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## TUNA AND BILLFISH IN THE EASTERN PACIFIC OCEAN

**INTRODUCTION**

This report is in preparation for the 70th meeting of the Inter-American Tropical Tuna Commission in June 2003.  It provides a summary of the fishery for tunas in the eastern Pacific Ocean, an assesment of the stocks of tunas and billfish which are exploited in the fishery and an appreciation of the pelagic ecosystem in the eastern Pacific.

The report is based on data available to the staff of the Commission in April 2003.

All tonnages are in metric tons (T).  The following abbreviations are used:

Species:

| | |
|---|---|
| ALB | Albacore tuna (*Thunnus alalunga*) |
| BEP | Bonito (*Sarda orientalis*) |
| BET | Bigeye tuna (*Thunnus obesus*) |
| BUM | Blue marlin (*Makaira nigricans*) |
| MLS | Striped marlin (*Tetrapturus audax*) |
| PBF | Pacific bluefin (*Thunnus orientalis*) |
| SKJ | Skipjack tuna (*Katsuwonus pelamis*) |
| SWF | Swordfish (*Xiphias gladius*) |
| YFT | Yellowfin tuna (*Thunnus albacares*) |

Fishing gears:

| | |
|---|---|
| LL | Longline |
| LP | Pole-and-line |
| PS | Purse seine |

Ocean areas:

| | |
|---|---|
| EPO | Eastern Pacific Ocean |
| WCPO | Western and Central Pacific Ocean |

Flags:

| | |
|---|---|
| BLZ | Belize |
| BOL | Bolivia |
| COL | Colombia |
| CRI | Costa Rica |
| ECU | Ecuador |
| ESP | Spain |
| GTM | Guatemala |
| HND | Honduras |
| JPN | Japan |
| KOR | Republic of Korea |
| MEX | Mexico |
| NIC | Nicaragua |
| PER | Peru |
| SLV | El Salvador |
| TWN | Taiwan |
| USA | United States of America |
| VEN | Venezuela |
| VUT | Vanuatu |

# A. THE FISHERY FOR TUNAS AND BILLFISHES IN THE EASTERN PACIFIC OCEAN IN 2002

## 1. THE SURFACE FLEET, AND CATCHES AND LANDINGS OF TUNAS AND BILLFISHES

### 1.1. The surface fleet

The IATTC maintains detailed records of gear, flag, and fish-carrying capacity for most of the vessels that fish with surface gear for yellowfin (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*), bigeye (*Thunnus obesus*), or Pacific bluefin (*T. orientalis*) tuna in the eastern Pacific Ocean (EPO). Historically, detailed records have not been maintained for most longline vessels, nor for sport-fishing vessels and small craft such as canoes and launches, though recently the staff began compiling and maintaining these records, and will continue to do so in the future. The fleet described here includes purse seiners and pole-and-line vessels (hereafter referred to as surface gear) that have fished all or part of the year in the EPO for these four species.

Historically the owner's or builder's estimates carrying capacities of individual vessels, in tons of fish, were used until landing records indicated that revision of these estimates was required. The vessels were grouped, by carrying capacity, originally in short tons and later in metric tons, into six size classes.

During the past several years the IATTC staff has used well volume, in cubic meters, instead of weight, in metric tons, to measure the carrying capacities of the vessels. Since a well can be loaded with different densities of fish, measuring carrying capacity in weight is subjective, as a load of fish packed into a well at a higher density weighs more than a load of fish packed at a lower density. Using volume as a measure of capacity eliminates this problem. The size classes and well volumes are as follows:

| Volume (cubic meters) | <53 | 53-106 | 107-212 | 213-319 | 320-425 | >425 |
|---|---|---|---|---|---|---|
| Class | 1 | 2 | 3 | 4 | 5 | 6 |

The IATTC staff began collecting capacity data by volume in 1999, but has not yet obtained this information for all vessels. For vessels for which reliable information on well volume is not available, a factor of 1.17 is used to convert the estimated capacity in metric tons to cubic meters. This conversion factor is consistent with the density at which the fish were packed into the wells of the vessels at the time that the size classification was developed. This conversion factor was also applied to all capacity data for 1961-1998 to facilitate comparisons among years (Table 1).

Until about 1960 fishing for tunas in the EPO was dominated by pole-and-line vessels operating in the more coastal regions and in the vicinity of offshore islands. During the late 1950s and early 1960s most of the larger pole-and-line vessels were converted to purse seiners, and by 1961 the EPO surface fleet was dominated by these vessels. From 1961 to 2001 the number of pole-and-line vessels decreased from 93 to 11, and their total well volume from about 11 to 1 thousand cubic meters ($m^3$). During the same period the number of purse seiners increased from 125 to 203, and their total well volume from about 32 thousand to 189 thousand $m^3$, an average of about 933 $m^3$ per vessel. An earlier peak in numbers and total well volume of purse seiners occurred from the mid-1970s to the early 1980s, when the number of vessels reached 282 and the total well volume about 196 thousand $m^3$, an average of about 693 $m^3$ per vessel.

The construction of new purse seiners, which began during the mid-1960s, resulted in an increase in the total well volume of the surface fleet from about 49 thousand $m^3$ in 1966 to about 195 thousand $m^3$ in 1976. From 1976 to 1981 the total well volume increased slightly. The construction of new vessels continued, but this was mostly offset by losses due to sinkings and vessels leaving the fishery. The catch

rates in the EPO were low during 1978-1981 due to concentration of fishing effort on small fish, and the situation was exacerbated by a major El Niño event, which began in mid-1982 and persisted until late 1983 and made the fish less vulnerable to capture. The total well volume then declined as vessels were deactivated or left the EPO to fish in other areas, primarily the western Pacific Ocean, and in 1984 it reached its lowest level since 1971, about 125 thousand m$^3$. In early 1990 the U.S. tuna-canning industry adopted a policy of not purchasing tunas caught during trips during which sets on tunas associated with dolphins were made. This caused many U.S.-flag vessels to leave the EPO, with a consequent reduction in the fleet to about 119 thousand m$^3$ in 1992. With increases in participation of vessels of other nations in the fishery, the total well volume has increased steadily since 1992, and in 2001 was 191 thousand m$^3$.

The 2001 and preliminary 2002 data for numbers and total well volumes of purse seiners and pole-and-line vessels that fished for tunas in the EPO are shown in Tables 2a and 2b. The fleet was dominated by vessels operating under the Mexican and Ecuadorian flags during 2002. The Mexican fleet, which has been the largest fleet since 1987, had about 24% of the total well volume during 2002, while vessels registered in Ecuador, Venezuela, Spain, and Panama comprised about 24, 15, 6, and 6% of the total well volume, respectively.

Class-6 purse seiners made up about 90% of the total well volume of the surface gear operating in the EPO during 2002.

## 1.2. Catches and landings

### 1.2.a.  Tunas

#### 1.2.a.1  Surface catches

Estimates of the catches and landings of tunas come from several sources, including logbooks kept by the fishermen, data recorded by observers aboard the vessels, unloading data provided by canneries and other processors, and export and import records. All data for 2002 are provisional. Estimating the total catch for a fishery is difficult, however, due to the lack of information on fish that are caught, but, for various reasons, discarded at sea. Data on fish discarded at sea by Class-6 vessels have been collected by observers since 1993. This information allows for better estimation of the total amounts of fish caught by the surface fleet. Estimates of the total amount of catch that is landed (hereafter referred to as retained catch) are based principally on data from unloadings. Annual estimates of the retained and discarded catches of the various species of tunas captured by vessels of the EPO surface fleet are shown in Table 3, which also includes catch data for U.S.-flag sport-fishing vessels and other miscellaneous types of surface gear. In the case of bluefin, the recreational catches have become an increasingly important component of the total catch in recent years.

The average annual retained catch of yellowfin in the EPO by surface gear during 1987-2001 was 268 thousand T (range: 219 to 396 thousand T). The preliminary estimate of the retained catch of yellowfin in 2002, 419 thousand T, is the greatest on record, exceeding the average for 1987-2001 by 56%. The average amount of yellowfin discarded at sea by the surface fisheries during 1993-2002 was about 2.1% (range: 0.9 to 2.6%) of the total surface catch of yellowfin (retained catch plus discards).

During 1987-2001 the annual retained catch of skipjack from the EPO averaged 120 thousand T (range: 62 to 266 thousand T). The preliminary estimate of the retained catch of skipjack in 2002, 158 thousand T, is less than those of 1999 and 2000, but 32% greater than the average for 1987-2001. The average amount of skipjack discarded at sea during 1993-2002 was about 11.8% (range: 7.5 to 18.2%) of the total catch of skipjack.

Prior to 1994 the average annual retained catch of bigeye in the EPO by surface gear was about 5 thousand T (range: <1 to 15 thousand T). After 1993 the annual retained catches increased from 29 thousand T in 1994 to 35 to 52 thousand T during 1995-1999 to a record high 70 thousand T in 2000. The catch of

bigeye decreased to 43 thousand T in 2001 and the preliminary estimate of the retained catch of bigeye in the EPO in 2002 is 35 thousand T.  These increasing catches of bigeye followed the development of fish-aggregating devices (FADs) placed in the water by fishermen to aggregate tunas.  The average amount of bigeye discarded at sea by the surface fisheries during 1993-2002 was about 7.4% (range: 2.7 to 11.3%) of the total surface catch of bigeye.  Small bigeye and yellowfin tuna are difficult to identify. A scientific species-composition sampling scheme has been carried out since 2000 that provides larger estimates of purse-seine catches of bigeye tuna.

While yellowfin, skipjack, and bigeye comprise the most significant portion of the retained catches of the surface fleet in the EPO, bluefin, albacore (*Thunnus alalunga*), black skipjack (*Euthynnus lineatus)*, bonito (*Sarda orientalis)*, and other species contribute to the overall harvest in this area.  The total retained catch of these other species by these fisheries was about 4 thousand T in 2002, which is well below the 1987-2001 annual average retained catch of about 8 thousand T (range: 2 to 17 thousand T).  The estimated retained and discarded catches of these species for the 1993-2002 period are presented in Table 3.

The retained catches in the EPO during 2001, by flag, and the landings of EPO-caught tunas taken by surface gear in the EPO, by country, are given in Table 4a, and preliminary estimates of the equivalent data for 2002 are given in Table 4b.  The estimated retained catch of all species in the EPO during 2002 was about 616 thousand T, which was about 5% greater than that for 2001, 588 thousand T, and much greater than the average for 1987-2001 of 421 thousand T.  Ecuadorian- and Mexican-flag vessels harvested about 26 and 22% respectively, and Venezuelan-flag vessels about 20%, of the retained catches of all species made in 2002.  Other countries with significant catches were Colombia, Panama, and Spain (5% each).

The landings are fish unloaded from fishing vessels during a calendar year, regardless of the year of catch.  The country of landing is that in which the fish were unloaded or, in the case of transshipments, the country that received the transshipped fish.  Preliminary landings data (Table 4b) indicate that, of the 632 thousand T of tunas landed in 2002, 41% was landed in Ecuador and 25% in Mexico.  Other countries with significant landings of tunas caught in the EPO included Costa Rica (6%) and Colombia and Venezuela (5% each).  It is important to note that when final information is available the landings currently assigned to various countries may change due to exports from storage facilities to processors in other nations.

Tunas are caught by surface gear in three types of schools, those in which the fish are associated with dolphins, those in which the fish are associated with floating objects, such as flotsam or FADs, and those in which the fish are associated only with other fish (unassociated schools).  Estimates of the numbers of purse-seine sets of each type in the EPO during the 1988-2002 period, and the retained catches of these sets, are listed in Table 5.  The estimates for Class-1 to -5 vessels were calculated from logbook data in the IATTC statistical data base, and those for Class-6 vessels were calculated from logbook data and from the observer data bases of the IATTC, the Programa de Observadores Pesqueros de Ecuador (PROBECUADOR), the EU On-Board National Observer Program, the Programa Nacional de Aprovechamiento del Atún y de Protección de Delfines (PNAAPD) of Mexico, the U.S. National Marine Fisheries Service, and the Programa Nacional de Observadores de Venezuela (PNOV).  The greatest numbers of sets on schools associated with floating objects and on unassociated schools of tuna were made during the period from the mid-1970s to the early 1980s.  Despite opposition to fishing for tunas associated with dolphins and the refusal of U.S. canners to accept tunas caught during trips during which sets were made on dolphin-associated fish, the numbers of sets made on fish associated with dolphins decreased only moderately during the mid-1990s, and in 2002 were the greatest since 1990.

There are two types of floating objects, flotsam and FADs.  The occurrence of the former is fortuitous, whereas the latter are constructed by fishermen specifically for the purpose of attracting fish.  FADs have been in use for only a few years, but their importance has increased during that period, while that of flotsam has decreased, as shown by the figure below.

**Floating-object sets, by type, 1993-2002**
**Lances sobre objetos flotantes, por tipo, 1993-2002**
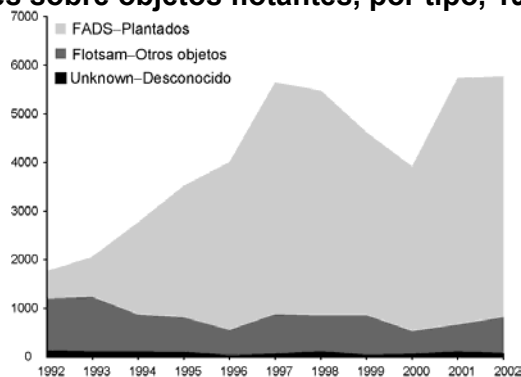


Number of sets on floating objects by Class-6 vessels, 1993-2002

The average annual distributions of the logged catches of yellowfin, skipjack, and bigeye by set type, by purse seiners in the EPO during the 1987-2001 period (1994-2001 for bigeye), are shown in Figures 1a, 2a, and 3a, and preliminary estimates for 2002 are shown in Figures 1b, 2b, and 3b. The distributions of the catches of yellowfin and skipjack during 2002 were similar to those of 1987-2001, although some differences are evident.

Bigeye are not often caught by surface gear north of about 7°N. The distribution of the catch of bigeye during 2002 was similar to those of 1994-2001, although some differences are evident. With the development of the fishery for tunas associated with floating objects, described above, the relative importance of the nearshore areas has decreased, while that of the offshore areas has increased.

### 1.2.a.2 Longline catches

Data on the retained catches for most of the larger longline vessels operating in the EPO, and for an increasing portion of the smaller ones, are obtained from various sources. These vessels, particularly the larger ones, direct their effort primarily at bigeye and yellowfin tuna. The annual retained catches of yellowfin, skipjack, bigeye, and bluefin by these fisheries are shown in Tables 6a, 6b, 6c, and 6d, respectively. The last year for which complete data are available for yellowfin, skipjack, and bigeye is 1999, and for bluefin 2001. During 1985-1999 the retained catches of yellowfin remained relatively stable, averaging about 20 thousand T (range: 13 to 34 thousand T) per year, or about 7.5% of the total retained catches of yellowfin. Prior to 1986 the retained longline catches of bigeye averaged about 50 thousand T (range: 29 to 73 thousand T). In about 1986 the level of retained catches of bigeye increased significantly to approximately 100 T. The retained longline catches remained high during 1986-1994, averaging about 85 thousand T (range: 72 to 102 thousand T). During 1970-1993, prior to the increased use of FADs and resultant greater catches of bigeye by purse-seine vessels, the longline fisheries, on average, accounted for 93% of the retained catches of this species from the EPO. During 1995-1999 the annual retained catches of bigeye by the longline fisheries ranged from about 33 to 49 thousand T (average: 43 thousand T), which is well within the pre-1986 historical range, but significantly less than the retained catches during 1986-1994. Small amounts of skipjack are caught by longline vessels, as shown in Table 6b. The catches of Pacific bluefin in the entire Pacific Ocean are shown in Table 6d. These data were compiled during the Second Meeting of the ISC [International Scientific Committee] Pacific Bluefin Tuna Working Group of the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean.

### 1.2.b.  Billfishes

Swordfish (*Xiphias gladius*) are fished in the EPO with longline gear and gillnets, and occasionally with recreational gear. Most of those caught with commercial gear are retained. Blue marlin (*Makaira nigricans*), black marlin (*M. indica*), striped marlin (*Tetrapturus audax*), shortbill spearfish (*T. angustirostris*), and sailfish (*Istiophorus platypterus*) are fished with longline and recreational gear, and they are occa-

sionally caught by purse-seine vessels. Most of the longline-caught marlins, spearfish, and sailfish are retained, and most of those caught with commercial surface gear are discarded at sea. Information on the commercial catches and bycatches of billfishes in the EPO is given in Table 7.

## 2. SIZE COMPOSITIONS OF THE SURFACE CATCHES OF TUNAS

Length-frequency samples are the basic source of data used for estimating the size and age compositions of the various species of fish in the landings. This information is necessary to obtain age-structured estimates of the population for various purposes, including age-structured population modeling. The results of age-structured population modeling can be used to estimate recruitment, which can be compared to spawning biomass and oceanographic conditions. Also, the estimates of mortality obtained from age-structured population modeling can be used, in conjunction with growth estimates, for yield-per-recruit modeling. The results of such studies have been described in several IATTC Bulletins and in all of its Annual Reports since that for 1954.

Length-frequency samples of yellowfin, skipjack, bigeye, Pacific bluefin, and occasionally black skipjack from purse-seine, pole-and-line vessels, and recreational catches made in the eastern Pacific Ocean (EPO) are collected by IATTC personnel at ports of landing in Ecuador, Mexico, Panama, the USA (California and Puerto Rico), and Venezuela. The catches of yellowfin and skipjack were first sampled in 1954, bluefin in 1973, and bigeye in 1975. Sampling has continued to the present.

The methods for sampling the catches of tunas are described in the IATTC Annual Report for 2000. Briefly, the fish in a well of a purse seiner or pole-and-line vessel are selected for sampling only if all the fish in the well were caught during the same calendar month, in the same type of set (floating-object, unassociated school, or dolphin), and in the same sampling area. These data are then categorized by fishery (Figure 4), based on the staff's most recent stock assessments.

Data for fish caught during the 1997-2002 period are presented in this report. With the exception of bluefin, two length-frequency histograms are presented for each species. For yellowfin, skipjack, and bigeye, the first shows the data by stratum (gear type, set type, and area) for 2002. The second, which is similar to those of previous years, shows the catch for the current year and the previous five years. For bluefin, histogram shows the 1997-2002 catches by commercial and recreational gear, combined. Samples from 916 wells (including those from recreational vessels) were taken during 2002.

There are ten yellowfin surface fisheries defined for stock assessments: four floating-object, two unassociated school, three dolphin, and one pole-and-line (Figure 4). Of the 916 wells sampled, 796 contained yellowfin. The estimated size compositions of the fish caught during 2002 are shown in Figure 5a. The majority of the yellowfin catch was taken by dolphin sets in the North and Inshore areas, but the largest fish on average, were caught in by dolphin sets in the Southern area. The average weight of yellowfin caught in unassociated school sets in the Southern area and by floating-object sets in the Inshore area in 2001 and 2002 were greater than those of the previous five years. A bimodal distribution is evident in some of the fisheries and is most apparent in both of the unassociated fisheries and the North and Inshore dolphin fisheries.

The estimated size compositions of the yellowfin caught by all fisheries combined during 1997-2002 are shown in Figure 5b. The size ranges of yellowfin are generally consistent over time (40-160 cm), but the size distributions differ among quarters and among years. The average weight of yellowfin caught during 2001 and 2002 was greater than during 1997 to 2000, probably due to catches of large fish in the southern areas. The bimodal distribution mentioned above

There are eight skipjack fisheries defined for stock assessments: four floating-object, two unassociated school, one dolphin, and one pole-and-line. The last two fisheries include all 13 sampling areas. Of the 916 wells sampled, 434 contained skipjack. The estimated size compositions of the fish caught during 2002 are shown in Figure 6a. The majority of the fish was taken in floating-object sets during 2002, par-

ticularly in the Southern area.  The average weight of skipjack caught in floating-object sets during 2002 was lower than that of 2001, especially in the northern and southern areas.  Negligible amounts of skipjack were caught in dolphin sets, or by pole-and-line vessels.

The estimated size compositions of the skipjack caught by all fisheries combined during 1997-2002 are shown in Figure 6b.  The average weight of the fish caught during 2002 was less than those of the fish caught since 1997-1998 and a distinct mode of smaller fish between 40-50 cm is apparent in the graphs for 1997, 1998, and 2002.

There are seven bigeye surface fisheries defined for stock assessments: four floating-object, one unassociated school, one dolphin, and one pole-and-line.  The last three fisheries include all 13 sampling areas.  Of the 916 wells sampled, 197 contained bigeye.  The estimated size compositions of the fish caught during 2002 are shown in Figure 7a.  In 2001 and 2002, the majority of the bigeye was caught in sets made on floating objects in the Southern area, whereas in 2000, the majority of the catch was made by floating-objects sets in the Galapagos area.  A small amount of bigeye was caught in unassociated school sets and in floating-object sets in the Inshore area.  Comparable to skipjack, the average weight of bigeye taken in floating object sets was less in 2002.  A mode of smaller fish between 40-80 cm is present throughout the floating object fishery, but especially defined in the northern and southern areas.  Negligible amounts of bigeye were taken in unassociated sets or in floating-objects sets in the Inshore area.  There were no recorded catches of bigeye in dolphin sets or by baitboats.

The estimated size compositions of the bigeye caught by all fisheries combined during 1997-2002 are shown in Figure 7b.  The average weight of the fish has decreased steadily since 2000, when the largest recorded catch of bigeye was taken.

Pacific bluefin are caught by surface gear by both commercial and sport-fishing vessels off California and Baja California from about 23°N to 35°N, with most of the catch being taken during May through October.  During 2002 bluefin were caught between 25°N and 37°N from May through October.  The majority of the catch of bluefin by commercial vessels was taken during July, September, and October, and most of the catches by sport-fishing vessels were taken in August.  In the past, commercial and recreational catches have been reported separately.  In 2002, only one bluefin sample was taken from a commercial vessel and 45 samples were taken from recreational vessels, therefore making it difficult to estimate the catches and size compositions separately.  Therefore, the commercial and recreational catches of bluefin were combined for the 1997-2002 period and the estimated size compositions are shown in Figure 8.

Black skipjack are caught incidentally by fishermen who are directing their effort toward yellowfin, skipjack, and bigeye tuna.  The demand for this species is low, so most of the catch is discarded at sea, but small amounts, mixed with the more desirable species, are sometimes retained.  Because only two samples of black skipjack were taken from the 916 wells sampled during 2002, length-frequency histograms for this species are not presented in this report.

**FIGURE 1a.** Average annual distributions of the logged purse-seine catches of yellowfin, by set type, 1987-2001.
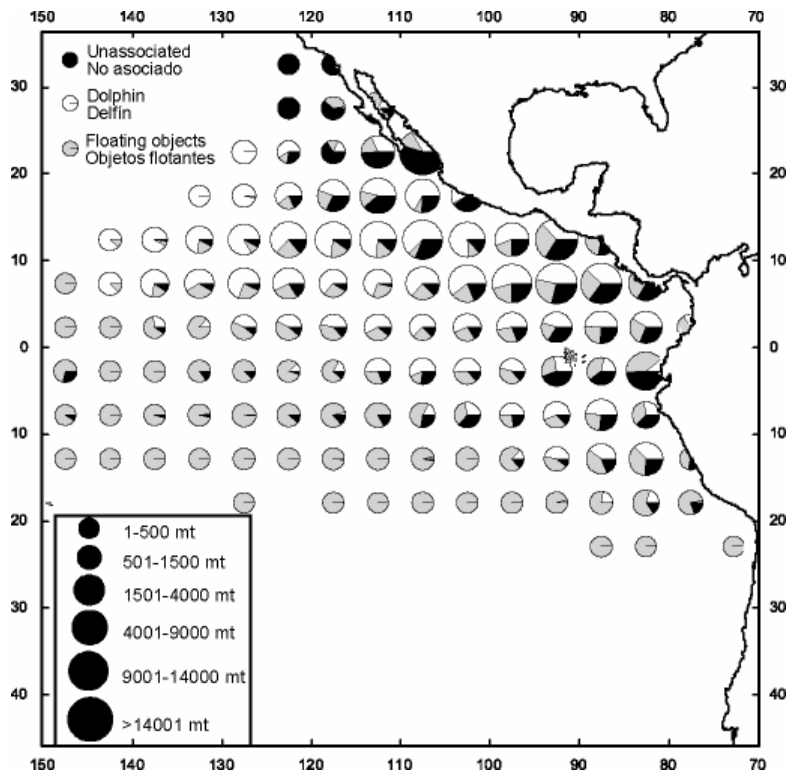


**FIGURE 1b.** Average annual distributions of the logged purse-seine catches of yellowfin, by set type, 2002 (preliminary).
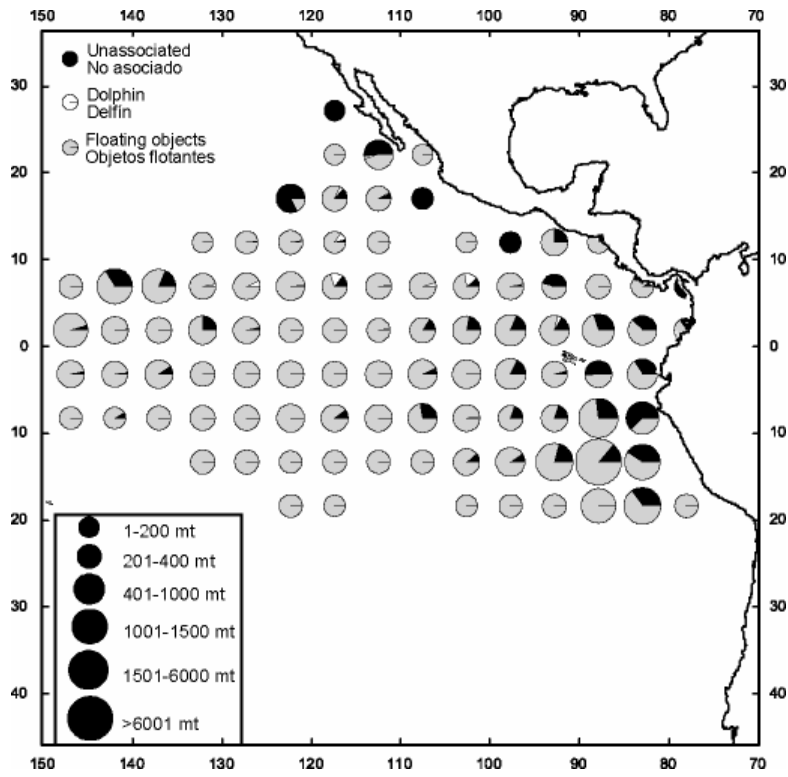
**FIGURE 2a.** Average annual distributions of the logged purse-seine catches of skipjack, by set type, 1987-2001.
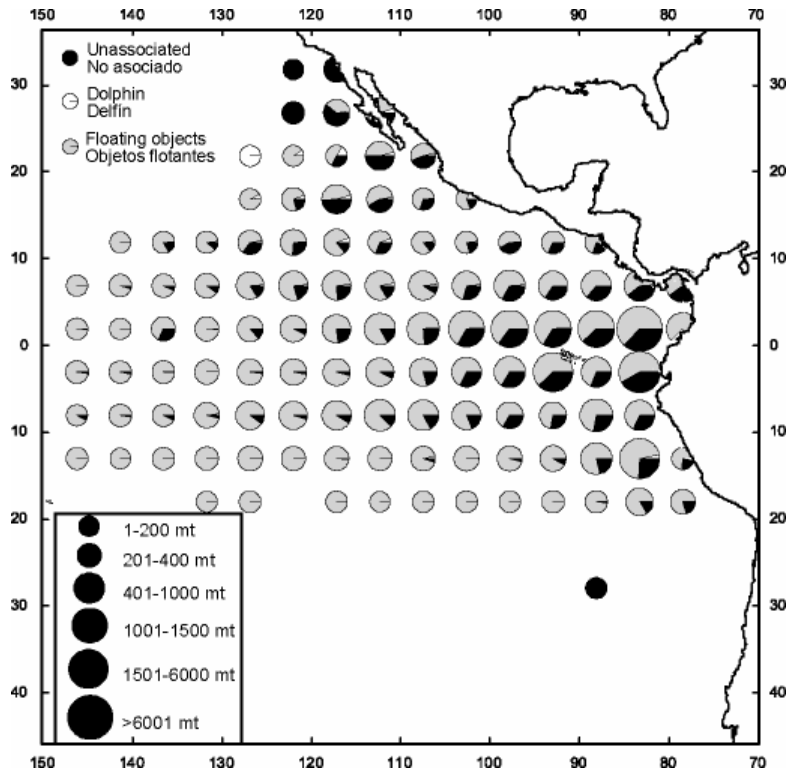


**FIGURE 2b.** Average annual distributions of the logged purse-seine catches of skipjack, by set type, 2002 (preliminary).
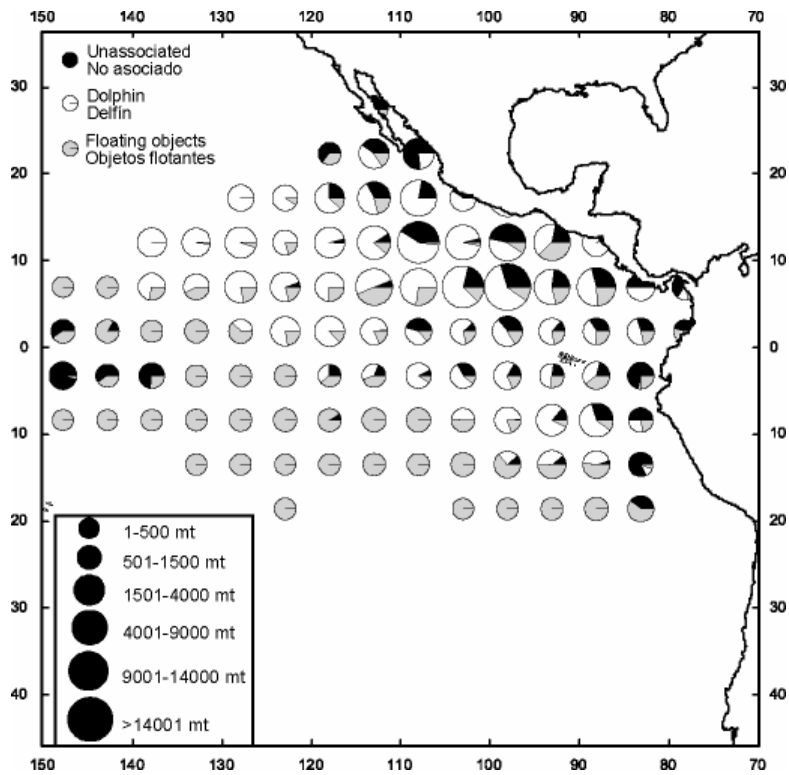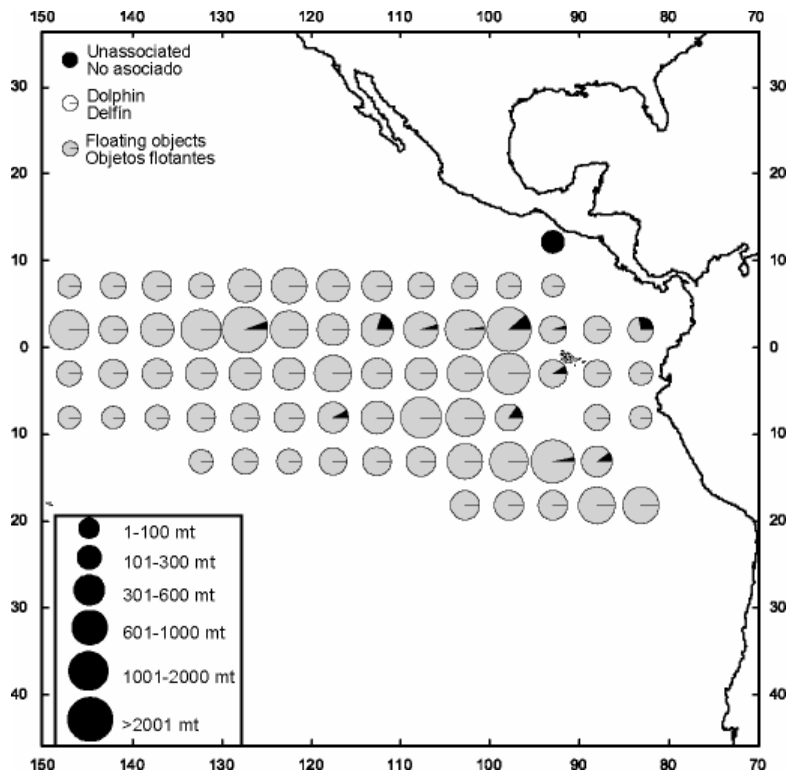
**FIGURE 3a.** Average annual distributions of the logged purse-seine catches of bigeye, by set type, 1994-2001.
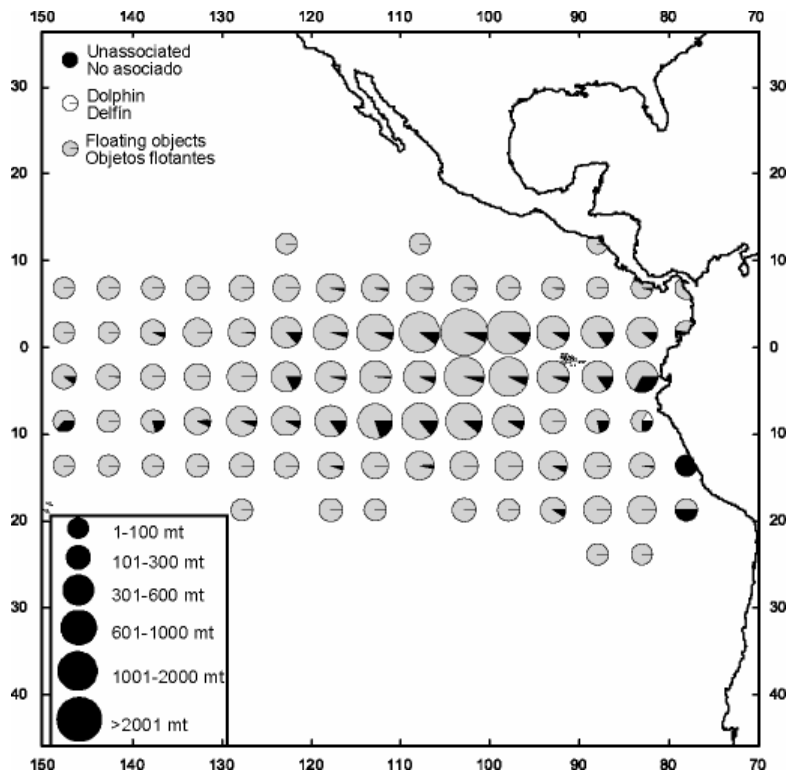


**FIGURE 3b.** Average annual distributions of the logged purse-seine catches of bigeye, by set type, 2002 (preliminary)

**Unassociated – Bigeye, bluefin**
**Dolphin – Bigeye, skipjack**
Pole-and-line vessels – All species

**No asociado – Patudo y aleta azul**
**Delfín – Patudo y barrilete**
Barcos cañeros – Todas especies
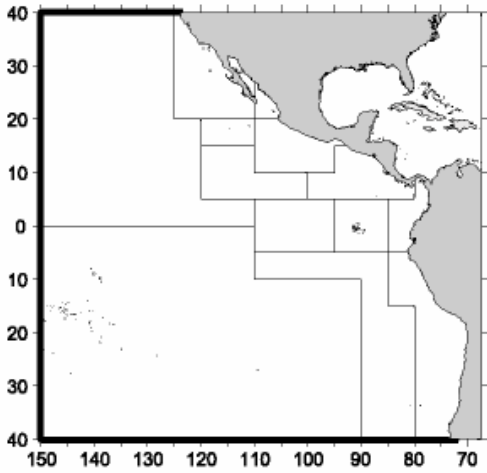
**Floating objects – All species**
**Objetos flotantes – Todas especies**
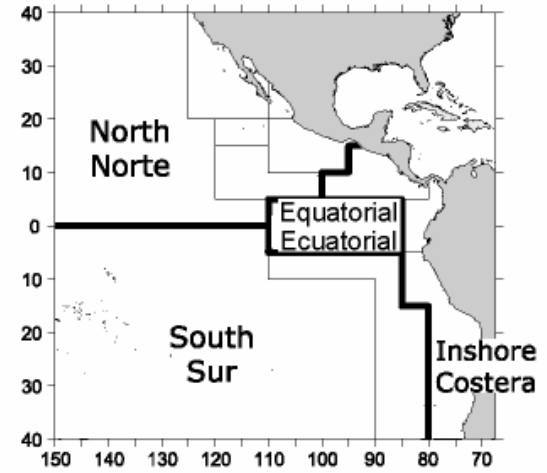
**Unassociated – Skipjack, yellowfin**
**No asociado – Barrilete y aleta amarilla**
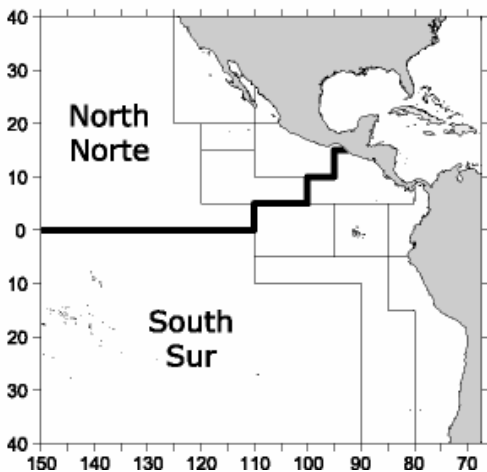
**Dolphin – Yellowfin**
**Delfín – Aleta amarilla**
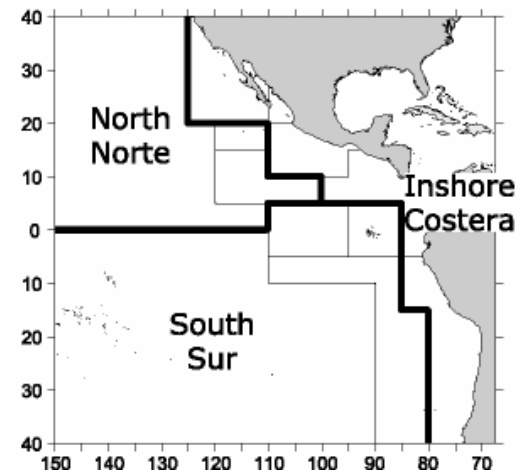
**FIGURE 4.** The fisheries defined by the IATTC staff for stock assessment of yellowfin, skipjack, and bigeye in the EPO. The thin lines indicate the boundaries of the 13 length-frequency sampling areas, and the bold lines the boundaries of the fisheries.
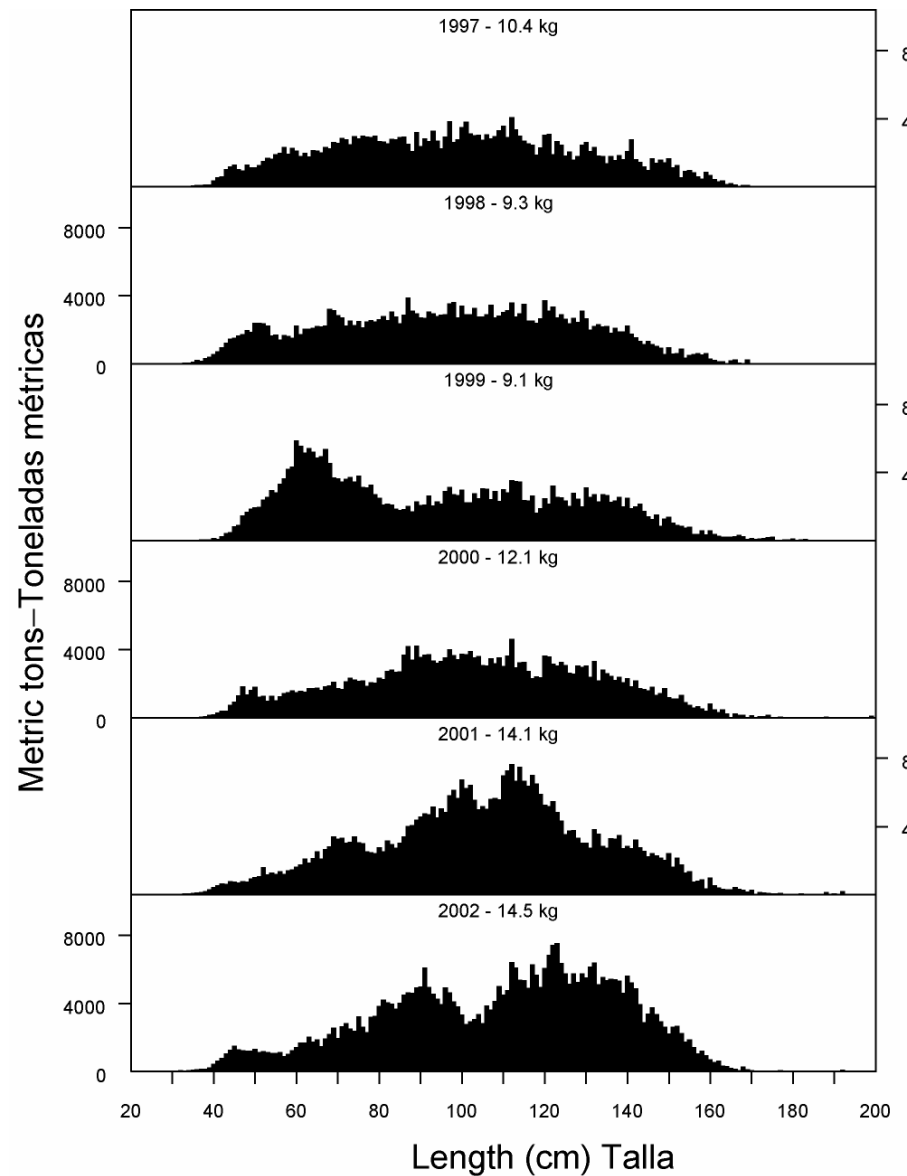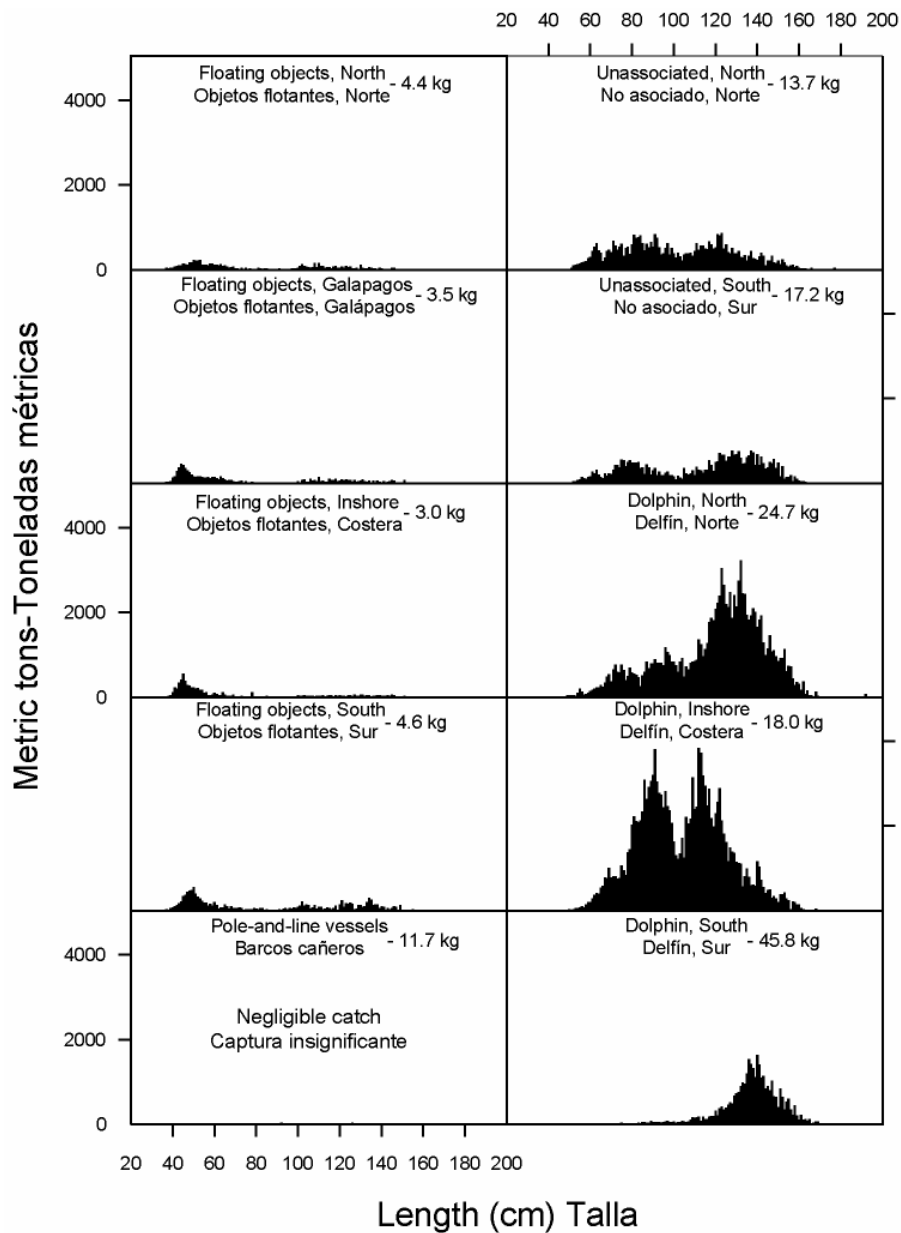
**FIGURE 5a and 5b.** Estimated size compositions of the yellowfin caught in each fishery of the EPO in 2002 (5a, left) and in the entire EPO in 1997-2002 (5b, right). The average weights of the fish in the samples are given at the tops of the panels.
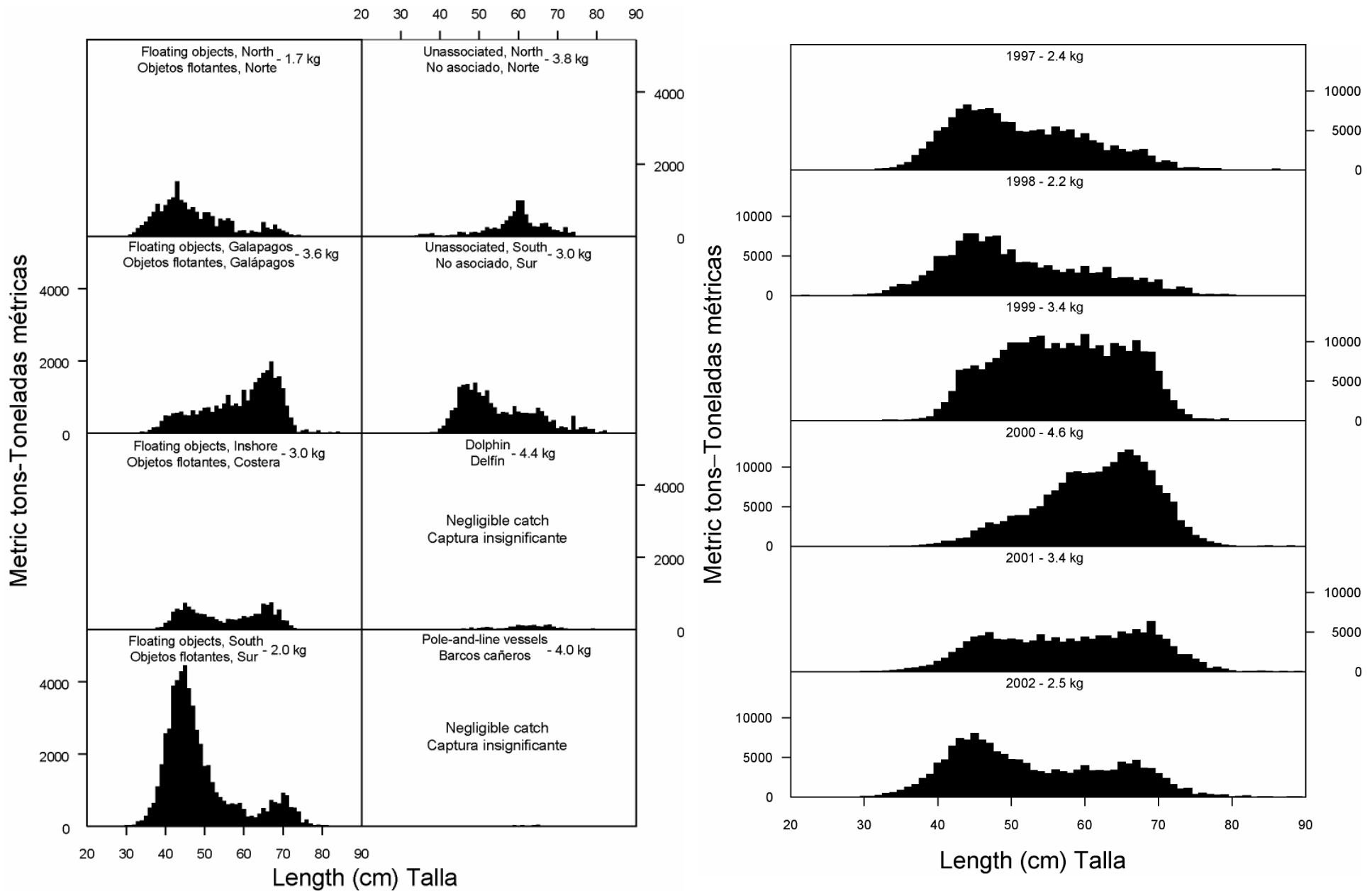
**FIGURE 6a and 6b.** Estimated size compositions of the skipjack caught in each fishery of the EPO in 2002 (6a, left) and in the entire EPO in 1997-2002 (6b, right). The average weights of the fish in the samples are given at the tops of the panels.
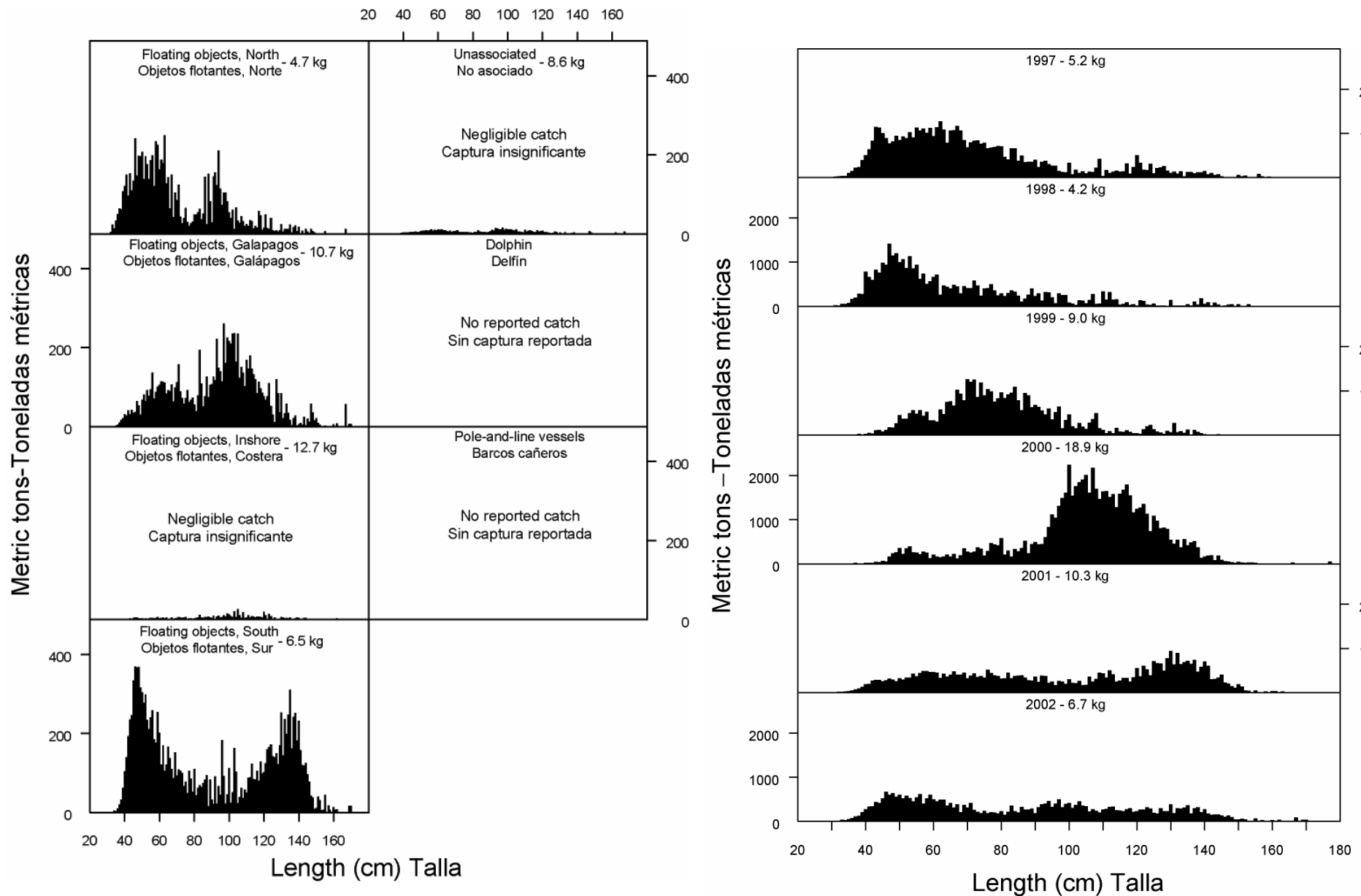
**FIGURE 7a and 7b.** Estimated size compositions of the bigeye caught in each fishery of the EPO in 2002 (7a, left) and in the entire EPO in 1997-2002 (7b, right). The average weights of the fish in the samples are given at the tops of the panels.
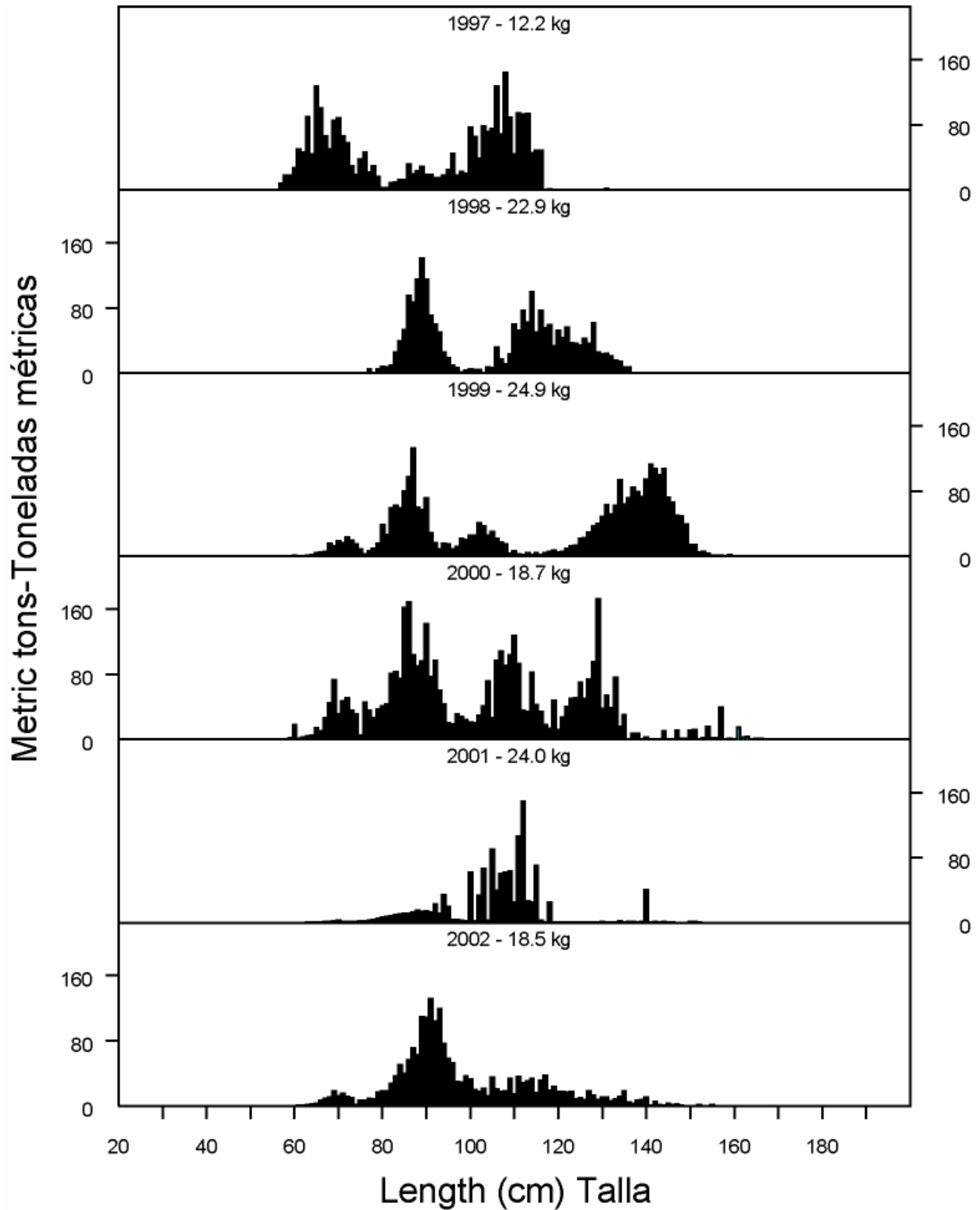
**FIGURE 8.** Estimated size compositions of the Pacific bluefin caught in the entire EPO in 1997-2002. The average weights of the fish in the samples are given at the tops of the panels.

**TABLE 1.** Numbers and well volumes, in cubic meters, of purse seiners and pole-and-line vessels of the eastern Pacific Ocean (EPO) tuna fleet.  Information for 1950-1960 (in short tons) is given in Table 4 of the IATTC Annual Report for 1988.  The data for 2002 are preliminary.

**TABLA 1**.  Número y volumen de bodega, en metros cúbicos, de los buques cerqueros y cañeros de la flota atunera del Océano Pacífico oriental (OPO).  En la Tabla 4 del Informe Anual de la CIAT de 1988 se presentan los datos de 1950-1960 (en toneladas cortas).  Los datos de 2002 son preliminares.

| Year | Purse seiners | | Pole-and-line vessels | | Total | |
|---|---|---|---|---|---|---|
| | **Number** | **Well volume** | **Number** | **Well volume** | **Number** | **Well volume** |
| | **Buques cerqueros** | | **Barcos cañeros** | | **Total** | |
| **Año** | **Número** | **Volumen de bodega** | **Número** | **Volumen de bodega** | **Número** | **Volumen de bodega** |
| 1961 | 125 | 31,896 | 93 | 11,171 | 218 | 43,068 |
| 1962 | 146 | 36,477 | 88 | 7,132 | 234 | 43,609 |
| 1963 | 159 | 42,782 | 111 | 6,409 | 270 | 49,191 |
| 1964 | 137 | 42,877 | 88 | 5,016 | 225 | 47,893 |
| 1965 | 163 | 45,332 | 116 | 6,338 | 279 | 51,670 |
| 1966 | 133 | 42,494 | 115 | 6,643 | 248 | 49,137 |
| 1967 | 130 | 42,899 | 108 | 6,234 | 238 | 49,133 |
| 1968 | 143 | 53,858 | 91 | 6,130 | 234 | 59,987 |
| 1969 | 153 | 60,641 | 72 | 5,343 | 225 | 65,984 |
| 1970 | 162 | 71,689 | 58 | 4,756 | 220 | 76,445 |
| 1971 | 191 | 94,423 | 168 | 7,525 | 359 | 101,948 |
| 1972 | 210 | 119,418 | 182 | 9,185 | 392 | 128,603 |
| 1973 | 219 | 140,150 | 134 | 8,052 | 353 | 148,202 |
| 1974 | 234 | 156,203 | 118 | 8,405 | 352 | 164,609 |
| 1975 | 253 | 174,016 | 111 | 8,055 | 364 | 182,072 |
| 1976 | 254 | 187,512 | 137 | 8,471 | 391 | 195,983 |
| 1977 | 253 | 189,967 | 116 | 6,780 | 369 | 196,746 |
| 1978 | 271 | 192,259 | 118 | 6,736 | 389 | 198,995 |
| 1979 | 282 | 195,494 | 50 | 4,341 | 332 | 199,835 |
| 1980 | 270 | 196,476 | 50 | 4,186 | 320 | 200,662 |
| 1981 | 251 | 196,484 | 41 | 3,308 | 292 | 199,792 |
| 1982 | 223 | 178,234 | 40 | 3,016 | 263 | 181,250 |
| 1983 | 215 | 149,404 | 60 | 3,940 | 275 | 153,344 |
| 1984 | 175 | 121,650 | 40 | 3,245 | 215 | 124,895 |
| 1985 | 178 | 137,814 | 25 | 2,574 | 203 | 140,387 |
| 1986 | 166 | 131,806 | 17 | 2,060 | 183 | 133,867 |
| 1987 | 177 | 152,351 | 29 | 2,376 | 206 | 154,727 |
| 1988 | 189 | 156,636 | 36 | 3,274 | 225 | 159,910 |
| 1989 | 178 | 141,956 | 30 | 3,135 | 208 | 145,091 |
| 1990 | 172 | 143,946 | 23 | 2,044 | 195 | 145,990 |
| 1991 | 155 | 124,501 | 19 | 1,629 | 174 | 126,131 |
| 1992 | 160 | 117,017 | 19 | 1,612 | 179 | 118,629 |
| 1993 | 152 | 118,730 | 15 | 1,543 | 167 | 120,272 |
| 1994 | 167 | 122,214 | 20 | 1,725 | 187 | 123,939 |
| 1995 | 175 | 124,096 | 20 | 1,784 | 195 | 125,880 |
| 1996 | 183 | 132,731 | 17 | 1,639 | 200 | 134,370 |
| 1997 | 194 | 146,533 | 23 | 2,105 | 217 | 148,637 |
| 1998 | 203 | 161,560 | 22 | 2,217 | 225 | 163,777 |
| 1999 | 208 | 180,652 | 14 | 1,656 | 222 | 182,308 |
| 2000 | 205 | 180,895 | 13 | 1,311 | 218 | 182,206 |
| 2001 | 205 | 189,865 | 10 | 1,259 | 215 | 191,124 |
| 2002 | 218 | 199,942 | 6 | 925 | 224 | 200,867 |

**TABLE 2a.** Estimates of the numbers and well volumes, in cubic meters, of the purse seiners and pole-and-line vessels of the EPO tuna fleet in 2001, by flag, gear, and size class. Each vessel is included in the totals for each flag under which it fished during the year, but is included only once in "Grand total." Therefore the grand totals may not equal the sums of the individual flag entries. PS = purse seiner; LP = pole-and-line vessel.

**TABLA 2a.** Estimaciones del número y volumen de bodega, en metros cúbicos, de los buques cerqueros y cañeros de la flota atunera en el OPO en 2001, por bandera, arte de pesca, y clase de arqueo. Se incluye cada buque en los totales de cada bandera bajo la cual pescó durante el año, pero solamente una vez en el "Total general"; por consiguiente, los totales generales no equivalen necesariamente a las sumas de las banderas individuales. PS = cerquero; LP = cañero.

| Flag | Gear | Size class—Clase de arqueo | | | | | | | Well volume |
|---|---|---|---|---|---|---|---|---|---|
| Bandera | Arte | 1 | 2 | 3 | 4 | 5 | 6 | Total | Volumen de bodega |
| **Number—Número** | | | | | | | | | |
| BLZ | PS | - | - | - | - | - | 2 | 2 | 1,822 |
| BOL | PS | - | - | 2 | - | - | 5 | 7 | 6,190 |
| COL | PS | - | - | 2 | 1 | 2 | 5 | 10 | 7,397 |
| ECU | PS | - | 5 | 12 | 11 | 7 | 38 | 73 | 48,310 |
| ESP | PS | - | - | - | - | - | 5 | 5 | 12,177 |
| GTM | PS | - | - | - | - | - | 4 | 4 | 7,640 |
| HND | PS | - | - | - | - | - | 3 | 3 | 2,254 |
| MEX | PS | - | - | 4 | 4 | 9 | 37 | 54 | 47,145 |
| | LP | 1 | 3 | 6 | - | - | | 10 | 1,271 |
| NIC | PS | - | - | - | - | - | 1 | 1 | 1,229 |
| PAN | PS | - | - | 2 | - | - | 6 | 8 | 9,157 |
| SLV | PS | - | - | - | - | - | 2 | 2 | 4,469 |
| USA | PS | - | - | 2 | - | 2 | 5 | 9 | 7,415 |
| VEN | PS | - | - | - | - | - | 25 | 25 | 31,687 |
| VUT | PS | - | - | - | - | - | 6 | 6 | 7,819 |
| | | - | - | - | - | - | | | |
| Grand total | PS | - | 5 | 22 | 18 | 20 | 140 | 205 | |
| Total general | LP | 1 | 3 | 6 | - | - | - | 10 | |
| | PS+LP | 1 | 8 | 28 | 18 | 20 | 140 | 215 | |
| **Well volume—Volumen de bodega** | | | | | | | | | |
| Grand total | PS | - | 453 | 3,970 | 5,207 | 9,156 | 171,079 | 189,865 | |
| Total general | LP | 53 | 293 | - | - | - | 913 | 1,259 | |
| | PS+LP | 53 | 746 | 3,970 | 5,207 | 9,156 | 171,992 | 191,124 | |

**TABLE 2b.** Preliminary estimates of the numbers and well volumes, in cubic meters, of the purse seiners and pole-and-line vessels of the EPO tuna fleet in 2002, by flag, gear, and size class. Each vessel is included in the totals for each flag under which it fished during the year, but is included only once in "Grand total." Therefore the grand totals may not equal the sums of the individual flag entries. PS = purse seiner; LP = pole-and-line vessel.

**TABLA 2b.** Estimaciones preliminares del número y volumen de bodega, en metros cúbicos, de buques cerqueros y cañeros de la flota atunera en el OPO en 2002, por bandera, arte de pesca, y clase de arqueo. Se incluye cada buque en los totales de cada bandera bajo la cual pescó durante el año, pero solamente una vez en el "Total general"; por consiguiente, los totales generales no equivalen necesariamente a las sumas de las banderas individuales. PS = cerquero; LP = cañero.

| Flag | Gear | Size class—Clase de arqueo | | | | | | | Well volume |
|------|------|---|---|---|---|---|---|---|---|
| Bandera | Arte | 1 | 2 | 3 | 4 | 5 | 6 | Total | Volumen de bodega |
| **Number—Número** | | | | | | | | | |
| BLZ | PS | - | - | 1 | - | - | 1 | 2 | 1,018 |
| BOL | PS | - | - | 2 | 1 | - | 7 | 10 | 7,910 |
| COL | PS | - | - | 2 | 1 | 2 | 5 | 10 | 7,397 |
| ECU | PS | - | 7 | 12 | 12 | 8 | 37 | 76 | 47,609 |
| ESP | PS | - | - | - | - | - | 5 | 5 | 12,177 |
| GTM | PS | - | - | - | - | - | 4 | 4 | 7,640 |
| HND | PS | - | - | - | - | - | 2 | 2 | 1,798 |
| MEX | PS | - | - | 5 | 4 | 11 | 36 | 56 | 47,832 |
|  | LP |  |  | 6 | - | - | - | 6 | 925 |
| NIC | PS | - | - | - | - | - | 1 | 1 | 1,229 |
| SLV | PS | - | - | - | - | - | 3 | 3 | 5,686 |
| PAN | PS | - | - | - | 2 | - | 8 | 10 | 11,706 |
| PER | PS | - | - | - | - | - | 1 | 1 | 1,022 |
| USA | PS | - | - | 2 | - | - | 9 | 11 | 13,339 |
| VEN | PS | - | - | - | - | - | 24 | 24 | 30,784 |
| VUT | PS | - | - | - | - | 1 | 4 | 5 | 4,024 |
| Unknown Desconocido | PS | - | - | - | - | - | 1 | 1 | 486 |
|  |  |  |  |  |  |  |  |  |  |
| Grand total | PS | - | 7 | 24 | 20 | 22 | 145 | 218 |  |
| Total general | LP | - | - | 6 | - | - | - | 6 |  |
|  | PS+PL | - | 7 | 30 | 20 | 22 | 145 | 224 |  |
| **Well volume—Volumen de bodega** | | | | | | | | | |
| Grand total | PS | - | 758 | 4,397 | 5,622 | 9,333 | 179,832 | 199,942 |  |
| Total general | LP | - | - | 925 | - | - | - | 925 |  |
|  | PS+LP | - | 756 | 5,322 | 5,622 | 9,333 | 179,832 | 200,867 |  |

**TABLE 3.** Estimated retained and discarded catches by surface gear, in metric tons, of the EPO tuna fleet. "Others" includes sharks, other tunas, and miscellaneous fishes. The 2001 and 2002 data are preliminary. Additional information concerning this table is given in the text.

**TABLA 3.** Estimaciones de capturas retenidas y descartadas, en toneladas métricas, por artes de superficie de la flota atunera del OPO. "Otros" incluye tiburones, otros atunes, y peces diversos. Los datos de 2001 y 2002 son preliminares. En el texto se presenta información adicional sobre esta tabla.

| Year | Yellowfin | | | Skipjack | | | Bigeye | | | Bluefin | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Retained | Discarded | Total | Retained | Discarded | Total | Retained | Discarded | Total | Retained | Discarded | Total |
| Año | Aleta amarilla | | | Barrilete | | | Patudo | | | Aleta azul | | |
| | Retenido | Descartado | Total | Retenido | Descartado | Total | Retenido | Descartado | Total | Retenido | Descartado | Total |
| 1970 | 155,626 | | 155,626 | 56,020 | | 56,020 | 1,332 | | 1,332 | 3,966 | | 3,966 |
| 1971 | 122,839 | | 122,839 | 104,721 | | 104,721 | 2,566 | | 2,566 | 8,360 | | 8,360 |
| 1972 | 177,127 | | 177,127 | 33,409 | | 33,409 | 2,238 | | 2,238 | 13,347 | | 13,347 |
| 1973 | 205,253 | | 205,253 | 43,954 | | 43,954 | 1,979 | | 1,979 | 10,744 | | 10,744 |
| 1974 | 210,364 | | 210,364 | 78,803 | | 78,803 | 890 | | 890 | 5,617 | | 5,617 |
| 1975 | 202,142 | | 202,142 | 123,868 | | 123,868 | 3,723 | | 3,723 | 9,583 | | 9,583 |
| 1976 | 236,347 | | 236,347 | 126,287 | | 126,287 | 10,243 | | 10,243 | 10,645 | | 10,645 |
| 1977 | 198,816 | | 198,816 | 86,337 | | 86,337 | 7,055 | | 7,055 | 5,473 | | 5,473 |
| 1978 | 180,594 | | 180,594 | 169,895 | | 169,895 | 11,759 | | 11,759 | 5,397 | | 5,397 |
| 1979 | 189,674 | | 189,674 | 132,024 | | 132,024 | 7,532 | | 7,532 | 6,117 | | 6,117 |
| 1980 | 159,425 | | 159,425 | 130,671 | | 130,671 | 15,421 | | 15,421 | 2,939 | | 2,939 |
| 1981 | 181,813 | | 181,813 | 119,606 | | 119,606 | 10,091 | | 10,091 | 1,089 | | 1,089 |
| 1982 | 125,084 | | 125,084 | 98,757 | | 98,757 | 4,102 | | 4,102 | 3,150 | | 3,150 |
| 1983 | 94,256 | | 94,256 | 58,142 | | 58,142 | 3,260 | | 3,260 | 853 | | 853 |
| 1984 | 145,061 | | 145,061 | 60,551 | | 60,551 | 5,936 | | 5,936 | 881 | | 881 |
| 1985 | 216,992 | | 216,992 | 49,460 | | 49,460 | 4,532 | | 4,532 | 4,055 | | 4,055 |
| 1986 | 268,274 | | 268,274 | 63,552 | | 63,552 | 1,939 | | 1,939 | 5,085 | | 5,085 |
| 1987 | 272,247 | | 272,247 | 62,345 | | 62,345 | 776 | | 776 | 1,005 | | 1,005 |
| 1988 | 288,403 | | 288,403 | 85,326 | | 85,326 | 1,053 | | 1,053 | 1,424 | | 1,424 |
| 1989 | 289,375 | | 289,375 | 92,374 | | 92,374 | 1,470 | | 1,470 | 1,170 | | 1,170 |
| 1990 | 273,329 | | 273,329 | 72,575 | | 72,575 | 4,712 | | 4,712 | 1,542 | | 1,542 |
| 1991 | 239,121 | | 239,121 | 63,260 | | 63,260 | 3,740 | | 3,740 | 461 | | 461 |
| 1992 | 239,849 | | 239,849 | 83,964 | | 83,964 | 5,497 | | 5,497 | 1,999 | | 1,999 |
| 1993 | 232,071 | 5,040 | 237,111 | 87,357 | 10,589 | 97,946 | 8,069 | 585 | 8,654 | 879 | 0 | 879 |
| 1994 | 219,261 | 4,614 | 223,875 | 74,534 | 10,314 | 84,848 | 29,375 | 2,305 | 31,680 | 1,062 | 0 | 1,062 |
| 1995 | 223,776 | 5,345 | 229,121 | 138,239 | 16,621 | 154,860 | 37,328 | 3,262 | 40,590 | 874 | 0 | 874 |
| 1996 | 250,170 | 6,660 | 256,830 | 112,205 | 24,970 | 137,175 | 51,353 | 5,786 | 57,139 | 8,259 | 0 | 8,259 |
| 1997 | 258,042 | 5,631 | 263,462 | 161,888 | 31,867 | 193,755 | 51,627 | 5,627 | 57,254 | 2,807 | 3 | 2,810 |
| 1998 | 265,781 | 4,718 | 270,437 | 145,115 | 22,856 | 167,971 | 35,154 | 2,853 | 38,007 | 2,223 | 0 | 2,223 |
| 1999 | 296,677 | 6,628 | 303,543 | 266,182 | 26,813 | 292,995 | 40,610 | 5,166 | 45,776 | 3,092 | 54 | 3,146 |
| 2000 | 273,245 | 6,815 | 279,226 | 211,252 | 26,364 | 237,616 | 70,153 | 5,624 | 75,777 | 4,127 | 0 | 4,127 |
| 2001 | 396,122 | 7,921 | 403,962 | 145,626 | 13,516 | 159,142 | 42,846 | 1,261 | 44,107 | 1,309 | 4 | 1,313 |
| 2002 | 418,967 | 3,956 | 422,923 | 158,043 | 12,793 | 170,836 | 35,201 | 977 | 36,178 | 1,777 | 6 | 1,783 |

TABLE 3. (continued)
TABLA 3. (continuación)

| Year / Año | Albacore / Albacora | | | Bonito / Bonito | | | Black skipjack / Barrilete negro | | | Others / Otros | | | All species combined / Todas las especies | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Retained / Retenido | Discarded / Descartado | Total | Retained / Retenido | Discarded / Descartado | Total | Retained / Retenido | Discarded / Descartado | Total | Retained / Retenido | Discarded / Descartado | Total | Retained / Retenido | Discarded / Descartado | Total |
| 1970 | 4,476 | | 4,476 | 4,738 | | 4,738 | 0 | | 0 | 27 | | 27 | 226,185 | | 226,185 |
| 1971 | 2,490 | | 2,490 | 9,600 | | 9,600 | 6 | | 6 | 61 | | 61 | 250,643 | | 250,643 |
| 1972 | 4,832 | | 4,832 | 8,872 | | 8,872 | 601 | | 601 | 367 | | 367 | 240,793 | | 240,793 |
| 1973 | 2,316 | | 2,316 | 7,864 | | 7,864 | 1,674 | | 1,674 | 355 | | 355 | 274,139 | | 274,139 |
| 1974 | 4,783 | | 4,783 | 4,436 | | 4,436 | 3,742 | | 3742 | 985 | | 985 | 309,620 | | 309,620 |
| 1975 | 3,332 | | 3,332 | 16,838 | | 16,838 | 511 | | 511 | 277 | | 277 | 360,274 | | 360,274 |
| 1976 | 3,733 | | 3,733 | 4,370 | | 4,370 | 1,526 | | 1,526 | 1,327 | | 1,327 | 394,478 | | 394,478 |
| 1977 | 1,963 | | 1,963 | 11,275 | | 11,275 | 1,458 | | 1,458 | 1,950 | | 1,950 | 314,327 | | 314,327 |
| 1978 | 1,745 | | 1,745 | 4,837 | | 4,837 | 2,162 | | 2,162 | 806 | | 806 | 377,195 | | 377,195 |
| 1979 | 327 | | 327 | 1,805 | | 1,805 | 1,366 | | 1,366 | 1,249 | | 1,249 | 340,094 | | 340,094 |
| 1980 | 601 | | 601 | 6,110 | | 6,110 | 3,680 | | 3,680 | 953 | | 953 | 319,800 | | 319,800 |
| 1981 | 739 | | 739 | 5,918 | | 5,918 | 1,911 | | 1,911 | 1,010 | | 1,010 | 322,177 | | 322,177 |
| 1982 | 553 | | 553 | 2,121 | | 2,121 | 1,338 | | 1,338 | 783 | | 783 | 235,888 | | 235,888 |
| 1983 | 456 | | 456 | 3,829 | | 3,829 | 1,236 | | 1,236 | 1,709 | | 1,709 | 163,741 | | 163,741 |
| 1984 | 5,351 | | 5,351 | 3,514 | | 3,514 | 666 | | 666 | 987 | | 987 | 222,947 | | 222,947 |
| 1985 | 919 | | 919 | 3,604 | | 3,604 | 296 | | 296 | 536 | | 536 | 280,394 | | 280,394 |
| 1986 | 133 | | 133 | 490 | | 490 | 595 | | 595 | 1,140 | | 1,140 | 341,208 | | 341,208 |
| 1987 | 417 | | 417 | 3,326 | | 3,326 | 557 | | 557 | 1,612 | | 1,612 | 342,285 | | 342,285 |
| 1988 | 288 | | 288 | 9,550 | | 9,550 | 1,267 | | 1,267 | 1,297 | | 1,297 | 388,608 | | 388,608 |
| 1989 | 1 | | 1 | 12,095 | | 12,095 | 783 | | 783 | 1,072 | | 1,072 | 398,340 | | 398,340 |
| 1990 | 184 | | 184 | 13,856 | | 13,856 | 792 | | 792 | 944 | | 944 | 367,934 | | 367,934 |
| 1991 | 834 | | 834 | 1,288 | | 1,288 | 446 | | 446 | 649 | | 649 | 309,799 | | 309,799 |
| 1992 | 255 | | 255 | 978 | | 978 | 104 | | 104 | 762 | | 762 | 333,408 | | 333,408 |
| 1993 | 1 | 0 | 1 | 599 | 12 | 611 | 104 | 3,950 | 4,054 | 314 | 1,981 | 2,295 | 329,394 | 22,157 | 351,551 |
| 1994 | 85 | 0 | 85 | 8,692 | 145 | 8,837 | 188 | 805 | 993 | 419 | 522 | 941 | 333,616 | 18,705 | 352,321 |
| 1995 | 465 | 2 | 467 | 8,009 | 55 | 8,064 | 187 | 1,415 | 1,602 | 172 | 668 | 840 | 409,050 | 27,368 | 436,418 |
| 1996 | 83 | 0 | 83 | 655 | 1 | 656 | 704 | 2,417 | 3,121 | 219 | 1,052 | 1,271 | 423,648 | 40,886 | 464,534 |
| 1997 | 60 | 0 | 60 | 1,104 | 5 | 1,109 | 101 | 2,582 | 2,683 | 148 | 3,407 | 3,555 | 475,777 | 49,122 | 524,899 |
| 1998 | 124 | 0 | 124 | 1,337 | 5 | 1,342 | 528 | 1,857 | 2,385 | 168 | 1,233 | 1,401 | 450,430 | 33,522 | 483,952 |
| 1999 | 274 | 0 | 274 | 1,710 | 0 | 1,710 | 178 | 3,412 | 3,590 | 218 | 3,096 | 3,314 | 607,941 | 45,169 | 653,110 |
| 2000 | 149 | 0 | 149 | 615 | 0 | 615 | 293 | 1,885 | 2,178 | 364 | 1,496 | 1,860 | 560,198 | 42,184 | 602,382 |
| 2001 | 20 | 0 | 20 | 18 | 0 | 18 | 1,961 | 1,261 | 3,222 | 441 | 766 | 1,207 | 588,343 | 24,729 | 613,072 |
| 2002 | 33 | 0 | 33 | 0 | 0 | 0 | 1,202 | 1,939 | 3,141 | 1039 | 1,828 | 2,867 | 616,262 | 21,499 | 637,761 |

**TABLE 4a.** Estimates of the retained catches and landings, in metric tons, of tunas caught by surface gear in the EPO in 2001, by species and vessel flag (upper panel) and location where processed (lower panel). Misc. = other species, including sharks, other tunas, and miscellaneous fishes.

**TABLA 4a.** Estimaciones de las capturas retenidas y descargas de atún capturado con artes de superficie en el OPO en 2001, por especie y bandera del buque (panel superior) y localidad donde fue procesado (panel inferior), en toneladas métricas. Misc. = otras especies, incluyendo tiburones, otros túnidos, y peces diversos.

| Flag<br>Bandera | YFT | SKJ | BET | PBF | ALB | BEP | BSJ | Misc. | Total | Percent of total<br>Porcentaje del total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Retained catches—Capturas retenidas | | | | | |
| Colombia | 24,871 | 2,523 | 150 | 0 | 0 | 0 | 79 | 12 | 27,635 | 4.7 |
| Ecuador | 54,661 | 70,388 | 19,878 | 0 | 0 | 0 | 1,802 | 426 | 147,155 | 25.0 |
| España—Spain | 10,967 | 21,564 | 6,724 | 0 | 0 | 0 | 0 | 0 | 39,255 | 6.7 |
| México | 134,401 | 8,123 | 91 | 863 | 18 | 18 | 0 | 0 | 143,514 | 24.4 |
| Panamá | 12,223 | 5,843 | 1,708 | 0 | 0 | 0 | 0 | 0 | 19,774 | 3.4 |
| U.S.A.—EE.UU. | 5,420 | 4,226 | 2,226 | 446 | 0 | 2 | 72 | 0 | 12,392 | 2.1 |
| Venezuela | 109,707 | 2,178 | 3 | 0 | 0 | 0 | 0 | 0 | 111,888 | 19.0 |
| Vanuatu | 10,654 | 8,047 | 3,785 | 0 | 0 | 0 | 0 | 0 | 22,486 | 3.8 |
| Other—Otros[1] | 33,218 | 22,734 | 8,281 | 0 | 0 | 0 | 8 | 3 | 64,244 | 10.9 |
| Total | 396,122 | 145,626 | 42,846 | 1,309 | 18 | 20 | 1,961 | 441 | 588,343 | |
| | | | | | Landings—Descargas | | | | | |
| Colombia | 38,918 | 6,662 | 2,017 | 0 | 0 | 0 | 8 | 0 | 47,605 | 8.1 |
| Costa Rica | 26,232 | 2,031 | 548 | 0 | 0 | 0 | 0 | 0 | 28,811 | 4.9 |
| Ecuador | 101,514 | 94,796 | 31,010 | 0 | 0 | 0 | 1,881 | 441 | 229,642 | 38.8 |
| España—Spain | 12,058 | 9,665 | 3,411 | 0 | 0 | 17 | 0 | 0 | 25,151 | 4.3 |
| México | 128,406 | 7,758 | 90 | 853 | 17 | 0 | 0 | 0 | 137,124 | 23.2 |
| Peru | 1,729 | 1,370 | 0 | 0 | 0 | 0 | 0 | 0 | 3,099 | 0.5 |
| Venezuela | 32,384 | 714 | 0 | 0 | 0 | 0 | 0 | 0 | 33,098 | 5.6 |
| Other-Otros[2] | 57,071 | 22,526 | 6,187 | 456 | 0 | 2 | 72 | 0 | 86,314 | 14.6 |
| Total | 398,312 | 145,522 | 43,263 | 1,309 | 17 | 19 | 1,961 | 441 | 590,844 | |

[1] Includes Belize, Bolivia, Guatemala, Honduras, Nicaragua, and El Salvador. This category is used to avoid revealing the operations of individual vessels or companies.

[1] Incluye Belice, Bolivia, Guatemala, Honduras, Nicaragua, y El Salvador. Se usa esta categoría para no revelar información sobre las actividades de buques o empresas individuales.

[2] Includes Guatemala, Panama, Thailand, U.S.A., and unidentified. This category is used to avoid revealing the operations of individual vessels or companies.

[2] Incluye Guatemala, Panamá, Tailandia, EE.UU., y no identificados. Se usa esta categoría para no revelar información sobre las actividades de buques o empresas individuales.

**TABLE 4b.** Preliminary estimates of the retained catches and landings, in metric tons, of tunas caught by surface gear in the EPO in 2002, by species and vessel flag (upper panel) and location where processed (lower panel).  Misc. = other species, including sharks, other tunas, and miscellaneous fishes

**TABLA 4b.** Estimaciones preliminares de las capturas retenidas y descargas de atún capturado con artes de superficie en el OPO en 2002, por especie y bandera del buque (panel superior) y localidad donde fue procesado (panel inferior), en toneladas métricas.  Misc. = otras especies, incluyendo tiburones, otros túnidos, y peces diversos.

| Flag<br><br>Bandera | YFT | SKJ | BET | PBF | ALB | BEP | BSJ | Misc. | Total | Percent of total<br>Porcentaje del total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Retained catches—Capturas retenidas** | | | | | | |
| Colombia | 30,291 | 2,299 | 151 | 0 | 0 | 0 | 0 | 329 | 33,070 | 5.4 |
| Ecuador | 38,710 | 77,285 | 18,185 | 0 | 0 | 0 | 588 | 632 | 135,400 | 22.0 |
| España—Spain | 5,199 | 22,076 | 4,606 | 0 | 0 | 0 | 0 | 0 | 31,881 | 5.2 |
| México | 151,969 | 8,822 | 3 | 1,727 | 0 | 30 | 390 | 0 | 162,941 | 26.4 |
| Panamá | 20,017 | 7,468 | 1,299 | 0 | 0 | 0 | 0 | 0 | 28,784 | 4.7 |
| U.S.A.—EE.UU. | 8,650 | 3,759 | 1,717 | 394 | 0 | 3 | 224 | 64 | 14,811 | 2.4 |
| Venezuela | 119,858 | 3,888 | 293 | 0 | 0 | 0 | 0 | 0 | 124,039 | 20.1 |
| Vanuatu | 5,717 | 6,792 | 1,912 | 0 | 0 | 0 | 0 | 0 | 14,421 | 2.3 |
| Other—Otros[1] | 38,556 | 25,654 | 7,035 | 0 | 0 | 0 | 0 | 14 | 71,259 | 11.6 |
| Total | 418,967 | 158,043 | 35,201 | 2,121 | 0 | 33 | 1,202 | 1,039 | 616,606 | |
| | | | | **Landings—Descargas** | | | | | | |
| Colombia | 29,181 | 2,700 | 1,012 | 0 | 0 | 0 | 0 | 0 | 32,893 | 5.2 |
| Costa Rica | 36,435 | 2,566 | 354 | 0 | 0 | 0 | 0 | 0 | 39,355 | 6.2 |
| Ecuador | 99,627 | 126,597 | 30,794 | 0 | 0 | 0 | 588 | 976 | 258,582 | 40.9 |
| España—Spain | 8,467 | 5,497 | 463 | 0 | 0 | 0 | 0 | 0 | 14,427 | 2.3 |
| México | 148,684 | 8,736 | 3 | 1,727 | 0 | 29 | 389 | 0 | 159,568 | 25.2 |
| U.S.A.—EE.UU. | 6,424 | 1,318 | 64 | 394 | 0 | 3 | 224 | 64 | 8,491 | 1.3 |
| Venezuela | 29,966 | 350 | 0 | 0 | 0 | 0 | 0 | 0 | 30,316 | 4.8 |
| Other-Otros[2] | 66,955 | 16,851 | 4,692 | 0 | 0 | 0 | 0 | 0 | 88,498 | 14.0 |
| Total | 425,739 | 164,615 | 37,382 | 2,121 | 0 | 32 | 1,201 | 1,040 | 632,130 | |

[1] Includes Belize, Bolivia, Guatemala, Honduras, Nicaragua, Peru, El Salvador , and unidentified.  This category is used to avoid revealing the operations of individual vessels or companies.

[1] Incluye Belice, Bolivia, Guatemala, Honduras, Nicaragua, Perú, El Salvador, y no identificados.  Se usa esta categoría para no revelar información sobre las actividades de buques o empresas individuales.

[1] Includes Canada, French Polynesia, Guatemala, Panama,  Peru, El Salvador, and unidentified.  This category is used to avoid revealing the operations of individual vessels or companies.

[1] Incluye Canadá, Polinesia Francesa, Guatemala, Panamá, Perú, El Salvador, y no identificados.  Se usa esta categoría para no revelar información sobre las actividades de buques o empresas individuales.

**TABLE 5.** Estimated numbers of sets by set type and vessel size class, and estimated retained catches, in metric tons, for yellowfin, skipjack, and bigeye tuna in the EPO, by purse-seine vessels. The data for 2001 are preliminary.

**TABLA 5.** Números estimados de lances, por tipo de lance y clase de arqueo de los buques, y capturas retenidas estimadas, en toneladas métricas, de atunes aleta amarilla, barrilete, y patudo en el OPO. Los datos de 2001 son preliminares.

| | Sets on fish associated with dolphins | | | | | |
|---|---|---|---|---|---|---|
| Year | Number of sets | | | Retained catch | | |
| | Classes 1-5 | Class 6 | Total | Yellowfin | Skipjack | Bigeye |
| | Lances sobre peces asociados con delfines | | | | | |
| Año | Número de lances | | | Captura retenida | | |
| | Clases 1-5 | Clase 6 | Total | Aleta amarilla | Barrilete | Patudo |
| 1987 | 57 | 13,286 | 13,343 | 190,432 | 332 | 20 |
| 1988 | 49 | 11,160 | 11,209 | 157,173 | 4,898 | 0 |
| 1989 | 33 | 12,827 | 12,860 | 194,846 | 1,447 | 0 |
| 1990 | 31 | 10,997 | 11,028 | 179,253 | 867 | 0 |
| 1991 | 0 | 9,661 | 9,661 | 159,255 | 786 | 38 |
| 1992 | 26 | 10,398 | 10,424 | 169,350 | 869 | 0 |
| 1993 | 34 | 6,953 | 6,987 | 110,045 | 714 | 97 |
| 1994 | 5 | 7,804 | 7,809 | 125,379 | 516 | 0 |
| 1995 | 0 | 7,185 | 7,185 | 131,932 | 1,032 | 0 |
| 1996 | 14 | 7,472 | 7,486 | 137,258 | 729 | 0 |
| 1997 | 43 | 8,977 | 9,020 | 156,163 | 6,004 | 35 |
| 1998 | 0 | 10,645 | 10,645 | 151,678 | 2,879 | 66 |
| 1999 | 0 | 8,648 | 8,648 | 143,503 | 1,214 | 0 |
| 2000 | 2 | 9,235 | 9,237 | 155,212 | 468 | 0 |
| 2001 | 6 | 9,847 | 9,853 | 240,873 | 1,289 | 10 |
| 2002 | 0 | 12,433 | 12,433 | 297,147 | 2,153 | 0 |

| | Sets on fish associated with floating objects | | | | | |
|---|---|---|---|---|---|---|
| Year | Number of sets | | | Retained catch | | |
| | Classes 1-5 | Class 6 | Total | Yellowfin | Skipjack | Bigeye |
| | Lances sobre peces asociados con objetos flotantes | | | | | |
| Año | Número de lances | | | Captura retenida | | |
| | Clases 1-5 | Clase 6 | Total | Aleta amarilla | Barrilete | Patudo |
| 1987 | 1,322 | 1,813 | 3,135 | 27,189 | 32,160 | 561 |
| 1988 | 823 | 2,281 | 3,104 | 23,933 | 35,949 | 569 |
| 1989 | 974 | 2,339 | 3,313 | 28,362 | 41,452 | 1,215 |
| 1990 | 719 | 2,558 | 3,277 | 34,247 | 34,980 | 3,359 |
| 1991 | 819 | 2,165 | 2,984 | 23,758 | 37,655 | 1,950 |
| 1992 | 868 | 1,763 | 2,631 | 13,057 | 45,556 | 1,154 |
| 1993 | 493 | 2,063 | 2,556 | 15,964 | 48,144 | 4,548 |
| 1994 | 668 | 2,770 | 3,438 | 17,362 | 47,992 | 27,472 |
| 1995 | 707 | 3,521 | 4,228 | 20,570 | 81,253 | 32,767 |
| 1996 | 1,230 | 4,007 | 5,237 | 31,073 | 74,260 | 48,251 |
| 1997 | 1,699 | 5,653 | 7,352 | 27,625 | 123,002 | 50,226 |
| 1998 | 1,198 | 5,481 | 6,679 | 31,271 | 115,370 | 31,332 |
| 1999 | 630 | 4,620 | 5,250 | 38,569 | 178,824 | 35,846 |
| 2000 | 494 | 3,916 | 4,410 | 43,116 | 123,857 | 67,514 |
| 2001 | 697 | 5,743 | 6,440 | 62,807 | 122,268 | 41,899 |
| 2002 | 778 | 5,775 | 6,553 | 37,159 | 121,891 | 34,541 |

**TABLE 5.** (continued)
**TABLA 5.** (continuación)

| | Sets on fish in unassociated schools | | | | | |
|---|---|---|---|---|---|---|
| **Year** | **Number of sets** | | | **Retained catch** | | |
| | **Classes 1-5** | **Class 6** | **Total** | **Yellowfin** | **Skipjack** | **Bigeye** |
| | Lances sobre peces en cardúmenes no asociados | | | | | |
| **Año** | **Número de lances** | | | **Captura retenida** | | |
| | **Clases 1-5** | **Clase 6** | **Total** | **Aleta amarilla** | **Barrilete** | **Patudo** |
| 1987 | 1,823 | 3,981 | 5,804 | 49,399 | 26,303 | 194 |
| 1988 | 4,147 | 7,536 | 11,683 | 102,042 | 39,535 | 481 |
| 1989 | 2,955 | 5,878 | 8,833 | 60,226 | 46,332 | 256 |
| 1990 | 3,683 | 5,397 | 9,080 | 56,551 | 35,788 | 1,351 |
| 1991 | 3,571 | 3,612 | 7,183 | 52,770 | 22,958 | 1,727 |
| 1992 | 4,010 | 4,079 | 8,089 | 53,507 | 35,333 | 4,343 |
| 1993 | 5,739 | 6,267 | 12,006 | 100,974 | 34,865 | 3,424 |
| 1994 | 5,440 | 5,064 | 10,504 | 72,765 | 22,916 | 1,902 |
| 1995 | 6,120 | 4,782 | 10,902 | 69,985 | 50,715 | 4,560 |
| 1996 | 5,807 | 5,118 | 10,925 | 77,343 | 34,635 | 3,102 |
| 1997 | 5,334 | 4,693 | 10,027 | 69,658 | 29,510 | 1,354 |
| 1998 | 5,700 | 4,631 | 10,331 | 77,642 | 25,108 | 3,757 |
| 1999 | 5,632 | 6,143 | 11,775 | 111,885 | 84,036 | 4,765 |
| 2000 | 6,119 | 5,482 | 11,601 | 72,487 | 86,695 | 2,641 |
| 2001 | 4,481 | 3,037 | 7,518 | 88,818 | 21,331 | 940 |
| 2002 | 5,008 | 3,405 | 8,413 | 83,764 | 33,404 | 658 |

| | Sets on all types of schools | | | | | |
|---|---|---|---|---|---|---|
| **Year** | **Number of sets** | | | **Retained catch** | | |
| | **Classes 1-5** | **Class 6** | **Total** | **Yellowfin** | **Skipjack** | **Bigeye** |
| | Lances sobre todos tipos de cardumen | | | | | |
| **Año** | **Número de lances** | | | **Captura retenida** | | |
| | **Clases 1-5** | **Clase 6** | **Total** | **Aleta amarilla** | **Barrilete** | **Patudo** |
| 1987 | 3,202 | 19,080 | 22,282 | 267,020 | 58,795 | 775 |
| 1988 | 5,019 | 20,977 | 25,996 | 283,148 | 80,382 | 1,050 |
| 1989 | 3,962 | 21,044 | 25,006 | 283,434 | 89,231 | 1,471 |
| 1990 | 4,433 | 18,952 | 23,385 | 270,051 | 71,635 | 4,710 |
| 1991 | 4,390 | 15,438 | 19,828 | 235,783 | 61,399 | 3,715 |
| 1992 | 4,904 | 16,240 | 21,144 | 235,914 | 81,758 | 5,497 |
| 1993 | 6,266 | 15,283 | 21,549 | 226,983 | 83,723 | 8,069 |
| 1994 | 6,113 | 15,638 | 21,751 | 215,506 | 71,424 | 29,374 |
| 1995 | 6,827 | 15,488 | 22,315 | 222,487 | 133,000 | 37,327 |
| 1996 | 7,051 | 16,597 | 23,648 | 245,674 | 109,624 | 51,353 |
| 1997 | 7,076 | 19,323 | 26,399 | 253,446 | 158,516 | 51,615 |
| 1998 | 6,898 | 20,757 | 27,655 | 260,591 | 143,357 | 35,155 |
| 1999 | 6,262 | 19,411 | 25,673 | 293,957 | 264,074 | 40,611 |
| 2000 | 6,615 | 18,633 | 25,248 | 270,815 | 211,020 | 70,155 |
| 2001 | 5,184 | 18,627 | 23,811 | 392,498 | 144,888 | 42,849 |
| 2002 | 5,786 | 21,613 | 27,399 | 418,070 | 157,448 | 35,199 |

**TABLE 6a.** Annual retained catches of yellowfin tuna, in metric tons.  In some cases .the data were converted from numbers of fish to weight in metric tons with average weight data estimated by the IATTC staff.  "Other" includes China, Costa Rica, Ecuador, El Salvador, French Polynesia, Guatemala, Mexico, Nicaragua, and the USA. Data for 2000-2002 are preliminary.

**TABLA 6a.**  Capturas retenidas anuales de atún aleta amarilla, en toneladas métricas.  En algunos casos se convirtieron los datos de números de peces a peso en toneladas métricas usando datos de peso promedio estimados por el personal de la CIAT  "Otros" incluye China, Costa Rica, Ecuador, EE.UU., El Salvador, Guatemala, México, Nicaragua, y Polinesia Francesa. Los datos de 2001 y 2002 son preliminares..

| Year | Surface[1] | Longline[2] | | | | | Total | | Grand total |
|------|---------|---------|------|------|-------|-------|---------|--------|--------|
| | | JPN | KOR | TWN | Other | Total | EPO | WCPO[3] | total |
| 1970 | 155,626 | 12,273 | * | 124 | * | 12,397 | 168,023 | 90,699 | 258,722 |
| 1971 | 122,839 | 7,368 | * | 276 | * | 7,644 | 130,483 | 79,800 | 210,283 |
| 1972 | 177,127 | 16,013 | * | 540 | * | 16,553 | 193,680 | 105,680 | 299,360 |
| 1973 | 205,253 | 11,413 | * | 344 | * | 11,757 | 217,010 | 127,474 | 344,484 |
| 1974 | 210,364 | 6,914 | * | 276 | * | 7,190 | 217,554 | 133,417 | 350,971 |
| 1975 | 202,142 | 10,299 | 138 | 313 | * | 10,749 | 212,891 | 133,787 | 346,678 |
| 1976 | 236,347 | 15,036 | 284 | 151 | * | 15,471 | 251,818 | 144,972 | 396,790 |
| 1977 | 198,816 | 11,222 | 558 | 104 | * | 11,884 | 210,700 | 171,674 | 382,374 |
| 1978 | 180,594 | 9,187 | 585 | 101 | * | 9,874 | 190,468 | 189,340 | 379,808 |
| 1979 | 189,674 | 10,909 | 312 | 107 | * | 11,328 | 201,002 | 185,392 | 386,394 |
| 1980 | 159,425 | 11,549 | 1,243 | 147 | * | 12,939 | 172,364 | 200,918 | 373,282 |
| 1981 | 181,813 | 7,090 | 680 | 109 | * | 7,880 | 189,693 | 206,036 | 395,729 |
| 1982 | 125,084 | 9,826 | 784 | 64 | * | 10,673 | 135,757 | 199,922 | 335,679 |
| 1983 | 94,256 | 9,404 | 1,057 | 42 | 49 | 10,552 | 104,808 | 252,875 | 357,683 |
| 1984 | 145,061 | 9,134 | 937 | 20 | * | 10,090 | 155,151 | 228,061 | 383,212 |
| 1985 | 216,992 | 10,633 | 1,995 | 21 | 2 | 12,651 | 229,643 | 205,035 | 434,678 |
| 1986 | 268,274 | 17,770 | 3,250 | 55 | 68 | 21,142 | 289,416 | 209,000 | 498,416 |
| 1987 | 272,247 | 13,484 | 4,370 | 118 | 272 | 18,244 | 290,491 | 272,984 | 563,475 |
| 1988 | 288,403 | 12,481 | 2,048 | 36 | 232 | 14,797 | 303,200 | 255,098 | 558,298 |
| 1989 | 289,375 | 15,335 | 1,543 | 215 | 9 | 17,103 | 306,478 | 285,927 | 592,405 |
| 1990 | 273,329 | 29,255 | 4,195 | 287 | * | 33,737 | 307,066 | 315,691 | 622,757 |
| 1991 | 239,121 | 23,721 | 5,697 | 326 | 171 | 29,914 | 269,035 | 327,132 | 596,167 |
| 1992 | 239,849 | 15,296 | 2,649 | 29 | 267 | 18,241 | 258,090 | 384,814 | 642,904 |
| 1993 | 232,071 | 20,339 | 3,178 | 144 | 874 | 24,534 | 256,605 | 363,227 | 619,832 |
| 1994 | 219,261 | 25,983 | 3,835 | 247 | 778 | 30,842 | 250,103 | 380,541 | 630,644 |
| 1995 | 223,776 | 17,042 | 2,826 | 90 | 763 | 20,722 | 244,498 | 318,049 | 562,547 |
| 1996 | 250,170 | 12,631 | 2,955 | 42 | 601 | 16,229 | 266,399 | 249,055 | 515,454 |
| 1997 | 258,042 | 16,218 | 4,187 | 131 | 1,042 | 21,578 | 279,620 | 403,999 | 683,619 |
| 1998 | 265,781 | 10,048 | 3,482 | 95 | 2,195 | 15,820 | 281,601 | 402,434 | 684,035 |
| 1999 | 295,677 | 7,186 | 2,768 | 45 | 3,134 | 13,134 | 308,811 | 355,784 | 664,595 |
| 2000 | 273,245 | 14,731 | 3,721 | * | 2,691 | 21,143 | 294,388 | 339,109 | 633,497 |
| 2001 | 396,122 | 14,781 | 5,617 | * | 2,958 | 23,356 | 419,478 | 382,948 | 802,426 |
| 2002 | 418,967 | 7,498 | * | * | 1,199 | 8,697 | 427,664 | * | * |

[1]    Source: Table 3—Fuente: Tabla 3
[2]    Sources:  published and unpublished data from the National Research Institute of Far Seas Fisheries (NRIFSF), Shimizu, Japan, Institute of Oceanography, National Taiwan University, Taipei, Taiwan, Ministry of Agriculture, People's Republic of China, and National Fisheries Research and Development Agency, Republic of Korea.
[2]    Fuentes: datos publicados e inéditos del Instituto Nacional de Investigación de Pesquerías de Ultramar (NRIFSF) en Shimizu (Japón), el Instituto de Oceanografía de la Universidad Nacional de Taiwan en Taipei, Ministerio de Agricultura, República Popular de China, y la Agencia Nacional de Investigación y Desarrollo Pesquero de Corea.
[3]    Source: Column 10 - Column 8—Fuente: Columna 10 - Columna 8
[6]    Source: IOTC data set for Fishstat+— Fuente: datos de CTOI para Fishstat+
*    not available—no disponible

**TABLE 6b.** Annual retained catches of skipjack tuna, in metric tons. WCPO = western and central Pacific Ocean. . In some cases the data were converted from numbers of fish to weight in metric tons with average weight data estimated by the IATTC staff. "Other" includes Costa Rica, French Polynesia, Mexico, and the USA. Data for 2000-2002 are preliminary.

**TABLA 6b.** Capturas retenidas anuales de atún barrilete, en toneladas métricas. OPOC = Océano Pacífico occidental y central. Otros" incluye Costa Rica, EE.UU., , México, y Polinesia Francesa. Los datos de 2001 y 2002 son preliminares.

| Year | Surface[1] | Longline[2] | | | | | Total | | Grand total |
|------|-----------|------|------|------|-------|-------|-------|--------|-------------|
| | | JPN | KOR | TWN | Other | Total | EPO | WCPO[3] | |
| 1970 | 56,020 | * | * | 4 | * | 4 | 56,024 | 257,807 | 313,831 |
| 1971 | 104,721 | * | * | * | * | * | 104,721 | 246,563 | 351,284 |
| 1972 | 33,409 | * | * | * | * | * | 33,409 | 311,134 | 344,543 |
| 1973 | 43,954 | * | * | * | * | * | 43,954 | 402,638 | 446,592 |
| 1974 | 78,803 | * | * | * | * | * | 78,803 | 445,528 | 524,331 |
| 1975 | 123,868 | * | 6 | * | * | 6 | 123,874 | 341,650 | 465,524 |
| 1976 | 126,287 | * | 7 | * | * | 7 | 126,294 | 428,343 | 554,637 |
| 1977 | 86,337 | * | 12 | 83 | * | 96 | 86,433 | 420,369 | 506,802 |
| 1978 | 169,895 | * | 10 | 7 | * | 17 | 169,912 | 532,660 | 702,572 |
| 1979 | 132,024 | * | 7 | 2 | * | 10 | 132,034 | 477,386 | 609,420 |
| 1980 | 130,671 | * | 5 | 2 | * | 8 | 130,679 | 508,504 | 639,183 |
| 1981 | 119,606 | * | 9 | 5 | * | 14 | 119,620 | 457,059 | 576,679 |
| 1982 | 98,757 | * | 9 | 7 | * | 16 | 98,773 | 469,188 | 567,961 |
| 1983 | 58,142 | * | 13 | 1 | * | 14 | 58,156 | 645,141 | 703,297 |
| 1984 | 60,551 | * | 9 | * | * | 9 | 60,560 | 765,493 | 826,053 |
| 1985 | 49,460 | * | 12 | 1 | * | 12 | 49,472 | 603,248 | 652,720 |
| 1986 | 63,552 | * | 21 | 1 | * | 22 | 63,574 | 745,181 | 808,755 |
| 1987 | 62,345 | * | 12 | 5 | * | 18 | 62,363 | 676,329 | 738,692 |
| 1988 | 85,326 | * | 6 | 7 | * | 13 | 85,339 | 842,574 | 927,913 |
| 1989 | 92,374 | * | 3 | 5 | * | 8 | 92,382 | 763,411 | 855,793 |
| 1990 | 72,575 | * | 7 | * | * | 7 | 72,582 | 858,142 | 930,724 |
| 1991 | 63,260 | * | 11 | 1 | 3 | 15 | 63,275 | 1,080,388 | 1,143,663 |
| 1992 | 83,964 | * | 5 | * | * | 5 | 83,969 | 911,266 | 995,235 |
| 1993 | 87,357 | * | 4 | 6 | * | 10 | 87,367 | 910,340 | 997,707 |
| 1994 | 74,534 | * | 2 | 125 | 3 | 130 | 74,664 | 976,050 | 1,050,714 |
| 1995 | 138,239 | * | 2 | 1 | 6 | 8 | 138,247 | 1,030,465 | 1,168,712 |
| 1996 | 112,205 | * | 5 | 5 | 24 | 33 | 112,238 | 1,019,585 | 1,131,823 |
| 1997 | 161,888 | 20 | 2 | 61 | 13 | 96 | 161,984 | 989,688 | 1,151,672 |
| 1998 | 145,115 | 44 | 3 | 18 | 31 | 95 | 145,210 | 1,274,157 | 1,419,367 |
| 1999 | 266,182 | 47 | 4 | 9 | 23 | 84 | 266,266 | 1,144,227 | 1,410,493 |
| 2000 | 211,252 | 23 | 4 | * | 49 | 76 | 211,328 | 1,208,072 | 1,419,400 |
| 2001 | 145,626 | 29 | 1 | * | 22 | 52 | 145,678 | 1,160,767 | 1,306,445 |
| 2002 | 158,043 | * | * | * | 38 | 38 | 158,081 | * | * |

[1]  Source: Table 3—Fuente: Tabla 3
[2]  Sources: published and unpublished data from the National Research Institute of Far Seas Fisheries (NRIFSF), Shimizu, Japan, Institute of Oceanography, National Taiwan University, Taipei, Taiwan, Ministry of Agriculture, People's Republic of China, and National Fisheries Research and Development Agency, Republic of Korea.
[2]  Fuentes: datos publicados e inéditos del Instituto Nacional de Investigación de Pesquerías de Ultramar (NRIFSF) en Shimizu (Japón), el Instituto de Oceanografía de la Universidad Nacional de Taiwan en Taipei, Ministerio de Agricultura, República Popular de China, y la Agencia Nacional de Investigación y Desarrollo Pesquero de Corea.
[3]  Source: Column 10 - Column 8—Fuente: Columna 10 - Columna 8
[4]  Source: FAO data set for Fishstat+—Fuente: datos de FAO para Fishstat+
*   not available—no disponible

**TABLE 6c.** Annual retained catches of bigeye tuna, in metric tons. In some cases the data were converted from numbers of fish to weight in metric tons with average weight data estimated by the IATTC staff. "Other" includes China, Costa Rica, Ecuador, El Salvador, French Polynesia, Guatemala, Mexico, and the USA. Data for 2000-2002 are preliminary.

**TABLA 6c.** Capturas retenidas anuales de atún patudo, en toneladas métricas. En algunos casos se convirtieron los datos de números de peces a peso en toneladas métricas usando datos de peso promedio estimados por el personal de la CIAT "Otros" incluye China, Costa Rica, Ecuador, EE.UU., El Salvador, Guatemala, México, y Polinesia Francesa. Los datos de 2001 y 2002 son preliminares.

| Year | Surface[1] | Longline[2] | | | | | Total | | Grand total |
|------|---------|-------|-------|-------|-------|--------|--------|-------------------|--------|
| | | **JPN** | **KOR** | **TWN** | **Other** | **Total** | **EPO** | **WCPO**[3] | **total** |
| 1970 | 1,332 | 32,521 | * | 392 | * | 32,913 | 34,245 | 50,246 | 84,491 |
| 1971 | 2,566 | 28,871 | * | 329 | * | 29,199 | 31,765 | 34,536 | 66,301 |
| 1972 | 2,238 | 35,113 | * | 831 | * | 35,944 | 38,182 | 49,960 | 88,142 |
| 1973 | 1,979 | 49,731 | * | 1,312 | * | 51,043 | 53,022 | 37,431 | 90,453 |
| 1974 | 890 | 36,013 | * | 576 | * | 36,589 | 37,479 | 50,583 | 88,062 |
| 1975 | 3,723 | 40,726 | 432 | 432 | * | 41,590 | 45,313 | 57,909 | 103,222 |
| 1976 | 10,243 | 52,827 | 807 | 217 | * | 53,852 | 64,095 | 65,052 | 129,147 |
| 1977 | 7,055 | 70,024 | 2,352 | 211 | * | 72,587 | 79,642 | 65,828 | 145,470 |
| 1978 | 11,759 | 67,214 | 2,090 | 156 | * | 69,460 | 81,219 | 40,767 | 121,986 |
| 1979 | 7,532 | 54,377 | 694 | 141 | * | 55,212 | 62,744 | 66,310 | 129,054 |
| 1980 | 15,421 | 61,951 | 1,453 | 555 | * | 63,959 | 79,380 | 52,434 | 131,814 |
| 1981 | 10,091 | 49,970 | 2,135 | 431 | * | 52,535 | 62,626 | 42,362 | 104,988 |
| 1982 | 4,102 | 50,199 | 2,300 | 103 | * | 52,601 | 56,703 | 52,758 | 109,461 |
| 1983 | 3,260 | 57,185 | 2,000 | 68 | * | 59,253 | 62,513 | 48,897 | 111,410 |
| 1984 | 5,936 | 44,587 | 1,362 | 45 | * | 45,994 | 51,930 | 51,908 | 103,838 |
| 1985 | 4,532 | 61,627 | 3,696 | 38 | * | 65,362 | 69,894 | 54,639 | 124,533 |
| 1986 | 1,939 | 91,981 | 7,570 | 77 | 0 | 99,628 | 101,567 | 48,957 | 150,524 |
| 1987 | 776 | 87,913 | 9,099 | 388 | 1 | 97,400 | 98,176 | 50,794 | 148,970 |
| 1988 | 1,053 | 66,015 | 5,625 | 436 | 1 | 72,076 | 73,129 | 46,745 | 119,874 |
| 1989 | 1,470 | 67,514 | 3,581 | 504 | * | 71,599 | 73,069 | 52,561 | 125,630 |
| 1990 | 4,712 | 86,148 | 9,651 | 327 | * | 96,126 | 100,838 | 61,820 | 162,658 |
| 1991 | 3,740 | 85,011 | 16,365 | 249 | 7 | 101,632 | 105,372 | 38,268 | 143,640 |
| 1992 | 5,497 | 74,466 | 7,837 | 54 | 114 | 82,470 | 87,967 | 70,503 | 158,470 |
| 1993 | 8,069 | 63,190 | 8,194 | 248 | 196 | 71,829 | 79,898 | 50,082 | 129,980 |
| 1994 | 29,375 | 61,471 | 10,444 | 261 | 128 | 72,303 | 101,678 | 43,069 | 144,747 |
| 1995 | 37,328 | 49,016 | 8,196 | 148 | 246 | 57,606 | 94,934 | 44,422 | 139,356 |
| 1996 | 51,353 | 36,685 | 8,034 | 91 | 170 | 44,980 | 96,333 | 35,337 | 131,670 |
| 1997 | 51,627 | 40,571 | 8,218 | 114 | 352 | 49,255 | 100,882 | 59,921 | 160,803 |
| 1998 | 35,154 | 35,752 | 8,233 | 149 | 1,064 | 45,198 | 80,352 | 83,984 | 164,336 |
| 1999 | 40,610 | 22,224 | 9,706 | 90 | 902 | 32,922 | 73,532 | 84,190 | 157,722 |
| 2000 | 70,153 | 27,865 | 9,854 | * | 989 | 38,708 | 108,861 | 71,442 | 180,303 |
| 2001 | 42,846 | 36,959 | 13,272 | * | 3,478 | 53,709 | 96,555 | 81,392 | 177,947 |
| 2002 | 35,201 | 29,843 | * | * | 568 | 30,411 | 65,612 | * | * |

[1]    Source: Table 3—Fuente: Tabla 3

[2]    Sources: published and unpublished data from the National Research Institute of Far Seas Fisheries (NRIFSF), Shimizu, Japan, Institute of Oceanography, National Taiwan University, Taipei, Taiwan, Ministry of Agriculture, People's Republic of China, and National Fisheries Research and Development Agency, Republic of Korea.

[2]    Fuentes: datos publicados e inéditos del Instituto Nacional de Investigación de Pesquerías de Ultramar (NRIFSF) en Shimizu (Japón), el Instituto de Oceanografía de la Universidad Nacional de Taiwan en Taipei, Ministerio de Agricultura, República Popular de China, y la Agencia Nacional de Investigación y Desarrollo Pesquero de Corea.

[3]    Source: Column 10 - Column 8—Fuente: Columna 10 - Columna 8

[4]    Source: FAO data set for Fishstat+—Fuente: datos de FAO para Fishstat+

*    not available—no disponible

**TABLE 6d.** Annual retained catches of Pacific bluefin, in metric tons.
**TABLA 6d.** Capturas retenidas anuales de aleta azul del Pacífico, en toneladas métricas.

| Year | Western Pacific nations[1] | | | Eastern Pacific nations | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | | | Surface[2] | | Longline[3] | Subtotal | |
| | Surface | Longline | Subtotal | Commercial | Recreational | | | |
| Año | Naciones del Pacífico occidental[1] | | | Naciones del Pacífico oriental | | | | Total |
| | | | | Superficie[2] | | Palangre[3] | Subtotal | |
| | Superficie | Palangre | Subtotal | Comercial | Deportiva | | | |
| 1970 | 7,505 | 1,123 | 8,628 | 3,966 | 15 | * | 3,981 | 12,610 |
| 1971 | 8,673 | 757 | 9,430 | 8,348 | 6 | * | 8,354 | 17,784 |
| 1972 | 7,951 | 724 | 8,675 | 13,334 | 12 | * | 13,346 | 22,020 |
| 1973 | 8,798 | 1,158 | 9,956 | 10,743 | 44 | * | 10,787 | 20,743 |
| 1974 | 14,763 | 3,533 | 18,296 | 5,617 | 47 | * | 5,664 | 23,960 |
| 1975 | 10,770 | 1,558 | 12,328 | 9,582 | 27 | * | 9,609 | 21,937 |
| 1976 | 9,186 | 520 | 9,706 | 10,645 | 17 | * | 10,662 | 20,368 |
| 1977 | 12,617 | 712 | 13,329 | 5,473 | 15 | * | 5,488 | 18,817 |
| 1978 | 21,285 | 1,049 | 22,334 | 5,398 | 4 | * | 5,402 | 27,735 |
| 1979 | 25,311 | 1,223 | 26,534 | 6,112 | 9 | * | 6,121 | 32,655 |
| 1980 | 18,372 | 1,170 | 19,542 | 2,939 | 6 | * | 2,945 | 22,487 |
| 1981 | 29,576 | 975 | 30,551 | 1,126 | 6 | * | 1,132 | 31,683 |
| 1982 | 24,095 | 1,056 | 25,151 | 3,021 | 7 | * | 3,028 | 28,179 |
| 1983 | 18,046 | 864 | 18,910 | 1,037 | 21 | * | 1,058 | 19,968 |
| 1984 | 10,562 | 831 | 11,393 | 801 | 31 | * | 832 | 12,225 |
| 1985 | 11,985 | 706 | 12,691 | 3,929 | 55 | * | 3,984 | 16,675 |
| 1986 | 14,496 | 319 | 14,815 | 4,920 | 7 | * | 4,927 | 19,742 |
| 1987 | 13,314 | 711 | 14,025 | 942 | 21 | * | 963 | 14,988 |
| 1988 | 7,331 | 349 | 7,680 | 1,250 | 4 | * | 1,254 | 8,934 |
| 1989 | 9,099 | 645 | 9,744 | 1,076 | 70 | * | 1,146 | 10,890 |
| 1990 | 6,294 | 585 | 6,879 | 975 | 40 | * | 1,015 | 7,894 |
| 1991 | 14,084 | 627 | 14,711 | 113 | 57 | * | 170 | 14,881 |
| 1992 | 10,221 | 1,037 | 11,258 | 1,088 | 93 | 9 | 1,190 | 12,448 |
| 1993 | 7,818 | 1,328 | 9,146 | 527 | 114 | 45 | 686 | 9,832 |
| 1994 | 10,964 | 1,697 | 12,661 | 972 | 24 | 24 | 1,020 | 13,681 |
| 1995 | 22,768 | 1,104 | 23,872 | 718 | 166 | 27 | 911 | 24,783 |
| 1996 | 10,119 | 1,934 | 12,053 | 8,381 | 30 | 25 | 8,436 | 20,489 |
| 1997 | 14,757 | 3,197 | 17,954 | 2,575 | 90 | 25 | 2,690 | 20,644 |
| 1998 | 7,357 | 3,170 | 10,527 | 1,908 | 213 | 54 | 2,175 | 12,702 |
| 1999 | 16,863 | 4,244 | 21,107 | 2,463 | 397 | 89 | 2,949 | 24,056 |
| 2000 | 17,888 | 3,898 | 21,786 | 3,386 | 218 | 22 | 3,626 | 25,412 |
| 2001 | 995 | 2,429 | 3,424 | 1,006 | 303 | 7 | 1,316 | 4,740 |

[1]  Source: Report of the Second Meeting of the ISC [International Scientific Committee] Pacific Bluefin Tuna Working Group of the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean

[1]  Fuente: Informe del Reunión Segundo del Grupo de Trabajo del ISC [Comité Científico Internacional] sobre el Atún Aleta Azul del Pacífico de la Convención sobre la Conservación y Ordenación de Poblaciones de Peces Altamente Migratorios en el Océano Pacífico Occidental y Central

[2]  Sources: 1970-1980 and 2001, IATTC data bases; 1981-2000, Report of the Second Meeting of the Working Group of the ISC

[2]  Fuentes: 1970-1980 y 2001, bases de datos de CIAT; 1981-2000, Informe del Reunión Segundo del Grupo de Trabajo del ISC

[3]  Sources: Report of the Second Meeting of the Working Group of the ISC and data bases of the IATTC and U.S. NMFS

[3]  Fuentes: Informe del Reunión Segundo del Grupo de Trabajo del ISC y  bases de datos de la CIAT y el NMFS de EE.UU.

*  not available—no disponible

**TABLE 7.** Estimates of the commercial catches, in metric tons, of billfishes in the eastern Pacific Ocean. Most of the longline-caught fish were retained, and, with the exception of swordfish and blue marlin, most of those caught by surface gear were discarded.
**TABLA7.** Estimaciones de las capturas comerciales, en toneladas métricas, de peces picudos en el Océano Pacífico oriental. La mayoría del pescado capturado con palangre fue retenida, y, a excepción de pez espada y marlín azul, la mayoría de la captura de superficie desechada.

| Year / Año | Swordfish / Pez espada | | Blue marlin / Marlín azul | | Black marlin / Marlín negro | | Striped marlin / Marlín rayado | | Shortbill spearfish / Marlín trompa corta | | Sailfish / Pez vela | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Longline / Palangre | Surface / Superficie | Longline / Palangre | Surface / Superficie | Longline / Palangre | Surface / Superficie | Longline / Palangre | Surface / Superficie | Longline / Palangre | Surface / Superficie | Longline / Palangre | Surface / Superficie |
| 1970 | 5,209 | 2,639 | 4,126 | | 346 | | 10,976 | | | | | |
| 1971 | 2,251 | 366 | 2,832 | | 271 | | 10,118 | | | | | |
| 1972 | 2,666 | 691 | 2,653 | | 309 | | 7,106 | | | | | |
| 1973 | 4,687 | 2,351 | 3,825 | | 460 | | 5,277 | | | | | |
| 1974 | 2,908 | 688 | 2,826 | | 303 | | 5,402 | | | | | |
| 1975 | 3,065 | 295 | 2,281 | | 245 | | 5,429 | | | | 554 | |
| 1976 | 3,526 | 308 | 3,271 | | 180 | | 6,473 | | | | 494 | |
| 1977 | 4,647 | 452 | 3,106 | | 291 | | 3,086 | | | | 753 | |
| 1978 | 5,946 | 492 | 3,630 | | 186 | | 2,496 | | | | 878 | |
| 1979 | 3,081 | 228 | 4,500 | | 284 | | 4,123 | | | | 251 | |
| 1980 | 5,047 | 320 | 4,030 | | 295 | | 4,879 | | | | 244 | |
| 1981 | 5,692 | 385 | 4,453 | | 178 | | 4,870 | | | | 379 | |
| 1982 | 5,354 | 439 | 4,717 | | 166 | | 4,682 | | | | 1,084 | |
| 1983 | 5,437 | 580 | 4,432 | | 186 | | 4,455 | | | | 889 | |
| 1984 | 5,736 | 446 | 5,163 | | 166 | | 2,652 | | | | 345 | |
| 1985 | 5,638 | 397 | 3,574 | | 121 | | 1,589 | | | | 395 | |
| 1986 | 6,561 | 768 | 5,268 | | 198 | | 3,482 | | 5 | | 583 | |
| 1987 | 8,257 | 1,942 | 6,967 | | 307 | | 7,476 | | 15 | | 651 | |
| 1988 | 10,497 | 4,026 | 5,643 | | 249 | | 5,218 | | 13 | | 651 | |
| 1989 | 11,232 | 4,744 | 5,297 | | 153 | | 3,397 | | 0 | | 194 | |
| 1990 | 13,712 | 3,851 | 5,284 | | 187 | | 3,128 | | 0 | | 0 | |
| 1991 | 16,122 | 3,306 | 6,467 | 81 | 178 | 58 | 2,905 | 76 | 1 | 1 | 718 | 40 |
| 1992 | 15,682 | 2,821 | 6,411 | 59 | 188 | 95 | 2,855 | 69 | 1 | 1 | 1,354 | 41 |
| 1993 | 11,784 | 2,739 | 6,636 | 60 | 189 | 64 | 3,399 | 35 | 3 | 0.1 | 2,269 | 36 |
| 1994 | 9,942 | 2,555 | 9,436 | 80 | 240 | 118 | 3,333 | 34 | 143 | 0.3 | 1,803 | 29 |
| 1995 | 8,052 | 2,098 | 7,369 | 93 | 136 | 83 | 3,150 | 21 | 156 | 0.5 | 1,406 | 31 |
| 1996 | 8,882 | 636 | 3,606 | 97 | 113 | 92 | 2,934 | 22 | 127 | 0.5 | 745 | 25 |
| 1997 | 14,498 | 994 | 5,673 | 154 | 146 | 125 | 3,958 | 25 | 164 | 1 | 1,187 | 29 |
| 1998 | 15,308 | 1,950 | 5,302 | 148 | 158 | 113 | 3,323 | 18 | 135 | 0.4 | 1,367 | 49 |
| 1999 | 10,124 | 873 | 3,711 | 194 | 89 | 141 | 2,430 | 31 | 187 | 0.5 | 1,246 | 42 |
| 2000 | 13,958 | 905 | 3,374 | 141 | 96 | 97 | 1,534 | 17 | 184 | 0.5 | 1,300 | 58 |
| 2001 | 15,087 | 4 | 4,054 | 181 | 99 | 113 | 1,819 | 20 | 188 | 0.3 | 1,326 | 37 |
| 2002 | 561 | | 557 | | 1 | | 191 | | 5 | | 134 | |

## B.  YELLOWFIN TUNA

An age-structured, catch-at-length analysis (A-SCALA) is used to assess yellowfin tuna in the EPO. The analysis method is described by Maunder and Watters (2003a), and readers are referred to that document for technical details.

The stock assessment requires a substantial amount of information. Data on retained catch, discards, fishing effort, and the size compositions of the catches from several different fisheries have been analyzed. Several assumptions regarding processes such as growth, recruitment, movement, natural mortality, fishing mortality, and stock structure have also been made. The assessment for 2003 differs in several aspects from the previous assessment carried out in 2002. Catch, effort, and length-frequency data for the surface fisheries have been updated to include new data for 2002 and revised data for 2000 and 2001. Catch data for the Japanese longline fisheries have been updated to include new data for 2001 and updated data for 1998 and 2000. Catch data for the Taiwan longline fisheries have been updated for 1998 and new data added for 1999. Longline effort data are based on neural-network-standardization of CPUE. Longline catch-at-length data was included for 1975-1980. Growth is constrained to equal the prior for more ages than in the previous assessment  The smoothness penalties for selectivity were chosen using cross-validation. The years used to average catchability for the projections and management quantities were calculated using retrospective analysis. Iterative reweighting was used to determine the sample size for catch-at-length data in a sensitivity analysis. Diagnostics including residual plots, correlation plots, and retrospective analysis were carried out.

Significant levels of fishing mortality have been observed in the yellowfin tuna fishery in the EPO (Figure YFT1). These levels are highest for middle-aged yellowfin (except for the estimates for the oldest yellowfin, which is an artifact of the model). Both recruitment (Figure YFT2) and exploitation have had substantial impacts on the yellowfin biomass trajectory (Figure YFT3). It appears that the yellowfin population has experienced two different productivity regimes (1975-1983 and 1984-2001), with greater recruitment during the second than the first. The two recruitment regimes (Figure YFT2) correspond to two regimes in biomass (Figure YFT3), the high-recruitment regime producing greater biomasses. The spawning biomass ratio (the ratio of spawning biomass to that for the unfished stock; SBR) of yellowfin in the EPO was below the level that will support the average maximum sustainable yields (AMSYs) during the low-recruitment regime, but above that level during the high-recruitment regime (Figure YFT4). The two different productivity regimes may support two different levels of AMSY and associated SBRs, an dthe AMSY reported here is an average for the two regimes. The current SBR is slightly below the SBR level at AMSY (Figure YFT4).  However, there is substantial uncertainty in the most recent estimate of SBR and there similar probability that current SBR is above the level which would produce AMSY as there is that current SBR is below this level.  The effort levels are estimated to be less than the levels that will support the AMSY (based on the current distribution of effort among the different fisheries). However, due to the large recruitment that entered the fishery in 1998, the catch levels are greater than the corresponding values at the AMSY (Table YFT1). Because of the flat yield curve, current effort levels are estimated to produce, under average conditions, catch that is only slightly less than AMSY. Future projections under the current effort levels and average recruitment indicate that the population will increase to an SBR level more than the current level and above that which will support the AMSY (Figure YFT4). These simulations were carried out using the average recruitment for the 1975-2002 period. If they had been carried out using the average recruitment for the 1984-2002 period it is likely that the estimates of SBR and catches would be higher.

The analysis indicates that strong cohorts entered the fishery in 1998 through 2000 and that these cohorts increased the population biomass during 1999 and 2000. However, they have now moved through the population, and the biomass decreased in 2001 and 2002.

The overall average weights of yellowfin tuna that are caught have consistently been much less than the critical weight, indicating that, from the yield-per-recruit standpoint, the yellowfin in the EPO are not

harvested at the optimal size. There is substantial variability in the average weights of the yellowfin taken by the different fisheries, however. In general, the floating-object (Fisheries 1-4), unassociated (Fisheries 5 and 6), and pole-and-line (Fishery 10) fisheries capture younger, smaller fish than do the dolphin-associated (Fisheries 7-9) and longline (Fisheries 11 and 12) fisheries. The longline fisheries and the purse-seine sets in the southern area on yellowfin associated with dolphins (Fishery 9) capture older, larger yellowfin than do the coastal (Fishery 8) and northern (Fishery 7) dolphin-associated fisheries. The AMSY calculations indicate that the yield levels could be greatly increased if the fishing effort were directed toward the fisheries that catch yellowfin closest to the critical weight (longlining and purse-seine sets on yellowfin associated with dolphins, particularly in the southern area). This would also increase the SBR levels.

Moderate changes in the level of surface fishing effort are predicted to affect the SBR, the total catch of the longline fleet, and the average weight of fish in the catch from all fisheries combined. Increasing the level of surface fishing effort to 125% of its recent average is predicted to decrease the SBR, average weight of fish in the combined catch, and total catch taken by the longline fleet compared to predictions using average effort. Reducing the level of surface fishing effort to 75% of its recent average would have the opposite effects. The catch from surface fisheries would increase only slightly with a 25% increase in the level of surface fishing effort. The catch from surface fisheries would decrease moderately with a 25% decrease in the level of surface fishing effort. Avoiding the capture of unmarketable yellowfin tuna around floating objects, particularly fish-aggregating devices (FADs), would not significantly affect the SBRs and catches, but would moderately increase the average weight of the fish caught. There is a large amount of uncertainty in the future predictions of catch and SBR.

A sensitivity analysis was carried out to determine the effect of a stock-recruitment relationship. The results suggest that the model with a stock-recruitment relationship fits the data slightly better than the base case. The results from the analysis with a stock-recruitment relationship are more pessimistic, and they suggest that the effort level is greater than that which would produce AMSY (Table YFT1); however the yield at this effort level is only slightly less than AMSY. The biomass is estimated to have been less than the biomass that would give rise to AMSY for most of the modeling period, except for most of the 1999-2002 period.

The assessment results are very similar to the results from the previous assessments. The major differences occur, as expected, in the most recent years. The current assessment and the 2002 assessment estimates that the biomass increased in 2000 whereas the earlier assessments estimated a decline. In addition, SBR and the SBR required to produce AMSY have increased compared to the earlier assessments because average recruitment has been calculated over a longer period, which includes more years from the low-recruitment regime, and due to changes in growth, fecundity, and current age-specific fishing mortality.
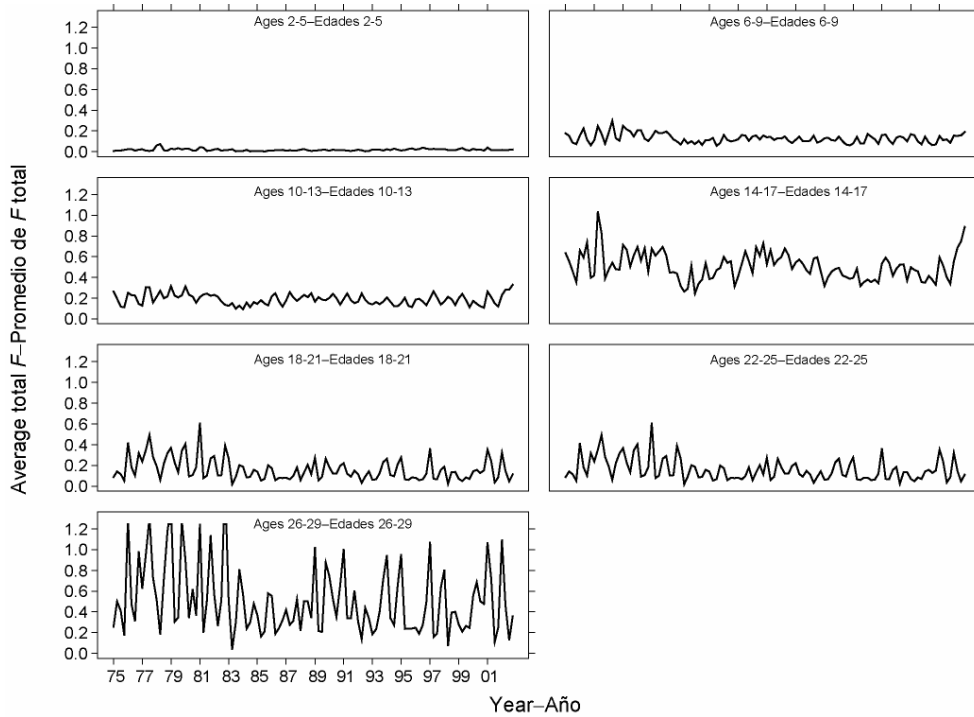
**FIGURE YFT1.** Time series of average total quarterly fishing mortality of yellowfin tuna recruited to the fisheries of the EPO. Each panel illustrates an average of four quarterly fishing mortality vectors that affected the fish of the age range indicated in the title of each panel. For example, the trend illustrated in the upper-left panel is an average of the fishing mortalities that affected fish that were 2-5 quarters old.
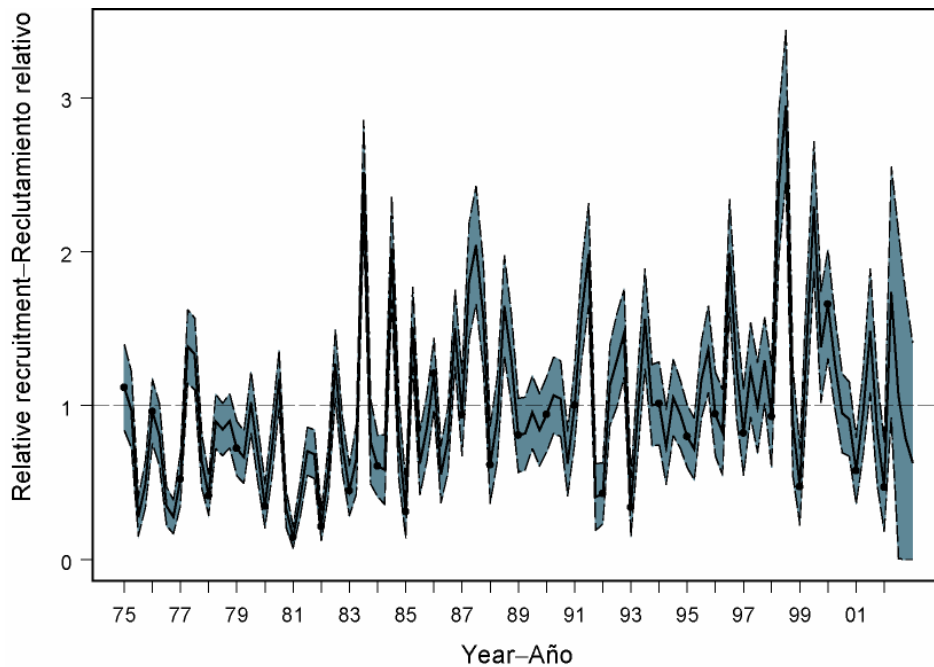


**FIGURE YFT2.** Estimated recruitment of yellowfin tuna to the fisheries of the EPO. The estimates are scaled so that the average recruitment is equal to 1.0. The bold line illustrates the maximum likelihood estimates of recruitment, and the thin lines indicate the approximate 95% confidence intervals around those estimates. The labels on the time axis are drawn at the start of each year, but, since the assessment model represents time on a quarterly basis, there are four estimates of recruitment for each year.

**FIGURE YFT3.** Biomass trajectory of a simulated population of yellowfin tuna that was not exploited during 1975-2002 ("no fishing") and that predicted by the stock assessment model ("fishing").
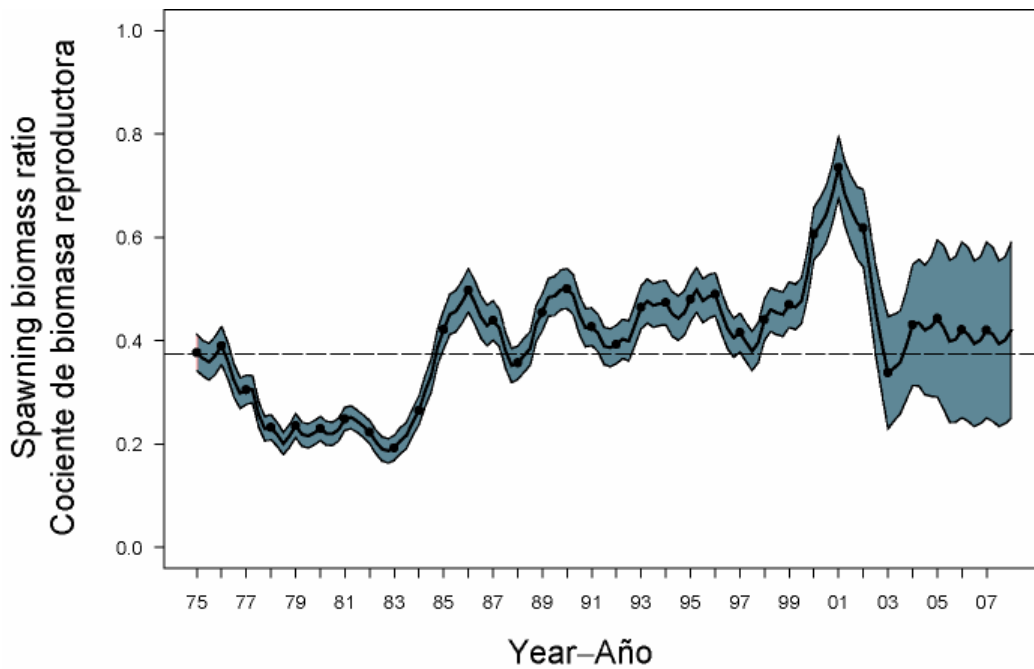


**FIGURE YFT4.** SBRs projected during 2003-2007 for yellowfin tuna in the EPO using the likelihood profile approximation method. The dashed horizontal line (at 0.37) identifies $SBR_{AMSY}$ (Section 5.3).

**Predicted purse seine catches**
**Captura cerquera predicha**

**Predicted longline catches**
**Captura palangrera predicha**
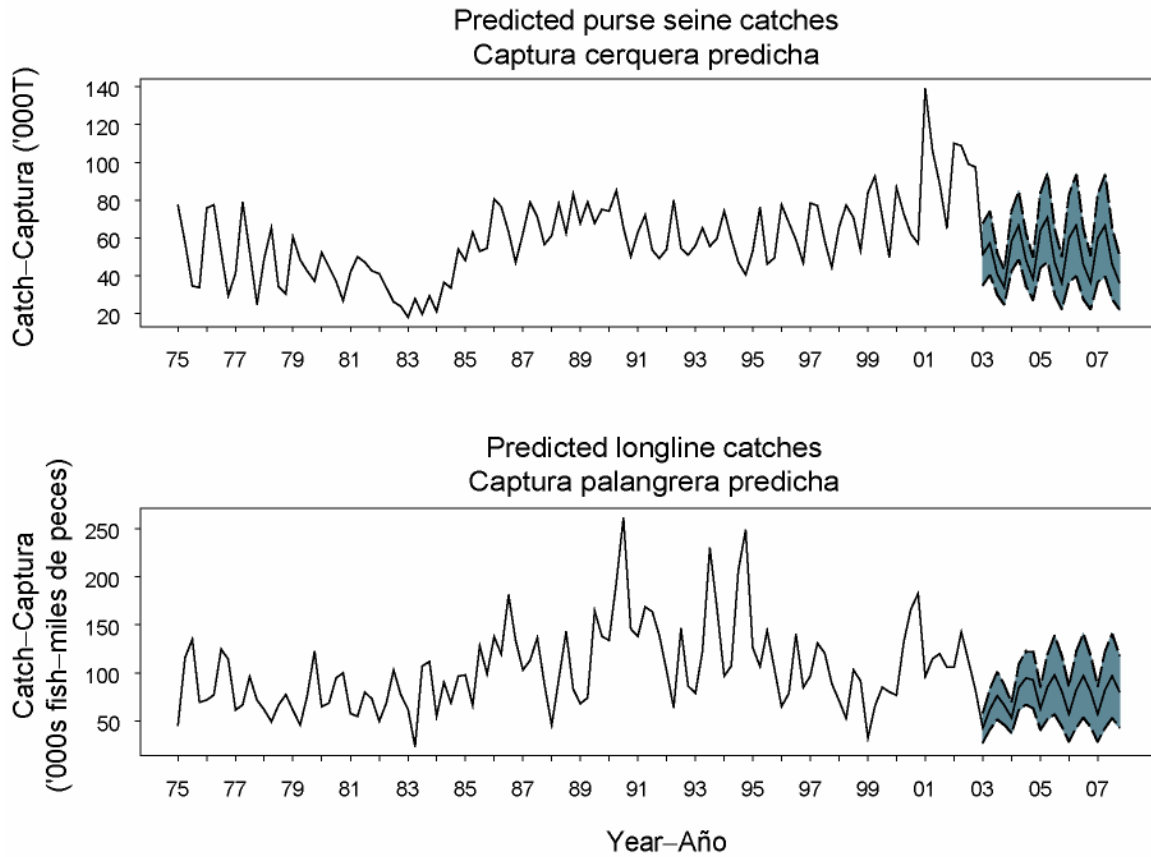
**FIGURE YFT5.** Simulated catches of yellowfin tuna taken by the primary surface fleet (Fisheries 1-10; top panel) and the the longline fleet (Fisheries 11 and 12, bottom panel) during 2003-2007 using the likelihood profile method.

**TABLE YFT1**. AMSY and related quantities for the base case and the stock recruitment relationship sensitivity analysis.

| | Basecase | h = 0.75 | Iterative reweighting |
|---|---|---|---|
| AMSY–RPMS | 254,723 | 266,371 | 250,750 |
| $B_{ms2}-B_{rm2}$ | 381,775 | 502,129 | 377,686 |
| $S_{ms2}-S_{rm2}$ | 6,010 | 7,946 | 5,990 |
| $C_{2002}$/AMSY—$C_{2002}$/RPMS | 1.72 | 1.64 | 1.76 |
| $B_{2003}/B_{AMSY}-B_{2003}/B_{RMS}$ | 0.89 | 0.70 | 0.74 |
| $S_{2003}/S_{AMSY}-S_{2003}/S_{RMS}$ | 0.89 | 0.70 | 0.74 |
| $S_{AMSY}/S_{F=0}-S_{RPMS}/S_{F=0}$ | 0.37 | 0.41 | 0.38 |
| $F$ multiplier—Multiplicador de $F$ | 1.20 | 0.89 | 1.36 |

| | Last years selectivity smoothness weighting factors | Species composition based catches |
|---|---|---|
| AMSY–RPMS | 254,334 | 253,594 |
| $B_{ms2}-B_{rm2}$ | 379,826 | 379,913 |
| $S_{ms2}-S_{rm2}$ | 5,965 | 5,983 |
| $C_{2002}$/AMSY—$C_{2002}$/RPMS | 1.72 | 1.63 |
| $B_{2003}/B_{AMSY}-B_{2003}/B_{RMS}$ | 0.86 | 0.87 |
| $S_{2003}/S_{AMSY}-S_{2003}/S_{RMS}$ | 0.87 | 0.87 |
| $S_{AMSY}/S_{F=0}-S_{RPMS}/S_{F=0}$ | 0.37 | 0.38 |
| $F$ multiplier—Multiplicador de $F$ | 1.18 | 1.20 |

## C. BIGEYE TUNA

An age-structured, catch-at-length analysis, A-SCALA, was used to assess bigeye tuna in the EPO. The version of A-SCALA is the similar to that used for the previous assessment with modifications to one of the assumptions. A-SCALA now allows missing values in environmental indices thought to be related to recruitment.

There are a number of other changes between this assessment and the previous assessment carried out for 2001 including: extending the model back to 1975, revising inputs for many biological parameters, using species composition estimates of catch from the purse seine fisheries, incorporating new and updated data from the purse seine fisheries and the Japanese and Taiwanese longline fisheries[1], calculating standardized CPUE for longline fisheries using a neural network, changing the selectivity smoothness penalties, and changing the years assumed for catchability and fishing mortality for projections and yield calculations.

Various sensitivity analyses were performed, including the incorporation of a stock recruitment relationship, replacing the species composition estimates purse seine catches with the cannery and unloading estimates used in previous assessments, replacing the database estimates of Korean longline catches with the estimates from the Secretariat of the Pacific Community[2], replacing the neural network standardized CPUE with the habitat-standardized CPUE used in the previous assessment, and replacing the assumed sample sizes for the length frequency data with estimates of the effective sample size calculated using an iterative procedure.

Two alternative scenarios were considered to assess the sensitivity of yield estimates and reference points to the period assumed to represent current (and future) fishing mortality and catchability. In the basecase, estimates of fishing mortality and catchability (plus effort deviates) for 2000 and 2001 were used in projections and yield calculations. For sensitivity, fishing mortality and catchability from (1) 1999 and 2000, were compared with (2) 2001 and 2002.

There have been important changes in the amount of fishing mortality caused by the fisheries that catch bigeye tuna in the EPO. On average, the fishing mortality on bigeye less than about 20 quarters old has increased substantially since 1993, and that on fish more than about 24 quarters old has decreased slightly since then (Figure BET1). The increase in average fishing mortality on the younger fish was caused by the expansion of the fisheries that catch bigeye in association with floating objects. The basecase assessment suggests that (1) the use of FADs has substantially increased the catchability of bigeye by fisheries that catch tunas associated with floating objects, and (2) that bigeye are substantially more catchable when they are associated with floating objects in offshore areas.

Recruitment of bigeye tuna to the fisheries in the EPO is variable, and the mechanisms that explain variation in recruitment have not been identified. Nevertheless, the abundance of bigeye tuna being recruited to the fisheries in the EPO appears to be related to zonal-velocity anomalies at 240 m during the time that these fish were assumed to have hatched. Over the range of spawning biomasses estimated by the basecase assessment, the abundance of bigeye recruits appears to be unrelated to the spawning potential of adult females at the time of hatching.

There are two important features in the estimated time series of bigeye. First, greater-than-average recruitments occurred in 1977, 1979, 1982-1983, 1992, 1994, and 1995-1997 (Figure BET2). However, the lower confidence bounds of these estimates were only greater than the estimate of virgin recruitment for 1994 and 1997, so it is uncertain whether these recruitments were, in fact, greater than the virgin

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[1] Additional longline data from China for 2001 and Korea for 1987-2000 were received too late to be included in this assessment.

[2] Revised Korean data for 1987-2000, received too late to be included in this assessment, were in between the higher SPC estimates and data previously held by the IATTC

recruitment.  An above average cohort is estimated for the first quarter of 2001 but this estimate is uncertain. Second, recruitment has been much lower than average for most of the recent period from the second quarter of 1998 to the end of 2000, and the upper confidence bounds of many of these recruitment estimates are below the virgin recruitment (Figure BET2).  Evidence for these low recruitments comes from the decreased CPUEs achieved by some of the floating-object and discard fisheries, the length frequency data, and by poor environmental conditions for recruitment.  The extended sequence of low recruitments is important because it is likely to produce a sequence of years in which the spawning biomass ratio will be below the level that would support the average maximum sustainable yield (AMSY).

Fishing has reduced the total biomass of bigeye present in the EPO, predicted to be at its lowest level by the end of 2003 (Figure BET3). There has been an accelerated decline in biomass since the small peak in 2000.

The estimates of recruitment and biomass are sensitive both to the way in which the assessment model is parameterized and to the data that are included in the assessment.  Including the SPC-estimated Korean longline catch increased estimates of biomass and recruitment. However, including a stock-recruitment relationship did not change the estimates of biomass or recruitment. The re-weighting of the length frequency sample sizes produced the greatest differences in biomass trajectories.  However, trends in effort deviates for the longline fisheries were inconsistent with CPUE data had been standardized. In general, the results of the sensitivity analysis and those presented by Watters and Maunder (2002) support the view that the basecase estimates of biomass are uncertain.

At the beginning of January 2003, the spawning biomass of bigeye tuna in the EPO was beginning to decline from a recent high level (Figure BET4).  At that time the SBR was about 0.27, about 49% greater than the level that would be expected to produce the AMSY, with lower and upper confidence limits ($\pm$ 2 standard deviations) of about 0.15 and 0.39.  The estimate of the lower confidence bound is only slightly less than the estimate of $SBR_{AMSY}$ (0.18), suggesting that, at the start of January 2003, the spawning biomass of bigeye in the EPO was greater than the level that is required to produce the AMSY.

Estimates of the average SBR projected to occur during 2003-2007 indicate that the SBR is likely to reach an historic low level in 2006 and remain below the level required if the population were to produce the AMSY until 2007 and probably after that (Figure BET4).  This decline is likely to occur regardless of environmental conditions and the amounts of fishing that occur in the near future because the projected estimates of SBR are driven by the small cohorts that were produced during 1998 to 2000.

The average weight of fish in the catch of all fisheries combined has been below the critical weight (about 54.7 kg) since 1993, suggesting that the recent age-specific pattern of fishing mortality is not satisfactory from a yield-per-recruit perspective.

The distribution of effort among fishing methods affects both the equilibrium yield per recruit and the equilibrium yield.  When floating-object fisheries take a large proportion of the total catch, the maximum possible yield per recruit is less than that when longline catches are dominant.  Also, if longline catches are dominant, the maximum yield per recruit (or a value close to it) can be obtained over a wide range of fishing effort.  When floating-object fisheries take a large proportion of the total catch, a more narrow range of fishing effort provides a yield per recruit that is close to the maximum.  When floating-object fisheries take a large proportion of the total catch and a stock-recruitment relationship exists, extremely large amounts of fishing effort would cause the population to crash.  When longline catches are dominant, the population can sustain substantially greater fishing effort.

Recent catches are estimated to have been about 40% above the AMSY level (Table BET1).  If fishing mortality is proportional to fishing effort, and the current patterns of age-specific selectivity are maintained, the level of fishing effort that is estimated to produce AMSY is about 79% of the current level of effort.  Decreasing the effort to 79% of its present level would only increase the long-term

average yield by 2%, but such an action would increase the spawning potential of the stock by about 50%. The catch of bigeye by the surface fleet may be determined largely by the strength of recruiting cohorts. Thus, the catches of bigeye taken by the surface fleet will probably decline when the large cohorts recruited during 1995-1998 are no longer vulnerable to the surface fisheries. The AMSY of bigeye in the EPO could be maximized if the age-specific selectivity pattern were similar to that for the longline fishery that operates south of 15°N.

With the exception of the steepness sensitivity, analyses suggest that at the start of 2003 the spawning biomass was above the level that would be present if the stock were producing the AMSY (Table BET1). MSY and the *F* multiplier are sensitive to how the assessment model is parameterized, the data that are included in the assessment, and the periods assumed to represent average fishing mortality.

The small cohorts of bigeye tuna that were apparently recruited to the fisheries in the EPO during 1998-2000 should cause the SBR to decrease throughout 2003 and to be substantially less than $SBR_{AMSY}$. During 2003, the spawning biomass of bigeye in the EPO should decline to historically low levels and continue to decline further. This decline is predicted to occur regardless of the amount of fishing effort and environmental conditions that occur in the near future. The SBR is projected to further decrease during 2004-2006.

Preventing the discards of small bigeye tuna from catches taken around floating objects (or ensuring that discarded fish survive) would increase the SBR, the yield per recruit, the catch taken by the surface fleet, and the catch taken by the longline fleet. Thus, any measure that effectively reduces the kill of bigeye that are about 2-5 quarters old may help to achieve a variety of management objectives.

The sensitivity analysis indicates that if fishing mortality rates continue at their recent (2001 and 2002) levels, longline catches and SBR will decrease dramatically to extremely low levels. As the basecase does not include a stock recruitment model, recruitment will not decline so purse-seine catches are predicted to stay at moderate levels (Figure BET5).
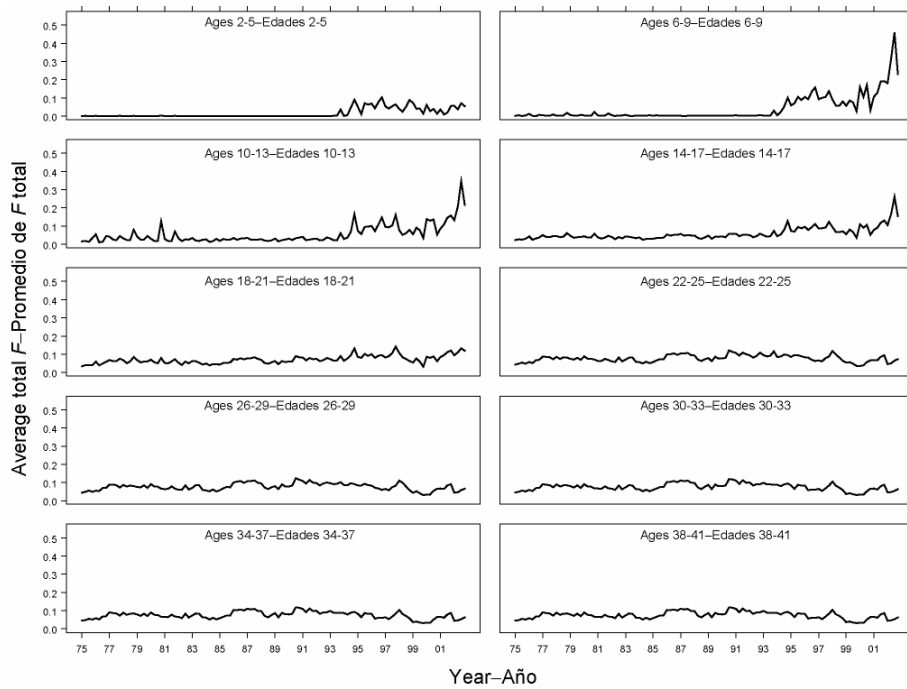
**FIGURE BET1.** Time series of average total quarterly fishing mortality on bigeye tuna recruited to the fisheries of the EPO. Each panel illustrates an average of four quarterly fishing mortality vectors that affected the fish in the age range indicated in the title of each panel. For example, the trend illustrated in the upper-left panel is an average of the fishing mortalities that affected fish that were 2-5 quarters old.
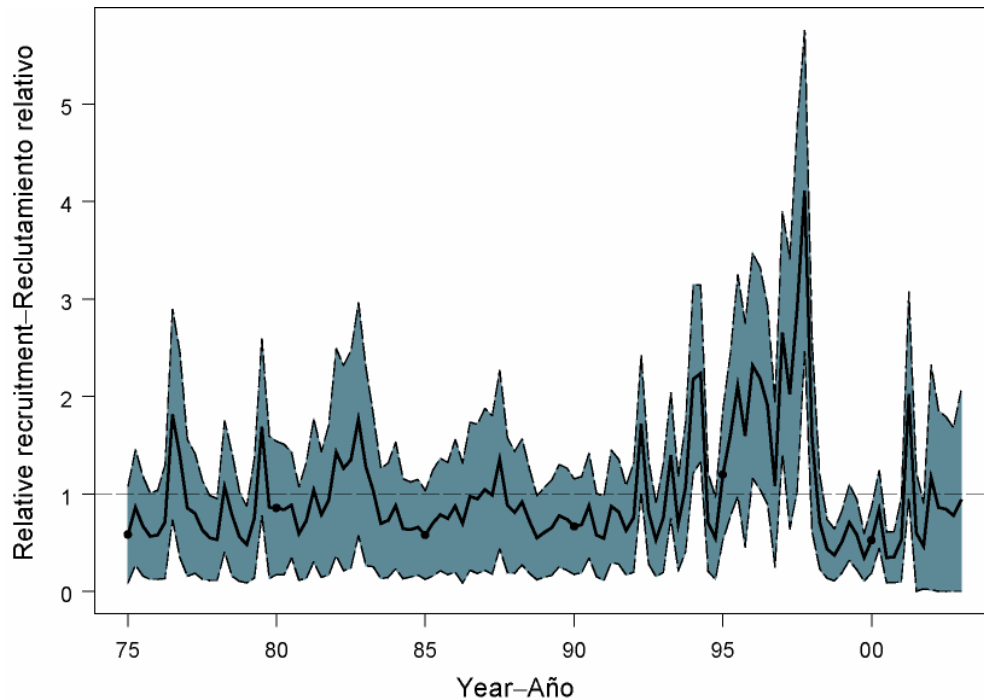


**FIGURE BET2.** Estimated recruitment of bigeye tuna to the fisheries of the EPO. The estimates are scaled so that the estimate of virgin recruitment is equal to 1.0. The bold line illustrates the maximum likelihood estimates of recruitment, and the thin lines are confidence intervals (±2 standard errors) around those estimates. The labels on the time axis are drawn at the start of each year, but, since the assessment model represents time on a quarterly basis, there are four estimates of recruitment for each year.
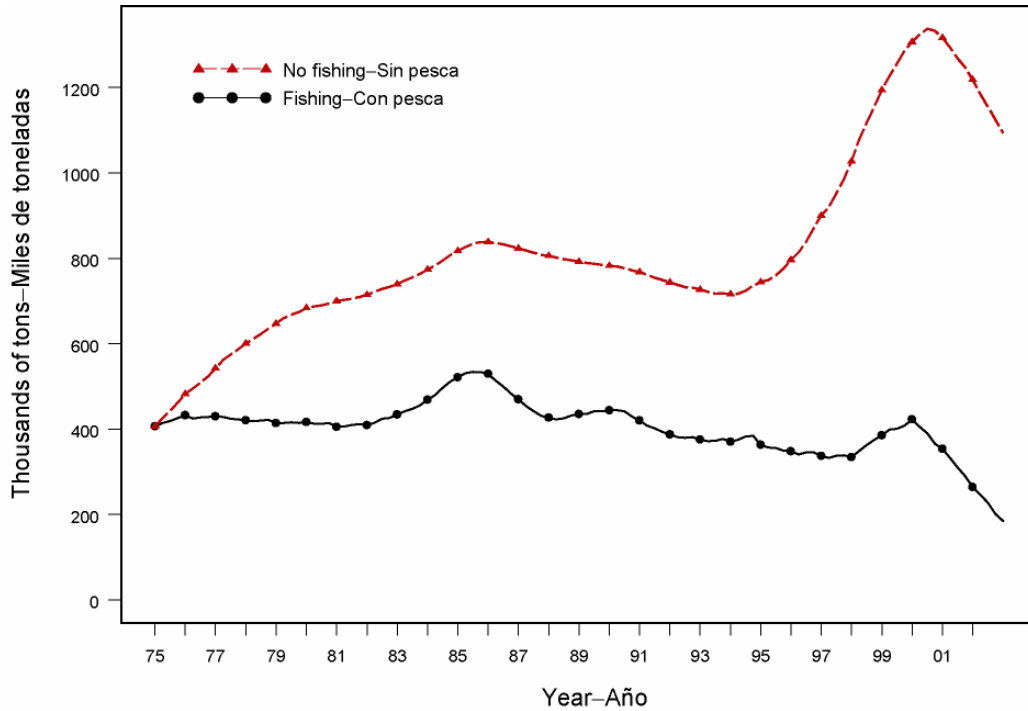
**FIGURE BET3.** Biomass trajectory of a simulated population of bigeye tuna that was not exploited during January 1975 through December 2002 ("no fishing") and that predicted by the stock assessment model ("fishing").
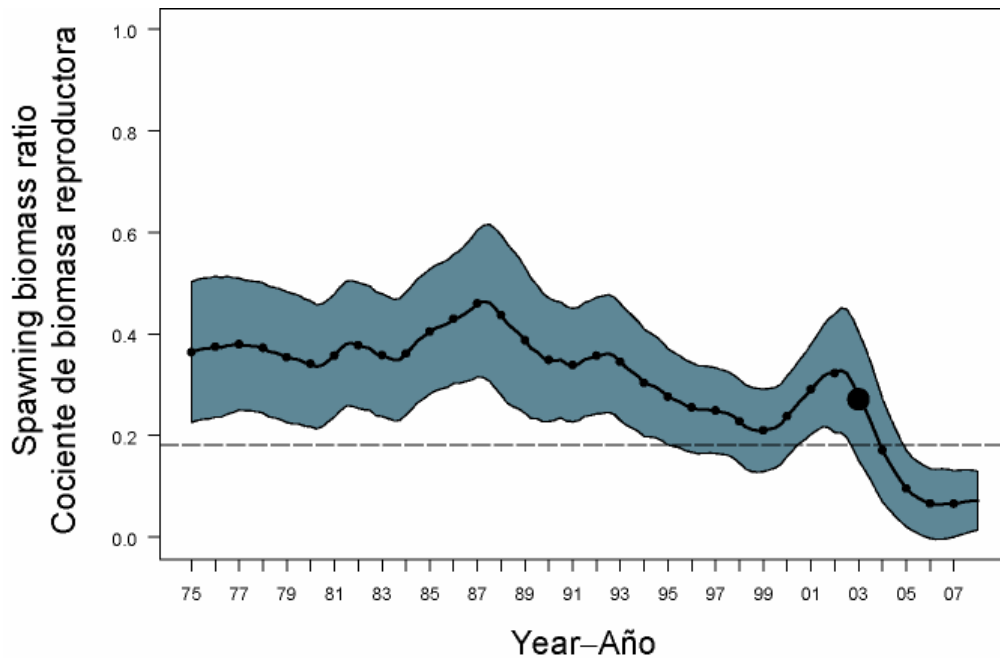


**FIGURE BET4.** Estimated time series of spawning biomass ratios (SBRs) for bigeye tuna in the EPO. The dashed horizontal line (at about 0.18) identifies the SBR at AMSY. The solid lines illustrate the maximum likelihood estimates, and the dashed lines are confidence intervals (±2 standard errors) around those estimates. The dashed line continuing the SBR trend indicates the SBR predicted to occur if, effort continues at the average of that observed in 2001 and 2002, catchability (with effort deviates) continues as the average for 2000 and 2001, average environmental conditions occur during the next five years.
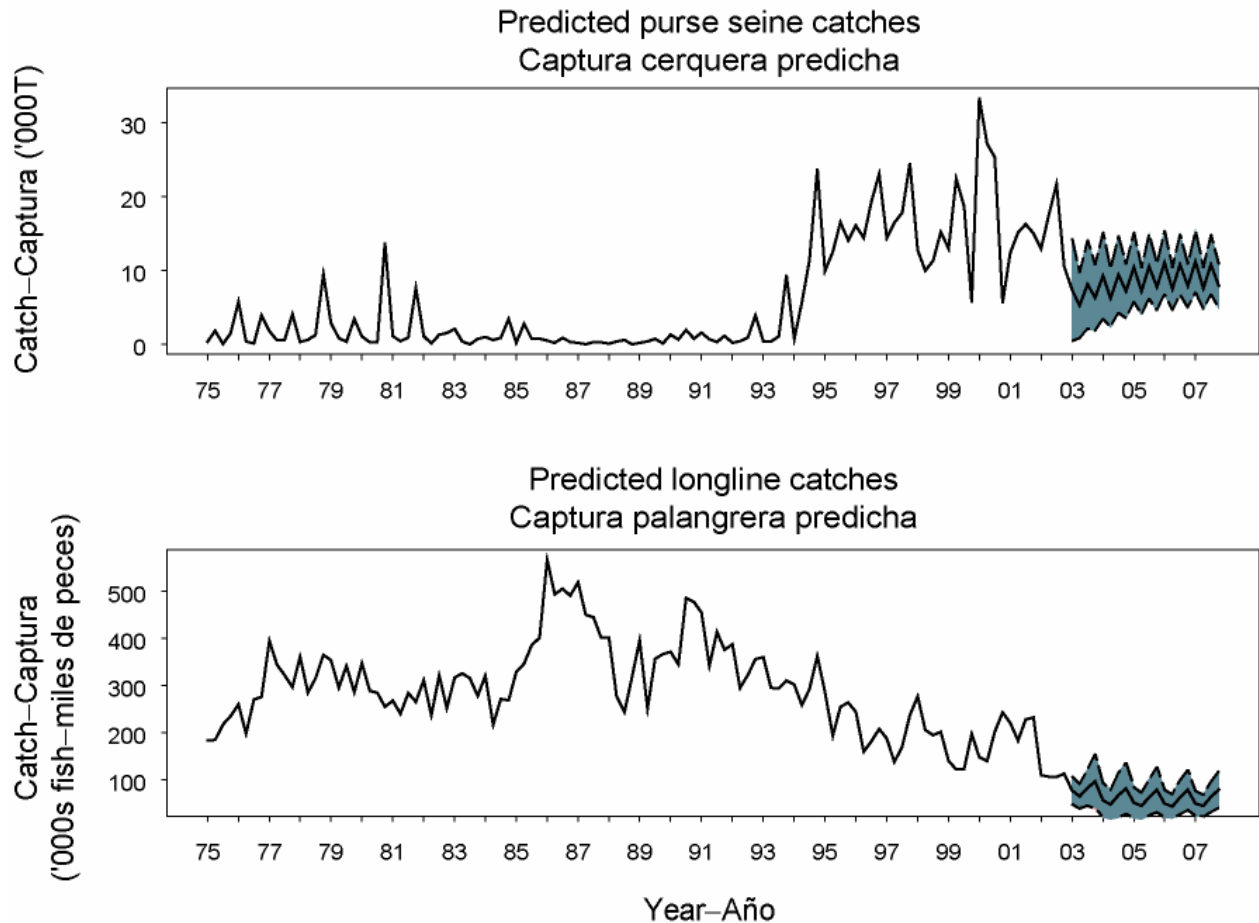
**FIGURE BET5.** Predicted catches for the surface (Fisheries 2, 3, 4, 5, and 7) and longline (Fisheries 8 and 9) fisheries based on average effort for 2002 and 2001 and average catchability for 2000 and 2001. Prediction were undertaken using the likelihood profile method described in Section 6. The shaded areas represent 95% confidence intervals for the predictions of future catches.

**TABLE BET1.** Estimates of the AMSY and its associated quantities for the basecase and sensitivity analyses. All analyses are based on average fishing mortality for 2000 and 2001. $B_{recent}$ and $B_{AMSY}$ are defined as the biomass of bigeye 1+ years old at the start of 2003 and at AMSY, respectively, and $S_{recent}$ and $S_{AMSY}$ are defined as indices of spawning biomass (therefore, they are not in metric tons). $C_{recent}$ is the estimated total catch in 2002.

| | Basecase | Steepness = 0.75 | Purse-seine un-loading data |
|---|---|---|---|
| AMSY (T)—RMSP (tm) | 67,948 | 65,882 | 63,256 |
| $B_{AMSY}$ (T)—$B_{RMSP}$ (tm) | 246,841 | 411,885 | 229,092 |
| $S_{AMSY}$—$S_{RMSP}$ | 28,989 | 59,414 | 26,728 |
| $B_{AMSY}/B_0$—$B_{RMSP}/B_0$ | 0.28 | 0.36 | 0.29 |
| $S_{AMSY}/S_0$—$S_{RMSP}/S_0$ | 0.18 | 0.29 | 0.19 |
| $C_{recent}$/AMSY—$C_{recent}$/RMSP | 1.40 | 1.45 | 1.14 |
| $B_{recent}/B_{AMSY}$—$B_{recent}/B_{RMSP}$ | 0.75 | 0.56 | 0.93 |
| $S_{recent}/S_{AMSY}$—$S_{recent}/S_{RMSP}$ | 1.49 | 0.86 | 1.66 |
| $F$ multiplier—Multiplicador de $F$ | 0.79 | 0.53 | 0.88 |

| | SPC Korean LL | HBS cpue | Iterative reweighting |
|---|---|---|---|
| AMSY (T)—RMSP (tm) | 78,895 | 68,246 | 65,393 |
| $B_{AMSY}$ (T)—$B_{RMSP}$ (tm) | 296,586 | 254,007 | 244,640 |
| $S_{AMSY}$—$S_{RMSP}$ | 35,902 | 30,531 | 28,628 |
| $B_{AMSY}/B_0$—$B_{RMSP}/B_0$ | 0.27 | 0.27 | 0.31 |
| $S_{AMSY}/S_0$—$S_{RMSP}/S_0$ | 0.18 | 0.18 | 0.20 |
| $C_{recent}$/AMSY—$C_{recent}$/RMSP | 1.32 | 1.41 | 1.46 |
| $B_{recent}/B_{AMSY}$—$B_{recent}/B_{RMSP}$ | 1.21 | 1.04 | 0.45 |
| $S_{recent}/S_{AMSY}$—$S_{recent}/S_{RMSP}$ | 2.45 | 2.11 | 0.66 |
| $F$ multiplier—Multiplicador de $F$ | 1.08 | 0.94 | 0.54 |

## D. SKIPJACK TUNA

An age-structured, catch-at-length analysis (A-SCALA) is used to assess skipjack tuna (*Katsuwonus pelamis*) in the EPO. The analysis method is described by Maunder and Watters (2003a), and readers are referred to that document for technical details. The assessment was carried out in 2002 and no new analysis was carried out in 2003. The stock assessment requires a substantial amount of information. Data on landings, discards, fishing effort, and the size compositions of the catches of several different fisheries have been analyzed. Several assumptions regarding processes such as growth, recruitment, movement, natural mortality, fishing mortality, and stock structure have also been made. Environmental influences on recruitment have been investigated. The assessment is still considered preliminary because 1) it is unknown if catch-per-day-fished is proportional to abundance for purse-seine fisheries, 2) it is possible that there is a population of large skipjack that is invulnerable to the fisheries, 3) stock structure in relation to the EPO and western and central Pacific stocks is uncertain, and 4) estimates of absolute biomass have changed by more than an order of magnitude from the previous assessment.

The rate of fishing mortality is estimated to be about the same or less than the rate of natural mortality; this is supported by estimates from tagging data (Figure SKJ1). The recruitment of skipjack tuna to the fisheries in the EPO is variable (Figure SKJ2). Biomass fluctuates mainly in response to the variations in recruitment, except for the low biomass levels in the early 1980s that were estimated to be a consequence of high fishing mortality rates (Figure SKJ3).

The analysis indicates that a group of very strong cohorts entered the fishery in 1998-99, and that these cohorts increased the biomass and catches during 1999 and 2000 (Figure SKJ2). There is also an indication that the most recent recruitments have been low, which may lead to lower biomasses (Figure SKJ3) and catches. However, these estimates of low recruitment are based on limited information, and are therefore very uncertain.

There is considerable variation in spawning biomass ratio (the ratio of the spawning biomass to the spawning biomass of the unexploited stock; SBR) for skipjack tuna in the EPO (Figure SKJ4). In 2002 the SBR is at a low level (about 0.23). AMSY and yield-per-recruit calculations estimate that maximum yields are achieved with infinite fishing mortality because the critical weight is less than the average weight at recruitment to the main fisheries. However, this is uncertain because of uncertainties in the estimates of natural mortality and growth.
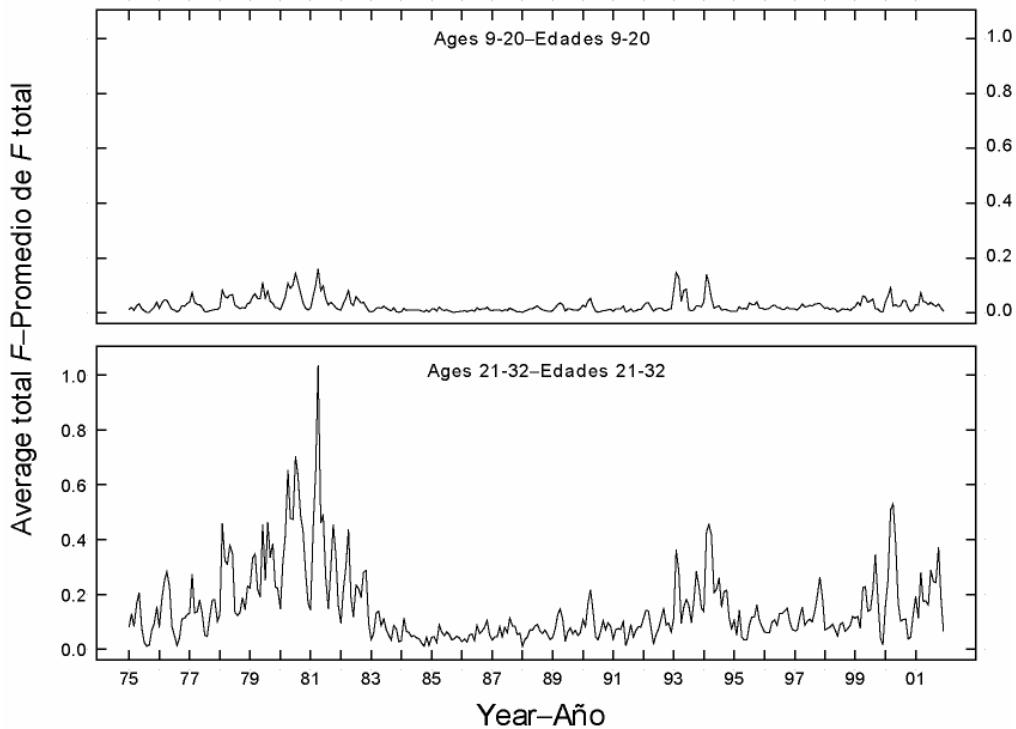
**FIGURE SKJ1.** Time series of average total monthly fishing mortality of skipjack tuna recruited to the fisheries of the EPO, from the monotonic selectivity assessment. Each panel illustrates an average of 12 monthly fishing mortality vectors that affected fish of the age range indicated in the title of each panel. For example, the trend illustrated in the upper panel is an average of the fishing mortalities that affected fish that were 9-20 months old.
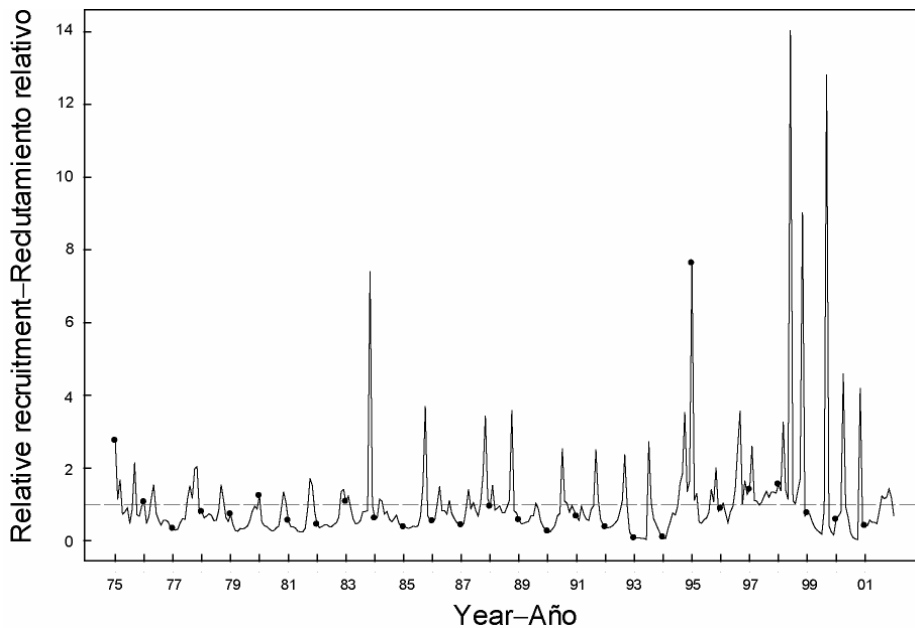


**FIGURE SKJ2.** Estimated recruitment of skipjack tuna to the fisheries of the EPO from the monotonic selectivity assessment. The estimates are scaled so that the average recruitment is equal to 1.0. The solid line illustrates the maximum-likelihood estimates of recruitment, and the dashed lines the 95% confidence intervals. The labels on the time axis are drawn at the start of each year, but, since the assessment model represents time on a monthly basis, there are 12 estimates of recruitment for each year.
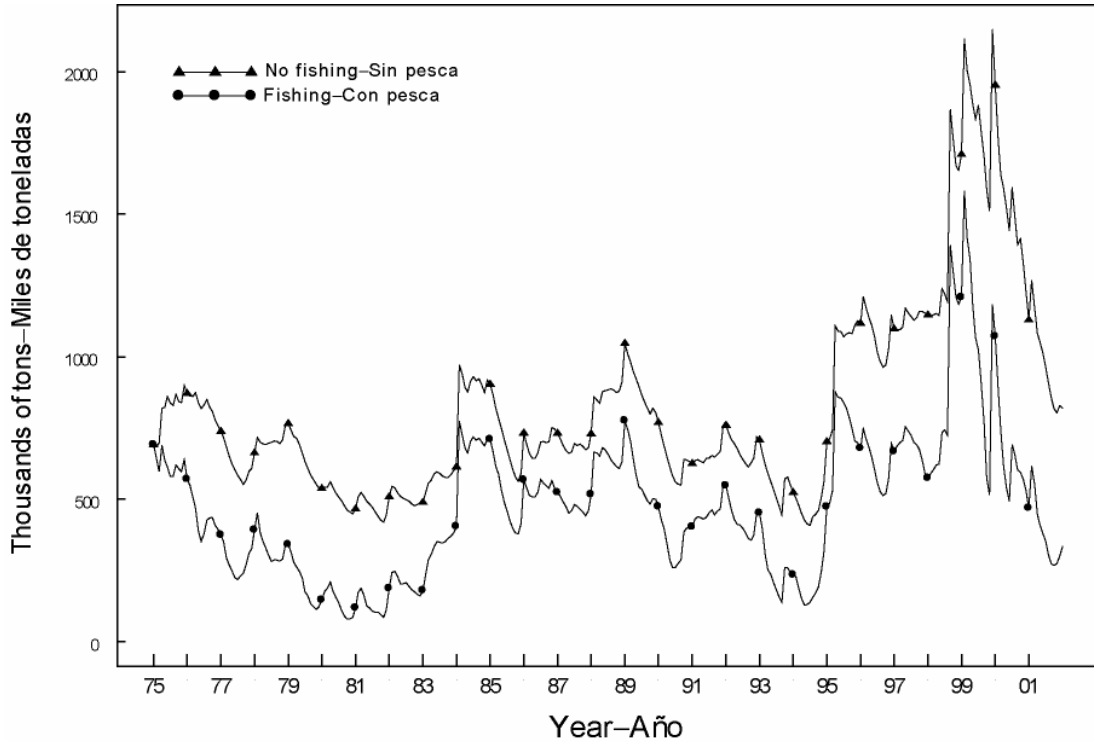
**FIGURE SKJ3.** Biomass trajectory of a simulated population of skipjack tuna that was not exploited during 1975-2002 ("no fishing") and that predicted by the stock assessment model ("fishing") from the monotonic selectivity stock assessment.
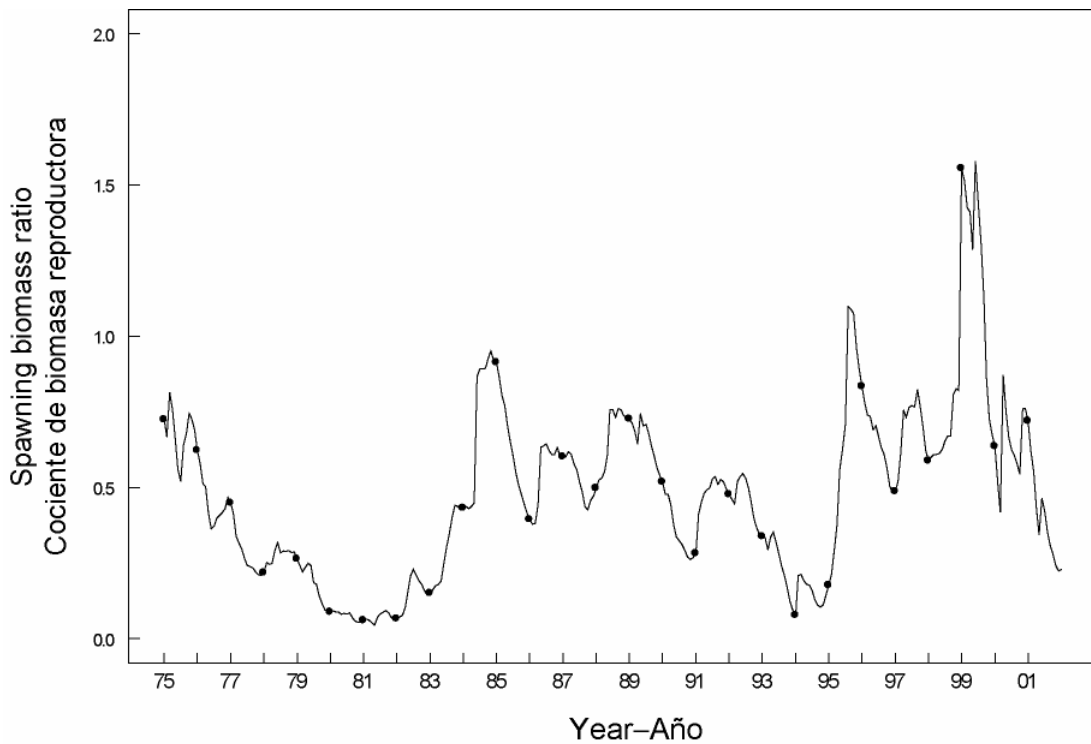


**FIGURE SKJ4.** Estimated time series of spawning biomass ratios (SBRs) for skipjack tuna in the EPO, from the monotonic selectivity assessment.

## E. PACIFIC BLUEFIN TUNA

Tagging studies have shown that there is exchange of bluefin, *Thunnus orientalis*, between the eastern and western Pacific Ocean. Larval, postlarval, and early juvenile bluefin have been caught in the western Pacific Ocean (WPO), but not the eastern Pacific Ocean (EPO), so it is likely that there is a single stock of bluefin in the Pacific Ocean.

Most of the catches of bluefin in the EPO are taken by purse seiners. Nearly all of the purse-seine catch is made west of Baja California and California, within about 100 nautical miles of the coast, between about 23°N and 33°N. In recent years a considerable portion of the purse-seine catch of bluefin has been transported to holding pens, where the fish are held for fattening and later sale as sashimi-grade fish. Lesser amounts of bluefin are caught by recreational, gillnet, and longline gear. Bluefin have been caught during every month of the year, but most of the fish are taken during May through October.

Bluefin are exploited by various gears in the WPO from Taiwan to Hokkaido. Age-0 fish about 15 to 30 cm in length are caught by trolling during July-October south of Shikoku Island and south of Shizuoka Prefecture. During November-April age-0 fish about 35 to 60 cm in length are taken by trolling south and west of Kyushu Island. Age-1 and older fish are caught by purse seining, mostly during May-September, between about 30°-42°N and 140°-152°E. Bluefin of various sizes are also caught by traps, gillnets, and other gear, especially in the Sea of Japan. Small amounts of bluefin are also caught near the southeastern coast of Japan by longlining.

The high-seas longline fisheries are directed mainly at tropical tunas, albacore, and billfishes, but small amounts of Pacific bluefin are caught by these fisheries. Small amounts of bluefin are also caught by Japanese pole-and-line vessels on the high seas.

Tagging studies, conducted with conventional and archival tags, have revealed a great deal of information about the life history of bluefin. As stated above, it appears that spawning occurs only in the WPO. Some fish apparently remain their entire lives in the WPO, while others migrate to the EPO. These migrations begin mostly, or perhaps entirely, during the first and second years of life. The first- and second-year migrants are exposed to various fisheries before beginning their journey to the EPO. The migrants, after crossing the ocean, are exposed to commercial and recreational fisheries off California and Baja California. Eventually, the survivors return to the WPO.

Bluefin are most often found in the EPO in waters where the sea-surface temperatures (SSTs) are between 17° and 23°C. Fish 15 to 31 cm in length are found in the WPO in waters where the SSTs are between 24° and 29°C. The survival of larval and early juvenile bluefin is undoubtedly strongly influenced by the environment. Conditions in the WPO probably influence the portions of the juvenile fish there that move to the EPO, and also the timing of these movements. Likewise, conditions in the EPO probably influence the timing of the return of the juvenile fish to the WPO.

Various indices of abundance of bluefin in the EPO have been calculated, but none of these is entirely satisfactory. The IATTC has calculated "habitat" and "bluefin-vessel" indices for the EPO routinely for several years.

A preliminary cohort analysis has indicated that the biomass of the spawning stock was relatively high during the 1960s, decreased during the 1970s and 1980s, and then increased during the 1990s. The recruitment was estimated to be highly variable, with four or five strong cohorts produced during the 1960-1998 period.

The total catches of bluefin have fluctuated considerably during the last 50 years (Figure PBF1). The presence of consecutive years of above-average catches (mid-1950s to mid-1960s) and below-average catches (early 1980s to early 1990s) could be due to consecutive years of above-average and below-average recruitment. The results of yield-per-recruit and cohort analyses indicate that greater catches could be obtained if the catches of age-0 and age-1 fish were reduced or eliminated.

Spawner-recruit analyses do not indicate that the recruitment of Pacific bluefin could be increased by permitting more fish to spawn.
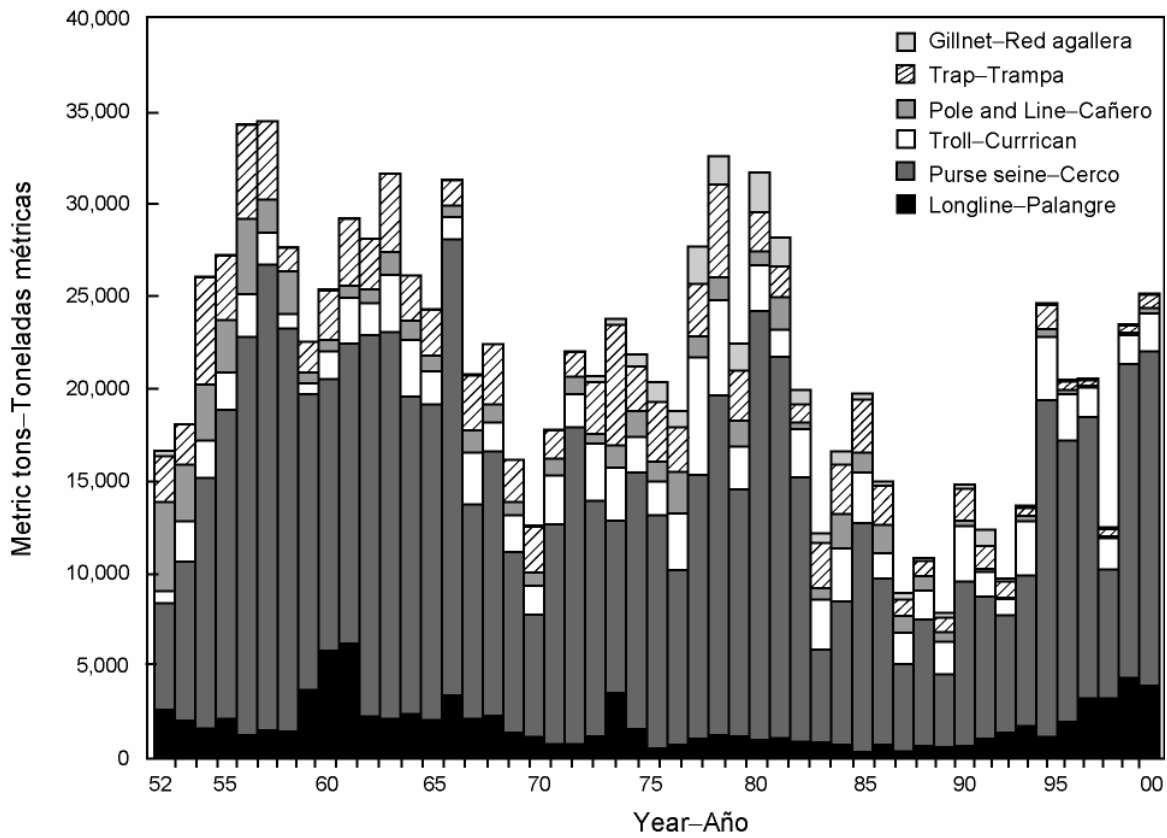


**FIGURE PBF1.** Retained catches of Pacific bluefin, 1952-2000.

# F. ALBACORE TUNA

Most scientists who have studied albacore, *Thunnus alalunga*, in the Pacific Ocean have concluded that there are two stocks, one occurring in the northern hemisphere and the other in the southern hemisphere. Albacore are caught by longliners in most of the North and South Pacific, but not often between about 10°N and 5°S, by trollers in the eastern and central North Pacific and the central South Pacific, and by pole-and-line vessels in the western North Pacific. In the North Pacific 55% of fish are taken in surface fisheries that catch smaller albacore versus 20% in the South Pacific. Total catches of albacore from the North Pacific peaked in the early 1970s at over 100,000 metric tons per year, and then declined. Catches recovered during the 1990s, and reached an all-time high of 127,800 metric tons in 1999 (Figure ALB1a). In the South Pacific, catches have ranged between about 25,000 and 55,000 metric tons during the 1980s and 1990s (Figure ALB1b).

The adults are caught mostly in the Kuroshio Current, the North Pacific Transition Zone, and the California Current in the North Pacific and the Subtropical Convergence Zone in the South Pacific, but spawning occurs in tropical and subtropical waters.

There appear to be two subgroups of albacore in the North Pacific Ocean. The fish of the northern subgroup are found mostly north of 40°N when they are in the eastern Pacific Ocean. There is considerable exchange of fish of this subgroup between the troll fishery of the eastern Pacific Ocean and the pole-and-line and longline fisheries of the western Pacific Ocean. The fish of the southern subgroup occur mostly south of 40°N in the eastern Pacific, and relatively few of them are caught in the western Pacific. Fish that were tagged in offshore waters of the eastern Pacific and recaptured in the coastal fishery of the eastern Pacific exhibited different movements, depending on the latitude of release. Most of the recaptures of those released north of 35°N were made north of 40°N, and most of the recaptures of those released south of 35°N were made south of 40°N.

Much less is known about the movements of albacore in the South Pacific Ocean. The juveniles move southward from the tropics when they are about 35 cm long, and then eastward along the Subtropical Convergence Zone to about 130°W. When the fish approach maturity they return to the tropics, where they spawn. Recoveries of tagged fish released in areas east of 155°W were usually made at locations to the east and north of the release site, whereas those of fish released west of 155°W were usually made at locations to the west and north of the release site.

New age-structured stock assessments were presented for the North and South Pacific stocks of albacore in 2002. The South Pacific assessment, carried out with MULTIFAN-CL by the Secretariat for the Pacific Community, incorporated catch and effort, length-frequency, and tagging data. The stock was estimated to be well above the level that would produce the average maximum sustainable yield (AMSY), the current catches of around 40,000 T being much less than the estimated AMSY of 117,000 T. Although the recent recruitments are estimated to be slightly below average, there appears to be no need to restrict the fisheries for albacore in the South Pacific Ocean.

Virtual population analyses of the North Pacific stock of albacore were carried out during the 18th North Pacific albacore workshop. The estimated current biomass, 510,000 T, is almost 40 percent greater than that estimated for 1975, the first year of the period modeled. The estimated recruitments of the 1990s were greater than those of the 1980s, and the catches per unit effort for most of the surface fisheries have increased in recent years. The fishing mortality for juvenile fish is estimated to be relatively high. Projections, under different assumptions of future recruitment, suggest that the biomass will decline if the current levels of fishing mortality persist. $F_{AMSY}$, the fishing mortality corresponding to the AMSY, was not estimated, but a proxy for it suggested that the stock is currently being fished at a $F_{20\%}$ level. In the near future the North Pacific stock of albacore will be analyzed with MULTIFAN-CL, using data for years prior to 1975, in addition to those for more recent years.
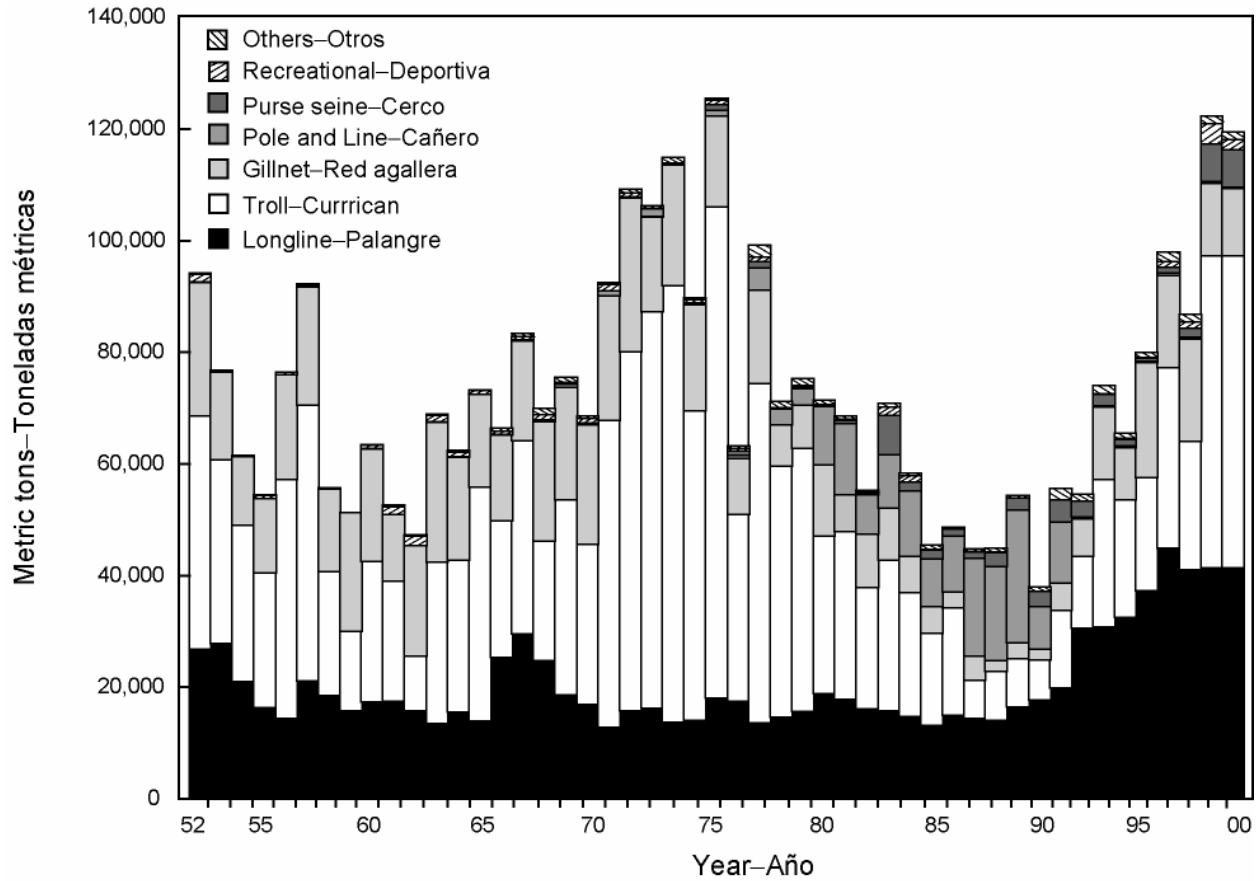
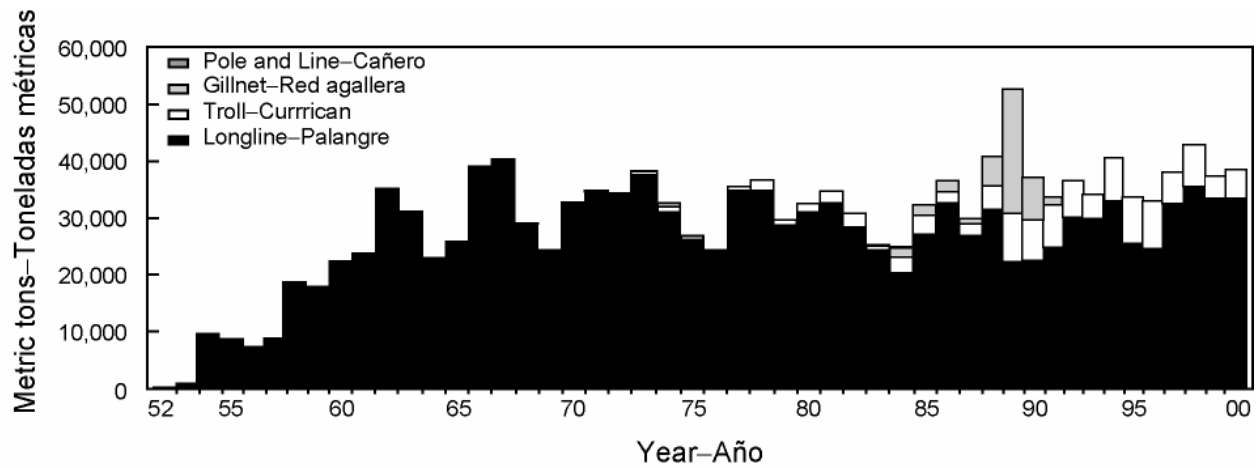**FIGURE ALB1a.** Catches of northern Pacific albacore, 1952-2000.



**FIGURE ALB1b.** Catches of southern Pacific albacore, 1952-2000.

## G. SWORDFISH

Swordfish, *Xiphias gladius*, occur throughout the Pacific Ocean between about 50°N and 50°S. They are caught mostly by the longline fisheries of Far East and Western Hemisphere nations (Figure SWF1). Lesser amounts are taken by gillnet and harpoon fisheries. They are seldom caught by recreational fishermen. During the most recent three year period the greatest catches in the EPO have been taken by vessels of Chile, the United States, Japan and Spain.

Swordfish reach maturity at about 5 to 6 years of age, when they are about 150 to 170 cm in length. They probably spawn more than once per season. Unequal sex ratios occur frequently. For fish greater than 170 cm in length, the proportion of females increases with increasing length.

Only fragmentary data are available on the movements of swordfish. They tend to inhabit waters further below the surface during the day than at night.

Swordfish tend to inhabit frontal zones. Several of these occur in the EPO, including areas off California and Baja California, off Ecuador, Peru, and Chile, and in the equatorial Pacific. Swordfish tolerate temperatures of about 5° to 27°C, but their optimum range is about 18° to 22°C. Swordfish larvae have been found only at temperatures exceeding 24°C.

There are probably one or two stocks of swordfish in the EPO, one with its center of distribution in the southeastern Pacific Ocean, and possibly another with its center of distribution off California and Baja California. As well, there may be movement of a northwestern Pacific stock of swordfish into the EPO at various times.

Production modeling indicates that the catches per unit of effort (CPUEs) of swordfish, although they have declined and then increased recently, are still greater than the CPUEs that correspond to the average maximum sustainable yield. This conclusion is tentative, due particularly to the current uncertainty regarding stock structure.
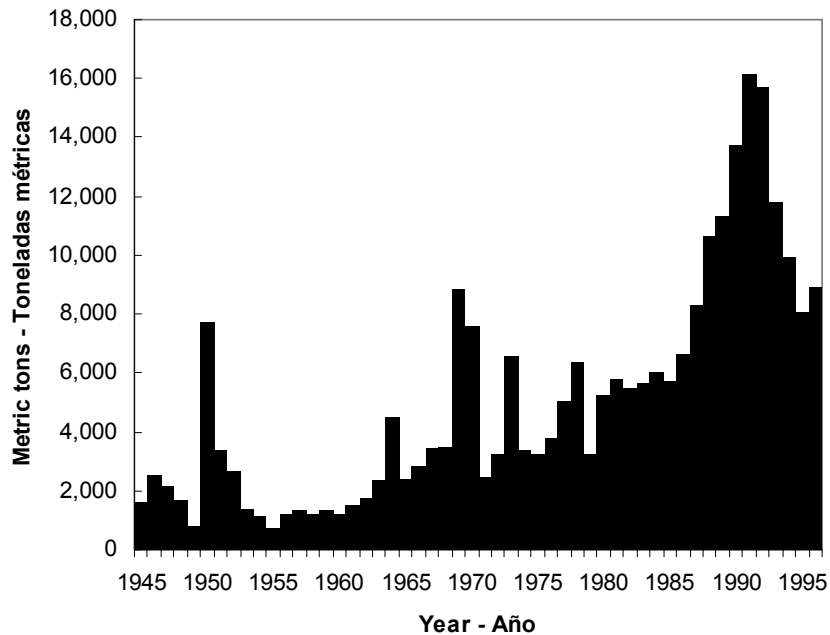


**FIGURE SWF1.** Retained catches of swordfish in the eastern Pacific Ocean, 1945-2001.

## H. BLUE MARLIN

The best knowledge currently available indicates that blue marlin, *Makaira nigricans*, constitutes a single world-wide species and that there is a single stock of blue marlin in the Pacific Ocean. For this reason statistics on catches (Figure BUM1) are compiled, and analyses of stock status are made, for the Pacific Ocean, though it is important to know how catches in the eastern Pacific Ocean (Figure BUM2) vary over time.

Blue marlin are taken by longline vessels of many nations that fish for tunas and billfishes between about 50°N and 50°S. Lesser amounts are taken by recreational fisheries and by various commercial surface fisheries.

Small numbers of blue marlin have been tagged, mostly by recreational fishermen, with conventional tags. A few of these fish have been recaptured long distances from the locations of release. In addition, blue marlin have been tagged with acoustic tags and their activities monitored for short periods.

Blue marlin usually inhabit regions where the sea-surface temperatures (SSTs) are greater than 24°C, and they spend about 90% of their time at depths in which the temperatures are within 1° to 2° of the SSTs.

The Deriso-Schnute delay-difference population dynamics model, a form of production model, was used to assess the status of the blue marlin stock in the Pacific Ocean. Data for the estimated annual total retained catches for 1951-1997 and standardized catch rates developed from catch and nominal fishing effort data for the Japanese longline fishery for 1955-1997 were used. It was concluded that the levels of biomass and fishing effort were near those required to maintain the average maximum sustainable yield.

A more recent analysis, using MULTIFAN-CL, was conducted to assess the blue marlin stocks in the Pacific Ocean and to evaluate the efficacy of habitat-based standardization of longline effort. There is considerable uncertainty regarding the levels of fishing effort that would produce the maximum sustainable yield. However, it was determined that blue marlin in the Pacific Ocean are close to fully exploited, *i.e.* that the population is somewhere near the top of the yield curve. It was also found that standardization of effort, using a habitat-based model, allowed estimation of parameters within reasonable bounds and with reduced confidence intervals about the estimates.
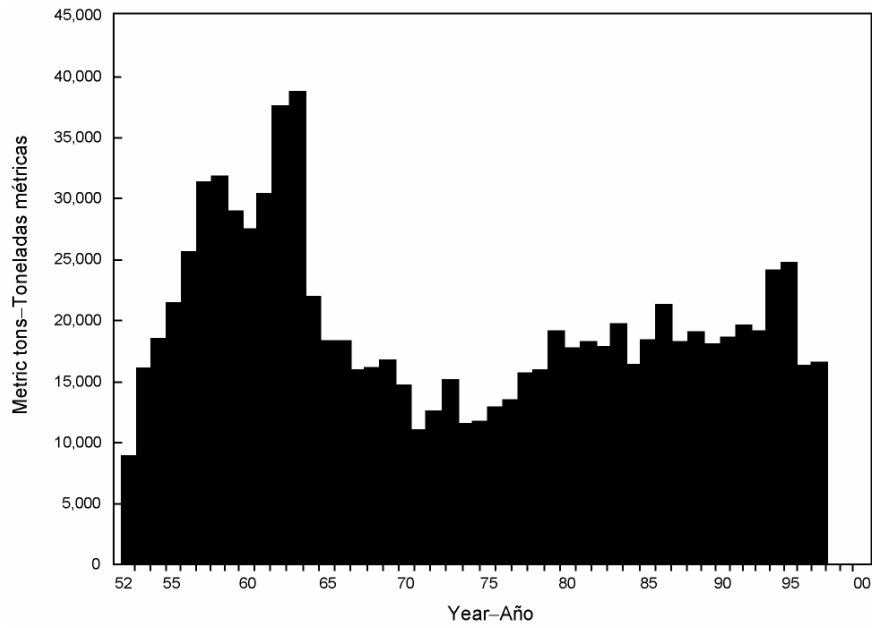
**FIGURE BUM1.** Retained catches of blue marlin in the Pacific Ocean, 1952-1998.
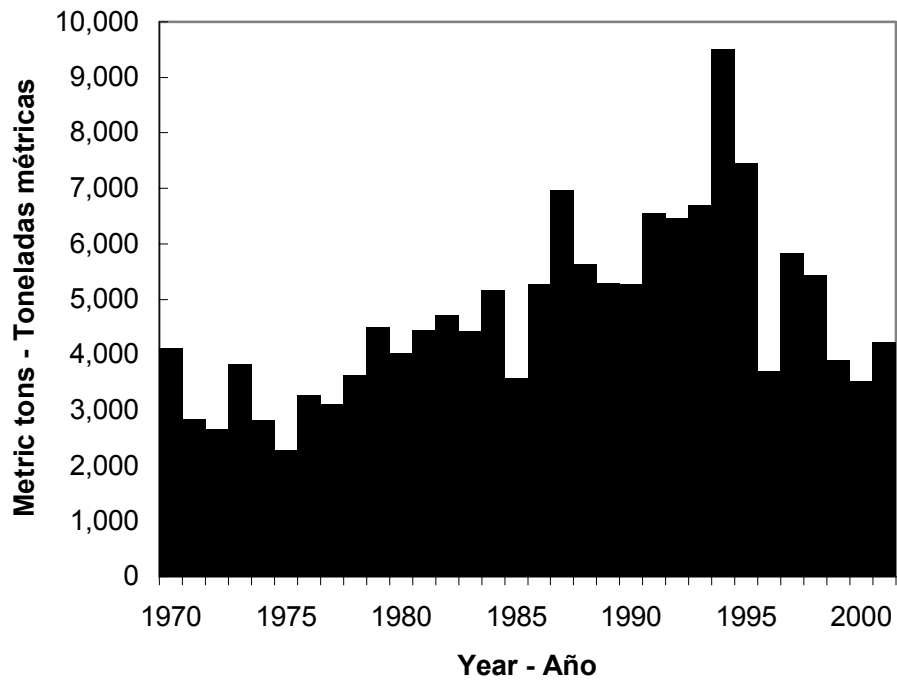


**FIGURE BUM2** Retained catches of blue marlin in the eastern Pacific Ocean, 1970-2001.

# I. STRIPED MARLIN

Striped marlin, *Tetrapturus audax*, occur throughout the Pacific Ocean between about 45°N and 45°S. They are caught mostly by the longline fisheries of Far East and Western Hemisphere nations. Lesser amounts are caught by recreational, gillnet and other fisheries. During recent years the greatest catches (Figure MLS1) in the EPO have been taken by fisheries of Japan, Costa Rica and Korea.

Striped marlin reach maturity when they are about 140 cm long, and spawning occurs in widely-scattered areas of the Pacific Ocean.

The stock structure of striped marlin in the Pacific Ocean is not well known. There are indications that there is only limited exchange of striped marlin between the eastern Pacific Ocean (EPO) and the central and western Pacific Ocean, so it is considered in this report that examinations of local depletions and independent assessments of the striped marlin of the EPO are meaningful. An analysis of trends in catch rates in subareas suggest that the fish in the EPO consist of one stock. Genetic studies have suggested that there are separate stocks in the eastern and western south Pacific and that there may be a separate stocks with centers of distribution in the regions proximate to Hawaii in the north-central Pacific and to Ecuador and to Mexico in the EPO. A preliminary examination of the distributions of lengths of fish landed in northern and southern subareas of the EPO supports the results of the genetic analysis.

Few tagging data are available on the movements of striped marlin. Tagged fish released off the tip of the Baja California peninsula generally have been recaptured in the same general area as where tagged, but some have been recaptured around the Revillagigedo Islands, a few around Hawaii, and one near Norfolk Island.

Thus the conclusions reached for a single stock model, chosen on the basis of trends in catch rates, should be considered tentative, and efforts should be undertaken to resolve the question of stock structure of striped marlin in the EPO. To this end a collaborative study to investigate the stock structure and status of striped marlin in the Pacific has been undertaken.

Analyses of stock status were made using two production models taking into account the time period when billfish were targeted by longline fishing in the EPO. The results from a Pella-Tomlinson model yielded estimates of maximum sustained yield (MSY) on the range of 3,700 to 5,000, with a current biomass to be about 47% of the unfished biomass. The current biomass is estimated to be greater than the biomass which would produce the MSY. The results from an analysis using the Deriso-Schnute delay difference model yielded estimates of MSY on the range of 8,700 to 9,200 mt, with current biomass larger than the biomass needed to produce the MSY and about 70% of the size of the unexploited biomass.

Landings and standardized fishing effort for striped marlin decreased in the EPO from 1990-1991 through 1998, and this decline has continued, reaching new lows in preliminary estimates of retained catch in 2000 and 2001 of about 1,500 mt, which are well below estimated MSY harvest levels. This may result in a continued increase in the biomass of the stock in the EPO.

Striped marlin stocks in the EPO are apparently in good condition, with current and near-term anticipated fishing effort less than $F_{MSY}$.
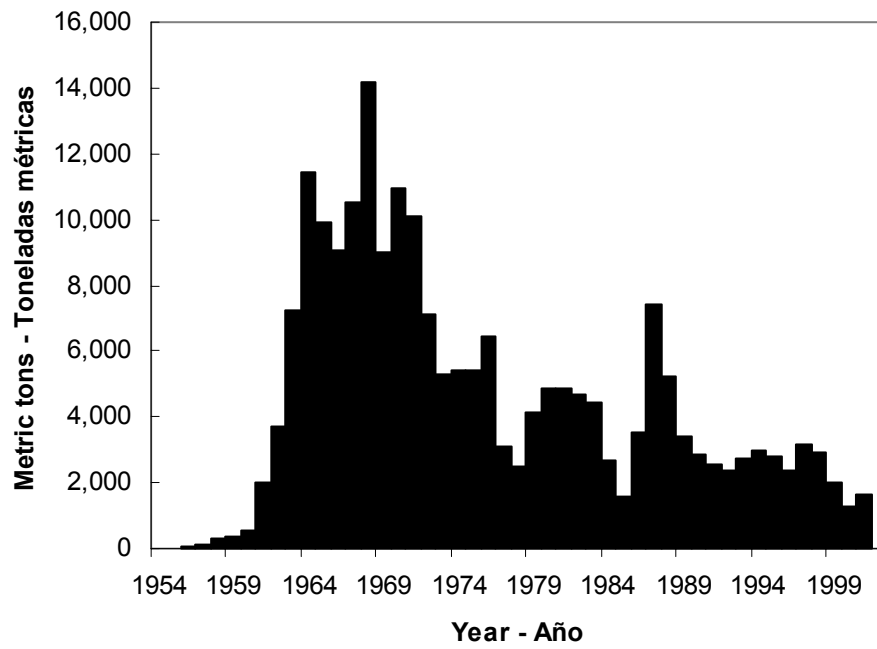
**FIGURE MLS1**. Retained catches of striped marlin in the eastern Pacific, 1954-2001.

## J.  ECOSYSTEM CONSIDERATIONS

## 1.  INTRODUCTION

The FAO Code of Conduct for Responsible Fisheries provides that management of fisheries should en-
sure the conservation not only of target species, but also of the other species belonging to the same eco-
system.   In 2001, the Reykjavik Declaration on Responsible Fisheries in the Ecosystem elaborated this
standard with a commitment to incorporate ecosystem considerations into fisheries management.

The IATTC has taken account of ecosystem issues in many of its decisions, but it has not often focused
its attention on the entire ecosystem in which the target species, the tunas and billfishes, reside.  This sec-
tion provides a coherent view, summarizing what is known about the direct impact of the fisheries upon a
number of species in the ecosystem, and reviews what is known about the environment and about other
species that are not directly impacted by the fisheries.  The purpose is to provide the Commission the op-
portunity to consider the ecosystem as a whole as part of its consideration of the status of the tuna and
billfish stocks and management measures.

This review does not suggest objectives for the incorporation of ecosystem considerations into the man-
agement of tuna or billfish fisheries or any new management measures.  Rather, its prime purpose is to
offer the Commission the opportunity to ensure that ecosystem considerations are clearly seen as part of
its agenda.

It is important also to remember that the view that we have of the ecosystem is based on the recent past;
we have no information about the ecosystem before exploitation began.  Also that that the environment is
subject to change on a variety of time scales, including the well known El Niño-Southern Oscillation
(ENSO) fluctuations and more recently recognized longer-term changes, such as the Pacific Decadal Os-
cillation and some other longer-term climate changes.

In addition to reporting the catches of the principal species of tunas and billfishes, the staff has reported
the bycatches of other species that are normally discarded.  In this paper these bycatches are presented in
the context of the effect of the fishery on the ecosystem.  Unfortunately, information for the entire fishery
is not available.  Relatively good information is available for tunas and billfishes.  The information is
comprehensive for large purse seiners that carry observers, and information on retained catches is also
reported for other purse seiners, pole-and-line vessels, and the much of the longline fleet.  Some informa-
tion is available on sharks that are retained by parts of the longline fleet.  Information on bycatches and
discards is also available for the large purse seine vessels that carry AIDCP observers and for some
smaller purse-seiners.  There is little information on bycatches and discards for other fishing vessels.

## 2. ANALYSIS OF THE IMPACT OF CATCHES

### 2.1. Single-species assessments

This section provides a summary of current information on the effect of the tuna fisheries on stocks of single species in the EPO. The section focuses on the current biomass of each stock considered compared to what it might have been in the absence of a fishery. The intention is to give a view of how the fishery may have altered the components of the ecosystem, rather than the detailed assessments, which can be found in other sections of this paper or in other Commission documents. The section below frequently refers to comparisons with the unexploited stock size. There are no direct measurements of this, and in any case it would have varied from year-to-year. What is normally meant by that is the stock size that would be produced in the absence of a fishery with the average recruitment observed during the period in which the stock was assessed.

### 2.1.a. Tunas

#### 2.1.a.1 Yellowfin

Since 1984 the yellowfin stock has been at or above the level that will provide the average maximum sustainable yield. To meet this objective, the spawning stock size must be kept above 37% of its unexploited size with the current mix of fishing methods. One estimate of the effect of this reduced stock size is that the predation by yellowfin on other parts of the ecosystem is reduced to about 30% of what it was in the absence of a fishery.

#### 2.1.a.2 Bigeye

Up to 1993 bigeye were taken mostly by longline fishing. By 1993 the stock size was estimated to be 42% of its unexploited size. After 1993, purse seining for tunas associated with fish-aggregating devices (FADs) took significant quantities of small and medium-sized bigeye. Currently, after several years of poor recruitment, the stock size is estimated to be at about 25% of its unexploited size. The biomass estimated for 2003 is the lowest since 1975, the first year included in the model.

#### 2.1.a.3 Skipjack

Skipjack assessments are far less certain than those for yellowfin and bigeye, in part because the fishery does not appear to be having much impact on the stock. However, it appears that fluctuations in recruitment cause large variations in stock size. In 2002, the stock size was estimated to be about 23% of the average unexploited stock size.

#### 2.1.a.4 Albacore

Albacore have generally been considered as northern and southern stocks. The southern stock is thought to be at about 60% of its unexploited size, while the northern stock appears to be at about 30% of its unexploited size.

### 2.1.b. Billfishes

#### 2.1.b.1 Swordfish

The variations in swordfish catch per unit of effort in the EPO show no trend, suggesting that catches to date have not affected the stock significantly. The stock size is likely to be near the unexploited size.

#### 2.1.b.2 Blue marlin

Recent stock assessments of blue marlin have suggested that the current stock size is between 50 and 90%

of the unexploited stock size.

### 2.1.b.3  Striped marlin

A recent stock assessment of striped marlin suggests that the current stock size is about 50 to 70% of the unexploited stock size.

### 2.1.b.4  Black marlin and sailfish

No recent formal stock assessment has been made for these species, although there are some data, presented in a bulletin series published jointly by the staff and Japanese scientists, which show trends in catches.

## 2.2. Dolphins

Table ECO1 shows the mortality in 2002 and a published NMFS estimate of stock size.  Studies of the association of tunas with dolphins have been an important component of the staff's long-term approach to understanding key interactions of the ecosystem.  The extent to which yellowfin tuna and dolphins compete for resources, or whether one or both of them benefits from the interaction, remain critical pieces of information to include in ecosystem models, given the large biomasses of both groups, and their high consumption of prey.  Populations of dolphins involved in the purse-seine fishery have been reduced from their unexploited levels and are now growing slowly.

## 2.3. Sea turtles

Olive Ridley turtles are, by far, the species of sea turtle taken most often by purse seiners.  They are followed by the green sea turtle, and, very occasionally, by loggerhead and hawksbill turtles.  Only one leatherback mortality has been recorded during the nine years of the program.  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, or some similar reason.  Sea turtles at times become entangled in the webbing under FADs.  The average annual mortalities of turtles caused by large purse-seine vessels during 1993-2002 were as follows:

| | Set type | | |
| --- | --- | --- | --- |
| | **Floating object** | **Unassociated** | **Dolphin** |
| Olive Ridley | 51.6 | 19.9 | 11.4 |
| Green | 6.3 | 4.3 | 0.8 |
| Loggerhead | 0.6 | 1.3 | 0.1 |
| Hawksbill | 0.6 | 0.2 | 0.2 |
| Leatherback | 0.1 | 0.0 | 0.0 |
| Unidentified | 23.5 | 11.3 | 4.6 |
| Average number of sets | 4,379 | 4,932 | 8,877 |

The mortalities of sea turtles due to purse seining for tunas are probably less than those due to other types of human activity.

There is no comprehensive information available on bycatches of turtles by longliners.  However, based on information from other parts of the world, the mortality rates due to longlining may be greater than those due to purse seining, particularly for shallow longlines targeting species such as swordfish. About 23 million of the 100 million hooks set each year in the EPO by distant-water longline vessels target swordfish with shallow longlines.  In addition, there is a sizeable fleet of locally-based longline vessels that fish for tunas and billfishes.

The populations of green, loggerhead, and olive Ridley turtles of the EPO are threatened, and the leatherback is endangered.  The lack of comprehensive information concerning the impact of the fishery on turtles is a serious weakness in understanding the effects of the fisheries for tunas and billfishes on the off-

shore pelagic ecosystem of the EPO.

## 2.4. Sharks and other large fishes

Sharks and other large fishes are taken by both purse-seine and longline vessels. The staff is analyzing the relative abundance of silky sharks, the most commonly caught species of shark in the purse-seine fishery. Preliminary estimates of an index of relative abundance for the equatorial region, between about 8°N and 10°S, show a decreasing trend in the indices over time. It is not known whether this decreasing trend might be due to the fishery, changes in the environment (perhaps associated with the 1997-98 El Niño), or other processes.

The average annual discards of sharks and other large fish during 1993-2002 (other than those discussed above) by large purse-seine vessels are as follows:

| | Set type | | |
|---|---|---|---|
| | **Floating object** | **Unassociated** | **Dolphin** |
| Dorado | 546,354 | 11,112 | 326 |
| Wahoo | 267,137 | 1,150 | 408 |
| Yellowtail | 40,551 | 18,780 | 1,309 |
| Rainbow runner | 60,396 | 1,275 | 11 |
| Sharks and rays | 38,699 | 10,024 | 4,869 |

There are no stock assessments available for these species in the EPO, and hence the impact of the bycatch on the stocks is not known.

The catch rates of other species in the purse-seine fishery are different for each type of set. With a few exceptions, the bycatch rates are higher in sets on floating objects, followed by unassociated sets and, at a much lower level, dolphin sets. Dolphin bycatch rates are highest for dolphin sets, followed by unassociated sets and, at a much lower level, floating-object sets. Sailfish, manta rays, and stingrays have higher bycatch rates in unassociated sets, followed by dolphin sets and then floating-object sets. Because of these differences, it is necessary to follow the changes in frequency of the different types of sets to interpret the changes in bycatch figures. The following table shows the number of sets during 1993-2002 by purse seiners that carried observers:

| | Set type | | |
|---|---|---|---|
| | **Floating object** | **Unassociated** | **Dolphin** |
| 1993 | 2,063 | 6,267 | 6,953 |
| 1994 | 2,770 | 5,070 | 7,804 |
| 1995 | 3,568 | 5,124 | 7,187 |
| 1996 | 4,160 | 5,387 | 7,483 |
| 1997 | 5,828 | 4,977 | 8,995 |
| 1998 | 5,481 | 4,631 | 10,644 |
| 1999 | 4,620 | 6,143 | 8,648 |
| 2000 | 3,916 | 5,482 | 9,235 |
| 2001 | 5,659 | 2,973 | 9,577 |
| 2002 | 5,727 | 3,262 | 12,242 |

## 2.5. Other groups

### 2.5.a. Marine mammals

The Southwest Fisheries Science Center (SWFSC) has made estimates of abundance of several species of marine mammals based on large-scale line-transect surveys carried out from oceanographic research vessels between 1986 and 2000 in the EPO. Of the species not significantly impacted by the tuna fishery,

short-finned pilot whales and three stocks of common dolphins showed increasing trends in abundance during that 15-year period. The apparent increased abundance of these mammals may have caused a decrease in the carrying capacity of the EPO for other predators that overlap in diet. Bryde's whales also increased in estimated abundance, but there is very little diet overlap between these baleen whales and the upper-level predators impacted by the fisheries. Striped dolphins showed no clear trend in estimated abundance over time, and sperm whales tended to have lower abundance estimates in recent years.

### 2.5.b.   Seabirds

Seabirds associate with subsurface predators such as fishes and cetaceans. Those predators drive prey to the surface where the prey become available to the birds. According to the Report of the Scientific Research Program under the International Dolphin Conservation Program Act, prepared by the Southwest Fisheries Science Center (SWFSC), NOAA Fisheries, in September 2002, there were no significant temporal trends in abundance estimates over the period 1986 to 2000 for any seabird species in the eastern tropical Pacific (ETP) except the Tahiti Petrel.

### 2.5.c.   Forage

The forage taxa occupying the middle trophic levels in the EPO are obviously an important component of the ecosystem, providing a link between environmental variability and the upper-trophic-level predators. Very little is known, however, about fluctuations in abundance of the large variety of prey species in the EPO. Scientists from SWFSC have recorded data on the distribution and abundance of common prey groups in the ETP, including lanternfishes, flyingfishes, and some squids, during 1986-1990 and 1998-2000. Mean abundance estimates of all fish taxa, and to a lesser extent for squids, increased from 1986 through 1990. Estimates were low again in 1998 and increased through 2000. Their interpretation of this pattern was that El Niño events in 1986-1987 and 1997-1998 had negative effects on these prey populations.

Frigate and bullet tunas (*Auxis* spp.) are a common prey of many of the upper-trophic-level animals in the ETP. In the ETP ecosystem model (see Section 5), *Auxis* spp. comprise 10% or more of the diet of 8 predator categories. Small quantities are captured and discarded at sea by purse-seine vessels, and by local artisanal fisheries in some coastal regions of Central and South America. The estimated annual discards of *Auxis* spp. in the EPO on fishing trips with observers onboard, in metric tons, during 1993 through 2002, were as follows:

|  | Set type | | |
|---|---|---|---|
|  | **Floating object** | **Unassociated** | **Dolphin** |
| 1993 | 1,814 | 165 | 2 |
| 1994 | 322 | 198 | 2 |
| 1995 | 543 | 119 | 6 |
| 1996 | 781 | 239 | 33 |
| 1997 | 2,756 | 626 | 25 |
| 1998 | 1,033 | 1678 | 32 |
| 1999 | 2,594 | 473 | 29 |
| 2000 | 1,290 | 185 | 21 |
| 2001 | 724 | 41 | 0 |
| 2002 | 1,384 | 161 | 283 |

## 3.   PHYSICAL ENVIRONMENT

Environmental conditions affect the target populations, all other components of the ecosystem, and the operations of the fishermen. Very few ocean areas of the world show the changes as dramatic as those

that take place in the EPO during an El Niño event. In addition, many less dramatic events are constantly taking place. In broad terms, water temperature controls the horizontal and vertical distributions of the tunas and billfishes. The drift of floating objects, with their associated communities, depends on the currents. Currents also transport eggs and larvae, determining their location and their patchiness. Fronts change the productive conditions, and in some cases create areas of attraction for tunas and billfishes. Upwelling brings nutrients from the deeper layers to the surface, and in the EPO the Peru Current is one of the most productive areas of the world. Turbulence, at a very small scale, has a significant impact on the survival of fish larvae. Along the coastline, the contributions of organic matter, fresh water, nutrients, and debris that rivers bring to the ocean are quite significant, and create special conditions that in some cases result in high productivity and areas that are very favorable for the development of the early life stages of many species. Topographic features, such as islands and seamounts, change oceanographic conditions around them, and many constitute very rich habitats. Some species are permanent residents in these locations; others use them as stages in longer migrations.

El Niño events change not only water temperature, but also current speed and direction, upwelling intensity, precipitation patterns, and many other components of the environment. Longer term inter-decadal changes were first described for the North Pacific a few years ago, but the most recent observations show that there are also changes with a periodicity of decades that affect the EPO ecosystem. One such shift may have happened in 1976-1978, and apparently 1998 may have been another pivotal year. The recruitment of yellowfin to the fishery was apparently greater during 1985-1999 than during 1975-1984. Because the productivity in the system can change dramatically under different regimes, their effect on all components of the ecosystem is very important. These changes increase the uncertainty about the parameters used to model the target stocks (*i.e.* the carrying capacity is not the same; recruitment, growth and mortality may respond to the changes, *etc.*), the trends observed for all populations, and even the fishing operations (*i.e.* changes in current speeds, depth of the thermocline, *etc.*).

This list, although by no means complete, shows the diversity and complexity of the ways in which the environment affects the target species and the rest of the ecosystem. It is, of course, not possible or necessary for the staff to address more than a small fraction of these. However, use is made of the results of work by national and international research groups that are investigating this area.

## 4.  AGGREGATE INDICATORS

Food web diagrams are useful for representing the structure and flows of ecosystems. A simplified food-web diagram, with approximate trophic levels (TLs), of the pelagic ETP is illustrated in Figure ECO1. Sharks (average TL 5.25) and billfishes (average TL 5.08) are top-level predators. Tunas and other pelagic fishes (*e.g.* dorado) occupy slightly lower TLs. Smaller pelagic fishes (*e.g. Auxis* spp.) and cephalopods 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 zooplankton (TL = 2) feed on the producers (TL = 1), phytoplankton and bacteria. In exploited pelagic ecosystems, the fisheries often act as apex predators.

Mean TL of fisheries catches and discards can be used as an index of sustainability in exploited marine ecosystems. TLs were estimated, based on the EPO ecosystem model (see Section 5), for a time series of total catches by year for three fishing modes of the purse-seine fishery from 1993 to 2001. The TLs of the summed catches of all surface fisheries was fairly constant from year to year (Figure ECO2: Average for surface gear). The TL of the floating-object sets varied more than those of the other fisheries. This was due to the interannual variability in the sizes of the tunas caught and the species composition of the bycatch in those sets.

Trophic levels were also estimated separately for the time series of retained and discarded catches by year for the surface fisheries from 1993 to 2001 (Figure ECO3). The TLs of the landings were quite stable from year to year, and the TLs of the discarded catches varied considerably. The largest variation

occurred for sets on unassociated fish.

## 5. ECOSYSTEM MODELING

It is clear that the different components of an ecosystem interact. The best way to describe the relationships and explore their effects is through ecosystem modeling. Our understanding of this complex maze of connections is at an early stage, and, consequently, the current ecosystem models are most useful as descriptive devices for exploring the effects of a mix of hypotheses and established connections among the ecosystem components. Ecosystem models must be compromises between simplistic representations on the one hand and unmanageable complexity on the other.

The staff has developed a model of the pelagic ecosystem in the tropical EPO 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 sensitive species (*e.g.* sea turtles). Some taxa are further separated into size categories (*e.g.* large and small marlins). The model has finer taxonomic resolution at the upper trophic levels, but most of the system's biomass is contained in the middle and lower trophic levels. Fisheries landings and discards were estimated for five fishing "gears," pole-and-line, longline, dolphin sets by purse seiners, floating-object sets by purse seiners, and sets on unassociated schools by purse seiners. The model focuses on the pelagic regions; localized, coastal ecosystems are not adequately described by the model.

Most of the information describing inter-specific interactions in the model comes from a joint IATTC-NMFS project, which included studies of the food habits of co-occurring yellowfin, bigeye, and skipjack tuna, dolphins, pelagic sharks, billfishes, dorado, wahoo, rainbow runner, and others. The impetus of the project was to contribute to the understanding of the tuna-dolphin association, and a community-level sampling design was adopted.

The ecosystem model has been used to evaluate the possible effects of variability in bottom-up forcing by the environment on the middle and upper trophic levels of the pelagic ecosystem. Predetermined time series of producer biomasses were put into the model as a proxy for changes in primary production that have been documented during El Niño and La Niña events and the dynamics of the remaining components of the ecosystem were simulated. The model was also used to evaluate the relative contributions of fishing and the environment in shaping ecosystem structure in the tropical pelagic EPO. This was done by using the model to predict which components of the ecosystem might be susceptible to top-down effects of fishing, given the apparent importance of environmental variability in structuring the ecosystem. In general, animals with relatively low turnover rates were influenced more by fishing than by the environment, and animals with relatively high ratios more by the environment than by fishing.

## 6. OTHER ECOSYSTEM STUDIES IN PROGRESS

A new study, jointly funded by the Pelagic Fisheries Research Program of the University of Hawaii; IATTC; CICIMAR, La Paz, Mexico; and the Secretariat of the Pacific Community, Nouméa, New Caledonia has commenced in 2003. Scientists from these four agencies will compare the pelagic food web in the EPO with that of the more-oligotrophic western Pacific using two kinds of analyses. This study will provide important information on the trophic position of the forage fishes and cephalopods in the tropical EPO, which is not currently available. Results will be incorporated in ecosystem models to help define the ecosystem linkages leading to tuna production and the effect of climate variability on fisheries production.

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

Both the IATTC and Agreement on the International Dolphin Conservation Program (AIDCP) have objectives that address the incorporation of ecosystem considerations into the management of the tuna fisheries in the EPO. Actions taken in the past include:

### 7.1. Dolphins

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

b. Studies to determine why tunas associate with dolphins have been carried out.

c. The incidental mortality of each stock of dolphins has been limited to levels which are insignificant compared to stock sizes.

### 7.2. Sea turtles

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

b. A resolution on releasing and handling of sea turtles captured in purse-seine nets has been adopted.

c. A resolution on webbing under FADs has been adopted.

### 7.3. Other species

A resolution on live release of sharks, rays, and other bycatch species has been adopted.

### 7.4. All species

a. Data on the bycatches by large purse-seiners have been collected, and plans have been made to expand the activity to smaller vessels and other gears.

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.

## 8. FUTURE DEVELOPMENTS FOR ECOSYSTEM ANALYSES

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

An array of measures has been proposed to study changes in ecosystem properties. This could include studies of average trophic level, size spectra, dominance, diversity, *etc.*, to describe the ecosystem in an aggregate way.

The distributions of the fisheries for tunas and billfishes in the EPO are such that several regions with different ecological characteristics ("Longhurst regions") 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 our analyses.
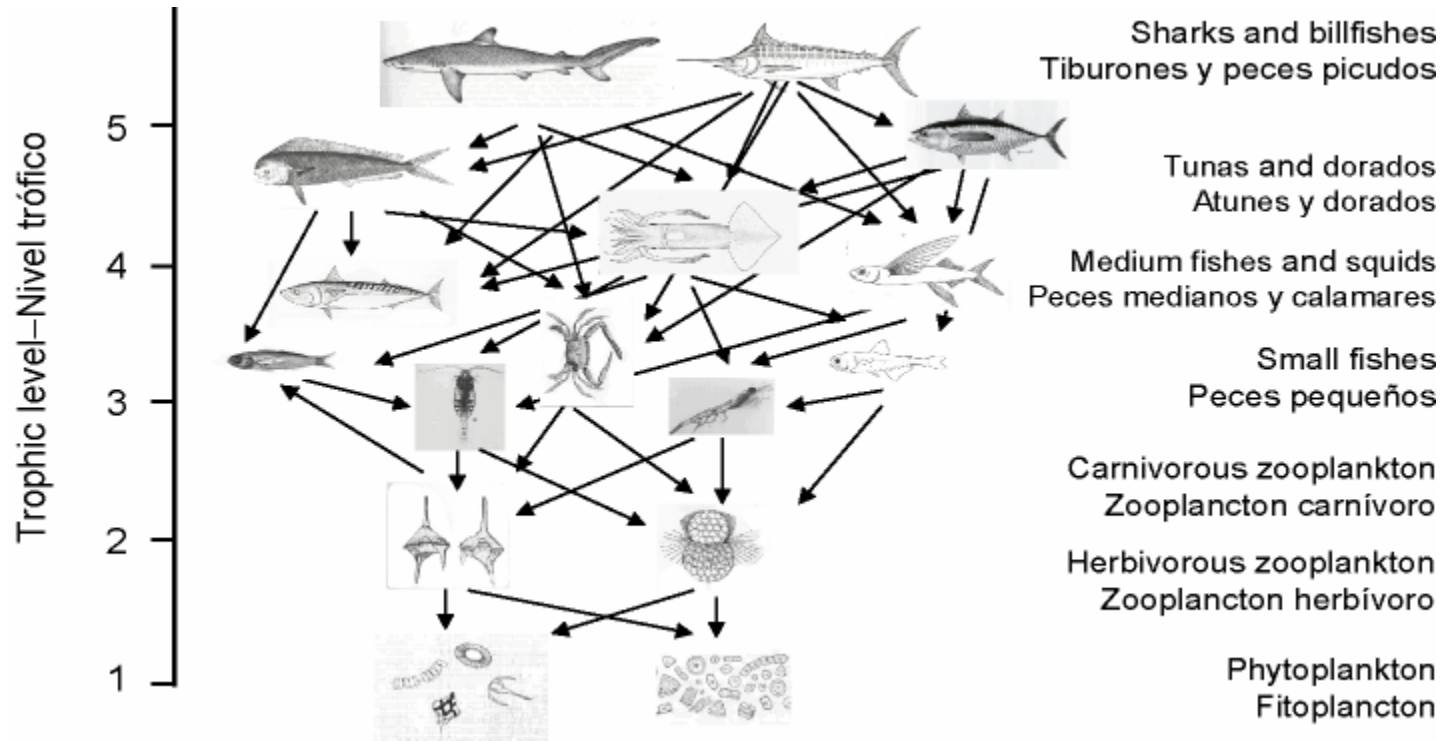
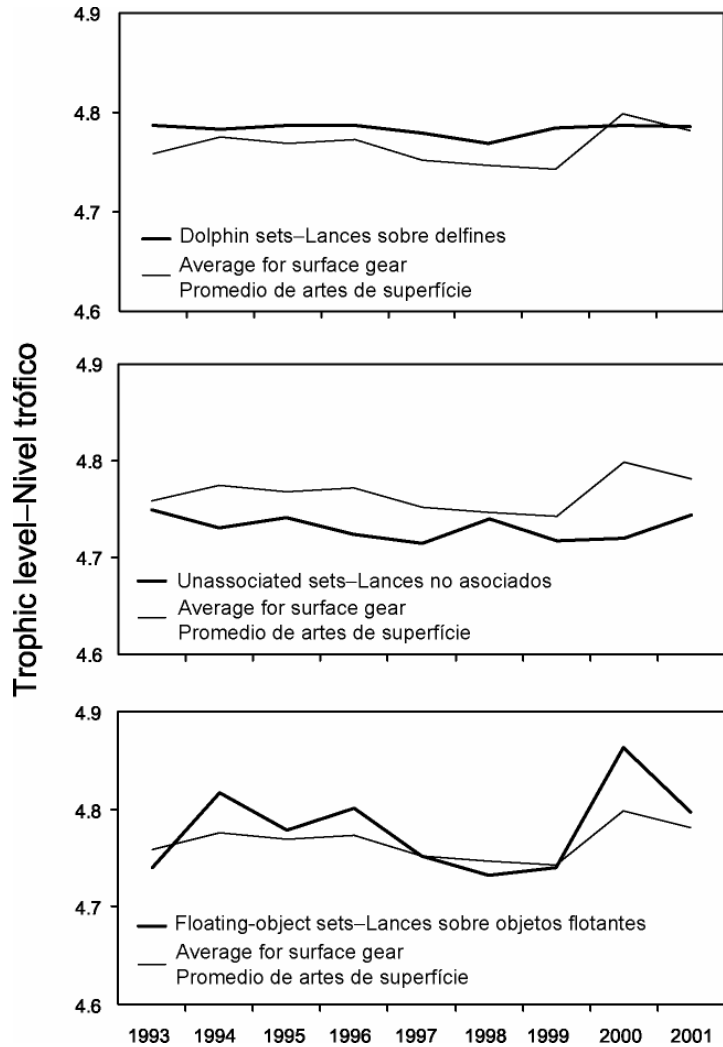**FIGURE ECO1.** Simplified food-web diagram of the pelagic ecosystem in the eastern tropical Pacific Ocean.

**FIGURE ECO2.** Yearly trophic level estimates of the catches (retained and discarded) by the purse-seine fishery in the eastern tropical Pacific Ocean.
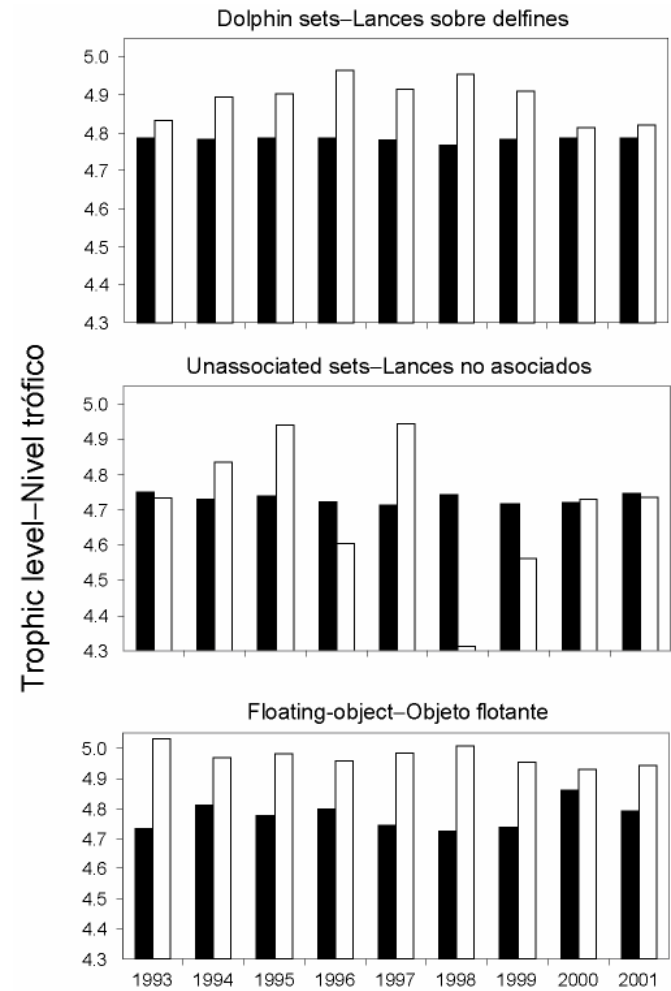
**FIGURE ECO3.** Trophic level estimates of the retained catches (solid bars) and discarded catches (open bars) by purse-seine fishing mode in the eastern tropical Pacific Ocean.

**TABLE ECO1.** Preliminary estimates of mortalities of dolphins in 2002, estimates of population abundance pooled for 1986-1990 (from Report of the International Whaling Commission, 43: 477-493), and estimates of relative mortality (with approximate 95-percent confidence intervals), by stock. All the data for 2002 are preliminary.

| Stock | Incidental mortality | Population abundance | Relative mortality (%) |
|---|---|---|---|
| Offshore spotted—Manchado de altamar | | | |
|     Northeastern—Nororiental | 442 | 730,900 | 0.08 (0.061, 0.101) |
|     Western/southern—Occidental y sureño | 203 | 1,298,400 | 0.024 (0.019, 0.033) |
| Spinner dolphin—Tornillo | | | |
|     Eastern—Oriental | 405 | 631,800 | 0.08 (0.046, 0.112) |
|     Whitebelly—Panza blanca | 186 | 1,019,300 | 0.04 (0.023, 0.048) |
| Common dolphin—Común | | | |
|     Northern—Norteño | 69 | 476,300 | 0.02 (0.011, 0.042) |
|     Central | 155 | 406,100 | 0.05 (0.026, 0.098) |
|     Southern—Sureño | 4 | 2,210,900 | <0.01 (0.001, 0.003) |
| Other dolphins—Otros delfines[1] | 50 | 2,802,300 | <0.01 (0.001, 0.002) |
| Total | 1,514 | 9,576,000 | 0.02 (0.019, 0.025) |

[1] "Other dolphins" includes the following species and stocks, whose observed mortalities were as follows: striped dolphins (*Stenella coeruleoalba*), 2; bottlenose dolphins (*Tursiops truncatus*), 10; Central American spinner dolphins (*Stenella longirostris centroamericana*), 3; rough-toothed dolphin (*Steno bredanensis*), 5; short-finned pilot whale (*Globicephala macrorhynchus*), 1; and unidentified dolphins, 29.