Agenda Item H.1
Situation Summary
June 2009

PACIFIC MACKEREL MANAGEMENT FOR 2009-2010

The Council is scheduled to review the current Pacific mackerel stock assessment and adopt a harvest guideline and management measures for the 2009-2010 Pacific mackerel fishing season, which opens July 1, 2009 and closes the earlier of June 30, 2010 or attainment of the directed fishery harvest guideline.

Full assessments for Pacific mackerel typically occur every third year, necessitating a three-year cycle for the Coastal Pelagic Species (CPS) Stock Assessment Review (STAR) process. The last STAR process for Pacific mackerel occurred in 2007. New modeling efforts were a major focus of the 2007 STAR process, but unresolved technical issues led the Council to recommend that the next full assessment and STAR process for Pacific mackerel occur in 2009 rather than 2010.

The National Marine Fisheries Service, Southwest Fisheries Science Center, took the lead in developing the 2009 full assessment of Pacific mackerel for the 2009-2010 fishing season (Agenda Item H.1.b, Attachment 1). The assessment was reviewed by a STAR Panel May 4-8, 2009 where the stock assessment team and the STAR Panel agreed on a base assessment model (Agenda Item H.1.b, Attachment 2). The Scientific and Statistical Committee (SSC), the Coastal Pelagic Species Management Team (CPSMT), and the Coastal Pelagic Species Advisory Subpanel (CPSAS) will review the full assessment and STAR Panel recommendations before developing harvest specifications and management measures at the June meeting (see Ancillary Meetings for details).

The first draft of the ninth annual Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches – Stock Assessment and Fishery Evaluation (SAFE) document for 2009 (Agenda Item H.1.a, Supplemental Attachment 1) was unavailable for the briefing book, but will be posted as supplemental material on the Council web site in advance of the June Council meeting. Once adopted, the 2009 Pacific Mackerel Stock Assessment and 2009-2010 management measures will be included in the 2009 CPS SAFE.

Council Action:

1. Approve Stock Assessment, Harvest Guideline, and Management Measures for the 2009-2010 Pacific Mackerel Fishery.

Reference Materials:

1. Agenda Item H.1.a, Supplemental Attachment 1 *Draft Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches – Stock Assessment and Fishery Evaluation 2009* (**electronic copy posted to Council web site**).
2. Agenda Item H.1.b, Attachment 1: *Pacific Mackerel (Scomber japonicus) Stock Assessment for U.S. Management in the 2009-2010 Season.*
3. Agenda Item H.1.b, Attachment 2: Pacific Mackerel, STAR Panel Meeting Report.
4. Agenda Item H.1.c, Supplemental SSC Report.
5. Agenda Item H.1.c, Supplemental CPSMT Report.
6. Agenda Item H.1.c, Supplemental CPSAS Report.

Agenda Order:

a. Agenda Item Overview — Mike Burner
b. National Marine Fisheries Service Report — Paul Crone
c. Reports and Comments of Management Entities and Advisory Bodies
d. Public Comment
e. **Council Action:** Approve Stock Assessment, Harvest Guideline, and Management Measures

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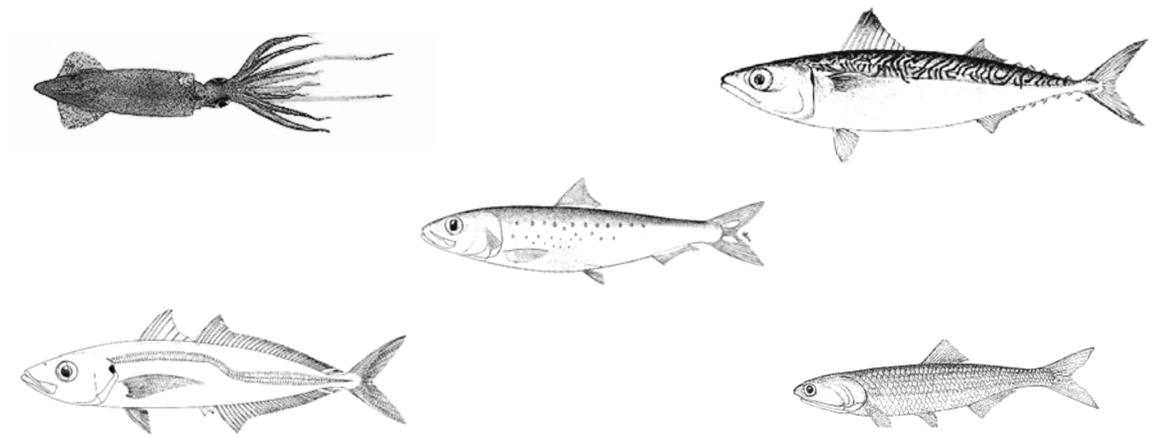
Agenda Item H.1.a
Supplemental Electronic Attachment 1
June 2009

STATUS OF THE PACIFIC COAST COASTAL PELAGIC SPECIES FISHERY AND RECOMMENDED ACCEPTABLE BIOLOGICAL CATCHES

STOCK ASSESSMENT AND FISHERY EVALUATION 2009



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BRIEFING BOOK DRAFT
JUNE 2009

ACKNOWLEDGMENTS

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LIST OF ACRONYMS AND ABBREVIATIONS

ABC	acceptable biological catch
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CANSAR-TAM	Catch-at-age Analysis for Sardine - Two Area Model
CCLME	California Current Large Marine Ecosystem
CDFG	California Department of Fish and Game
CESA	California Endangered Species Act
Commission	California Fish and Game Commission
CONAPESCA	National Commission of Aquaculture and Fisheries (Mexico)
Council	Pacific Fishery Management Council
CPFV	commercial passenger fishing vessel
CPS	coastal pelagic species
CPSAS	Coastal Pelagic Species Advisory Subpanel
CPSMT	Coastal Pelagic Species Management Team
CPSPDT	Coastal Pelagic Species Plan Development Team
CPUE	catch per unit effort
CUFES	Continuous Underway Fish Egg Sampler
CV	coefficient of variation
DEPM	daily egg production method
EA	Environmental Assessment
EBFM	ecosystem based fishery conservation and management
EEZ	exclusive economic zone
EFH	essential fish habitat
EIS	Environmental Assessment
ENSO	El Niño southern oscillation
ESA	Endangered Species Act
FMP	fishery management plan
GIS	Geographic Information System
GT	gross tonnage
HG	harvest guideline
INP	Instituto Nacional de la Pesca (Mexico)
LE	limited entry
LIDAR	light detection and ranging
Magnuson-Stevens Act	Magnuson-Stevens Fishery Conservation and Management Act
MAXCAT	maximum harvest level parameter
MSY	maximum sustainable yield
mt	metric ton
NMFS	National Marine Fisheries Service
NOI	Notice of Intent
ODFW	Oregon Department of Fish and Wildlife
OY	optimum yield
PacFIN	Pacific Coast Fisheries Information Network
PFAU	Pelagic Fisheries Assessment Unit
PRD	Protected Resource Division
RecFIN	Recreational Fishery Information Network
RFA	Regulatory Flexibility Act

RIR	regulatory impact review
ROV	remotely operated vehicle
SAFE	stock assessment and fishery evaluation
Secretary	U.S. Secretary of Commerce
SFD	Sustainable Fisheries Division
SS2	Stock Synthesis 2
SSC	Scientific and Statistical Committee
SST	sea surface temperature
st	short ton
STAR	Stock Assessment Review (Panel)
STAT	Stock Assessment Team
SWFSC	Southwest Fisheries Science Center (NMFS)
SWR	Southwest Region (NMFS)
USFWS	U.S. Fish and Wildlife Service
VPA	virtual population analysis
WDFW	Washington Department of Fish and Wildlife

1.0 INTRODUCTION

The Guidelines for Fishery Management Plans (FMPs) published by the National Marine Fisheries Service (NMFS) require that a stock assessment and fishery evaluation (SAFE) report be prepared and reviewed annually for each FMP. SAFE reports are intended to summarize the best available scientific information concerning the past, present, and possible future condition of the stocks, marine ecosystems, and fisheries being managed under federal regulation. Regional Fishery Management Councils use this information to determine annual harvest levels for each stock, document significant trends or changes in the resources, marine ecosystems, and fishery over time, and assess the relative success of existing state and federal fishery management programs.

This is the tenth *Status of the Pacific Coast Coastal Pelagic Species Fishery* SAFE document prepared for the Pacific Fishery Management Council (Council). Following NMFS guidelines, the purpose of this report is to briefly summarize aspects of the coastal pelagic species (CPS) FMP and to describe the history of the fishery and its management. Species managed under this FMP include: Pacific sardine (*Sardinops sagax*), Pacific mackerel (*Scomber japonicus*), northern anchovy (*Engraulis mordax*), jack mackerel (*Trachurus symmetricus*), and market squid (*Loligo opalescens*).

The SAFE report for Pacific coast CPS fisheries was developed by the Council's Coastal Pelagic Species Management Team (CPSMT) from information contributed by scientists at NMFS, Southwest Fisheries Science Center (SWFSC), California Department of Fish and Game (CDFG), Oregon Department of Fish and Wildlife (ODFW), and Washington Department of Fish and Wildlife (WDFW). Included in this report are descriptions of landings, fishing patterns, estimates of the status of stocks (including stock assessments for Pacific sardine and Pacific mackerel, Appendix 1 and Appendix 2), and acceptable biological catches (ABCs).

The ABC recommendations, together with social and economic factors, are considered by the Council in determining annual harvest guidelines and other measures for actively managed fisheries (i.e., Pacific mackerel and Pacific sardine).

2.0 THE CPS FISHERY

2.1 Management History

The CPS FMP is an outgrowth of the *Northern Anchovy Fishery Management Plan*, which was implemented in September 1978. The Council began to consider expanding the scope of the northern anchovy FMP in 1990, with development of the seventh amendment to the FMP. The intent was to develop a greatly modified FMP, which included a wider range of coastal pelagic finfish and market squid. A complete draft was finished in November of 1993, but the Council suspended further work because NMFS withdrew support due to budget constraints. In July 1994, the Council decided to proceed with public review of the draft FMP. NMFS agreed with the decision on the condition that the Council also consider the options of dropping or amending the northern anchovy FMP. Four principal options were considered for managing CPS fisheries:

1. Drop the anchovy FMP (results in no Federal or Council involvement in CPS).
2. Continue with the existing FMP for anchovy (status quo).
3. Amend the FMP for northern anchovy.
4. Implement an FMP for the entire CPS fishery.

In March 1995, after considering the four options, the Council decided to proceed with option four, developing an FMP for the entire CPS fishery. Final action was postponed until June 1995 when the Council adopted a draft plan that had been revised to address comments provided by NMFS and the Council's Scientific and Statistical Committee (SSC). Amendment 7 was submitted to the U.S. Secretary of Commerce (Secretary), but rejected by NMFS Southwest Region as being inconsistent with National Standard 7. NMFS announced its intention to drop the FMP for northern anchovy in a proposed rule published in the *Federal Register* on March 26, 1996 (61*FR*13148). The proposed rule was withdrawn on November 26, 1996 (61*FR*60254). Upon implementation of Amendment 8 (see below), the northern anchovy FMP was renamed the Coastal Pelagic Species Fishery Management Plan.

2.2 Recent Management

For a complete listing of formal Council actions and NMFS regulatory actions since implementation of the CPS FMP see Tables 2-1 and 2-2, respectively.

2.2.1 Amendment 8

Development of Amendment 8 to the northern anchovy FMP began during June 1997 when the Council directed the Coastal Pelagic Species Plan Development Team to amend the FMP for northern anchovy to conform to the recently revised Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) and to expand the scope of the FMP to include other species harvested by the CPS fishery.

In June 1999, NMFS partially approved the CPS FMP. Approved FMP elements included: (1) the management unit species, (2) CPS fishery management areas, consisting of a limited entry (LE) zone and two subareas, (3) a procedure for setting annual specifications including harvest guidelines (HG), quotas, and allocations, (4) provisions for closing directed fisheries when the directed portion of a harvest guideline or quota is taken, (5) fishing seasons for Pacific sardine and Pacific mackerel, (6) catch restrictions in the LE zone and, when the directed fishery for a CPS is closed, limited harvest of that species to an incidental limit, (7) a LE program, (8) authorization for NMFS to issue exempted fishing permits for the harvest of CPS that otherwise would be prohibited, and (9) a framework process to make management decisions without amending the FMP.

At that time, NMFS disapproved the optimum yield (OY) designation for market squid, because there was no estimate of maximum sustainable yield (MSY). Bycatch provisions were disapproved for lack of standardized reporting methodology to assess the amount and type of bycatch and because there was no explanation of whether additional management measures to minimize bycatch and the mortality of unavoidable bycatch were practicable.

On December 15, 1999, final regulations implementing the CPS FMP were published in the *Federal Register* (64*FR*69888). Provisions pertaining to issuance of LE permits were effective immediately. Other provisions, such as harvest guidelines, were effective January 1, 2000.

2.2.2 Amendment 9

During 1999 and 2000, the CPSMT developed Amendment 9 to the CPS FMP. Originally, Amendment 9 addressed both disapproved provisions of the FMP – bycatch and market squid MSY. The amendment also included provisions to ensure that treaty Indian fishing rights are implemented according to treaties between the U.S. and specific Pacific Northwest tribes.

The Council distributed Amendment 9 for public review on July 27, 2000. At its September 2000 meeting, the Council reviewed written public comments, received comments from its advisory bodies, and heard public comments. Based on advice about market squid MSY determination, the Council decided to include in Amendment 9 only the provisions for bycatch and treaty Indian fishing rights. The Council decided to conduct further analysis of the squid resource and prepare a separate amendment to address OY and MSY for squid. The Secretary approved Amendment 9 on March 22, 2001, and the final rule implementing Amendment 9 was published August 27, 2001 (66*FR*44986).

2.2.3 Amendment 10

In April 2001, the Council adopted a capacity goal for the CPS LE finfish fishery and asked the CPSMT to begin work on a 10th amendment to the FMP. Amendment 10 included the capacity goal, provisions for permit transferability, a process for monitoring fleet capacity relative to the goal, and a framework for modifying transferability provisions as warranted by increases or decreases in fleet capacity. The amendment also addressed determination of OY and MSY for market squid.

In June 2002, the Council adopted Amendment 10 to the CPS FMP. Relative to the LE fishery, the amendment established a capacity goal, provided for LE permit transferability to achieve and maintain the capacity goal, and established a process for considering new LE permits. The purpose of this action was to ensure fishing capacity in the CPS LE fishery is in balance with resource availability. Relative to market squid, Amendment 10 established an MSY (or proxy) for market squid to bring the FMP into compliance with the Magnuson-Stevens Act. The purpose of this action was to minimize the likelihood of overfishing the market squid resource. On December 30, 2002, the Secretary approved Amendment 10. On January 27, 2003, NMFS issued the final rule and regulations implementing Amendment 10 (68*FR*3819).

2.2.4 Sardine Allocation Regulatory Amendment

In September 2002, the Coastal Pelagic Species Advisory Subpanel (CPSAS) recommended the Council initiate a regulatory or FMP amendment and direct the CPSMT to prepare management alternatives for revising the sardine allocation framework. The Council directed the CPSMT to review CPSAS recommendations for revising the allocation framework. At the March 2003 Council meeting, the SSC and CPSAS reviewed analyses of the proposed management alternatives for sardine allocation. Based on the advisory body recommendations and public comment, the Council adopted five allocation management alternatives for public review. In April 2003, the Council took final action on the regulatory amendment. This change was implemented by NMFS on September 4, 2003 (68*FR*52523); the new allocation system: (1) changed the definition of Subarea A and Subarea B by moving the geographic boundary between the two areas from 35°40' N latitude (Point Piedras Blancas, California) to 39° N latitude (Point Arena, California), (2) moved the date when Pacific sardine that remains unharvested is reallocated to Subarea A and Subarea B from October 1 to September 1, (3) changed the percentage of the unharvested sardine that is reallocated to Subarea A and Subarea B from 50% to both subareas, to 20% to Subarea A and 80% to Subarea B, and (4) provided for coastwide reallocation of all unharvested sardine that remains on December 1. This revised allocation framework was in place for the 2003 and 2004 fishing seasons. It was also used in 2005 because the 2005 HG is at least 90% of the 2003 harvest guideline.

2.2.5 Amendment 11

The Council began developing options for a new allocation framework for the coastwide Pacific sardine fishery in 2003 while the fishery operated under the regulatory amendment described in the previous section. This revision to the sardine allocation framework will occur through Amendment 11 to the CPS FMP in 2006. The FMP amendment is intended to achieve optimal utilization of the resource and equitable allocation of harvest opportunity.

The Council tasked the CPSAS with initial development of a range of allocation alternatives. At the November 2004 meeting, the CPSAS presented several program objectives and a suite of alternative allocation formulae. The Council adopted for preliminary analysis a range of alternatives, including the CPSAS recommendations, as well as the following program objectives:

- Strive for simplicity and flexibility in developing an allocation scheme.
- Transfer quota as needed.
- Utilize OY.
- Implement a plan that balances maximizing value and historic dependence on sardine.
- Implement a plan that shares the pain equally at reduced HG levels.
- Implement a plan that produces a high probability of predictability and stability in the fishery.

For the analysis of the alternatives, the Council gave specific direction to the CPSMT, including:

- Analyze each alternative in a consistent manner.
- Review differential impacts on northern and southern sectors for each alternative.
- Review effects of high and low catch years by sector for each alternative.
- Review resulting effects at various HG levels ranging from 25,000 mt to 200,000 mt (at appropriate intervals) for each alternative.

- At the discretion of the CPSMT, combine aspects of the various alternatives to create new alternatives that meet program objectives.

At the April 2004 Council meeting, the CPSMT presented preliminary economic analyses of these alternatives to the Council and its advisory bodies. The economic analysis of alternative allocation schemes included five-year projections of the incremental change in producer surplus and landings projections for each fishing sector and subarea. Monthly landings projections were based on 2004 landings and were inflated by 10% annually to account for expected growth in the regional fishery sectors over the next five years. These projections identified months in which there would be a shortfall in landings, and months which would start out with no available allocation. These landings projections were conducted under three HG scenarios: (1) low HG = 72,000 mt, (2) Base case HG = 136,000 mt, and (3) high HG = 200,000 mt.

The Council reviewed the preliminary results and public testimony before following the advice of both the CPSAS and CPSMT when adopting the remaining range of alternatives for further analysis and public review. The Council directed the CPSMT to take into account the advice of the SSC as they proceed with the analysis. Specifically, the Council requested a sensitivity analysis of the effects of future fishery growth where varying growth assumptions by subarea are applied, rather than the previously assumed 10% growth of the fishery coastwide. The Council also recommended that two different provisions for the review of a sardine allocation framework be included in the documentation for public review. The first based on time, where sardine allocation would be reviewed after three, five, or seven years of implementation; the second based on the size of the HG, where sardine allocation would be revisited if the HG falls below 75,000 mt or 100,000 mt.

In June 2005, the Council adopted a long-term allocation framework to apportion the annual Pacific sardine harvest guideline among the various non-tribal sectors of the sardine fishery. The Council followed the unanimous opinion of the CPSAS when adopting a seasonal allocation scheme which provides the following allocation formula for the non-tribal share of the HG:

(1) January 1, 35% of the harvest guideline to be allocated coastwide;

(2) July 1, 40% of the HG, plus any portion not harvested from the initial allocation, to be reallocated coastwide; and

(3) September 15, the remaining 25% of the harvest guideline, plus any portion not harvested from earlier allocations, to be reallocated coastwide.

The Council also heeded the advice of the CPSAS, CPSMT, and SSC regarding the dynamic nature of the Pacific sardine resource and uncertainties inherent in long-term projections, and scheduled a formal review of the allocation formula in 2008. This review has been postponed until the fall of 2009 so that data on fishery closures in 2008 can be included in the analysis. The review will provide a comparison of the performance of the fishery to the projections used to evaluate the adopted allocation scheme and will include any new information from Pacific sardine research.

2.2.6 Amendment 12

At the November 2004 meeting the Council initiated development of a formal prohibition on directed fisheries for krill, and directed staff to begin development of management measures to regulate directed fisheries for krill within Council-managed waters. The proposal for a krill ban was first proposed for West Coast National Marine Sanctuary waters by the National Marine Sanctuary Program.

This Amendment was in recognition of the importance of krill as a fundamental food source for much of the marine life along the West Coast. Moreover, state laws prohibit krill landings by state-licensed fishing vessels into California, Oregon, and Washington, respectively. Thus, the action could provide for consistent Federal and state management. There are currently no directed krill fisheries in Council-managed waters.

At the November 2005 Council meeting the Council recommended that all species of krill be included in the CPS FMP as prohibited harvest species, and approved a range of krill fishing alternatives for public review and additional analysis over the winter. The Council narrowed the range of alternatives to: 1) status quo, 2) a prohibition on krill fishing in all Council-managed waters, and 3) an initial prohibition combined with the establishment of a process for considering future krill fishing opportunities. Of these alternatives, the Council adopted the second, a complete ban on krill fishing as a preliminary preferred alternative.

In March 2006, the Council adopted a complete ban on commercial fishing for all species of krill in West Coast Federal waters and made no provisions for future fisheries. They also specified essential fish habitat (EFH) for krill, making it easier to work with other Federal agencies to protect krill. This broad prohibition will apply to all vessels in Council-managed waters and will take form as Amendment 12 when fully implemented.

Although Amendment 12 has been approved by the Secretary and NMFS completed a public review of proposed implementing regulations, a final rule for this action is not yet adopted.

2.3 The CPS Fleet

During the 1940s and 1950s, approximately 200 vessels participated in the Pacific sardine fishery. Some present day CPS vessels are remnants of that fleet. CPS finfish landed by the roundhaul fleet (fishing primarily with purse seine or lampara nets) are sold as relatively high volume/low value products (e.g., Pacific mackerel canned for pet food, Pacific sardine frozen and shipped to Australia to feed penned tuna, and northern anchovy reduced to meal and oil). In addition to fishing for CPS finfish, many of these vessels fish for market squid, Pacific bonito, bluefin tuna, and Pacific herring.

A fishery for Pacific sardine has operated off Oregon and Washington since 1999. This fishery targets larger sardine, which have typically sold as bait for Asian longline tuna fisheries. Beginning in 2006, this fishery has been expanding into human consumption markets.

Along the West Coast, other vessels target CPS finfish in small quantities, typically selling their catch to specialty markets for relatively high prices. In recent years, these included:

- Approximately 18 live bait vessels in southern California and two vessels in Oregon and Washington that landed about 2,000 mt per year of CPS finfish (mostly northern anchovy and Pacific sardine) for sale to recreational anglers. Oregon's landings for live bait in 2005 totaled 2.6 mt of sardines by one vessel.
- Roundhaul vessels that take a maximum of 1,000 mt to 3,000 mt per year of northern anchovy that are sold as dead bait to recreational anglers.
- Roundhaul and other mostly small vessels that target CPS finfish (particularly Pacific mackerel and Pacific sardine) for sale in local fresh fish markets or canneries.

2.3.1 Limited Entry Fishery

The CPS LE fleet currently consists of 65 permits and 61 vessels (Table 2-3). The LE vessels range in age from 4 to 68 years, with an average age of 33 years (Table 2-4). Average vessel age has decreased by approximately four years since the initial fleet was established.

The capacity goal and transferability provisions established under Amendment 10 are based on calculated gross tonnage (GT) of individual vessels. Calculated GT serves as a proxy for each vessel's physical capacity and is used to track total fleet capacity. Calculated GT incorporates a vessel's length, breadth, and depth, which are consistent measures across vessel registration and U.S. Coast Guard documentation lists. As described at 46 CFR § 69.209, GT is defined as:

$$GT=0.67(length*breadth*depth)/100.$$

Vessel dimension data were obtained from the U.S. Coast Guard database, and each vessel's calculated GT was attached to the permit under Amendment 10. Original GT endorsements (specified in Table 2-3) remain with the permit, regardless of whether the permit is transferred to a smaller or larger vessel.

GT values for the current fleet range from 23.8 GT to 340.2 GT, with an average of 88.7 GT (Tables 3a and 3b). Total fleet GT decreased from 5,462.9 GT to 5,408.4 GT during 2004. This decrease was due to the loss of the "Connie Marie" (permit 64; sank in 2002), which has yet to be replaced by the owner. The fleet capacity goal established through Amendment 10 is 5,650.9 GT, and the trigger for restricting transferability is 5,933.5 GT (Goal + 5%). The current LE fleet is 5,408.4 GT, well within the bounds of the capacity goal.

2.3.2 Northern Fisheries

2.3.2.1 Oregon State Limited Entry Fishery

The Pacific sardine fishery off Oregon started in 1935, but there are recorded landings of sardine in Oregon dating back to 1928. The catch dropped off in the 1940's with 1948 being the last year of directed fishery landings until 1999 when the fishery was revived. Pacific sardine was managed as a developmental fishery from 1999 to 2005. In 2004, the sardine industry asked the Department of Fish and Wildlife to remove Pacific sardines from the developmental species list and create a limited entry system for the fishery. The Department began work with the Developmental Fisheries Board and the industry to develop alternatives for the fishery. In December 2005, the Oregon Fish and Wildlife Commission (Commission) moved the Pacific sardine fishery from a developing fishery into a state-run limited entry fishery system. Twenty Oregon permits were initially established and made available to qualifying participants for the 2006 fishery. The Commission amended an LE permit eligibility rule in August 2006 which resulted in an immediate addition of six permits for a total of 26 LE sardine fishery permits. Twenty-five permits were issued in 2008, but only 22 permits were actively utilized in the fishery. Table 2-5 contains information for vessels that participated in the 2008 fishery.

The Department held a series of three public meetings in late 2008 and early 2009 to discuss possible changes to regulations for the 2009 season. The Commission enacted a number of rule changes for the Pacific sardine fishery in April 2009. First, the Commission modified the requirement for minimum landings of sardines into Oregon to qualify for permit renewal that was enacted in 2006. The minimum landing requirements for permit renewal are now effective only when the federal coastwide maximum HG for the fishing year exceeds 100,000 mt. The minimum landing requirements themselves, either a minimum of ten landings of at least five mt each or landings totaling at least $40,000 exvessel price, were not changed. Second, the Commission waived the 2008 annual landing requirements for permit renewal industry wide. Next, the Commission eliminated a rule that became effective in 2008 which specified that permit holders must either own or operate a vessel that is permitted. The Commission also established a lottery system for sardine permits. If the number of permits issued falls below 24 a lottery may be held the following year, but the total number issued shall not exceed 26 LE permits. Finally, a new rule put in place for the sardine fishery defined catching vessels and limited catch sharing to catching vessels.

Although the primary CPS fishery in Oregon targets sardine, developmental fishery permits for harvesting anchovy have been issued since 1995. All developmental fisheries in Oregon have a limited number of permits available and landing requirements for permit renewal, but the number of permits and landing requirements differ by target species. In 2008 there were 5 of the 15 developmental fishery permits issued for the anchovy fishery.

2.3.2.2 Washington

Pacific sardines are the primary coastal pelagic species harvested in Washington waters. Participation in the sardine fishery has been managed under the Emerging Commercial Fishery provisions since 2000, which provides for the harvest of a newly classified species or harvest of a classified species in a new area or by new means. From 2000 to 2002, WDFW had trial purse seine fisheries for Pacific sardines that did not limit the number of participants. Absent limited participation, the Washington fishery was managed to a state HG of 15,000 mt.

The Pacific Northwest sardine fishery saw a rapid expansion of catch between the years 1999 to 2002 when landings increased from 771mt to 37,923 mt. during those years. Landings into Washington were 4,842 mt in 2000 and increased to 15,212 mt in 2002. In response to this situation, WDFW engaged in an extensive public process to address management needs in the fishery. In 2003, following this public process, a formal Sardine Advisory Board was created and the WDFW Director advanced the sardine fishery from a trial fishery to an experimental fishery under the Emerging Commercial Fisheries legislation. Experimental fisheries require participation to be limited.

In collaboration with the Sardine Advisory Board, WDFW developed and implemented an effort limitation program in 2003. The experimental fishery and LE program has continued through 2008. During the 2009 Washington State legislative session, WDFW proposed legislation that would establish a commercial license limitation program for the harvest and delivery of Pacific sardines into the state. The proposed bill allows for licenses to be issued to holders of a 2008 coastal sardine experimental fishery permit with an exception for past participants of the experimental fishery that became ineligible because of loss of their vessel at sea. The Department estimates 18 licenses will be eligible for a license under this proposed legislation. The draft bill also creates a new purse seine temporary annual permit that could be issued at the Director's discretion, provided the total number of licenses does not exceed 25. At the time of writing this update, the draft bill is still alive and working its way through the legislative process.

WDFW conducted a 5-year observer program from 2000 through 2004 to document bycatch levels in the Pacific sardine fishery. Overall observer coverage in this program was in excess of 25 percent and was financially supported by fishery participants as part of their permit conditions. The results of this observer program showed by-catch of non-targeted species in the

Washington sardine fishery to be relatively low. A mandatory logbook program has been in place since the fishery began in 2000. All logbook records must be submitted, and any outstanding observer or permit fees owed must be paid prior to receiving a permit for the current season.

Table 2-6 lists vessels designated on 2008 Washington Sardine Experimental Fishery Permits. In 2008, limited experimental fishery permits were issued to 16 fishers meeting the necessary permit criteria of previously holding such a permit and who also held a minimum of 50 percent ownership in the vessel designated on their 2008 sardine permit. Of the 16 permits that were issued, only five permits participated in the 2008 fishery. In addition to limiting participation in the fishery, WDFW also restricts the cumulative seasonal total of sardines that can go toward reduction to 15 percent for both the individual vessels and for processors.

Pacific sardines are the targeted catch in the Washington experimental fishery, but anchovy, mackerel, and squid can also be retained and landed. In 2008, landings for these other coastal pelagic species are as follows: 109 mt of anchovies, 2.7 mt of jack mackerel, and 9 mt of mackerel.

2.3.3 California's Market Squid Fishery

In 2001, legislation transferred the authority for management of the market squid fishery to the Commission. Legislation required that the Commission adopt a market squid fishery management plan and regulations to protect and manage the resource. In August and December of 2004, the Commission adopted the MSFMP, the environmental documentation, and the implementing regulations, which went into effect on March 28, 2005, just prior to the start of the 2005/2006 fishing season on April 1.

The goals of the MSFMP are to provide a framework that will be responsive to environmental and socioeconomic changes and to ensure long-term resource conservation and sustainability. The tools implemented to accomplish these goals include: (1) setting a seasonal catch limit of 107,048 mt (118,000 st) to prevent the fishery from over-expanding, (2) maintaining monitoring programs designed to evaluate the impact of the fishery on the resource, (3) continuing weekend closures that provide for periods of uninterrupted spawning, (4) continuing gear regulations regarding light shields and wattage used to attract

squid, (5) establishing a restricted access program that includes provisions for initial entry into the fleet, permit types, permit fees, and permit transferability that produces a moderately productive and specialized fleet, and (6) creating a seabird closure restricting the use of attracting lights for commercial purposes in any waters of the Gulf of the Farallones National Marine Sanctuary. Under this framework, the MSFMP provides the Commission with specific guidelines for making management decisions. The Commission has the ability to react quickly to changes in the market squid population off California and implement management strategies without the need for a full plan amendment. The MSFMP framework structure was also designed to achieve the goals and objectives of the MLMA and to be consistent with the management outlined in CPS FMP Amendment 10.

Under the restricted access program in the MSFMP, a permit is needed to participate in the fishery. Qualification for different types of permits and transferability options was based on historical participation in the fishery. In 2008, 93 vessel permits, 62 light boat permits, 22 brail permits, and zero experimental permits were issued. Of the 93 vessel permits issued, 71 vessels made commercial landings in 2008, as compared to 65 active permitted vessels in 2007. Fortytwo vessels made 90 percent of the landings in 2008. Market squid vessel permits allow a vessel to attract squid with lights and use large purse seines to capture squid. Brail permits allow a vessel to attract squid with lights and use brail gear to capture squid. Light boat permits only allow a vessel to attract squid with lights (30,000 watts, maximum). Experimental non-transferable market squid permits allow vessels to fish in areas not historically targeted by the market squid fishery (namely north of San Francisco). Landings of 2 st or less are considered incidental and no permit is required.

2.3.4 Treaty Tribe Fisheries

Tribal fisheries on sardine may evolve in waters north of Point Chehalis, Washington. The CPS FMP recognizes the rights of treaty Indian tribes to harvest Pacific sardine and provides a framework for the development of a tribal allocation. An allocation or a regulation specific to the tribes shall be initiated by a written request from a Pacific coast treaty Indian tribe to the NMFS Southwest Regional Administrator at least 120 days prior to the start of the fishing season.

The Makah Tribe sent a letter to NMFS expressing their intent attain an allocation and to enter the Pacific sardine fishery in 2006. In response, the Council created the Ad Hoc Sardine Tribal Allocation Committee made up of state, Federal, and tribal representatives, to immediately begin to work on this issue. If a tribal allocation is established, the non-tribal allocation formula will likely be applied to the remainder of the harvest guideline after accommodation of the tribal fishery.

No tribal letters of intent have been received since 2006 and the Ad Hoc Sardine Tribal Allocation Committee has never met.

3.0 STOCK ASSESSMENT MODELS

3.1 Pacific Sardine

The Pacific sardine (*Sardinops sagax caerulea*) resource is assessed each fall in support of the Council process that, in part, sets an annual HG (quota) for the U.S. commercial fishery. This process is centered on an environmentally-based control rule that establishes a U.S. coastwide HG for an annual (Jan. 1 to Dec. 31) management cycle. The primary purpose of the assessment is to provide an estimate of current biomass, which is used to calculate annual HGs. A general overview of the harvest control rule is provided in Sections 4.3.2 and 11.1.1.1 of this SAFE report. For background analyses regarding the harvest control rule, see Amendment 8 of the CPS FMP (PFMC 1998).

The Pacific sardine stock assessment used for 2009 management (Hill *et al*. 2008; see Appendix 1) was conducted using 'Stock Synthesis 2' (SS2), a likelihood-based, length- and age-structured model. The general estimation approach used in the SS2 model is a flexible, 'forward-simulation' that allows for the efficient and reliable estimation of a large number of parameters. The general population dynamics and estimator theory that serves as the basis of forward estimation models such as SS2 is described in Fournier and Archibald (1982), Deriso et al. (1985), Megrey (1989), and Methot (1990, 1998, 2005).

The final SS2 model was based on fishery-dependent data from three fisheries (Ensenada, Mexico; U.S. California; and U.S. Pacific northwest; 1981-2007) and a time series of relative SSB estimated from the SWFSC annual egg production surveys (see Lo et al. 1996, 2005, 2006, 2007a, 2008). An environmental index (i.e., a time series of sea-surface temperatures recorded at Scripps Pier, La Jolla, California) is used to determine a fishing mortality-based proxy for MSY, which is an additional parameter used in the harvest control rule for determination of annual HGs (see Section 11.1.1.1). For details regarding the current assessment model, readers should consult Hill et al. (2008; see Appendix 1). For descriptions of methods used in previous Pacific sardine assessment models (CANSAR, CANSAR-TAM, and ASAP), see Deriso et al. (1996), Legault and Restrepo (1999), and Hill et al. (1999, 2006, 2007).

3.2 Pacific Mackerel

A Pacific mackerel (*Scomber japonicus*) stock assessment is conducted annually in support of the Pacific Fishery Management Council (PFMC) process, which ultimately establishes a harvest guideline (HG) for the Pacific mackerel fishery that operates off the U.S. west coast. The HG for mackerel applies to a fishing/management season that spans from July 1st and ends on June 30th of the subsequent year (henceforth, presented as a 'fishing year'). The primary purpose of the assessment is to provide an estimate of current abundance (in biomass), which is used in a harvest control rule for calculation of annual-based HGs. For details regarding this species' harvest control rule, see Amendment 8 of the CPS FMP, Section 4.0 (PFMC 1998). 'Full' assessments for Pacific mackerel typically occur every third year, with assessment 'updates' used in interim years, see PFMC (2009) for detailed protocols regarding CPS assessment 'terms of reference.' The Pacific mackerel stock assessment conducted in May 2009 and presented here represented a full assessment, see STAR (2009). Finally, formal CPS stock assessments are the responsibility of the Southwest Fisheries Science Center (NOAA Fisheries, La Jolla Laboratory).

Parrish and MacCall (1978) were the first to provide stock status determinations for Pacific mackerel using an age-structured population model (i.e., traditional virtual population analysis, VPA). The ADEPT model (the 'ADAPT' VPA modified for Pacific mackerel; Jacobson 1993 and Jacobson et al. 1994) was used to evaluate stock status and establish management quotas for approximately 10 years. The assessment conducted in 2004 (for 2004-05 management) represented the final ADEPT-based analysis for this stock (see Hill and Crone 2004). A forward-simulation (age-structured) model (Age-structured Assessment Program, ASAP, see Legault and Restrepo 1998) was reviewed and adopted for Pacific mackerel at the 2004 STAR Panel (Hill and Crone 2004). The ASAP model remained in place for assessments and management advice from 2005 through the 2008-09 fishing year. For details regarding past assessments see Hill and Crone (2004, 2005), Crone et al. (2006), and Dorval et al. (2007, 2008). The stock assessment review (STAR) conducted in 2009 determined that the Stock Synthesis (SS) model provided the best (most flexible) platform for assessing the status of Pacific mackerel currently (i.e., the 2009-10 fishing year) and in the future STAR (2009). Finally, SS model version 3.0.12 (January 2009) was used in the current assessment.

The SS model (Methot 2005, 2009) model is founded on the AD Model Builder software environment, which essentially is a C++ library of automatic differentiation code for nonlinear statistical optimization (Otter Research 2001). The model framework is based on maximum likelihood method of estimation that allows full integration of both population size and age structure, with explicit parameterization both spatially and temporally. The model incorporates all relevant sources of variability and estimates goodness of fit in terms of the original data, allowing for final estimates of precision that accurately reflect uncertainty associated with the sources of data used as input in the overall modeling effort. Also, see Fournier and Archibald (1982), Deriso et al. (1985), Megrey (1989), and Methot (1990, 1998) for detailed information concerning the underlying population dynamics and estimator theory associated with forward-simulation models in general (such as the SS model).

The stock assessment conducted in 2009 addressed (and met) four objectives, including:

1st. develop the baseline (management) ASAP model (2009) with input data (i.e., time series updated with additional year) and parameterization similar to previous model used in the final assessment conducted in 2008;

2nd. develop a baseline (alternative) SS model with input data and parameterization similar to the ASAP model (2009) above, (i.e., a robust model that most closely resembles the ASAP model, given inherent differences between the two forward-estimation modeling platforms) and evaluate similarities and differences in results;

   a. in general, determine the applicability of the SS model as the 'management-based' model for formal management, particularly in the context of 'flexibility' evaluating a wide range of fish/fishery-related data, which typically is required in stock status assessments of species formally managed;

3rd. develop a suite of alternative SS models (scenarios) that include various combinations of available time series and additional models not used in any previous assessment; and finally,

4th. from the entire suite of SS model scenarios, identify the best configuration based on both statistical and practical considerations through both pre-STAR model scenario development and through interactive efforts during the STAR itself, to provide a robust Pacific mackerel stock assessment model based on SS for management purposes in the 2009-10 fishing year (and subsequent years).

The Pacific mackerel stock assessment conducted in 2009 was based on the SS model (Model "AA" as referenced in the assessment document and STAR Panel report, see Appendix 2), which included catch, biological distributions (age, length, and mean length-at-age), and a commercial-passenger fishing vessel (CPFV) index of relative abundance (i.e., catch-per-unit-effort time series), see Crone et al. (2009) for the complete stock assessment documentation. Following the STAR in May 2009, the completed assessment was presented, reviewed, and approved by the following management bodies in June 2009: Science and Statistical Committee (SSC); CPS Management Team (CPSMT); and the Pacific Fishery Management Council (PFMC.

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4.0 OPTIMUM YIELD, MAXIMUM SUSTAINABLE YIELD, AND MAXIMUM SUSTAINABLE YIELD CONTROL RULES

Information in this section is excerpted from: Amendment 8 (To the Northern Anchovy Fishery Management Plan) incorporating a name change to the Coastal Pelagic Species Fishery Management Plan. Pacific Fishery Management Council. Portland, Oregon. 1998.

4.1 Optimum Yield

The Magnuson-Stevens Act defines the term "optimum," with respect to the yield from a fishery, as the amount of fish which:

- Will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems.
- Is prescribed on the basis of the MSY from the fishery, as reduced by any relevant social, economic, or ecological factor.
- In the case of an overfished fishery, provides for rebuilding to a level consistent with producing the MSY in such fishery [50 C*FR* §600.310(f)(1)(i)].

Optimum yield for a CPS stock is defined to be the level of harvest which is less than or equal to ABC estimated using a MSY control rule, consistent with the goals and objectives of this FMP, and used by the Council to manage the stock. The ABC is a prudent harvest level calculated based on an MSY control rule. In practice, OY will be determined with reference to ABC. In particular, OY will be set less than ABC to the degree required to prevent overfishing.

4.2 Maximum Sustainable Yield, MSY Control Rules, and Acceptable Biological Catch

For CPS, an MSY control rule is defined to be a harvest strategy that provides biomass levels at least as high as the F_{MSY} (fishing mortality rate that maximizes catch biomass in the long term) approach while also providing relatively high and consistent levels of catch. According to Federal regulations (50 CFR §600.310(b)(1)(ii)), an MSY control rule is "a harvest strategy which, if implemented, would be expected to result in a long-term average catch approximating MSY." Similarly, MSY stock size "means the long-term average size of the stock or stock complex, measured in terms of spawning biomass or other appropriate units that would be achieved under an MSY control rule in which the fishing mortality rate is constant." The definition of an MSY control rule for CPS is more general, because it includes the definition in National Standard 1. It is also more conservative, because the focus for CPS is oriented primarily towards stock biomass levels at least as high as the MSY stock size. The primary focus is on biomass, rather than catch, because most CPS (Pacific sardine, northern anchovy, and market squid) are very important to the ecosystem as forage.

The MSY control rules in the CPS fishery may vary depending on the nature of the fishery, management goals, assessment and monitoring capabilities, and available information. Under the framework management approach used for CPS, it is not necessary to amend the CPS FMP in order to develop or modify MSY control rules or definitions of overfishing.

The use of an MSY control rule for actively managed stocks provides managers with a tool for setting and adjusting harvest levels on a periodic basis, while preventing overfishing and overfished stock conditions. All actively managed stocks must have stock-specific MSY control rules, a definition of overfishing, and a definition of an overfished stock. Definitions of overfishing and overfished are detailed below in Section 5.

The main use of an MSY control rule for a monitored stock is to help gauge the need for active management. MSY control rules and harvest policies for monitored CPS stocks may be more generic and simpler than those used for actively managed stocks. Under the FMP, any stock supporting catches approaching the ABC or MSY levels should be actively managed unless there is too little information or other practical problems.

4.3 MSY Control Rules for CPS

The Council may use the default MSY control rule for monitored species unless a better species-specific rule is available, e.g., the MSY-proxy approach adopted for market squid (see Section 4.3.4). The default MSY control rule can be modified under framework management procedures. The default MSY control rule sets ABC for the entire stock (U.S., Mexico, Canada, and international fisheries) equal to 25 percent of the best estimate of the MSY catch level. Overfishing occurs whenever total catch (U.S., Mexico, Canada, and international fisheries) exceeds ABC or whenever fishing occurs at a rate that is high enough to jeopardize the capacity of the stock to produce MSY. Overfishing of a monitored CPS stock is “approached” whenever projections or estimates indicate the overfishing will occur within two years.

In making decisions about active management, the Council may choose to consider ABC and catches in U.S. waters only. ABC in U.S. waters is the ABC for the entire stock prorated by an estimate of the fraction of the stock in U.S. waters. Active management may not be effective if U.S. catches are small, and overfishing is occurring in Mexico, Canada, or in international waters outside the jurisdiction of Federal authorities.

4.3.1 General MSY Control Rule for Actively Managed Species

The general form of the MSY control rule used for actively managed CPS fisheries was designed to continuously reduce the exploitation rate as biomass declines. The general formula used is:

$$H = (\text{BIOMASS-CUTOFF}) \times \text{FRACTION}$$

H is the harvest target level, CUTOFF is the lowest level of estimated biomass at which directed harvest is allowed, and FRACTION is the fraction of the biomass above CUTOFF that can be taken by the fishery. BIOMASS is generally the estimated biomass of fish age 1+ at the beginning the season. The purpose of CUTOFF is to protect the stock when biomass is low. The purpose of FRACTION is to specify how much of the stock is available to the fishery when BIOMASS exceeds CUTOFF. It may be useful to define any of the parameters in this general MSY control rule, so they depend on environmental conditions or stock biomass. Thus, the MSY control rule could depend explicitly on the condition of the stock or environment.

The formula generally uses the estimated biomass for the whole stock in one year (BIOMASS) to set harvest for the whole stock in the following year (H) although projections or estimates of BIOMASS, abundance index values or other data might be used instead. BIOMASS is an estimate only, it is never assumed that BIOMASS is a perfect measure of abundance. Efforts to develop a harvest formula must consider probable levels of measurement error in BIOMASS which typically have coefficient of variations of about 50% for CPS.

The general MSY control rule for CPS (depending on parameter values) is compatible with the Magnuson-Stevens Act and useful for CPS that are important as forage. If the CUTOFF is greater than zero, then the harvest rate (H/BIOMASS) declines as biomass declines. By the time BIOMASS falls as low as CUTOFF, the harvest rate is reduced to zero. The CUTOFF provides a buffer of spawning stock that is protected from fishing and available for use in rebuilding if a stock becomes overfished. The combination of a spawning biomass buffer equal to CUTOFF and reduced harvest rates at low biomass levels means that a rebuilding program for overfished stocks may be defined implicitly. Moreover, the harvest rate never increases above FRACTION. If FRACTION is approximately equal to F_{MSY}, then the MSY control rule harvest rate will not exceed F_{MSY}. In addition to the CUTOFF and FRACTION parameters, it may be advisable to define a maximum harvest level parameter (MAXCAT) so that total harvest specified by the harvest formula never exceeds MAXCAT. The MAXCAT is used to guard against extremely high catch levels due to errors in estimating biomass, to reduce year-to-year variation in catch levels, and to avoid overcapitalization during short periods of high biomass and high harvest. MAXCAT also prevents the catch from exceeding MSY at high stock levels and spreads the catch from strong year classes over a wider range of fishing seasons.

Other general types of control rules may be useful for CPS and this FMP does not preclude their use as long as they are compatible with National Standards and the Magnuson-Stevens Act.

4.3.2 MSY Control Rule for Pacific Sardine

The MSY Control Rule for Pacific sardine sets ABC for the entire sardine stock based on an estimate of biomass for the whole sardine stock, a CUTOFF equal to 150,000 mt, a FRACTION between 5% and 15% (depending on oceanographic conditions as described below), and MAXCAT of 200,000 mt. The U.S. ABC is calculated from the target harvest for the whole stock by prorating the total ABC based on 87% proportion of total biomass in U.S. waters.

FRACTION in the MSY control rule for Pacific sardine is a proxy for F_{MSY} (i.e., the fishing mortality rate for deterministic equilibrium MSY). FRACTION depends on recent ocean temperatures, because F_{MSY} and sardine stock productivity are higher under ocean conditions associated with warm water temperatures. An estimate of the relationship between F_{MSY} for sardine and ocean temperatures is:

$$FMSY = 0.248649805\ T^2 - 8.190043975\ T + 67.4558326,$$

where T is the average three-season sea surface temperature (SST) at Scripps Pier (La Jolla, California) during the three preceding seasons. Thus, the MSY control rule for Pacific sardine sets the control rule parameter FRACTION equal to F_{MSY}, except that FRACTION is never allowed to be higher than 15% or lower than 5%, which depends on recent average sea surface temperature.

Although F_{MSY} may be greater or lesser, FRACTION can never be greater than 15% or less than 5% unless the MSY control rule for sardine is revised, because 5% and 15% are policy decisions based on social, economic, and biological criteria. In contrast, relationships between FRACTION, F_{MSY} and environmental conditions are technical questions and estimates or approaches may be revised by technical teams (e.g. the CPSMT) to accommodate new ideas and data.

4.3.3 MSY Control Rule for Pacific Mackerel

The MSY control rule for Pacific mackerel sets the CUTOFF and the definition of an overfished stock at 18,200 mt and the FRACTION at 30%. Overfishing is defined as any fishing in excess of ABC calculated using the MSY control rule. No MAXCAT is defined because the U.S. fishery appears to be limited by markets and resource availability to about 40,000 mt per year. The target harvest level is defined for the entire stock in Mexico, Canada, and U.S. waters (not just the U.S. portion), and the U.S. target harvest level is prorated based on 70% relative abundance in U.S. waters.

4.3.4 MSY Control Rule for Market Squid

Although market squid is only a monitored species, a potential MSY Control Rule for market squid has been reviewed formally through a stock assessment review (STAR) conducted in 2001, as well as presented within the Council forum in 2002. The proposed MSY Control Rule is generally based on the Egg Escapement method, which currently serves as an informal assessment tool for this species (see Appendix 3 in PFMC (2002) for further discussion concerning specific details involved in this assessment approach, as well as review-related discussion). It is important to note that the main objective of a MSY Control Rule for a "monitored" stock (e.g., market squid) is to help assess the need for "active" management. That is, the MSY Control Rules and harvest policies for monitored CPS stocks may be based on broader concepts and constraints than those used for stocks with significant fisheries that fall under active management. Any fishery whereby catches approach an ABC or MSY level warrant consideration within active management processes, given catch statistics are scientifically based and management operations can be practically implemented. Overfishing of a monitored CPS stock is considered whenever current estimates or projections indicate that a minimum stock threshold will be realized within two years. In practical terms, the market squid fishery is monitored through a state-based management plan that includes an annual landings cap (CDFG 2005) and various spatial/temporal constraints. Whereas, within a research context only, population dynamics and biological reference point (say MSY-related) evaluations regarding this species are addressed through the Egg Escapement method and simulation analysis. Given the “monitored” status of this population, the above management/research approach appears reasonable; however, “active” management may need to be considered in the future if fishery operations change substantially (e.g., spatially expand, harvest high amounts of immature squid, etc.) and/or ongoing modeling efforts identify areas (spatial or temporal) of concern regarding egg escapement levels associated with commercial fishery sample data. A brief description of the Egg Escapement method follows, with further discussion presented in Section 11.2.3.

The Egg Escapement method is founded on conventional spawning biomass “per-recruit” theory. In general, the proposed MSY Control Rule for market squid is based on evaluating (throughout a fishing season) levels of egg escapement associated with the exploited population(s). The estimates of egg escapement are evaluated in the context of a “threshold” that is hypothesized to represent (generally) a biological reference point that, if not exceeded (and over the long-term and given favorable oceanographic conditions), will support sustainable abundance levels and some degree of surplus for fishery-related purposes. It is important to note that the threshold proposed currently (i.e., 30%) represents a strictly preliminary statistic and intended as a precautionary reference point, which ultimately, is expected to be revised (to some degree) as more sample data (spatially and temporally) are examined through egg escapement and simulation research. In this context, in fall 2006, the CPSMT reviewed results from ongoing research addressing egg escapement modeling efforts over the last two years. A working paper summarizing the results of this research was distributed in fall 2008 (Appendix 3).

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Pacific Fishery Management Council (PFMC). 2002. Status of the Pacific coast coastal pelagic species fishery and recommended acceptable biological catches: stock assessment and fishery evaluation (2002). Appendix 3: market squid MSY. Document can be obtained from Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220.

5.0 OVERFISHING CONSIDERATIONS

Information in this section is excerpted from: Amendment 8 (To the Northern anchovy fishery management plan) incorporating a name change to: the Coastal Pelagic Species Fishery Management Plan. Pacific Fishery Management Council. Portland, Oregon. 1998.

5.1 Definition of Overfishing

By definition, overfishing occurs in a fishery whenever fishing occurs over a period of one year or more at a rate that is high enough to jeopardize the capacity of the stock to produce MSY on a continuing basis if applied in the long-term. Overfishing in the CPS fishery is "approached" whenever projections indicate overfishing will occur within two years. The definition of overfishing is in terms of a fishing mortality or exploitation rate. Depending on the exploitation rate, overfishing can occur when CPS stocks are at either high or low abundance levels. The Council must take action to eliminate overfishing when it occurs and to avoid overfishing when exploitation rates approach the overfishing level.

In operational terms, overfishing occurs in the CPS fishery whenever catch exceeds ABC, and overfishing is approached whenever projections indicate that fishing mortality or exploitation rates will exceed the ABC level within two years. The definition of an overfished stock is an explicit part of the MSY control rule for CPS stocks.

5.2 Definition of an Overfished Stock

By definition, an overfished stock in the CPS fishery is a stock at a biomass level low enough to jeopardize the capacity of the stock to produce MSY on a continuing basis. An overfished condition is approached when projections indicate that stock biomass will fall below the overfished level within two years. The Council must take action to rebuild overfished stocks and to avoid overfished conditions in stocks with biomass levels approaching an overfished condition.

5.3 Rebuilding Programs

Management of overfished CPS stocks must include a rebuilding program that can, on average, be expected to result in recovery of the stock to MSY levels in ten years. It is impossible to develop a rebuilding program that would be guaranteed to restore a stock to the MSY level in ten years, because CPS stocks may remain at low biomass levels for more than ten years even with no fishing. The focus for CPS is, therefore, on the average or expected time to recovery based on realistic projections. If the expected time to stock recovery is associated with unfavorable ecosystem conditions and is greater than ten years, then the Council and the Secretary may consider extending the time period as described at 50 CFR § 600.310(e).

Rebuilding programs for CPS may be an integral part of the MSY control rule or may be developed or refined further in the event that biomass of a CPS stock reaches the overfished level.

6.0 BYCATCH AND DISCARD MORTALITY

Fishery management plans prepared by a fishery management council or by the Secretary must, among other things, establish a standardized reporting methodology to assess the amount and type of bycatch occurring in the fishery, and include conservation and management measures that, to the extent are practicable and in the following priority:

1. Minimize Bycatch.
2. Minimize the mortality of bycatch that cannot be avoided.

The Magnuson-Stevens Act defines bycatch as "fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic discards and regulatory discards. Such term does not include fish released alive under a recreational catch and release fishery management program" (16USC1802).

CPS vessels fish with roundhaul gear (purse seine or lampara nets of approximately one-half mile in total length). These are encircling type nets, which are deployed around a school of fish or part of a school. When the school is surrounded, the bottom of the net may be closed, then the net drawn next to the boat. The area including the free-swimming fish is diminished by bringing one end of the net aboard the vessel. When the fish are crowded near the fishing vessel, pumps are lowered into the water to pump fish and water into the ship's hold. Another technique is to lift the fish out of the net with netted scoops (e.g., brails). Roundhaul fishing results in little unintentionally caught fish, primarily because the fishers target a specific school, which usually consists of pure schools of one species. The tendency is for fish to school by size, so if another species is present in the school, it is typically similar in size. The most common incidental catch in the CPS fishery is another CPS species (e.g., Pacific mackerel incidental to the Pacific sardine fishery). If larger fish are in the net, they can be released alive before pumping or brailing by lowering a section of the cork-line or by using a dip-net. The load is pumped out of the hold at the dock, where the catch is weighed and incidentally-caught fish can be observed and sorted. Because pumping at sea is so common, any incidental catch of small fish would not be sorted at sea. Grates can be used to sort larger non-CPS from the catch. Grates are mandatory in Oregon to sort larger non-CPS from the catch. At-sea observers have record discard at one time or another since the year 2000 off the states of Oregon, Washington, and California. Incidental harvest of non-prohibited larger fish are often taken home for personal use or processed.

Historically, market squid have been fished at night with the use of powerful lights, which cause squid to aggregate, which enables fishermen to pump squid directly from the sea or to encircle them with a net. California actively manages the market squid fishery in waters off California and has developed an FMP for the state-managed fishery. California's market squid FMP established a management program for California's market squid resource with goals that are aimed at ensuring sustainability of the resource and reducing the potential for overfishing. The tools to accomplish these goals include:

- Establishing fishery control rules, including a seasonal catch limitation to prevent the fishery from over-expanding; continuing weekend closures, which provide for periods of uninterrupted spawning; continuing gear regulations regarding light shields and wattage used to attract squid; and maintaining monitoring programs designed to evaluate the impact of the fishery on the resource.

- Instituting a restricted access program, including provisions for initial entry into the fleet, types of permits, permit fees, and permit transferability.
- Establishing a general habitat closure area in northern California rarely used by the squid fishery to eliminate the potential of future negative interactions with seabirds, marine mammals, and important commercial and sport fishes, and adding limitations on using lights to attract squid around several of the Channel Islands, an effort intended to protect nesting seabirds.

In addition to the reasons discussed above, several circumstances in the fishery tend to reduce bycatch:

1. Most of what would be called bycatch under the Magnuson-Stevens Act is caught when roundhaul nets fish in shallow water over rocky bottom. Fishers try to avoid this to protect gear. Also, they may be specifically prohibited to fish these areas because of closures.
2. South of Pt. Buchon, California, many areas are closed to roundhaul nets under California law and the FMP, which reduces the chance for bycatch.
3. In California, a portion of the sardine caught incidentally by squid or anchovy fishers can be sold for reduction, which reduces discard.
4. The five tons or less allowable landing by vessels without LE permits under the FMP should reduce any regulatory discard, because those fish can be landed.
5. From 1996 to 2003, bycatch from the live bait logs was reported with an incidence of 10%. The primary species taken as incidental catch was barracuda. Virtually all fish caught incidentally in this fishery are either used for bait, for personal use, or released alive. See Tables 15, 16, and 17.
6. CDFG has implemented a logbook program for the squid fishery. The data to be collected includes bycatch.

Generally, fisheries for CPS can be divided into two areas: north and south of Pigeon Point, California (approximately 37°10' N latitude). In recent history, virtually the entire commercial fishery for CPS finfish and market squid has taken place south of Pigeon Point. The potential for taking salmon exists in this area, but diminishes south of Monterey, California (37° N latitude). Starting in 1999, CPS fisheries (notably, targeting Pacific sardine) increased in waters off Oregon and Washington. Oregon and Washington actively manage these northern fisheries, in part, because of the heightened potential for salmon bycatch. Section 6.1 through 6.2 describes the California fishery; Section 6.3 provides information on Oregon and Washington fisheries.

See Amendment 9 to the CPS FMP (Environmental Assessment/Regulatory Impact Review, March 2001) for a complete description of bycatch-related issues and monitoring and reporting requirements. Amendment 9 is available from the Council office.

6.1 Federal Protection Measures

National Marine Fisheries Service (NMFS) regularly conducts Endangered Species Act (ESA) section 7 consultations to ensure that federally threatened or endangered species are not adversely affected by federally managed fisheries. Since 1999 NMFS, Sustainable Fisheries Division (SFD), Southwest Region (SWR) has conducted eight consultations with other Federal agencies, including NMFS Protected Resource Division (PRD) and U.S. Fish and Wildlife Service (USFWS), regarding the CPS fishery.

Most recently, NMFS, SFD, SWR, initiated a formal section 7 consultation with NMFS, PRD, SWR, for the implementation of Amendment 11 to the CPS FMP. PRD completed a formal section 7 consultation on this action and in a Biological Opinion dated March 10, 2006, determined that fishing activities conducted under the CPS FMP and its implementing regulations are not likely to jeopardize the continued existence of any endangered or threatened species under the jurisdiction of NMFS or result in the destruction or adverse modification of critical habitat of any such species. Specifically, the current status of the Lower Columbia River Chinook, Snake River Fall Chinook, Upper Willamette Chinook, Puget Sound Chinook, and Lower Columbia River coho were deemed not likely to be jeopardized by the Pacific sardine fishery.

NMFS also initiated an ESA section 7 consultation with USFWS regarding the possible effects of implementing Amendment 11 to the CPS FMP. USFWS concurred with NMFS and determined that implementing Amendment 11 may affect, but was not likely to adversely affect (NLAA): the endangered tidewater goby, the threatened western snowy plover, the Santa Ana sucker, the endangered short tailed albatross, the endangered California brown pelican, the endangered California least-tern, the threatened marbled murrelet, the threatened bald eagle, the threatened bull trout, and the candidate Xantus's murrelet. Formal consultation, however, was deemed necessary on the possible effects to the southern sea otter. The resulting biological opinion signed June 16, 2006, concluded that fishing activities conducted under Amendment 11 and its implementing regulations were not likely to jeopardize the continued existence of the otter. As a result of this BO new reporting requirements and conservation measures were implemented within the CPS FMP to provide further protection for southern sea otters.

These reporting requirements and conservation measures require all CPS fishermen and vessel operators to employ avoidance measures when sea otters are present in the fishing area and to report any interactions that may occur between their vessel and/or fishing gear and otters. Specifically, these new measures and regulations are:

1. CPS fishing boat operators and crew are prohibited from deploying their nets if a southern sea otter is observed within the area that would be encircled by the purse seine.
2. If a southern sea otter is entangled in a net, regardless of whether the animal is injured or killed, such an occurrence must be reported within 24 hours to the Regional Administrator, NMFS Southwest Region.
3. While fishing for CPS, vessel operators must record all observations of otter interactions (defined as otters within encircled nets or coming into contact with nets or vessels, including but not limited to entanglement) with their purse seine net(s) or vessel(s). With the exception of an entanglement, which will be initially reported as described in #2 above, all other observations must be reported within 20 days to the Regional Administrator.

6.1.1 California Coastal Pelagic Species Pilot Observer Program

NMFS SWR initiated a pilot observer program for California-based commercial purse seine fishing vessels targeting CPS in July 2004 with hopes of augmenting and confirming bycatch rates derived from CDFG dockside sampling. SWR personnel trained the first group of CPS observers in mid-July in Long Beach, California. Frank Orth and Associates (FOA), a private contractor, hired and provided observers for training and subsequent deployment. Six observers who had previous experience in other SWR-observed fisheries attended and completed the course. The training course emphasized a review of ongoing observer programs (drift gillnet, pelagic longline) and introduction to the soon-to-be observed fisheries (purse seine, albacore hook-and-line). The training curriculum included vessel safety, fishing operations, species identification, and data collection.

In late July 2004, observers began going to sea aboard CPS vessels. Observers used ODFW's Sardine Bycatch Observations' form to record data on fishing gear characteristics, fishing operations, and target/non-target species catch and disposition. Observers also recorded data on trip specifics and protected species sightings/interactions. Observers had access to data field definitions in their SWR observer program Field Manuals. Most data detailing length, volume, or weight are obtained verbally from the vessel operator. Position and time data are recorded by the observer directly from hand-held or on-board electronics.

Data from this ongoing program has been compiled though January 2006 (Tables 6-1 through 6-4). A total of 107 trips by vessels targeting CPS (228 sets) were observed from July 2004 to January 2006. Tables 5-8 show incidental catch and bycatch data collected during this time and are categorized by target species of the trip (i.e., Pacific sardine, Pacific mackerel, market squid or anchovy). Additionally, from January 2006 to January 2008 a total of 199 trips (426 sets) were observed. Although incidental catch and bycatch data collected during this time is continuing to be analyzed and categorized, no marine mammals, sea turtles, or seabirds were observed as bycatch. Additionally, from January 2006 to January 2008 a total of 199 trips (426 sets) were observed. Although incidental catch and bycatch data collected during this time is continuing to be analyzed and categorized, no marine mammals, sea turtles, or seabirds were observed as bycatch.

Future needs of the CPS observer program include: standardization of data fields, development of a fishery-specific Observer Field Manual, construction of a relational database for the observer data, and creation of a statistically reliable sampling plan. A review of the protocol and catch data by NMFS Southwest Science Center staff, the CPS Management team and other CPS interested parties is planned in the future to help address some of these needs.

6.2 Fishery South of Pigeon Point

Information from at-sea observations of the CDFG and conversations with CPS fishers suggest that bycatch is not significant in these fisheries. However, some individuals have expressed concern that game fish and salmon might constitute significant bycatch in this fishery. This is a reasonable concern, because anchovy and sardine are forage for virtually all predators, but there are no data to confirm significant bycatch of these species. CDFG port samples indicate minimal incidental catch in the California fishery (Tables 6-5, 6-6, and 6-7). The behavior of predators, which tend to dart through a school of prey rather than linger in it, and can more easily avoid encirclement with a purse seine, may help to minimize bycatch.

CDFG port samplers collect information from CPS landings in Monterey and ports to the south. Biological samples are taken to monitor the fish stocks, and port samplers report incidentally caught fish. Reports of incidental catch by CDFG port samplers confirm small and insignificant landings of bycatch at California off-loading sites (Tables 6-5, 6-6, and 6-7). These data are likely representatives of actual bycatch, because (as noted) fish are pumped from the sea directly into fish holds aboard the vessel. Fishers do not sort catch at sea or what passes through the pump; however, large fishes and other animals that cannot pass through the pump are not observed by the port sampler. Unloading of fish also occurs with pumps. The fish is either pumped into ice bins and trucked to processing facilities in another location or to a conveyor belt in a processing facility, where fish are sorted, boxed, and frozen.

From 1985 through 1999, there were 5,306 CDFG port samples taken from the sardine and mackerel landings. From 1992 to 1999, incidental catch was reported on only 179 occasions, representing a 3.4 percent occurrence. Up to 1999 reports of incidental catch were sparse, and prior to 1992 none were reported. Earlier incidents of bycatch may not have been noted, because the harvest of anchovy and sardine was small, and only in recent years has the harvest of sardine increased. The incidental catch reported are primarily those species that are marketable and do not meet the definition of bycatch in the Magnuson-Stevens Act. During this period, unless an incidental species represented a significant portion of the load (at least a whole percentage point) the amount of the incidental catch was not recorded. Of the incidental catch reported from 1992 to 1999, the two most prevalent species were market squid at 79 percent, and northern anchovy at 12 percent incidence within samples (not by load composition). CDFG port samples provide useful information for determining the significance of bycatch in the CPS fishery off California (south of Pigeon Point).

In 2001, California wetfish port samplers began tallying undocumented incidental catch observed during landings in greater detail, and listed the occurrence of species in each sampled landing. The port sampling program records bycatch observed (i.e., presence or absence evaluations), but actual amounts of incidental catch have not been quantified to date. These observations are summarized for all areas in Table 11 for the last 5 years (2004 – 2008). The dynamic of the 2008 sardine fishery changed due to a decrease in the annual harvest guideline. Fishing activity no longer took place year around, but was truncated within each allocation period. This may have affected the types and frequencies of organisms observed during the offloading process of sardine. The most commonly occurring organisms in wetfish landings during 2008 were kelp, jellyfish, market squid, northern anchovy, California halibut, rays, jack mackerel, and California scorpionfish. Eighty-four incidental species were observed in total.

Kelp (specifically holdfasts), crustaceans, flatfish, California scorpionfish, and elasmobranchs can serve as an indication of shallow set depth. Larger fish and animals are typically sorted for market, personal consumption, or nutrient recycling in the harbor. To document bycatch more fully at sea, including marine mammal and bird interactions, which port samplers are not privy to, NOAA Fisheries has placed observers on a number of California purse seine vessels beginning in the summer of 2004 (see Sec. 11.6).

6.2.1 Incidental Catch Associated with the Market Squid Fishery

Because market squid frequently school with CPS finfish, mixed landings of market squid and incidentally caught CPS finfish occur intermittently. In 2008, about 7 percent of round haul market squid landings included reported incidental catch of CPS (Table 6-6).

Although non-target catch in market squid landings is considered minimal, the presence of incidental catch (i.e., species that are landed along with market squid that are not recorded through landing receipt processes [i.e., not sold] as is typically done for incidentally-caught species) has been documented through CDFG's port sampling program. The port sampling program records incidental catch observed (i.e., presence or absence evaluations), but actual amounts of incidental catch have not been quantified to date. During 2008, incidental catch consisted of 34 species (Table 6-7). Similar to previous years, most of this catch was other pelagic species, including Pacific sardine, Pacific mackerel, northern anchovy, and jack mackerel. However, kelp was also observed frequently.

Finally, the extent that market squid egg beds and bottom substrate are damaged by purse seine operations, which subsequently may contribute to mortality of early life stages is not definitively known at this time. However, information regarding the frequency of occurrence of market squid eggs in squid landings port-side generally indicates that egg bed-related impacts have increased over the last several years. For example, from October 1998 through September 2001, bycatch of market squid eggs had a 1.8 percent frequency of occurrence. In 2004, market squid egg capsule bycatch was 5.1 percent statewide, a 0.2 percent increase over 2003 (4.9 percent). In 2008, market squid egg cases were identified in 8.8 percent of observed landings. Since market squid exude egg cases while in a purse seine net, the observed egg cases need to be collected and aged. If egg cases are more than one day old, then the effect of nets of egg beds may be a concern. If bycatch of market squid egg capsules continues to increase and eggs are found to be taken from the bottom, some gear regulations may need to be implemented in the future (e.g., restrictions to the depth at which nets could be set, spatio-temporal closures of some shallow water habitats).

According to CDFG market squid logbooks, fishing nets in the northern fishery make contact with the bottom more frequently than in the southern fishery. In this context, further investigations regarding potential damage to market squid spawning beds from fishery-related operations would likely benefit status-based analyses concerning the overall market squid population off California, given eggs-per-recruit theory underlies the recently adopted market squid assessment method. In 2007, CDFG developed a protocol to retain egg capsules in order to determine first, if capsule age can be quickly determined in the laboratory, and second whether a measure of egg bed disturbance can be produced. Based on market squid embryo development and the condition of the outside of the egg capsule, determining if the egg case was laid in the net or collected from the bottom is possible.

6.3 Fishery North of Point Arena

Since 1999, limited fisheries for Pacific sardines have occurred off the Pacific Northwest. Oregon and Washington closely monitor these fisheries and collect information about landings. Information on bycatch from Oregon and Washington is summarized in Tables 6-8 through 6-10.

6.3.1 Oregon

Vessels landed 22,948.7 mt of Pacific sardine in 482 Oregon landings in 2008. The harvest was down 46 percent from the 42,151 mt of sardines landed in Oregon in 2007. All of the directed fishery harvest took place in allocation periods 2 and 3 during July, August and September. The decrease in harvest reflected the 42 percent reduction in the coastwide HG in 2008 from 2007 (Table 11-3) . The early closures of all three allocation periods limited fishing during the traditional peak months of August and September and prevented fishing off Oregon during June and October a time when the fishery was open and sardines were landed in past years and. As in the past spotter planes, hired by the industry, were used to locate fish schools. Sardines were landed primarily in Astoria and Warrenton at eight different processors, with 6 landings in Newport. Sardine value varied from $0.00 to $0.145 per pound, with 96.8 percent of fish landed valued at greater than $0.05/lb. The exvessel value of sardine landed in Oregon in 2008 was roughly $5.66 million with the average price slightly more than $0.11/lb or $246.6 per mt.

Oregon's sardine permit rules stipulate that an at sea observer be accommodated aboard vessels when requested by ODFW. ODFW currently does not have personnel dedicated to observe on sardine vessels whereby documenting bycatch of non-target species and no federal observers were placed on the vessels. Available state staff people made attempts to observe trips, however only one of the 482 trips (0.2 percent) was successfully observed. The observer viewed one Coho Salmon which was released alive by the crew with a dip net. The state requires the use of a grate over the intake of the hold to sort out larger species of fish, such as salmon or mackerel. The grate size spacing can be no larger then 2-3/8 inches between bars. Non-target species caught in the 2008 season included Pacific and jack mackerel, Pacific herring, Northern anchovy, Pacific hake, salmon and sharks. Oregon LE sardine permit rules require logbooks that record incidental catch including salmonids and other species (Table 6-9). Approximately 885 sets were made targeting sardines. The estimated total catch of salmon for the fishery, based on log data, was 198 salmon. The incidental catch rate was 0.008 salmon per mt of sardines landed. An estimated 62 percent of all salmon were released alive. Based on Oregon fish tickets, bycatch in the fishery continues to be low, with approximately 116.9 mt of non-target species caught for 22,948.9 mt of sardine (Table 6-10). More than half of the non-target species catch within the sardine fishery was Pacific mackerel (56.8 mt) which had an ex-vessel value of approximately $7,813. The other CPS components of incidental catch were 1.6 mt of jack mackerel and 2.4 mt of northern anchovy.

6.3.2 Washington

The Washington fishery opened by rule on April 1, 2008, however, the first landing into Washington did not occur until July 1 because the first period allocation for the January through June time period had been taken. The Department issued a total of 16 permits and 5 of the permit holders participated in the fishery. Three primary vessels accounted for 73 percent of the harvest. A total of 6,432 mt of sardines were landed into Washington. Of the 150 landings into Washington, 78 (52 percent were made in July, 21 (14 percent) were made in August and 51 (34 percent) were made in September. . A total of 191 sets were made, with 174 (91 percent) of them successful. The average catch per successful set was 36 mt.

As part of the trial fishery and the experimental LE fishery regulations from 2000 through 2004, WDFW required fishers to carry at-sea observers, as well as provide financial support for this observer effort. Bycatch information was collected in terms of species, amount, and condition; observers noted whether the fish were released or landed, and whether alive, dead, or in poor condition. During the five-year period of the program, overall observer coverage averaged over 25 percent of both total landed catch and number of landings made. Based on observer data, the bycatch of non-targeted species in the Washington sardine fishery has been relatively low. Due to low bycatch levels, as well as a WDFW commitment to industry that an observer fee would only be assessed until bycatch in the sardine fishery could be characterized, the mandatory observer program was suspended at the conclusion of the 2004 season. Since a comparison of logbooks to observer data from 2000 to 2004 indicates that logbook data, in general, tends to be under-reported by 20 percent to 80 percent (Culver and Henry, 2006), salmon bycatch in the Washington sardine fishery for subsequent fishing years has been calculated using the 5-year average bycatch rates from the observer program applied to total sardine catch. Bycatch and mortality estimates of incidentally captured salmon for the past eight years, by species, based upon 2000- 2004 observer information, is shown in Table 6-8.

6.4 Section References

Culver, M., and C. Henry, 2006. Summary Report of the 2005 Experimental Purse Seine Fishery for Pacific Sardine (Sardinops sagax). Washington Department of Fish and Wildlife, Montesano, Washington. 11 pp.

Hill, K. T., and P. R. Crone. 2004. Stock assessment of Pacific mackerel (Scomber japonicus) in 2004. Paper can be obtained from Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220. 44 p. and Appendices.

Wiedoff, B., 2008. Oregon's Sardine Fishery, 2007 Summary. Oregon Department of Fish and Wildlife, Newport Oregon. 18. pp.

NMFS. 2005. Endangered Species Act Section 7 Consultation Biological Opinion. Implementation of the 2005 Harvest Guideline for Pacific sardine fishery under the Coastal Pelagic Species Fishery Management Plan. 501 Ocean Blvd. Long Beach, CA 90802. 40 pp.

7.0 CALIFORNIA LIVE BAIT FISHERY

7.1 Introduction

Through much of the 20th century, CDFG monitored the harvest of CPS finfish in the California live bait fisheries by requiring live bait logs. Northern anchovy and Pacific sardine are the main species in this fishery, with a variety of other nearshore or CPS taken incidentally. An estimated 20% of this harvest is sold to private fishing vessels, with the remainder to the CPFV fleet, where payment to the bait haulers is on a percentage basis of the CPFV revenues (Thomson *et al.* 1994). An example of the first Live Bait Log from 1939, termed a "Daily Bait Record" as printed for the State of California, Department of Natural Resources, and Division of Fish and Game can be found in Aplin (1942). The nature of the data collected were self-reported daily estimates of the number of "scoops" taken and sold by the fishermen, by species. Although this variety of data does not lend itself readily to rigorous scientific analysis, there are at least 63 years of data available, collected in a reasonably uniform manner that can serve as an index to this low volume, high value fishery.

Studies conducted by CDFG, NMFS, and others have examined this fishery, generally with a focus on the dominant species taken over a given period. As in the directed commercial CPS fisheries, the local availability of each CPS to the bait fleet changes periodically. Problems with the live bait data such as conversion factors for scoops of live fish to weight, the economics of the fishery, the character of the fleet, and compliance rates in submitting logs have been addressed in various agency reports (Maxwell 1974; and Thomson *et al.* 1991, 1992, 1994).

7.2 Legislative History

Alpin (1942) describes the earliest implementation of the live bait log program in 1939, which followed a pilot program of verbal interaction with the fishermen that established four categories describing the variation in abundance or availability of CPS to the recreational industry.

Live bait logs have been at different times mandated by state law, or submitted to the CDFG on a voluntary basis. In the early 1990s sardine became more prevalent in the bait fishery, and quotas were imposed on their annual take pursuant to management efforts to recover the sardine population off California. In 1995, CDFG lifted quotas restricting the quantity of sardines that the live bait industry could harvest. The sardine population along the California Coast was increasing toward a "recovered" level, as anchovy showed a decline, and sardines became the preferred live bait over anchovy. With the sardine quota lifted, the level of scrutiny on the harvest of the live bait industry lessened.

7.3 Logbook Information

The CDFG Live Bait Log (Title 14, Section 158, California Code of Regulations: DFG 158, October 1989) requires only the estimated scoops taken daily of either anchovy or sardine be reported, and a check mark be made if other particular species were taken, with space for comments related to fishing. Other species noted, but not consistently enumerated in the live bait harvest, include white croaker (*Genyonemus lineatus*), queenfish (*Seriphus politus*), Pacific and jack mackerels (*Scomber japonicus and Trachurus symmetricus*), and various small fishes collectively known as "brown bait" that can include juvenile barracuda (*Sphyraena argentea*), Osmerids, Atherinids, and market squid (Table 6-11). Estimates of ancillary catch data has been documented in earlier reports, and in CPS FMP Amendment 9.

The CDFG Pelagic Fisheries Assessment Unit at the SWFSC in La Jolla presently archives the CDFG live bait logs. Preliminary estimates of the reported total live bait harvest in California through 2008 have been appended to previously reported estimates from Thomson *et al.* (1991, 1992, 1994) (Table 6-12). The CDFG is in the process of an evaluation of the current logbook structure, reporting requirements, and the information obtained in order to correct the data problems identified above, increase reporting compliance rates, and to better estimate the economics of the fishery.

7.4 Species Composition

The ratio of anchovy to sardine in the southern California live bait harvests shifts significantly as the populations of these two fish expand and contract over periods of years or decades. Much of the early reported harvest consisted of anchovy, following the collapse of the sardine fishery in the 1940s. Through the years 1994 to 2006 the proportion of anchovy in the total reported harvest ranged from a high of 58 percent in 1994 to a new low in 2004 of 5 percent. The proportion of sardine ranged from a low of 42 percent in 1994, to a new high of 95 percent in 2004 (Table 6-13).

A new market squid live bait fishery for has expanded in southern California in recent years. However, the amount of market squid harvested and the value of the fishery is largely unknown, as there are no permitting and reporting requirements. The live bait fishery is likely a low-volume, high-value endeavor, as recreational anglers targeting mainly white seabass are willing to pay up to $85 for a “scoop” of live squid.

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8.0 SAFETY AT SEA CONSIDERATIONS

In implementing any form of management, it is imperative to evaluate whether the strategy will impact the safety of fishing activities. Roundhaul fisheries operating off the Pacific coast are often limited by environmental conditions, most notably inclement weather. Given that the average age of permitted CPS vessels in the LE fishery is 32 years and many older vessels are constructed of wood, concern has been raised regarding their safety and seaworthiness. Implementing time/area closures or restricting transferability could impact safety by restricting the ability of an older vessel to be replaced with a newer, safer vessel or by promoting fishing activity during potentially hazardous weather conditions.

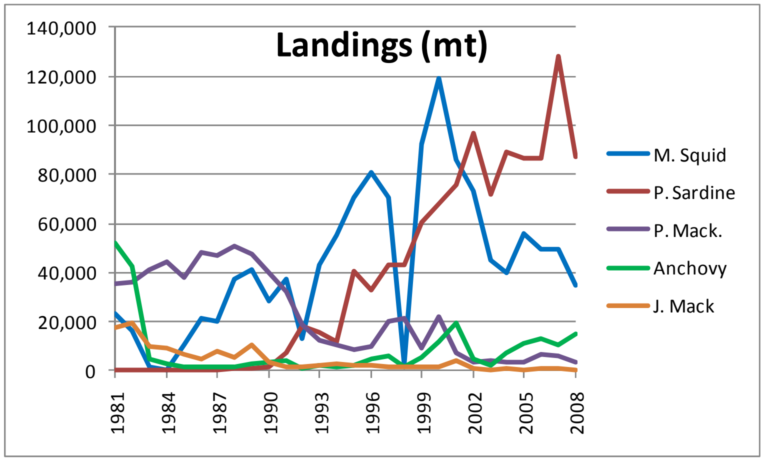
In January 2003, NMFS published final regulations to implement Amendment 10 to the CPS FMP, which allows LE permits to be transferred to another vessel and/or individual.

As discussed in Section 2.2, the Council has implemented a long-term allocation strategy for sardines under Amendment 11 to the CPS FMP. This action is not expected to have a substantial adverse impact on public health or safety. However, for Pacific Northwest fisheries, the action is anticipated to enhance safety at sea by advancing the reallocation date from October 1 to September 15. Waiting until October 1 to reallocate has the potential of inducing fishermen to fish in unsafe weather conditions. Ocean conditions off Oregon and Washington become increasingly rough in October. Also, crossing the Columbia River bar, always a hazardous exercise, becomes very dangerous during this time of year.

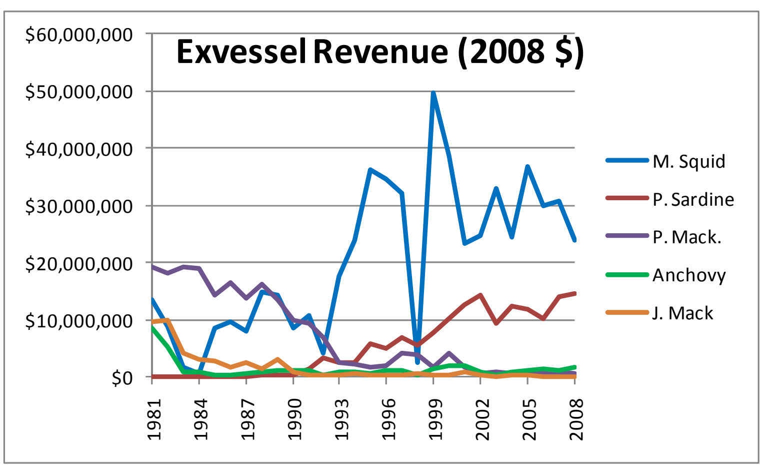
In 2008 and 2009 the directed Pacific sardine fishery experienced seasonal closures because harvest guidelines in these years have dropped while Pacific sardine continue to be available to the fishery and market demand is steady or increasing. This has lead to a “derby style” fishery where vessels complete for a share of the seasonal harvest guideline over a short period of time. This circumstance can create situations where safety considerations may be compromised as season duration is compressed and competition increases.

9.0 ECONOMIC STATUS OF WASHINGTON, OREGON, AND CALIFORNIA CPS FISHERIES IN 2008

This section summarizes economic data presented in Tables 9-1 through 9-11 (presented in the Tables section following Section 13) and Figures 9-1 through 9-8 (at the end of this Section). West coast landings of CPS totaled 140,292 mt in 2008, a 28 percent decrease from 2007. Market squid landings, all in California, totaled 34,639 mt in 2008, down 30 percent from 2007. Pacific sardine landings of 87,175 mt in 2008 decreased 32 percent from 2007 (127,766 mt). The exvessel revenue from all CPS landings was $40.9 million in 2008, down 13 percent from 2007 (2007 converted to 2008 dollars).



Market squid accounted for 25 percent and Pacific sardine 62 percent of total West coast, CPS landings in 2008. Landings of Pacific mackerel decreased 39 percent, and landings of northern anchovy rose 39 percent from 2007 to 2008. Real exvessel market squid revenues (2008 $) decreased 23 percent from 2007. The decrease in market squid landings was accompanied by an 11 percent increase in exvessel price from $623 to $689 per mt (2008 $). There was a 27 percent decrease in aggregate CPS finfish landings from 2007; exvessel revenue increased 4 percent, while the overall finfish exvessel price increased 43 percent from 2007. In 2008, market squid made up 7 percent of total West coast exvessel revenues, and CPS finfish accounted for almost 5 percent. Washington, Oregon and California shares of total west coast CPS landings in 2008 were 5 percent, 16 percent and 79 percent respectively.



California sardine landings were 57,791 mt in 2008 down 29 percent from 2007, 80,957 mt. Market squid ranked first in exvessel revenue generated by California commercial fisheries in 2008, with exvessel revenue of, $23.9 million, $2.1 million greater than that for Dungeness crab, in second place. Landings of Pacific sardine ranked forth highest in California exvessel revenues in 2008 at $7.6 million. California Pacific mackerel landings were 3,449 mt in 2008, down 31 percent from 2007. California landings of Northern anchovy were 14,285 mt in 2008, up 38 percent from 2007.

Oregon's landings of Pacific sardine decreased 46 percent in 2008, from 42,144 mt to 22,949 mt. Sardine generated $5.7 million in exvessel revenue for Oregon in 2008, 6 percent of the state's total exvessel revenues, ranking it seventh behind Dungeness crab in total exvessel revenues. Washington landings of Pacific sardine increased 38 percent from 4,665 mt in 2007 to 6,435 mt in 2008. With exvessel revenue less than 1 percent of the Washington total in 2008, sardine ranked 12th behind Dungeness crab in exvessel value.

Oregon landings of Pacific mackerel decreased from 702 mt in 2007 to 58 mt in 2008. Washington landings of Pacific mackerel decreased from 38 mt in 2007 to 9 mt in 2008 while anchovy landings fell from 153 mt to 109 mt.

In 2008, the number of vessels with West coast landings of CPS finfish was 196, down from 220 in 2007. With the decrease in vessels and a decrease in total CPS finfish landings, finfish landings per vessel, 539 mt in 2008, decreased 18 percent from 2007. Of the vessels landing CPS finfish in 2008, 21 percent depended on CPS finfish for the greatest share of their 2008 exvessel revenues. From 2007 to 2008, the number of vessels with West coast landings of market squid increased from 164 to 167, with 35 percent of these vessels dependent on market squid for the largest share of their total 2008 exvessel revenue. Market squid landings were 207 mt per vessel in 2008, down 31 percent from 2007. Market squid total exvessel revenue shares for vessels that depend mainly on market squid, and finfish total exvessel revenue shares for vessels that depend mainly on CPS finfish have averaged about 78 percent per vessel since 2000. In 2008 by far roundhaul gear accounted for the largest share of total CPS landings and exvessel revenue by gear in 2008, dip net gear was a far distant second.

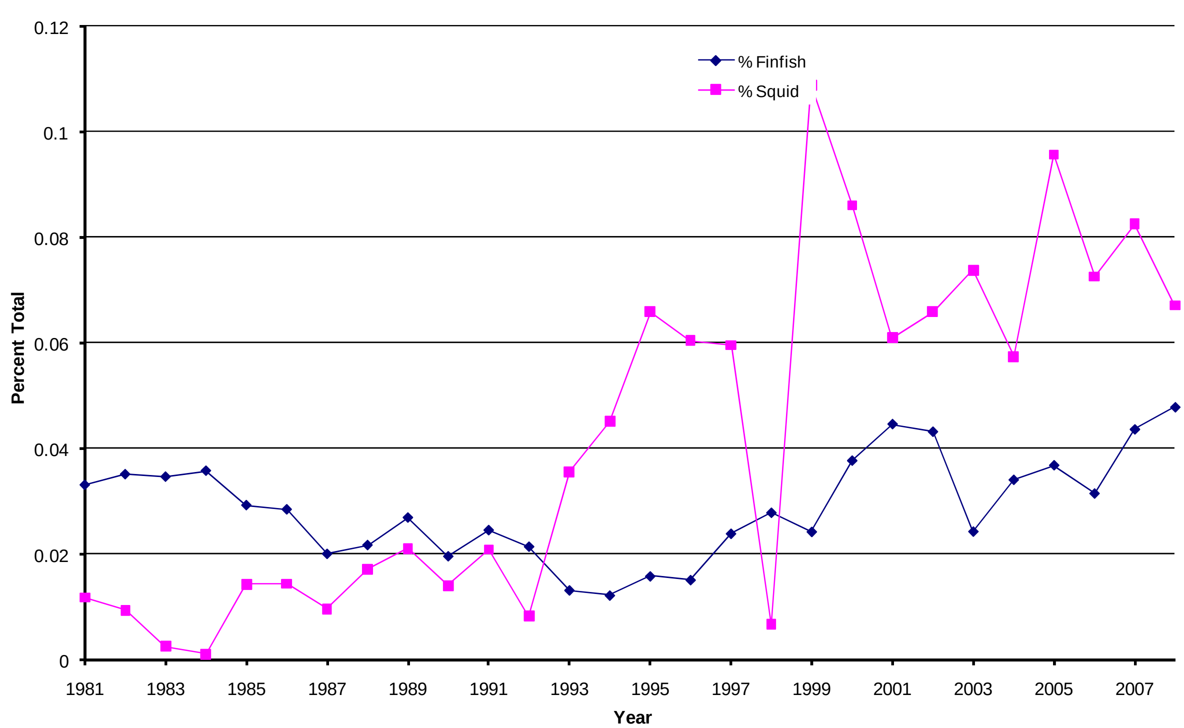
The major West coast processors and buyers of CPS finfish are concentrated in the Los Angeles, Santa Barbara-Ventura, Monterey and the Columbia River port areas of Oregon and Washington. The exvessel markets for market squid are mainly in the Los Angeles, Santa Barbara-Ventura and Monterey port areas.

In 2008, 34,535 mt of market squid were exported through West coast customs districts with an export value of $50.1 million; a 9 percent decrease in quantity, and a 3 percent decrease in the real value of West coast market squid exports from 2007. The primary country of export was China, 70 percent of the total, which received 24,026 mt, up 7 percent from the quantity exported to China in 2007. Eighty-five percent of market squid exports went to China and four additional countries: Japan (2,023 mt), Mexico (1,240 mt), U.K. (1,169 mt) and Spain (1,128 mt). Domestic sales were generally made to restaurants, Asian fresh fish markets or for use as bait.

In 2008, 75,095 mt, of sardines were exported through West coast customs districts down 31 percent from 2007. Sardine exports were valued at $59.8 million in 2008, down 18 percent from 2007. Almost 76 percent of sardine exports were in the frozen form, the balance were in the preserved form. Japan was the primary export market in 2008, receiving 19,708 mt, a 50 percent increase in its imports from 2007, and representing 26 percent of total West coast sardine exports in 2008. Australia was second with 16,643 mt, 22 percent of the total a 16 percent decrease from 2007, followed by Thailand, Malaysia and Nauru with 19 percent, 9 percent and 6 percent respectively. Together these five countries accounted for over 80 percent of total west coast sardine exports in 2008.

FIGURE 9-1. Annual West coast landings and real exvessel revenues for all CPS species, 1981-2008.

FIGURE 9-2. Percentage contribution of West coast CPS finfish and market squid landings to the total exvessel value of all Pacific coast landings, 1981-2008.



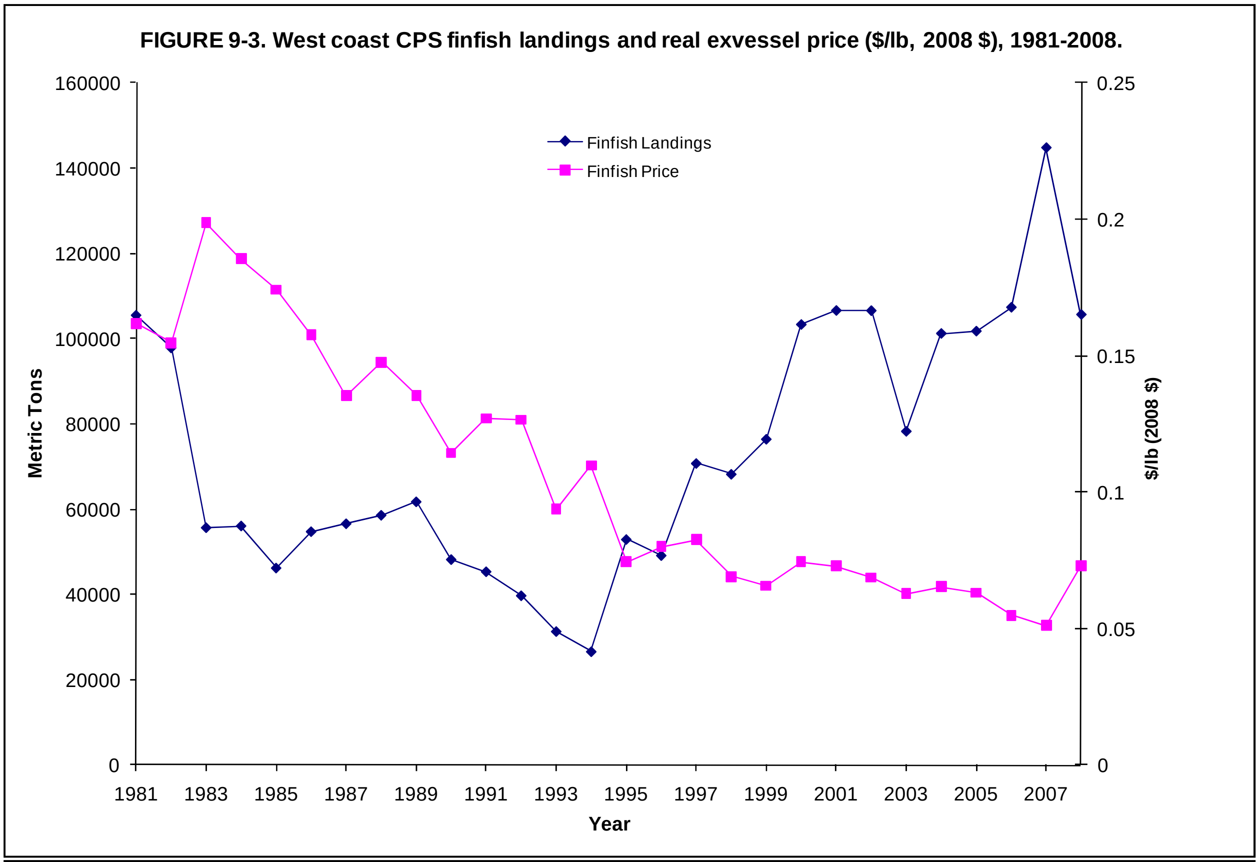


FIGURE 9-3. West coast CPS finfish landings and real exvessel price ($/lb, 2008 $), 1981-2008.
Finfish Landings
Finfish Price
Metric Tons
$/lb (2008 $)
Year
0
20000
40000
60000
80000
100000
120000
140000
160000
0
0.05
0.1
0.15
0.2
0.25
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007

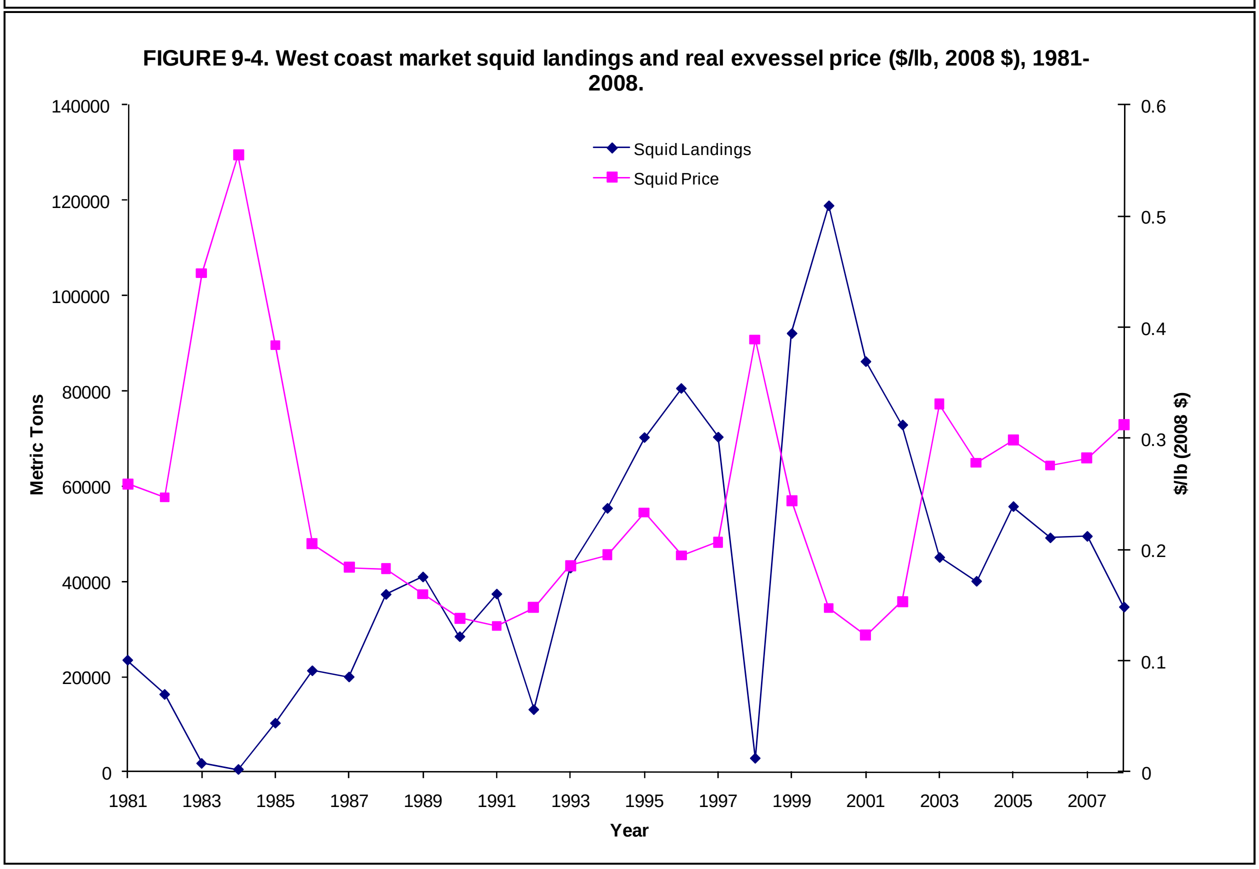


FIGURE 9-4. West coast market squid landings and real exvessel price ($/lb, 2008 $), 1981-2008.
Squid Landings
Squid Price
Metric Tons
$/lb (2008 $)
Year
0
20000
40000
60000
80000
100000
120000
140000
0
0.1
0.2
0.3
0.4
0.5
0.6
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007

FIGURE 9-5. Number of vessels with West coast landings of CPS finfish, and number for which CPS finfish was the principle species, 1981-2008.

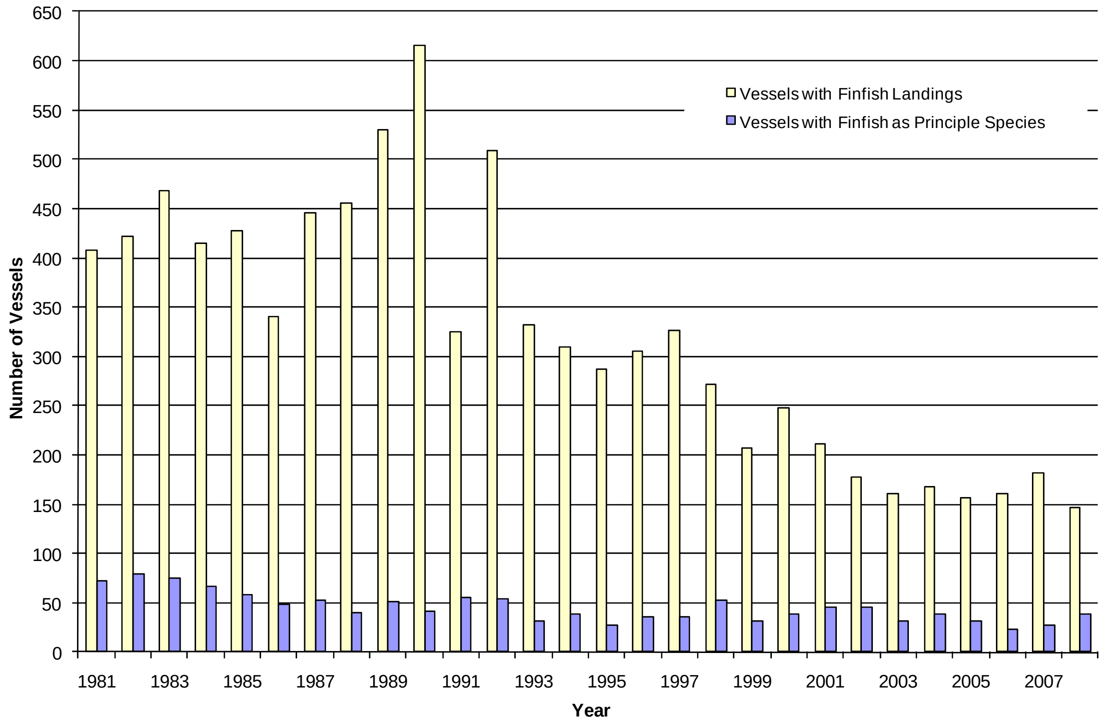


FIGURE 9-6. Number of vessels with West coast landings of market squid, and number for which market squid was the principle species, 1981-2008.

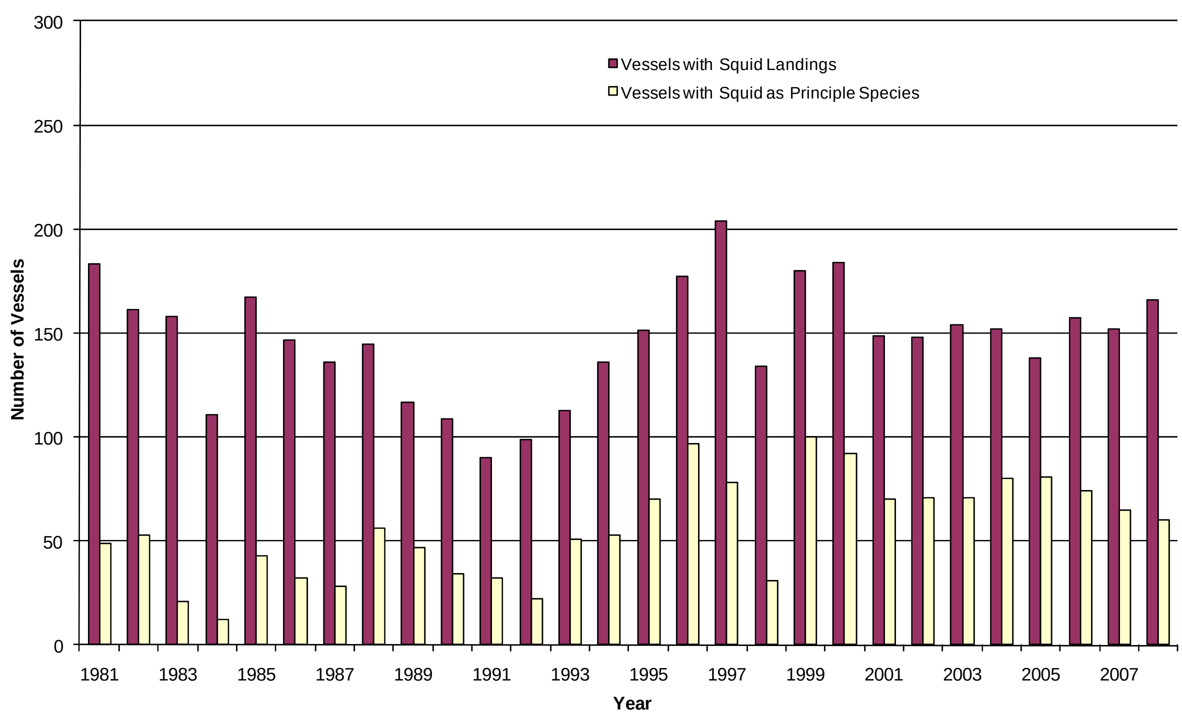


FIGURE 9-3. West coast CPS finfish landings and real exvessel price ($/lb, 2008 $), 1981-2008.

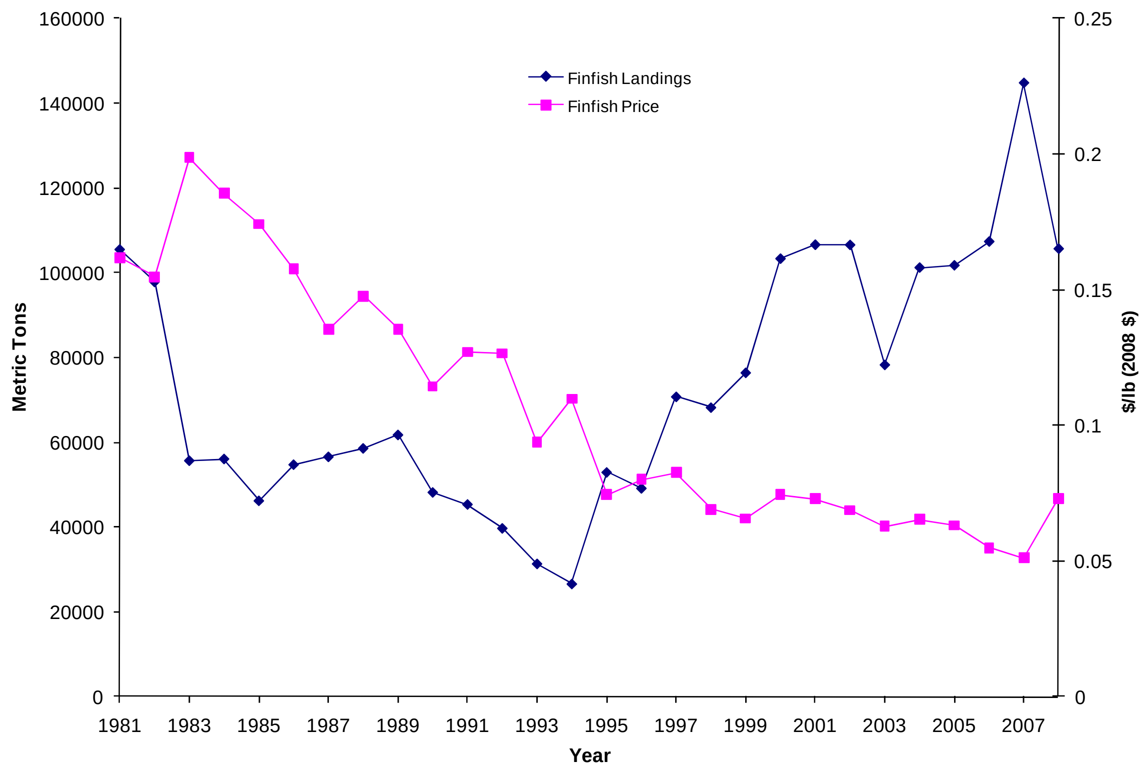


FIGURE 9-4. West coast market squid landings and real exvessel price ($/lb, 2008 $), 1981-2008.

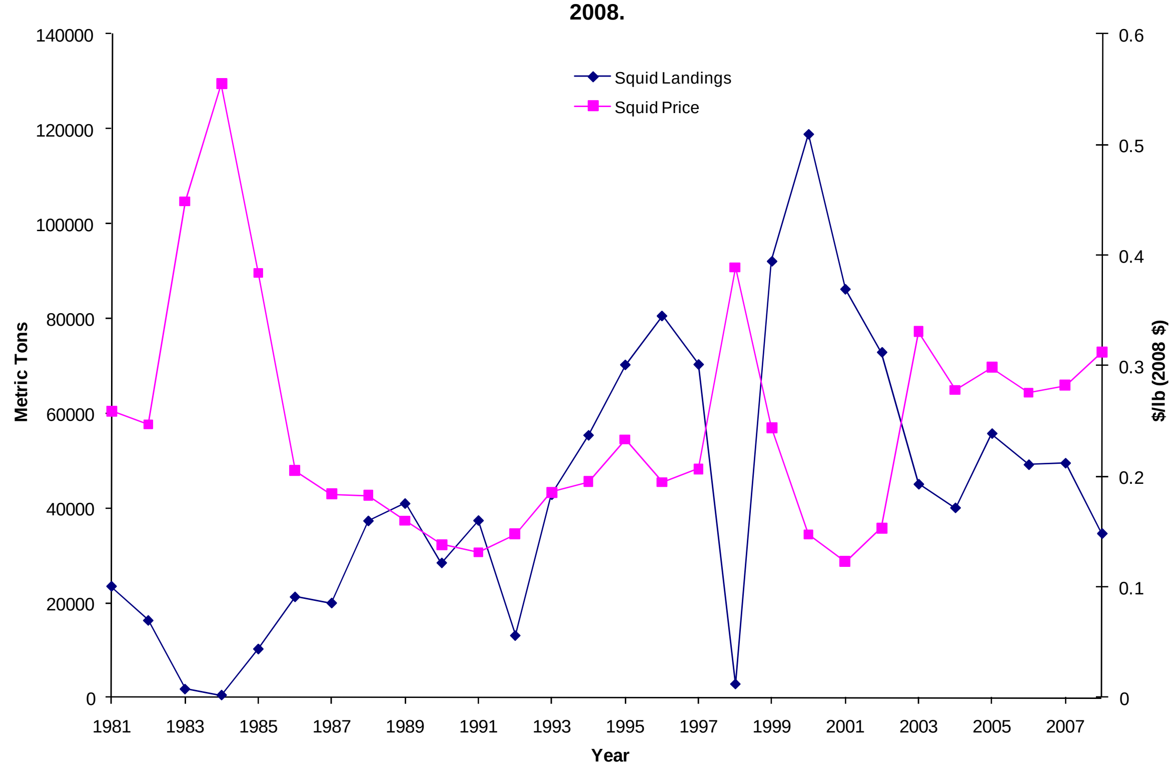


FIGURE 9-5. Number of vessels with West coast landings of CPS finfish, and number for which CPS finfish was the principle species, 1981-2008.

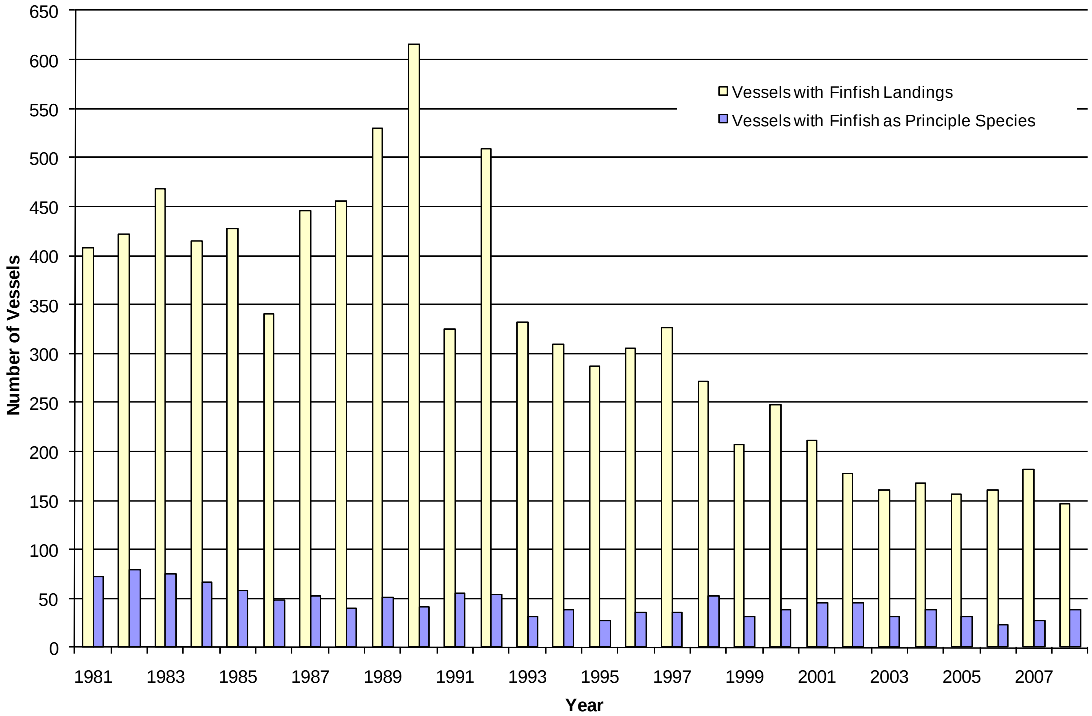


FIGURE 9-6. Number of vessels with West coast landings of market squid, and number for which market squid was the principle species, 1981-2008.

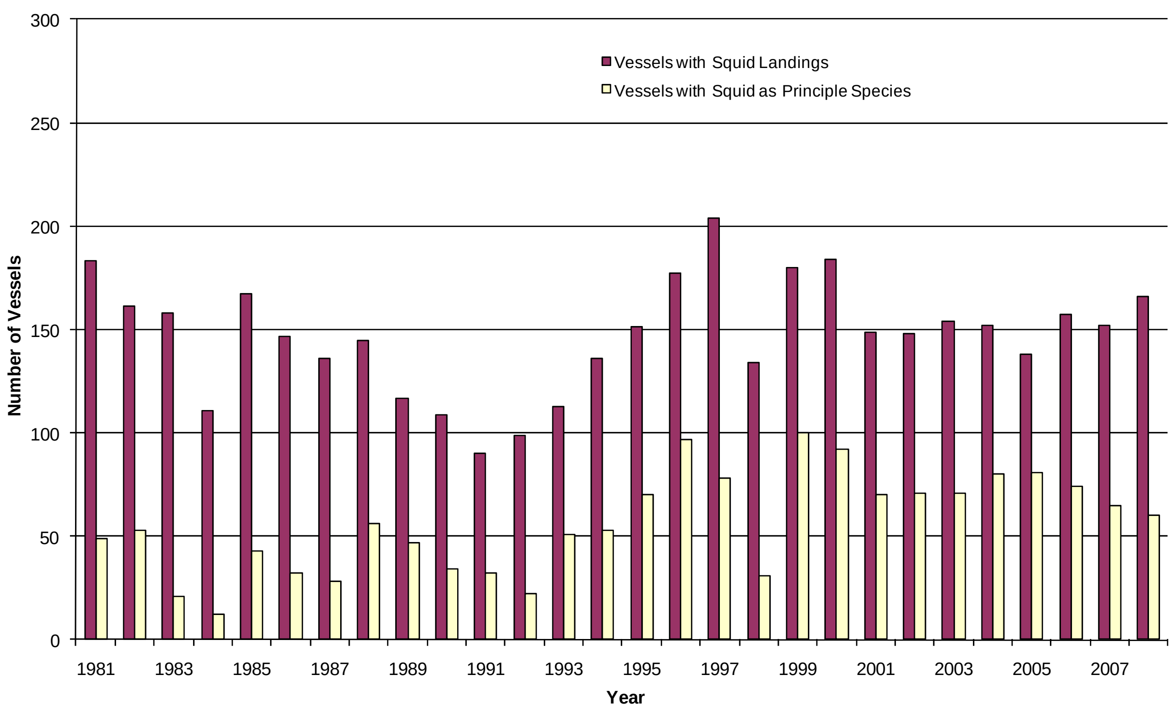
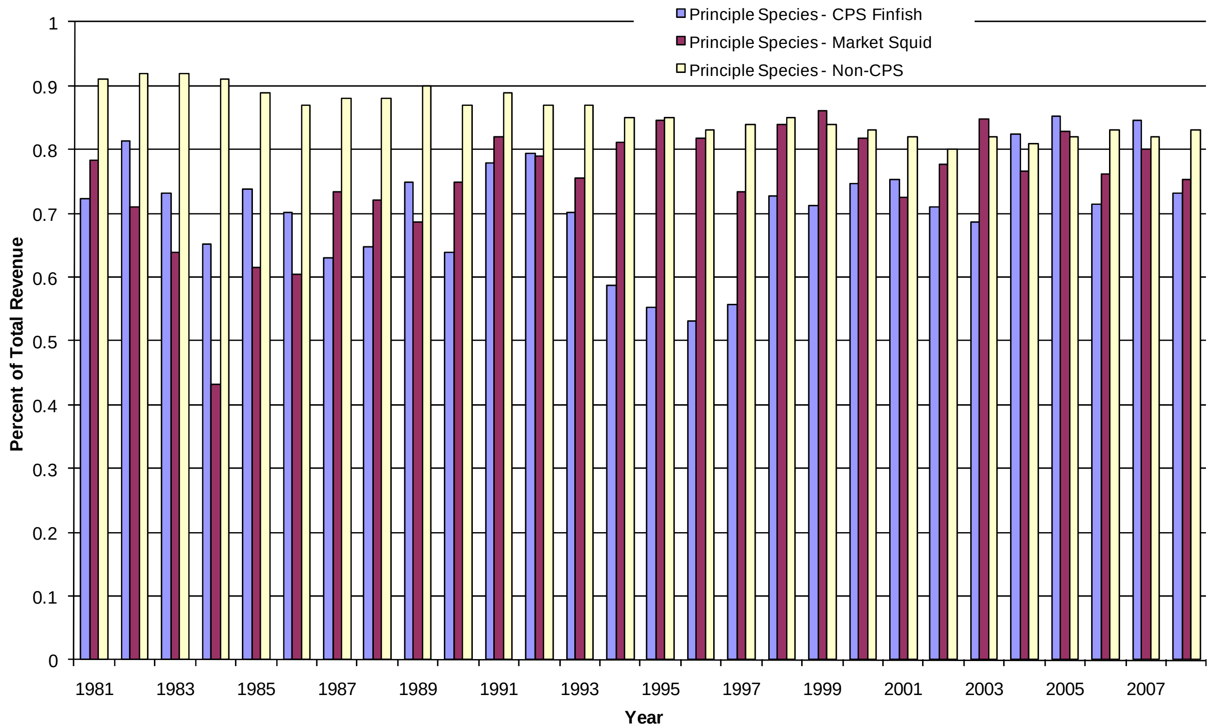
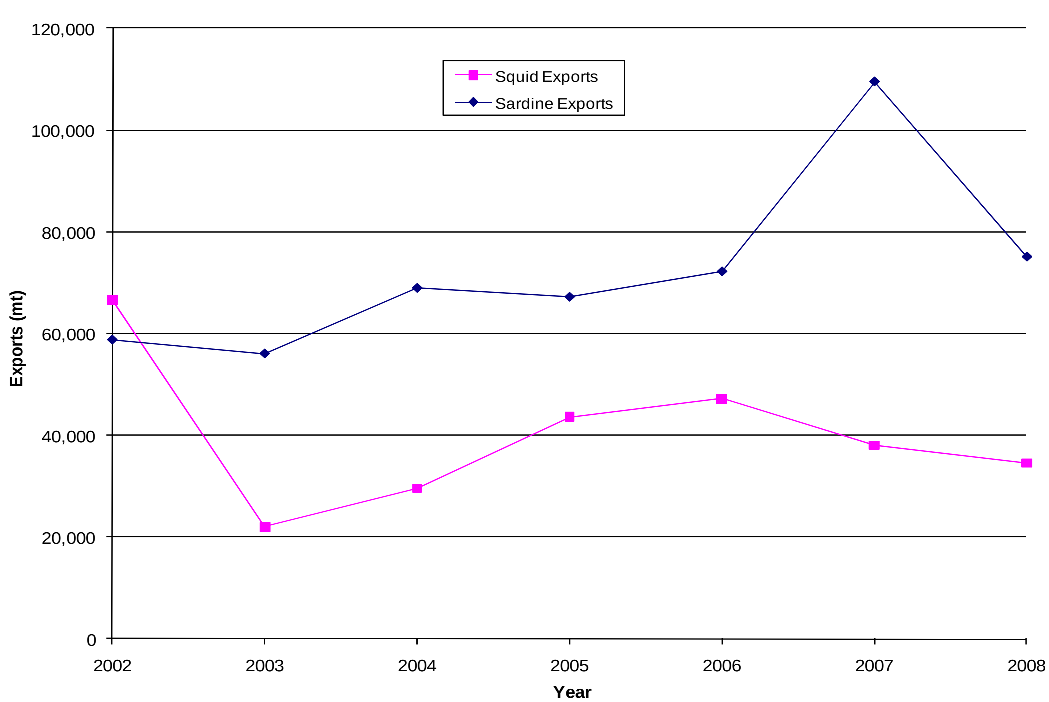


FIGURE 9-7. Average share principle species revenues of total revenues for vessels whose principle species was CPS finfish, market squid or non-CPS, 1981-2008.



Note: The principle species accounts for the largest share of the vessels annual exvessel revenue.

FIGURE 9-8. West coast sardine and squid exports, 2002-2008



10.0 ECOSYSTEM CONSIDERATIONS

10.1 Introduction

There is a growing national interest in augmenting existing single- species management approaches with ecosystem-based fishery management principles that could place fishery management decisions and actions in a the context of a broader scope. NMFS Science Centers around the country have been working on improving the science behind ecosystem-based fishery management including status monitoring and reporting on ecosystem health. This section provides a summary of trends and indicators being tracked by NMFS. Additionally, Appendix A of Amendment 8 to the CPS FMP provides a review of the life-cycles, distributions, and population dynamics of CPS and discusses their roles as forage and can be found on the Council's web site. Additionally, Appendix D provided a description of CPS essential fish habitat that is closely related to ecosystem health and fluctuation. Recent efforts to learn more about ecosystem functions and trophic interactions will likely result in future research results that will improve our knowledge base for improved CPS management decisions.

10.2 Description of the California Current Large Marine Ecosystem

The California Current (CC) is formed by the bifurcation of the North Pacific Current at approximately Vancouver Island, Canada and flows southward along the West Coast to mid Baja, Mexico. The current flows southward year round off shore from the shelf break to ~200 miles. Other coastal currents generally dominate along the continental shelf including the northward Davidson Current and California Undercurrent, the Southern California Countercurrent, as well as many eddies and smaller shelf currents (Figure 10-1).

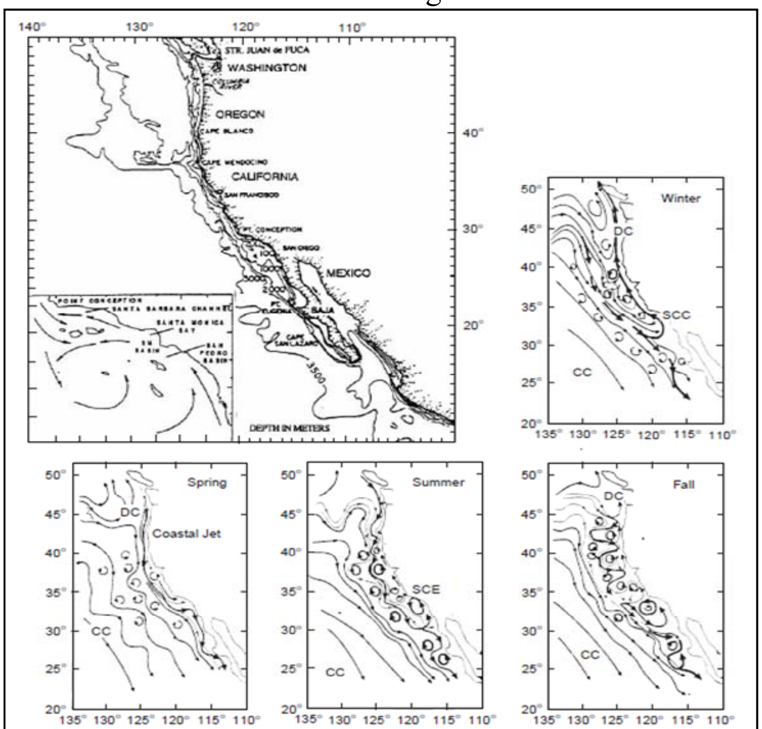


Figure 10-1. Seasonal variation of large-scale currents along the West Coast and rough bathymetry illustrate the dynamic conditions in the CCLME. The CC flows southward year round off shore from the shelf break to several hundred kilometers. Along the shelf break, several other currents affect the ecosystem to varying degrees including the Davidson Current (DC), Southern California Countercurrent, and the Southern California Eddy (SCE). (From Hickey and Royer 2001).

The California Current also defines the outer boundary of the California Current Large Marine Ecosystem (CCLME) that is delineated by bathymetry, productivity and trophic interactions. The LME is an organizational unit to facilitate management of an entire ecosystem and recognizes the complex dynamics between the biological and physical components[1]. NOAA's ecosystem based management approach uses the LME concept to define ecosystem boundaries.

The CCLME is characterized as having high biological productivity (>250 mg C/m2/day) that is primed by nutrients either upwelled along the shelf break or advected in surface currents from the Gulf of Alaska into the northern region (WA to Northern CA). The biological cornucopia can be seen in the extensive near shore kelp beds, large schools of CPS (e.g. sardine, anchovy, squid etc) and groundfish that, in turn, support large populations of marine mammals, sea birds and highly migratory species (e.g. tuna, sharks, billfish).

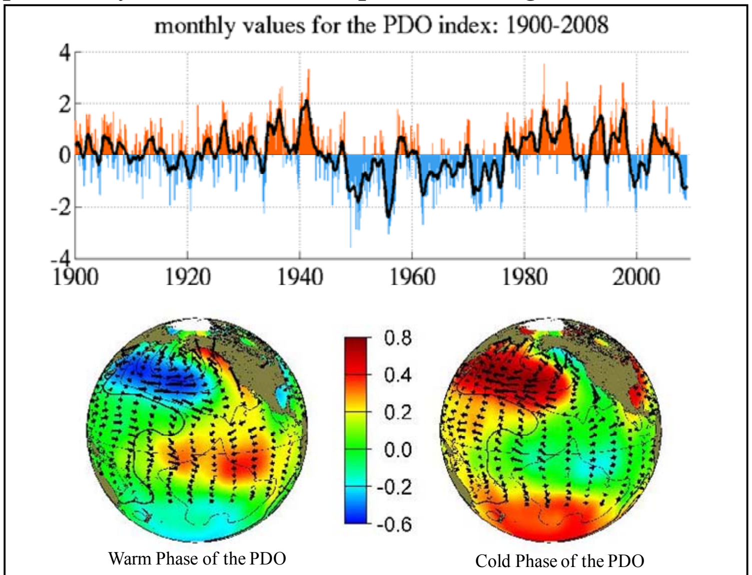


Figure 10-2. Phases of the Pacific Decadal Oscillation and associated changes in wind speed and direction as well as sea surface temperature. http://cses.washington.edu/cig/pnwc/aboutpdo.shtml

The CCLME is heavily influenced by climate at the annual, interannual and decadal time scales. Annually between the winter and spring, changes in large scale wind fields in the NE Pacific can reverse the prevailing shelf currents from a predominantly northward to southward direction. The transition in currents and concurrent increase in solar radiation in the spring leads to the dramatic increase in productivity labeled the 'spring transition'. The timing and duration of the Spring Transition is determined by NMFS' Newport, OR laboratory which has conducted monthly surveys of the CCLME since 1997. Additional data from new survey lines off Trinidad Head (Humboldt Co.), CA (NMFS) and Bodega, CA (Sonoma Water Agency-UCD) confirm the Newport prediction. Additional data from new survey lines off Trinidad Head, CA (NMFS-HSU) and Bodega, CA (SWCA-UCD) will be used to augment analysis of the spring transition off Oregon and northern California" At present, our data (at least for Trinidad Head Line) are too sparse in time to determine spring transition dynamics.

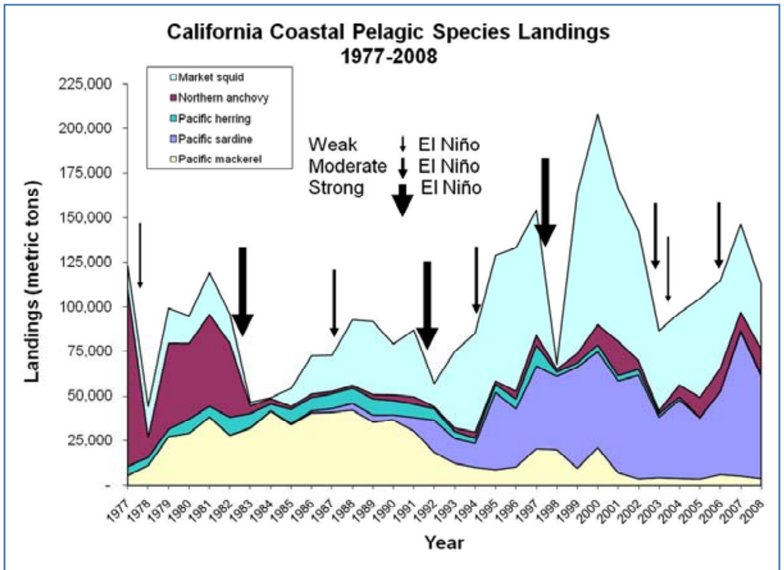


Figure 10-3 El Niño Events and California CPS Landings

[1] The CA Current LME (CCLME) is one of 10 LME's in the US EEZ and one of 64 worldwide. UN Atlas of the Ocean.

Along the OR coast, the timing and duration has been linked to coho salmon returns in the Columbia River (Peterson et al. 2006). The connection between the Spring Transition and CPS is not known at present.

On an interannual time scale of 3-7 years, the CCLME is affected by ENSO, El Niño/Southern Oscillation, whereby either warmer, salty surface water from the equator (El Niño) or cool, upwelled water (la Niña) affects the ecosystem. During El Niño, CPS landings along the CA coast are mixed with a large decrease of market squid, anchovy and Pacific herring while the landings for sardine and mackerel remain relatively constant (Figure 10-3, CDFG 2008).

At periods between 20 to 50 years, low frequency climatic forcing from the Pacific Decadal Oscillation (PDO) affect the CCLME. The mechanism(s) behind the PDO are still being researched (Beamish et al. 2004). The PDO was mostly negative (warm in the central North Pacific Ocean and cool near the west coast of the Americas) from 1942-1976 and from 1998-2001 and positive from 1977 to 1998. Since 2001, the PDO has fluctuated between positive and negative signaling an unusual climatic period for the CCLME.

The effects of the PDO on fisheries are mixed. In general, the warm of the PDO is associated with reduced landings of coho and Chinook salmon in the Pacific NW while the cool phase is associated with higher landings (Mantua et. 1997). For sardine, positive PDO indices seem to correlate with high landings along the CCLME while anchovy landings are generally low (Figure 10-4) (Takasura et al 2008).

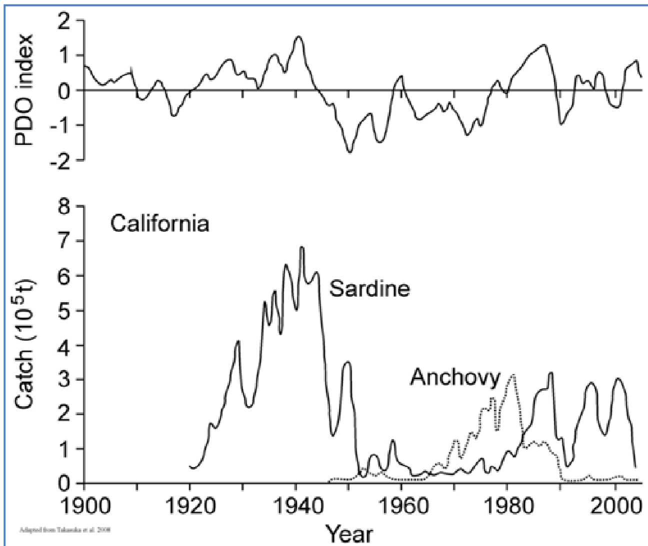


Figure 10-4. Sardine and Anchovy landings in California and PDO index for the same time period. (Adapted from Takasura et al (2008).

Like all marine ecosystems, the CCLME is very complex, and despite 60 years of surveys from CalCOFI, understanding and predicting recruitment success for any fishery including CPS remains elusive. In light of the complexity, ecological indicators are used as surrogates of ecosystem health and status of fisheries. Preliminary physical indicators and sentinel species are under development by NMFS and will take on increased importance as the agency embarks on an Integrated Ecosystem Assessment (IEA) in the CCLME. Since 2008, the Pacific Coast Ocean Observing System (PaCOOS) has produced a quarterly summary of climate and ecosystem science and management in the CCLME has tracked the indicators and sentinel species (visit www.pacoos.org).

10.3 Current Climate and Oceanographic Conditions.

10.3.1 Spring Transition

In 2008, the Spring Transition was early and very strong with temperature values the lowest since conductivity, temperature, and depth data collection began in 1997. Upwelling was initiated early in the year (day 88; 28 March 2008), but did not become strong until one month later on 28 April. Winds remained steady through much of the summer except for a lull (and southwesterly storms) in August, from days 204 through 240.

The early Spring Transition portends to a good return of Columbia River coho salmon starting in 2010 but any inference to CPS is still not clear.

10.3.2 El Niño/Southern Oscillation (ENSO)

The Multivariate El Niño/Southern Oscillation Index for the Northeast Pacific reflect La Niña conditions for 2008 with cold water dominating the CCLME with associated higher productivity along the coast (Figure 10-5). Based on model forecasts, La Niña conditions are expected to gradually weaken during the spring of 2009 leading to El Niño neutral conditions. Neutral conditions are still considered favorable for CPS.

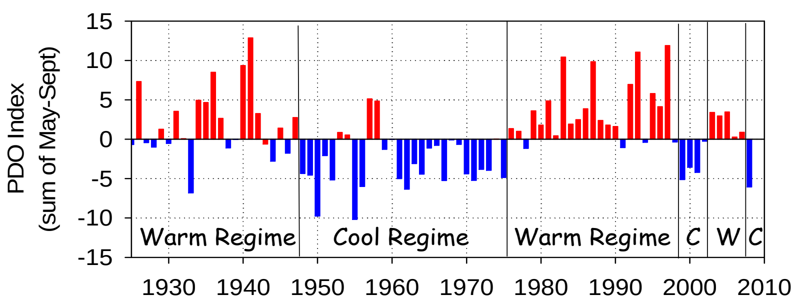


Figure 10-5. Time series of the PDO summed over May-September, 1925 to 2008. Note that the summer-time value in 2008 was the most negative since 1956. ***Source: Bill Peterson, NOAA*** http://jisao.washington.edu/pdo/PDO.latest, http://jisao.washington.edu/pdo/

10.3.3 Pacific Decadal Oscillation (PDO)

The Pacific Decadal Oscillation has remained negative since September 2007. A negative PDO value is considered favorable for anchovy but not sardine. Effects on other CPS such as squid are not known at this time.

10.4. Trends in Ecosystem Indicators.

Biological indicators for the CCLME are under development by NOAA and partners. The following are draft indicators that may change or be replaced over time.

10.4.1 Copepods.

The copepod species richness, as surveyed by the NMFS, NWFSC at the Newport Hydrographic survey line, was low in 2008 and dominated by boreal species (Figure 10-6). The presence of sub-arctic species is favorable for coho salmon returns to the Columbia River but has not been correlated to CPS in the area. Limited data from the Trinidad Head Line indicate that boreal and cold-water species dominated copepod assemblages off northern California during 2008.

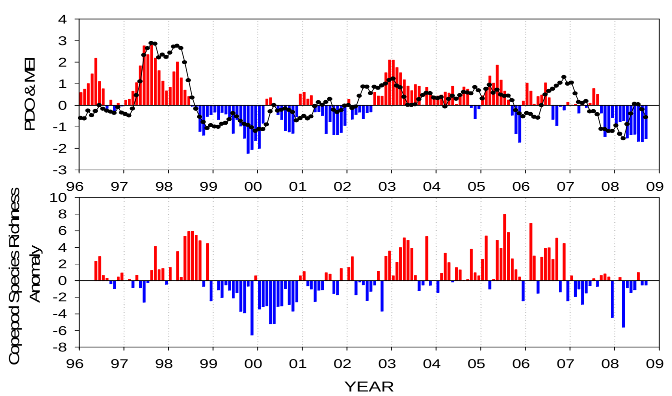


Figure 10-6. Time series of the monthly values of the Pacific Decadal Oscillation (PDO), Multivariate El Nino Index (MEI) and copepod species richness. Note that species richness tracks the PDO and MEI fairly closely; also note that richness has had negative anomalies since 2007. ***Source: Bill Peterson NOAA NWFSC.***

10.4.2 Juvenile Fish.

Surveys for juvenile fish are conducted by the NMFS, SWFSC off the Central California coast in the May-June time period since 1983 (Figure 10-7). Sardine numbers remain above the long-term average, but were down modestly while anchovy juveniles were down significantly in 2008. Market squid encounters were below average as well. Information on juvenile fish for 2009 was unavailable at the time of this report.

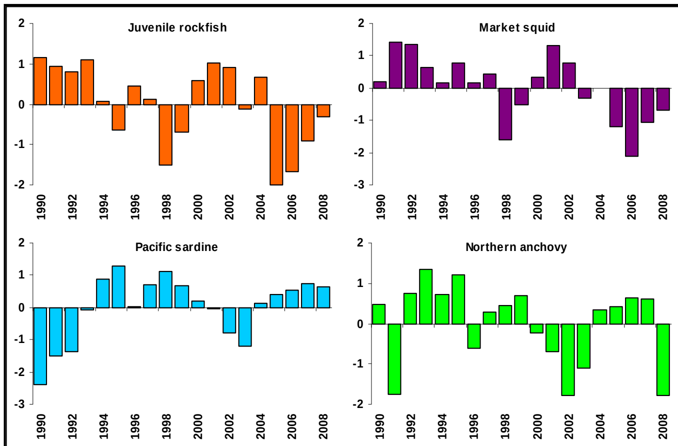


Figure 10-7. Standardized anomalies from the log of mean values by year for four key forage species from the annual juvenile fish survey. ***Source: Steve Ralston, John Field and Keith Sakuma, NOAA SWFSC.***

10.5 Pacific Sardine as Forage

Under a comprehensive, environmental-ecological-economic-based conservation and management approach or ecosystem-based fishery management (EBFM), the impacts of harvesting sardines will extend beyond directed commercial fisheries to consideration of the corresponding effects on sardine predators that constitute higher trophic level commercial and recreational fisheries, as well as non-commercial but ecologically important predators (e.g., marine mammals, seabirds).. Ongoing work in this area is focused on the development of a modeling framework for enumerating the benefits provided by Pacific sardine in the CCLME, and evaluating sardine EBFM conservation and harvest policy in terms of the tradeoff between benefits from sardines as a directed harvest and sardines as forage (Figure 10-7).

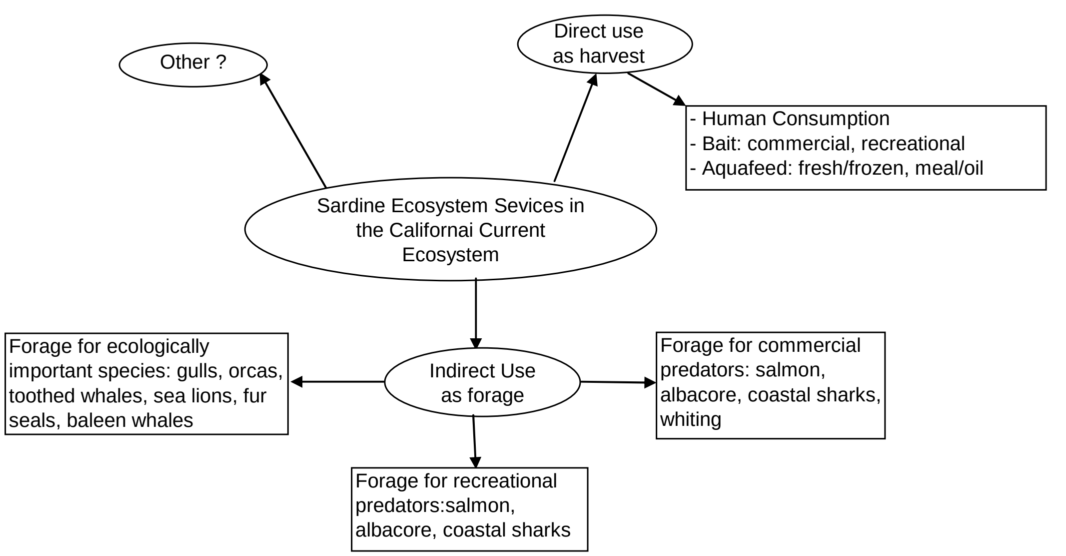


Figure 10-7. Pacific sardine California Current Ecosystem services.

Ecosystem Services of Pacific Sardine

- **Harvested** for human consumption, bait, aquafeeds, aquarium feeds
- **Forage**: direct consumption by commercial, non-commercial/recreational predators; indirect food web effects
- **Value added** from higher trophic level commercial fisheries
- **Value added** from higher trophic level recreational fisheries
- **Value added** from food for ecologically important species

Diagrammatically this problem can be illustrated in terms of an output transformation frontier (*TF*) and the values of the ecosystem services that the Pacific sardine resource provides. The stylized *TF* in Figure 10-8 represents the combination of ecosystem services in terms of forage (*F*) -- where forage is transformed into the annual production of commercial predators and non-commercial predators -- and commercial harvests (*H*) of sardines that the existing resource stock is capable of providing. The frontier will move inward or outward as the sardine biomass contracts or expands.

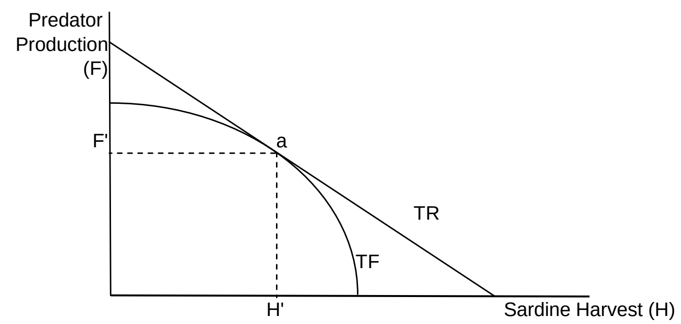


Figure 10-8 The Pacific sardine resource transformation frontier.

All points on the *TF* are points of maximum productive efficiency, meaning that each combination of *H* and F is being produced at the lowest possible cost so that the marginal cost of forage (MC_F) equals the marginal cost of harvest (MC_H). All points inside the *TF* are feasible but productively inefficient; all points outside the *TF* are infeasible for given sardine stock. Points along the *TF* describe the trade-off between *F* and *H*. If there is no increase in the sardine stock, increasing *F* has to entail decreasing *H* because biomass must be transferred to the first and away from the second. The sacrifice in the production of *H* is called the "opportunity cost" of *F*; an economic cost that is measured in the number of units of the *H* that are foregone for an additional unit of F. Concavity of the *TF* indicates increasing marginal opportunity costs.

Given the sardine forage-harvest *TF*, the management objective under EBFM would entail determining the combination of forage and harvest that maximizes the total social value from the sardine stock. If per unit monetary values for harvest (P_H) and forage (P_F) are available, a total revenue (*TR*) curve can be constructed (if per unit values are constant, $TR = HP_H + FP_F$, so that the marginal values of forage and harvest are P_F and P_H respectively). The socially optimum combination of sardine harvest and sardine for forage occurs at the point of tangency of the *TR* curve with the *TF* (point "a' in Figure 10-7). At point a, $MC_F = P_F$ and $MC_H = P_H$, and therefore the net social benefits from forage and harvest are equal. This is the condition which achieves the socially optimum allocation of the sardine stock between forage and harvest production, from which follows the socially optimum levels of sardine predator production and sardine harvest, *F'* and *H'* in Figure 10-8 respectively.

To quantitatively model this situation will require a great deal of detailed economic and ecological data. An indication of the data requirements can be seen from the economic and ecological interactions shown in Figure 10-8. On the economic side, the net benefits of harvesting sardines and their commercial predators can be derived from the market revenues and costs associated with their harvest. The non-commercial predators are not subject to market exchange: recreational catches are not sold; ecologically important species are public goods. Therefore, evaluating the tradeoffs between harvesting sardines and leaving them in the ocean as food for non-commercial predators will require the use of non-market valuation techniques to enumerate the related benefits and costs of the ecosystem services sardine provide in this role. The net per unit values of the non-market predators can then be used to derive shadow prices for sardines as forage for the recreational and ecologically important predators. The sardine shadow prices will then be incorporated into the existing modeling framework enabling it to evaluate various tradeoffs and determine the socially optimum allocation of the sardine resource as illustrated in Figure 10-8.

On the ecological side, current work in this area has relied on the ecosystem model of Field et al. (2006). This model was developed for dynamic simulations of the CCLME, starting in the 1960s but based on food habits data over a broader time period. At that time, sardines were at very low levels of abundance. As a result, the predation and food conversion parameters in the Field et al. model are not likely to be representative for periods with greater sardine abundance or for predators and prey in the southern part of the CCLME. The current work takes predation and food conversion parameters as being fixed at the 1960s levels. However, major changes in sardine abundance, catches and in predator stock levels that have occurred since then are likely to affect these parameters.

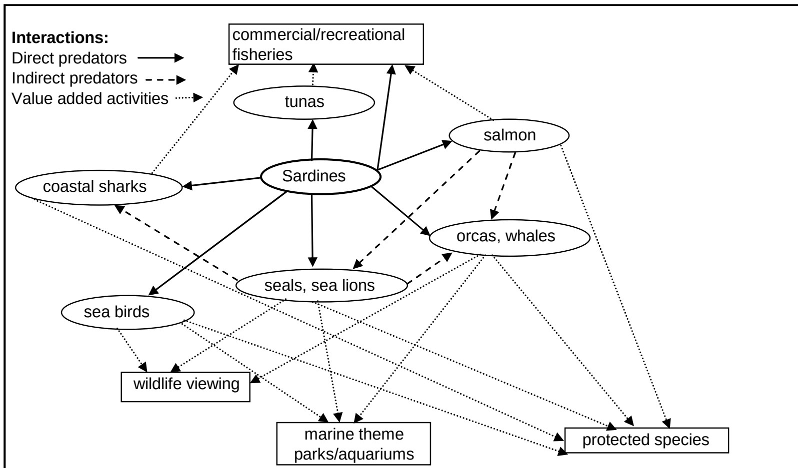


Figure 10-9 Sardine centric ecological and economic interactions.

Moreover, major changes in sardine stock levels and the spatial distribution of the sardine stock have been shown to be strongly influenced by climate induced environmental changes (Norton and Mason 2003, 2004, 2005; Herrick et al. 2007). These changes are propagated into the ecosystem which reacts by reorganizing trophic relationships and relative species composition. Incorporating the relevant environmental factors into the modeling framework is expected to greatly enhance its predictive and dynamic capabilities, particularly with regard to different climate change scenarios. Therefore to confidently predict and evaluate the effects of a drastic change in sardine stock levels, like the return of the sardine fishery, a more comprehensive model is required; one that will take into account dynamic relationships between environmental, ecological and economic variables.

While the data requirements for a comprehensive EBFM-based model may be monumental they are not insurmountable, and are expected to be realized in gradual manner. Nevertheless, incremental results from modeling efforts such as this will be useful for indicating the direction of changes and to illustrate that strategic consideration of the tradeoffs could be an important element of the decision-making and management process. From a comprehensive fishery conservation and management standpoint, the insights and information provided by this modeling effort will contribute greatly to the development of an EBFM framework.

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PaCOOS Quarterly Update of Climatic and Ecological Conditions in the CA Current Large Marine Ecosystem V4 2008, V1 2009 **(**http://www.pacoos.org)

Climate Indicators:
El Niño Southern Oscillation (ENSO):
Source: Bill Peterson, NOAA
Source: http://www.cdc.noaa.gov/people/klaus.wolter/MEI/mei.html
Pacific Decadal Oscillation (PDO):
Source: Jerrold Norton, NOAA (Jerrold.G.Norton@noaa.gov)
Environmental Research Division (ERD), NOAA, NMFS
The PDO and Sea Surface Temperature at Newport, Oregon:

Source: Bill Peterson, NOAA
http://jisao.washington.edu/pdo/, http://jisao.washington.edu/pdo/PDO.latest

California Current Ecosystem Indicators:
Copepods:
Source: Bill Peterson, NOAA
Source: Marc Trudel, Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, BC

Coastal Pelagics:
Ecosystem indicators for the Central California Coast, May-June 2008
Source: Steve Ralston, John Field and Keith Sakuma, Fisheries Ecology Division, SWFSC

11.0 SUMMARY OF STOCK STATUS AND MANAGEMENT RECOMMENDATIONS

The CPS FMP distinguishes between "actively managed" and "monitored" species. Actively managed species (Pacific sardine and Pacific mackerel) are assessed annually. Seasonal closures and allocations, HGs, incidental landing allowances, and other management controls are used. Other CPS species (northern anchovy, jack mackerel, and market squid) are monitored to ensure their stocks are stable, but annual stock assessments and Federal fishery controls are not used.

While this document focuses on U.S. fisheries, many CPS stocks are distributed coastwide, hence, catch information from Mexican fisheries is of interest. See Table 11-1 for information on commercial harvest of CPS finfish landed into Ensenada, Mexico (1978-2001) (Table 15, García and Sanchéz 2003).

11.1 Actively Managed Species

11.1.1 Pacific Sardine

Hill *et al.* (2008; see Appendix 1) summarized the status of the Pacific sardine resource off the U.S. Pacific coast and northern Baja California, Mexico. Pacific sardine landings for the fisheries off the Pacific Northwest (Oregon-Washington-Canada), California, and Ensenada (Mexico) totaled 166,156 mt in calendar year 2007 (Table 11-2). In 2008, landings in California (57,800 mt) decreased considerably from the previous year (80,981 mt in 2007; Table 20). Oregon-Washington landings were also lower in 2008 (29,384 mt) than in 2007 (46,809 mt; Table 20). The U.S. sardine fisheries are regulated using a quota-based HG management scheme (see Section 11.1.1.1). Since the mid-1990s, landings from the U.S.-based fisheries have typically been lower than the recommended HGs (Table 11-3). However the 2008 HG was 42% lower than the previous year, so the U.S. fishery was subject to several inseason closures throughout the 2008 management year.. Harvest of Pacific sardine by the Ensenada (Mexico) fishery is not regulated by a quota system, but there is a minimum legal size requirement of 150 mm SL, and measures are in place to control fleet capacity. The Ensenada fishery landed 36,847 mt in 2007, down from 57,237 mt in 2006 (Table 11-4). Ensenada landings for 2008 are not yet available. The Canadian sardine fishery captured 10,435 mt in 2008, up from 1520 mt in 2007 (Table 11-4).

Estimated stock biomass (ages 1+) from the assessment conducted in 2008 (Hill et al. 2008; see Appendix 1) indicates a decline in sardine abundance since the recent peak year (2000), with an estimate of roughly 662,886 mt in July 2008. Recent year class sizes are considerably lower than the recent peak of 14.06 billion fish in 2003. Biomass and recruitment estimates (1981-2008 from the most recent assessment are provided in Table 11-2 and Appendix 1.

Finally, estimates of Pacific sardine biomass from the 1930s (Murphy 1966 and MacCall 1979) indicate that the sardine population may have been more than three times its current size before the stock decline and eventual collapse observed in the 1960s. Considering this historical perspective, it would appear that the sardine population, under favorable oceanographic conditions, may still have growth potential beyond its current size. However, per capita recruitment estimates show a downward trend in recruits per spawner in recent years, which may be indicative of a stock that has reached a threshold under current environmental conditions.

11.1.1.1 Harvest Guideline for 2009

The Pacific sardine harvest guideline established for the U.S. fishery in calendar year 2009 was 66,932 mt. Statistics used to determine this harvest guideline are discussed below and in Sections 4.3.1-4.3.2. The maximum sustainable yield (MSY) control rule defined in Amendment 8 of the CPS FMP, Option J, Table 4.2.5-1, PFMC (1998) was used to calculate the harvest guideline for 2009. This formula is intended to prevent Pacific sardine from being overfished and maintain relatively high and consistent catch levels over the long-term. The Amendment 8 harvest formula for sardine is:

$$HG_{2008} = (BIOMASS_{2007} - CUTOFF) \bullet FRACTION \bullet DISTRIBUTION;$$

where HG_{2009} is the total USA (California-Oregon-Washington) harvest guideline in 2009, $BIOMASS_{2008}$ is the estimated July 1, 2008 stock biomass (ages 1+) from the current assessment (662,886 mt), CUTOFF is the lowest level of estimated biomass at which harvest is allowed (150,000 mt), FRACTION is an environment-based percentage (see below) of biomass above the CUTOFF that can be harvested by the fisheries, and DISTRIBUTION (87 percent) is the percentage of $BIOMASS_{2008}$ assumed in U.S. waters. The value for FRACTION in the MSY control rule for Pacific sardine is a proxy for F_{msy} (i.e., the fishing mortality rate that achieves equilibrium MSY). Given F_{msy} and the productivity of the sardine stock have been shown to increase when relatively warm-ocean conditions persist, the following formula has been used to determine an appropriate (sustainable) FRACTION value:

$$FRACTION \text{ or } F_{msy} = 0.248649805(T^2) - 8.190043975(T) + 67.4558326,$$

where T is the running average sea-surface temperature at Scripps Pier, La Jolla, California, during the three preceding seasons (July-June). Ultimately, under Option J (PFMC 1998), F_{msy} is constrained and ranges between 5 percent and 15 percent. Based on the T values observed throughout the period covered by this stock assessment, the appropriate F_{msy} exploitation fraction has consistently been 15 percent; and this remains the case under current oceanic conditions (T_{2008} = 17.83 °C). The HG established for 2009 (66,932 mt) is 25 percent lower than the 2008 HG (89,093 mt), and 56 percent lower than the HG in 2007 (152,564 mt; Table 11-3), so the U.S. fishery will likely be constrained at various points during the 2009 management season.

11.1.2 Pacific Mackerel

Total biomass (age-1+ biomass, *B*) of Pacific mackerel remained low from the early 1960s to the mid 1970s, at which time the population began to rapidly increase in size, reaching a peak in the early 1980s. From the mid 1980s to early 2000s, the stock declined steadily, with some signs of ‘rebuilding’ (on an increasing limb of a historical distribution say) observed recently. However, recent estimates of stock size are necessarily related to assumptions regarding the dynamics of the fish (biology) and fishery (operations) over the last several years, which generally confounds long-term (abundance) forecasts for this species (see Crone *et al.* 2009). It is important to note that exploitation of this stock has changed considerably over the last two decades, i.e., during the 1990s, the directed fisheries off California had average annual landings of roughly 18,000 mt, whereas since 2002, average yearly landings have decreased over 70 percent to approximately 5,000 mt/yr. This pattern of declining yields in the most recent years generally characterized all of the fisheries, including U.S. commercial and recreational fleets, as well as the commercial fishery of Mexico. Total annual harvest of Pacific mackerel by the Mexico fishery is not regulated, but there is a minimum legal size limit of 255 mm.

Determination of the status of the Pacific mackerel population for the 2009 fishing/management year (i.e., a fishing year that spans from July 2009 through June 2010) was based on the SS model *AA* (see sections 3.1 and 3.2, and Crone et al. 2009).

11.1.2.1 Harvest Guideline for 2009-2010

The 2009 full assessment of Pacific mackerel was reviewed by a STAR Panel meeting in May of 2009. The SSC, CPSMT, and CPSAS will meet at the June 2009 Council meeting where the Council is scheduled to develop final recommendations on the 2009-2010 directed Pacific mackerel fishery. The following information is based on results of the May STAR Panel and is tentative until after final action at the June Council meeting.

In Amendment 8 to the CPS FMP (PFMC 1998), the recommended MSY-based harvest control rule for Pacific mackerel is:

$$HG_{2009} = (\text{TOTAL STOCK BIOMASS}_{2009} - \text{CUTOFF}) \bullet \text{FRACTION} \bullet \text{STOCK DISTRIBUTION},$$

where HG_{2009} is the highest harvest guideline or ABC for all U.S. fisheries for the 2009 fishing year (July 2009- June 2010), TOTAL STOCK BIOMASS_{2009} is the estimated stock biomass in 2009 (i.e., 282,049 mt; ages ≥ 1), CUTOFF is the lowest level of estimated biomass at which harvest is allowed, FRACTION is an environment-based percentage of biomass above the CUTOFF that can be harvested by the fisheries, and STOCK DISTRIBUTION is the percentage of TOTAL STOCK BIOMASS_{2008} in U.S. waters. CUTOFF (18,200 mt), FRACTION (30 percent), and STOCK DISTRIBUTION (70 percent) are currently 'fixed' terms in the harvest control rule. See section 4.0 (PFMC 1998) and MacCall *et al.* (1985) for analyses applicable to parameters included in the harvest control rule.

Therefore, for the 2009-2010 fishing year:

$$HG_{2008} = (282{,}049 \text{ mt} - 18{,}200) \bullet 0.30 \bullet 0.70 = 55{,}408 \text{ mt},$$

Based on this new assessment and the Pacific mackerel harvest control rule, the Council recommends an ABC of 55,408 mt and a harvest guideline for the Pacific mackerel directed fishery of 40,000 mt for the fishery season from July 1, 2009 through June 30, 2010.

Setting the harvest guideline for the directed fishery substantially below the ABC is recommended as a precautionary measure in response to uncertainty associated in past assessments, the current assessment (e.g., selectivity/catchability), as well as general consensus that the domestic fishery appears to be market limited at roughly 40,000 mt. The buffer between the harvest guideline and ABC is also intended to prevent a reoccurrence of the 2000-01 Pacific mackerel fishing year where early attainment of the entire ABC in the directed fishery curtailed the Pacific sardine fishery, which incidentally lands mackerel.

Finally, full assessments for Pacific mackerel (and Pacific sardine) typically occur every third year, necessitating a three-year cycle for the Coastal Pelagic Species Stock Assessment Review (STAR) process, i.e., based on this schedule, the next full assessment of Pacific mackerel would be in 2012, with updated assessments occurring in interim years (see section 3.2 and PFMC 2009).

11.2 Monitored Species

The monitored species category of the CPS FMP includes northern anchovy, jack mackerel, and market squid.

11.2.1 Northern Anchovy

The most recent complete assessment for northern anchovy was described in Jacobson *et al.* (1995). California landings of northern anchovy began to increase in 1964, peaking in 1975 at 143,799 mt. After 1975, landings declined. From 1983 to 1999, landings did not exceed 6,000 mt per year until 2000. California landings of northern anchovy reported by Pacific coast Fisheries Information Network (PacFIN) totaled 11,752 mt in 2000; 9,187 mt in 2001; 4,650 mt in 2002; 1,676 mt in 2003; 6,877 mt in 2004; 68 mt in 2005; 12,788 mt in 2006 (mostly caught in the Monterey area), and 12,116 mt in 2007. There are no reported landings of northern anchovy in Oregon from 1981 through 2001, with 3.1 mt reported in 2002; 39 mt in 2003; 13 mt in 2004; 68 mt in 2005, 9 mt in 2006, and 5 mt in 2007. Washington reported about 42 mt in 1988, but didn't land more until 2003 when 214 mt was landed; no landings occurred from 2004 through 2006. In 2007 148 mt were landed. Through the 1970s and early 1980s, Mexican landings increased, peaking at 258,700 mt in 1981 (Table 18). Mexican landings decreased to less than 2,324 mt per year during the early 1990s, with a spike of 17,772 mt in 1995, primarily during the months of September through November. Catches in Ensenada decreased to 4,168 mt in 1996; and remained at less than 3,500 mt through 2003. Anchovy landings in Ensenada increased to 5,604 in 2005; however, no landings were reported (or were not available) for 2002, 2004 or 2006. In 2007, reported anchovy landings from Ensenada were not reported.

11.2.2 Jack Mackerel

Until 1999, jack mackerel were managed under the Council's groundfish FMP. Jack mackerel are now a monitored species under the CPS FMP. There is no evidence of significant exploitation of this species on the Pacific coast of North America, and accordingly, there have not been regular stock assessments or efforts to collect biological information. Management efforts to collect fishery-dependent age composition data, such as the CDFG Port Sampling Program, are in place for the two actively managed CPS (Pacific sardine and Pacific mackerel), but not for jack mackerel, aside from samples taken prior to 1995. Previous discussions of jack mackerel, such as in the groundfish FMP, were brief:

> Available data indicate that the current, nearly un-used spawning biomass is about one million mt, the natural mortality rate is in the range of 0.1 to 0.2, a fishery located north of 39° N latitude would harvest fish that are mostly older than age 16, and the long-term potential yield for this age range is 19,000 mt. The [Council's Groundfish Management Team] recommends continuation of the 52,600 mt ABC on the basis of a constant exploitation rate (equal to natural mortality) applied to estimates of current biomass of ages 16 and over. Biomass and short-term yield are expected to slowly decline under this level of exploitation. If this level of exploitation reduces long-term biomass to approximately 30% to 50% of the current biomass, the long-term average yields for this age range would be near 19,000 mt. The GMT recommended close tracking of this fishery and the age composition of the harvested fish, particularly if catches are begun outside the exclusive economic zone. (PFMC, 1998.)

Currently, most landings of jack mackerel are incidental to Pacific sardine and Pacific mackerel in California; however, pure landings do occur sporadically. In California, CDFG landing receipts for jack mackerel totaled 1,269 mt in 2000, 3,624 mt in 2001(these may be somewhat over-reported – the jump in jack mackerel landings in 2001 coincided with an early closure of the Pacific mackerel HG), 1,006 mt in 2002, dropped to only 189 mt in 2003, 1,199 mt in 2004, 253 mt in 2005, 1,499 mt in 2006, and 1,065 in 2007. Landings of jack mackerel in the California Pelagic Wetfish fishery through the decade of the 1990s reached a maximum of 5,878 mt in 1992, and averaged under 1,900 mt over 1990-2000. During the previous decade, California landings ranged from a high of 25,984 mt in 1982 to a low of 9,210 mt in 1985.

Oregon reported 161 mt in 2000, 183 mt in 2001, 9 mt in 2002, 74 mt in 2003, and 126 mt in 2004, 70 mt in 2005, 5 mt in 2006, and 8 mt in 2007. Washington reported 11.5 mt in 2002, 1.8 mt in 2003, and none in 2004, 2005, or 2006.

Mason (2001) concluded that spawning biomass estimates of the past were inadequate. Anecdotal evidence suggests that the spawning biomass may be large in California waters, but test fishing found the adult fish too scattered for economical harvest. Most of the contemporary catch is in small aggregations of young fish along rocky shores, or schooling with Pacific sardines or Pacific mackerel.

11.2.3 Market Squid

The CDFG is currently monitoring the market squid fishery through a state-based management plan including an annual landings cap and various spatial/temporal constraints, such as weekend closures and the establishment of marine protected areas (CDFG 2005). In addition, the Egg Escapement method and simulation modeling currently serve as informal assessment tools (see Appendix 3), within a research context only, to evaluate population dynamics and biological reference points (say MSY-related) regarding this species. Although it is presumed that market squid would be exempt from new ACL and AM provisions due to its short life cycle, the fishery control rules currently in place under the MSFMP, including a restricted access program which limits fishery participation, as well as the expansion of marine protected areas in California to protect spawning areas are thought to preclude the need for active management. However, if fishery operations change substantially (e.g., spatially expand, harvest high amounts of immature squid, etc.) in the future, additional management measures may be required.

Currently, limited information is available on market squid population dynamics, and data on its historical and current levels of absolute biomass are unavailable. A STAR Panel was convened in May 2001 to evaluate assessment methods for use in the management of the squid fishery and to assess the appropriateness of defining MSY for this species. Preliminary attempts to estimate biological reference points (e.g., MSY, FMSY, and BMSY) from surplus production models were unsuccessful. In view of the difficulties in determining traditional estimates of MSY for market squid, and given new, albeit limited, information on reproductive biology was available, the STAR Panel focused attention on reference points based on "egg escapement" and its related proxies, such as F. Egg escapement is defined here as the proportion of a female squid's potential lifetime fecundity is spawned, on average, before being harvested in the fishery. An Egg Escapement method (see Appendix) based on conventional yield and spawning biomass "per recruit" theories was fully developed by the Stock Assessment Team and the STAR Panel and subsequently, supported by the SSC, the CPSMT, and the CPSAS.

In practical terms, the Egg Escapement approach can be used to evaluate the effects of fishing mortality (F) on the spawning potential of the stock, and in particular to examine the relation between the stock's reproductive output and potential levels of fishing mortality that results in MSY (FMSY). However, it is important to note that this approach does not provide estimates of historical or current total biomass and thus, a definitive yield (i.e., quota or ABC) cannot be determined at this time. Ultimately, the Egg Escapement method can be used to assess whether the fleet is fishing above or below an a priori determination of sustainable exploitation, and in this context can be used as an effective management tool.

The STAR Panel provided general recommendations regarding analytical methods (i.e., the Egg Escapement method) and left determination of specific model configurations and other management-related parameters to the CPSMT. In this context, the CPSMT provided guidance concerning four critical areas of the Egg Escapement method, which were necessary to develop a pragmatic framework for monitoring/managing this species in the future, (1) selection of a "preferred" model scenario; (2) selection of a "threshold" level of egg escapement that can be considered a warning flag when tracking the status of the population; (3) fishery operations in (and after) El Niño/Southern Oscillation (ENSO) events; and finally, (4) important management-related constraints. Readers interested in details regarding assessment methods, STAR-related discussion and conclusions, and CPSMT decisions should refer to papers presented in Appendix 3 of the PFMC (2002).

Data collection programs and subsequent laboratory analysis has continued to the present in attempts to complement baseline information that served as the foundation for developing the Egg Escapement method described above. That is, as generally discussed in previous CPS-related documents [e.g., Appendix 3 of the PFMC (2002)] further work surrounding the Egg Escapement assessment approach has addressed the following: (1) collecting much needed samples from the fisheries to bolster the original source of reproductive data that was relied upon initially when developing the overall Egg Escapement method: additional sample data now span from 1999 to 2005; (2) critically evaluating spatial/temporal patterns of the overall fishery through stratified sampling (spatially and temporally) and subsequent analysis including data from 1999 to 2005; (3) in concert with the CPSMT, preparing preliminary analysis-related schedules that could be accommodated within the Council forum and meet the stipulations required for 'monitored' species (also see Section 6.1.1); and (4) conducting simulation modeling to further examine the relationship between critical biological reference points (i.e., 'threshold' levels) and absolute levels of squid population abundance off southern California–results from this research were presented in a working paper distributed (via CPSMT discussions) in the fall of 2008.

To date, preliminary analyses, including estimates of fishing mortality, egg escapement, and abundance estimates have been conducted on a regional/quarterly basis for data from 1999-2006. Furthermore, sensitivity analyses based on varying levels of influential (assumed) parameters, namely natural mortality and egg-laying rates, have also been completed for the same time period. Finally, simulation modeling has been performed to examine levels of fishing mortality and proportional egg escapement (eggs-per-recruit, relative to a maximum value, profiled across levels of fishing mortality) that are most likely to be sustainable, i.e., produce levels of recruitment that sustain long-term population abundance. Preliminary results from these analyses were presented to the CPSMT in fall 2006, and a working paper was submitted to the CPSMT for review in fall 2008 (see Section 4.3.4).

11.2.3.1 California's Market Squid Fishery

In 2001, legislation transferred the authority for management of the market squid fishery to the California Fish and Game Commission (Commission). Legislation required that the Commission adopt a market squid fishery management plan and regulations to protect and manage the squid resource. In August and December of 2004, the Commission adopted the Market Squid Fishery Management Plan (MSFMP), the environmental documentation, and the implementing regulations, which went into effect on March 28, 2005, just prior to the start of the 2005/2006 fishing season which started April 1.

The goals of the MSFMP are to provide a framework that will be responsive to environmental and socioeconomic changes and to ensure long term resource conservation and sustainability. The tools implemented to accomplish these goals include: (1) setting a seasonal catch limit of 107,047 mt (118,000 short tons) to prevent the fishery from over-expanding, (2) maintaining monitoring programs designed to evaluate the impact of the fishery on the resource, (3) continuing weekend closures that provide for periods of uninterrupted spawning, (4) continuing gear regulations regarding light shields and wattage used to attract squid, (5) establishing a restricted access program that includes provisions for initial entry into the fleet, permit types, permit fees, and permit transferability that produces a moderately productive and specialized fleet, and (6) creating a seabird closure restricting the use of attracting lights for commercial purposes in any waters of the Gulf of the Farallones National Marine Sanctuary. Under this framework, the MSFMP provides the Commission specific guidelines for making management decisions. The Commission has the ability to react quickly to changes in the market squid population off California and implement management strategies without the need for a full plan amendment. The MSFMP framework structure was also designed achieve the goals and objectives of the Marine Life Management Act and to be consistent with the management outlined in CPS FMP Amendment 10.

In 2008, the market squid fishery was California's second largest fishery in the state, with landings estimated at 38,100 mt. This is 23 percent less than in 2007 (49,801 mt) and 68 percent less than the record high set in 2000 (118,827 mt). The total ex-vessel value dropped from $29.1 million in 2007 to $26.5 million in 2008. The ex-vessel price per ton of market squid appears to have increased with three prices accounting for 90% of the 2008 landings: $661/t (44%), $771/t (36%), and $716/t (10%). The fishing permit season for market squid extends from 1 April through 31 March of the following year. During the 2008–09 season (as opposed to the 2008 calendar year) 34,050 mt were landed, a 26 percent decrease from the 2007–08 season (45,935 mt). There was an increase in catch in the northern fishery near Monterey with 474 mt landed. However, squid landings in northern California have remained low since the 2006-07 season probably the result of unusual environmental conditions observed during the past several years and the lingering La Niña Southern Oscillation event. In contrast, most of the market squid was taken from the southern California region during the season, accounting for 98.6 percent of the total catch (33,576 mt), similar to the previous two seasons, 2006-07 (98.5 percent) and 2007-08 (99.9 percent). This regional domination of catch last occurred during the 1998-99 and 1999–00 seasons (99.7 percent and 99.8 percent respectively) and was also influenced by a La Niña event

11.3 References

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12.0 EMERGING ISSUES

This section describes current and future issues that may need to be addressed relative to FMP species and management in general.

12.1 Pacific Sardine

12.1.1 Allocation

Beginning with the 2006 season, the Pacific sardine fishery has operated under a seasonal allocation framework adopted as Amendment 11 to the CPS FMP (see Section 2). When the Council approved Amendment 11, they scheduled a formal review of the allocation formula to provide a comparison of the performance of the fishery to the projections used to evaluate the adopted allocation scheme. Originally scheduled for June 2008, this review has been postponed until the September 2009 Council meeting, in part, to include data from the 2008 fishery, the first year under Amendment 11 that the fishery was constrained by the harvest guideline.

12.1.2 Exempted Fishing Permits and Aerial Survey

At its March 2009 meeting, the Council reviewed proposals for aerial survey research on Pacific sardine to be conducted under an exempted fishing permit with the goal of developing a new index of sardine abundance. The Council adopted the proposals for public review and recommended that they ultimately combine into a single project managed under its own collaborative team guided by a scientifically sound survey design. Sardine industry representatives and scientists have since collaborated on a single proposal that is posted on the Council web site. The Council has scheduled a stock assessment review panel May 4-8 in La Jolla, California to, in part, review survey methodologies proposed for 2009. The Council plans to consider adopting its final recommendations for 2009 exempted fishing permits at its June 13-18, 2009 meeting in Spokane, Washington.

The Council heard preliminary testimony that the survey proposals will likely require an increase in the 2009 research set-aside from 1,200 mt to 2,400 mt in order to conduct the survey work from Cape Flattery, Washington to Monterey Bay, California. Therefore the Council has recommended that National Marine Fisheries Service (NMFS) conduct the necessary rulemaking to increase the research set-aside to 2,400 mt by reducing the directed sardine fishery in the second and third fishing periods. The Council continues to support limiting use of the research set-aside to the second allocation period (July 1 through September 14, 2009) with any unused portion of the research set-aside to be transferred to the third period of the directed fishery.

The Council understands that there is minimal time available for rulemaking before the July 1, 2009 start of the second period. Should this rulemaking effort fail, the Council intends to continue its consideration of an exempted fishing permit for 2009 Pacific sardine research under the existing management regime and the initial 1,200 mt research set-aside. Under this scenario, the scope of the proposed research would need to be scaled back.

12.2 Pacific Mackerel

Pacific mackerel continue to be actively managed although recent landings have been well below the ABC. Pacific mackerel are currently undergoing the full assessment process. The assessment will be reviewed by the SSC and the CPS advisory bodies at the June 2009 Council meeting. Emerging issues for Pacific mackerel will be updated for the final version of this document.

12.3 Management Issues

Emerging management issues include implementation of new provisions is the reauthorized MSA, ecosystem-based fishery management, and international CPS fisheries.

12.3.1 Implementation of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006.

Although not unique to CPS management, implementation of new provisions in the MSA as reauthorized in 2007 will involve a reevaluation and potentially amendment of the CPS FMP to incorporate mechanisms to prevent overfishing such as annual catch limits and accountability measures. In accordance NMFS has revised is guidance on preventing overfishing under MSA National Standard 1.

Precautionary harvest control rules exist for Pacific sardine and Pacific mackerel which provide a solid foundation for the implementation of new fishery management provisions such as OFLs and ACLs. The CPS FMP's monitored stocks are either exempt from the new requirements because of their short life-cycle (market squid) or are currently harvested at relatively low levels (anchovy, jack mackerel). ACLs for monitored stocks may be appropriately implemented with greater flexibility but greater precaution than the actively managed species because they are assessed with less frequency. Scoping comments on amending the Council's Coastal Pelagic Species Fishery Management Plan for NS1 guidelines included recommendations to: assess scientific and management uncertainty, include krill and other forage species as ecosystem components of the FMP, improve accountability of live bait harvest and overall fishery discards, and to improve inseason harvest reporting. Council staff is preparing a scoping summary and the Council is scheduled to review preliminary CPS FMP amendment alternatives in November 2009.

12.3.2 Ecosystem Based Fishery Management

In November 2006, the Pacific Council initiated development of an EFMP. The EFMP is intended to serve as an "umbrella" plan over the four existing FMPs, helping with coastwide research planning and policy guidance and creating a framework for status reports on the health of the CCLME. The plan envisioned by the Pacific Council would not replace the existing FMPs, but would advance fishery management under these FMPs by introducing new science and new authorities to the current Pacific Council process.

The Pacific Council is currently pursuing the necessary funds to develop an EFMP and made preliminary recommendations on forming a plan development team that would include both scientists and industry representatives familiar with CPS.

12.4 International CPS Fisheries

There has been interest in coastwide management for the Pacific sardine fishery, which would entail a more consistent forum for discussion between the U.S. and Mexico. Continued U.S.-Mexico bilateral meetings indicate willingness from Mexico to continue scientific data exchange and cooperation on research, and engage in discussions of coordinated management. The Trinational Sardine Forum has been a good venue for international exchange. Mexico is tentatively scheduled to host the 2009 Trinational Sardine Forum.

13.0 RESEARCH AND DATA NEEDS

Several recent developments highlight the need to enhance current assessment procedures in order to meet the requirements of the FMP. These include (1) the development of a high-volume fishery for Pacific sardine in Oregon and Washington; (2) increasing recognition of the importance of CPS as principal forage for many salmon and groundfish stocks that are currently at low abundance levels; (3) the importance of CPS biomass estimates to the Council's annual determination of allowable coastal pelagic harvests; and (4) the need to monitor status of the market squid stock using data-intensive techniques. A pressing need exists for stock assessments that accurately reflect the reproductive characteristics of CPS stocks throughout their geographic range and for additional stock assessment personnel in NMFS and the three Pacific coast states to carry out these assessments.

In addition to research and data needs presented in this section, refer to the Council's comprehensive research and data needs document last revised in December 2008. The document includes a chapter dedicated to CPS matter and can be obtained by contacting the Council office or by visiting the Council web page. Also, the latest Pacific sardine and Pacific mackerel assessments and STAR Panel reports include detailed, species-specific, research and data needs.

The highest priority research and data needs for CPS are:

- Gain more information about the status of CPS resources in the north using egg pumps, trawl and sonar surveys, and spotter planes.
- Develop a coastwide (Mexico to British Columbia) synoptic survey of sardine and Pacific mackerel biomass; i.e., coordinate a coastwide sampling effort (during a specified time period) to reduce "double-counting" caused by migration.
- Develop a formal review process for the harvest control rules for Pacific sardine and Pacific mackerel. Currently this review is not part of the stock assessment process.
- Increase fishery sampling for age structure (Pacific sardine and Pacific mackerel) in the northern and southern end of the range. Establish a program of port sample data exchange with Mexican scientists.
- Evaluate the role of CPS resources in the ecosystem, the influence of climatic/oceanographic conditions on CPS, and define predatory-prey relationships.
- Routinely, collect detailed cost-earnings data to facilitate analyses for long-term changes to the sardine allocation structure.

13.1 Pacific Sardine

High priority research and data needs for Pacific sardine include:

1) gaining better information about Pacific sardine status through annual coastwide surveys that include ichthyoplankton, hydroacoustic, and trawl sampling;
2) standardizing fishery-dependent data collection among agencies, and improving exchange of raw data or monthly summaries for stock assessments;
3) obtaining more fishery-dependent and fishery-independent data from northern Baja California, México;

4) further refinement of ageing methods and improved ageing error estimates through a workshop of all production readers from the respective agencies;
5) further developing methods (e.g. otolith microchemistry, genetic, morphometric, temperature-at-catch analyses) to improve our knowledge of sardine stock structure. If sardine captured in Ensenada and San Pedro represent a mixture of the southern and northern stocks, then objective criteria should be applied to the catch and biological data from these areas;
6) exploring environmental covariates (e.g. SST, wind stress) to inform the assessment model.

13.2 Pacific Mackerel

California's Pacific mackerel fishery has been sampled by CDFG for age composition and size-at-age since the late-1920s. The current stock assessment model incorporates a complete time series of landings and age composition data from 1929 onward. Ensenada (Baja California) landings have rivaled California's over the past decade, however, no biological information is readily available from Mexico's fishery. Landings are accounted for in the assessment, but size and age composition are assumed to be similar to the San Pedro, California fishery. Like sardine, there is a need to establish a program of port sample data exchange with Mexican scientists (INP, Ensenada) to fill this major gap in the stock assessment.

Fishery-independent survey data for measuring changes in mackerel recruitment and spawning biomass are generally lacking. The current CalCOFI sampling pattern provides information on mackerel egg distributions in the Southern California Bight, the extreme northern end of the spawning area. Mexican scientists have conducted a number of egg and larval surveys off of Baja California in recent years (e.g., IMECOCAL program). Access to these data would enable us to continue the historical CalCOFI time series, which began in 1951. This information could be directly incorporated into the assessment model. Night-light surveys for newly recruited Pacific mackerel should be re-instituted in the Southern California Bight. Surveys following protocols employed during CDFG Sea Survey cruises (1950-1988) could allow splining the new recruitment data set to the historical time series. The new time series would represent the only recruitment index in the mackerel stock assessment and would strengthen the ability to accurately forecast age zero and total stock abundance for each coming fishing season.

Pacific mackerel biomass has been declining since the early 1980s, but recent El Niño events have concurrently extended their northern range to British Columbia. Pacific mackerel are caught incidentally in the Pacific whiting and salmon troll fisheries. Pacific mackerel are regularly caught in triennial survey trawls off the Pacific Northwest. A simple reporting system is needed to document incidental take of mackerel in fisheries to the north. Presence-absence information may allow us to detect southward movement or further decreases in biomass.

13.3 Market Squid

Currently, there exists limited understanding of market squid population dynamics, which has hampered assessing the status (health) of this valuable marine resource found off California. General information concerning important stock- and fishery-related parameters suggests maximum age is less than one year, and the average age of squid harvested is roughly six to seven months. Under the proposed National Standard 1 Guidelines, market squid will not be considered for updated ACL and AM provisions due to the short lifespan. However, in this context, the CPSMT advises that current monitoring programs continue for this species, including tracking fishery landings, collecting reproductive-related data from the fishery, and obtaining fishermen-related logbook information.

Although some information exists on coastwide squid distribution and abundance from fishery-independent midwater and bottom trawl surveys largely aimed at assessing other finfish species, there is no reliable measure of annual recruitment success beyond information obtained from the fishery. Given fishing activity generally occurs only on shallow-water spawning aggregations, it is unclear how fluctuations in landings are related to actual population abundance and/or availability to the fishery itself. That is, the general consensus from the scientific and fishery management communities is that squid do inhabit, to some degree, greater depths than fished by the fleet, however, species' range suppositions remain largely qualitative at this point in time. Better information on the extent and distribution of spawning grounds along the U.S. Pacific coast is needed, particularly, in deep water and areas north of central California. Additionally, fecundity, egg survival, and paralarvae density estimates are needed from different spawning habitats in nearshore areas and oceanographic conditions associated with the population. Furthermore, information describing mechanisms and patterns of dispersal of adults, as well as paralarvae, along the coast is required to clarify how local impacts might be mitigated by recruitment from other areas inhabited by this short-lived species.

Although some fishery effort information is now being collected with a logbook program in the State of California, the continuation of this program is essential to provide estimates of relative abundance (e.g., CPUE time series) in the future. Continuation and/or establishment of annual surveys using midwater trawls, bottom trawls, remotely operated vehicles (ROVs), and satellite and aerial surveys would also provide useful information for developing alternative indices of abundance other than those derived from logbook data.

Potential impacts to EFH-related issues would most likely arise in concert with fishing activity by the purse-seine fleet on spawning aggregations in shallow water when gear potentially makes contact with the sea floor (see Section 6.1.1). In this regard, there are two areas of potential concern that have not been quantified to date: (1) damage to substrate where eggs may be deposited; and (2) damage or mortality to egg masses from contact with the gear itself. The CDFG is currently working on research methods to evaluate egg stage of squid egg capsules collected in fishery landings to determine how long the egg capsule had been laid before being taken by the fishery.

Currently, market squid fecundity estimates, based on the Egg Escapement method (see Section 11.2.3), are used to assess the status of the stock and evaluate biological reference points, such as MSY. The Egg Escapement method is based on several assumptions, (1) immature squid are not harvested; (2) potential fecundity and standing stock of eggs are accurately measured; (3) life history parameters are accurately estimated (e.g., natural mortality, egg laying rate); and (4) instantaneous fishing mortality (F) translates into meaningful management units. Given the inherent uncertainty associated with these assumptions, it is imperative that each receive further scrutiny in the future, through continuation of rigorous sampling programs in the field that generate representative data for analysis purposes, as well as further histological evaluations in the laboratory and more detailed assessment-related work. For example, data collected through the CDFG port sampling program currently in place will provide information on the age and maturity stages of harvested squid. Further, laboratory work concerning general mantle condition, especially the rate of mantle 'thinning,' will likely benefit the current understanding of squid life history and subsequently, help improve the overall assessment of this species. Finally, other biological-related parameters that are currently poorly understood generally surround spawning and senescence (e.g., life history strategies concerning spawning frequency, the duration of time spent on spawning grounds, and the period of time from maturation to death).

13.4 Live Bait Fishery

Although tonnage of CPS and market squid taken in the live bait fishery is minimal compared with volume taken in the commercial fishery, better estimates of live bait landings and sales of sardine, anchovy and market squid are essential as it pertains to estimates of the overall economic value of these fisheries. Outdated estimates have previously shown that the value of the live bait fishery for sardine has equaled that of the commercial catch. In the case of market squid, there is no documentation of the dramatic expansion of live bait sales in southern California made by commercial light vessels in recent years.

The live bait fishery supplies product for several recreational fisheries along the Pacific coast, primarily in southern California, but as far north as Eureka. Live bait catch is generally comprised of both Pacific sardine and northern anchovy; the predominant species depends on biomass levels and local availability. Recent landings estimates range between 5,000 mt and 8,000 mt annually statewide, with effort increasing in summer months. However, these estimates are based only on logbooks provided by a limited number of bait haulers, and estimates provided by the CPFV industry. Since the sale of live bait in California is not permitted in a manner similar to that used for the commercial sale of CPS, estimates of tonnage and value are imprecise. Therefore, no estimates of volume or value for the sale of market squid for live bait are available at this time. However, the CDFG will reexamine reporting requirements and data needs to better estimate landings and value.

13.5 Socioeconomic Data

Economic analyses of management actions affecting coastal pelagic fisheries requires detailed, representative cost and earnings data for the sardine harvesters and processors making up each fishery sector. These data are used to evaluate the impact on net economic benefits in the commercial fisheries associated with a proposed management action. Experience with the long-term allocation of the Pacific HG emphasizes this need, and moreover underscores the necessity to collect these data on a routine basis. Collecting such data as needed to address an issue at hand often makes them suspect in a number of regards, particularly in terms of strategic bias.

Under Ecosystem-based fishery conservation and management we will have to expand the economic analyses to evaluate changes in yields from a number of different species. Such an undertaking inherently involves finding a socially optimum balance among the variety of ecosystem services CPS are capable of generating. The tradeoffs of interest are between benefits CPS provide as: (1) directed harvests; (2) food for higher trophic level commercial predators; (3) food for recreationally important predators; and, (4) food for non-commercial but ecologically important predators. The economic data required to evaluate tradeoffs involving species in categories (3) and (4) will entail the development of non-market data acquisition and valuation techniques.

13.5.1 Commercial Fisheries

Economic analyses of management actions effecting coastal pelagic fisheries require basic cost and earnings data for the sardine harvesters and processors making up each fishery sector. Experience with the long-term allocation of the Pacific HG emphasizes this need, and moreover underscores the necessity to collect these data on a routine basis. Collecting such data when needed to address an issue at hand makes them suspect in a number of regards particularly in terms of strategic bias.

A step in this direction would be a comprehensive CPS vessel logbook program for Washington, Oregon, and California vessels. Such a program will serve not only as a means of collecting biological and stock assessment related data, but also vessel-trip-level fishery economic data (e.g., fuel cost and consumption, number of crew, cost of provisions) across all CPS fishery operations. Moreover, the logbook program would want to include all fishery operations in which these vessels engage to be able to fully evaluate their economic opportunities. To get the full picture in terms of fleet economics the at sea data would have to be supplemented with annual expenditure data, and other data that is not trip-specific (e.g. interest payments). These data will have to be collected separately to obtain comprehensive economic data for harvesting vessels.

A parallel effort will need to be taken with regard to processors. To be able to fully evaluate the economic impacts of proposed management actions detailed, representative cost and earnings data for west coast sardine processors will also be needed on a routine basis. This will entail periodic surveys of CPS processors to collect representative economic data on their processing operations.

13.5.2 Non-market Values

Economic analyses of conservation and management actions affecting the availability of sardines as forage for non-commercial predators will entail developing a framework and compiling the data to estimate the non-market values of recreationally and ecologically important sardine predators. These nonmarket values can then be used to impute the economic value (shadow prices) of Pacific sardine as forage for these predators.

13.6 Observer Program

Bycatch in the California contingent of the CPS fishery has been qualitatively monitored by the CDFG's dockside monitoring program since the mid-1980s (Sweetnam and Laughlin, Pers. Comm., 2005). CDFG only gives qualitative descriptions of bycatch meaning they do not document the amount or quantity of bycatch but rather only document the species or type of bycatch encountered at the fish processing plant. In order to confirm bycatch rates derived from CDFG's dock-side sampling, NMFS started a pilot observer program in July 2004 on the California purse seine fishing vessels landing CPS in the LE fishery. The pilot observer program's main focus is to gather data on total catch and bycatch, and on interactions between their fishing gear and protected species such as marine mammals, sea turtles, and sea birds. See Section 6.1.1 for additional information and preliminary results from this program.

13.7 References

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APPENDICES

The following appendices will be added to this document when it is published in its final draft following the June 2009 Council meeting:

Appendix 1: Assessment of the Pacific sardine resource in 2008 for U.S. management in 2009.

Appendix 2: Pacific mackerel assessment for U.S. management in the 2009-10 fishing year.

Appendix 3: Market Squid Population Modeling and Assessment.

TABLE 2-1. HISTORY OF COUNCIL ACTIONS

- The Pacific Fishery Management Council (Council) initiated development of the fishery management plan (FMP) for Northern anchovy in January of 1977. The FMP was submitted to the U.S. Secretary of Commerce (Secretary) in June of 1978. Regulations implementing the FMP were published in the *Federal Register* on September 13, 1978 (43*FR*40868). Subsequently, the Council has considered seven amendments.

- The first amendment changed the method of specifying the domestic annual harvest for Northern anchovy and added a requirement for an estimate of domestic processing capacity and expected annual level of domestic processing. Approval for this amendment was published in the *Federal Register* on July 18, 1979 (44*FR*41806).

- The second amendment, which became effective on February 5, 1982, was published in the *Federal Register* on January 6, 1982 (47*FR*629). The purpose of this amendment was to increase the domestic fishing fleet's opportunity to harvest the entire optimum yield (OY) of Northern anchovy from the U.S. Exclusive Economic Zone (EEZ) by releasing, inseason, unutilized portions of the Northern quota.

- During the spring of 1982, the Council considered a third amendment that divided the quota for Northern anchovy into two halves and made release of the second half conditional on the results of a mid-season review of the status of the stock. The methods proposed for the mid-season assessment were considered too complex to implement, and the amendment was not approved.

- The fourth amendment, which had two parts, was published in the *Federal Register* on August 2, 1983 (48*FR*34963) and became effective on August 13, 1983. The first part abolished the five inch size limit in the commercial fishery and established a minimum mesh size of 5/8 inch for Northern anchovy. The mesh size requirement did not become effective until April 1986 in order to give the fleet additional time to comply without undue economic hardship. The second part established a mid-season quota evaluation that was simpler in design than the method proposed in Amendment 3.

- The fifth amendment in 1983 incorporated advances in scientific information concerning the size and potential yield of the central subpopulation of Northern anchovy. Additionally, the fifth amendment included changes to a variety of other management measures. Two or more alternative actions were considered in each of seven general categories; (1) OY and harvest quotas; (2) season closures; (3) area closures; (4) quota allocation between areas; (5) the reduction quota reserve; (6) minimum fish size or mesh size; and (7) foreign fishing and joint venture regulations. The alternatives for the fifth amendment were reviewed by the Council during 1983. The final rule was published in the *Federal Register* on March 14, 1984 (49*FR*9572).

- In 1990, the sixth amendment implemented a definition of overfishing for Northern anchovy consistent with National Standard 7, and addresses vessel safety (56*FR*15299, April 16, 1991).

- The Council began developing the seventh amendment as a new FMP for coastal pelagic species (CPS) on a motion from National Marine Fisheries Service (NMFS) and California in 1990. A complete draft was available in November of 1993, but the Council suspended further work, because NMFS withdrew support due to budget constraints. In July of 1994, the Council decided to proceed with the plan through the public comment period. NMFS agreed with the decision on the condition that the Council also consider the options of dropping or amending the anchovy FMP. Thus, four principal options were considered for managing CPS (1) drop the anchovy FMP (no Federal or Council involvement in CPS); (2) continue with the existing FMP for anchovy (status quo); (3) amend the FMP for Northern anchovy; and (4) implement an FMP for the entire CPS fishery. In March of 1995, the Council decided to proceed with the FMP for CPS. Final action was postponed until June 1995 when the Council adopted a draft plan that had been revised to address comments provided by NMFS and the SSC. Amendment 7 was submitted to the Secretary, but rejected by NMFS, Southwest Region, as being inconsistent with National Standard 7. NMFS announced its intention to drop the FMP for Northern anchovy (in addition to FMP=s other species) in the *Federal Register* on March 26, 1996 (61*FR*13148), but the action was never completed.

- Development of Amendment 8 began in June, 1997 when the Council directed the Coastal Pelagic Species Plan Development Team (CPSPDT) to amend the FMP for Northern anchovy to conform to the recently revised Magnuson-Stevens Fishery Conservation and Management Act and to expand the scope of the FMP to include the entire CPS fishery. Amendment 8 was partially approved by the U.S. Secretary of Commerce on June 10, 1999, and final regulations were published on December 15, 1999 (64*FR*69888). The FMP was implemented on January 1, 2000.

- At its meeting in June 1999, the Council directed its Coastal Pelagic Species Management Team (CPSMT) to recommend appropriate revisions to the FMP and report to the Council the following September. A public meeting of the CPSMT was held in La Jolla, California, on August 3 and 4, 1999, and August 24, 1999, and a meeting was held between the CPSMT and the Coastal Pelagic Species Advisory Subpanel (CPSAS) on August 24, 1999. At its September 1999 meeting, the Council gave further direction to the CPSMT regarding maximum sustainable yield (MSY) for squid. At its March 2000 meeting, the Council asked the CPSMT for a more thorough analysis of the alternatives proposed for establishing MSY for squid and for bycatch. At a public meeting in La Jolla, California, on April 20 and 21, 2000, the CPSMT reviewed comments from the Council, the Council's Scientific and Statistical Committee (SSC) and prepared additional material for establishing MSY for squid based on spawning area.

- The Council distributed Amendment 9 for public review on July 27, 2000. At its September 2000 meeting, the Council reviewed written comments, received comments from its advisory bodies, and heard public comments, and decided to submit only two provisions for Secretarial review. Based on testimony concerning MSY for squid, the Council decided to include in Amendment 9 only the bycatch provision and a provision providing a framework to ensure that Indian fishing rights are implemented according to treaties between the U.S. and the specific tribes. Since implementation of the FMP, the CPS fishery has expanded to Oregon and Washington. As a result, the FMP must discuss Indian fishing rights in these areas. These rights were not included in the FMP; and the

Council decided to address this issue in Amendment 9. The Council decided to conduct further analysis of the squid resource and will prepare a separate amendment that addresses OY and MSY for squid.

- The U.S. Secretary of Commerce approved Amendment 9 on March 22, 2001.

- In April 2001, the Council adopted the capacity goal and transferability provisions recommended by the CPSMT for inclusion in Amendment 10. The Council directed the CPSMT to develop an amendment to the CPS FMP that will include the capacity goal, provisions for permit transferability, a process for monitoring fleet capacity relative to the goal, and a framework for modifying transferability provisions as warranted by increases or decreases in fleet capacity. The amendment will also address determination of OY and MSY for market squid.

- In November 2001, the Council reviewed the findings of the market squid stock assessment review (STAR) workshop and endorsed the egg escapement approach as a proxy for squid MSY, as recommended by the market squid STAR Panel and CPSMT.

- In March 2002, the Council adopted draft Amendment 10 to the CPS FMP for public review.

- In June 2002, the Council adopted Amendment 10 to the CPS FMP.

- December 30, 2002, the Secretary of Commerce approved Amendment 10. On January 27, 2003 NMFS issued the final rule and regulations for implementing Amendment 10.

- September 2002, the Council requested NMFS take emergency action to reallocate the unharvested portion of the harvest guideline (HG) prior to October 1. The Council believed this action would minimize negative economic impacts in the northern fishery without causing market disruptions in the southern fishery. On September 26, 2002, through an emergency rule, NMFS reallocated the remaining Pacific sardine HG and reopened the northern subarea fishery, which had been closed on September 14, 2002.

- September 2002, the CPSAS recommended the Council initiate a regulatory or FMP amendment and direct the CPSMT to prepare management alternatives for revising the sardine allocation framework. The Council directed the CPSMT to review CPSAS recommendations for revising the allocation framework. A public meeting of the CPSMT was held on October 8, 2002. The CPSMT discussed information needs and prospective analyses for developing allocation management alternatives.

- On October 30, 2002, the Council initiated a regulatory amendment to address allocation problems.

- The CPSMT met January 30-31, 2003 to analyze various alternatives for revising the allocation framework and developed recommendations for Council consideration.

- At the March 2003 Council meeting, the SSC and CPSAS reviewed analyses of the proposed management alternatives for sardine allocation. Based on the advisory body recommendations and public comment, the Council adopted five allocation management alternatives for public review.

- At the April 2003 Council meeting, the CPSAS reviewed the five management alternatives and developed recommendations for the Council. The Council took final action on the regulatory amendment. The proposed action adopted by the Council would (1) change the definition of subarea A and subarea B by moving the geographic boundary between the two areas from 35° 40' N latitude to 39° N latitude, (2) move the date when Pacific sardine that remains unharvested is reallocated to Subarea A and Subarea B from October 1 to September 1, (3) change the percentage of the unharvested sardine that is reallocated to Subarea A and Subarea B from 50 percent to both subareas to 20 percent to Subarea A and 80 percent to Subarea B, and (4) reallocate all unharvested sardine that remains on December 1 coastwide. The Council's intent is for this interim revision to the allocation framework be in effect for the 2003 and 2004 seasons. The allocation regime could be extended to 2005 if the 2005 HG were at least 90 percent of the 2003 HG.

- The regulatory amendment for allocation of the Pacific sardine HG was approved on August 29, 2003. The final rule implementing the regulatory amendment was published September 4, 2003 (68*FR*52523).

- At the November 2003 Council meeting, the Council adopted a HG of 122,747 metric tons (mt) for the 2004 Pacific sardine fishery, within an incidental catch allowance of up to 45 percent. This HG is based on a biomass estimate of 1,090,587 mt. Per the revised allocation framework, on January 1, the HG will be allocated 33 percent to the northern subarea and 66 percent to the southern subarea, with a subarea dividing line at Point Arena, CA. The final rule implementing the HG was published December 3, 2003 (68*FR*67638).

- At the June 2004 Council meeting, the Council adopted the following management measures for the July 2004-June 2005 Pacific mackerel fishery: 1) total fishery HG of 13,268 mt; 2) directed fishery guideline of 9,100 mt; and 3) set-aside for incidental catches of 4,168 mt and an incidental catch rate limit of 40 percent when mackerel are landed with other CPS species, except that up to one mt of Pacific mackerel can be landed without landing any other CPS. The Council also requested NMFS track utilization of the directed fishery guideline and advise the Council at the March 2005 meeting if additional action (e.g. a mop-up fishery) is warranted. Additionally, the Council initiated an amendment to the CPS FMP with the primary purpose of allocating the coastwide Pacific sardine HG. The Council discussed a schedule that included final Council action on the FMP amendment by June 2005, which would enable implementation by January 2006. To facilitate development of the amendment, the Council directed the CPSAS to draft a range of alternative sardine allocation scenarios. The Council also directed the CPSMT to formally review the CPS FMP issues raised by NMFS to identify issues that could be addressed through amendment to the CPS FMP and if they could be addressed in the short-term or would require more extensive time to complete.

- At the September 2004 Council meeting, the Council adopted STAR Panel reports for Pacific mackerel and Pacific sardine. New assessment methodologies will be used for management of the 2005 sardine fishery and the 2005-2006 Pacific mackerel fishery. Relative to the CPS FMP amendment process, the Council requested the CPSAS to narrow the current broad range of Pacific Sardine allocation alternatives for Council consideration at the November 2004 meeting. The Council received information from the CPSMT about their consideration of several FMP-related issues raised by NMFS, and directed Council staff to communicate to NMFS the Council plans for further review of CPS essential fish habitat (EFH).

- At the November 2004 Council meeting, the Council adopted a HG of 136,179 mt for the 2005 Pacific sardine fishery. This HG is based on a biomass estimate of 1.2 million mt. Per the FMP allocation framework, on January 1 the HG will be allocated 33 percent to the northern subarea and 66 percent to the southern subarea with a subarea dividing line at Point Arena, California. Additionally, the Council directed the CPSMT and staff to begin development of Amendment 11 to the CPS FMP to include alternatives for sardine allocation, as recommended by the CPSAS as well as two additional alternatives The Council anticipates reviewing the draft analyses and considering formal adoption of allocation alternatives at the April 2005 Council meeting.

- At the March 2005 Council meeting, the Council reviewed a progress update from NMFS Southwest Region on a proposed course of action for management of krill in the West Coast EEZ and National Marine Sanctuaries under the auspices of the CPS FMP. The Council approved a draft outline for an alternatives analysis.

- At the April 2005 Council meeting, the Council approved a range of alternatives for the allocation of Pacific sardine for further analysis and public review. After reviewing preliminary results on the range of alternatives approved for analysis in November 2004 and reports of the CPS advisory bodies, the Council eliminated two alternatives (Alternatives 2 and 5) from further consideration. The Council recommended that the CPSMT follow the advice of the SSC as they complete the analysis of allocation alternatives for public review.

- At the June 2005 Council meeting, the Council addressed three CPS matters, pacific mackerel HG and management measures, long term Pacific sardine allocation and CPS EFH.

  Regarding Pacific mackerel, the Council adopted the new assessment and the following management measures for the July 2005-June 2006 Pacific mackerel fishery: 1) total fishery HG of 17,419 mt; 2) directed fishery guideline of 13,419 mt; and 3) set-aside for incidental catches of 4,000 mt and an incidental catch rate limit of 40 percent, when mackerel are landed with other CPS, except that up to one mt of Pacific mackerel can be landed without landing any other CPS. The Council requested NMFS track utilization of the directed fishery guideline and advise the Council at the March 2006 meeting if release of the incidental set-aside is warranted.

Regarding Pacific sardine allocation, the Council took final action on a long-term allocation of the annual Pacific sardine HG. The Council approved a modified version of Alternative 3, which provides the following allocation formula for the non-tribal share of the HG:

1. A seasonal allocation structure with 35 percent of the HG to be allocated coastwide on January 1.
2. 40 percent of the HG, plus any portion not harvested from the initial allocation, to be reallocated coastwide on July 1.
3. On September 15 the remaining 25 percent of the HG, plus any portion not harvested from earlier allocations, to be reallocated coastwide.

The Council also recommended a review of the allocation formula in 2008.

The Council adopted the 2005 Stock Assessment Fishery Evaluation (SAFE) document as drafted by the CPSMT including the required review of CPS EFH. The Council recommended no changes to the existing definition of EFH because the CPSMT review identified no new information on which to base EFH modifications. The Council agreed with the research needs identified by the CPSMT in the 2005 SAFE and stressed the importance of coastwide sardine research and harvest policy review.

- At the November 2005 Council meeting, the Council adopted a Pacific sardine HG of 118,937 mt for the 2006 season to be managed under the terms of the allocation arrangements under Amendment 11.

  The Council also approved a range of krill fishing alternatives for public review and additional analysis, including a preliminary preferred alternative to identify krill as a prohibited species in the EEZ. The proposed krill management measures will be implemented as Amendment 12 to the CPS FMP. At the June 2005 Council meeting, the Council addressed three CPS matters, pacific mackerel HG and management measures, long term Pacific sardine allocation and CPS EFH.

- At the March 2006 Council meeting, the Council took final action adopting CPS FMP Amendment 12 to prohibit harvest of all species of krill in the U.S. EEZ. Additionally, the Council adopted an EFH designation for all species of krill that extends the length of the West Coast from the shoreline to the 1,000 fm isobath and to a depth of 400 meters. No habitat areas of particular concern were identified.

- At the June 2006 meeting, the Council adopted the new assessment model and the following management measures for the July 2006-June 2007 Pacific mackerel fishery: a total fishery HG of 19,845 mt, a directed fishery guideline of 13,845 mt; and a set-aside for incidental catches of 6,000 mt and an incidental catch rate limit of 40 percent when mackerel are landed with other CPS, except that up to one mt of Pacific mackerel can be landed without landing any other CPS.

- At the November 2006 meeting, the Council adopted a HG of 152,654 mt for the 2007 Pacific sardine fishery. This HG is based on a biomass estimate of 1.32 million mt. Per the FMP allocation framework adopted under Amendment 11, the Pacific sardine HG is allocated seasonally with 35 percent of the HG to be allocated coastwide January 1, 40 percent of the HG, plus any portion not harvested from the initial allocation reallocated coastwide July 1; and the remaining 25 percent of the HG, plus any portion not harvested from earlier allocations, to be reallocated coastwide September 15. The Council also recommended a 45 percent incidental catch rate be allowed for other CPS fisheries in the event that a seasonal allocation be taken before the end of an allocation period or the HG is taken before the end of the year.

Additionally, the Council reviewed the draft Terms of Reference for the CPS stock assessment process scheduled for 2007 and directed Council staff to revise the document as recommended by the CPSAS, the CPSMT, and the SSC and distribute it for public review. The Council is scheduled to approve a final document in March 2007 for use during the review of full assessments for Pacific mackerel and Pacific sardine in May and September, respectively.

- At the March 2007 Council meeting, the Council approved the final Terms of Reference for the 2007 CPS stock assessment process. The final document was posted on the Council website and distributed for use during the review of full assessments for Pacific mackerel and Pacific sardine May 1-3 and September 18-21 respectively.

- At the June 2007 Council meeting, he Council adopted the new assessment model and the following management measures for the July 2007-June 2008 Pacific mackerel fishery: an acceptable biological catch (ABC) for U.S. fisheries of 71,629 mt, a directed fishery HG of 40,000 mt, and in the event the directed fishery reaches 40,000 mt, the directed fishery will revert to an incidental-catch-only fishery with a 45 percent incidental catch allowance when Pacific mackerel are landed with other CPS, except that up to 1 mt of Pacific mackerel could be landed without landing any other CPS. The Council and NMFS will track the 2007-08 Pacific mackerel fishery and will recommend an in-season review of the mackerel season for the March 2008 Council meeting, if needed, with the possibility of re-opening the directed fishery as a routine action. Additionally, the Council directed Council staff to send a letter to the U.S. State Department requesting increased coordination with Mexico on the exchange of data for the improvement of international management of CPS.

- In November 2007, the Council adopted an ABC or total harvest guideline (HG) of 89,093 mt for the 2008 Pacific sardine fishery. This ABC is based on a biomass estimate of 832,706 mt and the harvest control rule in the coastal pelagic species (CPS) fishery management plan. The Council recommends 80,083 mt of the HG for the directed fishery to be allocated seasonally per the Amendment 11 framework. To allow for incidental landings of Pacific sardines in other CPS fisheries and to ensure the fishery does not exceed the ABC, the Council recommends a set aside of 8,910 mt allocated across seasonal periods as follows:

	Jan 1- June 30	July 1- Sept 14	Sept 15 - Dec 31	Total
Seasonal Allocation (mt)	31,183	35,637	22,273	89,093
Set Aside %	5.2%	1.2%	3.6%	10%
Set Aside (mt)	4,632	1,070	3,208	8,910
Adjusted Allocation (mt)	26,550	34,568	19,065	80,083

  Regarding Pacific mackerel, the Council recommended no changes to Pacific mackerel assessment methodology for the 2008 assessment update and recommends the next CPS stock assessment review panel be convened in 2009 rather than 2010 to fully review the status of Pacific sardine and Pacific mackerel.

- In June 2008, the Council adopted an updated Pacific mackerel assessment and the following management measures for the July 2008-June 2009 Pacific mackerel fishery: 1) Establish a harvest guideline for the directed fishery at 40,000 metric ton (mt), providing an 11,772 mt set-aside for incidental landings in other fisheries. 2) Close the directed fishery and revert to an incidental-catch-only fishery with a 45 percent incidental landing allowance when Pacific mackerel are landed with other coastal pelagic species (CPS), except that up to 1 mt of Pacific mackerel could be landed without landing any other CPS. If needed, conduct an in-season review of the 2008-2009 Pacific mackerel fishery at the nearest feasible Council meeting, with the possibility of either releasing a portion of the incidental set-aside to the directed fishery or further constraining incidental landings to ensure total harvest remains below the acceptable biological catch.

- In November 2008, the Council adopted a harvest guideline (HG) of 66,932 mt for the 2009 Pacific sardine fishery. This HG is based on a biomass estimate of 662,886 mt and the harvest control rule in the Coastal Pelagic Species (CPS) Fishery Management Plan. The Council recommends that 1,200 mt of the HG be set-aside prior to allocation for dedicated Pacific sardine research activities in period 2. The Council recommends an adjusted allocation of 59,232 mt as the HG for the directed fishery to be allocated seasonally per the Amendment 11 framework. To allow for incidental landings of Pacific sardines in other CPS fisheries and to help to ensure the fishery does not exceed the total HG, the Council adopted a set aside of 6,500 mt allocated across seasonal periods as follows:

HG = 66,932 mt; Research set aside = 1,200 mt; Adjusted HG = 65,732 mt				
	Period 1	Period 2	Period 3	
	Jan 1- Jun 30	Jul 1- Sep 14	Sep 15 – Dec 31	Total
Seasonal Allocation (mt)	23,006	26,293	16,433	65,732
Incidental Set Aside (mt)	1,000	1,000	4,500	6,500
Adjusted Allocation (mt)	22,006	25,293	11,933	59,232

If a seasonal allocation to the directed fishery is reached or exceeded in any period NMFS would close the directed sardine fishery and the fishery would revert to an incidental fishery with an incidental landing allowance of no more that 20 percent Pacific sardine by weight.

Under this proposal, the Council recommends NMFS take the following inseason automatic actions:

- Any unused seasonal allocation to the directed fishery from Period 1 or Period 2 rolls into the next period's directed fishery.
- Any overage of a seasonal allocation to the directed fishery from Period 1 or Period 2 is deducted from the next Period's directed fishery.
- Any unused Seasonal Incidental Set-Aside from Period 1 or Period 2 rolls into the next period's directed fishery.
- If both the seasonal allocation to the directed fishery and the Seasonal Incidental Set-Aside are reached or exceeded in any period, the retention of Pacific sardine will be prohibited and the overage will be deducted from the next period's directed fishery.
- Any of the research set-aside that is not used in Period 2 rolls into the third seasonal period's directed fishery HG.

- In November 2008, the Council also adopted a public review draft of the terms of reference document for the 2009 STAR Panel process. The Council also tasked Council staff with scheduling two STAR Panels for 2009; one in May 2009 focused on a full Pacific mackerel assessment and Pacific sardine assessment methodology, and a second in September 2009 that focuses on the review of a full Pacific sardine assessment.

TABLE 2-2. REGULATORY ACTIONS

January 25, 2000. NMFS published HGs for Pacific sardine and Pacific mackerel for the fishing year beginning January 1, 2000. A HG of 186,791 mt was established for Pacific sardine, based on a biomass estimate of 1,581,346 mt. The HG was allocated for Subarea A, which is north of 35° 40' N latitude (Point Piedras Blancas) to the Canadian border, and for Subarea B, which is south of 35° 40' N latitude to the Mexican border. The northern allocation was 62,264 mt; the southern allocation was 124,527 mt. The sardine HG was in effect until December 31, 2000, or until it was reached and the fishery closed. A HG of 42,819 mt was established for Pacific mackerel based on a biomass estimate of 239,286 mt. The HG for Pacific mackerel was in effect until June 30, 2000, or until it was reached and the fishery closed. (65*FR*3890)

September 11, 2000. NMFS announced the annual HG for Pacific mackerel in the EEZ off the Pacific coast. Based on the estimated biomass of 116,967 mt and the formula in the FMP, a HG of 20,740 mt was calculated for the fishery beginning on July 1, 2000. This HG is available for harvest for the fishing season July 1, 2000, through June 30, 2001. (65*FR*54817)

November 1, 2000. NMFS announced the closure of the directed fishery for Pacific mackerel in the EEZ off the Pacific coast on October 27, 2000. The FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on a formula in the FMP and to close the fishery when the HG is reached. The HG of 20,740 mt is projected to be reached before the end of the fishing season on June 30, 2001, which requires closing the directed fishery and setting an incidental harvest limit for Pacific mackerel so that the harvest of other CPS will not be further restricted. The intended effect of this action is to ensure conservation of the Pacific mackerel resource. For the reasons stated here and in accordance with the FMP and its implementing regulations at 50 CFR 660.509, the directed fishery for Pacific mackerel will be closed October 27, 2000, after which time no more than 20 percent by weight of any landing of Pacific sardine may be Pacific mackerel. (65*FR*65272)

November 17, 2000. NMFS published a correction to the Pacific mackerel closure which was published on November 1, 2000. In 65*FR*65272, make the following correction: On page 65272, in the third column, under the heading SUPPLEMENTARY INFORMATION, the last sentence is corrected to read as follows: "For the reasons stated here and in accordance with the FMP and its implementing regulations at 50 CFR 660.509, the directed fishery for Pacific mackerel will be closed October 27, 2000, after which time no more than 20 percent by weight of a landing of Pacific sardine, northern anchovy, jack mackerel, or market squid may consist of Pacific mackerel." (65*FR*69483)

December 27, 2000. NMFS announced the annual HG for Pacific sardine in the EEZ off the Pacific coast for the January 1, 2001, through December 31, 2001, fishing season. This HG has been calculated according to the regulations implementing the FMP. The intended effect of this action is to establish allowable harvest levels for Pacific sardine off the Pacific coast. Based on the estimated biomass of 1,182,465 mt and the formula in the FMP, a HG of 134,737 mt was calculated for the fishery beginning January 1, 2001. The HG is allocated one third for Subarea A, which is north of 35° 40' N latitude (Point Piedras Blancas) to the Canadian border, and two thirds for Subarea B, which is south of 35° 40' N latitude to the Mexican border. Any unused resource in either area will be reallocated between areas to help ensure that the OY will be achieved. The northern allocation is 44,912 mt; the southern allocation is 89,825 mt. (65*FR*81766)

February 22, 2001. NMFS announced changes to the restriction on landings of Pacific mackerel for individuals participating in the CPS fishery and for individuals involved in other fisheries who harvest small amounts of Pacific mackerel. The incidental limit on landings of 20 percent by weight of Pacific mackerel in landings of Pacific sardine, northern anchovy, jack mackerel, and market squid remains in effect; however, CPS fishermen may land up to 1 mt of Pacific mackerel even if they land no other species from the trip. Non CPS fisherman may land no more than 1 mt of Pacific mackerel per trip. After the HG of 20,740 mt is reached, all landings of Pacific mackerel will be restricted to 1 mt per trip. This action is authorized by the FMP and is intended to ensure that the fishery achieves, but does not exceed, the HG while minimizing the economic impact on small businesses. For the reasons stated here, no fishing vessel may land more than 1 mt of Pacific mackerel per fishing trip, except that fishing vessels with other CPS on board may land more than 1 mt of Pacific mackerel in a fishing trip if the total amount of Pacific mackerel on board the vessel does not exceed 20 percent by weight of the combined weight of all CPS on board the vessel. (66*FR*11119)

March 30, 2001. NMFS announced the closure of the fishery for Pacific mackerel in the EEZ off the Pacific coast at 12:00 a.m. on March 27, 2001. The FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on a formula in the FMP and to close the fishery when the HG is reached. The HG of 20,740 mt has been reached. Following this date no more than 1 mt of Pacific mackerel may be landed from any fishing trip. The effect of this action is to ensure conservation of the Pacific mackerel resource. (66*FR*17373)

July 25, 2001. NMFS announced a HG of 13,837 mt for Pacific mackerel for the fishing season July 1, 2001 through June 30, 2002. A directed fishery of 6,000 mt was established, which, when attained, would be followed by an incidental allowance of 45 percent of Pacific mackerel in a landing of any CPS. If a significant amount of the HG remained unused before the end of the fishing season on June 30, 2002, the directed fishery would be reopened. This approach was taken because of concern about the low HG's potential negative effect on the harvest of Pacific sardine if the fishery for Pacific mackerel had to be closed. The two species occur together often and could present incidental catch problems. (66*FR*38571)

November 27, 2001. NMFS announced the closure of the directed fishery for Pacific mackerel in the EEZ off the Pacific coast at 12:00 noon on November 21, 2001. For the fishing season beginning July 1, 2001, 6,000 mt of the 13,837 mt HG was established for a directed fishery. More than 6,000 mt has been landed. Therefore, the directed fishery for Pacific mackerel was closed on November 21, 2001, after which time no more than 45 percent by weight of a landing of Pacific sardine, northern anchovy, jack mackerel, or market squid could consist of Pacific mackerel. The intended effect of this action was to ensure that the HG was achieved, but not exceeded, and to minimize bycatch of Pacific mackerel while other CPS were being harvested. (66*FR*59173)

December 27, 2001. NMFS published the HG for Pacific sardine for the fishing season beginning January 1, 2002. A HG of 118,442 mt was established for Pacific sardine based on a biomass estimate of 1,057,599 mt. The HG is allocated for Subarea A, which is north of 35° 40' N latitude (Point Piedras Blancas) to the Canadian border, and for Subarea B, which is south of 35° 40' N latitude to the Mexican border. The northern allocation is 39,481 mt; the southern allocation is 78,961mt. The sardine HG is in effect until December 31, 2002, or until it is reached and the fishery closed. (66*FR*66811)

April 5, 2002. NMFS announced the reopening of the directed fishery for Pacific mackerel in the U.S. EEZ off the Pacific coast on April 1, 2002. A significant portion of the Pacific mackerel HG remains unharvested (6,585 mt). Therefore, the incidental catch allowance that has been in effect since November 21, 2001 is removed, and any landing of Pacific mackerel may consist of 100 percent Pacific mackerel. This action was taken to help ensure that the HG is attained. If the HG is projected to be reached before June 30, 2002, the directed fishery will be closed and an appropriate incidental landing restriction imposed. (67*FR*16322)

July 11, 2002. NMFS proposed a regulation to implement the annual HG for Pacific mackerel in the EEZ off the Pacific coast. The CPS FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on the formula in the FMP. This action proposes allowable harvest levels for Pacific mackerel off the Pacific coast. Based on the estimated biomass of 77,516 mt and the formula in the FMP, a HG of 12,456 is proposed for the fishery beginning on July 1, 2002, and continue through June 30, 2003, unless the HG is attained and the fishery closed before June 30. (67*FR*45952)

September 18, 2002. NMFS announced the closure of the fishery for Pacific sardine in the U.S. EEZ off the Pacific coast north of Point Piedras Blancas, California, (35°□ 40' N latitude) at 0001 hrs local time on September 14, 2002. The closure will remain in effect until the reallocation of the remaining portion of the coastwide HG is required by the CPS FMP. That reallocation is expected to occur on or about October 1, 2002. The purpose of this action is to comply with the allocation procedures mandated by the FMP. (67*FR*58733)

September 26, 2002. Emergency rule. NMFS announced the reallocation of the remaining Pacific sardine HG in the U.S. EEZ off the Pacific coast. The CPS FMP requires that NMFS conduct a review of the fishery 9 months after the beginning of the fishing season on January 1, and reallocate any unharvested portion of the HG, with 50 percent allocated north and south of Point Piedras Blancas, California. The allocation north of Point Piedras Blancas was reached on September 14, 2002, and the fishery was closed until the scheduled time for reallocation on October 1, 2002. This action reallocates the remainder of the HG earlier than the date specified in the FMP in order to minimize the negative economic effects on fishing and processing, primarily in the Pacific Northwest, which would result from delaying the reallocation. (67*FR*60601)

October 3, 2002. NMFS issued a regulation to implement the annual HG for Pacific mackerel in the EEZ off the Pacific coast. The CPS FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on the formula in the FMP. This action is to conserve Pacific mackerel off the Pacific coast. Based on the estimated biomass of 77,516 mt and the formula in the FMP, a HG of 12,456 is proposed for the fishery beginning on July 1, 2002, and continue through June 30, 2003, unless the HG is attained and the fishery closed before June 30. There will be a directed fishery of at least 9,500 mt, and 3,035 mt of the HG will be utilized for incidental landings following the closure of the directed fishery. After closure of the directed fishery, no more than 40 percent by weight of a landing of Pacific sardine, northern anchovy, jack mackerel, or market squid may consist of Pacific mackerel, except that up to 1 mt of Pacific mackerel may be landed without landing any other CPS. The fishery will be monitored, and if a sufficient amount of the HG remains before June 30, 2003, the directed fishery will be reopened. The goal is to achieve the HG and minimize the impact on other coastal pelagic fisheries. 67*FR*61994)

October 30, 2002. NMFS proposed a regulation to implement Amendment 10 to the CPS FMP, which was submitted by the Council for review and approval by the Secretary of Commerce. Amendment 10 addresses the two unrelated subjects of the transferability of limited entry permits and maximum sustainable yield for market squid. Only the provisions regarding limited entry permits require regulatory action. The purpose of this proposed rule is to establish the procedures by which limited entry permits can be transferred to other vessels and/or individuals so that the holders of the permits have maximum flexibility in their fishing operations while the goals of the FMP are achieved. (67*FR*66103)

November 25, 2002. NMFS proposed a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season January 1, 2003, through December 31, 2003. This HG has been calculated according to the CPS FMP and establishes allowable harvest levels for Pacific sardine off the Pacific coast. Based on the estimated biomass of 999,871 mt and the formula in the FMP, a HG of 110,908 mt was determined for the fishery beginning January 1, 2003. The HG is allocated one third for Subarea A, which is north of 35° 40' N latitude (Point Piedras Blancas) to the Canadian border, and two thirds for Subarea B, which is south of 35° 40' N latitude to the Mexican border. The northern allocation is 36,969 mt; the southern allocation is 73,939 mt. (67*FR*70573)

December 31, 2002. NMFS issued a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season January 1, 2003, through December 31, 2003. This HG has been calculated according to the CPS FMP and establishes allowable harvest levels for Pacific sardine off the Pacific coast. Based on the estimated biomass of 999,871 mt and the formula in the FMP, a HG of 110,908 mt was determined for the fishery beginning January 1, 2003. The HG is allocated one third for Subarea A, which is north of 35° 40' N latitude (Point Piedras Blancas, California) to the Canadian border, and two thirds for Subarea B, which is south of 35° 40' North latitude to Mexican border. The northern allocation is 36,969 mt; the southern allocation is 73,939 mt. If an allocation or the HG is reached, up to 45 percent by weight of Pacific sardine may be landed in any landing of Pacific mackerel, jack mackerel, northern anchovy, or market squid. (67*FR*79889).

January 27, 2003. NMFS issued a regulation to implement Amendment 10 to the CPS FMP, which was submitted by the Council for review and approval by the Secretary of Commerce. Amendment 10 addresses the two unrelated subjects of the transferability of limited entry permits and maximum sustainable yield for market squid. Only the provisions regarding limited entry permits require regulatory action. The primary purpose of this final rule is to establish the procedures by which limited entry permits can be transferred to other vessels and/or individuals so that the holders of the permits have maximum flexibility in their fishing operations while the goals of the FMP are achieved. (68*FR*3819)

June 26, 2003. NMFS proposed a regulatory amendment to the CPS FMP. This amendment was submitted by the Council for review and approval by the Secretary. The proposed amendment would change the management subareas and the allocation process for Pacific sardine. The purpose of this proposed amendment is to establish a more effective and efficient allocation process for Pacific sardine and increase the possibility of achieving OY. (68*FR*37995)

July 29, 2003. NMFS proposed a regulation to implement the annual HG for Pacific mackerel in the EEZ off the Pacific coast. The CPS FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on the formula in the FMP. (68*FR*44518)

September 4, 2003. NMFS issued a final rule to implement a regulatory amendment to the CPS FMP that changed the management subareas and the allocation process for Pacific sardine. The purpose of this final rule was to establish a more effective and efficient allocation process for Pacific sardine and increase the possibility of achieving OY. (68*FR*52523)

September 9, 2003. NMFS announced the reallocation of the remaining Pacific sardine HG in the EEZ off the Pacific coast. On September 1, 2003, 59,508 mt of the 110,908 mt HG is expected to remain unharvested. The CPS FMP requires that a review of the fishery be conducted and any uncaught portion of the HG remaining unharvested in Subarea A (north of Pt. Arena, California) and Subarea B (south of Pt. Arena, California) be added together and reallocated, with 20 percent allocated to Subarea A and 80 percent to Subarea B; therefore, 11,902 mt is allocated to Subarea A and 47,600 mt is allocated to Subarea B. The intended effect of this action is to ensure that a sufficient amount of the resource is available to all harvesters on the Pacific coast and to achieve OY. (68*FR*53053)

October 3, 2003. NMFS issued a final rule to implement the annual HG for the July 1, 2003 - June 30, 2004 Pacific mackerel fishery in the EEZ off the Pacific coast. The CPS FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on the formula in the FMP. Based on this approach, the biomass for July 1, 2003, is 68,924 mt. Applying the formula in the FMP results in a HG of 10,652 mt, which is lower than last year but similar to low HGs of recent years. (68*FR*57379)

October 28, 2003. NMFS announced the closure of the fishery for Pacific sardine in the EEZ off the Pacific coast north of Pt. Arena, California (39° N latitude) at 12:01 a.m. local time on October 17, 2003. The purpose of this action is to comply with the allocation procedures mandated by the CPS FMP. (68*FR*61373)

December 3, 2003. NMFS proposed a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season January 1, 2004, through December 31, 2004. This HG was calculated according to the regulations implementing the CPS FMP and established allowable harvest levels for Pacific sardine off the Pacific coast. (68*FR*67638)

February 25, 2004. NMFS issued a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season January 1, 2004, through December 31, 2004. This action adopts a HG and initial subarea allocations for Pacific sardine off the Pacific coast that have been calculated according to the regulations implementing the CPS FMP. Based on a biomass estimate of 1,090,587 mt (in U.S. and Mexican waters), using the FMP formula, the HG for Pacific sardine in U.S. waters for January 1, 2004, through December 31, 2004 is 122,747 mt. The biomass estimate is slightly higher than last year's estimate; however, the difference between this year's biomass is not statistically significant from the biomass estimates of recent years. Under the FMP, the HG is allocated one third for Subarea A, which is north of 39° N latitude (Pt. Arena, California) to the Canadian border, and two thirds for Subarea B, which is south of 39° N latitude to the Mexican border. Under this final rule, the northern allocation for 2004 would be 40,916 mt and the southern allocation would be 81,831 mt. (69*FR*8572). July 20, 2004. NMFS proposed a regulation to implement the annual HG for Pacific mackerel in the EEZ off the Pacific coast for the fishing season July 1, 2004, through June 30, 2005. The CPS FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on the formula in the FMP. This action proposes allowable harvest levels for Pacific mackerel off the Pacific coast. (69 *FR* 43383)

September 14, 2004. Information memorandum. NMFS announced the reallocation of the remaining Pacific sardine HG in the U.S. EEZ off the Pacific coast. A regulatory amendment (69 *FR* 8572, February 25, 2003) requires that NMFS conduct a review of the fishery 10 months after the beginning of the fishing season on January 1, and reallocate any unharvested portion of the HG, with 20 percent allocated north of Point Area, California, and 80 percent allocated south of Point Arena, California. (69 *FR* 55360)

October 21, 2004. NMFS issued a final rule to implement the annual HG for the July 1, 2004 - June 30, 2005 Pacific mackerel fishery in the EEZ off the Pacific coast. The CPS FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on the formula in the FMP. Based on this approach, the biomass for July 1, 2003, is 81,383 mt. Applying the formula in the FMP results in a HG of 13,268 mt. (69 *FR* 61768)

December 8, 2004. NMFS proposed a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season January 1, 2005, through December 31, 2005. This HG was calculated according to the regulations implementing the CPS FMP and established allowable harvest levels for Pacific sardine off the Pacific coast. (69 *FR* 70973)

June 22, 2005. NMFS issues a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season January 1, 2005, through December 31, 2005. This HG was calculated according to the regulations implementing the CPS FMP and established allowable harvest levels for Pacific sardine off the Pacific coast. Based on a biomass estimate of 1,193,515 mt (in U.S. and Mexican waters) and using the FMP formula, NMFS calculated a HG of 136,179 mt for Pacific sardine in U.S. waters. Under the FMP, the HG is allocated one-third for Subarea A, which is north of 39°00′ N. lat. (Pt. Arena, California) to the Canadian border, and two-thirds for Subarea B, which is south of 39° 00′ N. lat. to the Mexican border. Under this final rule, the northern allocation for 2005 would be 45,393 mt, and the southern allocation would be 90,786 mt. (70 *FR* 36053)

August 29, 2005. NMFS proposes a regulation to implement the annual HG for Pacific mackerel in the U.S. EEZ off the Pacific coast. For specific regulations, see final rule language from October 21, 2005 below. (70 *FR* 51005)

October 21, 2005. NMFS issues a final rule to implement the annual HG for Pacific mackerel in the U.S. EEZ off the Pacific coast. The biomass estimate for July 1, 2005, would be 101,147 mt. Applying the formula in the FMP results in a HG of 17,419 mt, which is 32 percent greater than last year but similar to low HGs of recent years. For the last three years, the fishing industry has recommended dividing the HG into a directed fishery and an incidental fishery, reserving a portion of the HG for incidental harvest in the Pacific sardine fishery so that the Pacific sardine fishery is not hindered by a prohibition on the harvest of Pacific mackerel. At its meeting on June 15, 2005, the Subpanel recommended for the 2005–2006 fishing season that a directed fishery of 13,419 mt and an incidental fishery of 4,000 mt be implemented. An incidental allowance of 40 percent of Pacific mackerel in landings of any CPS would become effective if the 13,419 mt of the directed fishery is harvested. The Subpanel also recommended allowing up to 1 mt of Pacific mackerel to be landed during the incidental fishery without the requirement to land any other CPS. (70 *FR 61235*)

October 28, 2005. NMFS announces that the Pacific Fishery Management Council (Council) has submitted Amendment 11 to the CPS FMP for Secretarial review. Amendment 11 would change the framework for the annual apportionment of the Pacific sardine HG along the U.S. Pacific coast. The purpose of Amendment 11 is to achieve optimal utilization of the Pacific sardine resource and equitable allocation of the harvest opportunity for Pacific sardine. The public comment period on Amendment 11 was open through December 27, 2005. (70 *FR* 62087)

January 17, 2006. NMFS proposes a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season of January 1, 2006, through December 31, 2006. This HG has been calculated according to the regulations implementing the CPS FMP and establishes allowable harvest levels for Pacific sardine off the Pacific coast. (71 *FR* 2510)

June 29, 2006. NMFS issues the final rule to implement Amendment 11 to the CPS FMP which changes the framework for the annual apportionment of the Pacific sardine HG along the U.S. Pacific coast. The purpose of this final rule is to achieve optimal utilization of the Pacific sardine resource and equitable allocation of the harvest opportunity for Pacific sardine. (71 *FR* 36999)

July 5, 2006. NMFS issues a final rule to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season of January 1, 2006, through December 31, 2006. This HG has been calculated according to the regulations implementing the CPS FMP and establishes allowable harvest levels for Pacific sardine off the Pacific coast. Based on the estimated biomass of 1,061,391 mt and the formula in the FMP, a HG of 118,937 mt was determined for the fishery beginning January 1, 2006. (71 *FR* 38111)

August 21, 2006. This notice retracts the Notice of Intent (NOI) to prepare an Environmental Impact Statement (EIS) to analyze a range of alternatives for the annual allocation of the Pacific sardine HG proposed action published on July 19, 2004. Further scoping subsequent to the publication of the NOI revealed additional information indicating that it was unlikely the proposed action would result in significant environmental impacts. An Environmental Assessment (EA) was completed and a subsequent Finding of No Significant Impact (FONSI) was signed. (71 *FR* 48537)

October 20, 2006. NMFS proposes a regulation to implement the annual HG for Pacific mackerel in the U.S. EEZ off the Pacific coast. (71 *FR* 61944).

December 7, 2006. NMFS proposes a regulation to implement new reporting and conservation measures under the CPS FMP. These reporting requirements and prohibitive measures would require CPS fishermen/vessel operators to employ avoidance measures when southern sea otters are present in the area they are fishing and to report any interactions that may occur between their vessel and/or fishing gear and sea otters. The purpose of this proposed rule is to comply with the terms and conditions of an incidental take statement from a biological opinion issued by the U.S. Fish and Wildlife Service regarding the implementation of Amendment 11 to the CPS FMP. (71 *FR* 70941).

January 31, 2007. NMFS issues a final rule to implement the annual HG and management measure for the 2006-2007 Pacific Mackerel fishery. Based on the estimated biomass of 112,700 mt and the formula in the FMP, a HG of 19,845 mt is in effect for the fishery which began on July 1, 2006. This HG applies to Pacific mackerel harvested in the U.S. EEZ off the Pacific coast from July 1, 2006, through June 30, 2007, unless the HG is attained and the fishery is closed before June 30, 2007. All landings made after July 1, 2006, will be counted toward the 2006–2007 HG of 19,845 mt. There shall be a directed fishery of 13,845 mt, followed by an incidental fishery of 6,000 mt. An incidental allowance of 40 percent of Pacific mackerel in landings of any CPS will become effective after the date when 13,845 mt of Pacific mackerel is estimated to have been harvested. A landing of 1 mt of Pacific mackerel per trip will be permitted during the incidental fishery for trips in which no other CPS is landed. (72 *FR* 4464).

May 30, 2007. This action implements new reporting and conservation measures under the CPS FMP. The purpose of this action is to prevent interactions between CPS fisherman and southern sea otters, as well as establish methods for fishermen to report these occurrences when they occur. These reporting requirements and conservation measures require CPS fishermen/vessel operators to employ avoidance measures when southern sea otters are present in the area they are fishing and to report any interactions that may occur between their vessel and/or fishing gear and sea otters. (72 *FR* 29891).

September 28, 2007 NMFS proposes a regulation to implement the annual HG for Pacific mackerel in the U.S. EEZ Based on a total stock biomass estimate of 359,290 mt, the ABC for U.S. fisheries for the 2007/2008 management season is 71,629 mt. The estimated stock biomass for the 2006/2007 season was 112,700 mt, resulting in an ABC of 19,845 mt. off the Pacific coast for the fishing season of July 1, 2007, through June 30,2008.. (72 *FR* 55170).

October 25, 2007 NMFS issues the final rule to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast (California, Oregon, and Washington) for the fishing season of January 1, 2007, through December 31,2007. The Pacific sardine HG is apportioned based on the following allocation scheme established by Amendment 11to the CPS FMP: 35 percent (53,397 mt) is allocated coastwide on January 1; 40 percent (61,025 mt), plus any portion not harvested from the initial allocation is reallocated coastwide on July 1; and on September 15 the remaining 25 percent (38,141 mt), plus any portion not harvested from earlier allocations is released. (72 *FR* 60586).

January 31, 2008 NMFS issues the final rule to implement the annual HG for Pacific mackerel for the fishing season of July 1, 2007, through June 30, 2008. The HG for the 2007–2008 fishing season is 40,000 metric tons (mt). If this total is reached, Pacific mackerel fishing will be closed to directed harvest and only incidental harvest will be allowed at a 45 percent by weight incidental catch rate when landed with other CPS, except that up to one mt of Pacific mackerel can be landed without landing any other CPS. (73 *FR* 5760).

August 20, 2008 NMFS proposes a regulation to implement the annual HG for Pacific mackerel in the U.S. exclusive economic zone (EEZ) off the Pacific coast for the fishing season of July 1, 2008, through June 30, 2009. (73 *FR* 49156).

August 20, 2008 NMFS issues a final rule that notices effectiveness of reporting requirements of interactions that may occur between a CPS vessel and/or fishing gear and sea otters originally published on May 30, 2007 (see above). The May 30th final rule contained information collection requirements that at the time of publication had not yet been approved by OMB. The final rule stated that NMFS would publish a subsequent Federal Register notice announcing the effectiveness of those requirements. Therefore NMFS announces that OMB approved the collection of information requirements contained in the May 30, 2007, final rule under Control Number 0648-0566 with an expiration date of August 31, 2010. (73 *FR* 60191).

October 10, 2008 NMFS issues a final rule that notices effectiveness of reporting requirements of interactions that may occur between a CPS vessel and/or fishing gear and sea otters originally published on May 30, 2007 (see above). The May 30th final rule contained information collection requirements that at the time of publication had not yet been approved by OMB. The final rule stated that NMFS would publish a subsequent Federal Register notice announcing the effectiveness of those requirements. Therefore NMFS announces that OMB approved the collection of information requirements contained in the May 30, 2007, final rule under Control Number 0648-0566 with an expiration date of August 31, 2010. (73 *FR* 60191).

TABLE 2-3. Coastal pelagic species limited entry permit vessel listing, with U.S. Coast Guard registered measurements and calculated gross tonnage (GT) values for each vessel. (Page 1 of 2)

Vessel Name	Coast Guard Number	Year Built	Registered Measurements (ft)/1			Calculated Vessel GT/2	Permit No.	Permit GT Endorsement	Permit Transfer Allowance
			Length	Breadth	Depth				
PROVIDER	D572344	1976	49.60	19.00	10.10	63.8	1	63.8	70.2
PALOMA	D280452	1960	47.40	16.50	8.30	43.5	2	43.5	47.9
SEA VENTURE	D238969	1939	71.40	21.20	9.70	107.3	3	98.4	108.2
BARBARA H	D643518	1981	64.90	24.00	11.60	121.1	4	121.1	133.2
PACIFIC BULLY	D1186583	1937	72.10	19.50	8.70	82.0	5	82.0	90.2
MARY VINCENT	D632207	---	---	---	---	---	6	98.1	---
SAN PEDRO PRIDE	D549506	1973	79.60	24.50	12.30	160.7	7	160.7	176.8
FERRIGNO BOY	D602455	1978	69.60	23.70	12.60	139.3	8	139.3	153.2
KING PHILLIP	D1061827	1997	79.00	26.00	11.40	156.9	9	156.9	172.6
SEA WAVE	D951443	1989	78.00	22.00	18.00	206.9	10	206.9	227.6
MARY LOUISE	D247128	1944	58.30	18.00	8.00	56.2	11	56.2	61.8
BAINBRIDGE	D236505	1937	78.60	22.70	9.60	114.8	12	114.8	126.3
SUNRISE	D238918	1944	77.80	24.30	11.20	141.9	13	141.9	156.1
MARIA	D236760	1937	70.70	20.50	9.20	89.3	14	89.3	98.2
ST. JOSEPH	D633570	1981	62.90	22.00	9.10	84.4	15	84.4	92.8
	---	---	---	---	---	---	16	137.5	---
RETRIEVER	D582022	1977	54.20	19.60	8.70	61.9	17	61.9	68.1
ATLANTIS	D649333	1982	49.60	19.00	10.10	63.8	18	63.8	70.2
G. NAZZARENO	D246518	1944	78.00	22.70	10.50	124.6	19	124.6	137.1
SEA QUEEN	D583781	1974	68.40	22.00	11.10	111.9	20	111.9	123.1
PACIFIC LEADER	D643138	1981	59.50	21.00	9.20	77.0	21	77.0	84.7
CHOVIE CLIPPER	D524626	1970	51.10	18.00	10.30	63.5	22	63.5	69.9
PACIFIC JOURNEY	OR661ZK	2001	64.30	22.01	10.30	97.7	23	97.7	107.5
OCEAN ANGLE I	D584336	1977	49.60	19.00	10.10	63.8	24	63.8	70.2
MARIA T	D509632	1967	57.30	18.10	9.80	68.1	25	68.1	74.9
MANANA	D253321	1947	40.10	13.20	6.70	23.8	26	23.8	26.2
SHEELAGH B	D697944	---	---	---	---	112	27	55.5	61.1
MINEO BROS.	D939449	1989	58.00	21.00	9.00	73.4	28	73.4	80.7
LONG BEACH CARNAGE	D955501	1977	49.00	16.00	8.00	42.0	29	42.0	46.2
LITTLE JOE II	D531019	1971	50.10	16.00	7.60	40.8	30	40.8	44.9
CAITLIN ANN	D960836	1990	98.00	33.00	15.70	340.2	31	340.2	374.2
ELDORADO	D690849	1985	56.00	17.00	8.60	54.9	32	54.9	60.4
SEA PRINCESS	D630024	1980	87.00	26.00	12.80	194.0	33	194.0	213.4
JENNIFER LYNN	D550564	1973	71.50	23.00	11.40	125.6	34	125.6	138.2
ENDURANCE	D613302	1979	49.00	16.00	8.00	42.0	35	42.0	46.2
NEW SUNBEAM	D284470	1961	50.30	20.00	4.00	27.0	36	27.0	29.7
CALOGERA A	D984694	1992	57.75	21.00	10.50	85.3	37	85.3	93.8
EILEEN	D252749	1947	79.40	22.10	10.20	119.9	38	119.9	131.9
PAMELA ROSE	D693271	1985	54.00	19.00	9.00	61.9	39	61.9	68.1
NEW STELLA	D598813	1978	58.00	22.00	8.40	71.8	40	71.8	79.0
TRAVELER	D661936	1983	56.00	17.00	6.90	44.0	41	44.0	48.4
LUCKY STAR	D295673	1964	49.90	17.00	7.30	41.5	42	41.5	45.7
OCEAN ANGEL II	D622522	1980	74.50	28.00	10.70	149.5	43	149.5	164.5
CRYSTAL SEA	D1061917	1997	66.00	26.00	12.00	137.0	44	137.0	151.8
TRIONFO	D625449	1980	63.80	19.30	9.60	79.2	45	79.2	87.1
CORVA MAY	D615795	1979	49.60	19.00	10.10	63.8	46	85.0	93.5
HEAVY DUTY	D655523	1983	58.00	21.30	10.20	84.4	47	84.4	92.8
ALIOTTI BROS	D685870	1985	67.60	26.00	9.10	107.2	48	107.2	117.9
LADY J	D647528	1982	50.30	17.00	7.10	40.7	49	40.7	44.8
ANNA’S	D253402	1947	50.80	16.20	9.10	50.2	50	50.2	55.2
ENDEAVOR	D971540	1990	57.40	19.00	9.90	72.3	51	72.3	79.5

TABLE 2-3. Coastal pelagic species limited entry permit vessel listing, with U.S. Coast Guard registered measurements and calculated gross tonnage (GT) values for each vessel. (Page 2 of 2)

Vessel Name	Coast Guard Number	Year Built	Registered Measurements (ft)[1/]			Calculated Vessel GT[2/]	Permit No.	Permit GT Endorsement	Permit Transfer Allowance
			Length	Breadth	Depth				
ANTOINETTE W	D606156	1978	45.40	16.00	7.60	7.0	52	37.0	40.7
DONNA B	D648720	1982	73.20	25.00	12.90	158.2	53	158.2	174.0
PAPA GEORGE	D549243	1973	72.00	22.80	11.50	126.5	54	126.5	139.2
UNBELIEVABLE	D650376	1982	42.00	16.70	8.60	40.4	55	40.4	44.4
KATHY JEANNE	D507798	1967	65.90	22.20	8.80	86.3	56	86.3	94.4
MERVA W	D532023	1971	56.70	17.90	8.00	54.4	57	54.4	59.8
SANTA MARIA	D236806	1937	79.20	19.50	8.80	91.1	58	91.1	100.2
BUCCANEER	D592177	1978	62.10	19.90	9.00	74.5	59	74.5	82.0
MIDNIGHT HOUR	D276920	1958	61.10	18.00	8.60	63.4	60	63.4	69.7
ST. KATHERINE	D542513	1972	56.40	18.00	8.80	59.9	61	59.9	65.9
LETHAL WEAPON	D979365	1977	50.00	16.00	7.40	39.7	62	39.7	43.7
EMERALD SEA	D626289	1980	62.70	26.00	7.90	86.3	63	86.3	94.9
SHEELAGH B	D697944	---	---	---	---	112	64	54.5	60.0
BOUNTY	D629721	1980	40.90	14.70	6.60	26.4	65	26.4	29.0

1/ Vessel dimension information was obtained from the Coast Guard Website at: http://psix.uscg.mil/.
2/ Vessel Gross Tonnage GT=0.67(Length*Breadth*Depth)/100. See 46 CFR 69.209.
3/ Maximum transfer allowance is based on permit GT + 10%..

TABLE 2-4. Vessel age and calculated gross tonnage (GT) for the initial and current Federal limited entry fleet.

	Initial Fleet	Current Fleet
Number of Vessels	65	63
Average Vessel Age	35 years	33 years
Range of Ages	12 to 66 years	4 to 68 years
Average GT	71.3	88.7
Range of GT	12.8 to 206.9	23.8 to 340.2
Sum of Fleet GT	4,635.9	5,498.5
Capacity Goal (GT)[1/]	---	5,650.9
Transferability Trigger	---	5,933.5

1/ Established in Amendment 10 to the CPS FMP.

TABLE 2-5. 2008 Oregon limited entry sardine vessel information..

Vessel Name	Coast Guard Number	Year Built	Registered Measurements (ft)[1/]			Calculated Vessel GT [2/]
			Length	Breadth	Depth	
EXCELLER	659770	1983	57.8	24	10	92.9
ANTHONY G	605599	1979	58	24	8	74.6
PACIFIC PURSUIT	OR873ABY	1993	63	---	---	---
D C COLE	566145	1975	49.6	19	10.1	63.8
DARLENE Z	611694	1979	49.6	19	10.1	63.8
PACIFIC JOURNEY	OR661ZK	1996	71	22	10	104.7
LAUREN L KAPP	OR072ACX	---	72	---	---	---
EVERMORE	248555	1944	76.3	22.2	11.4	129.4
PACIFIC RAIDER	972638	1991	57.7	22.7	11	96.5
PACIFIC KNIGHT	OR155ABZ	1978	62	19.6	7.6	61.9
PAPA GEORGE	549243	1973	70.4	22.8	12	129.1
CRYSTAL SEA	1061917	1997	66	26	12	138.0
SUNRISE	238918	1939	80.2	22.2	10.2	121.7
DELTA DAWN	647246	1982	49.6	19	10.1	63.8
SPARTAN	607367	1979	58	19	10.1	74.6
RESOLUTION II	WN9665RJ	1979	59	---	---	---
EMERALD SEA	626289	1980	62	26	7.9	85.3
ST. TERESA	623983	1980	49	18.5	8.5	51.6
LADY LAW	1131965	2002	74.7	25	13.3	166.4
OCEAN ANGEL II	622522	1980	74.5	28	10.7	149.5
SEABOUND	AK9671AF	1982	67	20.5	9	82.8
OCEAN ANGEL I	584336	1977	49	19	10.1	63.0

1/ Vessel dimension information was obtained from NOAA at www.st.nmfs.noaa.gov/st1/CoastGuard/VesselByName.html.
2/ Vessel Gross Tonnage GT=0.67(Length*Breadth*Depth)/100 (The CPSMT is working on discrepancies between Tables 2-3 through 2-6.).

TABLE 2-6. Vessels designated on a Washington Sardine Experimental Fishery Permit in 2008.

Vessel Name	Coast Guard Number	Year Built	Registered Measurements (ft)[1/]			Calculated Vessel GT [2/]
			Length	Breadth	Depth	
ATLANTIS	649333	1982	49.6	19.0	10.1	63.8
BAINBRIDGE	236505	1937	78.6	22.7	9.6	114.8
DELTA DAWN	647246	1982	49.6	19.0	10.1	63.8
HUSTLER	943301	1989	55.0	17.0	8.2	51.4
KING PHILIP	1061827	1997	79.0	26.0	11.4	156.9
MARAUDER	975597	1991	58.0	22.8	10.5	93.0
	OR761ABL	2004	25.7			0.0
PACIFIC JOUNEY	OR661ZK	2001	64.3	22.0	10.3	97.7
PACIFIC LEADER	643138	1981	59.5	21.0	9.2	77.0
PACIFIC RAIDER	972638	1991	57.7	22.7	11.0	96.5
	OR108ADL	1980	68.0			
SPARTAN	607367	1979	58.0	19.0	10.1	74.6
ST. TERESA	623983	1980	49.0	18.5	8.5	51.6
ST. ZITA	648115	1982	49.6	21.5	10.5	75.0
VOYAGER	248217	1945	66.7	20.2	9.3	84.0
	WN1264JE	1973	16.0			0.0

1/ Vessel dimension information was obtained from NOAA at www.st.nmfs.noaa.gov/st1/CoastGuard/VesselByName.html.
2/ Vessel Gross Tonnage GT=0.67(Length*Breadth*Depth)/100 (The CPSMT is working on discrepancies between Tables 2-3 through 2-6.).

TABLE 6-1. Preliminary catch summary for vessels targeting Pacific sardine from NMFS-SWR coastal pelagic species pilot observer program. (Page 1 of 2).

Target species - Pacific sardine					
Species	Target Catch	Incidental Catch	Bycatch Returned		
			Alive	Dead	Unknown
Sardine	1495 mt		80 mt	100 lbs	100 lbs
Anchovy		9 mt	82	1300 lbs	
Bat Ray		1	143	14	1
Bat Star			5		
CA Barracuda		2	1	3	
CA Halibut		9		4	
Giant Sea Bass			2		
Jacksmelt		1			
Jack Mackerel		2 mt			
Midshipman			1	13	1
Moon Jelly		1			
Pacific Bonito		10 lbs			
Pacific Butterfish		3			
Pacific Electric Ray			2		
Pacific Mackerel		1 mt	100 lbs		
Pacific Tomcod		1			
Pompano		167			
Queenfish		49			
Sanddab			25 lbs	10 lbs	
Scorpionfish		1			1
Sculpin				1	3
Shovelnose Guitarfish			1		
Spanish Mackerel		100 lbs			
Squid		1 mt	2 mt		
Starry Flounder			2		
Stingray		2			
Thornback Ray			2		
Unid. Crab			1		1
Unid. Croaker		40			
Unid. Flatfish		78	8	130	12
Unid. Jellyfish		3	3		
Unid. Mackerel		8 mt	12 mt		
Unid. Octopus					2
Unid. Ray					2
Unid. Rockfish		2	1		
Unid. Seastar			41	135	1
Unid. Scorpionfish/Sculpin					1
Unid. Shark				2	
Unid. Skate				3	

TABLE 6-1. Preliminary catch summary for vessels targeting Pacific sardine from NMFS-SWR coastal pelagic species pilot observer program. (Page 2 of 2).

Target species - Pacific sardine					
Species	**Target Catch**	**Incidental Catch**	**Bycatch Returned**		
			Alive	**Dead**	**Unknown**
Unid. Smelt		2			
Unid. Surf Perch		1			
Unid. Turbot				60	
White Croaker		31 lbs	50 lbs		
Yellowfin Croaker		10 lbs			
CA Sea Lion			49		
Harbor Seal			1		
Unid. Gull			3	2	4

TABLE 6-2. Preliminary catch summary for vessels targeting market squid from NMFS-SWR coastal pelagic species pilot observer program.

Target species - Squid					
Species	**Target Catch**	**Incidental Catch**	**Bycatch Returned**		
			Alive	**Dead**	**Unknown**
Squid	1274 mt		28 mt	350 lbs	2 mt
Anchovy		100 lbs	120 lbs		
Jack Mackerel		2 mt	18 lbs	2 lbs	
Pacific Mackerel		20 mt	20 mt	180 lbs	1 lb
Sardine		12 mt	13 mt	1077 lbs	3 lbs
Spanish Mackerel		20 lbs			
Bat Ray			53		1
Bat Star			1		
Blue Shark			2		
Common Mola			1		
Pelagic Stingray			60		
Pacific Butterfish		19			1
Sunstar		30	4		
Squid Eggs					505 lbs
Lobster			3		
Brittle Star				3000	
Unid. Batfish				2 lbs	
Unid. Crab		1	1		93
Unid. Croaker		3	2	16 lbs	
Unid. Flatfish		1	1	6	2
Unid. Jellyfish		4			
Unid. Mackerel		2 lbs	102 lbs		
Unid. Octopus		1			
Unid. Rockfish		1	1	4	
Unid. Ray			4		1
Unid. Sanddab		4	3		4
Unid. Seastar		1			
Unid. Seaslug					21
Unid. Scorpionfish		1			
Unid. Surfperch				3	
Unid. Skate		3		1	
Unid. Smelt		49			
Unid. Stingray		9	17		
Unid. Shark					1
Thresher Shark		1			
CA Sea Lion			98		
Harbor Seal			3		
Common Dolphin				1	
Unid. Gull			16	1	

TABLE 6-3. Preliminary catch summary for vessels targeting Pacific mackerel from NMFS-SWR coastal pelagic species pilot observer program.

Target species - Pacific mackerel					
Species	Target Catch	Incidental Catch	Bycatch Returned		
			Alive	Dead	Unknown
Pacific Mackerel	40 mt				
Bat Ray			2		
CA Yellowtail			1		
Midshipman			1		
Sardine		16 mt			
Sea Cucumber		5			
Unid. Crab		1			
Unid. Flatfish			3		
Unid. Jellyfish			3		
Unid. Shark			1		

TABLE 6-4. Preliminary catch summary for vessels targeting northern anchovy and northern anchovy/Pacific sardine from NMFS-SWR coastal pelagic species pilot observer program.

Target species - Anchovy and Anchovy/Sardine					
Species	Target Catch	Incidental Catch	Bycatch Returned		
			Alive	Dead	Unknown
Anchovy	373 mt		2 mt	1 mt	
Sardine		21 mt	2 mt		
Bat Ray			4		
CA Lizardfish			4		
Kelp Bass		1			
Midshipman					5
Pacific Bonito			20 lbs		
Pacific Mackerel		2			
Queenfish		50 lbs	11 lbs		
Round Stingray			1		
Sculpin		2			
Spiny Dogfish			1		
Unid. Croaker		20	45		
Unid. Flatfish		10			
Unid. Hake		4			
Unid. Seastar			1		
Unid. Smelt		2			
Unid. Turbot			1	1	20
White Croaker		50 lbs	35 lbs		
Yellowfin Croaker		50 lbs	10 lbs		
CA Sea Lion			5		
Sea Otter			1		

TABLE 6-5. Percent frequency of bycatch in observed incidents of CPS finfish, by port, 2004-2008. (Page 1 of 4). *Includes Santa Barbara port complex. **Included in 2008.

	All Ports					San Pedro					Monterey				
Common Name	**2004**	**2005**	**2006**	**2007***	**2008**	**2004**	**2005**	**2006**	**2007***	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**
Finfish															
Anchovy, northern	7.4	6.1	9.2	5.6	5.4	4.2	5.8	3.5	1.7	4.9	32.6	18.2	24	10.8	6.4
Barracuda, California	0.5	0.4	0.4	0.9	0.2	0.6	0.4	0.3	0.8	0.4			0.4	0.9	
Bass, barred sand	1.1	1.1	0.6	0.6		1.2	1.2	0.9	1.0						
Bass, kelp		1.1	0.7		0.5		1.2	1		0.8					
Bass, striped					0.2					0.4					
Blacksmith			0.1	0.2				0.2	0.3						
Bonito, Pacific			2.1	0.7	0.5			2.9	1.3	0.8					
Butterfish, Pacific (Pompano)	4.7	5.5	6	2.8	1.2	5.1	5.2	6.4	3.2	1.9	2.3	18.2	4.9	2.2	
Cabezon			0.1										0.4		
Combfish, longspine			0.7	0.3	1.0			1	0.1	1.5				0.6	
Corbina, California			0.5	0.6				0.7	1.0						
Croaker, unspecified					0.5					0.8					
Croaker, white (kingfish)	6.9	0.2	5.8	4.3	1.7	5.7	0.2	6.4	5.1	1.5	16.3		4.4	3.2	2.1
Croaker, yellowfin				0.2					0.4						
Cusk-eel, basketweave					0.2					0.4					
Cusk-eel, spotted			0.9	0.5				0.9	0.4				0.9	0.6	
Cusk-eel, unspecified	1.3	4.7	2.1	0.5		1.5	4.8	2.9	0.8						
Eel, unspecified					0.2					0.4					
Eel, yellow snake															
Eel, wolf															
Fish, unspecified				0.3	0.7				0.4	1.1				0.2	
Flatfish, unspecified	1.8	0.2	0.6	2.2	1.7	2.1	0.2	0.7	3.4	2.7			0.4	0.7	
Flounder, starry	0.3		0.5	0.6	1.0						2.3		1.8	1.5	2.8
Flounder, unidentified					0.2					0.4					
Flyingfish	0.3	0.6				0.3	0.6								
Greenling, kelp				0.1										0.2	
Grunion, California	0.3		0.1		0.2			0.2		0.4	2.3				
Hagfish				0.1					0.1						
Halfmoon			0.1										0.4		
Halibut, California	4.2	7.6	2.5	3.7	4.0	4.8	7.7	3.3	5.9	5.7			0.4	0.7	0.7
Herring, Pacific			0.1	0.2	0.5								0.4	0.6	1.4
Jacksmelt	0.8	1.5	1.9	2.2	0.7	0.6	1	0.9	2.4	0.4	2.3	27.3	4.4	2.0	1.4
Kelpfish, giant			0.1	0.2				0.2	0.3						
Lingcod				0.1	0.2									0.2	0.7
Lizardfish, California	2.1	5.7	2.1	1.5	1.5	2.4	5.8	2.9	2.7	2.3					
Mackerel, jack**				2.5	3.5				0.7	1.5				4.8	7.1
Midshipman, plainfin			1.6	1.8	1.5			1.7	2.0	0.8			1.3	1.7	2.8
Midshipman, specklefin	1.3		1.6	0.6	1.2	1.5		2.2	1.1	1.9					
Midshipman, unspecified	2.1	0.6				2.4	0.6								
Opaleye					0.5					0.8					
Perch-like, unspecified					0.2					0.4					
Pipefish, bay				0.2					0.1					0.2	
Pipefish, kelp	1.1	0.6	0.1		0.2	1.2	0.6	0.2		0.4					

TABLE 6-5. Percent frequency of bycatch in observed incidents of CPS finfish, by port, 2004-2008. (Page 2 of 4). *Includes Santa Barbara port complex. **Included in 2008.

	All Ports					San Pedro					Monterey				
Common Name	**2004**	**2005**	**2006**	**2007***	**2008**	**2004**	**2005**	**2006**	**2007***	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**
Finfish															
Poacher, unspecified			0.1					0.2							
Queenfish			3.1	0.8	2.2			4.3	1.4	3.4					
Rockfish, chilipepper			0.1										0.4		
Rockfish, unspecified				0.5					0.8						
Salema			0.1					0.2							
Salmon, chinook				0.1										0.2	
Sanddab, longfin			0.2	0.1	0.2			0.3	0.1	0.4					
Sanddab, Pacific			1.4	3.4	2.2			1.9	1.1	0.8				6.3	5.0
Sanddab, speckled			0.1	0.7	1.2			0.2	0.4	0.0				1.1	3.5
Sanddab, unspecified	4	2.1	2.6	0.9	0.2	3.9	1.9	1.4	1.0		4.7	9.1	5.8	0.7	0.7
Scorpionfish, California	10	8.7	3.4	2.5	3.5	11.3	8.9	4.7	4.4	5.3					
Sculpin, pithead	1.3	0.2	0.1			0.3	0.2	0.2			9.3				
Sculpin, roughback				0.1										0.2	
Sculpin, staghorn			0.1	0.4					0.1				0.4	0.7	
Sculpin, unspecified			0.2		1.2			0.3		1.9					
Seabass, giant (black)			0.1					0.2							
Shad, American			0.9	0.8	0.2								3.1	1.9	0.7
Sheephead, California			0.1					0.2							
Silversides			0.5	0.1				0.7	0.1						
Smelt, surf				0.2										0.4	
Smelt, true				0.1	0.2				0.1						0.7
Snapper, Mexican				0.1					0.1						
Sole, C-O			0.6	0.2				0.3	0.1				1.3	0.2	
Sole, English			0.2	1.3	0.7				0.3				0.9	2.6	2.1
Sole, fantail				0.2	0.5				0.3	0.8					
Sole, petrale				0.2										0.6	
Sole. Rock				0.1										0.2	
Sole, sand	0.3		0.5	0.2	1.0					0.0	2.3		1.8	0.4	2.8
Sole, slender			0.1					0.2							
Sole, unspecified			0.2	0.1									0.9	0.2	
Sunfish, ocean			0.1										0.4		
Surfperch, barred			0.1										0.4		
Surfperch, black			0.1	0.1				0.2						0.2	
Surfperch, kelp				0.1										0.2	
Surfperch, pink			1.1	0.5	1.0			0.9	0.4	0.8				0.6	1.4
Surfperch, rainbow				0.1										0.2	
Surfperch, rubberlip			0.1					0.2					1.8		
Surfperch, shiner			0.9	0.5	0.2			1	0.7	0.0			0.4	0.2	0.7
Surfperch, unspecified			0.4	0.4	0.2			0.3	0.7	0.4			0.4		
Surfperch, walleye	0.3			0.2					0.3		2.3				
Tonguefish	2.1	1.9	1.4	0.9	0.5	2.4	1.9	1.7	1.1	0.8			0.4	0.6	
Topsmelt				0.4	0.2				0.7	0.4					
Turbot, curlfin			0.1	0.2				0.2	0.1					0.2	

TABLE 6-5. Percent frequency of bycatch in observed incidents of CPS finfish, by port, 2004-2008. (Page 3 of 4). *Includes Santa Barbara port complex. **Included in 2008.

	All Ports					San Pedro					Monterey				
Common Name	**2004**	**2005**	**2006**	**2007***	**2008**	**2004**	**2005**	**2006**	**2007***	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**
Finfish															
Turbot, diamond			0.2	0.6	1.0			0.3	1.0	1.5					
Turbot, hornyhead	4	6.1	2.9	2.6	2.5	4.5	6.2	3.6	3.7	3.4				1.3	0.7
Turbot, spotted			0.6	0.1					0.1						
Turbot, unspecified		1.1	1		0.2		1.2	1.4		0.4					
Whiting, Pacific			0.1	1.0	0.2								0.4	2.2	0.7
Total % Freq. Incidents	**58.2**	**56**	**64.4**	**53.8**	**50.7**	**56**	**55.6**	**64.7**	**54.9**	**54.0**	**76.7**	**72.8**	**62.9**	**52.3**	**44.7**
Elasmobranchs															
Guitarfish, shovelnose		1.5	0.2	0.6	0.7		1.5	0.3	1.1	1.1					
Ratfish, spotted			0.1	0.3	0.7			0.2	0.1	0.8				0.6	0.7
Ray, Bat	7.4	6.3	3	3.3	3.0	7.1	6.4	3.6	5.2	4.6	9.3		1.3	0.7	
Ray, California butterfly		0.2					0.2								
Ray, Pacific electric	0.3		1.2	3.3	3.7	0.3		0.9	0.3	0.8			2.2	7.3	9.2
Ray, Unspecified				0.2	0.2				0.4	0.4					
Shark, brown smoothhound			0.1	0.4	0.2			0.2	0.7	0.4	2.8				
Shark, gray smoothhound			0.2	0.3				0.3	0.6						
Shark, horn			0.6	0.2	0.2			0.9	0.4	0.4					
Shark, leopard				0.2					0.1					0.2	
Shark, Pacific angel			0.2	0.2				0.3	0.3						
Shark, pelagic thresher					0.2					0.4					
Shark, smooth hammerhead					0.2					0.4					
Shark, spiny dogfish	0.3		0.1	0.7	0.5					0.0	2.3		0.4	1.7	1.4
Shark, Unspecified				0.1	0.2				0.1	0.4					
Skate, Big			0.6	0.8	0.7			0.2	0.3	0.4			1.8	1.5	1.4
Skate, California			0.5	0.3	0.5			0.7	0.1	0.8				0.6	0.0
Skate, longnose	0.8					0.9									
Skate, thornback	2.4	3.6	1.6	1.8	0.7	2.7	3.7	1.9	3.1	1.1				0.2	
Skate, Unspecified			0.1					0.2							
Stingray, round	0.3	1.5	0.2	0.9	0.7	0.3	1.5	0.3	1.4	1.1				0.4	
Total % Freq. Incidents	**11.5**	**13.1**	**8.7**	**13.8**	**12.9**	**11.3**	**13.3**	**10**	**14.4**	**12.9**	**14.4**		**5.7**	**13.1**	**12.8**
Invertebrates and Plants															
Algae, marine			1.2	0.1	0.2					0.4			1.2	0.2	
Bryozoans			0.1	0.1									0.1	0.2	
Crab shells	0.8		0.3			0.9		0.3					0.4		
Crab, box			0.1	0.3				0.2	0.6				0.1		
Crab, decorator			0.2		0.2					0.0			0.2		0.7
Crab, Dungeness			0.1	0.2	0.2					0.4			0.1	0.4	
Crab, globe				0.3					0.6						
Crab, rock unspecified	1.3	0.2	0.2	1.5		1.5	0.2	0.3	2.4				0.2	0.4	
Crab, sheep			0.1	0.2				0.2	0.3				0.1		
Crab, slender				0.2	0.7					0.4				0.6	1.4
Crab, swimming			0.3	0.2				0.5	0.3				0.4		

TABLE 6-5. Percent frequency of bycatch in observed incidents of CPS finfish, by port, 2004-2008. (Page 4 of 4). *Includes Santa Barbara port complex. **Included in 2008.

	All Ports					San Pedro					Monterey				
Common Name	**2004**	**2005**	**2006**	**2007***	**2008**	**2004**	**2005**	**2006**	**2007***	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**
Invertebrates and Plants															
Crab, unspecified			0.5	0.3	0.2			0.7	0.4	0.4			0.5	0.2	
Eelgrass	1.1	1.5	2	0.6		1.2	1.5	1.4	0.7				2.1	0.4	
Gorgonians			0.6					0.9					0.6		
Invertebrate, unspecified					0.2					0.4					
Jellies	1.3	2.3	0.2	3.5	6.7	0.3	2.3	0.3	0.1	0.4	9.3		0.2	7.8	18.4
Kelp	15.3	15	10.4	10.6	13.9	17.3	14.9	10.4	11.8	16.7		18.2	11.2	8.9	8.5
Kelp, feather boa			0.3	0.2	1.2				0.4	1.5			0.4		0.7
Lobster, California spiny				0.2					0.4				0.9		
Nudibranch				0.1										0.2	
Octopus, unspecified			0.8	0.5	0.5			1	0.8	0.8			0.1		
Pleurobranch													0.5		
Prawn, ridgeback				0.2					0.3						
Prawn, spot			0.1		0.2			0.2		0.4			1.7		
Salps	0.5	0.2		0.1		0.6	0.2	0.7	0.1				0.1		
Sea cucumber	0.3	0.6	0.5	0.6	0.7	0.3	0.6		1.1	1.1			0.1		
Sea pansies		0.2		0.1		0	0.2	1.2					4.2	0.2	
Sea star	0.3	0.8	1.6	1.6	1.7	0.3	0.8		1.6	1.5				1.7	2.1
Shrimp, black-spotted bay		0.2		0.6	0.5	0	0.2			0.0				1.5	1.4
Shrimp, unspecified			7.6	1.8	1.0			0.2	3.2	1.5					
Snail, top				0.1					0.1						
Snail, Unspecified				0.2	0.2				0.3	0.4					
Sponge, unspecified			0.1		0.2			0.2							0.7
Squid, jumbo				0.1					0.1						
Squid, market (Egg Cases)	0.5			0.1		0.6								0.2	
Squid, market	9.2	10.2	3.9	5.9	6.2	10.1	10.3	5.9	4.8	6.1	2.3	9.1		7.3	6.4
Surfgrass				2.0	0.2									4.7	0.7
Tunicates				0.2					0.1					0.2	
Turkish Towel					0.5										1.4
Total % Freq. Incidents	**30.6**	**31.2**	**31.2**	**32.5**	**35.9**	**33.1**	**31.2**	**24.6**	**30.7**	**32.3**	**11.6**	**27.3**	**25.4**	**34.9**	**42.6**
Total All Incidents	**379**	**528**	**804**	**1,246**	**404**	**336**	**517**	**579**	**709**	**263**	**43**	**11**	**225**	**537**	**141**
Total Observed Landings	**205**	**199**	**266**	**253**	**148**	**180**	**199**	**172**	**142**	**106**	**33**	**25**	**94**	**111**	**42**

TABLE 6-6. Market squid incidental catch for 2003 - 2008. Incidental catch includes species landed with market squid and recorded on landing receipts (round haul gear).

	2004		2005		2006		2007		2008	
Species name	**Number of Landings**	**Metric Tons**	**Number of Landings**	**Metric Tons**	**Number of Landings**	**Metric Tons**	**Number of Landings**	**Metric Tons**	**Number of Landings**	**Metric Tons**
Anchovy, northern	17	616.1	31	1,042.9	19	122.3	38	89.7	28	84.4
Bonito	1	<0.1	1	1.3	3	3.3			8	1.9
Mackerel, jack	19	38.8	19	21.0	28	45.6	36	47.1	64	68.0
Mackerel, Pacific	23	143.1	187	571.5	169	360.3	127	351.9	146	442.3
Sardine, Pacific	122	1,525.7	179	1,076.9	184	534.6	287	1,596.7	305	1,826.1

TABLE 6-7. Percent frequency of bycatch in observed loads of California market squid by port, 2004-2008 (Page 1 of 4).

	Total All Ports					San Pedro					Santa Barbara/Ventura					Monterey/Moss Landing				
Common Name	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**
Finfish																				
Anchovy, northern	5.2	5.7	5.1	7.6	2.2	4.6	5.9	5.0	2.9	2.1	7.4	3.8	7.8	9.1	2.6	5.4	6.5	3.2	11.1	
Baracuda, California		0.3	1.3		1.1			0.8		1.4			3.9				0.7			
Bass, kelp			0.4		0.6			0.8		0.7										
Blacksmith			0.4					0.8												
Bonito, Pacific			0.4	0.4	0.6					0.7			2.0	0.5						
Butterfish, Pacific (Pompano)	1.4	0.5	2.6			2.0	0.7	4.2					2.0			1.2	0.7			
Combfish, longspine	0.3					0.7														
Croaker, white (kingfish)	0.3			0.4					1.5							0.6				
Croaker, unspecified	0.3					0.7														
Cusk-eel	0.3					0.7														
Eel, wolf	0.3															0.6				
Flatfish, unspecified	0.3		0.4		1.1	0.7				1.4								1.6		
Flounder, starry	0.6				0.6					0.7						1.2				
Flyingfish					0.6					0.7										
Greenling, painted	0.3					0.7														
Halibut, California					1.7					2.1										
Herring, Pacific	0.9	0.5														1.8	1.3			
Herring, round																				
Jacksmelt	7.5	3.1	0.4	0.4		0.7	0.7							0.5		14.9	7.2	1.6		
Lizardfish, California	0.3					0.7														
Mackerel, jack	7.2	6.5	12.4	6.2	8.8	7.8	10.5	15.0	4.4	11.2	7.4		2.0	6.5		6.5	5.9	15.9	11.1	
Mackerel, Pacific	8.9	21.0	18.8	17.4	13.3	11.1	25.7	17.5	20.6	13.3	25.9	41.3	33.3	17.1	13.2	4.2	5.9	9.5		
Mackerel, unspecified				1.5										2.0						
Midshipman, plainfin																				
Midshipman, specklefin			0.4	1.1	0.6			0.8	2.9	0.7				0.5						
Midshipman, unspecified	1.1	0.5			0.6	0.7				0.7		1.3				1.8	0.7			
Poacher , unspecified				0.4					1.5											

TABLE 6-7. Percent frequency of bycatch in observed loads of California market squid by port, 2004-2008 (Page 2 of 4).

	Total All Ports					San Pedro					Santa Barbara/Ventura					Monterey/Moss Landing				
Common Name	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**
Finfish																				
Rockfish, blue		0.3		0.4			0.7							0.5						
Rockfish, bocaccio	0.3					0.7														
Rockfish, chilipepper	0.9	0.3														1.8	0.7			
Rockfish, unspecified					0.6					0.7										
Roughback Sculpin																				
Salmon, Chinook	0.3		0.4													0.6		1.6		
Sanddab, longfin	0.3					0.7														
Sanddab, Pacific	1.4	2.1	1.3	1.8		2.0	1.3	0.8	1.5			1.3		1.5		1.2	3.3	3.2	11.1	
Sanddab, speckled	0.3				0.6	0.7				0.7										
Sanddab, unspecified	2.9	0.5		0.4	1.7	0.7				0.7				0.5	5.3	5.4	1.3			
Sardine, Pacific	17.8	21.6	22.2	26.8	23.2	21.6	23.7	26.7	27.9	18.2	44.4	25.0	33.3	27.1	42.1	10.1	17.6	4.8	11.1	
Scorpionfish, California	0.6	0.8		1.8	0.6	1.3	2.0		4.4	0.7				1.0						
Sculpin, pithead				0.4					1.5											
Sculpin, staghorn		0.3		0.4	0.6		0.7			0.7				0.5						
Sculpin, unspecified	0.3				0.6	0.7				0.7										
Silversides (jack- or topsmelt)		0.3					0.7													
Sole, sand	0.3															0.6				
Sole, unspecified	0.3										3.7									
Sunfish, ocean			0.4										2.0							
Surfperch, pink			0.4																	
Surfperch, shiner	0.9		0.4			2.0		0.8												
Surfperch, unspecified								0.8												
Topsmelt	0.6	0.3				0.7					3.7	1.3								
Turbot, hornyhead	0.3	0.3		0.4	0.6	0.7			1.5	0.7							0.7		11.1	
Turbot, spotted					0.6					0.7										
Turbot, unspecified	0.9	0.3				0.7										1.2	0.7			
Whitefish, ocean				0.4										0.5						
Total % Freq. Incidents	**63.2**	**65.2**	**67.7**	**68.2**	**60.2**	**62.7**	**72.6**	**74.0**	**70.6**	**59.4**	**92.6**	**74.0**	**86.3**	**67.8**	**63.2**	**58.9**	**53.2**	**41.4**	**55.5**	**0.0**

TABLE 6-7. Percent frequency of bycatch in observed loads of California market squid by port, 2004-2008 (Page 3 of 4).

	Total All Ports					San Pedro					Santa Barbara/Ventura					Monterey/Moss Landing				
Common Name	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**
Elasmobranchs																				
Ray, bat	1.1	2.1	1.3	1.8		1.3	3.3	0.8				3.8	3.9	2.5		1.2				
Ray, Pacific electric	3.2	3.9	0.4													6.5	9.8	1.6		
Ray , thornback																				
Ray, unspecified					1.1					1.4										
Shark, horn		0.3		0.7			0.7		1.5					0.5						
Shark, unspecified			0.4															1.6		
Skate, Long nosed					0.6					0.7										
Skate, unspecified		0.3															0.7			
Stingray, round	1.4					3.3														
Total % Freq. Incidents	**5.7**	**6.6**	**2.1**	**2.5**	**1.7**	**4.6**	**4.0**	**0.8**	**1.5**	**2.1**	**0.0**	**3.8**	**3.9**	**3.0**	**0.0**	**7.7**	**10.5**	**3.2**	**0.0**	**0.0**
Invertebrates and Plants																				
Algae, marine			0.9	0.4	0.6					0.7									11.1	
Cnideria (Sea Anenomes)			0.4															1.6		
Crab, box					0.6					0.7										
Crab, Dungeness	1.1					0.7										1.8				
Crab, elbow																				
Crab, sheep		0.3		0.7			0.7							1.0						
Crab, slender				0.4	0.7									0.5						
Crab, swimming				0.4										0.5						
Crab, rock unspecified		0.3		1.1	1.1		0.7			0.7				1.5	2.6					
Crab, shore					1.1					0.7					2.6					
Crab, unidentified					0.6					0.7										
Eelgrass	2.3	0.8	0.9	0.7	1.1	5.2	2.0	1.7		1.4				0.5						
Gorgonians	0.3		0.4			0.7		0.8												
Jellies	7.2	2.6	0.4									1.3				14.9	5.9	1.6		
Kelp	10.9	17.4	16.7	20.7	18.8	13.7	18.4	15.0	22.1	18.2	3.7	13.8	7.8	20.1	21.1	9.5	18.3	27.0	22.2	

TABLE 6-7. Percent frequency of bycatch in observed loads of California market squid by port, 2004-2008 (Page 4 of 4).

	Total All Ports					San Pedro					Santa Barbara/Ventura					Monterey/Moss Landing				
Common Name	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**
Invertebrates and Plants																				
Kelp, Feather boa					2.2					2.8										
Lobster, California spiny		0.3		0.4			0.7							0.5						
Octopus, unspecified																				
Salps	1.1					2.6														
Sea cucumber				0.4	1.1					1.4				0.5						
Sea cucumber, warty				0.4					1.5											
Sea hare					0.6					0.7										
Sea slug					0.6										2.6					
Sea star	1.1	0.5	1.3	1.1	2.2	0.7	1.3	0.8	1.5	1.4	3.7			1.1	5.3	1.2		3.2		
Squid, market, egg cases	6.6	1.6	8.5	1.1	7.2	8.5		5.8		8.4			2.0	1.5	2.6	6.0	3.9	19.0		
Squid, jumbo	0.3	4.9	0.4			0.7		0.8				7.5					8.5			
Turkish towel																				
Turtle grass				0.7										0.5					11.1	
Urchin, purple				0.4										0.5						
Total % Freq. Incidents	**31.0**	**28.7**	**29.9**	**28.9**	**38.3**	**32.7**	**23.8**	**24.9**	**25.1**	**37.8**	**7.4**	**22.6**	**9.8**	**28.7**	**36.8**	**33.3**	**36.6**	**52.4**	**44.4**	**0.0**
Total All Incidents	**348**	**384**	**234**	**276**	**181**	**153**	**152**	**120**	**68**	**143**	**27**	**79**	**51**	**199**	**38**	**168**	**153**	**63**	**9**	**0**
Total Observed Landings	**160**	**178**	**136**	**114**	**86**	**86**	**100**	**73**	**61**	**67**	**32**	**42**	**37**	**51**	**19**	**42**	**36**	**26**	**2**	**0**

TABLE 6-8. Expanded salmonid bycatch in Pacific sardine fisheries in Oregon and Washington, 2000-2008.

	Chinook (live)	Chinook (dead)	Coho (live)	Coho (dead)	Pink (live)	Unid (live)	Unid (dead)	Total (live)	Total (dead)	Grand Total
2008										
Oregon[2/]								123	75	198
Washington[3/]										
2007										
Oregon[2/]								349	170	519
Washington[3/]	33	108	20	124				53	232	285
2006										
Oregon[2/]								164	93	257
Washington[3/]	31	101	19	116				50	217	267
2005										
Oregon[2/]								411	176	587
Washington[3/]	47	156	29	178				76	334	410
2004										
Oregon[2/]								518	305	823
Washington	35	225	19	105	0	39	0	93	330	423
2003										
Oregon[2/]								315	185	500
Washington	92	262	81	231	0	173	0	346	493	839
2002										
Oregon[2/]								199	81	280
Washington	150	356	61	765	0	200	0	411	1211	1532
2001										
Oregon[1/]	45	45	201	134	22	45	0	313	179	492
Washington	449	170	571	504	0	80	0	1100	674	1774
2000										
Oregon[1/]	43	72	159	43	0	303	43	505	158	663
Washington	38	3	276	116	0	7	0	321	119	440

1/ Oregon salmon bycatch data 2000-2001 are expanded from a bycatch rate of salmon/trip based on vessel observation program.
2/ Oregon salmon bycatch data 2002-2008 are from logbooks.
3/ 2005 Washington totals calculated from observed 2000-2004 observed bycatch rates.

TABLE 6-9. Reported logbook and observed catches of non-target species caught in Oregon sardine fishery, 2008.

Species	2006 Logbook data	2007 Logbook data	2008 Logbook data
Blue shark	3	0	1
Thresher shark	2	3 (2 of 3 released alive)	0
unknown shark	1	5	0
Salmonids	257 (55% alive; 45% dead)	519 (67% alive; 33% dead)	198 (62% alive, 38% dead)
Mackerel	292,150 lbs.	473,441 lbs.	59,205 lbs.
Anchovy	1,000 lbs.	500 lbs.	8,300 lbs.
Pacific Herring	0	0	52,200 lbs.
Pacific Hake	250 lbs.	0	525 lbs.
Squid	150 lbs.	0	225 lbs.
Jelly fish	<100 lbs	0	0

TABLE 6-10. Recorded incidental catch (mt) in Oregon sardine fishery, 2001-2008 (from fish ticket data).

	2001	2002	2003	2004	2005	2006	2007	2008
Pacific mackerel	52.8	126.3	158.3	161.5	316.1	665	699.7	56.8
Jack mackerel	1.2	0.3	3.2	24.1	3.6	1.4	8	1.6
Pacific herring	-	3.3	-	10.3	0.1	1.2	-	55.8
Northern anchovy	-	0.2	-	1.0	68.4	8.6	-	2.4
American shad	-	0.3	-	1.2	-	0.44	-	0.3
Pacific hake	-	-	0.1	-	-	-	-	0.005
Sharks	-	-	0.3	0.3	0.4	0.16	0.14	0.01
Squid	-	-	-	13.9	-	-	-	-
Jellyfish	-	-	-	5.5	-	-	-	-

TABLE 6-11. Species noted as encountered on CDFG Live Bait Logs, 1996-2008.

Year	Days Fished	Jack Mackerel	Pacific Mackerel	Barracuda	Herring	Grunion	Smelts (Atherinids)	Shiner Surfperch	White Croaker	Queenfish	Market Squid	Pacific Bonito
2008	891	2	92	7							2	6
2007	970	2	245	22			2		1	1	7	12
2006	940	7	169	3								2
2005	1,045	49	188	27							1	6
2004	1,059	87	214	13						1	1	8
2003	1,123	18	140	23							2	
2002	1,105	9	147	1						1		
2001	1,052	11	176	56		1						
2000	488	25	87	34		1						
1999	449	16	77	7	1		1					
1998	809	8	189	69	1			1				
1997	773	46	190	104				3				
1996	522	10	45	27	3		5					

TABLE 6-12. Estimates of Pacific sardine and Northern anchovy live bait harvest in California. Data for 1939-1992 from Thomson et al. (1994), and 1993-2008 from CDFG live bait logs. Values are in metric tons with the assumption that 1 scoop =12.5 lbs.

Year	Anchovy	Sardine	Year	Anchovy	Sardine
1939	1,364	0	1975	5,577	0
1940	1,820	0	1976	6,202	0
1941	1,435	0	1977	6,410	0
1942	234	0	1978	6,013	107
1943	World War II	World War II	1979	5,364	0
1944	World War II	World War II	1980	4,921	12
1945	World War II	World War II	1981	4,698	6
1946	2,493	0	1982	6,978	38
1947	2,589	0	1983	4,187	193
1948	3,379	0	1984	4,397	53
1949	2,542	0	1985	3,775	11
1950	3,469	0	1986	3,956	17
1951	4,665	0	1987	3,572	216
1952	6,178	0	1988	4,189	50
1953	5,798	0	1989	4,594	100
1954	6,066	0	1990	4,842	543
1955	5,557	0	1991	5,039	272
1956	5,744	0	1992	2,572	1,807
1957	3,729	0	1993	669	176
1958	3,843	0	1994	2,076	1,506
1959	4,297	0	1995	1,278	2,055
1960	4,225	0	1996	703	1,801
1961	5,364	0	1997	1,077	2,344
1962	5,595	0	1998	304	2,037
1963	4,030	0	1999	453	2,411
1964	4,709	0	2000	834	1,270
1965	5,645	0	2001	1,238	1,245
1966	6,144	0	2002	965	1,701
1967	4,898	0	2003	1,085	3,028
1968	6,644	0	2004	192	3,900
1969	4,891	0	2005	1,464	2,949
1970	5,543	0	2006	476	3,629
1971	5,794	0	2006	476	3,629
1972	5,307	0	2007	700	3,358
1973	5,639	0	2008	686	2,943
1974	5,126	0			

TABLE 6-13. Ratio of anchovy to sardine in reported live bait catch in California, 1994-2008. Values are in metric tons with the assumption that 1 scoop =12.5 lbs.

Year	Anchovy	Sardine	Total	Proportion Anchovy	Proportion Sardine
2008	686	2,943	3,629	0.19	0.81
2007	700	3,358	4,058	0.17	0.83
2006	476	3,629	4,105	0.12	0.88
2005	1,464	2,949	4,413	0.33	0.67
2004	192	3,900	4,092	0.05	0.95
2003	1,085	3,028	4,113	0.26	0.74
2002	965	1,701	2,666	0.36	0.64
2001	1,238	1,245	2,483	0.50	0.50
2000	834	1,270	2,104	0.40	0.60
1999	453	2,411	2,864	0.16	0.84
1998	304	2,037	2,341	0.13	0.87
1997	1,077	2,344	3,420	0.31	0.69
1996	703	1,801	2,504	0.28	0.72
1995	1,278	2,055	3,333	0.38	0.62
1994	2,076	1,506	3,582	0.58	0.42

TABLE 9-1. West coast landings (mt) and real[1] exvessel revenues (2008 $) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid, 1981-2008.

Year	Pacific P. Sardine	Pacific Sardine Rev	Pacific P. Mack.	Pacific Mackerel Rev	Jack J. Mack	Jack Mackerel Rev	Anchovy	Anchovy Rev	M. Squid	Squid Rev
1981	15	$7,991	35,388	$19,280,334	17,778	$9,672,664	52,309	$8,666,324	23,510	$13,443,422
1982	2	$1,339	36,065	$18,075,914	19,617	$9,914,080	42,155	$5,387,321	16,308	$8,897,575
1983	1	$417	41,479	$19,148,958	9,829	$4,271,234	4,430	$994,481	1,824	$1,806,480
1984	1	$1,979	44,086	$18,886,904	9,154	$3,122,979	2,899	$946,853	564	$690,552
1985	6	$3,106	37,772	$14,415,987	6,876	$2,837,926	1,638	$524,045	10,276	$8,707,191
1986	388	$176,459	48,089	$16,611,481	4,777	$1,768,042	1,557	$500,508	21,278	$9,638,002
1987	439	$129,392	46,725	$13,685,803	8,020	$2,448,021	1,467	$634,433	19,984	$8,107,845
1988	1,188	$341,183	50,864	$16,337,850	5,068	$1,582,983	1,518	$829,634	37,316	$15,036,173
1989	837	$375,317	47,713	$13,566,117	10,745	$3,187,185	2,511	$1,341,577	40,974	$14,450,086
1990	1,664	$350,323	40,092	$9,848,401	3,254	$813,745	3,259	$1,149,272	28,447	$8,694,312
1991	7,587	$1,593,510	32,067	$9,531,287	1,712	$443,732	4,068	$1,162,286	37,389	$10,836,222
1992	18,056	$3,280,045	19,045	$7,007,961	1,526	$417,747	1,166	$391,321	13,112	$4,275,540
1993	15,347	$2,638,176	12,129	$2,572,854	1,950	$470,116	2,003	$815,902	42,830	$17,531,340
1994	11,644	$2,520,850	10,293	$2,390,385	2,906	$634,378	1,859	$915,849	55,383	$23,858,761
1995	40,256	$5,761,948	8,823	$1,863,383	1,877	$472,717	2,016	$597,203	70,252	$36,157,048
1996	32,553	$4,995,621	9,730	$2,087,866	2,437	$483,834	4,505	$1,110,217	80,561	$34,654,035
1997	43,290	$6,908,085	20,168	$4,326,778	1,533	$384,494	5,779	$1,262,515	70,329	$32,125,530
1998	43,312	$5,541,266	21,561	$3,885,325	1,777	$585,564	1,584	$375,093	2,895	$2,484,590
1999	60,476	$7,712,231	9,094	$1,625,270	1,557	$297,104	5,311	$1,426,107	92,101	$49,645,921
2000	67,982	$10,352,798	22,058	$4,171,648	1,451	$389,899	11,832	$2,055,992	118,903	$38,740,420
2001	75,801	$12,643,852	7,618	$1,666,590	3,839	$839,764	19,345	$1,981,766	86,203	$23,410,013
2002	96,897	$14,305,676	3,744	$708,254	1,026	$281,082	4,882	$840,776	72,895	$24,632,010
2003	71,923	$9,444,987	4,213	$853,994	231	$94,727	1,929	$443,180	45,056	$32,904,215
2004	89,339	$12,520,072	3,708	$714,504	1,160	$331,995	7,019	$1,018,042	40,068	$24,581,119
2005	86,464	$11,901,627	3,586	$676,004	294	$254,111	11,414	$1,315,186	55,755	$36,726,559
2006	86,608	$10,313,528	6,610	$977,956	1,174	$221,228	12,960	$1,481,903	49,180	$29,927,300
2007	127,766	$14,000,685	5,759	$897,450	646	$153,251	10,548	$1,260,006	49,499	$30,846,567
2008	87,175	$14,594,993	3,516	$684,886	308	$53,033	14,654	$1,657,965	34,639	$23,866,799

Source: PacFIN - 2006-2008 data extracted January-February 2009.

[1]Real values are current values adjusted to eliminate the effects of inflation. This adjustment has been made by dividing current values by the current year GDP implicit price deflator, with a base year of 2008.

[2]Pacific mackerel landings and revenues also include landings and revenues of unspecified mackerel.

TABLE 9-2. West coast landings (mt) and real[1] exvessel revenues ($ 2008) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid by landing area, 1981-2008.

	Landings (mt)					Exvessel Revenues (2008 $)				
Year	**Sardine**	**P. Mackerel**	**J. Mackerel**	**Anchovy**	**Squid**	**Sardine**	**P. Mackerel**	**J. Mackerel**	**Anchovy**	**Squid**
					San Diego					
1981		*	*	*	*		*	*	*	*
1982		29.9	0.1		*		$33,136	$324		*
1983		*	*	*	1.2		*	*	*	$1,709
1984	*	*	*		*	*	*	*		*
1985		*	*		*		*	*		*
1986		*	*		*		*	*		*
1987	*	*	*	*	*	*	*	*	*	*
1988	0.1	17.4	<0.1	5.5	18.6	$109	$23,812	$1	$6,425	$13,932
1989	0.1	7.6	<0.1	93.5	*	$301	$12,250	$28	$455,861	*
1990	0.2	7.7	0.1	18.4	*	$356	$10,613	$116	$76,438	*
1991		*	*	*			*	*	*	
1992	*	*	*	*	*	*	*	*	*	*
1993	*	*	*	*	*	*	*	*	*	*
1994	*	*	*	*	0.8	*	*	*	*	$360
1995	*	*	*	*	*	*	*	*	*	*
1996	*	*		*	1.8	*	*		*	$726
1997	*	*	*	*	2.6	*	*	*	*	$1,119
1998	*	*		*	*	*	*		*	*
1999	*	*	*	*	*	*	*	*	*	*
2000	19.2	1.7	0.2	4.3	*	$10,428	$3,043	$323	$2,465	*
2001	0.2	2.8	0.1	1.5	*	$137	$3,510	$152	$1,026	*
2002	*	*	*	*		*	*	*	*	
2003	*	*	*	*		*	*	*	*	
2004	*	*			*	*	*			*
2005	*	*		*		*	*		*	
2006	*	*		*	1.4	*	*		*	$891
2007	<0.1	0.4	<0.1	<0.1	*	$79	$440	$6	$49	*
2008		0.2			<0.1		$322			$84
					Orange/LA					
1981	14.7	29,084.7	14,699.9	38,216.3	*	$7,970	$15,968,575	$7,988,489	$6,175,638	*
1982	1.8	29,827.6	18,131.1	32,514.7	*	$1,232	$14,908,383	$9,185,391	$3,792,362	*
1983	0.6	33,902.3	6,785.8	900.2	853.6	$385	$16,134,849	$3,284,978	$243,347	$776,471
1984	*	*	*	*	66.3	*	*	*	*	$82,538
1985	3.4	32,012.6	5,860.1	43.1	3,095.9	$1,789	$12,610,763	$2,403,302	$38,537	$2,238,416
1986	286.6	41,071.7	4,289.0	140.8	*	$128,997	$14,369,358	$1,530,181	$46,960	*
1987	317.3	39,863.3	7,801.2	108.8	*	$95,919	$11,781,833	$2,374,519	$41,176	*
1988	1,172.1	47,656.6	4,939.1	92.9	*	$333,666	$15,198,685	$1,520,663	$34,346	*
1989	505.0	41,717.5	10,703.7	479.0	*	$112,120	$12,439,242	$3,124,433	$98,180	*
1990	1,179.4	37,123.6	2,968.0	193.2	*	$235,609	$9,161,899	$724,320	$53,458	*
1991	6,415.1	31,602.9	1,640.2	414.3	*	$1,361,880	$9,383,343	$408,308	$86,904	*
1992	13,950.8	18,071.7	1,095.7	136.6	1,700.5	$2,410,320	$6,805,946	$380,536	$46,771	$454,962
1993	13,977.6	11,714.9	1,268.9	118.7	12,889.7	$2,399,380	$2,499,429	$301,668	$29,157	$4,608,704
1994	9,031.7	9,842.3	2,459.8	136.6	*	$1,566,474	$2,268,785	$452,165	$27,441	*
1995	34,137.0	7,864.0	1,596.2	297.8	*	$4,855,802	$1,668,105	$314,443	$45,996	*
1996	23,922.6	8,764.9	2,054.0	239.1	14,993.9	$3,452,833	$1,798,467	$436,010	$39,179	$6,955,820
1997	26,533.7	14,002.6	822.6	1,120.8	17,779.1	$3,950,572	$3,437,007	$280,446	$148,509	$9,078,539
1998	31,702.3	18,149.6	1,012.4	338.1	227.5	$4,380,483	$3,519,469	$488,905	$56,721	$200,184
1999	39,084.2	8,551.1	927.4	1,418.2	27,684.1	$5,218,512	$1,541,076	$275,352	$324,177	$13,588,278
2000	39,104.1	21,646.1	1,209.5	1,280.1	44,839.9	$5,952,324	$4,116,716	$321,242	$209,123	$16,153,353
2001	40,763.6	6,676.6	3,623.8	3,657.7	39,170.6	$6,189,817	$1,473,807	$776,336	$445,373	$11,738,863
2002	39,308.0	3,367.8	1,003.5	1,205.7	28,136.9	$5,165,451	$657,763	$272,758	$137,063	$8,667,809
2003	22,882.7	3,941.3	133.4	205.5	7,758.8	$2,378,758	$805,583	$66,509	$39,721	$5,771,051
2004	23,677.4	3,018.3	1,027.1	147.2	10,504.3	$2,804,831	$620,479	$308,960	$45,359	$6,021,627
2005	*	*	*	*	31,846.0	*	*	*	*	$21,802,657
2006	*	*	*	*	37,107.1	*	*	*	*	$22,640,867
2007	*	*	*	*	*	*	*	*	*	*
2008	*	*	*	*	17,595.2	*	*	*	*	$12,074,753

TABLE 9-2. West coast landings (mt) and real[1] exvessel revenues ($ 2008) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid by landing area, 1981-2008.

	Landings (mt)					Exvessel Revenues (2008 $)				
Year	Sardine	P. Mackerel	J. Mackerel	Anchovy	Squid	Sardine	P. Mackerel	J. Mackerel	Anchovy	Squid
					Ventura/Santa Barbara					
1981	<0.1	4,872.1	2,846.6	9,034.5	*	$20	$2,658,337	$1,545,635	$1,479,042	*
1982		4,095.4	1,195.0	6,440.7	*		$2,172,848	$581,504	$867,256	*
1983	<0.1	3,905.0	559.1	2,727.1	3.2	$2	$1,690,802	$218,475	$373,149	$4,946
1984		1,263.2	52.1	141.0	7.1		$521,899	$23,012	$102,790	$19,239
1985		*	*	*	2,959.4		*	*	*	$1,668,586
1986	17.5	5,004.5	296.9	160.9	6,411.8	$6,413	$1,702,353	$111,352	$90,444	$2,275,186
1987	74.3	5,877.7	8.0	140.2	8,406.6	$22,528	$1,642,067	$3,369	$76,364	$3,104,172
1988	13.2	3,119.6	6.5	154.3	16,334.4	$5,842	$1,064,769	$2,230	$93,152	$6,138,529
1989	93.3	5,907.6		160.9	16,861.9	$20,561	$1,069,147		$100,347	$5,750,234
1990	*	*	*	*	10,600.5	*	*	*	*	$3,533,093
1991	186.4	138.1	8.6	189.9	16,904.8	$38,201	$27,111	$1,699	$105,339	$4,416,739
1992	973.4	92.2	<0.1	89.8	2,809.2	$121,646	$13,364	$4	$50,047	$781,255
1993	691.7	34.5	<0.1	298.1	17,367.2	$88,052	$6,179	$14	$143,290	$6,244,787
1994	315.0	39.5	47.5	340.8	21,333.6	$38,370	$13,314	$5,356	$232,473	$8,537,161
1995	354.5	249.1	0.4	346.3	41,184.3	$64,682	$38,501	$305	$231,065	$22,636,242
1996	461.1	66.8	11.1	374.5	46,435.3	$61,287	$47,556	$2,498	$236,790	$19,302,673
1997	3,357.3	1,160.3	7.4	510.4	34,610.6	$365,356	$160,739	$3,978	$140,677	$14,473,482
1998	899.3	1,305.7		239.1	2,175.6	$139,276	$104,980		$120,966	$1,900,557
1999	*	*	*	*	52,718.7	*	*	*	*	$29,881,167
2000	3,072.2	230.0	9.1	3,548.3	48,747.0	$424,028	$30,582	$1,240	$556,999	$14,213,907
2001	3,956.7	72.4	<0.1	3,909.3	31,876.3	$510,486	$9,179	$41	$623,009	$7,319,239
2002	5,064.5	<0.1	<0.1	732.2	11,814.1	$841,006	$18	$2	$245,053	$4,215,015
2003	*	*	*	*	13,199.8	*	*	*	*	$9,677,023
2004	4,711.0	67.4	<0.1	2,722.2	15,397.0	$535,916	$9,918	$10	$508,459	$9,655,338
2005	*	*	*	*	13,639.5	*	*	*	*	$8,607,188
2006	1,928.9	126.6		4,167.0	6,003.5	$199,926	$9,439		$691,601	$3,665,532
2007	*	*	*	*	17,772.8	*	*	*	*	$11,003,902
2008	*	*	*	*	8,441.1	*	*	*	*	$5,751,317
					San Luis Obispo					
1981		*	*	*	0.1		*	*	*	$202
1982		*	*		0.3		*	*		$597
1983		0.7			0.2		$765			$310
1984		5.0			0.1		$4,441			$176
1985	*	*	*	*	0.3	*	*	*	*	$585
1986		*	*	*	0.1		*	*	*	$180
1987		0.8		2.4	0.4		$940		$1,285	$532
1988	<0.1	0.2			*	$1	$414			*
1989		1.2	<0.1	0.2	*		$1,152	$6	$61	*
1990	121.1	1.9	16.5		0.1	$20,024	$1,554	$2,701		$99
1991		1.0	<0.1		*		$843	$15		*
1992		0.4	<0.1		0.2		$428	$95		$174
1993	*	*	*	*	*	*	*	*	*	*
1994	*	*	*	*	*	*	*	*	*	*
1995		<0.1	<0.1		182.5		$25	$5		$64,782
1996		*			216.8		*			$97,844
1997	*	*		*	<0.1	*	*		*	$19
1998	<0.1	0.3	<0.1		*	$49	$228	$61		*
1999		*		*	16.7		*		*	$6,904
2000		*	*		*		*	*		*
2001		*		*	*		*		*	*
2002	*				*	*				*
2003		*	*	*	*		*	*	*	*
2004		*			*		*			*
2005					*					*
2006	*					*				
2007		*			*		*			*
2008										

TABLE 9-2. West coast landings (mt) and real[1] exvessel revenues ($ 2008) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid by landing area, 1981-2008.

	Landings (mt)					Exvessel Revenues (2008 $)				
Year	**Sardine**	**P. Mackerel**	**J. Mackerel**	**Anchovy**	**Squid**	**Sardine**	**P. Mackerel**	**J. Mackerel**	**Anchovy**	**Squid**
					Monterey/Santa Cruz					
1981		*	*	*	12,822.7		*	*	*	$10,319,639
1982	*	*	*	*	10,607.3	*	*	*	*	$7,085,474
1983	*	*	*	*	500.0	*	*	*	*	$527,613
1984	0.3	7,151.1	5,486.0	1,894.7	*	$605	$1,799,100	$1,472,994	$259,024	*
1985	*	*	*	*	3,813.1	*	*	*	*	$4,328,215
1986	*	*	*	*	5,487.9	*	*	*	*	$2,830,569
1987	*	*	*	*	5,611.0	*	*	*	*	$2,491,638
1988	*	*	*	*	*	*	*	*	*	*
1989	*	*	*	*	7,145.5	*	*	*	*	$3,027,289
1990	*	*	*	*	7,917.5	*	*	*	*	$2,580,090
1991	*	*	*	*	6,703.2	*	*	*	*	$2,919,917
1992	*	*	*	*	6,111.3	*	*	*	*	$2,202,729
1993	*	*	*	*	*	*	*	*	*	*
1994	*	*	*	*	*	*	*	*	*	*
1995	*	*	*	*	2,449.1	*	*	*	*	$1,327,179
1996	*	*	*	*	*	*	*	*	*	*
1997	*	*	*	*	*	*	*	*	*	*
1998	10,009.0	1,456.7	32.5	901.2		$937,277	$217,183	$16,899	$103,215	
1999	*	*	*	*	*	*	*	*	*	*
2000	11,367.0	39.4	50.0	6,804.3	*	$1,378,092	$9,057	$38,324	$1,128,765	*
2001	7,102.5	172.2		11,660.3	*	$1,982,557	$26,155		$786,787	*
2002	*	*	*	*	25,084.8	*	*	*	*	$9,167,113
2003	*	*	*	*	*	*	*	*	*	*
2004	*	*	*	*	*	*	*	*	*	*
2005	*	*	*	*	*	*	*	*	*	*
2006	*	*	*	*	509.3	*	*	*	*	$282,104
2007	34,756.1	123.4	166.8	7,704.4	32.3	$3,369,123	$19,985	$38,263	$903,103	$8,088
2008	26,211.3	206.4	59.4	12,216.0	*	$4,021,274	$33,535	$10,801	$1,306,109	*
					San Francisco					
1981	*	*	*	*	*	*	*	*	*	*
1982		*	*	*	*		*	*	*	*
1983		*	*	*	*		*	*	*	*
1984		*	*	*	97.0		*	*	*	$123,370
1985		*	*	*	77.0		*	*	*	$74,643
1986		*		*	*		*		*	*
1987	*	*	*	*	*	*	*	*	*	*
1988	*	*	*	*	*	*	*	*	*	*
1989	*	*	*	*	*	*	*	*	*	*
1990	*	*	*	*	128.8	*	*	*	*	$56,608
1991		*	*	*	*		*	*	*	*
1992	*	*	*	*	*	*	*	*	*	*
1993		*	*	*	*		*	*	*	*
1994	*	*	*	*	*	*	*	*	*	*
1995	*	*	*	*	*	*	*	*	*	*
1996		*	*	*	*		*	*	*	*
1997	*	*	*	*	204.5	*	*	*	*	$107,691
1998	*	*	*	*	14.1	*	*	*	*	$23,716
1999	*	*	*	*	*	*	*	*	*	*
2000	0.5	<0.1	0.4	116.5	*	$297	$29	$965	$90,209	*
2001	*	*		*	*	*	*		*	*
2002	*	*		*	*	*	*		*	*
2003	0.1	<0.1	<0.1		*	$653	$187	$29		*
2004	370.1	0.1	<0.1	<0.1	164.5	$42,732	$148	$7	$34	$112,730
2005	309.0	<0.1	<0.1	<0.1	*	$31,808	$27	$4	$34	*
2006	130.9	0.7	0.2	70.5	*	$10,154	$923	$362	$5,175	*
2007	2.0	<0.1	<0.1		*	$136	$57	$17		*
2008	*		*	*	*	*		*	*	*

TABLE 9-2. West coast landings (mt) and real[1] exvessel revenues ($ 2008) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid by landing area, 1981-2008.

	Landings (mt)					Exvessel Revenues (2008 $)				
Year	**Sardine**	**P. Mackerel**	**J. Mackerel**	**Anchovy**	**Squid**	**Sardine**	**P. Mackerel**	**J. Mackerel**	**Anchovy**	**Squid**
					Northern California					
1981		1.9	<0.1		2.1		$1,332	$23		$2,641
1982		3.0	1.1		1.7		$1,376	$719		$2,263
1983		2.9	0.1		<0.1		$1,904	$40		$78
1984		0.1	<0.1	0.5	*		$100	$3	$1,369	*
1985					*					*
1986		*			*		*			*
1987		<0.1	<0.1		*		$21	$3		*
1988			*		*			*		*
1989		0.1	<0.1		*		$62	$2		*
1990		0.4			*		$320			*
1991		0.1			*		$80			*
1992		*	*	*	0.5		*	*	*	$1,936
1993		0.2	55.4	0.1	*		$192	$13,155	$87	*
1994	4.9	0.3	0.1	8.4	37.6	$2,419	$263	$110	$4,768	$17,424
1995	*	*	*		*	*	*	*		*
1996	0.3	3.1				$185	$2,714			
1997		5.7	2.2		3.4		$4,885	$1,896		$3,069
1998	*	*	*		*	*	*	*		*
1999		*	*		*		*	*		*
2000		1.7	0.1		*		$477	$128		*
2001	*			*	*	*			*	*
2002		0.2	0.1		*		$644	$48		*
2003	*		*			*		*		
2004	*	*	*		*	*	*	*		*
2005		*	*				*	*		
2006		<0.1	<0.1		*		$2	$14		*
2007										
2008			*					*		
					Oregon					
1981		<0.1					$3			
1982		<0.1		0.1			$103		$248	
1983		8.3					$18,599			
1984		3.0					$1,842			
1985		<0.1	<0.1	<0.1			$4	$2	$85	
1986		*					*			
1987		1.5					$1,067			
1988		*		*			*		*	
1989		4.7		<0.1			$2,154		$29	
1990		10.3					$6,614			
1991		0.5	19.3				$304	$4,327		
1992		462.3	316.5				$270	$1,395		
1993		279.9	276.6				$1,464	$4,541		
1994		252.2	202.3	0.9			$15,985	$12,883	$333	
1995		*	*	*			*	*	*	
1996		61.4	257.7				$6,062	$12,153		
1997		1,611.0	373.0				$3,559	$1,167		
1998	1.0	537.7	686.0			$1,186	$13,215	$66,944		
1999	*	*	*			*	*	*		
2000	*	*	*	*		*	*	*	*	
2001	12,780.4	322.0	183.1			$2,237,737	$44,300	$55,567		
2002	22,711.0	126.6	8.9	3.1		$3,802,562	$8,721	$5,163	$2,397	
2003	25,257.9	160.0	73.6	39.1		$3,812,116	$24,156	$20,624	$4,033	
2004	36,111.0	106.9	125.8	13.1		$6,051,956	$13,974	$21,005	$5,757	
2005	45,110.1	317.8	69.6	68.4	14.5	$7,233,620	$41,507	$189,335	$1,839	$8,626
2006	35,668.1	665.0	5.3	8.6	27.2	$4,154,926	$38,711	$99	$19	$17,356
2007	42,143.9	702.3	13.5	5.0	0.6	$4,805,635	$52,447	$1,045	$2,344	$312
2008	22,949.0	57.6	45.6	259.5		$5,665,290	$7,811	$415	$56,674	

TABLE 9-2. West coast landings (mt) and real[1] exvessel revenues ($ 2008) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid by landing area, 1981-2008.

	Landings (mt)					Exvessel Revenues (2008 $)				
Year	**Sardine**	**P. Mackerel**	**J. Mackerel**	**Anchovy**	**Squid**	**Sardine**	**P. Mackerel**	**J. Mackerel**	**Anchovy**	**Squid**
					Washington					
1981				*					*	
1982				*					*	
1983				*					*	
1984		*		*			*		*	
1985				*					*	
1986				*					*	
1987				*					*	
1988				*					*	
1989		*		*			*		*	
1990		*		*			*		*	
1991		*		*			*		*	
1992		*		*			*		*	
1993		*		*			*		*	
1994		*		*			*		*	
1995		7.5		118.3			$1,324		$105,909	
1996		*	*	*			*	*	*	
1997		*	*	*			*	*	*	
1998		*	*	*			*	*	*	
1999	*	*	*	*		*	*	*	*	
2000	*	*	*	*		*	*	*	*	
2001	*	*	*	*		*	*	*	*	
2002	*	*	*	*		*	*	*	*	
2003	*	*	*	*		*	*	*	*	
2004	8,934.3	22.2	7.1	213.4		$1,547,160	$2,893	$1,983	$79,422	
2005	6,721.1	23.6	10.8	163.7		$992,055	$4,185	$3,199	$41,706	
2006	4,363.1	41.2	1.8	161.1		$497,347	$14,988	$334	$41,729	
2007	*	*	*	*		*	*	*	*	
2008	*	*	*	*		*	*	*	*	
					Other Unknown					
1981		*	*	*	0.2		*	*	*	$131
1982		48.5	9.5	190.9	0.4		$31,074	$6,476	$89,484	$1,288
1983		179.1	25.5	144.7	*		$73,117	$33,854	$81,850	*
1984		49.7	49.3	110.1	2.7		$30,894	$19,882	$61,052	$3,399
1985		*	*	*	*		*	*	*	*
1986		*	*	*	*		*	*	*	*
1987	*	*		*	199.2	*	*		*	$63,345
1988	*	*	*	*	*	*	*	*	*	*
1989	*	*	*	*	*	*	*	*	*	*
1990	*	*	*	*	0.3	*	*	*	*	$382
1991		*	*	*	2.6		*	*	*	$1,942
1992	*	*	*	*	*	*	*	*	*	*
1993	*	*	*	*	*	*	*	*	*	*
1994		*	*	*	*		*	*	*	*
1995	*	*	*	*	*	*	*	*	*	*
1996	*	*	*	*	13,908.6	*	*	*	*	$5,944,814
1997	36.1	8.2		2.4	*	$108,597	$4,974		$1,260	*
1998	*	*			475.0	*	*			$357,728
1999	3.0	0.2	0.8	0.1	11,370.7	$431	$32	$694	$9	$6,041,809
2000	*	*	*	*	18,154.9	*	*	*	*	$5,630,202
2001	70.4	0.5	0.1		*	$9,627	$519	$132		*
2002	9.2	<0.1	<0.1		6,634.6	$1,458	$105	$9		$2,188,174
2003	1,547.2	16.8		122.9	*	$165,924	$2,396		$13,366	*
2004	*	*	*	*	*	*	*	*	*	*
2005	*	*	*	*	8,297.7	*	*	*	*	$5,131,984
2006	*	*		*	5,530.1	*	*		*	$3,320,294
2007	*	*	*	*	18,317.3	*	*	*	*	$11,243,583
2008	*	*		*	*	*	*		*	*

Source: PacFIN - 2006-2008 data extracted January-February 2009.

TABLE 9-2. West coast landings (mt) and real[1] exvessel revenues ($ 2008) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid by landing area, 1981-2008.

	Landings (mt)					Exvessel Revenues (2008 $)				
Year	**Sardine**	**P. Mackerel**	**J. Mackerel**	**Anchovy**	**Squid**	**Sardine**	**P. Mackerel**	**J. Mackerel**	**Anchovy**	**Squid**

[1]Real values are current values adjusted to eliminate the effects of inflation. This adjustment has been made by dividing current values by the current year GDP implicit price deflator, with a base year of 2008.

[2]Pacific mackerel landings and revenues also include landings and revenues of unspecified mackerel.

*Exvessel landings and revenues not reported because less than three vessels, with CPS finfish or market squid as principle species by principle landing area or not, or less than three processors accounted for total landings.

TABLE 9-3. Average annual real[1] exvessel prices ($ 2008) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid, 1981-2008.

Year	Pacific Sardine $/lb	Pacific Mackerel $/lb	Jack Mackerel $/lb	Anchovy $/lb	Squid $/lb
1981	$0.24	$0.25	$0.25	$0.08	$0.26
1982	$0.30	$0.23	$0.23	$0.06	$0.25
1983	$0.19	$0.21	$0.20	$0.10	$0.45
1984	$0.90	$0.19	$0.15	$0.15	$0.55
1985	$0.23	$0.17	$0.19	$0.15	$0.38
1986	$0.21	$0.16	$0.17	$0.15	$0.21
1987	$0.13	$0.13	$0.14	$0.20	$0.18
1988	$0.13	$0.15	$0.14	$0.25	$0.18
1989	$0.20	$0.13	$0.13	$0.24	$0.16
1990	$0.10	$0.11	$0.11	$0.16	$0.14
1991	$0.10	$0.13	$0.12	$0.13	$0.13
1992	$0.08	$0.17	$0.12	$0.15	$0.15
1993	$0.08	$0.10	$0.11	$0.18	$0.19
1994	$0.10	$0.11	$0.10	$0.22	$0.20
1995	$0.06	$0.10	$0.11	$0.13	$0.23
1996	$0.07	$0.10	$0.09	$0.11	$0.19
1997	$0.07	$0.10	$0.11	$0.10	$0.21
1998	$0.06	$0.08	$0.15	$0.11	$0.39
1999	$0.06	$0.08	$0.09	$0.12	$0.24
2000	$0.07	$0.09	$0.12	$0.08	$0.15
2001	$0.08	$0.10	$0.10	$0.05	$0.12
2002	$0.07	$0.09	$0.12	$0.08	$0.15
2003	$0.06	$0.09	$0.19	$0.10	$0.33
2004	$0.06	$0.09	$0.13	$0.07	$0.28
2005	$0.06	$0.09	$0.39	$0.05	$0.30
2006	$0.05	$0.07	$0.09	$0.05	$0.28
2007	$0.05	$0.07	$0.11	$0.05	$0.28
2008	$0.08	$0.09	$0.08	$0.05	$0.31

Source: PacFIN - 2006-2008 data extracted January-February 2009.

[1]Real values are current values adjusted to eliminate the effects of inflation. This adjustment has been made by dividing current values by the current year GDP implicit price deflator, with a base year of 2008.

[2]Pacific mackerel landings and revenues also include landings and revenues of unspecified mackerel.

TABLE 9-4. West coast landings (mt) and real[1] exvessel revenues ($ 2008) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid by state, 1981-08.

Year	Pacific Sardine mt	Pacific Sardine Rev	Pacific Mackerel mt	Pacific Mackerel Rev	Jack Mackerel mt	Jack Mackerel Rev	Anchovy mt	Anchovy Rev	Squid mt	Squid Rev
	California									
1981	15	$7,991	35,388	$19,280,331	17,778	$9,672,664	52,308	$8,665,542	23,510	$13,443,422
1982	2	$1,339	36,065	$18,075,811	19,617	$9,914,080	42,150	$5,363,483	16,308	$8,897,575
1983	1	$417	41,471	$19,130,359	9,829	$4,271,234	4,427	$981,673	1,824	$1,806,480
1984	1	$1,979	44,083	$18,884,866	9,154	$3,122,979	2,889	$924,027	*	*
1985	6	$3,106	37,772	$14,415,982	6,876	$2,837,923	1,626	$497,976	10,276	$8,707,191
1986	388	$176,459	48,089	$16,611,480	4,777	$1,768,042	1,535	$458,200	21,278	$9,638,002
1987	439	$129,392	46,724	$13,684,736	8,020	$2,448,021	1,390	$514,024	19,984	$8,107,845
1988	1,188	$341,183	50,863	$16,337,167	5,068	$1,582,983	1,478	$764,752	37,316	$15,036,173
1989	837	$375,317	47,708	$13,563,867	10,745	$3,187,185	2,449	$1,237,520	40,974	$14,450,086
1990	1,664	$350,323	40,081	$9,841,484	3,254	$813,745	3,208	$1,072,443	28,447	$8,694,312
1991	7,587	$1,593,510	32,066	$9,530,912	1,693	$439,404	4,014	$1,095,755	37,389	$10,836,222
1992	18,052	$3,280,045	18,577	$7,002,848	1,209	$416,350	1,124	$333,659	13,112	$4,275,540
1993	15,346	$2,638,176	11,819	$2,564,288	1,673	$465,575	1,959	$769,688	42,830	$17,531,340
1994	11,644	$2,520,850	10,008	$2,369,509	2,704	$621,495	1,789	$835,466	55,383	$23,858,761
1995	40,256	$5,761,948	8,626	$1,856,288	1,728	$461,070	1,886	$472,332	70,252	$36,157,048
1996	32,553	$4,995,621	9,603	$2,050,270	2,177	$470,596	4,419	$1,009,740	80,561	$34,654,035
1997	43,290	$6,908,085	18,401	$4,296,242	1,160	$383,203	5,720	$1,197,779	70,329	$32,125,530
1998	43,311	$5,540,080	20,978	$3,865,815	1,052	$513,247	1,481	$282,492	2,895	$2,484,590
1999	59,700	$7,582,108	8,788	$1,618,327	952	$278,905	5,214	$1,327,557	92,101	$49,645,921
2000	53,612	$7,775,501	21,920	$4,160,178	1,269	$362,225	11,753	$1,987,665	118,903	$38,740,420
2001	51,893	$8,692,808	6,925	$1,515,470	3,624	$776,662	19,277	$1,885,645	86,203	$23,410,013
2002	58,353	$7,890,685	3,369	$659,839	1,005	$273,492	4,650	$743,153	72,895	$24,632,010
2003	34,745	$3,727,642	3,999	$820,507	156	$73,949	1,676	$353,676	45,056	$32,904,215
2004	44,293	$4,920,956	3,579	$697,637	1,027	$309,006	6,793	$932,862	40,068	$24,581,119
2005	34,633	$3,675,951	3,244	$630,311	213	$61,577	11,182	$1,271,641	55,740	$36,717,933
2006	46,577	$5,661,256	5,904	$924,258	1,167	$220,794	12,791	$1,440,155	49,153	$29,909,944
2007	80,957	$8,678,020	5,018	$834,649	631	$151,964	10,390	$1,219,771	49,499	$30,846,255
2008	*	*	*	*	*	*	*	*	34,639	$23,866,799

TABLE 9-4. West coast landings (mt) and real[1] exvessel revenues ($ 2008) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid by state, 1981-08.

Year	Pacific Sardine mt	Pacific Sardine Rev	Pacific Mackerel mt	Pacific Mackerel Rev	Jack Mackerel mt	Jack Mackerel Rev	Anchovy mt	Anchovy Rev	Squid mt	Squid Rev
Oregon										
1981			<1	$3						
1982			<1	$103			<1	$248		
1983			8	$18,599						
1984			3	$1,842						
1985			<1	$4	<1	$2	<1	$85		
1986			*	*						
1987			1	$1,067						
1988			*	*			*	*		
1989			5	$2,154			<1	$29		
1990			10	$6,631						
1991			<1	$304	19	$4,327				
1992			462	$270	317	$1,397				
1993			280	$1,464	277	$4,541				
1994			252	$15,985	202	$12,883	1	$333		
1995			*	*	*	*	*	*		
1996			61	$6,062	258	$12,153				
1997			1,611	$3,559	373	$1,167				
1998	1	$1,186	538	$13,215	686	$66,944				
1999	*	*	*	*	*	*				
2000	*	*	*	*	*	*	*	*		
2001	12,780	$2,237,737	322	$44,300	183	$55,567				
2002	22,711	$3,802,562	127	$8,721	9	$5,163	3	$2,397		
2003	25,258	$3,812,116	160	$24,156	74	$20,624	39	$4,033		
2004	36,111	$6,051,956	107	$13,974	126	$21,005	13	$5,757		
2005	45,110	$7,233,620	318	$41,507	70	$189,335	68	$1,839	14	$8,626
2006	35,668	$4,154,926	665	$38,711	5	$99	9	$19	27	$17,356
2007	42,144	$4,805,635	702	$52,447	14	$1,045	5	$2,344	1	$312
2008	22,949	$5,665,290	58	$7,811	46	$415	260	$56,674		

TABLE 9-4. West coast landings (mt) and real[1] exvessel revenues ($ 2008) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid by state, 1981-08.

Year	Pacific Sardine mt	Pacific Sardine Rev	Pacific Mackerel mt	Pacific Mackerel Rev	Jack Mackerel mt	Jack Mackerel Rev	Anchovy mt	Anchovy Rev	Squid mt	Squid Rev
	Washington									
1981							*	*		
1982							*	*		
1983							*	*		
1984			*	*			*	*		
1985							*	*		
1986							*	*		
1987							*	*		
1988							*	*		
1989			*	*			*	*		
1990			*	*			*	*		
1991			*	*			*	*		
1992			*	*			*	*		
1993			*	*			*	*		
1994			*	*			*	*		
1995			7	$1,324			118	$105,909		
1996			*	*	*	*	*	*		
1997			*	*	*	*	*	*		
1998			*	*	*	*	*	*		
1999	*	*	*	*	*	*	*	*		
2000	*	*	*	*	*	*	*	*		
2001	*	*	*	*	*	*	*	*		
2002	*	*	*	*	*	*	*	*		
2003	*	*	*	*	*	*	*	*		
2004	8,934	$1,547,160	22	$2,893	7	$1,983	213	$79,422		
2005	6,721	$992,055	24	$4,185	11	$3,199	164	$41,706		
2006	4,363	$497,347	41	$14,988	2	$334	161	$41,729		
2007	*	*	*	*	*	*	*	*		
2008	*	*	*	*	*	*	*	*		

Source: PacFIN - 2006-2008 data extracted January-February 2009.

[1]Real values are current values adjusted to eliminate the effects of inflation. This adjustment has been made by dividing current values

TABLE 9-4. West coast landings (mt) and real[1] exvessel revenues ($ 2008) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid by state, 1981-08.

Year	Pacific Sardine mt	Pacific Sardine Rev	Pacific Mackerel mt	Pacific Mackerel Rev	Jack Mackerel mt	Jack Mackerel Rev	Anchovy mt	Anchovy Rev	Squid mt	Squid Rev

by the current year GDP implicit price deflator, with a base year of 2008.

[2]Pacific mackerel landings and revenues also include landings and revenues of unspecified mackerel.

*Exvessel landings and revenues not reported because less than three vessels, with CPS finfish or market squid as principle species by principle landing area or not, or less than three processors accounted for total landings.

TABLE 9-5. West coast CPS landings (mt) and real[1] exvessel revenues ($ 2008) by gear group, 1981-2008.

Year	Roundhaul or Lampara	Dip Net	Pot or Trap	Trawl	Hook and Line	Gillnet	Other or Unknown
Landings (metric tons)							
1981	120,578	8,231	<1	11	9	80	
1982	110,254	3,693	1	13	27	82	
1983	56,944	490	<1	8	2	44	40
1984	56,285	64	<1	4	1	189	
1985	55,494	495	1	20	9	430	<1
1986	75,784	88	4	3	<1	135	
1987	75,048	213	1	6	7	1,314	<1
1988	94,190	140	1	39	1	1,395	<1
1989	102,026	248	<1	132	3	100	
1990	76,010	489	1	15	34	72	
1991	81,817	724	37	128	4	63	
1992	47,666	4,322	3	802	15	31	
1993	68,346	5,171	2	592	3	44	
1994	78,350	2,997	59	510	49	11	13
1995	120,940	1,410	1	386	121	9	42
1996	128,354	855	1	401	64	23	
1997	138,534	247	<1	2,157	90	14	
1998	69,660	37	<1	1,334	44	5	
1999	166,933	528	72	961	12	10	
2000	219,844	1,568	45	275	420	4	<1
2001	190,196	1,791	1	621	153	3	
2002	178,656	761	<1	10	10	2	
2003	123,128	133	<1	76	10	<1	<1
2004	140,277	790	<1	110	7	<1	63
2005	154,875	2,504	11	106	9	<1	
2006	154,731	1,582	97	33	84	<1	
2007	193,312	826	36	15	25	<1	<1
2008	139,792	444		51	3	<1	
Revenues (2008 $)							
1981	$48,676,012	$2,216,896	$395	$10,266	$12,670	$76,169	
1982	$40,992,785	$1,127,765	$5,330	$10,343	$21,881	$60,881	
1983	$25,666,874	$457,428	$2,208	$6,490	$3,139	$31,640	$16,777
1984	$23,334,517	$79,197	$4,026	$4,437	$2,133	$111,073	
1985	$25,408,420	$683,851	$1,535	$20,116	$8,548	$289,474	$1,823
1986	$28,480,346	$56,713	$2,188	$3,869	$279	$88,233	
1987	$24,341,345	$83,271	$3,989	$4,878	$3,625	$501,437	$18
1988	$33,399,508	$64,713	$1,403	$57,863	$984	$502,663	$3
1989	$32,354,239	$82,417	$83	$57,451	$1,672	$48,209	
1990	$20,576,738	$84,495	$1,344	$12,289	$53,050	$54,401	
1991	$23,304,066	$95,947	$12,255	$42,373	$8,309	$33,171	
1992	$14,401,932	$835,070	$3,337	$12,418	$34,234	$19,622	
1993	$22,507,933	$1,339,296	$2,976	$15,582	$6,103	$32,362	
1994	$29,299,074	$780,873	$29,261	$46,418	$68,563	$9,235	$3,998
1995	$43,986,095	$585,050	$851	$28,135	$86,626	$7,429	$14,540
1996	$42,775,067	$301,406	$784	$63,906	$99,034	$17,524	
1997	$44,620,702	$132,732	$156	$47,146	$141,845	$10,465	
1998	$12,600,423	$37,734	$207	$118,238	$88,592	$4,504	
1999	$60,293,757	$279,639	$23,612	$50,043	$37,780	$8,806	
2000	$54,923,416	$561,514	$14,346	$37,807	$125,802	$2,832	$136
2001	$39,725,239	$529,974	$550	$184,829	$54,946	$2,250	
2002	$40,469,716	$251,228	$162	$7,418	$32,521	$1,768	
2003	$43,581,953	$96,526	$85	$22,005	$34,805	$157	$25
2004	$38,609,406	$462,417	$2	$18,974	$24,153	$127	$42,875
2005	$48,901,236	$1,734,799	$7,315	$203,184	$19,261	$182	
2006	$41,905,787	$955,589	$16,912	$17,272	$22,459	$191	
2007	$46,570,350	$530,115	$21,162	$3,775	$28,636	$70	$41
2008	$40,546,334	$296,145		$1,976	$10,718	$39	

Source: PacFIN - 2006-2008 data extracted January-February 2009.

[1]Real values are current values adjusted to eliminate the effects of inflation. This adjustment has been made by dividing current values by the current year GDP implicit price deflator, with a base year of 2008.

Tables 9-6 (finfish) and 9-7 (squid). Number of vessels with West coast landings of CPS finfish or market squid by landing area, 1981-2008.

Year	San Diego	Orange & LA	Ventura & Santa Barbara	San Luis Obispo	Monterey & Santa Cruz	San Francisco	Northern CA	Other CA	Oregon	Washington	Other
					CPS Finfish						
1981	64	136	71	46	82	9	6	*	5	4	24
1982	60	135	38	53	109	18	7		4	*	30
1983	53	113	28	49	117	47	15		64	*	15
1984	54	103	35	44	121	65	3	*	3	*	26
1985	51	124	49	34	115	74			4	*	24
1986	39	116	37	33	85	48	*	*	*	*	13
1987	38	110	41	30	77	63	5		92	*	21
1988	39	104	40	22	97	77	*		79	3	21
1989	46	99	31	28	62	111	5	*	152	3	20
1990	48	95	34	50	122	106	6		162	4	30
1991	53	96	34	33	48	21	4		39	4	18
1992	53	86	12	27	152	138	7		38	11	26
1993	46	103	14	16	73	41	5		28	10	23
1994	49	94	17	7	52	53	8	4	38	12	14
1995	40	96	32	3	35	38	*		44	6	18
1996	35	99	29	*	41	37	4		41	14	31
1997	27	102	20	3	49	53	7		50	18	14
1998	21	77	15	10	35	56	11		46	9	10
1999	17	80	17	*	24	21	5		44	10	7
2000	17	83	18	*	40	35	7		43	19	10
2001	18	76	17	3	27	14	4		43	28	6
2002	8	80	9	*	22	7	4		42	24	7
2003	8	58	14	*	22	6	*		43	20	9
2004	6	60	11	*	19	9	4		46	21	17
2005	4	66	12		14	7	*		42	25	16
2006	4	56	20	*	20	13	5		39	26	7
2007	6	52	25	*	22	9		*	47	34	22
2008	4	54	26		20	3	*		47	19	22

Tables 9-6 (finfish) and 9-7 (squid). Number of vessels with West coast landings of CPS finfish or market squid by landing area, 1981-2008.

Year	San Diego	Orange & LA	Ventura & Santa Barbara	San Luis Obispo	Monterey & Santa Cruz	San Francisco	Northern CA	Other CA	Oregon	Washington	Other
					Market Squid						
1981	6	61	26	9	53	*	10				3
1982	*	51	25	7	53	*	7				3
1983	4	44	12	4	32	22	3				7
1984	*	9	17	6	31	8	*				4
1985	*	44	32	5	59	10	*				23
1986	*	43	27	7	41	4	*				8
1987	7	41	30	3	33	17	*				7
1988	10	51	32	4	30	7	*				11
1989	3	48	31	7	28	3	*				5
1990	7	42	26	3	36	9	*				3
1991		36	24	*	30	7	*				3
1992	*	18	14	4	36	16	4				*
1993	*	43	25	13	33	13	*				9
1994	3	42	31	11	34	6	3	*			9
1995	*	59	44	8	28	4	*				27
1996	4	62	66	8	28	*					39
1997	3	55	50	3	28	4	11				22
1998	3	19	45	*		3	*				18
1999	*	76	80	3	13	*	*				43
2000	*	86	63	*	23	*	*				42
2001	4	62	50	*	18	3	3				27
2002		72	61	5	33	3	*				32
2003		43	54	9	36	17					29
2004	3	72	50	8	23	3	*				42
2005		90	40	*	12	*			28		28
2006	3	89	30		11	*	*		37		24
2007	*	61	41	*	4	*			13		40
2008	4	80	35		*	*			3		43

Source: PacFIN - 2006-2008 data extracted January-February 2009.

*Number of vessels not reported because less than three vessels accounted for total landings.

TABLE 9-8 (finfish) and 9-9 (squid). Number of vessels with CPS finfish or market squid as principle species[1] by principle landing area[2], 1981-2008.

Year	San Diego	Orange & LA	Ventura & Santa Barbara	San Luis Obispo	Monterey & Santa Cruz	San Francisco	Northern CA	Other CA	Oregon	Washington	Other
					CPS Finfish						
1981	4	53	6	*	3	*				*	5
1982	10	49	8	*	*	*				*	7
1983	8	50	7		7					*	3
1984	3	35	4		18	*				*	4
1985	*	40	6	*	3	*				*	*
1986	*	33	8	*	3	*				*	
1987	*	39	6		*	*				*	
1988	3	28	3		*	*			*	*	
1989	6	32	6		4	*				*	*
1990	5	28	3		*					*	*
1991	6	37	4		5					*	*
1992	5	37	4		3	*	*			*	*
1993	*	23	3	*	*	*					*
1994	*	27	6	*	*			*			
1995	*	18	5		*				*		
1996	*	19	7		9						
1997	*	26	3	*	5						
1998	3	37	4		8		*				
1999	*	19	*		7	*			*	*	
2000		26	3		3				6	*	
2001		24	3		3				11	6	
2002	*	23	4		*				10	8	
2003	*	10	*		*		*		10	5	
2004	*	13	3		5				13	6	
2005	*	8	*		*				14	4	*
2006	*	6	3		4				8	3	*
2007		9	*		6				8	*	*
2008		8	*		10	*			13	6	*

TABLE 9-8 (finfish) and 9-9 (squid). Number of vessels with CPS finfish or market squid as principle species[1] by principle landing area[2], 1981-2008.

Year	San Diego	Orange & LA	Ventura & Santa Barbara	San Luis Obispo	Monterey & Santa Cruz	San Francisco	Northern CA	Other CA	Oregon	Washington	Other
					Market Squid						
1981	x	14	3		33					*	
1982		16	*		35					*	
1983		6			4	*			*	7	*
1984					*				4	7	
1985		6	6		28				3		*
1986		9	4		16	*					*
1987	*	6	8		14						
1988	3	18	18		15						*
1989	*	16	12		15						*
1990	*	7	13		12						
1991		5	15		12	*					
1992			4		16	*					
1993		15	13	3	16						*
1994		8	18		19	*					4
1995		24	31		3	*				*	6
1996		30	41		7					*	15
1997		28	33		8						9
1998		3	22								6
1999		31	47		*						19
2000	*	43	30		8						9
2001	*	32	22		8	*					5
2002		33	11		17	*					6
2003		20	21		15	*					15
2004	*	41	15		8						9
2005		59	12		*						8
2006		61	4								6
2007		29	14								22
2008		43	5								11

Source: PacFIN - 2006-2008 data extracted January-February 2009.

[1]Principle species is the species that accounts for the greatest share of a vessel's total exvessel revenues across all species landed.

[2]Principle landing area is the area that accounts for the greatest share of a vessel's total exvessel revenues across all areas in which it had landings.

*Number of vessels not reported because less than three vessels accounted for total landings.

TABLE 9-10 and 9-11. Number of processors and buyers, by landing area, whose annual purchases of CPS finfish or market squid represents the largest share of their total annual exves expenditures, 1981-2008.

Year	San Diego	Orange & LA	Ventura & Santa Barbara	San Luis Obispo	Monterey & Santa Cruz	San Francisco	Northern CA	Other CA	Oregon	Washington	Other
					CPS Finfish						
1981	*	5	4	*	*	*					*
1982		3	7							*	5
1983	*	4	5		*	*				*	3
1984	*	*	3		3	*				*	3
1985		5	*	*	*	*				*	*
1986		5	4		*	*				*	*
1987	*	6	5		*	*				*	*
1988		7	4		*	*				*	*
1989	3	8	3		*	*				*	*
1990	6	5	*		*	*				*	*
1991	*	10	3		*	*				*	*
1992	*	7	4		*	*				*	
1993		4	5		*	*				*	
1994	*	6	4		*	*		*		*	
1995	*	7	4			*			*		*
1996	*	4	6		*	*				*	*
1997	*	9	6		*	*				*	
1998	*	11	6		3	*	*			*	*
1999	*	5	4		*	3	*			*	
2000		10	4		3				*	*	*
2001		6	6	*		*	*		4	*	
2002	*	7	6		*	*			3	*	
2003	*	8	5		*		*		3	*	
2004	*	7	8	*	*		*		5		*
2005	*	*	3		*				6		
2006	*	*	3		*				5		*
2007		*	*	*	3				4		
2008		*	*						3	*	*

TABLE 9-10 and 9-11. Number of processors and buyers, by landing area, whose annual purchases of CPS finfish or market squid represents the largest share of their total annual exves expenditures, 1981-2008.

Year	San Diego	Orange & LA	Ventura & Santa Barbara	San Luis Obispo	Monterey & Santa Cruz	San Francisco	Northern CA	Other CA	Oregon	Washington	Other
					Market Squid						
1981		*	*		5	4					
1982		*			7	*				*	
1983						3				3	
1984					*					*	
1985			3		5						*
1986		*	3		6	*					*
1987		*	3		4	*					
1988		*	3	*	*	*					
1989		*	11	*	3	*					
1990		*	6		4						
1991		*	6			*					
1992			4			3					
1993	*		8	*	*	*					
1994		*	16	*	*			*			*
1995		*	16								*
1996		4	10		*					*	3
1997		6	10		*						*
1998	*		3								
1999		6	19								5
2000	*	9	20	*	*						5
2001	*	3	14	*	*		*				*
2002		4	11	*							4
2003		4	11	*	*						*
2004		3	16	*	*						*
2005		7	9		*						3
2006		8	5	*							3
2007		*	6			*					5
2008			8								*

Source: PacFIN - 2006-2008 data extracted January-February 2009.

*Number of processors and buyers not reported because less than three accounted for total purchases.

TABLE 11-1. Commercial harvest (metric tons) of CPS finfish in Ensenada, Baja California, Mexico, for calendar years 1978-2007[1,2,3,4/]. Data not yet available for 2008. Market squid are not commercially fished off Ensenada.

Year	Pacific sardine	Northern anchovy	Pacific mackerel	Jack mackerel
1978	0	135,036	0	---
1979	0	192,476	0	---
1980	0	242,907	0	---
1981	0	258,745	0	---
1982	0	174,634	0	---
1983	274	87,429	135	---
1984	0	102,931	128	---
1985	3,722	117,192	2,582	---
1986	243	93,547	4,883	---
1987	2,432	124,482	2,082	---
1988	2,035	79,495	4,484	902
1989	6,224	81,811	13,687	0
1990	11,375	99	35,767	25
1991	31,391	831	17,500	30
1992	34,568	2,324	24,345	---
1993	32,045	284	7,741	---
1994	20,877	875	13,319	85
1995	35,396	17,772	4,821	0
1996	39,065	4,168	5,604	47
1997	68,439	1,823	12,477	78
1998	47,812	972	50,726	480
1999	58,569	3,482	10,168	781
2000	51,173	1,562	7,182	0
2001	22,246	76	4,078	0
2002	43,437	0	7,962	0
2003	30,540	1,287	2,678	0
2004	44,382	1,797	1,530	0
2005	55,323	4,873	2,343	0
2006	57,237	1,567	2,318	0
2007	36,847	4,058	3,057	0
2008	---	---	---	---

1/ Data for 1978 to 2002 from García and Sánchez (2003).
2/ Data for Jan-Nov 2003 provided by Dr. Celia Eva-Cotero, CRIP-INP Ensenada (pers. comm.).
3/ Sardine landings for 1989 through 2004 provided by Manuel Nevarrez, CRIP-INP Guaymas (pers. comm.).
4/ CPS landings from 2005 through 2007 from CONAPESCA:
http://www.conapesca.sagarpa.gob.mx/wb/cona/cona_anuario_estadistico_de_pesca

TABLE 11-2. Pacific sardine population numbers (millions), spawning and age 1+ biomasses (mt) at the beginning of each biological year, 1981-82 to 2008-09 (July-June) (Hill et al. 2008). Recruitment is defined as number at age-0. Age 1+ biomass as of July 2008 (bold) served as the basis for setting a HG for the U.S. fishery in calendar year 2009.

Biological	--------------- Population Numbers-at-age (millions) ----------------									Spawning	Age 1+
Year	0 (*R*)	1	2	3	4	5	6	7	8+	Biomass	Biomass
1981-82	22	15	2.8	1.0	0.3	0.2	0.1	0.5	1.1	1,257	1,315
1982-83	52	15	10	2	1	0.2	0.1	0.1	1	1,871	1,944
1983-84	93	35	9	5	1	0.3	0.1	0.0	0.5	2,803	2,904
1984-85	106	62	23	6	3	0.4	0.1	0.0	0.3	2,902	5,292
1985-86	137	71	34	5	0	0.2	0.0	0.0	0.0	5,193	5,919
1986-87	491	92	44	15	2	0.1	0.0	0.0	0.0	8,891	9,029
1987-88	909	329	57	22	6	1	0.0	0.0	0.0	18,480	19,674
1988-89	875	609	204	25	7	2	0.2	0.0	0.0	41,784	42,191
1989-90	882	587	399	120	13	4	1	0.1	0.0	60,375	70,887
1990-91	1,751	591	375	215	56	6	2	0.4	0.0	75,604	88,376
1991-92	2,869	1,172	374	201	102	26	3	1	0.2	92,485	117,160
1992-93	1,779	1,922	741	182	78	37	9	1	0.3	119,235	170,236
1993-94	5,194	1,160	853	278	82	41	21	5	1	153,156	170,178
1994-95	7,816	3,429	661	459	160	50	26	14	4	247,078	271,031
1995-96	3,067	5,112	1,836	342	260	97	31	17	11	389,916	437,942
1996-97	3,969	2,035	3,023	1,047	206	164	63	20	18	449,743	531,859
1997-98	7,841	2,635	1,204	1,714	629	130	105	41	25	415,710	559,613
1998-99	16,351	5,147	1,318	537	880	360	79	66	42	503,942	589,564
1999-00	3,649	10,795	2,764	673	302	531	226	50	70	778,204	887,809
2000-01	1,903	2,384	6,082	1,620	427	198	352	150	80	817,219	1,002,330
2001-02	7,086	1,222	1,249	3,421	997	272	127	226	148	676,213	878,841
2002-03	1,076	4,423	513	601	1,984	617	171	80	238	572,520	785,200
2003-04	14,063	682	1,938	241	338	1,193	378	106	197	471,793	610,683
2004-05	7,158	9,044	333	965	135	199	717	229	183	591,628	730,489
2005-06	9,820	4,689	4,979	171	536	79	119	429	247	688,977	847,585
2006-07	2,299	6,416	2,619	2,673	98	320	48	72	413	754,290	949,717
2007-08	2,603	1,468	3,341	1,409	1,574	60	200	30	304	625,704	867,100
2008-09	2,101	1,584	579	1,541	798	951	37	123	207	479,519	**662,886**

TABLE 11-3. Annual U.S. Pacific sardine landings and HGs (metric tons), 1981-2009.

Year	Southern California	Northern California	California Total	Oregon	Washington	U.S. Total	HG South	HG North	HG Total
1981	34.4	0.0	34.4	0.0	0.0	34.4	n/a	n/a	n/a
1982	1.8	0.0	1.8	0.0	0.0	1.8	n/a	n/a	n/a
1983	0.6	0.0	0.6	0.0	0.0	0.6	n/a	n/a	n/a
1984	0.9	0.3	1.2	0.0	0.0	1.2	n/a	n/a	n/a
1985	3.7	2.2	5.9	0.0	0.0	5.9	n/a	n/a	n/a
1986	304.0	84.4	388.4	0.0	0.0	388.4	n/a	n/a	n/a
1987	391.6	47.8	439.4	0.0	0.0	439.4	n/a	n/a	n/a
1988	1,185.4	3.0	1,188.4	0.0	0.0	1,188.4	n/a	n/a	n/a
1989	598.7	238.0	836.7	0.0	0.0	836.7	n/a	n/a	n/a
1990	1,537.1	127.1	1,664.2	0.0	0.0	1,664.2	n/a	n/a	n/a
1991	6,601.4	985.9	7,587.3	0.0	0.0	7,587.3	n/a	n/a	n/a
1992	14,821.9	3,127.6	17,949.5	4.0	0.0	17,953.5	n/a	n/a	n/a
1993	14,669.6	675.6	15,345.2	0.2	0.0	15,345.4	n/a	n/a	n/a
1994	9,348.5	2,300.0	11,648.5	0.0	0.0	11,648.5	n/a	n/a	n/a
1995	34,645.7	5,683.2	40,328.9	0.0	0.0	40,328.9	n/a	n/a	n/a
1996	24,565.0	7,988.6	32,553.6	0.0	0.0	32,553.6	n/a	n/a	n/a
1997	29,885.4	13,359.7	43,245.1	0.0	0.0	43,245.1	n/a	n/a	n/a
1998	32,462.1	10,514.3	42,976.4	1.0	0.0	42,977.4	n/a	n/a	n/a
1999	42,017.2	17,246.3	59,263.5	775.5	1.0	60,040.0	n/a	n/a	n/a
2000	42,248.0	11,367.5	53,615.5	9,527.9	4,842.0	67,985.4	124,527.3	62,263.7	186,791.0
2001	44,721.5	7,104.0	51,825.5	12,780.3	11,127.1	75,732.9	89,824.7	44,912.3	134,737.0
2002	44,464.0	13,881.0	58,345.0	22,710.8	15,820.0	96,875.8	78,961.3	39,480.7	118,442.0
2003	24,832.0	7,921.5	32,753.5	25,257.6	11,920.1	69,931.2	73,938.7	36,969.3	110,908.0
2004	32,393.4	15,308.3	47,701.8	36,110.7	8,911.0	92,723.5	81,831.3	40,915.7	122,747.0
2005	30,252.6	7,940.1	38,192.7	45,109.7	6,714.0	90,016.4	90,786.0	45,393.0	136,179.0
2006	33,285.8	17,743.1	51,028.9	35,648.2	4,362.3	91,039.4	n/a	n/a	118,937.0
2007	34,782.1	46,198.6	80,980.7	42,143.6	4,664.9	127,789.2	n/a	n/a	152,564.0
2008	26,711.0	31,089.3	57,800.2	22,948.8	6,435.2	87,184.2	n/a	n/a	89,093.0
2009	---	---	---	---	---	---	n/a	n/a	66,932.0

1/ As of 2003, the 'Southern Subarea' comprises fisheries and landings from Pt. Arena, California (39°N latitude) to the Mexican border.
2/ As of 2006, the U.S. sardine HG was no longer managed by subarea. HG's are now allocated coastwide and released on a seasonal basis.

TABLE 11-4. West Coast Pacific sardine landings by country, 1981-2008. Landings made by commercial fisheries based in Southern Baja California and the Gulf of California are not included. Ensenada landings for 2008 not yet available.

Year	Ensenada México	United States	Canada	Total
1981	0.0	34.4	0.0	34.4
1982	0.0	1.8	0.0	1.8
1983	274.0	0.6	0.0	274.6
1984	0.0	1.2	0.0	1.2
1985	3,722.0	5.9	0.0	3,727.9
1986	243.0	388.4	0.0	631.4
1987	2,432.0	439.4	0.0	2,871.4
1988	2,035.0	1,188.4	0.0	3,223.4
1989	6,224.0	836.7	0.0	7,060.7
1990	11,375.0	1,664.2	0.0	13,039.2
1991	31,391.0	7,587.3	0.0	38,978.3
1992	34,568.0	17,953.5	0.0	52,521.5
1993	32,045.0	15,345.4	0.0	47,390.4
1994	20,877.0	11,643.5	0.0	32,520.5
1995	35,396.0	40,326.9	25.0	75,747.9
1996	39,065.0	32,553.1	88.0	71,706.1
1997	68,439.0	43,245.1	34.0	111,718.1
1998	47,812.0	42,956.4	745.0	91,513.4
1999	58,569.0	60,040.0	1,250.0	119,859.0
2000	51,173.0	67,985.4	1,718.0	120,876.4
2001	22,246.0	75,732.4	1,600.0	99,578.4
2002	43,437.0	96,875.8	1,044.0	141,356.8
2003	30,540.0	69,917.2	954.0	101,411.2
2004	44,382.0	92,723.5	4,258.8	141,364.3
2005	55,322.5	90,016.4	3,200.0	148,539.0
2006	57,236.9	91,039.4	1,558.0	149,834.3
2007	36,846.8	127,789.2	1,520.0	166,156.0
2008	---	87,184.2	10,435.2	---

TABLE 11-5. RecFIN estimated recreational harvest of Pacific (chub) mackerel by state (type 'A+B1' estimate in metric tons), 1980-2008.

Year	California	Oregon	Washington	Total
1980	2,754.44	0.00	0.00	2,754.44
1981	1,394.47	0.00	0.00	1,394.47
1982	1,667.49	0.00	0.00	1,667.49
1983	1,467.35	1.50	0.00	1,468.85
1984	1,445.11	0.24	0.00	1,445.36
1985	1,076.62	0.02	0.00	1,076.64
1986	1,002.60	0.00	0.00	1,002.60
1987	1,271.19	0.00	0.00	1,271.19
1988	800.08	0.00	0.00	800.08
1989	610.57	0.00	0.00	610.57
1990	---	---	---	---
1991	---	---	---	---
1992	---	---	---	---
1993	621.92	2.08	0.00	624.00
1994	947.13	0.21	0.00	947.34
1995	1,026.32	0.12	0.00	1,026.44
1996	693.85	0.10	0.00	693.95
1997	966.96	0.31	0.00	967.27
1998	448.23	0.04	1.00	449.26
1999	196.04	0.00	0.33	196.37
2000	250.00	0.07	0.00	250.07
2001	561.39	0.05	0.00	561.44
2002	279.11	0.11	0.00	279.22
2003	341.35	0.27	0.00	341.61
2004	546.44	0.10	0.00	546.53
2005	312.06	0.07	0.00	312.13
2006	463.22	0.11	0.00	463.33
2007	239.35	0.92	0.00	240.27
2008	291.21	0.02	0.00	291.23

TABLE 11-6. RecFIN estimated recreational harvest of Pacific (chub) mackerel by fishing mode (type ‘A+B1’ estimate in metric tons), 1980-2008. Estimates for ‘Man Made Structures’ and ‘Beach/Bank’ were included in ‘Shore Modes.’

Year	Shore Modes	Party/ Charter	Private/ Rental	Total
1980	424.8	1,320.5	1,009.2	2,754.4
1981	288.1	590.7	515.7	1,394.5
1982	274.7	865.1	527.6	1,667.5
1983	361.9	702.6	404.3	1,468.9
1984	281.9	577.9	585.5	1,445.4
1985	142.0	544.7	389.9	1,076.6
1986	91.6	520.1	390.9	1,002.6
1987	450.8	244.6	575.8	1,271.2
1988	105.5	239.1	455.4	800.1
1989	256.7	134.8	219.1	610.6
1990	---	---	---	---
1991	---	---	---	---
1992	---	---	---	---
1993	88.8	172.5	362.7	624.0
1994	205.9	245.1	496.3	947.3
1995	121.2	373.5	531.8	1,026.4
1996	93.4	319.4	281.1	694.0
1997	148.3	168.6	650.4	967.3
1998	96.7	131.2	221.4	449.3
1999	62.4	60.7	73.3	196.4
2000	51.3	76.8	121.9	250.1
2001	347.0	52.2	162.2	561.4
2002	92.9	25.7	160.6	279.2
2003	208.4	25.4	107.8	341.6
2004	406.3	20.3	119.9	546.5
2005	225.0	45.5	41.6	312.1
2006	406.2	14.7	42.4	463.3
2007	187.0	19.1	34.1	240.3
2008	253.7	19.9	17.6	291.2

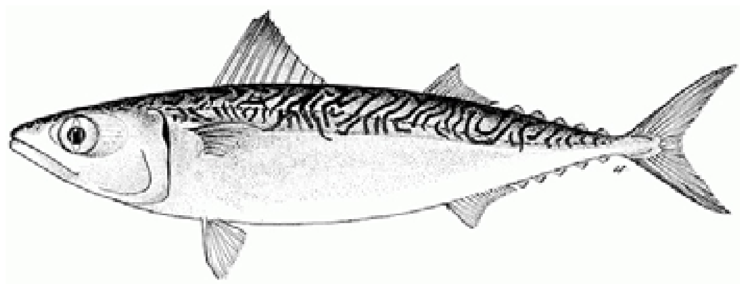
TABLE 11-7. Pacific mackerel HGs and landings (mt) by July-June fishing season.

Fishing Season	Quota or HG[a]	Landings
1992-93	34,010	25,584
1993-94	23,147	10,787
1994-95	14,706	9,372
1995-96	9,798	7,615
1996-97	8,709	9,788
1997-98	22,045	23,413
1998-99	30,572	19,578
1999-00	42,819	6,732
2000-01	20,740	20,937
2001-02	13,837	8,436
2002-03	12,535	3,541
2003-04	10,652	5,972
2004-05	13,268	5,012
2005-06	17,419	4,572
2006-07	19,845	7,531
2007-08	40,000	5,593
2008-09[b]	40,000	*2,051*

a/ California Quotas 1992-03 through 1998-99. PFMC HGs from 1999-00 onward.
b/ 2008-09 landings through March, 2009.

Agenda Item H.1.b
Attachment 1
June 2009

PACIFIC MACKEREL (*Scomber japonicus*) STOCK ASSESSMENT FOR USA MANAGEMENT IN THE 2009-10 FISHING YEAR



by

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Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, Oregon 97220-1384

June 15, 2009

Crone, P. R., K. T. Hill, J. D. McDaniel, and N. C. H. Lo. 2009. Pacific mackerel (*Scomber japonicus*) stock assessment for USA management in the 2009-10 fishing year. Pacific Fishery Management Council, Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220, USA. 197 p.

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PREFACE

A Pacific mackerel stock assessment is conducted annually in support of the Pacific Fishery Management Council (PFMC) process, which ultimately establishes a harvest guideline ('HG' or quota) for the Pacific mackerel fishery that operates off the USA Pacific coast. The HG for mackerel applies to a fishing/management season that spans from July 1st and ends on June 30th of the subsequent year (henceforth, presented as a 'fishing year'). In this context, in this document, both a two-year (2008-09) and single-year (2008) reference refer to the same fishing year that spanned from July 1, 2008 to June 30, 2009. The primary purpose of the assessment is to provide an estimate of current abundance (in biomass), which is used in a harvest control rule for calculation of annual-based HGs. For details regarding this species' harvest control rule, see Amendment 8 of the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP), section 4.0 (PFMC 1998).

The last updated assessment and quota-setting (HG) process was completed in May 2008, i.e., the assessment was considered a formal 'update,' as defined by the PFMC (see PFMC 2009). The 2008-09 fishing year (July1, 2008 – June 30, 2009) harvest guideline was 51,722 mt. The stock assessment presented here reflects a 'full' assessment that has undergone formal review as outlined by the PFMC and Science and Statistical Committee (SSC), see STAR (2009). Specifically, a week-long stock assessment review (STAR) panel was convened from May 4-8, 2009 (NOAA Fisheries, Southwest Fisheries Science Center in La Jolla, CA) to evaluate the ongoing Pacific mackerel stock assessment, as well as two independent surveys presently under consideration in the Pacific sardine assessment. Important areas of general consensus reached by the STAR panel that pertained to the stock assessment follow:

- The Pacific mackerel stock assessment team (STAT) met all four objective, including:
  1) produced an updated assessment based on the current model relied upon for management purposes, namely, the Age-structured Assessment Program (ASAP) model;
  2) produced a baseline Stock Synthesis (SS) model that generally mirrored the current management-based ASAP model;
  3) produced a suite of alternative SS model (scenarios) that improved upon the baseline SS model; and
  4) from the suite of SS model scenarios, identified the best configuration(s) based on both statistical and practical considerations.
- The recommended HG for the 2009-10 fishing year (July1, 2009 – June 30, 2010) is 55,408 mt:
  1) the final HG reflects substantial sensitivity analysis prior to and during the STAR;
  2) the final HG was based on SS model scenario (*AA*); and
  3) SS model scenario *AB* was identified as a meaningful alternative model and likely a candidate baseline model in the future, given issues surrounding critical areas of data availability (e.g., recreational fishery statistics) and related model parameterization (selectivity and catchability) can be addressed in the interim and within the overall assessment cycle.
- Documentation of the assessment report following the STAR should:
  1) 'begin with' the final consensus model from the STAR (namely, SS model *AA*) … objective four above;

2) provide cricital statistics from relevant scenarios involved in the overall sensitivity analysis (e.g., SS model *AB*) … objective three above;
3) use appendices for related analysis that supported the (draft) assessment initially presented at the STAR … objectives one and two above; and finally,
4) meet stipulations set forth in the CPS stock assessment 'terms of reference' (PFMC 2009).

EXECUTIVE SUMMARY

Stock

Pacific mackerel (*Scomber japonicus*) in the northeastern Pacific Ocean range from southeastern Alaska to Banderas Bay (Puerto Vallarta), Mexico, including the Gulf of California. The fish are common from Monterey Bay, California, to Cabo San Lucas, Baja California, but are most abundant south of Point Conception, California. There are possibly three spawning 'stocks' along the Pacific coasts of the USA and Mexico: one in the Gulf of California; one in the vicinity of Cabo San Lucas; and one along the Pacific coast north of Punta Abreojos, Baja California and extending north to waters off southern California and further, off the Pacific Northwest depending on oceanographic conditions (say regimes). This latter sub-stock, the 'northeastern Pacific Ocean' population, is harvested by fishers in the USA and Baja California, Mexico, and is the population considered in this assessment.

Catches

Pacific mackerel landings from both commercial and recreational fisheries in California and commercial landings in Baja California represent the catch time series (1962-08) used in the assessment, with landings pooled into the two broadly-defined fisheries for all modeling purposes, i.e., commercial and recreational fishing sectors, respectively. Historically, total catch time series over the last 100 years can be broadly defined by two or more 'modes,' e.g., late 1920s to mid 1960s and late 1970s to the present (Figure ES-1). Recent catches are presented in Table ES-1.

Currently, catch (including biological) data are largely collected through a California Department of Fish and Game (CDFG) port (commercial) sampling program. That is, the CDFG has collected biological data on Pacific mackerel landed in the San Pedro (southern California) fishery since the late 1920s. Further, to some degree, port sampling data have been collected by researchers from Ensenada, Mexico (Instituto Nacional de la Pesca, INP) since 1989; however, this information is only now being distributed at a broader scale through government/academic supported programs. Recreational catches are primarily associated with southern California's marine recreational angler community, including commercial passenger fishing vessel (CPFV) and private fisheries, with overall landings much lower than associated with the commercial fisheries (i.e., sport fisheries generate less than 5% of the total catch in any given year).

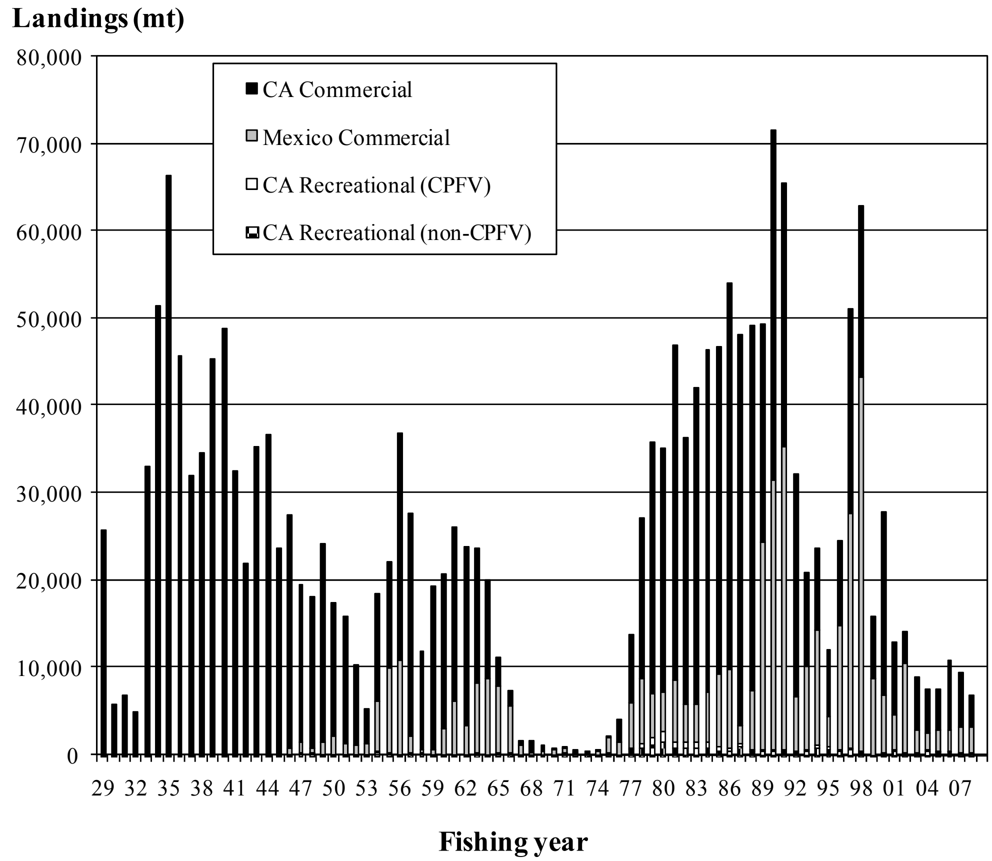

Figure ES-1. Commercial and recreational landings (mt) of Pacific mackerel in the USA (CA commercial, recreational-CPFV, and recreational-non-CPFV) and Mexico (commercial), (1929-08).

Table ES-1. Commercial and recreational landings (mt) of Pacific mackerel in the USA (CA commercial, recreational-CPFV, and recreational-non-CPFV) and Mexico (commercial), (1998-08).

Fishing year	USA Commercial (mt)	Mexico Commercial (mt)	Recreational CPFV (mt)	Recreational non-CPFV (mt)	Total (mt)
98	19,578	42,815	108	322	62,823
99	7,170	8,587	55	97	15,910
00	20,936	6,530	78	248	27,792
01	8,436	4,003	51	520	13,010
02	3,541	10,328	22	232	14,123
03	5,972	2,618	28	295	8,913
04	5,012	2,017	23	510	7,562
05	4,572	2,507	21	375	7,475
06	7,870	2,567	15	356	10,808
07	6,208	2,914	18	289	9,429
08	3,599	2,914	19	272	6,803

Data and assessment
Historically, various age-structured assessment models have been used to assess the status of Pacific mackerel off the west coast of North America, which were generally based on fishery landings, fishery age/length distributions, and relative indices of abundance. The last assessment of Pacific mackerel was completed in 2008 for USA management in the 2008-09 fishing year. The current assessment includes the following data (i.e., time series, with 'additional year' updates noted where applicable): catch (1962-08, updated); and a CPFV-based catch-per-unit-effort (CPUE) index (1962-08, updated). The final model (scenario) for management advice for the upcoming fishing year (2009-10) was based on the Stock Synthesis (SS) model (i.e., model scenario *AA*), which realized fruition through general consensus from STAR deliberations (see Preface).

Unresolved problems and uncertainties
First and foremost, given Pacific mackerel is a 'transboundary' stock, the assessment would benefit greatly from additional biological and/or 'survey' (e.g., relative abundance index data) from Mexico. In particular, there is currently no synoptic survey (fishery-independent) index of abundance that pertains to the entire (hypothesized) range of the modeled stock. Secondly, alternative model scenarios (e.g., model scenario *AB*) that included more detailed parameterization of both historical and recent patterns in selectivity and catchability provided a more realistic envelope of the uncertainty associated with stock status determinations for this species than otherwise indicated in a single baseline model, i.e., as expected, recent estimates of absolute abundance differ depending on assumptions regarding time-varying selectivity/catchability in the baseline model. Also, see Research and data needs below.

Total stock biomass
Total biomass (age-1+ biomass, *B*) remained low from the early 1960s to the mid 1970s, at which time the population began to rapidly increase in size, reaching a peak in the early 1980s (see Recruitment below). From the mid 1980s to early 2000s, the stock declined steadily, with some signs of 'rebuilding' (on an increasing limb of a historical distribution say) observed recently (Figure ES-2 and Table ES-2). However, as noted previously, recent estimates of stock size are necessarily related to assumptions regarding the dynamics of the fish (biology) and fishery (operations) over the last several years, which generally confounds long-term (abundance) forecasts for this species. For example, see estimated *B* time series from alternative SS model *AB*, which generally mirrored SS model *AA*, except in the most recent years, with stock size plateauing at historically low levels, rather than increasing (Figure ES-2).

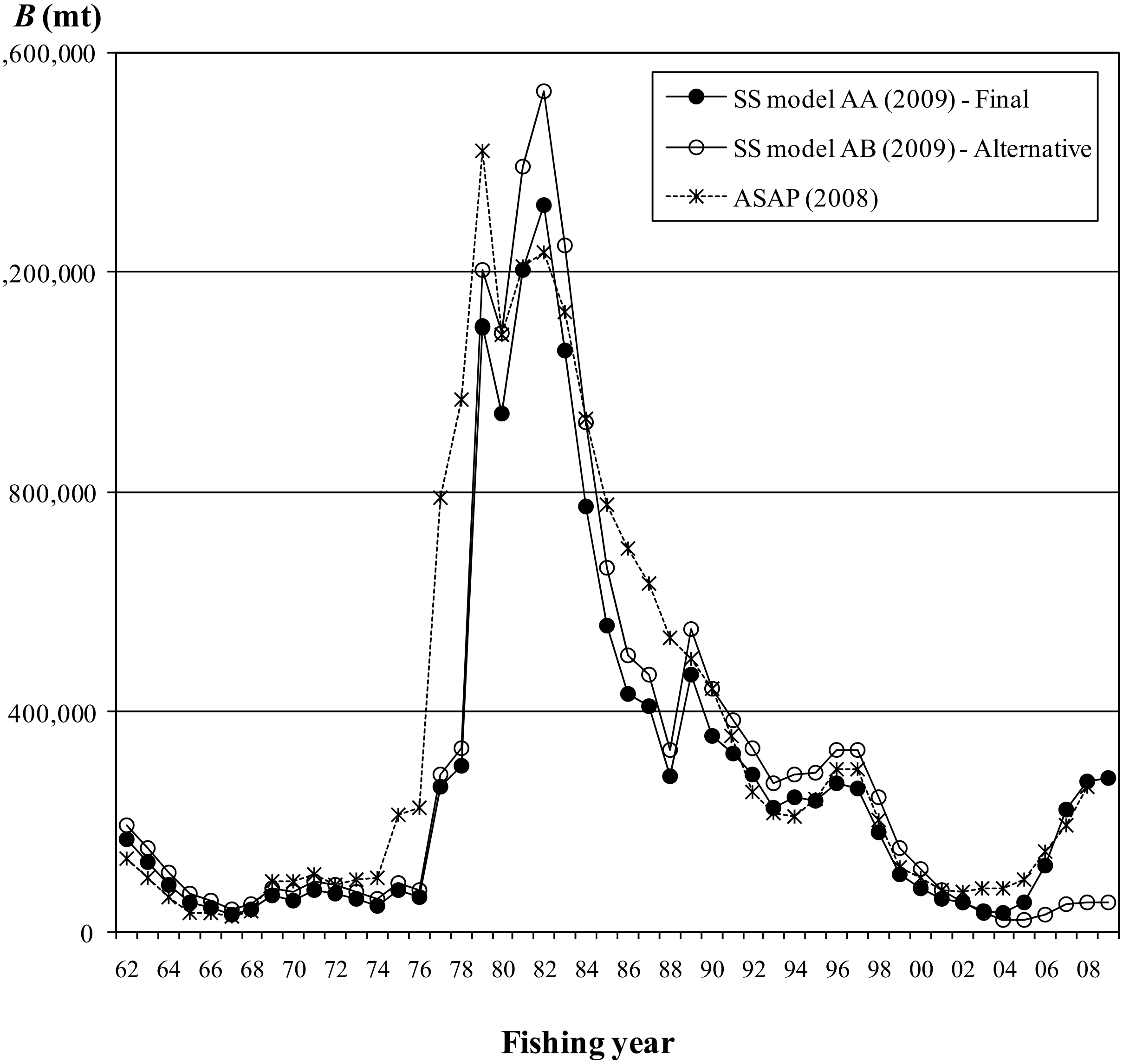

Figure ES-2. Estimated total stock biomass (age 1+ fish in mt, *B*) of Pacific mackerel based on the final SS model *AA* and alternative model *AB* (1962-09). Also, *B* time series from previous year's assessment (ASAP 2008) is presented for comparative purposes.

Table ES-2. Estimated recruitment (*R*), total biomass (*B*), and spawning stock biomass (*SSB*) of Pacific mackerel based on SS model *AA* (1962-09).

Fishing year	***R*** **(age-0, in 1,000s)**	***B*** **(age-1+, mt)**	***SSB*** **(mt)**
98	161,490	183,255	98,203
99	123,450	105,797	62,788
00	180,740	82,186	49,944
01	138,930	61,600	31,390
02	74,874	55,063	24,482
03	94,906	40,828	19,203
04	254,870	36,511	16,281
05	607,540	56,348	16,684
06	939,810	122,581	24,639
07	688,600	222,969	44,981
08	452,530	275,211	76,440
09		282,049	

Spawning stock biomass

Spawning stock biomass (*SSB*) followed the general trajectory as observed in the estimated *B* time series, with magnitudes that are roughly one-half the size of total stock biomass (Figure ES-3 and Table ES-2).

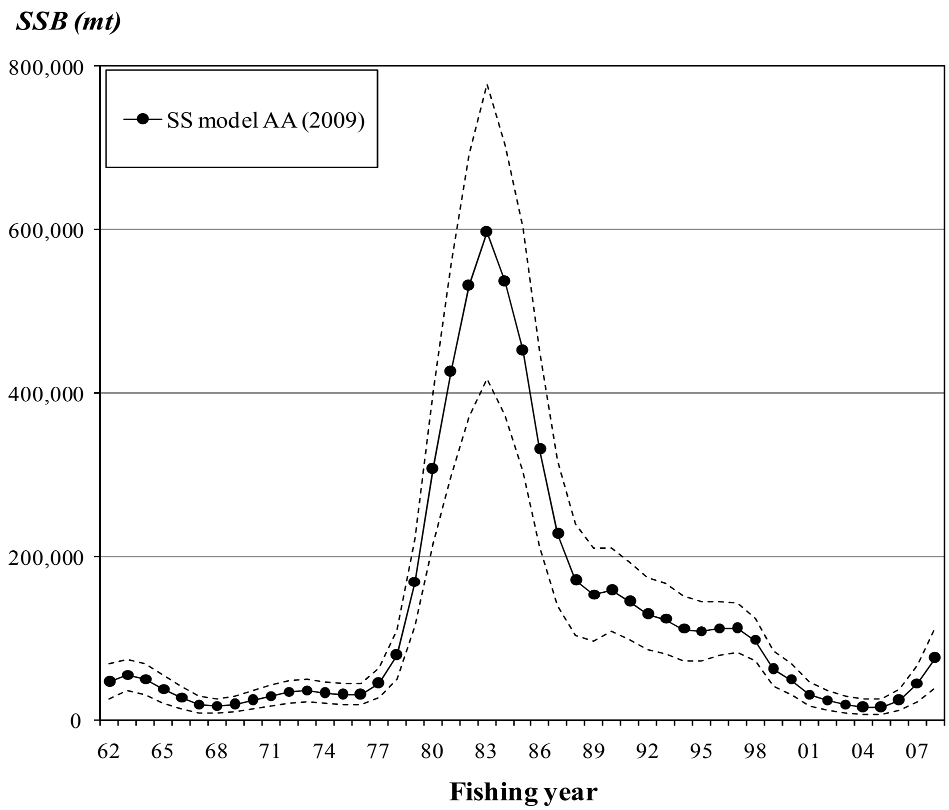

Figure ES-3. Estimated spawning stock biomass (*SSB*) of Pacific mackerel based on SS model *AA* (1962-08). Confidence interval (± 2 SD) is also presented as dashed lines.

Recruitment
As expected, historically, estimated recruitment (R) has been highly variable, remaining relatively low up until the mid 1970s, increasing markedly in magnitude from the late 1970s through the early 1980s, with stock productivity remaining relatively low since this time (Figure ES-4 and Table ES-2).

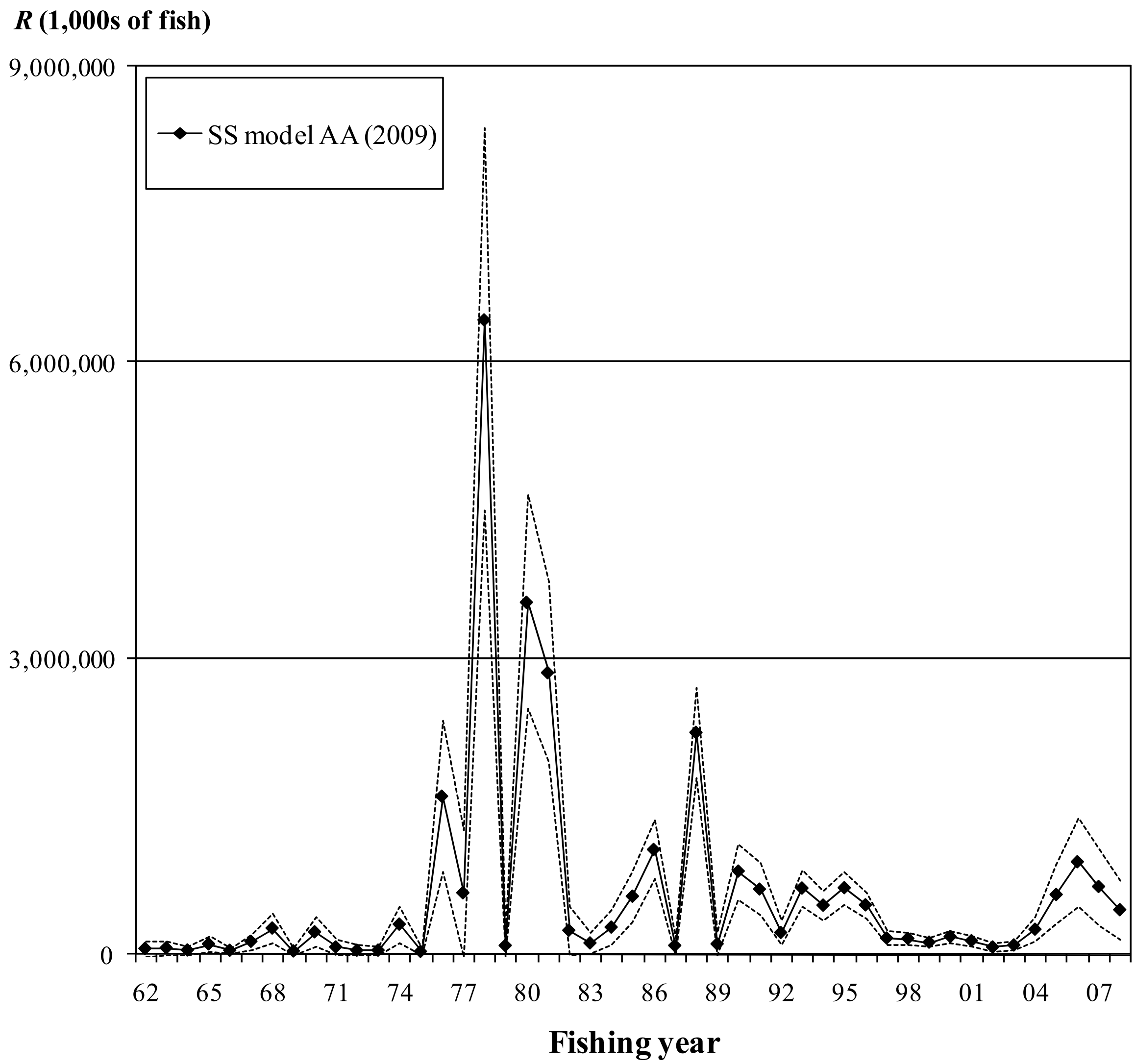

Figure ES-4. Estimated recruitment (age-0 fish in 1,000s, R) of Pacific mackerel based on SS model *AA* (1962-08). Confidence interval (± 2 SD) is also presented as dashed lines.

Management performance
Since 2000, Pacific mackerel has been managed under a Federal Management Plan (FMP) harvest policy, stipulating that a maximum sustainable yield (MSY) for this species should be set according to the following harvest control rule:

Harvest = (Biomass-Cutoff) • Fraction • Distribution,

where Harvest is the harvest guideline (HG), Cutoff (18,200 mt) is the lowest level of estimated biomass at which harvest is allowed, Fraction (30%) is the proportion of biomass above the Cutoff that can be harvested by fisheries, and Distribution (70%) is the average fraction of total Biomass (ages 1+) assumed in USA waters (PFMC 1998). The HGs under the federal FMP are applied to a July-June fishing 'year.' Landings and associated HGs since 1992 are presented in Figure ES-5.

The HG for the 2009-10 fishing year based on the current management-related ASAP model is 55,408 mt (Table ES-3).

From 1985 to 1991, the biomass exceeded 136,000 mt and no state quota restrictions were in effect. State quotas for 1992-00 fishing years averaged roughly 24,000 mt. The HGs averaged roughly 20,000 mt from 2001-06. In 2007, the HG was increased substantially to over 100,000 mt based largely on assumptions regarding variability surrounding estimated recruitment and has remained at an elevated level since then (Figure ES-5). It is important to note that since the 2001 fishing year, from a management context, the fishery has failed to fully utilize HGs, with average yields since this time of roughly 5,000 mt (Figure ES-5).

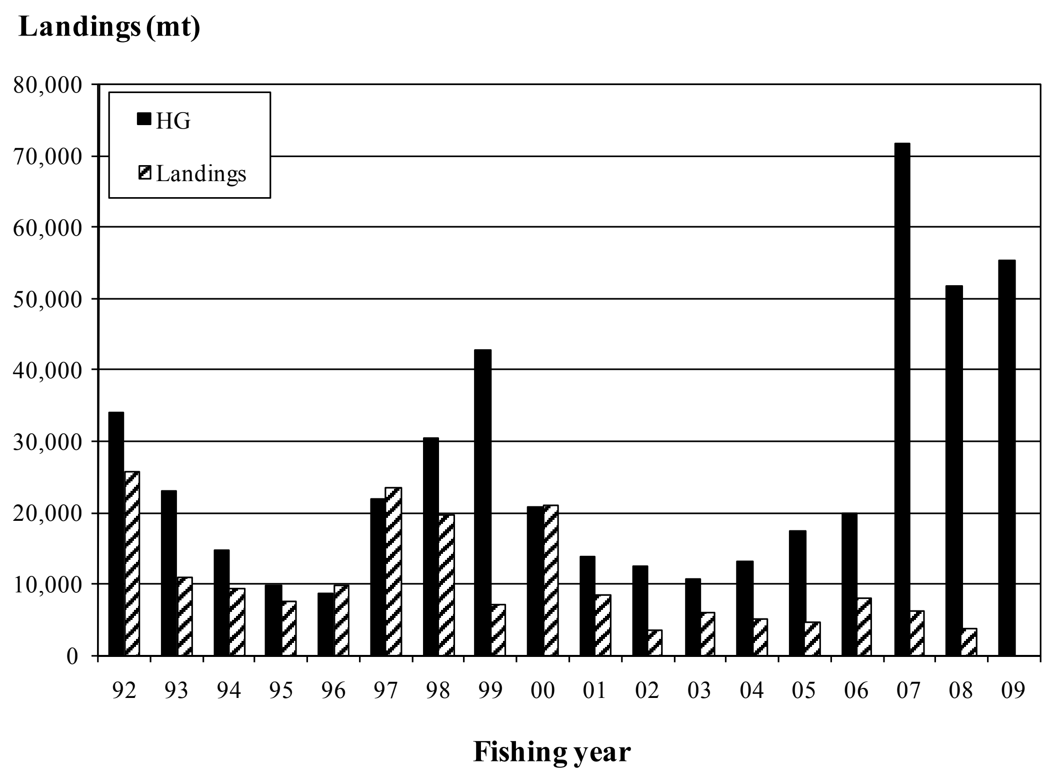

Figure ES-5. Commercial landings (California directed fishery, mt) and quotas (HGs, mt) for Pacific mackerel (1992-08).

Table ES-3. Harvest control rule statistics for the Pacific mackerel fishing year 2009-10.

B **(Age 1+, mt)**	**Cutoff (mt)**	**Fraction**	**Distribution**	**HG (mt)**
282,049	18,200	30%	70%	**55,408**

Research and data needs
First and foremost, given the transboundary status of this fish population, it is imperative that efforts continue in terms of encouraging collaborative research and data exchange between NOAA Fisheries (Southwest Fisheries Science Center) and researchers from both Canada's and in particular, Mexico's academic and federal fishery bodies, i.e., such cooperation is critical to providing a synoptic assessment that considers available sample data across the entire range of this species in any given year.

Second, fishery-independent survey data for measuring (relative) changes in mackerel spawning (or total) biomass are currently lacking. Further, at this time, a single index of relative abundance is used in the assessment, which is developed from a marine recreational fishery (CPFV fleet) that typically does not (directly) target the species. In this context, it is imperative that future research funds be focused on improvement of the current CPFV survey, with emphasis on a long-term horizon, which will necessarily rely on cooperative efforts between the industry, research, and management bodies. Additionally, we strongly support development of a well-designed logbook monitoring program associated with the current commercial (purse-seine) fishery, which has been long overdue.

Third, given the importance of age (and length) distribution time series to developing a sound understanding of this species' population dynamics, it is critical that data collection programs at the federal and particularly, the state-level continue to be supported adequately. In particular, CDFG/NOAA funding should be bolstered to ensure ongoing ageing-related laboratory work is not interrupted, as well as providing necessary funds for related biological research that is long overdue. For example, maturity-related time series currently relied upon in the assessment model are based on data collected over twenty years ago during a period of high spawning biomass that does not reflect current levels. Also, further work is needed to obtain more timely error estimates from production ageing efforts in the laboratory, i.e., accurate interpretation of age-distribution data used in the ongoing assessment necessarily requires a reliable ageing error time series. Finally, examinations of sex-specific age distributions will allow hypotheses regarding natural mortality/selectivity (i.e., absence of older animals in sex-combined age distributions) to be more fully evaluated.

Finally, the MSY control rule utilized in the Pacific mackerel federal CPS-FMP was developed in the mid-1980s using the historical time series of abundance. The harvest control rule should be re-examined using new data and simulation methods. Given substantial amounts of additional sample data have accumulated since the initial research that was undertaken to formally establish this harvest strategy, it would be prudent to conduct further simulation modeling work to address particular parameters included in the overall control rule (including 'cutoff,' 'fraction,' and 'distribution' values).

INTRODUCTION

Distribution

Pacific mackerel (*Scomber japonicus*; a.k.a. 'chub mackerel' or 'blue mackerel') in the northeastern Pacific range from southeastern Alaska to Banderas Bay (Puerto Vallarta), Mexico, including the Gulf of California (Hart 1973). They are common from Monterey Bay, California, to Cabo San Lucas, Baja California, but are most abundant south of Point Conception, California. Pacific mackerel usually occur within 30 km of shore, but have been captured as far as 400 km offshore (Fitch 1969; Frey 1971; Allen et al. 1990; MBC 1987).

Migration

Pacific mackerel adults are found in water ranging from 10 to 22.2°C (MBC 1987) and larvae may be found in water around 14°C (Allen et al. 1990). As adults, Pacific mackerel move north in summer and south in winter between Washington and Baja California (Fry and Roedel 1949; Roedel 1949), with northerly movement in the summer accentuated during El Niño events (MBC 1987). There is an 'inshore-offshore' migration off California, with increased inshore abundance from July to November and increased offshore abundance from March to May (Cannon 1967; MBC 1987). Adult Pacific mackerel are commonly found near shallow banks. Juveniles are found off sandy beaches, around kelp beds, and in open bays. Adults are found from the surface to 300 m depth (Allen et al. 1990). Pacific mackerel often school with other coastal pelagic species, particularly jack mackerel and Pacific sardine, and likely based on age-dependent attributes as well (Parrish and MacCall 1978).

Over the last two decades, the stock has likely more fully occupied the northernmost portions of its range in response to a warm oceanographic regime in the northeastern Pacific Ocean, with further evidence, given Pacific mackerel have been found as far north as British Columbia, Canada (Ware and Hargreaves 1993; Hargreaves and Hungar 1995). During the summer months, Pacific mackerel are commonly caught incidentally in commercial whiting and salmon fisheries off the Pacific Northwest, but historically, these catches have been limited. Pacific mackerel sampled from Pacific Northwest incidental fisheries are generally older and larger than those captured in the southern California fishery (Hill 1999). In addition, this species is harvested by recreational anglers on CPFVs and private vessels, but is typically not highly prized in the fishery, with catches relatively low when compared with commercial landings.

Life history

Pacific mackerel found off the Pacific coast of North America are the same species found elsewhere in the Pacific, Atlantic, and Indian Oceans (Collette and Nauen 1983). Synopses regarding the biology of Pacific mackerel are presented in Kramer (1969) and Schaefer (1980).

Currently, the general consensus within the coastal pelagic species research forum is that there are likely three spawning stocks in the northeastern Pacific Ocean: one in the Gulf of California, one near Cabo San Lucas, and one along the Pacific coast north of Punta Abreojos, Baja California to British Columbia, Canada. Spawning occurs from Point Conception, California to Cabo San Lucas from 3 to 320 km offshore (Moser et al. 1993). Off California, spawning occurs from late April to September at depths to 100 meters. Off central Baja California, spawning occurs year round, peaking from June through October. Around Cabo San Lucas, spawning occurs primarily from late fall to early spring. Pacific mackerel seldom spawn north of Point Conception (Fritzsche 1978; MBC 1987), although young-of-year (age-0) fish have been recently reported as far north as Oregon and Washington.

Like many coastal pelagic species with similar life history strategies, Pacific mackerel have indeterminate fecundity and appear to spawn whenever sufficient food is available and appropriate oceanographic conditions prevail. Individual fish may spawn eight times or more per year and release batches of 68,000 eggs per spawning. Actively spawning fish appear capable of spawning daily or every other day (Dickerson et al. 1992).

Pacific mackerel larvae eat copepods and other zooplankton, including fish larvae (Collette and Nauen 1983; MBC 1987). Juvenile and adult mackerel feed on small fish, fish larvae, squid, and pelagic crustaceans, such as euphausids (Clemmens and Wilby 1961; Turner and Sexsmith 1967; Fitch 1969; Fitch and Lavenberg 1971; Frey 1971; Hart 1973; Collette and Nauen 1983). Pacific mackerel larvae are subject to predation from a number of invertebrate and vertebrate planktivores. Juvenile and adults are eaten by larger fishes, marine mammals, and seabirds. Principal predators include porpoises, California sea lions, pelicans, and large piscivorous fishes, such as sharks and tunas. Pacific mackerel school as a defense against predation, often with other pelagic species, including jack mackerel and Pacific sardine.

Population dynamics of the Pacific mackerel stock off southern California have been extensively studied in the past and of particular importance was pioneering research conducted during the 1970s and 1980s, e.g., Parrish (1974), Parrish and MacCall (1978), Mallicoate and Parrish 1981, and Macall et al. (1985). More recently, USA-based research efforts associated with pelagic species that inhabit coastal areas of the Pacific coast of North America have focused on the Pacific sardine population. Pacific mackerel experience cyclical periods of abundance ('boom-bust'), which is typical of other small pelagic species that are characterized by relatively short life spans and high intrinsic rates of increase. Analysis of mackerel scale-deposition data (Soutar and Issacs 1974) indicated that periods of high biomass levels, such as during the 1930s and 1980s, are relatively rare events that might be expected to occur, on average, about once every 60 years (MacCall et al. 1985). It is important to note that assessment model structure and results generally support MacCall's research, with periods of strong recruitment estimates occurring no more frequently than at least 30 years or so. Recruitment is highly variable over space and time and not likely related to spawning biomass stock size (Parrish 1974), or at least not tightly linked to parent abundance levels within the historical range of estimated spawning stock biomass levels (Parrish and MacCall 1978).

Stock structure and management units

The full range of Pacific mackerel in the northeastern Pacific Ocean is from southeastern Alaska to Banderas Bay (Puerto Vallarta), Mexico, including the Gulf of California. The majority of the fish are typically distributed from Monterey Bay, California, to Cabo San Lucas, Baja California, being most abundant south of Point Conception, California. It is likely that multiple 'spawning' stocks exist along the Pacific coasts of the USA and Mexico, although at this time, stock structure exhibited by this species is not known definitively: one in the Gulf of California; one in the vicinity of Cabo San Lucas; and one along the Pacific coast north of Punta Abreojos, Baja California and extending north to waters off southern California and further, off the Pacific

Northwest depending on oceanographic conditions (say regimes). This latter sub-stock, the 'northeastern Pacific Ocean' population, is harvested by fishers in the USA and Baja California, Mexico, and is the population considered in this assessment.

The Pacific Fishery Management Council (PFMC) manages the northeastern Pacific stock as a single unit, with no area- or sector-specific allocations. However, the formal Fishery Management Plan (FMP) harvest control rule does include a stock distribution adjustment, based on a long-term assumption that roughly 70% of this transboundary population resides in USA waters in any given year (PFMC 1998).

Fishery descriptions
Pacific mackerel are currently harvested by three 'fisheries': the USA commercial fishery that primarily operates out of southern California; a sport fishery based largely in southern California; and the Mexico commercial fishery that is based in Ensenada and Magdalena Bay, Baja California. In the commercial fisheries, Pacific mackerel are landed by the same boats that catch Pacific sardine, anchovy, jack mackerel, and market squid (generally, referred to as the west coast 'wetfish' fleet). There is no directed fishery for mackerel in Oregon or Washington; however, small amounts (100-300 mt annually) are taken (incidentally) by whiting trawlers and salmon trollers. Catches in the Pacific Northwest peaked at 1,800 mt following the major El Niño event of 1997-98.

The history of California's Pacific mackerel fishery has been reviewed by Croker (1933; 1938), Roedel (1952), and Klingbeil (1983). Pacific mackerel supported one of California's major fisheries during the 1930s and 1940s and more recently, particular years in the 1980s and 1990s. During the early years of the fishery, Pacific mackerel were taken by lampara and pole-and-line boats, which were replaced in the 1930s by the same purse seine fleet that fished for sardine. Before 1929, Pacific mackerel were taken incidentally, in relatively small volumes, with sardine and sold as fresh fish (Frey 1971). Canning of Pacific mackerel began in the late 1920s and increased as greater processing capacities and more marketable 'packs' were developed. Landings decreased in the early 1930s due to the economic depression and subsequent decline in demand, but increased significantly by the mid-1930s (66,400 mt in 1935-36). During this period, Pacific mackerel were second only to Pacific sardine in total (annual) landings. Harvests subsequently underwent a long-term decline and for many years, demand for canned mackerel remained steady and exceeded supply. Supply reached record low levels in the early 1970s, at which time the State of California implemented a 'moratorium' on the directed fishery.

Following a period of 'recovery' that spanned from the mid to late 1970s, the moratorium was lifted and subsequently, through the 1990s, the fishery ranked third in volume for finfish landed in California. During this time, the market for canned mackerel fluctuated due to availability and economic conditions. Domestic demand for canned Pacific mackerel eventually waned and the last mackerel cannery in California closed in 1992. At present, most Pacific mackerel is used for human consumption or pet food, with a small, but increasing amount sold as fresh fish.

Pacific mackerel are caught by recreational anglers in southern California, but seldom as a target species (Young 1969). During the 1980s, California's recreational catch averaged 1,500 mt per year, with Pacific mackerel being one of the most important species harvested by the California-based CPFV fleet. Pacific mackerel are also harvested in California's recreational fishery as bait for directed fishing on larger pelagic species. Additionally, Pacific mackerel are caught by anglers in central California, but typically, only in small amounts. The state-wide sport harvest constitutes a small fraction (less than 5% in weight) of the total landings.

The Mexico fishery for Pacific mackerel is primarily based in Ensenada and Magdalena Bay, Baja California. The Mexico purse seine fleet has slightly larger vessels, but is similar to southern California's fleet with respect to gear (mesh size) and fishing practices. The fleet operates in the vicinity of ports and also targets other small pelagic species. Demand for Pacific mackerel in Baja California increased after World War II. Mexico landings remained stable for several years, rose to 10,725 mt in 1956-57, then declined to a low of 100 tons in 1973-74. Catches in Mexico remained relatively low through the late 1980s. Landings of Pacific mackerel in Ensenada peaked twice, first in 1991-92 at 34,557 mt, and again in 1998-99, at 42,815 mt. The Ensenada fishery has been comparable in volume to the southern California fishery since 1990. In Baja California, Pacific mackerel are either canned for human consumption or reduced to fish meal.

Management history

The state of California first applied management measures to Pacific mackerel in 1970, after the stock had collapsed in the mid 1960s. A moratorium was placed on the fishery at this time, with a small allowance for incidental catch in mixed-fish landings. In 1972, legislation was enacted that imposed a landing quota based on the estimate of age-1+ ($\geq$1-yr old fish) biomass generated from formal assessments. A couple of very strong year classes in the late 1970s triggered a stock recovery (increase in total abundance), which was followed by the fishery being reopened under a quota system in 1977. During the span of the recovery period from 1977 to 1985, various adjustments were made to quotas for directed take of Pacific mackerel and to incidental catch limits, i.e., even during the 'moratorium' substantial allowances were made for incidental catches associated with this species (Parrish and MacCall 1978).

State regulations enacted in 1985 imposed a moratorium on directed fishing when the total biomass was less than 18,200 mt, and limited the incidental catch of Pacific mackerel to 18% during such moratoriums. The fishing year was set to extend from July 1st to June 30th of the following year. Seasonal quotas, equal to 30% of the total biomass in excess of 18,200 mt, had been allowed when the biomass was between 18,200 and 136,000 mt, and there was no quota limitation when the total biomass was 136,000 mt or greater.

A federal fishery management plan (FMP) for coastal pelagic species, including Pacific mackerel, was implemented by the PFMC in January 2000 (PFMC 1998). The FMP's harvest policy for Pacific mackerel, originally implemented by the State of California, is based on simulation analysis conducted during the mid 1980s, with the addition of a proration to account nominally for the portion of the 'stock' assumed to inhabit USA waters, see MacCall et al. (1985) and PFMC (1998). The current maximum sustainable yield (MSY) control rule for Pacific mackerel is:

$$\text{Harvest} = (\text{Biomass-Cutoff}) \bullet \text{Fraction} \bullet \text{Distribution},$$

where Harvest is the harvest guideline (HG), Cutoff (18,200 mt) is the lowest level of estimated biomass at which harvest is allowed, Fraction (30%) is the proportion of biomass above the Cutoff that can be harvested by fisheries, and Distribution (70%) is the average fraction of total Biomass (ages 1+) assumed in USA waters. The HGs under the federal FMP are applied to a July-June fishing 'year.'

California's recreational catch of Pacific mackerel is included within the USA HG, but there are no other restrictions (e.g., size or bag limits) on this fishery. Total annual harvest of Pacific mackerel by the Mexico fishery is not regulated by quotas, but there is a minimum legal size limit of 255 mm. International management agreements between the USA and Mexico regarding transboundary stocks, such as Pacific mackerel, have not been developed to date (see Preface and Research and data needs).

Management performance
From 1985 to 1991, the biomass exceeded 136,000 mt and no state quota restrictions were in effect. State quotas for 1992-00 fishing years averaged roughly 24,000 mt. From 2001-06, HGs averaged roughly 20,000 mt. In 2007, the HG was increased substantially to over 100,000 mt based largely on assumptions regarding variability surrounding estimated recruitment and has remained at an elevated level since then. It is important to note that since the 2001 fishing year, from a management context, the fishery has failed to fully utilize HGs, with average yields since this time of roughly 5,000 mt.

ASSESSMENT

Ultimately, the final Pacific mackerel stock assessment model presented here reflects two primary changes from recently conducted assessments: (1) a transition from the ASAP model to the SS model was completed; and (2) two survey-related indices of abundance were omitted due to concerns associated with potential sampling biases (applicable to this species strictly), i.e., a spotter survey based on aerial sightings from planes and a California Cooperative Oceanic Fisheries Investigations (CalCOFI) index of daily larval abundance (see STAR 2009). Other changes associated with estimation methods for influential areas of parameterization were also necessary, given the transition to the new modeling platform (SS), e.g., more flexibility examining: the spatial/temporal structure of the baseline model; starting the model; recruitment; fishing mortality; and selectivity/catchability (pertinent changes are documented below). Parameterization details associated with SS model *AA* are presented below (see Model description). Also, see Responses to past STAR/SSC recommendations below.

A full suite of assessment-related displays for the final SS model *AA* are presented in the body of this document. Addtionally, for comparative purposes, results from alternative models examined through sensitivity analysis (e.g., SS model *AB*) are presented along with model *AA* for pertinent displays. Program files associated with SS model *AA* are presented in Appendix 1. Appendix 2A-B is used to present particular displays associated with the initial baseline SS model (*S1_aa*) and ASAP (2009) model, i.e., objectives one and two (see Preface). Finally, Table 4 (as well as Appendix Table A2B-1) presents a broad range of important parameter-related statistics associated with the key model scenarios reviewed during the recently conducted STAR in May 2009.

History of modeling approaches

Parrish and MacCall (1978) were the first to provide stock status determinations for Pacific mackerel using an age-structured population model (i.e., traditional virtual population analysis, VPA). The ADEPT model (the 'ADAPT' VPA modified for Pacific mackerel; Jacobson 1993 and Jacobson et al. 1994b) was used to evaluate stock status and establish management quotas for approximately 10 years. The assessment conducted in 2004 (for 2004-05 management) represented the final ADEPT-based analysis for this stock (see Hill and Crone 2004a). The forward-simulation model ASAP (Legault and Restrepo 1998) was reviewed and adopted for Pacific mackerel at the 2004 STAR Panel (Hill and Crone 2004b). The ASAP model has been in place for assessments and management advice since the 2005-06 fishing year. The STAR conducted in 2009 determined that the SS model provided the best (most flexible) platform for assessing the status of Pacific mackerel currently (i.e., the 2009-10 fishing year) and in the future, see Preface and STAR (2009).

Sources of data

Fishery-dependent data

<u>Overview</u>

Fishery-related data for assessing Pacific mackerel included landings (California commercial, California recreational, and Mexico commercial), port sample (biological) data from California's commercial (purse seine) and recreational (CPFV) fisheries, as well as logbook data from the CPFV fleet used to develop a catch-per-unit-effort (CPUE) index. Since 1992, the CDFG has collected biological data on Pacific mackerel landed in the southern California fishery (primarily San Pedro). Samples have also been collected from the Monterey fishery when available. For this assessment, raw sample data were available from 1939 through 2008. Biological samples include whole body weight, fork length, sex, maturity, and otoliths for age determination. Currently, CDFG collects 12 'random' (port) samples per month (25 fish per sample) to determine length/age distributions, catch-at-age, weight-at-age, etc. for the directed fishery. Mexico port sampling data have been collected by INP-Ensenada since 1989, but have not been available for purposes of inclusion in this ongoing assessment effort and thus, California commercial data were assumed to be representative of the combined commercial fisheries. Lack of Baja California port sampling data is not a serious problem for some years when Mexico catches were low. However, in recent years, Baja California and California catches have been roughly equal in volume, which necessarily increases the likelihood that potential biases associated with the omission of (and subsequent assumptions concerning) sample data from the Mexico fishery. Sample sizes associated with this data collection program are presented in Table 1.

Pacific mackerel were aged by CDFG biologists, based on identification of annuli in whole sagittae. Historically, a birth date of May 1^{st} was used to assign year class (Fitch 1951). In 1976, ageing protocols changed to a July 1^{st} birth date, which coincided with a rebounding resource, resumed fishery sampling, and a change in the management season from a May 1^{st} opening to a July 1^{st} start date.

Fishery inputs were compiled by 'biological year,' based on the birth dates used to assign age. Therefore, data prior to 1976-77 were aggregated in the biological year of May 1st ($year_x$) through April 30th ($year_{x+1}$), and data from 1976-77 forward were aggregated July 1st ($year_x$) through June 30th ($year_{x+1}$). The biological year used in this assessment is synonymous with the 'fishing year' defined previously, as well as with 'fishing season' as reported in the historical literature. That is, the change in birth date assignment from May 1st to July 1st coincided with a change in the management season in the mid-1970s, with historical sources of landings and biological data reflecting this change.

Catches

The assessment includes commercial and recreational landings in California and commercial landings in Baja California (Mexico) from 1962 to 2008. Annual (fishing year) landing estimates of Pacific mackerel are presented in Table 2 and Figure 1.

California commercial landings of Pacific mackerel were obtained from a variety of sources based on dealer landing receipts (CDFG) and in some cases, augmented with port sampling for mixed load portions. Data from 1929-61 were obtained from Parrish and MacCall (1978). Monthly landings for the period May 1962 to September 1976 were obtained from CDFG fish bulletins recovered to an electronic data base format (PFEL 2005). Raw landing receipt data for Pacific mackerel from 1976 to 1991 were of marginal quality, owing to the large quantities of Pacific mackerel landed as mixed loads with jack mackerel. During this period, many processors reported either species as 'unspecified' mackerel on landing receipts. For these years, mackerel landings receipts were augmented with shoreside 'bucket' sampling of mixed loads to estimate species compositions. The CDFG reported these data in two forms: (1) annual stock status reports to the California legislature; and (2) single page 'CDFG Wetfish Tables.' Both sources are considered more accurate than PacFIN or other landing receipt-based statistics for this period. Data sources from late 1976 to the present are as follows: October-December 1976 are from Klingbeil and Wolf (1986); January-December 1977 are from Wolf and Worcester (1988); January 1978-December 1981 are from Jacobson et al. (1994a); January 1982-February 2009 are from CDFG Wetfish Tables; and finally, landing estimates for March-June 2009 and July 2009-June 2010 were assumed to be similar to the analogous time blocks of the previous year, namely, March-June 2008 and July 2008-June 2009, respectively. Pacific mackerel landings from 1976-81 were only reported by quarterly increments and thus, for purposes of weighting catch-at-age estimates for this period (see Catch-at-age below), we apportioned quarters to months using monthly 'unspecified mackerel' landings from the PFEL LAS database (PFEL 2005).

California recreational landings (mt) from 1980 to the present (2-month 'wave' resolution) were obtained directly from Pacific RecFIN estimates. Historical estimates (pre-1980) of total recreational catch were derived from CPFV logbook data collected since 1936 (Hill and Schneider 1999). The CPFV catch (number) was converted to metric tons using an assumed average weight of 0.453 kg (1 lb) per individual, based on RecFIN samples and consistent with Parrish and MacCall (1978). The CPFV harvest was expanded to total recreational tonnage using wave-specific ratios from RecFIN. Nominal amounts of recreational removals were assumed for 1929-35 and 1941-46 when no recreational statistics were available.

Baja California data include landings from commercial purse seine fisheries in Ensenada, Cedros Island, and Magdalena Bay. Ensenada landings were compiled as follows: 1946-47 through 1969-70 (May-April) data are from Parrish and MacCall (1978); 1970-71 through 1975-76 (May-April) data are from Schaefer (1980); quarterly data from July 1976 through December 1986 are from Jacobson et al. (1994b); monthly data from January 1987 through November 2003 were provided by INP-Ensenada (Garcia and Sánchez, 2003; Celia Eva-Cotero, INP-Ensenada, personal communication, INP-Ensenada staff); monthly landings from December 2003 through December 2004 were not available and thus, were substituted with corresponding months from the previous year. Ensenada landings in 2005, available from Cota et al. (2006), were apportioned into monthly catch using ratios from the previous few years. Ensenada landings for January to June 2006 were taken from Cota et al. (2006). Monthly landing data for the Cedros Island (January 1981-December 1994) and Magdalena Bay (January 1981 – May 2003) fisheries were provided by R. Felix-Uraga (CICIMAR-IPN, La Paz, personal communication). The fishery off Cedros Island ceased in 1994. Magdalena Bay landings for June 2003 through June 2007 were substituted with corresponding months from the previous year. Monthly-resolution catch statistics for Mexico were not available for all seasons and thus, for purposes of weighting catch-at-age estimates (see Catch-at-age section), aggregate catch data (season or quarter) were apportioned to months by inflating the corresponding California data.

Small volumes (100 to 300 mt per year) of Pacific mackerel are taken incidentally in other fisheries (e.g., whiting, salmon troll, and Pacific sardine) off Oregon and Washington. Biological samples collected from these fisheries (Hill 1999) indicated fish from these waters are typically larger and older than the directed fishery off California and thus, these limited samples have not be included in the current assessment model presented here.

<u>Length distributions</u>

The SS model scenarios included length distributions for the USA recreational (CPFV) fishery only, i.e., utilizing age-based selectivity. In general, age-based selectivity was used in SS model scenarios, including: age distribution time series from the fishery, as well as mean length-at-age time series (see Age distributions and Mean length-at-age distributions below); and length distribution time series (no age data available) from the recreational fishery. Length distributions for the recreational fishery (CPFV fishing mode only) were developed from the Pacific RecFIN data base using angler examined catch data from 1992 to 2008 (Figure 2).

Length distributions were developed using 1-cm length (fork) bins, with the smallest bin equal to 1 cm and the largest equal to 60 cm. The 60-cm bin includes fish that were greater than or equal to 60 cm. The total number of lengths (say specimens measured for length) observed in each distribution (of each time step) was divided by 25 (the average number of fish collected per sample) and subsequently, used as the effective sample size in baseline model configurations. Ultimately, length distributions (in numbers of fish) were converted to proportion estimates for all modeling efforts.

<u>Age distributions</u>

Age distribution time series were developed from the same (CDFG) port sample data base described previously, i.e., the sampling program entails recording length, sex, age (via otolith collections), etc. from each fish in the 25-fish sample taken from a completed fishing trip. It is important to note that age (and length) distributions developed from this sampling program are considered to be representative of the landings associated with the (commercial) fishery and thus, serve as the foundation for evaluating cohort dynamics in the fully-integrated models. Ultimately, age distributions (in proportion-at-age) were based on 9 age bins that represented age-0 to age-8+, i.e., a 'plus group' that includes $\geq$8-yr old fish. The total number of ages (say specimens measured for age) observed in each distribution was divided by 25 (the average number of fish collected per sample) and subsequently, used as the effective sample size in baseline model configurations. Ultimately, age distributions (in numbers of fish) were converted to proportion estimates for all modeling efforts. In sensitivity analysis, biological distributions were based on both annual and quarter time-steps, depending on the model scenario, with the final SS model *AA* being annual-based. Annual age distributions (1962-08) associated with all models are presented in Figure 3. Mean age (annual) statistics are presented in Figure 4.

Mean length-at-age distributions

For the primary purpose of evaluating growth dynamics associated with this species, mean length-at-age time series (1962-08) were developed from the same (CDFG) port sample data base described above and used in conjunction with age distributions in SS model scenarios (Figure 5). Effective sample size estimates were obtained using the same 25-fish adjustment employed for the other biological distributions, based on typically sample sizes from a completed fishing trip.

Ageing error distribution

In efforts to provide the most realistic measure of uncertainty associated with estimated age distribution time series, an ageing error vector, based on standard 'double-read' methods, was also included in all model scenarios, i.e., a SD vector by age was used in all SS model scenarios (Figure 6). It is important to note that further ageing error analysis pertaining to this species is warranted, given the current vector is considered preliminary at this time.

Commercial passenger fishing vessel (CPFV) index of abundance

California Fish and Game legislation has required CPFV captains to provide records of catch and effort data to CDFG since 1936. In the past, Pacific mackerel have been among the top five species reported on CPFV logs, both in southern California and state-wide. This information resides in a logbook data base (Hill and Barnes 1998; Hill and Schneider 1999) that summarizes CPFV catch and effort by month and Fish and Game statistical blocks (10 nm^2). A single state-wide index of relative abundance was developed, based on a Delta-Generalized Linear Model (delta-GLM) approach for estimating year effects, i.e., a CPUE time series of relative abundance (Figure 7). The index is based on a fishing year basis, as is the case with other time series used in the models. Selectivity parameterization associated with this index mirrored the recreational fishery (i.e., age-based selectivity based on length distribution time series).

To account for potential changes in catchability associated with the CPFV fleet over time, a delta-GLM model was used to 'standardize' the data and separate effects from critical factors (e.g., spatial-temporal). That is, by incorporating year as a factor, the delta-GLM generates estimates of annual standardized catch rate and its variance that can be generally interpreted as a relative index of abundance of the population. Ultimately, the index of abundance is based on two GLMs: the first GLM estimates the probability of a positive observation, based on a binomial likelihood and logit link function; and the second GLM estimates the mean response for the positive observations, assuming a gamma error distribution. The final index is the product of the back-transformed year effects from the two GLMs. Technical details concerning the delta-GLM analysis follow:

(1) data were combined within year/quarter/fleet strata (i.e., the overall, statewide fishery was partitioned into a northern and southern ‘fleet’ based on latitude/longitude spatial fishing ‘blocks’);

(2) CPUE was calculated (number of fish/1,000 angler-hours fishing) for each spatial/temporal stratum;

(3) fishing years 1935-36 to 2008-09 were used in the analysis, with the exception of a few years that were omitted due to missing data (e.g., 1941-42 to 1945-46);

(4) latitude/longitude blocks were combined into broader spatial areas based on the fishing practices of the northern and southern CPFV fleets, i.e., historically, the southern fleet has exerted the vast amount of fishing pressure associated with this overall fishery (Pt. Conception was used as the ‘north/south’ delimiter to partition the two regional fleets);

(5) the delta-GLM method models the probability of obtaining a zero catch and the catch rate separately, given the catch rate is non-zero (Stefansson 1996; Maunder and Punt 2004). In this assessment, we estimate the probability of a positive observation using a binomial distribution and a logit link function. Then, the mean response for positive observations was estimated assuming a gamma distribution for the error term. The basic model for positive observations included the log of mean catch rate (μ) as a function of three main effects (fishing year *i*, quarter *j*, and fleet *k*),

$$\log_e(\mu_{ijk}) = U_R + Y_i + Q_j + F_k + \varepsilon_{ijk},$$

where μ_{ijk} is the mean catch rate (number of fish/1,000 angler-hours) in year *i*, quarter *j*, and fleet *k*. The fishing year effect is denoted by Y_i (i=1, 2, ..., I; I=67 fishing years). The quarter of the year effect is denoted by Q_j (j=1, 2, ..., J; J=4 quarters). The fleet effect is denoted as F_k (k=1, ..., K; K=2 fleets). The error term is denoted ε_{ijk}, where for each combination of indices, ε_{ijk} is *iid* and gamma distributed. Finally, the reference cell is denoted as *UR* (*R*=1 reference cell, i.e., year=2004, quarter=4, and fleet=south);

(6) no temporal/spatial interactions (e.g., year and fleet or quarter and fleet) were included in the final delta-GLM model, given such interactions had little effect on increasing the amount of variability in mean catch rate as a function of the suite of explanatory variables (i.e., minor improvement of R^2 statistic, see Hill and Crone 2005, Crone et al. 2006); and

(7) a delta-GLM function written in the statistical programming language R (personal communication, E. J. Dick, NOAA Fisheries, SWFSC, Santa Cruz, CA) was used to estimate a mean catch rate from the CPFV data set. A major feature of this function is that it estimates coefficients of variation (CV) for the relative index of abundance using a jackknife (leave-one-out) method. However, because the CPFV data were very extensive (over 80,000 observations), estimation of both year effects for the survey simultaneously with measures of dispersion (i.e., CVs) was problematic. In the current assessment, a year effect is first estimated using all available data and

subsequently, straightforward bootstrap re-sampling methods were employed for purposes of estimating variance (CV) estimates associated with the year effect estimates. Ultimately, the CVs were based on 200 bootstrap samples (with replacement), taken in each fishing year from 1935-36 to 2007-08.

Biological data

Weight-length

A weight-length (W-L) relationship for Pacific mackerel was modeled using port sample data collected by CDFG from 1962 to 2008 (see Fishery-dependent data above). A straightforward power function was used to determine the relationship between weight (kg) and fork length (cm) for both sexes combined:

$$W_L = a\,(L^b),$$

where W_L is weight-at-length L, and a and b are the estimated regression coefficients. Weight-length parameters based on data from 1962-08 (a = 3.1E-06 and b = 3.4) were used (fixed) in all model scenarios (Figure 8A). Also, time-varying weight-length relationships were evaluated in sensitivity analysis; however, little change in W-L has been observed over time (Appendix Figure A2B-6).

Length-at-age

The von Bertalanffy growth equation was used to model the relationship between fork length (cm) and age for Pacific mackerel (1962-08):

$$L_A = L_\infty\,(1 - e^{-k(A-to)}),$$

where L_A is the length-at-age A, L_∞ ('L-infinity') is the theoretical maximum length of the fish, k is the growth coefficient, and t_o ('t-zero') is the theoretical age at which a fish would have been zero length. Length-at-age was estimated internally in all SS model scenarios, generally based on the following baseline growth equation for this population calculated from the CDFG data base (1962-08): L_∞ = 39.3 mm, k = 0.342, and t_o = -1.752 (Figure 8B). Of particular note is the rapid growth exhibited by this species, i.e., past research (Parrish and MacCall 1978; Mallicoate and Parrish 1981), as well as analysis conducted here on recent biological sample data, indicates fish, on average, realize over 50% of their total growth (in length) in the first year of life and subsequently, grow a few cm per year until death at roughly 40 cm (approximately, age 7-8). Sensitivity analysis resulted in relatively robust estimates of K (von Bertalanffy growth equation) that ranged from roughly 0.2 to 0.4 (k = 0.22 for SS model *AA*).

Maximum size and age

The largest recorded Pacific mackerel was 63.0 cm in length (FL) and weighed 2.9 kg (Roedel 1938; Hart 1973), but the largest Pacific mackerel taken by commercial fishing (CA) was 47.8 cm FL and 1.72 kg. The oldest recorded age for a Pacific mackerel was 14 years, but most commercially caught Pacific mackerel are less than 4 years old, with few living beyond age 8 and larger than 45 cm.

Maturity-at-age

The estimated maturity schedule (ogive) used in the past for this stock was assumed in all model scenarios here (Table 3 and Figure 8C). That is, normalized net fecundity-at-age (the product of fraction mature, spawning frequency, and batch fecundity) was used to interpret CalCOFI ichthyoplankton data and ultimately, generate estimates of *SSB*. Fraction mature was estimated by fitting a logistic regression model to age and fraction mature data from Dickerson et al. (1992). Spawning frequency was estimated by fitting a straight line to age and spawning frequency data from the same study. Following Dickerson et al. (1992), batch fecundity per gram of female body weight was assumed constant.

Natural mortality

Natural mortality rate (*M*) was assumed to be 0.5 yr^{-1} for all ages and both sexes, and used in all modeling efforts presented here (Figure 8C). Parrish and MacCall (1978) estimated natural mortality for Pacific mackerel using early catch curves (M = 0.3-0.5), regression of Z on f (M = 0.5), and comparative studies of maximum age (M = 0.3-0.7; Beverton 1963) and growth rate (M = 0.4-0.6; Beverton and Holt 1959). The above authors considered the regression of Z on f to be the most reliable method, with the estimate M = 0.5 falling within the range of the plausible estimates, i.e., an instantaneous M = 0.5 can be practically interpreted as an annual rate of roughly 40% of the stock dying each year due to 'natural causes.' Finally, a range of *M*s was examined formally through sensitivity analysis on the initial baseline SS model reviewed early in the STAR (see Appendix Figure A2B-40 for estimated *B* time series from this profile).

Stock-recruitment

A Beverton-Holt (B-H) stock-recruitment (*S/R*) relationship was assumed for this population for all models scenarios, i.e., as observed in the historical literature, as well as from modeling efforts here, recruitment is highly variable and not likely related closely to absolute levels of *SSB* biomass (*SSB*). However, it is important to note that steepness (*h*) ranged from roughly 0.3 to 0.5 (h = 0.47 for SS model *AA*), depending on the model scenario, indicating that at low *SSB* levels, recruitment is estimated to decrease slightly to moderately (Figure 9). Parrish (1974) and Parrish and MacCall (1978) discussed general life history strategies for this population that are tightly linked to oceanographic conditions and further, that periods of strong year classes (cohorts) are likely produced only when *SSB* is high (or moderately so) and more importantly, not likely to occur more than once or twice every 60 years.

Responses to past STAR/SSC recommendations

The three overriding recommendations from past reviews focused on data availability from Mexico, omission/inclusion of available indices of relative abundance used in this ongoing assessment, and development of a robust alternative (SS) model that can be used for formal management advice. See STAR (2009) for further discussion regarding these issues.

Regarding relations with Mexico and issues surrounding future data exchange and professional collaboration on research projects … *SWFSC staff continue to engage in such discussions, meetings, conferences, etc. with academic colleagues and federal researchers from Mexico, e.g., updated landing information and additional, albeit preliminary, larval survey data have been made available recently.*

Regarding indices of relative abundance used in the current assessment … *both the spotter and CalCOFI survey indices were omitted from final baseline model scenarios for the current fishing year (2009-10), as well as in future assessment models. The remaining CPFV index, as well as related recreational fishery data, have now increased in importance in overall modeling efforts and subsequently, will need increased research support, as well as monitoring (see Research and Data Needs below).*

Regarding transitioning to the SS model for providing management advice … *the SS model was identified as the best modeling platform for assessing the status of the Pacific mackerel stock currently and in the future.*

Model description

<u>Overview</u>

The Stock Synthesis (SS, Methot 2005, 2009) model is founded on the AD Model Builder software environment, which essentially is a C++ library of automatic differentiation code for nonlinear statistical optimization (Otter Research 2001). The model framework allows full integration of both population size and age structure, with explicit parameterization both spatially and temporally. The model incorporates all relevant sources of variability and estimates goodness of fit in terms of the original data, allowing for final estimates of precision that accurately reflect uncertainty associated with the sources of data used as input in the overall modeling effort.

The SS model comprises three sub-models: (1) a population dynamics sub-model, where abundance, mortality, and growth patterns are incorporated to create a synthetic representation of the true population; (2) an observation sub-model that defines various processes and filters to derive expected values for different types of data; and (3) a statistical sub-model that quantifies the difference between observed data and their expected values and implements algorithms to search for the set of parameters that maximizes goodness of fit. This modeling platform is also very flexible in terms of estimation of management quantities typically involved in forecast analysis. Finally, from an international context, the SS model is rapidly gaining popularity, with SS-based stock assessments being conducted on numerous marine species throughout the world. The SS model used in this assessment was the most recently distributed version, namely, version 3.0.12 (January 2009).

<u>Likelihood components and model parameters</u>

Likelihood components and estimates for important SS model scenarios are presented in Table 4 (and Appendix Table A2B-1), including, fits to catch, age/length distributions, and indices, as well as parameter estimates for initial conditions (age distribution, recruitment, and fishing mortality), growth, recruitment, stock-recruitment relationship, etc.

<u>Convergence criteria</u>

The convergence criterion for maximum gradient determination was set to 0.0001 in the SS model. Fidelity of model convergence was explored by changing particular ‘starting’ values for multiple parameters and evaluating the converged ‘minimum’ values, i.e., evaluating ‘global’ vs. ‘local’ convergence properties of the overall, multi-dimensional numerical estimation.

Model selection and evaluation

We strongly adhered to model development (say parameterization involved in the various scenarios) that was based on the following: supports general consensus regarding this species' life history; results in no noticeable inconsistencies (across likelihood components) within the fully-integrated model scenario; addresses uncertainty in a sound, robust, and parsimonious manner; and finally, produces realistic (meaningful) results that can be directly assimilated into ongoing management efforts. Markov chain Monte Carlo (MCMC) methods were conducted on the initial baseline SS Model (*S1_aa*), whereby the Markov chain achieved a stationary (equilibrium) distribution, with no significant statistical violations observed across the estimated parameters, inclusive; however, due to time constraints, such diagnostics have not been conducted on the final SS model *AA* to date. The following outline summarizes model selection/evaluation development for the Pacific mackerel stock assessment conducted in 2009:

- developed the baseline (management) ASAP model (2009) … input data (i.e., time series updated with additional year) and parameterization similar to previous model used in the final assessment conducted in 2008 (see Appendix A2A);
- developed a baseline (alternative) SS model (*S1_aa*) … input data and parameterization similar to ASAP model (2009) above, i.e., a robust model that most closely resembled the ASAP model (see Appendix A2B);
- developed (two) suites of SS model scenarios via sensistivity analysis … one prior to the STAR and presented at the start of the review meeting (see Appendix Table A2B-1) and another during the review meeting (see Table 4); and
- developed a preferred SS model *AA* from the suites of alternative scenarios … this model scenario (along with SS model *AB*) provides the basis for the final assessment conclusions.

Key features of SS model *AA* follow, with comparative discussion regarding SS model *AB* presented where applicable, as well as identification of influential areas of parameterization that will likely be addressed further in future model development:

- *Time period*: 1962-08.
  Sensitivity analysis included starting the model later (late 1970s), but had little effect on overall results; however, it is likely that this area of parameterization in future models will need further evaluation.
- *Fishery structure*: two (USA/Mexico commercial and USA recreational).
- *Surveys*: One (CPFV index of relative abundance).
  Following much discussion and review of model scenarios, it was determined that both the spotter and CalCOFI indices be omitted from the current assessment analysis, given concerns regarding potential sampling biases associated with these indices at particular time periods, due to both the dynamics of the fish/fishery and implemented sampling designs (see STAR 2009).
- *Time-step*: annual.
  Sensitivity analysis included many scenarios based on a quarter time-step, with most of these configurations producing results generally similar to analogous (annual) time-step model scenarios.
- *Gender structure*: combined sexes.
- *Growth*: estimated and constant over time.

As presented in previous literature that addressed growth dynamics associated with this stock (Parrish and MacCall 1978), there is little evidence in support of growth changes over time (i.e., in terms of length-at-age). Further, sensitivity analysis resulted in robust estimates of *K* (von Bertalanffy growth equation) that ranged from approximately 0.2-0.4 (k = 0.22 for SS model *AA*). Additionally, sensitivity analysis that considered time-varying changes for growth in weight (i.e., in terms of weight-length/age), which in the vast majority of animal populations is the more 'plastic' growth attribute, revealed no indication that this growth parameter has changed markedly over the last 50 years (Appendix Figure A2B-6). Finally, additional mean size (length)-at-age time series allowed for detailed growth parameterization in all model scenarios. In this context, a model scenario was developed to address this issue (see below).

- *Selectivity (catch)*: Age-based and time-varying (three time blocks).
  Selectivity issues regarding age- or size-based approaches were given much attention, based on relations to the actual operation of the fisheries and dynamics of the stock. That is, we feel that the distribution exhibited by this species on any given year and subsequently, its probability of capture (selectivity) is more influenced by 'time' (say age) than by size (say length); this is true for all age groups, from the variability observed in the presence/absence of 0-1 yr-old fish to the adults in the estimated age distributions modeled here. Recognizing that in reality, both attributes are likely influential to some degree, it is more likely that movement (and capture) are driven by age, i.e., versus gear (mesh) constraints that also generally influence vulnerability. Given the biological sampling design in place provides 'random' samples of fish (for purposes of length, age, etc.) from completed boat trips, selectivity parameterization based on representative age distributions of the catch becomes the logical approach. Although the biological distributions from the recreational fishery were in terms of size (length, given no age data available), age-based selectivity was implemented for this fishery as well. Finally, preliminary modeling efforts indicated age- or size-based selectivity resulted in similar conclusions of stock status.
  - SS model *AB* included an additional time block (2000-08) for both the commercial and recreational fisheries, based on visual evaluations of changes in age/length distributions over time.
  - As with the modeled time period above, time-varying selectivity will likely be an important area of examination as the Pacific mackerel assessment model continues development in the future.
- *Selectivity (index)*: age-based (i.e., mirrors recreational fishery) and constant.
  - SS model *AB* included the CPFV index split into two indices (one that spanned 1962-99 and another for 2000-08) in efforts to keep both time-varying selectivity and catchability in line with one another.
  - As with the modeled time period and catch-related selectivity above, parameterization of time-varying catchability will necessarily be another important area of examination in future model development for this species.

- *Stock-recruitment*: Beverton-Holt stock-recruitment model.
  An asymptotic relationship between parents and offspring was assumed in all model scenarios. Estimated steepness (*h*) from sensitivity analysis ranged from roughly 0.3 to 0.5 (*h* = 0.47 for SS model *AA*). See Stock-recruitment above.
  - σ_R = 1.0.

  In recent previously conducted assessments, σ_R = 0.7. Increasing the variability surrounding recruitment estimation was supported in most model scenarios, with internal model estimates of root mean square errors associated with estimated recruitment ranging from roughly 0.9 to 1.3.
- *Variance adjustments to time series*: variance adjustments were used following diagnostic evaluations of input vs. effective sample size results from final model runs. That is, adjustments reflected doubled input sample sizes for the recreational length distributions only, i.e., in effect, reweighted effective sample sizes reflected total number of fish divided by 12.5 (vs. 25 as used for initial (baseline) sample sizes, see Length distributions above). Also, in some model scenarios, age distributions (commercial fishery) were 'down-weighted' (0.25) accordingly; however, model convergence (with no penalties) was problematic.
  - As with the modeled time period and selectivity/catchability above, variance adjustments to both biological distributions via sample size allocations and index of relative abundance via assumed error (CVs) associated with the CPFV index will necessarily warrant further consideration, given the influence such parameterization has on fully-integrated stock assessment models in general.

Sensitivity analysis
Alternative SS model scenarios are briefly summarized below, i.e., see Table 4. That is, many model scenarios were presented and reviewed at the start of the STAR, particularly; configurations based on a quarter time-step (see Appendix Table A2B-1 and Figure A2B-41). The following model scenarios represent key configurations developed during the STAR, which collectively, served to further the development of the final (consensus) SS model *AA* (and alternative SS model *AB*), see Model description above.

SS model *H2*: Similar to SS model *AA*, but no variance adjustment (effective sample sizes) to recreational length distribution time series.

SS model *N*: Similar to SS model *AA*, but σ-*R*=0.7 (i.e., more precise) and no variance adjustment (effective sample sizes) to recreational length distribution time series.

SS model *Q*: Similar to SS model *AA*, but σ-*R*=0.7 (i.e., more precise), fish greater than 55 cm in recreational length distribution were omitted, and no variance adjustment (effective sample sizes) to recreational length distribution time series.

SS model *U*: Similar to SS model *AB*, but no variance adjustment (effective sample sizes) to recreational length distribution time series.

SS model *P*: Similar to SS model *AB*, but CalCOFI ('super years') index was included, σ-*R*=0.7 (i.e., more precise), and no variance adjustment (effective sample sizes) to recreational length distribution time series.

Assessment model results (SS model *AA*)
Model fits to biological distributions are presented in the following displays: Figure 10A is observed vs. predicted estimates for the age distribution time series for the commercial fishery; Figure 10B is the associated Pearson residual plot for the age distribution fits; Figure 10C is the associated input vs. effective sample size plot for the age distribution fits; Figure 11A is observed vs. predicted estimates for the length distribution time series for the recreational fishery; Figure 11B is the associated Pearson residual plot for the length distribution fits; Figure 11C is the associated input vs. effective sample size plot for the length distribution fits; Figure 4 is the observed vs. predicted estimates for the mean length-at-age distribution time series for the commercial fishery; and Figure 12 is the associated Pearson residual plot for the mean length-at-age distribution fits. Estimated selectivity for the fishery catches is presented in Figure 13A (commercial fishery – three time blocks) and Figure 13B (recreational fishery – single time block).

In general, fits to biological distributions were relatively good; however, in some years, large 'pulses' of younger fish were not fit with high precision, i.e., 0-1 yr-old fish in the commercial fishery age distributions. Also, the rapid decline of older animals in many years may be due to non-constant natural mortality (say by sex) or potentially, due to selectivity changes over time (see Model selection and evaluation above).

Fits (normal and log space) to the CPFV index of relative abundance are presented in Figure 14A-B. In general, model fits to the CPFV index were very good and further, in all model runs (inclusive), this index was fit much more precisely than either of the other indices (i.e., spotter and CalCOFI indices) that were eventually omitted in final model scenarios. Selectivity for the CPFV index mirrored that estimated for the recreational fishery (Figure 13B).

Estimated Beverton-Holt stock-recruitment relationship is presented in Figure 9 (see Stock-recruitment above). Estimates of Pacific mackerel recruitment deviations and asymptotic standard errors for the deviations are presented in Figure 15A-B.

Harvest rate estimates are presented in Figure 16. As expected, harvest rates have varied substantially over time, with exploitation declining markedly since roughly 2000 to historically low levels.

Estimated time series for management-related derived quantities of interest are presented in the following displays: Figure 17 is total stock biomass (age 1+ fish in mt, *B*) for both the final SS model *AA* and alternative model *AB*; Figure 18 is spawning stock biomass (*SSB* in mt); and Figure 19 is recruitment (age-0 fish in numbers). Estimated *B* (and *SSB*) remained low from the early 1960s to the mid 1970s, at which time the population began to rapidly increase in size, reaching a peak in the early 1980s. From the mid 1980s to early 2000s, the stock declined steadily, with some signs of 'rebuilding' (on an increasing limb of a historical distribution say) observed recently. However, as noted previously, recent estimates of stock size are necessarily related to assumptions regarding the dynamics of the fish (biology) and fishery (operations) over the last several years, which generally confounds long-term (abundance) forecasts for this species (e.g., SS model *AA* and model *AB* are generally similar historically, but diverge in the mid 2000s, based on different assumptions surrounding both selectivity and catchability (see Model selection and evaluation above).

Results from a retrospective analysis are presented in Figure 20, i.e., data associated with terminal years 2008 to 2004 were omitted (sequentially) from the model. As observed in all past assessments, a retrospective pattern exists with this assessment model as well (albeit only moderate in severity), i.e., a tendency to overestimate stock abundance (*B*) in any current year, with future assessments based on additional data producing estimates lower in magnitude. However, given this model (SS model *AA*) is structured substantially different from past models used for the ongoing stock assessment, the usefulness of a retrospective evaluation at this time should be interpreted accordingly.

Finally, for comparative purposes, final estimated B time series for the historical assessment period (1994-09) are presented in Figure 21. It is important to note that in 2007, estimated *B* scaled upwards substantially, based largely on assumptions regarding variability surrounding estimated recruitment, i.e., since 2005, σ-*R* has increased from 0.25 to 0.7 to the current level of assumed variability of 1.0, which is more in line with internal estimation of recruitment uncertainty associated with assessment models developed recently for this species (also, see Harvest Control Rule for USA Management in 2009-10 below).

Assessment model uncertainty

Generally speaking, uncertainty in the overall assessment is evaluated using some combination of the following: the confidence intervals associated with estimated parameters of interest (e.g., time series of *SSB* and recruitment); sensitivity analysis (i.e., developing alternative model scenarios); examinations (qualitative and quantitative) of important residual plots from critical model fits (e.g., fits to biological distributions and index); and more rigorous multi-dimensional diagnostics via MCMC methods (see Model selection and evaluation above). All of the above were addressed in the assessment conducted here. Finally, it is important to note that model estimates of absolute stock size are likely more uncertain than presented here, given the final estimates are necessarily based on some combination of the following: strict probability samples in the field cannot be obtained; subjective assumptions used to develop model scenarios; potential weighting issues with particular data sources; and unaccounted for variability associated with related sources of data and parameters in the fully-integrated, multiple likelihood modeling platform.

Specificially, in addition to lacking ongoing data exchange with Mexico regarding catch, biology, and survey information associated with this species, a primary area of uncertainty in the overall assessment is assumptions and associated parameterization surrounding both selectivity for the fisheries, as well as catchability for the CPFV index of relative abundance. That is, the degree to which changes have occurred across time in terms of 'probability of capture' associated with the commercial and recreational fisheries has not been definitively evaluated at this time, but rather, will need further examination as the Pacific mackerel assessment progresses in the future. However, in the interim, it is important to note that fishing pressure on this stock has been very low for the last several years and coupled with this species' biology, likely indicates the stock is not highly vulnerable to overfishing presently, but rather, should be monitored closely in terms of both magnitude of landings in coming years, as well as evaluated through ongoing (improved) assessment efforts. See Research and Data Needs below.

HARVEST CONTROL RULE FOR USA MANAGEMENT IN 2009-10

As stipulated in Amendment 8 to the CPS FMP (PFMC 1998), the recommended maximum sustainable yield (MSY) control rule for Pacific mackerel is:

$$\text{Harvest} = (\text{Biomass-Cutoff}) \bullet \text{Fraction} \bullet \text{Distribution},$$

where Harvest is the harvest guideline (HG), Biomass is the estimated total stock biomass (age 1+) in 2009 (343, 180 mt), Cutoff (18,200 mt) is the lowest level of estimated biomass at which harvest is allowed, Fraction (30%) is the proportion of biomass above the Cutoff that can be harvested by fisheries, and Distribution (70%) is the average fraction of total biomass assumed in USA waters (PFMC 1998). The HGs under the federal FMP are applied to a July-June fishing 'year.' Landings and associated HGs since 1992 are presented in Figure 22A.

The HG for the 2009-10 fishing year is 55,408 mt:

***B* (Age 1+, mt)**	**Cutoff (mt)**	**Fraction**	**Distribution**	**HG (mt)**
282,049	18,200	30%	70%	**55,408**

From 1985 to 1991, the biomass exceeded 136,000 mt and no state quota restrictions were in effect. State quotas for 1992-00 fishing years averaged roughly 24,000 mt. From 2001-06, HGs averaged roughly 20,000 mt. In 2007, the HG was increased substantially to over 100,000 mt based largely on assumptions regarding variability surrounding estimated recruitment and has remained at an elevated level since then (Figure 22A). It is important to note that since the 2001 fishing year, from a management context, the fishery has failed to fully utilize HGs, with average yields since this time of roughly 5,000 mt. Finally, 'hypothetical' quotas and total landings, based on omission of the USA 'Distribution' parameter in the harvest control rule are presented in Figure 22B.

RESEARCH AND DATA NEEDS

First and foremost, given the transboundary status of this fish population, it is imperative that efforts continue in terms of encouraging collaborative research and data exchange between NOAA Fisheries (Southwest Fisheries Science Center) and researchers from both Canada's and in particular, Mexico's academic and federal fishery bodies, i.e., such cooperation is critical to providing a synoptic assessment that considers available sample data across the entire range of this species in any given year.

Second, fishery-independent survey data for measuring (relative) changes in mackerel spawning (or total) biomass are currently lacking. Further, at this time, a single index of relative abundance is used in the assessment, which is developed from a marine recreational fishery

(CPFV fleet) that typically does not (directly) target the species. In this context, it is imperative that future research funds be focused on improvement of the current CPFV survey, with emphasis on a long-term horizon, which will necessarily rely on cooperative efforts between the industry, research, and management bodies. Additionally, we strongly support development of a well-designed logbook monitoring program associated with the current commercial (purse-seine) fishery, which has been long overdue.

Third, given the importance of age (and length) distribution time series to developing a sound understanding of this species' population dynamics, it is critical that data collection programs at the federal and particularly, the state-level continue to be supported adequately. In particular, CDFG/NOAA funding should be bolstered to ensure ongoing ageing-related laboratory work is not interrupted, as well as providing necessary funds for related biological research that is long overdue. For example, maturity-related time series currently relied upon in the assessment model are based on data collected over twenty years ago during a period of high spawning biomass that does not reflect current levels. Also, further work is needed to obtain more timely error estimates from production ageing efforts in the laboratory, i.e., accurate interpretation of age-distribution data used in the ongoing assessment necessarily requires a reliable ageing error time series. Finally, examinations of sex-specific age distributions will allow hypotheses regarding natural mortality/selectivity (i.e., absence of older animals in sex-combined age distributions) to be more fully evaluated.

Finally, the MSY control rule utilized in the Pacific mackerel federal CPS-FMP was developed in the mid-1980s using the historical time series of abundance. The harvest control rule should be re-examined using new data and simulation methods. Given substantial amounts of additional sample data have accumulated since the initial research that was undertaken to formally establish this harvest strategy, it would be prudent to conduct further simulation modeling work to address particular parameters included in the overall control rule (including 'cutoff,' 'fraction,' and 'distribution' values).

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Table 1. Sample sizes associated with CDFG data collection program for Pacific mackerel (1962-08).

Fishing Year	Landings (mt)	# Fish Sampled	Fish per 1,000 mt
62	23,758	205	9
63	23,483	205	9
64	19,901	268	13
65	11,057	111	10
66	7,138	1,944	272
67	1,567	720	459
68	1,599	2,145	1,342
69	1,010	498	493
70	677	150	222
71	590	344	583
72	228	223	978
73	152	239	1,568
74	514	179	348
75	1,950	1,326	680
76	3,925	2,202	561
77	12,914	1,943	150
78	25,818	3,810	148
79	33,905	3,491	103
80	32,518	6,711	206
81	45,562	5,067	111
82	34,955	4,764	136
83	40,573	2,694	66
84	45,001	2,394	53
85	45,812	2,607	57
86	53,263	3,000	56
87	46,958	4,150	88
88	48,576	4,479	92
89	48,788	3,583	73
90	70,935	2,121	30
91	64,825	1,689	26
92	31,754	2,015	63
93	20,311	2,740	135
94	22,674	4,357	192
95	10,982	2,718	247
96	23,877	2,222	93
97	50,272	2,722	54
98	62,393	2,261	36
99	15,757	1,674	106
00	27,467	1,919	70
01	12,439	2,114	170
02	13,869	2,150	155
03	8,590	1,599	186
04	7,029	2,547	362
05	7,079	2,300	325
06	10,437	2,424	232
07	9,123	1,609	176
08	6,513	425	65

Table 2. Landings (mt) of Pacific mackerel by fishery (1962-2008).

Fishing year	USA Commercial (mt)	Mexico Commercial (mt)	Recreational CPFV (mt)	Recreational non-CPFV (mt)	Total (mt)
62	20,527	3,231	58	85	23,901
63	15,517	7,966	86	134	23,703
64	11,283	8,618	33	54	19,988
65	3,442	7,615	84	138	11,279
66	1,848	5,290	97	169	7,405
67	619	948	56	90	1,713
68	1,492	107	37	60	1,695
69	809	201	58	100	1,168
70	277	400	61	98	835
71	90	500	118	203	911
72	28	200	118	186	532
73	52	100	95	154	401
74	43	471	47	73	634
75	141	1,809	75	124	2,149
76	2,654	1,271	69	97	4,092
77	7,748	5,165	314	524	13,751
78	18,446	7,372	501	854	27,173
79	28,755	5,150	804	1149	35,858
80	27,972	4,546	1,277	1409	35,203
81	38,407	7,155	665	757	46,985
82	30,626	4,329	693	723	36,371
83	36,309	4,264	700	844	42,118
84	39,240	5,761	612	855	46,468
85	37,615	8,197	524	492	46,828
86	44,298	8,965	386	474	54,123
87	44,838	2,120	245	1020	48,223
88	41,968	6,608	181	507	49,265
89	25,063	23,724	167	451	49,406
90	39,974	30,961	230	386	71,551
91	30,268	34,557	252	429	65,505
92	25,584	6,170	135	329	32,217
93	10,787	9,524	196	413	20,920
94	9,372	13,302	226	837	23,737
95	7,615	3,368	439	574	11,996
96	9,788	14,089	320	366	24,563
97	23,413	26,860	104	700	51,076
98	19,578	42,815	108	322	62,823
99	7,170	8,587	55	97	15,910
00	20,936	6,530	78	248	27,792
01	8,436	4,003	51	520	13,010
02	3,541	10,328	22	232	14,123
03	5,972	2,618	28	295	8,913
04	5,012	2,017	23	510	7,562
05	4,572	2,507	21	375	7,475
06	7,870	2,567	15	356	10,808
07	6,208	2,914	18	289	9,429
08	3,599	2,914	19	272	6,803

Table 3. Normalized net fecundity calculations for Pacific mackerel, which in effect, represented the maturity schedule (ogive) used in all model scenarios[a].

Age (yrs)	Observed Fraction Mature	Predicted Fraction Mature	Observed Spawning Frequency (% spawning day^{-1})	Predicted Spawning Frequency (% spawning day^{-1})	Net Fecundity (eggs g^{-1})	Normalized Net Fecundity (eggs g^{-1})
0	0.000	0.000	0.000	0.000	0.000	**0.000**
1	0.214	0.487	0.000	1.380	0.672	**0.074**
2	0.867	0.636	3.900	3.520	2.240	**0.246**
3	0.815	0.763	6.800	5.660	4.320	**0.474**
4	0.851	0.855	9.900	7.800	6.670	**0.733**
5	0.882	0.916	7.700	9.940	9.110	**1.000**
6+	0.882	0.916	7.700	9.940	9.110	**1.000**

[a] Observed fraction mature and observed spawning frequency from Dickerson et al. (1992). Predicted fraction mature from logistic regression. Predicted spawning frequency from linear regression. Net fecundity is adjusted (normalized) to a maximum value of 1.0. Batch fecundity is assumed constant.

Table 4. Summary of SS model scenarios developed for the Pacific mackerel (2009) assessment, including: (A) new data sources and critical parameterizations; and (B) likelihood component estimates and derived quantities of importance.

(A)

	Model scenarios [a]						
Time series	***AA***	***AB***	***H2***	***N***	***Q***	***P***	***U***
Landings - USA/Mexico commerical (1962-08) - Fishery 1							
Landings - USA recreational (1962-08) - Fishery 2							
Age distributions (1962-08) - USA/Mexico commercial							
Length distributions (1992-08) - USA recreational							
Mean length-at-age distributions (1962-08) - USA/Mexico commercial							
CPFV survey (1962-08) - Survey 1 [b]							
CPFV survey (1962-99) and (2000-08) - Surveys 2 and 3, respectively							
CalCOFI survey (1978-08) - daily larv. prod. ('super years') - Survey 4 [c]							
Parameterization	***AA***	***AB***	***H2***	***N***	***Q***	***P***	***U***
Model structure							
Time period	1962-08	1962-08	1962-08	1962-08	1962-08	1962-08	1962-08
Number of fisheries	2	2	2	2	2	2	2
Number of surveys	1	2	2	1	2	3	1
Genders	1	1	1	1	1	1	1
Time-step	Annual	Annual	Annual	Annual	Annual	Annual	Annual
Biology							
Maturity-at-age	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Length-at-age	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
Weight-length	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Weight-at-age	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
Natural mortality (M)	Fixed - all ages (M=0.5)	Fixed - all ages (M=0.5)	Fixed - all ages (M=0.5)	Fixed - all ages (M=0.5)	Fixed - all ages (M=0.5)	Fixed - all ages (M=0.5)	Fixed - all ages (M=0.5)
Stock-recruitment							
$\ln(R_0)$	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
Offset for initial equilibrium R_1	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
Steepness (h)	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
σ-R	Fixed (σ-R=1.0)	Fixed (σ-R=1.0)	Fixed (σ-R=1.0)	Fixed (σ-R=0.7)	Fixed (σ-R=0.7)	Fixed (σ-R=0.7)	Fixed (σ-R=1.0)
Initial conditions for population dynamics							
Age distribution	Non-equilibrium	Non-equilibrium	Non-equilibrium	Non-equilibrium	Non-equilibrium	Non-equilibrium	Non-equilibrium
Fishing mortality (F) - Fishery 1[d]	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
Fishing mortality (F) - Fishery 2	Fixed (F_{init}=0.001)	Fixed (F_{init}=0.001)	Fixed (F_{init}=0.001)	Fixed (F_{init}=0.001)	Fixed (F_{init}=0.001)	Fixed (F_{init}=0.001)	Fixed (F_{init}=0.001)
Selectivity							
Fisheries							
Parameterization	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
Time block	Fishery 1=3 blocks Fishery 2=single	Fishery 1=4 blocks Fishery 2=2 blocks	Fishery 1=3 blocks Fishery 2=single	Fishery 1=3 blocks Fishery 2=single	Fishery 1=3 blocks Fishery 2=single	Fishery 1=4 blocks Fishery 2=2 blocks	Fishery 1=4 blocks Fishery 2=2 blocks
Shape	Dome-shaped	Dome-shaped	Dome-shaped	Dome-shaped	Dome-shaped	Dome-shaped	Dome-shaped
Surveys							
Parameterization	Fixed (mirrors Fishery 2)	Fixed (mirrors Fishery 2)	Fixed (mirrors Fishery 2)	Fixed (mirrors Fishery 2)	Fixed (mirrors Fishery 2)	Fixed (mirrors Fishery 2)	Fixed (mirrors Fishery 2)
Time block	Single	2 blocks	Single	Single	Single	2 blocks	2 blocks
Shape	Dome-shaped	Dome-shaped	Dome-shaped	Dome-shaped	Dome-shaped	Dome-shaped	Dome-shaped
Catchability							
q - Surveys	Est. (median unbiased)	Est. (median unbiased)	Est. (median unbiased)	Est. (median unbiased)	Est. (median unbiased)	Est. (median unbiased)	Est. (median unbiased)
Variance adjustment factors							
Biological distributions - Fishery 2 (ESS for length distributions)[e]	Doubled weight	Doubled weight	No additional weighting	No additional weighting	No additional weighting	No additional weighting	No additional weighting

Table 4. Continued.

(B)

Likelihood component	*AA*	*AB*	*H2*	*N*	*Q*	*P*	*U*
Biological distributions							
Age distributions							
USA/Mexico commercial - Fishery 1	700.4	673.9	673.3	695.5	687.6	670.5	657.5
Length distributions							
USA recreational - Fishery 2	201.4	183.8	117.0	117.1	114.2	104.6	110.1
Length-at-age distributions							
USA/Mexico commercial - Fishery 1	540.4	535.9	538.9	534.1	535.6	526.1	530.4
Surveys							
CPFV - Survey 1	-18.3	Na	-18.0	-15.7	-16.0	Na	Na
CPFV - Survey 2	Na	-10.0	Na	Na	Na	-11.0	-15.0
CPFV - Survey 3	Na	-6.0	Na	Na	Na	-8.6	-7.8
CalCOFI - Survey 4	Na	Na	Na	Na	Na	2.5	Na
Sub-total	-18.3	-16.0	-18.0	-15.7	-16.0	-17.2	-22.8
Recruitment							
Model time period (1958-08)	34.7	33.7	36.0	39.9	40.1	38.1	34.6
Forecast (2009)	0.016	0.006	0.002	0.038	0.005	0.102	0.009
Global							
Likelihood (*L*)	1,458.6	1,411.3	1,347.2	1,370.9	1,361.5	1,322.3	1,309.9
Number of estimated parameters	84	97	85	82	85	98	97
Key estimated parameters and derived quantities							
Biology							
Length-at-age (k)	0.22	0.28	0.28	0.28	0.28	0.30	0.29
$\ln(R_0)$	13.5	13.6	13.5	13.1	13.3	13.8	13.5
Offset for initial equilibrium R_1	0.2473	0.2916	0.2581	0.1510	0.1924	0.2743	0.2766
Steepness (h)	0.47	0.40	0.49	0.48	0.43	0.33	0.42
Initial conditions for population dynamics							
Fishing mortality (F) - Fishery 1[d]	0.65	0.51	1.22	1.30	0.74	0.89	1.09
Population time series							
SSB - 1962	47,534	61,882	52,485	35,085	41,234	93,908	60,595
SSB - 2008	76,441	17,264	80,540	76,441	76,453	134,186	26,235
B (1+) - 1962	171,865	196,629	181,367	129,586	154,541	307,827	198,645
B (1+) - 2009	282,049	55,003	293,719	229,556	274,032	329,342	81,637
HG - 2009	55,408	7,729	57,859	44,385	53,725	65,340	13,322

[a] Further parameterization details regarding model scenarios presented here can be found in STAR (2009).

[b] CPFV survey included two alternive formulations: Survey 1 (1962-08); and a split index that spanned 1962-99 (Survey 2) and 2000-08 (Survey 3).

[c] Initial sensitivity analysis regarding the CalCOFI survey presented at the onset of the STAR was based on three alternative indices (see Appendix 3B-C); however, a revised index (Survey 4) was used in subsequent sensitivity analysis conducted during the STAR, see STAR (2009).

[d] Estimated initial fishing mortality was not fit to 'equilibrium' catch, but rather, implemented for purposes of providing a more robust initial non-equilibrium age composition.

[e] Variance adjustments reflect doubled input sample sizes, i.e., in effect, reweighted effective sample sizes reflect total number of fish divided by 12.5 (vs. 25 as used for initial (baseline) sample sizes).

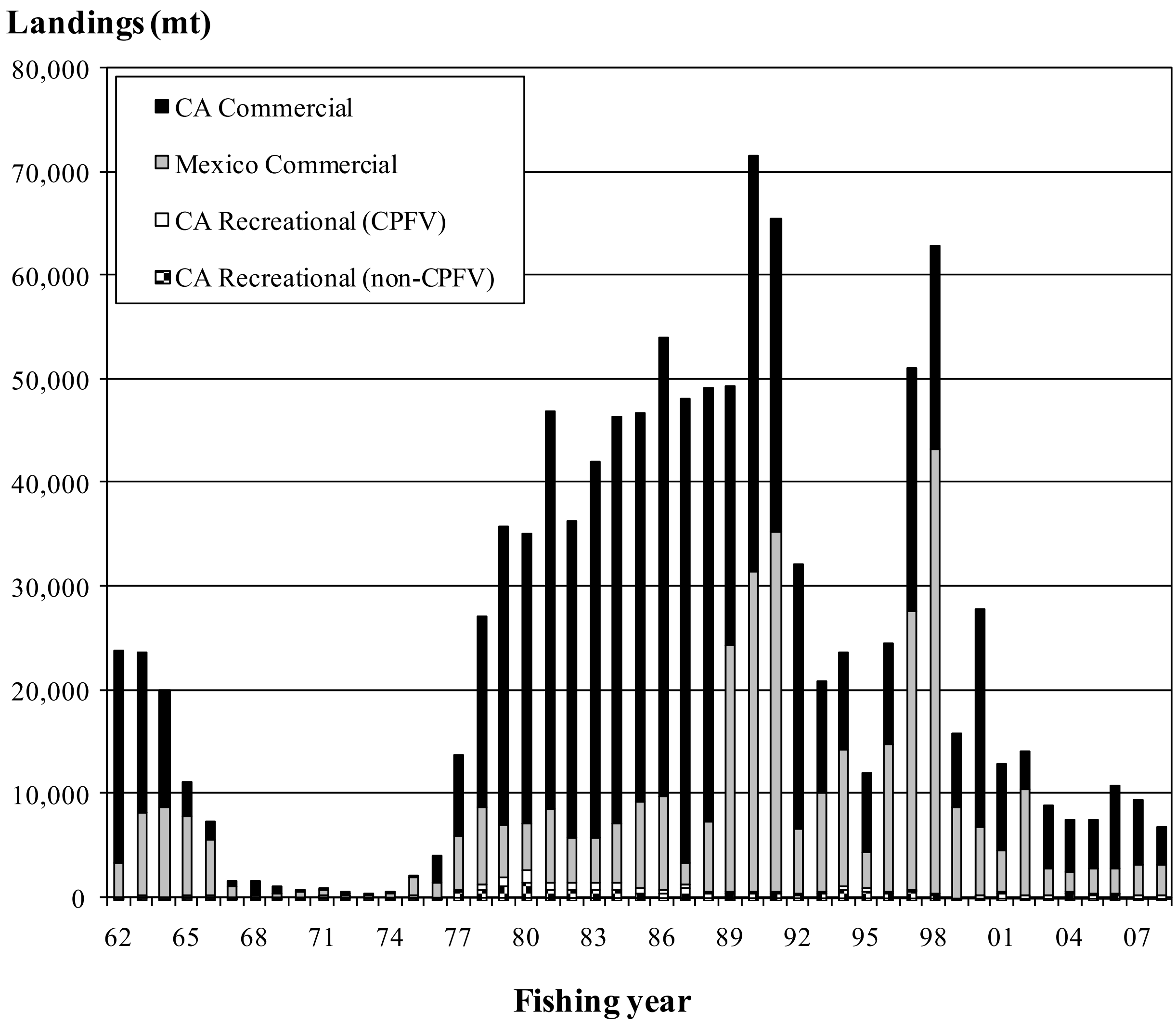


Figure 1. Commercial and recreational landings (mt) of Pacific mackerel in the USA (CA commercial, recreational-CPFV, and recreational-non-CPFV) and Mexico (commercial), (1962-08).

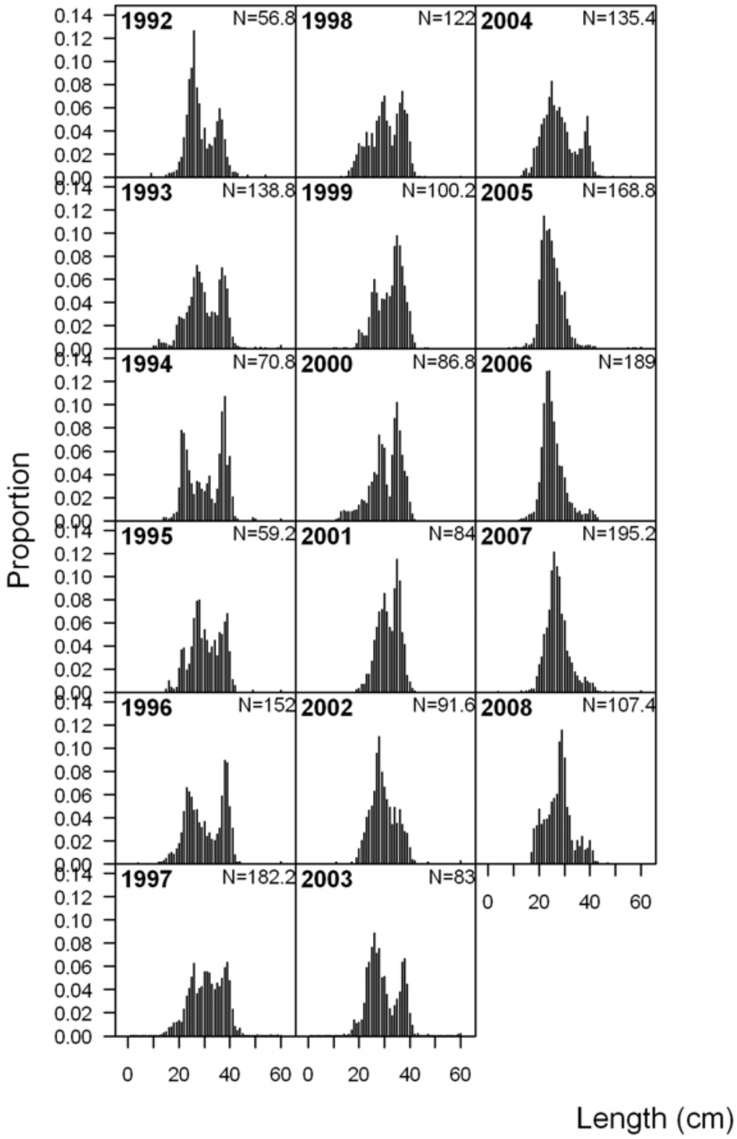


Figure 2. Length distributions of Pacific mackerel from RecFIN data base associated with the CPFV fishery (1992-08).

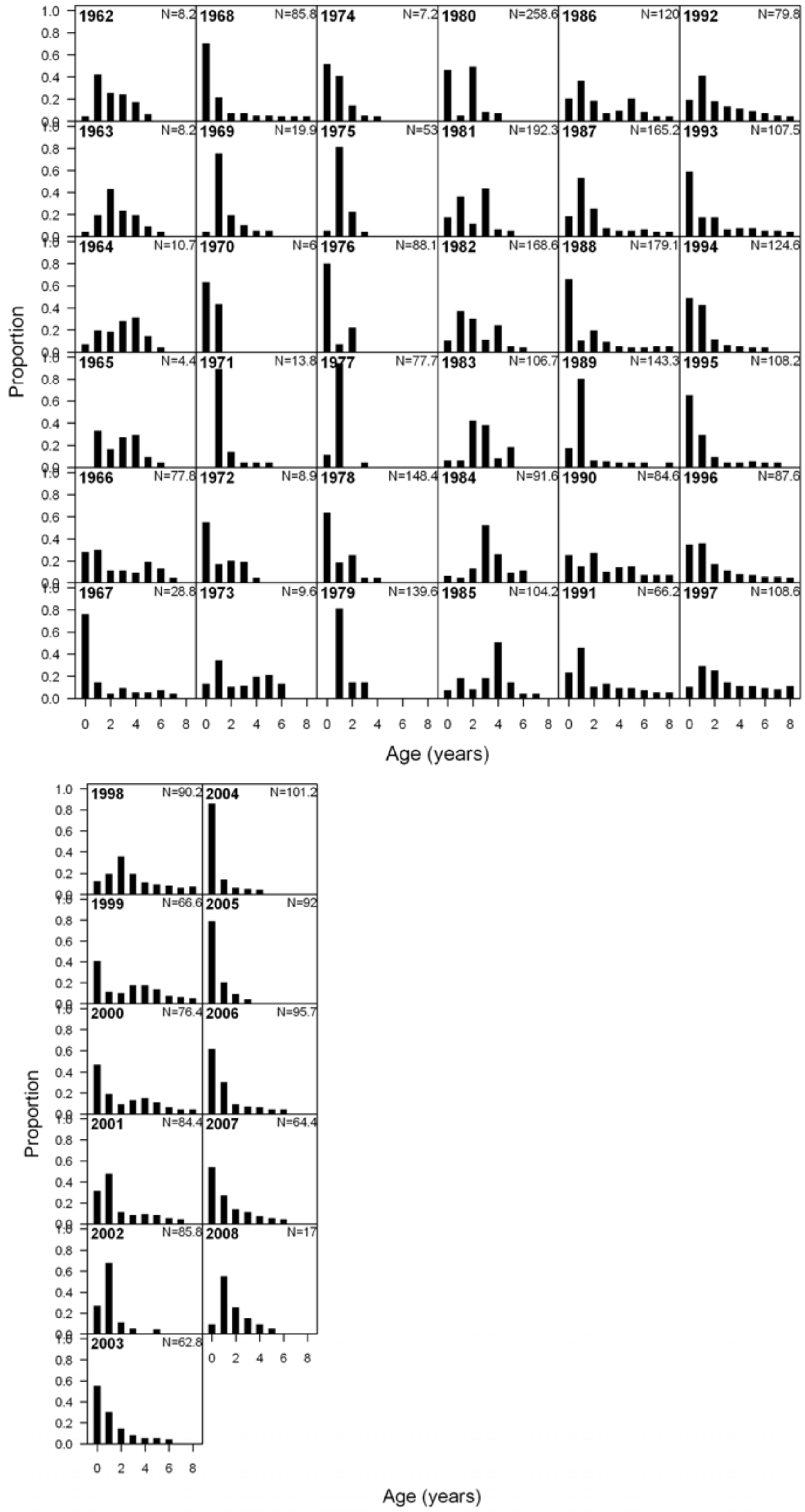


Figure 3. Age distributions of Pacific mackerel from CDFG (commercial fishery) port sampling program (1962-08).

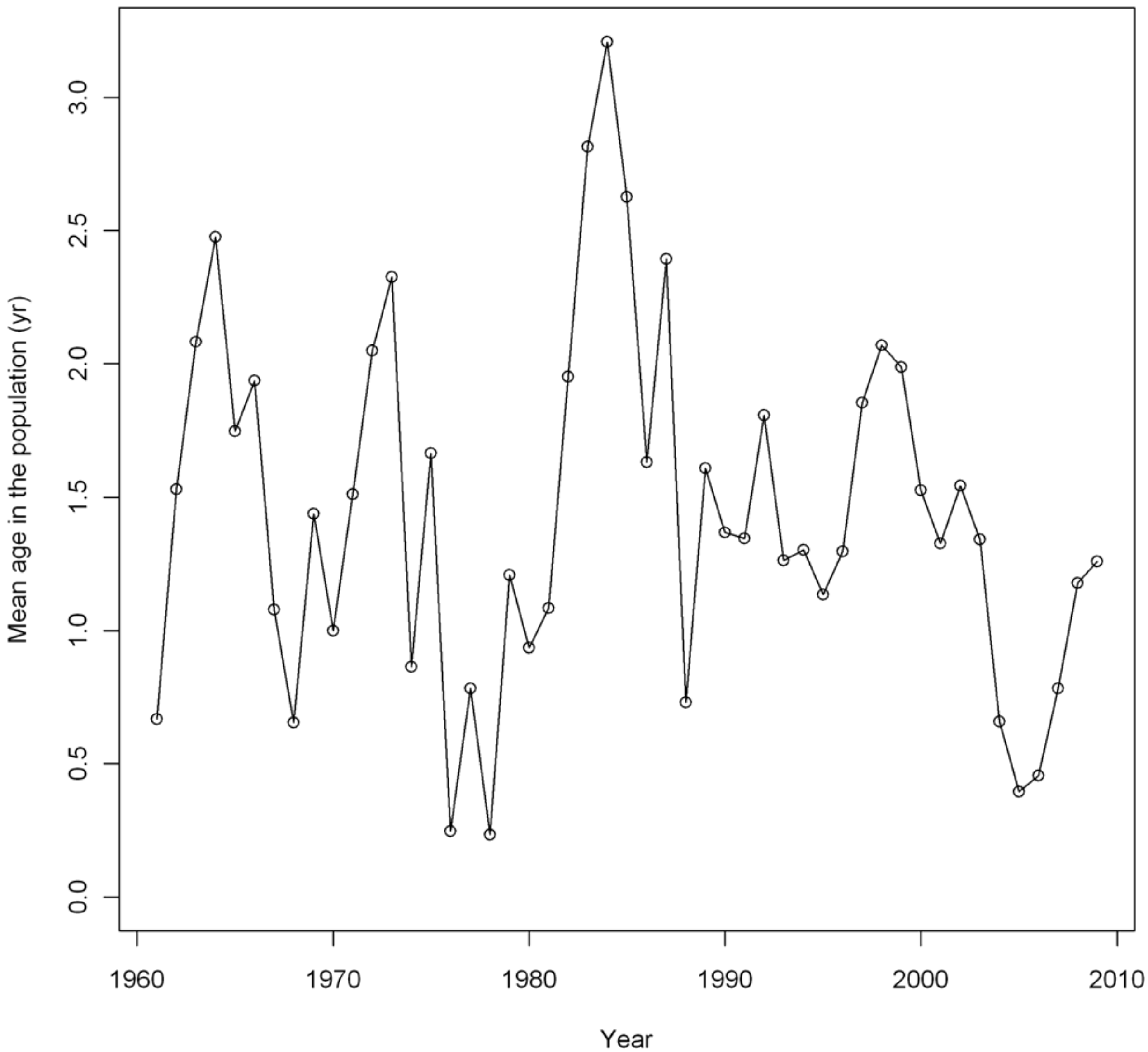


Figure 4. Estimated mean age time series of Pacific mackerel from CDFG (commercial fishery) port sampling program (1962-08).

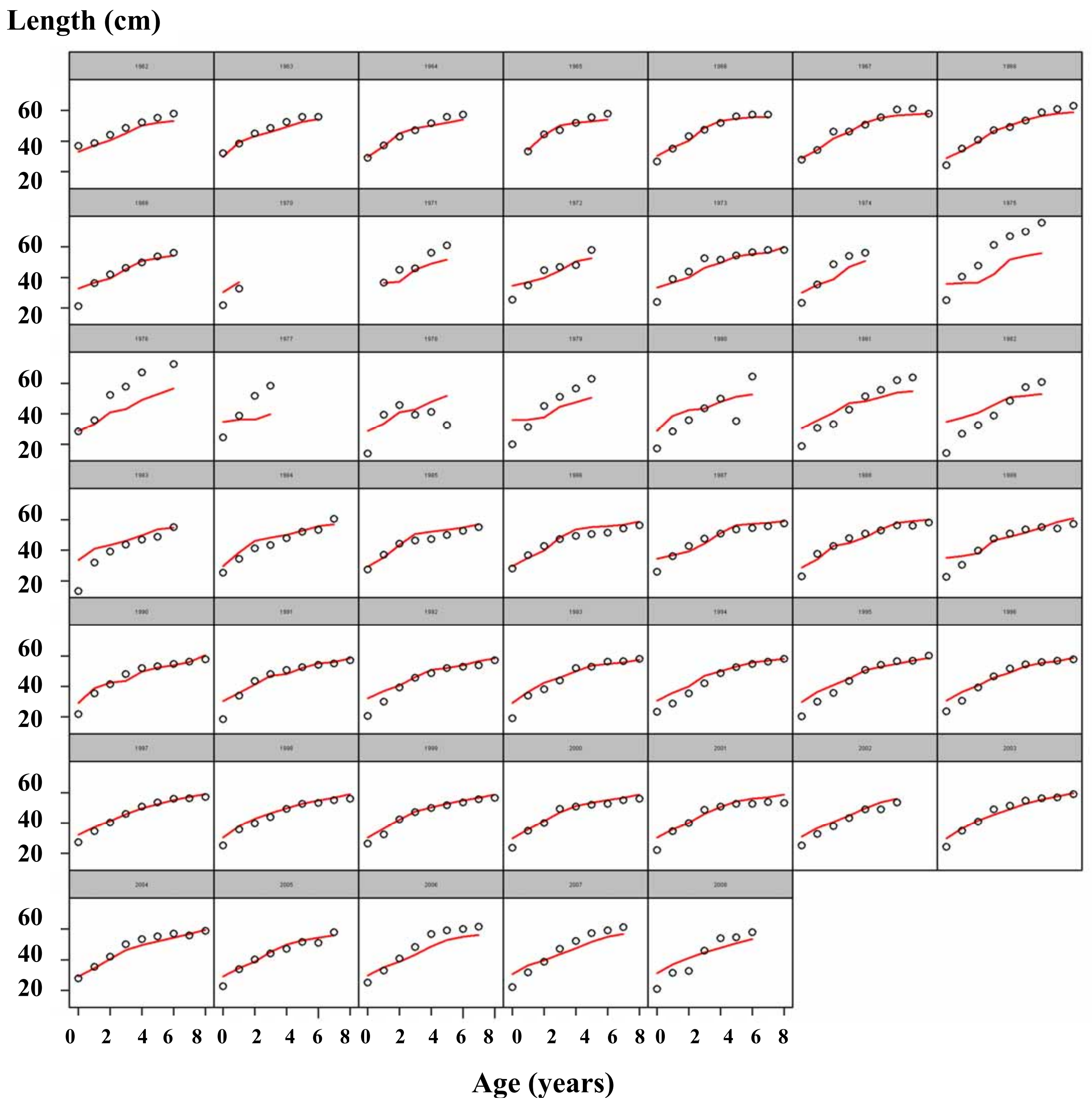


Figure 5. Estimated mean length-at-age (cm/yr, open circles) time series of Pacific mackerel from CDFG (commercial fishery) port sampling program (1962-08). Also, model fits to this time series are also presented (curved line in each display).

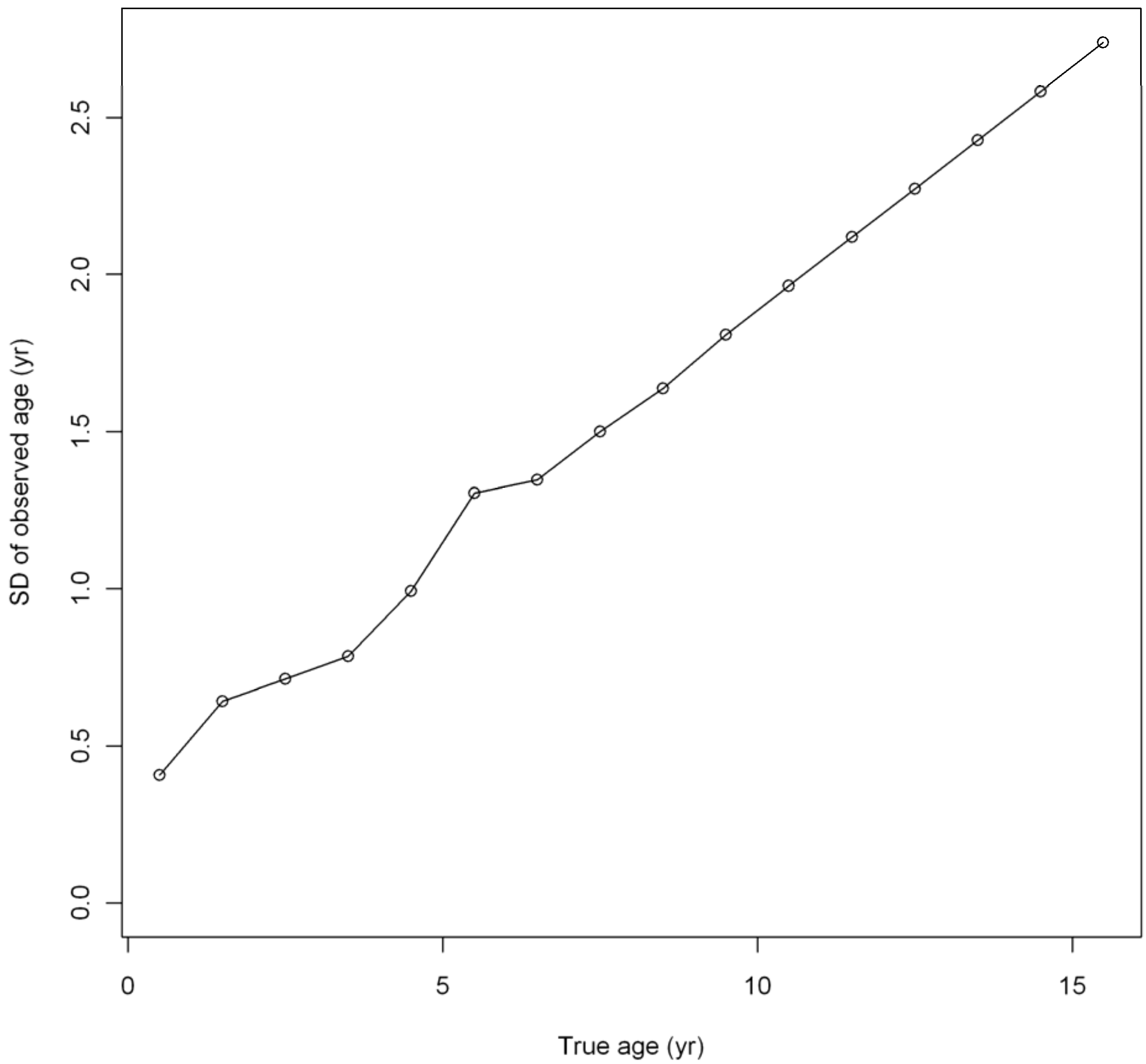


Figure 6. Ageing error vector (SD by age) from CDFG age production laboratory based on double-read analysis.

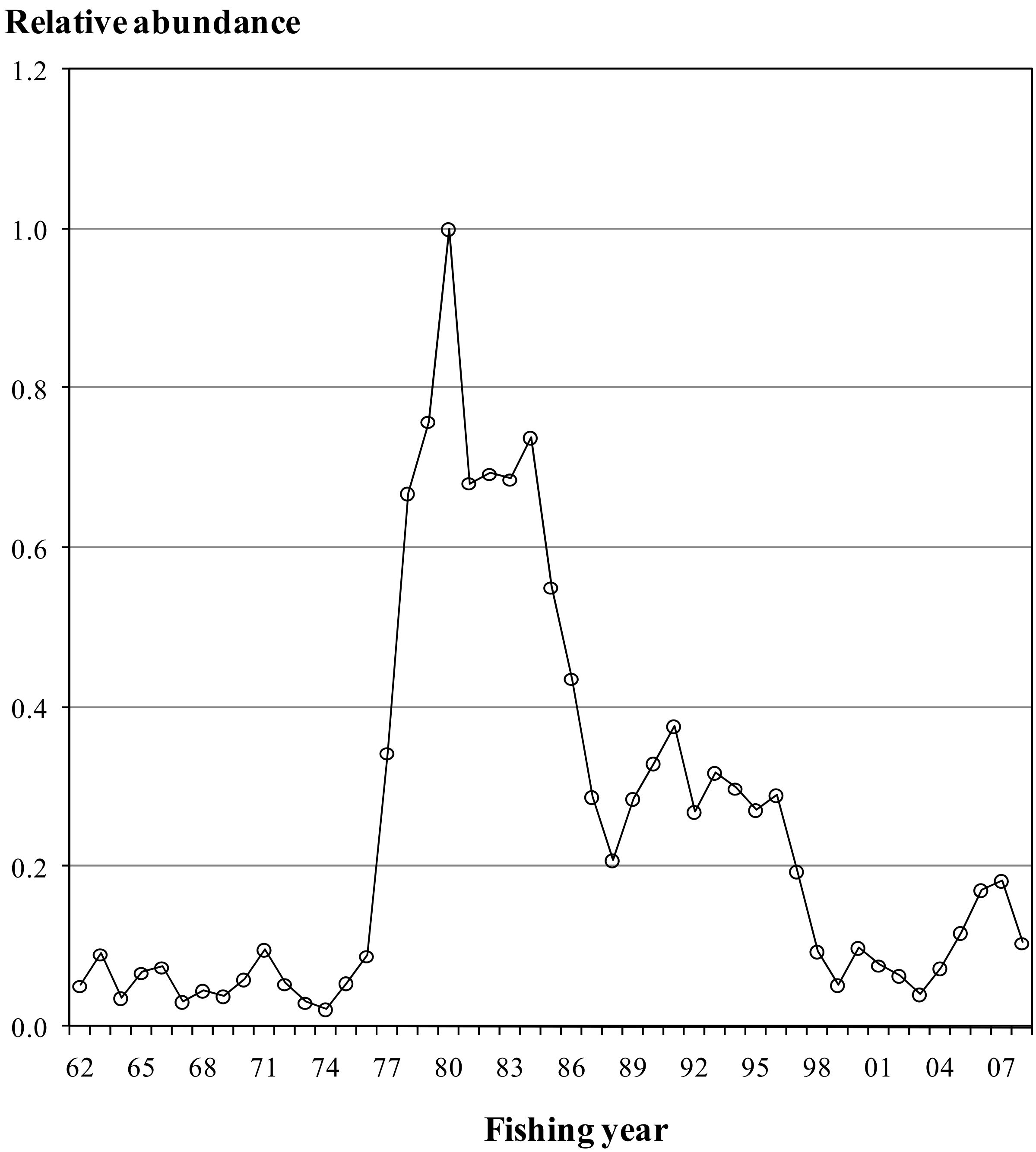


Figure 7. The CPFV index of relative abundance (CPUE) time series for Pacific mackerel (1962-08). Index is presented as a rescaled (normalized) time series.

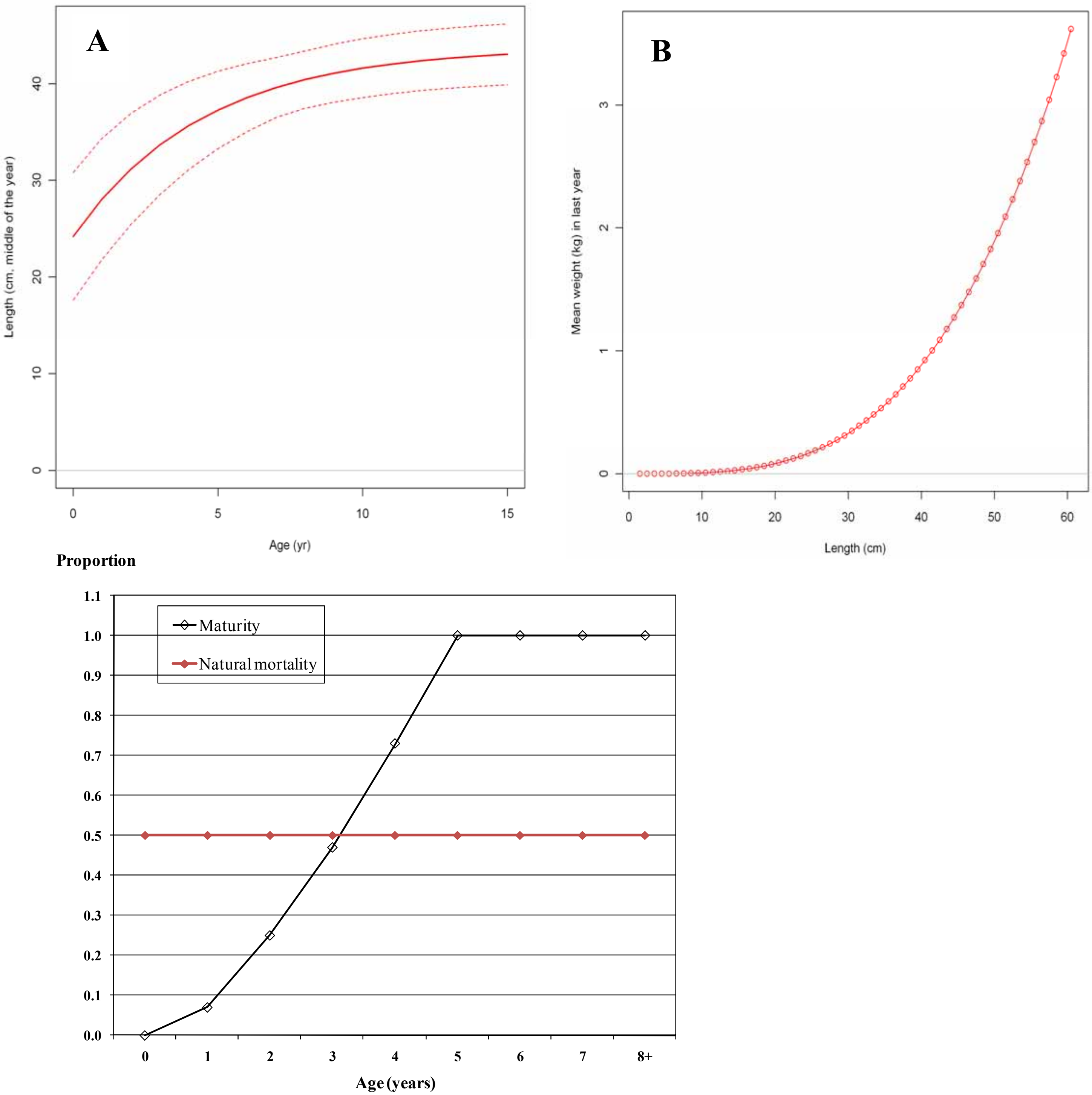


Figure 8. Biological parameters for Pacific mackerel either assumed or estimated in the assessment models: (A) weight-length relationship; (B) length (cm)-at-age (yr); and (C) maturity (also, see Table 3) and natural mortality (*M*).

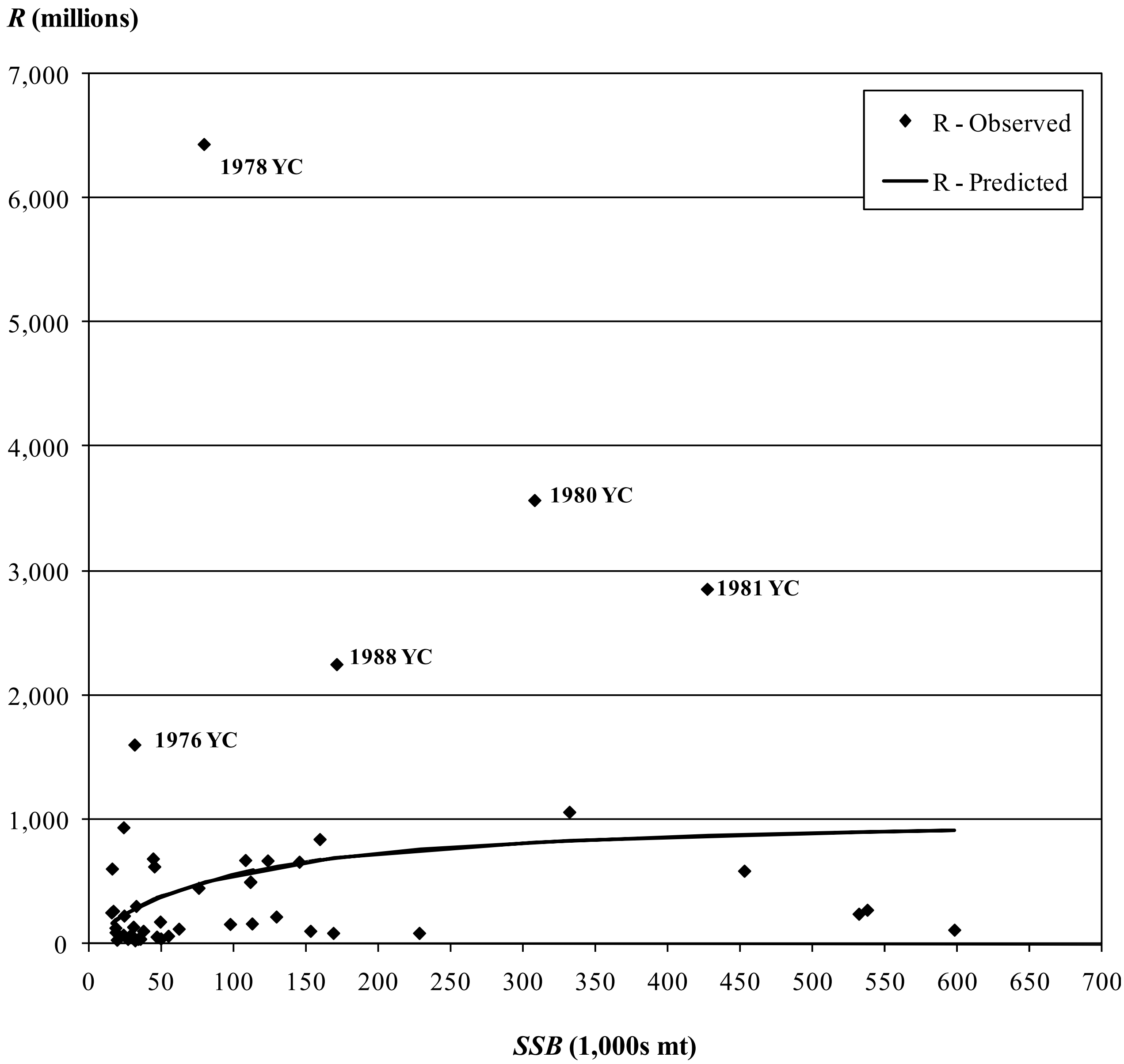
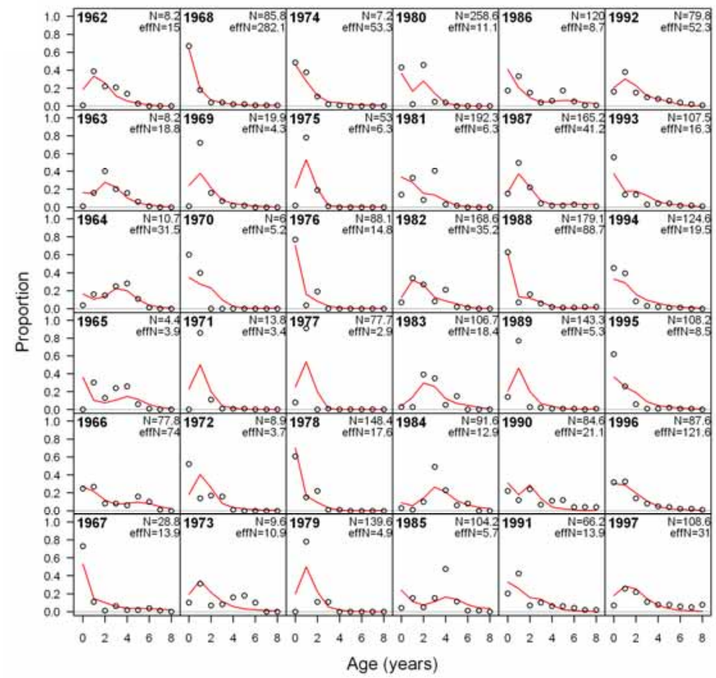


Figure 9. Beverton-Holt stock (*SSB* in 1000s mt)-recruitment (*R* in millions of fish) relationship for Pacific mackerel estimated in the final SS model *AA* (2009). Recruitment estimates are presented as (year+1) values. Strong year classes are highlighted. Steepness=0.47.

A



A

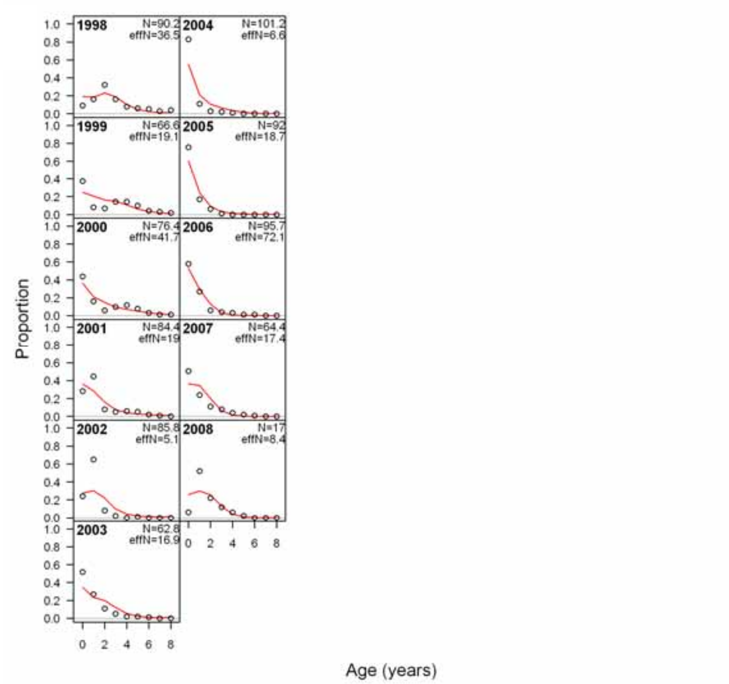


Figure 10. Model (SS model *AA*) fit diagnostics associated with the commercial fishery age distribution time series (1962-08): (A) observed (open circles) vs. predicted (line) estimates; (B) Pearson standardized residuals (observed – predicted; maximum bubble size = 10.94; dark circles represent positive values); and (C) effective vs. observed (input) sample sizes for the commercial fishery age distribution time series. Solid line represents a 1:1 relationship and the dashed line reflects a loess smoother.

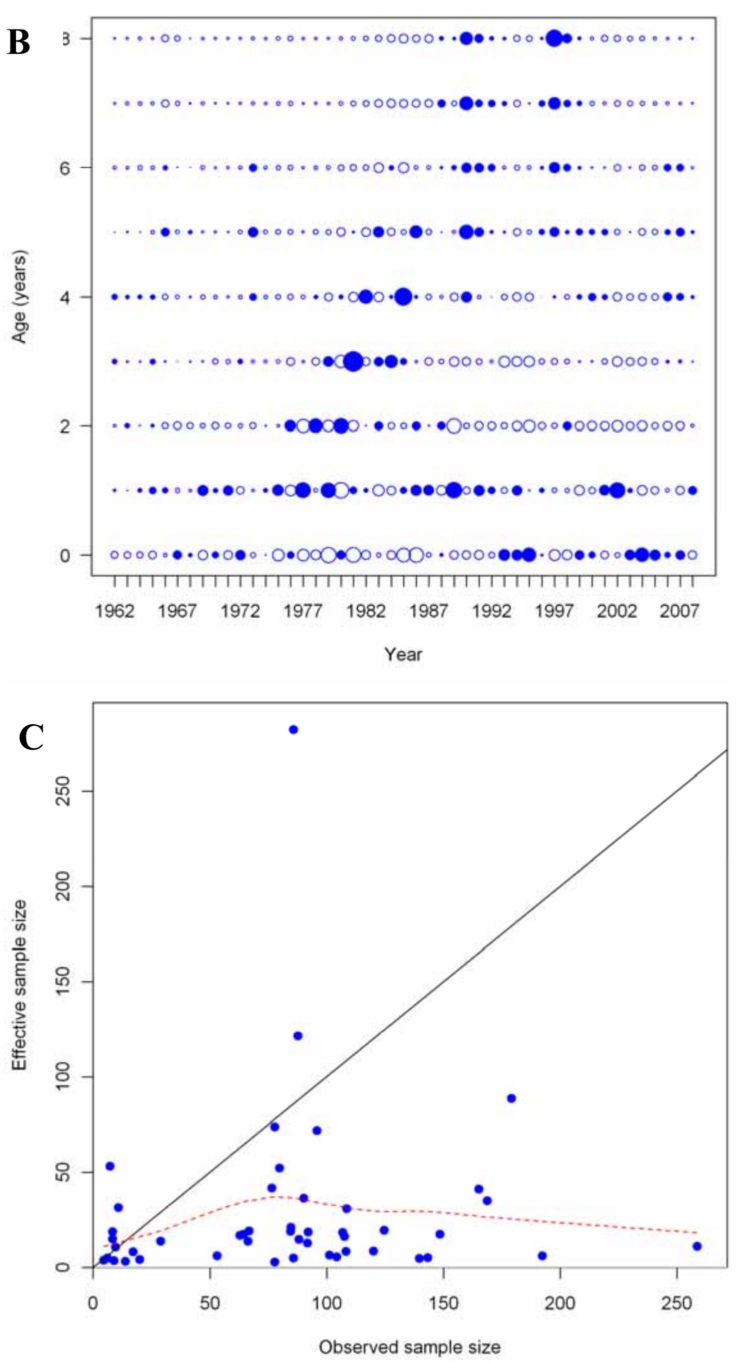


Figure 10. Continued.

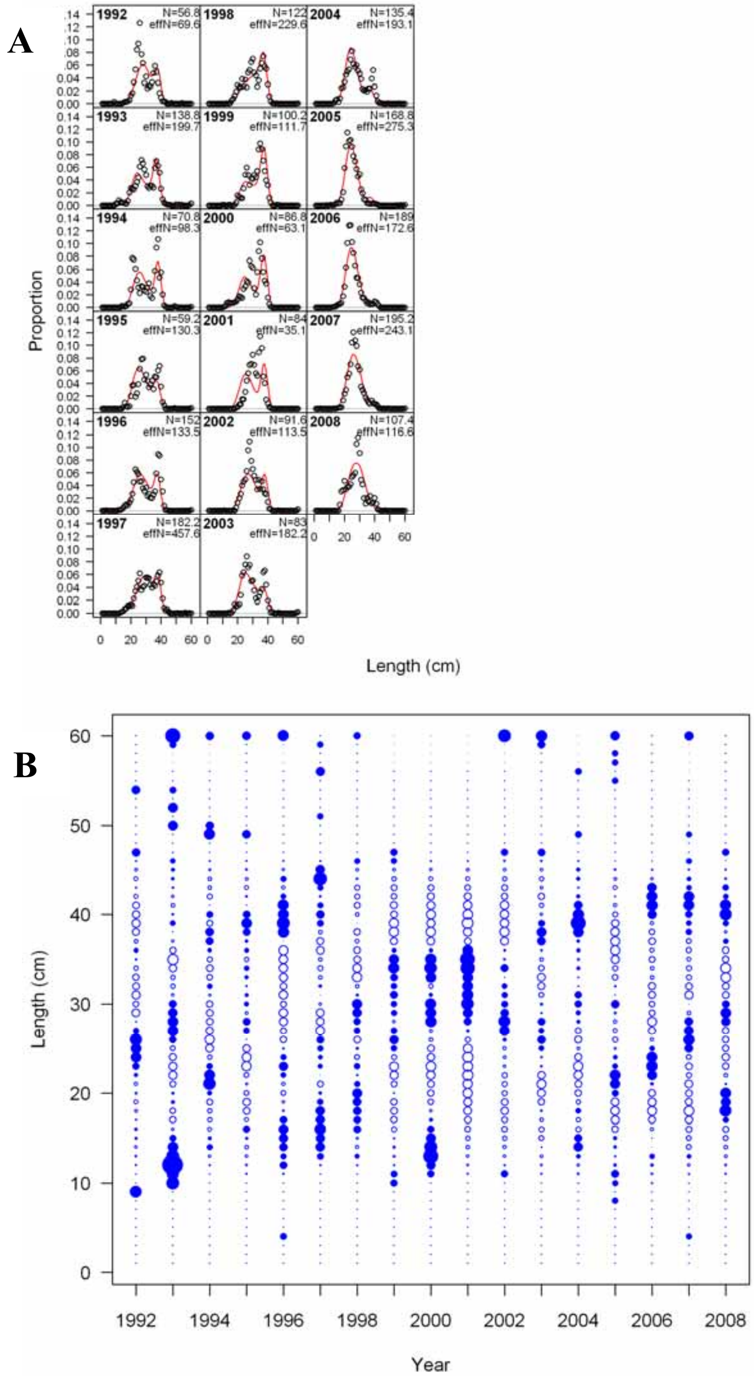


Figure 11. Model (SS model *AA*) fit diagnostics associated with the recreational (CPFV) fishery length distribution time series (1992-08): (A) observed (open circles) vs. predicted (line) estimates; (B) Pearson standardized residuals (observed – predicted; maximum bubble size = 6.38; dark circles represent positive values); and (C) effective vs. observed (input) sample sizes for the commercial fishery age distribution time series. Solid line represents a 1:1 relationship and the dashed line reflects a loess smoother.

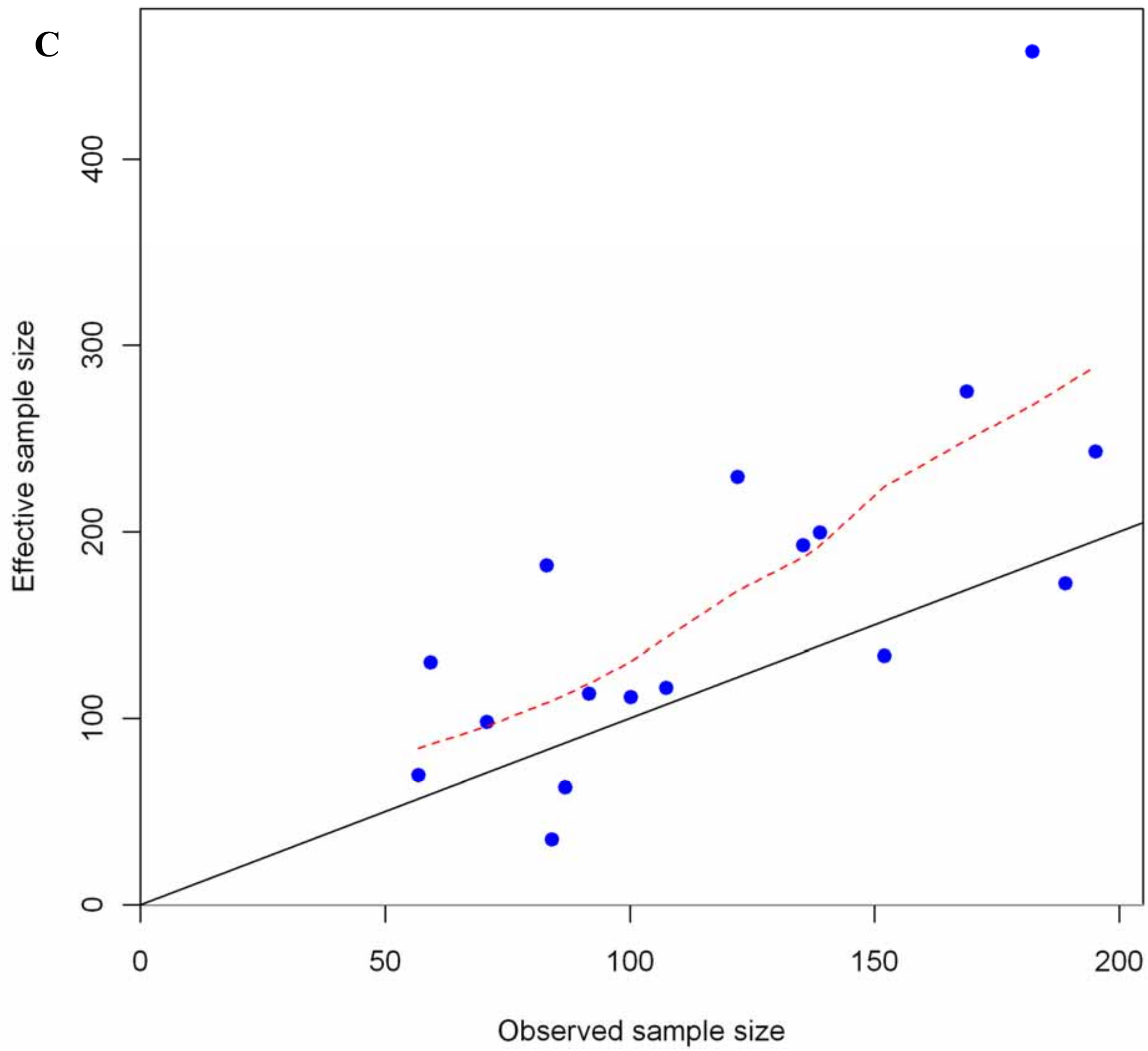


Figure 11. Continued.

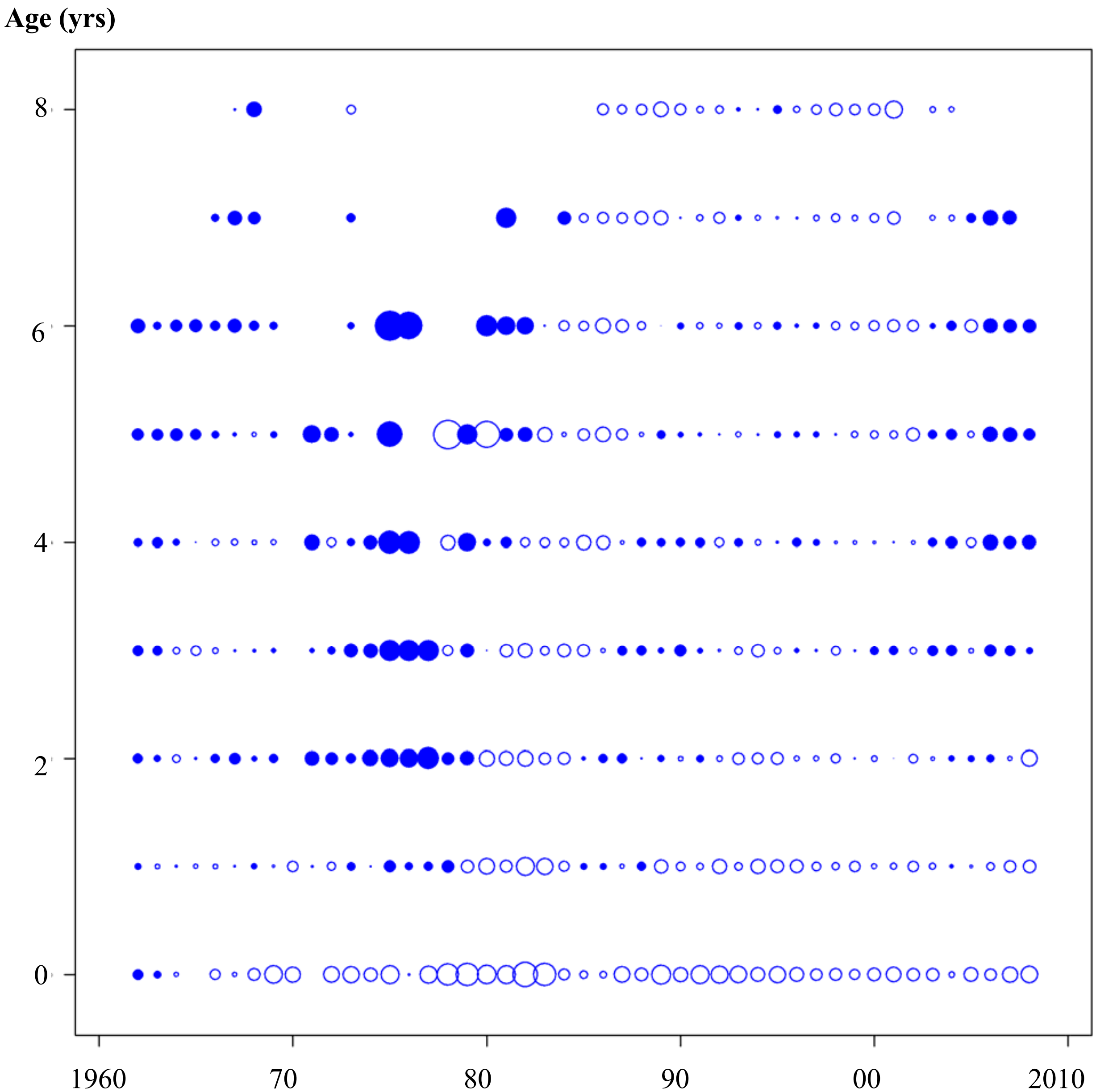
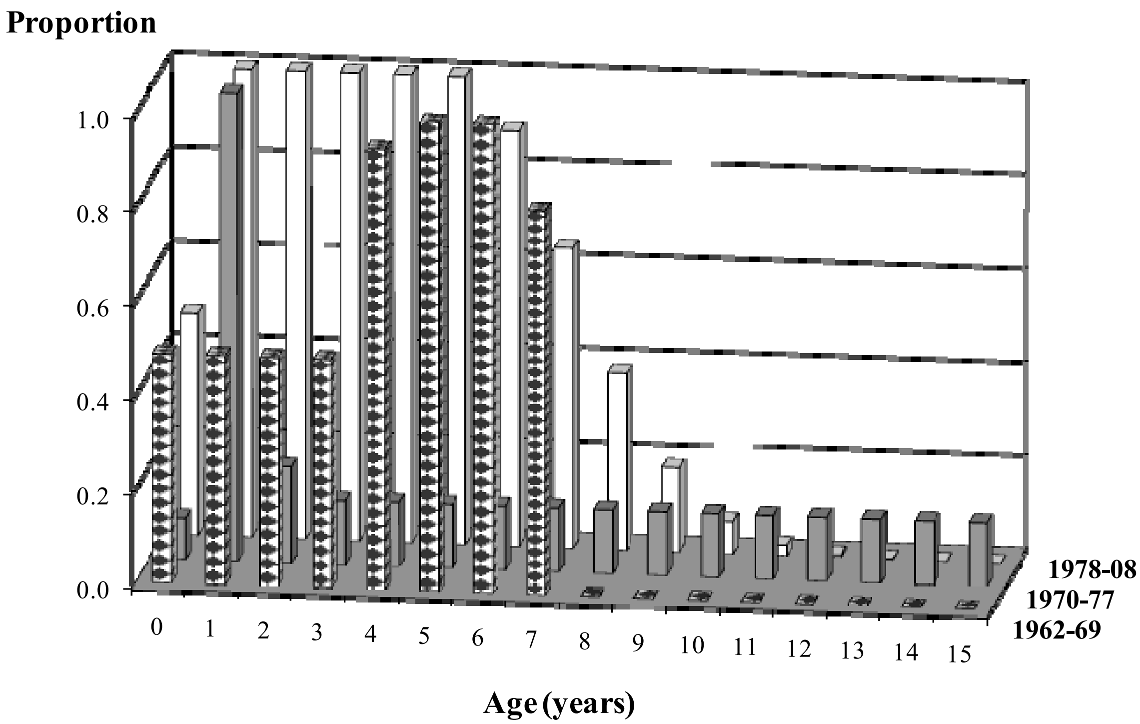


Figure 12. Model (SS model *AA*) fit diagnostics associated with the commercial fishery mean length-at-age (cm/yr, open circles) time series (1962-08), i.e., see Figure 5 for observed (open circles) vs. predicted (line) estimates and the associated Pearson standardized residuals plot (observed – predicted; maximum bubble size = 4.33; dark circles represent positive values) is presented here.

A



B

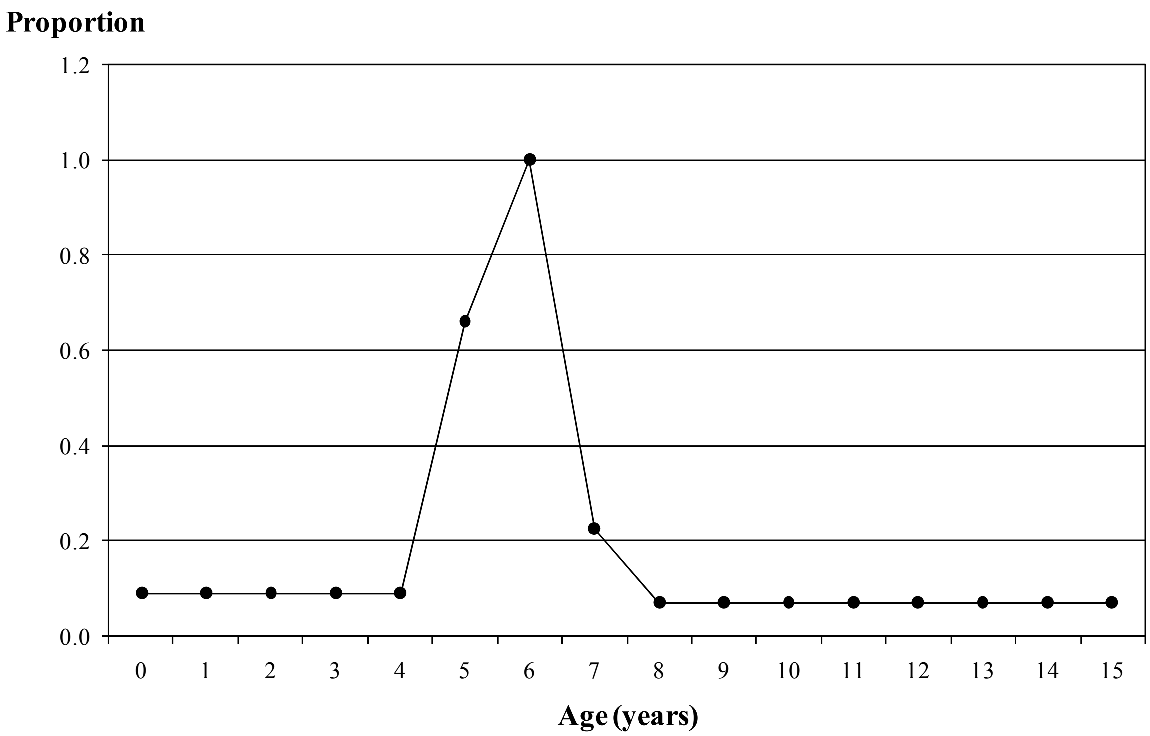


Figure 13. Estimated selectivity schedules associated with SS model *AA*: (A) time-varying for the commercial fishery (1962-69, 1970-77, 1978-08); and constant for recreational fishery (1962-08). Note that selectivity associated with the CPFV index mirrored the recreational fishery.

A

B

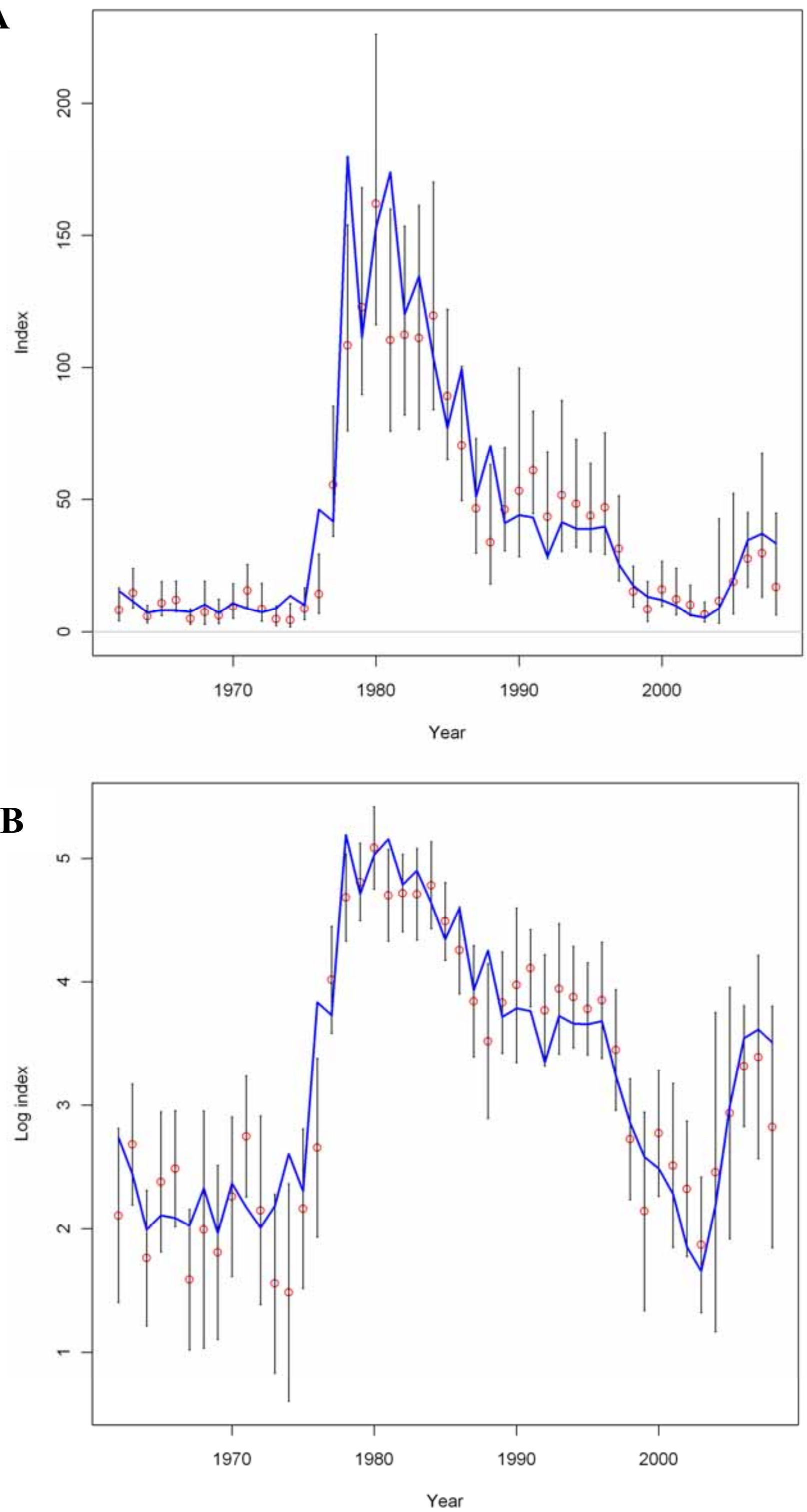


Figure 14. Model (SS model *AA*) fits to the CPFV index of relative abundance: (A) normal space; and (B) log space.

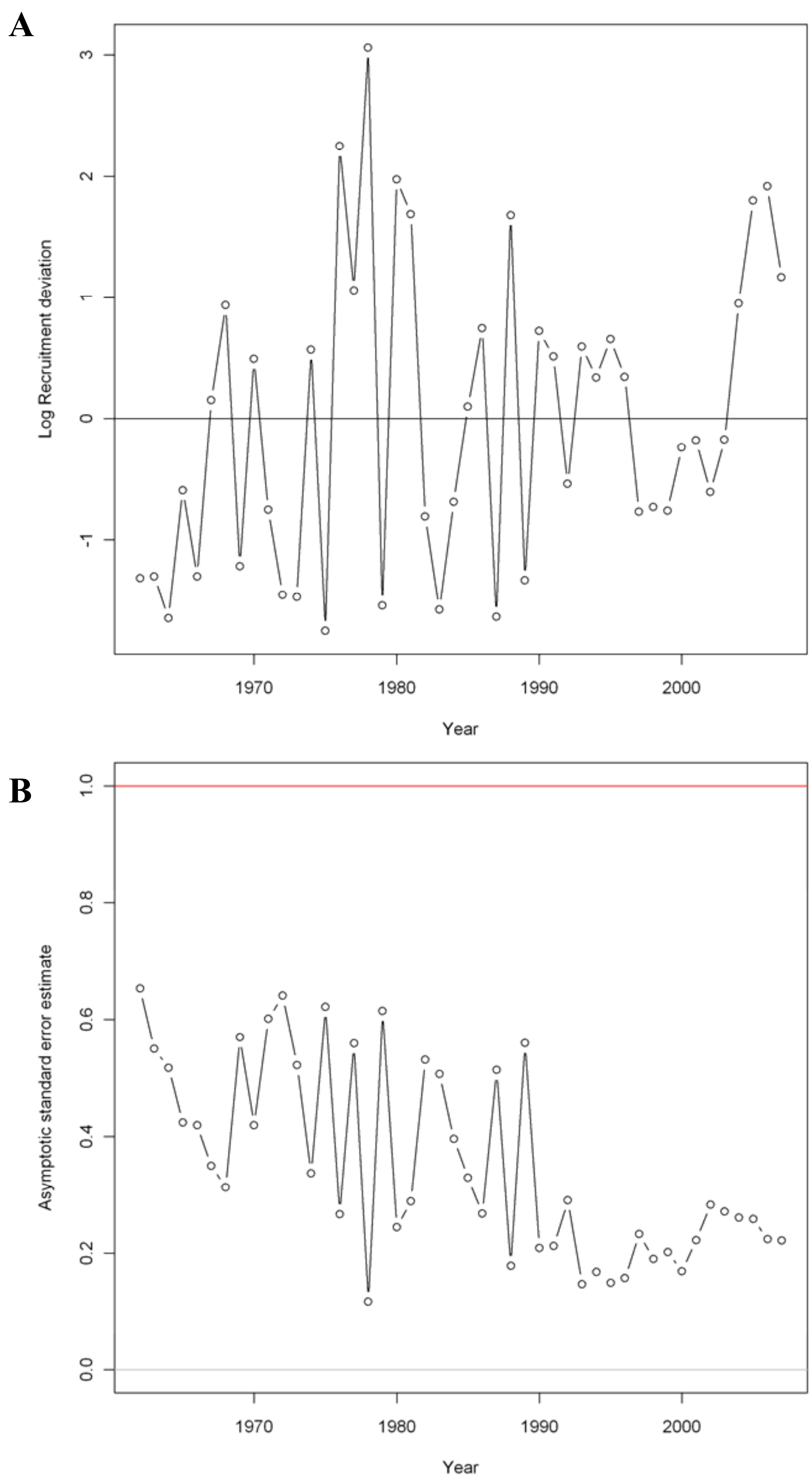


Figure 15. Recruitment-related estimates from SS model *AA*: (A) recruitment deviations; and (B) SEs associated with the deviations (horizontal line indicates the estimate of the standard deviation of log recruitment deviations, i.e., fixed σ-*R* =1.0).

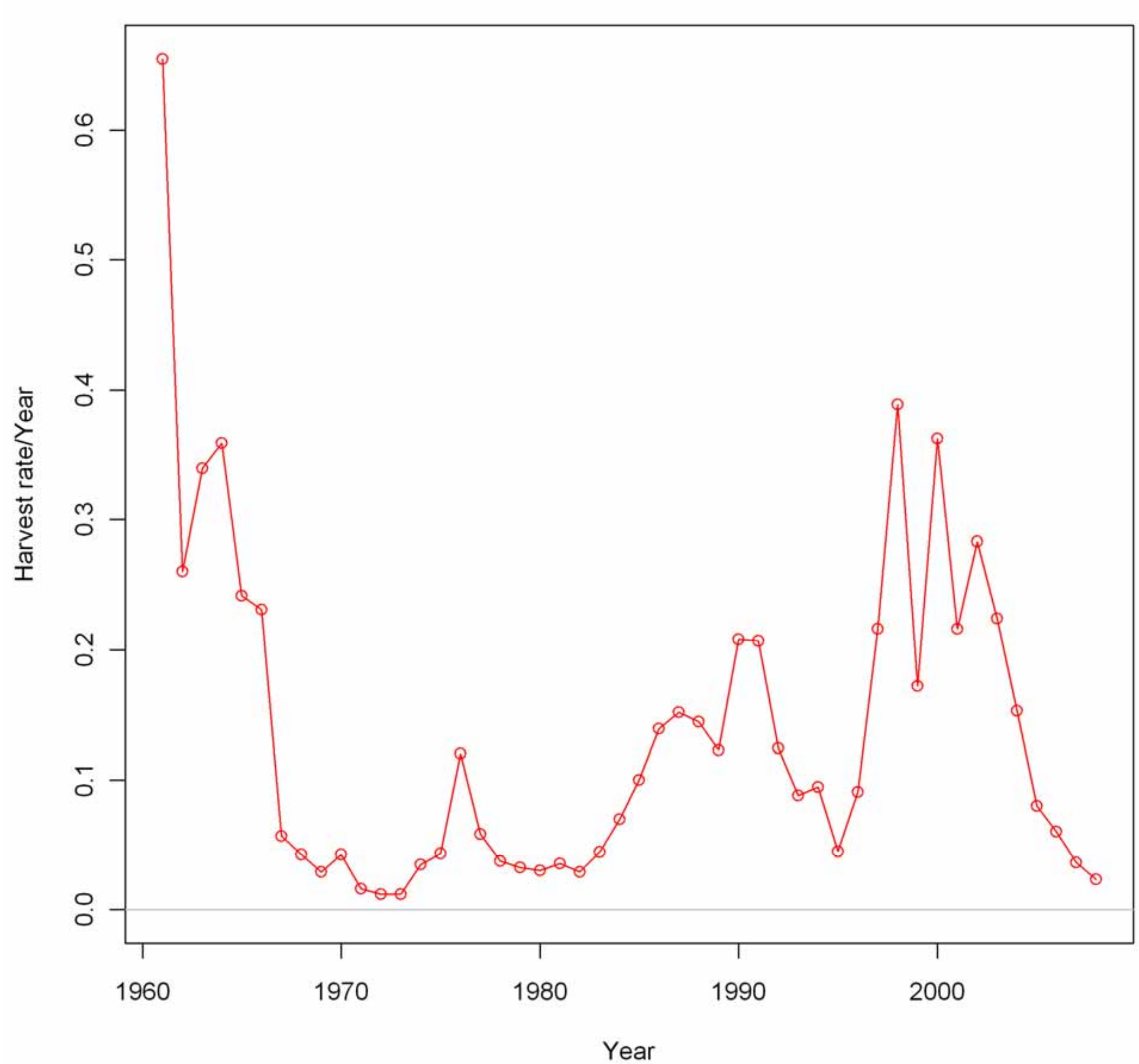


Figure 16. Estimated harvest rate (fishing mortality, *F*) time series from SS model *AA* (1962-08).

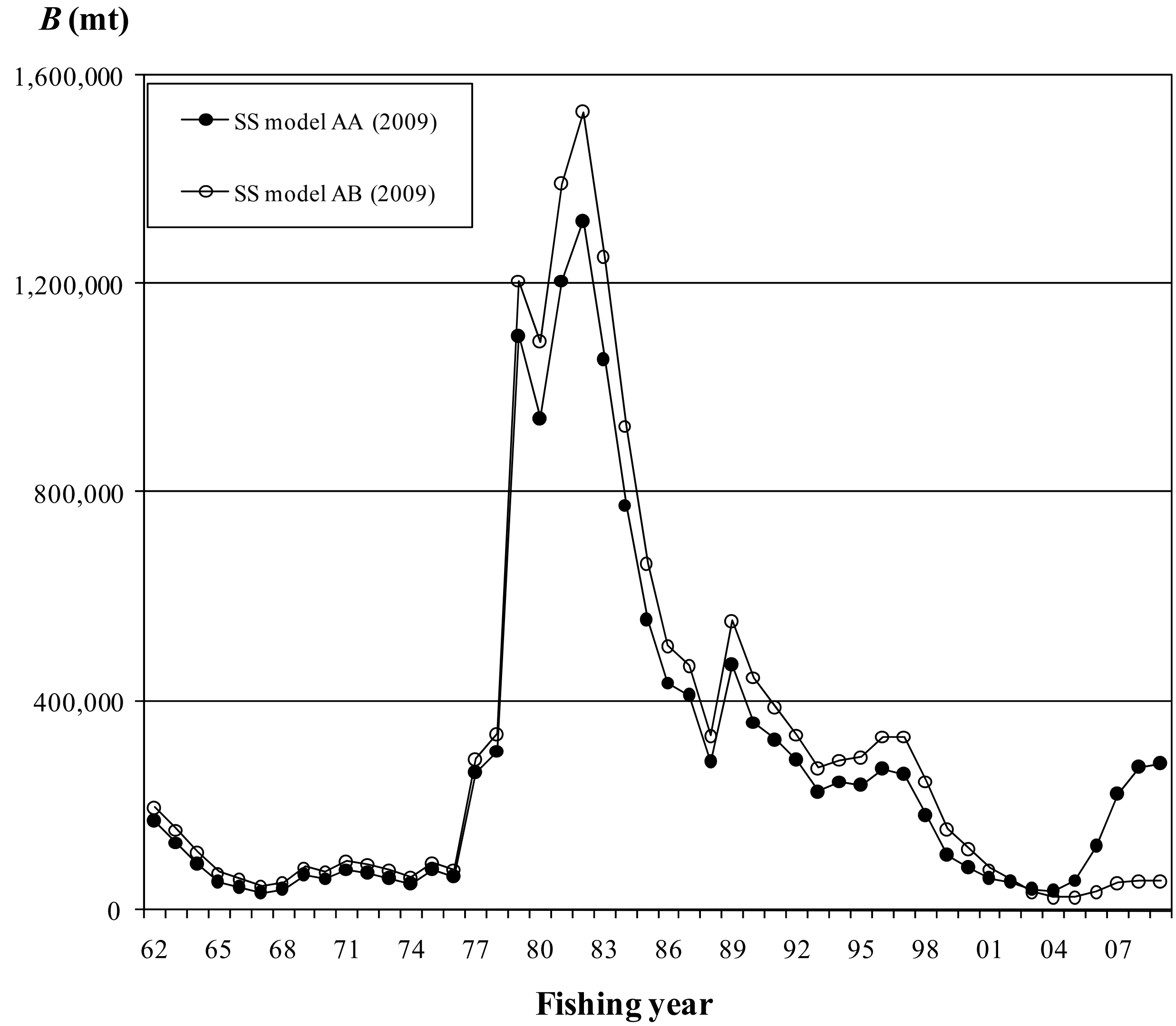


Figure 17. Estimated total stock biomass (age 1+ fish in mt, *B*) of Pacific mackerel based on the final SS model *AA* and alternative model *AB* (1962-09).

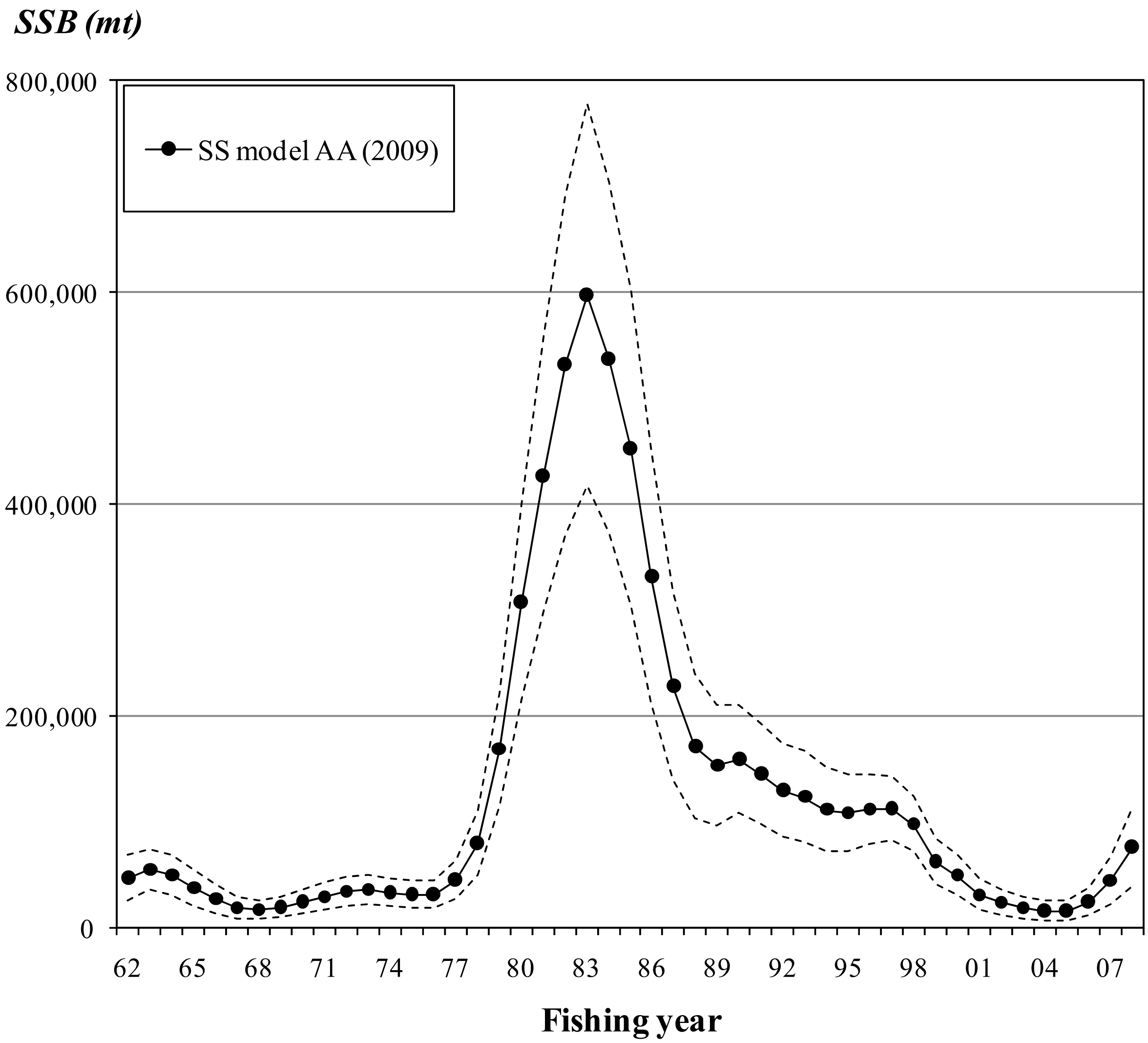


Figure 18. Estimated spawning stock biomass (*SSB*) of Pacific mackerel based on SS model *AA* (1962-08). Confidence interval (± 2 SD) is also presented as dashed lines.

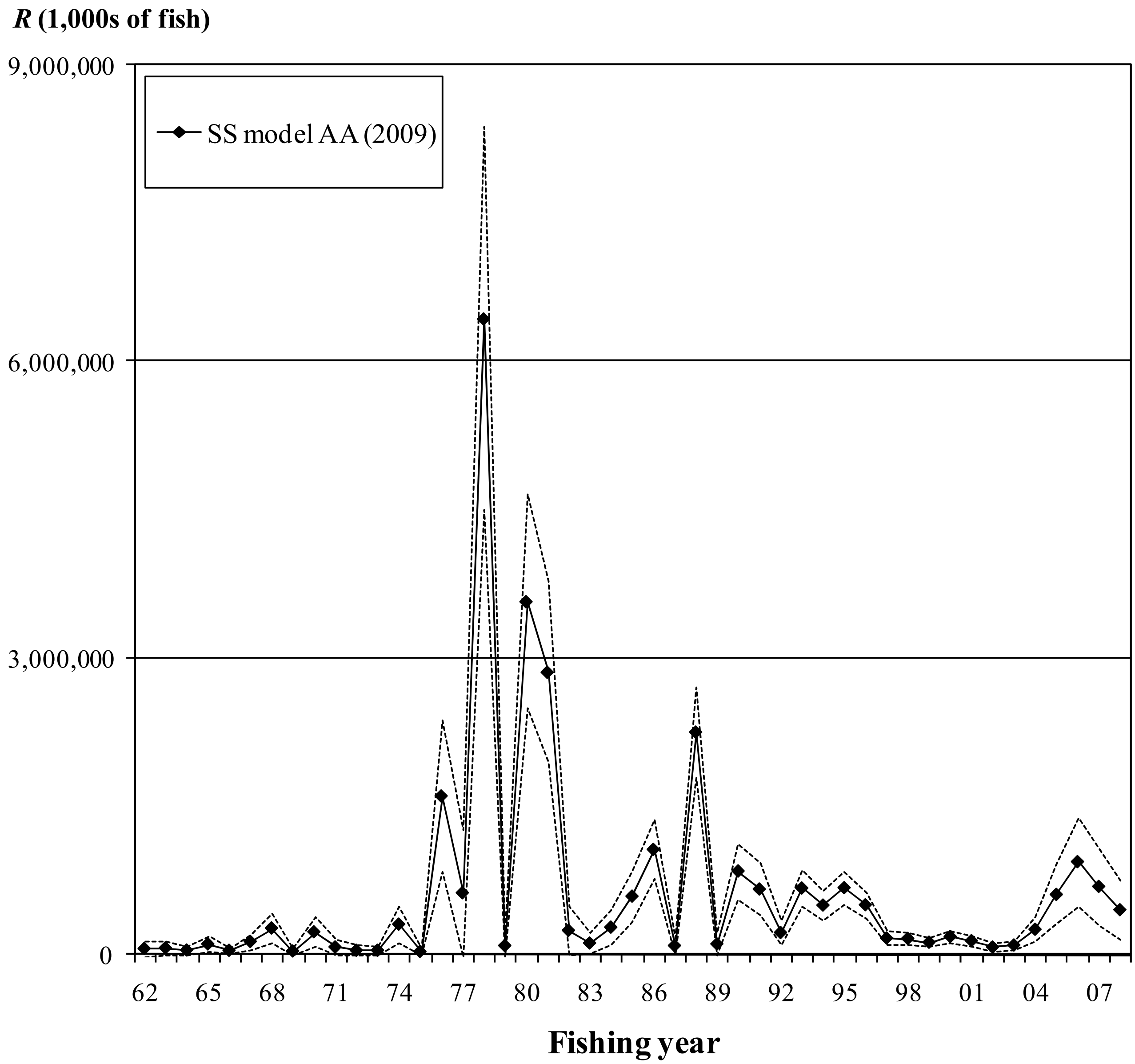


Figure 19. Estimated recruitment (age-0 fish in 1,000s, *R)* of Pacific mackerel based on SS model *AA* (1962-08). Confidence interval (± 2 SD) is also presented as dashed lines.

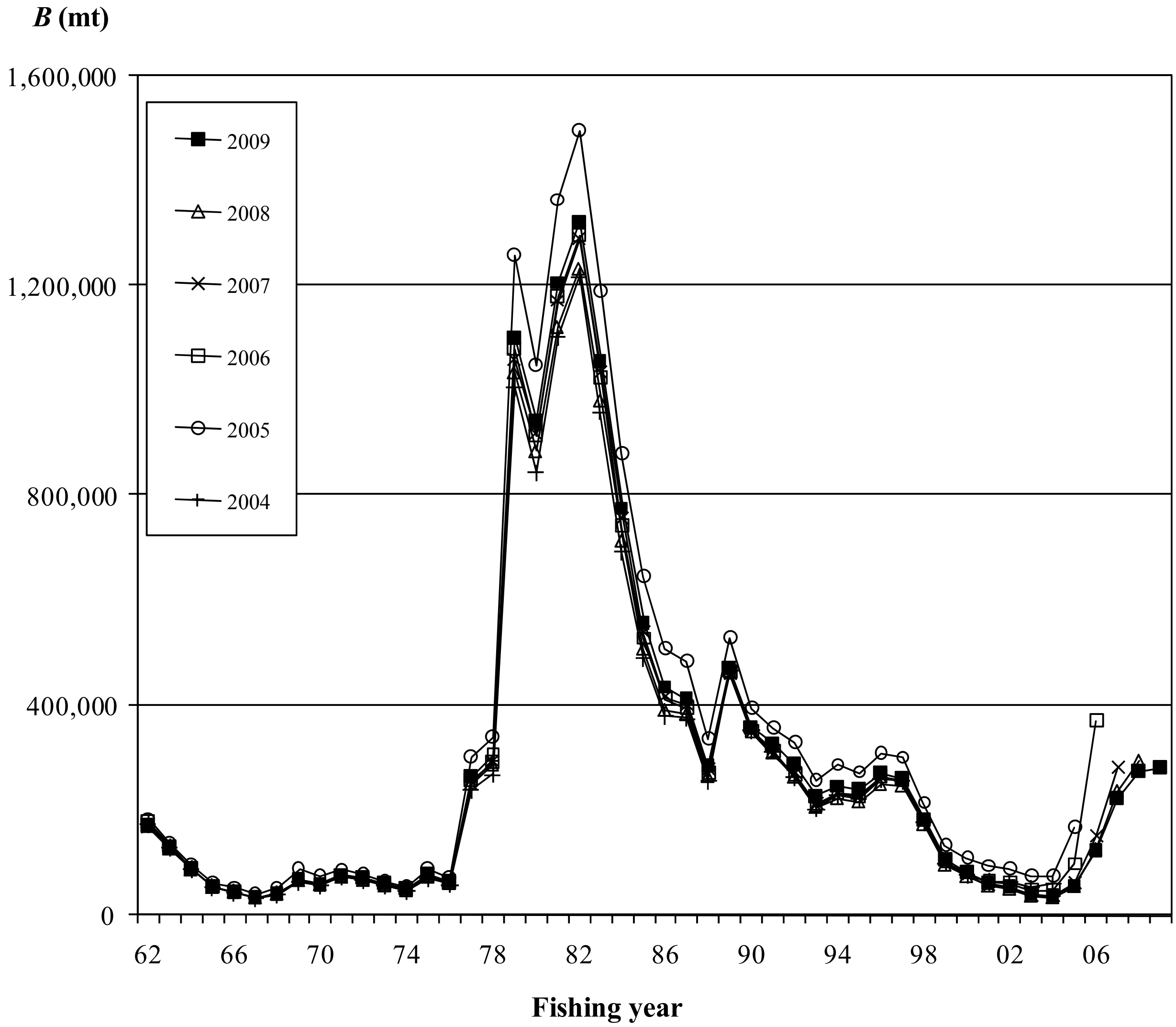


Figure 20. Estimated total stock biomass (age 1+ fish in mt, *B*) of Pacific mackerel based on retrospective analysis that omitted one year of data in chronological order (2004-09), i.e., 2009 time series represents final SS model *AA*.

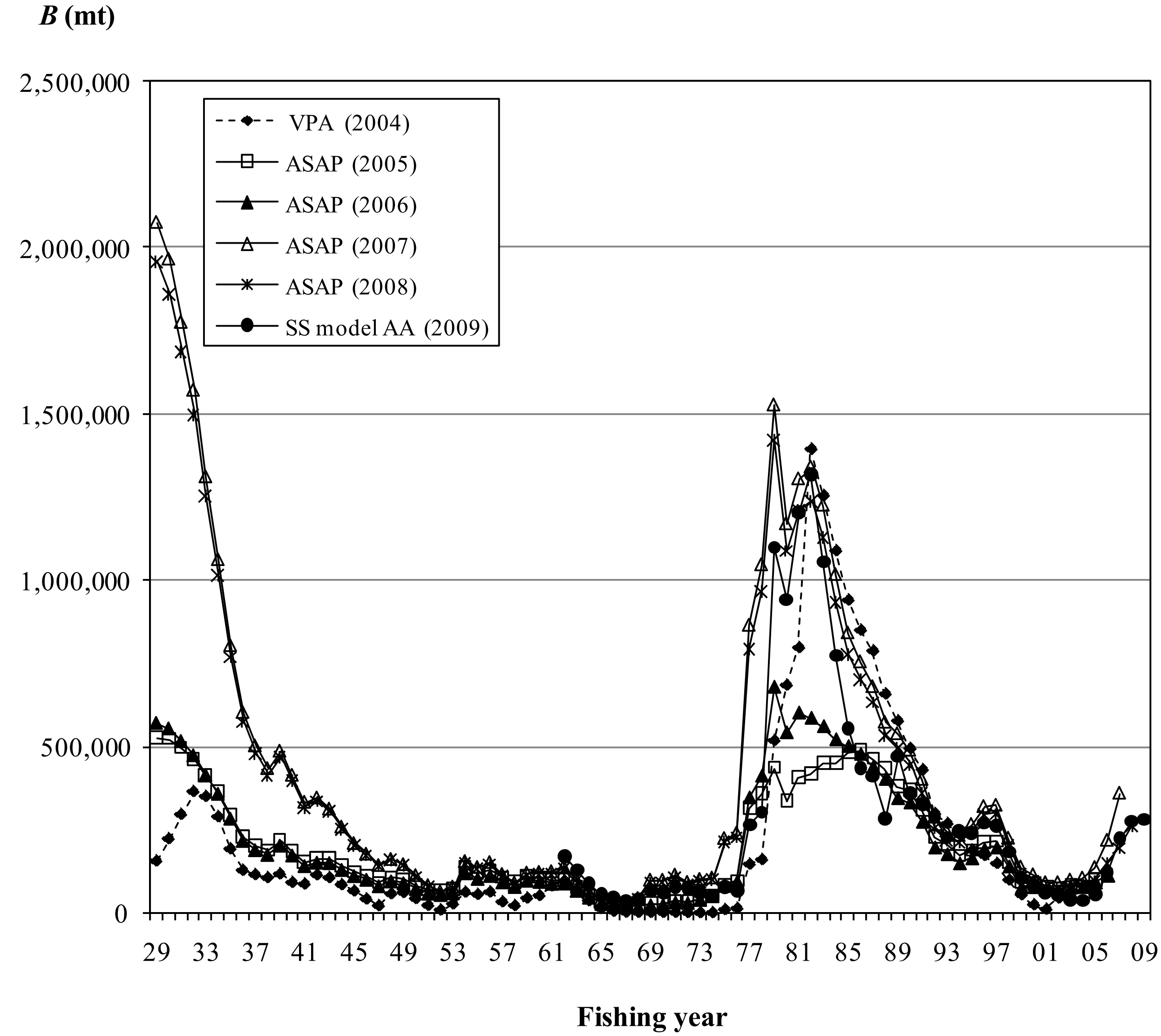


Figure 21. Estimated total stock biomass (*B* age 1+ fish in mt) of Pacific mackerel for historical assessment period (1994-09): VPA model-based assessments from 1994-04; ASAP model-based from 2005-08; and SS model-based currently (2009).

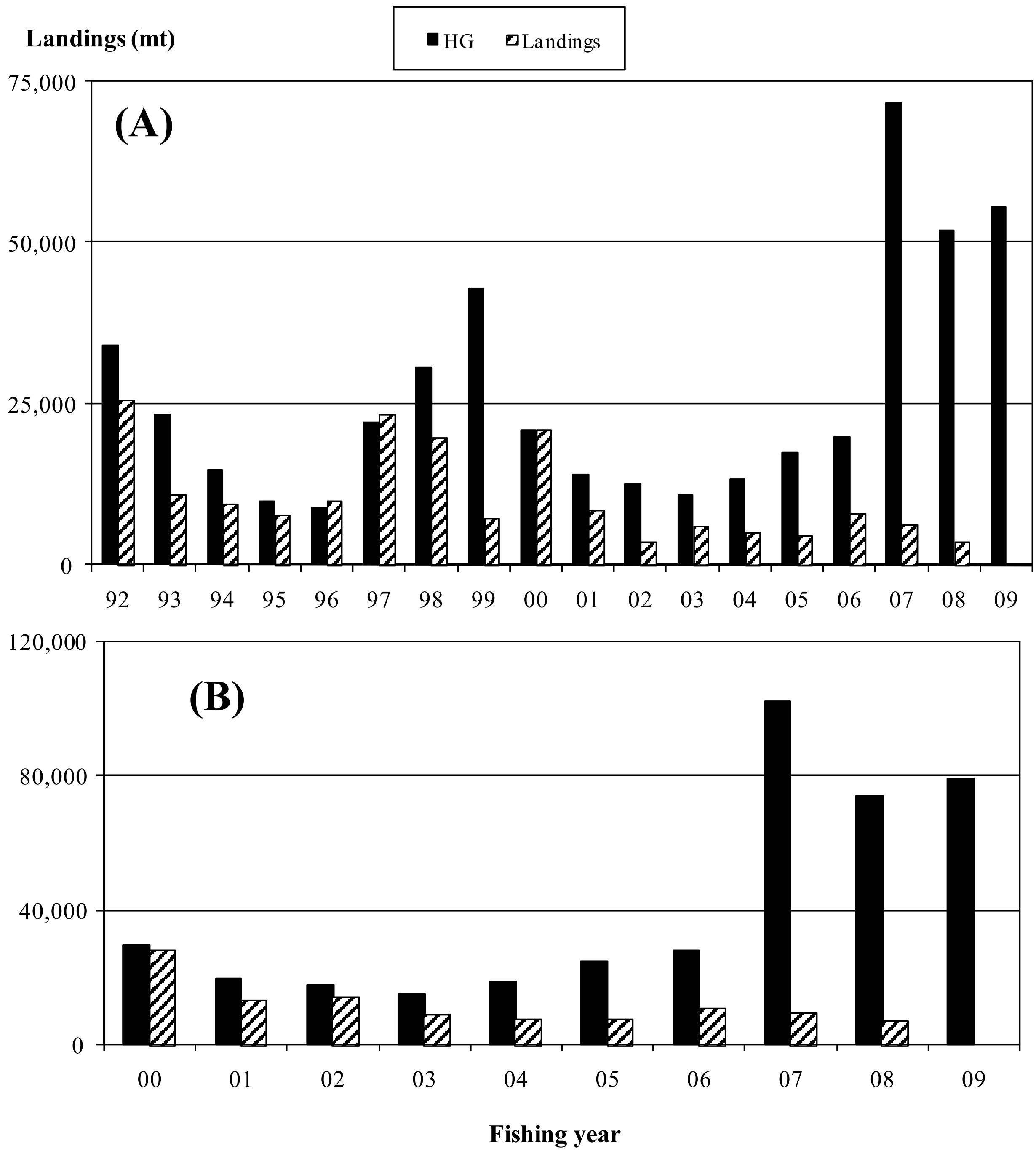


Figure 22. Harvest guideline statistics for Pacific mackerel: (A) commercial landings (California directed fishery in mt) and quotas (HGs in mt), (1992-09); and (B) total landings (mt) and hypothetical quotas based on no USA 'Distribution' parameter in the harvest control rule. Incidental landings from Pacific Northwest fisheries are not included, but typically are limited, ranging 100 to 300 mt per year.

Appendix 1

SS model *AA* (2009) files

```
###############################################################################

# P. mackerel stock assessment (1962-08)
# P. R. Crone (March 2009)
# Stock Synthesis 3 (v. 3.0.12) - R. Methot
# Model AA: number of fisheries = 2 / surveys = 1 / time-step = annual /
biological distributions = age, length, and mean size-at-age / selectivity =
age-based
#
# NOTES: ** ... ** = Pending questions and/or comments
#
```

 # STARTER FILE

```
#
AA.dat # Data file
AA.ctl # Control file
0 # Read initial values from 'par' file: 0 = no, 1 = yes
1 # DOS display detail: 0, 1, 2
1 # Report file detail: 0, 1, 2
0 # Detailed checkup.sso file: 0 = no, 1 = yes
0 # Write parameter iteration trace file during minimization
1 # Write cumulative report: 0 = skip, 1 = short, 2 = full
0 # Include prior likelihood for non-estimated parameters
1 # Use soft boundaries to aid convergence: 0 = no, 1 = yes
0 # Number of bootstrap data files to produce
20 # Last phase for estimation
1 # MCMC burn-in interval
1 # MCMC thinning interval
0 # Jitter initial parameter values by this fraction
-1 # Minimum year for SSB sd_report: (-1 = styr-2, i.e., virgin population)
-1 # Maximum year for SSB sd_report: (-1 = endyr, -2 = endyr+N_forecastyrs
0 # N individual SD years
0.0001 # final convergence criteria (e.g. 1.0e-04)
0 # Retrospective year relative to end year (e.g., -4)
1 # Minimum age for 'summary' biomass
1 # Depletion basis (denominator is: 0 = skip, 1 = relative X*B0, 2 =
    relative X*Bmsy, 3 = relative X*B_styr
1 # Fraction for depletion denominator (e.g., 0.4)
1 # (1-SPR) reporting: 0 = skip, 1 = (1-SPR)/(1-SPR_tgt), 2 = (1-SPR)/(1-
    SPR_MSY), 3 = (1-SPR)/(1-SPR_Btarget), 4 = raw_SPR
1 # F SD reporting: 0 = skip, 1 = exploitation(Bio), 2 = exploitation(Num), 3
    = sum(F_rates)
0 # F reporting: 0 = raw, 1 = F/Fspr, 2 = F/Fmsy, 3 = F/Fbtgt
999 # End of file
```

```
################################################################################
# P. mackerel stock assessment (1962-08)
# P. R. Crone (March 2009)
# Stock Synthesis 3 (v. 3.0.12) - R. Methot
# Model AA: number of fisheries = 2 / surveys = 1 / time-step = annual / biological distributions = age, length, and mean size-at-age / selectivity = age-based
#
# NOTES: ** ... ** = Pending questions and/or comments
#
```

FORECAST FILE

```
#
1 # Forecast: 0 = none, 1 = F_SPR, 2 = F_MSY, 3 = F_btgt, 4 = F_endyr, 5 = Avg_F (enter yrs), 6 = read F_mult
2008 # First year for averaging selectivity to use in forecast (e.g., 2004 or use -x to be relative endyr)
2008 # Last year for averaging selectivity to use in forecast
1 # Benchmarks: 0 = skip, 1 = calculate (F_SPR, F_btgt, F_MSY)
2 # MSY: 0 = none, 1 = set to F_SPR, 2 = calculate F_MSY, 3 = set to F_Btgt, 4 = set to F(endyr)
0.3 # SPR target (e.g., 0.40)
0.4 # Biomass target (e.g., 0.40)
1 # Number of forecast years
#
0 # Read 10 advanced forecast options: (0/1) ** Placeholders **
# Do West Coast groundfish rebuilder output: (0/1)
# Rebuilder: first year catch could have been set to zero
# Rebuilder: year for current age structure (Yinit)
# Control rule method: 1 = West Coast adjust catch, 2 = adjust F
# Control rule biomass level for constant F (as fraction of B_0, e.g., 0.40)
# Control rule Biomass level for no F (as fraction of B_0, e.g., 0.10)
# Control rule fraction of F_limit (e.g., 0.75)
# Maximum annual catch during forecast ** Placeholder **
# Implementation error: 1 = use implementation error in forecast ** Placeholder **
# SD of log(realized F/target F) in forecast ** Placeholder **
#
1 # Fleet allocation (in terms of F): 1 = use endyr pattern (no read), 2 = read below
# Rows = seasons and columns = fisheries
# 0 0 # Relative F for forecast when based on F, seasons, fleets within seasons
2 # Number of forecast catch levels to input (for additional years, catch estimates based on forecasted F)
1 # Basis for input forecasted catch: 1 = retained catch, 2 = total dead catch
# Columns: Year Season Fishery Catch
2009 1 1 6513
2009 1 2 290
999 # End of file
```

##
P. mackerel stock assessment (1962-08)
P. R. Crone (March 2009)
Stock Synthesis 3 (v. 3.0.12) - R. Methot
Model AA: number of fisheries = 2 / surveys = 1 / time-step = annual / biological distributions = age, length, and mean size-at-age / selectivity = age-based

NOTES: ** ... ** = Pending questions and/or comments

CONTROL FILE

MODEL DIMENSION PARAMETERS
==

Morph parameterization

1 # Number of growth patterns (morphs)
1 # Number of sub-morhps within morphs

Note: 'conditional' (8) lines follow, based on above morp/season/area parameterization

Time block parameterization (time-varying parameterization)
1 # Number of block designs
3 # Blocks in design 1: Selectivity (Fishery 1)

1962 1969 1970 1977 1978 2008 # Blocks - design 1

BIOLOGICAL PARAMETERS
==

0.5 # Fraction = female (at birth)
Natural mortality (M)
0 # Natural mortality type: 0 = 1 parameter, 1 = N_breakpoints, 2 = Lorenzen, 3 = age-specific, 4 = age-specific with season interpolation
Placeholder for number of M breakpoints (if M type option >0)
Placeholder for Age (real) at M breakpoints
Growth
1 # Growth model: 1 = VB with L1 and L2, 2 = VB with A0 and Linf, 3 = Richards, 4 = readvector
0.5 # Growth_age at L1 (L_min): Age_min for growth
8 # Growth_age at L2 (L_max) - (to use L_inf = 999): Age_max for growth
0 # SD constant added to length-at-age (LAA)
0 # Variability of growth: 0 = CV_f(LAA), 1 = CV_f(A), 2 = SD_f(LAA), 3 = SD_f(A)
Maturity
3 # Maturity option: 1 = logistic (length), 2 = logistic (age), 3 = fixed (vector of proportion-at-age), 4 = read age fecundity
Maturity-at-age (if maturity option = 3) ** based on 'accumulator age'+1 **
0 0.07 0.25 0.47 0.73 1 1 1 1 1 1 1 1 1 1 1 # Maturity-at-age (proportion)
0 # First mature age (no read if maturity option = 3)
1 # Fecundity option: 1 is eggs=Wt*(a+b*Wt), 2 is eggs=(a*L^b), 3 is eggs=(a*Wt^b)
1 # MG parameter offset option: 1 = none, 2 = M,G,CV_G as offset from GP1, 3 = like SS2

```
1 # MG parameter adjust method: 1 = do SS2 approach, 2 = use logistic
    transformation to keep between bounds of base parameter approach
#
# M, maturity, and growth parameterization
# Low High Initial Prior_mean Prior_type SD Phase Env_var Use_dev Dev_minyr
    Dev_maxyr Dev_stddev Block_def Block_type
# M parameterization
0.3 0.7 0.5 0 -1 0 -3 0 0 0 0 0 0 0 # M_p1 ** M = 0.5 (fixed) all ages **
# Growth parameterization
# Length-at-age
4 35 15 0 -1 0 3 0 0 0 0 0 0 0 # VB_L_Amin ** Length at age = 0.5 **
30 80 45 0 -1 0 3 0 0 0 0 0 0 0 # VB_L_Amax  ** Length at age = 8 **
0.1 0.7 0.35 0 -1 0 3 0 0 0 0 0 0 0 # VB_K
0.01 0.5 0.1 0 -1 0 3 0 0 0 0 0 0 0 # CV_young
0.01 0.5 0.1 0 -1 0 3 0 0 0 0 0 0 0 # CV_old
# Weight-length
-1 5 3.12e-006 0 -1 0 -3 0 0 0 0 0 0 0 # W-L_a
1 5 3.40352 0 -1 0 -3 0 0 0 0 0 0 0 # W-L_b
# Maturity parameterization ** fixed vector for maturity-at-age **
-3 3 3 0 -1 0 -3 0 0 0 0 0 0 0 # Maturity (inflection)
-3 3 3 0 -1 0 -3 0 0 0 0 0 0 0 # Maturity (slope)
-3 3 1 0 -1 0 -3 0 0 0 0 0 0 0 # Eggs/gm (intercept)
-3 3 0 0 -1 0 -3 0 0 0 0 0 0 0 # Eggs/gm (slope)
# Population recruitment apportionment (distribution) ** Placeholders **
-4 4 0 0 -1 0 -4 0 0 0 0 0 0 0 # Recruitment distribution (growth pattern)
-4 4 1 0 -1 0 -4 0 0 0 0 0 0 0 # Recruitment distribution (area)
-4 4 0 0 -1 0 -4 0 0 0 0 0 0 0 # Recruitment distribution (season)
# Cohort growth deviation
1 5 1 0 -1 0 -4 0 0 0 0 0 0 0 # Cohort growth deviation
#
# Custom environment (MG) parameterization: (0/1)
#
# Custom block (MG) parameterization: (0/1)
#
# Seasonal effects on biology parameters
0 0 0 0 0 0 0 0 0 0 # ** Placeholder **
#
# Stock-recruit (S-R)
3 # S-R function: 1 = B-H w/flat top, 2 = Ricker, 3 = standard B-H, 4 = no
    steepness or bias adjustment
# Low High Initial Prior_mean Prior_type SD Phase
1 30 10 0 -1 0 1 # ln(R0)
0.1 1 0.9 0 1 0 5 # Steepness
0 2 1.0 0 -1 0 -3 # Sigma_R
-5 5 0 0 -1 0 -3 # Env link coefficient
-15 15 0 0 -1 0 1 # Initial eqilibrium recruitment offset
0 2 0 0 -1 0 -3 # Autocorrelation in recruitment devs
0 # Index for environment variable to be used
0 # Environment target
#
# Recruitment residual (recruitment devs) parameterization
1 # Recruitment dev type: 0 = none, 1 = dev_vector, 2 = simple
1958 # Start year for recruitment devs
2007 # Last year for recruitment devs
1 # Phase for recruitment devs
0 # Read 11 advanced recruitment options: 0 = off, 1 = on - ** Placeholders
    **
```

```
# Start year for (early) recruitment devs
# Phase for (early) recruitment devs
# Phase for forecast recruitment devs
# Lambda for forecast recruitment devs (before endyr+1)
# Last recruitment dev with no bias adjustment
# First year of full bias correction adjustment
# Last year for full bias correction adjustment in MPD
# First recent year no bias adjustment in MPD
# Lower bound for recruitment devs
# Upper bound for recruitment devs
# Read initial values for recruitment devs
#
# FISHING MORTALITY PARAMETERS
=============================================================================
#
# Fishing mortality (F) parameterization
0.1 # F ballpark for tuning early phases
-2000 # F ballpark year (negative value = off)
1 # F method: 1 = Pope, 2 = instantaneous F, 3 = hybrid
0.9 # F or Harvest rate (depends on F method)
# No additional F input needed for F method = 1 - ** Placeholders **
# Read overall start F value, overall phase, N detailed inputs to read for F
  method = 2
# Read N iterations for tuning for F method = 3 (recommend 3 to 7)

# Initial F parameters ** non-equilibrium initial age distribution
  implemented **
# Low High Initial Prior_mean Prior_type SD Phase
0.01 5 0.1 0 -1 0 1 # Initial F (Fishery 1)
0.0001 5 0.001 0 -1 0 -1 # Initial F (Fishery 2)

# CATCHABILITY (q) PARAMETERS
=============================================================================

# Catchability (q) parameterization
# Column definitions follow
# A = do power: 0 = off (survey is proportional to abundance), 1 = add
  parameter for non-linearity
# B = env link: 0 = off, 1 = add parameter for env effect on q
# C = extra SD: 0 = off, 1 = add parameter for additive constant to input SE
  (ln space)
# D = dev type: <0 = mirror other fishery/survey, 0 = no parameter q (median
  unbiased), 1 = no parameter q (mean unbiased),
  # 2 = estimate parameter for ln(q), 3 = ln(q)+set of devs about ln(q) for
  all years, 4 = ln(q)+set of devs about q for indexyr-1
# E = units: 0 = numbers, 1 = biomass
# F = error type: 0 = lognormal, >0 = t-dist. (df = input value)
# A B C D E F
# Create one parameter for each entry >0 (by row, in columns A-D)
0 0 0 0 1 0 # F1 = COM (USA commercial and Mexico commercial)
0 0 0 0 1 0 # F2 = REC (USA recreational)
0 0 0 0 0 0 # S1 = CPFV
# Placeholder line: 0 = read one parameter for each fleet with random q, 1 =
  read a parameter for each year of index
# q parameters
# Low High Initial Prior_mean Prior_type SD Phase
# -10 10 1.99024e-06 0 -1 0 -1 # ln(q) - CPFV (S1)
```

```
#
# SELECTIVITY (S) PARAMETERS
=============================================================================

# Selectivity/retention parameterization
# Size (length) parameterization
# A = selectivity option: 1 - 24
# B = do retention: 0 = no, 1 = yes
# C = male offset to female: 0 = no, 1 = yes
# D = mirror selectivity (fishery/survey)
# A B C D
# Size selectivity (S) - ** No size-based S **
0 0 0 0 # F1
0 0 0 0 # F2
0 0 0 0 # S1
#
# Age selectivity (S) - ** Age-based S is implemented **
20 0 0 0 # F1 (double-normal distribution)
20 0 0 0 # F2 (double-normal distribution)
15 0 0 2 # S1 (mirror F2)
#
# S (age) parameters
# Low High Initial Prior_mean Prior_type SD Phase Env_var Use_dev Dev_minyr
  Dev_maxyr Dev_stddev Block_def Block_type
# F1 (double-normal) ** selectivity = 3 time blocks: 1962-69, 1970-77, 1978-
  08 **
-10 10 3.98 0 -1 0 -4 0 0 0 0 0 1 2 # P_1 (1978-08, peak size)
-10 10 -4.12 0 -1 0 -4 0 0 0 0 0 1 2 # P_2 (1978-08, top logistic)
-10 10 3.22 0 -1 0 -4 0 0 0 0 0 1 2 # P_3 (1978-08, ascending limb width -
  exp)
-10 10 -0.01 0 -1 0 -4 0 0 0 0 0 1 2 # P_4 (1978-08, descending limb width -
  exp)
-10 10 -0.38 0 -1 0 -4 0 0 0 0 0 1 2 # P_5 (1978-08, initial S - at first age
  bin)
-10 10 -0.46 0 -1 0 -4 0 0 0 0 0 1 2 # P_6 (1978-08, final S - at last age
  bin)
#
# F2 (double-normal)
-10 20 4.47 0 -1 0 4 0 0 0 0 0 0 0 # P_1 (peak size)
-10 10 -4.01 0 -1 0 4 0 0 0 0 0 0 0 # P_2 (top logistic)
-10 20 2.64 0 -1 0 4 0 0 0 0 0 0 0 # P_3 (ascending limb width - exp)
-20 10 -1.50 0 -1 0 4 0 0 0 0 0 0 0 # P_4 (descending limb width - exp)
-10 10 -2.38 0 -1 0 4 0 0 0 0 0 0 0 # P_5 (initial S - at first age bin)
-10 10 -2.35 0 -1 0 4 0 0 0 0 0 0 0 # P_6 (final S - at last age bin)
#
# S1 (mirror F2) ** no additional parameter lines needed **
#
# Custom S-env parameterization: (0/1) - ** Placeholder **
# Low High Initial Prior_mean Prior_type SD Phase
#
1 # Custom S-block parameterization: (0/1)
#
# F1 S time blocks (design 1) ** For age-based S **
# Low High Initial Prior_mean Prior_type SD Phase
# F1 (double-normal)
-10 20 4.47 0 -1 0 4 # P_1 (1962-69, peak size)
-10 10 0.16 0 -1 0 4 # P_1 (1970-77, peak size)
```

```
-10 20 3.98 0 -1 0 4 # P_1 (1978-08, peak size)
#
-10 10 -4.01 0 -1 0 4 # P_2 (1962-69, top logistic)
-10 10 -4.32 0 -1 0 4 # P_2 (1970-77, top logistic)
-10 10 -4.12 0 -1 0 4 # P_2 (1978-08, top logistic)
#
-20 10 2.64 0 -1 0 4 # P_3 (1962-69, ascending limb width - exp)
-10 10 2.64 0 -1 0 4 # P_3 (1970-77, ascending limb width - exp)
-20 10 3.92 0 -1 0 4 # P_3 (1978-08, ascending limb width - exp)
#
-20 10 -1.50 0 -1 0 4 # P_4 (1962-69, descending limb width - exp)
-20 10 -1.38 0 -1 0 4 # P_4 (1970-77, descending limb width - exp)
-20 10 -0.01 0 -1 0 4 # P_4 (1978-08, descending limb width - exp)
#
-10 10 -2.38 0 -1 0 4 # P_5 (1962-69, initial S - at first age bin)
-10 10 -1.28 0 -1 0 4 # P_5 (1970-77, initial S - at first age bin)
-10 10 -0.38 0 -1 0 4 # P_5 (1978-08, initial S - at first age bin)
#
-10 10 -2.35 0 -1 0 4 # P_6 (1962-69, final S - at last age bin)
-10 10 -1.24 0 -1 0 4 # P_6 (1970-77, final S - at last age bin)
-10 10 -10 0 -1 0 -4 # P_6 (1978-08, final S - at last age bin)
#
# Custom selectivity_env_dev (phase) parameterization - ** Placeholder **
1 # Block adjust method: 1 = standard, 2 = logistic transition to keep in
  base parameter bounds
0 # Tagging flag: 0 = no tagging parameters, 1 = read tagging parameters
#
# LIKELIHOOD COMPONENT PARAMETERS
=============================================================================

1 # Variance and sample size/effective sample size adjustments (by
  fleet/survey): (0/1)
# F1 F2 S1
0 0 0 # constant (added) to survey CV
0 0 0 # constant (added) to discard SD
0 0 0 # constant (added) to body weight SD
1 2 1 # scalar (multiplied) to length distribution sample size (effective ss)
1 1 1 # scalar (multipled) to age distribution sample size (effective ss)
0 0 0 # scalar (multiplied) to size-at-age distribution sample size
  (effective ss)
#
0 # Discard observations df
0 #_Mean body weight observations df
1 # Maximum lambda phase: 1 = none
1 # SD offset: 1 = include
#
# Likelihood component (lambda) parameterization
# Likelihood component codes:
# 1 = survey, 2 = discard, 3 = mean body weight, 4 = length distribution, 5 =
  age distribution, 6 = weight distribution, 7 = size-at-age distribution,
# 8 = catch, 9 = initial equilibrium catch, 10 = recruitment devs, 11 =
  parameter priors, 12 = parameter devs, 13 = crash penalty, 14 = morph
  composition
# 15 = tag composition, 16 = tag neg_bin
#
4 # Number of changes to likelihood components
```

```
# Columns: Likelihood_comp Fishery/Survey Phase Lambda_value
  Size_distribtuion_method
# Priors
11 1 1 0 1 # All priors = off
#
# Equilibrium catch
9 1 1 0 1 # Equilibrium catch F1
9 2 1 0 1 # Equilibrium catch F2
#
# Length distribution sensitivity analysis
# Omit length distributions (annual)
4 1 1 0 1 # Omit F1
# 4 2 1 0 1 # Omit F2
#
# Age distribution sensitivity analysis
# Omit age distributions (annual and age-at-length)
# 5 1 1 0 1 # Omit F1
#
# Mean size-at-age distribution sensitivity analysis
# Omit mean size-at-age distributions
# 7 1 1 0 1 # Omit F1
#
0 # SD reporting option: (0/1)
999 # End of file
```

##

INPUT DATA FILE

```
# P. mackerel stock assessment (1962-08)
# P. R. Crone (March 2009)
# Stock Synthesis 3 (v. 3.0.12) - R. Methot
# Model AA: number of fisheries = 2 / surveys = 1 / time-step = annual /
biological distributions = age, length, and mean size-at-age / selectivity =
age-based
#
# NOTES: ** ... ** = Pending questions and/or comments
#
# INPUT DATA FILE
#
1962 # Start year
2008 # End year
1 # Number of 'seasons' (quarters)
12 # Number of months per season
1 # Spawning season
2 # Number of fishing 'fleets' (fisheries)
# F1 = COM (USA commercial and Mexico commercial)
# F2 = REC (USA recreational)
1 # Number of 'surveys' (CPUE Indices: annual-based)
# S1 = CPFV
#
1 # Number of areas (populations)
COM%REC%CPFV
0.5 0.5 0.5 # Fishery/survey timing within time block
1 1 1 # Area assignment for each fishery/survey
#
```

```
1 1 # Catch units: 1=biomass, 2=numbers
0.01 0.01 # SE of ln(catch), i.e., equals CV in ln space
#
1 # Number of genders
15 # Number of ages (accumulator age)
# Catch: initial (annual) 'equilibrium' catch (mt)
10022 167
# Number of catch records (lines)
47
# Catch time series (biomass in mt): Columns=fisheries, year, season
23758.11    142.87      1962  1
23482.86    220.14      1963  1
19900.64    87.29 1964  1
11057.20    222.24      1965  1
7138.22     266.96      1966  1
1567.16     146.16      1967  1
1598.71     96.32 1968  1
1009.75     158.46      1969  1
677.04      158.45      1970  1
589.76      321.49      1971  1
228.00      304.00      1972  1
152.43      248.50      1973  1
513.94      119.87      1974  1
1950.41     198.88      1975  1
3925.07     166.58      1976  1
12913.81    837.45      1977  1
25817.57    1355.06     1978  1
33905.12    1952.97     1979  1
32517.89    2685.18     1980  1
45561.92    1422.63     1981  1
34955.38    1416.01     1982  1
40573.39    1544.12     1983  1
45001.01    1467.32     1984  1
45811.90    1015.90     1985  1
53263.39    859.20      1986  1
46958.31    1264.46     1987  1
48576.06    688.56      1988  1
48787.53    618.27      1989  1
70934.59    616.06      1990  1
64824.75    680.14      1991  1
31753.59    463.87      1992  1
20311.09    608.80      1993  1
22674.40    1062.65     1994  1
10982.43    1013.40     1995  1
23877.14    685.54      1996  1
50272.33    803.99      1997  1
62393.05    429.61      1998  1
15757.21    152.65      1999  1
27466.58    325.32      2000  1
12439.36    571.05      2001  1
13868.67    254.10      2002  1
8589.59     323.26      2003  1
7028.76     533.46      2004  1
7079.24     395.84      2005  1
10436.81    371.42      2006  1
9122.65     306.35      2007  1
6512.89     290.47      2008  1
```

```
#
# Number of observations (lines) for all surveys (indices)
47
# Survey time series: Columns=year, season, survey, estimate, CV/SE
# CPFV survey
1962  1     3     8.22  0.36
1963  1     3     14.63 0.25
1964  1     3     5.83  0.28
1965  1     3     10.79 0.29
1966  1     3     12.00 0.24
1967  1     3     4.89  0.29
1968  1     3     7.34  0.49
1969  1     3     6.10  0.36
1970  1     3     9.58  0.33
1971  1     3     15.63 0.25
1972  1     3     8.58  0.39
1973  1     3     4.74  0.37
1974  1     3     4.41  0.45
1975  1     3     8.69  0.33
1976  1     3     14.26 0.37
1977  1     3     55.51 0.22
1978  1     3     108.24      0.18
1979  1     3     122.74      0.16
1980  1     3     161.94      0.17
1981  1     3     110.22      0.19
1982  1     3     112.20      0.16
1983  1     3     111.09      0.19
1984  1     3     119.53      0.18
1985  1     3     89.13 0.16
1986  1     3     70.52 0.18
1987  1     3     46.63 0.23
1988  1     3     33.79 0.32
1989  1     3     46.17 0.21
1990  1     3     53.25 0.32
1991  1     3     61.01 0.16
1992  1     3     43.43 0.23
1993  1     3     51.59 0.27
1994  1     3     48.31 0.21
1995  1     3     43.91 0.19
1996  1     3     47.03 0.24
1997  1     3     31.45 0.25
1998  1     3     15.25 0.25
1999  1     3     8.51  0.41
2000  1     3     16.03 0.26
2001  1     3     12.33 0.34
2002  1     3     10.20 0.28
2003  1     3     6.48  0.28
2004  1     3     11.69 0.66
2005  1     3     18.86 0.52
2006  1     3     27.60 0.25
2007  1     3     29.68 0.42
2008  1     3     16.86 0.50
#
1 # Discard type
0 # Number of discard observations (lines)
0 # Number of mean body weight observations (lines)
#
```

```
# Population size distributions
1 # Length bin method: 1 = use fishery length bins below, 2 = generate from
min/max/width below, 3 = read count and vector below
# Placeholder for number of population length bins
# Placeholder for vector of population length bins
#
#
-0.01 # Compression of length/age distribution 'tails'
0.0001 # Constant added to length/age data (constant added to expected
frequencies)
#
0 # Combine males and females at or below this bin number
#
# Fishery/CPFV size distributions
60 # Number of length bins
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55
56 57 58 59 60
#
64 # Number of fishery length distribution observations (lines) ** Length
distributions for Fishery 1 are not used (included for
provisional/comparative purposes only **
# Length distributions (1962-08) - annual (percent)
# Length distributions: Columns=year, season, fishery/survey, gender,
partition, sample size, length bin observations (in numbers)
1962  1     1     0     0     8.2   0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00488     0.01463     0.02439     0.03415
      0.05366     0.06829     0.12195     0.11220     0.10244     0.08780
      0.09756     0.10244     0.06341     0.06829     0.01951     0.02439
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000
1963  1     1     0     0     8.2   0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00488     0.00000     0.00976     0.00488     0.00976
      0.03415     0.05854     0.06829     0.08780     0.11707     0.10244
      0.12683     0.12195     0.08780     0.08293     0.05366     0.02927
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000
1964  1     1     0     0     10.7  0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00373     0.00000     0.00000     0.00373
      0.00000     0.00746     0.00746     0.00373     0.00746     0.02612
      0.03731     0.06716     0.05597     0.06716     0.08582     0.09328
      0.08955     0.14925     0.08582     0.10448     0.05970     0.03358
      0.01119     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
```

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     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000
1965 1     1    0     0    4.4  0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00901    0.01802    0.03604    0.03604    0.05405    0.03604
     0.04505    0.03604    0.05405    0.06306    0.05405    0.09910
     0.09910    0.05405    0.10811    0.09009    0.06306    0.03604
     0.00901    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000
1966 1     1    0     0    77.8 0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00051    0.00257    0.00566    0.01646    0.02469
     0.02726    0.05864    0.07510    0.07562    0.05864    0.04424
     0.03447    0.04475    0.03961    0.04064    0.04527    0.03909
     0.03858    0.02984    0.02006    0.06276    0.11060    0.07356
     0.02675    0.00412    0.00051    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000
1967 1     1    0     0    28.8 0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00139    0.01806    0.05278    0.05972
     0.09722    0.08472    0.05556    0.14028    0.14722    0.10417
     0.05278    0.02222    0.00278    0.00278    0.00972    0.03472
     0.02083    0.01389    0.01111    0.00417    0.00556    0.01667
     0.01528    0.01944    0.00417    0.00139    0.00139    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000
1968 1     1    0     0    85.8 0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00047    0.00140    0.00699    0.02937    0.07086    0.12587
     0.15338    0.16317    0.11002    0.03170    0.00886    0.03636
     0.05548    0.04802    0.02611    0.01072    0.00699    0.02145
     0.02284    0.01865    0.00886    0.00653    0.00746    0.00559
     0.00839    0.00979    0.00326    0.00140    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000
1969 1     1    0     0    19.9 0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00201    0.00803    0.00000
     0.00803    0.00201    0.01004    0.02610    0.05020    0.11446
     0.21285    0.19277    0.13052    0.07229    0.05221    0.06225
     0.01406    0.01807    0.01205    0.00201    0.01004    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
     0.00000    0.00000    0.00000
```

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1970  1     1     0     0     6.0  0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.03333    0.10667    0.33333
      0.12000    0.01333    0.03333    0.07333    0.09333    0.10000
      0.07333    0.01333    0.00667    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000
1971  1     1     0     0     13.8  0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00291
      0.00581    0.01163    0.01453    0.02326    0.04651    0.17442
      0.22674    0.16570    0.10174    0.05523    0.07558    0.07849
      0.00291    0.00000    0.00000    0.00291    0.00291    0.00291
      0.00291    0.00291    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000
1972  1     1     0     0     8.9  0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00448    0.02242    0.04036    0.04036    0.05830
      0.10762    0.08969    0.03587    0.01345    0.06726    0.10314
      0.04933    0.01345    0.00448    0.03587    0.10314    0.13004
      0.05381    0.00897    0.00897    0.00448    0.00000    0.00448
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000
1973  1     1     0     0     9.6  0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00418    0.04184
      0.03347    0.01255    0.00000    0.02092    0.02510    0.04184
      0.07531    0.05439    0.02510    0.00837    0.01674    0.02929
      0.09623    0.07950    0.08787    0.16736    0.12134    0.05439
      0.00418    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000
1974  1     1     0     0     7.2  0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.04469    0.08380    0.02793    0.00559
      0.08939    0.18994    0.05587    0.00559    0.07821    0.07821
      0.08380    0.07821    0.04469    0.00559    0.00000    0.01676
      0.04469    0.02793    0.01117    0.02235    0.00559    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000
1975  1     1     0     0     53.0  0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
```

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      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00226    0.00830
      0.02338    0.02866    0.03394    0.02262    0.01433    0.01357
      0.01659    0.04148    0.09578    0.18552    0.18703    0.14253
      0.11463    0.04374    0.01207    0.00075    0.00302    0.00000
      0.00226    0.00000    0.00377    0.00000    0.00151    0.00075
      0.00075    0.00000    0.00075    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000
1976  1     1    0     0    88.1  0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00091    0.00045    0.00045    0.00000
      0.00318    0.00772    0.00681    0.01272    0.02361    0.03906
      0.06222    0.13306    0.14260    0.10536    0.09537    0.07266
      0.05540    0.03088    0.00999    0.00272    0.00500    0.01635
      0.02997    0.03270    0.02089    0.02679    0.02725    0.02407
      0.00772    0.00091    0.00091    0.00000    0.00045    0.00091
      0.00045    0.00000    0.00045    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000
1977  1     1    0     0    77.7  0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00051
      0.00000    0.00000    0.00772    0.00206    0.00412    0.01029
      0.01801    0.01801    0.02985    0.03345    0.04889    0.07566
      0.11786    0.19403    0.17293    0.11065    0.06536    0.04323
      0.02779    0.00823    0.00257    0.00154    0.00103    0.00257
      0.00257    0.00103    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000
1978  1     1    0     0    148.4 0.00000    0.00000    0.00000
      0.00000    0.01752    0.02156    0.04178    0.03100    0.01752
      0.00135    0.00135    0.00000    0.00000    0.00000    0.00000
      0.00027    0.03585    0.11159    0.15660    0.06900    0.01698
      0.01024    0.02318    0.02345    0.03181    0.01429    0.01914
      0.01887    0.03962    0.04609    0.05445    0.04636    0.04420
      0.04528    0.02237    0.01887    0.01024    0.00270    0.00216
      0.00350    0.00081    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000
1979  1     1    0     0    139.6 0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00057    0.00229
      0.02206    0.07648    0.15612    0.16987    0.12031    0.07935
      0.05357    0.03838    0.04239    0.03036    0.04239    0.03323
      0.03495    0.03266    0.02463    0.02263    0.00888    0.00315
      0.00172    0.00115    0.00229    0.00057    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000
1980  1     1    0     0    258.6 0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      0.00000    0.00000    0.00000    0.00000    0.01253    0.06542
      0.08212    0.03371    0.03387    0.05428    0.04841    0.06093
```

```
     0.03526     0.01268     0.01655     0.03078     0.07191     0.09527
     0.07393     0.05258     0.04655     0.04036     0.03433     0.03047
     0.01887     0.01469     0.01098     0.01036     0.00665     0.00387
     0.00124     0.00046     0.00046     0.00031     0.00015     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1981 1     1     0     0     192.3 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00083     0.00000
     0.00208     0.00499     0.00416     0.00208     0.00125     0.00749
     0.01082     0.00790     0.01019     0.02787     0.02933     0.03993
     0.05782     0.02787     0.02121     0.04451     0.06593     0.06094
     0.05761     0.08319     0.09859     0.08819     0.07051     0.05928
     0.03869     0.02933     0.01872     0.01352     0.00603     0.00582
     0.00146     0.00083     0.00042     0.00042     0.00021     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1982 1     1     0     0     168.6 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00190     0.00569
     0.00095     0.00498     0.00688     0.00095     0.00119     0.00119
     0.01803     0.01257     0.01874     0.04696     0.03771     0.04910
     0.09772     0.06618     0.04056     0.04649     0.03582     0.03250
     0.03534     0.04269     0.04246     0.05835     0.05432     0.05289
     0.04673     0.04317     0.03226     0.02894     0.01471     0.00996
     0.00735     0.00261     0.00142     0.00071     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1983 1     1     0     0     106.7 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00037     0.00225     0.00075     0.00300     0.00300
     0.00150     0.00450     0.00300     0.00150     0.00262     0.00300
     0.00000     0.00112     0.00525     0.00937     0.02211     0.03636
     0.06297     0.09370     0.12969     0.14355     0.14318     0.13718
     0.08883     0.05022     0.02849     0.01237     0.00600     0.00187
     0.00187     0.00037     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1984 1     1     0     0     91.6  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00044     0.00306     0.00480
     0.01135     0.00436     0.00567     0.00262     0.00262     0.00000
     0.01528     0.04845     0.10170     0.16194     0.16019     0.12353
     0.10214     0.08904     0.07071     0.04801     0.02750     0.01091
     0.00393     0.00175     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1985 1     1     0     0     104.2 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00038     0.00230
     0.00652     0.01266     0.00959     0.00767     0.01880     0.02916
     0.02533     0.04490     0.04029     0.07252     0.13315     0.17920
```

```
     0.16500     0.10860     0.07905     0.04068     0.01765     0.00422
     0.00153     0.00077     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1986 1     1     0     0     120.0 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00100     0.00967     0.01633     0.00400     0.00933
     0.00800     0.01133     0.01767     0.04000     0.06067     0.07867
     0.09633     0.09800     0.06600     0.05633     0.05700     0.06567
     0.09267     0.07833     0.06000     0.03867     0.01767     0.01000
     0.00433     0.00133     0.00067     0.00033     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1987 1     1     0     0     165.2 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00194     0.00509     0.01332     0.01502
     0.02349     0.03391     0.04384     0.06491     0.08695     0.08937
     0.07798     0.07145     0.09106     0.11940     0.08646     0.04626
     0.03197     0.02228     0.02180     0.02083     0.01502     0.01380
     0.00315     0.00048     0.00024     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1988 1     1     0     0     179.1 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00022     0.00156     0.01474     0.11660     0.20415
     0.16038     0.08979     0.02859     0.00960     0.00692     0.00893
     0.01631     0.02993     0.04333     0.04981     0.04646     0.03931
     0.03239     0.02792     0.01720     0.01273     0.01631     0.01407
     0.00871     0.00290     0.00089     0.00022     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1989 1     1     0     0     143.3 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00056     0.00112     0.02428     0.05833
     0.04996     0.09433     0.21100     0.19620     0.13536     0.07089
     0.03684     0.02623     0.01423     0.01144     0.00726     0.00977
     0.00893     0.00893     0.01144     0.00921     0.00670     0.00558
     0.00084     0.00056     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1990 1     1     0     0     84.6  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00095     0.01183     0.02933     0.03926     0.04494
     0.05771     0.02365     0.00473     0.00757     0.01892     0.02838
     0.04588     0.04730     0.07569     0.06575     0.04730     0.03453
     0.03974     0.06433     0.09413     0.10218     0.06575     0.02980
     0.01372     0.00520     0.00142     0.00000     0.00000     0.00000
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     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1991 1     1     0     0     66.2  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00121     0.02236     0.05619     0.04592     0.02961     0.02840
     0.01873     0.01390     0.01873     0.04773     0.08520     0.09184
     0.08761     0.06767     0.03625     0.01269     0.02477     0.04230
     0.05438     0.04955     0.05015     0.04773     0.03565     0.01873
     0.00846     0.00363     0.00060     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1992 1     1     0     0     79.8  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00100     0.00150     0.01153     0.02758     0.05065     0.03862
     0.02909     0.06620     0.09478     0.10782     0.08024     0.04965
     0.03009     0.02407     0.03410     0.03059     0.03661     0.03410
     0.05817     0.05918     0.05316     0.03912     0.02758     0.00903
     0.00401     0.00150     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1993 1     1     0     0     107.5 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00446     0.04576     0.11942     0.12649     0.09710     0.08966
     0.04018     0.02493     0.01414     0.03460     0.03832     0.04167
     0.04799     0.05952     0.03720     0.02344     0.01079     0.00632
     0.00967     0.02121     0.02269     0.02902     0.02641     0.01860
     0.00670     0.00335     0.00000     0.00037     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1994 1     1     0     0     124.6 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00032     0.00000     0.00417     0.01638     0.05845     0.12139
     0.13712     0.15125     0.16506     0.11689     0.05652     0.03565
     0.02408     0.01574     0.01991     0.01413     0.01060     0.00578
     0.00385     0.00417     0.00803     0.01509     0.00867     0.00450
     0.00161     0.00064     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1995 1     1     0     0     108.2 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00333     0.04361     0.14412     0.19586     0.13673
     0.09054     0.04435     0.05839     0.07095     0.06689     0.04028
     0.02772     0.00776     0.00665     0.00517     0.00665     0.00333
     0.00333     0.00296     0.00407     0.01109     0.01220     0.00739
     0.00333     0.00296     0.00037     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
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     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1996 1     1     0     0     87.6  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00091     0.00183     0.00594     0.04523     0.09228
     0.10233     0.09274     0.09045     0.07766     0.06578     0.04888
     0.04797     0.03609     0.03518     0.02421     0.02101     0.02878
     0.02787     0.02969     0.02330     0.03563     0.02787     0.02604
     0.01005     0.00137     0.00046     0.00000     0.00046     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1997 1     1     0     0     108.6 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00074     0.00074     0.00221     0.00626     0.00774
     0.00516     0.01363     0.02174     0.05232     0.06890     0.08364
     0.07148     0.06043     0.05453     0.05269     0.05748     0.03758
     0.04422     0.04937     0.05453     0.07443     0.08438     0.06190
     0.02763     0.00590     0.00037     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1998 1     1     0     0     90.2  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00044     0.00089     0.00576     0.00710     0.01330
     0.02217     0.02483     0.01729     0.01729     0.02483     0.03991
     0.07894     0.12772     0.11264     0.09534     0.06962     0.05366
     0.03503     0.05144     0.07317     0.06208     0.03503     0.01951
     0.01020     0.00177     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1999 1     1     0     0     66.6  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00060     0.00900     0.02821
     0.09364     0.09844     0.08884     0.06002     0.03241     0.02281
     0.01681     0.01801     0.02161     0.02641     0.03541     0.06002
     0.08643     0.08944     0.07263     0.06843     0.03902     0.01981
     0.00780     0.00180     0.00180     0.00060     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
2000 1     1     0     0     76.4  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00209     0.00524     0.00681     0.01728     0.05079     0.10419
     0.12094     0.09110     0.04764     0.02513     0.01675     0.01623
     0.03874     0.04607     0.03665     0.02094     0.01047     0.01990
     0.05445     0.09319     0.06702     0.05288     0.03665     0.00995
     0.00471     0.00366     0.00052     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
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2001  1     1     0     0     84.4  0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00284     0.01137     0.04121     0.06821     0.05590
      0.03932     0.03648     0.04074     0.05921     0.08764     0.09664
      0.10137     0.06490     0.03932     0.02795     0.02226     0.01611
      0.03316     0.04074     0.04500     0.03221     0.02416     0.00758
      0.00521     0.00047     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000
2002  1     1     0     0     85.8  0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00140     0.01119     0.02797     0.05035
      0.05221     0.06900     0.08159     0.11608     0.14592     0.15758
      0.14079     0.06247     0.03683     0.01772     0.00839     0.00420
      0.00373     0.00373     0.00186     0.00326     0.00233     0.00140
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000
2003  1     1     0     0     62.8  0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00255     0.01338     0.04777     0.11911
      0.13567     0.13376     0.04841     0.03822     0.05796     0.06943
      0.08025     0.06369     0.04013     0.02229     0.02102     0.01656
      0.01911     0.01529     0.01847     0.01656     0.01083     0.00573
      0.00191     0.00127     0.00064     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000
2004  1     1     0     0     101.2 0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00119     0.00356     0.00514     0.01463     0.02847     0.05299
      0.11111     0.13642     0.14591     0.14037     0.11190     0.07078
      0.07038     0.03361     0.01423     0.01305     0.00989     0.00830
      0.00395     0.00751     0.00633     0.00237     0.00435     0.00237
      0.00079     0.00040     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000
2005  1     1     0     0     92.0  0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00043
      0.00304     0.01914     0.02305     0.06916     0.15485     0.17529
      0.13658     0.08830     0.04959     0.04045     0.04393     0.03045
      0.03871     0.03958     0.04002     0.02044     0.01305     0.00783
      0.00261     0.00000     0.00043     0.00130     0.00087     0.00087
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000
2006  1     1     0     0     95.7  0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
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      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00084     0.00084     0.00919     0.01713     0.03886     0.09193
      0.13623     0.12996     0.11032     0.10155     0.06979     0.06728
      0.04931     0.03636     0.02591     0.01546     0.01379     0.01212
      0.01588     0.00501     0.00125     0.00669     0.01087     0.01421
      0.01045     0.00627     0.00125     0.00042     0.00042     0.00042
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000
2007  1     1     0     0     64.4  0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00062
      0.00808     0.03791     0.01740     0.02051     0.06464     0.13735
      0.11933     0.09136     0.07769     0.06588     0.05221     0.03294
      0.02548     0.03543     0.02735     0.02921     0.01927     0.02113
      0.01989     0.02610     0.02300     0.01429     0.01305     0.00622
      0.00808     0.00373     0.00186     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000
2008  1     1     0     0     17.0  0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00235     0.00000     0.00471     0.02118     0.02353     0.04706
      0.02824     0.06353     0.06353     0.06824     0.13176     0.13412
      0.15294     0.05412     0.01176     0.00471     0.01412     0.03059
      0.03059     0.04000     0.01882     0.01647     0.01176     0.01412
      0.00706     0.00471     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000
1992  1     2     0     0     28.4  0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00282
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00141
      0.00282     0.00282     0.00423     0.00563     0.01268     0.01690
      0.03380     0.05352     0.08451     0.09437     0.12676     0.07746
      0.06338     0.03239     0.04225     0.02394     0.02817     0.02676
      0.03380     0.04789     0.05915     0.04930     0.03239     0.01690
      0.00986     0.00423     0.00423     0.00282     0.00000     0.00000
      0.00000     0.00141     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00141     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000
1993  1     2     0     0     69.4  0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00230     0.00230     0.00806     0.00461     0.00461     0.00403
      0.00288     0.00230     0.00691     0.02016     0.02765     0.02650
      0.02535     0.03111     0.03687     0.04435     0.06164     0.07200
      0.06624     0.05703     0.04839     0.03053     0.02765     0.03168
      0.03111     0.02823     0.05933     0.07028     0.06279     0.05184
      0.02650     0.00979     0.00403     0.00230     0.00115     0.00058
      0.00058     0.00000     0.00000     0.00000     0.00115     0.00000
      0.00115     0.00000     0.00058     0.00000     0.00000     0.00000
      0.00000     0.00058     0.00288
1994  1     2     0     0     35.4  0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00226     0.00226
      0.00113     0.00226     0.00565     0.00678     0.02825     0.07797
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     0.07571     0.06102     0.04294     0.03164     0.02260     0.03390
     0.03277     0.02712     0.02486     0.03164     0.03842     0.01808
     0.01469     0.02712     0.05763     0.09379     0.10734     0.04746
     0.05537     0.02034     0.00339     0.00113     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00226     0.00113     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00113
1995 1     2     0     0     29.6  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00271
     0.00947     0.00406     0.00271     0.00406     0.02030     0.03654
     0.03789     0.01894     0.02436     0.03924     0.06360     0.07848
     0.07984     0.04601     0.05413     0.04465     0.03383     0.03924
     0.04465     0.03112     0.05142     0.05007     0.06089     0.06766
     0.03518     0.01083     0.00541     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00135     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00135
1996 1     2     0     0     76.0  0.00000     0.00000     0.00000
     0.00053     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00105     0.00105     0.00263     0.00474
     0.00843     0.01001     0.00843     0.01316     0.01738     0.02686
     0.04529     0.06582     0.06214     0.05793     0.04634     0.04687
     0.03581     0.03160     0.03686     0.02370     0.02686     0.02106
     0.02001     0.02580     0.03107     0.05898     0.08952     0.08741
     0.04950     0.03107     0.00790     0.00105     0.00158     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00158
1997 1     2     0     0     91.1  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00088     0.00219     0.00307
     0.00702     0.00746     0.01097     0.01141     0.01317     0.01141
     0.02283     0.03424     0.04083     0.05048     0.06234     0.03600
     0.04083     0.04258     0.05531     0.05531     0.05443     0.04434
     0.03995     0.04565     0.04258     0.04960     0.05882     0.06365
     0.04741     0.02283     0.00790     0.00439     0.00658     0.00176
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00044
     0.00000     0.00000     0.00000     0.00000     0.00088     0.00000
     0.00000     0.00044     0.00000
1998 1     2     0     0     61.0  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00066     0.00000     0.00066
     0.00525     0.00787     0.01312     0.01903     0.02887     0.02625
     0.02559     0.03871     0.02690     0.03740     0.02559     0.04856
     0.05249     0.06496     0.07021     0.04856     0.04396     0.02690
     0.03609     0.05446     0.06365     0.07415     0.05774     0.05446
     0.03018     0.01115     0.00394     0.00066     0.00066     0.00000
     0.00066     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00066
1999 1     2     0     0     50.1  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00080     0.00080     0.00000     0.00000     0.00080     0.00080
     0.00000     0.00000     0.00080     0.00399     0.01596     0.01357
     0.01117     0.01117     0.02713     0.04868     0.05986     0.04789
     0.03272     0.04310     0.04230     0.04789     0.04469     0.05427
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     0.08859     0.09816     0.08939     0.07103     0.05427     0.03990
     0.03192     0.01197     0.00479     0.00000     0.00000     0.00000
     0.00080     0.00080     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
2000 1     2     0     0     43.4  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00092     0.00185     0.00738     0.00830     0.00738
     0.00738     0.00738     0.00830     0.00923     0.01292     0.01753
     0.01661     0.01476     0.02952     0.03321     0.04151     0.03967
     0.07380     0.06550     0.06273     0.03044     0.02030     0.05627
     0.08856     0.10240     0.07749     0.05627     0.04244     0.03782
     0.01568     0.00554     0.00092     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
2001 1     2     0     0     42.0  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00190     0.00285     0.00666
     0.00666     0.01522     0.01522     0.02664     0.04472     0.05614
     0.06946     0.07136     0.08563     0.06946     0.05614     0.05233
     0.08944     0.11513     0.09610     0.05138     0.04091     0.01427
     0.00856     0.00285     0.00095     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
2002 1     2     0     0     45.8  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00087     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00087     0.00000     0.00524     0.01310     0.02009
     0.02707     0.04017     0.04629     0.04978     0.06288     0.09607
     0.11004     0.07948     0.06638     0.05590     0.04891     0.03406
     0.04891     0.03493     0.04716     0.03406     0.02795     0.02620
     0.01397     0.00349     0.00262     0.00000     0.00000     0.00000
     0.00000     0.00087     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00262
2003 1     2     0     0     41.5  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00096     0.00000
     0.00096     0.00482     0.01350     0.01061     0.01157     0.01350
     0.02797     0.05882     0.06365     0.07618     0.08872     0.07136
     0.07522     0.05014     0.05111     0.03568     0.02314     0.01736
     0.02604     0.03182     0.03761     0.06365     0.06654     0.04436
     0.01929     0.00868     0.00096     0.00193     0.00000     0.00000
     0.00000     0.00096     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00096     0.00193
2004 1     2     0     0     67.7  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00118     0.00532     0.00709
     0.00295     0.00827     0.02481     0.02599     0.03426     0.04548
     0.05021     0.05375     0.06911     0.08269     0.06202     0.05729
     0.06025     0.05139     0.04666     0.03839     0.02363     0.02067
     0.02185     0.01890     0.02422     0.02422     0.03898     0.05257
     0.02658     0.01299     0.00413     0.00118     0.00118     0.00059
```

```
     0.00000     0.00000     0.00000     0.00059     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00059     0.00000
     0.00000     0.00000     0.00000
2005 1     2     0     0     84.4  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00047     0.00000
     0.00047     0.00095     0.00047     0.00047     0.00190     0.00427
     0.00284     0.00379     0.00901     0.02086     0.05927     0.09388
     0.11522     0.10194     0.10384     0.09341     0.07824     0.06970
     0.05785     0.04599     0.04931     0.02560     0.01944     0.00948
     0.00853     0.00379     0.00284     0.00237     0.00237     0.00284
     0.00284     0.00190     0.00142     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00047     0.00000     0.00047
     0.00047     0.00000     0.00095
2006 1     2     0     0     94.5  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00042     0.00127     0.00127     0.00296
     0.00466     0.00550     0.00719     0.01777     0.03259     0.06306
     0.10114     0.12907     0.12950     0.10284     0.08548     0.06602
     0.04740     0.04655     0.03682     0.02328     0.01566     0.01481
     0.01058     0.00635     0.00804     0.00466     0.00550     0.00550
     0.00931     0.00804     0.00466     0.00212     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
2007 1     2     0     0     97.6  0.00000     0.00000     0.00000
     0.00041     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00082     0.00000     0.00082
     0.00164     0.00246     0.00246     0.01353     0.02378     0.03034
     0.05002     0.05576     0.07093     0.10496     0.12136     0.10865
     0.09963     0.06724     0.06191     0.03526     0.03034     0.02501
     0.01763     0.01394     0.00984     0.00779     0.01271     0.00902
     0.00738     0.00738     0.00410     0.00082     0.00041     0.00000
     0.00041     0.00000     0.00000     0.00041     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00082
2008 1     2     0     0     53.7  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00968     0.03053     0.03276     0.04765     0.03425
     0.03797     0.03872     0.04244     0.05361     0.05659     0.06031
     0.10573     0.11616     0.09159     0.04914     0.04170     0.02010
     0.01117     0.02010     0.01489     0.02383     0.01191     0.01340
     0.02010     0.01117     0.00223     0.00149     0.00000     0.00000
     0.00000     0.00074     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
#
# Fishery age distributions
9 # Number of age_bins
0 1 2 3 4 5 6 7 8
#
1 # Number of ageing error matrices (use 'accumulator age' above: (15) + 1
vectors)
0.5 1.5 2.5 3.5 4.5 5.5 6.5 7.5 8.5 9.5 10.5 11.5 12.5 13.5 14.5 15.5 # Age
bin mid-points
```

```
0.406 0.642 0.712 0.784 0.992 1.304 1.345 1.5 1.637 1.809 1.964 2.119 2.273
2.428 2.583 2.738 # Age bin SD
#
47 # Number of age distributions observations (lines)
2 # Length bin method for Lbin_lo and Lbin_hi: 1 = use population length bin
index, 2 = use length data bin index, 3 = actual lengths (must use population
length index option)
-1 # Combine males and females at or below this bin number
#
# Age distributions (1962-08) - annual (percent)
# Age distributions: Columns=year, season, fishery/survey, gender, partition,
ageing error (age bin SD), Lbin_lo, Lbin_hi, sample size, age bin
observations (in percent)
1962  1     1     0     0     1     -1    -1    8.2   0.01  0.39  0.22  0.21
      0.14  0.03  0.00  0.00  0.00
1963  1     1     0     0     1     -1    -1    8.2   0.01  0.16  0.40  0.20
      0.16  0.06  0.01  0.00  0.00
1964  1     1     0     0     1     -1    -1    10.72 0.04  0.16  0.15  0.25
      0.28  0.11  0.01  0.00  0.00
1965  1     1     0     0     1     -1    -1    4.44  0.00  0.30  0.13  0.24
      0.26  0.06  0.01  0.00  0.00
1966  1     1     0     0     1     -1    -1    77.76 0.25  0.27  0.08  0.08
      0.06  0.16  0.10  0.01  0.00
1967  1     1     0     0     1     -1    -1    28.8  0.73  0.11  0.01  0.06
      0.02  0.02  0.04  0.01  0.00
1968  1     1     0     0     1     -1    -1    85.8  0.67  0.18  0.04  0.04
      0.02  0.02  0.01  0.01  0.01
1969  1     1     0     0     1     -1    -1    19.92 0.01  0.72  0.16  0.07
      0.02  0.02  0.00  0.00  0.00
1970  1     1     0     0     1     -1    -1    6     0.60  0.40  0.00  0.00
      0.00  0.00  0.00  0.00  0.00
1971  1     1     0     0     1     -1    -1    13.76 0.00  0.87  0.11  0.01
      0.01  0.01  0.00  0.00  0.00
1972  1     1     0     0     1     -1    -1    8.92  0.52  0.14  0.17  0.16
      0.01  0.00  0.00  0.00  0.00
1973  1     1     0     0     1     -1    -1    9.56  0.10  0.31  0.07  0.08
      0.16  0.18  0.10  0.00  0.00
1974  1     1     0     0     1     -1    -1    7.16  0.49  0.38  0.11  0.02
      0.01  0.00  0.00  0.00  0.00
1975  1     1     0     0     1     -1    -1    53.04 0.02  0.78  0.19  0.01
      0.00  0.00  0.00  0.00  0.00
1976  1     1     0     0     1     -1    -1    88.08 0.77  0.04  0.19  0.00
      0.00  0.00  0.00  0.00  0.00
1977  1     1     0     0     1     -1    -1    77.72 0.08  0.91  0.00  0.01
      0.00  0.00  0.00  0.00  0.00
1978  1     1     0     0     1     -1    -1    148.4 0.60  0.15  0.22  0.01
      0.01  0.00  0.00  0.00  0.00
1979  1     1     0     0     1     -1    -1    139.64      0.00  0.78  0.11
      0.11  0.00  0.00  0.00  0.00  0.00
1980  1     1     0     0     1     -1    -1    258.64      0.43  0.02  0.46
      0.05  0.04  0.00  0.00  0.00  0.00
1981  1     1     0     0     1     -1    -1    192.32      0.14  0.33  0.08
      0.41  0.03  0.02  0.00  0.00  0.00
1982  1     1     0     0     1     -1    -1    168.64      0.07  0.34  0.27
      0.08  0.21  0.02  0.01  0.00  0.00
1983  1     1     0     0     1     -1    -1    106.72      0.03  0.03  0.39
      0.35  0.05  0.15  0.00  0.00  0.00
```

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1984  1     1     0     0     1     -1    -1    91.64 0.03  0.01  0.10  0.49
      0.23  0.06  0.08  0.00  0.00
1985  1     1     0     0     1     -1    -1    104.24      0.04  0.15  0.05
      0.15  0.47  0.11  0.01  0.01  0.00
1986  1     1     0     0     1     -1    -1    120   0.17  0.33  0.15  0.04
      0.06  0.17  0.05  0.01  0.01
1987  1     1     0     0     1     -1    -1    165.16      0.15  0.50  0.22
      0.04  0.02  0.02  0.03  0.01  0.01
1988  1     1     0     0     1     -1    -1    179.08      0.63  0.07  0.16
      0.06  0.02  0.01  0.01  0.02  0.02
1989  1     1     0     0     1     -1    -1    143.32      0.14  0.77  0.03
      0.02  0.01  0.01  0.01  0.00  0.01
1990  1     1     0     0     1     -1    -1    84.56 0.22  0.12  0.24  0.07
      0.11  0.12  0.04  0.04  0.04
1991  1     1     0     0     1     -1    -1    66.2  0.20  0.42  0.07  0.10
      0.06  0.06  0.04  0.02  0.02
1992  1     1     0     0     1     -1    -1    79.76 0.16  0.38  0.15  0.10
      0.08  0.06  0.04  0.02  0.01
1993  1     1     0     0     1     -1    -1    107.52      0.56  0.14  0.14
      0.03  0.04  0.04  0.02  0.02  0.01
1994  1     1     0     0     1     -1    -1    124.56      0.45  0.39  0.08
      0.03  0.02  0.01  0.01  0.00  0.00
1995  1     1     0     0     1     -1    -1    108.24      0.62  0.26  0.06
      0.01  0.01  0.02  0.01  0.01  0.00
1996  1     1     0     0     1     -1    -1    87.56 0.32  0.33  0.14  0.08
      0.05  0.04  0.02  0.02  0.01
1997  1     1     0     0     1     -1    -1    108.56      0.07  0.26  0.22
      0.11  0.08  0.08  0.06  0.05  0.08
1998  1     1     0     0     1     -1    -1    90.2  0.09  0.16  0.32  0.16
      0.08  0.06  0.05  0.03  0.04
1999  1     1     0     0     1     -1    -1    66.64 0.37  0.08  0.07  0.14
      0.14  0.10  0.04  0.03  0.02
2000  1     1     0     0     1     -1    -1    76.4  0.44  0.16  0.06  0.10
      0.12  0.08  0.03  0.01  0.01
2001  1     1     0     0     1     -1    -1    84.44 0.28  0.44  0.08  0.05
      0.06  0.05  0.02  0.01  0.00
2002  1     1     0     0     1     -1    -1    85.8  0.24  0.65  0.08  0.02
      0.00  0.01  0.00  0.00  0.00
2003  1     1     0     0     1     -1    -1    62.8  0.52  0.27  0.11  0.05
      0.02  0.02  0.01  0.00  0.00
2004  1     1     0     0     1     -1    -1    101.16      0.83  0.11  0.03
      0.02  0.01  0.00  0.00  0.00  0.00
2005  1     1     0     0     1     -1    -1    91.96 0.75  0.17  0.06  0.01
      0.00  0.00  0.00  0.00  0.00
2006  1     1     0     0     1     -1    -1    95.72 0.58  0.27  0.06  0.04
      0.03  0.01  0.01  0.00  0.00
2007  1     1     0     0     1     -1    -1    64.36 0.51  0.24  0.11  0.08
      0.04  0.02  0.01  0.00  0.00
2008  1     1     0     0     1     -1    -1    17    0.06  0.52  0.22  0.12
      0.06  0.02  0.00  0.00  0.00
#
# Fishery size-at-age distributions
47 # Number of mean size-at-age observations (lines)
# Mean size-at-age distributions (1962-08) - annual (cm)
# Mean size-at-age distributions: Columns=year, season, fishery/survey,
gender, partition, ageing error, sample size (nominal only), mean size-at-age
observations (in cm), mean size-at-age sample sizes
```

```
1962  1     1     0     0     1     1     28.50 29.43 32.07 34.37 36.14 37.67
      39.00 -1.00 -1.00 0.08000     3.20000     1.80000     1.72000
      1.12000     0.24000     0.04000     0.00000     0.00000
1963  1     1     0     0     1     1     26.00 29.16 32.47 34.36 36.24 38.00
      38.00 -1.00 -1.00 0.08000     1.28000     3.24000     1.68000
      1.32000     0.52000     0.08000     0.00000     0.00000
1964  1     1     0     0     1     1     24.50 28.63 31.40 33.59 35.87 37.90
      38.75 -1.00 -1.00 0.40000     1.72000     1.60000     2.64000
      3.04000     1.16000     0.16000     0.00000     0.00000
1965  1     1     0     0     1     1     -1.00 26.67 32.21 33.59 35.93 37.86
      39.00 -1.00 -1.00 0.00000     1.32000     0.56000     1.08000
      1.16000     0.28000     0.04000     0.00000     0.00000
1966  1     1     0     0     1     1     23.34 27.50 31.65 33.77 35.96 38.03
      38.75 38.67 -1.00 19.76000    21.28000    5.92000     6.12000
      4.36000     12.08000    7.64000     0.60000     0.00000
1967  1     1     0     0     1     1     23.99 27.03 33.17 33.14 35.33 37.87
      40.39 40.63 39.00 21.04000    3.12000     0.24000     1.72000
      0.60000     0.60000     1.12000     0.32000     0.04000
1968  1     1     0     0     1     1     22.08 27.48 30.47 33.57 34.68 36.68
      39.48 40.48 41.56 57.52000    15.28000    3.08000     3.72000
      1.76000     1.88000     1.08000     0.84000     0.64000
1969  1     1     0     0     1     1     20.57 28.11 31.06 33.15 34.90 36.80
      38.00 -1.00 -1.00 0.28000     14.28000    3.20000     1.32000
      0.40000     0.40000     0.04000     0.00000     0.00000
1970  1     1     0     0     1     1     20.93 26.38 -1.00 -1.00 -1.00 -1.00
      -1.00 -1.00 -1.00 3.60000     2.40000     0.00000     0.00000
      0.00000     0.00000     0.00000     0.00000     0.00000
1971  1     1     0     0     1     1     -1.00 28.22 32.56 33.00 38.00 40.50
      -1.00 -1.00 -1.00 0.00000     11.92000    1.56000     0.08000
      0.12000     0.08000     0.00000     0.00000     0.00000
1972  1     1     0     0     1     1     22.66 27.32 32.31 33.40 34.00 39.00
      -1.00 -1.00 -1.00 4.60000     1.24000     1.56000     1.40000
      0.08000     0.04000     0.00000     0.00000     0.00000
1973  1     1     0     0     1     1     22.00 29.51 31.88 36.22 35.79 37.21
      38.25 39.00 39.00 0.92000     2.96000     0.68000     0.72000
      1.52000     1.72000     0.96000     0.04000     0.04000
1974  1     1     0     0     1     1     21.72 27.65 34.32 37.00 38.00 -1.00
      -1.00 -1.00 -1.00 3.52000     2.72000     0.76000     0.12000
      0.04000     0.00000     0.00000     0.00000     0.00000
1975  1     1     0     0     1     1     22.55 30.30 33.84 40.67 43.50 45.00
      48.00 -1.00 -1.00 1.24000     41.20000    10.04000    0.36000
      0.08000     0.08000     0.04000     0.00000     0.00000
1976  1     1     0     0     1     1     24.23 27.95 36.21 39.00 43.67 -1.00
      46.33 -1.00 -1.00 67.72000    3.64000     16.40000    0.08000
      0.12000     0.00000     0.12000     0.00000     0.00000
1977  1     1     0     0     1     1     22.26 29.39 36.00 39.19 -1.00 -1.00
      -1.00 -1.00 -1.00 6.44000     70.48000    0.16000     0.64000
      0.00000     0.00000     0.00000     0.00000     0.00000
1978  1     1     0     0     1     1     16.95 29.79 32.93 29.82 30.68 26.33
      -1.00 -1.00 -1.00 89.56000    22.52000    31.96000    2.00000
      1.76000     0.60000     0.00000     0.00000     0.00000
1979  1     1     0     0     1     1     20.00 25.70 32.58 35.59 38.40 41.47
      -1.00 -1.00 -1.00 0.04000     108.48000   15.44000    14.88000
      0.20000     0.60000     0.00000     0.00000     0.00000
1980  1     1     0     0     1     1     18.67 24.20 27.95 31.83 35.05 27.63
      42.20 -1.00 -1.00 110.60000   5.04000     118.64000   12.56000
      10.84000    0.76000     0.20000     0.00000     0.00000
```

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1981  1     1     0     0     1     1     19.42 25.34 26.67 31.49 35.72 37.95
      41.00 42.00 -1.00 26.20000    63.20000    15.32000    79.36000
      4.92000     3.12000     0.08000     0.12000     0.00000
1982  1     1     0     0     1     1     17.07 23.38 26.34 29.44 34.32 38.73
      40.44 -1.00 -1.00 11.52000    57.92000    45.32000    13.76000
      36.12000    3.00000     1.00000     0.00000     0.00000
1983  1     1     0     0     1     1     16.69 26.03 29.62 31.87 33.46 34.46
      37.50 -1.00 -1.00 2.68000     2.68000     41.96000    37.04000
      5.84000     16.28000    0.24000     0.00000     0.00000
1984  1     1     0     0     1     1     22.59 27.14 30.71 31.76 34.03 36.10
      36.64 40.25 -1.00 2.84000     0.56000     9.48000     45.04000
      21.20000    5.32000     7.04000     0.16000     0.00000
1985  1     1     0     0     1     1     23.66 28.55 32.11 33.15 33.61 35.06
      36.34 37.57 -1.00 4.24000     15.76000    5.28000     16.12000
      49.36000    10.96000    1.40000     1.12000     0.00000
1986  1     1     0     0     1     1     23.94 28.44 31.43 33.63 34.66 35.27
      35.76 37.13 38.17 20.96000    39.88000    17.88000    4.56000
      7.68000     20.96000    6.20000     0.96000     0.92000
1987  1     1     0     0     1     1     22.98 28.03 31.41 33.85 35.41 36.77
      37.24 37.92 38.77 25.04000    82.48000    36.76000    6.08000
      3.16000     3.88000     4.76000     2.12000     0.88000
1988  1     1     0     0     1     1     21.51 28.83 31.43 33.94 35.50 36.54
      38.16 38.08 39.10 112.00000   13.20000    28.44000    11.52000
      2.72000     1.84000     2.44000     3.80000     3.12000
1989  1     1     0     0     1     1     21.35 25.20 29.88 33.87 35.53 36.86
      37.50 37.08 38.61 19.36000    111.00000   4.76000     3.00000
      1.72000     1.16000     0.88000     0.52000     0.92000
1990  1     1     0     0     1     1     21.02 27.82 30.80 34.15 36.07 36.62
      37.47 38.08 38.93 18.20000    9.92000     20.48000    6.24000
      9.56000     9.84000     3.64000     3.20000     3.48000
1991  1     1     0     0     1     1     19.30 26.99 31.83 34.03 35.47 36.34
      37.12 37.54 38.61 13.56000    28.00000    4.88000     6.60000
      4.00000     4.00000     2.68000     1.04000     1.44000
1992  1     1     0     0     1     1     20.44 25.01 29.66 32.87 34.36 36.08
      36.49 37.00 38.63 12.80000    30.32000    11.68000    8.20000
      6.76000     4.80000     2.96000     1.60000     0.64000
1993  1     1     0     0     1     1     19.68 27.00 29.05 31.97 36.08 36.48
      38.08 38.24 39.06 60.44000    15.32000    14.84000    3.60000
      4.08000     3.80000     2.04000     2.04000     1.36000
1994  1     1     0     0     1     1     21.76 24.51 27.75 31.04 34.44 36.38
      37.36 38.21 39.00 55.60000    48.60000    10.08000    4.04000
      2.64000     1.36000     1.32000     0.56000     0.36000
1995  1     1     0     0     1     1     20.24 25.00 27.92 31.82 35.45 37.08
      38.32 38.38 40.10 67.16000    28.64000    6.36000     1.12000
      0.80000     1.92000     1.00000     0.84000     0.40000
1996  1     1     0     0     1     1     21.90 25.28 29.72 33.37 35.87 37.18
      37.96 38.41 38.96 27.64000    29.16000    11.88000    6.96000
      4.60000     3.16000     1.80000     1.36000     1.00000
1997  1     1     0     0     1     1     23.69 27.33 30.10 33.00 35.44 36.77
      38.01 38.16 38.56 7.28000     28.20000    23.92000    12.48000
      8.92000     8.52000     6.08000     5.00000     8.16000
1998  1     1     0     0     1     1     22.55 27.94 29.90 32.01 34.62 36.26
      36.59 37.45 37.98 8.52000     14.20000    28.84000    14.40000
      7.52000     5.76000     4.60000     2.92000     3.44000
1999  1     1     0     0     1     1     23.24 26.21 31.15 33.65 34.92 35.81
      36.71 37.87 38.24 24.80000    5.44000     4.68000     9.56000
      9.32000     6.88000     2.80000     1.80000     1.36000
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2000  1     1     0     0     1     1     21.89 27.38 29.95 34.71 35.47 35.98
      36.37 37.50 38.00 33.28000    12.48000    4.32000     7.28000
      9.08000     5.80000     2.60000     0.96000     0.60000
2001  1     1     0     0     1     1     21.15 27.26 29.92 34.37 35.42 36.30
      36.31 36.95 36.60 23.68000    36.88000    6.88000     4.28000
      5.04000     4.32000     2.08000     0.88000     0.40000
2002  1     1     0     0     1     1     22.58 26.38 28.95 31.67 34.56 34.55
      36.71 -1.00 -1.00 20.52000    55.44000    7.04000     1.72000
      0.36000     0.44000     0.28000     0.00000     0.00000
2003  1     1     0     0     1     1     22.11 27.41 30.49 34.46 35.67 37.38
      38.13 38.40 39.50 32.60000    17.24000    7.12000     3.04000
      0.96000     0.96000     0.60000     0.20000     0.08000
2004  1     1     0     0     1     1     23.94 27.68 31.05 35.08 36.72 37.67
      38.50 38.00 39.50 84.00000    10.76000    3.28000     2.08000
      0.72000     0.12000     0.08000     0.04000     0.08000
2005  1     1     0     0     1     1     21.31 27.00 30.13 32.04 33.64 35.83
      35.50 39.00 -1.00 68.96000    15.36000    5.84000     1.00000
      0.44000     0.24000     0.08000     0.04000     0.00000
2006  1     1     0     0     1     1     22.55 26.51 30.47 34.16 38.46 39.68
      40.05 40.83 -1.00 55.60000    26.28000    5.88000     3.48000
      2.44000     1.00000     0.80000     0.24000     0.00000
2007  1     1     0     0     1     1     21.11 25.87 29.37 33.63 36.16 38.70
      39.64 40.67 -1.00 32.68000    15.52000    7.00000     5.20000
      2.32000     1.08000     0.44000     0.12000     0.00000
2008  1     1     0     0     1     1     20.40 25.77 26.30 33.02 37.04 37.29
      39.00 -1.00 -1.00 1.00000     8.84000     3.76000     2.04000
      1.00000     0.28000     0.08000     0.00000     0.00000
#
0 # Number of 'environmental' variables
0 # Number of 'environmental' observations
0 # Weight distributions
0 # Tag data
0 # Morph data
999 # End of file

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Appendix 2A

Preface

The following suites of displays (Appendix 2A: ASAP model (2009); and Appendix 2B: SS model *S1_aa*) are associated with objectives 1 and 2 (see Preface above). That is, results from these two model scenarios were presented in initial STAR discussions, reviewed accordingly, deemed satisfactory for meeting objectives 1 and 2, and are presented here.

ASAP model (2009) displays

Table A2A-1. Sample sizes associated with CDFG data collection program for Pacific mackerel 1939-08).

Fishing Year	Landings (mt)	# Fish Sampled	Fish per 1,000 mt	Fishing Year	Landings (mt)	# Fish Sampled	Fish per 1,000 mt
1939-40	45,341	1,524	34	**1974-75**	514	179	348
1940-41	48,786	2,258	46	**1975-76**	1,950	1,326	680
1941-42	32,547	2,445	75	**1976-77**	3,925	2,202	561
1942-43	21,872	1,287	59	**1977-78**	12,914	1,943	150
1943-44	35,291	2,250	64	**1978-79**	25,818	3,810	148
1944-45	36,644	1,520	41	**1979-80**	33,905	3,491	103
1945-46	23,588	2,088	89	**1980-81**	32,518	6,711	206
1946-47	27,566	2,637	96	**1981-82**	45,562	5,067	111
1947-48	19,237	1,397	73	**1982-83**	34,955	4,764	136
1948-49	17,843	631	35	**1983-84**	40,573	2,694	66
1949-50	24,059	1,835	76	**1984-85**	45,001	2,394	53
1950-51	17,401	1,019	59	**1985-86**	45,812	2,607	57
1951-52	15,792	911	58	**1986-87**	53,263	3,000	56
1952-53	10,223	397	39	**1987-88**	46,958	4,150	88
1953-54	5,182	447	86	**1988-89**	48,576	4,479	92
1954-55	18,023	811	45	**1989-90**	48,788	3,583	73
1955-56	21,998	572	26	**1990-91**	70,935	2,121	30
1956-57	36,663	1,011	28	**1991-92**	64,825	1,689	26
1957-58	27,544	931	34	**1992-93**	31,754	2,015	63
1958-59	11,687	903	77	**1993-94**	20,311	2,740	135
1959-60	19,221	755	39	**1994-95**	22,674	4,357	192
1960-61	20,705	488	24	**1995-96**	10,982	2,718	247
1961-62	26,059	422	16	**1996-97**	23,877	2,222	93
1962-63	23,758	205	9	**1997-98**	50,272	2,722	54
1963-64	23,483	205	9	**1998-99**	62,393	2,261	36
1964-65	19,901	268	13	**1999-00**	15,757	1,674	106
1965-66	11,057	111	10	**2000-01**	27,467	1,919	70
1966-67	7,138	1,944	272	**2001-02**	12,439	2,114	170
1967-68	1,567	720	459	**2002-03**	13,869	2,150	155
1968-69	1,599	2,145	1,342	**2003-04**	8,590	1,599	186
1969-70	1,010	498	493	**2004-05**	7,029	2,547	362
1970-71	677	150	222	**2005-06**	7,079	2,300	325
1971-72	590	344	583	**2006-07**	10,437	2,424	232
1972-73	228	223	978	**2007-08**	9,123	1,609	176
1973-74	152	239	1,568	**2008-09**	6,513	425	65

Table A2A-2. Landings (mt) of Pacific mackerel by fishery (1926-08).

Fishing year	USA Commercial (mt)	Mexico Commercial (mt)	Recreational CPFV (mt)	Recreational non-CPFV (mt)	Total (mt)
29	25,716	0	6	11	25,734
30	5,809	0	6	11	5,826
31	6,873	0	6	11	6,890
32	4,922	0	6	11	4,939
33	33,055	0	6	11	33,072
34	51,467	0	6	11	51,484
35	66,400	0	6	11	66,417
36	45,697	0	6	11	45,714
37	31,954	0	13	21	31,988
38	34,502	0	22	38	34,562
39	45,341	0	42	70	45,454
40	48,786	0	30	52	48,868
41	32,547	0	0	13	32,561
42	21,872	0	0	13	21,886
43	35,291	0	0	13	35,305
44	36,644	0	0	13	36,657
45	23,588	0	0	13	23,601
46	26,715	851	1	15	27,582
47	17,975	1,262	75	124	19,437
48	17,329	515	103	178	18,125
49	22,708	1,352	48	81	24,189
50	15,372	2,029	34	58	17,493
51	14,472	1,320	24	41	15,857
52	9,171	1,052	38	64	10,326
53	4,005	1,177	31	53	5,266
54	12,342	5,681	163	278	18,465
55	12,200	9,798	76	127	22,201
56	25,938	10,725	64	108	36,835
57	25,509	2,034	78	132	27,753
58	11,238	449	70	117	11,875
59	18,725	495	39	73	19,332
60	17,724	2,981	42	75	20,823
61	20,094	5,964	52	88	26,199
62	20,527	3,231	58	85	23,901
63	15,517	7,966	86	134	23,703
64	11,283	8,618	33	54	19,988
65	3,442	7,615	84	138	11,279
66	1,848	5,290	97	169	7,405
67	619	948	56	90	1,713
68	1,492	107	37	60	1,695
69	809	201	58	100	1,168
70	277	400	61	98	835
71	90	500	118	203	911
72	28	200	118	186	532
73	52	100	95	154	401
74	43	471	47	73	634
75	141	1,809	75	124	2,149
76	2,654	1,271	69	97	4,092
77	7,748	5,165	314	524	13,751
78	18,446	7,372	501	854	27,173
79	28,755	5,150	804	1149	35,858
80	27,972	4,546	1,277	1409	35,203
81	38,407	7,155	665	757	46,985
82	30,626	4,329	693	723	36,371
83	36,309	4,264	700	844	42,118
84	39,240	5,761	612	855	46,468
85	37,615	8,197	524	492	46,828
86	44,298	8,965	386	474	54,123
87	44,838	2,120	245	1020	48,223
88	41,968	6,608	181	507	49,265
89	25,063	23,724	167	451	49,406
90	39,974	30,961	230	386	71,551
91	30,268	34,557	252	429	65,505
92	25,584	6,170	135	329	32,217
93	10,787	9,524	196	413	20,920
94	9,372	13,302	226	837	23,737
95	7,615	3,368	439	574	11,996
96	9,788	14,089	320	366	24,563
97	23,413	26,860	104	700	51,076
98	19,578	42,815	108	322	62,823
99	7,170	8,587	55	97	15,910
00	20,936	6,530	78	248	27,792
01	8,436	4,003	51	520	13,010
02	3,541	10,328	22	232	14,123
03	5,972	2,618	28	295	8,913
04	5,012	2,017	23	510	7,562
05	4,572	2,507	21	375	7,475
06	7,870	2,567	15	356	10,808
07	6,208	2,914	18	289	9,429
08	3,599	2,914	19	272	6,803

Table A2A-3. Catch-at-age from ASAP (2009) model (1929-08).

Fishing Year	0	1	2	3	4	5	6	7	8+
29	9	12,434	22,467	20,819	5,208	3,875	3,198	1,273	507
30	0	1,393	7,164	4,838	1,916	670	44	17	7
31	0	957	9,991	6,190	1,307	753	371	148	59
32	0	144	3,222	5,845	1,394	940	489	195	77
33	0	4,620	19,017	31,887	23,363	8,277	2,731	1,087	433
34	0	4,894	53,354	35,598	40,808	15,508	5,669	2,257	898
35	0	10,872	12,737	61,704	63,820	33,633	6,206	2,470	983
36	0	2,248	20,404	17,399	33,062	35,159	5,252	2,091	832
37	129	1,476	2,592	8,035	15,910	26,039	7,865	3,131	1,246
38	772	11,577	31,967	16,528	4,309	10,884	6,608	2,631	1,047
39	1,803	23,228	23,713	33,698	11,094	6,310	3,744	1,525	485
40	3,199	18,453	59,415	27,594	17,025	2,514	686	114	0
41	638	18,397	31,228	28,818	6,522	922	71	71	0
42	0	28,455	10,343	15,109	6,149	1,096	143	48	0
43	426	14,144	62,073	10,523	7,413	1,022	170	85	0
44	0	20,800	20,685	35,320	8,873	1,613	230	0	58
45	2,034	15,337	12,076	8,920	8,320	4,825	1,930	600	391
46	3,290	16,673	20,262	11,041	6,704	4,287	1,819	1,097	548
47	7,427	4,646	10,460	9,228	6,068	3,508	1,896	695	221
48	2,723	37,273	9,107	3,662	4,037	1,408	657	282	94
49	566	21,983	36,329	9,173	3,071	1,980	808	121	81
50	44	6,588	17,066	17,154	3,183	531	398	44	44
51	1,031	4,005	6,860	11,816	11,301	674	238	79	79
52	510	324	1,992	1,992	8,709	4,679	93	46	0
53	11,077	2,069	1,339	1,380	568	812	771	0	0
54	694	47,800	10,177	2,159	1,234	0	308	154	0
55	15,608	17,731	25,097	10,738	1,124	125	250	125	375
56	420	54,867	22,555	19,093	8,812	315	0	0	0
57	1,996	7,915	30,079	10,875	8,535	3,029	1,308	344	0
58	11,505	2,666	4,595	7,401	3,157	1,438	912	0	0
59	1,690	46,897	7,774	3,633	2,450	1,014	254	0	0
60	1,629	12,726	17,002	10,181	5,091	1,731	1,324	0	0
61	7,345	28,680	15,564	14,690	5,771	1,224	525	0	0
62	739	23,299	12,554	10,472	7,072	1,421	187	0	0
63	284	6,843	18,432	10,339	8,843	2,842	425	0	0
64	1,389	7,716	6,521	9,629	10,969	4,240	715	0	0
65	13,074	1,265	767	1,701	5,525	8,677	1,563	0	0
66	3,689	8,093	1,458	1,168	992	2,240	1,220	91	0
67	4,530	1,003	88	632	228	163	192	45	4
68	7,418	499	221	353	89	86	68	52	37
69	46	2,354	606	221	71	61	9	0	0
70	1,405	3,004	0	0	0	0	0	0	0
71	0	2,853	224	10	12	8	0	0	0
72	1,319	197	293	318	9	7	0	0	0
73	50	547	153	33	75	88	49	2	2
74	2,154	769	244	39	13	0	0	0	0
75	130	6,335	90	66	2	4	2	0	0
76	13,974	164	1,763	1	23	0	27	0	0
77	11,071	36,734	78	287	0	0	0	0	0
78	73,773	18,837	28,598	1,166	1,006	257	0	0	0
79	27	102,762	14,944	15,204	222	675	0	0	0
80	63,978	3,376	77,514	8,221	7,379	407	126	0	0
81	19,073	45,822	10,974	69,210	4,792	3,067	76	123	0
82	16,129	36,225	33,231	9,921	31,045	2,318	768	0	0
83	2,841	2,812	44,336	40,174	6,319	17,770	251	0	0
84	2,875	533	9,589	48,965	25,204	6,271	7,986	198	0
85	3,251	17,478	5,189	16,256	50,114	10,704	1,389	1,047	0
86	18,857	44,528	23,016	5,276	9,002	25,599	7,435	1,024	1,085
87	18,059	71,920	32,698	5,326	2,862	3,517	4,718	2,064	849
88	104,977	15,168	36,143	13,133	2,849	1,943	2,574	4,155	3,178
89	21,821	161,291	8,376	6,715	4,513	2,718	2,543	867	1,677
90	29,559	19,434	43,284	11,974	16,878	19,588	8,229	6,546	8,187
91	27,181	91,782	21,912	21,684	10,412	9,327	6,709	3,023	4,448
92	11,121	30,147	12,343	9,853	10,637	8,100	5,594	2,629	1,025
93	51,845	9,383	10,677	3,440	3,366	5,043	2,885	2,893	1,651
94	25,604	38,016	9,946	4,530	5,751	3,022	1,869	1,485	606
95	46,200	21,302	5,281	983	552	1,417	759	529	336
96	28,944	43,914	12,554	6,006	3,741	2,567	1,368	1,073	756
97	24,318	49,846	32,822	12,959	8,404	7,622	4,901	4,166	6,853
98	13,603	19,878	38,777	23,702	15,523	13,343	10,668	6,472	7,980
99	11,997	2,949	2,680	6,120	5,834	4,447	1,946	1,330	966
00	29,467	15,355	5,178	8,769	10,300	6,638	2,845	1,141	630
01	14,207	20,422	3,517	1,951	2,408	2,134	984	555	299
02	7,247	51,289	5,176	1,192	228	365	253	0	0
03	21,539	10,745	3,701	1,342	518	449	249	55	65
04	36,128	3,915	1,147	755	276	41	28	15	28
05	41,331	6,563	2,595	445	181	108	40	17	0
06	31,524	17,158	3,649	1,682	709	269	188	97	0
07	22,924	10,607	4,575	3,125	1,197	594	189	70	0
08	14,385	7,130	3,684	2,837	1,309	527	207	31	0

Table A2A-4. Weight-at-age from the ASAP (2009) model (1929-08).

Fishing Year	0	1	2	3	4	5	6	7	8+
29	0.074	0.167	0.297	0	0.523	0.615	1	0.8	0.83
30	0.06	0.139	0.301	0	0.511	0.603	1	0.8	0.83
31	0.077	0.114	0.276	0	0.527	0.606	1	0.8	0.83
32	0.058	0.081	0.277	0	0.508	0.604	1	0.8	0.83
33	0.059	0.083	0.2	0	0.493	0.585	1	0.8	0.83
34	0.065	0.142	0.198	0	0.431	0.538	1	0.8	0.83
35	0.079	0.186	0.217	0	0.379	0.472	1	0.79	0.83
36	0.086	0.193	0.284	0	0.393	0.453	1	0.75	0.82
37	0.119	0.176	0.318	0	0.461	0.502	1	0.74	0.8
38	0.124	0.174	0.31	0	0.532	0.582	1	0.726	0.79
39	0.191	0.246	0.363	0	0.583	0.68	1	0.795	0.878
40	0.18	0.26	0.339	0	0.527	0.64	1	0.834	0.82
41	0.115	0.259	0.343	0	0.559	0.65	1	0.807	0.85
42	0.18	0.236	0.373	0	0.546	0.626	1	0.909	0.83
43	0.165	0.292	0.339	0	0.574	0.65	1	0.881	1
44	0.144	0.271	0.379	0	0.587	0.66	1	0.735	0.948
45	0.121	0.234	0.383	0	0.611	0.704	1	0.819	0.842
46	0.125	0.261	0.384	0	0.617	0.679	1	0.778	0.812
47	0.119	0.291	0.4	0	0.622	0.709	1	0.788	0.818
48	0.107	0.227	0.354	1	0.616	0.706	1	0.895	0.871
49	0.109	0.192	0.319	0	0.607	0.725	1	0.917	0.917
50	0.084	0.249	0.323	0	0.564	0.664	1	0.799	0.871
51	0.162	0.255	0.346	0	0.569	0.694	1	0.835	0.853
52	0.173	0.297	0.386	0	0.568	0.719	1	0.988	0.85
53	0.162	0.296	0.411	1	0.603	0.763	1	0.85	1.1
54	0.084	0.257	0.387	1	0.585	0.744	1	0.879	0.87
55	0.14	0.253	0.357	0	0.583	0.744	1	0.778	0.878
56	0.111	0.248	0.373	0	0.598	0.752	1	0.91	0.87
57	0.179	0.31	0.374	1	0.602	0.649	1	0.7	1
58	0.176	0.292	0.396	0	0.617	0.685	1	0.75	0.75
59	0.132	0.251	0.398	1	0.602	0.702	1	0.84	0.85
60	0.102	0.276	0.391	1	0.611	0.699	1	0.82	0.87
61	0.144	0.252	0.389	0	0.584	0.647	1	0.83	0.85
62	0.276	0.32	0.42	1	0.622	0.712	1	0.89	0.86
63	0.197	0.298	0.434	1	0.627	0.73	1	0.84	0.93
64	0.181	0.3	0.4	1	0.612	0.748	1	0.82	0.87
65	0.109	0.195	0.384	1	0.596	0.723	1	0.88	0.85
66	0.149	0.273	0.419	1	0.658	0.79	1	0.85	0.93
67	0.166	0.235	0.488	1	0.599	0.723	1	0.917	0.849
68	0.138	0.266	0.391	1	0.593	0.709	1	0.952	1.07
69	0.103	0.322	0.428	1	0.662	0.746	1	1	1.1
70	0.099	0.232	0.402	1	0.73	0.837	1	1	1.2
71	0.266	0.282	0.457	0	0.74	0.955	1	0.9	1.2
72	0.147	0.266	0.449	1	0.552	0.746	1	0.9	1.1
73	0.119	0.329	0.433	1	0.606	0.686	1	0.803	0.838
74	0.107	0.303	0.604	1	0.837	0.8	1	0.8	1
75	0.127	0.361	0.517	1	1.053	1.029	1	0.9	0.9
76	0.17	0.297	0.672	1	1.291	1.223	2	1.2	1
77	0.122	0.322	0.6	1	1.063	1.1	1	1.5	1.3
78	0.062	0.334	0.473	1	0.908	1.1	1	1.4	1.6
79	0.082	0.189	0.44	1	0.81	0.969	1	1.3	1.5
80	0.072	0.176	0.27	0	0.598	0.874	1	1.3	1.4
81	0.083	0.19	0.239	0	0.597	0.715	1	0.929	1.4
82	0.032	0.151	0.237	0	0.516	0.773	1	1	1.2
83	0.049	0.191	0.302	0	0.458	0.511	1	0.9	1.1
84	0.12	0.235	0.351	0	0.505	0.614	1	0.871	0.91
85	0.157	0.285	0.418	0	0.484	0.56	1	0.697	0.85
86	0.148	0.29	0.408	1	0.561	0.595	1	0.719	0.784
87	0.133	0.272	0.414	1	0.6	0.691	1	0.766	0.826
88	0.101	0.301	0.415	1	0.666	0.734	1	0.815	0.899
89	0.104	0.193	0.381	1	0.647	0.749	1	0.739	0.827
90	0.094	0.267	0.377	1	0.649	0.68	1	0.775	0.803
91	0.071	0.217	0.397	1	0.591	0.664	1	0.766	0.799
92	0.087	0.175	0.33	0	0.544	0.661	1	0.725	0.805
93	0.073	0.228	0.294	0	0.583	0.607	1	0.756	0.832
94	0.1	0.156	0.248	0	0.493	0.597	1	0.733	0.785
95	0.081	0.179	0.275	0	0.586	0.689	1	0.758	0.92
96	0.105	0.182	0.318	0	0.589	0.649	1	0.705	0.751
97	0.149	0.239	0.333	0	0.572	0.637	1	0.718	0.749
98	0.139	0.267	0.325	0	0.53	0.615	1	0.667	0.689
99	0.148	0.228	0.399	1	0.575	0.633	1	0.754	0.768
00	0.114	0.266	0.37	1	0.59	0.608	1	0.712	0.731
01	0.103	0.253	0.347	1	0.567	0.619	1	0.635	0.627
02	0.133	0.218	0.303	0	0.552	0.687	1	0.728	0.65
03	0.125	0.284	0.414	1	0.679	0.745	1	0.794	0.838
04	0.159	0.28	0.407	1	0.685	0.821	1	0.639	0.902
05	0.106	0.267	0.38	0	0.556	0.665	1	0.797	0.797
06	0.126	0.222	0.353	1	0.752	0.824	1	0.918	0.918
07	0.102	0.22	0.34	1	0.639	0.808	1	0.94	0.94
08	0.108	0.213	0.278	0	0.645	0.78	1	0.948	0.948

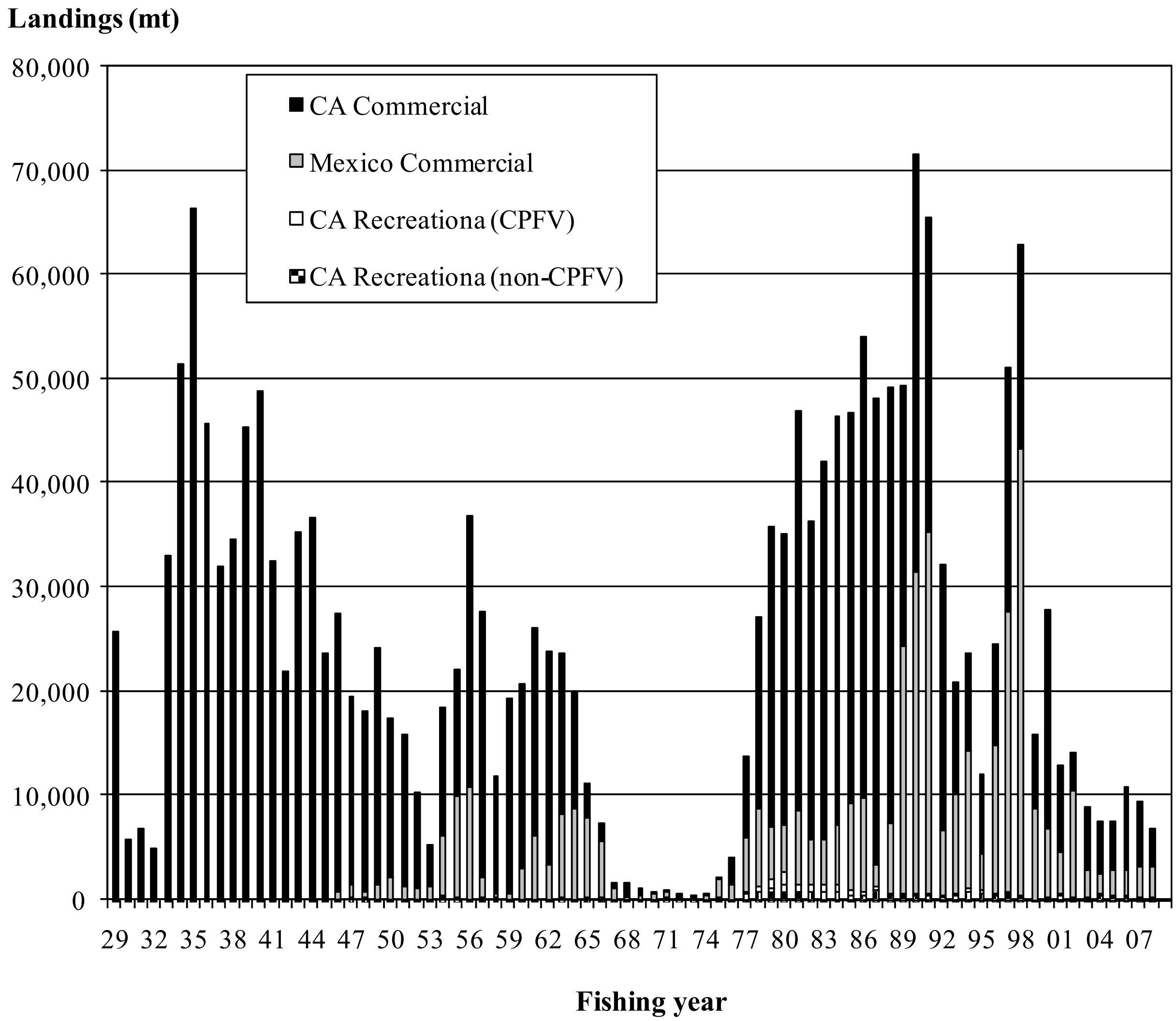


Figure A2A-1. Commercial and recreational landings (mt) of Pacific mackerel in the USA (CA commercial, recreational-CPFV, and recreational-non-CPFV) and Mexico (commercial), (1929-08).

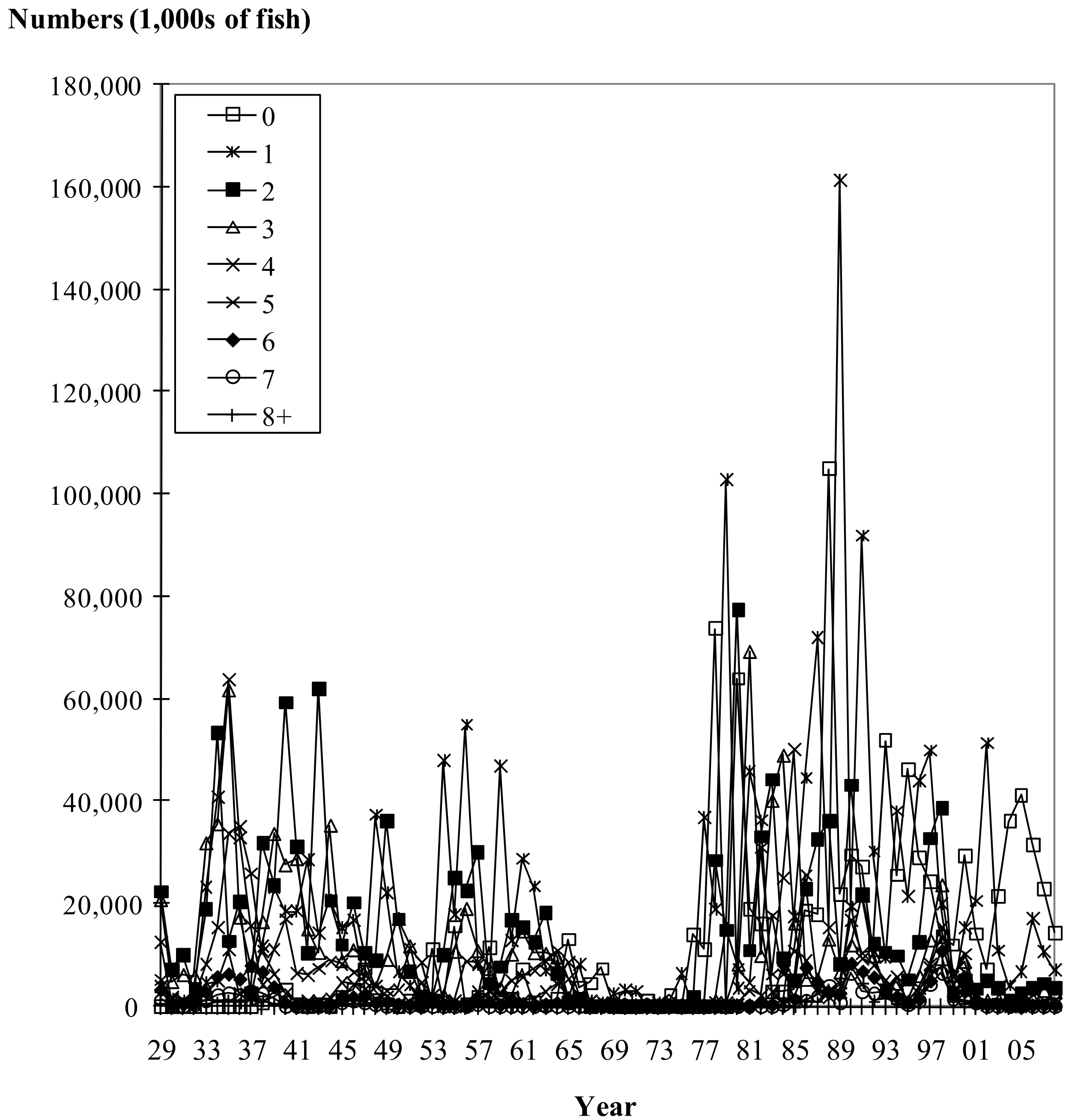


Figure A2A-2. Pacific mackerel catch-at-age (numbers of fish in 1,000s) estimates used in the ASAP (2009) model (1929-08).

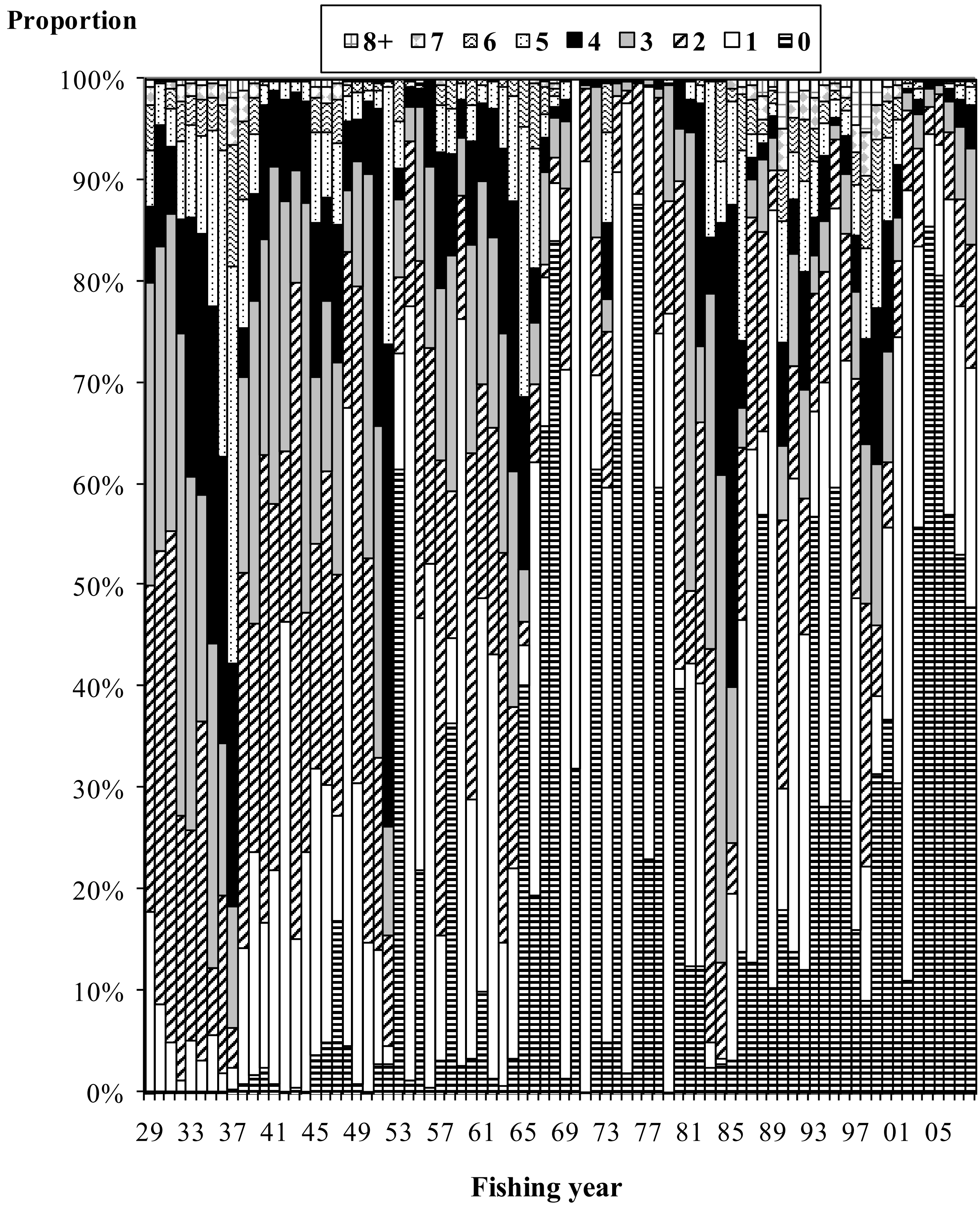
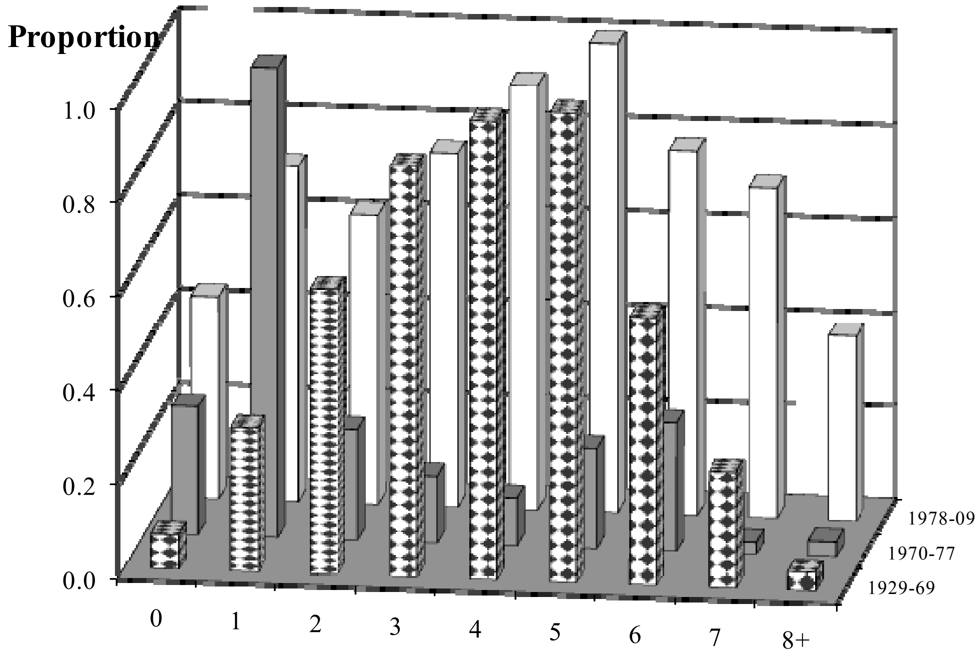


Figure A2A-3. Pacific mackerel catch-at-age (in proportion) estimates used in the ASAP (2009) model (1929-08).



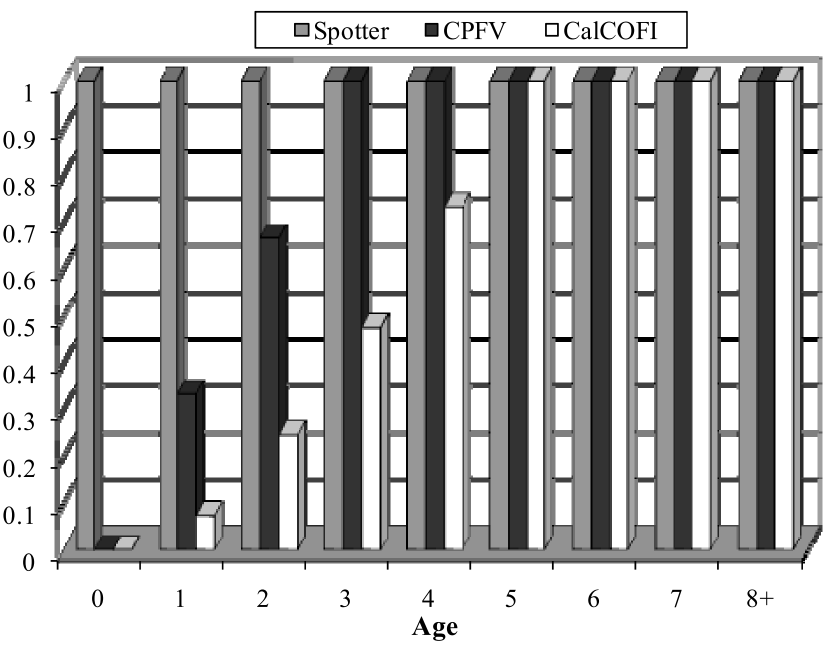


Figure A2A-4. Estimated selectivity schedule for fishery (catch-at-age) data (top display) and assumed selectivity ogives for survey-related indices of abundance (Spotter, CPFV, and CalCOFI) from the ASAP (2009) model. Note that CPFV ogive represents (1990-09), with ogive for 1929-89 parameterized with slightly different probabilities for ages 1 and 2.

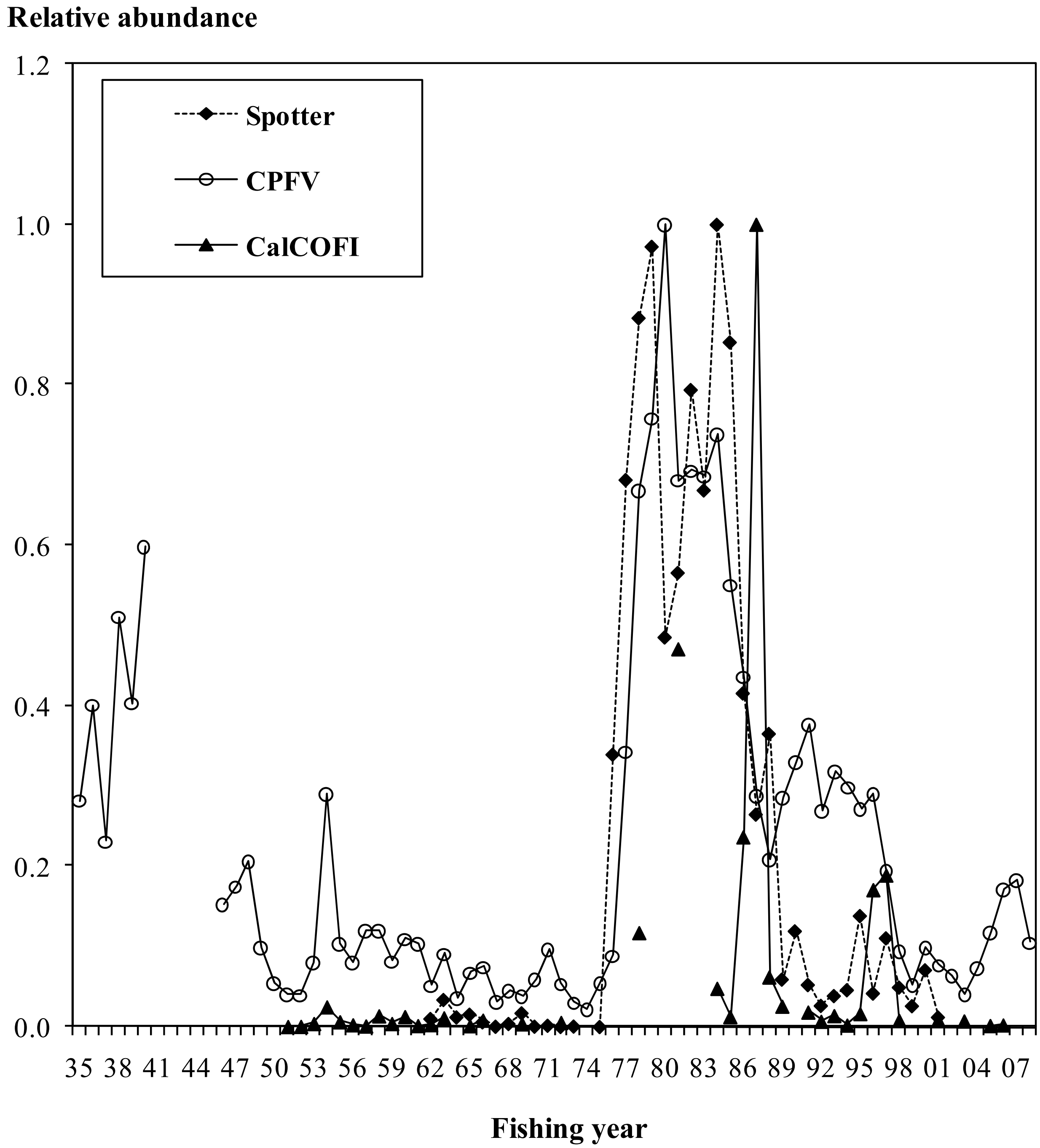


Figure A2A-5. Indices of abundance time series for Pacific mackerel used in the ASAP (2009) model (1929-08). Indices are rescaled (normalized).

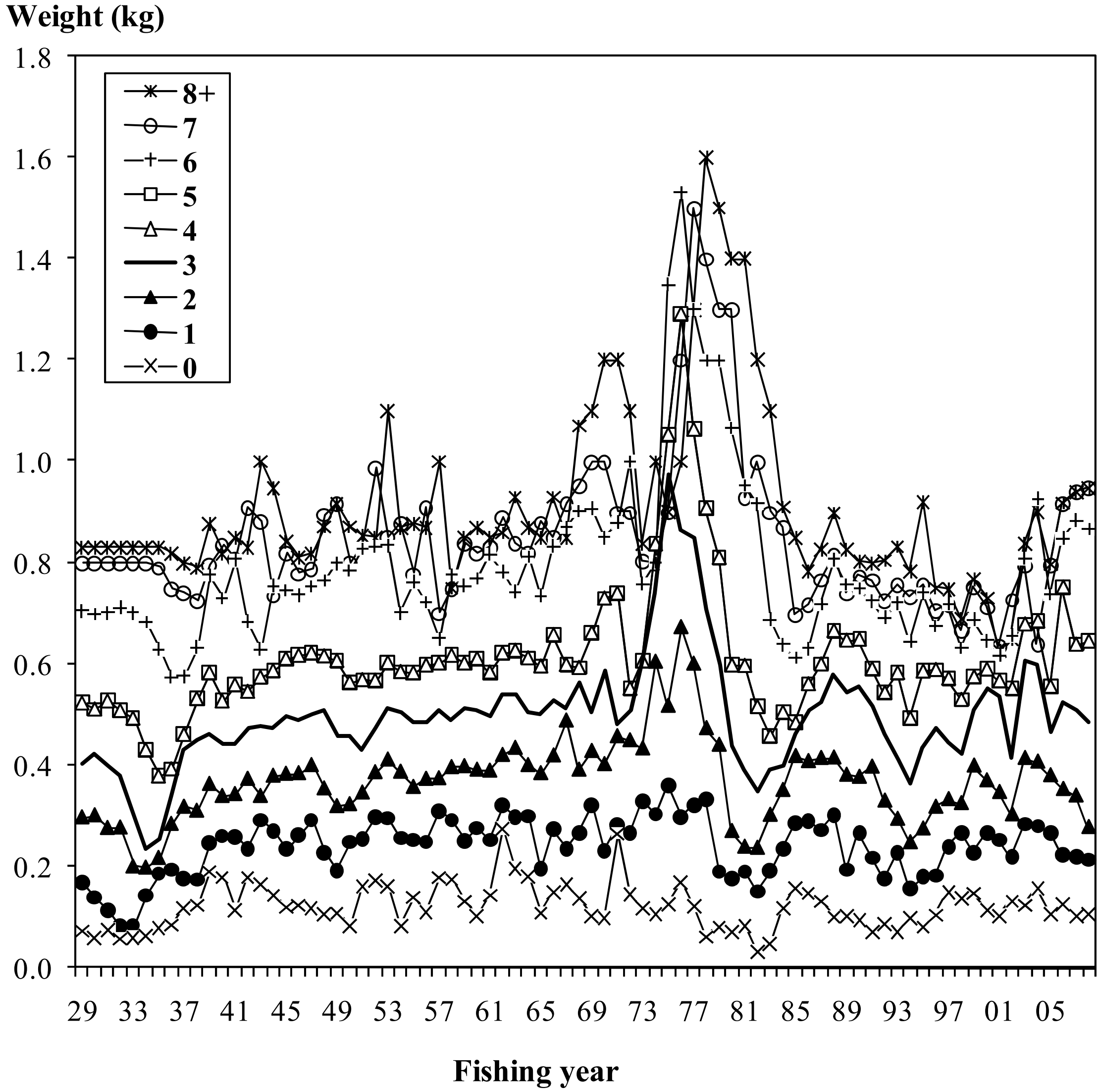


Figure A2A-6. Pacific mackerel weight-at-age (kg) estimates used in the ASAP (2009) model (1929-08).

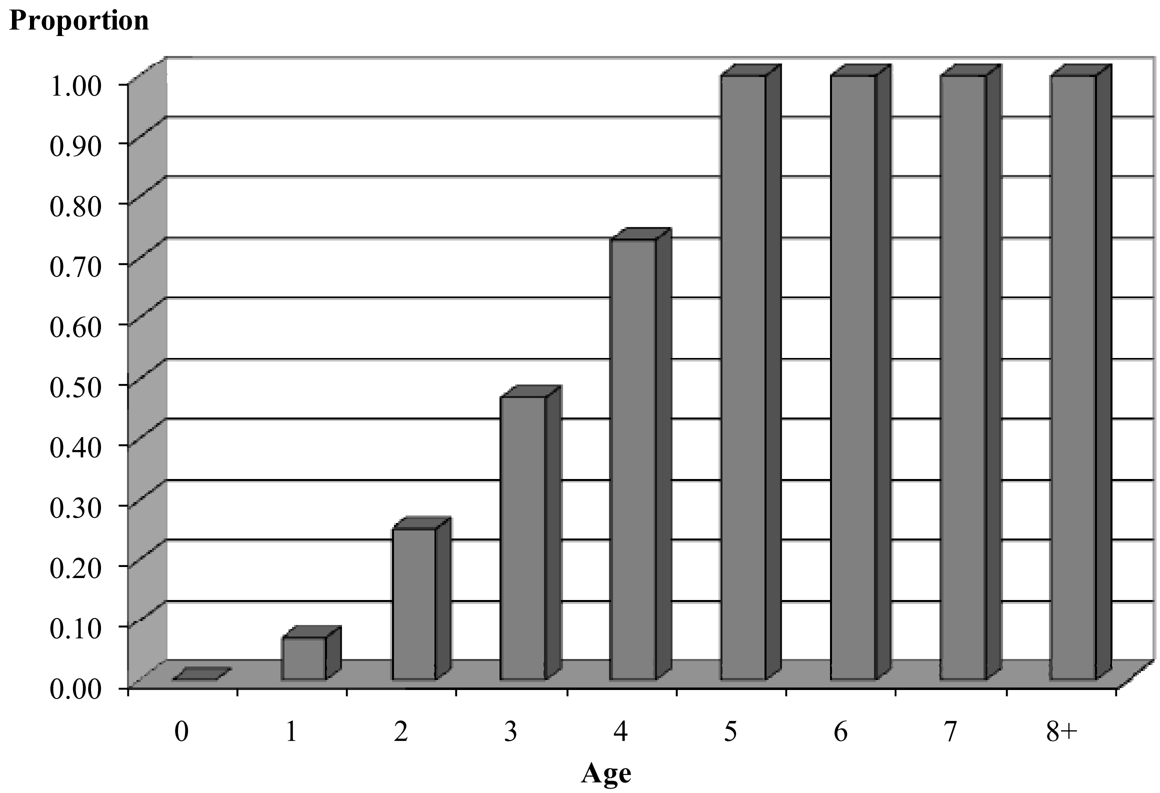


Figure A2A-7. Pacific mackerel maturity schedule used in the ASAP (2009) model.

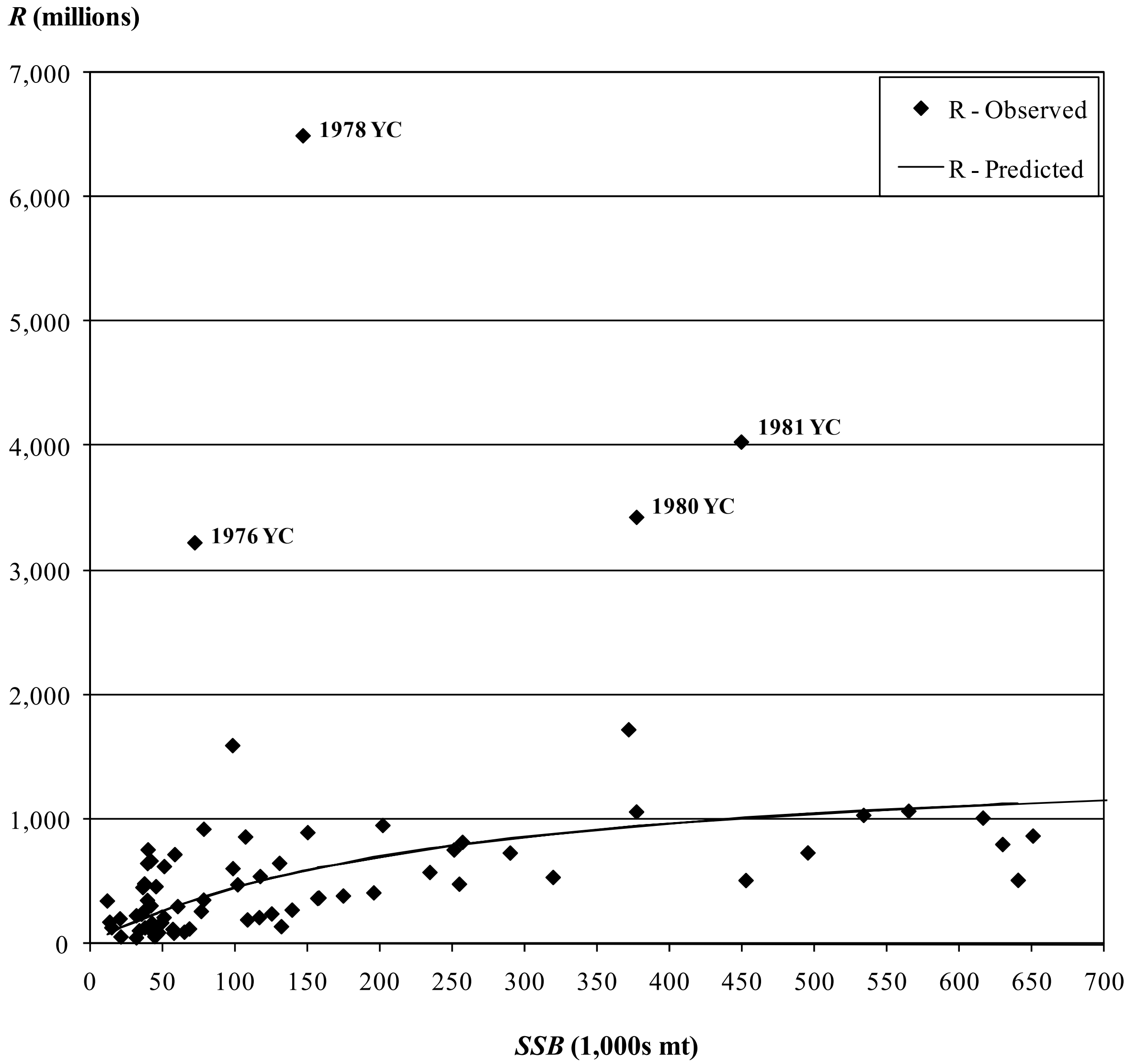


Figure A2A-8. Beverton-Holt stock (SSB in 1000s mt)-recruitment (R in millions of fish) relationship for Pacific mackerel estimated in the ASAP (2009) model (1929-09). Recruitment estimates are presented as (year+1) values. Strong year classes are highlighted. Steepness=0.31.

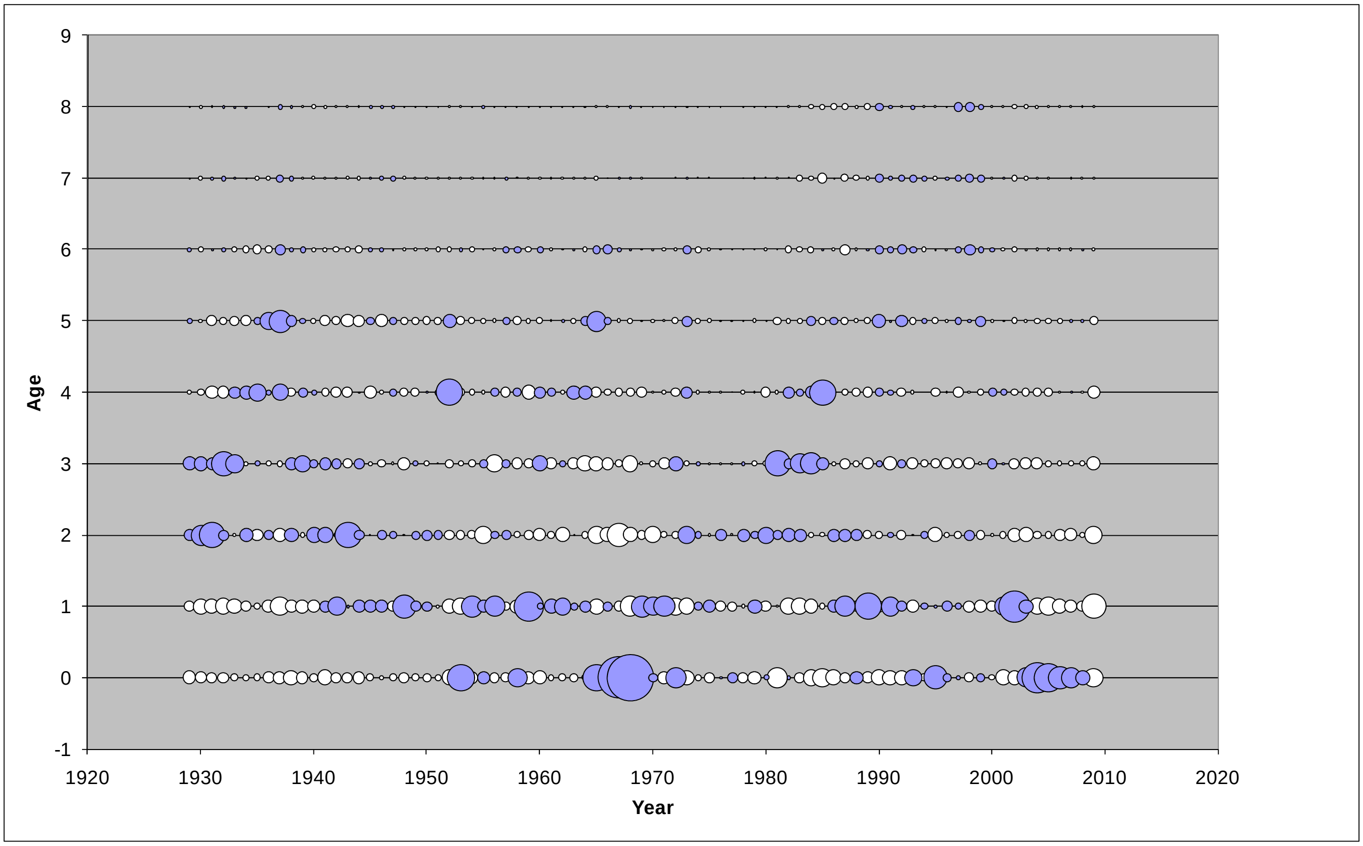


Figure A2A-9. Residual plot of catch-at-age fits associated with the ASAP (2009) model (1929-08). Grey-shaded bubbles indicate positive values and white bubbles indicate negative values.

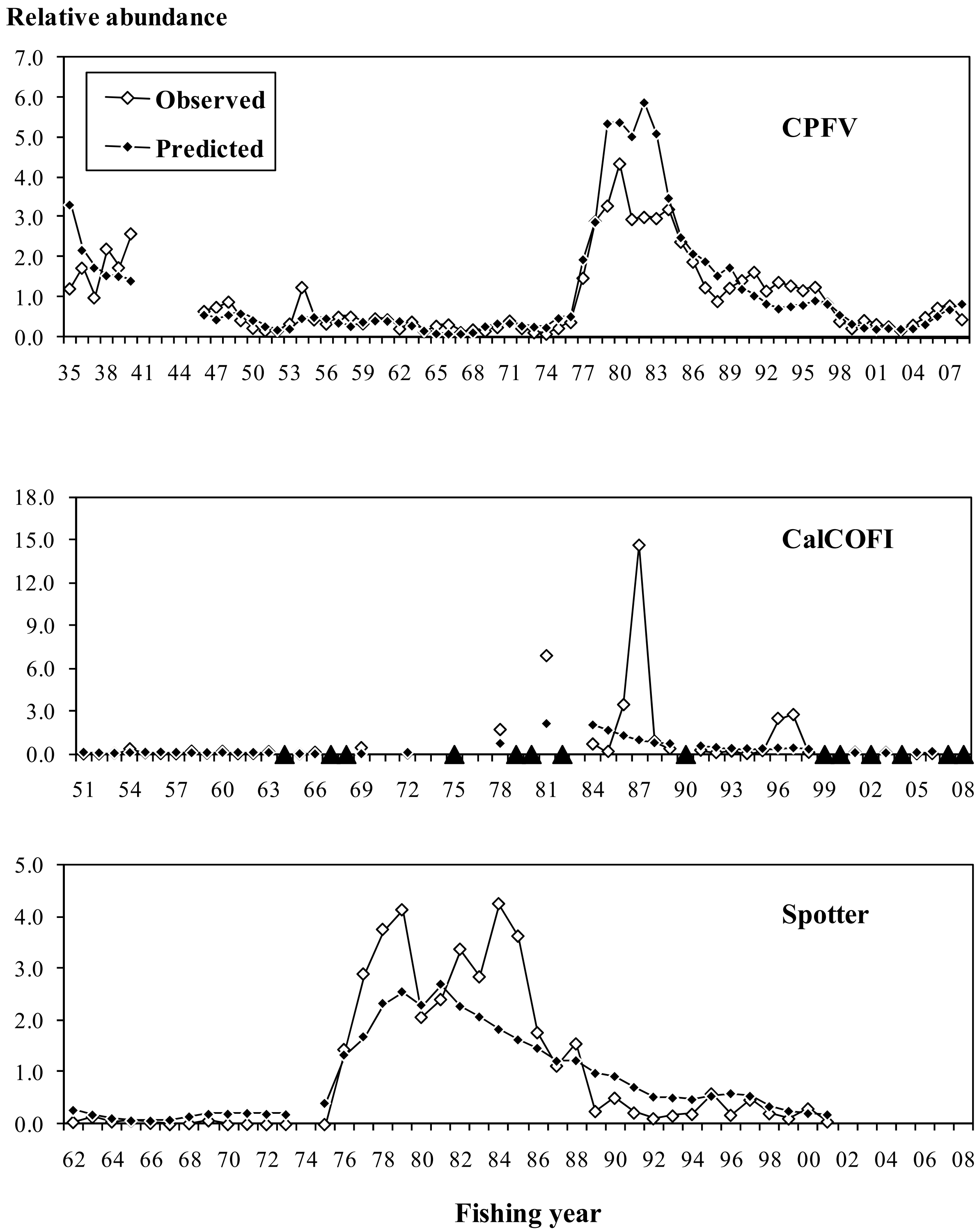


Figure A2A-10. Observed and predicted estimates from survey index fits generated from the ASAP (2009) model (1929-08): CPFV; CalCOFI (solid triangles reflect years that survey was conducted, but no observations); and Spotter.

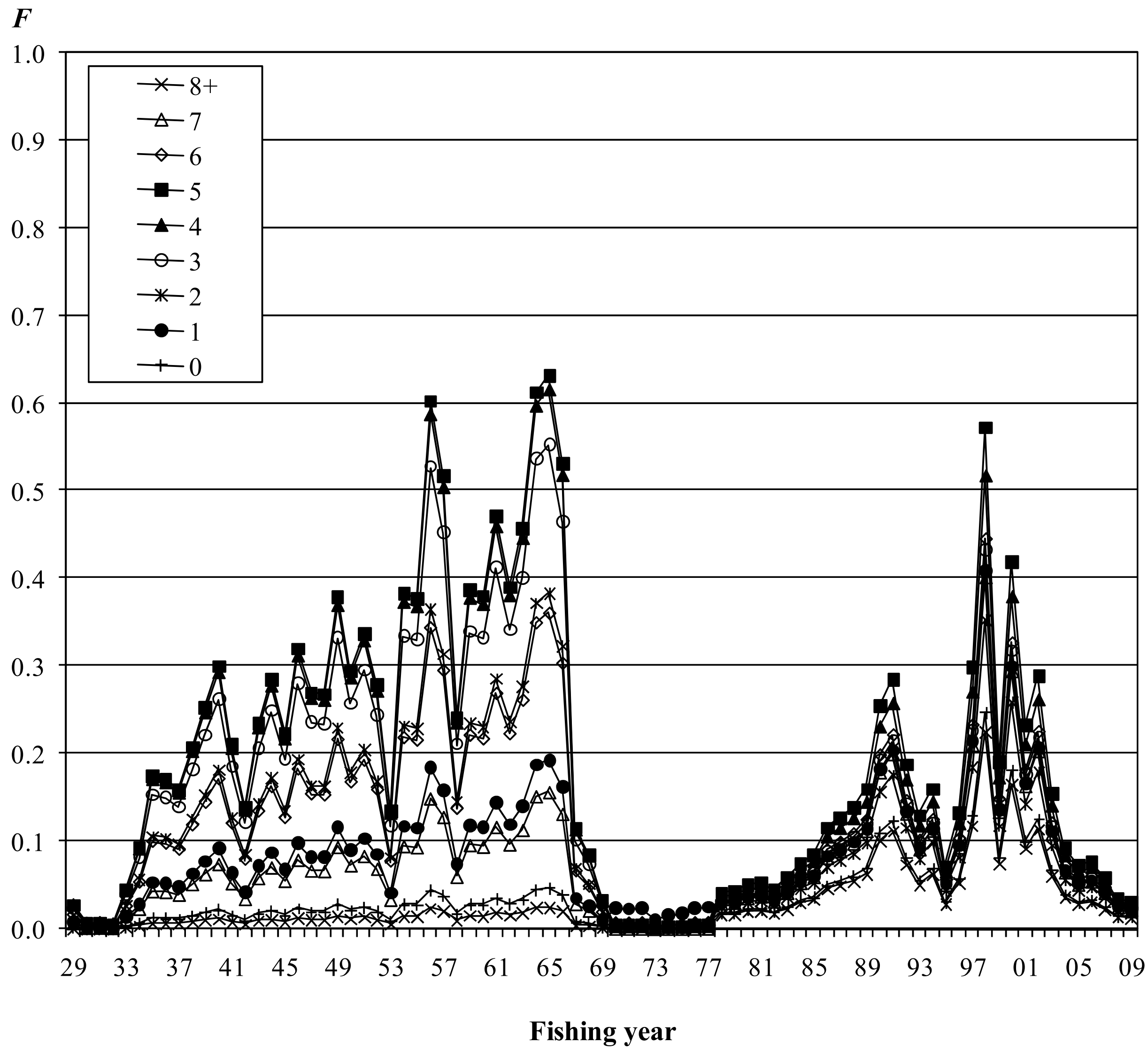


Figure A2A-11. Estimated (total) fishing mortality (*F*-at-age) for Pacific mackerel based on the ASAP (2009) model (1929-09).

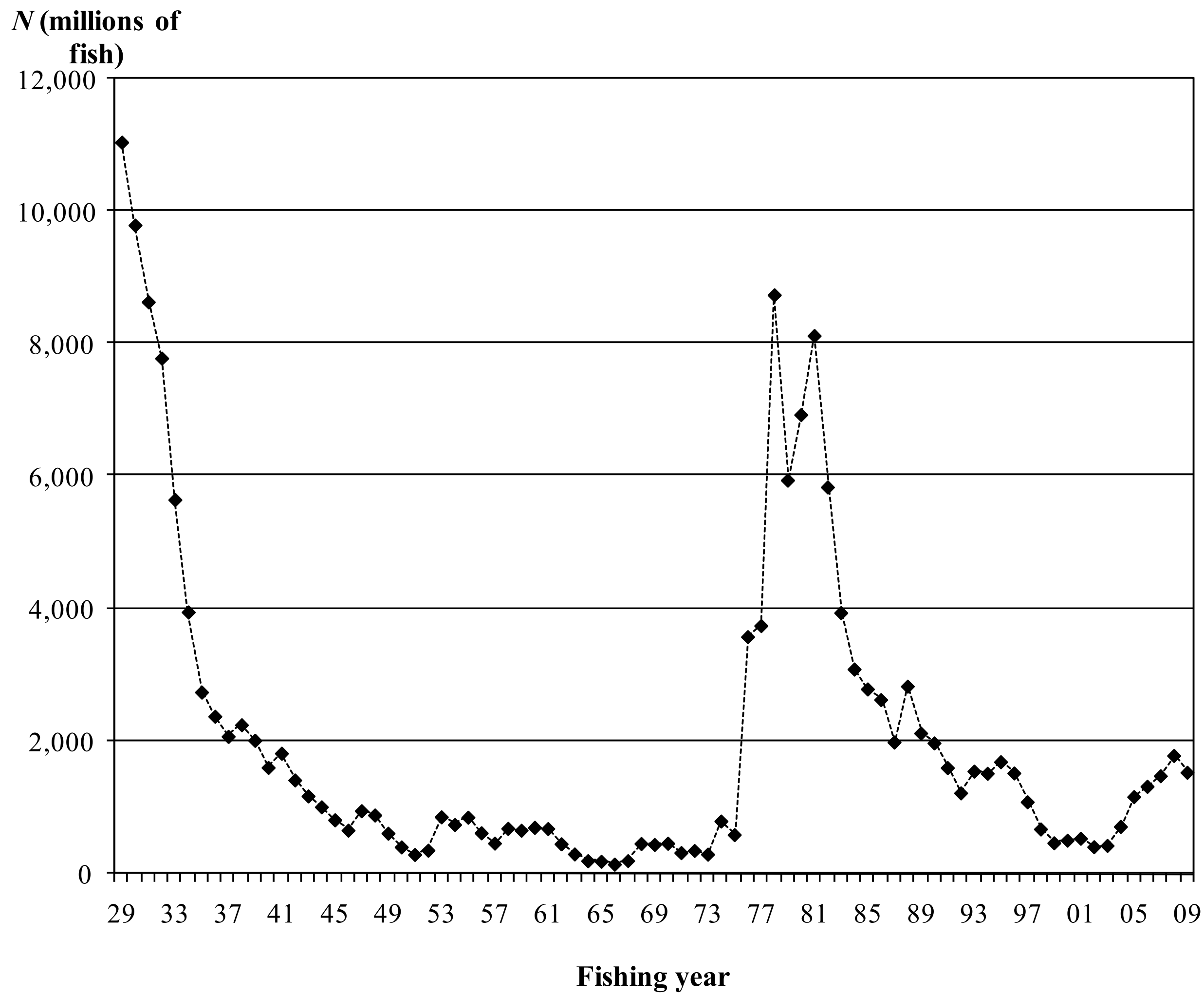


Figure A2A-12. Estimated total population abundance (*N* in millions of fish) of Pacific mackerel based on the ASAP (2009) model (1929-09).

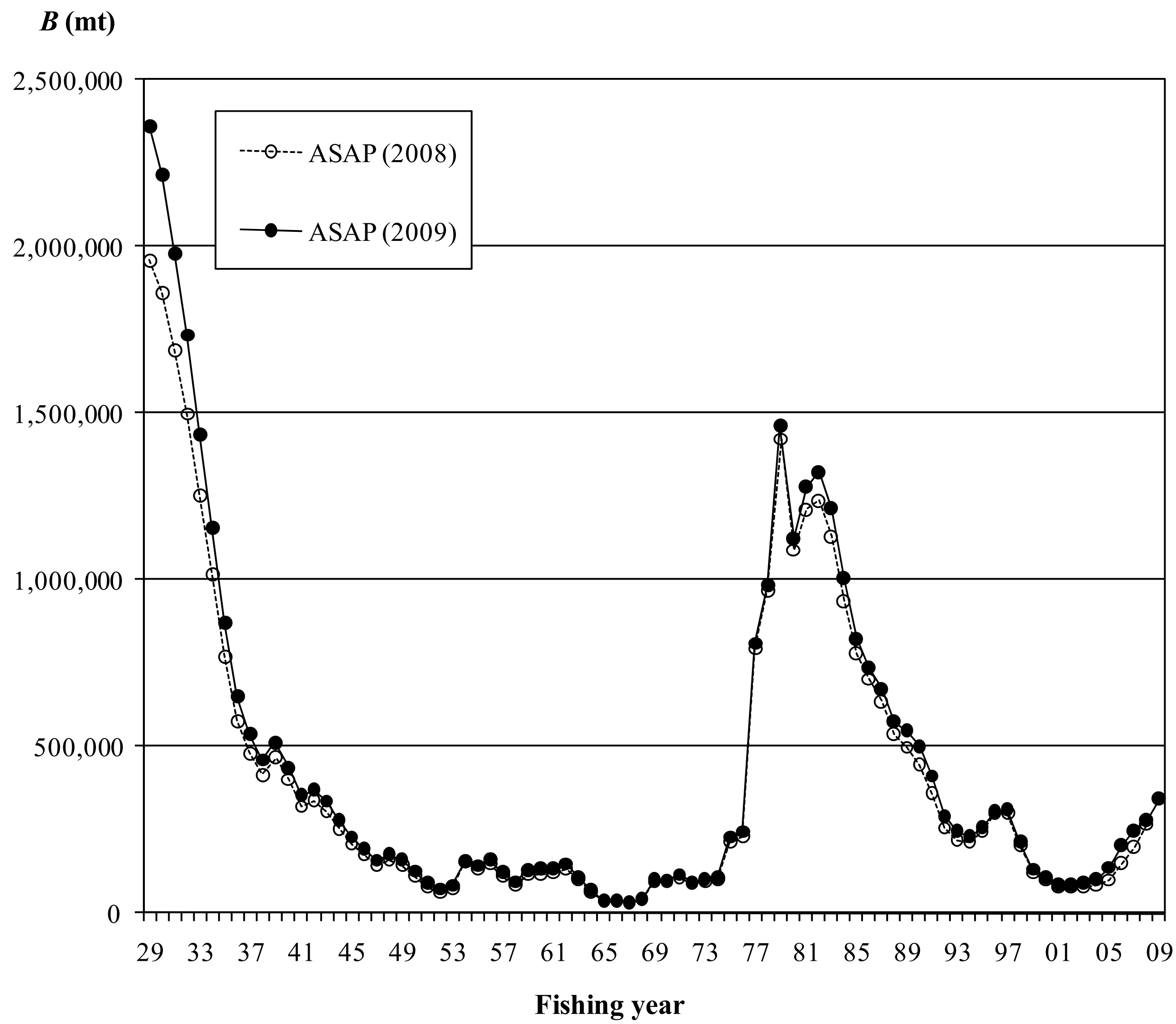


Figure A2A-13. Estimated total stock biomass (age 1+ fish in mt, *B*) of Pacific mackerel based on the ASAP (2009) model (1929-09). Estimated *B* for the ASAP (2008) final model is also presented.

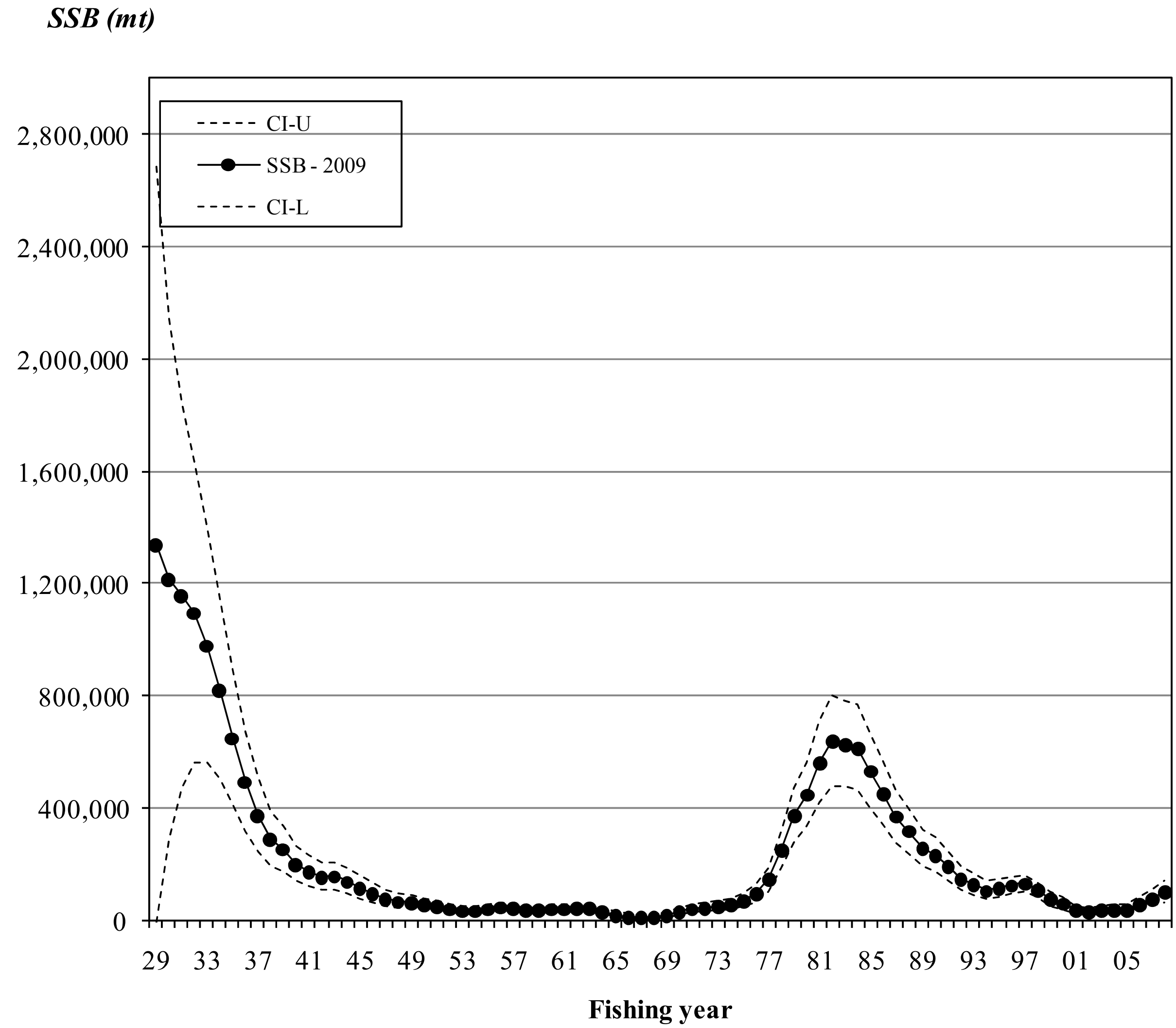


Figure A2A-14. Estimated spawning stock biomass of Pacific mackerel based on the ASAP (2009) model (1929-08). Confidence interval (± 2 SD) is also presented.

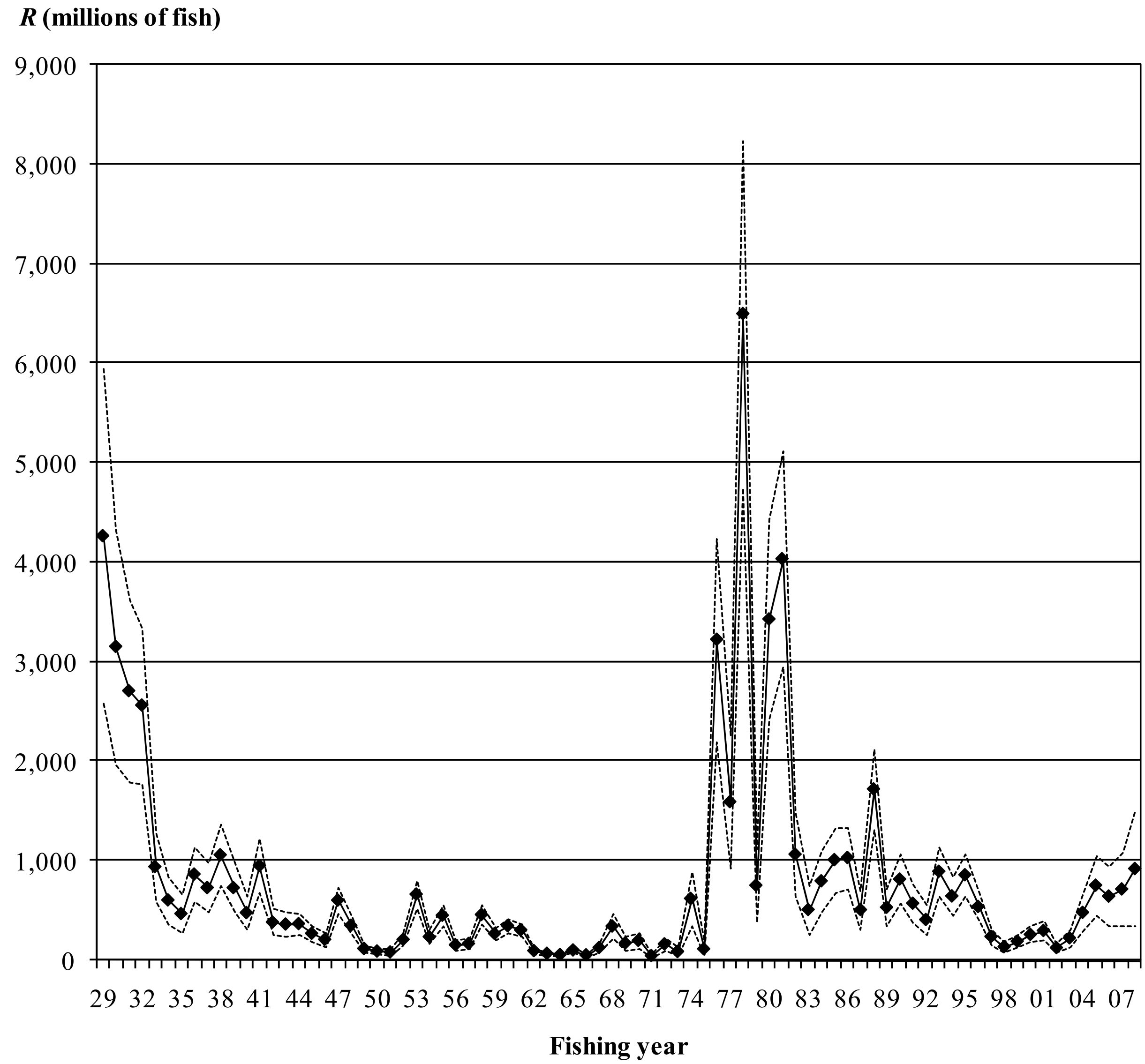


Figure A2A-15. Estimated recruitment (age-0 fish in millions, R) of Pacific mackerel based on the ASAP (2009) model (1929-08). Confidence interval (± 2 SD) is also presented.

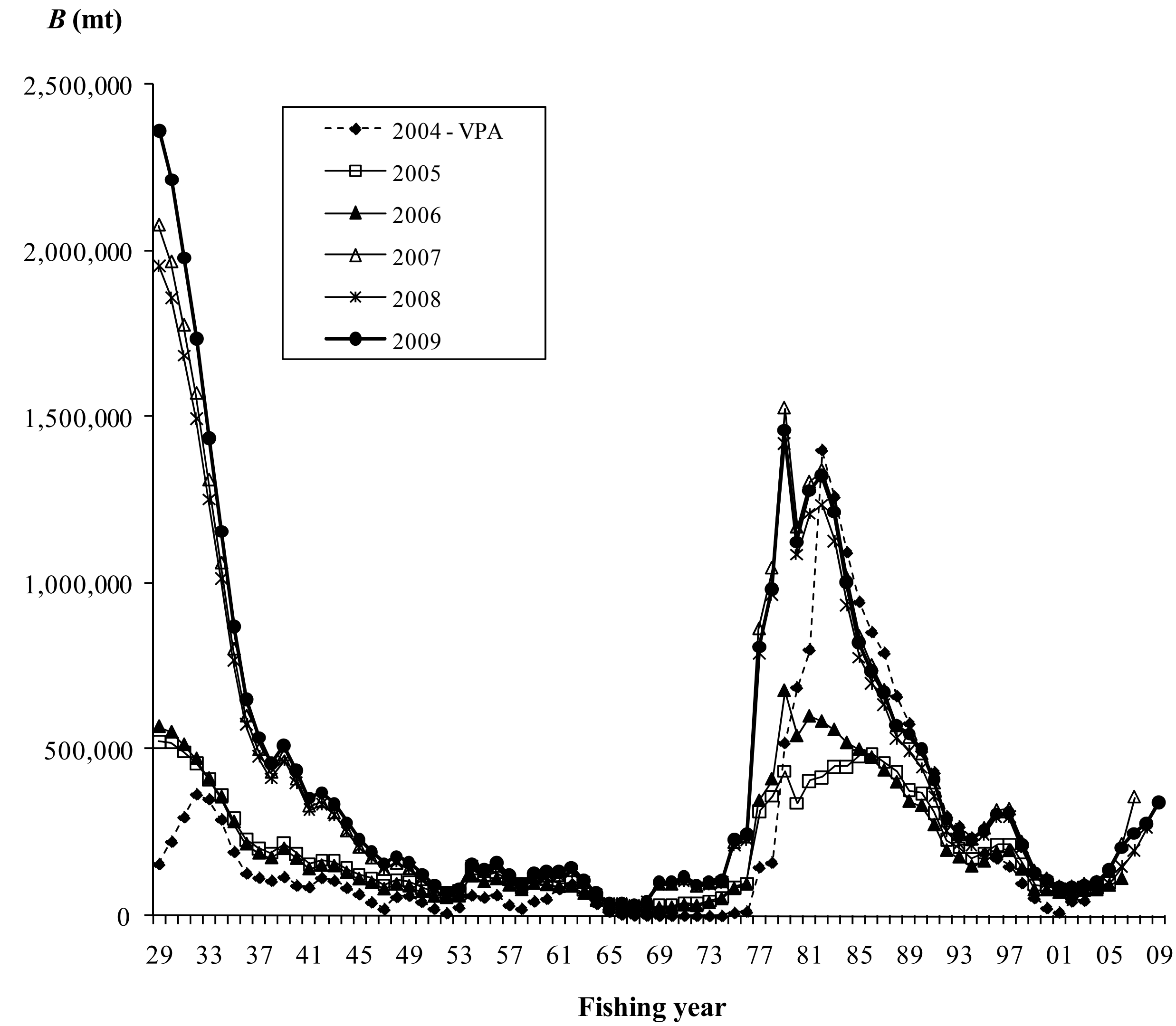


Figure A2A-16. Estimated total stock biomass (*B* age 1+ fish in mt) of Pacific mackerel for historical assessment period (1994-09): VPA model-based assessments from 1994-04; and ASAP model-based from 2005 to the present.

Appendix 2B

SS model (*S1_aa*) displays

Table A2B-1 Summary of model scenarios developed for the Pacific mackerel (2009) assessment, including: (A) new data sources and critical parameterizations for SS and ASAP; (B) likelihood component estimates for SS and and derived quantities of importance for SS and ASAP; and (C) likelihood component estimates for ASAP.

(A)

New Data	*ASAP*	*S1_aa*	*S1_qa*	*S1_qa1*	*S1_qa21*
Landings - USA/Mexico commerical (2003-08) - Fishery 1					
Landings - USA recreational (2008) - Fishery 2					
Age distributions (2008) - USA/Mexico commercial					
Length distributions (2008) - USA recreational					
Mean length-at-age distributions (1962-08) - USA/Mexico commercial					
Spotter survey - Survey 1 [1]					
CPFV survey (2008) - Survey 2					
CalCOFI survey (2008) - daily larval prod. ('missing' years) - Survey 3 [2]					
CalCOFI survey (2008) - daily larval prod. ('zero' years) - Survey 4					
CalCOFI survey (2008) - daily larval prod. (larval density - CA/MX) - Survey 5					
	Model scenarios				
Parameterization	***ASAP***	***S1_aa***	***S1_qa***	***S1_qa1***	***S1_qa21***
Model structure					
Time period	1929-08	1962-08	1962-08	1962-08	1962-08
Number of fisheries	1	2	2	2	2
Number of surveys	3	3	3	3	3
Genders	Combined	Combined	Combined	Combined	Combined
Time-step	Annual	Annual	Quarter	Quarter	Quarter
Biology					
Maturity-at-age	Fixed	Fixed	Fixed	Fixed	Fixed
Length-at-age	Na	Estimated	Estimated	Estimated	Estimated
Weight-length	Na	Fixed	Fixed	Fixed	Fixed
Weight-at-age	Fixed (annual blocks)	Estimated (constant)	Estimated (constant)	Estimated (constant)	Estimated (constant)
Mortality	Fixed (0.5)	Fixed (0.5)	Fixed (0.5)	Fixed (0.5)	Fixed (0.5)
Stock-recruitment					
$\ln(R_0)$	Estimated	Estimated	Estimated	Estimated	Estimated
Offset for initial equilibrium R_1	Na	Estimated	Estimated	Estimated	Estimated
Steepness (*h*)	Estimated	Estimated	Estimated	Estimated	Estimated
σ-*R*	Fixed (0.7)	Fixed (0.7)	Fixed (0.7)	Fixed (0.7)	Fixed (0.7)
Initial conditions for population dynamics					
Age distribution	Non-equilibrium	Non-equilibrium	Non-equilibrium	Non-equilibrium	Non-equilibrium
Fishing mortality (*F*) - Fishery 1[3]	Na	Estimated (F1) and fixed (F2=0.0001)	Estimated (F1) and fixed (F2=0.0001)	Estimated (F1) and fixed (F2=0.0001)	Fixed (F1=0.5 and F2=0.0001)
First year *R* bias adjustment	Na	1958	1958	1958	1958
Selectivity					
Fisheries					
Parameterization	Estimated	Fixed (similar to ASAP)	Fixed (similar to ASAP)	Estimated	Estimated
Time block	Time-varying (3 blocks)	Time-varying (3 blocks)	Time-varying (3 blocks)	Time-varying (3 blocks)	Time-varying (3 blocks)
Shape	Dome-shaped	Dome-shaped	Dome-shaped	Dome-shaped	Dome-shaped
Surveys					
Parameterization	Fixed	Fixed (similar to ASAP)	Fixed (similar to ASAP)	Fixed (S1, S3) and estimated (F1, F2, S2)	Fixed (S1, S4) and estimated (F1, F2, S2)
Time block	One	One	One	One	One
Shape	Asymptotic	Asymptotic	Asymptotic	Asymptotic	Asymptotic
Catchability					
q - Surveys	Median unbiased	Median unbiased	Median unbiased	Median unbiased	Median unbiased

[1] Spotter survey is included under 'New Data' for purposes of continuity only, i.e., survey has not been updated since 2001.

[2] CalCOFI surveys reflect current survey (Survey 3) used in assessment and two alternative surveys (Surveys 4-5) used in sensitivity analysis.

[3] In SS model scenarios, estimated initial fishing mortality is not fit to 'equilibrium' catch, but rather, implemented for purposes of providing a more realistic initial non-equilibrium age composition.

Table A2B-1 (A). Continued.

(A)

New Data	***S1_qa22***	***S1_qa23***	***S1_qa24***	***S1_qa25***	***S1_qa3***
Landings - USA/Mexico commerical (2003-08) - Fishery 1					
Landings - USA recreational (2008) - Fishery 2					
Age distributions (2008) - USA/Mexico commercial					
Length distributions (2008) - USA recreational					
Mean length-at-age distributions (1962-08) - USA/Mexico commercial					
Spotter survey - Survey 1 [1]					
CPFV survey (2008) - Survey 2					
CalCOFI survey (2008) - daily larval prod. ('missing' years) - Survey 3 [2]					
CalCOFI survey (2008) - daily larval prod. ('zero' years) - Survey 4					
CalCOFI survey (2008) - daily larval prod. (larval density - CA/MX) - Survey 5					
	Model scenarios				
Parameterization	***S1_qa22***	***S1_qa23***	***S1_qa24***	***S1_qa25***	***S1_qa3***
Model structure					
Time period	1962-08	1962-08	1962-08	1962-08	1962-08
Number of fisheries	2	2	2	2	2
Number of surveys	3	2	2	1	1
Genders	Combined	Combined	Combined	Combined	Combined
Time-step	Quarter	Quarter	Quarter	Quarter	Quarter
Biology					
Maturity-at-age	Fixed	Fixed	Fixed	Fixed	Fixed
Length-at-age	Estimated	Estimated	Estimated	Estimated	Estimated
Weight-length	Fixed	Fixed	Fixed	Fixed	Fixed (4 blocks)
Weight-at-age	Estimated (constant)	Estimated (constant)	Estimated (constant)	Estimated (constant)	Estimated (constant)
Mortality	Fixed (0.5)	Fixed (0.5)	Fixed (0.5)	Fixed (0.5)	Fixed (0.5)
Stock-recruitment					
$\ln(R_0)$	Estimated	Estimated	Estimated	Estimated	Estimated
Offset for initial equilibrium R_1	Estimated	Estimated	Estimated	Estimated	Estimated
Steepness (*h*)	Estimated	Estimated	Estimated	Estimated	Estimated
σ-*R*	Fixed (0.7)	Fixed (0.7)	Fixed (0.7)	Fixed (0.7)	Fixed (0.7)
Initial conditions for population dynamics					
Age distribution	Non-equilibrium	Non-equilibrium	Non-equilibrium	Non-equilibrium	Non-equilibrium
Fishing mortality (*F*) - Fishery 1[3]	ixed (F1=0.5 and F2=0.000	Estimated (F1) and fixed (F2=0.0001)	Fixed (F1=0.5 and F2=0.0001)	Estimated (F1) and fixed (F2=0.0001)	Estimated (F1) and fixed (F2=0.0001)
First year *R* bias adjustment	1958	1958	1958	1958	1958
Selectivity					
Fisheries					
Parameterization	Estimated	Estimated	Estimated	Estimated	Estimated
Time block	Time-varying (3 blocks)	Time-varying (3 blocks)	Time-varying (3 blocks)	Time-varying (3 blocks)	Time-varying (3 blocks)
Shape	Dome-shaped	Dome-shaped	Dome-shaped	Dome-shaped	Dome-shaped
Surveys					
Parameterization	S1, S5) and estimated (F1,	Fixed (S1) and estimated (F1, F2, S2)	Fixed (S4) and estimated (F1, F2, S2)	Estimated (F1, F2, S2)	Estimated (F1, F2, S2)
Time block	One	One	One	One	One
Shape	Asymptotic	Asymptotic	Asymptotic	Asymptotic	Asymptotic
Catchability					
q - Surveys	Median unbiased	Median unbiased	Median unbiased	Median unbiased	Median unbiased

[1] Spotter survey is included under 'New Data' for purposes of continuity only, i.e., survey has not been updated since 2001.

[2] CalCOFI surveys reflect current survey (Survey 3) used in assessment and two alternative surveys (Surveys 4-5) used in sensitivity analysis.

[3] In SS model scenarios, estimated initial fishing mortality is not fit to 'equilibrium' catch, but rather, implemented for purposes of providing a more realistic initial non-equilibrium age composition.

Table A2B-1 (B). Continued.

(B)

Likelihood component	***ASAP***	***S1_aa***	***S1_qa***	***S1_qa1***	***S1_qa21***	***S1_qa22***	***S1_qa23***	***S1_qa24***	***S1_qa25***	***S1_qa3***
Biological distributions										
Age distributions										
USA/Mexico commercial - Fishery 1		711.13	1,326.01	1,311.89	1,307.57	1,315.84	1,313.49	1,309.05	1,317.69	1,317.73
Length distributions										
USA recreational - Fishery 2		Na	Na	296.82	297.23	297.32	295.69	297.29	295.36	295.38
Length-at-age distributions										
USA/Mexico commercial - Fishery 1		519.81	1,738.41	1,744.80	1,746.96	1,742.57	1,742.78	1,742.77	1,740.08	1,740.13
Surveys										
Spotter - Survey 1		80.80	83.47	79.77	80.20	83.35	82.18	Na	Na	Na
CPFV - Survey 2		14.68	15.80	18.29	23.73	16.28	15.79	7.39	-2.00	-2.15
CalCOFI - Survey 3		73.78	72.93	74.10	Na	Na	Na	Na	Na	Na
CalCOFI - Survey 4		Na	Na	Na	205.42	Na	Na	209.09	Na	Na
CalCOFI - Survey 5		Na	Na	Na	Na	142.94	Na	Na	Na	Na
Sub-total		169.26	172.21	172.17	309.35	242.57	97.97	216.49	-2.00	-2.15
Recruitment										
Model time period (1958-08)		42.656	37.693	38.305	42.773	42.188	38.834	39.520	39.146	39.383
Forecast (2009)		0.220	0.341	0.443	0.522	0.450	0.422	0.517	0.427	0.422
Global										
Likelihood (L)		1,443.1	3,274.7	3,564.4	3,704.4	3,641.0	3,489.2	3,605.6	3,390.7	3,390.9
Number of estimated parameters		61	61	85	84	84	85	84	85	85
Key estimated parameters and derived quantities										
Biology										
Length-at-age (k)	Na	0.40	0.38	0.33	0.34	0.33	0.32	0.34	0.33	0.33
$\ln(R_0)$	12.127	13.335	13.415	13.656	13.473	13.549	13.693	13.410	13.554	13.572
Offset for initial equilibrium R_1	Na	-0.1063	-0.1951	-0.1262	-0.9910	-0.6025	-0.1502	-0.3603	-0.0232	-0.0345
Steepness (h)	0.30	0.48	0.49	0.45	0.49	0.44	0.44	0.47	0.43	0.43
Initial conditions for population dynamics										
Fishing mortality (F) - Fishery 1[3]	Na	0.78	0.65	1.24	Na	Na	1.09	Na	0.79	0.80
Population time series										
SSB - 1962	46,001	22,789	28,778	38,189	54,792	88,273	44,133	47,252	54,449	55,212
SSB - 2008	101,999	97,040	86,497	96,513	59,547	89,840	115,412	47,094	94,645	94,471
B (1+) - 1962	147,838	98,251	105,640	118,588	117,684	162,916	126,759	122,850	146,719	150,297
B (1+) - 2009	343,180	304,886	278,944	326,163	207,456	294,465	381,251	166,308	314,526	313,764
HG - 2009	68,246	60,204	54,756	64,672	39,744	58,016	76,241	31,103	62,228	62,068

[1] Spotter survey is included under 'New Data' for purposes of continuity only, i.e., survey has not been updated since 2001.

[2] CalCOFI surveys reflect current survey (Survey 3) used in assessment and two alternative surveys (Surveys 4-5) used in sensitivity analysis.

[3] In SS model scenarios, estimated initial fishing mortality is not fit to 'equilibrium' catch, but rather, implemented for purposes of providing a more realistic initial non-equilibrium age composition.

Table A2B-1 (C). Continued.

(C)

Likelihood component[4]	*n*	*λ*	*RSS*	*L*	% of Total
Catch (weight) - fishery	81	150	0.005	0.789	<1%
Catch-at-age (proportions) - fishery	729	na	na	525.02	53.2%
Fits - Survey indices					
Spotter	39	1	168.67	123.93	12.5%
CPFV	69	1	15.56	90.21	9.1%
CalCOFI	37	1	82.04	133.24	13.5%
All	145	3	266.27	347.38	35.2%
Recruitment (deviations)	81	1	59.04	59.04	6.0%
Stock-recruit fit	81	1	59.04	55.41	5.6%
F penalty	729	0.001	2.22	0.002	<1%
Number of estimated parameters (Total)	202	Na	Na	Na	Na
Objective function (Total)	Na	Na	Na	987.6	100%

[4]ASAP model-related notation is as follows: *n* is number of observations; λ is lambda (weight value in overall fit); *RSS* is residula sum of squares; and *L* is likelihood value.

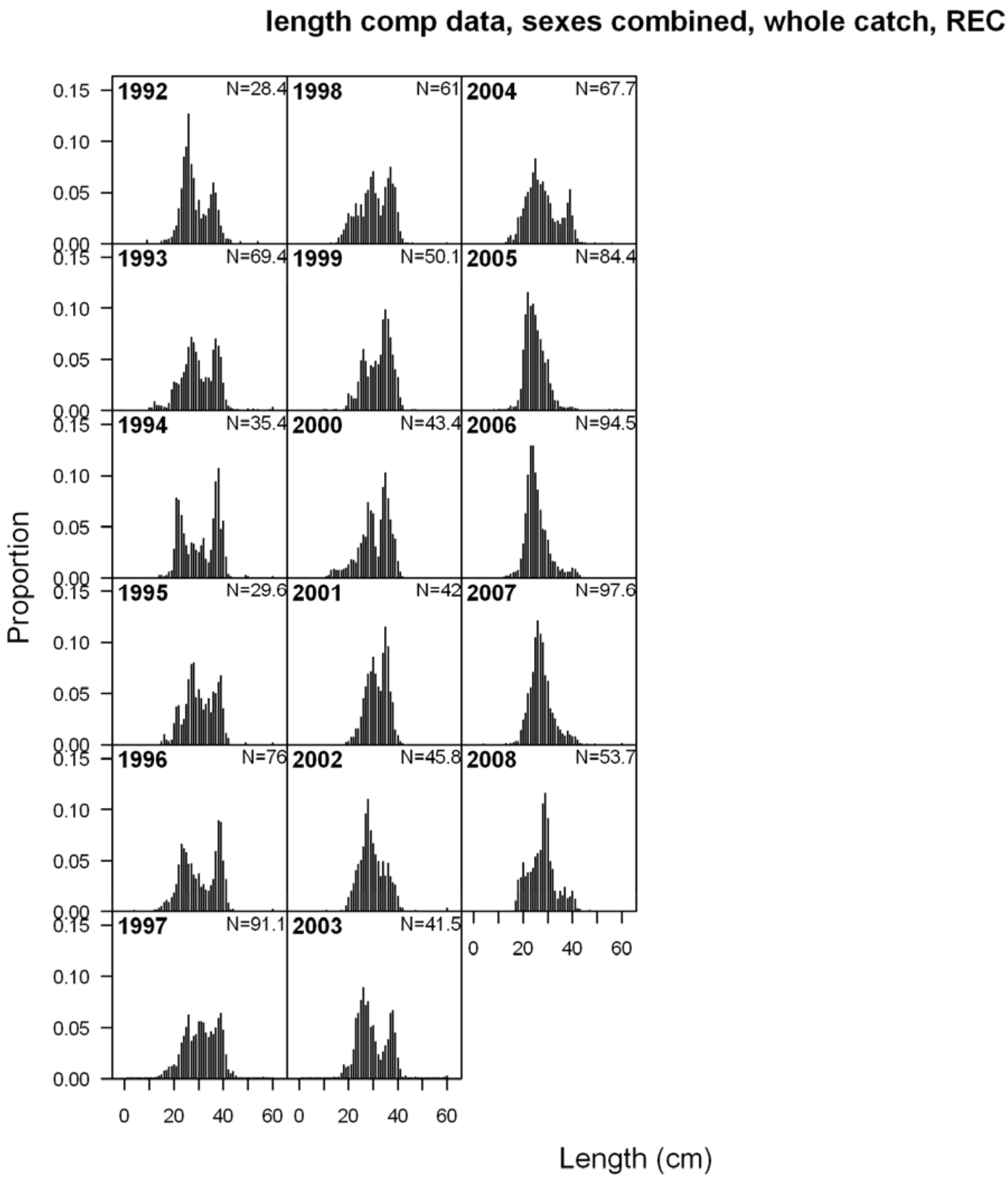
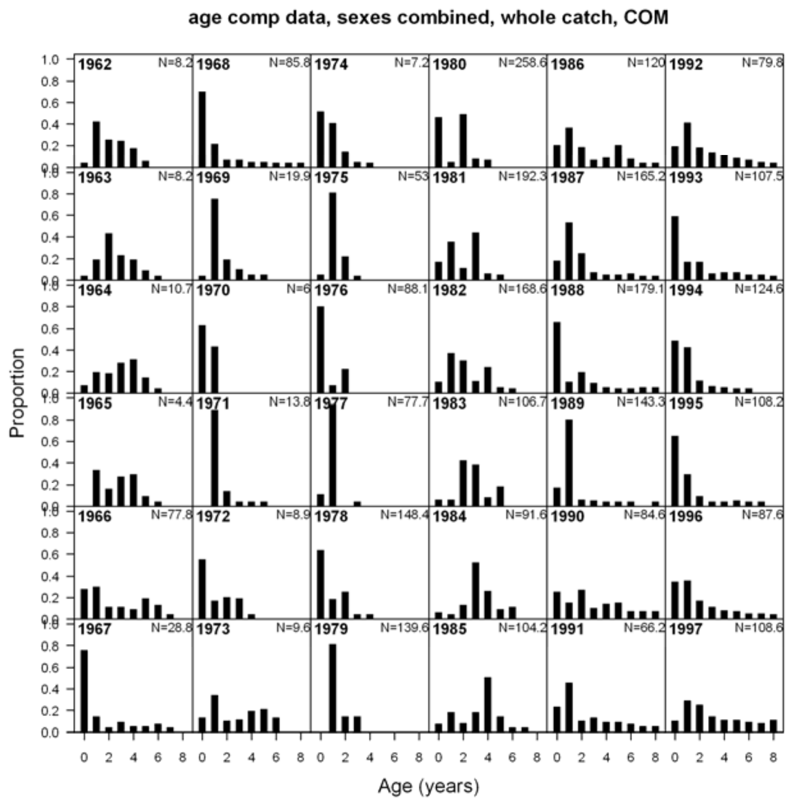


Figure A2B-1. Length distributions from RecFIN data base associated with CPFV fishery (1992-08).



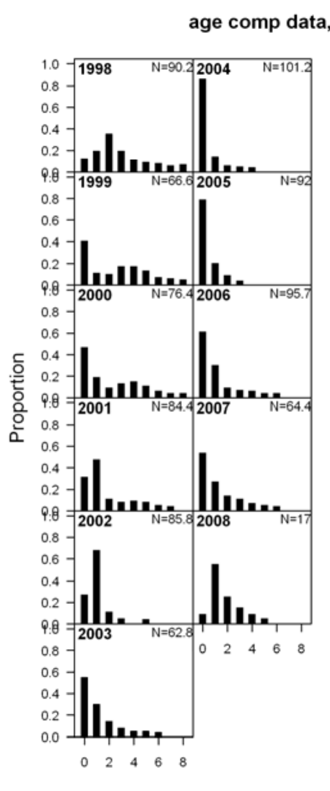


Figure A2B-2. Age distributions from CDFG port sampling program (1962-08).

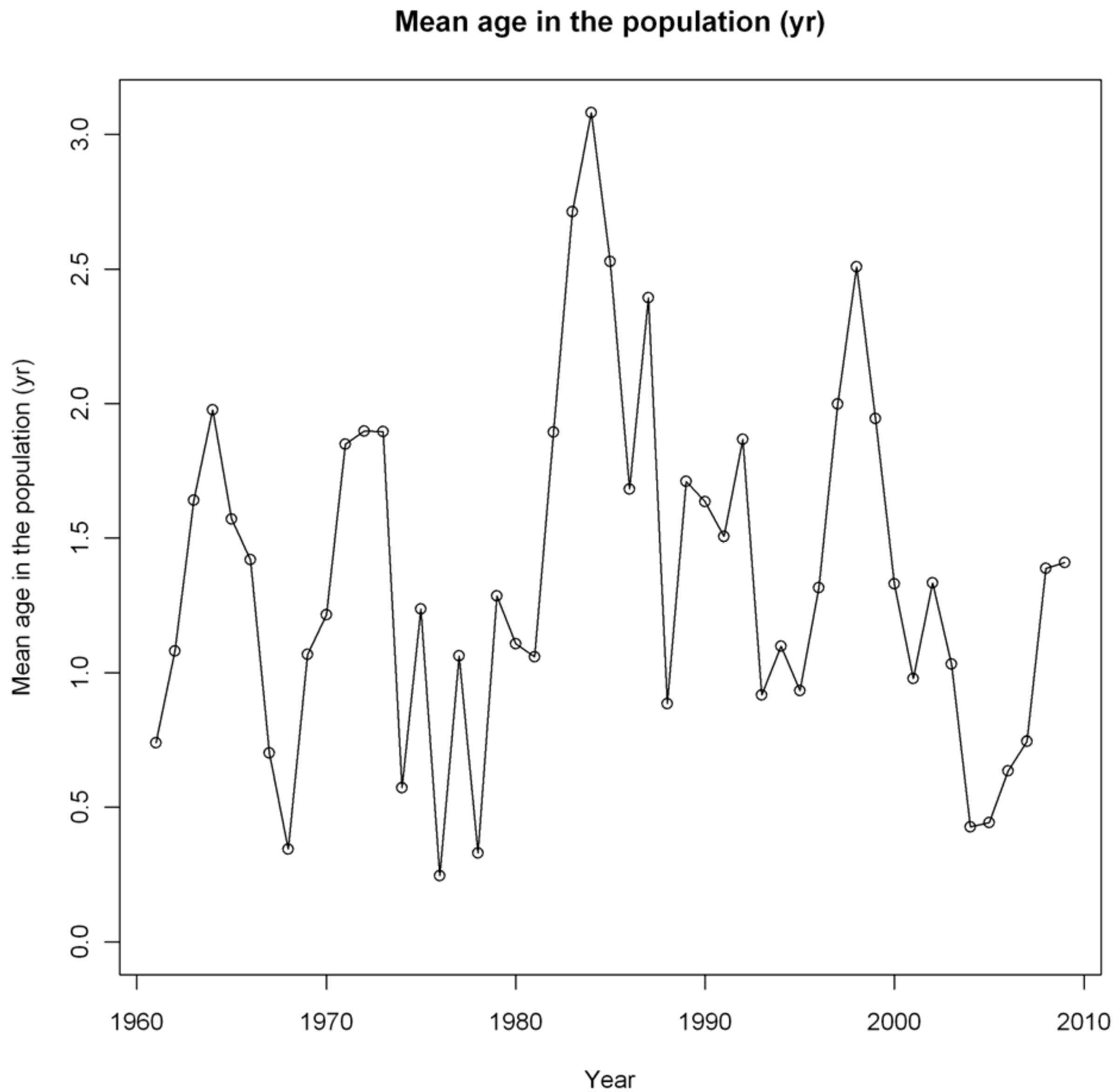


Figure A2B-3. Mean age estimated time series (1962-08).

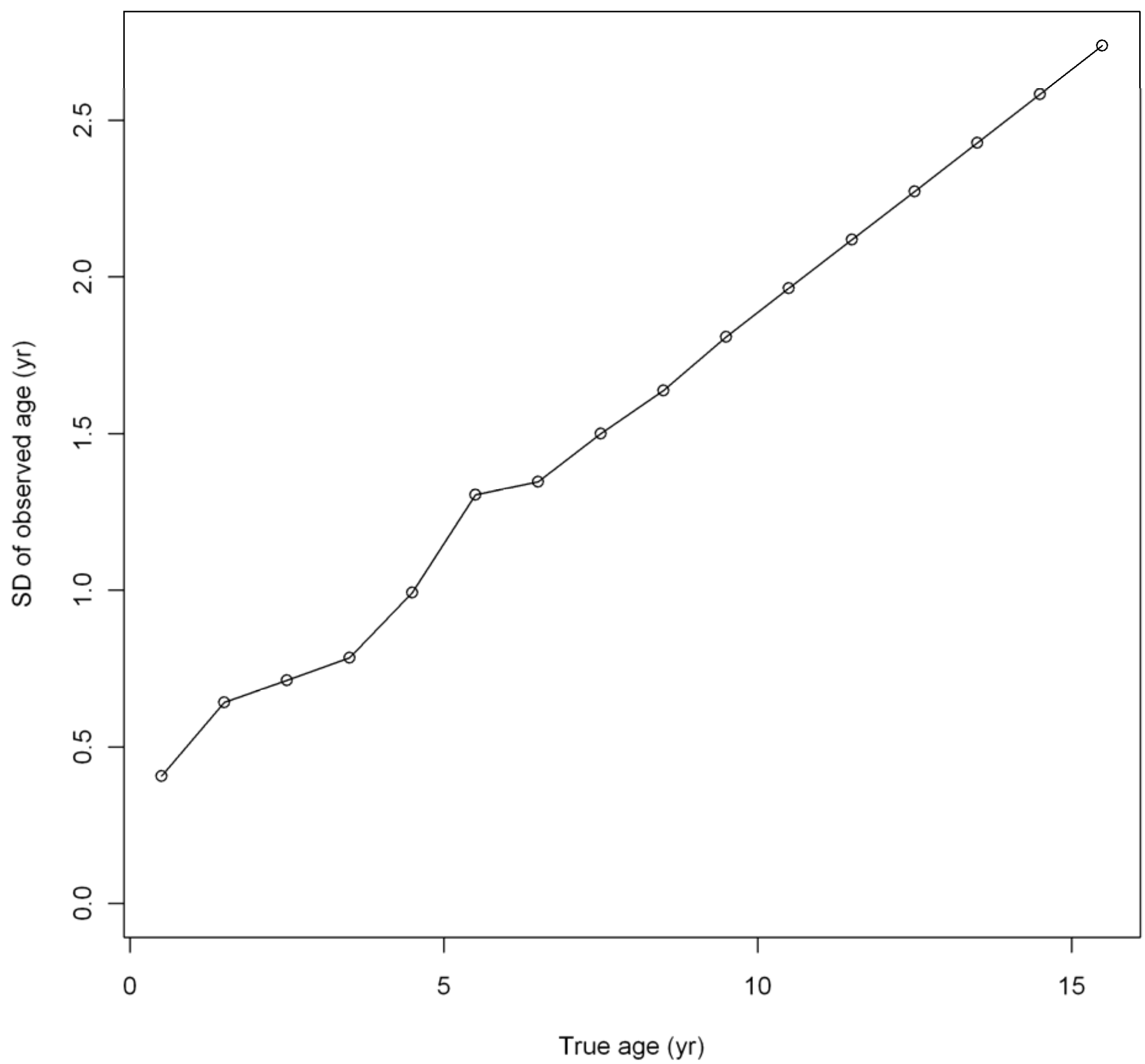


Figure A2B-4. Ageing error vector from CDFG age production laboratory based on doule read analysis.

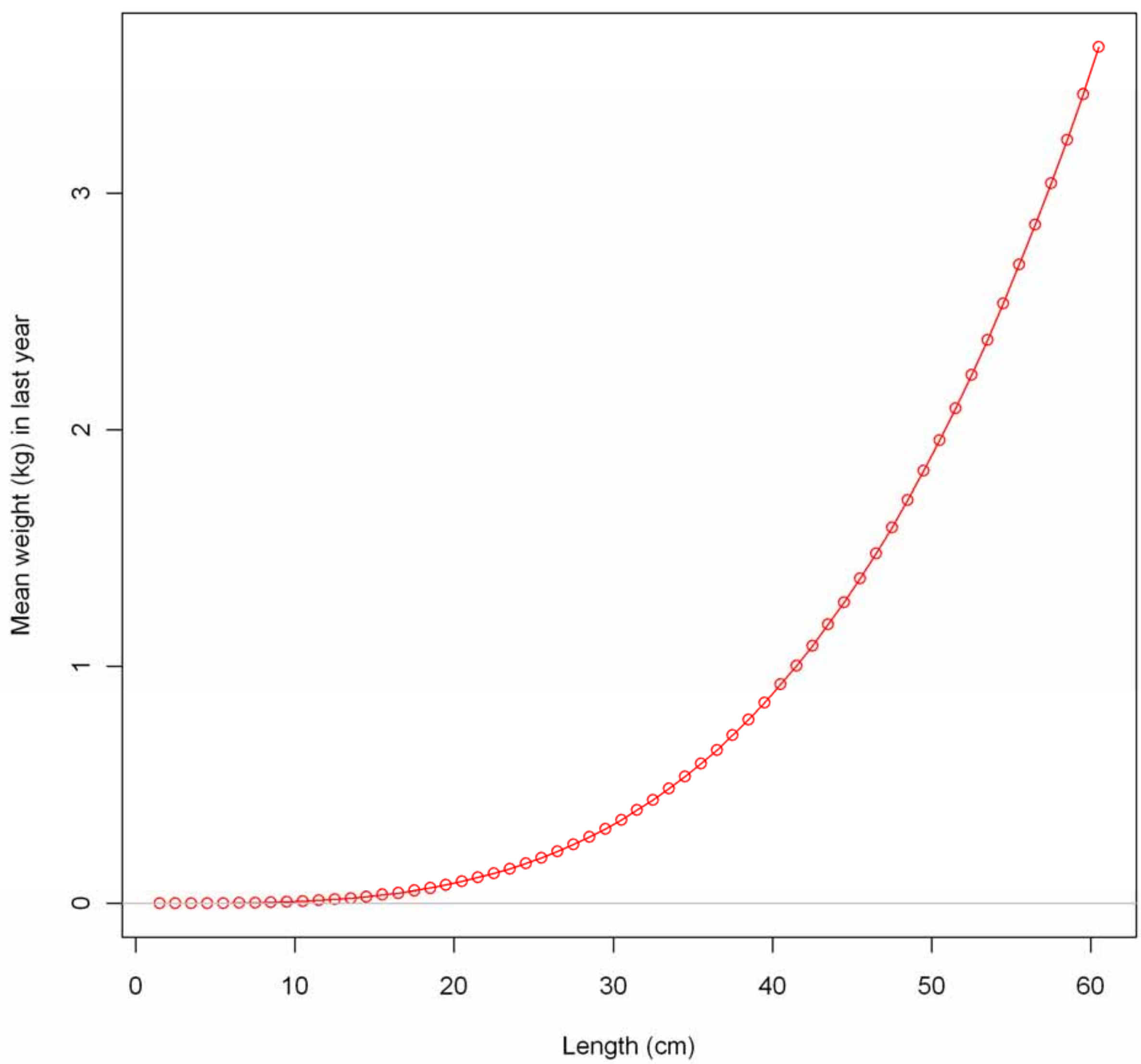
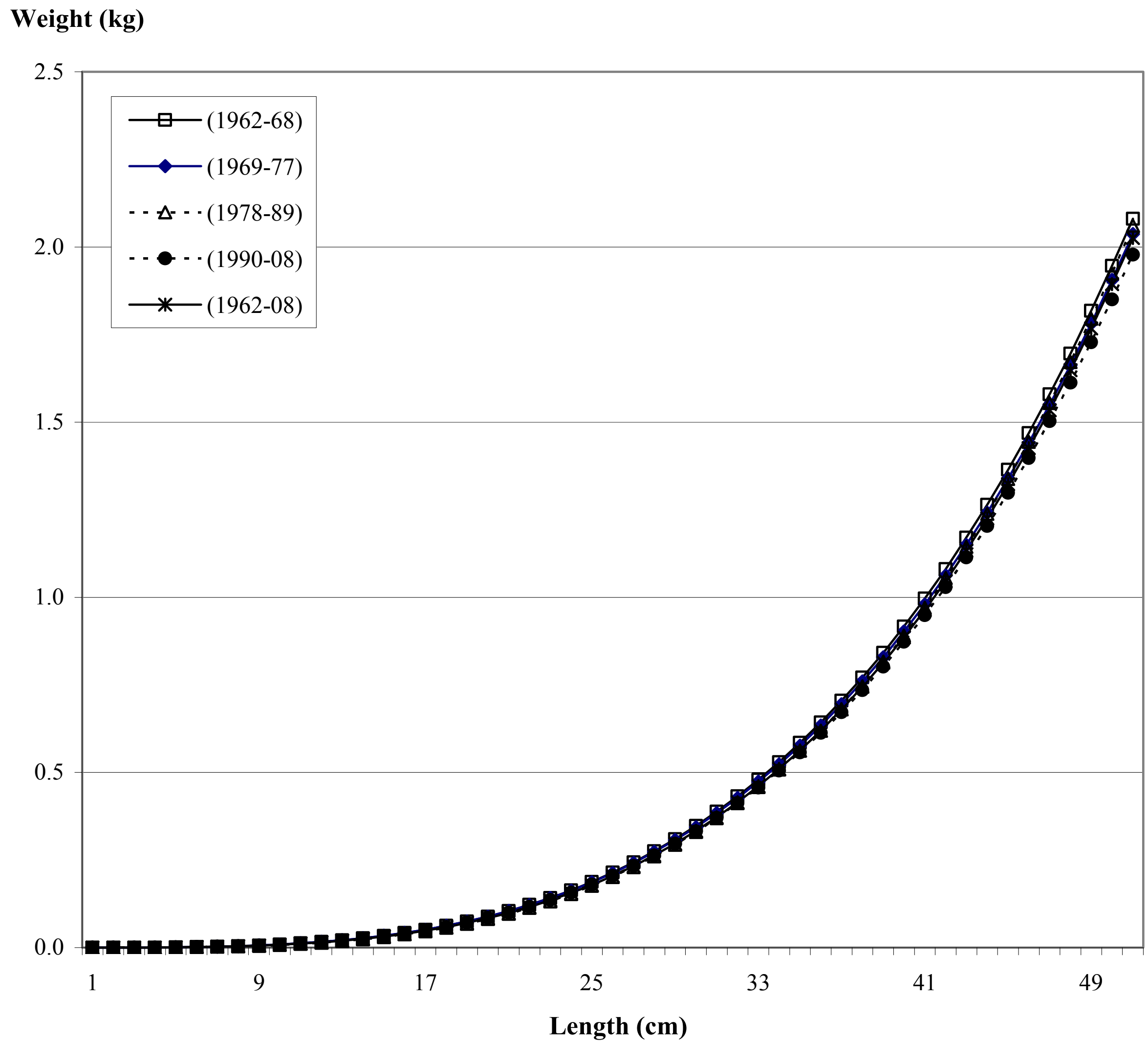


Figure A2B-5. Weight-length relationship.



Time block	a	b	n	R^2
1962-68	3.60340E-06	3.37410	5,598	0.984
1969-77	3.84101E-06	3.35245	7,104	0.967
1978-89	2.62897E-06	3.45186	45,957	0.971
1990-06	3.53906E-06	3.36574	37,102	0.971
1962-08	3.12517E-06	3.40352	95,761	0.971

Figure A2B-6. Weight-length (W-L) relationships used in time-varying growth model scenario S1_qa3 (see Table 1A-B).

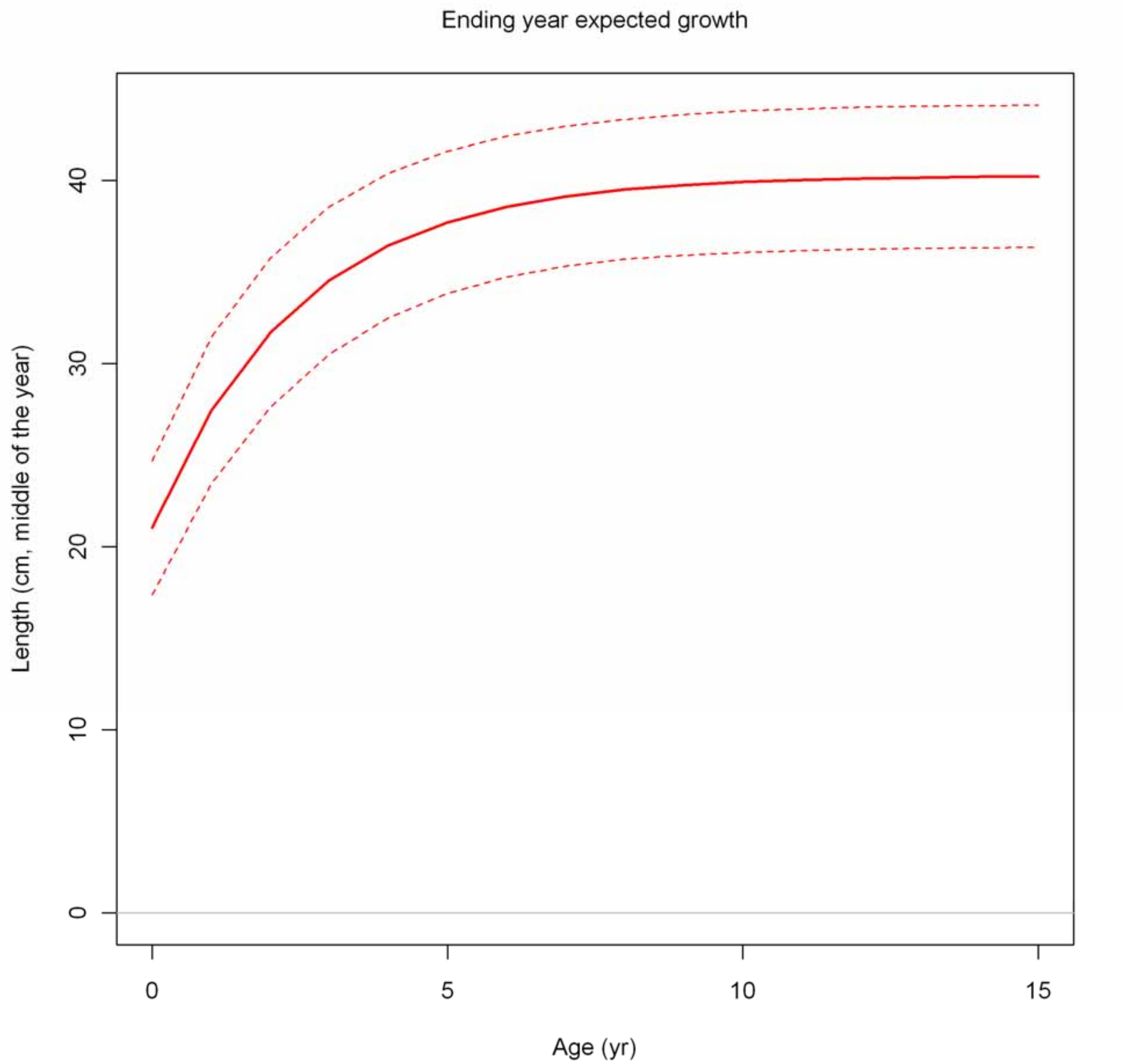


Figure A2B-7. Length-at-age relationship (K = 0.40).

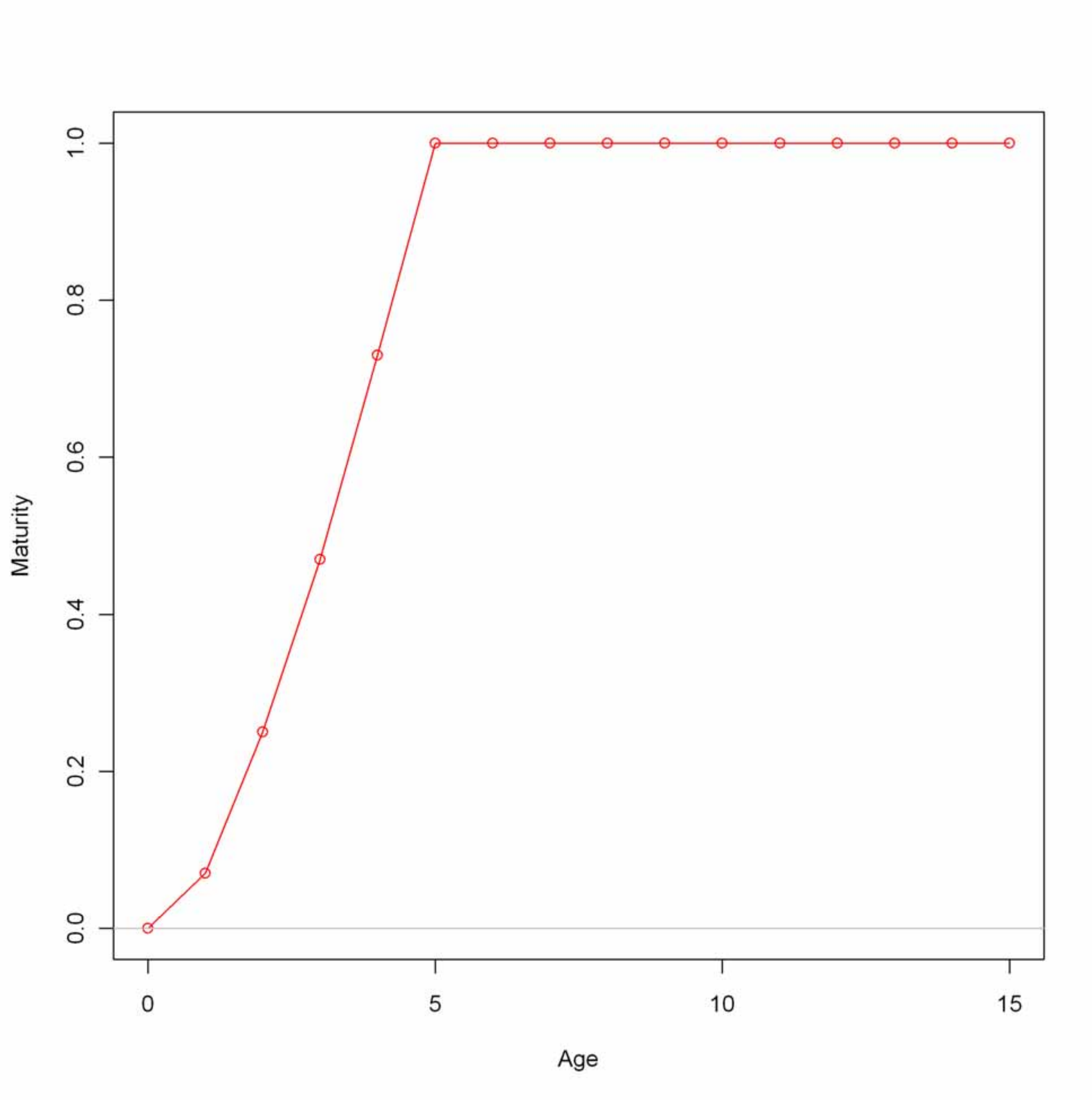


Figure A2B-8. Maturity-at-age schedule.

Time-varying selectivity for COM

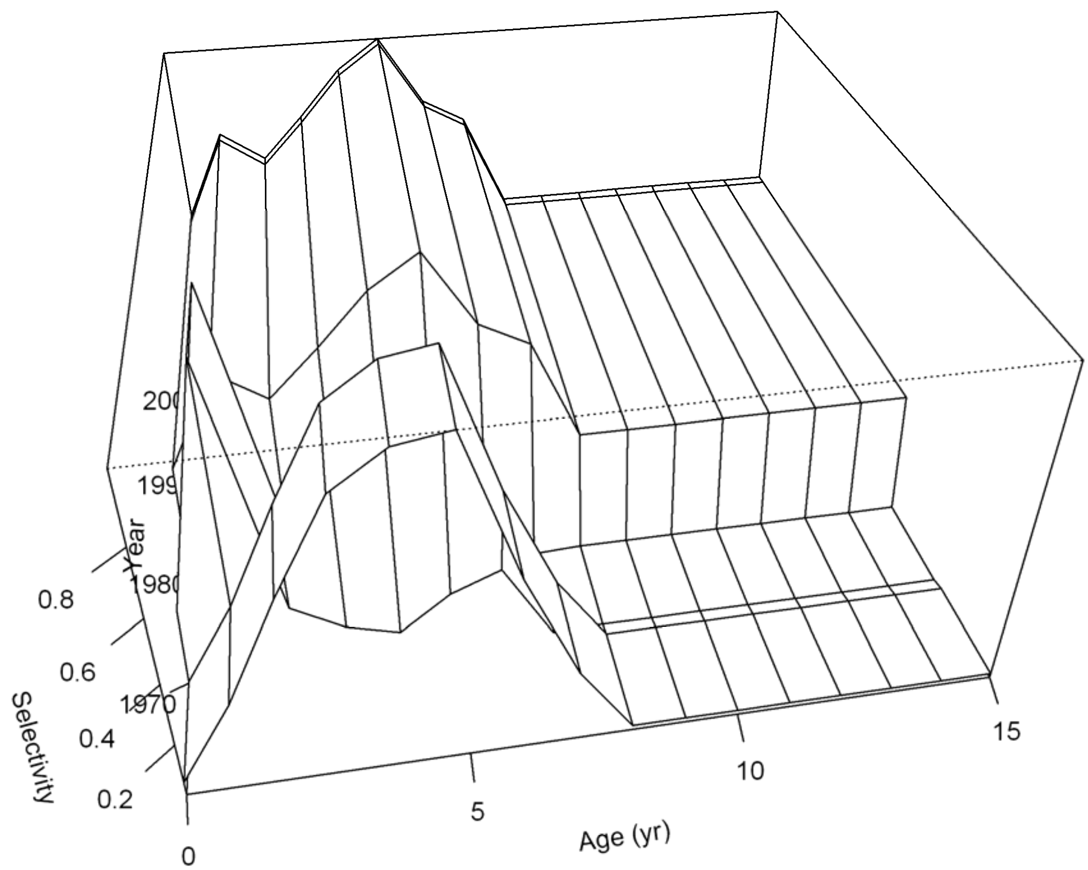


Figure A2B-9. Time-varying (fixed) selectivity associated with the commercial fishery (three blocks: 1962-69, 1970-77, and 1978-08).

Time-varying selectivity for REC

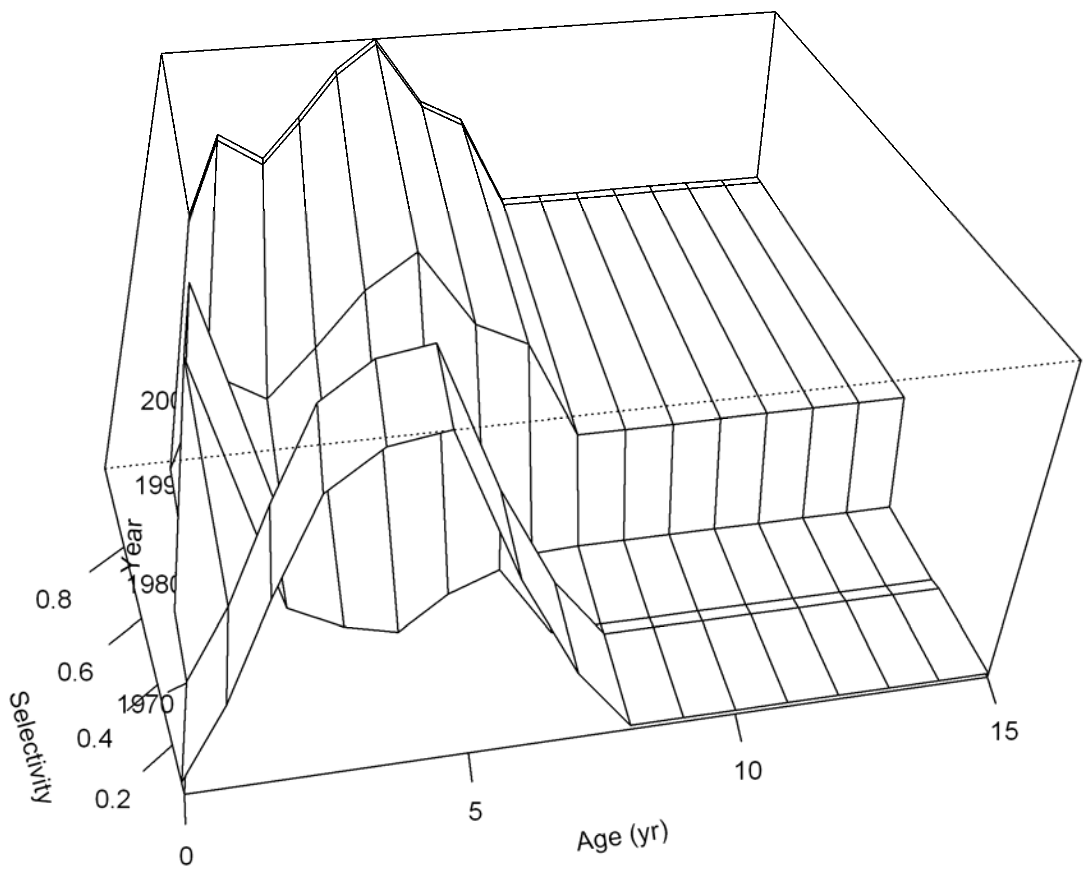


Figure A2B-10. Time-varying (fixed) selectivity associated with the recreational fishery, i.e., in Model S1_aa, mirrors commercial fishery.

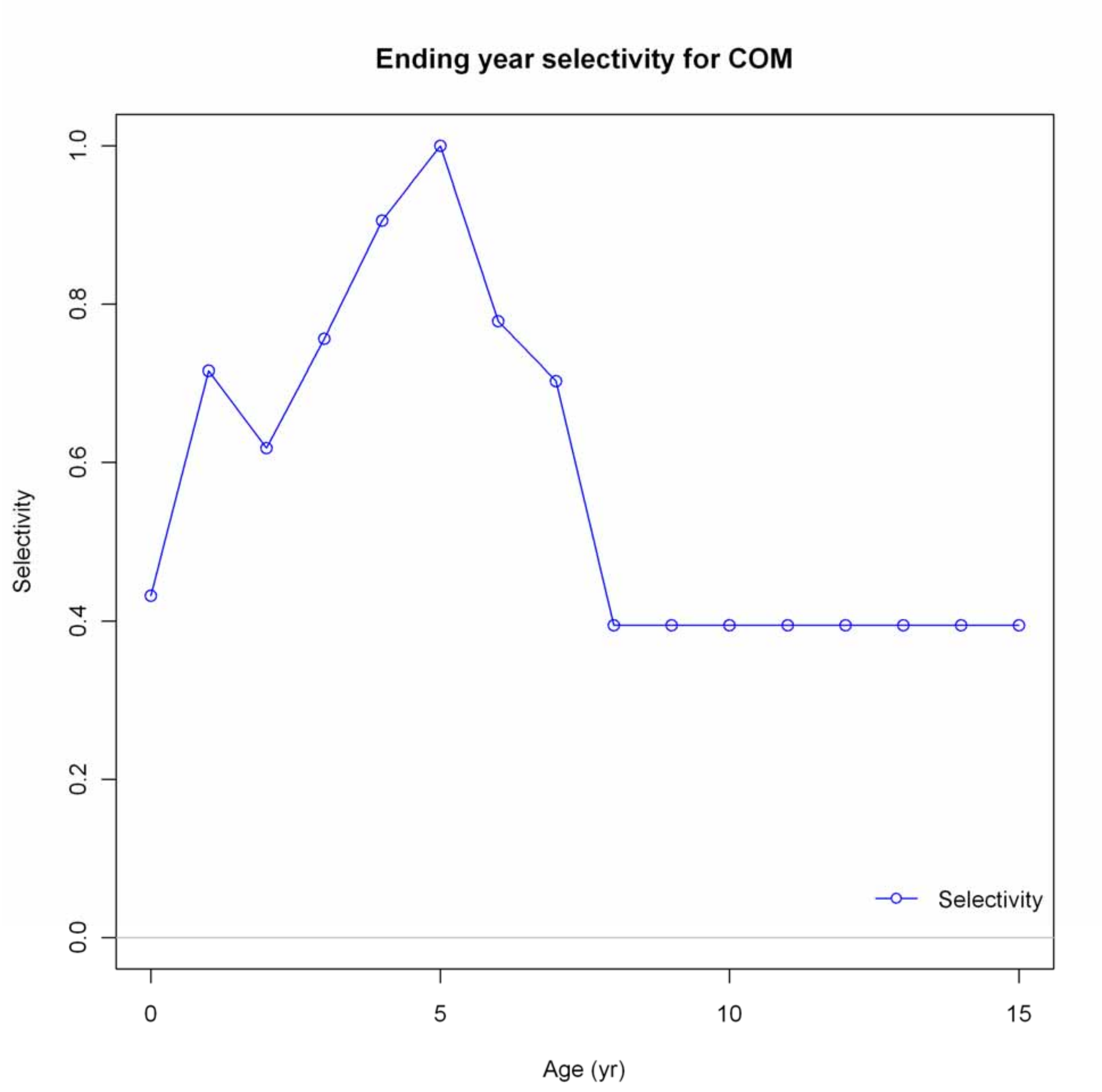


Figure A2B-11. Ending year (fixed) selectivity associated with the commercial fishery.

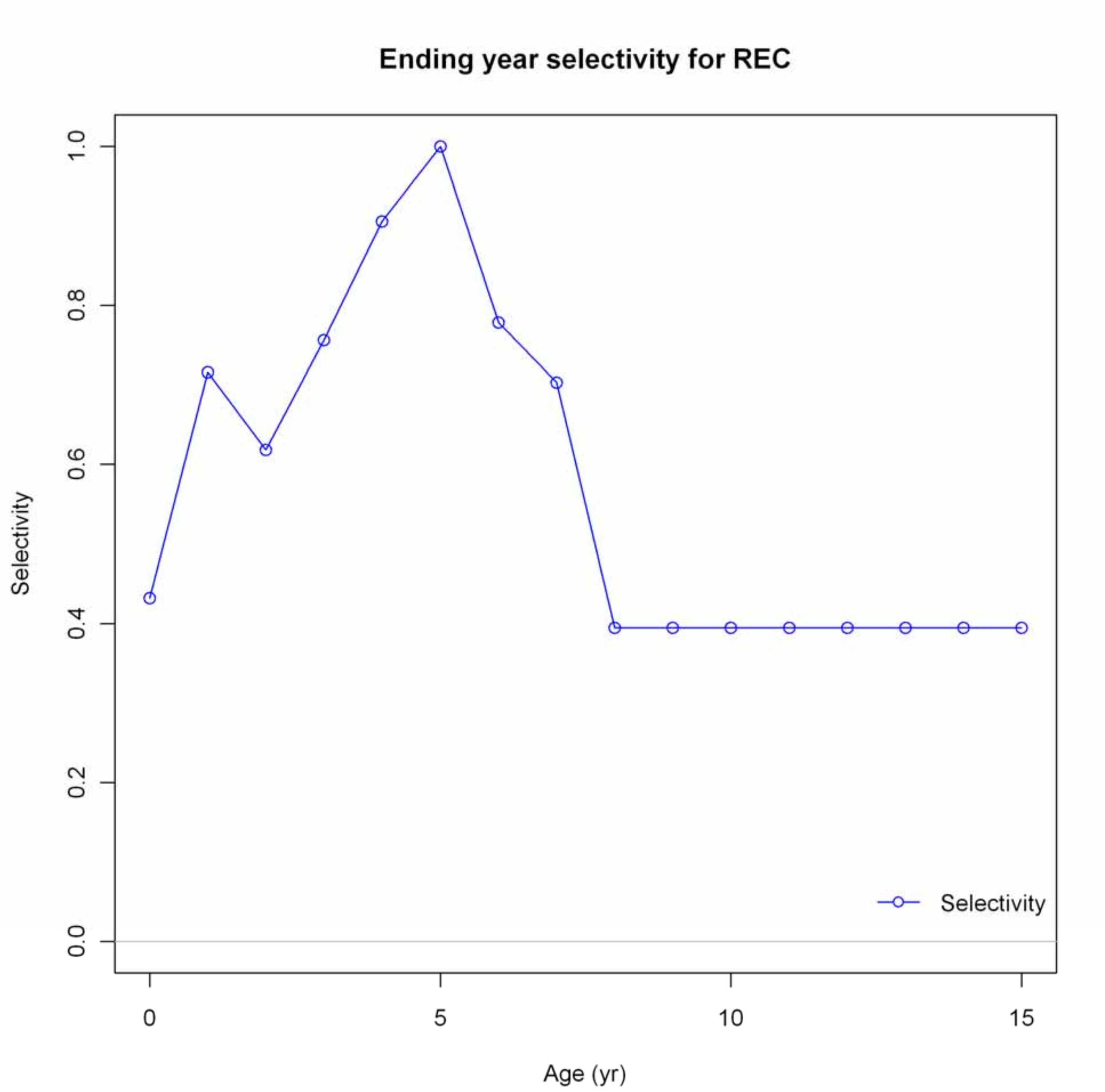


Figure A2B-12. Ending year (fixed) selectivity associated with the recreational fishery, i.e., mirrors commercial fishery.

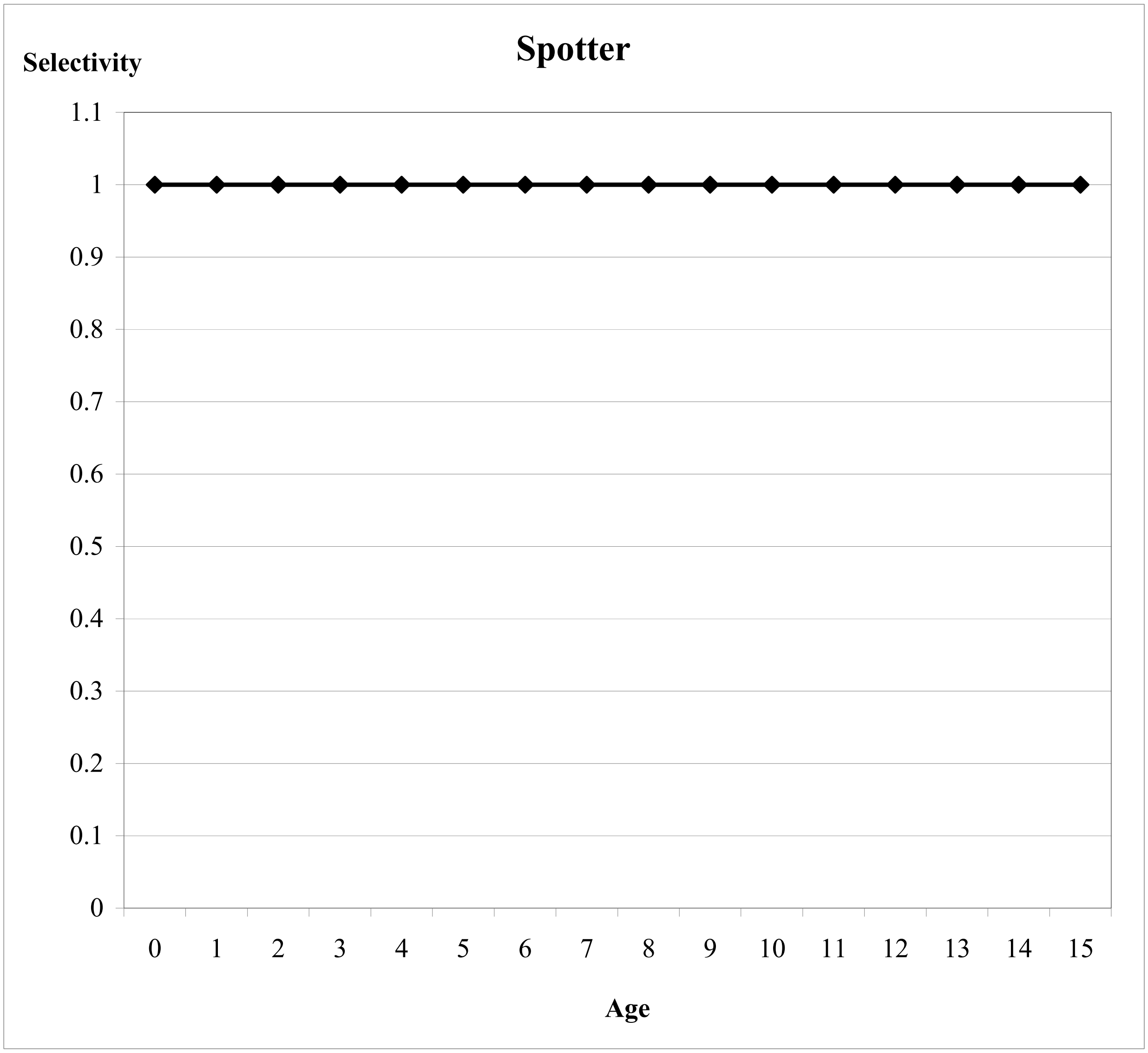


Figure A2B-13. Constant (fixed) selectivity, including ending year, associated with the Spotter index, i.e., all ages fully selectivity.

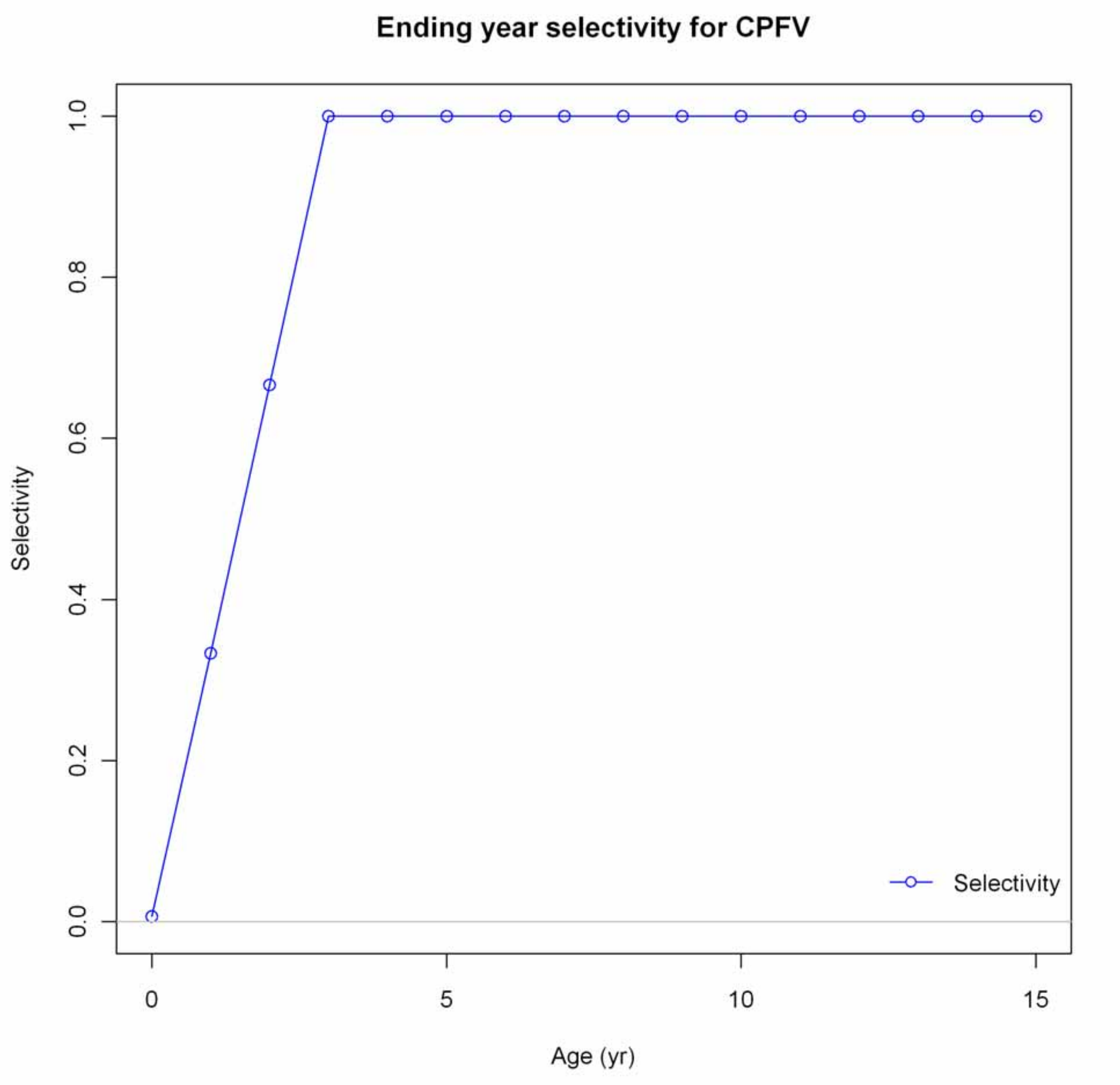


Figure A2B-14. Constant (fixed) selectivity, including ending year, associated with the CPFV index.

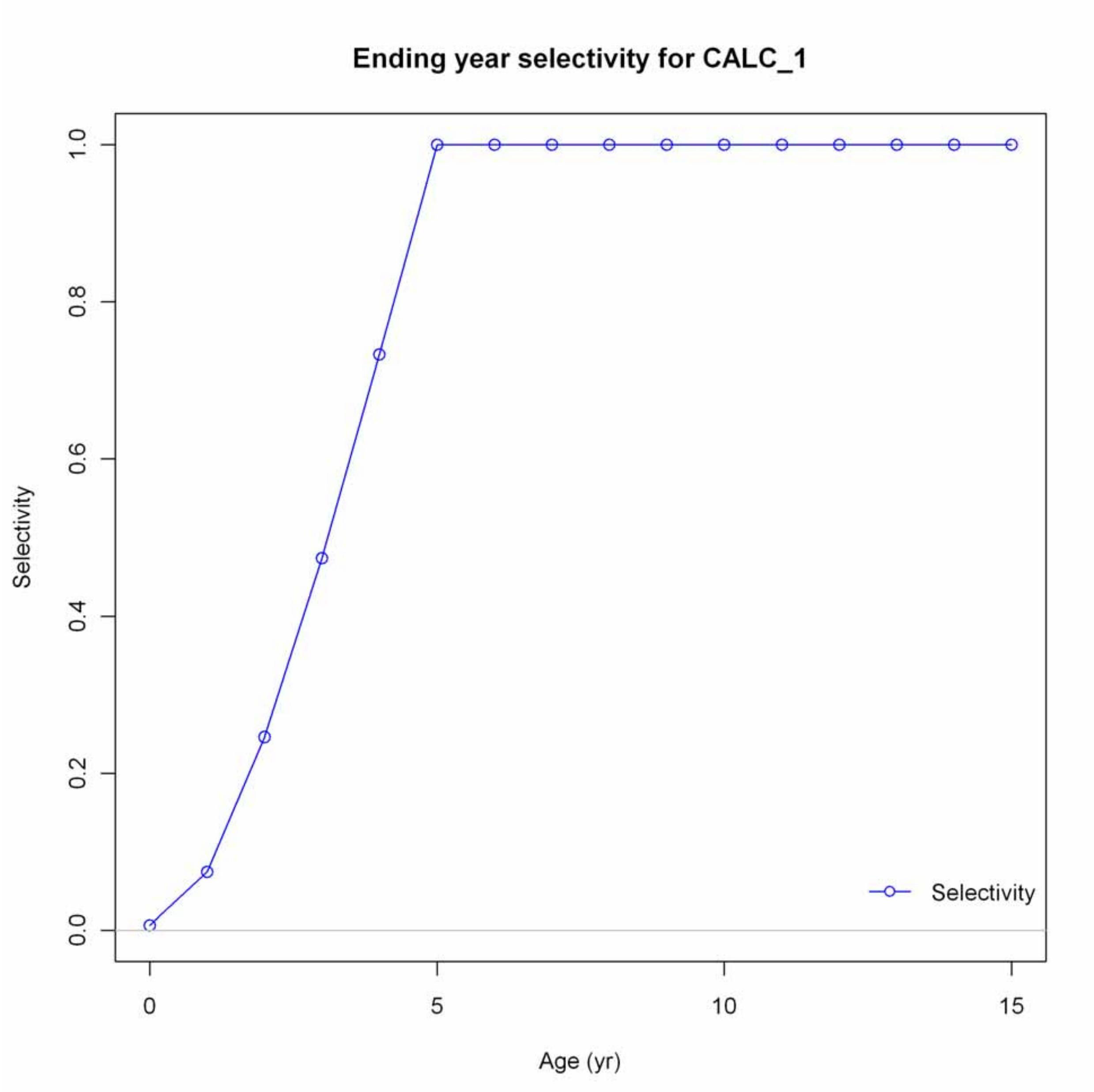


Figure A2B-15. Constant (fixed) selectivity, including ending year, associated with the CalCOFI index.

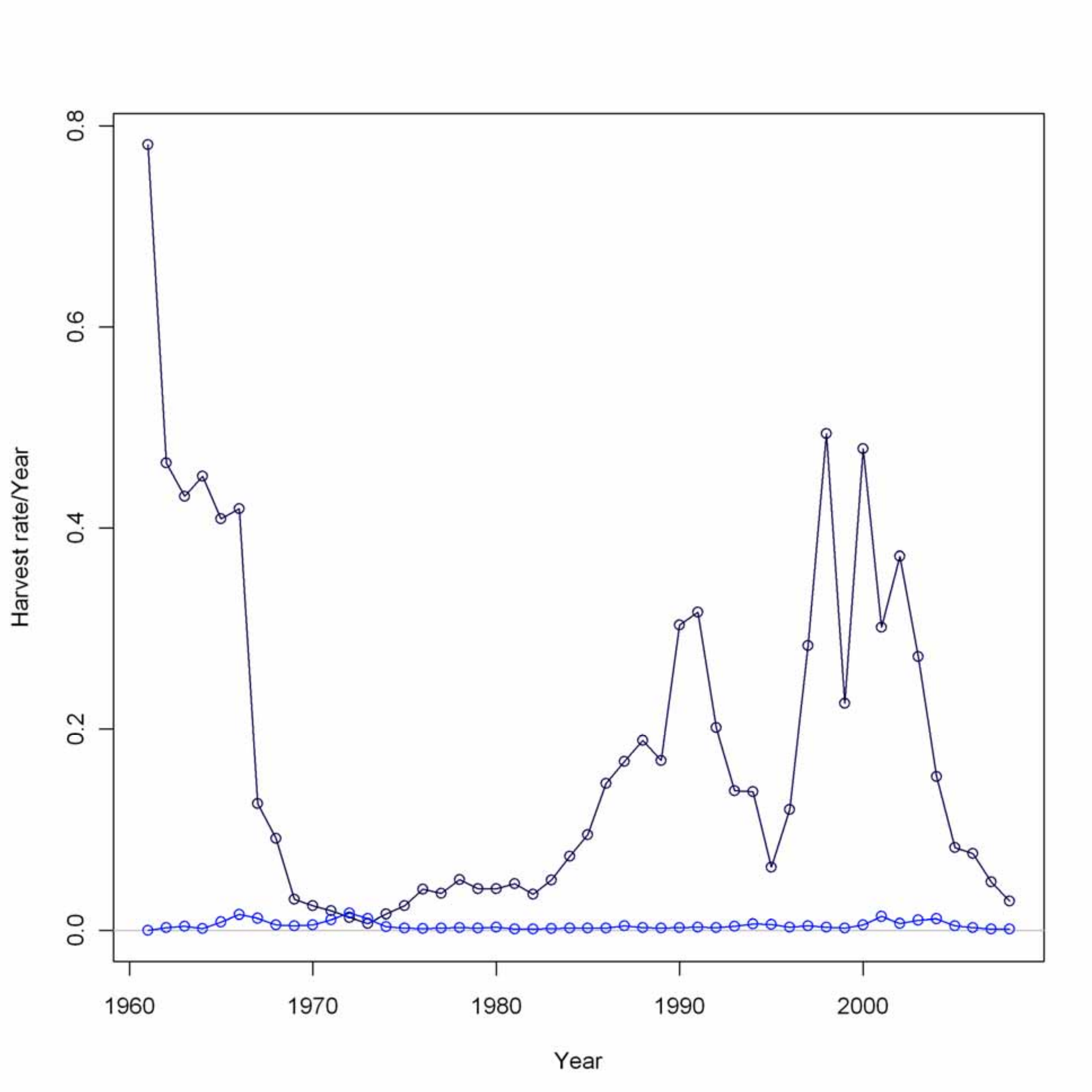


Figure A2B-16. Estimated harvest rate (1962-08). Disregard horizontal-like time series at bottom of display.

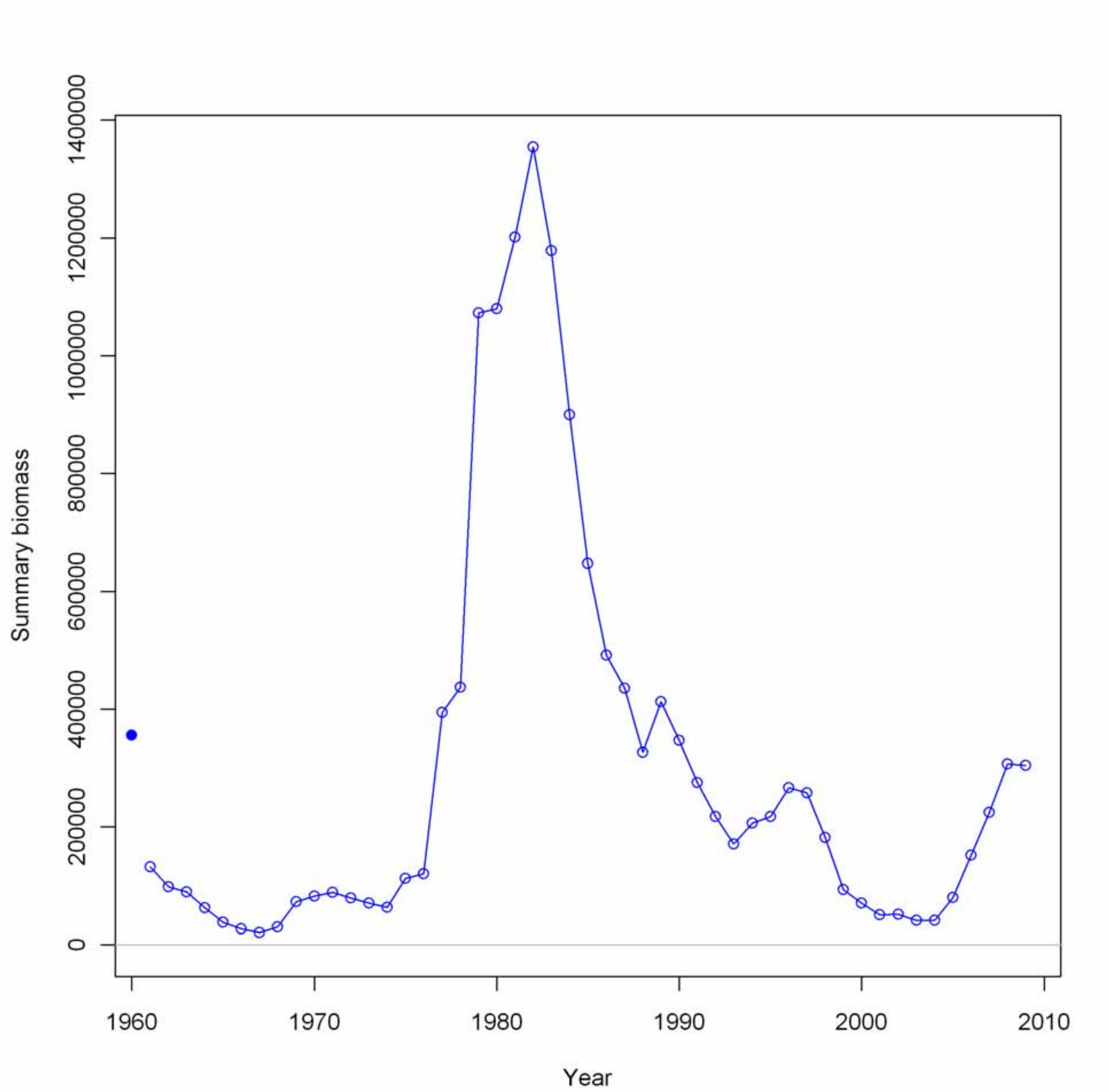


Figure A2B-17. Estimated total stock biomass (age 1+ fish in mt, *B*) of Pacific mackerel. Dark-shaded circle reflects estimated 'virgin' stock size.

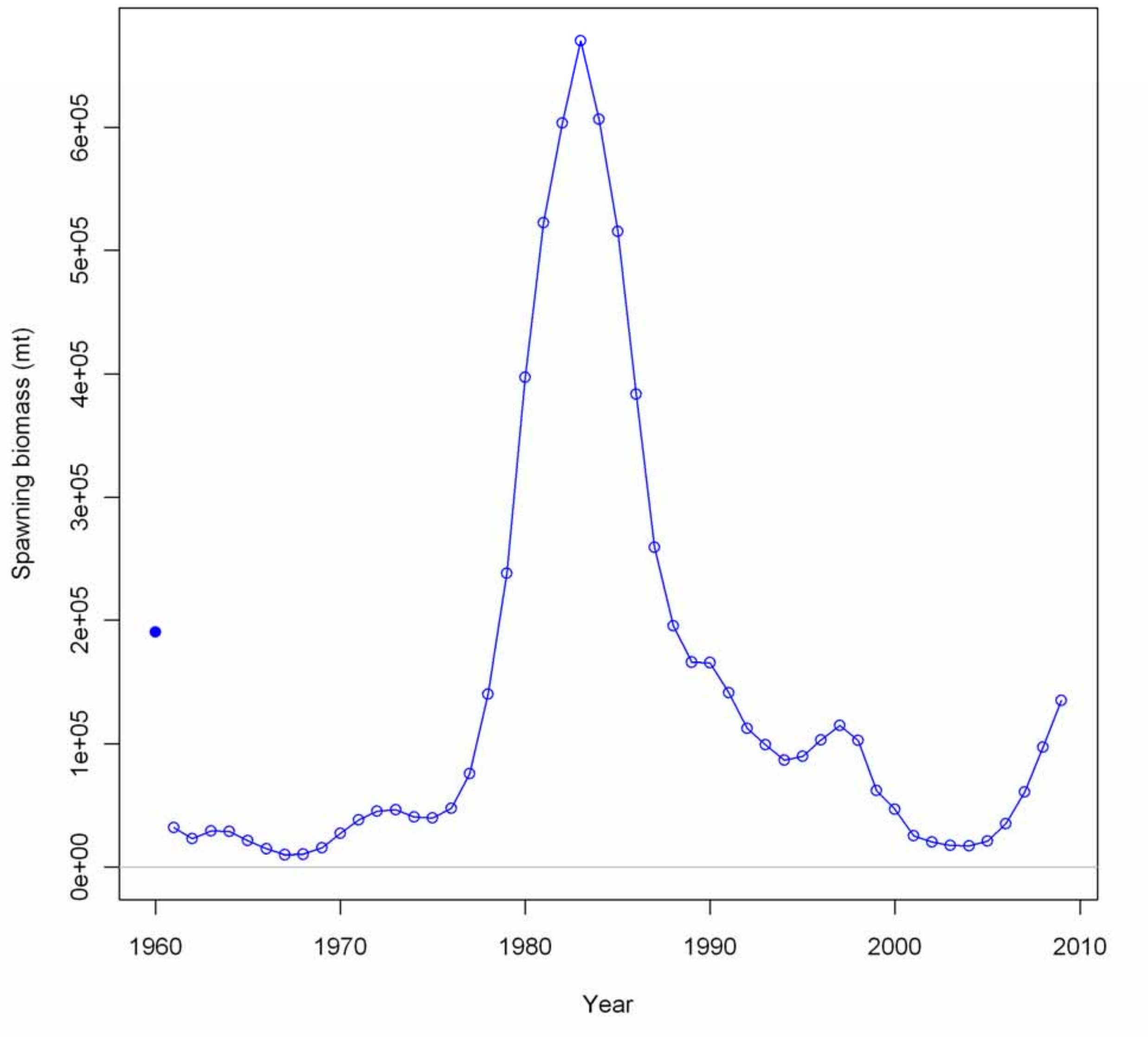


Figure A2B-18. Estimated spawning stock biomass (*SSB*) of Pacific mackerel. Dark-shaded circle reflects estimated 'virgin' level of *SSB*.

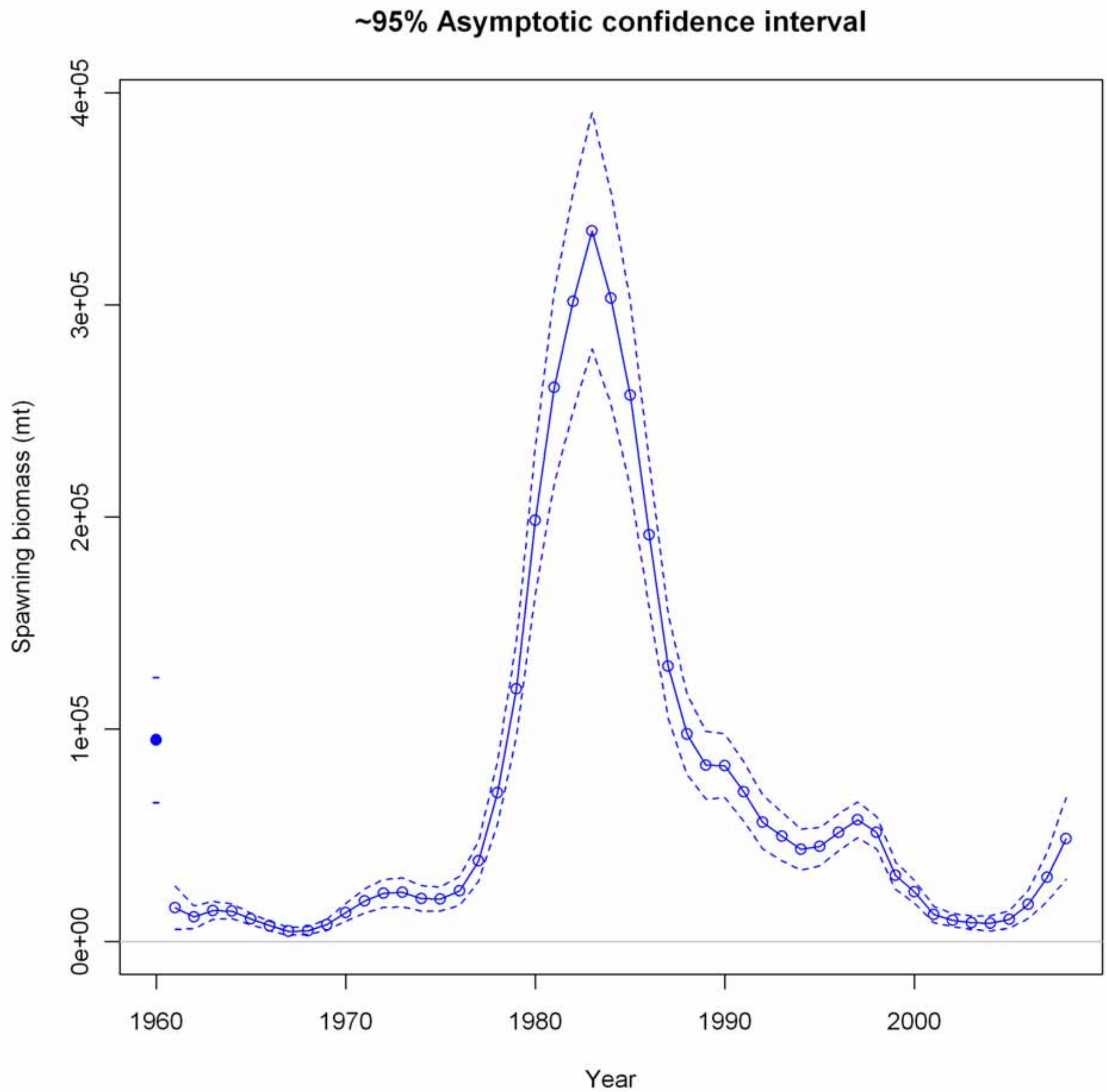


Figure A2B-19. Estimated spawning stock biomass (*SSB*) of Pacific mackerel with accompanying 95% CIs. Dark-shaded circle reflects estimated 'virgin' level of *SSB*, bounded by 95% CI. Note that Y-axis scale is incorrect, see previous display (Figure A4B-18) for correct interval notation, i.e., correct interval is: 0, 2e+05, 4e+05, 6e+05, 8e+05.

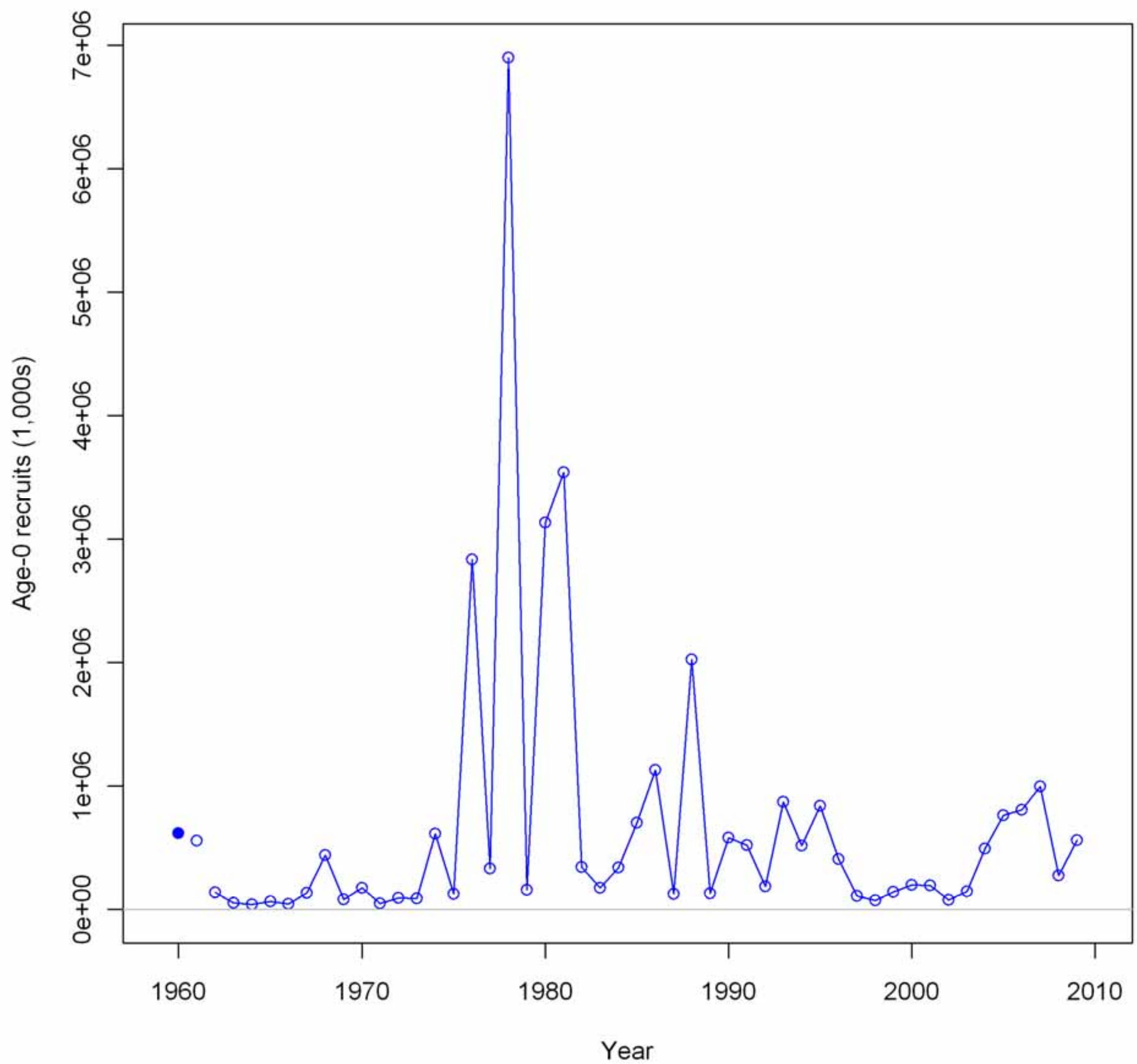


Figure A2B-20. Estimated recruitment (age 0 fish in 1,000s of fish, *R*) of Pacific mackerel. Dark-shaded circle reflects estimated 'virgin' level of *R*.

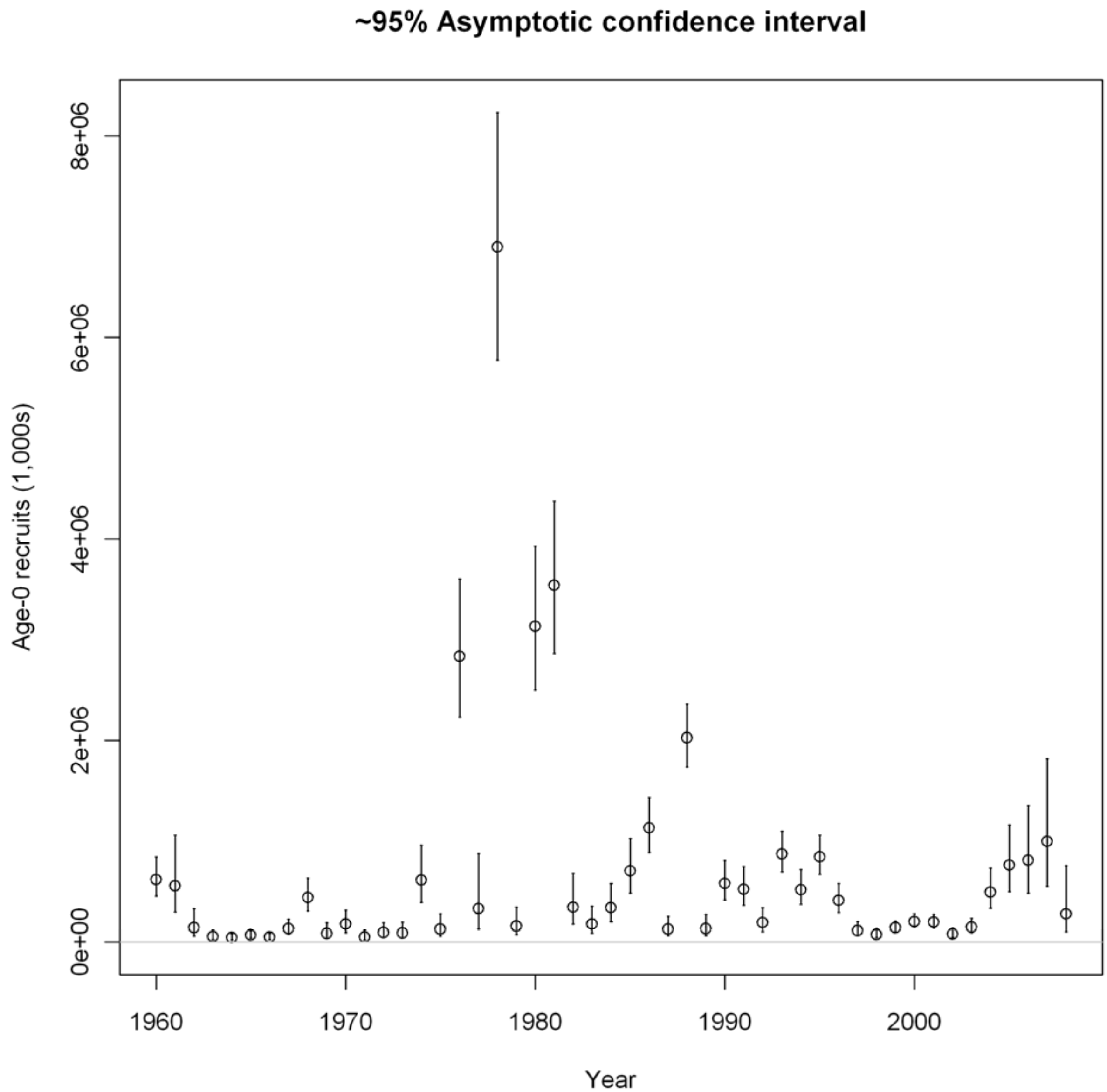


Figure A2B-21. Estimated recruitment (age 0 fish in 1,000s of fish, *R*) of Pacific mackerel, with accompanying 95% CIs.

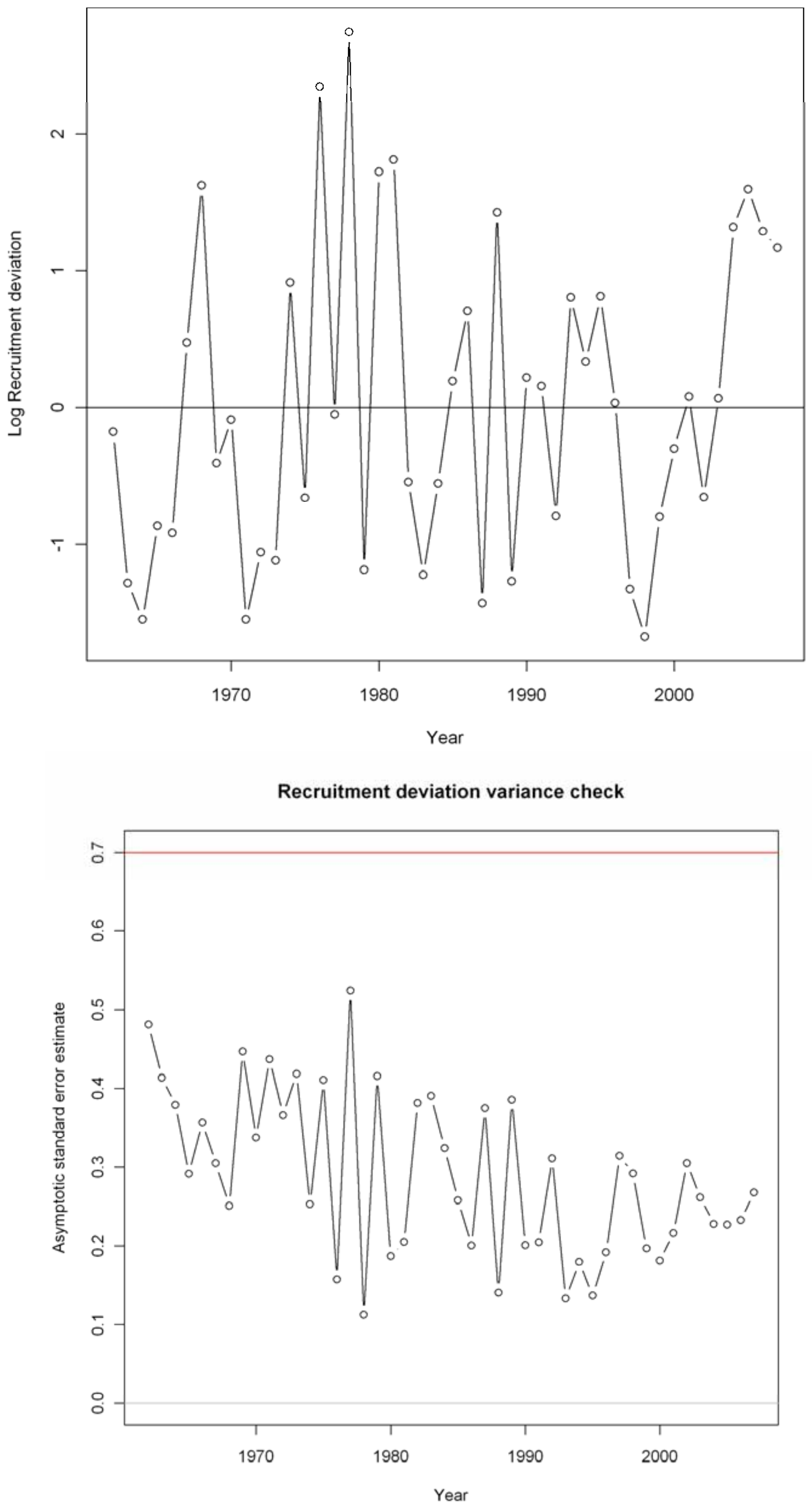


Figure A2B-22. Estimates of recruitment deviations (top panel), and SEs associated with the deviations (bottom panel). Horizontal line in bottom panel indicates the estimate of the standard deviation of log recruitment deviations, fixed σ-*R* = 0.7.

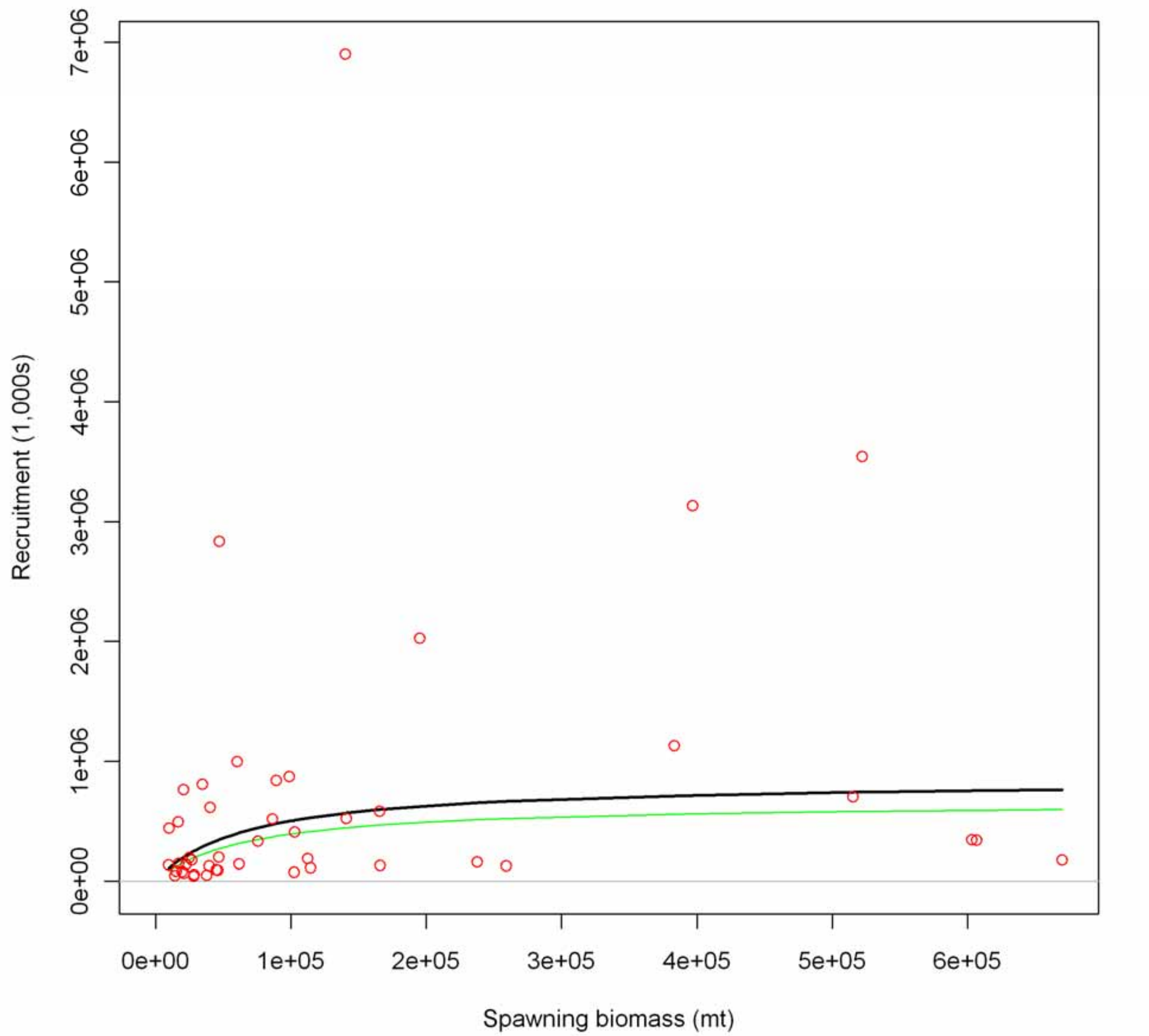


Figure A2B-23. Beverton-Holt stock (*SSB*)-recruitment (*R* in 1,000s of fish) relationship. Steepness=0.48.

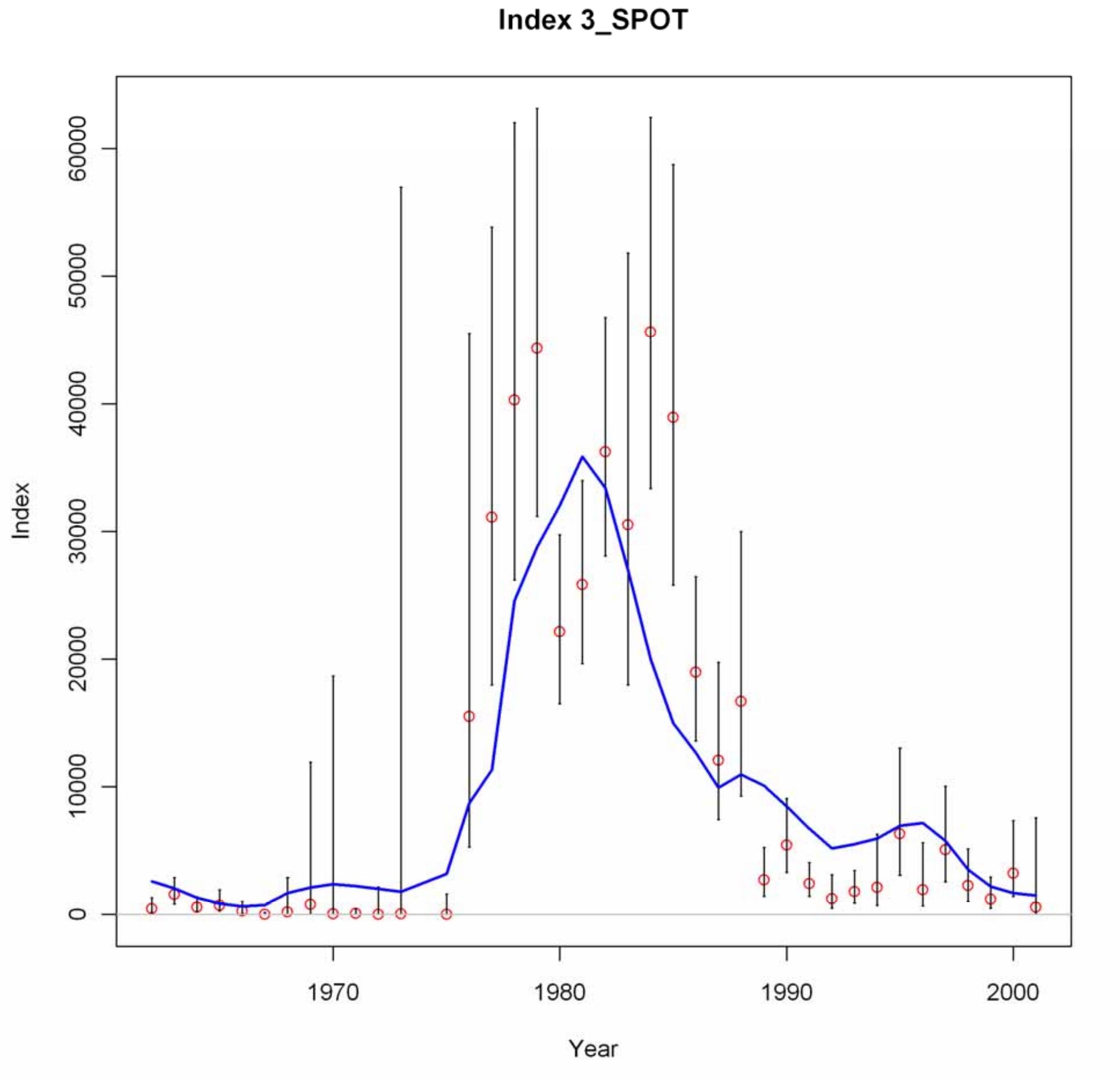


Figure A2B-24. Estimated fits (observed=red circles, with 95% CIs; predicted=line) associated with the Spotter index.

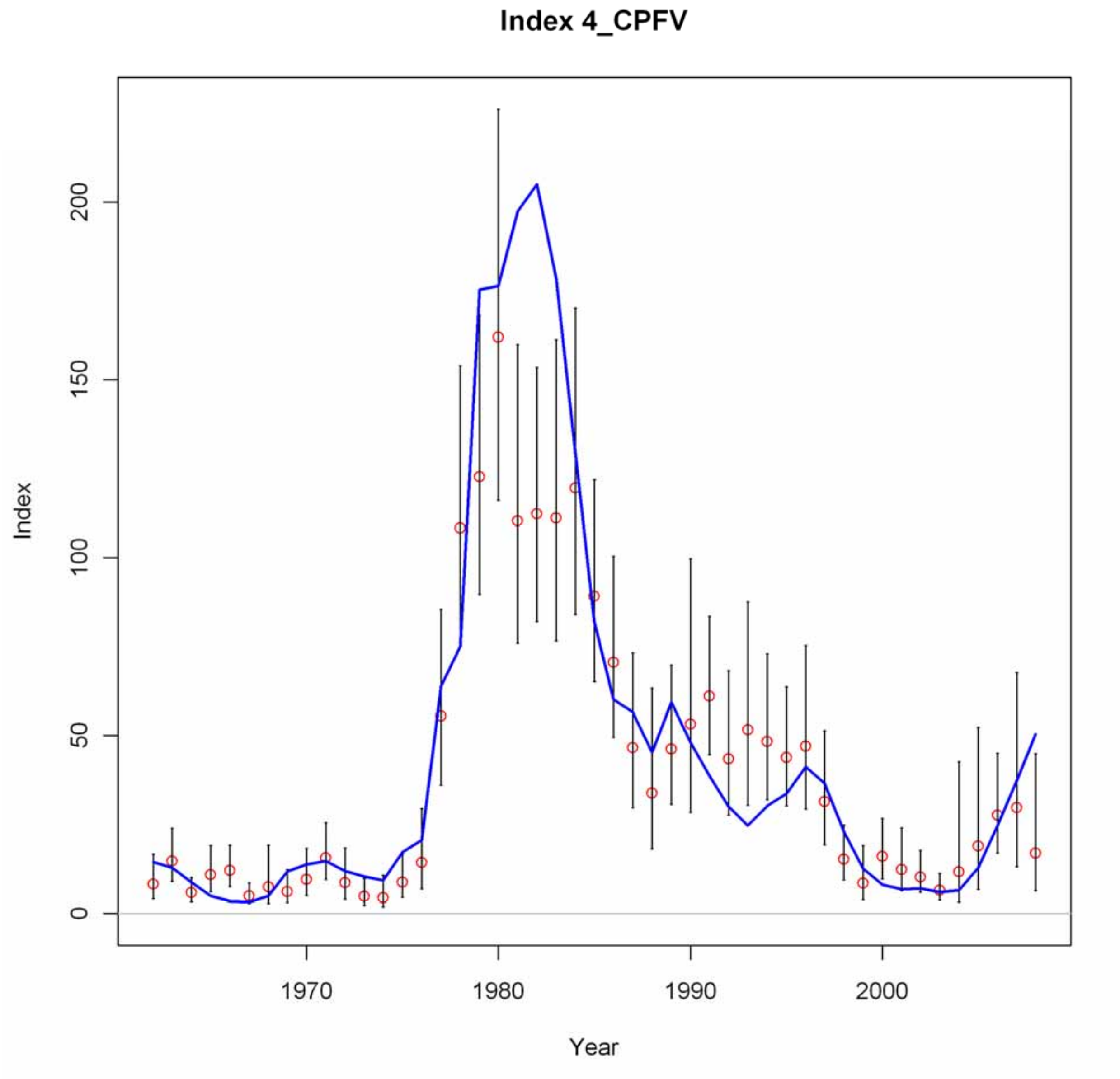


Figure A2B-25. Estimated fits (observed=red circles, with 95% CIs; predicted=line) associated with the CPFV index.

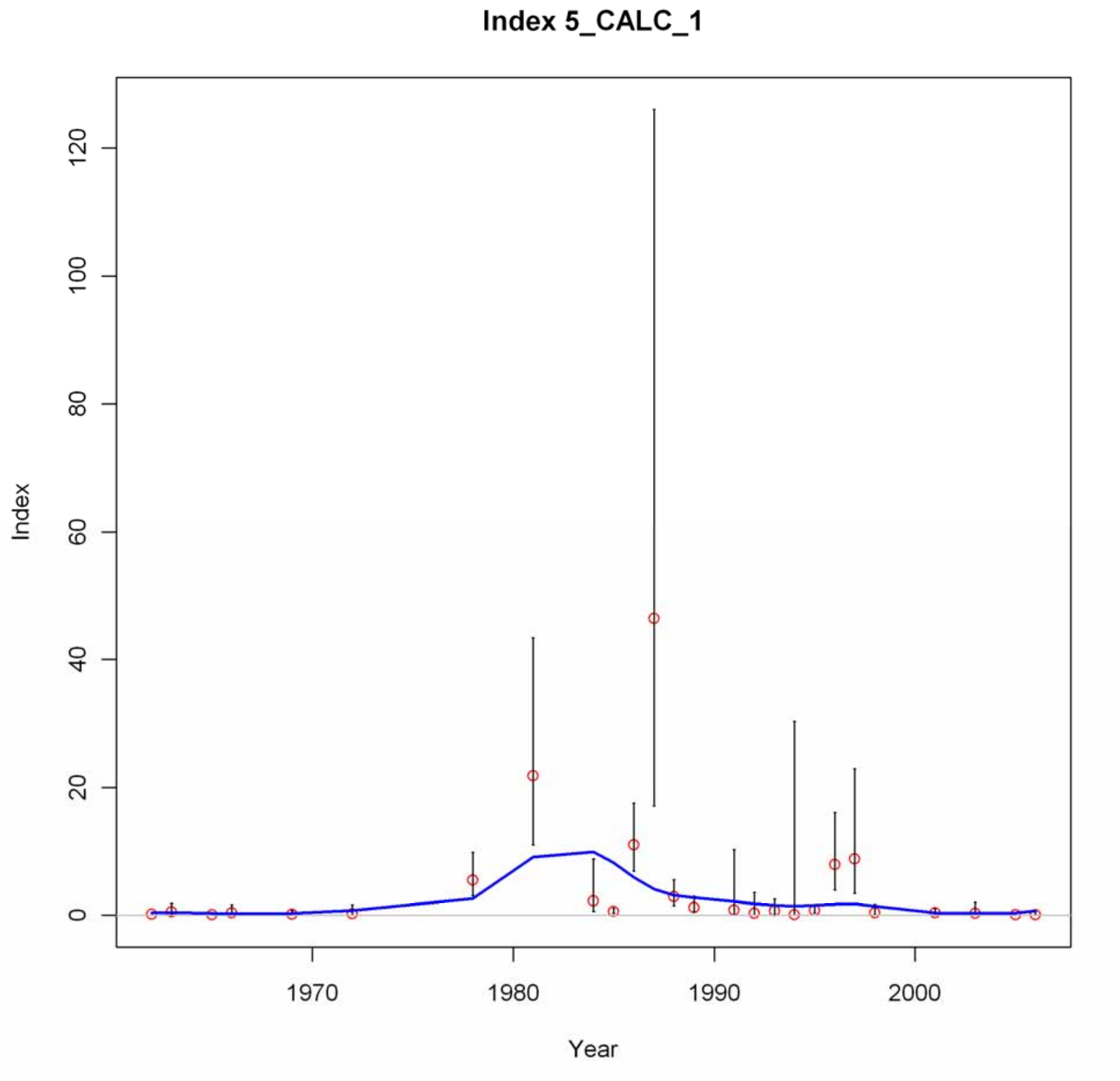


Figure A2B-26. Estimated fits (observed=red circles, with 95% CIs; predicted=line) associated with the CalCOFI index.

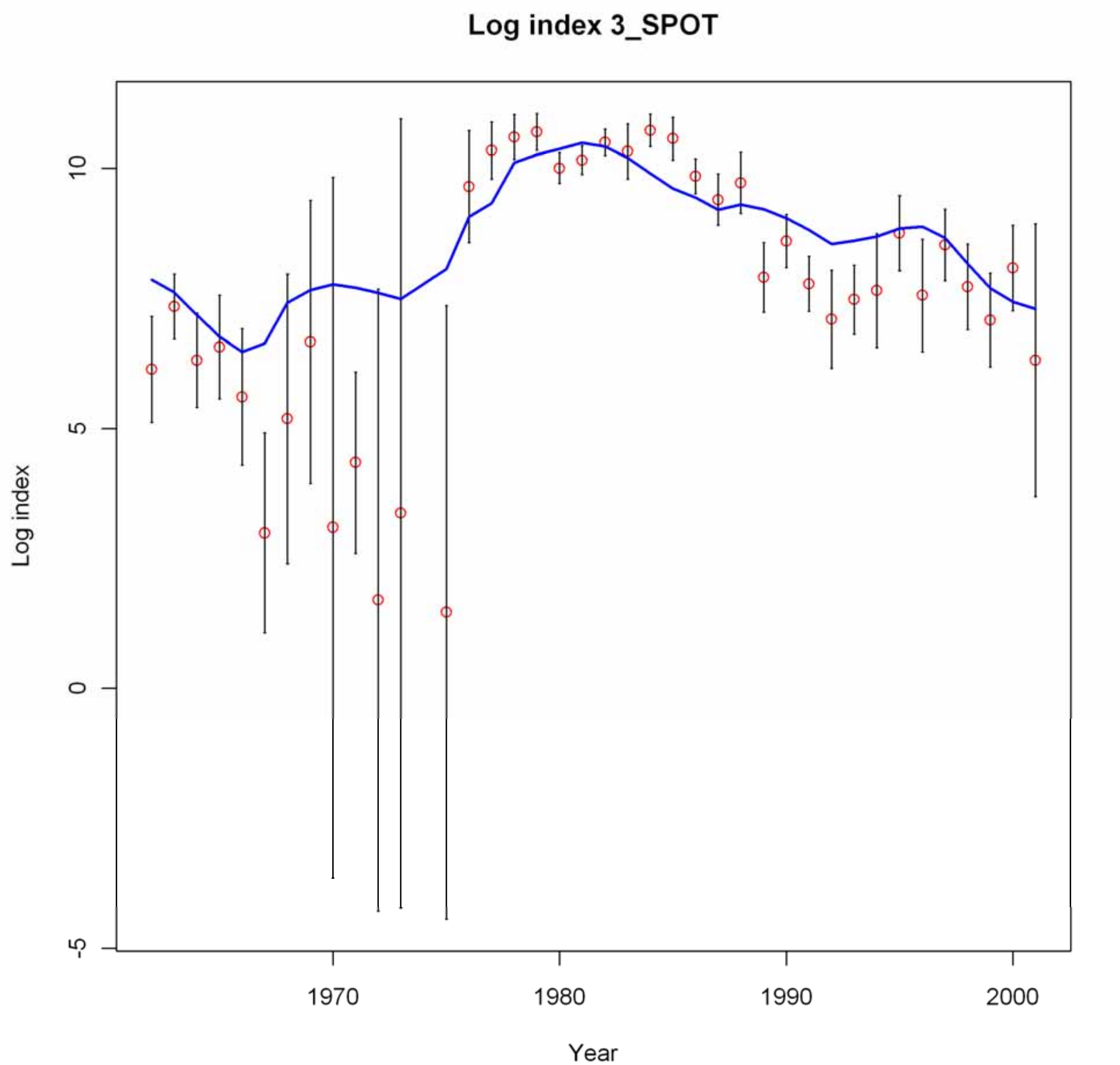


Figure A2B-27. Estimated fits (observed=red circles, with 95% CIs; predicted=line) in log space associated with the Spotter index.

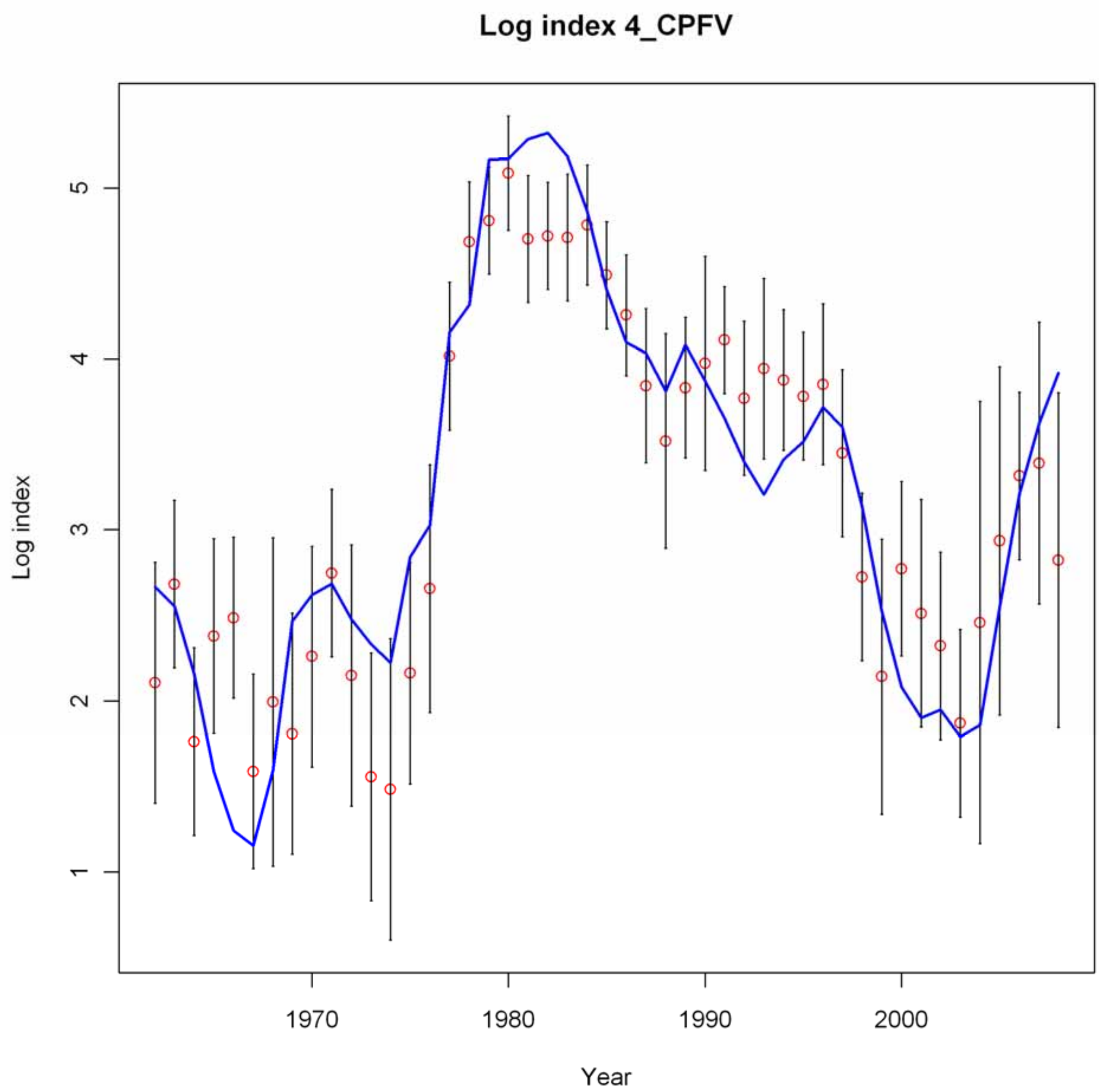


Figure A2B-28. Estimated fits (observed=red circles, with 95% CIs; predicted=line) in log space associated with the CPFV index.

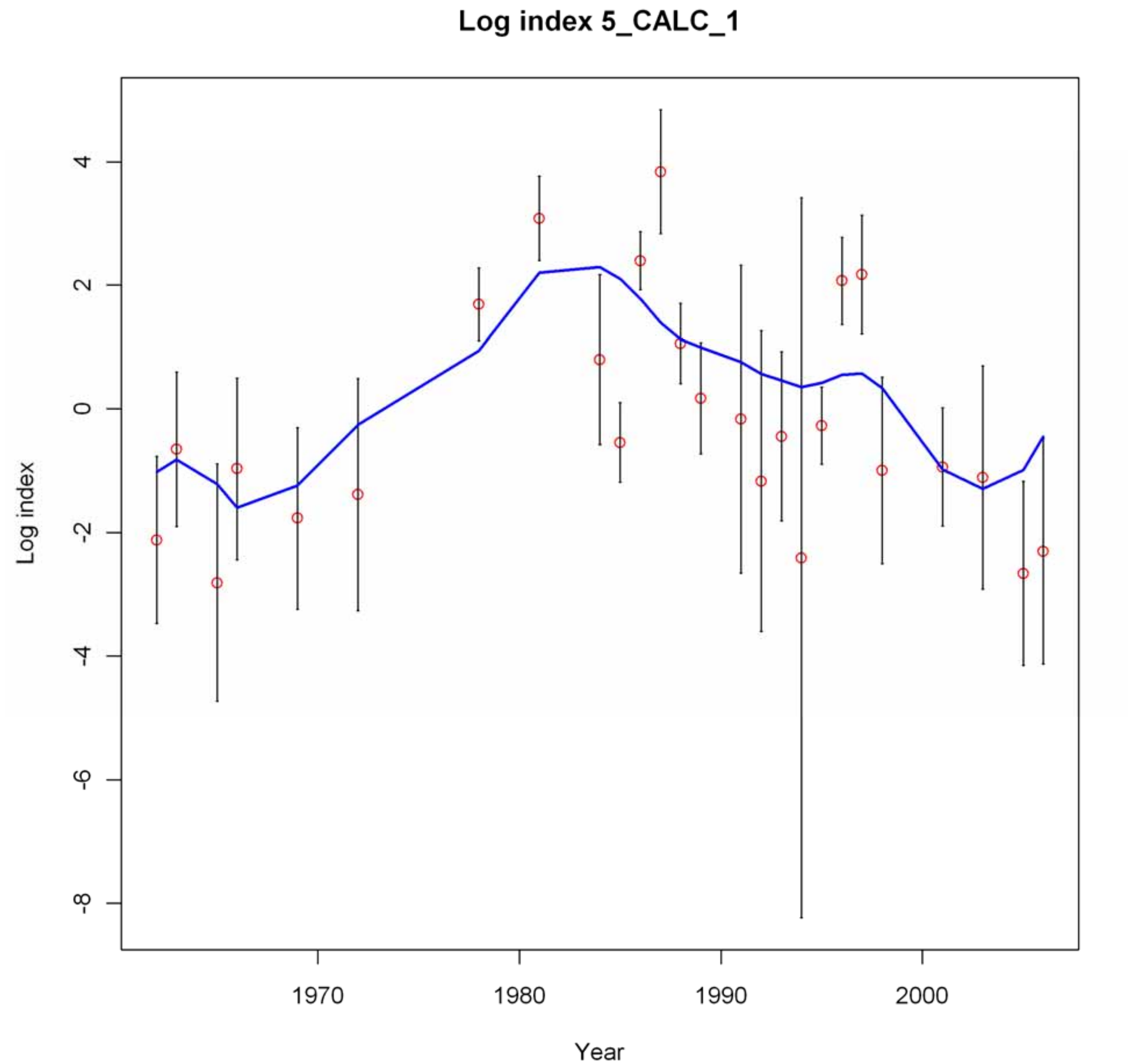


Figure A2B-28. Estimated fits (observed=red circles, with 95% CIs; predicted=line) in log space associated with the CalCOFI index.

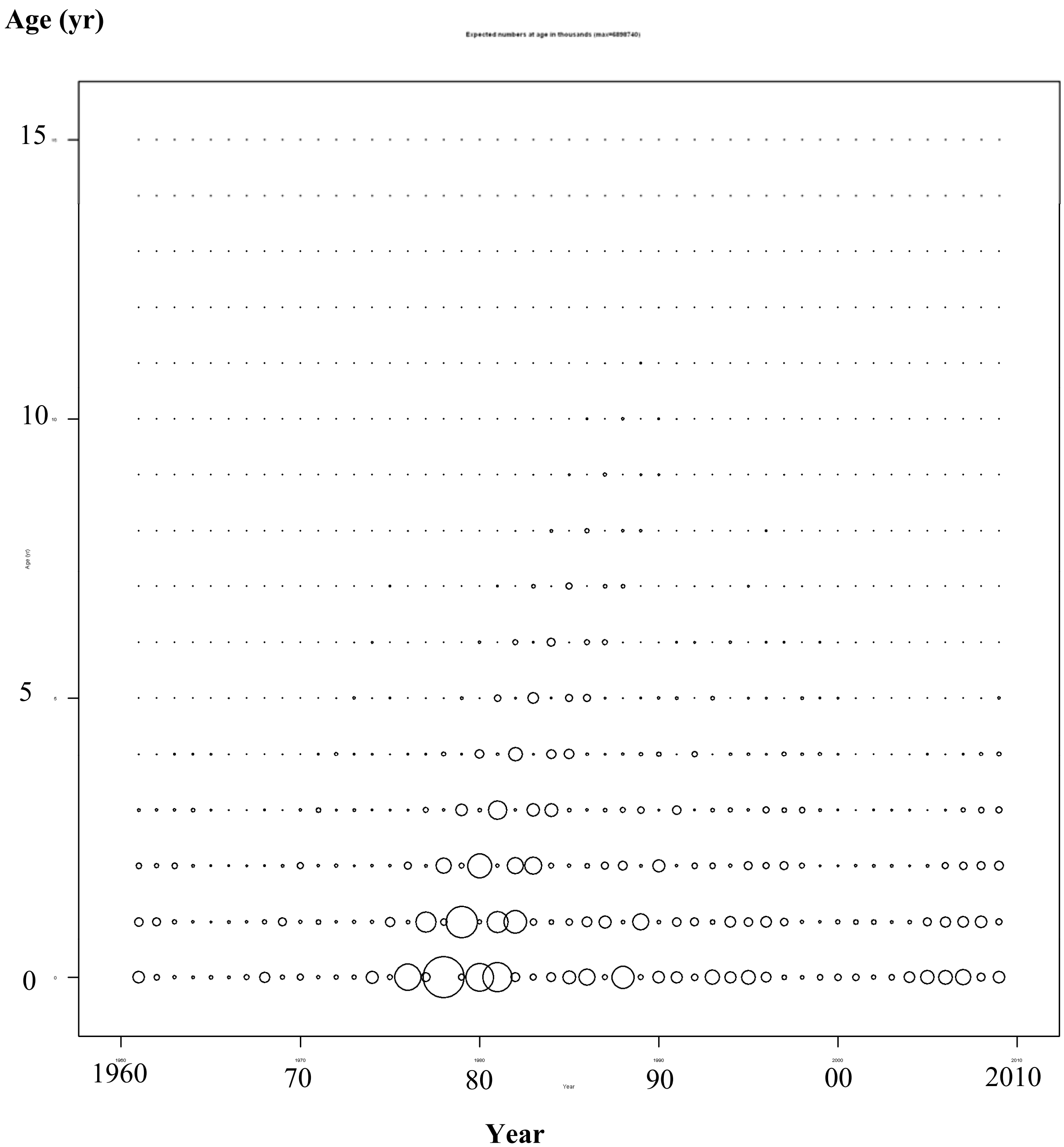


Figure A2B-29. Estimated population size (numbers-at-age), (1962-09).

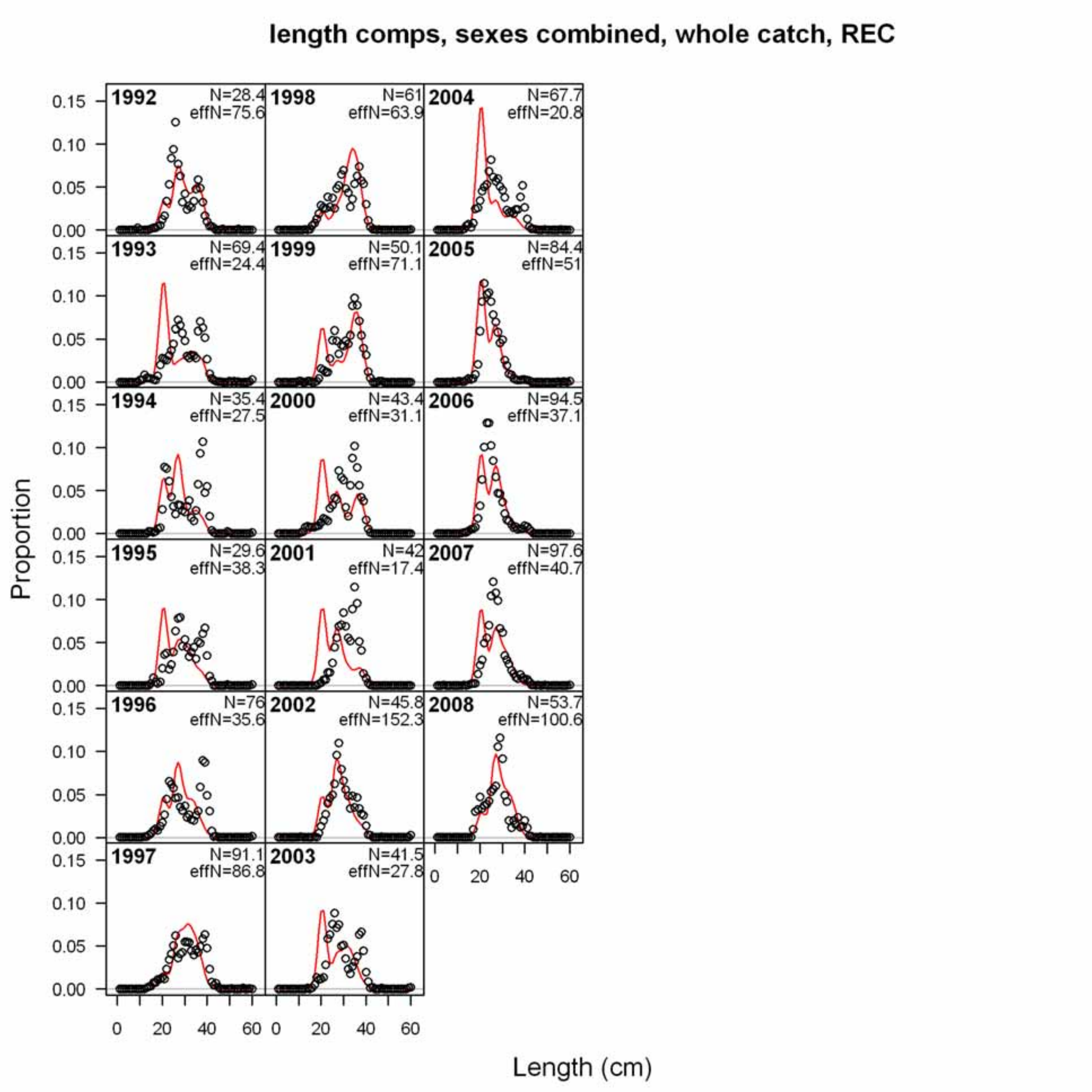


Figure A2B-30. Estimated fits (observed=black circles; predicted=line) associated with the recreational fishery length distribution time series.

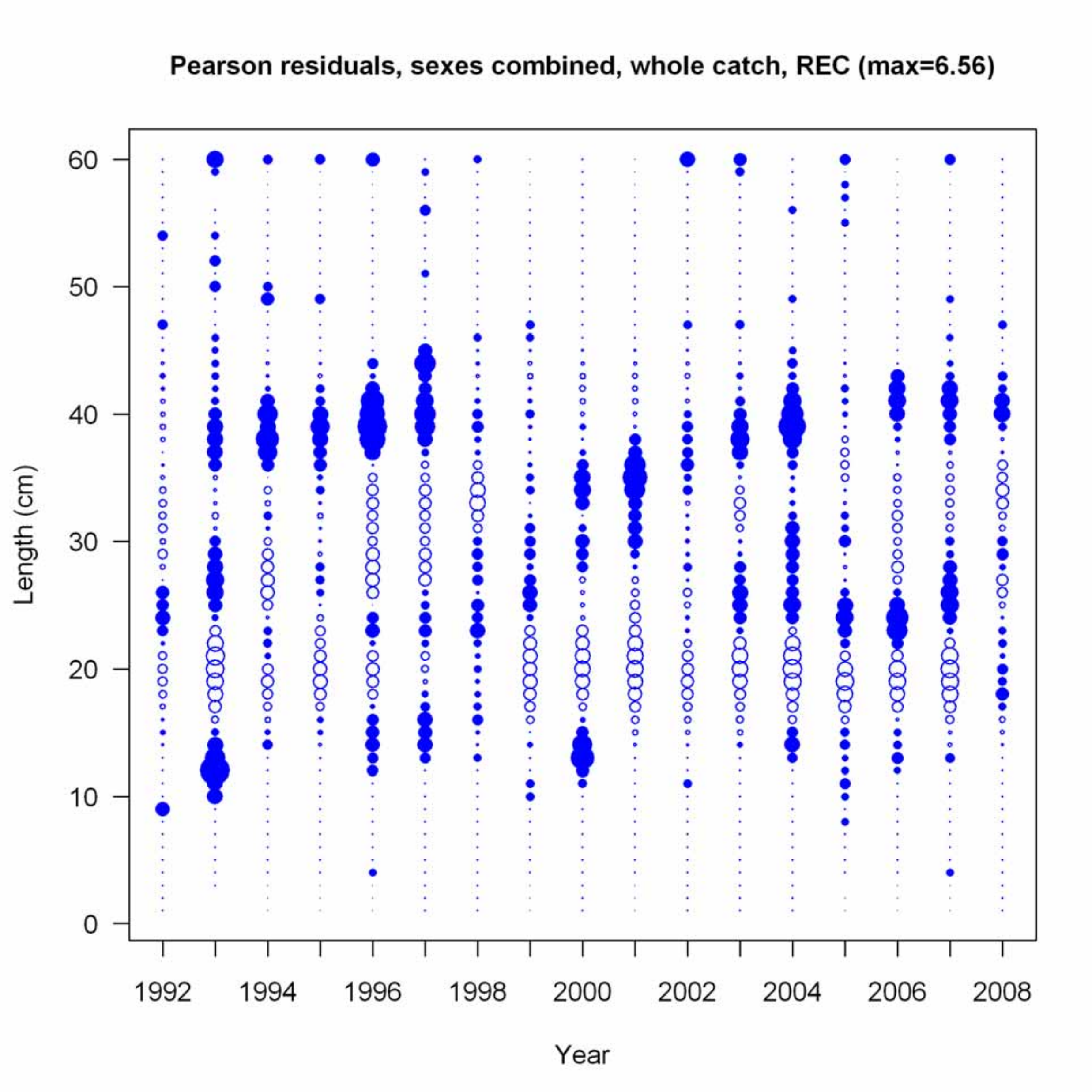


Figure A2B-31. Pearson standardized residuals (observed - predicted) for model fits to the recreational fishery length distribution time series (1992-08). Maximum bubble size = 6.56 (dark circles represent positive values).

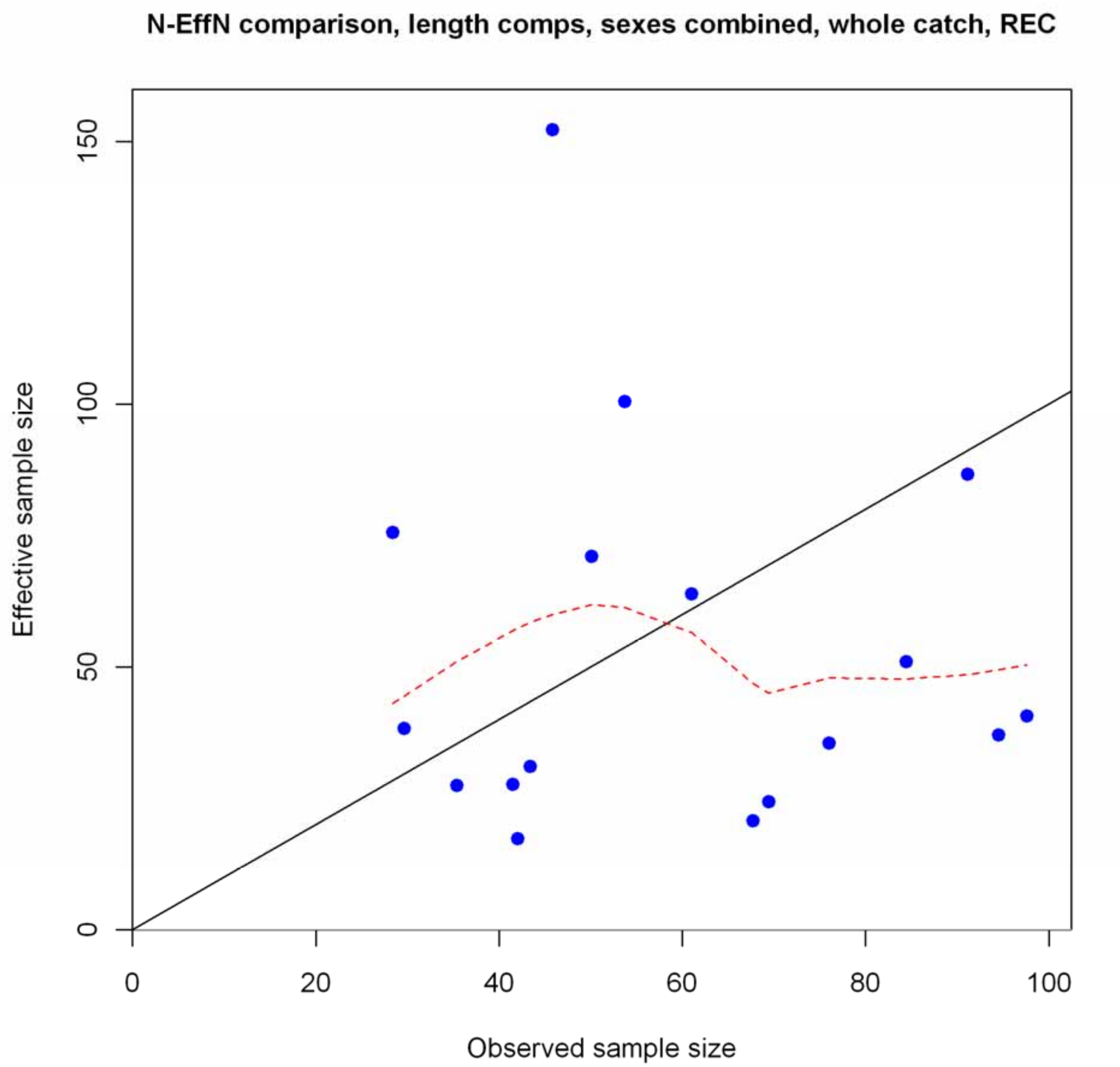
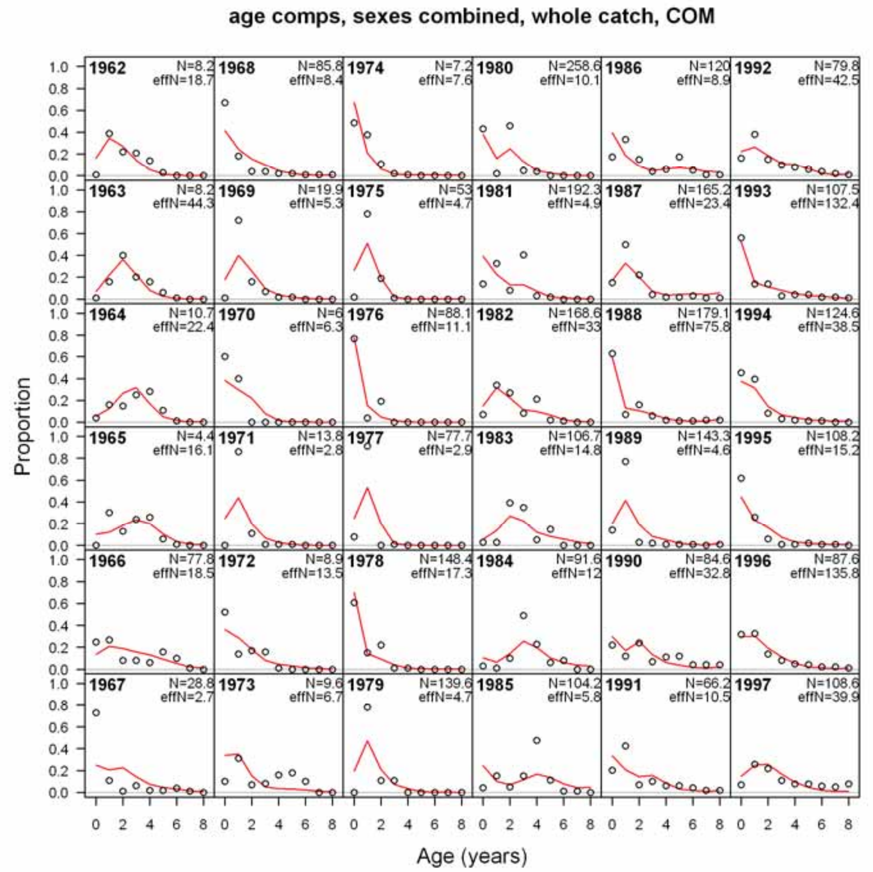


Figure A2B-32. Effective vs. observed (input) sample sizes for the recreational fishery length distribution time series. Solid line represents a 1:1 relationship and the dashed line reflects a loess smoother.



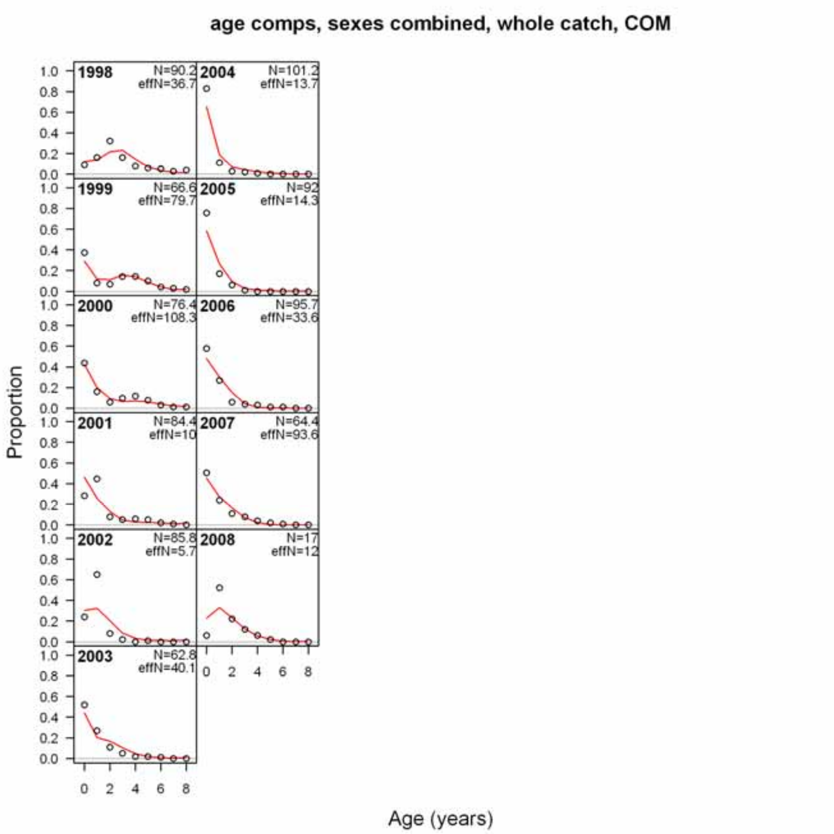


Figure A2B-33. Estimated fits (observed=black circles; predicted=line) associated with the commercial fishery age distribution time series.

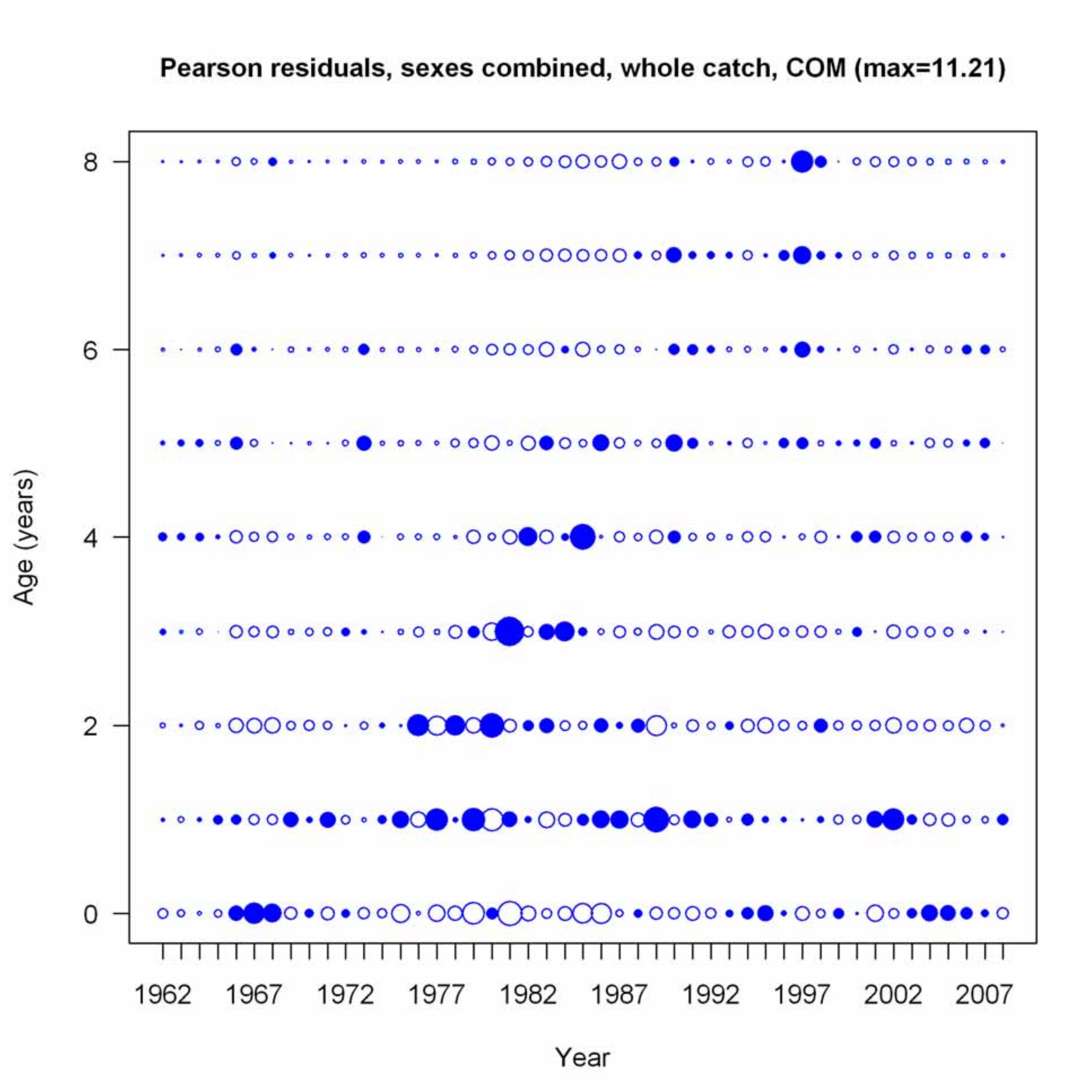


Figure A2B-34. Pearson standardized residuals (observed - predicted) for model fits to the commercial fishery age distribution time series (1962-08). Maximum bubble size = 11.21 (dark circles represent positive values).

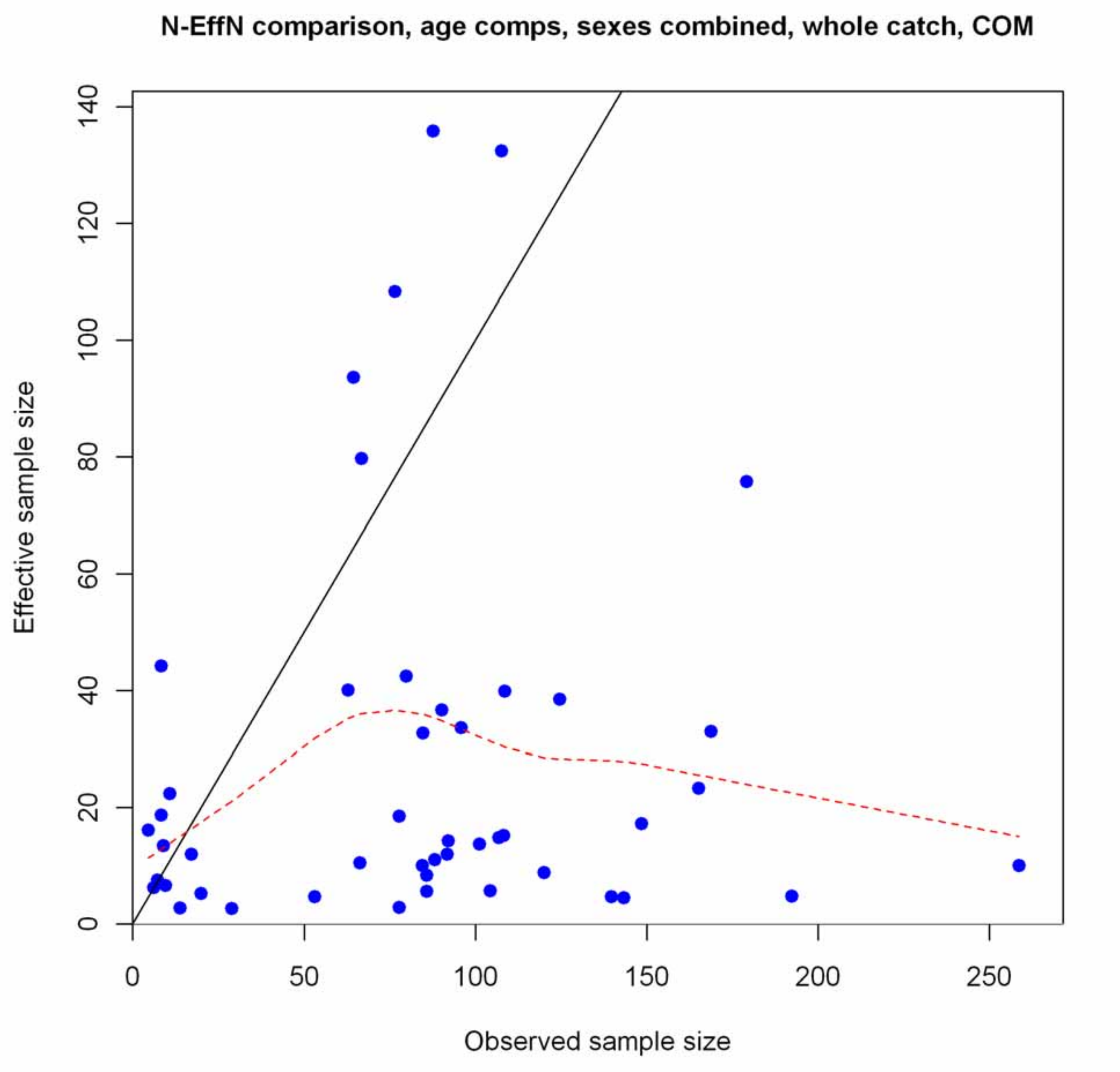


Figure A2B-35. Effective vs. observed (input) sample sizes for the commercial fishery age distribution time series. Solid line represents a 1:1 relationship and the dashed line reflects a loess smoother.

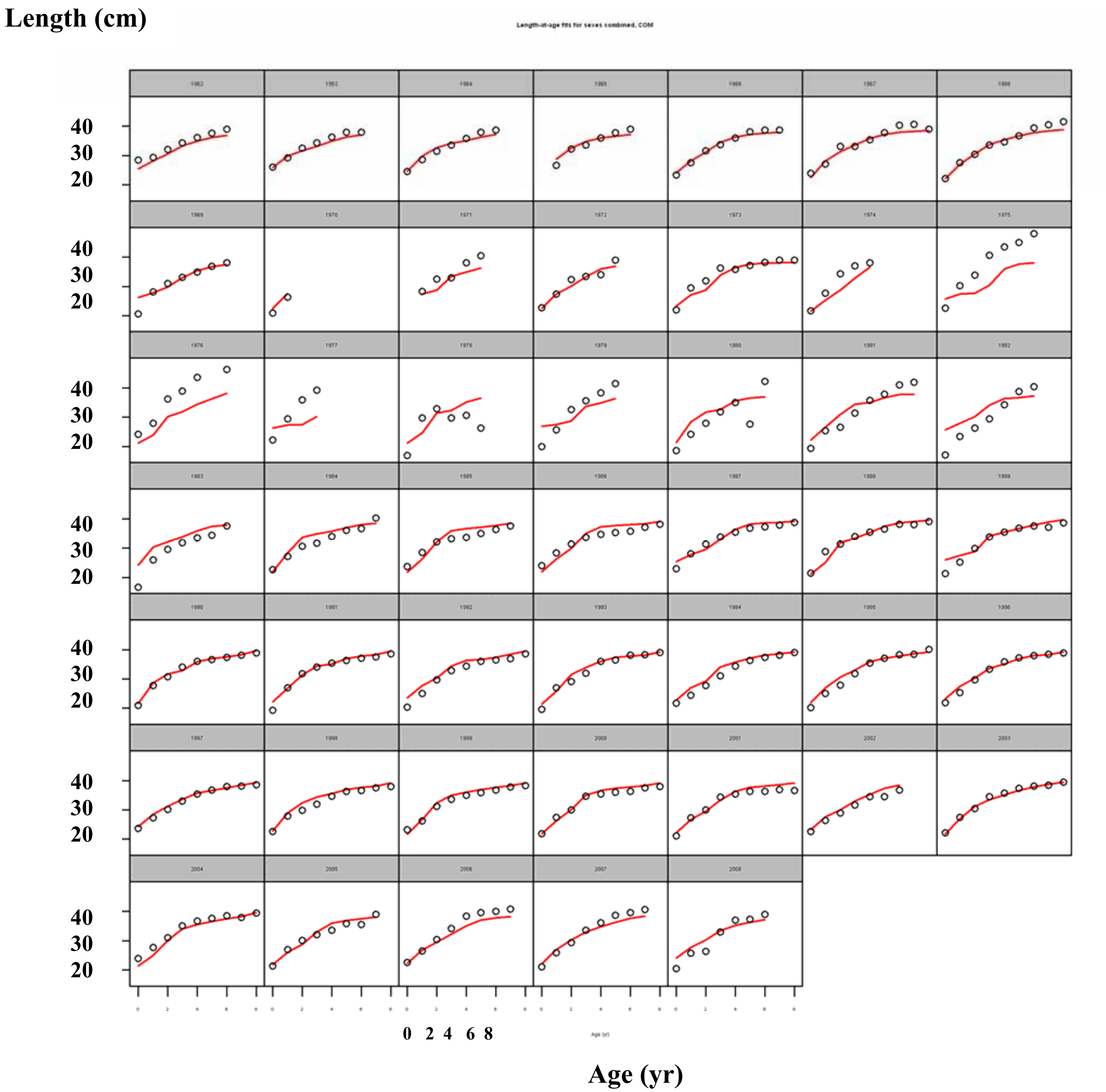


Figure A2B-36. Estimated fits (observed=black circles; predicted=line) associated with the commercial fishery mean size-at-age distribution time series.

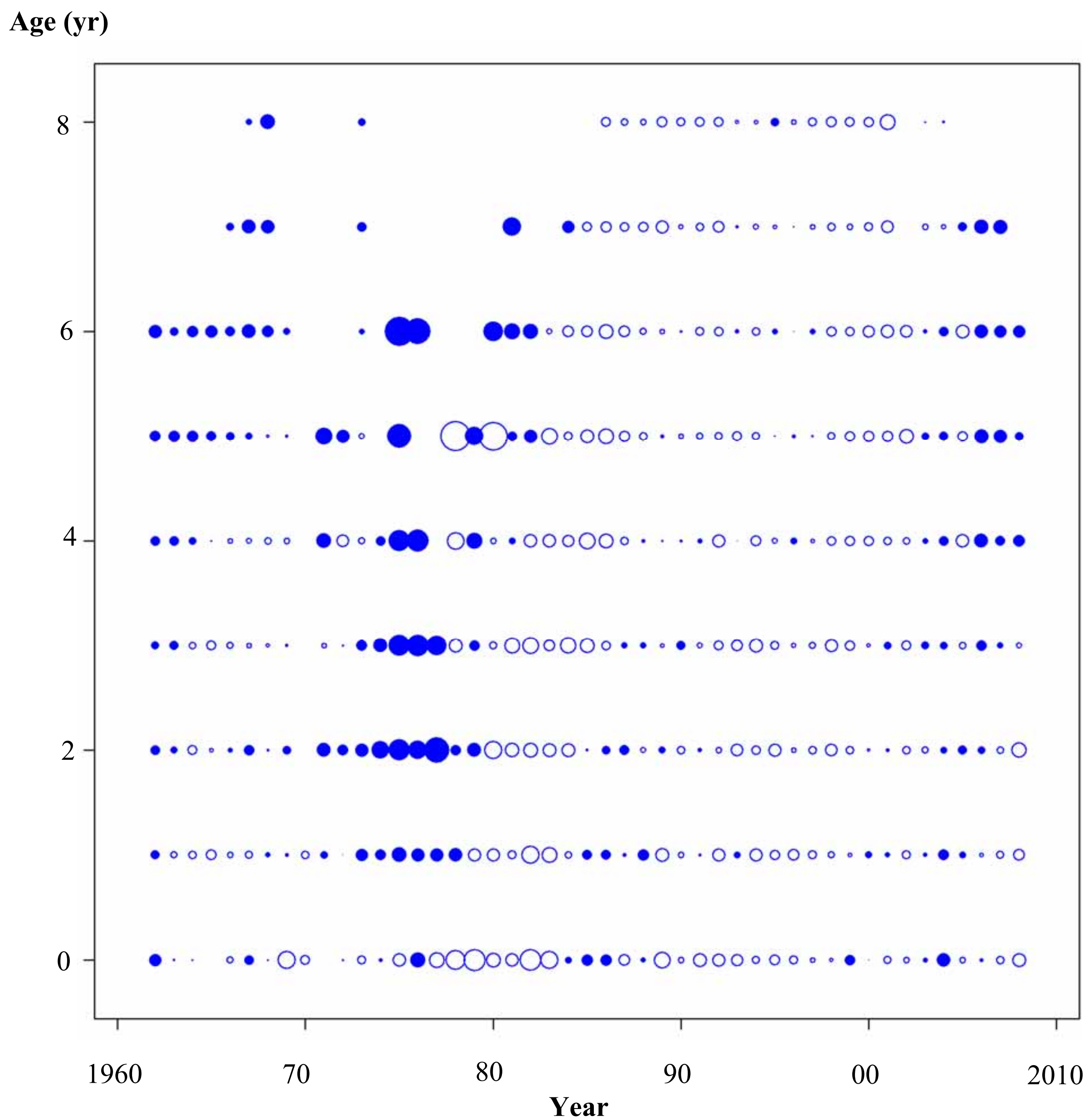


Figure A2B-37. Pearson standardized residuals (observed - predicted) for model fits to the commercial fishery mean size-at-age distribution time series (1962-08). Maximum bubble size = 4.79 (dark circles represent positive values).

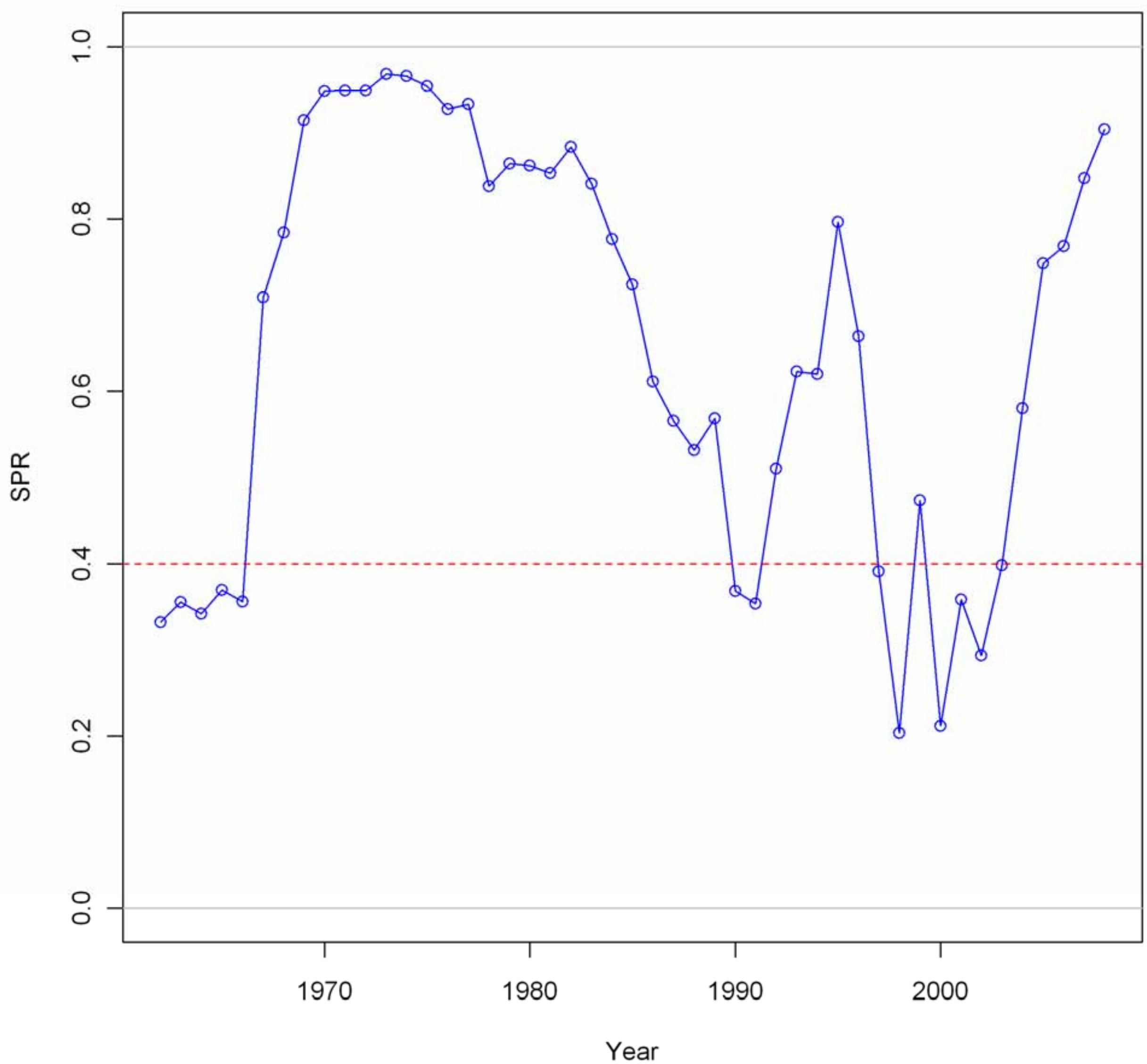


Figure A2B-38. Estimate spawning potential ratios (SPR), (1962-08). Dashed line represents reference SPR only.

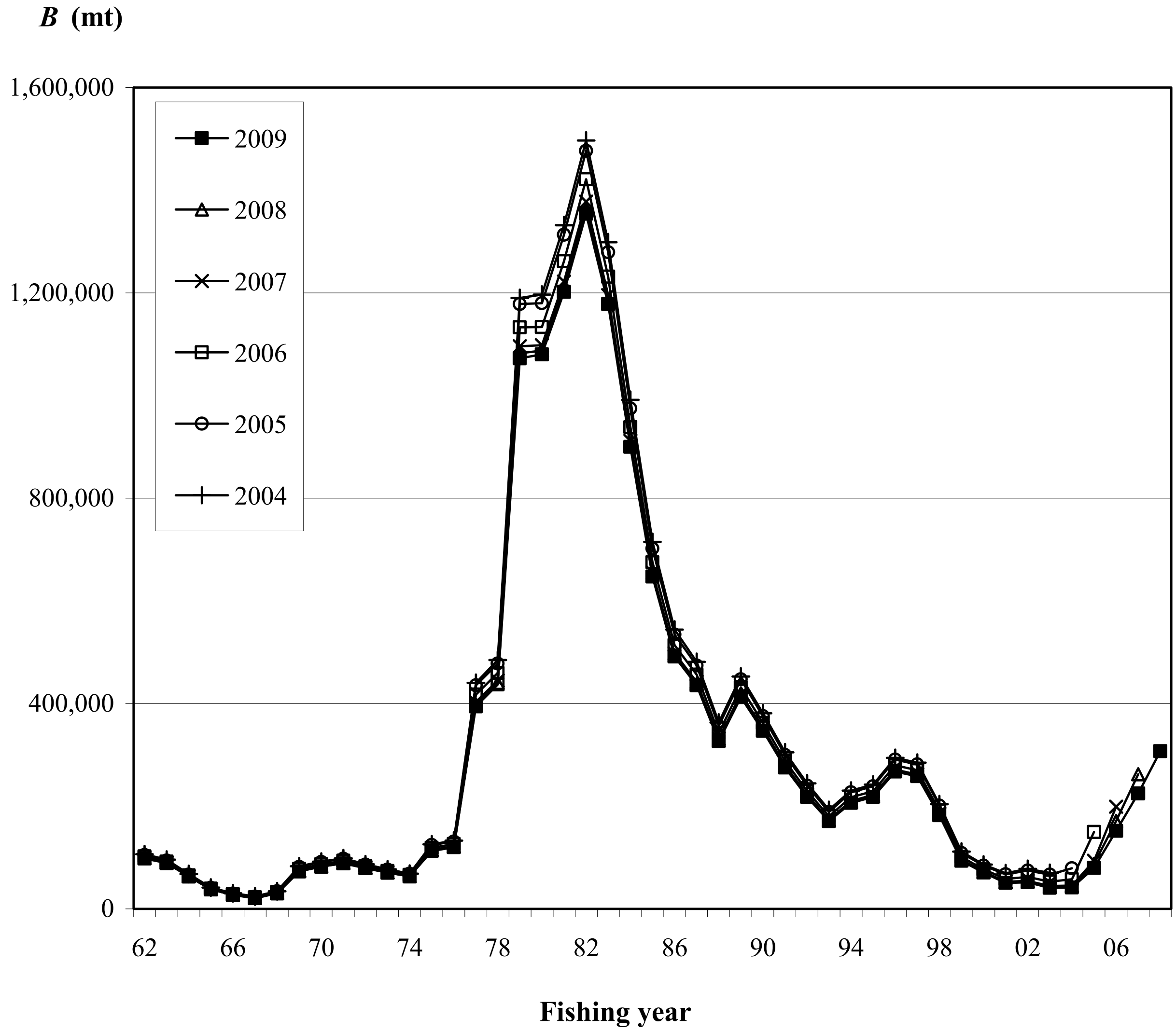


Figure A2B-39. Estimated total stock biomass (age 1+ fish in mt, B) of Pacific mackerel based on retrospective analysis that omitted one year of data in chronological order (1962-09).

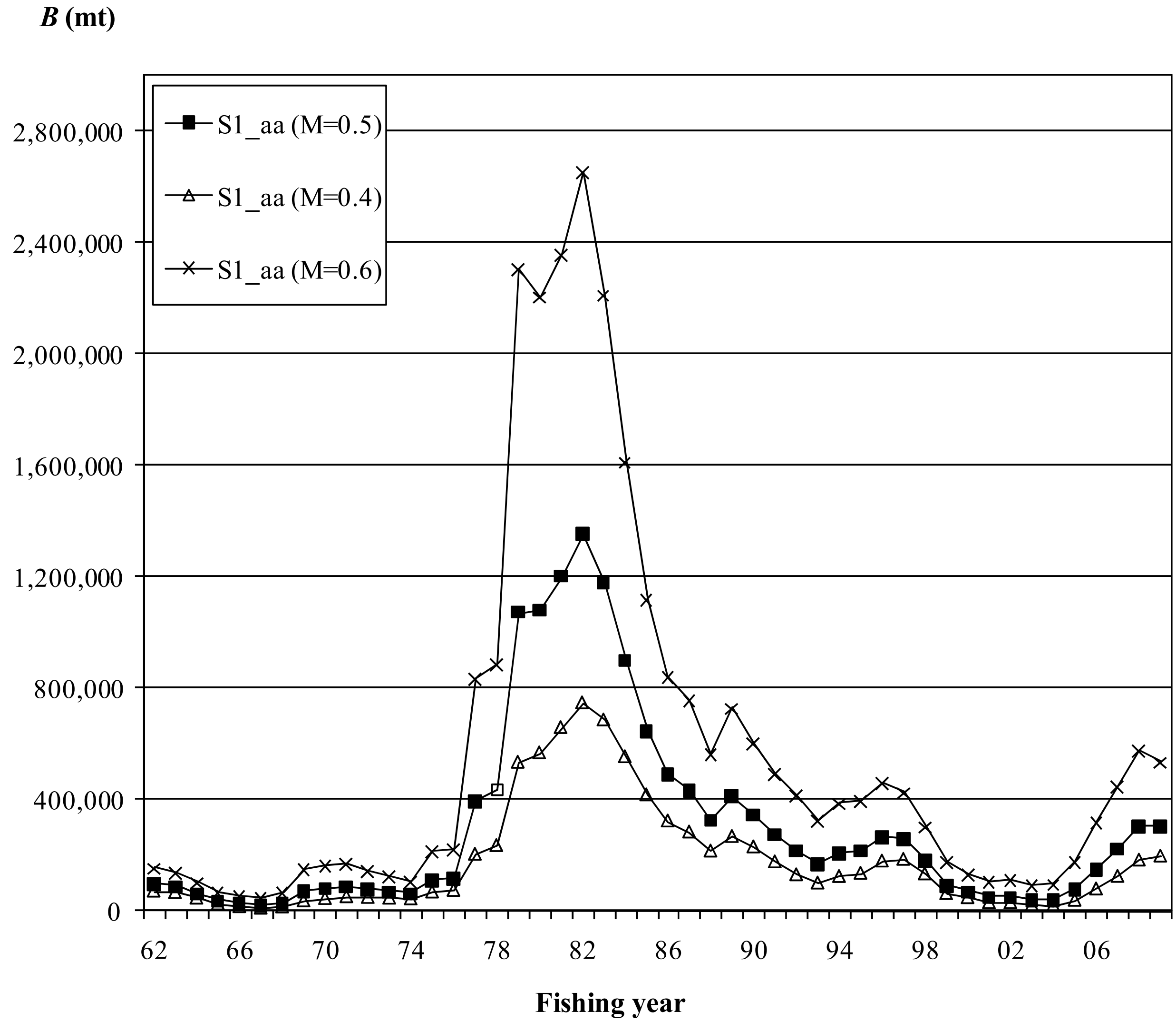


Figure A2B-40. Estimated total stock biomass (age 1+ fish in mt, B) of Pacific mackerel based on different assumptions concerning natural mortality (M), (1962-09).

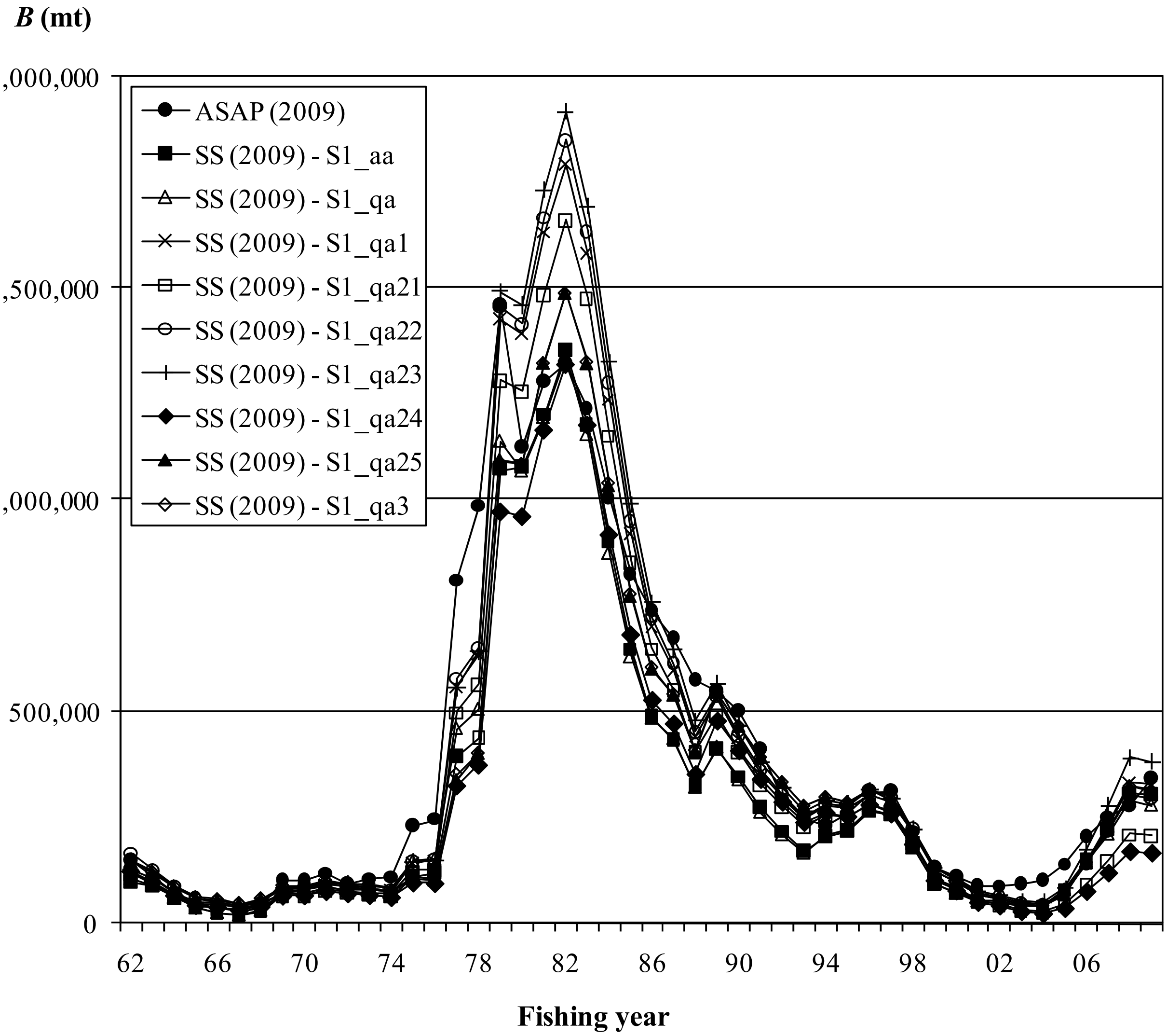


Figure A2B-41. Estimated total stock biomass (age 1+ fish in mt, *B*) of Pacific mackerel based on the ASAP (2009) model and SS model scenarios developed in sensitivity analysis (1962-09). Also, see Table A2B-1 (A-C).

Appendix 3A

Spotter Data Analysis for Pacific Mackerel From 1963-2005 Using a Delta GAM

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Introduction

From 1963 to 2003 pilots, employed by the fishing fleet to locate schools of pelagic fish, reported data for each flight on standardized logbooks and provided them to NOAA Fisheries for a fee per flying hour ($1.00-5.00). These data were used to derive Spotter-based indices of abundance for pelagic fish, such as anchovy and young sardine. These indices were calculated as year effects estimated using delta log-normal linear models (LLM; Lo et al. 1992). However, after the year 2000, there was rapid decline in both the number of active pilots and total logbooks returned (Tables 1 and 2), as well as a southward shift in effort to offshore areas around Baja California. To remedy this problem, NOAA Fisheries started to contract professional spotter pilots to survey the Southern California Bight region beginning in 2004 primarily for assessment of young sardine. Newly available data from this enhanced survey were incorporated into the index, and a new time series was calculated using a delta Generalized Linear Model (GLM) for young sardine. This paper presents estimates of the spotter survey index from 1963 to 2005 for Pacific mackerel (*Scomber japonicus*) However, due to the lower number of flights with positive sightings of Pacific mackerel in the spotter survey, I used a Generalized Additive Model (GAM) to obtain estimates of total tonnage as a relative index for the Pacific mackerel.

The old time series had an informal design. Pilots flew the year around at night and in the day, and in areas and seasons frequented by the fishery. The pilots' searching behavior, like most fishermen, might be characterized as "adaptive", meaning that searches for target species may be concentrated in areas where schools were previously sighted. There is no doubt that a formal fishery independent survey design would provide more precise and less biased estimates than the present indices. However, by altering the design, one would lose the most valuable property of the old aerial surveys, i.e., a time series that extends back to 43 years. Regardless of its merit, a new index will have little value in stock assessment until it extends over at least 5-10 years. Clearly, the time series that ended in 2000 needs to be extended, but it would also be valuable to develop a new, more precise index with less potential bias.

The new aerial survey was based on a line transect design with regular occupation of fixed grid lines spaced at regular intervals with random starting points. Concurrently, a "simulated old survey" was implemented by employing an adaptive design to simulate fishing conditions, where having found a school the fishermen will search the vicinity to find others. After searching the pilot returned to the transect line and continued along the line. In this way we could gather information appropriate to both old and new survey designs. Factors such as month, area and day/light in the new surveys are close to those standardized conditions used in the spotter index model developed by Lo et al. (1992):

Experienced pilots under contracts flew along the predetermined track lines in March and April from San Diego to San Francisco, at a maximum of 100 nm offshore(Figure 1). However, in reality, pilots were unable to conduct all assigned surveys in March and April due to weather conditions and their flying schedules. In addition, they only flew in the daytime and not in the nightime alone. As a result, flights in 2004 took place throughout the entire year, but during March and April in 2005. No surveys were conducted in 2006 due to unavailability of pilots during the pre-assigned survey months: March and April. This restriction will be relaxed to the first half of the year. In 2004, a total of 5 surveys by month (3,4,5,7, and 9) were accomplished from March-November, including two single-pilot flights in September and November. In 2005, we had two 3-pilot complete surveys, three 2-pilot surveys and one 1-pilot survey during March and April.

Statistical methods

Delta linear models

The relative abundance of pelagic species, like northern anchovy, or sardine can be expressed as the product of density and a measure of area:

$$(1)\ I = DA$$

where $\boldsymbol{I}$ is the index of relative abundance for a given year (tons). D is density of fish (tons per block) and A is the area (blocks 10' by 10' defined by California Department of Fish and Game (Caruso et al 1979) covered by fish spotters. In the original data analysis of the relative abundance of anchovy, it was reasonable to assume that fish spotters flew over an area that was at least as large as the area occupied by the anchovy stock in each year. This is not so for the entire population of other species like Pacific sardine and Pacific mackerel. For the case of sardine, it suffices to apply to young sardines (<=2 year old). In the current analysis for sardine, units for the index (I) are tons of young sardine, sighted by fish spotters.

Density of fish (D) for each year can be expressed as the product of d and P:

$$(2)\ D = dP$$

where d is a standardized measure of fish density (tons per block) for positive flights (flights during which fish of interest were seen) and P is a standardized measure of the proportion of blocks that were covered by positive flights (referred to as proportion positive) (Table 1). We used the product in order to avoid problems that arise from including a large number of zeros; therefore the distribution of D is Delta distribution.

Delta lognormal linear model (LLM)

In the original lognormal linear model, we assumed that the number of tons/block (y) or proportion positive (p) follows a lognormal distribution and varies with some covariates, i.e. log(y) or log(p+1) was a function of many covariates: year, region, season, pilot, night/day flights plus some interaction terms:

$$\log(y) \text{ or } \log(p+1) = x'B$$

The final estimates of standardized d and P were obtained by taking anti-log of the linear equations (x'B) plus correction terms. Thus, the relative abundance for each year is:

$$\hat{I} = \hat{d}\hat{P}A$$

Delta GAM model

To continue including spotter pilot data for the stock assessment, from the new datasets,we decided to switch from Delta lognormal linear model to a more flexible model, like GLM or GAM using S-Plus, to allow us to incorporate other possible distribution of tonnages/block (y) of sardine sighted by the pilots for the positive flights and the proportion of positive flights (p) with appropriate link functions for the expected values (d and P), respectively. As stated in Lo et al. (1992), although we used lognormal linear models for components of the delta distribution, other linear or nonlinear models based on other statistical distributions could be used instead.' The Delta GLM has been used for Pacific sardine. For Pacific mackerel, the GAM was chosen because it is more flexible than GLM due to the low sighting of Pacific mackerel and no sighting in 1974.

As done for the delta GLM, we chose a family of Poisson distribution and used log as the link function for the number of tons/block of positive flights (d), e.g., log (of the expected tonnage/block) = x'B; whereas a family of Binomial distribution and the logistic link function, for the proportion of positive flight (P), e.g. log(P/(1-P)) = x'B. In the GAM model, the year effect was modeled by a smoothing spline fit with d.f.=12 while other independent variables: day/night, season, region and survey type were treated as categorical data.

The estimate of density of Pacific mackerel is $\hat{D} = \hat{d}\hat{P}$, with variance estimated as (Goodman 1960):

$$\text{var}(\hat{D}) = \text{var}(\hat{d}\hat{P}) = \hat{P}^2\,\text{var}(\hat{d}) + \hat{d}^2\,\text{var}(\hat{P}) - \text{var}(\hat{d})\,\text{var}(\hat{P})$$

where the estimated variance of estimates of d and P came directly from S-Plus. No correction of *d* and *P* was included in the variance of *D* because the correlation from the data was not significant. The final estimate of the relative abundance (I) and its CV are simply as follows.

$$\hat{I} = \hat{D}A \text{ and}$$
$$CV(\hat{I}) = CV(\hat{D})$$

where A is total number of blocks within the traditional area covered by spotter pilots each year.

Results

The time series of the density (d=tonnage/block), the proportion of positives (p), the survey area (A=blocks) and the total tonnage (D) of Pacific mackerel were presented (Table 1). The estimates of density (d) and proportion of positives (p) were adjusted for night time, season 1(Jan-March), region 2,pilot number 17 and survey 1(traditional aerial survey prior to 2004). The adjusted relative tonnages serve as the relative abundance of Pacific mackerel from spotter data set were presented using the delta-GAM (Table 1). We also presented the time series of total number of flights with sightings of Pacific mackerel and number of blocks with Pacific mackerel (Figures 2 and 3).

Discussion

The relative abundance of Pacific mackerel peaked at the mid-1980 and has been decreased since 1985.The total number of flights decreased continuous since late 1990's(Figure 2). However total number of blocks covered has been similar except 2003 (Figure 3). So, the decrease of the relative abundance of Pacific mackerel could reflect the decline of the population rather than the coverage of the aerial survey in terms of time and space.

Because the effort has been reduced traumatically since 2001 off California, we compared the overall time (season) and space(region) between this two period by the total number of flights (Table 2). The overall distributions between these two periods are similar where most of the efforts were in regions 1-3 for all season and much of the efforts were shifted to regions 4-6 in second half of the year(Figure 1). Thus the reduced effort does not appear to introduce much bias in terms of time and space.

The LLM was used in the past prior to 2000. We compared time series of the relative abundance of Pacific mackerel based on the LLM and GAM (Figure 4). These two time series have similar shape except that the time series from LLM fluctuated more than that from Delta GAM. The CVs from LLM (Bradu and Munklak 1970) were higher than those from GAM (Figure 5) partially because the variances of the estimates from LLM included those of bias-correlation terms for the parameter estimates of lognormal distribution, which may not be so for the variance of estimates used in GAM(Lo et al. 1992, Chambers and Hastie 1992).

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Table 1: Summary of tonnage/block for positive flights (T/B+;d), and proportion of blocks covered by positive flights(%BLK;p), relative abundance(REL_ABN;I) and associated standard errors(SE) and coefficient of variation(CV), 1963-2005

YEAR	T/B+(d)	SE_T/B+(se(d))	%BLK(p)	SE_%BLK(se(p)	T/B(D)	SE_T/B(se(D)	BLOCKS: A	REL_ABN (I)	SE_RA(SE(I))	CV_RA(CV(I))
1963	10.9765	0.256	0.3948	0.126	4.334	1.386	180	780.1215	249.4857	0.3198
1964	9.1412	0.2097	0.2954	0.1009	2.7003	0.9246	206	556.2621	190.4636	0.3424
1965	7.9056	0.2247	0.2112	0.0846	1.6698	0.6701	208	347.3205	139.3901	0.4013
1966	7.2327	0.2471	0.1433	0.0674	1.0363	0.4881	224	232.1204	109.3434	0.4711
1967	7.0751	0.2736	0.0941	0.0513	0.666	0.3633	200	133.2097	72.6574	0.5454
1968	7.4065	0.3059	0.0641	0.0394	0.4748	0.2925	221	104.9266	64.644	0.6161
1969	8.263	0.3458	0.0457	0.0311	0.3777	0.2572	223	84.2257	57.3583	0.681
1970	9.7486	0.395	0.0351	0.0256	0.3417	0.2495	143	48.8633	35.6745	0.7301
1971	12.1586	0.4611	0.0288	0.0217	0.3504	0.2646	175	61.326	46.2968	0.7549
1972	16.4332	0.5719	0.0257	0.0194	0.4221	0.3194	184	77.6658	58.763	0.7566
1973	24.4208	0.761	0.0268	0.0195	0.6548	0.4756	320	209.5514	152.1861	0.7262
1974	39.512	0.3545	0.0368	0.024	1.4542	0.9487	303	440.6126	287.4576	0.6524
1975	68.2695	1.3696	0.0672	0.036	4.5882	2.4608	272	1247.999	669.3363	0.5363
1976	122.8261	1.6234	0.1425	0.0569	17.5023	6.9915	320	5600.725	2237.292	0.3995
1977	211.1617	1.8301	0.2805	0.0785	59.2229	16.5939	274	16227.06	4546.726	0.2802
1978	273.5644	2.1046	0.4336	0.0886	118.6293	24.2472	277	32860.31	6716.464	0.2044
1979	245.675	1.8841	0.5405	0.0886	132.7758	21.7868	279	37044.45	6078.508	0.1641
1980	207.3972	1.6878	0.5996	0.0854	124.3496	17.7401	196	24372.52	3477.056	0.1427
1981	175.8748	1.4067	0.6123	0.0821	107.6835	14.4608	232	24982.57	3354.899	0.1343
1982	163.2234	1.3314	0.5872	0.0816	95.8495	13.3451	249	23866.53	3322.929	0.1392
1983	158.6598	1.2833	0.5474	0.0829	86.8545	13.1711	363	31528.16	4781.096	0.1516
1984	201.1422	1.4698	0.5156	0.0823	103.7128	16.5765	390	40447.99	6464.815	0.1598
1985	230.6762	1.5536	0.4888	0.0802	112.7574	18.5052	382	43073.30	7068.985	0.1641
1986	163.6113	1.215	0.4568	0.079	74.7448	12.9438	372	27805.07	4815.101	0.1732
1987	103.1131	0.8812	0.4219	0.0789	43.5071	8.1407	401	17446.36	3264.440	0.1871
1988	72.0007	0.7326	0.3759	0.0778	27.0675	5.6059	372	10069.09	2085.409	0.2071
1989	49.0351	0.5382	0.3353	0.0743	16.4421	3.649	379	6231.567	1382.970	0.2219

1990	36.58	0.4025	0.31	0.0704	11.3401	2.5772	390	4422.646	1005.100	0.2273
1991	31.8418	0.3669	0.2719	0.0655	8.659	2.0887	355	3073.959	741.5032	0.2412
1992	29.4926	0.386	0.2175	0.059	6.4155	1.7429	365	2341.645	636.1745	0.2717
1993	30.1896	0.4177	0.1819	0.0537	5.4916	1.6235	439	2410.830	712.7012	0.2956
1994	35.3125	0.4781	0.1697	0.0524	5.9936	1.8525	406	2433.403	752.0986	0.3091
1995	45.4523	0.5974	0.1725	0.0546	7.839	2.4819	343	2688.784	851.3066	0.3166
1996	54.9084	0.7079	0.1844	0.0578	10.1266	3.1762	373	3777.207	1184.711	0.3136
1997	47.649	0.6301	0.1972	0.0603	9.3949	2.8733	516	4847.761	1482.637	0.3058
1998	35.2852	0.5236	0.2005	0.0611	7.073	2.1568	464	3281.873	1000.741	0.3049
1999	26.2324	0.4727	0.1872	0.0604	4.912	1.5854	450	2210.402	713.4182	0.3228
2000	20.2908	0.4709	0.1662	0.0613	3.3722	1.2453	423	1426.445	526.7597	0.3693
2001	16.0772	0.5273	0.1254	0.0577	2.016	0.9295	473	953.5639	439.6377	0.461
2002	12.8185	0.1654	0.0768	0.0444	0.9843	0.5689	227	223.4301	129.1322	0.578
2003	10.2487	0.1381	0.0364	0.0255	0.3729	0.261	38	14.1711	9.9175	0.6998
2004	8.217	0.7163	0.0123	0.0109	0.1009	0.0892	342	34.5127	30.5233	0.8844
2005	6.6032	0.7399	0.0028	0.0037	0.0183	0.0244	278	5.0749	6.7749	1.335

Table 2. Total number of flights by region (figure 1) and season prior to 2000 and after 2000:

Prior to 2000: 1963-1999

Season	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6
1	133	1947	1499	-	2	-
2	191	2612	1184	36	134	-
3	329	4761	1938	263	1522	76
4	207	2315	2373	32	26	-

2000-2005

Season	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6
1	19	29	11	-	-	-
2	41	97	14	-	12	17
3	12	295	4	11	198	33
4	13	16	3	-	-	-

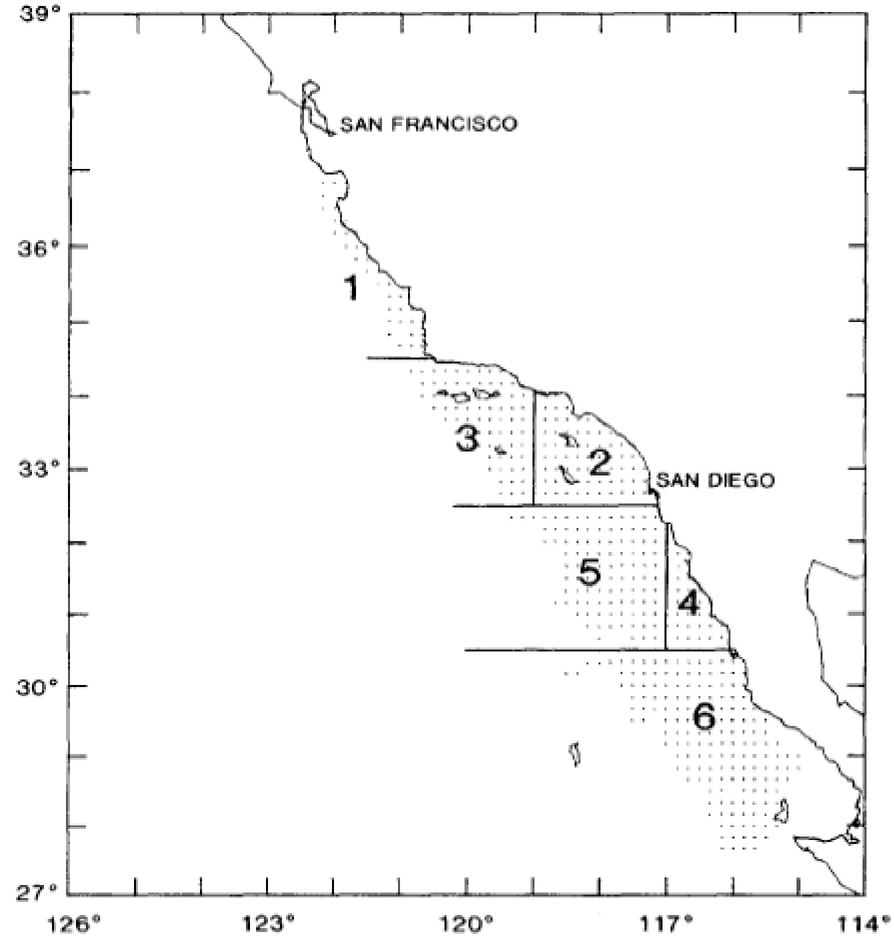

FIG. 2. Study area, regions, and blocks covered by fish spotters in 1989. Regions are outlined and denoted by numbers. Blocks are denoted by dots.

Figure 1 Study area, regions, and blocks covered by fish spotter in 1989. Regions are outlined and denoted by numbers. Blocks are denoted by dots (reproduced from Lo et al. 1992)

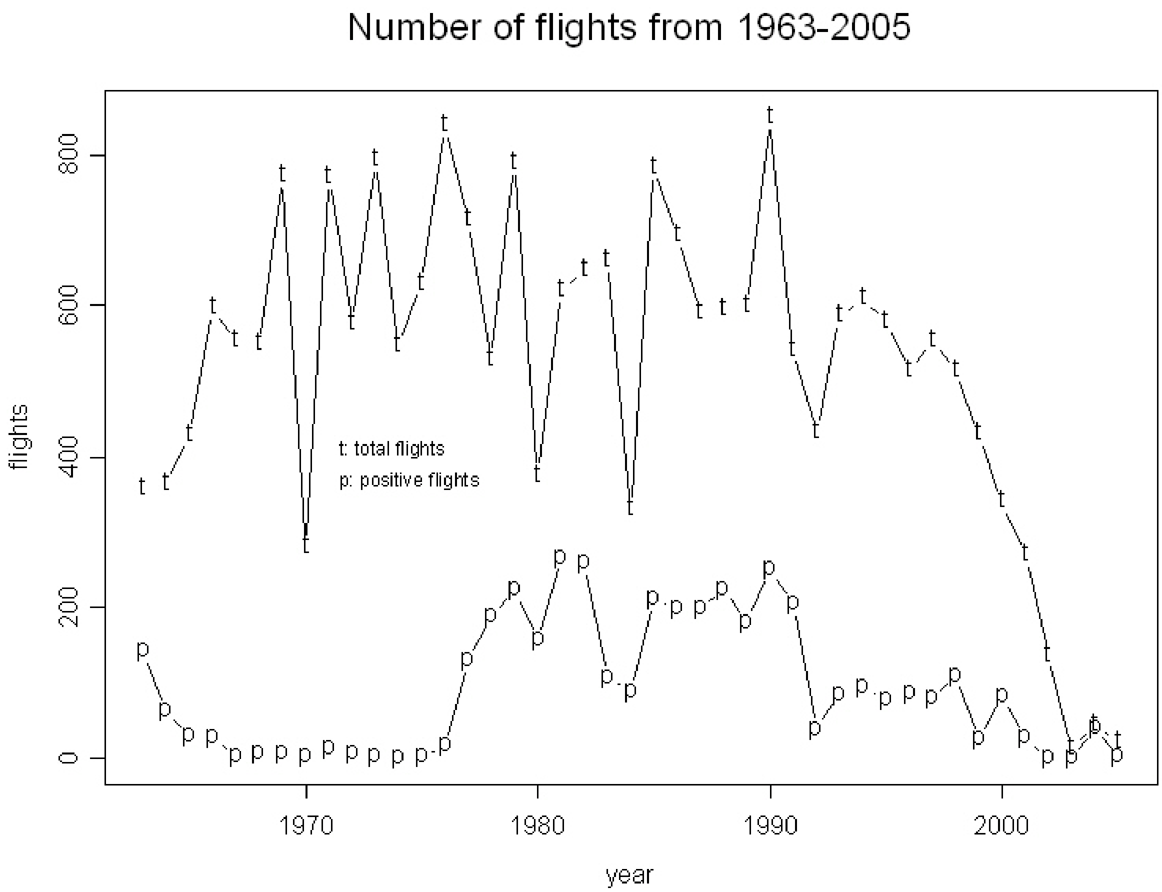

Figure 2. Total flights and number of flights with positive sightings of Pacific mackerel, 1963-2005

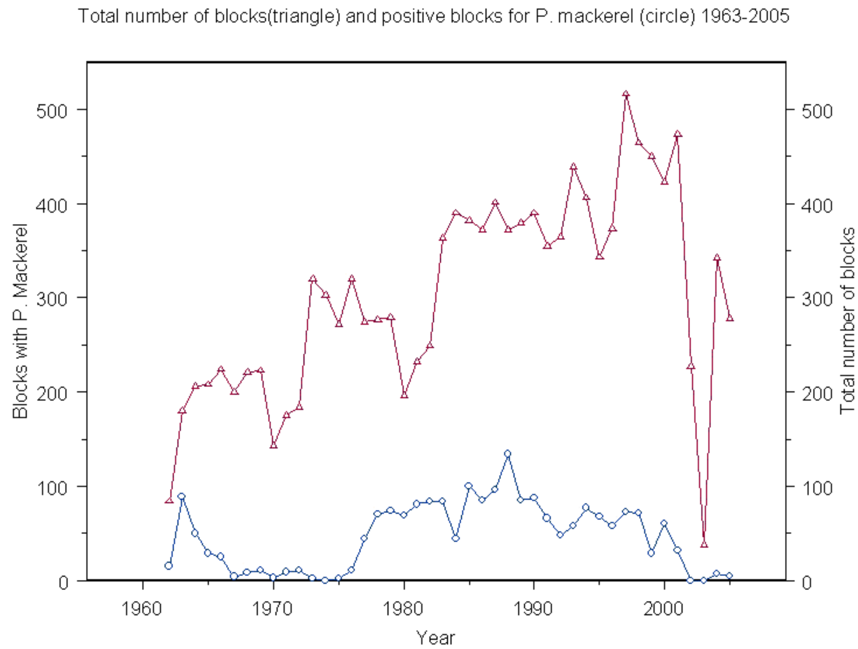

Figure 3. Total number of blocks covered (triangle)and blocks covered by flights with positive sighting (circle) of Pacific mackerel, 1963-2005

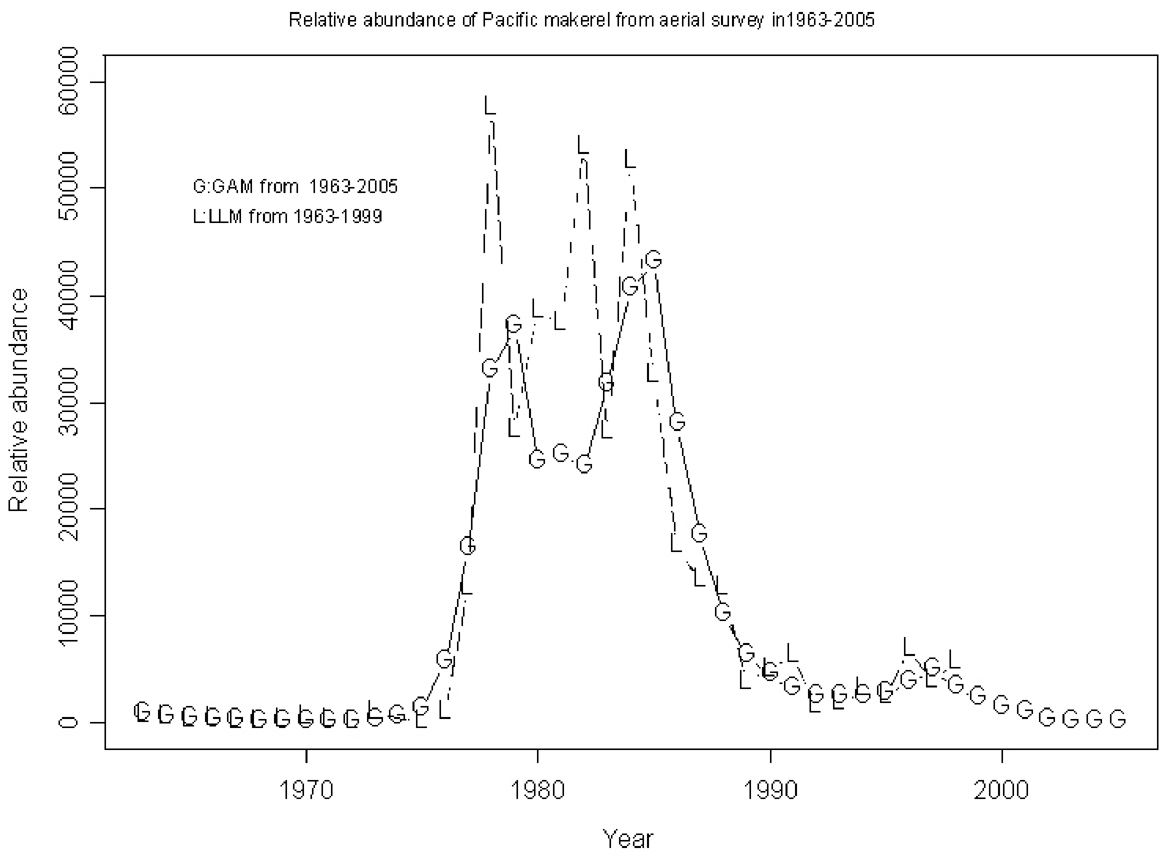

Figure 4: Time series of relative abundance (total tonnage) of Pacific mackerel from 1963-2005 using GAM and that of 1963-1999 using LLM

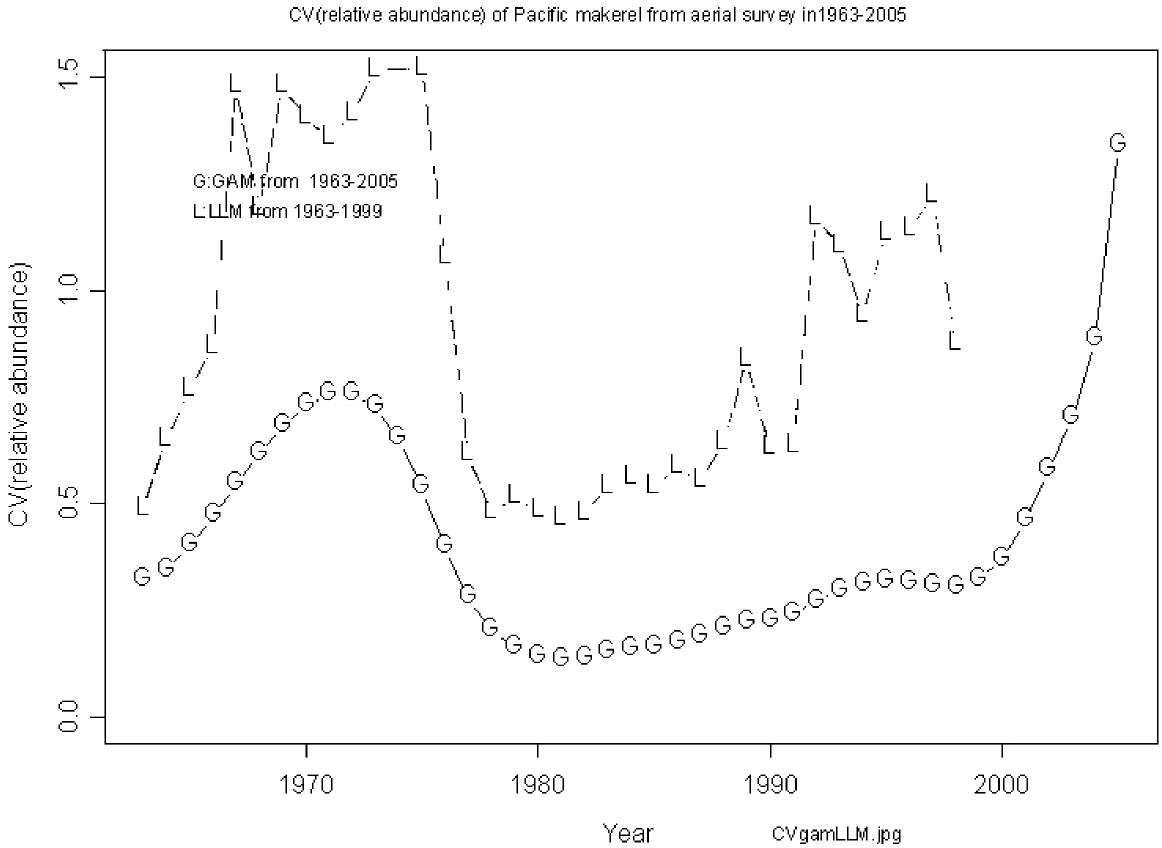

Figure 5: Time series of CV(relative abundance)(total tonnage) of Pacific mackerel from 1963-2005 using GAM and that using LLM from 1963-1999..

Appendix 3B

Daily Larval Production of Pacific Mackerel (*Scomber japonicus*) Off California From 1951-2006

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ABSTRACT

Daily larval production at hatching /10m^2 of Pacific mackerel (*Scomber japonicus*) from 1951-2006 was estimated based on data collected from California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys off the coast from San Diego to Avila Beach, north of Point Conception, California in April-July, the peak spawning time of Pacific mackerel off California. This area has been covered by all CalCOFI surveys. The time series showed the peak daily larval production was in 1987 with 46.39/10m^2/d, with minor peaks were in 1981, and 1986. The density of daily larval production has been decreasing since 1997. The larval production was particularly low in 2003- 2006. This cost-effective fishery-independent time series should be beneficial to the assessment and better understanding of the dynamics of the Pacific mackerel population.

INTRODUCTION

The time series of Pacific mackerel larval abundance and distribution by month from 1951-56 was reported by Kremer (1960) and from 1951-84 by Moser et al (1993) for historical survey area from San Francisco to Baja California. Since 1985, the CalCOFI survey area has been reduced to cover the area in the Southern California Bight (CalCOFI line 93 – line 77, Fig.1 2 and 3), primarily most years in 1985-present.

The purpose of constructing the time series of daily larval production was to use this time series as an index for the spawning biomass in the stock assessment. Ideally, methods such as the daily egg production method (DEPM) for pelagic fishes (Lo et al. 1996) should be used to estimate spawning biomass of Pacific mackerel. This kind of method requires data on fish egg stages, duration and abundance plus the reproductive output of adult fishes (MacGregor 1966). Due to the high patchiness of Pacific mackerel eggs and larvae, and the fact that the eggs were consistently identified only in the last 10 years, it is not possible to carry out a DEPM analysis over the whole 1951-2006 time period at this moment. Fortunately, mackerel larval data from CalCOFI surveys are readily available from 1951 and comprehensive correction algorithms can be applied to reduce the possible biases of measurement, such as extrusion through the net mesh, avoidance from the net, etc. It seems reasonable to consider the larval production of Pacific mackerel as a possible index of spawning biomass (Ahlstrom 1959) as has been done for many other fish populations (Smith 1972, Lo 1986, Lo et al. 1989). In this paper,we analyzed Pacific mackerel larval data from 1951-2006 for the current CalCOFI survey area in April-July (Fig.1). Although this area is smaller than that of the historical CalCOFI survey (Fig. 2), it encompasses the primary spawning area of Pacific mackerel off California (Moser et al. 1993).

METERIAL AND METHODS

The CalCOFI survey was conducted annually from 1949- 1966, after which it was conducted every 3 years through 1984, covering the area from Baja California to the north of San Francisco (Fig. 2). Starting in 1985, the survey was conducted annually but covered only the southern area from San Diego to Avila Beach, just north of Point Conception. As Pacific mackerel larvae are most concentrated in mid-Baja California in the summer and second off Southern California in Spring, for consistency of available datasets, only Pacific mackerel larval data from the CalCOFI database from April-July were used in this study (Ahlstrom 1959, Moser et al. 2001). Larvae were collected by oblique tows with a 1-m ring net to 150 m from 1951-68, and the depth was increased to 210 m in 1969. Bongo net replaced 1-m ring net in 1978. A standard haul factor used to compute number of larvae / 10m^2 ws intended to account for variability in the volume of water filtered per unit of depth (Smith and Richardson 1975).

Sampler biases caused by net selectivity for small larvae and gear avoidance for larger larvae were adjusted following the method of Lo (1985). Retention rates for extrusion can be expressed as function of larval length and mesh size (Lenarz 1972; Zweifel and Smith 1981; Lo 1983) and those for avoidance can be expressed as a function of larval length and the diurnal time of capture (Hewitt and Methot 1982). All larval abundance data were adjusted to conform to the following standard condition: no extrusion, no day-night difference in avoidance, and a constant water volume filtered per unit depth. The data were then converted to daily production/10m^2 (P_t) by dividing the corrected total number of larvae in each length group by the duration (the number of days larvae remain within each length group). A set of laboratory data on larval growth conducted by Hunter and Kimbrell (1980) was used to model temperature dependent larval growth curves which were used to convert length to age from hatching.

CORRECTION FACTORS

Extrusion

There are no existing data on the length-specific extrusion rate for Pacific mackerel. Therefore, the retention coefficient of jack mackerel larvae due to extrusion was used as a proxy for mackerel. Jack mackerel larvae and Pacific mackerel larvae are approximately the same length at hatching and are morphologically similar: jack mackerel hatch at about 2-2.5mm and Pacific mackerel at about 2-3mm; morphology of both is similar in yolk sac stage. On average, Pacific mackerel tend to be just slightly longer and more robust than jack mackerel (Watson pers. Comm.). Hewitt et al. (1985) reported that only the smallest class of jack mackerel larvae (3.0 mm) are extruded to a significant degree through the 0.505 mm CalCOFI nets, with 28% of the catch in that size class retained in the net. The extrusion correction factor is equal to 1/.28 or 3.571. Although 0.55mm mesh net was used prior to 1968, the difference in extrusion of mackerel larvae is likely to be insignificant as was the case for anchovy larvae (Lo 1983).

Avoidance /evasion

The correction factor for avoidance/evasion was estimated using the algorithm developed for anchovy and Pacific hake (Lo et al. 1989, Lo in submission). Because larvae are able to avoid or evade the net to the same degree under sufficient light to see, and larger larvae are better able to avoid the sampler, we used the model by Lo et al. (1989) for the retention (or capture) coefficient of mackerel larvae for a specific larval length (*L*) and hour of the day (*h*):

$$R_{L,h} = \left(\frac{1+D_L}{2}\right) + \left(\frac{1-D_L}{2}\right) * \cos\left(\frac{2\pi * h}{24}\right) \qquad (1)$$

where D_L is the noon/night catch ratio for length L. Data from 1951 to 1978 in the historical large area were used to model the catch ratio:

$$D_L = \frac{\bar{y}_{L,noon}}{\bar{y}_{L,night}}$$

The numerator is the mean catch at noon (11:00 am – 1:00 pm) of larvae size L. The denominator is the mean catch in the night (9:00 pm - 3:00 am) of larval length L. We then used an exponential curve to model the relationship between D_L and larval length L.

Shrinkage

The shrinkage factor was based on the work on Pacific hake (Bailey 1982) which reported on the percentage of shrinkage in the standard length of first-feeding larvae due to preservatives and time of handling for Pacific hake. Shrinkage was 8.9% for formalin-preserved larvae (L). Because in regular CalCOFI surveys, formalin is the standard preservative used, a correction factor is needed to convert formalin-preserved length (L) to life length (L_L) in order to apply the larval Pacific mackerel growth curves derived from laboratory data by Hunter and Kimbrell (1980). The multiplier applied to larvae from 2.5 -11.5 mm from CalCOFI surveys is 1/(1-0.089)=1.098 to convert formalin preserved-length to live length, i.e., $L_L = L * 1.098$.

GROWTH OF MACKEREL LARVAE

Growth curves

Hunter and Kimbrell (1980) reported growth data for seven groups of Pacific mackerel reared at different temperatures from 16.8 – 22.1°C. A temperature-dependent logistic growth curve was derived where the coefficient of the age was a polynomial function of temperature (Bartsch 2005):

$$L_L = \frac{28.2616}{1+\exp(-\beta_{temp} t + 2.3476)} \quad \text{for } t<25 \text{ d} \qquad (2)$$

where L_L is the life length, $\beta_{temp} = 0.2828 - 0.0229 temp + 0.0007 temp^2$, t (days) is age (d) from hatch, and *temp* is temperature in ^{o}C.

To convert length to age from hatching, we inverted the equation (2) and obtained:

$$t = \frac{2.3476 - \ln(28.2616/(L*1.098)-1)}{\beta_{temp}} \text{ for } 2.23\text{mm}<=\text{L}<20\text{mm} \qquad (3)$$

where t is age after hatching and L is formalin-preserved length. Note the logistic growth curve gave minimum live length being 2.45 mm for newly hatched larvae at t=0.

The larvae collected in each tow were grouped as 2.5 mm (2.0 mm - 3.0 mm), 3.75 (3.5 and 4.0 mm), and 4.75 (4.5 and 5.0mm). To obtain the final age of a larva, the actual length of a larva in each length group from each tow was generated by a random selection from a uniform distribution within each length category. For the larvae in the length category of 2.5 mm, age 0 was assigned for formalin-preserved length <2.23 mm

Size class duration and daily larval production

The duration was estimated by the difference of the mid-ages where the mid-ages are the ages corresponding to the mid-lengths: the midpoint between two size groups. The daily larval production in each age group was the larval density in each age group divided by its duration, the time the larvae stayed in each size group.

DAILY LARVAL PRODUCTION AT HATCHING (P_h)

The daily larval production at hatching (P_h) was estimated for each year from a larval mortality curve in the form of exponential function, unlike that of northern anchovy (Lo 1985, 1986) and Pacific hake (Hollowed 1992) whose daily mortality rates decreased with age as the larvae matured. Larvae with length >11.75mm length group were excluded because few larvae of those sizes observed due to their evasion from the net is uncertain. A weighted nonlinear regression was used to obtain estimates of the coefficients for years with sufficient catch-length data:

$$P_t = P_h \exp(\alpha t) \qquad (4)$$

where P_t is the daily mackerel larval production at age t days from hatching, and α is the daily instantaneous mortality rate.

For most years, we fitted equation (4) to the data using a weighted nonlinear regression to estimate the P_h and α, where the weight was 1/SD for each 4-day interval: 0-4, 5-8, …, 17-20 d. As larvae older than 20 days occurred in few tows each year, the mortality curve was constructed based on larvae of age <=20 days at most, to avoid bias. However due to the patchiness of larvae and their ability to avoid the net, the unweighted nonlinear regression was used for some years because the large variances in the young age categories down-weighted the corresponding larval productions too much to produce reasonable estimates of P_h and mortality rate. There were also some years where only one or two length groups had positive catches, mostly small larvae say larvae <4 mm, P_h was estimated by inverting the mortality curve (equation 4)

$$\hat{P}_h = \overline{P}_L \exp(-\hat{\alpha} t_L) \qquad (5)$$

and the variance of $\hat{P}_h$ was estimated as:

$$\mathrm{var}(\hat{P}_h) = \mathrm{var}(\overline{P}_L)(\exp(-\hat{\alpha} t_L))^2 + (\overline{P}_L \exp(-\hat{\alpha} t_L)(-t_L))^2 \,\mathrm{var}(\hat{\alpha}) - \mathrm{var}(\overline{P}_L)(\exp(-\hat{\alpha} t_L)(-t_L))^2 \,\mathrm{var}(\hat{\alpha})$$

where $\overline{P}_L$ is the mean daily larval production at length L=2.5mm and t_L is the associated age of 2.5mm and the over all mean mortality rate was used for $\hat{\alpha}$ (Goodman 1960).

RESULTS

Avoidance

The relationship between the mean noon/night catch ratio (D_L) and larval length (L) based on data of 1951-1978 is

$$D_L = 2.7 \exp(-0.39L) \qquad (6)$$

where the standard errors of two coefficients are 0.47 and 0.05. (Fig.4). The estimated capture rates of larvae by length and time of day (equation 1) are shown in Fig. 5.

Mortality curves and the daily larval production at hatching (P_h)

Mortality curves were constructed for years when the data are sufficient (Table 1). The mortality curve and larval production at age for 1981 are given for illustration (Fig. 6). For those years, the estimates of the daily larval production/10m^2 were the intercepts of the mortality curves (equation 4) (Table 1). An unweighed nonlinear regression was used for years 1985, 1986, 1988, and 1992. For other years when the data were not sufficient, an overall mortality rate was used in equation (5) for1953, 1962, 1969, 1972, 1993, 1994, 2003, and 2006.

The time series of daily larval production (P_h/10m^2) from 1951-2006 off the California coast from San Diego to north of Point Conception fluctuated with the highest peak of 46.38 larvae/day/10m^2 in 1987 and minor peaks at 1981 and 1986 (Table 1 and Fig. 7). The larval production has been declining with moderate fluctuations since 1997 in this survey area.

For comparative purposes, we computed the mean counts of larvae per 10m^2 with corrected for biases. The time series of P_h and mean counts of larvae had similar trend but the time series of simple means was more variable than that of P_h (Fig. 7 and 8). Nevertheless, the fluctuations in the time series of Pacific mackerel larvae are partially due to the fact that Pacific mackerel larvae are one of the most 'patchy distributed' pelagic species in the CalCOFI time series and that patches can be very large and dense.

Analyses in this study were based on larval abundance corrected for all possible biases. The extrusion factor was based on Jack mackerel larval data, therefore future surveys on Pacific mackerel larvae are recommended to obtain direct measurements and to verify if the extrusion factor based on Jack mackerel larvae is reasonable to use for Pacific mackerel larvae. The avoidance correction factor was based on 1951-1978 data because including other year's data did not contribute to the modeling of the day/night ratio with the length.

The long time series of daily Pacific mackerel larval production, a cost-effective fishery-independent population index obtained yearly, is beneficial to the assessment of the Pacific mackerel population and better understanding of the dynamics of the Pacific mackerel population (Deriso and Quinn, NRC 1998).

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Table 1. mackerel larval production at hatch (P_h), the mortality coefficient (β) and their standard errors (SE), total number of tows (n) , positive tows (n_p) larvae/10m^2(density),mean temperatures(temp) and weighted temperature(wt-temp).

year	P_h	se(Ph)	β	se(β)	n	n_p	density <=11.75mm	se(density)	Temp	wt-tmep	Idex
1951	0.015	0.019	-0.051	0.148	128	6	0.152	0.102	14.99	16.04	1
1952	0.023	0.023	-0.013	0.123	200	7	0.256	0.115	14.51	15.76	1
1953	0.187	0.096	**-0.327**	**0.023**	244	2	0.423	0.407	13.82	15.52	4
1954	1.148	0.312	-0.629	0.069	200	17	2.183	0.890	14.58	17.03	1
1955	0.287	0.143	-0.392	0.072	194	7	2.152	1.394	14.88	15.27	1
1956	0.113	0.058	-0.342	0.097	220	5	0.257	0.208	14.43	15.10	1
1957	0.044	0.029	-0.139	0.074	223	2	0.272	0.230	17.45	18.26	1
1958	0.629	0.157	-0.287	0.039	257	26	2.934	0.779	16.40	17.00	1
1959	0.184	0.062	-0.292	0.060	271	16	0.785	0.256	15.65	17.14	1
1960	0.585	0.309	-0.338	0.087	213	6	2.327	1.582	15.37	16.76	1
1961	0.067	0.035	-0.131	0.062	110	3	0.225	0.142	15.16	17.82	1
1962	0.125	0.148	**-0.327**	**0.023**	78	2	0.279	0.196	15.14	13.51	4
1963	0.517	0.331	-0.370	0.122	125	6	3.146	1.974	15.84	16.08	2
1965	0.057	0.056	-0.233	0.171	132	4	0.320	0.193	14.54	15.49	2
1966	0.381	0.288	-0.336	0.152	213	7	1.382	0.728	16.10	16.57	2
1969	0.167	0.086	**-0.327**	**0.023**	170	2	0.366	0.312	14.71	18.04	4
1972	0.246	0.126	**-0.327**	**0.023**	73	1	0.577	0.577	15.48	15.70	4
1978	5.436	1.652	-0.280	0.037	198	34	35.729	12.459	16.00	16.00	1
1981	21.845	7.563	-0.329	0.045	209	51	84.943	26.113	15.58	17.32	1
1984	2.222	1.560	-0.494	0.112	175	10	9.515	5.751	15.79	16.67	1
1985	0.579	0.192	-0.222	0.113	53	5	2.340	1.188	14.18	14.31	3
1986	10.974	2.634	-0.519	0.271	56	15	30.586	14.484	14.72	16.07	3
1987	46.389	23.731	-0.889	0.121	66	13	83.368	53.892	15.43	14.94	2
1988	2.876	0.963	-0.157	0.097	55	13	9.832	6.776	14.42	16.07	3
1989	1.187	0.551	-0.370	0.100	123	14	4.100	1.887	16.10	17.10	1

1991	0.848	1.075	-0.009	0.209	36	4	6.372	5.911	16.66	16.10	2
1992	0.315	0.390	-0.092	0.127	132	12	1.941	1.653	16.64	16.29	3
1993	0.643	0.236	**-0.327**	**0.023**	57	2	1.623	1.162	14.78	14.66	4
1994	0.094	0.449	**-0.327**	**0.023**	91	1	0.053	0.053	15.24	15.90	4
1995	0.758	0.244	-0.221	0.042	121	11	3.209	1.312	15.61	15.80	1
1996	7.922	2.884	-0.560	0.075	60	9	13.742	8.541	15.12	15.87	1
1997	8.767	4.288	-0.821	0.103	128	13	14.960	10.659	15.98	16.98	1
1998	0.370	0.286	-0.326	0.249	161	7	1.330	0.613	16.27	14.57	2
2001	0.394	0.195	-0.148	0.399	132	3	1.697	1.160	15.22	14.76	1
2003	0.333	0.280	**-0.327**	**0.023**	128	1	0.756	0.756	15.60	14.80	4
2005	0.068	0.052	-0.039	0.076	190	10	2.162	0.842	15.12	15.19	1
2006	0.103	0.305	**-0.327**	**0.023**	147	1	0.245	0.245	13.36	15.10	4
Whole	**1.618**	**0.301**	**-0.327**	**0.023**							

Index

1. Weighted nls for age<=20 d
2. Weighted nls for age<=10 d
3. Unweighted nls for age <=20 d
4. Equation (5) using larval production at length 2.5mm

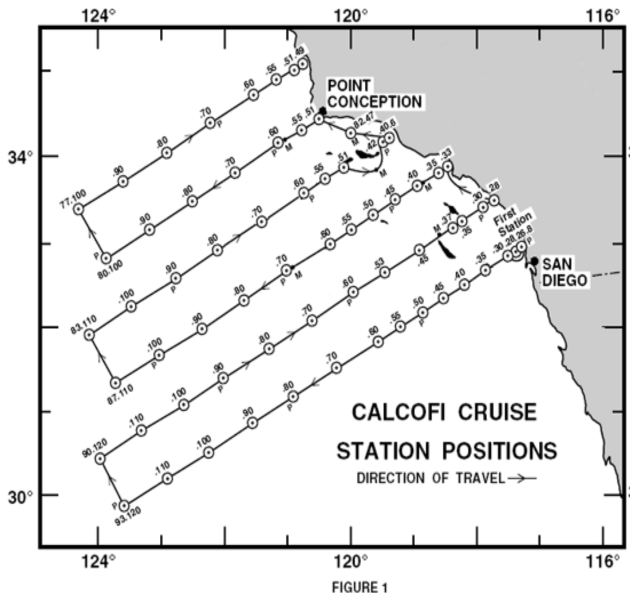

Figure 1. CalCOFI survey area from 1985-present from CalCOFI lines 93.3-76.7

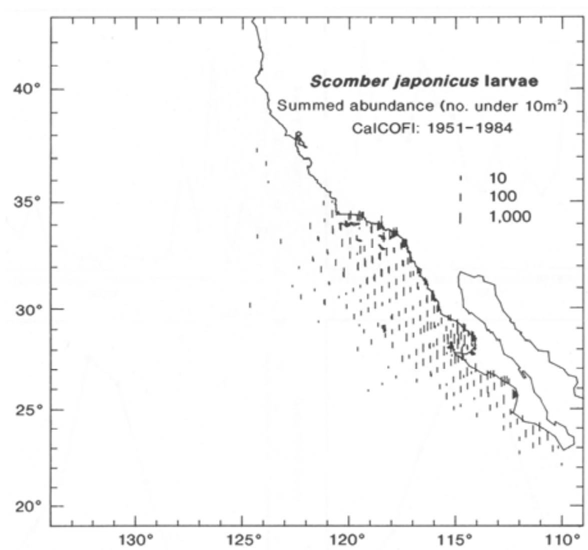

Figure 2.Total Pacific mackerel larval abundance/10m^2 from CalCOFI surveys from 1951-1984 (Moser et al. 1993).

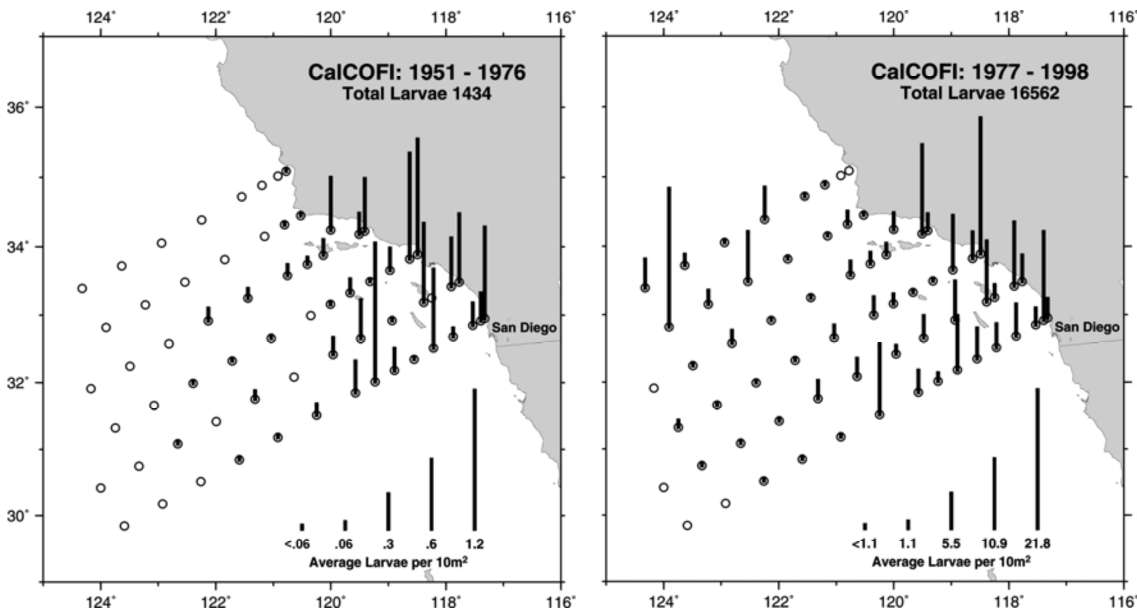

Figure 3. The average Pacific mackerel larvae/10m^2 in the current CalCOFI survey area from 1951-1976 and from 1977-1998 over all cruises (Moser et al. 2001)

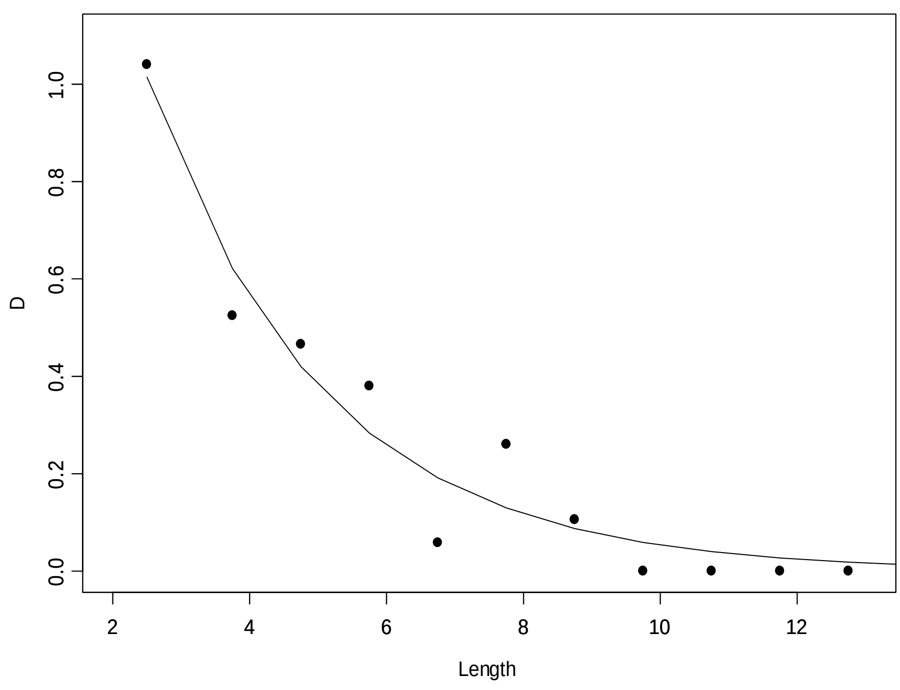

Figure 4: Noon/night catch rates of Pacific mackerel larvae (D) and larval length (mm) based on data of 1951-1978.

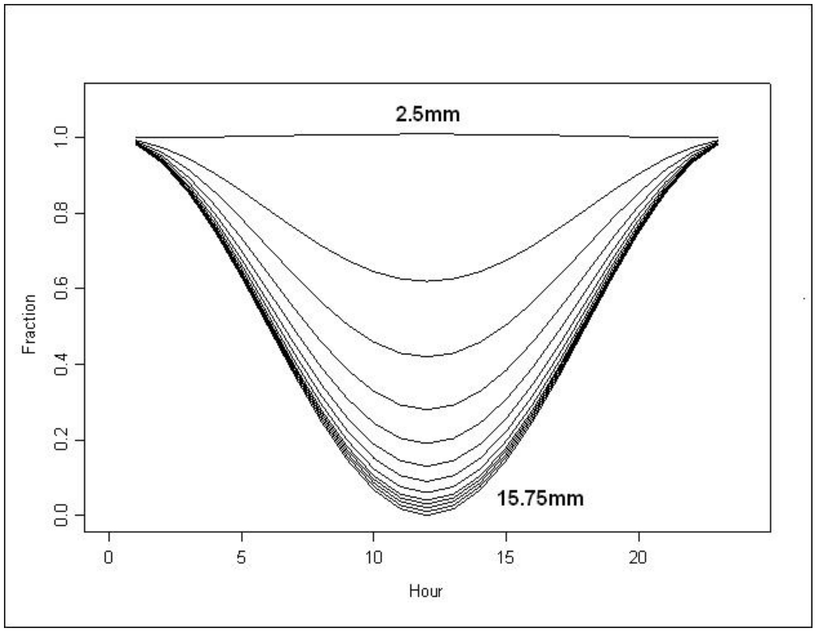

Figure 5. Fraction of Pacific mackerel larvae captured as a function of time of day for 2.5mm-15.75mm.

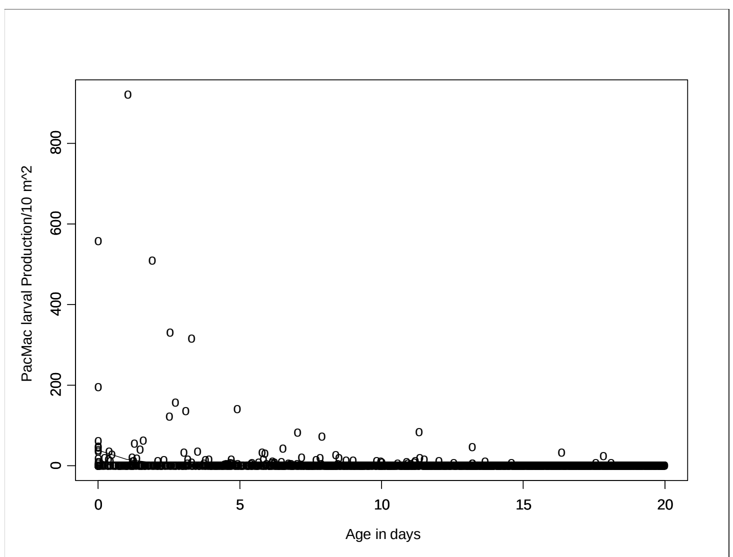

Figure 6: Daily larval production/10m^2 and age with Mortality curve (p_t=21.84 exp (-.33t)) in 1981.

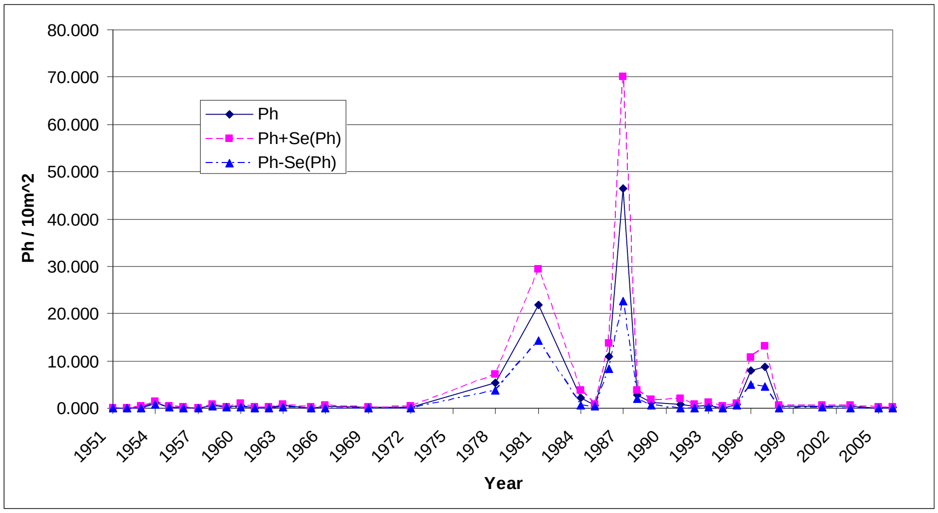

Figure 7: Mackerel larval production /10m^2 at hatching (p_h) off area from San Diego to San Francisco, in April-July from 1951 – 2006.

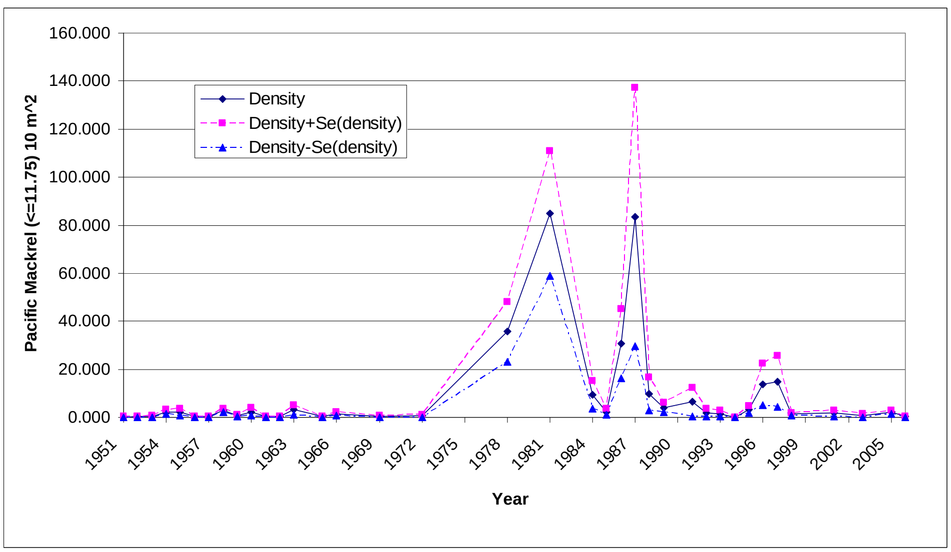

Figure 8: The time series of larval density (number/10m^2) off area from San Diego to San Francisco in 1951-2006.

Appendix 3C

Time series of relative abundance of Pacific mackerel from ichthyoplankton surveys and aerial surveys in 1951-2008

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Introduction

Two time series of relative abundance indices of Pacific mackerel used for the 2007 and 2008 stock assessment (Appendix I and II Dorval et al. 2007 and Crone et al. 2009) were a fishery-independent time series of daily Pacific mackerel larval production at hatching (P_h), and Delta GLM relative abundance based on logbooks of aerial spotter pilots.

The P_h time series was based on data collected during April-July, the peak time of larval densities, from 1951-2006 in the current CalCOFI survey area from San Diego to the north of Point Conception (Figure 1-3; Appendix II). The other abundance index was the time series of Delta GLM relative abundance based on data collected by the spotter pilots hired by fishing vessels off California from fishing years (July-June) 1962-2001(calendar years 1963-2002)(Figure 4, appendix I). The estimation procedures for both time series were described in Dorval et al. (2007) and Crone et al.(2009).The spotter pilot time series has not been updated since 2007, and the original time series from 1962-2001 fishing year was used in the current stock assessment. As to the larval production time series off California, no larvae were observed in 2007 and 2008, therefore the current time series of larval production is basically the original time series plus two zeros for 2007 and 2008

One of concerns of the 2007 STAR panel was about the time series of P_h in that this time series was based larval data collected from the current CalCOFI survey area and it may not be representative of the spawning biomass of the entire Pacific mackerel population, because Pacific mackerel are distributed from Baja California to north of California (Figure 1c). One of the reasons why P_h was constructed only for the current CalCOFI area was the lack of the larval data from Mexico after 1984. We also believe that the P_h in the CalCOFI survey area is likely to be representative of the whole population. To examine possible bias of the time series of P_h from the CalCOFI area and to extend the time series of larval densities of both CalCOFI and Mexican regions to the current time period, we constructed a time series in this report based on available larval data from California and Mexico from 1951-1984 and 1998-2000, with data from Mexico in the later period made available to us in 2008. We also updated the relative abundance from the spotter pilot data from 1962-2001 to 1962-2006 fishing year even though only the time series of 1962-2001 fishing year was used in the stock assessment.

Time series of Larval densities/10m^2 in 1951-1984 and 1998-2000 off California and Mexico

The historical CalCOFI survey covered waters of California and Mexico (Figure 1) from 1951-1984 and annual indexes of larval abundance were examined by MacCall and Prager (1988). Beginning in 1985 the CalCOFI surveys covered only the southern California from San Diego to just north of Point Conception

(Figure 1a and 1d). No systematic ichthyoplankton surveys were conducted off Mexico in 1985-1996 till the establishment of the Investigaciones Mexicanas de la Corriente de California (IMECOCAL) in September 1997 (Baumgartner et al. 2008). IMECOCAL surveys are conducted four times a year, similar to the current CalCOFI survey schedule, to collect ichthyoplankton samples from CalCOFI lines 100-137 and to offshore CalCOFI station 80 (193,000km^2) (Figure 1a). Data of Pacific mackerel larvae from October 1997-January 2001 were provided by Instituto Politécnico Nacional (IPN) Mexico.

Based on historical data, the peak month of larval densities is May off California and August off Mexico. To extend the months to increase sample size for this analysis, we chose months prior and after the peak month: April-July off California and June-September off Mexico (Figure 2). Thus larval data from IMECOCAL in June –September and the current CalCOFI region in April-July, were used to construct a new time series for a large survey area. Because the data from Mexico included only total larvae caught without number of larvae by length group, it was impossible to compute the daily larval production (P_h) as the P_h requires larval counts by length (Appendix II). Therefore we computed a simple weighted mean larval density for each year during the peak larval months. The final mean larvae densities were weighted mean larval densities from these two regions with weights being the survey area size:198,000km^2 and 193,000km^2 for CalCOFI and IMOCOCAL, respectively, for 1951-1984 and 1998-2000 when both areas were covered (Figure 5)

We constructed another time series of the simple mean larval density/10 m^2 in the current CalCOFI area for April- June, 1951-2008 to provide a 'continuity' across the time series of the weighted mean from CalCOFI and IMECOCAL, in the gaps from 1985-1997 and 2001-2008.

Updated GLM relative abundance of Pacific mackerel from 1962-2006

GLM relative abundance from the spotter data (Appendix I) was updated to fishing years 1962-2006 from 1962-2001 to include data from fishery-independent aerial surveys conducted by spotter pilots contracted by the SWFSC in 2004, 2005 and 2007 (Figure 4 and 6).

Results

The time series of weighted mean of larval densities for 1951-1984 and 1998-2001, time series of simple mean larval densities in the IMMECOCAL survey area in the same period and the time series of simple mean for the CalCOFI area from 1951-2008 showed the peak points during 1980s off California and smaller increases in the first half of 1960s (1962 and 1963) and in 1998-2000 off Mexico(Figure 5 and Table 1). During the peak times, 1981 and 1987, larvae were densest in California waters (MacCall and Prager 1988). Lacking data from Mexico in 1987, we know at least larval production was high off California. In the late 1990s, larvae were densest in Mexican waters. Therefore, the spawning area of Pacific mackerel moved between California and Mexico with higher density during peak time off California. Because the larval densities were relative low after 1990s and so were landings off Mexico, data from Mexico may not have much effect on the general trend of the spawning biomass of Pacific mackerel.

To determine whether the time series of the larval production (P_h) in the CalCOFI area was representative for the whole area of California and Mexico, we computed a simple correlation coefficient between P_h off California and the weighted mean off California and Mexico for 1951-1984 (Table 1). The correlation was 0.94 for all years excluding years when no larvae were caught. The correlation (0.23) was low for years with low densities, say P_h <5. Thus, the P_h time series off California captured the high peak years while for years with low larval densities, the two time series did not match well, mainly for years prior to 1965 (Figure 7). Although years of high larval densities may vary between California and Mexico, the magnitude of larval density in California waters was much higher than those in Mexican waters. As it is unlikely to construct a time series for both regions from 1951-present in a timely fashion, the time series of P_h from the current CalCOFI region can serve as a conservative index of spawning biomass for recent years when the population is low, and it does catch the high peak years. The P_h time series is a better index for the spawning biomass than the simple larval density estimates because it estimates the daily larval production at hatching (Appendix II). Note the time series of larval densities for the current CalCOFI survey area corrected for bias due to extrusion and avoidance of the net for 1951-2006 was also included in Appendix II (Figure 8).

For the time series of spotter pilot data (Figure 4,Table 1)), even though only the 1962-2001 time series is used for the stock assessment, we included the data from surveys conducted in 2004,2005 and 2007 in the GLM model adjusted for many factors: day/night (night) , season (April-June), region (region 2, Southern California bight) , pilot (number 17, arbitrary) and survey type (surveys prior to 2002) (Appendix I).This time series from 1962-2006 fishing year indicated that the relative population is still low in recent years. This time series could, theoretically, be included in the future to increase the length of the time series of the relative abundance for the stock assessment.

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Table 1. Pacific mackerel daily larval production/10m^2(P_h), weighted mean, simple mean, number of tows (n), relative abundance (REL_ABN) from spotter pilot log book and survey data, and egg densities.

	1. Ph in CalCOFI area				2 Wt mean in CalCOFI and IMECOCAL area			3.Mean in CalCOFI area	
Year	P_h	cv	n	n.pos	wt mean	cv	n	Larvae/10m^2	cv
1951	0.015	1.271	128	6	1.33	0.83	324	0.12	0.45
1952	0.023	0.978	200	7	0.59	0.16	550	0.32	0.48
1953	0.187	0.790	244	2	1.07	0.45	499	0.11	0.96
1954	1.148	0.272	200	17	1.84	0.52	424	0.71	0.37
1955	0.287	0.496	194	7	1.67	0.86	459	0.70	0.62
1956	0.113	0.511	220	5	1.98	1.12	489	0.16	0.52
1957	0.044	0.664	223	2	2.24	0.60	533	0.09	0.86
1958	0.629	0.250	257	26	0.99	0.28	545	1.22	0.27
1959	0.184	0.336	271	16	0.51	0.12	711	0.34	0.29
1960	0.585	0.528	213	6	1.22	0.82	528	0.85	0.63
1961	0.067	0.533	110	3	0.17	0.09	252	0.08	0.59
1962	0.125	0.688	78	2	4.80	2.83	205	0.07	0.70
1963	0.517	0.640	125	6	6.60	3.31	271	0.96	0.57
1964	0	0	204	-	0.46	0.21	340	0.02	1.00
1965	0.057	0.982	132	4	0.46	0.12	405	0.15	0.54
1966	0.381	0.754	213	7	0.77	0.22	562	0.45	0.52
1967	0.000	0.000	60	0	0.70	0.29	170	0.36	0.88
1968	0.000	0.000	56	0	0.00	0.00	110	0.00	0.00
1969	0.167	0.751	170	2	0.27	0.10	467	0.10	0.85
1972	0.246	0.958	73	1	0.33	0.23	176	0.14	1.00
1975	0.000	0.000	202	0	0.04	0.04	383	0.00	0.00
1978	5.436	0.304	198	34	9.85	2.70	468	11.51	0.30
1979	0	0	51	-	0.00	0.00	51	0.00	0.00
1980	0	0	90	-	0.00	0.00	90	0.00	0.00
1981	21.845	0.346	209	51	17.13	4.81	316	30.83	0.30
1982	0.000	0.000	11	0	0.00	0.00	11	0.00	0.00
1984	2.222	0.702	175	10	1.85	0.86	270	2.95	0.55
1985	0.579	0.331	53	5				3.32	0.74
1986	10.974	0.240	56	15				11.12	0.38
1987	46.389	0.512	66	13				32.69	0.53
1988	2.876	0.335	55	13				16.04	0.59
1989	1.187	0.465	123	14				2.19	0.34
1990	0.000	0.000	80	0				0.00	0.00
1991	0.848	1.268	36	4				4.59	0.88
1992	0.315	1.239	132	12				2.31	0.65
1993	0.643	0.699	57	2				0.45	0.72
1994	0.094	2.975	91	1				0.05	1.00
1995	0.758	0.322	121	11				1.46	0.35
1996	7.922	0.364	60	9	2.13	1.31	121	4.24	0.61
1997	8.767	0.489	128	13				4.73	0.67
1998	0.370	0.773	161	7	**4.23**	**2.48**	**301**	0.39	0.44
1999	0.000	0.000	61	0	**2.30**	**1.00**	**204**	0.00	0.00
2000	0.000	0.000	132	0	**3.87**	**1.56**	**280**	0.00	0.00

2001	0.394	0.494	132	3	0.34	0.82
2002	0.000	0.000	114	0	0.00	0.00
2003	0.333	0.915	128	1	0.21	1.00
2004	0.000	0.000	120	0	0.00	0.00
2005	0.068	0.758	190	10	1.23	0.46
2006	0.103	0.932	147	1	0.07	1.00
2007	0.000	0.000	125	0	0.00	0.00
2008	0.000	0.000	30	0	0.00	0.00

4. Biase-correct larval density in CalCOFI area			5. Spotter data from fishing year 1962-2001				6. Spotter data from fishing year 1962-2006		7. Egg density in CalCOFI area from March - Sept 1990-2008			
year	density<= 11.75mm	cv	Fishing YEAR	REL_ABN	CV_RA	BLOCKS	REL_ABN	CV_RA	Year	**eggs/10m^2**	**cv**	**n**
1951	0.15	0.67	1962	461.35	0.52	151	488.16	0.50				
1952	0.26	0.45	1963	1541.53	0.32	186	1591.38	0.31				
1953	0.42	0.96	1964	549.34	0.46	198	579.43	0.44				
1954	2.18	0.41	1965	707.89	0.51	206	740.52	0.50				
1955	2.15	0.65	1966	272.08	0.67	220	286.63	0.66				
1956	0.26	0.81	1967	19.88	0.98	210	20.58	0.97				
1957	0.27	0.85	1968	178.55	1.42	215	184.72	1.42				
1958	2.93	0.27	1969	782.89	1.39	217	817.66	1.38				
1959	0.78	0.33	1970	22.03	2.44	148	23.36	2.43				
1960	2.33	0.68	1971	76.70	0.89	176	79.81	0.88				
1961	0.22	0.63	1972	5.46	2.05	217	5.75	2.05				
1962	0.28	0.70	1973	28.95	2.87	226	30.55	2.87				
1963	3.15	0.63	1975	4.31	3.01	214	4.55	3.01				
1964	0.00	0	1976	15492.54	0.55	242	16225.21	0.54				
1965	0.32	0.60	1977	31112.79	0.28	206	31970.60	0.27				
1966	1.38	0.53	1978	40320.84	0.22	229	41144.15	0.21				
1967	0.00	0.00	1979	44380.55	0.18	214	45256.61	0.17				
1968	0.00	0.00	1980	22164.44	0.15	199	22486.83	0.15				
1969	0.37	0.85	1981	25829.50	0.14	210	26060.76	0.13				
1972	0.58	1.00	1982	36237.16	0.13	251	36694.46	0.12				
1975	0.00	0.00	1983	30524.24	0.27	271	31642.33	0.26				
1978	35.73	0.35	1984	45635.38	0.16	305	46928.21	0.15				
1979	0.00	0	1985	38944.25	0.21	315	40481.34	0.19				
1980	0.00	0	1986	18979.22	0.17	268	19354.60	0.16				
1981	84.94	1.00	1987	12087.23	0.25	295	12351.81	0.25				
1982	0.00	0.00	1988	16673.37	0.30	300	17292.42	0.29				
1984	9.51	0.60	1989	2700.95	0.34	252	2845.31	0.33				
1985	2.34	0.51	1990	5445.68	0.26	276	5657.61	0.25				
1986	30.59	0.47	1991	2391.01	0.27	250	2457.52	0.26				
1987	83.37	0.65	1992	1207.58	0.48	293	1255.72	0.47				
1988	9.83	0.69	1993	1764.32	0.34	328	1937.48	0.32				
1989	4.10	0.46	1994	2097.70	0.56	283	2187.12	0.55				
1990	0.00	0.00	1995	6317.02	0.37	246	6557.24	0.36	1990	3.75	0.60	172
1991	6.37	0.93	1996	1907.85	0.55	255	1991.96	0.53	1991	9.88	0.59	121
1992	1.94	0.85	1997	5050.92	0.35	390	5166.42	0.34	1992	9.23	0.38	154
1993	1.62	0.72	1998	2248.20	0.42	324	2336.47	0.41	1993	14.12	0.41	131
1994	0.05	1.00	1999	1187.88	0.46	332	1239.30	0.45	1994	1.51	0.60	199
1995	3.21	0.41	2000	3230.88	0.42	283	3341.78	0.40	1995	9.13	0.65	121

1996	13.74	0.62	2001	548.80	1.34	306	389.37	1.33	1996	13.97	0.57	131
1997	14.96	0.71	2002			408	0.00	0.00	1997	25.48	0.45	173
1998	1.33	0.46	2003			340	274.97	0.89	1998	18.72	0.34	256
1990	0.00	0.00	2004			297	1353.12	1.05	1999	1.26	0.89	125
2000	0.00	0.68	2005			0		2.59	2000	11.14	0.77	132
2001	1.70	0.00	2006			258	637.22		2001	5.29	0.70	131
2002	0.00	1.00							2002	0.07	1.00	131
2003	0.76	0.93							2003	0.49	0.68	128
2004	0.00	0.00							2004	3.44	0.69	135
2005	2.16	0.39							2005	2.27	1.00	150
2006	0.25	1.00							2006	4.92	0.72	153
2007	0.00	0.00							2007	1.94	0.74	134
2008	0.00	0.00							2008	0.00	0.00	103

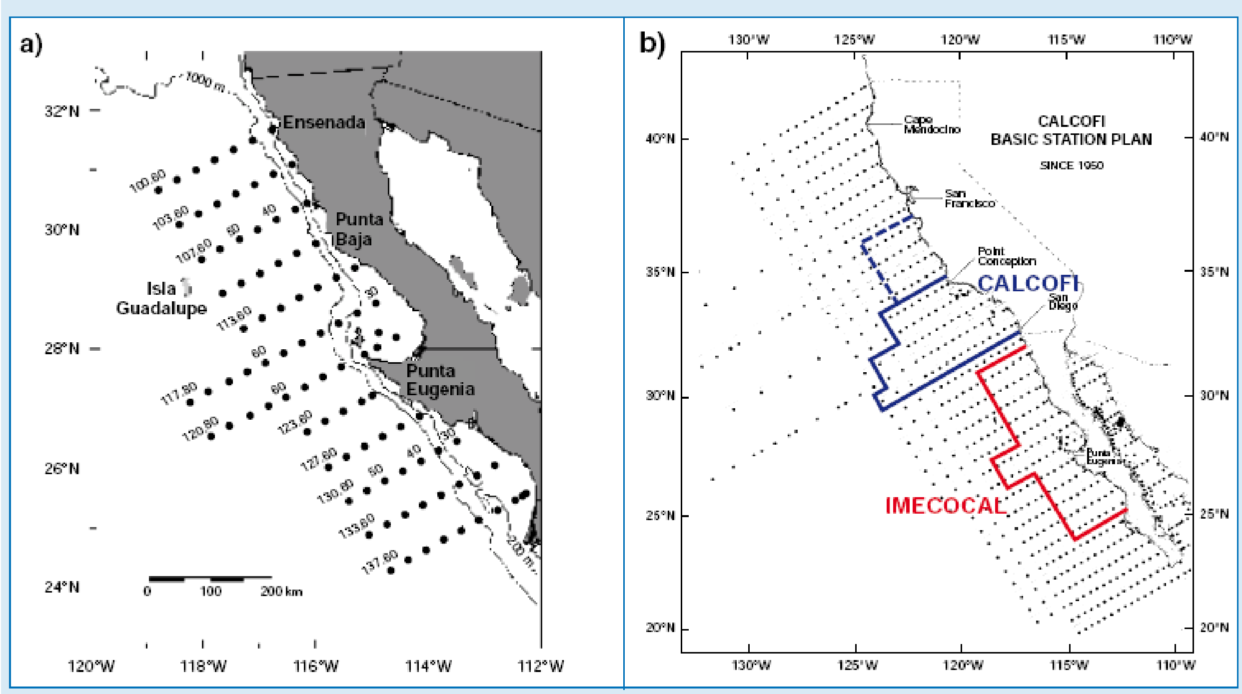


Figure 1 a. IMECOCAL survey with line and station numbers. b. Historical CalCOFI survey area, the current CalCOFI area from San Diego to north of Point Conception, IMECOCAL survey area. The area above the CalCOFI area is the additional survey area for daily egg production method for Pacific sardine (Baumgartner et al. 2008)

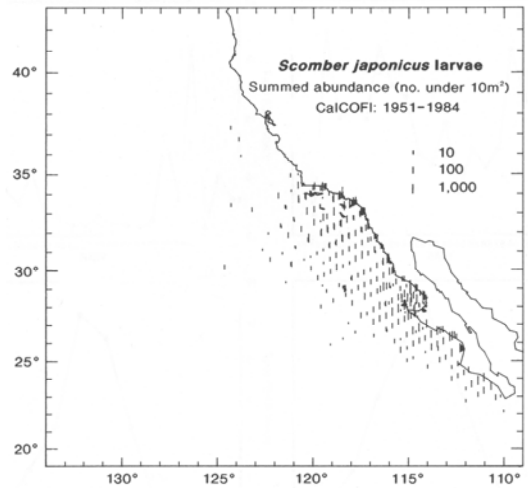


Figure 1c.Total Pacific mackerel larval abundance/10m^2 from CalCOFI surveys from 1951-1984 (Moser et al. 1993)

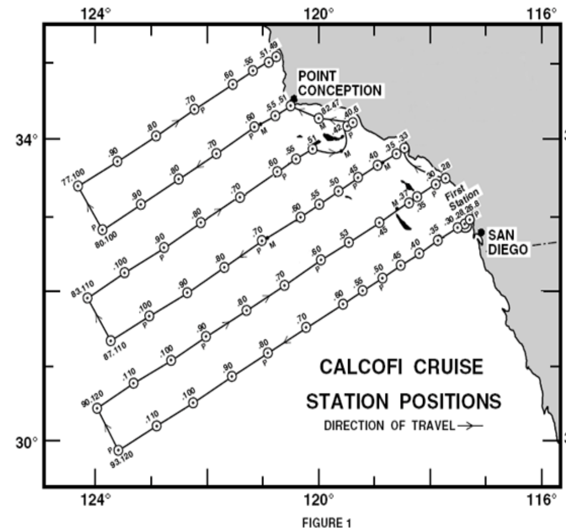


Figure 1d. CalCOFI survey area from 1985-present from CalCOFI lines 93.3-76.7.

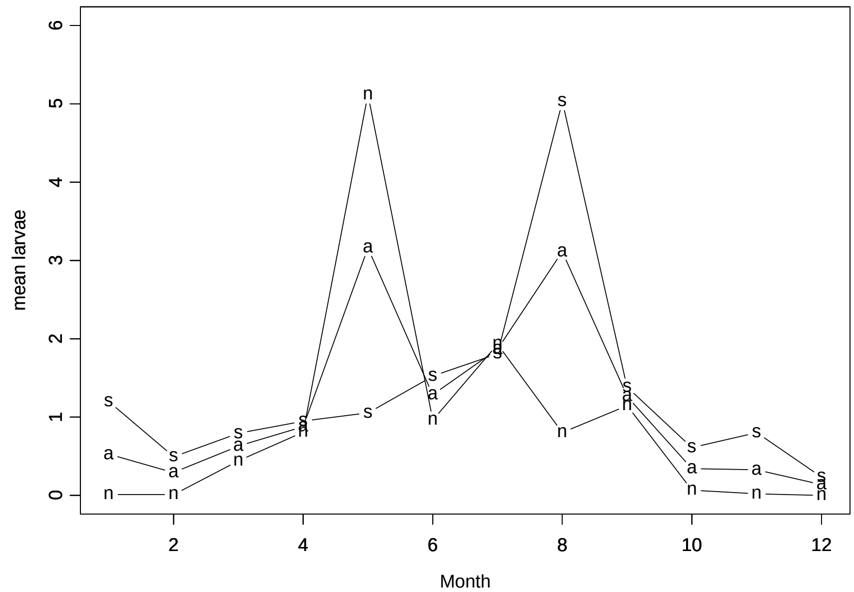


Figure 2. Mean larvae /10m^{2}by month for the north of the US-Mexico boarder (n), south (s), and the historical total CalCOFI survey area (a), from 1951-1984

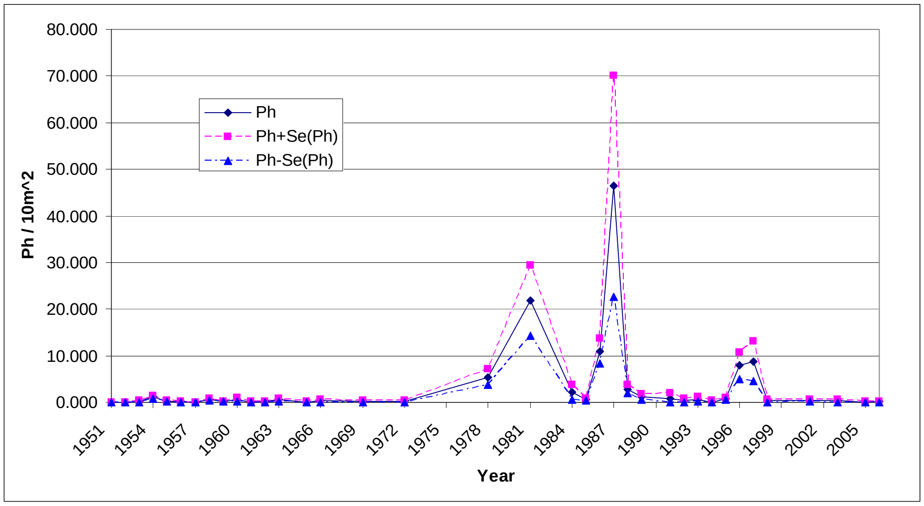


Figure 3: Pacific mackerel larval production /10m^2 at hatching (p_h) off area from San Diego to San Francisco, in April-July from 1951 –2006 (see Appendix II)

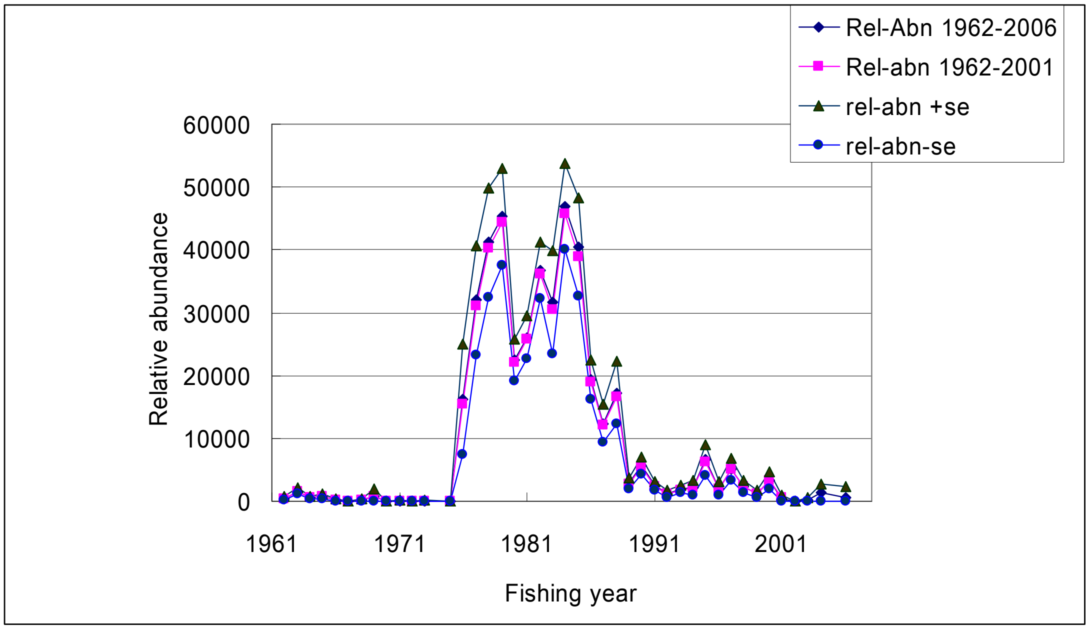


Figure 4: Time series of relative abundance (total tonnage) of Pacific mackerel using GLM from 1962-2001 and from 1962-2006.

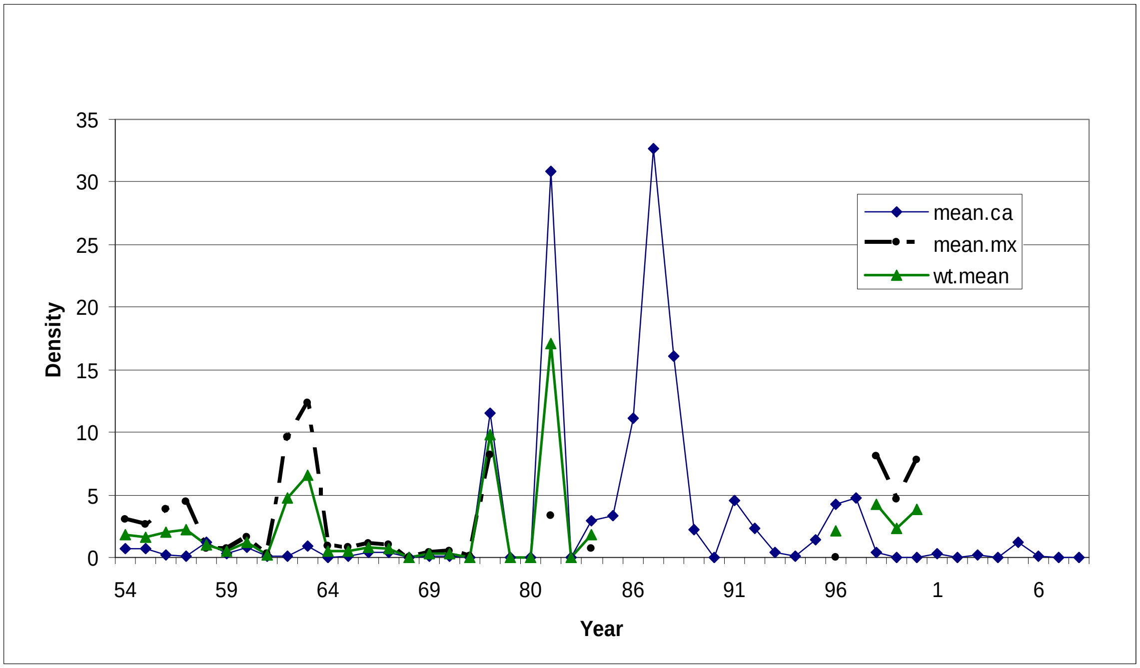


Figure 5. Simple mean larval densities (number of larvae/10 m^2) for current CalCOFI area in April-July (diamond), for IMECOCAL in July-September (circle) and weighted mean larval densities (triangle)

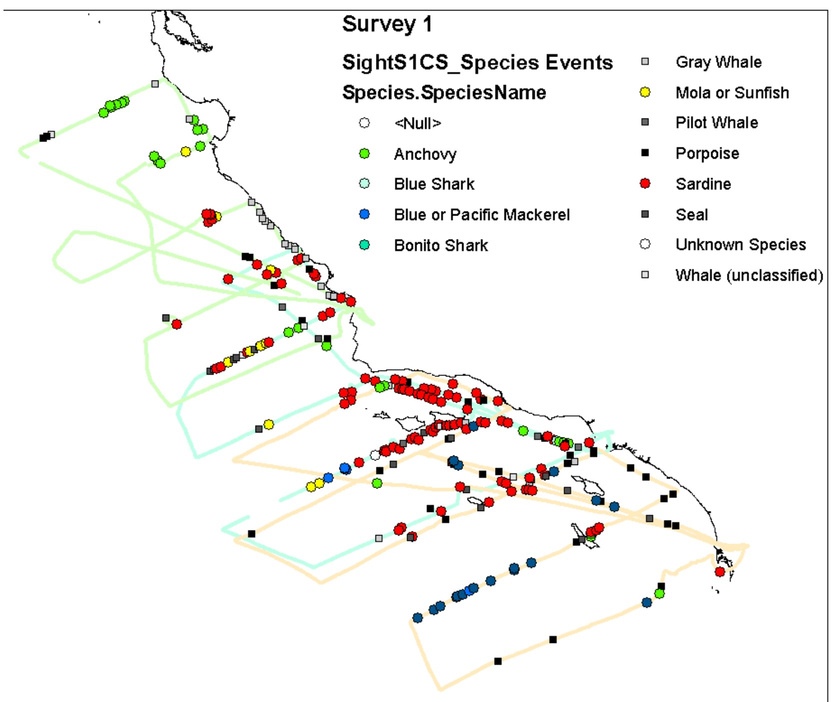


Figure 6. The first fishery-independent aerial survey conducted by three pilots in early March 2004 with sightings of difference fish/mammal

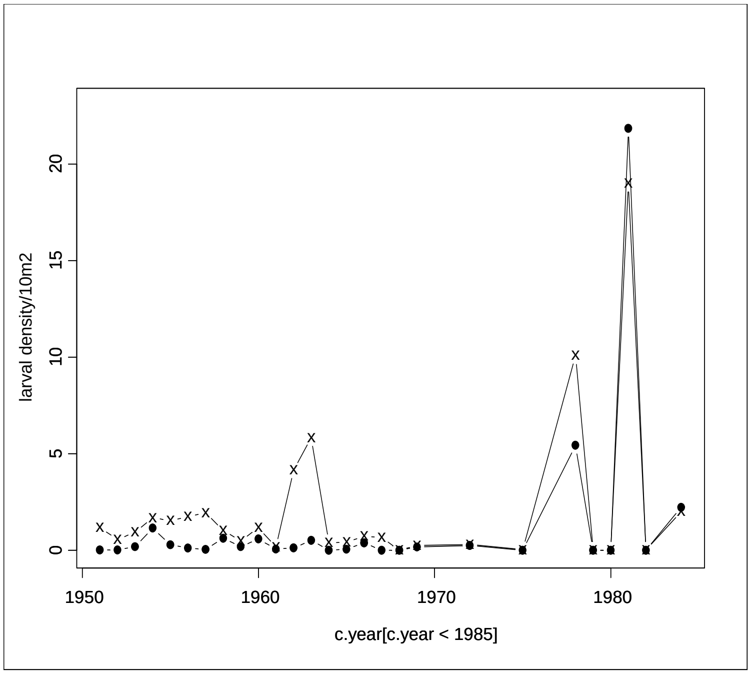


Figure 7. Time series of Pacific mackerel larval production (P_h) off California region (dots) and weighted mean (x) from CalCOFI and IMECOCAL in 1951-1984.

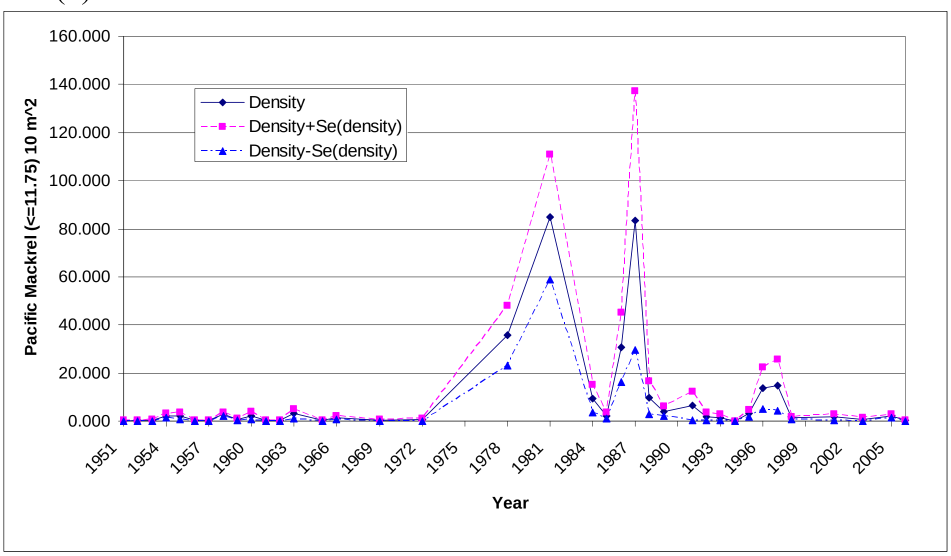


Figure 8: The time series of larval density (number/10m^2) corrected from bias off area from San Diego to San Francisco in 1951-2006 (see Appendix II).

Pacific Mackerel

DRAFT STAR Panel Meeting Report

NOAA / Southwest Fisheries Science Center
La Jolla, California
May 4-8, 2009

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
Owen Hamel, SSC, NMFS, Northwest Fisheries Science Center
Gary Melvin, Center for Independent Experts (CIE),
Alec MacCall, External Reviewer, Southwest Fisheries Science Center (SWFSC)
Ken Burnham, External Reviewer, Colorado State University

Pacific Fishery Management Council (Council) Representatives:
Greg Krutzikowsky, Coastal Pelagic Species Management Team (CPSMT)
Mike Okoniewski, Coastal Pelagic Species Advisory Subpanel (CPSAS)
Mike Burner, Council Staff

Pacific Mackerel Stock Assessment Team:
Paul Crone, NMFS, SWFSC
Kevin Hill, NMFS, SWFSC
Jenny McDaniel, NMFS, SWFSC
Nancy Lo, NMFS, SWFSC

1) Overview

The Pacific mackerel Stock Assessment Review (STAR) Panel (henceforth, referred to as Panel) met at the Southwest Fisheries Science Center (La Jolla, CA) from May 4-8, 2009 to review a draft assessment by the Stock Assessment Team (STAT) for Pacific mackerel. Introductions were made (see list of attendees, Appendix 1), and Mike Burner (Council Staff) reviewed the Terms of Reference for coastal pelagic species (CPS) assessments with respect to how the Panel would be conducted. Draft assessment documents, model input and output files, and extensive background material (previous assessments, previous Panel reports, Science and Statistical Committee (SSC) statements, etc.) were provided to the Panel in advance of the meeting on a file-transfer protocol (FTP) site, which served as a timely and convenient means to distribute the material for review. A file server was provided at the meeting room to provide common access to all presentation material and the additional model runs that were conducted during the course of the Panel meeting.

Paul Crone, with assistance from Nancy Lo, led the presentation on the draft assessment.

The previous assessments (2007, 2008) were conducted using the Age-structured Assessment Program (ASAP) model and included catch combined from the commercial and recreational fisheries, age data from the commercial fishery, and three indices of relative abundance: commercial passenger fishing vessel (CPFV), spotter, and California Cooperative Oceanic Fisheries Investigations (CalCOFI). However, the ASAP model was not capable of including length-composition data and thus, it was not possible to independently estimate the selectivity pattern for the recreational fishery (and hence that for the CPFV index). In addition, the version of the ASAP model on which past assessments have been based assumed that the weight-at-age for the catch is the same as that for the population, which implies that any stock recruitment relationship may be biased. Further, selectivity parameterization in the ASAP model could not be adequately evaluated, given limitations addressing fishery (e.g., time blocks specific to a single fishery only), index (e.g., must be linked to a fishery or fixed accordingly), and selectivity-at-age estimation (e.g., strictly by age, with no capability of examining underlying functional forms, such as normal- and logistic-related distributions). Finally, the ASAP model does not allow alternative assumptions to be explored regarding ‘beginning year’ dynamics associated with the fish/fishery, i.e., formulation of population abundance in the first year of the model time period cannot be perturbed to evaluate equilibrium vs. non-equilibrium initial conditions or related issues surrounding initial age composition, recruitment, and fishing mortality.

There have been attempts to change the modelling platform from ASAP to Stock Synthesis (SS) over the past few years. While this was not successful in the past, it was again the goal for this assessment. The objectives of the STAT in developing the draft assessment were to:

(1) build the ASAP “management model,” i.e., update the current ASAP model using new data;
(2) construct an SS alternative base-model that mirrors ASAP;

(3) develop a suite of alternative SS models that is an improvement to the SS base-model; and
(4) choose a preferred SS model from the suite of alternative models.

The STAT achieved these four objectives. The Panel agreed that the SS baseline model was adequately equivalent to the ASAP model. The suite of alternative SS models included changing to a quarterly time step, adding length frequency data for the recreational fleet, estimating selectivity patterns for the commercial and recreational fleets, and removing or revising the spotter and/or the CalCOFI indices. The STAT preferred model in the draft assessment (S1_qa25) did not include the spotter and CalCOFI indices, and allowed for estimation of commercial selectivity in three time blocks and recreational selectivity for a single time block. Selectivity for the CPFV index, which is based on the recreational fishery, was set equal to that recreational fleet.

There was considerable discussion during the meeting regarding the relative usefulness of the indices, as well as a number of modelling issues. These are detailed in Section 2 of this report. In particular, the details of the CalCOFI data collection and analysis were discussed in some detail. While several ways of improving the treatment of CalCOFI data were suggested, the lack of information from Mexico, the preponderance of zeroes in the data, and the conflict in relative scale with the CPFV index led to the conclusion that a CalCOFI index should not be included in the base-model, or in alternative models in its current form. A blocked (super year) version of the CalCOFI index was developed during the meeting for consideration. However this index, while more consistent with the final base-model, was not included in this model. Further, at this time, the general consensus from both the Panel and STAT was to also remove the spotter survey index from future SS models, given documented concerns regarding spatial sampling biases over time and subsequently, its abbreviated status in the current model (i.e., time series ends in 2002).

The final base model ("AA") returned to an annual time step, had an increased input σ_R of 1.0, doubled the weight on the recreational length compositions compared to that in model S1_qa25 and continued to exclude both the CalCOFI and spotter indices. An alternative model ("AB") was also produced, but was not fully developed. This model reflected a recent change in selectivity using an additional selectivity time block for both the recreational and commercial fisheries starting in 2000 and by splitting the CPFV index in 2000. This alternative model improves the fit by about 40 log likelihood points, is more consistent with the low commercial fishery catches in recent years, and removes the conflict with the CalCOFI index even though the fit to that index was not included in the likelihood. The biomass at the end of the time period for this alternative model is lower than for the final base-model (Fig. 1), and, although there are plausible reasons why a change in selectivity and/or catchability might have occurred around 2000, it is not clear that the magnitude of the change is accurately reflected in this model.

The Panel reiterates the recommendations from previous CPS Panels that standard data processing procedures be developed for CPS species, similar to those developed for groundfish species, and that a 'data document' be developed that provides, in considerable detail, how the basic data sources (e.g., catches, CPFV indices, etc.) are constructed. Much of this information has been published in the past, but a single (and ‘living’) document describing the basic data will assist assessment authors and future review panels.

The Panel commended the STAT for their excellent presentations, well-written and complete documentation, and their willingness to respond to the Panel’s requests for additional analyses.

4) Discussion and Requests Made to the STAT during the Meeting

The STAT presented the equivalent of an update assessment by applying the ASAP model on which the last assessment was based using updated data, and also a generally equivalent SS model S1_aa. The Panel agreed that the SS model was adequately equivalent to the ASAP model. The STAT then changed the time step of the model from annual (model S1_aa) to seasonal or quarter (model S1_qa), and showed a suite of alternative models working forward from S1_qa. The STAT preferred base-model, S1_qa25, did not include the spotter or CalCOFI indices. The Panel moved forward in evaluating S1_qa25 and requesting sensitivities to this model.

A: The Panel requested information about potential area block effects in the CPFV fishery and index. Area blocks are not currently used in the analysis of these data. In particular, it would be useful to see the distribution of effort and catch by block, and a list of potential explanatory variables.
Rationale: Area block effects may be important in determining catch rate and therefore should be considered. Moreover, there may have been changes in fishing practices in recent years given the considerable changes in management arrangements over this period.
Response: The distribution of fishing effort has not changed in a substantial manner across years. However overall effort has decreased (Appendix 2).

B: The Panel requested a new treatment of the CalCOFI data: (a) construct time blocks of six years duration (weighted average P_h values) starting with the first year in which a new net was used (1978) and use only data from off of California (not Mexico), and (b) construct a separate series of 6-year blocks using all data (including data from Mexico) for the years prior to 1978. Within each 6-year block, weight the annual mean egg counts by the number of tows each year. Use the root mean squared error (RMSE) to determine a constant standard deviation (SD) in log space (= constant coefficient of variation [CV] in real space).
Rationale: This is a way to deal with zeroes in the data, to smooth year to year variability, while still allowing data to be used to inform different periods.
Response: New indices were produced as requested.

The STAT presented the results of two sensitivities that had been discussed but were not formal requests:
(i) The Panel was concerned about possible bias in the CPFV data since 2004. However, removing the CPFV index data prior to 2006 from the assessment leads to a catastrophic and unsupported decrease in biomass. Removing only the 2007 and 2008 CPFV indices aggravates the potential bias. The Panel agreed that removing the CPFV index data from 2004 was not sensible.

(ii) The Panel was interested in seeing the impact of adding an extra block for commercial selectivity from 2000 onwards. In this configuration, selectivity for age 0 increases and for age 6 decreases. This line of inquiry was continued with request “E” below.

C: Start the model later than 1962 (once the stock begins to increase).
Rationale: There isn’t much information to inform the beginning of the current model.
Response: The Panel assigned this task low priority and, while models with alternative start-years were explored, the Panel ultimately decided to retain the STAT choice of 1962 for the start year of the model.

D: Force commercial selectivity to be asymptotic in the final time block.
Rationale: To see if there is a substantial change in likelihood; the current decrease in selectivity with age occurs at an age to which few animals would survive, given the assumed value for natural mortality, and so this decline may be based on few data and have little impact.
Response: Forcing asymptotic for the commercial fishery resulted in changes to the biomass trajectory (a lower peak in the mid-1980s). Also, the objective function increased from 3390.7 to 3412.66 with three fewer estimated parameters. The biggest impact of the change appears to be on recreational selectivity, with much lower selection for the younger ages. Forcing asymptotic selectivity for the commercial fishery did not impact the fits qualitatively, although the likelihood values suggested that the model fits the age-composition data better, the recreational length compositions worse, and the survey index somewhat better.

E: Add an additional selectivity time block from 2000 onwards for both the recreational and the commercial fisheries.
Rationale: To better reflect current fisheries.
Response: Under this model configuration, the biomass collapses in recent years and there are marked changes in selectivity for the recreational fishery. Allowing for a change in selection in 2000 led to a reduction in the objective function from 3390.7 to 3345.9 with an additional 12 estimable parameters. The model fitted the survey index and the age- and length-compositions better, but fitted the size-at-age data worse. The Panel noted that this model configuration assumed that catchability remained constant for the recreational fleet and therefore considered a follow-up analysis in which separate catchability parameters were estimated pre- and post 2000 (see “O” below).

F: Use and estimate double normal length-based selectivity for the recreational fishery.
Rationale: To better fit the length data: fish are growing quickly at a young age, and the smallest mackerel (<10 cm) appear not to be selected, but the model with age-based selectivity predicts that such animals should be caught in the recreational fishery.
Response: The fit to the recreational length-frequency data was better in that no small fish were estimated to be caught. However, this modification did not change the overall biomass trajectory and the objective function was larger than when selectivity was assumed to be age-based (3404.3 vs. 3390.7). The STAT stated it would prefer to assume that selectivity is age-based. The eventual change back to annual time steps for the final

base model resolved the mismatch of season-independent age-based selectivity and rapid growth within the first year.

G: Remove the largest (> 55 cm) and smallest (<10 cm) animals from the recreational length compositions by setting these to zero.
Rationale: Large fish in the length compositions may be misidentifications of other species as Pacific mackerel fish may be misidentified as Pacific mackerel, and small fish are rare and not representative.
Response: This was not completed during the Wednesday round of requests. A revised request is given at "Q" below.

H: Use annual time step instead of a quarterly time step.
Rationale: This may improve the fit to the age- and length-composition data because age-based selectivity that does not account for growth within the year.
Response: The STAT ran an annual model based on the specifications of model S1_qa25, but did not estimate the selectivity parameters. See "H2" below for a model configuration which did implement the specifications requested by the Panel.

I: Ignore ageing error.
Rationale: The model cannot fit large catches of a single year-class due to smoothing across year-classes. Ageing error appears to be too high at least for 0- and 1-year-olds (in some years).
Response: Ignoring ageing error led to lower estimated biomass during the 1980s and at the end of the modelled period. However, while the fits to the age-compositions were improved, those to the survey index and size-at-age data were poorer. The Panel agreed to retain the current ageing error matrix and recommended that better quantifying ageing error remain a research priority.

J: Remove the size-at-age data from 1974 through 1980.
Rationale: The model does not fit the size-at-age data well during these years. Ignoring these data allows the impact of this misfit to be explored.
Response: Ignoring the size-at-age data resulted in an increase to the estimates of the biomass during the 1980s and at the end of the time series. There appears to be a conflict between the size-at-age and the length-composition data. The model behaved generally as expected, and without a large impact on current biomass when these data were omitted. The STAT and Panel agreed that this is not a major source of sensitivity.

K: Divide the CV on the last CPFV index data point by 100 to force the model to get closer to this data point.
Rationale: This will force the model to get closer to the last CPFV data point and reveal what in the data is causing the model to not fit this point.
Response: This sensitivity behaved as expected; the trajectory of predicted CPFV catch per unit of effort (CPUE) was forced through the last point in the CPFV series. One of the selectivity parameters hit a bound.

L: Add in the new (time-blocked) CalCOFI indices (from Request B).
Rationale: To see if these data can be fit adequately and if they inform the model.

Response: This had little impact on the results. The model shows a plausible fit to the five data points in the second blocked CalCOFI time series. The first blocked CalCOFI time series contains only two points in the period considered by the model, and is therefore not informative.

M: Model with new CalCOFI indices in and CPFV index out.
Rationale: To see if the revised CalCOFI index provides enough information to drive the model, and what is the result.
Response: This run did not converge.

H2: Repeat request "H" as intended (i.e. a model exactly like S1_qa25 except with annual time steps).
Rationale: This is what the Panel asked for in "H" above.
Response: There are trade-offs between the seasonal and annual models. The STAT stated that it preferred to use the annual model for the current assessment, and planned to explore quarterly models again in the future. The SS model may need to be revised to better address quarterly time-steps. **This model configuration became the working base-model.**

N: Make commercial selectivity time block from 1978-present asymptotic (based on the working base-model).
Rationale: As for request "D".
Response: The estimated biomass during the 1980s and recently is again lower.

O: Add an additional selectivity time block from 2000 onwards for both the recreational and commercial fisheries. Split the CPFV index into two series (still mirroring recreational selectivity).
Rationale: This is a potential alternative model which may more accurately reflect the reality of recent fishery selectivities.
Response: The hessian matrix did not invert. See request "U" below.

P: As for request "O", except that the post-1980 blocked CalCOFI index is included in the objective function.
Rationale: As for "O", except also to determine if the model can fit the CalCOFI index and if its inclusion has an effect on biomass estimation.
Response: The biomass estimates were substantially larger historically than for the working base-model, but similar to those from the working base-model at present. The selection patterns for the recreational and commercial fisheries during the recent period appear similar to those during the 1970s The model appeared able to fit the blocked CalCOFI index, although the very low point at the end of the time series gets very high weight due to the assumption of a constant CV (constant SD in log space).

Q: Drop all fish larger than 55 cm from the length-frequency data for the recreational fishery.
Rationale: Large fish may be misidentified, data may be anomalous.
Response: The results were qualitatively identical to those for the working base-model. The STAT and Panel agreed not to delete these data.

R: Conduct a series of model runs based on the working base-model to determine the relationship between the input and output values for σ_R. Consider input σ_R values of 0.7, 0.9, 1.1, and 1.3. Also, try once (using linear interpolation) to match the input and output σ_R values.
Rationale: The output σ_R is about 1.1 for the working base-model (input σ_R = 0.7). Try to find where the input and output σ_R values match by increasing the input σ_R.
Response: The output σ_R continues to be larger than the input σ_R, even when the input σ_R exceeds 2.0. See also request "S".

S: Show detailed results for the working base-model when σ_R is set to 1.0.
Rationale: Similar to one iteration for an original input σ_R of 0.7 with one significant digit.
Response: Small changes overall, the output σ_R is closer to the input value than before. **The STAT and Panel agreed to make this model the working base-model.**

T: Using the working base-model (see "S"), reduce λ for the age-composition data to 0.25 and increase λ for the length-composition data to 2.0.
Rationale: Reducing the emphasis on the commercial age-composition data and increasing that on the recreational length-composition data allows the input and effective sample sizes to match better.
Response: The entire biomass time-series was lower. The fit to the CPFV index was better, the output σ_R was 0.994, and the effective and input samples sizes for the recreational and commercial composition data matched better. However, one of the selectivity parameters hit a bound. The Panel and the STAT discussed whether this model reflected better performance and whether it should (following resolution of the bound problem) form the base-model. See request "V" below.

U: Repeat request "O", but with the working base-model.
Rationale: To carry forward the alternative model.
Response: Age-0 animals are now fully-selected by the commercial fishery in the last time-block. The fits to the CPFV series are good while those to the age- and length-composition are similar to those for the working base-model. The objective function is lower (1309.4 vs. 1347.2) with 10-15 additional parameters. The Panel noted that run "P" led to higher biomasses, but dropping the last CalCOFI data point led to results more similar to run "U". This suggests that the very low data point at the end of CalCOFI series is very influential because of the assumption of a constant SD in log space for all data points. The Panel concluded that there is very little information in the new time-blocked CalCOFI index (except that caused by the way the variances had been specified).

V: Repeat request "T" "fixing" the selectivity bound problem.
Rationale: This is the tentative base-model and the Panel wanted to check that the bound had no qualitative impact on the model outputs.
Response: There was a "crash penalty" in the early 1960s (see request "W").

W: As for request "V", but starting the model in 1969.
Rationale: To keep reweighting in and hopefully eliminate the crash penalty.
Response: This model continued to hit bounds, suggesting that starting the model later did not resolve the crash penalty problem.

AA: Using model "S", increase the weight on the recreational length-frequency data by a factor of 2, but do not down-weight the age-composition data (start the model in 1962).
Rationale: Apply reweighting where possible, see if model behaves.
Response: This model configuration fit all of the data sources adequately and the match between the effective and input sample sizes was improved compared to the working base-model. **The STAT and Panel agreed that this model configuration would be the final base-model.**

AB: Repeat "O" for the final base-model (AA) – i.e. add an additional selectivity time block from 2000 onwards for both the recreational and commercial fisheries, and split the CPFV index into two series (still mirroring recreational selectivity).
Rationale: This is the major sensitivity identified, so the Panel wished to see it relative to the final base-model.
Response: This alternative model is more consistent with the relative difficulty in catching Pacific Mackerel in recent years. The biomass at the end of the time period is lower than for the final base model. While there are reasons to believe a change in selectivity may have occurred sometime in the vicinity of 2000, this run does not represent a full exploration of the possibilities regarding this change. Adding in any time block where all selectivities and catchabilities change will necessarily lead to overfitting of data and some loss of signal. None-the-less, this model configuration represents an important sensitivity to the base model

The key features of the final base-model are:

- Annual time-step.
- σ_R set to 1.
- The weight on the recreational length-frequency data set to the actual number of fish measured divided by 12.5 (25 divided by 2 - twice the weighting used in model configurations in general).
- Fitted only to the CPFV index.

The Panel recommended that the assessment document that will be presented to the Council in June should focus on the final base-model (additional sensitivity tests should, of course, be conducted and documented). The alternative model (AB) should be included in the report, noting that it represents an alternative plausible view of the situation, but that there is no direct evidence (except model fit) to support splitting the recreational data in 2000. The comparison between the ASAP model and the corresponding SS model (S1_aa) should be included in an Appendix.

3) Technical Merits and/or Deficiencies of the Assessment
The SS model is an improvement over the ASAP model, given its capability of including a broad range of data sources and its underlying flexibility addressing critical areas of model development, including overall estimation methods, virgin state dynamics,

biology, selectivity, catchability, and projections. The Panel supports the STATs base model ("AA") as the basis for management advice with the caution that there is a plausible alternative model indicating a severe decline in the resource.

4) Areas of Disagreement

There were no major areas of disagreement between the STAT and the Panel. There was disagreement within the Panel whether the assumption that 12.5 equals 25 divided by 2 was properly documented.

5) Unresolved Problems and Major Uncertainties

Problems unresolved at the end of the meeting form the basis for some of the research recommendations in Section 6.

1) While the best estimates of the landings off Mexico are included in the assessment, there is a continuing lack of size- and age-composition data from these catches. Previous Panels recommended that efforts be made to obtain biological sampling data from the Mexican component of the fishery. The SWFSC began the process of acquiring this information by organizing a US-Mexico workshop in 2007 and obtaining commitments for data provision in time for future assessments. Obtaining data from the Mexican fishery might help remove this important source of uncertainty.
2) The CPFV index is based on the logbook data from the CPFV fleet for California (although limited data do exist for Mexico). Given that it is based on fishery-dependent data, the use of CPFV index in the assessment as an index of stock abundance is predicated on the assumption that catchability and selectivity have not changed over time, or that the changes have been adequately included in the model configuration.
3) The outcomes from models AA and AB differ markedly for the recent years. It is unlikely that either model AA or AB captures the temporal pattern of selectivity and catchability for the CPFV fleet perfectly.

6) Research Recommendations

A. Collect biological data on mackerel caught in Pacific NW.
B. Improve collaboration with fishery researchers from Mexico and Canada. A large fraction of the catch is taken off Mexico. In particular, catches of mackerel have been as large as those off California in recent years. Efforts should continue to be made to obtain length, age, and related biological data from the Mexican fisheries for inclusion in stock assessments.
C. The data on catches come from several sources. The catch history from 1926-27 to present should be documented in a single report.
D. Reconsider the suite of indices and make recommendations for future assessments.
E. Review and analyse the raw data on which the CPFV index is based and consider area blocks as a factor in generalized linear models (GLMs).
F. Bolster the current monitoring program for CPFV fleet to improve data collection.
G. Look at correlation of Pacific mackerel catch in CPFV with other CPS species to explore the possibility of changes in targeting practices within the CPFV fleet across years. Perhaps apply the MacCall and Stephens subsetting approach.

H. Increase support of current port sampling and laboratory analysis programs for CPS. In particular, there is need to reanalyse biological parameters such as maturity-at-age, ageing error, sex ratio, sex-specific parameters, and natural mortality rates (*M*), including the possibility of larger *M* on 0- and 1-year-old Pacific mackerel.
I. Ageing error should be revisited. There are currently very few otoliths that have been read multiple times so additional readings need to be made. An age validation study should be conducted for Pacific mackerel. Such a study should compare age readings based on whole and sectioned otoliths and consider a marginal increment analysis and other validation methods.
J. Conduct a study to update the information used to determine maturity-at-length (and maturity-at-age).
K. Do more research/assessment on related/competing species including anchovy and jack mackerel.
L. Future SS assessments should consider fitting to the length-composition and the conditional age-at-length information. This may require estimating time-varying growth curves and may require multiple time-steps within each year.
M. Future assessments should consider sex-structured models.

The developers of SS should be requested to modify the seasonal model so that age-based selectivity more correctly handles within-year changes in age. In addition, the output viewer appeared to contain some glitches when applied to output from a seasonal model. The viewer made the work of the Panel much easier and its development (and refinement) should continue. One suggestion is that it should be made easier to specify output of only a subset of the possible plots.

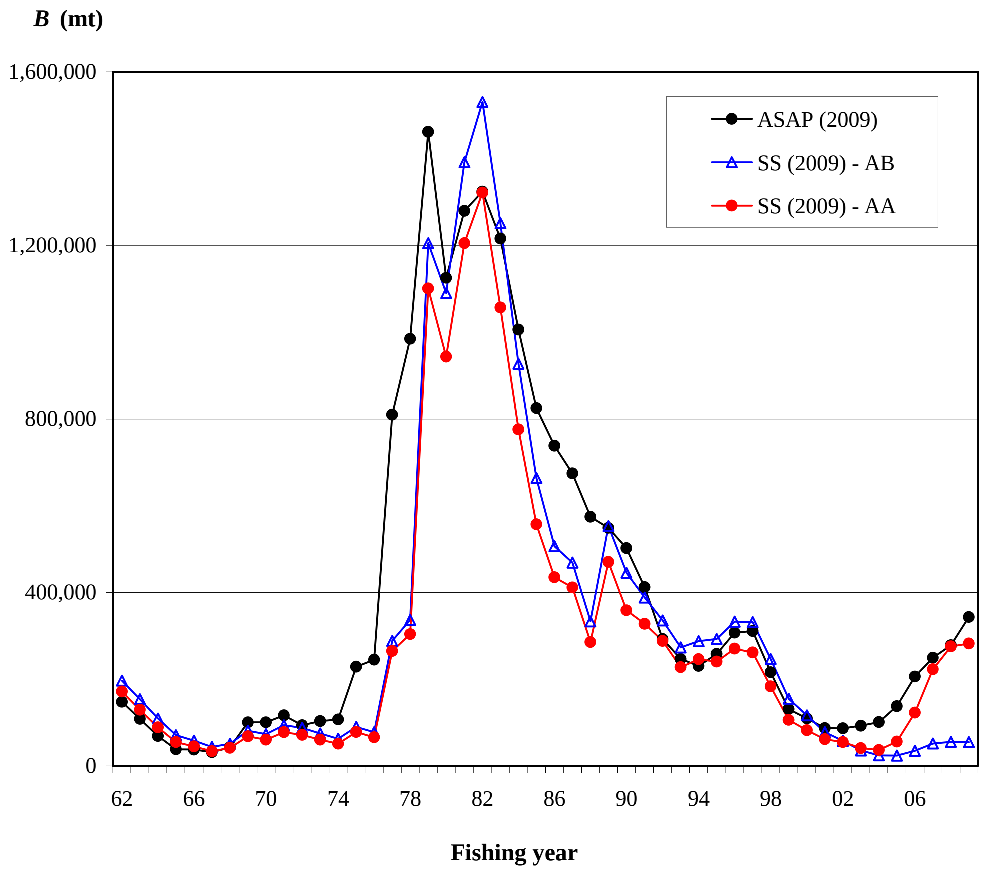


Figure 1. Time-trajectory of 1+ biomass from the ASAP model, the final base-model (AA), and the alternative model (AB).

Appendix 1

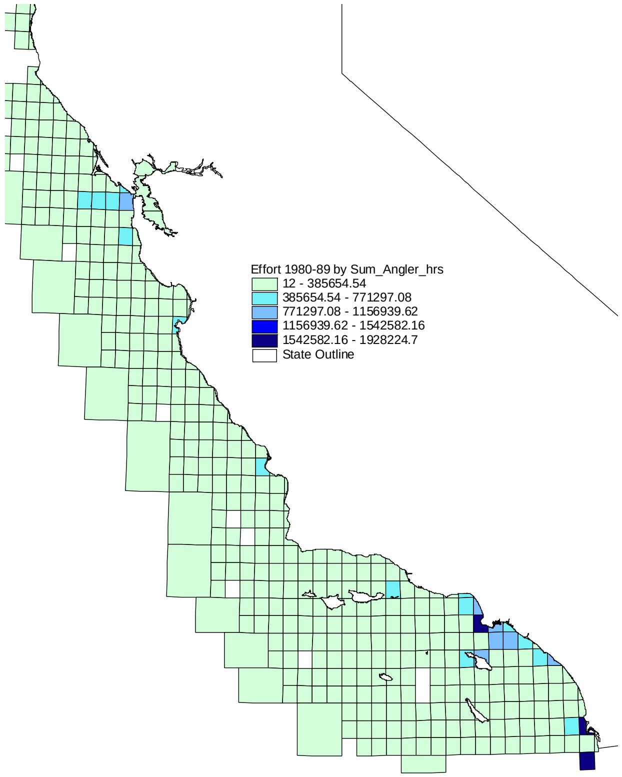
STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington,
Owen Hamel, SSC, NMFS, Northwest Fisheries Science Center
Gary Melvin, Center for Independent Experts (CIE),
Alec MacCall, External Reviewer, Southwest Fisheries Science Center (SWFSC)
Ken Burnham, External Reviewer, Colorado State University

Pacific Fishery Management Council (Council) Representatives:
Greg Krutzikowsky, Coastal Pelagic Species Management Team (CPSMT)
Mike Okoniewski, Coastal Pelagic Species Advisory Subpanel (CPSAS)
Mike Burner, Council Staff

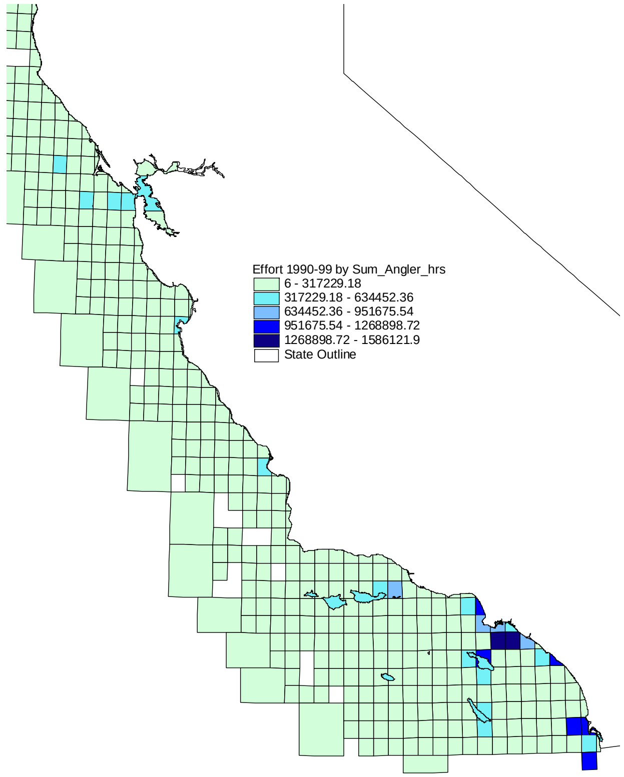
Pacific Mackerel Stock Assessment Team:
Paul Crone, NMFS, SWFSC
Kevin Hill, NMFS, SWFSC
Jenny McDaniel, NMFS, SWFSC
Nancy Lo, NMFS, SWFSC

Others in Attendance
Alexandre Aires-da-Silva, Inter-American Tropical Tuna Commission (IATTC)
Briana Brady, California Department of Fish and Game (CDFG), CPSMT
Tom Barnes, CDFG, SSC
Ray Conser, SWFSC, SSC
Doyle Hanan, Hanan and Associates
Sam Herrick, SWFSC, CPSMT
Rodger Hewitt, SWFSC
Ryan Kapp, Astoria Fisherman
Josh Lindsay, NMFS, Southwest Regional Office
Mark Maunder, IATTC
Sam McClatchie, SWFSC
Jonathan Phinney, SWFSC
Kevin Piner, SWFSC
Dianne Pleschner-Steele, California Wetfish Producers Association, CPSAS
Rosa Runcie, SWFSC
John Rutter, SWFSC
Bob Seidel, Astoria Holdings Inc.
Sarah Shoffler, SWFSC
Dale Sweetnam, CDFG, CPSMT
Akinori Takasuka, SWFSC
Russ Vetter, SWFSC
Ed Weber, SWFSC

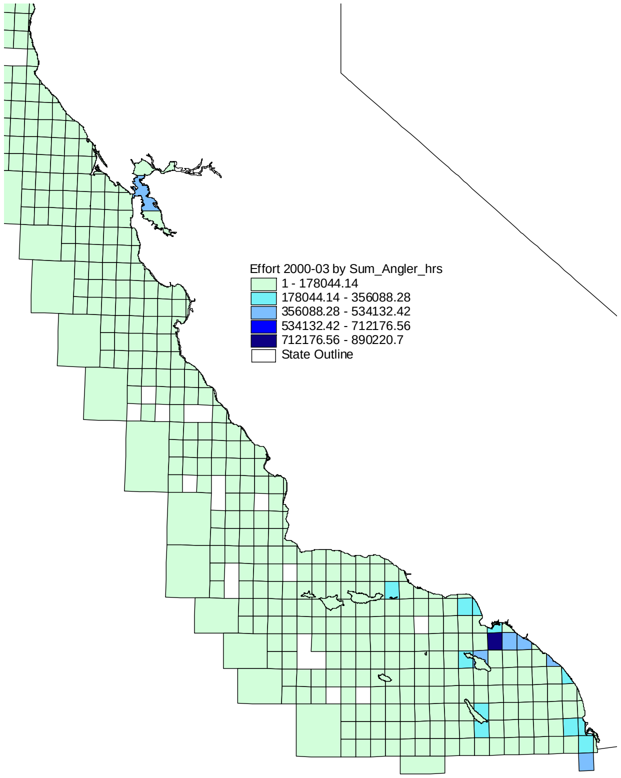
Appendix 2

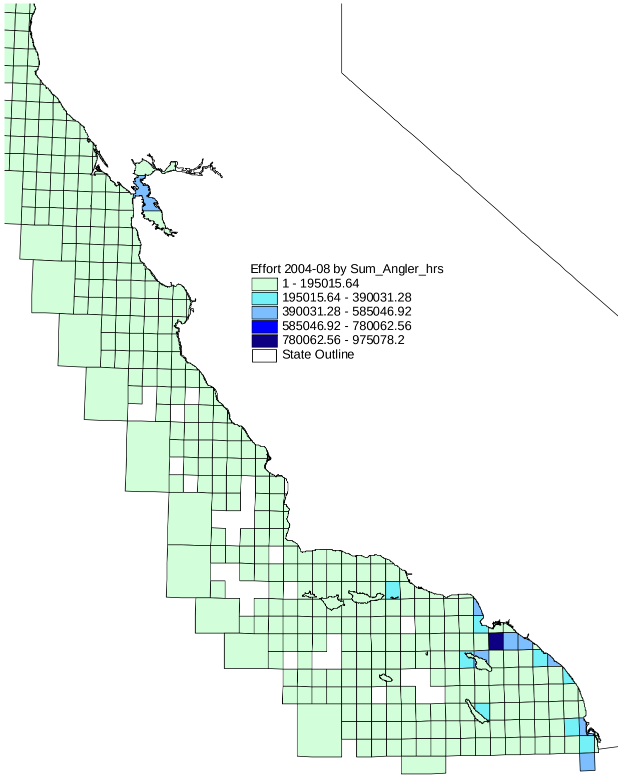


Effort 1980-89 by Sum_Angler_hrs
12 - 385654.54
385654.54 - 771297.08
771297.08 - 1156939.62
1156939.62 - 1542582.16
1542582.16 - 1928224.7
State Outline



Effort 1990-99 by Sum_Angler_hrs
6 - 317229.18
317229.18 - 634452.36
634452.36 - 951675.54
951675.54 - 1268898.72
1268898.72 - 1586121.9
State Outline


Effort 2000-03 by Sum_Angler_hrs
1 - 178044.14
178044.14 - 356088.28
356088.28 - 534132.42
534132.42 - 712176.56
712176.56 - 890220.7
State Outline


Effort 2004-08 by Sum_Angler_hrs
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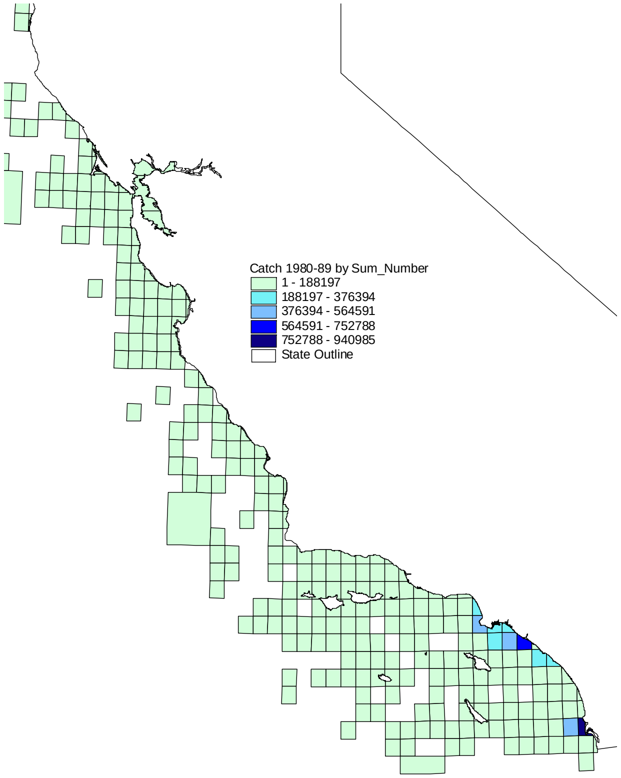
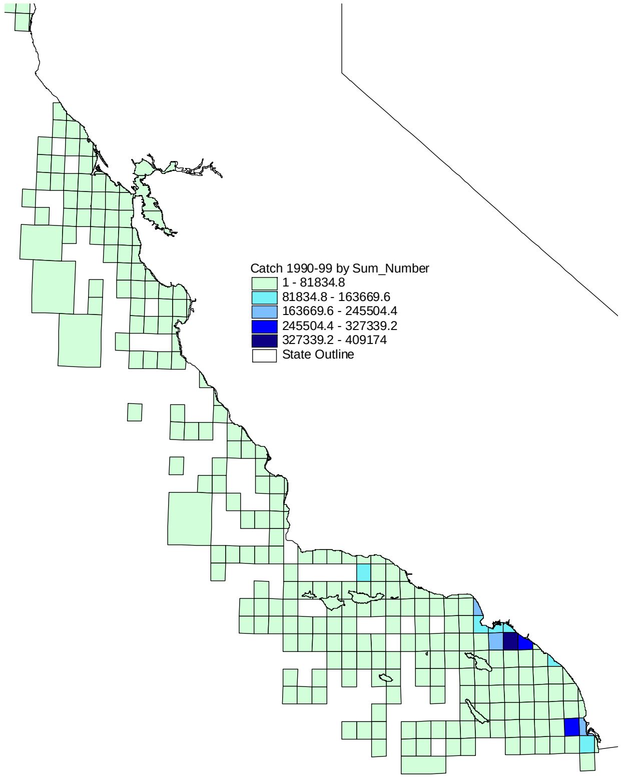
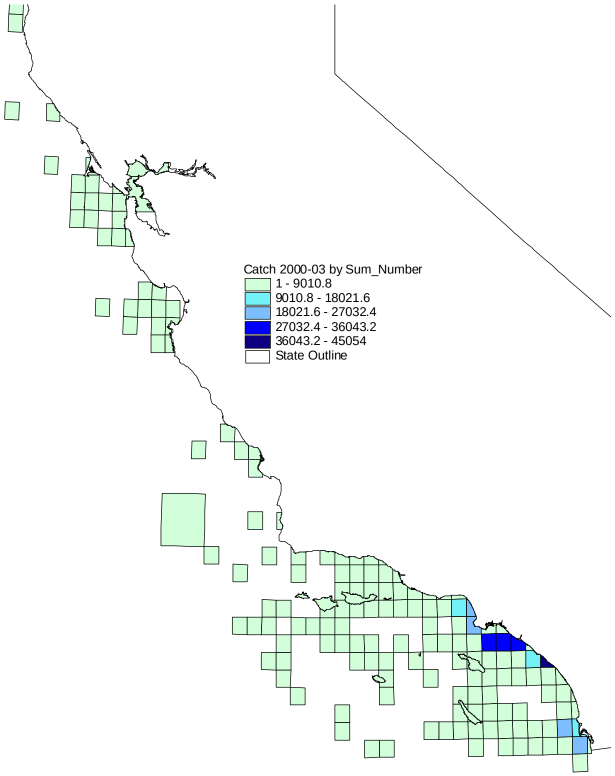
195015.64 - 390031.28
390031.28 - 585046.92
585046.92 - 780062.56
780062.56 - 975078.2
State Outline


Catch 1980-89 by Sum_Number
1 - 188197
188197 - 376394
376394 - 564591
564591 - 752788
752788 - 940985
State Outline


Catch 1990-99 by Sum_Number
1 - 81834.8
81834.8 - 163669.6
163669.6 - 245504.4
245504.4 - 327339.2
327339.2 - 409174
State Outline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18021.6 - 27032.4
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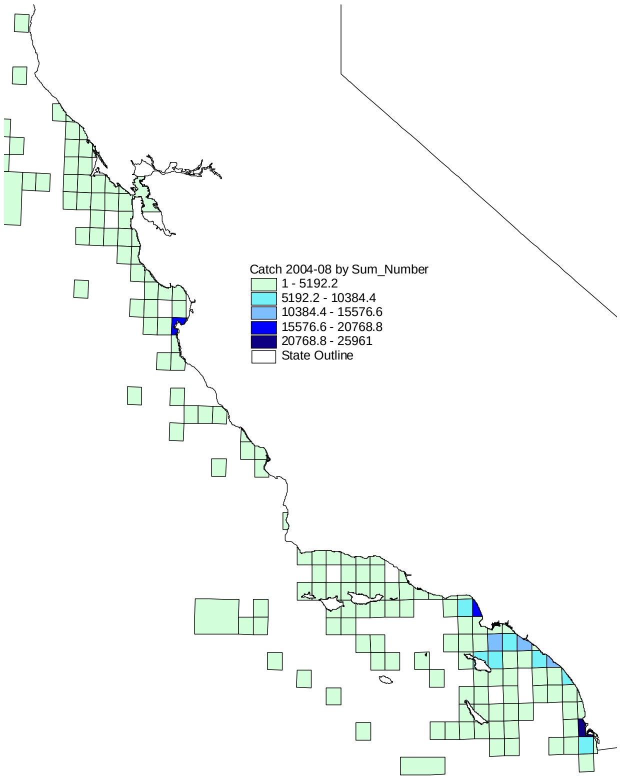
36043.2 - 45054
State Outline


Catch 2004-08 by Sum_Number
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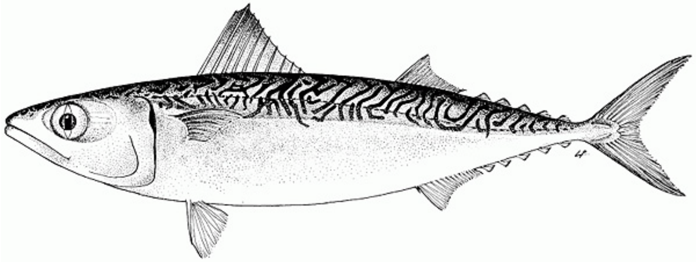
5192.2 - 10384.4
10384.4 - 15576.6
15576.6 - 20768.8
20768.8 - 25961
State Outline

Agenda Item H.1.b
Supplemental Pacific Mackerel PowerPoint (Crone)
June 2009

Pacific Mackerel Stock Assessment for USA Management in the 2009-10 Fishing Year

P. R. Crone, K. T. Hill, J. D. McDaniel, and N. C. H. Lo



Pacific Mackerel Stock Assessment (2009)

- ***Objectives (pre STAR) … see p. 1***
  - Develop stock assessment that includes …
    1) ASAP (2009) – ‘management’ model
    2) SS (2009) – alternative (baseline) model that mirrors ASAP (2009)
    3) A suite of alternative SS models (scenarios) that improves on SS (2009) baseline model
    4) **‘Best’ (preferred) SS (2009) model(s) from the suite of alternative scenarios**

Pacific Mackerel Stock Assessment (2009)

- ***Final models (post STAR) … see p. 1***
  - Management model for 2009-10 fishing year
    - SS model *AA*
  - Alternative model
    - SS model *AB*
- ***Key parameterization issues … see p. 24***
  - Time period
  - Fishery structure
  - Time step
  - Growth
  - Stock-recruitment
  - Selectivity
  - Indices of abundance
  - Diagnostics (fits to time series and MCMC evaluations)

Pacific Mackerel Stock Assessment (2009)

- ***Model description***
  - SS model
    - Key properties of modeling platform
      - Analysis: 'forward' simulation
      - Method of estimation: maximum likelihood
      - Objective function: based on normal, lognormal, multinomial, et al. error distributions and multiple likelihood components (sources of data or time series)
      - Platform underpinnings: ADMB libraries based on C++ language, with much flexibility in number of (and estimation within) components
      - Fishery/population dynamics: spatial/temporal explicit (sub-stock/multiple fishery/seasonal time-step), sex-specific, length- and/or age-structured
    - Review key parameterizations and results … see *Table 1*

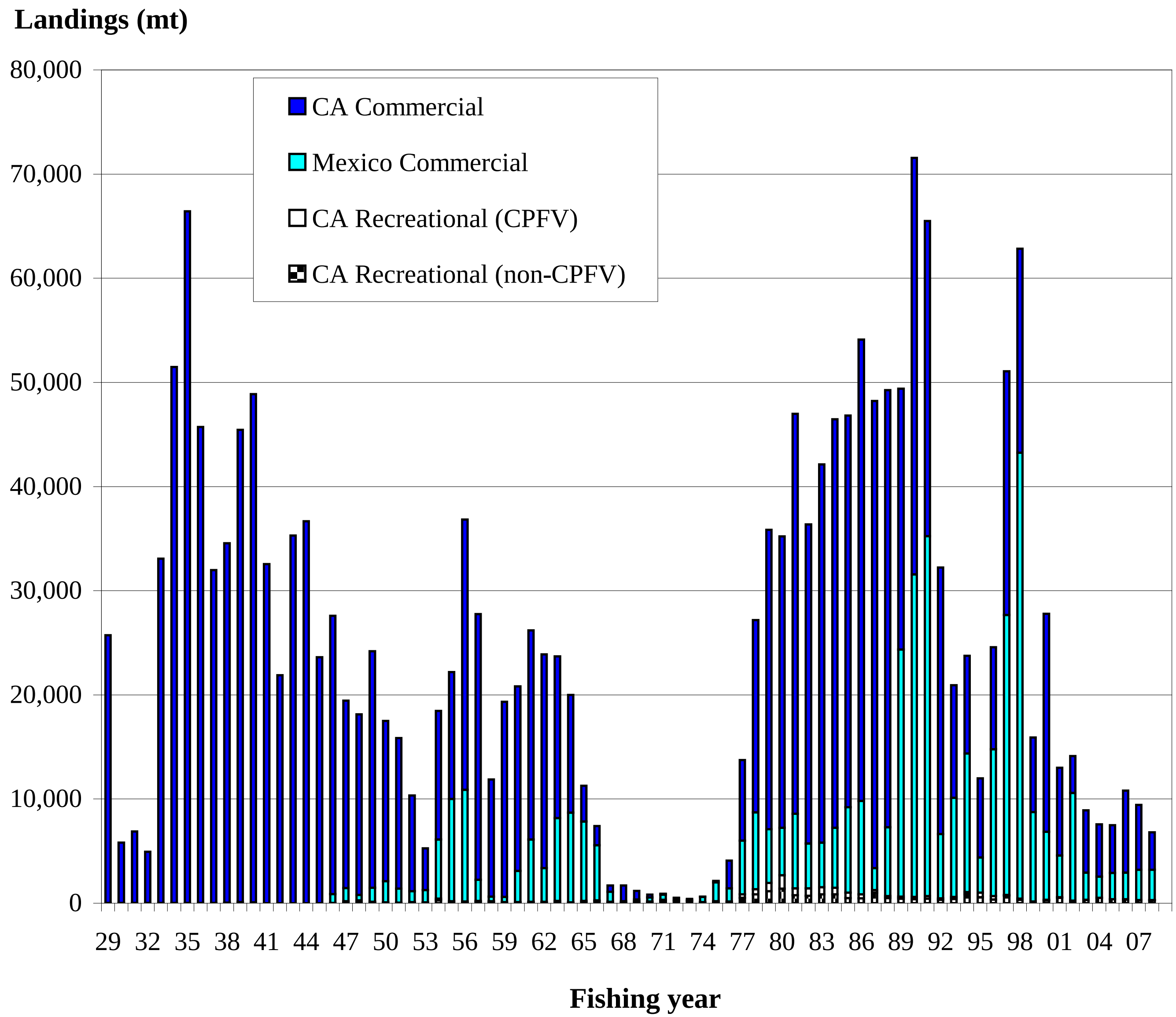
Biology

Distribution

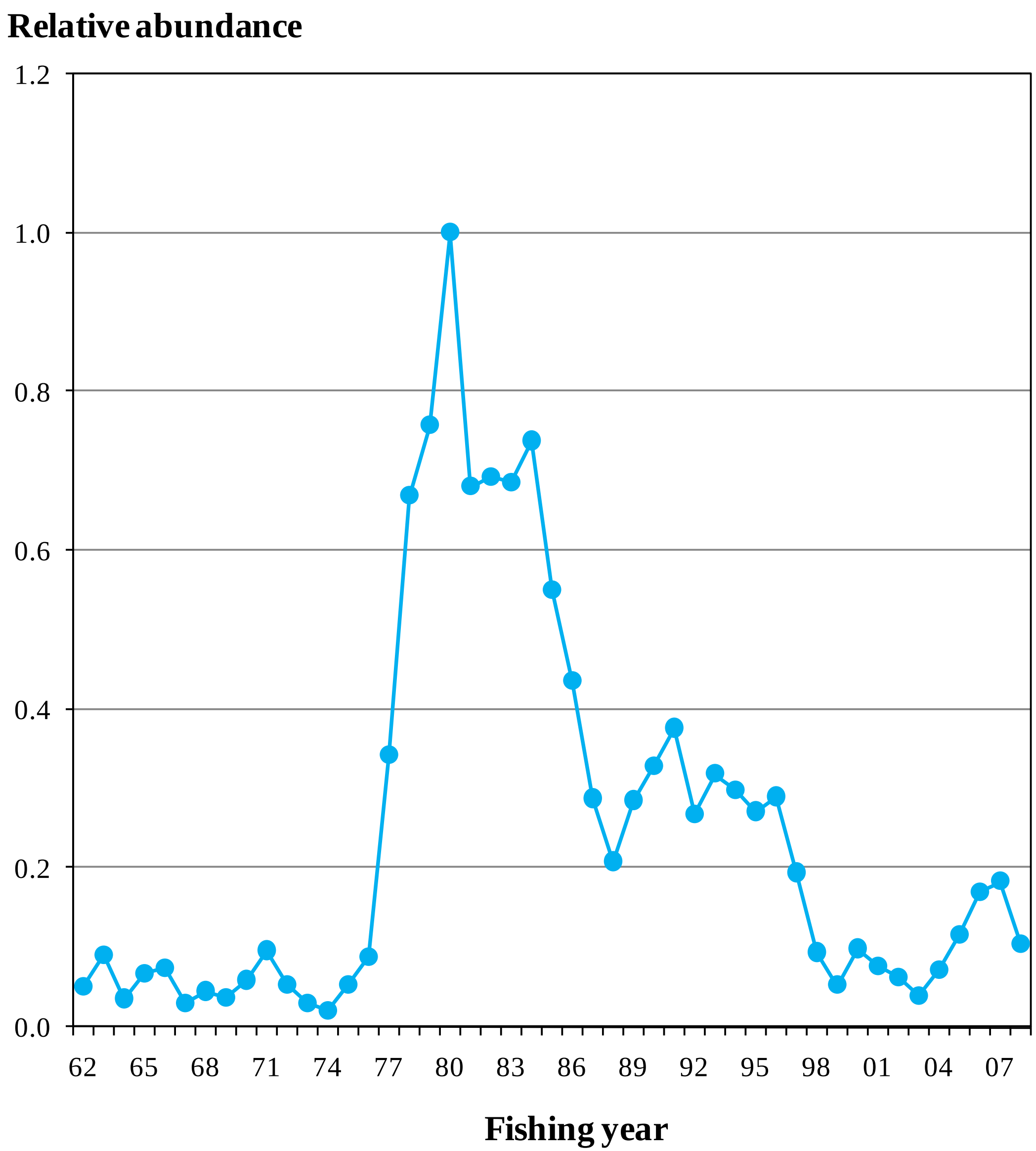
Spawning Area

Fisheries

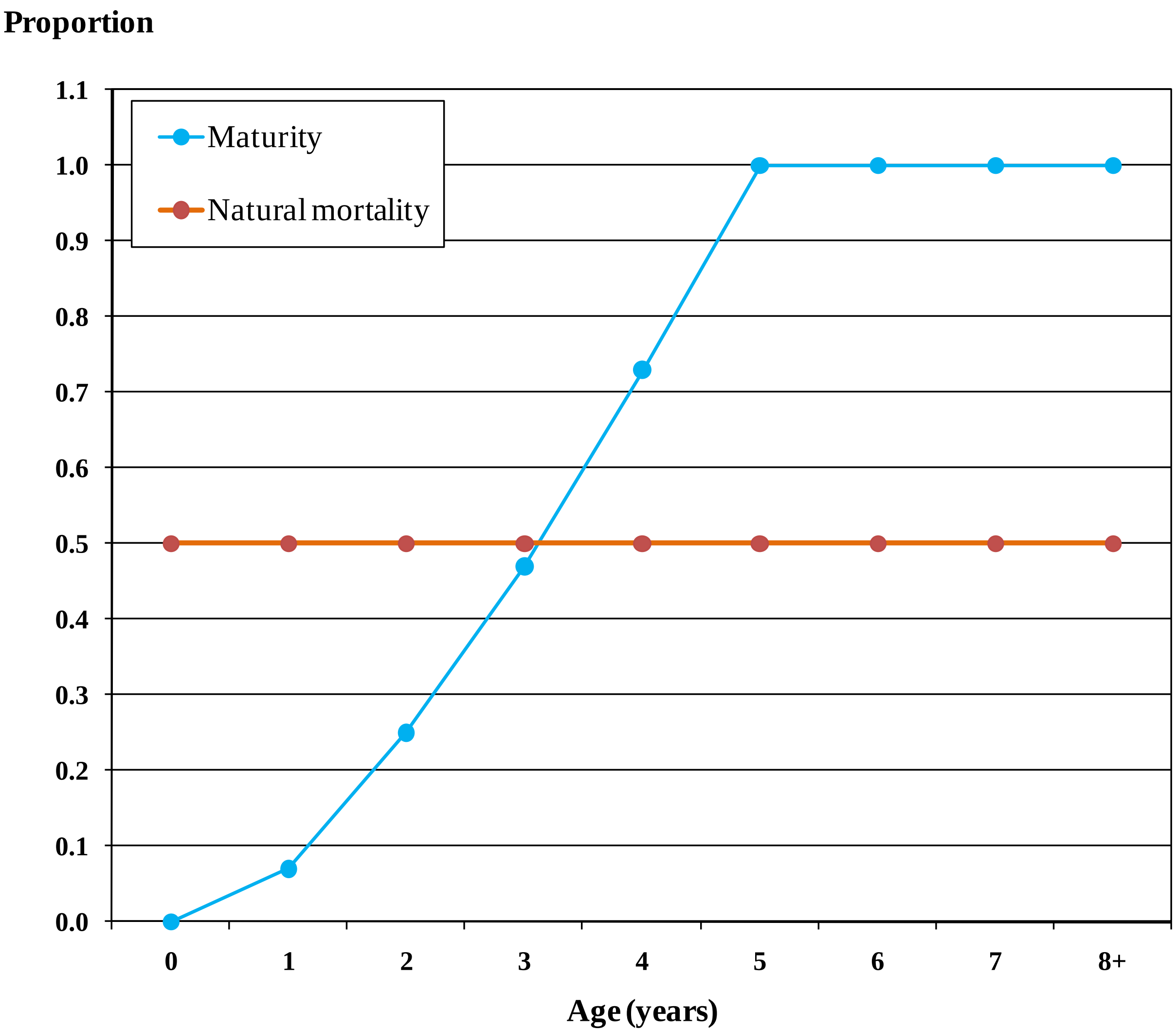
Landings

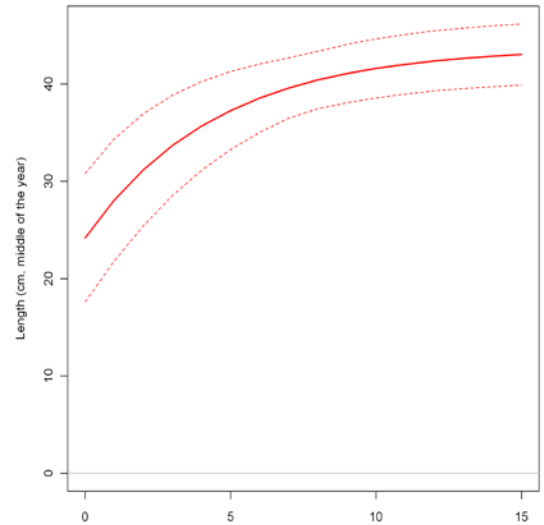

Landings (mt)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
CA Commercial
Mexico Commercial
CA Recreational (CPFV)
CA Recreational (non-CPFV)
29
32
35
38
41
44
47
50
53
56
59
62
65
68
71
74
77
80
83
86
89
92
95
98
01
04
07
Fishing year

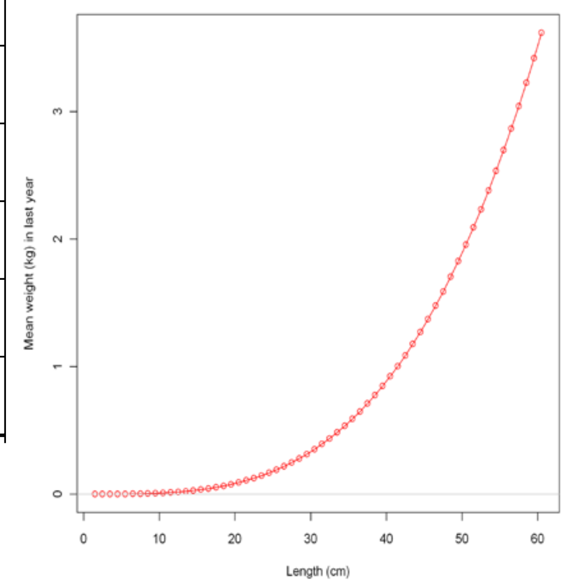
Index of abundance (CPFV)



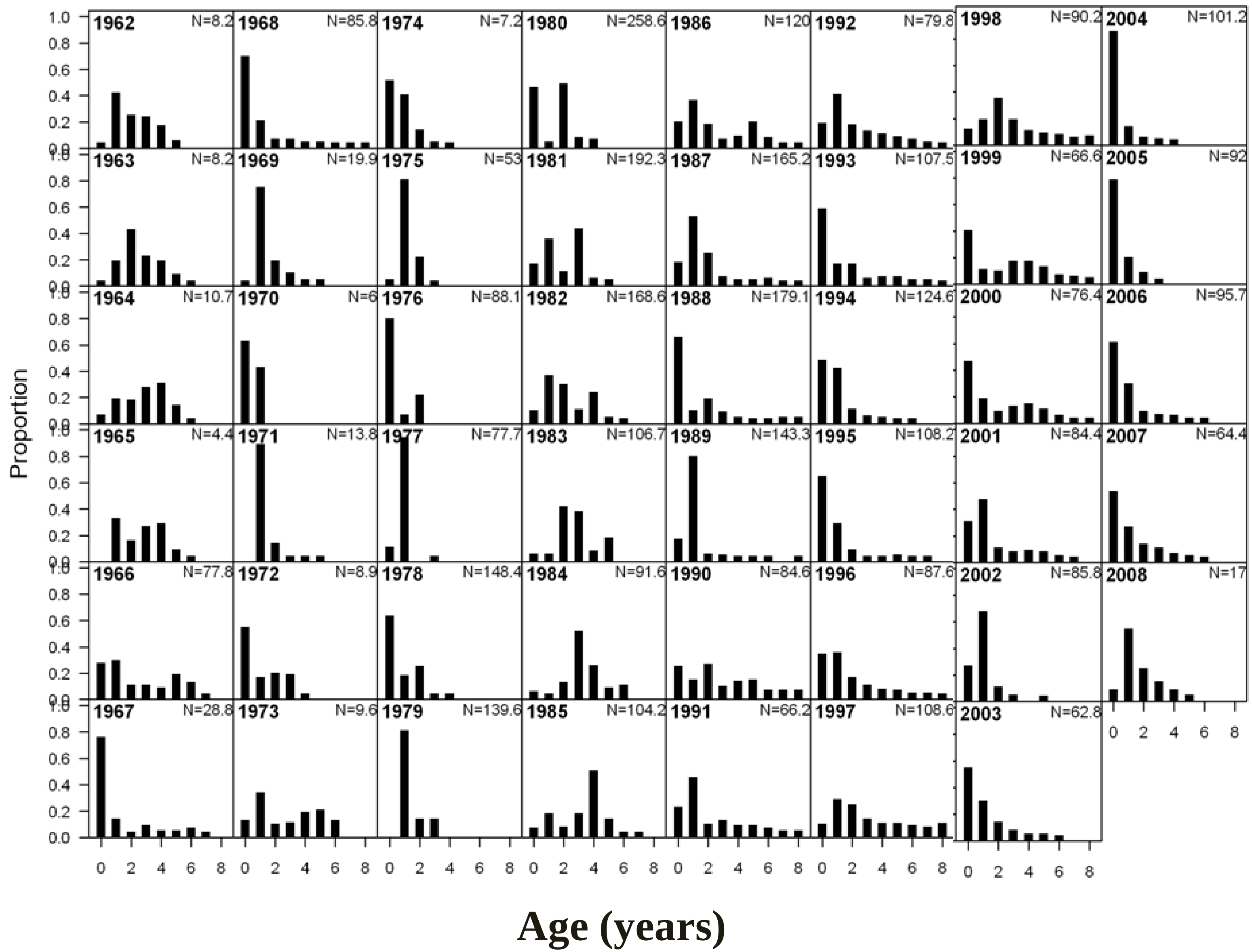
Biological parameters



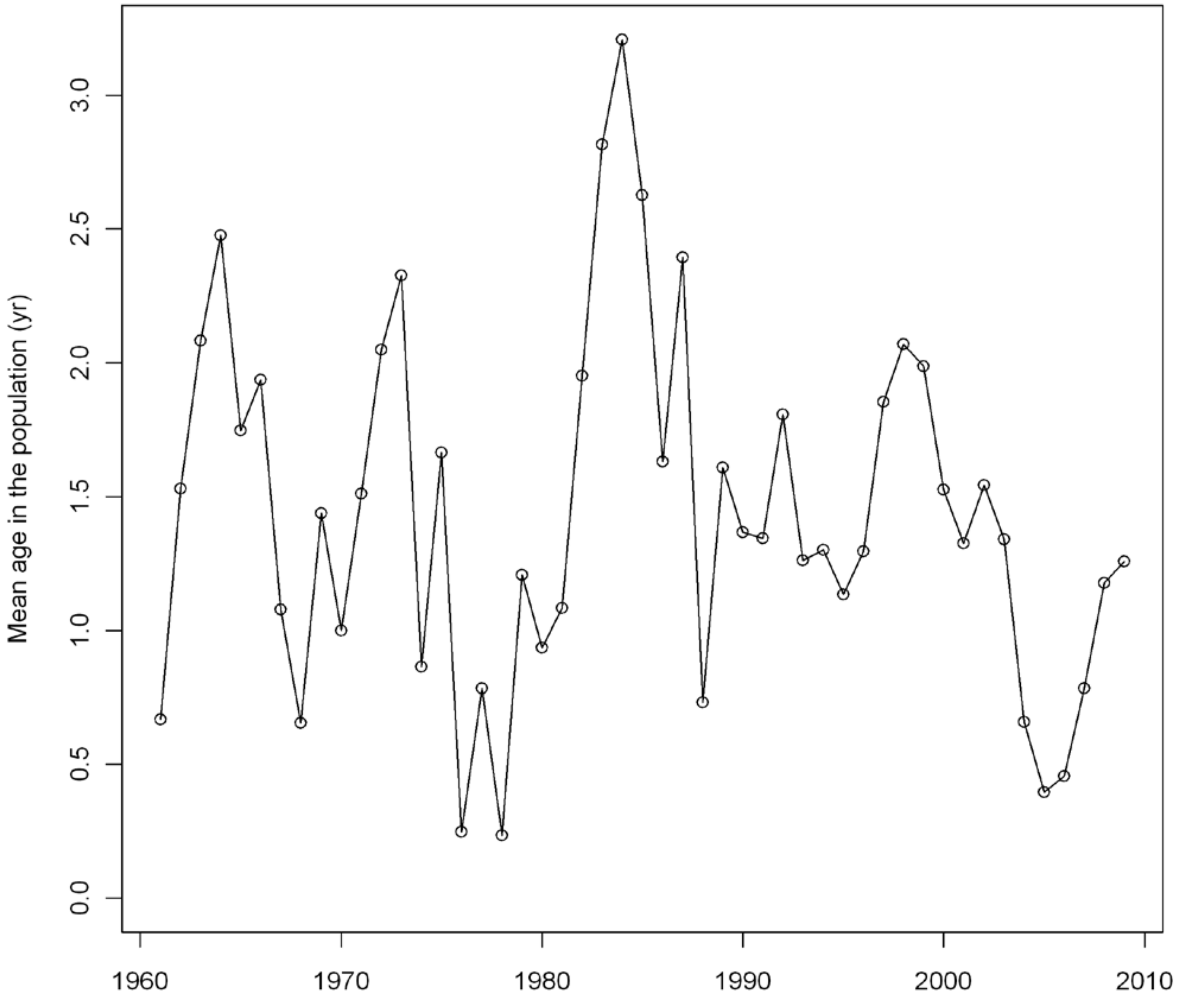




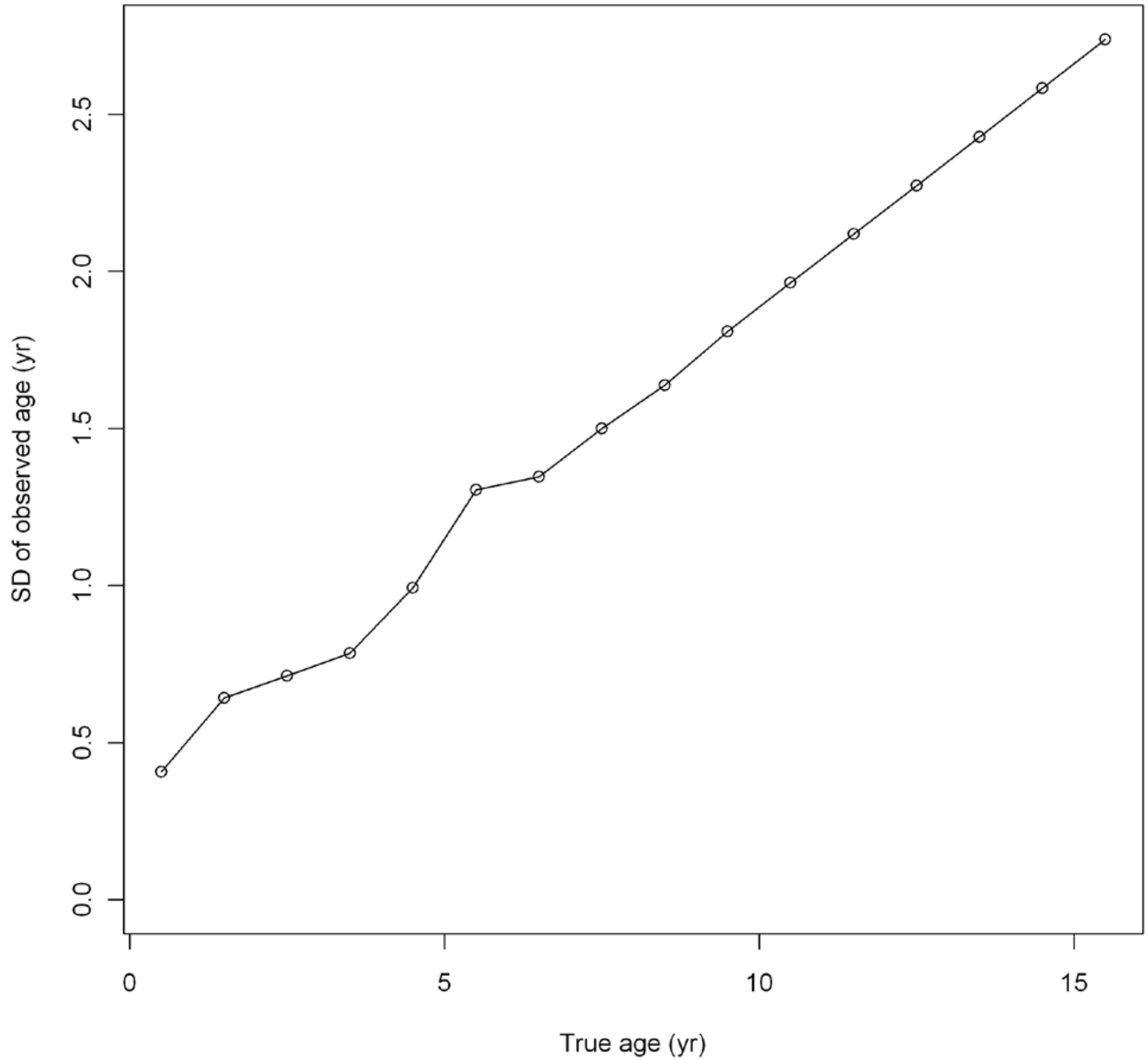
Age distribution time series – commercial fishery



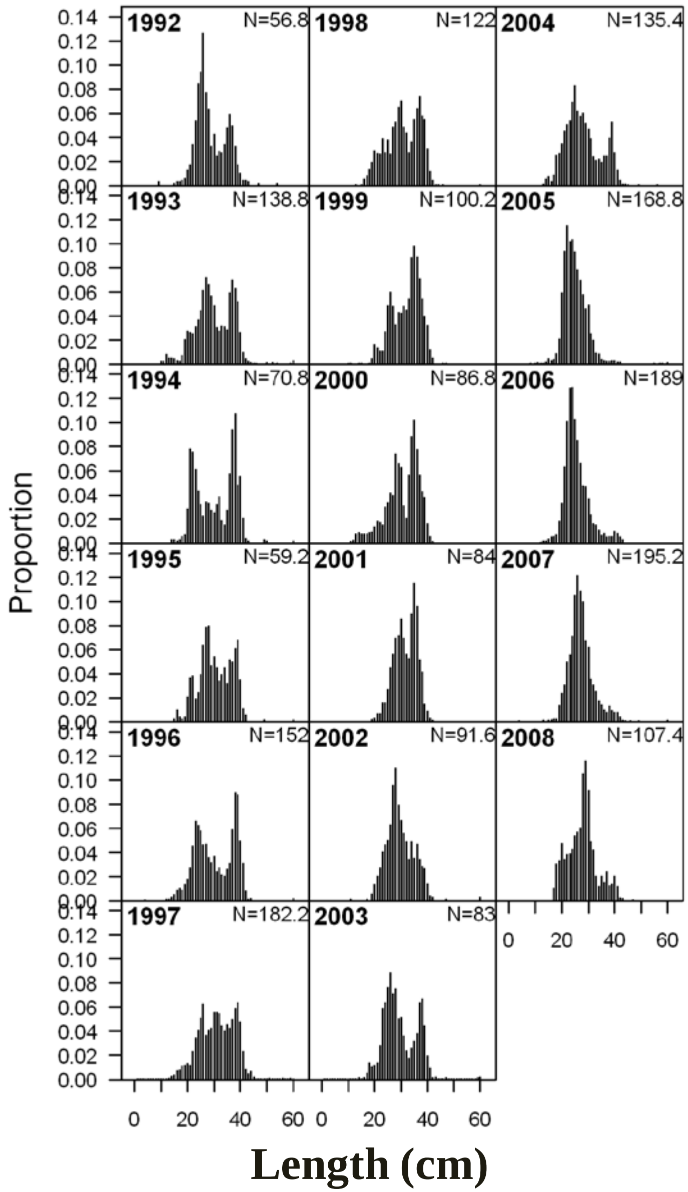
Mean age time series (commercial fishery)



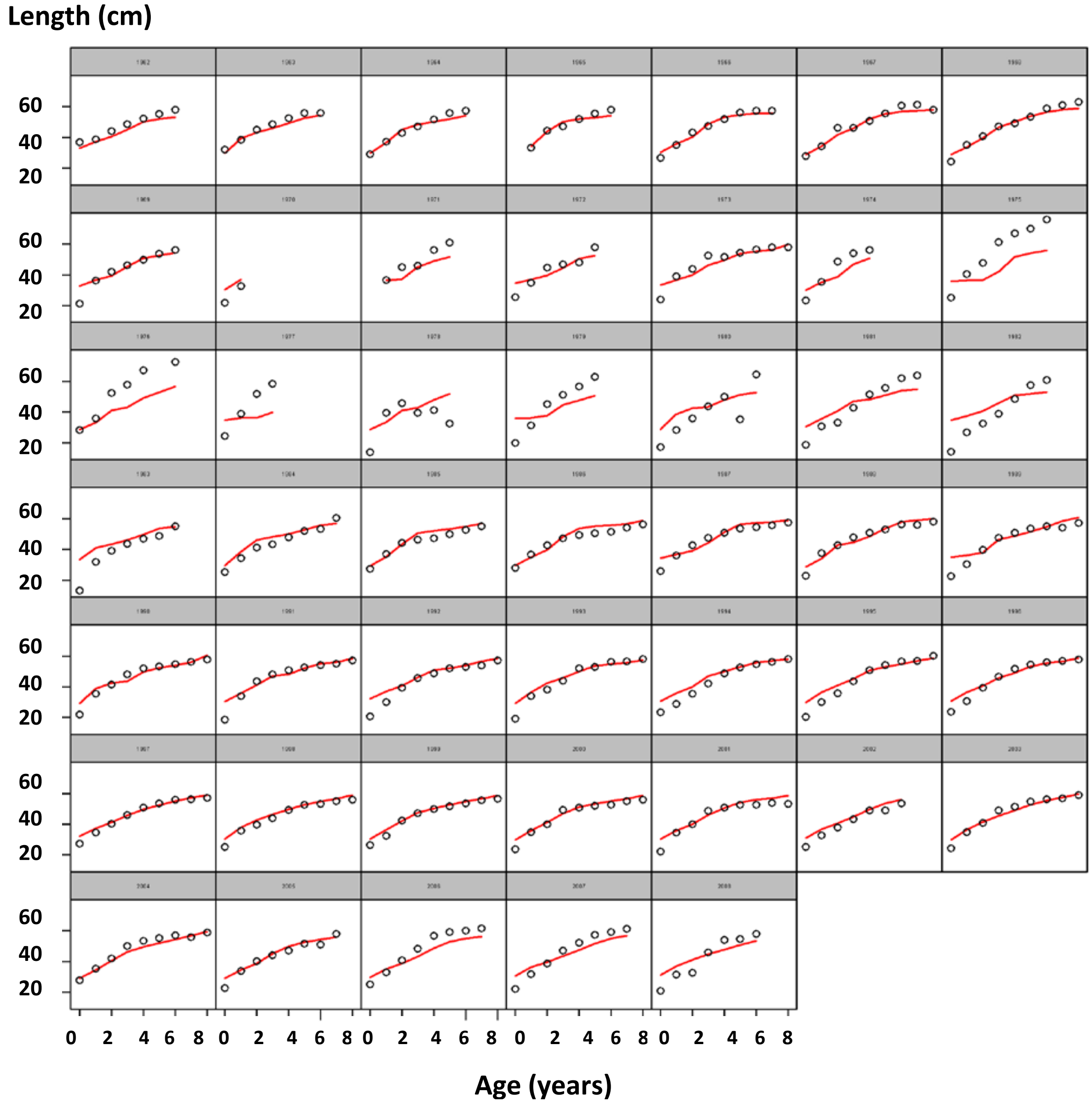
Ageing error vector (by age)



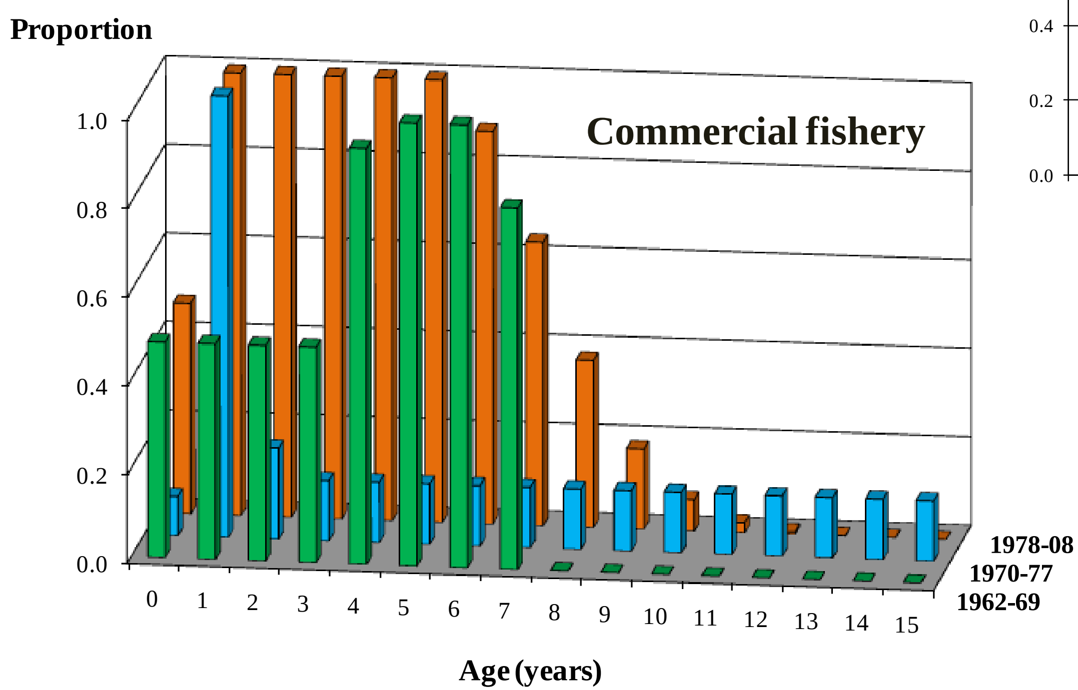
Length distribution time series – recreational fishery

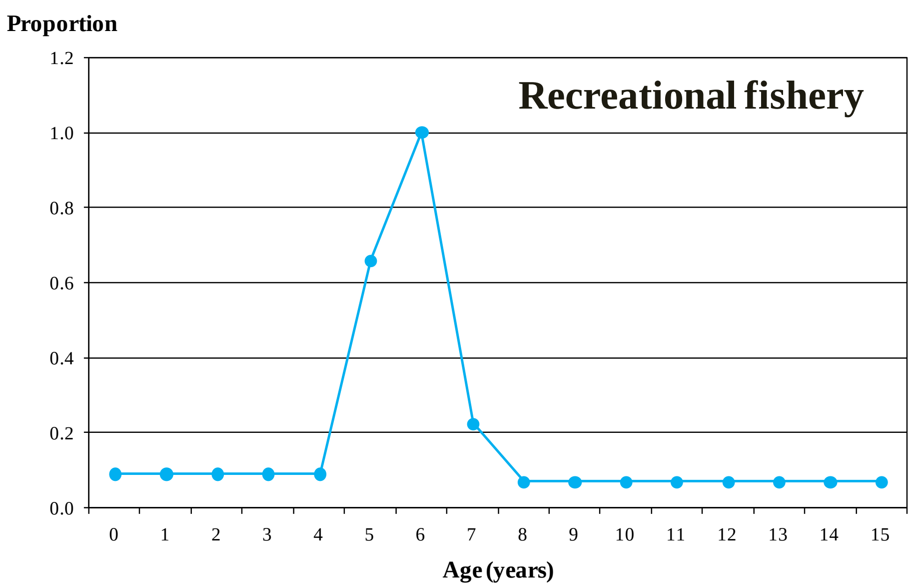


Mean length-at-age time series – commercial fishery

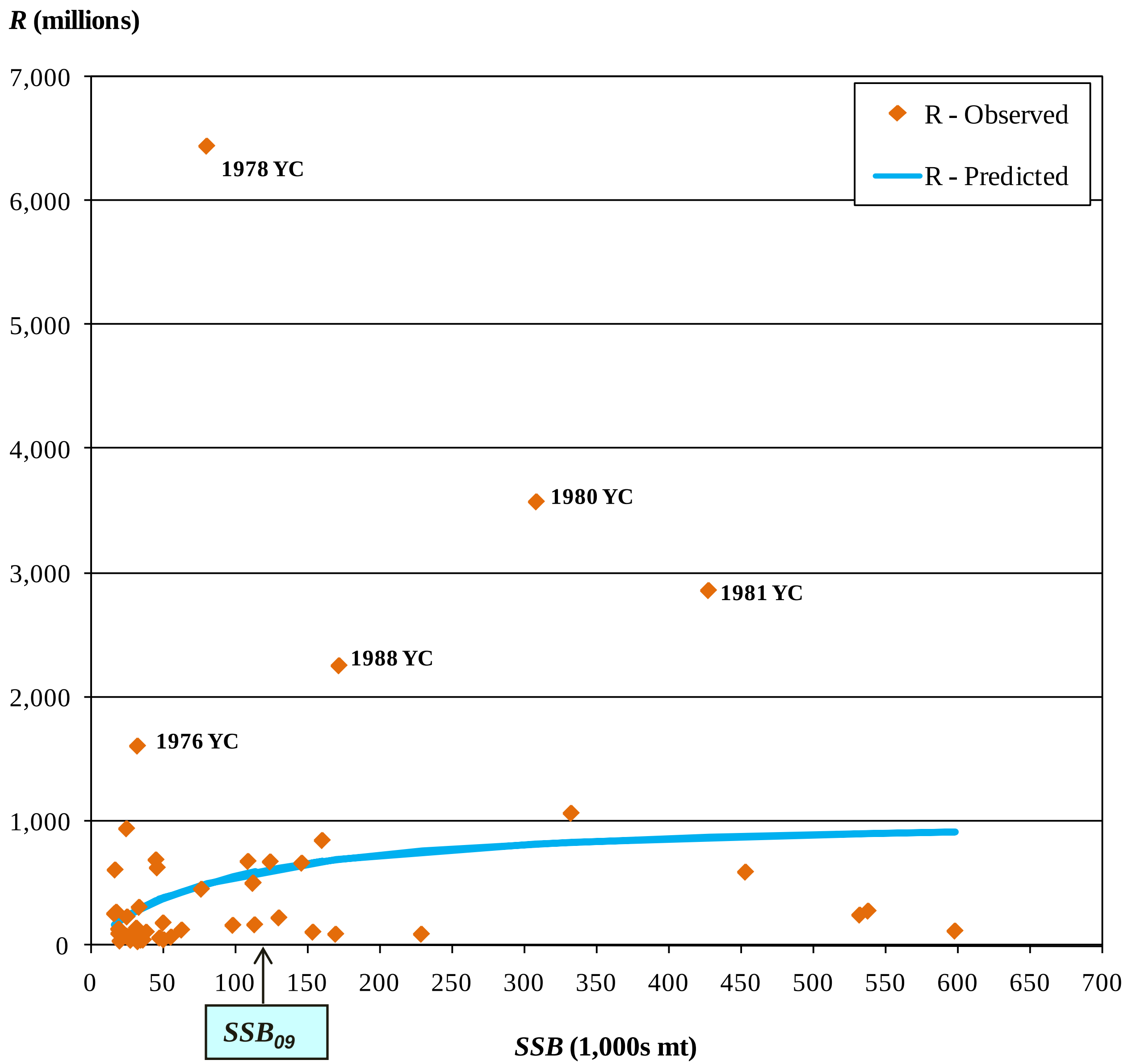


Selectivity

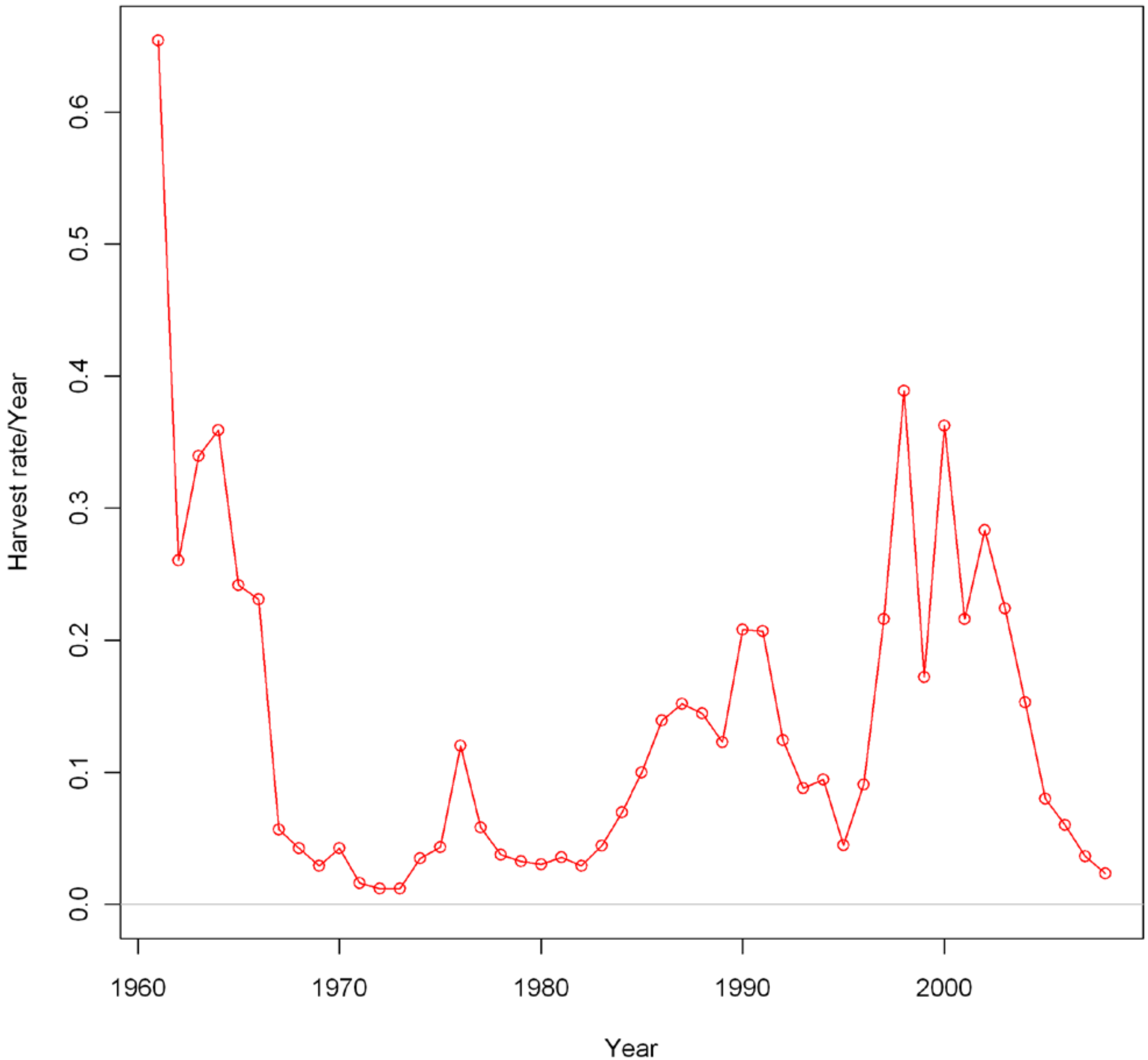




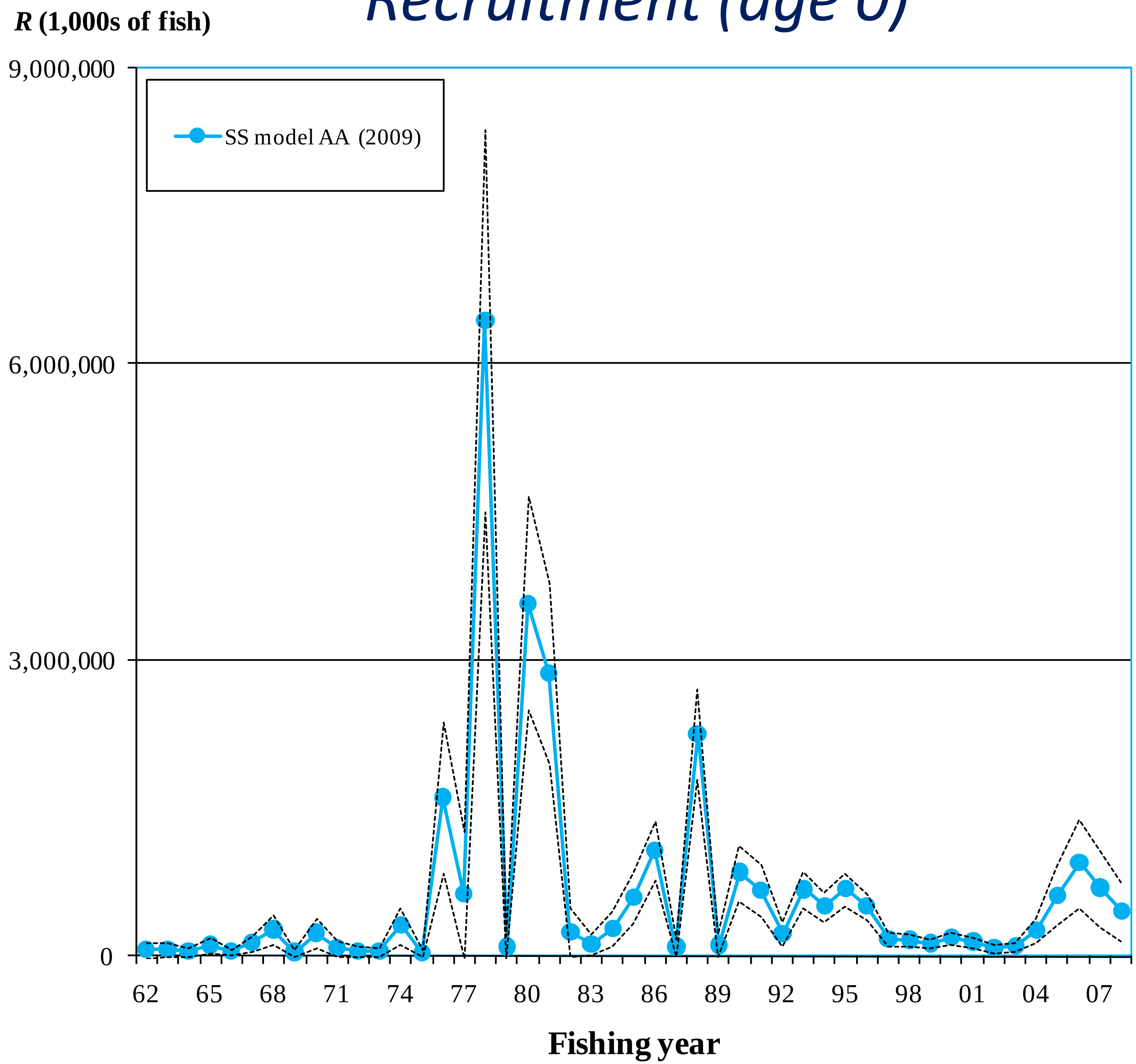
Stock-recruitment relationship



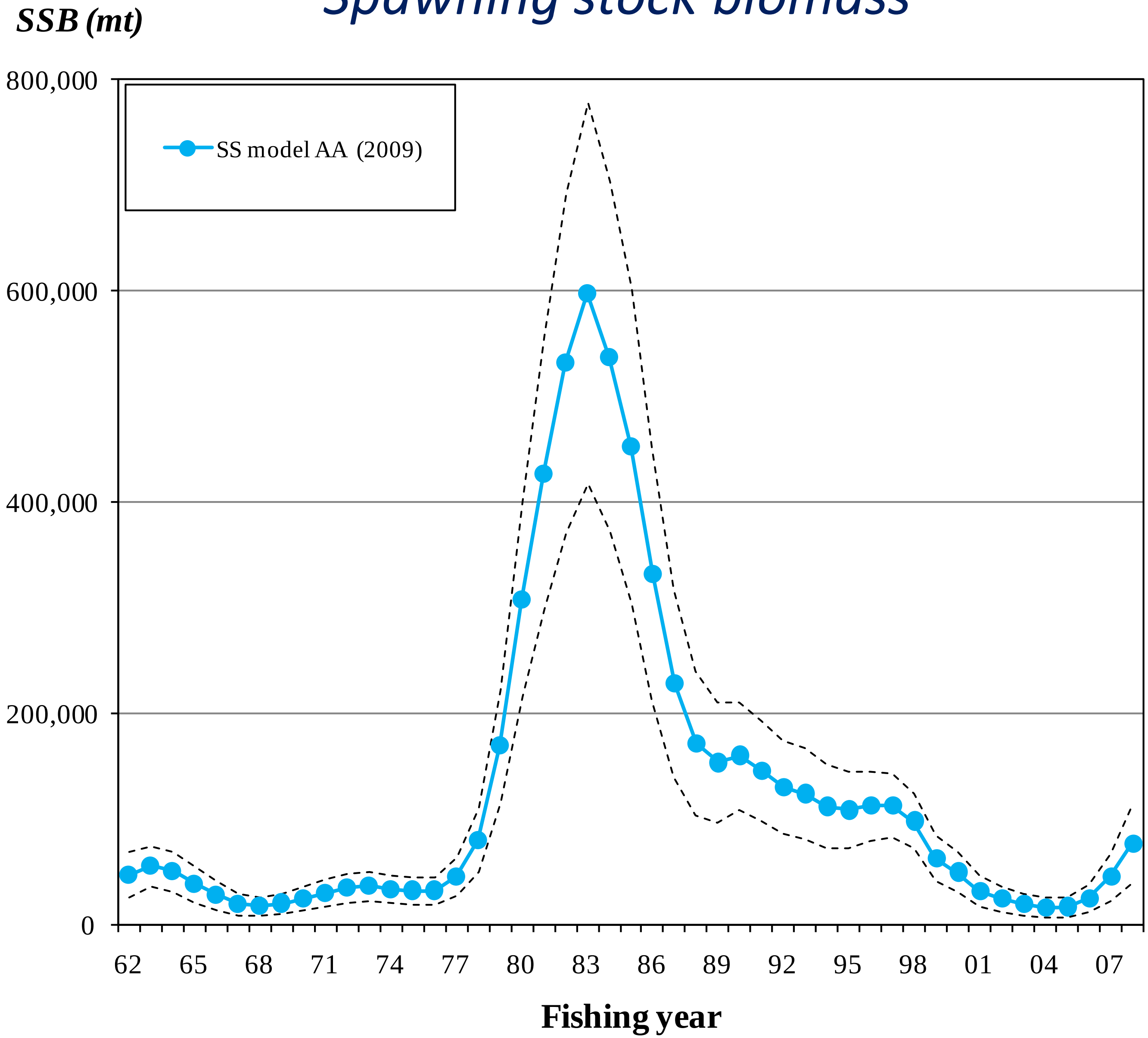
Harvest rate (F) time series



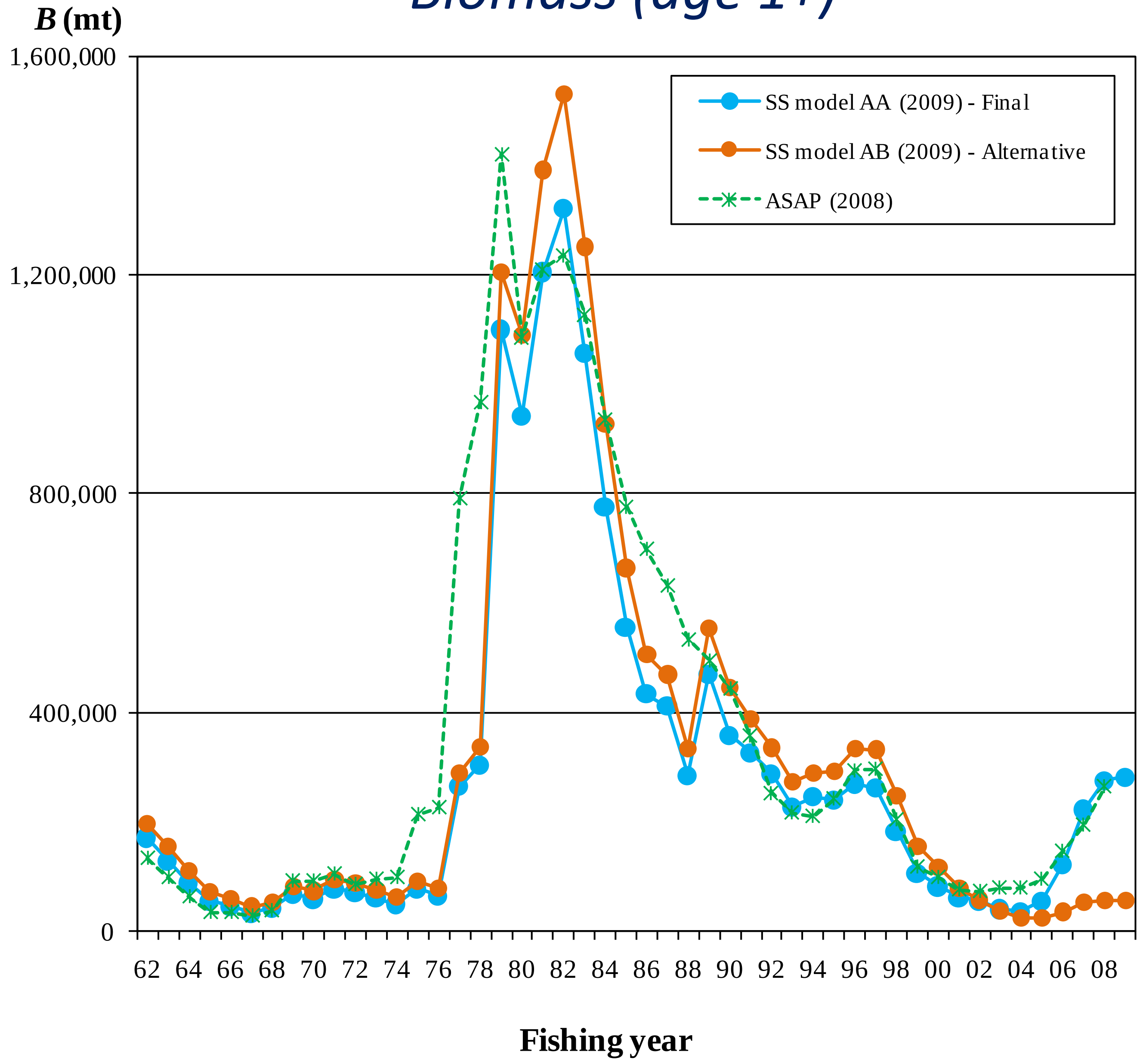
Recruitment (age 0)



Spawning stock biomass



Biomass (age 1+)



Sensitivity analysis – SS models AA and AB

	Model scenarios	
	AA	***AB***
Landings - USA/Mexico commerical (1962-08) - Fishery 1		
Landings - USA recreational (1962-08) - Fishery 2		
Age distributions (1962-08) - USA/Mexico commercial		
Length distributions (1992-08) - USA recreational		
Mean length-at-age distributions (1962-08) - USA/Mexico commercial		
CPFV survey (1962-08) - Survey 1		
CPFV survey (1962-99) and (2000-08) - Surveys 2 and 3, respectively		
CalCOFI survey (1978-08) - daily larv. prod. ('super years') - Survey 4		
Parameterization	***AA***	***AB***
Model structure		
Time period	1962-08	1962-08
Number of fisheries	2	2
Number of surveys	1	2
Genders	1	1
Time-step	Annual	Annual
Biology		
Maturity-at-age	Fixed	Fixed
Length-at-age	Estimated	Estimated
Weight-length	Fixed	Fixed
Weight-at-age	Estimated	Estimated
Natural mortality (*M*)	Fixed - all ages (*M*=0.5)	Fixed - all ages (*M*=0.5)
Stock-recruitment		
$\ln(R_0)$	Estimated	Estimated
Offset for initial equilibrium R_1	Estimated	Estimated
Steepness (*h*)	Estimated	Estimated
σ-*R*	Fixed (σ-*R*=1.0)	Fixed (σ-*R*=1.0)
Initial conditions for population dynamics		
Age distribution	Non-equilibrium	Non-equilibrium
Fishing mortality (*F*) - Fishery 1	Estimated	Estimated
Fishing mortality (*F*) - Fishery 2	Fixed (F_{init}=0.001)	Fixed (F_{init}=0.001)

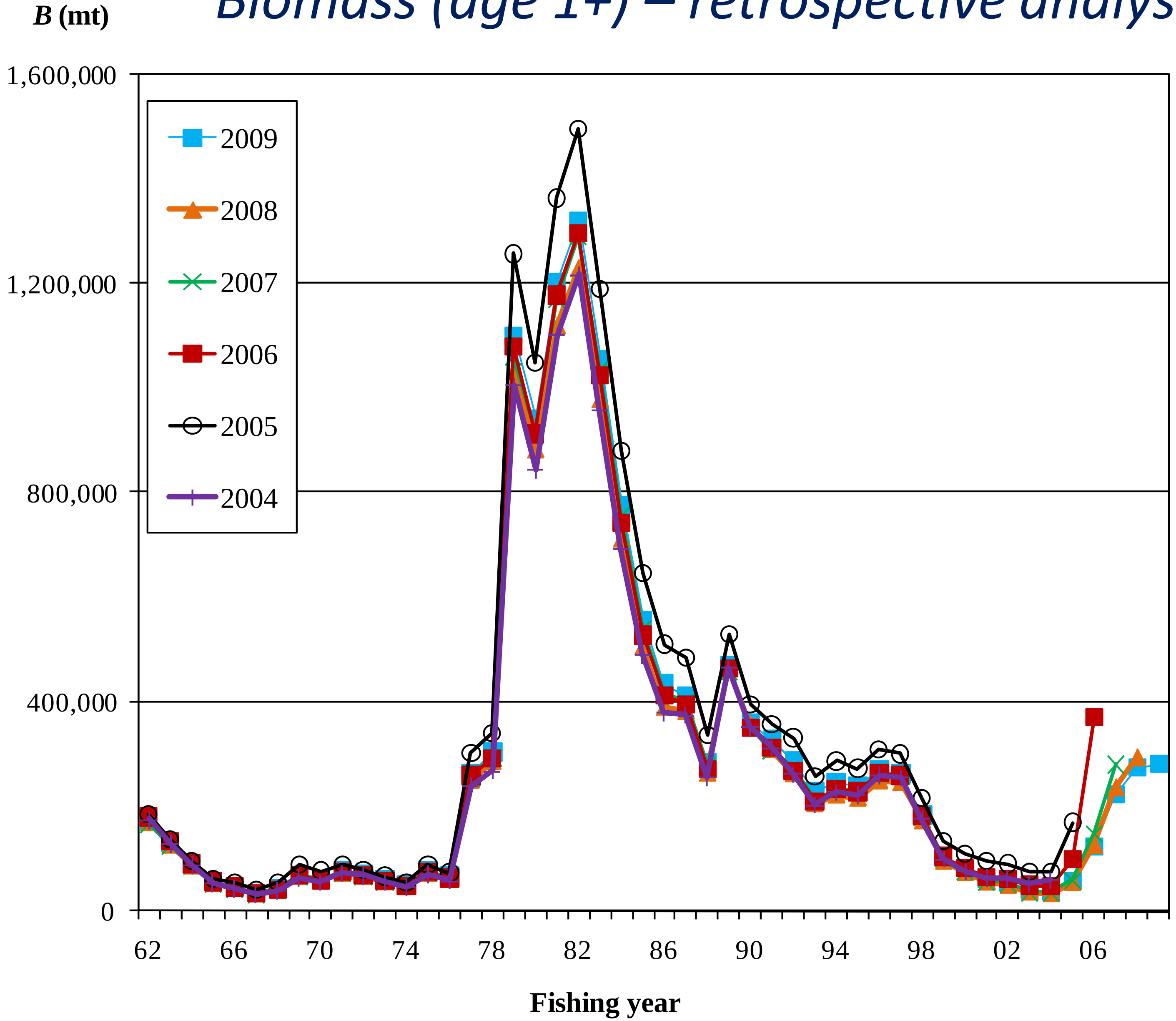
Sensitivity analysis – SS models AA and AB

	Model scenarios	
	AA	***AB***
Landings - USA/Mexico commerical (1962-08) - Fishery 1		
Landings - USA recreational (1962-08) - Fishery 2		
Age distributions (1962-08) - USA/Mexico commercial		
Length distributions (1992-08) - USA recreational		
Mean length-at-age distributions (1962-08) - USA/Mexico commercial		
CPFV survey (1962-08) - Survey 1		
CPFV survey (1962-99) and (2000-08) - Surveys 2 and 3, respectively		
CalCOFI survey (1978-08) - daily larv. prod. ('super years') - Survey 4		
Parameterization	***AA***	***AB***
Selectivity		
Fisheries		
Parameterization	Estimated	Estimated
Time block	Fishery 1=3 blocks Fishery 2=single	Fishery 1=4 blocks Fishery 2=2 blocks
Shape	Dome-shaped	Dome-shaped
Surveys		
Parameterization	Fixed (mirrors Fishery 2)	Fixed (mirrors Fishery 2)
Time block	Single	2 blocks
Shape	Dome-shaped	Dome-shaped
Catchability		
q - Surveys	Est. (median unbiased)	Est. (median unbiased)
Variance adjustment factors		
Biological distributions - Fishery 2 (ESS for length distributions)	Doubled weight	Doubled weight

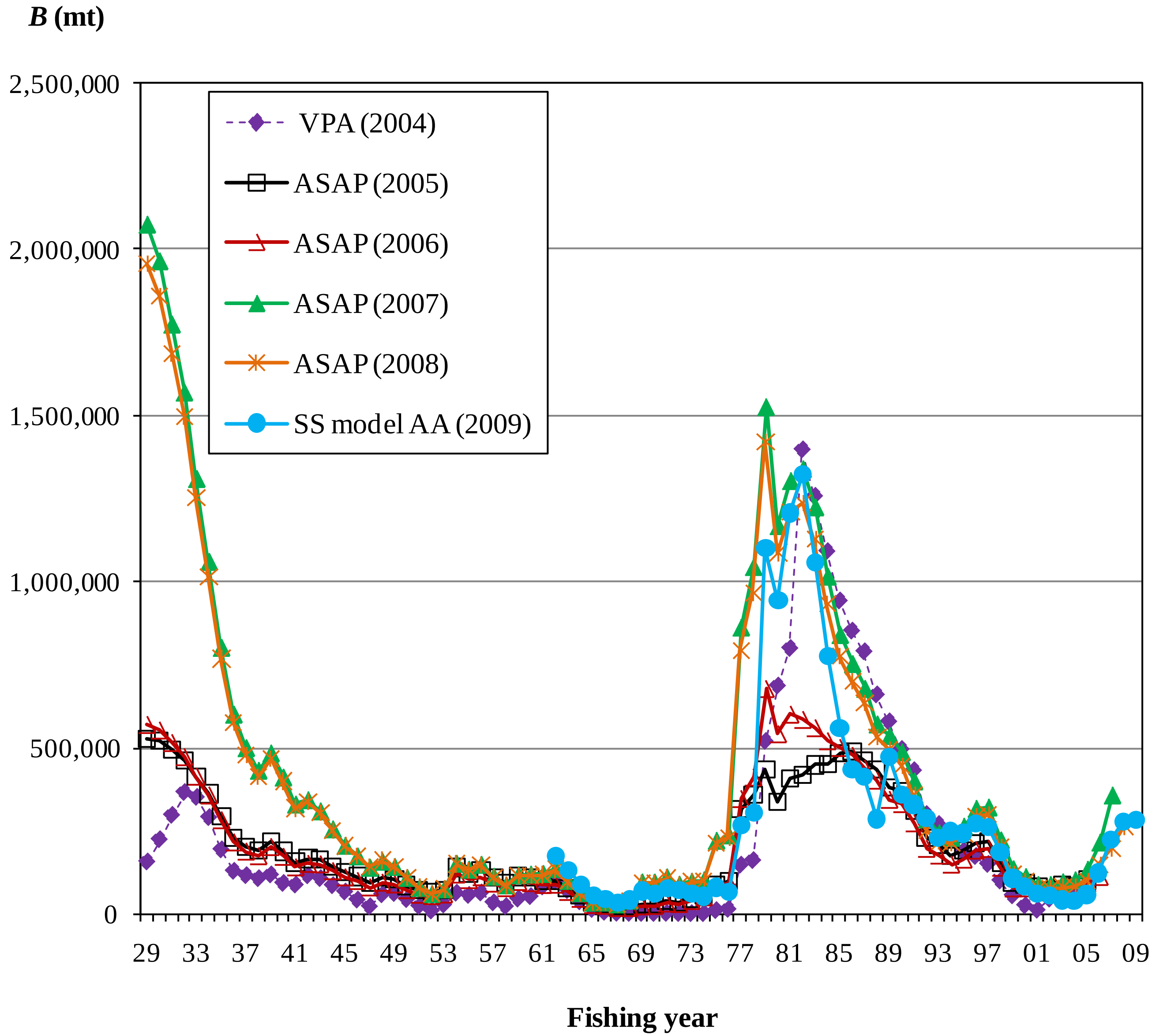
Sensitivity analysis – SS models AA and AB

Likelihood component	*AA*	*AB*
Biological distributions		
Age distributions		
USA/Mexico commercial - Fishery 1	700.4	673.9
Length distributions		
USA recreational - Fishery 2	201.4	183.8
Length-at-age distributions		
USA/Mexico commercial - Fishery 1	540.4	535.9
Surveys		
CPFV - Survey 1	-18.3	Na
CPFV - Survey 2	Na	-10.0
CPFV - Survey 3	Na	-6.0
CalCOFI - Survey 4	Na	Na
Sub-total	-18.3	-16.0
Recruitment		
Model time period (1958-08)	34.7	33.7
Forecast (2009)	0.016	0.006
Global		
Likelihood (L)	1,458.6	1,411.3
Number of estimated parameters	84	97
Key estimated parameters and derived quantities		
Biology		
Length-at-age (k)	0.22	0.28
$\ln(R_0)$	13.5	13.6
Offset for initial equilibrium R_1	0.2473	0.2916
Steepness (h)	0.47	0.40
Initial conditions for population dynamics		
Fishing mortality (F) - Fishery 1	0.65	0.51
Population time series		
SSB - 1962	47,534	61,882
SSB - 2008	76,441	17,264
B (1+) - 1962	171,865	196,629
B (1+) - 2009	282,049	55,003
HG - 2009	55,408	7,729

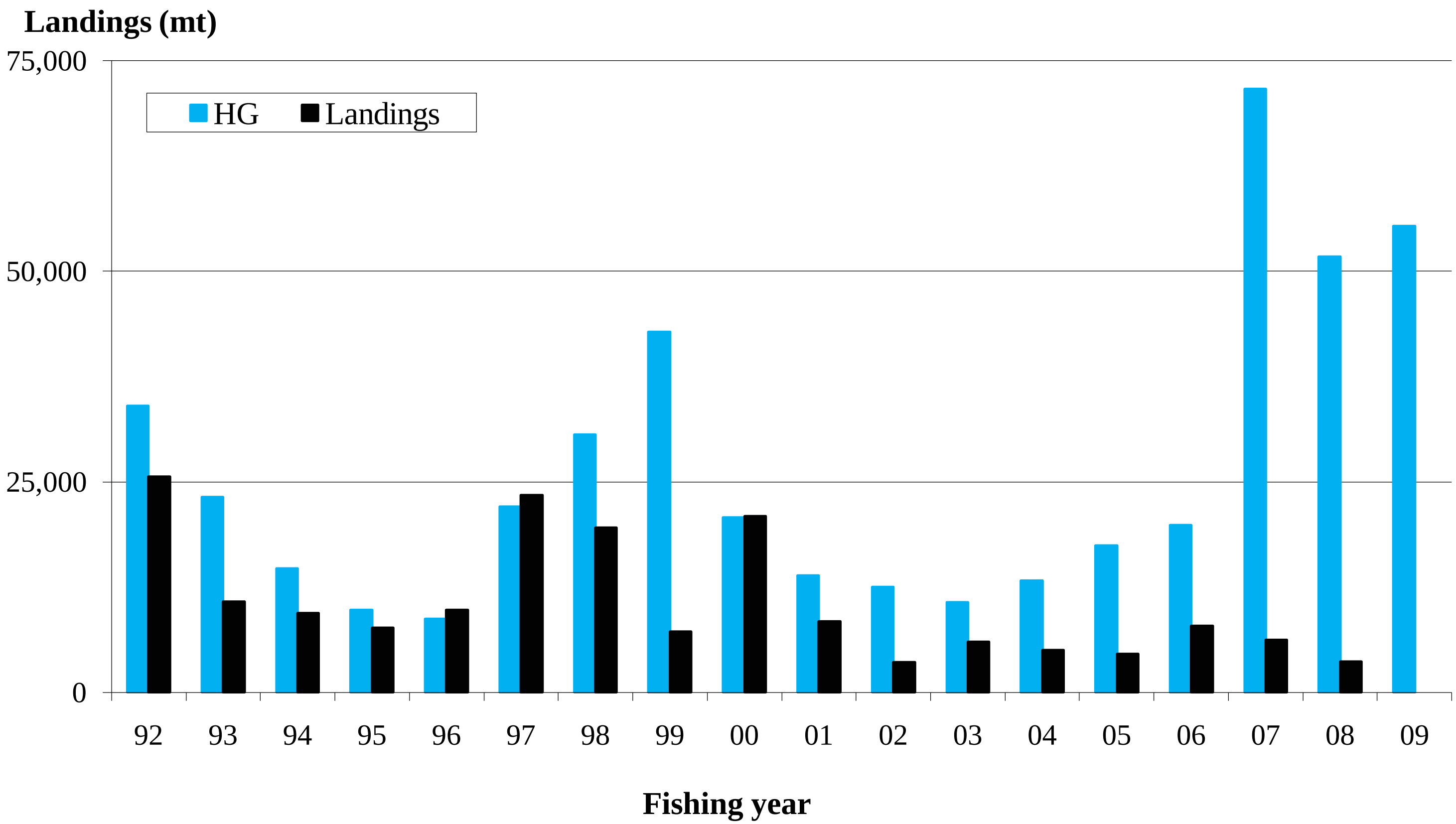
Biomass (age 1+) – retrospective analysis



Biomass (age 1+) – historical assessments



Harvest Guideline



B (Age 1+, mt)	Cutoff (mt)	Fraction	Distribution	HG (mt)
282,049	18,200	30%	70%	**55,408**

Pacific Mackerel Stock Assessment (2009)

- ***Conclusions***
  - Ongoing management-based model (ASAP 2009) was completed … pre-STAR
  - Alternative SS model (*S1_aa*) was completed and represented a robust model scenario that mirrored ASAP-related models … pre-STAR
  - A suite of SS model scenarios was completed through sensitivity analysis, which allowed final model determination for management purposes … pre- and during STAR
  - **SS model *AA*** represented the final model for management advice in 2009-10 and SS model *AB* represented an alternative model … during STAR

- ***Stock status ↔ Assessment protocol ↔ Review process***
  - Stock status … species formal classification
    - 'Managed' vs. 'monitored' … merits/drawbacks
  - Assessment protocol … for next fishing season (i.e., 2010-11)
    - 'Full' vs. 'update' … merits/drawbacks
  - Review process … for providing management advice
    - 'One phase' (i.e., "inquisition-like and inefficient …") vs. 'two-phase' ("humane-like and efficient …") … merits/drawbacks

Pacific Mackerel Stock Assessment (2009)

- ***Research and data needs … see p. 29***
  - Improved collaboration with fishery researchers from Mexico and Canada
  - Indices of relative abundance
    - Fishery-independent (‘survey’) index is lacking
    - Better coordination/sampling effort associated with ongoing monitoring program for CPFV fleet
  - Increased support of current port sampling/laboratory analysis programs underway for CPS (CDFG/NOAA Fisheries joint projects)
    - Begin efforts to bolster biology-related projects
      - Maturity
      - Ageing error
      - Sex ratio/natural mortality
  - Re-examination of (FMP) harvest control rule currently in place
  - Begin formal research on related CPS to address ‘ecosystem’ component

Pacific Mackerel Stock Assessment (2009)

- ***Acknowledgements … see p. 30***
  - Data collection / laboratory analysis
    - *ODFW* and *WDFW* port sampling teams and in particular, *CDFG* staff (both in the field and laboratory) …
  - Management process
    - Industry representatives (soCal and PNW), CPSMT folks, and Council staff (in particular, Mike …)
  - Time series development / modeling
    - Kevin, Alex, HuiHua, Rick, Ian^2, and in particular, Mark ...
  - Review process (STAR contingent)
    - Alec, Owen, Ken, Gary, and in particular, Andre …

COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON PACIFIC MACKEREL MANAGEMENT FOR 2009-2010

The Coastal Pelagic Species Advisory Subpanel (CPSAS) heard a report from Dr. Paul Crone of the Pacific Mackerel Stock Assessment Team and Dr. Owen Hamel, Pacific Mackerel Stock Assessment Review (STAR) Panel representative, regarding the Pacific mackerel stock assessment and proposed harvest guideline (HG) for the 2009-2010 season. The CPSAS thanks and commends Dr. Crone, Dr. Hamel and the Pacific Mackerel Assessment Team for their dedication and hard work in developing the recommendation.

The CPSAS, sadly, supports the assessment team and the Coastal Pelagic Species Management Team (CPSMT) finding that this assessment is based on the best available science. The CPSAS concurs with the CPSMT and STAR Panel that the final base model (SS – AA) model finding of 282,000 mt age 1+ biomass should be used in the harvest control rule formula in the calculation of the allowable biological catch (ABC) for the 2009-2010 season.

Based on the current assessment and harvest control rule for Pacific mackerel, the ABC for the 2009-2010 season is estimated to be 55,408 metric tons (mt). The CPSAS acknowledges the SSC and CPSMT recommendation to set an HG below the ABC in light of uncertainty reflected in the alternative model (SS-AB). The CPSAS recommends setting a HG of 35,000 mt, 30,000 mt of which is for use in the directed fishery, with 5,000 mt set aside for incidental catches in other fisheries or the possibility of reopening the directed fishery. This leaves a substantial buffer between the HG and the ABC as a precautionary measure.

The CPSAS strongly recommends that better data and better monitoring of the commercial passenger fishing vessel (CPFV) fleet are essential to better inform this index of abundance, particularly now that the CPFV index is the sole index remaining in the SS model. This research is sorely needed to produce more accurate Pacific mackerel stock assessments in the future. In addition, the CPSAS recommends exploring alternative indices that might inform the assessment. One potential source of data in the future could be to include mackerel in the aerial survey that is now scheduled to be conducted by industry in the sardine fishery.

The CPSAS further recommends that the Council provide guidance to the National Marine Fisheries Service that, in the event the directed fishery reaches 30,000 mt and closes, allow a 45 percent incidental catch allowance when Pacific mackerel are landed with other coastal pelagic species (CPS), except that up to 1 mt of Pacific mackerel could be landed without landing any other CPS.

PFMC
06/16/09

COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON PACIFIC MACKEREL HARVEST GUIDELINE FOR 2009-2010

The Coastal Pelagic Species Management Team (CPSMT) met June 15, 2009, to review the latest stock assessment of Pacific mackerel. In 2009, a full assessment for Pacific mackerel was conducted and reviewed by a Stock Assessment Review (STAR) Panel in La Jolla, California May 4-8, 2009. The CPSMT heard presentations by Dr. Paul Crone of the Stock Assessment Team (STAT) and the Scientific and Statistical Committee (SSC) representative Dr. Owen Hamel. The CPSMT supports conclusions from the Pacific mackerel stock assessment and STAR Panel. For the 2009-2010 management season, the CPSMT further recommends the Pacific Fishery Management Council (Council) adopt the resulting acceptable biological catch (ABC) associated with the harvest control rule stipulated in the Coastal Pelagic Species Fishery Management Plan. Based on a total stock biomass estimate of 282,049 mt, the ABC for U.S. fisheries is 55,408 mt.

The CPSMT agrees with the STAR Panel and SSC conclusions that the merits of an alternative model provides a better understanding of the uncertainty associated with this stock assessment. In this context, as was done for the previous two assessments, the CPSMT recommends setting a harvest guideline (HG) lower than the ABC. The CPSMT recommends setting the HG at 30,000 mt as a conservative strategy to address the uncertainty, while also providing stability within the fishery. It is important to note that recent U.S. annual landings have been well below the established HGs for the directed fishery.

The CPSMT agrees to the research and data needs identified by the STAT, STAR, and SSC. To accomplish identified research efforts a review of the assessment cycle will be necessary, i.e., less frequent assessments will enable scientists to address research priorities. To improve future assessments for Pacific mackerel the CPSMT recommends:

- better research collaboration with Mexico and Canada,
- enhance monitoring of the Commercial Passenger Fishing Vessel fleet and related recreational fisheries,
- re-evaluation of California Cooperative Oceanic Fisheries Investigations (CalCOFI) survey and other fishery-independent and dependent data,
- increase support for current port sampling and laboratory analysis programs, and
- begin formal research on related coastal pelagic species to address an ecosystem-based management approach.

PFMC
06/16/09

Agenda Item H.1.c
Supplemental SSC Report
June 2009

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON PACIFIC MACKEREL MANAGEMENT FOR 2009-2010

The Scientific and Statistical Committee (SSC) received a presentation on the 2009 Pacific mackerel stock assessment by Dr. Paul Crone. Dr. Owen Hamel was present to answer questions about the review of this assessment by the Stock Assessment and Review (STAR) Panel, held in La Jolla, California, during May 4-8, 2009.

The last full assessment of Pacific mackerel occurred in 2007. The 2008 assessment was an update assessment. There are two primary changes in the 2009 assessment compared to the assessments conducted recently. First, the assessments of Pacific mackerel for the past years were conducted using the ASAP model. The 2009 assessment reflects a continued effort by the Stock Assessment Team (STAT) to change the modeling platform from ASAP to the more flexible Stock Synthesis (SS). Second, unlike the assessments for the past years which were based on three indices of abundance (California Cooperative Oceanic Fisheries Investigations [CalCOFI], commercial passenger fishing vessel [CPFV], and spotter), the 2009 assessment excluded the CalCOFI and spotter indices, and used only the CPFV index due to concerns associated with potential sampling biases for Pacific mackerel.

In addition to the SS baseline model (model AA), an alternative SS model (model AB) was developed by the STAT for the purpose of comparison and sensitivity analysis.

The harvest guideline (HG) for the 2009-10 fishing year was 55,408 mt based on the baseline model and 7,729 mt based on the alternative model AB. The results of alternative models AA and AB differ for the recent years because an additional selectivity time block 2000-2008 for both the commercial and recreational fisheries was added to model AB, and the single CPFV index in model AA was split into two indices in model AB, one for 1962-1999 and another for 2000-2008. The differences in the results of models AA and AB reflect a range of uncertainty for the model estimates. The SSC endorses the use of the baseline model (AA) for setting the acceptable biological catch, but recommends that the results of model AB be taken into account when setting the HG.

Despite unresolved problems, such as a lack of biological sampling data from Mexico, and a lack of fishery-independent index of relative abundance, the current assessment represents best available science, and can serve as the basis for Council management decisions.

The SSC agrees to the research and data needs identified by the STAT and STAR Panel to improve future assessments of Pacific mackerel. These include better collaboration with Mexico and Canada in data collection, enhanced monitoring of the CPFV fleet, and increased sampling for biological data.

A new assessment for Pacific mackerel would not be a high priority if catches remain at recent low levels. A substantial increase in catch levels could potentially trigger the need for a new assessment.

PFMC
06/14/09

SURVEY METHODOLOGY REVIEW AND EXEMPTED FISHING PERMIT (EFP)

At its March 2009 meeting, the Council reviewed proposals for aerial survey research on Pacific sardine to be conducted under an exempted fishing permit with the goal of developing a new index of sardine abundance. The Council adopted the proposals for public review and recommended that they ultimately be combined into a single project managed under its own collaborative team guided by a scientifically sound survey design. Sardine industry representatives and scientists have since collaborated on a single proposal (Agenda Item H.2.a, Attachment 1).

The Council conducted a Stock Assessment Review (STAR) Panel May 4-8, 2009 in La Jolla, California to, in part, review survey methodologies proposed for 2009. The May STAR Panel reviewed both the industry proposed aerial survey as well as the Pacific sardine biomass survey conducted annually by the National Marine Fishery Service (NMFS), Southwest Fisheries Science Center (SWFSC) (Agenda Item H.2.a, Attachment 2). The May STAR Panel recommendations are contained in two separate reports; one for the industry proposed aerial survey (Agenda Item H.2.a, Attachment 3) and one for the SWFSC biomass survey (Agenda Item H.2.a, Attachment 4). Survey methodologies and the STAR Panel reports will be reviewed at the June meeting by the Scientific and Statistical Committee (SSC), the Coastal Pelagic Species Management Team (CPSMT), and the Coastal Pelagic Species Advisory Subpanel (CPSAS) (see Ancillary Meetings for details).

The Council heard testimony in March that the survey proposals will likely require an increase in the 2009 research set-aside from 1,200 mt to 2,400 mt in order to conduct the survey work from Cape Flattery, Washington to Monterey Bay, California. The May STAR Panel concluded that a set-aside of 2,400 mt provides a “good outlook” for survey success and that if the set-aside remains at 1,200 mt, the geographic scope of the survey should be reduced to maintain adequate sample sizes. At the Council’s request, NMFS has initiated the necessary rulemaking to increase the research set-aside to 2,400 mt by reducing the directed sardine fishery in the second and third fishing periods (Agenda Item H.2.a, Attachment 5). The comment period for the proposed rulemaking runs through June 5, 2009. The Council continues to support limiting use of the research set-aside to the second allocation period (July 1 through September 14, 2009) with any unused portion of the research set-aside to be transferred to the third period of the directed fishery.

At the June meeting the Council is tasked with adopting final recommendations to NMFS regarding the issuance of an exempted fishing permit for conducting the industry proposed aerial survey in the second period of the 2009 Pacific sardine fishery. The Council may also provide guidance on the implementation of Pacific sardine surveys in 2009, including their potential application to the next full assessment of Pacific Sardine in the fall of 2009. This full assessment and its supporting data and indices will be the subject of a September 21-28, 2009 STAR Panel and subsequent review by the Council and its Advisory Bodies at the November 2009 Council meeting in Costa Mesa, California.

Council Action:

1. **Adopt final Exempted Fishing Permit recommendations;**
2. **Provide guidance on the implementation of Pacific sardine surveys in 2009, including their potential application to the next full assessment of Pacific Sardine in the fall of 2009.**

Reference Materials:

1. Agenda Item H.2.a, Attachment 1: West Coast Sardine Survey Application for Exempted Fishing Permit in 2009.
2. Agenda Item H.2.a, Attachment 2: Spawning Biomass of Pacific Sardine (*Sardinops sagax*) Off U.S. in 2008, NOAA Technical Memorandum NMFS.
3. Agenda Item H.2.a, Attachment 3: STAR Panel Report, Aerial Survey Methods for Pacific Sardine, May 2009.
4. Agenda Item H.2.a, Attachment 4: STAR Panel Report, Daily Egg Production Methods for Pacific Sardine, May 2009.
5. Agenda Item H.2.a, Attachment 5: NMFS Proposed Rule, Coastal Pelagic Species Fisheries, Annual Specifications Modification, (74*FR*20897).
6. Agenda Item H.2.b, Supplemental SSC Report.
7. Agenda Item H.2.b, Supplemental CPSMT Report.
8. Agenda Item H.2.b, Supplemental CPSAS Report.
9. Agenda Item H.2.c, Public Comment.

Agenda Order:

a. Agenda Item Overview — Mike Burner
b. Reports and Comments of Management Entities and Advisory Bodies
c. Public Comment
d. **Council Action**: Adopt Final EFP Recommendations

PFMC
05/26/09

West Coast Sardine Survey

Application for Exempted Fishing Permit in 2009

submitted

April 27, 2009

by

Resource Analysts International

and

Tom Jagielo Consulting

for

California Wetfish Producers Association

c/o Diane Pleschner-Steele, Executive Director

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Bellingham, Washington 98225

This Exempted Fishing Permit (EFP) application is submitted to NMFS to obtain access to the 2,400 mt proposed to be withheld from the sardine OY for research surveys in 2009. The application contains a program description and methodology to be applied coastwise between the US-Canada border and Monterey Bay area. The research proposed is an expansion of a pilot project conducted in 2008 and contains refinements learned from that research. This documentation was prepared by the principal investigators of the 2008 pilot study on behalf of both the Northwest Sardine Survey, LLC (NWSS-LLC), which funded last year's pilot project, and the California Wetfish Producers Association (CWPA) who wish to collaborate with NWSS-LLC and expand the project into Northern and Central California in 2009.

The pilot study conducted in 2008 was a "proof of concept" project to determine if high quality, quantitative digital aerial imagery could be collected and processed on a scale large enough and rapidly enough for a practical fisheries stock assessment application – namely the in-season enumeration and measurement of sardine schools (Wespestad et al. 2008). The project was successful in this endeavor. In approximately one month's time (from late August through late September 2008), over 2000 images were processed by one scientific technician, who discerned and individually measured the surface area of over 3000 sardine schools. Furthermore, every school selected and measured on the digital images was documented and archived to allow for subsequent examination and review by other observers.

Aerial counts of school number and measurements of school surface area (SSA) as collected in 2008 are recognized as useful metrics to begin to develop an index of abundance extending over a period of years for the sardine stock. However, a direct point estimate of biomass is also desired to more quickly characterize the stock status. Our initial work has shown that "point sets" (sardine schools fully captured by purse seine vessels), coupled with quantitative digital imagery, are a promising method to establish the relationship between SSA and biomass for this purpose. Sampling limitations in 2008, however, resulted in too few samples to quantify this relationship with good accuracy or precision. A research set-aside of sardine quota was not available in 2008 and it was necessary to conduct research sampling opportunistically during the fishery. As a result, short and intense fishing periods and poor weather conditions limited our ability to fully test the methodology in our pilot project year. Hopefully with the full research set aside available in 2009, we will develop a much larger data set than in 2008.

The objective of this EFP request is to provide an opportunity to expand the spatial scale of the aerial survey, and to collect more data to evaluate our ability to quantify the relationship between SSA and biomass under controlled conditions and in a directed manner -- separate from the open period of the fishery. The survey design to be employed in 2009 largely follows the plan developed and executed successfully in 2008. The primary differences in 2009 will be: 1) to extend the coverage of the aerial survey northward to the Canadian border, and southward to the Monterey Bay area in California, and 2) to make use of the portion of the sardine quota explicitly set-aside for research (2400 mt), to obtain better estimates of the relationship between sardine SSA and biomass than could otherwise be obtained during the directed fishery.

Sardine harvested under this EFP will be used to help fund the survey research. The sardine research set-aside will be apportioned equally to two survey areas of equal size. The CWPA will conduct aerial survey work and purse seine vessel point sets at-sea from the Oregon-California border to the Monterey Bay area (southern area). Likewise, the NWSS-LLC will conduct aerial survey work and point sets from the Canadian border to the Oregon-California border (northern area).

Both industry groups will work under the direction of the Principal Investigators (PIs), Vidar Wespestad and Tom Jagielo, who will be responsible for scientific accountability. Under the direction of the PIs, Doyle Hanan will oversee the southern area research component; Ryan Howe will oversee the northern area research component and will additionally coordinate coastwide consistency in data collection and data reduction.

Materials and Methods

I. Survey Design

Our survey will take a two-stage sampling approach. Stage 1 will be aerial transect sampling to estimate sardine school surface area (SSA) (in units of m^2); Stage 2 will be at-sea point set sampling to estimate biomass per m^2 of SSA (mt/m^2). Sampling will be closely coordinated by the PIs and synchronized on a coastwise basis. Under the direction of the PIs, NWSS-LLC will be responsible for conducting Stage 1 and Stage 2 sampling in the northern area; CWPA will be responsible for conducting Stage 1 and Stage 2 sampling in the southern area.

Stage 1: Aerial Survey

Logistics
As in 2008, our aerial survey will employ the belt transect method using a systematic random sampling design, with each transect a single sampling unit (Elzinga et al 2001). From a random starting point, parallel transects will be conducted in an east-west orientation, generally parallel to the gradient of sardine schools distributed along the coast. To fully encompass the expected westward (offshore) extent of the sardine school distribution, transects will originate three miles from the shoreline and will extended

westward for 35 miles (possibly further offshore in the southern area, if needed). Transects will be spaced 10 miles apart. In 2008, 10 parallel transects were sampled off the coast of Washington-Oregon near the Columbia River with three replicate surveys. The intention for 2009 is to expand the spatial coverage of the survey northward (to the Canadian border), and southward (to the Monterey Bay area) (Figure 1). Twenty six transects will be conducted in the northern area and twenty six transects will be conducted in the southern (Table 1).

The PIs will strive to schedule survey transect flights such that the northern and southern areas will be sampled in synchrony (as one coastwise survey). The goal will be to conduct sampling on days when coastwide weather conditions permit clear visibility of the ocean surface from an altitude of 8000 ft (2438 m). The coastwide total of 52 transects to be sampled for each replicate of the survey will be completed as a unit in as short a time frame as is practicable (generally within one week or less). Three replicates of the 52 transect coastwide survey will be sampled as close together in time as is practicable.

Data Collection and Reduction

The photogrammetric-aerial digital camera mounting system and data acquisition system used in 2008 will be used to acquire digital images and to log transect data (Aerial Imaging Solutions; Appendix I). The system records altitude, position, and spotter observations, which are directly linked to the time stamped quantitative digital imagery. At the nominal survey altitude of 8000 feet, the approximate width-swept by the camera with a 24 mm lens is 12,000 ft (3,657 m). Digital images will be collected with 60% overlap to ensure seamless photogrammetric coverage of the transects.

In 2008, quantitative aerial photogrammetry was validated by collecting digital imagery of an object of known size (an airplane hangar) at a series of altitudes ranging from 500 ft. to 8000 ft. Additional validation will be conducted in 2009 to determine if a calibration constant should be used to improve accuracy based on this ground-truth information.

Digital images will be analyzed to determine the number, size, and shape of sardine schools on each transect. Adobe *Photoshop Lightroom 2.0* software will be used to bring the sardine schools into clear resolution and measurements of sardine school size (m^2) and shape (circularity) will be made using Adobe *Photoshop CS3-Extended*. Transect width will be determined from the digital images using the basic photogrammetric relationship:

$$\frac{I}{F} = \frac{GCS}{A}$$

and solving for *GCS*:

$$GCS = \frac{I}{F}A$$

where I = Image width of the camera sensor (e.g. 36 mm), F = the focal length of the camera lens (e.g. 24mm), A = altitude, and GCS = "ground cover to the side" or width of the field of view of the digital image. Transect width is then obtained by taking the average of GCS for all images collected on the transect. Transect length is obtained from the distance between start and stop endpoints using the GPS data logged by the data acquisition system. Transect area is then the product of mean transect GCS and transect length.

Data Analysis

As described below, we will use the data collected from the aerial survey to estimate: 1) school density, 2) the total number of schools, and 3) school cover (SSA).

School density (number of schools per m^2 of ocean surface). Belt or strip transects represent a special case of quadrat sampling; with the additional consideration that all transects may not be of equal length or area. In our survey, unequal transect areas can result from either 1) variation of transect width (e.g. from a lower visibility causing reduced flight altitude) or 2) variation in transect length (e.g. due to premature transect termination due to fog or other weather conditions). To account for this contingency, we will employ an unequal-area transect density estimator computed by dividing the mean number of sardine schools per transect by the mean transect area (Stehman and Salzer 2000). In this formulation

$$\widehat{D} = \frac{\bar{y}}{\bar{a}}$$

Where $\widehat{D}$ = the sample-based estimator of density, $\bar{y}$ = sample mean number of schools per transect, and $\bar{a}$ = sample mean transect area. The estimated variance of $\widehat{D}$ is derived from standard ratio estimation theory (Thompson 1992) as

$$\hat{V}(\widehat{D}) = \frac{1}{\bar{a}^2}\left(\frac{N-n}{N}\right)\frac{s_e^2}{n}$$

where N = the total number of transects in the region, n = the number of transects sampled in the region, and

$$s_e^2 = \sum_s \left(y - \widehat{D}\, a_u\right)^2 / (n-1)$$

where y_u = the number of schools in transect u, and a_u = the area of transect u. Stehman and Salzer (2000) note that, while $\hat{V}(\widehat{D})$ is an approximation generally valid for a sample size of 30 (Cochran 1977), simulations suggest it may also be valid for smaller sample sizes if the distribution of transect areas is nearly symmetric, or if the correlation between *a* and *y* is close to 1.

Total number of schools. Given the estimate of density $(\widehat{D})$ and the total study area (A), an estimate of the total number of schools $(\hat{T})$ is

$$(\hat{T}) = (\widehat{D})A$$

and its standard error $\widehat{SE}(\hat{Z})$

$$\widehat{SE}(\hat{T}) = \widehat{SE}(\widehat{D})A \quad .$$

School surface area (SSA): Cover. Our measurements of the surface area of individual sardine schools from the digital imagery affords us the opportunity to estimate total sardine school cover (SSA). Cover is defined as the vertical projection of an object from the ground as viewed from above (Elzinga et al 2001). Let c_u denote the value for sardine school cover (m^2) on transect u. Cover for the entire study area $(\hat{C})$ can then be estimated using the unbiased estimator for a population total, $\hat{C} = N\bar{c}$ with estimated variance

$$\hat{V}(\hat{C}) = \frac{N^2\left(1 - \frac{n}{N}\right)s_e^2}{n}$$

where s_e^2 is the sample variance of c.

Stage 2: At-Sea Point Set Sampling

<u>*Logistics*</u>

Fishing taking place under this EFP will occur following the July, 2009 open fishing period. We expect all fishing will be completed by mid to late August, 2009. The EFP fish will be taken in the course of making the research point sets. It is likely that most of the point sets will be conducted harvested in close proximity to the mouth of Columbia River in the northern area, and in close proximity to Monterey Bay in the southern area.

Purse seine vessels operating under the EFP will capture fish from aerially photographed and measured sardine schools. Purse seine point sets conducted under Stage 2 sampling will be the means used to determine the relationship between SSA (as documented with quantitative aerial photographs) and the biomass of fish schools (as measured from the landed weight of fully captured schools). For fully captured schools, the total weight of the school will be recorded and numbers per unit weight will also be determined, based on biological sampling of the point set hauls. Additionally, school height information will be recorded from vessel sonar or down sounders.

Point set samples will be stratified into two groups based on school size. The sampling strata will be: 1) schools less than or equal to 25 mt in landed weight ("small") , and 2) schools greater than 25 mt in landed weight ("large"). For each size stratum, 32 schools will be sampled, for a total of 64 schools coastwide. Sampling will be distributed between the northern and southern areas such that 32 schools will be sampled in the south (16 small; 16 large), and 32 schools will be sampled in the north (16 small; 16 large).

Biological Sampling

Biological samples of individual point sets will be collected at fish processing plants upon landing. Fishermen participating in the EFP research study will keep research hauls in separate holds upon capture so the tonnage of each aerially photographed and measured point set haul may be determined separately upon landing. Samples will be collected from the unsorted catch while being pumped from the vessels. Fish will be systematically taken at the start, middle, and end of a delivery as it is pumped. The three samples will then be combined and a random subsample of fish will be taken.

Length, weight, and maturity from the point set hauls are of primary interest. Sardine weights will be taken using an electronic scale accurate to 0.5 gm. Sardine lengths will be taken using a millimeter length strip provided attached to a measuring board. Standard length will be determined by measuring from sardine snout to the last vertebrae. Sardine maturity will be established by referencing maturity codes (female- 4 point scale, male- 3 point scale) supplied by Beverly Macewicz NMFS, SWFSC (Table 2).

Sample Size (Number of Point Sets)

The sample size of n = 32 schools per size stratum was arrived at based on 1) the amount of sardine set-aside for research for 2009 (2400 mt), and 2) the distribution of sardine school sizes and information from point sets observed in the 2008 pilot study, as described below.

The size distribution of 3024 schools photographed and measured in the 2008 pilot study is shown in Figure 2. With our Stage 2 sampling technique (purse seine capture) we are logistically capable of sampling schools of up to approximately 95 mt per haul. From the 2008 pilot study, we also found that n = 8 point sets (schools photographed, measured, and captured) averaged 0.027 mt/m^2. Using this information, we defined our Stage 2 sampling frame as schools less than or equal to approximately 3500 m^2. This cut off accounted for approximately 90.25% of schools by number, and 61.65% of schools by estimated weight in the pilot study (Table 3). From the cumulative frequency curve of schools in the sampling frame (<= 3,500 m^2), it was determined that 25 mt was a good break point for the small school/large school stratification: approximately 50% of the schools were less than this size, and 50% were greater than this size (Table 4). Thus, in order to obtain equal sample sizes for the two strata, and to stay within the 2,400 mt sardine research set-aside, a sample size of n = 32 point sets for each strata was selected.

Statistical Power Analysis

We conducted a power analysis to evaluate the utility of the n = 32 sample size to estimate the relationship between sardine school biomass and surface area for both small and large sardine schools. We employed the two-sample t-test of means. The t-test requires that 1) the two sample means are estimated from random samples drawn from normally distributed populations, and 2) the variance of the two populations are equal.

Power analysis is a theoretical "what if" exercise, which asks the question: "If the effect being measured is *this* big, would the test be likely to detect it with *this* sample size?" Effect size can be thought of as the degree to which a phenomenon exists (Cohen, 1988). While the choice of effect size values used for a power analysis are arbitrary, they should be set at some meaningful threshold level, such that if the true effect is less than a given threshold, it would not be important to detect. Usually, the effect size is the quantity being tested, thus it is unknown.

We begin with the sample size (n = 32) as given, based on the amount of sardine available for the EFP research study (described above). Also, in the 2008 Pilot Study, a sample of n = 8 point sets suggested that the ratio of biomass to cover may vary by school size (Figure 3). Given our desire to be able to estimate the relationship between biomass and cover for a wide range of school sizes, a reasonable effect size threshold is the effect size necessary to discern the relationship between biomass and cover if a difference in this parameter exists between small vs. large sardine schools. Thus we construct our hypothesis test as follows:

H_0: $m_s = m_l$; no difference in the mean biomass per unit cover between small and large sardine schools.

H_A: $m_s \neq m_l$; a difference in the mean of biomass per unit cover between small and large sardine schools.

Statistical power (i.e. the probability of correctly rejecting a false null hypothesis) is inversely related to the significance criterion (α) and is positively correlated with sample size and effect size (Peterman, 1990). The significance criterion is the rate of rejecting a true null hypothesis (the probability of Type I error) and was fixed at 0.05 for our analysis. Given a significance level and sample size, power is a function of the effect size we require to be detectable.

In our power analysis we used the approximation

$$Z_{1-b} = \frac{d(n-1)\sqrt{2n}}{2(n-1)+1.21(Z_{1-a}-1.06)} - Z_{1-a} \qquad [1]$$

(Dixon and Massey, 1957; Cohen, 1988)

where

$Z_{1\text{-}b}$ = the percentile of the unit normal which gives power,

$Z_{1\text{-}a}$ = the percentile of the unit normal for the significance criterion; for a two-tailed test, $\alpha = \alpha_{(2)}/2$,

d = the standardized effect size index for the two-tailed t-test; calculated as

$$d = \frac{|m_s - m_l|}{s_p} \qquad [2]$$

where m_s and m_l are the true densities for small and large schools, respectively, and s_p^2 is the true pooled variance. By design, our study will draw independent samples of equal size (n = 32) from each of the two school size strata, and

$$s_p^2 = (s_s^2 + s_l^2)/2 \; .$$

The power approximation procedure is convenient to use, in lieu of an exact method, as it is only dependent on the effect size index (*d*) and sample size. Note that *d* is unitless, and is cast in terms of the variability under consideration; it is effectively equal to the number of standard deviations of the distribution of interest.

Using the power approximation equation [1], we can iteratively solve for the detectable effect size given the desired sample size, power, and alpha values for the two sample test of means. For example, when n = 32, power = 0.8, and alpha = 0.05, we obtain a detectable effect size of d = 0.71 (Table 5). Thus, we could expect to detect a difference in means on the order of 71% of the standard deviation. Figure 4 shows the power curve for values of *d* from 0.1 to 1.2 .

From our 2008 pilot study, we have a first look at the variability we might expect to see in the SSA to biomass relationship. With n = 8 point sets, the pilot study sample standard deviation was 0.022389, the mean was 0.026954 mt/m^2 and the values ranged from 0.009 to 0.077 mt/m^2 (Table 6). Using the standardized effect size equation [2]; substituting 0.71 for *d*, and the pilot study standard deviation 0.022389 for s_p we obtain

$$0.71 = \frac{|m_s - m_l|}{0.022389}$$

Solving for $|m_s - m_l|$, we get 0.16 . Thus, we could expect to be able to detect a difference between small and large sardine schools on the order of 0.16 mt/m^2.

Data Analysis

Using samples collected from the two school size strata (small and large) we employ the stratified random sampling estimator of the population mean to estimate mean biomass per unit cover

$$\bar{y}_{st} = \frac{1}{N}(N_s\bar{y}_s + N_l\bar{y}_l)$$

with estimated variance

$$\hat{V}(\bar{y}_{st}) = \frac{1}{N^2}\left(N_s^2\left(\frac{N_s - n_s}{N_s}\right)\left(\frac{s_s^2}{n_s}\right) + N_l^2\left(\frac{N_l - n_l}{N_l}\right)\left(\frac{s_l^2}{n_l}\right)\right)$$

where

$N =$ number of sampling units in the population,

$N_s \; and \; N_l =$ number of sampling units in the small and large school strata, respectively,

$n_s \; and \; n_l =$ sample size taken in the small and large school strata, respectively,

$\bar{y}_s \; and \; \bar{y}_l =$ sample means of biomass per unit cover in the small and large school strata, respectively, and

$s_s^2 \; and \; s_l^2 =$ sample variance of biomass per unit cover in the small and large school strata, respectively.

Estimation of Biomass from Stage 1 and Stage 2 Sampling

An estimate of sardine biomass can be obtained as:

$$\hat{B} = \hat{C}\widehat{\left(\frac{b}{a}\right)}$$

where

$\hat{B} =$ estimate of total biomass of the survey area (mt)

$\hat{C} =$ estimate of sardine cover for the survey area (from Stage 1 sampling)

$\widehat{\left(\frac{b}{a}\right)}$ = estimate of biomass per unit cover ($\bar{y}_{st}$) (from Stage 2 sampling)

Our pilot study in 2008 demonstrated that reasonably good estimates of sardine cover $\widehat{(C)}$ may be obtained using the aerial survey methodology (CV = 0.23); however, we do not yet know if an estimate of biomass per unit cover $\widehat{\left(\frac{b}{a}\right)}$ may be obtained with acceptable precision. With our proposed method, the error of estimating each of these two quantities will propagate through to the estimation of biomass $(\widehat{B})$. Thus, our success in estimating $\hat{B}$ will depend on our results from both Stage 1 and Stage 2 sampling in 2009.

School Classification

In our 2008 pilot study, we began to explore the utility of measuring certain school morphometric (shape and size) parameters to better understand ways of classifying sardine schools for the purpose of improving variance estimation on the survey parameters. For example, it would be very useful if a relationship could be established between school height, school surface area (cover), school shape (e.g. circularity), and school biomass -- for the purpose of classifying schools on a morphological basis. One possible hypothesis is that it may be possible to classify schools into two broad categories: 1) semi-stationary “feeding” schools, and 2) transitory “migrating” schools. If possible, such a classification scheme may serve to reduce the variability in estimation of sardine biomass.

Hydroacoustic Measurement of School Height

In 2009, vessels equipped with echo sounders will be employed to measure the height of schools (distance from the top of the school to the bottom of the school in the water column), and position in the water column relative to the surface. Two vessels in both the northern and southern survey area will be equipped with a Simrad ES 60 recording echo sounders and connected to the ships 50/200 mHz single beam transducers. This configuration allows registration of fish in an 11 degree band under the vessel. The sounders employed are not capable of quantitative acoustic echo integration, so we are not estimating biomass via echo integration; rather, our primary use of the sonar registrations is to record the vertical distribution of schools that will be used with simultaneous aerial estimates of surface area.

The California survey will have one or two vessels with full echo integration capability and will attempt to perform estimation of biomass of schools to compare with the aerial survey- seine set density abundance estimates.

As in 2008, echo sign will again be recorded continually throughout the season; however, in 2009, a directed effort will also be made during the EFP portion of the fishery to collect paired echo sign and aerial survey observations. The recorded echo sign will be analyzed using Simrad Bergen Integrator software to measure school parameters.

If time and funding permit we may try to run short 5-10 mi transects to compare acoustic and aerial detection of sardine in order to try and quantify the relationship between aerial observation and acoustic registrations. This combined work may also provide some information on vessel avoidance.

II. Survey Logistics

Project Contacts: Roles and Responsibilities

Scientific Contacts (see Appendix II for Resumes and Curriculums Vitae):

Name: Vidar Wespestad, PhD
Affiliation: Resource Analysts International
Address: 21231 8th Pl. W., Lynnwood, WA 98036
Email: vidarw@verizon.net
Role: Co-Principal Investigator
Responsibilities: Co-design and direction of EFP sardine survey and related research. Ensure appropriate use of available funds to accomplish projects scientific objectives. Provide scientific guidance and oversight for project execution. Analysis of data and preparation of final report. Represent project in public fora (e.g. PFMC, STAR panels, SSC) to present and interpret scientific results.

Name: Tom Jagielo, MSc
Affiliation: Tom Jagielo, Consulting
Address: P.O. Box 93, Copalis Beach, WA 98535
Email: TomJagielo@msn.com
Role: Co-Principal Investigator
Responsibilities: Co-design and direction of EFP sardine survey and related research. Ensure overall appropriate use of available funds to accomplish projects scientific objectives. Provide scientific guidance and oversight for project execution. Analysis of data and preparation of final report. Represent project in public fora (e.g. PFMC, STAR panels, SSC) to present and interpret scientific results.

Name: Doyle Hanan, PhD
Affiliation: Hanan & Associates, Inc.
Email: drhanan@cox.net
Role: Scientific Field Lead, California (southern area)
Responsibilities: Under direction of Co-PIs: Ensure appropriate use of available funds to accomplish projects scientific objectives specific to the southern area. Coordinate collection of scientific data and project execution specific to the southern area. Assist with data analysis and preparation of final report. Present project results as appropriate and/or required.

Name: Ryan Howe, BSc
Affiliation: Consultant
Email: ryanhowe9@yahoo.com
Role: Scientific Field Lead, (northern area)
Responsibilities: Under direction of Co-PIs: Ensure appropriate use of available funds to accomplish projects scientific objectives specific to the northern area. Coordinate collection of scientific data and project execution specific to the northern area. Additionally, coordinate consistency of data collection coastwide (from both northern and southern areas). Assemble data from both northern and southern areas and perform data reduction for analysis. Assist with data analysis and preparation of final report. Present project results as appropriate and/or required.

Industry Contacts:

Name: Diane Pleschner-Steele
Affiliation: Executive Director, California Wetfish Producers Association
Address: PO Box 1951, Buellton, CA 93427
Email: dplesch@earthlink.net
Phone: (805) 693-5430
Role: Industry EFP Co-Lead: CWPA (southern area)
Responsibilities: Coordinate sale of EFP sardine from southern area with participating processors. Administration of EFP funds collected in southern area; direct funds to project PIs as required to accomplish project scientific objectives in the southern area. Contract with vessels, pilots, and others as needed to execute project in the southern area under direction of project PIs.

Name: Jerry Thon
Affiliation: Principal, Northwest Sardine Survey, LLC
Address: 12 Bellwether Way, Suite 209, Bellingham, WA 98225
Email: jthon2@msn.com
Phone: (360) 201-8449
Role: Industry EFP Co-Lead: NWSS-LLC (northern area)
Responsibilities: Coordinate sale of EFP sardine from northern area with participating processors. Administration of EFP funds collected in northern area; direct funds to project PIs as required to accomplish project scientific objectives in the northern area. Contract with vessels, pilots, and others as needed to execute project in the northern area under direction of project PIs.

EFP Requirements

A point by point discussion of EFP criteria is given in Appendix IV.

At the March 2009 meeting of the PFMC, the Council approved for public review two EFP proposals for an industry-sponsored Pacific sardine research survey in 2009, and furthermore requested that Pacific sardine industry representatives work to provide a detailed single proposal that addresses the recommendations of the SSC and the Coastal Pelagic Species Management Team (CPSMT). The present document is a result of this synthesis. A STAR panel meeting is scheduled for early May, where the survey methodology presented herein will receive a detailed evaluation.

Sardine to be harvested under the EFP are accounted for in the PFMC OY allocation process. Also at the March meeting, the Council recommended National Marine Fisheries Service (NMFS) adjust the research set-aside for this effort from 1200 metric ton (mt) to 2400 mt.

EFP Purse Seine Vessel Selection

Our priorities for selecting vessels to participate under this EFP include: 1) vessels which have installed the necessary electronic equipment or have the capacity to install this equipment, and 2) vessels having the ability to separate the point sets into different hatches.

With the narrow time window for sampling it is desirable to have a field of boats we can draw on. The main reason to have several boats in this period is to maximize the number of point sets we can bring in. These boats will only be used for point sets. Some vessels do not have recording sounders, but do have sonar's that can measure school height and log it. Having a slate of potential vessels to draw from removes the possibility of losing operational days from problems like engine failure. Being able to pick vessels from the following list and reporting the vessels that will be operating at any given time to local enforcement will help to meet the EFP goals.

Vessels: Northern area

The NWSS-LLC will have the option to draw upon the following vessels during the EFP work:

1. Vessel: Pacific Pursuit
   Skipper: Keith Omey
   Owner: Pacific Pursuit, LLC
   OR Reg#: OR873ABY
   OR Sardine Permit#: 30920
   Length: 73’

2. Vessel: Lauren L. Kapp
   Skipper: Ryan Kapp
   Owner: Daryll Kapp
   OR Reg#: OR072ACX
   OR Sardine Permit #: ?
   Length: ?

3. Vessel: Pacific Knight
   Skipper: Mike Hull
   Owner: Dulcich, Inc.
   OR Reg#: OR155ABZ
   OR Sardine Permit#: 57011
   Length: 62’

4. Vessel: Pacific Raider
   Skipper: Nick Jerkovich
   Owner:
   OR Reg#: 972638
   OR Sardine Permit#: 57010
   Length: 58’

The CWPA will have the option to draw upon the following vessels during the EFP work:

1. Vessel: King Philip
   Skipper: Anthony Russo (alt. Paul Morse)
   Owner: Sea Wave Corp. – Sal Tringali
   USCG Doc. No. 1061827
   CPS Limited Entry Permit #9
   Length 79 feet, GRT 156.9

2. Vessel: Barbara H
   Skipper: David Haworth
   Owner: F/V Barbara H Inc.- David Haworth
   USCG Doc. No. 643518
   CPS Limited Entry Permit #4
   Length 64.9 feet, GRT 121.1

3. Vessel: Ocean Angel IV
   Skipper: David Tibbles
   Owner: Ocean Angel LLC
   OR Reg No. 868ADK
   CPS Limited Entry Permit #22
   Length 60.5 feet, GRT 63.5

4. Vessel: Trionfo
   Skipper: Aniello (Neil) Guglielmo
   Owner: Aniello Guglielmo
   USCG Doc. No. 625449

CPS Limited Entry Permit #45
Length 63.8 feet GRT, 79.2

Disposition of fish harvested under the EFP

Fish harvested under this EFP will be sold to help fund the sardine research described above. Participating processors receiving point set EFP product in California from sardine quota set-aside to CWPA and in the Northwest from sardine quota set-aside to NWSS-LLC will be identified prior to any fish deliveries made under this EFP, and they will process the fish by bid. Fish Tickets will be tabulated to verify that the sardine harvested under the EFP do not exceed the amount of harvest allocated for the research set-aside to the recipients, and that the amounts harvested correspond to the total of the amounts harvested while conducting the point set research.

Budget

An itemized budget is provided as Appendix III. At this juncture the amount of funds that will be available to the project from the sale of sardine harvested and sold under the EFP is of necessity a rough estimate; this number will be refined as bids for processing are received and the amount of funds potentially available can be firmed up. On the cost side, we have detailed components of the project that will be required to complete the work proposed. Field work always includes uncertainty (weather, fish availability, etc.) and contingency amounts have been included to attempt to address some of this uncertainty.

The financial structure of the project is as follows:

1. Funds derived from the capture and sale of the sardine research set-aside will be used to pay for the research to be conducted under this proposed EFP. The costs of the project in California will be the responsibility of the CWPA from their 1200mt portion and in the Northwest will be the responsibility of the NWSS-LLC from their 1200mt portion. Costs will be paid for by the sale of the fish captured during the point sets.

2. Fishing vessels will be chartered by NWSS-LLC and CWPA to catch the sardines during point sets and conduct echo soundings of fish schools with ES-60 equipment.

3. Participating processors will not profit on the sale of the EFP sardine quota; rather, they will process the fish at cost. The NW processor(s) for this project will be chosen after submitting bids. The lowest bids will be accepted. CWPA has identified processors who have volunteered to participate in this research according to the provisions of this EFP.

4. Airplanes conducting the photo surveys and assisting in point set captures will work under hourly rates or by contract to CWPA and/or NWSS-LLC.

5. Equipment needs, and operational costs including scientific support will be paid for by the CWPA and the NWSS-LLC from the sale of their individual 1200 mt research quotas. Joint expenses of the PIs to design the research plan, attend STAR panel and Scientific Team Meetings before during and after the survey period will be borne by each side equally. The PIs will invoice the CWPA and the NWSS- LLC for 50% of such joint administration costs. Costs by the PIs to deal specifically with CWPA or the NWSS-LLC will be billed directly to that group only. We anticipate the revenue from the fish sales will be sufficient to cover the costs to capture, process, and conduct the survey.

Conclusion

In summary, the proposed EFP will contribute substantially toward improving the data available to assess the sardine stock for management on the Pacific Coast. Building on the successful pilot survey work conducted in the 2008, the EFP research study in 2009 will enable us to obtain critical information needed to convert aerial survey measurements of sardine school surface area into estimates of sardine biomass. Our efforts to accomplish this in 2008 were hampered without a set-aside of sardine OY for research. The research set-aside of OY under the EFP will provide a reliable source of funds and will allow us to conduct our work in a controlled, methodical manner, separate from the race for fish which ensues during the open access fishery. This will enable us to obtain a larger and more representative sample of point-sets to more precisely and accurately estimate sardine school density – an important parameter needed for sardine biomass estimation using the aerial survey method

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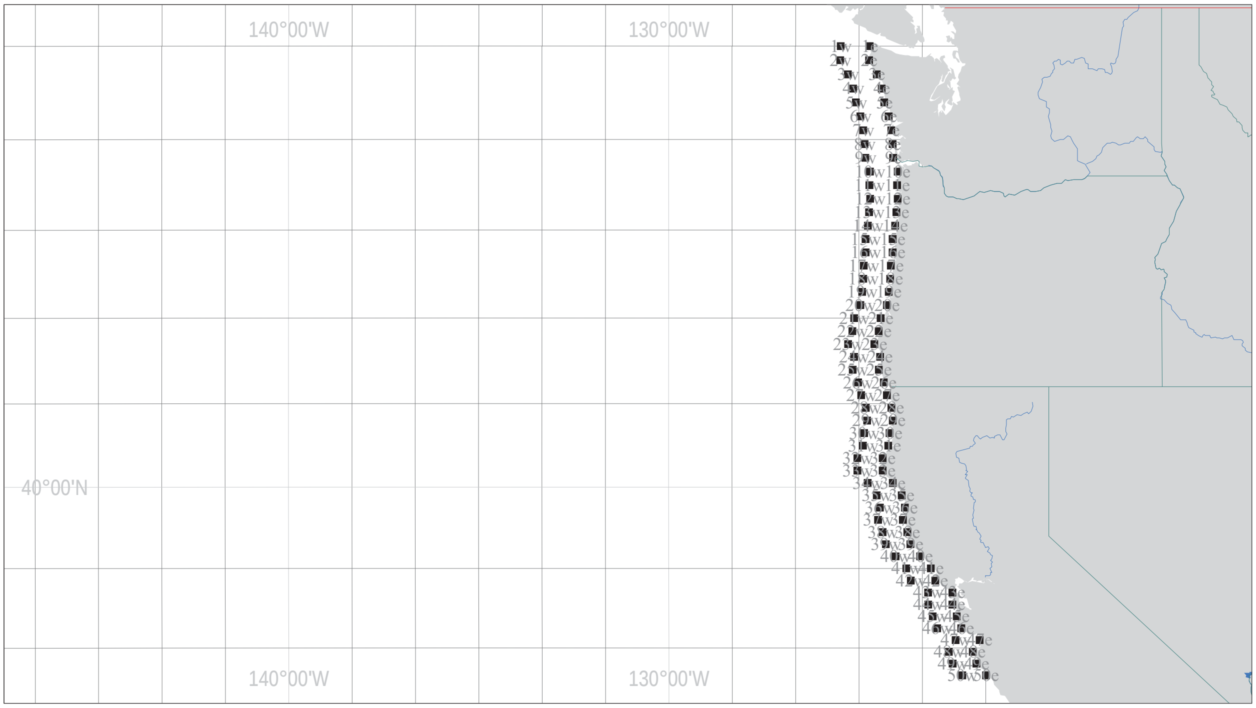
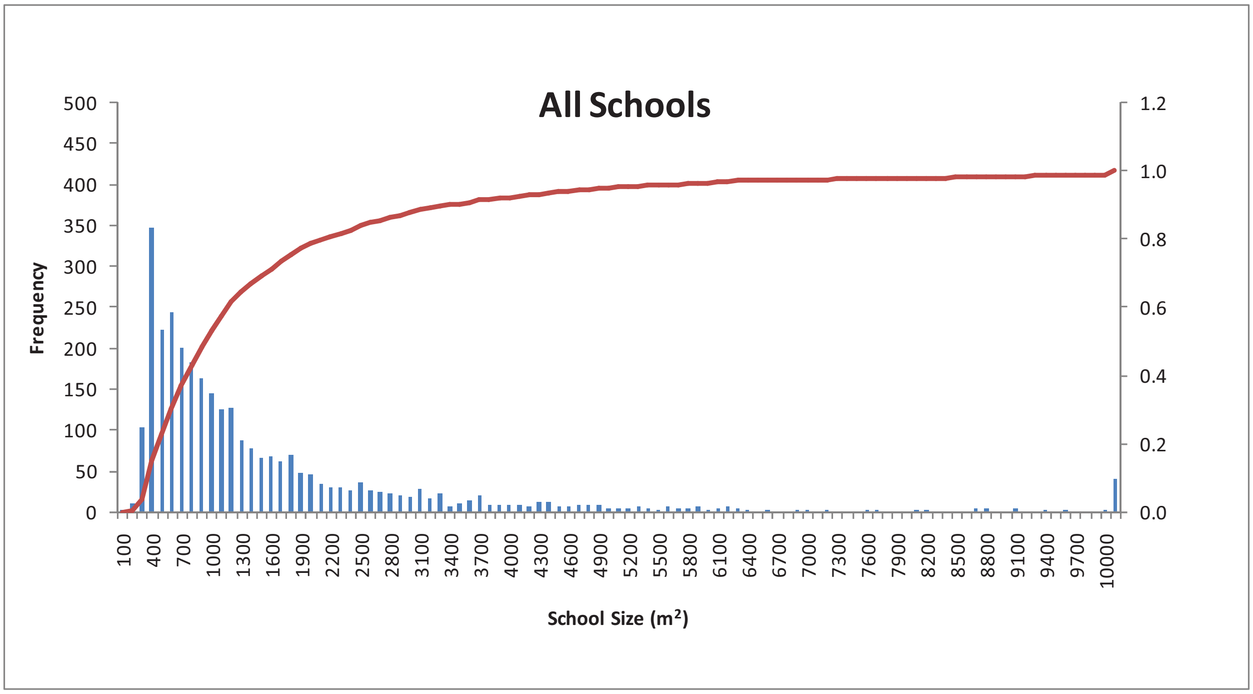


Figure 1. Transect Locations for 2009 Sardine EFP Survey – Full Coast



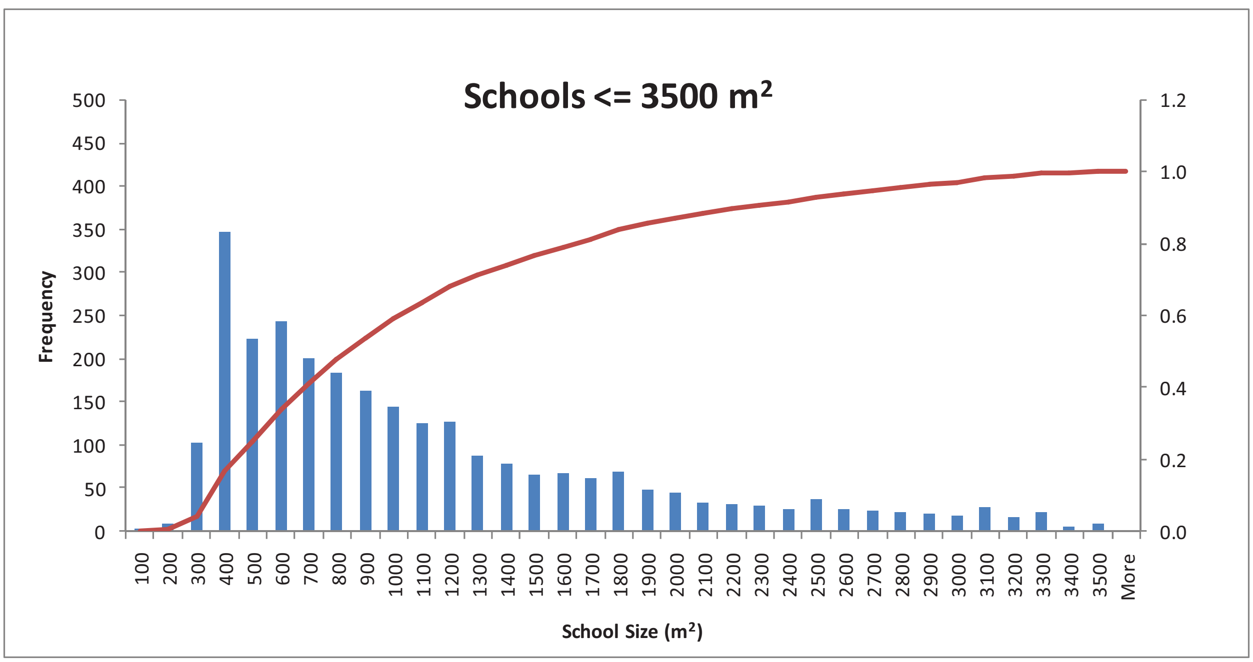


Figure 2. Size distribution of sardine schools measured in 2008 Pilot Study. Top: Distribution of all schools measured. Bottom: Distribution of schools that measured less than 3,500 m^2.

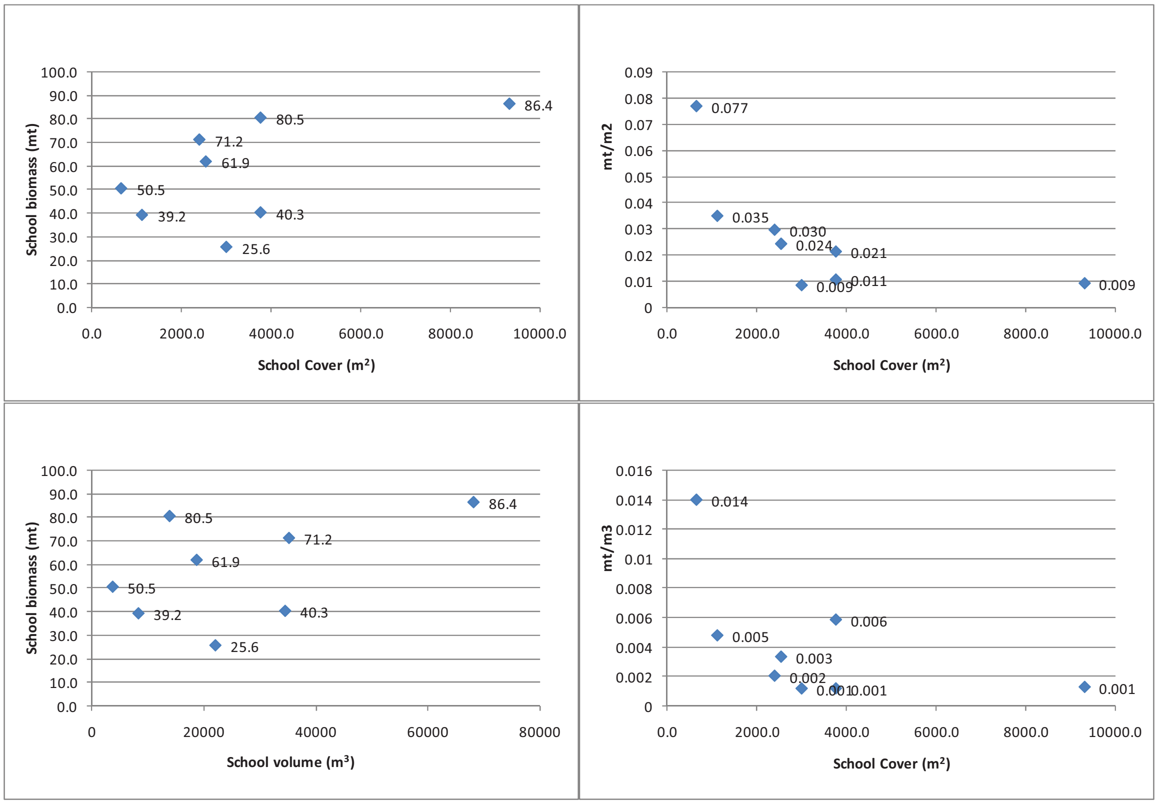


Figure 3. Sample of n = 8 point sets taken during 2008 Pilot Study. Top Left: school biomass (mt) as a function of school cover (m^2). Top Right: biomass to cover ratio (mt/m^2) as a function of school cover (m^2). Bottom Right: biomass to volume ratio (mt/m^3) as a function of school cover (m^2). Bottom Left: biomass as a function of school volume (m^3). Note: school volume was approximated as the volume of a cylinder: i.e. the product of school surface area and school height.

Figure 4. Statistical power as a function of the standardized effect size index (*d*) for a two-sample t-test of means with sample size n = 32 (alpha = 0.05).

Table 1. Example of transect locations for 2009 Sardine EFP survey.

	Survey	Transect	Transect Latitude		West End			East End		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Washington	N	1	48	20.000	125	28.49	1w	124	42.91	1e
Washington	N	2	48	5.000	125	29.24	2w	124	43.89	2e
Washington	N	3	47	50.000	125	17.01	3w	124	31.87	3e
Washington	N	4	47	35.000	125	8.78	4w	124	23.85	4e
Washington	N	5	47	20.000	125	4.55	5w	124	19.83	5e
Washington	N	6	47	5.000	124	57.32	6w	124	12.81	6e
Washington	N	7	46	50.000	124	53.09	7w	124	8.80	7e
Washington	N	8	46	35.000	124	50.87	8w	124	6.78	8e
Washington	N	9	46	20.000	124	49.66	9w	124	5.76	9e
Oregon	N	10	46	5.000	124	42.44	10w	123	58.75	10e
Oregon	N	11	45	50.000	124	43.22	11w	123	59.73	11e
Oregon	N	12	45	35.000	124	42.02	12w	123	58.71	12e
Oregon	N	13	45	20.000	124	43.81	13w	124	0.70	13e
Oregon	N	14	45	5.000	124	45.61	14w	124	2.68	14e
Oregon	N	15	44	50.000	124	49.41	15w	124	6.66	15e
Oregon	N	16	44	35.000	124	49.20	16w	124	6.65	16e
Oregon	N	17	44	20.000	124	52.00	17w	124	9.63	17e
Oregon	N	18	44	5.000	124	52.81	18w	124	10.62	18e
Oregon	N	19	43	50.000	124	54.62	19w	124	12.60	19e
Oregon	N	20	43	35.000	124	57.43	20w	124	15.59	20e
Oregon	N	21	43	20.000	125	7.25	21w	124	25.57	21e
Oregon	N	22	43	5.000	125	10.06	22w	124	28.56	22e
Oregon	N	23	42	50.000	125	16.88	23w	124	35.54	23e
Oregon	N	24	42	35.000	125	7.70	24w	124	26.53	24e
Oregon	N	25	42	20.000	125	9.52	25w	124	28.51	25e
Oregon	N	26	42	5.000	125	1.35	26w	124	20.50	26e
California	S	27	41	50.000	124	56.17	27w	124	15.49	27e
California	S	28	41	35.000	124	49.00	28w	124	8.47	28e
California	S	29	41	20.000	124	46.84	29w	124	6.46	29e
California	S	30	41	5.000	124	51.67	30w	124	11.45	30e
California	S	31	40	50.000	124	53.50	31w	124	13.43	31e
California	S	32	40	35.000	125	2.34	32w	124	22.42	32e
California	S	33	40	20.000	125	2.18	33w	124	22.41	33e
California	S	34	40	5.000	124	46.02	34w	124	6.40	34e
California	S	35	39	50.000	124	31.87	35w	123	52.38	35e
California	S	36	39	35.000	124	26.71	36w	123	47.37	36e
California	S	37	39	20.000	125	29.56	37w	124	50.36	37e
California	S	38	39	5.000	124	22.41	38w	123	43.35	38e
California	S	39	38	50.000	124	17.26	39w	123	38.34	39e
California	S	40	38	35.000	124	2.11	40w	123	23.32	40e
California	S	41	38	20.000	123	44.97	41w	123	6.31	41e
California	S	42	38	5.000	123	37.83	42w	122	59.30	42e
California	S	43	37	50.000	123	10.68	43w	122	32.29	43e
California	S	44	37	35.000	123	10.55	44w	122	32.28	44e
California	S	45	37	20.000	123	3.40	45w	122	25.27	45e
California	S	46	37	5.000	122	56.27	46w	122	18.26	46e
California	S	47	36	50.000	122	27.13	47w	121	49.25	47e
California	S	48	36	35.000	122	38.00	48w	122	0.24	48e
California	S	49	36	20.000	122	31.87	49w	121	54.23	49e
California	S	50	36	5.000	122	16.74	50w	121	39.22	50e
California	S	51	35	50.000	122	16.74	50w	121	39.22	50e
California	S	52	35	35.000	122	16.74	50w	121	39.22	50e

Table 2. Sardine maturity codes. Source: Beverly Macewicz NMFS, SWFSC.

Female maturity codes	Male maturity codes
1. Clearly immature- ovary is very small; no oocytes present	1. Clearly immature- testis is very small thin, knifed-shaped with flat edge
2. Intermediate- individual oocytes not visible but ovary is not clearly immature; includes maturing and regressed ovaries	2. Intermediate- no milt evident and is not a clear immature; includes maturing or regressed testis
3. Active- yolked oocytes visible; any size or amount as long as you can see them with the unaided eye in ovaries	3. Active- milt is present; either oozing from pore, in the duct, or when testis is cut with knife.
4. Hydrated oocytes present; yolked oocytes may be present	

Table 3. Frequency distribution of all schools measured in the 2008 Pilot Study

School Size (m^2)	Frequency	Cumulative Frequency	mt/school	mt	Cumulative mt	Cumulative mt (%)
500	685	0.2250	13.5	9231.9	9231.9	0.0585
1000	934	0.5317	27.0	25175.4	34407.2	0.2181
1500	484	0.6906	40.4	19568.9	53976.1	0.3422
2000	292	0.7865	53.9	15741.3	69717.5	0.4420
2500	158	0.8384	67.4	10647.0	80364.4	0.5095
3000	113	0.8755	80.9	9137.5	89502.0	0.5675
3500	82	0.9025	94.3	7735.9	97237.9	0.6165
4000	60	0.9222	107.8	6469.0	103706.9	0.6575
4500	46	0.9373	121.3	5579.6	109286.5	0.6929
5000	37	0.9494	134.8	4986.6	114273.0	0.7245
5500	22	0.9567	148.2	3261.5	117534.5	0.7452
6000	24	0.9645	161.7	3881.4	121415.9	0.7698
6500	21	0.9714	175.2	3679.3	125095.2	0.7931
7000	7	0.9737	188.7	1320.8	126416.0	0.8015
7500	4	0.9750	202.2	808.6	127224.6	0.8066
8000	8	0.9777	215.6	1725.1	128949.7	0.8176
8500	5	0.9793	229.1	1145.6	130095.2	0.8248
9000	10	0.9826	242.6	2425.9	132521.1	0.8402
9500	8	0.9852	256.1	2048.5	134569.7	0.8532
10000	5	0.9869	269.5	1347.7	135917.4	0.8617
10500	2	0.9875	283.0	566.0	136483.4	0.8653
11000	5	0.9892	296.5	1482.5	137965.9	0.8747
11500	2	0.9898	310.0	620.0	138585.9	0.8787
12000	0	0.9898	323.5	0.0	138585.9	0.8787
12500	1	0.9901	336.9	336.9	138922.8	0.8808
13000	4	0.9915	350.4	1401.6	140324.4	0.8897
13500	0	0.9915	363.9	0.0	140324.4	0.8897
14000	3	0.9924	377.4	1132.1	141456.5	0.8969
14500	1	0.9928	390.8	390.8	141847.3	0.8993
15000	2	0.9934	404.3	808.6	142656.0	0.9045
15500	3	0.9944	417.8	1253.4	143909.3	0.9124
16000	0	0.9944	431.3	0.0	143909.3	0.9124
16500	1	0.9947	444.7	444.7	144354.1	0.9152
17000	0	0.9947	458.2	0.0	144354.1	0.9152
17500	1	0.9951	471.7	471.7	144825.8	0.9182
18000	0	0.9951	485.2	0.0	144825.8	0.9182
18500	1	0.9954	498.7	498.7	145324.4	0.9214
19000	1	0.9957	512.1	512.1	145836.6	0.9246
19500	1	0.9961	525.6	525.6	146362.2	0.9280
20000	0	0.9961	539.1	0.0	146362.2	0.9280
20500	0	0.9961	552.6	0.0	146362.2	0.9280
21000	1	0.9964	566.0	566.0	146928.2	0.9316
21500	0	0.9964	579.5	0.0	146928.2	0.9316
22000	0	0.9964	593.0	0.0	146928.2	0.9316
22500	1	0.9967	606.5	606.5	147534.7	0.9354
23000	0	0.9967	620.0	0.0	147534.7	0.9354
23500	1	0.9970	633.4	633.4	148168.1	0.9394
24000	0	0.9970	646.9	0.0	148168.1	0.9394
24500	1	0.9974	660.4	660.4	148828.5	0.9436
25000	1	0.9977	673.9	673.9	149502.4	0.9479
25500	0	0.9977	687.3	0.0	149502.4	0.9479
26000	0	0.9977	700.8	0.0	149502.4	0.9479
26500	0	0.9977	714.3	0.0	149502.4	0.9479
27000	0	0.9977	727.8	0.0	149502.4	0.9479
27500	0	0.9977	741.2	0.0	149502.4	0.9479
28000	0	0.9977	754.7	0.0	149502.4	0.9479
28500	1	0.9980	768.2	768.2	150270.6	0.9527
29000	0	0.9980	781.7	0.0	150270.6	0.9527
29500	0	0.9980	795.2	0.0	150270.6	0.9527
30000	0	0.9980	808.6	0.0	150270.6	0.9527
30500	0	0.9980	822.1	0.0	150270.6	0.9527
31000	0	0.9980	835.6	0.0	150270.6	0.9527
31500	0	0.9980	849.1	0.0	150270.6	0.9527
32000	0	0.9980	862.5	0.0	150270.6	0.9527
32500	0	0.9980	876.0	0.0	150270.6	0.9527
33000	0	0.9980	889.5	0.0	150270.6	0.9527
33500	0	0.9980	903.0	0.0	150270.6	0.9527

School Size (m^2)	Frequency	Cumulative Frequency	mt/school	mt	Cumulative mt	Cumulative mt (%)
33500	0	0.9980	903.0	0.0	0.0	0.0000
34000	0	0.9980	916.4	0.0	0.0	0.0000
34500	0	0.9980	929.9	0.0	0.0	0.0000
35000	0	0.9980	943.4	0.0	0.0	0.0000
35500	0	0.9980	956.9	0.0	0.0	0.0000
36000	0	0.9980	970.4	0.0	0.0	0.0000
36500	0	0.9980	983.8	0.0	0.0	0.0000
37000	1	0.9984	997.3	997.3	997.3	0.0063
37500	0	0.9984	1010.8	0.0	997.3	0.0063
38000	0	0.9984	1024.3	0.0	997.3	0.0063
38500	0	0.9984	1037.7	0.0	997.3	0.0063
39000	0	0.9984	1051.2	0.0	997.3	0.0063
39500	0	0.9984	1064.7	0.0	997.3	0.0063
40000	0	0.9984	1078.2	0.0	997.3	0.0063
40500	0	0.9984	1091.7	0.0	997.3	0.0063
41000	0	0.9984	1105.1	0.0	997.3	0.0063
41500	1	0.9987	1118.6	1118.6	2115.9	0.0134
42000	0	0.9987	1132.1	0.0	2115.9	0.0134
42500	0	0.9987	1145.6	0.0	2115.9	0.0134
43000	0	0.9987	1159.0	0.0	2115.9	0.0134
43500	0	0.9987	1172.5	0.0	2115.9	0.0134
44000	0	0.9987	1186.0	0.0	2115.9	0.0134
44500	0	0.9987	1199.5	0.0	2115.9	0.0134
45000	1	0.9990	1212.9	1212.9	3328.9	0.0211
45500	0	0.9990	1226.4	0.0	3328.9	0.0211
46000	0	0.9990	1239.9	0.0	3328.9	0.0211
46500	1	0.9993	1253.4	1253.4	4582.2	0.0291
47000	1	0.9997	1266.9	1266.9	5849.1	0.0371
47500	0	0.9997	1280.3	0.0	5849.1	0.0371
48000	0	0.9997	1293.8	0.0	5849.1	0.0371
48500	0	0.9997	1307.3	0.0	5849.1	0.0371
49000	0	0.9997	1320.8	0.0	5849.1	0.0371
49500	0	0.9997	1334.2	0.0	5849.1	0.0371
50000	0	0.9997	1347.7	0.0	5849.1	0.0371
50500	0	0.9997	1361.2	0.0	5849.1	0.0371
51000	0	0.9997	1374.7	0.0	5849.1	0.0371
51500	0	0.9997	1388.1	0.0	5849.1	0.0371
52000	0	0.9997	1401.6	0.0	5849.1	0.0371
52500	0	0.9997	1415.1	0.0	5849.1	0.0371
53000	0	0.9997	1428.6	0.0	5849.1	0.0371
53500	0	0.9997	1442.1	0.0	5849.1	0.0371
54000	0	0.9997	1455.5	0.0	5849.1	0.0371
54500	0	0.9997	1469.0	0.0	5849.1	0.0371
55000	0	0.9997	1482.5	0.0	5849.1	0.0371
55500	0	0.9997	1496.0	0.0	5849.1	0.0371
56000	0	0.9997	1509.4	0.0	5849.1	0.0371
56500	0	0.9997	1522.9	0.0	5849.1	0.0371
57000	0	0.9997	1536.4	0.0	5849.1	0.0371
57500	0	0.9997	1549.9	0.0	5849.1	0.0371
58000	0	0.9997	1563.4	0.0	5849.1	0.0371
58500	0	0.9997	1576.8	0.0	5849.1	0.0371
59000	0	0.9997	1590.3	0.0	5849.1	0.0371
59500	1	1.0000	1603.8	1603.8	7452.9	0.0473
60000	0	1.0000	1617.3	0.0	7452.9	0.0473
				0.0		

Table 4. Frequency distribution of schools that measured <= 3500 m^2 in the 2008 Pilot Study.

School Size (m^2)	Frequency	mt/school	mt	Cumulative Frequency	Stratum Avg mt	Stratum n
100	3	2.7	8.1	0.00	12.1	32
200	10	5.4	53.9	0.00		
300	103	8.1	832.9	0.04		
400	346	10.8	3730.5	0.17		
500	223	13.5	3005.4	0.25		
600	243	16.2	3929.9	0.34		
700	200	18.9	3773.6	0.41		
800	183	21.6	3946.1	0.48		
900	163	24.3	3954.2	0.54	59.3	32
1000	145	27.0	3908.4	0.59		
1100	125	29.6	3706.2	0.63		
1200	128	32.3	4140.2	0.68		
1300	88	35.0	3083.6	0.71		
1400	78	37.7	2943.4	0.74		
1500	65	40.4	2628.1	0.77		
1600	68	43.1	2932.6	0.79		
1700	62	45.8	2841.0	0.81		
1800	69	48.5	3347.7	0.84		
1900	48	51.2	2458.2	0.86		
2000	45	53.9	2425.9	0.87		
2100	34	56.6	1924.5	0.88		
2200	31	59.3	1838.3	0.90		
2300	30	62.0	1859.9	0.91		
2400	26	64.7	1682.0	0.92		
2500	37	67.4	2493.3	0.93		
2600	27	70.1	1892.2	0.94		
2700	24	72.8	1746.6	0.95		
2800	23	75.5	1735.9	0.96		
2900	20	78.2	1563.4	0.96		
3000	19	80.9	1536.4	0.97		
3100	28	83.6	2339.6	0.98		
3200	16	86.3	1380.1	0.99		
3300	22	88.9	1956.9	0.99		
3400	6	91.6	549.9	1.00		
3500	10	94.3	943.4	1.00		

Table 5. Statistical power of the two sample t-test of means given sample size (n) , significance level (a), and effect size (d).

For a two-sample t-test for means, this tool calculates power (1-b), given sample size (n) for each sample, significance level (a), and effect size (d).

Type of Test (1=one sided, 2=two sided):	2		
Alpha level:	0.05	**Z1-a**	1.960
Standardized Effect Size Index (d):	0.71		

n	Z1-b	Power
5	-0.97	0.17
6	-0.85	0.20
7	-0.74	0.23
8	-0.64	0.26
9	-0.55	0.29
10	-0.46	0.32
11	-0.38	0.35
12	-0.30	0.38
13	-0.23	0.41
14	-0.16	0.44
15	-0.09	0.46
16	-0.02	0.49
17	0.04	0.52
18	0.10	0.54
19	0.16	0.57
20	0.22	0.59
21	0.28	0.61
22	0.34	0.63
23	0.39	0.65
24	0.44	0.67
25	0.49	0.69
26	0.55	0.71
27	0.60	0.72
28	0.64	0.74
29	0.69	0.76
30	0.74	0.77
31	0.79	0.78
32	0.83	0.80
33	0.88	0.81
34	0.92	0.82
35	0.96	0.83
36	1.01	0.84
37	1.05	0.85
38	1.09	0.86
39	1.13	0.87
40	1.17	0.88

Table shows: Power at alpha=0.05 for a range of sample size (n) and effect size (d) for a two-sided t test.

n \ d =	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
5	0.034319	0.046321	0.061482	0.080267	0.103095	0.130307	0.162123	0.198609	0.23965	0.284929
6	0.035634	0.049721	0.067932	0.090909	0.119203	0.153205	0.193084	0.23873	0.289722	0.345315
7	0.036852	0.052947	0.074172	0.101352	0.135151	0.175965	0.223827	0.278328	0.338596	0.403314
8	0.04	0.06	0.08	0.11	0.15	0.20	0.254307	0.31724	0.38596	0.458466
9	0.03909	0.059058	0.086265	0.121908	0.1668	0.221162	0.284454	0.355302	0.431549	0.510444
10	0.040136	0.061993	0.092187	0.132092	0.182546	0.243573	0.314191	0.392367	0.475161	0.559045
11	0.041145	0.064869	0.098053	0.142238	0.198245	0.265823	0.343443	0.428312	0.516646	0.604167
12	0.042123	0.067697	0.103876	0.152357	0.213895	0.287882	0.372142	0.463035	0.555909	0.645799
13	0.043074	0.070485	0.109666	0.162454	0.229488	0.309718	0.400225	0.496458	0.592898	0.683992
14	0.044002	0.073239	0.115431	0.172533	0.245014	0.331301	0.42764	0.528522	0.627596	0.718852
15	0.04491	0.075966	0.121175	0.182594	0.260464	0.352602	0.454343	0.559189	0.660021	0.750521
16	0.045799	0.078668	0.126903	0.192637	0.275827	0.373595	0.480295	0.588436	0.690215	0.779171
17	0.046673	0.081349	0.132618	0.202662	0.291092	0.394256	0.505469	0.616256	0.718238	0.804986
18	0.047532	0.084012	0.138321	0.212667	0.306249	0.414563	0.52984	0.642652	0.744167	0.828165
19	0.048378	0.086659	0.144016	0.222649	0.321286	0.434498	0.553392	0.667641	0.768093	0.848905
20	0.049212	0.089293	0.149703	0.232607	0.336195	0.454043	0.576116	0.691246	0.79011	0.867408
21	0.050035	0.091914	0.155384	0.242537	0.350966	0.473185	0.598004	0.713498	0.810322	0.883865
22	0.050849	0.094524	0.161058	0.252438	0.365589	0.491911	0.619056	0.734436	0.828833	0.898463
23	0.051653	0.097125	0.166727	0.262305	0.380058	0.510211	0.639276	0.754101	0.845751	0.91138
24	0.052449	0.099718	0.17239	0.272136	0.394363	0.528076	0.658669	0.772539	0.861179	0.922781
25	0.053237	0.102303	0.178048	0.281929	0.408499	0.545501	0.677246	0.789799	0.875223	0.932822
26	0.054017	0.104881	0.183701	0.291681	0.422457	0.56248	0.695019	0.805931	0.887982	0.941646
27	0.054791	0.107453	0.189348	0.301388	0.436233	0.57901	0.712004	0.820987	0.899555	0.949384
28	0.055559	0.11002	0.19499	0.311048	0.449821	0.595089	0.728216	0.83502	0.910034	0.956157
29	0.05632	0.112582	0.200626	0.320658	0.463216	0.610718	0.743675	0.848082	0.919507	0.962075
30	0.057076	0.11514	0.206257	0.330216	0.476413	0.625896	0.7584	0.860224	0.928059	0.967237
31	0.057827	0.117694	0.21188	0.339719	0.48941	0.640626	0.772413	0.871497	0.935767	0.971731
32	0.058573	0.120244	0.217497	0.349164	0.502201	0.654911	0.785735	0.881953	0.942706	0.975638
33	0.059314	0.122791	0.223107	0.35855	0.514785	0.668754	0.798389	0.891638	0.948943	0.979029
34	0.060051	0.125335	0.228708	0.367874	0.527159	0.68216	0.810399	0.900601	0.954544	0.981969
35	0.060784	0.127876	0.234302	0.377135	0.53932	0.695135	0.821786	0.908887	0.959566	0.984513
36	0.061513	0.130415	0.239887	0.386329	0.551268	0.707683	0.832576	0.916539	0.964064	0.986712
37	0.062238	0.132952	0.245463	0.395455	0.563	0.719813	0.842791	0.923599	0.968088	0.98861
38	0.06296	0.135487	0.251029	0.404511	0.574515	0.731531	0.852455	0.930107	0.971685	0.990247
39	0.063678	0.13802	0.256585	0.413496	0.585814	0.742845	0.86159	0.936101	0.974896	0.991657
40	0.064393	0.140551	0.26213	0.422408	0.596895	0.753762	0.87022	0.941616	0.97776	0.992869

Table 6. Summary data from n = 8 point sets taken during 2008 Pilot Study.

School Cover (m^2)	School Biomass (mt)	Biomass:Cover mt/m^2	School Height (m)	School Volume (m^3)	Biomass:Volume mt/m3
3763.9	80.5	0.021	3.7	13767	0.006
2543.9	61.9	0.024	7.3	18609	0.003
3763.8	40.3	0.011	9.1	34416	0.001
1121.7	39.2	0.035	7.3	8206	0.005
9308.4	86.4	0.009	7.3	68092	0.001
657.4	50.5	0.077	5.5	3607	0.014
3001.9	25.6	0.009	7.3	21959	0.001
2399.8	71.2	0.030	14.6	35110	0.002

Appendix I: Aerial Imaging Solutions FMC Mount System

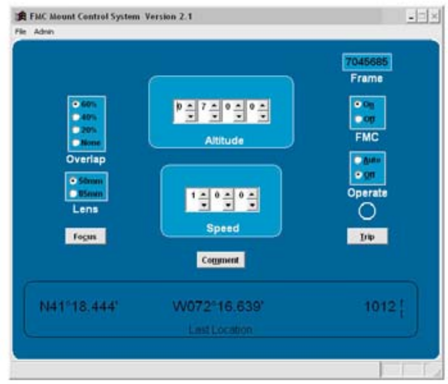
AERIAL IMAGING SOLUTIONS
FMC MOUNT SYSTEM

DESCRIPTION

An aerial mount system for digital cameras that reduces image blur caused by the forward motion of the aircraft while the shutter is open. The mount and camera are connected to, and remotely controlled by, a program running on a customer-supplied (Windows-based) computer. Flight and camera parameters entered by the computer's operator determine the required forward motion compensation (FMC) and camera firing interval. The system also takes inputs from the customer-supplied GPS and radar altimeter and will, optionally, use these data to automatically determine the required FMC and firing interval. The system includes a remote viewfinder that displays the image seen through the camera's eyepiece on a small monitor to permit the computer operator to observe camera operation to ensure successful coverage of sites. It also includes a data acquisition system that interfaces with the camera, GPS, radar altimeter, and computer to record position and altitude readings as each frame is collected.

Aerial Imaging Solutions 5 Myrica Way, Old Lyme, CT 06371 (860)434-3637

AERIAL IMAGING SOLUTIONS
FMC MOUNT SYSTEM



TECHNICAL SPECIFICATIONS

Cameras Accepted
- Canon EOS-1Ds (Standard)
- Any small or medium format digital camera (Custom)

- **FMC Drive**
  - Servo motor with closed-loop control circuit
- **Weight and Dimensions (Approximate)**
  - Weight w/Camera and cables: 15 lbs (6.8 kg)
  - Length: 11.3" (287 mm)
  - Width: 9.8" (250 mm)
  - Height: 9.3" (237 mm)
- **Environmental**
  - 32° F to 113° F (0° C to 45° C)
- **Power**
  - 28 V DC @ 3A
- **Setup and Pre-flight Testing Time**
  - Approximately 2 hours

Contents of System
- Mount
- Mount Controller
- Control Program
- Data Logger
- Cables
- Transportation Box

West Coast Sardine Survey

Application for Exempted Fishing Permit in 2009

Appendix II: Scientific Personnel Curriculums Vitae

Vidar G. Wespestad
21231 8th Place W.
Lynnwood, WA 98036
Telephone:425 672-7603
E-mail: Vidarw@verizon.net

2002-present Adjunct Professor, University of Alaska, Fairbanks.

1998- present **Fisheries Consultant**
Current and recent projects

Development of combined aerial and acoustic survey of Pacific sardine off Washington and Oregon.
Developing and supervising research for the Pacific Whiting Conservation Cooperative including conducting annual cooperative assessment of Pacific whiting prerecruit abundance;
Science consultant to American Fisheries Research Foundation for North Pacific albacore data and population models;
Assisting in stock assessments of marine fishes in central Chile;
Modeling and forecasting Bering Sea walleye pollock recruitment using biophysical data for the Alaska Fish. Sci. Center.
European Fish Ageing Network – consultation on length based stock assessment methodology
Reviewer and consultant to the Norwegian Research Council on fisheries assessment and management.
U.S. delegate to International Albacore Stock Assessment Working Group
Member, NOAA National MPA implementation Team
Member, Pacific Fisheries Management Council, Scientific and Statistical Committee.

1992-1997: Supervisory Fisheries Research Biologist, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way N. E. Seattle, WA 98115. In charge of stock assessment task for the Bering Sea. I also served as a scientific advisor, delegate or representative to: Coastal Pelagic Working Group, PICES, Northeast Arctic Working Group, ICES
1977 – 1992: Fisheries Research Biologist, National Marine Fisheries Service, Northwest and Alaska Fisheries Center, 7600 Sand Point Way N. E. Seattle, WA 98115.

Education
Doctor of Philosophy in Fisheries Science, 1991, University of Washington, Seattle, WA 98195
Master of Science in Fisheries Science, 1975, Colorado State University, Fort Collins, CO 80521
Bachelor of Science (cum laude), 1973, Colorado State University, Fort Collins, CO 80521

Professional and honorary society memberships
American Association for th Advancement of Science
American Institute of Fishery Research Biologists
American Fisheries Society:
Co-chair, World Fishery Congress (Athens, 1992) Steering Committee
International Fisheries Section, President 1989-91
Colorado State Chapter, President 1972-73
Marine Fisheries Section,
Gamma Sigma Delta
Xi Sigma Pi

Awards
NOAA Special Achievement, 1979
Full-time long term university training, 1982
NOAA Outstanding Performance, 1983
Honorable Mention for Best Paper in Fishery Bulletin, 1983
Senior Scientist Fellowship, Norwegian Fishery Research Council, 1986

Norwegian Marshall Fund, Research Fellowship, 1991.
American Fisheries Society Distinguished Service Award, 1992
Rockefeller Foundation Scholar-in-Resident, Bellagio Center, Bellagio, Italy, 1996.

Membership on Symposia Organizing Committees
International Herring Symposium, Anchorage, AK, 1980
International Hydroacoustic Symposium, Seattle, WA 1987
International Pollock Symposium, Anchorage, Ak 1988
International Herring Symposium, Anchorage, AK, 1990
World Fisheries Congress (Co-chair), Athens, Greece, 1992
International Symposium on Ocean Ranching, Arendal, Norway, 1993
International Forage Fish Symposium, Anchorage, AK 1996
Third World Fisheries Congress, Beijing, China 2000
Resiliency of Gadid Stocks to Fishing and Climate Change, 24th Lowell Wakefield Fisheries Symposium

Publications

Professional papers	40
Refereed journal papers	30

Recent Publications and Presentations

Botsford, Louis D, R. Brumbaugh, C. Grimes, J. B. Kellner, John Largier, Michael R. O'Farrell,S.Ralston, E. Soulanille and V. Wespestad. 2008. Connectivity, sustainability, and yield: bridging the gap between conventional fisheries management and marine protected areas Rev. Fish Biology and Fisheries

A. Phillips, V. Wespestad, R. Emmett, N. Lo, S. Ralston, R.Brodeur 2007. Northern Shift in the Location of Spawning and Recruitment of Pacific Hake (Merluccius productus) in the California Current. Calcofi Vol 48, 2007.

Keith M. Sakuma, Stephen Ralston, and Vidar G. Wespestad. 2006. Interannual and Spatial Variation in the Distribution of Young-of-the-year Rockfish (Sebastes spp.): expanding and coordinating a survey sampling frame. CalCOFI Rep., Vol. 47, 2006

Fleischer, Guy, Rebecca Thomas, Patrick Ressler, Ken Cooke, Stephen Pierce, John Holmes, Stephen de Blois, Lawrence Hufnagle, Thomas Helser and Vidar Wespestad.. 2006. Distribution and Abundance of Adult and Juvenile Pacific Hake (Merluccius productus) off the West Coast of North America in 2005. 14th Western Groundfish Conf, Newport, OR.. http://oregonstate.edu/heppell/groundfish/pdfs/wgcprogram.pdf

Ressler, Patrick, Guy Fleischer1 and Vidar Wespestad. 2006. Recent Acoustic and Video Observations Used in the Development of a Commercial Vessel-Based Survey Methodology for Widow Rockfish (Sebastes entomelas). 14th Western Groundfish Conf., Newport, OR. .http://oregonstate.edu/heppell/groundfish/pdfs/wgcprogram.pdf

Fleischer, G.W. , Ressler, P.H. , Thomas, R.E., de Blois, S.K. , Cooke, K.D. , Holmes, J.A., Hufnagle, L.C. , Helser, T.E. , and Wespestad, V.G. 2004. The distribution and abundance of adult and juvenile Pacific hake (Merluccius productus) off the west coast of North America in 2003. Proceedings West. Groundfish Conf., Victoria, B.C.

ICES Annual Science Meeting, Tallinn, Estonia October, 2003. "Rebuilding west coast groundfish, how do you know when you get there when you don't know where you are, or where you are going." Symposium on stock rebuilding.

Dorn, M. W. Karp, J. Ianelli, T. Quinn, and V. Wespestad. 2002 (Poster). Using fishing vessels to collect acoustic data for scientific purposes: preliminary results from midwater trawlers in the Eastern Bering Sea walleye pollock fishery. ICES International Acoustics Symposium, Montpelier, France, June 2002.

Thomas H. Jagielo

PO Box 93
Copalis Beach, Washington 98535
(360) 791-9089
Email: TomJagielo@msn.com

Employment

[2008-Present] Tom Jagielo, Consulting Seattle, WA

Fisheries Science Consultant

- Recent Projects include: Feasibility of using an aerial survey to estimate sardine abundance off the coast of Washington-Oregon.
- Pacific Islands Regional Office, NMFS: Evaluation of Annual Catch Limits and accountability measures for WPFMC.
- Environmental Defense Fund: Evaluation of Morro Bay groundfish – past, present and projected ABC's and OY's.

[1984-2008] Washington Dept. of Fish and Wildlife Olympia, WA

Senior Research Scientist

- Principal Investigator on projects including: *Groundfish Stock Assessment* – Developed work products used by Pacific Fishery Management Council for management of the Washington, Oregon, and California Continental Shelf marine fish resources; *Undersea Manned Submersible Research* – NURP; Developed 3-Beam quantitative laser survey tool with engineers from Harbor Branch Oceanographic Institution; *Groundfish Survey Design* - Tagging studies for estimation of movement, survival, and abundance.

[1979-1984] University of Washington Fish. Res. Institute Seattle, WA

Biologist

- Various projects including: *Japanese Foreign Fisheries Observer* (On Bering Sea for 6 months); *Limnology of Lake Roosevelt*; *Toutle River salmon survival* - following Mt. St. Helens volcanic eruption.

Education

[1988-1992] University of Washington Seattle, WA

Post MS Graduate Study

- Fishery Population Dynamics, Statistical Sampling and Estimation

[1986-1988] University of Washington Seattle, WA

Master of Science

- MS in Fisheries – Limnology of Lake Roosevelt, WA.

[1974-1977] Pennsylvania State University University Park, PA

Bachelor of Science

- BS in Biology and Marine Science

Scientific

- Pacific Fishery Management Council Scientific and Statistical

Committees

Committee: Chairman (2002-2003); Vice Chairman (2000-2001); Member: (1992-2008).

- US/Canada Groundfish Technical Subcommittee: Chairman (2003, 1987-1988); Member 1986-2008.

Selected Publications

Jagielo, T.H. 1988. The spatial, temporal, and bathymetric distribution of coastal lingcod trawl landings and effort in 1986. State of Wa. Dept. of Fish. Prog. Rept. No. 268. June 1988. 46 pp.

Jagielo, T.H. 1990. Movement of tagged lingcod, (*Ophiodon elongatus*), at Neah Bay, Washington. Fish. Bull. 88:815-820.

Jagielo, T.H. 1991. Synthesis of mark-recapture and fishery data to estimate open population parameters. *In* Creel and Angler Surveys in Fisheries Management, American Fisheries Society Symposium 12:492-506.

Jagielo, T.H. 1994. Assessment of lingcod (*Ophiodon elongatus*) in the area north of Cape Falcon (45^0 46’ N.) and south of 49^0 N. in 1994. *In* Pacific Fishery Management Council, 1994. Status of the Pacific Coast Groundfish Fishery Through 1994 and Recommended Acceptable Biological Catches for 1995. Appendix I. Pacific Fishery Management Council, Portland, Oregon.

Jagielo, T.H. 1995. Abundance and survival of lingcod (*Ophiodon elongatus*) at Cape Flattery, Washington. Trans. Amer. Fish. Soc. 124(2).

Jagielo, T. H., LeClair, L.L., and B.A. Vorderstrasse. 1996. Genetic variation and population structure of lingcod. Trans Amer. Fish Soc. 125(3).

Jagielo, T.H., Adams, P., Peoples, M., Rosenfield, S., Silberberg, K, and T. Laidig. 1997. Assessment of lingcod (Ophiodon elongatus) for the Pacific Fishery Management Council in 1997. *In* Pacific Fishery Management Council, 1997. Status of the Pacific Coast Groundfish Fishery Through 1997 and Recommended Acceptable Biological Catches for 1998. Pacific Fishery Management Council, Portland, Oregon.

Jagielo, T.H. 1999. Rebuilding analysis for lingcod. Report prepared for the Pacific Fishery Management Council, Portland, OR.

Jagielo, T.H. 1999. Movement, mortality, and size selectivity of sport and trawl caught lingcod (*Ophiodon elongatus*) off Washington. Trans. Amer. Fish. Soc. 128:31-48.

Jagielo, T.H., Vandenberg, D.V., Sneva, J., Rosenfield, and F. Wallace. 2000. Assessment of lingcod (Ophiodon elongatus) for the Pacific Fishery Management Council in 2000. *In* Pacific Fishery Management Council, 2001. Status of the Pacific Coast Groundfish Fishery Through 2000 and Recommended Acceptable Biological Catches for 2001. Pacific Fishery Management Council, Portland, Oregon.

Jagielo, T.H. and J. Hastie 2001. Updated rebuilding analysis for lingcod. Report prepared for the Pacific Fishery Management Council, Portland, OR.

Kocak, D.M., Caimi, F.M., **Jagielo, T.H**. and J. Kloske. 2002. Laser Projection Photogrammetry and Video System for Quantification and Mensuration. Oceans 2002, Marine Technology Society. Biloxi MS.

Jagielo, T.H., Hoffmann, A., Tagart, J. and M. Zimmermann 2003. Demersal Groundfish Densities in Trawlable and Untrawlable Habitats off Washington: Implications for Estimation of the Trawl Survey Habitat Bias. Fish. Bull. July, 2003(In Press).

Doyle A. Hanan

Post Office Box 8914
Rancho Santa Fe, California 92067
858-832-1159

Education:

PhD, Biology 1996
University of California
Los Angeles

MA, Marine Biology 1976
California State University
Long Beach

BA, Biology 1969
California Lutheran University
Thousand Oaks

Affiliations and panel experience:

Member: Pacific Fishery Management Council's Highly Migratory Species Advisory Subpanel; **Representative:** California Cooperative Oceanic Fisheries Investigations (CalCOFI) committee; **Representative:** Pacific Scientific Review Group (advising Secretary of Commerce on marine mammals in the Pacific); **Member**: Pacific Drift Gillnet Take Reduction Team; **Member:** Congressional pinniped/salmon interaction working group; **Co-chair:** Pacific Fishery Management Council's CPS fishery management plan development team; **Chair:** Pacific Fishery Management Council's Coastal Pelagic Fisheries Management team; **Member:** Congressional National Ecosystem Principles Panel; **Representative:** Mexus-Pacifico; **Advisor:** United Nations Food and Agricultural Organization on shark fisheries management; **Member**: marine mammal society; Associate **Editor:** *California Fish and Game* quarterly periodical; Journal **Referee:** *Fisheries Bulletin*, *Marine Mammal Science*, *Fisheries Oceanography*, International Whaling Commission *Special Reports*, and *CalCOFI Fisheries Investigations Reports, Brazilian Journal of Oceanography*; Research and Grant **Reviewer**: California Sea Grant, Saltonstall-Kennedy, and City of San Diego; **Court-recognized Expert witness**: on retainer City of San Diego. **Member:** Scientific Advisory Team, State of California MLPA initiative.

Professional Experience:

Hanan & Associates, Inc.
President/ Chief Scientist
2001-Present

HDR Engineering, Inc.
Director Marine Coastal Program
Senior Biologist/Project Manager
2000-2001

California Dept of Fish and Game
Senior Marine Biologist, Supervisor
Pelagic Ecosystems 1993-2000
Associate Marine Biologist
Marine Mammals 1983-1993
Assistant Marine Biologist
Fisheries Analyses 1979-1983
Assistant Marine Biologist
Kelp Bed Ecosystem 1974-1979

California State Univ. Long Beach
Part-time Faculty
Invertebrate Zoology 1975-1976
Teaching Assistant
Vertebrate Zoology 1973-1975
Graduate Assistant
Biology 1972-1975
Teaching Assistant
General Biology 1973-1975

PVSD, Camarillo, CA
Teacher
Biology/Science 1969-1973

USMCR 1969-1975
Sergeant E-6 Honorable discharge

Personal **publication history** includes 27 peer-reviewed papers and 60+ contract or administrative reports.
Dissertation: Dynamics of abundance and distribution in the Pacific harbor seal, *Phoca vitulina richardsi,* on the coast of California

Doyle A. Hanan
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Dr. Hanan formed and is president of Hanan & Associates, Inc. a marine consulting firm providing expertise to fisheries and wildlife agencies, municipalities, and foundations. After an early retirement as a senior marine biologist supervisor for California Department of Fish and Game, he was employed as marine director for HDR Engineering, Inc. At CDFG, he directed and participated in research teams investigating nearshore and offshore fisheries, as well as, marine mammals, invertebrates and plants. His projects focused on marine ecosystems and population biology; development and implementation of fishery management plans (white seabass plan, CPS plan, market squid plan); applied research, and fisheries analysis. He designed and implemented observer programs for the shark/swordfish drift gillnet fishery, the nearshore setnet fisheries, salmon troll fishery, and CPFV fishery. He was the state=s voting member of California Cooperative Oceanic Fisheries Investigations (CalCOFI). He was selected to serve on two standing committees to advise the Secretary of Commerce: 1) Pacific Scientific Review Group which reviews all marine mammal stocks, research, and fisheries interactions in the Pacific Ocean; and 2) Drift Gillnet/Pacific Cetacean Take Reduction Team which was charged with developing overseeing a plan to reduce marine mammal bycatch in this fishery. The plan did effect an 80% reduction in this bycatch. He served on the National Ecosystem Principles Panel commissioned by Congress through the Sustainable Fisheries Act to develop recommendations expanding the application of ecosystem principles in fishery conservation and management activities. He participated in the working and contributing groups for the Report to Congress on Salmon-Pinniped and Greater Ecosystem Interactions commissioned by Congress in the reauthorization of the Marine Mammal Protection Act. For PFMC, he was co-chair of the CPS FMP development team and chair of the CPS management team that developed, wrote, and implemented the CPS FMP. He served recently on the PFMC Highly Migratory Species Advisory Sub panel. He recently served on the MLPA scientific advisory team for the State of California. H&A, Inc. has contracted with National Marine Fisheries Service, Pacific States Marine Fisheries Commission, Gulf & South Atlantic Fisheries Foundation, Inc., the City of San Diego, California Wetfish Producers Association, Sportfishing Association of California, and American Sportfishing Association. H&A projects include fish, fisheries, marine mammal research and consulting.

Ryan Anthony Howe

Ryanhowe9@yahoo.com · (989) 941-2241 · 1425 NE 7th Ave. Portland, OR 97232

Objective: To further my experience in the fisheries field while working with public and private stakeholders and government agencies.

Education: University of Alaska: Anchorage, AK
North Pacific Groundfish Observer Program
Level 1 Observer (October 2006)
Level 2 Observer (March 2008)

Michigan State University: East Lansing, MI
Bachelor's of Science Degree (August 2006): Fisheries and Wildlife

Educational Experience:

Ichthyology	Environmental Fish Physiology
Population Analysis	Ecological Problem Solving
Human Dimensions	Wildlife Biometry
Wetland Ecosystem Mgt.	Aquatic Ecosystem Mgt.

Work Experience:

Fisheries Technician
Northwest Sardine Survey LLC: Bellingham, WA July 2008 – Present

- Assisted with structure and methodology for 2008 Northwest Sardine Survey
- Interaction with state and federal agencies and private and public stakeholders
- Collect biological information routinely of sardine from fishing vessels and fish processing plants (i.e. otolith, scale, sex/length/weight, maturity)
- Daily data entry using Microsoft Excel
- Enhancement and analysis of digital photos using Adobe Photoshop CS3 and Adobe Lightroom 2
- Experience with Simrad ES60 hydro acoustics echo sounder

Fisheries Technician
Pacific Whiting Conservation Cooperative: Seattle, WA May 2008 - Present

- Collect biological information daily of Pacific Whiting along with other species (i.e. species I.D., length/weight, species retention and storage)
- Record raw data on deck forms and enter in Microsoft Excel daily
- Coordinate with NOAA research vessel David Starr Jordan during project
- Assist in Seabird CTD operations (conductivity, temperature, depth)
- Work with vessel operator and crew to accomplish project tasks

North Pacific Fisheries Observer
TechSea International Inc.: Seattle, WA September 2006 – March 2008

- Collect biological information for NMFS (i.e. otolith, scale, s/l/w, tissue, species id, species retention)
- Collect and record catch and positional information on fishing vessels within the Bering Sea and Gulf of Alaska
- Interaction with state and federal officials along with private and public stakeholders

Fisheries Technician
Michigan State University: East Lansing, MI June 2006 – August 2006

- Electro-shocked streams in northwestern and southwestern Ontario, Canada for a Ph.D. candidates Sea Lamprey research project.
- Maintained electro-shocking equipment and USGS vehicle provided for project
- Recorded biological, positional and catch information of sampled transects.

Fisheries Technician
Michigan State University: East Lansing, MI Fall 2005

- Aided in electro-shocking of streams across southern lower Michigan to capture mottled sculpin for an undergraduate research project
- Used dip nets to capture stunned fish
- Gained teamwork skills by working with other technicians to accomplish the project goals

Fisheries Technician
Michigan State University: East Lansing, MI Fall 2005

- Gained communication skills through interaction with hatchery biologists of the Michigan Department of Natural Resources
- Collect and bagged tissues (i.e. kidney, liver, spleen, heart and gonads) of over 100 Chinook Salmon for future genetic analysis and to check for the presence of bacterial kidney disease (BKD).

West Coast Sardine Survey

Application for Exempted Fishing Permit in 2009

Appendix III: Estimated Budget

Appendix III

Estimated EFP Project Budget - April 2009

CALIFORNIA (SOUTH): Revenues projected from the sale of research quota are based on the following formula, for the purpose of constructing this budget: $700 mt delivered Asia * 1,200 mt = $840,000. Estimated processing cost for 20 kilo polywrap = approx. $400/mt. Proceeds (exclusive of cost of fish) = approximately $300/mt. Net revenue projected = $360,000.

NOTE: CWPA established a Special Sardine Assessment, with revenues accounted for in a dedicated account, to help fund this research. Any costs incurred beyond the proceeds generated by sale of the research fish will be paid from the dedicated sardine research account. Any proceeds received in excess of costs will be held in a dedicated account for the next year's survey.

EXPENSES - CA:						Weather		
Aerial Transects	# Transects	Hrs/transect	$/hr	Total/Set	Replicates	contingency	Total	Extension
Flying the transects	26	1	$250	$6,500	3	1.5	$29,250	
Processing transect images	26	4	$20	$2,080	3		$6,240	
Point Sets	# Point sets	#Sets/day	$/Day	# Days				
Point sets on schools	32	2	$4,000	16			$64,000	
	Hrs/Day		$/Hr	# Days				
Flying the point sets	8		$250	16			$32,000	$131,490
CA Scientific staff - hours							$63,750	
CA Scientific staff - expenses							$2,900	
CA Sample collection & coordination							$16,000	
								$82,650
Equipment								
FMC Camera System	$38,000.00						$38,000	
FMC Support	$3,000.00						$3,000	
ES 60 Sounders (2)	$30,000.00						$30,000	
Biosonics DT-X Mod.Transducer	$4,500.00						$4,500	
Biosonics Field Oversight	$4,900.00						$4,900	
Laptop (2)	$3,300.00						$3,300	
								$83,700
50:50 Share - PI Planning & Oversight								
Scientific staff - hours							$64,125	
Scientific staff - expenses							$7,050	
								$71,175
Accounting/bookkeeping							$5,000	
Office equipment, software & misc. expense							$1,800	
10% contingency on operations							$29,212	
								$36,012
PROJECT SUBTOTAL - CALIFORNIA								**$405,027**

Appendix III, Continued

Estimated EFP Project Budget - April 2009

PACIFIC NORTHWEST (NORTH): Revenues projected from the sale of research quota are based on the following formula, for the purpose of constructing this budget: $800 mt FOB container yard * 1,200 mt = $960,000. Estimated processing cost for ______________________ Proceeds (exclusive of cost of fish) = approximately _________/mt. Net revenue projected = ___________.

EXPENSES - PNW:

Aerial Transects	# Transects	Hrs/transect	$/hr	Total/Set	Replicates	Weather contingency	Total	Extension
Flying the transects	26	1	$250	$6,500	3	1.5	$29,250	
Processing transect images	26	4	$20	$2,080	3		$6,240	
Point Sets	# Point sets	#Sets/day	$/Day	# Days				
Point sets on schools	32	1	$4,500	32			$144,000	
	Hrs/Day		$/Hr	# Days				
Flying the point sets	8		$250	16			$32,000	$211,490
PNW Scientific staff support - hours							$32,000	
PNW Scientific staff - expenses							$14,600	
								$46,600
Equipment								
FMC Camera System (2)	$76,000.00						$76,000	
ES 60 Sounders (2)	$45,000.00						$45,000	
Laptop	$1,100.00						$1,100	
								$122,100
- PI Planning & Oversight								
Scientific staff - hours							$64,125	
Scientific staff - expenses							$7,050	
								$71,175
Accounting/bookkeeping							$5,000	
Office equipment, software & misc. expense							$1,800	
10% contingency on operations							$33,607	
								$40,407
PROJECT SUBTOTAL - PACIFIC NORTHWEST								**$491,772**
TOTAL Estimated PROJECT COST (California plus Pacific Northwest)								**$896,798**

West Coast Sardine Survey

Application for Exempted Fishing Permit in 2009

Appendix IV: Exempted Fishing Permit Criteria

1. Applicant Contact Information

Name:	Vidar Wespestad
Affiliation:	Resource Analysts International
Address:	21231 8th Pl. W., Lynnwood, WA 98036
Email:	vidarw@verizon.net
Phone:	(206) 619-2449
Role:	Co-Principal Investigator

Name:	Tom Jagielo
Affiliation:	Tom Jagielo, Consulting
Address:	P.O. Box 93, Copalis Beach, WA 98535
Email:	TomJagielo@msn.com
Phone:	(360) 791-9089
Role:	Co-Principal Investigator

Name:	Diane Pleschner-Steele
Affiliation:	Executive Director, California Wetfish Producers Association
Address:	PO Box 1951, Buellton, CA 93427
Email:	dplesch@earthlink.net
Phone:	(805) 693-5430
Role:	Industry EFP Co-Lead: CWPA (Southern Area)

Name:	Jerry Thon
Affiliation:	Principal, Northwest Sardine Survey, LLC
Address:	12 Bellwether Way, Suite 209, Bellingham, WA 98225
Email:	jthon2@msn.com
Phone:	(360) 201-8449
Role:	Industry EFP Co-Lead: NWSS (Northern Area)

2. Purpose, Goals, And Arrangements For Disposition Of All Harvested Species Under The EFP

This proposal requests an EFP for 2009 to permit participating vessels to catch Pacific sardine under a PFMC recommended 2400 mt HG set-aside (pending NMFS rulemaking approval) for sardine research during the closed periods between seasonal allocations, in order to perform a synoptic survey of the sardine biomass off the U.S. West Coast. The intent is that (pending approval at a STAR panel review) this survey will provide an additional data source to be included in the Pacific sardine stock assessment to be used by PFMC to estimate sardine abundance. The PFMC has scheduled the STAR Panel review for May 4-8, 2009. If the survey methodology is approved, and the survey is conducted successfully during the summer of 2009, the results will be available for review at the Pacific sardine assessment STAR panel scheduled for September 21-25, 2009.

In recent years, the Pacific sardine stock assessment has indicated that stocks are in decline, which has resulted in significant harvest guideline reductions for 2008 and 2009. This conclusion, however, does not reflect the observations of fishermen and spotter pilots who instead report an apparent increase in biomass.

In the November, 2008 PFMC briefing book, it is noted that "… although the advisory bodies that participated in the October meetings all shared concerns with the level of uncertainty in the assessment of Pacific sardine, there was disagreement on the validity and application of the 2008 assessment update for use in managing the fishery in 2009…" and "…the majority of the CPSAS expressed substantial concerns with the assessment model and the data upon which it is based."

In 2008, members of the Pacific Northwest sardine industry, along with a panel of experts, began looking into an alternative methodology for the survey of Pacific sardine stock abundance. Subsequently, the NW Sardine Survey, LLC was formed, and, with the help of scientific advisors Vidar Wespestad and Tom Jagielo, performed a pilot survey of the sardine biomass off a section of the Oregon and Washington Coast to test the new methodology. This survey demonstrated the feasibility of using aerial survey data, in conjunction with fishing vessel observation data, to provide a scientifically rigorous alternative survey approach for incorporation into the Pacific sardine stock assessment. The pilot survey report (Wespestad et al 2008), was presented to the SSC and CPS at their October 7th meeting. As noted in the November, 2008 PFMC briefing book, [the pilot survey was] "… favorably received and shows promise of being further developed into a new index of abundance for future assessments."

At the March 2009 PFMC meeting the Council recommended that an additional 1,200 mt of Pacific sardine be added to the 1,200 mt approved in 2009 management measures, providing a total 2,400 mt for sardine research, and that the additional research set aside be deducted proportionately from the 2009 harvest allocation for summer and fall directed fishing. This recommendation is awaiting NMFS rulemaking for approval.

Because of the small size of the 2008 pilot survey, it was possible to conduct limited survey work during the open fishing periods. It will not be possible, however, to conduct the expanded survey proposed for 2009 solely in this fashion. Competition for resources (spotter pilots and fishing vessels) and the short open fishing periods (which were only 38 days and 7 days for the second and third fishing periods in 2008, respectively) preclude an effective survey effort of the scope proposed for 2009 during the open fishing periods alone.

By allowing for sardine harvest during the closed periods, this EFP will enable both Northern and Southern sardine industry participants (each operating under the central direction of the project PI's) to expand the geographical area of survey coverage in 2009. The EFP fishery will allow the survey to be conducted in an orderly fashion, on days best suited for the aerial survey method. It will also permit industry resources (spotter planes and fishing vessels) to be focused on survey objectives without the distraction of economically directed fishing activities. By focusing on survey activities alone, it will be possible for industry participants to achieve the scientific objectives (e.g. obtaining an adequate survey sample size of point sets) as detailed in the Survey Design section of the main document.

In addition to the survey effort to be held during the EFP fishery, research point sets will also be conducted during open fishing periods, as is practicable, to further increase the survey sample size.

Under this EFP, all species caught within the limits authorized for the EFP will be retained. Participating vessels will deliver all species to participating processing/freezing facilities within the survey area. It is anticipated that these deliveries will occur into the ports of Astoria and Westport in the Northern area, and into the ports of Monterey and Moss Landing in the Southern area. Industry representatives Jerry Thon (Northern area) and Diane Pleschner-Steele (Southern area) will work with participating processing/freezing facilities on the sale of finished products. These sales will be used to aid in funding the survey, along with contributions from industry participants.

3. Justification For The Issuance Of The EFP

Under this EFP, the West Coast Sardine Survey (a consortium of Northern and Southern sardine industry participants) will perform a synoptic survey of the sardine biomass off the U.S. West Coast using aerial survey data in conjunction with fishing vessel observation data. This survey will expand upon the pilot scale work conducted in 2008, to develop an additional index of abundance for potential use in the Pacific sardine stock assessment. As noted above, the PFMC has indicated support for the further development of this work, and has voted to set-aside a research allocation totaling 2400 mt for the project. This recommendation is currently pending NMFS approval.

4. Broader Significance Of The EFP

The research to be conducted under this EFP will further test a new, scientifically rigorous method to survey the Pacific sardine resource, and will potentially provide valuable Pacific sardine stock assessment data to the Council and to NOAA Fisheries. This information is considered a high priority research and data need by NOAA Fisheries. This survey has been recommended by the Council and its sub-panels for review and consideration for use in developing an index of abundance for use in future stock assessments.

Sardine industry participants assert, based on the observations of fishing vessels and spotter pilots, that the survey to be conducted under this EFP will show a significantly greater Pacific sardine biomass than has been estimated under the current stock assessment model. If this assertion is proven to be true, the Pacific sardine HG may be expected to increase over that called for under the current stock assessment model. In any event this survey methodology appears promising as a valuable second index of abundance to expand understanding of the Pacific sardine resource.

A greater HG would provide benefits to all Pacific sardine and other CPS fisheries industry participants, including the fishermen, processers, spotter pilots, and all those employed by them, as well as to the coastal communities that support these industries. Due to the reduced HG in 2008, fishing was limited to 135 days in the first seasonal allocation period, 38 days in the second seasonal allocation period, and 7 days in the third seasonal allocation period, resulting in 185 lost fishing days. It is expected that fishing days will be further limited in 2009. These lost fishing days mean reduced employment for fishing vessel and processing plant crews, and reduced income for coastal communities.

5. Expected Total Duration Of The EFP

This EFP will be valid for one year, allowing for catching of Pacific sardine during the closed periods between seasonal allocations throughout the 2009 season.

6. Number Of Vessels Covered Under The EFP

Up to 8 participating vessels are identified on pages 14 and 15 of the main document. Routine operation of the survey in the Northern area will utilize the first two vessels listed, with the remaining two vessels standing by as back-up participants in the event of unexpected difficulties (e.g. engine failure, etc.). In the Southern area, the four vessels listed will be operating routinely; 2 boats w/ ES 60 capability and deeper nets, and two boats working with the hydroacoustic equipment.

Operating with multiple boats allows the survey to maximize effectiveness and reduce costs by targeting more than two sets per day (possible only if the plane has multiple boats to set). All participating boats will be working under the direction of the field project leaders, as supervised by the PIs; they will not have the opportunity to set at will.

7. Description And Quantity Of Species To Be Harvested Under The EFP

Under this EFP, participating vessels will target Pacific sardine exclusively. At the November 2008 meeting, the Council recommended that 1200mt of Pacific sardine be deducted from the 2009 Harvest Guideline prior to allocation and set aside for the dedicated sardine research to be conducted under this EFP. Subsequently, at the March, 2009 PFMC meeting, the Council modified this recommendation to increase the set aside to 2400 mt. This recommendation is awaiting NMFS rulemaking approval. If approved, the harvested quantity under this EFP will be limited to this Council recommended 2400 mt set-aside.

Bycatch is generally low in CPS fisheries because most CPS vessels fish with roundhaul gear, which encircles schools of fish with nets. This gear targets specific schools, which usually contain only one species. The most common incidental catches in the CPS fishery are other CPS species; Pacific mackerel, jack mackerel, Loligo squid, and Northern anchovy, may be encountered in small numbers and will be retained if captured. Quantities of these other coastal pelagics species are expected to be nominal, and within the harvest guidelines for those species. No other species are expected to be encountered or harvested under this EFP.

8. Description Of Mechanism To Ensure That Harvest Limits For Targeted And Incidental Species Are Not Exceeded

Under this EFP, participating vessels will deliver all species harvested to participating processing/freezing facilities within the survey area. Each participating vessel and participating processing/freezing facility will be responsible for collecting and recording catch data for each species delivered. Each participant will be responsible for the issuing and reporting of fish tickets to State authorities, as required by law.

Each participant will also be required to report all catch and fish ticket data to the survey Scientific Field Leader on a daily basis. Daily reporting is necessary to achieve the project objectives as specified in the Survey Design section of the main document. Individual point set catches will be kept in separate vessel holds and will be individually weighed at the dock upon landing. These individual point set catch weights will be tallied by the Scientific Field Leader to monitor the attainment of the project sample size goals which specify that point sets are to be collected in specific size categories (small and large) required under the survey design . This detailed accounting of daily catch will allow for a likewise detailed reporting to NMFS authorities and will ensure that the total sardine set aside amount of 2400 mt will not be exceeded. We propose that survey catch reporting to NMFS could begin on a weekly basis and would shift to a daily basis as the EFP approaches the set aside limit.

Any bycatch of other CPS species will be retained and a tally of the catch by species will be maintained by the Scientific Field Leader and reported to NMFS authorities on a weekly basis to ensure that the harvest guidelines of incidental species taken are not exceeded. We do not expect more than a nominal amount of incidental species to be taken.

The PFMC website notes that, according to NMFS Biological Opinion, "… fishing activities conducted under the CPS FMP are not likely to jeopardize the continued existence of any endangered or threatened species." It is not expected that any fishing under this EFP would have any effect on any endangered or threatened species.

9. Description Of Data Collection And Analysis Methodology

This information is described in detail in the Survey Design section of the main document.

10. Description Of How Participating Vessels Will Be Chosen

Our priorities for selecting vessels to participate under this EFP include: 1) vessels which have installed the necessary electronic equipment or have the capacity to install this equipment, and 2) vessels having the ability to separate the point sets into different hatches.

Additionally, participating vessels must meet the PFMC eligibility requirements for participating in an EFP fishery as described in Council Operating Procedure No. 19, and must also hold necessary State and Federal permits required for the fishing of Pacific sardine/Coastal Pelagic Species.

With the narrow time window for sampling it is desirable to have a field of boats we can draw on. The main reason to have several boats in this period is to maximize the number of point sets we can bring in. These boats will only be used for point sets. Some vessels do not have recording sounders, but do have sonar's that can measure school height and log it. Having a slate of potential vessels to draw from removes the possibility of losing operational days from problems like engine failure. Being able to pick vessels from the list provided and then reporting the vessels that will be operating at any given time to local enforcement will help to meet the EFP goals.

11. Approximate Times And Places Fishing Will Occur And Description Of Gear To Be Used For Each Participating Vessel

Under this EFP, participating vessels will have the opportunity to catch Pacific sardine under the Council recommended 2400 mt set-aside for dedicated sardine research (if approved by NMFS) during the closed periods between seasonal allocations.

Fishing will take place along the entire U.S. West Coast.

Participating vessels will use purse seine gear.

All fishing by participating vessels will be done in compliance with state and federal regulations, with the exception of the exemptions granted by this EFP.

Appendix V.
Response to comments following review of the survey design at the May, 2009 STAR Panel

Stage 1: Estimation of sardine school surface area

Species misidentification
Prior to the onset of production scale photo analysis, we will investigate the potential for school misidentification by photo analysis personnel. Images will be collected from areas where sardine are intermixed with other species (e.g. anchovy). Spotter pilots experienced with the problem of discriminating between species in aerial surveys of schooling fishes will aid in the preparation of a reference set of photographs with "known" species images. Photo analysis personnel will be trained to discriminate between species using the reference set of images. A set of test images will be compiled to evaluate within and between reader error in the parameters measured by the photo analysis personnel. The test images will be used in a double-blind experiment to measure variability in the entire process of image analysis, including: image enhancement, species identification, school enumeration, and area measurement. The development of a reference collection of photographs will be made carefully and validated, with the consideration that they will be used by photo analysis personnel for training purposes. Additional photos may be added to the reference collection in future years.

In addition to the above procedures, we will review the available data from other surveys to get a sense of species other than sardine that we may expect to see in our aerial survey. Data sources include: 1) trawl survey data (Emmett et al) and historical spotter data (Squire et al).

We also plan to evaluate the effect of altitude on species identification in the aerial survey. An experiment will be conducted with two airplanes to evaluate the altitude effect. One pilot will fly along a pre-designated test transect at the nominal survey altitude of 8,000 ft. and will keep a log of schools observed, by species. The second airplane will fly at a lower altitude (e.g. 500 ft) with an observer on board for detailed note taking. There will be no communication between pilots regarding schools observed during the transect, in order to keep the two sets of observations independent. Photographs taken from the two airplanes will be analyzed and schools will be identified and compared between the two sets of images on a school by school basis. Pilots will be permitted to use their logbooks and notes made during the transect to assist in analyzing the photographs collected for the comparison. The rate of between-pilot agreement in school identification will be determined from the comparison of the two sets of photographs. To eliminate the pilot effect from the test, the pilots will switch altitude positions and will repeat the procedure on subsequent transects.

School detection
We recognize that an unknown proportion of schools in any given area photographed will be too deep to detect via the proposed aerial survey method, and thus we acknowledge that the method will tend to underestimate total school surface area. Data collected from Stage 2 of the survey will include measurements of school height and vertical distribution in the water column. These data are a sample of schools visible from the aerial survey, and will be photographed at the nominal survey altitude of 8,000 ft. During the fishery, two vessels in each region (north and south) will be operating with ES-60 sounders logging data onto hard disks in continuous-

operation mode. These data will be processed to obtain a sample distribution of school height measurements (location of the top and bottom of the school in the water column). We expect that some of these schools will be distributed below the surface such that they would be too deep for aerial detection. Comparison of these data with the range of school height measurements from the 64 schools captured in Stage 2 point set sampling will give us a qualitative look at the rate of encountering schools not likely to be detected by the aerial survey method.

Weather conditions (e.g. marginal cloud cover, haze, elevated sea state) can conspire to create situations where schools would be likely to go undetected with the aerial survey method. We will determine a range of acceptable conditions for survey commencement (and termination). The survey pilots will judge whether or not conditions are acceptable for conducting surveys on a day to day basis. A detailed log will be kept to document when and why transects are terminated early due to prevailing weather conditions. From the Pilot Study we found that conditions such as glare and scattered cloud shadows over the ocean surface can be handled operationally by increasing the overlap rate of the photographic coverage. We have found that an image overlap rate of 60% is effective for dealing with this issue under most circumstances.

School area determination
Calibration of aerial images to measure the size of known objects was conducted during the pilot study in 2008 and will be continued in the 2009 survey year. We will extend the calibration experiments to evaluate the level of distortion on the periphery of the digital images. It is possible to address this issue by either a theoretical or an empirical approach. For example, a theoretical approach could involve collecting measurements from photographs to determine if objects on the image edge are on average smaller than objects found in the image center, and then deriving a theoretical relationship from this information. Alternately, an empirical approach could involve comparing real-world measurements of objects photographed in the image periphery with the sizes of the same objects as determined from the software analysis procedure.

Stage 2: Estimation of sardine biomass per unit surface area

Comparability to images in Stage 1
To ensure that the surface area measurements collected in Stage 2 are comparable to those collected in Stage 1 of the survey, we will collect the point set images at the same nominal altitude of the survey (i.e. 8,000 ft). Measurements of school surface area for point sets will be taken prior to purse seine vessel approach. Photographs will be taken throughout the point set process to examine potential school responses to the fishing vessel.

Target selection by pilot
Pilots will be given a daily schedule of school sizes to be targeted for capture. The pilots will maintain a logbook which will contain a record of every school identified for point set capture. To ensure Stage 2 sampling frame comparability to the set of images collected in Stage 1 of the survey, pilots will identify point set targets from the nominal survey altitude of 8,000 ft. In the event that the pilot identifies a school for point set capture at 8,000 ft, and the school is subsequently found to be a species other than sardine (e.g. when the pilot descends to a lower altitude for a better look, and after the vessel has approached the school for capture and is

capable of making on the water observations and jigging), this information will be duly recorded and used to estimate the sardine mis-identification rate of pilots in Stage 2 sampling.

Non-linear biomass to area relationship
A simple ratio estimator of biomass is not desirable if a pronounced non-linear relationship is observed in the biomass to area relationship. During the data analysis phase of the survey, we will evaluate the alternative of integrating biomass over the size range of schools observed. It will be important to ensure sufficient contrast in the sizes of schools sampled for this purpose. During the data analysis phase, we will look for non-linearity in the surface are to biomass relationship, and will subsequently make the determination whether a standard regression vs. an errors-in- variables approach is more appropriate for survey data analysis.

Regional differences
We anticipate regional differences will be observed in the parameters associated with both Stage 1 and Stage 2 sampling; however, we have no a priori information for effective stratification beyond a simple north-south treatment at this time. Thus, in this first survey year, we are distributing the sampling effort such that 1) an equal amount of area will be surveyed in the north and the south, and 2) an equal number of point sets will be collected in the north and the south. With the information we seek to collect in 2009, we may be able to reduce the variance on our parameter estimates by alternative stratification schemes going forward.

This survey design is limited to the area extending from Cape Flattery to Monterey Bay and nominally to 35 miles offshore. Sardine distribution is known to extend into Canada to the north, and into Mexico to the south, and may extend further offshore than 35 miles in some areas. Thus, we recognize that the survey will underestimate sardine abundance for this reason. We do not anticipate sampling north or south of the area specified; however, we will examine the east-west distribution by systematically extending a set of transect beyond 35 miles to determine the offshore distribution of sardine and the utility of the 35 mile cut-off for the design of future surveys.

Behavioral patterns
We recognize that sardine behavioral patterns will influence the variability of measurements that we will record during the aerial survey. For example, feeding, spawning, and transiting behaviors can be expected to result in different levels of aggregation/dispersion and thus will increase the variability in the surface area to biomass relationship. We expect that our ability to classify schools by behavioral category will improve as we obtain observations over a period of years and under a variety of conditions. The parameters we will be examining in our 2009 survey that have potential for beginning the development of a school classification scheme include: 1) school height (from ES-60 data) and 2) school shape (i.e. perimeter to area; circularity).

Abundance Estimation

Edge effects – procedure for handling schools not completely within the photograph

Edge effects are not a problem on the top and bottom of the images because image overlap provides for multiple observations of schools in the direction of aircraft travel; however, schools will encountered from time to time on the side edges of the images will cut off (i.e. not photographed in their entirety. This is a problem because of the potential for non-linearity in the surface area to biomass relationship. This situation is not uncommon in quadrat based sampling and methods for dealing with it are available in the survey design literature. We will review the literature and will establish an appropriate procedure for data reduction and analysis to deal with this issue. Two methods were suggested by the STAR panel. One method would involve drawing lines some distance from the edge (e.g. 1 inch) and re-defining the area-swept using the new (reduced) width. This approach allows for empirical measurements of schools straddling the edges. Another method would involve drawing a line down the middle of the image and studying the edge effect by examining schools that are split by the line.

Calculation of total biomass
As noted above, we will evaluate non-linearity in the surface area to biomass relationship. If deemed appropriate, we will integrate biomass over the range of observed school sizes.

Other

Comparison of pilot estimate vs. measured point set tonnage
In the survey logbook to be maintained by the pilots, the estimate of school tonnage prior to each point set will be recorded. This information will be summarized and compared to actual landed point set tonnage.

Quality Assurance

To insure accurate data and prevent operation errors the scientific technical team has devised the following procedures:

1. A vessel contact that sets forth the duties and responsibilities of the vessel and the scientific party. This insures that the vessel is cognizant of the operational plans and interaction with the scientific party and the pilot on data collection and processing. The operational contract will also be the base document for attaching modifications and daily operational instructions. <u>An example of this document is attached.</u>
2. A similar document is being assembled for pilots for operational instructions with equipment checklist and camera operational instructions.
3. A field reference for biological data collection and data handling and processing.

The P.I.s will review project data on a weekly basis to insure that data is collected consistently and in conformity with sampling protocols.

Attachment – Example contract for vessels laying forth operational requirements.

TIME CHARTER AGREEMENT AND VESSEL OPERATING AGREEMENT

This TIME CHARTER AGREEMENT is entered into by and between the vessel operator and NW Sardine Survey LLC with reference to the following facts:

A. Owner owns the fishing vessel _______, Official No. ________ (the "Vessel"). Charterer wishes to hire a fishing vessel to conduct certain research operations in the US EEZ off Oregon and Washington in fulfillment of the Experimental Fishing Permit (EFP) to be issued by National Marine Fisheries Service of the U.S. Department of Commerce ("NMFS") to Charterer in order to assess the abundance of sardine in the region of survey.

B. Charterer distributed that certain Request For Proposals (the "RFP") soliciting bids from fishing vessel owners interested in providing the vessel and services necessary to satisfy Charterer's obligations under the terms of the EFP and this agreement. Owner has reviewed and responded to the RFP, and Charterer is willing to hire Owner and the Vessel to fulfill Charterer's obligations under the EFP, on the following terms and conditions.

Now, therefore, the parties agree as follows:

1. Nature of Charter. On the terms and conditions set forth in this Charter, Owner agrees to let and Charterer agrees to hire the Vessel on a time charter basis. Nothing in this agreement shall be construed as a bareboat charter or demise of the Vessel to the Charterer. Notwithstanding any provision to the contrary herein, as between Owner and Charterer, Owner shall at all times remain in possession, command and control of the Vessel, and shall be solely responsible for all costs related to crew wages and injury claims. Owner shall supply, operate, maintain, repair and insure the Vessel and its equipment, gear and appurtenances, other than as specifically set forth herein. Owner shall pay all costs associated with Vessel operations during the term of this Charter, other than as specifically set forth herein.

2. Vessel Condition and Operations.

a. The Survey Plan is attached hereto as <u>Exhibit 1</u>, and are hereby incorporated into this agreement by reference.

b. Owner warrants that the Vessel and its equipment shall throughout the term of this Charter meet or exceed the requirements set forth in the SURVEY PLAN and EFP. Owner shall provide Coast Guard approved Arctic-type survival suits for the survey crew. Owner shall provide workspace, power for computers.

c. Throughout the term of this Charter, Owner shall staff the Vessel with a crew of not less than 3 individuals, including a Captain with a minimum of three years of seine fishing experience as a master of a comparably sized vessel in Pacific Ocean, and at least three years total experience as a fishing vessel master; a lead fisherman, with experience in seine fishing; a fisherman seine fishing experience.

d. Owner shall operate the Vessel and employ its crew to safely perform Charterer's obligations under the EFP in accordance with the Survey Plan, subject to the directions of the Scientist Staff (Tom Jagiello, Ryan Howe, and Vidar Wespestad) in matters other than navigation and the safety of the Vessel and its crew. Owner acknowledges that seine sets and associated survey crew activity are expected to take up to approximately 12 hours per day, and that the Vessel will frequently be required to travel from survey sites during periods outside of the survey crew's normal 12 hour working day. At the commencement of this Charter, the Vessel shall be ready and waiting at Astoria, Oregon or nearby ports such as Newport, Oregon, and Ilwaco, or Westport, Washington.

(1). During Test Sets the vessel will set on schools as directed by the scientific field party chief. The set determination will be decided between the pilot and the scientist in consultation with the vessel captain. Once a set has been determined the vessel will follow the direction of the pilot during a set. The scientist will direct on deck sampling and stowage of the catch. Prior to starting operations for the day the vessel will be provided with a schedule of hauls that include general size of sets. Set design will be so that a vessel can catch a maximum amount for each trip, but in a manner that insures scientific integrity of each individual haul and avoids mixing samples. All sets will be segregated to allow accurate weight measurement at a shore plant; unless, the vessel has bin-boards or some other system to physically isolate catches from each set.

(2). Vessel captains will log and provide the scientist or the setting pilot, if there is no scientist on board, the haul information relating to school depth, school height, vessel estimate of school size. The fish will then be stored in a separate hole for total tonnage and biological sampling at a designated processing plant.

(3). Vessels chartered to do ES 60 surveys will be required to run track lines to measure schools. This work may be done in conjunction with aerial test sets, or may require running transects from the coast to offshore and could require remaining at sea for 2 to 3 days. The transects and activities will be developed into specific survey instructions with the Captain in advance of specific transect. In the absence of a scientist on board the crew will be directed to set on schools determined by the pilot for spot sets or species identification.

(4) In all instances all charter vessels will sign and retain a copy of this agreement and all specific daily survey instructions that direct survey operations and sampling protocol. Failure to follow protocols is agreed by both parties to be sufficient ground for termination of this charter agreement.

3. Charter Term. The term of this Charter shall commence as of July 1, 2009 at 0700 hours and shall terminate as of the earlier of the (i) termination by Owner or Charterer in accordance with Section 3.a or 3.b, below, or (ii) September 1, 2009

a. Charterer may terminate this Charter by written notice to Owner upon the occurrence of any one or more of the following:

(1) non-issuance of the EFP for any reason;

(2) the Vessel suffering loss, damage, breakdown, or arrest that the Charterer reasonably concludes will prevent the Vessel from fulfilling the terms of this Charter or the EFP and the Cruise Plan;

(3) failure of Owner to crew, equip, operate, or maintain the Vessel in accordance with the terms of this Charter, the EFP, or the directions of the Scientists identified above;

(4) a breach by Owner of any material term or condition of this Charter or of any of Owner's covenants or warranties given hereunder not cured within ten (10) days of Owner receiving notice of breach from Charterer; or

(5) the filing of a petition in bankruptcy by or against Owner, entry of an order adjudging Owner bankrupt, Owner making a general assignment for the benefit of creditors, appointment of a receiver for Owner of any kind, or filing by Owner of a petition for reorganization under any applicable bankruptcy law.

b. Owner may terminate this Charter by written notice to Charterer upon the occurrence of any one or more of the following:

(1) the Vessel suffering loss, damage breakdown or arrest that Owner reasonably concludes will prevent the Vessel from fulfilling the terms of this Charter or the EFP and survey plan; or

(2) a breach by Charterer of any material term or condition of this Charter not cured within ten (10) days of Charterer receiving notice of breach from Owner.

4. Charter Hire. In consideration for the services to be provided and costs to be borne by the Owner hereunder, The Owner will be paid a daily rate the duration of this contract for the charter based on a term of 12 hour fishing days. Charter may prorate payment to vessels in the event that a full fishing day cannot be achieved due to vessel breakdown. The Hire shall be

paid by the Charterer NW Sardine Survey LLC at a rate negotiated between the owner and the Charterer. Payment will be made within fifteen (15) days of Owner delivering the related invoice to the Charterer.

a. Suspension of Hire. If during the term of this Charter the Vessel for any reason becomes temporarily unable to conduct the operations required under the EFP and the Survey Plan, and Charterer then determines there is a reasonable prospect that the Vessel will be able to resume operations in a period of time acceptable to them, Charterer may, in lieu of terminating this Charter, pay no Hire for the period the Vessel ceases operations.

5. Fuel and Lubrication Oil. Owner agrees to pay the costs of fuel and lubricating oil consumed by the Vessel during the term of this Charter.

6. Gear. NW Sardine Survey LLC has agreed to provide the following gear: all fish sampling gear. Owner shall provide the Vessel equipped with seines, seine skiff, and associated gear needed to set and retrieve a sardine seine, all in good working order, in accordance with the Survey Plan and the EFP.

7. Survey Crew Food. Owner agrees to provide meals on a regular basis.

8. Insurance. Owner shall throughout the full term of this Charter maintain at its own expense insurance protecting Charterer against all claims or liabilities arising out of or related to chartering, owning, operating, or maintaining the Vessel, or conducting any of the activities contemplated under this Charter and the EFP, including but not limited to protection and indemnity insurance, including pollution liability coverage, in an amount not less than Five Million Dollars ($5,000,000.00). Charterer shall be named as additional insured on such policies for the term of the Charter. Owner shall specifically arrange to have all survey personnel aboard the Vessel covered by such insurances. All deductible amounts shall be paid by Owner. A certificate of insurance evidencing the coverages referenced above shall be delivered to Charterer not less than three (3) days before the effective date of this Charter. All insurance maintained under this Section shall require at least thirty (30) days prior written notice to Charterer to be cancelled or modified.

9. Indemnification. Owner shall indemnify, defend and hold NMFS, Charterer and its members, directors, officers, employees, agents and contractors harmless against all claims, demands, actions, damages, liabilities and expenses of whatever nature (including without limitation attorneys' fees and related costs) arising out of or related to (i) any breach by Owner of any provision of this Charter; (ii) any lien of whatever nature arising against the Vessel while this Charter remains in effect; (iii) injuries to or deaths of crew members, including all members of the survey crew; (iv) loss of or damage to any survey gear, equipment or supplies, or personal property of the crew, including the survey crew; and (v) operation of the Vessel while this Charter remains in effect.

10. Governing Law. This Charter shall be interpreted and enforced in accordance with the maritime law of the United States.

11. Entire Agreement. This Charter is the entire agreement among the parties hereto as to the matters addressed herein and supersedes all prior negotiations, representations, or agreements, whether written or oral. In the case of a conflict between this Charter and the EFP, or the SURVEY PLAN, this Charter shall control. This Charter may be amended or modified only by written agreement between the parties.

12. Notices. Any notice to be given pursuant to this Agreement by any party to the other shall be effected either by personal delivery, by mail or by telefacsimile transmission ("fax"). Notices given by personal delivery shall be deemed given when delivered. Notices given by fax shall be deemed delivered when transmitted with receipt confirmation. Notices delivered by mail shall be deemed delivered three (3) business days after being sent prepaid first class mail. Notices shall be delivered as follows:

Owner:

Owner

Address
Address
Phone

Charterer:

Northwest Sardine Survey LLC

13. Effect of Partial Invalidity. A determination that any term or provision of this Charter is invalid or unenforceable shall not affect the validity or enforceability of the remainder of this Charter.

14. Counterparts. This Charter may be executed in counterparts, which, when taken together, shall have the same validity as a fully executed original.

15. Arbitration.

a. Any controversy, claim, or dispute arising out of or relating to this Charter or the breach thereof shall be resolved by arbitration in King County, Washington pursuant to R.C.W. 7.04 et seq., or its successor statute, and judgment upon the award rendered by the arbitrator may be entered in any court adjudication of all matters submitted to arbitration. The arbitrator shall have broad authority to fashion an equitable remedy, including the authority to award specific performance.

b. The parties shall select a single arbitrator within ten (10) days of the date a written demand for arbitration is received by either party from the other. In the event the parties fail to select an arbitrator within said 10-day period, either party may make immediate application to the King County Superior Court for the appointment of an arbitrator. The parties agree to be bound by the Court's appointment of an arbitrator.

c. It is the intent of the parties by this arbitration provision to provide for a speedy and efficient means of resolving disputes.

OWNER:	CHARTERER:
Name.	Northwest Sardine Survey, LLC
By ______________________	By______________________
Its date	Its date

Agenda Item H.2.a
Attachment 2
June 2009

NOAA Technical Memorandum NMFS

NOVEMBER 2008

SPAWNING BIOMASS OF PACIFIC SARDINE *(Sardinops sagax)* OFF U.S. IN 2008

Nancy C.H. Lo
Beverly J. Macewicz
David A. Griffith
Richard L. Charter

NOAA-TM-NMFS-SWFSC-430

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

The National Oceanic and Atmospheric Administration (NOAA), organized in 1970, has evolved into an agency that establishes national policies and manages and conserves our oceanic, coastal, and atmospheric resources. An organizational element within NOAA, the Office of Fisheries is responsible for fisheries policy and the direction of the National Marine Fisheries Service (NMFS).

In addition to its formal publications, the NMFS uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series, however, reflect sound professional work and may be referenced in the formal scientific and technical literature.

NOAA Technical Memorandum NMFS
This TM series is used for documentation and timely communication of preliminary results, interim reports, or special purpose information. The TMs have not received complete formal review, editorial control, or detailed editing.

NOVEMBER 2008

SPAWNING BIOMASS OF PACIFIC SARDINE *(Sardinops sagax)* OFF U.S. IN 2008

Nancy C.H. Lo
Beverly J. Macewicz
David A. Griffith
Richard L. Charter

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SUMMARY

The spawning biomass of the Pacific sardine (*Sardinops sagax*) in April - May 2008 was estimated by the daily egg production method (DEPM) to be 135,301 mt (CV = 0.43) for an area of 667,162 km^2 off the west coast of North America from San Diego, U.S.A. to Cape Flattery, Washington (30°- 48.47°N), primarily for the area south of 39.5°N. For the entire survey area, the daily egg production estimate (P_0) was 0.218/.05m^2 (CV = 0.22), although no eggs were collected in the area north of latitude 39.5°N. The daily specific fecundity was calculated as 21.82 (number of eggs/population weight (g)/day) using the estimates of reproductive parameters from 187 mature female Pacific sardine collected from 12 positive trawls: *F*, mean batch fecundity, 29802 eggs/batch (CV = 0.06); *S*, fraction spawning per day, 0.118 females spawning per day (CV = 0.31); W_f, mean female fish weight, 102.21 g (CV = 0.06); and *R*, sex ratio of females by weight, 0.631 (CV = 0.09). The standard survey area off California, from San Diego to San Francisco (CalCOFI lines 95 to 60), in 2008 was 297,949 km^2. For the standard area, using the egg production estimate of 0.43/0.05m^2 (CV = 0.21) and the daily specific fecundity of 21.82 (number of eggs/population weight (g)/day), the spawning biomass was estimated to be 117,426 mt (CV=0.43). Only a single sardine was caught north of CalCOFI line 60. The spawning biomass north of CalCOFI line 60, near San Francisco, was 17,041 mt. In 2008, trawling was conducted randomly or at CalCOFI stations, which resulted in sampling adult sardines in both high (Region 1) and low (Region 2) sardine egg density areas.

The estimates of spawning biomass of the Pacific sardine off California in 1994 - 2008 are 127,000 mt, 80,000 mt, 83,000 mt, 410,000 mt, 314,000 mt, 282,000 mt, 1.06 million mt, 791,000 mt, 206,000 mt, 485,000 mt, 300,000 mt, 600,000 mt, 837,000 mt, 392,00 mt and 117,000 mt (for the standard DEPM area), respectively. Therefore, the estimates of spawning biomass have been fluctuating, peaked in 2000 and 2006 and have been declining in the recent three years. The time series of spawning biomass starting from 1985 is one of the fishery-independent inputs to the annual stock assessment of the Pacific sardine

INTRODUCTION

The spawning biomass of the Pacific sardine (*Sardinops sagax*) during 1986 (Scannel et al. 1996), 1987 (Wolf 1988a), 1988 (Wolf 1988b), 1994 (Lo et al. 1996), and 1996 (Barnes et al. 1997) was estimated independently using the daily egg production method (DEPM: Lasker 1985). The DEPM estimates spawning biomass by: 1) calculating the daily egg production from ichthyoplankton survey data, 2) estimating the reproductive parameters of females from adult fish samples, and 3) calculating the biomass of spawning adults. Before 1996, sardine egg production was estimated from CalVET plankton net samples. Adult fish were sampled in various ways prior to 1996 to obtain specimens for batch fecundity, spawning fraction, sex ratio, and average female fish weight (Wolf 1988a, 1988b; Scannell et al. 1996; Macewicz et al. 1996; Lo et al. 1996).

Since 1996, in addition to CalVET and Bongo nets, the Continuous Underway Fish Egg Sampler (CUFES; Checkley, et al. 1997) has been used as a routine sampler for fish eggs, and data for sardine eggs collected with CUFES have been incorporated in various ways depending on the survey design in the estimation procedures of the daily egg production. In the 1997 sardine egg survey (Hill et al. 1998, Lo et al. 2001), CUFES was used to allocate CalVET tows in an adaptive sampling plan. From 1998 to 2000, data for sardine eggs collected with both CalVET and CUFES during each April California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruise were used to estimate daily egg production (Hill et al. 1999). Use of the full data sets from both samplers in the DEPM can be time consuming. Furthermore, the CUFES samples are exclusively from 3 m depth and it is not clear whether the distributions of sardine egg stages from CUFES samples are representative. Use of the CUFES data also requires an estimated conversion factor from eggs/min to eggs/0.05m^2. Starting with the 1999 April CalCOFI survey, an adaptive allocation survey design similar to the 1997 survey was implemented. In this design, CalVET tows are added in areas where they were not preassigned if sardine egg densities in CUFES collections are high.

Since 2001, a cost-effective alternative has been adopted to retain the DEPM index, but in a revised form that reduces effort in calculation and egg staging for the CUFES collections. This revised DEPM index only uses CalVET samples of eggs and yolk-sac larvae and Bongo samples of yolk-sac larvae in the high density area (Region 1) to provide an estimate of P_0, the variance of which may be large due to small sample size (fewer than 100 plankton tows). Adult samples were collected sporadically in 1997, 2001, and 2002.

Since 2004, full-scale surveys have been conducted for collection of Pacific sardine eggs, larvae, and adults to estimate the spawning biomass of Pacific sardine in the area off California from San Diego to San Francisco (Lo and Macewicz 2004, 2006; Lo et al. 2005,2006, 2007a and 2007b; Hill et al. 2005, 2006, 2007). The 2008 April survey was extended to Cape Flattery, Washington, to cover the majority of the area occupied by the sardine population off the west coast of North America. To better understand the spatial distribution of the population, length distribution and movement of Pacific sardines along the west coast of the United States (U.S.), through the year, a coast-wide California Current Ecosystem (CCE) survey was conducted in spring and summer of 2008. During March-April 2008 two NOAA ships were used: the *David Starr Jordan* covered the area from San Diego to San Francisco and the *Miller Freeman* covered the northern part from Cape Flattery, WA to San Francisco, CA while during July-August 2008 the *David Starr Jordan* covered the whole area. In this report, we provided the estimate of the spawning biomass and related biological information for the Pacific sardine off the west coast of the U.S. based on the 2008 April CCE survey.

MATERIALS AND METHODS

Data

The spring 2008 CCE survey was conducted aboard two NOAA research vessels: the *David Starr Jordan* (March 24-May 1) to cover the area off California from San Diego to San Francisco (CalCOFI lines 93.3 to 62.3) and the *Miller Freeman* (April 1-30) to cover the area from Cape Flattery, Washington to San Francisco (48.47°N to 36.6°N, down to CalCOFI line 63.3). During the CCE surveys, CalVET tows, Bongo tows and CUFES and trawls were conducted aboard both vessels. Prior to the CCE survey, the routine April CalCOFI survey was carried out aboard *David Starr Jordan* from March 24-April 9 to cover six lines from 93.3 to 76.6 and only CalVET and Bongo tows were taken. Data from both CCE and CalCOFI suryes were included in estimation of spawning biomass of Pacific sardines.

In addition to sardine eggs and yolk-sac larvae collected with the CalVET net, yolk-sac larvae collected with the Bongo net have been included to model the sardine embryonic mortality curve since 2000. Beginning in 2001 (Lo 2001), the CUFES data from the ichthyoplankton surveys have been used only to map the spatial distribution of the sardine spawning population with the survey area post-stratified into high density (Region 1) and low density (Region 2) areas according to the egg density from CUFES collections. Staged eggs from CalVET tows and yolk-sac larvae from CalVET and Bongo tows in the high density area have been used to model the embryonic mortality curve in the high density area and later converted to the daily egg production, P_0, for the whole survey area.

During the 2008 survey, thirty three distinct transects were occupied by the research vessels. The David Starr Jordan occupied 15 lines out of 17 lines planned and the Miller Freeman occupied 18 lines. The distance between lines ranged from 20 to 40 nm. Due to weather condition, some lines were not fully occupied by the Jordan, e.g. line 80, 70, 60, and others. For the CCE survey, CalVET tows were taken at 4 nm intervals on each line after the egg density from each of two consecutive CUFES samples exceeded 1 egg/min, and CalVET tows were stopped after the egg density from each of two consecutive CUFES samples was less than 1 egg/min. The threshold of 1 egg/min was reduced from the number used in years prior to 2002 (2 eggs/min) to increase the area identified as the high density area and, subsequently, to increase the number of CalVET samples. One egg/min is equivalent to two to seven eggs/CalVET tow, depending on the degree of water mixing. This adaptive allocation sampling was similar to that used inthe 1997 survey (Lo et al. 2001). As the threshold changed beginning in 2002, caution should be taken when the size of the area of Region 1 is compared.

The size of the whole survey area was 677,162 km^2. Only the area south of 39.5°N latitude (396,517 km^2) was used to estimate the initial P_0 because no eggs or adults were collected north of 39.5°N. This area was post-stratified into two regions: Region 1, the high egg density area, and Region 2, the low egg density area. Region 1 encompassed the area where the egg density in CUFES collections was at least 1 egg per minute. The sizes of Region 1 and the entire survey area were calculated using the formula for a trapezoid area based on the distance between CalCOFI lines and the distance between CalCOFI stations. The area of Region 1 was 53,514 km^2, 13.5% of the area south of 39.5°N (396,517 km^2). The rest of the area south of 39.5°N was Region 2 (343,003 km^2, Figure 1). We also estimated the spawning biomass in the standard DEPM survey area off California to be compared with the past years. Over the years, although the standard DEPM survey area has varied in size, it is approximately from San Francisco (about 37.8°N) to San Diego or between CalCOFI lines 60 and 95. For 2008, this area was calculated as 297,949 km^2.

A total of 1643 CUFES samples were collected from both the *Miller Freeman* (591) and *David Starr Jordan* (1052) cruises over the whole survey area. For the area south of 39.5°N, 1190 CUFES samples were taken by both the *Miller Freeman* (138) and *David Starr Jordan* (1052). CUFES sampling intervals ranged from 1 to 60 minutes with a mean of 27.84 minutes and median of 30 minutes. The total number of CalVET tows was 240 for the entire survey area, 170 south of 39.5°N and 151 in the regular DEPM survey area, south of line 60. A total of 85 CalVET samples caught at least one egg (Table 1). Egg densities from each CalVET sample and from the CUFES samples taken within an hour before and after the CalVET tow, were paired and used to derive a conversion factor (*E*) from eggs/min of CUFES sample to CalVET catch (eggs/tow). We used a regression estimator to compute the ratio of mean eggs/min from CUFES to mean eggs/tow from CalVET: $E = \mu_y / \mu_x$ where *y* is eggs/min and *x* is eggs/tow.

For adult samples, the survey plan was to use the *Miller Freeman* and the *David Starr Jordan* to conduct 2-4 trawls a night either at pre-assigned stations, or near regular CalCOFI stations or at random sites on the survey line regardless of the presence of sardine eggs in CUFES collections from April 1-May 1, 2008. This survey design would have enabled us to obtain an estimate of biomass from trawl catches using the swept trawl area method as well as spawning biomass using the DEPM and is different from the adaptive trawling conducted in 2004 and 2005 where the presence of sardine eggs in CUFES collections identified potential trawl sites. On both ships trawling was conducted at night near the surface (0-6 fathoms) using a Nordic 264 mid-water trawl. The *Miller Freeman* completed 42 trawls. Bad weather encountered by the *David Starr Jordan* reduced the amount of survey time, and hence the number of trawls completed was only 29. For the whole CCE survey, 71 trawls were conducted and the 13 nighttime trawls positive for Pacific sardines were located in the area south of 39.5°N (Figure 1).

Up to 50 sardines were randomly sampled from each positive trawl (Table 2). If necessary, additional mature females were collected to obtain 25 mature females per trawl for reproductive parameters or for use in estimating batch fecundity. Each fish was sexed, standard length (mm) and weight (g) were measured, otoliths were removed for aging, tissue was preserved in 95% ethanol for genetics, and for females their ovaries were removed and preserved in 10% neutral buffered formalin. Each preserved ovary was blotted and weighed to the nearest milligram in the laboratory. Ovary wet weight was calculated as preserved ovary weight times 0.78 (unpublished data, CDFG 1986). A piece of each ovary was removed and prepared as hematoxylin and eosin (H&E) histological slides. All slides were analyzed for oocyte development, atresia, and postovulatory follicle age to assign female maturity and reproductive state (Macewicz et al. 1996).]

Daily egg production (P_0)

Because no eggs or adults were collected north of 39.5°N, the spawning biomass was most likely distributed in the survey area south of 39.5°N. For continuity and comparison purposes, we also estimated the spawning biomass for the standard DEPM survey area (i.e., the area from CalCOFI line 60 to San Diego) which has been surveyed for estimation of the annual spawning biomass of Pacific sardine in the past. For each area, appropriate parameter estimates required by the DEPM were obtained.

Similar to the 2001-2005 procedure (Lo 2001), we used the net tow as the sampling unit. Sardine eggs from CalVET tows and sardine yolk-sac larvae from both CalVET and Bongo tows in Region 1 were used to compute egg production, primarily based on data from 12 transects (Figure 1). In Region 1, a total of 65 out of 76 CalVET samples contained at least 1 sardine egg; these eggs were examined for their developmental stages (Figure 2 and Table 1).

Based on aboard-ship counts of sardine eggs in CUFES samples, 556 of the 1643 collections were positive for sardine eggs over the whole survey area (556 of 1190 collections S of 39.5°N). In Region 1, there were 232 positive CUFES collections out of 243 total collections. In Region 2, 324 of the total 1400 collections (324 of 947, S of 39.5°N) were positive (Table 1).

For modeling the embryonic mortality curve, yolk-sac larvae (larvae $\leq$5 mm in preserved length) were included assuming the mortality rate of yolk-sac larvae was the same as that of eggs (Lo 1986). Yolk-sac larval production was computed as the number of yolk-sac larvae/0.05m^2 divided by the duration of the yolk-sac stage (number of larvae/0.05m^2/day), and the duration was computed based on the temperature-dependent growth curve (Table 3 of Zweifel and Lasker 1976) for each tow. For yolk-sac larvae caught by the Bongo net, the larval abundance was further adjusted for size-specific extrusion from 0.505 mm mesh (Table 7 of Lo 1983) and for the percent of each sample that was sorted. The adjusted yolk-sac larvae/0.05 m^2 was then computed for each tow and was termed daily larval production/0.05 m^2.

In the whole survey area, 61 of 240 (of 170, S of 39.5°N) CalVET and 25 of 155 (of 85, S of 39.5°N) Bongo samples had at least one yolk-sac larva (Figure 3). In Region 1, 47 of 76 CalVET and 10 of 10 Bongo samples were positive for yolk-sac larvae. In Region 2, 27 of 180 (of 110, S of 39.5°N) CalVET and 15 of 145 (of 75, S of 39.5°N) Bongo samples were positive for yolk-sac larvae (Table 1). For the standard DEPM survey area (CalCOFI line 95 to CalCOFI line 60), please see Table 1.

Daily egg production for the whole survey area (30°N – 48.47°N)

Because no eggs were collected in the area north of latitude 39.5°N, the overall P_0 (daily egg production/0.05m^2) was first computed for the area south of 39.5°N and then prorated to the whole survey area simply by multiplying P_0 by the area south of 39.5°N divided by the size of the whole survey area.

Daily egg production in Region 1 ($P_{0,1}$) for the area south of 39.5°N

Sardine eggs and yolk-sac larvae and their ages were used to construct an embryonic mortality curve (Lo et al. 1996). Sardine egg density for each developmental stage was computed based on CalVET samples (Figure 2). The density of eggs in 2008 was lower than in previous years (Lo 2003; Lo and Macewicz 2002, 2004,2005 and 2006, Lo et al. 2007a and 2007b). Like most past years, the density of eggs in stage 6 was highest among all stages, followed by the densities of eggs in stage 3 and stage 11. The average sea surface temperature for CalVET tows with ≥ 1 egg from the *David Starr Jordan* was 13.3°C which is low compared with other years (Lo et al. 2007b). A temperature-dependent stage-to-age model (Lo et. al. 1996) was used to assign age to each stage. Sardine eggs and estimated ages were used directly in nonlinear regression. Eggs ≤ 3-h old and eggs older than 2.5 days were excluded because of possible bias. The average sea surface temperature for CalVET tows from the *David Starr Jordan* was 13.1°C while from the Miller Freeman it was 9.6°C for all tows.

The sardine embryonic mortality curve was modeled by an exponential decay curve (Lo et al. 1996):

$$P_t = P_{\mathbf{0}} e^{-zt} \qquad [1]$$

where P_t is either eggs/0.05m^2/day from CalVET tows or yolk-sac-larvae/0.05m^2/day from CalVET and Bongo tows, and t is the age (days) of eggs or yolk-sac larvae from each tow. A weighted nonlinear regression was used to estimate two parameters in equation (1) where the weights were 1/SD. The standard deviation (SD) of eggs was 2.06, 3.7, and 3.8 for day one, day two and day three age groups from CalVET samples, respectively, and SD for yolk-sac larvae was 0.67 and 1.03 from CalVET and Bongo samples, respectively.

A simulation study (Lo 2001) indicated that $P_{0,1}$ computed from a weighted nonlinear regression based on the original data points has a relative bias (RB) of -0.04 of the estimate, where the RB = (mean of 1,000 estimates - true value)/mean of 1,000 estimates. Therefore the bias-corrected estimate of egg production in Region 1 is calculated: $P_{0,1,c} = P_{0,1} * (1- \mathrm{RB}) = P_{0,1} *(1.04)$, and SE ($P_{0,1,c}$) = SE($P_{0,1}$) * 1.04.

Daily egg production in Region 2 ($P_{0,2}$) for the area south of 39.5°N

Although 94 CalVET samples were taken in Region 2, only 20 tows had ≥ 1 sardine egg, ranging from 1 to 8 eggs per tow (Table 1). Therefore, we estimated daily egg production in Region 2 ($P_{0,2}$) as the product of the bias-corrected egg production in Region 1 ($P_{0,1,c}$) and the ratio (q) of egg density in Region 2 to Region 1 from CUFES samples, assuming the catch ratio of eggs/min from CUFES to eggs/tow from CalVET was the same for the whole survey area:

$$P_{\mathbf{0,2}} = P_{\mathbf{0,1},c}\, q \qquad [2]$$

$$q = \frac{\sum_i \frac{\bar{x}_{2,i}}{\bar{x}_{1,i}} m_i}{\sum_i m_i} \qquad [3]$$

$$\mathrm{var}(q) = \frac{[n/(n-1)]\sum_i m_i^2 (q_i - q)^2}{\left(\sum_i m_i\right)^2}$$

where q is the ratio of eggs/min between the low density and high density areas, m_i was the total CUFES time (minutes) in the i[th] transect, $\bar{x}_{j,i}$ is eggs/min of the i[th] transect in the j[th] Region, and $q_i = \frac{\bar{x}_{2,i}}{\bar{x}_{1,i}}$ is the catch ratio in the i[th] transect. The estimates of q were computed from a total of 11 transect lines occupied by the *David Starr Jordan*; most lines occupied by the *Miller Freeman* south of 39.5°N had very low eggs/min.

Daily egg production (P_0) for the area south of 39.5°N and for the whole survey area

P_0 was computed as the weighted average of $P_{0,1}$ and $P_{0,2}$:

$$\begin{aligned} P_0 &= \frac{P_{0,1,c}A_1 + P_{0,2}A_2}{A_1 + A_2} \\ &= P_{0,1,c}w_1 + P_{0,2}w_2 \\ &= P_{0,1,c}[w_1 + qw_2] \end{aligned} \qquad [4]$$

and

$$mse(P_0) = mse(P_{0,1,c})(w_1 + w_2 q)^2 + P_{0,1,c}^2 w_2^2 V(q) - mse(P_{0,1,c}) w_2^2 V(q)$$

(Goodman 1960) where $mse\,(P_{0,1,c}) = \mathrm{v}(P_{0,1}) + \mathrm{bias}^2 = \mathrm{v}(P_{0,1}) + (P_{0,1}\,\mathrm{RB})^2$

and $w_i = \frac{A_i}{A_1 + A_2}$, and A_i is the area size for i = 1 or 2.

The above P_0 was computed for the area S of 39.5°N. The estimate of P_0 for the whole survey area is P_0 times (the area S of 39.5°N divided by the total survey area) = P_0 x (396,517/677,162) = P_0 x 0.59.

Daily egg production for the standard DEPM survey area off California.

$\boldsymbol{P_{0,1}}$ for the region 1 and $\mathbf{P_{02}}$ region 2 were the same as the estimates for the area up to N.39.5

with area size of region 2 (244,435 km^2) smaller than that (343,003 km^2) for the area up to 39.5°N.

A total of 75 CalVET samples were taken in Region 2, and 20 tows were positive for sardine (Table 1). The number of positive tows was higher than any of the previous surveys.

The P_0 for the standard DEPM survey area off California (from about San Diego to San Francisco) was obtained based on equation (4). All estimates of egg production were adjusted for bias-correction.

Adult parameters

Four adult parameters are needed for estimation of spawning biomass: 1) daily spawning fraction or the number of spawning females per mature female per day (*S*); 2) the average batch fecundity (*F*); 3) the proportion of female fish mature by weight (sex ratio, *R*); and 4) the average weight of mature females (g, W_f). Population values for *S, R, F* and W_f were estimated by methods in Picquelle and Stauffer (1985). Daily specific fecundity (number of eggs per population weight (g) per day) is $(RSF)/W_f$. Correlations among all pairs of adult parameters were calculated for computing the variance of the estimate of spawning biomass (Parker 1985). An MS ACCESS[1] Visual Basic program (Chen et al. 2003) was used to summarize the trawl adult parameters, calculate adult parameter correlations and covariance, and estimate spawning biomass and its coefficient of variation.

Spawning fraction (S). A total of 187 mature female sardines were analyzed and considered to be a random sample of the population in the area trawled. Histological criteria can be used to identify four different spawning nights: postovulatory follicles aged 44-54 hours old indicated spawning two nights before capture (A); postovulatory follicles aged about 20-30 hours old indicated spawning the night before capture (B); hydrated oocytes or new (without deterioration) postovulatory follicles indicated spawning the night of capture (C); and early stages of migratory-nucleus oocytes indicated that spawning would have occurred the night after capture (D). The daily spawning fraction can be estimated by using the number of females spawning on one night, an average of several nights, or all nights. We used the number of females identified as having spawned the night before capture (B) and the adjusted number of mature females caught in each trawl (Table 2) to estimate the population spawning fraction and variance, which is the default spawning night in the EPM program (Chen et al. 2003) and the traditional method of Picquelle and Stauffer (1985).

Batch fecundity (F). Batch fecundity (number of oocytes per spawn) was considered to be the number of migratory-nucleus-stage oocytes or the number of hydrated oocytes in the ovary (Hunter et al., 1985). We used the gravimetric method (Macewicz et al. 1996; Hunter et al. 1985, 1992) to estimate mean batch fecundity for 47 females caught during the April-May 2008 survey. The relationship of batch fecundity (F_b) to female weight (without ovary, W_{of}), as determined by simple linear regression, was $F_b = 14118 + 172.04W_{of}$,where $r^2 = 0.111$ but the intercept did not

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[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

differ from zero (P = 0.071). Therefore we forced the regression through 0, yielding the relationship $F_b = 305.14W_{of}$ where W_{of} ranged from 64.6 to 127.6 grams (Figure 4). We used this equation to predict batch fecundity for each of the 187 mature Pacific sardine females that had been analyzed for the estimation of spawning frequency.

Female weight (W_f). The observed female weight was adjusted downward for females with hydrated ovaries because their ovary weights were temporarily inflated. We obtained the adjusted female weight by the linear equation $W_f = 1.04W_{of}$ where W_f is wet weight and W_{of} is ovary-free wet weight based on data from non-hydrated females taken during the April 2008 survey.

Sex ratio (R). The female proportion by weight was determined for each trawl (or each collection). The average weight of males and females (calculated from the first 10 males and 25 females) was multiplied by the number of males or females in the collection of 50 randomly selected fish to calculate total weight by sex in each collection. Thus, the female proportion by weight in each collection (Table 2) was calculated as estimated total female weight divided by estimated total weight in the sample. The estimate of the population's sex ratio by weight was calculated (Picquelle and Stauffer, 1985).

Spawning biomass (B_s)

The spawning biomass was computed according to:

$$B_s = \frac{P_0 AC}{RSF/W_f} \qquad [5]$$

where A is the survey area in units of $0.05m^2$, S is the fraction of mature females spawning per female per day, F is the batch fecundity (number of eggs per mature female released per spawning), R is the fraction of mature female fish by weight (sex ratio), W_f is the average weight of mature females (g), and C is the conversion factor from grams (g) to metric tons (mt). P_0A is the total daily egg production in the survey area, and the denominator (RSF/W_f) is the daily specific fecundity (number of eggs/population weight (g)/day).

The variance of the spawning biomass estimate $(\hat{B}_s)$ was computed from the Taylor expansion and in terms of the coefficient of variation (CV) for each parameter estimate and covariance for adult parameter estimates (Parker 1985):

$$VAR(\hat{B}_s) = \hat{B}_s^{\,2}\left[CV(\hat{P}_0)^2 + CV(\hat{W}_f)^2 + CV(\hat{S})^2 + CV(\hat{R})^2 + CV(\hat{F})^2 + 2COVS\right] \qquad [6]$$

The last term, involving the covariance term, on the right-hand side is

$$COVS = \sum_i \sum_{i<j} sign \frac{COV(x_i, x_j)}{x_i x_j}$$

where x's are the adult parameter estimates, and subscripts i and j represent different adult parameters; e.g., $x_i = F$ and $x_j = W_f$. The sign of any two terms is positive if they are both in the numerator of B_S or denominator of B_S (equation 5); otherwise, the sign is negative. The covariance term is

$$\mathrm{cov}(x_{i,}x_j) = \frac{[n/(n-1)]\sum_k m_k (x_{i,k} - x_i) g_k (x_{j,k} - x_j)}{\left(\sum_k m_k\right)\left(\sum_k g_k\right)}$$

where k refers to k^{th} tow, and $k = 1,\ldots,n$. The terms of m_k and g_k are sample sizes and $x_{i,k}$ and $x_{j,k}$ are sample means from the k^{th} tow for x_i and x_j respectively.

RESULTS

Daily egg production (P_0) for the whole survey area

In Region 1, the initial daily egg production ($P_{0,1}$) from the mortality curve was 1.39/0.05 m^2/day (CV = 0.18; equation 1 and Figure 5). The bias-corrected egg production, ($P_{0,1,c}$) is 1.45 (CV = 0.18) (Table 3) for an area of 53,514 km^2 (south of CalCOFI line 73.3). The ratio (q) of egg density between Region 2 and Region 1 from CUFES samples was 0.139 (CV=0.27) (equation 3). In Region 2 (South of 39.5°N) , the egg production ($P_{0,2}$) was 0.202 /0.05 m^2/day (CV = 0.32) for an area of 343,003 km^2 (100,220 nm^2). The estimate of the daily egg production for the area south of 39.5°N was 0.37/0.05 m^2 (CV = 0.22) (equation 4) for 396,517 km^2 (115,856 nm^2) (Table 3). Egg mortality (0.13 (CV=0.29)) was lower than most years (Table 4). The P_0 for the whole survey area (30°N-51°N) based on the ratio of area sizes was 0.37 x 0.59 = 0.218/0.05 m^2/day.

Daily egg production (P_0) for the standard DEPM survey area off California

The estimates of the egg production and egg mortality in the region 1 and the q value are the same as those for the whole survey area because region 1 was south of CalCOFI line 73.3. In Region 2, the egg production ($P_{0,2}$) was 0.202/0.05 m^2/day (CV = 0.32) for an area of 244,435 km^2 (71,420 nm^2). The estimate of the daily egg production for this area of 297,949 km^2 (87,056 nm^2) was 0.43/0.05 m^2 (CV = 0.21) (equation 4 and Table 3).

Catch ratio between CUFES and CalVET (E)

Although this ratio is no longer needed in the current estimation procedure, we computed it for comparison purposes. The catch ratio of eggs/min to eggs/tow (eggs/min = E * eggs/0.05 m^2) was computed from 150 pairs of CalVET tows and CUFES collections from *David Starr Jordan* cruises (Figure 6). The eggs/min corresponding to each positive CalVET tow was the mean of all CUFES collections taken from one hour before to one hour after each positive

CalVET tow. The catch ratio was 0.19 (CV=0.06) in comparison to the 2007 estimate of 0.15 (CV=0.09), the 2006 estimate of 0.32(CV=0.12) , the 2005 estimate of 0.18 (CV = 0.28), the 2004 estimate of 0.22 (CV = 0.09) and the 2003 estimate of 0.39 (CV = 0.11). A ratio of 0.19 means that one egg/tow from a CalVET tow was equivalent to approximately 0.19 egg/min from a CUFES sample, or one egg/minute from the CUFES was equivalent to 5.3 eggs/tow from the CalVET sample.

Adult parameters

Over the whole survey area (30°- 48.47°N) in April 2008, one Pacific sardine was taken at 39.98°N and 353 sardines were taken in the standard DEPM survey area off California (from San Diego to San Francisco). Standard length (SL) of the first 50 randomly selected sardine, in each trawl ranged from 163 to 246 mm for 135 males and from 167 to 253 mm for 219 females. The smallest mature female was 167 mm SL. The length at which 50% of females are mature (ML_{50}) was not calculated because immature female sardines were not captured in the survey. Since the single sardine taken north of the standard DEPM area was a male (236 mm), female reproductive parameters were calculated for the standard DEPM area and used for estimating spawning biomass in both the whole survey and standard DEPM areas.

Reproductive parameters of 187 mature female sardines (up to 25 mature analyzed per trawl) for the individual trawls are given in Table 2. The April 2008 population sex ratio (R), was 0.631 (CV = 0.098) (Table 5). Estimates of the other female sardine parameters were: F, mean batch fecundity, 29,802 eggs/batch (CV = 0.07); S, spawning fraction, 0.1186 per day (CV = 0.31); and W_f, mean female fish weight, 102.2 grams (CV = 0.06). The average interval between spawning (spawning frequency) was about 8 days (inverse of spawning fraction or 1/0.1186), and the daily specific fecundity was 21.82 eggs/population weight (g)/day (Table 5). The correlation matrix for the adult parameter estimates over the whole survey area is shown in Table 5.

Spawning biomass (B_s)

The final estimate of spawning biomass of Pacific sardine in 2008 (equation 5, Table 4 and 5) is 135,301 mt (CV=0.43) or 148,831 short tons (st) (=135,301 x 1.1) for the entire survey area of 677,162 km^2 (258,736 nm^2) from San Diego to Cape Flattery, Washington. For the standard DEPM area of 297,949 km^2 (87,056 nm^2) off California, the estimate of spawning biomass is 117,426 mt (CV=0.43) or 129,169 st. The point estimates of spawning biomass of Pacific sardine off California in 1994-2008 are, respectively 127,102; 79,997; 83,176; 409,579; 313,986; 282,248; 1,063,837; 790,925; 206,333; 485,121; 281,639; 621,657; 837,501; 392,492 and 117,426 mt (Table 4).

DISCUSSION

Sardine eggs

Sardine eggs were concentrated most in the area south of CalCOFI line 73.3 in a narrow strip (Figure 1) compared to the egg distribution in 2007 (Lo et al. 2007b). This could be due to low water temperature or other environmental conditions. The area north of 39.5°N latitude has been sampled on all fixed stations using ichthyoplankton net tows. The area of high concentration of sardine eggs was within the standard DEPM survey area, an indication of a spawning ground for sardine. In the DEPM survey area, the daily egg production of 0.43 eggs/0.05m^2 (Table 3) in 2008 was lower than previous years: 0.864 eggs/0.05m^2 in 2007, 1.936 eggs/0.05m in 2006 (Table 4). In addition, similar to recent years, in 2008 spawning activity was strong in the southern part of the survey area, off San Diego. The extent of spawning south of San Diego will not be known without information from Mexican surveys, i.e. IMCECOCAL.

The adaptive allocation sampling procedure was used aboard the *David Starr Jordan* and the *Miller Freeman*, north of CalCOFI line 63.3, except for the six CalCOFI lines of the regular CalCOFI cruise aboard the *David Starr Jordan*: CalCOFI lines 93.3, 90.0,…76.7. For the six regular CalCOFI lines, 14 out of 55 tows were in the high density area, but additional CalVET tows that the adaptive sampling procedure would have allocated were not taken. As a result, only 151 total CalVET tows were taken in the standard DEPM survey area. This was higher than the 84 in 2007, 123 in 2006, and 74 tows in 2005 but smaller than other recent years: 217 in 2002, 192 in 2003 and 124 in 2004. Again, we highly recommend that the adaptive allocation sampling be applied aboard the research vessel that conducts the spring (March-April) routine CalCOFI survey in the future to ensure the quality of the estimate of the spawning biomass of Pacific sardine.

Embryonic mortality curve

The estimates of the daily egg production at age 0 (P_0/0.05 m^2=1.39) and the daily embryonic mortality (0.13) directly from the mortality curve in Region 1 were similar to that in 2007 but lower than previous years. These low values were partially caused by the distribution of egg developmental stages (Figure 2). In 2008, the peak density among egg developmental stages was that of stage 6, as seen in past years. The latter phenomenon is not understood and needs thorough investigation. The overall P_0 or the DEPM (0.43 eggs/0.05m^2) and the entire survey area (0.218 eggs/0.05m^2) were lower than previous years (Table 3 and 4), partially due to the small area size of the high density area (Figure 1).

Catch ratio between CUFES and CalVET (E)

The 2008 catch ratio between CUFES and CalVET (0.139) computed from data obtained from the *David Starr Jordan* appeared to be similar to that of 2007 (0.15) and lower than that of 2006 (0.32(CV=0.12)) , of 2005 (0.18 (CV=0.28)), 2004 (0.22 (CV = 0.09)), 2002 (0.24 (CV = 0.06)), 2001 (0.145 (CV = 0.026)), and 2000 (0.27), in 1998 (0.32), 1999 (0.34), and 2003 (0.39 (CV = 0.11)). This 2008 value is quite different from the 1996 estimate of 0.73. This could be because the 1996 CalVET samples were taken only in the southern area near San Diego (routine

CalCOFI survey area) while after 1997 CalVET samples were taken in a larger area extending far north of San Diego (Lo et al. 2005). It would be informative to examine the relationship between the catch ratio and the degree of water mixing over the years (Lo et al. 2001).

The ratio of egg densities of two regions from pump samples (q)

The *q* value: ratio of eggs/min in Region 1 to eggs/min in Region 2, serves as the calibration factor to estimate $P_{0,2}$ in Region 2 (equation 2) because low abundance of eggs observed in Region 2 prevents us from using the egg mortality curve to directly estimate $P_{0,2}$. For the 2008 survey, the *q* value was obtained from 11 transect lines between CalCOFI lines 93.3 and 75.0 including transient lines: 0.139 (CV = 0.27) for the standard DEPM sampling area. This value, even though lower than that of 2007 (0.48), was higher than those of previous years. The q values ranged from 0.036 to 0.065 since 2001 with an increasing trend. If this trend continues, it may mean that the spatial distribution of the spawning population is becoming less aggregated.

Adult parameters

Trawling during the April 2008 CCE survey covered a large area off the west coast of the U.S. from Cape Flattery, WA to San Diego, CA. The only previous trawling conducted off the whole west coast was during the April-May 2006 Coastwide Pacific Sardine survey (Lo et al. 2007a). We examined the range of sea temperatures at 3m depth, recorded during trawl operations, in three areas off the coast: Washington and Oregon (8.2-11.6^{o}C), northern CA (7.8-11.6^{o}C), and in the standard DEPM area (11.2-13.9^{o}C). They were lower than those in 2006 (Table 7), and we found that during April 2008 sardine eggs and adults were present only in northern CA and the standard DEPM area while during the warmer April 2006 they were present in all three areas. Off northern CA in 2008 the eggs densities were <1 egg/min (Figure 1) and only a single adult male were taken, while 101 sardine adults (averaging 91g) and eggs at densities ≥ 1egg/min were collected in 2006 (Lo et al 2007b). Although in the standard DEPM area sardine adults and eggs are always collected, in 2008 the area of Region 1 was much smaller than in 2006 (Table 3); in addition, the average sardine female was larger in 2008 (102.2g) than in 2006 (67.4g) (Table 6). We believe that the colder temperatures encountered in 2008 may have delayed/restricted movement of sardines north.

During the April 2008 survey in the standard DEPM survey area, we were again able to collect some trawl samples (Table 2) in areas of high (Region 1) and low (Region 2) egg density to yield a better estimate of Pacific sardine spawning biomass for the whole population in the large oceanic area from San Diego to San Francisco. We found that the average mature female weight (W_f) was similar in both regions (107.3 grams (SE = 6.6) in Region 1 and 100.2 grams (SE =8.4) in Region 2, Table 3) while the fraction of females spawning per day, *S*, (based on females that spawned the night before capture, night *B* or "Day 1") was higher in Region 1 (0.25 females/day (SE = 0.03)) than Region 2 (0.085 females/day (SE = 0.03)). This regional difference in the fraction of females spawning (high in 1 and lower in 2) was similar to the case in past DEPM surveys in 2005, 2006 (Lo and Macewicz 2006, Lo et al. 2007a) and 2007 (when one unusual trawl is removed, Lo et al. 2007b). Because more females are spawning per day in Region 1 than Region 2, it is necessary to continue to trawl in both regions to ensure an unbiased estimate of spawning biomass for the whole population. Additionally, in 2008, when the collection of adult sardines occurred (before May) during typical peak spawning (Lo et al. 2007) and was within 15 days or less of sardine egg sampling, S was similar (0.1186 females/day) to recent point estimates in 1997, 2004, 2005, and 2007 but higher than in 2006, when adults were sampled 15-30 days after egg collection (Table 6). As in the past, spawning fraction in 2008 had a high CV (0.31), most likely due to the low number of trawls with sardines and high variability of spawning. Therefore, we recommend that the number of trawls be increased, in both high and low egg density areas, for future biomass surveys.

We investigated the relationship of batch fecundity and female weight (without ovary) for the 47 females taken in 2008 to that of females taken in 2006 (n = 27) and 2007 (n = 27) because the r^2 was small (0.11) for the simple linear regression in 2008 compared to r^2 values of 0.83 in 2006 (Lo et al. 2007a) and 0.88 in 2007 (Lo et al. 2007b). We plotted the relationships for each female (Figure 7) and used covariance analysis to test for differences in the relation between batch fecundity and female weight (without ovary) in sardine from 2006, 2007, and 2008. No statistical difference existed among slopes from the three data sets (P = 0.094). Assuming that the slopes were equal, covariance analysis indicated that the adjusted group means were not different at the 8% level ($F_{2,\ 100}$ = 2.65, P = 0.076). Combining the data from all three years (Figure 7) yielded the equation: $F_b = -1147 + 307.14W_{of}$ where r^2 = 0.683, but the intercept did not differ from zero (P = 0.572). We forced the regression through 0, yielding the equation F_b = $295.708W_{of}$ where W_{of} ranged from 35 to 200 grams. We feel confident that using the equation ($F_b = 305.14W_{of}$) derived from 2008 females for estimation of the population mean in 2008 was resonable. If advanced females for batch fecundity were not available in a year, the 3 year combined equation would be acceptable to use.

We examined the sardines taken in the standard DEPM area in 2008 and compared them to those taken during a similar period in 2005-2007 (within the standard DEPM area, from surveys, CPS observer sampling, and port sampling (data provided by CDF&G)). We plotted the standard length distributions from each year divided into offshore and inshore (near islands or the coast) areas (Figure 8). The mean size of sardines (male and females) was always larger offshore. CPS or port samples generally are not preserved and can not be used to estimate spawning fraction which requires histological analysis. We recommend that to improve the whole population adult parameter analyses more trawls should be added in the inshore areas to obtain spawning and maturity information on smaller fish.

Spawning biomass

The 2008 estimate of spawning biomass,135,301mt, primarily in the area south of 39.5^{o}N, based on the egg production of 0.218 eggs/0.05m$^{2/}$day, and the daily specific fecundity of 21.8 eggs/g/day, is considerably lower than for most previous years (Table 4). The low spawning biomass is primarily due to the small size of the high density area (Table 4) and the high adult reproductive output (Table 3). Note that the egg production rate of 1.39 eggs/0.05m^2 in the high density area was similar to that of 2007: 1.27 eggs/.05m^2 (Lo et al. 2007b). For the standard DEPM area, the egg production, 0.43 eggs/0.05m^2/day, was lower than in most years: 0.864 in 2007, 1.936 in 2006, 1.916 eggs/0.05m^2 in 2005. The area of Region 1 of 53,514 km^2 was the 2nd smallest of all years. The low egg production rate and the high value of the daily specific fecundity (21.82) may indicate that the adults were survivors of the strong 2003 year class and low incoming classes since 2003.

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Table 1. Number of positive tows of sardine eggs from CalVET, yolk-sac larvae from CalVET and Bongo, eggs from CUFES and positive sardine trawls in Region 1 (eggs/min ≥ 1), Region 2 (eggs/min < 1) for *David Starr Jordan* (Jord), and *Miller Freeman* (MF) cruises of 0804. Jordan occupied the standard DEPM survey area from CalCOFI line 93.3-66.7, including routine CalCOFI (CC) survey. Miller Freeman occupied the area north of CalCOFI line of 66.7 (Wh).

For Whole survey (W) area and area South of 39.5°N latitude

		Region 1			**Region 2**					**Grand Total**				
		Total	Jord	MF	Total		Jord	MF		Total		Jord	MF	
		W and S of 39.5°N		W and S of 39.5°N	W	S of 39.5°N		Wh	S of 39.5°N	W	S of 39.5°N		W	S of 39.5°N
CalVET Eggs	Positive	65	65	0	20	20	20	0	0	85	85	85	0	0
	Total	76	76	0	164	94	75	89	19	240	170	151	89	19
CalVET Yolk-sac	Positive	47	47	0	14	14	14	0	0	61	61	61	0	0
	Total	76	76	0	180	94	75	89	19	240	170	151	89	19
Bongo Yolk-sac	Positive	10	10	0	15	15	15	0	0	25	25	25	0	0
	Total	10	10	0	145	75	56	89	19	155	85	66	89	19
CUFES Eggs[1]	Positive	232	232	0	324	324	310	14	14	556	556	542	14	14
	Total	243	243	0	1400	947	809	591	138	1643	1190	1052	591	138
Trawls	Positive	4	4	0	9	9	8	1	1	13	13	12	1	1
	Total	11	11	0	60	22	18	42	4	71	33	29	42	4

For Standard DEPM survey area: CalCOFI line 95 to CalCOFI line 66.7

		Region 1			**Region 2**			**Grand Total**		
		Total	CC	DEPM	Total	CC	DEPM	Total	CC	DEPM
CalVET Eggs	Positive	65	12	43	20	12	8	85	24	61
	Total	76	14	62	75	41	34	151	55	96
CalVET Yolk-sac	Positive	47	7	40	14	12	2	61	19	42
	Total	76	14	62	75	41	34	151	55	96
Bongo Yolk-sac	Positive	10	10	0	15	12	3	25	22	3
	Total	10	10	0	56	45	11	66	55	11
CUFES Eggs	Positive	232	93	139	310	145	165	542	238	304
	Total	243	94	149	809	363	446	1052	457	595
Trawls	Positive	4	--	4	8	--	8	12	--	12
	Total	11	--	11	18	--	18	29	--	29

[1] Cufes for Jordan includes samples from Calcofi line 66.7 to San Francisco.

Table 2. Individual trawl information, sex ratio[a], and parameters for mature female *Sardinops sagax*, used in the estimation of the April 2008 west coast spawning biomass. Collections 2302-2304 are in the standard DEPM sampling area off California.

COLLECTION INFORMATION										MATURE FEMALES								
				Location											Number spawning		
Sardine egg density regions 1=high 2=low	No.	Month-Day	Time	Latitude °N	Longitude °W	Surface Temp. °C	Number of fish sampled	Proportion of females	No. anal-yzed	Body weight (g) Ave.	Weight without ovary (g) Ave.	Batch Fecundity Ave.	Adj. No.	Night of capture	Night before capture	2 Nights before capture
2	2409	4-26	2:28	38.984	125.4585	11.5	1	0.000	0	-	-	-	-	-	-	-
2	2328	4-27	3:27	35.469	121.624	11.8	2	1.000	2	97.50	92.58	28250	2	0	0	0
2	2327	4-26	21:09	35.297	121.963	11.2	25	0.559	13	115.73	110.51	33720	13	0	0	2
2	2326	4-26	2:22	34.558	123.500	12.8	26	0.678	17	109.68	104.99	32036	16	5	4	0
1	2319	4-22	19:10	34.511	122.781	12.4	2	1.000	2	143.00	137.50	41958	3	0	1	1
2	2325	4-25	20:01	34.278	124.081	13.0	50	0.591	25	126.98	120.14	36661	28	0	3	3
2	2316	4-21	20:01	34.085	122.028	11.8	11	0.822	9	122.33	116.47	35539	11	0	2	3
1	2323	4-24	21:24	33.822	123.379	12.8	2	0.458	1	116.00	106.87	32612	1	0	0	0
2	2311	4-17	23:46	33.430	120.177	11.4	50	0.618	25	83.44	80.66	24612	26	0	1	0
2	2309	4-17	3:13	32.861	119.806	11.6	30	0.610	18	68.92	65.34	19938	18	0	0	0
2	2307	4-16	18:57	32.478	120.615	12.8	50	0.282	25	90.42	86.77	26477	27	0	2	2
1	2302	4-13	19:58	31.764	120.414	13.6	55	0.794	25	97.49	93.69	28587	3	22	0	1
1	2304	4-14	2:58	31.505	120.882	13.9	50	0.783	25	113.94	108.78	33193	29	4	8	7
									187				187	26	21	19

[a]Sex ratio, proportion of females by weight, based on average weights (Picquelle and Stauffer 1985).

Table 3. Egg production (P_0) of the Pacific sardine in 2008 based on egg data from CalVET and yolk-sac larval data from CalVET and Bongo in Region 1 (eggs/min ≥ 1) and Region 2 (eggs/min < 1) from *David Starr Jordan* (March 24-May 1), and *Miller Freeman* (April 1-30) cruises, adult parameters from positive trawls (April 13-27), and 2008 spawning biomass estimate. For comparison, spawning biomass estimates are given using 2007 adult parameter data.

	Area South of 39.5°N latitude				**Whole**	Standard DEPM survey Area			
Parameter	Region 1	Region 2	Total[a]		**Survey[b]**	Region 1	Region 2	Total[a]	
CUFES samples	243	1400	1643	1643	**1643**	243	809	1052	1052
CalVET samples	76	164	240	240	**240**	76	75	141	141
P_0 / 0.05m^2	1.45	0.202	0.37	0.37	**0.218**	1.45	0.202	0.43	0.43
CV	0.18	0.32	0.22	0.22	**0.22**	0.18	0.32	0.21	0.21
Area (km^2)	53,514	343,003	396,517	396,517	**677,162**	53,514	244,435	297,949	297,949
%	13.50	86.50	100	100		17.96	82.04	100	100
Year for adult samples	2008	2008	2008	2007	**2008**	2008	2008	2008	2007
Female fish wt (W_f)	107.32	100.20	102.22	81.62	**102.22**	107.32	100.20	102.22	81.62
Batch fecundity (F)	31340	29194	29802	21761	**29802**	31340	29194	29802	21761
Spawning fraction (S)	0.250	0.085	0.1186	0.114	**0.1186**	0.250	0.085	0.1186	0.114
Sex ratio (R)	0.786	0.558	0.631	0.515	**0.631**	0.786	0.558	0.631	0.515
(RSF)/W_f	57.40	13.84	21.82	15.68	**21.82**	57.40	13.84	21.82	15.68
Spawning biomass (mt)	27,037	100,083	134,467	187,127	**135,301**	27,037	71,323	117,426	163,412
CV	0.23	0.49	0.43	0.43	**0.43**	0.23	0.49	0.43	0.42
Daily mortality (Z)	0.13					0.13			
CV	0.29					0.29			
eggs/min	1.87	0.28	0.49			1.87	0.28	0.49	
CV	0.13	0.341	0.03			0.13	0.341	0.03	
q = eggs/min in Reg.2 / eggs/min in Reg.1			0.139					0.139	
CV			0.27					0.27	
E = (eggs/min)/(eggs/tow)			0.19					0.19	
CV			0.06					0.06	
Bongo samples	10	75	85		**155**	10	56	66	
Area in nm^2	20,447	131,058	151,505		**258,736**	20,447	93,396	87,056	
Spawning biomass (short ton)	29,741	110,091	147,914		**148,831**	29,741	78,455	129,169	

a: Two columns under total: one uses estimates of adult parameter from 2008 survey and the other one uses 2007 estimates
b 70CalVET and 70 Bongo tows above 39.5°N latitude were not included in the computation of spawning biomass because they contained zero eggs and larvae.

Table 4. Estimates of daily egg production (P_0)[a] for the survey area, daily instantaneous mortality rates (Z) from high density area (Region 1), daily specific fecundity (RSF/W), spawning biomass of Pacific sardines and average sea surface temperature for the years 1994 to 2008.

Year	$\boldsymbol{P_0}$ (CV)	$\boldsymbol{Z}$ (CV)	Area (km^2) (Region 1)	RSF/W	Spawning biomass (mt) (CV)[b]	Mean Temp. for positive egg or yolk-sac samples	Mean temperature all CalVETs
1994	0.193 (0.210)	0.120 (0.91)	380,175 (174,880)	11.38	127,102 (0.32)	14.3	14.7
1995	0.830 (05)	0.400 (0.4)	113,188.9 (113188.9)	23.55[c]	79,997 (0.6)	15.5	14.7
1996	0.415 (0.42)	0.105 (4.15)	235,960 (112,322)	23.55	83,176 (0.48)	14.5	15.0
1997	2.770 (0.21)	0.350 (0.14)	174,096 (66,841)	23.55[d]	409,579 (0.31)	13.7	13.9
1998	2.279 (0.34)	0.255 (0.37)	162,253 (162,253)	23.55	313,986 (0.41)	14.38	14.6
1999	1.092 (0.35)	0.100 (0.6)	304,191 (130,890)	23.55	282,248 (0.42)	12.5	12.6
2000	4.235 (0.4)	0.420 (0.73)	295,759 (57,525)	23.55	1,063,837 (0.67)	14.1	14.4
2001	2.898 (0.39)	0.370 (0.21)	321,386 (70,148)	23.55	790,925 (0.45)	13.3	13.2
2002	0.728 (0.17)	0.400 (0.15)	325,082 (88,403)	22.94	206,333 (0.35)	13.6	13.6
2003	1.520 (0.18)	0.480 (0.08)	365,906 (82,578)	22.94	485,121 (0.36)	13.7	13.8
2004	0.960 (0.24)	0.250 (0.04)	320,620 (68,234)	21.86[e]	281,639 (0.3)	13.4	13.7
2005	1.916 (0.417)	0.579 (0.20)	253,620 (46,203)	15.67	621,657 (0.54)	14.21	14.1
2006	1.936 (0.256)	0.31 (0.25)	336,774 (98,034)	15.57[f]	837,501[f] (0.46)	14.95	14.5
2007	0.864 (0.256)	0.133 (0.36)	356,159 (142,403)	15.68	392,492 (0.45)	13.7	13.6
2008[g]	0.43 (0.21)	0.13 (0.29)	297,949 (53,514)	21.82	117,426 (0.43)	13.3	13.1
2008[h]	0.218 (0.22)	0.13 (0.29)	677,162 (53,514)	21.82	135,301 (0.43)	13.1	12.7

a weighted non-linear regression on original data and bias correction of 1.04, except in 1994 and 1997 when grouped data and a correction factor of 1.14 was used (appendix Lo 2001).
b $CV(B_s) = (CV^2(P_0) + \text{allotherCOV}^2)^{1/2} = (CV^2(P_0)+0.054)^{1/2}$. For years 1995-2001 allotherCOV^2 was from 1994 data (Lo et al. 1996). For year 2003, allotherCOV was from 2002 data (Lo and Macewicz 2002)
c 23.55 was from computation for 1994 based on S = 0.149 (the average spawning fraction (day 0 + day 1) of active females from 1986-1994; Macewicz et al. 1996).
d is 25.94 when calculated from parameters in table 6 and estimated spawning biomass is 371,725 mt with CV=0.36
e uses R = 0.5 (Lo and Macewicz 2004); if use actual R = 0.618, then value is 27.0 and biomass is estimated at 227,746 mt
f value for standard DEPM sampling area off California when calculated using S = 0.126, the average of females spawning the night before capture ("day 1") from 1997, 2004, 2005, and 2007. When survey S of 0.0698 was previously used (Lo et al. 2007a), the 2006 DEPM spawning biomass was estimated as 1,512,882 mt (CV 0.46) and the 2006 coast-wide spawning biomass was estimated as 1,682,260 mt
g standard DEPM sampling area off California from San Diego to CalCOFI line 66.7
h whole 2008 survey area off west coast of North America from about 31°N to 48.47°N latitude.

Table 5. The 2008 output for the standard DEPM survey area from "frmBIOMASS" form in the EPM program after input of 2008 parameters and estimation of adult parameters (top box)**,** and 'Estimate Correlation and Biomass also' (bottom box) (Appendix II Chen et al. 2003).

EPM PROGRAM

Calculate Correlation, Biomass and CV

Input Parameters:

Enter first collection number	4302
Enter last collection number	4328
Enter first collection number of 2nd set	
Enter last collection of 2nd set	
Mean gonad-free weight used in regression	104.22
Number of fish used in regression	47
Variance about regression	50113778
Variance of regression slope	96.45
Po (eggs/day - 0.05m2)	0.43
Variance of Po	0.008
Area (square kilometers)	297949

Statistic Results:

	Average	Variance
Whole Body Weight	102.21549262	38.570425605
Gonad Fee Weight	97.666828877	33.536856137
Batch fecundity	29802.056164	4627875.5699
Spawners, Day 0	0.1657754011	0.0122026101
Spawners Day 1	0.1186440678	0.001362793
Sex Ratio	0.6308143561	0.0038059834
Daily specific fecundity	21.821123118	
Number of Sets	12	

Enter the name of DBSET table: DBSET08

Estimate Average and Variance only — Estimate

Estimate Correlation and Biomass also — Estimate

EGG PRODUCTION VALUES

Po (eggs/day - .05 m2):	0.43
CV of Po:	0.20800632349
Area (square kilometers):	297949

BIOMASS ESTIMATE

Biomass (m - tons) =	117425.734056
CV (biomass) =	0.42692884302

CORRELATIONS

Parameter	W	F	S	R
Whole - Body Weight (W)		0.8209939	0.57029284	0.2462784
Batch Fecundity (F)			0.475212	0.2073116
Fraction Spawning (S)				0.51164116
Sex Ratio (R)				

Table 6. Pacific sardine female adult parameters for surveys conducted in the standard daily egg production method (DEPM) sampling area off California (1994 includes females from off Mexico).

		1994	1997	2001	2002	2004	2005	2006	2007	2008
Midpoint date of trawl survey		April 22	March 25	May 1	April 21	April 25	April 13	May 2	April 24	April 16
Beginning and ending dates of positive collections		04/15-05/07	03/12-04/06	05/01-05/02	04/18-04/23	04/22-04/27	03/31-04/24	05/01-05/07	04/19-04/30	04/13-04/27
N collections with mature females		37	4	2	6	16	14	7	14	12
N collection within Region 1		11	4	2	6	16	6	2	8	4
Average surface temperature (°C) at collection locations		14.36	14.28	12.95	12.75	13.59	14.18	14.43	13.6	12.4
Female fraction by weight	**R**	0.538	0.592	0.677	0.385	0.618	0.469	0.451	0.515	0.631
Average mature female weight (grams):										
with ovary	$\mathbf{W_f}$	82.53	127.76	79.08	159.25	166.99	65.34	67.41	81.62	102.21
without ovary	$\mathbf{W_{of}}$	79.33	119.64	75.17	147.86	156.29	63.11	64.32	77.93	97.67
Average batch fecundity[a] (mature females, oocytes estimated)	**F**	24283	42002	22456	54403	55711	17662	18474	21760	29802
Relative batch fecundity (oocytes/g)		294	329	284	342	334	270	274	267	292
N mature females analyzed		583	77	9	23	290	175	86	203	187
N active mature females		327	77	9	23	290	148	72	187	177
Spawning fraction of mature females[b]	**S**	0.074	0.133	0.111	0.174	0.131	0.124	0.0698	0.114	0.1186
Spawning fraction of active females[c]	$\mathbf{S_a}$	0.131	0.133	0.111	0.174	0.131	0.155	0.083	0.134	0.1187
Daily specific fecundity	$\frac{\mathbf{RSF}}{\mathbf{W}}$	11.7	25.94	21.3	22.91	27.04	15.67	8.62	15.68	21.82

[a] 1994-2001 estimates were calculated using F_b = -10858 + 439.53 W_{of} (Macewicz et al. 1996), 2004 used $F_b = 356.46W_{of}$. (Lo and Macewicz 2004), 2005 used F_b = -6085 + 376.28 W_{of} (Lo and Macewicz 2006), 2006 used F_b = -396 + 293.39 W_{of} (Lo et al. 2007a); and 2007 used $F_b = 279.23W_{of}$. (Lo et al. 2007b).
[b] Mature females include females that are active and those that are postbreeding (incapable of further spawning this season).
[c] Active mature females are capable of spawning and have ovaries containing oocytes with yolk or postovulatory follicles less than 60 hours old.

Table 7. Temperature range (3m depth) and presence (+) of Pacific sardine eggs collected in CUFES samples and adults taken in trawls during the spring 2006 Sardine Coastwide and 2008 CCE surveys off the west coast of the United States.

	Washington-Oregon: 48.5° - 42°N	Northern California: 42°N- CalCOFI line 60	standard DEPM: CalCOFI lines 60-93 (San Francisco - San Diego)
April 2008			
Sea Temperature	8.2-10.1 °C	7.8-11.6°C [a]	11.2-13.9°C
Number of trawls	25	15	31
positive trawls	0	1	12
Number of adults	-	1	353
Mean body weight (g)	-	148	105
Eggs, Region 1	-	-	+
Eggs, Region 2	-	+	+
April 2006			
Sea Temperature	9.1-11.8°C	10.8-12.2°C	13.3-16.6°C
Number of trawls	9	4	22
positive trawls	0	3	7
Number of adults	-	101	194
Mean body weight (g)	-	91	67
Eggs Region 1	+	+	+
Eggs Region 2	+	+	+

[a] one negative offshore trawl at 38.4°N was an anomalous 13.2°C

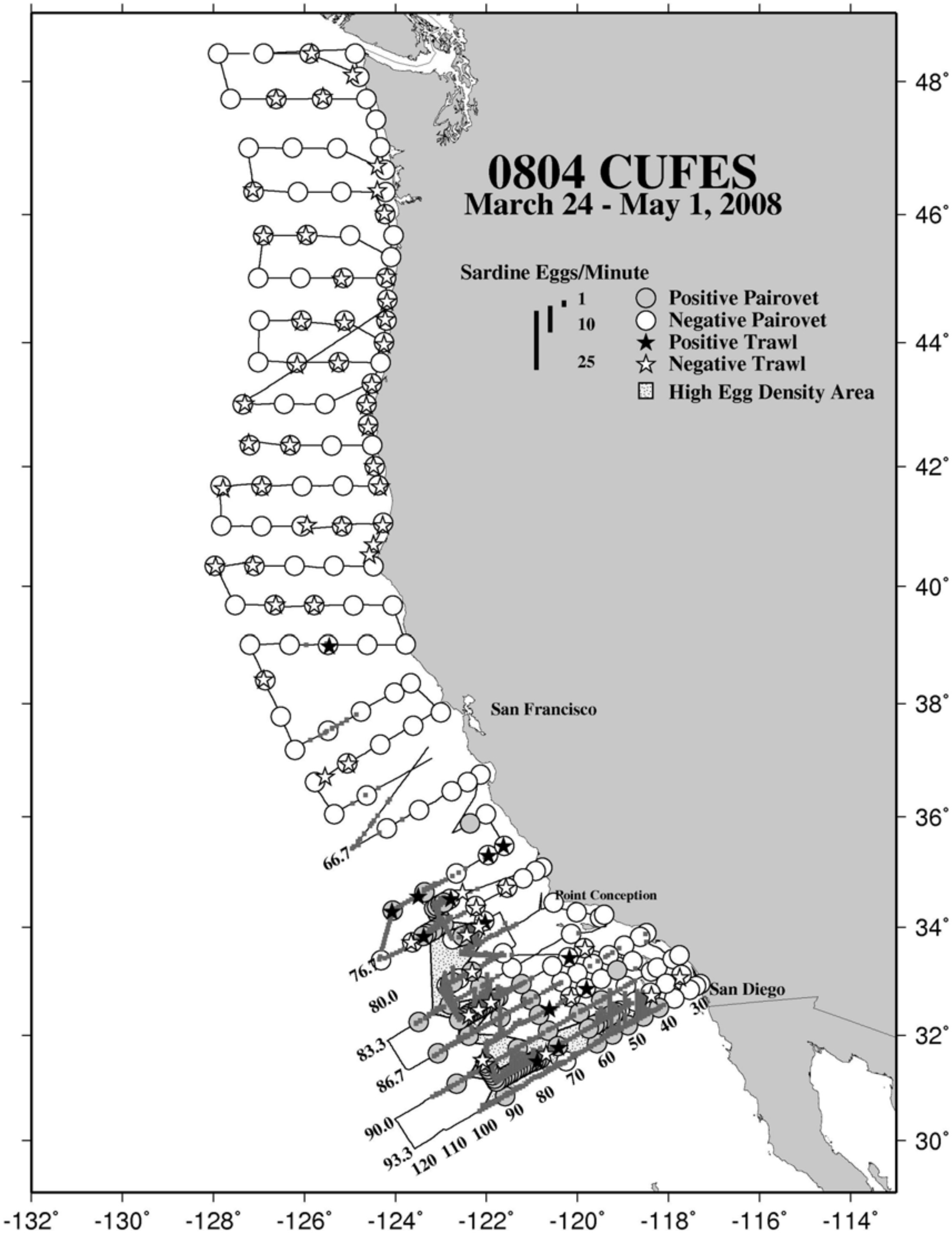


Figure 1. Location of sardine eggs collected from CalVET, a.k.a. Pairovet; (solid circle is a positive catch and open circle is zero catch) and from CUFES (stick denotes positive collection), and trawl locations (solid star is catch with sardine adults and open star is catch without sardines) during the 2008 survey. Region 1 is high density area. Dates of cruises refer to the first and last tow.

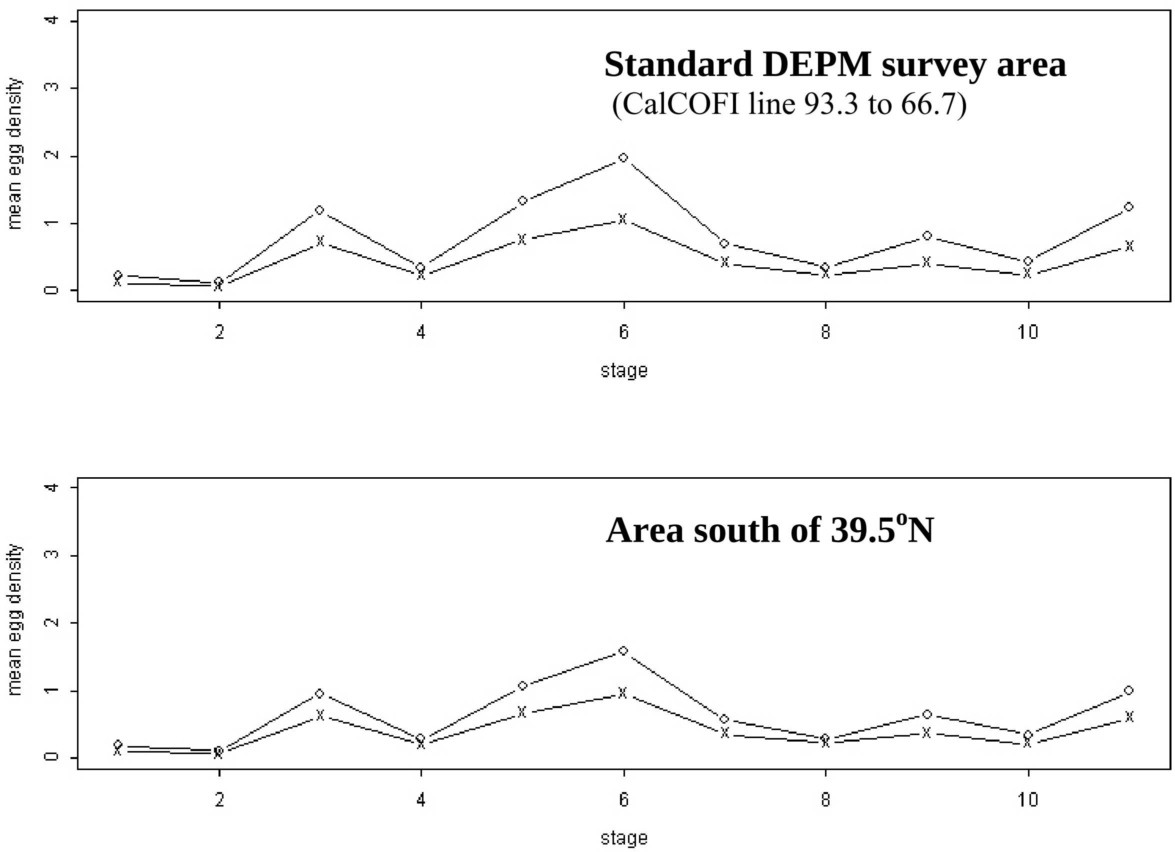
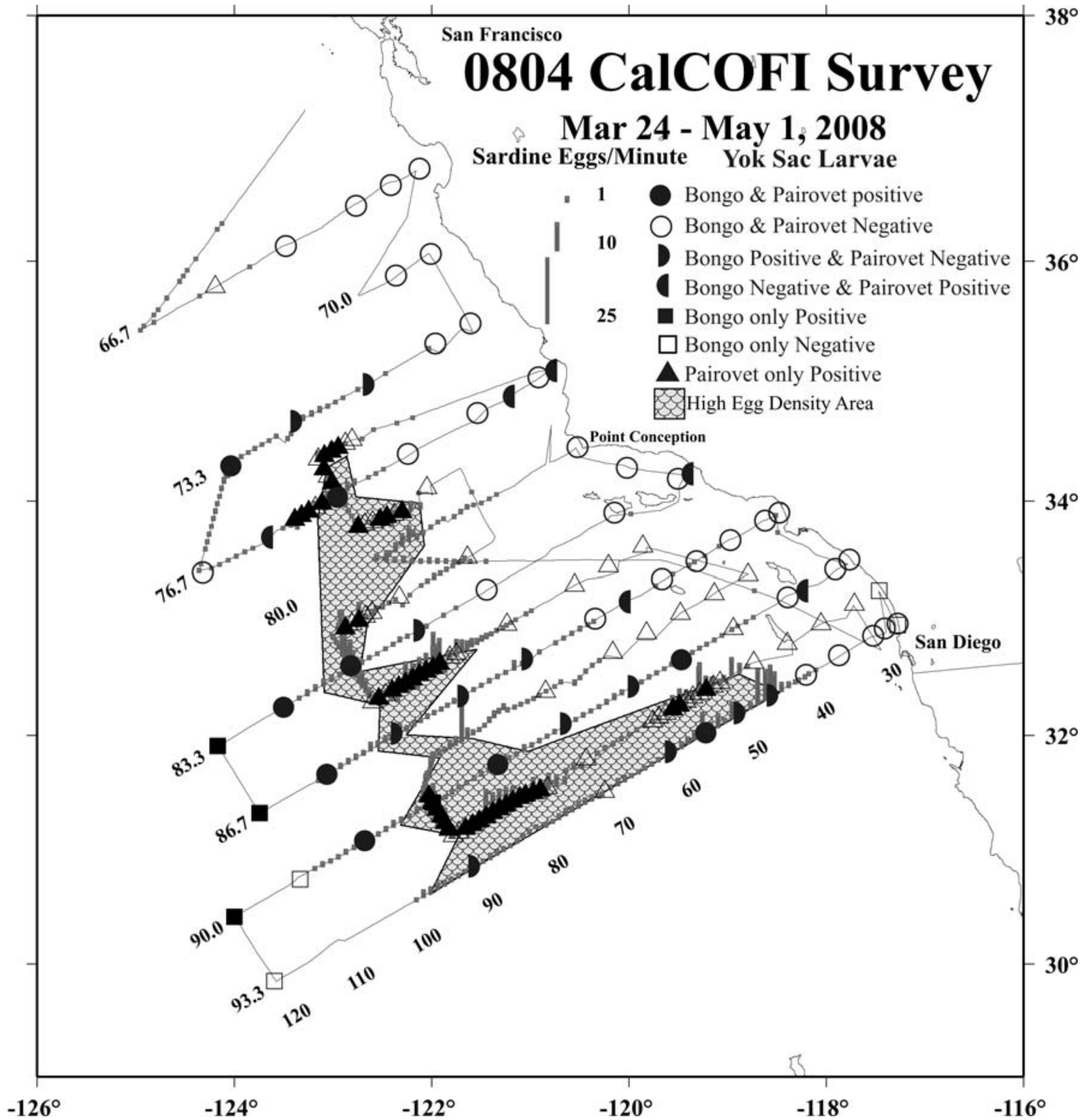


Figure 2. Mean sardine egg density (eggs per 0.05 m^2) for each developmental stage within each area for April - May, 2008. Symbols: o = Region 1 and x = area surveyed. Note that latitude and Calcofi line were used to describe the area sor each of these two graphs due to different orientations of transect lines (Figure 1 and 3).



`Figure 3. Location of sardine yolk-sac larvae collected from CalVET (or Pairovet; circle and triangle) and from Bongo (circle and square) during the 2008 survey. Solid symbols are positive and open symbols are zero catch. Zero yolk-sac larvae were caught north of CalCOFI line 73.3.

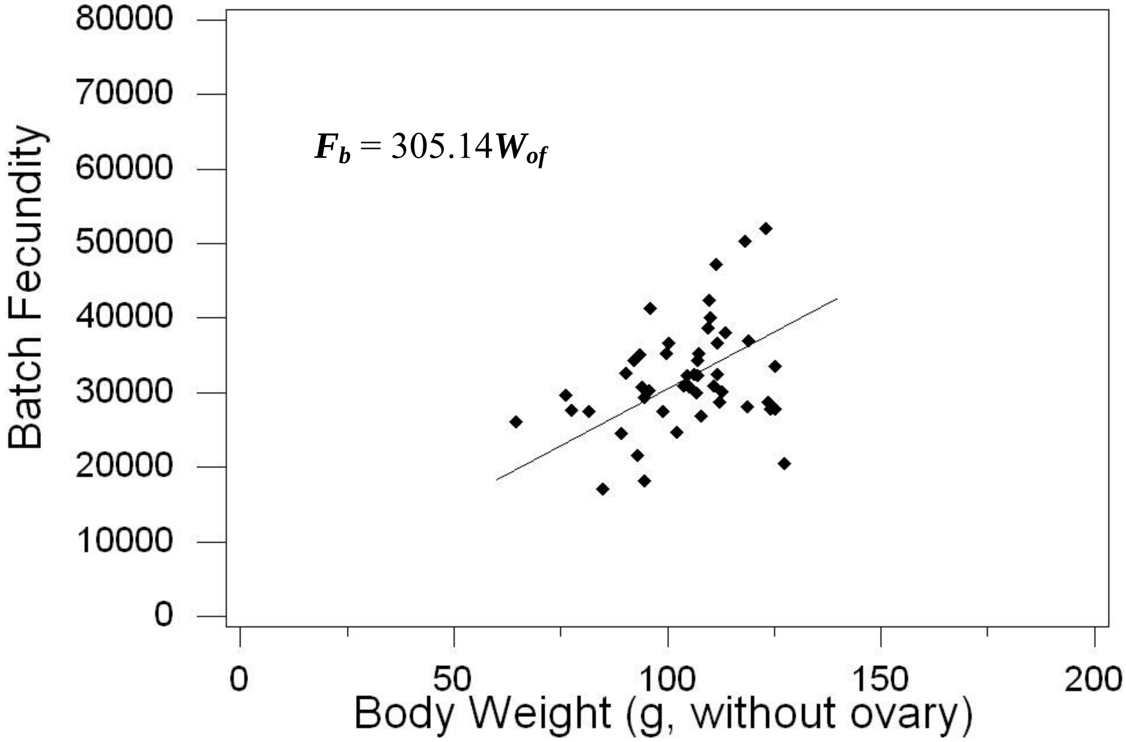


Figure 4. Batch fecundity (F_b) of *Sardinops sagax* as a function of female body weight (W_{of}, without the ovary) for 47 females taken during April 2008. The batch was estimated from numbers of hydrated or migratory-nucleus-stage oocytes.

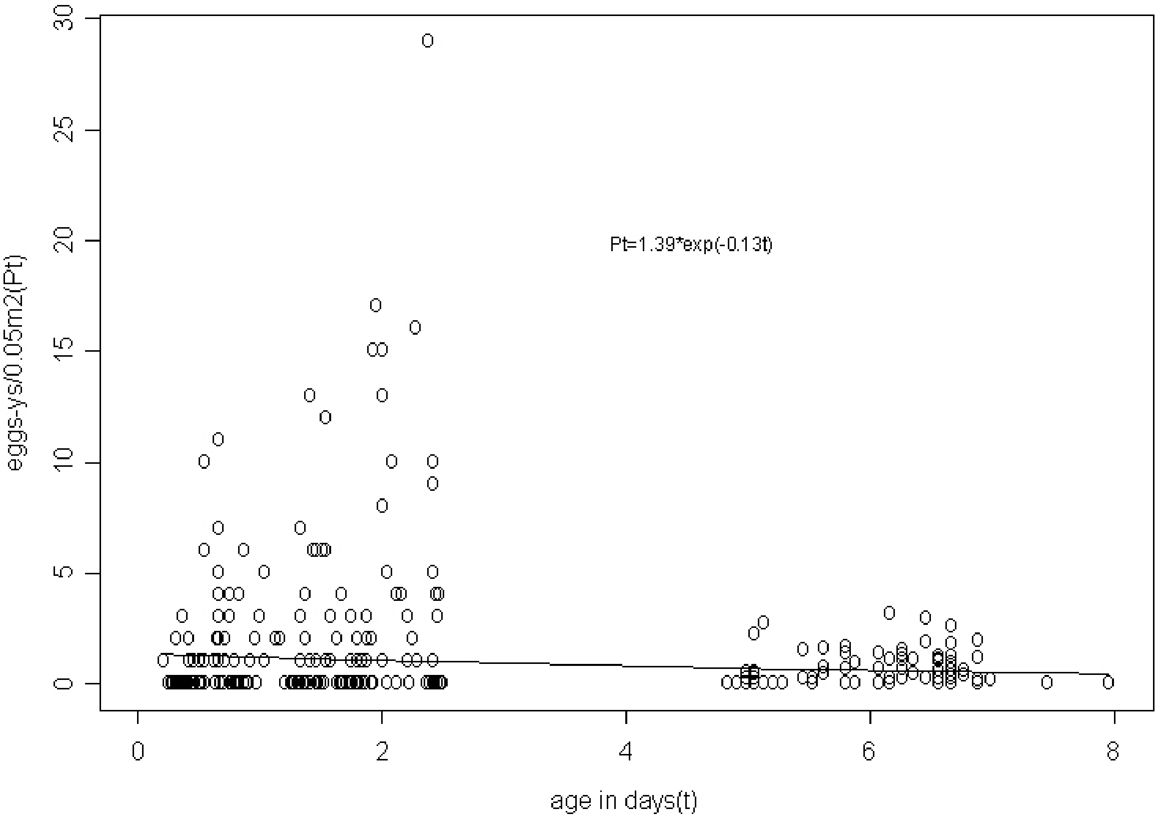


Figure 5. Embryonic mortality curve of Pacific sardines. Staged egg data were from CalVET and yolk-sac larval data were from CalVET and Bongo during April – May 2008, Jordan cruise. The number,1.39 (P_0), is the estimate of daily egg production at age 0 before correction for bias..

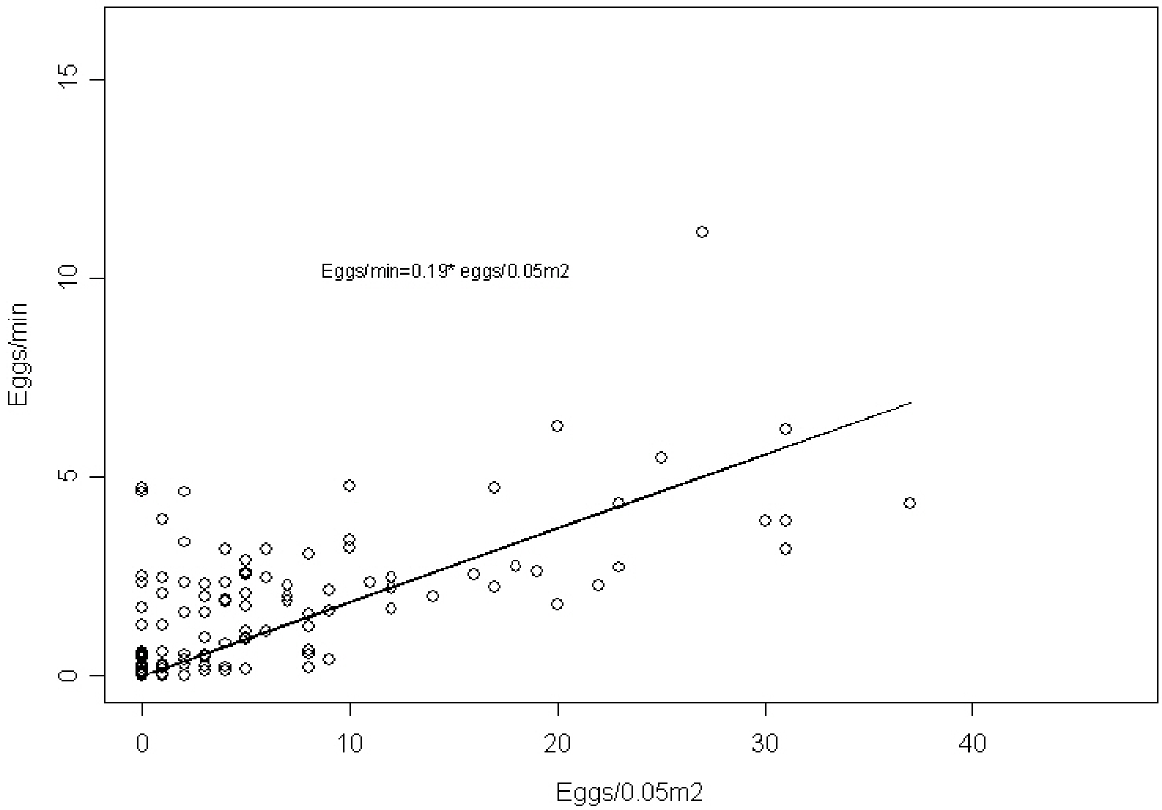


Figure 6. Catch ratio of eggs/min from CUFES to eggs/0.05m^2 from CalVET during April – May 2008. from *David Starr Jordan*

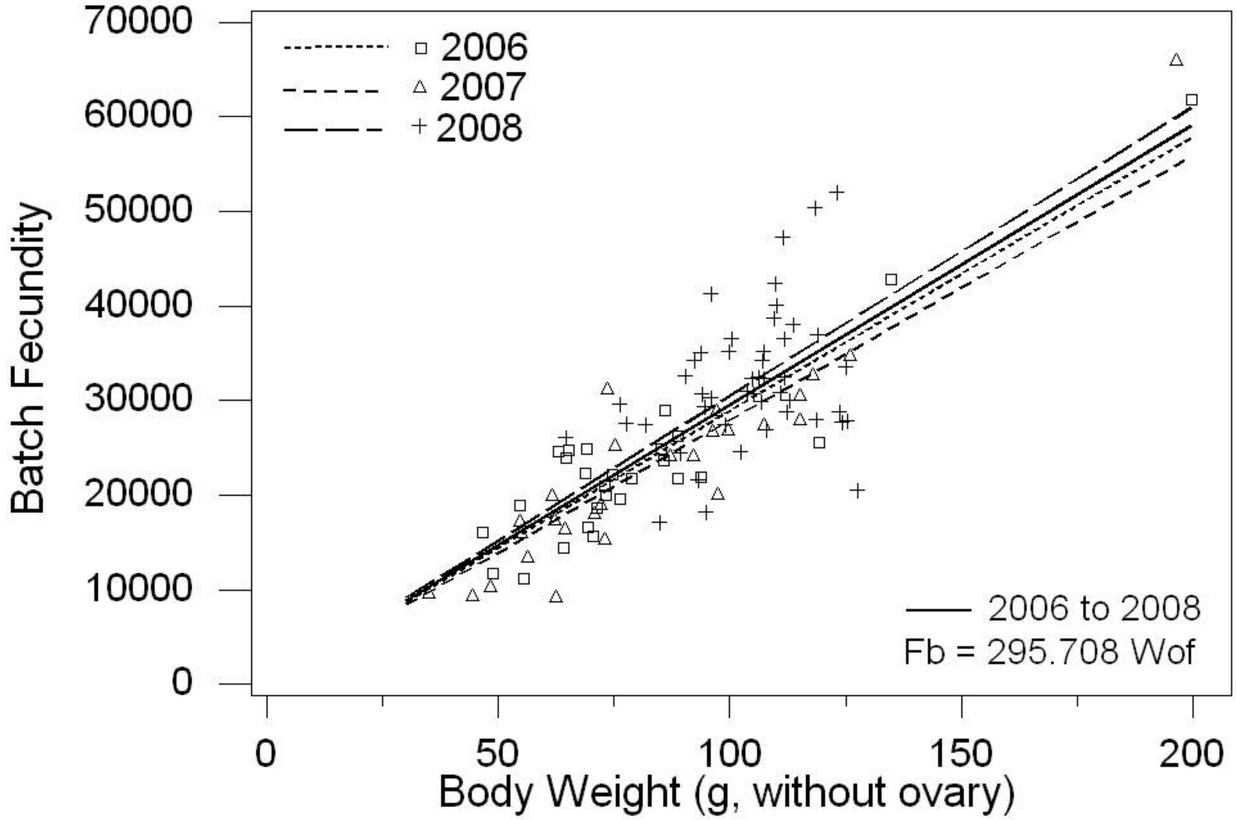


Figure 7. Batch fecundity (F_b) of Pacific sardines as a function of female weight (W_{of}, without ovary) for 101 females from trawl surveys in 2006-2008; where $r^2 = 0.683$ (solid line). 2006 (Lo et al. 2007a), 2007 (Lo et al. 2007b), and 2008 are plotted for comparisons.

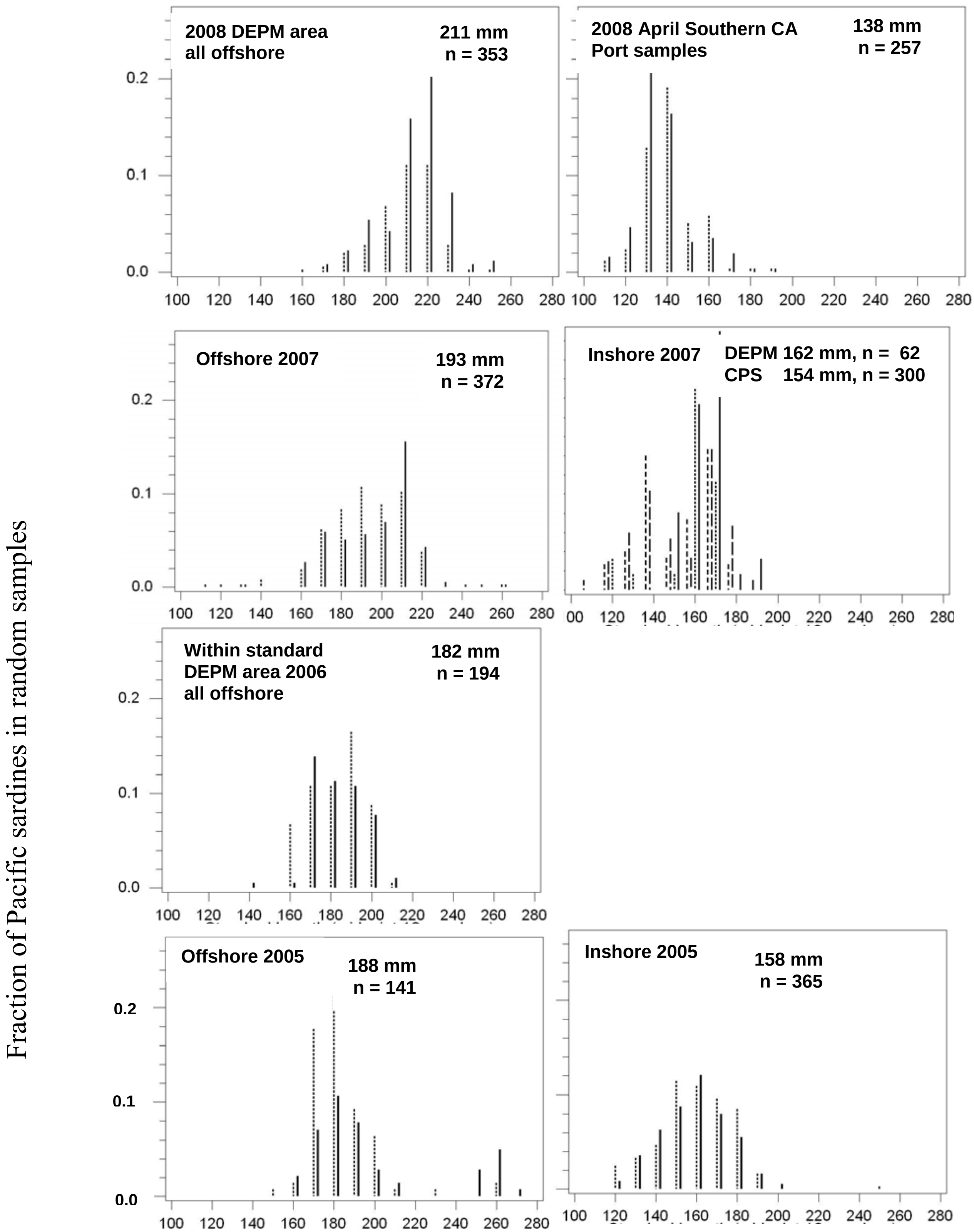


Figure 8. Length distribution and mean length of Pacific sardines caught in the 2005 to 2008 survey by each subarea and for 2007 small pelagic fish (CPS) observer samples and 2008 port samples. Males indicated by dotted bars and females by solid bar.

RECENT TECHNICAL MEMORANDUMS

SWFSC Technical Memorandums are accessible online at the SWFSC web site (http://swfsc.noaa.gov). Copies are also available form the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (http://www.ntis.gov). Recent issues of NOAA Technical Memorandums from the NMFS Southwest Fisheries Science Center are listed below:

NOAA-TM-NMFS-SWFSC-420 Marine mammal data collected during the Pacific islands cetacean and ecosystem assessment survey (PICEAS) conducted aboard the NOAA ship *McArthur II*, July - November 2005.
J. BARLOW, S. RANKIN, A. JACKSON, and A. HENRY
(March 2008)

421 Marine mammal data collected during a survey in the eastern tropical Pacific ocean aboard NOAA ships *David Starr Jordan* and *McArthur II*, July 28 - December 7, 2006.
A. JACKSON, T. GERRODETTE, S. CHIVERS, M. LYNN, S. RANDIN, and S. MESNICK
(April 2008)

422 Estimates of 2006 dolphin abundance in the eastern tropical Pacific, with revised estimates from 1986-2003.
T. GERRODETTE, G. WATTERS, W. PERRYMAN, and L. BALLANCE
(April 2008)

423 A framework for assessing the viability of threatened and endangered salmon and steelhead in the north-central California coast recovery domain.
B.C. SPENCE, E.P. BJORKSTEDT, J.C. GARZA, J.J. SMITH, D.G. HANKIN D. FULLER, W.E. JONES, R. MACEDO, T.H. WILLIAMS, and E. MORA
(April 2008)

424 Zooplankton night/day ratios and the oxygen minimum layer in the eastern Pacific.
P.C. FIEDLER and J.F. LORDA
(April 2008)

425 Habitat restoration cost references for salmon recovery planning.
C.J. THOMSON and C. PINKERTON
(April 2008)

426 Fish and invertebrate bycatch estimates for the California drift gillnet fishery targeting swordfish and thresher shark, 1990-2006.
J.P. LARESE and A.L. COAN, JR.
(July 2008)

427 AMLR 2007/2008 field season report: Objectives, Accomplishments, and Tentative Conclusions.
A.M. VAN CISE, Editor
(October 2008)

428 Killer whales of the ETP: A catalog of photo-identified individuals
P. OLSON and T. GERRODETTE
(November 2008)

429 Acoustic studies of Marine Mammals during seven years of combined visual and acoustic line-transect surveys for cetaceans in the eastern and central Pacific Ocean.
S. RANKIN, J. BARLOW, J. OSWALD, and L. BALLANCE
(November 2008)

Agenda Item H.2.a
Attachment 3
June 2009

Aerial Survey Methods for Pacific Sardine

Report of STAR Panel Meeting

NOAA / Southwest Fisheries Science Center
La Jolla, California
May 4-8, 2009

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
Owen Hamel, SSC, NMFS, Northwest Fisheries Science Center
Gary Melvin, Center for Independent Experts (CIE)
Alec MacCall, External Reviewer, Southwest Fisheries Science Center (SWFSC)
Ken Burnham, External Reviewer, Colorado State University

Pacific Fishery Management Council (Council) Representatives:
Greg Krutzikowsky, Coastal Pelagic Species Management Team (CPSMT)
Mike Okoniewski, Coastal Pelagic Species Advisory Subpanel (CPSAS)
Mike Burner, Council Staff

Sardine Aerial Survey Technical Team:
Tom Jagielo
Vidar Wespestad
Doyle Hanan
Ryan Howe

1) Overview

This review was specifically of an aerial survey being proposed by the sardine fishing industry, and not of aerial methods in general, nor of any specific alternative approach.

The review of a new aerial survey method as it could be applied to Pacific Sardine was conducted by a Stock Assessment Review Panel (Panel) which met at the Southwest Fisheries Science Center, La Jolla, CA, from May 4-8, 2009. The membership of the Panel was broader than is normal for assessment reviews to include expertise on survey methodology and design as well stock assessment. Material documenting the methodology used for west coast aerial surveys was provided to the Panel in advance of the meeting. A file server was provided at the meeting room to provide common access to all presentation material.

The Panel reviewed the available material in terms of the following key questions:

- The design of sampling scheme used to collect the basic data used in the proposed aerial survey.
- The analytical treatment of the data in terms of the ability to estimate (A) absolute abundance and (B) trends in abundance.
- Consequences of the implementation of survey protocols.
- Evaluation of precision and bias.
- Use of aerial survey abundance estimates in stock assessments for Pacific Sardine.

Only minor requests were made of the Technical Team, for additional information and description, and for minor clarifications. These requests were not recorded formally, and are not listed here. In all cases these minor requests were well-received, and the responses were satisfactory. Appendix 2 is a voluntary response by the Technical Team to issues raised during the review, including those listed in Table 1 (which provides an overview of the various uncertainties the Panel identified, and which provided a focus for the discussion).

2) Design of the Sampling Scheme

The survey consists of an aerial photogrammetric survey (Stage 1) to determine the school surface area, and a calibration study (Stage 2) intended to determine the relationship between school surface area and school biomass (Stage 2 involves the physical capture of schools by purse seine). A small proof-of-principle survey (henceforth referred to as the "2008 pilot survey") was conducted in 2008 off the northern Oregon coast, with promising results.

2.1) "Stage 1" School Surface Area Survey

Three replicate sets of aerial survey transects (two groups of 26 transects, from 3 to 35 nautical miles offshore) will be conducted. The transects will be 15 nautical miles apart during each replicate. The Panel **recommended** establishing three alternative fixed starting points five miles apart, and choosing one of the three without replacement at the start of each replicate survey. The northern group of transects will be off Washington and Oregon, and the southern group will be off northern California down to Monterey. These two groups of transects will be conducted semi-independently. Each group will be conducted by separate observers/planes/pilots (but with the possibility of exchanging pilots and/or equipment for purposes of inter-calibration).

The aircraft will be fitted with high resolution digital cameras, which take a continuous sequence of photographs. The aircraft will normally fly at 8000 feet, with a photographed strip width of

12,000 feet, and 60 percent overlap of successive images. Photos will be time-stamped with Global Positioning System (GPS) position, GPS altitude, and possible observer comments. It is anticipated that the aircraft may have to fly lower sometimes due to clouds etc., but the Panel **cautions** that this flexibility would necessitate appropriate calibration.

The digital photographs will be software enhanced (Adobe Photoshop) following the survey to reveal schools, help identify probable species, measure surface areas and other attributes (e.g., irregularity or an index of circularity) of detected fish schools. The Panel noted that image enhancement involves many case-by-case decisions, and may not be an easily standardized process. The Panel also **cautioned** that it is also important to be sure that informative features (e.g., edge properties) are not removed from the images during image processing.

The schools and their attributes will be recorded in a processing log/database for statistical processing. The Panel **recommended** that the log include a record of qualitative information regarding the processing and the difficulty in assigning species and calculating school areas.

The Panel discussed a number of specific issues, summarized below and also in Table 1.

School Identification: Species identification of schools is one of the most controversial aspects of the survey. The Panel was assured by the Technical Team that the results of the 2008 pilot study indicate that species identification is sufficiently reliable in the north so as not to pose a problem in that region. Although work has yet to be conducted in the south, spotter pilots are able to detect and identify fish schools, which suggests that species identification from enhanced photographs should be possible. The 2008 pilot survey demonstrated that fish schools can be identified from the photographic records, and the Technical Team is confident that species identification will not be a problem. Work on the spectral criteria for species identification will be ongoing. The airplane pilot is an experienced professional fish spotter, and also will contribute to the identification process by means of comments and observations recorded while underway. Overflights at low altitude can provide better observation for identification purposes, but such overflights are not possible during Stage 1 transects. The targeted purse seine sets in Stage 2 will also provide a practical test of species identification.

Some forms of supplementary information, such as species composition from concurrent trawl surveys or from commercial fishing in the area, are not directly useful for abundance estimation as part of the aerial survey. However, the need to carefully evaluate the potential to see and recognize non-sardine schools will be further emphasized if these sources indicate the presence of species other than sardines.

The species identification issue can only be evaluated by practical experience. The Technical Team is most concerned about how often schools thought to be sardine are in fact not sardine (referred to as “Type 2 error” in Table 1), which is associated with a tendency to overestimate sardine abundance. There are presently no plans to sample schools that are not thought by the pilot to be sardines during Stage 2 sampling. Such sampling could have been used to determine the extent of “Type 1 error” (where schools of sardines fail to be recognized as such, an error that would lead to an underestimate of sardine abundance). The Panel noted that the frequency of Type 2 error is likely to be related to the relative abundance of sardine schools. At high relative abundances of sardines, the prior (i.e., uninformed by any observational data) probability that a school is not sardines is low. However, at relatively low sardine abundances, schools thought to be sardine have a higher prior probability of not being sardines. Ultimately this phenomenon could result in a nonlinear relationship between survey estimates and true local abundance, and merits careful attention.

The survey plan emphasizes species identification primarily from the enhanced photographic images without auxiliary information. Image processing technicians will be trained by processing a library of images with known species composition. In this regard it is vitally important that the identification of the species in the training set be known.

Image Size Calibration: Initial calibration of image size suggests a bias toward overestimating the size of observed schools, but this bias may cancel if the tonnage of fish caught in Stage 2 is calibrated directly to a representative camera image. However, accurate calibration is always desirable so that different equipment can be used interchangeably, and changes to new equipment do not pose a problem.

Although the images appear to have relatively little edge distortion[1], a trigonometric argument suggests that this is probably not negligible. At a height of 8,000 ft, the left and right edges of the photographic field are 6,000 ft from the track line. Therefore schools at the edge of the frame are 10,000 ft from the observer (this being congruent to a 3-4-5 triangle), or 25 percent farther away than schools directly beneath the aircraft (Fig. 1). While a theoretical calibration curve could easily be derived, the Panel **recommends** that an empirical calibration curve may be more reliable and robust. Both approaches should be attempted and compared, but the Panel favors the empirical approach. In this respect, the Panel suggested that having both planes fly a small number of transects 6,000 ft apart would provide an additional source of information to quantify the impact of edge distortion.

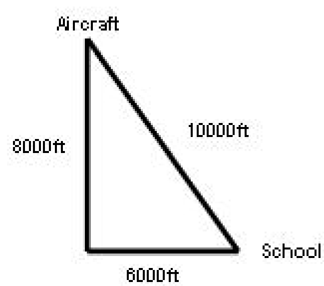


Figure 1. Distance to a school that is a perpendicular distance of 6,000 ft from the aircraft.

School Area Determination: The Panel agrees that total school area is a useful summary statistic related to abundance for long-term comparisons, and is better than alternative metrics such as a numerical count of schools.

Consistency Issues: The criteria of how and when to do the survey should be consistent over time, so there is no unintended change in q. Although the best weather and visibility conditions

[1] Distortion is defined in this report as being when an image appears different (or has a different detection probability) than it would have had had the image been directly beneath the aircraft.

occur in the fall, the surveys will have to be conducted several months earlier so that the results are available for use in the sardine stock assessment.

Weather variability and associated operational constraints are necessarily a problem for consistency. It is important to have pre-determined and quantifiable criteria for deciding when a portion of a transect cannot be used, or when a transect must be shortened or abandoned altogether. Such decisions should be thoroughly documented so that consistency and lack of bias can be evaluated.

There is a potential for observer (or equipment) differences in several aspects of the survey. Such differences include: (a) changes over time in personnel and equipment, and (b) differences among pilots, and among photographic processing technicians during a single survey. The Panel notes that periodic refresher training can be used to reduce those differences in some cases, but **recommends** that ultimately it may be most effective to quantify any consistent differences by means of double-blind comparisons and similar techniques.

2.2) "Stage 2" Area to Tonnage Calibration by Targeted Fishing

The relationship between school surface area and school tonnage will be estimated using directed purse seine sets on example schools. The target school will be photographed before the vessel interacts with it, and will also be photographed continuously while it is being caught. It is important to take the reference photograph under standard survey conditions, including the standard 8,000 ft altitude, to obtain comparable photographic images and nominal identifications of the target school before descending to a lower altitude if it is necessary to direct the set. Although the photographic processing technician will be aware that the target was initially thought to be sardine, maintaining comparability requires that the technician is not aware of the definitive identification from actual capture.

The Panel **recommends** that the targeted schools should be representative of the types and sizes of schools observed in the Stage 1 transects. To the extent practicable, captured schools should attempt to include representative samples from areas that are distant, both offshore and alongshore, from the base fishing port.

There would be value in following individual schools photographically for a period of time before catching them. This would reveal useful aspects of the variation in school area for schools of known tonnages. Together with photographic monitoring during the capture, this would help assure that the initially observed school is captured in its entirety.

3) Analytic Treatment of the Data

In principle, the estimate of survey biomass is straightforward to calculate, i.e. biomass = area of cover*(biomass/area) where the first quantity is obtained from Stage 1, and the ratio is obtained from Stage 2. The Technical Team initially intended to estimate total school surface area before estimating biomass, but the Panel **recommends** that each school be converted to an estimated tonnage before integrating over the survey area, because this allows for nonlinearity in the relationship between school tonnage and school surface area. The Panel expects this relationship will be nonlinear, and notes that quantification of the extent of nonlinearity is an important objective of Stage 2 sampling. Another problem related to nonlinearity is extrapolation uncertainty for the biomass/area of schools much larger than those that were sampled.

If the area to tonnage relationship is nonlinear, "edge effects" (schools that extend outside the photographic frame) pose a special problem. Edge effects are much less severe along the fore and aft direction of travel because of the extensive overlap of successive images, and the "edge effects" of concern mainly involve the "right" and "left" edges of the photographic images. There are a variety of techniques for addressing edge effects, but one simple approach might be to end the accounting frame somewhat short of the edge of the photograph, so that full images of most "edge schools" are available for analysis and quantification.

4) Implementation of Survey Protocols

An important question is whether the total exempted fishing permit (EFP) allocation (and how it is allocated to each area) is sufficient to achieve a useful survey.

- At 1,200 tons from each area, the suggestion of the Technical Team (i.e., a total EFP allocation of 2400 tons), the Panel concluded that there is a good outlook for successful calibration.
- The Panel doubts whether sufficient precision would be achieved if only 600 tons were taken from each area (a total of 1,200 tons is currently allocated for an EFP). In the case where a total of only 1,200 tons was available, the Panel **recommends** that the entire 1,200 tons be used in only one of the two possible survey areas. Moreover, the Panel saw no compelling reason to recommend that the tonnage be assigned to a particular area of the two areas, and would prefer that the Technical Team decide how they would best use the allocation, were it only 1,200 tons. However, the Panel would not expect that an estimate based on a small number of point sets would provide a sufficient basis for a robust and precise estimate of abundance. If all of the allocation was taken from one area, this would provide a basis to estimate the relationship between school size and tonnage for that area, but it could not be used to estimate abundance for the entire survey area (Canadian border to Point Conception).

The 2008 pilot survey involved 13 point sets, eight of which were usable; the rest of which were unusable due to partial escapement. The Technical Team is hoping for about 32 sets in each of the two areas in 2009. There is substantial room for optimizing the information that can be obtained from a fixed allocation of catch biomass, including maximizing the precision of the calibration and detecting and quantifying nonlinearity in the relationship. Special considerations apply to the high end of school tonnages. The maximum school size that a single vessel can accommodate is about 95 tons (hold capacity), but a purse seine net can take up to about 300 tons, which would require multiple vessels to receive the fish. These large schools are likely to be important in the biomass/area calibration, but quickly use up tonnage and would require a substantially larger EFP allocation. Larger schools may also be more difficult to catch in their entirety.

5) Evaluation of Precision and Bias

An overview of issues regarding precision and bias is given in Table 1[2], and some further thought from the Technical Team are given in Appendix 2. The Panel notes that the survey is well enough described/designed that it is amenable to close study of component details and procedures.

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[2] This report uses the informal terms "overestimate" and "underestimate" rather than the technically correct equivalents of "positive bias" and negative bias."

Two of the largest sources of bias are expected to result in underestimates: (a) the survey does not cover the entire region occupied by Pacific sardine, and (b) there will also be no correction factor for undetectable (e.g., deep) schools, so the estimate of biomass will probably be an underestimate, even within the survey area. Moreover, although the Technical Team and the Panel have identified sources leading to both over- and underestimates of abundance, the survey plan will only attempt to correct for overestimates (see Appendix 2). Consequently, the Panel expects that the overall result will be an underestimate of the total biomass of northern subpopulation of Pacific sardine. This conclusion is consistent with experience from analogous surveys.

6) Use of Aerial Survey in Stock Assessments of Sardine

The 2008 data were from a pilot study, and the Panel notes that it should not be used for stock assessment purposes. The first usable data will presumably be collected during 2009.

The proposed survey presents a problem of how to utilize an absolute estimate for an uncertain portion of the total area. It is "an estimate of a minimum", at least. One somewhat analogous example is the use of an absolute estimate of the biomass of cowcod in the Cowcod Conservation Area of southern California, in the Pacific Fishery Management Council cowcod assessment. The abundance estimate was based on strip transect observations from a submersible. The assessment combined the precision estimate from the submersible survey with uncertainty in the value of q, which in this case was the estimated fraction of the cowcod population that resides in the survey area.

It is important to get accurate size composition data for the surveyed fish, so that a selectivity curve can be estimated with the assessment model, and so that the survey biomass estimate can be compared with an appropriate demographic subset of the assessment stock. Age-composition data would be even more useful in this regard.

There will be ongoing and probably increasing benefit from continuing the survey for many years. Also the cumulative sampling and experience will result in progressive improvement in precision of the survey.

It is anticipated that if the surveys continue over multiple years, it would provide a basis for a new relative index of abundance.

Table1: Sources of uncertainty in proposed aerial survey for sardines

Stage 1 – Estimation of sardine school area

Source of Uncertainty or Bias	Direction	Ways of Addressing the issue
Category: Species misidentification		
Type 1: Sardine misidentified as other spp./features	Underestimate	Directed sets, jigging, include low overflight
Type 2a: Other spp. misidentified as sardines	Overestimate	Directed sets, jigging
Type 2b: Other features misidentified as sardine	Overestimate	Avoid cloudy conditions??
Density dependent misidentification (a nonlinearity)	Hyperstability?	Long-term comparisons
Variability among pilots		
Category: School detection (note: timing needed for assessment schedule is not optimal for survey conditions)		
Schools too deep	Underestimate	Quantify water clarity (e.g. secchi depth), Echo sounder evidence
Schools lost in glare	Underestimate	Time of day, compare adjacent frames
Schools too diffuse (hypothetical)	Unknown	Relate to behavioral patterns?
Marginal cloud cover, reduced visibility	Underestimate	Determine range of acceptable conditions
Sea state	Underestimate	Determine range of acceptable conditions
Technician variability–image enhancement	Unknown	Double-blind re-analyses
Weather is consistently prohibitive	Unknown	Use better season and delay input one year
Category: School area determination		
Calibration of scale (photogrammetry)	Overestimate (maybe neutral)	Continue calibration
Calibrate distortion at edge of frame	Unknown	Continue calibration
Precision and repeatability	Unknown	Repeat photos of same school over time; Compare morning and afternoon views
Schools extending outside visual frame	Depends on B/A relationship	Problem mainly if nonlinearity exists
Diffuse school boundary	Overestimate?	Disturb with vessel and compare area?
Complex shape or diffuse	Overestimate?	Repeat photos of same school over time; Disturb with vessel and compare
Technician variability–image enhancement	Unknown	Blind" reanalyses of photos, within and among technicians.

Stage 2 – Estimation of biomass per unit area

Source of Uncertainty or Bias	Direction	Ways of Addressing the issue
Comparability to images in Stage 1	Unknown	Choose conditions and school types similar to aerial survey. Use similar altitude.
Pro-sardine target selection	Overestimate	Select schools only on size criterion
Nonlinear biomass/area relationship	Variance issue	Increase sample size, contrast
Statistical imprecision	Variance issue	Increase sample size
Regional differences	Unknown	Compare northern and southern cases
Behavioral patterns		
Feeding, spawning, transiting	Variance issue	Stratification
Mixed species	Unknown	
Response to fishing vessel	Overestimate	Get photo before vessel approaches
Oceanographic conditions (e.g., El Niño)	Overestimate (contraction)	Caution in among-year data sharing
Distance offshore	Unknown	
Present but undetectable–directed sets impossible	Underestimate	Conduct blind sets (e.g., Pearcy's work)
Variable relationship depending on school thickness	Variance issue	Voluntary logbooks at time of survey to compare school thicknesses among years
Density-dependent mixed schooling	Unknown	Long-term fishery catch compositions

Source of Uncertainty or Bias	Direction	Ways of Addressing the issue
Abundance estimation		
Pre-integrate area–works if there is linearity	Unknown	Depends on Stage 2 results; Edge effect is neutral if linear
Integrate biomass over schools–works best if nonlinear	N/A	Need to deal with edge effects
Other		
Survey stratification (transect density depends on school density)	N/A	Possible with further experience, but not currently proposed
Survey does not cover whole area	Underestimate	Maybe extend transects offshore; Go into Canada, Mexico

Appendix 1. List of Participants

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington,
Owen Hamel, SSC, NMFS, Northwest Fisheries Science Center
Gary Melvin, Center for Independent Experts (CIE),
Alec MacCall, External Reviewer, Southwest Fisheries Science Center (SWFSC)
Ken Burnham, External Reviewer, Colorado State University

Pacific Fishery Management Council (Council) Representatives:
Greg Krutzikowsky, Coastal Pelagic Species Management Team (CPSMT)
Mike Okoniewski, Coastal Pelagic Species Advisory Subpanel (CPSAS)
Mike Burner, Council Staff

Aerial Survey Technical Team:
Tom Jagielo
Vidar Wespestad
Doyle Hanan
Ryan Howe

Others in Attendance
Alexandre Aires-da-Silva, Inter-American Tropical Tuna Commission (IATTC)
Briana Brady, California Department of Fish and Game (CDFG), CPSMT
Tom Barnes, CDFG, SSC
Ray Conser, SWFSC, SSC
Paul Crone, SWFSC
Sam Herrick, SWFSC, CPSMT
Roger Hewitt, SWFSC
Kevin Hill, SWFSC
Ryan Kapp, Astoria Fisherman
Josh Lindsay, NMFS, Southwest Regional Office
Nancy Lo, SWFSC
Mark Maunder, IATTC
Sam McClatchie, SWFSC
Jenny McDaniel, SWFSC
Jonathan Phinney, SWFSC
Kevin Piner, SWFSC
Dianne Pleschner-Steele, California Wetfish Producers Association, CPSAS
Rosa Runcie, SWFSC
John Rutter, SWFSC
Bob Seidel, Astoria Holdings Inc.
Sarah Shoffler, SWFSC
Dale Sweetnam, CDFG, CPSMT
Akinori Takasuka, SWFSC
Russ Vetter, SWFSC
Ed Weber, SWFSC

Appendix 2. Technical Team Response to Various Issues

Response to comments following review of the survey design at the May, 2009 STAR Panel

Stage 1: Estimation of sardine school surface area

Species misidentification

Prior to the onset of production scale photo analysis, we will investigate the potential for school misidentification by photo analysis personnel. Images will be collected from areas where sardine are intermixed with other species (e.g. anchovy). Spotter pilots experienced with the problem of discriminating between species in aerial surveys of schooling fishes will aid in the preparation of a reference set of photographs with "known" species images. Photo analysis personnel will be trained to discriminate between species using the reference set of images. A set of test images will be compiled to evaluate within and between reader error in the parameters measured by the photo analysis personnel. The test images will be used in a double-blind experiment to measure variability in the entire process of image analysis, including: image enhancement, species identification, school enumeration, and area measurement. The development of a reference collection of photographs will be made carefully and validated, with the consideration that they will be used by photo analysis personnel for training purposes. Additional photos may be added to the reference collection in future years.

In addition to the above procedures, we will review the available data from other surveys to get a sense of species other than sardine that we may expect to see in our aerial survey. Data sources include: 1) trawl survey data (Emmett et al.) and historical spotter data (Squire et al.).

We also plan to evaluate the effect of altitude on species identification in the aerial survey. An experiment will be conducted with two airplanes to evaluate the altitude effect. One pilot will fly along a pre-designated test transect at the nominal survey altitude of 8,000 ft and will keep a log of schools observed, by species. The second airplane will fly at a lower altitude (e.g. 500 ft) with an observer on board for detailed note taking. There will be no communication between pilots regarding schools observed during the transect, in order to keep the two sets of observations independent. Photographs taken from the two airplanes will be analyzed and schools will be identified and compared between the two sets of images on a school by school basis. Pilots will be permitted to use their logbooks and notes made during the transect to assist in analyzing the photographs collected for the comparison. The rate of between-pilot agreement in school identification will be determined from the comparison of the two sets of photographs. To eliminate the pilot effect from the test, the pilots will switch altitude positions and will repeat the procedure on subsequent transects.

School detection

We recognize that an unknown proportion of schools in any given area will be too deep to detect via the proposed aerial survey method, and thus we acknowledge that the method will tend to underestimate total school surface area. Data collected from Stage 2 of the survey will include measurements of school height and vertical distribution in the water column. These data are a sample of schools visible from the aerial survey, and will be photographed at the nominal survey altitude of 8,000 ft. During the fishery, two vessels in each region (north and south) will be operating with ES-60 sounders logging data onto hard disks in continuous-operation mode.

These data will be processed to obtain a sample distribution of school height measurements (location of the top and bottom of the school in the water column). We expect that some of these schools will be distributed below the surface such that they would be too deep for aerial detection. Comparison of these data with the range of school height measurements from the 64 schools captured in Stage 2 point set sampling will give us a qualitative look at the rate of encountering schools not likely to be detected by the aerial survey method.

Weather conditions (e.g. marginal cloud cover, haze, elevated sea state) can conspire to create situations where schools would be likely to go undetected with the aerial survey method. We will determine a range of acceptable conditions for survey commencement (and termination). The survey pilots will judge whether or not conditions are acceptable for conducting surveys on a day to day basis. A detailed log will be kept to document when and why transects are terminated early due to prevailing weather conditions. From the Pilot Study we found that conditions such as glare and scattered cloud shadows over the ocean surface can be handled operationally by increasing the overlap rate of the photographic coverage. We have found that an image overlap rate of 60 percent is effective for dealing with this issue under most circumstances.

School area determination

Calibration of aerial images to measure the size of known objects was conducted during the pilot study in 2008 and will be continued in the 2009 survey year. We will extend the calibration experiments to evaluate the level of distortion on the periphery of the digital images. It is possible to address this issue by either a theoretical or an empirical approach. For example, a theoretical approach could involve collecting measurements from photographs to determine if objects on the image edge are on average smaller than objects found in the image center, and then deriving a theoretical relationship from this information. Alternately, an empirical approach could involve comparing real-world measurements of objects photographed in the image periphery with the sizes of the same objects as determined from the software analysis procedure.

Stage 2: Estimation of sardine biomass per unit surface area

Comparability to images in Stage 1

To ensure that the surface area measurements collected in Stage 2 are comparable to those collected in Stage 1 of the survey, we will collect the point set images at the same nominal altitude of the survey (i.e. 8,000 ft). Measurements of school surface area for point sets will be taken prior to purse seine vessel approach. Photographs will be taken throughout the point set process to examine potential school responses to the fishing vessel.

Target selection by pilot

Pilots will be given a daily schedule of school sizes to be targeted for capture. The pilots will maintain a logbook which will contain a record of every school identified for point set capture. To ensure Stage 2 sampling frame comparability to the set of images collected in Stage 1 of the survey, pilots will identify point set targets from the nominal survey altitude of 8,000 ft. In the event that the pilot identifies a school for point set capture at 8,000 ft, and the school is subsequently found to be a species other than sardine (e.g. when the pilot descends to a lower altitude for a better look, and after the vessel has approached the school for capture and is capable of making on the water observations and jigging), this information will be duly recorded and used to estimate the sardine mis-identification rate of pilots in Stage 2 sampling.

Non-linear biomass to area relationship

A simple ratio estimator of biomass is not desirable if a pronounced non-linear relationship is observed in the biomass to area relationship. During the data analysis phase of the survey, we will evaluate the alternative of integrating biomass over the size range of schools observed. It will be important to ensure sufficient contrast in the sizes of schools sampled for this purpose. During the data analysis phase, we will look for non-linearity in the surface area to biomass relationship, and will also make the determination whether a standard regression vs. an errors-in-variables approach is more appropriate for survey data analysis.

Regional differences

We anticipate regional differences will be observed in the parameters associated with both Stage 1 and Stage 2 sampling; however, we have no a prior information for effective stratification beyond a simple north-south treatment at this time. Thus, in this first survey year, we are distributing the sampling effort such that 1) an equal amount of area will be surveyed in the north and the south, and 2) an equal number of point sets will be collected in the north and the south. With the information we seek to collect in 2009, we may be able to reduce the variance on our parameter estimates by alternative stratification schemes going forward.

This survey design is limited to the area extending from Cape Flattery to Monterey Bay and nominally to 35 miles offshore. Sardine distribution is known to extend into Canada to the north, and into Mexico to the south, and may extend further offshore than 35 miles in some areas. Thus, we recognize that the survey will underestimate sardine abundance for this reason. We do not anticipate sampling north or south of the area specified; however, we will examine the east-west distribution by systematically extending a set of transect beyond 35 miles to determine the offshore distribution of sardine and the utility of the 35 mile cut-off for the design of future surveys.

Behavioral patterns

We recognize that sardine behavioral patterns will influence the variability of measurements that we will record during the aerial survey. For example, feeding, spawning, and transiting behaviors can be expected to result in different levels of aggregation/dispersion and thus will increase the variability in the surface area to biomass relationship. We expect that our ability to classify schools by behavioral category will improve as we obtain observations over a period of years and under a variety of conditions. The parameters we will be examining in our 2009 survey that have potential for beginning the development of a school classification scheme include: 1) school height (from ES-60 data) and 2) school shape (i.e. perimeter to area; circularity).

Abundance Estimation

Edge effects – procedure for handling schools not completely within the photograph

Edge effects are not a problem on the top and bottom of the images because image overlap provides for multiple observations of schools in the direction of aircraft travel; however, the images of schools could from time to time have the edges cut off (i.e. not photographed in their entirety. This is a problem because of the potential for non-linearity in the surface area to biomass relationship. This situation is not uncommon in quadrate based sampling and methods for dealing with it are available in the survey design literature. We will review the literature and will establish an appropriate procedure for data reduction and analysis to deal with this issue.

Two methods were suggested by the Panel. One method would involve drawing lines some distance from the edge (e.g. 1 inch) and re-defining the area-swept using the new (reduced) width. This approach allows for empirical measurements of schools straddling the edges. Another method would involve drawing a line down the middle of the image and studying the edge effect by examining schools that are split by the line.

Calculation of total biomass

As noted above, we will evaluate non-linearity in the surface area to biomass relationship. If deemed appropriate, we will integrate biomass over the range of observed school sizes.

Other

Comparison of pilot estimate vs. measured point set tonnage

In the survey logbook to be maintained by the pilots, the estimate of school tonnage prior to each point set will be recorded. This information will be summarized and compared to actual landed point set tonnage.

Agenda Item H.2.a
Attachment 4
June 2009

Daily Egg Production Methods for Pacific Sardine

Report of STAR Panel Meeting

NOAA / Southwest Fisheries Science Center
La Jolla, California
May 4-8, 2009

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
Owen Hamel, SSC, NMFS, Northwest Fisheries Science Center
Gary Melvin, Center for Independent Experts (CIE)
Alec MacCall, External Reviewer, Southwest Fisheries Science Center (SWFSC)
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Pacific Fishery Management Council (Council) Representatives:
Greg Krutzikowsky, Coastal Pelagic Species Management Team (CPSMT)
Mike Okoniewski, Coastal Pelagic Species Advisory Subpanel (CPSAS)
Mike Burner, Council Staff

Sardine Daily Egg Production Method (DEPM) Technical Team:
Nancy Lo, NMFS, SWFSC
Beverly Macewicz, NWFS, SWFSC
Kevin Hill, NMFS, SWFSC

1) Overview

The review of the Daily Egg Production Method (DEPM) as it is applied to Pacific Sardine was conducted by a Stock Assessment Review Panel ((Panel) which met at the SWFSC, La Jolla, CA, from May 4-8, 2009. The membership of the Panel was broader than is normal for assessment reviews in order to include expertise on survey methodology and design as well stock assessment. Material documenting the methodology used for DEPM generally, and as it has been applied to Pacific Sardine, was provided to the Panel in advance of the meeting. A file server was provided at the meeting room to provide common access to all presentation material and the additional analyses that were conducted during the course of the meeting.

The Panel reviewed the available material in terms of the following key questions:

- The design of sampling scheme used to collect the basic data used in the DEPM.
- The analytical treatment of the data in terms of the ability to estimate (A) absolute abundance and (B) trends in abundance.
- Consequences of the implementation of survey protocols.
- Use of DEPM estimates in stock assessments for Pacific Sardine.

2) Design of the Sampling Scheme

The sampling scheme follows a design originally developed for northern anchovy in the early 1980s, and which has since found widespread use in fisheries around the world. The most important difference from the anchovy DEPM and that for sardine is the much larger geographic scope of the sardine population, which ranges from Mexico to Canada. The survey consists of concurrent and complementary surveys of pelagic egg abundance and of adult spawning rates conducted in a relatively short period of time, e.g., one month. The estimate of adult biomass is the number of pelagic eggs spawned per day divided by the average daily quantity of eggs produced per unit weight of mature adult sardines.

2.1) Pelagic Egg Abundance

The egg survey uses an adaptive sampling scheme based on near-surface egg densities measured by a continuous underway sampling system (CUFES). The survey is generally conducted during April, which is a peak time of spawning activity. Eggs have been sampled using a vertically-retrieved plankton net of relatively small diameter (CalVet: CalCOFI Vertical Egg Tow). Since 1997, high egg abundance areas are sampled more intensely than low density area, and the subsequent calculations are based on a two-stratum (high vs. low) estimation scheme. Egg age is determined by stage of development, and the production rate of freshly spawned eggs is calculated from a regression of daily egg and yolksac larvae production on age. The most substantial problem with the egg abundance portion of the DEPM is incomplete coverage of the spawning area, which is unavoidable due to the current inability to access ichthyoplankton data from Mexican waters in a timely manner. The attempts to cover the full geographic range of spawning in U.S. waters have been commendable, and the lack of complete coverage is usually due to factors beyond control, such as adverse weather, equipment malfunction, and limited ship time and staff. The review did not identify any serious problems with operational aspects of the pelagic egg survey portion of the sardine DEPM.

2.2) Adult Spawning Rate

The Panel considered several issues and potential problems with sampling and calculation of adult spawning rate and its component parameters. Unfortunately, many of the necessary data were unavailable for use during the review, preventing the Panel from reaching some conclusions or from recommending appropriate changes in procedures and calculations (see "Data Accessibility" below).

<u>Population Heterogeneity:</u> The present methodology treats each trawl sample as being equally representative of the population, with the main pattern of heterogeneity being related to the high and low egg density strata, as described in Section 2.1. There appear to be other patterns of heterogeneity which could result in recommended methodological changes. Specifically, there is clear evidence for spatial heterogeneity in average fish weight, with larger fish tending to occur to the north and offshore, suggesting a possible benefit from further stratification of the adult samples. Although the limited available data appeared to indicate that the size composition of sampled fish approximately reflected regional size patterns in fishery-caught sardines, there remained some concern within the Panel that the northernmost portion of the stock may not be adequately represented in the adult samples. It also appears that this northern segment may not be spawning as actively as the better-sampled more southerly portion of the population at the time of the DEPM survey. If this is the case, the estimated population spawning rate would be somewhat lower if these northern fish were represented, and the DEPM estimate of spawning biomass would be somewhat larger. Available data did not allow evaluation of this hypothesis.

The Panel agreed with the Technical Team that annual adult sample sizes (both in terms of positive sites and number of fish) are undesirably small. The Panel **recommends** that efforts should be made to increase the number of adult samples.

3) Analytic Treatment of the Data

<u>Stratification:</u> The Panel **recommends** more extensive use of stratification in estimation of the adult spawning rate parameters, but recognizing that small sample sizes place a constraint on the amount of stratification that should be considered (also see Section 4 in this regard). A first level of stratification would be to estimate the adult reproductive parameters using the same high and low production regions identified by the pelagic egg sampling survey. This approach has been presented in recent DEPM reports, but with an unweighted stratification scheme. The Panel **recommends** that the two strata (regions 1 and 2) should be weighted by their relative adult abundance. Trawl catch rates appear to be too variable to serve as a basis for this weighting. However, an approximate measure of the adult abundance is given by the present unweighted stratified calculation of DEPM estimates of spawning biomass, therefore a single iteration of reweighting should suffice. Other patterns of heterogeneity could provide motivation for further stratification of adult spawning rate estimates.

<u>Hierarchical (Random Effects) Modelling:</u> The present and historical treatment of DEPM estimates has been to rely entirely on contemporary sample-based measurements of parameters as much as possible. In years when sampling has failed to produce a reliable estimate of a parameter, there has been a pattern of *ad-hoc* borrowing of needed quantities from previous years. Importantly, the present practice is to produce a DEPM estimate (which, should be noted, is done under severe time pressure), with no explicit intent to revise the entire time-series of estimates on a regular basis.

The Panel **recommends** that a hierarchical modelling approach (a.k.a. random effects modelling) should be adopted for estimation of spawning rate parameters. Each new annual estimate would be based both on new data and on the historical data, with substantial improvement in precision. If new data are lacking, the *ad-hoc* "borrowing" would be replaced by a well-documented statistical basis for estimating missing parameters. This would allow construction of estimates of spawning biomass for all years for which estimates of egg production (P_0) are available. At present, estimates of egg production for such years are treated as a separate data series in the stock assessment (referred to as Total Egg Production [TEP]). It should be noted that the entire estimated time series of spawning rate parameters would change somewhat with each new year of samples. Once the statistical model has been developed and implemented (there are relevant procedures in many commonly-used statistical packages such as *R*, *SAS*, WinBUGS, and *SPLUS*), annual updates would require very little time and effort. Initial development would require more work, and probably should not be attempted for 2009 unless help can be obtained from a statistician who has experience in this specialty.

There also may be an opportunity to improve the precision of the estimated fraction spawning. The present procedure is to use only day 1 post-ovulatory follicles, but day 2 and day 3 follicles should be informative, and a properly specified model should provide a basis for using the additional information. This would in effect increase the sample size without additional sampling effort and the Panel **recommends** that this approach be explored further.

It was noted that there are some fish at depths deeper than those depths sampled by the trawl. The Panel **recommends** that the relative abundance of these deeper fish be determined (perhaps by means of acoustics) and an evaluation conducted to assess whether they are a significant source of uncertainty.

4) Implementation of Survey Protocols

Operationally, one of the major difficulties facing the DEPM for sardines is the ability to obtain a sufficiently large number of adult samples over a sufficiently large portion of the adult range, all in the relatively short time window of the survey. The Panel **recommends** that additional sources of adult fish samples should be explored. Commercial fishing vessels are a potential source of adult samples, and cooperative research with the fishing industry would be worth pursuing. The latter may require an exempted fishing permit (EFP) from the Council, and the project would be a good candidate for NMFS cooperative research funding.

5) Use of DEPM in Stock Assessments of Sardine

The original DEPM methodology estimated the biomass of mature males and females combined, based on an estimated sex ratio parameter. In the historical context of DEPM usage for anchovy management, the abundance estimate was used directly in setting annual harvest levels, and this combined-sex treatment was appropriate for that purpose. However, the present usage for sardine assessment differs in that the DEPM is one of many data inputs to a demographic model Stock Synthesis (SS). In SS, it is more suitable to input the female spawning biomass (or more accurately, the population egg production), in which case the sex ratio parameter is not a necessary part of the DEPM calculation. Because the sex ratio parameter is an estimated parameter that is subject to sampling error, its deletion should also result in some improvement in the relative precision of the abundance estimate. However, the DEPM estimates are treated as relative indexes (q is estimated, and is less than 1), so use of female-only spawning biomass estimates would have less benefit than would be the case for an estimate of absolute estimate.

The Panel **recommends** that the DEPM estimates should be input to the stock assessment in the form of the biomass of spawning females (i.e. ignore the sex-ratio of mature animals when computing the indices).

Trawl data are effectively missing for 2006 (i.e. the trawl and the egg samples were not synchronized in that year due to operational reasons), therefore the Panel **recommends** that this estimate should not be treated as a DEPM estimate. The 1995 survey only collected ichthyoplankton data from the standard CalCOFI grid. The Panel **recommends** this estimate not be included in the stock assessment at all, because it not comparable with the remainder of the time-series and to re-specify the SS model accordingly.

The Panel **recommends** that a complete and annotated table similar to Table 3 in the 2008 report, including the information from the 1980s CDFG surveys, should be available (and included in the stock assessment report) for the upcoming sardine assessment.

6) Data Accessibility

The Panel was not able to fully evaluate the sensitivity of the estimates of spawning biomass from the DEPM to important methodological assumptions because much of the raw data from the trawl surveys were not available to the analysts (and hence the Panel) during the review meeting. While the analysts attempted to address the Panel's requests for additional analyses to the extent possible given the available data (essentially the summary data published in previous reports), the lack of raw data constrained the Panel's ability to examine issues and to draw definitive conclusions.

The Panel **strongly recommends** that the Terms of Reference for Stock Assessments for CPS (and other Council fishery management plan (FMP) species) be modified to require raw data for key model inputs be available at STAR Panels to allow for further analyses. The need for raw data is critical for any future STAR Panel tasked with reviewing survey methodology. Although some data sources may be excessively large, and other data sources may not yet be in machine-readable format, suitable database management systems exist, and are within all agencies' capability to employ and maintain. Moreover, use of formal databases is nearly always beneficial to research programs that require extensive data collection.

7) Areas of Disagreement

There were no major areas of disagreement between the Technical Team and Panel.

8) Summary of Research Recommendations

General

- The Terms of Reference for Stock Assessments for CPS (and other Council FMP species) should be modified to require raw data for key model inputs be available at STAR Panels to allow for further analyses.

Tasks to be Completed Prior to the September 2009 Sardine Assessments

- The estimates of spawning biomass for 1985, 1986 and 1988 should be re-calculated using a statistical system that is consistent with the more recent DEPM estimates.
- Estimate the adult reproductive parameters using the same high and low production regions identified by the pelagic egg sampling survey.
- The two strata (regions 1 and 2) should be weighted by their relative adult abundance.

- The DEPM estimates should be input to the stock assessment in the form of the biomass of spawning females (i.e. ignore the sex-ratio of mature animals when computing the estimates).
- The data for 2006 should be used in the assessment as an estimate of TEP rather than as part of the DEPM series.
- Estimates of abundance based on the 1995 survey should not be included in the stock assessment at all and re-specify the SS model accordingly.
- A complete and annotated table similar to Table 3 in the 2008 report, including the information from the 1980s CDFG surveys, should be available (and included in the stock assessment report) for the upcoming sardine assessment.

Longer-term research priorities

- Efforts should be made to increase the number of samples of adults.
- A hierarchical modelling approach (a.k.a. random effects modelling) should be adopted for estimation of spawning rate parameters.
- The use of day 2 and day 3 follicles should be explored as a way to estimate the spawning fraction.
- The relative abundance of fish deeper than can be sampled by the trawls should be determined (perhaps by means of acoustics) and an evaluation conducted whether these fish represent a significant source of uncertainty.
- Additional sources of adult fish samples should be explored.

Appendix 1

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington,
Owen Hamel, SSC, NMFS, Northwest Fisheries Science Center
Gary Melvin, Center for Independent Experts (CIE),
Alec MacCall, External Reviewer, Southwest Fisheries Science Center (SWFSC)
Ken Burnham, External Reviewer, Colorado State University

Pacific Fishery Management Council (Council) Representatives:
Greg Krutzikowsky, Coastal Pelagic Species Management Team (CPSMT)
Mike Okoniewski, Coastal Pelagic Species Advisory Subpanel (CPSAS)
Mike Burner, Council Staff

Sardine Daily Egg Production Method (DEPM) Technical Team:
Nancy Lo, NMFS, SWFSC
Beverly Macewicz, NWFS, SWFSC
Kevin Hill, NMFS, SWFSC

Others in Attendance
Alexandre Aires-da-Silva, Inter-American Tropical Tuna Commission (IATTC)
Briana Brady, California Department of Fish and Game (CDFG), CPSMT
Ray Conser, SWFSC, SSC
Doyle Hanan, Hanan and Associates
Sam Herrick, SWFSC, CPSMT
Roger Hewitt, SWFSC
Ryan Kapp, Astoria Fisherman
Josh Lindsay, NMFS, Southwest Regional Office
Mark Maunder, IATTC
Sam McClatchie, SWFSC
Jonathan Phinney, SWFSC
Kevin Piner, SWFSC
Diane Pleschner-Steele, California Wetfish Producers Association, CPSAS
Rosa Runcie, SWFSC
John Rutter, SWFSC
Bob Seidel, Astoria Holdings Inc.
Sarah Shoffler, SWFSC
Dale Sweetnam, CDFG, CPSMT
Akinori Takasuka, SWFSC
Russ Vetter, SWFSC
Ed Weber, SWFSC

Appendix 2 Requests and Responses

A. Compare the size-composition of the trawl samples with the assessment model estimates of the size-composition of the total population. Do the same comparison for ages, if possible. Possibly divide the trawl samples into northern and southern segments.
Reason: Is there evidence for biased selection in the trawl samples? Is there evidence for north/south population heterogeneity that is somehow a problem?
Response: The DEPM Technical Team (TEAM) didn't have access to the size-composition data from the trawl samples. Data are partially in figures in the Team report–forthcoming.

B1. For some of the years, re-calculate adult spawning parameters and the biomass estimate using samples weighted by trawl catch.
B2. Correlate/scattergram of biological values vs trawl catch size.
B3. Do alternative B2 using Table 2 in the 2007 document to compare biological values with number sampled.
Reason: Possibility of better statistical treatment of sample data.
Response: Sex ratio and spawning fraction don't seem to vary with latitude, but average fish weight does. This suggests that latitudinal population structure merits more investigation. The plot of spawning fraction against sample size shows possible (but not conclusive) correlation of trawl catch with spawning fraction. These patterns need larger sample sizes to confirm. The existence of high and low egg density regions suggests possible spatial differences in sex ratio and spawning fraction. Weighting by catches was influenced by a single outlier in the case that was examined. This does not allow determination of an optimal weighting system. The subject would benefit from a meta-analysis to determine the best weighting scheme, based on variance as a function of trawl catch size.

C. Drop, or expand the 1995 survey to include the probable central California segment.
Reason: The 1995 survey covered a small area and there were no trawls; the survey result is based on CalCOFI eggs, not DEPM.
Response: No response was necessary during the review. This applies to the upcoming assessment.

D. Summarize information on the 1986, 1987, and 1988 surveys using a format similar to Tables 4 and 6 of the 2008 report. Also document any peculiarities.
Reason: These surveys are poorly documented.
Response: The Team found the original CDFG reports. The egg data exist, but it is unclear whether all of the adult data still exist. The 1980s CDFG surveys were conducted later in the year than is the case now (fish were thought to spawn during the summer, based on historical experience). If the original data can be obtained, the Panel **recommends** that the estimates should be re-calculated using a statistical system that is consistent with the more recent DEPM estimates.

E. Re-stratify trawl balance in high and low density areas consistently.
Reason: Too many changes make it difficult to do comparisons. Also, methodological changes can be a source of estimation variability.
Response: The Team revisited the high-low area stratification. There is a precision benefit from stratified estimation of adult parameters

F: Do separate DEPM calculations for high and low density regions, at least for 2007, but preferably for several different years. Compare the results with the original estimates (and their precisions).
Reason: There is a possible heterogeneity of adult parameters in the high and low egg density regions. How does the estimate change if we stratify the adult parameters similarly?
Response: The Team revisited the high-low area stratification. There is a precision benefit from stratified estimation of adult parameters

G: Re-calculate the 1998 estimate using conventional stratification and statistical treatment.
Reason: The original estimate used region 1 only -- We don't know what the consequences were of treating it differently, and this will allow us to compare estimates. Consistent methodology is desirable, other things equal. This is an extension of request E.
Response: This was done.

H: Reweight the 2007 and 2008 stratified estimates by abundances
Reason: Weighting by area is an approximation, but can be improved by iterative reweighting based on the estimated spawning population in each area (one-time iterative reweighting). The ideal approach is to weight by actual abundance in the two areas, however, we were unable to get an index from trawl catch rates.
Response: The Team presented the results, which suggested that stratification improved the precision of the estimates.

Federal Register / Vol. 74, No. 86 / Wednesday, May 6, 2009 / Proposed

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 52

[EPA–R09–OAR–2009–0083; FRL–8900–3]

Revisions to the California State Implementation Plan, Santa Barbara County Air Pollution Control District

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: EPA is proposing to approve revisions to the Santa Barbara County Air Pollution Control District (SBCAPCD) portion of the California State Implementation Plan (SIP). This action revises and adds various definitions of terms used by the SBCAPCD. Under authority of the Clean Air Act as amended in 1990 (CAA or the Act), we are proposing to approve a local rule that is administrative and address changes for clarity and consistency.

DATES: Any comments on this proposal must arrive by *June 5, 2009.*

ADDRESSES: Submit comments, identified by docket number EPA–R09–OAR–2009–0083, by one of the following methods:

1. *Federal eRulemaking Portal: www.regulations.gov.* Follow the on-line instructions.
2. *E-mail: steckel.andrew@epa.gov.*
3. *Mail or deliver:* Andrew Steckel (Air-4), U.S. Environmental Protection Agency Region IX, 75 Hawthorne Street, San Francisco, CA 94105–3901.

Instructions: All comments will be included in the public docket without change and may be made available online at *www.regulations.gov,* including any personal information provided, unless the comment includes Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Information that you consider CBI or otherwise protected should be clearly identified as such and should not be submitted through *www.regulations.gov* or e-mail. *www.regulations.gov* is an ''anonymous access'' system, and EPA will not know your identity or contact information unless you provide it in the body of your comment. If you send e-mail directly to EPA, your e-mail address will be automatically captured and included as part of the public comment. If EPA cannot read your comment due to technical difficulties and cannot contact you for clarification, EPA may not be able to consider your comment. Electronic files should avoid the use of special characters, any form of encryption, and be free of any defects or viruses.

Docket: The index to the docket for this action is available electronically at *www.regulations.gov* and in hard copy at EPA Region IX, 75 Hawthorne Street, San Francisco, California. While all documents in the docket are listed in the index, some information may be publicly available only at the hard copy location (*e.g.,* copyrighted material), and some may not be publicly available in either location (*e.g.,* CBI). To inspect the hard copy materials, please schedule an appointment during normal business hours with the contact listed in the **FOR FURTHER INFORMATION CONTACT** section.

FOR FURTHER INFORMATION CONTACT: Cynthia Allen, EPA Region IX, (415) 947–4120, *allen.cynthia@epa.gov.*

SUPPLEMENTARY INFORMATION: This proposal addresses the following local rule: Rule 102, Definitions. In the Rules and Regulations section of this **Federal Register,** we are approving this local rule in a direct final action without prior proposal because we believe this SIP revision is not controversial. If we receive adverse comments, however, we will publish a timely withdrawal of the direct final rule and address the comments in subsequent action based on this proposed rule. Please note that if we receive adverse comment on an amendment, paragraph, or section of this rule and if that provision may be severed from the remainder of the rule, we may adopt as final those provisions of the rule that are not the subject of an adverse comment.

We do not plan to open a second comment period, so anyone interested in commenting should do so at this time. If we do not receive adverse comments, no further activity is planned. For further information, please see the direct final action.

Dated: March 2, 2009.

Laura Yoshii,

Acting Regional Administrator, Region IX.

[FR Doc. E9–10535 Filed 5–5–09; 8:45 am]

BILLING CODE 6560–50–P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

50 CFR Part 660

[Docket No.090421699–9797–01]

RIN 0648–XO74

Fisheries Off West Coast States; Coastal Pelagic Species Fisheries; Annual Specifications Modification

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Proposed rule.

SUMMARY: NMFS proposes a regulation to adjust the harvest specifications for Pacific sardine in the U.S. exclusive economic zone (EEZ) off the Pacific coast for the fishing season of January 1, 2009, through December 31, 2009. The proposed action would increase the tonnage of Pacific sardine allocated for industry conducted research from 1200 metric tons (mt) to 2400 mt and decreases the second and third period directed harvest allocations by 750 mt and 450 mt, respectively.

DATES: Comments must be received by June 5, 2009.

ADDRESSES: You may submit comments on this proposed rule identified by 0648–XO74 by any of the following methods:

- Electronic Submissions: Submit all electronic public comments via the Federal eRulemaking Portal *http://www.regulations.gov*
- Mail: Rodney R. McInnis, Regional Administrator, Southwest Region, NMFS, 501 West Ocean Blvd., Suite 4200, Long Beach, CA 90802.
- Fax: (562)980–4047

Instructions: All comments received are a part of the public record and will generally be posted to *http://www.regulations.gov* without change. All Personal Identifying Information (for example, name, address, etc.) voluntarily submitted by the commenter may be publicly accessible. Do not submit Confidential Business Information or otherwise sensitive or protected information.

NMFS will accept anonymous comments (enter N/A in the required fields if you prefer to remain anonymous). Attachments to electronic comments will be accepted in Microsoft Word, Excel, WordPerfect, or Adobe PDF file formats only.

FOR FURTHER INFORMATION CONTACT: Joshua Lindsay, Southwest Region, NMFS, (562) 980–4034.

SUPPLEMENTARY INFORMATION: On February 20, 2009, NMFS published a final rule implementing the harvest guideline (HG) and annual specifications for the 2009 Pacific sardine fishing season off the U.S. West Coast (74 FR 7826) under the Magnuson-Stevens Fishery Conservation and Management Act, 16 U.S.C. 1801 et seq (Magnuson-Stevens Act). These specifications and associated management measures were based on recommendations adopted by the Pacific Fishery Management Council (Council) at their November 2008 public meeting in San Diego, California (73 FR 60680). For the 2009 Pacific sardine fishing season, the Council adopted, and NMFS approved, an acceptable biological catch (ABC) or maximum HG of 66,932 mt. This ABC/HG was determined according to the regulations implementing the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP)(50 CFR part 660, subpart I). The Council also recommended, and NMFS approved, that 1,200 mt be initially subtracted from the ABC and reserved for an industry-conducted research project, which is planned but not yet approved. This 1,200 mt set-aside was intended to allow research fishing, which is planned for the second seasonal period (July 1—September 15, 2009), to continue if that period's allocation is reached and directed fishing is closed. As stated in the final rule implementing the 2009 specifications, the use of the 1,200 mt would require NMFS to issue an Exempted Fishing Permit (EFP) because fishing would occur after the directed fishery is closed.

At the Council's March 2009 public meeting the Council reviewed two industry research/EFP proposals for conducting Pacific sardine biomass surveys and moved the two proposals forward for public comment with the recommendation that industry combine the proposals to create a single EFP application to be reviewed for final adoption at the June 2009 Council meeting. After hearing the research proposals and public comment, the Council then recommended that the original 1200 mt set-aside be increased to 2400 mt. To account for the additional 1,200 mt, the Council recommended that the second and third period directed fishery allocations be reduced by 750 mt and 450 mt respectively. This is approximately a proportional reduction in the two allocations.

NMFS will publish a notice in the **Federal Register** requesting comments on the proposed EFP in the near future and a decision on whether to issue an EFP for the use of the research set-aside will be made prior to the start of the second seasonal period (July 1, 2009). If NMFS determines that an EFP cannot be issued, then the set-aside -either the current 1,200 mt or the proposed 2,400 mt-will be re-allocated to the third period's directed harvest allocation.

Classification

Pursuant to section 304(b)(1)(A) of the Magnuson-Stevens Act, the NMFS Assistant Administrator has determined that this proposed rule is consistent with the CPS FMP, other provisions of the Magnuson-Stevens Act, and other applicable law, subject to further consideration after public comment.

These proposed specifications are exempt from review under Executive Order 12866.

The Chief Counsel for Regulation of the Department of Commerce certified to the Chief Counsel for Advocacy of the Small Business Administration that this proposed rule, if adopted, would not have a significant economic impact on a substantial number of small entities as follows:

The purpose of this proposed action is to make minor modifications to the 2009 Pacific sardine specifications. This proposed rule does not make significant changes to those specifications, which were implemented through proposed and final rulemaking and for which an Initial and a Final Regulatory Flexibility Analysis was completed.

The small entities that would be affected by the proposed action are the 63 vessels that compose the West Coast CPS finfish fleet. These vessels are considered small business entities by the U.S. Small Business Administration because the vessels do not have annual receipts in excess of $4.0 million. Therefore, there would be no economic impacts resulting from disproportionality between small and large business entities under the proposed action.

The profitability of these vessels as a result of this proposed rule is based on the average Pacific sardine ex-vessel price per mt. When the 2009 Pacific sardine specifications were implemented it was determined that if the fleet were to take the entire 2009 Pacific sardine HG of 65,732 metric tons (mt), the potential revenue to the fleet would be approximately $11 million. This proposed action has the potential, if an Exempted Fishing Permit is approved at a later date, to reduce the available HG by 1200 mt (750 mt in the second period and 450 mt in the third period) and potential fleet revenue by $168,000. However, over the course of the fishing season these amounts represent very small portions of the overall allowable harvest and equal less than half the amount taken by the fleet in a normal fishing day. Therefore the potential drop in profitability to fleet overall would be small. Furthermore, even the re-allocated 1200 mt of sardine would be sold commercially by members of the fleet, also small business entities, operating under an exempted fishing permit.

Based on the disproportionality and profitability analysis above, this rule if adopted, will not have a significant economic impact on a substantial number of these small entities.

As a result, an Initial Regulatory Flexibility Analysis is not required and none has been prepared.

Authority: 16 U.S.C. 1801 *et seq.*

Dated: April 30, 2009.

James W. Balsiger,

Acting Assistant Administrator For Fisheries, National Marine Fisheries Service.

[FR Doc. E9–10506 Filed 5–5–09; 8:45 am]

BILLING CODE 3510–22–S

COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON AN EXEMPTED FISHING PERMIT (EFP) FOR SARDINE RESEARCH

The Coastal Pelagic Species Advisory Subpanel (CPSAS) reviewed and discussed the exempted fishing permit application for a Pacific Coast sardine survey to utilize the 2,400 mt set-aside recommended by the Scientific and Statistical Committee (SSC) and approved by the Council at its November 2008 and March 2009 meetings for survey work in the second period of the 2009 directed fishery. The CPSAS supports the application and unanimously recommends its implementation and its adoption by the Council. The CPSAS understands that survey design and implementation will be under the oversight of Dr. Tom Jagielo and Dr. Vidar Wespestad with Dr. Doyle Hanan coordinating the California field work.

The application was vetted by the May 2009 Stock Assessment Review Panel and SSC, including a finding that the 2,400 mt is a crucial element of the survey. The CPSAS looks forward to a successful survey in 2009 also anticipates that this survey work will continue into the future.

PFMC
06/15/09

COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON SURVEY MEHODOLOGY REVIEW AND EXEMPTED FISHING PERMIT (EFP)

The Coastal Pelagic Species Management Team (CPSMT) met June 15, 2009 to review an exempted fishing permit (EFP) application and detailed survey methodology and sampling design developed by the Northwest Sardine Survey, LLC in conjunction with the California Wetfish Producers Association. The EFP application was submitted for the industry to utilize 2,400 mt of the sardine harvest guideline (HG) that would be set aside for research. The CPSMT has repeatedly recommended that additional fishery-independent indices of Pacific sardine abundance be developed. To achieve this goal, the CPSMT approves the survey methodology and sampling design, and endorses the request by the coastwide sardine fishing industry for an EFP to conduct a cooperative sardine survey to collect sound scientific data for inclusion in the stock assessments for Pacific sardine. The CPSMT stresses the importance of developing a comprehensive, repeatable, synoptic survey, as indices with long time series tend to be most informative. The CPSMT further endorses increasing the research set-aside from 1,200 mt to 2,400 mt in order to provide adequate sample sizes and the greatest geographic coverage.

The Enforcement Consultants met with CPSMT to address specific needs associated with EFP enforcement concerns. The CPSMT discussed these concerns and supports their position.

The CPSMT recognizes the value of the EFP and supports this research, but prefers that all conditions adopted in the 2009 permit do not set precedence for exempted fishery permits that may be adopted in the future. There may be a need to adapt research needs in the future based on information and experience gained during the 2009 exempted permit fishery.

The CPSMT concurs with the Scientific and Statistical Committee (SSC) and the Stock Assessment Review (STAR) Panel that the aerial survey has the potential of improving sardine stock assessments. However, the use of data produced from these surveys should be fully evaluated by the STAR Panel in September and the SSC and Coastal Pelagic Species Advisory Bodies in November.

PFMC
06/15/09

Agenda Item H.2.b
Supplemental EC Report
June 2009

ENFORCEMENT CONSULTANTS REPORT ON SURVEY METHODOLOGY REVIEW AND EXEMPTED FISHING PERMIT (EFP)

The Enforcement Consultants (EC) would like to recommend a few changes to the 2009 West Coast Sardine EFP.

This EFP, if approved, will take place when the sardine fishery season is closed. Because of this, the EC strongly recommends that participants be required to notify the Regional NOAA Office For Law Enforcement and the appropriate State Fish and Wildlife Enforcement entity a minimum of 24 hours prior to carrying out any fishing under the EFP. The following information should be included in the notification:

- Date of fishing trip
- Time fishing to be conducted
- Boat name
- Operator\Permittee name
- Location to be fished
- Location catch will be landed/stored

The EC does not have a full understanding with regard to what the appropriate level of concern is with this particular fishing activity in terms of bycatch encounters. If concerns are low, at a minimum the EFP should require full retention, sorting at time of landing, and accurate reporting on fish receiving tickets. If the concerns are higher, human and electronic monitoring should be considered in order to guarantee accurate catch accounting.

The EFP application requests that the fish be sold to help defray the costs, but does not clearly discuss how bycatch will be handled. The Northern Coastal Pelagic Species fleet has encountered salmon in the past and a process has been developed to properly dispose of those fish without illegally placing them in the market place. For example, it would be inappropriate (and illegal) to sell Coho Salmon in California as they have no allowed commercial seasons. Instead, a donation strategy should be developed after the fish are sampled and accounted for.

PFMC
06/16/09

Agenda Item H.2.b
Supplemental SSC Report
June 2009

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON EXEMPTED FISHING PERMIT (EFP) FOR SARDINE RESEARCH

The Scientific and Statistical Committee (SSC) was briefed by Mr. Tom Jagielo on the west coast sardine survey application for an EFP in 2009. The proposed survey is an expansion of a pilot study that was conducted off the Oregon coast in 2008. Mr. Ryan Howe of the survey team was also present to answer questions about survey design. Dr. Owen Hamel represented the SSC at the May 2009 Stock Assessment Review (STAR) Panel review of the survey methodology, and briefed the SSC on the STAR Panel's report.

The 2009 EFP application is for a combined survey that would range from Monterey Bay to the US/Canada international boundary. Survey design is a two-stage sampling approach that includes: 1) a photographic aerial survey, and 2) an at-sea point set sampling to estimate species composition, school density, and biological characteristics of the fish. The applicants addressed the SSC request from March 2009 to standardize methods throughout the study area and develop a rigorous survey design. In addition, a power analysis was presented in the application to inform the discussion about adequate sample size to characterize school variability. Based upon the results of that analysis, the SSC concurs with the applicants and the STAR Panel report that an EFP set-aside of 2,400 mt would be sufficient to provide an expectation of successful calibration, which is a crucial element of the survey. If only 1,200 mt were to be available for conducting the survey, the SSC suggests that the applicants be asked to develop a revised proposal that presents the trade-offs associated with alternative ways to conduct the study under that undesirable constraint.

The SSC concurs with the STAR Panel that the application has merit and should be approved. Current sardine assessment results are particularly uncertain with respect to the portion of the stock that occurs to the north of Monterey Bay. As discussed in the STAR Panel report, survey results would be expected to underestimate overall abundance. Therefore, the findings from the proposed study would potentially provide a lower bound for the size of the northern portion of the stock, which could inform the next assessment. In addition, the survey has the potential to make even greater improvements to the overall stock assessment if it is continued annually for sufficient years to develop a time series.

PFMC
06/14/09

CALIFORNIA WETFISH PRODUCERS ASSOCIATION

Representing California's Historic Fishery

VISIT WWW.CALIFORNIAWETFISH.ORG FOR INFORMATION

May 14, 2009

Mr. Don Hansen, Chair &
Dr. Don McIsaac, Executive Director
Pacific Fishery Management Council
7700 NE Ambassador Place #200
Portland OR 97220-1384

RE: Agenda Item: Experimental Fishing Permit (EFP) for Pacific coast Sardine Research including CA

Dear Chairman Hansen, Dr. McIsaac and Council members,

The California Wetfish Producers Association (CWPA) represents the majority of active wetfish fishermen and processors from both Monterey and southern California. We very much appreciate this opportunity, once again, to address the Council on the subject of Pacific sardine research.

As we testified in November 2008 and March 2009, we believe developing a second index of sardine abundance is essential to expand understanding of the sardine resource and improve sardine resource management. We very much appreciate the Council's interest in this industry-sponsored aerial/acoustic research plan, leading to your recommendation to the National Marine Fisheries Service (NMFS) to increase the research set aside by an additional 1,200 mt to provide a robust and scientifically defensible synoptic survey extending into California.

Since the March meeting we have worked closely with principal investigators of the Northwest industry survey to combine the two EFP proposals into a single Pacific coast survey, extending from Cape Flattery to Monterey Bay. The California portion of the survey is now an integral part of the EFP proposal submitted for your approval. We're making progress to execute the research plan, following Council adoption of the final EFP proposal and NMFS approval of the additional research set aside. Our activities to date include identifying participating boats and processors, committing significant funds to obtain required camera system and hydroacoustic equipment {in fact the camera system is slated for installation in the airplane on May 20 and the first of two Simrad ES 60s will also be installed the same week}. We're also planning coordination and timing of the survey itself, in routine communication with the PIs. In short, we are well on our way to readiness to begin implementing the research plan as soon as the July fishing season begins and the weather and Mother Nature cooperate – subject to final adoption and issuance of the EFP and approval of the proposed rule modifying annual harvest specifications.

In planning for this project, we attended the recent aerial survey methodology STAR, and were pleased with the overall outcome and recommendations of the panel. Borrowing from the report:

> ***4) Implementation of Survey Protocols***
> *An important question is whether the total EFP allocation (and how it is allocated to each area) is sufficient to achieve a useful survey.*
> - ***At 1200 tons from each area, the suggestion of the Technical Team (i.e., a total EFP allocation of 2400 tons), the Panel concluded that there is a good outlook for successful calibration.***

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The panel also voiced concerns similar to the Science and Statistical Committee's earlier discussion questioning the scientific value of the initial 1,200 mt set aside, in essence reaffirming the Council's recommendation to increase the research allocation:

- *The Panel doubts whether sufficient precision would be achieved if only 600 tons were taken from each area (a total of 1200t is currently allocated for an EFP). In the case where a total of only 1200 tons was available, the Panel recommends that the entire 1200 tons be used in only one of the two possible survey areas. Moreover, the Panel saw no compelling reason to recommend that the tonnage be assigned to a particular area of the two areas, and would prefer that the Technical Team decide how they would best use the allocation, were it only 1200t.* ***However, the Panel would not expect that an estimate based on a small number of point sets would provide a sufficient basis for a robust and precise estimate of abundance. If all of the allocation was taken from one area, this would provide a basis to estimate the relationship between school size and tonnage for that area, but it could not be used to estimate abundance for the entire survey area (Canadian border to Point Conception).***

Clearly, this industry-sponsored research plan holds great promise to expand knowledge of the Pacific sardine resource **IF** it is conducted in the manner described in the Pacific coast EFP application, including the full 2,400 mt research allocation, apportioned 1,200 mt to the PNW and 1,200 mt to California, and with survey area as synoptic as possible, at least covering the coast from Cape Flattery to Monterey Bay.

CWPA, California's wetfish industry and the CA members of the CPS Advisory Subpanel recognize the importance of this research and urge the Council to approve the Pacific coast sardine EFP as amended. We further support the Council's recommendation that the original 1,200 mt research set aside be increased to 2,400 mt to provide sufficient point sets in each area to enable a robust survey that has the potential to be considered as a minimum estimate of absolute abundance of Pacific sardine. A successful survey will be useful to inform the 2009 sardine stock assessment. Moreover, by continuing the survey over multiple years, it will provide a basis for a new relative index of abundance.

We are fully committed to ensure the success of this research project. In CA the use of the research set aside will be taken under the guidance of CA scientists, in coordination with PNW scientists, with the goal to achieve representative samples of school size. In addition, we will also use our Biosonics DT-X, modified {at further expense} and deployed with both down-sound and side-looking capabilities to better quantify school height and density. Further, the SW Fisheries Science Center is interested in participating in expanded hydroacoustic research, and has offered to deploy its state-of-the-art acoustic equipment in conjunction with our summer survey, with the intent of developing an acoustic estimate of abundance that can be expanded into southern CA in the fall.

Again, we appreciate the Council's interest in this research and urge the Council to approve the Pacific coast sardine EFP application, allowing CA to participate in this research project after the summer directed fishing period has closed. We also encourage the Council to reaffirm your recommendation to NMFS to expeditiously approve the additional 1,200 mt research set aside, and to issue the experimental permits without delay.

Thank you for your consideration.
Best regards,

Diane Pleschner-Steele

Diane Pleschner-Steele
Executive Director