CHANGES TO ROUTINE MANAGEMENT MEASURES FOR 2009-2010 SEASONS

Section 8.3.2 in the Fishery Management Plan (FMP) for U.S. West Coast Fisheries for Highly Migratory Species (HMS) describes the biennial management cycle. A biennial cycle is described with decision making occurring at the June, September, and November Council meetings to establish or adjust harvest specifications for a 2-year period beginning on April 1 of the following year—the start of the next fishing year. This agenda item commences the second biennial management cycle since FMP implementation, with any regulations proposed by the Council becoming effective on or after April 1, 2009. Such regulations continue in effect for at least 2 years unless subsequently modified through the Council process.

At this meeting, the Council will review the regulatory changes proposed by the HMS Management Team (HMSMT) and determine which changes should be considered further. The Council also has the option of identifying other, additional management measures to be implemented during the 2009–10 biennium. According to the FMP, the Council then directs the HMSMT to prepare a draft regulatory analysis for the measures identified by the Council. This analysis will support Council decision making at the September meeting—when the Council adopts proposed actions for public review—and the November meeting—when the Council takes final action.

One issue has been preliminarily identified where new regulations may be appropriate. A recreational fishery targeting thresher sharks has developed over the past few years in the Southern California Bight. Although limited data are available on resulting thresher shark fishing mortality, it is thought to be substantial and perhaps comparable to catch in commercial fisheries. Furthermore, the Southern California Bight is an important pupping ground for thresher sharks. Like many sharks, threshers are viviparous and have low fecundity. Therefore, catches of pregnant females has a greater effect on stock productivity. The drift gillnet fishery has been prohibited from fishing in this area to protect the stock. At the time this regulation was implemented the recreational fishery was of modest size but has since expanded substantially.

The HMSMT will submit a supplemental report providing a more detailed description of the issue and the need for new recreational management measures to limit thresher shark catches.

<u>Council Task:</u>

Council discussion and guidance on initial selection of preliminary proposals for further consideration.

<u>Reference Materials</u>:

None.

Agenda Order:

a. Agenda Item Overview Kit Dahl
b. Reports and Comments of Advisory Bodies
c. Public Comment
d. Council Discussion and Guidance on Initial Selection of Preliminary Proposals for further Consideration

PFMC
05/27/08

JUN 0 9 2008

The Honorable Mark Leno
Assemblyman, Thirteenth District
California State Capitol
P.O. Box 942849
Sacramento, California 94249-0013

Dear Mr. Leno:

I am writing in response to your May 22, 2008, letter and accompanying Assembly Joint Resolution 62 requesting that NOAA's National Marine Fisheries Service (NMFS) deny approval of a shallow-set longline (SSLL) exempted fishing permit (EFP) application until decisions are made on leatherback sea turtle critical habitat and the status of North Pacific loggerhead sea turtle and its critical habitat is clarified. Final decision on these actions is expected in late 2008 and members of my staff are on the teams reviewing the petitions. The EFP would preliminarily explore whether SSLL gear is effective at catching swordfish within the U.S. West Coast exclusive economic zone (EEZ) while minimizing impacts to protected species. If approved, NMFS would require specific terms and conditions for how the EFP would be conducted. The complete list of mitigation measures, including 100 percent observer coverage, trip and set limits, and a variety of measures aimed at minimizing adverse environmental impacts from the activity are attached. In 2007, my staff conducted an Endangered Species Act Section 7 consultation and wrote a biological opinion on the action and contributed to the NEPA analysis of this project. Both of those documents are available online and contain the best available and updated information on protected species and marine resources.

Your letter and resolution speak to threats to living marine resources, especially Pacific leatherback and loggerhead sea turtles, from the use of SSLL gear. NMFS shares your concern over the potential impacts to these and other living marine resources from fishing gear. However, NMFS scientists, their colleagues and the fishing industry continue to improve SSLL gear and its deployment as a more selective, and thus "cleaner" method for targeting swordfish while continuing to reduce ecosystem impacts. These technological and operational modifications have proven very successful in reducing sea turtle interactions and post-hooking mortalities in existing domestic (i.e., Atlantic and Hawaii) and international (e.g., Italy, Brazil, and Uruguay) swordfish fisheries compared to the use of traditional SSLL gear, while maintaining economically viable fisheries. NMFS is committed to encouraging the use of modified SSLL gear as a means of providing protection to sea turtles, which are highly migratory and travel across entire ocean basins.

The EFP was vetted through the Pacific Fishery Management Council (Pacific Council) process and they recommended that NMFS approve the permit. The Pacific Council, among the other seven regional councils, was established under the authority of the Magnuson-Stevens Fishery Conservation and Management Act to exercise sound judgment in the stewardship of fishery resources and the Pacific Council has demonstrated significant leadership for ensuring that fishery management recommendations are integrated into ecosystem sustainability. Their recent recommendation to prohibit fishing for krill off the West Coast is testimony to that leadership.

There is no doubt that cost-effective fishing gears will interact to some degree with protected species. The EFP would allow a glimpse as to whether modified SSLL gear is as successful in catching swordfish off California as has been shown in the Hawaii and North Atlantic SSLL domestic swordfish fisheries while minimizing interactions with protected species. This small step may also preview an important conservation strategy that is being lost in this debate. Sea turtles and marine mammals migrate across large areas of the ocean and are exposed to fishery impacts from many nations. NMFS believes that if a selective fishing method can be found to harvest swordfish in the EEZ off its coast, California can become less reliant on foreign imports of swordfish to meet market demand. By not allowing the proposed EFP to go forward, California will forego exploring an opportunity that has the potential to reduce this reliance and will continue meeting U.S. demand for swordfish by supporting fishing in other nations. It is important to note that many of those nations do not regulate their fishing impacts on sea turtles and other living marine resources, therefore, reliance on foreign caught swordfish can have result in significant bycatch and mortality of sea turtles and other marine resources.

In closing, I want to thank you for your interest in conserving Pacific sea turtles and hope that this interest can be channeled in assisting NMFS, industry and non-governmental organizations in seeking cost-effective conservation strategies for restoring Pacific sea turtle populations that yield the greatest biological benefits while preserving the viability of California fishing communities.

Sincerely,

Rodney R McInnis

Rodney R. McInnis
Regional Administrator

Attachment

cc:
Assembly Member Berg
Assembly Member Evans
Assembly Member Hancock
Assembly Member Jones
Assembly Member Nava
Senator Wiggins

HIGHLY MIGRATORY SPECIES (HMS) FACT SHEET

Exempted Fishing Permit to Conduct Shallow-set Longline Fishing for Swordfish

Exploring New Fishing Techniques: Exempted fishing permits (EFP) are issued by NOAA's National Marine Fisheries Service (NMFS) to allow for experimental fishing activities otherwise prohibited under regulations for HMS fishing off Washington, Oregon and California. This EFP would allow a single vessel to explore whether shallow-set longline gear, using the latest gear and operational modifications proven to reduce protected species bycatch in other longline fisheries, is a cost-effective alternative for reducing bycatch in the California and Oregon swordfish fishery in an area 50 to 200 nautical miles offshore. No information currently exists on how this gear, specifically designed to reduce sea turtle bycatch while effectively maintaining a commercially viable catch of target swordfish, will operate in the California Current.

Reduced Sea Turtle Bycatch: The vessel in question would target swordfish utilizing large circle hooks (18/0) and fish bait. This combination has proven successful in existing domestic (Atlantic and Hawaii) and foreign (Italy, Brazil, and Uruguay) swordfish fisheries for reducing sea turtle interactions with longline gear as compared to traditional J-hooks with squid bait while maintaining an economically viable fishery.[1,2,3,4]

Protected Species Interactions: It is not likely that short-finned pilot whales or short-tailed albatross will be incidentally taken in the fishery; however, species caps[5] were included as precautionary steps by the Pacific Fishery Management Council.

Reduced Fish Bycatch Mortality Rates: The use of circle hooks alone does not appreciably reduce bycatch of non-target species (e.g. blue sharks) but it does appear to lead to increased survivorship of released fish because circle hooks catch fish in the mouth more often than traditional J-hooks which hook fish more often in the throat or gills.[1,6] Hawaii shallow-set longline observer records for trips utilizing circle hooks indicate approximately 95 percent of captured blue sharks were released alive.[1]

100 Percent Observer Coverage: NMFS trained observers would accompany all trips and monitor 100 percent of the fishing operations. The amount of fishing would be strictly regulated by imposed trip limits and longline set limits, and a variety of mitigation measures (see following page) would be required to minimize adverse environmental impacts from the activity.

Potential Benefits to West Coast Fishing Communities: Using more conservative methods to catch swordfish is important for West Coast-based fishermen because it could maintain, or potentially increase, swordfish catch-per-unit of effort while decreasing bycatch and bycatch mortality. Fish processors and

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[1] Gilman, E., D. Kobayashi, T. Swenarton, P. Dalzell, I. Kinan, and N. Brothers. 2006b. Analyses of Observer Program Data for the Hawaii-based Longline Swordfish Fishery for (i) Effects of Sea Turtle Regulations on Sea Turtle Interactions, Catch Rates of Retained Marketable Species and Catch Rate of Sharks; (ii) Economic Viability and Potential for Temporal or Spatial Closures to Reduce Turtle Captures; (iii) Comparison Between 2005 and 2006 Turtle Catch Rates and Temporal Distribution of Effort to Explain the Cause of a Loggerhead Cap Being Reached in 2006 and not 2005; and (iv) Hook Position of Caught Turtles and Fish. Western Pacific Regional Fishery Management Council, Honolulu, HI, U.S.A WCPFC-SC2-2006/EB IP-1.
[2] Watson and Kerstetter. 2006. (Mar Tech Soc. J., 40 (3): 6-10).
[3] Boggs, C. and Y. Swimmer. 2007. Developments (2006-2007) in scientific research on the use of modified fishing gear to reduce longline bycatch of sea turtles. WCPFC-SC3-EB SWG/WP-7.
[4] Lewison, R. I. and L. Crowder. 2007. Putting longline bycatch of sea turtles into perspective. Conservation Biology 21:79-86.
[5] If any species cap is reached the exempted fishing permit would be revoked.
[6] Kerstetter, D.W. and J.E. Graves. 2006. Effects of circle versus J-style hooks on target and non-target species in a pelagic longline fishery. Fisheries Research 80: 239-250.

consumers would benefit from an additional supply of locally-caught fresh swordfish while reducing U.S. reliance on foreign imports which are not captured nor managed with the same level of scrutiny and high standards that U.S. fisheries must meet. This issue is also important to fishery scientists and managers who view this gear as a realistic means to further minimize bycatch while establishing a commercially viable fishery.

Summary of Terms & Conditions of the Exempted Fishing Permit:

1. 100 percent observer coverage, paid for by NMFS
2. All observers shall carry satellite phones provided by NMFS and immediately inform NMFS of any marine mammal, sea turtle, or seabird capture or interaction
3. A single vessel participating
4. Maximum of 14 sets per trip
5. Maximum of four trips between September and December (up to 56 total sets for the entire duration of the proposed EFP)
6. Fishing is only authorized within the West Coast EEZ and no SSLL gear shall cross this boundary
7. No fishing within the Southern California Bight as defined by the applicant
8. Utilizing shallow-set longline gear configuration:
   a. 50–100 km mainline
   b. 18 m floatline
   c. 24 m branchlines
   d. 2–8 hooks between floats
   e. 400–1,200 hooks per set
   f. Set fishing gear so hooks are at a depth of 40–45 m below the surface
9. Use 18/0 circle hooks with a 10 degree offset to fish for swordfish (as described at 50 CFR 665.33(f))
10. Use mackerel or mackerel-type bait (as described at 50 CFR 665.33(g))
11. Allow the use of light sticks
12. Require use of TDRs to estimate fishing depth (The number of TDR units deployed per set and per trip would be determined by NMFS in consultation with the applicant.)
13. Gear may not be set until one hour after local sunset and must be fully deployed before local sunrise
14. Prohibit the use of a line shooter for setting the gear
15. Require use of a NMFS-approved dehooking device to maximize finfish (e.g., blue shark) bycatch survivability
16. A catch cap[7] of 12 striped marlin
17. A take cap of one short-finned pilot whale (this species is not ESA-listed)
18. A take cap of five leatherback turtles , or one leatherback mortality
19. A cap of one short-tailed albatross
20. No fishing north of 45° N. latitude
21. No fishing within 50 nmi of the coastline

Link to the complete Environmental Assessment, Finding of No Significant Impact and Biological Opinion for the exempted fishing permit:

http://swr.nmfs.noaa.gov/fmd/longline/Default.htm.

June 2008

SOUTHWEST REGIONAL OFFICE
National Marine Fisheries Service
501 West Ocean Blvd.
Long Beach, CA 90802-4213
(562) 980-4000

[7] Once any cap is reached the EFP will immediately be terminated.

Agenda Item D.1.b
Supplemental HMSAS Report
June 2008

HIGHLY MIGRATORY SPECIES ADVISORY SUBPANEL REPORT ON CHANGES TO ROUTINE MANAGEMENT MEASURES FOR 2009-2010 SEASONS

Recreational Thresher Shark Management

The Highly Migratory Species Advisory Subpanel (HMSAS) recognizes and supports the work being done by the Highly Migratory Species Management Team (HMSMT) related to the recreational thresher shark fishery. Recreational fishing for thresher sharks is a popular activity and represents an important opportunity for recreational fishermen. It is an overall impression that private boat effort for thresher sharks is expanding, in relationship to other modes.

The HMSAS received and reviewed a report by Craig Heberer at the June 3-4, 2008, joint meeting of the HMSAS and HMSMT. The report summarizes the recreational thresher shark fishery and reports on a series of seminars conducted with the cooperation of the National Marine Fisheries Service (NMFS) Pacific Coast Recreational Fisheries Coordinator and United Anglers of Southern California. The HMSAS would like to note that 95 percent of fishermen surveyed in the seminars support more restrictive recreational bag limits for the recreational thresher shark fishery.

The HMSAS also supports continued research into issues of tail-hooking and survivability of thresher sharks in the catch and release of thresher sharks. If research indicates a high level of mortality of released fish, regulations that limit gear and tactics that minimize thresher shark mortality may be required.

Members of the public and individual HMSAS members recommend that the Council give consideration of the following list of potential management measures to address this issue:

- Seasonal closures
- Alignment of commercial and recreational fishing seasons
- Effort restrictions
- Gear restrictions
- Bag limit changes

Rod McInnis Letter to the Council Regarding Albacore Effort Control (Informational Report #1)

The HMSAS expresses concern that the May 21, 2008, letter sent by National Oceanic and Atmospheric Administration (NOAA) Fisheries to the Council calling for “vigor” in addressing potential management initiatives for North Pacific albacore was written without consultation of stakeholders most affected by any potential effort controls. We do agree that a fair and reasonable discussion of ways to maintain current levels of effort as outlined by the Western and Central Pacific Fisheries Commission (WCPFC) and Inter-American Tropical Tuna Commission (IATTC) resolutions should be approached if scientific findings show problems with albacore stocks. The HMSAS does not see the requests of the NOAA Fisheries letter as a high priority issue for the Council to take on at this time. The U.S. albacore industry was instrumental in agreeing to the resolutions, and should be kept up to date and included on details of any effort control initiatives by management bodies.

A minority of the HMSAS submits the following statement regarding the May 21, 2008, letter from the NOAA Regional Administrator, Rod McInnis to Chairman of the Pacific Fishery Management Council, Don Hansen regarding the development of management controls for the North Pacific albacore fishery.

In 2005, the IATTC and the WCPFC adopted resolutions identifying North Pacific albacore populations requiring member and cooperating non-member nations to "take necessary measures to ensure that the level of fishing effort by their vessels fishing for North Pacific albacore tuna is not increased."[1] Likewise, the International Scientific Committee (ISC) reported that fishing levels would need to be reduced based on future biomass projections if albacore continues to be fished at current rates. Similarly, the first Stock Assessment and Fishery Evaluation (SAFE) Report for the U.S. West Coast HMS FMP warned that "[t]he current fishing mortality rate is high relative to commonly used reference points, and may be cause for concern regarding the current stock status of North Pacific albacore."[2] The report further cautioned that "if rates of F continue at assumed levels, under most of the scenarios considered within the suite of uncertainty analyses, it is unlikely that the [spawning stock biomass] will rebuild to spawning stock biomass maximum sustainable yield (SSBMSY) levels within a five-year time horizon."[3].

At its June 2006 meeting, the Council directed the HMSMT and HMSAS to continue developing the information necessary to characterize current effort in the U.S. North Pacific albacore fishery. Effective management requires managers to be able to both quantify and control fishing effort; however lack of effort data should not preclude the Council and NMFS from acting quickly and with precaution to reduce fishing pressure on albacore.

In 2007, the California Department of Fish and Game (CDFG) proposed and the Council approved bag limits on North Pacific Albacore on the recreational sector.[4] While this is an important precautionary step, we note that bag limits in and of themselves will not guarantee effort reduction without parallel constraints on capacity in all sectors. As such, we support NMFS' intent to begin consideration of possible management controls to ensure that future catch and effort remains within the bounds of historical fishing effort. Towards that end, we recommend that the Council and NMFS take the precautionary step of establishing limited entry programs for recreational charter vessels and commercial fisheries targeting North Pacific albacore along the U.S. west coast.

PFMC
6/7/08

[1] PROP IATTC-73-C1, June 2005

[2] 2005 HMS Stock Assessment and Fishery Evaluation Report, Section 5.3.1, page 106.

[3] *Id*.

[4] "Implement Daily Bag Limits for North Pacific Albacore and Northern Bluefin Tuna Caught by Recreational Anglers in Federal Exclusive Economic Zone Waters Adjacent to California," Agenda Item C.2.a, Attachment 2, November 2006 PFMC Briefing Book.

HIGHLY MIGRATORY SPECIES MANAGEMENT TEAM REPORT ON CHANGES TO ROUTINE MANAGEMENT MEASURES FOR 2009-2010 SEASONS

The common thresher shark is one of 13 highly migratory species (HMS) actively managed under the Fishery Management Plan for U.S. West Coast Fisheries for Highly Migratory Species (HMS FMP). The landings of thresher shark are monitored under a precautionary annual harvest guideline currently set at 340 metric tons (mt). This precautionary management approach reflects, among other things, the low fecundity and productivity of thresher sharks coupled with their low resiliency to overexploitation.

During the early spring through summer months, thresher sharks migrate to the waters of the Southern California Bight to feed on concentrations of bait fish and for pregnant females to pup. Commercial and recreational fisheries targeted this annual aggregation and the resulting catch of both pregnant and recently pupped animals contributed to the overexploitation of the population. Due to this overexploitation, the commercial fishery was regulated to mitigate the targeting of mother and pups by establishing a time/area closure. At that time, the recreational fishery, which is primarily a private boat fishery, was believed to be a relatively minor component of the total thresher shark landings and comparable time/area regulations were not imposed. Current California state recreational regulations allow the harvest of two HMS sharks per person per day with no season, size, or area restrictions.

In recent years, the recreational fishery for thresher sharks has experienced a significant increase in effort and landings, including both mothers and pups. Additionally, a second window of opportunity for recreational catch and effort on thresher sharks has surfaced during the fall, and raises concerns in regards to the cumulative impacts on the species when added to the existing spring fishery.

Although only limited data are available on the total recreational fishing mortality, it is thought to be substantial and perhaps comparable to catch in commercial fisheries, which was approximately 100 mt in 2006. In 2007, the total harvest of thresher shark from both commercial and recreational fisheries may have approached or, due to the level of uncertainty in the landings data, may have exceeded, the 340 mt harvest guideline.

Highly Migratory Species Management Team Recommendation

The Highly Migratory Species Management Team (HMSMT) is concerned that existing management measures and regulations may not be adequate to keep the landings of thresher shark under the prescribed harvest guideline and recommends that a suite of potential recreational fishing management measures be developed for Council consideration.

PFMC
6/7/08

The Southern California Recreational Thresher Shark Fishery

Consideration of Regulatory Changes for 2009-2010 HMS FMP Biennial Management Measures Cycle

HMSMT Supplemental Report
Pacific Fishery Management Council
June 8-14, 2008
Foster City, California

Executive Summary

The Fishery Management Plan for U.S. West Coast Fisheries for Highly Migratory Species (HMS FMP) implements a biennial management cycle to establish or adjust harvest specifications for a 2-year period. The specifications become effective on April 1 of the following year which coincides with the start of the next fishing year. The Pacific Council targets the June, September, and November Council meetings for review and decision making of proposed management cycle changes. At the June 2008 meeting, the Council will consider the need for recreational fishing regulatory changes for the conservation and sustainable management of common thresher sharks as proposed by the HMS Management Team (HMSMT). This supplemental report provides background information on the current status of the southern California recreational thresher shark fishery to help guide Council deliberation on this agenda item.

Background

The common thresher shark (*Alopias vulpinus)*, is one of 13 highly migratory species actively managed under the HMS FMP. The landings of thresher shark are monitored under a precautionary annual harvest guideline currently set at 340 metric tons (mt). This precautionary management approach reflects, among other things, the low fecundity and productivity of thresher sharks coupled with their low resiliency to overexploitation. The main commercial fishery harvesting thresher shark on the west coast is the swordfish large mesh drift gillnet fishery (DGN). This fishery has been heavily regulated since the early 1980s due to bycatch and protected species concerns, as well as the over-exploitation of thresher sharks. The past commercial catch history depressed the thresher shark population status to a critically low level necessitating establishment of conservation and management measures (Hanan et al., 1993; Smith and Aseltine-Neilson, 2001). Based in part on the apparent success of these measures, the thresher shark landings were substantially reduced (Figure 1) and the population now appears to be in a rebounding phase.

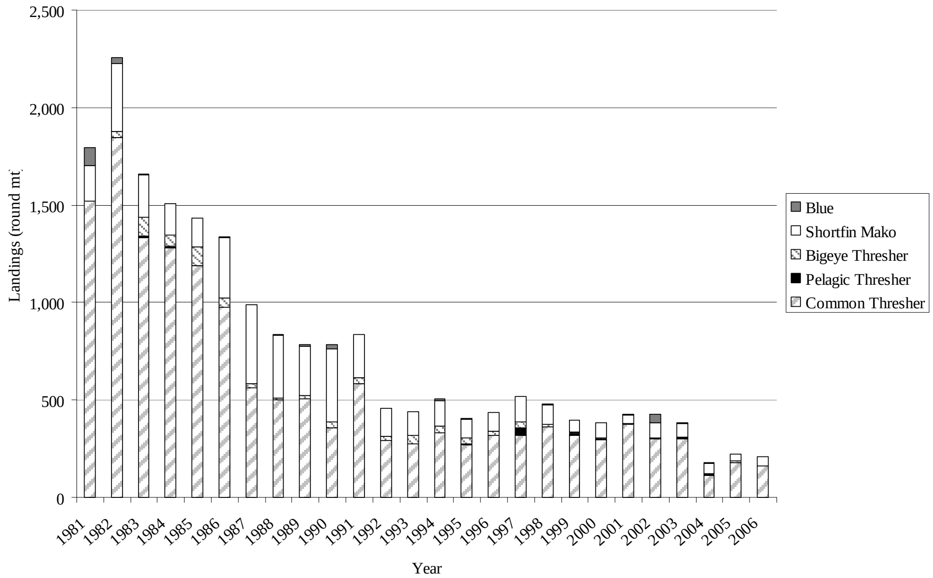

Figure 1. West Coast landings of HMS sharks, 1981-2007. (PFMC SAFE, 2007).

During the early spring through summer months, thresher sharks migrate to the waters of the Southern California Bight (SCB) to feed on concentrations of bait fish and for pregnant females to pup (Smith and Aseltine-Neilson, 2001; DePriest, 2004). Commercial and recreational fisheries targeted this annual aggregation and the resulting catch of both pregnant and recently pupped animals contributed to the overexploitation of the population. Due to this overexploitation, the commercial fishery was regulated to mitigate the targeting of mother and pups by establishing a time/area closure. At that time, the SCB recreational fishery, which is primarily a private boat fishery, was believed to be a relatively very minor component of the total thresher shark landings and comparable time/area regulations were not imposed. The California Commercial Passenger Fishing Vessel (CPFV) fleet has a minor history of participation in the recreational thresher shark fishery (Tables 3-4).

Current California state recreational regulations[1] allow the harvest of two HMS sharks in combination (thresher, mako, and blue sharks) per person per day with no season, size, or area restrictions.

In recent years, the SCB recreational fishery for thresher sharks has experienced a significant increase in effort and landings, including harvest of both mothers and pups (Table 1). Additionally, a second window of opportunity for recreational catch and effort on thresher sharks has recently surfaced during the fall period in the SCB (WON, 2007). Historically, fishing effort during this fall period was very minor but the increased effort now raises concerns in regards to the cumulative impacts on the species when added to the existing spring fishery.

Although only limited data are available on the total recreational fishing mortality, it is thought to be substantial and perhaps comparable to catch in commercial fisheries, which was

[1] The state regulation was adopted without change as a management measure under the HMS FMP.

approximately 100 mt in 2006 (PFMC, 2007 SAFE)[2]. In 2007, the total harvest of thresher shark from both commercial and recreational fisheries may have approached or, due to the level of uncertainty in the landings data, may have exceeded, the 340 mt harvest guideline.

Table 1. Estimated Catch (numbers) of Common Thresher Shark by Marine Recreational Anglers in California from January 2005 - December 2007[3]

	Estimate	PSE*
2005	275	21
2006	635	33
2007	1,544	52

*PSE = percent standard error as calculated by RecFIN query

The primary techniques developed in the SCB recreational thresher shark fishery entail trolling heavy (1-2 lb) baited lures (DePriest, 2004). Since this species uses its elongate upper caudal lobe to stun prey before it is consumed, thresher sharks are typically foul-hooked by the tail and subsequently hauled in backwards during the fight (Sepulveda et al., 2007). Like most pelagic species, the common thresher relies on obligate ram ventilation and thus requires forward momentum to extract oxygen from the water. A pilot study last year estimated approximately 25 percent of the released tail-hooked animals did not survive. The results of the pilot study led to the funding of a larger scale post-release survivorship study which is currently underway. This study is a cooperative effort amongst researchers from the Pfleger Institute of Environmental Research, NMFS Southwest Region, and NMFS Southwest Fisheries Science Center.

Although accurate and comprehensive recreational landings data are lacking for this species, including the level and impact of catch-and-release fishing, direct observations,[4] fishing tackle sales,[5] and weigh-station records[6] all suggest a dramatic expansion of this fishery in recent years. Increased effort can likely be attributed to a series of factors including: the rebuilding of an overexploited population; educational seminars on thresher shark fishing techniques; information sharing on the internet and through popular literature publications; the high cost of fuel making near shore fishing options more attractive; and the possible re-allocation of effort once directed at fisheries that are now restricted (i.e., groundfish).

Because the common thresher shark is well known for its susceptibility to over-exploitation, advocating the practice of catch and release remains a primary conservation tool proposed by managers and recreational groups alike. However, in order for catch-and-release techniques to be an effective management tool, the fate of released sharks must be known.

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[2] Commercial fishermen did not aggressively target thresher sharks in 2006 or 2007 given the low ex-vessel prices being offered (Pers. comm., Jeremiah O'Brien, President, Morro Bay Commercial Fishermen's Association).

[3] Recreational Fisheries Information Network (RecFIN) sampler examined catch for all modes of fishing in all marine areas

[4] Observations made by C. Sepulveda and S. Aalbers during Scipps Institute of Oceanography thresher shark field studies 2000-2004.

[5] D. Primrose , Owner, Ballyhood International Fishing Lures, Santa Ana, CA. Pers. comm.

[6] J. White, Manager, Dana Landing Market and Fuel Dock, Mission Bay, CA. Pers. comm..

Thresher Shark Fishing Seminars

With assistance from the NMFS Pacific Coast Recreational Fisheries Coordinator and the United Anglers of Southern California, a series of educational seminars was conducted in the spring of 2008 at three key locations in southern California (Newport, Oceanside, and San Diego). The seminars were intended to increase angler awareness, keep stakeholders abreast of the status of thresher shark conservation and management efforts, and to engage experienced shark anglers on innovative gear modifications and potential techniques to reduce the proportion of tail-hooked sharks. Anglers were given the opportunity to complete a voluntary questionnaire at the seminars. The results are summarized in Table 2.

In general, 60 percent of the anglers surveyed started fishing thresher sharks after 2005 and landed approximately 1-5 sharks per season. Roughly 50% of anglers released 1-5 sharks per season with trolling baited lures identified as the most popular way to target threshers (75 percent). A large percentage of surveyed anglers favored a season limit of 1-2 sharks per season (47 percent).

Table 2. Summary Statistics for a Voluntary Thresher Shark Questionnaire based on approximately 125 angler responses.

What year did you first start fishing for thresher sharks?

a. < 1980’s	b. 1980 – 2000	c. 2000 - 2005	d. 2005 - present
8%	20%	13%	59%

How many thresher sharks do you harvest per year?

a. 0	b. 1 - 5	c. 6 - 10	d. > 11
39%	58%	3%	

How many thresher sharks do you catch and release per year?

a. 0	b. 1 - 5	c. 6 - 10	d. > 11
42%	50%	7%	

What is the fishing technique that you typically use for thresher sharks?

a. Slow-trolling lures 73% b. Slow-trolling live bait (no lure) 15%
c. Chumming 12%

What percentages of the sharks that you catch are tail-hooked?

a. 0 – 25%	b. 26 – 50%	c. 51 – 75%	d. 76 – 100%
24%	9%	24%	42%

What percentage of thresher sharks do you lose with trailing gear?

a. 0 – 25%	b. 26 – 50%	c. 51 – 75%	d. 76 – 100%
62%	23%	13%	2%

What would you consider a reasonable limit for common thresher sharks?

a. Status quo (no change) = 5% b. 1 shark / person / day = 16%
c. 1 shark / boat / day = 31% d. Season limit = 47%

Table 3. Estimated thresher shark catch (numbers) by anglers fishing on California Commercial Passenger Fishing Vessels (CPFVs). (CDFG logbook data)

Year	No. Trips	Kept	Thrown Back
1997	34	49	0
1998	27	28	2
1999	37	47	13
2000	39	40	4
2001	14	14	1
2002	15	11	4
2003	25	26	1
2004	20	18	3
2005	24	23	9
2006	24	27	4
2007	34	40	14

Table 4. Estimated number of yearly CPFV thresher shark trips made by port. (CDFG logbook data).

Year	Eureka	Bay Area	Monterey Area	SB/Ventura	LA/OC	San Diego Area
1997		12		6	12	4
1998		5	2	1	12	7
1999		3		2	17	15
2000		8	1	7	19	4
2001		4		3	6	1
2002		2	1	3	8	1
2003		3	4		12	6
2004		12			2	6
2005	1	4	3	1	9	6
2006		2		3	10	9
2007		1		8	14	11

Literature Cited

DePriest, B. 2004. Thresher Tactics, How to take one without losing your teeth. *Pacific Coast SportFishing*. July: 80-85.

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Attachment 2

Draft 2008 HMS SAFE Report Outline

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1.1 Goals and Objectives of the Fishery Management Plan
1.2 Purpose of the SAFE Report
1.3 The Management Cycle
1.4 Highly Migratory Species Management Team

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PETER H. FLOURNOY

May 29, 2008

Mr. Donald K. Hansen
Chair, Pacific Fishery Management Council
7700 NE Ambassador Place, Ste. 101
Portland, Oregon 97220-1384

Re: Rodney R. McInnis Letter to Council of May 21, 2009

Dear Don:

I am writing you on behalf of the Western Fishboat Owner's Association and the American Fishermen's Research Foundation. We were surprised and concerned over Dr. McInnis's letter suggesting that NOAA Fisheries was going to produce a report for the Council's consideration concerning potential management options for the North Pacific albacore fishery, with a Fall completion date. It is our understanding that this will be done under a consulting contract, I would assume out of the Region's budget for this fiscal year. We believe this is a waste of money and resources at a time when there are many more worthwhile projects concerning HMAS fisheries which remain undone for want of funding. While we realize that the budgets of the Council, the Region and the Science Center are separate, we are aware that in the past the Region has contributed to the HMS budget for the Council. Given the obviously ill effects of the present HMS workload on at least one member of the Council staff, to the point of threatening his health, we believe this money could be better spent by the Council or the Science Center.

We are even more amazed and confused with the statement in the same letter that "NOAA Fisheries believes that the Council should begin considering possible management controls to *insure that future catch and effort does indeed remain within the bounds of the historical fishing effort. (Emphasis added)* It is not that NOAA Fisheries is somehow uninformed, since earlier in the letter Dr. McInnis acknowledges the ISC report that the spawning biomass is the second highest in the known history of the fishery, as well as the information that the albacore fleet is not increasing now and has been stable through out the 1996-2005 time

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period as reported by the PFMC HMS-MT.

NOAA Fisheries is also aware, although the Council my not be, that the SWFSC is so understaffed and underfunded that it took it 3 years to analyze data collected from albacore archive tags (a project which AFRF supported). The Center is apparently still are unable to correlate the albacore logbooks in a timely manner. These logbooks have been mandatory since the approval of the HMS-FMP in 2005. We believe these are at least two tasks which should receive adequate funding before NOAA-Fisheries embarks on studies that may prove at best out of date when they are needed, and at worst totally unnecessary.

Indeed, the Council is aware of the repeated delays in processing EFPs due to either the Region's or the Science Center's lack of resources in both personnel and funding. I would also assume that the Council is aware of the lack of promotion and support given by NOAA-Fisheries to its website which gives the public information on the sustainability of various fish species. This has encouraged a plethora of private organizations such as MSC and Greenpeace to set up their own criteria for sustainability and permitted them to mis-characterize many fisheries over which the Council has jurisdiction, much to the detriment and frustration of the Council's constituents, and I believe of the Council as well.

The list of desperately needed research into the life history of many HMS species including albacore that is not being done due to the lack of funding and personnel is too long to repeat here. I would urge the Council to review pages 30 and 31, Section 5.2.1 of Agenda Item C.3.a, Attachment 1, Research and Data Needs 2008 for the short list of *high priority* items. We believe "management options" should be based on science, not merely the best scientific information available when that is inadequate because of inadequate funding.

I would suggest the Council write a strong letter to Dr. McInnis, and if appropriate to Dr. Balsiger, to discourage projects such as that suggested in the May 21, 2008 letter which are unwarranted and wasteful, and at the same time encourage greater funding for the SWFSC and the Region to pursue some of the projects and goals which I have listed above.

Sincerely,

Peter H. Flournoy

WESTERN FISHBOAT OWNERS ASSOCIATION©

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May 28, 2008

Mr. Don Hansen
Chair, Pacific Fisheries Management Council
7700 NE Ambassador Place, Ste. 101
Portland, OR 97220-1384

Re: Rodney McInnis May 21, 2008 Letter to the PFMC

Dear Chairman Hansen:

Western Fishboat Owners Association is extremely concerned over the unexpected letter that Rod McInnis wrote to the PFMC on May 21, 2008. The letter requested that the PFMC address management of the commercial albacore fishery with “vigor.” Mr. McInnis cites the establishment of daily bag limits on albacore in the recreational fishery as one reason to pursue management of albacore.

The letter does state that NOAA Fisheries sees no increase in the albacore effort and has been stable from 1996. Thus, the haste to act unilaterally based on a presumption that fishing effort is high internationally in troubling. If fishing effort is the problem internationally, and the U.S. effort is stable, then why are we in such a rush?

Right now salmon and albacore trollers are hammered by the management regimes, and now getting further marginalized arbitrarily.

The NMFS position is a double whack; especially since it was WFOA that asked for control limits on Asian fleets moving to the Eastern Pacific! WFOA and AFRF representatives discussed all of the problems of this approach with Dr. Bill Fox while he was at the SWFSC, and have also discussed this with representatives of the SWRO. We thought we had made clear to NOAA that the potential problem was not with the U.S. albacore fleet but with foreign entry. We feel this coming from NOAA/NMFS at this time is extremely troubling to the U.S. albacore industry.

The idea of effort stabilization in the commercial fleet is a valid discussion at some point if conditions warrant and other nations are acting in the same manner. However, and most troubling is why NOAA Fisheries suddenly sent this letter to the council with no consultations with groups such as ours. WFOA has worked with NOAA/NMFS on many management & regulatory issues. American Fishermen's Research Foundation (AFRF), also has a 37-year history of cooperative research with NOAA/NMFS. Therefore you can understand our shock when we are blindsided by this type of initiative.

The U.S. west coast albacore industry hopes that the PFMC will advise NOAA Fisheries that the current management system is adequate to manage the U.S. troll fishery at this time. WFOA strongly urges the PFMC to reject this request by NOAA Fisheries.

Sincerely,

Wayne Heikkila
Executive Director

cc: Don McIsaac - PFMC Executive Director
Rod McInnis - NOAA/NMFS
Mark Helvey - NOAA/NMFS

COUNCIL RECOMMENDATIONS TO REGIONAL FISHERY MANAGEMENT ORGANIZATIONS

At the April 2008 meeting, the Council made recommendations to the U.S. delegation to the Inter-American Tropical Tuna Commission (IATTC) for positions the U.S. should advance at the upcoming 78th meeting (June 23-27, 2008). Attachment 1 is the letter describing those recommendations, which was sent to Rod McInnis, National Marine Fisheries Service Southwest Regional Administrator and a U.S. Commissioner to the IATTC. The Council left open the possibility of making additional recommendations based on information coming out of the IATTC's 9th Stock Assessment Review Meeting, which occurred May 12-16, 2008.

Attachments 2 and 3 are the stock assessments for yellowfin and bigeye tunas resulting from the 9th Stock Assesment Review Meeting (the executive summary is included with the printed materials; the full assessments are posted on the Council's web site and included on the briefing book CD-ROM). Both of these stocks have been declared subject to overfishing by the Secretary of Commerce. To date the IATTC has been unable to adopt a new resolution containing conservation measures for yellowfin and bigeye tunas to replace Resolution C-06-02, which expired at the end of 2007. Attachment 4 is an IATTC staff paper describing the effect of the previous resolution and projected changes to spawning stock biomass in the absence of a comparable new resolution. Attachment 5 summarizes the various conservation proposals made at the 75th, 76th, and 77th IATTC meetings. As noted, the IATTC was unable to adopt a conservation resolution based on these proposals. There is a strong desire that the IATTC adopt an effective conservation resolution at their 78th meeting.

The Northern Committee is a subsidiary body of the Western and Central Pacific Fisheries Commission, responsible for making recommendations for Highly Migratory Species (HMS) stocks occurring principally north of 20° N latitude. Currently this body has identified as their responsibility the North Pacific stocks of albacore tuna, bluefin tuna, and swordfish. The Northern Committee may request scientific information and advice regarding these fish stocks from the International Scientific Committee for Tuna and Tuna-like Species (ISC). As reported at the September 2007 Council meeting, the 7th plenary meeting of the ISC adopted a stock assessment for albacore tuna. It indicated that spawning stock biomass is at historically high levels but that current fishing mortality is high relative to most reference points. The current F would gradually reduce spawning stock biomass to the long term average by the mid 2010s. The ISC recommended the development and adoption of reference points for determining albacore stock status and guiding the development of management measures. The Northern Committee took this under advisement with the intention of developing proposals for their 2008 meeting. In April 2008 the Council was briefed on the ISC's stock assessment results for striped marlin, which indicates that the stock is substantially depleted. The Northern Committee has not adopted striped marlin as a stock under its purview, because there are questions as to whether striped marlin in fact principally occur north of 20° N latitude. However, there have been calls for them to take on striped marlin so that management measures can be coordinated across the North Pacific.

The Northern Committee will hold its 4th annual meeting September 9-11, 2008. Any conservation recommendations they make are presented to the 5th regular session of the Western and Central Pacific Fisheries Commission, December 8-12, 2008. Because the next Northern

Committee meeting occurs at the same time as the Council's September meeting, the only opportunity for the Council to develop positions for consideration by the Northern Committee is at this meeting.

Council Action:

1. Approve recommendations on HMS management to the Northern Committee of the Western and Central Pacific Fisheries Commission and Inter-American Tropical Tuna Commission.

Reference Materials:

1. Agenda Item D.2.a, Attachment 1: Letter to Rodney McInnis containing Council's recommendations to the U.S. delegation to the IATTC.
2. Agenda Item D.2.a, Attachment 2: Document SARM-9-06a Status Of Yellowfin Tuna in the Eastern Pacific Ocean in 2007 and Outlook For The Future (Executive Summary; complete document on web and CD-ROM).
3. Agenda Item D.2.a, Attachment 3: Document SARM-9-06b Status Of Bigeye Tuna in the Eastern Pacific Ocean (Executive Summary; complete document on web and CD-ROM).
4. Agenda Item D.2.a, Attachment 4: Document SARM-9-06c Evaluation of the Effect of Resolutions C-04-09 and C-06-02.
5. Agenda Item D.2.a, Attachment 5: Document SARM-9-05 Summary of Conservation Proposals.

Agenda Order:

a. Agenda Item Overview — Kit Dahl
b. Reports and Comments of Advisory Bodies
c. Public Comment
d. **Council Action**: Approve Recommendations on HMS Management to the Northern Committee of the Western and Central Pacific Fisheries Commission and Inter-American Tropical Tuna Commission

PFMC
05/27/08

Pacific Fishery Management Council

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Donald K. Hansen, Chairman Donald O. McIsaac, Executive Director

April 18, 2008

Mr. Rodney McInnis
Regional Administrator, Southwest Region
National Marine Fisheries Service
501 W Ocean Blvd., Ste. 4200
Long Beach, CA 90802-4213

Re: Recommendations for the U.S. Delegation to the Inter-American Tropical Tuna Commission

Dear Mr. McInnis, Rod

At their April 7–12, 2008, meeting the Council made three recommendations for the U.S. delegation to the Inter-American Tropical Tuna Commission (IATTC) to consider when developing positions to be taken at the IATTC's 78th meeting, June 23–27, 2008.

First, the Council is concerned that the IATTC has been unable to adopt a new resolution containing conservation measures for yellowfin and bigeye tunas to replace Resolution C-06-02, which expired at the end of 2007. The Council urges the U.S. delegation to advocate vigorously for conservation and management measures sufficient to end overfishing on these two stocks. However, the Council notes that U.S. west coast coastal purse seine vessels occasionally target yellowfin tuna on those infrequent occasions when they occur off of Southern California. Their catches represent a very small proportion of total catches in the Eastern Pacific Ocean, but are an important economic opportunity for this fleet. Noting that any effective conservation and management measures would likely require a seasonal closure for purse seine vessels, the Council asks that the U.S. delegation work with the IATTC to explore the implications of an exemption for smaller, Class I-V vessels (well volume less than 426 m^3) for the success of conservation and management measures. While an exemption for U.S. vessels alone may not impede successfully ending overfishing, we recognize that any such exemption would likely be applicable to vessels in these size classes from all member nations, potentially increasing the number of exempted vessels too much. One approach would be to model an exemption after the formula in C-06-02 used to limit catches of bigeye tuna by longline vessels. An exemption would be based on historical catch by vessels in these size categories for each nation. If catches were below a certain level, then the nation's Class I-V vessels would be exempted from the closure up to some small catch limit. For example, the U.S. fleet averaged less than 500 mt catch of yellowfin tuna in 2001–05, so an exemption based on a value of that general magnitude, along with a requirement that the national fleet not exceed some amount of catch, could be a workable formula. This would depend on the number of other nations potentially qualifying for such an exemption, and the overall level of catch that could ensue. IATTC scientific staff should conduct such an evaluation.

Second, we recommend the U.S. delegation emphasize to IATTC our growing concern about the status of the striped marlin stock in the North Pacific. A stock assessment published by the International Scientific Committee for Tuna and Tuna-like Species in 2007, based on the assumption that striped marlin is a single stock in the North Pacific, concluded that the stock is substantially depleted from historic levels. The IATTC has not conducted a striped marlin stock assessment since 2003. The U.S. should encourage the IATTC to conduct a new stock assessment as a basis for considering whether conservation and management measures are necessary. Any such stock assessment should critically evaluate available information on stock structure in order to determine whether an Eastern Pacific Ocean stock should be managed separately or as part of a single North Pacific stock.

Third, the Council notes that the U.S. has complied with Resolution C-05-02 by defining historical levels of fishing effort by U.S. vessels on the North Pacific albacore stock and demonstrating that effort has not increased. However, it does not appear that other nations have complied with the resolution in a similarly transparent way. We recommend the U.S. delegation request the IATTC emphasize that member nations formally demonstrate compliance with the resolution. Furthermore, in bilateral discussions, we recommend the U.S. encourage member nations to openly communicate how they are complying with the requirements of the resolution.

Clearly, the Council shares your concern about the status of the highly migratory species stocks in the IATTC arena. Addressing potential unsustainable fishing effort on these stocks requires international success on the difficult task of achieving consensus on effective management measures. The Council asks you to convey the views expressed in this letter to the U.S. delegation and the IATTC. We also stand ready to assist as necessary in this important matter.

Sincerely,

D. O. McIsaac, Ph.D.
Executive Director

CRD:kam

cc: Council Members
Mr. David Hogan
Mr. Peter Flournoy
Ms. Rebecca Lent
Mr. Bill Robinson
Ms. Kitty Simonds
Mr. Paul Dalzell

Agenda Item D.2.a,
Attachment 2
June 2008

INTER-AMERICAN TROPICAL TUNA COMMISSION

9TH STOCK ASSESSMENT REVIEW MEETING

LA JOLLA, CALIFORNIA (USA)
12-16 MAY 2008

DOCUMENT SARM-9-06a

STATUS OF YELLOWFIN TUNA IN THE EASTERN PACIFIC OCEAN IN 2007 AND OUTLOOK FOR THE FUTURE

Mark N. Maunder and Alexandre Aires-Da-Silva

CONTENTS

1. EXECUTIVE SUMMARY

This report presents the most current stock assessment of yellowfin tuna (*Thunnus albacares*) in the eastern Pacific Ocean (EPO). An age-structured, catch-at-length analysis (A-SCALA) was used in the assessment, which is based on the assumption that there is a single stock of yellowfin in the EPO. Yellowfin are distributed across the Pacific Ocean, but the bulk of the catch is made in the eastern and western regions. The purse-seine catches of yellowfin are relatively low in the vicinity of the western boundary of the EPO. The movements of tagged yellowfin are generally over hundreds, rather than thousands, of kilometers, and exchange between the eastern and western Pacific Ocean appears to be limited. This is consistent with the fact that longline catch-per-unit-of-effort (CPUE) trends differ among areas. It is likely that there is a continuous stock throughout the Pacific Ocean, with exchange of individuals at a local level, although there is some genetic evidence for local isolation. Movement rates between the EPO and the western Pacific cannot be estimated with currently-available tagging data.

The stock assessment requires substantial amounts of information, including data on retained catches, discards, fishing effort, and the size compositions of the catches of the various fisheries. Assumptions have been made about processes such as growth, recruitment, movement, natural mortality, fishing mortality, and stock structure. The assessment for 2008 differs from that of 2007 in the following ways. The catch and length-frequency data for the surface fisheries have been updated to include new data for 2007 (except the first quarter) and revised data for 2000-2006 and the first quarter of 2007. New or updated longline catch data are available for Chinese Taipei (2004-2006) and Japan (2003-2006).

In general, the recruitment of yellowfin to the fisheries in the EPO is variable, with a seasonal component. This analysis and previous analyses have indicated that the yellowfin population has experienced two, or possibly three, different productivity regimes (1975-1982, 1983-2001, and 2002-2006) corresponding to low, high, and intermediate levels of recruitment. The productivity regimes correspond to regimes in biomass, higher-productivity regimes producing greater biomasses. A stock-recruitment relationship is also supported by the data from these regimes, but the evidence is weak, and is probably an artifact of the apparent regime shifts. The analysis indicates that strong cohorts entered the fishery during 1998-2001, and that these cohorts increased the biomass during 1999-2001. However, these cohorts have now moved through the population, so the biomass decreased during 2002-2007. The biomass in 2005-2008 was at levels similar to those prior to 1985.

The average weights of yellowfin taken from the fishery have been fairly consistent over time, but vary substantially among the different fisheries. In general, the floating-object, unassociated, and pole-and-line fisheries capture younger, smaller yellowfin than do the dolphin-associated and longline fisheries. The longline fisheries and the dolphin-associated fishery in the southern region capture older, larger yellowfin than do the northern and coastal dolphin-associated fisheries.

Significant levels of fishing mortality have been estimated for the yellowfin fishery in the EPO. These levels are highest for middle-aged yellowfin. Most of the yellowfin catch is taken in sets associated with dolphins, and, accordingly, this method has the greatest impact on the yellowfin population, although it has almost the least impact per unit of weight captured of all fishing methods.

Historically, the spawning biomass ratio (ratio of the spawning biomass to that of the unfished population, SBR) of yellowfin in the EPO was below the level corresponding to the maximum sustainable yield (MSY) during the lower productivity regime of 1975-1983, but above that level for most of the following years, except for the recent period (2003-2007). The increase in the SBR in 1984 is attributed to the regime change, and the recent decrease may be a reversion to an intermediate productivity regime. The two different productivity regimes may support two different MSY levels and associated SBR levels. The SBR at the start of 2008 is estimated to be above the level corresponding to the MSY. The effort levels are estimated to be less than those that would support the MSY (based on the current distribution of effort among the different fisheries), but recent catches are substantially below the MSY.

If a stock-recruitment relationship is assumed, the outlook is more pessimistic, and current biomass is estimated to be below the level corresponding to the MSY.

The current average weight of yellowfin in the catch is much less than the critical weight. The MSY calculations indicate that, theoretically at least, catches could be increased if the fishing effort were directed toward longlining and purse-seine sets on yellowfin associated with dolphins. This would also increase the SBR levels.

The MSY has been stable during the assessment period, which suggests that the overall pattern of selectivity has not varied a great deal through time. However, the overall level of fishing effort has varied with respect to the MSY multiplier.

Under current levels of fishing mortality, it is predicted that the biomass will increase and then decrease but remain above the current level, and that the SBR will follow a similar trend, remaining above the level corresponding to the MSY. A comparison of the biomass and SBR predicted with and without the restrictions from Resolutions C-04-09 and C-06-02 suggests that, without the restrictions, they would be at lower levels than at present, and would decline to about the level corresponding to the MSY.

These simulations were carried out, using the average recruitment for the 1975-2007 period. If they had been carried out using the average recruitment for the 1983-2001 period, the projected trend in SBR and catches would have been more positive. Conversely, if they had been carried out using the average recruitment for the 2002-2006 period, the projected trend in SBR and catches would have been more negative.

Summary

1. The results are similar to the previous assessments, except that the current effort is less than that corresponding to MSY.
2. There is uncertainty about recent and future recruitment and biomass levels.
3. The recent fishing mortality rates are close to those corresponding to the MSY.
4. Increasing the average weight of the yellowfin caught could increase the MSY.
5. There have been two, and possibly three, different productivity regimes, and the levels of MSY and the biomasses corresponding to the MSY may differ between the regimes. The population may have recently switched from the high to an intermediate productivity regime.
6. The results are more pessimistic if a stock-recruitment relationship is assumed.

2. DATA

Catch, effort, and size-composition data for January 1975-December 2007, plus biological data, were used to conduct the stock assessment of yellowfin tuna, *Thunnus albacares*, in the eastern Pacific Ocean (EPO). The data for 2007, which are preliminary, include records that had been entered into the IATTC databases by 15 April 2007. All data are summarized and analyzed on a quarterly basis.

2.1. Definitions of the fisheries

Sixteen fisheries are defined for the stock assessment of yellowfin. These fisheries are defined on the basis of gear type (purse seine, pole and line, and longline), purse-seine set type (sets on schools associated with floating objects, unassociated schools, and dolphin-associated schools), and IATTC length-frequency sampling area or latitude. The yellowfin fisheries are defined in Table 2.1, and their spatial extents are shown in Figure 2.1. The boundaries of the length-frequency sampling areas are also shown in Figure 2.1.

In general, fisheries are defined so that, over time, there is little change in the size composition of the catch. Fishery definitions for purse-seine sets on floating objects are also stratified to provide a rough distinction between sets made mostly on fish-aggregating devices (FADs) (Fisheries 1-2, 4, 13-14, and 16), and sets made on mixtures of flotsam and FADs (Fisheries 3 and 15).

2.2. Catch and effort data

To conduct the stock assessment of yellowfin tuna, the catch and effort data in the IATTC databases are stratified according to the fishery definitions described in Section 2.1 and shown in Table 2.1. "Landings" is catch landed in a given year even if the fish were not caught in that year. Catch that is taken in a given year and not discarded at sea is termed retained catch. Throughout the document the term "catch" will be used to reflect either total catch (discards plus retained catch) or retained catch, and the reader is referred to the context to determine the appropriate definition.

All three of these types of data are used to assess the stock of yellowfin. Removals by Fisheries 10-12 are simply retained catch (Table 2.1). Removals by Fisheries 1-4 are retained catch plus some discards resulting from inefficiencies in the fishing process (see Section 2.2.3) (Table 2.1). The removals by Fisheries 5-9 are retained catch, plus some discards resulting from inefficiencies in the fishing process and from sorting the catch. Removals by Fisheries 13-16 are only discards resulting from sorting the catch taken by Fisheries 1-4 (see Section 2.2.2) (Table 2.1).

New and updated catch and effort data for the surface fisheries (Fisheries 1-10 and 13-16) have been incorporated into the current assessment. New catch and effort data for 2007 (except the first quarter, which was used in the previous assessment) and updated data for earlier years are used for the surface fisheries.

The species-composition method (Tomlinson 2002) was used to estimate catches of the surface fisheries. Comparisons of catch estimates from different sources show consistent differences between cannery and unloading data and the results of species composition sampling. Comparing the two sets of results is complex, as the cannery and unloading data are collected at the trip level, while the species-composition samples are collected at the well level, and represent only a small subset of the data. Differences in catch estimates could be due to the proportions of small tunas in the catch, differences in identification of the fish at the cannery, or even biases introduced in the species-composition algorithm in determining the species composition in strata for which no species-composition samples are available. In this assessment we calculated average quarterly and fishery-specific scaling factors for 2000-2005 and applied these to the cannery and unloading estimates for 1975-1999. Harley and Maunder (2005) compared estimates of the catches of bigeye obtained by sampling catches with estimates of the catches obtained from cannery data. Maunder and Watters (2001) provide a brief description of the method that is used to estimate fishing effort by surface gear (purse seine and pole-and-line).

Updates and new catch and effort data for the longline fisheries (Fisheries 11 and 12) have also been incorporated into the current assessment. New or updated catch data were available for Chinese Taipei (2004-2006) and Japan (2003-2006).

The amount of longlining effort was estimated by dividing standardized estimates of the catch per unit of effort (CPUE) from the Japanese longline fleet into the total longline landings. Estimates of standardized CPUE were obtained using a delta-lognormal generalized linear model (Stefansson 1996) that took into account latitude, longitude, and numbers of hooks between floats (Hoyle and Maunder 2006b).

2.2.1. Catch

A substantial proportion of the longline catch data for 2007 were not available, so effort data were assumed (see Section 2.2.2), and the catch was estimated by the stock assessment model. Therefore, the total 2007 longline catch is a function of the assumed 2007 longline effort, the estimated number of yellowfin of catchable size in the EPO in 2007, and the estimated selectivities and catchabilities for the longline fisheries. Catches for the longline fisheries for the recent years for which the data were not available were set equal to the last year for which catch data were available.

Trends in the catch of yellowfin in the EPO during each quarter from January 1975 to March 2007 are shown in Figure 2.2. It should be noted that there were substantial surface and longline fisheries for yellowfin prior to 1975 (Shimada and Schaefer 1956; Schaefer 1957; Okamoto and Bayliff 2003). The majority of the catch has been taken by purse-seine sets on yellowfin associated with dolphins and in unassociated schools. One main characteristic of the catch trends is the increase in catch taken since about 1993 by purse-seine sets on fish associated with floating objects, especially FADs in Fisheries 1 and 2. However, this is a relatively small part of the total catch.

Although the catch data in Figure 2.2 are presented as weights, the catches in numbers of fish were used to account for most of the longline catches of yellowfin in the stock assessment.

2.2.2. Effort

New effort data for 2007 (except the first quarter, which was used in the previous assessment) and updated data for earlier years are used for the surface fisheries.

A complex algorithm, described by Maunder and Watters (2001), was used to estimate the amount of fishing effort, in days fished, exerted by purse-seine vessels. The longline effort data for yellowfin have been estimated from standardized CPUE data, as follows. Detailed data on catch, effort, and hooks between floats by latitude and longitude from the Japanese longline fleet, provided by Mr. Adam Langley of the Secretariat of the Pacific Community, were used in a generalized linear model with a delta lognormal link function to produce an index of standardized CPUE (E.J. Dick, NOAA Santa Cruz, personal communication); see Stefansson (1996) for a description of the method and Hoyle and Maunder (2006b) for more detailed information. The Japanese effort data were scaled by the ratio of the Japanese catch to the total catch to compensate for the inclusion of catch data from the other nations into the assessment. This allows inclusion of all the longline catch data into the assessment, while using only the Japanese effort data to provide information on relative abundance.

Effort information from the Japanese longlining operations conducted in the EPO during 2007 was not available for this assessment. The longline effort exerted during each quarter of 2007 was assumed to be equal to the estimated effort exerted during the corresponding quarter of 2006. No longline catch data were input for 2007 (see above).

Trends in the amount of fishing effort exerted by the 16 fisheries defined for the stock assessment of yellowfin in the EPO are plotted in Figure 2.3. Fishing effort for surface gears (Fisheries 1-10 and 13-16) is in days fishing. The fishing effort in Fisheries 13-16 is equal to that in Fisheries 1-4 (Figure 2.3) because the catches taken by Fisheries 13-16 are derived from those taken by Fisheries 1-4 (see Section 2.2.3). Fishing effort for longliners (Fisheries 11 and 12) is in standardized units.

2.2.3. Discards

For the purposes of stock assessment, it is assumed that yellowfin are discarded from catches made by purse-seine vessels because of inefficiencies in the fishing process (when the catch from a set exceeds the remaining storage capacity of the fishing vessel) or because the fishermen sort the catch to select fish that are larger than a certain size. In either case, the amount of yellowfin discarded is estimated with information collected by IATTC or national observers, applying methods described by Maunder and Watters (2003a). Regardless of why yellowfin are discarded, it is assumed that all discarded fish die. Maunder and Watters (2001) describe how discards were implemented in the yellowfin assessment. In the present assessment the discard rates are not smoothed over time, which should allow for a better representation of recruitment in the model.

Estimates of discards resulting from inefficiencies in the fishing process are added to the retained catches (Table 2.1). No observer data are available to estimate discards prior to 1993, and it is assumed that there were no discards due to inefficiencies before that time. There are periods for which observer data are not sufficient to estimate the discards, in which case it is assumed that the discard rate (discards/retained catches) is equal to the discard rate for the same quarter in the previous year or, if not available, a proximate year.

Discards that result from the process of sorting the catches are treated as separate fisheries (Fisheries 13-16), and the catches taken by these fisheries are assumed to be composed only of fish that are 2-4 quarters old (see Figure 4.5). Maunder and Watters (2001) provide a rationale for treating such discards as separate fisheries. The discard rate prior to 1993 is assumed to be the average rate observed in each fishery after this time. Estimates of the amounts of fish discarded during sorting are made only for fisheries that take yellowfin associated with floating objects (Fisheries 2-5) because sorting is infrequent in the other purse-seine fisheries.

Time series of discards as proportions of the retained catches for the surface fisheries that catch yellowfin in association with floating-objects are presented in Figure 2.4. It is assumed that yellowfin are not discarded from longline fisheries (Fisheries 11 and 12).

2.3. Size-composition data

The fisheries of the EPO catch yellowfin of various sizes. The average size composition of the catch from each fishery defined in Table 2.1 is shown in Figure 4.2. Maunder and Watters (2001) describe the sizes of yellowfin caught by each fishery. In general, floating-object, unassociated, and pole-and-line fisheries catch smaller yellowfin, while dolphin-associated and longline fisheries catch larger ones. New purse-seine length-frequency data were included for the last three quarters of 2007, and revised data for 2000-2005 and the first quarter of 2007.

New longline length-frequency data for 2005 for the Japanese fleet, and updated data for that fleet for 2002-2004, were included. Size composition data for the other longline fleets are not used in the assessment.

The length frequencies of the catches during 2007 from the four floating-object fisheries were similar to those observed over the entire modeling period (compare Figures 4.2 and 4.8a). The appearance, disappearance, and subsequent reappearance of strong cohorts in the length-frequency data is a common phenomenon for yellowfin in the EPO. This may indicate spatial movement of cohorts or fishing effort, limitations in the length-frequency sampling, or fluctuations in the catchability of the fish. Bayliff (1971) observed that groups of tagged fish have also disappeared and then reappeared in this fishery, which he attributed to fluctuations in catchability.

2.4. Auxiliary data

Age-at-length estimates (Wild 1986) calculated from otolith data were integrated into the stock assessment model in 2005 (Hoyle and Maunder 2006a) to provide information on mean length at age and variation in length at age. His data consisted of ages, based on counts of daily increments in otoliths, and lengths for 196 fish collected between 1977 and 1979. The sampling design involved collection of 15 yellowfin in each 10-cm interval in the length range of 30 to 170 cm. The model has been altered to take this sampling scheme into account (see Section 3.1.1).

3. ASSUMPTIONS AND PARAMETERS

3.1. Biological and demographic information

3.1.1. Growth

The growth model is structured so that individual growth increments (between successive ages) can be estimated as free parameters. These growth increments for all ages were highly constrained to be similar to a Richards growth curve. The Richards growth equation, $L_t = L_\infty \left(1 - \frac{\exp\left(-K\left(t - t_0\right)\right)}{b}\right)^b$, fitted to data from Wild (1986) was used as the prior (Figure 3.1) (L_∞ = 185.7 cm, annual K= 0.761, t_0 = 1.853 years, b = -1.917). The growth increments are also constrained so that the mean length is a monotonically increasing function of age. The size at which fish are first recruited to the fishery must be specified, and it is assumed that yellowfin are recruited to the discard fisheries (Fisheries 13-16) when they are 30 cm long and two quarters old.

Expected asymptotic length (L_∞) cannot be reliably estimated from data such as those of Wild (1986) that do not include many old fish. However, Hoyle and Maunder (2007) found that the results were insensitive to the value of L_∞.

An important component of growth used in age-structured statistical catch-at-length models is the variation in length at age. Age-length information contains information about variation of length at age, in addition to information about mean length at age. Unfortunately, as in the case of the data collected by Wild (1986), sampling is usually aimed at getting fish of a wide range of lengths. Therefore, this sample may represent the population in variation of age at length, but not variation of length at age. However, by applying conditional probability the appropriate likelihood can be developed.

This assessment used the approach first employed by Hoyle and Maunder (2006a) to estimate variation in length at age from the data. Both the sampling scheme and the fisheries and time periods in which data were collected were taken into account. The mean lengths of older yellowfin were assumed to be close to those indicated by the growth curve of Wild (1986).

The following weight-length relationship, from Wild (1986), was used to convert lengths to weights in this stock assessment:

$$w = 1.387 \times 10^{-5} \cdot l^{3.086}$$

where w = weight in kilograms and l = length in centimeters.

A more extensive unpublished data set of length and weight data gives a slightly different relationship, but inclusion of this alternative data set in the stock assessment model gives essentially identical results.

3.1.2. Recruitment and reproduction

The A-SCALA method allows a Beverton-Holt (1957) stock-recruitment relationship to be specified. The Beverton-Holt curve is parameterized so that the relationship between spawning biomass and recruitment is determined by estimating the average recruitment produced by an unexploited population (virgin recruitment) and a parameter called steepness. Steepness is defined as the fraction of virgin recruitment that is produced if the spawning stock size is reduced to 20% of its unexploited level, and it controls how quickly recruitment decreases when the size of the spawning stock is reduced. Steepness can vary between 0.2 (in which case recruitment is a linear function of spawning stock size) and 1.0 (in which case recruitment is independent of spawning stock size). In practice, it is often difficult to estimate steepness because of lack of contrast in spawning stock size, high inter-annual (and inter-quarter) variation in recruitment, and confounding with long-term changes in recruitment, due to environmental effects not included in the model that affect spawning stock size. The base case assessment assumes that there is no relationship between stock size and recruitment. This assumption is the same as that used in the previous assessments. The influence of a Beverton-Holt stock-recruitment relationship is investigated in a sensitivity analysis.

It is assumed that yellowfin can be recruited to the fishable population during every quarter of the year. Hennemuth (1961) reported that there are two peaks of spawning of yellowfin in the EPO, but it is assumed in this study that recruitment may occur more than twice per year because individual fish can spawn almost every day if the water temperatures are in the appropriate range (Schaefer 1998).

An assumption is made about the way that recruitment can vary around its expected level, as determined from the stock-recruitment relationship. This assumption is used to penalize the temporal recruitment deviates. It is assumed that the logarithm of the quarterly recruitment deviates is normally distributed with a standard deviation of 0.6.

Yellowfin are assumed to be recruited to the discard fisheries in the EPO at about 33 cm (about 2 quarters old) (Section 3.1.1). At this size (age), the fish are vulnerable to capture by fisheries that catch fish in association with floating objects (*i.e.* they are recruited to Fisheries 13-16).

The spawning potential of the population is estimated from the numbers of fish, proportion of females, percentage of females that are mature, batch fecundity, and spawning frequency (Schaefer 1998). These quantities (except numbers) are estimated for each age class, based on the mean length at age given by the Richards growth equation fitted to the otolith data of Wild (1986). Maunder and Watters (2002) describe the method, but using the von Bertalanffy growth curve. These quantities were re-estimated when investigating sensitivity to different growth curves. The spawning potential of the population is used in the stock-recruitment relationship and to determine the spawning biomass ratios (ratios of spawning biomass to that for the unfished stock, SBRs). The relative fecundity at age and the sex ratio at age are shown in Figures 3.2 and 3.3, respectively.

3.1.3. Movement

The evidence of yellowfin movement within the EPO is summarized by Maunder and Watters (2001) and new research is contained in Schaefer *et al.* (2007). Schaefer *et al.* (2007) found that movements of yellowfin tuna released off southern Baja California, including those at liberty in excess of one year, are geographically confined. Therefore, the level of mixing between this area and others in the EPO should be expected to be very low. This result is consistent with the results of various tagging studies (conventional and archival) of tropical tunas throughout the Pacific. This indicates that fishery-wide controls of effort or catch will most likely be ineffective to prevent localized depletions of these stocks (Schaefer *et al.* 2007). For the purposes of the current assessment, it is assumed that movement does not affect the stock assessment results. However, given the results of Schaefer *et al.* (2007), investigation of finer spatial scale or separate sub-stocks should be considered.

3.1.4. Natural mortality

For the current stock assessment, it is assumed that, as yellowfin grow older, the natural mortality rate (*M*) changes. This assumption is similar to that made in previous assessments, for which the natural mortality rate was assumed to increase for females after they reached the age of 30 months (*e.g.* Anonymous 1999: 38). Males and females are not treated separately in the current stock assessment, and *M* is treated as a rate for males and females combined. The values of quarterly *M* used in the current stock assessment are plotted in Figure 3.4. These values were estimated by making the assumptions described above, fitting to sex ratio at length data (Schaefer 1998), and comparing the values with those estimated for yellowfin in the western and central Pacific Ocean (Hampton 2000; Hampton and Fournier 2001). Maunder and Watters (2001) describe in detail how the age-specific natural mortality schedule for yellowfin in the EPO is estimated.

3.1.5. Stock structure

The exchange of yellowfin between the EPO and the central and western Pacific has been studied by examination of data on tagging, morphometric characters, catches per unit of effort, sizes of fish caught, *etc.* (Suzuki *et al.* 1978), and it appears that the mixing of fish between the EPO and the areas to the west of it is not extensive. Therefore, for the purposes of the current stock assessment, it is assumed that there is a single stock, with little or no mixing with the stock(s) of the western and central Pacific.

3.2. Environmental influences

Recruitment of yellowfin in the EPO has tended to be greater after El Niño events (Joseph and Miller 1989). Previous stock assessments have included the assumption that oceanographic conditions might influence recruitment of yellowfin in the EPO (Maunder and Watters 2001, 2002; see Maunder and

Watters 2003b for a description of the methodology). This assumption is supported by observations that spawning of yellowfin is temperature dependent (Schaefer 1998). To incorporate the possibility of an environmental influence on recruitment of yellowfin in the EPO, a temperature variable was incorporated into previous stock assessment models to determine whether there is a statistically-significant relationship between this temperature variable and estimates of recruitment. Previous assessments (Maunder and Watters 2001, 2002) showed that estimates of recruitment were essentially identical with or without the inclusion of the environmental data. Maunder (2002a) correlated recruitment with the environmental time series outside the stock assessment model. For candidate variables, Maunder (2002) used the sea-surface temperature (SST) in an area consisting of two rectangles from 20°N-10°S and 100°W-150°W and 10°N-10°S and 85°W-100°W, the total number of 1°x1° areas with average SST≥24°C, and the Southern Oscillation Index. The data were related to recruitment, adjusted to the period of hatching. However, no relationship with these variables was found. No investigation using environmental variables was carried out in this assessment.

In previous assessments it has also been assumed that oceanographic conditions might influence the efficiency of the various fisheries described in Section 2.1 (Maunder and Watters 2001, 2002). It is widely recognized that oceanographic conditions influence the behavior of fishing gear, and several different environmental indices have been investigated. However, only SST for the southern longline fishery was found to be significant. Therefore, because of the use of standardized longline CPUE, environmental effects on catchability were not investigated in this assessment.

4. STOCK ASSESSMENT

A-SCALA, an age-structured statistical catch-at-length analysis model (Maunder and Watters 2003a), and information contained in catch, effort, size-composition, and biological data are used to assess the status of yellowfin in the EPO. The A-SCALA model is based on the method described by Fournier *et al.* (1998). The term "statistical" indicates that the model implicitly recognizes the fact that data collected from fisheries do not perfectly represent the population; there is uncertainty in our knowledge about the dynamics of the system and about how the observed data relate to the real population. The model uses quarterly time steps to describe the population dynamics. The parameters of the model are estimated by comparing the predicted catches and size compositions to data collected from the fishery. After these parameters have been estimated, the model is used to estimate quantities that are useful for managing the stock.

The A-SCALA method was first used to assess yellowfin in the EPO in 2000 (Maunder and Watters, 2001), and was modified and used for subsequent assessments. The following parameters have been estimated for the current stock assessment of yellowfin in the EPO:

1. recruitment to the fishery in every quarter from the first quarter of 1975 through the first quarter of 2008;
2. quarterly catchability coefficients for the 16 fisheries that take yellowfin from the EPO;
3. selectivity curves for 12 of the 16 fisheries (Fisheries 13-16 have an assumed selectivity curve);
4. initial population size and age-structure;
5. mean length at age (Figure 3.1);
6. parameters of a linear model relating the standard deviations in length at age to the mean lengths at age.

The values of the following parameters are assumed to be known for the current stock assessment of yellowfin in the EPO:

1. fecundity of females at age (Figure 3.2);
2. sex ratio at age (Figure 3.3);
3. natural mortality at age (Figure 3.4);

4. selectivity curves for the discard fisheries (Fisheries 13-16);
5. steepness of the stock-recruitment relationship (steepness = 1 for the base case assessment).

Yield and catchability estimates for estimations of the average maximum sustainable yield (MSY) or future projections were based on estimates of quarterly fishing mortality for 2005 to 2007. Sensitivity of estimates of key management quantities to this assumption was tested.

There is uncertainty in the results of the current stock assessment. This uncertainty arises because the observed data do not perfectly represent the population of yellowfin in the EPO. Also, the stock assessment model may not perfectly represent the dynamics of the yellowfin population nor of the fisheries that operate in the EPO. Uncertainty is expressed as approximate confidence intervals and coefficients of variation (CVs). The confidence intervals and CVs have been estimated under the assumption that the stock assessment model perfectly represents the dynamics of the system. Since it is unlikely that this assumption is satisfied, these values may underestimate the amount of uncertainty in the results of the current assessment.

4.1. Indices of abundance

CPUEs have been used as indices of abundance in previous assessments of yellowfin in the EPO (*e.g.* Anonymous 1999). It is important to note, however, that trends in the CPUE will not always follow trends in the biomass or abundance. There are many reasons why this could be the case. For example, if, due to changes in technology or targeting, a fishery became more or less efficient at catching yellowfin while the biomass was not changing, the CPUEs would increase or decrease despite the lack of trend in biomass. Fisheries may also show hyper- or hypo-stability, in which the relationship between CPUE and abundance is non-linear (Hilborn and Walters 1992; Maunder and Punt 2004). The CPUEs of the 16 fisheries defined for the current assessment of yellowfin in the EPO are shown in Figure 4.1. Trends in longline CPUE are based only on the Japanese data. As mentioned in Section 2.2.2, CPUE for the longline fisheries was standardized using general linear modeling. Discussions of historical catch rates can be found in Maunder and Watters (2001, 2002), Maunder (2002a), Maunder and Harley (2004, 2005), and Hoyle and Maunder (2006a), but trends in CPUE should be interpreted with caution. Trends in estimated biomass are discussed in Section 4.2.3.

4.2. Assessment results

Below we describe important aspects of the base case assessment (1 below) and changes for the sensitivity analyses (2 below):

1. Base case assessment: steepness of the stock-recruitment relationship equals 1 (no relationship between stock and recruitment), species-composition estimates of surface fishery catches scaled back to 1975, delta-lognormal general linear model standardized CPUE, and assumed sample sizes for the length-frequency data.
2. Sensitivity to the steepness of the stock-recruitment relationship. The base case assessment included an assumption that recruitment was independent of stock size, and a Beverton-Holt stock-recruitment relationship with a steepness of 0.75 was used for the sensitivity analysis.

The results of the base case assessment are described in the text, and the stock-recruitment relationship sensitivity analysis is described in the text, with figures and tables presented in Appendix A1.

The A-SCALA method provides a reasonably good fit to the catch and size-composition data for the 16 fisheries that catch yellowfin in the EPO. The assessment model is constrained to fit the time series of catches made by each fishery almost perfectly. The 16 predicted time series of yellowfin catches are almost identical to those plotted in Figure 2.2. It is important to predict the catch data closely, because it is difficult to estimate biomass if reliable estimates of the total amount of fish removed from the stock are not available.

It is also important to predict the size-composition data as accurately as possible, but, in practice, it is more difficult to predict the size composition than to predict the total catch. Accurately predicting the size composition of the catch is important because these data contain most of the information necessary for modeling recruitment and growth, and thus for estimating the impact of fishing on the stock. A description of the size distribution of the catch for each fishery is given in Section 2.3. Predictions of the size compositions of yellowfin caught by Fisheries 1-12 are summarized in Figure 4.2, which simultaneously illustrates the average observed and predicted size compositions of the catches for these 12 fisheries. (Size-composition data are not available for discarded fish, so Fisheries 13-16 are not included in this discussion.) The predicted size compositions for all of the fisheries with size-composition data are good, although the predicted size compositions for some fisheries have lower peaks than the observed size compositions (Figure 4.2). The model also tends to over-predict larger yellowfin in some fisheries. However, the fit to the length-frequency data for individual time periods shows much more variation (Figure 4.8).

The results presented in the following section are likely to change in future assessments because (1) future data may provide evidence contrary to these results, and (2) the assumptions and constraints used in the assessment model may change. Future changes are most likely to affect estimates of the biomass and recruitment in recent years.

4.2.1. Fishing mortality

There is variation in fishing mortality exerted by the fisheries that catch yellowfin in the EPO, with fishing mortality being higher before 1984, during the lower productivity regime (Figure 4.3a), and since 2003. Fishing mortality changes with age (Figure 4.3b). The fishing mortalities for younger and older yellowfin are low. There is a peak at around ages of 14-15 quarters, which corresponds to peaks in the selectivity curves for fisheries on unassociated and dolphin-associated yellowfin (Figures 4.3b and 4.4). The fishing mortality of young fish has not greatly increased in spite of the increase in effort associated with floating objects that has occurred since 1993 (Figure 4.3b).

The fishing mortality rates vary over time because the amount of effort exerted by each fishery changes over time, because different fisheries catch yellowfin of different ages (the effect of selectivity), and because the efficiencies of various fisheries change over time (the effect of catchability). The first effect (changes in effort) was addressed in Section 2.2.1 (also see Figure 2.3); the latter two effects are discussed in the following paragraphs.

Selectivity curves estimated for the 16 fisheries defined in the stock assessment of yellowfin are shown in Figure 4.4. Purse-seine sets on floating objects select mostly yellowfin that are about 4 to 14 quarters old (Figure 4.4, Fisheries 1-4). Purse-seine sets on unassociated schools of yellowfin select fish similar in size to those caught by sets on floating objects (about 5 to 15 quarters old, Figure 4.4, Fisheries 5 and 6), but these catches contain greater proportions of fish from the upper portion of this range. Purse-seine sets on yellowfin associated with dolphins in the northern and coastal regions select mainly fish 7 to 15 quarters old (Figure 4.4, Fisheries 7 and 8). The dolphin-associated fishery in the south selects mainly yellowfin 12 or more quarters old (Figure 4.4, Fishery 9). Longline fisheries for yellowfin also select mainly older individuals about 12 or more quarters old (Figure 4.4, Fisheries 11 and 12). Pole-and-line gear selects yellowfin about 4 to 8 quarters old (Figure 4.4, Fishery 10).

Discards resulting from sorting purse-seine catches of yellowfin taken in association with floating objects are assumed to be composed only of fish recruited to the fishery for three quarters or less (age 2-4 quarters, Figure 4.4, Fisheries 13-16). (Additional information regarding the treatment of discards is given in Section 2.2.3.)

The ability of purse-seine vessels to capture yellowfin in association with floating objects has generally declined over time (Figure 4.5a, Fisheries 1-4). These fisheries have also shown high temporal variation in catchability. Changes in fishing technology and behavior of the fishermen may have decreased the catchability of yellowfin during this time.

The ability of purse-seine vessels to capture yellowfin in unassociated schools has also been highly variable over time (Figure 4.5a, Fisheries 5 and 6).

The ability of purse-seine vessels to capture yellowfin in dolphin-associated sets has been less variable in the northern and coastal areas than in the other fisheries (Figure 4.5a, Fisheries 7 and 8). The catchability in the southern fishery (Fishery 9) is more variable. All three dolphin-associated fisheries have had greater-than-average catchability during most of 2001-2005. However, catchability was estimated to decrease during 2006 and 2007.

The ability of pole-and-line gear to capture yellowfin has been highly variable over time (Figure 4.5a, Fishery 10). There have been multiple periods of high and low catchability.

The ability of longline vessels to capture yellowfin has been more variable in the northern fishery (Fishery 11), which catches fewer yellowfin, than in the southern fishery (Fishery 12). Catchability in the northern fishery has been very low since the late 1990s.

The catchabilities of small yellowfin by the discard fisheries (Fisheries 13-16) are shown in Figure 4.5b.

In previous assessments catchability for the southern longline fishery has shown a highly significant correlation with SST (Maunder and Watters 2002). Despite its significance, the correlation between SST and catchability in that fishery did not appear to be a good predictor of catchability (Maunder and Watters 2002), and therefore it is not included in this assessment.

4.2.2. Recruitment

In a previous assessment, the abundance of yellowfin recruited to fisheries in the EPO appeared to be correlated to SST anomalies at the time that these fish were hatched (Maunder and Watters 2001). However, inclusion of a seasonal component in recruitment explained most of the variation that could be explained by SST (Maunder and Watters 2002). No environmental time series was investigated for this assessment.

Over the range of predicted biomasses shown in Figure 4.9, the abundance of yellowfin recruits appears to be related to the relative potential egg production at the time of spawning (Figure 4.6). The apparent relationship between biomass and recruitment is due to an apparent regime shift in productivity (Tomlinson 2001). The increased productivity caused an increase in recruitment, which, in turn, increased the biomass. Therefore, in the long term, above-average recruitment is related to above-average biomass and below-average recruitment to below-average biomass.

A sensitivity analysis was carried out, fixing the Beverton-Holt (1957) steepness parameter at 0.75 (Appendix A). This means that recruitment is 75% of the recruitment from an unexploited population when the population is reduced to 20% of its unexploited level. Given the information currently available, the hypothesis of two regimes in recruitment is as plausible as an effect of population size on recruitment. The results when a stock-recruitment relationship is used are described in Section 4.5.

The estimated time series of yellowfin recruitment is shown in Figure 4.7, and the estimated annual total recruitment in Table 4.1. The large recruitment that entered the discard fisheries in the third quarter of 1998 (6 months old) was estimated to be the strongest cohort of the 1975-2003 period. A sustained period of high recruitment was estimated for mid-1999 until the end of 2000. A large recruitment is estimated for 2007, but there is considerable uncertainty in the estimate. The assessment model has shown a tendency to overestimate recent recruitment strengths in the last few assessments.

Another characteristic of the recruitment, which was also apparent in previous assessments, is the regime change in the recruitment levels, starting during the second quarter of 1983. The recruitment was, on average, consistently greater after 1983 than before. This change in recruitment levels produces a similar change in biomass (Figure 4.9a). There is an indication that the recruitments in five recent years (2002-

2006) were at low levels, similar to those prior to 1983, perhaps indicating a change back to a low productivity regime.

The confidence intervals for recruitment are relatively narrow, indicating that the estimates are fairly precise, except for that of the most recent year (Figure 4.7). The standard deviation of the estimated recruitment deviations (on the logarithmic scale) is 0.60, which is equal to the 0.6 assumed in the penalty applied to the recruitment deviates. The estimates of uncertainty are surprisingly small, considering the inability of the model to fit modes in the length-frequency data (Figure 4.8). These modes often appear, disappear, and then reappear.

The estimates of the most recent recruitments are highly uncertain, as can be seen from the large confidence intervals (Figure 4.7). In addition, the floating-object fisheries, which catch the youngest fish, account for only a small portion of the total catch of yellowfin.

4.2.3. Biomass

Biomass is defined as the total weight of yellowfin that are 1.5 or more years old. The trends in the biomass of yellowfin in the EPO are shown in Figure 4.9a, and estimates of the biomass at the beginning of each year in Table 4.1. Between 1975 and 1983 the biomass of yellowfin declined to about 250,000 metric tons (t); it then increased rapidly during 1983-1986, and reached about 540,000 t in 1986. During 1986-1999 it remained relatively constant at about 450,000-550,000 t; it then peaked in 2001 and subsequently declined to levels similar to those prior to 1984. The confidence intervals for the biomass estimates are relatively narrow, indicating that the biomass is well estimated.

The spawning biomass is defined as the relative total egg production of all the fish in the population. The estimated trend in spawning biomass is shown in Figure 4.9b, and estimates of the spawning biomass at the beginning of each year in Table 4.1. The spawning biomass has generally followed a trend similar to that for biomass, described in the previous paragraph. The confidence intervals on the spawning biomass estimates indicate that it is also well estimated.

It appears that trends in the biomass of yellowfin can be explained by the trends in fishing mortality and recruitment. Simulation analysis is used to illustrate the influence of fishing and recruitment on the biomass trends (Maunder and Watters, 2001). The simulated biomass trajectories with and without fishing are shown in Figure 4.10a. The large difference in the two trajectories indicates that fishing has a major impact on the biomass of yellowfin in the EPO. The large increase in biomass during 1983-1984 was caused initially by an increase in average size (Anonymous 1999), followed by an increase in average recruitment (Figure 4.7), but increased fishing pressure prevented the biomass from increasing further during the 1986-1990 period.

The impact of each major type of fishery on the yellowfin stock is shown in Figures 4.10b and 4.10c. The estimates of biomass in the absence of fishing were computed as above, and then the biomass trajectory was estimated by setting the effort for each fisheries group, in turn, to zero. The biomass impact for each fishery group at each time step is derived as this biomass trajectory minus the biomass trajectory with all fisheries active. When the impacts of individual fisheries calculated by this method are summed, they are greater than the combined impact calculated when all fisheries are active. Therefore, the impacts are scaled so that the sum of the individual impacts equals the impact estimated when all fisheries are active. These impacts are plotted as a proportion of unfished biomass (Figure 4.10b) and in absolute biomass (Figure 4.10c).

4.2.4. Average weights of fish in the catch

The overall average weights of the yellowfin caught in the EPO predicted by the analysis have been consistently around 12 to 22 kg for most of the 1975-2007 period, but have differed considerably among fisheries (Figures 4.11). The average weight was high during the 1985-1992 period, when the effort for the floating-object and unassociated fisheries was less (Figure 2.3). The average weight was also high in

1975-1977 and in 2001-2004. The average weight of yellowfin caught by the different gears varies widely, but remains fairly consistent over time within each fishery (Figure 4.11). The lowest average weights (about 1 kg) are produced by the discard fisheries, followed by the pole-and-line fishery (about 4-5 kg), the floating-object fisheries (about 5-10 kg for Fishery 3, 10 kg for Fisheries 2 and 4, and 10-15 kg for Fishery 1), the unassociated fisheries (about 15 kg), the northern and coastal dolphin-associated fisheries (about 20-30 kg), and the southern dolphin-associated fishery and the longline fisheries (each about 40-50 kg).

4.3. Comparisons to external data sources

No external data were used as a comparison in the current assessment.

4.4. Diagnostics

We present diagnostics in three sections: (1) residual plots, (2) parameter correlations, and (3) retrospective analysis.

4.4.1. Residual plots

Residual plots show the differences between the observations and the model predictions. The residuals should show characteristics similar to the assumptions used in the model. For example, if the likelihood function is based on a normal distribution and assumes a standard deviation of 0.2, the residuals should be normally distributed with a standard deviation of about 0.2.

The estimated annual effort deviations, which are one type of residual in the assessment and represent temporal changes in catchability, are shown plotted against time in Figure 4.5a. These residuals are assumed to be normally distributed (the residual is exponentiated before multiplying by the effort so the distribution is actually lognormal) with a mean of zero and a given standard deviation. A trend in the residuals indicates that the assumption that CPUE is proportional to abundance is violated. The assessment assumes that the southern longline fishery (Fishery 12) provides the most reasonable information about abundance (standard deviation (sd) = 0.2) while the dolphin-associated and unassociated fisheries have less information (sd = 0.3), the floating-object, the pole-and-line fisheries, and the northern longline fishery have the least information (sd = 0.4), and the discard fisheries have no information (sd = 2). Therefore, a trend is less likely in the southern longline fishery (Fishery 12) than in the other fisheries. The trends in effort deviations are estimates of the trends in catchability (see Section 4.2.1). Figure 4.5a shows no overall trend in the southern longline fishery effort deviations, but there are some consecutive residuals that are all above or all below the average. The standard deviations of the residuals are greater than those assumed. These results indicate that the assessment gives more weight to the CPUE information than it should. The effort residuals for the floating-object fisheries have a declining trend over time, while the effort residuals for the northern and coastal dolphin-associated fisheries have slight increasing trends over time. These trends may be related to true trends in catchability.

The observed proportion of fish caught in a length class is assumed to be normally distributed around the predicted proportion, with the standard deviation equal to the binomial variance, based on the observed proportions, divided by the square of the sample size (Maunder and Watters 2003a). Previous analyses have indicated that the length-frequency residuals appear to be less than the assumed standard deviation .

4.4.2. Parameter correlation

Often quantities, such as recent estimates of recruitment deviates and fishing mortality, can be highly correlated. This information indicates a flat solution surface, which implies that alternative states of nature had similar likelihoods.

There is negative correlation between the current estimated effort deviates for each fishery and estimated recruitment deviates lagged to represent cohorts entering each fishery. The negative correlation is most obvious for the discard fisheries. Earlier effort deviates are positively correlated with these recruitment deviates.

Current spawning biomass is positively correlated with recruitment deviates lagged to represent cohorts entering the spawning biomass population. This correlation is greater than for earlier spawning biomass estimates. Similar correlations are seen for recruitment and spawning biomass.

4.4.3. Retrospective analysis

Retrospective analysis is a useful method to determine how consistent a stock assessment method is from one year to the next. Inconsistencies can often highlight inadequacies in the stock assessment method. The estimated biomass and SBR (defined in Section 3.1.2) from the previous assessment and the current assessment are shown in Figure 4.12a and 4.12b. However, data differ between these assessments, so differences may be expected (see Section 4.6). Retrospective analyses are usually carried out by repeatedly eliminating one year of data from the analysis while using the same stock assessment method and assumptions. This allows the analyst to determine the change in estimated quantities as more data are included in the model. Estimates for the most recent years are often uncertain and biased. Retrospective analysis and the assumption that more data improves the estimates can be used to determine if there are consistent biases in the estimates. Retrospective analysis carried out by Maunder and Harley (2004) suggested that the peak in biomass in 2001 had been consistently underestimated, but the 2005 assessment estimated a slightly lower peak in 2001. The assessment model has shown a tendency to overestimate recent recruitment strengths in the last few assessments, indicating a possible retrospective pattern in recruitment estimates.

4.5. Sensitivity to assumptions

Sensitivity analyses were carried out to investigate the incorporation of a Beverton-Holt (1957) stock-recruitment relationship (Appendix A1).

The base case analysis assumed no stock-recruitment relationship, and an alternative analysis was carried out with the steepness of the Beverton-Holt stock-recruitment relationship fixed at 0.75. This implies that when the population is reduced to 20% of its unexploited level, the expected recruitment is 75% of the recruitment from an unexploited population. As in previous assessments, (Maunder and Watters 2002, Hoyle and Maunder 2006a) the analysis with a stock-recruitment relationship fits the data better than the analysis without the stock-recruitment relationship. However, the regime shift could also explain the result, since the period of high recruitment is associated with high spawning biomass, and vice versa. When a Beverton-Holt stock-recruitment relationship (steepness = 0.75) is included, the estimated biomass (Figure A1.1) and recruitment (Figure A1.2) are almost identical to those of the base case assessment.

Several other sensitivity analyses have been carried out in previous assessments of yellowfin tuna. Increasing the sample size for the length frequencies based on iterative re-weighting to determine the effective sample size gave similar results, but narrower confidence intervals (Maunder and Harley 2004). The use of cannery and landings data to determine the surface fishery catch and different size of the selectivity smoothness penalties (if set at realistic values) gave similar results (Maunder and Harley 2004). The results were not sensitive to the value for the asymptotic length parameter of the Richards growth curve or to the link function used in the general linear model (GLM) standardization of the longline effort data (Hoyle and Maunder 2007).

4.6. Comparison to previous assessments

The estimated biomass and SBR trajectories are similar to those from the previous assessment presented by Maunder (2007) (Figure 4.12). These results are also similar to those obtained using cohort analysis (Maunder 2002b). This indicates that estimates of absolute biomass are robust to the assumptions that have been changed as the assessment procedure has been updated. The estimate of the recent biomass is lower in the current assessment.

4.7. Summary of the results from the assessment model

In general, the recruitment of yellowfin to the fisheries in the EPO is variable, with a seasonal component. This analysis and previous analyses have indicated that the yellowfin population has experienced two, or possibly three, different productivity regimes (1975-1983, 1984-2000, and 2001-2006). The productivity regimes correspond to regimes in biomass, higher-productivity regimes producing greater biomass levels. A stock-recruitment relationship is also supported by the data from these regimes, but the evidence is weak, and is probably an artifact of the apparent regime shifts. The analysis indicates that strong cohorts entered the fishery during 1998-2000, and that these cohorts increased the biomass during 1999-2000. However, these cohorts have now moved through the population, so the biomass decreased during 2001-2007. The biomass in 2005-2008 was at levels similar to those prior to 1985.

The average weights of yellowfin taken from the fishery have been fairly consistent over time, but vary substantially among the different fisheries (Figure 4.11). In general, the floating-object (Fisheries 1-4), unassociated (Fisheries 5 and 6), and pole-and-line (Fishery 10) fisheries capture younger, smaller yellowfin than do the dolphin-associated (Fisheries 7-9) and longline (Fisheries 11 and 12) fisheries. The longline fisheries and the dolphin-associated fishery in the southern region (Fishery 9) capture older, larger yellowfin than do the northern (Fishery 7) and coastal (Fishery 8) dolphin-associated fisheries.

Significant levels of fishing mortality have been estimated for the yellowfin fishery in the EPO. These levels are highest for middle-aged yellowfin. Most of the yellowfin catch is taken in schools associated with dolphins, and, accordingly, this method has the greatest impact on the yellowfin population, although it has almost the least impact per unit of weight captured of all fishing methods.

5. STATUS OF THE STOCK

The status of the stock of yellowfin in the EPO is assessed by considering calculations based on the spawning biomass, yield per recruit, and MSY.

Precautionary reference points, as described in the FAO Code of Conduct for Responsible Fisheries and the United Nations Fish Stocks Agreement, are being widely developed as guides for fisheries management. The IATTC has not adopted any target or limit reference points for the stocks that it manages, but some possible reference points are described in the following subsections. Possible candidates for reference points are:

1. S_{MSY}, the spawning biomass corresponding to the MSY;
2. F_{MSY}, the fishing mortality corresponding to the MSY;
3. S_{min}, the minimum spawning biomass seen in the modeling period.

Maintaining tuna stocks at levels that will permit the MSY is the management objective specified by the IATTC Convention. The S_{min} reference point is based on the observation that the population has recovered from this population size in the past (*e.g.* the levels estimated in 1983). A technical meeting on reference points was held in La Jolla, California, USA, in October 2003. The outcome from this meeting was (1) a set of general recommendations on the use of reference points and research and (2) specific recommendations for the IATTC stock assessments. Several of the recommendations have been included in this assessment. Development of reference points that are consistent with the precautionary approach to fisheries management will continue.

5.1. Assessment of stock status based on spawning biomass

The spawning biomass ratio, SBR, defined in Section 3.1.2, is useful for assessing the status of a stock. The SBR has been used to define reference points in many fisheries. Various studies (*e.g.* Clark 1991, Francis 1993, Thompson 1993, Mace 1994) suggest that some fish populations can produce the MSY when the SBR is in the range of about 0.3 to 0.5, and that some fish populations are not able to produce the MSY if the spawning biomass during a period of exploitation is less than about 0.2. Unfortunately, the types of population dynamics that characterize tuna populations have generally not been considered in these studies, and their conclusions are sensitive to assumptions about the relationship between adult biomass and recruitment, natural mortality, and growth rates. In the absence of simulation studies that are designed specifically to determine appropriate SBR-based reference points for tunas, estimates of SBR_t can be compared to an estimate of SBR for a population that is producing the MSY ($SBR_{MSY} = S_{MSY}/S_{F=0}$).

Estimates of quarterly SBR_t for yellowfin in the EPO have been computed for every quarter represented in the stock assessment model (the first quarter of 1975 to the second quarter of 2007). Estimates of the spawning biomass during the period of harvest (S_t) are discussed in Section 4.2.3 and presented in Figure 4.9b. The equilibrium spawning biomass after a long period with no harvest ($S_{F=0}$) was estimated by assuming that recruitment occurs at an average level expected from an unexploited population. SBR_{MSY} is estimated to be about 0.34.

At the beginning of 2008 the spawning biomass of yellowfin in the EPO had increased relative to 2006, which was probably its lowest level since 1983. The estimate of SBR at the beginning of 2008 was about 0.36, with lower and upper 95% confidence limits of 0.29 and 0.43, respectively (Figure 5.1a). The current assessment's estimate of SBR_{MSY} (0.34) is similar to the previous assessment (Figure 4.12b).

In general, the SBR estimates for yellowfin in the EPO are reasonably precise. The relatively narrow confidence intervals around the SBR estimates suggest that for most quarters during 1985-2003 the spawning biomass of yellowfin in the EPO was greater than S_{MSY} (see Section 5.3). This level is shown as the dashed horizontal line drawn at 0.34 in Figure 5.1a. For most of the early period (1975-1984) and the most recent period (2005-2007), however, the spawning biomass was estimated to be less than S_{MSY}. The spawning biomass at the start of 2008 is estimated to be above the level corresponding to MSY.

5.2. Assessment of stock status based on MSY

MSY is defined as the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions. MSY calculations are described by Maunder and Watters (2001). The calculations differ from those of Maunder and Watters (2001) in that the present calculations include the Beverton-Holt (1957) stock-recruitment relationship when applicable. To calculate MSY, the current fishing mortality rate is scaled so that it maximizes the catch. The value *F* multiplier scales the "current" fishing mortality, which is taken as the average over 2005-2007. The value *F*scale uses the fishing mortality in the year of interest. Therefore, *F*scale for the most recent year may not be the same as the *F* multiplier.

At the beginning of 2008, the biomass of yellowfin in the EPO appears to have been above the level corresponding to the MSY, and the recent catches have been substantially below the MSY level (Table 5.1).

If the fishing mortality is proportional to the fishing effort, and the current patterns of age-specific selectivity (Figure 4.4) are maintained, the current (average of 2005-2007) level of fishing effort is below that estimated to produce the MSY. The effort at MSY is 113% of the current level of effort. Due to reduced fishing mortality in 2007, repeating the calculations based on a fishing mortality averaged over 2005-2006 indicates that current effort would have to be increased by 6% to reach effort at MSY. It is important to note that the curve relating the average sustainable yield to the long-term fishing mortality (Figure 5.2, upper panel) is very flat around the MSY level. Therefore, changes in the long-term levels of effort will only marginally change the long-term catches, while considerably changing the biomass. The spawning stock biomass changes substantially with changes in the long-term fishing mortality (Figure 5.2, lower panel). Decreasing the effort would increase CPUE and thus might also reduce the cost of fishing. Reducing fishing mortality below the level at MSY would provide only a marginal decrease in the long-term average yield, with the benefit of a relatively large increase in the spawning biomass.

The apparent regime shift in productivity that began in 1984 suggests alternative approaches to estimating the MSY, as different regimes will give rise to different values for the MSY (Maunder and Watters 2001).

The estimation of the MSY, and its associated quantities, is sensitive to the age-specific pattern of selectivity that is used in the calculations. To illustrate how MSY might change if the effort is reallocated among the various fisheries (other than the discard fisheries) that catch yellowfin in the EPO, the previously-described calculations were repeated, using the age-specific selectivity pattern estimated for groups of fisheries. If the management objective is to maximize the MSY, the age-specific selectivity of the longline fisheries will perform the best, followed by that of the dolphin-associated fisheries, the unassociated fisheries, and finally the floating-object fisheries (Table 5.2a). If an additional management objective is to maximize the S_{MSY}, the order is the same. The age-specific selectivity of the purse-seine fisheries alone gives slightly less than the current MSY (Table 5.2c). It is not plausible, however, that the longline fisheries, which would produce the greatest MSYs, would be efficient enough to catch the full MSYs predicted. On its own, the effort by the purse-seine fishery for dolphin-associated yellowfin would have to doubled to achieve the MSY.

If it is assumed that all fisheries but one are operating, and that each fishery maintains its current pattern of age-specific selectivity, the MSY would be increased by removing the floating-object or unassociated fisheries, and reduced by removing the dolphin-associated or longline fisheries (Table 5.2b). If it is assumed that all fisheries are operating, but either the purse-seine or the longline fisheries are adjusted to obtain MSY, the purse-seine fisheries would have to be increased by 7%, or the longline fisheries 37-fold. If it is also assumed that there is a stock-recruitment relationship, the MSY would be achieved with lower effort levels (Table 5.2c).

MSY and S_{MSY} have been very stable during the modeled period (Figure 4.12c). This suggests that the overall pattern of selectivity has not varied a great deal through time. The overall level of fishing effort, however, has varied with respect to *F*scale.

The historical status of the population with respect to both the SBR and fishing mortality reference points is shown in Figure 5.1b. The fishing mortality has generally been below that corresponding to the MSY, except for the period before 1984 and during 2003-2005 (Figure 4.12c).

5.3. Summary of stock status

Historically, the SBR of yellowfin in the EPO was below the level corresponding to the MSY during the lower productivity regime of 1975-1983 (Section 4.2.1), but above that level for most of the following years, except for the recent period (2003-2007). The 1984 increase in the SBR is attributed to the regime change, and the recent decrease may be a reversion to an intermediate productivity regime. The two different productivity regimes may support two different MSY levels and associated SBR levels. The SBR at the start of 2008 is estimated to be above the level corresponding to the MSY. The effort levels are estimated to be less than those that would support the MSY (based on the current distribution of effort among the different fisheries), but recent catches are substantially below MSY.

If a stock-recruitment relationship is assumed, the outlook is more pessimistic, and current biomass is estimated to be below the level corresponding to the MSY.

The current average weight of yellowfin in the catch is much less than the critical weight. The MSY calculations indicate that, theoretically, at least, catches could be increased if the fishing effort were directed toward longlining and purse-seine sets on yellowfin associated with dolphins. This would also increase the SBR levels.

The MSY has been stable during the assessment period, which suggests that the overall pattern of selectivity has not varied a great deal through time. However, the overall level of fishing effort has varied with respect to the MSY multiplier.

6. SIMULATED EFFECTS OF FUTURE FISHING OPERATIONS

A simulation study was conducted to gain further understanding as to how, in the future, hypothetical changes in the amount of fishing effort exerted by the surface fleet might simultaneously affect the stock of yellowfin in the EPO and the catches of yellowfin by the various fisheries. Several scenarios were constructed to define how the various fisheries that take yellowfin in the EPO would operate in the future, and also to define the future dynamics of the yellowfin stock. The assumptions that underlie these scenarios are outlined in Sections 6.1 and 6.2.

A method based on the normal approximation to the likelihood profile (Maunder *et al.* 2006) , which considers both parameter uncertainty and uncertainty about future recruitment, has been applied. A substantial part of the total uncertainty in predicting future events is caused by uncertainty in the estimates of the model parameters and current status, so this should be considered in any forward projections. Unfortunately, the appropriate methods are often not applicable to models as large and computationally-intense as the yellowfin stock assessment model. Therefore, we have used a normal approximation to the likelihood profile that allows for the inclusion of both parameter uncertainty and uncertainty about future recruitment. This method is implemented by extending the assessment model an additional 5 years with effort data equal to that assumed for the projection period (see below). No catch or length-frequency data are included for these years. The recruitments for the five years are estimated as in the assessment model with a lognormal penalty with a standard deviation of 0.6. Normal approximations to the likelihood profile are generated for SBR, surface catch, and longline catch.

6.1. Assumptions about fishing operations

6.1.1. Fishing effort

Several future projection studies were carried out to investigate the influence of different levels of fishing effort on the biomass and catch. The projected fishing mortality was based on the quarterly averages during 2005-2007.

The scenarios investigated were:

1. Quarterly fishing mortality for each year in the future equal to the quarterly average for 2005-2007, which reflects the reduced effort due to the conservation measures of Resolutions C-04-09 and C-06-02;
2. Quarterly fishing mortality for each year in the future and for 2004-2007 was set equal to the fishing mortality in scenario 1, adjusted for the effect of the conservation measures. For the adjustment, the fishing mortality for the purse-seine fishery in the fourth quarter was increased by 85%, and that for the southern longline fishery by 39%.

6.2. Results of the simulation

The simulations were used to predict future levels of the SBR, total biomass, the total catch taken by the primary surface fisheries, which would presumably continue to operate in the EPO (Fisheries 1-10), and the total catch taken by the longline fleet (Fisheries 11 and 12). There is probably more uncertainty in the future levels of these outcome variables than is suggested by the results presented in Figures 6.1-6.5. The amount of uncertainty is probably underestimated because the simulations were conducted under the assumption that the stock assessment model accurately describe the dynamics of the system, and because no account is taken for variation in catchability.

These simulations were carried out using the average recruitment for the 1975-2007 period. If they had been carried out using the average recruitment for the 1984-2001 period, the projected trend in SBR and catches would have been more positive. Conversely, if they had been carried out with the average recruitment for the 2002-2006 period, the projected trend in SBR and catches would have been more negative.

6.2.1. Current effort levels

Under current levels of fishing mortality (2005-2007), the biomass is predicted to increase and then decrease, but remain above the current level (Figure 6.1), and the SBR is predicted to follow a similar trend. The SBR is predicted to remain above the level corresponding to the MSY (Figure 6.2). However, the confidence intervals are wide, and there is a moderate probability that the SBR will be substantially above or below this level. It is predicted that the surface catches will increase, while the longline catches will remain about the same (Figure 6.3).

6.2.2. No management restrictions

Resolutions C-04-09 and C-06-02 called for restrictions on purse-seine effort and longline catches for 2004-2007: a 6-week closure during the third or fourth quarter of the year for purse-seine fisheries, and longline catches not to exceed 2001 levels. To assess the utility of these management actions, we projected the population forward five years, assuming that these conservation measures had not been implemented.

Comparison of the biomass and SBR predicted with and without the restrictions from the resolutions show some difference (Figures 6.4 and 6.5). The simulations suggest that, without the restrictions, biomass and SBR would have declined to slightly lower levels than seen at present, and would decline to about the level corresponding to MSY.

6.3. Summary of the simulation results

Under current levels of effort fishing mortality, the biomass is predicted to increase, and then decrease, but remain above the current level, and the SBR is predicted to follow a similar trend. The SBR is predicted to remain above the level corresponding to the MSY. A comparison of the biomass and SBR predicted with and without the restrictions from Resolutions C-04-09 and C-06-02 suggests that, without the restrictions, they would be at lower levels than those seen at present, and would decline to about the level corresponding to MSY.

These simulations were carried out using the average recruitment for the 1975-2007 period. If they had been carried out using the average recruitment for the 1983-2001 period, the projected trend in SBR and catches would have been more positive. Conversely, if they had been carried out using the average recruitment for the 2002-2006 period, the projected trend in SBR and catches would have been more negative.

7. FUTURE DIRECTIONS

7.1. Collection of new and updated information

The IATTC staff intends to continue its collection of catch, effort, and size-composition data for the fisheries that catch yellowfin in the EPO. New and updated data will be incorporated into the next stock assessment.

7.2. Refinements to the assessment model and methods

The IATTC staff is considering changing to the *Stock Synthesis II* (SS2) general model (developed by Richard Methot at the U.S. National Marine Fisheries Service) for its stock assessments, based on the outcome of the workshop on stock assessment methods held in November 2005. Preliminary assessments for yellowfin and bigeye tuna were conducted in SS2 and presented at a workshop on management strategies held in November 2006. The current bigeye assessment was conducted using SS2, and the IATTC staff intends to conduct the next yellowfin assessment using SS2, once the growth curve in SS2 is made flexible enough to model the growth of yellowfin appropriately .

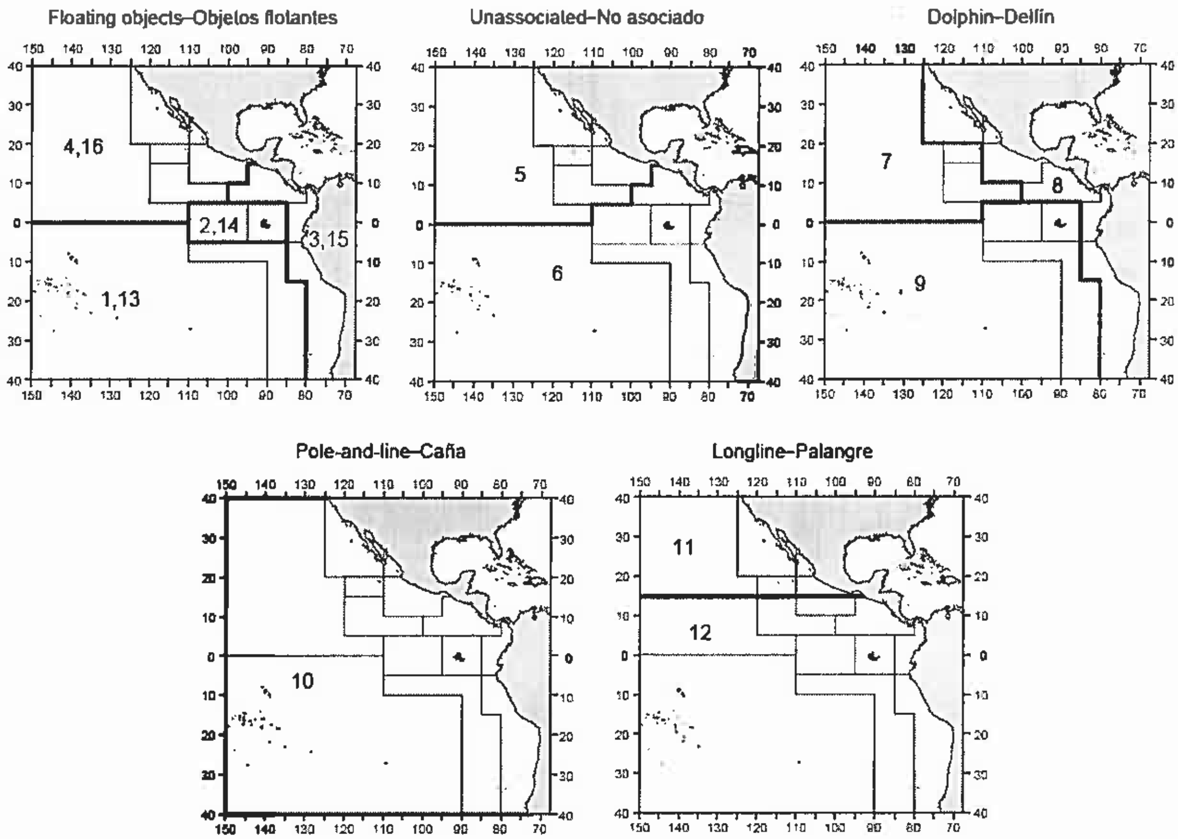


FIGURE 2.1. Spatial extents of the fisheries defined by the IATTC staff for the stock assessment of yellowfin tuna in the EPO. The thin lines indicate the boundaries of 13 length-frequency sampling areas, the bold lines the boundaries of each fishery defined for the stock assessment, and the bold numbers the fisheries to which the latter boundaries apply. The fisheries are described in Table 2.1.

FIGURA 2.1. Extensión espacial de las pesquerías definidas por el personal de la CIAT para la evaluación del atún aleta amarilla en el OPO. Las líneas delgadas indican los límites de 13 zonas de muestreo de frecuencia de tallas, las líneas gruesas los límites de cada pesquería definida para la evaluación del stock, y los números en negritas las pesquerías correspondientes a estos últimos límites. En la Tabla 2.1 se describen las pesquerías.

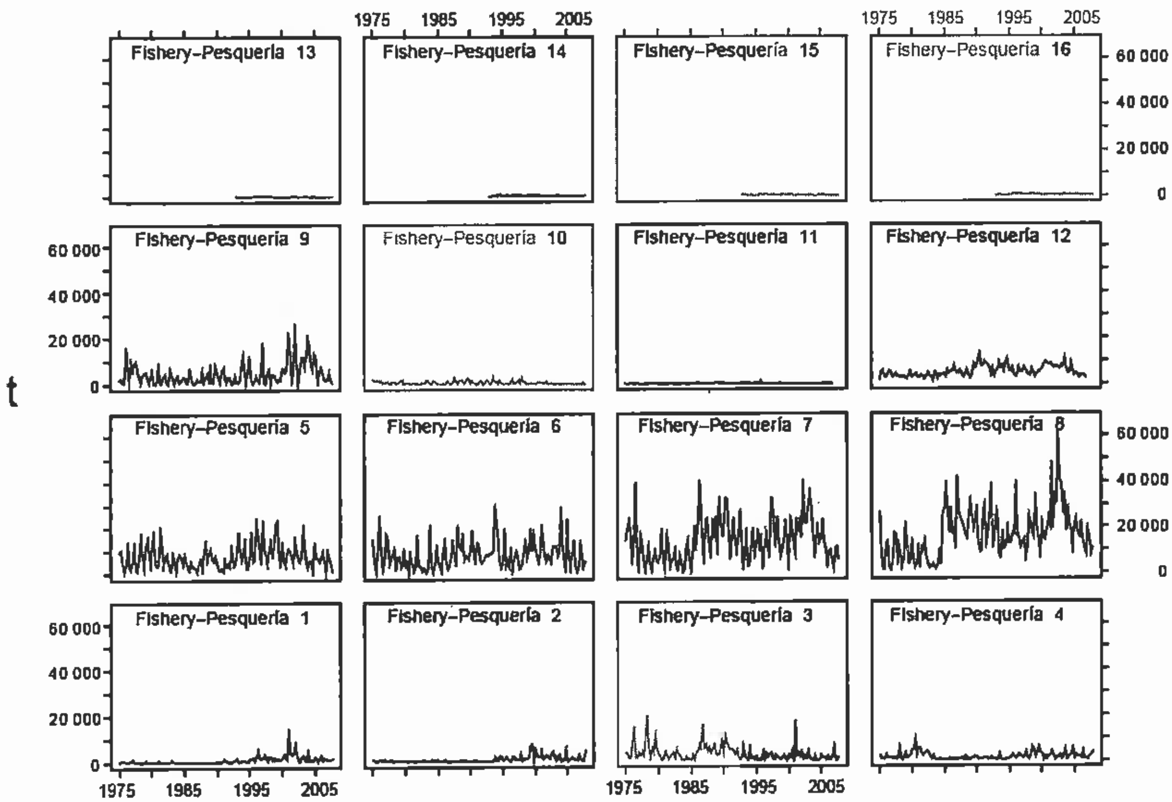


FIGURE 2.2. Catches by the fisheries defined for the stock assessment of yellowfin tuna in the EPO (Table 2.1). Since the data were analyzed on a quarterly basis, there are four observations of catch for each year. Although all the catches are displayed as weights, the stock assessment model uses catches in numbers of fish for Fisheries 11 and 12. Catches in weight for Fisheries 11 and 12 are estimated by multiplying the catches in numbers of fish by estimates of the average weights. t = metric tons.

FIGURA 2.2. Capturas de las pesquerías definidas para la evaluación del stock de atún aleta amarilla en el OPO (Tabla 2.1). Ya que se analizaron los datos por trimestre, hay cuatro observaciones de captura para cada año. Se expresan todas las capturas en peso, pero el modelo de evaluación del stock usa captura en número de peces para las Pesquerías 11 y 12. Se estiman las capturas de las Pesquerías 11 y 12 en peso multiplicando las capturas en número de peces por estimaciones del peso promedio. t = toneladas métricas.

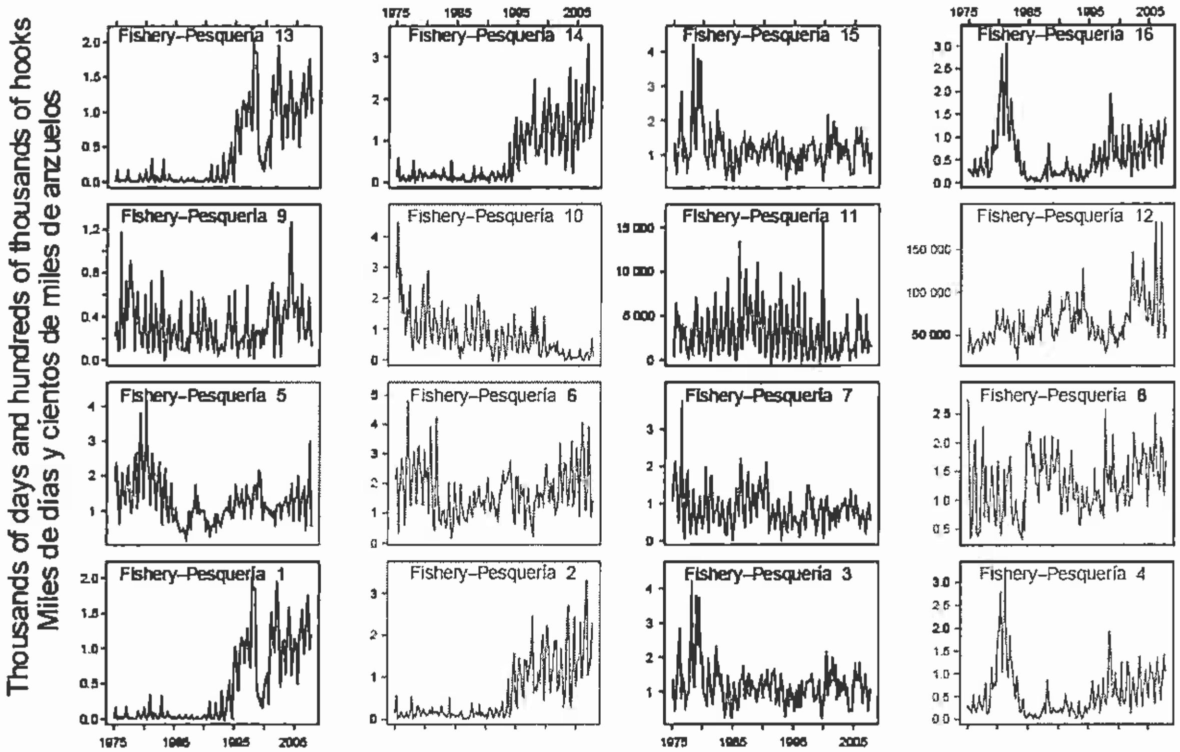


FIGURE 2.3. Fishing effort exerted by the fisheries defined for the stock assessment of yellowfin tuna in the EPO (Table 2.1). Since the data were summarized on a quarterly basis, there are four observations of effort for each year. The effort for Fisheries 1-10 and 13-16 is in days fished, and that for Fisheries 11 and 12 is in standardized numbers of hooks. Note that the vertical scales of the panels are different.

FIGURA 2.3. Esfuerzo de pesca ejercido por las pesquerías definidas para la evaluación del stock de atún aleta amarilla en el OPO (Tabla 2.1). Ya que se analizaron los datos por trimestre, hay cuatro observaciones de esfuerzo para cada año. Se expresa el esfuerzo de las Pesquerías 1-10 y 13-16 en días de pesca, y el de las Pesquerías 11 y 12 en número estandardizado de anzuelos. Nótese que las escalas verticales de los recuadros son diferentes.

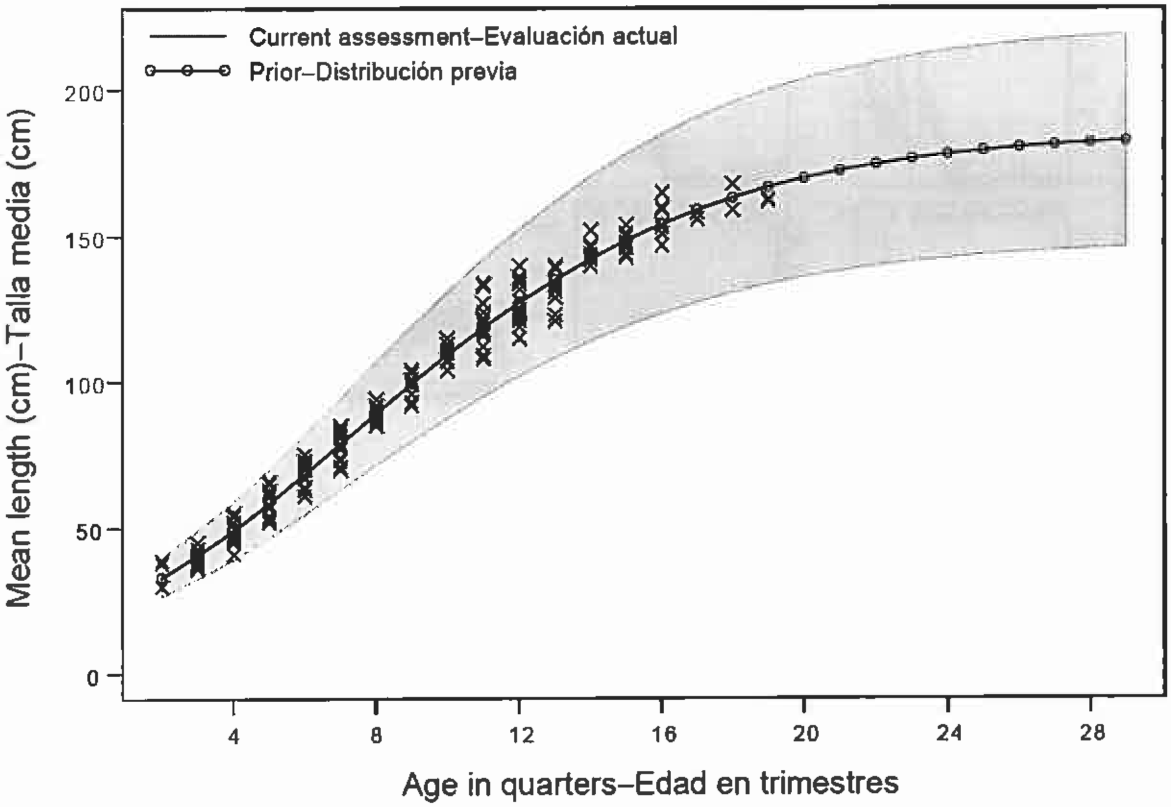


FIGURE 3.1. Growth curve estimated for the assessment of yellowfin tuna in the EPO (solid line). The connected points represent the mean length-at-age prior used in the assessment. The crosses represent length-at-age data from otoliths (Wild 1986). The shaded region represents the variation in length at age (± 2 standard deviations).

FIGURA 3.1. Curva de crecimiento usada para la evaluación del atún aleta amarilla en el OPO (línea sólida). Los puntos conectados representan la distribución previa (*prior*) de la talla por edad usada en la evaluación. Las cruces representan datos de otolitos de talla por edad (Wild 1986). La región sombreada representa la variación de la talla por edad (± 2 desviaciones estándar).

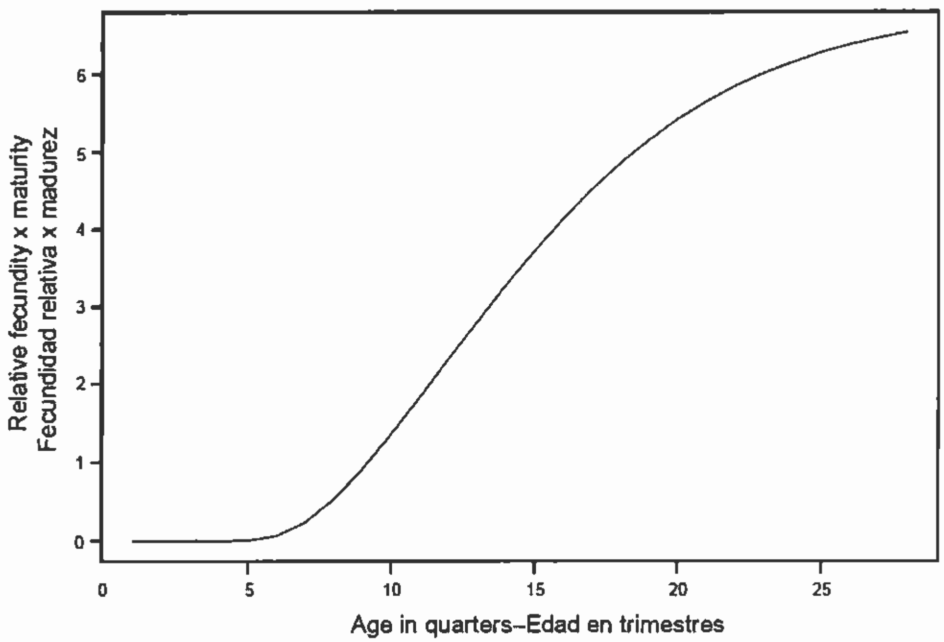


FIGURE 3.2. Relative fecundity-at-age curve (from Schaefer 1998) used to estimate the spawning biomass of yellowfin tuna in the EPO.
FIGURA 3.2. Curva de madurez relativa por edad (de Schaefer 1998) usada para estimar la biomasa reproductora del atún aleta amarilla en el OPO.

FIGURE 3.3. Sex ratio curve (from Schaefer 1998) used to estimate the spawning biomass of yellowfin tuna in the EPO.
FIGURA 3.3. Curva de proporciones de sexos (de Schaefer 1998) usada para estimar la biomasa reproductora de atún aleta amarilla en el OPO.

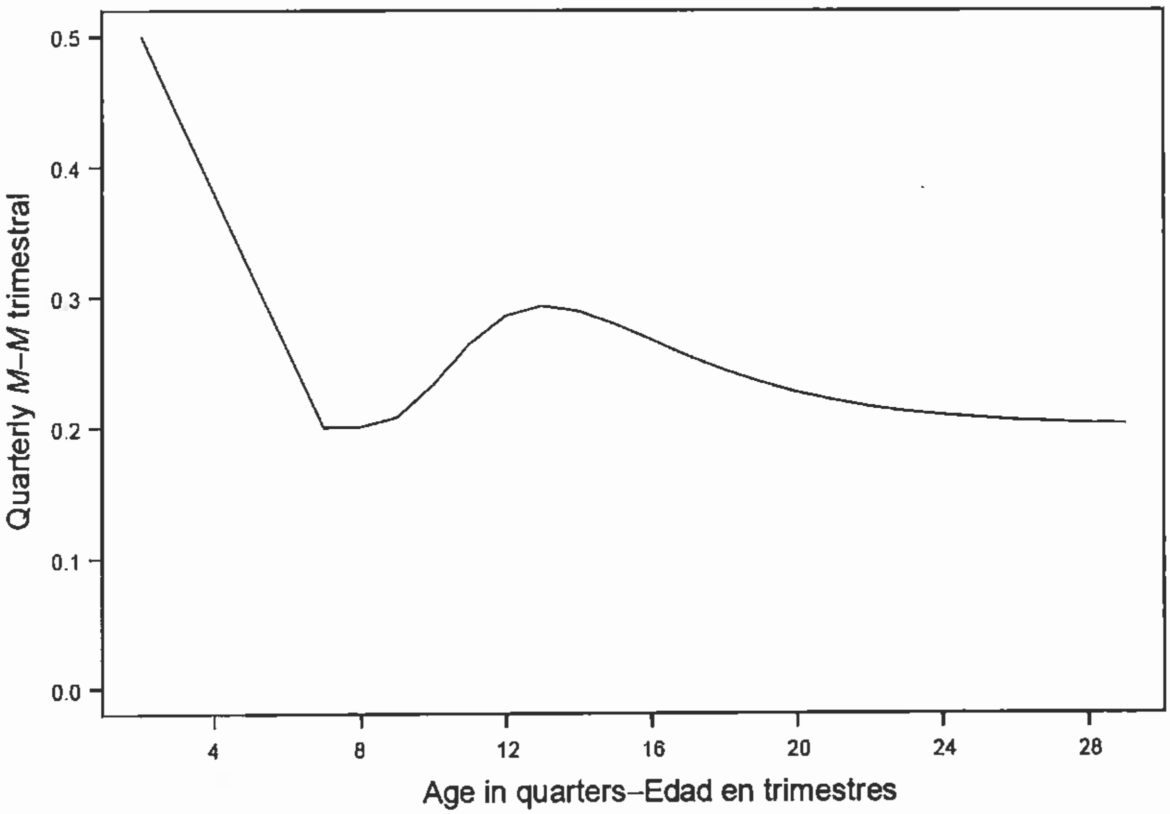


FIGURE 3.4. Natural mortality (*M*) rates, at quarterly intervals, used for the assessment of yellowfin tuna in the EPO. Descriptions of the three phases of the mortality curve are provided in Section 3.1.4.
FIGURA 3.4. Tasas de mortalidad natural (*M*), a intervalos trimestrales, usadas para la evaluación del atún aleta amarilla en el OPO. En la Sección 3.1.4 se describen las tres fases de la curva de mortalidad.

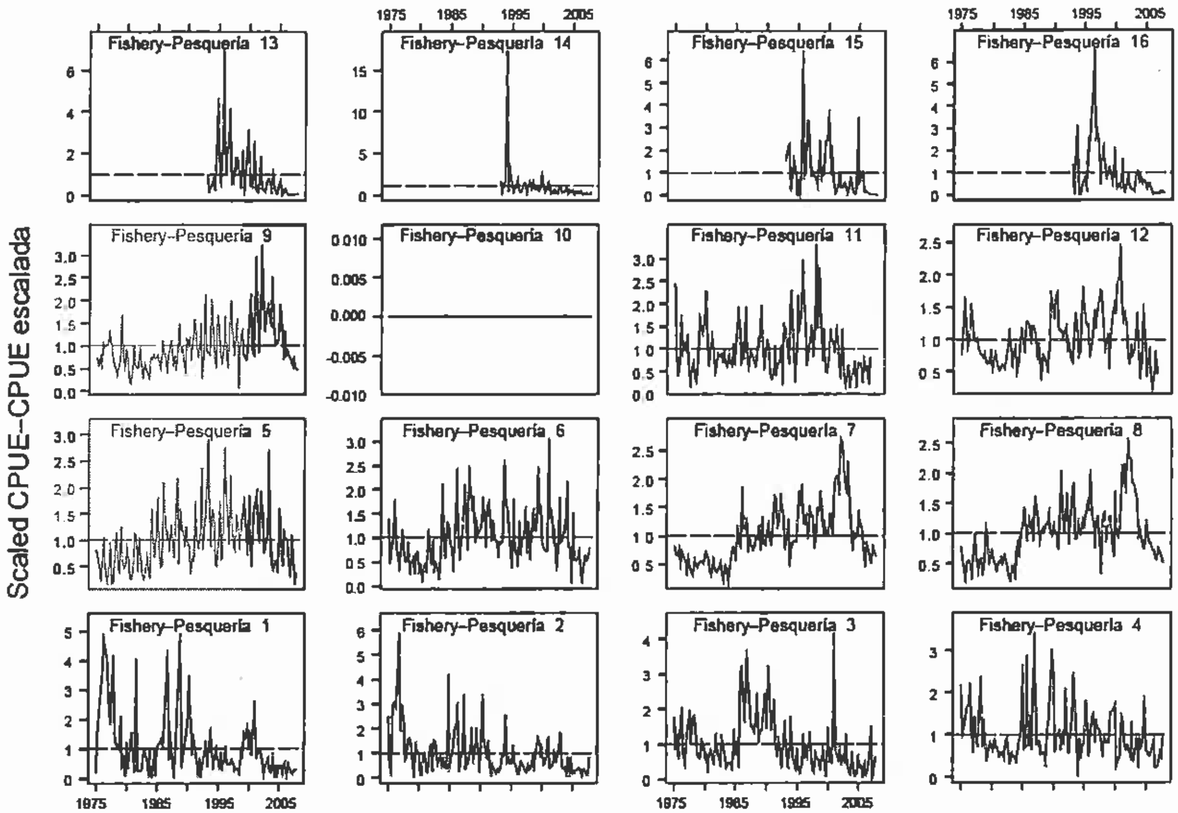


FIGURE 4.1. CPUEs for the fisheries defined for the stock assessment of yellowfin tuna in the EPO (Table 2.1). Since the data were summarized on a quarterly basis, there are four observations of CPUE for each year. The CPUEs for Fisheries 1-10 and 13-16 are in kilograms per day fished, and those for Fisheries 11 and 12 are standardized units based on numbers of hooks. The data are adjusted so that the mean of each time series is equal to 1.0. Note that the vertical scales of the panels are different.

FIGURA 4.1. CPUE de las pesquerías definidas para la evaluación de la población de atún aleta amarilla en el OPO (Tabla 2.1). Ya que se resumieron los datos por trimestre, hay cuatro observaciones de CPUE para cada año. Se expresan las CPUE de las Pesquerías 1-10 y 13-16 en kilogramos por día de pesca, y las de las Pesquerías 11 y 12 en unidades estandarizadas basadas en número de anzuelos. Se ajustaron los datos para que el promedio de cada serie de tiempo equivalga a 1,0. Nótese que las escalas verticales de los recuadros son diferentes.

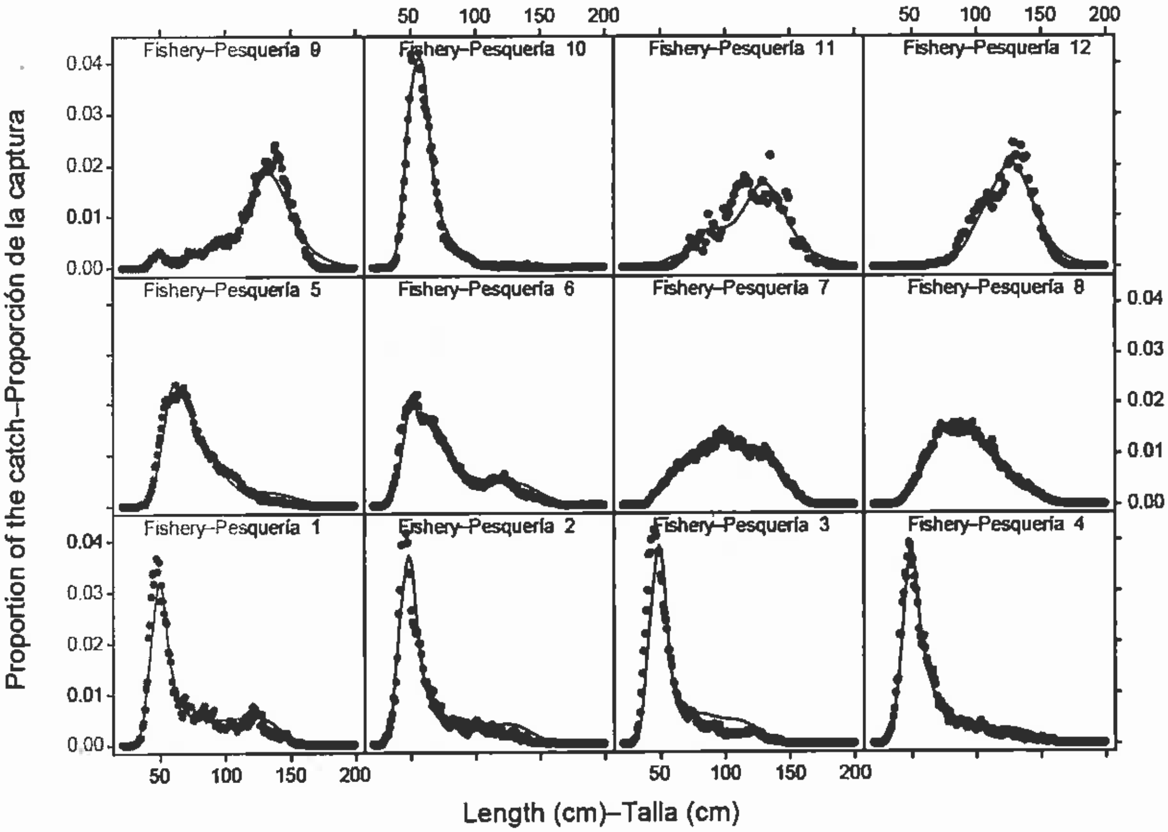


FIGURE 4.2. Average observed (dots) and predicted (curves) size compositions of the catches taken by the fisheries defined for the stock assessment of yellowfin tuna in the EPO.

FIGURA 4.2. Composición media por tamaño observada (puntos) y predicha (curvas) de las capturas realizadas por las pesquerías definidas para la evaluación de la población de atún aleta amarilla en el OPO.

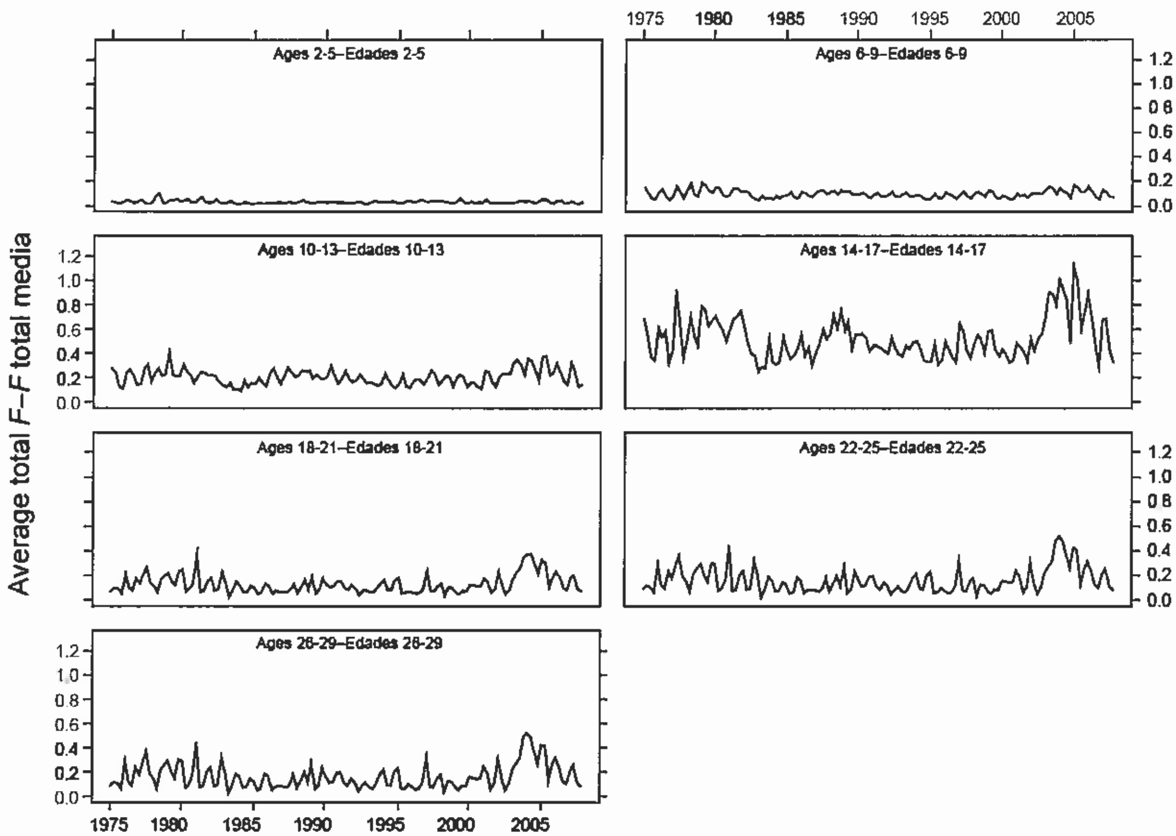


FIGURE 4.3a. Average quarterly fishing mortality (*F*) at age, by all gears, of yellowfin tuna recruited to the fisheries of the EPO. Each panel illustrates an average of four quarterly fishing mortality vectors that affected the fish within the range of ages indicated in the title of each panel. For example, the trend illustrated in the upper-left panel is an average of the fishing mortalities that affected the fish that were 2-5 quarters old.

FIGURA 4.3a. Mortalidad por pesca (*F*) trimestral media por edad, por todas las artes, de atún aleta amarilla reclutado a las pesquerías del OPO. Cada recuadro ilustra un promedio de cuatro vectores trimestrales de mortalidad por pesca que afectaron los peces de la edad indicada en el título de cada recuadro. Por ejemplo, la tendencia ilustrada en el recuadro superior izquierdo es un promedio de las mortalidades por pesca que afectaron a los peces de entre 2 y 5 trimestres de edad.

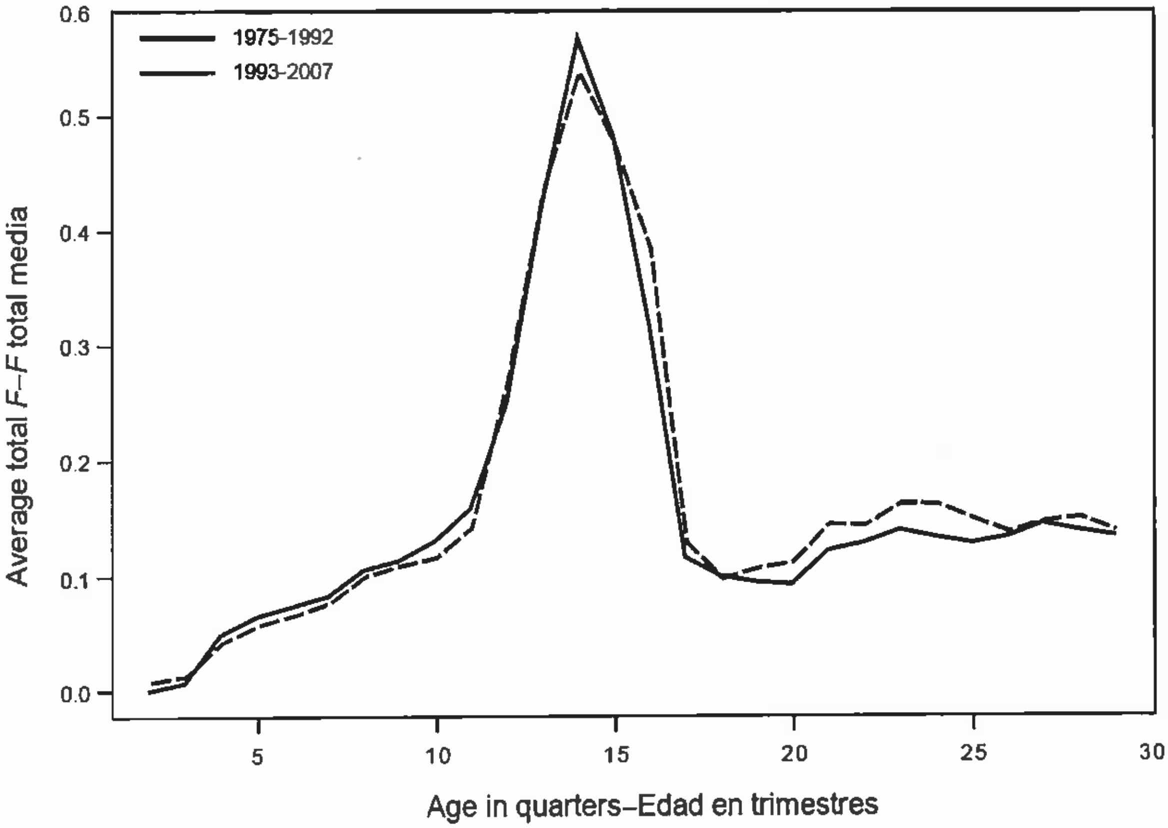


FIGURE 4.3b. Average quarterly fishing mortality (*F*) of yellowfin tuna by age in the EPO, by all gears. The estimates are presented for two periods, before and after the increase in effort associated with floating objects.

FIGURA 4.3b. Mortalidad por pesca (*F*) trimestral media de atún aleta amarilla por edad en el OPO, por todas las artes. Se presentan estimaciones para dos periodos, antes y después del aumento del esfuerzo asociado con objetos flotantes.

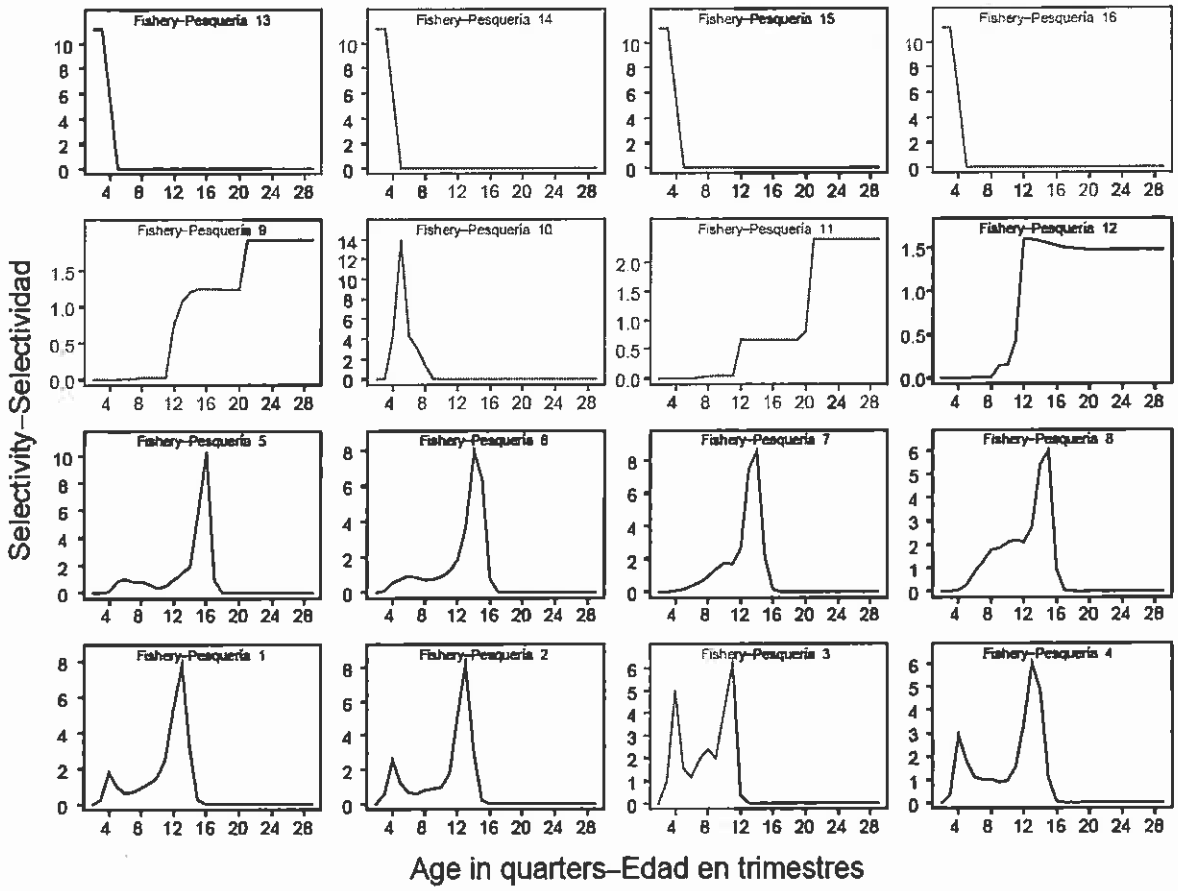


FIGURE 4.4. Selectivity curves for the 16 fisheries that take yellowfin tuna in the EPO. The curves for Fisheries 1-12 were estimated with the A-SCALA method, and those for Fisheries 13-16 are based on assumptions. Note that the vertical scales of the panels are different.

FIGURA 4.4. Curvas de selectividad para las 16 pesquerías que capturan atún aleta amarilla en el OPO. Se estimaron las curvas de las Pesquerías 1-12 con el método A-SCALA, y las de la Pesquerías 13-16 se basan en supuestos. Nótese que las escalas verticales de los recuadros son diferentes.

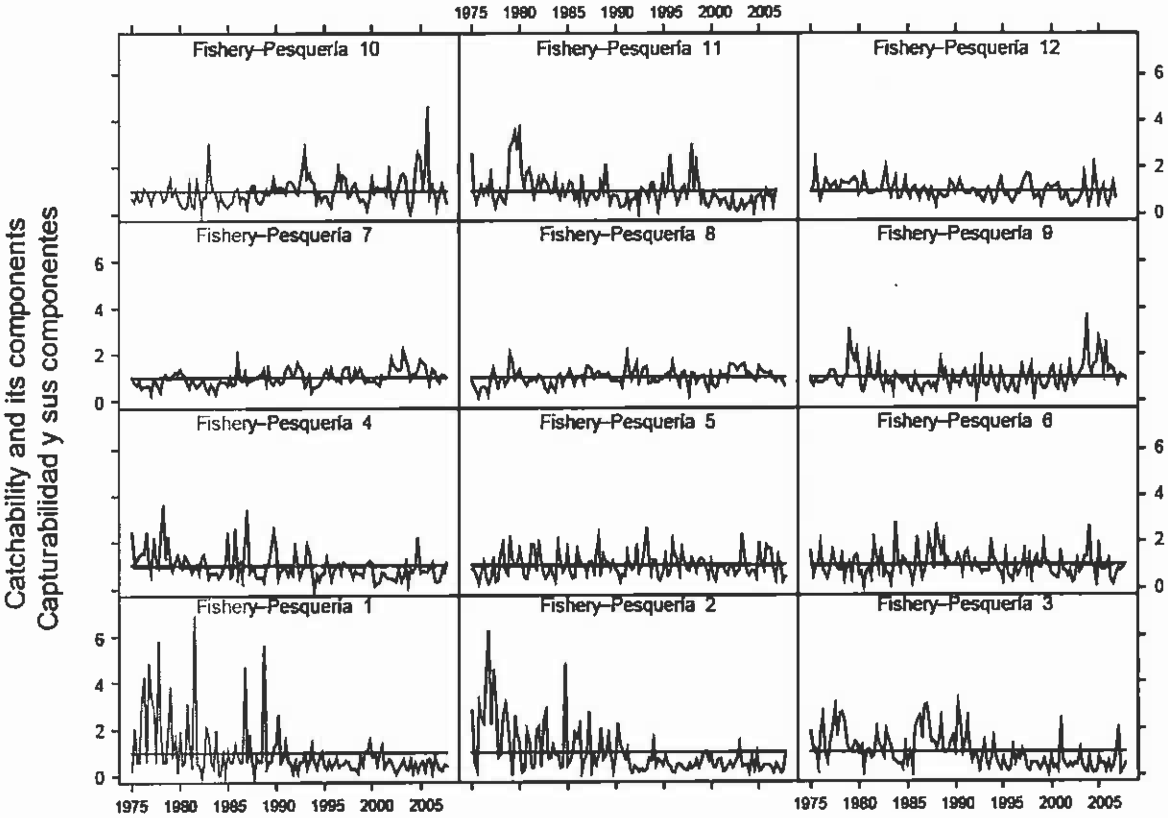


FIGURE 4.5a. Trends in catchability (q) for the 12 retention fisheries that take yellowfin tuna in the EPO. The estimates are scaled to average 1.
FIGURA 4.5a. Tendencias de la capturabilidad (q) en las 12 pesquerías de retención que capturan atún aleta amarilla en el OPO. Se escalan las estimaciones a un promedio de 1.

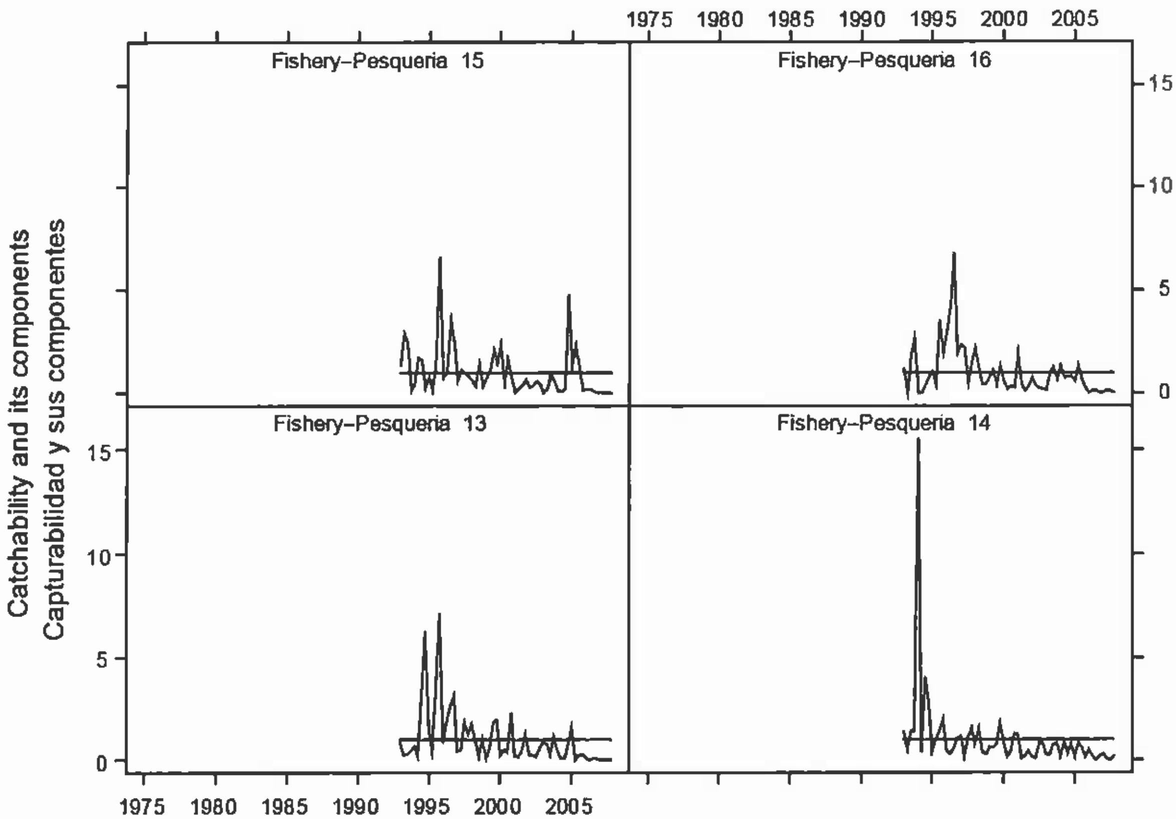


FIGURE 4.5b. Trends in catchability (q) for the four discard fisheries that take yellowfin tuna in the EPO. The estimates are scaled to average 1.

FIGURA 4.5b. Tendencias de la capturabilidad (q) en las cuatro pesquerías de descarte que capturan atún aleta amarilla en el OPO. Se escalan las estimaciones a un promedio de 1.

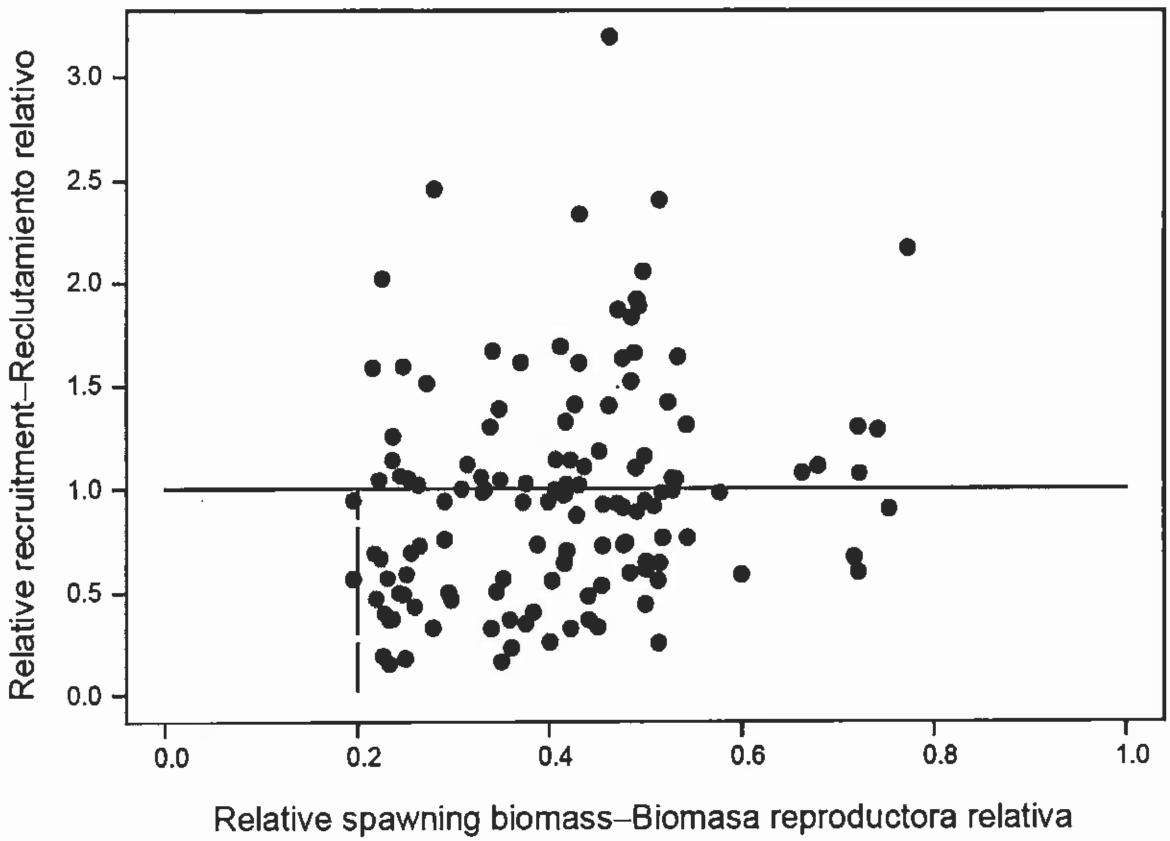


FIGURE 4.6. Estimated relationship between recruitment of yellowfin tuna and spawning biomass. The recruitment is scaled so that the average recruitment is equal to 1.0. The spawning biomass is scaled so that the average unexploited spawning biomass is equal to 1.0.

FIGURA 4.6. Relación estimada entre el reclutamiento y la biomasa reproductora del atún aleta amarilla. Se escala el reclutamiento para que el reclutamiento medio equivalga a 1,0, y la biomasa reproductora para que la biomasa reproductora media no explotada equivalga a 1,0.

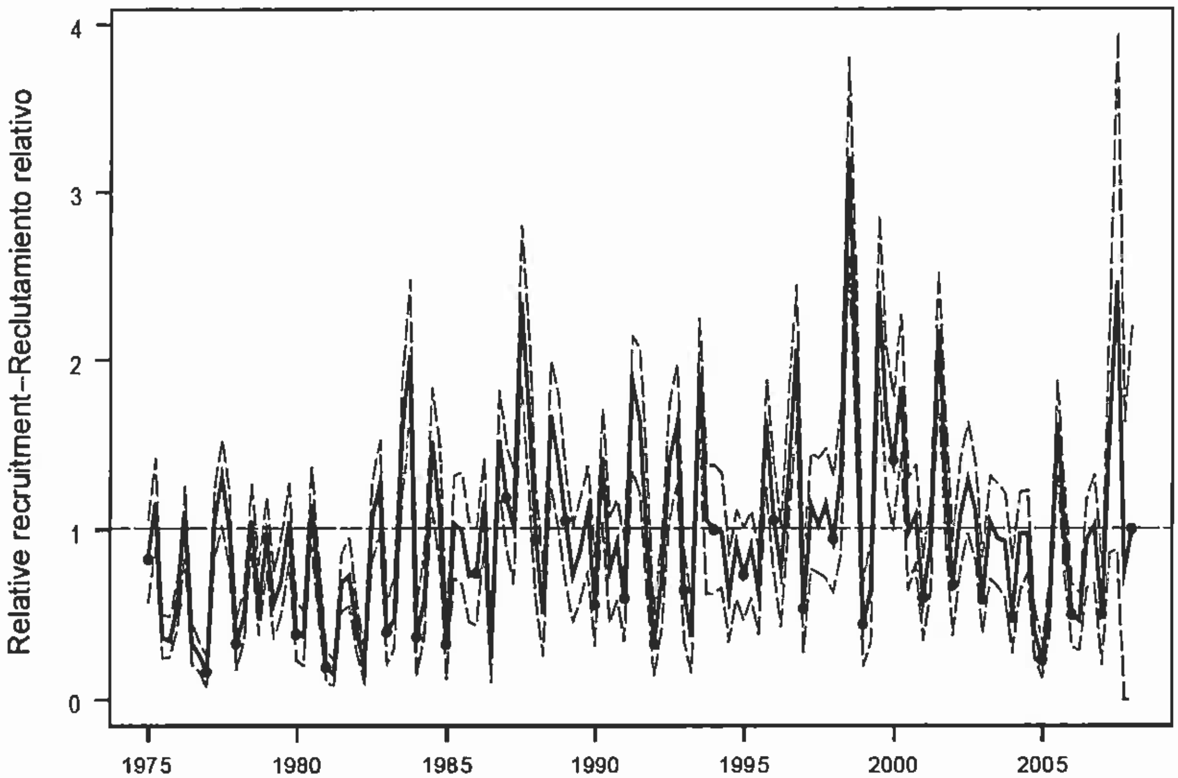


FIGURE 4.7. Estimated recruitment of yellowfin tuna to the fisheries of the EPO. The estimates are scaled so that the average recruitment is equal to 1.0. The bold line illustrates the maximum likelihood estimates of recruitment, and the shaded area indicates the approximate 95% confidence intervals 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.

FIGURA 4.7. Reclutamiento estimado de atún aleta amarilla a las pesquerías del OPO. Se escalan las estimaciones para que el reclutamiento medio equivalga a 1,0. La línea gruesa ilustra las estimaciones de verosimilitud máxima del reclutamiento, y el área sombreada los intervalos de confianza de 95% aproximados de esas estimaciones. Se dibujan las leyendas en el eje de tiempo al principio de cada año, pero, ya que el modelo de evaluación representa el tiempo por trimestres, hay cuatro estimaciones de reclutamiento para cada año.

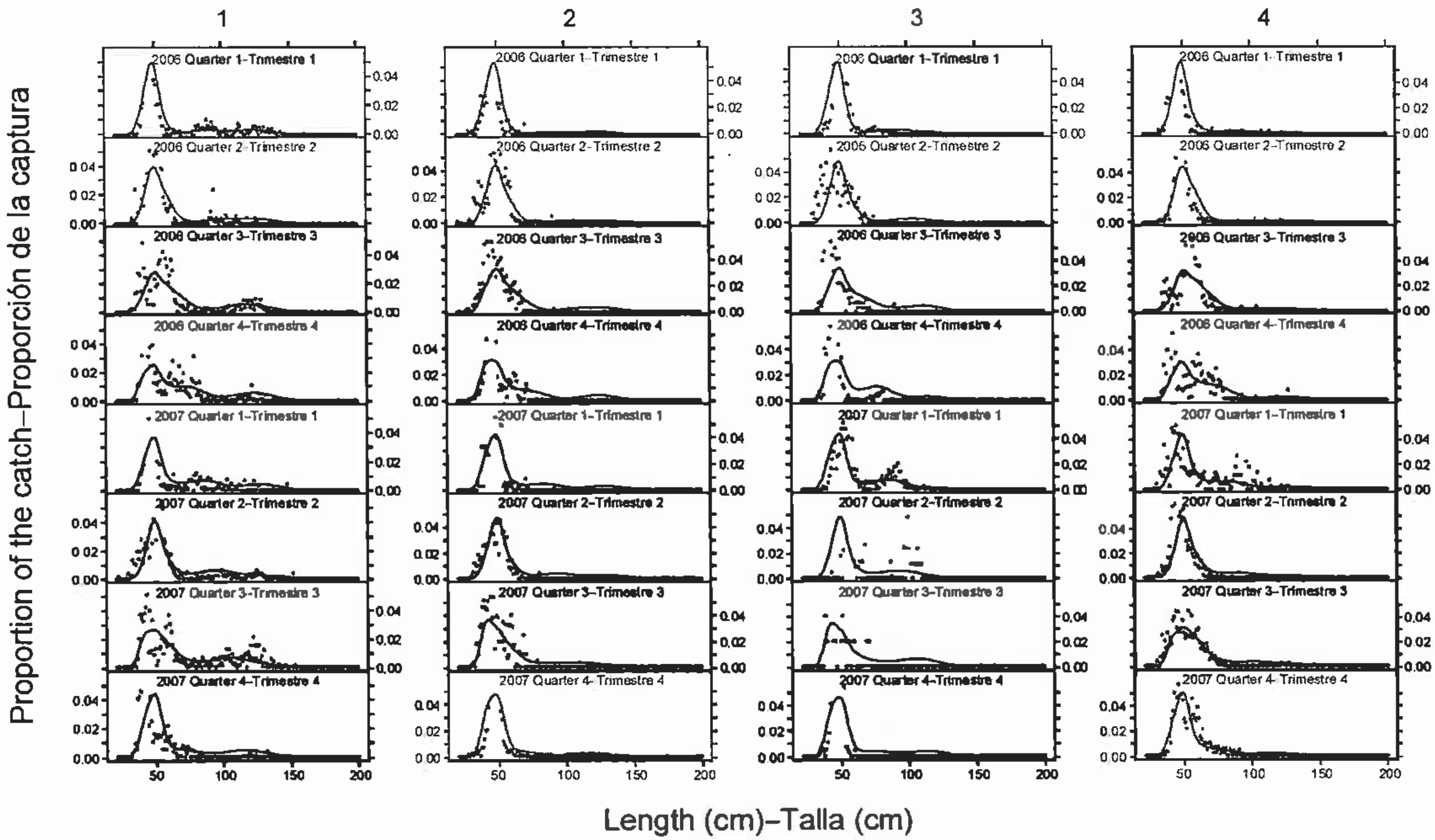


FIGURE 4.8a. Observed (dots) and predicted (curves) size compositions of the recent catches of yellowfin by the fisheries that take tunas in association with floating objects (Fisheries 1-4).

FIGURA 4.8a. Composiciones por tamaño observadas (puntos) y predichas (curvas) de las capturas recientes de aleta amarilla por las pesquerías que capturan atún en asociación con objetos flotantes (Pesquerías 1-4).

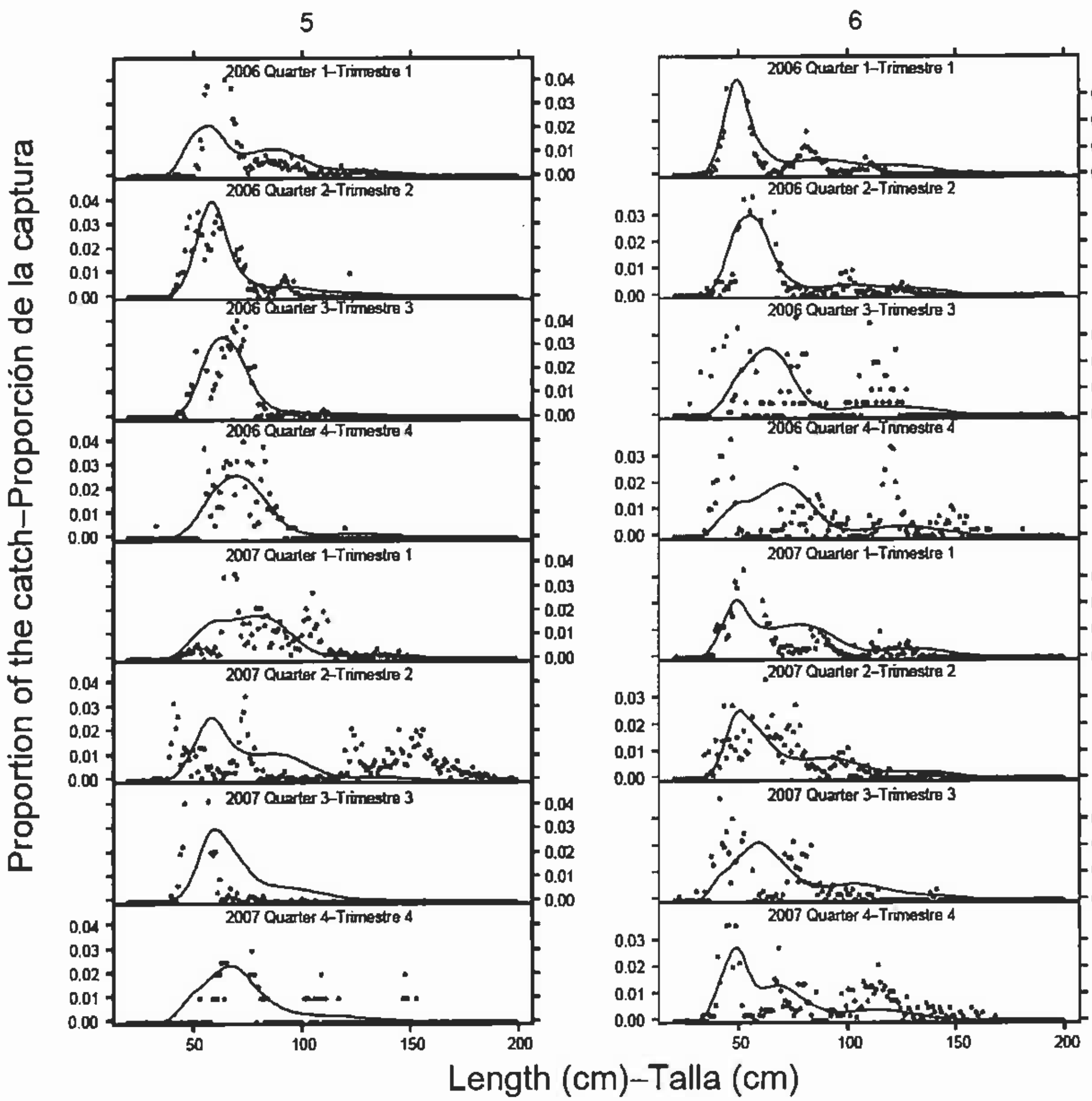


FIGURE 4.8b. Observed (dots) and predicted (curves) size compositions of the recent catches of yellowfin tuna by the fisheries that take tunas in unassociated schools (Fisheries 5 and 6).
FIGURA 4.8b. Composiciones por tamaño observadas (puntos) y predichas (curvas) de las capturas recientes de atún aleta amarilla por las pesquerías que capturan atún en cardúmenes no asociados (Pesquerías 5 y 6).

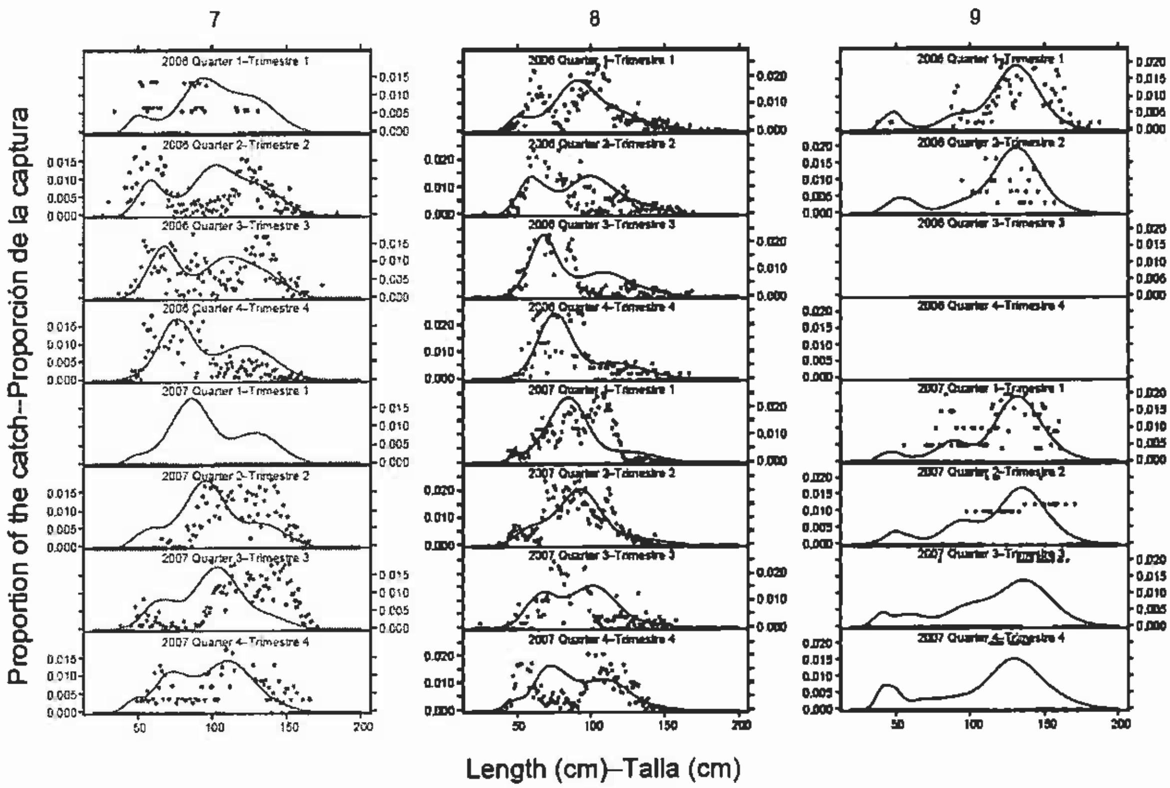


FIGURE 4.8c. Observed (dots) and predicted (curves) size compositions of the recent catches of yellowfin tuna by the fisheries that take tunas in association with dolphins (Fisheries 7-9).

FIGURA 4.8c. Composiciones por tamaño observadas (puntos) y predichas (curvas) de las capturas recientes de atún aleta amarilla por las pesquerías que capturan atún en asociación con delfines (Pesquerías 7-9).

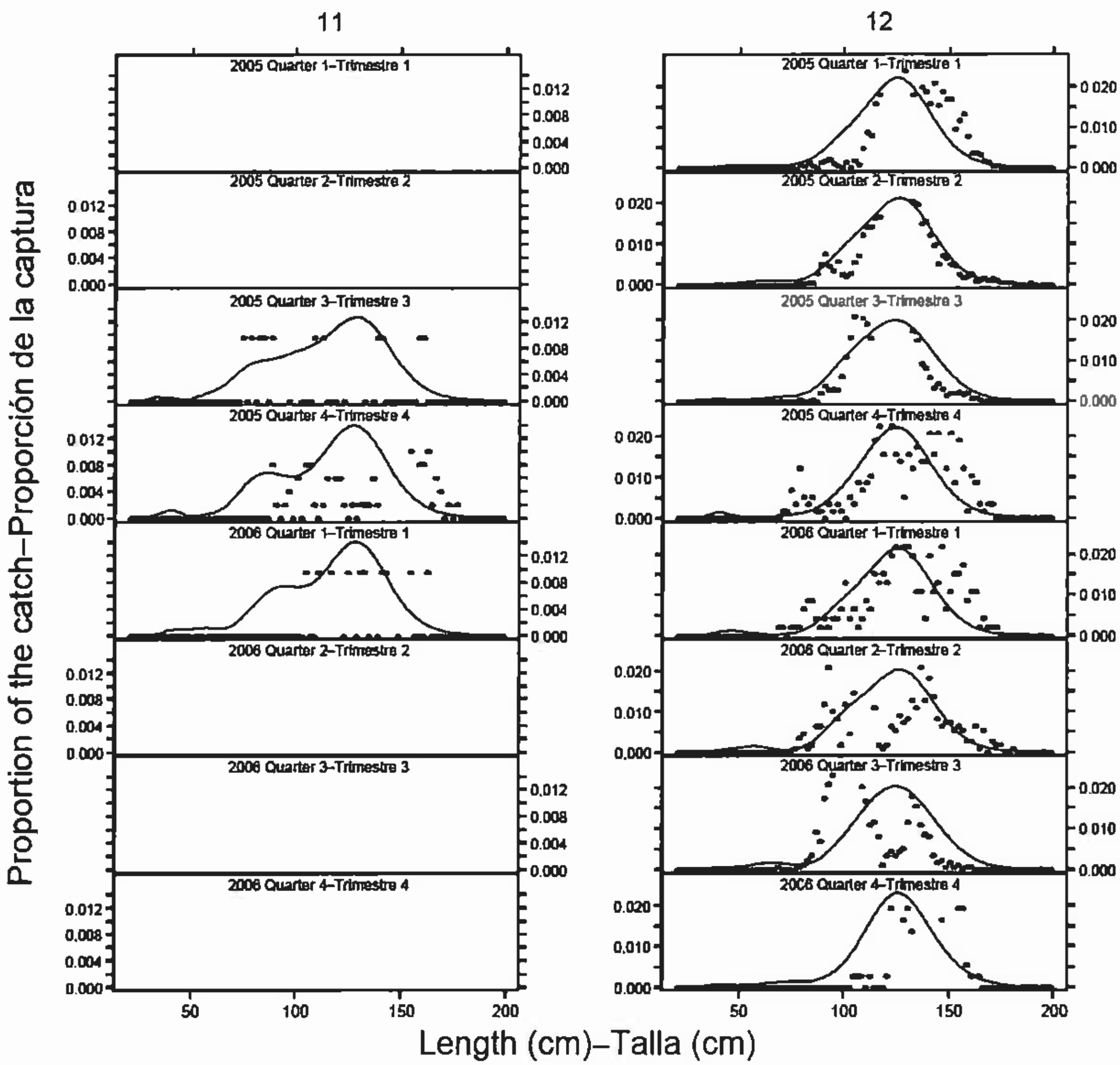


FIGURE 4.8d. Observed (dots) and predicted (curves) size compositions of the recent catches of yellowfin tuna by the longline fisheries (Fisheries 11-12).

FIGURA 4.8d. Composición por talla observada (puntos) y predicha (curvas) de las capturas recientes de atún aleta amarilla por las pesquerías palangreras (Pesquerías 11 y 12).

FIGURE 4.9a. Estimated biomass of yellowfin tuna in the EPO. The bold line illustrates the maximum likelihood estimates of the biomass, and the thin dashed lines the approximate 95% confidence intervals around those estimates. Since the assessment model represents time on a quarterly basis, there are four estimates of biomass for each year. t = metric tons.

FIGURA 4.9a. Biomasa estimada de atún aleta amarilla en el OPO. La línea gruesa ilustra las estimaciones de verosimilitud máxima de la biomasa, y las líneas delgadas de trazos los límites de confianza de 95% aproximados de las estimaciones. Ya que el modelo de evaluación representa el tiempo por trimestres, hay cuatro estimaciones de biomasa para cada año. t = toneladas métricas.

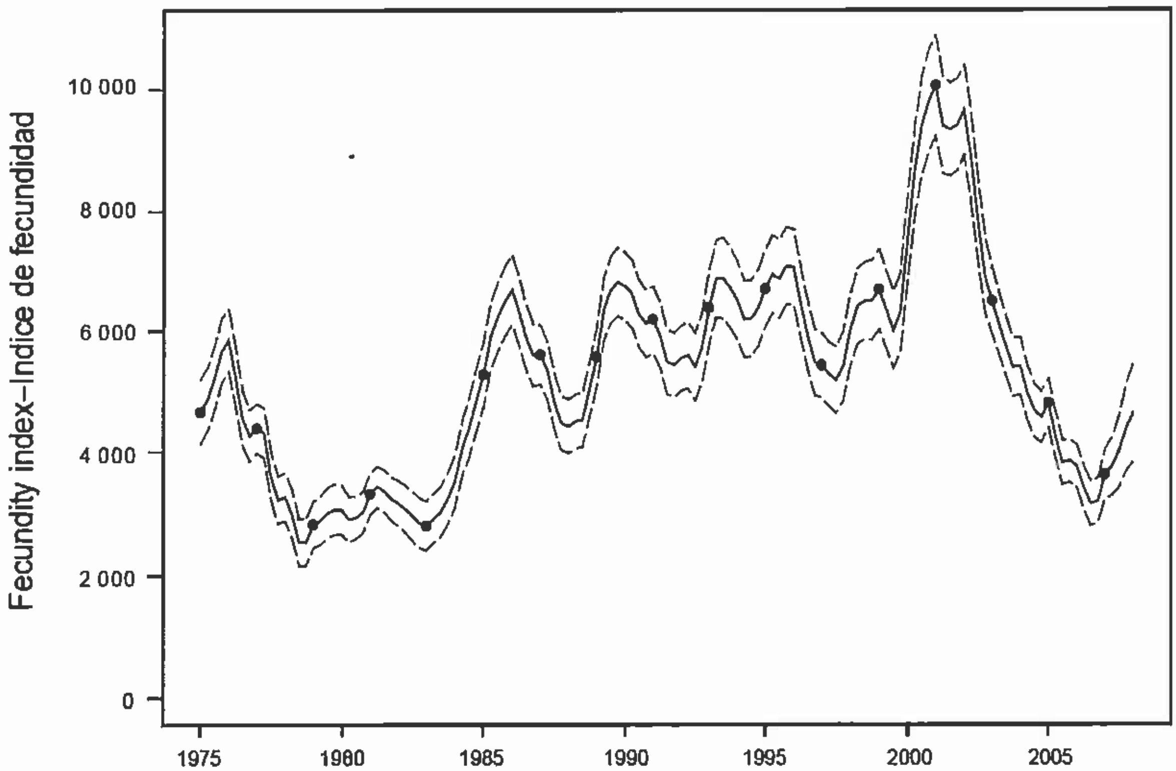


FIGURE 4.9b. Estimated relative spawning biomass of yellowfin tuna in the EPO. The bold line illustrates the maximum likelihood estimates of the biomass, and the thin dashed lines the approximate 95% confidence intervals around those estimates. Since the assessment model represents time on a quarterly basis, there are four estimates of biomass for each year.

FIGURA 4.9b. Biomasa reproductora relativa estimada del atún aleta amarilla en el OPO. La línea gruesa ilustra las estimaciones de verosimilitud máxima de la biomasa, y las líneas delgadas de trazos los límites de confianza de 95% aproximados de las estimaciones. Ya que el modelo de evaluación representa el tiempo por trimestres, hay cuatro estimaciones de biomasa para cada año.

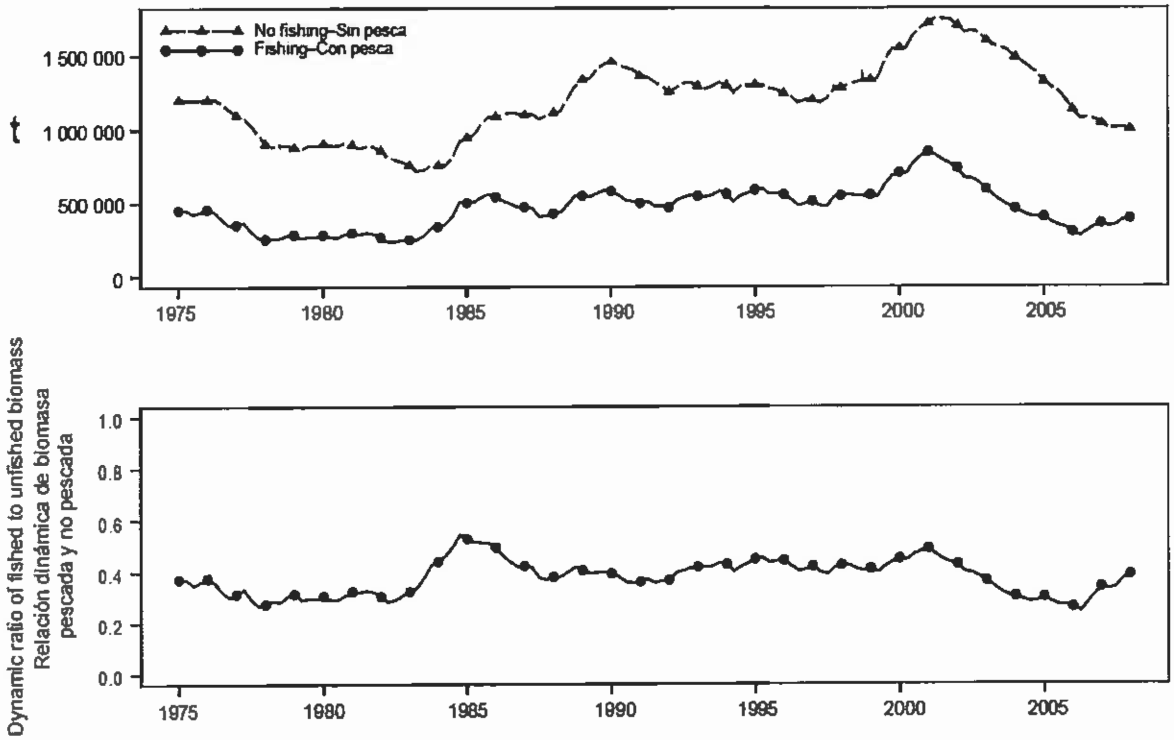


FIGURE 4.10a. Biomass trajectory of a simulated population of yellowfin tuna that was never exploited ("no fishing") and that predicted by the stock assessment model ("fishing"). t = metric tons.

FIGURA 4.10a. Trayectoria de la biomasa de una población simulada de atún aleta amarilla que nunca fue explotada ("sin pesca") y aquélla predicha por el modelo de evaluación de la población ("con pesca"). t = toneladas métricas.

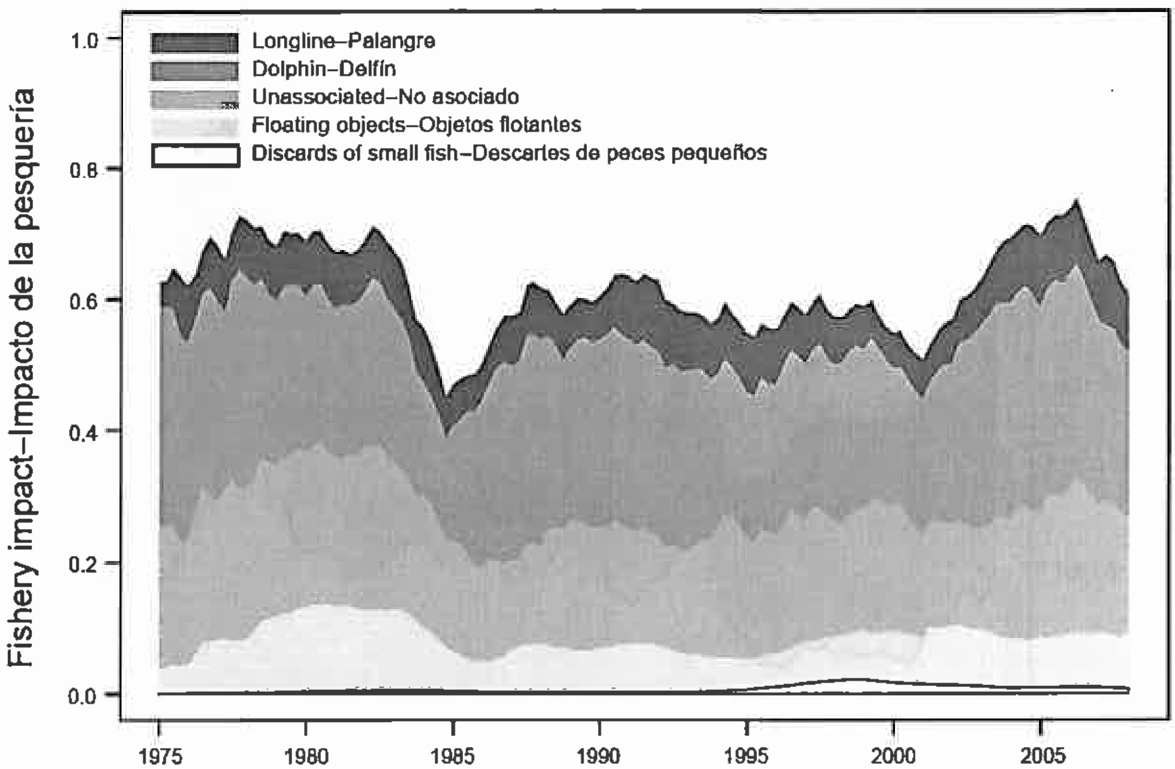


FIGURE 4.10b. Comparison of the relative impacts of the major fisheries on the biomass of yellowfin tuna in the EPO.

FIGURA 4.10b. Comparación de los impactos relativos de las pesquerías más importantes sobre la biomasa de atún aleta amarilla en el OPO.

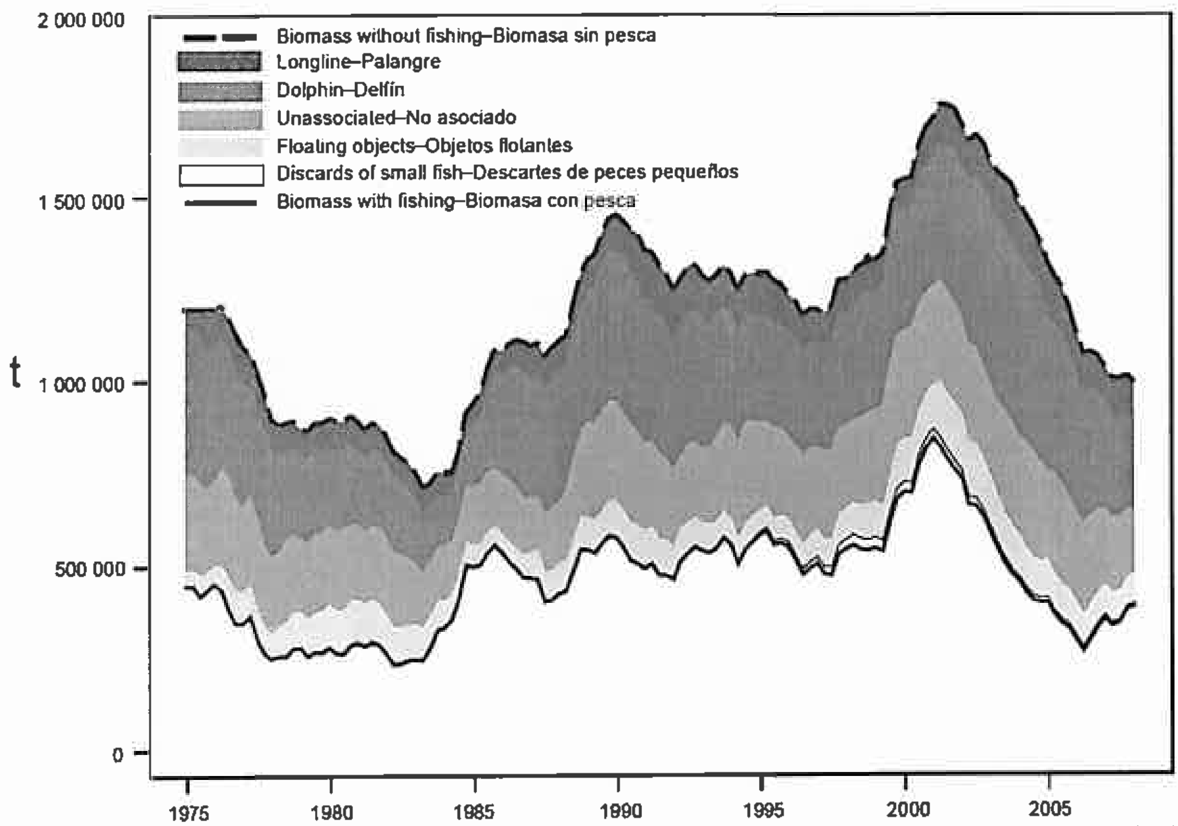


FIGURE 4.10c. Biomass trajectory of a simulated population of yellowfin tuna that was never exploited (dashed line) and that predicted by the stock assessment model (solid line). The shaded areas between the two lines show the portions of the fishery impact attributed to each fishing method. t = metric tons.

FIGURA 4.10c. Trayectoria de la biomasa de una población simulada de atún aleta amarilla que nunca fue explotada (línea de trazos) y aquélla predicha por el modelo de evaluación (línea sólida). Las áreas sombreadas entre las dos líneas representan la porción del impacto de la pesca atribuida a cada método de pesca. t = toneladas métricas.

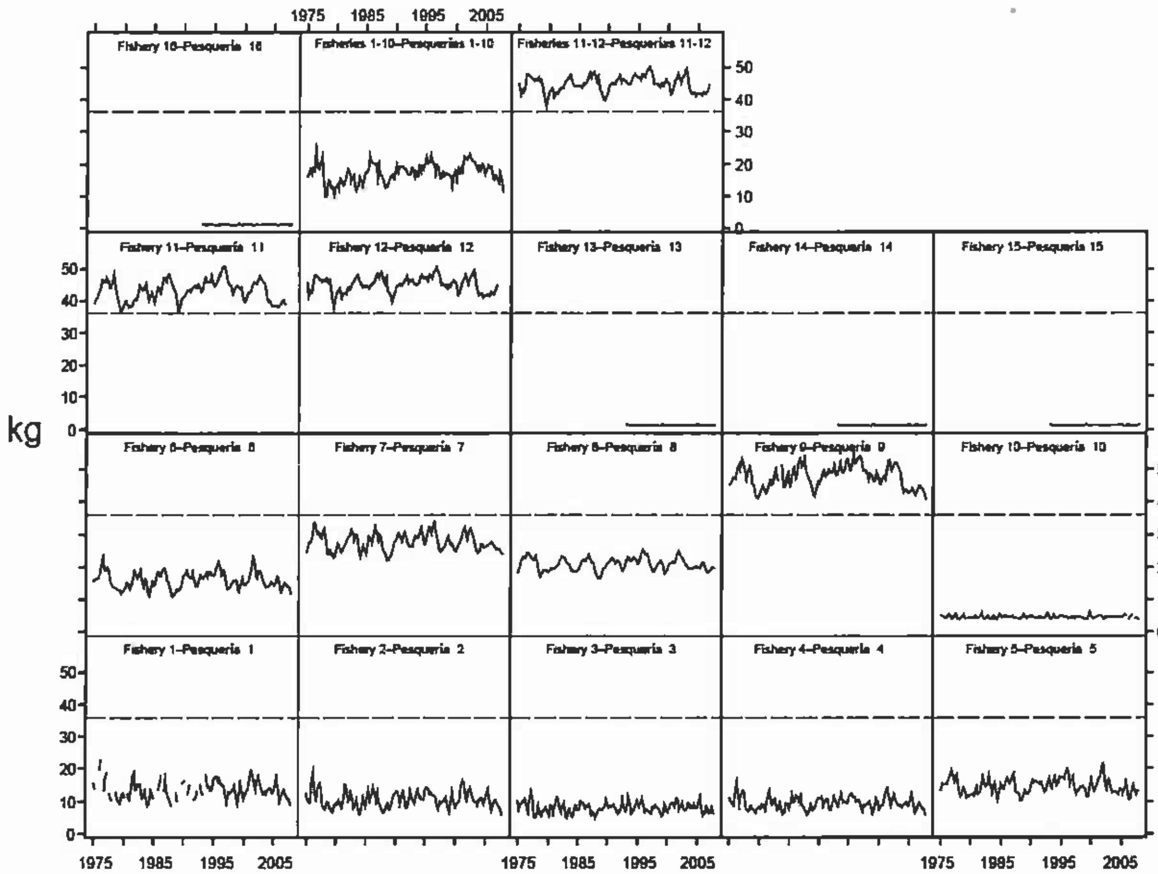


FIGURE 4.11. Estimated average weights of yellowfin tuna caught by the fisheries of the EPO. The time series for "Fisheries 1-10" is an average of Fisheries 1 through 10, and that for "Fisheries 11-12" is an average of Fisheries 11 and 12. The dashed line identifies the critical weight (35.2 kg).

FIGURA 4.11. Peso medio estimado de atún aleta amarilla capturado en las pesquerías del OPO. La serie de tiempo de "Pesquerías 1-10" es un promedio de las Pesquerías 1 a 10, y la de "Pesquerías 11-12" un promedio de las Pesquerías 11 y 12. La línea de trazos identifica el peso crítico (35,2 kg).

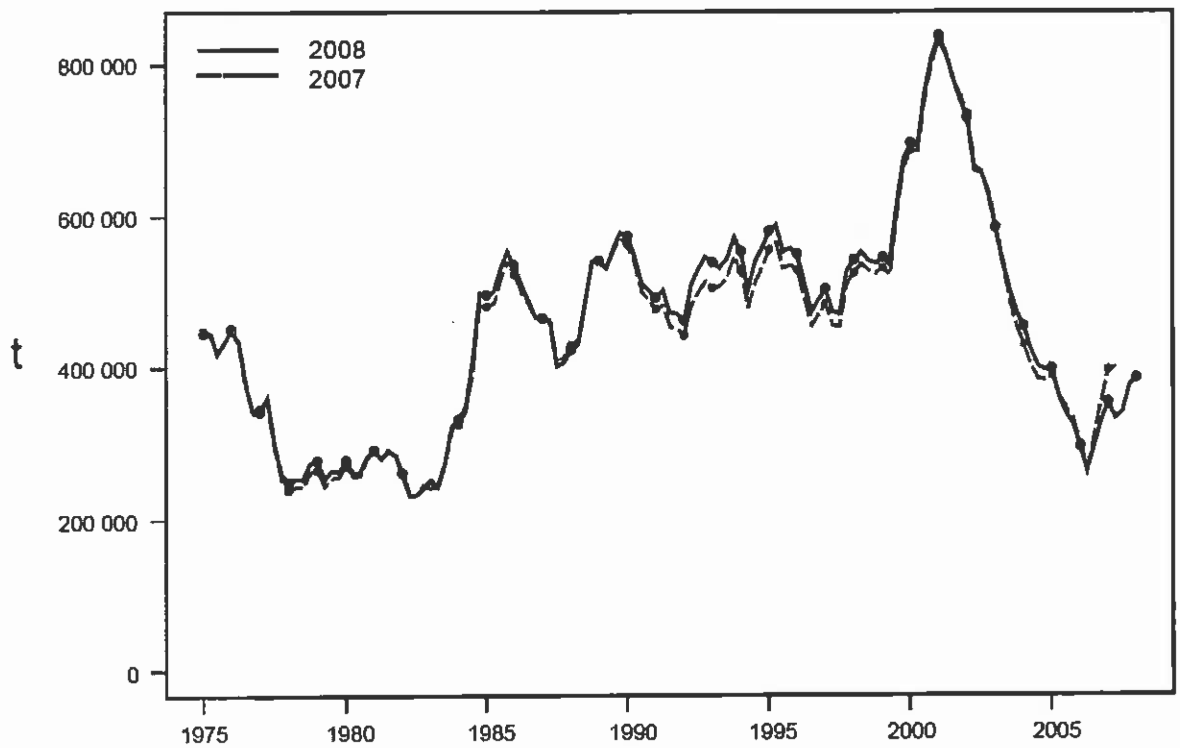


FIGURE 4.12a. Comparison of estimated biomasses of yellowfin tuna in the EPO from the most recent previous assessment and the current assessment. t = metric tons.
FIGURA 4.12a. Comparación de la biomasa estimada de atún aleta amarilla en el OPO de la evaluación previa más reciente y de la evaluación actual. t = toneladas métricas.

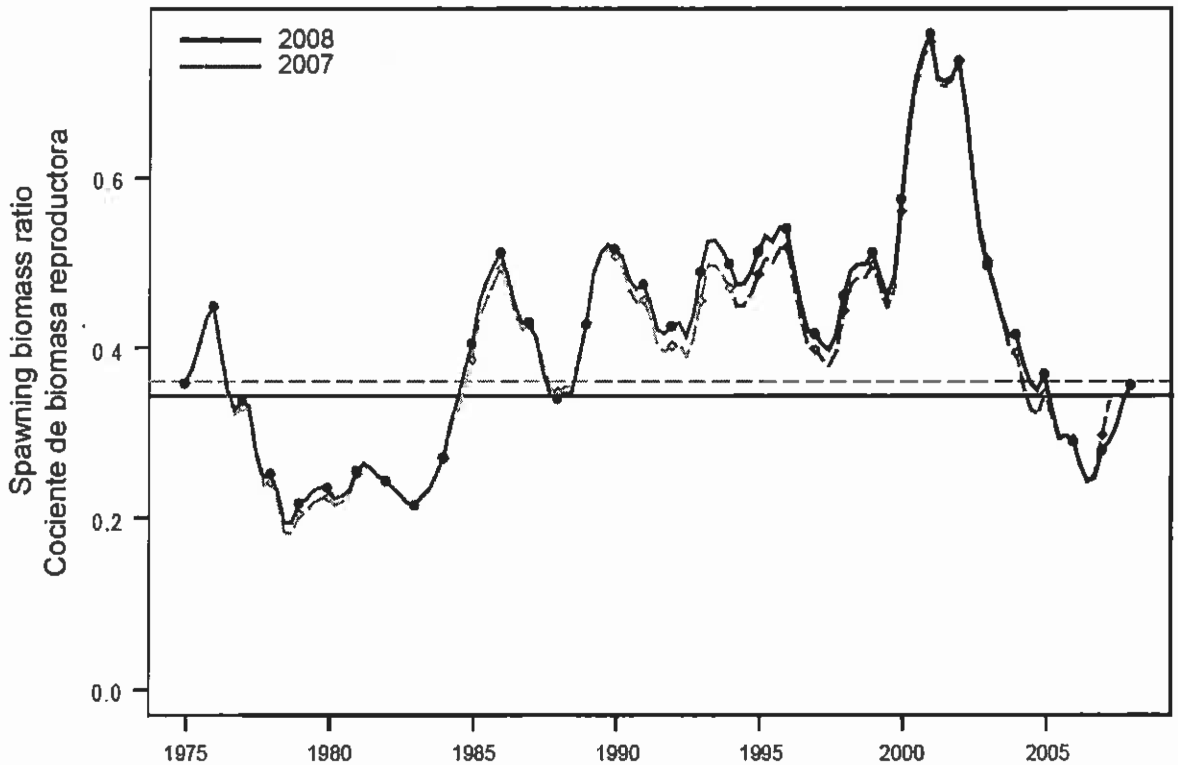


FIGURE 4.12b. Comparison of estimated spawning biomass ratios (SBRs) of yellowfin tuna from the current assessment with the most three recent previous assessments. The horizontal lines identify the SBRs at MSY.

FIGURA 4.12b. Comparación del cociente de biomasa reproductora (SBR) estimado de atún aleta amarilla de la evaluación actual y las tres evaluaciones previas más recientes. Las líneas horizontales identifican el SBR en RMS.

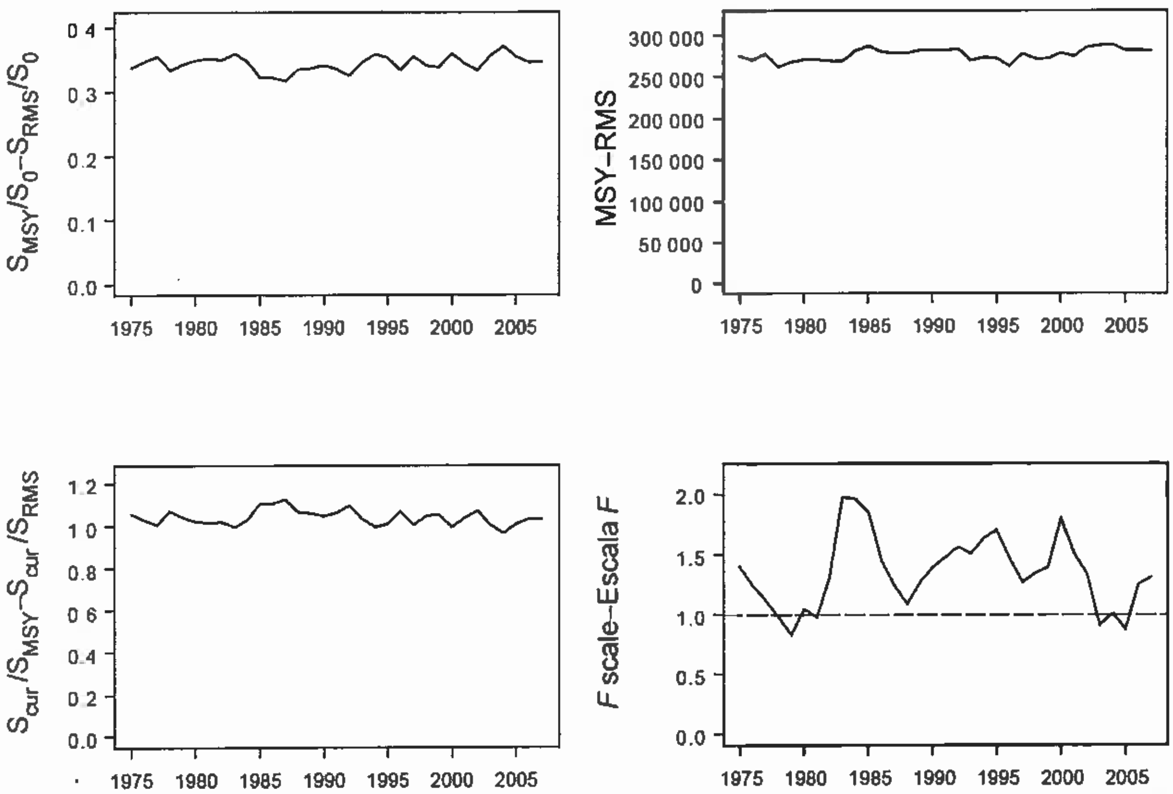


FIGURE 4.12c. Estimates of MSY-related quantities calculated using the average age-specific fishing mortality for each year (*i.e.* the values for 2006 are calculated using the average age-specific fishing mortality in 2006 scaled by the quantity *F*scale, which maximizes the equilibrium yield). (S_{cur} is the spawning biomass at the start of the second quarter of 2007). See the text for definitions.

FIGURA 4.12c. Estimaciones de cantidades relacionadas con el RMS calculadas a partir de la mortalidad por pesca media por edad para cada año (o sea, se calculan los valores de 2006 usando la mortalidad por pesca media por edad escalada por la cantidad *F*scale, que maximiza el rendimiento de equilibrio). (S_{cur} es la biomasa reproductora al principio del segundo trimestre de 2007). Ver definiciones en el texto.

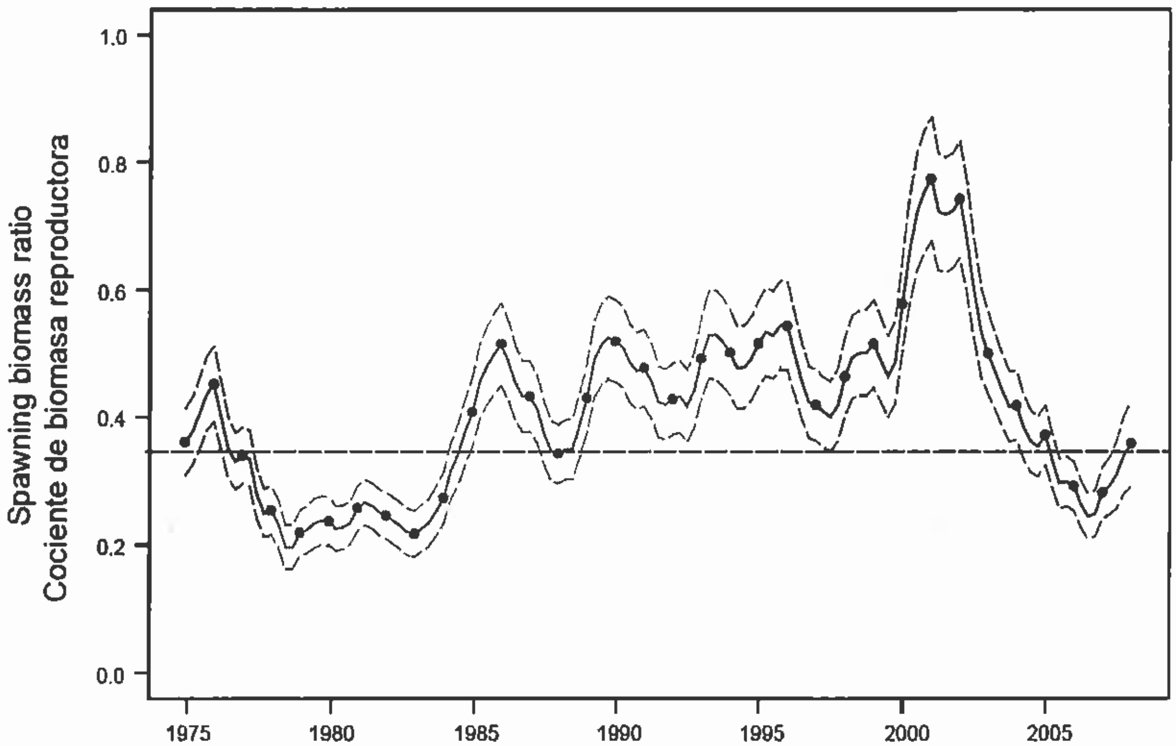


FIGURE 5.1a. Estimated spawning biomass ratios (SBRs) for yellowfin tuna in the EPO. The thin dashed lines represent approximate 95% confidence intervals. The dashed horizontal line identifies the SBR at MSY.

FIGURA 5.1a. Cocientes de biomasa reproductora (SBR) estimados del atún aleta amarilla en el OPO. Las líneas delgadas de trazos representan los intervalos de confianza de 95% aproximados. La línea de trazos horizontal identifica el SBR en RMS.

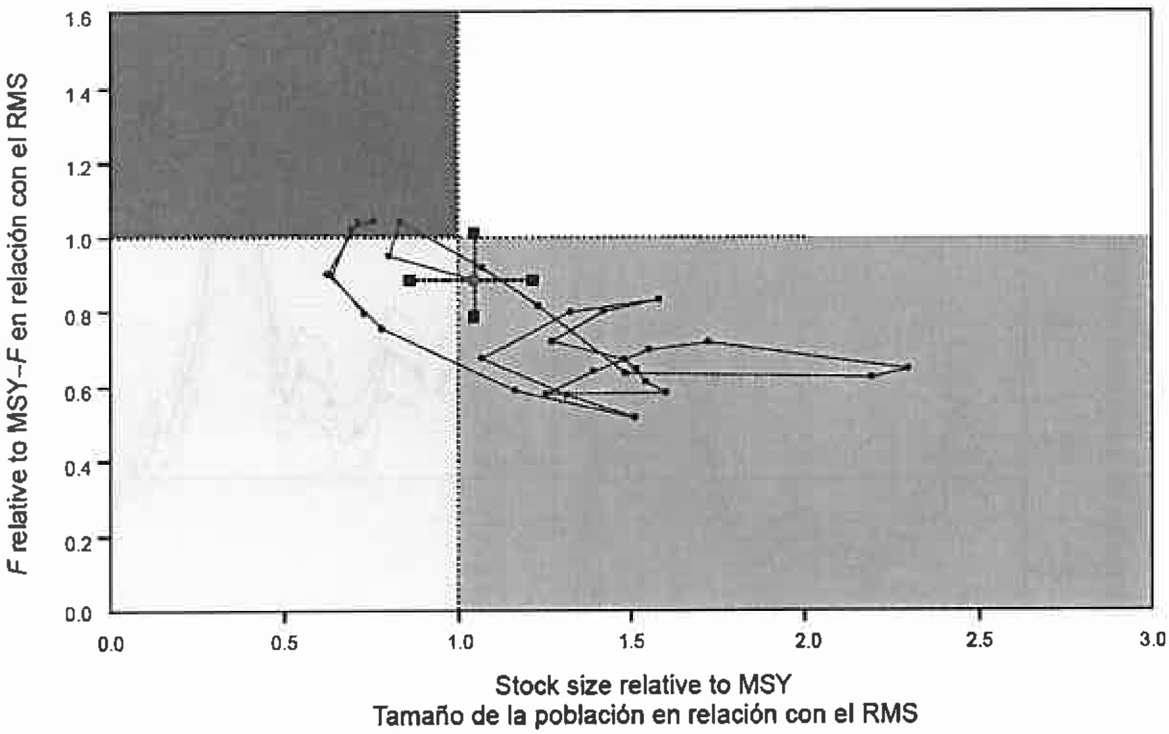
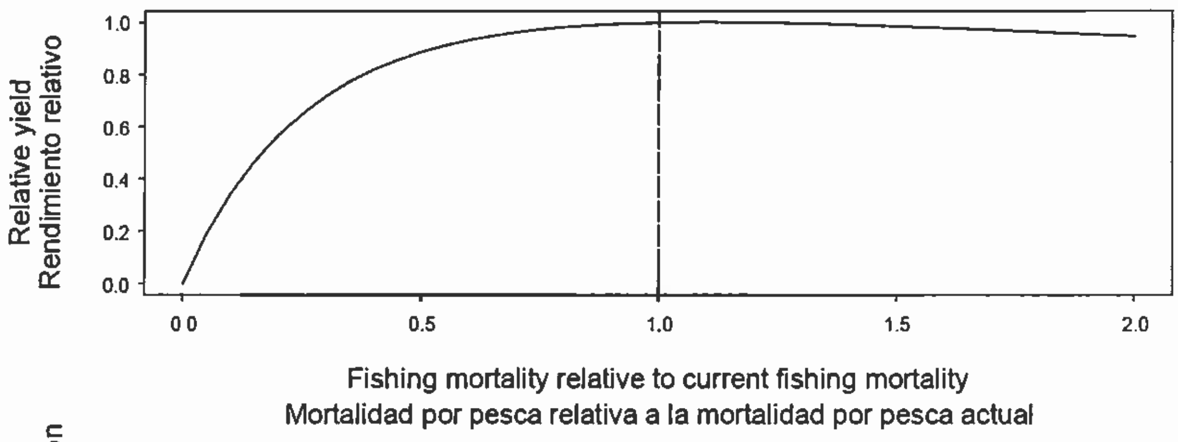


FIGURE 5.1b. Phase plot of the time series of estimates for stock size and fishing mortality relative to their MSY reference points. Each dot is based on the average exploitation rate over three years; the large red dot indicates the most recent estimate. The squares represent approximate 95% confidence intervals.
FIGURA 5.1b. Gráfica de fase de la serie de tiempo de las estimaciones del tamaño de la población y la mortalidad por pesca en relación con sus puntos de referencia de RMS. Cada punto se basa en la tasa de explotación media de tres años; el punto rojo grande indica la estimación valor más reciente. Los puntos cuadrados representan los intervalos de confianza de 95% aproximados.



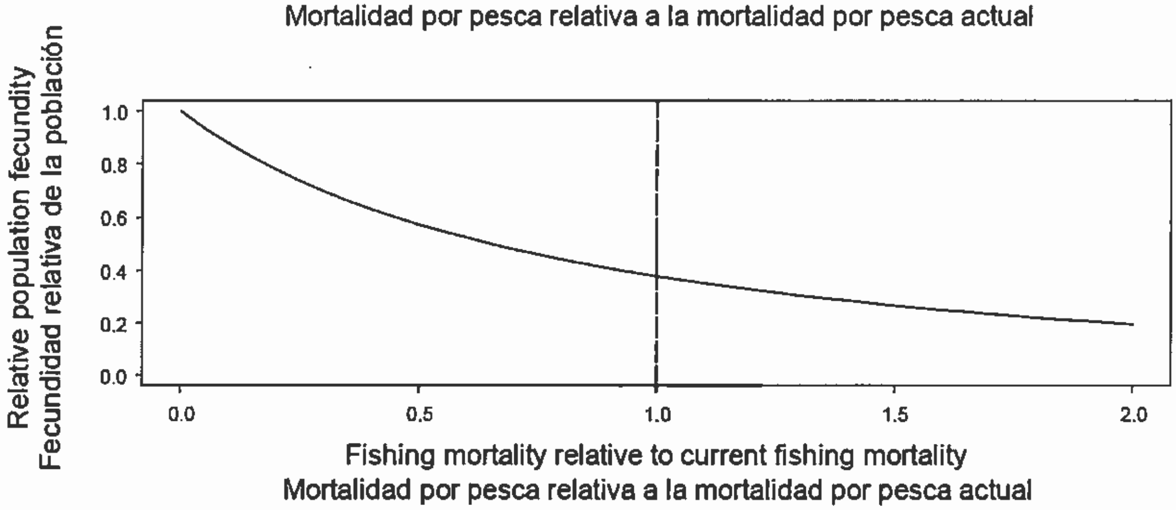


FIGURE 5.2. Predicted effects of long-term changes in fishing effort on the yield (upper panel) and spawning biomass (lower panel) of yellowfin tuna under average environmental conditions, constant recruitment, and the current age-specific selectivity pattern of all fisheries combined. The yield estimates are scaled so that the MSY is at 1.0, and the spawning biomass estimates so that the spawning biomass is equal to 1.0 in the absence of exploitation.

FIGURA 5.2. Efectos predichos de cambios a largo plazo en el esfuerzo de pesca sobre el rendimiento (recuadro superior) y la biomasa reproductora (recuadro inferior) del atún aleta amarilla, bajo condiciones ambientales medias, reclutamiento constante, y el patrón actual de selectividad por edad de todas las pesquerías combinadas. Se escalan las estimaciones de rendimiento para que el RMS esté en 1,0, y las de biomasa reproductora para que ésta equivalga a 1,0 en ausencia de explotación.

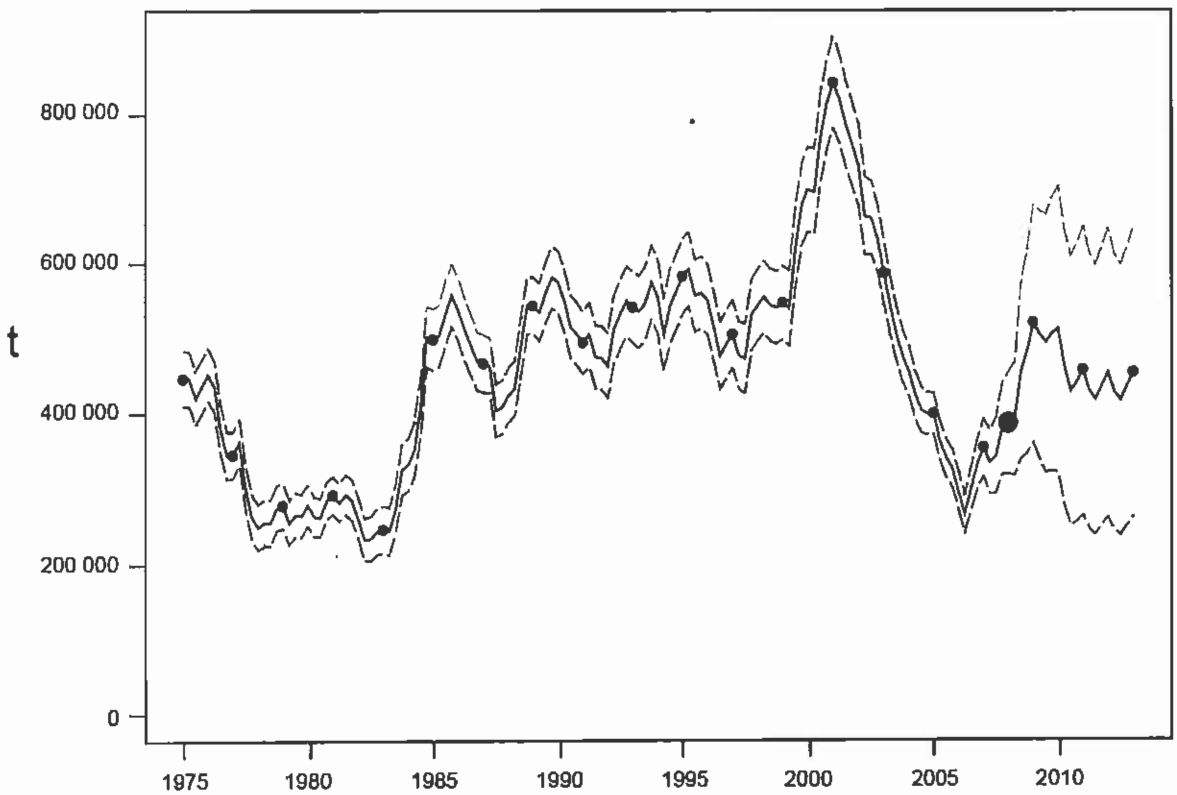


FIGURE 6.1. Biomasses projected for yellowfin tuna in the EPO during 2008-2012 under current effort. The thin dashed lines represent the 95% confidence intervals. The estimates after 2008 indicate the biomasses predicted if the fishing mortality continues at the average of that observed during 2005-2007, and average environmental conditions occur during the next 5 years. t = metric tons.

FIGURA 6.1. Biomasa predicha de atún aleta amarilla en el OPO durante 2008-2012 con el esfuerzo actual. Las líneas delgadas de trazos representan los intervalos de confianza de 95%. Las estimaciones a partir de 2008 señalan la biomasa predicha si la mortalidad por pesca continúa en el nivel medio observado durante 2005-2007, y con condiciones ambientales promedio en los 5 años próximos. t = toneladas métricas.

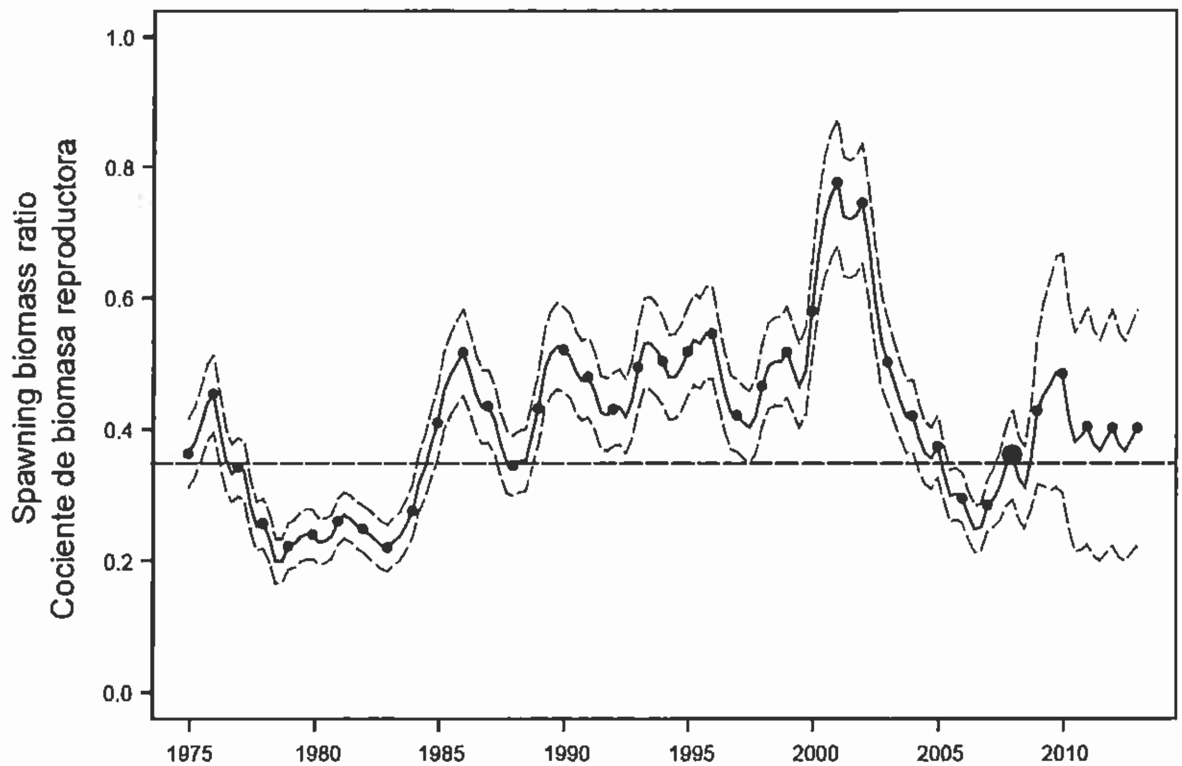


FIGURE 6.2. Spawning biomass ratios (SBRs) for 1975-2007 and SBRs projected during 2008-2012 for yellowfin tuna in the EPO. The dashed horizontal line identifies SBR_{MSY} (Section 5.3), and the thin dashed lines represent the 95% confidence intervals of the estimates. The estimates after 2008 indicate the SBR predicted if the fishing mortality continues at the average of that observed during 2005-2007, and average environmental conditions occur during the next 5 years.

FIGURA 6.2. Cocientes be biomasa reproductora (SBR) de 1975-2007 y SBR proyectados durante 2008-2012 para el atún aleta amarilla en el OPO. La línea de trazos horizontal identifica el SBR_{RMS} (Sección 5.3), y las líneas delgadas de trazos representan los intervalos de confianza de 95% de las estimaciones. Las estimaciones a partir de 2008 señalan el SBR predicho si la mortalidad por pesca continúa en el nivel medio observado durante 2005-2007 y con condiciones ambientales promedio en los 5 años próximos.

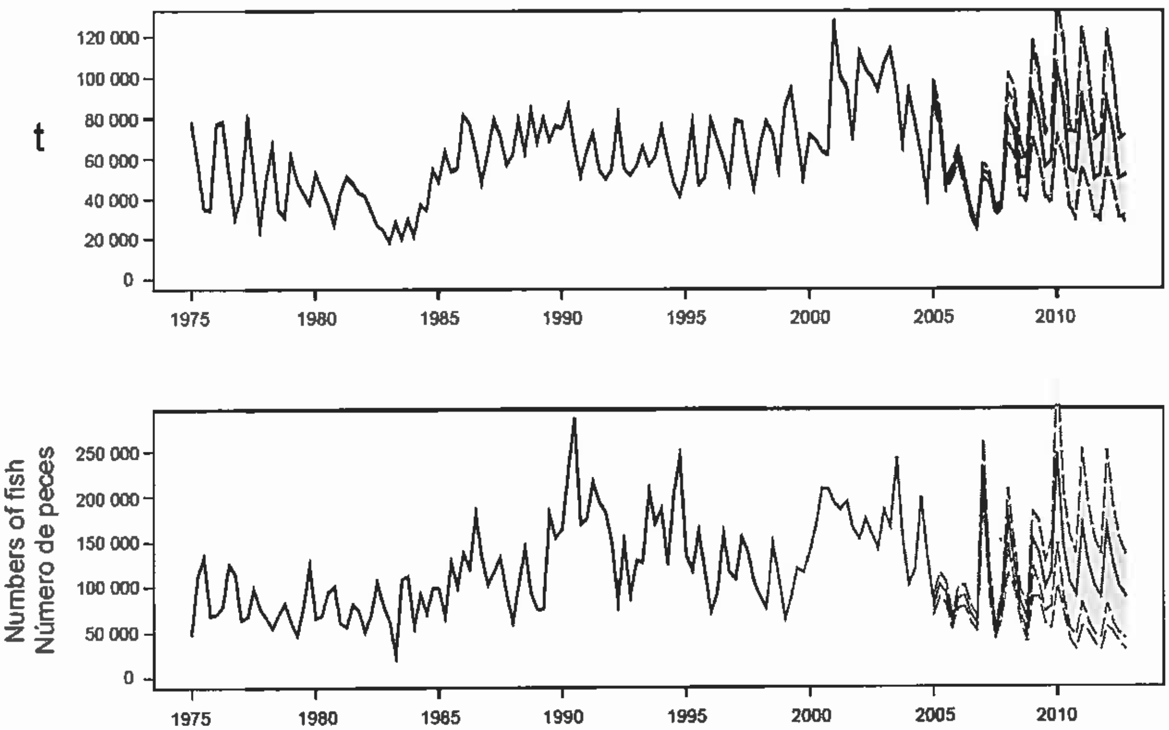


FIGURE 6.3. Catches of yellowfin tuna during 1975-2007 and simulated catches of yellowfin tuna during 2008-2012 by the purse-seine and pole-and-line fleets (upper panel) and the longline fleet (lower panel). The thin dashed lines represent the estimated 95% confidence limits of the estimates. The estimates after 2007 indicate the catches predicted if the fishing mortality continues at the average of that observed during 2005-2007, and average environmental conditions occur during the next 5 years. t = metric tons.

FIGURA 6.3. Capturas de atún aleta amarilla durante 1975-2007 y capturas simuladas de atún aleta amarilla durante 2008-2012 por las flotas de cerco y caña (recuadro superior) y la flota palangrera (recuadro inferior). Las líneas delgadas de trazos representan los intervalos de confianza de 95% de las estimaciones. Las estimaciones a partir de 2007 señalan las capturas predichas si la mortalidad por pesca continúa en el promedio del nivel observado durante 2005-2007, y con condiciones ambientales medias en los 5 años próximos. t = toneladas métricas.

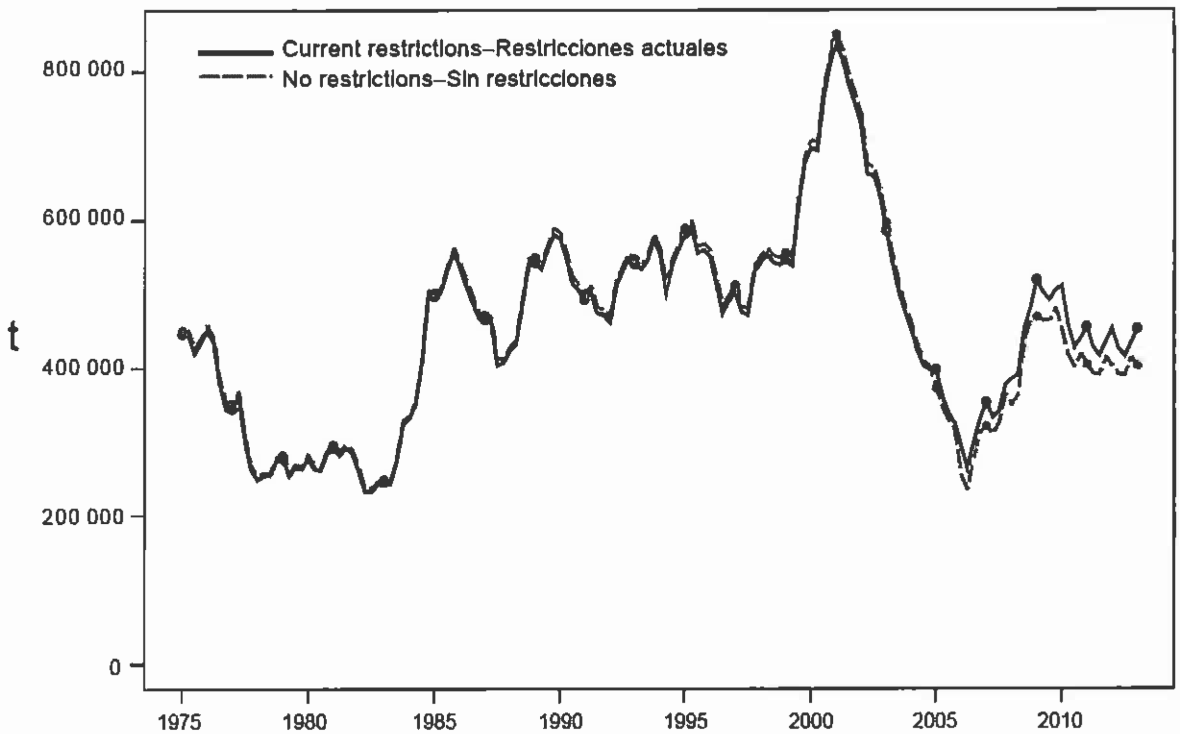


FIGURE 6.4. Biomass projected for yellowfin tuna in the EPO during 2005-2013 under Resolutions C-04-09 and C-06-02, and under effort projected without the resolutions. t = metric tons.

FIGURA 6.4. Proyección de la biomasa de atún aleta amarilla en el OPO durante 2005-2013, bajo las Resoluciones C-04-09 y C-06-02, y con el esfuerzo proyectado sin las resoluciones. t = toneladas métricas.

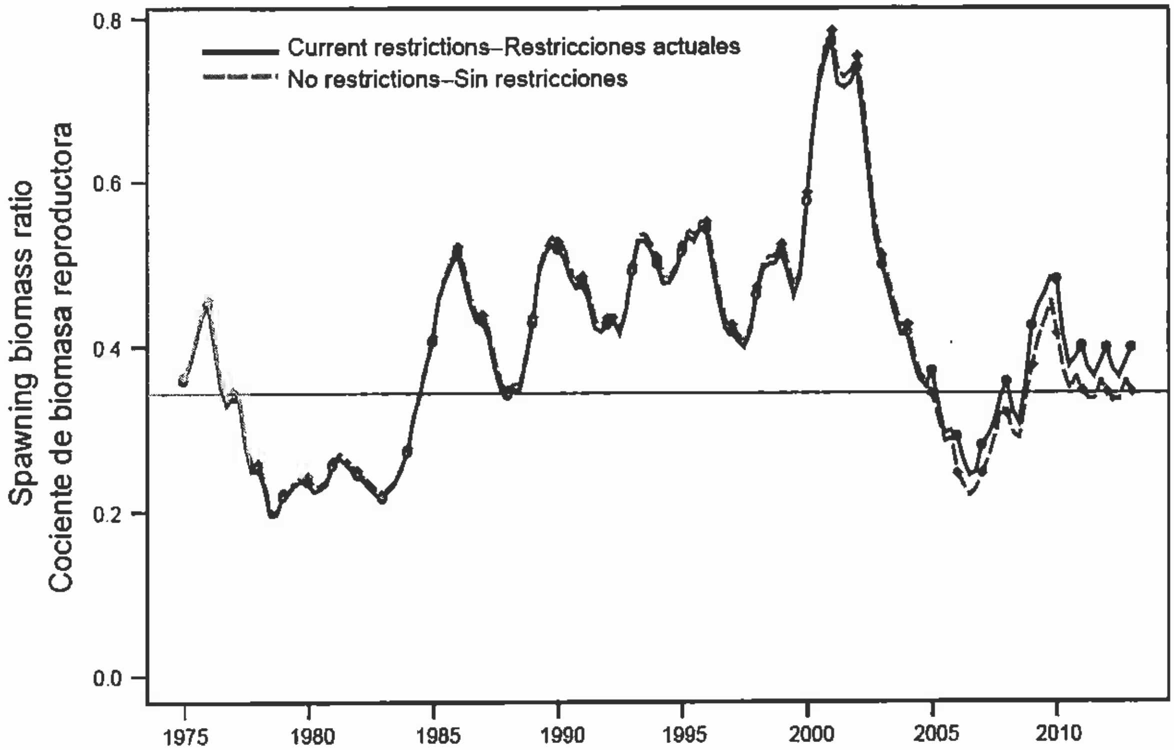


FIGURE 6.5. Spawning biomass ratios (SBRs) projected for yellowfin tuna in the EPO during 2005-2013 under Resolutions C-04-09 and C-06-02, and under effort projected without the Resolutions. The horizontal line (at 0.37) identifies SBR_{MSY} (Section 5.3).

FIGURA 6.5. Cocientes de biomasa reproductora (SBR) de atún aleta amarilla en el OPO proyectados durante 2005-2013, bajo las Resoluciones C-04-09 y C-06-02, y con el esfuerzo proyectado sin las resoluciones. La línea horizontal (en 0.38) identifica SBR_{RMS} (Sección 5.3).

TABLE 2.1. Fisheries defined by the IATTC staff for the stock assessment of yellowfin tuna in the EPO. PS = purse seine; LP = pole and line; LL = longline; OBJ = sets on floating objects; NOA = sets on unassociated fish; DEL = sets on dolphin-associated schools. The sampling areas are shown in Figure 3.1, and descriptions of the discards are provided in Section 2.2.2.

TABLA 2.1. Pesquerías definidas por el personal de la CIAT para la evaluación del stock de atún aleta amarilla en el OPO. PS = red de cerco; LP = caña; LL = palangre; OBJ = lances sobre objeto flotante; NOA = lances sobre atunes no asociados; DEL = lances sobre delfines. En la Figura 3.1 se ilustran las zonas de muestreo, y en la Sección 2.2.2 se describen los descartes.

Fishery	**Gear type**	**Set type**	**Years**	**Sampling areas**	**Catch data**
Pesquería	**Tipo de arte**	**Tipo de lance**	**Año**	**Zonas de muestreo**	**Datos de captura**
1	PS	OBJ	1975-2007	11-12	retained catch + discards from inefficiencies in fishing process–captura retenida + descartes por ineficacias en el proceso de pesca
2	PS	OBJ	1975-2007	7, 9	
3	PS	OBJ	1975-2007	5-6, 13	
4	PS	OBJ	1975-2007	1-4, 8, 10	
5	PS	NOA	1975-2007	1-4, 8, 10	retained catch + discards–captura retenida + descartes
6	PS	NOA	1975-2007	5-7, 9, 11-13	
7	PS	DEL	1975-2007	2-3, 10	
8	PS	DEL	1975-2007	1, 4-6, 8, 13	
9	PS	DEL	1975-2007	7, 9, 11-12	
10	LP		1975-2007	1-13	retained catch only— captura retenida solamente
11	LL		1975-2007	N of-de 15°N	
12	LL		1975-2007	S of-de 15°N	
13	PS	OBJ	1993-2007	11-12	discards of small fish from size-sorting the catch by Fishery 1–descartes de peces pequeños de clasificación por tamaño en la Pesquería 1
14	PS	OBJ	1993-2007	7, 9	discards of small fish from size-sorting the catch by Fishery 2–descartes de peces pequeños de clasificación por tamaño en la Pesquería 2
15	PS	OBJ	1993-2007	5-6, 13	discards of small fish from size-sorting the catch by Fishery 3–descartes de peces pequeños de clasificación por tamaño en la Pesquería 3
16	PS	OBJ	1993-2007	1-4, 8, 10	discards of small fish from size-sorting the catch by Fishery 4–descartes de peces pequeños de clasificación por tamaño en la Pesquería 4

TABLE 4.1. Estimated total annual recruitment to the fishery at the age of two quarters (thousands of fish), initial biomass (metric tons present at the beginning of the year), and spawning biomass (relative to maximum spawning biomass) of yellowfin tuna in the EPO. Biomass is defined as the total weight of yellowfin one and half years of age and older; spawning biomass is estimated with the maturity schedule and sex ratio data of Schaefer (1998) and scaled to have a maximum of 1.

TABLA 4.1. Reclutamiento anual total estimado a la pesquería a la edad de dos trimestres (en miles de peces), biomasa inicial (toneladas métricas presentes al principio de año), y biomasa reproductora relativa del atún aleta amarilla en el OPO. Se define la biomasa como el peso total de aleta amarilla de año y medio o más de edad; se estima la biomasa reproductora con el calendario de madurez y datos de proporciones de sexos de Schaefer (1998) y la escala tiene un máximo de 1.

Year	Total recruitment	Biomass of age-1.5+ fish	Relative spawning biomass
Año	Reclutamiento total	Biomasa de peces de edad 1.5+	Biomasa reproductora relativa
1975	114,444	446,742	0.47
1976	95,744	452,388	0.58
1977	149,444	345,700	0.44
1978	103,651	249,422	0.33
1979	137,895	278,246	0.28
1980	108,846	278,712	0.31
1981	74,865	292,245	0.33
1982	124,490	261,217	0.32
1983	190,245	246,023	0.28
1984	152,489	332,510	0.35
1985	130,630	497,627	0.53
1986	156,136	537,416	0.67
1987	264,530	466,116	0.56
1988	191,059	423,918	0.44
1989	159,516	542,701	0.55
1990	155,640	575,129	0.67
1991	213,508	493,254	0.62
1992	171,988	462,779	0.55
1993	169,155	540,737	0.64
1994	148,736	555,343	0.65
1995	166,150	581,959	0.67
1996	220,183	551,002	0.70
1997	162,990	504,760	0.54
1998	312,177	543,030	0.60
1999	219,089	547,056	0.67
2000	225,099	698,714	0.75
2001	211,166	841,411	1.00
2002	176,001	731,587	0.96
2003	148,982	586,082	0.65
2004	120,449	454,463	0.54
2005	144,313	399,137	0.48
2006	124,520	295,340	0.38
2007	225,527	354,047	0.36
2008		386,284	0.46

TABLE 4.2. Estimates of the average sizes of yellowfin tuna. The ages are expressed in quarters after hatching.
TABLA 4.2. Estimaciones del tamaño medio de atún aleta amarilla. Se expresan las edades en trimestres desde la cría.

Age (quarters) Edad (trimestres)	Average length (cm) Talla media (cm)	Average weight (kg) Peso medio (kg)	Age (quarters) Edad (trimestres)	Average length (cm) Talla media (cm)	Average weight (kg) Peso medio (kg)
2	33.06	0.7	16	154.22	80.98
3	40.76	1.33	17	159.06	89.08
4	48.92	2.34	18	163.25	96.52
5	58.32	4.03	19	166.84	103.22
6	68.47	6.61	20	169.89	109.16
7	78.72	10.16	21	172.48	114.38
8	89.2	14.95	22	174.67	118.92
9	99.43	20.9	23	176.51	122.83
10	109.28	27.97	24	178.06	126.18
11	118.64	36.04	25	179.35	129.03
12	127.37	44.87	26	180.43	131.44
13	135.18	53.92	27	181.33	133.47
14	142.29	63.16	28	182.08	135.18
15	148.64	72.28	29	182.7	136.61

TABLE 5.1. MSY and related quantities for the base case and the stock-recruitment relationship sensitivity analysis, based on average fishing mortality (*F*) for 2005-2007. The quantities are also given based on average *F* for 2005-2006. B_{recent} and B_{MSY} are defined as the biomass of fish 2+ quarters old at the start of the second quarter of 2007 and at MSY, respectively, and S_{recent} and S_{MSY} are defined as indices of spawning biomass (therefore, they are not in metric tons). C_{recent} is the estimated total catch from the second quarter of 2006 through the first quarter of 2007.
TABLA 5.1. RMS y cantidades relacionadas para el caso base y los análisis de sensibilidad a la relación población-reclutamiento, basados en la mortalidad por pesca (*F*) media de 2005-2007. Se presentan también las cantidades basadas en la *F* media de 2005-2006. Se definen B_{recent} y B_{RMS} como la biomasa de peces de 2+ trimestres de edad al principio del segundo trimestre de 2007 y en RMS, respectivamente. y S_{recent} y S_{RMS} como los índices de biomasa reproductora (por lo tanto, no se expresan en toneladas métricas). C_{recent} es la captura total estimada desde el segundo trimestre de 2006 hasta el primer trimestre de 2007, inclusive.

	Base case Caso base	h = 0.75	Average *F* *F* promedio 2005-2006
MSY–RMS	281,902	290,236	282,043
B_{MSY}–B_{RMS}	400,484	530,326	399,405
S_{MSY}—S_{RMS}	4,489	6,224	4,474
C_{recent}/MSY—C_{recent}/RMS	0.68	0.67	0.68
B_{recent}/B_{MSY}–B_{recent}/B_{RMS}	0.96	0.72	0.97
S_{recent}/S_{MSY}–S_{recent}/S_{RMS}	1.04	0.74	1.04
$S_{MSY}/S_{F=0}$–$S_{RMS}/S_{F=0}$	0.34	0.40	0.34
F multiplier—Multiplicador de *F*	1.13	0.77	1.06

TABLE 5.2a. Estimates of the MSY and its associated quantities, obtained by assuming that each fishery is the only fishery operating in the EPO and that each fishery maintains its current pattern of age-specific selectivity (Figure 4.4). The estimates of the MSY and B_{MSY} are expressed in metric tons. OBJ = sets on floating objects; NOA = sets on unassociated fish; DEL = sets on dolphin-associated fish; LL = longline.
TABLA 5.2a. Estimaciones del RMS y sus cantidades asociadas, obtenidas suponiendo que cada pesquería es la única que opera en el OPO y que cada pesquería mantiene su patrón actual de selectividad por edad (Figure 4.4). Se expresan las estimaciones de RMS y B_{RMS} en toneladas métricas. OBJ = lance sobre objeto flotante; NOA = lance sobre atunes no asociados; DEL = lances sobre delfines; LL = palangre.

Fishery	MSY	B_{MSY}	S_{MSY}	$B_{MSY}/B_{F=0}$	$S_{MSY}/S_{F=0}$	F multiplier
Pesquería	RMS	B_{RMS}	S_{RMS}	$B_{RMS}/B_{F=0}$	$S_{RMS}/S_{F=0}$	Multiplicador de F
All—Todas	281,902	400,484	4,489	0.34	0.34	1.13
OBJ	212,479	308,808	3,377	0.26	0.26	9.26
NOA	260,293	395,167	4,558	0.33	0.35	3.70
DEL	306,525	397,836	4,213	0.33	0.32	2.56
LL	358,755	461,893	4,962	0.39	0.38	47.19

TABLE 5.2b. Estimates of the MSY and its associated quantities, obtained by assuming that one fishery is not operating in the EPO and that each fishery maintains its current pattern of age-specific selectivity (Figure 4.4). The estimates of the MSY and B_{MSY} are expressed in metric tons. OBJ = sets on floating objects; NOA = sets on unassociated fish; DEL = sets on dolphin-associated fish; LL = longline.
TABLA 5.2b. Estimaciones del RMS y sus cantidades asociadas, obtenidas suponiendo que una pesquería no opera en el OPO y que cada pesquería mantiene su patrón actual de selectividad por edad (Figure 4.4). Se expresan las estimaciones de RMS y B_{RMS} en toneladas métricas. OBJ = lance sobre objeto flotante; NOA = lance sobre atunes no asociados; DEL = lances sobre delfines; LL = palangre.

Fishery	MSY	B_{MSY}	S_{MSY}	$B_{MSY}/B_{F=0}$	$S_{MSY}/S_{F=0}$	F multiplier
Pesquería	RMS	B_{RMS}	S_{RMS}	$B_{RMS}/B_{F=0}$	$S_{RMS}/S_{F=0}$	Multiplicador de F
All—Todas	281,902	400,484	4,489	0.34	0.34	1.13
No OBJ	291,443	408,154	4,533	0.34	0.35	1.35
No NOA	290,590	407,747	4,524	0.34	0.35	1.61
No DEL	259,384	403,265	4,702	0.34	0.36	2.08
No LL	277,741	396,828	4,442	0.33	0.34	1.19

TABLE 5.2c. Estimates of the MSY and its associated quantities, obtained by assuming that each fishery maintains its current pattern of age-specific selectivity (Figure 4.4), and by adjusting the effort to obtain MSY. Either all gears are adjusted, one fishery only is adjusted while the other is set to zero, or one fishery is adjusted while the other remains at its current level. The estimates of the MSY and B_{MSY} are expressed in metric tons.

TABLA 5.2c. Estimaciones del RMS y sus cantidades asociadas, obtenidas suponiendo que cada pesquería mantiene su patrón actual de selectividad por edad (Figure 4.4) y ajustando el esfuerzo para obtener el RMS. Se ajustan todas las artes de pesco, o se ajusta solamente una pesquería y se fija la otra en cero, o se ajusta una pesquería y la otra sigue en su nivel actual. Se expresan las estimaciones de RMS y B_{RMS} en toneladas métricas.

	All gears	Purse-seine only	Longline only	Purse-seine adjusted	Longline adjusted
	Todas artes	Cerco solamente	Palangre solamente	Cerco ajustado	Palangre ajustado
Steepness—Inclinación = 1 (Base case-Caso base)					
MSY—RMS	281,902	277,741	358,755	281,367	307,647
B_{MSY}—B_{RMS}	400,484	396,828	461,893	414,427	320,750
S_{MSY}—S_{RMS}	4,489	4,442	4,962	4,686	3,138
B_{MSY}/B_0—B_{RMS}/B_0	0.34	0.33	0.39	0.35	0.27
S_{MSY}/S_0—S_{RMS}/S_0	0.34	0.34	0.38	0.36	0.24
F multiplier—Multiplicador de F	1.13	1.19	47.19	1.07	37.46
Steepness—Inclinación = 0.75					
MSY—RMS	290,236	285,335	376,352	292,627	287,643
B_{MSY}—B_{RMS}	530,326	528,075	577,587	553,679	391,912
S_{MSY}—S_{RMS}	6,224	6,173	6,727	6,534	4,367
B_{MSY}/B_0—B_{RMS}/B_0	0.37	0.37	0.41	0.39	0.28
S_{MSY}/S_0—S_{RMS}/S_0	0.40	0.40	0.43	0.42	0.28
F multiplier—Multiplicador de F	0.77	0.82	22.99	0.71	5.32

APPENDIX A: SENSITIVITY ANALYSIS FOR THE STOCK-RECRUITMENT RELATIONSHIP
ANEXO A: ANÁLISIS DE SENSIBILIDAD A LA RELACIÓN POBLACIÓN-RECLUTAMIENTO

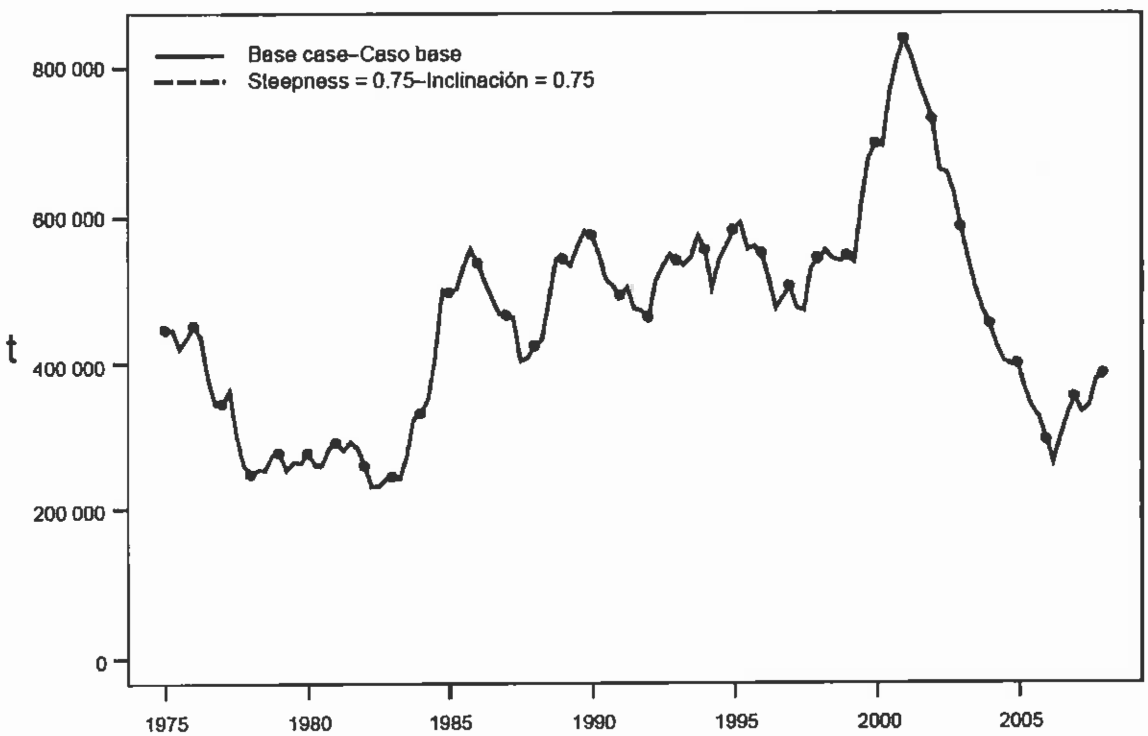


FIGURE A.1. Comparison of the estimates of biomass of yellowfin tuna from the analysis without a stock-recruitment relationship (base case) and with a stock-recruitment relationship (steepness = 0.75).
FIGURA A.1. Comparación de las estimaciones de la biomasa de atún aleta amarilla del análisis sin relación población-reclutamiento (caso base) y con relación población-reclutamiento (inclinación = 0,75).

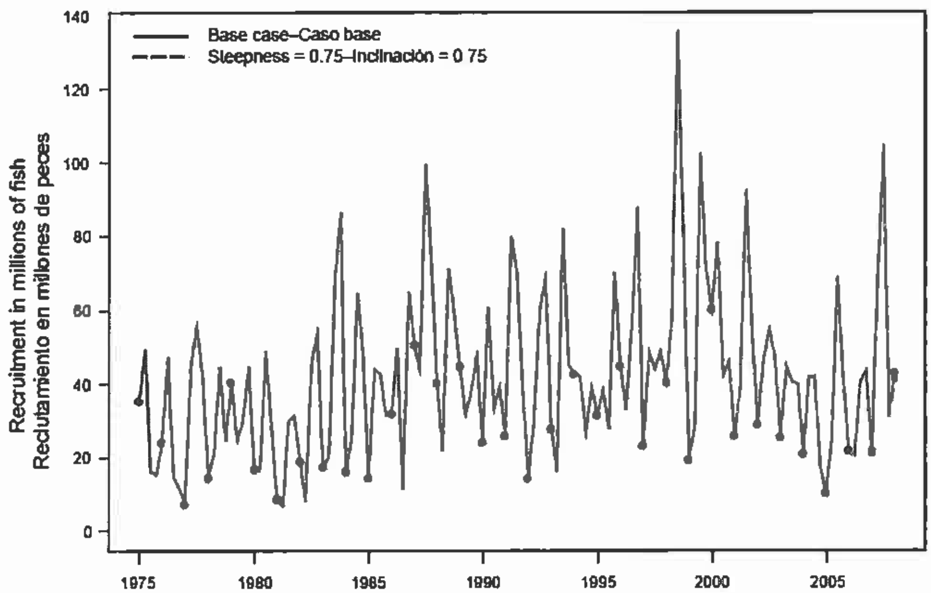


FIGURE A.2. Comparison of estimates of recruitment of yellowfin tuna from the analysis without a stock-recruitment relationship (base case) and with a stock-recruitment relationship (steepness = 0.75).
FIGURA A.2. Comparación de las estimaciones de reclutamiento de atún aleta amarilla del análisis sin relación población-reclutamiento (caso base) y con relación población-reclutamiento (inclinación = 0,75).

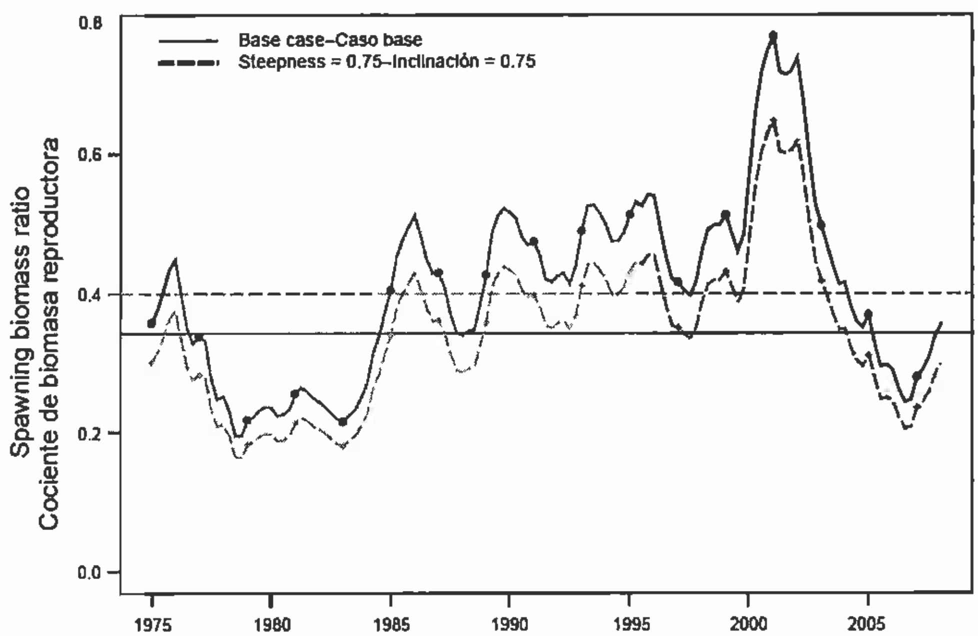


FIGURE A.3a. Comparison of estimates of the spawning biomass ratio (SBR) of yellowfin tuna from the analysis without a stock-recruitment relationship (base case) and with a stock-recruitment relationship (steepness = 0.75). The horizontal lines represent the SBRs associated with MSY for the two scenarios.
FIGURA A.3a. Comparación de las estimaciones del cociente de biomasa reproductora (SBR) de atún aleta amarilla del análisis sin (caso base) y con relación población-reclutamiento (inclinación = 0,75). Las líneas horizontales representan el SBR asociado con el RMS para los dos escenarios.

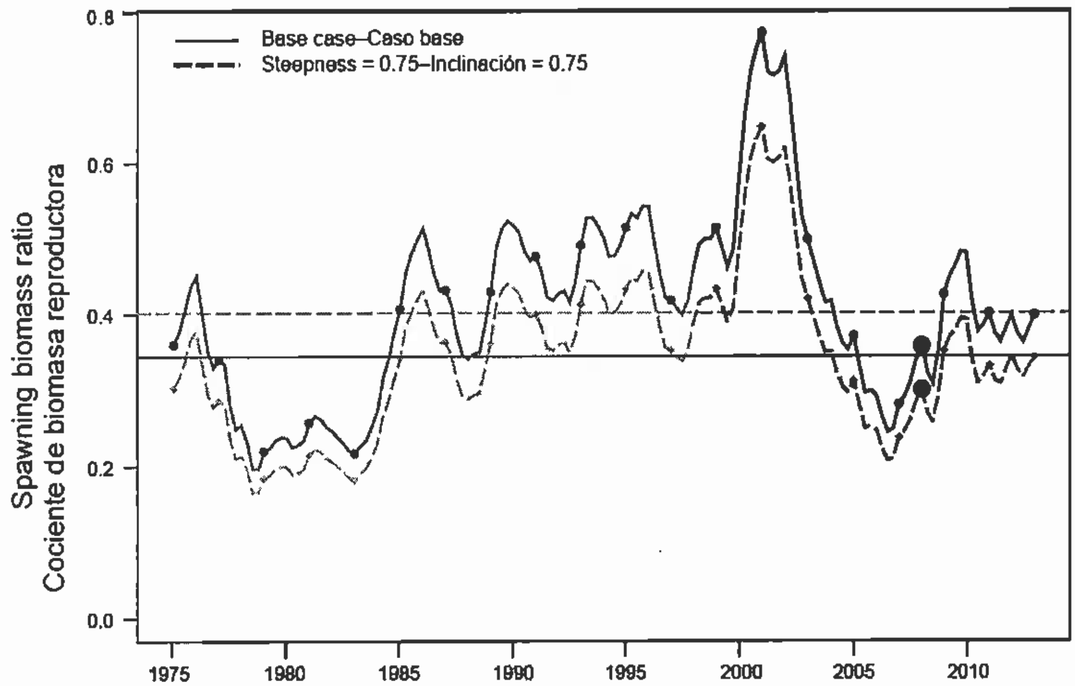


FIGURE A.3b. Comparison of estimates of the spawning biomass ratios (SBRs) projected during 2008-2013 for yellowfin tuna from the analysis without (base case) and with (steepness = 0.75) a stock-recruitment relationship. The horizontal lines represent the SBRs associated with MSY for the two scenarios.

FIGURA A.3b. Comparación de las estimaciones del cociente de biomasa reproductora (SBR) de atún aleta amarilla durante 2008-2013 del análisis sin (caso base) y con (inclinación = 0,75) una relación población-reclutamiento. Las líneas horizontales representan el SBR asociado con el RMS para los dos escenarios.

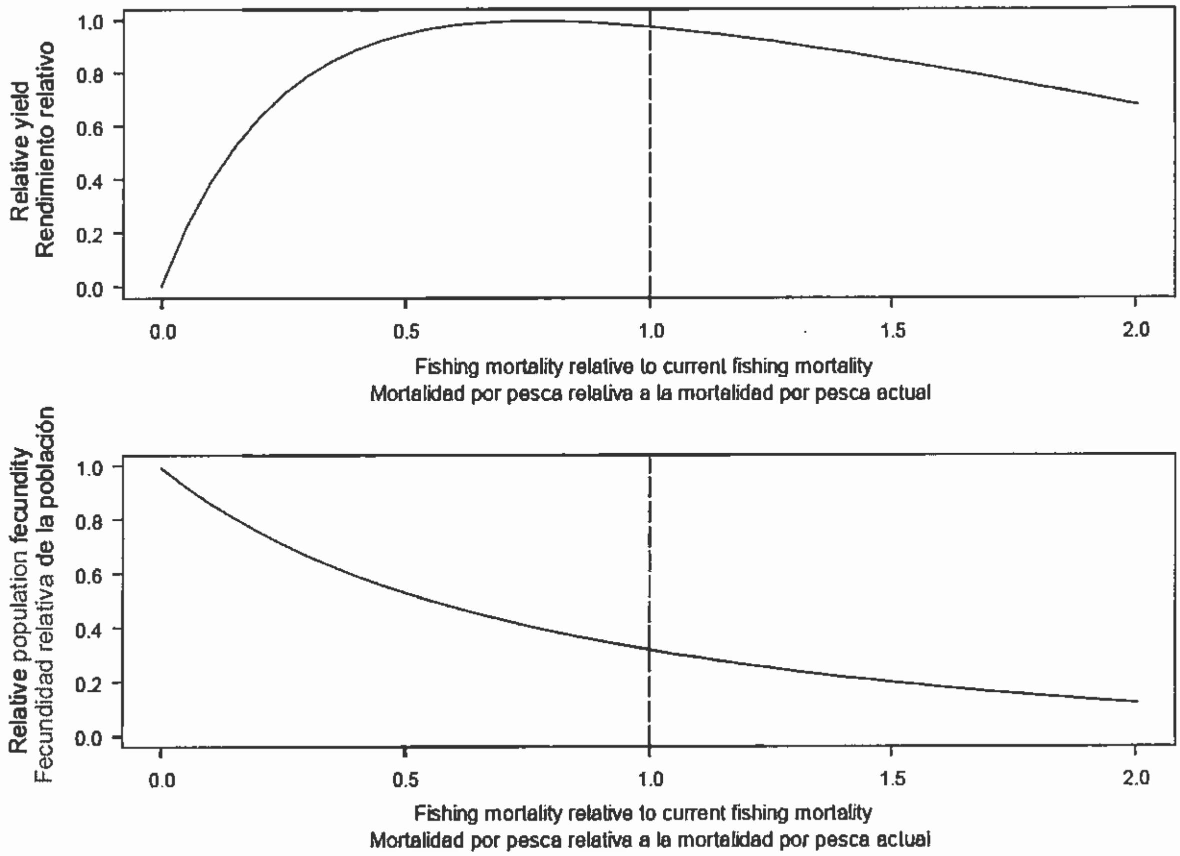


FIGURE A.4. Relative yield (upper panel) and the associated spawning biomass ratio (lower panel) of yellowfin tuna when the stock assessment model has a stock-recruitment relationship (steepness = 0.75).
FIGURA A.4. Rendimiento relativo (recuadro superior) y el cociente de biomasa reproductora asociado (recuadro inferior) de atún aleta amarilla cuando el modelo de evaluación de la población incluye una relación población-reclutamiento (inclinación = 0.75).

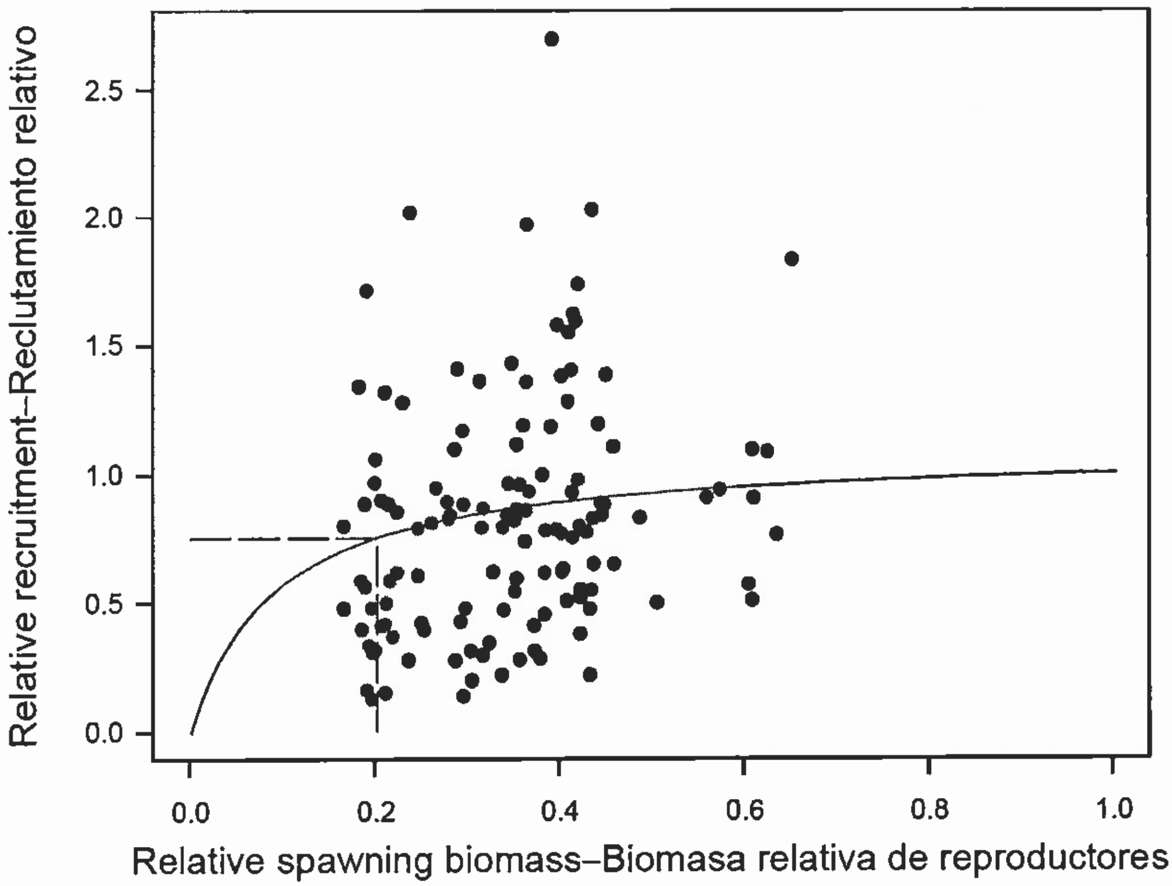


FIGURE A.5. Recruitment plotted against spawning biomass of yellowfin tuna when the analysis has a stock-recruitment relationship (steepness = 0.75).

FIGURA A.5. Reclutamiento graficado contra biomasa reproductora de atún aleta amarilla cuando el análisis incluye una relación población-reclutamiento (inclinación = 0,75).

APPENDIX B: ADDITIONAL RESULTS FROM THE BASE CASE ASSESSMENT

This appendix contains additional results from the base case assessment of yellowfin tuna in the EPO. These results are annual summaries of the age-specific estimates of abundance and total fishing mortality rates. This appendix was prepared in response to requests received during the second meeting of the Scientific Working Group.

ANEXO B: RESULTADOS ADICIONALES DE LA EVALUACION DEL CASO BASE

Este anexo contiene resultados adicionales de la evaluación de caso base del atún aleta amarilla en el OPO: resúmenes anuales de las estimaciones por edad de la abundancia y las tasas de mortalidad por pesca total. Fue preparado en respuesta a solicitudes expresadas durante la segunda reunión del Grupo de Trabajo Científico.

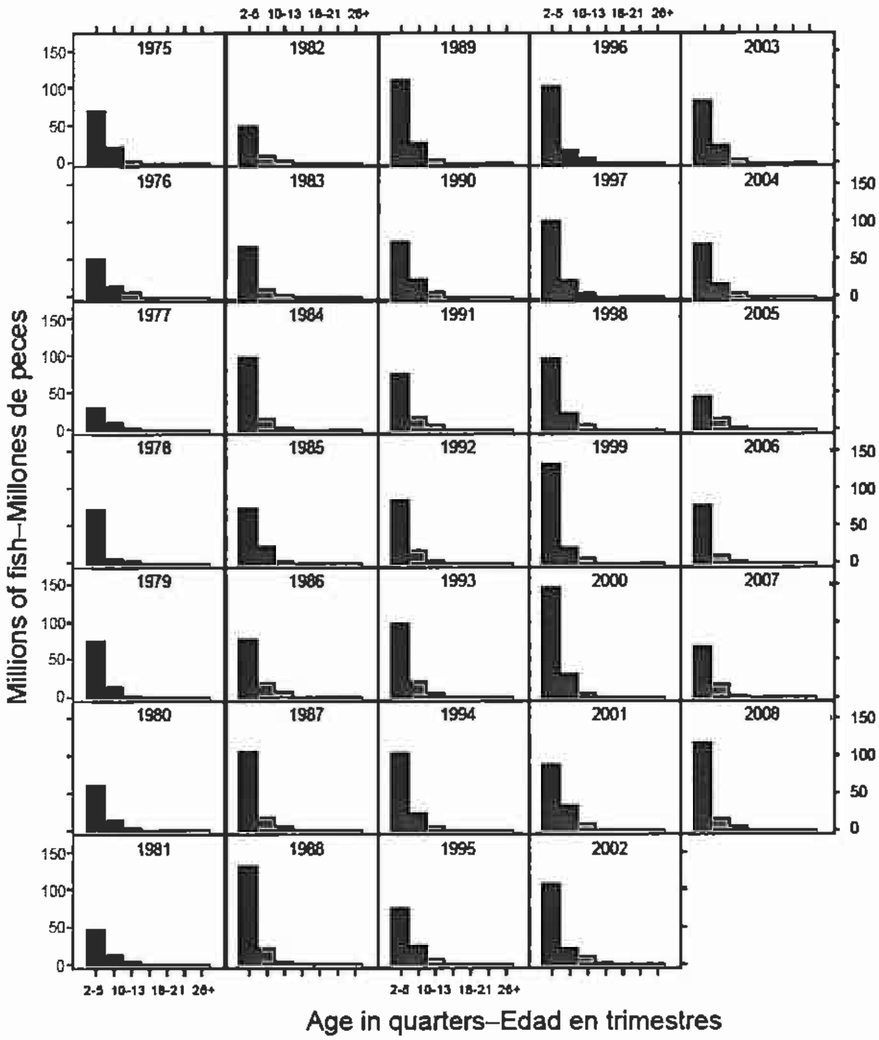


FIGURE B.1. Estimated numbers of yellowfin tuna present in the EPO on January 1 of each year.
FIGURA B.1. Número estimado de atunes aleta amarilla presentes en el OPO el 1 de enero de cada año.

TABLE B.1. Average annual fishing mortality rates for yellowfin tuna in the EPO.
TABLA B.1. Tasas de mortalidad por pesca anual media del atún aleta amarilla en el OPO.

Year	Age in quarters—Edad en trimestres						
Año	2-5	6-9	10-13	14-17	18-21	22-25	26+
1975	0.1353	0.4398	1.2080	1.9906	0.3053	0.3594	0.3593
1976	0.1958	0.4488	1.2114	1.8056	0.6246	0.7895	0.7879
1977	0.2540	0.4984	1.2176	1.7920	0.8133	0.9407	0.9420
1978	0.3561	0.6355	1.2993	2.1678	0.5187	0.5870	0.5878
1979	0.2551	0.7006	1.7628	2.6919	0.7733	0.9531	0.9523
1980	0.2148	0.5188	1.4321	2.2090	0.6212	0.6963	0.6942
1981	0.2928	0.5046	1.1953	2.0784	0.8731	1.0119	1.0091
1982	0.1658	0.4296	1.0375	2.0607	0.5970	0.6971	0.6968
1983	0.1391	0.2251	0.7750	0.8861	0.3909	0.4833	0.4827
1984	0.1122	0.2812	0.7409	0.9669	0.3646	0.4451	0.4444
1985	0.0953	0.3947	0.8816	1.2262	0.3343	0.3823	0.3823
1986	0.1336	0.4718	1.1340	1.3740	0.3101	0.3868	0.3860
1987	0.1463	0.5328	1.3005	1.1472	0.3243	0.3594	0.3601
1988	0.1969	0.5222	1.3269	1.7163	0.3983	0.4419	0.4429
1989	0.1355	0.4842	1.0610	1.7283	0.5377	0.6868	0.6856
1990	0.1455	0.4103	1.1874	1.6206	0.4803	0.5445	0.5444
1991	0.1453	0.4132	1.0383	1.3850	0.4641	0.5481	0.5471
1992	0.1580	0.4373	1.0619	1.3132	0.2933	0.3270	0.3267
1993	0.1534	0.3900	0.9575	1.3463	0.3200	0.3465	0.3473
1994	0.1150	0.3256	1.0397	1.4313	0.5007	0.5965	0.5956
1995	0.1107	0.2940	0.8658	0.9784	0.4195	0.5061	0.5043
1996	0.1361	0.3970	0.8785	1.5281	0.2452	0.2702	0.2704
1997	0.1556	0.4163	1.1710	1.9020	0.5782	0.7385	0.7364
1998	0.1686	0.4103	0.9842	1.5064	0.3671	0.4515	0.4508
1999	0.1771	0.4285	1.0702	1.8994	0.2256	0.2569	0.2570
2000	0.1095	0.3119	0.8601	1.2065	0.4805	0.5745	0.5743
2001	0.1712	0.3622	1.1377	1.4116	0.5205	0.6726	0.6706
2002	0.1451	0.4910	1.1447	1.3856	0.5699	0.7420	0.7393
2003	0.1921	0.6255	1.8508	2.4975	0.9689	1.0859	1.0878
2004	0.1643	0.5385	1.7254	3.3270	1.4271	1.8529	1.8514
2005	0.2634	0.6628	1.7725	3.6479	1.1377	1.4090	1.4067
2006	0.1545	0.5302	1.3250	2.8573	0.7217	0.9191	0.9170
2007	0.1403	0.4529	1.4326	2.0955	0.6337	0.7289	0.7278

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STATUS OF BIGEYE TUNA IN THE EASTERN PACIFIC OCEAN

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CONTENTS

1. EXECUTIVE SUMMARY

This report presents the current stock assessment of bigeye tuna (*Thunnus obesus*) in the eastern Pacific Ocean (EPO). As in the last assessment, this assessment was conducted using Stock Synthesis II (SS2; Methot 2005). The assessment reported here is based on the assumption that there is a single stock of bigeye in the EPO, and that there is no exchange of fish between the EPO and the western and central Pacific Ocean.

The stock assessment requires a substantial amount of information. Data on retained catch, discards, catch per unit of effort (CPUE), used as indices of abundance, and size compositions of the catches from several different fisheries have been analyzed. Several assumptions regarding processes such as growth, recruitment, movement, natural mortality, and fishing mortality, have also been made. Catch, CPUE, and length-frequency data for the surface fisheries have been updated to include new data for 2007 and revised data for 2003-2006. For the longline fisheries, catch has been updated to include new data for 2007. Two additional years of new CPUE data (2005-2006) are available for the longline fisheries. Updated (2002-2004) and new (2004-2006) length-frequency data are available for the Japanese longline fishery.

The base case stock assessment model assumes that there is no relationship between stock and recruitment (*i.e.*, the steepness of the stock-recruitment relationship equals 1), and includes the CPUE time series for the floating-object and the longline fisheries. A single time-block is assumed for the size-selectivities of the different fisheries. Updated natural mortality (M) schedules are used for both sexes.

Analyses were carried out to assess the sensitivity of results to: 1) a stock–recruitment relationship; 2) use of the southern longline CPUE data only; 3) using two time blocks for the size selectivities of the floating-object fisheries, separated by the implementation in 2001 of IATTC Resolution C-00-08, which prohibited discards of tunas in the EPO.

There have been important changes in the amount of fishing mortality caused by the fisheries that catch bigeye tuna in the EPO. On average, since 1993 the fishing mortality of bigeye less than about 15 quarters old has increased substantially, and that of fish more than about 15 quarters old has increased slightly. The increase in the fishing mortality of the younger fish was caused by the expansion of the fisheries that catch tuna in association with floating objects.

Over the range of spawning biomasses estimated by the base case assessment, the abundance of bigeye recruits appears to be unrelated to the spawning potential of adult females at the time of hatching.

There are several important features in the estimated time series of bigeye recruitment. First, estimates of recruitment before 1993 are very uncertain, as the floating-object fisheries were not catching significant amounts of small bigeye. There was a period of above-average recruitment in 1995-1998, followed by a period of below-average recruitment in 1999-2000. The recruitments have been above average since 2000, and were particularly large in 2005. The most recent recruitment is very uncertain, due to the fact that recently-recruited bigeye are represented in only a few length-frequency samples. The extended period of relatively large recruitments in 1995-1998 coincided with the expansion of the fisheries that catch bigeye in association with floating objects.

The biomass of 3+-quarter-old bigeye increased during 1983-1984, and reached its peak level of about 626 thousand metric tons (t) in 1986, after which it decreased to an historic low of 270 thousand t at the beginning of 2007. Spawning biomass has generally followed a trend similar to that for the biomass of 3+-quarter-olds, but lagged by 1-2 years. There is uncertainty in the estimated biomasses of both 3+-quarter-old bigeye and spawners. Nevertheless, it is apparent that fishing has reduced the total biomass of bigeye in the EPO. The biomasses of both 3+-quarter-old fish and spawners were estimated to have increased slightly in recent years.

The estimates of recruitment and biomass are only moderately sensitive to the steepness of the stock-recruitment relationship. Specifically, the estimates of biomass are greater than in the base case assessment, but the trends are similar. The recruitment time series is similar to that of the base case assessment.

When only the CPUE for the southern longline fishery was used, the estimates of biomass are greater than in the base case, but the trends are similar. The recruitment time series is very similar to that of the base case assessment. The recruitment estimates, however, are slightly different in 2007, for which CPUE data for the southern longline fishery are not available.

When two time blocks were applied to the size selectivity of the floating object fisheries, the estimated biomasses and recruitment estimates were very similar to those obtained for the base case assessment.

At the beginning of January 2008, the spawning biomass of bigeye tuna in the EPO was near the historic low level. At that time the spawning biomass ratio (the ratio of the spawning biomass at that time to that of the unfished stock; SBR) was about 0.17, which is about 10% less than the level corresponding to the maximum sustainable yield (MSY).

Recent catches are estimated to have been about the MSY level. If fishing mortality (F) is proportional to fishing effort, and the current patterns of age-specific selectivity are maintained, the level of fishing effort corresponding to the MSY is about 82% of the current (2005-2007) level of effort. The MSY 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 because it catches larger individuals that are close to the critical weight. Before the expansion of the floating-object fishery that began in 1993, the MSY was greater than the current MSY and the fishing mortality was less than F_{MSY}.

All four scenarios considered suggest that, at the beginning of 2008, the spawning biomass (S) was below S_{MSY}. 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, but under all scenarios considered, fishing mortality is well above F_{MSY}.

Recent spikes in recruitment are predicted to result in increased levels of SBR and longline catches for the next few years. However, high levels of fishing mortality are expected to subsequently reduce the SBR. Under current effort levels, the population is unlikely to remain at levels that support MSY unless fishing mortality levels are greatly reduced or recruitment is above average for several consecutive years.

The effects of IATTC Resolution C-04-09, adopted in 2004, and C-06-02, adopted in 2006, are estimated to be insufficient to allow the stock to remain at levels that would support the MSY.

These simulations are based on the assumption that selectivity and catchability patterns will not change in the future. Changes in targeting practices or increasing catchability of bigeye as abundance declines (*e.g.* density-dependent catchability) could result in differences from the outcomes predicted here.

2. DATA

Catch, effort, and size-composition data for January 1975 through December 2007 were used to conduct the stock assessment of bigeye tuna, *Thunnus obesus*, in the eastern Pacific Ocean (EPO). The data for 2007, which are preliminary, include records that had been entered into the IATTC databases as of mid-March 2008. All data are summarized and analyzed on a quarterly basis.

2.1. Definitions of the fisheries

Fifteen fisheries are defined for the stock assessment of bigeye tuna. These fisheries are defined on the basis of gear type (purse seine, pole and line, and longline), purse-seine set type (on floating objects, unassociated schools, and dolphins), time period, IATTC length-frequency sampling area or latitude, and unit of longline catch (numbers caught or catch in weight).

The bigeye fisheries are defined in Table 2.1, and the spatial extent of each fishery and the boundaries of the length-frequency sampling areas are shown in Figure 2.1.

In general, fisheries are defined so that, over time, there is little change in the average size composition of the catch. Fishery definitions for purse-seine sets on floating objects are also stratified to provide a rough distinction between sets made mostly on flotsam (Fishery 1), sets made mostly on fish-aggregating devices (FADs) (Fisheries 2-3, 5, 10-11, and 13), and sets made on a mixture of flotsam and FADs (Fisheries 4 and 12). It is assumed that it is appropriate to pool data relating to catches by pole-and-line gear and by purse-seine vessels setting on dolphins and unassociated schools (Fisheries 6 and 7). Relatively few bigeye are captured by the first two methods, and the data from Fisheries 6 and 7 are dominated by information on catches from unassociated schools of bigeye. Given this latter fact, Fisheries 6 and 7 will be referred to as fisheries that catch bigeye in unassociated schools in the remainder of this report.

In previous assessments, two longline fisheries with catch data in numbers were assumed (Fisheries 8 and 9). However, the catch data reported by the longline fisheries are a mixture of catch in numbers and weight records. Since SS2 has the flexibility of including catch data in either numbers or weight, two additional longline fisheries that report catch in weight were defined (Fisheries 14 and 15).

2.2. Catch

To conduct the stock assessment of bigeye tuna, the catch and effort data in the IATTC databases are stratified according to the fishery definitions described in Section 2.1 and presented in Table 2.1. The three definitions relating to catch data used in previous reports (landings, discards, and catch) are described by Maunder and Watters (2001). The terminology in this report is consistent with the standard terminology used in other IATTC reports. Catches taken in a given year are assigned to that year even if they were not landed until the following year. Catches are assigned to two categories, retained catches and discards. Throughout the document the term "catch" will be used to reflect either total catch (discards plus retained catch) or retained catch, and the reader is referred to the context to determine the appropriate definition.

Three types of catch data are used to assess the stock of bigeye tuna (Table 2.1). Removals by Fisheries 1 and 8-9 are simply retained catch. Removals by Fisheries 2-5 and 7 are retained catch, plus some discards resulting from inefficiencies in the fishing process (see Section 2.2.3). Removals by Fisheries 10-13 are discards resulting only from sorting the catch taken by Fisheries 2-5 (see Section 2.2.1).

Updated and new catch data for the surface fisheries (Fisheries 1-7 and 10-13) have been incorporated into the current assessment. The species-composition method (Tomlinson 2002) was used to estimate catches of the surface fisheries. We calculated average scaling factors for 2000-2007 by dividing the total catch for all years and quarters for the species composition estimates by the total catch for all years and quarters for the standard estimates and applied these to the cannery and unloading estimates for 1975-1999. For Fisheries 1, 6, and 7 we used the average over Fisheries 2-5, for Fisheries 2 and 3 we used the average over Fisheries 2 and 3, and for Fisheries 4 and 5 we used the average over Fisheries 4 and 5. Harley and Maunder (2005) provide a sensitivity analysis that compares the results from the stock assessment using the species composition estimates of purse-seine fishery landings with the results from the stock assessment using cannery unloading estimates. Watters and Maunder (2001) provide a brief description of the method that is used to estimate surface fishing effort.

New or updated catch data for the longline fisheries (Fisheries 8–9 and 14-15) are available for Chinese Taipei (2004-2006) and Japan (2003-2006). Catch data for 2007 are available for Chinese Taipei, the Peoples Republic of China, the Republic of Korea, Japan, the United States, and Vanuatu from the monthly reporting statistics.

Trends in the catches of bigeye tuna taken from the EPO during each year of the 1975-2007 period are shown in Figure 2.2. There has been substantial annual variation in the catches of bigeye by all fisheries operating in the EPO (Figure 2.2). Prior to 1996, the longline fleet (Fisheries 8-9 and 14-15) removed more bigeye (in weight) from the EPO than did the surface fleet (Fisheries 1-7 and 10-13) (Figure 2.2). Since 1996, however, the catches by the surface fleet have mostly been greater than those by the longline fleet (Figure 2.2). It should be noted that the assessment presented in this report uses data starting from 1 January, 1975, and substantial amounts of bigeye were already being removed from the EPO by that time.

2.2.1. Discards

For the purposes of stock assessment, it is assumed that bigeye tuna are discarded from the catches made by purse-seine vessels for one of two reasons: inefficiencies in the fishing process (*e.g.* when the catch from a set exceeds the remaining storage capacity of the fishing vessel) or because the fishermen sort the catch to select fish that are larger than a certain size. In either case, the amount of discarded bigeye is estimated with information collected by IATTC or national observers, applying methods described by Maunder and Watters (2003). Regardless of why bigeye are discarded, it is assumed that all discarded fish die.

Estimates of discards resulting from inefficiencies in the fishing process are added to the retained catches made by purse-seine vessels (Table 2.1). No observer data are available to estimate discards for surface fisheries that operated prior to 1993 (Fisheries 1 and 6), and it is assumed that there were no discards from these fisheries. For surface fisheries that have operated since 1993 (Fisheries 2-5 and 7), there are periods for which observer data are not sufficient to estimate the discards. For these periods, it is assumed that the discard rate (discards/retained catches) is equal to the discard rate for the same quarter of the previous year or, if not available, the closest year.

Discards that result from the process of sorting the catch are treated as separate fisheries (Fisheries 10-13), and the catches taken by these fisheries are assumed to be composed only of fish that are 2-4 quarters old (Maunder and Hoyle 2007). Watters and Maunder (2001) provide a rationale for treating such discards as separate fisheries. Estimates of the amounts of fish discarded during sorting are made only for fisheries that take bigeye associated with floating objects (Fisheries 2-5) because sorting is thought to be infrequent in the other purse-seine fisheries.

Time series of discards as proportions of the retained catches for the surface fisheries that catch bigeye tuna in association with floating objects are shown in Figure 2.3. For the largest floating-object fisheries (2, 3, and 5), the proportions of the catches discarded have been low for the last seven years relative to those observed during fishing on the strong cohorts produced in 1997. There is strong evidence that some of this is due to the weak year classes after 1997. However, there have been large recruitments since 1997 (Figure 4.5). It is possible that regulations prohibiting discarding of tuna have caused the proportion of discarded fish to decrease.

It is assumed that bigeye tuna are not discarded from longline fisheries (Fisheries 8-9 and 14-15).

2.3. Indices of abundance

Indices of abundance were derived from purse-seine and longline catch and effort data. Fishing effort data for the surface fisheries (Fisheries 1-7 and 10-13) have been updated and new data included for 2007. New or updated catch and effort data are available for the Japanese longline fisheries (2003-2006). Trends in the amount of fishing effort exerted by the 15 fisheries defined for the stock assessment of bigeye tuna in the EPO are shown in Figure 2.4. Fishing effort for surface gears is in days of fishing, and that for longliners (Fisheries 8-9 and 14-15) is in standardized hooks.

The CPUE for the purse-seine fisheries was calculated as catch divided by number of days fished. The number of days fished by set type was calculated from the number of sets, using a multiple regression of total days fished against number of sets by set type (Maunder and Watters, 2001).

Estimates of standardized catch per unit effort (1975-2006) were obtained for the longline fisheries (Fisheries 8 and 9). A delta-lognormal general linear model, in which the explanatory variables were latitude, longitude, and hooks per basket, was used (Hoyle and Maunder 2006).

The nominal CPUE time series for the different fisheries are presented in Figure 2.5. The indices of abundance that were considered appropriate for use in the assessment were those from Fisheries 2, 3, and 5 (purse-seine sets on floating objects) and 8 and 9 (longline fisheries). The fisheries excluded were considered inappropriate because the catch rates were extremely low. In addition, the first two years of the purse-seine fisheries were excluded because these fisheries were still expanding. Observations with few effort data were also excluded.

2.4. Size composition data

New length-frequency data for 2007 and updated data for previous years are available for the surface fisheries. New or updated length-frequency data are available for the Japanese longline fleet are available (2002-2004). Size composition data for the other longline fleets are not used in the assessment.

The fisheries of the EPO catch bigeye tuna of various sizes. The average size compositions of the catches from each fishery defined in Table 2.1 have been described in previous assessments. The fisheries that catch bigeye associated with floating objects typically catch small (<75 cm) and medium-sized (75 to 125 cm) bigeye (Figures 2.6a-i, Fisheries 1-5). Prior to 1993, the catch of small bigeye was roughly equal to that of medium-sized bigeye (Figure 2.6a , Fishery 1). Since 1993, however, small bigeye from fisheries that catch bigeye in association with floating objects have dominated the catches (Figures 2.6b-e, Fisheries 2-5). An exception is the 1999-2002 period, when a strong cohort moved through the fishery and large fish dominated the catch.

Prior to 1990, mostly medium-sized bigeye were captured in unassociated schools (Figure 2.6f, Fishery 6). Since 1990, more small and large (>125 cm long) bigeye have been captured in unassociated schools (Figure 2.6g, Fishery 7). The catches taken by the two longline fisheries (Fisheries 8 and 9) have distinctly different size compositions. In the area north of 15°N (Fishery 8), longliners catch mostly medium-sized fish, and the average size composition has two distinct peaks (these appear as bands at 80 cm and 120 cm in Figure 2.6h). In the area south of 15°N (Fishery 9), longliners catch substantial numbers of both medium-sized and large bigeye (Figure 2.6i). However, there appears to have been a transition from medium to large fish in about 1984.

The length-frequency data for the Chinese Taipei fleet include more smaller fish than those for the Japanese fleet. However, there is concern about the representativeness of the length-frequency samples from the Chinese Taipei fleet (Stocker 2005, Anonymous 2006). Maunder and Hoyle (2007) conducted a sensitivity analysis, using the Chinese Taipei fleet as a separate fishery.

3. ASSUMPTIONS AND PARAMETERS

3.1. Biological and demographic information

3.1.1. Growth

Schaefer and Fuller (2006) used both tag-recapture data and otolith daily increments to estimate growth curves for bigeye tuna in the EPO. The two data sources provided similar estimates, with an apparent bias in the tagging data, which is hypothesized to be due to shrinkage because the recaptured bigeye tuna were measured at unloading (after they had been stored frozen). The growth curve estimated by Schaefer and Fuller (2006) is substantially different from the growth curves used in previous assessments (Figure 3.1). In particular, it shows growth to be approximately linear, and produces larger fish for a given age. The asymptotic length of the von Bertalanffy growth curve estimated by Schaefer and Fuller (2006) is much greater than any length recorded. This is reasonable as long as no biological meaning is given to the asymptotic length parameter and that the model is used only as a representation of the ages of fish that they sampled. The maximum age of the bigeye tuna in their data set is around 4 years (16 quarters) and their von Bertalanffy growth curve is not considered appropriate for ages greater than this. Maunder and Hoyle (2006) fit a Richards growth curve, using a lognormal likelihood function with constant variance and the asymptotic length parameter set at about the length of the largest-sized bigeye in the data (186.5

cm). Maunder and Hoyle (2007) used the resulting growth curve as a prior for all ages in the stock assessment. This growth curve is also used to convert the other biological parameters to age from length and for the estimation of natural mortality.

Previous assessments (*e.g.* Harley and Maunder 2005), the EPO yellowfin tuna assessments (*e.g.* Maunder 2002), and tuna assessments in the western and central Pacific Ocean (Lehodey *et al.* 1999; Hampton and Fournier 2001a, 2001b) suggest that the growth of younger tuna does not follow a von Bertalanffy growth curve. However, this observation may be a consequence of length-specific selectivity for small fish.

The length at age used in the assessment model is based on the von Bertalanffy growth curve. The parameters of the growth curve were estimated by obtaining the best correspondence of length at age used by Maunder and Hoyle (2007).

Hampton and Maunder (2005) found that the results of the stock assessment are very sensitive to the assumed value for the asymptotic length parameter. Therefore, Maunder and Hoyle (2007) conducted sensitivity analyses to investigate the influence of the assumed value of that parameter. A lower value of 171.5 cm, which is around the value estimated by stock assessments for the western and central Pacific Ocean (Adam Langley, Secretariat of the Pacific Community, pers. com.), and an upper value of 201.5 cm were investigated. A sensitivity analysis of the bigeye assessment to these same two values was also conducted by Aires-da-Silva and Maunder (2007). A lesser value of the asymptotic length parameter produced greater biomasses and recruitments.

Another important component of growth used in age-structured statistical catch-at-length models is the variation in length at age. Age-length information contains information about variation of length at age, in addition to information about mean length at age. Variation in length at age was taken from the previous assessment. A sensitivity analysis that estimated mean length and variation of length at age by integrating age-length data from otolith readings (Schaefer and Fuller 2006) in the assessment model was conducted.

The following weight-length relationship, from Nakamura and Uchiyama (1966), was used to convert lengths to weights in the current stock assessment:

$$w = 3.661 \times 10^{-5} \cdot l^{2.90182}$$

where w = weight in kilograms and l = length in centimeters.

3.1.2. Natural mortality

Age-specific vectors of natural mortality (M) are assumed for bigeye. This assessment uses a sex-specific model and therefore natural mortality schedules are provided for each sex (Figure 3.2). The previous stock assessment assumes constant natural mortality (M = 0.1) for fish 0-4 quarters old (Aires-da-Silva and Maunder 2007). New features have been implemented in SS2 which provide more flexibility in the treatment of natural mortality. As a result, a higher natural mortality estimate (M = 0.25) is assumed for fish of both sexes 0 quarters old, decreasing to 0.1 at 5 quarters of age. As in the previous assessment, it is assumed that the natural mortality of females increases after they mature. These age-specific vectors of natural mortality are based on fitting to age-specific proportions of females, maturity at age, and natural mortality estimates of Hampton (2000).

The previous observation that different levels of natural mortality had a large influence on the absolute population size and the population size relative to that corresponding to the maximum sustainable yield (MSY) (Watters and Maunder 2001) is retained. Harley and Maunder (2005) performed a sensitivity analysis to assess the effect of increasing natural mortality for bigeye younger than 10 quarters.

3.1.3. Recruitment and reproduction

It is assumed that bigeye tuna can be recruited to the fishable population during every quarter of the year.

Recruitment may occur continuously throughout the year, because individual fish can spawn almost every day if the water temperatures are in the appropriate range (Kume 1967; Schaefer *et al.* 2005).

SS2 allows a Beverton-Holt (1957) stock-recruitment relationship to be specified. The Beverton-Holt curve is parameterized so that the relationship between spawning biomass (biomass of mature females) and recruitment is determined by estimating the average recruitment produced by an unexploited population (virgin recruitment), a parameter called steepness. Steepness controls how quickly recruitment decreases when the spawning biomass is reduced. It is defined as the fraction of virgin recruitment that is produced if the spawning biomass is reduced to 20% of its unexploited level. Steepness can vary between 0.2 (in which case recruitment is a linear function of spawning biomass) and 1.0 (in which case recruitment is independent of spawning biomass). In practice, it is often difficult to estimate steepness because of a lack of contrast in spawning biomass and because there are other factors (*e.g.* environmental influences) that can cause recruitment to be extremely variable. For the current assessment, recruitment is assumed to be independent of stock size (steepness = 1). There is no evidence that recruitment is related to spawning stock size for bigeye in the EPO and, if steepness is estimated as a free parameter, it is estimated to be close to 1. We also present a sensitivity analysis with steepness = 0.75. In addition to the assumptions required for the stock-recruitment relationship, a constraint on quarterly recruitment deviates with a standard deviation of 0.6 is applied.

Reproductive inputs are based on the results of Schaefer *et al.* (2005) and data provided by Dr. N. Miyabe of the National Research Institute of Far Seas Fisheries (NRIFSF) of Japan. Information on age-at-length (Schaefer and Fuller 2006) was used to convert fecundity and proportion mature at length into ages (Figure 3.3, Table 3.1).

3.1.4. Movement

The current assessment does not consider movement explicitly. Rather, it is assumed that the population is randomly mixed at the beginning of each quarter of the year. The IATTC staff is studying the movement of bigeye within the EPO, using data recently collected from conventional and archival tags, and these studies indicate substantial levels of regional fidelity of bigeye within the EPO. The results of these studies may eventually provide information useful for stock assessment. . A spatially-structured framework will be considered in future stock assessments.

3.1.5. Stock structure

Document SARM-9-08 provides an overview of current knowledge about the stock structure of bigeye in the EPO. The results of tagging studies indicate regional fidelity of the species in the region, and suggest a very low level of mixing between the eastern and the western Pacific (Schaefer and Fuller 2002; Schaefer and Fuller 2008). Accordingly, and for the purposes of the current stock assessment, it is assumed that there are two stocks, one in the EPO and the other in the western and central Pacific, and that there is no net exchange of fish between these regions. The IATTC staff currently conducts a Pacific-wide assessment of bigeye in collaboration with scientists of the Oceanic Fisheries Programme of the Secretariat of the Pacific Community, and of the NRIFSF. This work may help indicate how the assumption of a single stock in the EPO is likely to affect interpretation of the results obtained from the SS2 method. Recent analyses (Hampton *et al.* 2003) that estimate movement rates within the Pacific Ocean provided biomass trends very similar to those estimated by Harley and Maunder (2004).

3.2. Environmental influences

Oceanographic conditions might influence the recruitment of bigeye tuna to fisheries in the EPO. In previous assessments (*e.g.* Watters and Maunder 2001), zonal-velocity anomalies (velocity anomalies in the east-west direction) at 240 m depth and in an area from 8°N to 15°S and 100° to 150°W were used as the candidate environmental variable for affecting recruitment. The zonal-velocity anomalies were estimated from the hindcast results of a general circulation model obtained at http://ingrid.ldeo.columbia.edu/. Maunder and Hoyle (2007) conducted a sensitivity analysis to investigate the relationship between recruitment and the El Niño index; this showed that there was a significant negative relationship, but it explained only a small proportion of the total variability in the recruitment.

In previous assessments (Watters and Maunder 2001, 2002; Maunder and Harley 2002) it was assumed that oceanographic conditions might influence the efficiency of the fisheries that catch bigeye associated with floating objects (Fisheries 1-5). In the assessment of Maunder and Harley (2002), an environmental influence on catchability was assumed for Fishery 3 only. It was found that including this effect did not greatly improve the results, and no environmental influences on catchability have been considered in this assessment.

4. STOCK ASSESSMENT

The SS2 method was first used to assess the status of bigeye tuna in the EPO by Aires-da-Silva and Maunder (2007). It consists of a size-based, age-structured, integrated (fitted to many different types of data) statistical stock assessment model.

The model is fitted to the observed data (indices of relative abundance and size compositions) by finding a set of population dynamics and fishing parameters that maximize a penalized likelihood, given the amount of catch taken by each fishery. Many aspects of the underlying assumptions of the model are described in Section 3. It also includes the following important assumptions:

1. Bigeye tuna are recruited to the discard fisheries (Fisheries 10-13) one quarter after hatching, and these discard fisheries catch only fish of the first few age classes.
2. As bigeye tuna age, they become more vulnerable to longlining in the area south of 15°N (Fisheries 9 and 14) and Fishery 7, and the oldest fish are the most vulnerable to these gears.
3. The data for fisheries that catch bigeye tuna from unassociated schools (Fisheries 6 and 7), the pre-1993 and coastal floating-object fisheries (Fisheries 1 and 4), and fisheries whose catch is composed of the discards from sorting (Fisheries 10-13) provide relatively little information about biomass levels, because they do not direct their effort at bigeye. For this reason, the CPUE time series for these fisheries were not used as indices of abundance.

The following parameters have been estimated in the current stock assessment of bigeye tuna from the EPO:

1. recruitment in every quarter from the first quarter of 1975 through the fourth quarter of 2007 (includes estimation of virgin recruitment and temporal recruitment anomalies);
2. catchability coefficients for the five CPUE time series that are used as indices of abundance;
3. selectivity curves for 9 of the 15 fisheries (Fisheries 10-13 have an assumed selectivity curve, and the selectivities of Fisheries 14 and 15 are the same as those of Fisheries 8 and 9, respectively);
4. initial population size and age structure.

The parameters in the following list are assumed to be known for the current stock assessment of bigeye in the EPO:

1. sex- and age-specific natural mortality rates (Figure 3.2);
2. age-specific maturity curve (Table 3.1 and Figure 3.3);
3. selectivity curves for the discard fisheries (Fisheries 10-13);
4. the steepness of the stock-recruitment relationship;
5. mean length at age (Section 3.1.1., Figure 3.1);
6. parameters of a linear model relating the standard deviations in length at age to the mean lengths

at age.

The estimates of management quantities and future projections were computed based on 3-year average harvest (exploitation) rates, by gear, for 2005-2007. The sensitivity of estimates of key management quantities to including the last year (2007) in the 3-year average harvest rate estimate was tested. For this purpose, a 2-year (2005-2006) average harvest rate was used in the calculations.

There is uncertainty in the results of the current stock assessment. This uncertainty arises because the observed data do not perfectly represent the population of bigeye tuna in the EPO. Also, the stock assessment model may not perfectly represent the dynamics of the bigeye population or of the fisheries that operate in the EPO. Uncertainty is expressed as approximate confidence intervals and coefficients of variation (CVs). The confidence intervals and CVs have been estimated under the assumption that the stock assessment model perfectly represents the dynamics of the system. Since it is unlikely that this assumption is satisfied, these values may underestimate the amount of uncertainty in the results of the current assessment.

4.1. Assessment results

Below we describe the important aspects of the base case assessment (1 below) and the three sensitivity analyses (2-4):

1. Base case assessment: steepness of the stock-recruitment relationship equals 1 (no relationship between stock and recruitment), CPUE time series for the floating-object Fisheries 2-5 and the longline Fisheries 8-9, time-invariant size selectivities for the different fisheries (a single time-block).
2. Sensitivity to the steepness of the stock-recruitment relationship. The base case assessment included an assumption that recruitment was independent of stock size, and a Beverton-Holt (1957) stock-recruitment relationship with a steepness of 0.75 was used for the sensitivity analysis.
3. Sensitivity to the indices of abundance. The base case assessment included the CPUE time series for Fisheries 2, 3, and 5 (purse-seine sets on floating objects) and 8 and 9 (longline fisheries). A sensitivity analysis of the assessment results to the use of only the standardized CPUE for Fishery 9 was conducted. Standardized CPUE for Fishery 8 was not included, due to the seasonal nature of this fishery.
4. Sensitivity to assuming two time blocks for the size selectivities of the floating-object Fisheries 2-5. A requirement that purse-seine vessels retain all catches of tuna, originally introduced in IATTC Resolution C-00-08, has been in force since 2001 This could have resulted in changes in the selectivity of the retained catches of these fisheries, particularly for smaller fish, which might not have been observed in the size samples taken before the Resolution. Accordingly, two selectivity time blocks were considered: pre-Resolution (1975-2000) and post-Resolution (2001-present). The selectivity patterns of the discard Fisheries (10-13) remained unchanged in this analysis.

The results presented in the following sections are likely to change in future assessments because (1) future data may provide evidence contrary to these results, and (2) the assumptions and constraints used in the assessment model may change. Future changes are most likely to affect absolute estimates of biomass, recruitment, and fishing mortality.

4.1.1. Fishing mortality

There have been important changes in the amount of fishing mortality on bigeye tuna in the EPO. On average, the fishing mortality on fish less than about 15 quarters old has increased since 1993, and that on fish more than about 15 quarters old has increased slightly since then (Figure 4.1). The increase in average fishing mortality on younger fish can be attributed to the expansion of the fisheries that catch bigeye in association with floating objects. These fisheries (Fisheries 2-5) catch substantial amounts of bigeye (Figure 2.2), select fish that are generally less than about 100 cm in length (Figure 4.2), and have expended a relatively large amount of fishing effort since 1993 (Figure 2.4).

Temporal trends in the age-specific amounts of annual fishing mortality on bigeye tuna are shown in Figure 4.3. These trends reflect the distribution of fishing effort among the various fisheries that catch bigeye (see Figure 2.4) and changes in catchability. The trend in annual fishing mortality rate by time shows that fishing mortality has increased greatly for young fish and only slightly for older fish since about 1993. An annual summary of the estimates of total fishing mortality is presented in Appendix D (Table D.1).

4.1.2. Recruitment

Previous assessments found that abundance of bigeye tuna being recruited to the fisheries in the EPO appeared to be related to zonal-velocity anomalies at 240 m during the time that these fish are assumed to have hatched (Watters and Maunder 2002). The mechanism that is responsible for this relationship has not been identified, and correlations between recruitment and environmental indices are often spurious, so the relationship between zonal-velocity and bigeye recruitment should be viewed with skepticism. Nevertheless, this relationship tends to indicate that bigeye recruitment is increased by strong El Niño events and decreased by strong La Niña events. Analyses in which no environmental indices were included produced estimates of recruitment similar to those that used zonal velocity (Harley and Maunder 2004). This suggests that there is sufficient information in the length-frequency data to estimate most historical year-class strengths, but the index may be useful for reducing uncertainty in estimates of the strengths of the most recent cohorts, for which few size-composition samples are available. A previous sensitivity analysis to the effect of including the environmental index showed that the index was not statistically significant (Maunder and Hoyle 2006), or explained only a small proportion of the total variation in recruitment (Maunder and Hoyle 2007). Therefore, no environmental index was included in the analysis.

Over the range of estimated spawning biomasses shown in Figure 4.7, the abundance of bigeye recruits appears to be unrelated to the spawning biomass of adult females at the time of hatching (Figure 4.4). Previous assessments of bigeye in the EPO (*e.g.* Watters and Maunder 2001, 2002) also failed to show a relationship between adult biomass and recruitment over the estimated range of spawning biomasses. The base case estimate of steepness is fixed at 1, which produces a model with a weak assumption that recruitment is independent of stock size. The consequences of overestimating steepness, in terms of lost yield and potential for recruitment overfishing, are far worse than those of underestimating it (Harley *et al.* unpublished analysis). A sensitivity analysis is presented in Appendix B that assumes that recruitment is moderately related to stock size (steepness = 0.75).

The time series of estimated recruitment of bigeye is shown in Figure 4.5, and the total recruitment estimated to occur during each year is presented in Table 4.1. There are several important features in the time series of estimated recruitment of bigeye. First, estimates of recruitment before 1993 are very uncertain, as the techniques for catching small bigeye associated with floating-objects were not in use. There was a period of above-average recruitment in 1994-1998, followed by a period of below-average recruitment in 1999-2000. The recruitments have been above average since 2001, and were particularly large in 2005 and 2006. The recent recruitment estimates are very uncertain, due to the fact that recently-recruited bigeye are represented in only a few length-frequency data sets. The extended period of relatively large recruitments in 1994-1998 coincided with the expansion of the fisheries that catch bigeye in association with floating objects.

4.1.3. Biomass

Trends in the biomass of 3+-quarter-old bigeye tuna in the EPO are shown in Figure 4.6, and estimates of the biomass at the beginning of each year are presented in Table 4.1. The biomass of 3+-quarter-old bigeye increased during 1983-1984, and reached its peak level of about 626,000 t in 1986, after which it decreased to an historic low of about 270,000 t at the beginning of 2007.

The trend in spawning biomass is also shown in Figure 4.7, and estimates of the spawning biomass at the beginning of each year are presented in Table 4.1. The spawning biomass has generally followed a trend similar to that for the biomass of 3+-quarter-old bigeye, but with a 1- to 2-year time lag. The biomasses of both 3+-quarter-old fish and spawners were estimated to have increased slightly in recent years.

There is uncertainty in the estimated biomasses of spawners. The average CV of the spawning biomass estimates is 0.15.

Given the amount of uncertainty in the estimates of both biomass and recruitment (Sections 4.1.2 and 4.1.3), it is difficult to determine whether trends in the biomass of bigeye have been influenced more by variation in fishing mortality or recruitment. Nevertheless, the assessment suggests two conclusions. First, it is apparent that fishing has reduced the total biomass of bigeye present in the EPO. This conclusion is drawn from the results of a simulation in which the biomass of bigeye tuna estimated to be present in the EPO if fishing had not occurred was projected, using the time series of estimated recruitment anomalies, and the estimated environmental effect, in the absence of fishing. The simulated biomass estimates are always greater than the biomass estimates from the base case assessment (Figure 4.8). Second, the biomass of bigeye can be substantially increased by strong recruitment events. Both peaks in the biomass of 3+-quarter-old bigeye (1986 and 2000; Figure 4.6) were preceded by peak levels of recruitment (1982-1983 and 1997-1998, respectively; Figure 4.5) as is the recent slight increase in biomass.

To estimate the impact that different fisheries have had on the depletion of the stock, we ran simulations in which each gear was excluded and the model was run forward as is done in the no-fishing simulation. The results of this analysis are also provided in Figure 4.8. It is clear that the longline fishery had the greatest impact on the stock prior to 1995, but with the decrease in effort by the longline fisheries, and the expansion of the floating-object fishery, at present the impact of the purse-seine fishery on the population is far greater than that of the longline fishery. The discarding of small bigeye has a small, but detectable, impact on the depletion of the stock. Overall the spawning biomass is estimated to be about 17% of that expected had no fishing occurred.

4.1.4. Average weights of fish in the catch

Trends in the average weights of bigeye captured by the fisheries that operate in the EPO are shown in Figure 4.9. The fisheries that catch bigeye in association with floating objects (Fisheries 1-5) have taken mostly small fish that, on average, weigh less than the critical weight, which indicates that these fisheries do not maximize the yield per recruit (see Maunder and Hoyle 2007). The average weight of bigeye taken by the longline fisheries (Fisheries 8 and 9) has been around the critical weight, which indicates that this fishery tends to maximize the yield per recruit (see Maunder and Hoyle 2007). The average weight for all fisheries combined declined substantially after 1993 as the amount of purse-seine effort on floating objects increased.

The average weight in both surface and longline fisheries declined around 1997-1998 as a strong cohort entered the fishery. The average weights then increased as the fish in that cohort increased in size. The average weight then declined as that cohort was removed from the population.

The average weights for the surface fishery predicted by the model differ from the "observed" mean weights, particularly before 1984. The "observed" average weights are estimated by scaling up the length-frequency samples to the total catch, which differs from the method used in the stock assessment model which uses the fixed selectivity curves and estimated harvest rates for each fishery to estimate the average weight.

4.2. Comparisons to external data sources

No comparisons to external data were made in this assessment.

4.3. Diagnostics

Diagnostics are discussed in two sections: residual and retrospective analysis.

4.3.1. Residual analysis

The model fits to the CPUE data from different fisheries are presented in Figure 4.10. As expected, the model fits the southern longline CPUE observations closely. The fits to the other CPUE data series are less satisfactory.

Pearson residual plots are presented for the model fits to the length composition data (Figures 4.11a to 4.11i). The solid and open circles represent observations that are less and greater than the model predictions, respectively. The area of the circles is proportional to the absolute value of the residuals. There are several notable characteristics of the residuals. The model overestimates the large and small fish for the post-1993 floating-object fisheries. In particular, it overestimates the large fish during 1999-2002, when a strong cohort moved through the fishery. Conversely, the model overestimates medium-sized fish for the southern longline fishery. This overestimation is centered around 80 cm prior to 1988 and then increases to 180 cm, indicating a change in selectivity. A sensitivity analysis was conducted in the previous assessment in which two time blocks were considered for the selectivity and catchability of the southern longline fishery. The residual pattern of the model fit to the size composition data for this fishery was improved. The model fitted the southern longline CPUE index of abundance very closely. However, the biomasses during the early part of the historical period were less than those estimated by the base case assessment.

The fit to the data, as measured by root mean square error, suggests that the model fits the CPUE index for Fishery 9 better (CV = 0.17) than those for other fisheries. The worst fits to the CPUE data are those for Fisheries 3 and 5 (CV = 0.79), followed by Fishery 2 (CV = 0.42). With respect to the length-frequency data, and except for Fisheries 6 and 7, the model fits the data better (as indicated by the estimated effective sample size) than is reflected by the assumed sample sizes in the likelihood functions. In the last assessment (Aires-da-Silva and Maunder 2007), a sensitivity analysis, using iterative reweighting, was conducted to investigate the weighting of the data sets. Specifically, the appropriate standard deviations and sample sizes for the likelihood functions were determined iteratively, based on the fit to the data. When iterative reweighting was applied, more weight was given to the length-frequency data, and the biomasses were estimated to be lower in the earlier and later segments of the historical period.

4.3.2. Retrospective analysis

Retrospective analysis is useful for determining how consistent a stock assessment method is from one year to the next. Inconsistencies can often highlight inadequacies in the stock assessment method. This approach is different from the comparison of recent assessments (Section 4.5), in which the model assumptions differ among these assessments, and differences would be expected. Retrospective analyses are usually carried out by repeatedly eliminating one year of data from the analysis while using the same method and assumptions. This allows the analyst to determine the change in estimated quantities as more data are included in the model. Estimates for the most recent years are often uncertain and biased. Retrospective analysis, and the assumption that the use of more data improves the estimates, can be used to determine if there are consistent biases in the estimates.

Retrospective analyses were conducted by removing one year (2007), two years (2007 and 2006), three years (2007, 2006, 2005) and four years (2007, 2006, 2005, 2004) of data (Figure 4.12). The retrospective analyses show an increase in biomass over 2004, 2005, 2006, and 2007 whereas the base case shows a nearly stable trend over the same period. This corroborates the results of previous retrospective analyses, which show that the recent estimates of biomass are subject to retrospective bias (Harley and Maunder 2004; Aires-da-Silva and Maunder 2007). Although the trends in the biomasses are the same, in general, the retrospective analysis also shows that the biomass estimates from the base case model are lower than those estimated when the last years of data are not incorporated in the model. Retrospective bias does not necessarily indicate the magnitude and direction of the bias in the current assessment, just that the model may be misspecified.

4.4. Sensitivity analyses

The results from the three sensitivity analyses are presented in the appendices: sensitivity to the stock–recruitment relationship (Appendix A), use of the southern longline CPUE data only (Appendix B), and using two time blocks for selectivity of the floating-object fisheries (Appendix C). Here we describe differences in model fit and model prediction, and defer our discussion of differences in stock status until Section 5. A comparison table of the likelihoods for the base case and sensitivity analyses is provided in Table 4.3.

The steepness of the Beverton-Holt (1957) stock-recruitment relationship was set equal to 0.75. The estimates of biomass (Figure A.1) are greater than those estimated in the base case assessment, but the trends are similar. The recruitment time series is similar to the base case (Figure A.2). The estimated stock-recruitment relationship is presented in Figure A.4.

When only the CPUE for the southern longline fishery was used, the estimated biomass was generally greater. However, the estimated biomass trends for the sensitivity analysis and the base case model are very similar (Figure B.1). The recruitment estimates are also very similar for both models (Figure B.2); however, they are slightly different for the most recent quarters in 2007, for which CPUE data for the southern longline fishery are not available. The model fit to the CPUE time series of Fishery 9 is shown in Figure B.4.

Two time blocks were considered for the size selectivities of floating-object Fisheries 2-5; specifically, the periods before (1975-2000) and after (2001-present) Resolution C-00-08, which prohibited discards of small tunas. Minor differences in the size-selectivity curves of these fisheries were obtained (Figure C.4), but the estimated biomasses and recruitment estimates were very similar to those obtained for the base case model.

Other sensitivity analyses, including investigation of growth estimation, environmental effects on recruitment and catchability, natural mortality, use of iterative reweighting, and use of two time blocks for selectivity and catchability for the southern longline fishery, were conducted by Watters and Maunder (2002), Harley and Maunder (2004, 2005), Maunder and Hoyle (2007) and Aires-da-Silva and Maunder (2007).

4.5. Comparison to previous assessments

The summary and the spawning biomasses (Figures 4.14 and 4.15, respectively) estimated by the current and the previous stock assessment model (Aires-da-Silva and Maunder 2007) are very similar in absolute terms. The starting biomasses, however, are slightly lower for the current stock assessment. The recruitments estimated by the current assessment are slightly greater than the estimates from the previous assessment (Figure 4.16a). As expected, because of the increase in natural mortality, recruitments are higher in the base case when compared to the previous assessment. However, the relative recruitments are very similar (Figure 4.16b).

There is a slightly greater absolute difference between the estimates of the spawning biomass ratios (SBRs) from the current and the previous assessments (Aires-da-Silva and Maunder 2007), particularly during the starting years of the model (1975-1980). The trends in the SBRs, however, are very similar.

4.6. Summary of results from the assessment model

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 15 quarters old has increased substantially since 1993, and that on fish more than about 15 quarters old has increased slightly since then. The increase in fishing mortality on the younger fish was caused by the expansion of the fisheries that catch bigeye in association with floating objects.

Over the range of spawning biomasses estimated by the base case assessment, the abundance of bigeye recruits appears to be unrelated to the spawning potential of adult females at the time of hatching.

There are several important features in the estimated time series of bigeye recruitment. First, estimates of recruitment before 1993 are very uncertain, as the floating-object fisheries were not catching significant amounts of small bigeye. There was a period of above-average recruitment in 1995-1998, followed by a period of below-average recruitment in 1999-2000. The recruitments have been above average since 2001, and were particularly large in 2005 and 2006. The most recent recruitment is very uncertain, due to the fact that recently-recruited bigeye are represented in only a few length-frequency samples. The extended period of relatively large recruitments in 1995-1998 coincided with the expansion of the fisheries that catch bigeye in association with floating objects.

The biomass of 3+-quarter-old bigeye increased during 1983-1984, and reached its peak level of 625,649 t in 1986, after which it decreased to an historic low of 269,266 t at the beginning of 2007. Spawning biomass has generally followed a trend similar to that for the biomass of 3+-quarter-olds, but lagged by 1-2 years. There is uncertainty in the estimated biomasses of both 3+-quarter-old bigeye and spawners. Nevertheless, it is apparent that fishing has reduced the total biomass of bigeye in the EPO. The biomasses of both 3+-quarter-old fish and spawners were estimated to have increased in recent years (2005-2007).

The estimates of biomass are only moderately sensitive to the steepness of the stock-recruitment relationship. Specifically, the estimates of biomass are greater than those estimated in the base case assessment, but the trends are similar. The recruitment time series is similar to the base case.

When only the CPUE for the southern longline fishery is used, the estimates of biomass are greater than those estimated in the base case, but the trends are similar. The recruitment time series is very similar to the base case. The recruitment estimates, however, are slightly different in 2007, for which CPUE data for the southern longline fishery are not available.

When two time blocks were applied to the size selectivity of the floating-object fisheries, the estimates of biomass and recruitment were very similar to those obtained with the base case model.

5. STOCK STATUS

The status of the stock of bigeye tuna in the EPO is assessed by considering calculations based on the spawning biomass and the maximum sustainable yield (MSY).

Precautionary reference points, as described in the FAO Code of Conduct for Responsible Fisheries and the United Nations Fish Stocks Agreement, are being widely developed as guides for fisheries management. Maintaining tuna stocks at levels that produce the MSY to be taken is the management objective specified by the IATTC Convention. The IATTC has not adopted any target or limit reference points for the stocks it manages, but some possible reference points are described in the following subsections.

5.1. Assessment of stock status based on spawning biomass

The spawning biomass ratio (the ratio of the spawning biomass at that time to that of the unfished stock; SBR), described by Watters and Maunder (2001), has been used to define reference points in many fisheries. It has a lower bound of zero. If it is near zero, the population has been severely depleted, and is probably overexploited. If the SBR is one, or slightly less than that, the fishery has probably not reduced the spawning stock. If the SBR is greater than one, it is possible that the stock has entered a regime of increased production.

Various studies (*e.g.* Clark 1991, Francis 1993, Thompson 1993, Mace 1994) suggest that some fish populations are capable of producing the MSY when the SBR of about 0.3 to 0.5, and that some fish populations are not capable of producing the MSY if the spawning biomass during a period of exploitation is less than about 0.2. Unfortunately, the types of population dynamics that characterize tuna populations have generally not been considered in these studies, and their conclusions are sensitive to assumptions about the relationship between adult biomass and recruitment, natural mortality, and growth rates. In the absence of simulation studies that are designed specifically to determine appropriate SBR-based reference points for tunas, estimates of SBR can be compared to an estimate of SBR corresponding to the MSY ($SBR_{MSY} = S_{MSY}/S_{F=0}$).

Estimates of SBR for bigeye tuna in the EPO have been computed from the base case assessment. Estimates of the spawning biomass during the study period (1975-2007) are presented in Section 4.1.3. The SBR corresponding to the MSY (SBR_{MSY}) is estimated to be about 0.19.

At the beginning of January 2008, the spawning biomass of bigeye tuna in the EPO was near the historical low level (Figure 5.1). At that time the SBR was about 0.17, 10% less than the level corresponding to the MSY.

At the beginning of 1975, the SBR was about 0.26 (Figure 5.1), which is consistent with the fact that bigeye was being fished by longliners in the EPO for a long period prior to 1975 and that the spawning biomass is made up of older individuals that are vulnerable to longline gear. The SBR increased, particularly during 1984-1986, and by the beginning of 1987 was 0.47. This increase can be attributed to the above-average recruitment during 1982 and 1983 (Figure 4.5) and to the relatively small catches that were taken by the surface fisheries during that time (Figure 2.2, Fisheries 1 and 6). This peak in spawning biomass was soon followed by a peak in the longline catch (Figure 2.2, Fishery 9). After 1987 the SBR decreased to a level of about 0.20 by mid-1999. This depletion can be attributed mostly to a long period (1984-1993) during which recruitment was low. Also, it should be noted that the southern longline fishery took relatively large catches during 1985-1994 (Figure 2.2, Fishery 9). In 1999 the SBR began to increase, and reached about 0.33 in 2002. This increase can be attributed to the relatively high levels of recruitment that are estimated to have occurred during 1994-1998 (Figure 4.5). During the latter part of 2002 through 2003, the SBR decreased rapidly, due to the weak year classes in 1999 and 2000 and the large catches from surface fisheries and increased longline catches.

Over time, the SBR shows a trend similar to that of the previous assessment (Figure 4.15). However, the estimated SBR levels are lower than that estimated in the previous assessment (Aires-da-Silva and Maunder 2007), particularly in the early years of the study period (1975-1980).

5.2. Assessment of stock status based on MSY

Maintaining tuna stocks at levels that permit the MSY to be taken is the management objective specified by the IATTC Convention. MSY is defined as the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions. Watters and Maunder (2001) describe how the MSY and its related quantities are calculated. These calculations have, however, been modified to include, where applicable, the Beverton-Holt (1957) stock-recruitment relationship (see Maunder and Watters (2003) for details). It is important to note that estimates of the MSY and its associated quantities are sensitive to the steepness of the stock-recruitment relationship (Section 5.4), and, for the base case assessment, steepness was fixed at 1 (an assumption that recruitment is independent of stock size); however, a sensitivity analysis (steepness = 0.75) is provided to investigate the effect of a stock-recruitment relationship.

The MSY-based estimates were computed with the parameter estimates from the base case assessment and estimated fishing mortality patterns averaged over 2005 and 2007. Therefore, while these MSY-based results are currently presented as point estimates, there are uncertainties in the results. While analyses to present uncertainty in the base case estimates were not undertaken as in a previous assessment

(Maunder and Harley 2002), additional analyses were conducted to present the uncertainty in these quantities in relation to the periods assumed to represent catchability and fishing mortality.

At the beginning of January 2008, the spawning biomass of bigeye tuna in the EPO appears to have been about 10% less than S_{MSY}, and the recent catches are estimated to have been about 8% greater than the MSY (Table 5.1).

If fishing mortality is proportional to fishing effort, and the current patterns of age-specific selectivity (Figure 4.2) are maintained, F_{MSY} is about 82% of the current level of effort.

The MSY-based quantities are estimated by assuming that the stock is at equilibrium with fishing, but during 1995-1998 that was not the case. This has potentially important implications for the surface fisheries, as it suggests that the catch of bigeye by the surface fleet may be determined largely by the strength of recruiting cohorts. For example, the catches of bigeye taken by the surface fleet declined when the large cohorts recruited during 1995-1998 were no longer vulnerable to those fisheries.

Estimates of the MSY, and its associated quantities, are sensitive to the age-specific pattern of selectivity that is used in the calculations. The MSY-based quantities described previously were based on an average selectivity pattern for all fisheries combined (calculated from the current allocation of effort among fisheries). Different allocations of fishing effort among fisheries would change this combined selectivity pattern. To illustrate how the MSY might change if the effort is reallocated among the various fisheries that catch bigeye in the EPO, the previously-described calculations were repeated, using the age-specific selectivity pattern estimated for each group of fisheries (Table 5.2). If only the purse-seine fishery were operating the MSY would be about 30% less. If bigeye were caught only by the longline fishery the MSY would about 89% greater than that estimated for all gears combined. To achieve this MSY level longline effort would need to be increased by 320%.

The MSY-related quantities vary as the size composition of the catch varies. The evolution of four of these over the course of 1975-1995 is shown in Figure 5.2. Before the expansion of the floating-object fishery that began in 1993, MSY was greater than the current MSY and the fishing mortality was less than that corresponding to MSY (Figure 5.2).

When MSY is estimated using the average fishing mortality rates for 2005-2006, it is 416 t (0.5%) less than the base case.

Figure 5.3 shows the historical time series of exploitation rates and spawning biomass relative to the MSY reference points. Overall, the reference points have not been exceeded until recent years. The two most recent estimates indicate that the bigeye stock in the EPO is probably overexploited ($S < S_{MSY}$) and that overfishing is taking place ($F > F_{MSY}$); the confidence intervals on spawning biomass straddle the MSY level.

5.3. Sensitivity to alternative parameterizations and data

Yields and reference points are moderately sensitive to alternative model assumptions, input data, and the periods assumed for fishing mortality (Tables 5.1 and 5.2).

The sensitivity analysis that included a stock-recruitment model with a steepness of 0.75 estimated the SBR required to support the MSY to be at 0.30, compared to 0.19 for the base case assessment (Table 5.1). The sensitivity analysis for steepness estimates an F multiplier considerably less than that for the base case assessment (0.57). All analyses estimate the current SBR to be less than SBR_{MSY}.

The management quantities are only moderately sensitive to the recent periods for fishing mortality used in the calculations (Table 5.2).

5.4. Summary of stock status

At the beginning of January 2008, the spawning biomass of bigeye tuna in the EPO was near the historic low level (Figure 5.1). At that time the SBR was about 0.17, about 10% less than the level corresponding to the MSY.

Recent catches are estimated to have been about the MSY level (Table 5.1). If fishing mortality is proportional to fishing effort, and the current patterns of age-specific selectivity are maintained, the level of fishing effort corresponding to the MSY is about 82% of the current (2005-2007) level of effort. The MSY 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 because it catches larger individuals that are close to the critical weight. Before the expansion of the floating-object fishery that began in 1993, the MSY was greater than the current MSY and the fishing mortality was less than F_{MSY} (Figure 5.2).

All analyses indicate that, at the beginning of 2008, the spawning biomass was probably below S_{MSY} (Tables 5.1 and 5.2). The 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, but under all scenarios considered, fishing mortality is well above F_{MSY}.

6. SIMULATED EFFECTS OF FUTURE FISHING OPERATIONS

A simulation study was conducted to gain further understanding as to how, in the future, hypothetical changes in the amount of fishing effort exerted by the surface fleet might simultaneously affect the stock of bigeye tuna in the EPO and the catches of bigeye by the various fisheries. Several scenarios were constructed to define how the various fisheries that take bigeye in the EPO would operate in the future and also to define the future dynamics of the bigeye stock. The assumptions that underlie these scenarios are outlined in Sections 6.1 and 6.2.

A method based on the normal approximation to the likelihood profile has been applied (Maunder *et al.* 2006). Unfortunately, the appropriate methods are not often applicable to models as large and computationally intense as the bigeye stock assessment model. Therefore, we have used a normal approximation to the likelihood profile that allows for the inclusion of both parameter uncertainty and uncertainty about future recruitment. This method is implemented by extending the assessment model an additional five years with exploitation rates equal to the average for 2005 and 2007. No catch or length-frequency data are included for these years. The recruitments for the five years are estimated as in the assessment model, with a lognormal penalty with a standard deviation of 0.6.

6.1. Assumptions about fishing operations

6.1.1. Fishing effort

Future projection studies were carried out to investigate the influence of different levels of fishing effort (harvest rates) on the stock biomass and catch.

The analyses carried out were:

1. Quarterly harvest rates for each year in the future were set equal to the average harvest rates from 2005 to 2007, to simulate the reduced effort due to the conservation measures of IATTC Resolution C-04-09.
2. An additional analysis was carried out that estimates the population status if the resolution was not implemented. For 2004-2007, purse-seine catch in the third quarter was increased by 86% and the catch in the southern longline fishery was increased by 39% in all quarters. For 2008-2012, the purse-seine harvest rate was increased by 13% for all quarters and the harvest rate in the southern longline fishery was increased by 39% in all quarters.

6.2. Simulation results

The simulations were used to predict future levels of the SBR, total biomass, the total catch taken by the primary surface fisheries that would presumably continue to operate in the EPO (Fisheries 2-5 and 7), and the total catch taken by the longline fleet (Fisheries 8-9 and 14-15). There is probably more uncertainty in the future levels of these outcome variables than suggested by the results presented in Figures 6.1-6.4. The amount of uncertainty is probably underestimated, because the simulations were conducted under the assumption that the stock assessment model accurately describes the dynamics of the system and with no account taken of variation in catchability.

6.2.1. Current harvest rates

Projections were undertaken, assuming that harvest rates would remain at the average 2005-2007 levels (including the effort and catch restrictions in IATTC Resolutions C-04-09 and C-06-02).

SBR is estimated to have been increasing slightly in recent years (Figure 5.1). This increase is attributed to two spikes in recent recruitment. If recent levels of effort and catchability continue, the SBR is predicted to increase above the level that would support MSY during 2009-2010, and then to decline during 2011-2013 to a level slightly below to that which would support MSY (Figure 6.1a). The spawning biomass is estimated to increase slightly from 2005-2007, but it will probably decline in the future (Figure 6.2).

Purse-seine catches are predicted to decline during the projection period (Figure 6.3, left panels). Longline catches are predicted to increase moderately in 2008, but start declining by 2009 under current effort (Figure 6.3, right panels). The catches would decline slightly further if a stock-recruitment relationship was included, due to reductions in the levels of recruitment that contribute to purse-seine catches.

Predicted catches for both gears are based on the assumption that the selectivity of each fleet will remain the same and that catchability will not increase as abundance declines. If the catchability of bigeye increases at low abundance, catches will, in the short term, be greater than those predicted here.

6.2.2. No management restrictions

IATTC Resolutions C-04-09 and C-06-02 call for restrictions on purse-seine effort and longline catches during 2004-2007: a 6-week closure during the third *or* fourth quarter of the year for purse-seine fisheries, and longline catches not to exceed 2001 levels. To assess the utility of these management actions, we projected the population forward 5 years, assuming that these conservation measures are not implemented in the future. Projected catches would be less if the resolution had not been adopted (Figure 6.3, lower panels).

Comparison of the SBR predicted with and without the restrictions from the resolution show some difference (Figure 6.4). Without the restrictions, SBR would increase only slightly and then decline to lower levels.

The reductions in fishing mortality that could occur as result of the continuation of IATTC Resolution C-06-02 are insufficient to allow the population to maintain above levels corresponding to the MSY in the long term, although an increase above the MSY level is expected for a few years, due to recent high recruitment.

6.2.3. Sensitivity analysis

The analysis that includes a stock-recruitment relationship indicates that the population is substantially below SBR_{MSY} and will remain at this level under current effort levels (Figure 6.1b).

6.3. Summary of the simulation results

Recent spikes in recruitment are predicted to result in increased levels of SBR and longline catches for the next few years. However, high levels of fishing mortality are expected to subsequently reduce SBR. Under current effort levels, the population is unlikely to remain at levels that support MSY unless fishing mortality levels are greatly reduced or recruitment is above average for several consecutive years.

The effects of IATTC Resolutions C-04-09 and C-06-02 are estimated to be insufficient to allow the stock to remain at levels that would support MSY.

These simulations are based on the assumption that selectivity and catchability patterns will not change in the future. Changes in targeting practices or increasing catchability of bigeye as abundance declines (*e.g.* density-dependent catchability) could result in differences from the outcomes predicted here.

7. FUTURE DIRECTIONS

7.1. Collection of new and updated information

The IATTC staff intends to continue its collection of catch, effort, and size-composition data from the fisheries that catch bigeye tuna in the EPO. Updated and new data will be incorporated into the next stock assessment.

The IATTC staff will continue to compile longline catch and effort data for fisheries operating in the EPO. In particular, it will attempt to obtain data for recently-developed and growing fisheries.

7.2. Refinements to the assessment model and methods

The IATTC staff will continue developing the Stock Synthesis II assessment for bigeye tuna in EPO. Much of the progress will depend on how the Stock Synthesis II software is modified in the future. The following changes would be desirable for future assessments:

1. Use a more flexible growth curve (*e.g.* the Richards growth curve) or input a vector of length-at-age so that the growth curve better represents that used in previous assessments using A-SCALA.
2. Make it easier to run projections with fixed harvest rates.
3. Re-evaluate the definitions of fisheries.
4. Determine appropriate weighting of the different data sets.
5. Include available tagging data in the assessment.

Collaboration with staff members of the Secretariat of the Pacific Community on the Pacific-wide bigeye model will continue.

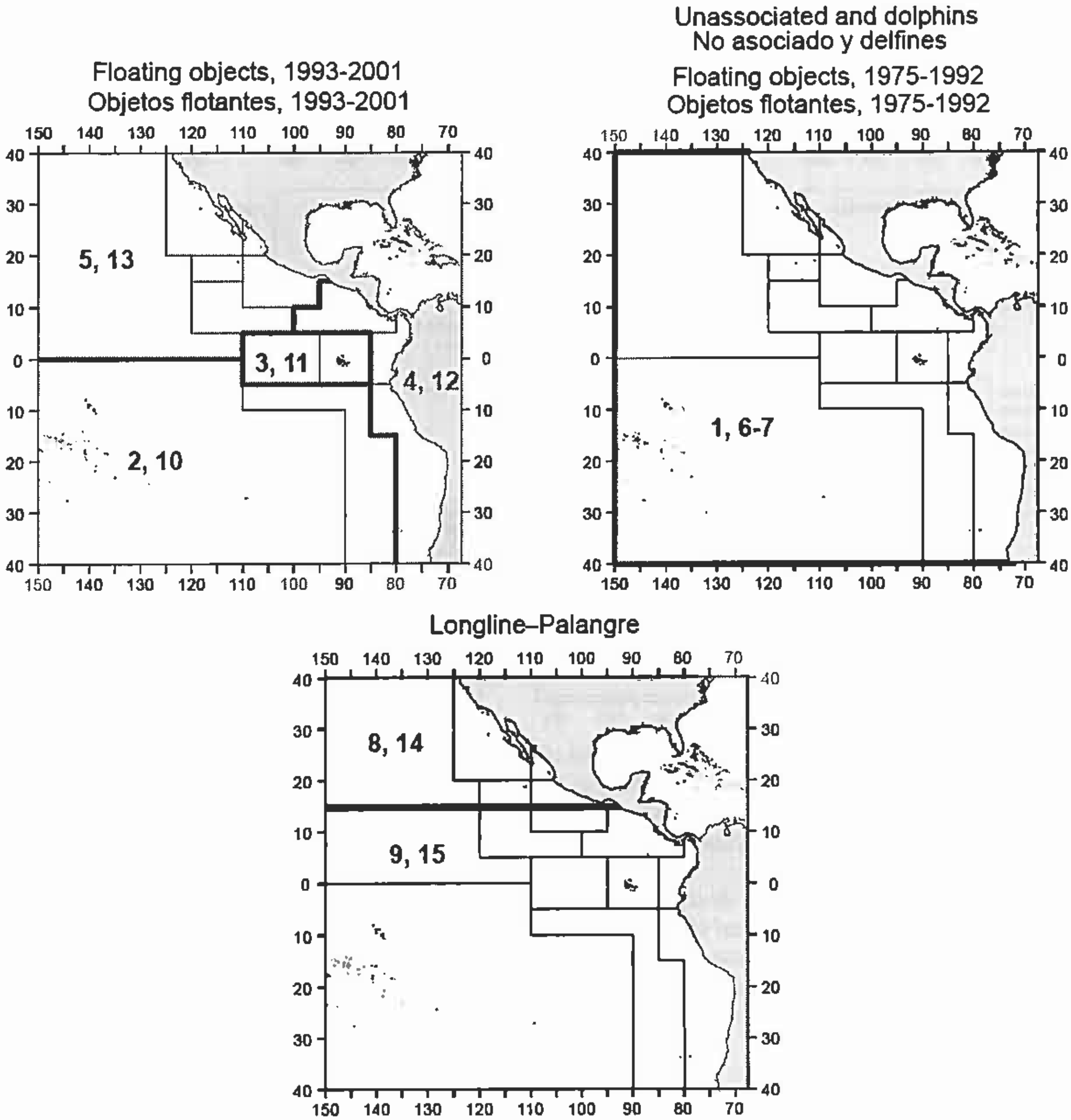

FIGURE 2.1. Spatial extents of the fisheries defined for the stock assessment of bigeye tuna in the EPO. The thin lines indicate the boundaries of 13 length-frequency sampling areas, the bold lines the boundaries of each fishery defined for the stock assessment, and the bold numbers the fisheries to which the latter boundaries apply. The fisheries are described in Table 2.1.

FIGURA 2.1. Extensión espacial de las pesquerías definidas para la evaluación de la población de atún patudo en el OPO. Las líneas delgadas indican los límites de 13 zonas de muestreo de frecuencia de tallas, las líneas gruesas los límites de cada pesquería definida para la evaluación de la población, y los números en negritas las pesquerías correspondientes a estos últimos límites. En la Tabla 2.1 se describen las pesquerías.

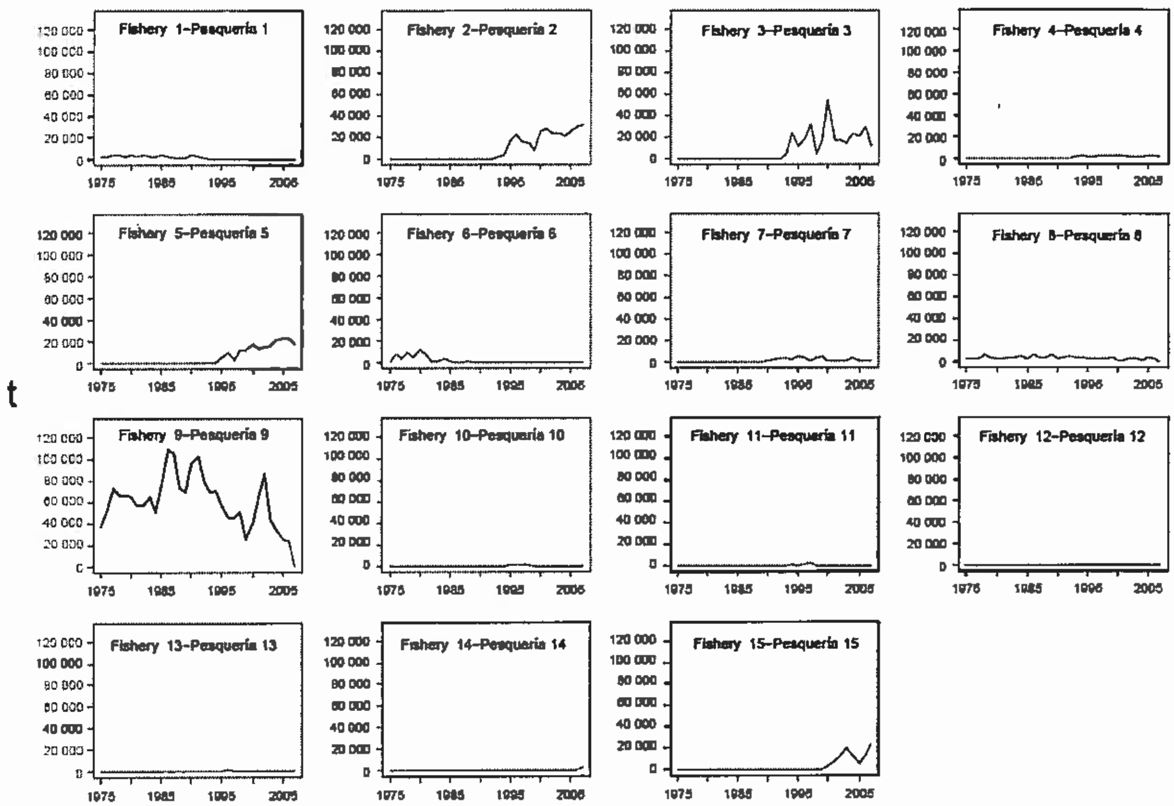

FIGURE 2.2. Annual catches of bigeye tuna taken by the fisheries defined for the stock assessment of that species in the EPO (Table 2.1). Although all the catches are displayed as weights, the stock assessment model uses catches in numbers of fish for Fisheries 8 and 9. Catches in weight for Fisheries 8 and 9 were estimated by multiplying the catches in numbers of fish by estimates of the average weights. t = metric tons.

FIGURA 2.2. Capturas anuales de atún patudo realizadas por las pesquerías definidas para la evaluación de la población de esa especie en el OPO (Tabla 2.1). Aunque se presentan todas las capturas como pesos, el modelo de evaluación usa capturas en número de peces para las Pesquerías 8 y 9. Se estimaron las capturas en peso para las Pesquerías 8 y 9 multiplicando las capturas en número de peces por estimaciones del peso medio. t = toneladas métricas.

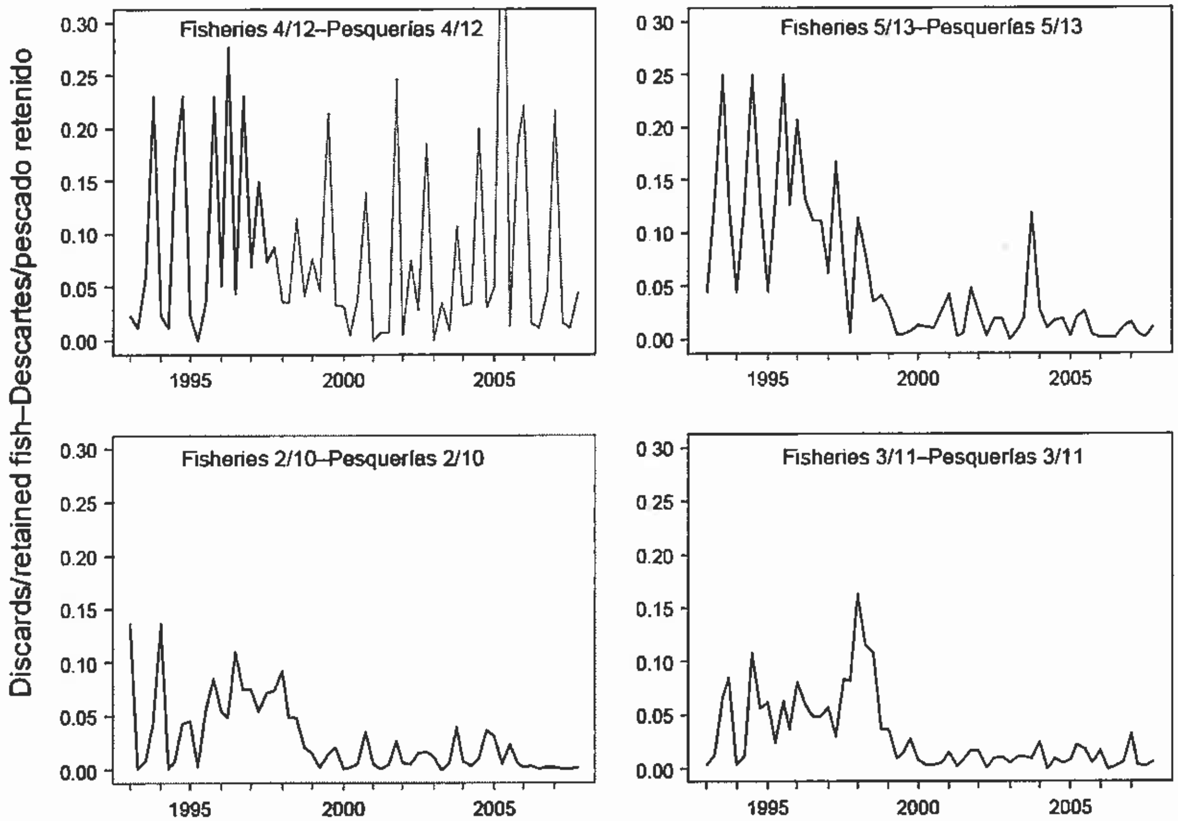

FIGURE 2.3. Weights of discarded bigeye tuna as proportions of the retained quarterly catches for the four floating-object fisheries. Fisheries 2, 3, 4, and 5 are the "real" fisheries, and Fisheries 10, 11, 12, and 13 are the corresponding discard fisheries.

FIGURA 2.3. Pesos de atún patudo descartado como proporción de las capturas trimestrales retenidas de las cuatro pesquerías sobre objetos flotantes. Las pesquerías 2, 3, 4, y 5 son las pesquerías "reales", y las Pesquerías 10, 11, 12, y 13 las pesquerías de descarte correspondientes.

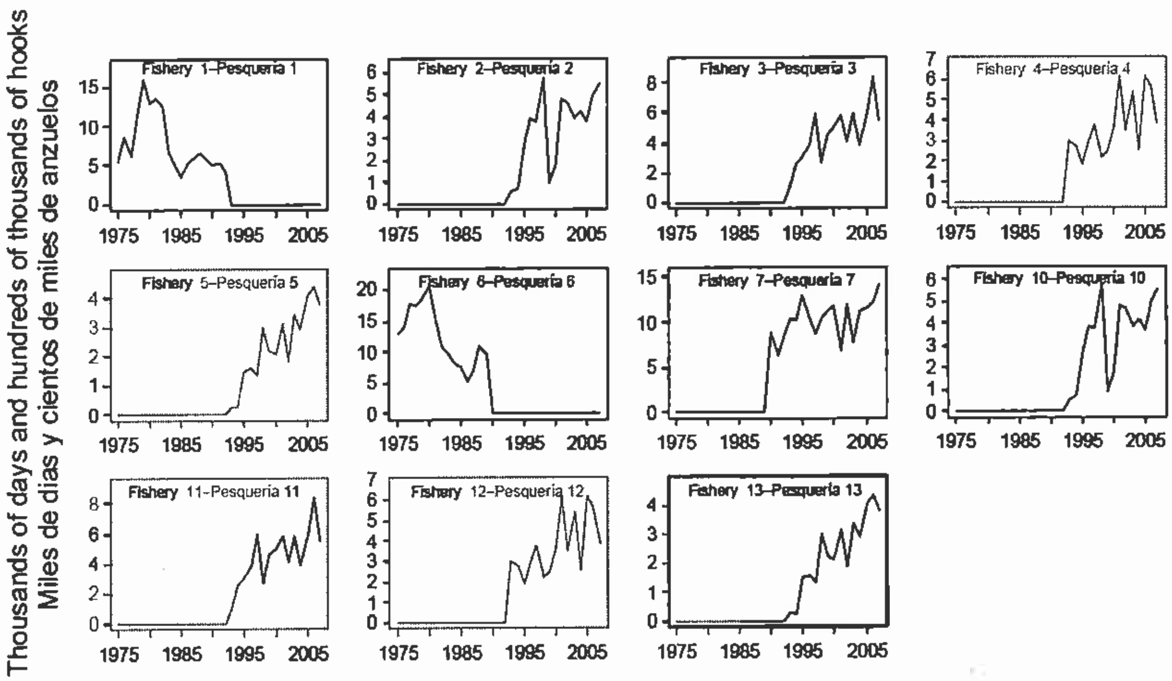

FIGURE 2.4. Annual fishing effort exerted by the fisheries defined for the stock assessment of bigeye tuna in the EPO (Table 2.1). The effort for Fisheries 1-7 and 10-13 is in days fished, and that for Fisheries 8-9, and 13-15 in standardized numbers of hooks. Note that the vertical scales of the panels are different.
FIGURA 2.4. Esfuerzo de pesca anual ejercido por las pesquerías definidas para la evaluación de la población de atún patudo en el OPO (Tabla 2.1). Se expresa el esfuerzo de las Pesquerías 1-7 y 10-13 en días de pesca, y el de las Pesquerías 8, 9, y 13-15 en número estandardizado de anzuelos. Nótese que las escalas verticales de los recuadros son diferentes.

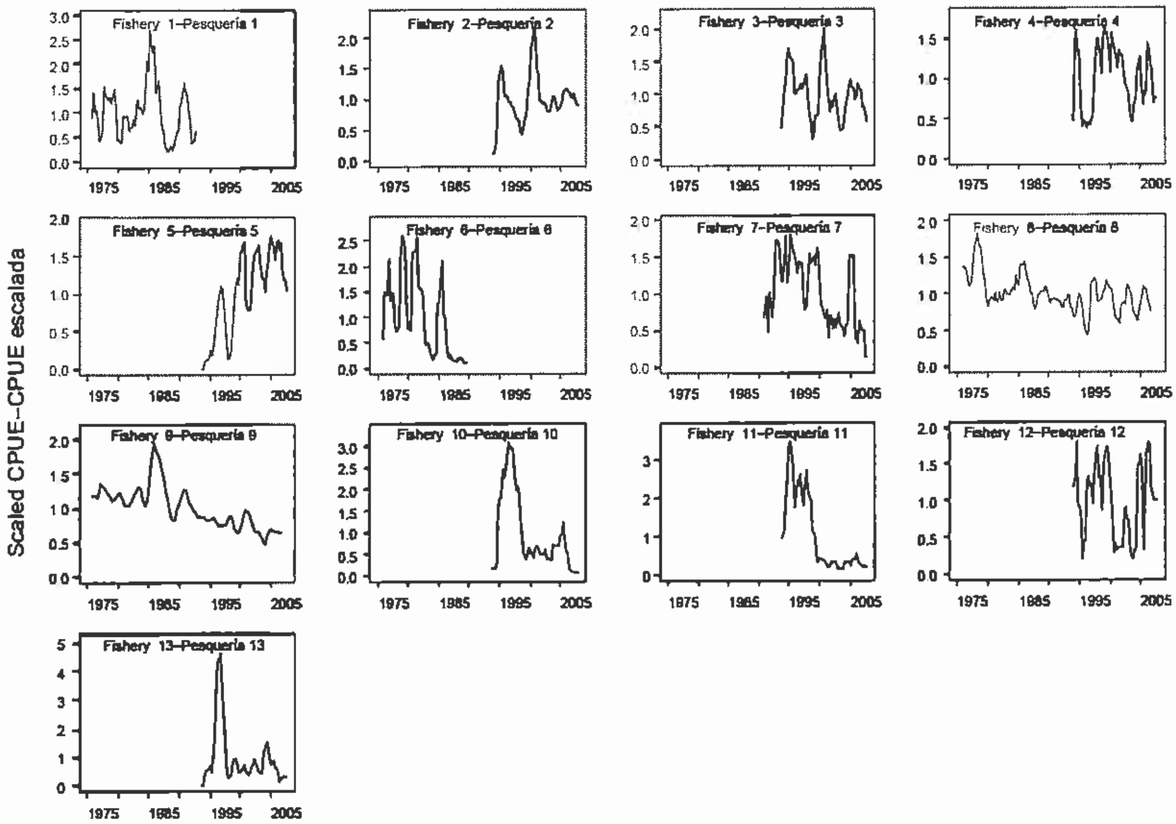

FIGURE 2.5. Four-quarterly running average CPUEs of the fisheries defined for the stock assessment of bigeye tuna in the EPO (Table 2.1). The CPUEs for Fisheries 1-7 and 10-13 are in kilograms per day fished, and those for Fisheries 8 and 9 in numbers of fish caught per standardized number of hooks. The data are adjusted so that the mean of each time series is equal to 1.0. Note that the vertical scales of the panels are different.

FIGURA 2.5. Promedio móvil de cuatro trimestres de las CPUE de las pesquerías definidas para la evaluación de la población de atún patudo en el OPO (Tabla 2.1). Se expresan las CPUE de las Pesquerías 1-7 y 10-13 en kilogramos por día de pesca, y las de las Pesquerías 8 y 9 en número de peces capturados por número estandarizado de anzuelos. Se ajustaron los datos para que el promedio de cada serie de tiempo equivalga a 1,0. Nótese que las escalas verticales de los recuadros son diferentes.

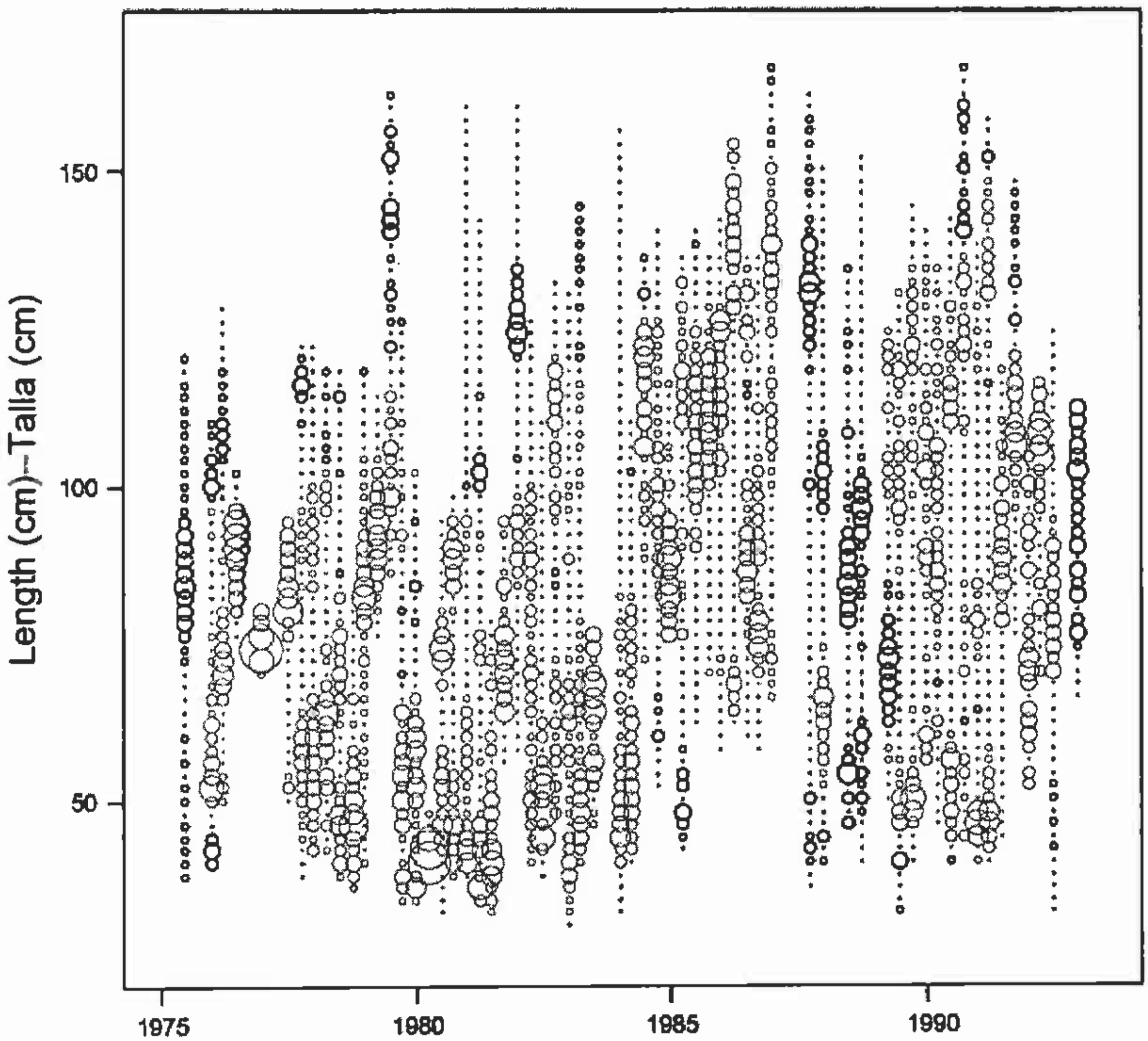

FIGURE 2.6a. Size compositions of the catches of bigeye tuna taken by Fishery 1, by quarter. The sizes of the circles are proportional to the catches.

FIGURA 2.6a. Composición por talla de las capturas de patudo de la Pesquería 1, por trimestre. El tamaño de los círculos es proporcional a la captura.

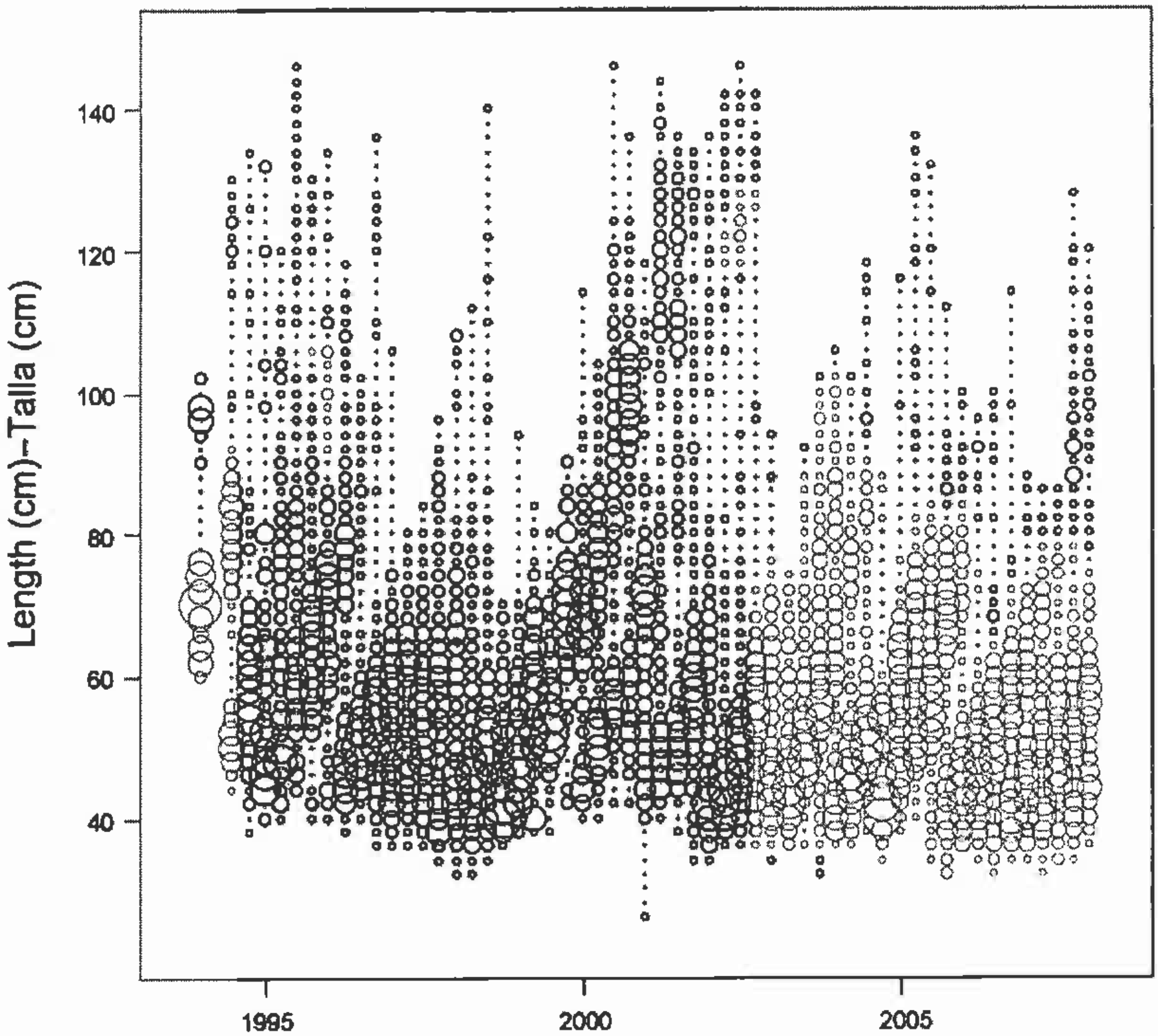

FIGURE 2.6b. Size compositions of the catches of bigeye tuna taken by Fishery 2, by quarter. The sizes of the circles are proportional to the catches.

FIGURA 2.6b. Composición por talla de las capturas de patudo de la Pesquería 2, por trimestre. El tamaño de los círculos es proporcional a la captura.

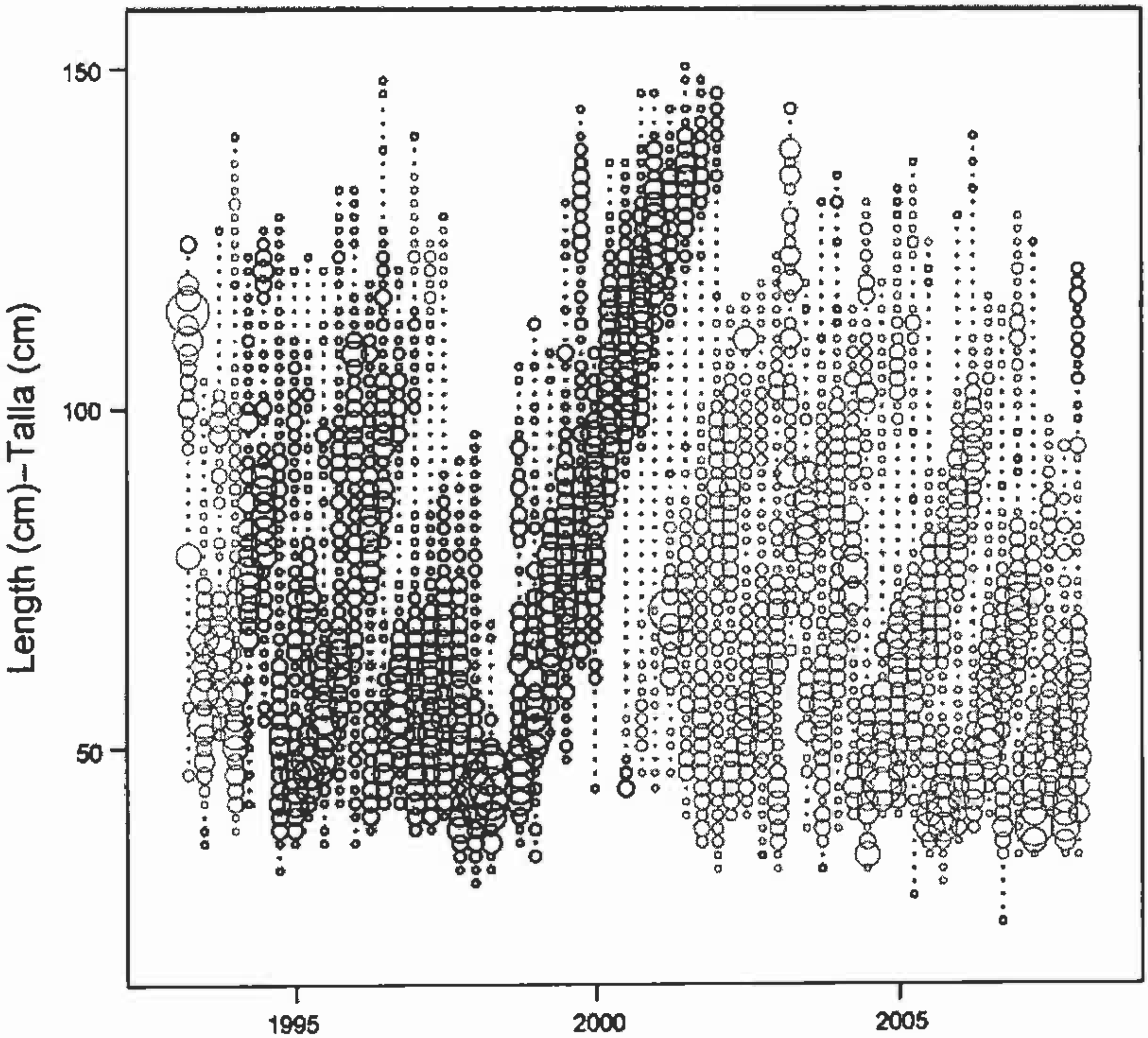

FIGURE 2.6c. Size compositions of the catches of bigeye tuna taken by Fishery 3, by quarter. The sizes of the circles are proportional to the catches.

FIGURA 2.6c. Composición por talla de las capturas de patudo de la Pesquería 3, por trimestre. El tamaño de los círculos es proporcional a la captura.

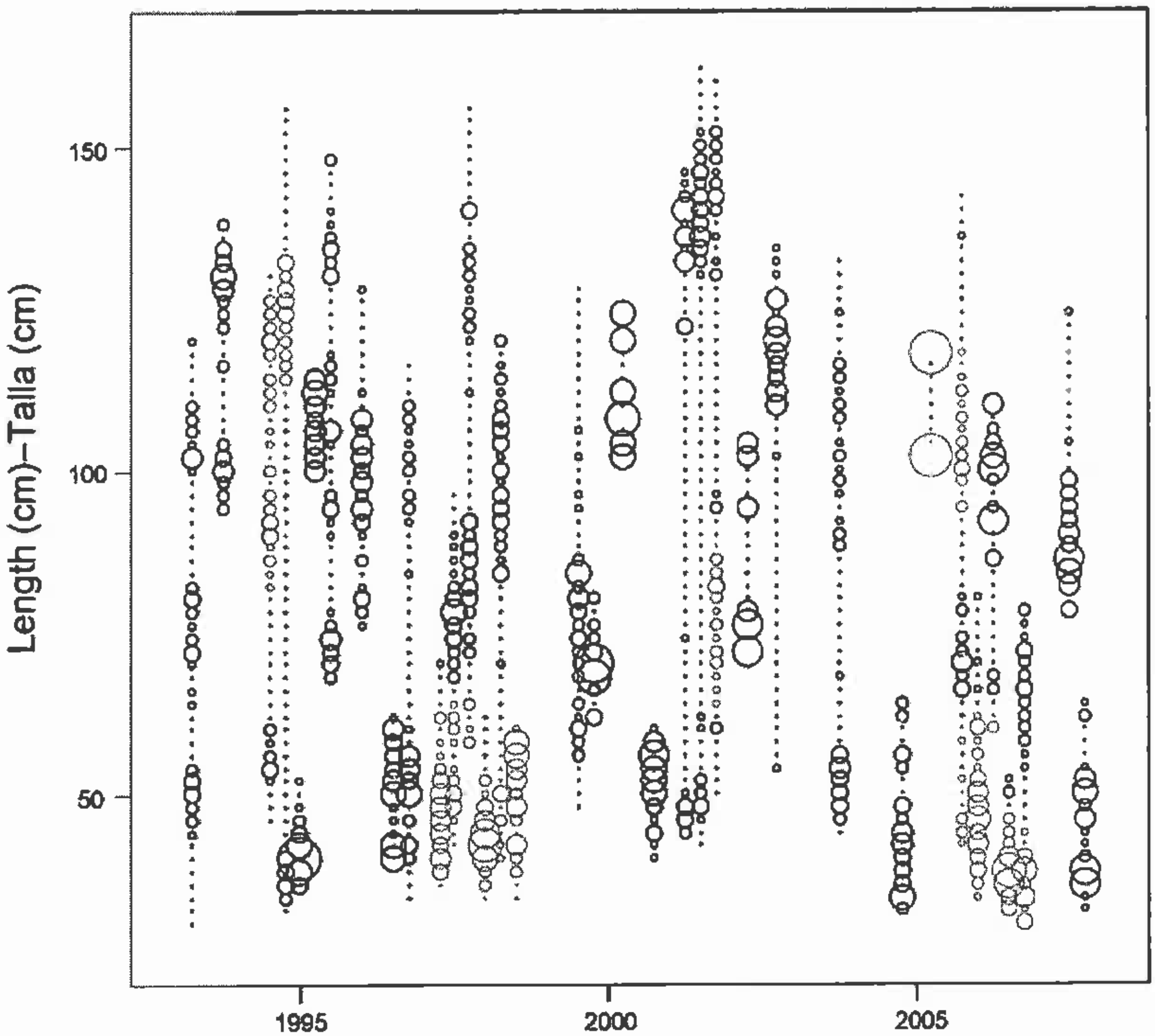

FIGURE 2.6d. Size compositions of the catches of bigeye tuna taken by Fishery 4, by quarter. The sizes of the circles are proportional to the catches.

FIGURA 2.6d. Composición por talla de las capturas de patudo de la Pesquería 4, por trimestre. El tamaño de los círculos es proporcional a la captura.

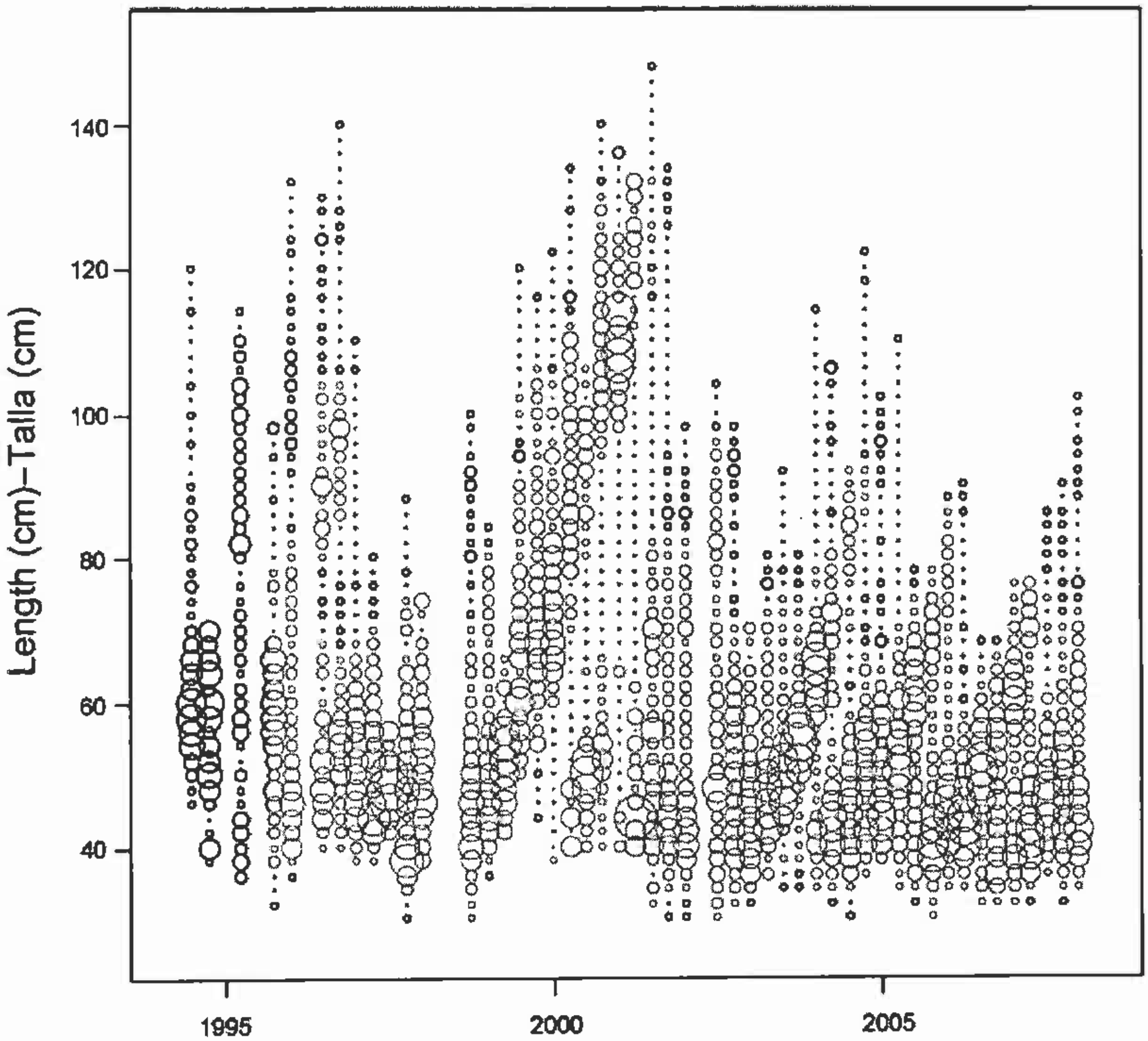

FIGURE 2.6e. Size compositions of the catches of bigeye tuna taken by Fishery 5, by quarter. The sizes of the circles are proportional to the catches.

FIGURA 2.6e. Composición por talla de las capturas de patudo de la Pesquería 5, por trimestre. El tamaño de los círculos es proporcional a la captura.

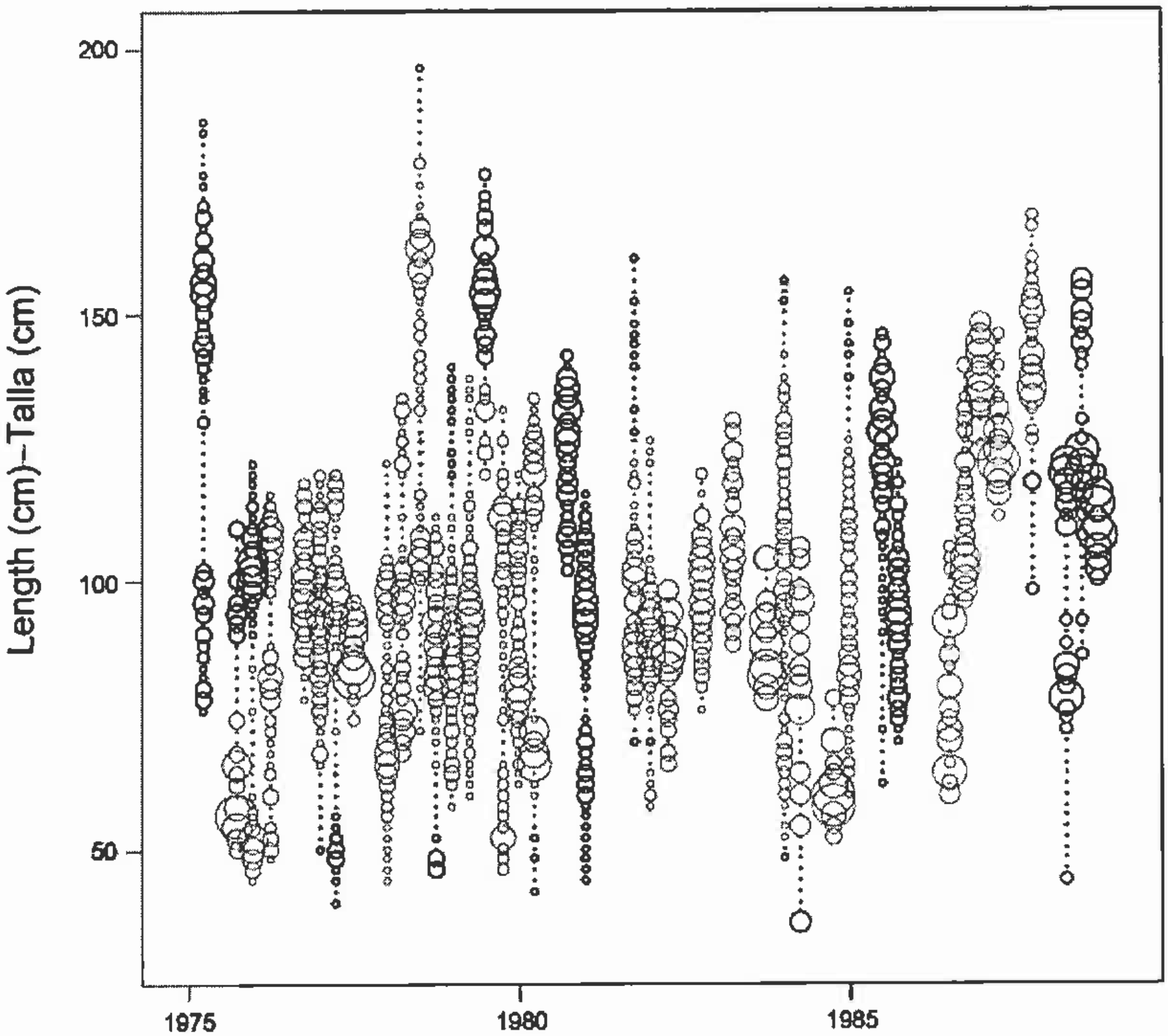

FIGURE 2.6f. Size compositions of the catches of bigeye tuna taken by Fishery 6, by quarter. The sizes of the circles are proportional to the catches.
FIGURA 2.6f. Composición por talla de las capturas de patudo de la Pesquería 6, por trimestre. El tamaño de los círculos es proporcional a la captura.

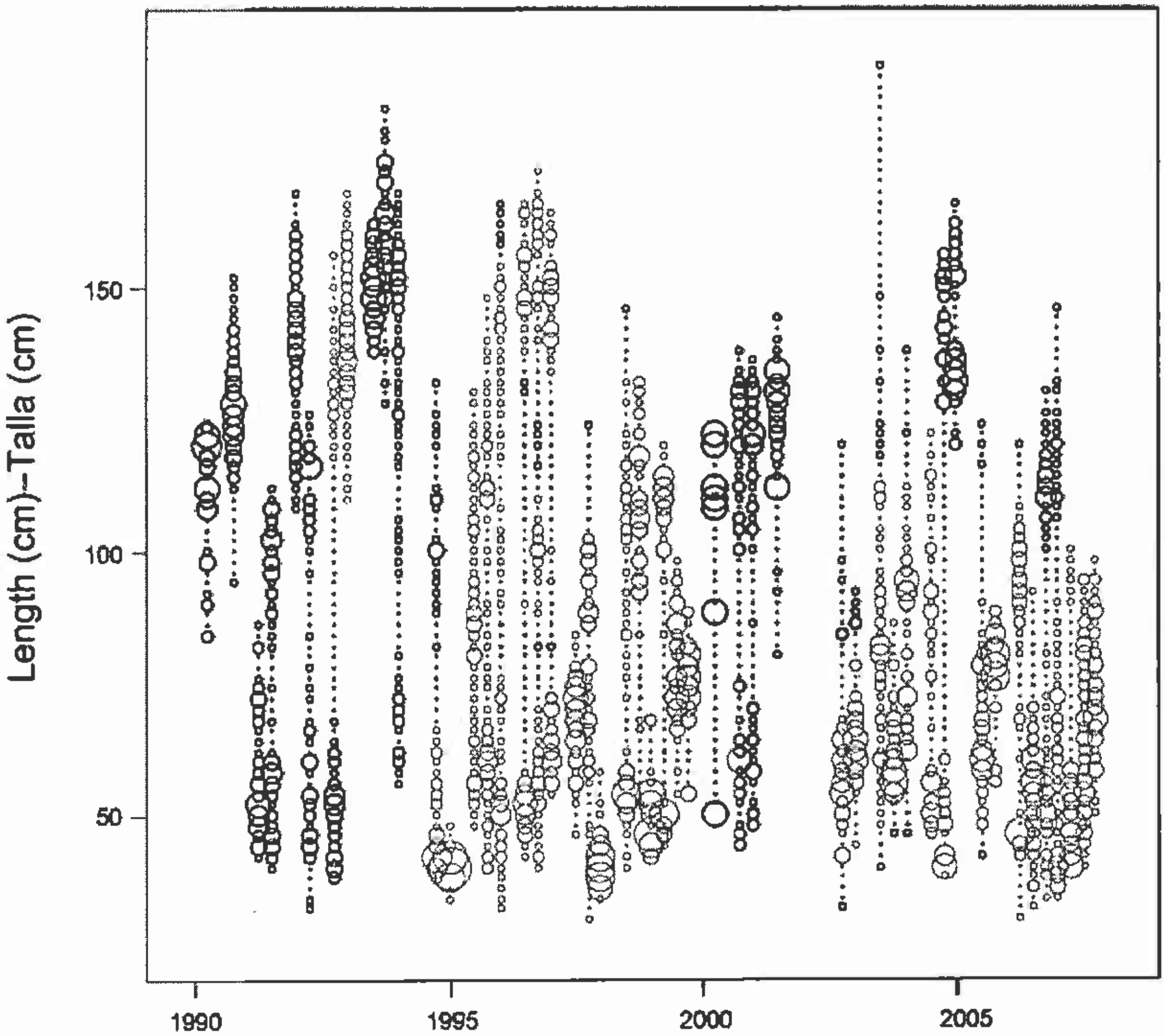

FIGURE 2.6g. Size compositions of the catches of bigeye tuna taken by Fishery 7, by quarter. The sizes of the circles are proportional to the catches.

FIGURA 2.6g. Composición por talla de las capturas de patudo de la Pesquería 7, por trimestre. El tamaño de los círculos es proporcional a la captura.

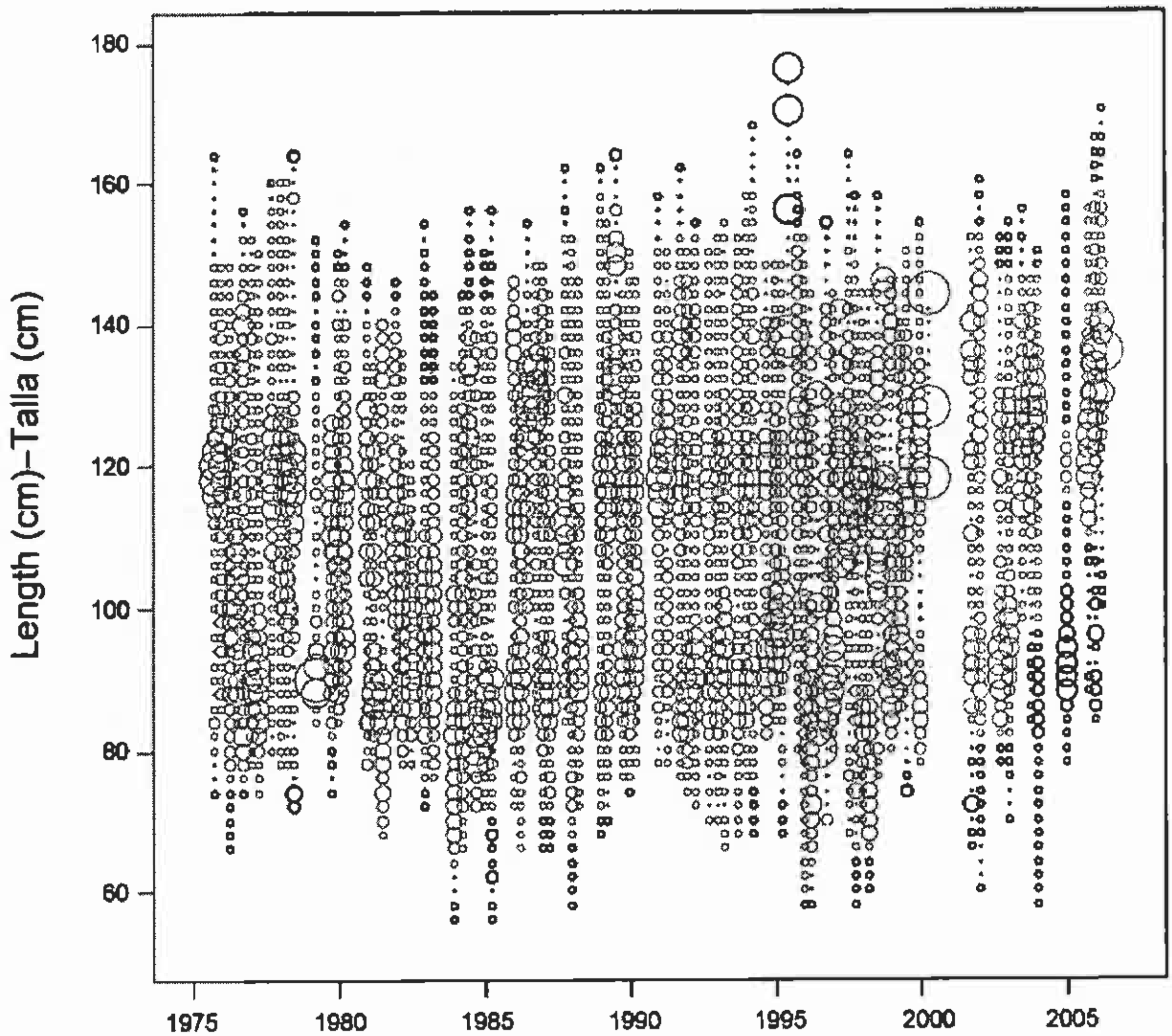

FIGURE 2.6h. Size compositions of the catches of bigeye tuna taken by Fishery 8, by quarter. The sizes of the circles are proportional to the catches.
FIGURA 2.6h. Composición por talla de las capturas de patudo de la Pesquería 8, por trimestre. El tamaño de los círculos es proporcional a la captura.

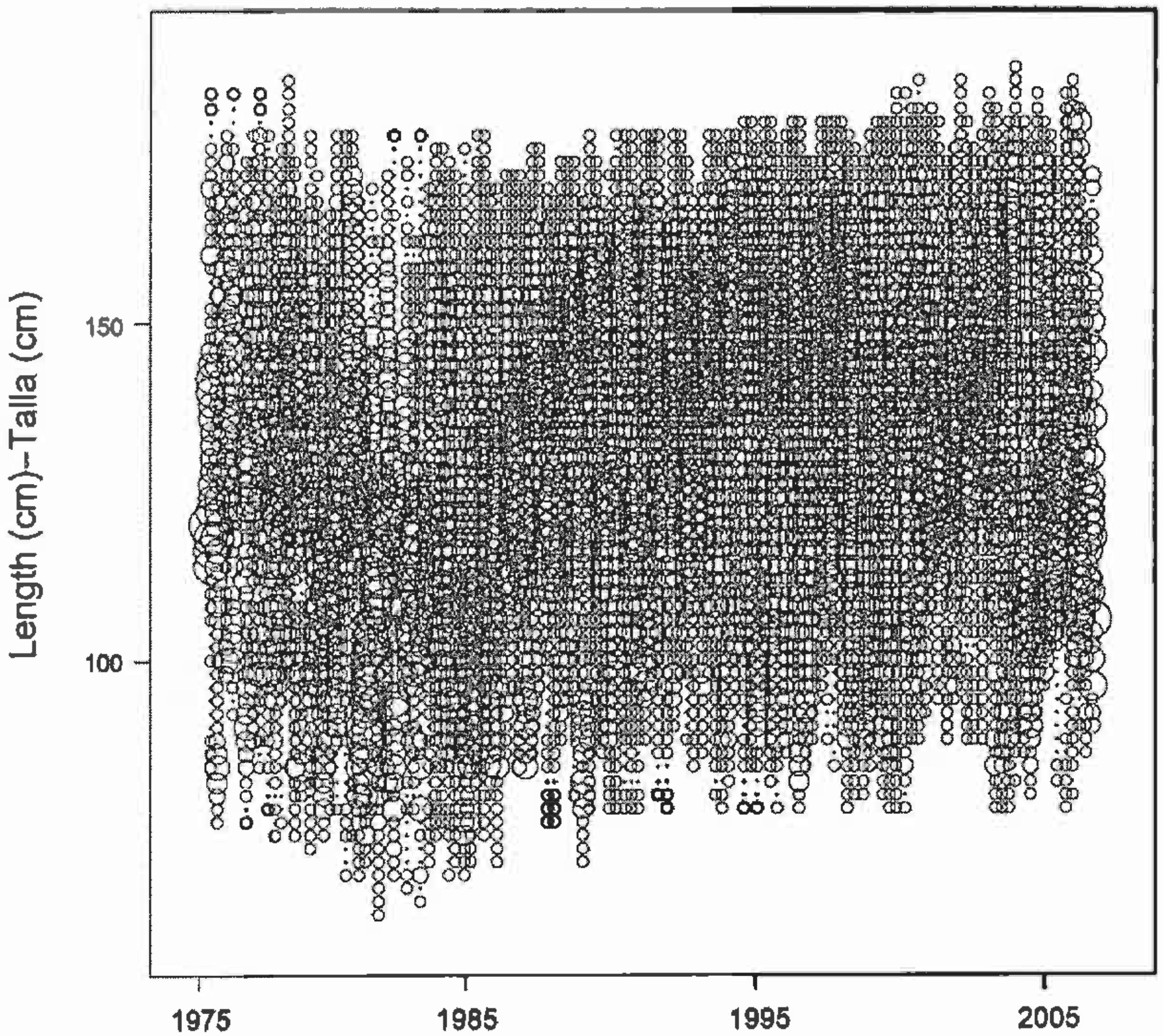

FIGURE 2.6l. Size compositions of the catches of bigeye tuna taken by Fishery 9, by quarter. The sizes of the circles are proportional to the catches.
FIGURA 2.6l. Composición por talla de las capturas de patudo de la Pesquería 9, por trimestre. El tamaño de los círculos es proporcional a la captura.

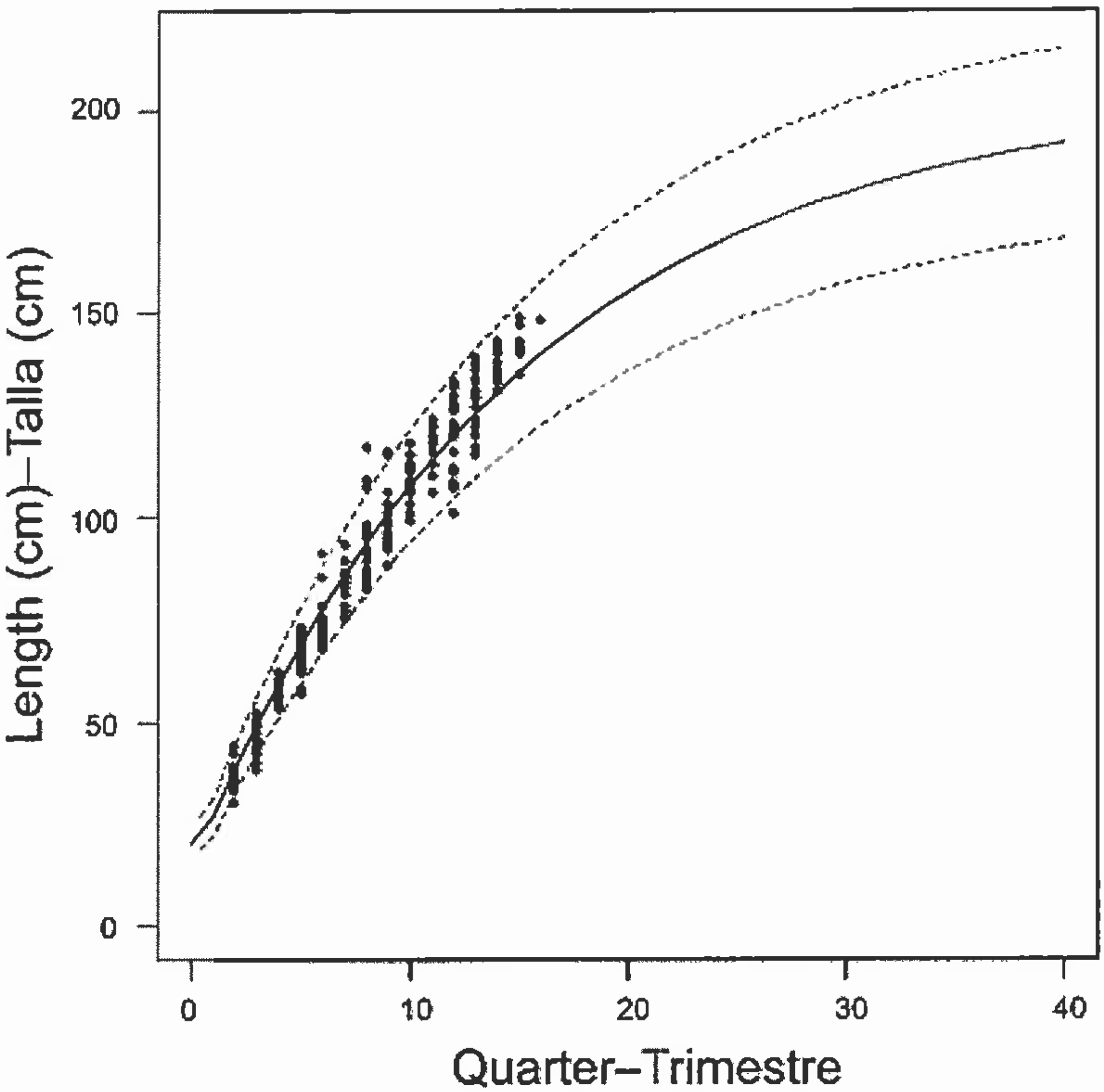

FIGURE 3.1. Estimated average lengths at age for bigeye tuna in the EPO. The dots represent the otolith age-length data from Schaefer and Fuller (2006). The dashed lines indicate the confidence intervals (±2 standard deviations) of the mean lengths at age.

FIGURA 3.1. Talla a edad media estimada del atún patudo en el OPO. Los puntos representan los datos de otolitos de talla a edad de Schaefer y Fuller (2006). Las líneas de trazos indican los intervalos de confianza (±2 desviaciones estándar) de la talla media a edad.

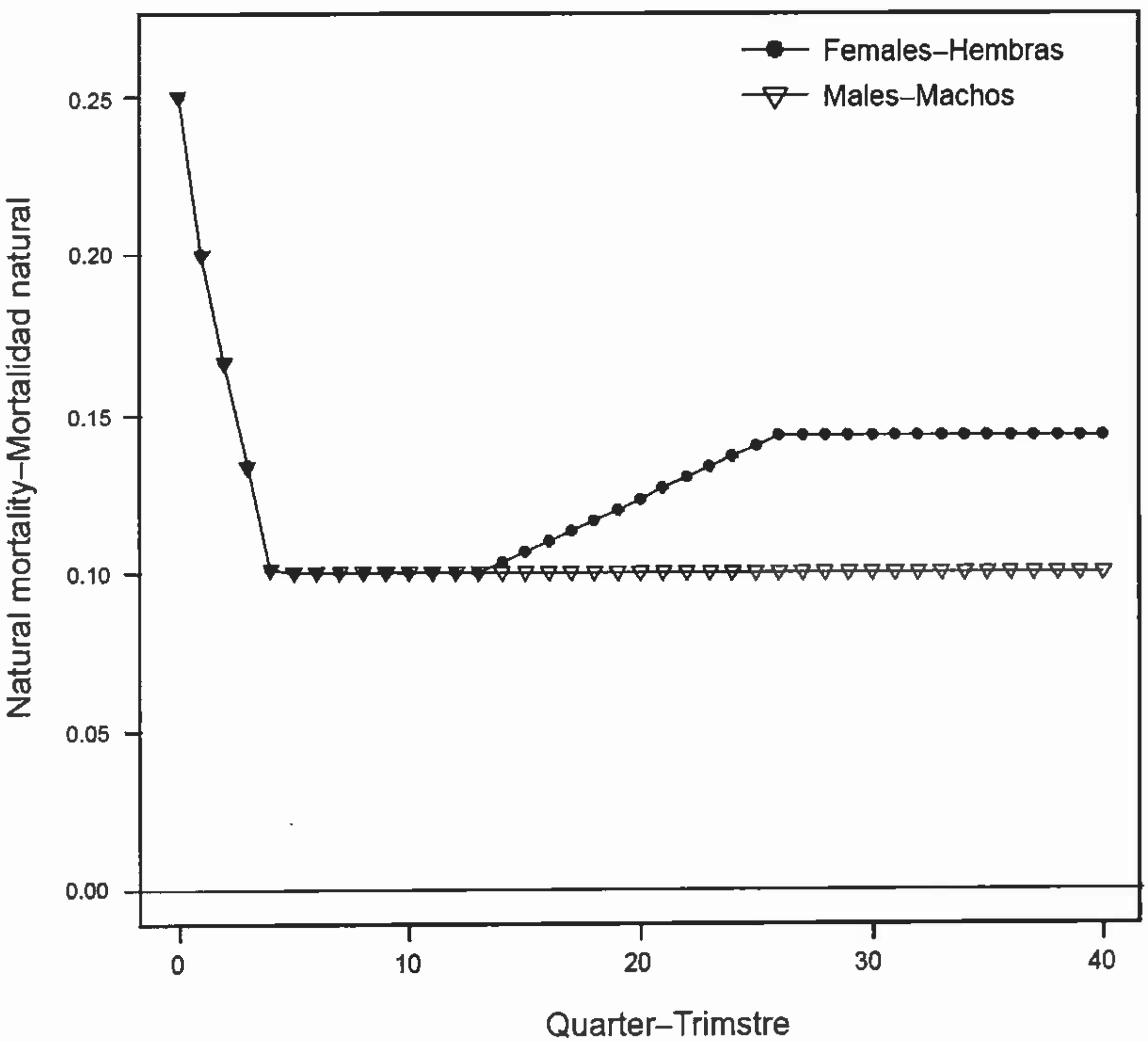

FIGURE 3.2. Quarterly natural mortality (*M*) rates used for the base case assessment of bigeye tuna in the EPO.

FIGURA 3.2. Tasas trimestrales de mortalidad natural (*M*) usadas en la evaluación del caso base del atún patudo en el OPO.

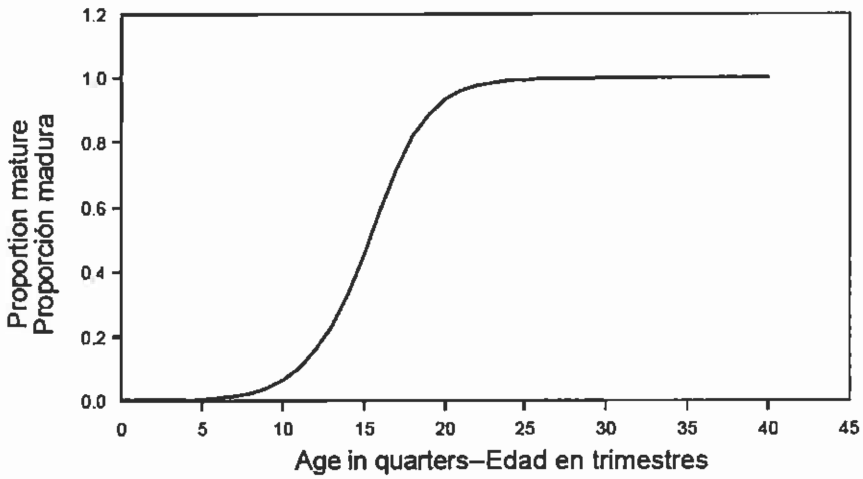

FIGURE 3.3. Age-specific index of fecundity of bigeye tuna as assumed in the base case model and in the estimation of natural mortality.
FIGURA 3.3. Índice de fecundidad por edad de atún patudo supuesto en el modelo del caso base y en la estimación de la mortalidad natural.

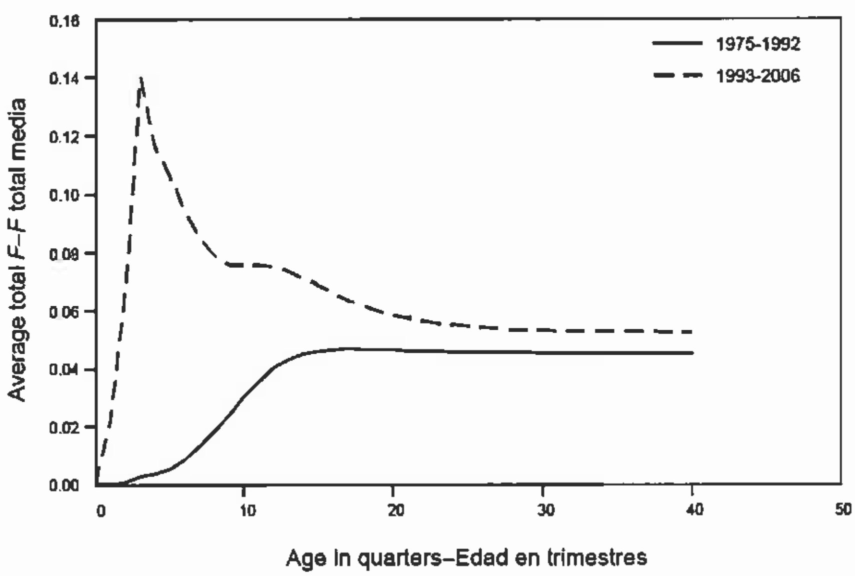

FIGURE 4.1. Average quarterly fishing mortality (approximated by exploitation rate) at age of bigeye tuna, by all gears, in the EPO. The curves for 1975-1992 and 1993-2007 display the averages for the periods prior to and since the expansion of the floating-object fisheries, respectively.
FIGURA 4.1. Mortalidad por pesca trimestral media (aproximada por la tasa de explotación) por edad de atún patudo en el OPO, por todas las artes. Las curvas de 1975-1992 y 1993-2007 muestran los promedios de los períodos antes y después de la expansión de las pesquerías sobre objetos flotantes, respectivamente.

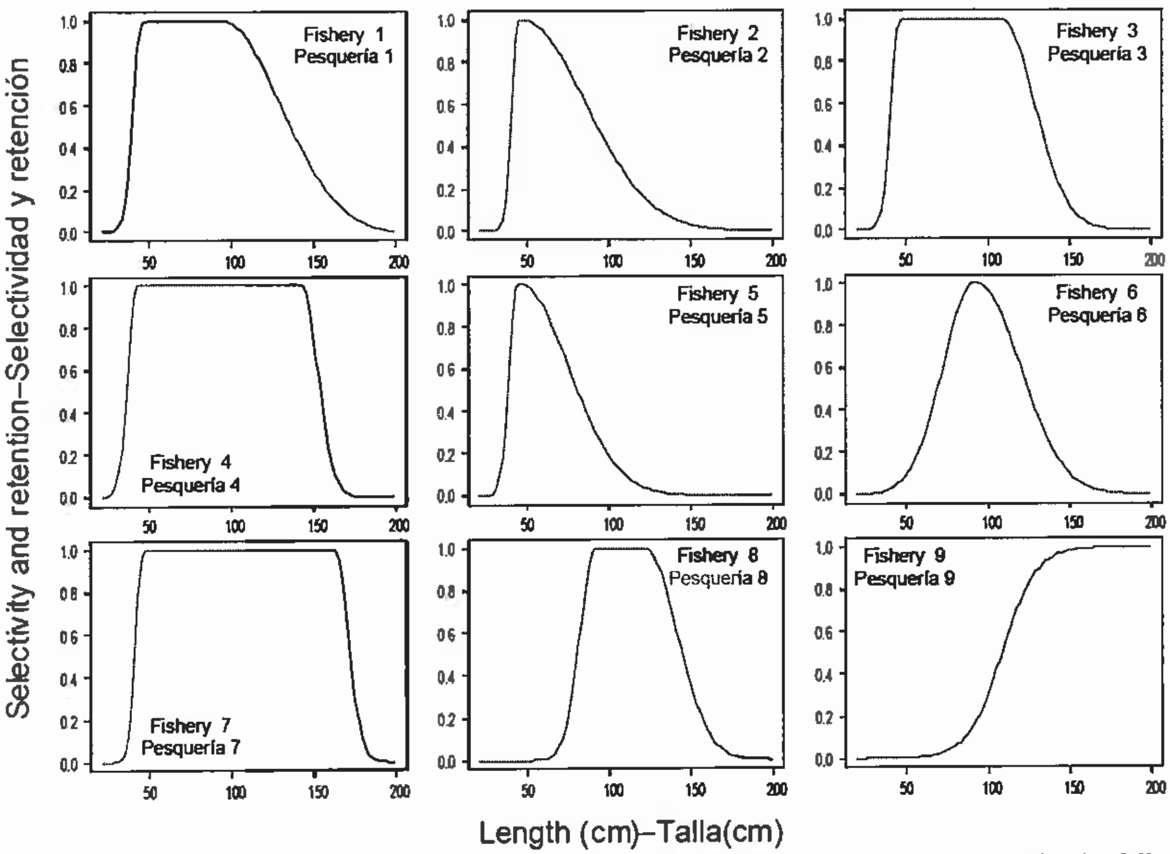

FIGURE 4.2. Size selectivity curves for Fisheries 1-9, estimated with SS2. Fish are assumed to be fully selected for the discard Fisheries 10-13. The selectivity curves for Fisheries 14 and 15 are the same as Fisheries 8 and 9, respectively.

FIGURA 4.2. Curvas de selectividad por talla correspondientes a las Pesquerías 1 a 9, estimadas con SS2. En el caso de las pesquerías de descarte (10-13), se supone que el pescado es plenamente seleccionado. Las curvas de selectividad de las Pesquerías 14 y 15 son iguales que las de las Pesquerías 8 y 9, respectivamente.

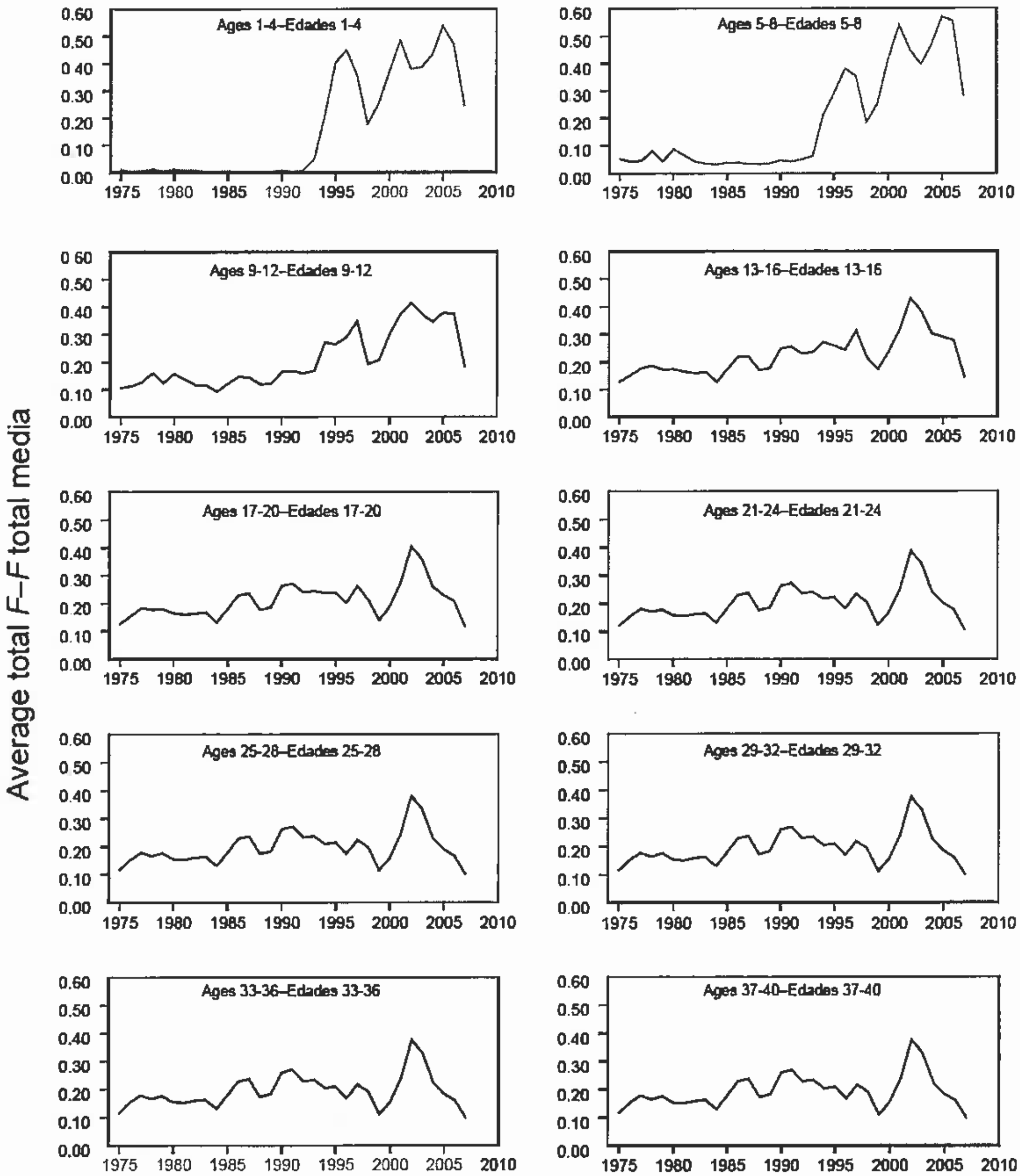

FIGURE 4.3. Average annual fishing mortality, by all gears, of bigeye tuna recruited to the fisheries of the EPO. Each panel illustrates an average of four annual fishing mortality vectors that affected the fish within the range of ages indicated in the title of each panel. For example, the trend illustrated in the upper-left panel is an average of the fishing mortalities that affected the fish that were 1-4 quarters old.

FIGURA 4.3. Mortalidad por pesca anual media, por todos los artes, de atún patudo reclutado a las pesquerías del OPO. Cada recuadro ilustra un promedio de cuatro vectores anuales de mortalidad por pesca que afectaron los peces de la edad indicada en el título de cada recuadro. Por ejemplo, la tendencia ilustrada en el recuadro superior izquierdo es un promedio de las mortalidades por pesca que afectaron a los peces de entre 1-4 trimestres de edad.

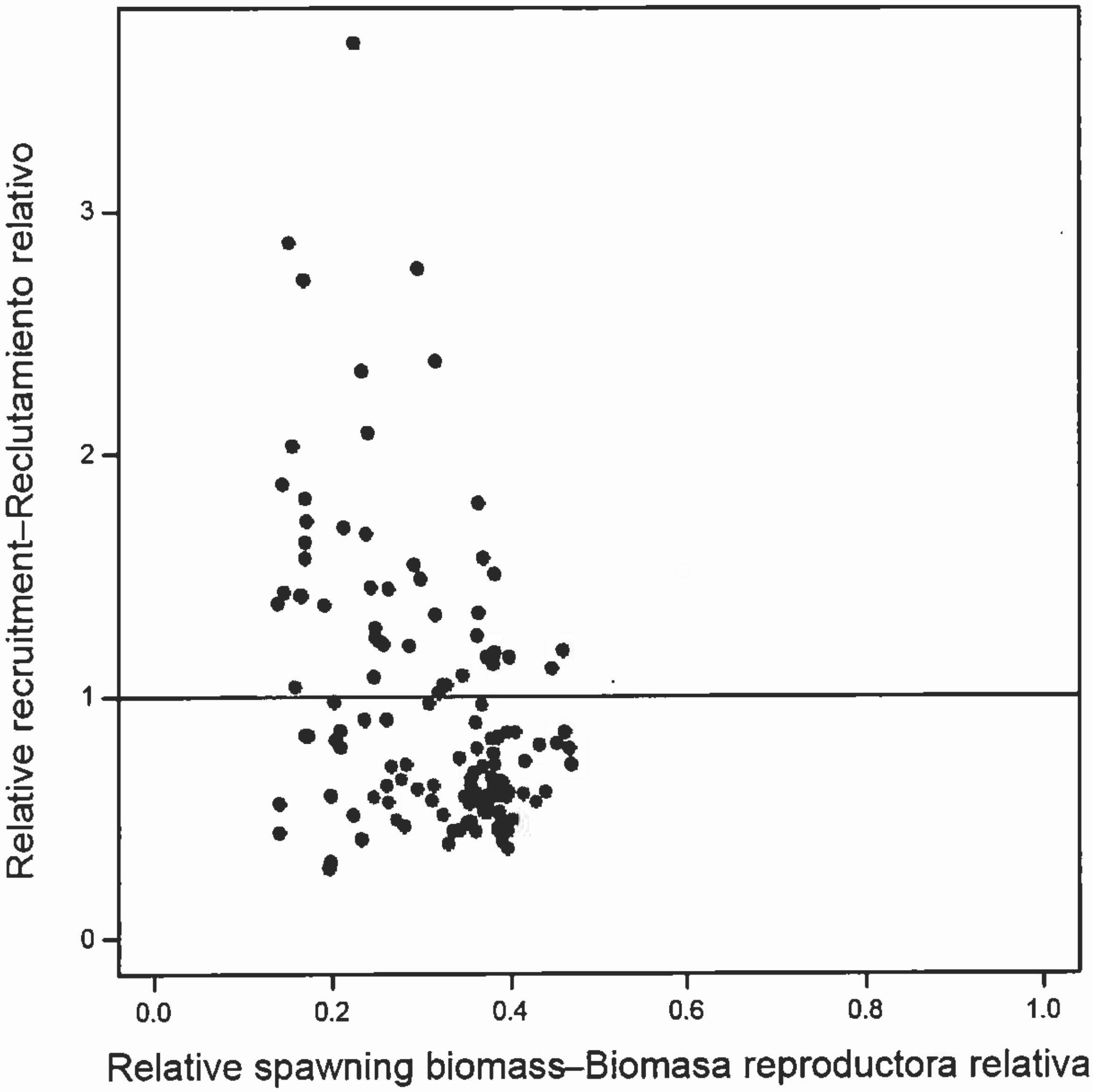

FIGURE 4.4. Estimated relationship between the recruitment of bigeye tuna and spawning biomass. The recruitment is scaled so that the estimate of virgin recruitment is equal to 1.0. Likewise, the spawning biomass is scaled so that the estimate of virgin spawning biomass is equal to 1.0. The horizontal line represents the assumed stock-recruitment relationship.

FIGURA 4.4. Relación estimada entre el reclutamiento y la biomasa reproductora de atún patudo. Se escala el reclutamiento para que la estimación de reclutamiento virgen equivalga a 1,0, y la biomasa reproductora para que la estimación de biomasa reproductora virgen equivalga a 1,0. La línea horizontal representa la relación población-reclutamiento supuesta.

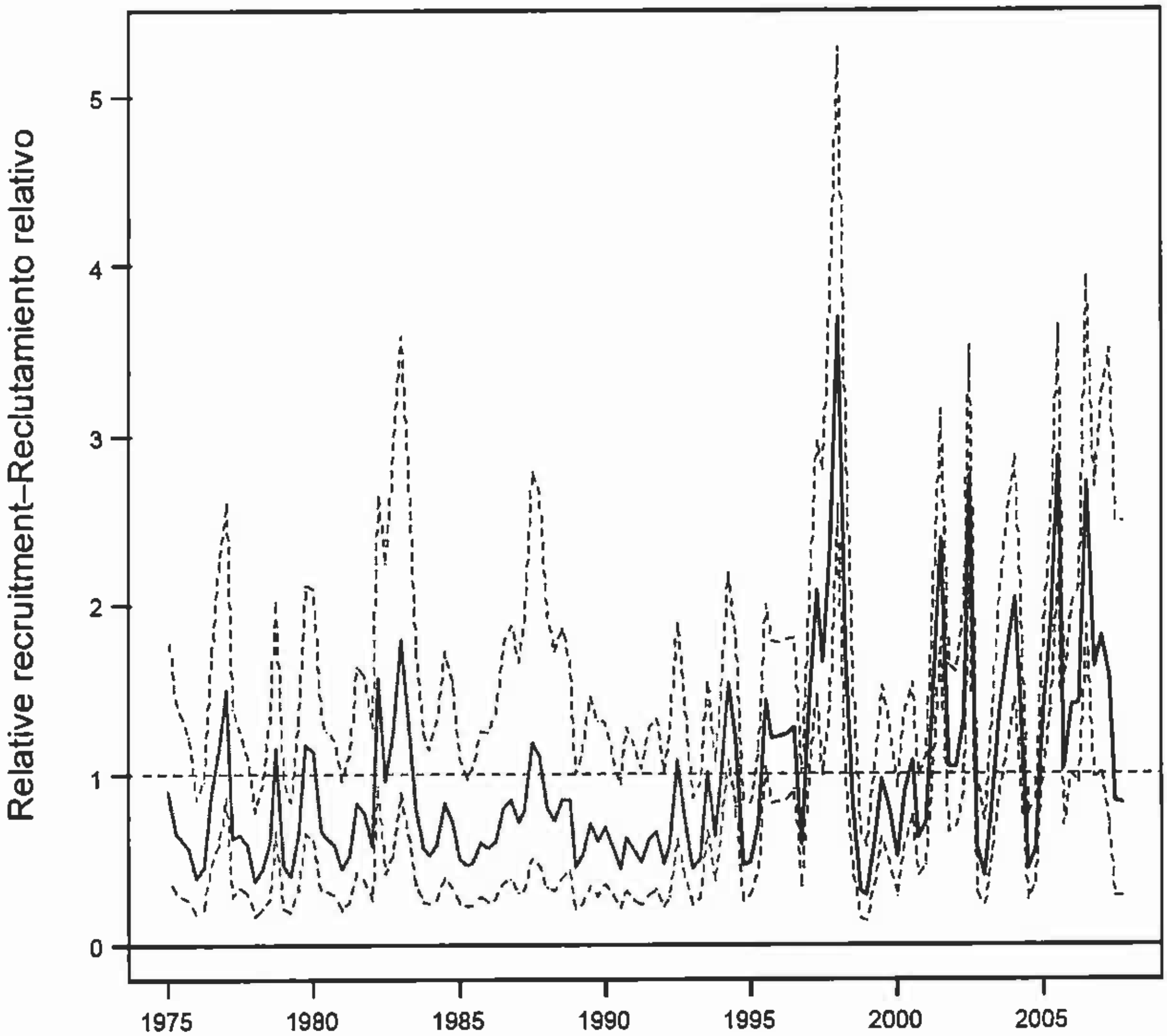

FIGURE 4.5. Estimated recruitment of bigeye tuna to the fisheries of the EPO. The estimates are scaled so that the estimate of virgin recruitment is equal to 1.0. The bold line illustrates the maximum likelihood estimates of recruitment, and the thin dashed lines the confidence intervals (±2 standard deviations) around those estimates. The dashed horizontal line represents the average recruitment for the period. The labels on the time axis are drawn at the beginning of each year, but, since the assessment model represents time on a quarterly basis, there are four estimates of recruitment for each year.

FIGURA 4.5. Reclutamiento estimado de atún patudo a las pesquerías del OPO. Se escalan las estimaciones para que la estimación de reclutamiento virgen equivalga a 1,0. La línea gruesa ilustra las estimaciones de reclutamiento de verosimilitud máxima, y las líneas delgadas de trazos los intervalos de confianza (±2 desviaciones estándar) alrededor de esas estimaciones. La línea horizontal de trazos representa el reclutamiento promedio del período. Se dibujan las leyendas en el eje de tiempo al principio de cada año, pero, ya que el modelo de evaluación representa el tiempo por trimestres, hay cuatro estimaciones de reclutamiento para cada año.

FIGURE 4.6. Maximum likelihood estimates of the biomass of bigeye tuna 3+ quarters old in the EPO (summary biomass). Since the assessment model represents time on a quarterly basis, there are four estimates of biomass for each year. t = metric tons.

FIGURA 4.6. Estimaciones de verosimilitud máxima de la biomasa de atún patudo de 3+ trimestres de edad en el OPO (biomasa sumaria). Ya que el modelo de evaluación representa el tiempo por trimestre, hay cuatro estimaciones de biomasa para cada año. t = toneladas métricas.

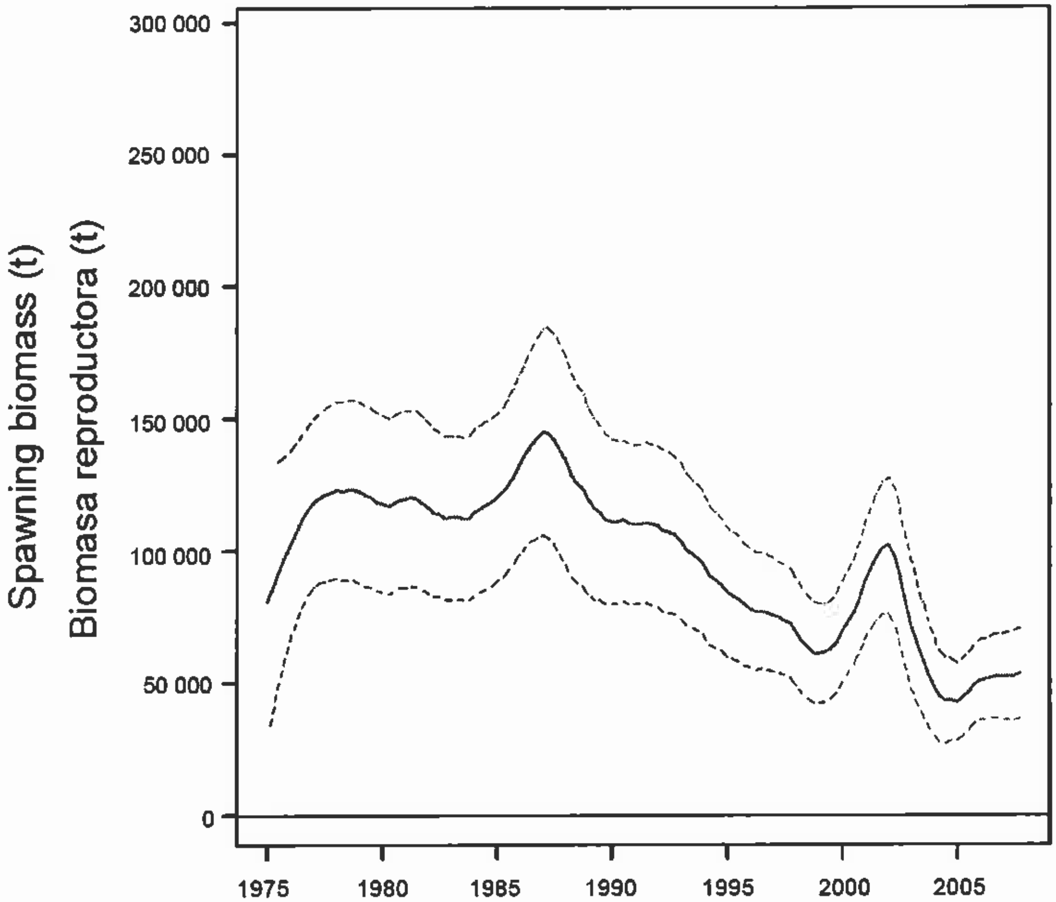

FIGURE 4.7. Maximum likelihood estimates of the spawning biomass (see Section 4.1.3) of bigeye tuna in the EPO. The bold line illustrates the maximum likelihood estimates of the biomasses, and the thin dashed lines the confidence intervals (±2 standard deviations) around those estimates. Since the assessment model represents time on a quarterly basis, there are four estimates of the index for each year. t = metric tons.

FIGURA 4.7. Estimaciones de verosimilitud máxima del índice de biomasa reproductora (ver Sección 4.1.3) de atún patudo en el OPO. La línea gruesa ilustra las estimaciones de verosimilitud máxima de la biomasa, y las líneas delgadas de trazos los intervalos de confianza (±2 desviaciones estándar) alrededor de estas estimaciones. Ya que el modelo de evaluación representa el tiempo por trimestre, hay cuatro estimaciones del índice para cada año. t = toneladas métricas.

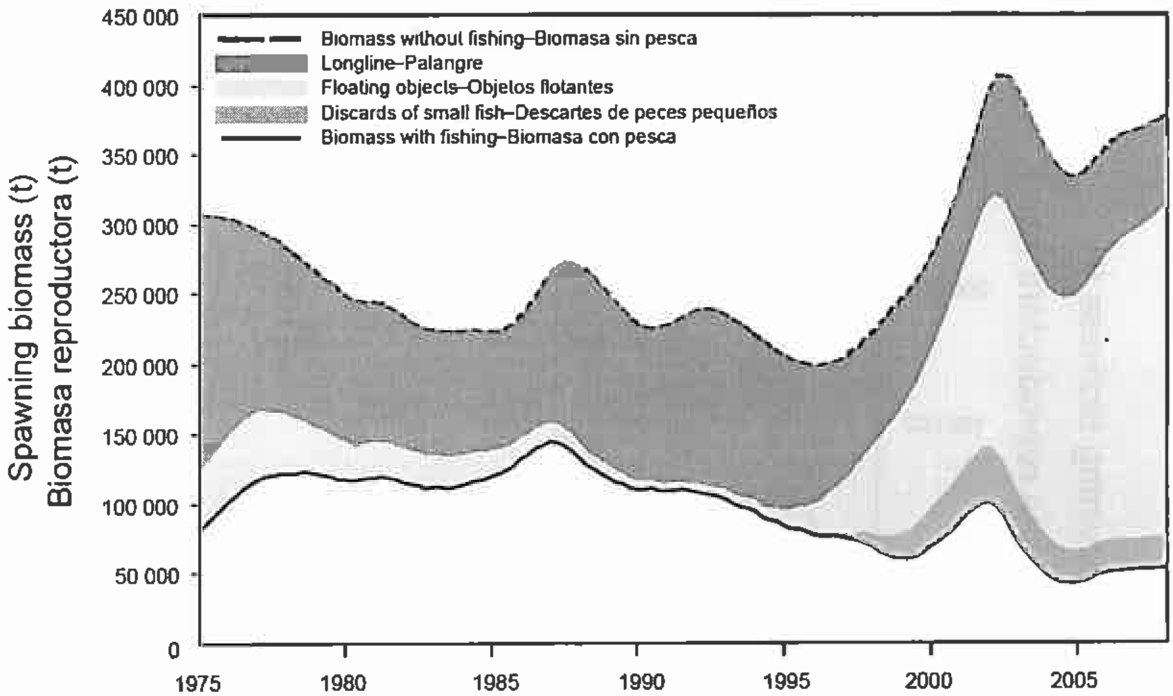

FIGURE 4.8. Trajectory of the spawning biomass of a simulated population of bigeye tuna that was not exploited (top line) and that predicted by the stock assessment model (bottom line). The shaded areas between the two lines show the portions of the impact attributed to each fishing method. t = metric tons.
FIGURA 4.8. Trayectoria de la biomasa reproductora de una población simulada de atún patudo no explotada (línea superior) y la que predice el modelo de evaluación (línea inferior). Las áreas sombreadas entre las dos líneas señalan la porción del efecto atribuida a cada método de pesca. t = toneladas métricas.

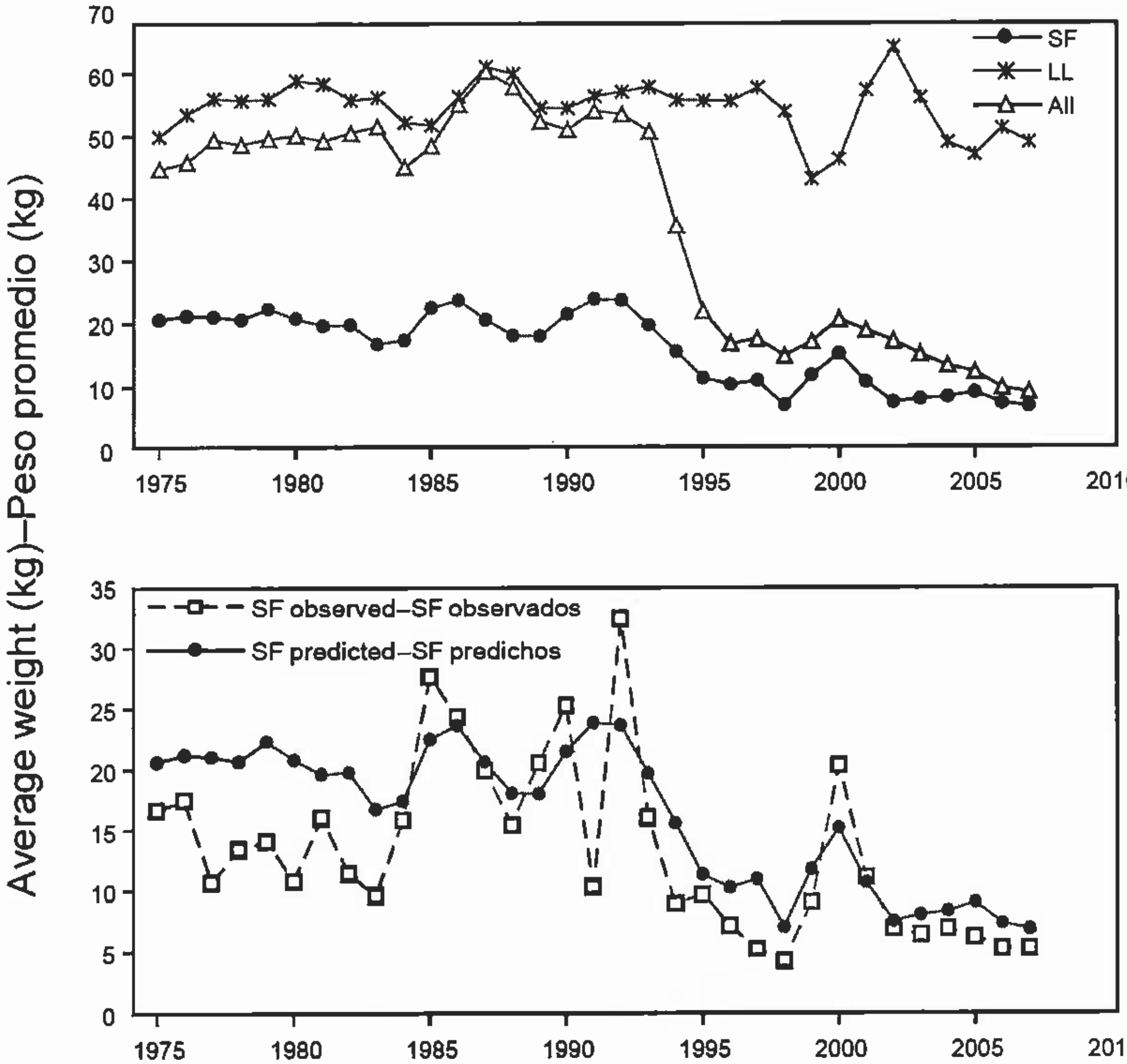

FIGURE 4.9. Average weights of bigeye tuna caught in the EPO, 1975-2007, by the surface fisheries (SF, Fisheries 1-7), longline fisheries (LL, Fisheries 8-9 and 14-15), and all fisheries combined (All). Upper panel: predicted average weights; lower panel: predicted and observed average weights for the surface fisheries.

FIGURA 4.9. Peso medio estimado de atún patudo capturado en el OPO, 1975-2007,por las pesquerías de superficie (SF, Pesquerías 1-7), de palangre (LL, Pesquerías 8, 9 y 14-15), y todas las pesquerías combinadas (All). Recuadro superior: pesos medios predichos; recuadro inferior: pesos medios predichos y observados de las pesquerías de superficie.

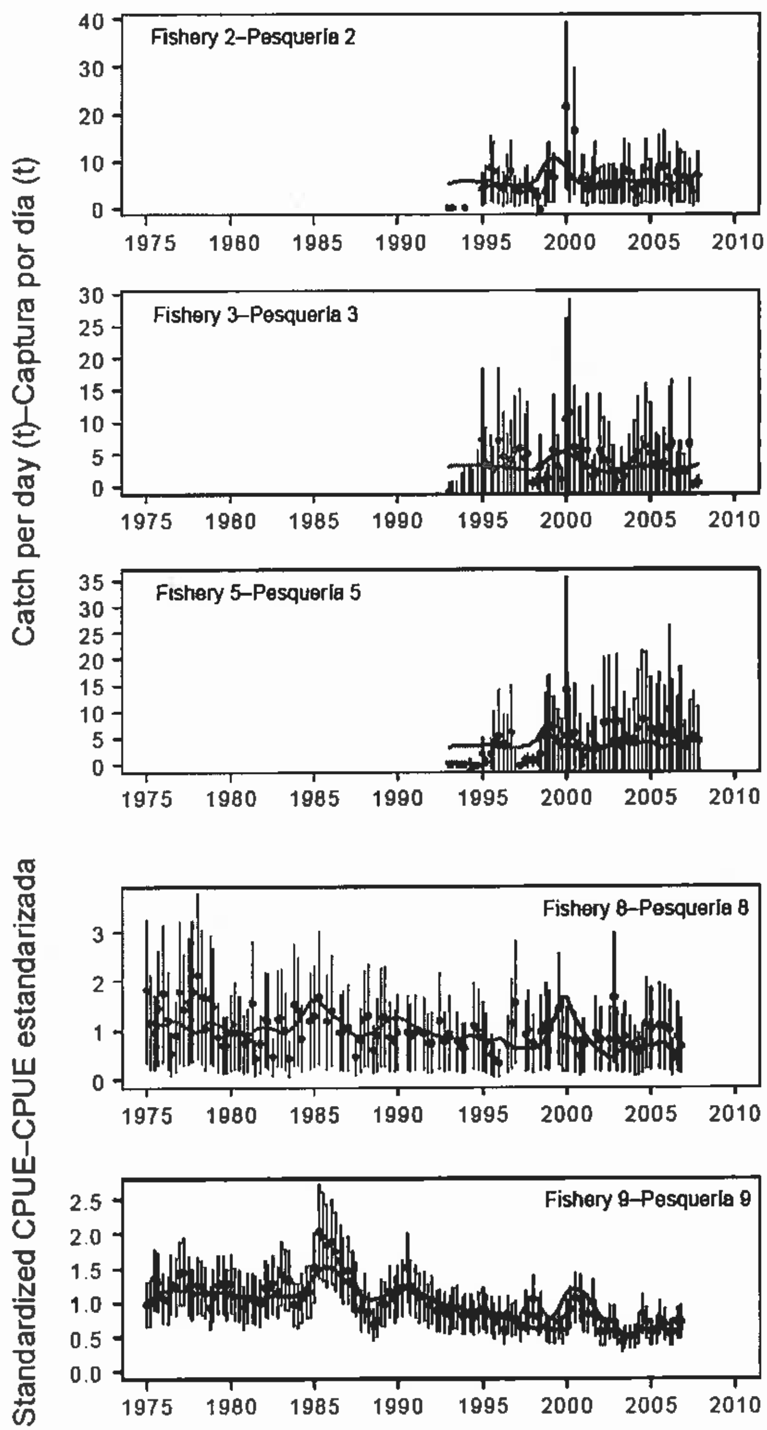

FIGURE 4.10. Model fit to the CPUE data from different fisheries.
FIGURA 4.10. Ajuste del modelo a los datos de CPUE de varias pesquerías.

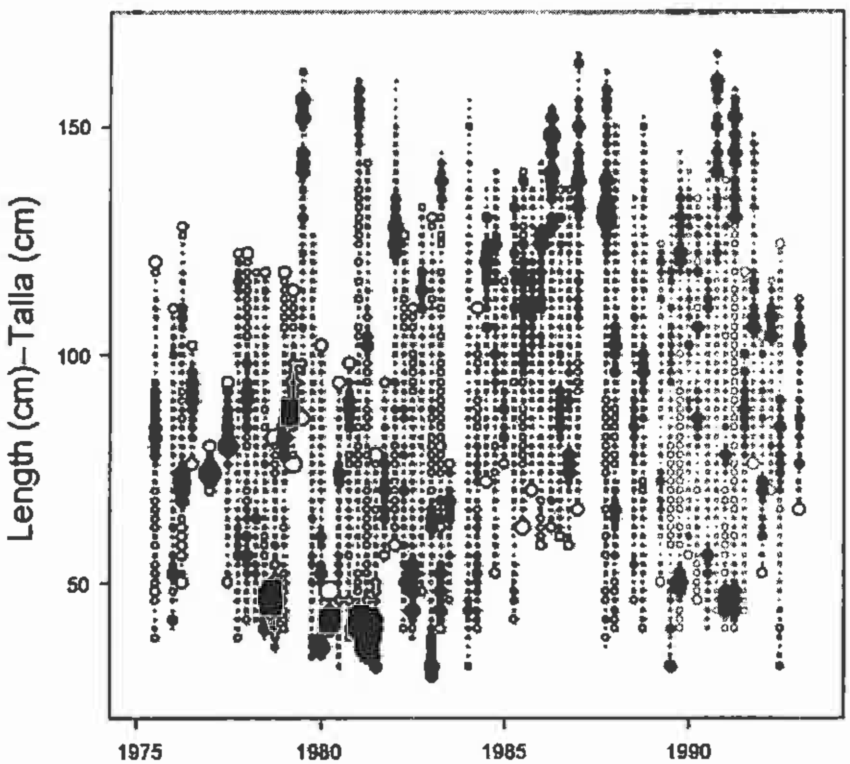

FIGURE 4.11a. Pearson residual plots for the model fits to the length composition data for Fishery 1. The open and solid circles represent observations that are higher and lower, respectively, than the model predictions. The sizes of the circles are proportional to the absolute values of the residuals.

FIGURA 4.11a. Gráficas de residuales de Pearson para los ajustes del modelo a los datos de composición por talla de la Pesquería 1. Los círculos abiertos y sólidos representan observaciones mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional al valor absoluto de los residuales.

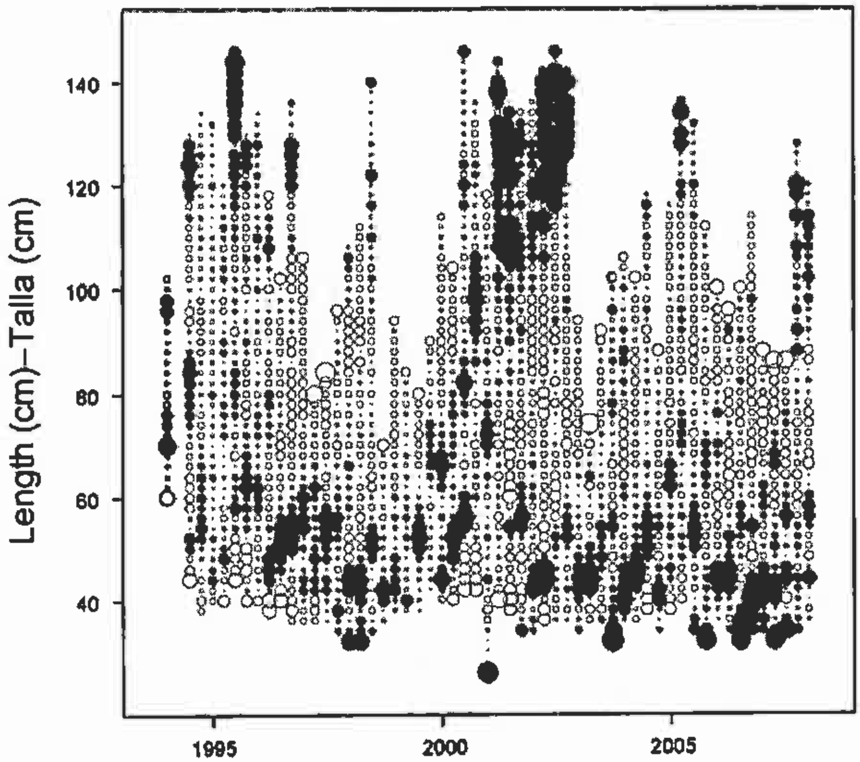

FIGURE 4.11b. Pearson residual plots for the model fits to the length composition data for Fishery 2. The open and solid circles represent observations that are higher and lower, respectively, than the model predictions. The sizes of the circles are proportional to the absolute values of the residuals.

FIGURA 4.11b. Gráficas de residuales de Pearson para los ajustes del modelo a los datos de composición por talla de la Pesquería 2. Los círculos abiertos y sólidos representan observaciones mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional al valor absoluto de los residuales.

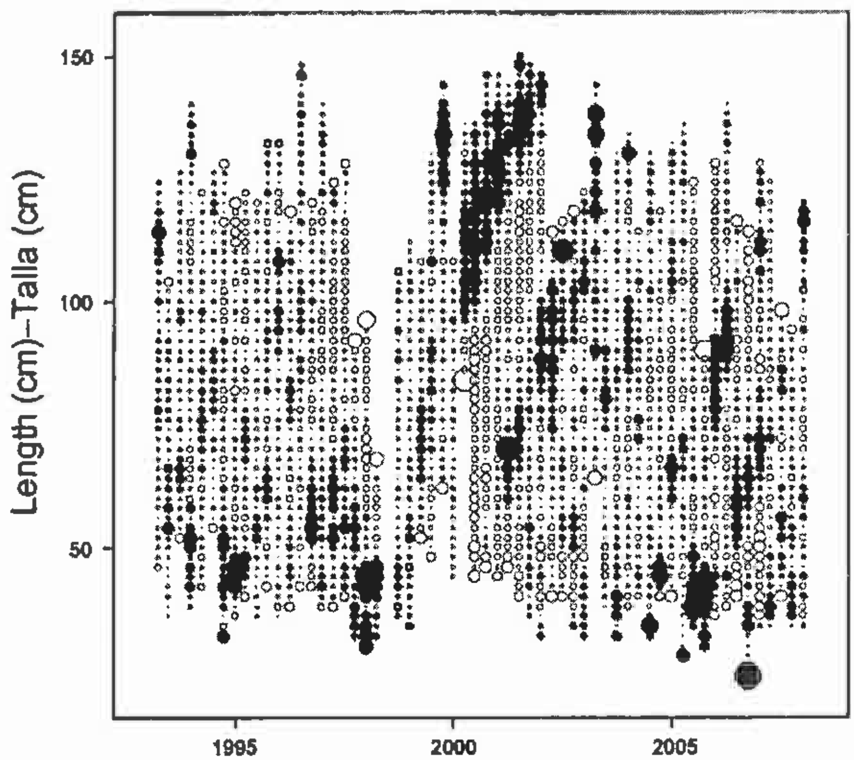

FIGURE 4.11c. Pearson residual plots for the model fits to the length composition data for Fishery 3. The open and solid circles represent observations that are higher and lower, respectively, than the model predictions. The sizes of the circles are proportional to the absolute values of the residuals.

FIGURA 4.11c. Gráficas de residuales de Pearson para los ajustes del modelo a los datos de composición por talla de la Pesquería 3. Los círculos abiertos y sólidos representan observaciones mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional al valor absoluto de los residuales.

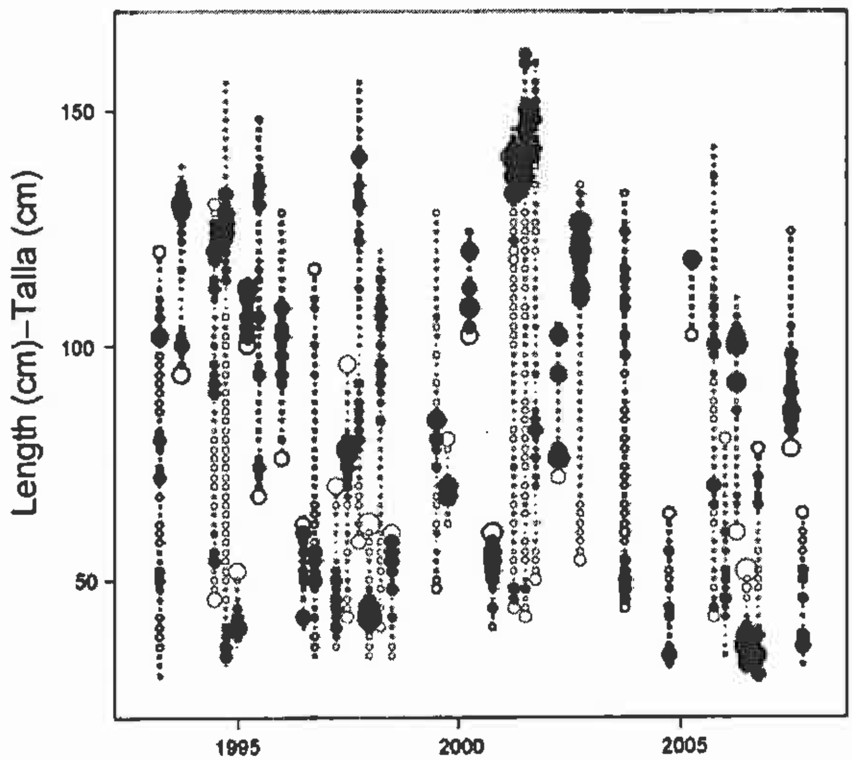

FIGURE 4.11d Pearson residual plots for the model fits to the length composition data for Fishery 4. The open and solid circles represent observations that are higher and lower, respectively, than the model predictions. The sizes of the circles are proportional to the absolute values of the residuals.
FIGURA 4.11d. Gráficas de residuales de Pearson para los ajustes del modelo a los datos de composición por talla de la Pesquería 4. Los círculos abiertos y sólidos representan observaciones mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional al valor absoluto de los residuales.

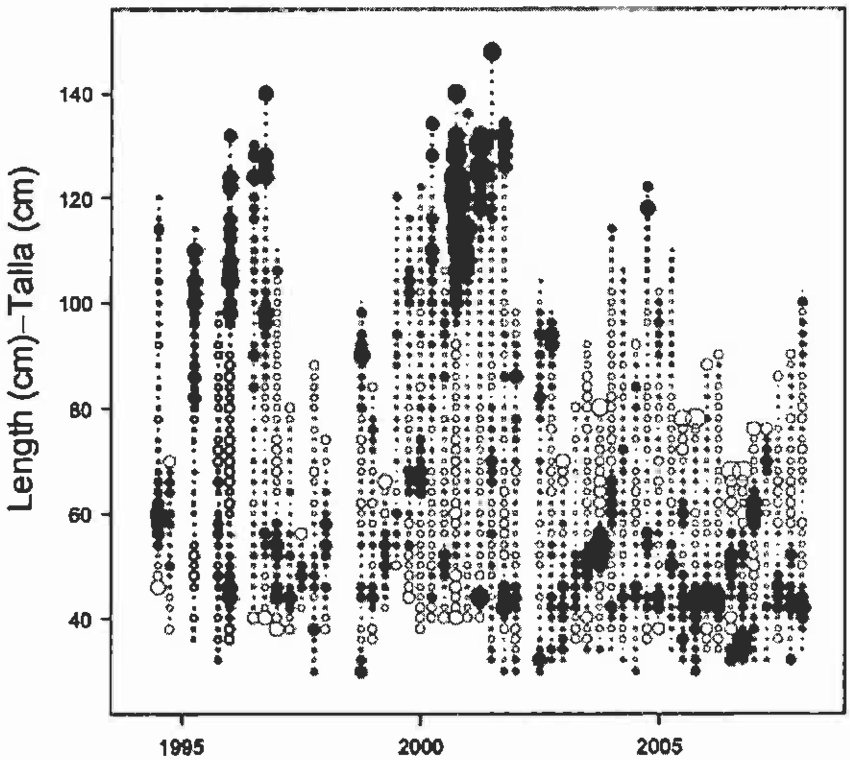

FIGURE 4.11e. Pearson residual plots for the model fits to the length composition data for Fishery 5. The open and solid circles represent observations that are higher and lower, respectively, than the model predictions. The sizes of the circles are proportional to the absolute values of the residuals.

FIGURA 4.11e. Gráficas de residuales de Pearson para los ajustes del modelo a los datos de composición por talla de la Pesquería 5. Los círculos abiertos y sólidos representan observaciones mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional al valor absoluto de los residuales.

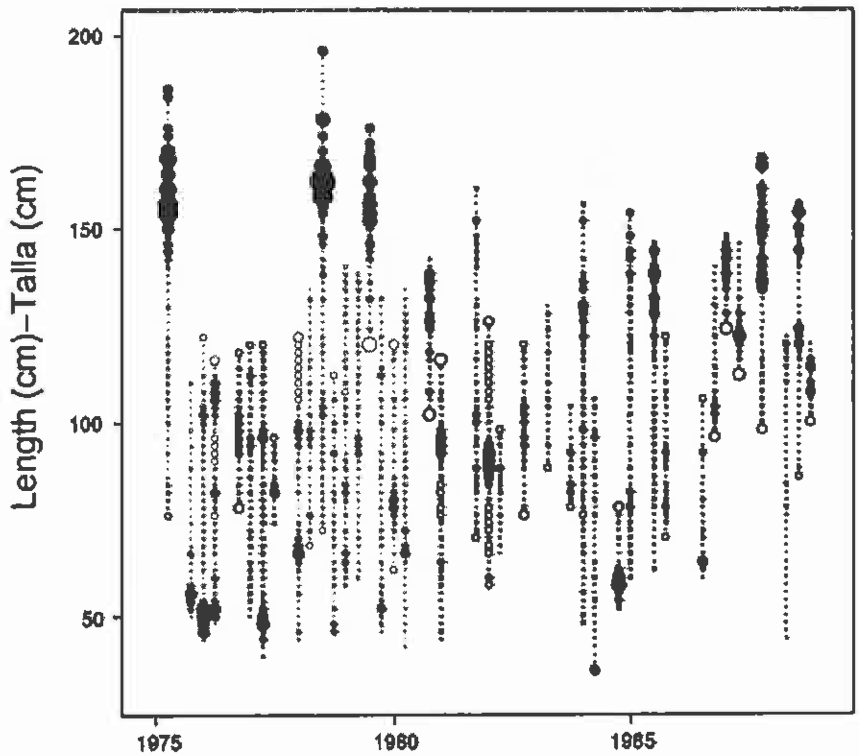

FIGURE 4.11f. Pearson residual plots for the model fits to the length composition data for Fishery 6. The open and solid circles represent observations that are higher and lower, respectively, than the model predictions. The sizes of the circles are proportional to the absolute values of the residuals.

FIGURA 4.11f. Gráficas de residuales de Pearson para los ajustes del modelo a los datos de composición por talla de la Pesquería 6. Los círculos abiertos y sólidos representan observaciones mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional al valor absoluto de los residuales.

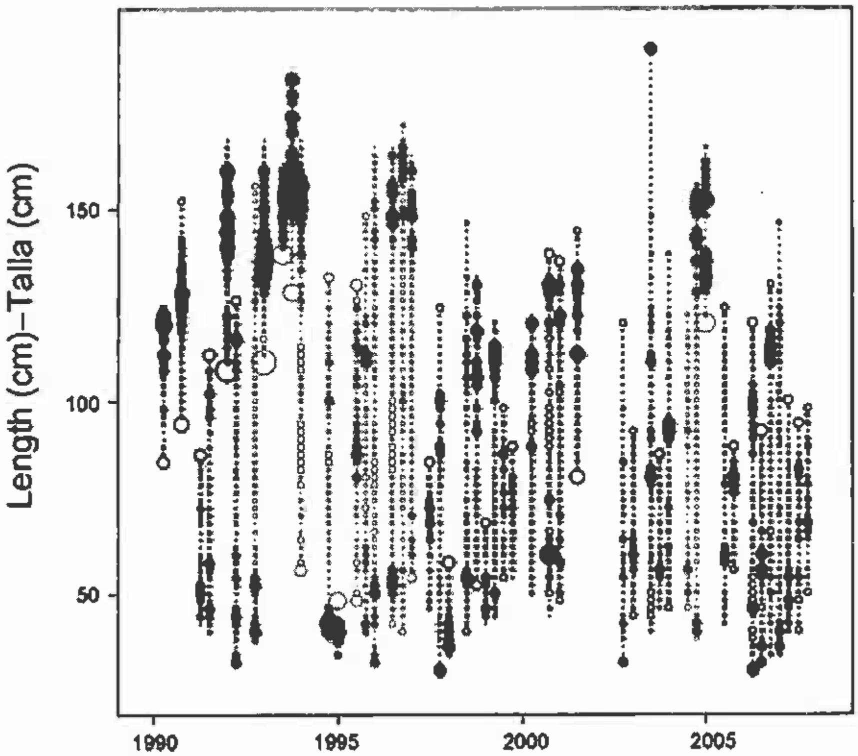

FIGURE 4.11g. Pearson residual plots for the model fits to the length composition data for Fishery 7. The open and solid circles represent observations that are higher and lower, respectively, than the model predictions. The sizes of the circles are proportional to the absolute values of the residuals.
FIGURA 4.11g. Gráficas de residuales de Pearson para los ajustes del modelo a los datos de composición por talla de la Pesquería 7. Los círculos abiertos y sólidos representan observaciones mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional al valor absoluto de los residuales.

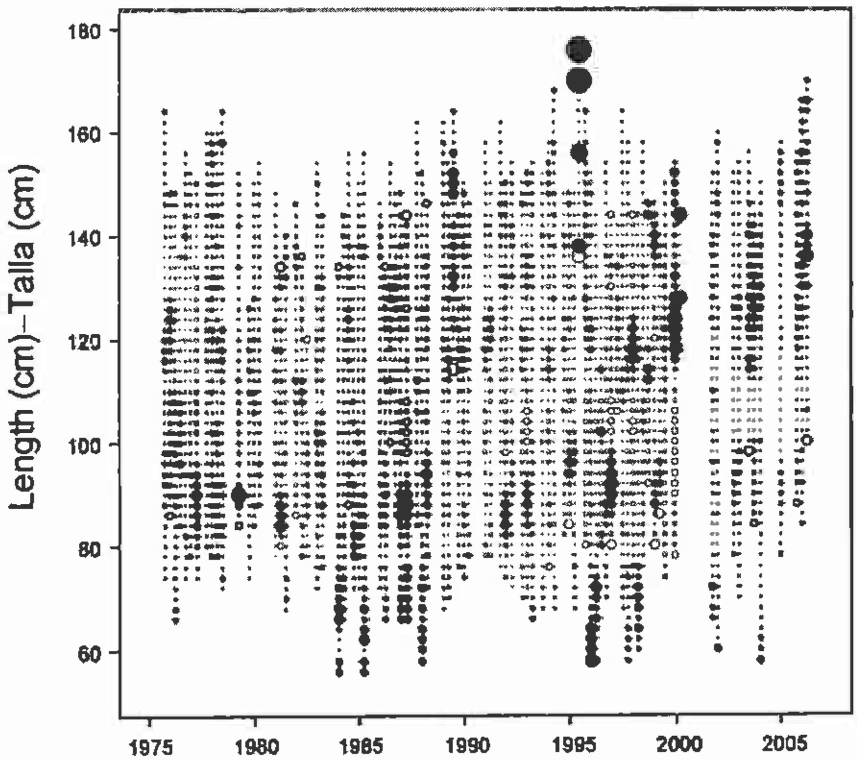

FIGURE 4.11h. Pearson residual plots for the model fits to the length composition data for Fishery 8. The open and solid circles represent observations that are higher and lower, respectively, than the model predictions. The sizes of the circles are proportional to the absolute values of the residuals.

FIGURA 4.11h. Gráficas de residuales de Pearson para los ajustes del modelo a los datos de composición por talla de la Pesquería 8. Los círculos abiertos y sólidos representan observaciones mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional al valor absoluto de los residuales.

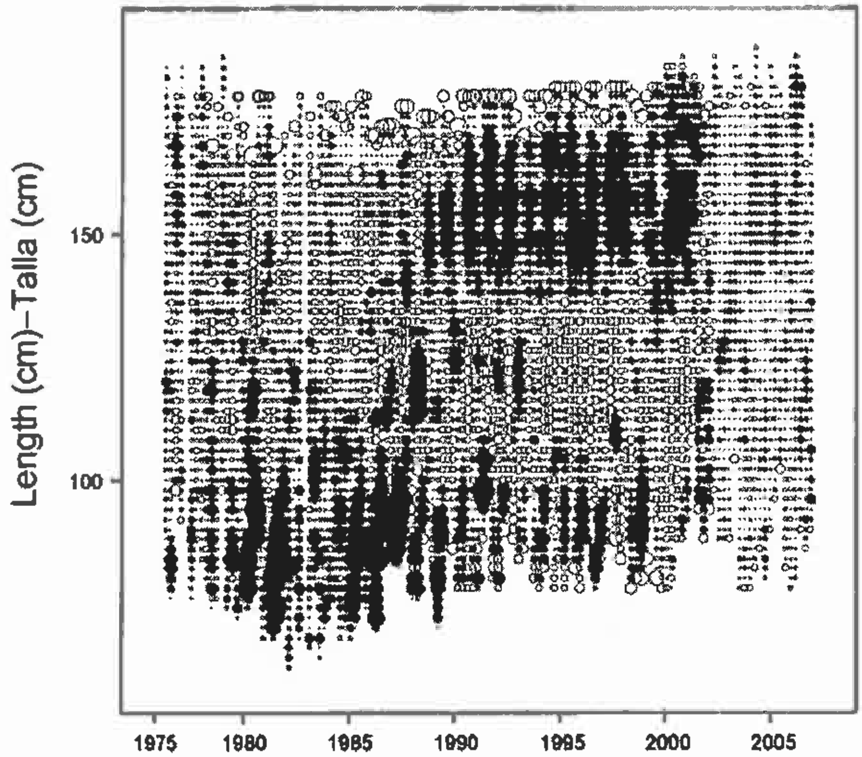

FIGURE 4.111. Pearson residual plots for the model fits to the length composition data for Fishery 9. The open and solid circles represent observations that are higher and lower, respectively, than the model predictions. The sizes of the circles are proportional to the absolute values of the residuals.
FIGURA 4.111. Gráficas de residuales de Pearson para los ajustes del modelo a los datos de composición por talla de la Pesquería 9. Los círculos abiertos y sólidos representan observaciones mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional al valor absoluto de los residuales.

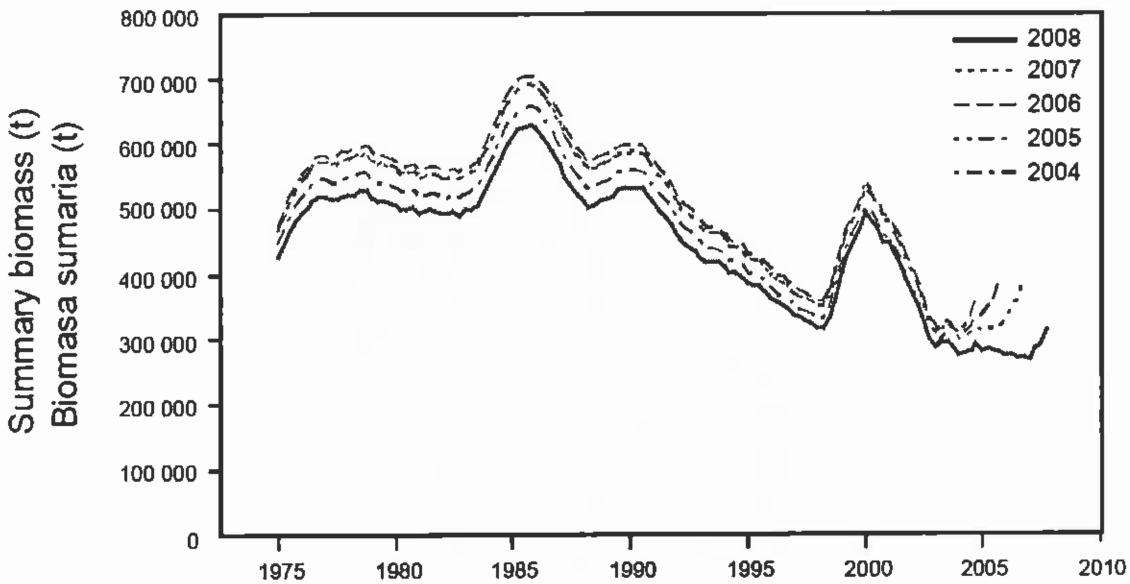

FIGURE 4.12. Retrospective comparisons of estimates of the summary biomass (fish of age 3 quarters and older) of bigeye tuna in the EPO. The estimates from the base case model are compared with the estimates obtained when the most recent year (2007), two years (2007 and 2006), three years (2007, 2006 and 2005) or four years (2007, 2006, 2005 and 2004) of data were excluded. t = metric tons.

FIGURA 4.12. Comparaciones retrospectivas de las estimaciones de la biomasa sumaria (peces de 3 trimestres y más de edad) de atún patudo. Se comparan las estimaciones del modelo del caso base con aquéllas obtenidas cuando se excluyeron los datos del año más reciente (2007), a de los dos años (2007 y 2006), tres años (2007, 2006, y 2005), o cuatro años (2007, 2006, 2005 y 2004) más recientes. t = toneladas métricas.

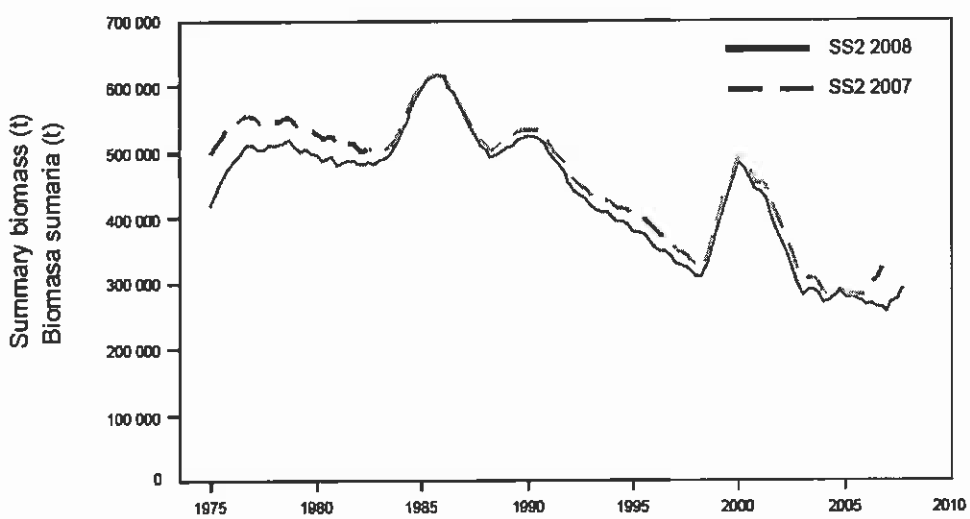

FIGURE 4.13. Comparison of estimates of the summary biomass (fish of age 3 quarters and older) of bigeye tuna from the most recent assessment (2007) and the current assessment, both using SS2. t = metric tons.

FIGURA 4.13. Comparación de las estimaciones de la biomasa sumaria (peces de 3 trimestres y más de edad) de atún patudo de la evaluación más reciente (2007) y la evaluación actual, ambas con SS2. t = toneladas métricas.

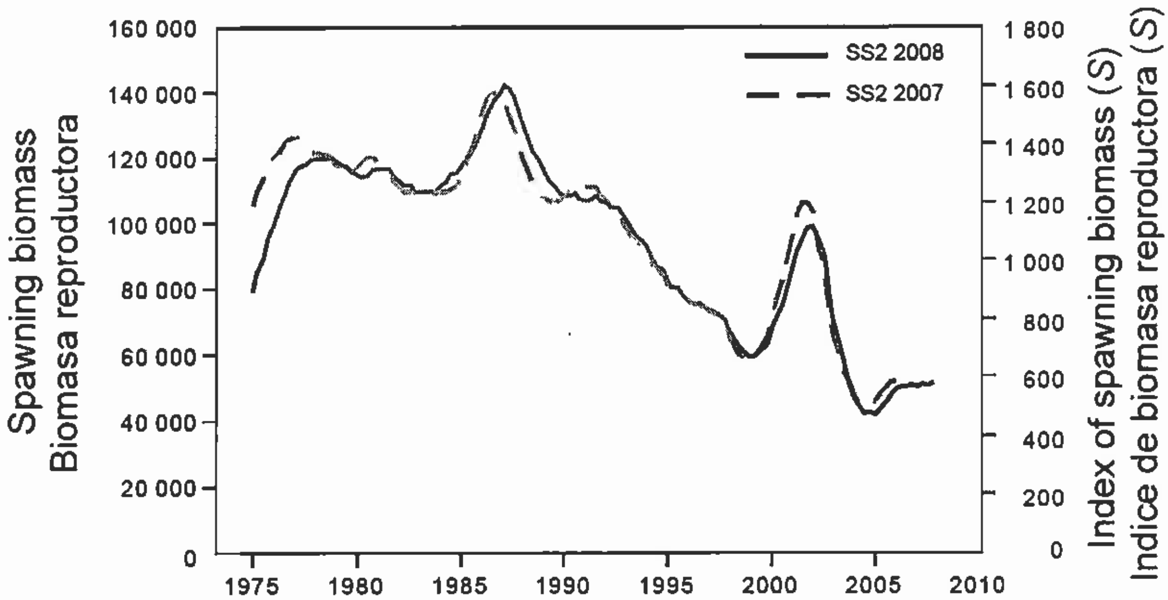

FIGURE 4.14. Comparison of estimates of the index of spawning biomass for bigeye tuna in the EPO from the most recent assessment (2007) and the current assessment (SS2), both using SS2.

FIGURA 4.14. Comparación del índice de biomasa reproductora estimada del atún patudo en el OPO de la evaluación más reciente (2007) y la evaluación actual, ambas con SS2.

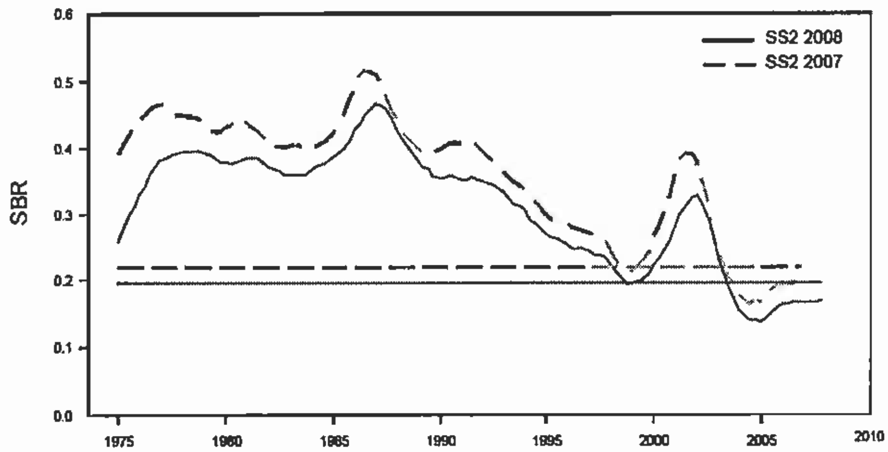

FIGURE 4.15. Comparison of estimated spawning biomass ratios (SBRs) for bigeye tuna in the EPO from the most recent assessment (2007) and the current assessment, both using SS2. The horizontal line (at about 0.22) indicates the SBR at MSY.

FIGURA 4.15. Comparación del cociente de biomasa reproductora (SBR) del atún patudo en el OPO de la evaluación más reciente (2007) y la evaluación actual, ambas con SS2. La línea horizontal (en aproximadamente 0,22) indica el SBR en RMS.

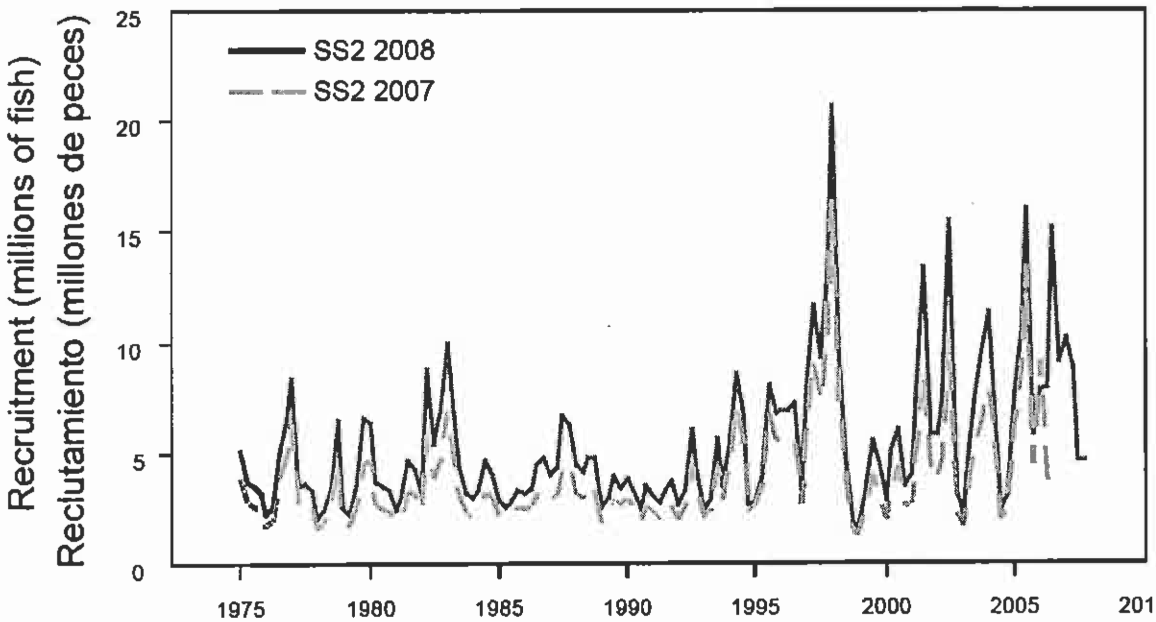

FIGURE 4.16a. Comparison of estimated recruitment of bigeye tuna in the EPO from the most recent assessment (2007) and the current assessment (SS2), both using SS2.
FIGURA 4.16. Comparación del reclutamiento estimado del atún patudo en el OPO de la evaluación más reciente (2007) y la evaluación actual (SS2), ambas con SS2.

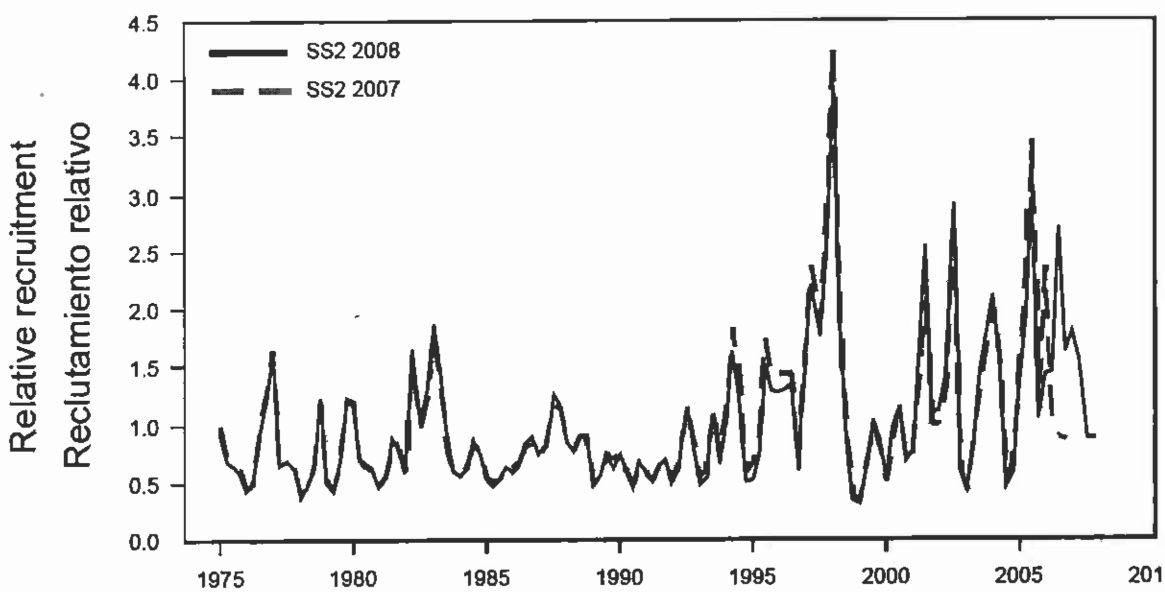

FIGURE 4.16b. Comparison of estimated relative recruitment of bigeye tuna in the EPO from the most recent assessment (2007) and the current assessment (SS2), both using SS2.
FIGURA 4.16b. Comparación del reclutamiento relativo estimado del atún patudo en el OPO de la evaluación más reciente (2007) y la evaluación actual (SS2), ambas con SS2.

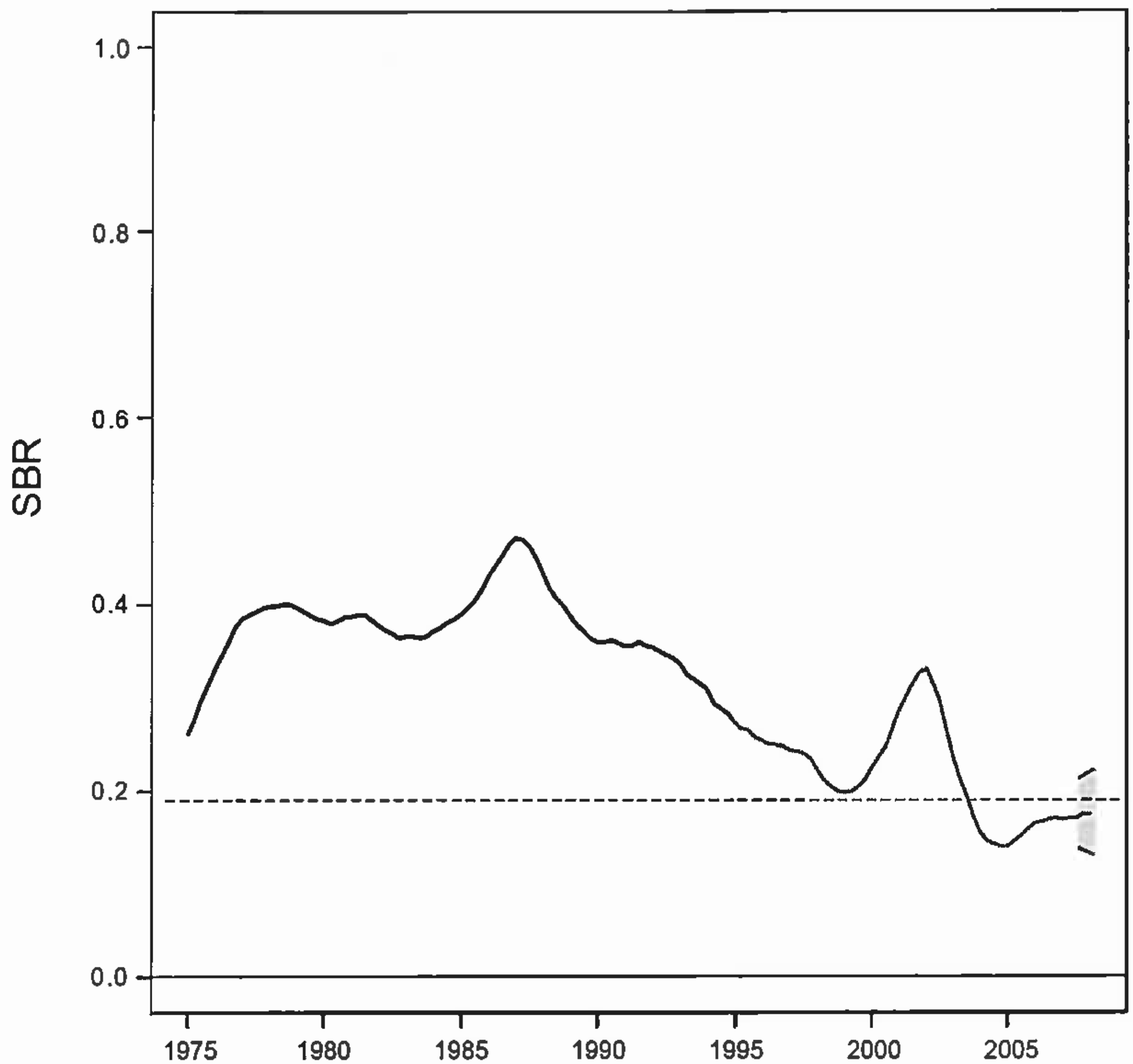

FIGURE 5.1. Estimated spawning biomass ratios (SBRs) for bigeye tuna in the EPO. The dashed horizontal line (at about 0.19) identifies the SBR at MSY. The curve illustrates the maximum likelihood estimates, and the dots at the end of the time series represents the confidence intervals (±2 standard deviations) around those estimates.

FIGURA 5.1. Cocientes de biomasa reproductora (SBR) estimados para el atún patudo en el OPO. La línea de trazos horizontal (en aproximadamente 0,22) identifica el SBR en RMS. La curva ilustra las estimaciones de verosimilitud máxima, y los puntos al fin de la serie de tiempo representan los intervalos de confianza (±2 desviaciones estándar) alrededor de esas estimaciones.

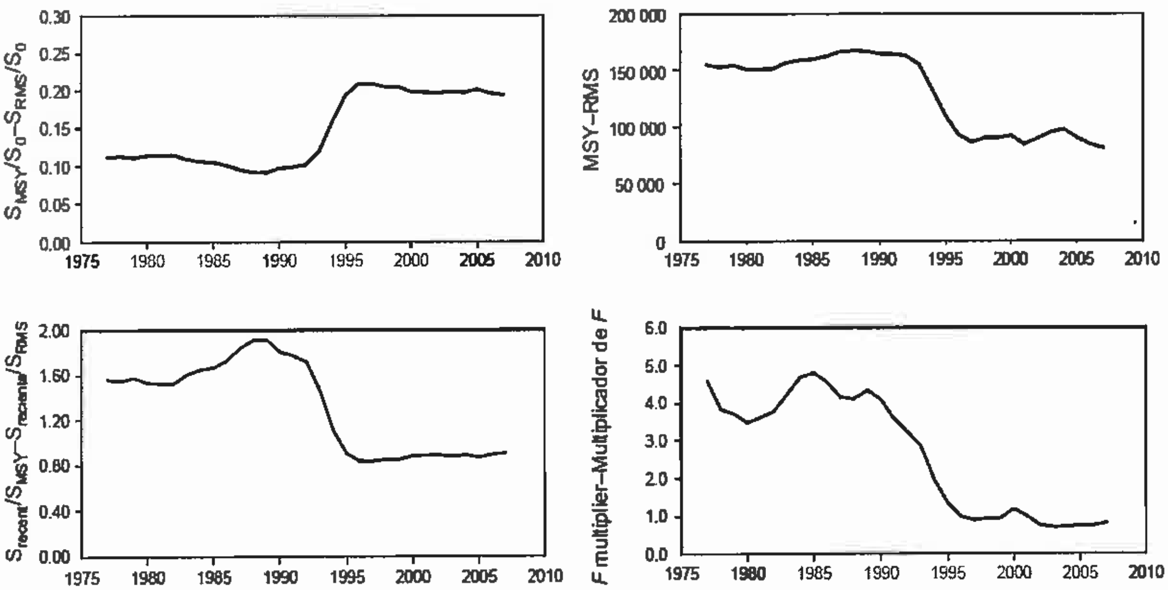

FIGURE 5.2. Estimates of MSY-related quantities calculated using the average age-specific fishing mortality for each year. (S_{recent} is the spawning biomass at the beginning of 2006.)
FIGURA 5.2. Estimaciones de cantidades relacionadas con el RMS calculadas usando la mortalidad por pesca por edad para cada año. ($S_{reciente}$ es la biomasa reproductora al principio de 2006.)

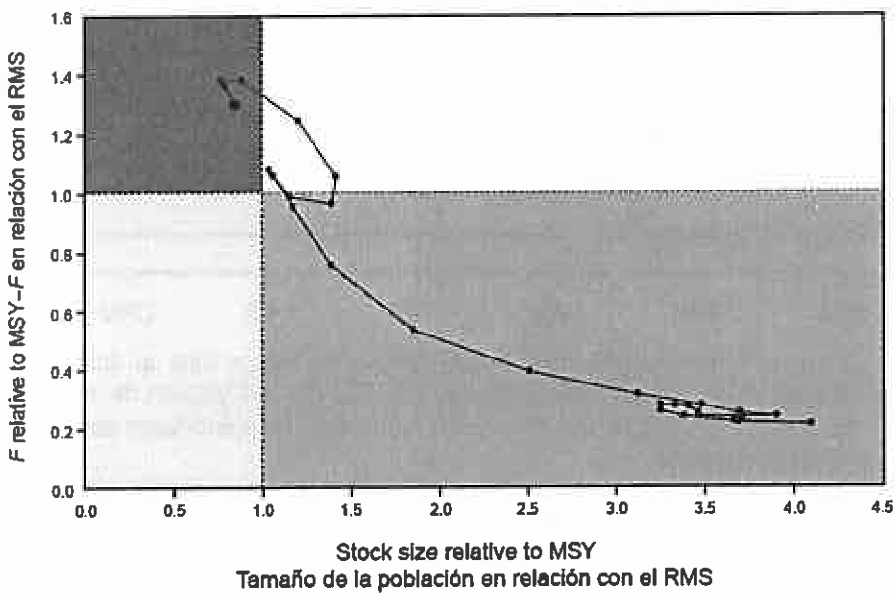

FIGURE 5.3. Phase plot of the time series of estimates of stock size and fishing mortality relative to their MSY reference points. Each dot is based on the average exploitation rate over three years; the large dot indicates the most recent estimate.
FIGURA 5.3. Gráfica de fase de la serie de tiempo de las estimaciones del tamaño de la población y la mortalidad por pesca en relación con sus puntos de referencia de RMS. Cada punto representa un promedio móvil de tres años. Cada punto se basa en la tasa de explotación media de tres años: el punto grande indica la estimación más reciente.

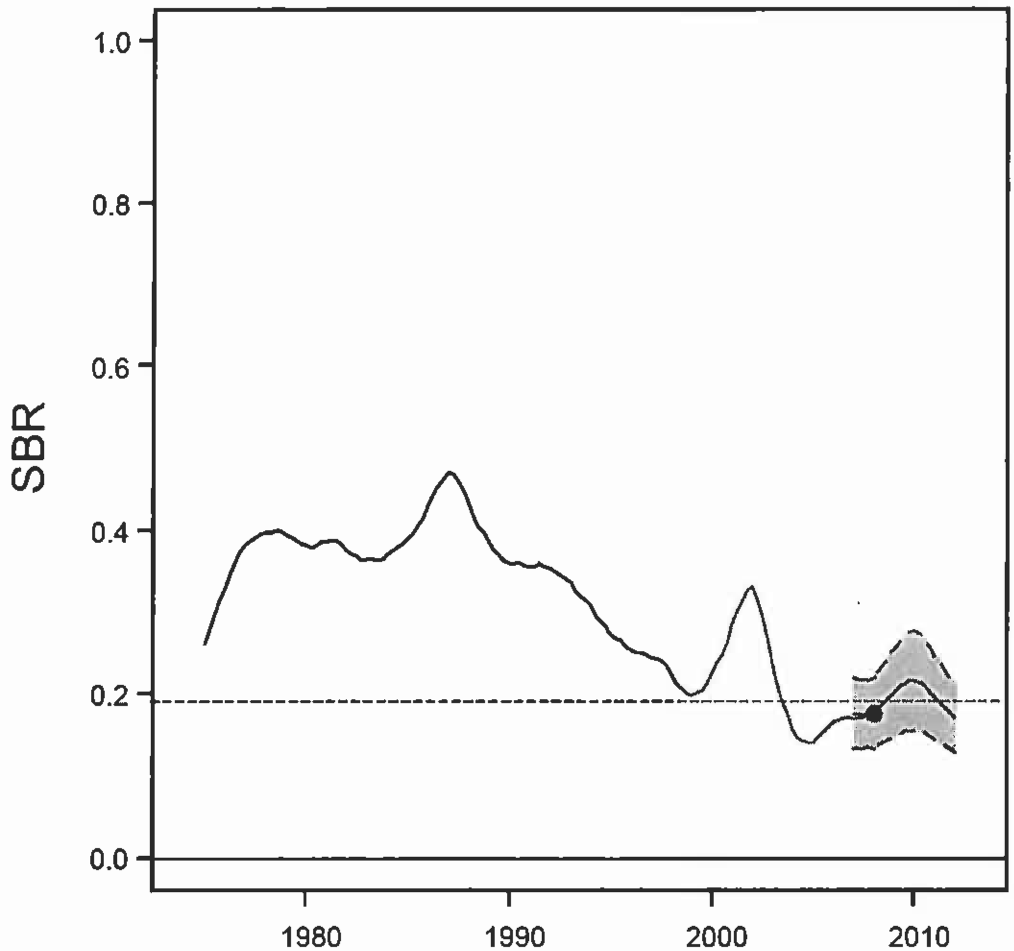

FIGURE 6.1a. Spawning biomass ratios (SBRs) of bigeye tuna in the EPO. The dashed horizontal line (at about 0.22) identifies the SBR at MSY. The solid curve illustrates the maximum likelihood estimates, and the estimates after 2006 (the large dot) indicate the SBR predicted to occur if fishing mortality rates continue at the average of that observed in 2004 and 2005. The dashed lines are the 95-percent confidence intervals around these estimates.

FIGURA 6.1a. Cocientes de biomasa reproductora (SBR) del atún patudo en el OPO. La línea de trazos horizontal (en aproximadamente 0.22) identifica el SBR en RMS. La curva sólida ilustra las estimaciones de verosimilitud máxima, y las estimaciones a partir de 2006 (el punto grande) señalan el SBR predicho si las tasas de mortalidad por pesca continúa en el promedio observado en 2004 y 2005. Las líneas de trazos representan los intervalos de confianza de 95% alrededor de esas estimaciones.

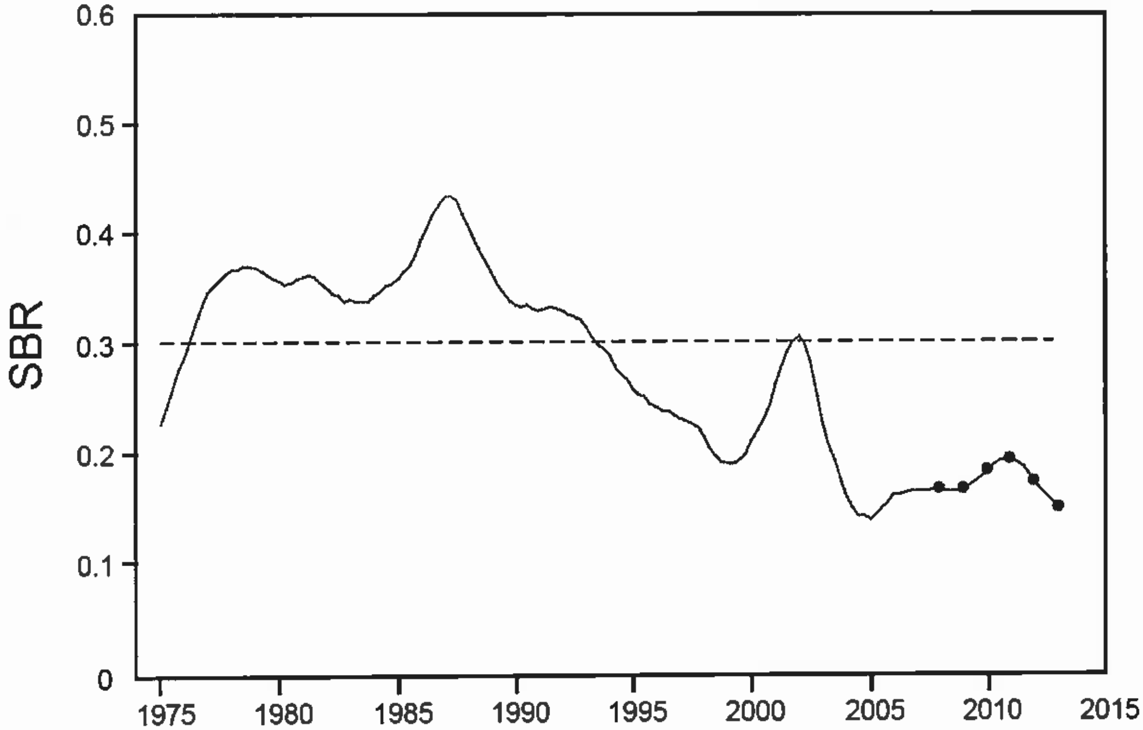

FIGURE 6.1b. Spawning biomass ratios (SBRs) of bigeye tuna in the EPO from the stock-recruitment sensitivity analysis. The dashed horizontal line (at about 0.31) identifies the SBR at MSY.
FIGURA 6.1b. Cocientes de biomasa reproductora (SBR) para el atún patudo en el OPO del análisis de sensibilidad de población-reclutamiento. La línea de trazos horizontal (en aproximadamente 0,31) identifica el SBR en RMS.

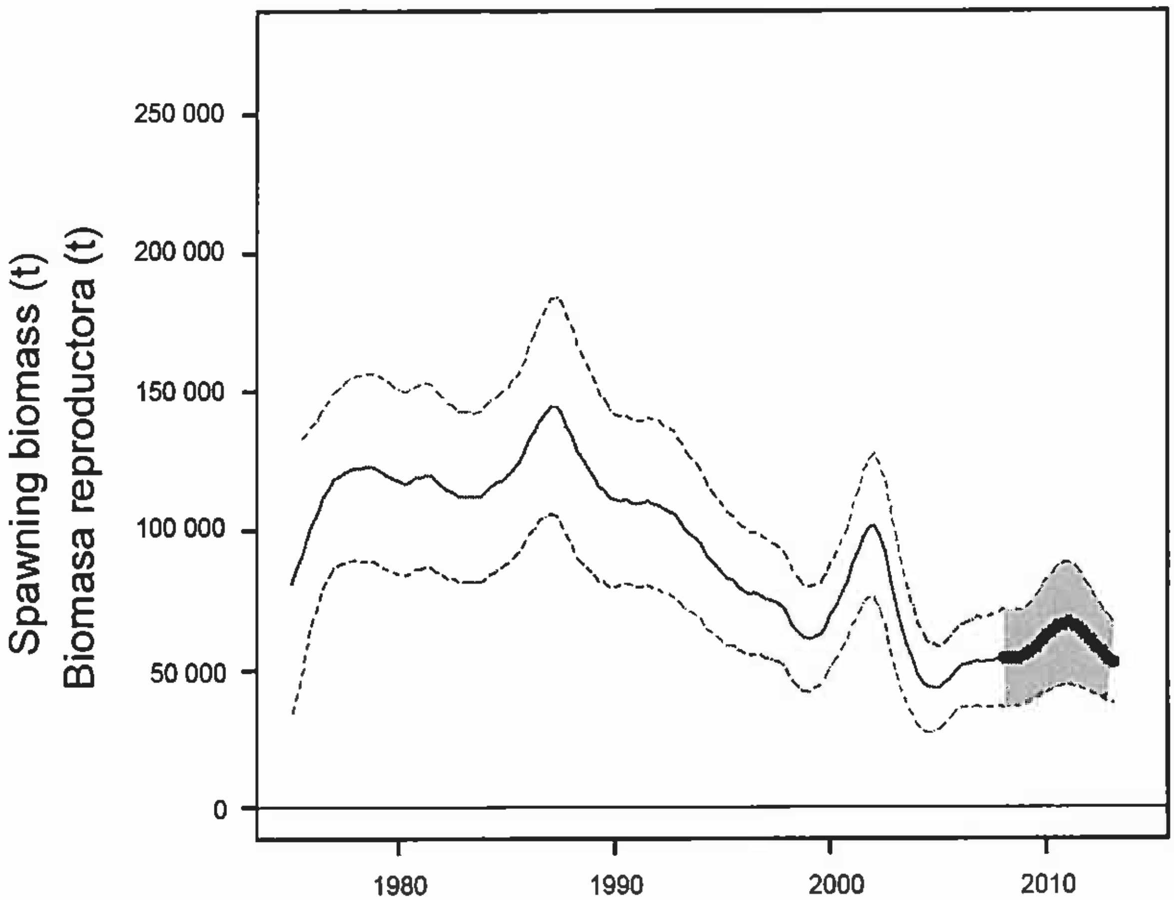

FIGURE 6.2. Spawning biomass of bigeye tuna, including projections for 2006-2010 with average fishing mortality rates for 2004-2005. These calculations include parameter estimation uncertainty and uncertainty about future recruitment. The areas between the dashed curves indicate the 95-percent confidence intervals, and the large dot indicates the estimate for the first quarter of 2007. t = metric tons.
FIGURE 6.2. Biomasa reproductora de atún patudo, incluyendo proyecciones para 2006-2010 con las tasas de mortalidad por pesca media de 2004-2005. Los cálculos incluyen incertidumbre en la estimación de los parámetros y sobre el reclutamiento futuro. Las zonas entre las curvas de trazos señalan los intervalos de confianza de 95%, y el punto grande indica la estimación correspondiente al primer trimestre de 2007. t = toneladas métricas.

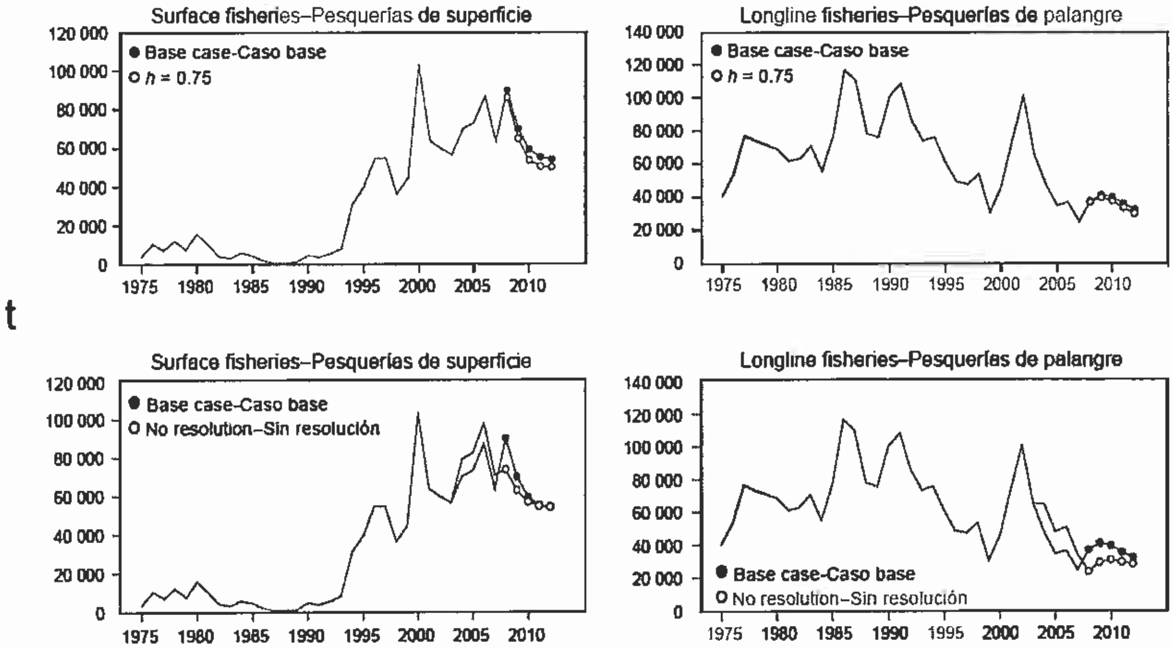

FIGURE 6.3. Predicted quarterly catches of bigeye tuna for the purse-seine and pole-and-line (left panels) and longline (right panels) fisheries, based on fishing mortality rates for 2004 and 2005. Predicted catches are compared between the base case and the analysis in which a stock-recruitment relationship was used (upper panels), and the analysis assuming that IATTC Resolution C-04-09 was not implemented (lower panels). t = metric tons.

FIGURA 6.3. Capturas trimestrales predichas de atún patudo en las pesquerías de cerco y caña (recuadros izquierdos) y palangreras (recuadros derechos), basadas en las tasas de mortalidad por pesca de 2004 y 2005. Se comparan las capturas predichas entre el caso base y el análisis en el que se usó una relación población-reclutamiento (recuadros superiores), y el análisis que supuso que la Resolución C-04-09 de la CIAT no fue aplicada (recuadros inferiores). t = toneladas métricas.

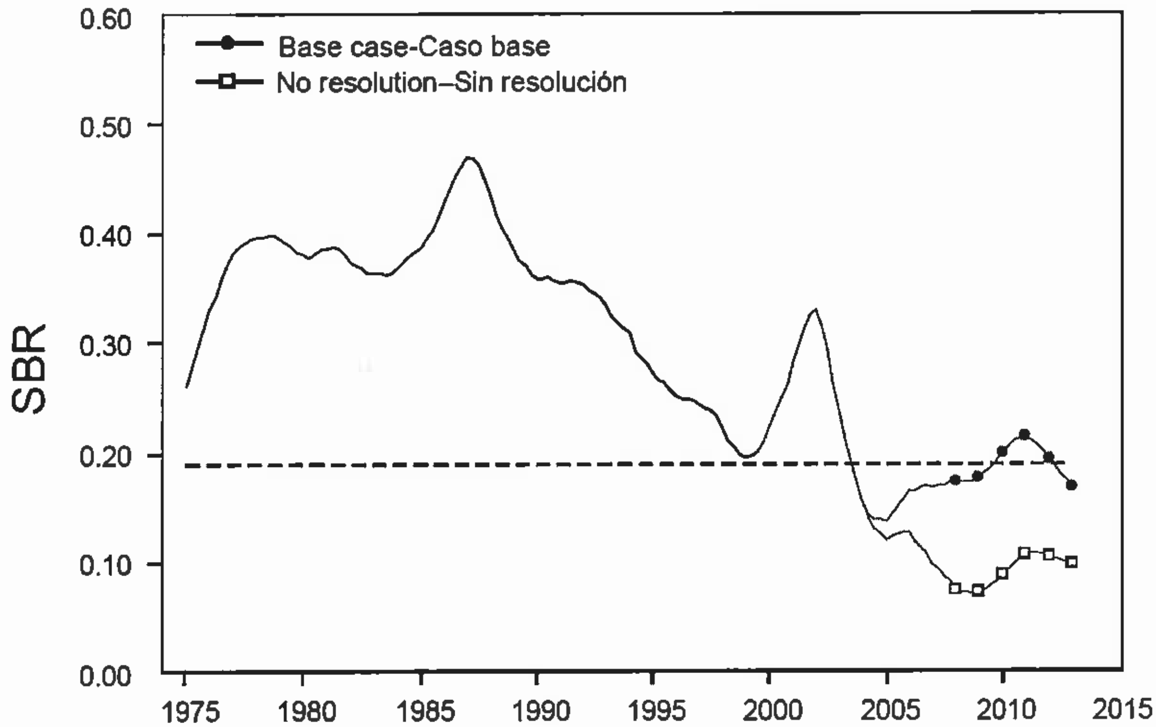

FIGURE 6.4. Predicted spawning biomass ratio (SBR) from the base case model and without restriction from IATTC Resolution C-04-09.

FIGURA 6.4. Cociente de biomasa reproductora (SBR) predicho del modelo de caso base y sin la restricción de la Resolución C-04-09 de la CIAT.

TABLE 2.1. Fishery definitions used for the stock assessment of bigeye tuna in the EPO. PS = purse-seine; LP = pole and line; LL = longline; OBJ = sets on floating objects; NOA = sets on unassociated fish; DEL = sets on dolphins. The sampling areas are shown in Figure 2.1, and descriptions of the discards are provided in Section 2.2.2.

TABLA 2.1. Pesquerías definidas para la evaluación de la población de atún patudo en el OPO. PS = red de cerco; LP = caña; LL = palangre; OBJ = lances sobre objeto flotante; NOA = lances sobre atunes no asociados; DEL = lances sobre delfines. En la Figura 2.1 se ilustran las zonas de muestreo, y en la Sección 2.2.2 se describen los descartes.

Fishery	Gear	Set type	Years	Sampling areas	Catch data
Pesquería	**Arte**	**Tipo de lance**	**Años**	**Zonas de muestreo**	**Datos de captura**
1	PS	OBJ	1975-1992	1-13	retained catch only–captura retenida solamente
2	PS	OBJ	1993-2007	11-12	retained catch + discards from inefficiencies in fishing process–captura retenida + descartes de ineficacias en el proceso de pesca
3	PS	OBJ	1993-2007	7, 9	
4	PS	OBJ	1993-2007	5-6, 13	
5	PS	OBJ	1993-2007	1-4, 8, 10	
6	PS LP	NOA DEL	1980-1989	1-13	retained catch only–captura retenida solamente
7	PS LP	NOA DEL	1990-2007	1-13	retained catch + discards from inefficiencies in fishing process–captura retenida + descartes de ineficacias en el proceso de pesca
8	LL		1975-2007	N of–de 15°N	retained catch only (in numbers)–captura retenida solamente (en número)
9	LL		1975-2007	S of–de 15°N	retained catch only (in numbers) –captura retenida solamente (en número)
10	PS	OBJ	1993-2007	11-12	discards of small fish from size-sorting the catch by Fishery 2–descartes de peces pequeños de clasificación por tamaño en la Pesquería 2
11	PS	OBJ	1993-2007	7, 9	discards of small fish from size-sorting the catch by Fishery 3–descartes de peces pequeños de clasificación por tamaño en la Pesquería 3
12	PS	OBJ	1993-2007	5-6, 13	discards of small fish from size-sorting the catch by Fishery 4–descartes de peces pequeños de clasificación por tamaño en la Pesquería 4
13	PS	OBJ	1993-2007	1-4, 8, 10	discards of small fish from size-sorting the catch by Fishery 5–descartes de peces pequeños de clasificación por tamaño en la Pesquería 5
14	LL		1975-2007	N of–de 15°N	retained catch only (in weight) –captura retenida solamente (en peso)
15	LL		1975-2007	S of–de 15°N	retained catch only (in weight) –captura retenida solamente (en peso)

TABLE 3.1. Age-specific fecundity indices used to define the spawning biomass.
TABLA 3.1. Indices de fecundidad por edad usados para definir la biomasa reproductora.

Age (quarters) Edad (trimestres)	Proportion mature Proporción madura	Age (quarters) Edad (trimestres)	Proportion mature Proporción madura
1	0.00	21	0.96
2	0.00	22	0.98
3	0.00	23	0.98
4	0.00	24	0.99
5	0.00	25	0.99
6	0.01	26	1.00
7	0.01	27	1.00
8	0.02	28	1.00
9	0.04	29	1.00
10	0.06	30	1.00
11	0.10	31	1.00
12	0.16	32	1.00
13	0.23	33	1.00
14	0.33	34	1.00
15	0.45	35	1.00
16	0.59	36	1.00
17	0.71	37	1.00
18	0.82	38	1.00
19	0.89	39	1.00
20	0.93	40	1.00

TABLE 4.1. Estimated total annual recruitment (thousands of fish), summary biomass (fish of age 3 quarters and older), spawning biomass (metric tons), and spawning biomass ratio (SBR) of bigeye tuna in the EPO.

TABLA 4.1. Reclutamiento anual total estimado (miles de peces), biomasa sumaria (peces de 3 trimestres de edad o más), biomasa reproductora (toneladas métricas), y cociente de biomasa reproductora (SBR) de atún patudo en el OPO.

	Total recruitment	Summary biomass	Spawning biomass	SBR
	Reclutamiento total	Biomasa sumaria	Biomasa reproductora	SBR
1975	15,338	427,658	80,521	0.26
1976	16,163	493,735	101,649	0.33
1977	18,740	517,906	118,106	0.38
1978	14,362	520,505	122,406	0.40
1979	15,025	516,832	121,751	0.40
1980	16,852	504,587	117,604	0.38
1981	14,318	492,050	118,996	0.39
1982	24,314	490,930	115,565	0.38
1983	25,029	497,205	112,265	0.36
1984	14,825	538,212	113,814	0.37
1985	11,486	607,408	119,768	0.39
1986	15,734	625,649	132,436	0.43
1987	21,241	566,617	144,627	0.47
1988	18,052	316,600	68,973	0.22
1989	12,819	515,483	119,009	0.39
1990	12,987	532,348	110,604	0.36
1991	12,899	508,176	109,307	0.35
1992	16,114	459,742	108,763	0.35
1993	14,524	425,610	103,356	0.34
1994	23,386	410,968	95,086	0.31
1995	21,536	383,839	84,041	0.27
1996	24,167	362,174	78,039	0.25
1997	42,093	336,192	75,197	0.24
1998	36,458	316,600	68,973	0.22
1999	14,792	392,346	60,771	0.20
2000	17,451	491,649	69,165	0.22
2001	31,451	446,712	87,335	0.28
2002	31,842	369,524	101,459	0.33
2003	24,346	287,106	71,941	0.23
2004	24,944	274,856	48,030	0.16
2005	39,998	281,335	42,747	0.14
2006	40,093	274,956	50,988	0.17
2007	28,242	269,266	52,205	0.17
2008		330,719	53,831	0.17

TABLE 4.2. Estimates of the average sizes of bigeye tuna. The ages are quarters after hatching.
TABLA 4.2. Estimaciones del tamaño medio del atún patudo. La edad es en trimestres desde la cría.

Age (quarters)	Average length (cm)	Average weight (kg)	Age (quarters)	Average length (cm)	Average weight (kg)
Edad (trimestres)	**Talla media (cm)**	**Peso medio (kg)**	**Edad (trimestres)**	**Talla media (cm)**	**Peso medio (kg)**
1	26.61	0.51	21	158.52	89.67
2	38.25	1.46	22	161.52	94.69
3	49.12	3.01	23	164.33	99.54
4	59.29	5.18	24	166.96	104.22
5	68.79	7.97	25	169.41	108.71
6	77.67	11.33	26	171.70	113.00
7	85.97	15.21	27	173.84	117.09
8	93.72	19.54	28	175.85	120.96
9	100.97	24.25	29	177.72	124.61
10	107.74	29.27	30	179.47	128.03
11	114.07	34.53	31	181.10	131.22
12	119.99	39.99	32	182.63	134.17
13	125.51	45.57	33	184.06	136.89
14	130.68	51.22	34	185.39	139.40
15	135.51	56.90	35	186.64	141.69
16	140.02	62.57	36	187.80	143.78
17	144.24	68.19	37	188.89	145.68
18	148.18	73.74	38	189.91	147.41
19	151.86	79.18	39	190.86	148.97
20	155.30	84.49	40	191.75	150.40

TABLE 4.3. Likelihood components obtained for the base case and sensitivity analyses. OBJ: fishery on floating objects.

TABLA 4.3. Componentes de verosimilitud obtenidos para la análisis del caso base y de sensibilidad. OBJ: pesquería sobre objetos flotantes.

Data		Base case	h = 0.75	CPUE Fishery 9	Time blocks (OBJ)
Datos		**Caso base**	**h = 0.75**	**CPUE Pesquería 9**	**Bloques de tiempo (OBJ)**
CPUE					
Fishery Pesquería	2	-17.83	-17.32	103.47	-18.1856
	3	13.78	13.77	112.26	13.614
	5	12.93	13.42	105.79	14.2527
	8	-44.92	-44.80	237.11	-45.4316
	9	-165.95	-166.86	-151.11	-166.918
Size composition Composición por talla					
Fishery Pesquería	1	171.03	170.85	170.87	171.044
	2	260.51	261.00	250.31	259.993
	3	298.24	298.19	289.48	297.602
	4	67.87	67.74	66.92	67.2198
	5	169.72	170.17	164.04	161.977
	6	144.66	144.91	144.17	144.66
	7	133.18	131.97	131.24	133.677
	8	126.10	125.89	126.21	125.937
	9	313.39	317.37	316.47	312.761
Age at length Edad a talla		-	-	-	-
Recruitment Reclutamiento		-21.93	-17.53	-19.52	-22.0554
Total		**1460.77**	**1468.78**	2047.71	1450.1469

TABLE 5.1. Estimates of the MSY and its associated quantities for bigeye tuna for the base case assessment and sensitivity analyses. All analyses are based on average fishing mortality during 2005-2007. B_{recent} and B_{MSY} are defined as the biomass of fish 3+ quarters old at the beginning of 2006 and at MSY, respectively, and S_{recent} and S_{MSY} are defined as indices of spawning biomass (therefore, they are not in metric tons). C_{recent} is the estimated total catch in 2006. OBJ: fishery on floating objects.

TABLA 5.1. Estimaciones del RMS y sus cantidades asociadas de atún patudo para la evaluación del caso base y los análisis de sensibilidad. Todos los análisis se basan en la mortalidad por pesca promedio de 2005-2007. Se definen B_{recent} y B_{RMS} como la biomasa de peces de 3+ trimestres de edad al principio de 2006 y en RMS, respectivamente, y S_{recent} y S_{RMS} como los índices de la biomasa reproductora (por lo tanto, no se expresan en toneladas métricas). C_{recent} es la captura total estimada en 2006. OBJ: pesquería sobre objetos flotantes.

	Base case	**h = 0.75**	**CPUE Fishery 9**	**Time blocks (OBJ)**
	Caso base	**h = 0.75**	**CPUE Pesquería 9**	**Bloques de tiempo (OBJ)**
MSY—RMS	81,350	78,150	85,005	79,654
B_{MSY}—B_{RMS}	287,912	500,357	303,515	287,613
S_{MSY}—S_{RMS}	59,626	118,154	63,318	59,963
B_{MSY}/B_0—B_{RMS}/B_0	0.26	0.34	0.25	0.26
S_{MSY}/S_0—S_{RMS}/B_0	0.19	0.30	0.19	0.20
C_{recent}/MSY—C_{recent}/RMS	1.08	1.12	1.03	1.18
B_{recent}/B_{MSY}—B_{recent}/B_{RMS}	1.15	0.74	1.23	1.12
S_{recent}/S_{MSY}—S_{recent}/S_{RMS}	0.90	0.56	0.90	0.89
F multiplier—Multiplicador de F	0.82	0.57	0.85	0.81

TABLE 5.2. Estimates of the MSY and its associated quantities for bigeye tuna, obtained by assuming that there is no stock-recruitment relationship (base case), that each fishery maintains its current pattern of age-specific selectivity (Figure 4.5), and that each fishery is the only fishery operating in the EPO. The estimates of the MSY and B_{MSY} are in metric tons. The F multiplier indicates how many times effort would have to be effectively increased to achieve the MSY in relation to the average fishing mortality from 2005-2007. A sensitivity of the management quantities estimates to using the average fishing mortality rates for the period 2005-2006, is also presented. "only" means that only that gear is used and the fishing mortality for the other gears is set to zero.

TABLA 5.2. Estimaciones del RMS y sus cantidades asociadas de atún patudo, obtenidas suponiendo que no existe una relación población-reclutamiento (caso base), que cada pesquería mantiene su patrón actual de selectividad por edad (Figura 4.5), y que cada pesquería es la única que opera en el OPO. Se expresan las estimaciones del RMS y B_{RMS} en toneladas métricas. El multiplicador de F indica cuántas veces el esfuerzo necesitaría ser incrementado efectivamente para obtener el RMS en relación con la mortalidad por pesca promedio durante 2003-2004, 2005-2006 y 2004-2006. "solamente" significa que se usa solamente ese arte, y se fija la mortalidad por pesca de las otras artes en cero.

	Base case	Purse-seine only	Longline only	2005-2006
	Caso base	**Cerco solamente**	**Palangre solamente**	**2005-2006**
MSY—RMS	81,350	57,503	168,419	80,934
B_{MSY}—B_{RMS}	287,912	223,293	300,043	287,750
S_{MSY}—S_{RMS}	59,626	50,080	26,604	59,685
B_{MSY}/B_0—B_{RMS}/B_0	0.26	0.20	0.27	0.26
S_{MSY}/S_0—S_{RMS}/B_0	0.19	0.16	0.09	0.19
C_{recent}/MSY—C_{recent}/RMS	1.08	1.53	0.52	1.08
B_{recent}/B_{MSY}—B_{recent}/B_{RMS}	1.15	1.48	1.10	1.15
S_{recent}/S_{MSY}—S_{recent}/S_{RMS}	0.90	1.07	2.02	0.90
F multiplier—Multiplicador de F	0.82	1.24	5.56	0.74

APPENDIX A: SENSITIVITY ANALYSIS FOR STEEPNESS
ANEXO A: ANÁLISIS DE SENSIBILIDAD A LA INCLINACIÓN

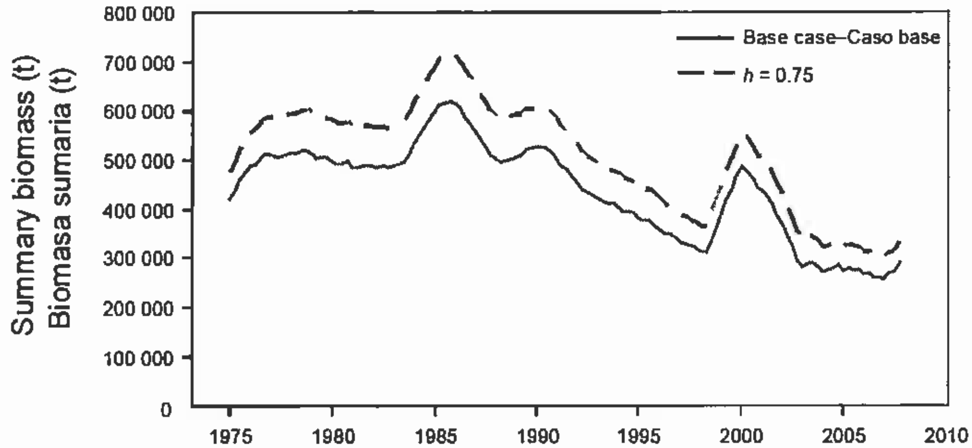

FIGURE A.1. Comparison of estimates of biomass of bigeye tuna from the analysis without a stock-recruitment relationship (base case) and with a stock-recruitment relationship (steepness = 0.75). t = metric tons.
FIGURA A.1. Comparación de las estimaciones de la biomasa de atún patudo del análisis sin una relación población-reclutamiento (caso base) y con dicha relación (inclinación = 0.75). t = toneladas métricas.

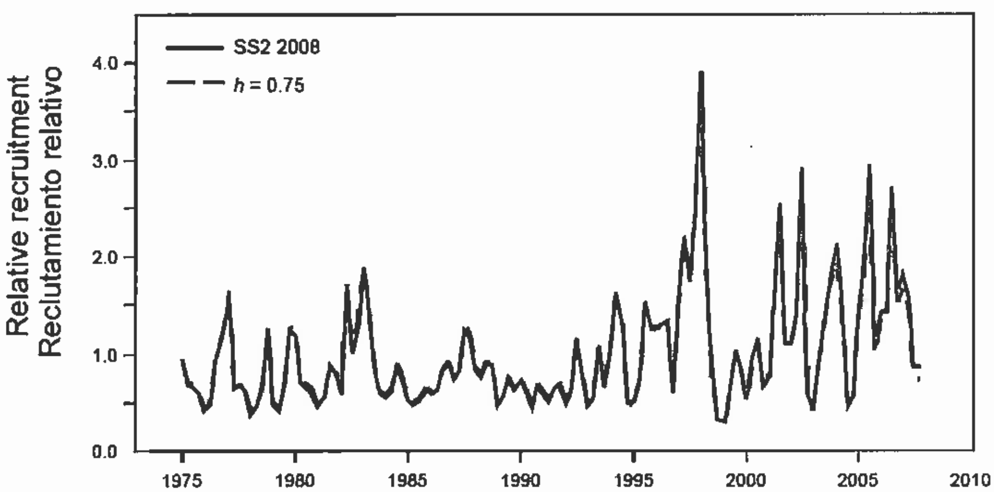

FIGURE A.2. Comparison of estimates of relative recruitment for bigeye tuna from the analysis without a stock-recruitment relationship (base case) and with a stock-recruitment relationship (steepness = 0.75).
FIGURA A.2. Comparación de las estimaciones de reclutamiento relativo de atún patudo del análisis sin una relación población-reclutamiento (caso base) y con dicha relación (inclinación = 0.75).

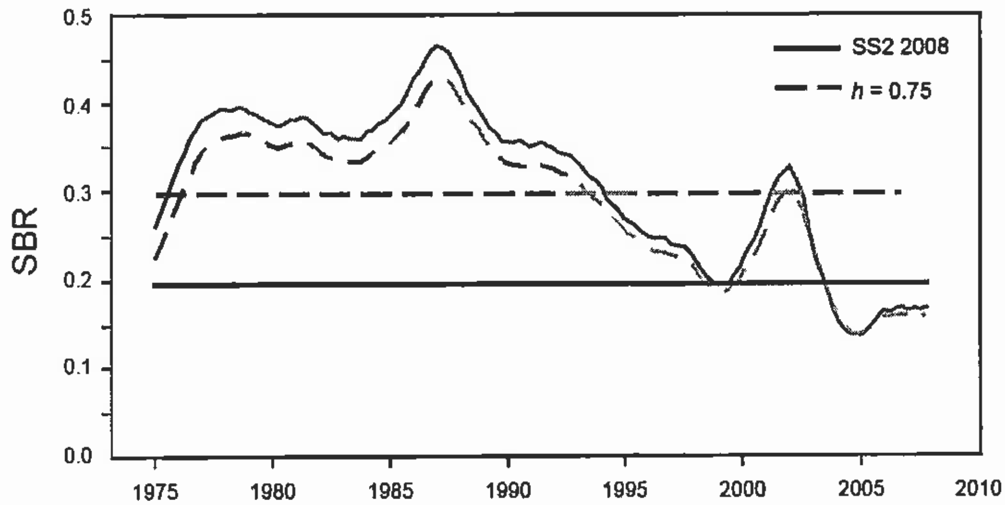

FIGURE A.3. Comparison of estimates of the spawning biomass ratio (SBR) of bigeye tuna from the analysis without a stock-recruitment relationship (base case) and with a stock-recruitment relationship (steepness = 0.75). The horizontal lines represent the SBRs associated with MSY under the two scenarios.

FIGURA A.3. Comparación de las estimaciones del cociente de biomasa reproductora (SBR) de atún patudo del análisis sin una relación población-reclutamiento (caso base) y con dicha relación (inclinación = 0.75). Las líneas horizontales representan los SBR asociados con el RMS en los dos escenarios.

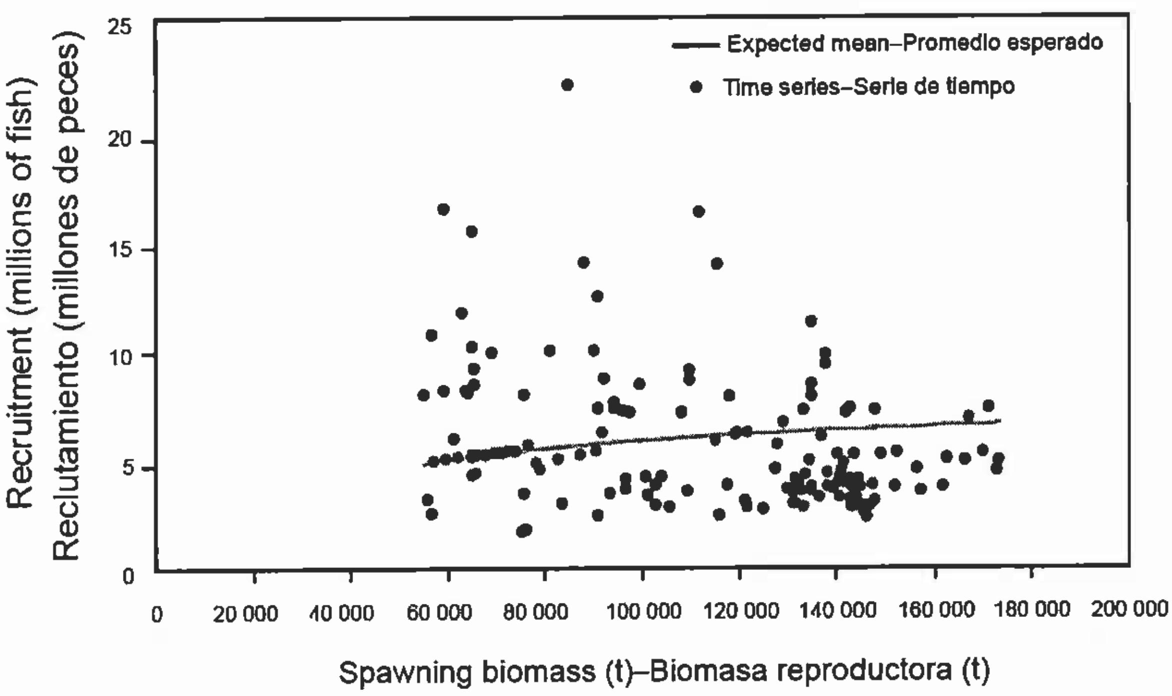

FIGURE A.4. Recruitment of bigeye tuna plotted against spawning biomass when the analysis has a stock-recruitment relationship (steepness = 0.75).

FIGURA A.4. Reclutamiento de atún patudo graficado contra biomasa reproductora cuando el análisis incluye una relación población-reclutamiento (inclinación = 0.75).

APPENDIX B: SENSITIVITY ANALYSIS USING CPUE DATA FOR SOUTHERN LONGLINE FISHERY ONLY

ANEXO B: ANÁLISIS DE SENSIBILIDAD USANDO DATOS DE CPUE DE LA PESQUERÍA DE PALANGRE DEL SUR SOLAMENTE

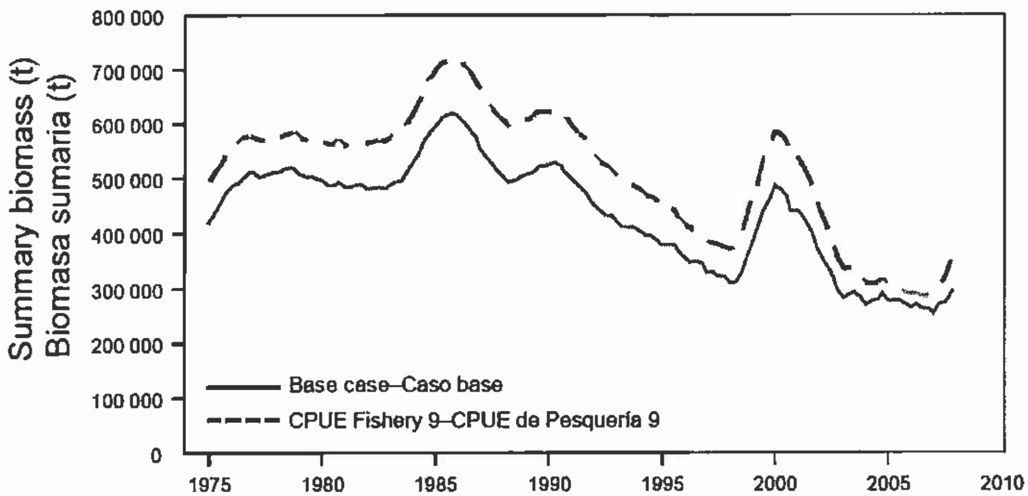

FIGURE B.1. Comparison of estimates of biomass of bigeye tuna from the base case analysis with a model in which only the CPUE data for the southern longline fishery (Fishery 9) were used. t = metric tons.

FIGURA B.1. Comparación de las estimaciones de biomasa de atún patudo del análisis del caso base con un modelo en el cual se usaron los datos de CPUE de la pesquería de palangre del sur (Pesquería 9) solamente. t = tonelades métricas.

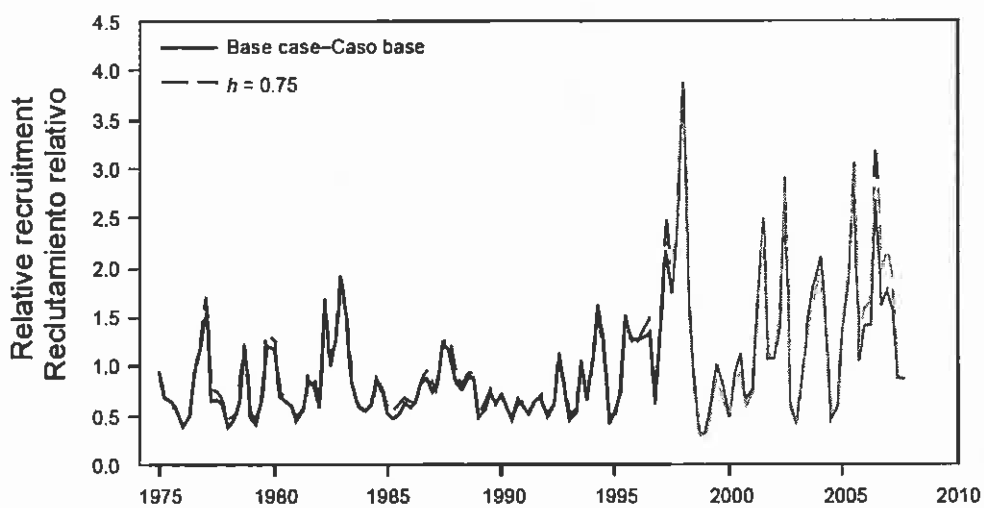

FIGURE B.2. Comparison of estimates of recruitment for bigeye tuna from the base case analysis with a model in which only the CPUE data for the southern longline fishery (Fishery 9) were used.

FIGURA B.2. Comparación de las estimaciones de reclutamiento de atún patudo del análisis del caso base con un modelo en el cual se usaron los datos de CPUE de la pesquería de palangre del sur (Pesquería 9) solamente.

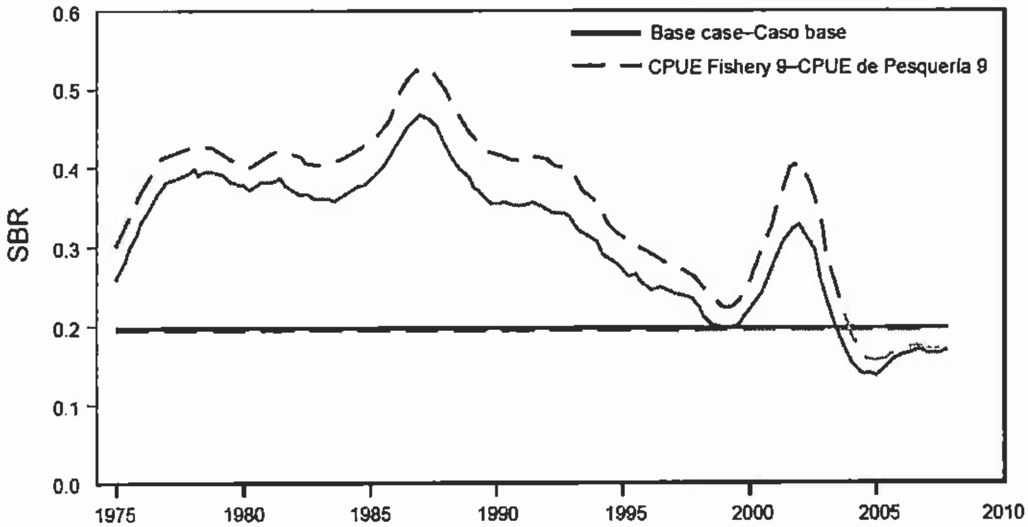

FIGURE B.3. Comparison of estimates of the spawning biomass ratio (SBR) of bigeye tuna from the base case analysis with a model in which only the CPUE data for the southern longline fishery (Fishery 9) were used. The horizontal lines represent the SBRs associated with MSY under the two scenarios.

FIGURA B.3. Comparación de las estimaciones del cociente de biomasa reproductora (SBR) de atún patudo del análisis del caso base con un modelo en el cual se usaron los datos de CPUE de la pesquería de palangre del sur (Pesquería 9) solamente. Las líneas horizontales representan los SBR asociados con el RMS en los dos escenarios.

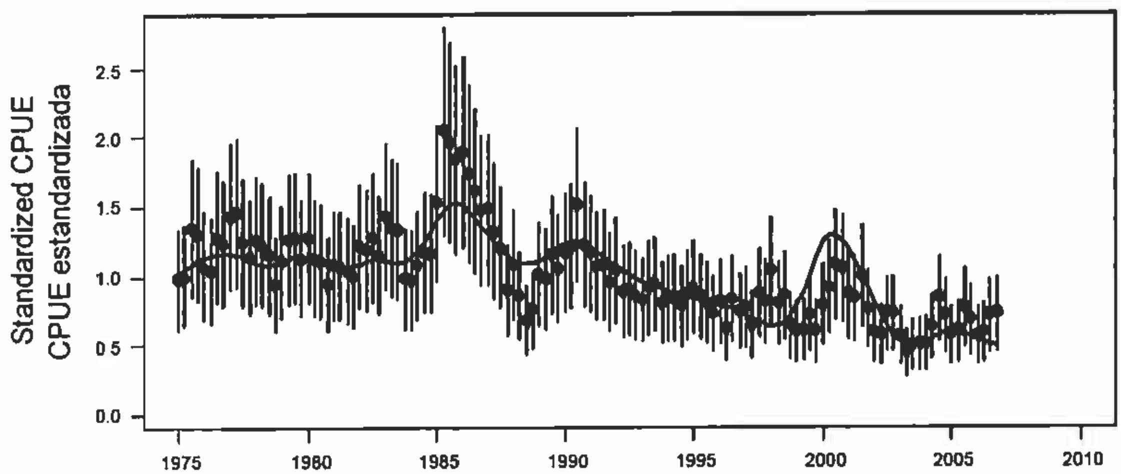

FIGURE B.4. Model fit to the CPUE data for the southern longline fishery (Fishery 9). The vertical lines are the approximate 95% confidence intervals.

FIGURA B.4. Ajuste del modelo a los datos de CPUE de la pesquería de palangre del sur (Pesquería 9). Las líneas verticales representan los intervalos de confianza aproximados de 95%

APPENDIX C: SENSITIVITY ANALYSIS TO ASSUMING TWO TIME BLOCKS FOR THE SELECTIVITIES OF THE FLOATING-OBJECT FISHERIES

ANEXO C: ANÁLISIS DE SENSIBILIDAD AL SUPUESTO DE DOS BLOQUES DE TIEMPO PARA LA SELECTIVIDAD DE LAS PESQUERÍAS SOBRE OBJETOS FLOTANTES

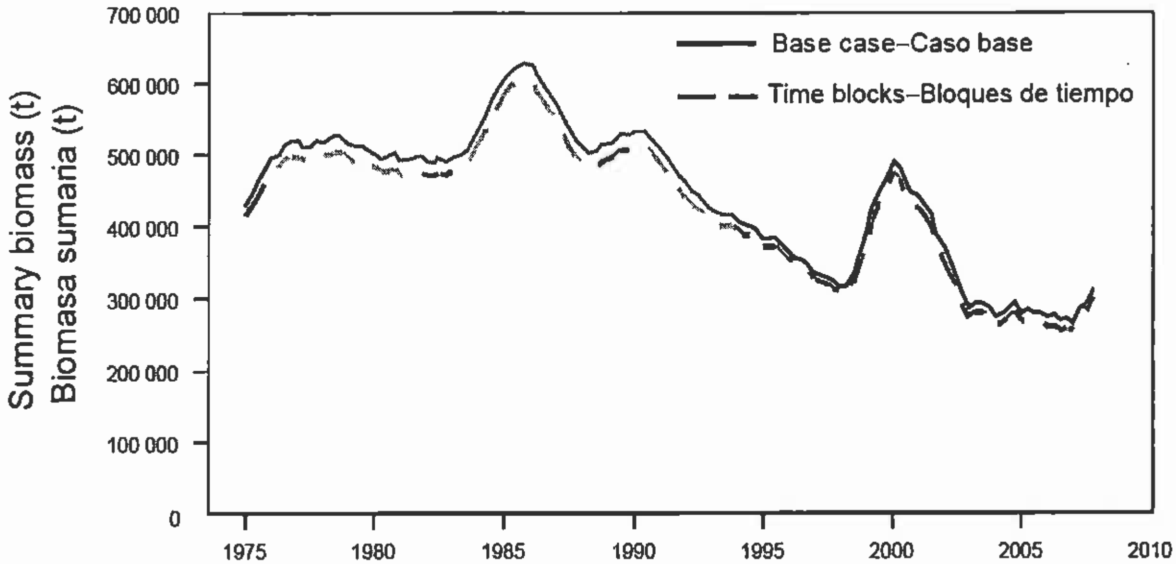

FIGURE C.1. Comparison of estimates of biomass of bigeye tuna from the base case analysis with a model in which two time blocks for the floating-object fisheries were used. t = metric tons.
FIGURA C.1. Comparación de estimaciones de la biomasa de patudo del análisis de caso base con un modelo en el cual se usaron dos bloques de tiempo para las pesquerías sobre objetos flotantes. t = toneladas métricas.

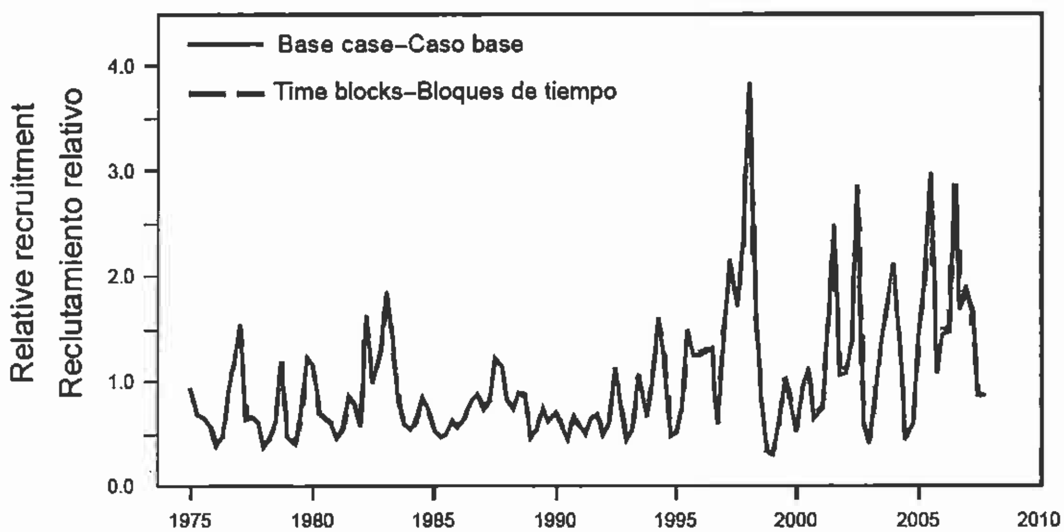

FIGURE C.2. Comparison of estimates of recruitment for bigeye tuna from the base case analysis with a model in which two time blocks for the floating-object fisheries were used.
FIGURA C.2. Comparación de estimaciones del reclutamiento de patudo del análisis de caso base con un modelo en el cual se usaron dos bloques de tiempo para las pesquerías sobre objetos flotantes.

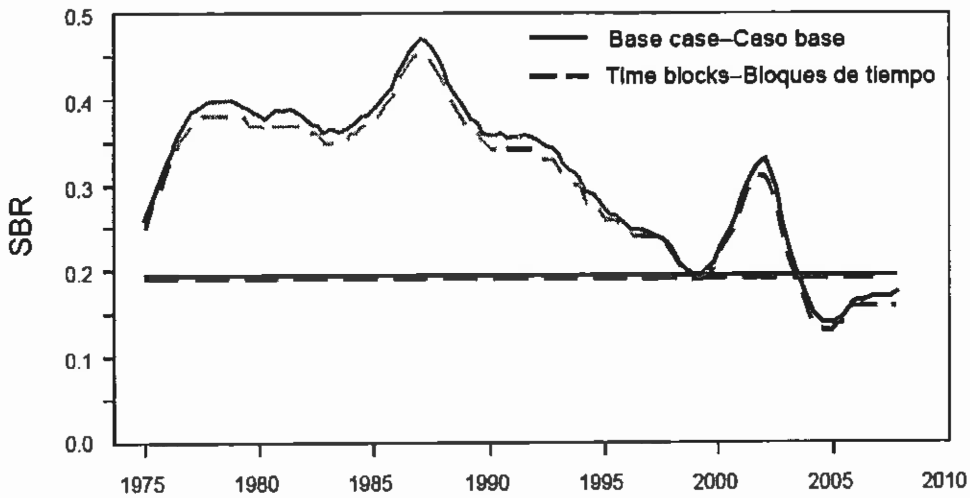

FIGURE C.3. Comparison of estimates of the spawning biomass ratio (SBR) of bigeye tuna from the base case analysis with a model in which two time blocks for the floating-object fisheries were used. The horizontal lines represent the SBRs associated with MSY under the two scenarios.
FIGURA C.3. Comparación de estimaciones del cociente de biomasa reproductora (SBR) de patudo del análisis de caso base con un modelo en el cual se usaron dos bloques de tiempo para las pesquerías sobre objetos flotantes. Las líneas horizontales representan los SBR asociados con el RMS para los dos escenarios.

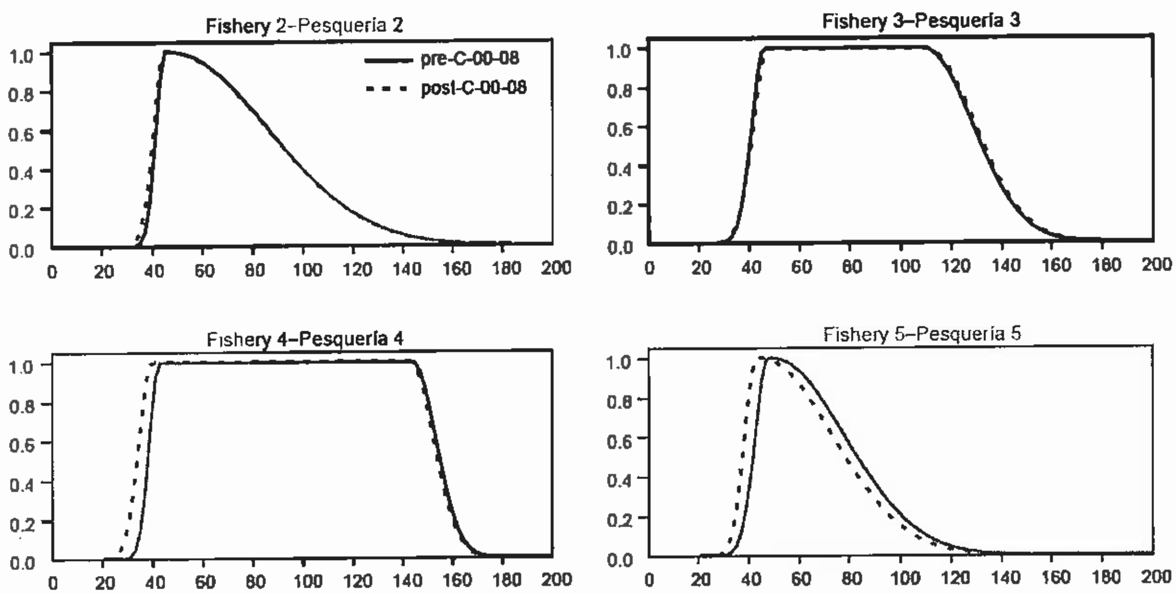

FIGURE C.4. Size selectivity curves for the floating object fisheries (Fisheries 2-5) for two periods: 1) pre-Resolution C-00-08 (1975-2000), and post-Resolution C-00-08 (2001-present).
FIGURA C.4. Curvas de selectividad de tamaño de las pesquerías sobre objetos flotantes (Pesquerías 2-5) durante dos períodos: 1) antes de la Resolución C-00-08 (1975-2000), y después de la misma (2001-presente).

APPENDIX D: ADDITIONAL RESULTS FROM THE BASE CASE ASSESSMENT

This appendix contains additional results from the base case assessment of bigeye tuna in the EPO. These results are total fishing mortality rates. This appendix was prepared in response to requests received during the second meeting of the Scientific Working Group.

ANEXO D: RESULTADOS ADICIONALES DE LA EVALUACIÓN DEL CASO BASE

Este anexo contiene resultados adicionales de la evaluación de caso base del atún patudo en el OPO. Estos resultados son tasas de mortalidad por pesca total. Fue preparado en respuesta a solicitudes expresadas durante la segunda reunión del Grupo de Trabajo Científico.

TABLE D.1. Average annual fishing mortality rates for bigeye tuna in the EPO for the base case assessment.
TABLA D.1. Tasas medias de mortalidad anual por pesca de atún patudo en el OPO para la evaluación del caso base.

Year	Age (quarters - Edad (trimestres)									
	1-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32	33-36	37-40
1975	0.01	0.03	0.08	0.12	0.12	0.12	0.11	0.11	0.11	0.11
1976	0.01	0.05	0.11	0.14	0.14	0.14	0.13	0.13	0.13	0.13
1977	0.01	0.05	0.13	0.18	0.19	0.18	0.18	0.18	0.18	0.18
1978	0.01	0.07	0.15	0.18	0.18	0.17	0.17	0.17	0.17	0.17
1979	0.01	0.05	0.13	0.17	0.17	0.17	0.17	0.17	0.17	0.17
1980	0.01	0.08	0.16	0.18	0.18	0.17	0.17	0.17	0.17	0.17
1981	0.01	0.06	0.13	0.16	0.16	0.16	0.15	0.15	0.15	0.15
1982	0.01	0.04	0.11	0.16	0.16	0.16	0.15	0.15	0.15	0.15
1983	0.01	0.04	0.12	0.17	0.18	0.17	0.17	0.17	0.17	0.17
1984	0.01	0.04	0.10	0.13	0.13	0.13	0.13	0.13	0.13	0.13
1985	0.01	0.03	0.11	0.15	0.16	0.16	0.16	0.16	0.16	0.16
1986	0.00	0.04	0.14	0.21	0.23	0.22	0.22	0.22	0.22	0.22
1987	0.00	0.03	0.15	0.22	0.24	0.24	0.24	0.24	0.24	0.24
1988	0.00	0.03	0.12	0.18	0.19	0.19	0.19	0.19	0.19	0.19
1989	0.00	0.03	0.12	0.18	0.19	0.18	0.18	0.18	0.18	0.18
1990	0.01	0.04	0.15	0.23	0.24	0.24	0.24	0.24	0.24	0.24
1991	0.01	0.05	0.17	0.26	0.27	0.27	0.27	0.27	0.27	0.27
1992	0.01	0.05	0.16	0.23	0.24	0.24	0.23	0.23	0.23	0.23
1993	0.05	0.06	0.16	0.22	0.23	0.22	0.22	0.22	0.22	0.21
1994	0.17	0.18	0.27	0.29	0.26	0.25	0.24	0.24	0.24	0.24
1995	0.34	0.26	0.25	0.25	0.24	0.22	0.21	0.21	0.21	0.21
1996	0.47	0.39	0.29	0.25	0.21	0.19	0.18	0.18	0.18	0.18
1997	0.38	0.36	0.35	0.29	0.23	0.20	0.19	0.19	0.19	0.18
1998	0.21	0.21	0.23	0.26	0.26	0.25	0.24	0.24	0.24	0.24
1999	0.17	0.17	0.16	0.16	0.14	0.12	0.12	0.11	0.11	0.11
2000	0.41	0.45	0.32	0.23	0.17	0.15	0.14	0.14	0.13	0.13
2001	0.46	0.50	0.34	0.28	0.24	0.22	0.22	0.21	0.21	0.21
2002	0.42	0.51	0.45	0.44	0.41	0.38	0.38	0.37	0.37	0.37
2003	0.38	0.39	0.37	0.39	0.36	0.35	0.34	0.34	0.34	0.34
2004	0.41	0.45	0.35	0.33	0.30	0.28	0.27	0.26	0.26	0.26
2005	0.51	0.52	0.34	0.26	0.20	0.18	0.17	0.16	0.16	0.16
2006	0.50	0.59	0.41	0.32	0.24	0.21	0.20	0.19	0.19	0.19
2007	0.33	0.39	0.25	0.20	0.16	0.14	0.13	0.13	0.13	0.13

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EVALUATION OF THE EFFECT OF RESOLUTIONS C-04-09 AND C-06-02

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1. INTRODUCTION

Resolution C-04-09 on the conservation of tuna in the eastern Pacific Ocean called for restrictions on purse-seine effort and longline catches for 2004 to 2006: a 6-week closure during the third or fourth quarter of the year for purse-seine fisheries, and for limits on the longline catches of each country equal to their 2001 longline catches or, in the case of Japan, 34,076 metric tons (t). Resolution C-06-02 extended the measures into 2007. We investigate the effectiveness of this management measure, first by examining the changes in purse-seine fishing effort (measured by days fishing) and the longline catches of bigeye, and then with a simulation of the effect of assumed purse-seine effort and longline catch in the absence of the resolutions.

2. PURSE-SEINE EFFORT

In this section the effort by purse-seine vessels, in number of days fished, is compared with the effort by purse-seine vessels in 2003. Previous analyses had suggested that the conservation measures in that year had little effect on the purse-seine fishery.

In 2004 there was a reduction of effort in the floating-object fisheries, particularly in the third quarter (Tables 1 and 2). Overall, there was a 22% reduction in days fished, with a 46% reduction in the third quarter. However, in 2005, 2006, and 2007, respectively, the third-quarter effort was only 26%, 8%, and 27% less, and the total effort was 6%, 21%, and 7% greater than in 2003.

Effort in the fisheries for unassociated fish was reduced by 16% in the fourth quarter of 2004, but this was more than offset by increased effort in the second and third quarters, resulting in 6% more days fished for the year (Tables 3 and 4). In 2005, 2006, and 2007, the number of days fished in the fourth quarter was 37% greater, 42% less, and 27% less, respectively, than in 2003; the annual totals were 17%, 8%, and 19% greater, respectively, than in 2003.

Effort in the dolphin-associated fisheries fell by 25% in the fourth quarter of 2004, but increases in the first through third quarters resulted in an overall 15% increase in days fished in 2004 (Tables 3 and 4). Dolphin-associated effort in the second quarter was again greater in 2005 than in 2003, but in all other quarters was lower, resulting in 2% less effort than in 2003. The effort, compared to that in 2003, in 2006 was lower in all but the first quarter, and the annual total was 10% lower, and in 2007 was lower in all but the second quarter, and the annual total was 11% lower.

3. LONGLINE CATCH

Data for longline catch are provided to the IATTC staff on a monthly basis. The data from the most recent years are not complete, but, due to the monthly reporting, the majority of the catch is accounted for. The longline catch of bigeye has decreased substantially since 2001 (Table 5); in 2006 it was only 51% of that in 2001 and 62% of the combined catch limit for Chinese Taipei, China, Korea, and Japan. The data for 2007 are too incomplete to make any comparisons, but the catches reported for the major fishing nations are lower than in 2006.

4. SIMULATION OF EFFECTS OF MEASURES

4.1. Methods

To assess the utility of these management actions, we projected the population forward through 2012, assuming that the conservation measures were not implemented, as described below. We started the projections in 2004, to include the first year of the management measure. To approximate the choice of closure period made by the fishing nations, it was assumed that the 6-week closure occurred in the third and fourth quarters for bigeye and yellowfin, respectively, and that the effect of the closure was to reduce fishing effort by about 12%. For the longline fisheries whose catches were restricted in 2004, the ratio of catch in 2003 to catch in 2004 was used to increase the effort to represent no restrictions; the actual reduction of catches of bigeye in 2004 compared to 2003 was used as the basis for the simulation of fishing with restrictions. This was a greater reduction than that required by the resolutions. It was also assumed that the limitations on bigeye catches resulted in the same reduction of fishing effort for yellowfin as for bigeye.

Bigeye tuna: For each year in the projection (2008-2012), quarterly fishing mortality was set equal to the average for 2005-2007 adjusted to remove the effect of the conservation measures. The *Stock Synthesis II* software used for this assessment of bigeye does not allow effort to be predicted by quarter , so the effect of the resolutions is spread over all quarters. For 2004-2006, purse-seine catch in the third quarter was increased by 86%, and the catch in the southern longline fishery was increased by 39% in all quarters. For all quarters of 2008-2012, purse-seine effort was increased by 13% and the effort in the southern longline fishery was increased by 39%.

Yellowfin tuna: For each year in the projection (2008-2012), quarterly fishing mortality was set equal to the average for 2005-2007 adjusted to remove the effect of the conservation measures. For all years (2004-2012), the purse-seine effort in the fourth quarter was increased by 86%, and the effort in the southern longline fishery was increased by 39% in all quarters.

4.2. Results

With the management restrictions, the spawning biomass of bigeye at the end of 2007 is about 131% greater than it would have been if no restrictions had been implemented (Table 6). The spawning biomass has recently increased, due to recent spikes in recruitment, and will continue increasing through 2011 before declining again. It is predicted to increase above the level corresponding to the maximum sustainable yield (MSY), but decrease below that level by 2013 (Figure 1). It will decline even further if no restrictions are implemented.

If no restrictions had been implemented, the purse-seine catch of bigeye in 2004-2007 would have been 12% greater, and the longline catch 39% greater. (This is a consequence of the method used to model the effect of the restriction.) However, it is predicted that by 2008, the catches based on the lesser effort resulting from the restrictions would be greater than those based on the unrestricted effort (Table 6).

The spawning biomass of yellowfin at the end of 2007 with the management restrictions is about 12% greater than it would be if no restrictions had been implemented (Table 7, Figure 2).

If no restrictions had been implemented, the purse-seine catch of yellowfin in 2004 and 2005 would have been 10% and 4% greater, and the longline catch 32% and 21% greater, respectively. It is predicted that the purse-seine catch in 2006 would have been be lower without the restriction; however, by 2007 it would be similar with and without restrictions. Catches in the longline fishery are predicted to remain lower with the restricted effort than without the restrictions.

5. DISCUSSION

Most yellowfin are taken in sets on schools associated with dolphins, and all the effort on such schools is directed at yellowfin. Fishing effort of this type, measured by days fished, increased in 2004 and decreased in 2005-2007, relative to 2003. The effect of the resolutions was reduced by the fact that nine large purse-seine vessels continued to fish during the closure in 2004, contributing to the greater effort.

In all the years with closures, the effort on unassociated schools was greater than in 2003. However, some of the effort on unassociated schools during the second and third quarters of the year is directed at bluefin tuna. Notwithstanding these factors, the simulation probably overestimates the effect of the management measures on yellowfin.

In the floating-object fishery, the fishing effort decreased in 2004 and increased in 2005-2007, relative to 2003.

The capacity of the purse-seine fleet, in cubic meters of well volume, increased steadily during 2003-2007, from 203,000 to 227,000 m^3. This growth in capacity, together with the operational adjustments to the closures made by the fleet, is constraining the effect of the management measures. A comparison of changes in effort over time, by purse-seine set type, indicates that the majority of this increase in capacity is directed at tuna associated with floating objects or unassociated schools (Figure 3).

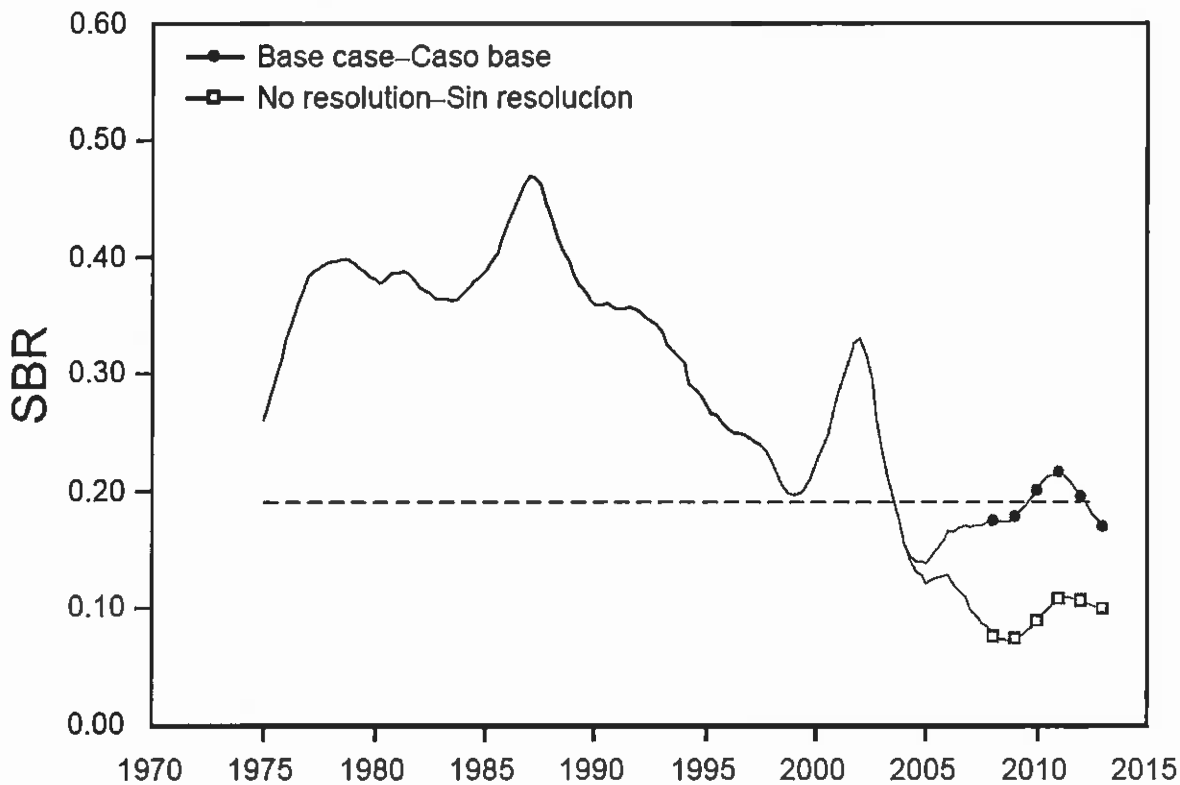

FIGURE 1. Maximum likelihood estimates of the projected spawning biomass ratios (SBRs) of bigeye, using average fishing mortality rate for 2005-2007 ("Base case") and with purse-seine effort in the third quarter increased by 86% and effort increased in all quarters by 39% for the southern longline fishery to approximate the effect of no restrictions ("No resolution"). The horizontal line indicates the SBR_{MSY} (0.19).

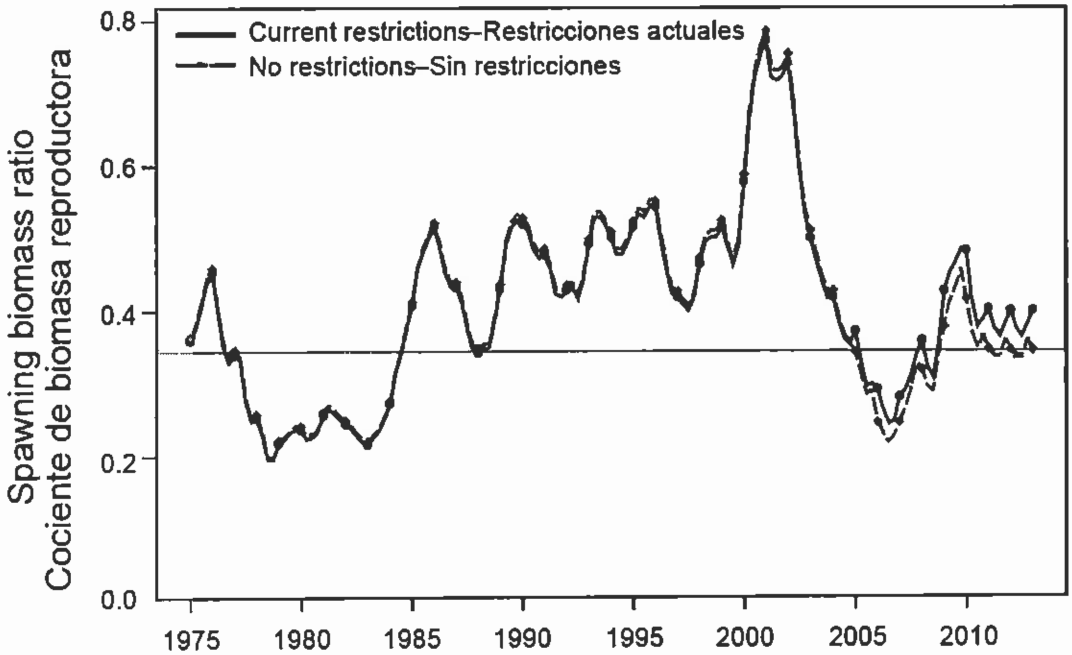

FIGURE 2. Maximum likelihood estimates of the projected spawning biomass ratios (SBRs) of yellowfin, with current fishing effort (based on the average fishing mortality during 2005-2007) ("Current restrictions") and with purse-seine effort in the fourth quarter since 2004 increased by 86% and effort since 2004 increased in all quarters by 39% for the southern longline fishery to approximate the effect of no restrictions ("No restrictions"). The horizontal line indicates the SBR_{MSY} (0.37).

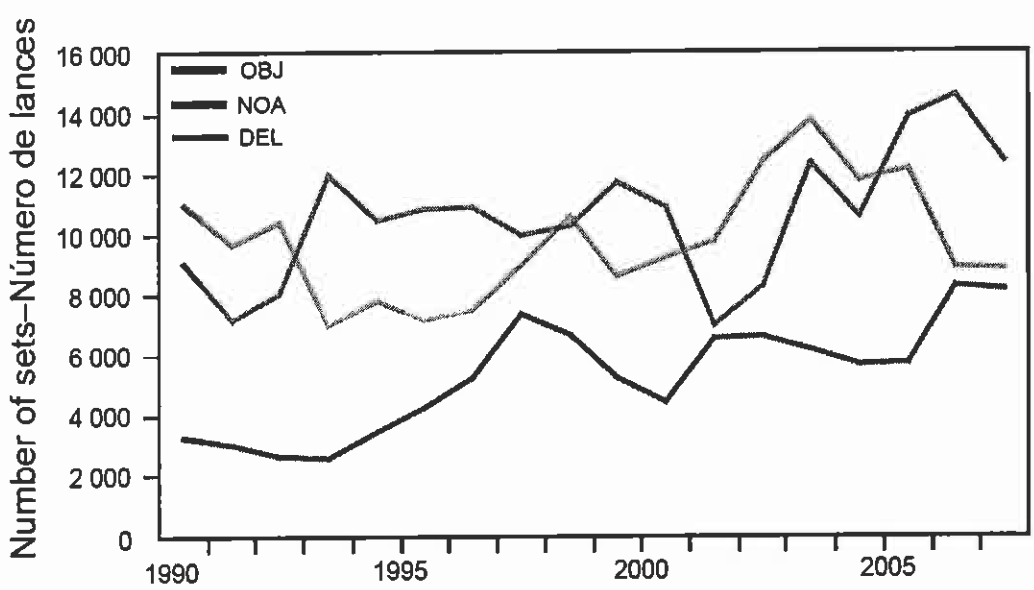

FIGURE 3. Purse-seine effort, in number of sets, by set type, 1990-2007. OBJ: floating object; NOA: unassociated; DEL: dolphin.

TABLE 1. Effort, in days fished, for the floating-object fisheries defined in the bigeye assessment.

Year	Quarter	Fishery 2	Fishery 3	Fishery 4	Fishery 5	Total
2003	1	1086	386	1203	336	3011
	2	1108	581	1025	828	3540
	3	628	2401	1465	1389	5884
	4	1123	2746	878	722	5470
Total		3944	6114	4571	3275	17905
2004	1	1517	438	1162	287	3404
	2	1416	305	412	787	2920
	3	605	1094	449	1040	3189
	4	872	2462	446	690	4469
Total		4410	4299	2469	2804	13982
2005	1	1114	769	1309	478	3670
	2	1055	1346	1705	1190	5296
	3	492	1457	1326	1061	4335
	4	1096	2327	1315	903	5641
Total		3756	5899	5655	3632	18942
2006	1	1337	965	1720	341	4363
	2	1561	1511	1299	1184	5554
	3	917	2558	648	1298	5422
	4	1066	3308	1150	802	6327
Total		4881	8343	4817	3626	21666
2007	1	1644	1045	1497	405	4591
	2	1759	1239	887	868	4753
	3	980	1474	516	1319	4289
	4	1192	2272	1044	1047	5555
Total		5574	6030	3945	3640	19188

TABLE 2. Change in effort relative to that in 2003 for the floating-object fisheries defined in the bigeye assessment.

Year	Quarter	Fishery 2	Fishery 3	Fishery 4	Fishery 5	Total
2004	1	1.40	1.13	0.97	0.85	1.13
	2	1.28	0.52	0.40	0.95	0.82
	3	0.96	0.46	0.31	0.75	0.54
	4	0.78	0.90	0.51	0.95	0.82
Total		1.12	0.70	0.54	0.86	0.78
2005	1	1.03	1.99	1.09	1.42	1.22
	2	0.95	2.32	1.66	1.44	1.50
	3	0.78	0.61	0.90	0.76	0.74
	4	0.98	0.85	1.50	1.25	1.03
Total		0.95	0.96	1.24	1.11	1.06
2006	1	1.23	2.50	1.43	1.02	1.45
	2	1.41	2.60	1.27	1.43	1.57
	3	1.46	1.07	0.44	0.93	0.92
	4	0.95	1.20	1.31	1.11	1.16
Total		1.24	1.36	1.05	1.11	1.21
2007	1	1.51	2.71	1.24	1.21	1.53
	2	1.59	2.13	0.87	1.05	1.34
	3	1.56	0.61	0.35	0.95	0.73
	4	1.06	0.83	1.19	1.45	1.02
Total		1.41	0.99	0.86	1.11	1.07

TABLE 3. Effort, in days fished, for the unassociated and dolphin-associated fisheries defined in the yellowfin assessment.

Year	Quarter	Fishery 5	Fishery 6	Fishery 7	Fishery 8	Fishery 9	Unassociated	Dolphin
2003	1	1093	2679	981	1685	469	3772	3135
	2	1241	2637	916	1267	532	3878	2715
	3	1359	1231	1101	1598	375	2589	3075
	4	1125	1568	908	1499	387	2694	2793
Total		4818	8115	3905	6048	1764	12933	11718
2004	1	938	2710	540	1942	1119	3648	3602
	2	1407	3440	976	1807	1265	4846	4048
	3	1674	1306	1264	1824	583	2979	3671
	4	686	1568	804	879	419	2254	2102
Total		4705	9024	3584	6453	3387	13728	13424
2005	1	1338	3207	656	1382	510	4544	2548
	2	1408	2544	1217	1920	554	3952	3691
	3	2009	866	763	1638	161	2875	2563
	4	702	2993	861	1498	330	3695	2689
Total		5457	9610	3498	6438	1555	15067	11491
2006	1	1117	4071	311	2525	701	5188	3536
	2	1485	3017	662	1581	435	4502	2678
	3	1626	1107	772	1476	192	2733	2439
	4	416	1146	487	1155	199	1562	1841
Total		4644	9341	2232	6736	1527	13985	10495
2007	1	1332	3932	173	2032	340	5264	2546
	2	1509	2816	806	1906	579	4325	3291
	3	3013	856	945	1050	248	3869	2242
	4	565	1388	565	1673	134	1953	2371
Total		6419	8992	2488	6661	1301	15411	10450

TABLE 4. Change in effort relative to that in 2003 for the unassociated and dolphin-associated fisheries defined in the yellowfin assessment.

Year	Quarter	Fishery 5	Fishery 6	Fishery 7	Fishery 8	Fishery 9	Unassociated	Dolphin
2004	1	0.86	1.01	0.55	1.15	2.38	0.97	1.15
	2	1.13	1.30	1.07	1.43	2.38	1.25	1.49
	3	1.23	1.06	1.15	1.14	1.55	1.15	1.19
	4	0.61	1.00	0.89	0.59	1.08	0.84	0.75
Total		0.98	1.11	0.92	1.07	1.92	1.06	1.15
2005	1	1.22	1.20	0.67	0.82	1.09	1.20	0.81
	2	1.13	0.96	1.33	1.52	1.04	1.02	1.36
	3	1.48	0.70	0.69	1.03	0.43	1.11	0.83
	4	0.62	1.91	0.95	1.00	0.85	1.37	0.96
Total		1.13	1.18	0.90	1.06	0.88	1.17	0.98
2006	1	1.02	1.52	0.32	1.50	1.49	1.38	1.13
	2	1.20	1.14	0.72	1.25	0.82	1.16	0.99
	3	1.20	0.90	0.70	0.92	0.51	1.06	0.79
	4	0.37	0.73	0.54	0.77	0.52	0.58	0.66
Total		0.96	1.15	0.57	1.11	0.87	1.08	0.90
2007	1	1.22	1.47	0.18	1.21	0.72	1.40	0.81
	2	1.22	1.07	0.88	1.50	1.09	1.12	1.21
	3	2.22	0.70	0.86	0.66	0.66	1.49	0.73
	4	0.50	0.88	0.62	1.12	0.35	0.73	0.85
Total		1.33	1.11	0.64	1.10	0.74	1.19	0.89

TABLE 5. Annual longline catches of bigeye, in metric tons, for China, Japan, Korea, and Chinese Taipei, total catch, and change relative to 2001.

	China	Japan	Korea	Chinese Taipei	Total catch	Relative to 2001
2001	2639	38048	12576	9285	68754	1.00
2002	7614	34193	10358	17253	74424	1.08
2003	10066	24888	10272	12016	59776	0.87
2004	2645	21236	10729	7384	43478	0.63
2005	2104	19401	11580	6441	41720	0.61
2006	709	18017	8694	6412	35363	0.51
2007		13262	5611	5859	25560	0.37
Catch limit	**2639**	**34076**	**12576**	**7953**		

TABLE 6. Bigeye spawning biomass and catch adjusted to represent no restrictions as a ratio of those quantities estimated under current effort levels, which are restricted by Resolution C-06-02.

	End-of-year spawning biomass	Purse-seine catch	Longline catch[1]
2004	0.88	1.13	1.36
2005	0.77	1.13	1.38
2006	0.59	1.13	1.40
2007	0.43	1.12	1.39
2008	0.41	0.82	0.64
2009	0.44	0.90	0.72
2010	0.50	0.96	0.78
2011	0.55	0.99	0.83
2012	0.59	1.00	0.88

[1] The catch ratio in 2004-2007 differed slightly from the ratio of 1.39 used to restrict catches because catch is implemented in the assessment model in both weight and numbers, but presented in weight in this table.

TABLE 7. Yellowfin spawning biomass and catch adjusted to represent no restrictions as a ratio of those quantities estimated under current effort levels, which are restricted by Resolution C-06-02.

Year	End-of-year spawning biomass	Purse-seine catch	Longline catch
2004	0.92	1.10	1.32
2005	0.85	1.04	1.21
2006	0.88	0.95	1.12
2007	0.89	1.03	1.12
2008	0.88	1.03	1.16
2009	0.86	1.02	1.15
2010	0.86	0.98	1.13
2011	0.86	1.00	1.13
2012	0.87	1.00	1.13

INTER-AMERICAN TROPICAL TUNA COMMISSION

9TH STOCK ASSESSMENT REVIEW MEETING

LA JOLLA, CALIFORNIA (USA)
12-16 MAY 2008

DOCUMENT SARM-9-05

SUMMARY OF CONSERVATION PROPOSALS

This paper summarizes the different proposals for the conservation of bigeye and yellowfin tuna in the eastern Pacific Ocean (EPO) presented by the IATTC staff, member countries, and the Chairman of IATTC during the Annual Meeting in June 2007 and the subsequent meetings on October 2007 and March 2008.

There are currently no measures in force to restrict purse-seine fishing effort or longline catches in the EPO.

At the Annual Meeting in June 2007, the Commission's scientific staff proposed (Document IATTC-75-07b), for yellowfin tuna, extending the closure of the purse-seine fishery by 32 additional days, to 74 days, and that the closure period be extended further if the capacity of the purse-seine fleet continues to increase. An alternative proposal for the purse-seine fishery for yellowfin was a total allowable catch (TAC) of 200,000 metric tons (t), with four possible increments of 30,000 t each, to be authorized at the Director's discretion.

Also, the Commission staff recommended, in addition to the above measures for yellowfin, three options for the conservation of bigeye tuna:

1. Close the purse-seine fishery on floating objects in the EPO for an additional 35 days; or
2. Set a TAC for bigeye taken by purse-seine, and prohibit sets on floating objects after a TAC of 48,000 t is reached, with the possibility of four increments of 5,500 t each, to be authorized at the Director's discretion; or
3. Limit the total annual catch of bigeye by each purse-seine vessel in a way that the sum of the individual-vessel limits equals 68,000 t. and prohibit further sets on floating objects by any vessel that has reached its limit.

The staff's conservation recommendations generated considerable discussion and debate. Three additional proposals were presented, by the United States, Ecuador/Spain, and Mexico; these, and the staff's proposal, are summarized in Table 1. However, the Commission could not reach agreement on any proposal, and agreed to convene another meeting to discuss conservation and management measures for bigeye and yellowfin tuna beyond 2007.

Accordingly, an extraordinary meeting was held in October 2007. At the October meetings, additional proposals were presented by Venezuela and by a group of countries (Colombia, Guatemala, Nicaragua, Panama, and Peru) (Table 2). Also, the staff presented an evaluation of the three proposals made in June (Document IATTC-76-04). Again, no agreement was reached, so a further meeting was scheduled for March 2008.

At the March meeting, the staff presented a new proposal (Document IATTC-77-04), consisting of two components: a 12-week closure of the entire EPO from 20 June through 11 September, and a closure of an offshore area (between 94° and 110°W and from 3°N to 5°S) from 12 September through 31 December. On the basis of the discussion, the IATTC Chairman, in consultation with heads of delegations, presented a document which was, in essence, a draft resolution with numerous brackets in an effort to advance the discussions (Appendix A). However, despite considerable discussion by the governments, no agreement could be reached on any of the proposals.

TABLE 1. Summary of tuna conservation proposals presented at the 75th Annual Meeting of the IATTC, June 2007.

JUN 2007	IATTC staff	USA	Ecuador, Spain	Mexico
Duration	2008	2008-2010	2008-2011	2008
Coverage	All purse-seine and longline fisheries for tunas	All purse-seine and longline vessels	Purse-seine and longline vessels, except purse-seine vessels less than 363 t capacity	All purse-seine and longline fisheries for tunas
PURSE SEINE				
Closures/Catch limits	(a) Extend the closure period to 74 days, and extend it further if the carrying capacity of the purse-seine fleet continues to increase; or (b) Set a TAC of 200,000 t for purse-seine catches of yellowfin, TAC may be increased by up to four increments of 30,000 t each	Close the fishery for the rest of the year when a TAC of 200,000 t of yellowfin is reached; TAC may be decreased or increased by no more than 4 reductions or increments of 30,000 t each	Close the fishery for yellowfin and bigeye from either (1) 1 August-11 September; or (2) 20 November-31 December Close the fishery for yellowfin for the rest of the year when a TAC of 290,000 t of yellowfin is reached; thereafter, the landings of fisheries not targeting yellowfin may include a maximum of 15% of yellowfin relative to its total catch	Extend the closure period to 73 days, 20 November 2007-2 February 2008. If there are 2 closure periods, vessels observing the August-October closure may not fish north of 5ºN during the November-February closure, and vessels observing the November-February closure may not fish south of 5ºN during the August-October closure
Specific measures for bigeye	One of 3 options: 1) In addition to yellowfin closure, close the purse-seine fishery on floating objects for an additional 35 days; or 2) TAC of 48,000 t; up to four increments of 5,500 t each, for bigeye taken by purse-seine; sets on floating objects prohibited after TAC is reached; or 3) Limit the total annual catch of bigeye by each purse-seine vessel so that the sum of the individual-vessel limits equals 68,000 t. and prohibit further sets on floating objects by any vessel that has reached its limit	Limit annual catch of bigeye by each purse-seine vessel to 500 t	Close offshore area (94°W-110°W, 3ºN-5°S) to purse-seine vessels greater than 363 t, 1 August-31 December	None

Specific measures for FADs	Mark FADs; maintain a record of the number of FADs on board at the beginning and end of each trip and of the numbers and positions of FADs deployed at sea; make this information available to IATTC	None	None	Mark FADs; maintain record of number of FADs and beepers aboard Record position of deployment and recovery of FADs; FADs should be recovered
		LONGLINE		
Specific catch limits	China 2,190 t Japan 28,283 t Korea 10,438 t Chinese Taipei 6,601 t	China 2,190 t Japan 28,283 t Korea 10,438 t Chinese Taipei 6,601 t	China 2,190 t Japan 28,283 t Korea 10,438 t Chinese Taipei 6,601 t	None
Limits for other CPCs	For each CPC, annual longline catches of bigeye not to exceed the greater of 83% of 2001 catches or 500 t	For each CPC, annual longline catches of bigeye not to exceed the greater of 2001 catches or 500 t	For each CPC, annual longline catches of bigeye not to exceed the greater of 83% of 2001 catches or 500 t	Each CPC to provide monthly reports of longline catches of bigeye

TABLE 2. Summary of tuna conservation proposals presented at the 76th and 77th Meetings of the IATTC, October 2007 and March 2008.

OCT 2007 MAR 2008	**IATTC staff**	**Venezuela**	**Colombia, Guatemala, Nicaragua, Panama, Peru**
Duration	2008-2010	2008	2008-2009
Coverage	All purse-seine and longline fisheries for tunas	All purse-seine and longline vessels	All purse-seine and longline fisheries for bigeye
		PURSE SEINE	
Closures/Catch limits	2 components: a) 12-week closure in the entire EPO, 20 June-11 September, b) Close offshore area (94°W-110°W, 3°N-5°S), 12 September-31 December.	a) Close fishery for 60 days, either 1 August-30 September, or 2 November-31 December b) Set minimum catch size for yellowfin (3.2 kg), bigeye (3.2 kg), and skipjack (1.8 kg) c) Catch of small tunas not to exceed 10% of vessel capacity d) Time/area closures in areas of high concentrations of juvenile yellowfin and/or bigeye	Close the fishery for the rest of the year when a TAC of 200,000 t of yellowfin is reached; TAC may be increased by no more than 4 increments of 30,000 t each
Specific measures for bigeye	None	None	TAC of 55,000 t; up to 3 increments of 5,500 t each
Specific measures for FADs	Mark FADs; maintain a record of the number of FADs on board at the beginning and end of each trip and of the numbers and positions of FADs deployed at sea; make this information available to IATTC	Vessels with an annual average of 60% of its sets on floating objects shall place sorting grids for juveniles. Mark FADs; maintain record of number of FADs and beepers aboard; record position of deployment and recovery of FADs; retrieve at least 40% of FADs deployed before returning to port	None
		LONGLINE	
Specific catch limits	China 2,190 t Japan 28,283 t Korea 10,438 t Chinese Taipei 6,601 t	None	China 2,190 t Japan 28,283 t Korea 10,438 t Chinese Taipei 6,601 t
Limits for other CPCs	For each CPC, annual longline catches of bigeye not to exceed the greater of 83% of 2001 catches or 500 t	Each CPC to provide monthly reports of longline catches of bigeye	For each CPC, annual longline catches of bigeye not to exceed the greater of 83% of 2001 catches or 500 t

Appendix A

INTER-AMERICAN TROPICAL TUNA COMMISSION

77TH MEETING

LA JOLLA, CALIFORNIA (USA)
5-7 MARCH 2008

CHAIR'S DOCUMENT

[RESOLUTION] [RECOMMENDATION] ON A [MULTI-ANNUAL] PROGRAM FOR THE CONSERVATION OF TUNA IN THE EASTERN PACIFIC OCEAN IN 2008 [AND 2009]

The Inter-American Tropical Tuna Commission (IATTC), at its 77th Meeting in La Jolla, California (USA) in March 2008:

Having responsibility for the scientific study of the tunas and tuna-like species of the eastern Pacific Ocean (EPO), defined as the area bounded by the coastline of the Americas, the 40°N parallel, the 150°W meridian, and the 40°S parallel, and for the formulation of recommendations to Contracting Parties, cooperating non-Parties, fishing entities and regional economic integration organizations (collectively "CPCs") with regard to these tuna resources, and having maintained since 1950 a continuous scientific program directed toward the study of tuna resources;

Recognizes, based on past experience in the fishery, that the potential production from the tuna resource can be reduced by excessive fishing effort;

Being aware with grave concern that, despite the previous conservation and management measures adopted by the Commission, although the catches of bigeye and yellowfin tunas have declined recently, capacity continues to increase and overfishing of bigeye tuna and yellowfin tuna is occurring;

Notes that the tuna resource of the EPO supports one of the most significant surface fisheries for tunas in the world;

Taking into account the best scientific information available, as reflected in the recommendations of the staff and the report of the meeting of the Working Group on Stock Assessments in May 2007;

Considering that the studies of yellowfin and bigeye tunas presented at this meeting show that the stocks are at a level below that which would produce the average maximum sustainable yield (AMSY);

Considering that the increase in the use of fish-aggregating devices (FADs) with the latest generation of satellite equipment and other technologies increases in practice the fishing capacity in the EPO; and

Recognizing the importance of urging the Western and Central Pacific Fisheries Commission (WCPFC) to adopt parallel measures to conserve the tuna stocks in that region, and in particular, the shared stocks of highly migratory tunas in the Pacific Ocean;

[Resolves][Recommends] as follows:

1. This [resolution][recommendation] is applicable in [the years] 2008 [and 2009] to all purse-seine vessels and all longline vessels fishing for yellowfin, bigeye, and skipjack tunas in the EPO, defined as the area bounded by the coastline of the Americas, the 40°N parallel, the 150°W meridian, and the 40°S parallel.
2. Pole-and-line, troll, and sportfishing vessels [and purse-seine vessels of carrying capacity less than 363 metric tons] are not subject to this [resolution][recommendation].

3. That the fishery for yellowfin, bigeye, and skipjack tuna by purse-seine vessels in the EPO shall, in 2008 [and 2009], be closed

   a. [for a 84-day period, either (1) from 0000 hours on 20 June to 2400 hours on 11 September, or (2) from 0000 hours on 9 October to 2400 hours on 31 December.]

   b. [for a 60-day period, either (1) from 0000 hours on 14 July to 2400 hours on 11 September, or (2) from 0000 hours on 1 December to 2400 hours on 31 January.]

   c. [for a 42-day period, from 0000 hours on 1 August to 2400 hours on 11 September.]

   d. [Each flag government shall decide the dates of the closure period to be observed by each of its vessels.]

4. [That the fishery for yellowfin, bigeye, and skipjack tuna by purse-seine vessels in the EPO shall, in 2008 and 2009, be closed from 0000 hours on [12 September][1 December] to 2400 hours on 31 December within the area between [94° and 110°][100° and 116°]W from 3°N and 5°S illustrated in Figure 1.

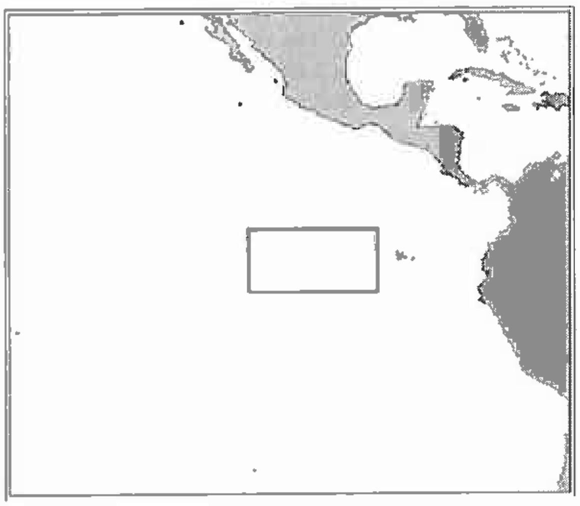

FIGURE 1. Closure area for the purse-seine fishery.]

5. Each CPC shall[, for each year concerned,] choose [which of the two specified periods will be closed to purse-seine fishing by all of its vessels][the dates of the closure applicable to each of its vessels][which of the two specified periods will be closed to purse-seine fishing by each of its vessels], and notify the Director by [15 April] [for 2008, and 1 January for 2009].[1] [All vessels of a national fleet][The vessel] must stop purse-seine fishing during the closure period [selected]. Every vessel that fishes in 2008 [and 2009], regardless of the flag under which it operates, or whether it changes flag or the jurisdiction of the CPC under which it fishes during the year, must observe the closure period to which it committed.

6. [In the event that there are two closure periods, to ensure the effectiveness of the closures, those CPCs that choose the August-October closure period shall not be able to fish north of the 5°N parallel during the December-January closure period. Reciprocally, CPCs that choose the December-January closure period will not be able to fish south of that parallel during the August-October closure period.]

7. Each CPC shall, for purse-seine fisheries:

[1] If option c in paragraph 3 is adopted, the shaded text would be deleted

a. Before the date of entry into force of the closure, take the legal and administrative measures necessary to implement the closure;

b. Inform all interested parties in its national tuna industry of the closure;

c. Inform the Director that these steps have been taken;

d. Ensure that at the time a closure begins, and for the entire duration of the closure, all purse-seine vessels fishing for yellowfin, bigeye, or skipjack tunas flying its flag, or operating under its jurisdiction, in the EPO are in port, except that vessels carrying an observer from the AIDCP On-Board Observer Program may remain at sea, provided they do not fish in the EPO. The only other exception to this provision shall be that vessels carrying an observer from the AIDCP On-Board Observer Program may leave port during the closure, provided they do not fish in the EPO.

8. Each CPC shall take the measures necessary to control the total annual catch of bigeye tuna in the EPO during 2008 [and 2009] by longline tuna vessels fishing under its jurisdiction.

9. China, Japan, Korea, and Chinese Taipei shall take the measures necessary to ensure that their total annual longline catches of bigeye tuna in the EPO during 2008 [and 2009] does not exceed the following levels:

China	2,639 metric tons
Japan	34,076 metric tons
Korea	12,576 metric tons
Chinese Taipei	7,953 metric tons

10. Other CPCs shall take the measures necessary to ensure that their total annual longline catches of bigeye tuna in the EPO during 2008 [and 2009] do not exceed the greater of 500 metric tons or their respective catches of bigeye tuna in 2001.[2] CPCs whose annual catches have exceeded 500 metric tons shall provide monthly catch reports to the Director.

11. To prohibit landings, transshipments and commercial transactions in tuna or tuna products that have been positively identified as originating from fishing activities that contravene this [resolution][recommendation]. The Director shall provide relevant information to the Parties to assist them in this regard. The Commission shall develop transparent and non-discriminatory criteria and procedures to promote compliance in the EPO, consistent with international law, including World Trade Organization agreements and other applicable trade agreements.

12. Each CPC shall[, in each of the years covered by this [resolution][recommendation],] notify the Director by [15 April][for 2008, and 1 January for 2009] of national actions taken to implement this [resolution][recommendation], including any controls it has imposed on its fleets and any monitoring, control, and compliance measures it has established to ensure compliance with such controls.

13. To evaluate progress towards the objectives of this [resolution][recommendation], in 2008 [and 2009] the IATTC Scientific Working Group will analyze the effects on the stocks of the implementation of this [resolution][recommendation], Resolution C-06-02, Resolution C-04-09, and previous conservation and management measures, and will propose, if necessary, appropriate measures to be applied in future years.

14. [[Without prejudice to the obligation of the Parties, under applicable international law, t][T]o implement a program of collecting information on FADs deployed in the EPO, to include, *inter alia*, a system of marking each FAD and recording information on the position of each FAD when it is deployed and recovered.

[2] The Parties acknowledge that France, as a coastal State, is developing a tuna longline fleet on behalf of its overseas territories situated in the EPO.

The Director shall, in consultation with the scientific institutions of CPCs, organize this program, and be responsible for maintaining the corresponding data base, in accordance with the Commission's rules of confidentiality.]

14bis. [Ask the Director to develop a draft program for collecting information on FADs in the EPO, with the aim of submitting it to the consideration of the Parties at the 78th Meeting of the Commission.]

15. [All vessels that fish on FADs, at the beginning and end of the trip, shall mark (number) these devices and maintain a record of the number of FADs and beepers aboard. They shall also record information on the position of the FADs at the time they are deployed in the water and, if applicable, when they are recovered. This information shall be sent to the flag CPC at the end of each trip.]

16. [Vessels that fish on FADs are encouraged to recover the greatest possible number of their own FADs.]

17. [Subject to the availability of the necessary funding, the Director shall develop a voluntary experimental program to examine the effectiveness of sorting grids in reducing the mortality of juvenile tunas in the purse-seine fishery. The Director shall develop an experimental protocol, including parameters for the materials to be used for the sorting grids, and the methods for their construction, installation, and deployment. The Director shall also specify the methods and format for the collection of scientific data to be used for analysis of the performance of the sorting grids.] [The foregoing is without prejudice to each CPC carrying out its own experimental programs with sorting grids and presenting its results to the IATTC Secretariat.]

17bis. [Continue the experiments with sorting grids for juvenile tunas and other species of non-target fish en the purse-seine nets of vessels that fish on FADs and on unassociated schools, voluntarily and documenting each experience exhaustively.]

18. [Instruct the Director to continue efforts that will allow the IATTC and the WCPFC to have equivalent management measures.]

19. [The WCPFC is encouraged to adopt, in the shortest time possible, conservation measures comparable to those adopted in this [resolution][recommendation], with the aim of maximizing the effectiveness of the collective measures of the two organizations, and ensuring a positive result for the resources.]

20. Each CPC shall comply with this [resolution][recommendation].

HIGHLY MIGRATORY SPECIES ADVISORY SUBPANEL REPORT ON COUNCIL RECOMMENDATIONS TO REGIONAL FISHERY MANAGEMENT ORGANIZATIONS

The Highly Migratory Species Advisory Subpanel (HMSAS) requests that the Council recommend to the U.S. delegation to the Northern Committee of the Western and Central Pacific Fisheries Commission (WCPFC):

1. The Northern Committee facilitate more comprehensive and timely data collection on North Pacific albacore.

2. The Northern Committee consider the striped marlin stock assessment.

3. The Northern Committee encourage member nations to gather and provide catch data on North Pacific albacore from the areas both east and west of 150° W longitude, either all inclusive or reported separately by area.

4. The Northern committee review the report from the International Scientific Committee on North Pacific albacore considering current levels of effort, and strive for more scientifically-based reference points for albacore.

5. The Northern Committee encourage and foster greater cooperation between WCPFC and Inter-American Tropical Tuna Commission.

6. The Northern Committee facilitate collecting information on other nations' recreational fishing fleets.

PFMC
6/8/08

HIGHLY MIGRATORY SPECIES MANAGEMENT TEAM REPORT ON COUNCIL RECOMMENDATIONS TO REGIONAL FISHERY MANAGEMENT ORGANIZATIONS

The Highly Migratory Species Management Team (HMSMT) suggests the Council provide conservation and management recommendations to the U.S. delegations of the Inter-American Tropical Tuna Commission (IATTC) and the Northern Committee of the Western and Central Pacific Fisheries Commission (WCPFC) prior to their upcoming meetings as detailed below.

In addition to the HMSMT recommendations made at the April 2008 Council meeting, the team suggests the following recommendation for the IATTC:

1) That the IATTC develop an annual reporting requirement in the form of an annual Member and Cooperating Non-Member National Report containing information on their respective fisheries and management activities. The format for this report should incorporate applicable elements of the IATTC Data Provision Resolution (C-03-05). In addition to descriptive statistics, the report should specifically detail the manner and magnitude in which compliance with IATTC resolutions is occurring. Currently, there is no reporting mechanism to monitor national compliance. Without a scorecard on compliance, the IATTC will not be able to conduct an adequate review of its performance as agreed to at the recently held meeting of RFMO's in San Francisco.

The HMSMT suggests the following recommendation for the Northern Committee:

1) That the Northern Committee of the WCPFC formally add striped marlin to the species complex under its authority so that management measures can be coordinated across the North Pacific. The recent pessimistic stock assessment results for striped marlin in the North Pacific conducted by the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific (ISC) demonstrates that management is needed. The stock assessment demonstrated that catch of striped marlin north of 20° N latitude is significant. However, there is uncertainty about the stock structure of striped marlin in the Pacific with potential separation of stocks in the eastern and western Pacific.

Finally, the HMSMT makes the following suggestions for both commissions:

1) Regarding striped marlin, the Council should urge that both the IATTC and WCPFC work to resolve the stock structure question as soon as possible based on the best available scientific information so that appropriate management and conservation measures can be implemented. The 2007 ISC assessment indicated that the status of striped marlin in the North Pacific is substantially depleted. However, the IATTC's most recent assessment of striped marlin in the eastern Pacific Ocean (EPO) was completed in 2003 and indicated that the status of striped marlin in the EPO was above MSY. These conflicting results without understanding the stock structure may mislead management.

2) That improved coordination take place between the IATTC and the WCPFC for species and stocks co-occurring under their respective authorities, particularly to address the time lag between a stock assessment and consideration of management measures. For example, the ISC produced an albacore assessment in late 2006. The WCPFC adopted this assessment in July 2007, too late for consideration by the IATTC at its June 2007 meeting.

PFMC
06/08/08