NORTH PACIFIC ALBACORE TUNA FISHERIES ECONOMIC ANALYSIS

The National Marine Fisheries Service Southwest Fisheries Science Center (SWFSC) contracted with Lisa Wise Consulting, Inc. (LWC) to conduct a socioeconomic study of the U.S. west coast fishery for North Pacific albacore. LWC involved members of the Highly Migratory Species Management Team and Highly Migratory Species Advisory Subpanel in the early planning stages of the report, reviewed a report draft with the two committees at the April 2011 Council meeting, and solicited their comments on the draft.

The report provides the Council with an overview of current economic conditions in the commercial fishery relevant to future management.

Council Action:

Discussion.

Reference Materials:

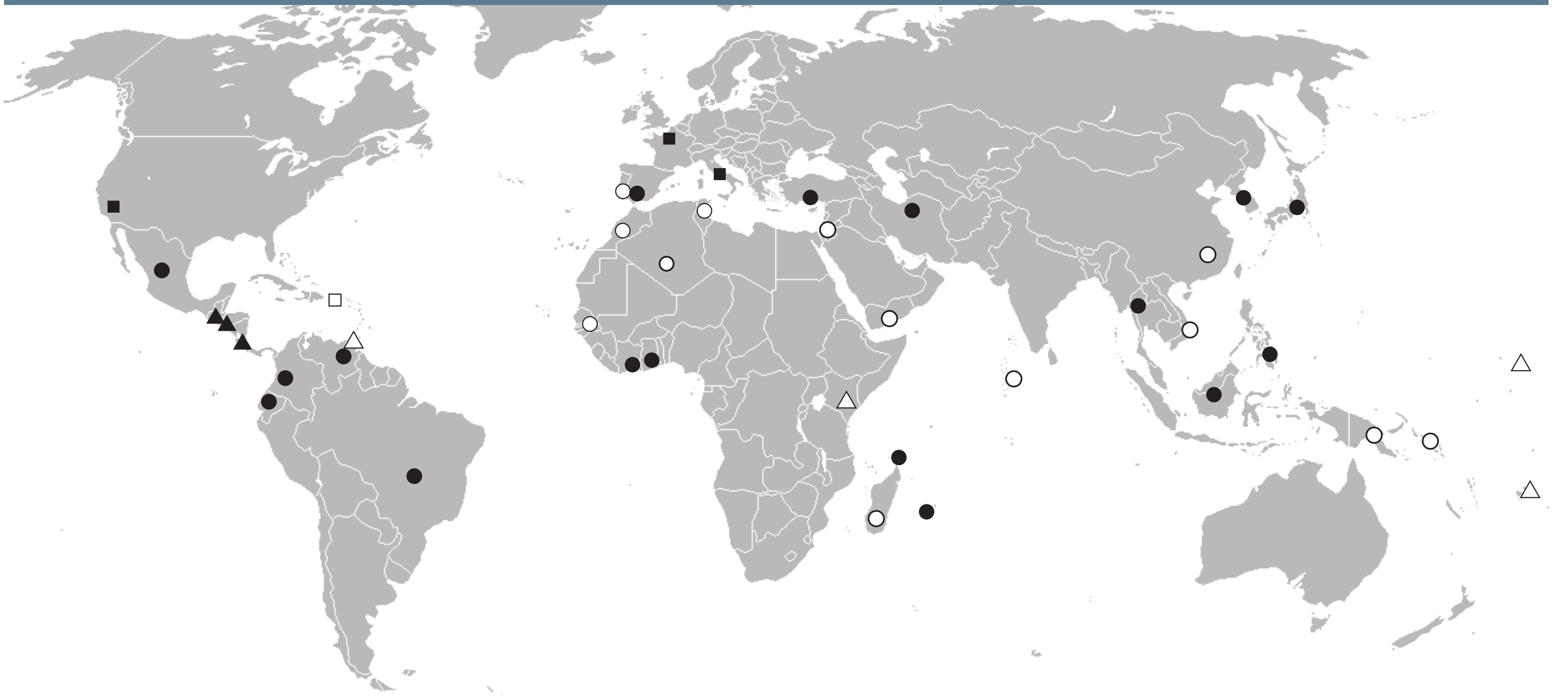
1. Agenda Item D.1.b, Attachment 1: West Coast U.S. Commercial Albacore Fishery Economic Analysis.

Agenda Order:

a.	Agenda Item Overview	Kit Dahl
b.	Report by Lisa Wise Consulting, Inc.	Henry Pontarelli
c.	Reports and Comments of Advisory Bodies and Management Entities	
d.	Public Comment	
e.	Council Discussion	

PFMC
05/17/11

Agenda Item D.1.b
Attachment 1
June 2011



West Coast U.S. Commercial Albacore Fishery
ECONOMIC ANALYSIS

MAY, 2011

lisa wise consulting, inc.

West Coast U.S. Commercial Albacore Fishery

ECONOMIC ANALYSIS

MAY, 2011

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EXECUTIVE SUMMARY

This analysis and report is a collaborative effort between the U.S. West Coast commercial albacore industry, the National Marine Fisheries Service (NMFS), and the private sector. It is aimed at informing regulators of the potential implications of adopting policy to manage the fishery.

Statistical analyses of databases on landings, earnings, expenses, number of vessels, and employment played a large role in informing the study. In addition, a major intent of the research was to include input from fishermen and industry stakeholders (processors, regulators, enforcement and port representatives) from each commercial albacore association, across ports. As such, the authors of the report conducted 30 formal one-on-one interviews. This is seen as an important and much needed opportunity to include the voice of the fishermen and industry stakeholders and their perceptions of the challenges facing the industry.

The geographic focus of this analysis is the albacore fleet that lands their catch along the West Coast of the U.S. (California, Washington, Oregon). Most of this activity takes place in the U.S. Exclusive Economic Zone (EEZ).

To summarize, the study finds that:

KEY FINDING #1: The number of vessels operating in the U.S. commercial albacore industry has fluctuated over time and trended downward since 1977. While the size of the U.S. fleet has declined recently, overall U.S. commercial albacore fishing activity has not.

KEY FINDING #2: Market and regulatory conditions faced by the U.S. commercial albacore industry have changed fundamentally over the last 30 years. Today's U.S. commercial albacore fleet faces rising operating costs and declines in the real prices. This may lead to declining profitability in the industry, unless fishermen compensate by increasing the volume of their catch or by differentiating their product.

KEY FINDING #3: Globalization has increased the complexity and challenges faced by U.S. commercial albacore fishermen. Global and domestic market forces from the late 1980s to the early 21st century have necessitated the commercial albacore industry to evolve in order to survive.

KEY FINDING #4: While biological factors are a significant determinant of U.S. commercial albacore fishing activity, market conditions (as measured by employment and fuel costs) are also significant. However, regressions at the mean suggest that economic factors are not as significant an indicator of fishing activity as are biological factors.

KEY FINDING #5: Based on a limited, but widespread sample of interviews (see page 33 to page 47), the shift in concentration of commercial fishing activity towards northern ports are primarily due to shifts in albacore migratory patterns toward nearshore waters north of Eureka, California and south of Canada. Interviews also revealed industry participants' concerns over rising operations cost, mainly fuel and labor as well as uncertainties in future regulations. Fishermen also pointed out the high risk associated with a seasonal (4 month) fishery like albacore. At the same time, their outlook is optimistic given increased worldwide and, particularly, domestic demand of albacore. Increased demand for their products is seen as due to product differentiation and improvements in labeling (in particular, MSC certification) and marketing efforts by both AAFA and WFOA. In general, fishermen report that as the general public become more aware of the benefits of U.S. caught albacore, including higher oil and lower mercury content, catch methods with little or no environmental impacts, positive trends in prices paid for their product will continue.

INTRODUCTION

Today's U.S. commercial albacore fisherman faces numerous risks and has been forced to adapt to rapidly changing conditions at sea, in the global market, and in the regulatory arena. Over the last 100 years, U.S. albacore fishermen have dealt with excessive landing fees in foreign ports (e.g. Mexico in the 1920s), requisition of their vessels during World War II, fishing prohibitions in Mexican and Canadian waters, to the 1990s and 2000s' outsourcing of processing and purchasing, negative press, and health advisories warning against tuna consumption. In addition, fishermen face labor market risk, as fishermen are more likely to get injured than the typical American worker and experienced crew must be available at a reasonable price during the fishing season. There are also traditional business risks (cash flow, lack of credit) given today's commercial albacore industry has stagnant prices and rising costs. This study asks whether these non-biological factors are significant determinants of commercial albacore fishing activity relative to biological factors such as stock abundance and reproduction rates.

The focus of this report is on commercial fishermen that land albacore in ports along the West Coast of the U.S., whether caught by surface troll or pole and line. The majority of the activity takes place in the U.S. EEZ but it does not exclude albacore caught on the high seas and landed in California, Washington or Oregon. Data for the statistical analysis ranges from 1981 to 2010 and was chosen due to its availability and consistency and that it reflects the current status of the industry with 30 years of history.

In addition, the research included formal input from 30 industry stakeholders with representation across ports and from each commercial albacore association (AAFA and WFOA). Considerable time and effort were invested to gain input from industry participants, stakeholders, regulators and those engaged in enforcement of the commercial albacore fishery. The aim of the industry engagement is to understand the economic challenges facing the U.S. commercial albacore fleet from an insider's viewpoint. This method relies on industry participants and stakeholders to have a more intimate knowledge and advantage in understanding what might benefit the industry and what may hinder it.

U.S. COMMERCIAL ALBACORE FISHERMEN INDICATE THAT THERE ARE SUBSIDIES IN FOREIGN COMMERCIAL FISHERIES THAT ERODE THEIR ABILITY TO COMPETE.

Because albacore is a highly migratory species that ranges across international boundaries and jurisdictions, the fleet is under obligation to participate and contribute to international efforts to understand and manage the species. The purchase, processing, and distribution of albacore also takes place in a global market, pitting the U.S. West Coast albacore fisherman and processors against uncertain odds as foreign fleets operate under varied management oversight, lower costs and access to vastly different labor markets. This international stage ranges from our close neighbors in Canada and relatively similar fishery-based practices, to Asia and regulators and fishermen with vastly different perspectives on resource management, business practices, and the priority of seafood in their diet and their economy.

THE FAO REPORTS THAT SINCE THE 1990S, THAILAND HAS BECOME THE TOP PRODUCER OF CANNED TUNA WITH 46 PERCENT OF THE MARKET, FOLLOWED BY SPAIN AT 10 PERCENT.

As a highly migratory species, albacore and all of the world's tuna are subject to research and management by Regional Fishery Management Organizations (RFMO). The RFMOs that are primarily responsible for the U.S. West Coast fisheries are the Inter-American Tropical Tuna Commission (IATTC) and the Western and Central Pacific Fisheries Commission (WCPFC). The International Science Committee for Tuna and Tuna-like Species in the North Pacific (ISC) is responsible for providing scientific and management advice to the Northern Committee of the WCPFC and invites IATTC staff to its meetings. In the U.S., the albacore fishery is managed as a highly migratory species (HMS) by the National Oceanic and Atmospheric Administration (NOAA) and the National Marine Fisheries Service (NMFS). NMFS receives recommendations on management and regulation from the Pacific Fisheries Management Council (PFMC), one of several regional councils. The fishery is an open access protocol. As such, the HMS albacore

BOTH MAJOR COMMERCIAL ALBACORE ASSOCIATIONS HAVE INVESTED IN MARINE STEWARDSHIP COUNCIL(MSC) APPROVAL, THE WFOA IN 2009 AND THE AAFA IN 2007.

fishery is not subject to input controls (trip limits, limited entry permit systems) or output controls (catch limits, catch quotas, etc.). Permits are available to those willing to purchase them and abide by reporting requirements, designation of gear type(s), and timely license renewals.

Since the last tuna cannery in Southern California closed its doors around 1988, the U.S. West Coast albacore fisherman has been forced to rely on canneries that are foreign-owned or located much closer to foreign markets. U.S. West Coast albacore fishermen have described their effort as "filling in" for foreign fleets, since Asian fisheries are a priority for the Asian canneries as European catch is a priority for canneries in Spain and Portugal. American albacore fishermen see their role as residual suppliers to be mainly responsible for stagnant albacore prices.

SUBSIDIES THAT INCREASE FISHING CAPACITY ARE ESTIMATED TO TOTAL $16 BILLION GLOBALLY EACH YEAR. THIS REPRESENTS CLOSE TO 20 PERCENT OF THE TOTAL VALUE OF MARINE CATCH (SUMAILA, RASHID & LESLIE DELAGRAN 2010).

Some American commercial albacore fishermen indicate their industry shows signs of vibrancy. Landings per vessel are on the rise (see page 12) as is U.S. consumption of canned and fresh or frozen tuna. Many U.S. West Coast albacore fishermen have successfully differentiated their product by adopting production techniques that include blast freezing, deep cold storage to accommodate the fresh market, and bleeding. They have also made strides to gain a more thorough understanding of albacore biology, genetics and behavior, and adopting marketing proactive marketing strategies. Both major commercial albacore associations have invested in Marine Stewardship Council (MSC) approval, the WFOA in 2009 and the AAFA in 2007. Both associations are engaged in marketing and educational programs that have expanded the fresh/fresh frozen and boutique can markets in the U.S. and influenced demand and pricing.

U.S. commercial albacore fishermen indicate that there are subsidies in foreign commercial fisheries that erode their ability to compete. From the FAO technical paper, Introducing Fisheries Subsidies, Schrank (2003) writes "The discussion of fishery subsidies has shown that the subject is complicated and that there is considerable confusion both about what actually are subsidies, and about their effects and impacts" (pg. iii). How subsidies in foreign fleet affects the U.S. commercial albacore industry is an important topic worthy of further research.

Previous studies have reviewed and analyzed developments in the albacore fishery and world tuna fisheries more generally (for example, see the FAO Fisheries and Aquaculture Technical Paper, Recent Development in the Tuna Industry). These studies tended to be global in scope or were more narrowly focused on technical developments in tuna fisheries (for example, see Miyake 2005) or on biological factors (see PFMC SAFE reports for HMS). This report adds to this discussion changes in the economic environment faced by the U.S. commercial albacore fleet, which have had a significant impact on their activity.

Conclusion

The United States has gone from dominating the Eastern Pacific tuna industry in the late 1970s and early 1980s to accounting for roughly 15 percent of the total North Pacific wide albacore catch between 2000 and 2009 (HMS-MT, April 2011). History shows that dominance in world markets is temporary and usually comes about from shifts in national comparative advantages.

IT IS IMPERATIVE THAT SOCIOECONOMIC AND ECOLOGICAL CONSIDERATIONS ARE INTEGRATED INTO DECISION-MAKING PROCESSES ALONGSIDE CAPACITY AND ALLOCATION ISSUES (MIYAKE / FAO, 2010).

The story of American commercial albacore fishermen is one of resilience given shifting comparative advantages. Proponents of sustainable fishing can find much to like in this story of survival and adaptation, and moves towards production techniques that minimize the carbon footprint, reduce bycatch and target fish in a consistent age and size class.

What this study does show is that the West Coast commercial albacore fishery is a seasonal fishery, active for four months, that it is closely interrelated with other fisheries, that there is a high level of risk associated with participation and investment in the fishery because of the uncertainties of the resource and the market. These forces can create complications for policy makers seeking traditional one-size-fits-all solutions to resource management problems. Policy that encourages sustainable fishing in one fishery or one area may induce fishermen to increase effort in other areas or other fisheries.

Biological factors are important in setting policy but should not be relied on solely...market and economic factors should be included in policy decision making (Interview, 2011).

This report employs formal statistical modeling and relies heavily on input and engagement from industry participants and stakeholders. Considerable time and effort was invested to gain input from industry participants and stakeholders, regulators and those engaged in

CO-MANAGEMENT IS A PARTICIPATORY MANAGEMENT STRATEGY THAT PROVIDES AND MAINTAINS A FORUM OR STRUCTURE FOR DIALOGUE, COMMUNICATION, AND DEVELOPMENT AMONG PARTNERS (POMEROY & RIVERA-GUIEB, 2006).

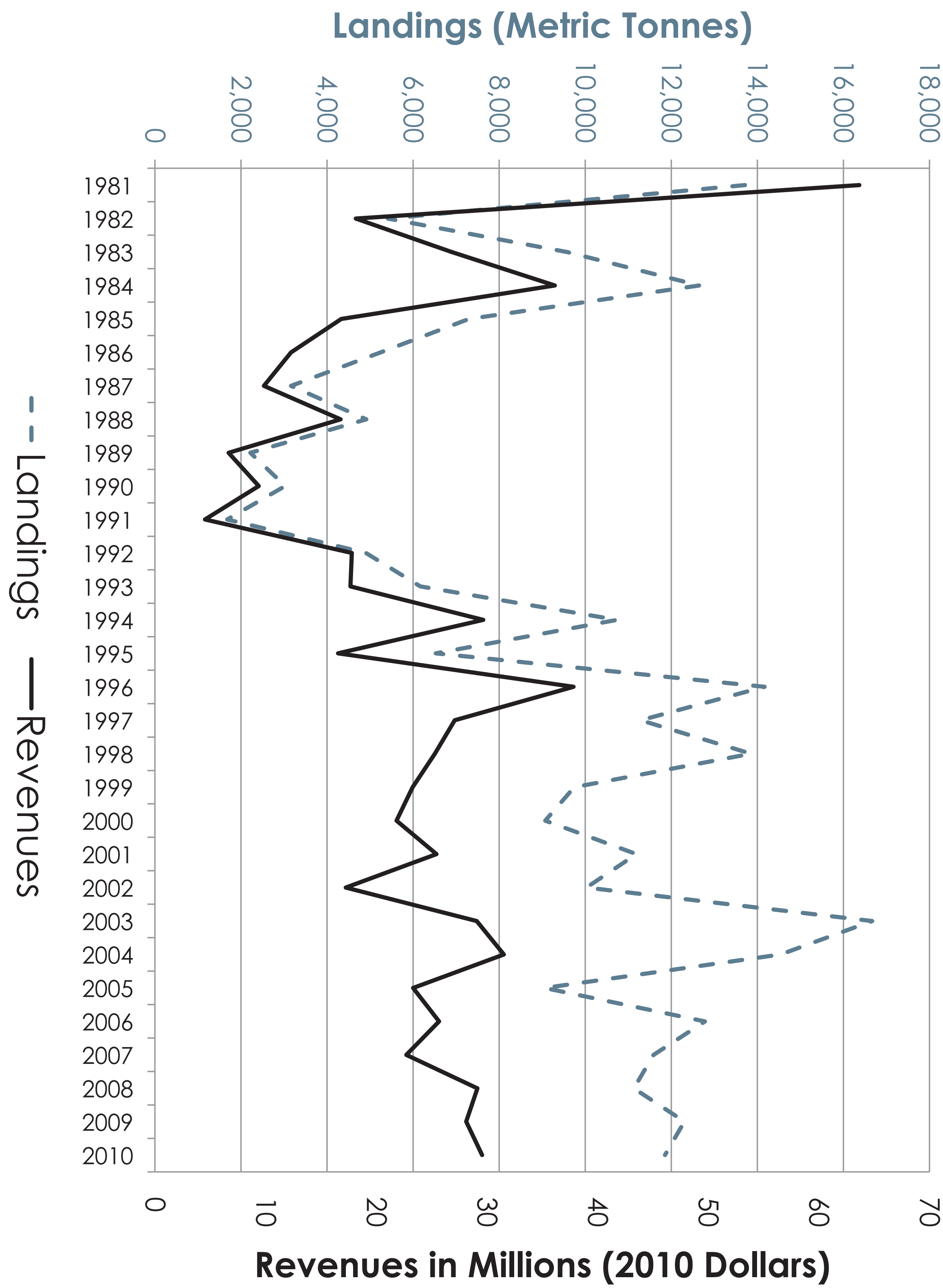
enforcement of the commercial albacore fishery. The aim of the industry engagement is to understand the economic challenges facing the U.S. commercial albacore fleet from an insider's viewpoint. This method has value in that industry participants and stakeholders have a more intimate knowledge of the fishery. While industry opinion and experience is by no means homogeneous, this method is an attempt to find consensus and bring that message to the regulators.

The project was defined by a strict budget, scope and timeline. There are several instances where the team has identified concepts or questions that fell outside of these constraints but deserve further scrutiny. As such, this project raises questions as well as provides answers. It should be considered a work in progress and a vehicle for continuing dialogue between the commercial fishing community and regulators on the formation of policy.

This effort is also an example of the practice of co-management and represents responsible participation on the part of fishermen, one that balances rights and responsibilities. Through this type of collaboration and communication with regulators, commercial albacore fishermen and stakeholders are taking a broader and increasingly active approach at stewardship and shared decision-making. The work complements the structure of the Highly Migratory Species Advisory Subpanel as part of the PFMC and a process of resource management that adjusts and adapts to changing conditions over time. In the last decade, there has been a shift toward the emphasis of co-management. While the concept has received much attention in scientific literature, its practice is still evolving and being defined. Elinor Ostrom, Nobel Prize winning economist, concurs that co-management systems are "complex, and they take time." The goal of this work is to contribute to that definition and make one more step toward long term sustainability in the U.S. West Coast albacore fishery.

In order to further describe the changes in the commercial West Coast albacore industry over time, Figure 1 on page 8 depicts landings and earnings on the y-axes and time on the x-axis.

Figure 1. Landings and Revenues Over Time



Source: Washington, Oregon and California (W-O-C) Report; Retrieved 11 January 2011 from: http://pacfin.psmfc.org/pacfin_pub/all_species_pub/woc_cw_albc_csv.php

METHODOLOGY

This project was conceived and facilitated by West Coast U.S. commercial albacore fishermen with the intent of informing regulators on the significance of non-biological or economic constraints on the fishery so they may be considered when setting policy.

In order to gain a comprehensive view of these constraints, the research team used a combination of statistical analysis and community engagement through one-on-one interviews. The interviews brought qualitative data to fill in explanatory gaps in the quantitative analysis.

Findings from the quantitative analysis are summarized in Key Findings #1 through #4. Several statistical techniques were used to establish relationships between the indicators of commercial fishing activity and economic and biological factors. A description of the methods of analysis is included in the narrative with the findings. Variables and relationships between variables include: landings, earnings, employment costs and fuel costs.

Findings from the interviews are interspersed throughout the document, in the text and in text boxes. The interviews are summarized in Key Finding #5. Note, the findings are not numbered in hierarchy or priority. A complete discussion of the interviews is included in the Interviews with Industry Stakeholders section from page 33 to page 47. Thirty in-depth interviews were conducted with fishermen and industry stakeholders who were chosen through a non-probability, purposive sampling, with interviewees selected through key industry informants' personal judgment. The distribution of interviewees included fishermen and industry stakeholders from both the AAFA and the WFOA in California, Washington and Oregon, buyer/processors, regulators and enforcement personnel, the science community, and other key industry stakeholders. The survey instrument was designed to be qualitative, and employed open-ended questions that invited conversation and gathered information on an individual's personal history, perspectives and experiences within the commercial albacore fishery as well as information about the fleet, and market forces that have influenced commercial albacore fishermen's behavior.

Data Sources

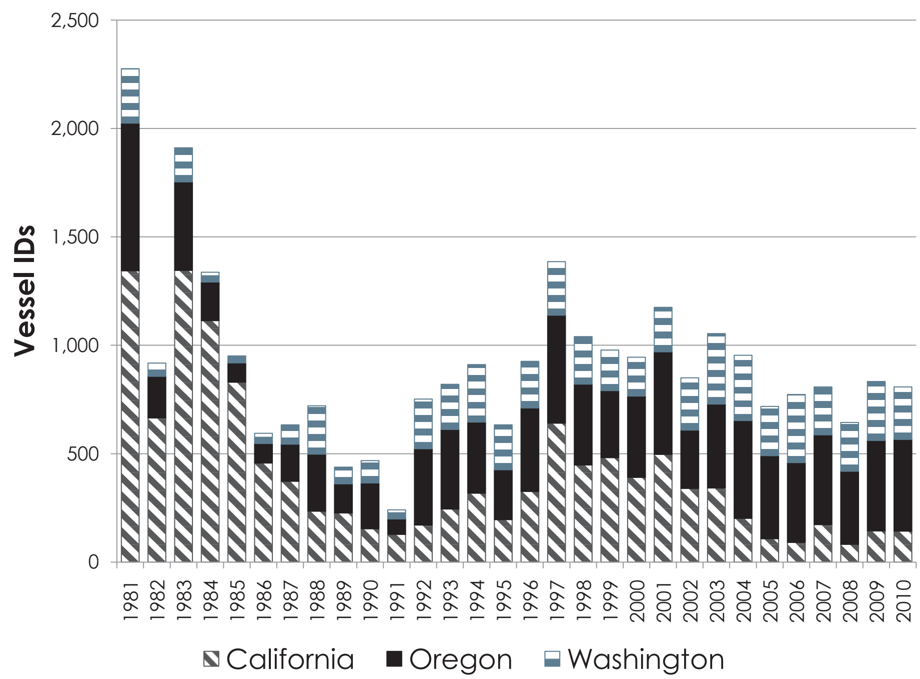
Data sources for the regression analysis include on-highway diesel prices from the U.S. Energy Administration (EIA) Monthly Energy Review database, the Employment Cost Index (ECI) for wages, and salaries calculated for the manufacturing industry. The (ECI) is a quarterly measure of changes in labor costs. It is one of the principal economic indicators used by the Federal Reserve Bank.

THE EMPLOYMENT COST INDEX (ECI) IS A QUARTERLY MEASURE OF CHANGES IN LABOR COSTS. IT IS ONE OF THE PRINCIPAL ECONOMIC INDICATORS USED BY THE FEDERAL RESERVE BANK.

KEY FINDINGS

KEY FINDING #1: The number of vessels operating in the U.S. commercial albacore industry fluctuated over the last 30 years and have trended downward since 1997 (Figure 2). While the size of the U.S. fleet has declined, overall U.S. commercial albacore fishing activity has not.

Figure 2. Size of U.S. West Coast Commercial Albacore Fleet

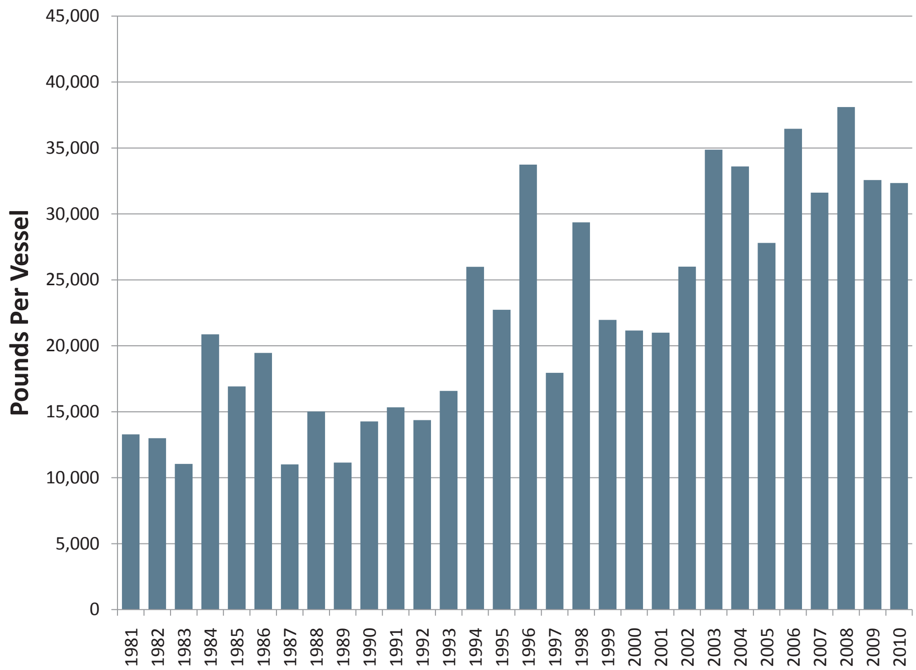


Source: Washington, Oregon and California (W-O-C) Report; Retrieved 11 January 2011 from: http://pacfin.psmfc.org/pacfin_pub/all_species_pub/woc_cw_albc_csv.php

Size of U.S. Commercial Albacore Fleet

The number of vessels landing albacore in U.S. ports fell around 1984 and kept declining over the late 1980s to a low in 1991. The fleet grew again in the early 1990s to reach more than 1,300 vessels landing albacore by 1997. The overall rate of decline in the size of the fleet appears to have tapered off over the late 1990s and 2000s.

Figure 3. Landings Per Vessel



Source: Washington, Oregon and California (W-O-C) Report; Retrieved 11 January 2011 from: http://pacfin.psmfc.org/pacfin_pub/all_species_pub/woc_cw_albc_csv.php

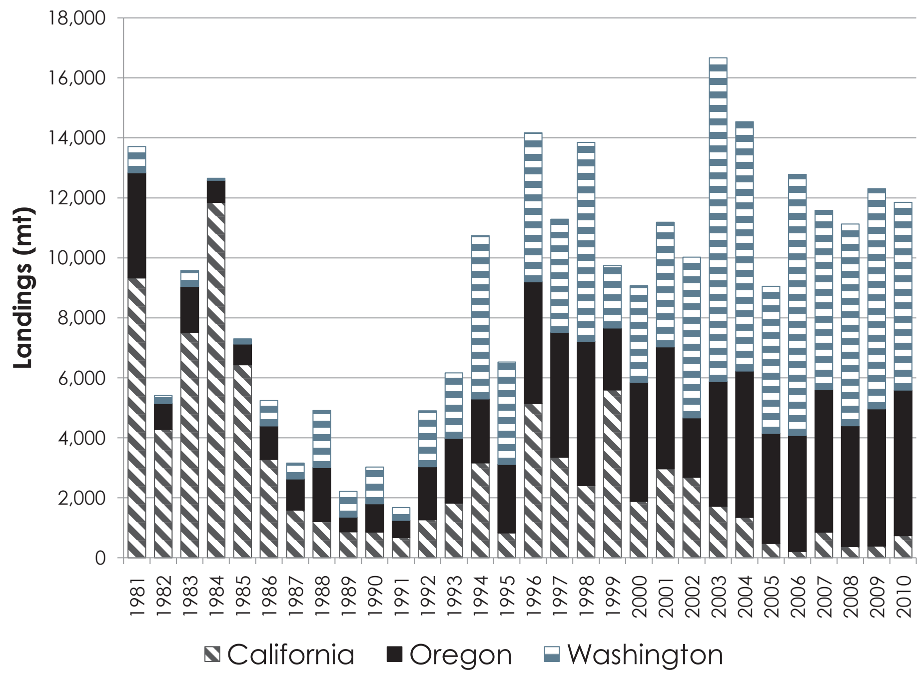
Geographic Shift in Fishing Activity

"When Mexico pulled permits, everyone began fishing north of San Francisco" (Interview, 2011).

As the size of the U.S. fleet declined, overall and per-vessel landings of albacore have not. Total weight of albacore landings (Figure 4) declined over the 1980s and particularly dramatically from 1984, reaching a low in 1991. Landings increased annually from 1991 to 1994, dipped to 1993 levels in 1995, then increased up to 1998. Overall, albacore landings have stayed at a fairly similar level from the late 1990s to 2010. Landings in the 2000-2010 decade are at about the early 1980s levels, with a high in 2003.

There is also a marked shift in the distribution of albacore fishing activity across states over the last 30 years. An increasing share of vessels and landings moved away from California and moved north, towards ports in Washington and Oregon.

Figure 4. Total Weight of Landings in Metric Tons Across States



Source: Washington, Oregon and California (W-O-C) Report; Retrieved 11 January 2011 from: http://pacfin.psmfc.org/pacfin_pub/all_species_pub/woc_cw_albc_csv.php

"We go where the fish show up, and the fish have been showing up north lately" (Interview, 2011).

Commercial albacore fishermen travel from as far as San Diego and other ports like Morro Bay and Moss Landing to access the resource off of the coast of Oregon and Washington. Such a trip can take up to 6 days (from Morro Bay) and can use up to 600 gallons of fuel, adding approximately $2,000 and the investment of time before the first hook is set. Note, these costs are doubled when the boat returns to its home port.

The last major landing of albacore in Morro Bay was in 2001. The loss of albacore activity is perceived to be one more setback for Morro Bay (Interview, 2011). Coupled with the steep decline of the trawl fleet and weakening salmon landings, investment in commercial fishing infrastructure and spending on ice, fuel and supplies have declined in the area making locally landed fish even less available to local consumers. Commercial fishing ports, like fishermen, rely on several species/fisheries to survive.

The decline in the commercial albacore fleet size and the concurrent marked shift in location of landings towards the northern part of the U.S. West Coast may indicate one or more of several things:

- **A decline in associated port infrastructure for processing albacore along the U.S. West Coast;**

- **Increasing lack of access to a market (i.e. buyers) for albacore;**
- **A shift in fishermen's personal preferences for where to land, who to do business with and sell fish to**
- **The physical movement and migration patterns of the resource**
- **A rise in costs associated with offloading at different ports**
- **Availability of bait**
- **Differences in landing taxes, fees and licensing requirements**

KEY FINDING #2: Market and regulatory conditions faced by the U.S. commercial albacore industry have changed fundamentally over the last 30 years. Today's U.S. commercial albacore fleet faces rising operating costs and declines in real prices. This may mean declining profitability in the industry, unless fishermen compensate by increasing the volume of their catch. and/or effectively differentiating their product.

Operating Costs

The loss of albacore activity was one more setback for Morro Bay (Interview, 2011).

To work as a U.S. commercial albacore fisherman requires expert knowledge of boats, harvest gear, vessel and gear maintenance, complex regulations, weather and tides, various fish handling and cooling methods, and how to locate albacore. Good relationships with other members of the fleet may lead to cooperation among some fishermen (i.e. sharing knowledge of where albacore are abundant), allowing individual members to reduce some of their operating costs. The West Coast U.S. commercial albacore fisherman must also develop and maintain relationships with buyers, processors, transhippers and off-loaders wherever they land—up and down the coast and in Canada.

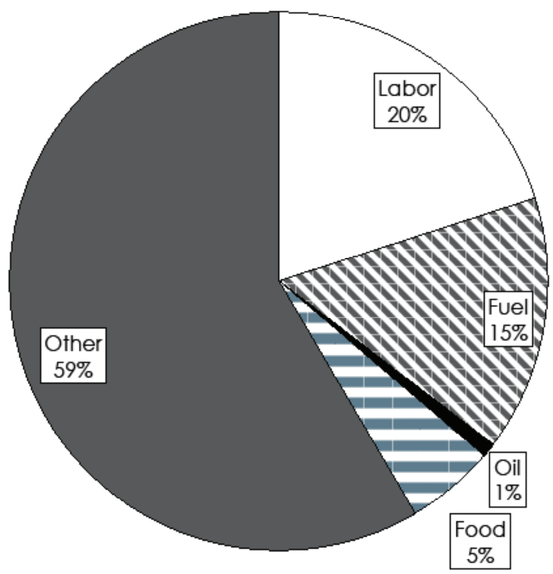
Some operating costs are incurred regardless of the level of a vessel's fishing activity. These are regarded as fixed costs, and include boat repair and maintenance, engine replacement, navigation and communication equipment, mooring and slip fees, insurance, permit fees, license fees and membership dues to trade associations, among others. Variable costs are incurred only if fishing occurs, such as: crew wages/share, fuel, bait, ice, offloading fees and supplies.

Unfortunately, there is limited data on costs and expenditures of albacore fishing operations and no data covering the same period that we have examined all other indicators of activity exist. However, we can glean insight from the NMFS/AFRF Cost Expense Survey, 1996-1999.

Figure 5 depicts the relative fixed and variable costs from this data across the four years. Variable costs may or may not be directly proportional to catch. For instance, expenditures on fuel are independent of catch while labor costs grow with the level of catch. From this data, labor, food, and fuel together comprise about 40 percent of albacore fishing vessels' expenditures. From interviews, fishermen report that, while fuel costs have averaged between 10 percent and 15 percent of total costs, but in 2010 and 2011 fuel costs have run and are expected to run 20 percent. Costs vary from operation to operation. Also, the Bureau of Labor Statistics reports that over the 1990s, the cost of labor in the fishing industry increased more than 20 percent in adjusted currency.

Ultimately profit determines whether or not albacore is the target species of a commercial fisherman and the intensity of his effort.

Figure 5. Proportion of Total Expenditures: AFRF Survey (1996-1999)



Source: American Fisheries Research Foundation (2011). Expenditure Data 1996-1999. Furnished by D. Squires 16 March 2011.

Costs for fuel, food, and crew on a small (<50 foot) bait boat with two crew constitute about 50 percent of total expenses and 40 percent of total expenses on the same boat on troll, with one crew member.

Meanwhile, fixed and other costs comprise more than half of total expenditures (59 percent). These expenses include the costs of licensing, permits, boat and gear repair and maintenance, slip fees, engine replacement, and navigation and communication equipment such as auto pilot, doppler, Comstat, VHF, Sideband, GPS and chart plotter,

THE COST OF LABOR IN THE FISHING INDUSTRY INCREASED MORE THAN 20 PERCENT IN THE 1990S.

satellite/cellular phone, Fax, radar, and sonar. Fixed expenses also include purchase and maintenance of safety gear and safety training.

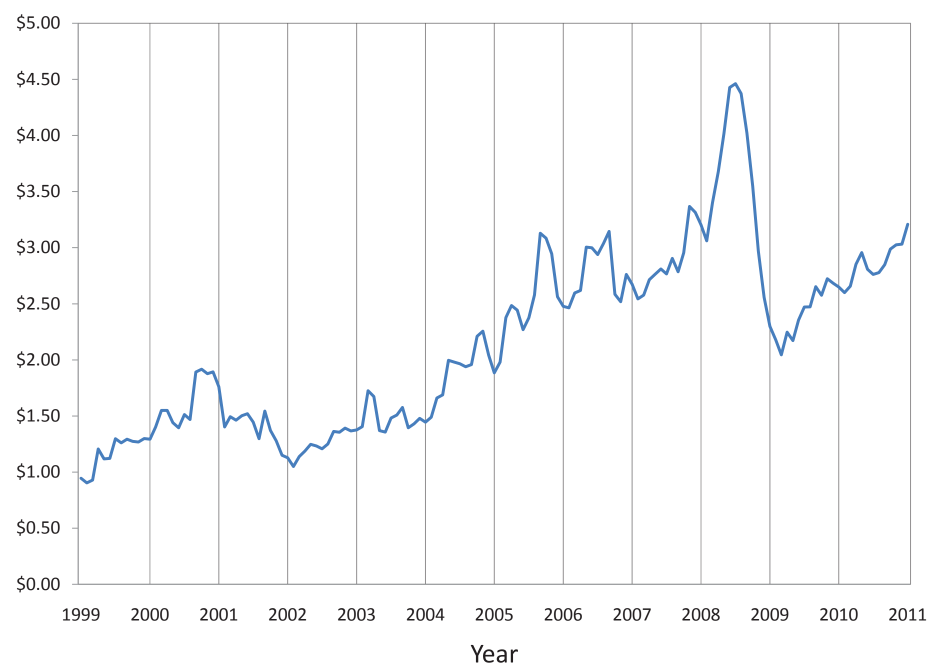
A comprehensive assessment of expenses and how operating costs have changed over time is warranted to better understand the market conditions facing the U.S. West Coast commercial albacore fishermen. Expenses are likely to vary across location, vessel size and age, gear type, seasonal conditions (weather, water temperature), individual fisherman ability, and other factors.

To shed some light on how operating costs in the commercial albacore industry may have changed over time, we refer to existing databases on fuel prices.

As illustrated in Figure 5, fuel comprises approximately 15 percent of total vessel expenditures. Coast-wide diesel price per gallon has grown nearly 250 percent between 1999 to early 2011 (Source: Pacific State Marine Fisheries Commission, 2011).

"In 1996, diesel was $.70 dockside. In 2007, it was $4.68 dockside. Last year, I spent $40,000 on fuel alone, which is a huge amount. The price of fish has to offset price of fuel by A LOT" (Interview, 2011).

Figure 6. Coastwide Diesel Price Per Gallon 1999-2011 (2010 Dollars)



Source: PSFMC The fisheries economics Program Marine Diesel Fuel Prices 1999-2011. Retrieved 24 February 2011 from: http://www.psmfc.org/efin/data/fuel.html#Data

Licensing and Other Requirements

Fixed and other costs comprise nearly 60 percent of total expenditures for the typical albacore fisherman. A component of this approximately 60 percent is the cost of licensing and other regulations.

Beginning in April 2005, the HMS Fishery Management Plan (FMP) required U.S. commercial fishing vessels to obtain an HMS permit from NMFS for HMS fishing efforts in the FMP management area (North Pacific from 3 to 200 nautical miles offshore and bounded by the International Boundaries with Mexico and Canada). These HMS permits also include a specific HMS gear type endorsement. In addition, the West Coast HMS FMP monitoring plan required HMS fishery participants to complete and submit logbooks documenting catch, effort and landing data to NMFS. In some cases, logbooks were submitted voluntarily to NMFS prior to the HMS FMP.

Additional West Coast HMS FMP measures include compliance with observer coverage for all HMS fishing vessels and VMS requirements for all vessels fishing west of 150° West, or in the South Pacific albacore fishery. Through the FMP, NMFS can require vessels targeting albacore to carry observers and provide them with living quarters, meals and other considerations the crew receives. To comply with U.S. commercial fishing regulations for the albacore fishery, a West Coast albacore fisherman must:

- **Obtain and hold valid HMS Permit**
- **Hold a gear type endorsement**
- **Fulfill logbook requirements (Federal)**
- **Fulfill observer requirements**
- **Comply with VMS requirements**

Real Price of Albacore Over Time

The price per pound of albacore declined in real terms over the last 30 years. Similar to the figures on landings, real prices fluctuate along a cyclical trend. Prices declined over the early 1980s, reaching a low by 1985 (Figure 7). Prices increased from 1986 to the early 1990s, declined over the 1990s, and have been trending slightly upward again since 2002. While there are annual and cyclical fluctuations in prices, from 1981 to 2010 real prices of albacore have trended downward and slowly decreased over time.

Figure 7. Distribution of Real Albacore Prices Across Ports (2010 Dollars)

Source: Washington, Oregon and California (W-O-C) Report; Retrieved 11 January 2011 from: http://pacfin.psmfc.org/pacfin_pub/all_species_pub/woc_cw_albc_csv.php

In response to market challenges, U.S. commercial albacore fishermen have increasingly differentiated their products. For instance, they utilize multiple refrigeration methods on the boat such as ice, spray brine and blast freezing. While more albacore fishermen recognize the benefits of blast freezing for the sashimi market, what has really affected the market is bleeding. In the interviews, fishermen related that blast bled fish are sold to the sashimi and loin markets, fetching an additional $100 to $200 per ton. However, blast freezing requires expensive equipment and additional space on the boat as well as additional crew to process and operate the freezing systems. While the bleeding process adds value to the product, the cost in time and loss of up to 5 percent of the fish weight (due to blood loss) can outweigh the benefits.

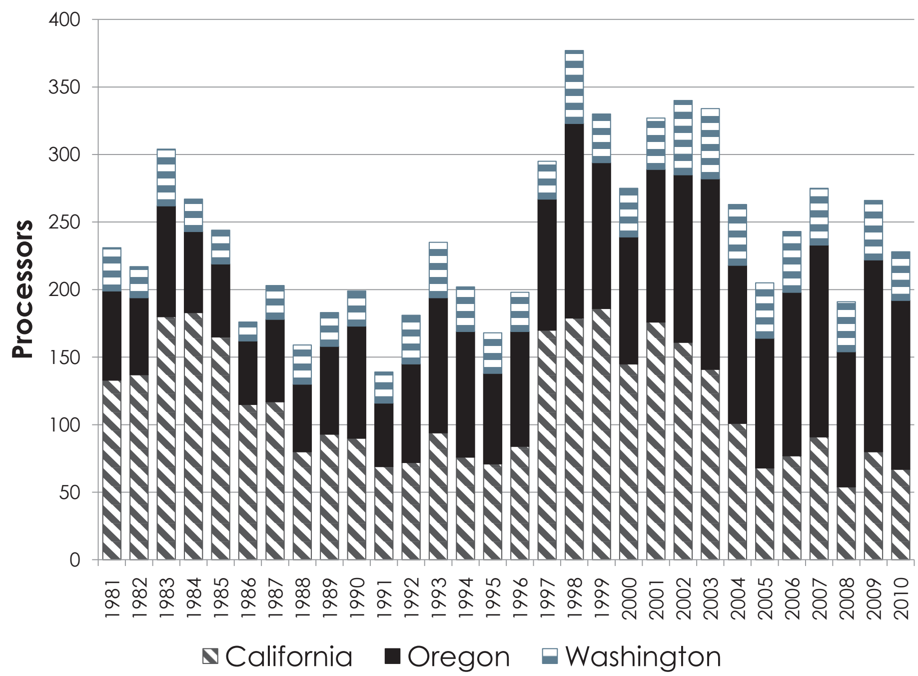
Pricing of albacore can even vary with the temperature at which the fish are frozen, with colder temperatures fetching higher prices. There may be up to 12 levels of pricing depending on how fish are handled and stored (Interview, 2011). Thus, differences in price of albacore may reflect quality differences, whether real or perceived.

Number of Processors

The number of albacore processors declined over the late 1980s, increased from 1995-98, and has trended down over the 2000s. As the commercial albacore fleet has moved north, processors have moved away from California.

The bleeding process adds value to the fisherman and can fetch an additional $100-$200 per ton but barely covers the cost in time and loss of weight (Interview, 2011).

Figure 8. Number of Albacore Processors Across States

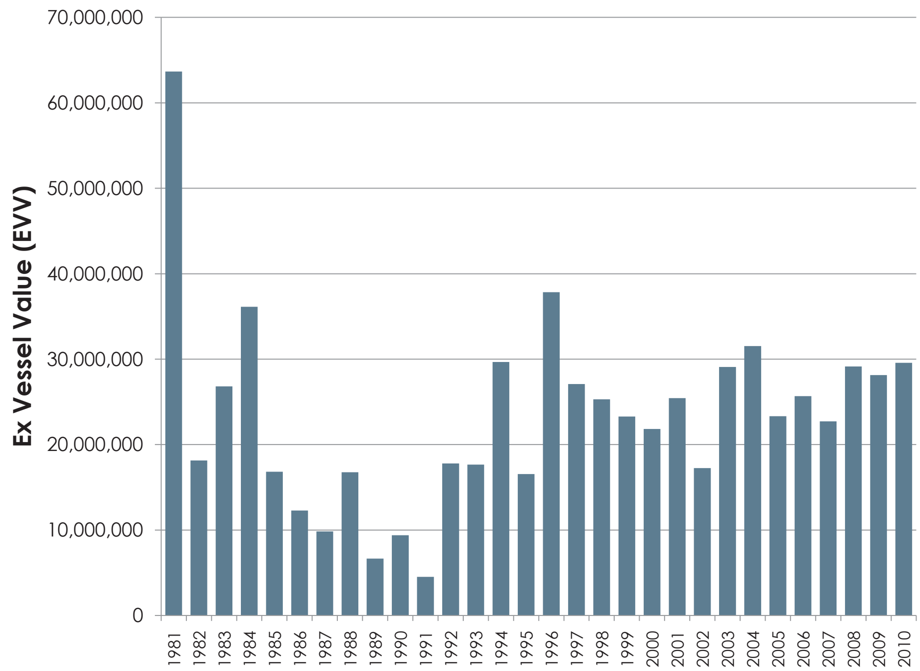


Source: Washington, Oregon and California (W-O-C) Report; Retrieved 11 January 2011 from: http://pacfin.psmfc.org/pacfin_pub/all_species_pub/woc_cw_albc_csv.php

Industry Revenues

Total industry earnings for the U.S. West Coast commercial albacore industry have followed a similar trend as landings (Figure 9), dropping from highs in the early 1980s to a trough in the early 1990s, then growing through the late 1990s to a high in 1996, and averaging around $28 million per year from 2000 to 2010 (Figure 9). The U.S. West Coast albacore industry has generated almost $700 million from 1981 to 2010. In the last 10 years (2000 to 2010) the commercial albacore fishery generated over $280 million. In contrast, for the same periods in Washington, Oregon and California, the salmon fishery generated over $2.25 billion (1981 to 2010) and over $354 million (2000 to 2010). Note, the salmon fishery data is sourced from PacFIN by county for Washington, Oregon and California, and this data set only included "non-confidential data."

Figure 9. EVV for West Coast Commercial Albacore Fishery



Source: Washington, Oregon and California (W-O-C) Report; Retrieved 11 January 2011 from: http://pacfin.psmfc.org/pacfin_pub/all_species_pub/woc_cw_albc_csv.php

ALBACORE PROCESSORS HAVE MOVED AWAY FROM CALIFORNIA TOWARDS NORTHERN PORTS.

The number of albacore fishing vessels operating on the West Coast (Figure 2) has decreased from highs between 2,000 and 2,500 in the early 1980s to a trough in the late 1980s and early 1990s, recovering to approximately 1,400 vessels by 1997 and then shown a downward trend to approximately 800 vessels by 2010. At the same time, landings per vessel (Figure 3) have risen fairly steadily from 1981 to 2010, from approximately 14,000 pounds to 32,000 pounds, respectively. Earnings per vessel (Figure 10) show that higher earners (90th percentile) are earning much more than fishermen at the median.

Figure 10. Earnings Per Vessel (2010 Dollars)

Source: Washington, Oregon and California (W-O-C) Report; Retrieved 11 January 2011 from: http://pacfin.psmfc.org/pacfin_pub/all_species_pub/woc_cw_albc_csv.php

KEY FINDING #3: Globalization has increased the complexity and challenges faced by U.S. commercial albacore fishermen. Global and domestic market forces from the late 1980s to the early 21st century have necessitated the commercial albacore industry to evolve in order to survive.

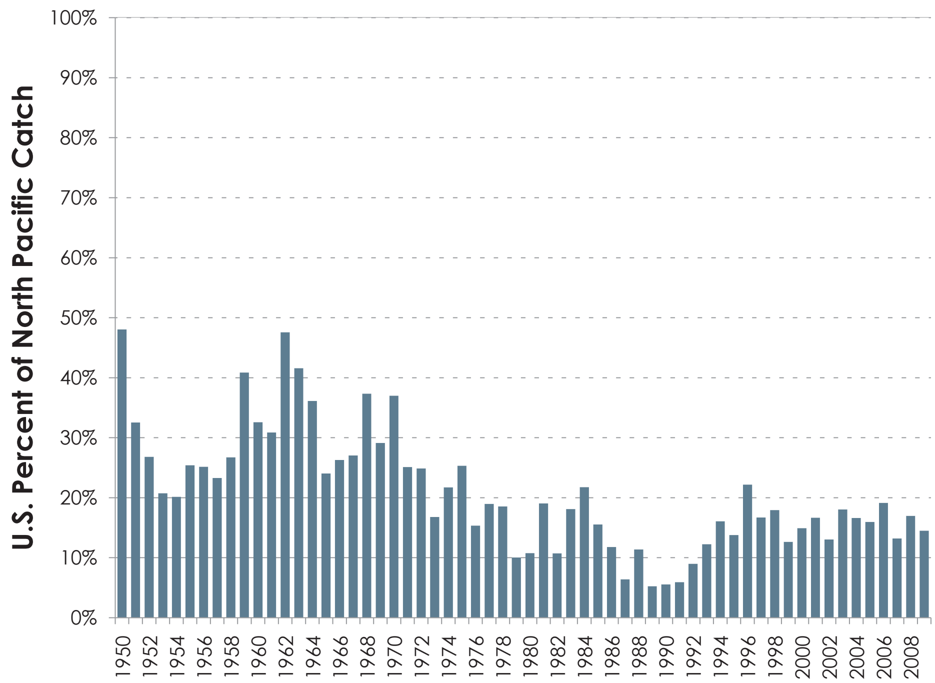
Implications of Globalization

Viewing the productive activities of the U.S. commercial albacore fleet in the context of a globalized market is critically important. American commercial albacore fishermen compete with foreign fleets in catching an elusive and highly mobile resource. In addition, globalization has dramatically shifted where and how albacore is processed, distributed, and consumed. Meanwhile, the tuna consumer market has expanded as a direct result of increased trade, U.S. and global population changes, and the growth of middle classes in developing countries who can afford more protein in their diet.

Globalization and U.S. Albacore Market Share

According to a 2010 FAO report by Miyake et. al., global tuna catches have been constantly increasing from 1950 to 2005. Catches in the Pacific dominate the world catch (64 percent in recent years). Miyake (2010) gives a striking account of the U.S. share of global tuna catch peaking in the early 1960s and thereafter declining very rapidly its proportion to global total catch, even as global total catch increased (Figure 11).

Figure 11. Percent of North Pacific Albacore Landings for United States



Source: WCPFC Tuna Fishery Yearbook 2009, Retrieved 13 January 2011 from: http://www.wcpfc.int/node/2502

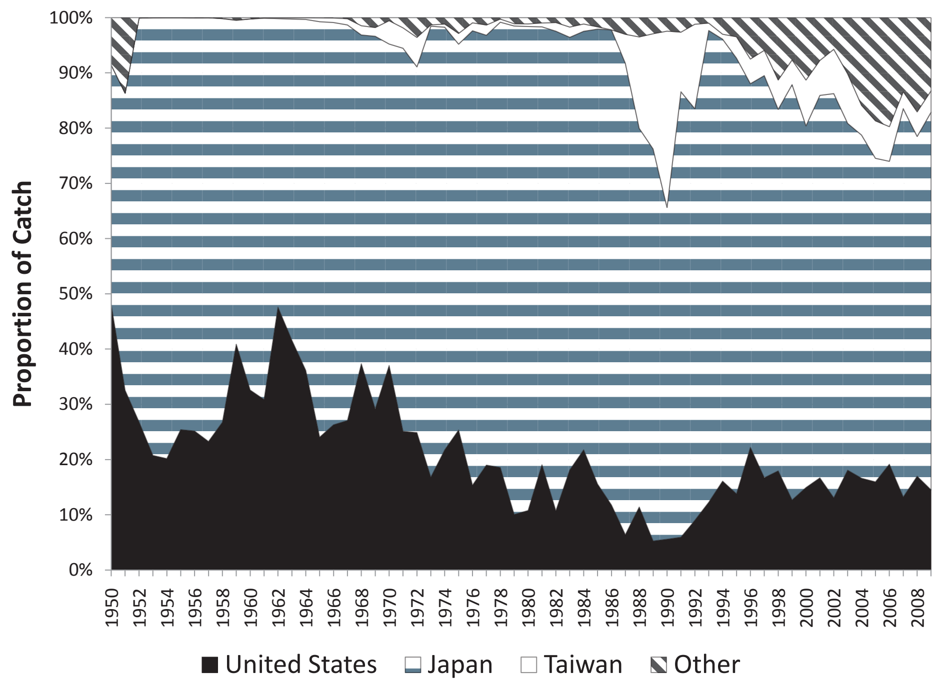
The North Pacific fishery was previously dominated by Japan (73 percent between 1950 to 1990) and to a lesser extent the United States (24 percent between 1950 to 1990). There has been a clear and rapid increase in catch and market share by Taiwan and the Republic of Korea (Figure 12). Much of the increase in these fleets' catches is driven by purse seine fleet landings.

The U.S. commercial albacore fleet has accounted for roughly 15 percent of the total North Pacific albacore catch between 2000 and 2009 (HMSMT, H.2.b, April 2011). Albacore landings from U.S. commercial efforts have dropped since the 1950s and 1960s and have been relatively stable since the mid to late 1990s. The decision of U.S. commercial albacore fishermen to participate in the fishery and how much to land is based on market/economic and biological pressures. In light of market pressures, globalization and fragmentation of processing, rising costs, shifting fish

THE GROWTH OF LANDINGS FROM "OTHER" NATIONS REPRESENTS A CHALLENGE FOR THE U.S. COMMERCIAL ALBACORE FLEET IN INCREASED SUPPLY ON THE WORLD MARKET AND CONTINUED PRESSURE TO DIFFERENTIATE U.S. CAUGHT PRODUCT AND MAINTAIN AND INCREASE PRICES.

stocks and difficulties in attracting competent crew, it is a resilient and ingenious fishermen that has held landings steady for over 10 years.

Figure 12. North Pacific Albacore Landings (mt) Across Countries



Source: WCPFC Tuna Fishery Yearbook 2009, Retrieved 13 January 2011 from: http://www.wcpfc.int/node/2502
**Note: Analysis used YB_NPAC Data file covering "Annual catch estimates by gear, flag and species for the Pacific Ocean, north of the equator" (WCPFC, 2009)

Globalization and Tuna Production and Processing

LANDINGS FROM "OTHER" NATIONS ALSO MAKES MANAGEMENT OF WORLD TUNA STOCKS MORE COMPLICATED.

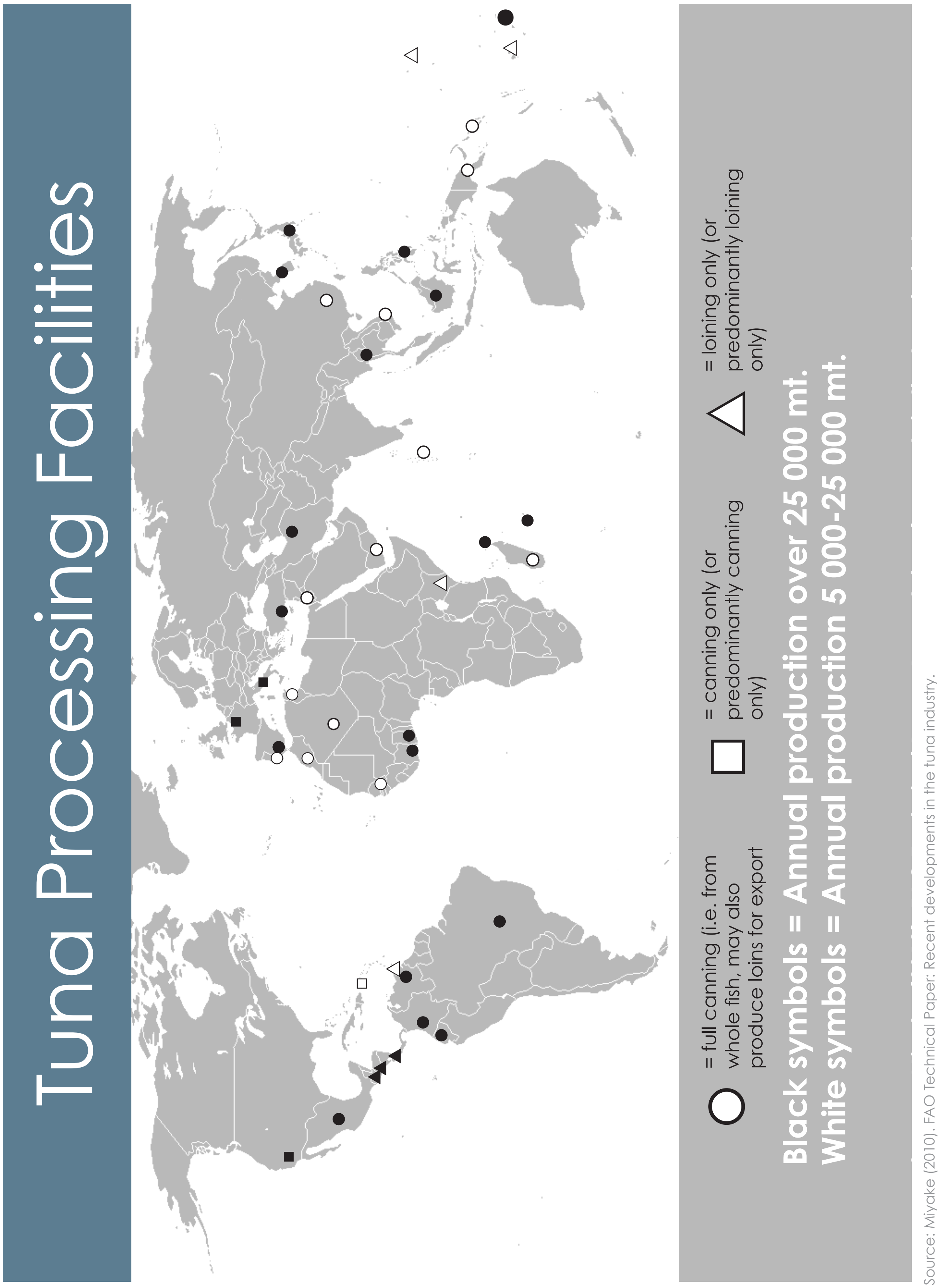
A well-known outcome of increased trade with developing countries is the fragmentation of the production process. Most commonly seen in manufacturing, an illustrative example is in the production of t-shirts. Fragmentation in this industry has led to a production process with designers based in Southern California, low-wage factories in China producing the low-priced t-shirt that eventually is sold at Wal-Mart.

One result of increased globalization and trade between developing and developed nations is that low-pay, labor intensive jobs become tradeable goods. It is cheaper to produce the t-shirt in China; thus, manufacturing jobs are traded to China. In the commercial albacore industry, jobs such as boat crew and processor plant worker essentially become tradeable with increased globalization.

Between 1990 and 2001, nearly all tuna canning plants in the mainland U.S. and Puerto Rico closed down. A major reason was the increasingly high labor costs in tuna processing. While the United States used to dominate the canning industry, with the "big three" processors—StarKist, Bumble Bee and Chicken of the Sea—located on its soil, today it has been replaced by Thailand and other low-wage Southeast Asian countries such as the Philippines and Indonesia. In addition, the U.S. market was initially protected from relocation of tuna production to South America by its high tariffs. As tariffs on products from Andean countries were reduced in recent years, the prices of some tuna products from South America have become competitive. Lower wages and reductions in tariffs due to the Andean Trade Preference Act has enabled Ecuador and other Andean countries to gain market share in the United States, and further reduced the United States' stake of the processing of tuna for domestic consumption (Miyake et. al., 2010).

Miyake et. al. (2010) shows the locations of tuna processing facilities around the world as of 2006 (Figure 13). Not only are processing plants increasingly located in low-wage countries, they are also closer to fishing grounds (e.g. Thailand, Philippines, Indonesia, Papua New Guinea, Ecuador), resulting in greater cost savings in operations. In fact, "Thailand's aggressive marketing efforts, low labor costs, lax environmental and labor laws and weak currency against the U.S. dollar (and other world currencies) makes it the largest exporter of canned tuna in the world" (DOL, 2009). Many of Thailand's advantages are shared by South American countries: low labor costs, relatively lax environmental and labor laws, and weak currency.

Figure 13. Global Tuna Processing Facilities (Figure 52 from Miyake, et. al)



Another reduction in operating costs for the processing industry comes from using imported tuna loins. Cooking, cleaning, and loining the fish accounts for 80 percent of the labor cost of producing one can of tuna (Miyake et. al., 2010; U.S. DOL, 2009). Further specialization between pure canning and loin production has also occurred, as seen in Figure 13.

Dolphin bycatch mitigation measures implemented in 1990 and 1992 indirectly led to increased commercial use of tuna loins for canned tuna (Hall, 1998). According to Miyake et. al. (2010), the U.S. catch of tuna in the Eastern Pacific Ocean dramatically declined under the U.S. Marine Mammal Protection Act. Canneries in Puerto Rico and the U.S., and later around the world, were increasingly forced to rely heavily on loins as the primary raw material.

Since loins represent only about 60 percent of tuna weight, and are more easily shipped in containers, processing costs are substantially reduced when loins are transshipped as opposed to whole fish.

Concurrent with the outsourcing of tuna processing, the structure of the tuna canning industry itself has become more global in nature. Mergers and acquisitions have taken place, and some of the larger food conglomerates (i.e., Heinz, Nestle, etc.) have sold their units to financial holding companies such as Lehman Brothers and Emerging Capital Partners (Miyake et. al., 2010).

Increased globalization has resulted in the greater fragmentation of albacore production. Fragmentation increases the complexity and adds to costs in transportation and marketing, which are often borne by the fisherman. It is perhaps the increased fixed costs in this industry that justify the mergers, acquisitions, and consolidation among the larger tuna processing firms. Consolidation allows these firms to take advantage of economies of scale, thus reducing average costs and allowing the transfer in cost savings to the consumer in the form of lower prices.

Global Tuna Consumer Market

Consumer demand for canned tuna has been estimated to be relatively inelastic, particularly compared to the demand for sashimi and raw tuna. To gauge how sensitive consumers are to changes in the price of tuna, economists use demand elasticities. This estimate refers to the percentage

THE U.S. RETAIL CANNED TUNA MARKET HAS A RELATIVELY INELASTIC DEMAND, WHILE CONSUMER DEMAND FOR HIGH-VALUED TUNA AND TUNA FAMILY CONSUMPTION ARE MORE SENSITIVE AND ELASTIC TO PRICE CHANGES.

change in quantity demanded in response to a 1 percent change in market price. If this estimate is (smaller) greater than one, demand is said to be (in-) elastic.

Campbell (1995) finds the own-price elasticity for retail canned tuna in the U.S. to be between 0.20 and 0.16. This means a 1percent change in the price of tuna leads to a 0.20 percent reduction in retail canned tuna demand. Other studies estimate higher elasticities for high-valued tuna and tuna for family consumption, in the range of 0.72 to 1.67 (e.g. Reid Vakurepe and Campbell, 2003).

In addition, Bertignac et. al. (2001) estimates the elasticity of demand from the canning industry for catch of the purse seine and baitboat fleets in the Western and Central Pacific to be 1.55. This means that a 1percent increase in frozen tuna prices results in a 1.55 percent decrease in demand by the processing industry.

KEY FINDING #4: While biological factors are a significant determinant of U.S. commercial albacore fishing activity, market conditions and operating costs are also significant.

Irrespective of whether it has direct or indirect effects, biological factors and the natural environment clearly affect the albacore fishery and the activity of the U.S. commercial albacore fleet. At the margin, fishermen choose their target species, fishing season, and location based on which combination of the three produces the greatest profits, a balance between operating costs, fish price, and fish abundance.

To gauge the relative significance of market conditions versus biological factors in explaining variation in U.S. commercial fishing activity, we estimate a simple descriptive model (with results in Table 1):

$$Y_{pt} = \alpha M_t + \beta B_t + \pi_p + \varepsilon_{pt}$$

Y represents indicators or outcomes of the U.S. commercial albacore fleet, observed at *p*=port (54 ports) and time *t*=year (1981 to 2010). *M* represents prevailing economic conditions that affect the commercial albacore market at time *t*, while *B* indicates the abundance or stock status of albacore at time t.

Thus, α forms an estimate of the relationship between market conditions and an indicator of U.S. commercial fishing activity, while β is an estimate of the relationship between biological conditions and industry indicators.

We use two indicators of input costs to proxy for prevailing market conditions *M*. As the previous section and Figure 6 indicates, fuel prices have been rising over time. Given fuel costs comprise around 15 percent of vessel expenditures, changes over time in the price of fuel can have a major impact on the nature and extent of commercial fishing activity.

Similarly, changes over time in employment costs can contribute significantly in determining U.S. commercial albacore fishing activity. To measure changes in employment costs in a time-consistent manner, we use the Employment Cost Index for manufacturing calculated by the Bureau of Labor Statistics and used by the Federal Reserve.

To measure the biological factors, we use the stock biomass from Fisheries and Oceans Canada's 2004 report of the Nineteenth North Pacific Albacore Workshop.

Table 1. Contemporaneous and Logged Models

OLS Regressions					
	(1)	(2)	(3)	(4)	(5)
VARIABLES	ln(No of Vessels)	ln(Real Revenues)	ln(Revenues/Vessel)	ln(Landings Wt in MT)	ln(No of Processors)
INPUT COSTS					
ln(Employment Cost Index for Mfg)	-2.420***	-2.692***	-0.272	-2.751***	-0.445**
	[0.293]	[0.477]	[0.314]	[0.489]	[0.172]
ln(Fuel Price)	-0.195*	-0.205	-0.00957	-0.345**	-0.0811
	[0.102]	[0.166]	[0.109]	[0.170]	[0.0599]
ln(Biomass Index)	3.512***	4.224***	0.712*	5.061***	1.482***
	[0.346]	[0.564]	[0.371]	[0.578]	[0.203]
Constant	35.56***	48.11***	12.55***	47.15***	13.10***
	[3.814]	[6.211]	[4.089]	[6.368]	[2.242]
PORT FIXED EFFECTS	Yes	Yes	Yes	Yes	Yes
Observations	849	849	849	849	849
R-squared	0.651	0.717	0.665	0.726	0.616

Standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1

We also control for all other port-specific time-invariant factors by including port fixed effects (π). Port fixed effects account for time-invariant differences across ports, which may stem from historical differences in geographic and weather conditions, social and regulatory institutions, port infrastructure, and other factors.

Since biomass and economic factors are not measured on the same scale, we take the natural log of the dependent variables and regressors. By estimating log-log regressions, the parameters have the interpretation of quasi-elasticities, that is, a 1 percent change in the regressor is associated with the parameter estimate percent change in the dependent variable.

The estimates show that when operating costs in albacore fishing is low, the fleet is relatively more active. Significantly more vessels land (column (1)) and landings are significantly higher (column (4)) when employment and fuel costs are lower. That is, a 1percent increase in the Employment Cost Index is associated with a 2.42 percent decline in the size of the albacore fleet (column (1)) and 2.75 percent decline in metric-ton landings (column (4)). Similarly, a 1 percent increase in fuel price is significantly associated with a 0.35 percent decline in landings.

At the same time, a 1 percent increase in the Biomass Index and greater abundance of albacore is significantly associated with a 3.5 percent increase in fleet size (column (1)), 5.1 percent increase in landings (column (4)), and 1.5 percent more processors (column (5)).

It is noteworthy that while the Employment Cost and Biomass Indices are significantly related with overall revenues (column (2)), they are no longer statistically significant once fleet size is accounted for (column (3)). However, the parameter estimates are still economically (if not statistically) significant, in that input costs are negatively associated with per-vessel revenues while fish abundance is positively associated with per-vessel revenues.

The challenge to a more systematic analysis of the U.S. commercial albacore industry is that landings and target species are not random. A vessel in this fleet can fish for other species of tuna, salmon, or other target species. It is possible that when operating costs are greater and albacore prices are lower relative to other species, vessels of a certain size and productive capacity switch away from targeting albacore. Accounting for this choice in an econometrically robust framework will involve more micro-data across fisheries and over time periods.

The main takeaway from these regressions is that biological factors and fish abundance are not the only significant determinants of albacore fishing activity. Indicators of market conditions and operating costs are just as significant, suggesting that both economic and biological factors are important determinants of commercial albacore fishing activity.

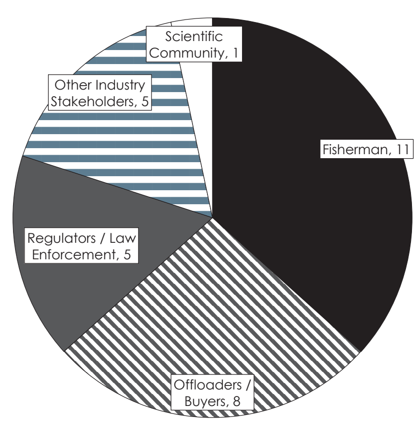
INTERVIEWS WITH INDUSTRY STAKEHOLDERS

THE FISHERMEN INTERVIEWED AVERAGED 36 YEARS IN THE COMMERCIAL FISHING INDUSTRY.

IN THIS SECTION, THE TERMS "ALBACORE" AND "TUNA" ARE OFTEN USED INTERCHANGEABLY AND REFLECT FISHERMEN'S OWN CHOICE OF TERMS.

Sampling was based on a selection of 30 individuals: 11 fishermen, eight offloaders and processors, three law enforcement officials, four industry representatives, a member of the scientific community, a harbor manager, and two regulators. All industry participants are from ports in California, Oregon and Washington. These included: San Diego, Morro Bay, Bodega Bay, Eureka, Coos Bay, Garibaldi, Astoria, Ilwaco and Westport. Five of the fishermen and two industry representatives are affiliated with the American Albacore Fishing Association (AAFA) while six fishermen and four industry representatives are members of the Western Fishboat Owners Association (WFOA). While findings are constrained by the size of the sample, they are important as indicators of trends as understood by fishermen and an emic perception of the fishery.

Figure 14. Interview Distribution



OVERVIEW: A SNAPSHOT OF FISHING OPERATIONS

The day-to-day operations of an albacore fisherman are made up of an ongoing series of decisions. Some decisions are facilitated by past experience, by a knowledge of market forces, and by an understanding of personal constraints, such as one's vessel size. However, many decisions are complicated by a set of unknown factors, including pending regulations, future migratory patterns of the species, and uncertainty of market forces. Overall, there are a number of variables with which a fisherman has to work to decide whether or not to enter the fishery and/or to remain in it and risks, as well as potential opportunities, are always associated with each decision.

Fishermen noted that the 2010 season showed both a northward and westward (offshore) movement of albacore.

The extent to which the albacore fishery is or remains a desirable fishery also has been dependant on associated costs and regulations. As one fisherman notes, the albacore fishery is a tenuous business at best, as the ex-vessel value (EVV) for albacore has stagnated while costs have risen. From interviews, EVV for albacore was said to be $1.00 per pound in 1980, rising only $.10 per pound by 2010. According to the fisherman, this translates to less experimentation (looking for fish) and more cooperation and sharing amongst the fleet.

The number of vessels in the fleet expands and contracts with the migratory patterns of albacore; in years when albacore move "inshore" (within 200 hundred miles of shore), smaller vessels that cannot travel long distances due to fuel capacity and safe travel, along with vessels that have not invested in either brine holds or blast freeze systems for storage, are able to enter this open-access fishery. Conversely, in years when the albacore remain offshore, participation is limited to larger vessels that can remain on the water for long periods of time. Fishermen report the stock moving offshore to inshore waters beginning in 2001 and ending in 2010. Their observations of the stock as moving offshore to inshore and back to offshore in a cyclical pattern allows them to adapt accordingly and decide whether an investment for an upcoming season is economically advantageous. One fisherman expands on this point:

> *"There is an influx in boats when other fisheries are closed. Many boats will enter the fishery*

> *whether they have refrigeration or not; they just become "ice boats", meaning that they cannot stay out for long periods of time and are constrained to more local waters. There have been entire decades, such as the 1990s, where the U.S. fleet caught less than 10percent of the fish inside of 200 miles. All through the 1990s, through to 2001, the U.S. fleet caught most of their catch offshore, off of 200 miles. I remember fishing on the International Date Line when 9/11 happened. Since 2002, fishermen have been catching fish inside of 200 miles. They have been inside since then. In 2010, I took only one trip offshore – 900 miles out. But that has been an exception rather than the norm in the past decade"* (Interview, 2011).

Nevertheless, this, coupled with the unknown variables of the foreign buyer's demand cycles, has made the fishery a high-risk business and has discouraged new entrants. One fisherman highlights the concern with the fleet's stagnation in growth, particularly with respect to the building of pole and bait boats: "There has not been a new bait boat built since the 1970s." He and others note that there have been only "a handful of jig boats" built, and this was predominantly in the mid 1990s out of the Gulf of Mexico Region. These troll boats were larger than the 30-to 80-ton vessels built in the 1970s, with some carrying 100 tons or more. However, troll vessel construction since this time has slowed and bait vessel construction has long been negligible.

Having the option to shift to an open access fishery for a year or two can make the difference between making car or rent payments or not.

At the same time, however, as a result of closures (e.g. salmon) and increasing pressure or years of a down cycle (e.g. crab) in other fisheries, there is increasing reliance on albacore as a "backup fishery", or option. For example, with the closure of waters south of the Klamath River Management Zone in 2008 and 2009, coupled with these same low crab production years, salmon/crab combination vessels became dependant on the albacore fishery to make essential payments necessary to maintain ongoing operation. One fisherman notes that, when queried, fishermen will likely note that they participate in the HMS fishery, as they can easily move to the open access model. Having the option to shift to an open access fishery for a year or two can make the difference between making car or rent payments or not. As such, despite it being identified as a high-risk fishery for some with unclear consequences, positive or negative, upon entrance, it is considered an important fishery for maintaining the general health of the U.S. West Coast fishing fleet in general.

"JIG" AND "TROLL" ARE USED INTERCHANGEABLY FOR TROLL FISHING OPERATIONS.

A number of considerations will be weighed before a fisherman decides how and to what extent to engage in the fishery. With heightened awareness of need to produce a sustainable fishery, the U.S. albacore fleet that accesses the North Pacific waters does so using troll or "jig" and pole and bait. Many fishermen will use both troll and pole methods, relying on troll in the earlier part of the season when the albacore do not "school" and are more spread out. They will then switch to pole and bait method in the latter part of the season when the fish are grouped more closely together and tend to go for bait. The pole and bait method of fishing is said to bring in far more fish than troll. According to one fisherman, "In October in good weather, a jig (boat) does about three ton a day versus a pole (boat) which is about 20 ton a day. A good season is about 250 ton" (Interview, 2011). While there are significant differences in catch size by method, pole method requires a larger crew. For example, one fisherman notes that his boat, being only 60 feet, is "stuck" with a limited crew of three plus himself and the cook. This is a small crew compared to other (pole and bait) boats. However, his labor costs are offset when he jigs. Pole and bait method is also dependent on access to bait, either through purchase or through catch. Some captains hold their own permit to catch bait. Though while seemingly cost effective, catching one's own bait potentially reduces the profit margin in terms of time taken out of fishing for albacore and the length of time anchovies can stay in a hold.

"We can go offshore and look around, but, with the high price of fuel, it's a big risk" (Interview, February 2011, San Diego).

Importantly, it is reported that both troll and pole and bait methods target younger, shallower swimming fish that contain less mercury and waste products than older, deeper swimming fish that can only be targeted using other catch methods, such as purse seine and longline. Although there are no restrictions for longline use, and presents a concern for U.S. fishermen who are attentive to quality control, troll and pole and bait remain the predominant methods.

The means by which a fisherman stores his/her product influences the operation and at once both drives and is driven by market factors. Three methods of storage are currently used by the U.S. West Coast fleet: ice, brine, and blast.

Ice storage is generally used by smaller vessels that have not invested in either brine holds or blast freezer systems. Ice storage allows a fisherman to easily enter into the fishery, but it also restricts his/her range of travel. Fish cannot be delivered more than five days after the catch, and the average time out to sea is three to four days. This translates into travel primarily in waters within 200 miles of shore. This method of storage is dependent on dockside ice availability. Ice fish is said to be growing trend in Washington ports, where domestic buyers prefer fresh fish either for direct consumption or canning.

Brine storage cools a fish more slowly than does a blast freeze system and permits a larger catch. The larger storage allows for greater flexibility when traveling offshore. Conversely, blast freeze systems bring the temperature of the fish down very quickly, but due to the mechanics of the system, is not able to accommodate large catches. The low temperatures of the system create the necessary requirements for sashimi-grade tuna. Facilities that can accommodate fish at below zero temperatures are crucial.

The U.S. West Coast albacore is a 4 month fishery...that makes marketing more difficult and puts fishermen at greater risk of poor weather and unpredictable fish stocks (Interview, April 2011, San Diego).

With any one of these storage methods, a fisherman can choose to bleed or not bleed the fish, thus producing nine different modes of delivery to the market. Where unbled brine typically is said to cater to the "Big Three" canneries and their markets, whereas bled iced caters to the niche domestic fresh markets. Bleeding a fish requires added time and additional labor, and as such is more conducive to troll fishing rather than pole; but is essential for certain markets. Bleeding is said to produce a "whiter" product with a different taste from unbled fish. Markets cater to both bled and unbled albacore. In most cases, it is the loin of the albacore that is sought.

SUMMARY OF THE INTERVIEWS:

An examination of key trends in the fishery, as in all fisheries, reveals that the albacore fishery is highly dynamic, and can only be analyzed in a broader context. Landings data highlight major trends that have occurred across past decades, while interviews with fishermen emphasize major trends that are presently occurring and shed light on the near future of the fishery.

For example, landings data reveal that one trend has been an increasing share of vessels are concentrating their effort in the northern ports of Oregon and Washington rather than California. A number of reasons as specified by fishermen are attributed to this shift. First, increasing regulations and offloading costs associated with California waters pushed fishermen to offload in Oregon and Washington. Fishermen out of Oregon ports report avoiding landing in California ports "at all costs", as licensing and offloading fees are exorbitant and cut into already limited profits.

Second, the 1990s further signaled a change in U.S. / Mexico relations, such that fishermen experienced increasing regulatory challenges to fishing in Mexican waters. Although the tuna fishery in Mexican waters was concentrated on skipjack and blue fin, albacore was also fished during occurring migratory patterns. Fishermen report "not wanting to risk" large fines associated with fishing, or even looking for fish, near the international border.

Third and perhaps most important, the albacore migratory pattern has reported to have shifted such that stock are primarily found in north of Eureka, California and south of the Canadian border. "We go where the fish show up, and they seem to have been showing up up north lately," summarizes one fisherman. This is not to say that stocks may not appear elsewhere; but, given the rising price of fuel, there is little, if no, economic room for "exploring" or trying new fishing grounds where fish may or may not be.

All above-mentioned factors have combined to create conditions conducive to offloading and micro-processing in northern ports, notably those in northern Oregon and Washington. A number of small-scale offloaders and canners have come into business in the past decade or so as a result of increased effort in northern waters. Fishermen may establish long term social ties, sometimes based on shared values, with these offloaders and canners, and this can influence where one chooses to offload.

Conversely, where a fisherman will land in the northern ports is largely determined by buyers and canner available in the ports. It is also determined by the availability of ice and bait. Westport for example, is reported to be a principle bait port where a fisherman can either catch or purchase bait. When offloading jig fish, a fisherman may offload wherever it is convenient, including Newport, Garibaldi, Columbia River, or Westport. When he is offloading in between bait trips, he will strive for bait ports, for example Westport; but if there is a long offloading line there, he may run down to Astoria and offload/retrieve bait here.

While many variables contribute to the complexity of the fishery, two key trends are understood as most significant to fishermen: the changing movement of stocks offshore and the rising costs of operations.

The movement of the stock offshore is reported to be an upcoming trend observed by many fishermen. In years from 2001 up to 2010, fishermen report stocks having moved closer inshore. This pattern has contributed to the large number of small vessels entering the fishery and a rise in the ice, or fresh domestic market. Many fishermen observed that, as of the 2010 season, this pattern appears to be shifting, such that stocks are moving offshore.

ROUGHLY 20 PERCENT OF ONE BLOCK OF TUNA, REPRESENTING HALF OF THE TUNA CAUGHT ON THE WEST COAST, IS SOLD DOMESTICALLY.

A second major trend is the rising cost of fuel. A fisherman notes, "We may need to travel 1,800 miles to reach a school, but the price of fuel can constrain how far you go" (Interview, 2011). Fuel is also used for generators to keep bait alive and also for storage systems. One fisherman reports, "Where in the past fuel might have run as much as 15 percent of overall costs, last year (2010) it was more like 20 percent of overall cost and this year (2011) look like it will be the same." While fuel is further discussed below and elsewhere in this report, it is essential to note that the intersection of rising fuel costs and movement of stock offshore could indicate an upcoming attrition in the albacore fleet. The extent to which such attrition would remain constant is dependant on many variables, including the continuation of everyday constraints and challenges discussed below.

AS WORLD POPULATION GROWS, SO TOO DOES THE DEMAND FOR PROTEIN. AND THIS IS A TREND THAT IS NOT FORESEEN TO DIMINISH.

From the perspective of processors, offloaders, and marketers, key trends include rising costs in operations such as labor and operation materials. At the same time, however, there is a concomitant upward trend in worldwide and, importantly, domestic demand of albacore. One stakeholder reports that seven years ago, Americans "barely" consumed tuna. Now, roughly 20 percent of one block of tuna, representing half of the tuna caught on the West Coast, is sold domestically. Another reports that the demand for fresh (ice stored) fish in the Pacific Northwest has risen in the past five years from 5 percent to 25 percent of his total catch. This is attributed, in part, to the improvement in labeling, including MSC certification standards. It is also attributed to the basic fact that, as world population grows, so too does the demand for protein. And this is a trend that is not foreseen to diminish.

Constraints in the Fishery

From the depiction above, three predominant constraining factors that influence a fisherman's decision as to how much effort will be expended in the fishery are fuel, labor, and market prices.

Nearly all fishermen interviewed mentioned fuel as at least a "challenge," emphasizing the rise in cost over the past five to ten years. One fisherman comments:

> *"In 1996, diesel was $.70 dockside. In 2007, it was $4.68 dockside. Fishermen from about 2001 to 2010 fished inshore. In 2007, they fished within 60 miles of port. Last year, I spent $40,000 on fuel alone, which is a huge amount. I paid as much in fuel as for crew, about 1/3 of gross. The price of fish has to offset price of fuel by A LOT. If we're going to fish out there, we have to get set up with freighter; we have to be able to offload offshore. Otherwise, we can't do it" (Interview, 2011).*

Fuel prices are said to vary between ports and, moreover, between states. Another notes, "Diesel is expensive in CA, about $.50 higher at the dockside. Just a trip up the coast from Astoria runs about 1500 gallons to arrive up north (to Westport)" (Interview, 2011).

WORKING ON A FISHING VESSEL IS LABOR-INTENSIVE, UNCOMFORTABLE, AND REQUIRES BEING AWAY FROM FAMILY FOR LONG PERIODS AT A TIME.

Labor presents another constraint. Labor in the U.S., and particularly for a fisherman, is difficult to find and to hold. Working on a fishing vessel is labor-intensive, uncomfortable, and requires being away from family for long periods at a time. One fisherman reports labor as the second largest challenge to his operation, providing the following insight:

> *"Getting American crew is difficult. We have to bring crew in from other countries, but getting them on the boats is the challenge in terms of*

> *the proper paperwork and working with U.S. customs. This has become more difficult with the changing immigration laws. By the time a fisherman has picked up his crew through immigration, he has lost a week of work. A captain might get a good American guy every so often. This is always a problem. Being out to sea is uncomfortable and people don't like it" (Interview, 2011).*

Moreover, crew workers are typically paid not by the hour, but rather by the catch share, which can be upwards of 30 percent of the total catch value. As such, fuel and labor together comprise a significant constraint on effort. As a snapshot of costs of operations, one fisherman using the pole and bait method and brine storage reports that, of a 2010 gross revenue of $73,611, $12,616 was spent on fuel and other expense and $18,402 on crew alone. Roughly $31,000, or more than half of net revenue, was devoted to operation costs.

Other economic constraints and determinants of operation include cost of licenses, cost of bait, cost of insurance, and mooring fees. Non-economic constraints pertain to: weather; safety and; the long time fishermen must stay out to sea and away from home and family life, along with other hardships associated with spending long periods exposed to the elements. These factors, coupled with relative imbalance between large expenses and low financial gains, are said to have caused a shift away from a year-long and bi-hemisphere tuna fishery to a seasonal and northern hemisphere-only fishery. Fishermen report that, in the past up to 50 vessels of the U.S. fleet would travel to the South Pacific to fish, fueling in Tahiti or Samoa and offloading in Samoa. Presently, six vessels are fishing these same waters today.

> *"Fishermen used to seine out of San Diego and San Pedro 20 to 30 years ago. This was the death knell for the southern run" (Interview, 2011).*

Economic constraints in the form of expenditures is only relative to the revenues gained from the fishery. As noted elsewhere in this report, the price offered for tuna is in part set by the "Big Three" overseas canneries and is influenced by the tuna fishery in other parts of the world, most notably Thailand, along with fishing methods. One fisherman summarizes this concern:

> *"Now, we're competing with boats from other countries and other fishing methods. We can't*

compete with long line. The fishery lasts about four months a year. As such, we have had to heavily promote our style of fishing – troll and poll" (Interview, 2011).

Market constraints for brine product include low prices set by canners overseas. As one stakeholder notes, "The departure of the canneries dealt a one-two punch." He points out that fishermen were getting $1,300 to $1,500 a ton before 2006, whereas now they are receiving $2,000 to $2,500 a ton. However, he adds, "This is not quite catching up with fuel prices" (Interview, 2011).

"Only a small percentage of my overall catch goes to... the boutique company. Rather, about 90 percent of the catch goes overseas. We need a domestic canner; then we would not have to send our fish out" (Interview, 2011).

With the AAFA and WFOA attaining MSC certification and efforts at educating American consumers, the reliance on the prices set by overseas canners is dissipating. It is now said that American fishermen set their own prices and have more say in the market. Because of the sustainable method of catch and of the younger fish targeted, American tuna fishermen are able to value-add to their pricing. Nevertheless, two challenges noted by fishermen face the marketing end. These are: lack of education among the general public in terms of purchasing a sustainable product and; political forces pushing the mercury front.

Most fundamentally, and one of the largest constraints seen among U.S. West Coast fishermen is the lack of any large domestic canning operations. Without a facility to sell directly to, fishermen must share a portion of their profit with the receivers who offload the product and ship it overseas. Some fishermen choose to sell to small canners or have even set up their own canning business. However, even for these canners, operation prices are rising such that they reveal the time is short at hand for raising their prices. Further, the domestic market is only capable of handling a small portion of the catch – up to 10 percent - while the majority of the catch - up to 90 percent - still must be sent overseas. As one fisherman highlights, "Only a small percentage of my overall catch goes to…. the boutique company. Rather, about 90 percent of the catch goes overseas. We need a domestic canner; then we would not have to send our fish out" (Interview, 2011).

Small canneries and processors are taking over the domestic market left by the large canneries, though again, rising costs – primarily in the form of insurance, permits, and materials - present a challenge. One stakeholder points to the lack of government assistance available to other food harvesters, such as farmers. "We can't get low interest loans. The government gives out $300 billion to farmers because it is a 'controlled resource'. Fishermen don't receive anything unless it's an emergency. It should be equitable" (Interview, 2011).

Lastly, the decline in port infrastructure conducive to working waterfronts forms another constraint on fishermen. Of particular note has been the decline in port infrastructure in California. One fisherman points to the number of concerns in this state:

> *"There has been a consolidation in the fish buying companies. For example, Pac Choice has consolidated. This is the last infrastructure for buying and selling. Ice facilities seem to be in decline, too, which will eventually affect the smaller ice boats. There are not many buyers in CA, but this has not effected the fishery very much recently, as most of the fish have been in OR and WA. In California, too, the haulouts to serve boats are not good. They seem to have left with the salmon closures. California is said to have lost a third of its footing financially."* (Interview, 2010)

Concerns and Challenges

Concerns facing the fishery and pointing to uncertainties in its direction include the determination of future regulations; Illegal, Unregulated and Unreported Fishing; the Canadian Treaty; and lack of regulations on gear.

ALL STAKEHOLDERS BELIEVE MANY VARIABLES NEED TO BE ASSESSED TO ACCOUNT FOR THE CHANGING, DYNAMIC NATURE OF THE FISHERY IF ANY REGULATION SHOULD BE IMPOSED.

Being an open-access fishery and in light of stock assessments, the albacore fishery is poised for potential regulations. Stakeholders recognize that any regulation could have significant consequences for the future of the fishery. While some believe the fishery to be a "dumping ground for other fisheries" (Interview, 2011), others see the fleet's contraction and expansion to be cyclical and linked to migratory patterns. Nevertheless, all stakeholders believe many variables need to be assessed to account for the changing, dynamic nature of the fishery if any regulation should be imposed. As one stakeholder notes, "If there is a reduction in catch, any regulation would have to consider the complicated nature of the fishery."

One major concern in the fishery as related to potential changes in open access is access to the fishery across generations. The future of the fishery is understood to be dependent on the entrance of younger generations. While a lag in albacore vessel construction may point to a lack of growth in the industry, the entrance of younger fishermen, either from other fisheries or across generations, counters this assumption. Regardless, who is able to ultimately hold a permit is considered a key question, if not the key question. There are significant concerns that regulations could set a trend towards the disenfranchisement of small family businesses and the consolidation of permits under a large corporation, or at worst require reductions so low as to make any level of participation in the fishery unfeasible.

Illegal, Unregulated and Unreported (IUU) fishing is an ongoing concern among fishermen. Several fishermen fishing in the 1980s noted that this was an era when highseas driftnet fishing had significant impact on the stock. While they report that, in general in recent years the situation has appeared to improve, they also note that there have been more netmarked fish this past year (2010). One fisherman feels as though one remedy to this situation is establishing MSC certification internationally: "The MSC certificate is the best defense, because the product is reported and tracked. There is an awareness of the issue within the U.S. and European markets. The Asian markets are not as concerned."

The Treaty with Canada was noted as another major challenge to fishermen, canners, and marketers. There is general consensus among some stakeholders - both AAFA and WFOA members - that the treaty gives Canadian fishermen an unfair advantage that has yet to be neutralized. One stakeholder reports that, while 98 percent of the Canadian fish are caught in U.S. waters, Canada is marketing it as Canadian fish, emphasizing its low mercury content. This is in stark contrast to the "confusion-generating" marketing of albacore in the U.S., which is marred by FDA concerns over mercury content and safe consumption by people of certain ages and pregnant women.

Moreover, fishermen, offloaders and canners note that Canadian landings have grown in tonnage through the sales of permits from smaller vessel fishermen to larger vessel fishermen. It is reported that they generally do not offload in U.S. ports, nor do they inject money into the U.S. economy by purchasing fuel, buying groceries, or utilizing any amenities that U.S. ports offer. "Where is the financial viability for U.S. fishing families, processing, and ports in this treaty?" asks one stakeholder (Interview, 2011).

THE MAJORITY OF FISHERMAN INTERVIEWED REPORTED THAT ANY IMPOSITION OF REGULATION ON THE U.S. ALBACORE FLEET WILL BE HIGHLY UNFAVORABLE AS LONG AS BOTH IUUs GO UNREGULATED AND A FOREIGN FLEET HAS AN ADVANTAGE IN U.S. WATERS.

Finally, fishermen report the Canadian fleet to be aggressive, moving into a fishing area and driving U.S. fishermen out. "The biggest problem is the treaty with Canada….The treaty was supposed to have benefits to U.S. ports, but there isn't any….There is an issue of common courtesy, but Canadians fish in close to other fishermen" (Interview, 2011).

Importantly, the majority of fishermen interviewed report that any imposition of regulation on the U.S. albacore fleet will be highly unfavorable as long as both IUUs go unregulated and a foreign fleet has an advantage in U.S. waters.

Opportunities

The constraints that determine a fisherman's effort, while increasing, are mitigated by the opportunities available, particularly those that have arisen within the past decade. With the efforts of AAFA, for example, and increased marketing efforts by WFOA, prices are said to have stabilized and opportunities for new markets opened. Fishermen speak of opportunities in markets based on each of the three methods of storage as well as in the loin market.

The blast-bled market for sashimi-grade tuna is strong in Japan, U.S., and Canada. Fishermen note that Canadian fishermen primarily target the sashimi market and that fishermen in the U.S. have not sought this market as strongly as they could. Again, however, the constraint with this opportunity is higher labor costs associated with bleeding each fish, a task extremely time consuming, and the limited storage space associated with blast freezing. Although the value of the fish is higher, sometimes more than double that of brine, the limited product is said to equal out to brine-stored fish.

Fishermen and canners alike point to the growing domestic market for fresh and fresh frozen tuna, particularly as value-added products. They point to the growing number of canneries in the Pacific Northwest and the upward trend for home canning. Constraints here, as noted above, include lack of education within general public of the quality of American tuna as compared to foreign tuna and pressure from the mercury front. However, the opportunity to form a marketing coalition in the near-future is seen as a powerful mechanism that will diminish confusion within the American market, increase education, promote positive marketing of domestic caught and processed tuna, and increase domestic consumption. A marketing coalition should have profound implications and facilitate the growth of the fishery as a value-added product.

Another stakeholder adds the following:

> *"Marketing is better. Seven years ago we started educating the public. There is little environmental impact in the way we fish. We started canning out our own tuna and it is sold nationwide. Going domestic is the answer. Then, it won't matter what kind of season we have" (Interview, 2011).*

A key trend in the industry, and one that points to the growing opportunities in the fishery, is the stabilization of price per pound offered to fishermen, much of which is attributed to marketing by both WFOA and AAFA. As one fisherman notes,

> *"In 2006, the price was way down. Albacore is traded on the world market and getting canneries to buy it is key. The price of fish helped to offset rising fuel costs. At one time, fishermen were getting about $1,000 a ton, or $.55 a pound. Now, the price they are getting is not under a $1.00 a pound. Recently, AAFA has negotiated a fixed price, at $1.13 from January 1 to November 1. This helps U.S. tremendously in adjusting our expenses. Before, when the price was all over the place, it was difficult for U.S. to calculate, predict, and manage our expenditures."*

Conclusion and Considerations:

Thirty Interviews were conducted for this report. Generally interviewees were pleased to participate in the process and generous with information. There is a perception that the needs of the fisherman and fishing communities plays a secondary role to biological data and pressure from international and domestic regulators. Most of the interviews revealed that the U.S. albacore fisherman operates within a framework of general uncertainty with respect to shifting markets, shifting stocks, and pending regulations.

Constraints including fuel, labor, and market prices, along with concerns over regulations, IUUs, and international competition, all shape the daily decisions a fisherman makes as to his engagement within the fishery. As the U.S. albacore fisherman employs more environmentally sensitive catch methods of troll and pole, he will continue to be constrained by rising operation costs. At the same time, there is no indication that fishermen are adjusting their mode of fishing to accommodate rising costs. Rather, they are looking to work with the opportunities available to them, including increased targeting of the domestic market, heightened marketing efforts, and increased pricing based on value-adding. The suggested upward trends of domestic consumption of American-caught tuna, of the presence of micro-canneries, and of the expansion of existing canneries act as anchors within the uncertainty.

The U.S. was once a world leader in tuna landings and processing. Due to prohibitions in Mexican waters, the dolphin bycatch movement, mercury scares, loss of the U.S. canneries, reliance on foreign markets, competition from foreign fleets with little or no regulatory oversight and lower operating costs, fishermen expressed the belief that the U.S. West Coast albacore fishery is already very effectively regulated. Rising costs in fuel and labor are another constraining factor. While U.S. albacore landings have remained constant, other nation's percentages have grown (particularly Japan). This is believed to be hard evidence that the fishery could be in jeopardy if effort or catch restrictions were imposed. The commercial albacore industry participants interviewed for this report acknowledge that biological factors are important in setting policy but should not be relied on solely, that market and economic factors should be included in policy decision making. It is hoped that through this work the dialogue between regulators and industry participants is improved and the significance of non biological influences is taken into greater account as regulators set domestic policy and comply with international treaties.

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Agenda Item D.1b
Supplemental LWC PowerPoint
June 2011

WEST COAST U.S. COMMERCIAL ALBACORE FISHERY

Economic Analysis

lisa wise consulting, inc.
planning economics natural resources

West Coast U.S. Commercial Albacore Fishery Economic Analysis

Project Description

NMFS Funded, Industry Guided

Objective

Biological, Economic Influences

Approach

Formal Economic Analysis, Community Engagement

KEY FINDINGS

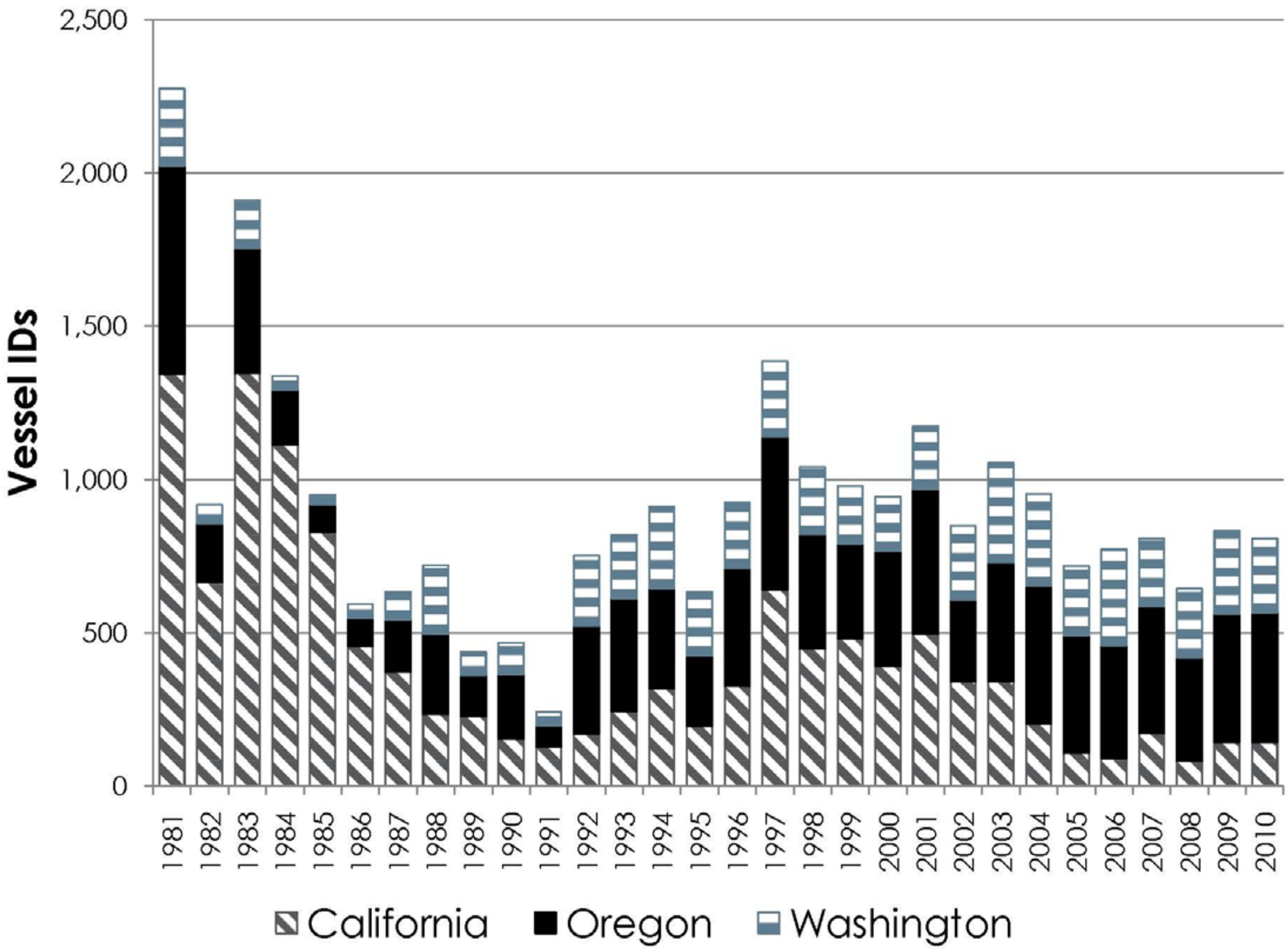
Key Finding 1:
Fleet Size, Landings, & Earnings

Key Finding 2:
Market & Regulations

Key Finding 3:
Impacts of Globalization

Key Finding 4:
Market Significance

Key Finding 1:
Fleet Size, Landings, & Earnings



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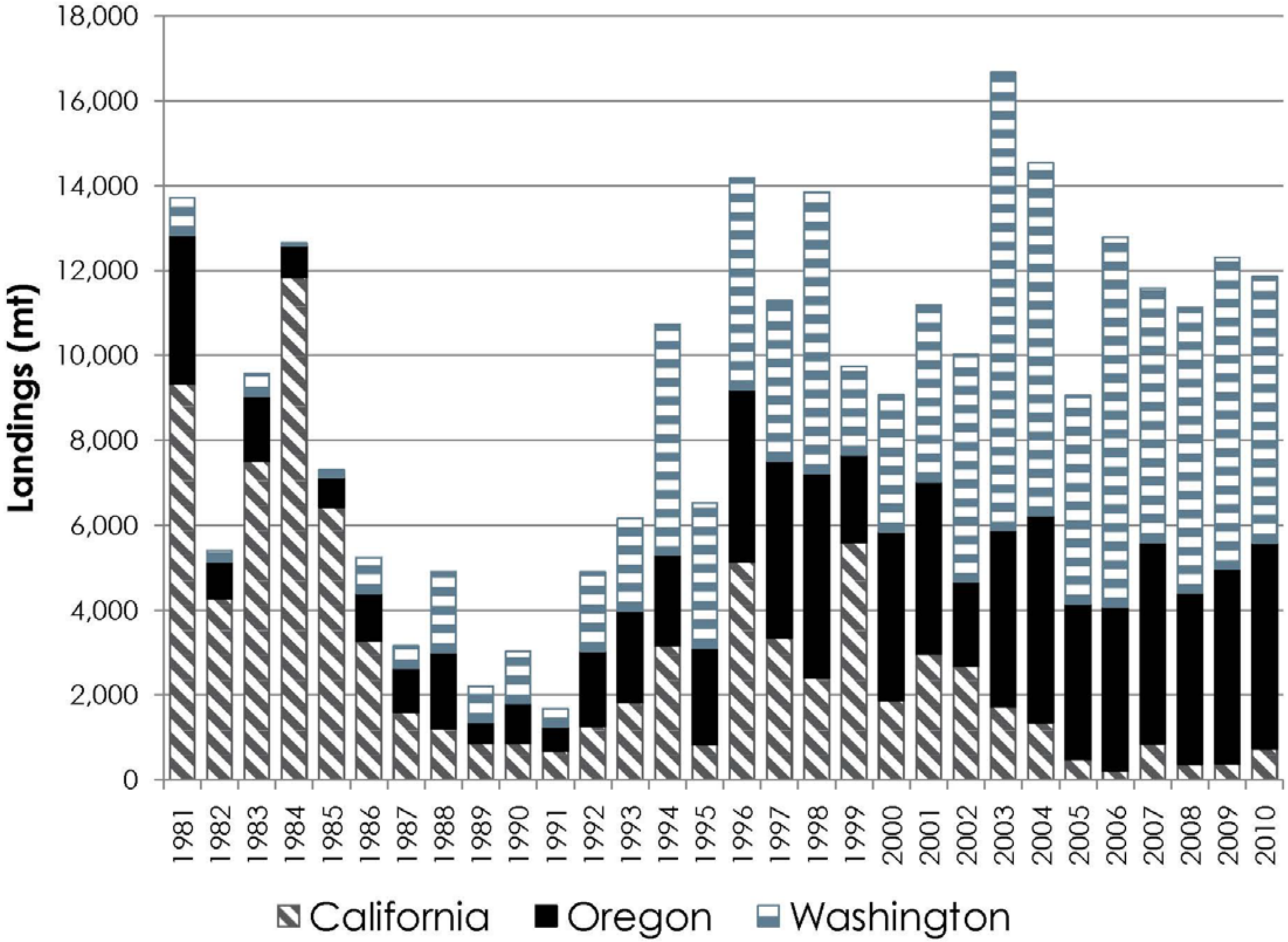
Fleet Size, Landings, & Earnings



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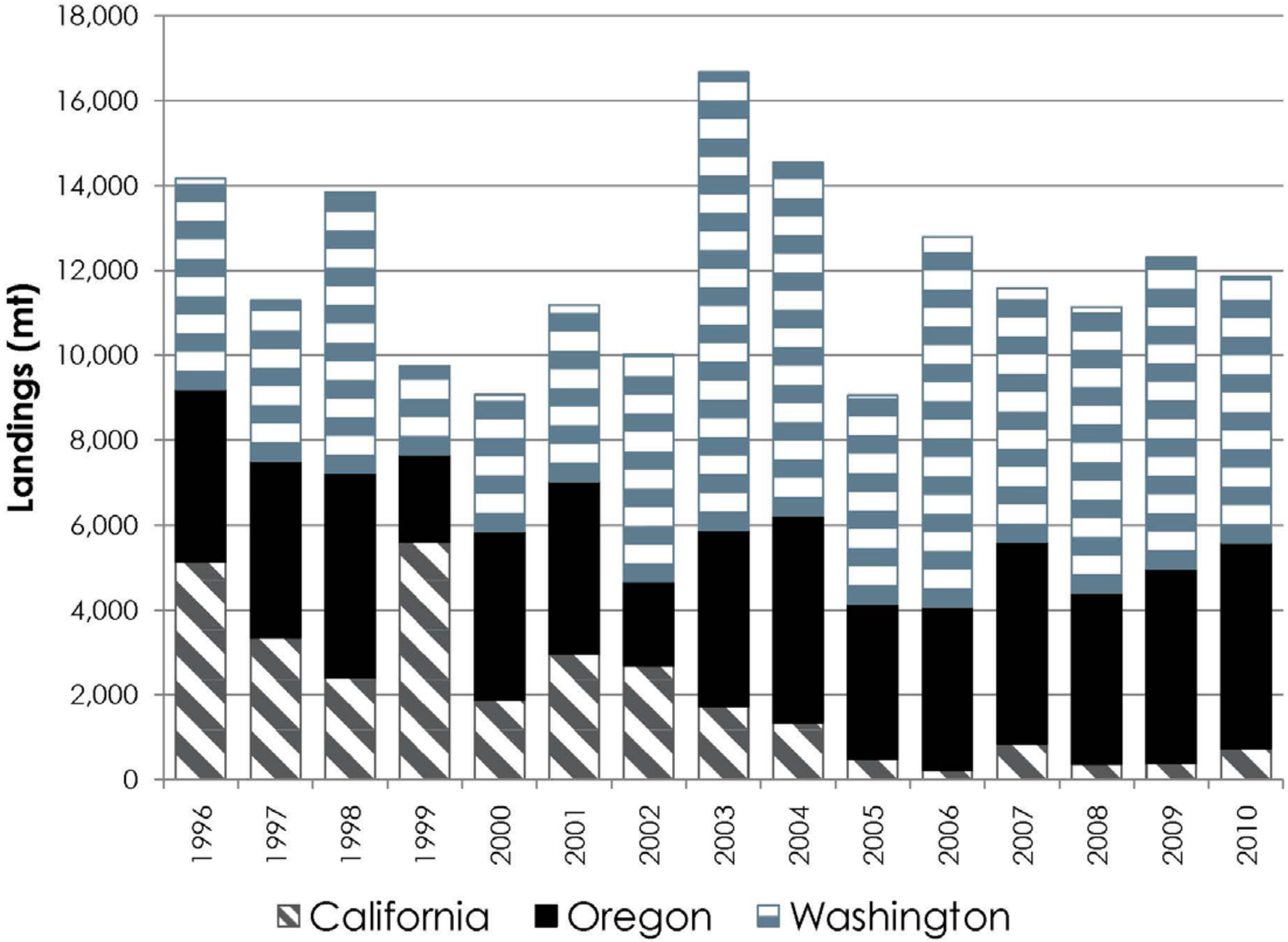

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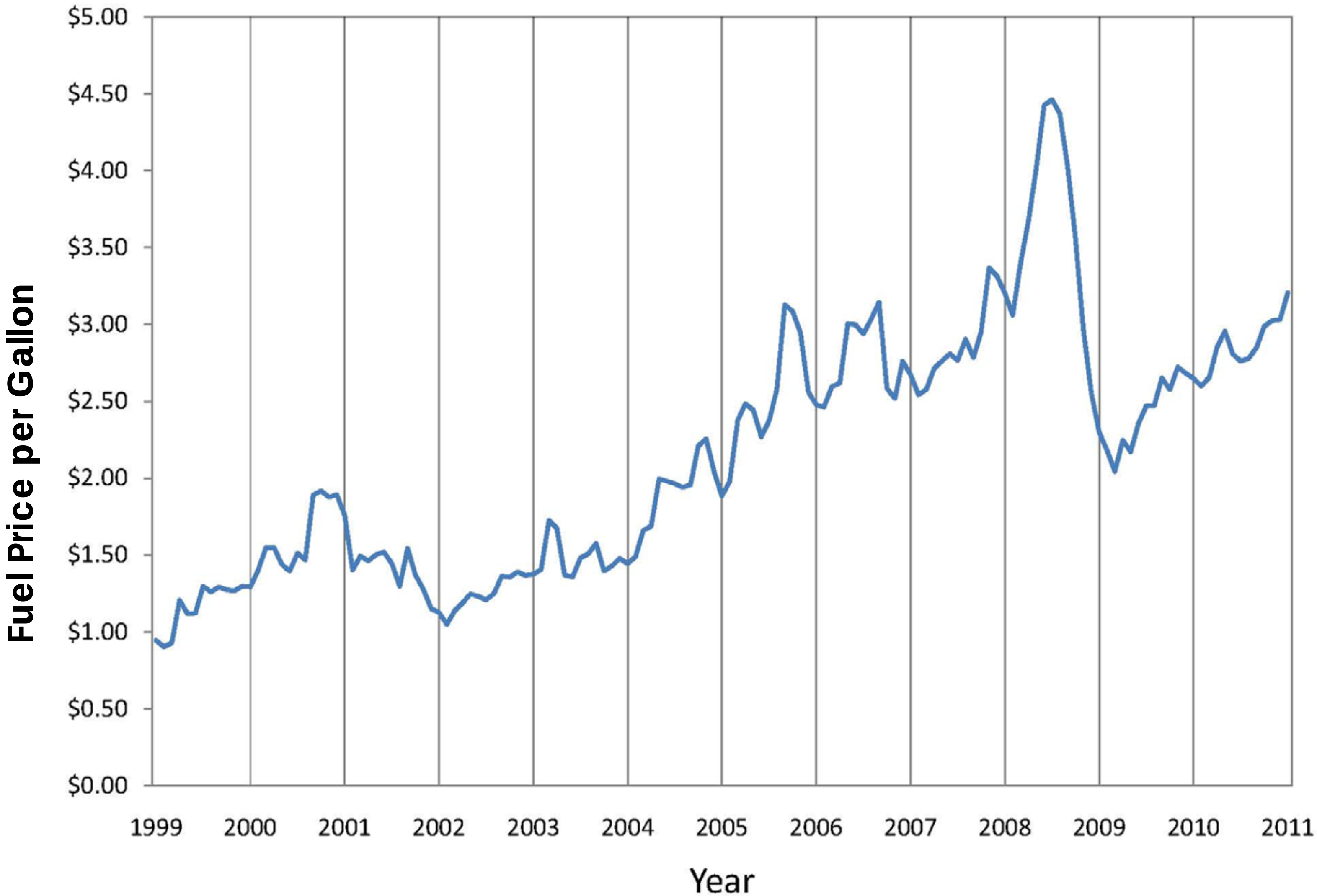

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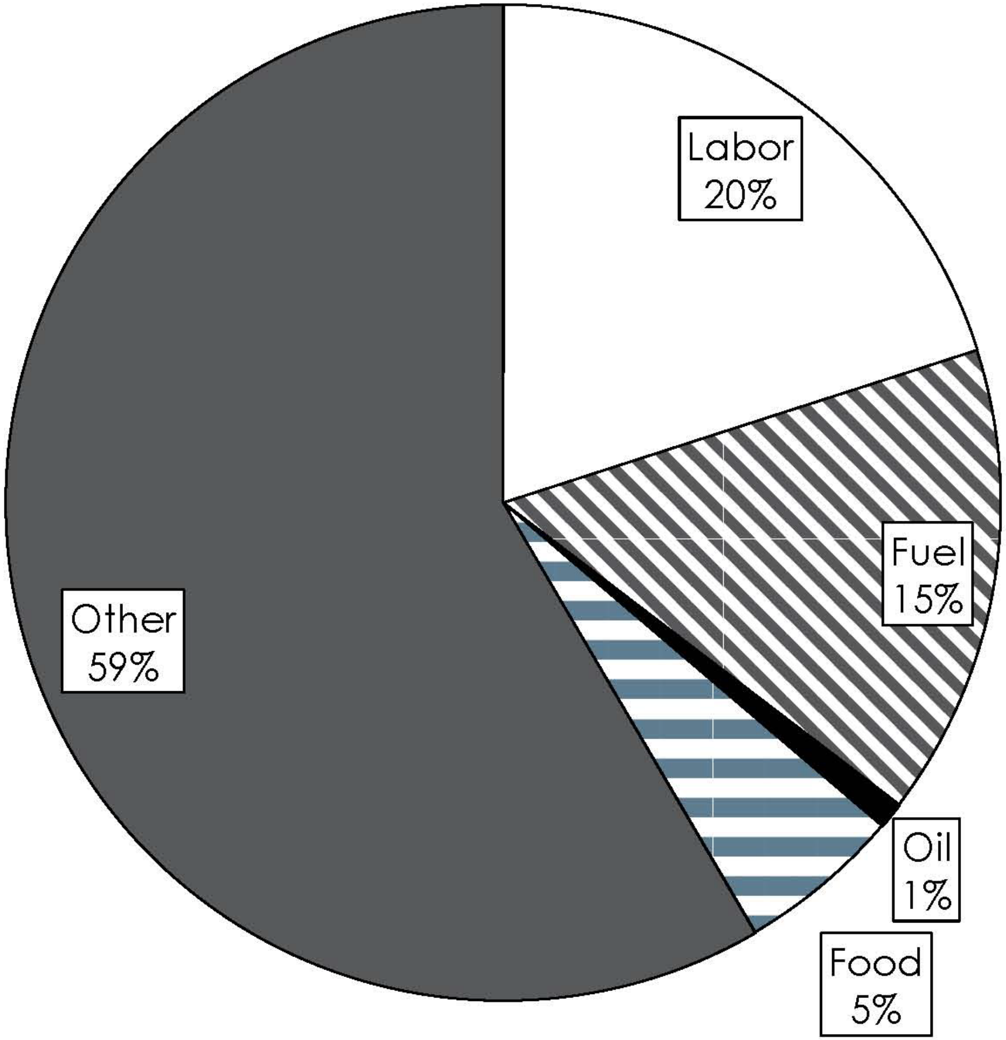
Market & Regulations



Source: American Fisheries Research Foundation

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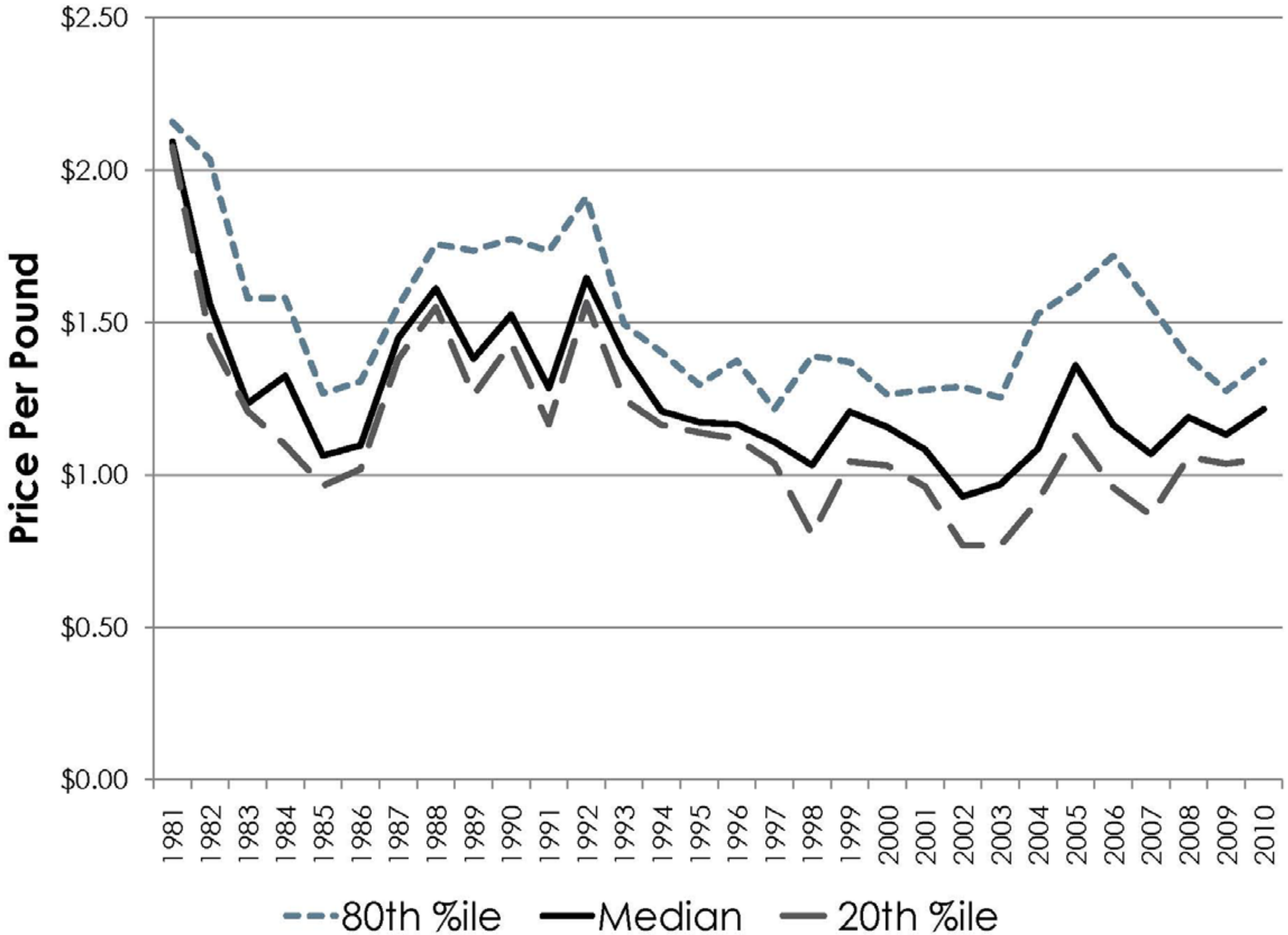
Market & Regulations



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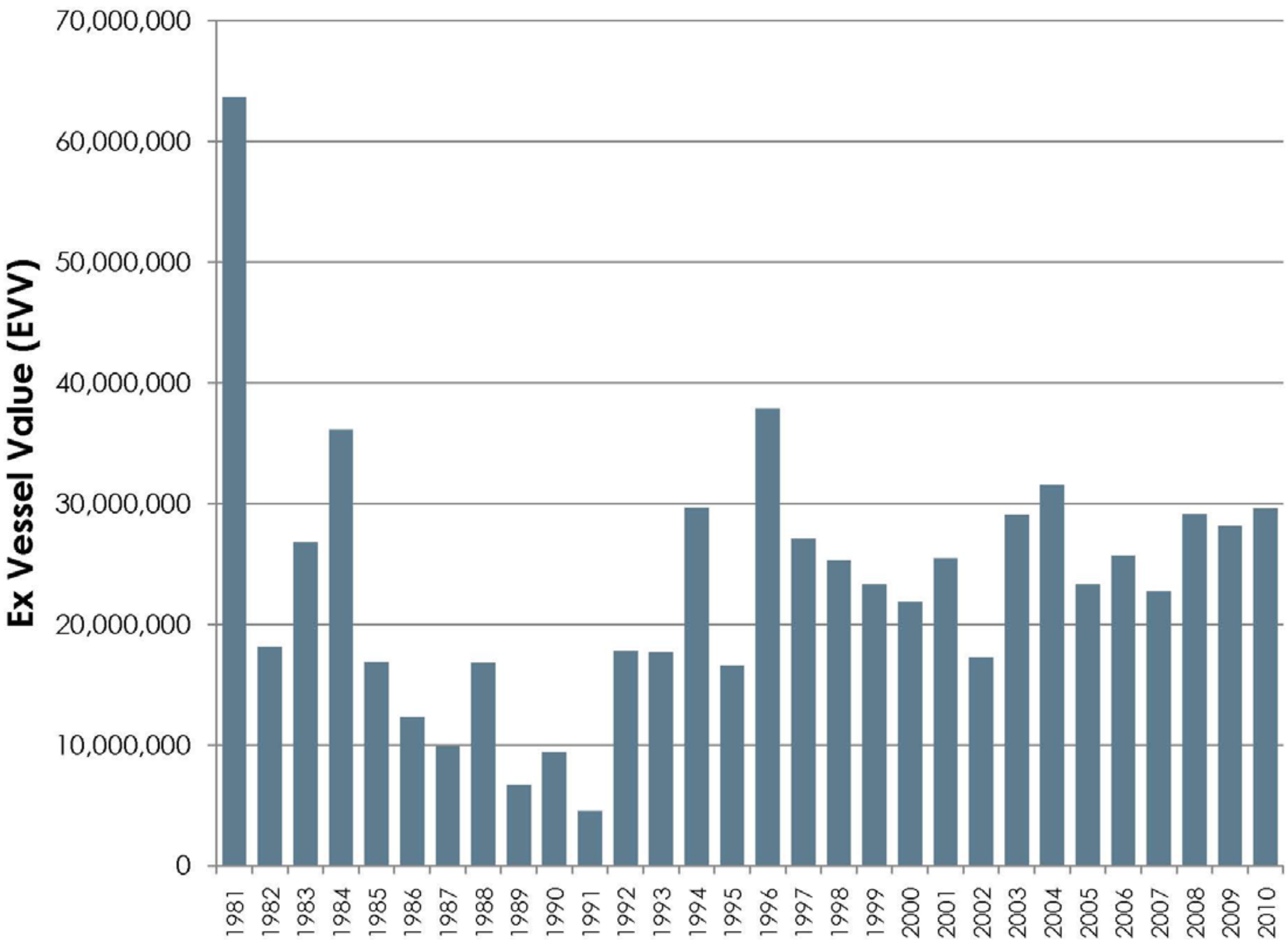

Source: PacFIN

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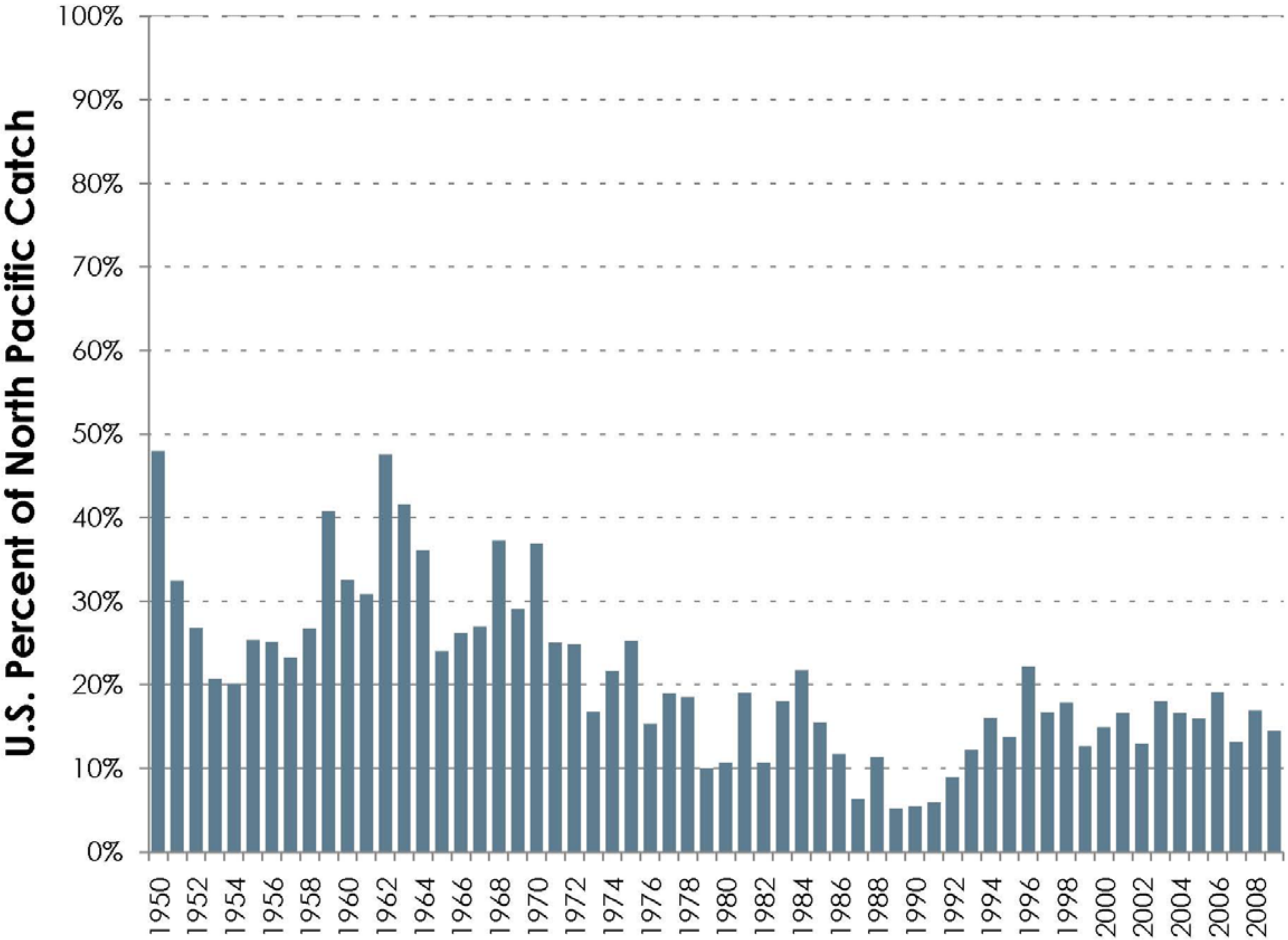
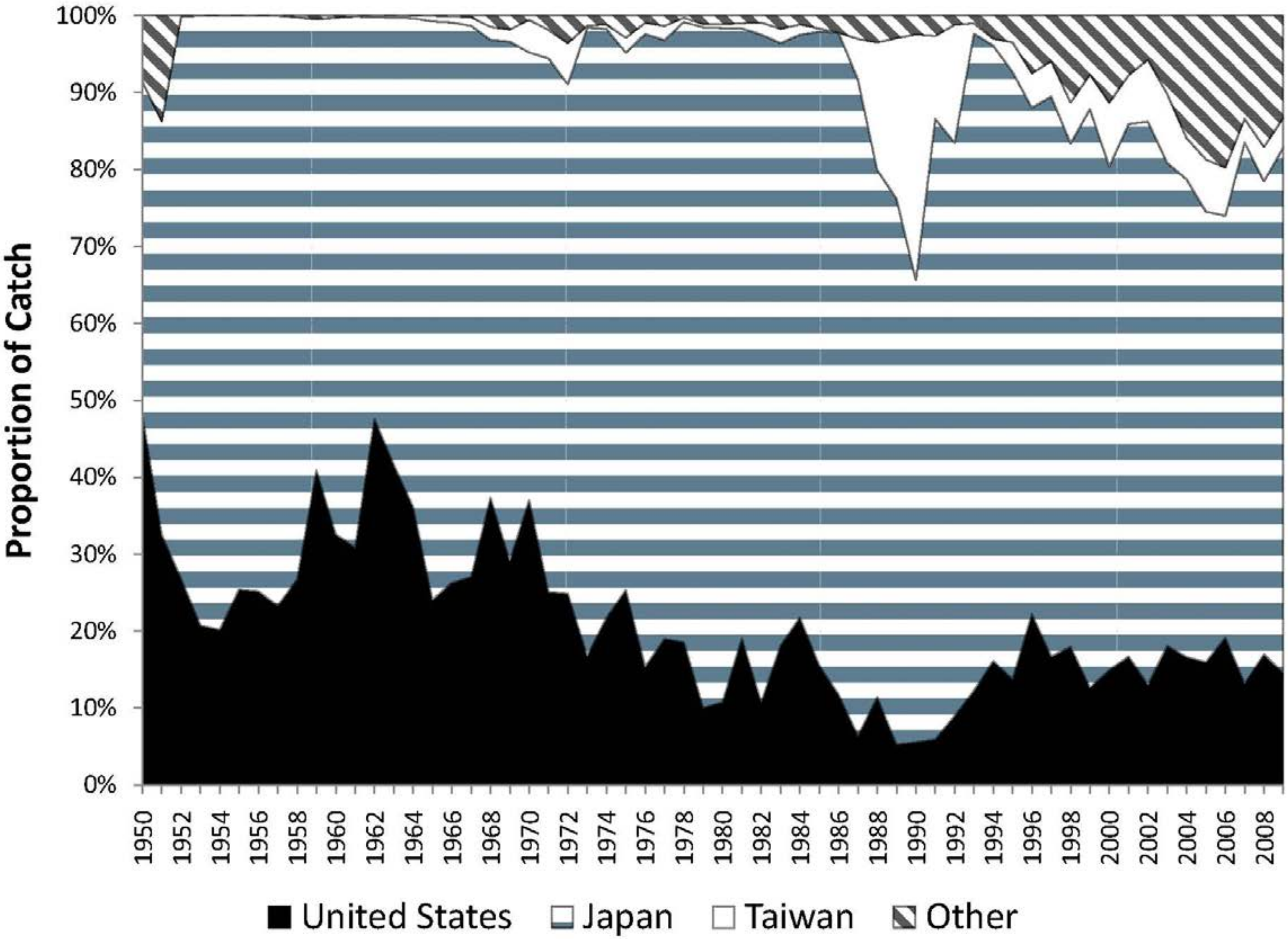


Source: WCPFC

Key Finding 3:
Impacts of Globalization



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KEY FINDINGS

Key Finding 1:
Fleet Size, Landings, & Earnings

Key Finding 2:
Market & Regulations

Key Finding 3:
Impacts of Globalization

Key Finding 4:
Market Significance

Key Finding 4:
Market Significance

- Formal Economic Analysis

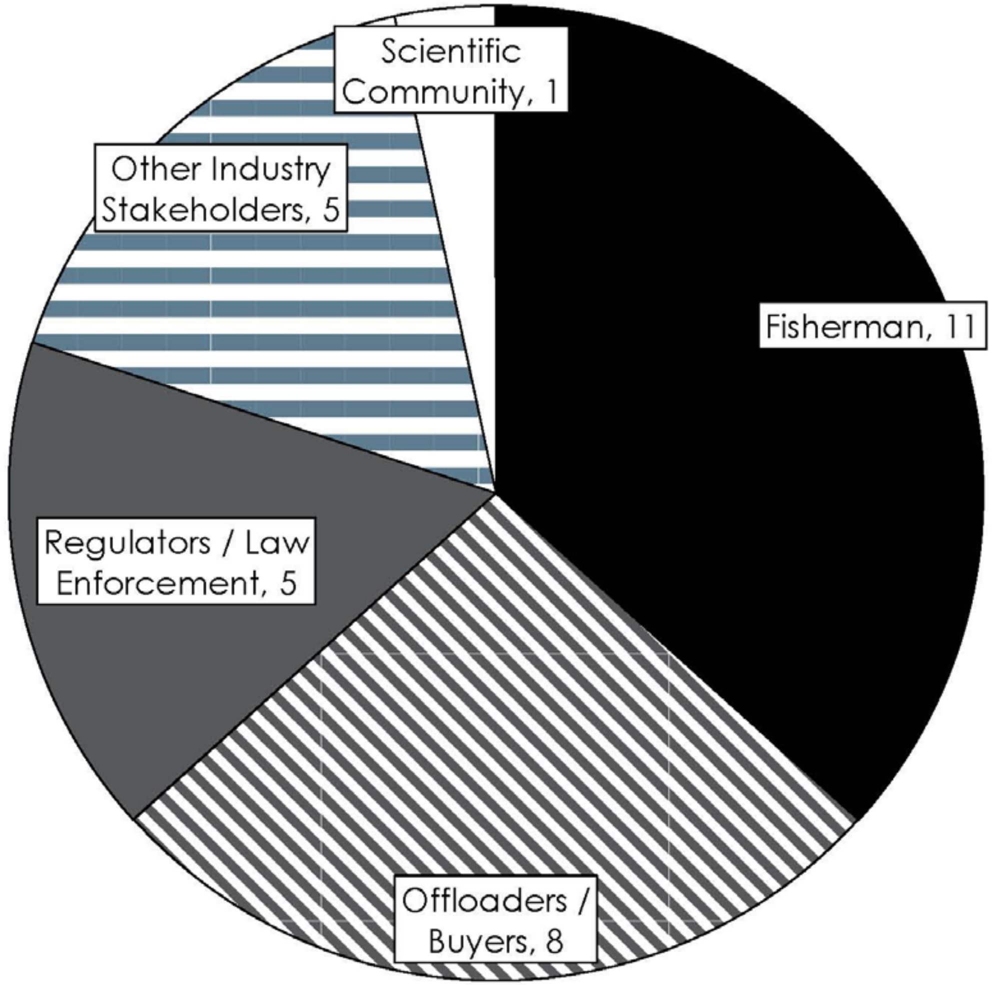
  Variable

  - Biomass
  - Employment Costs
  - Fuel Costs
  - Activity
    - Size of Fleet
    - Revenue, Revenue Per Vessel
    - Landings
    - Number of Processor/Buyers

Key Finding 4:
Market Significance

- Both biological and economic factors are important determinants of commercial albacore fishing activity

Community Engagement: Interview Support



Source: American Fisheries Research Foundation

West Coast U.S. Commercial Albacore Fishery Economic Analysis

The industry is already restricted by both biological and market/economic factors

- **Tenuous**
- **Uneven Playing Field**
- **Interconnected**
- **Capable**

Any restrictions in catch or effort are not warranted

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HIGHLY MIGRATORY SPECIES ADVISORY SUBPANEL REPORT ON NORTH PACIFIC ALABCORE TUNA FISHERIES ECONOMIC ANALYSIS

The Highly Migratory Species Advisory Subpanel (HMSAS) supports the Economic Analysis produced by Lisa Wise Consulting (LWC). The HMSAS recognizes that LWC had limited time and funding to do a complete, detailed, and thorough report. The HMSAS recognizes this analysis as a first step in defining a number of aspects of the fishery. The HMSAS encourages the Council to support further building on this analysis by supporting future funding and informational/technical support.

The HMSAS feels the final paragraph on Page 47 of the report encompasses the most important findings of this report and reads as follows:

"The U.S. was once a world leader in tuna landings and processing. Due to prohibitions in Mexican waters, the dolphin bycatch movement, mercury scares, loss of U.S. canneries, reliance on foreign markets, competition from foreign fleets with little or no regulatory oversight and lower operating costs, fishermen expressed the belief that the U.S. West Coast albacore fishery is already very effectively regulated. Rising costs in fuel and labor are another constraining factor. While U.S. albacore landings have remained constant, other nation's percentages have grown (particularly Japan). This is believed to be hard evidence that the fishery could be in jeopardy if effort or catch restrictions were imposed. . ."

The HMSAS concurs that the next segment of the final paragraph is most important in summing up the analysis:

". . . The commercial albacore industry participants interviewed for this report acknowledge that biological factors are important in setting policy but should not be relied on solely, that market and economic factors should be included in policy decision making. It is hoped that through this work the dialogue between regulators and industry participants is improved and the significance of non biological influences is taken into greater account as regulators set domestic policy and comply with international treaties."

PFMC
06/08/11

HIGHLY MIGRATORY SPECIES ADVISORY SUBPANEL REPORT ON
NORTH PACIFIC ALBACORE TUNA FISHERIES ECONOMIC ANALYSIS

The Highly Migratory Species Management Team (HMSMT) heard a presentation by Lisa Wise Consulting (LWC) of their economic report on the West Coast U.S. commercial albacore fishery at the April 2011 HMSMT meeting. The HMSMT accepted the opportunity to subsequently review the report, and HMSMT comments were incorporated into the final version of the report. The HMSMT acknowledges LWC efforts to provide insights to the recent operation of the West Coast U.S commercial albacore fishery.

At this meeting, the HMSMT discussed the content of the final LWC report. The HMSMT notes that West Coast commercial albacore fisheries use multiple gears and target multiple species; the report does not analyze these multiple-gear and multiple-species interactions in detail. The HMSMT recognizes that this was not intended to be a comprehensive economic analysis; a future analysis could provide greater detail on multiple-gear and multiple-species interactions.

PFMC
06/08/11

SCIENTIFIC AND STATISTICAL REPORT ON NORTH PACIFIC ALBACORE FISHERIES ECONOMIC ANALYSIS

Mr. Henry Pontarelli (Lisa Wise Consulting Inc.) briefed the Scientific and Statistical Committee (SSC) on the report "West Coast U.S. Commercial Albacore Fishery Economic Analysis" (Agenda Item D.1.b, Attachment 1). The report describes trends and economic conditions in the U.S. albacore fishery.

To demonstrate the relative effects of economic versus biological factors on the fishery, the report includes five regression equations that relate fishing activity (measured in number of boats, exvessel revenues, revenue per vessel, landings, and number of processors) to an employment cost index, fuel cost, and an albacore biomass index. The report was not written as a scientific paper so details needed by the SSC to adequately review this analysis were not provided. Some SSC concerns regarding the analysis are as follows:

- The regressions are estimated using time series data (1981-2010) for 54 ports. Thus, regression diagnostics such as tests for autocorrelation and heteroscedasticity should be conducted as part of model estimation.
- An employment cost index for manufacturing was used as a proxy for crew costs in the albacore fishery. It is not clear how closely the index resembles crew costs, particularly since crew remuneration is based on a share of landings.
- A 2004 Department of Fisheries and Oceans (DFO) Canada report was cited as the source of the biomass estimates. The DFO report includes biomass estimates for years up to 2002. Since the data in the regression cover the period 1981-2010, it is not clear what biomass estimates were used in the regression for the post-2002 years. Also, a more recent assessment was conducted in 2006, so the biomass estimates used are not the most current.
- Because U.S. trollers largely target juvenile albacore, the portion of the biomass relevant to their fishing activity is age 2-5 fish. It is not clear whether the biomass estimates used in the regression pertain only to those age classes.
- The regression assumes a fixed port effect. Given that albacore landings have markedly declined in California and markedly increased in Oregon and Washington over the past decade, a fixed port effect does not appear reasonable.

The Council requested that the SSC consider this report in terms of its utility for management. The report provides an overview of trends in the U.S. albacore troll fishery and economic conditions faced by the fishery. It is not obvious how the report could be used as a scientific basis for management. The SSC notes that the analysis focuses on the commercial fishery and that Council management may affect the recreational fishery as well.

PFMC
06/09/11

RECOMMENDATIONS TO INTERNATIONAL FISHERIES ORGANIZATIONS

There is an expectation that the Pacific Council will provide comments and recommendations to U.S. delegations attending upcoming meetings of regional fishery management organizations (RFMOs), according to the terms of the Memorandum of Understanding signed in 2010 (http://www.pcouncil.org/wp-content/uploads/G1b_ATT1_MOU_RFMCs_APRIL_2010_BB.pdf). RFMOs of particular relevance to the Pacific Council include the Inter-American Tropical Tuna Commission (IATTC), the Western and Central Pacific Fisheries Commission (WCPFC), and their subsidiary bodies. The IATTC will have held three meetings by the start of the June Pacific Council meeting and four RFMO meetings will take place between the June and September 2011 Council meetings. Attachment 1 lists RFMO meetings of interest for the balance of 2011, and meeting agenda links if available. Attachment 2 summarizes the results of meetings held between the April and June Pacific Council meetings. Attachment 3 contains available stock assessments reviewed by the IATTC Scientific Advisory Committee.

Under Magnuson-Stevens Act authority the National Marine Fisheries Service has declared three stocks in the Pacific Council's Fishery Management Plan for U.S. West Coast Fisheries for Highly Migratory Species subject to overfishing: bigeye tuna, yellowfin tuna, and Pacific bluefin tuna. In 2010 the IATTC adopted a "recommendation" on conservation measures for tropical tuna management for the period 2011-2013, although these measures are likely to be revisited at their upcoming meeting. (See Agenda Item J.3.a, Attachment 1, November 2010 for a summary of last year's IATTC meeting.)

The WCPFC adopted a conservation and management measure for Pacific bluefin tuna at their December 2010 meeting (replacing a measure adopted in 2009) applicable in 2011 and 2012. Attachment 4 is the text of this measure. In the Western Pacific the bulk of the catch is made by Japan, Korea, and Chinese Taipei; in the Eastern Pacific, Mexico accounts for most of the catch. Since Pacific bluefin is considered a single stock across the North Pacific, coordination between these nations (particularly Japan and Mexico) is important, and prompted scheduling a specific meeting on May 13, 2011, as noted in Attachment 1.

Although currently not declared subject to overfishing, the last International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean- (ISC) sponsored stock assessment for North Pacific albacore tuna, completed in 2005, raised concerns that current levels of fishing mortality could lead to a decline in stock biomass over the long term. The ISC's Albacore Working Group is scheduled to meet June 4-11 in Shimizu, Japan to prepare a new stock assessment, which will be reviewed at the ISC Plenary meeting as the basis for conservation recommendations. The first opportunity for any action on these recommendations is likely to be the WCPFC Northern Committee meeting in early September. Both the IATTC and WCPFC adopted parallel conservation measures for North Pacific albacore in 2005. Depending on the stock assessment results the Northern Committee could propose a replacement measure.

The timing of the availability of the stock assessment (Albacore Working Group), development of conservation recommendations (ISC Plenary), and proposed conservation measures (Northern

Committee) is not optimally conducive to the Pacific Council developing conservation and management recommendations, since it will not be known at the time of the June Council meeting and will have been already considered at the WCPFC Northern Committee (and possibly the IATTC annual meeting) before the September Pacific Council meeting convenes. Thus, the HMSAS and HMSMT have been tasked with preparing draft recommendations and supporting information based on hypothetical stock assessment results, so that contingent recommendations can be considered by the Pacific Council at the June Pacific Council meeting for possible presentation to U.S. delegations to the IATTC annual meeting and the WCPFC Northern Committee meeting. Hypothetical stock assessment results could range from a steep reduction in biomass to no reduction or even a slight increase. Recognizing that the only status determination criterion adopted by RFMOs for North Pacific albacore is the Northern Committee's interim reference point F_{AHTL}, alternate management recommendations could be developed consistent with the quadrants of a "Kobe" phase plot (i.e., stock above B_{MSY}, fishing mortality below F_{MSY}, stock above B_{MSY}, fishing mortality above F_{MSY} [overfishing], stock below B_{MSY} [approaching overfished], fishing mortality below F_{MSY}, etc.).

The preparation of hypothetical conservation measures, somewhat analogous to past and current RFMO conservation measures designed for various species and conditions, could help to develop potential management recommendations tied to alternative North Pacific albacore stock assessment outcomes. Such measures could include the measures in the current North Pacific albacore conservation measures (IATTC Resolution C-05-02, WCPFC CMM 2005-03), the IATTC's "correlito" closure principally intended to reduce incidental catch of bigeye tuna, and the range of measures in WCPFC Conservation and Management Measure 2008-01 for bigeye and yellowfin tuna (purse seine time and area closures, longline total allowable catch quotas, etc.). Attachment 5 details the tasking of HMS advisory bodies with preparing contributions for this agenda item.

Council Action:

Adopt Recommendations for U.S. Delegations to the 82nd Meeting of the Inter-American Tropical Tuna Commission and the 7th Regular Session of the Northern Committee.

Reference Materials:

1. Agenda Item D.2.a, Attachment 1: Pacific Regional Fishery Management Organization Meetings in 2011.
2. Agenda Item D.2.a, Attachment 2: Summary Report of Recent IATTC Committee Meetings and Upcoming Kobe III Meeting.
3. Agenda Item D.2.a, Attachment 3: 2010 IATTC Stock Assessments (Partially Extracts).
4. Agenda Item D.2.a, Attachment 4: WCPFC Conservation and Management Measure 2010-04 for Pacific Bluefin Tuna.
5. Agenda Item D.2.a, Attachment 5: Guidance from the Executive Director to the HMSAS and HMSMT.

<u>Agenda Order:</u>

a. Agenda Item Overview Kit Dahl
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. **Council Action**: Adopt Recommendations for U.S. Delegations to the 82nd Meeting of the Inter-American Tropical Tuna Commission and the 7th Regular Session of the Northern Committee

PFMC
05/24/11

PACIFIC REGIONAL FISHERY MANAGEMENT ORGANIZATION MEETINGS IN 2011

- Eleventh Meeting of the Permanent Working Group on Fleet Capacity of the Inter-American Tropical Tuna Commission (IATTC), April 26-28 in San Jose, Costa Rica
- Second Meeting of the Scientific Advisory Committee of the IATTC, held May 9-12 in La Jolla, California
- Joint Western and Central Pacific Fisheries Commission (WCPFC) Northern Committee / IATTC on Pacific bluefin tuna, May 13 in La Jolla, California
- Eighty-Second IATTC Annual Meeting, July 4-8 in La Jolla, California. (Provisional agenda available at http://www.iattc.org/Meetings2011/Jun/PDFfiles/IATTC-82-Provisional-agenda-July-2011.pdf)
- Third Joint Tuna RFMOs meeting (Kobe III), July 11-15 in La Jolla, California. (Draft agenda available at http://www.tuna-org.org/Documents/TRFMO3/K3_Agenda_DRAFT_Tri.pdf)
- Eleventh Plenary Meeting of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean, July 20-25, San Francisco, California[1]
- Seventh Regular Session of the WCPFC Scientific Committee, August 9-17 in Pohnpei, Federated States of Micronesia
- Seventh Regular Session of the WCPFC Northern Committee, September 6-9 (dates provisional), location to be determined
- Seventh Regular Session of the WCPFC Technical and Compliance Committee, September 28 - October 4 in Pohnpei, Federated States of Micronesia
- Eighth Regular Session of the WCPFC, December 5-9 in Koror, Palau

PFMC
05/19/11

[1] Several preparatory working group meetings will occur before the plenary. For information on these meetings see http://isc.ac.affrc.go.jp/meetings/future_meetings.html.

SUMMARY REPORT OF RECENT INTER-AMERICAN TROPICAL TUNA COMMISSION (IATTC) COMMITTEE MEETINGS AND UPCOMING KOBE III MEETING

Prepared by Heidi Hermsmeyer
Highly Migratory Species Management Team / National Marine Fisheries Service Southwest Region

Recommendations of the 11th Meeting of the IATTC Working Group on Capacity

The IATTC Permanent Working Group on Capacity met in San Jose, Costa Rica from April 26-28, 2011. The first day of the meeting was largely dedicated to reviewing the documents provided by the Secretariat that are available on the IATTC website (CAP-11-04: IATTC Capacity Plan; CAP-11-05: Target Fleet Capacity; CAP-11-06: Implementation of Resolution C-02-03; and CAP-11-07: Vessel Charters and Capacity Loans). Two presentations that were given in reference to these documents have also been posted on the IATTC website.

It was decided that the working group should focus on three main issues: 1) developing and agreeing to rules and procedures for implementation of Resolution C-02-03 to avoid potential capacity disputes in the future, 2) considering a broader and more holistic approach to capacity management within the IATTC; and 3) addressing the outstanding capacity issues of certain member countries. To initiate this process, the Heads of Delegation requested that the Secretariat prepare a draft rules and procedures document incorporating the points included in the CAP-11-06 background document for discussion on day three of the meeting (this document – CAP-11-06b – has now been posted on the IATTC website), and requested that each member requesting additional capacity or with a dispute over capacity provide the Secretariat with the exact amount of capacity being requested and a description of the basis for the request to facilitate discussions on day three.

On the final day of meetings, Peru made a heartfelt speech requesting that the working group focus on the outstanding capacity requests first, before moving on to a discussion of rules and procedures; thus, the focus of day three was development of a “road map” and timeline for the Commission to resolve the outstanding capacity issues. This discussion developed into a “Recommendations to the Commission” document that included, among other things, the following recommendations to the Commission: 1) categorize the types of outstanding capacity requests; 2) prioritize these categories; 3) establish an *ad hoc* group to resolve capacity disputes between member countries; 4) establish a 2012 deadline to resolve all such capacity requests; 5) develop and agree on rules and procedures for implementing Resolution C-02-03; 6) review the Capacity Management Plan and consider strategies to reduce total purse seine capacity; 7) review tradeoffs of different scenarios that could resolve capacity requests and disputes; and 8) review scenarios of shifting between gear types and consider capacity limits in the longline fishery. The complete set of recommendations and the spreadsheet summarizing all outstanding capacity requests or capacity claims with justifications for those requests are available on the

IATTC website: http://www.iattc.org/Meetings2011/Apr-PWGFC/PDFs/CAP-11-RecommendationsREV.pdf.

Outcomes of bluefin tuna meeting between Japan, Mexico, and the IATTC

Masa Miyahara, Chair of the WCPFC Northern Committee, requested that a Northern Committee-IATTC meeting on Pacific bluefin tuna be convened in order to discuss management measures. The following delegations attended the meeting: Japan, Mexico, and the United States. The main points of discussion were the 1) fishery for bluefin in the EPO and WCPO; 2) the ISC stock assessment results and advice; 3) the current conservation and management measure in the WCPFC and the recommendations of the IATTC scientific staff for bluefin measures in the IATTC; 4) the comparability of measures in the EPO and WCPO; and 5) recommendations to the IATTC. There was detailed discussion of the characteristics of the bluefin fisheries in the EPO and WCPO, the shortcomings of the WCPFC measure, and the need for further conservation of bluefin tuna. The group recommended that the IATTC consider and agree to management measures for bluefin at the 2011 Commission meeting.

2nd Meeting of the IATTC Scientific Advisory Committee (SAC)

The IATTC SAC met in La Jolla, California, from May 9-12, 2011. The IATTC scientific staff provided the SAC with stock assessment results for bigeye, yellowfin, and skipjack tunas, and swordfish stocks in the EPO, as well as stock status indicators for Pacific bluefin tuna. The IATTC SAC also discussed the SAC draft rules and procedures, the kobe strategy matrix, capacity scenarios that had been requested by the IATTC Working Group on Capacity, and various research studies being carried out by the IATTC scientific staff.

The 2011 IATTC stock assessments indicate that the yellowfin tuna stock in the EPO is in an overfished condition (spawning stock biomass is below the level corresponding to MSY) and the bigeye tuna stock in the EPO is subject to overfishing (the fishing mortality rate is above the level corresponding to MSY). Despite these changes in stock status, the Secretariat did not indicate that additional management measures were needed at this time beyond what was already in place (e.g., IATTC Recommendation C-10-01). The skipjack and swordfish stock assessment results indicate that both stocks are not conservation concerns at this time. Regarding Pacific bluefin, the IATTC developed a fishery-impact-based management reference level for Pacific bluefin tuna based on the stock assessment conducted by the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC). The indicator is meant to calculate the impact of fisheries on Pacific bluefin tuna. This analysis led the IATTC Secretariat to recommend to the Commission that total catch of bluefin tuna in the IATTC Convention Area should be limited to the average catch from 1994-2007, and the effort in the sportfishing fleet should be limited to the average effort from 2006-2010. The Secretariat provided an overview of their conservation recommendations from 2010 and what portions of the current IATTC recommendations are subject to review and recommendations of the SAC. The Secretariat also noted that they will most likely not be recommending measures for albacore this year because the ISC stock assessment was delayed and will not be completed by the July 2011 IATTC meeting.

The draft rules and procedures were also discussed by the SAC participants. The discussion was focused on clarifications that the SAC was requesting regarding the participation of non-governmental organizations in the SAC, the need for consensus in adopting recommendations of the SAC, and the requirement of having a quorum (two-thirds of the Commission members in attendance) in order to convene an official meeting of the SAC. These draft rule and procedures and recommendations of the SAC will be considered by the IATTC at this year's meeting in July 2011.

The IATTC scientific staff also provided an evaluation of the Kobe Strategy Matrix and its potential use in the IATTC. There was a general discussion about the obstacles and considerations that need to be addressed when developing and using the Kobe Strategy Matrix in the IATTC, including selecting the appropriate models to undertake projections, sampling from the uncertainty envelope of accepted models, assumptions regarding future recruitments, what level of catches or effort are used for the various fisheries, and reevaluation of the reference point definition with temporal changes in the fishing mortality-at-age matrix. The presentation is available on the IATTC website: http://www.iattc.org/Meetings2011/May-SAC-Shark/PDFfiles/Evaluation-of-Kobe-plot-and-matrix.pdf. There was general agreement that the Kobe Strategy Matrix is a useful tool, but further analysis is needed before it is utilized in the IATTC.

The Secretariat compiled a list of recommendations of the SAC that will be considered by the IATTC based on the discussions during the SAC meeting and posted it on the IATTC website: http://www.iattc.org/Meetings2011/May-SAC-Shark/PDFfiles/SAC-02-Recommendations.pdf.

Meeting of the five tuna regional fishery management organizations (Kobe III)

The third joint meeting of the five tuna RFMOs is being hosted by the United States in La Jolla from July 12 to 14, 2011. The Kobe III meeting will follow up on the four 2010 Kobe II workshops on science, monitoring, control, and surveillance (MCS), bycatch, and capacity. During Kobe III, participants will also discuss data confidentiality and data sharing, common issues in RFMO scientific bodies, unique vessel identifiers and harmonization of IUU vessel lists, capacity and allocation, RFMO decision-making principles, standardized report cards on data submission, port state measures, market measures including catch documentation schemes and trade tracking, and the future of the Kobe process. Kobe III will be preceded on July 11 by the first meeting of the Joint Technical Bycatch Working Group envisioned at the Kobe II Bycatch Workshop and a joint IATTC-WCPFC workshop to discuss issues in the overlapping convention area, both of which will report out during the regular Kobe III meeting. The International Seafood Sustainability Foundation (ISSF) is also sponsoring a workshop on July 11th on rights-based management.

INTER-AMERICAN TROPICAL TUNA COMMISSION

SCIENTIFIC ADVISORY COMMITTEE

2ND MEETING

La Jolla, California (USA)
9-12 May 2011

DOCUMENT SAC-02-07

STATUS OF BIGEYE TUNA IN THE EASTERN PACIFIC OCEAN IN 2010 AND OUTLOOK FOR THE FUTURE

Alexandre Aires-da-Silva and Mark N. Maunder

This report presents the most current stock assessment of bigeye tuna (*Thunnus obesus*) in the eastern Pacific Ocean (EPO). An integrated statistical age-structured stock assessment model (Stock Synthesis Version 3.20b) was used in the assessment. This model is the same as the base case model used in the previous assessment (IATTC Stock Assessment Report 11).

Bigeye tuna are distributed across the Pacific Ocean, but the bulk of the catch is made to the east and to the west. The purse-seine catches of bigeye are substantially lower close to the western boundary (150ºW) of the EPO; the longline catches are more continuous, but relatively low between 160ºW and 180º. Bigeye are not often caught by purse seiners in the EPO north of 10ºN, but a substantial portion of the longline catches of bigeye in the EPO is made north of that parallel. Bigeye tuna do not move long distances (95% of tagged bigeye showed net movements of less than 1000 nautical miles), and current information indicates minimal net movement between the EPO and the western and central Pacific Ocean. 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 local levels. The assessment is conducted as if there were a single stock in the EPO, and there is limited exchange of fish between the EPO and the western and central Pacific Ocean. Its results are consistent with results of other analyses of bigeye tuna on a Pacific-wide basis. In addition, analyses have shown that the results are insensitive to the spatial structure of the analysis. Currently, there are not enough tagging data to provide adequate estimates of movement 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), and age-at-length data 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 (see IATTC Stock Assessment Report 11). Catch and CPUE for the surface fisheries have been updated to include new data for 2010. New or updated longline catch data are available for French Polynesia (2009), Japan (2008-2010), the Republic of Korea (2009) and the United States (2008-2009). Longline catch data for 2010 are available for China, Chinese Taipei and Vanuatu from the monthly reporting statistics. New or updated CPUE data are available for the Japanese longline fleet (2008-2010). New purse-seine length-frequency data are available for 2010. New or updated length-frequency data are available for the Japanese longline fleet (2007-2009).

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 to a much lesser extent (Figures 1 and 2). The increase in the fishing mortality of the younger fish was caused by the expansion of the purse-seine fisheries that catch tuna in association with floating objects. It is clear that the longline fishery had the greatest impact on the stock prior to 1995, but with the decrease in longline effort 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 (Figure 3). The discarding of small bigeye has a small, but detectable, impact on the depletion of the stock.

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 (Figure 4). First, estimates of recruitment before 1993 are more uncertain, as the floating-object fisheries were not catching significant amounts of small bigeye. There was a period of above-average annual recruitment in 1994-1998, followed by a period of below-average recruitment in 1999-2000. The recruitments were above average from 2001 to 2006, and were particularly high in 2005 and 2006. The 2009 recruitment was below average, but the recruitment in 2010 appears to have been particularly high. However, this recent estimate is very uncertain and should be regarded with caution, due to the fact that recently-recruited bigeye are represented in only a few length-frequency samples.

Since the start of 2005, when the spawning biomass ratio (the ratio of the spawning biomass at that time to that of the unfished stock; SBR) was at its historic low level of 0.16, the bigeye stock has shown a recovery trend, to an SBR of 0.24 at the start of 2011 (Figure 5). According to the base case model, this most recent SBR is about 21% higher than the maximum sustainable yield (MSY) level (Table 1). This recent recovery trend is subsequent to the IATTC tuna conservation resolutions initiated in 2004.

Recent catches are estimated to have been 8% greater than those corresponding to the MSY levels (Table 1). 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 93% of the current (2008-2010) level of effort (Table 1).

According to the base case results, the two most recent estimates indicate that the bigeye stock in the EPO is probably not overfished ($S>S_{MSY}$), but that fishing mortality slightly exceeds the level corresponding to the MSY (overfishing is taking place, $F>F_{MSY}$) (Figure 6). This interpretation, however, is subject to uncertainty as indicated by the approximated confidence intervals around the most recent estimate in the Kobe plot (Figure 6). The addition of new data for 2010 and updated data for earlier years lowered the SBR compared to the previous assessment. Similar retrospective patterns also occurred in previous assessments when adding new and updated data. The changes are generally within the confidence intervals of the estimated quantities and well within the ranges estimated under different sensitivity analyses from the previous assessment.

The MSY of bigeye in the EPO could be maximized if the age-specific selectivity pattern were similar to that of the longline fisheries, because they catch 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 7).

Under the current levels of fishing mortality, recent spikes in recruitment are predicted not to sustain the increasing trend observed for SBR since 2004. Both the base case and the assessment assuming a stock-recruitment relationship indicate that the population is likely to drop below the level corresponding to MSY under average recruitment conditions (Figure 5). It is estimated that catches will be lower in the future at current levels of fishing effort if a stock-recruitment relationship is assumed, particularly for the surface fisheries (Figure 8).

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.

Key results

1. The results of this assessment indicate a recent recovery trend for bigeye tuna in the EPO (2005-2010), subsequent to IATTC tuna conservation resolutions initiated in 2004. However, under the current levels of fishing mortality, recent spikes in recruitment are predicted not to sustain this increasing trend.
2. There is uncertainty about recent and future recruitment and biomass levels;
3. The recent fishing mortality rates are estimated to be slightly above the level corresponding to MSY, and the recent levels of spawning biomass are estimated to be above that level. As described in IATTC Stock Assessment Report 11, these interpretations are uncertain and highly sensitive to the assumptions made about the steepness parameter of the stock-recruitment relationship, the average size of the older fish, the assumed levels of natural mortality for adult bigeye, and the historic period of the bigeye exploitation used in the assessment. The results are more pessimistic if a stock-recruitment relationship is assumed, if a higher value is assumed for the average size of the older fish, if lower rates of natural mortality are assumed for adult bigeye, and if only the late period of the fishery (1995-2009) is included in the assessment;
4. The results are more optimistic if a lower value is assumed for the average size of the older fish, and if higher levels of natural mortality are assumed for adult bigeye;

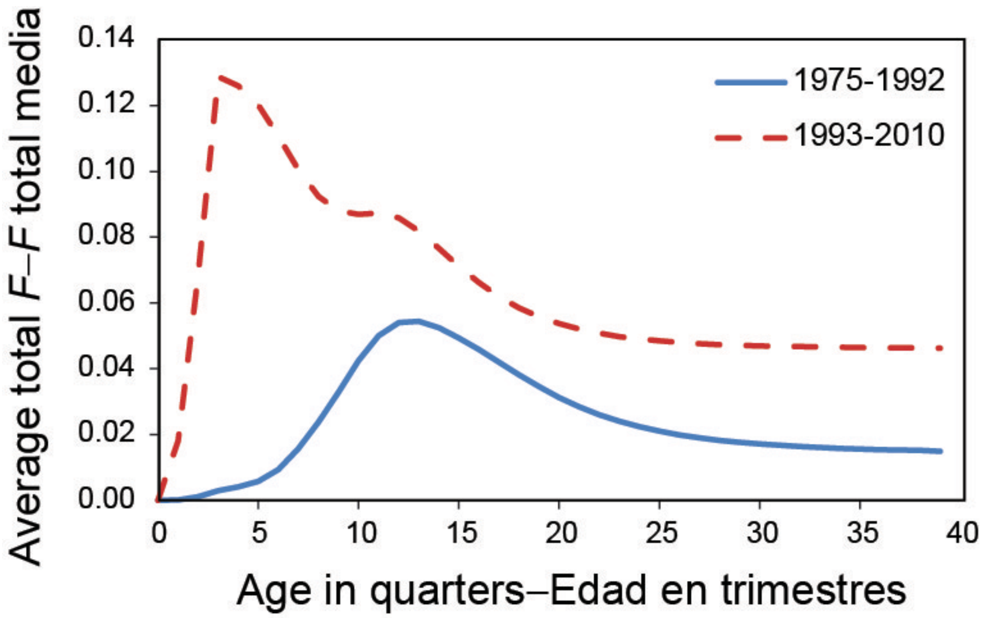

FIGURE 1. Average quarterly fishing mortality at age of bigeye tuna, by all gears, in the EPO. The curves for 1975-1992 and 1993-2010 display the averages for the periods before and after the expansion of the floating-object fisheries, respectively.

FIGURA 1. Mortalidad por pesca trimestral media por edad de atún patudo en el OPO, por todas las artes. Las curvas de 1975-1992 y 1993-2010 indican los promedios de los períodos antes y después de la expansión de las pesquerías sobre objetos flotantes, respectivamente.

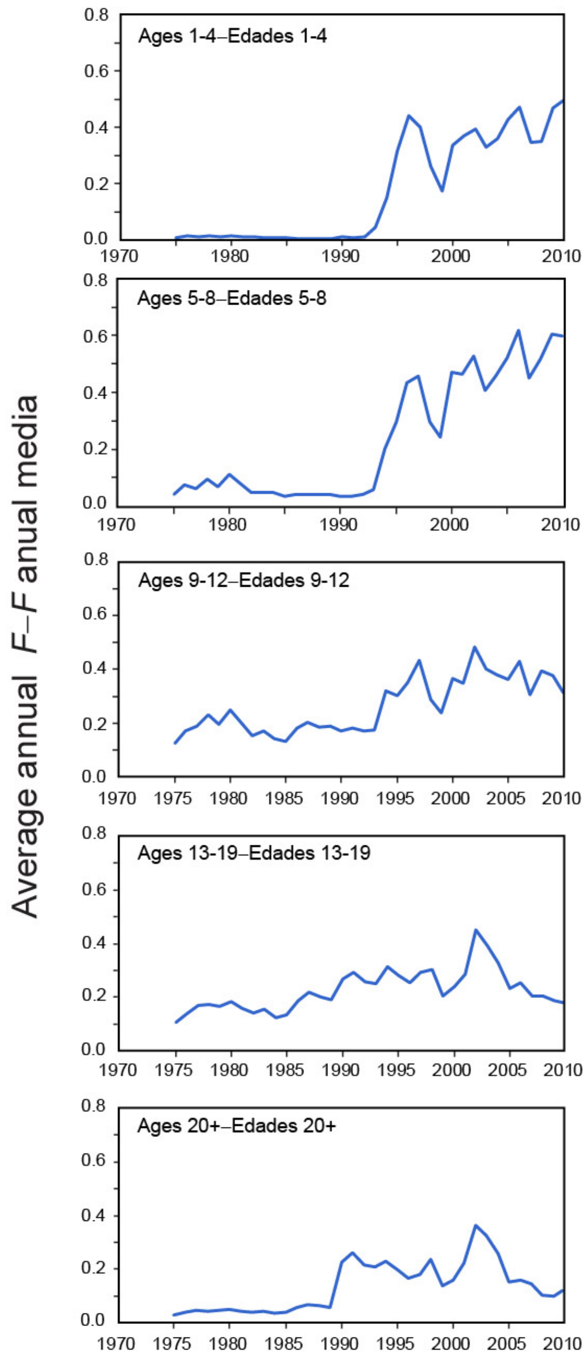

FIGURE 2. Average annual fishing mortality, by all gears, of bigeye tuna recruited to the fisheries of the EPO. Each panel illustrates the average fishing mortality rates that affected the fish within the range of ages indicated in the title of each panel. For example, the trend illustrated in the top panel is an average of the fishing mortalities that affected the fish that were 1-4 quarters old.

FIGURA 2. Mortalidad por pesca anual media, por todas las artes, de atún patudo reclutado a las pesquerías del OPO. Cada recuadro ilustra las tasas medias de mortalidad por pesca que afectaron a los peces de la edad indicada en el título de cada recuadro. Por ejemplo, la tendencia ilustrada en el recuadro de más arriba es un promedio de las mortalidades por pesca que afectaron a los peces de entre 1 y 4 trimestres de edad.

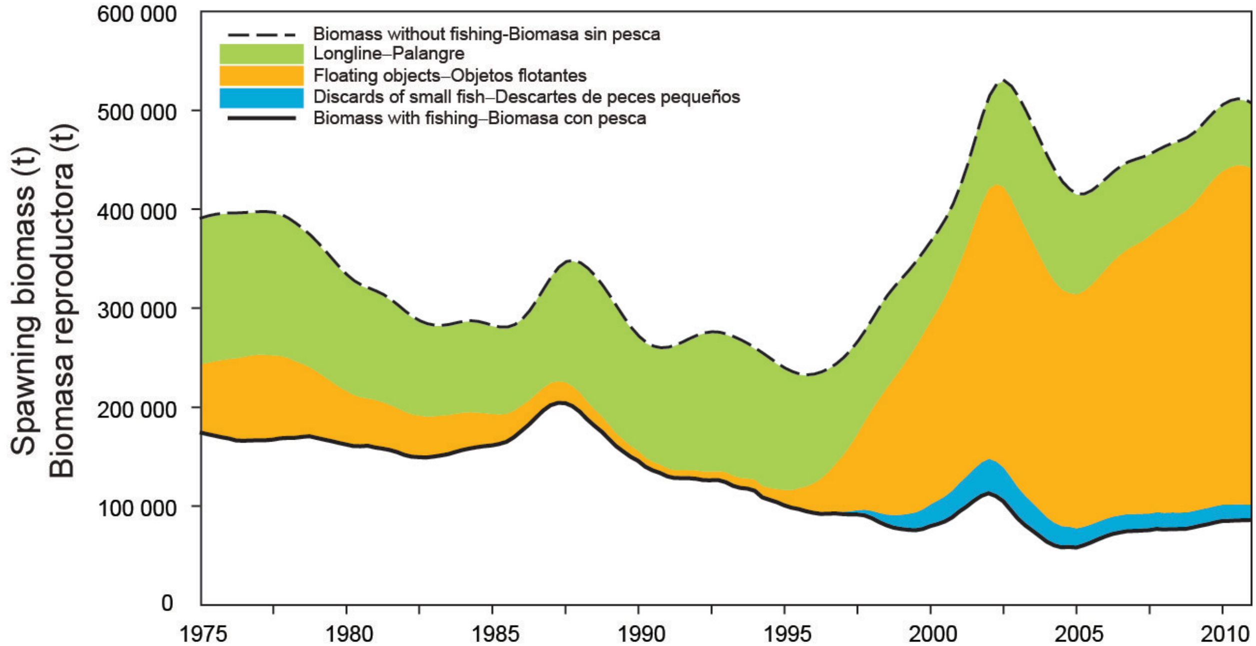

FIGURE 3. Trajectory of the spawning biomass of a simulated population of bigeye tuna that was not exploited (top line) and that predicted by the stock assessment model (bottom line). The shaded areas between the two lines show the portions of the impact attributed to each fishing method. t = metric tons.

FIGURA 3. 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.

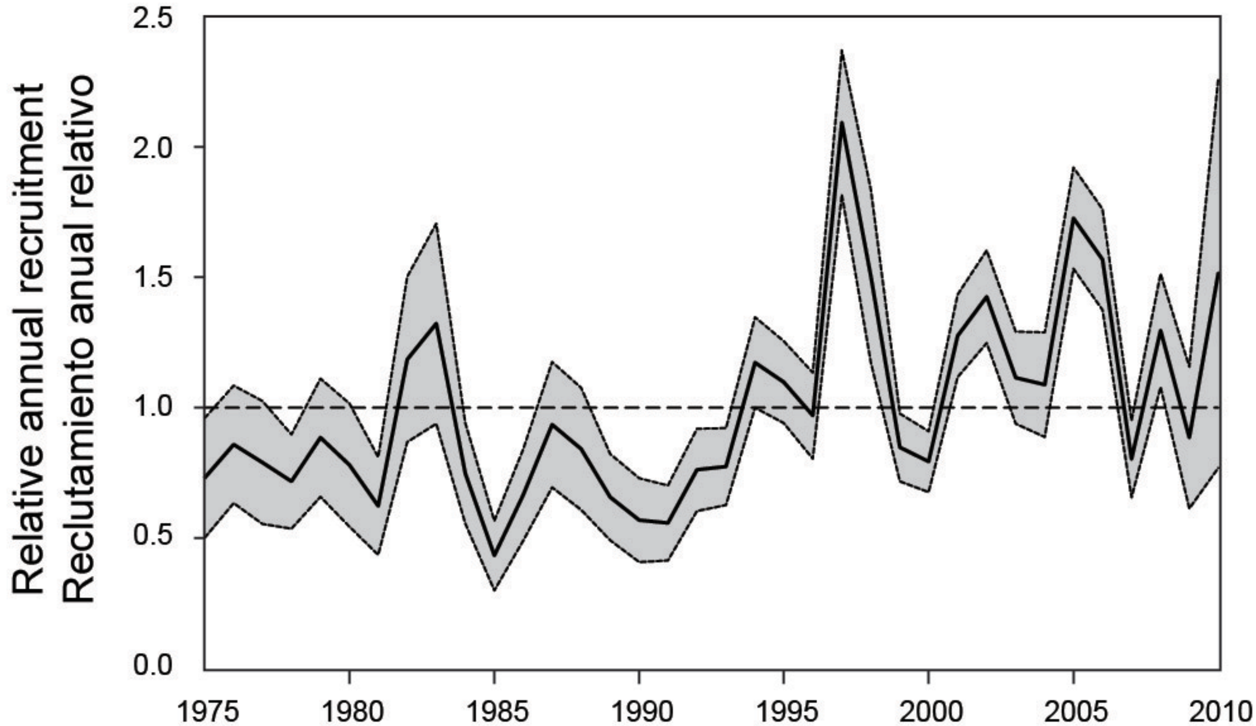

FIGURE 4. Estimated annual recruitment of bigeye tuna to the fisheries of the EPO. The estimates are scaled so that the estimate of virgin recruitment is equal to 1.0 (dashed horizontal line). The solid line shows the maximum likelihood estimates of recruitment, and the shaded area indicates the approximate 95% intervals around those estimates.

FIGURA 4. 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 (línea de trazos horizontal). La línea sólida indica las estimaciones de reclutamiento de verosimilitud máxima, y el área sombreada indica los intervalos de confianza de 95% aproximados de esas estimaciones.

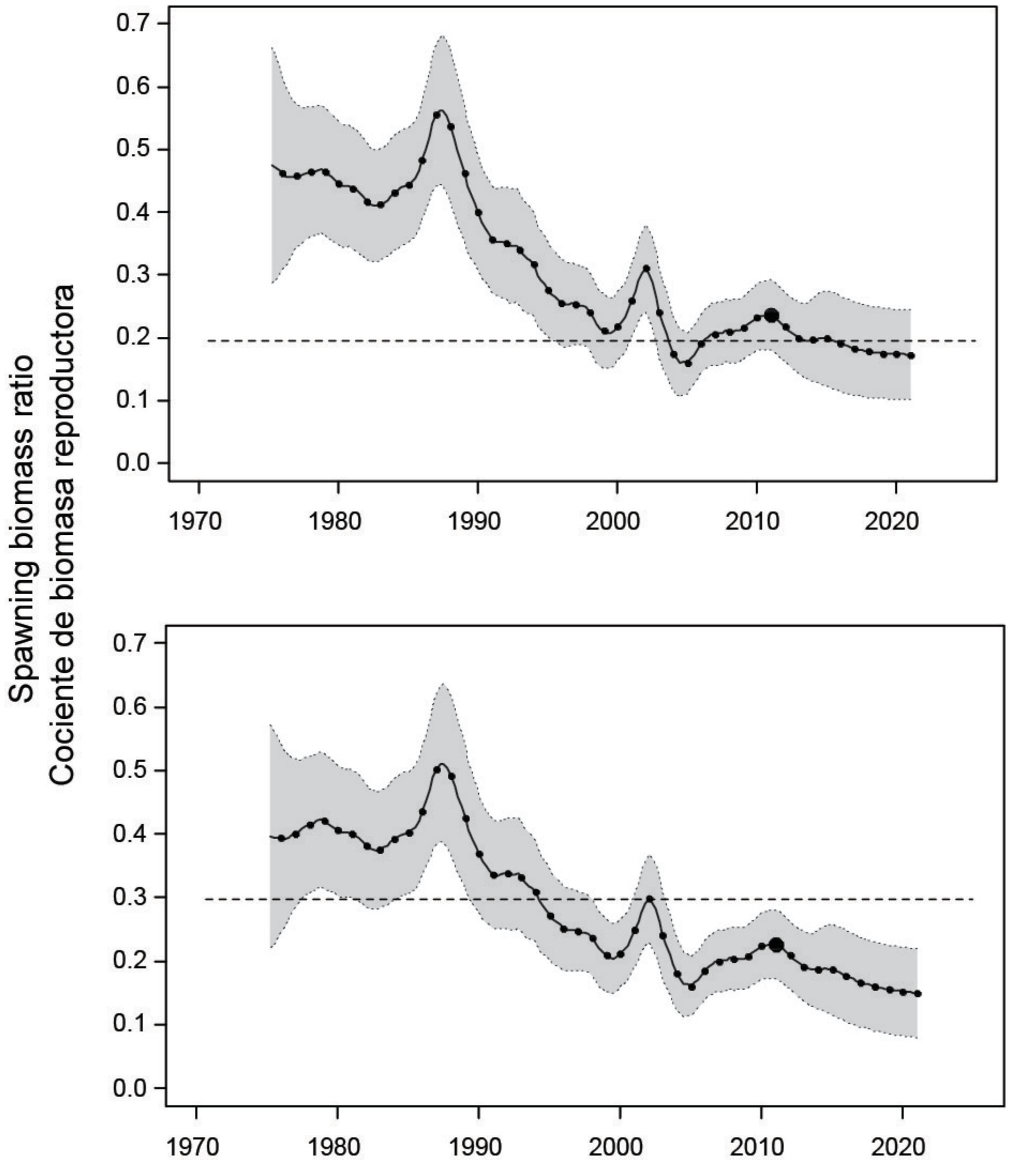

FIGURE 5. Spawning biomass ratios (SBRs) of bigeye tuna in the EPO, including projections for 2011-2020 based on average fishing mortality rates during 2008-2010 from the base case (top) and the analysis of sensitivity to the steepness of the stock-recruitment relationship (bottom). The dashed horizontal line (at about 0.19 and 0.30, respectively) identifies the SBR at MSY. The solid line illustrates the maximum likelihood estimates, and the estimates after 2010 (the large dot) indicate the SBR predicted to occur if fishing mortality rates continue at the average of those observed during 2008-2010. The dashed lines are the 95-percent confidence intervals around these estimates.

FIGURA 5. Cocientes de biomasa reproductora (SBR) del atún patudo en el OPO, incluyendo proyecciones para 2011-2020 basadas en las tasas medias de mortalidad por pesca durante 2008-2010 del caso base (arriba) y el análisis de sensibilidad a la inclinación de la relación población-reclutamiento (abajo). La línea de trazos horizontal (en aproximadamente 0.19 y 0.30, respectivamente) identifica el SBR en RMS. La línea sólida ilustra las estimaciones de verosimilitud máxima, y las estimaciones a partir de 2010 (el punto grande) señalan el SBR predicho si las tasas de mortalidad por pesca continúan en el promedio de aquéllas observadas durante 2008-2010. Las líneas de trazos representan los intervalos de confianza de 95% alrededor de esas estimaciones.

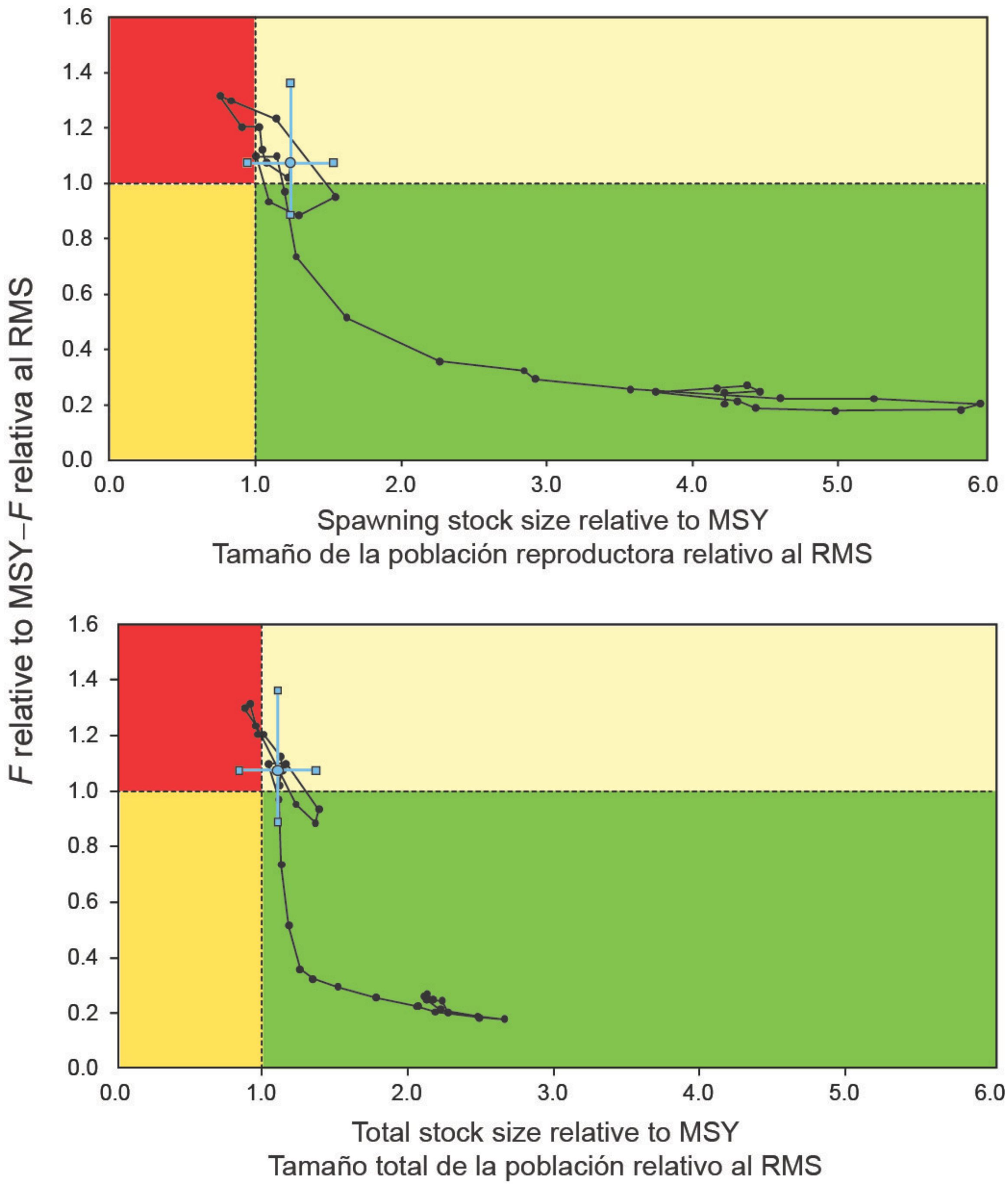

FIGURE 6. Kobe (phase) plot of the time series of estimates of stock size (top: spawning biomass; bottom: total biomass) and fishing mortality relative to their MSY reference points. Each dot is based on the average fishing mortality rate over three years; the large dot indicates the most recent estimate. The squares around the most recent estimate represent its approximate 95% confidence interval.

FIGURA 6. Gráfica de Kobe (fase) de la serie de tiempo de las estimaciones del tamaño de la población (arriba: biomasa reproductora; abajo: biomasa total) 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 un trienio; el punto grande indica la estimación más reciente. Los cuadrados alrededor de la estimación más reciente representan su intervalo de confianza de aproximadamente 95%.

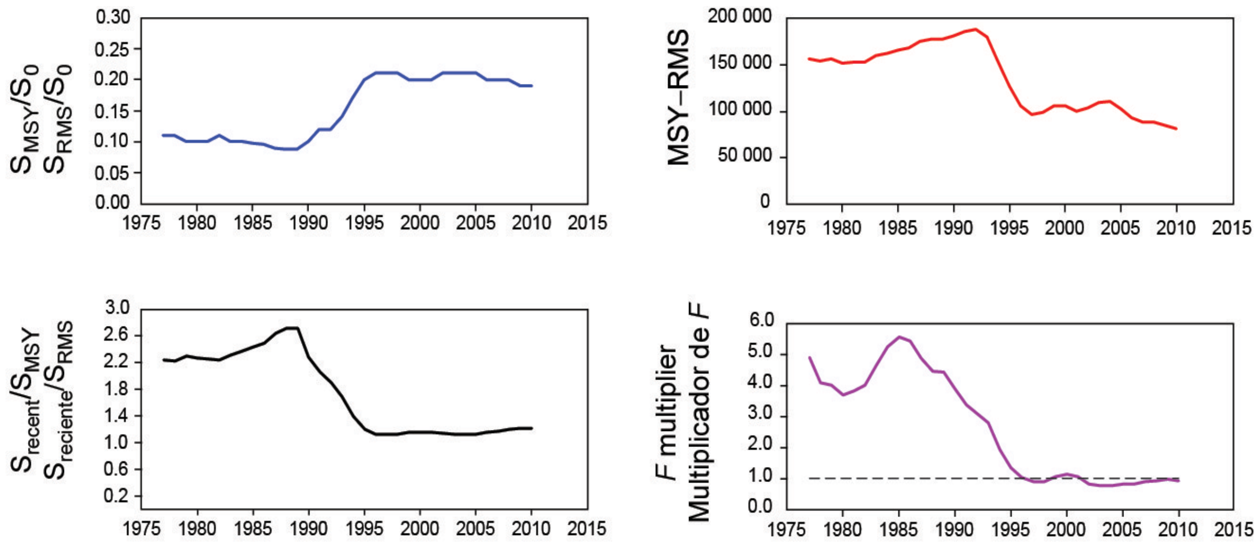

FIGURE 7. Estimates of MSY-related quantities calculated using the average age-specific fishing mortality for each year. (S_{recent} is the spawning biomass at the end of the last year in the assessment.)
FIGURA 7. Estimaciones de cantidades relacionadas con el RMS calculadas usando la mortalidad por pesca por edad media para cada año. ($S_{reciente}$ es la biomasa reproductora al fin del último año en la evaluación.)

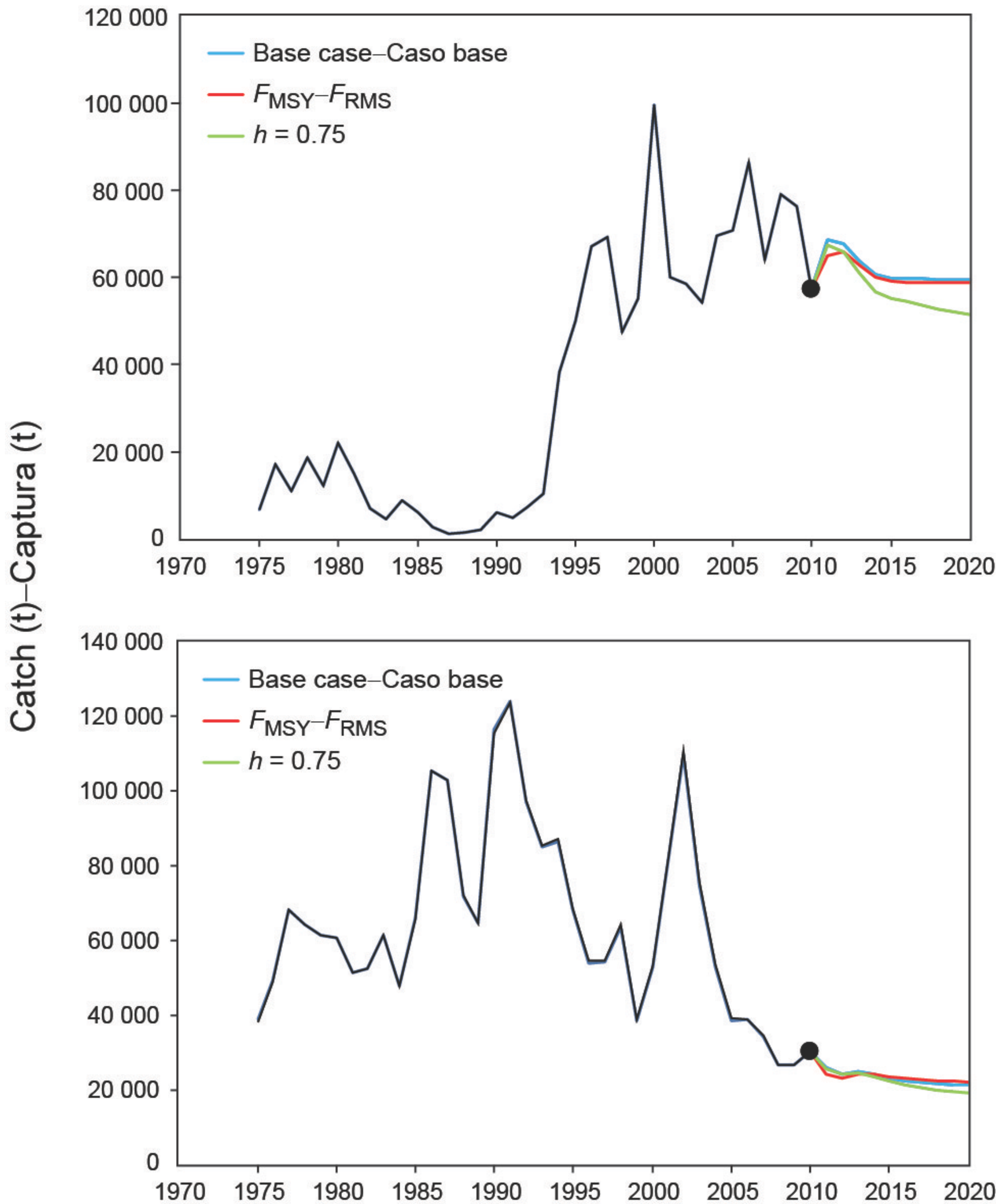

FIGURE 8. Historic and projected annual catches of bigeye tuna by the surface (top panel) and longline (bottom panel) fisheries from the base case while fishing with the current effort, the base case while fishing at the fishing mortality corresponding to MSY (F_{MSY}), and the analysis of sensitivity to steepness (h = 0.75) of the stock-recruitment relationship while fishing with the current effort.

FIGURA 8. Capturas anuales históricas y proyectadas de patudo por las pesquerías de superficie (arriba) y de palangre (abajo) del caso base con la pesca en el nivel actual de esfuerzo, del caso base con la pesca en la mortalidad por pesca correspondiente al RMS (F_{RMS}), y el análisis de sensibilidad a la inclinación (h = 0.75) de la relación población-reclutamiento al pescar con el esfuerzo actual.

TABLE 1. MSY and related quantities for the base case and the stock-recruitment relationship sensitivity analysis, based on average fishing mortality (*F*) for 2008-2010. B_{recent} and B_{MSY} are defined as the biomass, in metric tons, of fish 3+ quarters old at the start of the first quarter of 2010 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 for 2010.

TABLA 1. RMS y cantidades relacionadas para el caso base y el análisis de sensibilidad a la relación población-reclutamiento, basados en la mortalidad por pesca (*F*) media de 2008-2010. Se definen B_{reciente} y B_{RMS} como la biomasa, en toneladas, de peces de 3+ trimestres de edad al principio del primer trimestre de 2010 y en RMS, respectivamente, y S_{reciente} y S_{RMS} como índices de biomasa reproductora (por lo tanto, no se expresan en toneladas). C_{reciente} es la captura total estimada de 2010.

	Base case – Caso base	***h* = 0.75**
MSY–RMS	80,963	77,473
B_{MSY} –B_{RMS}	311,247	547,291
S_{MSY} —S_{RMS}	70,509	137,670
C_{recent}/MSY—C_{reciente}/RMS	1.08	1.13
$B_{\text{recent}}/B_{\text{MSY}}$ –$B_{\text{reciente}}/B_{\text{RMS}}$	1.11	0.75
$S_{\text{recent}}/S_{\text{MSY}}$ –$S_{\text{reciente}}/S_{\text{RMS}}$	1.21	0.77
$B_{\text{MSY}}/B_{F=0}$ –$B_{\text{RMS}}/B_{F=0}$	0.24	0.33
$S_{\text{MSY}}/S_{F=0}$ –$S_{\text{RMS}}/S_{F=0}$	0.19	0.30
F multiplier—Multiplicador de *F*	0.93	0.65

INTER-AMERICAN TROPICAL TUNA COMMISSION

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2ND MEETING

La Jolla, California (USA)
9-12 May 2011

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STATUS OF YELLOWFIN TUNA IN THE EASTERN PACIFIC OCEAN IN 2010 AND OUTLOOK FOR THE FUTURE

Alexandre Aires-da-Silva and Mark N. Maunder

CONTENTS

1. SUMMARY

This report presents the most current stock assessment of yellowfin tuna (*Thunnus albacares*) in the eastern Pacific Ocean (EPO). An integrated statistical age-structured stock assessment model (Stock Synthesis Version 3.20b) 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, and 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. The bulk of the catches of yellowfin is made in the eastern and western regions, although the purse-seine catches are relatively low in the vicinity of the western boundary of the EPO at 150°W. The movements of tagged yellowfin generally cover hundreds, rather than thousands, of kilometers, and exchange of fish 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. 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, indices of abundance, 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 (*F*), and stock structure. The catch data for the surface fisheries have been updated, and new data added for 2010. New or updated longline catch data are available for French Polynesia (2008), Japan (2008-2010), Korea (2009) and the United States (2008-2009). Surface fishery CPUE data were updated, and new CPUE data added for 2010. New or updated CPUE data are available for the Japanese longline fleet (2008-2010). New surface fishery size-composition data for 2010 were added. New or

updated length-frequency data are available for the Japanese longline fleet (2007-2009).

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 recruitment productivity regimes (1975-1982, 1983-2002, and 2003-2010). The productivity regimes correspond to regimes in biomass, with 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 this is probably an artifact of the apparent regime shifts. A recent sharp decline in the levels of spawning biomass since 2009 follows a series of below-average recruitments from the second quarter of 2007 through the last quarter of 2008.

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, northern unassociated, and pole-and-line fisheries capture younger, smaller yellowfin than do the southern unassociated, dolphin-associated, and longline fisheries. The longline fisheries and the dolphin-associated fishery in the southern region capture older, larger yellowfin than 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. The dolphin-associated and unassociated purse-seine fisheries have the greatest impact on the spawning biomass of yellowfin, followed by the floating-object fisheries. The impact of the longline and purse-seine discards is much less.

There is a large retrospective pattern of overestimating recent recruitment. This pattern, in combination with the wide confidence intervals of the estimates of recent recruitment, indicate that these estimates and those of recent biomass are uncertain.

Historically, the spawning biomass ratio (the 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 1975-1983, coinciding with the low productivity regime, but above that level during most of the following years, except for the recent period (2004-2007 and 2010). 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 2011 was estimated to be at 0.18, below the level corresponding to the MSY (0.25). 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), and recent catches are below MSY.

It is important to note that the curve relating the average sustainable yield to the long-term fishing mortality is very flat around the MSY level. Therefore, changes in the long-term levels of effort will change the long-term catches only marginally, while changing the biomass considerably. Reducing fishing mortality below the level at MSY would result in only a marginal decrease in the long-term average yield, with the benefit of a relatively large increase in the spawning biomass. In addition, if management is based on the base case assessment (which assumes that there is no stock-recruitment relationship), when in fact there is such a relationship, there would be a greater loss in yield than if management is based on assuming a stock-recruitment relationship when in fact there is no relationship.

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 (1975-2010), 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 level corresponding to MSY.

If a stock-recruitment relationship is assumed, the outlook is more pessimistic, and current effort is estimated to be above the level corresponding to the MSY. The status of the stock is also sensitive to the value assumed for the average size of the oldest fish. If the CPUE of the northern dolphin-associated fishery, rather than that of the southern longline fishery, is assumed to be the most reliable index of abundance, the current spawning stock biomass is estimated to be at about the level corresponding to MSY.

Under current levels of fishing mortality (2008-2010), the spawning biomass is predicted to rebuild, and remain above the level corresponding to MSY. However, the confidence intervals are wide, a retrospective pattern exists in recent recruitment, and there is a moderate probability that the SBR will be substantially above or below this level. Fishing at F_{msy} is predicted to reduce the spawning biomass slightly from that under current effort and produces slightly higher catches.

Key Results

1. There is uncertainty about recent and future levels of recruitment and biomass, and there are retrospective patterns of overestimating recent recruitment.
2. The recent fishing mortality rates are lower than those corresponding to the MSY.
3. The recent levels of spawning biomass are below 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 among the regimes. The population may have recently switched from a high to an intermediate productivity regime.
6. The results are more pessimistic if a stock-recruitment relationship is assumed.
7. The results are sensitive to the average size assumed for the oldest fish.

2. DATA

Catch, indices of abundance, and size-composition data for January 1975-December 2010, plus biological data, were used to conduct the stock assessment of yellowfin tuna, *Thunnus albacares,* in the eastern Pacific Ocean (EPO). The data for 2010, which are preliminary, include records that had been entered into the IATTC databases by 15 April 2011. 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. They 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. Catches

To conduct the stock assessment of yellowfin tuna, the catch and effort data in the IATTC databases are stratified in accordance with 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, and "retained catch" is the catch that is taken in a given year and not discarded at sea. "Catch" is used for either total catch (discards plus retained catch) or retained catch; the context determines the appropriate definition.

All three 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 (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 (Table 2.1).

New and updated catch data for the surface fisheries (Fisheries 1-10 and 13-16) have been incorporated into the current assessment. New catch data for 2010 and updated data for earlier years are used for the surface fisheries.

The species-composition method (Tomlinson 2002) was used to estimate the 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 data 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. Updated and new catch data for the longline fisheries (Fisheries 11 and 12) have also been incorporated into the current assessment. In particular, new or updated catch data were available for French Polynesia (2008), Japan (2008-2010), Korea (2009) and the United States (2008-2009).

A substantial proportion of the longline catch data for 2010 was not available, so catches for the longline fisheries in the recent years for which the data were not available were set equal, by flag, 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 December 2010 are shown in Figures 2.2a and 2.2b. It should be noted that there were substantial surface and longline fisheries for yellowfin prior to 1975 (Shimada and Schaefer 1956; Schaefer 1957; Matsumoto and Bayliff 2008). The majority of the catch has been taken in 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, most of the longline catches of yellowfin in the stock assessment were expressed in numbers of fish.

2.2.1. 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.

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. Maunder and Watters (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 yellowfin associated with floating objects (Fisheries 2-5) because sorting is infrequent in the other purse-seine fisheries.

Time series of annual discards as proportions of the total (retained plus discarded) catches for the surface fisheries that catch yellowfin in association with floating-objects are presented in Figure 2.3. The figure shows a reduction in bycatch rates beginning around 2001, possibly as a consequence of a series of resolutions adopted by the IATTC during 2001-2007 which prohibited discarding catches of small tunas. No such resolution was in force during 2008, but the bycatch rates continue to be low. It is assumed that yellowfin are not discarded from longline fisheries (Fisheries 11 and 12).

2.3. Indices of abundance

Indices of abundance were derived from purse-seine and longline catch and effort data. New fishing effort and catch data for the surface fisheries (Fisheries 1-9) have been added for 2010 and updated for earlier years. New or updated catch and effort data are available for the Japanese longline fisheries (2008-2010). Trends in the amount of fishing effort exerted by 11 of the 16 fisheries defined for the stock assessment of yellowfin tuna in the EPO are shown in Figure 2.4, which does not include the pole-and-line and four discard fisheries.

The catch per unit of effort (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 estimated 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 CPUE (1975-2010) were obtained for the longline fisheries (Fisheries 11 and 12), using a delta-lognormal general linear model (Hoyle and Maunder 2006) in which the explanatory variables were latitude, longitude, and hooks per basket.

The 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 5 and 6 (purse-seine sets on unassociated schools), 7 and 8 (purse-seine sets on yellowfin associated with dolphins), and 12 (the southern longline fishery). The fisheries excluded were considered inappropriate because the fishing effort or catch rates were extremely low, highly variable, or had variable length-frequency data and are considered not representative of yellowfin abundance.

2.4. Size-composition data

New purse-seine length-frequency data were included for 2010. New or updated longline length-frequency data for 2007-2009 for the Japanese fleet were included. Size composition data for the other longline fleets are not used in the assessment.

The fisheries of the EPO catch yellowfin of various sizes, as described by Maunder and Watters (2001). In general, floating-object, unassociated, and pole-and-line fisheries catch smaller yellowfin, while dolphin-associated and longline fisheries catch larger ones. The temporal variation of the catch from each fishery defined in Table 2.1 is shown in Figures 2.6a-2.6e.

2.5. Auxiliary data

Age-at-length estimates (Wild 1986) calculated from otolith data were integrated into the stock assessment model to provide information on mean length-at-age and variability of the length-at-age. Wild’s data consists 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.

3. ASSUMPTIONS AND PARAMETERS

3.1. Biological and demographic information

3.1.1. Growth

In this assessment, the Richards growth curve is used to model growth (Figure 3.1). The parameters of the model are taken from Maunder and Aires-da-Silva (2009), and are based on the fit to the data from Wild (1986).

Expected asymptotic length (L_∞) cannot be reliably estimated from data such as those of Wild (1986) that do not include many old fish.

The coefficient of variation in length-at-age is assumed constant, and is taken from Maunder and Aires-da-Silva (2009).

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 including this alternative data set in the stock assessment model gives essentially identical results.

3.1.2. Natural mortality

For this 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, in which M was assumed to increase for females after they reached the age of 30 months (*e.g.* Anonymous 1999: 38). Males and females are treated separately in this assessment, and M differs between males and females. The values of quarterly M used in this assessment are plotted in Figure 3.2. 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.

3.1.3. Recruitment and reproduction

The Stock Synthesis software 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. As in the previous assessments, the base case assessment assumes that there is no relationship between stock size and recruitment. 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 assessment 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.

Recruitment is modeled at age zero in Stock Synthesis. Age zero is used for convenience, and the assumed natural mortality for ages not vulnerable to the fisheries is not intended to represent the actual natural mortality, and only arbitrarily scales the recruitment at age zero. Therefore, the assumed level of natural mortality for these ages has no impact on the assessment results.

The spawning potential of the population is estimated from the numbers of mature females adjusted for batch fecundity and spawning frequency (Schaefer 1998). 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 is shown in Figure 3.3.

3.1.4. Movement

The evidence of yellowfin movement within the EPO is summarized by Maunder and Watters (2001), and the results of more recent research are given by Schaefer *et al.* (2007). They 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 is expected to be very low. This result is consistent with the results of various tagging studies, using conventional and archival tags, 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 this assessment, it is assumed that movement does not affect the results. However, given the results of Schaefer *et al*. (2007), investigation of finer spatial scale or separate sub-stocks should be considered.

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 there is limited mixing of fish between the EPO and the areas to the west of it. Therefore, for the purposes of the this 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 the 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 (2002a) 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

The Stock Synthesis software (Methot 2005, 2009) is used to assess the status of yellowfin tuna in the EPO. It consists of an integrated (fitted to many different types of data) statistical age-structured stock assessment model, and uses quarterly time steps to describe the population dynamics.

The model is fitted to the observed data (indices of relative abundance based on CPUE and size compositions) by finding a set of population dynamics and fishing parameters that maximize a penalized (for recruitment temporal deviates) 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. Yellowfin are recruited to the discard fisheries (Fisheries 13-16) one quarter after hatching, and these discard fisheries catch only fish of the first few age classes.
2. As yellowfin age, they become more vulnerable to Fisheries 6, 9, and 12, and the oldest fish are the most vulnerable to these gears (*i.e.* asymptotic selectivity is assumed).
3. The data for fisheries that catch yellowfin on floating objects (Fisheries 1-4), associated with dolphins in the south (Fishery 9), the pole-and-line fishery (Fishery 10), the northern longline fishery (Fishery 11), and fisheries whose catch is composed of the discards from sorting (Fisheries 13-16) provide relatively little information about biomass levels, either because they do not direct their effort at yellowfin or because there is too much variability in the fishery. For this reason, the CPUE time series for these fisheries were not used as indices of abundance. The CPUE time series fitted in the assessment are series from Fisheries 5, 6, 7, 8, and 12.
4. The data for the fishery associated with dolphins in the south (Fishery 9) is considered too variable, so its selectivity curve is assumed to be equal to Fishery 12, and its size-composition data is not fitted in the model.

The following parameters have been estimated for the current stock assessment of yellowfin in the EPO:

1. Recruitment to the fishery in every quarter of the year from the first quarter of 1975 through the first quarter of 2011 (average recruitment and quarterly recruitment deviates);
2. Catchability coefficients for the five CPUE time series that are used as indices of abundance (Fisheries 5-8 and 12);
3. Coefficients of variation (CVs) for four of the CPUE indices used as indices of abundance (Fisheries 5-8). Following a recommendation by an external review of the IATTC staff's assessment of bigeye tuna, the CV of one CPUE index was fixed rather than estimated, in this case the CV of the southern longline fishery (Fishery 12), assumed as the most reliable index of abundance.
4. Selectivity curves for 11 of the 16 fisheries (Fishery 9 mirrors the selectivity of Fishery 12, and Fisheries 13-16 have assumed selectivity curves);
5. Initial population size and age structure (recruitment offset, initial fishing mortality, and deviates for ages 1 to 16 quarters).

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

1. Mean length at age (Section 3.1.1, Figure 3.1);

2. Parameters of a linear model relating the coefficient of variation of length at age to age.
3. Sex- and age-specific natural mortality (Figure 3.2);
4. Fecundity of females at age (Figure 3.3);
5. Selectivity curves for the discard fisheries (Fisheries 13-16);
6. The steepness of the stock-recruitment relationship (steepness = 1 for the base case assessment).

The estimates of management quantities and future projections were computed based on 3-year average fishing mortality rates (*F*), by gear, for 2008-2010. The sensitivity of estimates of key management quantities to including the most recent year (2010) in the 3-year average estimate of *F* was tested. For this purpose, a 2-year (2008-2009) average *F* was used in the calculations.

There is uncertainty in the results of the current stock assessment. It arises because the observed data do not perfectly represent the population of yellowfin in the EPO. Also, the stock assessment model does 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 this assumption is unlikely to be satisfied, these values may underestimate the amount of uncertainty in the results of the assessment. Additional sources of uncertainty are investigated in several sensitivity analyses.

The following summarizes the important aspects of the base case assessment (1) and the three sensitivity analyses:

Base case assessment:

1. Steepness of the stock-recruitment relationship = 1 (no relationship between stock and recruitment); growth parameters are fixed to the estimates obtained in an earlier assessment (Maunder and Aires-da-Silva 2009); fitted to CPUE time series for purse seine Fisheries 5-8 and longline Fishery 12; mirror selectivity curves of Fisheries 9 and 12, assumed to be asymptotic; selectivity curves of all other fisheries assumed dome-shape.
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. In addition, a likelihood profile for steepness was computed (steepness ranging from 0.6 to 1, with 0.1 increments).
3. **Sensitivity to the average size of the older fish** (L_2 parameter of the Richards growth function). L_2 is fixed at 182.3 cm in the base case model, an estimate of L_2 that was obtained in an earlier assessment (Maunder and Aires-da-Silva, 2009).Two alternative fixed values of L_2 were considered for the sensitivity analysis, a lower and a higher value of 170 cm and 190 cm, respectively.
4. **Sensitivity to fitting to the CPUE of the northern dolphin-associated fishery** (Fishery 9) as the main index of abundance (rather than the CPUE of the southern longline Fishery 12). For this purpose, the CV of Fishery 9 was fixed at 0.2 and CVs of other fisheries are estimated

4.1. Assessment results

The results of the base case assessment and sensitivity analyses are described below. 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 is variation in fishing mortality (F) exerted by the fisheries that catch yellowfin in the EPO (Figure 4.1). Fishing mortality changes with age (Figure 4.2a), being greatest for middle-aged fish. There is a peak at around ages of 14-15 quarters (Figures 4.2a, 4.2b), which corresponds to peaks in the selectivity curves for fisheries on unassociated and dolphin-associated yellowfin (Figure 4.3). 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 (Figures 4.1 and 4.2a).

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 2.3 (also see Figure 2.4).

Selectivity curves are estimated for 11 of the 16 fisheries defined in the assessment of yellowfin (Figure 2.1) and are shown in Figure 4.3. Purse-seine sets on floating objects (Fisheries 1-4) tend to select smaller yellowfin, except in the southern and inshore fisheries, which catche larger fish (Figure 4.3). Purse-seine sets on unassociated schools of yellowfin in the north select fish similar in size to those caught by sets on floating objects (Figure 4.3, Fishery 5). Purse-seine sets on unassociated schools of yellowfin in the south and on yellowfin associated with dolphins select larger yellowfin (Figure 4.3, Fisheries 6-8). The selectivity curve for the pole-and-line fishery selects mainly smaller yellowfin (Figure 4.3, Fishery 10). The longline fisheries for yellowfin also select mainly larger individuals, particularly in the southern fishery (Figure 4.3, Fisheries 11 and 12). Since it became difficult to estimate the selectivity curve of the southern dolphin-associated fishery (Fishery 9), this curve was not estimated, and mirrored Fishery 12, which catches similar size fish (Figure 4.3). In the future, it may be necessary to allow for time-varying selectivity to better estimate the selectivity curve of this fishery.

Discards resulting from sorting purse-seine catches of yellowfin taken in association with floating objects are assumed to be composed only of fish of ages 2-4 quarters (Fisheries 13-16).

4.1.2. Recruitment

Over the range of estimated spawning biomasses shown in Figure 4.7, the abundance of yellowfin recruits appears to be related to the relative potential egg production at the time of spawning (Figure 4.4). The apparent relationship between spawning 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 spawning biomass. Therefore, in the long term, above-average recruitment is related to above-average spawning biomass, and below-average recruitment to below-average spawning 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 at least as plausible as an effect of population size on recruitment. The results when a stock-recruitment relationship is included are described in Section 4.4.

The estimated time series of yellowfin recruitment is shown in Figure 4.5, and the estimated annual total recruitments are listed in Table 4.1. The large cohort spawned in the first quarter of 1998 was estimated to be the strongest cohort of the 1975-2010 period. A sustained period of high recruitment was estimated from 1999 until the start of 2002. A large recruitment was estimated for the first quarter of 2007, followed by a series of continuous below-average recruitments through the last quarter of 2008. The recruitment estimate for the first quarter of 2010 is particularly high; however, it is very uncertain and should be regarded with caution, due to the fact that recently-recruited yellowfin are represented in only a few length-frequency samples and there is a retrospective pattern (see section 4.3.2).

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, and produced a similar change in biomass (Figure 4.6). There is an indication that the recruitments from 2003-2009 were at low levels, similar to those prior to 1983, perhaps indicating a lower productivity regime (Figure 4.5).

The confidence intervals for recruitment are relatively narrow, indicating that the estimates are fairly precise, except for that of the most recent year (Figure 4.5). The estimates of uncertainty are surprisingly small, considering the inability of the model to fit modes in the length-frequency data (Figure 4.11). These modes often appear, disappear, and then reappear.

4.1.3. Biomass

Biomass is defined as the total weight of yellowfin that are three quarters old or more. The trends in the biomass of yellowfin in the EPO are shown in Figure 4.6, and estimates of the biomass at the beginning of each year are listed in Table 4.1. Between 1975 and 1983 the biomass of yellowfin was at low levels; it then increased rapidly during 1983-1985, remained relatively constant during 1986-1999, then increased rapidly again, peaking in 2001, but by 2005 had declined to levels similar to those prior to 1984. The biomass in recent years has remained at levels below those of 1985-1998.

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 4.7, and estimates of the SBR (defined in Section 3.1.3) at the beginning of each year are shown 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 index of spawning biomass estimates indicate that it is well estimated. The recent sharp decline of the spawning biomass observed since 2009 is partially attributed to a series of continuous below-average recruitments from the second quarter of 2007 through the last quarter of 2008.

It appears that trends in the spawning 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 spawning biomass trends (Maunder and Watters, 2001). The simulated index of spawning biomass trajectories with and without fishing are shown in Figure 4.8b. The large difference in the two trajectories indicates that fishing has a major impact on the spawning biomass of yellowfin in the EPO (Figure 4.8a). The large increase in spawning biomass during 1983-1984 was caused initially by an increase in average size (Anonymous 1999), followed by an increase in average recruitment (Figure 4.5), but increased fishing pressure prevented the spawning biomass from increasing further during the 1986-1990 period.

The impact of each major type of fishery on the yellowfin stock is shown in Figure 4.8b. The estimates of the index of spawning biomass in the absence of fishing were computed as above, and then the biomass trajectory was estimated by setting the catch for each fisheries group, in turn, to zero (Wang *et al.* 2010). The spawning biomass impact for each fishery group at each time step is derived as this index of spawning biomass trajectory minus the index of spawning 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. The fishery associated with dolphins and unassociated purse-seine fisheries have a greatest impact on the spawning biomass of yellowfin, followed by the floating-object fisheries. The impact of the longline and discard fisheries is much smaller.

4.1.4. 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 10 to 15 kg for most of the 1975-2010 period, but have differed considerably among fisheries (Figure 4.9). The average weight was high during 1975-1977, 1985-1992, 2001-2004, and 2008-2010, when the catches of the dolphin-associated fisheries were greater (Figure 2.2). The average weight of yellowfin caught by the different gears varies widely, but remains fairly consistent over time within each fishery (Figure 4.9). The lowest average weights occur in the floating-object and pole-and-line fisheries, followed by the unassociated fisheries, then the dolphin-associated, and finally the longline fisheries. The average weight caught also varies within these fisheries groups, as indicated by the selectivity curves (Figure 4.3).

4.2. Comparisons to external data sources

The mean length at age assumed in the model corresponds well with the otolith age-at-length data, but the assumed variation of length-at-age is much wider than indicated by the otolith data (Figure 3.1). The narrower variation of length-at-age seen in the otolith data may be due to the limited temporal and spatial characteristics of the data.

4.3. Diagnostics

Diagnostics of the model are presented as residual plots and retrospective analysis.

4.3.1. Residual plots

The model fits to the CPUE data from different fisheries are presented in Figure 4.10. The model fits the CPUE observations for the dolphin-associated purse-seine and southern longline fisheries reasonably well (Figures 4.10c and 4.10d, respectively). However, the peak in 2001 is predicted too early in the former and too late in the latter. Also, the model fits less well to the early CPUE of the southern longline fishery (Figure 4.10.d). The fits to the CPUE data series for the unassociated purse-seine fisheries are less satisfactory (Figure 4.10.b). The model is not fit explicitly to the CPUE of the floating-object fisheries; however, it corresponds well to the CPUE of these fisheries in the late period (post-1995), but poorly in the early period (pre-1995) of highly variable CPUE (Figure 4.10a). The fit to the CPUE data, as measured by the mean square error, indicates that the best fits are to the CPUEs of the southern longline fishery (CV = 0.36) and the dolphin-associated purse-seine fisheries (CVs of 0.39 and 0.38 for Fisheries 7 and 8, respectively) (Table 4.3).

Pearson residual plots are presented for the model fits to the length-composition data (Figures 4.11a to 4.11d). The grey and black circles represent observations that are less and greater, respectively, than the model predictions. The areas of the circles are proportional to the absolute values of the residuals. There are several notable characteristics of the residuals. The model underestimates (black circles) the proportions of large and small fish for the floating-object fisheries; conversely, it underestimates medium-sized fish for the southern longline fishery. There is a substantial residual pattern for the southern dolphin-associated purse-seine fishery (Fishery 9), but this is expected, because the selectivity curve is mirrored with another fishery (southern longline, Fishery 12) and so the model is not fitted to the catch-at-length data of Fishery 9. There is also a noticeable residual pattern for both unassociated fisheries, consisting of an early period of about 5 years (1975-1980) with positive residuals (black circles) mainly for smaller fish, unlike in subsequent years.

For all fisheries, the model fits the length-frequency data better (as indicated by the estimated effective sample size) than the assumed sample size used in the model (Table 4.4). The average fits to the observed size compositions of the catches taken by each fishery are shown in Figure 4.11e. The model fits to the size-compositions of the recent catches of yellowfin are also shown for different fisheries (Figures 4.11f-i).

The appearance, disappearance, and subsequent reappearance of strong cohorts in the length-frequency data is a common phenomenon for yellowfin in the EPO. It may indicate spatial movement of cohorts or fishing effort, limitations in the length-frequency sampling, or fluctuations in the catchability and/or selectivity 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 and/or selectivity.

4.3.2. 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 reveal inadequacies in the method. Retrospective analyses are usually carried out by repeatedly eliminating one year of data from the analysis while using the same assessment method and assumptions. This allows the change in estimated quantities to be determined as more data are included in the model. Estimates for the most recent years are often uncertain and biased. Retrospective analysis can be used to determine if there are consistent patterns in the estimates. These patterns are often viewed as biases by assuming that the estimates are more accurate when more years of data are included in the analysis. However, they really indicate only a model misspecification, because it is possible that the estimates are biased when additional years of data are added to the analyses, depending on the model misspecification. The retrospective analysis indicates a tendency to overestimate the strengths of recent recruitment (Figure 4.13), and consequently to overestimate recent levels of summary biomass (fish 3+ quarters old), which includes the most recent cohorts (Figures 4.12). However, the recent levels of the SBR (defined in section 3.1.3) are apparently not subject to the same retrospective pattern, since they are less affected by recent recruitment estimates. A sensitivity analysis conducted on an early assessment (Maunder and Aires-da-Silva 2010) suggests that removing the size-composition data of the floating-object fisheries from the analyses removes this retrospective pattern. This indicates that the size-composition data for these fisheries are inconsistent with the size-composition data for the other fisheries at greater ages. Resolution C-00-08, adopted in 2000, prohibited the discarding of yellowfin tuna due to size, which changed the selectivity curves of the floating-object fisheries in 2001 and could potentially cause the retrospective pattern. However, another sensitivity analysis incorporating this into the stock assessment did not remove the retrospective pattern (Maunder and Aires-da-Silva 2010).

4.4. Sensitivity to assumptions

Three sensitivity analyses were carried out to investigate the incorporation of a Beverton-Holt (1957) stock-recruitment relationship (Appendix A), average size of the older fish (Appendix B), and fitting to the CPUE data of the northern dolphin-associated fishery (Fishery 9) as the main index of abundance (Appendix C). Here we describe differences in model fit and model prediction, and defer our discussion of differences in stock status to Section 5. A comparison of the likelihoods for the base case and sensitivity analyses is provided in Table 4.5.

1. The base case assessment 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 that from an unexploited population. As in previous assessments, the analysis with a stock-recruitment relationship fits the data better than the analysis without the stock-recruitment relationship. However, as stated previously, 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 A.1) and recruitment (Figure A.2) are almost identical to those of the base case assessment. A likelihood profile on steepness confirms that the model fits better at lower fixed values for this parameter, with its maximum likelihood apparently occurring at about 0.7.

2. The base case model assumes a Richards (1959) growth function. The choice of the average size of the older fish – the L_2 parameter – is somewhat arbitrary, since otolith readings are not available for larger (older) fish. In the base case, L_2 is fixed at 182.3 cm, a value estimated in a previous assessment (Maunder and Aires-da-Silva 2009). A sensitivity analysis was done to study the effect of fixing L_2 at different values (a lower and a higher value, 170 and 190, respectively) (Figure B.1). The estimated biomass and recruitment time series are very sensitive to the assumed value of L_2 (Figures B.2 and B.3), they are greater for a lesser value of the parameter.

3. The base case model assumes the CPUE of the southern longline fishery (Fishery 12) to be the most reliable index of abundance (CV = 0.2). However, this fishery mainly targets bigeye tuna, not yellowfin. If instead the model is fitted more closely to the northern dolphin-associated fishery

(Fishery 9, CV = 0.2), the biomass and recruitment trajectories are still very similar to those from the base case (Figures C1 and C2, respectively). This suggests that there is consistency in the information provided by the two CPUE indices. However, the recent decline in biomass levels estimated by the base case is not so strongin the sensitivity analysis, particularly for spawning biomass (Figure C.3). This result is mainly due to the model fitting more closely to the recent CPUE trends of the northern dolphin-associated fishery (C.4a), rather than the southern longline fishery (Figure C.4b). The model fit to the CPUE of the northern dolphin-associated fishery is not so indicative of the pronounced recent decline as indicated by the base case model which fits more closely to the CPUE of the southern longline fishery (Figure 4.10c and 4.10d).

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 estimate the catch of the surface fishery, and a different size of the selectivity smoothness penalties (if set at realistic values), yielded similar results (Maunder and Harley 2004). The results were not sensitive to the link function used in the general linear model (GLM) standardization of the longline effort data (Hoyle and Maunder 2007).

Other sensitivity analyses conducted in early assessments include: fitting to all the data (size composition and CPUE data for all fisheries except the discard fisheries and pole and line fishery); estimating natural mortality for mature fish while fitting to sex ratio data; excluding the size-composition data for the floating-object fisheries from the analysis; including a change in selectivity for the floating-object fisheries starting in 2001 due to the Resolution C-00-08. The results of these sensitivities are described in Maunder and Aires-da-Silva (2010).

4.5. Comparison to previous assessment

The estimates of biomass (Figure 4.15) and the index of spawning biomass (Figure 4.16) from this assessment are very similar to those of the previous assessment. The estimates of recruitment are also very similar, except in 2009, the last year of the previous assessment, for which recruitment is estimated to be very high (Figures 4.17a and b). This is not surprising, considering the retrospective tendency to overestimate recent recruitment strengths, described in Section 4.3.2. As updated data for 2009 and new data for 2010 became available, the 2009 recruitment estimated in the current assessment became much smaller. The historic estimates of the SBR (defined in Section 3.1.3) are also very similar to those of the previous assessment (Figure 4.18).

4.6. 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 indicate that the yellowfin population has experienced two, or possibly three, different recruitment productivity regimes (1975-1982, 1983-2002, and 2003-2010). The productivity regimes correspond to regimes in biomass, higher-productivity regimes producing higher 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 recently observed sharp decline in the levels of spawning biomass since 2009 follows a series of below average recruitments from the second quarter of 2007 through the last quarter of 2008

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, northern unassociated, and pole-and-line fisheries capture younger, smaller yellowfin than do the southern unassociated and dolphin-associated purse-seine fisheries and the longline fisheries. The longline fisheries and the dolphin-associated purse seine fishery in the southern region capture older, larger yellowfin than do the northern and coastal dolphin-associated purse-seine fisheries.

Significant levels of fishing mortality have been estimated for the yellowfin fishery in the EPO. These levels are highest for middle-aged yellowfin. The fisheries associated with dolphins and unassociated purse-seine fisheries have the greatest impact on the spawning biomass of yellowfin, followed by the floating-object fisheries. The impact of the longline and discard fisheries is much smaller (Figure 4.8).

There is a large retrospective pattern of overestimating recent recruitment in the yellowfin stock assessment. A previous assessment (Maunder and Aires-da-Silva 2010) indicated that this pattern is due to the size composition data for the floating object fishery. These, in combination with the wide confidence intervals for estimates of recent recruitment, indicate that estimates of recent recruitment and recent biomass are uncertain. The estimated biomasses and recruitments are very similar to those produced in the latest stock assessment (Maunder and Aires-da-Silva 2011)

5. STOCK STATUS

The status of the stock of yellowfin in the EPO is assessed from calculations based on the spawning biomass, yield per recruit, and the maximum sustainable yield (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 and with the current distribution of types of gear and how these gears are deployed.

Maintaining tuna stocks at levels that will permit the MSY is the management objective specified by the IATTC Convention. The IATTC has not adopted any target of limit reference points for the stocks that it manages, but some possible reference points are described in the following sections.

5.1. Assessment of stock status based on spawning biomass

The SBR, defined in Section 3.1.3, is 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 first quarter of 2011). Estimates of the index of spawning biomass during the period of harvest (S_t) are discussed in Section 4.1.3 and presented in Figure 4.7. The equilibrium index of 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 0.25. This is lower than estimated in the previous assessment (0.27), due mainly to the use of different selectivity curves.

The spawning biomass of yellowfin in the EPO has declined since 2009, when it peaked at 0.35. The estimate of SBR at the beginning of 2011 was about 0.18, with lower and upper 95% confidence limits of 0.15 and 0.22, respectively (Figure 5.1). 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 0.25 in Figure 5.1. For most of the early period (1975-1984), 2005-2007, and during the most recent year (2010, however, the spawning biomass was estimated to be less than S_{MSY}. The spawning biomass at the start of 2011 is estimated to be at 0.18, 28% below than the level corresponding to MSY.

5.2. Assessment of stock status based on MSY

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 2008-2010.

At the beginning of 2011, the biomass of yellowfin in the EPO appears to have been below 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 4.2) are maintained, the current (average of 2008-2010) level of fishing effort is less than that estimated to produce the MSY. The effort at MSY is 113% of the current level of effort. Due to reduced fishing mortality in 2008, repeating the calculations based on a fishing mortality averaged over 2008-2009 indicates that effort at MSY is 129% of the current level. It is important to note that the curve relating the average sustainable yield to the long-term fishing mortality is very flat around the MSY level (Figure 5.2). Therefore, changes in the long-term levels of effort will only marginally change the long-term catches, while considerably changing the biomass. Reducing fishing mortality below the level at MSY would result in only a marginal decrease in the long-term average yield, with the benefit of a relatively large increase in the spawning biomass. In addition, fishing at levels corresponding to MSY estimated from the base case, which assumes that recruitment is independent of spawning biomass,when the true dynamics includes a stock-recruitment relationship, causes a greater loss in yield than fishing at levels corresponding to MSY estimated from the analysis of sensitivity to a stock-recruitment relationship when recruitment is, in fact, independent of spawning biomass (Figure 5.2).

The historical time series of exploitation rates, spawning biomass, and summary biomasses relative to the MSY reference points are shown in Figure 5.3a. The fishing mortality has generally been below that corresponding to the MSY, except for the period before 1982 and during 2004-2007 (Figure 5.4a). The spawning biomass has generally been above the level corresponding to MSY, except during the low-productivity regime prior to 1984, and the years since 2004 except for 2008 and 2009. According to the base case assessment, the most recent estimate indicates that the yellowfin stock in the EPO is overfished ($S<S_{MSY}$), but that overfishing is not taking place ($F>F_{MSY}$). The high precision of this most recent estimate, as indicated by its narrow approximate confidence intervals (Figure 5.3a), does not allow for other interpretations of stock status under the base case assumptions. However, the stock status interpretation is sensitive to the assumptions made about the steepness parameter of the stock-recruitment relationship and the average size of the older fish (Table 5.1).

5.3. Comparisons with previous assessments

Estimates of management quantities are compared to estimates from previous assessments in Figure 5.4b. This figure simply takes the estimates of each management quantity from each previous stock assessment and plots them. The estimates differ because each consecutive year has additional data, because of the mix of fishing effort by gear and the total changes over time, because recruitment changes over time, and because the assumptions used in the assessments can differ from year to year as the understanding of the stock dynamics improves. The estimates of MSY and the SBR corresponding to MSY (Figure 5.4b) are similar to those produced in the previous assessment. The estimates of the F multiplier and the recent level of SBR with respect to that of the MSY are lower than those from the previous assessment.

5.4. Impact of fishing methods

The estimation of 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 purse-seine fisheries, the unassociated fisheries, and finally the floating-object fisheries (Table 5.2). If an additional management objective is to maximize S_{MSY}, the order is similar, but with dolphin-associated purse-seine fisheries slightly better than longline. 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 more than double to achieve MSY.

MSY and S_{MSY} have been very stable during the model period (Figure 4.12b). 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 the fishing effort corresponding to MSY.

6. IMPACT OF ENVIRONMENTAL CONDITIONS

The apparent regime shift in productivity that began in 1984 and the recent lower level of productivity suggest alternative approaches to estimating MSY, as different regimes will give rise to different values for MSY (Maunder and Watters 2001). The MSY and spawning biomass corresponding to MSY are directly proportional to the average recruitment used, but the fishing mortality corresponding to MSY is not impacted. For example, if the average recruitment during 1985-2010 was used instead of during the whole time period, MSY and the spawning biomass corresponding to MSY would be increased. This would mean that greater yields would be possible, but the fishery would be overexploited (the current biomass does not change while the spawning biomass corresponding to MSY increases). If the most recent low average recruitment was used, the opposite would occur. An alternative approach is to calculate the dynamic SBR (dSBR) by comparing the index of spawning biomass with the index of spawning biomass simulated over time in the absence of fishing (Figure 4.8a). This approach takes the fluctuations of recruitment into consideration.

6.1. Sensitivity analyses

As shown in Table 5.1, including a stock-recruitment relationship in the stock assessment produces more pessimistic results, with the current spawning biomass being below that corresponding to MSY and fishing effort being higher than that corresponding to MSY. However, it increases the level of MSY that can be achieved. Fixing the mean size of the oldest age class to a lower value than that assumed in the base case (*e.g.*, 170 cm) produces more optimistic results, with the spawning biomass being at about the level corresponding to MSY and current effort being substantially below that level, but the level of MSY that can be obtained is about the same. In contrast, fixing the mean size of the oldest age class to a higher value than that assumed in the base case (*e.g.*,190 cm) produces more pessimistic results, with the spawning biomass being below that corresponding to MSY and current effort dropping below the level corresponding to MSY, but the level of MSY that can be obtained changes little. The sensitivity analyses showed that fitting more closely to the CPUE data of the northern dolphin-associated fishery (CV fixed at 0.2), rather than taking the CPUE of the southern longline fishery as the main index of abundance, produces a more optimistic assessment of the status of the stock. While the recent spawning biomass is estimated to be about the level corresponding to MSY, the recent levels of fishing effort are estimated to be well below those corresponding to MSY.

6.2. Summary of stock status

The SBR of yellowfin in the EPO was below the level corresponding to MSY during the lower productivity regime of 1975-1983), but above that level for most of the following years, except for the recent period (2004-2007 and 2010). The 1984 increase in the SBR is attributed to the regime change, and the recent decrease may be a reversion to an lower productivity regime. The two different productivity regimes may support two different MSY levels and associated SBR levels. The SBR at the start of 2011 was estimated to be at 0.18, below the level corresponding to MSY (0.25).. The effort levels are estimated to be less than those that would support MSY (based on the current distribution of effort among the different fisheries), and recent catches are substantially below MSY.

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 level corresponding to MSY.

If a stock-recruitment relationship is assumed, the outlook is more pessimistic, and current effort is estimated to be above the level corresponding to MSY. The status of the stock is also sensitive to the value assumed for the average size of the oldest fish. If the CPUE of the northern dolphin-associated fishery is assumed to be the most reliable index of abundance, instead of the CPUE of the southern longline fishery, the current spawning stock biomass is estimated to be at about the level corresponding to MSY.

7. SIMULATED EFFECTS OF FUTURE FISHING OPERATIONS

A simulation study was conducted to gain further understanding of 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.

7.1. Assumptions about fishing operations

7.1.1. Fishing effort

Future projection studies were carried out to investigate the influence of different levels of fishing effort on biomass and catch. The projected fishing mortality was based on the averages during 2008-2010.

The scenarios investigated were:

1. Quarterly fishing mortality for each year in the future equal to the average for 2008-2010;
2. Quarterly fishing mortality for each year in the future set to that corresponding to MSY.

7.2. Results of the simulation

The simulations were used to predict future levels of the SBR, total biomass, and the total catch taken by the surface (purse-seine) fisheries. There is probably more uncertainty in the future levels of these outcome variables than is suggested by the results presented in Figures 6.1-6.3. 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 of variation in catchability.

These simulations were carried out using the average recruitment during 1975-2010. If they had been carried out using the average recruitment during 1984-2001, the projected trend in SBR and catches would have been more positive. Conversely, if they had been carried out with the average recruitment during 2002-2010, the projected trend in SBR and catches would have been more negative.

7.2.1. Current effort levels

Under current levels of fishing mortality (2008-2010), the spawning biomass is predicted to rebuild, and remain above the level corresponding to MSY (Figure 6.1). 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 catches will be greater over the near term than in 2010, but will decline slightly in the future (Figure 6.3).

7.2.2. Fishing at F_{MSY}

Fishing at F_{msy} is predicted to reduce the spawning biomass slightly from that with current effort (Figure 6.2) and produces slightly greater catches (Figure 6.3).

7.3. Summary of the simulation results

Under current levels of fishing mortality (2008-2010), the spawning biomass is predicted to rebuild and remain above the level corresponding to MSY. However, the confidence intervals are wide, and there is a moderate probability that the SBR will be substantially above or below this level. Fishing at F_{msy} is predicted to reduce the spawning biomass slightly from that under current effort and produces slightly higher catches, particularly for the longline fishery.

8. FUTURE DIRECTIONS

8.1. 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.

8.2. Refinements to the assessment model and methods

The IATTC staff will continue developing the Sock Synthesis assessment model for yellowfin tuna in the EPO. Much of the progress will depend on how the software is modified in the future. The following improvements will be explored in future assessments:

1. Determine appropriate weighting of the different data sets;
2. Explore alternative assumptions on stock structure (spatial analysis);
3. Time-variant selectivity for the floating-object purse-seine fisheries.
4. More robust selectivity curves.

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Many IATTC and member country staff provided data for the assessment. Richard Deriso, Patrick Tomlinson, IATTC staff members, and member country scientists provided advice on the stock assessment, fisheries, and biology of yellowfin tuna. William Bayliff and Nicholas Webb provided editorial assistance and Nicholas Webb translated the report to Spanish. Christine Patnode provided graphical assistance.

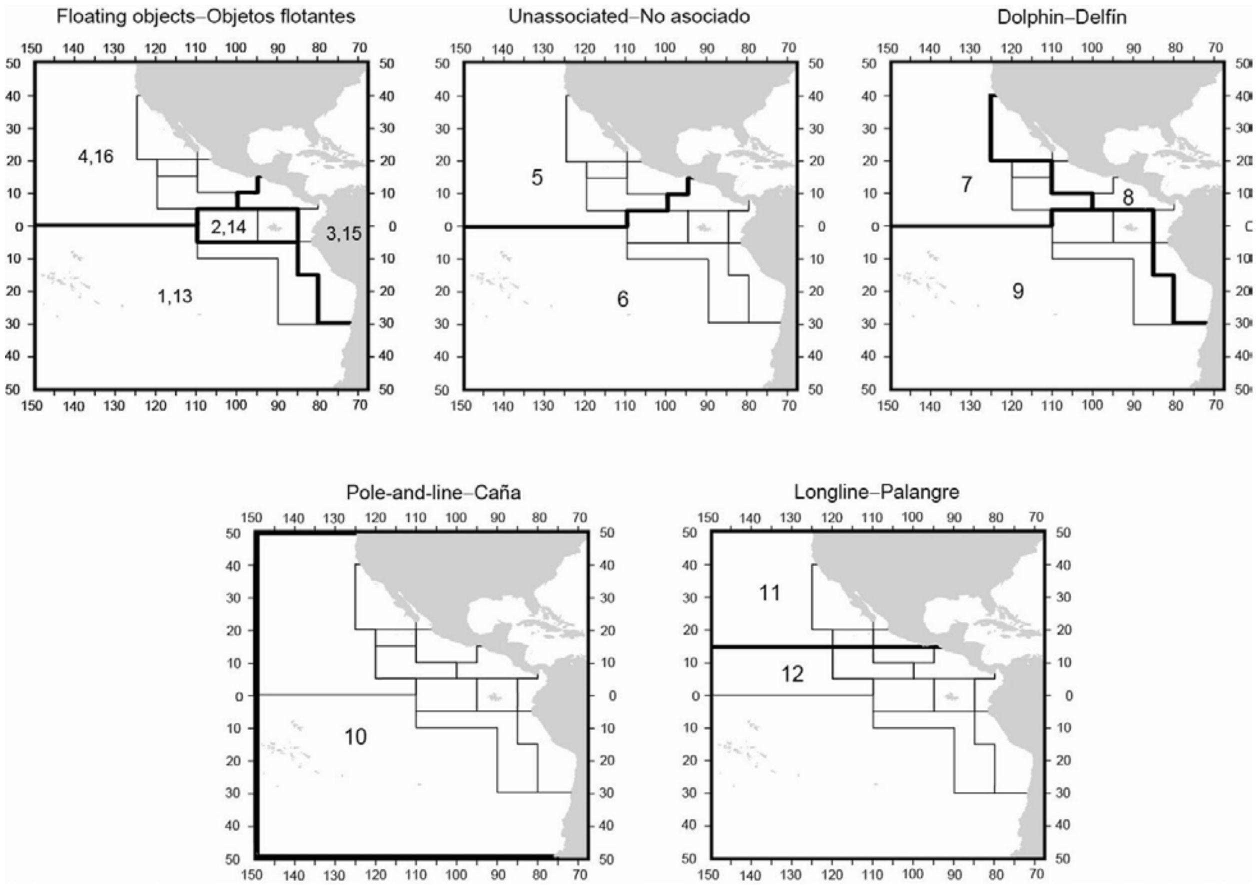

FIGURE 2.1. Spatial extents of the fisheries defined by the IATTC staff for the stock assessment of yellowfin tuna in the EPO. The thin lines indicate the boundaries of 13 length-frequency sampling areas, the bold lines the boundaries of each fishery defined for the stock assessment, and the bold numbers 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 de la población, y los números en negritas las pesquerías correspondientes a estos últimos límites. En la Tabla 2.1 se describen las pesquerías.

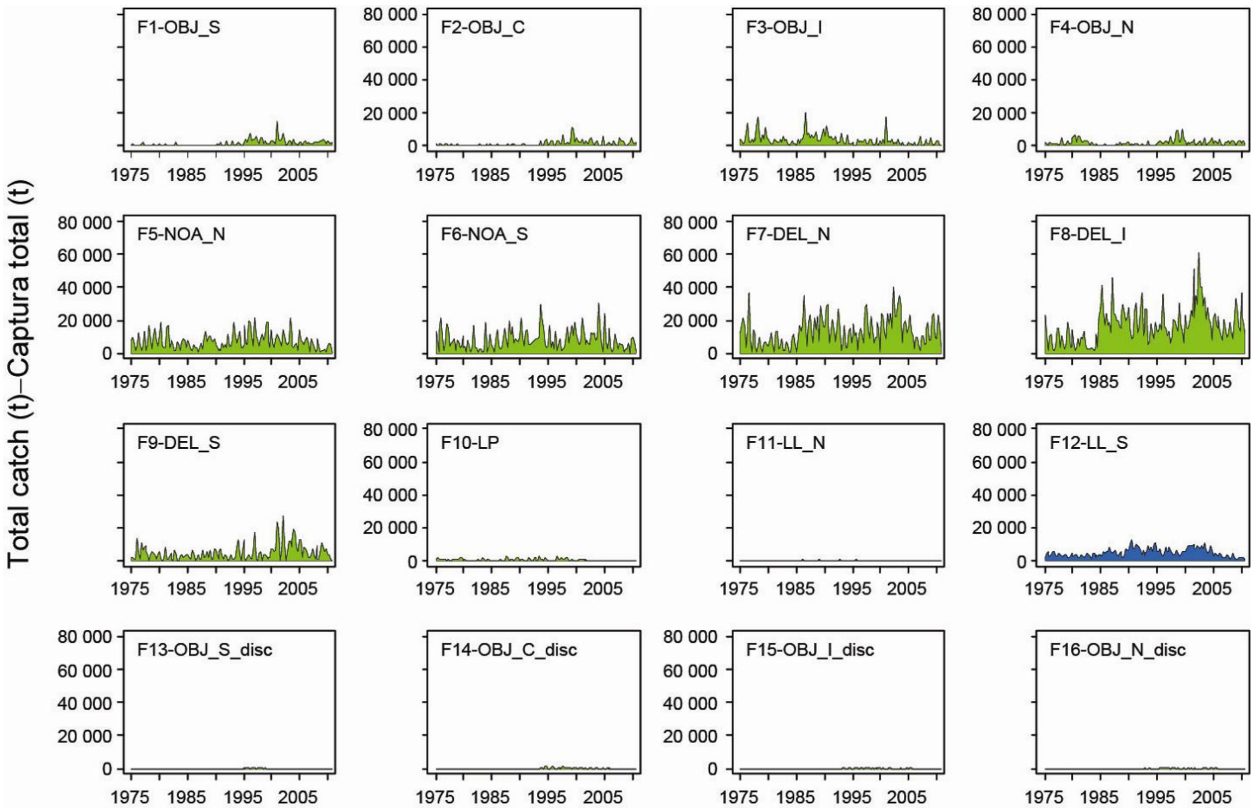

FIGURE 2.2a. Quarterly catches by the fisheries defined for the stock assessment of yellowfin tuna in the EPO (Table 2.1). Since the data were analyzed on a quarterly basis, there are four observations of catch for each year. Although all the catches are displayed as weights, the stock assessment model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

FIGURA 2.2a. Capturas trimestrales de las pesquerías definidas para la evaluación de la población del 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 de la población usa captura en número de peces para las Pesquerías 11 y 12. Las capturas en peso de las Pesquerías 11 y 12 son estimadas internamente por *Stock Synthesis*, multiplicando las capturas en número de peces por estimaciones del peso promedio.

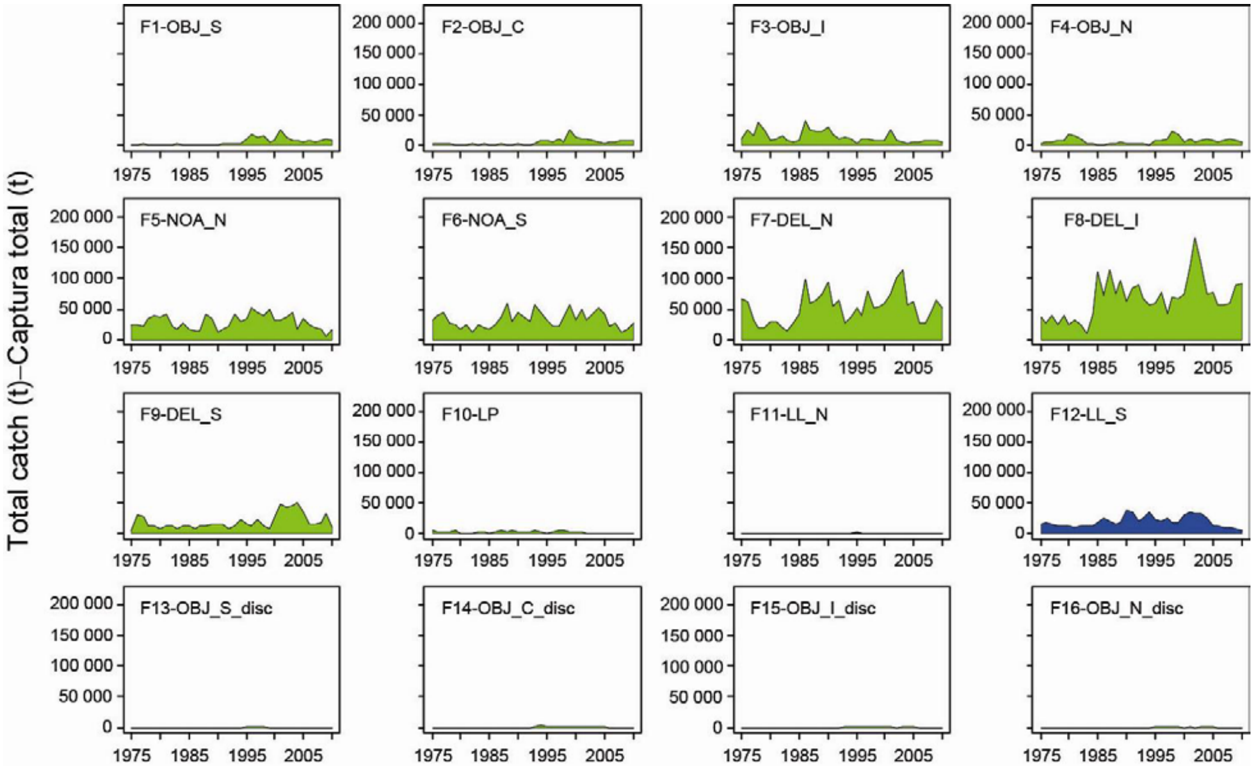

FIGURE 2.2b. Annual catches by the fisheries defined for the stock assessment of yellowfin tuna in the EPO (Table 2.1). Although all the catches are displayed as weights, the stock assessment model uses catches in numbers of fish for Fisheries 11 and 12. Catches in weight for Fisheries 11 and 12 are estimated internally by Stock Synthesis by multiplying the catches in numbers of fish by estimates of the average weights.

FIGURA 2.2b. Capturas anuales de las pesquerías definidas para la evaluación de la población del atún aleta amarilla en el OPO (Tabla 2.1). Aunque se expresan todas las capturas en peso, el modelo de evaluación de poblaciones usa captura en número de peces para las Pesquerías 11 y 12. Las capturas en peso de las Pesquerías 11 y 12 son estimadas internamente por *Stock Synthesis*, multiplicando las capturas en número de peces por estimaciones del peso promedio.

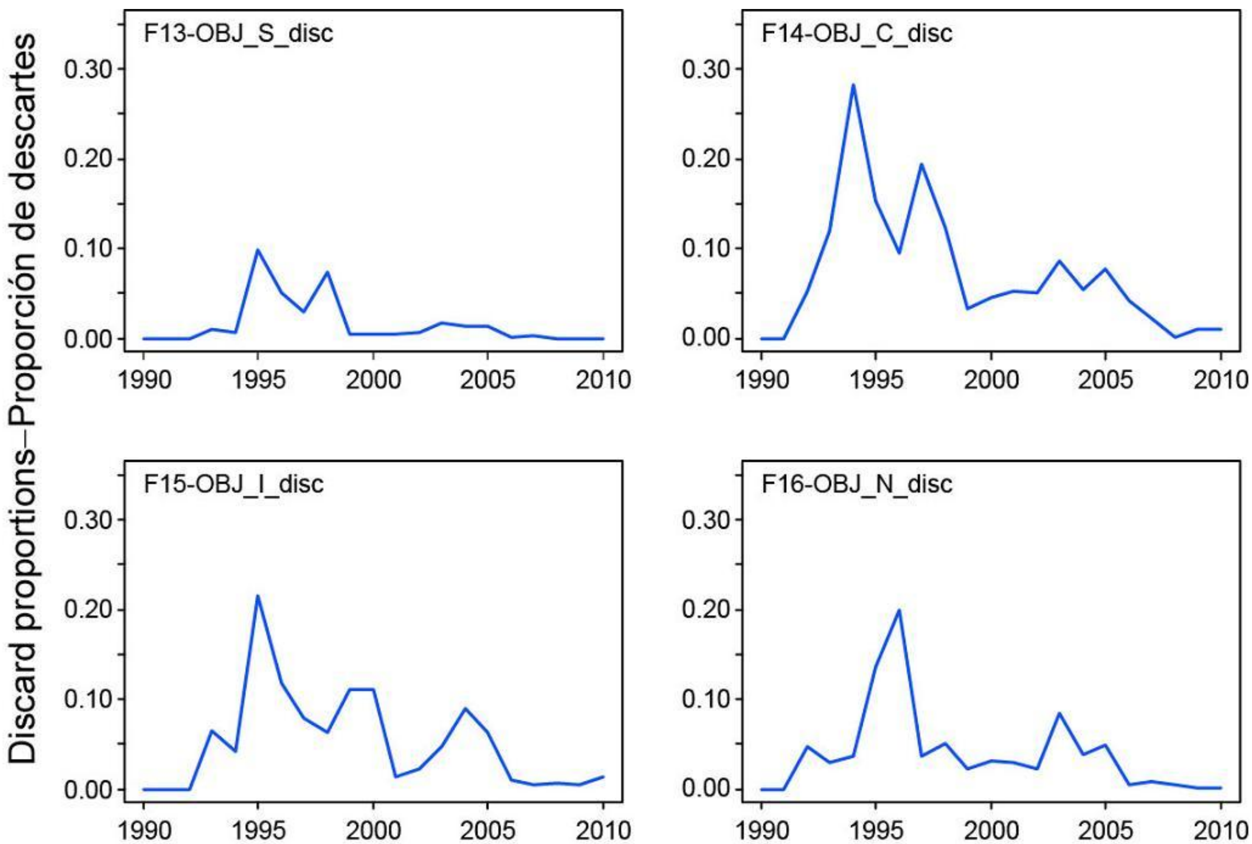

FIGURE 2.3. Weights of discarded yellowfin tuna as proportions of the total (retained plus discarded) annual catches for the four floating-object fisheries. Fisheries 1-4 are the 'real' fisheries, and Fisheries 13-16 are the corresponding discard fisheries. The numbers in the panels correspond to the numbers designating the fisheries in Table 2.1.

FIGURA 2.3. Pesos de atún aleta amarilla descartado como proporciones de las capturas anuales totales (retenidas más descartadas) de las cuatro pesquerías sobre objetos flotantes. Las Pesquerías 1-4 son las pesquerías 'reales', y las Pesquerías 13-16 son las pesquerías de descarte correspondientes. Los números en los paneles corresponden a los números que designan las pesquerías en la Tabla 2.1.

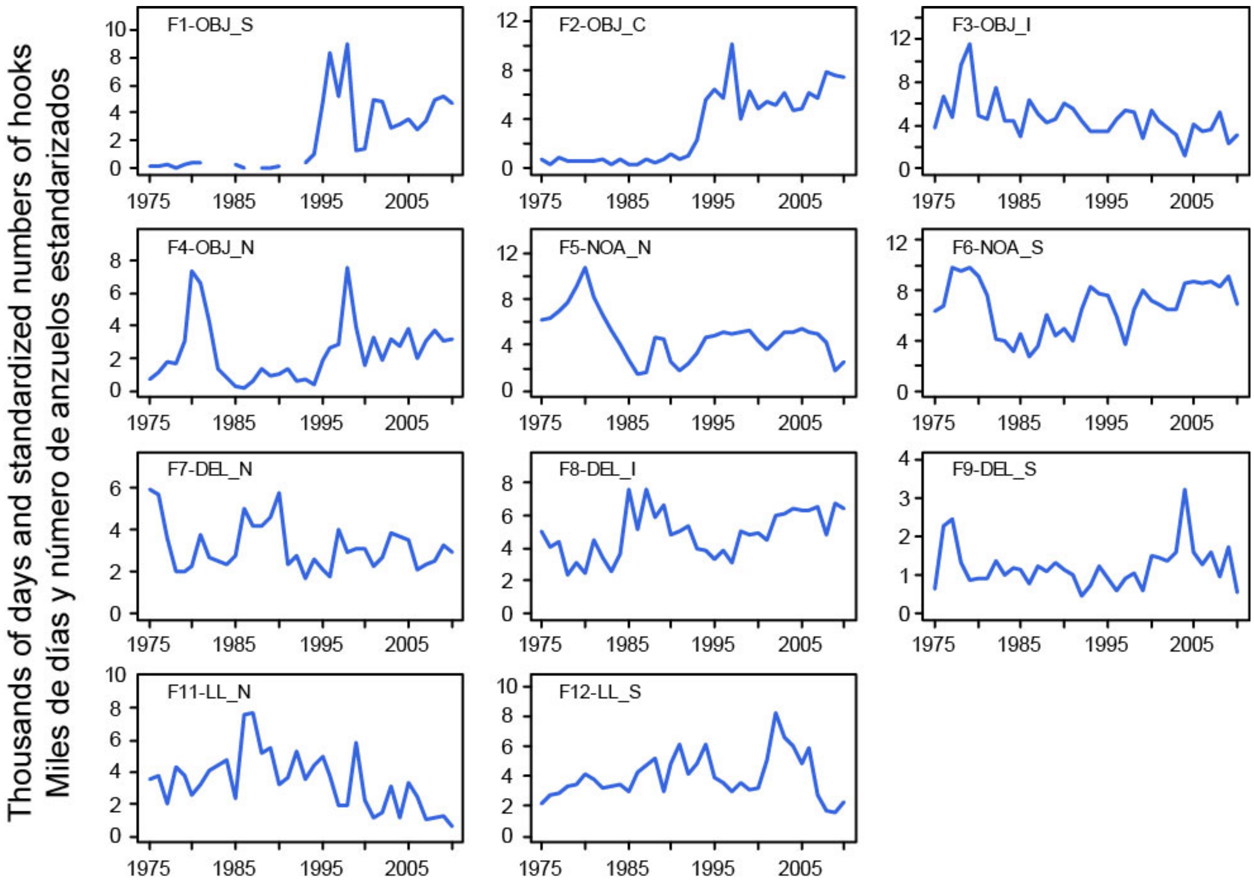

FIGURE 2.4. Annual fishing effort exerted by the fisheries defined for the stock assessment of yellowfin tuna in the EPO (Table 2.1). The effort for Fisheries 1-10 and 13-16 is in days fished, and that for Fisheries 11 and 12 is in standardized numbers of hooks. Fishing effort for the discard fisheries (13-16) is that of their corresponding 'real' fisheries' (1-4). Note that the vertical scales of the panels are different. The numbers in the panels correspond to the numbers designating the fisheries in Table 2.1.

FIGURA 2.4. Esfuerzo de pesca anual ejercido por las pesquerías definidas para la evaluación de la población de atún aleta amarilla en el OPO (Tabla 2.1). 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 de anzuelos estandarizados. Nótese que las escalas verticales de los recuadros son diferentes. Los números de los paneles corresponde a los números que designan las pesquerías en la Tabla 2.1.

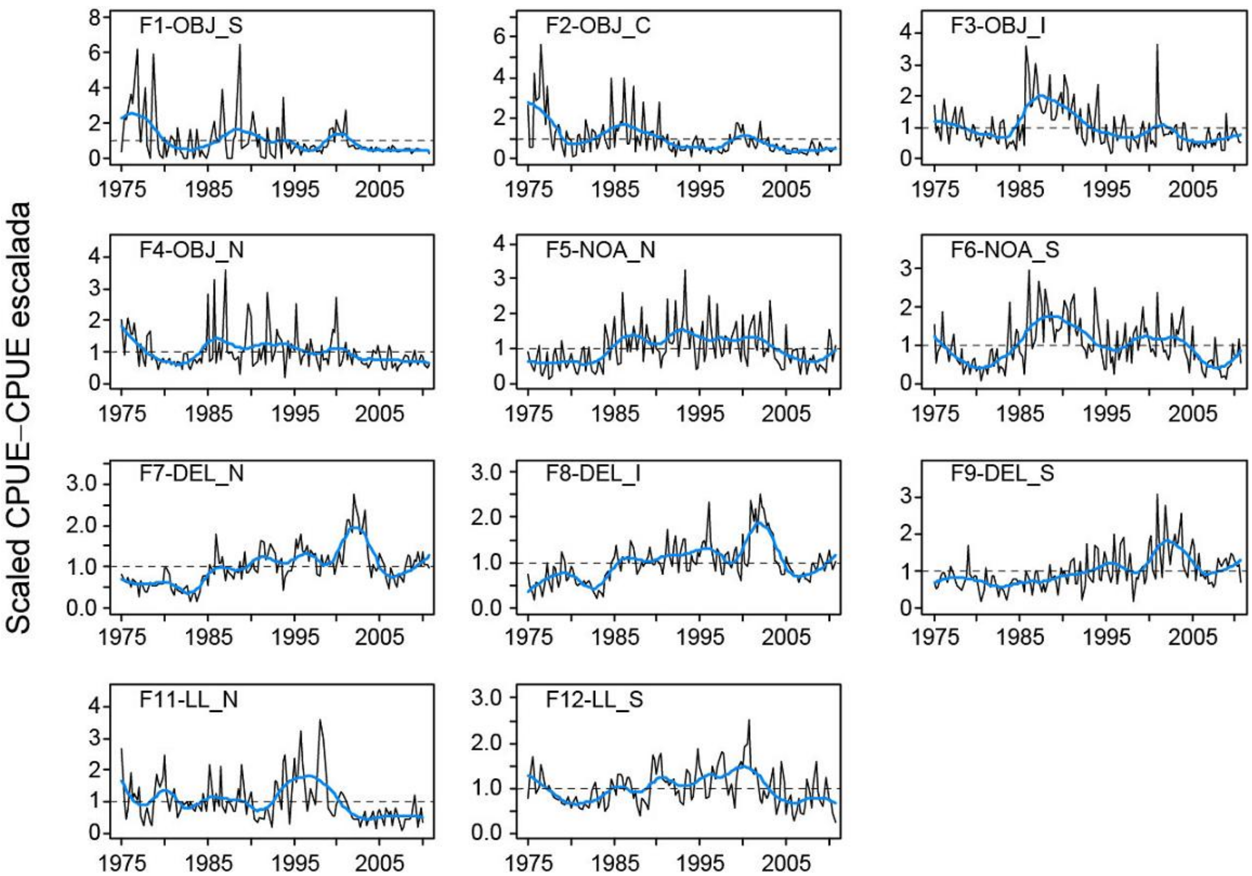

FIGURE 2.5. Quarterly CPUEs for the fisheries defined for the stock assessment of yellowfin tuna in the EPO (Table 2.1). Since the data were summarized on a quarterly basis, there are four observations of CPUE for each year. The CPUEs for Fisheries 1-9 are in tons per day fished, and those for Fisheries 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. The thick line is a smoother to illustrate the general CPUE trend.

FIGURA 2.5. CPUE trimestrales 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 a 9 en toneladas por día de pesca, y las de las Pesquerías 11 y 12 en unidades estandarizadas basadas en el 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. La línea gruesa representa un suavizador para ilustrar la tendencia general de la CPUE.

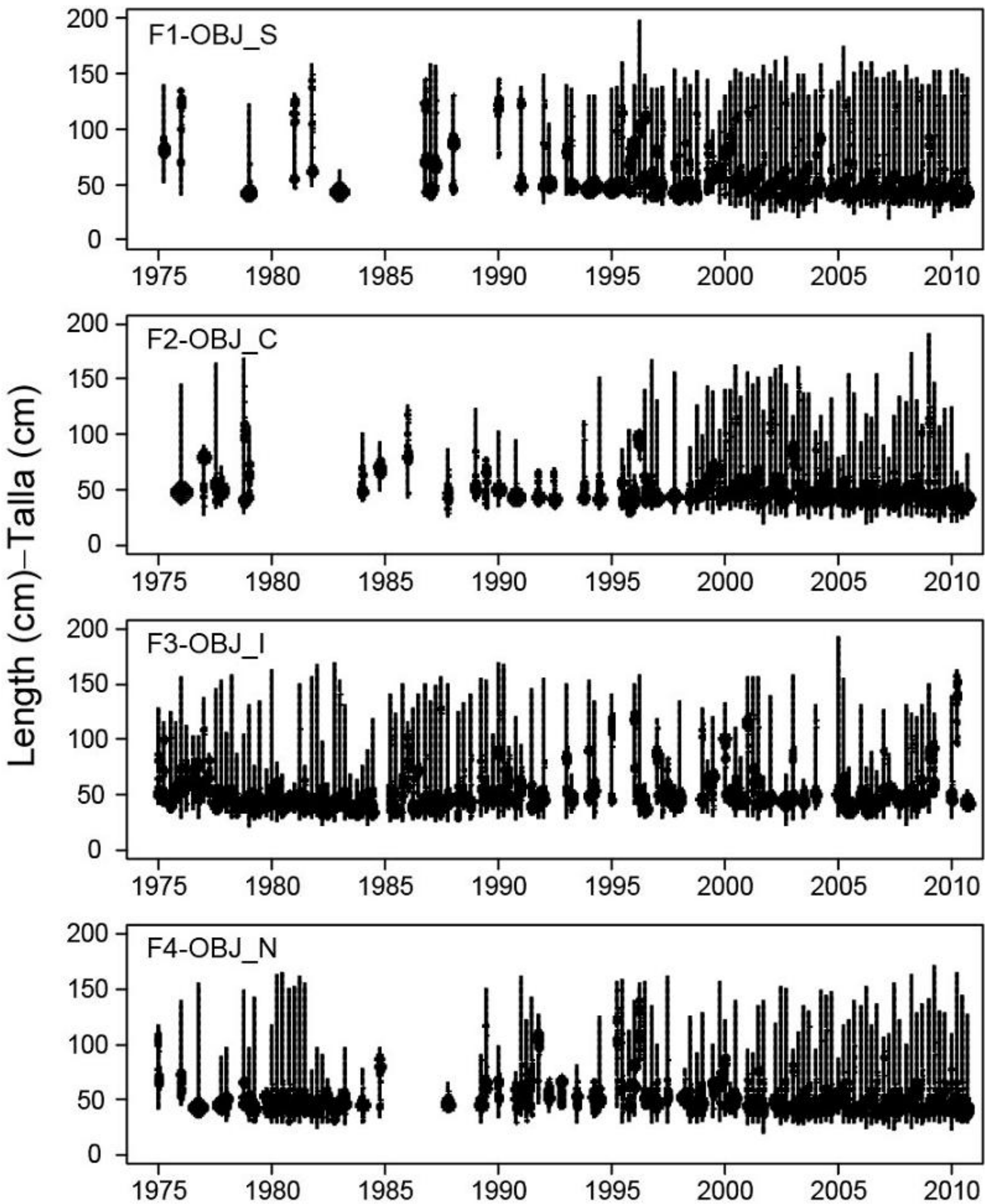

FIGURE 2.6a. Observed length compositions of the catches of yellowfin tuna taken by the floating-object fisheries, by quarter. The areas of the circles are proportional to the catches.
FIGURA 2.6a. Composición por talla observada de las capturas de atún aleta amarilla por las pesquerías sobre objetos flotantes, por trimestre. El tamaño de los círculos es proporcional a las capturas.

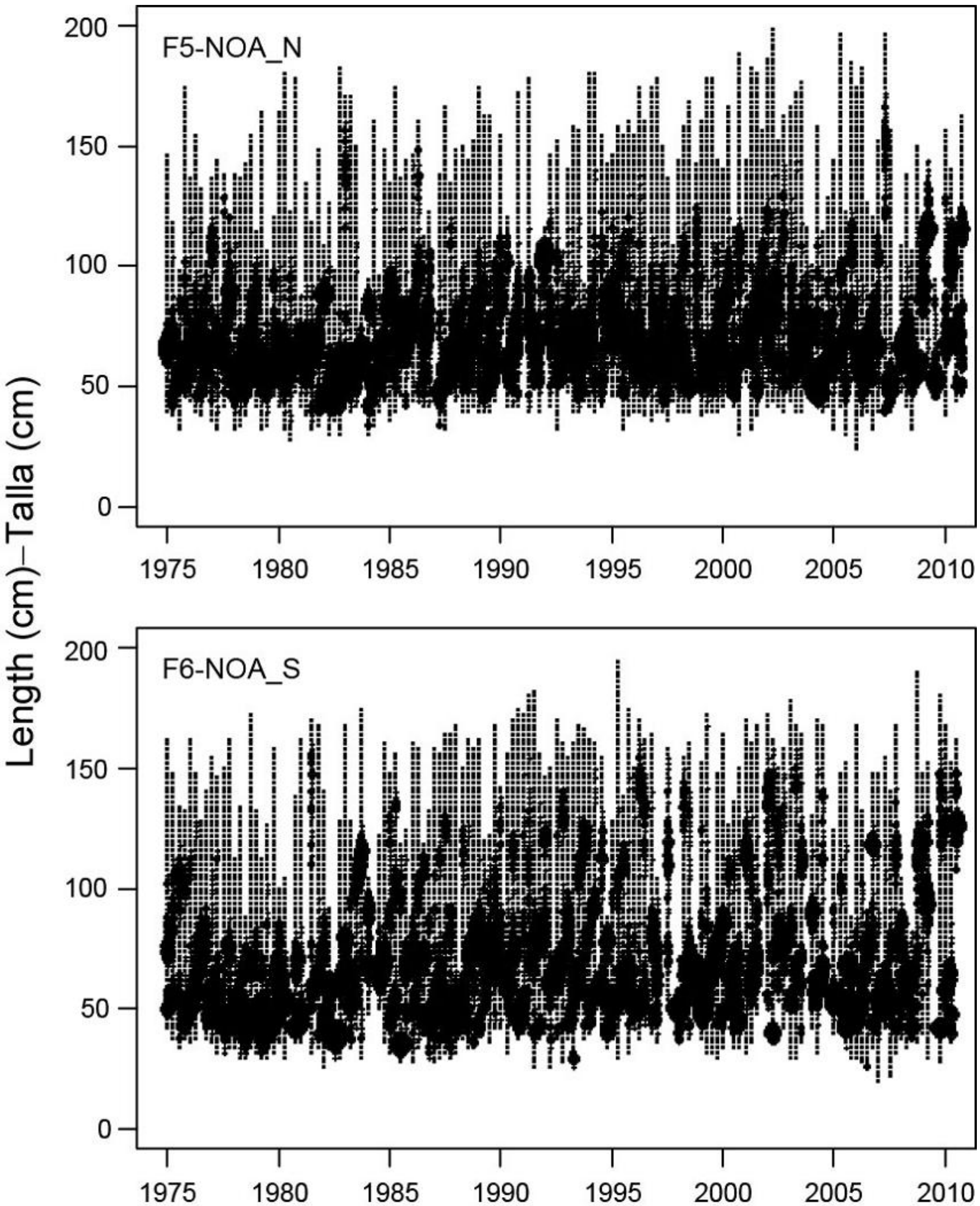

FIGURE 2.6b. Observed length compositions of the catches of yellowfin tuna taken by the unassociated fisheries, by quarter. The areas of the circles are proportional to the catches.
FIGURA 2.6b. Composición por talla observada de las capturas de atún aleta amarilla por las pesquerías no asociadas, por trimestre. El tamaño de los círculos es proporcional a las capturas.

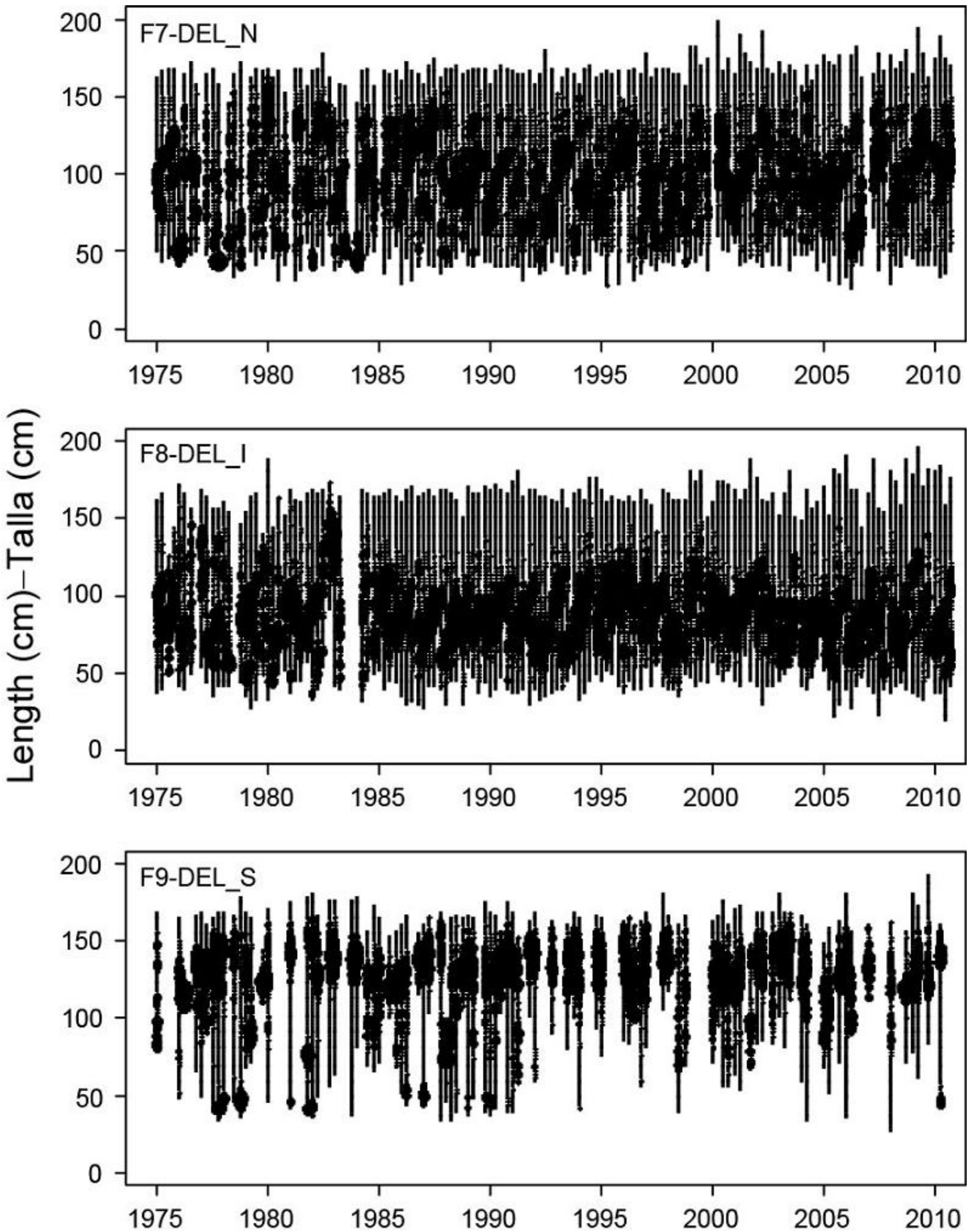

FIGURE 2.6c. Observed length compositions of the catches of yellowfin tuna taken by the dolphin-associated purse-seine fisheries, by quarter. The areas of the circles are proportional to the catches.
FIGURA 2.6c. Composición por talla observada de las capturas de atún aleta amarilla por las pesquerías de cerco asociadas con delfines, por trimestre. El tamaño de los círculos es proporcional a las capturas.

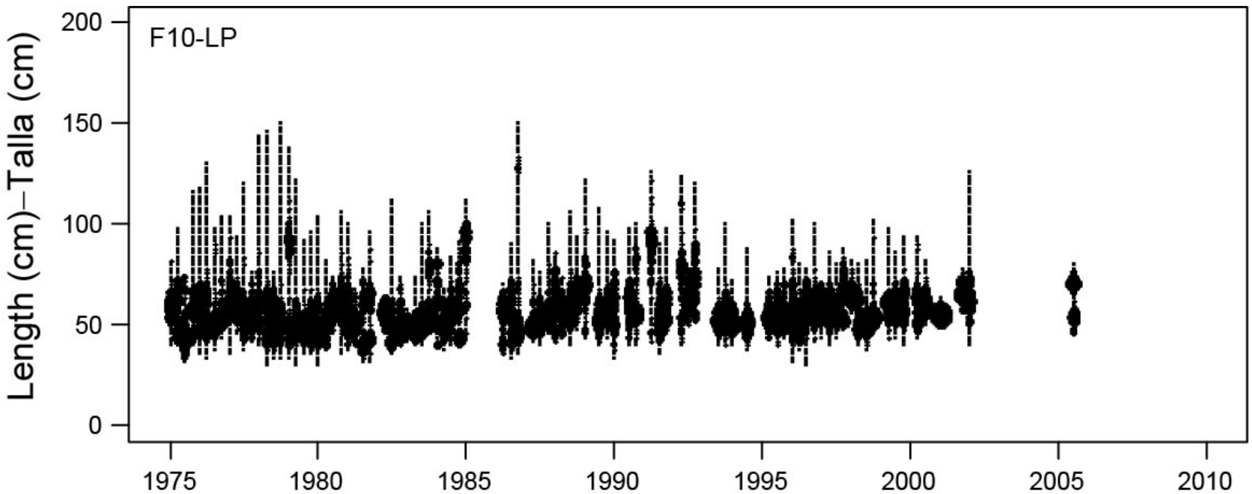

FIGURE 2.6d. Observed length compositions of the catches of yellowfin tuna taken by the pole-and-line fishery, by quarter. The areas of the circles are proportional to the catches.
FIGURA 2.6d. Composición por talla observada de las capturas de atún aleta amarilla por la pesquería cañera, por trimestre. El tamaño de los círculos es proporcional a las capturas.

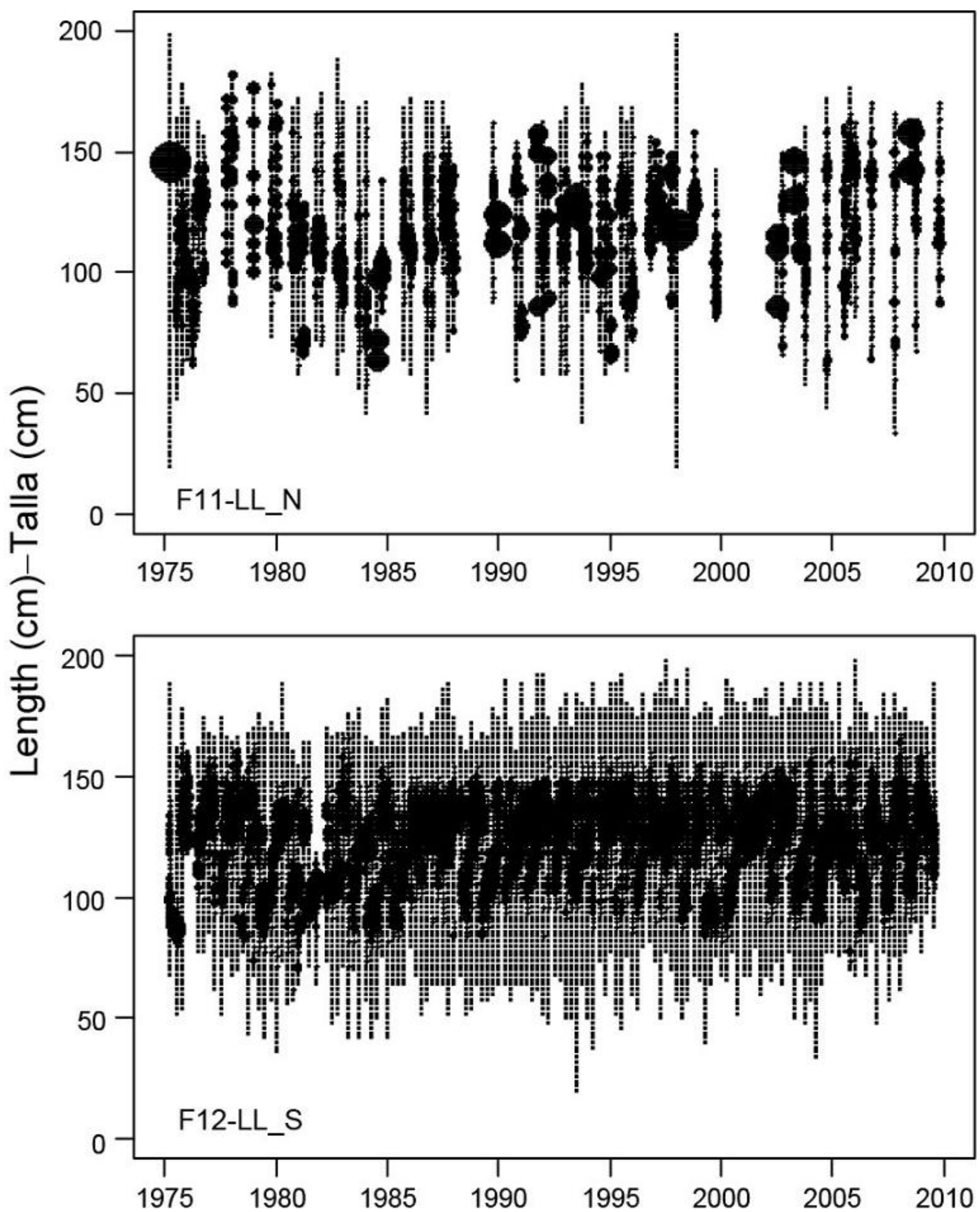

FIGURE 2.6e. Observed length compositions of the catches of yellowfin tuna taken by the longline fisheries, by quarter. The areas of the circles are proportional to the catches.

FIGURA 2.6e. Composición por talla observada de las capturas de atún aleta amarilla por las pesquerías de palangre, por trimestre. El tamaño de los círculos es proporcional a las capturas.

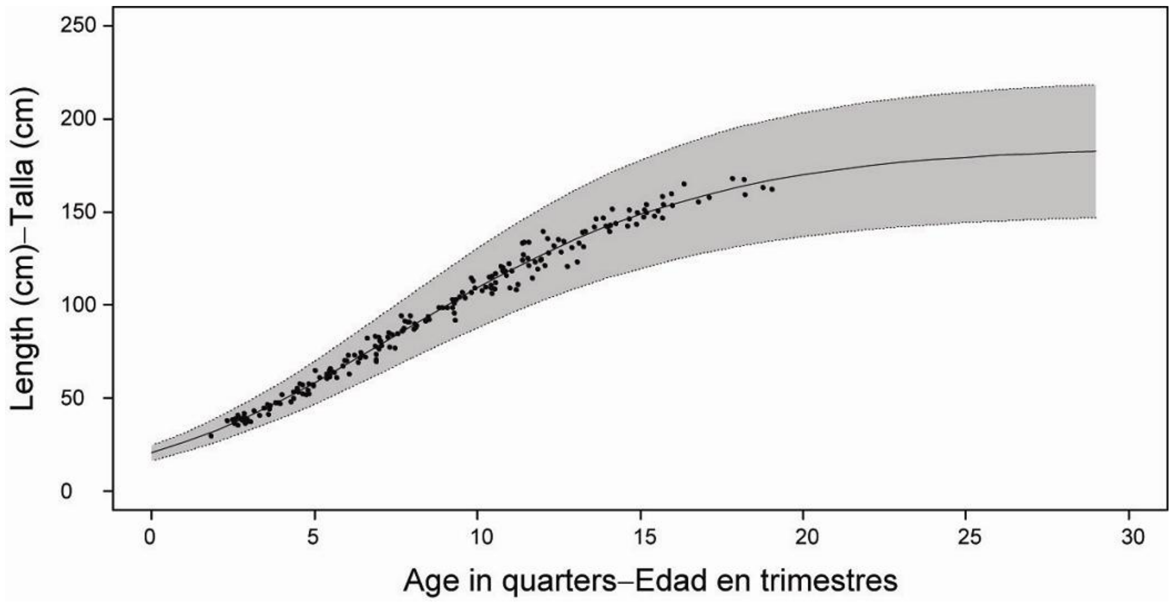

FIGURE 3.1. Growth curve estimated for the assessment of yellowfin tuna in the EPO. The points represent length-at-age data from otoliths (Wild 1986). The shaded region represents the assumed variation in length at age (± 2 standard deviations).
FIGURA 3.1. Curva de crecimiento estimada para la evaluación del atún aleta amarilla en el OPO. Los puntos representan los datos de talla por edad de otolitos (Wild 1986). La región sombreada representa la variación supuesta de la talla por edad (± 2 desviaciones estándar).

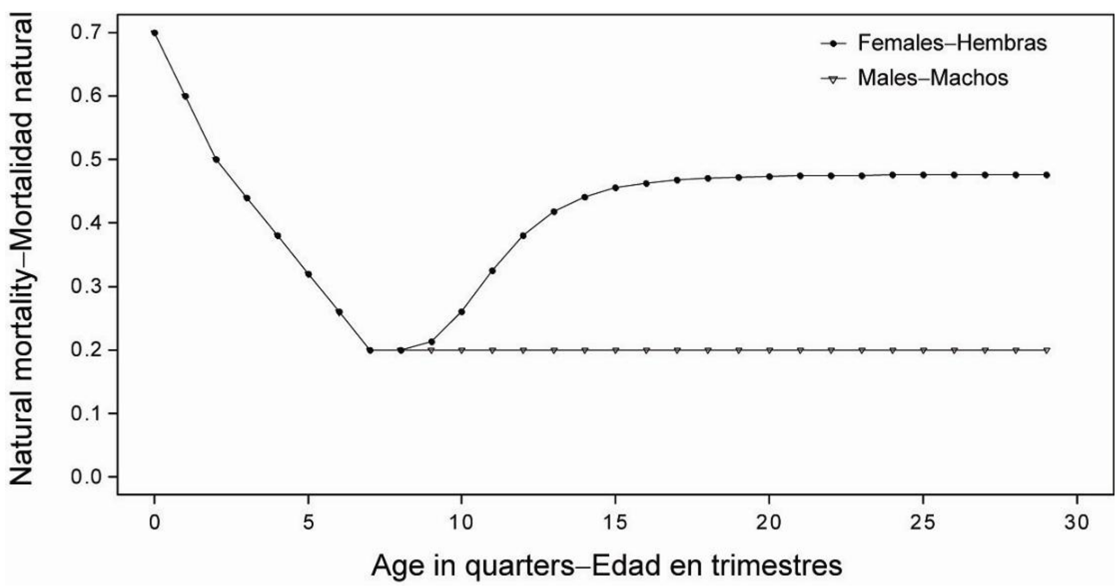

FIGURE 3.2. Rates of natural mortality (*M*) rates, at quarterly intervals, used for the assessment of yellowfin tuna in the EPO. Descriptions of the three phases of the mortality curve are provided in Section 3.1.2.
FIGURA 3.2. Tasas de mortalidad natural (*M*), por intervalo trimestral, usadas para la evaluación del atún aleta amarilla en el OPO. En la Sección 3.1.2 se describen las tres fases de la curva de mortalidad.

FIGURE 3.3. Relative fecundity-at-age curve (from Schaefer 1998) used to estimate the index of spawning biomass of yellowfin tuna in the EPO.
FIGURA 3.3. Curva de fecundidad relativa por edad (de Schaefer 1998) usada para estimar el índice de biomasa reproductora del atún aleta amarilla en el OPO.

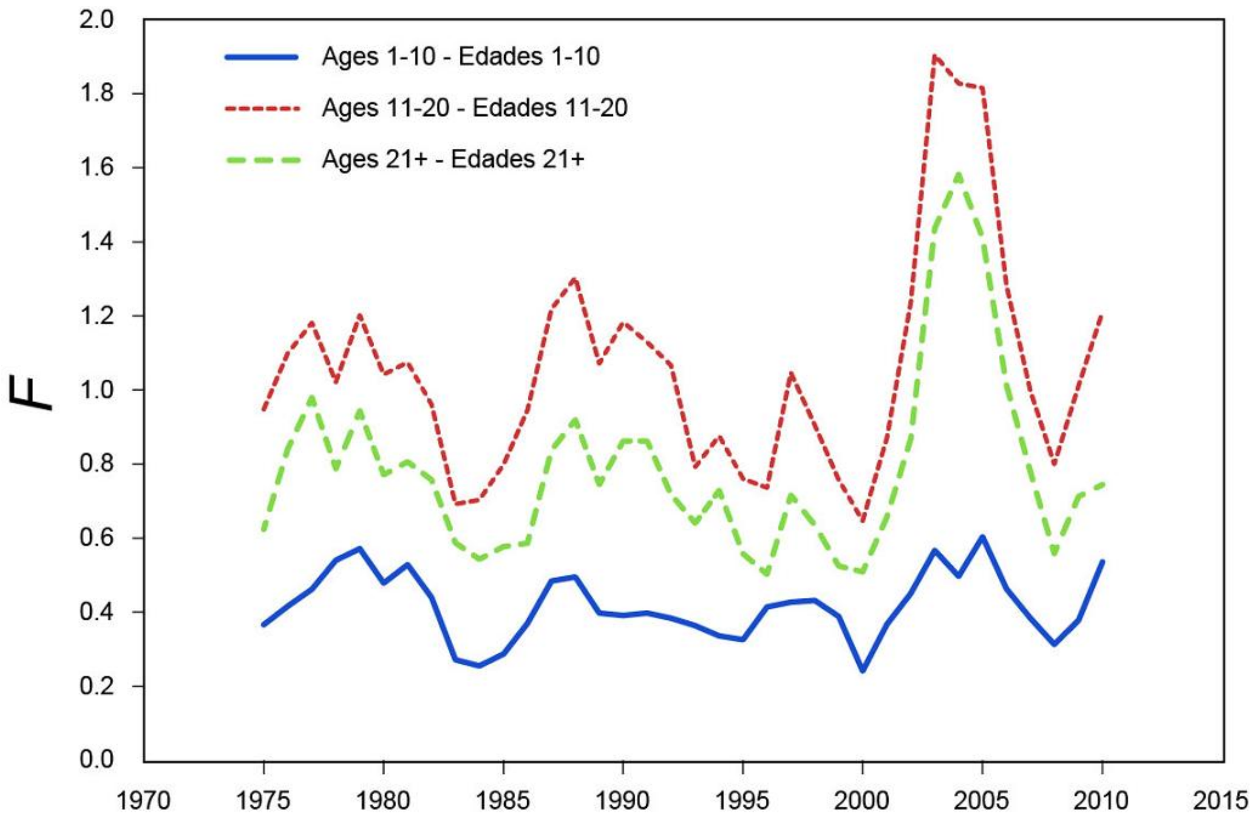

FIGURE 4.1. Average annual fishing mortality (*F*) by age groups, by all gears, of yellowfin tuna recruited to the fisheries of the EPO. The age groups are defined by age in quarters.

FIGURA 4.1. Mortalidad por pesca (*F*) anual media, por grupo de edad, por todas las artes, de atún aleta amarilla reclutado a las pesquerías del OPO. Se definen los grupos de edad por edad en trimestres.

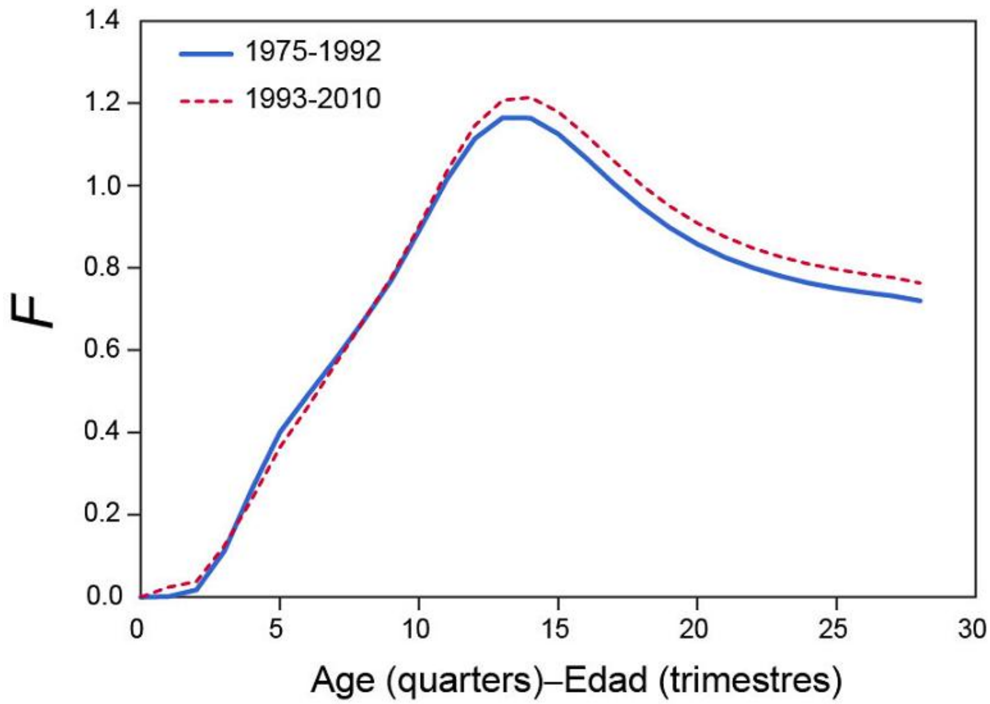

FIGURE 4.2a. Average annual fishing mortality (*F*) of yellowfin tuna by age in the EPO, by all gears. The estimates are presented for two periods, before and after the increase in effort associated with floating objects.

FIGURA 4.2a. Mortalidad por pesca (*F*) anual media de atún aleta amarilla por edad en el OPO, por todas las artes. Se presentan estimaciones para dos períodos, antes y después del aumento del esfuerzo asociado con objetos flotantes.

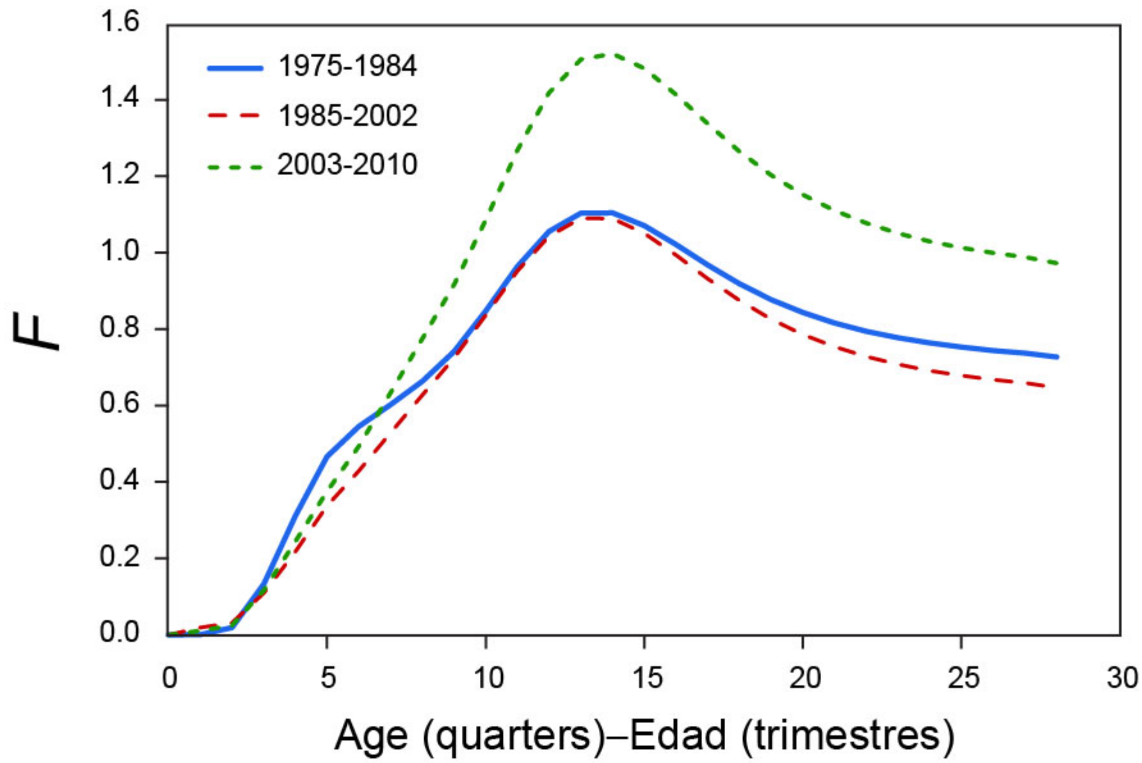

FIGURE 4.2b. Average annual fishing mortality (*F*) of yellowfin tuna by age in the EPO, by all gears. The estimates are presented for three periods corresponding to possible productivity regimes.

FIGURA 4.2b. Mortalidad por pesca (*F*) anual media de atún aleta amarilla por edad en el OPO, por todas las artes. Se presentan estimaciones para tres períodos correspondientes a posibles regímenes de productividad.

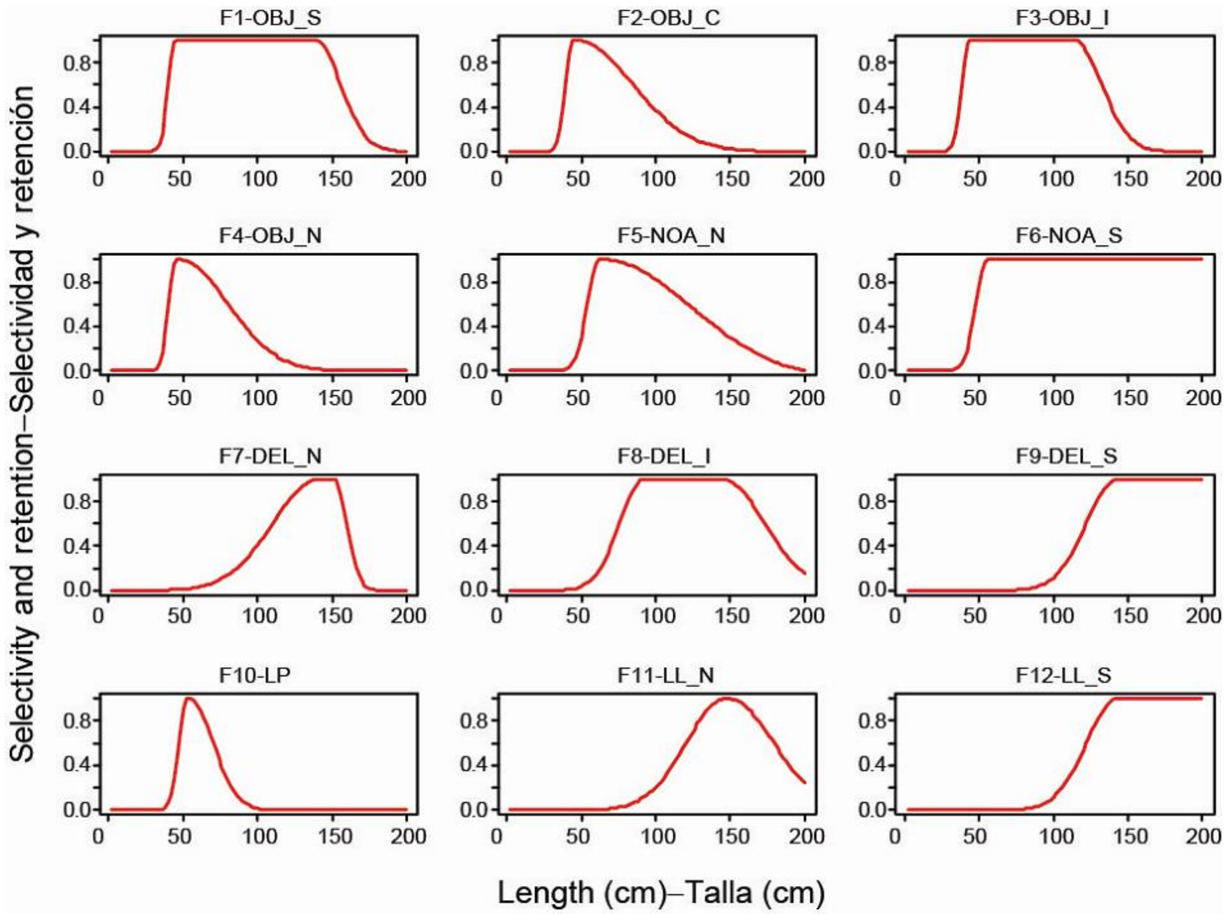

FIGURE 4.3. Selectivity curves for 12 of the 16 fisheries that catch yellowfin tuna in the EPO. The selectivity curves for the discard fisheries (Fisheries 13-16) are fixed at assumed values.

FIGURA 4.3. Curvas de selectividad para 12 de las 16 pesquerías que capturan atún aleta amarilla en el OPO. Se fijan las curvas de selectividad de las pesquerías de descartes (Pesquerías 13-16) en valores supuestos.

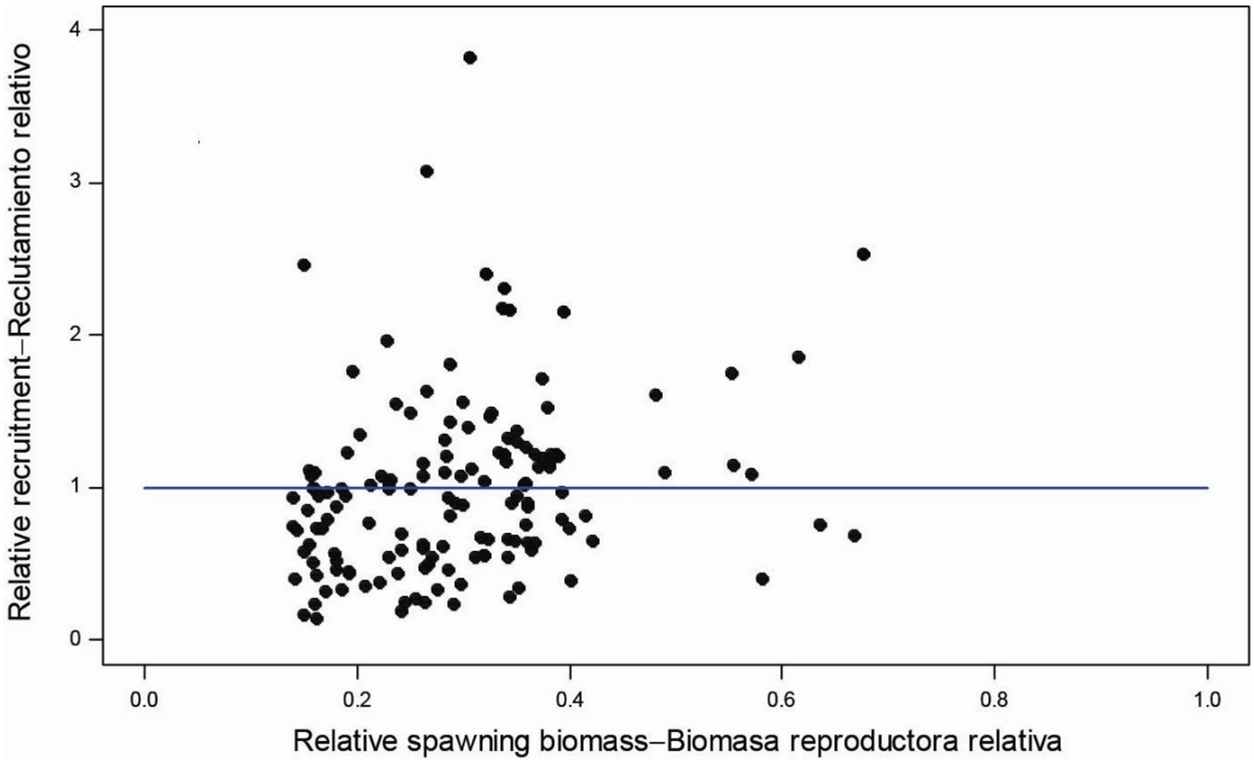

FIGURE 4.4. Estimated relationship between recruitment and spawning biomass of yellowfin tuna. The recruitment is scaled so that the average recruitment is equal to 1.0. The spawning biomass is scaled so that the average unexploited spawning biomass is equal to 1.0.

FIGURA 4.4. 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.

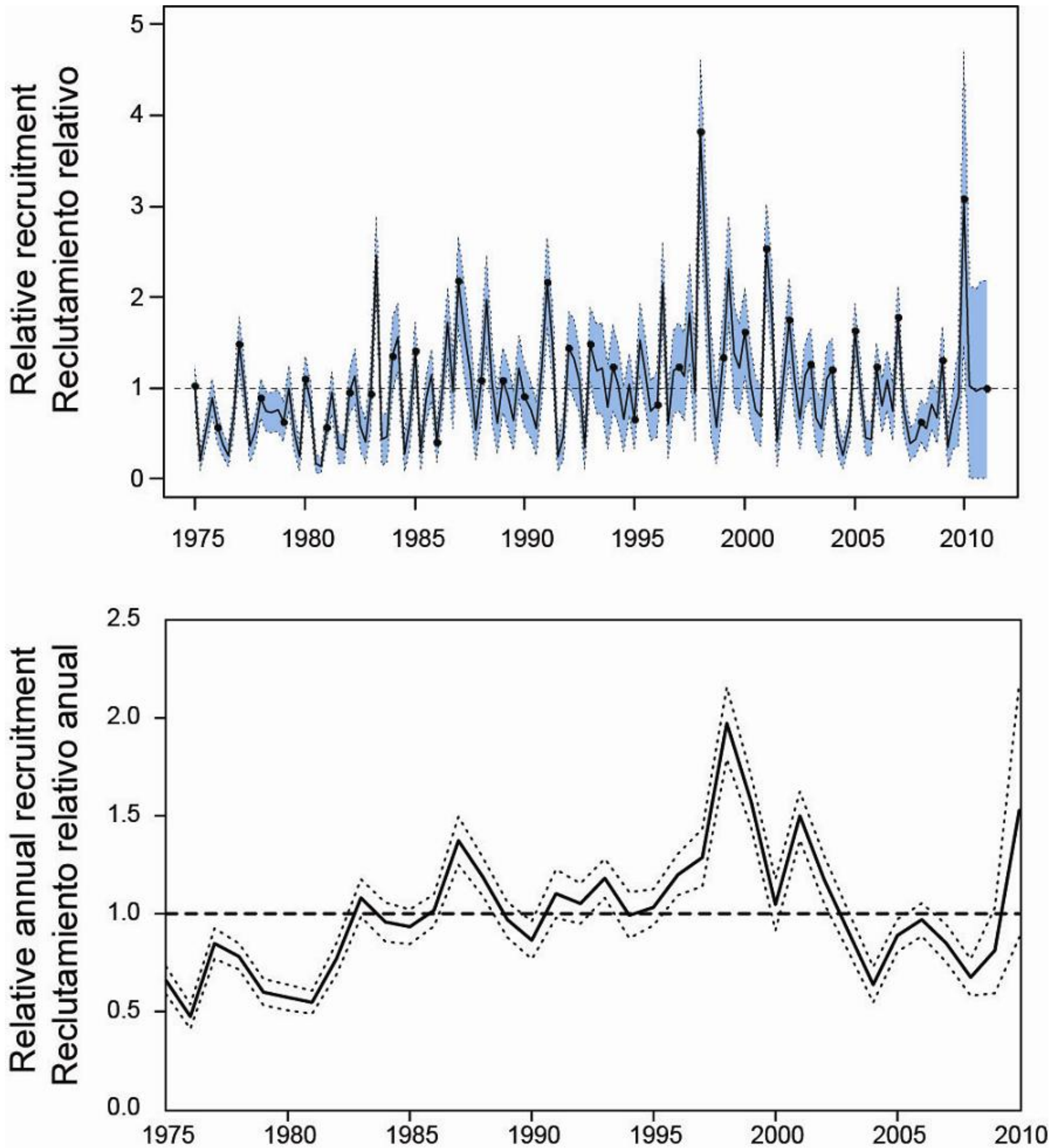

FIGURE 4.5. Estimated recruitment of yellowfin tuna to the fisheries of the EPO: a) quarterly recruitment; b) annual recruitment. The estimates are scaled so that the average recruitment is equal to 1.0 (dashed horizontal line). The bold line illustrates the maximum likelihood estimates of recruitment, 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 in the quarterly recruitmet figure a).

FIGURA 4.5. Reclutamiento (a) trimestral y (b) anual 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.

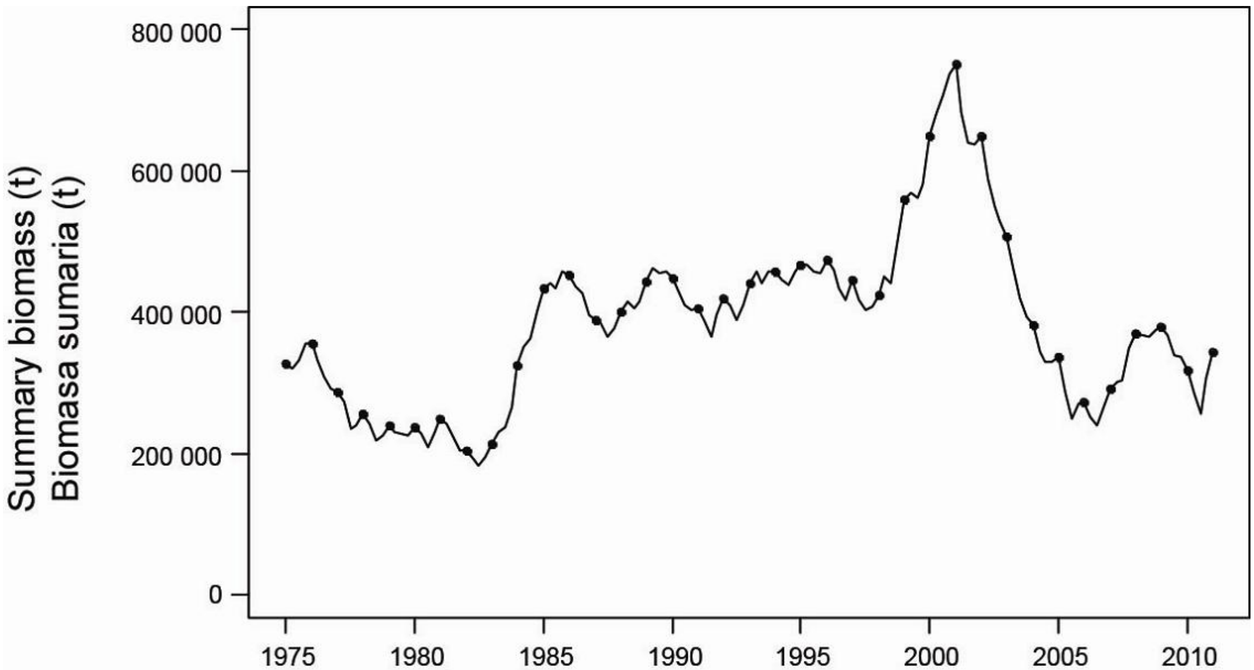

FIGURE 4.6. Estimated biomass of yellowfin tuna aged three quarters and older in the EPO. The line illustrates the maximum likelihood estimates of the biomass. Since the assessment model represents time on a quarterly basis, there are four estimates of biomass for each year.

FIGURA 4.6. Biomasa estimada de atún aleta amarilla de tres trimestres y más de edad en el OPO. La línea ilustra las estimaciones de verosimilitud máxima de la biomasa. Ya que el modelo de evaluación representa el tiempo por trimestres, hay cuatro estimaciones de biomasa para cada año.

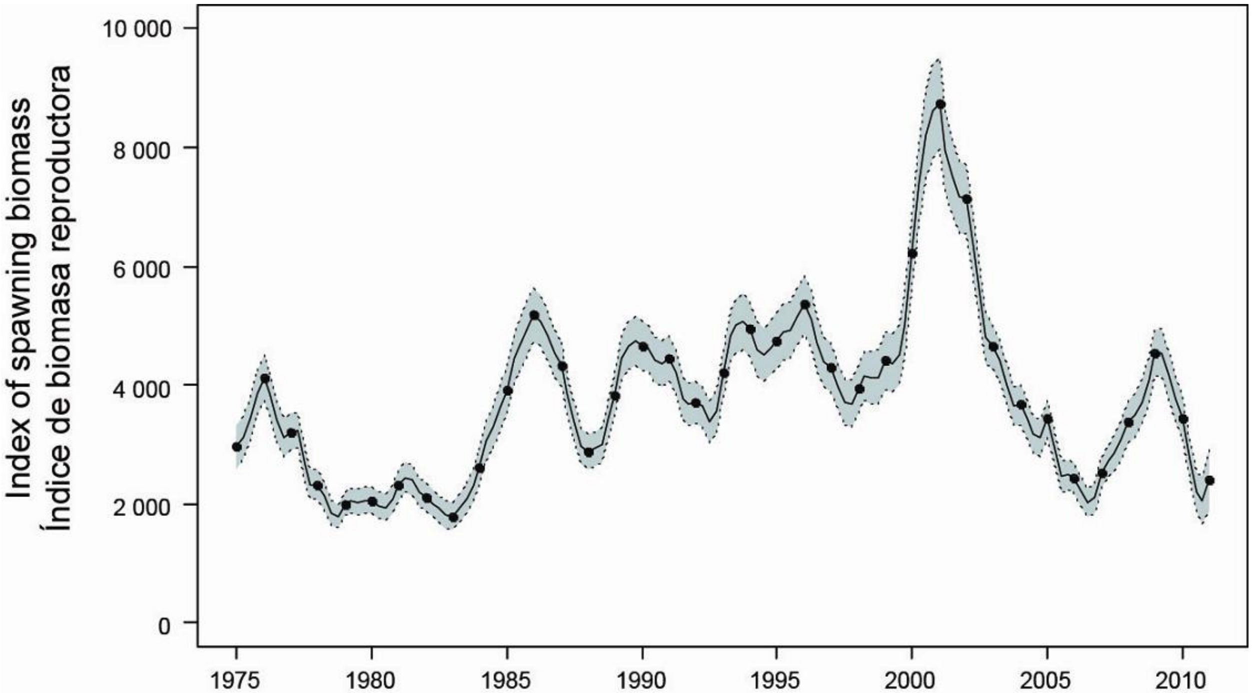

FIGURE 4.7. Estimated index of spawning biomass of yellowfin tuna in the EPO. The solid line illustrates the maximum likelihood estimates of the biomass, and the dashed lines the approximate 95% confidence intervals around those estimates. Since the assessment model represents time on a quarterly basis, there are four estimates of biomass for each year.
FIGURA 4.7. Índice estimado de la biomasa reproductora del atún aleta amarilla en el OPO. La línea sólida ilustra las estimaciones de verosimilitud máxima de la biomasa, y las líneas 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.

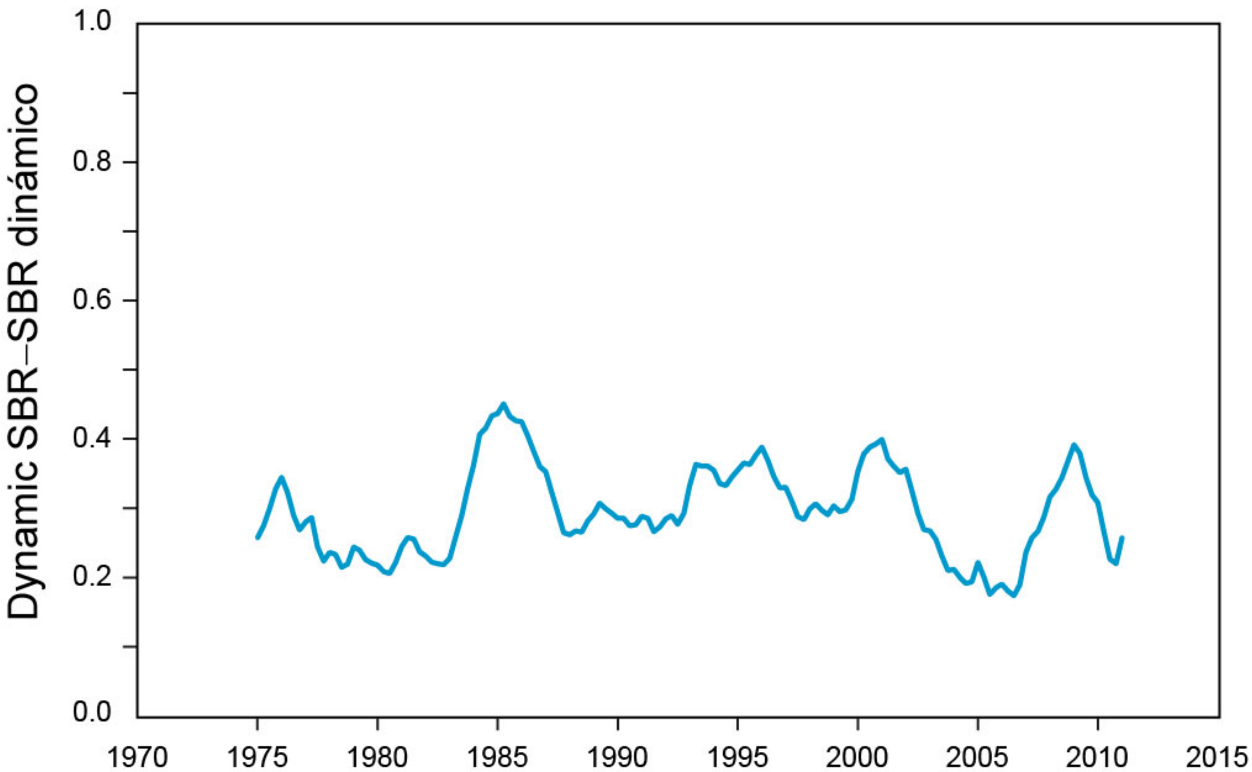

FIGURE 4.8a. Spawning biomass as a ratio of the trajectory of spawning biomass simulated from a population of yellowfin tuna that was never exploited. Dynamic SBR is the spawning biomass as a ratio of the unfished spawning biomass calculated by modeling the population over time in the absence of fishing.

FIGURA 4.8a. Biomasa reproductora como cociente de la trayectoria de la biomasa reproductora simulada de una población de atún aleta amarilla que nunca fue explotada. El SBR dinámico es la biomasa reproductora como cociente de la biomasa reproductora no explotada calculada mediante el modelado de la población a lo largo del tiempo en la ausencia de pesca.

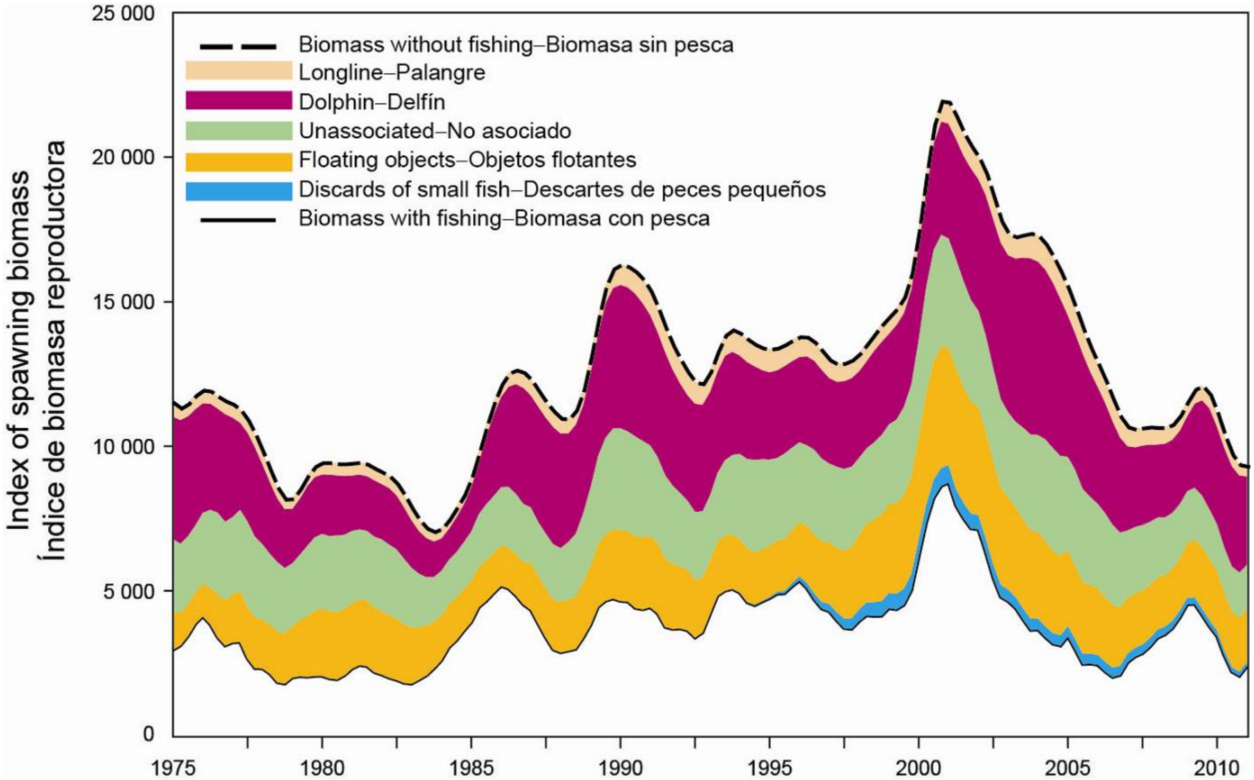

FIGURE 4.8b. Biomass trajectory of a simulated population of yellowfin tuna that was never exploited (dashed line) and that predicted by the stock assessment model (solid line). The shaded areas between the two lines show the portions of the fishery impact attributed to each fishing method.

FIGURA 4.8b. 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.

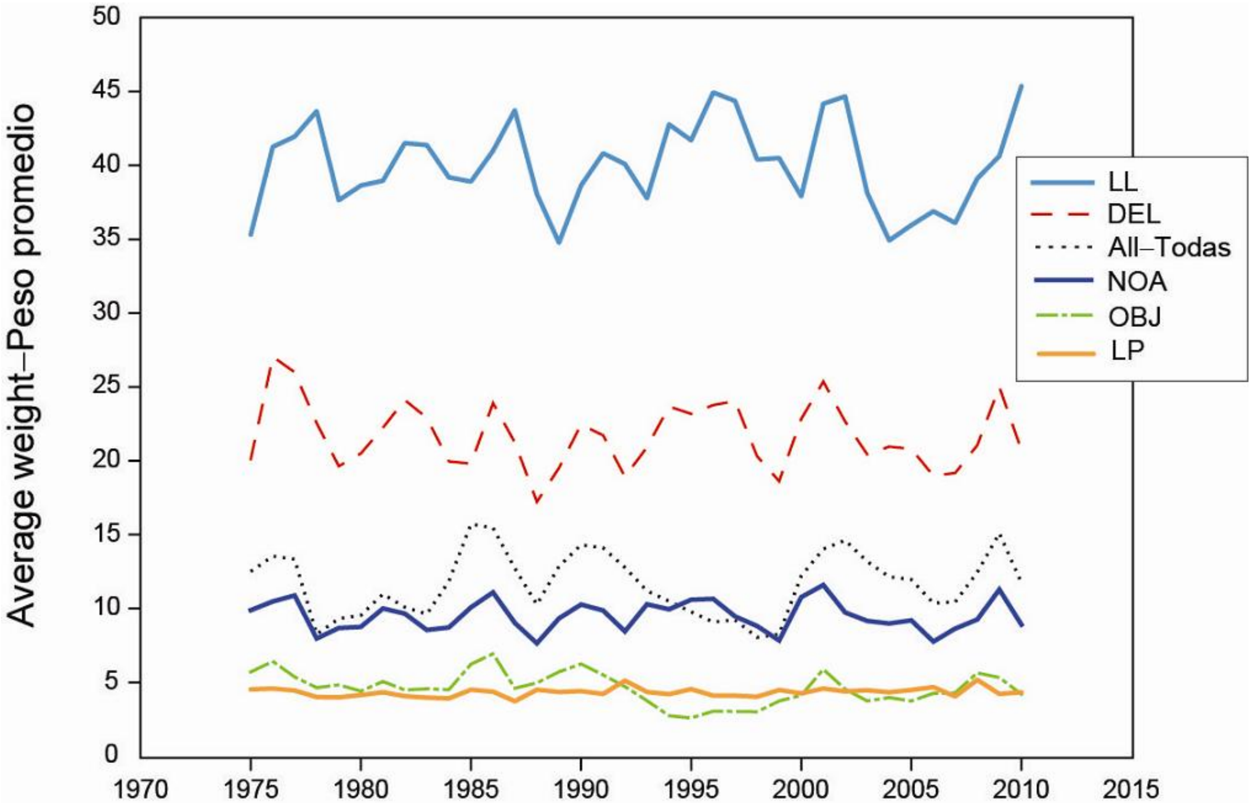

FIGURE 4.9. Estimated average weights of yellowfin tuna caught by the fisheries of the EPO (OBJ = purse-seine sets on floating objects; NOA = purse-seine sets on unassociated schools; DEL = purse-seine sets on schools associated with dolphins; LL = longline; All = all fisheries combined).

FIGURA 4.9. Peso promedio estimado de atún aleta amarilla capturado en las pesquerías del OPO. (OBJ = lances cerqueros sobre objetos flotantes; NOA = lances cerqueros sobre atunes no asociados; DEL = lances cerqueros sobre atunes asociados con delfines; LL = palangre; Todas = todas las pesquerías combinadas).

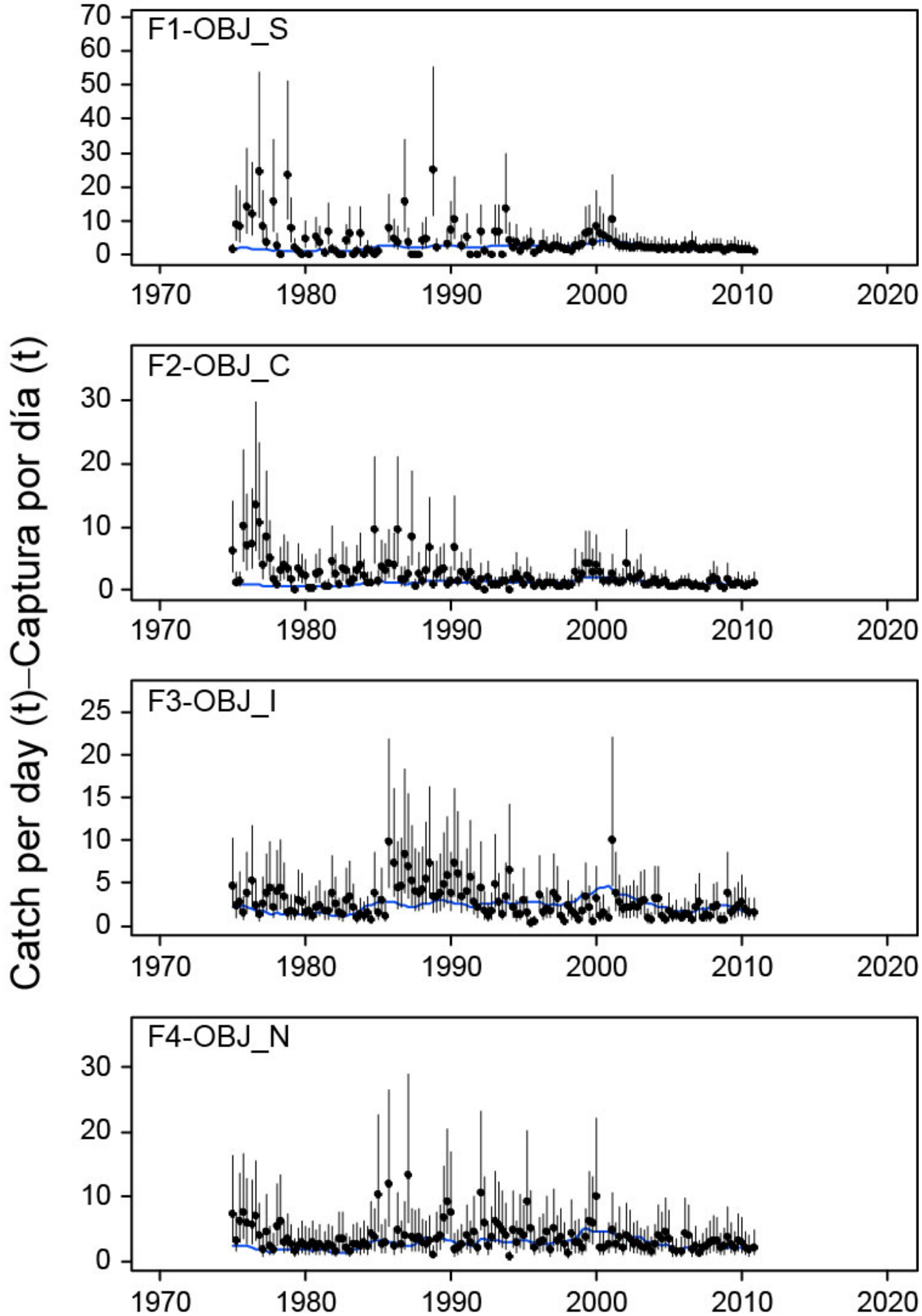

FIGURE 4.10a. Model fits to the CPUE-based indices of abundance for the floating-object fisheries. The vertical lines are the 95% confidence intervals for the observed data based on the internally-estimated standard deviations for the lognormal-based likelihood function.

FIGURA 4.10a. Ajustes a los índices de abundancia basados en CPUE correspondientes a las pesquerías sobre objetos flotantes. Las líneas verticales representan los intervalos de confianza de 95% correspondientes a los datos observados basados en las desviaciones estándar estimadas internamente para la función de verosimilitud basada en logaritmos normales.

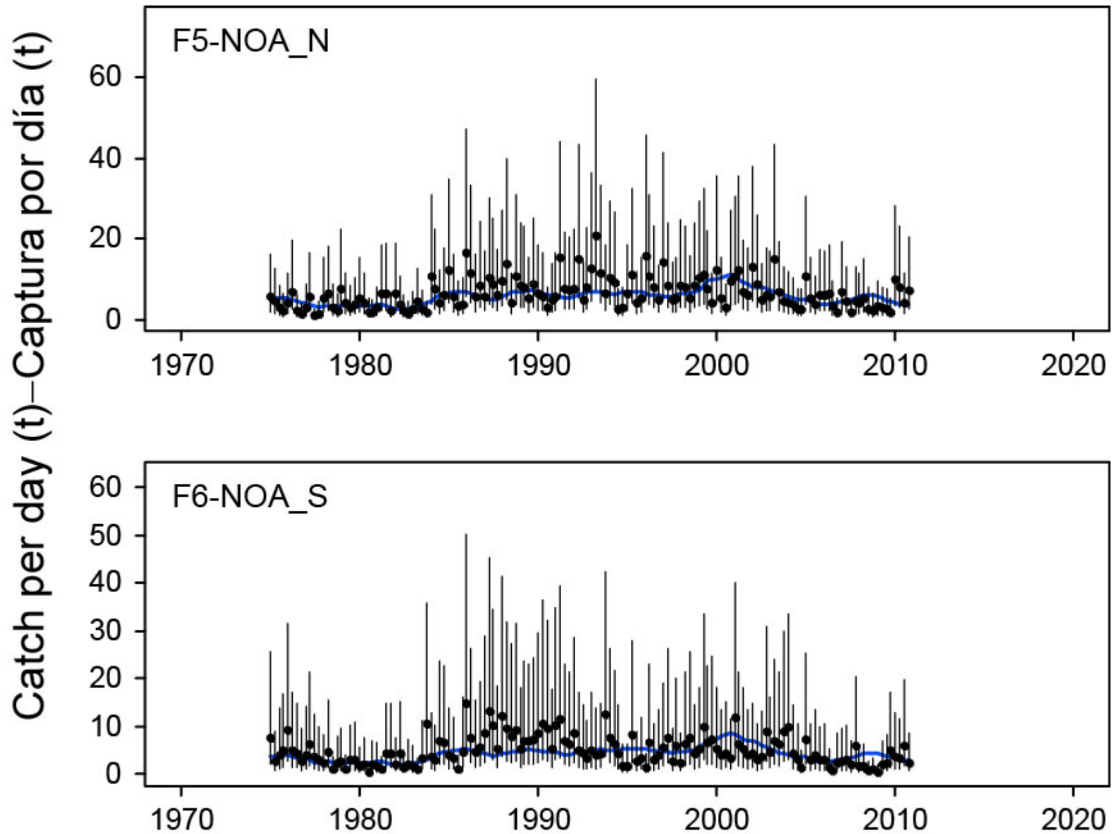

FIGURE 4.10b. Model fits to the CPUE based indices of abundance for the unassociated fisheries. The vertical lines are the 95% confidence intervals for the observed data based on the internally-estimated standard deviations for the lognormal-based likelihood function.

FIGURA 4.10b. Ajustes a los índices de abundancia basados en CPUE correspondientes a las pesquerías no asociadas. Las líneas verticales representan los intervalos de confianza de 95% correspondientes a los datos observados basados en las desviaciones estándar estimadas internamente para la función de verosimilitud basada en logaritmos normales.

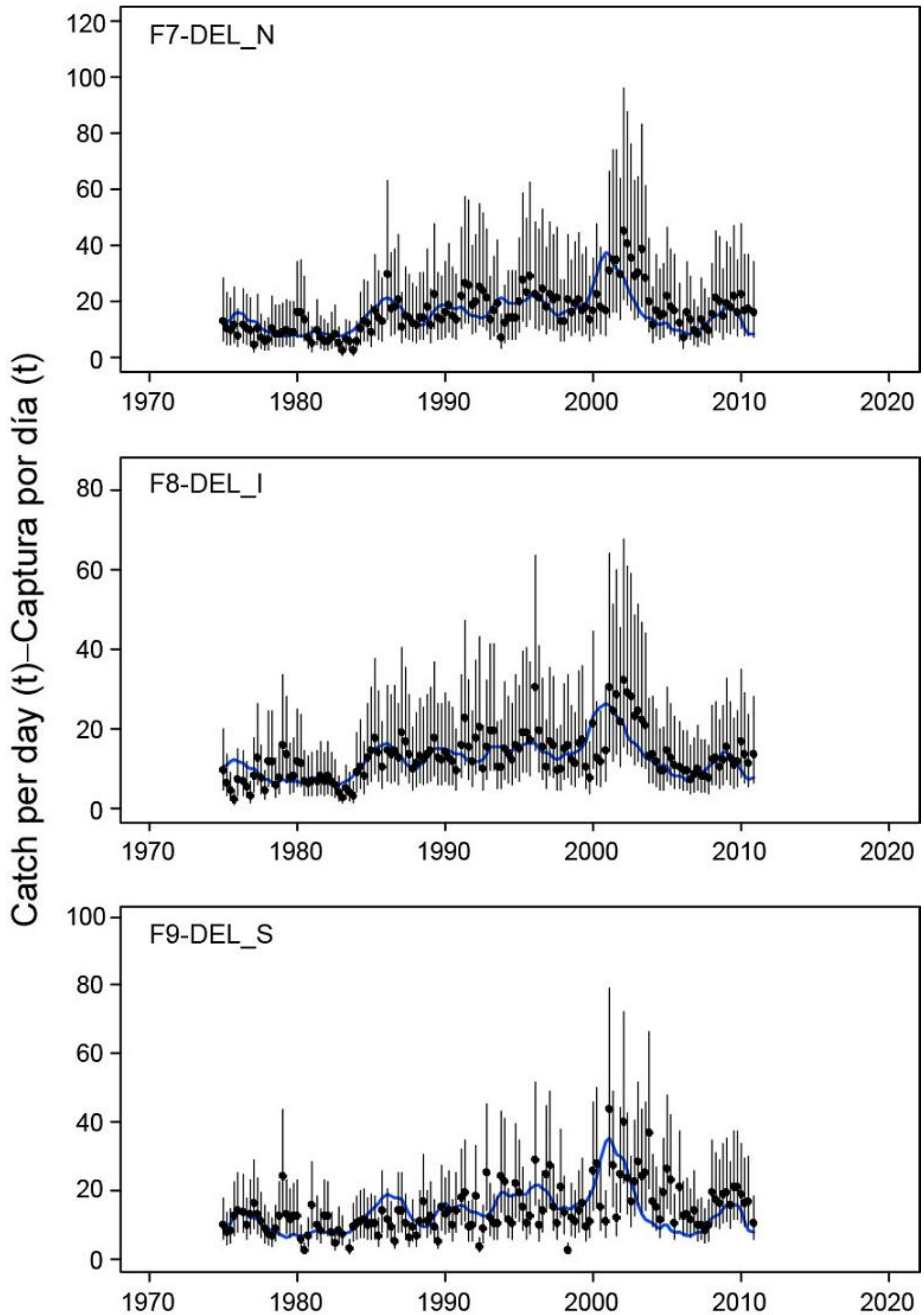

FIGURE 4.10c. Model fits to the CPUE based indices of abundance for the dolphin fisheries. The vertical lines are the 95% confidence intervals for the observed data based on the internally-estimated standard deviations for the lognormal-based likelihood function.

FIGURA 4.10c. Ajustes a los índices de abundancia basados en CPUE correspondientes a las pesquerías sobre delfines. Las líneas verticales representan los intervalos de confianza de 95% correspondientes a los datos observados basados en las desviaciones estándar estimadas internamente para la función de verosimilitud basada en logaritmos normales.

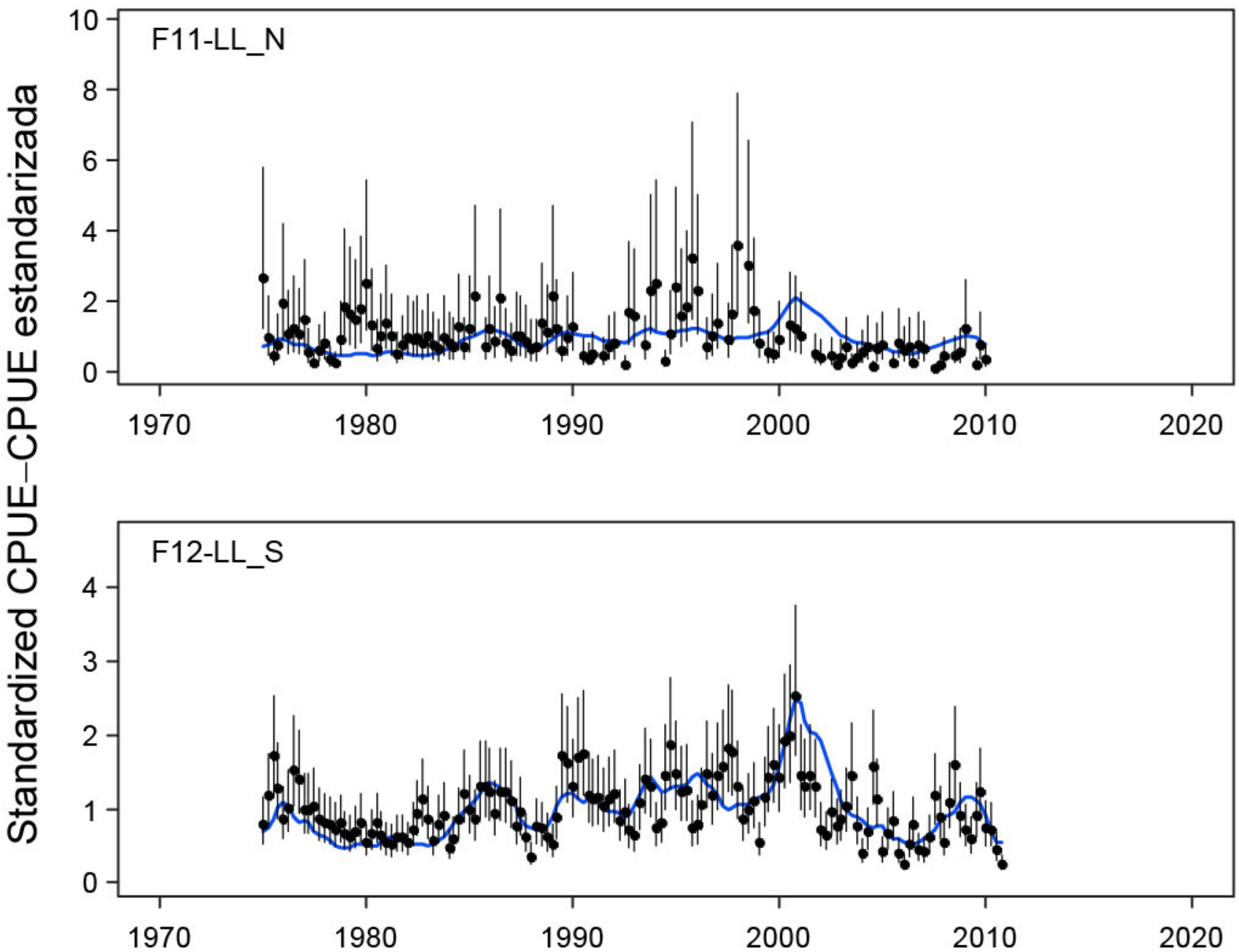

FIGURE 4.10d. Model fits to the CPUE based indices of abundance for the longline fisheries. The vertical lines are the 95% confidence intervals for the observed data based on the internally-estimated standard deviations for the lognormal-based likelihood function.

FIGURA 4.10d. Ajustes a los índices de abundancia basados en CPUE correspondientes a las pesquerías de palangre. Las líneas verticales representan los intervalos de confianza de 95% correspondientes a los datos observados basados en las desviaciones estándar estimadas internamente para la función de verosimilitud basada en logaritmos normales.

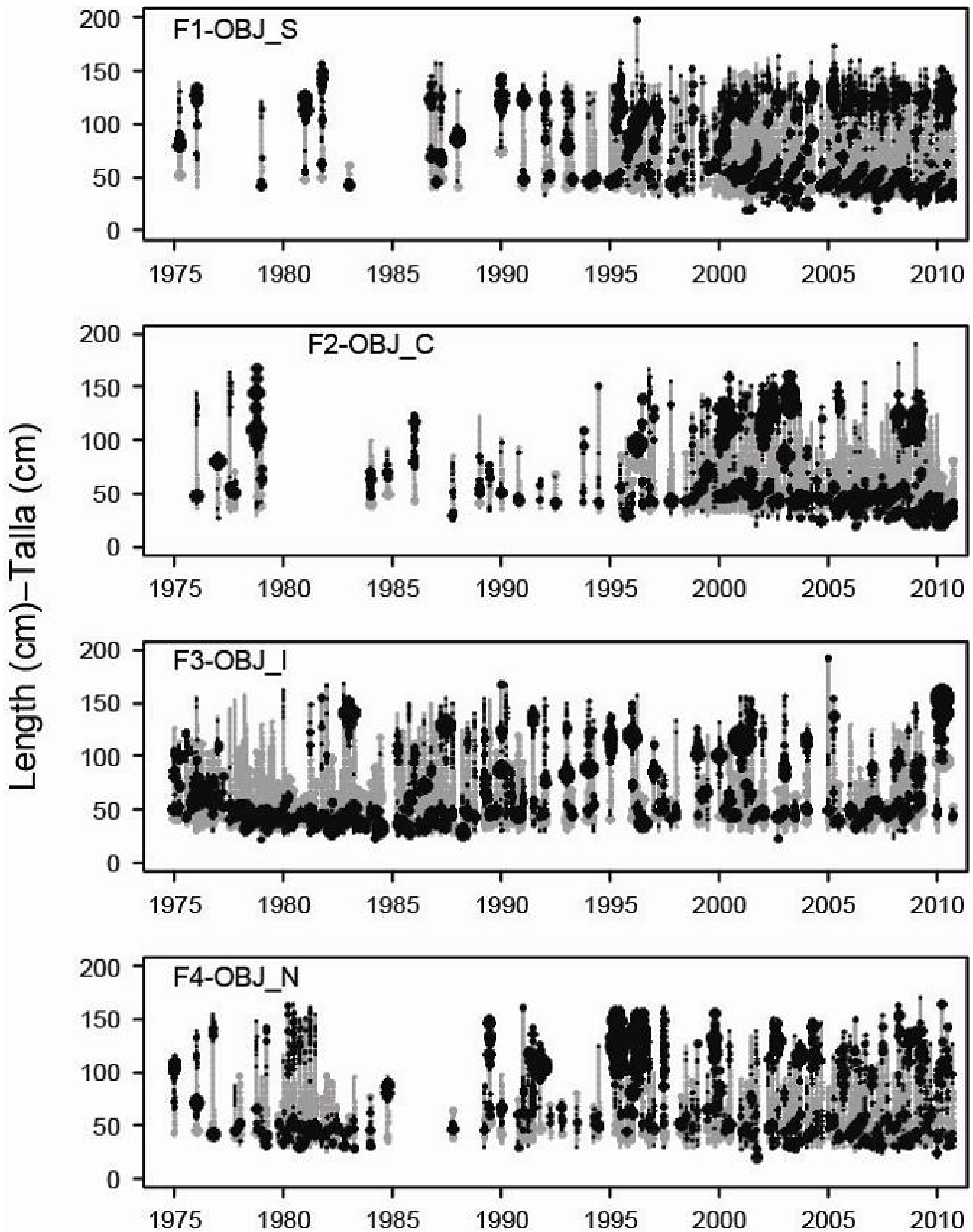

FIGURE 4.11a. Pearson residual plots for the model fits to the length-composition data for the floating-object fisheries. The black and grey circles represent observations that are higher and lower, respectively, than the model predictions. The areas of the circles are proportional to the absolute values of the residuals.

FIGURA 4.11a. Gráficas de residuales de Pearson de los ajustes del modelo a los datos de composición por talla de las pesquerías sobre objetos flotantes. Los círculos negros y grises representan observaciones que son mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional a los valores absolutos de los residuales.

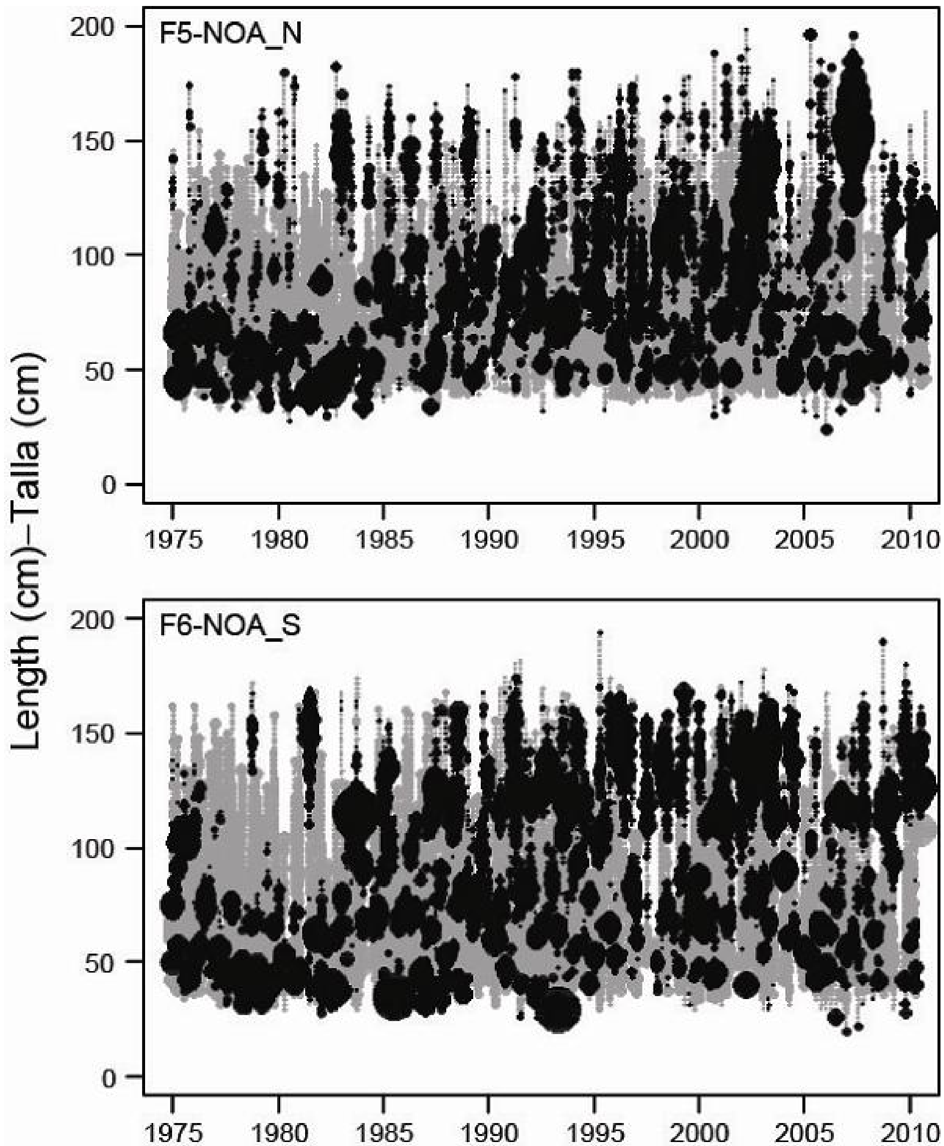

FIGURE 4.11b. Pearson residual plots for the model fits to the length-composition data for the unassociated fisheries. The black and grey circles represent observations that are higher and lower, respectively, than the model predictions. The areas of the circles are proportional to the absolute values of the residuals.

FIGURA 4.11b. Gráficas de residuales de Pearson de los ajustes del modelo a los datos de composición por talla de las pesquerías no asociadas. Los círculos negros y grises representan observaciones que son mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional a los valores absolutos de los residuales.

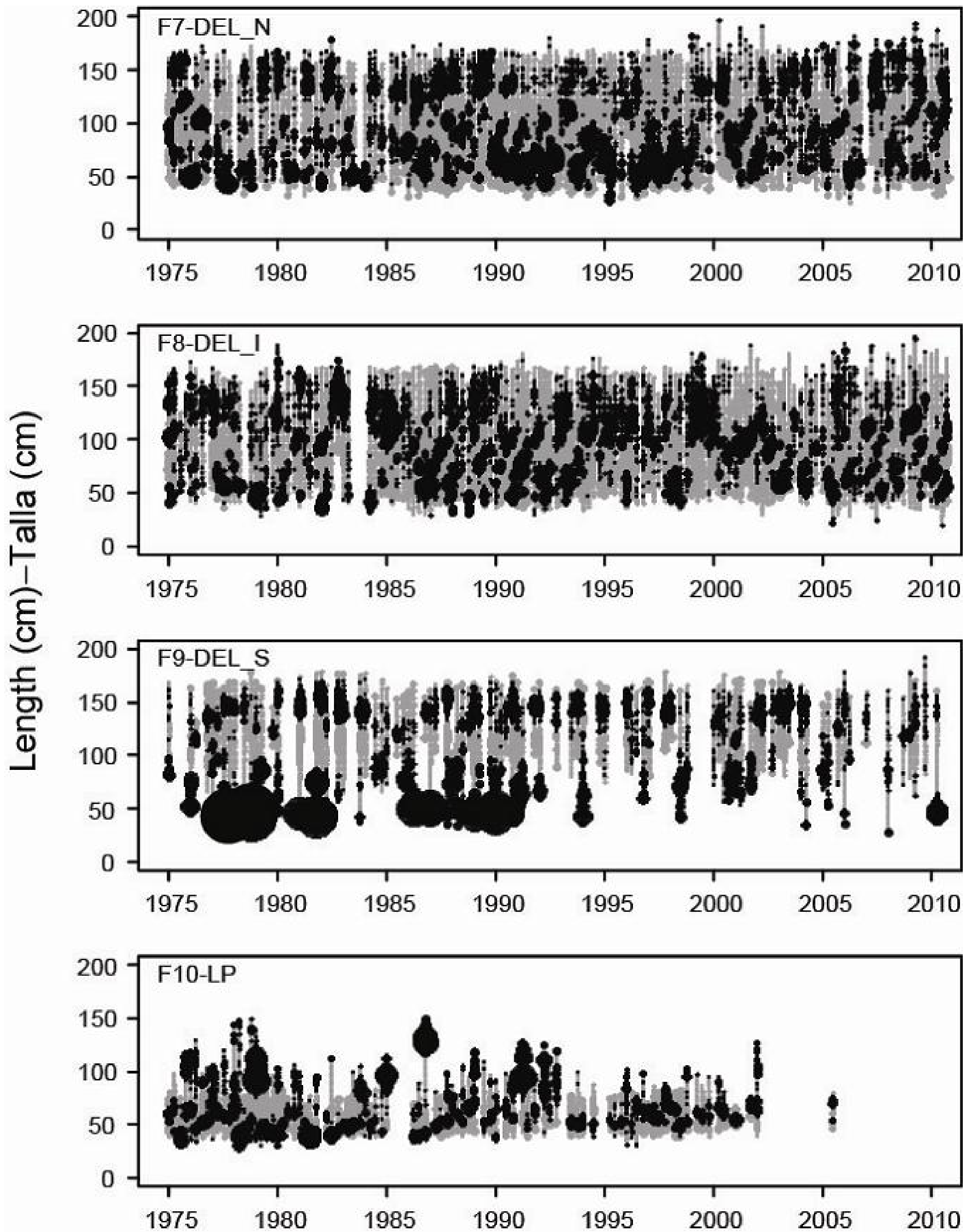

FIGURE 4.11c. Pearson residual plots for the model fits to the length-composition data for the dolphin-associated purse-seine fisheries and the pole-and-line fishery. The black and grey circles represent observations that are higher and lower, respectively, than the model predictions. The areas of the circles are proportional to the absolute values of the residuals.

FIGURA 4.11c. Gráficas de residuales de Pearson de los ajustes del modelo a los datos de composición por talla de las pesquerías asociadas con delfines y la pesquería de caña. Los círculos negros y grises representan observaciones que son mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional a los valores absolutos de los residuales.

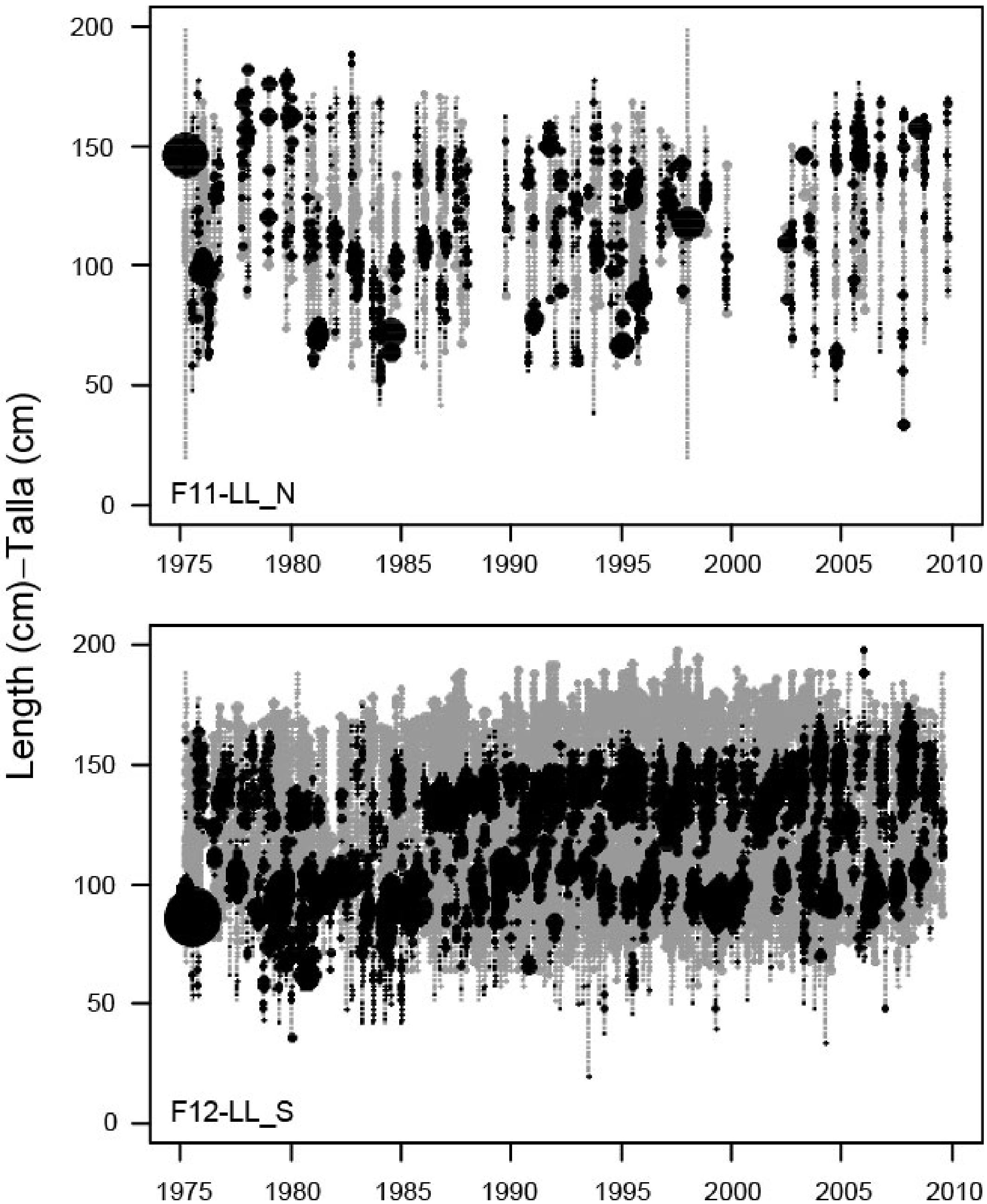

FIGURE 4.11d. Pearson residual plots for the model fits to the length-composition data for the longline fisheries. The black and grey circles represent observations that are higher and lower, respectively, than the model predictions. The areas of the circles are proportional to the absolute values of the residuals.

FIGURA 4.11d. Gráficas de residuales de Pearson de los ajustes del modelo a los datos de composición por talla de las pesquerías de palangre. Los círculos negros y grises representan observaciones que son mayores y menores, respectivamente, que las predicciones del modelo. El tamaño de los círculos es proporcional a los valores absolutos de los residuales.

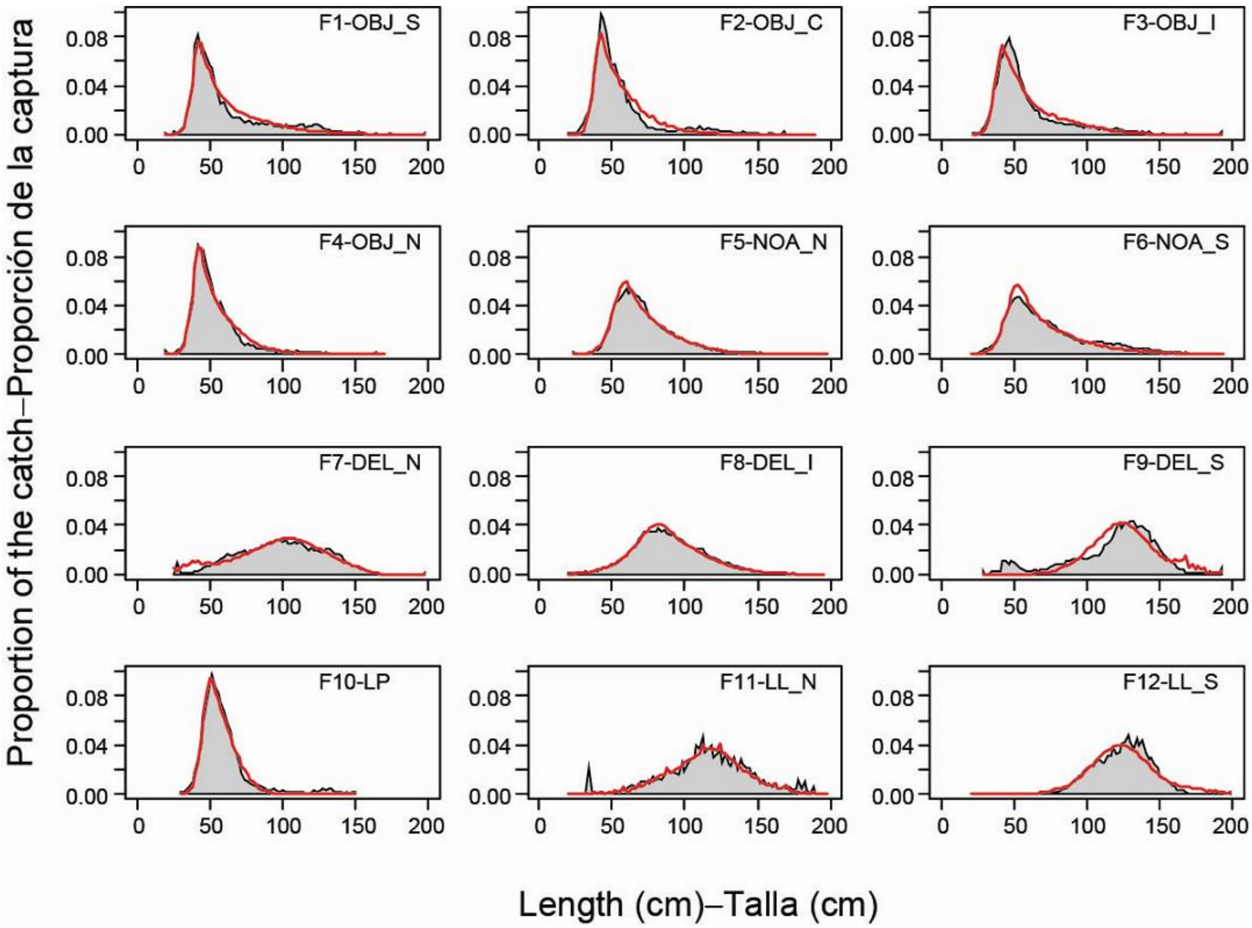

FIGURE 4.11e. Average observed (shaded area) and predicted (curves) length compositions of the catches taken by the fisheries defined for the stock assessment of yellowfin tuna in the EPO.

FIGURA 4.11e. Composición por talla media 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.

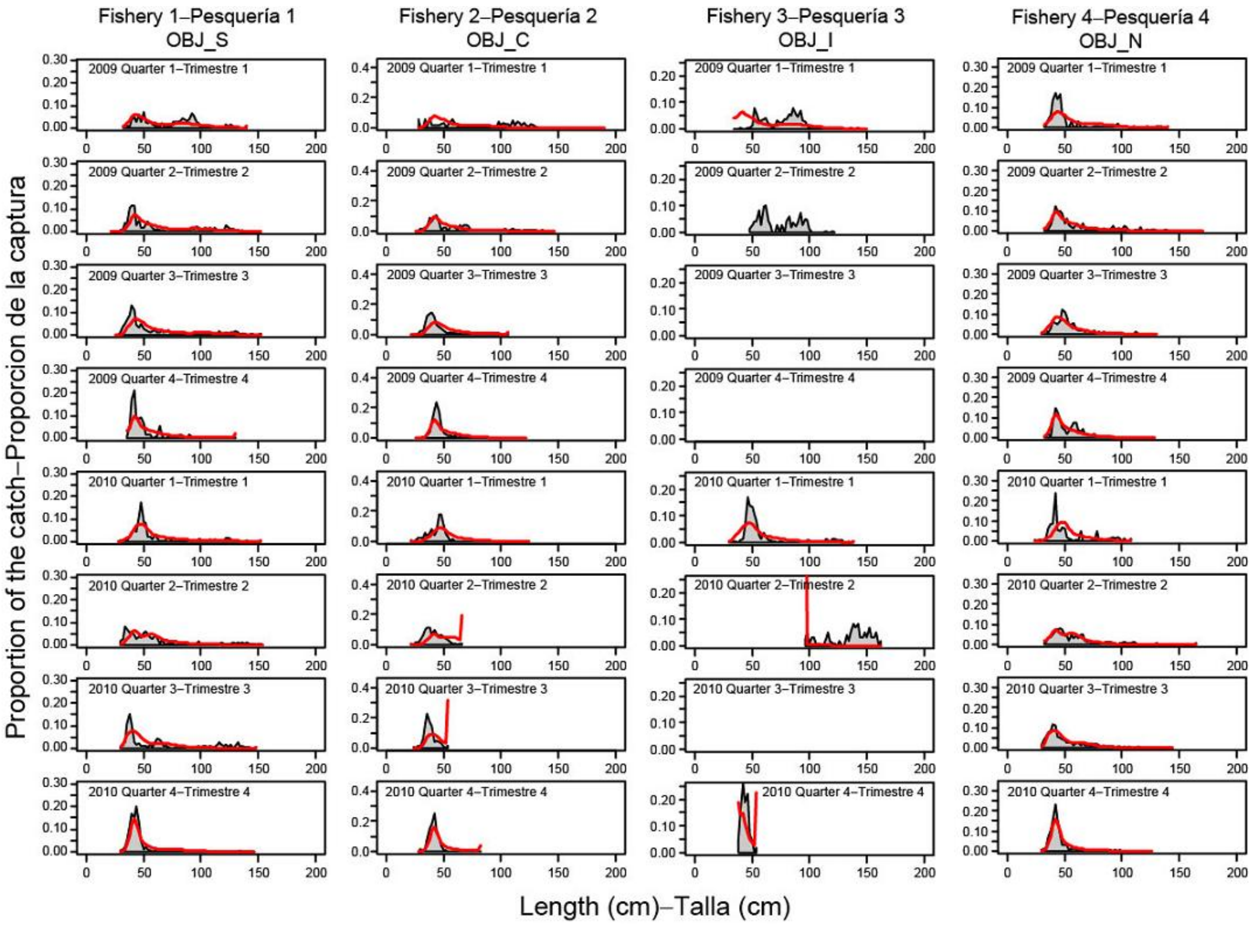

FIGURE 4.11f. Observed (shaded area) and predicted (curves) length compositions of the recent catches of yellowfin by the fisheries that take tunas in association with floating objects (Fisheries 1-4).

FIGURA 4.11f. Composición por talla observada (puntos) y predicha (curvas) de las capturas recientes de aleta amarilla por las pesquerías que capturan atún en asociación con objetos flotantes (Pesquerías 1-4).

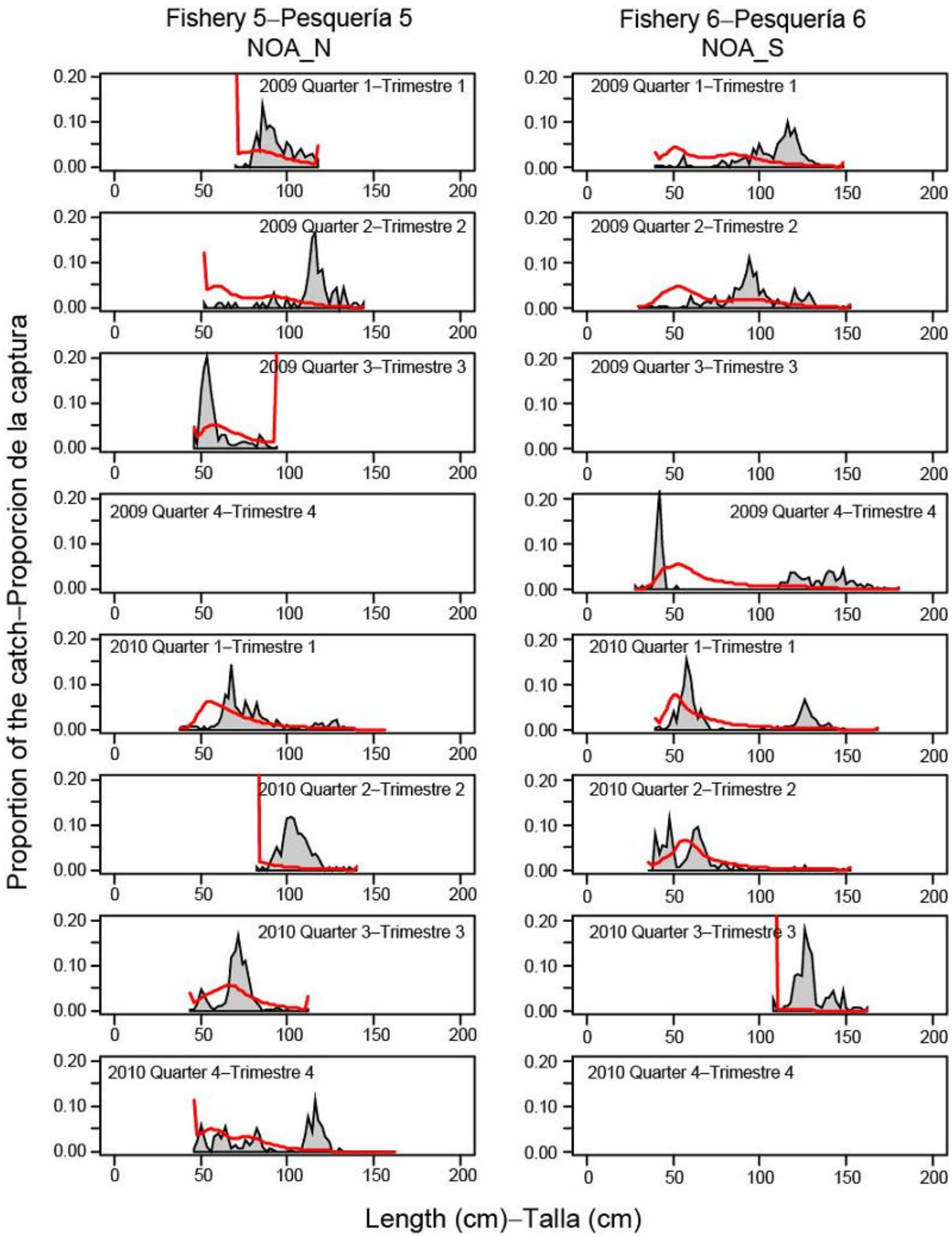

FIGURE 4.11g. Observed (shaded area) and predicted (curves) length compositions of the recent catches of yellowfin by the fisheries that take tunas in unassociated schools (Fisheries 5 and 6).
FIGURA 4.11g. Composición por talla observada (puntos) y predicha (curvas) de las capturas recientes de aleta amarilla por las pesquerías que capturan atún en cardúmenes no asociados (Pesquerías 5 y 6).

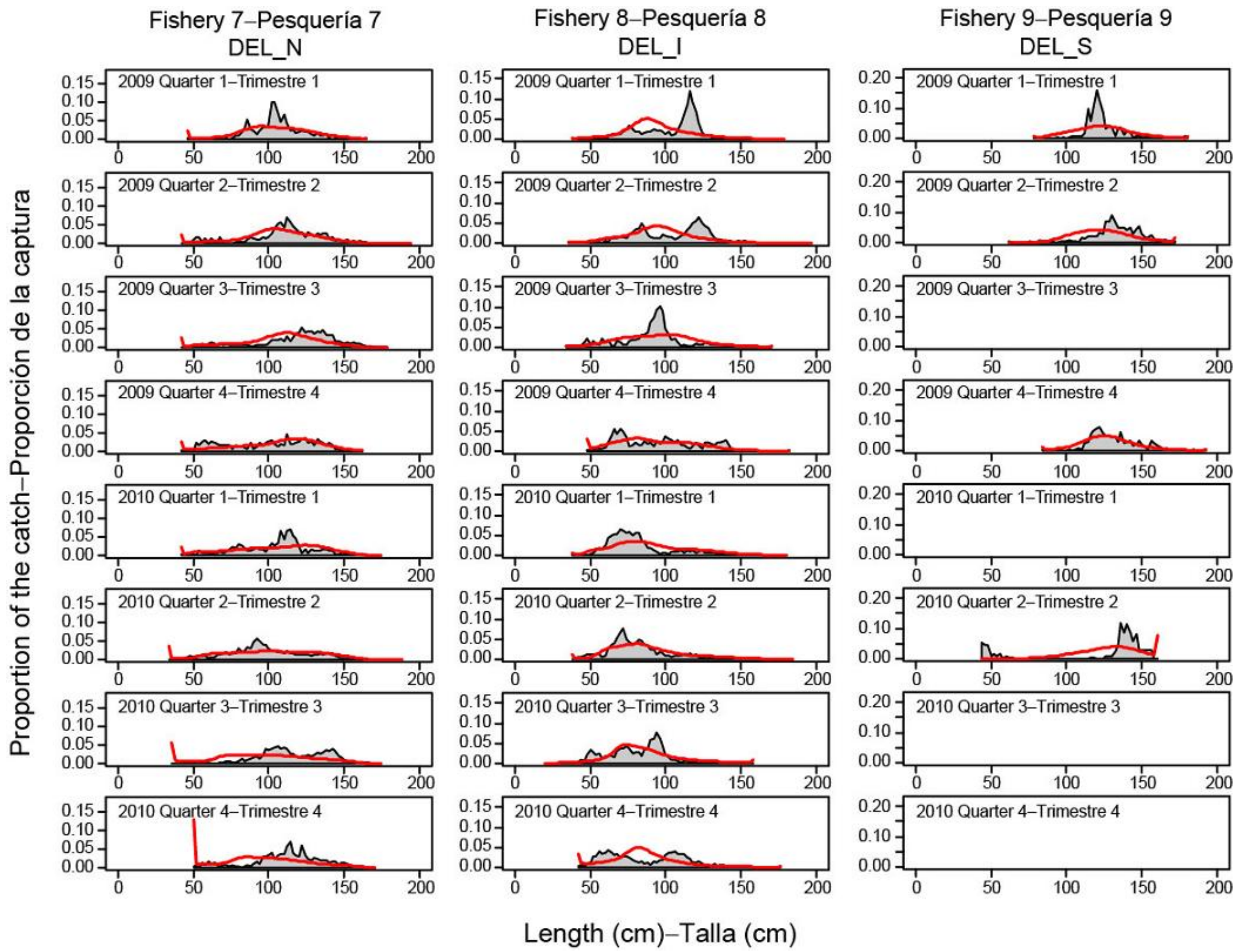

FIGURE 4.11h. Observed (shaded area) and predicted (curves) length compositions of the recent catches of yellowfin tuna by the fisheries that take tunas in association with dolphins (Fisheries 7-9).

FIGURA 4.11h. Composición por talla observada (puntos) y predicha (curvas) de las capturas recientes de atún aleta amarilla por las pesquerías que capturan atún en asociación con delfines (Pesquerías 7-9).

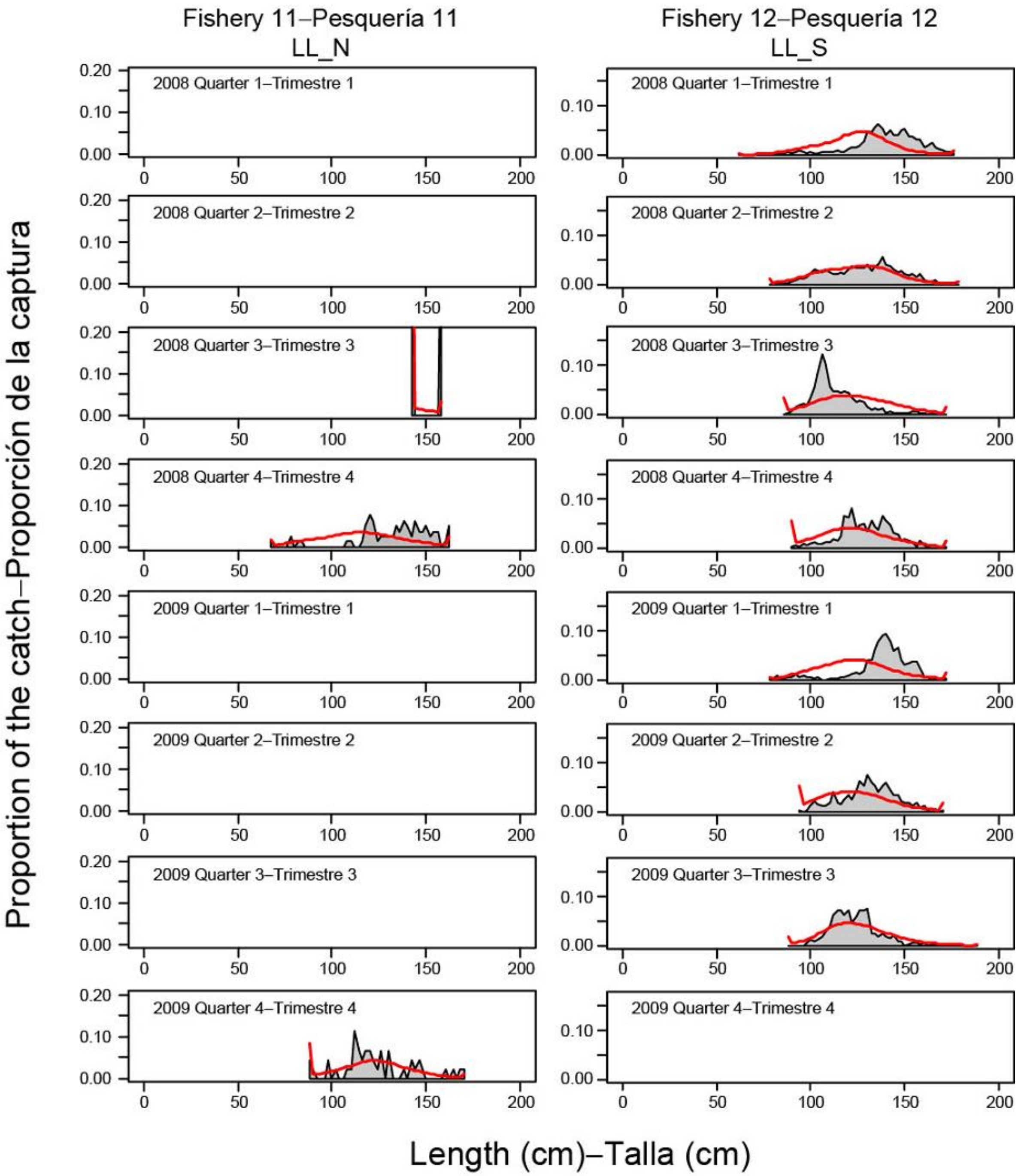

FIGURE 4.11i. Observed (shaded area) and predicted (curves) length compositions of the recent catches of yellowfin tuna by the southern longline fishery (Fishery 12). There are no recent size composition data for the northern longline fishery.

FIGURA 4.11i. Composición por talla observada (puntos) y predicha (curvas) de las capturas recientes de atún aleta amarilla por la pesquería de palangre del sur (Pesquería 12). No se cuenta con datos recientes de composición por talla de la pesquería de palangre del norte.

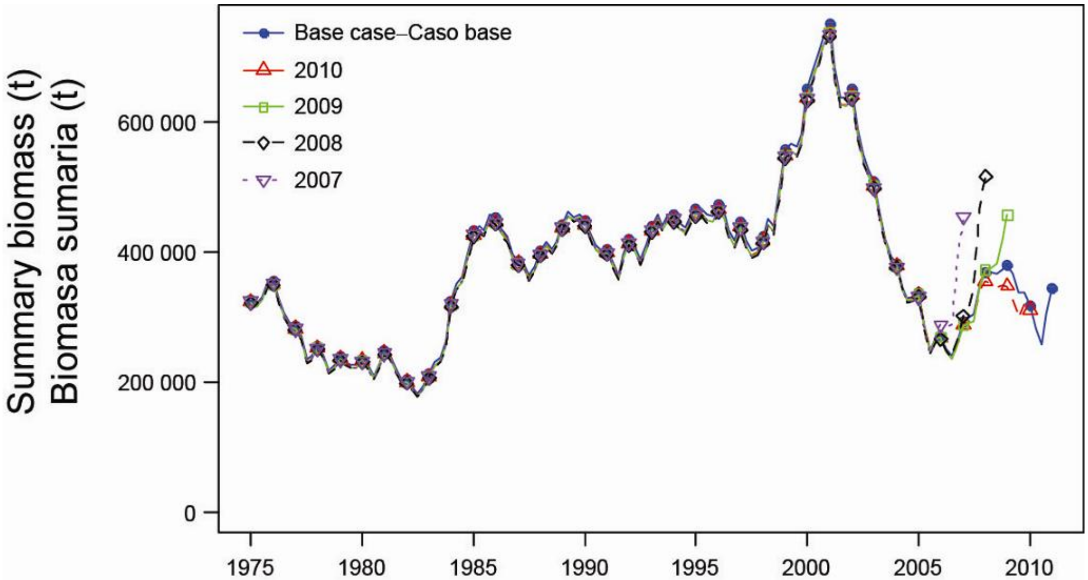

FIGURE 4.12. Comparison of estimated biomasses of yellowfin tuna aged three quarters and older in the EPO from the current assessment and from retrospective analyses that remove recent data.
FIGURA 4.14a. Comparación de las biomasas estimadas de atunes aleta amarilla de tres trimestres y más de edad en el OPO de la evaluación actual y de los análisis retrospectivos que eliminan los datos recientes.

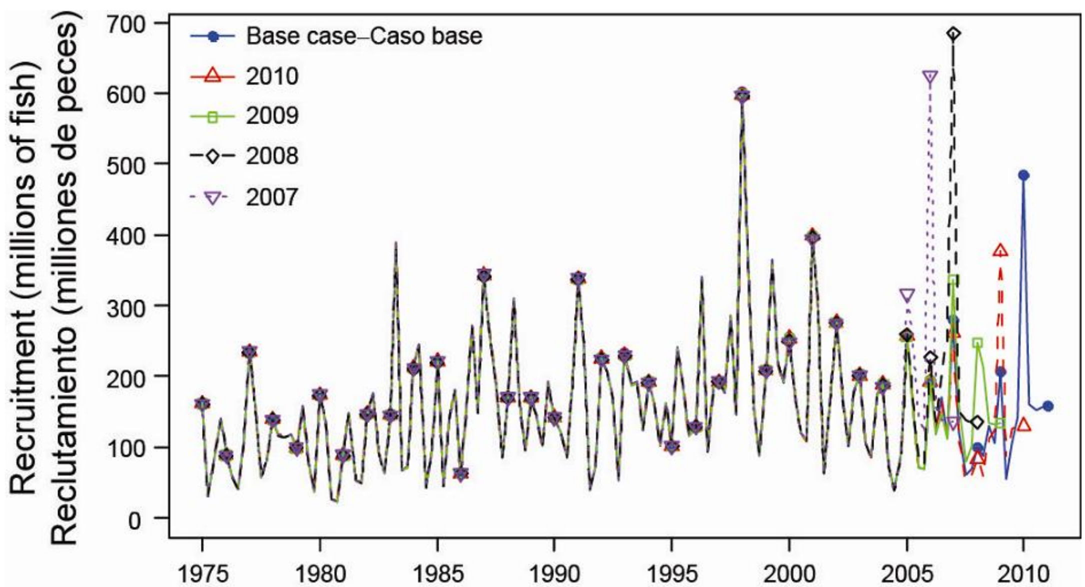

FIGURE 4.13. Comparison of estimated recruitment of yellowfin tuna in the EPO from the current assessment and from retrospective analyses that remove recent data
FIGURA 4.13. Comparación del reclutamiento estimado de atún aleta amarilla en el OPO de la evaluación actual y de los análisis retrospectivos que eliminan los datos recientes.

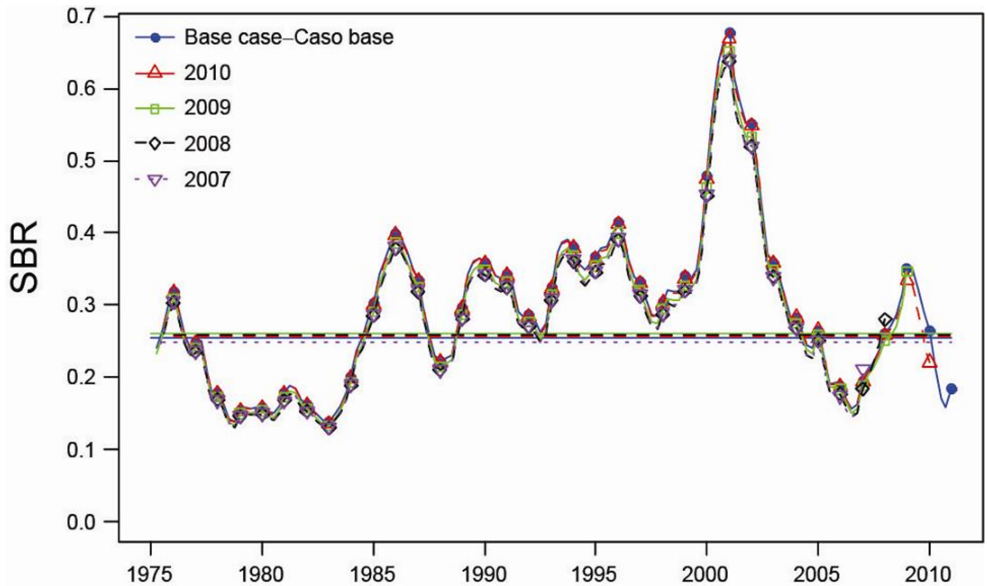

FIGURE 4.14. Comparison of estimated spawning biomass ratio (SBR) of yellowfin tuna in the EPO from the current assessment and from retrospective analyses that remove recent data. The horizontal line represents the SBR that corresponds to MSY estimated in the current assessment.
FIGURA 4.14. Comparación del cociente de biomasa reproductora (SBR) estimado del atún aleta amarilla en el OPO de la evaluación actual y de los análisis retrospectivos que eliminan los datos recientes. La línea horizontal representa el SBR que corresponde al RMS estimado en la evaluación actual.

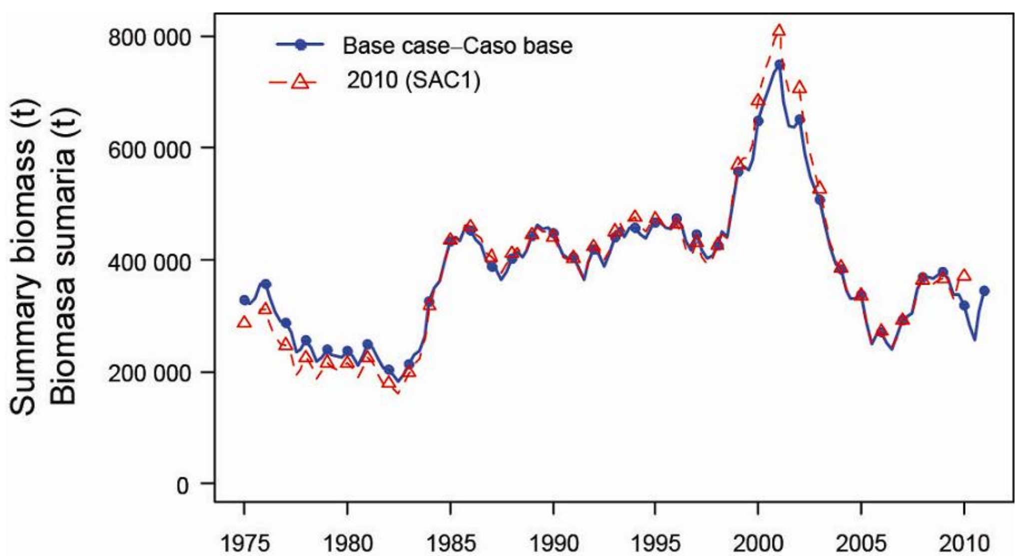

FIGURE 4.15. Comparison of estimated biomasses of yellowfin tuna aged three quarters and older in the EPO from the most recent previous assessment (dashed line) and from the current assessment (solid line).
FIGURA 4.15. Comparación de la biomasa estimada de atún aleta amarilla de tres trimestres y más de edad en el OPO de la evaluación previa más reciente y de la evaluación actual.

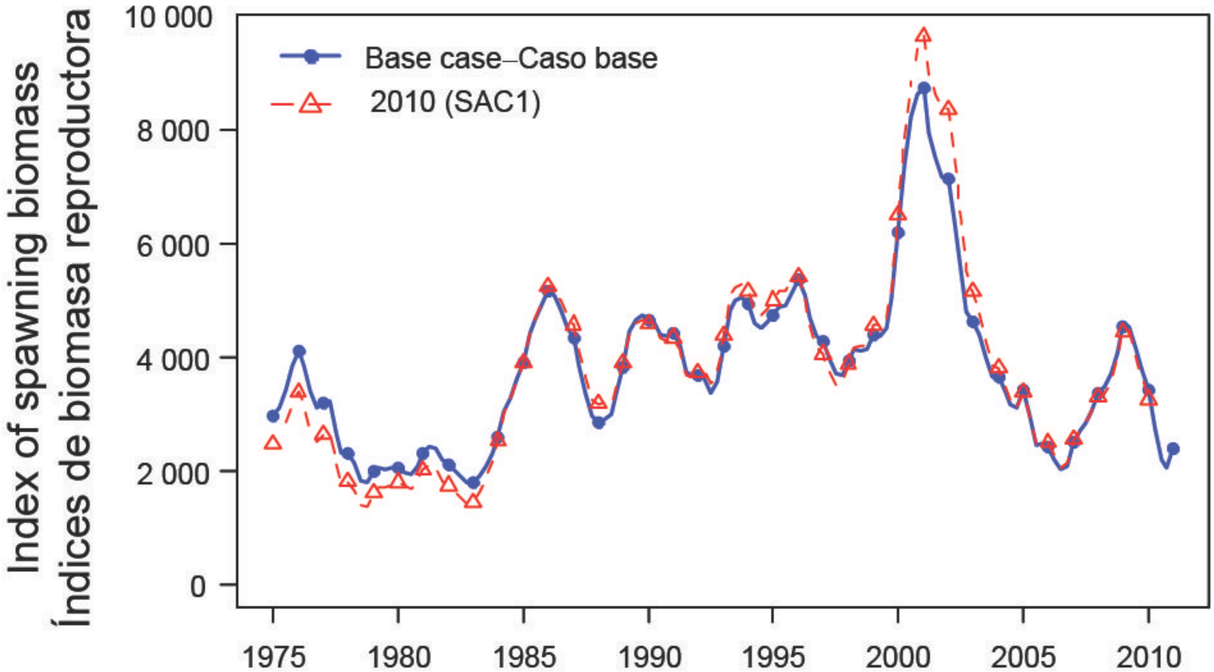

FIGURE 4.16. Comparison of estimated indices of spawning biomass of yellowfin tuna in the EPO from the most recent previous assessment (dashed line) and from the current assessment (solid line).
FIGURA 4.16. Comparación de los índices estimados de biomasa reproductora del atún aleta amarilla en el OPO de la evaluación previa más reciente (línea de trazos) y de la evaluación actual (línea sólida).

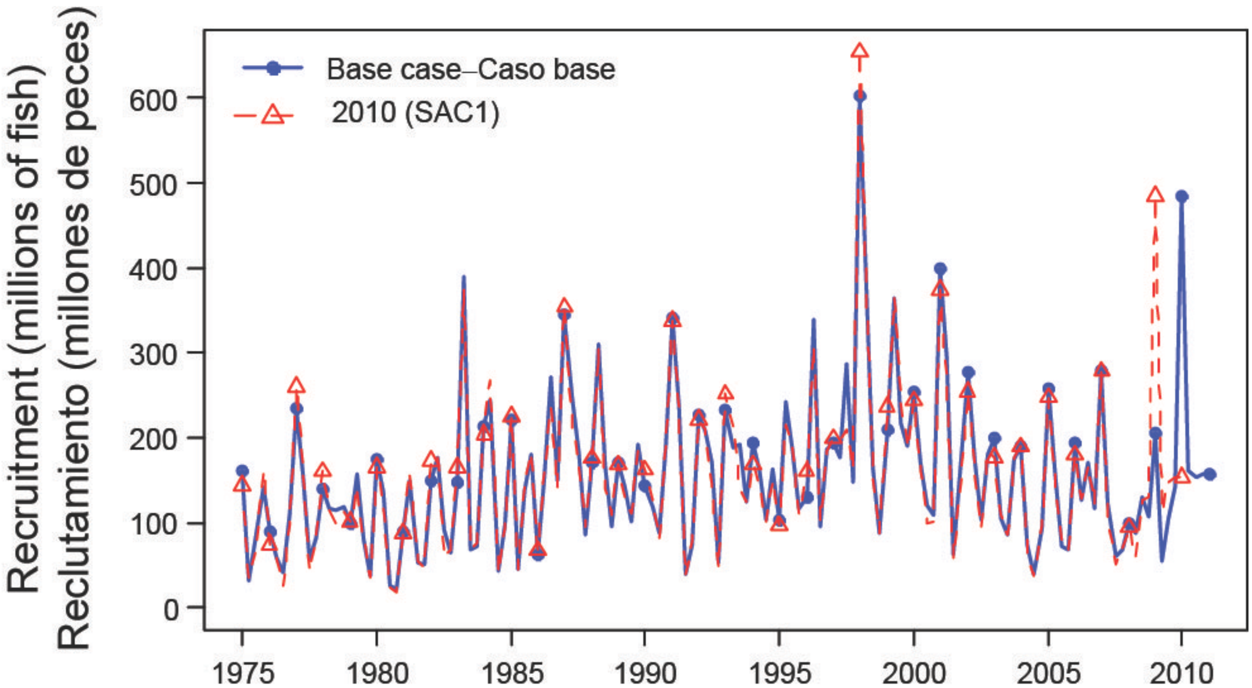

FIGURE 4.17a. Comparison of estimated recruitment of yellowfin in the EPO from the most recent previous assessment (dashed line) and from the current assessment (solid line).
FIGURA 4.17a. Comparación del reclutamiento estimado de aleta amarilla en el OPO de la evaluación previa más reciente (línea de trazos) y de la evaluación actual (línea sólida).

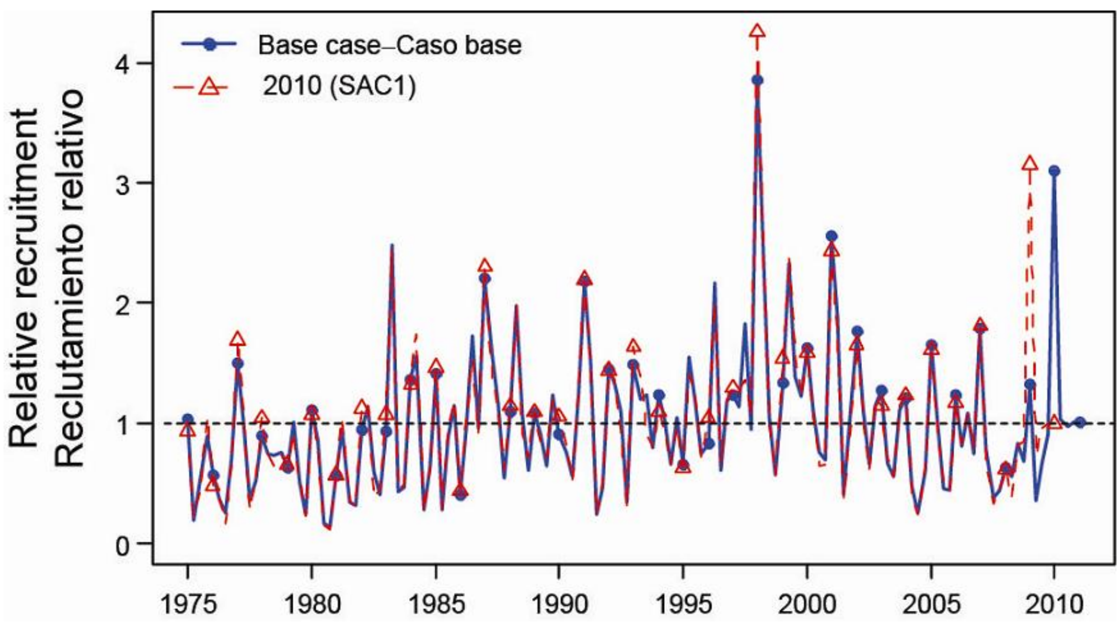

FIGURE 4.17b. Comparison of estimated relative recruitment of yellowfin in the EPO from the most recent previous assessment (dashed line) and from the current assessment (solid line).
FIGURA 4.17b. Comparación del reclutamiento relativo estimado de aleta amarilla en el OPO de la evaluación previa más reciente (línea de trazos) y de la evaluación actual (línea sólida).

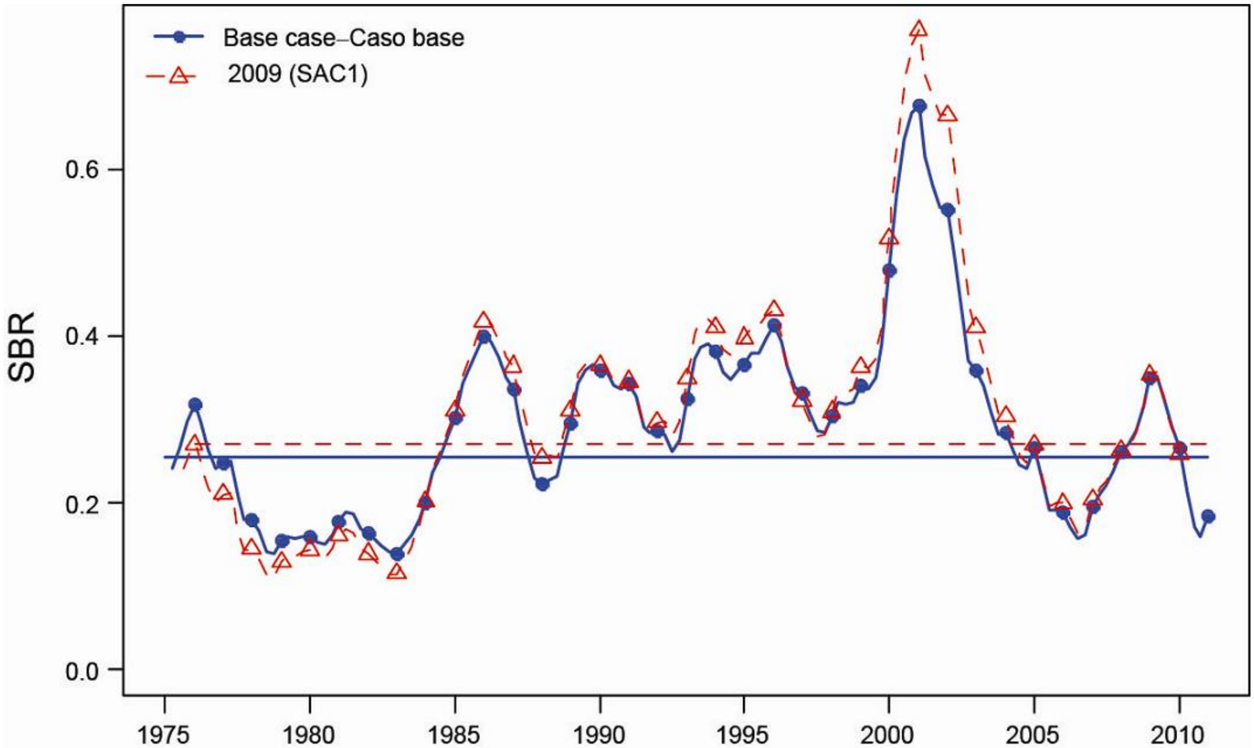

FIGURE 4.18. Comparison of estimated spawning biomass ratios (SBRs) of yellowfin tuna from the current assessment (solid line) and from the most recent previous assessment (dashed line). The horizontal lines identify the SBRs at MSY.

FIGURA 4.18. Comparación del cociente de biomasa reproductora (SBR) estimado de atún aleta amarilla de la evaluación actual (línea sólida) y las evaluaciones previas más recientes (línea de trazos). Las líneas horizontales identifican los SBR en RMS.

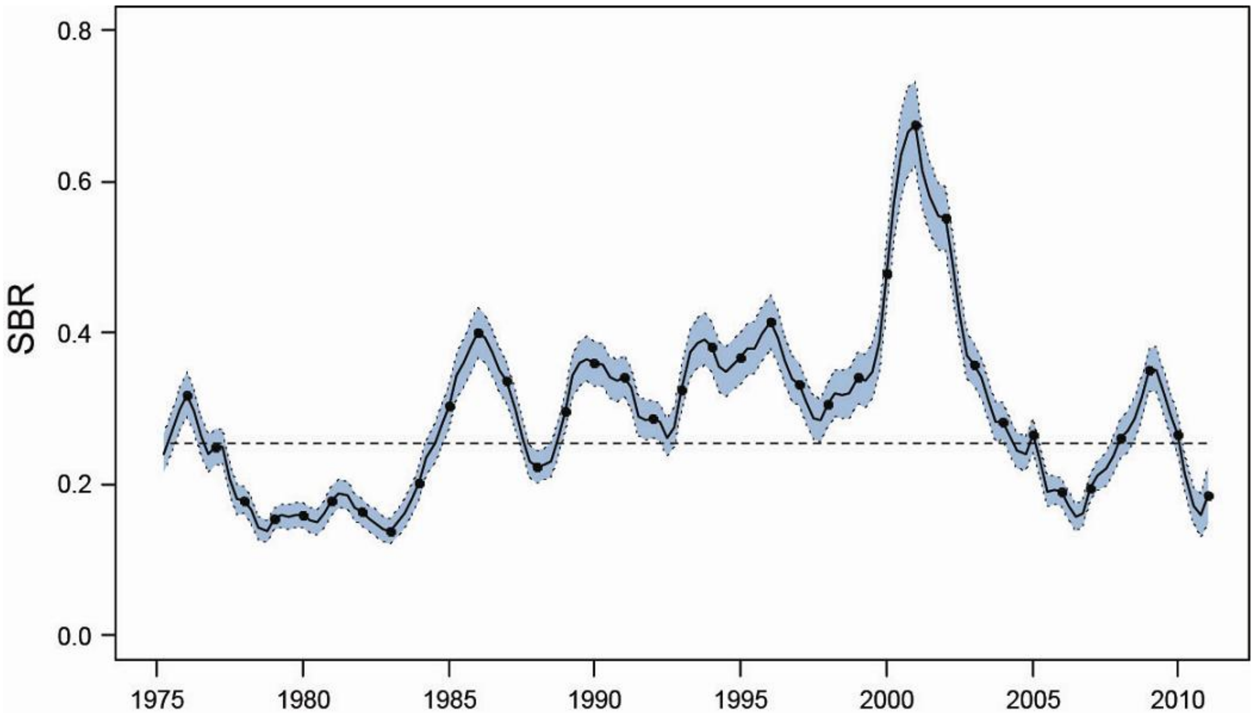

FIGURE 5.1. Estimated spawning biomass ratios (SBRs) for yellowfin tuna in the EPO. The thin dashed lines represent approximate 95% confidence intervals. The dashed horizontal line identifies the SBR at MSY.

FIGURA 5.1. 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.

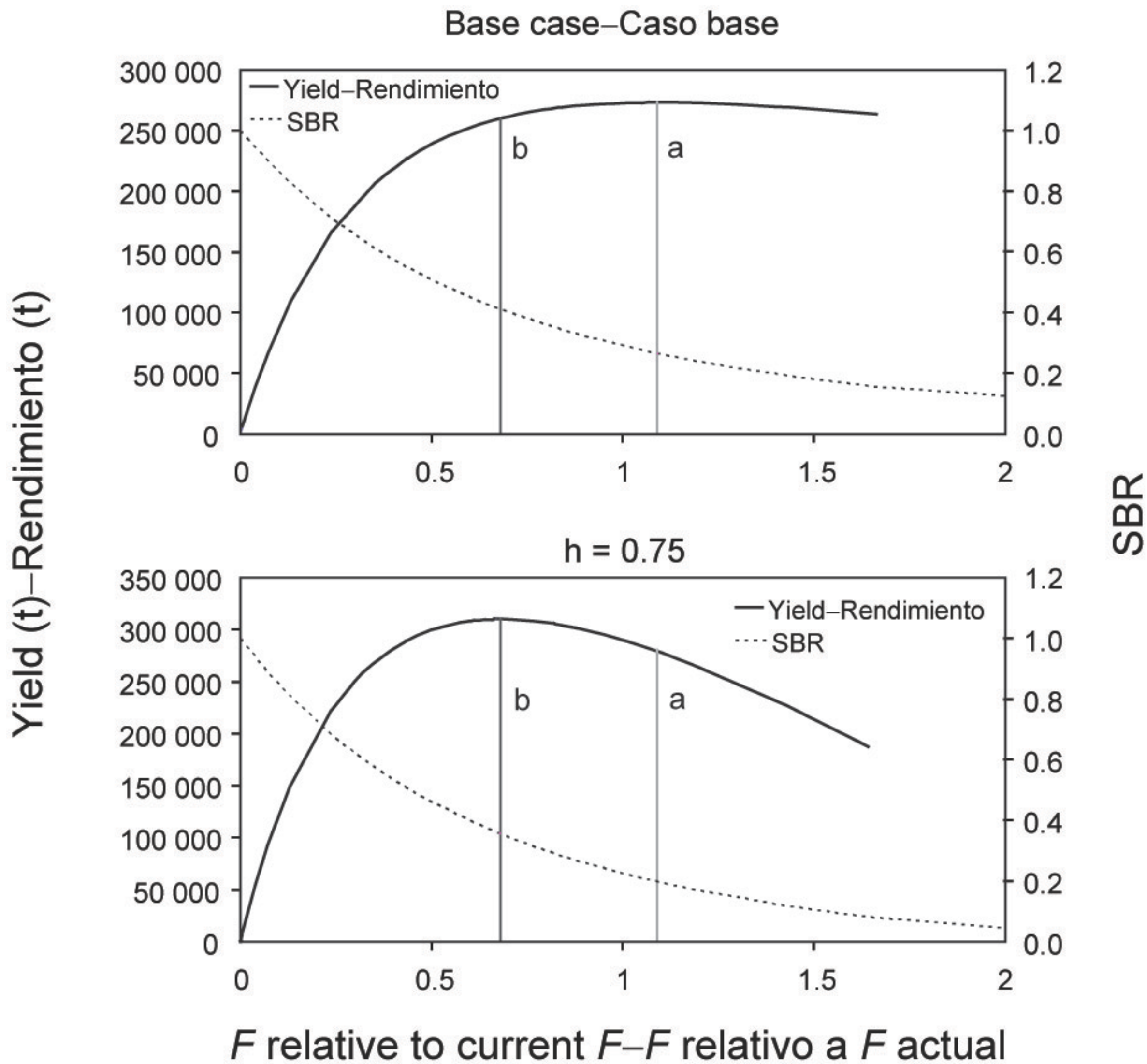

FIGURE 5.2. Yield and spawning biomass ratio (SBR) as a function of fishing mortality relative to the current fishing mortality. The vertical lines represent the fishing mortality corresponding to MSY for the base case and the sensitivity analysis that uses a stock-recruitment relationship (*h* = 0.75).
FIGURA 5.2. Rendimiento y cociente de biomasa reproductora (SBR) como función de la mortalidad por pesca relativa a la mortalidad por pesca actual. Las líneas verticales representan la mortalidad por pesca correspondiente al RMS del caso base y del análisis de sensibilidad que usa una relación población-reclutamiento (*h* = 0.75).

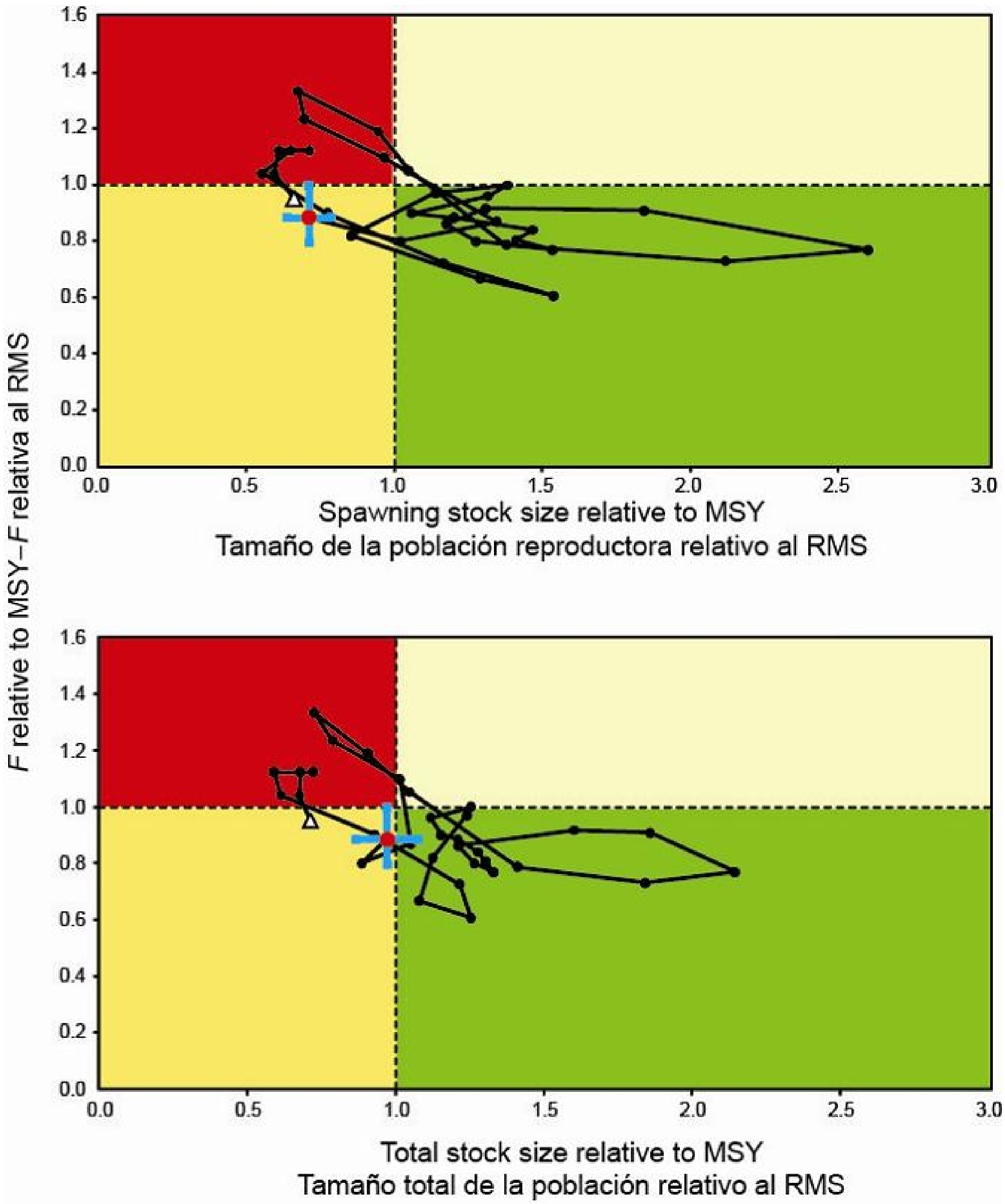

FIGURE 5.3. Phase (Kobe) plot of the time series of estimates for stock size (top: spawning biomass; bottom: total biomass) and fishing mortality relative to their MSY reference points. Each dot is based on the average exploitation rate over three years; the large triangle and the red dot indicate the earliest and most recent estimates, respectively. The squares represent approximate 95% confidence intervals around the most recent estimate.

FIGURA 5.3. Gráfica de fase (Kobe) de la serie de tiempo de las estimaciones del tamaño de la población (arriba: biomasa reproductora; abajo: biomasa total) 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 triángulo grande y el punto rojo indican las estimaciones más antiguas y más recientes, respectivamente. Los cuadrados representan los intervalos de confianza de 95% aproximados.

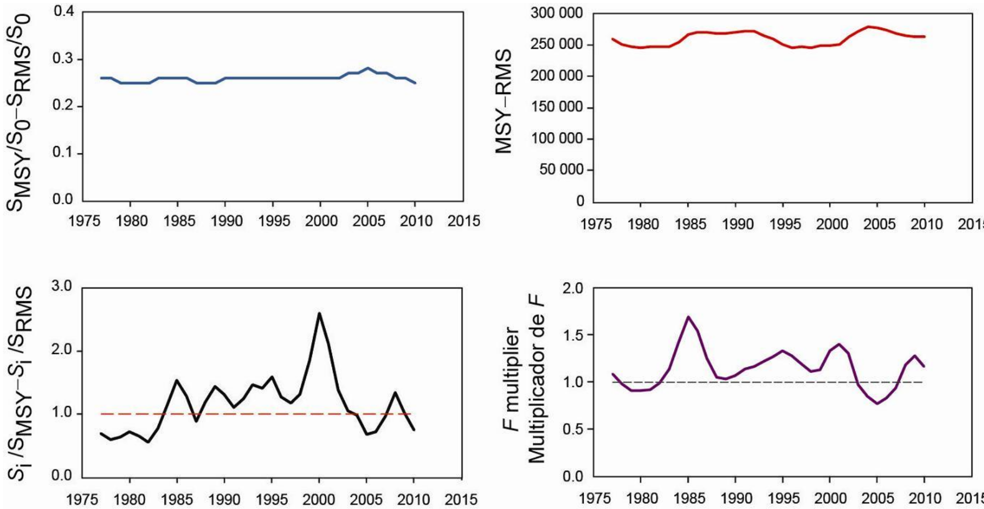

FIGURE 5.4a. Estimates of MSY-related quantities calculated using the three-year average age-specific fishing mortality for each year on the x-axis, including its two previous years. (S_i is the index of spawning biomass at the start of the year on the x-axis.) See the text for definitions.
FIGURA 5.4a. Estimaciones de cantidades relacionadas con el RMS calculadas a partir de la mortalidad por pesca media por edad para cada año en el eje x, incluyendo los dos años previos. (S_i es el índice de la biomasa reproductora al principio del año en el eje x.) Ver definiciones en el texto.

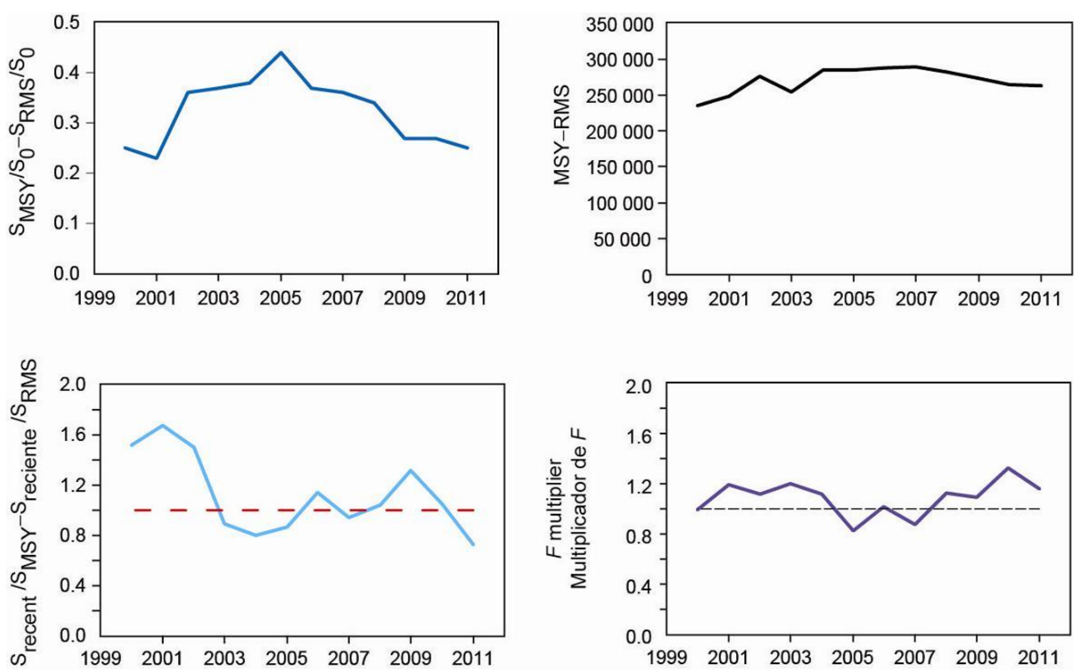

FIGURE 5.4b. Estimates of MSY-related quantities from the current assessment compared to those estimated in previous assessments. (S_{recent} is the index of spawning biomass at the latest year in the assessment). See the text for definitions.
FIGURA 5.4b. Estimaciones de cantidades relacionadas con el RMS de la evaluación actual comparadas con aquéllas estimadas en evaluaciones previas. ($S_{reciente}$ es el índice de la biomasa reproductora en el último año en la evaluación). Ver definiciones en el texto.

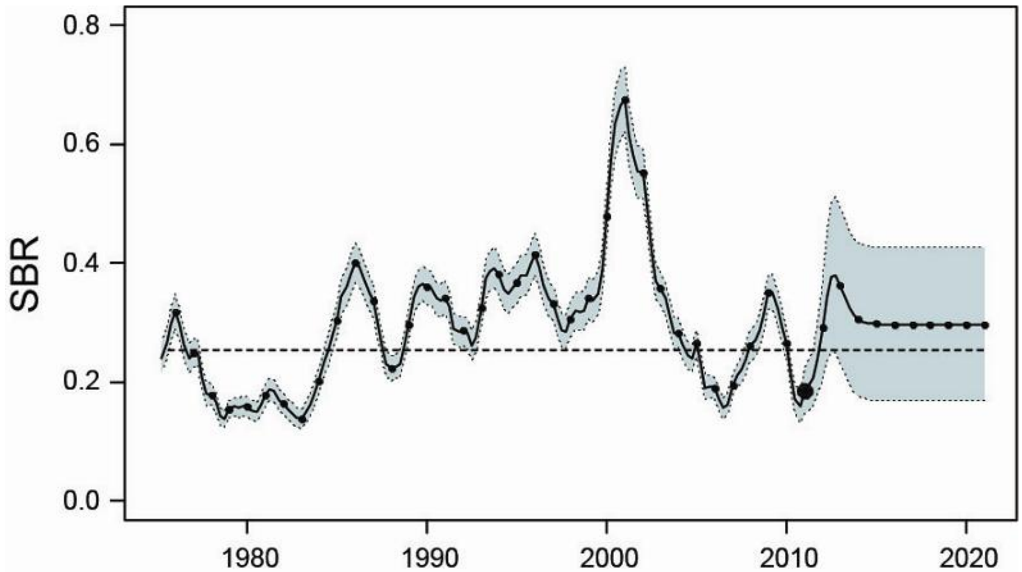

FIGURE 6.1. Spawning biomass ratios (SBRs) for 1975-2010 and SBRs projected during 2011-2020 for yellowfin tuna in the EPO. The dashed horizontal line identifies SBR_{MSY} (Section 5.1), and the thin dashed lines represent the 95% confidence intervals of the estimates. The estimates after 2010 indicate the SBR predicted if the fishing mortality continues at the average of that observed during 2006-2008, and average environmental conditions occur during the next 10 years.

FIGURA 6.1. Cocientes de biomasa reproductora **(**SBR) de 1975-2010 y SBR proyectados durante 2011-2020 para el atún aleta amarilla en el OPO. La línea de trazos horizontal identifica el SBR_{RMS} (Sección 5.1), y las líneas delgadas de trazos representan los intervalos de confianza de 95% de las estimaciones. Las estimaciones a partir de 2010 señalan el SBR predicho si la mortalidad por pesca continúa en el nivel medio observado durante 2006-2008 y con condiciones ambientales promedio en los 5 años próximos.

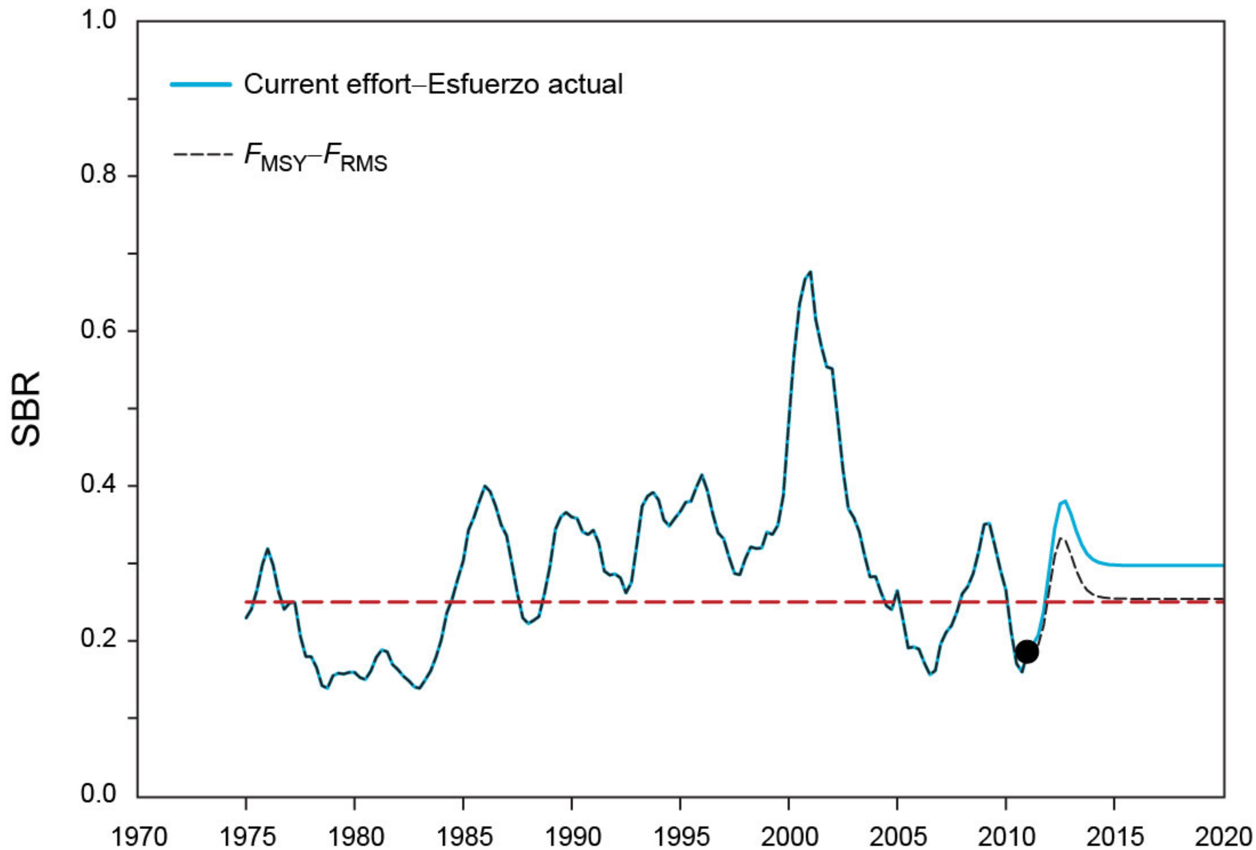

FIGURE 6.2. Spawning biomass ratios (SBRs) projected for yellowfin tuna in the EPO during 2011-2020 under current effort and under effort corresponding to MSY. The horizontal line (at 0.25) identifies SBR_{MSY} (Section 5.1).

FIGURA 6.2. Cocientes de biomasa reproductora (SBR) de atún aleta amarilla en el OPO proyectados durante 2011-2020, con el esfuerzo actual y con el esfuerzo correspondiente al RMS. La línea horizontal (en 0.25) identifica SBR_{RMS} (Sección 5.1).

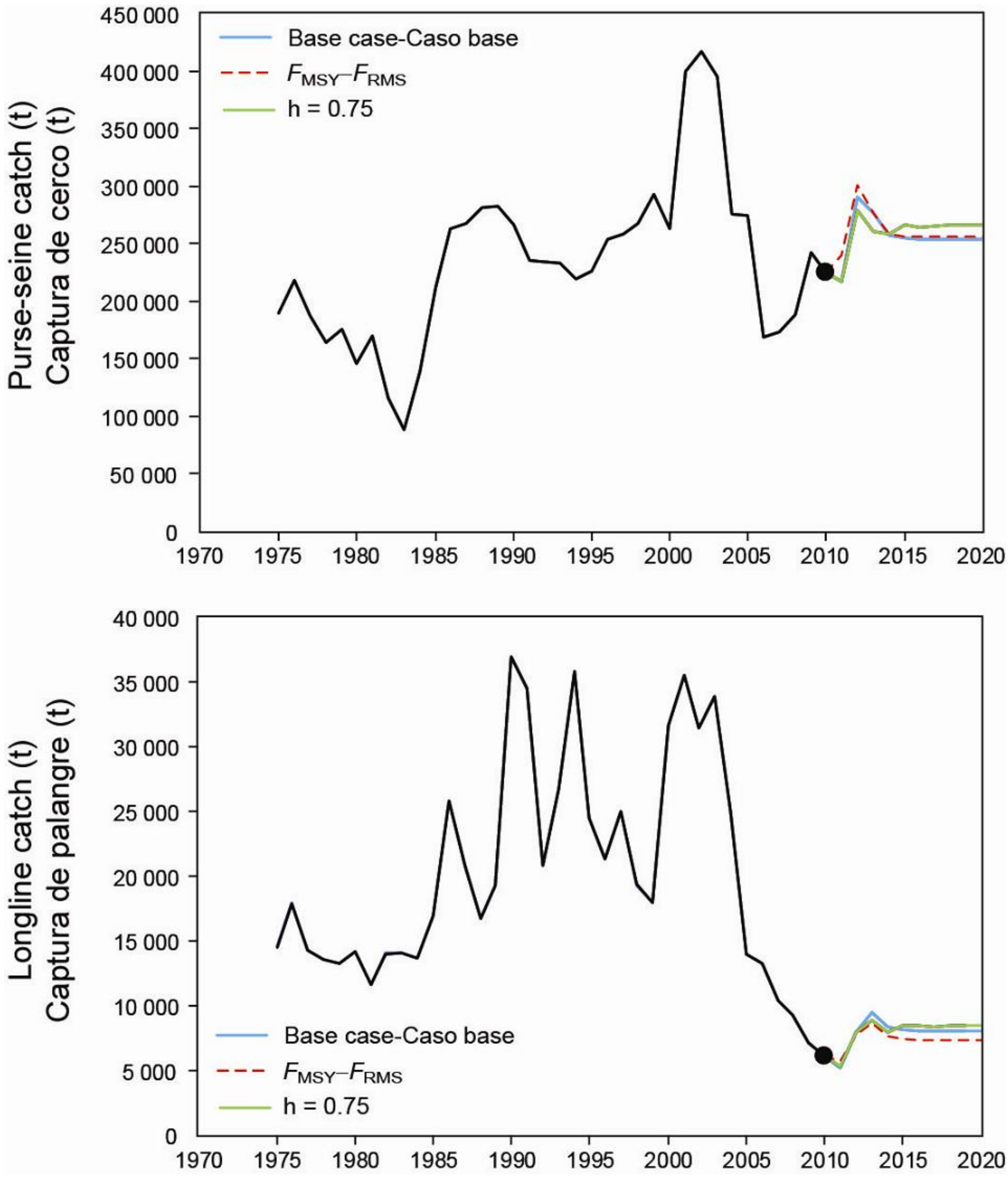

FIGURE 6.3. Historic and projected purse-seine and longline catch from the base case while fishing with the current effort, the base case while fishing at the fishing mortality corresponding to MSY (F_{MSY}), and the analysis of sensitivity to steepness of the stock-recruitment relationship (*h*) while fishing with the current effort.

FIGURA 6.3. Capturas de cerco y de palangre históricas y proyectadas del caso base con la pesca en el nivel actual de esfuerzo, del caso base con la pesca en la mortalidad por pesca correspondiente al RMS (F_{RMS}), y el análisis de sensibilidad a la inclinación de la relación población-reclutamiento (*h*) al pescar con el esfuerzo actual.

TABLE 2.1. Fisheries defined 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 2.1, and the discards are described in Section 2.2.1.

TABLA 2.1. Pesquerías definidas para la evaluación de la población de atún aleta amarilla en el OPO. PS = red de cerco; LP = caña; LL = palangre; OBJ = lances sobre objetos flotantes; NOA = lances sobre atunes no asociados; DEL = lances sobre atunes asociados con delfines. En la Figura 2.1 se ilustran las zonas de muestreo, y en la Sección 2.2.1 se describen los descartes.

Fishery	Gear type	Set type	Years	Sampling areas	Catch data
Pesquería	**Tipo de arte**	**Tipo de lance**	**Años**	**Zonas de muestreo**	**Datos de captura**
1	PS	OBJ	1975-2010	11-12	retained catch + discards from inefficiencies in fishing process–captura retenida + descartes por ineficacias en el proceso de pesca
2	PS	OBJ	1975-2010	7, 9	
3	PS	OBJ	1975-2010	5-6, 13	
4	PS	OBJ	1975-2010	1-4, 8, 10	
5	PS	NOA	1975-2010	1-4, 8, 10	retained catch + discards–captura retenida + descartes
6	PS	NOA	1975-2010	5-7, 9, 11-13	
7	PS	DEL	1975-2010	2-3, 10	
8	PS	DEL	1975-2010	1, 4-6, 8, 13	
9	PS	DEL	1975-2010	7, 9, 11-12	
10	LP		1975-2010	1-13	retained catch only (in numbers)— captura retenida solamente (en número)
11	LL		1975-2010	N of-de 15°N	
12	LL		1975-2010	S of-de 15°N	
13	PS	OBJ	1993-2010	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	1993-2010	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	1993-2010	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	1993-2010	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 time of spawning (thousands of fish), biomass (metric tons present at the beginning of the year), and spawning biomass ratio (SBR) of yellowfin tuna in the EPO at the beginning of the year. Biomass is defined as the total weight of yellowfin aged three quarters or more.

TABLA 4.1. Reclutamiento anual total estimado a la pesquería en el momento de desove (en miles de peces), biomasa (toneladas métricas presentes al principio de año), y cociente de biomasa reproductora (SBR) del atún aleta amarilla en el OPO. Se define la biomasa como el peso total de aleta amarilla de tres trimestres o más de edad.

Year	**Total recruitment**	**Biomass of 3 quarters+ fish**	
Año	**Reclutamiento total**	**Biomasa de peces de edad 3 trimestres+**	**SBR**
1975	412,283	327,929	0.23
1976	296,433	355,987	0.32
1977	529,966	286,818	0.25
1978	488,572	256,642	0.18
1979	374,687	239,564	0.15
1980	357,419	236,638	0.16
1981	342,036	248,880	0.18
1982	481,308	204,445	0.16
1983	675,799	213,116	0.14
1984	598,555	325,181	0.20
1985	583,703	433,989	0.30
1986	636,024	452,537	0.40
1987	858,688	387,864	0.34
1988	742,582	401,717	0.22
1989	606,005	442,857	0.30
1990	540,831	448,359	0.36
1991	689,146	404,739	0.34
1992	657,546	420,047	0.29
1993	738,519	440,724	0.32
1994	620,151	458,514	0.38
1995	645,929	467,751	0.37
1996	750,099	474,309	0.41
1997	804,810	446,297	0.33
1998	1,234,582	425,355	0.31
1999	981,989	558,744	0.34
2000	654,466	650,190	0.48
2001	938,097	750,325	0.68
2002	733,082	650,417	0.55
2003	565,763	508,006	0.36
2004	398,717	382,538	0.28
2005	555,754	337,682	0.27
2006	606,024	272,015	0.19
2007	530,555	292,794	0.20
2008	421,575	369,409	0.26
2009	508,284	379,526	0.35
2010	956,492	318,930	0.27
2011		344,999	0.19

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)	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	26.42	0.35	16	154.31	81.12
2	33.04	0.70	17	159.16	89.20
3	40.64	1.32	18	163.33	96.52
4	49.17	2.38	19	166.91	103.00
5	58.48	4.06	20	169.95	108.63
6	68.38	6.58	21	172.52	113.45
7	78.66	10.14	22	174.69	117.51
8	89.05	14.87	23	176.51	120.91
9	99.31	20.82	24	178.04	123.73
10	109.22	27.92	25	179.31	126.07
11	118.59	36.00	26	180.37	128.00
12	127.30	44.80	27	181.26	129.58
13	135.24	54.00	28	181.99	130.89
14	142.39	63.31	29	182.60	131.97
15	148.74	72.43			

TABLE 4.3. Measure of the goodness of fit (root mean square error, RMSE) to the CPUE data of different fisheries.
TABLA 4.3. Medida de la bondad del ajuste (raíz del error cuadrado medio, RECM) a los datos de CPUE de distintas pesquerías.

Fishery	RMSE	Used
Pesquería	**RECM**	**Usado**
F1-OBJ_S	0.35	No
F2-OBJ_C	0.41	No
F3-OBJ_I	0.69	No
F4-OBJ_N	0.41	No
F5-NOA_N	0.54	Yes/Sí
F6-NOA_S	0.62	Yes/Sí
F7-DEL_N	0.39	Yes/Sí
F8-DEL_I	0.38	Yes/Sí
F9-DEL_S	0.51	No
F10-BB	N/A	No
F11-LL_N	0.75	No
F12-LL_S	0.36	Yes/Sí

TABLE 4.4. Mean input and effective sample sizes of the size composition of different fisheries.
TABLA 4.4. Tamaño de muestra medio de insumo y efectivo de la composición por talla de distintas pesquerías.

Fishery	Mean input sample size	Mean effective sample size	Used
Pesquería	**Tamaño de muestra medio de insumo**	**Tamaño de muestra medio efectivo**	**Usado**
F1-OBJ_S	14	33	Yes/Sí
F2-OBJ_C	14	28	Yes/Sí
F3-OBJ_I	13	23	Yes/Sí
F4-OBJ_N	11	57	Yes/Sí
F5-NOA_N	23	56	Yes/Sí
F6-NOA_S	21	34	Yes/Sí
F7-DEL_N	32	120	Yes/Sí
F8-DEL_I	30	129	Yes/Sí
F9-DEL_S	9	53	No
F10-LP	12	36	Yes/Sí
F11-LL_N	2	31	Yes/Sí
F12-LL_S	30	104	Yes/Sí

TABLE 4.5. Likelihood components obtained for the base case and sensitivity analyes.
TABLA 4.5. Componentes de verosimilitud obtenidos para el caso base y los análisis de sensibilidad.

Data	Base case	h = 0.75	L_2 170 cm	L_2 190 cm	CPUE DEL-N
Datos	**Caso base**				
CPUE	-140.54	-140.23	-143.58	-138.48	-177.80
Size compositions – Composiciones por talla	8300.04	8299.45	8260.65	8336.89	8272.20
Age at length – Talla por edad	100.87	100.99	122.68	107.05	104.76
Recruitment - Reclutamiento	-2.37	-7.39	0.53	-5.36	-0.74
Total	8257.99	8252.83	8240.27	8300.10	8198.41

TABLE 5.1. Estimates of the MSY and its associated quantities for yellowfin tuna for the base case assessment and the sensitivity analyses. All analyses are based on average fishing mortality during 2008-2010. B_{recent} and B_{MSY} are defined as the biomass of fish 3+ quarters old (in metric tons) at the beginning of 2011 and at MSY, respectively. S_{recent} and S_{MSY} are in metric tons. C_{recent} is the estimated total catch in 2010. 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 during 2008-2010.

TABLA 5.1. Estimaciones del RMS y sus cantidades asociadas para el 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 2008-2010. Se definen B_{recent} y B_{RMS} como la biomasa de peces de 3+ trimestres de edad (en toneladas métricas) al principio de 2011 y en RMS, respectivamente. Se expresan S_{recent} y S_{MSY} en toneladas métricas. C_{recent} es la captura total estimada en 2010. El multiplicador de *F* indica cuántas veces se tendría que incrementar el esfuerzo para lograr el RMS en relación con la mortalidad por pesca media durante 2008-2010.

			L_2		
Data / **Datos**	**Base case** / **Caso base**	h **= 0.75**	**170 cm**	**190 cm**	**CPUE DEL-N**
MSY-RMS	263418	289677	272506	264428	266738
B_{MSY}- B_{RMS}	354737	557185	366631	357984	360749
S_{MSY}- S_{RMS}	3287	5947	3754	3138	3365
B_{MSY}/B_0- B_{RMS}/B_0	0.31	0.36	0.31	0.31	0.31
S_{MSY}/S_0- S_{RMS}/S_0	0.25	0.34	0.24	0.26	0.26
C_{recent}/MSY- C_{recent}/RMS	0.88	0.8	0.85	0.88	0.87
B_{recent}/B_{MSY}- B_{recent}/B_{RMS}	0.97	0.62	1.18	0.87	1.26
S_{recent}/S_{MSY}-S_{recent}/S_{RMS}	0.73	0.41	0.99	0.61	1.02
F multiplier-Multiplicador de *F*	1.16	0.72	1.58	0.98	1.33

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 (Figura 4.4). Se expresan las estimaciones de RMS y B_{RMS} en toneladas métricas. OBJ = lances sobre objetos flotantes; NOA = lances sobre atunes no asociados; DEL = lances sobre atunes asociados con delfines; LL = palangre.

Data -Datos	**All - Todas**	**OBJ**	**NOA**	**DEL**	**LL**
MSY-RMS	262,857	166,349	221,759	307,523	407,748
B_{MSY}- B_{RMS}	354,958	208,259	295,992	363,447	380,574
S_{MSY}- S_{RMS}	3,305	1,607	2,485	3,139	3,137
B_{MSY}/B_0- B_{RMS}/B_0	0.31	0.18	0.26	0.32	0.33
S_{MSY}/S_0- S_{RMS}/S_0	0.26	0.13	0.19	0.24	0.24
C_{recent}/MSY- C_{recent}/RMS	0.88	1.39	1.04	0.75	0.57
B_{recent}/B_{MSY}- B_{recent}/B_{RMS}	0.96	1.64	1.15	0.94	0.89
S_{recent}/S_{MSY}-S_{recent}/S_{RMS}	0.71	1.47	0.95	0.75	0.75
F multiplier-Multiplicador de *F*	1.13	8.11	7.79	2.20	138.30

Appendices—Anexos

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

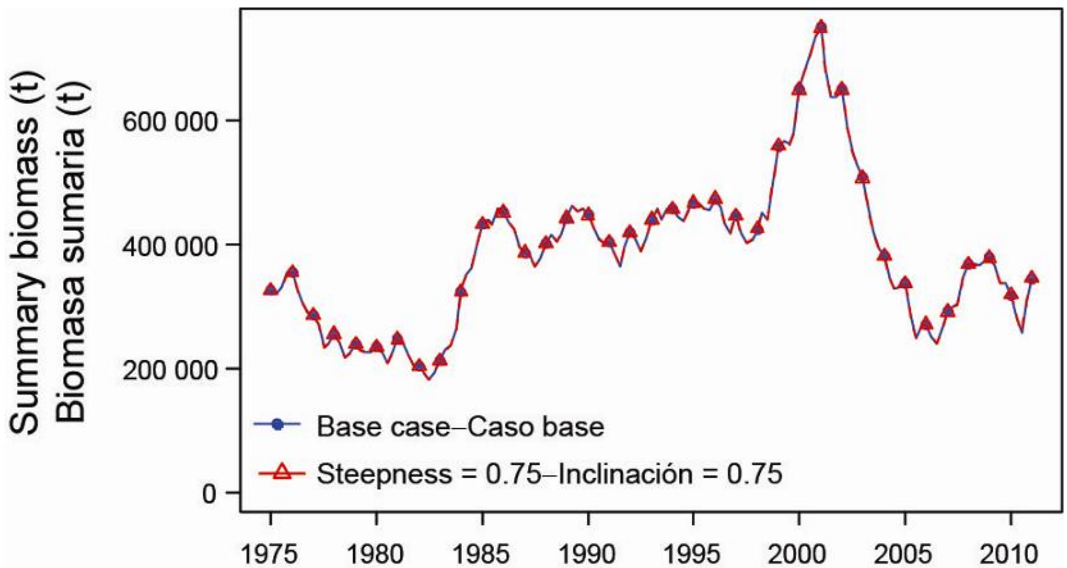

FIGURE A.1. Comparison of the estimates of biomass of yellowfin tuna from the analysis without a stock-recruitment relationship (base case) and with a stock-recruitment relationship (steepness = 0.75).
FIGURA A.1. Comparación de las estimaciones de la biomasa de atún aleta amarilla del análisis sin relación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

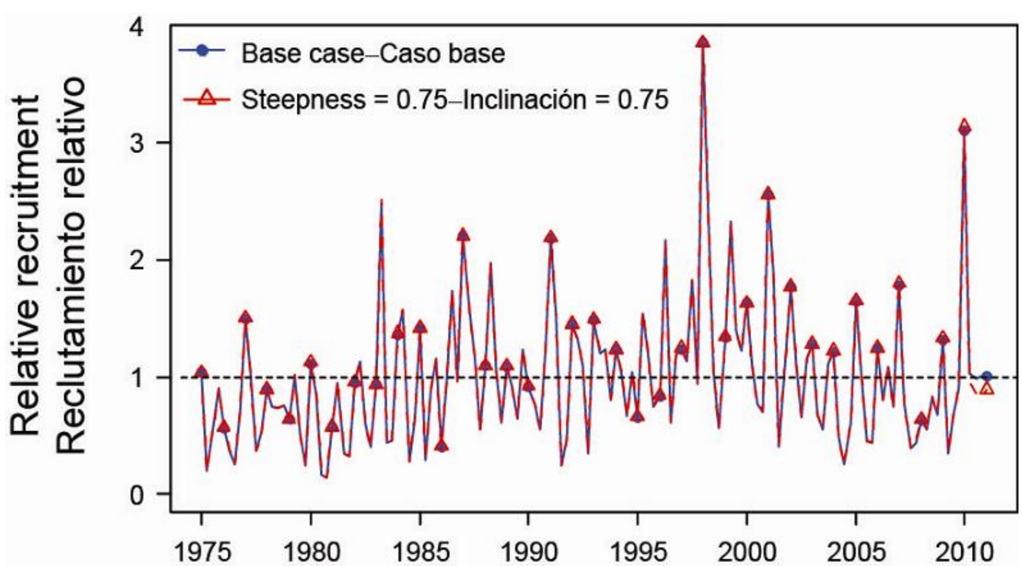

FIGURE A.2. Comparison of estimates of recruitment of yellowfin tuna from the analysis without a stock-recruitment relationship (base case) and with a stock-recruitment relationship (steepness = 0.75).
FIGURA A.2. Comparación de las estimaciones de reclutamiento de atún aleta amarilla del análisis sin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

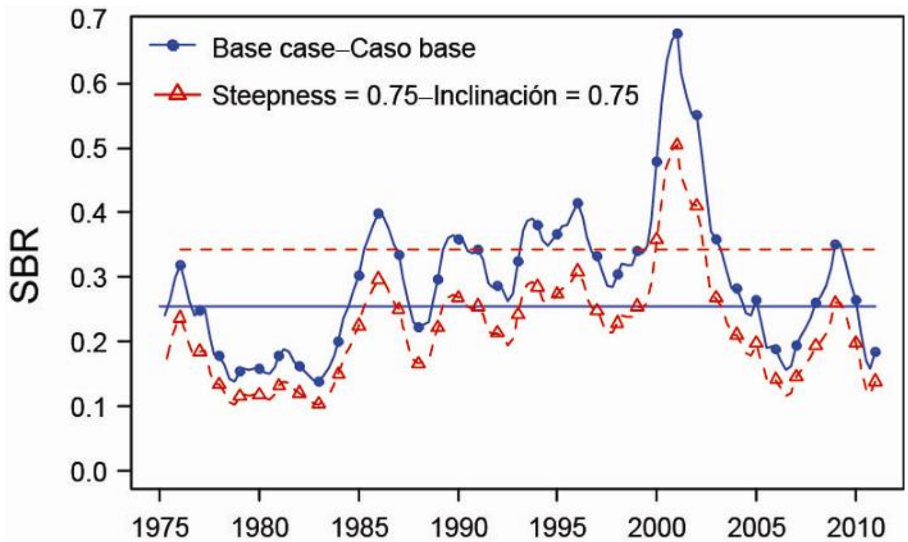

FIGURE A.3a. Comparison of estimates of the spawning biomass ratio (SBR) of yellowfin tuna from the analysis without a stock-recruitment relationship (base case) and with a stock-recruitment relationship (steepness = 0.75). The horizontal lines represent the SBRs associated with MSY for the two scenarios.
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 los SBR asociados con el RMS para los dos escenarios.

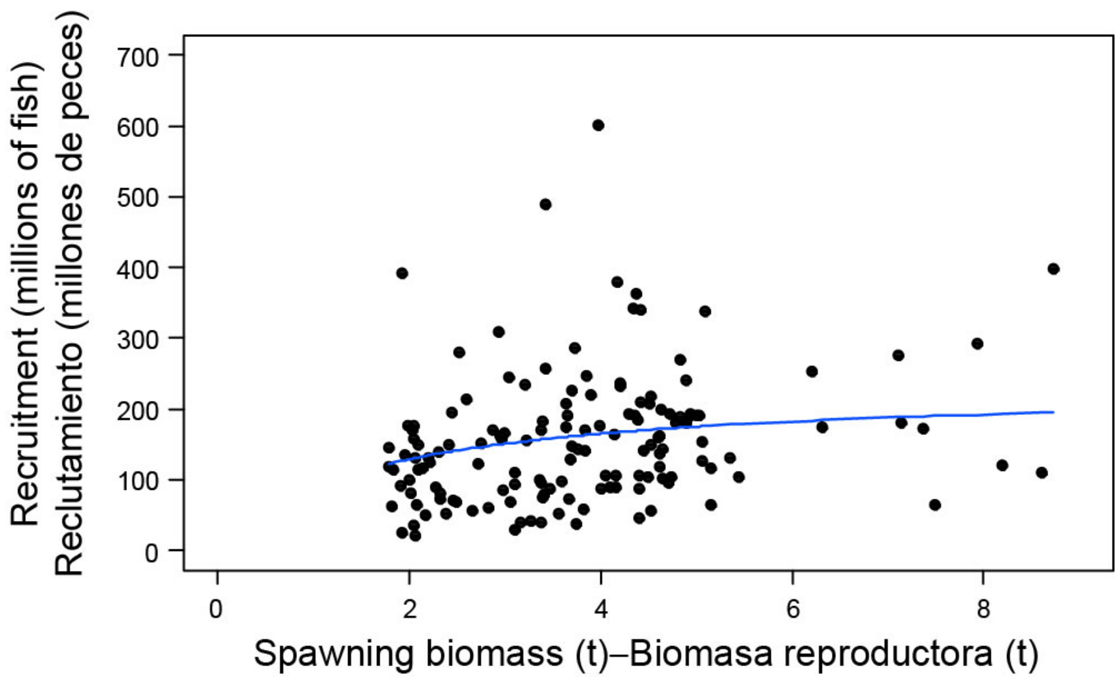

FIGURE A.4. Recruitment plotted against the index of spawning biomass of yellowfin tuna when the analysis has a stock-recruitment relationship (steepness = 0.75).
FIGURA A.4. Reclutamiento graficado como función de la biomasa reproductora de atún aleta amarilla cuando el análisis incluye una relación población-reclutamiento (inclinación = 0,75).

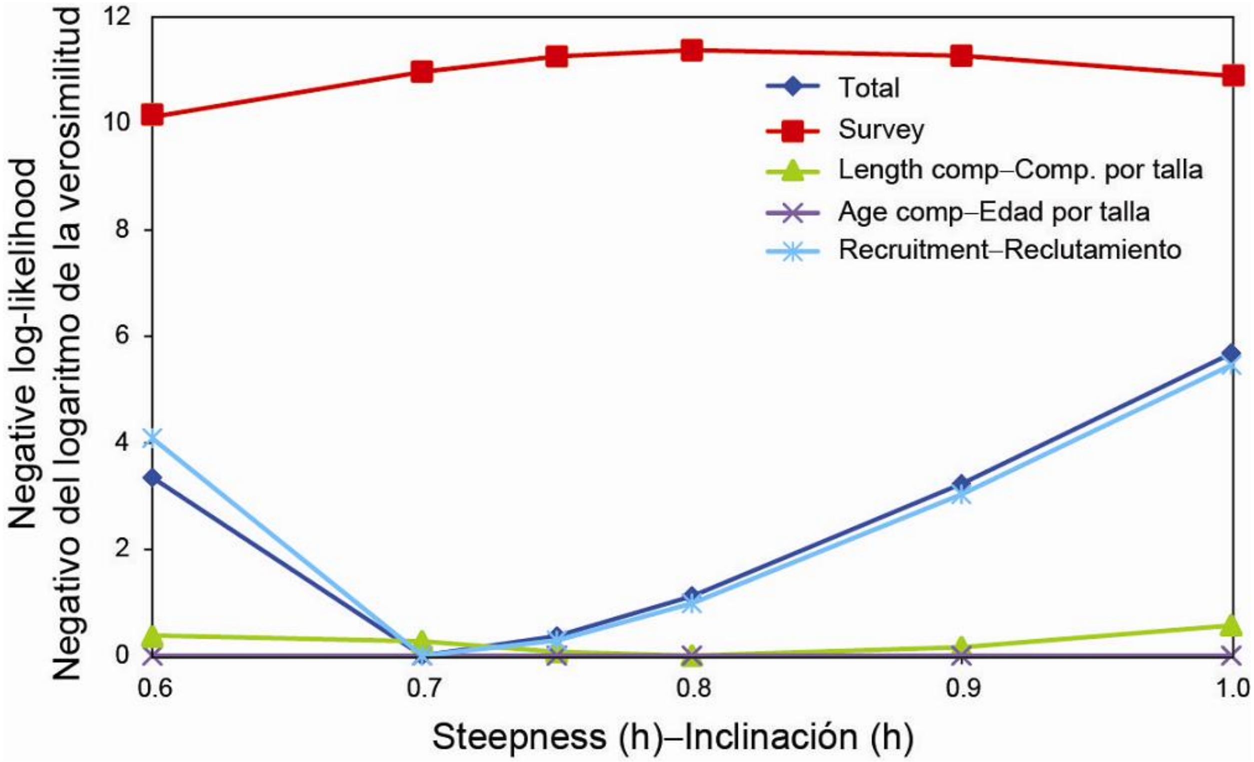

FIGURE A.5. Likelihood profile on steepness.
FIGURA A.5. Perfil de verosimilitud en inclinación.

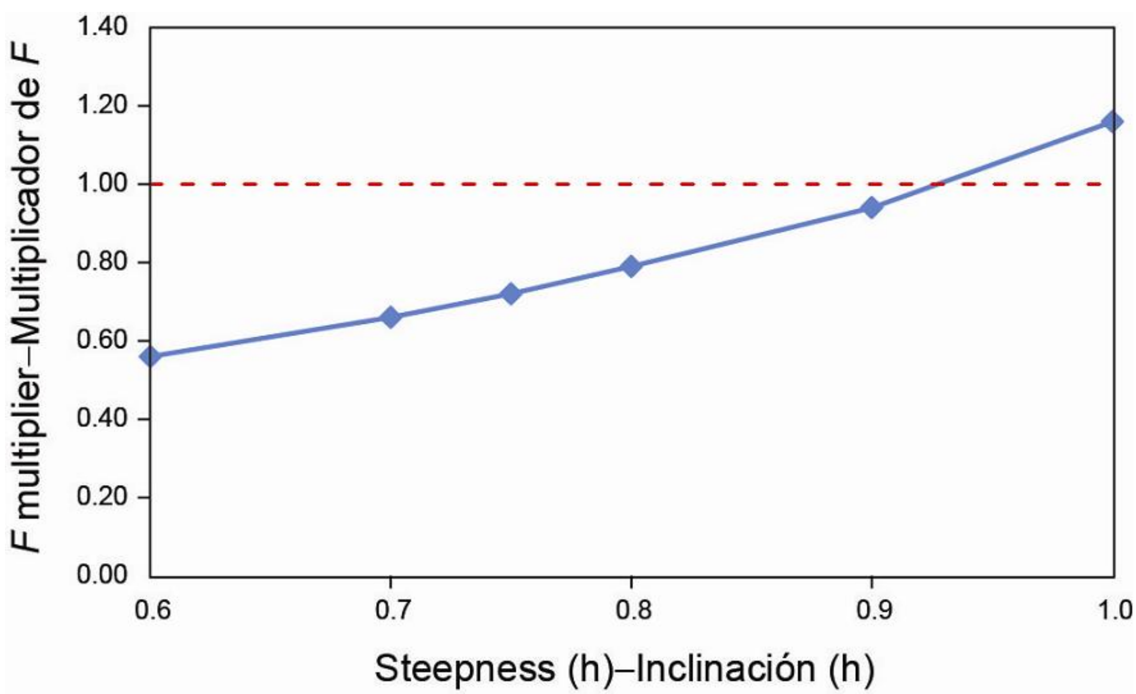

FIGURE A.6. *F* multiplier as a function of steepness.
FIGURA A.6. Multiplicador de *F* como función de la inclinación.

APPENDIX B: SENSITIVITY ANALYSIS TO THE AVERAGE SIZE OF THE OLDEST FISH PARAMETER, L_2

ANEXO B: ANÁLISIS DE SENSIBILIDAD AL PARÁMETRO DE LA TALLA MEDIA DE LOS PECES DE MAYOR EDAD, L_2

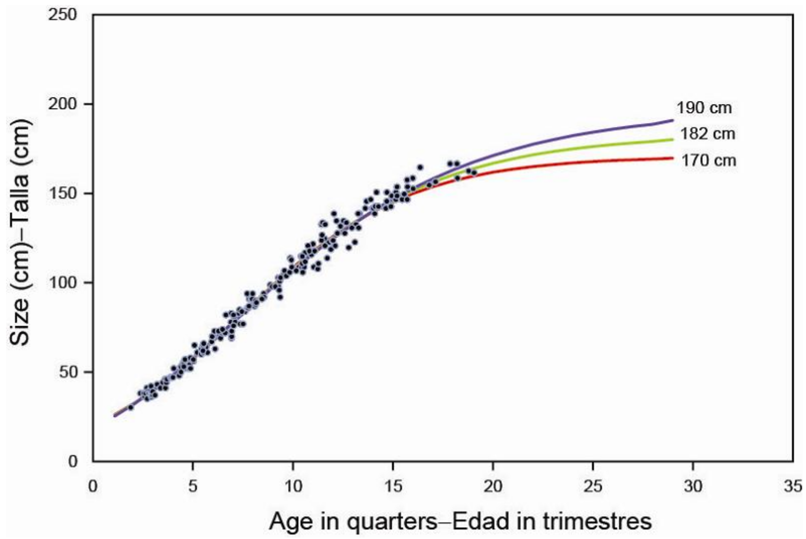

FIGURE B.1. Comparison of the Richards growth curves (sensitivity) for yellowfin tuna, assuming different fixed values for the average size of the oldest fish (L_2) parameter.
FIGURA B.1. Comparación de las curvas de crecimiento de Richards (sensibilidad) del atún alleta amarilla, con diferentes supuestos de valor fijo del parámetro de talla media de los peces de mayor edad (L_2).

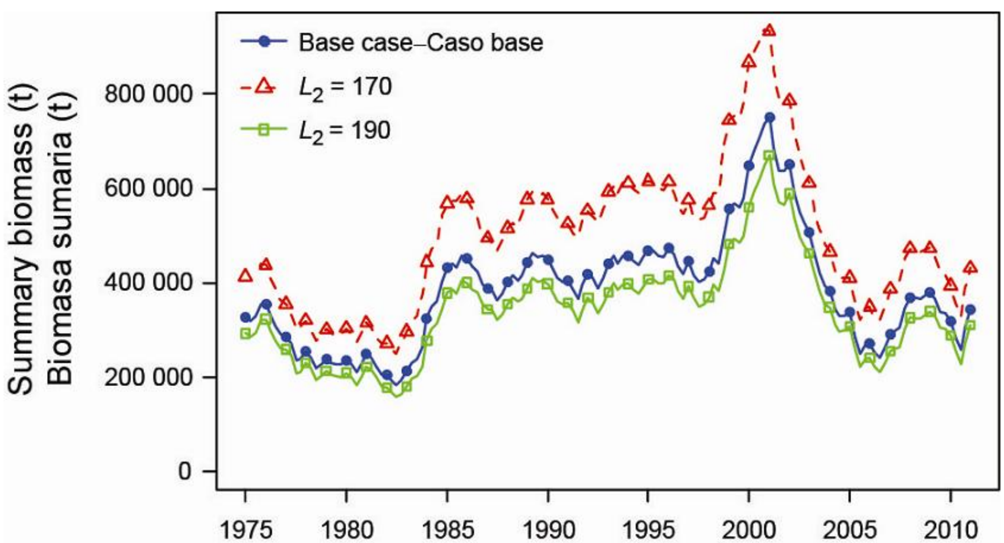

FIGURE B.2. Comparison of estimates of biomass of yellowfin tuna from the base case analysis using a Richards growth curve with the average size of the oldest fish (L_2) fixed at 182 cm, and two alternative models with L_2 fixed at a lower (170 cm) and a higher value (190 cm). t = metric tons.
FIGURA B.2. Comparación de las estimaciones de biomasa de atún alleta amarilla del análisis del caso base que usa una curva de crecimiento de Richards con el tamaño promedio de los peces de mayor edad (L_2) fijado en 182 cm, y dos modelos alternativos con L_2 fijado en valores menor (170 cm) y mayor (190 cm). t = toneladas métricas.

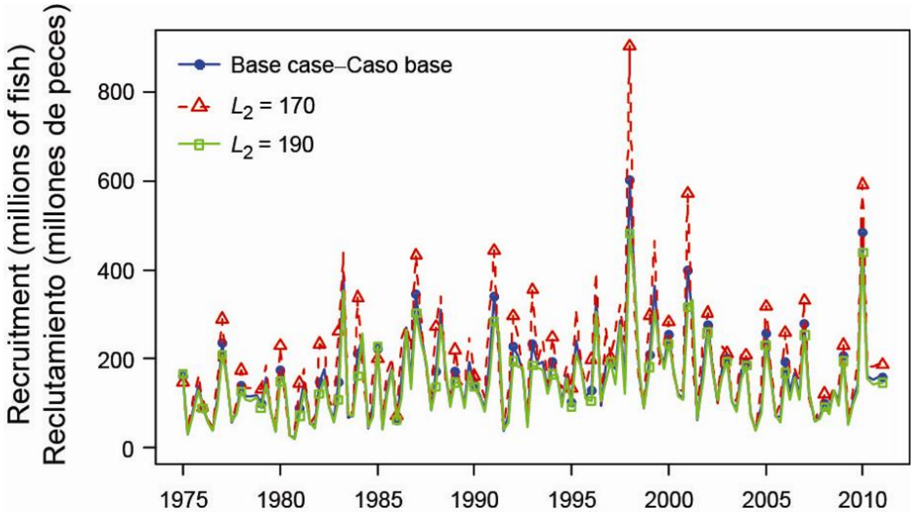

FIGURE B.3a. Comparison of estimates of absolute recruitment (in millions of fish) for yellowfin tuna from the base case analysis using a Richards growth curve with the average size of the oldest fish (L_2) fixed at 182 cm, and two alternative models with L_2 fixed at a lower (170 cm) and a higher value (190 cm).

FIGURA B.3a. Comparación de las estimaciones de reclutamiento absoluto (en millones de peces) de atún alleta amarilla del análisis del caso base que usa una curva de crecimiento de Richards con la talla promedio de los peces de mayor edad (L_2) fijado en 182 cm, y dos modelos alternativos con L_2 fijado en valores menor (170 cm) y mayor (190 cm).

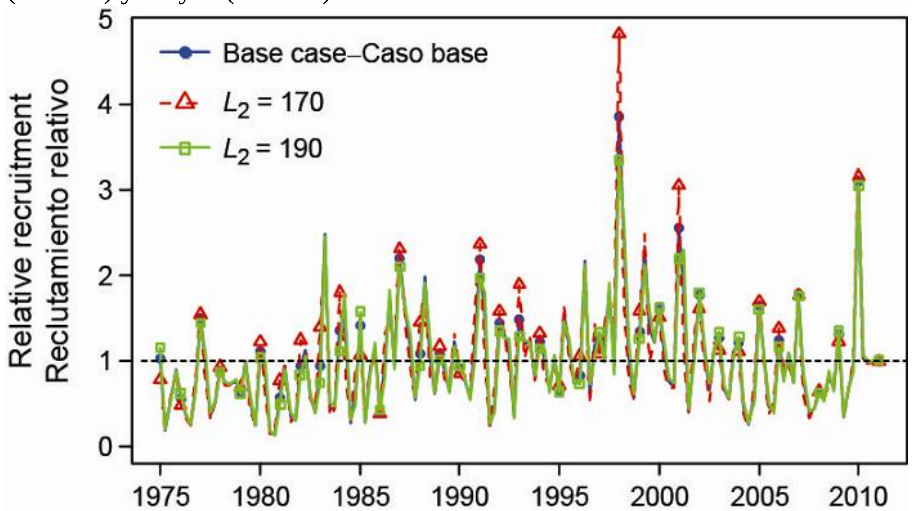

FIGURE B.3b. Comparison of estimates of relative recruitment for yellowfin tuna from the base case analysis using a Richards growth curve with the average size of the oldest fish (L_2) fixed at 182 cm, and two alternative models with L_2 fixed at a lower (170 cm) and a higher value (190 cm). The estimates are scaled so that the estimate of average recruitment is equal to 1.0 (dashed horizontal line).

FIGURA B.3b. Comparación de las estimaciones de reclutamiento relativo de atún alleta amarilla del análisis del caso base que usa una curva de crecimiento de Richards con el tamaño promedio de los peces de mayor edad (L_2) fijado en 182 cm, y dos modelos alternativos con L_2 fijado en valores menor (170 cm) y mayor (190 cm). Se escalan las estimaciones para que la estimación de reclutamiento medio equivalga a 1,0 (línea de trazos horizontal).

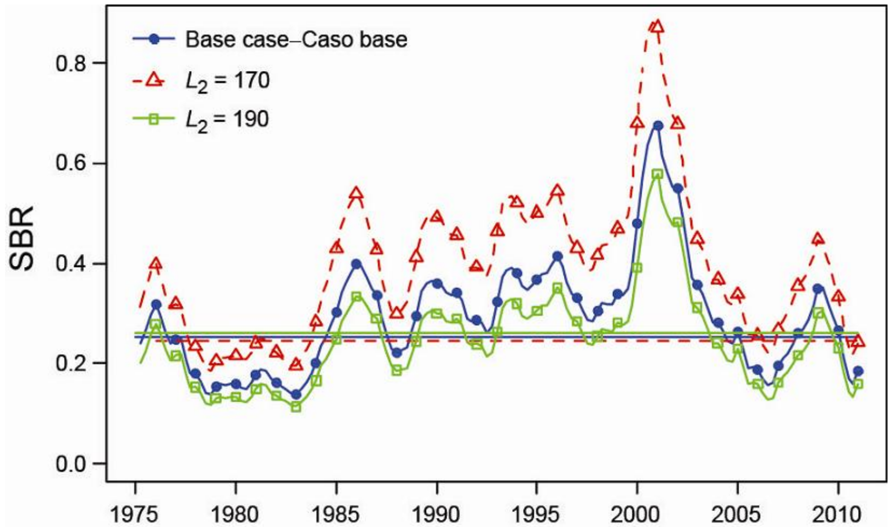

FIGURE B.4. Comparison of estimates of the spawning biomass ratio (SBR) of yellowfin tuna from the base case analysis using a Richards growth curve with the average size of oldest fish (L_2) fixed at 182 cm, and two alternative models with L_2 fixed at a lower (170 cm) and a higher value (190 cm). The horizontal lines represent the SBRs associated with MSY under the two scenarios.

FIGURA B.4. Comparación de las estimaciones del cociente de biomasa reproductora (SBR) de atún aleta amarilla del análisis del caso base que usa una curva de crecimiento de Richards con el tamaño promedio de los peces de mayor edad (L_2) fijado en 182 cm, y dos modelos alternativos con L_2 fijado en valores menor (170 cm) y mayor (190 cm). Las líneas horizontales representan los SBR asociados con el RMS en los dos escenarios.

APPENDIX C: SENSITIVITY ANALYSIS TO FITTING THE CPUE OF THE NORTHERN DOLPHIN ASSOCIATED FISHERY AS THE MAIN INDEX OF ABUNDANCE
ANEXO C: ANÁLISIS DE SENSIBILIDAD AL AJUSTE DE LA CPUE DE LA PESQUERÍA ASOCIADA CON DELFINES DEL NORTE COMO ÍNDICE PRINCIPAL DE LA ABUNDANCIA

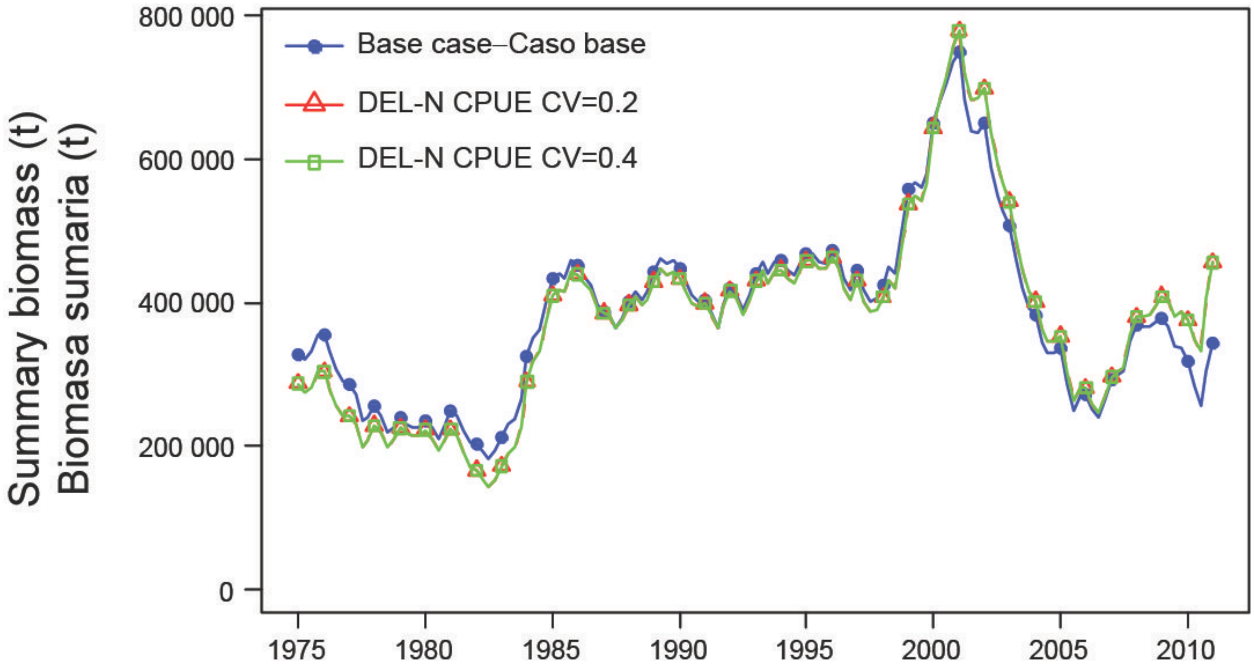

FIGURE C.1. Comparison of the estimates of biomass of yellowfin tuna from the model fitting more closely to the CPUE of the southern longline fishery (base case) and the model fitting more closely to the CPUE of the northern dolphin fishery.
FIGURA C.1. Comparación de las estimaciones del reclutamiento de atún aleta amarilla del modelo que se ajusta más estrechamente a la CPUE de la pesquería de palangre del sur (caso base) y el modelo que se ajusta más estrechamente a la CPUE de la pesquería sobre delfines del norte.

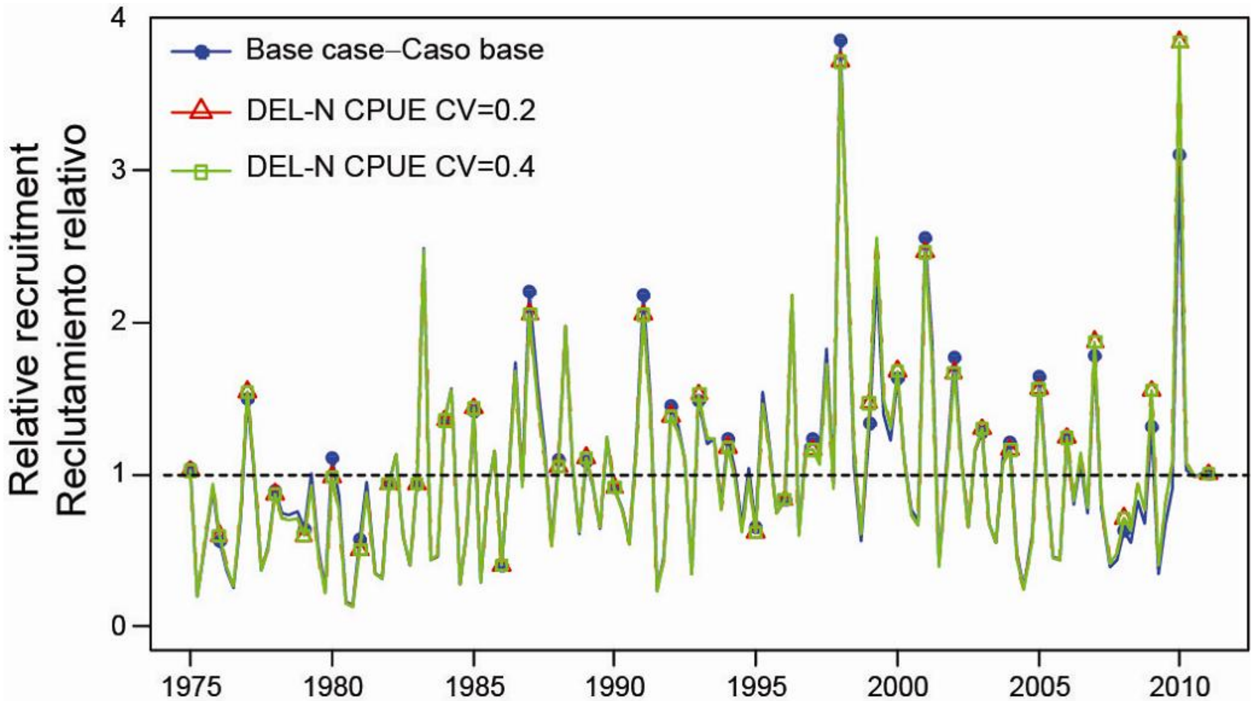

FIGURE C.2. Comparison of estimates of recruitment of yellowfin tuna from the model fitting more closely to the CPUE of the southern longline fishery (base case) and the model fitting more closely to the CPUE of the northern dolphin fishery.
FIGURA C.2. Comparación de las estimaciones del reclutamiento de atún aleta amarilla del modelo que se ajusta más estrechamente a la CPUE de la pesquería de palangre del sur (caso base) y el modelo que se ajusta más estrechamente a la CPUE de la pesquería sobre delfines del norte.

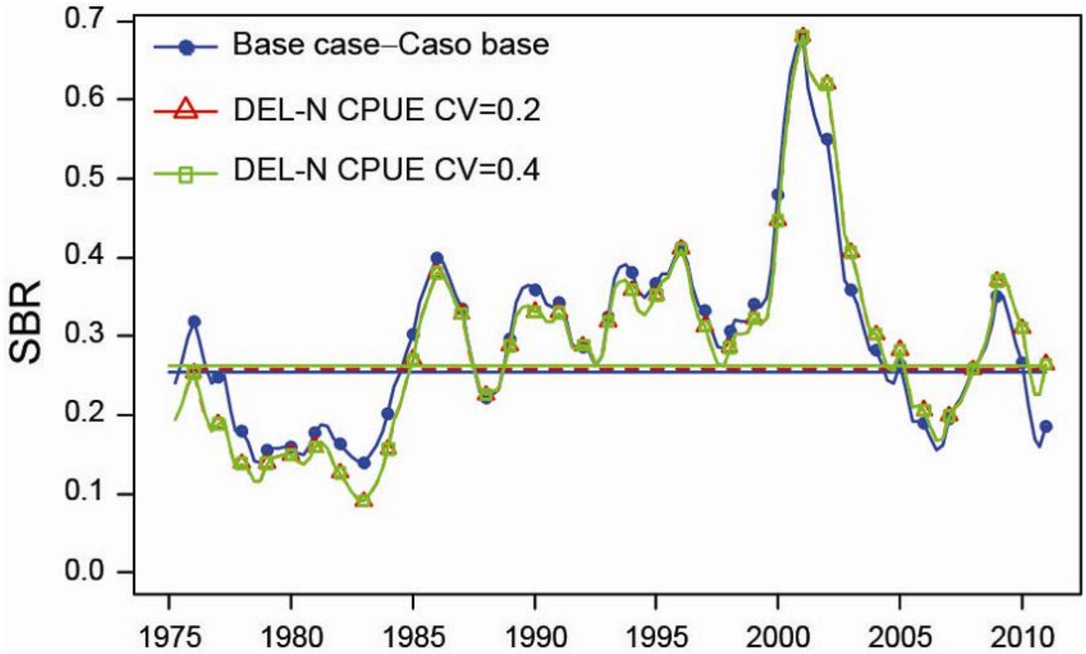

FIGURE C.3. Comparison of estimates of the spawning biomass ratio (SBR) of yellowfin tuna from the model fitting more closely to the CPUE of the southern longline fishery (base case) and the model fitting more closely to the CPUE of the northern dolphin fishery. The horizontal lines represent the SBRs associated with MSY for the two scenarios.

FIGURA C.3. Comparación de las estimaciones del cociente de biomasa reproductora (SBR) de atún aleta amarilla del modelo que se ajusta más estrechamente a la CPUE de la pesquería de palangre del sur (caso base) y el modelo que se ajusta más estrechamente a la CPUE de la pesquería sobre delfines del norte. Las líneas horizontales representan los SBR asociados con el RMS correspondiente a cada escenarios.

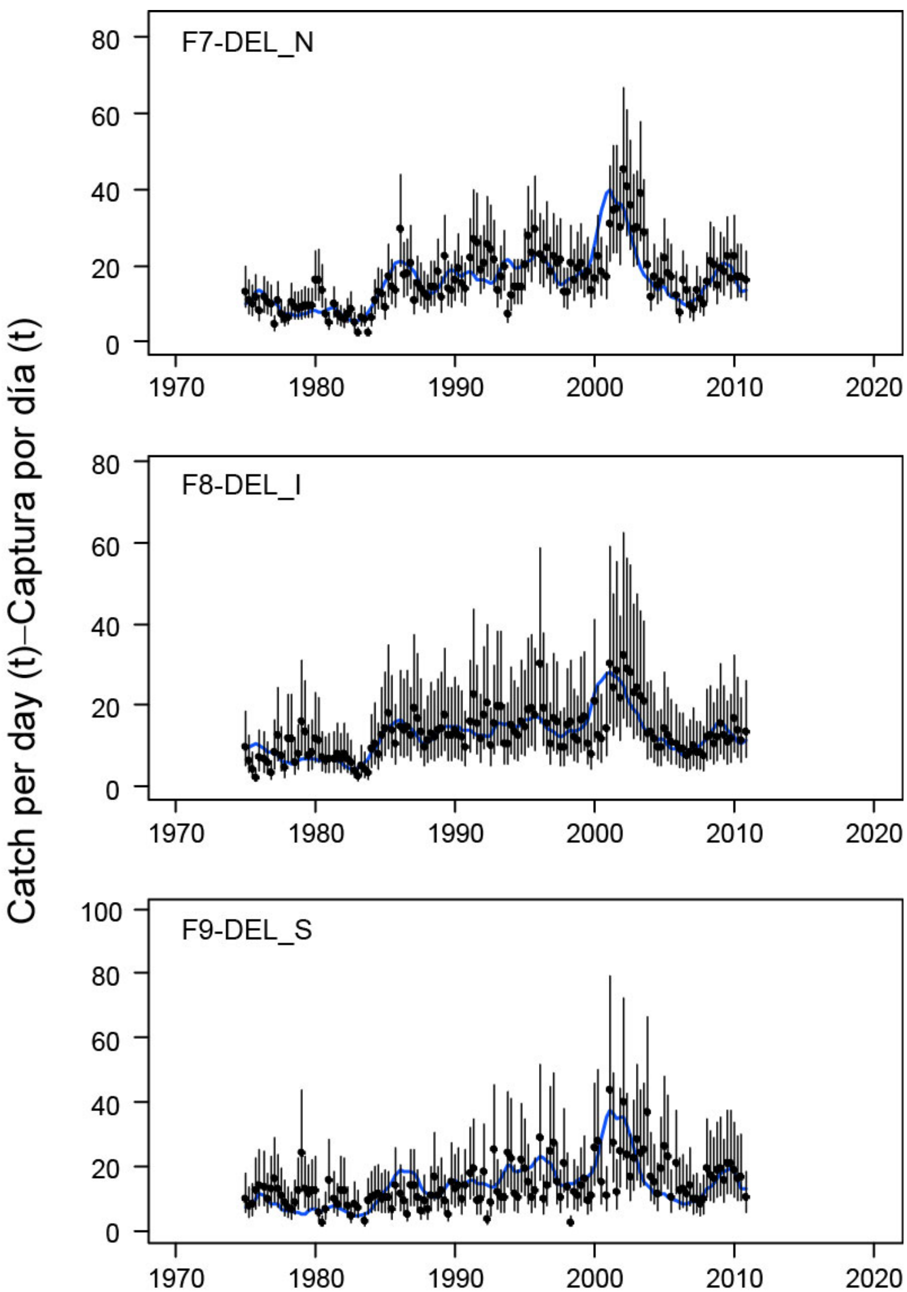

FIGURE C.4a. Model fits to the CPUE-based indices of abundance for the dolphin-associated fisheries, from the model fitting more closely to the CPUE of the northern dolphin fishery. The vertical lines represent the 95% confidence intervals for the observed data based on the internally-estimated standard deviations for the lognormal-based likelihood function.

FIGURA C.4a. Ajustes del modelo a los índices de abundancia basados en CPUE correspondientes a las pesquerías asociadas con delfines del modelo que se ajusta más estrechamente a la CPUE del pesquería sobre delfines del norte. Las líneas verticales representan los intervalos de confianza de 95% correspondientes a los datos observados basados en las desviaciones estándar estimadas internamente para la función de verosimilitud basada en logaritmos normales.

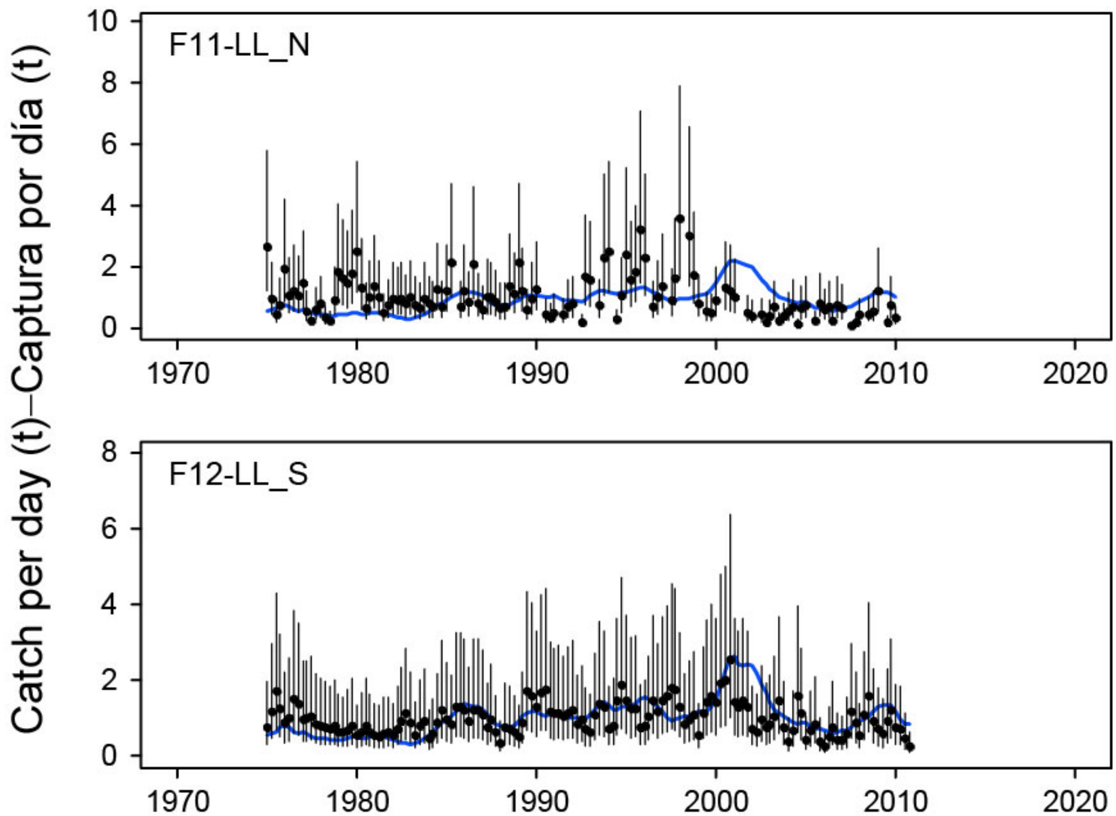

FIGURE C.4b. Model fits to the CPUE-based indices of abundance for the longline fisheries, from the model fitting more closely to the CPUE of the northern dolphin fishery. The vertical lines are the 95% confidence intervals for the observed data based on the internally-estimated standard deviations for the lognormal-based likelihood function.

FIGURA C.4b. Ajustes del modelo a los índices de abundancia basados en CPUE correspondientes a las pesquerías de palangre del modelo que se ajusta más estrechamente a la CPUE del pesquería sobre delfines del norte. Las líneas verticales representan los intervalos de confianza de 95% correspondientes a los datos observados basados en las desviaciones estándar estimadas internamente para la función de verosimilitud basada en logaritmos normales.

APPENDIX H: 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 H: 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.

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

	Age in quarters - Edad en trimestres		
	1-10	**11-20**	**21+**
1975	0.37	0.95	0.62
1976	0.42	1.10	0.84
1977	0.46	1.18	0.98
1978	0.54	1.02	0.79
1979	0.57	1.20	0.94
1980	0.48	1.04	0.77
1981	0.53	1.07	0.81
1982	0.44	0.96	0.76
1983	0.27	0.69	0.59
1984	0.26	0.70	0.54
1985	0.29	0.80	0.58
1986	0.37	0.95	0.59
1987	0.48	1.22	0.84
1988	0.50	1.30	0.92
1989	0.40	1.07	0.74
1990	0.39	1.18	0.86
1991	0.40	1.13	0.86
1992	0.38	1.07	0.72
1993	0.36	0.79	0.64
1994	0.34	0.88	0.73
1995	0.33	0.76	0.56
1996	0.41	0.74	0.50
1997	0.43	1.05	0.72
1998	0.43	0.90	0.64
1999	0.39	0.76	0.52
2000	0.24	0.65	0.51
2001	0.37	0.87	0.66
2002	0.45	1.24	0.87
2003	0.57	1.90	1.44
2004	0.50	1.83	1.58
2005	0.60	1.82	1.41
2006	0.46	1.28	1.01
2007	0.38	1.00	0.78
2008	0.31	0.80	0.56
2009	0.38	1.01	0.71
2010	0.54	1.21	0.74

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INTER-AMERICAN TROPICAL TUNA COMMISSION

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UPDATED INDICATORS OF STOCK STATUS FOR SKIPJACK TUNA IN THE EASTERN PACIFIC OCEAN

Mark N. Maunder

A major management objective for tunas in the eastern Pacific Ocean (EPO) is to keep stocks at levels capable of producing maximum sustainable yields (MSYs). Management objectives based on MSY or related reference points (*e.g.* fishing mortality that produces MSY (F_{MSY}); spawner-per-recruit proxies) are in use for many species and stocks worldwide. However, these objectives require that reference points and quantities to which they are compared be available. The various reference points require different amounts and types of information, ranging from biological information (*e.g.* natural mortality, growth, and stock-recruitment relationship) and fisheries characteristics (*e.g.* age-specific selectivity), to absolute estimates of biomass and exploitation rates. These absolute estimates generally require a formal stock assessment model. For many species, the information required to estimate these quantities is not available, and alternative approaches are needed. Even more data are required if catch quotas are to be used as the management tool.

Skipjack tuna is a notoriously difficult species to assess. Due to skipjack's high and variable productivity (*i.e.* annual recruitment is a large proportion of total biomass), it is difficult to detect the effect of fishing on the population with standard fisheries data and stock assessment methods. This is particularly true for the stock of the EPO, due to the lack of age-frequency data and the limited tagging data. The continuous recruitment and rapid growth of skipjack mean that the temporal stratification needed to observe modes in length-frequency data make the current sample sizes inadequate. Previous assessments have had difficulty in estimating the absolute levels of biomass and exploitation rates, due to the possibility of a dome-shaped selectivity curve (Maunder 2002; Maunder and Harley 2005), which would mean that there is a cryptic biomass of large skipjack that cannot be estimated. The most recent assessment of skipjack in the EPO (Maunder and Harley 2005) is considered preliminary because it is not known whether the catch per day fished for purse-seine fisheries is proportional to abundance. The results from that assessment are more consistent among sensitivity analyses than the earlier assessments, which suggests that they may be more reliable. However, in addition to the problems listed above, the levels of age-specific natural mortality are uncertain, if not unknown, and current yield-per-recruit (YPR) calculations indicate that the YPR would be maximized by catching the youngest skipjack in the model (Maunder and Harley 2005). Therefore, neither the biomass- nor fishing mortality-based reference points, nor the indicators to which they are compared, are available for skipjack in the EPO.

One of the major problems mentioned above is the uncertainty as to whether the catch per unit of effort (CPUE) of the purse-seine fisheries is an appropriate index of abundance for skipjack, particularly when the fish are associated with fish-aggregating devices (FADs). Purse-seine CPUE data are particularly problematic, because it is difficult to identify the appropriate unit of effort. In the current assessment, effort is defined as the amount of searching time required to find a school of fish on which to set the purse seine, and this is approximated by number of days fished. Few skipjack are caught in the longline fisheries or dolphin-associated purse-seine fisheries, so these fisheries cannot be used to develop reliable indices of abundance for skipjack. Within a single trip, purse-seine sets on unassociated schools are generally intermingled with floating-object or dolphin-associated sets, complicating the CPUE calculations. Maunder and Hoyle (2007) developed a novel method to generate an index of abundance, using data from the floating-object fisheries. This method used the ratio of skipjack to bigeye in the catch and the "known" abundance of bigeye based on stock assessment results. Unfortunately, the method was of limited usefulness, and more research is needed to improve it. Currently, there is no reliable index of relative abundance for skipjack in the EPO. Therefore, other indicators of stock status, such as the average weight of the fish in the catch, should be investigated.

Since the stock assessments and reference points for skipjack in the EPO are so uncertain, developing alternative methods to assess and manage the species that are robust to these uncertainties would be beneficial. Full management strategy evaluation (MSE) for skipjack would be the most comprehensive method to develop and test alternative assessment methods and management strategies (Maunder 2007); however, developing MSE is time-consuming, and has not yet been conducted for skipjack. In addition, higher priority for MSE is given to yellowfin and bigeye tuna, as available data indicate that these species are more susceptible to overfishing than skipjack. Therefore, Maunder and Deriso (2007) investigated some simple indicators of stock status based on relative quantities. Rather than using reference points based on MSY, they compared current values of indicators to the distribution of indicators observed historically. They also developed a simple stock assessment model to generate indicators for biomass, recruitment, and exploitation rate. We update their results to include data for 2010. To evaluate the current values of the indicators in comparison to historical values, we use reference levels based on the 5th and 95th percentiles, as the distributions of the indicators are somewhat asymmetric.

Eight data- and model-based indicators are shown in Figure 1. The standardized effort, which is a measure of exploitation rate, is calculated as the sum of the effort, in days fished, for the floating-object (OBJ) and unassociated (NOA) fisheries. The floating-object effort is standardized to be equivalent to the unassociated effort by multiplying by the ratio of the average floating-object CPUE to the average unassociated CPUE. The purse-seine catch has been increasing since 1985, and has fluctuated around the upper reference level since 2003, but declined in 2010. Except for a large peak in 1999, the floating-object CPUE has generally fluctuated around an average level since 1990. The unassociated CPUE has been higher than average since about 2003 and was at its highest level in 2008, but declined in 2010. The standardized effort indicator of exploitation rate has been increasing since about 1991 and has been above the upper reference level in recent years, but dropped below it in 2009 and 2010. The average weight of skipjack has been declining since 2000, and in 2009 was below the lower reference level, but increased in 2010. The recent trend is consistent among the floating object fisheries, but is not seen in the unassociated fisheries (Figure 2). The expansion of the fisheries to the west might partially explain the reduction in mean weight and a more detailed spatial analysis of mean weight is needed. The biomass, recruitment, and exploitation rate have been increasing over the past 20 years, and have fluctuated at high levels since 2003, but declined in 2010.

The main concern with the skipjack stock is the constantly increasing exploitation rate. However, the data- and model-based indicators have yet to detect any adverse consequence of this increase. The average weight was below its lower reference level in 2009, which can be a consequence of overexploitation, but it can also be caused by recent recruitments being greater than past recruitments. The continued decline in average length is a concern and, combined with leveling off of catch and CPUE, may indicate that the exploitation rate is approaching or above the level associated with MSY. The trend in many of the indicators changed in 2010, but it is uncertain what this implies.

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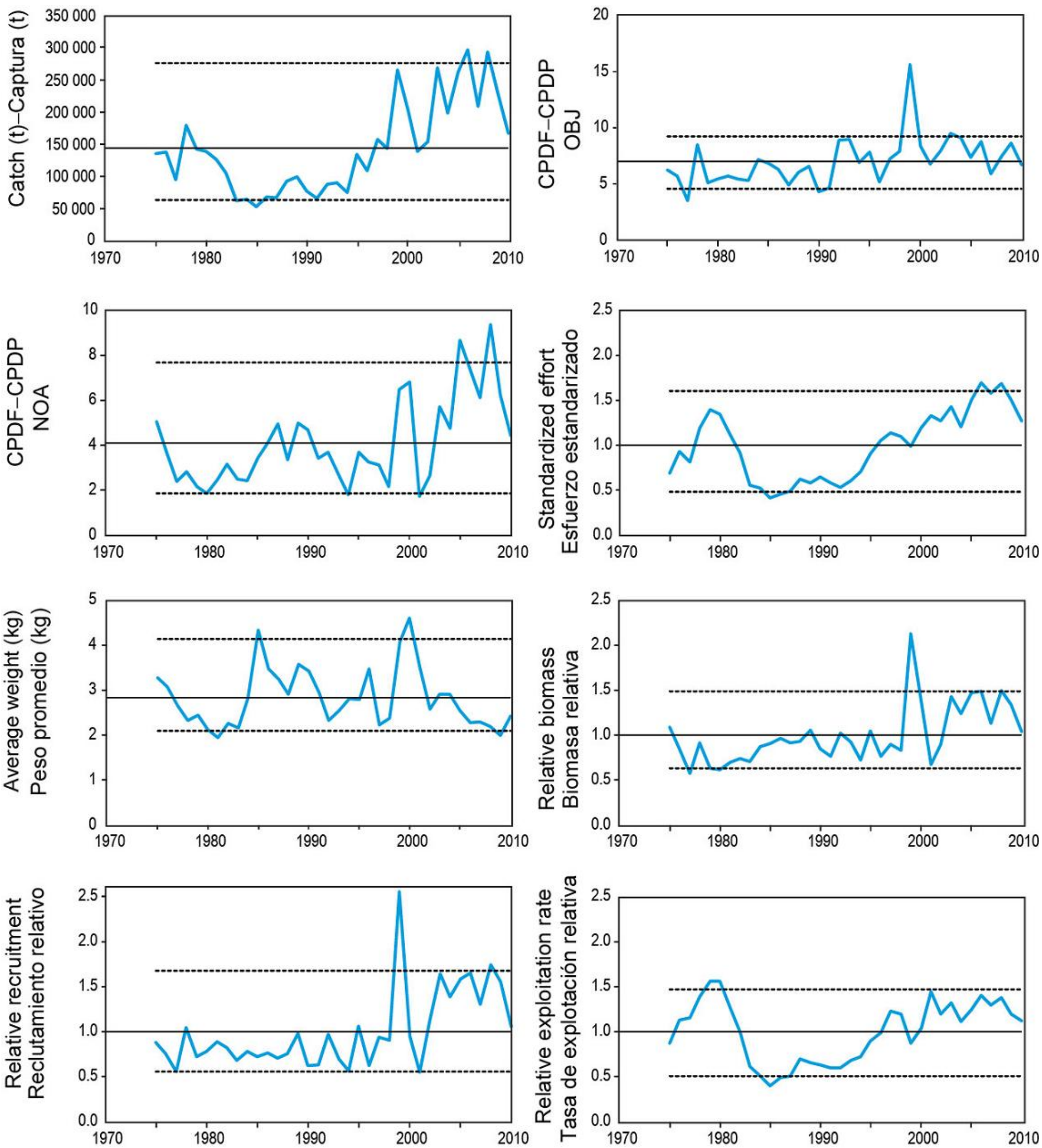

FIGURE 1. Indicators of stock status for skipjack tuna in the eastern Pacific Ocean. OBJ: floating-object fishery; NOA: unassociated fishery. All indicators are scaled so that their average equals one.
FIGURA 1. Indicadores del estatus de la población de atún barrilete en el Océano Pacífico oriental. OBJ: pesquería sobre objetos flotantes; NOA: pesquería no asociada. Se escalan todos los indicadores para que su promedio equivalga a uno.

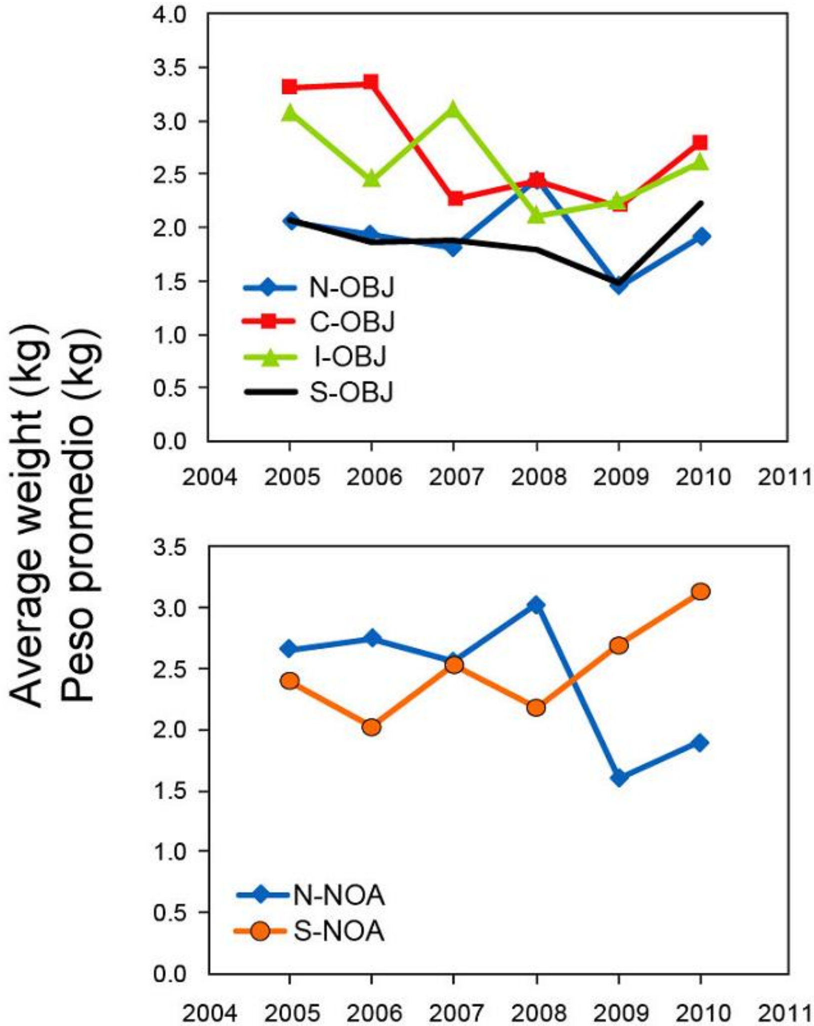

FIGURE 2. Average weight from the floating object (OBJ; upper panel) and unassociated (NOA; lower panel) purse-seine fisheries defined in the previous assessments for recent years.
FIGURA 2. Peso promedio de las pesquerías de cerco sobre objetos flotantes (OBJ; panel superior) y no asociadas (NOA; panel inferior) definidas en las evaluaciones previas de años recientes.

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STATUS OF SWORDFISH IN THE EASTERN PACIFIC OCEAN IN 2010 AND OUTLOOK FOR THE FUTURE

Michael G. Hinton and Mark N. Maunder

1. SUMMARY

This report presents the status and trends of swordfish (*Xiphias gladius*) in the southeast Pacific Ocean (SEPO). The assessment was conducted with Stock Synthesis using data that were updated as of 22 April 2011.

The stock structure of swordfish is not well known in the Pacific. A number of specific regions of spawning are known, and analyses of fisheries and genetic data indicate that there is only limited exchange of swordfish between geographical areas, including between the eastern and western, and the northern and southern, Pacific Ocean, so it is considered that examinations of local depletions and independent assessments of the swordfish of the eastern Pacific Ocean (EPO) are meaningful. Though this assessment did not include parameters for trans-region movements of this or other stocks, it recognized that there may be limited exchange of fish between the southeast Pacific Ocean and stocks in adjacent regions.

Genetic and fishery data indicate that the swordfish of the southeastern Pacific Ocean (SEPO, south of 5°S) constitute a distinct stock.

Key results

1. The swordfish stock in the southeast Pacific Ocean is not experiencing overfishing and is not overfished.
2. The spawning biomass ratio is about 1.45, indicating that the spawning biomass is about 50 percent above the carrying capacity, and substantially above the level which is expected to produce catch at the level of maximum sustained yield (MSY).
3. Recent annual catch levels (~14,300 t) are significantly below the estimated MSY (~25,000 t).
4. There have been a series of recent high recruitments to the swordfish stock..

5. Catch rates and catches under current levels of fishing effort and fleet configurations will tend to decrease over the coming 10-year period, assuming average recruitment returns to pre-high recruitment levels, as those recruits pass through the fishery.

2. DATA

The principal fisheries that capture swordfish in the eastern Pacific Ocean (EPO) have been detailed in Hinton et al (2005). In the SEPO, the principal fisheries are those of Chile (Barbieri et al, 1998; Yáñez et al, 2003), Japan (Okamoto and Bayliff 2003; Yokawa 2005) and Spain (Mejuto and García-Cortés 2005). Chilean fisheries took a combined average annual catch of about 5,200 t during the 1990s and about 2,300 t since. Annual catch of Japanese fisheries harvests increased from about 1,500 – 2,000 t in the latter 1990s to about 5,000 t in the early 2000s, and since has decreased to about 2,000 t. The Spanish-flag fishery has dominated the catches made by individual fleets in recent years, with landings of about 5,700 t annually during the 2002-2009 period.

Figure 2 presents a general summary of the temporal coverage of the catch, effort, and size-composition data from 1945 through December 2010 by fishery (see below) that were used in the analyses.

2.1. Definitions of the fisheries

Six fisheries were defined for this assessment. These were based on the gear type, country, and/or spatial distributions of the fisheries so that, in general, there it is expected that there would be little change over time in their size-specific selectivity (Hinton and Maunder 2007).

The longline fisheries were separated into a coastal and an offshore fishery (Figure 2.1). These regions generally correspond to regions of spawning and juvenile rearing (offshore) and adults (coastal) identified in studies of Chilean fisheries (Anonymous 2005). Catches of longline fisheries that were considered similar in operation and targeting to the Japanese fisheries were compiled with those of Japan. These included catches in various years of Belize, China, Ecuador, French Polynesia, Korea, Uruguay, and Vanuatu.

The Spanish fleet changed from its traditional gear to American gear in about 2000- 2001, which changed the characteristics of the fishery (Mejuto and García-Cortes 2005). Therefore, the Spanish coastal fishery was modeled with a time-block separating the fisheries into pre- and post-2000.

The artisanal and longline fisheries of Chile capture fish of significantly different ages and operate in different areas (Yáñez et al. 2003), so they were modeled individually to account for differences in their selectivities using the categories established by the Servicio Nacional de Pesca (SERNAP)[1]. The artisanal fishery tends to catch larger fish using predominantly harpoon and gillnet gear, and the industrial longline fishery tends to capture somewhat younger, smaller fish. Though there is overlap in the regions fished by the industrial longline and artisanal fisheries, the longline fishery operates in waters to the west of those fished by the artisanal fisheries. The reported catches of Peru were pooled with those of the Chilean artisanal fishery in the analyses.

Fishery	Description	Principal area of operation[2]
F1	Chile industrial longline	Offshore
F2	Chile artisanal and Peru	Coastal
F3	Japan and Japan-like longline	Offshore
F4	Japan and Japan-like tuna longline	Coastal
F5	Spain longline	Offshore
F6	Spain longline	Coastal

[1] Servicio Nacional de Pesca: http://www.sernapesca.cl/
[2] Coastal – east of 90°W; Offshore – west of 90°W

2.2. Catch

Total catch (t) by flag is provided in Table 2.2, and the catch (t) by fishery used in model is shown in Figure 2.2.

Catch data for Chinese Taipei, Japan, Korea and Spain were available in numbers of fish. Data for most years were available in both numbers and weight for Chinese Taipei, Japan, Korea and Spain. Data for Chile were available only in weight.

Catch[3] (numbers of fish and kilograms) for the Spanish-flag longline fishery was available for 1990-2009. Total catch by the Spanish-flag fishery in 2010 was assumed equal to and distributed as that taken in 2009.

Catch data for the Chilean fisheries are described in Table 2.2.1c of Hinton et al. 2005. This catch series was augmented by adding data for Peru (Weidner and Serrano 1997, Appendix B2a, Columns “Smith” and “FAO”, p. 401), and it was extended to 1945 for Chile (Weidner and Serrano 1997, Appendix E2a1, p. 776). Data for more recent years was obtained from catch reports posted on-line by SERNAP.

Data for each fishery were compiled by calendar quarter for the assessment. Generally this was accomplished using proportions of catch-by-quarter observed in catch and effort data aggregated at a resolution of month by 5° latitude by 5° longitude, or from tabled catch by month data. When these data were not available, catches were apportioned using the average distributions from the available data.

The Chilean- and the Spanish-flag fisheries display seasonality in annual catch, generally with peak catches occurring in calendar quarters two and three. In the case of the Chilean-flag fisheries, the distribution of catch-by-quarter from recent years (artisanal: 2002-2008; industrial: 2002-2009) was used to apportion the series of reported annual catch to quarter for years prior to 2002, for artisanal fisheries in 2009-2010, and industrial fisheries in 2010. In the case of Spanish-flag fisheries, the distribution of catch-by-quarter over the period 1998-2006 was used to apportion catch to quarter over the 1990-1997 period.

	Proportion of annual catch by calendar quarter			
Fishery	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Chile artisanal	0.0154	0.439	0.484	0.062
Chile industrial	0.0255	0.397	0.366	0.212
Spanish	0.0720	0.382	0.363	0.183

2.3. Discards

An observation of no discards was reported for Spanish-flag longline fisheries. There were no discard data available from other fisheries.

2.4. Indices of abundance

Indices of abundance were obtained using delta-lognormal models (Pennington 1983) fitted in TIBCO Spotfire S+ 8.1[4] for Windows. Initial identification of model parameters was made using functions “step.glm” and “stepAIC”. Final selection of model parameters was made by comparing the decrease in the Akaike Information Criteria (AIC) resulting from addition of the individual parameters suggested by the initial fittings, and including only those that resulted in a decrease in AIC of O(100) (Burnham and Anderson 1998). Initial model scopes included oceanographic parameters that might be expected to be correlated with the presence and vulnerability of swordfish (see e.g. et al. 2009). The general form fitted for both components of the delta-lognormal model was:

F(CPUE) = Year + Month + Latitude + Longitude + Environment + Interactions

[3] Instituto Español de Oceanografía (IEO) (A Coruña, Spain)
[4] http://spotfire.tibco.com/products/s-plus/statistical-analysis-software.aspx

Interactions were considered only for significant main effects, and in the end, no significant interactions were identified for any model. Models fit to catch and effort data of Japan that included information on the number of hooks placed between floats on the mainline (HPB data) were compiled into four categories of gear configuration: HPB < 8; 8 < HPB < 12; 12 < HPB < 16; and HPB ≥ 16. For the period prior to 1975, which brought the introduction of deep longline fisheries to the EPO, it was assumed that HPB < 8 (Hinton 2003).

Scaling of oceanographic parameters to the levels of available catch and effort data is problematic and not all oceanographic or environmental parameters are suitable for inclusion every models. A number of parameters were available or could be estimated on the scale of the one-degree catch and effort data, which is on the order of the linear dimension of a longline set (mainline length ~ 100 km). These were sea surface temperature[5] (sst: IGOSS); sea surface height (ssh), salinity, and meridional (tauy) and zonal (taux) surface velocities[6] (SODA 2.1.6); mixed-layer depth temperature and depth of the 20°C isotherm[7]; and the probability of encountering a temperature front in the area (FPI: frontal probability index)[8]. Estimates of these parameters on a five-degree grid level may be made, but at that level, they are not measures of the local conditions in the area of fishing operations and would not be expected to carry significant information on the relationship of catch rates to oceanographic conditions..

Environmental parameters with basin-wide extent and long timescales provide information on physical forcing and the general distributions of physical oceanographic parameters, and thus might be expected to correlate on these scales with the distribution of fisheries and swordfish. Such parameters that were included in standardization analyses were the Northern (NOIx)[9] and the Southern (SOIx) extra-tropical Oscillation Indices; the Southern Oscillation Index (SOI); and the Multivariate ENSO Index (MEI)[10]. As indicators of physical forcing and longer-term large scale ocean properties, it might be expected that correlations with catch rates on these larger scales may be realized via influence on future recruitment levels, therefore estimates of these parameters were included in the initial scope of the standardization models with lags of zero to six months.

Catch and effort data for fisheries of Chinese Taipei, Korea and Spain were available only at a 5-degree latitude x 5-degree longitude geographical resolution (5x5 data) and did not include data on gear configuration. Standardizations based on 5x5 data generally mirror closely the nominal catch rate series. Parameters for local environmental conditions that may influence the fishing operations, including such as decisions on where and when to initiate gear operations, do not scale in a meaningful way to the public-domain level 5x5 aggregated fishing data, so parameters such as sea surface temperature and height, current velocities, wind sheer and salinity were not included in attempts to standardize 5x5 data. In the end, no satisfactory standardized catch-per-unit effort series was found for fisheries of Chinese Taipei, Korea or Spain. Nominal CPUE time series for these fisheries and that of Japan based on 5x5 data is shown in Figure 2.4.1.

The nominal catch rates for Chilean fisheries (Serra et al. 2009: Tables 6 and 7) are shown in Figure 2.4.2. No data were available to develop standardized catch rate indices for Chilean fisheries, however Serra et al. (2009) present standardized indices for the Chilean longline fisheries which are generally consistent with and higher than the nominal rates, particularly in the offshore region.

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[5] Integrated Global Ocean Services System, Reyn_SmithOIv2 monthly sst; 1981-11 to 2010-; accessed 2011-04-09: http://iridl.ldeo.columbia.edu/SOURCES/.IGOSS/.nmc/.Reyn_SmithOIv2/.monthly/.sst/http://iridl.ldeo.columbia.edu/SOURCES/.IGOSS/.nmc/.Reyn_SmithOIv2/.monthly/.

[6] Simple Ocean Data Assimilation: soda pop 2.1.6; 1971-01 to 1981-10 (sst), 1971-2010; accessed 2011-04-08: http://apdrc.soest.hawaii.edu/dchart/

[7] European Centre for Medium-Range Weather Forecasts, Ocean Reanalysis, S3: yyyy-mm to yyyy-mm; accessed 2011-04-07: http://apdrc.soest.hawaii.edu/dchart/

[8] Pelagic Habitat Analysis Module:1971-01 to 2010: accessed 2011-04-07: http://phamlite.com/

[9] NOAA Pacific Fisheries Environmental Laboratory; 1971-01 to 2010: http://www.pfeg.noaa.gov/products/PFEL/modeled/indices/NOIx/noix.html

[10] NOAA/Earth Systems Research Laboratory. Wolter, K.: 19// to 2010: http://www.esrl.noaa.gov/psd/people/klaus.wolter/MEI/

The offshore fishery of Japan began in the EPO in about 1952, but the geographical expansion did not reach the coastal regions of the SEPO (Hinton 2003, Figure 2, Area 4) until about 1967 (Joseph et al. 1974, Figure 1). Data series starting in the early 1950s were available for these fisheries as 5x5 data. Data series starting in 1971 with higher resolution, and series with and without gear-configuration information, were also available for these fisheries. The first of these was a series at 1-degree latitude x 1-degree longitude geographical resolution (1x1 data) starting in 1971 was available for the Japanese fisheries. Data series from these fisheries were also available with gear-configuration information as 5x5 data starting in 1975 and as 1x1 data starting in 1999. CPUE time series were generated for both the Japanese coastal and Japanese offshore fisheries (see Sec. 2.1 Fisheries).

2.5. Size composition data

Size-frequency data from the Spanish-flag longline fishery were available in lower jaw-fork length (LJFL), and from Japanese-flag fisheries in eye-fork length (EFL). Since the growth model used in the assessment was developed using measures of LJFL, and it has been found that the growth rates of swordfish in the southeastern and the central north Pacific (Hawaii region) are very similar (Cerna, 2009), EFL data were converted to LJFL using the method of Uchiyama et al. (1999: Table 1, pg. 19: LJFL = 8.0084 + 1.07064 × EFL).

Size frequency measurements were aggregated into 5 cm length bins by quarter for fisheries F3, F4, F5 and F6. These aggregates had observed sample sizes on the range of one to tens of thousands. Aggregates with 10 or fewer observations were excluded from the model. In the process of developing the assessment model, the effective sample size for the size frequency data estimated from the initial model runs was used to reweigh (Maunder 2011) the observed sample sizes used in a subsequent model fitting. The size frequency distributions in the assessment are presented below with the results of the assessment.

2.6. Age composition data

Age composition data for Chilean fisheries that was compiled for the previous assessment (Hinton and Maunder 2007) were included in this assessment. These included data for both the industrial and the artisanal fisheries of Chile. No updated or additional age composition data were available.

3. ASSUMPTIONS AND PARAMETERS

3.1. Biological and demographic information

3.1.1. Growth

Swordfish grow in length very rapidly, with both males and the faster-growing females reaching lower-jaw-fork lengths of more than a meter during their first year (DeMartini et al. 2007, Cerna 2009, Chong and Aguayo 2009).

Cerna (2009) and Chong and Aguayo (2009) present recent analyses of the growth rates of swordfish in the SEPO. The results of their independent analyses are consistent, though estimates of the asymptotic maximum length (L infinity: L_{inf}) from von Bertalanffy growth models by Cerna (2009) for both males (279 cm) and females (321 cm) were slightly higher than those of Chong and Aguayo (2009) (males, 275 cm; females, 305 cm). Estimates of the annual von Bertalanffy K by Cerna (2009) were lower (males, 0.158; females, 0.133) than those of Chong and Aguayo (2009) (males, 0.177; females, 0.153).

Considering the relatively high proportion of fish at lengths greater than 350 cm in the data, the parameters for the von Bertalanffy model of Cerna (2009) were used in the assessment.

The L_{inf} parameter may be estimated or specified, and in the assessment it was fixed for females at 321 cm, which equates to 290 cm at age 15, the maximum age in the model; and for males at 279 cm.

The von Bertalanffy equation in Stock Synthesis does not use the standard t_0 parameterization and instead it was parameterized with the length at age one equal to 118cm and 122 cm for females and males respectively.

There is no information about the variation of length at age and a constant coefficient of variation fixed at 0.1 was used in the assessment.

The choice of the length-weight relationship for the assessment was important, because it was used in calculating biomass and in making comparable the catch and the size-frequency data. The relationships used in the assessment were those of Cerna (2009), making them consistent with the growth model used in the assessment:

Females	Weight (kg) = $3.7 \times 10^{-6} \times$ [Lower-jaw-fork length (cm)]$^{3.26}$; and
Males	Weight (kg) = $4.5 \times 10^{-6} \times$ [Lower-jaw-fork length (cm)]$^{3.21}$

3.1.2. Natural mortality

The instantaneous natural mortality rate (M) of swordfish is not know. It has frequently been assumed that because of the large size attained by swordfish, M might be as low as 0.2 (Hinton et al. 2005). With the development of techniques for aging swordfish it has been found that most swordfish do not live longer than about 12 years (DeMartini et al. 2007, Chong and Aguayo 2009), which suggests that M is higher than the values that have been assumed in a number of previous studies. In the assessment we used a constant annual instantaneous natural mortality rate (M) of 0.4.

3.1.3. Recruitment and reproduction

A summary of the distributions of adult and juvenile swordfish and of spawning areas in the SEPO may be found in Anonymous (2005).

Swordfish in the SEPO spawn during the austral summer, principally during January and February (Claramunt et al. 2009). Size at 50 percent maturity for males is estimated to be about 115-120 cm LJFL, and for females, about 165-175 cm (DeMartini et al. 2007, Claramunt et al. 2009), which based on age-maturity studies corresponds to ages two to three.

The age of first maturity was assumed to be two. The maturity schedule in the assessment was set using a vector of proportion of females mature-at-age, with proportions for years zero through three of 0.0, 0.0, 0.6, and 0.8; and a value of 1 for ages greater than three.

The assessment model estimates spawning in season 1 and 2, with the estimate for season 2 relative to the level estimated for season 1.

It is generally considered that environmental conditions are the principal influence on recruitment levels of the pelagic tunas and tuna-like species, including swordfish, and that recruitment is not substantially reduced as a result of the level of the spawning biomass. Therefore, a Beverton-Holt stock-recruitment relationship (Beverton and Holt 1957) was used in the assessment. In the Stock Synthesis model, the Beverton-Holt relationship has been parameterized to include steepness (h) (Francis 1992, Appendix 1). Steepness equals that fraction of the recruitment to an unexploited stock (R0) that would be produced by a spawning biomass that has been reduced to 20 percent of the unexploited spawning biomass (S_0), viz. $hR_0 = F(0.2S_0)$, where F is the Beverton-Holt stock-recruitment relationship. 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 observations of spawning biomass and because other factors (e.g. environmental) may cause extreme variability in recruitments from a given spawning biomass. Simulation analyses have shown that estimation of steepness is problematic, with large uncertainty and frequent estimates equal to one, even when the true steepness is moderately less than one (Conn et al. 2010).

There was no evidence that recruitment was related to spawning stock size for swordfish in the SEPO, so $h = 1$ in the assessment. A sensitivity analysis was carried out with h = 0.75 to investigate the effect of including a stock-recruitment relationship.

3.1.4. Movement

The assessment did not include explicit parameters for movement. There is very little information on the movements of swordfish. It was assumed that the population was randomly mixed at the beginning of each year, and though not explicitly modeled, some aspects of movement within the SEPO were accommodated by differences in selectivity and catchability by the spatial definition of fisheries. Though the assessment did not include parameters for trans-region movements of this or other stocks, it was recognized that from time-to-time there may be limited exchange of fish between the swordfish stock in the SEPO and those in adjacent regions.

3.1.5. Stock structure

The stock structure of swordfish is not well known in the Pacific. There have been a number of studies of stock structure of swordfish in the Pacific, and certain elements of the distribution of stocks seem more clear than others. A number of specific regions of spawning are known, and analyses of fisheries and genetic data indicate that there is only limited exchange of swordfish between geographical areas, including between the eastern and western, and the northern and southern, Pacific Ocean, so it is considered that examinations of local depletions and independent assessments of the swordfish of the eastern Pacific Ocean (EPO) are meaningful. Though this assessment did not include parameters for trans-region movements of this or other stocks, it recognized that there may be limited exchange of fish between the southeast Pacific Ocean and stocks in adjacent regions. In the eastern Pacific Ocean it is considered that there is a single stock in the SEPO (Alvarado Bremer et al. 2006), and the area chosen for the assessment, south of 5°S and east of 150°W, is expected to extend across the principal distribution of the stock.

3.2. Environmental influences

Environmental data were used in the catch-rate standardization (Section 2.4).

4. STOCK ASSESSMENT

The assessment was conducted using Stock Synthesis (Methot 2009). Stock Synthesis is a sex-specific, age-structured, integrated (fitted to many different types of data) statistical stock assessment model. Data included in the assessment were those available on 22 April 2011. The available data determined, to a great degree, the structure of the assessment model. In addition to the data, estimates of a number of population characteristics, such as natural mortality rate, growth rates, and age at first maturity, were obtained from studies and were included in the assessment as assumed or fixed parameters. Stock Synthesis was fitted to a suite of scenarios using the method of maximum likelihood. The value of the negative log-likelihood from each of the scenarios was used for evaluation and comparison of results.

4.1. Assessment model structure

The earliest data included in the assessment are the estimated catches in 1945. During the period from 1945 until 1965 the average annual catch was about 1,000 t. Over the next 10 years, as the longline fisheries of Japan, directed principally at tunas, extended operations into the eastern Pacific Ocean, the average annual catch of swordfish from the SEPO increased to about 1,600 t. These longline fleet operations continued to increase both in space and intensity, becoming the dominate harvesters of swordfish in the region by the mid- to late-1970s. In the late 1980s the fisheries for swordfish in the SEPO experienced significant increases with the development of industrial longline fisheries of Chile, followed closely thereafter by entry of longline fisheries of Spain into the region. As the fisheries expanded, desirable locations and conditions for capture of swordfish were identified. During the 10-year period ending in 2009, the average annual catch of swordfish from the SEPO was about 12,000 t.

A number of the basic assumptions common to most assessments become dubious in situations such as described above; for example, the assumption that standardized catch rates are proportional to abundance over the entire period, or that the geographical distribution of the stock has been identified and well sampled through time by the fisheries.

The steps taken to address these problems were to structure the assessment in temporal and spatial strata over which those basic assumptions were considered reasonable, while also extracting as much information as possible from the strata over which the assumptions were less tenable. This approach was consistent with that taken in stock assessments of striped marlin, and of yellowfin and bigeye tunas in the EPO.

The assessment model starts in 1945. Considering the given the low level of catch during the initial years of the data series and that it was unlikely catches had been higher or significantly different during the years of WWII which immediately preceded, the stock was assumed to be in an unfished virgin condition at the start of the model.

The model is gender-specific, which means that model parameters may differ for females and males, e.g. as noted in the sections on growth and maturity above. The assessment also included the following initial conditions, assumptions and fixed parameter values:

1. The model was a seasonal model, with four seasons each year, and with a single area.
2. Recruitment deviates beginning in 1964, six-years prior to the beginning of the size-frequency data, which includes information on the cohorts entering the fishery prior to the beginning of the data series.
3. Recruitment occurred in seasons 1 and 2, with that for season 2 estimated relative to recruitment in season Natural mortality (M) = 0.4.
4. Steepness (h) = 1.0
5. von Bertalanffy growth model parameters for females: K = 0.113 and L_{inf} = 321; and for males: K = 0.158 and L_{inf} = 279.
6. Length at age one was fixed at 118cm and 122 cm for females and males respectively. This was done because the growth function well described adult swordfish, but not the rapid allometric growth of juveniles. This caused problems with model fits due to the fairly high number of small fish (< 100 cm) taken in some of the fisheries
7. Coefficient of variation of length at age = 1.0
8. Age 15 was modeled as a plus group which accumulates all fish aged 15 and older.
9. The coefficients of variation (CVs) of the standardized catch rate observations for fisheries F3 and F4, which were used as indices of abundance, were fixed at 0.2.
10. Selectivities of fisheries F3, F4, F5 and F6 were estimated using a double-normal distribution function, which allowed estimation of domed shaped or asymptotic selectivities.
11. Selectivity of F2 was assumed asymptotic and estimated using a double-normal distribution with parameters for (1) the selectivity for the first size interval, (2) the rate of increase at the inflection point and (3) the age when selectivity equals one. Preliminary fitting of the assessment model, selectivity of F1 was asymptotic, so on the final model fitting, selectivity of F1 was made asymptotic, as discussed for F2. In addition the size at which selectivity reached its asymptote was fixed at the largest size in the model. This was done to reduce the number of parameters estimated in the final model.
12. The assessment included time blocks for selectivity of F6. In about 2000 the gear used in these fisheries underwent a complete change in configuration and operation. Examination of residuals in the size frequency data from preliminary analyses clearly indicated a change in selectivity, indicating the need for this additional structure in the model.

13. Data that was for an annual, vs. seasonal, period were assigned to season 2. These included such as the annual abundance indices and the age-frequency for Chilean fisheries.

4.2. Assessment results

The assessment was conducted with Stock Synthesis[11] (SS-V3.20b-safe) using data and information available on 22 April 2011. The model was fit to the standardized abundance indices of F3 and F4; to the size-frequency data for F3, F4, F5, and F6; and to the age-frequency data for F1 and F2. The assessment model was quite unstable with convergence issues due to local minima. This instability was probably due to the selectivity parameterization. Several different starting values and phases of optimization were used to check that the final result was not a local minima. However, it is never certain that a better solution is not possible.

4.2.1. Fishing mortality

Estimated selectivity-by-size by fishery are shown in Figure 4.2.1. Fisheries 5 and 6, the longline fisheries of Spain, had the highest selectivity for small fish, with fish fully selected at sizes near 75 cm lower-jaw-fork length (LJFL). Swordfish remained fully selected across all sizes in Fishery 5, despite being allowed to be dome shape, while selectivity of Fishery 6 was dome-shaped, with selection dropping below 10 percent at sizes at and above about 275 cm. Fisheries 3 and 4, the Japanese longline fisheries, exhibited selection of swordfish at or above the 10 percent level at sizes of about 100 cm. Fishery 4, the Japanese fishery in the coastal region, exhibited asymptotic selectivity, despite being allowed to be dome shape,. Fisheries 1 and 2, the fisheries of Chile, were modeled with asymptotic selectivity and exhibited selectivity for large swordfish.

4.2.2. Recruitment

The trend in estimated annual recruitment is presented in Figure 4.2.2. Recruitment level estimates were started in 1964, decreasing immediately thereafter. They remained relatively stable until about 1999-2000, at which point they increased by a factor of almost two during a period of increasing harvests. They continued a general increasing pattern until peaking at about six-times the levels observed in the 1960s and 1970s. It is expected that this increase is a result of environmental conditions, since the annual catches of swordfish remained relatively constant at about 12,000 t during this period.

4.2.3. Biomass

The trend in estimated spawning biomass from the assessment is presented in Figure 4.2.3.1 along with the annual estimates of spawning biomass in the absence of fishing. It is clear that fishing has had a minor impact on the level of spawning biomass during the period. The level of spawning biomass expected to provide catches at the level of MSY (S_{MSY}) was about 11,000 t, which is significantly less than the lowest observed spawning biomass since 1945, which was about 43,000 t in 1993. Spawning biomass has steadily increased since 1993 and was estimated to be about 135,000 t in 2010.

The estimated ratio of the spawning biomass in 2010 to the spawning biomass in the unexploited stock (*SBR*) was about 1.45 (Figure 4.2.3.2), which was well above the estimated level expected to provide catches at the level of MSY (SBR_{MSY} = 0.11).

4.3. Comparisons to external data sources

No comparisons to external data were made in this assessment.

4.4. Diagnostics

4.4.1. Residual analysis

The assessment was fitted to the standardized abundance indices of Fisheries 3 and 4, the longline

[11] http://nft.nefsc.noaa.gov/SS3.html

fisheries of Japan in the offshore and the coastal areas (Figure 2.1). The estimated trends in abundance fitted the index of abundance for the offshore Japanese fishery well, but fit the index of abundance for the inshore Japanese fishery poorly (Figure 4.4.1.1)

The assessment estimates of the size measurement data for the Japanese and Spanish longline fisheries are shown in Figure 4.4.1.2, and Pearson residual plots for these estimates are provided in Figure 4.4.1.3. (Japanese offshore and coastal fisheries) and Figure 4.4.1.4. (Spanish offshore and coastal fisheries). Estimates of the size frequency tended to underestimate the number of fish less than about 100 cm in a number of years in both the Japanese and Spanish coastal fisheries, though in general the assessment estimates fit the observed data fairly well.

The assessment estimates of age-frequency of catch in the fisheries of Chile are shown in Figure 4.4.1.5. In general, as was the case with the size-frequency data, the assessment-based estimates fit the observed age frequencies fairly well for the artisanal fishery, but there is a substantial residual pattern in the industrial fishery (Figure 4.4.1.6).

4.4.2. Sensitivity analyses

Uncertainty in assessment results, which can be difficult to quantify, occur due to sampling and process errors. In the first instance, the sample data could not perfectly represent the population parameters of swordfish in the SEPO, or more generally those of any population. In the second instance, the model structure used for the assessment provides only an approximation to the dynamics of the stock and the fisheries that harvest them. These approximations may result in process, or model-misspecification, errors. The confidence intervals for parameter estimates arising from the likelihood-based solution obtained for the assessment were estimated under the assumption that the population dynamics model "perfectly" (or at least adequately) represented the dynamics of the system. Since it was unlikely that this assumption could ever be satisfied, the estimates of uncertainty obtained from the assessment likely underestimate the "true" uncertainties.

A principal concern in this assessment was the potential for errors resulting from a failure of the assumption that the standardized indices of abundance used in the model were not proportional to the abundance of the population swordfish in the SEPO. In order to examine this potential, the model was fitted to the abundance indices with the last four years (2007-2010), the years showing the rapid increase, excluded from the analysis. This left only the size frequency data for those years in place to inform on the abundance of the stock during this period.

The results of this analysis are shown in terms of the spawning biomass ratio (Figure 4.4.2.1). It is clear that the increase in relative abundance was supported by the observed size-frequency data. It was also noted that the indicated increase in relative abundance from the standardized catch rate indices was consistent with increases seen in the nominal catch rates of other fisheries, particularly for the distant water nations and the offshore area (Figures 2.4.1 and 2.4.2).

The assessment was conducted with an assumed steepness of one. A sensitivity analysis with steepness of 0.75 was conducted, even though the stock has not been driven below a *SBR* of about 0.46, and as a result it would not be expected that there would be information in the data to estimate the impact of an incorrect assumption of steepness. The results of this sensitivity analysis are shown in Figure 4.2.2.2. in comparisons of the yield (t) and the *SBR* at levels of fishing effort (*F*) relative to current fishing effort for the assessment and for the model with steepness of 0.75.

4.5. Comparison to previous assessment

The previous assessment of swordfish in the southeast Pacific Ocean (Hinton and Maunder 2007) was conducted with data through 2003. That assessment indicated that the spawning biomass had declined significantly over the 1945-2003 period, and that it was then at about twice the level which would support fisheries at a maximum sustained yield of 13,000-14,000 metric tons. Catches had increased substantially since 2001, and recent annual harvests were on the order of 14,000-15,000 t.

This assessment was conducted with data through 2010. We found that the spawning biomass had decreased to a low of about 43,000 t in 1993 and had been increasing since, reaching about 135,000 t in 2010, a level at which *SBR* = 1.45. At the same time that there was an increasing spawning biomass, the annual catch by all fisheries was maintained at an average 12,000 t during the 10-year period ending in 2010.

A comparison of estimated *SBR* from the previous assessment and from this assessment is presented in Figure 4.5.

5. STOCK STATUS

The objective of the Antigua Convention is to"… ensure the long-term conservation and sustainable use of the fish stocks covered by [the] Convention, in accordance with the relevant rules of international law," and calls on the members to "… determine whether, according to the best scientific information available, a specific fish stock … is fully fished or overfished and, on this basis, whether an increase in fishing capacity and/or the level of fishing effort would threaten the conservation of that stock."

The parties to the Convention have not established specific biological or management reference points, so the status of the swordfish stock in the northeast Pacific Ocean has been, as in the past, presented in terms of commonly-cited management parameters based on MSY (Table 5). These estimates were made using the 3-year (2008-2010) average fishing mortality rates for each of the fisheries, thus they represented current operating conditions and practices in these fisheries.

The level of recent catch (~14,300 t) is less than half of the estimated MSY catch (~25,000 t); the recent biomass level (~424,300 t) is a factor of 10 higher than the biomass (~40,800 t) expected to support catches at the level of MSY, and the recent spawning biomass level (~158,000 t) is nearly 15 times the level expected to support catch at MSY levels.

The *F*-multiplier, the factor by which current fishing mortality would be changed in order to achieve the fishing effort expected to provide catches at the level of *MSY*, is about 18 in the assessment and about 7 in the model fit with steepness equal to 0.75. It is apparent that if steepness is one, then an increase in *F* by a multiple of 7 would achieve catch near the level of *MSY*, and that if *F* is 0.75, then an increase in *F* greater than 7 would result in catches less than those expected at *MSY*.

The trends of spawning stock biomass relative to MSY vs. *F* relative to MSY is shown in Figure 5 for the most recent 20-year period. The figure clearly shows that swordfish in the SEPO are not experiencing overfishing and are not being overfished.

The swordfish stock in the southeastern Pacific Ocean is in good condition, with spawning biomass at levels (SBR~1.45) well above those expected to yield catch at the level of *MSY* (~25,000 t). The assessment suggests that fishing effort would need to increase significantly to achieve catch at the level of *MSY* (Figure 4.2.2.2).

6. SIMULATED EFFECTS OF FUTURE FISHING OPERATIONS

The assessment indicates that there was a recent period of very high recruitment to the swordfish stock in the southeast Pacific Ocean. This high recruitment might be expected to provide catches at levels in excess of what might be expected from current fisheries operating with current estimated fishing mortality rates. However, such increased catch levels would be expected to decrease over time as the impact of their presence in the population wanes.

Estimates of current fishing effort were used to forecast the expected spawning biomass ratio (*SBR*) and the expected catch by fishery for the 2011-2020 period (Figure 6) were current levels to persist over that time period. The trend in *SBR* clearly shows the expected decline in the spawning biomass as the impact of the high recruitment passes through the stock. The trend in expected catch also shows the expected decrease in catch that results from decreasing catch rates at the assumed constant effort over the period.

7. FUTURE DIRECTIONS

7.1. Collection of new and updated information

It is not expected that the stock of swordfish in the southeast Pacific Ocean will be harvested at levels of MSY without a significant increase in fishing effort. We have no indication that such an increase is planned or will occur, but catch and catch rates should be monitored closely to ensure that any increase that may occur is recognized in time that analyses of impacts and assessments may be made before the stock can be overfished.

The assessment would have benefitted from standardized catch rate series for the fisheries of Chile and Spain, and from detailed size-frequency and age-frequency data for the fisheries of Chile (Serra et al. 2009). Efforts should be made to obtain these data prior to the next assessment.

Estimates of discards from fisheries were available only for the fisheries of Spain, in which there were no reported discards. An accurate estimate of total removals from a stock is necessary to an accurate assessment. Effort should be directed to obtaining information on discards from other fisheries.

7.2. Refinements to the assessment model and methods

The IATTC scientific staff will continue developing the assessment for swordfish. Much of the progress will depend on how the Stock Synthesis software is modified in the future. The ability to do the following would be desirable:

1. Determine appropriate weighting among the data sets;
2. Include data from conventional and satellite-based tagging.

There are continuing investigations of stock structure of swordfish in the Pacific and relevant information which may be found thereby should be incorporated into future assessments. These studies may also inform on whether the fishery for swordfish that occurs in the far western SEPO is on the same stock as that identified for this assessment. A collaborative effort may be made to more explicitly examine this element of the fisheries for swordfish in the south Pacific.

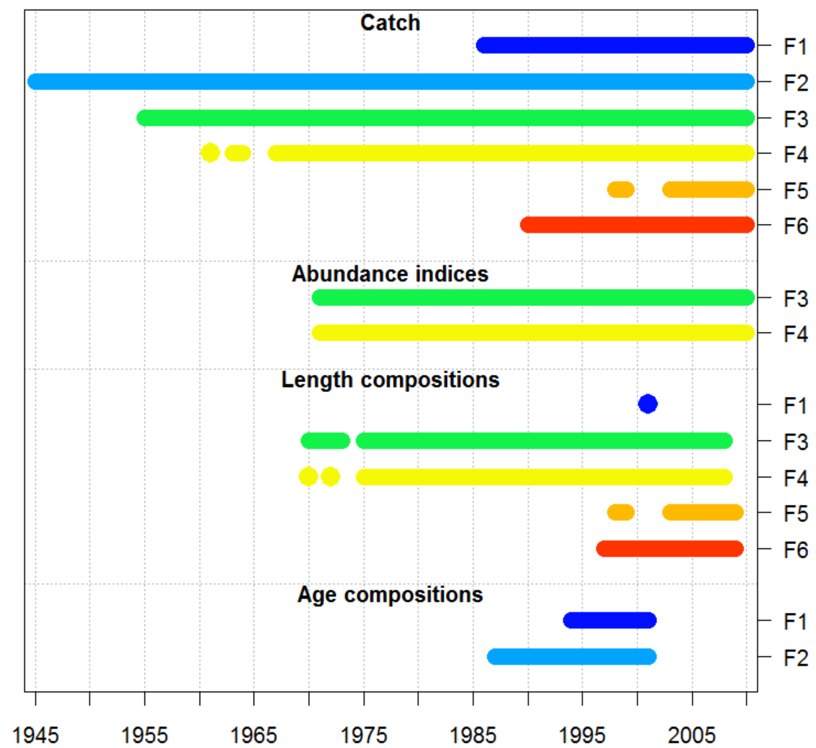

FIGURE 2. Temporal coverage of data used in the assessment by type and fishery. Note that the length composition data for Fishery 1were not used in the assessment.

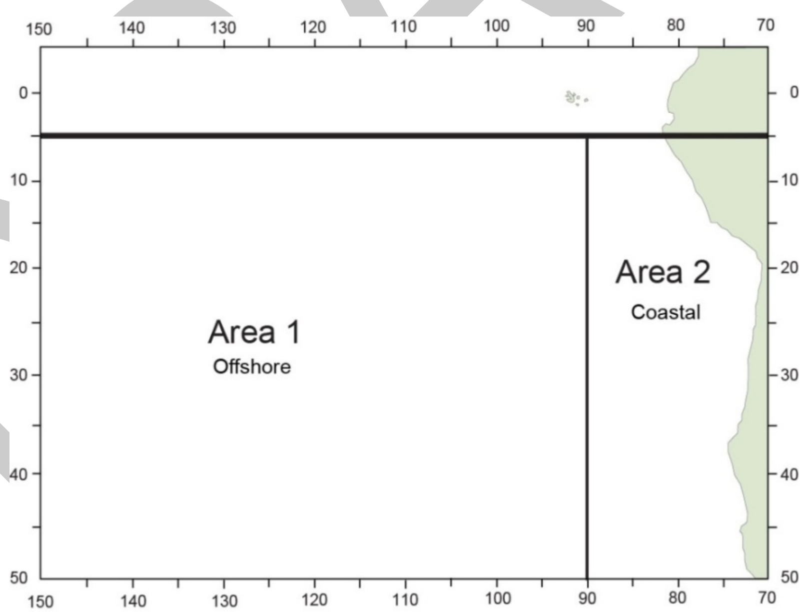

FIGURE 2.1. Area stratification for analysis of swordfish stocks in the eastern Pacific Ocean.

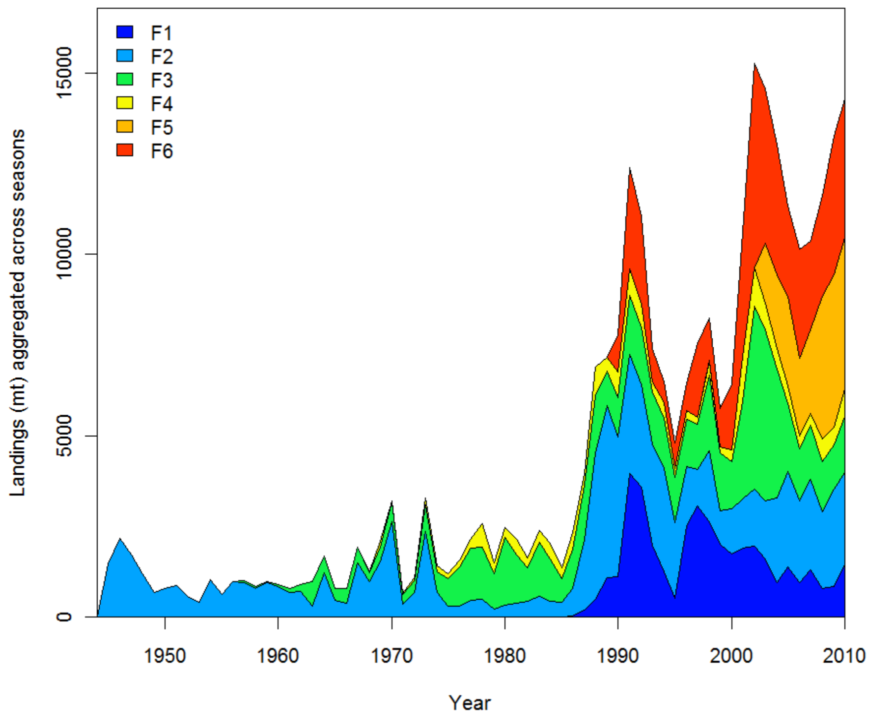

FIGURE 2.2. Catch (t) by fishery (see text for definitions) by year .

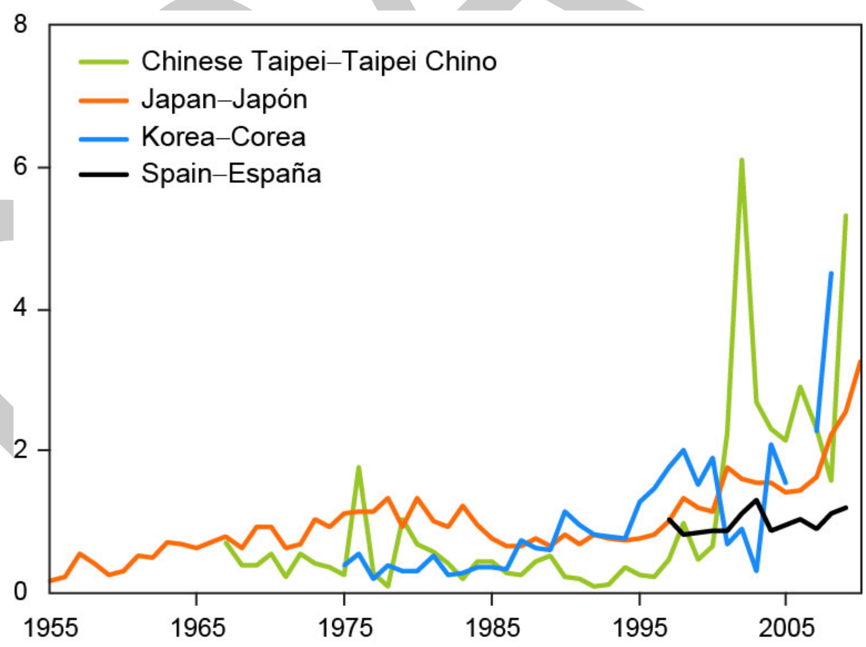

FIGURE 2.4.1. Nominal catch rates by year and flag scaled by the respective average catch rates.

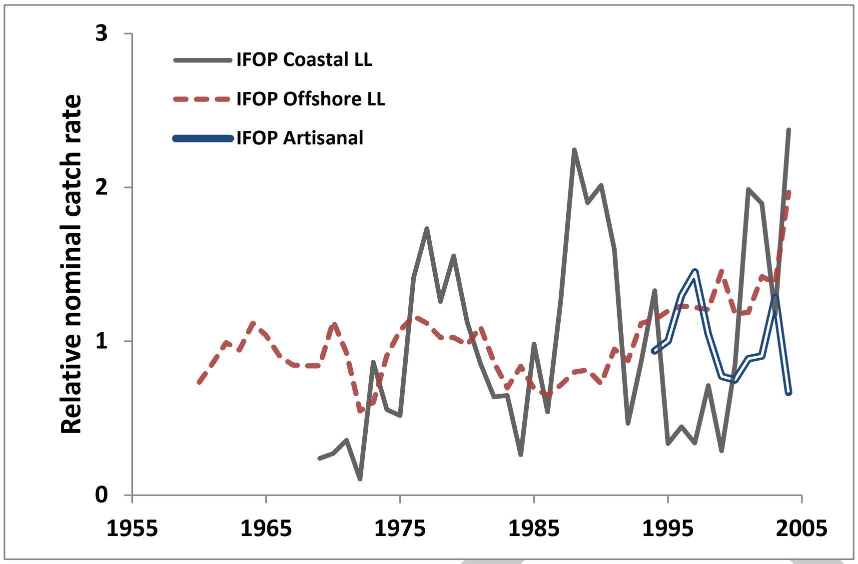

FIGURE 2.4.2. Nominal catch rates of Chilean longline and artisanal fisheries scaled by the respective average catch rate (Source: Serra et al. 2009).

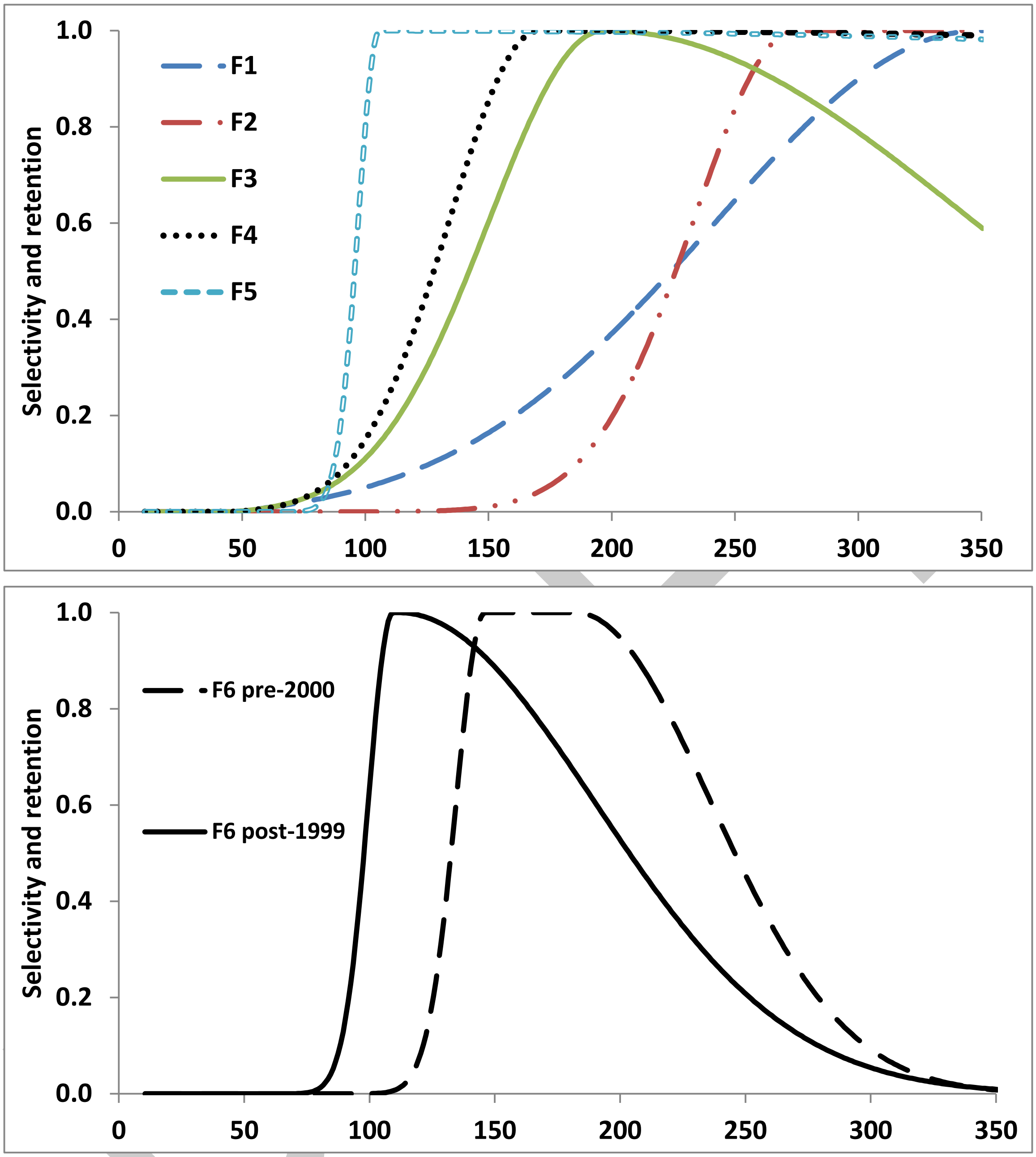

FIGURE 4.2.1. Selectivity for swordfish by lower-jaw-fork length for Fisheries 1-5 (upper panel), and for Fishery 6 (lower panel) prior to 2000 and after 1999 (see text for description of fisheries).

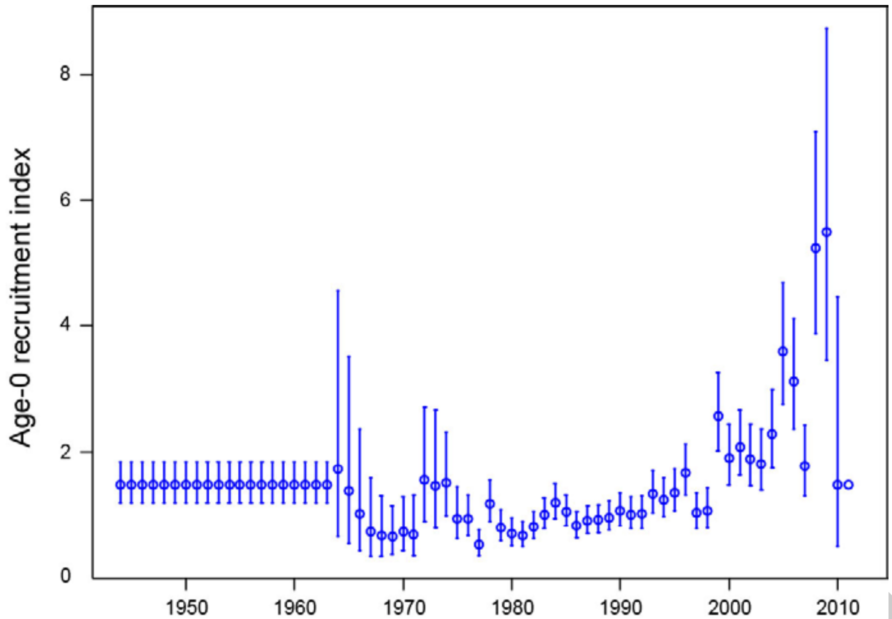

FIGURE 4.2.2. Relative annual estimated level of age-zero recruits and approximate 95 percent confidence levels.

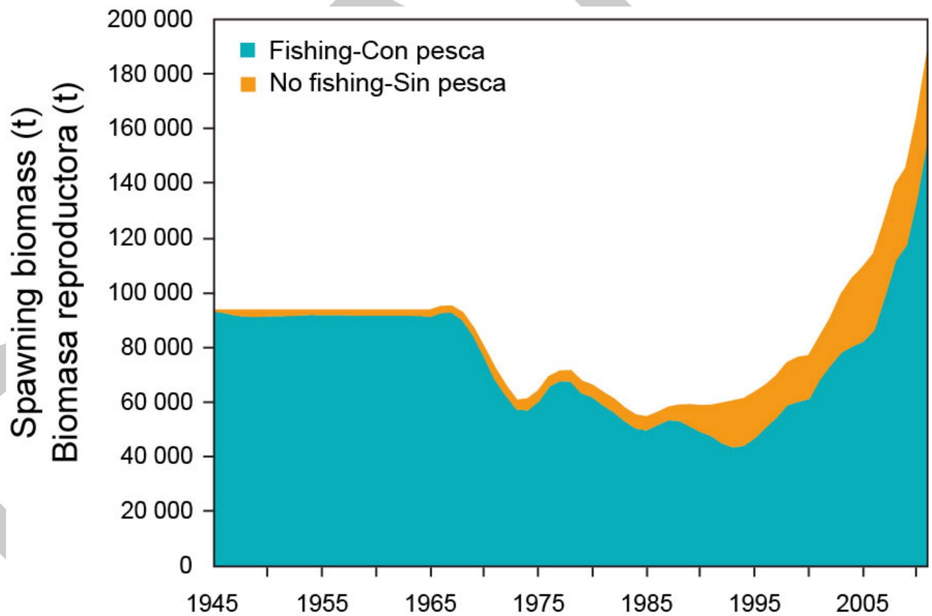

FIGURE 4.2.3.1. Estimated annual spawning biomass with and without fishing. The yellow shaded area represents the impact of the fisheries on the spawning biomass.

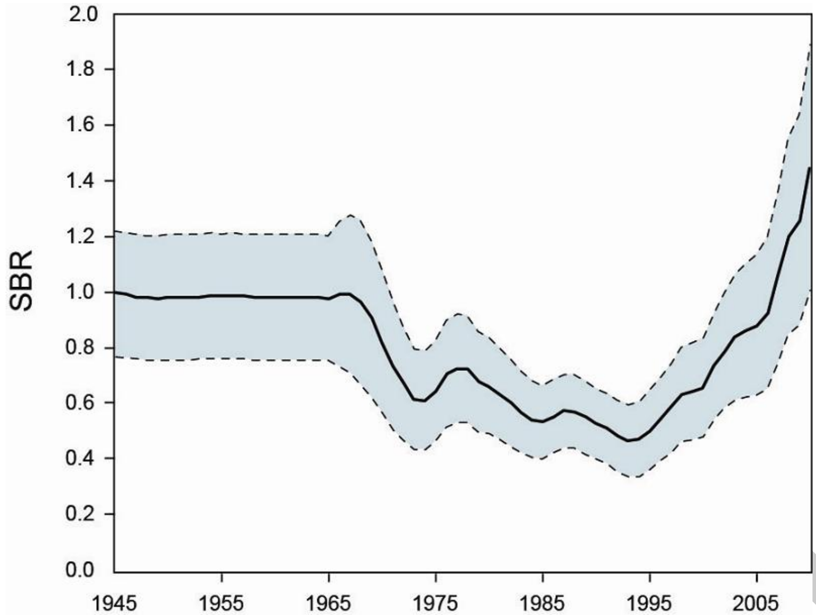

FIGURE 4.2.3.2. Estimated annual spawning biomass ratio and the approximate 95 percent confidence interval.

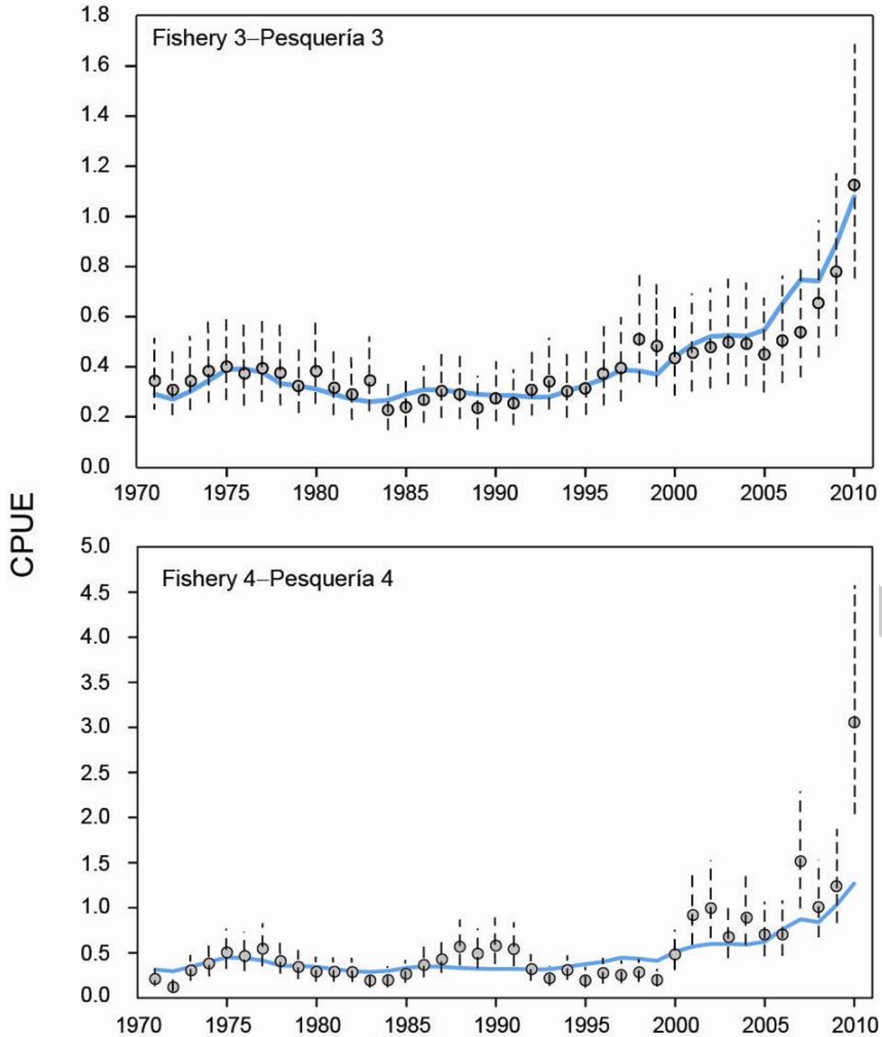

FIGURE 4.4.1.1. Estimated trends in annual abundance from the assessment (solid lines), and the standardized abundance indices (dots) with approximate 95 percent confidence intervals for the Japanese Offshore (F3) and Coastal (F4) longline fisheries.

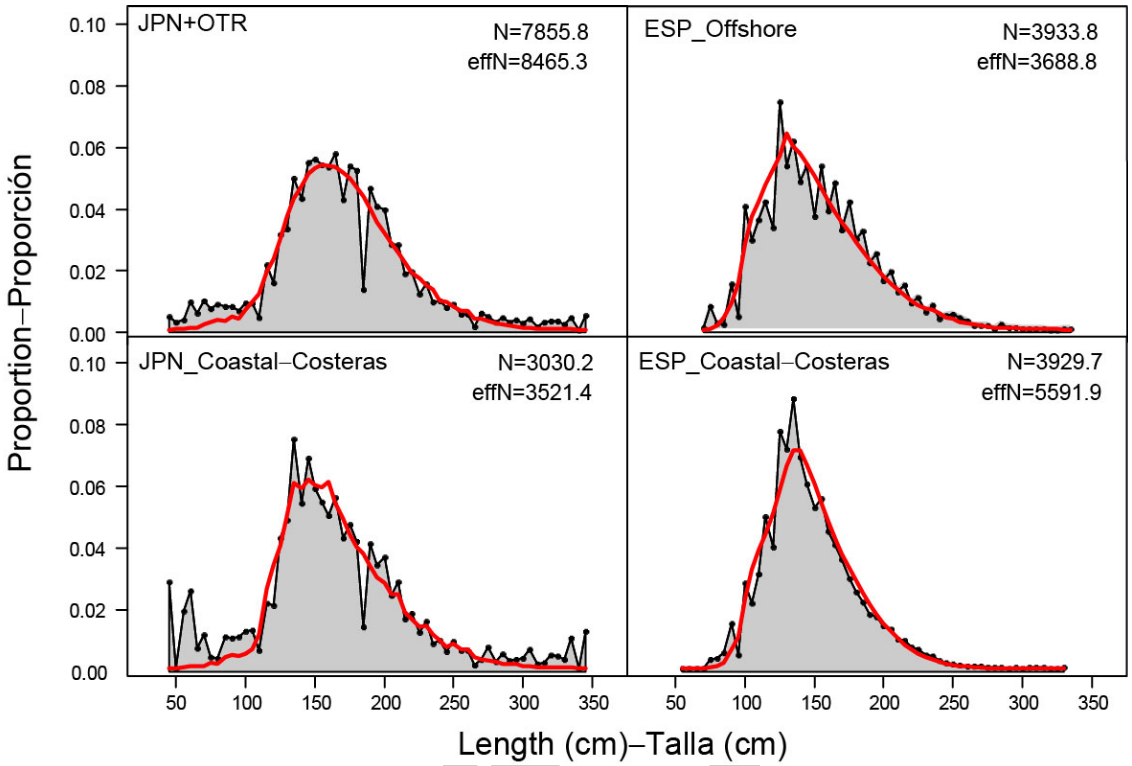

FIGURE 4.4.1.2 Observed (grey areas) and estimated (red lines) size-frequency distributions from the assessment for the Japanese and Spanish offshore and coastal fisheries averaged over all years for which the data are available

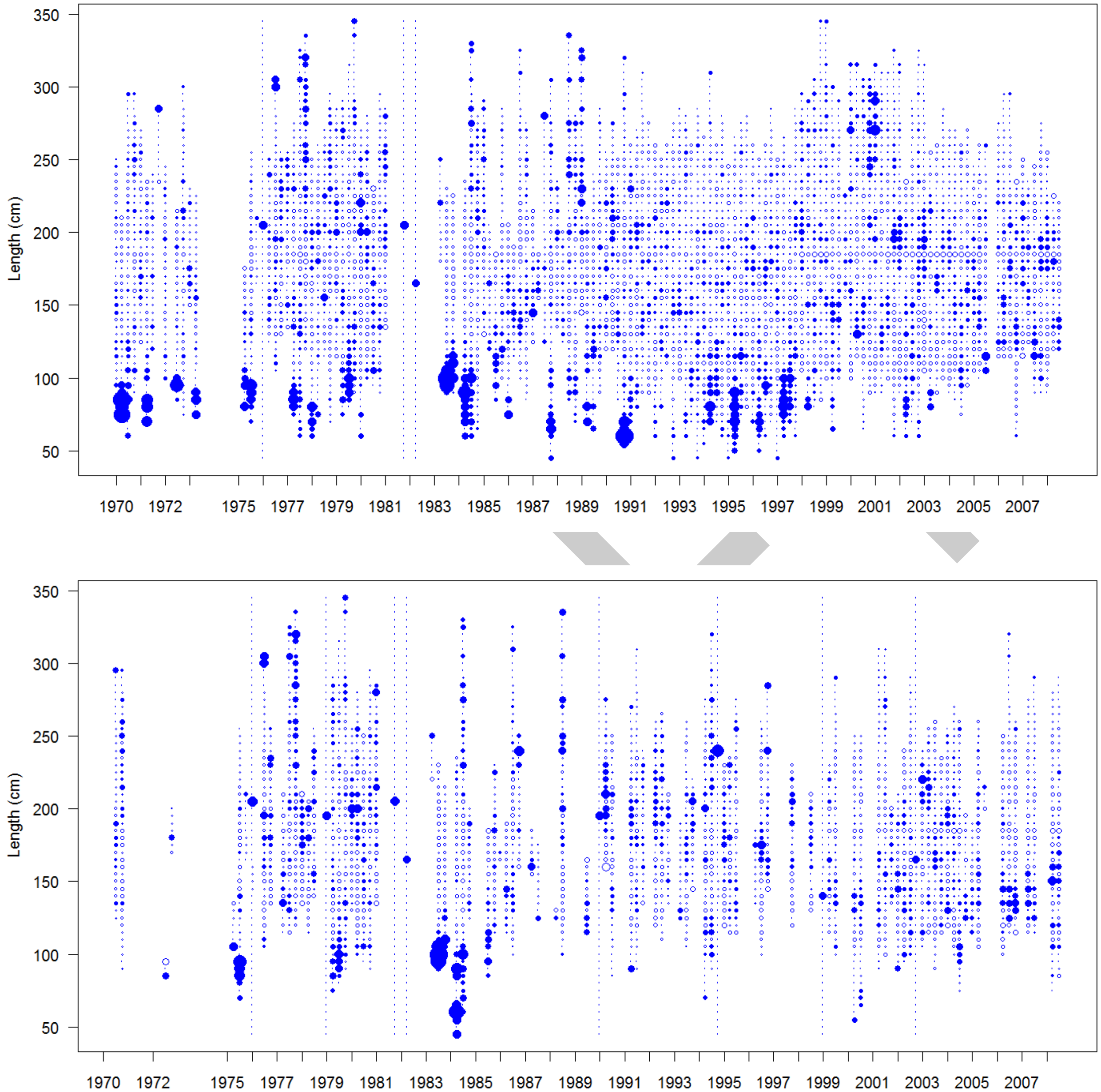

FIGURE 4.4.1.3. Pearson residuals from the estimates from the assessment of the size frequency data for the offshore (upper panel) and coastal (lower panel) longline fisheries of Japan. . The open circles represent observed values that are greater than predicted values and the open circles represent observed values that are less than the predicted values.

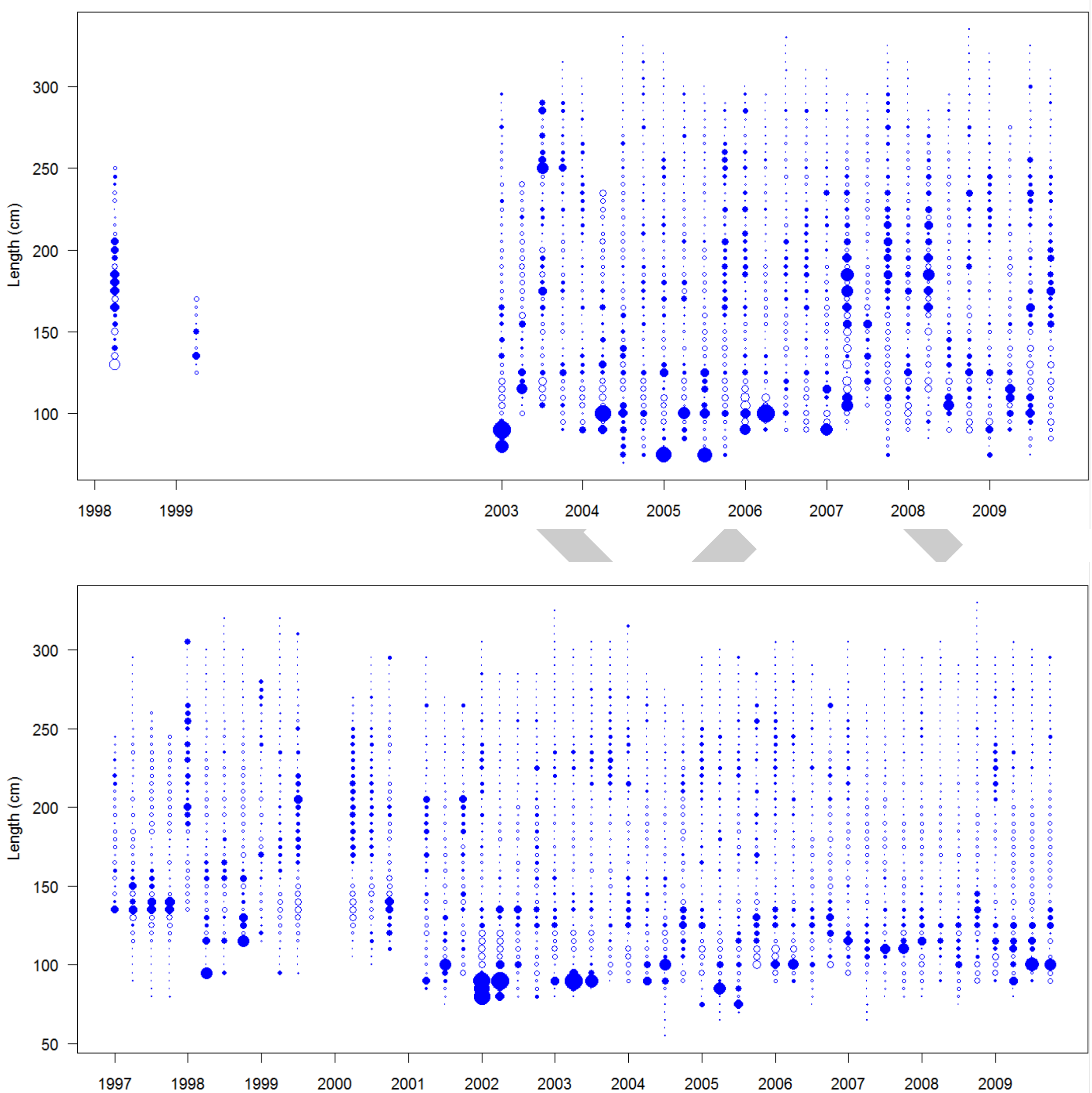

FIGURE 4.4.1.4. Pearson residuals for the estimates from the assessment of the size frequency data for the offshore (upper panel) and coastal (lower panel) longline fisheries of Spain. . The open circles represent observed values that are greater than predicted values and the open circles represent observed values that are less than the predicted values.

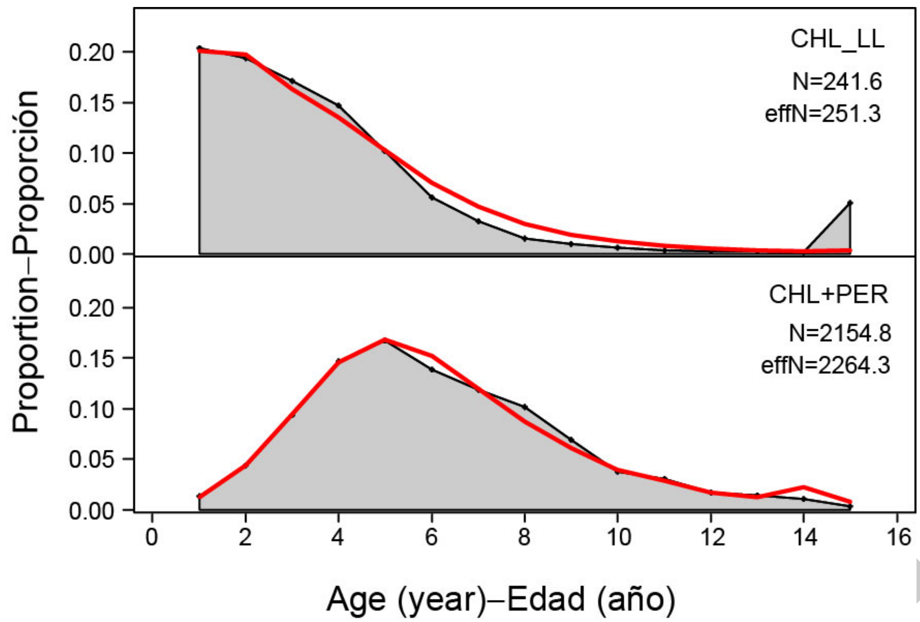

FIGURE 4.4.1.5. Assessment-based estimates (red lines) and observations (shaded area) of the age-frequency distribution distributions of the industrial longline (upper) and artisanal (lower) fisheries of Chile averaged over all years for which the data were available.

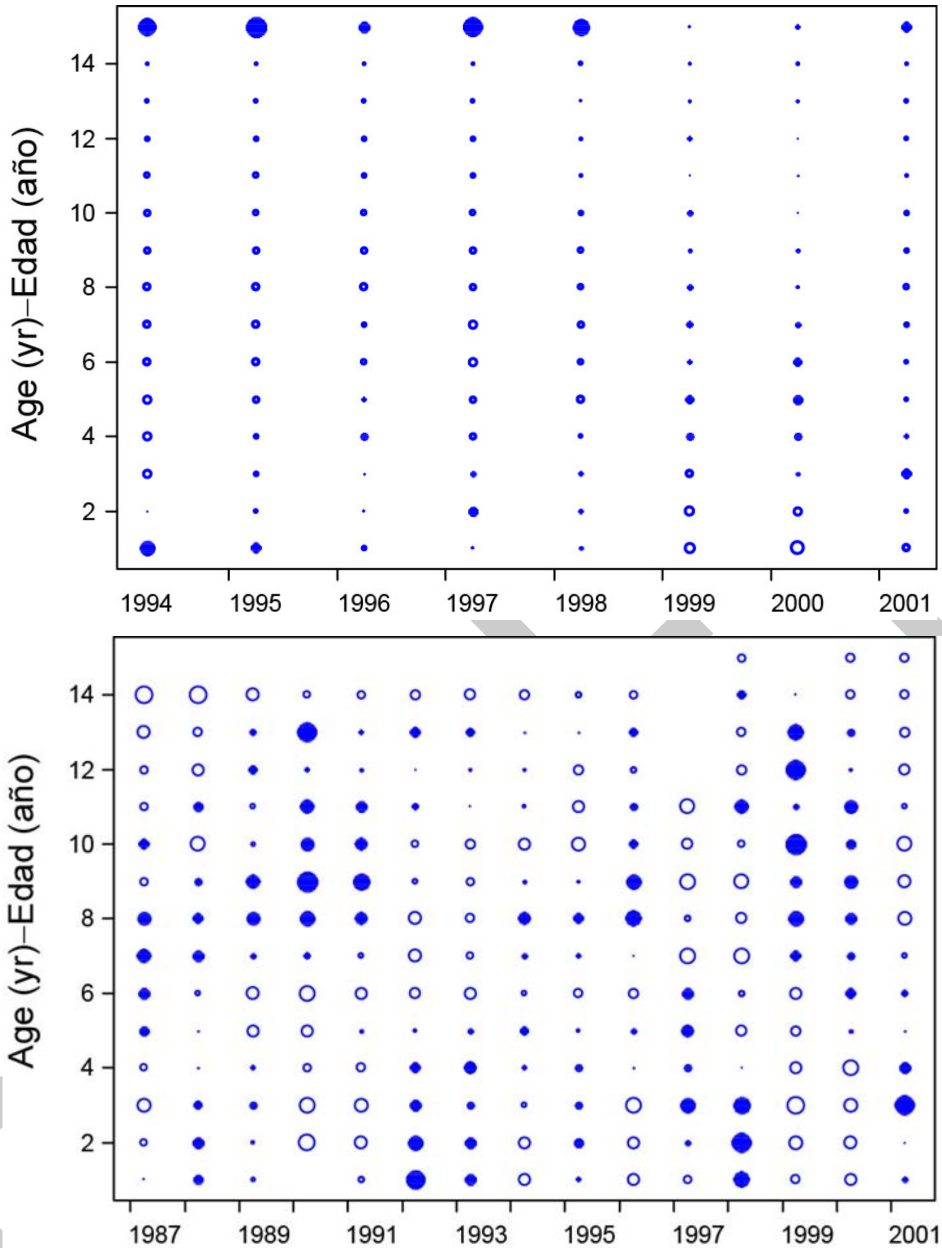

FIGURE 4.4.1.6. Pearson residuals for the estimates from the assessment of the size frequency data for the industrial (upper panel) and artisanal (lower panel) fisheries of Chile. . The open circles represent observed values that are greater than predicted values and the open circles represent observed values that are less than the predicted values.

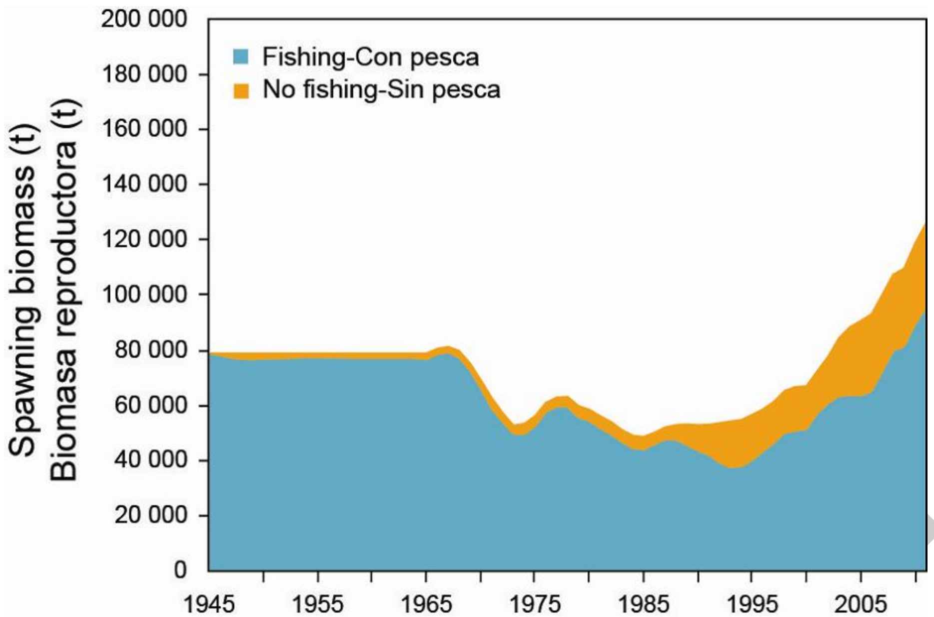

FIGURE 4.4.2. Estimated trends in spawning biomass, with and without fishing, from fits of the assessment without catch rate indices for the recent (2007-2010) period. The yellow shaded area represents the impact of the fisheries on the spawning biomass.

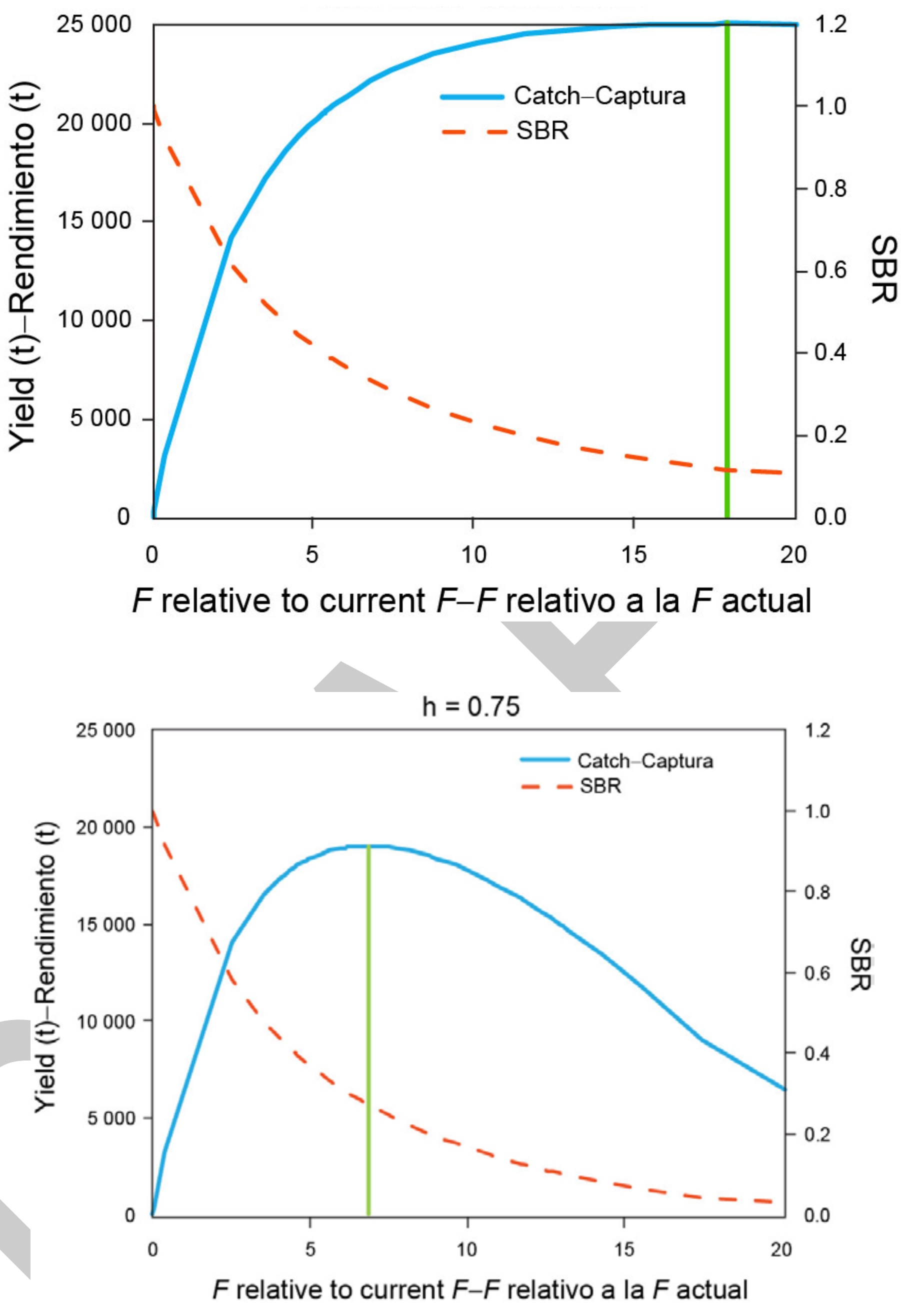

FIGURE 4.2.2.2. Estimated yield and *SBR* from the assessment (upper panel) and from the model with steepness of 0.75 (lower panel) as a function of fishing mortality relative to the current level of fishing mortality. The green vertical bar indicates the relative fishing mortality expected to provide catch at the level of *MSY*.

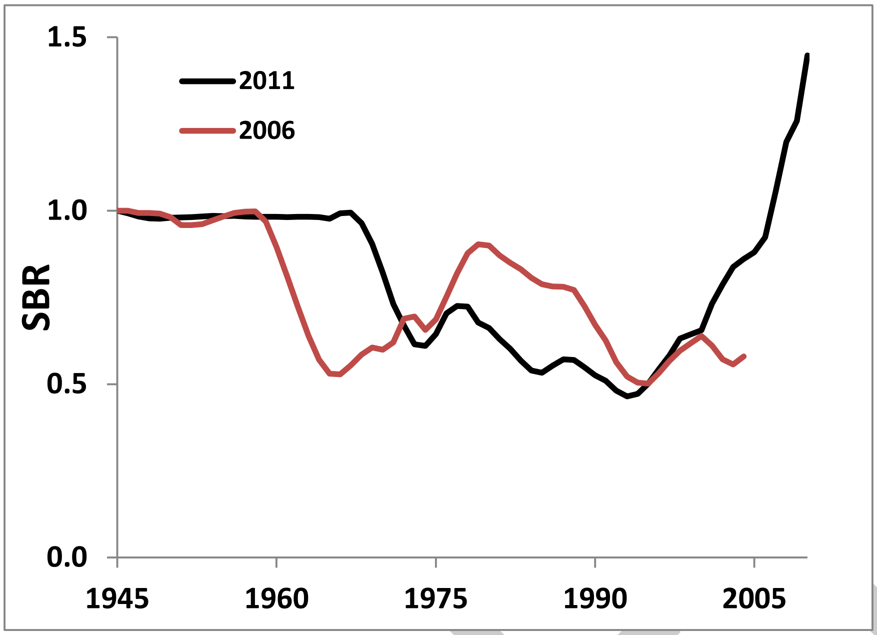

FIGURE 4.5. Comparison of the estimated spawning biomass ratios (SBR) from assessments of swordfish in the SEPO in 2006, which used data through 2003, and from the assessment in 2011, which used data through 2010.

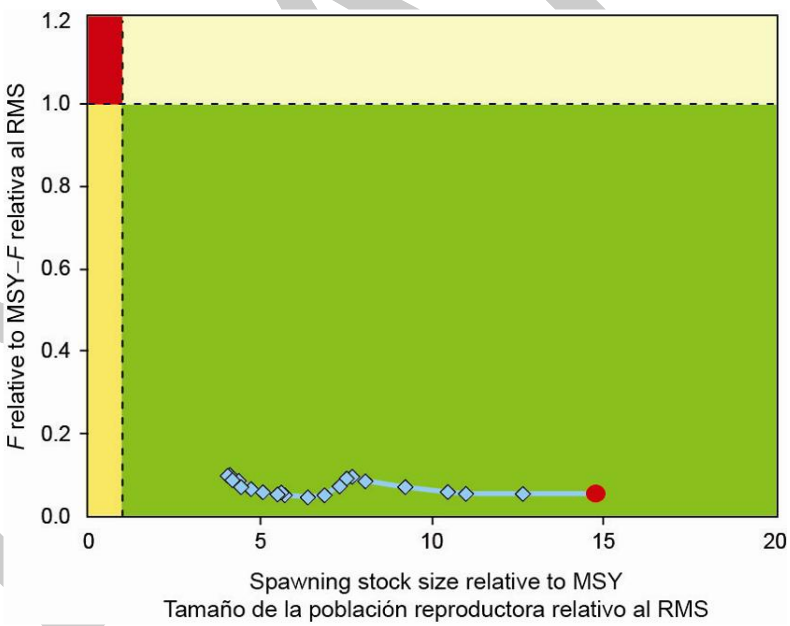

FIGURE 5. The relationship between spawning stock biomass relative to MSY and fishing mortality rate (*F*) relative to MSY.

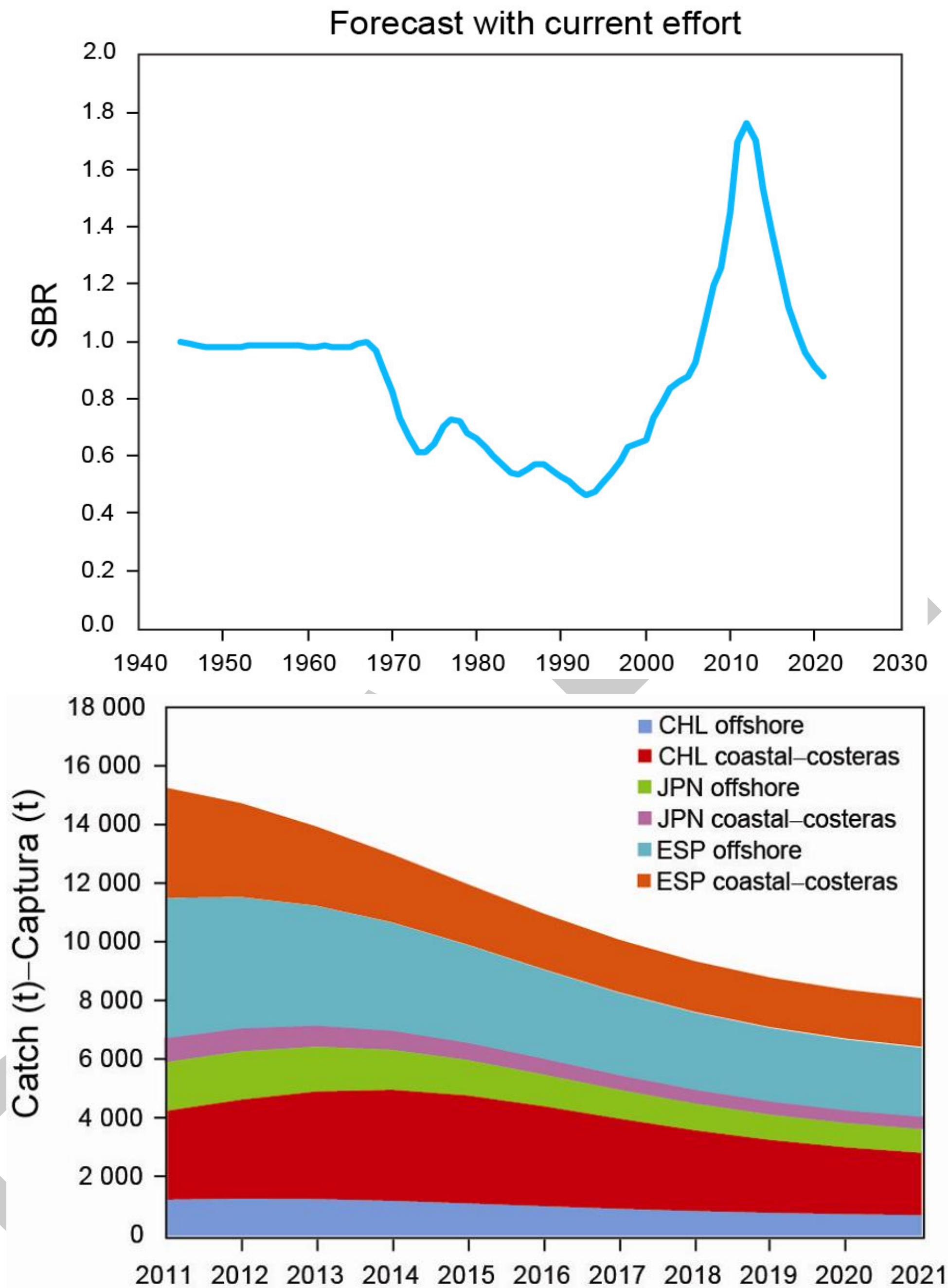

FIGURE 6. Projected spawning biomass ratio (*SBR:* upper panel) and catch by fishery (lower panel) by fishery for the 2011-2020 period, assuming current (average 2008-2010) levels of fishing mortality and effort by fishery persist over the period.

TABLE 2.2. Catches of swordfish from the SEPO, in metric tons.

	CHL	CHN	CRI	ESP	JPN	KOR	PER	PYF	TWN	OTR	Total
1945	1,455	-	-	-	-	-	-	-	-	-	1,455
1946	2,166	-	-	-	-	-	-	-	-	-	2,166
1947	1,701	-	-	-	-	-	-	-	-	-	1,701
1948	1,209	-	-	-	-	-	-	-	-	-	1,209
1949	690	-	-	-	-	-	-	-	-	-	690
1950	786	-	-	-	-	-	-	-	-	-	786
1951	870	-	-	-	-	-	-	-	-	-	870
1952	570	-	-	-	-	-	-	-	-	-	570
1953	416	-	-	-	-	-	-	-	-	-	416
1954	334	-	-	-	0	-	700	-	-	-	1,034
1955	237	-	-	-	1	-	400	-	-	-	638
1956	386	-	-	-	3	-	600	-	-	-	989
1957	357	-	-	-	54	-	600	-	-	-	1,011
1958	392	-	-	-	64	-	400	-	-	-	856
1959	555	-	-	-	32	-	400	-	-	-	987
1960	456	-	-	-	36	-	400	-	-	-	892
1961	394	-	-	-	104	-	300	-	-	-	798
1962	297	-	-	-	211	-	400	-	-	-	908
1963	94	-	-	-	676	-	200	-	-	-	970
1964	312	-	-	-	471	-	900	-	-	-	1,683
1965	151	-	-	-	344	-	300	-	-	-	795
1966	175	-	-	-	401	-	200	-	-	-	776
1967	203	-	-	-	390	-	1,300	-	31	-	1,924
1968	175	-	-	-	261	-	800	-	18	-	1,254
1969	314	-	-	-	569	-	1,200	-	6	-	2,089
1970	243	-	-	-	542	-	2,396	-	26	-	3,207
1971	181	-	-	-	261	-	185	-	18	-	645
1972	141	-	-	-	368	-	550	-	38	-	1,097
1973	410	-	-	-	912	-	1,941	-	30	-	3,293
1974	218	-	-	-	694	-	470	-	34	-	1,416
1975	137	-	-	-	882	3	158	-	9	-	1,189
1976	13	-	-	-	1,209	15	295	-	36	-	1,568
1977	32	-	-	-	1,654	16	420	-	31	-	2,153
1978	56	-	-	-	2,045	29	436	-	8	-	2,574
1979	40	-	-	-	1,226	13	188	-	30	-	1,497
1980	104	-	-	-	2,103	32	216	-	17	-	2,472
1981	294	-	-	-	1,653	79	91	-	32	-	2,149
1982	285	-	-	-	1,143	26	154	-	31	-	1,639
1983	342	-	-	-	1,771	28	238	-	9	-	2,388
1984	103	-	-	-	1,538	37	343	-	15	-	2,036
1985	342	-	-	-	868	70	55	-	12	-	1,347
1986	764	-	-	-	1,473	60	21	-	12	-	2,330
1987	2,059	-	-	-	1,661	144	73	-	28	-	3,965
1988	4,455	-	-	-	2,233	110	54	-	38	-	6,890
1989	5,824	-	-	-	1,216	42	3	-	74	-	7,159
1990	4,955	-	-	1,007	1,596	170	1	-	24	-	7,753
1991	7,255	-	107	2,794	1,896	402	3	-	28	29	12,514
1992	6,379	-	27	2,435	2,020	172	16	2	27	-	11,078
1993	4,712	-	20	928	1,505	159	76	2	19	-	7,421
1994	3,801	-	27	576	1,627	121	310	16	44	-	6,522
1995	2,594	-	29	698	1,213	290	7	25	6	-	4,862
1996	3,145	-	315	772	1,186	332	1,013	25	12	-	6,800
1997	4,040	-	1,072	2,018	1,169	250	24	23	37	-	8,633

	CHL	CHN	CRI	ESP	JPN	KOR	PER	PYF	TWN	OTR	Total
1998	4,492	-	419	1,238	2,005	361	98	20	78	6	8,717
1999	2,925	-	99	1,092	1,257	401	15	30	84	-	5,903
2000	2,973	-	407	1,807	1,184	354	2	46	109	3	6,885
2001	3,262	111	653	3,426	2,436	154	2	47	462	536	11,089
2002	3,523	321	638	5,629	2,363	146	14	4	2,080	661	15,379
2003	3,848	815	286	5,913	2,286	136	26	87	1,454	320	15,171
2004	3,268	236	179	5,607	1,783	583	19	63	799	476	13,013
2005	3,979	308	191	4,962	1,254	146	28	51	561	34	11,514
2006	3,147	*	444	5,149	1,153	*	63	64	614	19	10,653
2007	3,741	147	242	4,730	1,309	159	46	51	246	119	10,790
2008	2,792	335	44	6,718	1,678	94	124	60	129	90	12,064
2009	3,514	*	37	8,011	1,617	89	25	59	91	*	13,443
2010	*	*	*	*	2,312	*	*	*	*	*	2,312

CHL: Chile; CHN: China; CRI: Costa Rica; ESP: España-Spain; JPN: Japan-Japón; KOR: Republic of Korea-República de Corea; PER: Perú; PYF: French Polynesia-Polinesia Francesa TWN: Chinese Taipei-Taipei Chino.
OTR: Includes Belize, Colombia, Ecuador, El Salvador, Guatemala, Mexico, Nicaragua, Panama and Vanuatu. Incluye Belice, Colombia, Ecuador El Salvador, Guatemala, México, Nicaragua, Panamá y Vanuatú.

TABLE 5. Estimates of selected model outputs and MSY-based parameters from the assessment and from sensitivity analyses in which h = 0.75 and in which the high catch rates observed in the 2007-2010 period were not included in the model.

Estimate – Estimación	Assessment – Evaluación	h = 0.75	2007-2010 cpue excluded
MSY	25,044	19,029	21,046
B_{MSY}	40,782	72,717	34,111
S_{MSY}	10,705	26,772	8,920
B_{MSY}/B_0	0.20	0.34	0.20
S_{MSY}/S_0	0.11	0.27	0.11
C_{RECENT}/MSY	0.57	0.75	0.68
B_{RECENT}/B_{MSY}	10.40	5.14	6.40
S_{RECENT}/S_{MSY}	14.76	5.99	10.68
F_{mult}	17.92	6.86	11.67

RECENT = average value for the three most recent years.

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Agenda Item D.2.a
Attachment 4
June 1011

SEVENTH REGULAR SESSION
Honolulu, Hawaii, USA
6-10 December 2010

CONSERVATION AND MANAGEMENT MEASURE FOR PACIFIC BLUEFIN TUNA

Conservation and Management Measure 2010-04[1]

The Western and Central Pacific Fisheries Commission (WCPFC):

Recognizing that WCPFC6 adopted Conservation and Management Measure for Pacific bluefin tuna (CMM2009-07);

Recalling that the WCPFC6 requested the Northern Committee to develop a new draft CMM applying to the Korean EEZ for consideration at the WCPFC7;

Taking account of the conservation advice from the 10th meeting of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) on this stock, which highlighted the importance that the level of F is decreased below the 2002-2004 levels, particularly on juvenile age classes;

Also recognizing that the trend of spawning stock biomass has been influenced substantially by the annual level of recruitment and that collecting of fisheries data in an accurate and timely manner is critically important for the proper management of this stock, and;

Further recalling that paragraph (4), Article 22 of the WCPFC Convention which requires cooperation between the Commission and the IATTC to reach agreement to harmonize CMMs for fish stocks such as Pacific bluefin tuna that occur in the Convention Areas of both organizations;

Adopts, in accordance with Article 10 of the WCPFC Convention that:

1. The interim management objective for Pacific bluefin tuna is to ensure that the current level of fishing mortality rate is not increased in the Convention Area. Initially, control over fishing effort will be used to achieve this objective as follows:

2. The Commission Members, Cooperating Non-Members and participating Territories (hereinafter referred to as CCMs) shall take measures necessary to ensure that total fishing effort by their vessels fishing for Pacific bluefin tuna in the area north of the 20 degrees north shall stay below the 2002-2004 levels for 2011 and 2012, except for artisanal fisheries. Such measures shall include those to reduce catches of juveniles (age 0-3) below the 2002-2004 levels, except for Korea. Korea shall take necessary measures to regulate the catches of juveniles (age 0-3) by managing Korean fishery in accordance with this CMM. CCMs shall cooperate for this purpose.

[1] Replaces CMM 2009-07

3. CCMs shall also take measures necessary to strengthen data collecting system for Pacific bluefin tuna fisheries in order to improve the data quality and timeliness of all the data reporting;

4. CCMs shall report to Executive Director by 31 July 2011 and 2012 measures they used to implement paragraphs 2, 3, 6 and 7 of this CMM. The Northern Committee shall annually review reports CCMs submit pursuant to this paragraph;

5. The Northern Committee at its Regular session in 2012 shall review this CMM based on the new ISC stock assessment for Pacific bluefin tuna scheduled in 2012 and take appropriate actions;

6. The WCPFC Executive Director shall communicate this Conservation Management Measure to the IATTC Secretariat and its contracting parties whose fishing vessels engage in fishing for Pacific bluefin tuna and request them to take equivalent measures in conformity with paragraphs 2 and 3 above;

7. To enhance effectiveness of this measure, CCMs are encouraged to communicate with and, if appropriate, work with the concerned IATTC contracting parties bilaterally.

8. The provisions of paragraph 2 shall not prejudice the legitimate rights and obligations under international law of those small island developing State Members and participating territories in the Convention Area whose current fishing activity for Pacific bluefin tuna is limited, but that have a real interest in fishing for the species, that may wish to develop their own fisheries for Pacific bluefin tuna in the future.

9. The provisions of paragraph 8 shall not provide a basis for an increase in fishing effort by fishing vessels owned or operated by interests outside such developing coastal State, particularly Small Island developing State Members or participating territories, unless such fishing is conducted in support of efforts by such Members and territories to develop their own domestic fisheries.

-------- Original Message --------
Subject: Albacore Tuna Considerations at the June Pacific Council Meeting
Date: Tue, 24 May 2011 14:15:44 -0700
From: Donald O. McIsaac <Donald.McIsaac@noaa.gov>
To: Pete Dupuy <lapazkd@aol.com>, augustfelando@aol.com, cfarwell@mbayaq.org, sfoltz@chesapeakefish.com, fvseedler@aol.com, Douglas Fricke <fricked@techline.com>, WFOA <wfoa@charter.net>, Bob Osborn <bob@pacificangler.com>, pierrem@ilwacofish.com, mthompson041@cox.net, Pamela Tom <pdtom@ucdavis.edu>, Bill Sutton <seafreshto@aol.com>, Craig Heberer <Craig.Heberer@noaa.gov>, rbelmontes@iattc.org, Cyreis Schmitt <cyreis.c.schmitt@dfw.state.or.us>, Heidi Hermsmeyer <Heidi.Hermsmeyer@noaa.gov>, suzanne.kohin@noaa.gov, llaughlin@dfg.ca.gov, Stephen.Stohs@noaa.gov, hmann@seafoodschool.org, kirt.hughes@dfw.wa.gov, fishon@garibaldicharters.com, Peter Flournoy <phf@international-law-offices.com>
CC: Kit Dahl <kit.dahl@noaa.gov>, Kathy Fosmark <kfosmark@aol.com>

Members of the HMSMT and HMSAS,

Thanks in advance for your preparations for, and your participation at, the upcoming June Council Meeting in Spokane, Washington. The purpose of this email is to elaborate on the challenge at this meeting relative to developing recommendations for management of the northern albacore tuna fishery in the international arenas for the balance of 2011, and the important role the HMS Advisory Bodies can play in successful development of meaningful positions.

As noted in the Situation Summary for this agenda item (attached), the unfortunate timing of the availability of new stock assessment information makes the situation particularly awkward. The stock assessment information will not be known by the time of the June Council meeting, yet the US positions in IATTC and WCPFC arenas need to be presented prior to the next Council meeting in September. However, simply abdicating from any input from the Pacific Council does not seem acceptable, nor does expecting Pacific Council representatives at these meetings to "think on their feet" on such a complicated and important matter.

Thus, we are asking that you think creatively in a hypothetical matter towards possible solutions. In general, we are asking you to imagine if you were a Council Member in this situation: what information would you like to see, what alternatives would you like to have been explored, and what hypothetical management measures would logically align with different stock assessment results? If there are reasonable responses to different stock assessment results, they could conceivably be adopted on a contingent basis to be applied to whatever the true stock assessment results are. For example, if the stock assessment shows identical results to the current condition, then perhaps the current US positions might be a reasonable recommendation from the Pacific Council; this is a hypothetical contingent conclusion that could be developed now. On the other hand, if the stock assessment shows a considerable reduction in biomass and a higher fishing intensity than the current condition, then additional conservation management measures might be a reasonable recommendation from the Pacific Council; this is also a hypothetical contingent conclusion that could be developed now, albeit dependent on just how much biomass reduction or fishing intensity changes.

As noted in the Situation Summary, hypothetical stock assessment results could range from a steep reduction in biomass to no reduction or even a slight increase, together with static, increased, or decreased fishing rates; a "Kobe" phase plot could show conditions across the range of the international equivalents of overfished status with overfishing occurring to a high, healthy biomass with no overfishing concerns. There is an enormous range of potential hypothetical stock assessment results possible, so it will be necessary to isolate a few reasonable benchmarks to make the task manageable. We do not want to stifle what the HMSAS and HMSMT might want to work on as good benchmarks, but suggest looking at the matrix below to stimulate thinking.

There is also an enormous set of management measures potentially applicable to different stock assessment results. We encourage you to look at, particularly in the hypothetical case of negative stock assessment results, such measures as time and area closures, fishing gear restrictions, hard caps on total allowable catches by sector, and others as currently in place under IATTC Resolutions or SCPFC CMMs for tuna species other than albacore. While obviously these measures are designed specifically for other species and different stock conditions, and thus not necessarily applicable to northern albacore fishery management, the idea is to sort through these measures for any that might be applicable or might be creatively adjusted to albacore tuna applicability. It is acknowledged that exact correlation of some management measures to a biomass or fishing rate parameter change is difficult; however, the unattainability of specific precision should not be an absolute stopper of any progress.

BIOMASS	**FISHING RATE**	**MANAGEMENT MEASURES**	**SUPPORT INFORMATION**
No Change	No Change		
30% Decrease	No Change		
	15% Increase		
	15% Decrease		
15% Increase	No Change		
	15% Increase		
	15% Decrease		

In closing it would seem a failure for the Pacific Council to conclude nothing can be done absent firm, singular stock assessment results. We have too much talent on the HMSAS and HMSMT to come up empty in this regard. We hope you can help the Council Members successfully develop contingent recommendations that can build toward strong US positions in the upcoming IATTC and WCPFC Northern Committee meetings.

Thanks again in advance for your efforts on this challenge,
Don

--
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HIGHLY MIGRATORY SPECIES ADVISORY SUBPANEL RECOMMENDATIONS TO INTERNATIONAL FISHERIES ORGANIZATIONS

1. The Highly Migratory Species Advisory Subpanel (HMSAS) respectfully requests the Council to send a letter extending its grave concern and sympathy to the Government of Japan and the fishermen of Japan for the loss of life and extensive damage sustained by the Japanese coastal fishing communities resulting from the recent earthquake and tsunami.

2. The HMSAS would like to emphasize that these recommendations are for transmittal to U.S. delegations and sections to the international Regional Fishery Management Organizations (RFMOs) and have no application to domestic regulations at this time.

3. With regard to the Inter-American Tropical Tuna Commission (IATTC) Annual Meeting in July the HMSAS recommends the following actions to the Council, which support the IATTC's scientific advice:

   a. Take no action on North Pacific albacore pending the completion and presentation of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) July 2011 Assessment;

   b. Encourage the establishment of national observer programs to put observers on longline vessels;

   c. Continue the bigeye tuna longline fixed limits for China, Japan, Korea, and Chinese Taipei the same as were in place for 2010 season and for other members to limit their bigeye tuna longline catch to those in 2001 or 500 mt;

   d. Set the catch for North Pacific bluefin in the Convention area by commercial vessels not to exceed the average catch during the 1994-2007 period. However, contrary to the staff's recommendation, the Council should not support limitation of recreational catch to the 2006-2010 period, but instead urge the IATTC to exempt sport fishing vessels. If this is not successful, urge the IATTC to limit the sport fishing vessels catch to the average catch during the 1994-2007 period, the same as commercial vessels;

   e. Recommend IATTC members to prohibit their fishing vessels from fishing or interacting with data buoys. However, contrary to the staff's recommendation, the Council should urge the elimination of the one nautical mile (two nautical miles in diameter) provision; a clear definition of data buoy is needed and it should exclude any drifting buoy; provide a publically accessible database for buoy location; and exclude violations of the resolution from being the basis for an illegal, unregulated, and unreported listing.

4. If the results of the July 2011 ISC albacore stock assessment are favorable, the HMSAS recommends the following actions to the Council for the Western and Central Pacific Fisheries Commission (WCPFC) Northern Committee (NC):

a. Seek agreement with Mexico on renewed access to the Mexican Exclusive Economic Zone (EEZ) for U.S. albacore troll and baitboat fishermen on an equitable basis;

b. Seek to convince U.S. delegations and sections to international RFMOs to be as supportive of U.S. fishermen in the albacore fishery as representatives from, for example, Canada and Japan have been.

5. Regardless of the results of the July 2011 ISC albacore stock assessment, the HMSAS recommends the following actions to the Council for the WCPFC NC:

   a. Encourage agreement among the concerned countries on the best way to measure effort for management measures and assign to the Highly Migratory Species Management Team (HMSMT) and HMSAS the tasks of examining what measures would be most advantageous to U.S. fishermen. This examination of the different potential measures for regulating effort should include, but not be limited to, well capacity, days at sea, closed periods with vessels at dock, length of vessels, number of vessels, total allowable catch, number of hooks, etc;

   b. Convince U.S. delegation and sections to international RFMOs to ensure that any management and conservation measures enacted by the members be subject to the same accountability and enforcement measures that will be placed on U.S. fishermen;

   c. Encourage the U.S. Government to gather information on exactly which fisheries, including shoreside facilities, have been damaged by the Japanese tsunami and to what extent;

   d. Encourage members of the WCPFC NC, particularly Japan, to define artisanal fisheries and a method to quantify their harvest capacity;

   e. Encourage the WCPFC NC and the IATTC to establish a timetable for implementing biological reference points for North Pacific albacore;

   f. Provide the funding and support of an HMSAS and HMSMT joint meeting after the ISC's July 2011 albacore assessment is presented, but before the WCPFC NC meeting in Japan in September, for the purpose of reviewing the assessment and making recommendations to the Council; and

   g. Arrange for the Council to meet by whatever method available to review the recommendations suggested by the HMSAS and HMSMT.

6. The HMSAS requests the Council to remind NMFS of the commitment made during the April 2011 Council meeting in response to the Council's request to secure data from the Canadian government on landings by Canadian vessels in Canadian ports of albacore caught in the U.S. west coast EEZ.

7. The HMSAS would like to update the Council on the shark finning situation. There is a California Bill AB 376 that will be detrimental to the commercial fishery. AB 376 prohibits the sale of shark fins and shark fin products. The bill as written will shut down commercial

fishing for sharks from well-managed, sustainable and high value fisheries. Concerning the Federal shark finning law, members of the HMSAS are contacting their Federal representatives in efforts to start an amendment process to pursue less burdensome regulation for all west coast fishermen.

PFMC
06/09/11

HIGHLY MIGRATORY SPECIES MANAGEMENT TEAM REPORT ON RECOMMENDATIONS TO INTERNATIONAL FISHERIES ORGANIZATIONS

The Highly Migratory Species Management Team (HMSMT) discussed recommendations the Council might consider making to the U.S. delegations attending the upcoming meeting of the Inter-American Tropical Tuna Commission (IATTC) in July 2011 and the Western and Central Pacific Fishery Commission (WCPFC) Northern Committee meeting in September 2011.

North Pacific Albacore Tuna

The HMSMT notes that results from the stock assessment for North Pacific albacore will be unavailable until after the June 2011 Council meeting. Absent the results, we offer the following guidance to the Council to manage the North Pacific albacore stock without placing the U.S. fleet at a disadvantage. The HMSMT offers interim guidance for U.S. delegations to Regional Fishery Management Organizations (RFMOs) and recommends that the HMSMT and Highly Migratory Species Advisory Subpanel (HMSAS) be tasked to develop a proactive management framework.

Current Status

The last International Scientific Committee (ISC) for Tuna and Tuna-like Species in the North Pacific Ocean stock assessment, conducted in 2006, indicated that albacore spawning stock biomass was high relative to estimated levels throughout the assessment time period, and fishing mortality for albacore was high compared to most generally accepted biological reference points (BRPs). For management purposes, the HMSMT supports the Northern Committee’s proposed three-year assessment cycle. Another HMSMT recommendation is to update the life history parameters used in the stock assessment, such as maturity, age, and growth. The HMSMT supports conducting life history studies to address this need throughout the North Pacific Ocean.

The HMSMT believes it is critical for RFMOs to agree on target management levels based on fishing mortality and spawning stock biomass. However, for albacore, there is a limited basis for quantifying stock status relative to BRPs. The HMSMT reviewed the suite of BRPs that have been considered by international bodies and notes that the only reference point that has been selected at the international level is $F_{SSB-ATHL}$, the average fishing mortality rate associated with the ten historically lowest estimates of spawning stock biomass. Because $F_{SSB-ATHL}$ is an interim reference point that is not precautionary, RFMOs have recognized the need to agree on more robust BRPs and have assigned working groups to recommend the most appropriate BRPs; however, this analysis has not been completed. The HMSMT recommends defining reference points for management and utilizing simulation analyses of potential BRPs, as appropriate.

The HMSMT notes that Amendment 2 to the HMS FMP will provide the Council with the option to adopt alternatives to standard MSY-based reference points. If an RFMO with management authority over HMS FMP stocks identifies reference points for any HMS FMP-managed stock, the Council could recommend the use of those reference points.

Potential Response to New Stock Assessment Results

The Council is in a largely reactive position for recommending management measures in response to new stock assessment results and the HMSMT proposes interim guidance until the Council has an opportunity to review the stock assessment results. In addition, the HMSMT recommends pursuing a more long-term management strategy.

For the interim, the HMSMT developed possible management recommendations based on hypothetical stock assessment results. If the assessment results are similar to the 2006 stock assessment results, the HMSMT recommends that current management measures (i.e., IATTC Resolution C-05-02; CMM-2005-03) be maintained and clarified, for instance by defining metrics for "current effort," and compliance with data reporting should be promoted. The IATTC resolution could be improved by requiring data reporting requirements on effort as well as catch by gear type.

If the assessment results indicate that biomass is declining and approaching the spawning stock biomass level associated with the interim BRP ($F_{SSB\text{-}ATHL}$**)**, the HMSMT recommends that international management measures be implemented to reduce fishing mortality. The degree of reduction in fishing mortality and the length of time to reduce that mortality would depend upon proximity to the reference point. The HMSMT notes that the Laurs and Powers report (2009) included tables of potential management measures with pros and cons that the HMSMT considered. Given the short time frame before the IATTC and Northern Committee meetings and the complexity involved, catch limit and time-area approaches do not seem feasible at this time. Therefore, if fishing mortality reductions are necessary, the HMSMT recommends commensurate reductions in fishing effort in proportion to the relative impacts of fishing nations on the stock.

To develop a more proactive international management framework, the HMSMT also suggests that the Council request the HMSMT and HMSAS to conduct a comprehensive cost benefit analysis of different management options. Such an analysis would include, among other things, comparison of catch, effort, and capacity limit management options and evaluation of the relationships between the albacore and other west coast fisheries. This analysis would draw from the Laurs and Powers (2009) and Lisa Wise Consulting (2011) reports and other relevant resources. If the Council chooses to move forward with this analysis, the HMSMT could develop a work plan in collaboration with the HMSAS and other interested stakeholders for Council consideration at an upcoming meeting.

In summary, the HMSMT recommends that the Council consider the following recommendations for albacore to the U.S. Delegations to the IATTC and Northern Committee:

1. Support management measures that address the relative impacts of all international fisheries participants without disadvantaging the U.S. fleet;
2. Support the Northern Committee's proposed three year stock assessment cycle;
3. Promote research to update the life history parameters such as maturity, and age and growth in the stock assessment, efforts which will require additional sampling and data collection;
4. Define reference points for international management and utilize simulation analyses of potential BRPs, as appropriate;

5. Give weight to management measures for which monitoring, compliance, and enforcement are effective;
6. If the stock assessment results are similar to the 2006 stock assessment results, the HMSMT recommends that current management measures be maintained and clarified, and compliance with data reporting requirements should be promoted; and
7. If the assessment results indicate that biomass is declining and approaching the spawning stock biomass level associated with the interim BRP ($F_{SSB-ATHL}$**)**, the HMSMT suggests a recommendation that international management measures be implemented to reduce fishing mortality via fishing effort reductions.
8. In addition, the Council could consider tasking the HMSMT and HMSAS to conduct a comprehensive cost benefit analysis of different management options to support development of a proactive management framework.

Additional Recommendations to the U.S. Delegation to the IATTC

Pacific Bluefin Tuna

The HMSMT supports the adoption of biological reference points and effective conservation measures for bluefin tuna in the IATTC. Currently, no biological reference points are agreed upon for bluefin tuna; however, with respect to all potential reference points examined by the ISC, the fishing mortality rate appears to exceed that which would support maximum sustainable yield. The HMSMT recommends that management measures for Pacific bluefin tuna are adopted at the 2011 IATTC meeting following the advice of the IATTC scientific staff to limit commercial catch to the average annual catch from1994-2007; however, the HMSMT does not support adopting the effort limitation in the recreational fishery. It is the HMSMT's understanding that the IATTC scientific staff included this provision to prevent a shift in effort to the recreational fishery and subsequent sale of recreationally caught fish; however, the State of California, where the majority of West Coast recreational bluefin catch occurs, already has a law in place to prohibit the sale of all recreationally caught fish so no effort shift is anticipated.

Yellowfin and Bigeye Tuna

The HMSMT recommends that the non-binding recommendations agreed to at last year's IATTC meeting (Recommendation C-10-01 on tropical tuna measures, Recommendation C-10-02 on seabird mitigation measures, and Recommendation C-10-03 on prohibiting fishing around data buoys), be reopened for adoption as binding resolutions at this year's meeting. The HMSMT believes that the provisions in the tropical tuna measure, which include time and area closures in the purse seine fishery and bigeye catch limits in the longline fishery, should be maintained at a minimum when adopted as formal resolutions, given that 2011 IATTC stock assessment results for the yellowfin and bigeye tuna stocks in the EPO are slightly more pessimistic than in 2010 assessments.

Compliance and Data Collection Measures

With respect to U.S. proposals for conservation measures that are likely to be discussed at the upcoming IATTC meeting, the HMSMT recommends that the Council support proposals that would increase compliance with IATTC management measures; for example, the proposal to clarify and improve Illegal, Unreported, and Unregulated (IUU) vessel listing procedures. The HMSMT also recommends that the U.S. delegation advocate for more comprehensive data reporting and collection by members of the IATTC. In particular, the HMSMT supports the adoption of a proposal that would require five percent observer coverage in longline fisheries.

In summary, the HMSMT suggests that the Council consider the following recommendations to the U.S. Delegation to the IATTC:

1. Support the adoption of biological reference points and effective conservation measures for Pacific bluefin tuna, as identified above;
2. Support the adoption of management measures in the commercial fisheries for Pacific bluefin tuna;
3. Do not support the adoption of management measures in the recreational fisheries for Pacific bluefin tuna;
4. Support reopening the non-binding recommendations for tropical tunas agreed to at last year's IATTC meeting for adoption as binding resolutions at this year's meeting, Recommendation C-10-01 on tropical tuna measures, Recommendation C-10-02 on seabird mitigation measures, and Recommendation C-10-03 on prohibiting fishing around data buoys;
5. Support proposals that would increase compliance with IATTC management measures; and
6. Advocate for more comprehensive data reporting and collection by members of the IATTC.

PFMC
06/09/11