.80 | 1.80 |
| | *Pomadasys jubelini* | Sompat grunt | Ronco sompat | BUR | 3.00 | 1.80 | 0.80 |
| | *Scomberesox saurus* | Atlantic saury | Paparda del Atlántico | SAU | 3.00 | 2.20 | 1.20 |
| | *Acanthocybium solandri* | Wahoo | Peto | WAH | 2.80 | 2.80 | 1.81 |
| | *Euthynnus lineatus* | Black skipjack | Barrilete negro | BKJ | 3.00 | 2.40 | 1.40 |
| | *Sarda orientalis* | Striped bonito | Bonito mono | BIP | 3.00 | 2.00 | 1.00 |
| | *Sphyraena barracuda* | Great barracuda | Picuda barracuda | GBA | 3.00 | 1.80 | 0.80 |