# NATIONAL MARINE FISHERIES SERVICE REPORT

Mr. Mark Helvey (NMFS SWR) will provide any pertinent regulatory updates for the Council, as appropriate. Dr. Russ Vetter will give a brief update on spring research activities, and Dr. Steve Ralston will provide a summary of the May 23-24 sardine survey methods workshop II.

**Council Task:**

**Discussion.**

Reference Materials:

None

Agenda Order:

a. Regulatory Activities — Mark Helvey
b. Fisheries Science Center Activities — Russ Vetter and Steve Ralston
c. Reports and Comments of Advisory Bodies and Management Entities
d. Public Comment
e. Council Discussion

PFMC
05/20/11

Agenda Item G.1.b
Supplemental SWFSC PowerPoint (Crone)
June 2011 Briefing Book

Science, Service, Stewardship

# Preliminary Results From Spring 2011 Coastwide Sardine Survey: Cruise Tracks, Egg Pump, Acoustic Backscatter,Trawl Composition

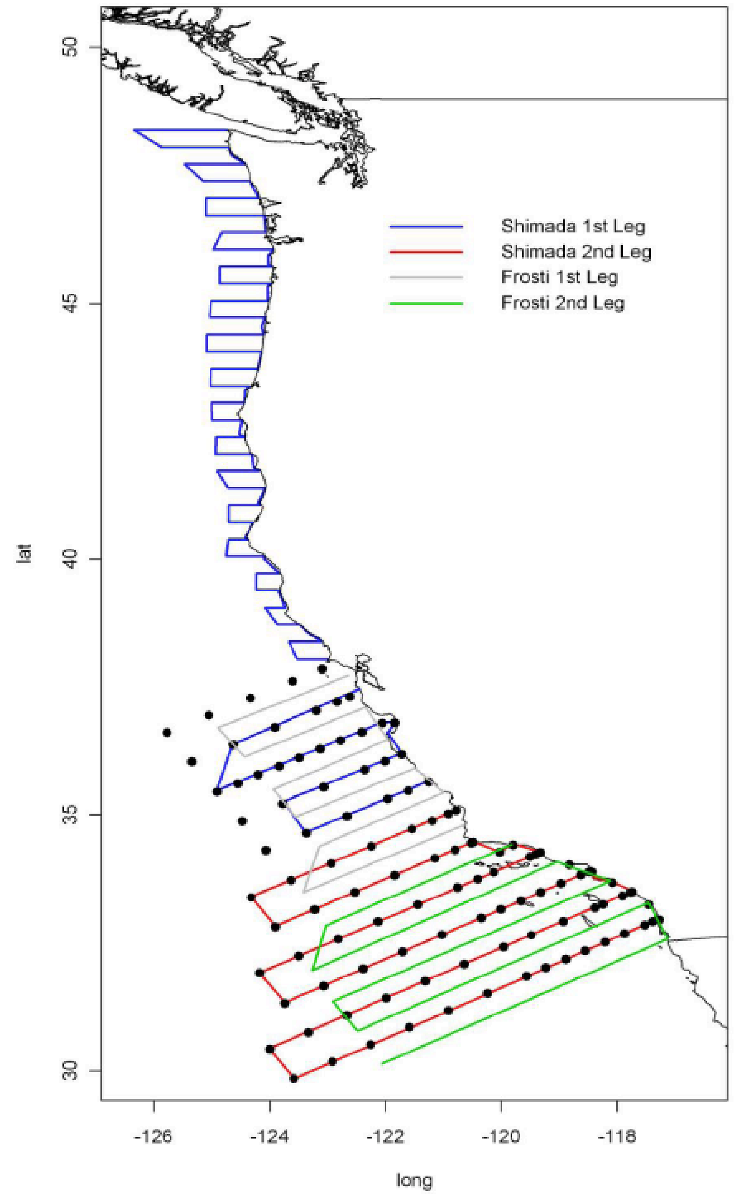
Fisheries Resources Division
Southwest Fisheries Science Center

June 11, 2011

NOAA FISHERIES SERVICE

NOAA FISHERIES SERVICE

# Planned Spring, 2011 two ship coastwide CPS egg, acoustic, trawl, CalCOFI survey



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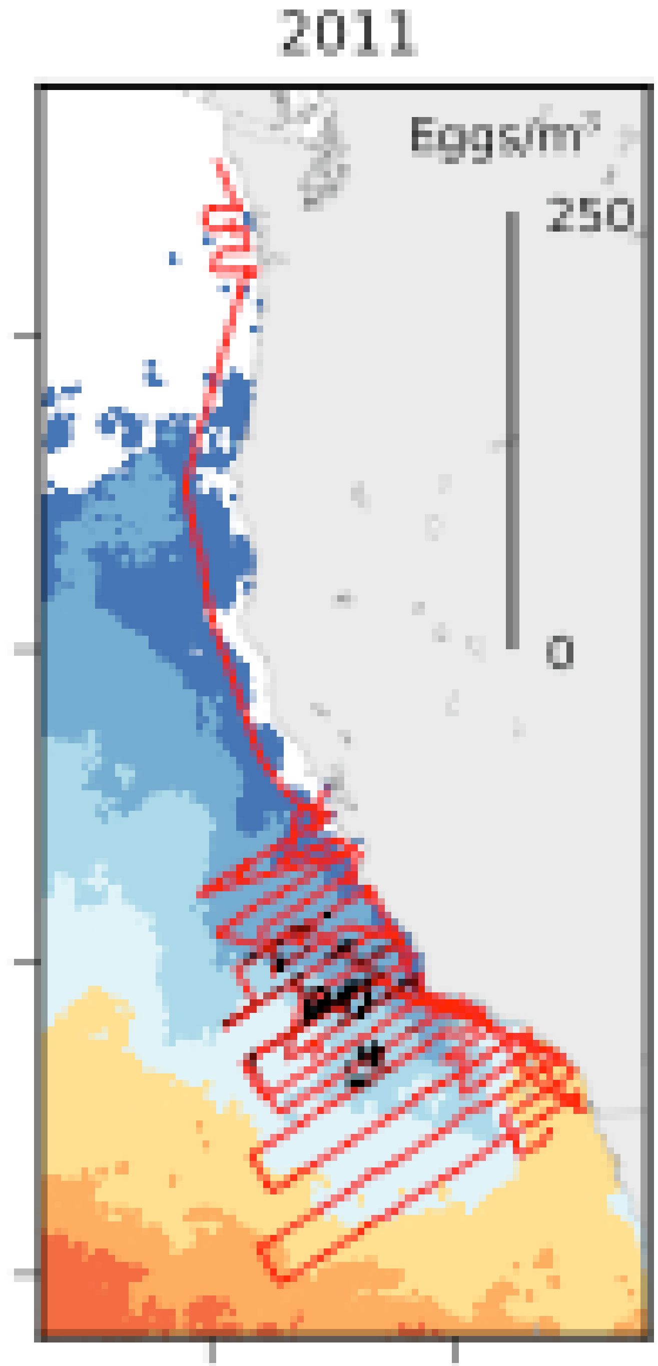
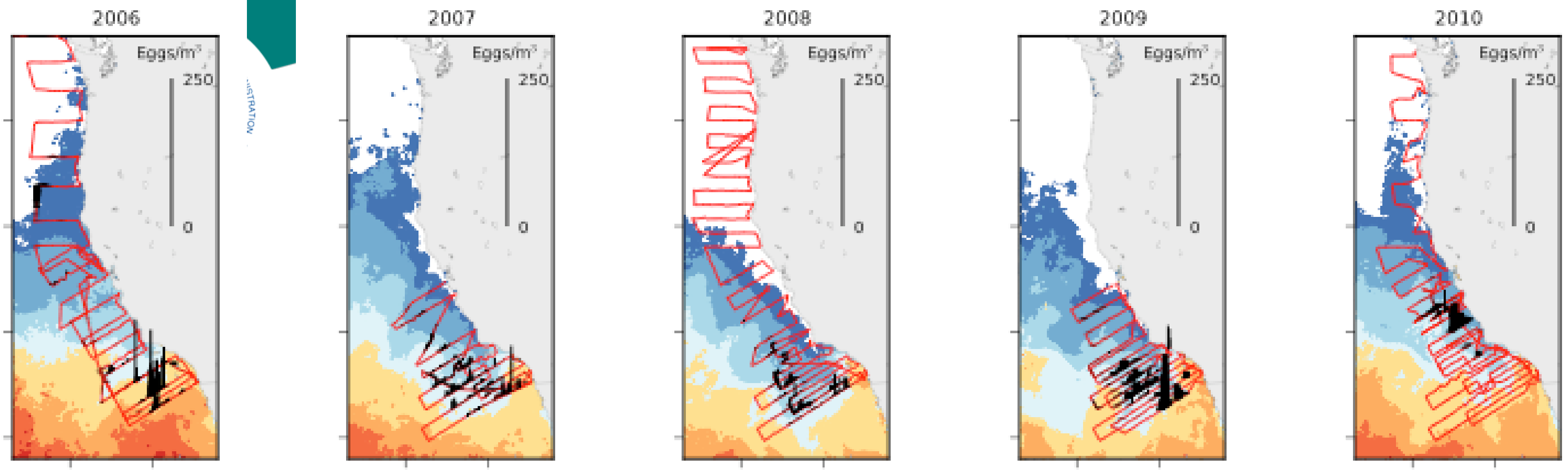
# Actual

# Spring, 2011 two ship coastwide tracks (red)*

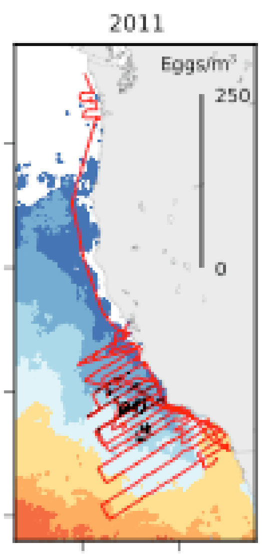
# Sardine egg pump: locations and densities (black)




* cruise tracks less due to weather, ship problems and government shutdown.




# Sardine Egg Distribution Compared to Previous Years



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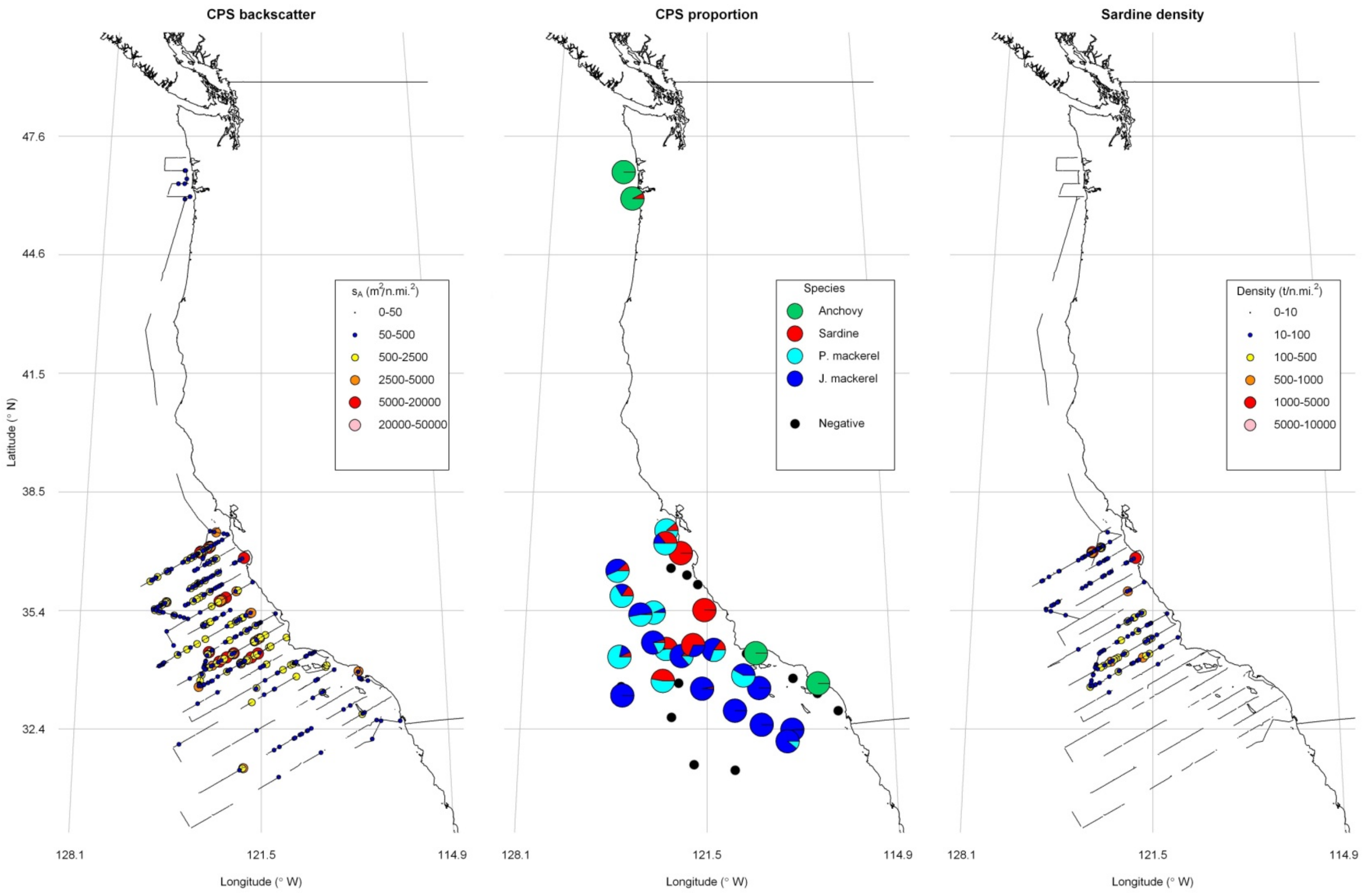
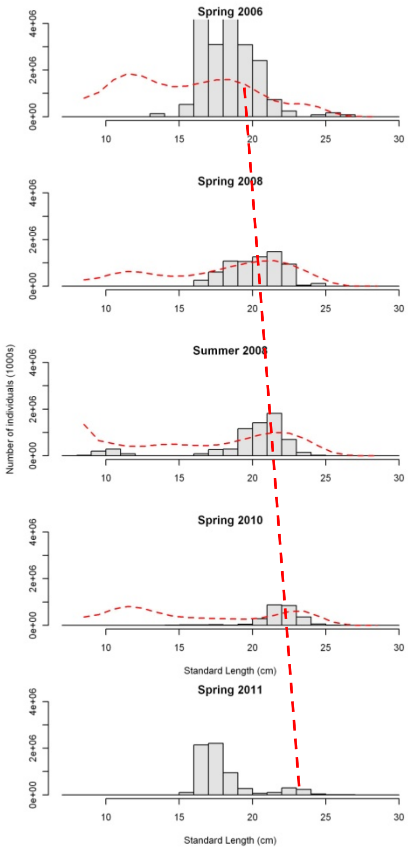
# CPS Acoustic/ Trawl Maps

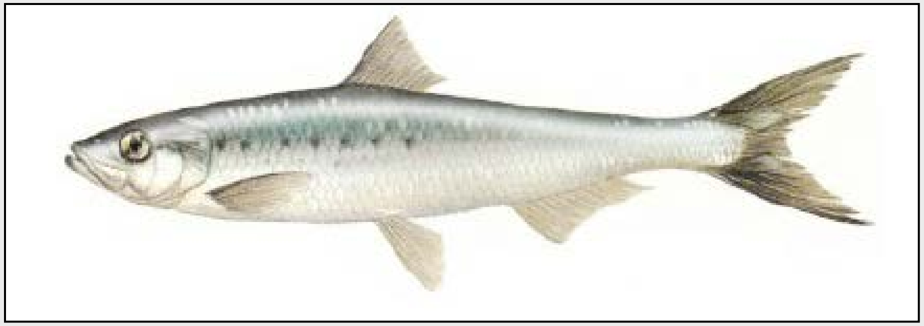


# Sardine Lengths from Trawl



Agenda Item G.1.b
Supplemental SWFSC PowerPoint (Ralston)
June 2011

# Workshop on Enhancing Stock Assessments of Pacific Sardine in the California Current through Coordinated Comparative Surveys
# - Round 2 -



May 23-24, 2011
La Jolla, California

Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101, Portland, OR 97220-1384
Phone 503-820-2280 | Toll free 866-806-7204 | Fax 503-820-2299 | www.pcouncil.org
David W. Ortmann, Chairman
Donald O. McIsaac, Executive Director

National Marine Fisheries Service
NOAA Fisheries

## Objectives of the Sardine-1 Workshop
## (June 1-3, 2010 – La Jolla, CA)

To achieve common understandings among stakeholders regarding the:

(1) advantages, limitations, and challenges with, and possible improvements to, survey methods relevant to estimating biomass for stock assessments in 2011 and beyond

(2) identity of current investigators and users of each method

(3) opportunities for collaboration

## Sardine-1 Workshop

Participants concluded different methods are not comparable because they are deployed in different times and places

Group concluded the "methods need to be tested and compared under similar conditions and standards."

A design team should "design an experiment that will compare all of the Pacific sardine survey methods (aerial, DEPM, LIDAR, trawl, satellite, acoustic) under similar conditions, such as season, area, environmental conditions, and sizes of sardine."

# Workshop Goals and Objectives

- Develop a coordinated synoptic sardine survey plan that would allow a comparison of abundance estimates developed from different survey methods. The comparisons are expected to assist interpretation of the data elements that are incorporated into the sardine stock assessment

- Improve collaborative research opportunities and coordination between the sardine industry and NMFS

- Develop a proposed survey budget, timeframe, PIs, and operational requirements

# Participants

**Executive Committee**

Mark Helvey (chairman) – SWR
Kerry Griffin – PFMC
Kristen Koch – SWFSC
Mike Okoniewski – OR/WA Industry
Diane Pleschner-Steele – CA Industry
Sarah Shoffler – SWFSC
Cisco Werner – SWFSC
Steve Ralston (facilitator) – SWFSC

**Core Participants**

SWFSC survey: Russ Vetter – SWFSC
Acoustics survey: Dave Demer – SWFSC
Aerial survey: Tom Jagielo – NWSS
  Don LeRoi – CWPASS
Daily Egg Production Method: Nancy Lo – SWFSC
  Tim Baumgartner – CICESE
LIDAR survey: Jim Churnside – NOAA OAR
Trawl survey (swept area): Bob Emmett – NWFSC
  Jake Schwiegert – DFO

# Participants

**Subject Matter Experts**

Fishing:
- David Haworth – California
- John Lenic – Canada

Oceanography: Ed Weber – SWFSC

Sardine Biology & Management:
- Dale Sweetnam – CDFG
- Lorna Wargo – WDFW
- Greg Krutzikowsky – ODFW
- Sandy McFarlane – DFO

Stock Assessment: Kevin Hill – SWFSC

**Observers**

Paul Crone – SWFSC
Bev Macewicz – SWFSC
Roger Hewitt – SWFSC
Rosa Runcie – SWFSC

## Accomplishments

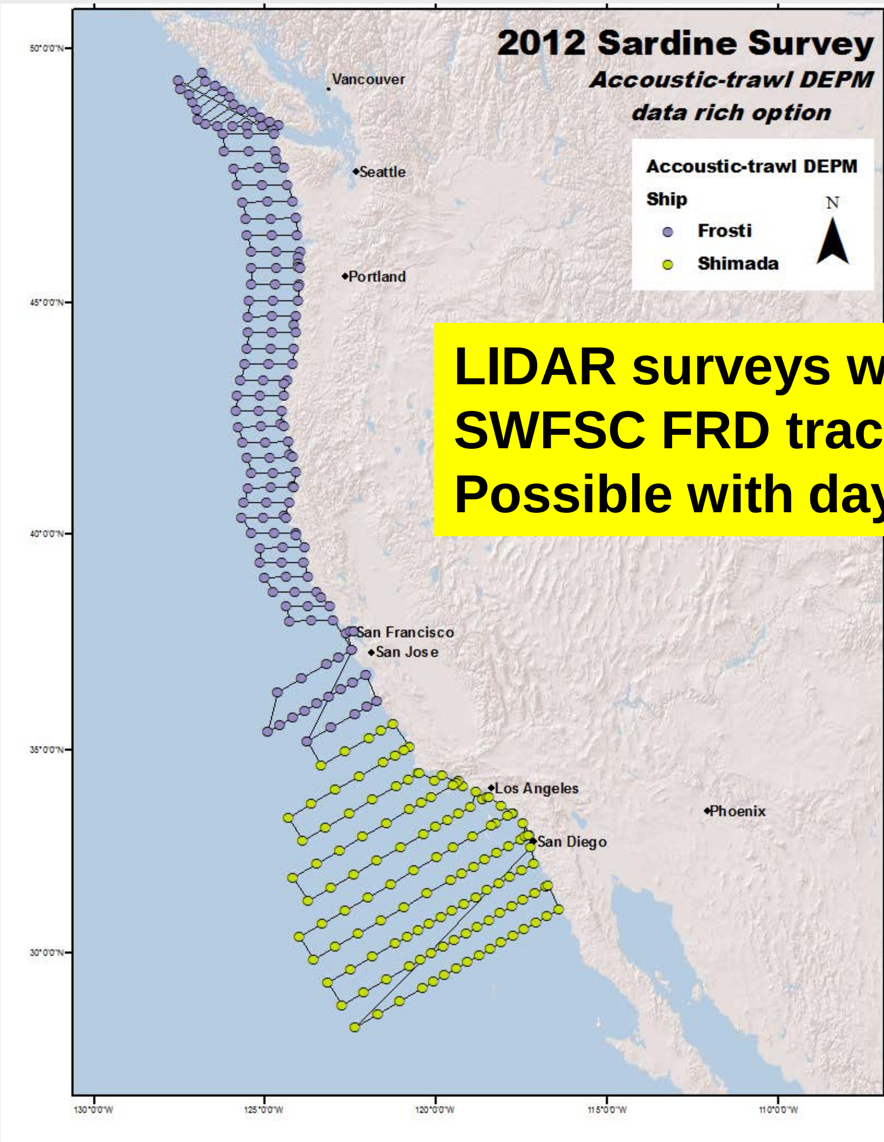
- Queried in advance to determine the optimal time and place to execute each type of survey, of which there are five
  - acoustic-trawl
  - daily egg-production method
  - aerial imaging (two-stage with point sets)
  - aerial LIDAR
  - trawl (swept-area biomass)

- Determine opportunities to develop robust comparisons of absolute biomass estimates

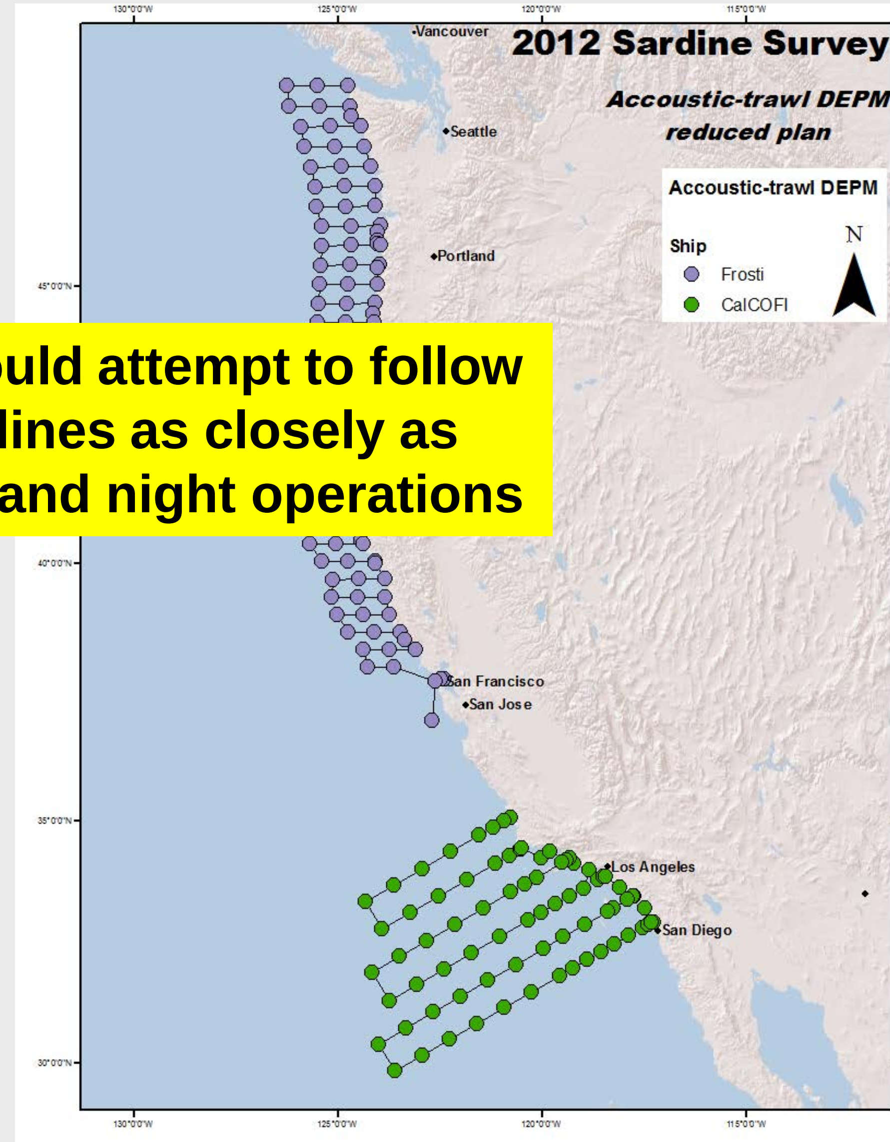
- Develop preliminary budgets for fully funded and level funded scenarios

# SWFSC FRD – Acoustic-trawl and DEPM

Full funding scenario



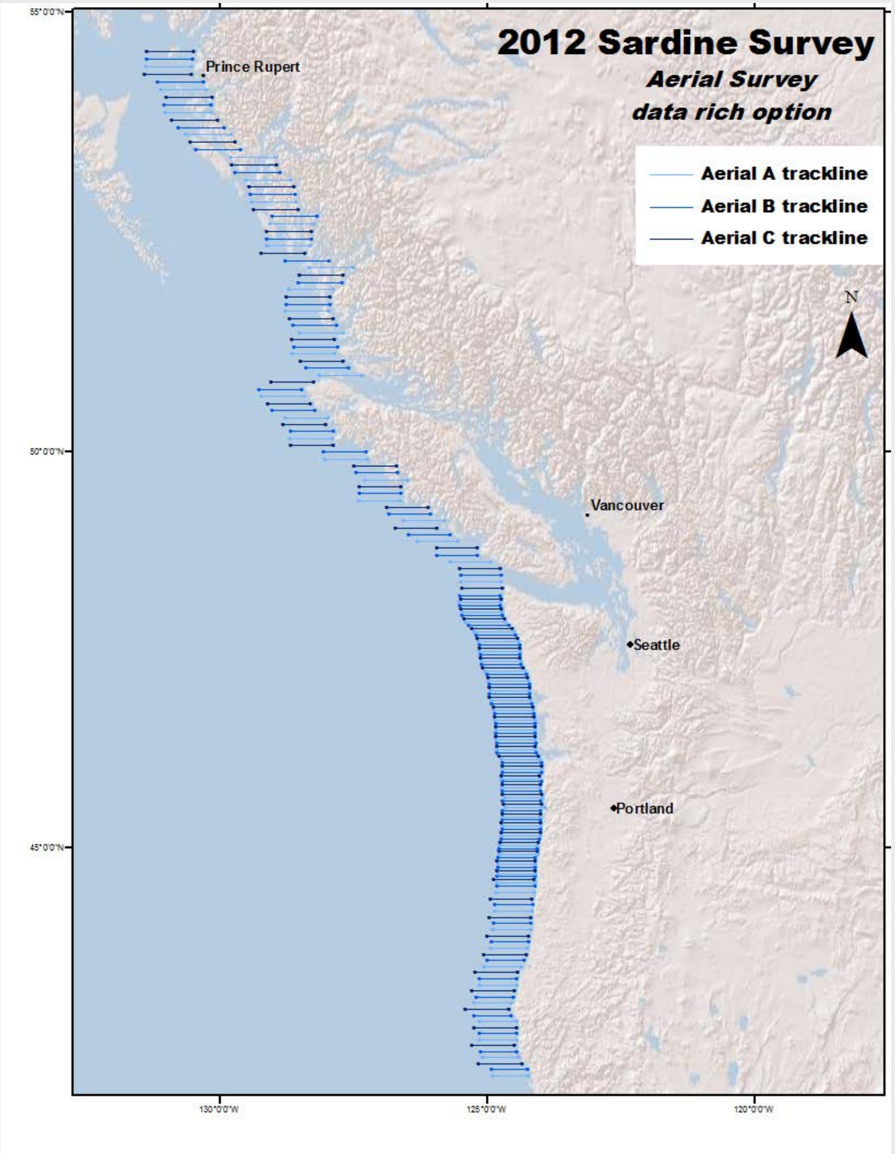

Level funding scenario



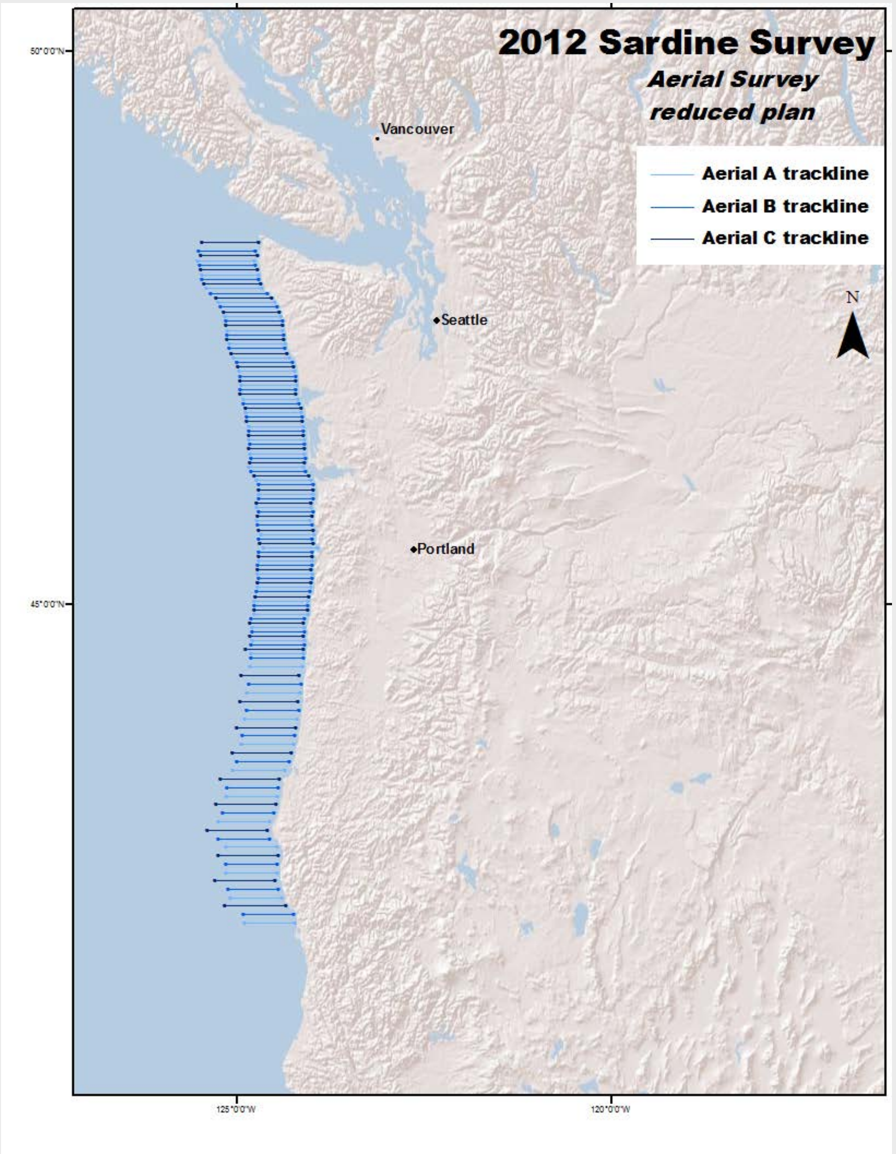

**LIDAR surveys would attempt to follow SWFSC FRD tracklines as closely as Possible with day and night operations**

# Northwest Sardine Survey – Aerial Imaging

Full funding scenario

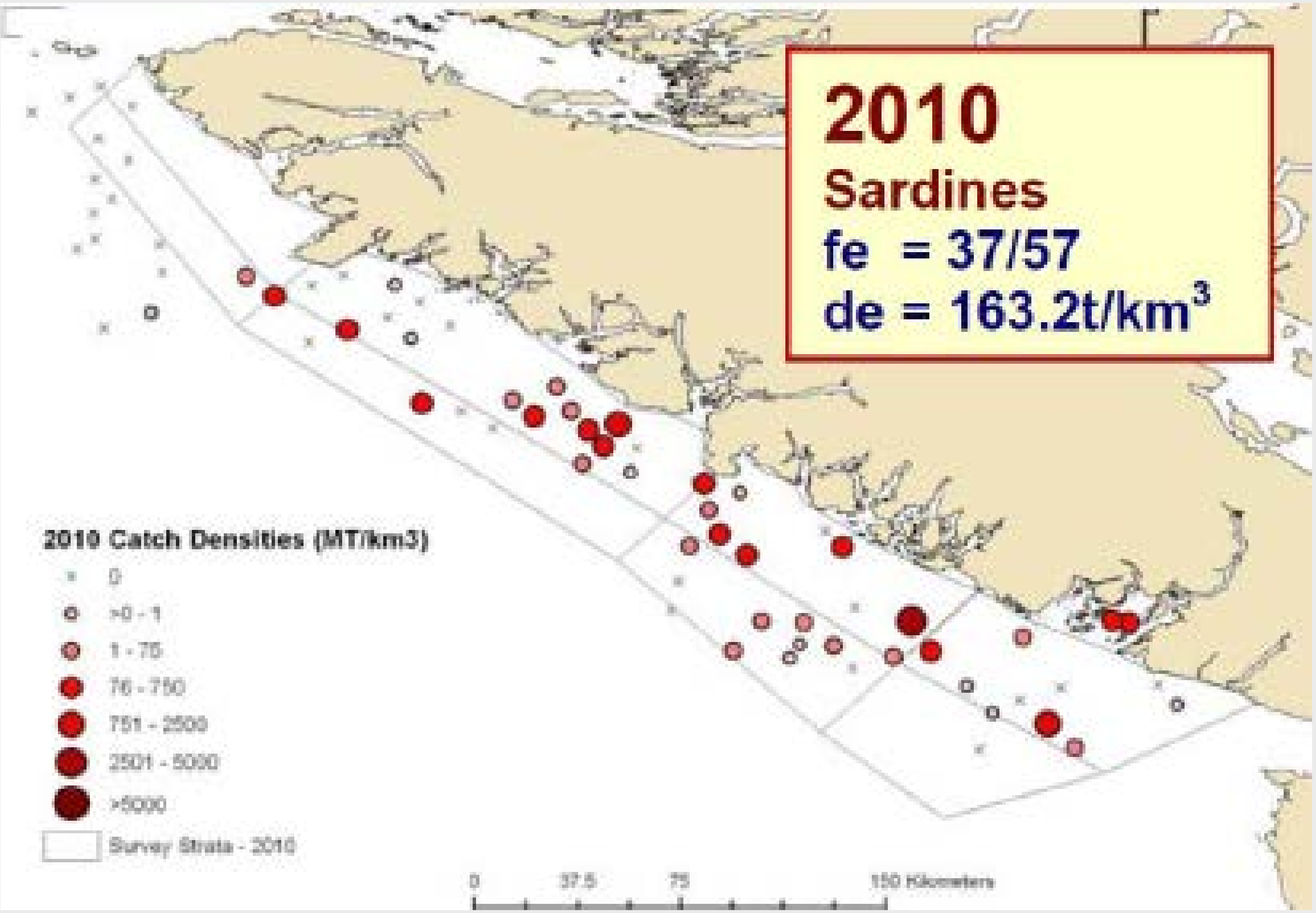



Level funding scenario

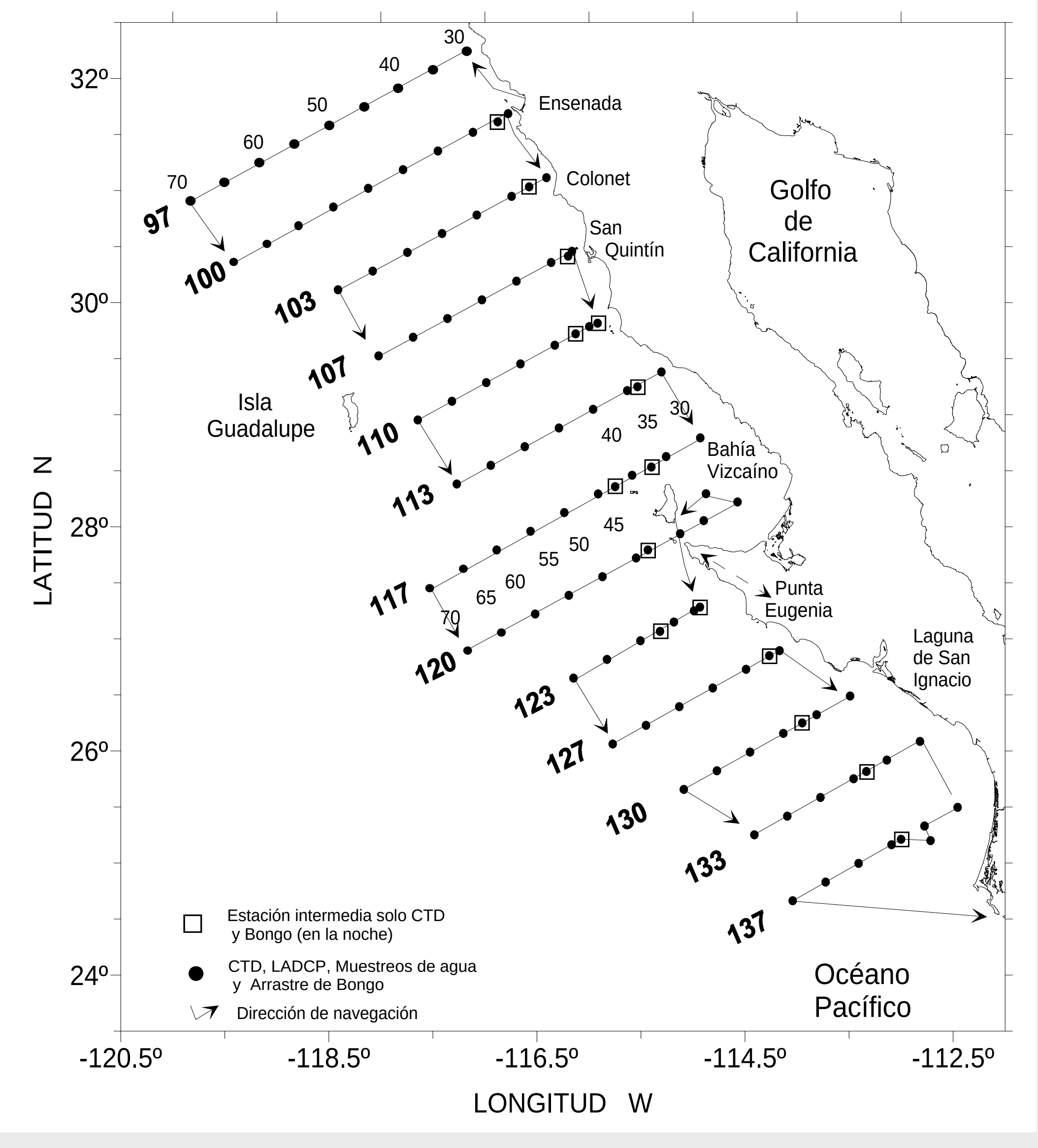


# DFO Canada – Trawl swept-area biomass

(both funding scenarios)

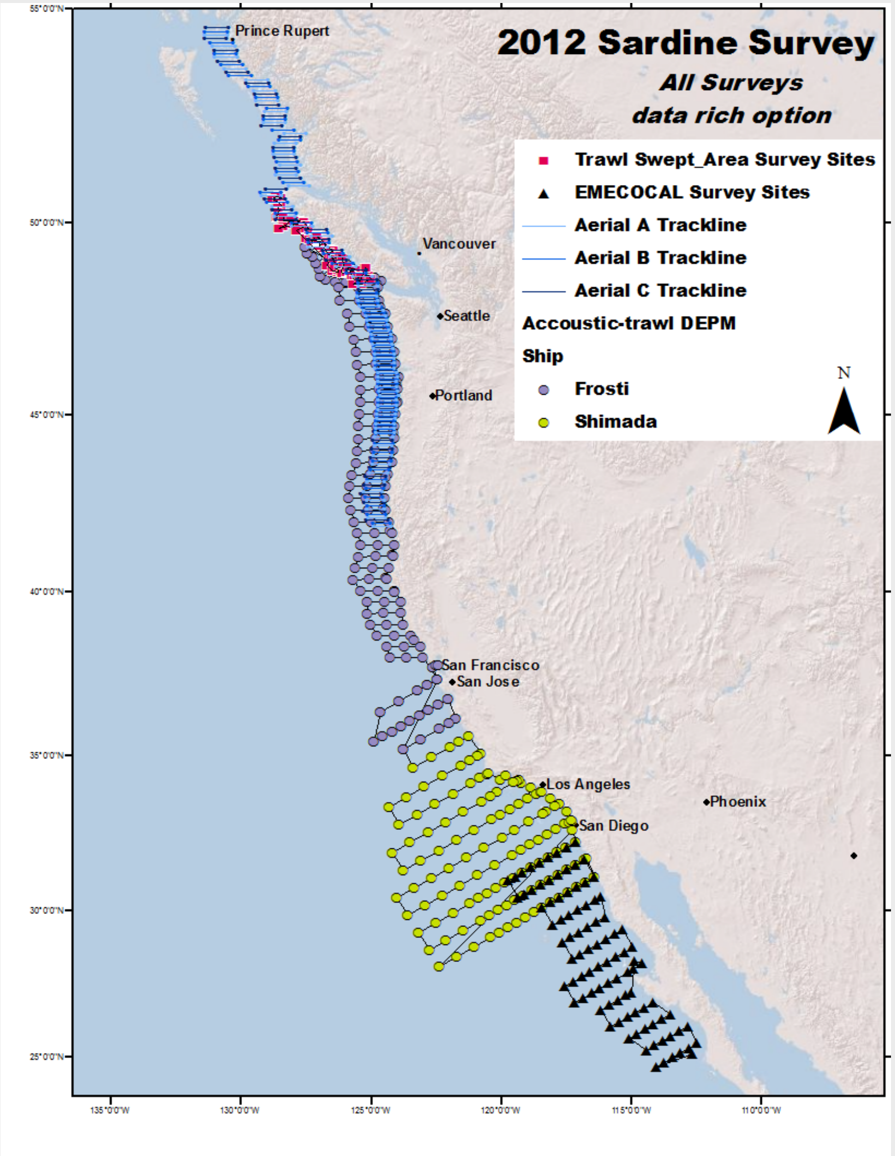


# CICESE IMECOCAL
# DEPM (and Acoustic-trawl if fully funded)

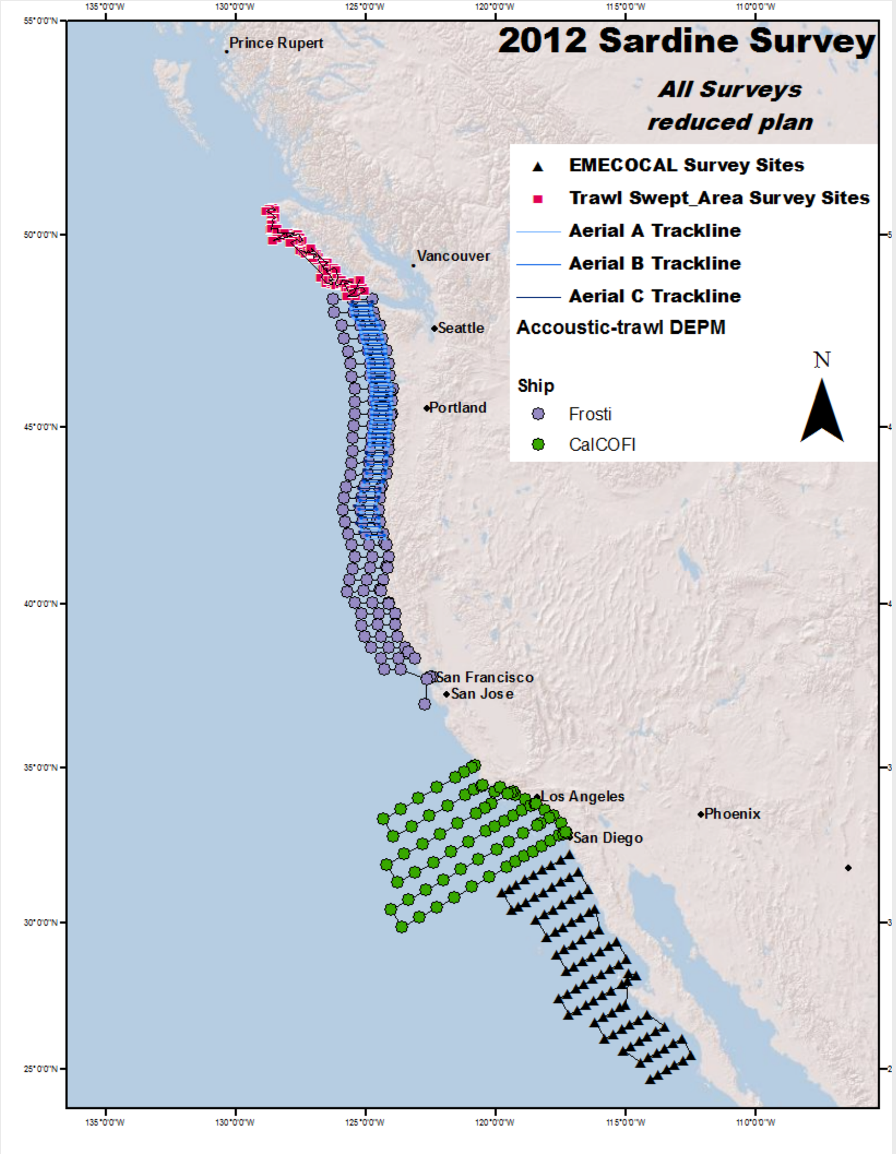


# Composite of All Survey Methods

Full funding scenario




Level funding scenario



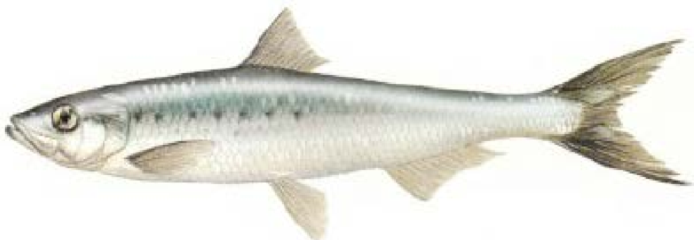
# Summary of Possible Comparisons Of Absolute Biomass Estimates of Pacific Sardine

| Survey Method | **A-T (FRD)** | DEPM (FRD) | Aerial Imaging | DFO Trawl | IMECOCAL(+) |
|---|---|---|---|---|---|
| **DEPM (FRD)** | yes** | | | | |
| **Aerial Imaging** | **yes** | yes (south) | | | |
| DFO Trawl | yes | no | yes | | |
| IMECOCAL(+) | yes* | yes | yes* | no | |
| LIDAR | yes | yes (south) | yes | yes | yes* |

*Where there is overlap with three transects in SoCal/Mexico
**Only if spawning females are present in summer survey
(+) IMECOCAL may add multiple methods, dependent on availability, funding, etc (see #4 below)

**Workshop on Enhancing Stock Assessments of Pacific Sardine in the California Current through Coordinated Comparative Surveys**

May 23-24, 2011
La Jolla, California



## Introduction

The Pacific sardine (*Sardinops sagax*) fishery on the US west coast provides important contributions to the nation's economy, both historically and currently (PFMC 2010). This species is managed by the Pacific Fishery Management Council under its Coastal Pelagic Species (CPS) fishery management plan (FMP). Annual sardine landings recently peaked in 2007 at over 120,000 mt, with an ex-vessel value close to $14,000,000 (PFMC 2010). Regionally the sardine fishery is important to local fishing communities and generates employment opportunities to residents, both in fishing and processing sectors.

Up until 2008, the stock assessment of sardine was largely driven by fishery independent spawning biomass estimates based on the daily egg production method (DEPM). This data input to the assessment is derived from NOAA Fisheries Service data collected by the SWFSC Fisheries Resource Division (FRD), primarily during surveys conducted during the spring. In the Pacific Northwest, however, large concentrations of sardine occur and are harvested over continental shelf waters off of Oregon and Washington during the late summer and early fall. As a consequence, the sardine industry in the Pacific Northwest initiated the development of a pilot aerial survey in 2008, which was reviewed by the PFMC's Scientific and Statistical Committee (SSC)[1] and was endorsed for further development and potential incorporation into the 2009 stock assessment. A more fully developed aerial Sardine Survey was conducted during the summer of 2009, which was funded by the industry in both the Northwest and California, largely based on proceeds from sardine landings under an EFP that was granted by the PFMC and NMFS. The absolute biomass estimate that was derived from the Sardine Survey in 2009 (incorporating only data gathered in Northwest due to weather limitations in the south) was then incorporated into a full stock assessment that was conducted later that year[2]. There were, however, a large differences in the precision and estimated size of the sardine stock, depending on the data source, i.e., the DEPM or the aerial survey. The aerial survey was conducted again in 2010 and was expanded into southern California. However, although point sets were successfully obtained in southern California, persistent marine layer precluded point sets off Monterey for the second year, the survey was again restricted to the Pacific Northwest (Washington and Oregon) and was included as an absolute biomass estimate of the stock ($\boldsymbol{q}$ = 1.00) (Hill *et al*. 2010).

Due to differences between the DEPM and aerial survey data, concerns were raised about the accuracy of these approaches and a workshop was held to compare and contrast methods appropriate to surveying the sardine stock[3]. A variety of survey methods were considered at the workshop, including: (1) DEPM, (2) acoustic-trawl, (3) aerial/purse-seine, (4) aerial LIDAR, and (5) trawl swept-area. The strengths and weaknesses of each of these approaches to surveying sardine were discussed and summarized.

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[1] Aerial Survey Methods for Pacific Sardine – Report of STAR Panel Meeting. Agenda Item H.2.a, Attachment 3, June 2009.
[2] Pacific Sardine STAR Panel Meeting Report. Agenda Item I.1.c, STAR Panel Report, November 2009.
[3] Workshop on Enhancing Stock Assessments of Pacific Sardine in the California Current Through Cooperative Surveys. Agenda Item I.1.b., Attachment 1, November 2010.

To develop a research plan to experimentally compare survey methods for estimating the biomass of Pacific sardine (*Sardinops sagax*) off the US West Coast, NOAA National Marine Fisheries Service (NMFS) and the Pacific Fishery Management Council (PFMC) conducted a workshop, May 23-24, 2011 in La Jolla, California. The workshop was a follow-up to the 2010 sardine workshop. The objectives of the 2011 workshop, as identified in the terms of reference, were to: (1) develop a plan for a coordinated synoptic sardine survey designed to compare the estimates of abundance estimates from different survey methods, (2) enhance collaborative research opportunities and coordination between the sardine industry and NMFS, and (3) develop a plan for a coordinated survey including budget, timeframe, PIs, and operational requirements.

Technical experts in five survey methods for estimating Pacific sardine biomass (acoustic-trawl, aerial, DEPM, LIDAR, and trawl swept-area) participated in the workshop and in developing a coordinated survey proposal for 2012. Experts in the fields of oceanography, sardine fishing, stock assessment, and sardine management also participated. Participants were drawn from the sardine fishing industry, the NMFS, the States of Oregon, Washington, and California, the PFMC, Canada and Mexico. In addition to differences between methods, it was acknowledged that sardine are migratory and seasonal shifts in biomass and length composition are routinely observed in fishery landings between the three countries and among the three US states participating in the fishery. As a result it was deemed important that methods be compared synoptically.

The group reviewed proposed plans to implement five survey methods and together developed a coordinated 2012 survey plan for comparing sardine biomass estimates derived from data collected with each of the methods. Two budget scenarios were evaluated, i.e., a base expected 2012 budget, ‘base budget’, and a ‘full budget’ that would fulfill the needs of implementing a comprehensive west coast sardine survey. The full-budget scenario would enable a comparison of aerial-LIDAR, aerial-imaging, acoustic-trawl, DEPM, and trawl swept-area methods.

What follows is the coordinated survey plan that the group developed. This plan represents increased collaboration opportunities within NMFS (between the Southwest Fisheries Science Center (SWFSC) and the Northwest Fisheries Science Center (NWFSC)) as well as between NMFS and the fishing industry. Conducting the proposed surveys will also enhance the Pacific sardine stock assessments as well as support those who depend on the fishery. The resulting comparisons will provide a better understanding of how the methods and the resources required can be best leveraged for maximum gain.

## 2012 Pacific Sardine Biomass Survey Plans

The following section outlines two different budget scenarios. The first option is based on the assumption that full funding will be available for all survey approaches to accomplish an optimal sampling effort during the late summer of 2012. The second scenario assumes level budgets (no increase in survey funds will be available).

### Budget Scenario I – Full Funding Assumption

Key aspects of this scenario are: (1) a two-ship survey conducted by the SWFSC Fisheries Resources Division (FRD) encompassing Canadian to Mexican waters collecting acoustic-trawl and DEPM data, (2) three replicate aerial-imaging surveys conducted by the Northwest Sardine Survey (NWSS), extending from Queen Charlotte Sound in Canada to the California-Oregon border, a portion of which (at least one replicate) will be scheduled to coincide with the FRD survey in Canada/WA/OR, (3) a west coast aerial-LIDAR survey led by the NOAA Earth System Research Laboratory (ESRL) tracking the FRD acoustic-trawl survey, (4) a cooperative industry-agency California aerial-LIDAR survey following the FRD survey track lines in southern California coordinated with the west coast LIDAR survey, potentially with additional point sets, (5) a ship survey conducted by the Canadian Department of Fisheries and Oceans (DFO) off the west coast of Vancouver Island collecting trawl data for calculating swept-area biomass, and (6) a two ship survey conducted by Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) in Mexican waters collecting ichthyoplankton and acoustic-trawl data.

<u>FRD Acoustic-trawl & DEPM</u>

*Principal Investigators*: Vetter and McClatchie

*Operating Equipment*: R/V *Bell M. Shimada* = 40 days (5 in Mexico), F/V *Frosti* = 45 days (5 in Canada), total = 85 vessel days at sea, echosounder, trawl, and ichthyoplankton sampling

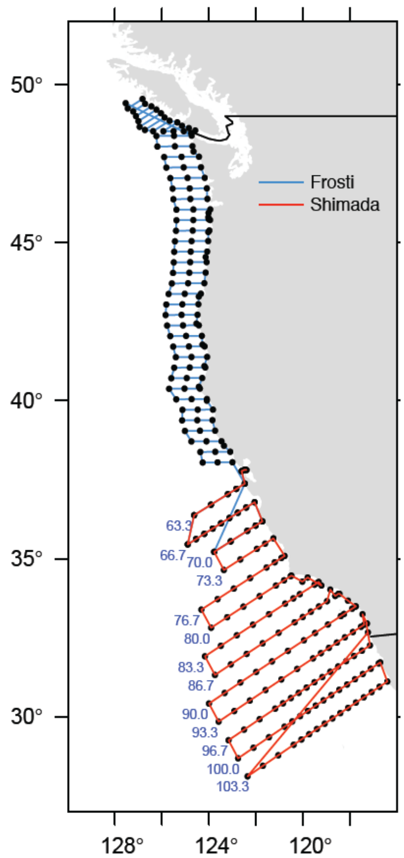
*Timeframe*: July 20 – August 31, 2012

*Field Operations*: echosounder, trawl, and ichthyoplankton sampling

*Data Collected*: species, length, reproductive state, age, genetics,abundance, and distribution

*Number and Position of Stations and Tracklines*: see map for the 308 stations occupied by *Shimada* (153) and *Frosti* (155)

*Analytical Methods to be Used*: DEPM procedure, trawl biomass, acoustic-trawl biomass, spatial, and regional analysis




*Budget*:

| Category | Item | Cost - Full funding |
|---|---|---|
| Ship time | Frosti charter | $360,000 |
| | Shimada | $680,000 |
| | | |
| Equipment | Trawl net | $100,000 |
| | Marine-mammal excluder | $20,000 |
| | Sonar for Frosti | $325,000 |
| | | |
| Shipping | Equipment to Frosti | $8,000 |
| | Equipment to Shimada | $8,000 |
| | | |
| Travel | San Diego to Vancouver - Frosti | $750 |
| | San Diego to San Francisco - Shima( | $600 |
| | | |
| Personnel | Pre-cruise preparation Frosti | $4,185 |
| | Pre-cruise preparation Shimada | $4,185 |
| | Days at sea Frosti | $165,042 |
| | Days at sea Shimada | $176,045 |
| | Sample processing, data processing and statistical analysis to include larval sorting, histology, otolith analysis, acoustic analysis, IMECOCAL data processing, and DEPM analysis | $252,603 |
| | | |
| TOTAL | | $2,104,409 |

*Permits Required*: Yes (Mexico portion)

<u>Canadian Swept-Area Trawl Survey</u>

*Principal Investigator(s)*: Schweigert

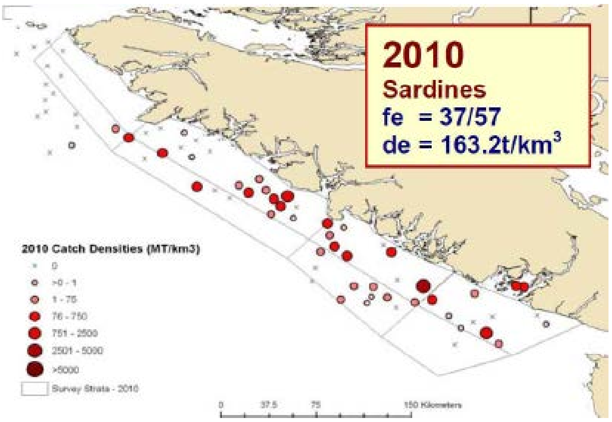
*Operating Equipment*: R/V *Ricker*

*Timeframe*: July 15 – August 31

*Field Operations*: Stratified-random station selection off west coast of Vancouver Island

*Data Collected*: sardine lengths, biomass, and distribution; trawl performance

*Number and Position of Stations and Tracklines*: see figure below for 2010 stations




*Analytical Methods to be Used*: swept-area of trawls and sardine biomass yield density estimates in spatial strata; sample frame includes depths to 100 m; stratified abundance estimates applied to stratum size and aggregated over strata

*Budget*: does not apply

*Permits Required*: none

<u>Coastwide Aerial-LIDAR and Imaging Survey</u>

*Principal Investigator(s)*: Churnside (ESRL)

*Operating Equipment*: NOAA Twin Otter (40 days and 100 hrs), LIDAR, video and FMC cameras, ocean color radiometry suite, and SST radiometer

*Timeframe*: July 20 – August 31, 2012

*Field Operations*: Follow ship (either *Shimada* or *Frosti*) tracks within 2 days, day and night

*Data Collected*: LIDAR and images

*Number and Position of Stations and Tracklines*: survey follows FRD acoustic-trawl tracklines with double (day and night) coverage

*Analytical Methods to be Used*: manual ID of schools, echo-integration, compare biomasses from other methods, e.g., laboratory target strength, historical point sets

*Budget*: ~$140 K (for Twin Otter), $250 K (labor – data collection and analysis), $10 K (travel, etc.)

*Permits Required*: clearance to fly US plane in non-US airspace

Northwest Sardine Survey

*Principal Investigator(s)*: Jagielo

*Operating Equipment*: three airplanes (two Piper Super Cubs, one Cessna 337), Aerial Imaging Solutions FMC mount system (3), four commercial purse-seine vessels

*Timeframe*: July 10 – September 15 (will depend on EFP)

*Field Operations*: Two-stage sampling design: stage one is aerial-transect sampling, stage two is at-sea point-set sampling

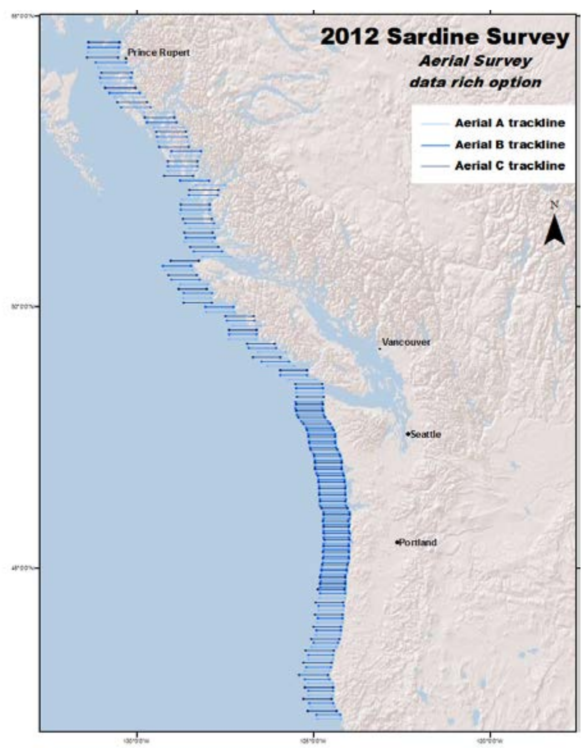
*Data Collected*: measurements of school surface area from digital images, landed weight and biological characteristics of fully-captured schools

*Number and Position of Stations and Tracklines*: three replicate sets of strip transects with the starting latitude of each randomized (see figure below); aerial survey conducted in Canadian waters in Queen Charlotte Sound and off the west coast of Vancouver Island.

*Analytical Methods to be Used*: measurements of school, size, and shape using image analysis software

*Budget*: US portion assumes EFP is awarded at a static level; Canadian portion requires additional funding

*Permits Required*: possibly for Canada; EFP required for US portion



SoCal Cooperative Aerial-LIDAR

*Principal Investigator(s)*: Churnside and LeRoi

*Operating Equipment*: NOAA Twin Otter (50 additional hours within the same 40 days and 100 hrs as FRD survey), LIDAR, video and FMC cameras, ocean color radiometry suite, SST radiometer, image intensifier lens for camera, and four charter vessels

*Timeframe*: the early part of July 20 – August 31, 2012 (with *Shimada* survey), depending on sardine location and timing of EFP (for point sets)

*Field Operations*: Follow *Shimada* tracks within two days, day and night.

*Data Collected*: LIDAR return, bioluminescence, and images, point sets (number to be determined)

*Number and Position of Stations and Tracklines*: offshore boundary defined by CalCOFI lines for the LIDAR but may include additional adaptive flights to survey specific sites with point sets, line extensions when appropriate, and/or high-density areas; point sets likely to be more spatially restricted.

*Analytical Methods to be Used*: Aerial imaging similar to NWSS, combine images and LIDAR with point sets.

*Budget*: ~$225 K for charter vessels ($7500/day/vessel), $50 K (aircraft), $125 K (labor); sale of EFP catch will cover costs for scientists, data processing, and spotter pilot.

*Permits Required*: EFP for point sets.

IMECOCAL

*Principal Investigator(s)*: Baumgartner (CICESE), Salinas, and possibly Quinones

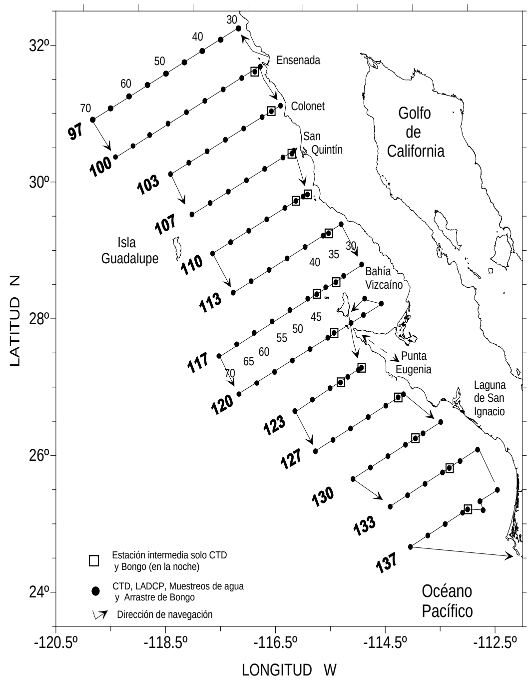
*Operating Equipment*: RV *Ulloa*, FV *Leifo Pol*, EK60

*Timeframe*: 20 July – 11 August 2012

*Field Operations*: ichthyoplankton sampling with CUFES, bongo and Calvet (*Ulloa*); acoustic (EK60) and trawling (*Leifo Pol*)

*Data Collected*: egg concentrations and distributions, species length compositions, reproductive states, ages, abundance, integrated echo-return.

*Number and Position of Stations and Tracklines*: 94 stations following the trackline shown below; all sample sites are CalCOFI stations; *Leifo Pol* to follow *Ulloa* over the same trackline gathering acoustic-trawl samples.



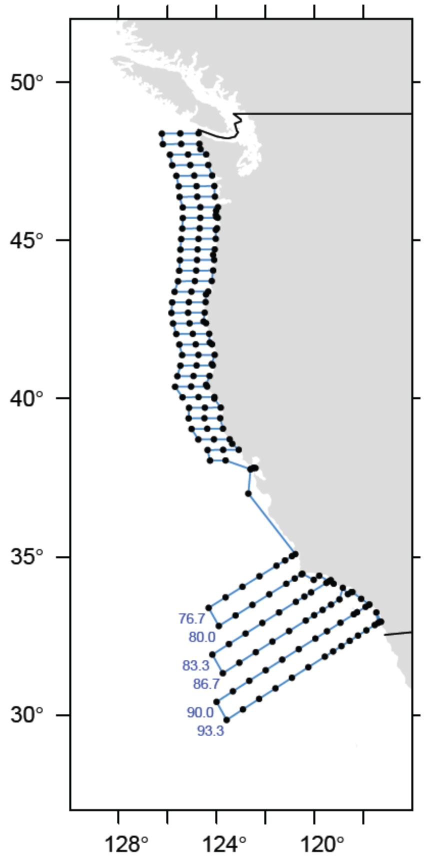

*Analytical Methods to be Used*: SWFSC FRD protocols for both DEPM and acoustic-trawl methods for estimating biomass.
*Budget*: 20 days *Ulloa* shiptime and 15-20 days for *Leifo Pol*
*Permits Required*: experimental fishing permit pending for *Leifo Pol.*

### Budget Scenario II – Level Funding Assumption

This budget scenario represents a contraction of the full funding scenario by: (1) dropping one of the two FRD survey vessels (*Shimada*), (2) reducing (or dropping) the Canadian aerial strip-transect lines from the NWSS while retaining a comparison opportunity (at least one replicate) with the FRD survey in WA/OR, and possibly Canada, (3) limiting the west coast LIDAR survey to the region sampled by the FRD research vessel, (4) limiting the Southern California cooperative survey to the CalCOFI survey area, and (5) dropping the acoustic-trawl sampling in Mexican waters. The DFO survey would not be altered under this scenario.

<u>FRD Acoustic-trawl & DEPM</u>
*Principal Investigators*: Vetter and McClatchie
*Operating Equipment*: *Frosti* for 40 days working south from Canada; California waters sample by July CalCOFI; echosounder, trawl, and ichthyoplankton sampling
*Timeframe*: July 20 – August 31, 2012
*Field Operations*: echosounder, trawl, and ichthyoplankton sampling.
*Data Collected*: species, lengths, reproductive state, age, genetics, abundance and distribution.
*Number and Position of Stations and Tracklines*: see map below for 190 stations occupied by *Frosti* and July CalCOFI cruise

*Analytical Methods to be Used*: DEPM, trawl, and acoustic-trawl




*Budget*:

| Category | Item | Cost - Level funding |
|---|---|---|
| Ship time | Frosti charter | $320,000 |
| | Shimada | $0 |
| | | |
| Equipment | Trawl net | $50,000 |
| | Marine-mammal excluder | $10,000 |
| | Sonar for Frosti | $325,000 |
| | | |
| Shipping | Equipment to Frosti | $8,000 |
| | Equipment to Shimada | $0 |
| | | |
| Travel | San Diego to Vancouver - Frosti | $750 |
| | San Diego to San Francisco - Shima | $0 |
| | | |
| Personnel | Pre-cruise preparation Frosti | $4,185 |
| | Pre-cruise preparation Shimada | $0 |
| | Days at sea Frosti | $146,704 |
| | Days at sea Shimada | $0 |
| | Sample processing, data processing and statistical analysis to include larval sorting, histology, otolith analysis, acoustic analysis, IMECOCAL data processing, and DEPM analysis | $157,000 |
| | | |
| TOTAL | | $1,021,639 |

*Permits Required*: None

Canadian Trawl Survey

*Principal Investigator(s)*: Schweigert

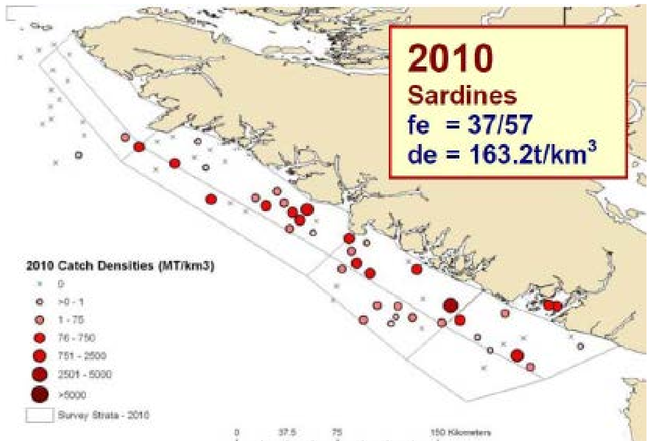
*Operating Equipment*: *Ricker*

*Timeframe*: July 15 – August 31

*Field Operations*: Stratified random station selection off west coast of Vancouver Island

*Data Collected*: sardine biomass and lengths; trawl performance

*Number and Position of Stations and Tracklines*: see figure below for 2010 stations.




*Analytical Methods to be Used*: swept-area of trawls and sardine biomass yield density estimates in spatial strata; sample frame includes depths to 100 m; stratified abundance estimates applied to stratum size and aggregated over strata

*Budget*: does not apply

*Permits Required*: None

Coastwide Aerial-LIDAR and Imaging Survey[4]

*Principal Investigator(s)*: Churnside (ESRL)

*Operating Equipment*: LIDAR, video and FMC cameras, ocean color radiometry suite, and SST radiometer

*Timeframe*: July 20 – Aug 31, 2012

*Field Operations*: aerial strip transects in Pacific Northwest

*Data Collected*: LIDAR return and imagery

*Number and Position of Stations and Tracklines*: follow *Frosti* tracklines within 2 day (both night and day)

*Analytical Methods to be Used*: manual ID of schools, echo-integration, compare biomasses from other methods, e.g., laboratory target strength, historical point sets

*Budget*: $125K LIDAR labor + $10K shipping and travel

*Permits Required*: None

[4] Funds currently do not exist for this survey but it was included for completeness

Northwest Sardine Survey

*Principal Investigator(s)*: Jagielo

*Operating Equipment*: three airplanes (two Piper Super Cubs, one Cessna 337), Aerial Imaging Solutions FMC-mount system (3), four commercial purse-seine vessels

*Timeframe*: July 10 – September 15 (will depend to some extent on EFP)

*Field Operations*: two-stage sampling design: stage one is aerial-transect sampling, stage two is at-sea point-set sampling.

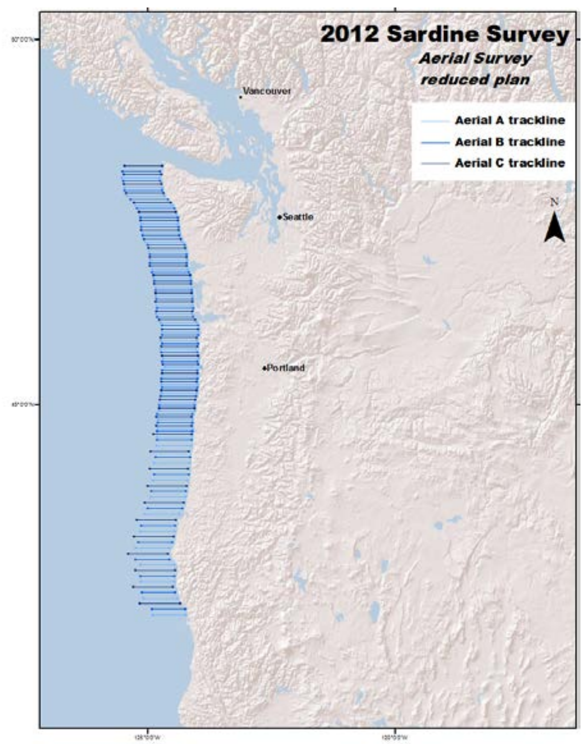
*Data Collected*: measurements of school surface area from digital images, landed weight and biological characteristics of fully-captured schools

*Number and Position of Stations and Tracklines*: three replicate sets of strip transects off the coast of Washington and Oregon only, with the starting latitude of each randomized (see figure below).

*Analytical Methods to be Used*: measurements of school size and shape using image-analysis software

*Budget*: US portion assumes EFP awarded at static level.

*Permits Required*: EFP required for US portion.



SoCal Cooperative Aerial-LIDAR

*Principal Investigator(s)*: Churnside, LeRoi, and Sweetnam

*Operating Equipment*: CDFG Partanavia, LIDAR, video or FMC cameras, image intensifier lens for camera, three charter vessels (30 point sets)

*Timeframe*: the early part of July 20 – August 31, 2012 (with *New Horizon*/CalCOFI survey) depending on sardine location and timing of EFP (for point sets)

*Field Operations*: Follow CalCOFI tracklines within two days, day and night

*Data Collected*: measurements of school surface area from digital images, landed weight and biological characteristics of fully-captured schools; LIDAR return for school density and depth, approximately 30 point sets, bioluminescence images

*Number and Position of Stations and Tracklines*: for LIDAR, offshore boundary defined by CalCOFI lines completed by the FRD, but may include additional adaptive flights to estimate abundance at specific sites where point sets have occurred, line extensions when appropriate, and/or high-density areas; point sets likely to be more spatially restricted

*Analytical Methods to be Used*: Aerial imaging similar to NWSS, combine images with LIDAR and point set data

*Budget*: $113K for charter vessels ($7500/day/vessel); $125K LIDAR labor + $10K shipping and travel; sale of EFP catch to cover the costs for scientists, data processing, and spotter pilot

*Permits Required*: EFP for point sets

IMECOCAL

*Principal Investigator(s)*: Baumgartner (CICESE)

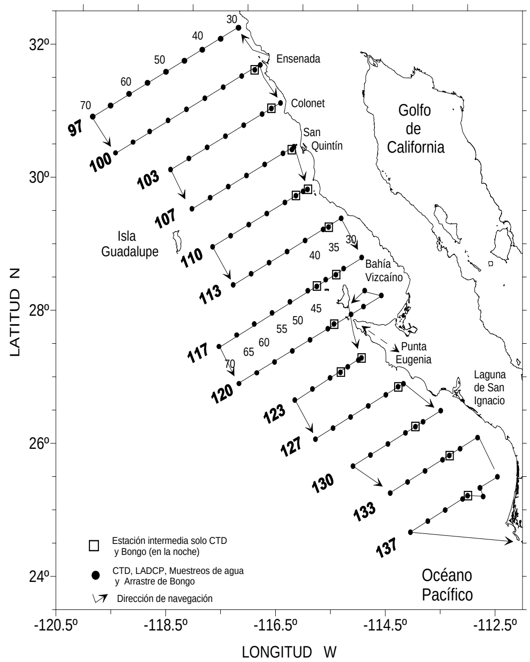
*Operating Equipment*: *Ulloa*

*Timeframe*: July 20 – August 11, 2012

*Field Operations*: ichthyoplankton sampling with CUFES, bongo and Calvet

*Data Collected*: egg and larval concentrations and distributions

*Number and Position of Stations and Tracklines*: 94 ichthyoplankton stations following the trackline shown below; cruise will progress from the north to the south; all sample sites are CalCOFI stations

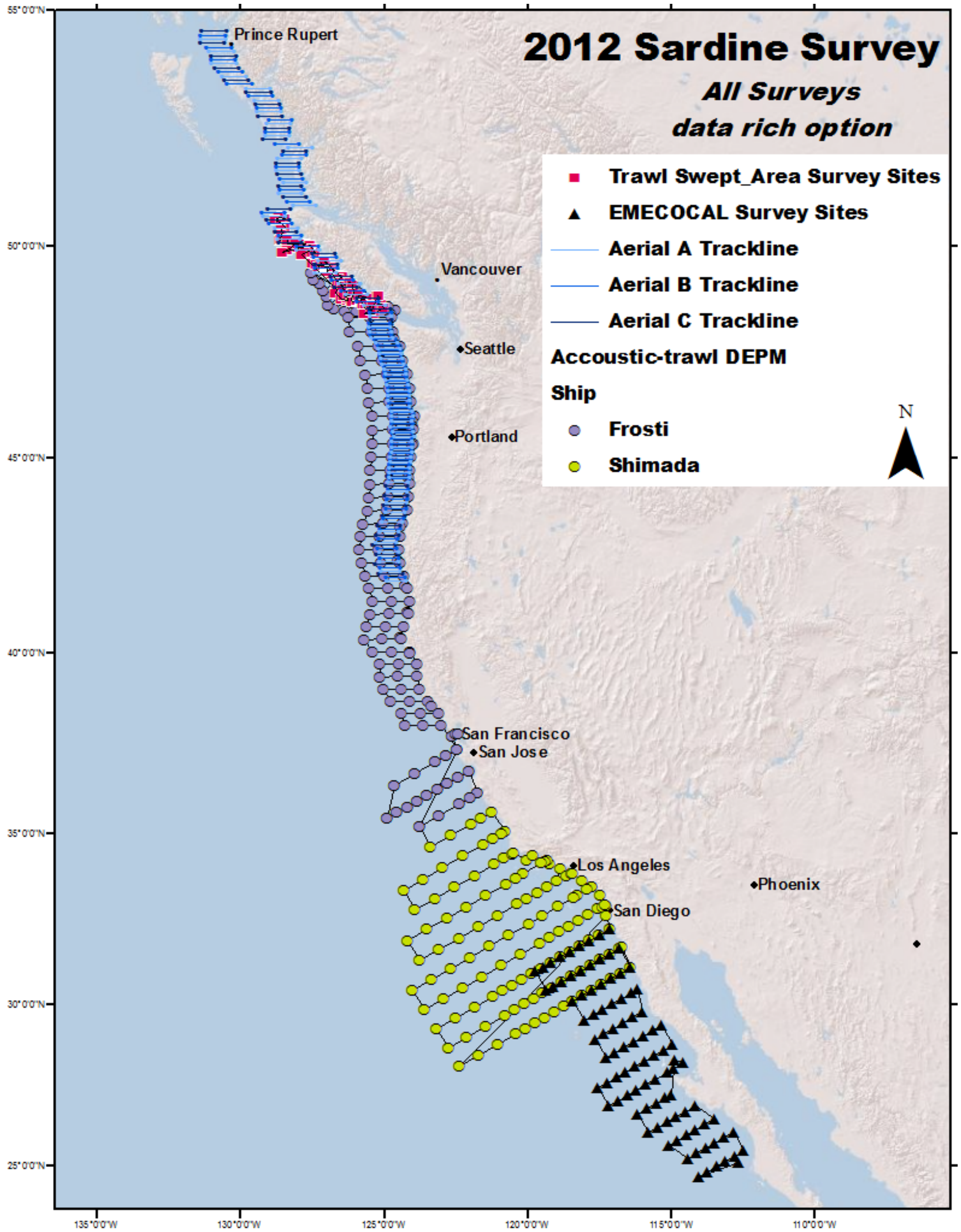



*Analytical Methods to be Used*: SWFSC FRD protocols for both DEPM and acoustic-trawl methods

*Budget*: 20 days *Ulloa* shiptime, $5 K technician time

*Permits Required*: none

The following figure shows the fully funded survey plan, with station locations for all sampling methods superimposed.



**Discussion**

Completion of these surveys in the manner described above will allow for a number of comparisons of the different methods. In particular, we can compare absolute sardine biomass estimates obtained from six different survey approaches, including: (1) FRD acoustic-trawl (A-T (FRD)), (2) FRD DEPM (DEPM (FRD)), (3) NWSS (aerial imaging), (4) DFO trawl (DFO Trawl), (5) Mexican acoustic-trawl and ichthyoplankton (IMECOCAL), and (6) aerial-LIDAR (LIDAR) surveys. Possible comparisons of abundance estimates derived from these six survey approaches are summarized in the table below.

| Survey Method | **A-T (FRD)** | DEPM (FRD) | Aerial Imaging | DFO Trawl | IMECOCAL(+) |
|---|---|---|---|---|---|
| **DEPM (FRD)** | yes** | | | | |
| **Aerial Imaging** | **yes** | yes (south) | | | |
| DFO Trawl | yes | no | yes | | |
| IMECOCAL(+) | yes* | yes | yes* | no | |
| LIDAR | yes | yes (south) | yes | yes | yes* |

*Where there is overlap with three transects in SoCal/Mexico
**Only if spawning females are present in summer survey
(+) IMECOCAL may add multiple methods, dependent on availability, funding, etc (see #4 below)

In some instances it should be possible to make a robust comparison of methods. For example, if the acoustic-trawl survey and the NWSS are fully funded, there will be an extensive region of spatial overlap in the surveys, which will largely be conducted contemporaneously. This particular comparison (bolded in blue) is perhaps the single most important one to conduct, given the differences in survey biomass estimates that was described in the Introduction and the resulting reservations by industry concerning the accuracy of the stock assessment. On the other hand, comparisons of alternative survey methods with results of the DEPM are unlikely to be very powerful because late summer ichthyoplankton surveys for sardine will not likely encounter high abundances of eggs. However, a comparison of the DEPM and the acoustic-trawl method can probably be achieved by summarizing the FRD's previously conducted spring surveys that were conducted in the Southern California Bight and along the central California coast. These three survey approaches (FRD acoustic-trawl, NWSS aerial-imaging, and DEPM) are currently the only three survey methods that have been approved by the PFMC's SSC for inclusion in the Pacific sardine stock assessment. In that sense the two other methods (LIDAR and trawl swept-area biomass) are in an earlier stage of development. Finally, it is also important to reiterate that the objective is not to compare the various methods and then select the "best." Rather, the objective is to evaluate the relative advantages and disadvantages of each, so that they can be combined to provide the best balance between cost and precision.

Although not specifically addressed in the workshop Terms of Reference (Appendix 1), an additional important source of uncertainty in the sardine stock assessment is the extent to which fish migrate into Canadian waters. Although a comparison of the FRD acoustic-trawl and the NWSS aerial survey methods will be possible, even under the level funding scenario, a full evaluation of the proportion of the stock north of the US-Canada border may only be accomplished under the full funding scenario. Even then, interannual variation in the extent of northward migration of the sardine stock is likely to occur and a single year of sampling would not be able to determine that variation.

**References**

Hill, K.T., N.C.H. Lo, B.J. Macewicz, P.R. Crone, and R. Felix-Uraga. 2010. Assessment of the Pacific sardine resource in 2010 for U.S. management in 2011. NOAA Technical Memorandum NMFS, NOAA-TM-NMFS-SWFSC-469, 142 p.

PFMC. 2010. Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches – Stock Assessment and Fishery Evaluation 2010. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland OR 97220, 71 p.

**List of Briefing Materials**

<u>Documents</u>

Document 1 Proposed coast-wide lidar survey of sardines
*J. Churnside, NOAA Earth System Research Laboratory*

Document 2 Summary of the Coast-wide Sardine Trawl Survey Plan for 2011
*J. Schweigert, DFO Canada*

Document 3 Summary of the Northwest Sardine Survey (NWSS) Aerial Sardine Survey Plan
*T. Jagielo, NWSS*

Document 4 Spawning biomass of Pacific sardine using the DEPM method for 2010 spring CCE survey and 2008 spring and summer CCE surveys
*N. Lo, B. Macewicz, D. Griffith, NOAA Fisheries SWFSC*

Document 5 Acoustic-trawl survey conducted during the Spring 2011 California Current Ecosystem Survey from FV *Frosti* and FSV *Bell M. Shimada*
*Juan P. Zwolinski, Kyle A. Byers, George R. Cutter Jr., Thomas S. Sessions, Beverly J. Macewicz, and David A. Demer*

<u>Informational Papers</u>

Paper 1 Summary of advantages and limitations & challenges of survey methods (extracted from the 2010 Pacific Sardine Workshop report <u>http://swfsc.noaa.gov/SardineWorkshop2010/</u>)

Paper 2 West Coast Aerial Sardine Survey 2011 Application for Exempted Fishing Permit

Paper 3 Acoustic-Trawl Survey Method for Coastal Pelagic Species Report of Methodology Review Panel Meeting

Paper 4 Aerial surveys of fish in estuaries: a case study in Chesapeake Bay
*J.H. Churnside, A.F. Sharov, R.A. Richter*

Paper 5 Proceedings of the Sardine Symposium 2000

Paper 6 Predicting habitat to optimize sampling of Pacifdic sardine (*Sardinops sagax*)
*J.P. Zwolinski, R.L. Emmett, D.A. Demer*

## Appendix 1 – Terms of Reference

Goals and Objectives:

1. Develop a coordinated synoptic sardine survey plan that will allow a comparison of abundance estimates developed from different survey methods. The comparisons are expected to assist interpretation of the data elements that are incorporated into the sardine stock assessment.
2. Improve collaborative research opportunities and coordination between the sardine industry and NMFS;
3. Develop a proposed survey budget, timeframe, PIs, and operational requirements.

Responsibilities/Roles:

*Core participants* include the Executive Committee and the survey experts of each method. Their responsibilities include:

1. review all documents pertinent to the workshop;
2. provide proposed survey plans as working papers for their respective methods;
3. develop and draft an executable sardine survey plan for 2012;
4. provide constructive recommendations for developing a coordinated survey plan;
5. maintain flexibility and openness to survey designs that accomplish the primary goal of the workshop;
6. collaborate to develop a final executable sardine survey plan for 2012;
7. survey experts will consider both the scientific credibility of the survey designs, i.e. the ability of a proposed plan to provide the intended abundance estimate, as well as the budgetary and logistical requirements;
8. the Executive Committee will consider and comment on the budgetary and logistical needs of the plan (funding and availability of platforms and personnel).

*Subject matter experts* include experts in oceanography, stock assessments, sardine fishing, and general sardine knowledge pertinent to the workshop objectives. Their responsibilities include:

1. provide relevant subject material and commentary as requested by the Core Participants, Facilitator or Chair of the Workshop to help the Core Participants develop an acceptable survey plan during the Workshop itself.

*The facilitator* responsibilities include:

1. guide the Working Group (Core participants and Subject matter experts) in developing the plan, adhering to this Terms of Reference, and finding mutually agreeable solutions;
2. coordinate writing of survey plan;
3. manage discussions and public comment so that work can be completed.

*The workshop chairman's* responsibilities include:

1. guide the Executive Committee in developing a workshop and assisting the Facilitator in ensuring the Working Group meets it's objectives;
2. develop a workshop agenda;
3. review the Working Group workshop report before it is forwarded to the SWFSC and presented to the Pacific Fishery Management Council.

*The public* will have at least one period for commenting on the activities of the workshop; comments should be germane to the topic at hand.

Expectations:

The primary purpose of the workshop will be to develop a coordinated synoptic sardine survey plan that will allow a comparison of sardine abundance estimated using different survey methods. The Working Group will not revisit, but will build on discussion and topics resulting from the Sardine-I workshop. The Working Group will begin its work with the SWFSC 2012 summer cruise as a proposed survey design, to be spatially and temporally coordinated with other approaches to estimating sardine abundance, as appropriate and reasonable.

Survey Methods to be Considered

- Acoustic-trawls
- Aerial surveys
- DEPM
- LIDAR
- Swept Area Trawl

Draft Product – to be completed within one week of workshop.
Final Product – to be delivered to SWFSC within two weeks of workshop.

An executable sardine survey plan for 2012 including the following for each survey method:

1. Principal Investigators
2. operating equipment
3. timeframe
4. field operations to be conducted
5. data to be collected
6. number and position of stations and track lines
7. analytical methods to be used to summarize the data collected
8. budget

Participants:

Chairman – Mark Helvey
Executive Committee

- Kerry Griffin
- Kristen Koch
- Mike Okoniewski
- Diane Pleschner-Steele
- Sarah Shoffler
- Cisco Werner

Facilitator – Steve Ralston
Survey Experts

- Acoustics: David Demer
- Aerial Survey: Tom Jagielo, Don LeRoi
- DEPM: Nancy Lo
- LIDAR: James Churnside
- Trawl survey (swept area): Bob Emmett, Jake Schweigert

SWFSC survey: Russ Vetter

Subject Matter Experts

- Fishing: David Haworth, John Lenic
- Oceanographic: Ed Weber
- Sardine: Dale Sweetnam, Lorna Wargo, Greg Krutzikowsky, Sandy McFarlane
- Stock Assessment: Kevin Hill
- IMECOCAL Survey: Baumgartner

**Appendix 2 – Agenda**

Workhsop on Enhancing Stock Assessments of Pacific Sardine in the California Current Through Coordinated Comparative Surveys

May 23-24, 2011
La Jolla, California

I. Opening and introduction

II. Arrangements and process

III. Review of plans for ship-based sardine survey methods

1. DEPM survey
2. Acoustic-trawls survey
3. Swept area trawl survey

IV. Review of plans for plane-based sardine survey methods
1. Aerial survey
2. LIDAR survey

IV. Draft plan(s) for different budget scenarios.

V. Clearing of plan and commitments for follow through and clean up

1. Discussion on follow through
2. Clearing of plan

VI. Close of workshop

## Appendix 3 – Alphabetical List of Attendees

Tim Baumgartner
Jim Churnside
Paul Crone
Bob Emmett
Kerry Griffin
David Haworth
Mark Helvey
Roger Hewitt
Kevin Hill
Tom Jagielo
Kristen Koch
Greg Krutzikowsky
John Lenic
Don LeRoi
Nancy Lo
Bev Macewicz
Sandy McFarlane
Diane Pleshner-Steele
Steve Ralston
Rosa Runcie
Jake Schweigert
Sarah Shoffler
Dale Sweetnam
Lorna Wargo
Cisco Werner
Russ Vetter
Ed Weber

# COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON NATIONAL MARINE FISHERIES SERVICE REPORT

The Coastal Pelagic Species Advisory Subpanel (CPSAS) heard the report delivered by Dr. Steve Ralston on the recent Sardine Workshop II. The workshop was sponsored by the Council and the National Marine Fisheries Service (NMFS) and hosted by the Southwest Fisheries Science Center (SWFSC). Several CPSAS Members attended and are part of the Workshop's Executive Committee.

We commend Dr. Ralston for doing an excellent job facilitating the second Sardine Workshop and writing up the final report. In addition, we would like to thank Dr. Cisco Werner, Dr. Donald McIsaac, Ms. Kristen Koch, Mr. Mark Helvey, the SW and NW Science Centers, the states, and the Council staff for their collaboration in putting the Workshop together.

The CPSAS believes the Workshop objectives, if realized, would provide important collaborative information that could fill in many gaps in our understanding of sardine population dynamics, trans-boundary geographic range, and total biomass. We note that this could start an international process of collaborative work with Canadian and potentially Mexican scientists and stakeholders. In addition, this work could provide insight into the populations and range of other CPS species. This could be valuable for future ecosystem-based management as well as single stock assessments

We further note that elements of this proposed work under the “fully-funded” Budget One do require additional funding. We point out that the entire sardine industry, thanks to Council support, has already contributed a great amount of funding to gain additional data for our stock assessment. The fully funded budget model would still receive funding from our industry to continue the aerial survey. In addition, Canada would cover a portion of the costs for work in Canadian waters. This is important, as we do not know the true extent of biomass or geographic range of Pacific sardine in Canada, or in Mexico.

To accomplish the entire collaborative project outlined in the fully funded model would require additional funds for ship time and NOAA LIDAR work. The CPSAS strongly believes this is money well spent. This investment has the potential to pave the way for new income and jobs for our hard hit coastal communities. The CPSAS asks the Council for their support to seek additional funding for this collaborative effort. We appreciate the previous work of Dr. McIsaac, Mr. Don Hansen, and the Council, which were successful in obtaining cooperative research funds that helped to support the 2010 aerial survey as well as the recent sardine research workshop.

PFMC
06/10/11

Agenda Item G.1.c
Supplemental CPSMT Report
June 2011

# COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON NATIONAL MARINE FISHERIES SERVICE REPORT

On June 9, 2011 the Coastal Pelagic Species Management Team (CPSMT) and with the Coastal Pelagic Species Advisory Subpanel heard a presentation by Dr. Steve Ralston on the results of the second workshop on enhancing stock assessment of Pacific sardine through coordinated comparative surveys that were held in La Jolla , CA in May 2011. The CPSMT also reviewed the workshop report.  The CPSMT recommends that the Council support the fully funded survey option outlined in the workshop report. If realized, this survey would allow for meaningful comparisons of biomass estimates in defined sampling frames derived by various survey methods. The fully funded survey would also realize the longstanding recommendations of the CPSMT for better cooperation with both Mexico and Canada on all trans-boundary CPS stocks.

The CPSMT would like to thank the workshop executive committee and participants for their efforts in putting together a successful workshop. Dr. Ralston should also be congratulated for his outstanding job facilitating and writing the results of the workshop report.

PFMC
06/10/11

Agenda Item G.2
Situation Summary
June 2011

PACIFIC MACKEREL MANAGEMENT FOR 2011-2012

The Pacific Fishery Management Council (Council) is scheduled to review the current Pacific mackerel stock assessment and adopt a harvest guideline for the 2011-2012 Pacific mackerel fishing season, which runs from July 1, 2011 through June 30, 2012. Prior to this year, the last full assessment of Pacific mackerel was in 2009, and was used as the basis to inform both the 2009-10 as well as the 2010-11 mackerel management measures. The Council and the 2009 mackerel Stock Assessment Review (STAR) Panel cited research and data needs in choosing to forego an assessment for one year.

The National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center (SWFSC) led the development of a new full assessment this year (Agenda Item G.2.b Attachment 1), which was reviewed by a STAR Panel May 2-5, 2011, in La Jolla, California (Agenda Item G.2.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 Council meeting.

The draft 2011 Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches - Stock Assessment and Fishery Evaluation (SAFE) document (Agenda Item G.2.a Attachment 1) will be posted as supplemental material on the Council web site in advance of the June Council meeting. Once adopted, the 2011 Pacific Mackerel Stock Assessment and 2011-2012 management measures will be included in the SAFE document.

**Council Action:**

**Approve Stock Assessment, Harvest Guideline, and Management Measures.**

Reference Materials:

1. Agenda Item G.2.a, Supplemental Attachment 1: Draft Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches - Stock Assessment and Fishery Evaluation (SAFE) document (*available electronically only*).
2. Agenda Item G.2.b, Attachment 1: Pacific Mackerel (*Scomber japonicus*) Stock Assessment for USA Management in the 2011-2012 Fishing Year.
3. Agenda Item G.2.b, Attachment 2: Pacific Mackerel STAR Panel Meeting Report.

Agenda Order:

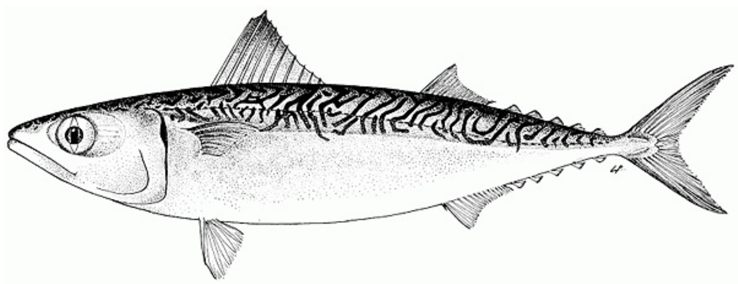
a. Agenda Item Overview — Kerry Griffin
b. Summary of Mackerel Stock Assessment — Paul Crone

c. Reports and Comments of Advisory Bodies and Management Entities
d. Public Comment
e. **Council Action:** Approve Stock Assessment, Harvest Guideline, and Management Measures

PFMC
05/24/11

Agenda Item G.2.b
Attachment 1
June 2011

# PACIFIC MACKEREL (*Scomber japonicus*) STOCK ASSESSMENT FOR USA MANAGEMENT IN THE 2011-12 FISHING YEAR



by


P. R. Crone[1], K. T. Hill[1], J. D. McDaniel[1], and K. Lynn[2]

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Submitted to

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

June 2011

Crone, P. R., K. T. Hill, J. D. McDaniel, and K. Lynn. 2011. Pacific mackerel (*Scomber japonicus*) stock assessment for USA management in the 2011-12 fishing year. Pacific Fishery Management Council, Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220, USA. 99 p.

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# PREFACE

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 1$^{st}$ and ends on June 30$^{th}$ of the subsequent year (henceforth, presented as a 'fishing year'). In this context, in this document, both a two-year (2010-11) and single-year (2010) reference refer to the same fishing year that spanned from July 1, 2010 to June 30, 2011. 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). It is important to note that in 2010, federal mandates required regional fishery Councils to begin transitioning to a revised process for quota determination, which relies on additional statistics not previously included in stock assessment documents and thus, such information is presented here along with the typical HG-related parameters of interest, see Amendment 13 of the CPS FMP (PFMC 2010a) and Ralston et al. (2011) for details regarding these changes.

The last stock assessment and related reviews for this species were completed in 2009 (Crone et al. 2009), with a HG serving for two years (PFMC 2010b). That is, in the past, this species was assessed annually, but given both the population's biology and limited fishing pressure the two-year span was deemed reasonable and adopted by the PFMC in 2009. 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 PFMC (2010c). Specifically, a stock assessment review (STAR) panel was convened from May 2-5, 2011 (NOAA Fisheries, Southwest Fisheries Science Center in La Jolla, CA) to evaluate the ongoing Pacific mackerel stock assessment. Important areas of general consensus reached by the STAR panel regarding the Pacific mackerel stock assessment conducted in 2011 follow [for further details of the week-long review see STAR (2011a)]:

- first and foremost, the stock assessment documentation/presentation followed stipulations set forth in the CPS stock assessment 'Terms of Reference' (PFMC 2010c) and produced a 'base case' model on which to provide formal management advice regarding exploitation of the Pacific mackerel population harvested off the Pacific coast of the United States (USA);
- a base case model (henceforth, Model *XA*) was identified as the final model configuration (hypothesized 'state of nature' or model 'scenario'), included fishery-dependent sources of data (landings, biological distributions, and catch-per-unit-effort indices of abundance), and represented a robust model that was developed via statistical (model fits and diagnostics supported 'inside the model') and pragmatic bases (sound assumptions/parameterizations supported 'outside the model');
- Model *XA* represented the culmination of substantial work over an extended timeframe, including evaluations at the data source (time series) and modeling (sensitivity analysis) levels, however, the current 'final' model is an ongoing effort that is improved upon as more pertinent time series become available and as such, still includes areas of uncertainty regarding the species' biology and influential model parameterizations, which necessarily

precludes precise estimation of absolute abundance and ultimately, may warrant consideration when setting harvest levels for this species [see Assessment uncertainty and Research and Data Needs sections, and STAR (2011a)].

Given the inherent difficulties presenting the voluminous amount of results from stock assessment modeling efforts extended over a broad time period, discussion and related displays are largely presented only for the final Model *XA*, with summaries/comparisons/etc. to other models of interest where appropriate (e.g., estimated time series from previous assessments and/or the sensitivity analysis conducted in 2011).

## 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 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. Note that a historically complete catch time series is presented for illustrative purposes only, given the final Model *XA* began in 1983.

Currently, catch (including biological) data are largely collected through a California Department of Fish and Game (CDFG) port (commercial) sampling program, as well as via the Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fish and Wildlife (WDFW). 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), as well as other modes of fishing, such as pier and private vessel. Recreational fishery-based landings are much lower than those related to commercial fisheries (i.e., sport fisheries generate less than 5% of the total catch in any given year).

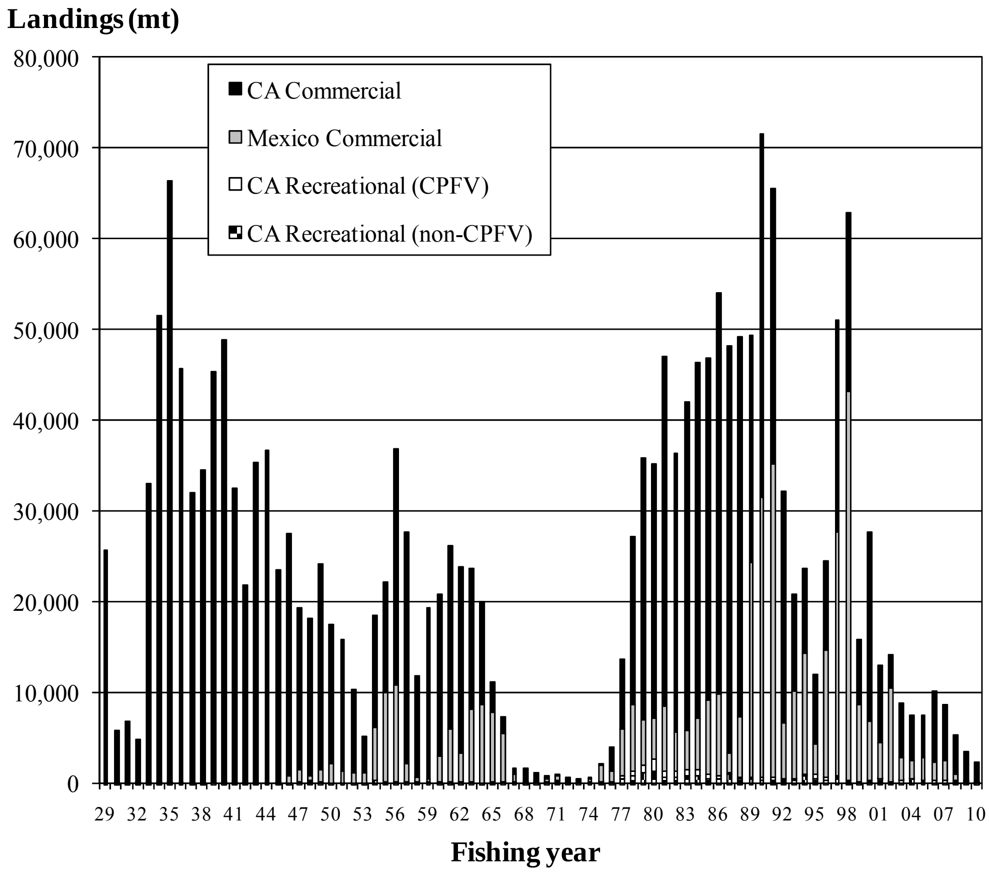


Figure ES-1. Commercial and recreational landings (mt) of Pacific mackerel in the USA (CA commercial, recreational-CPFV, and recreational-non-CPFV) and Mexico (commercial), (1929-10).

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), (2000-10).

| Fishing year | USA Commercial (mt) | Mexico Commercial (mt) | Recreational CPFV (mt) | Recreational non-CPFV (mt) | Total (mt) |
|---|---|---|---|---|---|
| 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 | 1,986 | 16 | 356 | 10,228 |
| 07 | 6,208 | 2,218 | 19 | 291 | 8,737 |
| 08 | 4,281 | 803 | 13 | 267 | 5,364 |
| 09 | 3,011 | 171 | 13 | 254 | 3,450 |
| 10 | 2,086 | 171 | 5 | 95 | 2,357 |

**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 and length/age distributions, as well as relative indices of abundance from fisheries and/or research surveys. The last assessment of Pacific mackerel was completed in 2009 for USA management in the 2009-10 fishing year. The current assessment includes the following primary sources of data: catch time series (USA/Mexico commercial and USA recreational fisheries); length (USA recreational fishery) and age (USA commercial fishery) distribution time series; and index of abundance time series from recreational fishery surveys.

**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’ data (e.g., index of abundance time series) 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. However, it is important to note that progress continues in terms of addressing these two research efforts, which are expected to gain further support in the coming years. That is, the need for formal data exchange workshops with Mexico (as well as Canada) researchers, and commitment to synoptic surveys that provide representative sample data, particularly, programs related to the CalCOFI and acoustic-trawl survey operations based at the SWFSC. Also, see Research and data needs below.

**Total stock biomass**

Total biomass (age-1+ biomass, *B*) has steadily declined from the mid 1980s to the early 2000s, at which time the population began to increase moderately in size, with some signs of ‘rebuilding’ observed over the last several years (Figure ES-2 and Table ES-2). However, in historical terms, the population remains at a relatively low abundance level, due primarily to oceanographic conditions, given limited fishing pressure over the last decade has not likely compromised this species' biology (i.e., role in the larger CPS assemblage off the Pacific coast of North America). Finally, 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 (also see Assessment uncertainty section).

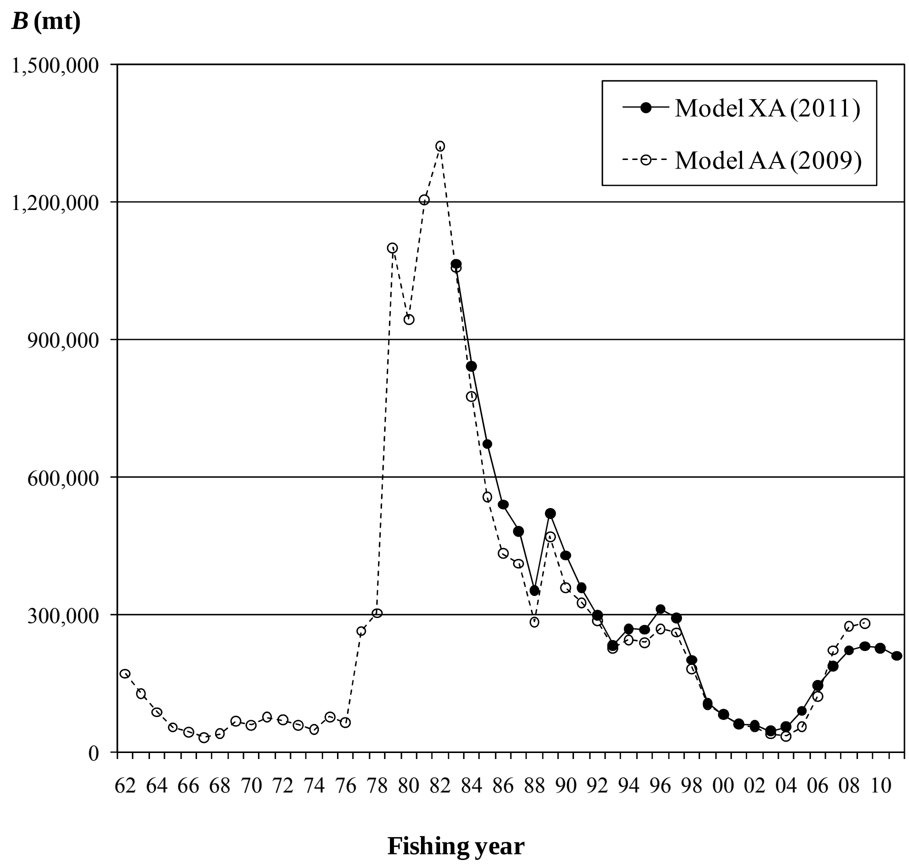


Figure ES-2. Estimated total stock biomass (age 1+ fish in mt, *B*) of Pacific mackerel based on the final Model *XA* (1983-11). Also presented is estimated *B* time series from the previous assessment conducted in 2009 (Model *AA*, 1962-09). Note Model *XA* starts in 1983 (vs. 1962).

Table ES-2. Estimated recruitment (*R*), total biomass (*B*), and spawning stock biomass (*SSB*) of Pacific mackerel based on the final Model *XA* (1983-11).

| Fishing year | ***R*** (age-0, in 1,000s) | ***B*** (age-1+, mt) | ***SSB*** (mt) |
|---|---|---|---|
| 98 | 91,301 | 202,367 | 116,867 |
| 99 | 158,241 | 108,333 | 73,713 |
| 00 | 206,257 | 83,644 | 56,033 |
| 01 | 197,479 | 62,130 | 32,964 |
| 02 | 90,622 | 60,757 | 25,380 |
| 03 | 225,580 | 47,902 | 21,127 |
| 04 | 435,040 | 56,302 | 20,756 |
| 05 | 625,105 | 91,182 | 25,241 |
| 06 | 585,916 | 146,630 | 37,196 |
| 07 | 589,941 | 188,743 | 55,562 |
| 08 | 427,113 | 222,844 | 77,881 |
| 09 | 371,214 | 231,853 | 99,082 |
| 10 | 280,972 | 228,015 | 112,880 |
| 11 | | 211,126 | |

### 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).

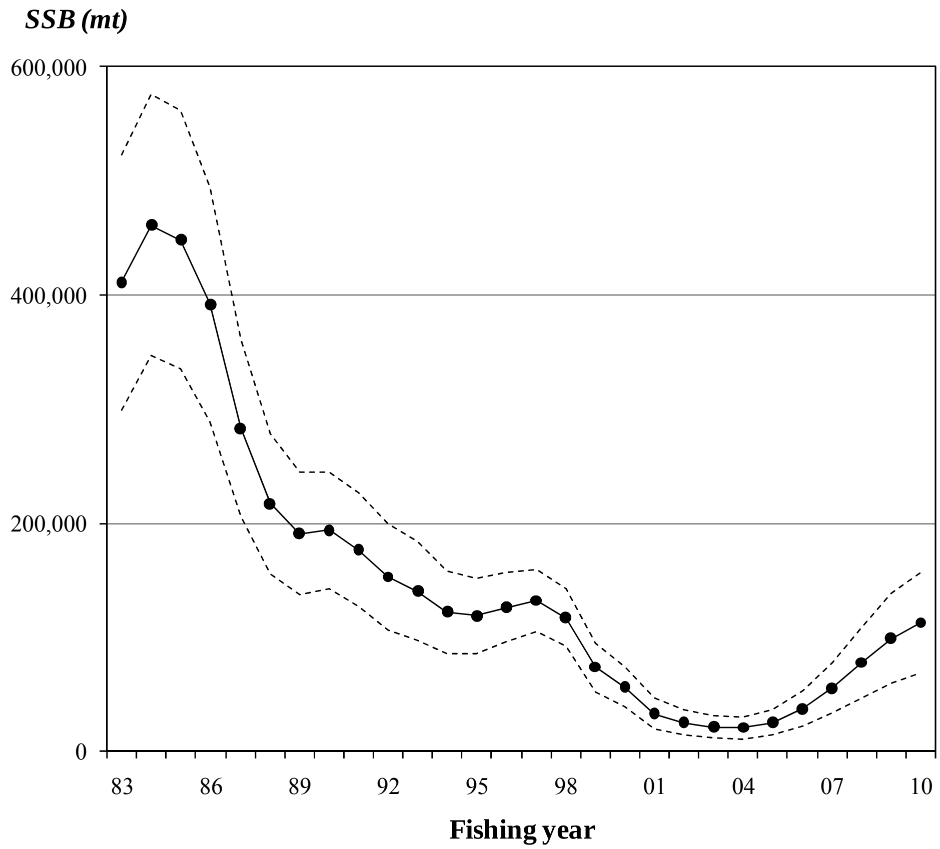


Figure ES-3. Estimated spawning stock biomass (*SSB*) of Pacific mackerel based on the final Model *XA* (1983-10). A confidence interval (95% CI) is also presented as dashed lines.

### Recruitment
As expected, historically, estimated recruitment (*R*) has been highly variable, remaining relatively low since the population's last period of (high) recruitment success in the mid 1980s and moderate recruitment levels in the mid 1990s (Figure ES-4 and Table ES-2).

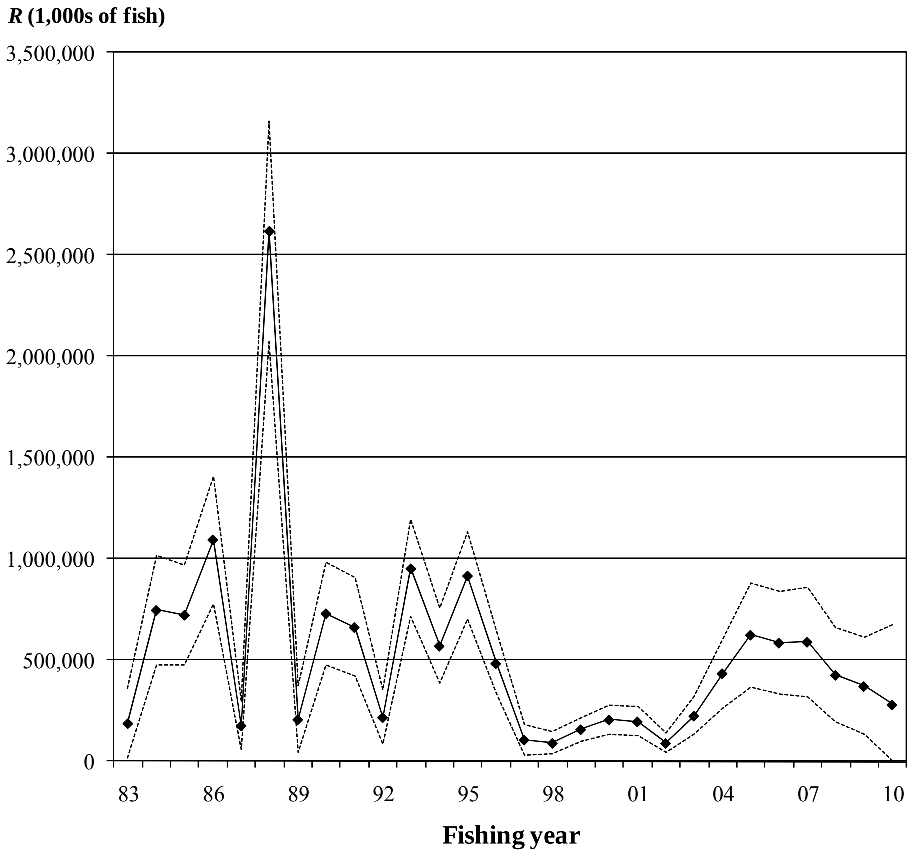


Figure ES-4. Estimated recruitment (age-0 fish in 1,000s, *R*) of Pacific mackerel based on the final Model *XA* (1983-10). A confidence interval (95% CI) is also presented as dashed lines.

**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 2011-12 fishing year based on Model *XA* is 40,514 mt (Table ES-3). Also see Harvest Control Rule for USA Management in 2011-12 section for alternative methods for quota determination that are used in concert with the current HG.

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 15,000 mt from 2001-06. In 2007, the HG was increased substantially to over 70,000 mt based largely on assumptions regarding variability surrounding estimated recruitment and remained at an elevated level until 2009, when the calculated HG (55,408 mt) was reduced by management (PFMC) to 10,000 mt to address uncertainty related to two alternative models (see Preface and PFMC 2010b); the 10,000 mt HG was adopted in 2010 as well. Finally, note that the HG in 2011 (40,514 mt) is strictly preliminary, given formal adoption of the HG will be addressed at the next Council meeting in June 2011. It is important to note that over the last decade, from a management context, the fishery has not fully utilized HGs, with average yields since this time of roughly 5,000 mt (Figure ES-5).

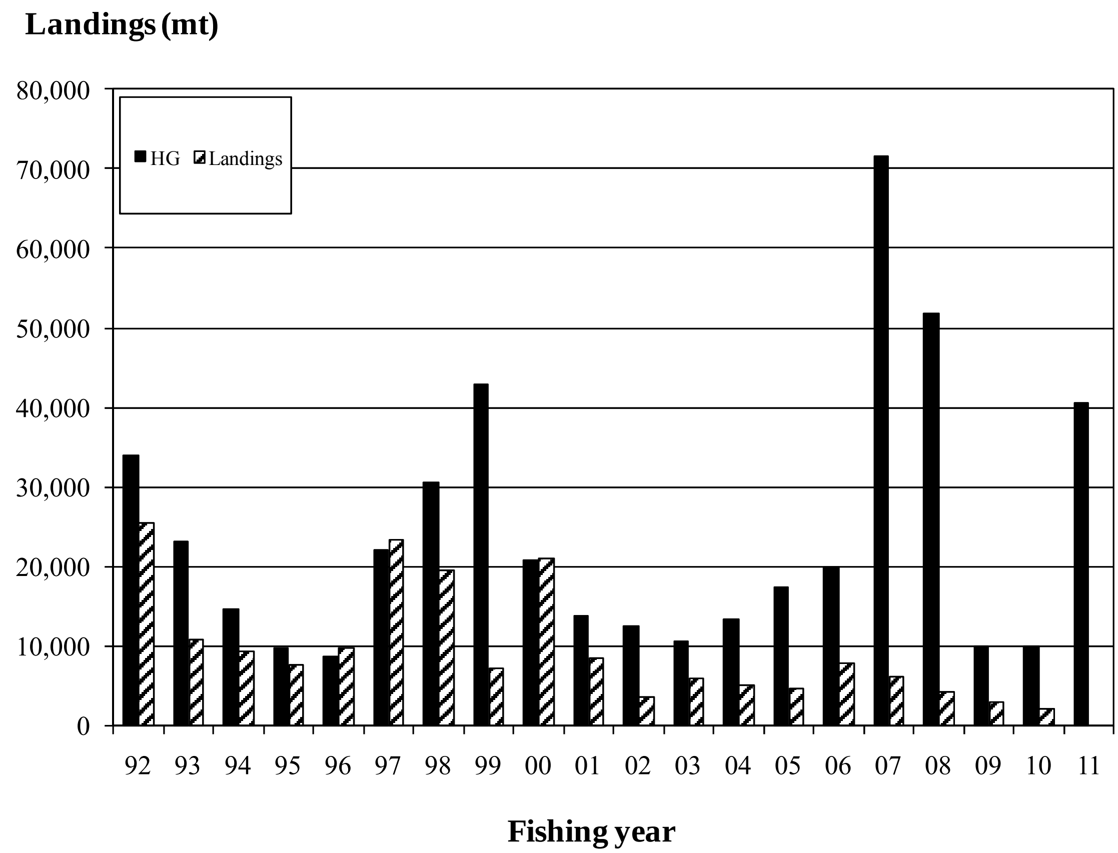


Figure ES-5. Commercial landings (USA directed fishery in mt) and quotas (HGs, mt) for Pacific mackerel (1992-11).

Table ES-3. Harvest control rule statistics for the Pacific mackerel fishery (2011-12). Also, see Harvest Control Rule for USA Management in 2011-12.

| ***B*** **(Age 1+, mt)** | **Cutoff (mt)** | **Fraction** | **Distribution** | **HG (mt)** |
|---|---|---|---|---|
| 211,126 | 18,200 | 30% | 70% | **40,514** |

**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, two indices of relative abundance are used in the assessment, which are developed from a marine recreational fishery (CPFV fleet and related fishing modes) that typically do not (directly) target the species. That is, the recently implemented CRFS provides useful information regarding this species' dynamics and further, represents a valuable survey for obtaining abundance trends for finfish generally targeted by marine recreational fishers in coastal waters off California. In this context, it is imperative that future research funds be focused on improvement (e.g., broadening the scope and increasing the frequency) of the current fishery-independent surveys operating out of the NOAA's SWFSC (e.g., CalCOFI and acoustic-trawl surveys), with emphasis on a long-term horizon, which will necessarily rely on cooperative efforts between the industry, research, and management, as well as cooperation from international fishery agencies.

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, i.e., the SWFSC and CDFG have begun field/laboratory efforts collecting, processing, and analyzing reproductive samples from Pacific mackerel harvested in both the recreational and commercial fisheries. 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, the MSY control rule utilized in the Pacific mackerel federal CPS-FMP was developed in the mid-1980s based on estimated abundance and stock-recruitment data at that time and thus, the 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 (CPS), 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 1$^{st}$ to June 30$^{th}$ 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. The HGs averaged roughly 15,000 mt from 2001-06. In 2007, the HG was increased substantially to over 70,000 mt based largely on assumptions regarding variability surrounding estimated recruitment and remained at an elevated level until 2009, when the calculated HG (55,408 mt) was reduced by management (PFMC) to 10,000 mt to address uncertainty related to two alternative models (see Preface and PFMC 2010b); the 10,000 mt HG was adopted in 2010 as well. It is important to note that over the last decade, from a management context, the fishery has not fully utilized HGs, with average yields since this time of roughly 5,000 mt. Finally, recent legislation concerning management of exploited fisheries in the USA now require alternative methods for quota determination that are used in concert with the HG method above [see PFMC (2010a), SSC (2010), and Ralston et al. (2011) for methods used to derive OFL, ABC, ACL, and associated buffer values]. Also, see Harvest Control Rule for USA Management in 2011-12 section below.

## ASSESSMENT

Ultimately, the Pacific mackerel stock assessment final Model *XA* presented here reflects two primary changes from recently conducted assessments, including: (1) an additional index of abundance derived from recreational fishery data collected through the newly implemented California Recreational Fishery Survey (CRFS, 2004-10); and (2) additional (historical) length distribution data collected from an observer (CPFV) sampling program conducted by CDFG from 1985-89. Other changes associated with estimation methods for influential areas of parameterization were also necessary, particularly, those related to selectivity/catchability associated with biological distributions and indices of abundance. Parameterization details associated with Model *XA* are presented below (see Model description sections) and in Table 5.

A full suite of assessment-related displays for the final Model *XA* are presented in the body of this document. Additionally, SS program files associated with Model *XA* are presented in Appendix 1. Finally, Table 5 presents a broad range of important parameter-related statistics associated with Model *XA*, as well as for the final model adopted in the previous formal assessment conducted in 2009 (aka Model *AA*).

**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). That is, 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 was used for assessments and management advice from 2005 through 2008. 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 STAR (2009).

**Sources of data**

*Fishery-dependent data*

Overview

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; biological (length) data from an observer (CPFV) sampling program coordinated through the CDFG; and logbook (CPFV) and survey (CRFS) data from marine recreational fisheries for purposes of developing catch-per-unit-effort (CPUE) indices. 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 1962 through 2010. 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 1$^{st}$ (year$_x$) through April 30$^{th}$ (year$_{x+1}$), and data from 1976-77 forward were aggregated July 1$^{st}$ (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 1983 to 2010. Annual (fishing year) landing estimates of Pacific mackerel are presented in Table 2 and Figure 1.

The following discussion regarding harvest prior to 1983 is provided for general information only, given the current assessment model (Model *XA*) begins in 1983. 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-December 2010 are from CDFG Wetfish Tables, as well as PacFIN (for the limited landings from Oregon and Washington); and finally, landing estimates for January-June 2011 and July 2011-June 2012 were assumed to be similar to the analogous time blocks of the previous year, namely, January-June 2010 and July 2010-June 2011, respectively.

California recreational landings (mt) from 1980 to the present (2-month 'wave' resolution) were obtained directly from Pacific RecFIN data base 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.

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 (García 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. For 2003 to 2009, commercial landings for the Ensenada and Magdalena Bay fisheries were taken from CONAPESCA's web archive of Mexican fishery yearbook statistics (CONAPESCA 2010).

Finally, 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 been included in the current assessment model presented here.

Length distributions

All model scenarios included length distributions for the USA recreational fisheries, including CPFV (1985-89, 1992-10) and non-CPFV (2004-10) time series, i.e., utilizing age-based selectivity. Age-based selectivity was used in all 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 fisheries. Length distributions for the recreational fisheries were partitioned into CPFV (Figure 2A) and non-CPFV time series (Figure 2B): CPFV time series is developed from both a CDFG observer sampling program (1985-89) and the Marine Recreational Fishing Statistical Survey (MRFSS and related Pacific RecFIN data base) using sample examined catch data (1992-10); and non-CPFV time series developed from the California Recreational Fishery Survey (2004-10).

The CDFG conducted a CPFV onboard observer sampling program in southern California from 1975-78 and from 1985-89, and in central and northern California from 1987-98. That is, the earlier time series (1975-78) was omitted, given the model started in 1983, and the latter time series (1987-98) was omitted, given limited sample data over this time period, as well as having a representative time series for these data already in the model (i.e., 1992-10). Ultimately, selectivity parameterization for both the recreational fishery and CPFV index of abundance (i.e., mirrored the recreational fishery) was based on the length distribution developed from only the CPFV fishery. Finally, see Reilly et al. (1998) for further details of this sampling program and overall data collected.

The length distribution from CRFS represented fish caught via all recreational fishing modes, but the CPFV fleet, which allowed for the most reasonable selectivity parameterization for the CRFS index of abundance, see CRFS abundance index section below.

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.

Age distributions

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 ≥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. Annual age distributions (1983-10) associated with all models are presented in Figure 3.

Mean length-at-age distributions

For the primary purpose of evaluating growth dynamics associated with this species, mean length-at-age time series (1983-10) were developed from the same (CDFG) port sample data base described above and used in conjunction with age distributions in SS model scenarios (Figure 4). 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 5). 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; however, the species is not typically targeted per say by the fishery. 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 (Dick 2010), i.e., a CPUE time series of relative abundance (Figure 6A). 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 1983 to 2010 were used in the analysis;
(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 ($\mu$) 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 $\mu_{ijk}$ 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, ..., $I$; $I$=49 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, ..., $K$; $K$=3 fleets). The error term is denoted $\varepsilon_{ijk}$, where for each combination of indices, $\varepsilon_{ijk}$ 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 (Dick 2010) 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 (nearly 90,000 observations), estimation of both year effects for the survey simultaneously with measures of dispersion (i.e., CVs) was problematic and ultimately, unsuccessful, i.e., an average CV (0.30) was used for each annual estimate of the time series.

Finally, note that all other estimation techniques used to evaluate these data, including GLMs, GAMs, and even nominal mean time series resulted in very similar results, i.e., ultimately, trajectories used in the model to model relative population size over time.

<u>California Recreational Fisheries Survey (CRFS) index of abundance</u>

The California Recreational Fisheries Survey (CRFS) began in 2004 to provide catch and effort estimates for California marine recreational finfish fisheries in six coastal districts and four fishing modes. It represents a collaborative effort between the CDFG and the Pacific States Marine Fisheries Commission (PSMFC) and provides higher spatial and temporal resolution than the previous federal-based survey (MRFSS, 1980-03). See PSMFC (2010) for details regarding survey goals, methods, data availability/accessibility, etc.

The CRFS index of abundance was evaluated at the fishing mode level (Figure 6B), and developed in a similar manner as that above for the CPFV logbook-related index, with the final time series used in modeling efforts having the following differences:

(1) all fishing modes, with the exception of the CPFV fleet (Figure 6A-B);
(2) CPUE was calculated as the number of fish per fishing party/day, i.e., data base structure and limited (examined) sample information precluded calculations at a finer scale (e.g., angler/hour), however, the units of CPUE are likely inconsequential to the overall analysis, given 'positive catch' records composed roughly 1-4% (depending on fishing mode) of the total records (see Table 3 for summary CRFS statistics and Figure 6A-B applicable to Pacific mackerel and the overall survey); and
(3) fishing years 2004 to 2010 were used in the analysis.

Finally, this time series represents an additional index of abundance that has not been included in past assessments and was considered an alternative index in sensitivity analysis conducted in 2011, which in effect, complements the CPFV index above, given it includes data from leisure fishing modes not included in the CPFV analysis.

*Biological data*

<u>Weight-length</u>

A weight-length (W-L) relationship for Pacific mackerel was modeled using port sample data collected by CDFG from 1962 to 2010 (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 1962-10 ($a$ = 3.1E-06 and $b$ = 3.4) were used (fixed) in all model scenarios (Figure 7).

Length-at-age
The von Bertalanffy growth equation was used to model the relationship between fork length (cm) and age for Pacific mackerel (1962-10):

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

where $L_A$ is the length-at-age $A$, $L_\infty$ ('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 (1962-10): $L_\infty$ = 39.3 mm, $k$ = 0.342, and $t_o$ = -1.752 (Figure 7). 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 $k \approx 0.30$.

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 4 and Figure 7). 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 7). 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.'

<u>Stock-recruitment</u>
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 0.35 to 0.75, depending on the model scenario, indicating that at low *SSB* levels, recruitment is estimated to decrease slightly to moderately (Figure 8). 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/parameterization of available indices of relative abundance used in the ongoing assessment, and updating biological parameters considered influential in the overall modeling effort. 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 … *substantial progress was made with developing an alternative index of abundance (see CRFS index of abundance above), sensitivity analysis that addressed inclusion/omission of the suite of alternative indices, and further examinations of time-varying catchability/selectivity within an index (see Model description sections, Assessment model results, and Assessment uncertainty below).*

Regarding updating biological parameters used in the ongoing assessment ... *SWFSC and CDFG have jointly begun field/laboratory efforts collecting, processing, and analyzing reproductive samples from Pacific mackerel harvested in both the recreational and commercial fisheries. It is important to note that an 'aggressive' sampling plan over a 2 to 4 year time horizon will be required to accumulate enough samples to develop an updated maturity schedule for use in stock assessments due to limited landings of this species, coupled with few field-based surveys*.

**Model description**
<u>Overview</u>
The Stock Synthesis (SS, Methot 2005, 2011) 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 3.20b (January 2011).

Likelihood components and model parameters

Likelihood components and estimates for important SS model scenarios are presented in Table 5, 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.

Convergence criteria

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 constructed in sensitivity analysis) 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.

Sensitivity analysis

Sensitivity analysis resulted in a suite of models for review at the onset of the STAR meeting in May 2011, as well as numerous model scenarios developed during the interactive meeting itself. In keeping with final assessment documentation protocols, model presentation is largely devoted to the final base case model selected by the STAR panel and STAT (i.e., Model *XA*). Pertinent summary statistics for both Model *XA* and for comparative purposes, the previous assessment final model (Model *AA*) adopted in 2009 are presented in Table 5A-D. Additionally, final sensitivity analysis for Model *XA* is presented in Table 5D, i.e., influential parameterizations were evaluated via 16 model scenarios to ensure the final model was both robust and generally consistent across data sources. Readers interested in details regarding the plethora of model scenarios evaluated in the review meeting via sensitivity analysis should consult STAR (2011). Finally, note that other model scenarios involved in the overall sensitivity analysis were generally similar to Model *XA*, i.e., parameterization differences largely reflected a step-wise approach, whereby a single change in a parameter of interest (e.g., selectivity for a fishery, omission/addition of time series, etc.). A complete suite of displays is presented for Model *XA* within the body of the document. Key features of the final Model *XA* follow:

Model *XA*:

- *Time period*: 1983-10 (new parameterization, i.e., previously, 1962);
- *Fishery structure*: two (USA/Mexico commercial and USA recreational);
- *Surveys*: two indices of relative abundance (CPFV index and the new CRFS index);
- *Time-step*: annual;
- *Gender structure*: combined sexes;
- *Longevity*: 12 years (new parameterization, i.e., previously, 15 years);
- *Natural mortality*: 0.5 for all ages. Also, see Natural mortality above.
- *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 noticeable growth changes over time (i.e., in terms of length-at-age). However, growth during the species last period of high recruitment success (late 1970s to late 1980s) was potentially different (say faster and realizing larger sizes) than observed over the last two decades or so, but given a start year of 1983, growth was observed to be much more consistent over the last two decades. Finally, overall sensitivity analysis resulted in robust estimates of *K* (*K*s ≈ 0.30). 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 20 years;
- *Selectivity (biological distributions)*: age-based, a single time block, and asymptotic for the commercial fishery and dome-shaped for the recreational fishery. 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), i.e., this is true for all age groups, from the high 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 estimated from CPFV length distribution for this fishery as well. Finally, preliminary

modeling efforts indicated age- or size-based selectivity resulted in similar conclusions of stock status;

- *Selectivity (indices)*: age-based, a single time block, and dome-shaped (i.e., mirrors recreational fishery) for the CPFV index of abundance and age-based, a single time block, and dome-shaped (estimated from non-CPFV length distribution);
- *Catchability*: constant over time, with CVs = 0.30 for year effects;
- *Stock-recruitment*: Beverton-Holt stock-recruitment model. An asymptotic relationship between parents and offspring was assumed in all model scenarios. Also, see Stock-recruitment above. Variance associated with log recruitment estimation was fixed, i.e., $\sigma_R$ = 1.0 (in most model scenarios, generated root MSEs were roughly = 1.0 (0.8-1.25); and
- *Variance adjustments to time series*: None. Note that in the final model in 2009, a variance adjustment was implemented for the recreational fishery length distribution parameterization, i.e., this re-weighting was not deemed necessary for the final model in 2011.

**Assessment model results (Model *XA*)**

Results are summarized below, with discussion regarding important topics related to the overall population analysis presented in the Assessment uncertainty section below. Trends of estimated trajectories of management-related time series (e.g., biomass, spawning stock biomass, and recruitment) from updated model scenarios in 2011 were very similar to those generated from the previous assessment in 2009, with strictly magnitude differences observed for the most dynamic period of the historical time series, i.e., higher estimates of stock size and recruitment in the late 1970s to late 1980s in the updated 2011 models, which were expected, given: (1) the additional length time series included in the updated models, i.e., 1975-78 and 1985-89 distributions, which were composed of large and old fish (also, see Length distributions section above); (2) related changes to estimated selectivity and time blocks associated with this roughly 10-yr period; (3) the inclusion of the mean length-at-age time series, coupled with a maturity schedule that is based on larger/older individuals being more fecund than smaller/younger fish; (4) catches and catch rates increasing markedly; which ultimately, (5) represented the high recruitment success for that narrow timeframe. It is important to note that the points above are essentially moot, given the final Model *XA* has a start year of 1983, which essentially resulted in a period of consistent growth over the modeled timeframe (1983-10).

Model fits to biological distributions are presented in the following displays: Figure 9A is observed vs. predicted estimates for the age distribution time series for the commercial fishery; Figure 9B is the associated Pearson residual plot for the age distribution fits; Figure 9C is the associated input vs. effective sample size plot for the age distribution fits; Figures 10A and 10D are observed vs. predicted estimates for the length distribution time series from the recreational fishery, CPFV and CRFS (non-CPFV fishing modes), respectively; Figures 10B and 10E are the associated Pearson residual plot for the length distribution fits, CPFV and CRFS (non-CPFV fishing modes), respectively; Figures 10C and 10F are the associated input vs. effective sample size plots for the length distribution fits, CPFV and CRFS (non-CPFV fishing modes), respectively; Figure 4 is the observed vs. predicted estimates for the mean length-at-age distribution time series for the commercial fishery; and Figure 11 is the associated Pearson residual plot for the mean length-at-age distribution fits. Estimated selectivity for the fishery catches is presented in Figure 12A (commercial fishery) and Figure 12B [recreational fishery, CPFV and CRFS (non-CPFV fishing modes)]. In general, fits to biological distributions were relatively good; however, in some years, large 'pulses' of younger fish were not fit with high precision, e.g., 0-1 yr-old fish in the commercial fishery age distributions.

Fits (normal and log space) to the indices of abundance are presented in Figures 13 and 14, for CPFV and CRFS, respectively. In general, model fits to the indices were relatively good; however, as previously noted above, no iterative reweighting of variance was conducted and thus, fits could be improved for the indices, noting that fits to the biological distributions would be compromised to some degree.

Estimated Beverton-Holt stock-recruitment relationship is presented in Figure 8 (see Stock-recruitment section above). Estimates of recruitment deviations and associated asymptotic standard errors are presented in Figure 15.

The estimated *F*-based spawning potential ratio (SPR) time series is presented in Figure 16. As expected, SPR estimates have varied over time, with exploitation declining markedly since roughly 2000 to historically low levels (see Assessment uncertainty below).

Estimated time series for management-related derived quantities of interest for Model *XA* are presented in the following displays: Figure 17 is total stock biomass (age 1+ fish in mt, *B*); Figure 18 is spawning stock biomass (*SSB* in mt); and Figure 19 is recruitment (age-0 fish in numbers). Both *B* and *SSB* as steadily declined from the mid 1980s to the early 2000s, at which time the population began to increase moderately in size, with some signs of 'rebuilding' observed over the last several years. 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 few, which generally confounds long-term (abundance) forecasts for this species. Again, estimated *B* time series from the overall sensitivity analysis were very similar in trend and as noted above, differed in magnitude only for a short period of time historically, when additional length data/selectivity from particularly the 1970s are included in the model scenario. Results from retrospective and prospective analyses for Model *XA* are presented in Figure 20A-B, i.e., for the retrospective analysis, data associated with terminal years 2010 to 2005 were omitted (sequentially) from the model and for the prospective analysis, the model was begun one year later than 1983 in a sequential manner. As observed in all past assessments, a retrospective pattern was evident in the current assessment as well, 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. The prospective analysis indicated moderate variability in model results based on later start years, but the pattern was not consistent from a chronological context as was the case with the retrospective. For comparative purposes, final estimated *B* time series for the historical assessment period (2004-11) 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, $\sigma_R$ 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 (and other) species.

**Assessment uncertainty**

Assessment uncertainty can be partitioned into essentially two inter-related areas.

First and foremost, the collective information, i.e., all sample data (time series used in the stock assessment presented here) and modeling results (via sensitivity analysis), as well as time series from available survey data, laboratory research, and related stock status studies conducted in the past, indicate the following:

- in terms of life history strategy, the Pacific mackerel population off the Pacific coast of North America is in many (most really …) ways a typical coastal pelagic species, but in a (key) few, unique as well, including;
    - exhibiting high recruitment success not on a decadal basis, say like many small, large-schooling pelagic species, but rather, on a multi-decadal cycle spanning 30 to 50 or more years;
    - growing rapidly from a prey existence to a predator role, with nearly 70% of growth in size (length) realized by age 1;
    - upon reaching adult status, it maintains a relatively low profile at the CPS assemblage level for extended periods of time, until oceanographic conditions are favorable and SSB is at least average in size, which produces a brief period of population expansion;
- it is important to note that although the stock is currently at a low level (i.e., not experiencing the 50-yr or so boom in recruitment), it is not very likely due to fishing pressure, but rather a less than ideal oceanographic regime (say for this species);
    - harvest rates have been very low over the last decade (see Harvest Control Rule for USA Management in 2011-12 below), e.g., recent $F_{SPR}$ estimates are 90%-95%, which is a very small removal of reproductive potential for such a species with a moderately high intrinsic rate of increase (*r*);
    - further, the species' has a relatively short life span, with longevity of roughly 8-10 years likely, which provides additional resiliency to ongoing artificial perturbations, such as fishing operations managed under conservative exploitation schemes; and
    - the bottom-line is this is a classical recruitment fishery situation, whereby the stock provides relatively little benefit to fishing interests (commercial or leisure) for protracted periods, with narrow windows of opportunity (very high abundance) every 30-60 years.

In terms of this stock assessment modeling effort, the following areas contribute the most variation in the overall model and in this context, would benefit from further evaluation, i.e., model robustness could be improved by further addressing the following:

- which data source(s) are emphasized in the model scenario, e.g., decisions regarding 'weighting' biological distributions vs. indices of abundance, the inclusion/omission of length and/or mean length-at-age distributions, etc.;
- selectivity and catchability parameterization;
    - selectivity estimation associated with age (commercial fishery) and length (recreational fisheries) distributions were sensitive in particular model scenarios of interest and related to other influential parameterizations, such as growth;

  - catchability estimation associated with the CPFV and CRFS indices of abundance is necessarily an ongoing parameterization effort, given re-weighting and model emphasis considerations regarding the sources of data included in the model scenario of interest;
- the need for two fisheries, given both the commercial and recreational fisheries harvest very similar fish and at low levels, particularly, the leisure fishery;
  - a model with fisheries combined was evaluated, but differences in some years concerning the size (and age) of fish harvested in each of the fisheries precluded further development of this model scenario at this time, i.e., further examinations of differences/similarities between the two fisheries is warranted, given such a parameterization would substantially simplify the current assessment; and finally,
- stock-recruitment parameterization related to sensitivity analysis should include evaluating the influence of steepness ($h$) set at different (hypothetical) values, particularly, $h = 1.0$, given suppositions regarding this species' reproductive compensation at low SSB levels.

Generally speaking, uncertainty in the overall assessment was 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); and examinations (qualitative and quantitative) of important residual plots from critical model fits (e.g., fits to biological distributions and indices of abundance). 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 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 within the fully-integrated, multiple likelihood modeling platform.

## HARVEST CONTROL RULE FOR USA MANAGEMENT IN 2011-12

As stipulated in Amendment 8 to the CPS FMP (PFMC 1998), the recommended maximum sustainable yield (MSY) control rule for Pacific mackerel is (Table 6A):

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 22A.

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 15,000 mt from 2001-06. In 2007, the HG was increased substantially to over 70,000 mt based largely on assumptions regarding variability surrounding estimated recruitment and remained at an elevated level until 2009, when the calculated HG (55,408 mt) was reduced by management (PFMC) to 10,000 mt to address uncertainty related to two alternative models (see Preface and PFMC 2010b); the 10,000 mt HG was adopted in 2010 as well. Note that the HG in 2011 (40,514 mt) is strictly preliminary, given formal adoption of the HG will be addressed at the next Council meeting in June 2011. It is important to note that over the last decade, from a management context, the fishery has not fully utilized HGs, with average yields since this time of roughly 5,000 mt (Figure 22A). 'Hypothetical' quotas and total landings, based on omission of the USA 'Distribution' parameter in the harvest control rule are presented in Figure 22B. Finally, recent legislation concerning management of exploited fisheries in the USA now require alternative methods for quota determination that are used in concert with the HG method above, see PFMC (2010a) and SSC (2010), and Ralston et al. (2011) for methods used to derive OFL, ABC, ACL, and associated buffer values (Table 6B).

## 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, two indices of relative abundance are used in the assessment, which are developed from a marine recreational fishery (CPFV fleet and related fishing modes) that typically do not (directly) target the species. That is, the recently implemented CRFS provides useful information regarding this species' dynamics and further, represents a valuable survey for obtaining abundance trends for finfish generally targeted by marine recreational fishers in coastal waters off California. In this context, it is imperative that future research funds be focused on improvement (e.g., broadening the scope and increasing the frequency) of the current fishery-independent surveys operating out of the NOAA's SWFSC (e.g., CalCOFI and acoustic-trawl surveys), with emphasis on a long-term horizon, which will necessarily rely on cooperative efforts between the industry, research, and management, as well as cooperation from international fishery agencies.

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, i.e., the SWFSC and CDFG have begun field/laboratory efforts collecting, processing, and analyzing reproductive samples from Pacific mackerel harvested in both the recreational and commercial fisheries. 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, the MSY control rule utilized in the Pacific mackerel federal CPS-FMP was developed in the mid-1980s based on estimated abundance and stock-recruitment data at that time and thus, the 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 (1983-10).

| | Commercial | Recreational |
|---|---|---|
| Fishing Year | Age | Length |
| 83 | 2,668 | |
| 84 | 2,291 | |
| 85 | 2,606 | 2,038 |
| 86 | 3,000 | 5,953 |
| 87 | 4,129 | 4,354 |
| 88 | 4,477 | 3,904 |
| 89 | 3,583 | 3,678 |
| 90 | 2,114 | |
| 91 | 1,655 | |
| 92 | 1,994 | 710 |
| 93 | 2,688 | 1,736 |
| 94 | 3,114 | 885 |
| 95 | 2,706 | 739 |
| 96 | 2,189 | 1,899 |
| 97 | 2,714 | 2,278 |
| 98 | 2,255 | 1,524 |
| 99 | 1,666 | 1,253 |
| 00 | 1,910 | 1,084 |
| 01 | 2,111 | 1,051 |
| 02 | 2,145 | 1,145 |
| 03 | 1,570 | 1,037 |
| 04 | 2,529 | 1,693 |
| 05 | 2,299 | 2,109 |
| 06 | 2,393 | 2,363 |
| 07 | 1,609 | 2,439 |
| 08 | 723 | 1,998 |
| 09 | 422 | 1,783 |
| 10 | 298 | 350 |

Table 2. Landings (mt) of Pacific mackerel by fishery (1983-2010).

| Fishing year | USA Commercial (mt) | Mexico Commercial (mt) | Recreational CPFV (mt) | Recreational non-CPFV (mt) | Total (mt) |
|---|---|---|---|---|---|
| 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 | 1,986 | 16 | 356 | 10,228 |
| 07 | 6,208 | 2,218 | 19 | 291 | 8,737 |
| 08 | 4,281 | 803 | 13 | 267 | 5,364 |
| 09 | 3,011 | 171 | 13 | 254 | 3,450 |
| 10 | 2,086 | 171 | 5 | 95 | 2,357 |

Table 3. California Recreational Fisheries Survey (CRFS) summary statistics relevant to the CRFS index of abundance derived for Pacific mackerel (2004-10): Region is number of samples (i.e., interviewed party=sample) and NC=northern CA and SC=southern CA; Modes are number of samples, with All=zero catch and positive catch samples and Positive Creel=positive catch samples; Party Size is number of samples; Catch Size is number of samples (by number of fish in creel); Avg. No. Anglers in Party is average number of anglers; and Avg. Trip Length is average trip length in hours.

**REGION**

| Fishing Year | NC | SC |
|---|---|---|
| 04 | 33,491 | 36,069 |
| 05 | 31,882 | 35,330 |
| 06 | 32,632 | 36,407 |
| 07 | 27,052 | 36,124 |
| 08 | 26,579 | 40,329 |
| 09 | 27,453 | 35,974 |
| 10 | 12,384 | 13,519 |
| **Total** | 191,473 | 233,752 |
| **Grand total** | **425,225** | |

**PARTY SIZE**

| Fishing Year | 0 | 1 | 2-4 | ≥5 |
|---|---|---|---|---|
| 04 | 12,585 | 40,359 | 28,113 | 1,088 |
| 05 | 3,283 | 38,988 | 27,168 | 1,056 |
| 06 | 7,741 | 41,908 | 26,046 | 1,085 |
| 07 | 15,845 | 40,633 | 21,563 | 980 |
| 08 | 16,269 | 44,720 | 21,115 | 1,073 |
| 09 | 14,500 | 42,706 | 19,740 | 981 |
| 10 | 6,257 | 17,014 | 8,514 | 375 |
| **Total** | 76,480 | 266,328 | 152,259 | 6,638 |
| **Grand total** | | **501,705** | | |

**CATCH SIZE (ALL)**

| Fishing Year | 0 | 1 | 2-4 | ≥5 |
|---|---|---|---|---|
| 04 | 68,030 | 492 | 503 | 535 |
| 05 | 65,842 | 423 | 409 | 538 |
| 06 | 67,692 | 406 | 440 | 501 |
| 07 | 61,556 | 439 | 552 | 629 |
| 08 | 65,265 | 437 | 581 | 625 |
| 09 | 61,916 | 467 | 473 | 571 |
| 10 | 25,504 | 125 | 128 | 146 |
| **Total** | 415,805 | 2,789 | 3,086 | 3,545 |
| **Grand total** | | **425,225** | | |

**MODE (ALL)**

| Fishing Year | Man-made | Beach-Bank | Party-Charter | Private-Rental |
|---|---|---|---|---|
| 04 | 17,231 | 2,144 | 12,287 | 37,898 |
| 05 | 15,657 | 1,947 | 12,712 | 36,896 |
| 06 | 18,585 | 2,371 | 12,326 | 35,757 |
| 07 | 18,311 | 2,092 | 13,674 | 29,099 |
| 08 | 20,587 | 2,567 | 14,669 | 29,085 |
| 09 | 20,045 | 2,079 | 13,751 | 27,552 |
| 10 | 7,342 | 30 | 6,433 | 12,098 |
| **Total** | 117,758 | 13,230 | 85,852 | 208,385 |
| **Grand total** | | **425,225** | | |

**MODE (POSITIVE CREEL)**

| Fishing Year | Man-made | Beach-Bank | Party-Charter | Private-Rental |
|---|---|---|---|---|
| 04 | 523 | 9 | 389 | 609 |
| 05 | 558 | 2 | 309 | 501 |
| 06 | 443 | 3 | 318 | 583 |
| 07 | 457 | 0 | 486 | 677 |
| 08 | 556 | 0 | 553 | 534 |
| 09 | 531 | 1 | 507 | 472 |
| 10 | 138 | 0 | 158 | 103 |
| **Total** | 3,206 | 15 | 2,720 | 3,479 |
| **Grand total** | | **9,420** | | |

**AVG. NO. ANGLERS IN PARTY (INTERVIEW)**

| Fishing Year | Man-made | Beach-Bank | Party-Charter | Private-Rental |
|---|---|---|---|---|
| 04 | 1.09 | 1.07 | 1.11 | 2.20 |
| 05 | 1.07 | 1.03 | 1.13 | 2.20 |
| 06 | 1.05 | 1.04 | 1.14 | 2.20 |
| 07 | 1.04 | 1.04 | 1.16 | 2.21 |
| 08 | 1.04 | 1.03 | 1.16 | 2.20 |
| 09 | 1.05 | 1.03 | 1.17 | 2.17 |
| 10 | 1.04 | 1.00 | 1.21 | 2.10 |
| **Total** | 1.06 | 1.04 | 1.15 | 2.18 |
| **Grand total** | | **1.36** | | |

**AVG. TRIP LENGTH (INTERVIEW)**

| Fishing Year | Man-made | Beach-Bank | Party-Charter | Private-Rental |
|---|---|---|---|---|
| 04 | 3.02 | 2.63 | 3.48 | 4.52 |
| 05 | 2.97 | 2.64 | 3.34 | 4.37 |
| 06 | 3.00 | 2.77 | 3.13 | 4.51 |
| 07 | 2.92 | 2.85 | 3.20 | 4.55 |
| 08 | 2.95 | 2.84 | 3.12 | 4.63 |
| 09 | 3.05 | 2.91 | 3.30 | 4.84 |
| 10 | 3.09 | 2.94 | 3.26 | 4.69 |
| **Total** | 3.00 | 2.80 | 3.26 | 4.59 |
| **Grand total** | | **3.41** | | |

Table 4. 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 5. Model scenario summaries for the final model (Model *XA*) selected for management purposes of the Pacific mackerel stock in the current year 2011 and for the previous assessment conducted in 2009 (Model *AA*), including: (A) new data sources and critical parameterizations; (B) likelihood component estimates and derived quantities of importance; (C) model parameters included in Model *XA*; and D) final sensitivity analysis for Model *XA*.

**(A)**

| | ***Model scenario*** | |
|---|---|---|
| **Time series** | ***AA* (2009)** | ***XA* (2011)** |
| *Landings - Commercial (USA/Mexico fisheries)* | | |
| *Landings - Recreational (USA fishery)* | | |
| *Age distributions - Commercial fishery* | | |
| *Length distributions - Recreational fishery (1992-10) - All fishing modes* | | |
| *Length distributions - Recreational fishery (1985-89) - CPFV (**new time series (2011**)* | | |
| *Length distributions - Recreational fishery (1992-10) - CPFV* | | |
| *Length distributions - Recreational fishery (2004-10)- non-CPFV* | | |
| *Mean length-at-age distributions - Commercial fishery* | | |
| *CPFV index* | | |
| *CRFS index (2004-10) - **new time series (2011)*** | | |
| **Parameterization** | ***AA (2009)*** | ***XA (2011)*** |
| **Model structure** | | |
| Time period | 1962-10 | 1983-10 |
| Number of fisheries | 2 | 2 |
| Number of surveys | 1 | 2 |
| Genders | Combined | Combined |
| Time-step | Annual | Annual |
| **Biology** | | |
| Maturity-at-age | Fixed | Fixed |
| Length-at-age (*k*) | 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*) - Commercial fishery | Estimated | Estimated |
| Fishing mortality (*F*) - Recreational fishery | Fixed | Fixed |
| **Selectivity** | | |
| *Fisheries* | | |
| Parameterization | Estimated | Estimated |
| Time block | Commercial fishery=3 blocks / Recreational fishery=single | Single |
| Shape | Dome-shaped | Commercial fishery=asymptotic / Recreational fishery=dome-shaped |
| *Surveys* | | |
| Parameterization | CPFV=mirrors recreational fishery | CPFV=mirrors recreational fishery / CRFS=dome-shaped |
| Time block | Single | Single |
| Shape | Dome-shaped | Dome-shaped |
| **Catchability** | | |
| *q* - Surveys | Estimated (median unbiased) | Estimated (median unbiased) |
| **Variance adjustment factors** | | |
| *Biological distributions and indices* | No additional weighting | No additional weighting |

Table 5. Continued.

**(B)**

| Likelihood component | *AA (2009)* | *XA (2011)* |
|---|---|---|
| **Biological distributions** | | |
| *Age distributions* | | |
| Commercial fishery | 700.4 | 368.0 |
| *Length distributions* | | |
| Recreational fishery (All fishing mode: 1992-10) | 201.4 | Na |
| Recreational fishery (CPFV: 1985-10) | Na | 184.9 |
| Recreational fishery (non-CPFV: 2004-10)) | Na | 57.3 |
| Sub-total | | 242.2 |
| *Length-at-age distributions* | | |
| Commercial fishery | 540.4 | 232.4 |
| **Surveys** | | |
| *CPFV* | -18.3 | -6.4 |
| *CRFS* | Na | -5.3 |
| Sub-total | -18.3 | -11.7 |
| **Recruitment** | | |
| Model time period | 34.7 (1958-08) | 11.34 (1978-10) |
| Forecast | 0.016 (2009) | 0.245 (2011) |
| **Global** | | |
| Likelihood ($L$) | 1,458.6 | 842.5 |
| Number of estimated parameters | 84 | 57 |
| Softbounds | 0.0036 | 0.0028 |
| **Key estimated parameters and derived quantities** | | |
| **Biology** | | |
| Length-at-age ($k$) | 0.22 | 0.33 |
| $\ln(R_0)$ | 13.5 | 13.6 |
| Offset for initial equilibrium $R_1$ | 0.2473 | 0.4731 |
| Steepness ($h$) | 0.47 | 0.70 |
| **Initial conditions for population dynamics** | | |
| Fishing mortality ($F$) - Commercial fishery[a] | 0.654 | 0.014 |
| Fishing mortality ($F$) - Recreational fishery | 0.001 | 0.001 |
| **Population time series** | | |
| *SSB* (peak year) | 598,046 (1983) | 461,354 (1984) |
| *SSB* (end year) | 76,441 (2008) | 112,880 (2010) |
| *B* (peak year) | 1,321,550 (1982) | 1,065,990 (1983) |
| *B* (end year) | 282,849 (2009) | 211,126 (2011) |
| *HG* (current year) | 55,408 | 40,514 |

[a]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.

Table 5. Continued.
**(C)**

| Parameter | Min_Value | Max_Value | Init_Value | Fin_Value | SD |
|---|---|---|---|---|---|
| NatM_p_1_Fem_GP_1 | 0.3 | 0.7 | 0.5 | 0.5 | _ |
| L_at_Amin_Fem_GP_1 | 4 | 35 | 15 | 21.116 | 0.205664 |
| L_at_Amax_Fem_GP_1 | 30 | 70 | 45 | 40.0231 | 0.197782 |
| VonBert_K_Fem_GP_1 | 0.1 | 0.7 | 0.35 | 0.325098 | 0.0128458 |
| CV_young_Fem_GP_1 | 0.01 | 0.5 | 0.1 | 0.279009 | 0.010219 |
| CV_old_Fem_GP_1 | 0.0001 | 0.5 | 0.01 | 0.01 | _ |
| Wtlen_1_Fem | -1 | 5 | 0.00000312 | 3.12E-06 | _ |
| Wtlen_2_Fem | 1 | 5 | 3.40352 | 3.40352 | _ |
| Mat50%_Fem | -3 | 3 | 3 | 3 | _ |
| Mat_slope_Fem | -3 | 3 | 3 | 3 | _ |
| Eggs/kg_inter_Fem | -3 | 3 | 1 | 1 | _ |
| Eggs/kg_slope_wt_Fem | -3 | 3 | 0 | 0 | _ |
| RecrDist_GP_1 | -4 | 4 | 0 | 0 | _ |
| RecrDist_Area_1 | -4 | 4 | 1 | 1 | _ |
| RecrDist_Seas_1 | -4 | 4 | 0 | 0 | _ |
| CohortGrowDev | 1 | 5 | 1 | 1 | _ |
| SR_R0 | 1 | 30 | 10 | 13.6014 | 0.217755 |
| SR_steep | 0.1 | 1 | 0.9 | 0.699827 | 0.211953 |
| SR_sigmaR | 0 | 2 | 1 | 1 | _ |
| SR_envlink | -5 | 5 | 0 | 0 | _ |
| SR_R1_offset | -15 | 15 | 0 | 0.47311 | 0.527798 |
| SR_autocorr | 0 | 2 | 0 | 0 | _ |
| Main_InitAge_5 | _ | _ | _ | -0.472933 | 0.843491 |
| Main_InitAge_4 | _ | _ | _ | 0.268622 | 0.759753 |
| Main_InitAge_3 | _ | _ | _ | 0.150757 | 0.772089 |
| Main_InitAge_2 | _ | _ | _ | 2.08434 | 0.398218 |
| Main_InitAge_1 | _ | _ | _ | -0.506919 | 0.596872 |
| Main_RecrDev_1983 | _ | _ | _ | -1.00104 | 0.489547 |
| Main_RecrDev_1984 | _ | _ | _ | 0.366911 | 0.296722 |
| Main_RecrDev_1985 | _ | _ | _ | 0.337156 | 0.279371 |
| Main_RecrDev_1986 | _ | _ | _ | 0.759464 | 0.264261 |
| Main_RecrDev_1987 | _ | _ | _ | -1.03251 | 0.37629 |
| Main_RecrDev_1988 | _ | _ | _ | 1.68254 | 0.195281 |
| Main_RecrDev_1989 | _ | _ | _ | -0.836794 | 0.413652 |
| Main_RecrDev_1990 | _ | _ | _ | 0.420333 | 0.233331 |
| Main_RecrDev_1991 | _ | _ | _ | 0.334561 | 0.228476 |
| Main_RecrDev_1992 | _ | _ | _ | -0.759672 | 0.321362 |
| Main_RecrDev_1993 | _ | _ | _ | 0.731879 | 0.164942 |
| Main_RecrDev_1994 | _ | _ | _ | 0.242322 | 0.186322 |

Table 5. Continued.

**(C)**

| Parameter | Min_Value | Max_Value | Init_Value | Fin_Value | SD |
|---|---|---|---|---|---|
| Main_RecrDev_1995 | _ | _ | _ | 0.723032 | 0.151321 |
| Main_RecrDev_1996 | _ | _ | _ | 0.0728743 | 0.19468 |
| Main_RecrDev_1997 | _ | _ | _ | -1.44384 | 0.362163 |
| Main_RecrDev_1998 | _ | _ | _ | -1.5808 | 0.306414 |
| Main_RecrDev_1999 | _ | _ | _ | -0.924772 | 0.200919 |
| Main_RecrDev_2000 | _ | _ | _ | -0.577272 | 0.211409 |
| Main_RecrDev_2001 | _ | _ | _ | -0.412906 | 0.338449 |
| Main_RecrDev_2002 | _ | _ | _ | -1.06413 | 0.443654 |
| Main_RecrDev_2003 | _ | _ | _ | -0.0524016 | 0.458841 |
| Main_RecrDev_2004 | _ | _ | _ | 0.614432 | 0.457423 |
| Main_RecrDev_2005 | _ | _ | _ | 0.869945 | 0.397333 |
| Main_RecrDev_2006 | _ | _ | _ | 0.621383 | 0.293877 |
| Main_RecrDev_2007 | _ | _ | _ | 0.476419 | 0.219778 |
| Main_RecrDev_2008 | _ | _ | _ | 0.0534656 | 0.236146 |
| Main_RecrDev_2009 | _ | _ | _ | -0.144445 | 0.289408 |
| Late_RecrDev_2010 | _ | _ | _ | -0.699974 | 0.699216 |
| ForeRecr_2011 | _ | _ | _ | 0 | 1 |
| Impl_err_2011 | _ | _ | _ | 0 | _ |
| InitF_1COM | 0.0001 | 5 | 0.1 | 0.0144242 | 0.0897996 |
| InitF_2REC | 0.00001 | 5 | 0.001 | 0.001 | _ |
| AgeSel_1P_1_COM | -20 | 15 | 1 | 0.0576732 | 2.81372 |
| AgeSel_1P_2_COM | -20 | 15 | -5 | -5 | _ |
| AgeSel_1P_3_COM | -20 | 15 | 4 | -7.37128 | 121.562 |
| AgeSel_1P_4_COM | -20 | 15 | 1.5 | 1.5 | _ |
| AgeSel_1P_5_COM | -20 | 20 | -1 | 0.104554 | 24.0497 |
| AgeSel_1P_6_COM | -20 | 20 | 15 | 15 | _ |
| AgeSel_2P_1_REC | -10 | 15 | 2 | 2.00031 | 0.320612 |
| AgeSel_2P_2_REC | -10 | 15 | -4 | -2.3412 | 3.39767 |
| AgeSel_2P_3_REC | -15 | 15 | -1 | -0.940619 | 0.654569 |
| AgeSel_2P_4_REC | -20 | 15 | -4 | -2.09116 | 22.7202 |
| AgeSel_2P_5_REC | -25 | 15 | -5 | -15.9471 | 104.601 |
| AgeSel_2P_6_REC | -20 | 15 | -2 | -0.426842 | 0.341071 |
| AgeSel_4P_1_CRFS | -10 | 15 | 2 | 0.505643 | 0.404807 |
| AgeSel_4P_2_CRFS | -10 | 15 | -4 | -8.49388 | 30.5612 |
| AgeSel_4P_3_CRFS | -15 | 15 | -1 | 3.69201 | 128.658 |
| AgeSel_4P_4_CRFS | -20 | 15 | -4 | -4.27335 | 70.9969 |
| AgeSel_4P_5_CRFS | -25 | 15 | -5 | -13.2365 | 131.22 |
| AgeSel_4P_6_CRFS | -20 | 15 | -2 | -12.6752 | 91.1591 |

Table 5. Continued.

**(D)**

| Sensitivity run | Model | *B* (2011) | *B* (2011) - Peak | *-ln L* (Total) | *-ln L* (CPFV) | *-ln L* (CRFS) |
|---|---|---|---|---|---|---|
| Base case | XA | 211,126 | 1,065,990 | 842.5 | -6.4 | -5.3 |
| 2x λ (CPFV index) | XA1 | 219,896 | 1,123,910 | 830.4 | -16.3 | -6.2 |
| 2x λ (CRFS index) | XA2 | 200,383 | 1,073,720 | 836.4 | -7.6 | -6.6 |
| 2x λ (Recreational length distribution) | XA3 | 287,442 | 1,025,710 | 1,029.7 | -5.8 | -3.9 |
| 2x λ (Commercial age distribution) | XA4 | 178,682 | 981,870 | 1,188.6 | 10.8 | -1.5 |
| 2x λ (Length-at-age distribution) | XA5 | 210,748 | 1,103,060 | 864.1 | -5.9 | -5.6 |
| Omit CRFS data (inclusive) | XA6 | 251,550 | 1,047,730 | 785.2 | -0.5 | na |
| $M = 0.3$ yr$^{-1}$ | XA7 | 95,667 | 323,656 | 853.9 | 4.4 | -4.8 |
| $M = 0.4$ yr$^{-1}$ | XA8 | 130,857 | 444,452 | 860.2 | -1.8 | -3.4 |
| $M = 0.6$ yr$^{-1}$ | XA9 | 606,752 | 3,676,670 | 840.3 | -8.6 | -5.9 |
| $M = 0.7$ yr$^{-1}$ [a] | XA10 | ** | ** | 839.3 | -6.7 | -5.9 |
| Start in 1978 | XA11 | 171,415 | 1,080,300 | 1,231.6 | -1.1 | -5.2 |
| Start in 1981 | XA12 | 190,897 | 1,096,960 | 1,007.1 | -4.3 | -5.0 |
| Start in 1990 | XA13 | 217,789 | 556,043 | 455.0 | -9.9 | -4.9 |
| Length-at-age max - estimate CV | XA14 | 226,929 | 1,082,290 | 851.5 | -8.4 | -4.3 |
| Sigma r = 0.8 | XA15 | 210,172 | 1,053,200 | 841.4 | -6.9 | -5.4 |
| Sigma r = 1.2 | XA16 | 211,258 | 1,071,720 | 845.0 | -6.2 | -5.3 |

**Biomass estimate from sensitivity run was essentially infinite and hessian may not be positive definite.

Table 6. Harvest control rule information for the Pacific mackerel fishery (2011-12) based on Model *XA*, including: (A) 'harvest guideline' statistics (see Harvest Control Rule and USA Management in 2011-12) ; and (B) harvest formulas associated with recent regulations associated with reauthorization of National Standards 1 of the MSFCMA, see PFMC (2010a) for parameter definitions (σ=0.36).

**(A)**

| ***B*** **(Age 1+, mt)** | **Cutoff (mt)** | **Fraction** | **Distribution** | **HG (mt)** |
|---|---|---|---|---|
| 211,126 | 18,200 | 30% | 70% | **40,514** |

**(B)**

| **Harvest Formula Parameters** | **Value** | | | |
|---|---|---|---|---|
| BIOMASS (ages 1+, mt) | 211,126 | | | |
| Pstar (probability of overfishing) | 0.45 | 0.4 | 0.3 | 0.2 |
| $BUFFER_{Pstar}$ | 0.95577 | 0.91283 | 0.82797 | 0.73861 |
| $F_{MSY}$ | 0.3 | | | |
| FRACTION | 0.3 | | | |
| CUTOFF (mt) | 18,200 | | | |
| DISTRIBUTION (U.S.) | 0.7 | | | |

| **Amendment 13 Harvest Formulas** | **MT** |
|---|---|
| OFL = BIOMASS * $F_{MSY}$ * DISTRIBUTION | 44,336 |
| $ABC_{0.45}$ = BIOMASS * BUFFER0.45 * $F_{MSY}$ * DISTRIBUTION | 42,375 |
| $ABC_{0.40}$ = BIOMASS * BUFFER0.40 * $F_{MSY}$ * DISTRIBUTION | 40,472 |
| $ABC_{0.30}$ = BIOMASS * BUFFER0.30 * $F_{MSY}$ * DISTRIBUTION | 36,709 |
| $ABC_{0.20}$ = BIOMASS * BUFFER0.20 * $F_{MSY}$ * DISTRIBUTION | 32,747 |
| ACL=LESS THAN OR EQUAL TO ABC | TBD |
| HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION | 40,514 |
| ACT=EQUAL TO HG OR ACL, WHICHEVER VALUE IS LESS | TBD |

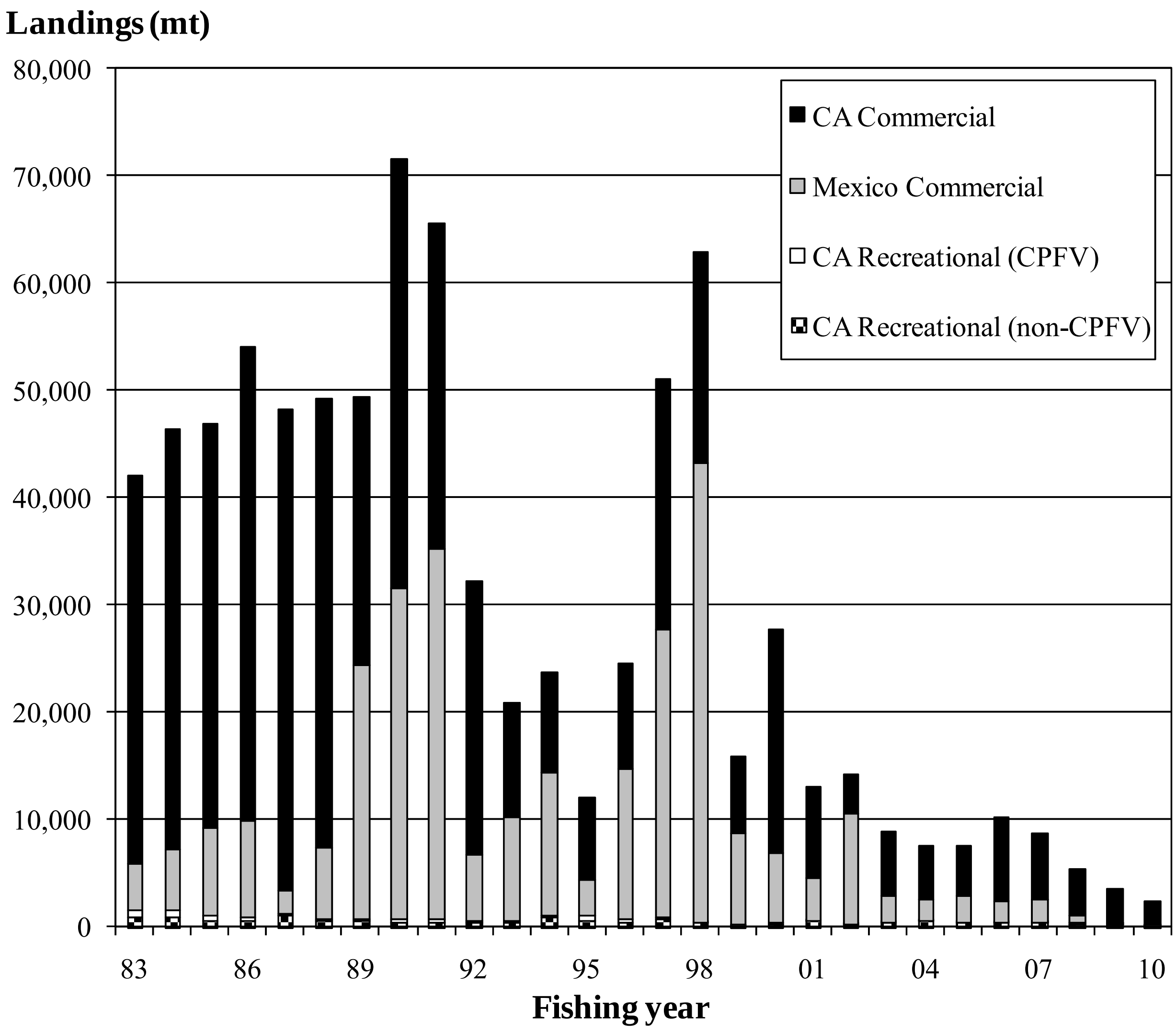
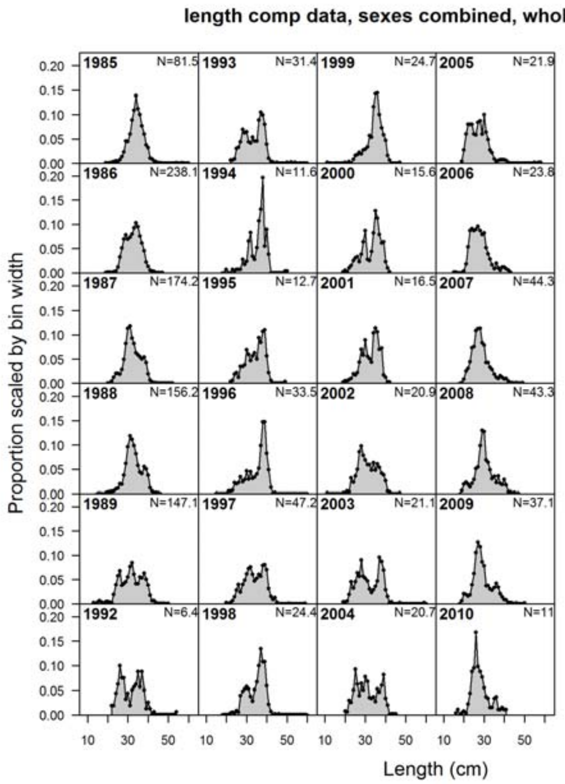



Figure 1. Commercial and recreational landings (mt) of Pacific mackerel in the USA (CA commercial, recreational-CPFV, and recreational-non-CPFV) and Mexico (commercial), (1983-10).

(**A**)




**(B)**

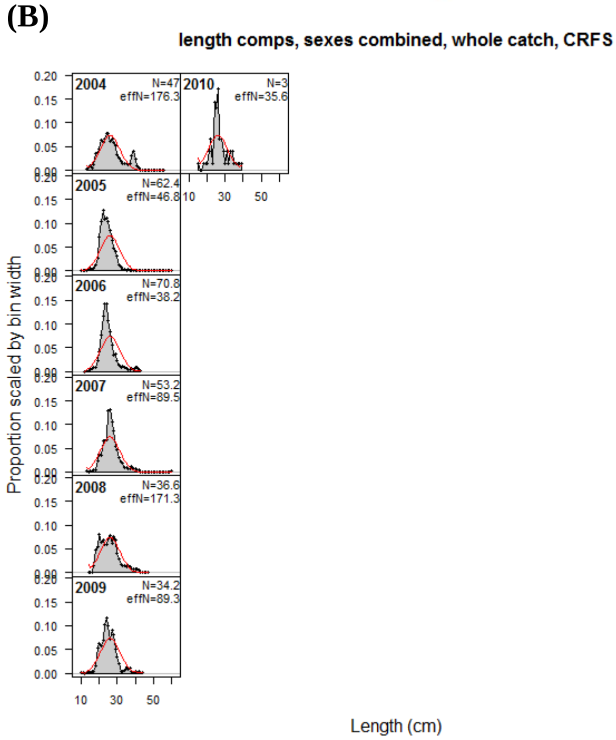



Figure 2. Length distributions of Pacific mackerel from: (A) the CDFG observer sampling program (1985-89) and RecFIN (CPFV) data base (1992-10) associated with the CPFV fishery; and (B) the CRFS sampling program (2004-10) associated with the non-CPFV fisheries.

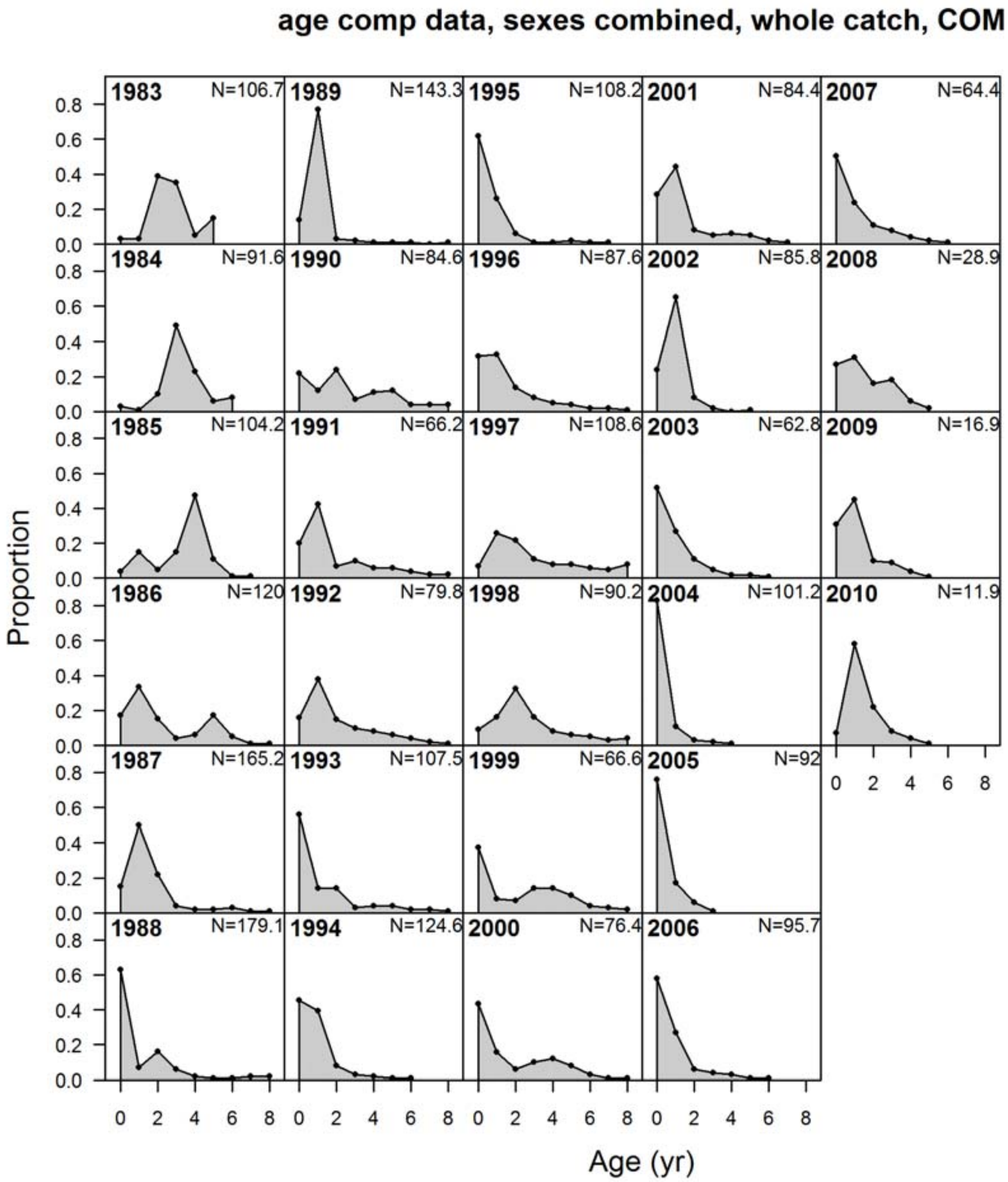



Figure 3. Age distributions of Pacific mackerel from the CDFG (commercial fishery) port sampling program (1983-10).

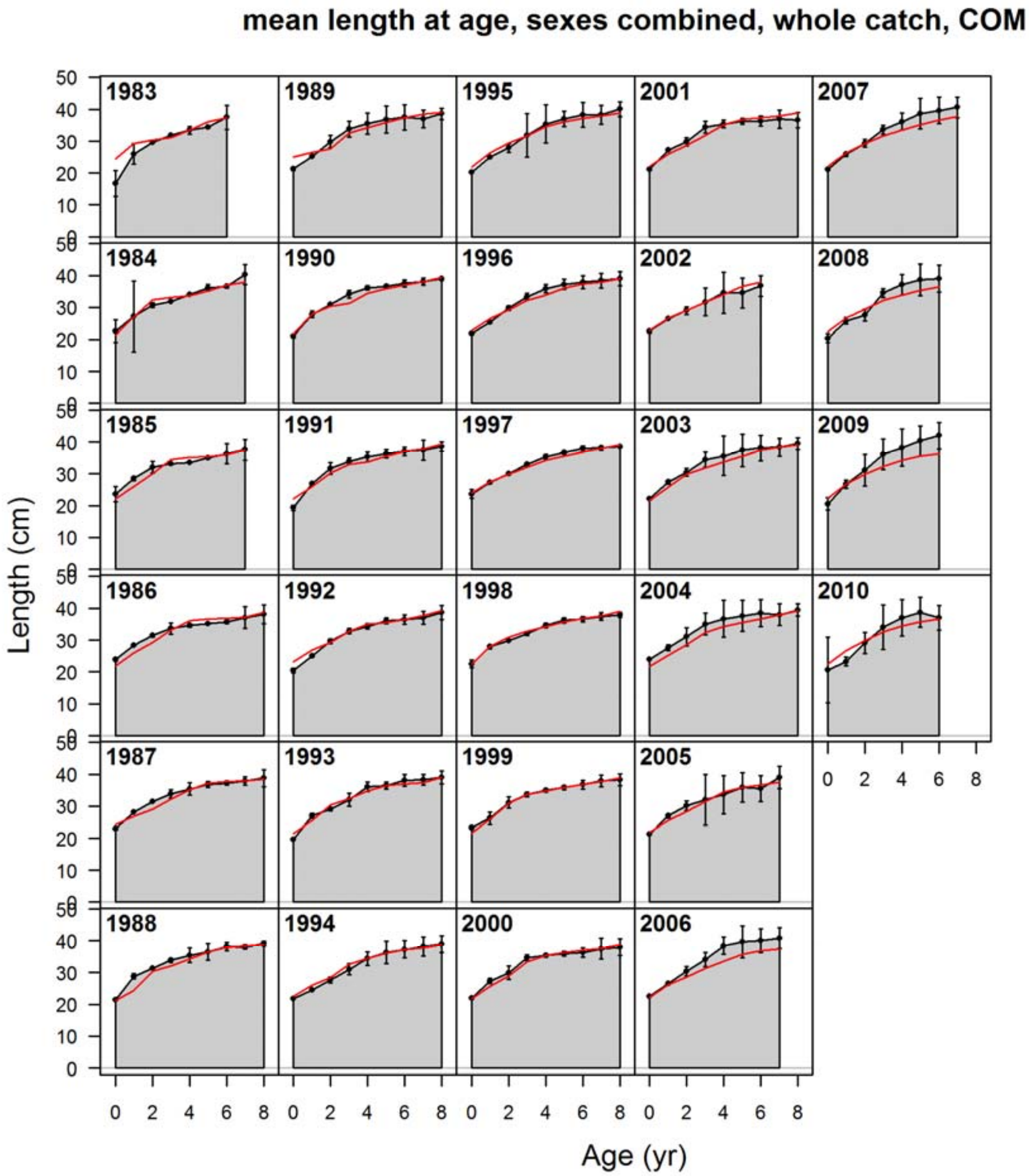



Figure 4. Estimated mean length-at-age (cm/yr, open circles) time series of Pacific mackerel from CDFG (commercial fishery) port sampling program (1983-10). Also, model fits to this time series are presented (curved line in each display).

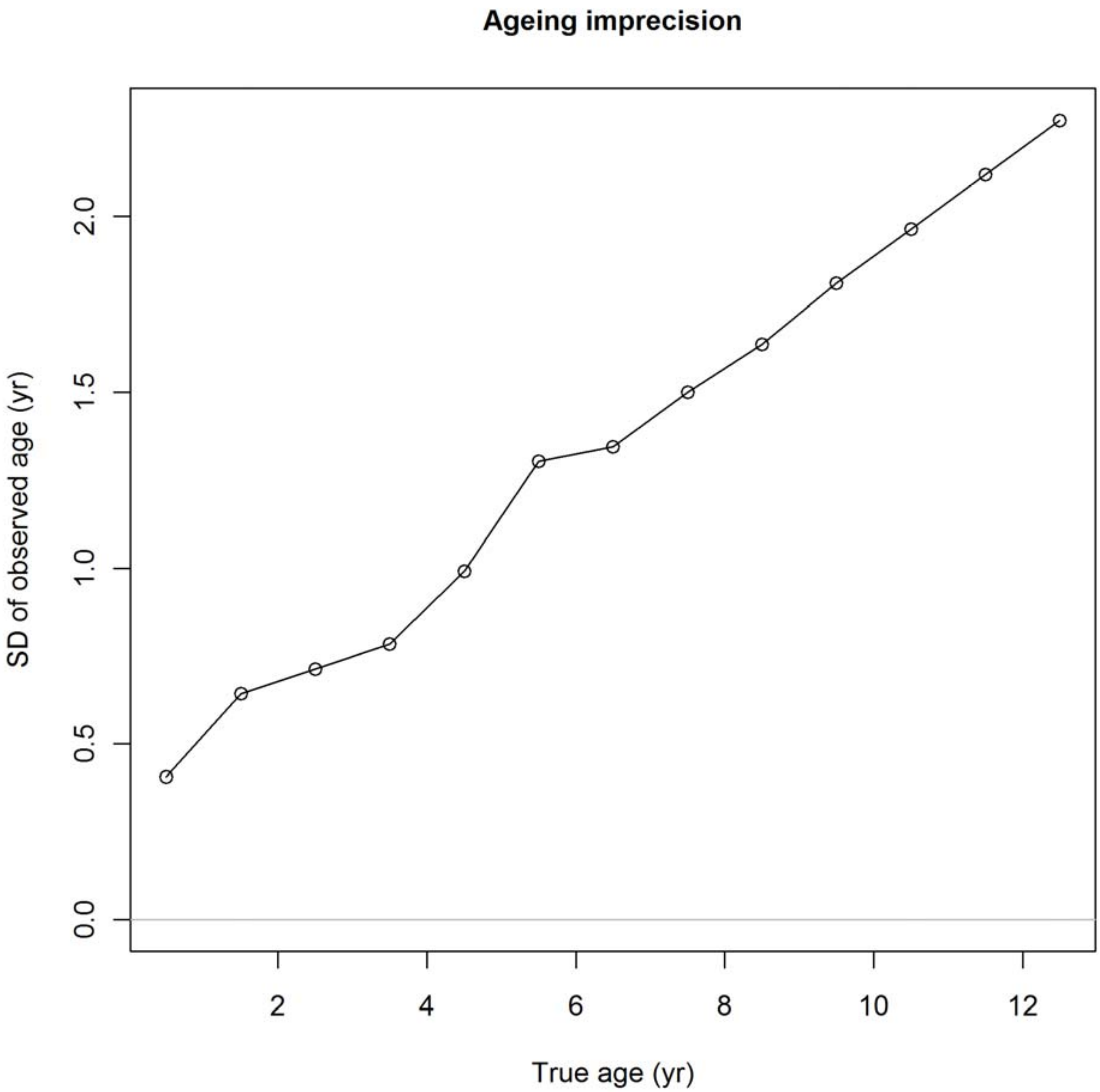



Figure 5. Pacific mackerel ageing error vector (SD by age) from CDFG age production laboratory based on double-read analysis.

(A)

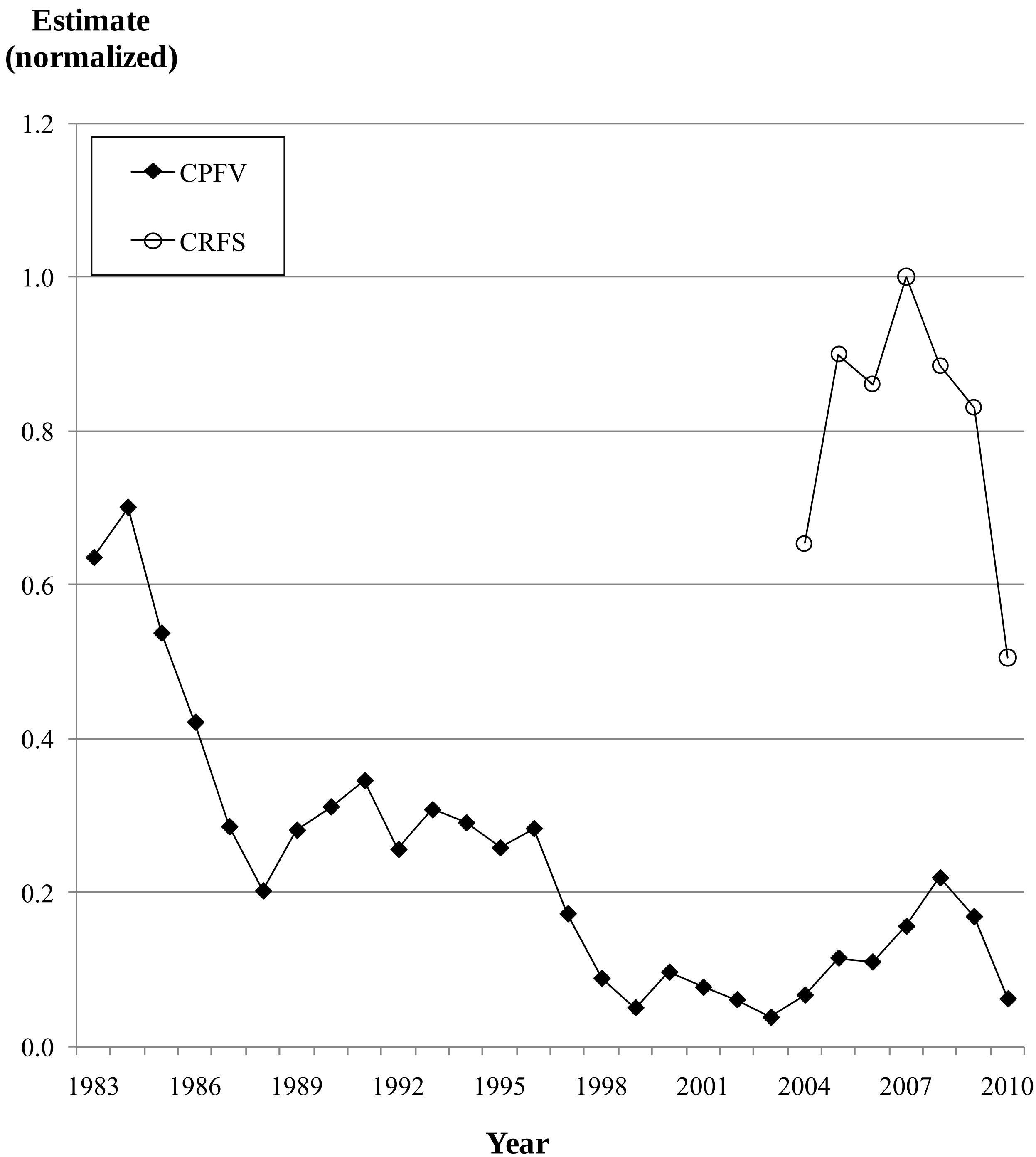
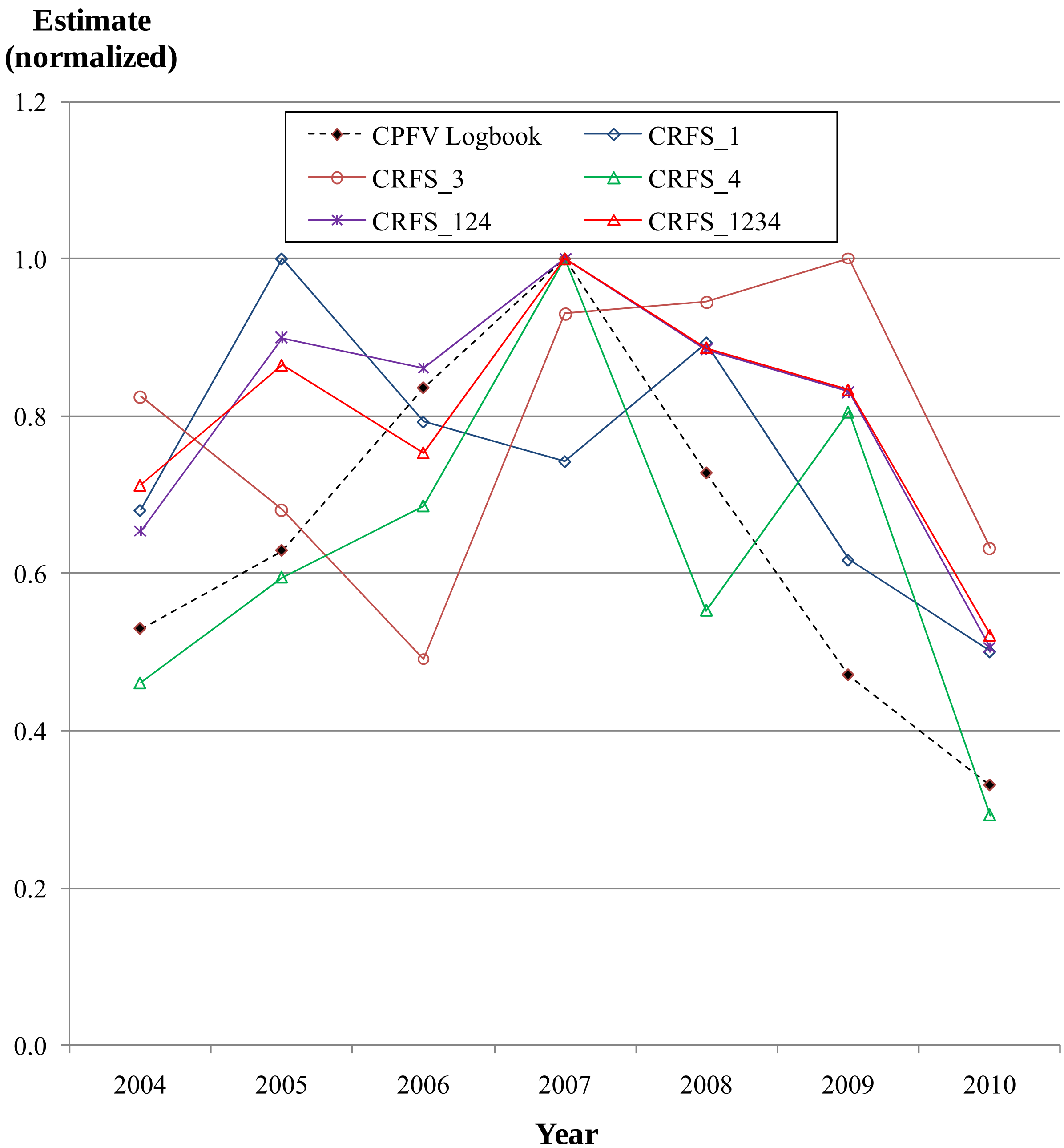
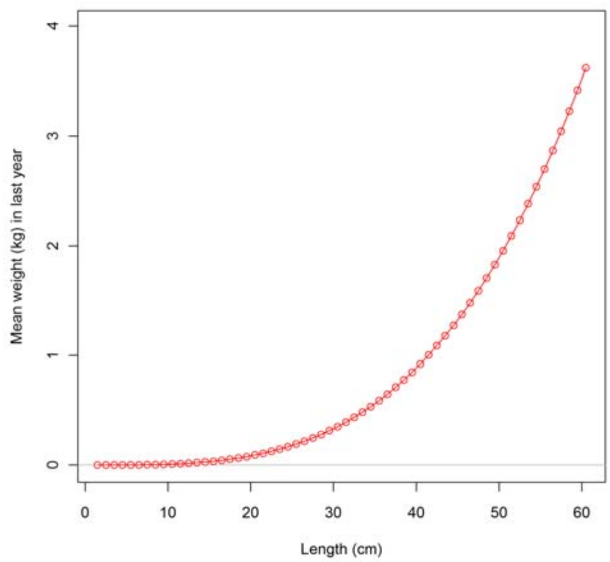



Figure 6. Indices of abundance: (A) CPFV (CPFV logbook sampling program) and CRFS (non-CPFV fisheries); and (B) the CRFS survey time series evaluated at the fishing mode level (CPFV Logbook=abbreviated CPFV in 6A, CRFS_1 = man-made, CRFS_2=beach/bank, CRFS_3=charter/party, CRFS_4=private/rental, CRFS_124=omits charter/party, and CRFS_1234=all modes). Note that only the CPFV and CRFS_124 indices were used in Model *XA*. Also, missing lines between data points reflects years with no sampling.

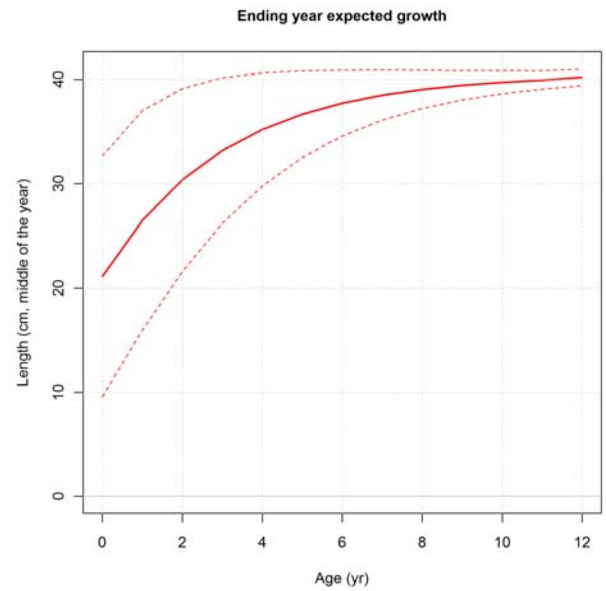
(B)


Estimate (normalized)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
CPFV Logbook
CRFS_1
CRFS_3
CRFS_4
CRFS_124
CRFS_1234
2004
2005
2006
2007
2008
2009
2010
Year

(A)




(B)




(C)

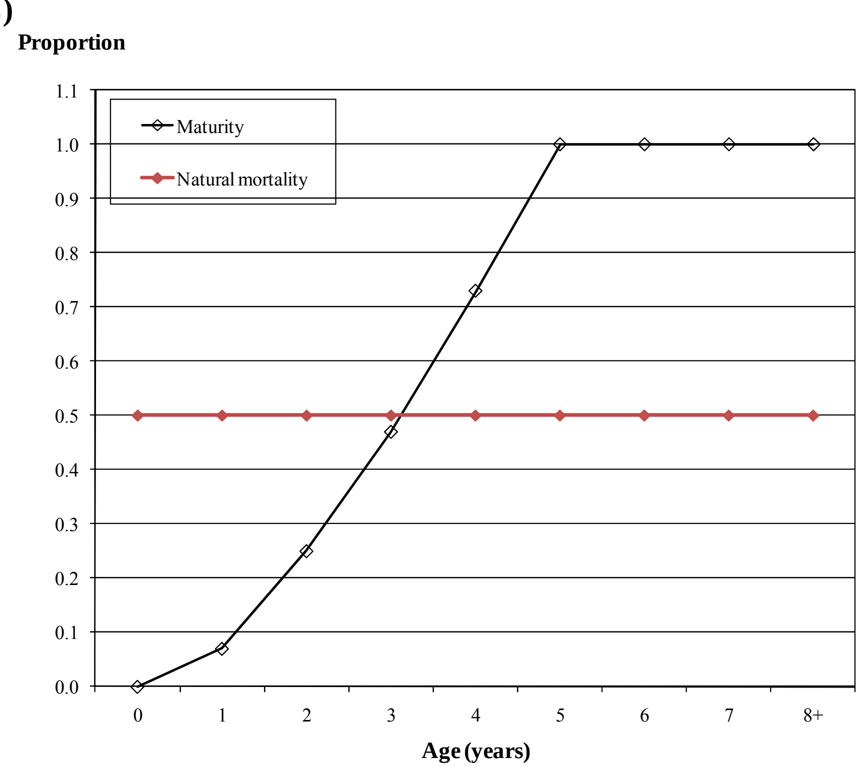



Figure 7. Biological parameters for Pacific mackerel either assumed or estimated in the assessment models: (A) weight-length relationship; (B) length (cm)-at-age (yr); and (C) maturity (also, see Table 4) and natural mortality (*M*).

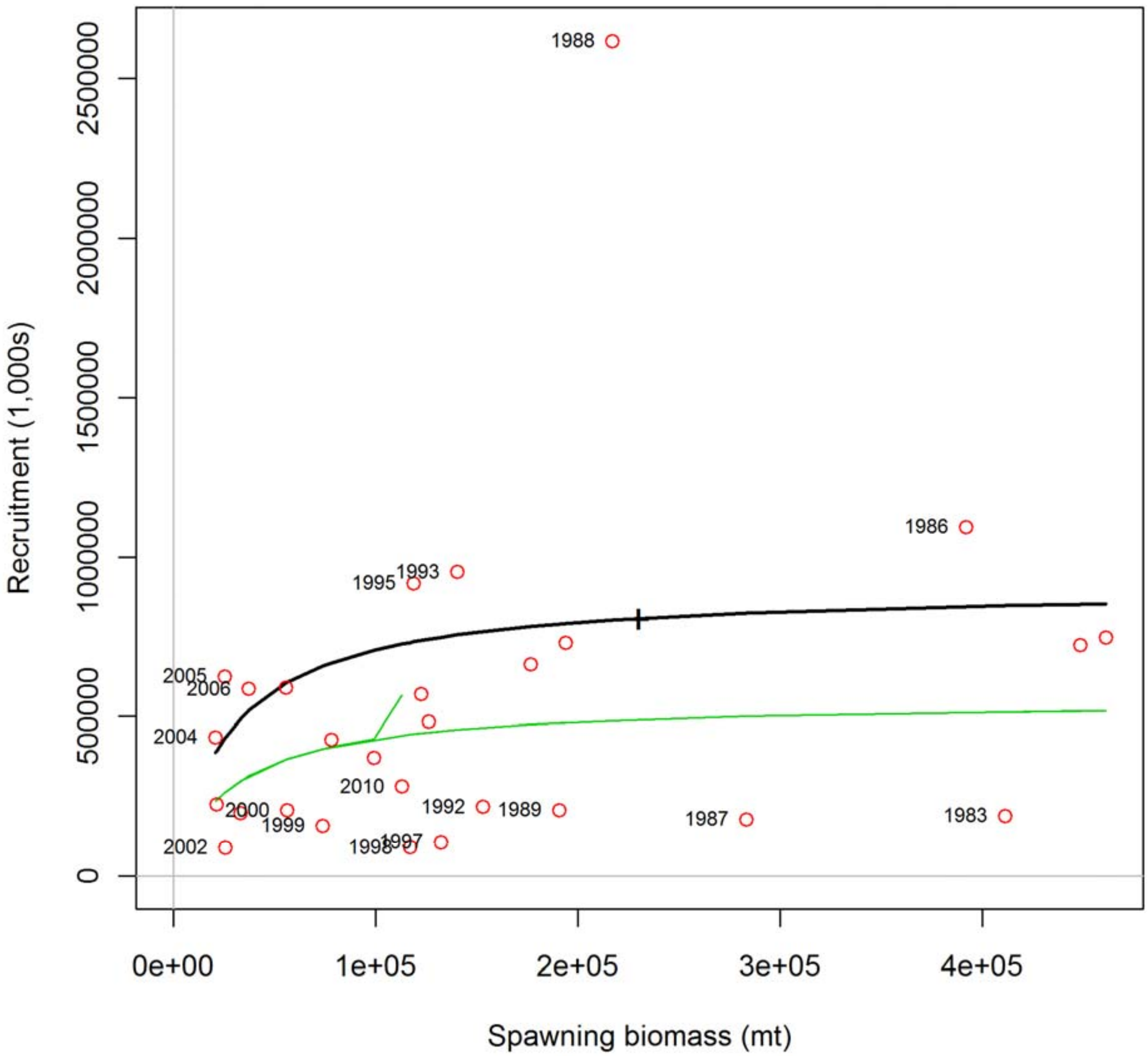



Figure 8. Beverton-Holt stock (*SSB* in 1000s mt)-recruitment (*R* in millions of fish) relationship for Pacific mackerel estimated in the final Model *XA*. Recruitment estimates are presented as (year+1) values. Strong year classes are highlighted and steepness (*h*) = 0.70.

(A)

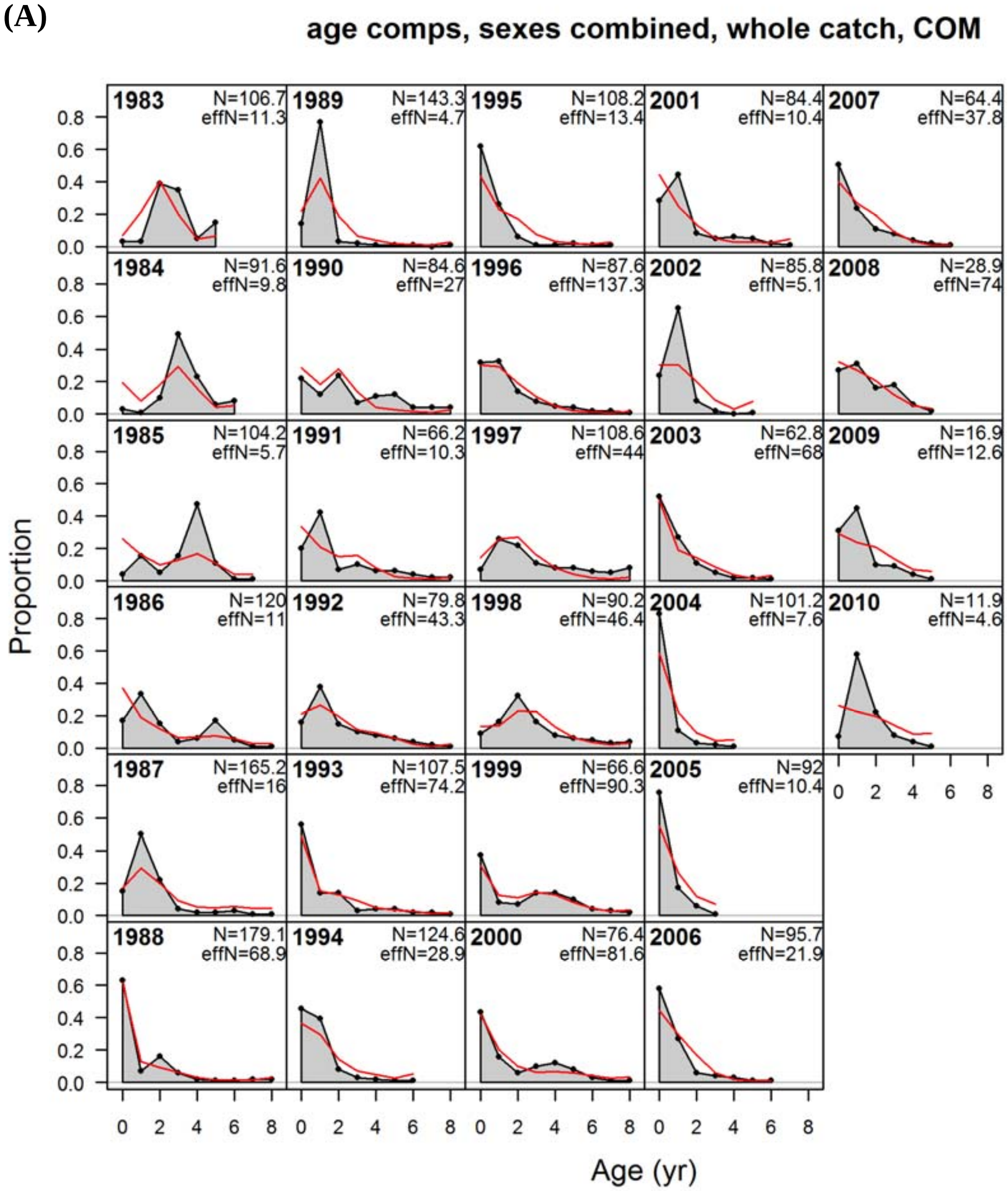
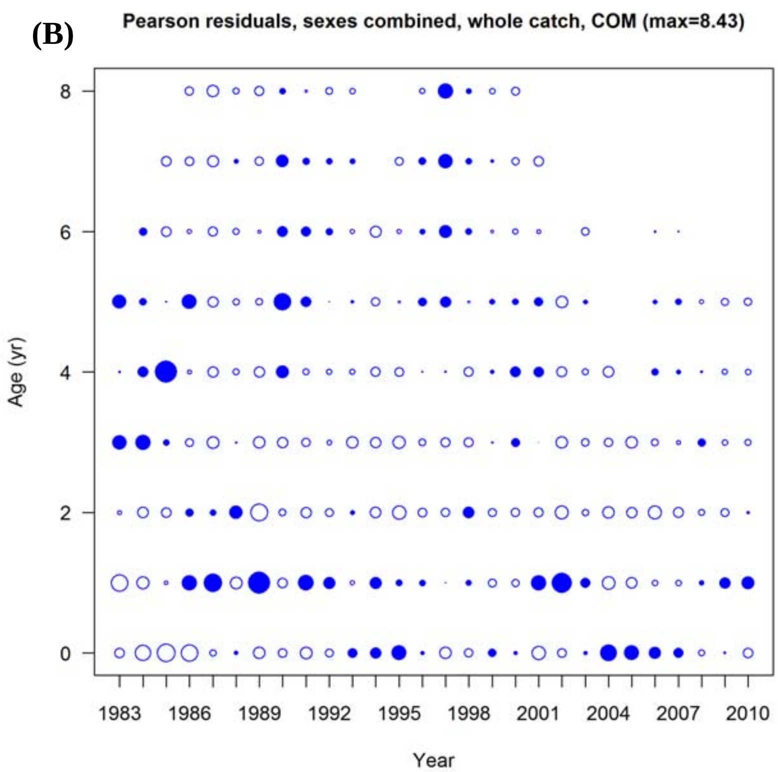



Figure 9. Model *XA* fit diagnostics associated with the commercial fishery age distribution time series (1983-10): (A) observed (open circles) vs. predicted (line) estimates; (B) Pearson standardized residuals (observed – predicted; maximum bubble size = 8.43; dark circles represent positive values); 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).

(B)




(C)

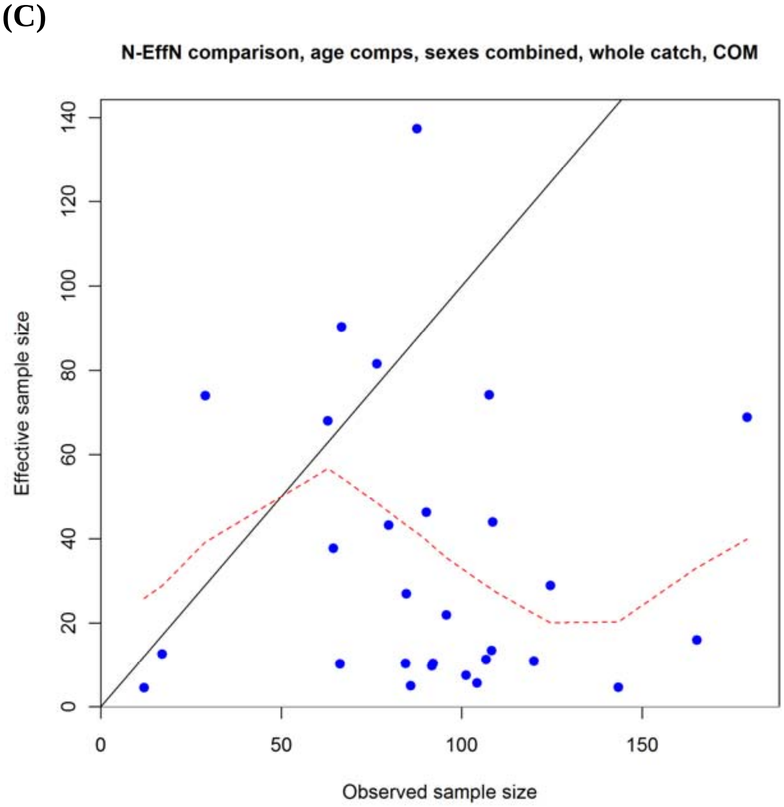



Figure 9. Continued.

(A)

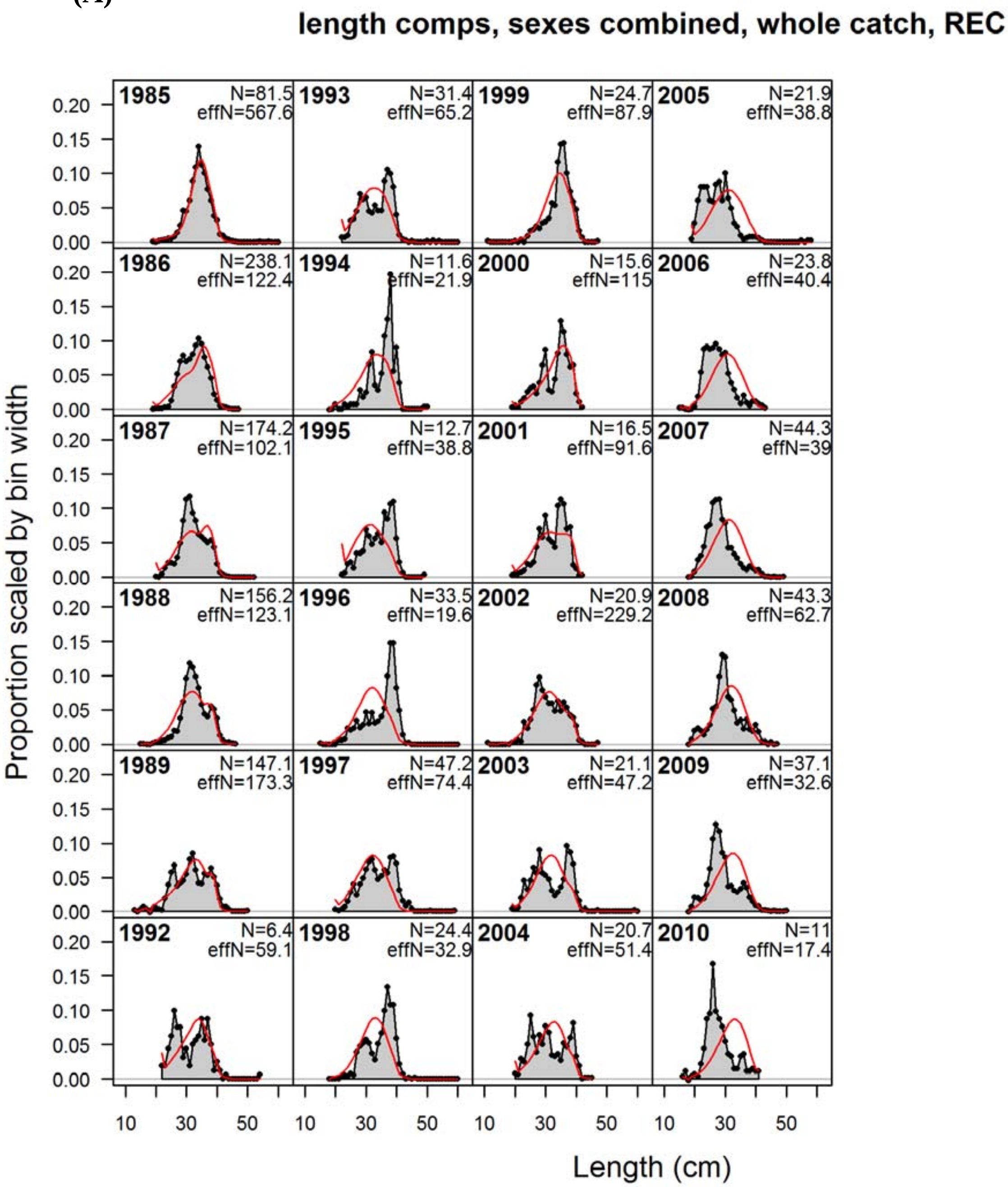
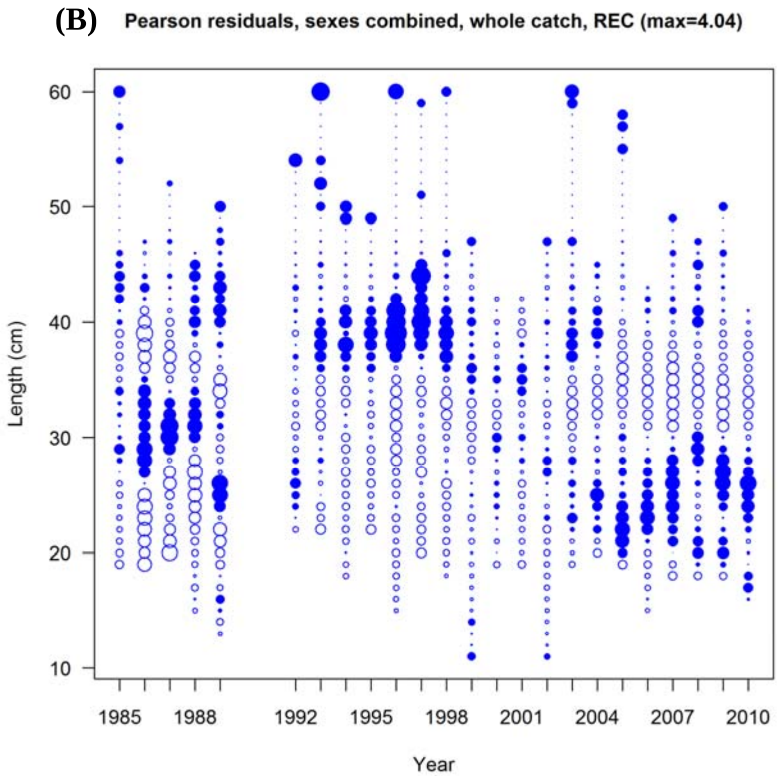



Figure 10. Model *XA* fit diagnostics associated with the recreational fisheries length distribution time series (displays A-C=CPFV fishery via CPFV logbook sampling program and displays D-F=non-CPFV fisheries via CRFS): (A and D) observed (open circles) vs. predicted (line) estimates; (B and E) Pearson standardized residuals (observed – predicted; maximum bubble size = 4.04 and 3.88, dark circles represent positive values); and (C and F) 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).

(B)




(C)

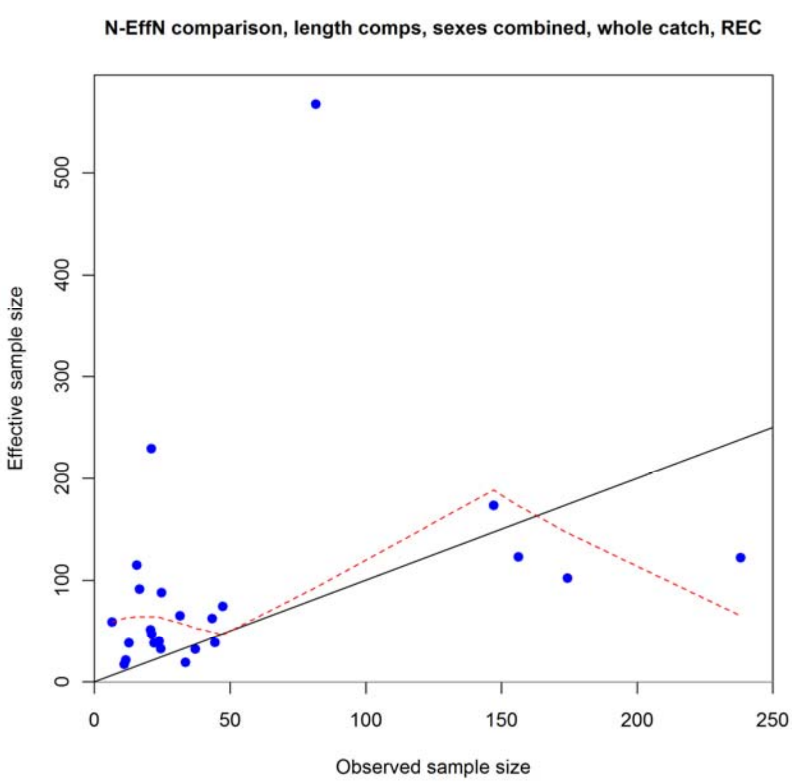



Figure 10. Continued.

(D)

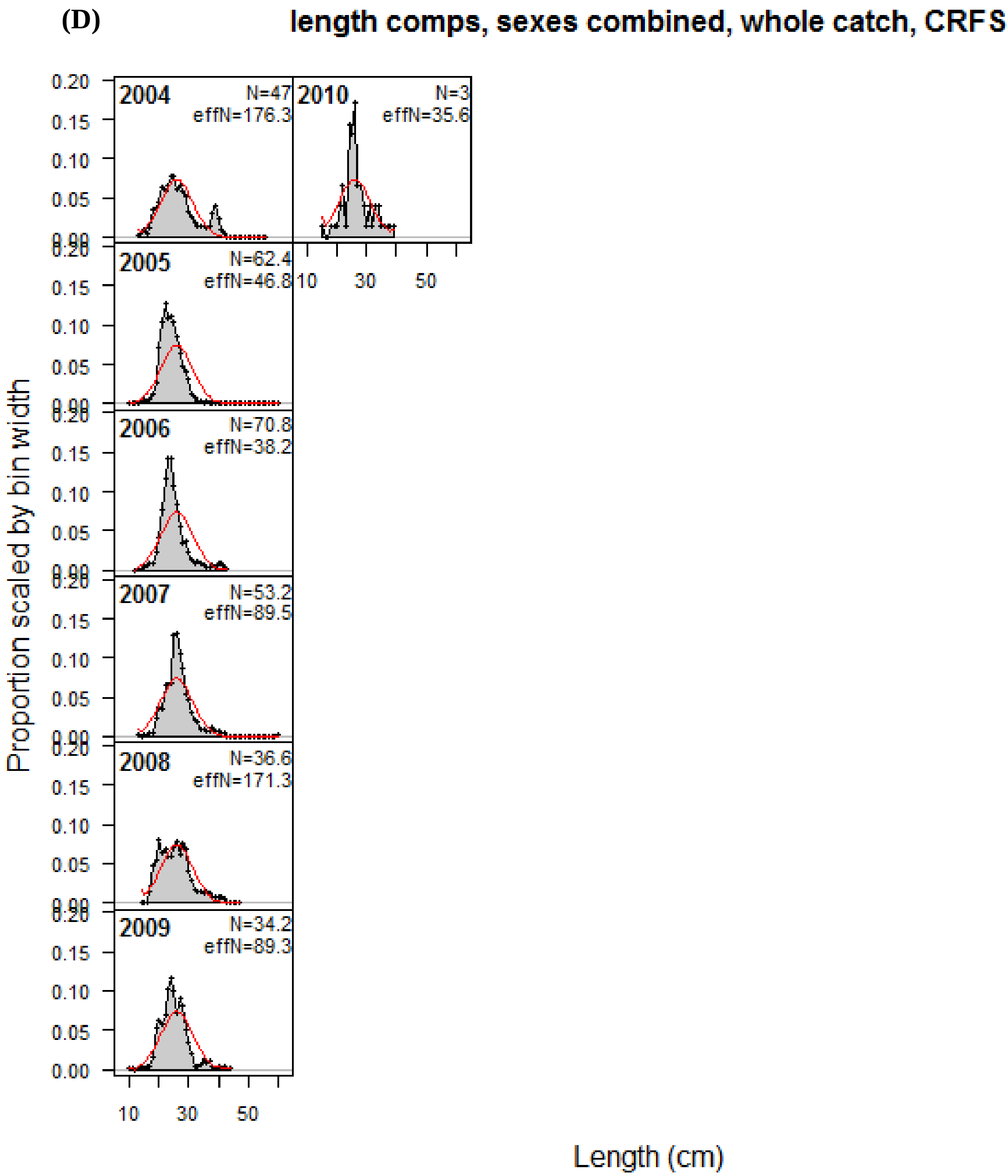
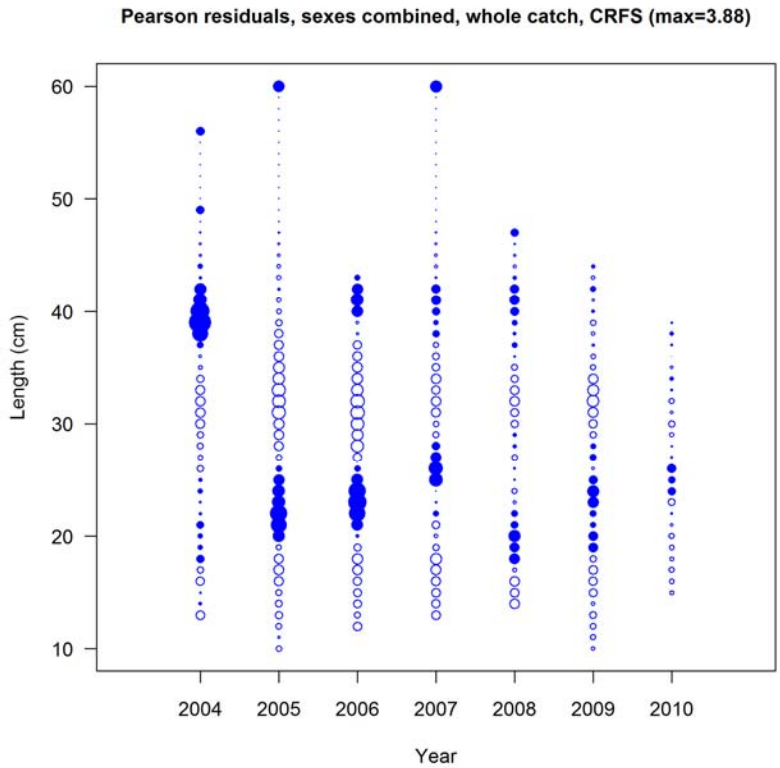



Figure 10. Continued.

**(E)**




**(F)**

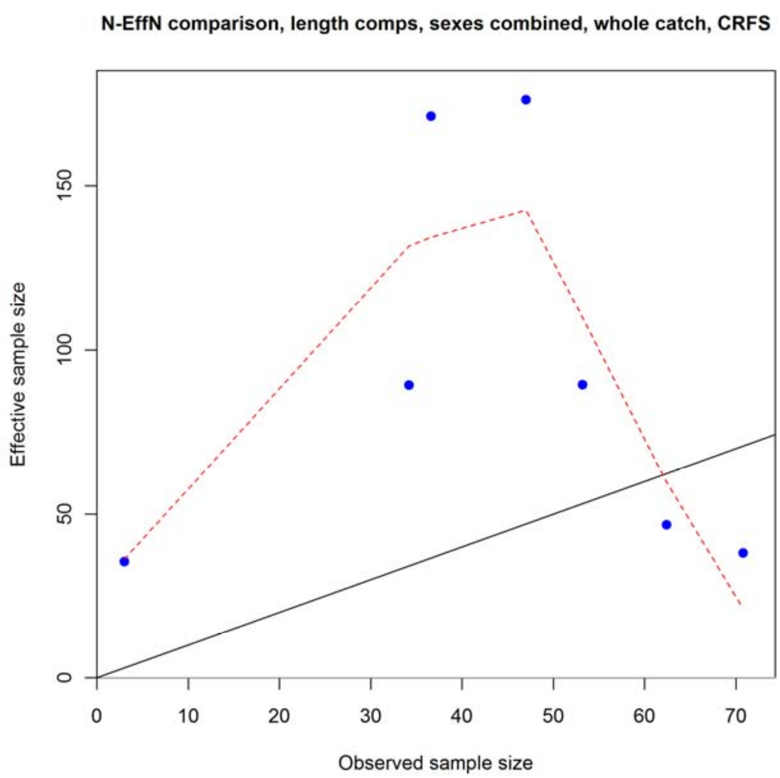



Figure 10. Continued.

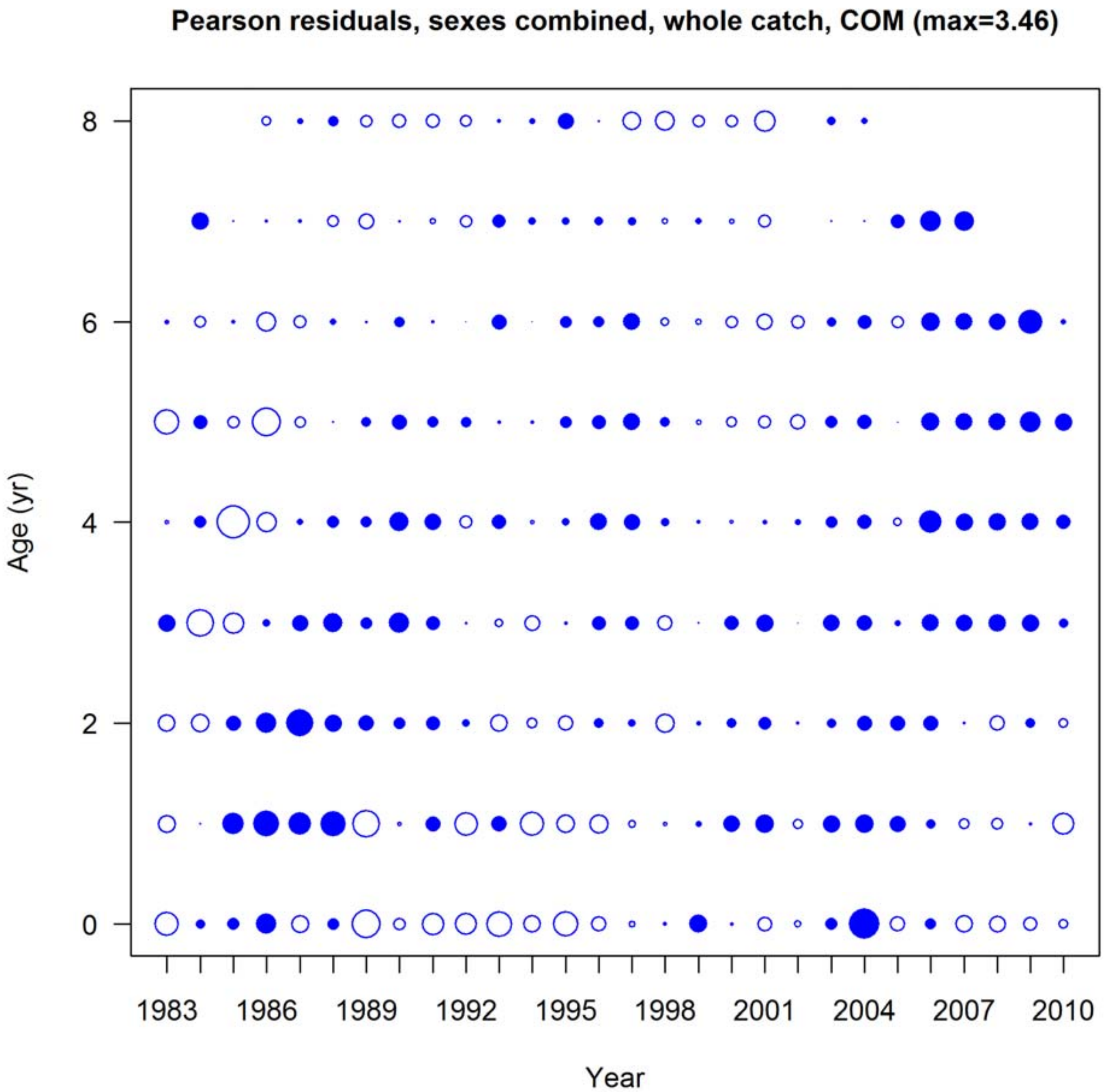
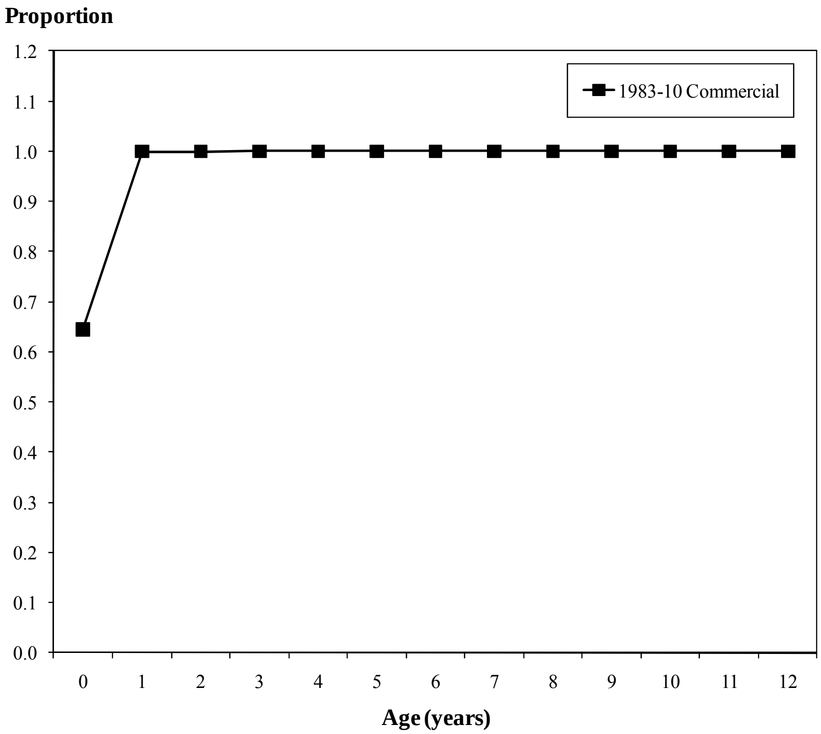



Figure 11. Model *XA* fit diagnostics associated with the commercial fishery mean length-at-age time series (1983-10), i.e., the associated Pearson standardized residuals plot (observed – predicted; maximum bubble size = 3.46; dark circles represent positive values). Also, see Figure 4 related diagnostics.

(A)




(B)

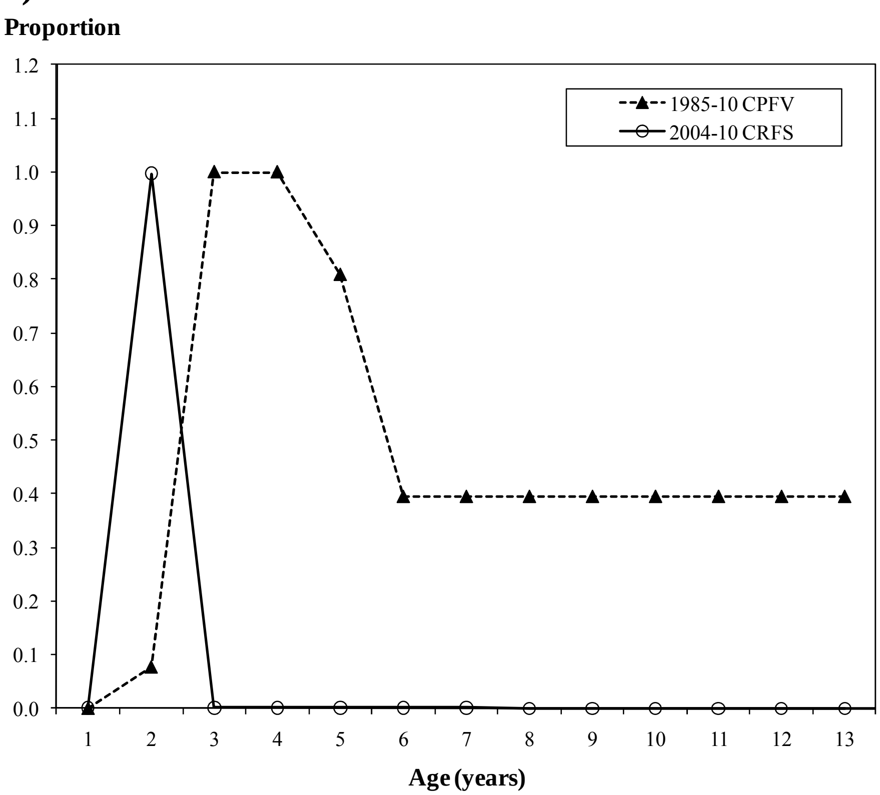
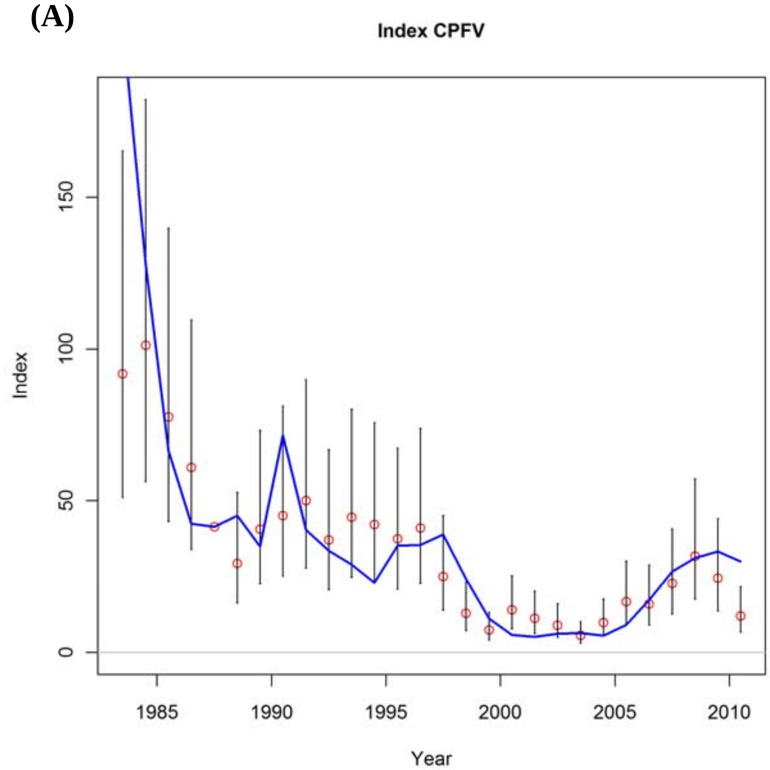



Figure 12. Estimated time-varying age-based selectivity distributions associated with model *XA*: (A) commercial fishery (1983-10); and (B) recreational fishery (1985-10 CPFV) and (2004-10 CRFS).

(A)




(B)

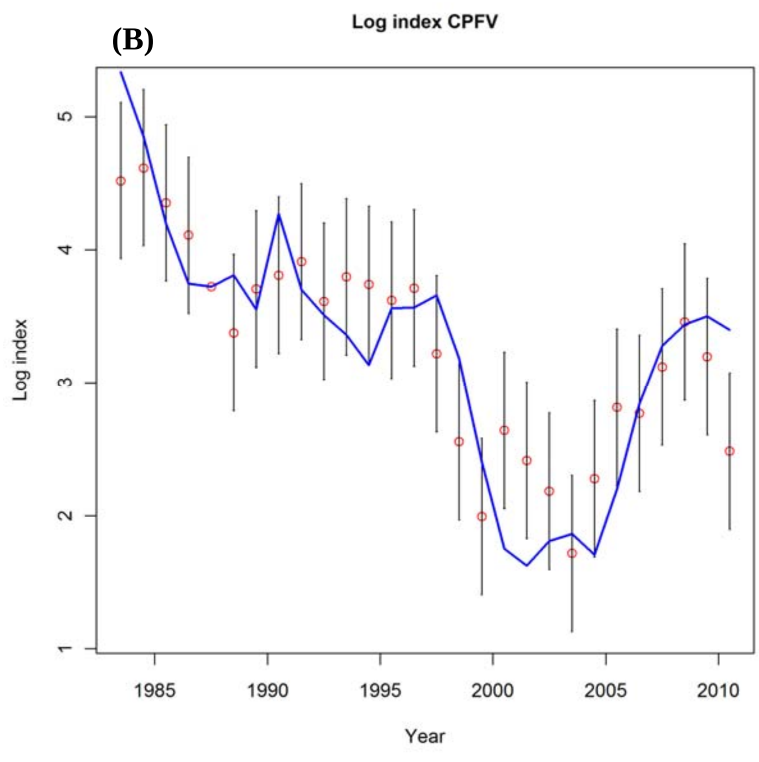
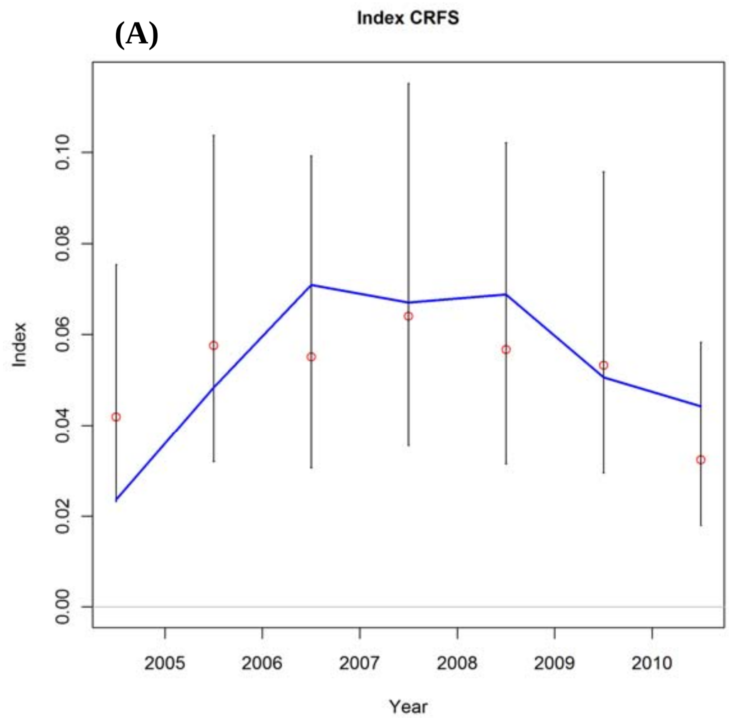



Figure 13. Model *XA* fits to the CPFV index of relative abundance (one time block, 1983-10): (A) normal space; and (B) log space.

**(A)**




**(B)**

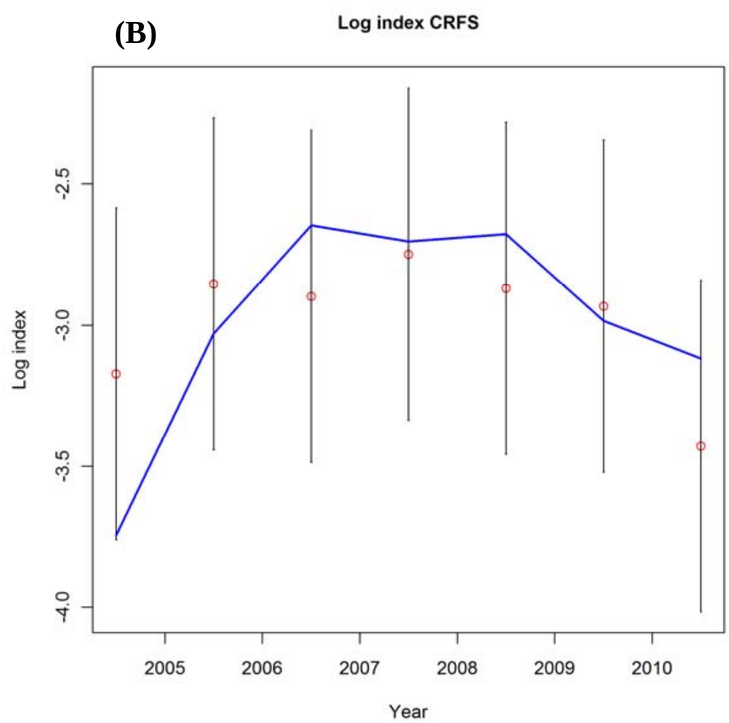
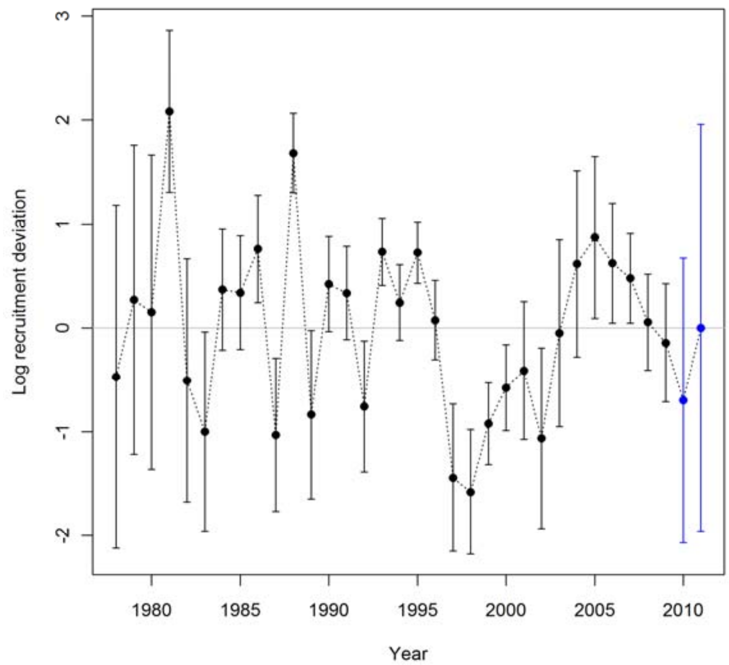



Figure 14. Model *XA* fits to the CRFS index of relative abundance (one time block, 2004-10): (A) normal space; and (B) log space.

**(A)**




**(B)**

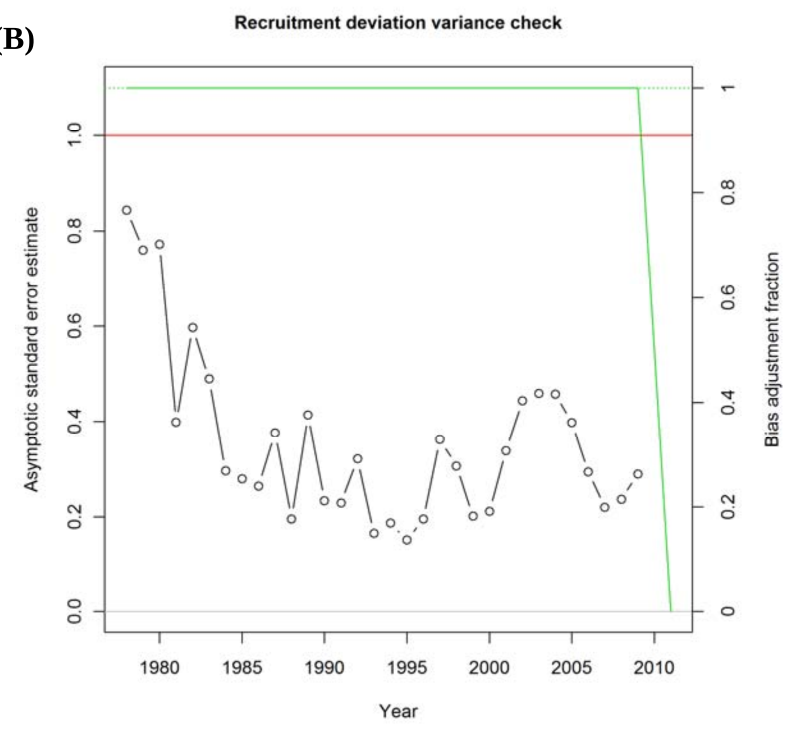



Figure 15. Recruitment-related estimates from model *XA*: (A) recruitment deviations; and (B) SEs associated with the deviations (horizontal line indicates the estimate of the standard deviation of log recruitment deviations, i.e., fixed $\sigma_R$ =1.0).

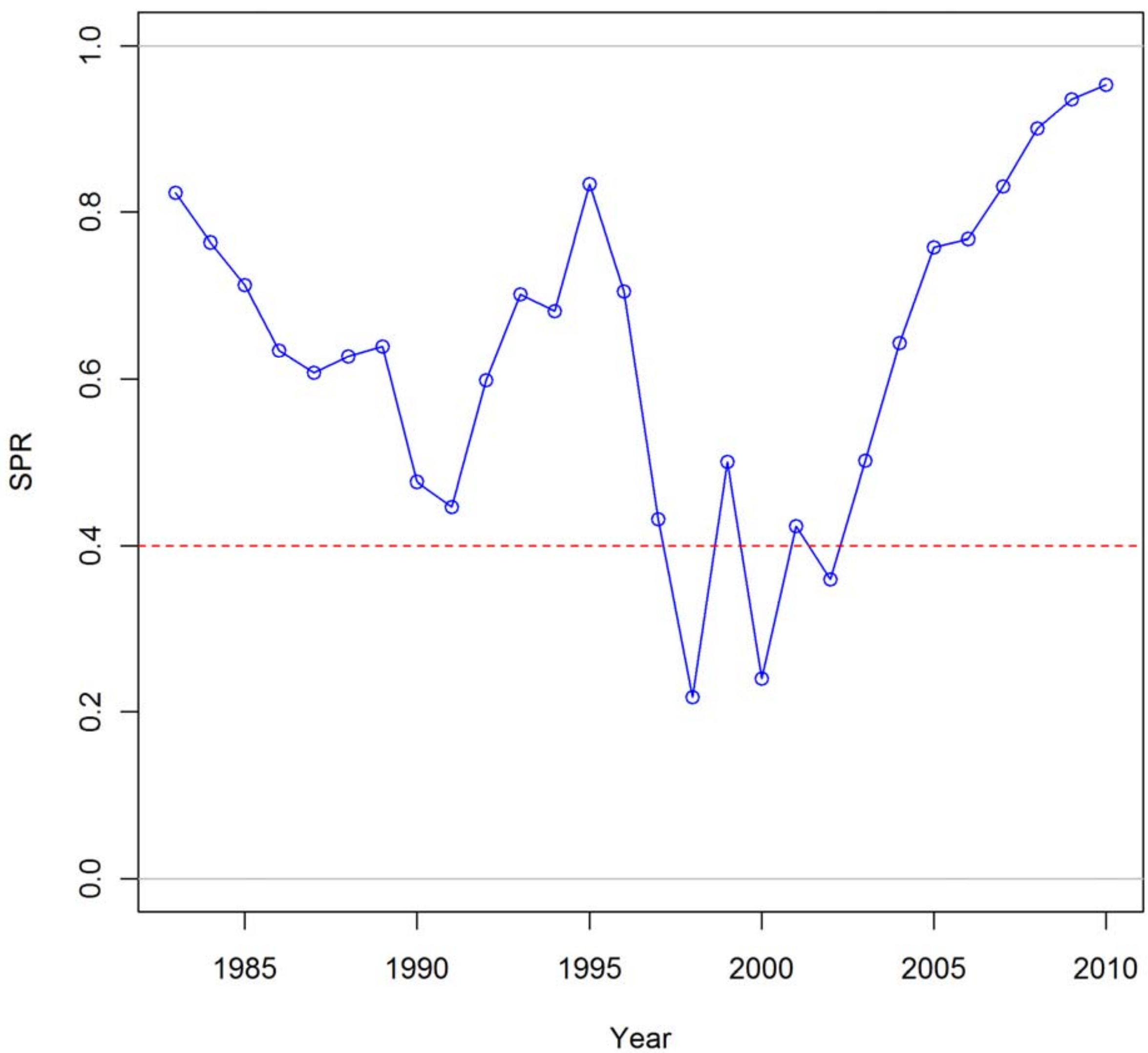



Figure 16. Estimated *F*-based spawning potential ratio time series for model *XA* (1983-10).

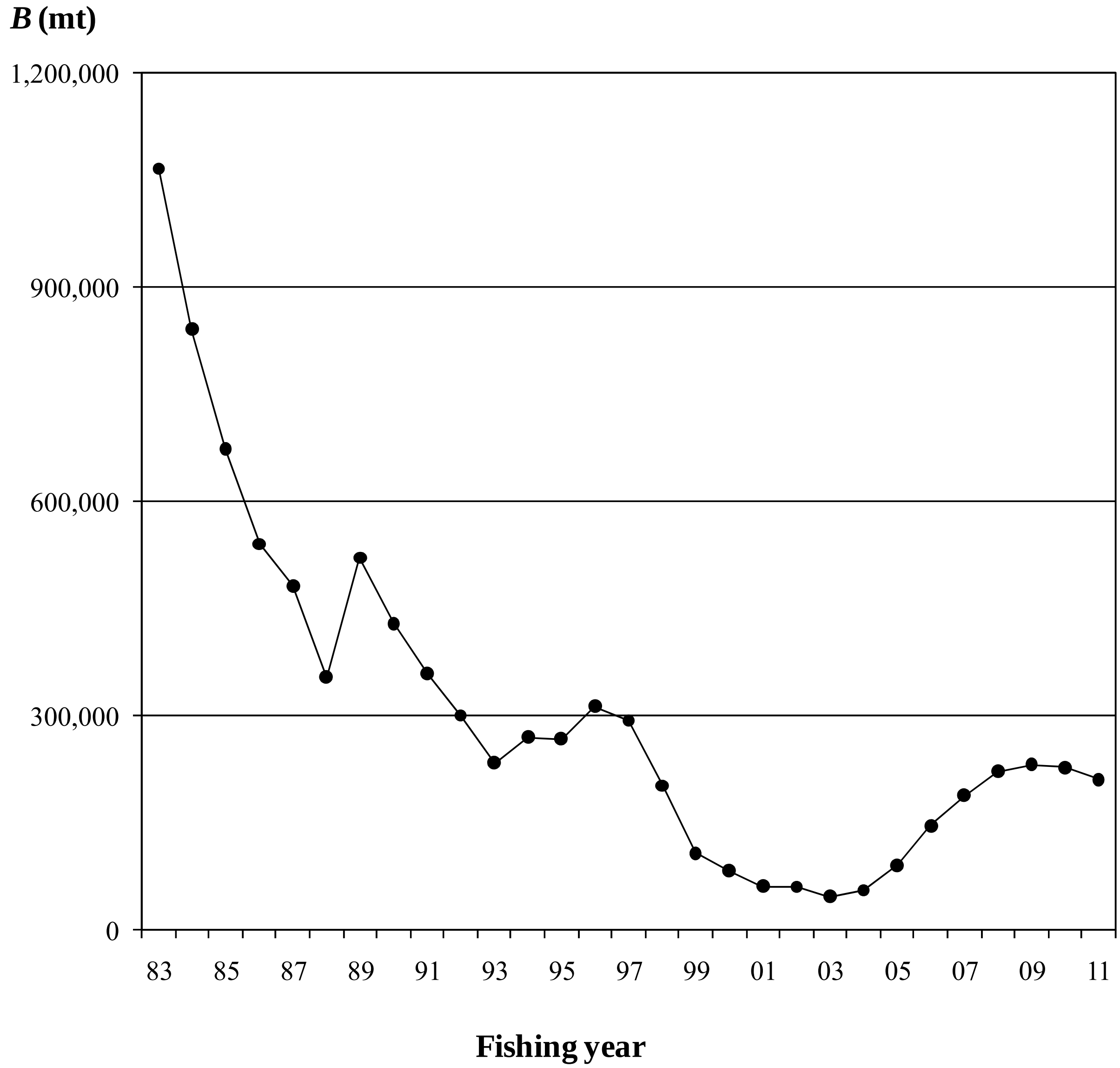



Figure 17. Estimated total stock biomass (age 1+ fish in mt, *B*) of Pacific mackerel based on Model *XA* (1983-11).

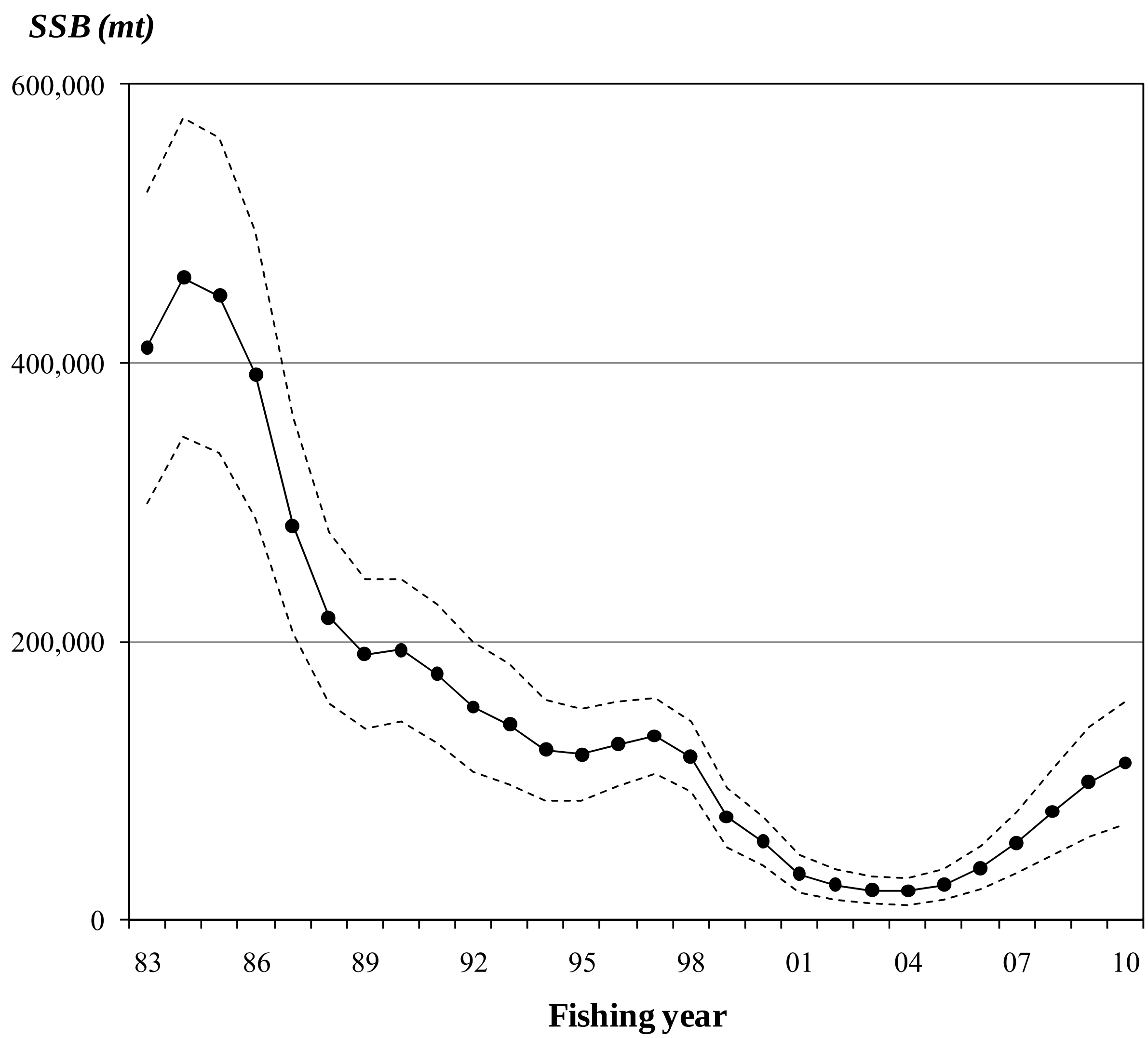



Figure 18. Estimated spawning stock biomass (*SSB*) of Pacific mackerel based on Model *XA* (1983-10). A confidence interval (95% CI) is also presented as dashed lines.

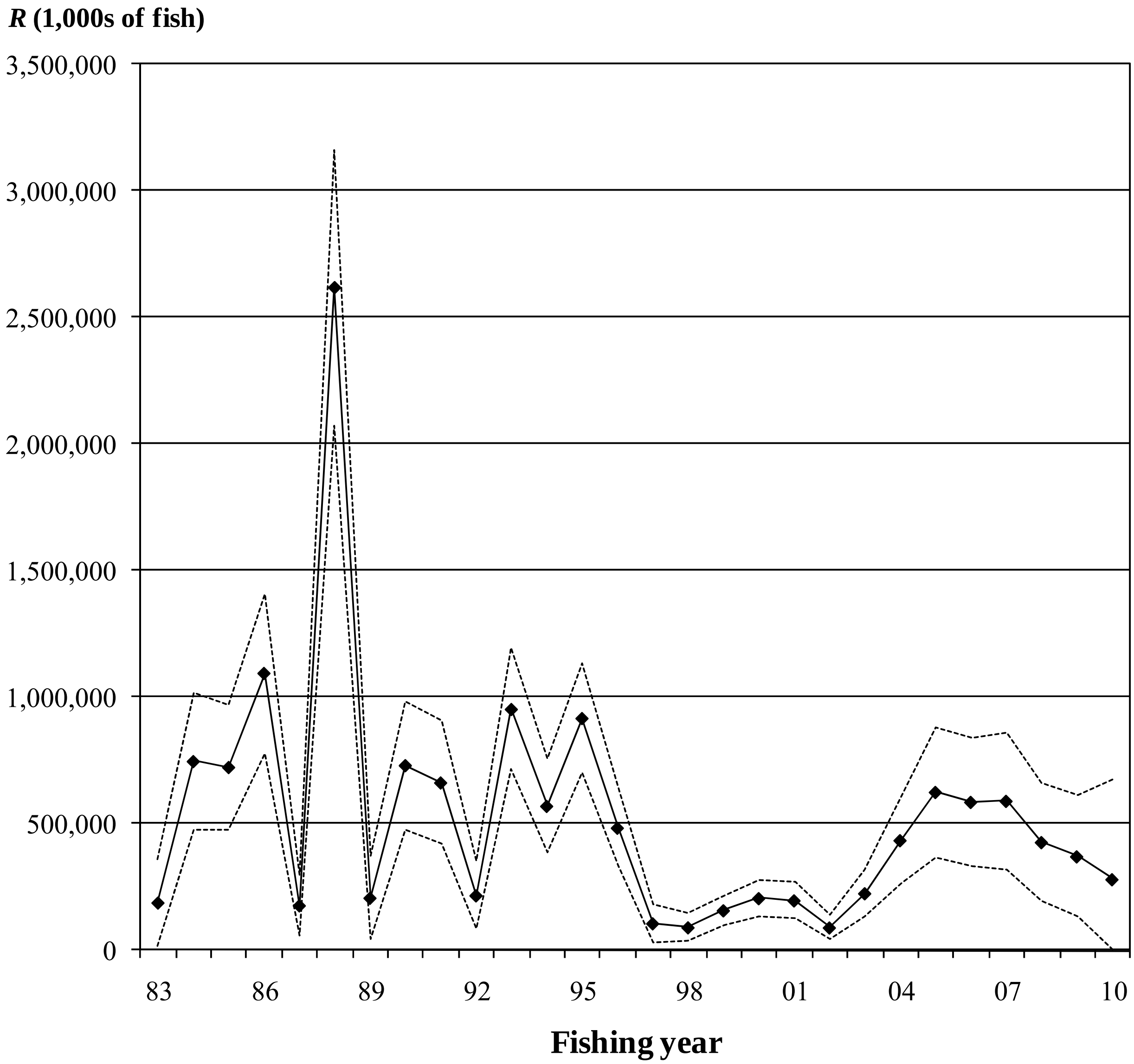
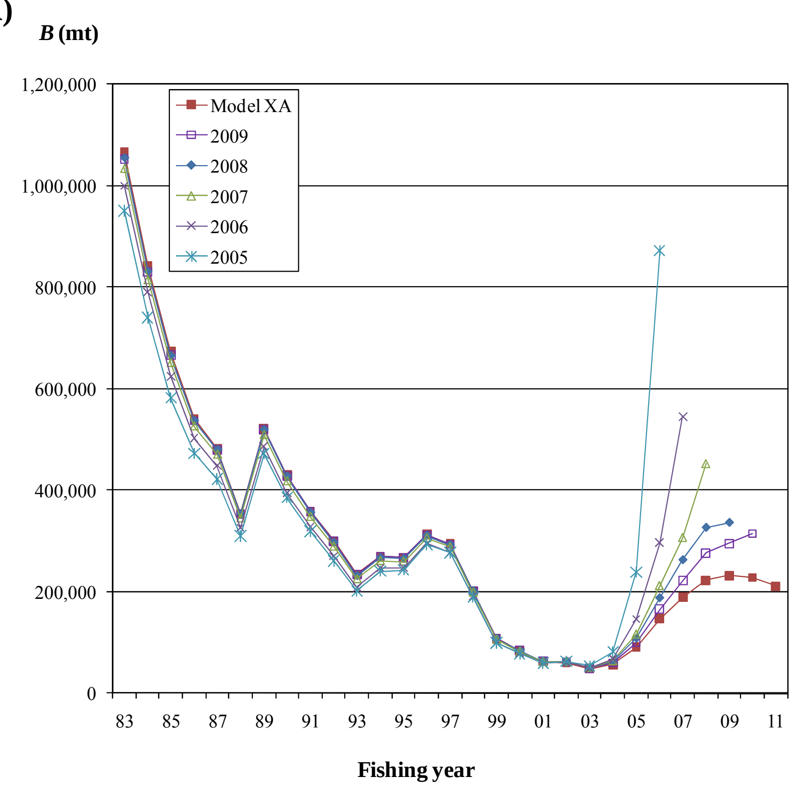



Figure 19. Estimated recruitment (age-0 fish in 1,000s, *R)* of Pacific mackerel based on Model *XA* (1983-10). A confidence interval (95% CI) is also presented as dashed lines.

(A)




(B)

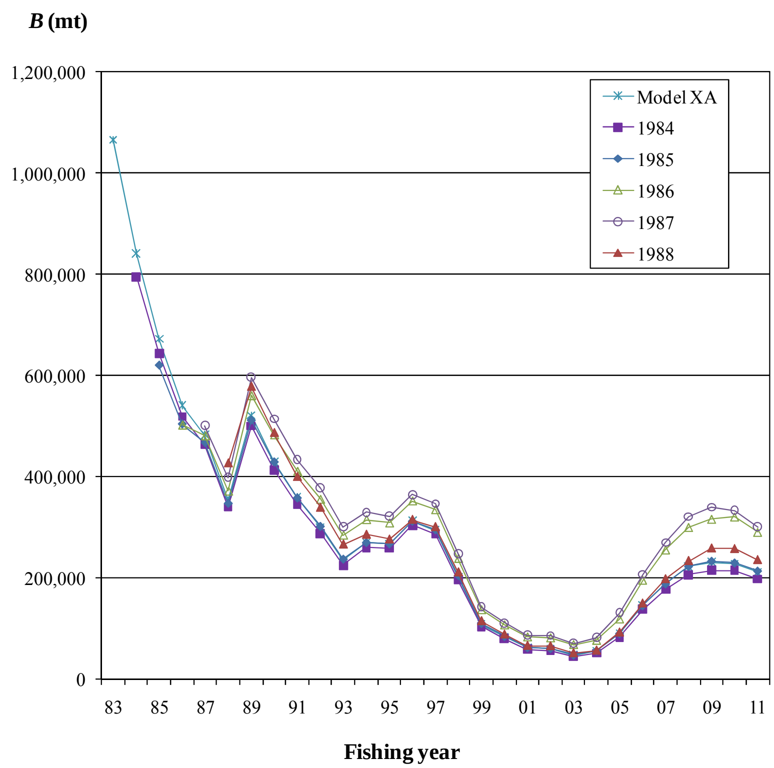



Figure 20. Estimated total stock biomass (age 1+ fish in mt, *B*) of Pacific mackerel based on a: (A) retrospective analysis that omitted one year of data in chronological order (2006-10), i.e., Model *XA*=2010; and (B) prospective analysis that started the model one year later in chronological order, i.e., Model *XA*=1983.

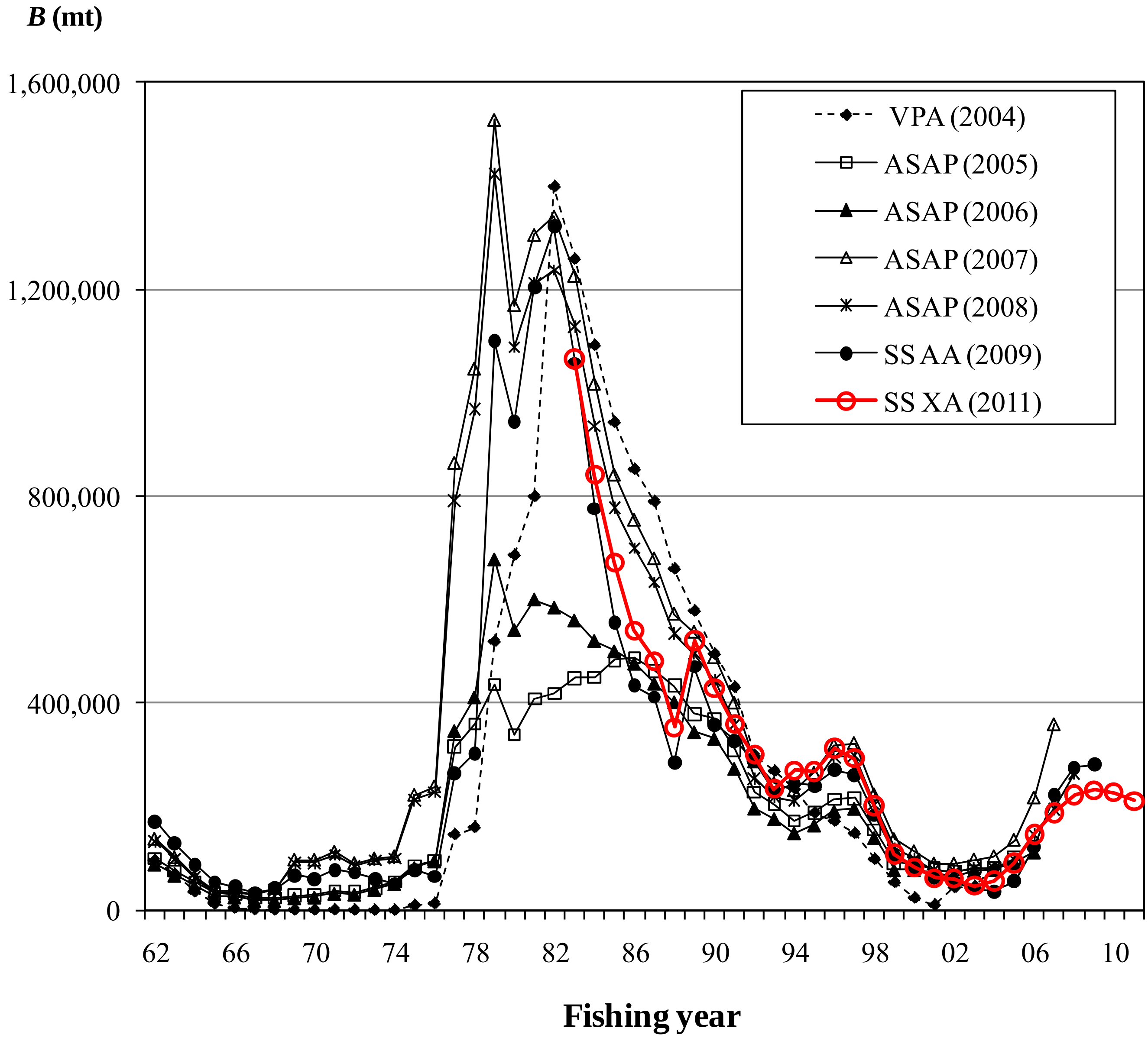



Figure 21. Estimated total stock biomass (*B* age 1+ fish in mt) of Pacific mackerel for the historical assessment period (2004-11): VPA model-based assessments from 1994-04; ASAP model-based (2005-08); and SS model-based (2009-11).

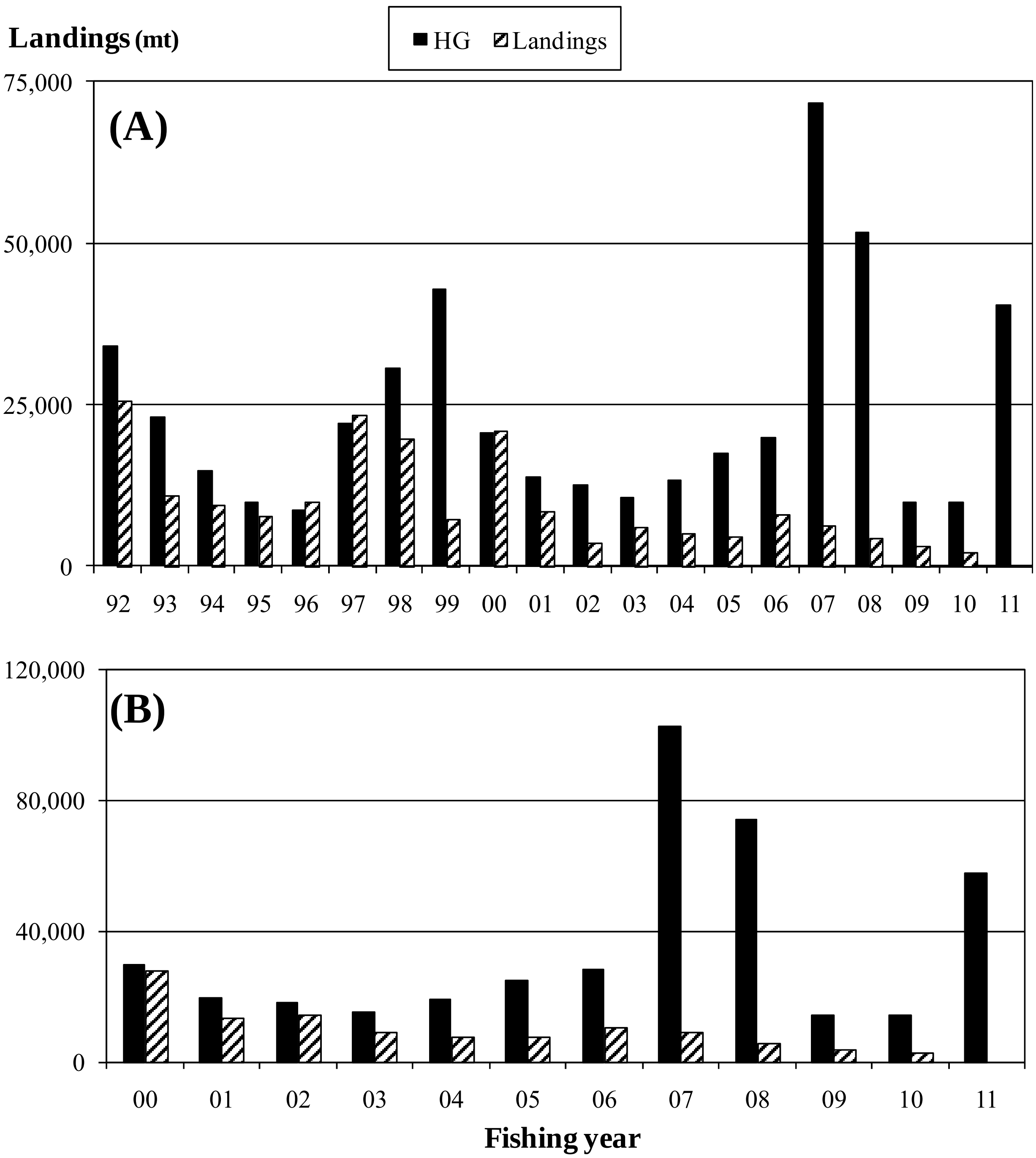



Figure 22. Harvest guideline statistics for Pacific mackerel: (A) commercial landings (USA directed fishery in mt) and quotas (HGs in mt), (1992-11); and (B) total landings (mt) and hypothetical quotas based on no USA 'Distribution' parameter in the harvest control rule. Incidental landings from Pacific Northwest fisheries are not included, but typically are limited, ranging 100 to 300 mt per year. Also, see Harvest Control Rule for USA Management in 2011-12 section.

## Appendix 1

## SS Model *XA (2011)* files

```
###############################################################################
# P. mackerel stock assessment (1983-10)
# P. R. Crone (June 2011)
# Stock Synthesis 3 (v. 3.20b) - R. Methot
# Model XA: number of fisheries = 2 / surveys = 2 / time-step = annual /
  biological distributions = age, length, and mean length-at-age /
  selectivity = age-based
#
# NOTES: ** ... ** = Pending questions and/or comments
#
```

**# STARTER FILE**

```
#
XA.dat # Data file
XA.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 (recommended)
1 #   Number of bootstrap data files to produce    ** New parameterization **
20 #  Last phase for estimation
10 #  MCMC burn-in interval
2 #   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)
-2 #  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
0.6 # Fraction for depletion denominator (e.g., 0.4)
1 #   (1-SPR) report basis: 0 = skip, 1 = (1-SPR)/(1-SPR_tgt), 2 = (1-
      SPR)/(1-SPR_MSY), 3 = (1-SPR)/(1-SPR_Btarget), 4 = raw_SPR ** If no
      Forecast, then option = 4 **
1 #   F SD report basis: 0 = skip, 1 = exploitation(Bio), 2 =
      exploitation(Num), 3 = sum(F_rates) ** If no Forecast, then option = 0
      **
1 #   F report basis: 0 = raw, 1 = F/Fspr, 2 = F/Fmsy, 3 = F/Fbtgt  ** New
      parameterization **
999 # End of file
```

```
################################################################################
# P. mackerel stock assessment (1983-10)
# P. R. Crone (June 2011)
# Stock Synthesis 3 (v. 3.20b) - R. Methot
# Model XA: number of fisheries = 2 / surveys = 2 / time-step = annual /
  biological distributions = age, length, and mean length-at-age / selectivity
  = age-based
#
# NOTES: ** ... ** = Pending questions and/or comments
#
```

# # FORECAST FILE

```
1 #   Benchmarks: 0 = skip, 1 = calculate (F_SPR, F_btgt, F_MSY) ** Related
      to Benchmark relative_F basis, Forecast, and F and SPR report basis (in
      ctl file) options **
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 - relative to B0 (e.g., 0.3)
      0.5 # Biomass target - relative to B0 (e.g., 0.5)
#     Benchmark years: begin_bio, end_bio, begin_selex, end_selex,
      begin_relative F, end_relative F (enter actual year, -999 = start_yr, 0
      = end_yr, <0 = relative end_yr)
0 0 0 0 0 0
1 #   Benchmark relative_F basis: 1 = use year range, 2 = set relative_F same
      as Forecast below
#
1 #   Forecast: 0 = none, 1 = F_SPR, 2 = F_MSY, 3 = F_Btgt, 4 = Avg_F (uses
      first-last relative_F years), 5 = input annual F scalar
1 #   Number of forecast years
1.0 # F scalar (only used for Forecast = 5)
#     Forecast years: begin_selex, end_selex, begin_relative F, end_relative
      F (enter actual year, -999 = start_yr, 0 = end_yr, <0 = relative
      end_yr)
0 0 0 0
#
1 #   Control rule method: 1 = catch = f(SSB) West Coast, 2 = F = f(SSB)
      0.5 # Control rule Biomass level (as fraction of B0, e.g. 0.40) above
      which F is constant
0.1 # Control rule Biomass level (as fraction of B0, e.g. 0.10) below which F
     is set to 0
0.75# Control rule target as fraction of F_limit (e.g., 0.75)
3 #   Number of forecast loops (1-3: fixed at 3 for now)
3 #   First forecast loop with stochastic recruitment
0 #   Forecast loop control #3 (reserved for future bells&whistles)
0 #   Forecast loop control #4 (reserved for future bells&whistles)
0 #   Forecast loop control #5 (reserved for future bells&whistles)
2015 # First year for caps and allocations (should be after years with fixed
inputs)
0 #   SD of log(realized F/target F) in forecast (set value >0.0 to cause
      active implementation error)
0 #   Do West Coast groundfish rebuilder output (0 = no, 1 = 0)
2007 #Rebuilder: first year catch could have been set to zero (Ydecl)(-1 to
      set to 1999)
2010 #Rebuilder: year for current age structure (Yinit) (-1 to set to
     endyear+1)
```

```
1 #   fleet relative F: 1 = use first-last allocation year, 2 = read
      season(row) x fleet(column) below
#     Note: that fleet allocation is used directly as average F if Forecast =
      4
2 #   Basis for forecast catch tuning and for forecast catch caps and
      allocation: 2 = dead_bio, 3 = retain_bio, 5 = dead_num, 6 = retain_num
#      Conditional input if relative F = 2 (total of 4 lines)
#      Fishery relative F: rows = seasons and columns = Fishery
#      Fishery: F1 F2 F3
# 0.1 0.1
#      Maximum total catch by fishery (-1 to have no max)
-1 -1
#      Maximum total catch by area (-1 to have no max)
-1
#      Fleet assignment to allocation group (enter group ID# for each Fishery,
0      for not included in an allocation group)
0 0
#      Conditional on >1 allocation groups (total of 3 lines)
#      Allocation fraction for each of: 0 allocation groups
#      No allocation groups
2 #    Number of forecast catch levels to input (otherwise calculate catch
       from forecast F)
2 #    Basis for input forecast catch: 2 = dead catch, 3 = retained catch, 99
       = input Hrate(F) with units that are from fishery units (note new codes
       in SSv3.20b)
#      Input fixed catch values: year, season, Fishery, catch (or F)
2011 1 1 2257
2011 1 2 100
999 # End of file
```

```
################################################################################
# Pacific mackerel stock assessment (1983-10)
# P. R. Crone (June 2011)
# Stock Synthesis 3 (v. 3.20b) - R. Methot
# Model XA: number of fisheries = 2 / surveys = 2 / time-step = annual /
  biological distributions = age, length, and mean length-at-age / selectivity
  = age-based
#
```

# # 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: Selectivity/Catchability
2 #    Blocks in design 1
#
1983 1989 1990 2011 # 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
12 #   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)
0 0.07 0.25 0.47 0.73 1 1 1 1 1 1 1 1 # Maturity-at-age (proportion) for
       option = 3, i.e., 'Accumulator age' + 1 **;
1 #    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)
0 #    Hermaphroditism option: 0 = none, 1 = invoke female to male transition
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, 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 70 45 0 -1 0 3 0 0 0 0 0 0 0 # VB_L_Amax  (Length-at-age = 12)
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
0.0001 0.5 0.01 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
#
# 1 # Custom environment (MG) parameterization
#
# 1 # Custom block (MG) parameterization ** No time block for growth
      parameterization **
#     Low High Initial Prior_mean Prior_type SD Phase
# -5 5 0 0 -1 0 3 # VB_L_Amin: (1962-89)
# -5 5 0 0 -1 0 3 # VB_L_Amin: (1990-10)
# -5 5 0 0 -1 0 3 # VB_L_Amax: (1962-89)
# -5 5 0 0 -1 0 3 # VB_L_Amax: (1990-10)
# -5 5 0 0 -1 0 3 # VB_K: (1962-89)
# -5 5 0 0 -1 0 3 # VB_K: (1990-10)
#
#     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
1978 # Start year for recruitment devs
2009 # 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
0.0001 5 0.1 0 -1 0 1 # Initial F (F1)
0.00001 5 0.001 0 -1 0 -1 # Initial F (F2)
#
# CATCHABILITY (q) PARAMETERS
=============================================================================
#
#     Catchability (q) parameterization
#     Columns: Do den_dep power (0 = off and survey is proportional to
      abundance, 1 = add parameter for non-linearity); Do env_link (0 = off,
      1 = add parameter for env effect on q);
#     Do extra SD (0 = off, 1 = add parameter for additive constant to input
      SE in ln space); q_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 - parm_rand_dev,
#     4 = ln(q)+set of devs about q for index_yr-1 - parm_rand_walk)
0 0 0 0 # F1 = COM (USA commercial and Mexico commercial)
0 0 0 0 # F2 = REC (USA recreational)
0 0 0 0 # S1 = CPFV
0 0 0 0 # S2 = CRFS
#     q parameters (if any)
```

```
#     Low High Initial Prior_mean Prior_type SD Phase
# -1 1 0.0001 0 -1 99 3 # ln(q) - 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
0 0 0 0 # S2
#
#     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)
20 0 0 0 # S2 (double-normal distribution)
#
#     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)
-20 15 1 0 -1 0 4 0 0 0 0 0 0 0 # P_1 (1983-10, peak size)
-20 15 -5 0 -1 0 -4 0 0 0 0 0 0 0 # P_2 (1983-10, top logistic)
-20 15 4 0 -1 0 4 0 0 0 0 0 0 0 # P_3 (1983-10, ascending limb width - exp)
-20 15 1.5 0 -1 0 -4 0 0 0 0 0 0 0 # P_4 (1983-10, descending limb width -
     exp)
-20 20 -1 0 -1 0 4 0 0 0 0 0 0 0 # P_5 (1983-10, initial S - at first age
     bin)
-20 20 15 0 -1 0 -4 0 0 0 0 0 0 0 # P_6 (1983-10, final S - at last age bin)
#
#     F2 (double-normal)
-10 15 2 0 -1 0 4 0 0 0 0 0 0 0 # P_1 (1983-10, peak size)
-10 15 -4 0 -1 0 4 0 0 0 0 0 0 0 # P_2 (1983-10, top logistic)
-15 15 -1 0 -1 0 4 0 0 0 0 0 0 0 # P_3 (1983-10, ascending limb width - exp)
-20 15 -4 0 -1 0 4 0 0 0 0 0 0 0 # P_4 (1983-10, descending limb width - exp)
-25 15 -5 0 -1 0 4 0 0 0 0 0 0 0 # P_5 (1983-10, initial S - at first age
    bin)
-20 15 -2 0 -1 0 4 0 0 0 0 0 0 0 # P_6 (1983-10, final S - at last age bin)
#
#     S1 (mirror F2) ** no additional parameter lines needed **
#
#     S2 (double-normal)
-10 15 2 0 -1 0 4 0 0 0 0 0 0 0 # P_1 (1983-10, peak size)
-10 15 -4 0 -1 0 4 0 0 0 0 0 0 0 # P_2 (1983-10, top logistic)
-15 15 -1 0 -1 0 4 0 0 0 0 0 0 0 # P_3 (1983-10, ascending limb width - exp)
-20 15 -4 0 -1 0 4 0 0 0 0 0 0 0 # P_4 (1983-10, descending limb width - exp)
-25 15 -5 0 -1 0 4 0 0 0 0 0 0 0 # P_5 (1983-10, initial S - at first age
      bin)
-20 15 -2 0 -1 0 4 0 0 0 0 0 0 0 # P_6 (1983-10, final S - at last age bin)
```

```
#
# 1 # Conditional: custom Sel_env parameterization ** No time block for
      selectivity parameterization **
#     Low High Initial Prior_mean Prior_type SD Phase
# -2 2 0 0 -1 99 -2
#
# 1 # Conditional: custom Sel-block parameterization
#     F1 S time blocks (block design 1) ** For age-based S **
#     Low High Initial Prior_mean Prior_type SD Phase
#
# 1 # Conditional: selparm trends
# 1 # Conditional: for selparm_dev_Phase
# 1 # Conditional: env/block/dev adjust method (1 = standard, 2 = logistic
      transition to keep in base parm bounds, 3 = standard with no bound
      check)
#
#     Tag loss and reporting parameterization
0 #   TG_custom: 0 = no read, 1 = read if tags exist
#     Conditional if no tag parameters
#     Low High Initial Prior_mean Prior_type SD Phase Env_var Use_dev
      Dev_minyr Dev_maxyr Dev_stddev Block_def Block_type
# -6 6 1 1 2 0.01 -4 0 0 0 0 0 0 0
#
# LIKELIHOOD COMPONENT PARAMETERS
=============================================================================
#
1 #   Variance and sample size/effective sample size adjustments (by
      fleet/survey): (0/1)
#     F1 F2 S1 S2
0 0 0 0 # constant (added) to survey CV
0 0 0 0 # constant (added) to discard CV
0 0 0 0 # constant (added) to body weight CV
1 1 1 1 # scalar (multiplied) to length distribution sample size (effective
     ss)
1 1 1 1 # scalar (multipled) to age distribution sample size (effective ss)
1 1 1 1 # scalar (multiplied) to size-at-age distribution sample size
     (effective ss)
#
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
#
#     Surveys
# 1 3 1 0 1 # Survey off = S1
```

```
# 1 4 1 0 1 # Survey off = S2
#
#     Length distributions
4 1 1 0 1 # Length distribution off = F1
#
#     Age distributions
# 5 1 1 0 1 # Length distribution off = F1
#
#     Mean size-at-age distributions
# 7 1 1 0 1 # Size-at-age distribution off = F1
#
#     Equilibrium catch
9 1 1 0 1 # Equilibrium catch off = F1
9 2 1 0 1 # Equilibrium catch off = F2
#
#     Priors
11 1 1 0 1 # Priors = off
#
0 #   SD reporting option: (0/1)
999 # End of file
```

```
################################################################################
# Pacific mackerel stock assessment (1983-10)
# P. R. Crone (June 2011)
# Stock Synthesis 3 (v. 3.20b) - R. Methot
# Model XA: number of fisheries = 2 / surveys = 2 / time-step = annual /
  biological distributions = age, length, and mean length-at-age /
  selectivity = age-based
#
```

# # INPUT DATA FILE

```
#
1983 # Start year
2010 # 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)
2 #   Number of 'surveys' (CPUE Indices: annual-based)
#     S1 = CPFV
#     S2 = CRFS
#
1 #   Number of areas (populations)
      COM%REC%CPFV%CRFS
0.5 0.5 0.5 0.5 # Fishery/survey timing within time block
1 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
12 #  Number of ages (accumulator age)
#     Catch: initial (annual) 'equilibrium' catch (mt)
100 100
#     Number of catch records (lines)
28
#     Catch time series (biomass in mt): Columns=fisheries, year, season
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
9856.14     372.11      2006  1
8426.80     310.00      2007  1
5084.47     280.00      2008  1
3182.60     267.00      2009  1
2256.99     100.00      2010  1
#
#     Number of observations (lines) for all surveys (indices)
35
#     Columns: Fishery/Survey, Units (0=numbers, 1=biomass, 2=F), Error type
      (-1=normal, 0=lognormal), >0=t-dist. (df = input value)
1 1 0 # F1 = COM (USA commercial and Mexico commercial)
2 1 0 # F2 = REC (USA recreational)
3 0 0 # S1 = CPFV
4 0 0 # S2 = CRFS
#
#     Columns: Year, Season, Survey, Observation, Error
1983  1     3     91.82 0.30
1984  1     3     101.23      0.30
1985  1     3     77.63 0.30
1986  1     3     60.91 0.30
1987  1     3     41.32 0.00
1988  1     3     29.28 0.30
1989  1     3     40.64 0.30
1990  1     3     45.04 0.30
1991  1     3     49.95 0.30
1992  1     3     37.06 0.30
1993  1     3     44.49 0.30
1994  1     3     42.05 0.30
1995  1     3     37.36 0.30
1996  1     3     40.95 0.30
1997  1     3     24.98 0.30
1998  1     3     12.89 0.30
1999  1     3     7.34  0.30
2000  1     3     14.03 0.30
2001  1     3     11.19 0.30
2002  1     3     8.88  0.30
2003  1     3     5.56  0.30
2004  1     3     9.75  0.30
2005  1     3     16.70 0.30
2006  1     3     15.95 0.30
2007  1     3     22.64 0.30
2008  1     3     31.73 0.30
2009  1     3     24.45 0.30
2010  1     3     12.00 0.30
2004  1     4     0.0419      0.30
2005  1     4     0.0576      0.30
2006  1     4     0.0551      0.30
2007  1     4     0.0640      0.30
2008  1     4     0.0567      0.30
2009  1     4     0.0532      0.30
2010  1     4     0.0324      0.30
#
#     Discard parameterization
```

```
0 #   Number of Fisheries with discard
#     Placeholder for discard units (1 = same as catch units, 2 = fraction, 3
      = number)
#     Placeholder for Fishery discard error type (>0 = df of t-dist - read CV
      below, 0 = normal with CV, -1 = normal with se, -2 = lognormal)
#     Columns: Fishery, Units, Error type
0 #   Number of discard observations (lines)
#     Placeholder for discard lines
#     Columns: Year, Season, Fishery, Observation, Error
#
#     Mean body weight parameterization
0 #   Number of mean body weight observations (lines)
100 # df for t-dist - not conditional, i.e., needs number even if no mean
      body weight observations
#
#     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 #   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/Survey 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
#
59 #  Number of fishery length distribution observations (lines) ** Length
      distributions for Fishery 1 are not used (included for
      provisional/comparative purposes only **
#     Length distributions (1983-10) - annual (percent)

#     Length distributions: Columns=year, season, fishery/survey, gender,
      partition, sample size, length bin observations (in numbers)
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
     0.00000    0.00000    0.00000    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
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     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
     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
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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
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
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     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
     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     28.9  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
     0.00138     0.00000     0.01107     0.04841     0.09544     0.09820
     0.05394     0.04149     0.03873     0.04149     0.07746     0.07884
     0.08990     0.03320     0.00830     0.00968     0.00968     0.03596
     0.04149     0.05256     0.04426     0.03596     0.02213     0.01660
     0.00553     0.00553     0.00138     0.00138     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
2009 1     1     0     0     16.9  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     0.00474     0.05924     0.12085     0.06872
     0.02370     0.01422     0.03318     0.07583     0.10664     0.11137
     0.10664     0.06635     0.01896     0.00237     0.02133     0.01185
     0.02133     0.01422     0.01659     0.04739     0.01185     0.01659
     0.00948     0.01185     0.00474     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
2010 1     1     0     0     11.9  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     0.01342     0.08725     0.14094
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     0.10738     0.06040     0.05369     0.08389     0.06376     0.04698
     0.05034     0.03356     0.06711     0.02685     0.02013     0.03691
     0.03356     0.00671     0.01678     0.01342     0.02349     0.00671
     0.00671     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     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     2     0     0     81.5  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
     0.00000     0.00000     0.00000     0.00049     0.00000     0.00098
     0.00196     0.00294     0.00491     0.00442     0.00736     0.01374
     0.02355     0.04563     0.04514     0.06035     0.08881     0.10893
     0.13935     0.11237     0.10059     0.07704     0.06035     0.03778
     0.03189     0.01079     0.00883     0.00491     0.00294     0.00098
     0.00049     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00049     0.00000     0.00000     0.00049
     0.00000     0.00000     0.00147
1986 1     2     0     0     238.1 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     0.00000     0.00000     0.00034     0.00118     0.00101
     0.00084     0.00252     0.00403     0.01209     0.03292     0.05107
     0.06971     0.07845     0.06971     0.07324     0.07979     0.09306
     0.10297     0.09525     0.07593     0.06165     0.04569     0.02217
     0.01361     0.00521     0.00353     0.00286     0.00084     0.00017
     0.00000     0.00017     0.00000     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     2     0     0     174.2 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     0.00046     0.00023
     0.00436     0.01263     0.02067     0.02067     0.01883     0.02825
     0.04892     0.08222     0.11346     0.11805     0.09348     0.08199
     0.06270     0.05926     0.05489     0.04984     0.05397     0.04318
     0.01929     0.00666     0.00299     0.00138     0.00092     0.00023
     0.00000     0.00023     0.00000     0.00000     0.00000     0.00000
     0.00023     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
1988 1     2     0     0     156.2 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     0.00026
     0.00051     0.00000     0.00154     0.00179     0.00307     0.00435
     0.00512     0.00564     0.00948     0.01101     0.01998     0.01895
     0.03817     0.06199     0.09606     0.11885     0.11194     0.09887
     0.08171     0.05815     0.04406     0.04073     0.05507     0.05072
     0.03765     0.01230     0.00538     0.00205     0.00282     0.00154
     0.00026     0.00000     0.00000     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     2     0     0     147.1 0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00190     0.00027     0.00299
     0.00653     0.00299     0.00625     0.00381     0.00489     0.00299
     0.00218     0.01876     0.03915     0.05791     0.06770     0.03752
     0.04160     0.04568     0.05492     0.07667     0.08510     0.06090
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     0.04160     0.04133     0.05546     0.05356     0.06362     0.05057
     0.03834     0.01767     0.00625     0.00598     0.00245     0.00054
     0.00027     0.00054     0.00027     0.00000     0.00082     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     6.4   0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0.01875     0.01875     0.04375     0.0625      0.1   0.075
     0.075 0.03125     0.04375     0.01875     0.05  0.05625     0.0625
     0.0875      0.05625     0.0875      0.05  0.0125      0.025 0.0125
     0     0.00625     0     0     0     0     0     0     0     0     0
     0     0.00625     0     0     0     0     0     0
1993 1     2     0     0     31.44 0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0.00636     0.00636     0.00891     0.03053     0.03308
     0.04453     0.06997     0.06234     0.06489     0.04453     0.04198
     0.05344     0.0458      0.0458      0.08906     0.1056      0.09924
     0.08015     0.03944     0.01018     0.00382     0.00254     0
     0.00127     0     0     0     0     0.00127     0     0.00254     0
     0.00127     0     0     0     0     0     0.00509
1994 1     2     0     0     11.56 0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0.00346
     0     0.00692     0     0     0.00692     0.00346     0.00692
     0.00692     0.00692     0.02768     0.0173      0.02422     0.06574
     0.08304     0.0346      0.02768     0.0519      0.10727     0.13149
     0.19723     0.05536     0.08997     0.03806     0     0     0     0
     0     0     0     0.00346     0.00346     0     0     0     0     0
     0     0     0     0     0
1995 1     2     0     0     12.72 0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0.00314     0.00629     0.01887     0.02201     0.01258
     0.03459     0.03459     0.03774     0.06918     0.05975     0.04717
     0.0566      0.06289     0.05031     0.09434     0.08491     0.10692
     0.11006     0.0566      0.02201     0.00629     0     0     0     0
     0     0     0.00314     0     0     0     0     0     0     0     0
     0     0     0
1996 1     2     0     0     33.48 0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0.00119     0     0     0
     0     0     0.00597     0.00597     0.00717     0.0227      0.02031
     0.0227      0.03465     0.02389     0.02867     0.04659     0.02987
     0.0454      0.03106     0.03345     0.04062     0.05257     0.09916
     0.14815     0.14815     0.08244     0.04898     0.01314     0.00119
     0.00239     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0.00358
1997 1     2     0     0     47.24 0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0.00254     0.00085     0.00254     0.00593     0.01439     0.02794
     0.0398      0.02371     0.0398      0.04911     0.06181     0.07282
     0.07621     0.06097     0.04742     0.0525      0.06097     0.05673
     0.07959     0.08129     0.07028     0.03133     0.01524     0.00847
     0.0127      0.00339     0     0     0     0     0     0.00085     0
     0     0     0     0     0     0     0.00085     0
1998 1     2     0     0     24.44 0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0.00164
     0     0     0     0.00327     0.00491     0.00327     0.00818
     0.00491     0.03928     0.04746     0.05237     0.05728     0.05237
     0.03764     0.02782     0.05074     0.0671      0.09984     0.13421
```

```
     0.10802     0.10802     0.05892     0.02128     0.00655     0
     0.00164     0     0.00164     0     0     0     0     0     0     0
     0     0     0     0     0     0     0.00164
1999 1     2     0     0     24.68 0     0     0     0     0     0     0
     0     0     0     0.00162     0     0     0.00162     0     0     0
     0     0     0.00162     0     0.00324     0     0.0081      0.01621
     0.01783     0.02269     0.01945     0.02755     0.02917     0.03404
     0.05673     0.05348     0.11669     0.14263     0.14425     0.10049
     0.07293     0.05835     0.047 0.01621     0.00648     0     0     0
     0     0.00162     0     0     0     0     0     0     0     0     0
     0     0     0     0
2000 1     2     0     0     15.6  0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0
     0.00256     0.00513     0.00256     0.01026     0.01538     0.02564
     0.03077     0.03333     0.02308     0.03846     0.0641      0.08718
     0.02821     0.02564     0.04359     0.08205     0.12821     0.11282
     0.07949     0.06154     0.0641      0.02308     0.01026     0.00256
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0
2001 1     2     0     0     16.52 0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0
     0.00242     0.00484     0.00484     0.00726     0.00969     0.01937
     0.01695     0.02179     0.04358     0.07022     0.05811     0.08959
     0.05569     0.05085     0.04358     0.10412     0.1138      0.10654
     0.07022     0.07264     0.01695     0.01211     0.00242     0.00242
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0
2002 1     2     0     0     20.88 0     0     0     0     0     0     0
     0     0     0     0.00192     0     0     0     0     0     0     0
     0.00192     0.00192     0.00575     0.00383     0.03257     0.02299
     0.0364      0.04981     0.08621     0.0977      0.07854     0.06897
     0.05939     0.05939     0.04789     0.06322     0.04789     0.0613
     0.05364     0.04215     0.03831     0.02682     0.00575     0.00383
     0     0     0     0     0.00192     0     0     0     0     0     0
     0     0     0     0     0     0     0
2003 1     2     0     0     21.12 0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0
     0.00379     0.00379     0.00568     0.01894     0.04545     0.0322
     0.04545     0.06439     0.05682     0.09091     0.05682     0.05303
     0.04735     0.0303      0.02273     0.02841     0.03598     0.04735
     0.09659     0.08712     0.07008     0.02841     0.01515     0.00189
     0.00379     0     0     0     0.00189     0     0     0     0     0
     0     0     0     0     0     0     0.00189     0.00379
2004 1     2     0     0     20.68 0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0.00774     0.0058      0.02901     0.02515     0.05029     0.09284
     0.0619      0.03868     0.06383     0.05029     0.07737     0.0677
     0.03482     0.03288     0.03675     0.02708     0.05222     0.04642
     0.05996     0.08124     0.03288     0.01934     0     0.00193
     0.00193     0.00193     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0
2005 1     2     0     0     21.88 0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0
     0.00366     0.02742     0.06033     0.08044     0.08044     0.08044
     0.06033     0.0585      0.0841      0.08775     0.06033     0.10055
     0.06399     0.04936     0.02742     0.02194     0.00914     0.00366
     0.00548     0.00731     0.00731     0.00731     0.00548     0.00183
```

0 0 0 0 0 0 0 0 0 0 0 0
0.00183 0 0.00183 0.00183 0 0
2006 1 2 0 0 23.76 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0.00168 0.00168 0
0.00168 0 0.00337 0.01852 0.05387 0.08754
0.09091 0.08754 0.08923 0.09596 0.08754 0.07912
0.08249 0.05219 0.03872 0.02862 0.01684 0.00842
0.0202 0.0101 0.00505 0.01178 0.01178 0.00842
0.00505 0.00168 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
2007 1 2 0 0 44.28 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0.0009
0.0009 0.00813 0.02529 0.03071 0.04426 0.07317
0.07588 0.1084 0.11292 0.11382 0.08401 0.07859
0.04246 0.04246 0.03342 0.028 0.01897 0.01265
0.00994 0.01536 0.01265 0.00903 0.00994 0.00452
0.0009 0.0009 0 0.0009 0 0 0.0009 0
0 0 0 0 0 0 0 0 0 0
2008 1 2 0 0 43.32 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0.00185
0.00646 0.01939 0.02308 0.01939 0.01385 0.02124
0.02862 0.05171 0.05448 0.0988 0.13019 0.12742
0.06925 0.06464 0.04894 0.03047 0.03509 0.02216
0.03601 0.02124 0.01847 0.02862 0.01754 0.00369
0.00369 0 0.00277 0 0.00092 0 0 0 0
0 0 0 0 0 0 0 0 0
2009 1 2 0 0 37.08 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0.00108
0.00647 0.0205 0.01942 0.01618 0.01834 0.03883
0.06257 0.10572 0.12729 0.11758 0.0863 0.07875
0.03668 0.03776 0.0302 0.02805 0.03344 0.04207
0.03452 0.0205 0.01402 0.00863 0.00755 0.00216
0.00216 0.00108 0 0.00108 0 0 0 0.00108
0 0 0 0 0 0 0 0 0 0
2010 1 2 0 0 10.96 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0.00365 0.01095
0.01095 0.00365 0.0073 0.00365 0.0219 0.0438
0.08759 0.09489 0.16788 0.09854 0.08759 0.07664
0.05474 0.0365 0.03285 0.0146 0.0146 0.03285
0.0365 0.01095 0.01095 0.0146 0.01095 0.01095
0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
2004 1 4 0 0 47.0 0.00000 0.00000 0.00000
0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
0.00000 0.00000 0.00000 0.00170 0.00765 0.01020
0.00425 0.01190 0.03571 0.03741 0.04592 0.06293
0.05952 0.06633 0.07738 0.07823 0.06207 0.06548
0.05867 0.05187 0.03316 0.02551 0.01871 0.01531
0.01531 0.01531 0.01190 0.01446 0.02976 0.03997
0.02381 0.01020 0.00595 0.00085 0.00085 0.00000
0.00000 0.00000 0.00000 0.00085 0.00000 0.00000
0.00000 0.00000 0.00000 0.00000 0.00085 0.00000
0.00000 0.00000 0.00000
2005 1 4 0 0 62.4 0.00000 0.00000 0.00000
0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
0.00064 0.00128 0.00064 0.00064 0.00256 0.00577
0.00384 0.00512 0.01217 0.02691 0.07047 0.10570

```
     0.12748     0.10955     0.11211     0.10506     0.08520     0.06470
     0.04741     0.04100     0.03139     0.01217     0.00897     0.00320
     0.00384     0.00192     0.00256     0.00128     0.00064     0.00128
     0.00128     0.00064     0.00128     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00128
2006 1     4     0     0     70.8  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00057     0.00170     0.00170     0.00339
     0.00565     0.00735     0.00904     0.02374     0.04240     0.07801
     0.11702     0.14302     0.14245     0.10797     0.08423     0.05596
     0.03392     0.03561     0.02148     0.01357     0.00791     0.01018
     0.00848     0.00565     0.00396     0.00283     0.00565     0.00339
     0.00848     0.00791     0.00452     0.00226     0.00000     0.00000
     0.00000     0.00000     0.00000     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     4     0     0     53.2  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00150     0.00000     0.00150
     0.00301     0.00451     0.00376     0.02404     0.03681     0.03456
     0.06612     0.06536     0.06912     0.12923     0.13223     0.10518
     0.08790     0.05334     0.04808     0.02930     0.02029     0.01803
     0.00902     0.00977     0.00751     0.00601     0.01052     0.00601
     0.00601     0.00526     0.00376     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     0.00000     0.00000
     0.00000     0.00000     0.00150
2008 1     4     0     0     36.6  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     0.00109     0.00000
     0.00000     0.01530     0.04809     0.05355     0.08087     0.06448
     0.06995     0.06011     0.06011     0.07213     0.07760     0.06230
     0.07541     0.06885     0.04044     0.02951     0.01749     0.01421
     0.01421     0.01202     0.01421     0.01311     0.00765     0.00656
     0.00765     0.00656     0.00437     0.00109     0.00000     0.00000
     0.00000     0.00109     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
2009 1     4     0     0     34.2  0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00117     0.00000     0.00000     0.00000     0.00467     0.00117
     0.00234     0.00467     0.01636     0.05257     0.06308     0.05841
     0.07009     0.10280     0.11682     0.10047     0.07126     0.08995
     0.08061     0.05023     0.03388     0.01986     0.00467     0.00234
     0.00584     0.01285     0.00935     0.01051     0.00467     0.00117
     0.00350     0.00117     0.00234     0.00000     0.00117     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
     0.00000     0.00000     0.00000
2010 1     4     0     0     3.0   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     0.01316
     0.00000     0.00000     0.01316     0.01316     0.01316     0.03947
     0.06579     0.01316     0.14474     0.13158     0.17105     0.06579
     0.06579     0.03947     0.01316     0.03947     0.01316     0.03947
```

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      0.03947     0.01316     0.01316     0.01316     0.01316     0.01316
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
      0.00000     0.00000     0.00000     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 ('Accumulator age' (12) + 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 # 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 # Age bin SD
#
28 #  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
#
#     Fishery age distributions (1983-10) - 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)
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
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   28.92 0.27  0.31  0.16  0.18
      0.06 0.02 0.00 0.00 0.00
2009  1    1    0    0    1    -1   -1   16.88 0.31  0.45  0.10  0.09
      0.04 0.01 0.00 0.00 0.00
2010  1    1    0    0    1    -1   -1   11.92 0.07  0.58  0.22  0.08
      0.04 0.01 0.00 0.00 0.00
#
#     Fishery mean length-at-age distributions
28 #  Number of mean length-at-age observations (lines)
#      Mean length-at-age distributions (1983-10) - annual (cm)
#     Mean length-at-age distributions: Columns=year, season, fishery/survey,
      gender, partition, ageing error, sample size (nominal only), mean
      length-at-age observations (in cm), mean length-at-age sample sizes
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
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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
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     20.44 25.77 27.59 34.54 37.11 38.64
      39.00 -1.00 -1.00 7.84000     9.04000     4.56000     5.12000
      1.84000     0.44000     0.08000     0.00000     0.00000
2009  1     1     0     0     1     1     20.57 26.73 31.19 36.14 38.29 40.33
      42.00 -1.00 -1.00 5.16000     7.68000     1.68000     1.48000
      0.68000     0.12000     0.08000     0.00000     0.00000
```

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2010  1     1     0     0     1     1     20.60 23.26 29.03 34.04 37.00 38.75
      37.00 -1.00 -1.00 0.80000     6.88000     2.60000     0.96000
      0.48000     0.16000     0.04000     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
```

# Pacific Mackerel

# STAR Panel Meeting Report

NOAA / Southwest Fisheries Science Center
La Jolla, California
May 2-5, 2011

**STAR Panel Members:**
André Punt Chair, SSC, Univ. of Washington
John Casey, CIE, Cefas
Jonathan Deroba, NMFS, Northeast Fisheries Science Center

**Pacific Fishery Management Council (Council) Representatives:**
Briana Brady, CPSMT, CDFG
David Haworth, CPSAS
Kerry Griffin, Council Staff

**Pacific Mackerel Stock Assessment Team**:
Paul Crone, NMFS, SWFSC
Kevin Hill, NMFS, SWFSC
Jenny McDaniel, NMFS, SWFSC
Kirk Lynn, CDFG

**1) Overview**

The Pacific Mackerel STAR Panel (Panel) met at the Southwest Fisheries Science Center, La Jolla, CA, Laboratory from May 2-5, 2011 to review a draft assessment by the Stock Assessment Team (STAT) for Pacific Mackerel. Dr. Carlos Garza (SWFSC, SSC), an original member of the Panel, was unable to make the meeting owing to illness. Introductions were made (see list of attendees, Appendix 1), and Mr. Kerry Griffin (Council Staff) reviewed the Terms of Reference for CPS assessments with respect to how the STAR Panel would be conducted. Draft assessment documents, model input and output files, and extensive background material (previous assessments, previous STAR Panel reports, SSC statements, etc.) were provided to the Panel in advance of the meeting on an 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 led the presentation on the draft assessment. Juan Zwolinski provided the Panel with an overview of the acoustic-trawl surveys for pelagic species conducted by the Advanced Survey Technologies group at the SWFSC, and Ed Weber outlined models to predict the presence/absence of Pacific mackerel larvae off the U.S. and Mexican west coasts. The Panel welcomed the latter two presentations, noting that a lack of a synoptic survey was a major deficiency in this and previous assessments of Pacific mackerel.

The last assessment of Pacific mackerel in May 2009 was conducted using Stock Synthesis (SS). Prior to 2009, the assessment of Pacific mackerel was based on the ASAP framework. The 2009 assessment was based on a single index of relative abundance using Commercial Passenger Fishing Vessel (CPFV) data. A base (AA) and an alternative (AB) model were developed. The base model was provided to the Council for decision making, and the 2009 STAR Panel recommended that the AB model represented an alternative plausible view of the situation, but that there was no direct evidence (except model fit) to support it.

The 2011 Panel focused on identifying a model that: (a) fitted all the available data sources (index, recreational fishery length, and commercial fishery age and length-at-age data) adequately for the years included in the assessment; and (b) which did not invoke assumptions regarding changes in selectivity and catchability that cannot be justified on *a priori* grounds. The Panel and STAT agreed on a base model that includes two fisheries (commercial and recreational), two indices (CPFV and California Recreational Fisheries Survey [CRFS]), and starts the assessment in 1983 after which growth appears to have been stable. This base model provided adequate fits to the available data and the Panel and the STAT agreed that this model represents the best available science regarding the abundance and trends for Pacific mackerel. However, the results from this assessment, including values for the Overfishing Level (OFL) and Harvest Guideline (HG), are very sensitive to model specifications and, consistent with past assessment models, there is evidence for a strong retrospective bias pattern. The Panel recommended that the PFMC and its SSC take account of this sensitivity when making decisions regarding ABCs and catch levels.

The extreme sensitivity observed highlights the critical need for a synoptic survey that is able to provide estimates of absolute abundance for Pacific mackerel. The Panel noted that the acoustic-trawl surveys should be able to provide such estimates. However, the current estimates of abundance from the acoustic-trawl surveys are very imprecise primarily because of relatively low sampling intensity. Furthermore, the estimates from these surveys may not adequately represent the true extent of inter-annual changes in stock abundance because they do not cover the entire range of the stock. The Panel therefore strongly supported efforts to increase survey sampling and for the surveys to cover the entire range of the stock off the west coast of North America (Canada, US, and Mexico).

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. The SWFSC staff were once again thanked for their excellent hospitality and for the meeting facilities.

**2) Discussion and Requests Made to the STAT during the Meeting**

The STAT first applied SS using the same model specifications and data as the 2009 base model (model AA [2009]). The STAT then showed results for models in which the software version was changed (model AA [2011]), the 2009 age, length, and length-at-age data were added (model A), 'new' historical length-frequency data for the CPFV fleet (1975-78; 1985-89) were added (model B), and a new CPUE index based on the CRFS data was added (model C1). The draft assessment document provided full diagnostics for model C1. The STAT noted a preference for a 'robust' (simple) model and highlighted model F (provided to the Panel as supplementary material on the first day of the meeting) as the preferred candidate base model. In model F, the weights-at-age were set to the empirical weights-at-age, the recreational and commercial fisheries were pooled into a single fishery, and the model was fitted to the commercial age-composition data along with the CPFV and CRFS indices.

**Monday Requests**

*A. Request*: Obtain the CPFV length-composition data for the recreational fisheries from the Marine Recreational Fisheries Statistic Survey (MRFSS)-CRFS data set (1992-2010). Fit model C1 to this alternative data set.
*Rationale*: The length frequencies may differ among recreational modes, but the CPUE index pertains to the CPFV fleet only.
*Response*: Omitting the length-composition data for the other modes in Model C1 led to slightly higher biomass trajectories for all years.

*B. Request*: Summarize the changes between the versions of SS3 on which models AA (2009) and AA (2011) are based (3.0.12 and 3.20b respectively).
*Rationale*: The STAT stated that the only change between these models is how SS3 is specified.
*Response*: Model AA in the draft assessment report (unintentionally) did not use the length-at-age data. Once model AA (2011) was correctly implemented, there were only minor (but systematic) differences between models AA (2009) and AA (2011).

*C. Request*: Conduct model runs based on sequential changes to the data-types (landings, length-at-age, age and length) for 2009 and 2010 included in model AA to assess the reasons for the changes in biomass outputs between models AA to A.
*Rationale*: There is a large change in the scale of the biomass between these two models, particularly from the late 1970s to the late 1980s (last high recruitment and peak abundance period) even though the only difference between the model scenarios relates to updated time series for the most recent years (2009-10).
*Response*: This was not completed during the review. The Panel did not need this information given the change to the base model and the results of the sensitivity and retrospective analyses (see Wednesday Request AB).

*D. Request*: Construct a model F1 from model F that has two fisheries in which the selectivity parameters for the two fisheries are mirrored.
*Rationale*: To be able to move from model F to C1 in a coherent way.
*Response*: The results from models F1 and F should have been identical (except for the impact of the initial fishing mortality), but this was not the case. However, the Panel was no longer interested in this comparison given the results from request H, which suggested that model F was not supported by the data.

*E. Request*: Construct a model C1a from model C1 in which the selectivity pattern for fishery 2 mirrors that for fishery 1.
*Rationale*: To be able to move from model C1 to F in a coherent way.
*Response*: The Panel was no longer interested in this comparison given the results from request H, which suggested that there are systematic and substantial differences in length compositions between the recreational and commercial fleets.

*F. Request*: Compare the empirical weights-at-age with those predicted from the model C1.
*Rationale*: Model F assumes that the empirical weights-at-age are correct while model C1 estimates weight-at-age.
*Response*: The average empirical weight for animals aged 4+ is higher than average model prediction. The revised base model (see Request X) fitted the empirical length-at-age data adequately.

*G. Request*: Modify model C1 so that the commercial age-composition and length-at-age data are ignored and the model is fitted to the conditional age-at-length data from the commercial fishery and commercial and recreational length-frequency data.
*Rationale*: This represents an alternative way of fitting the commercial age-composition data.
*Response*: The estimated biomass trajectory was markedly lower during the period of peak abundance. However, the fit to the CPFV and CRFS indices was markedly poorer than for model C1.

*H. Request*: Plot (by year) the CPFV length-frequency data versus the commercial length-frequency data.

*Rationale*: Model F implicitly assumes that the age and length data from the commercial and recreational fisheries are the same. These plots could have informed the issue of whether there was a change in the sampling scheme between the CPFV observer data (1975-78 and 1985-89) and the latest MRFSS-CRFS data.
*Response*: The 1975 length frequencies are similar between the commercial and recreational fisheries. However, there is a consistent difference between the length-frequencies for the commercial and recreational fisheries (the recreational fishery catches somewhat larger fish on average). The Panel agreed that it was necessary to include at least two fisheries in the model based on this information.

*I. Request*: Consider a version of model C1 with three selectivity time-blocks (1962-69, 1970-77, 1978-10) for the commercial fishery (maintaining two time-blocks for the recreational fishery).
*Rationale*: There was a moratorium implemented on the commercial fishery during 1970-77 when the biomass was low. Catches during this period largely represented bycatch in other fisheries.
*Response*: The estimated biomass was much higher (~6,000,000mt) in 1983. However, this model did not converge (i.e., it was not possible to calculate variance estimates for this model, which may reflect a statistically-inappropriate solution for this model scenario); later exploration suggested that it had been implemented incorrectly.

*J. Request*: Consider a model with asymptotic selectivity for all fleets [recreational and commercial] (models C1 and F).
*Rationale*: Visual examination of the plots of estimated selectivity against age and length for model C1 suggest that the "dome" in selectivity occurs for ages that are very poorly represented in the catch age compositions.
*Response*: The biomass was markedly lower during the period of peak biomass compared to model C1. However, the model did not mimic the data as well as model C1 (the log-likelihood was substantially larger – 1,837 compared to 1,694) for the alternative model suggesting there is little support for asymptotic selectivity for all fleets.

*K. Request*: What is the change in *q* in 1990 (models C1 and F)?
*Rationale*: The CPFV index data are fitted under the assumption that catchability changes in 1989. The Panel was interested in assessing whether the extent of change in catchability was realistic.
*Response*: Catchability for the CPFV fleet after 1990+ is approximately 50% of that for 1975-89. The Panel agreed there was no *a priori* reason why catchability should have changed in 1989-90.

*L. Request*: Estimate a single (1962-2010; no time-blocks) dome-shaped selectivity pattern by fleet for models C1 and F.
*Rationale*: Most of the difference in the selectivity patterns occurs for ages that are beyond those that make up a large fraction of the catch.
*Response*: The biomass was markedly lower during the period of peak biomass compared to model C1. However, the log-likelihood was substantially larger (2,243 compared to 1,694) for the revised model suggesting there is little support for no time-blocks.

*M. Request*: Fit model C1 in which the CV of length-at-age for the maximum age is 0.1 rather than 0.01.
*Rationale*: The variance in length-at-age drops markedly with age for model C1. The Panel questioned whether this was realistic.
*Response*: The ability of the model to mimic the data was poorer when the CV was increased to 0.1.

*N. Request*: Fit a Michaelis-Menten model, $N_{eff} = \frac{\alpha N_{obs}}{\beta + N_{obs}}$, to the observed and effective sample sizes for the commercial fleet and then re-run the assessment (models C1 and F).
*Rationale*: The observed and effective sample sizes for this fleet do not fit the 1-1 line very well.
*Response*: This request was deferred to request X.

*O. Request*: Implement a ramped bias-correction factor.
*Rationale*: The standard errors of the recruitment estimates are much higher for the earliest years of the time series.
*Response*: The ramp-in occurred over 1957-1963. However, this request was deferred to request X.

**Tuesday Requests:**
P. *Request*: Construct a model based on model C1 in which (a) there is no time-blocking for the recreational fishery; and (b) the commercial fishery is split into two fisheries with the catches for 1970-77 treated as a separate fishery. Assume time-invariant dome-shaped selectivity for the two commercial fisheries (no mirroring).
*Rationale*: There was no clear basis for the previous blocking structure. The Panel wished to start with a blocking scheme which matched actual changes to the fishery.
*Response*: This model had six fewer parameters than model C1. However, ability of this model to mimic the data was markedly poorer (a likelihood of 2,059 compared to 1,694 for model C1).

Q. *Request*: Same as request P, except that all of the non-CPFV length-composition data are ignored (see request A).
*Rationale*: The model then includes a comparable time-series of CPFV length-frequencies.
*Response*: The fit to the index data was much better than for model P.

R. *Request*: Same as request Q, except drop all of the pre-2004 recreational data.
*Rationale*: The Panel wished to further examine the extent to which the recreational length data are inconsistent with the other data sources.
*Response*: The fit to the index data was improved (a negative log-likelihood for the index data of -22.0 compared to 72 for model P). This result further highlighted the inconsistency between the recreational length-frequency data and the CPFV index. The ability of the model to mimic the CPFV index was poor if it was treated as a single index (the model was fitted to the CPFV data separated into two series in 1989/90).

S. *Request*: Same as request Q, except start the model in 1978.
*Rationale*: The Panel wanted to determine if the pre-1978 data were the cause for the inability to fit the recreational and commercial data well at the same time.
*Response*: The fits were improved, but the ability of the model to mimic the CPFV index was poor if it was treated as a single index (the model was fitted to the CPFV data separated into two series in 1989/90).

T. *Request*: Same as request Q, except omit the pre-1992 recreational data and the CRFS index.
*Rationale*: The Panel wished to understand which data sources are inconsistent.
*Response*: The results from this model were similar to those from the model developed under request R.

U. *Request*: Same as request S, except start the model in 1980.
*Rationale*: The Panel wished to start the model after the major changes in growth rate (perhaps associated with low Pacific mackerel abundance and high anchovy abundance).
*Response*: The model behaved as expected.

V. *Request*: Same as request S, except start the model in 1983.
*Rationale*: The Panel wished to start the model after the major changes in growth rate (perhaps associated with low Pacific mackerel abundance and high anchovy abundance).
*Response*: The model doesn't fit the recent (2002+) length-at-age distributions. However, these length-at-age data are more imprecise than the earlier length-at-age data so this result is perhaps not unexpected.

W. *Request*: Same as request V, except base the assessment on a single CPFV index (1983-2010) instead of two CPFV indices (1983-89; 1990-2010).
*Rationale*: The Panel was satisfied with the fits of the model developed for request V, but didn't see any basis for a change in catchability in 1989-90.
*Response*: The model developed in response to this request fitted all of the available data sources adequately, except the CRFS index.

X. *Request*: Construct a model based on request W, except create a new survey for the CRFS index, estimate a dome-shaped selectivity pattern for this index based on fitting the 2004+ non-CPFV length-composition data for the recreational fisheries. After a model is developed, (a) test whether any (all) of the selectivity patterns could be made to be asymptotic, (b) implement a bias-correction ramp, and (c) reweight the age, length, and index data.
*Rationale*: The Panel deemed this a potentially new base-model, which could fit all of the data sources and base the fit to the CRFS data on the length composition data for same recreational sectors that are used to construct the index.
*Response*: The variant of model W, which included the 2004+ non-CPFV length-composition data for the recreational fisheries, and assumed dome-shaped selectivity patterns for the commercial and CPFV fisheries and the CRFS index, generally mimicked all of the available data adequately. This model did not fit the first and last two years of the CPFV index and the fit

to the length-at-age data after 2002 was worse than that for the pre-2002 time series. Attempts to assume asymptotic selectivity patterns for the two fisheries or the CRFS index led to noticeably poorer fits to the index data and the length-frequency data for the two recreational indices of abundance. The Panel and the STAT agreed that model X (without a ramp in the bias-correction factor nor adjustments to the effective sample sizes and index CVs) represented the best (revised) base model.

Y. *Request*: Plot the length-at-age distributions for males and females separately.
*Rationale*: The previous Panel suggested that consideration be given to constructing a sex-structured model.
*Response*: There was no evidence for sex-specific growth (Figure 1).

Z. *Request*: Plot the CPFV and non-CPFV length-frequency distributions.
*Rationale*: The CRFS index pertains to the non-CPFV recreational modes, but is assumed to pertain to the CPFV mode when it is included in the model considered thus far.
*Response*: The non-CPFV fisheries tend to capture smaller fish than the CPFV fishery and in several cases led to length-compositions which were more similar to the commercial fisheries.

AA. *Request*: Repeat request X in which the model starts 1978.
*Rationale*: This is an alternative base model that uses more of the available data
*Response*: The fit of this model to the 1978-83 data for CPFV index was clearly mis-specified and the fits to the recreational length-frequency data were much poorer than for model X.

**Wednesday Requests:**
AB. *Request*: Conduct sensitivity analyses related to changing the weights assigned to the various data sources, changing *M*, changing the start year of the model, and changing to assumed variation about the stock-recruitment relationship for the revised base model.
*Rationale*: The Panel wished to explore various features of the revised base model.
*Response*: The biomass estimates for some of the sensitivity tests (e.g. those changing *M*) led to essentially infinite biomass. The Panel compared a model in which selectivity for the commercial fishery was asymptotic within the revised base model. This selectivity pattern was less stable among runs than the other two selectivity patterns. The difference in negative log-likelihood was 5.0 for 3 fewer parameters when the commercial selectivity pattern was assumed to be asymptotic. The Panel and STAT agreed that the variant of model X in which the commercial selectivity pattern is assumed to be asymptotic should form the basis for the final base model. Ultimately, this model was defined as Model XA, which represented the final base case model for Pacific mackerel in 2011.

AC. *Request*: Conduct sensitivity analyses related to changing the weights assigned to the various data sources, changing *M*, changing the start year of the model, and changing to assumed variation about the stock-recruitment relationship for the final base model.
*Rationale*: The Panel wished to explore various features of the revised base model.
*Response*: Table 1 and Figure 2 summarize the results of the sensitivity analysis. There is considerable variability in model outputs among the cases considered and some of the analyses

failed to converge. In particular, the between-sensitivity test variation in biomass far exceeds that which can be inferred from the asymptotic variance for current biomass from the final base model.

AD. *Request*: Conduct a retrospective analysis, a prospective analysis and a likelihood profile on *M* for the final base model.
*Rationale*: The Panel wished to explore various features of the revised base model.
*Response*: The retrospective analysis (Figure 3) indicates a strong retrospective pattern (adding years of data lead to increasingly pessimistic appraisals of stock status). There is also a "prospective effect" (Figure 4), but the retrospective pattern is much stronger than the prospective pattern. The likelihood profile for M was generally flat but indicated a best value of ~0.7$yr^{-1}$, which may be considered somewhat high for a species such as Pacific mackerel**.**

**3) Technical Merits and/or Deficiencies of the Assessment**
The key features of the final base model are:

- Annual time-step starting in 1983
- *M*=0.5$yr^{-1}$; $\sigma_R = 1$
- Estimated growth curve (except for the CV of length-at-age for age 12)
- Two fisheries (recreational and commercial)
- Two surveys (CPFV and CRFS)
- Dome-shaped (double normal) selectivity patterns for the recreational fishery and the CRFS index (no time-blocking) and asymptotic selectivity for the commercial fishery (no time-blocking).
- Fitted to length-frequency data for the CPFV and non-CPFV fisheries, age-composition data from the commercial fishery, the CPFV and CRFS indices, and length-at-age data from the commercial fishery.

The final base stock assessment selected by the STAT and the Panel fits all of the available data sources, and all of the selectivity and growth curves seem plausible. Unlike the previous (2009) stock assessment, there are no time-blocks in selectivity and catchability, and the starting year is 1983 rather than 1962. Notwithstanding this, the Panel noted a number of deficiencies in the assessment:

A) The stock assessment relies on two fishery-dependent indices. The CRFS index is a new index in this assessment. However, the CRFS index only covers a short, recent time period. The Panel reiterates previous concerns regarding the use of the CPFV index as a measure of Pacific mackerel abundance. The Panel was advised by the CPSAS advisor that there may be inconsistent reporting of Pacific mackerel by charterboat skippers and recreational fishers in general. This potential reporting problem adds to the uncertainty related to the CPFV and CRFS indices and further emphasizes the need for representative fishery-independent estimates of stock abundance. The acoustic-trawl methodology was reviewed by a PFMC Methodology Panel in February 2011. However, the data from these surveys are not currently ready for inclusion in the stock assessment.

B) The Panel noted inconsistencies among some of the data sources included in the stock assessment. In particular, there appears to be an inconsistency in the signals from the CPFV index and the recreational length-frequency data. The impact of this inconsistency was removed by starting the model in 1983, but this does not eliminate the inconsistency itself.
C) Fish spawned during the 1970s appear to have grown faster than average. This characteristic of the stock has led to patterns in the residuals in the fits to the commercial catch-at-age data in previous assessments.
D) The estimates of peak biomass are very sensitive to what appear to be relatively small changes to the assumptions of the assessment (e.g. the value of natural mortality over a narrow range). The Panel was presented with assessments in which the peak biomass ranged from 500,000t to essentially infinity based on models which differed in seemingly small ways from the final base model.

**4) Areas of Disagreement**
There were no major areas of disagreement between the STAT and the STAR Panel.

**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 7.

A) In common with previous Panels, the current Panel wishes to emphasize the importance of obtaining data (in particular data on the catch biomass for recent years) from Mexico. There is a complete lack of length- and age-composition data for the Mexican catches which is addressed in the current assessment by assuming that the selectivity pattern for the Mexican catches is the same as that for the US commercial catches.
B) There is currently no usable fishery-independent index of absolute abundance for the whole Pacific mackerel stock and there are concerns with the reliability and suitability of the indices used in the present and previous assessments. The results in Figure 2 suggest that the final base model is unable to reliably identify stock biomass in absolute terms well. Future assessments would be substantially enhanced by an index which provides a measure of absolute biomass.

**6) Concerns raised by the CPSMT and CPSAS representatives during the meeting**
The CPSAS representative reported that Pacific mackerel are readily available and catchable by recreational anglers up and down the coast, in the kelp beds and off piers, although they have not been observed in commercial quantities consistently. However, fishermen have occasionally reported seeing an abundance of young mackerel. He noted that it is important to be aware that the rising cost of fuel and infrequent use of spotter pilots in recent years has prevented the fleet from surveying offshore banks, which were the traditional Pacific mackerel fishing grounds.

After polling recreational anglers and charter boat captains, the CPSAS representative voiced concern that there may be problems with inconsistent reporting of Pacific mackerel encounters, whether the fish are caught and retained for consumption or for bait, or caught and released. Recreational anglers surveyed also reported that dockside surveys did not always ask about

Pacific mackerel that were used for bait or retained. Therefore the party boat logs and dockside surveys may be underreporting the occurrence of Pacific mackerel.

The Panel noted these concerns regarding inconsistent reporting of Pacific mackerel and developed research recommendation F to help address them.

**7) Research Recommendations**

A) Biological (e.g., length, age, sex) data on mackerel caught in the Pacific Northwest should be collected if a directed fishery develops in this region.

B) Improve collaboration with fishery researchers from Mexico and Canada. A large fraction of the catch is taken off Mexico. In particular, catches of Pacific 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. Furthermore, collaboration with Mexico will be necessary for the development of a synoptic acoustic-trawl survey, which is especially pertinent given the need for a fishery independent survey for this stock (see recommendation D).

C) Reconsider the suite of indices and make recommendations for future assessments. Especially important is the need to develop a fishery independent survey. For example, continue work on the acoustic (and CalCOFI) survey and develop new indices as available (as was done for CRFS in this assessment).

D) Review and analyse the raw data on which the CPFV index is based and consider area blocks (i.e., spatial blocks within areas) as a factor in generalized linear models (GLMs).

E) Look at correlation of Pacific mackerel catch in CPFV with other CPS to explore the possibility of changes in targeting practices within the CPFV fleet among years. Perhaps apply the MacCall and Stephens (2004) subsetting approach.

F) Determine if CRFS training or protocol should be revisited so that samplers are more certain to inquire of bait fish caught. This recommendation stems from the observation that some fishermen may not currently report those mackerel caught and used for bait, and it is unknown if this amount is significant.

G) Increase support of current port sampling and laboratory analysis programs for CPS. In particular, there is a need to reanalyse biological parameters including sex ratio, sex-specific parameters, and natural mortality rates ($M$), including the possibility of larger $M$ on 0- and 1-year old Pacific mackerel.

H) Ageing error should be revisited. Few otoliths have currently 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. The method of Punt et al. (2009) for estimating ageing error should also likely be considered.

I) Conduct a study to update the information used to determine maturity-at-length (and maturity-at-age).

J) Revisit the basis for the current estimate of $M$ and explore the use of historical tagging data to estimate $M$.

K) Indices of abundance based on the CPFV fishing mode of CRFS sampling and the CPFV logbook records were inconsistent. Paired trips sampled by CRFS and CPFV should be explored in an attempt to resolve this discrepancy.

L) Compare catch rate trends of CPFV observer data and CPFV logbook data for the years 1985-89. This work may help validate trends in the logbook data.

M) Standard data processing procedures should be developed for CPS, similar to those developed for groundfish species, and a 'data document' should be developed which 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.

Table 1. Results of sensitivity tests for the final base model (Base=Model XA).

| Scenario No | Description | $B_{1+}$ (2011) | $B_{1+}$ (peak) | -LnL (total) | -LnL (CPFV) | -LnL (CRFS) |
|---|---|---|---|---|---|---|
| 0 | Base | 211,126 | 1,065,990 | 842.5 | -6.4 | -5.3 |
| 1 | 2x λ (CPFV index) | 219,896 | 1,123,910 | 830.4 | -16.3 | -6.2 |
| 2 | 2x λ (CRFS index) | 200,383 | 1,073,720 | 836.4 | -7.6 | -6.6 |
| 3[&] | 2x λ (Rec length data) | 287,442 | 1,025,710 | 1,029.7 | -5.8 | -3.9 |
| 4 | 2x λ (Com age data) | 178,682 | 981,870 | 1,188.6 | 10.8 | -1.5 |
| 5 | 2x λ (Length-at-age data) | 210,748 | 1,103,060 | 864.1 | -5.9 | -5.6 |
| 6 | Omit all CRFS data | 251,550 | 1,047,730 | 785.2 | -0.5 | na |
| 7 | $M = 0.3\ yr^{-1}$ | 95,667 | 323,656 | 853.9 | 4.4 | -4.8 |
| 8[&] | $M = 0.4\ yr^{-1}$ | 130,587 | 444,452 | 860.2 | -1.8 | -3.4 |
| 9 | $M = 0.6\ yr^{-1}$ | 606,752 | 3,676,670 | 840.3 | -8.6 | -5.9 |
| 10 | $M = 0.7\ yr^{-1}$ | ** | ** | 839.3 | -6.7 | -5.9 |
| 11 | Start in 1978 | 171,415 | 1,080,300 | 1,231.6 | -1.1 | -5.2 |
| 12 | Start in 1981 | 190,897 | 1,096,960 | 1,007.1 | -4.3 | -5.0 |
| 13 | Start in 1990 | 217,789 | 556,043 | 455.0 | -9.9 | -4.9 |
| 14 | Estimate CV(amax) | 226,929 | 1,082,290 | 851.5 | -8.4 | -4.3 |
| 15 | $\sigma_R = 0.8$ | 210,172 | 1,053,200 | 841.4 | -6.9 | -5.4 |
| 16 | $\sigma_R = 1.2$ | 211,258 | 1,071,720 | 845.0 | -6.2 | -5.3 |

** Biomass is essentially infinite and Hessian may not be positive definite

& Hessian may not be positive definite

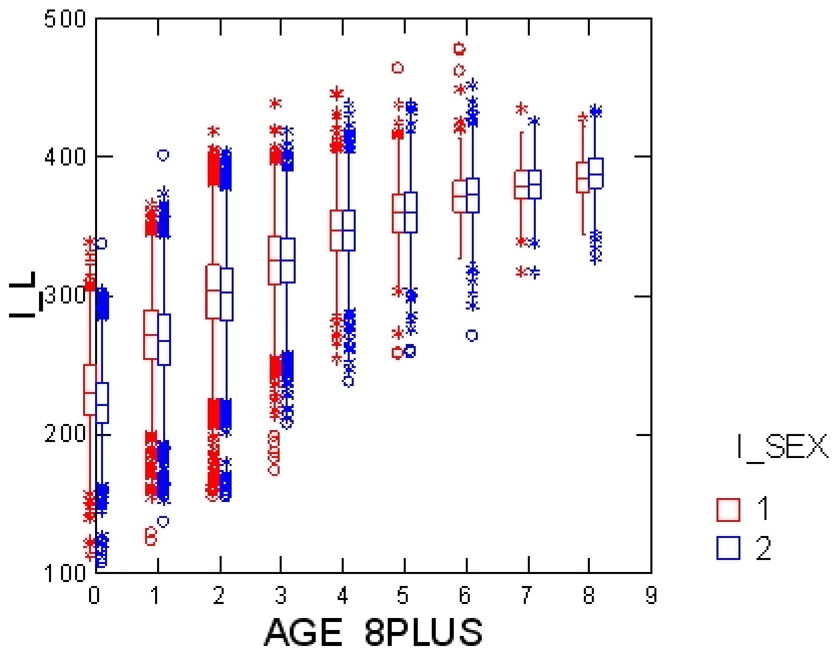


**Figure 1**. Pacific mackerel sex-specific Length-at-age relationship (1962-2008)

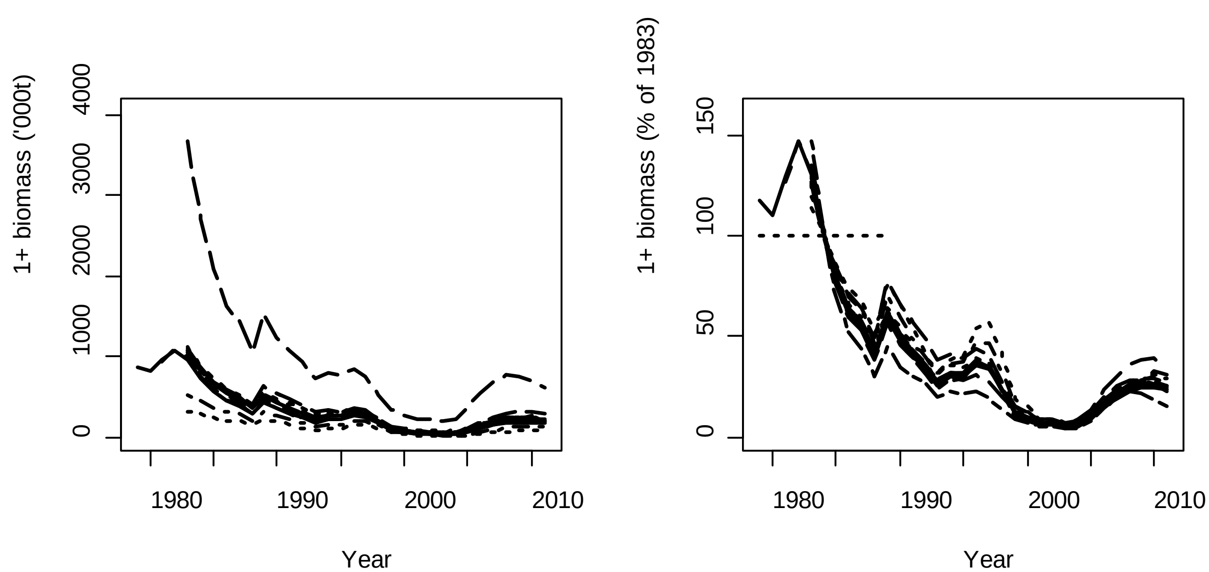


**Figure 2**. Time-trajectories of 1+ biomass from the sensitivity tests (absolute [left panel] and relative [right panel]). The results for scenario 10 are omitted from the left panel, given estimates are essentially infinite and hence implausible.

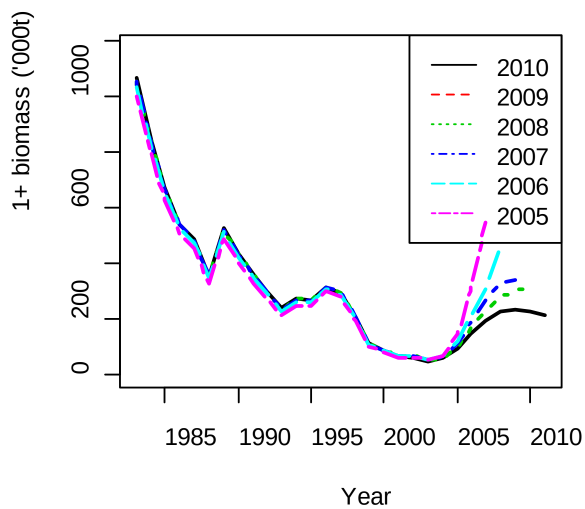


**Figure 3.** Results of the retrospective analysis for the final base model (Model XA).

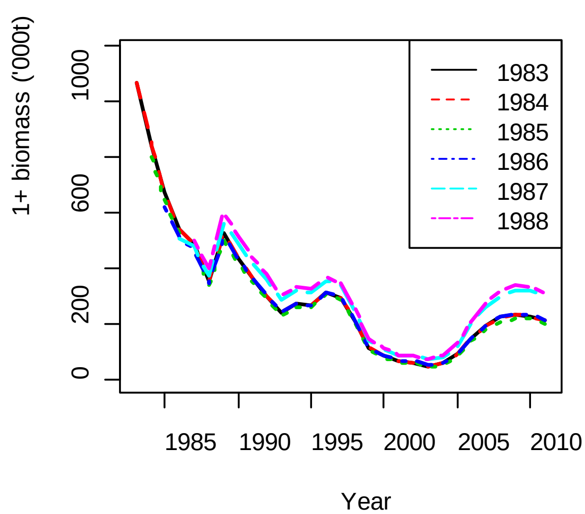


**Figure 4.** Results of the prospective analysis for the final base model (Model XA).

**Appendix 1**

**STAR Panel Members:**
André Punt Chair, SSC, Univ. of Washington
John Casey, CIE, Cefas
Jonathan Deroba, NMFS, Northeast Fisheries Science Center

**Pacific Fishery Management Council (Council) Representatives:**
Briana Brady, CPSMT, CDFG
David Haworth, CPSAS
Kerry Griffin, Council Staff

**Pacific Mackerel Stock Assessment Team**:
Paul Crone, NMFS, SWFSC
Kevin Hill, NMFS, SWFSC
Jenny McDaniel, NMFS, SWFSC
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**Others in Attendance**
Alexandre Aires-da-Silva, Inter-American Tropical Tuna Commission (IATTC)
John Butler, SWFSC
Ray Conser, SWFSC, SSC
Suzy Kohin, SWFSC
Emmanis Dorval, SWFSC
Sam Herrick, SWFSC, CPSMT
Nancy Lo, SWFSC
Mark Maunder, IATTC
Bev Macewicz, SWFSC
Charles Pereti, UCSD
Dale Sweetnam, CDFG, CPSMT
Steve Teo, SWFSC
Russ Vetter, SWFSC
Ed Weber, SWFSC

**Appendix 2 : Responses to 2009 Research Recommendations**

A. Collect biological data on mackerel caught in Pacific NW.
   **Very few Pacific mackerel are typically caught in the Pacific NW**. **However, larger fish are also more adept at avoiding nets.**
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.
   **The Mexican data have been updated to 2009. The Panel re-iterated the importance of collaboration with Mexico and Canada.**
C. The data on catches come from several sources. The catch history from 1926-27 to present should be documented in a single report.
   **This recommendation was not addressed.**
D. Reconsider the suite of indices and make recommendations for future assessments.
   **The assessment includes a new index (CRFS) and examined two alternative indices (CalCOFI and acoustic-trawl).**
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).
   **This recommendation was not addressed.**
F. Bolster the current monitoring program for CPFV fleet to improve data collection.
   **The monitoring program has not been bolstered since 2009.**
G. Look at correlation of Pacific mackerel catch in CPFV with other CPS to explore the possibility of changes in targeting practices within the CPFV fleet across years. Perhaps apply the MacCall and Stephens subsetting approach.
   **This recommendation was not addressed.**
H. Increase support of current port sampling and laboratory analysis programs for CPS. In particular, there is need to reanalyze 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.
   **The Panel continues to support this recommendation. Revision of the maturity-at-age relationship is currently underway.**
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.
   **This recommendation was not addressed.**
J. Conduct a study to update the information used to determine maturity-at-length (and maturity-at-age).
   **Revision of the maturity-at-age relationship is currently underway.**
K. Do more research/assessment on related/competing species including anchovy and jack mackerel.

**The acoustic-trawl surveys provide information on the majority of the pelagic species in the California Current System, including anchovy and jack mackerel. The data from these surveys were presented to the Panel but not included in the base-model.**

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.
**This recommendation was addressed during the review (see Request G)**

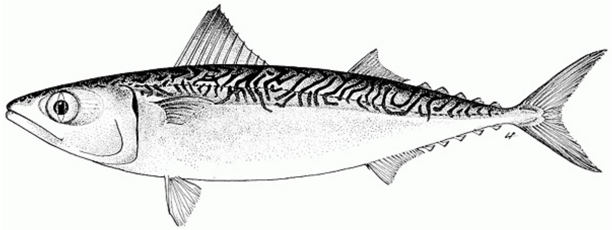
M. Future assessments should consider sex-structured models.
**This recommendation was addressed during the review (see Request Y)**

**Appendix 3: List of Acronyms**

ABC: Acceptable Biological Catch
ASAP: Age-structured assessment program
CalCOFI: California Cooperative Oceanic Fisheries Investigations
CDFG: California Department of Fish and Game
Cefas: Centre for Environment, Fisheries, and Aquaculture Science
CIE: Center for Independent Experts
CPFV: Commercial passenger fishing vessel
CPS: Coastal pelagic species
CPSAS: Coastal pelagic species advisory subpanel
CPSMT: Coastal pelagic species management team
CPUE: Catch per unit effort
CRFS: California Recreational Fisheries Survey
CV: Coefficient of variation
GLMs: Generalized linear model
HG: Harvest guideline
IATTC: Inter-American Tropical Tuna Commission
M: Natural Mortality
MRFSS: Marine Recreational Fisheries Statistics Survey
NMFS: National Marine Fisheries Service
NEFSC: Northeast Fisheries Science Center
OFL: Overfishing limit
SS: Stock Synthesis (model)
SSC: Scientific and Statistical Committee (of the Pacific Fishery Management Council)
STAR Stock assessment review
SWFSC: Southwest Fisheries Science Center
UCSD: University of California at San Diego

Agenda Item G.2.b
Supplemental SWFSC PowerPoint (Crone)
June 2011

# Pacific Mackerel Stock Assessment for USA Management in the 2011-12 Fishing Year



**P. R. Crone[1], K. T. Hill[1], J. D. McDaniel[1], and K. Lynn[2]**

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## Presentation outline

- Goals … *flat-out responsibilities of this stock assessment*
- Overview … *top-down look at both this species' biology and management*
- Data … *availability/quality (past, present, and future), time series development, etc.*
- Stock assessment model … *general and specific model discussion*
- Results … *estimated time series, parameter diagnostics, etc. for final baseline model*
- Conclusions … *I'm pretty brief (say kind of, sort of anyway, but I digress)*

# Pacific Mackerel Stock Assessment (2011)

## Objectives … *p.* 1

- First and foremost, develop a 'robust' analysis (say 'inside' the model) … that makes sense (say 'outside' the model)
  - Not highly sensitive to addition/omission of data (time series), minor parameter adjustments, etc.
  - Bottom-line is to develop a model that provides management bodies with sound advice regarding this species vulnerability to fishing pressure (say in the context of availability and sustainability)

- Via a fair bit of sensitivity analysis, prior and during the Review in May 2011, evaluate potential model scenarios and identify a final baseline model … aka Model *XA*
  - Develop a sound population model that includes the 'best available data in the most reasonable manner' (say time series included in the model are rigorously evaluated and collectively, parameterized based on statistical, as well as practical considerations)
  - Model development is ongoing and includes both short- and long-term objectives, which are largely based on data availability as presented in Research and Data Needs (*Crone et al. 2011*, p. 30)

*Biology*

**Distribution**

**Spawning Area**

**Fisheries**

# Harvest Control Rule Information (Model *XA*)

| *B* (Age 1+, mt) | Cutoff (mt) | Fraction | Distribution | HG (mt) |
|---|---|---|---|---|
| 211,126 | 18,200 | 30% | 70% | **40,514** |

| Harvest Formula Parameters | Value | | | |
|---|---|---|---|---|
| BIOMASS (ages 1+, mt) | 211,126 | | | |
| Pstar (probability of overfishing) | 0.45 | 0.4 | 0.3 | 0.2 |
| $BUFFER_{Pstar}$ | 0.95577 | 0.91283 | 0.82797 | 0.73861 |
| $F_{MSY}$ | 0.3 | | | |
| FRACTION | 0.3 | | | |
| CUTOFF (mt) | 18,200 | | | |
| DISTRIBUTION (U.S.) | 0.7 | | | |

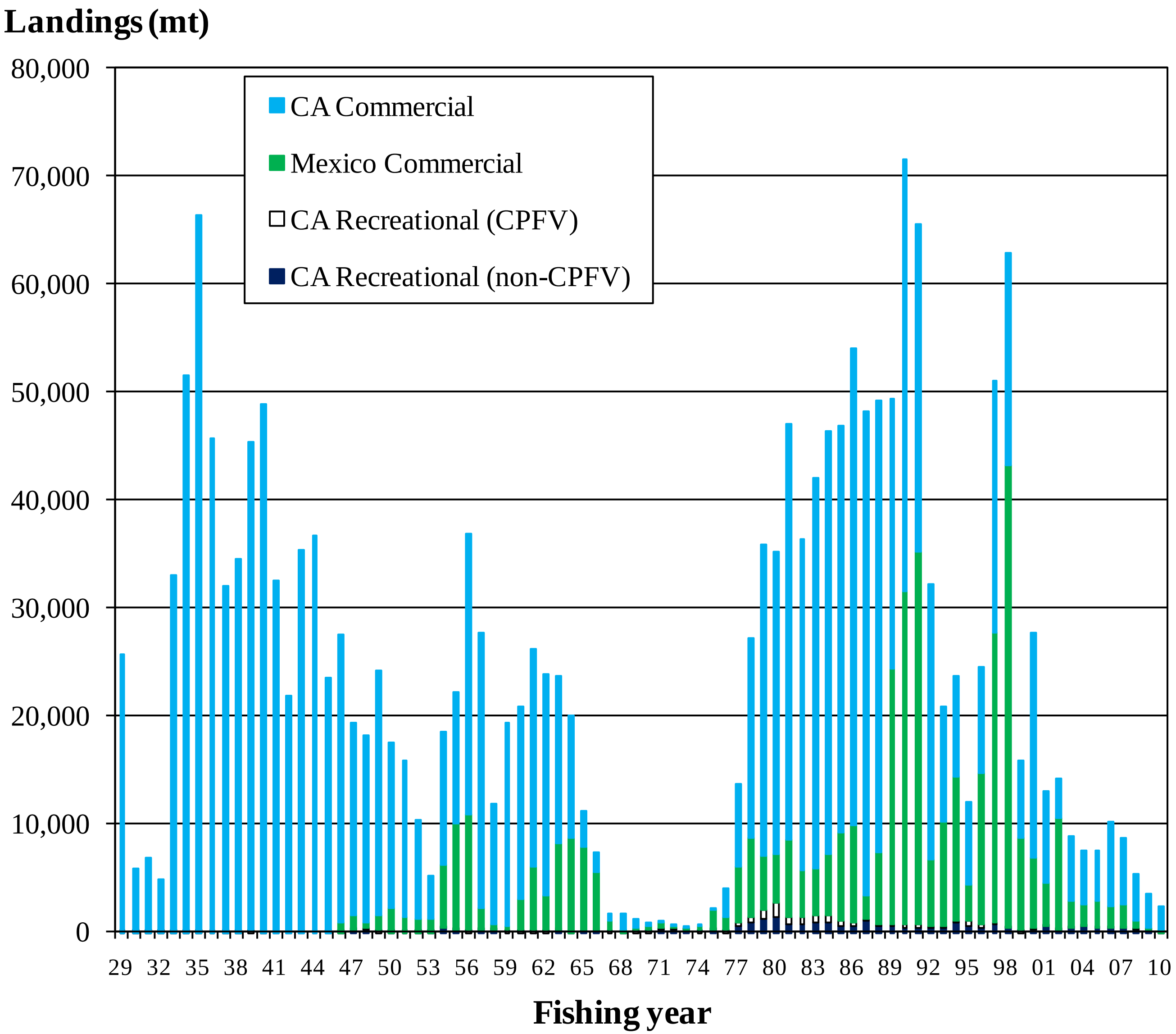
| Amendment 13 Harvest Formulas | MT |
|---|---|
| OFL = BIOMASS * $F_{MSY}$ * DISTRIBUTION | 44,336 |
| $ABC_{0.45}$ = BIOMASS * BUFFER0.45 * $F_{MSY}$ * DISTRIBUTION | 42,375 |
| $ABC_{0.40}$ = BIOMASS * BUFFER0.40 * $F_{MSY}$ * DISTRIBUTION | 40,472 |
| $ABC_{0.30}$ = BIOMASS * BUFFER0.30 * $F_{MSY}$ * DISTRIBUTION | 36,709 |
| $ABC_{0.20}$ = BIOMASS * BUFFER0.20 * $F_{MSY}$ * DISTRIBUTION | 32,747 |
| ACL=LESS THAN OR EQUAL TO ABC | TBD |
| HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION | 40,514 |
| ACT=EQUAL TO HG OR ACL, WHICHEVER VALUE IS LESS | TBD |

# Pacific Mackerel Stock Assessment (2011)

## Data availability for STAR (2011) … *p. 16*

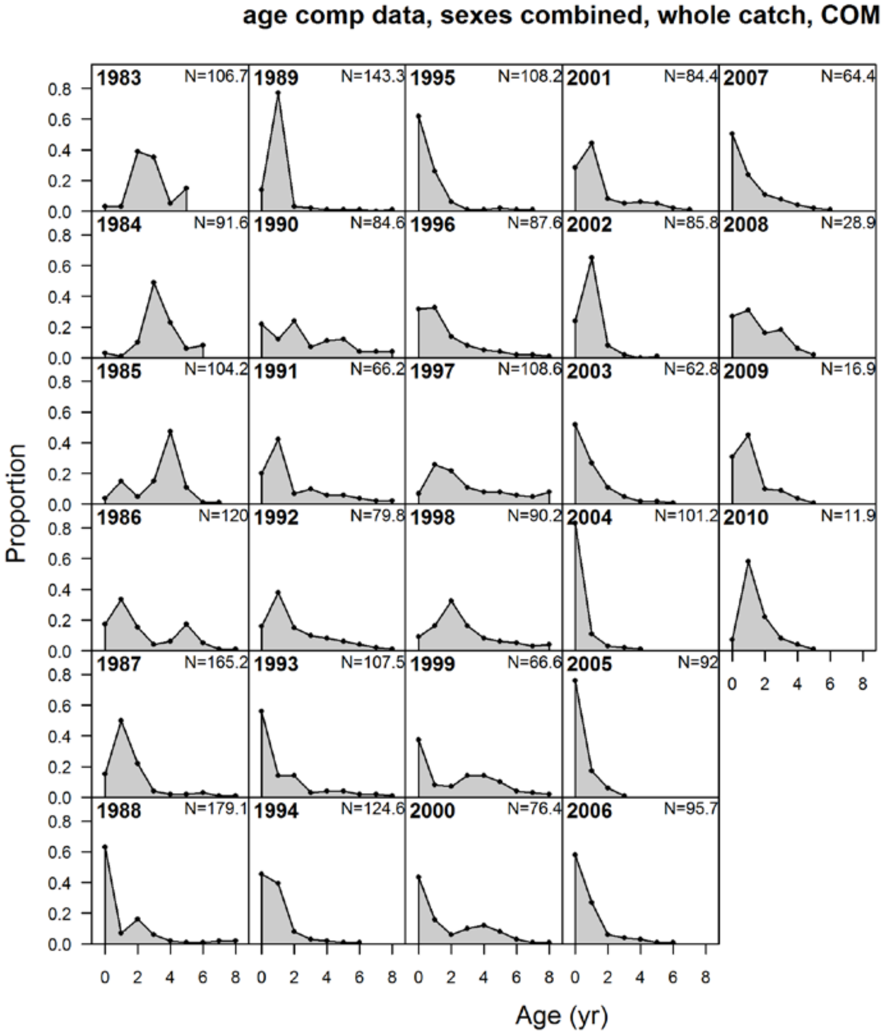
- Landings — *from PacFIN and available at a fine scale, but …*
  - Monitoring international landings … *inherently problematic, blah, blah, blah*
- Biology — *from state/federal sampling/laboratory programs and available at a fine scale, but ...*
  - Length … *recreational fishery length information prior to 1992 (and you could even argue 2004) caveats*
  - Age … *no recreational fishery age information*
  - Weight … *see Length above*
  - Maturity … *'long in the tooth' caveats*
- Indices of abundance — *from state sampling programs and available at a fine scale, but …*
  - CPFV logbook sampling program … *future 'applicability' of this data source needs further review*
  - CRFS program … *long-term funding horizon*

# Landings

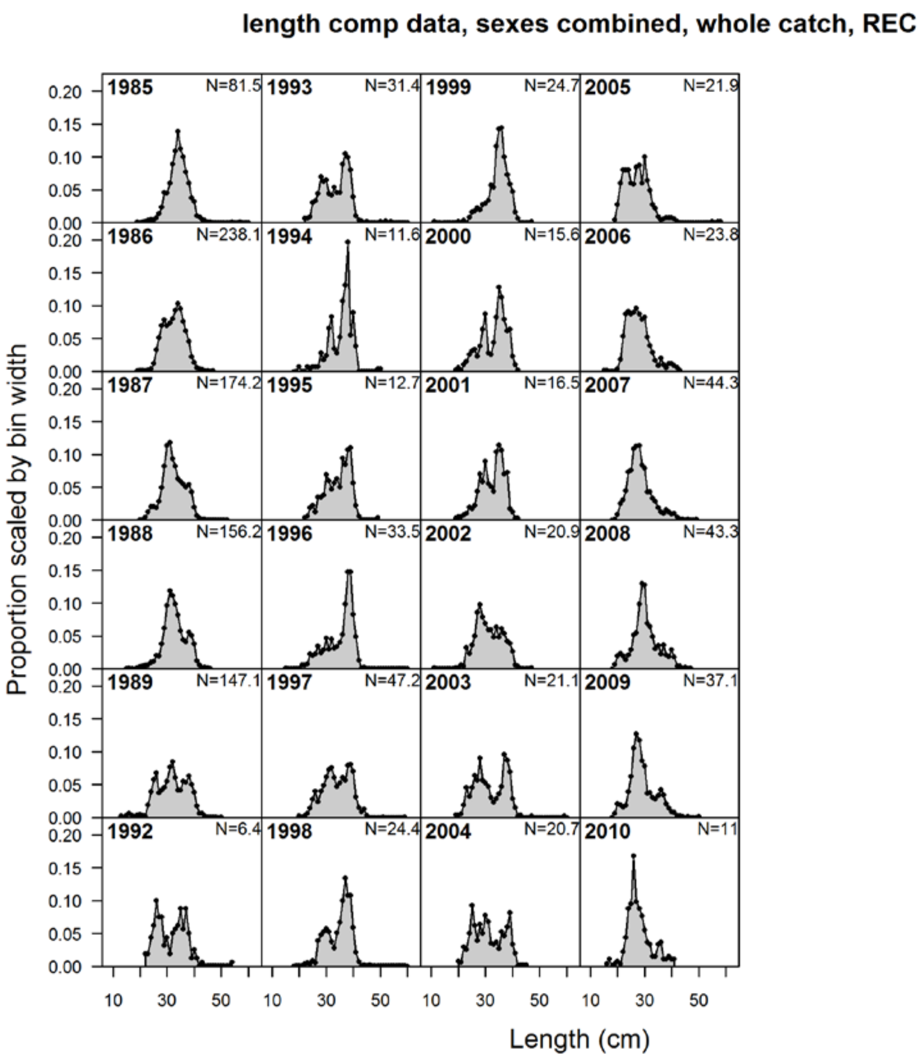


Landings (mt)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
CA Commercial
Mexico Commercial
CA Recreational (CPFV)
CA Recreational (non-CPFV)
29 32 35 38 41 44 47 50 53 56 59 62 65 68 71 74 77 80 83 86 89 92 95 98 01 04 07 10
Fishing year

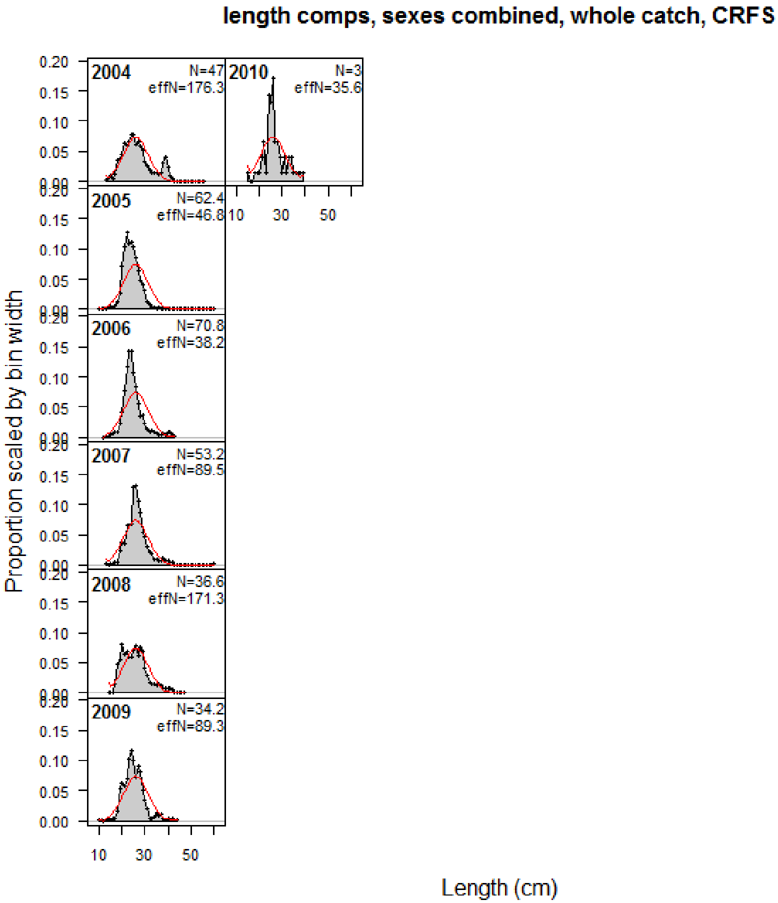
# Age Distribution Time Series (1983-10) Commercial Fishery



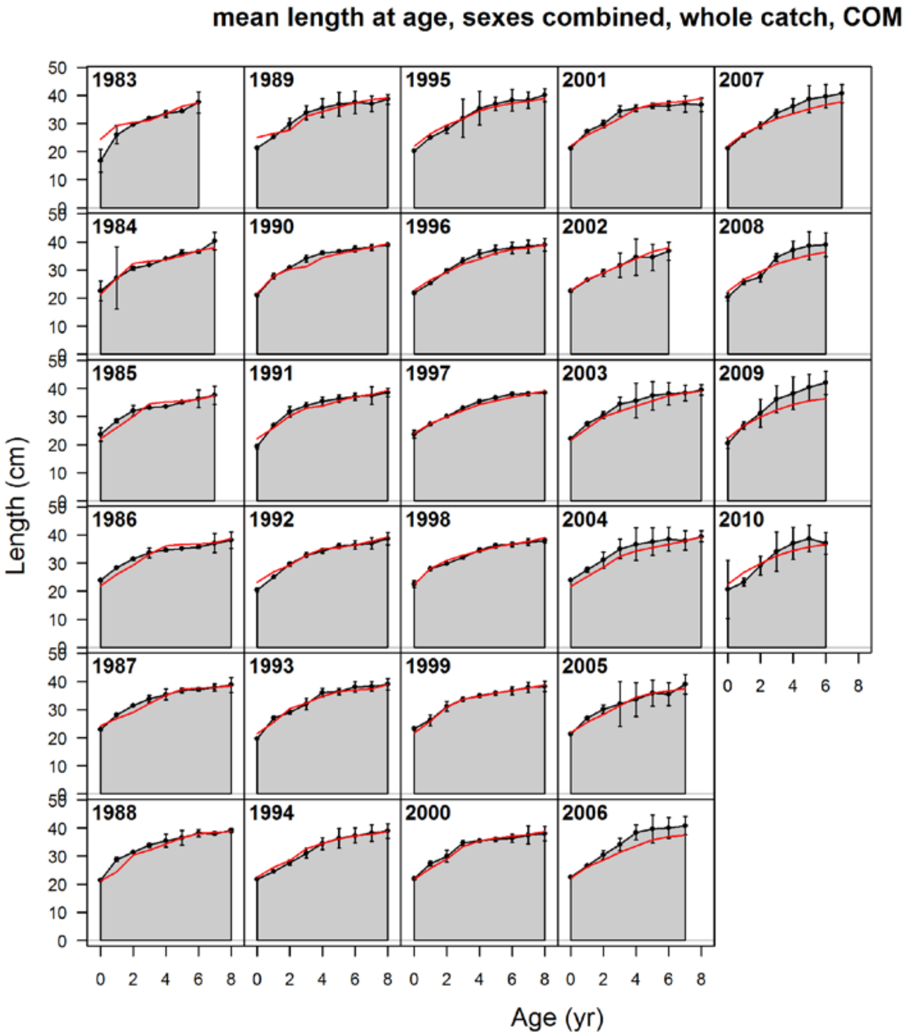
# Length Distribution Time Series (1985-10)
# Recreational Fishery



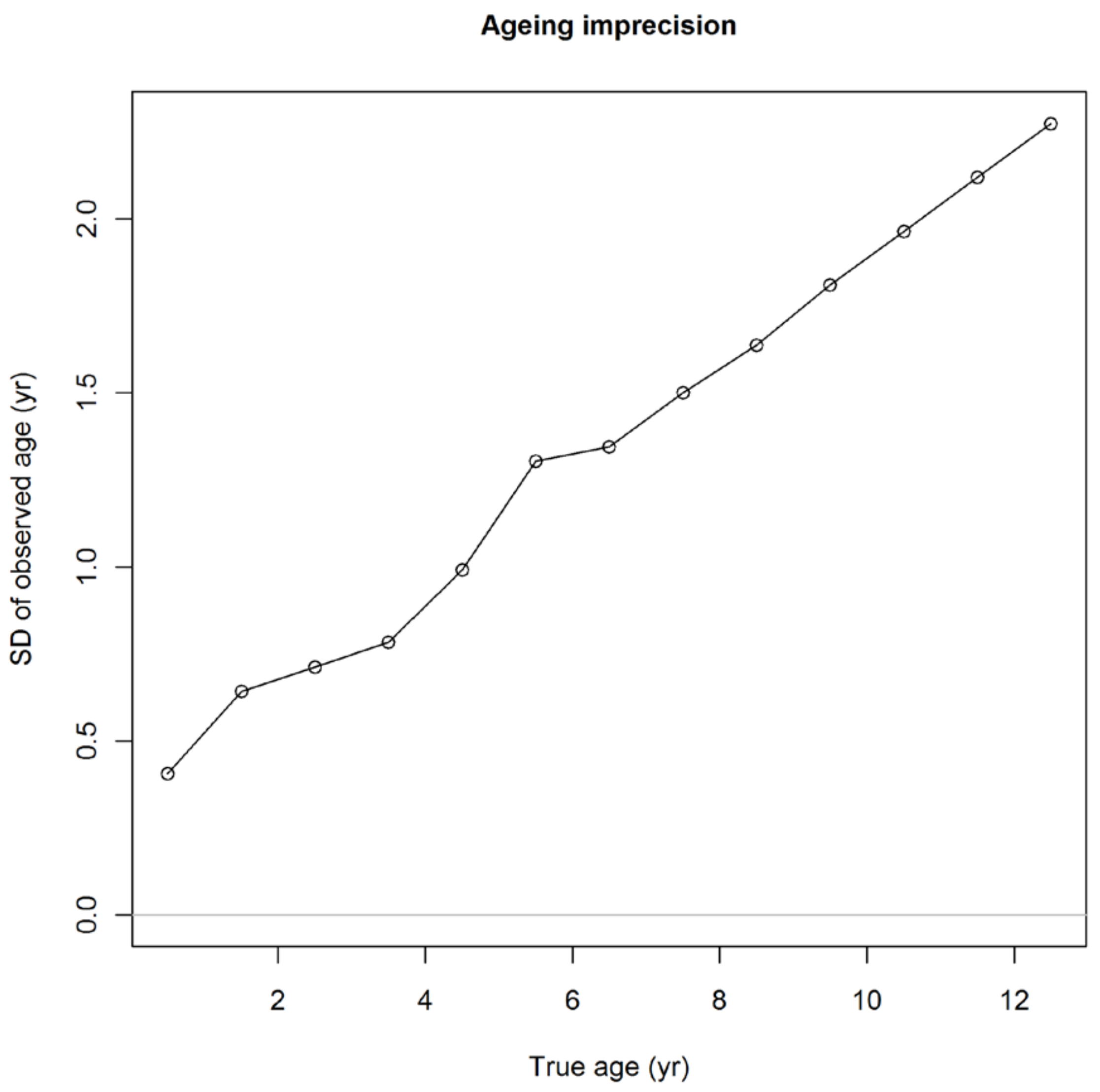
# Length Distribution Time Series (2004-10) CRFS



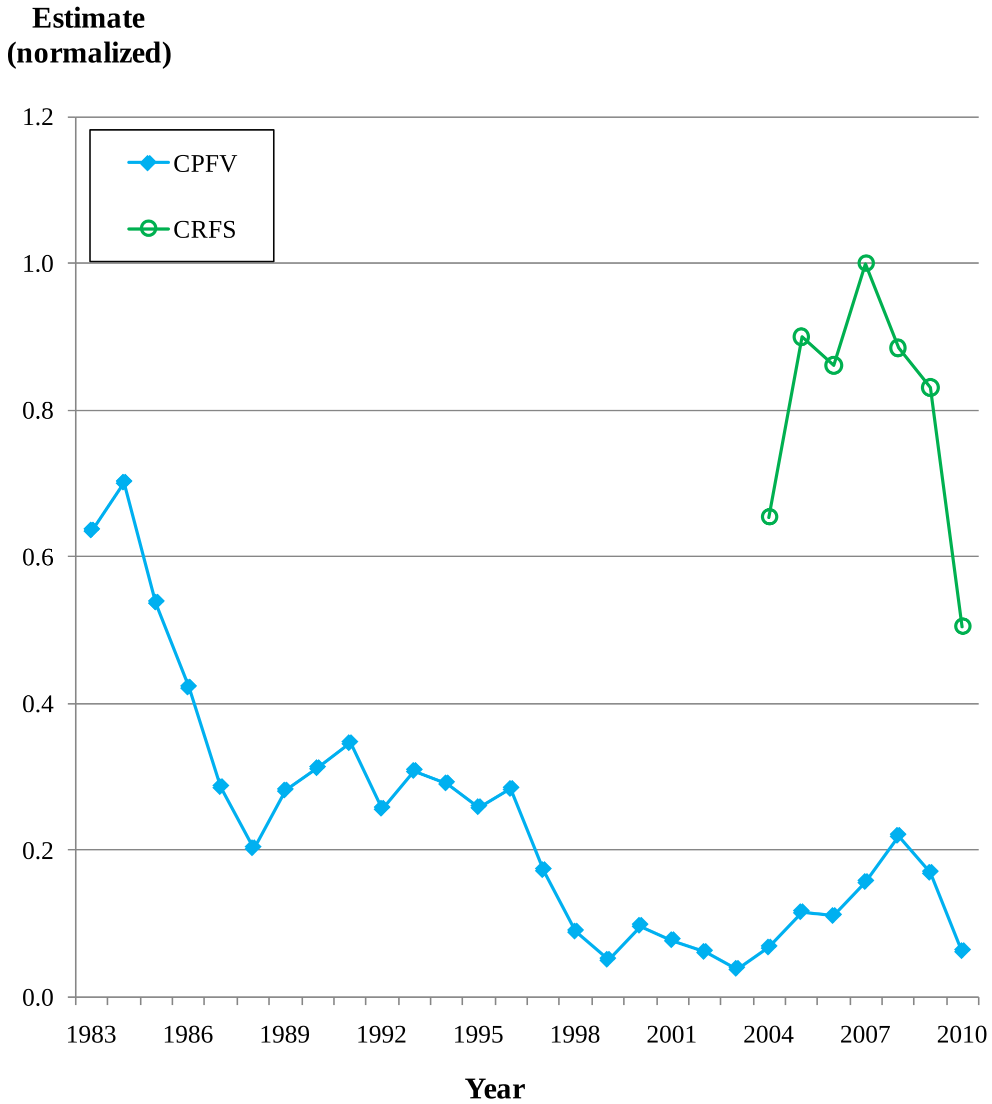
# Mean Length-at-age Time Series (1983-10) Commercial Fishery



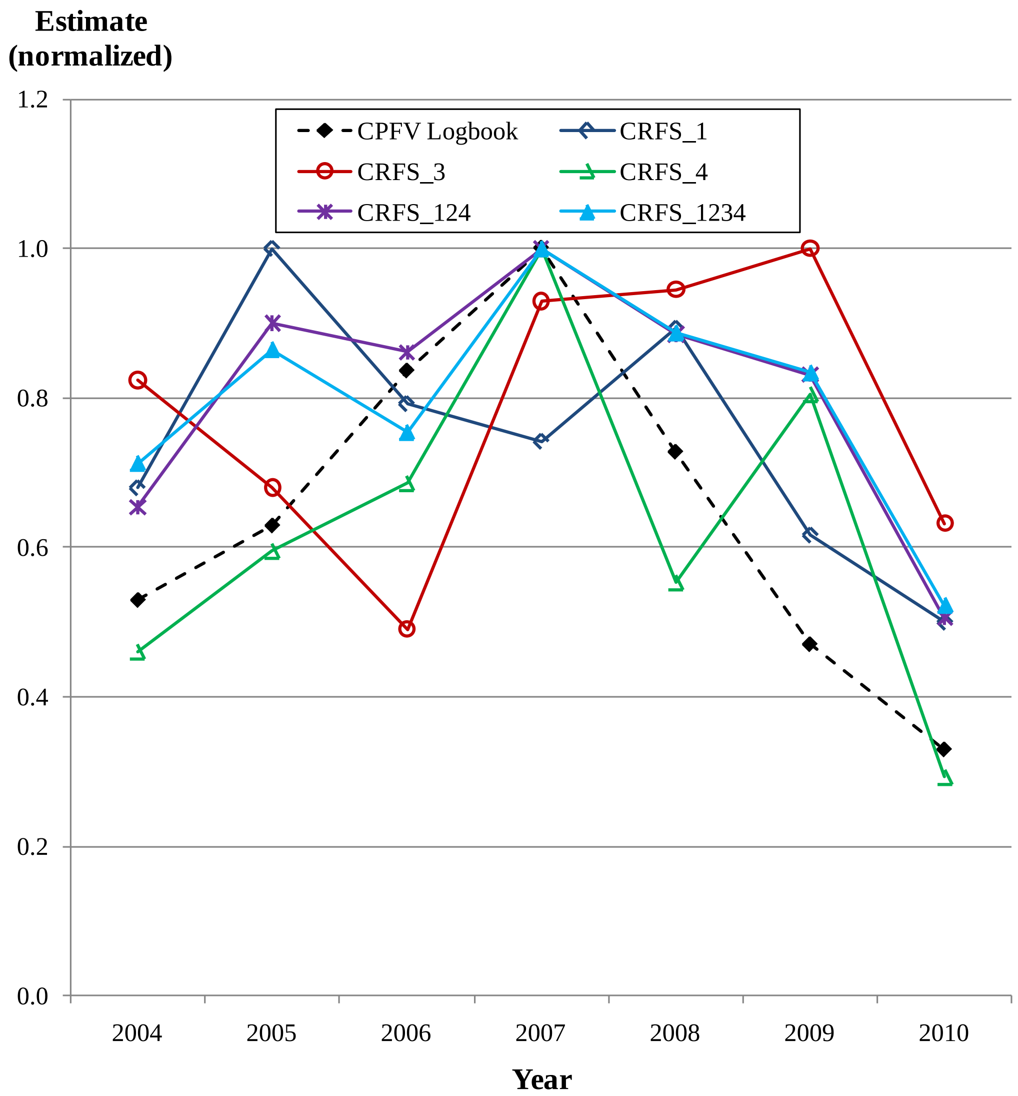
# Ageing Error Time Series



# Indices of Abundance



# Indices of Abundance – Recreational Fishery



# CRFS Summary Statistics

| REGION | | |
|---|---|---|
| Fishing Year | NC | SC |
| 04 | 33,491 | 36,069 |
| 05 | 31,882 | 35,330 |
| 06 | 32,632 | 36,407 |
| 07 | 27,052 | 36,124 |
| 08 | 26,579 | 40,329 |
| 09 | 27,453 | 35,974 |
| 10 | 12,384 | 13,519 |
| **Total** | 191,473 | 233,752 |
| **Grand total** | **425,225** | |

| MODE (ALL) | | | | |
|---|---|---|---|---|
| Fishing Year | Man-made | Beach-Bank | Party-Charter | Private-Rental |
| 04 | 17,231 | 2,144 | 12,287 | 37,898 |
| 05 | 15,657 | 1,947 | 12,712 | 36,896 |
| 06 | 18,585 | 2,371 | 12,326 | 35,757 |
| 07 | 18,311 | 2,092 | 13,674 | 29,099 |
| 08 | 20,587 | 2,567 | 14,669 | 29,085 |
| 09 | 20,045 | 2,079 | 13,751 | 27,552 |
| 10 | 7,342 | 30 | 6,433 | 12,098 |
| **Total** | 117,758 | 13,230 | 85,852 | 208,385 |
| **Grand total** | | **425,225** | | |

| AVG. TRIP LENGTH (INTERVIEW) | | | | |
|---|---|---|---|---|
| Fishing Year | Man-made | Beach-Bank | Party-Charter | Private-Rental |
| 04 | 3.02 | 2.63 | 3.48 | 4.52 |
| 05 | 2.97 | 2.64 | 3.34 | 4.37 |
| 06 | 3.00 | 2.77 | 3.13 | 4.51 |
| 07 | 2.92 | 2.85 | 3.20 | 4.55 |
| 08 | 2.95 | 2.84 | 3.12 | 4.63 |
| 09 | 3.05 | 2.91 | 3.30 | 4.84 |
| 10 | 3.09 | 2.94 | 3.26 | 4.69 |
| **Total** | 3.00 | 2.80 | 3.26 | 4.59 |
| **Grand total** | | **3.41** | | |

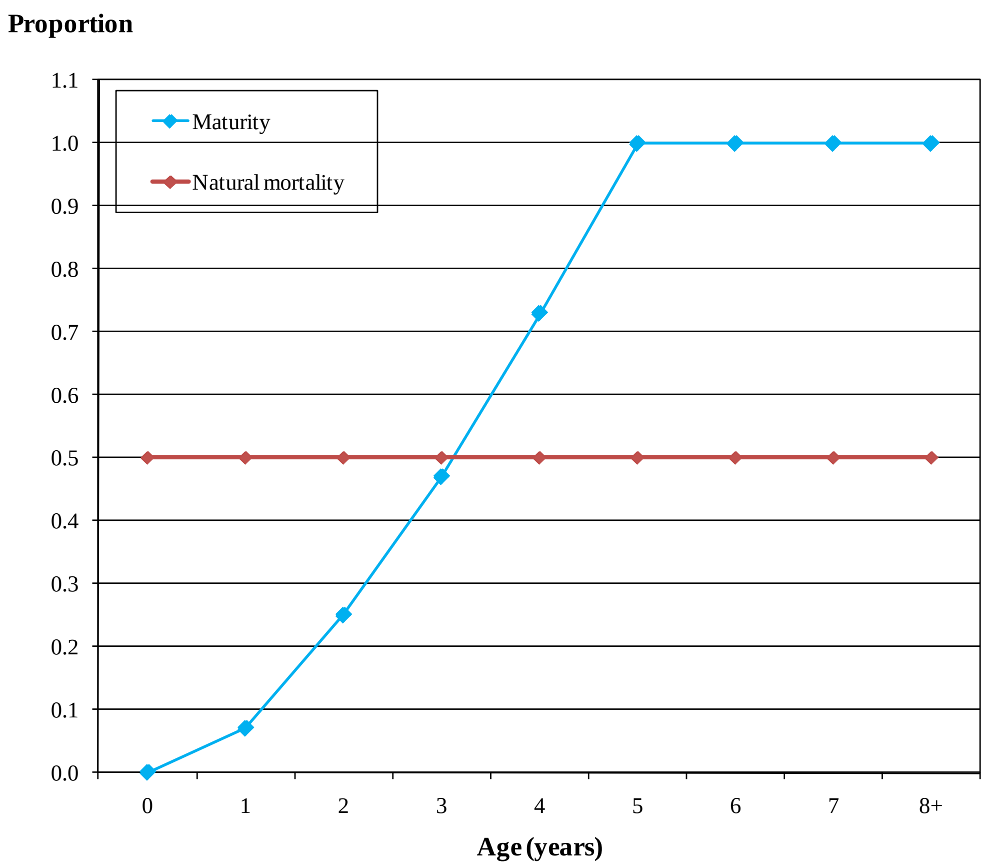
| PARTY SIZE | | | | |
|---|---|---|---|---|
| Fishing Year | 0 | 1 | 2-4 | ≥5 |
| 04 | 12,585 | 40,359 | 28,113 | 1,088 |
| 05 | 3,283 | 38,988 | 27,168 | 1,056 |
| 06 | 7,741 | 41,908 | 26,046 | 1,085 |
| 07 | 15,845 | 40,633 | 21,563 | 980 |
| 08 | 16,269 | 44,720 | 21,115 | 1,073 |
| 09 | 14,500 | 42,706 | 19,740 | 981 |
| 10 | 6,257 | 17,014 | 8,514 | 375 |
| **Total** | 76,480 | 266,328 | 152,259 | 6,638 |
| **Grand total** | | **501,705** | | |

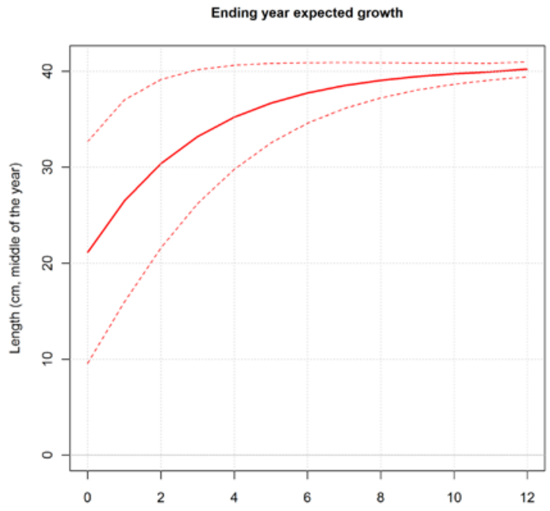
| MODE (POSITIVE CREEL) | | | | |
|---|---|---|---|---|
| Fishing Year | Man-made | Beach-Bank | Party-Charter | Private-Rental |
| 04 | 523 | 9 | 389 | 609 |
| 05 | 558 | 2 | 309 | 501 |
| 06 | 443 | 3 | 318 | 583 |
| 07 | 457 | 0 | 486 | 677 |
| 08 | 556 | 0 | 553 | 534 |
| 09 | 531 | 1 | 507 | 472 |
| 10 | 138 | 0 | 158 | 103 |
| **Total** | 3,206 | 15 | 2,720 | 3,479 |
| **Grand total** | | **9,420** | | |

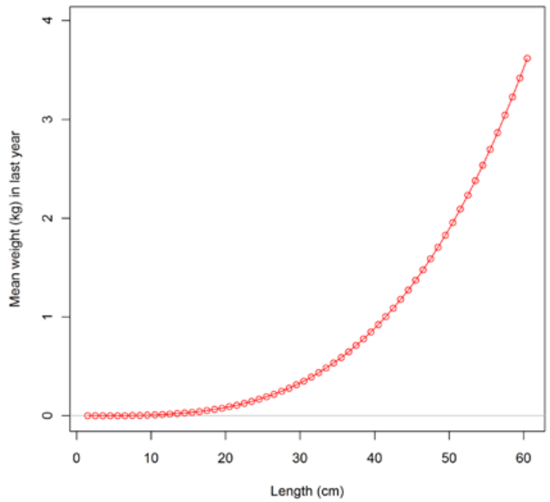
| CATCH SIZE (ALL) | | | | |
|---|---|---|---|---|
| Fishing Year | 0 | 1 | 2-4 | ≥5 |
| 04 | 68,030 | 492 | 503 | 535 |
| 05 | 65,842 | 423 | 409 | 538 |
| 06 | 67,692 | 406 | 440 | 501 |
| 07 | 61,556 | 439 | 552 | 629 |
| 08 | 65,265 | 437 | 581 | 625 |
| 09 | 61,916 | 467 | 473 | 571 |
| 10 | 25,504 | 125 | 128 | 146 |
| **Total** | 415,805 | 2,789 | 3,086 | 3,545 |
| **Grand total** | | **425,225** | | |

| AVG. NO. ANGLERS IN PARTY (INTERVIEW) | | | | |
|---|---|---|---|---|
| Fishing Year | Man-made | Beach-Bank | Party-Charter | Private-Rental |
| 04 | 1.09 | 1.07 | 1.11 | 2.20 |
| 05 | 1.07 | 1.03 | 1.13 | 2.20 |
| 06 | 1.05 | 1.04 | 1.14 | 2.20 |
| 07 | 1.04 | 1.04 | 1.16 | 2.21 |
| 08 | 1.04 | 1.03 | 1.16 | 2.20 |
| 09 | 1.05 | 1.03 | 1.17 | 2.17 |
| 10 | 1.04 | 1.00 | 1.21 | 2.10 |
| **Total** | 1.06 | 1.04 | 1.15 | 2.18 |
| **Grand total** | | **1.36** | | |

# Biological Parameters



# Pacific Mackerel Stock Assessment (2011)

## Model description … see *p.* 23

- Stock Synthesis model (SS)
  - 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
    - ✓ *Dimensionality/Complexity*: high, keeping in mind that an operative word here is allows and not requires, given the platform is also very useful for developing a population analysis based on less-detailed interpretations of the data and ultimately, more robust (and understandable), blah, blah, blah …
  - Review key parameterizations and results … see Table 5 (*p*. 41)
    - ✓ Review pertinent model parameters

# Pacific Mackerel Stock Assessment (2011)

## Final baseline model … see *p.* 25 and STAR (2011)

- Management model selected for 2011-12 fishing year
  - Model *XA*
- Alternative models reviewed
  - Models *A, B, C1-C3, D, E, F, G, …*

## Key parameterization issues

- Time period … importance=moderate
- Fishery structure … importance=high
- Growth … importance=low
- Stock-recruitment … importance=moderate
- Selectivity … importance=high
- Indices of abundance … importance=high
- Diagnostics … importance=high

# Sensitivity Analysis

| Time series | *Model scenario* | |
|---|---|---|
| | ***AA* (2009)** | ***XA* (2011)** |
| *Landings - Commercial (USA/Mexico fisheries)* | ■ | ■ |
| *Landings - Recreational (USA fishery)* | ■ | ■ |
| *Age distributions - Commercial fishery* | ■ | ■ |
| *Length distributions - Recreational fishery (1992-10) - All fishing modes* | ■ | |
| *Length distributions - Recreational fishery (1985-89) - CPFV (* ***new time series (2011***) | | ■ |
| *Length distributions - Recreational fishery (1992-10) - CPFV* | | ■ |
| *Length distributions - Recreational fishery (2004-10)- non-CPFV* | | ■ |
| *Mean length-at-age distributions - Commercial fishery* | ■ | ■ |
| *CPFV index* | ■ | ■ |
| *CRFS index (2004-10)* - ***new time series (2011)*** | | ■ |
| **Parameterization** | ***AA (2009)*** | ***XA (2011)*** |
| **Model structure** | | |
| Time period | 1962-08 | 1983-10 |
| Number of fisheries | 2 | 2 |
| Number of surveys | 1 | 2 |
| Genders | Combined | Combined |
| Time-step | Annual | Annual |
| **Biology** | | |
| Maturity-at-age | Fixed | Fixed |
| Length-at-age ($k$) | 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 |
| $\sigma$-$R$ | Fixed ($\sigma$-$R$=1.0) | Fixed ($\sigma$-$R$=1.0) |
| **Initial conditions for population dynamics** | | |
| Age distribution | Non-equilibrium | Non-equilibrium |
| Fishing mortality ($F$) - Commercial fishery | Estimated | Estimated |
| Fishing mortality ($F$) - Recreational fishery | Fixed | Fixed |
| **Selectivity** | | |
| *Fisheries* | | |
| Parameterization | Estimated | Estimated |
| Time block | Commercial fishery=3 blocks / Recreational fishery=single | Single |
| Shape | Dome-shaped | Commercial fishery=asymptotic / Recreational fishery=dome-shaped |
| *Surveys* | | |
| Parameterization | CPFV=mirrors recreational fishery | CPFV=mirrors recreational fishery / CRFS=dome-shaped |
| Time block | Single | Single |
| Shape | Dome-shaped | Dome-shaped |
| **Catchability** | | |
| $q$ - Surveys | Estimated (median unbiased) | Estimated (median unbiased) |
| **Variance adjustment factors** | | |
| *Biological distributions and indices* | No additional weighting | No additional weighting |

# Sensitivity Analysis

| Likelihood component | AA (2009) | XA (2011) |
|---|---|---|
| **Biological distributions** | | |
| *Age distributions* | | |
| Commercial fishery | 700.4 | 368.0 |
| *Length distributions* | | |
| Recreational fishery (All fishing mode: 1992-10) | 201.4 | Na |
| Recreational fishery (CPFV: 1985-10) | Na | 184.9 |
| Recreational fishery (non-CPFV: 2004-10)) | Na | 57.3 |
| Sub-total | | 242.2 |
| *Length-at-age distributions* | | |
| Commercial fishery | 540.4 | 232.4 |
| **Surveys** | | |
| *CPFV* | -18.3 | -6.4 |
| *CRFS* | Na | -5.3 |
| Sub-total | -18.3 | -11.7 |
| **Recruitment** | | |
| Model time period | 34.7 (1958-08) | 11.34 (1978-10) |
| Forecast | 0.016 (2009) | 0.245 (2011) |
| **Global** | | |
| Likelihood (*L*) | 1,458.6 | 842.5 |
| Number of estimated parameters | 84 | 57 |
| Softbounds | 0.0036 | 0.0028 |
| **Key estimated parameters and derived quantities** | | |
| **Biology** | | |
| Length-at-age (*k*) | 0.22 | 0.33 |
| $\ln(R_0)$ | 13.5 | 13.6 |
| Offset for initial equilibrium $R_1$ | 0.2473 | 0.4731 |
| Steepness (*h*) | 0.47 | 0.70 |
| **Initial conditions for population dynamics** | | |
| Fishing mortality (*F*) - Commercial fishery[a] | 0.654 | 0.014 |
| Fishing mortality (*F*) - Recreational fishery | 0.001 | 0.001 |
| **Population time series** | | |
| *SSB* (peak year) | 598,046 (1983) | 461,354 (1984) |
| *SSB* (end year) | 76,441 (2008) | 112,880 (2010) |
| *B* (peak year) | 1,321,550 (1982) | 1,065,990 (1983) |
| *B* (end year) | 282,849 (2009) | 211,126 (2011) |
| *HG* (current year) | 55,408 | 40,514 |

[a]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.

# Pacific Mackerel Stock Assessment (2011) – Parameter Estimates (Model *XA*)

| Parameter | Min_Value | Max_Value | Init_Value | Fin_Value | SD |
|---|---|---|---|---|---|
| NatM_p_1_Fem_GP_1 | 0.3 | 0.7 | 0.5 | 0.5 | _ |
| L_at_Amin_Fem_GP_1 | 4 | 35 | 15 | 21.116 | 0.205664 |
| L_at_Amax_Fem_GP_1 | 30 | 70 | 45 | 40.0231 | 0.197782 |
| VonBert_K_Fem_GP_1 | 0.1 | 0.7 | 0.35 | 0.325098 | 0.0128458 |
| CV_young_Fem_GP_1 | 0.01 | 0.5 | 0.1 | 0.279009 | 0.010219 |
| CV_old_Fem_GP_1 | 0.0001 | 0.5 | 0.01 | 0.01 | _ |
| Wtlen_1_Fem | -1 | 5 | 0.00000312 | 3.12E-06 | _ |
| Wtlen_2_Fem | 1 | 5 | 3.40352 | 3.40352 | _ |
| Mat50%_Fem | -3 | 3 | 3 | 3 | _ |
| Mat_slope_Fem | -3 | 3 | 3 | 3 | _ |
| Eggs/kg_inter_Fem | -3 | 3 | 1 | 1 | _ |
| Eggs/kg_slope_wt_Fem | -3 | 3 | 0 | 0 | _ |
| RecrDist_GP_1 | -4 | 4 | 0 | 0 | _ |
| RecrDist_Area_1 | -4 | 4 | 1 | 1 | _ |
| RecrDist_Seas_1 | -4 | 4 | 0 | 0 | _ |
| CohortGrowDev | 1 | 5 | 1 | 1 | _ |
| SR_R0 | 1 | 30 | 10 | 13.6014 | 0.217755 |
| SR_steep | 0.1 | 1 | 0.9 | 0.699827 | 0.211953 |
| SR_sigmaR | 0 | 2 | 1 | 1 | _ |
| SR_envlink | -5 | 5 | 0 | 0 | _ |
| SR_R1_offset | -15 | 15 | 0 | 0.47311 | 0.527798 |
| SR_autocorr | 0 | 2 | 0 | 0 | _ |
| Main_InitAge_5 | _ | _ | _ | -0.472933 | 0.843491 |
| Main_InitAge_4 | _ | _ | _ | 0.268622 | 0.759753 |
| Main_InitAge_3 | _ | _ | _ | 0.150757 | 0.772089 |
| Main_InitAge_2 | _ | _ | _ | 2.08434 | 0.398218 |
| Main_InitAge_1 | _ | _ | _ | -0.506919 | 0.596872 |
| Main_RecrDev_1983 | _ | _ | _ | -1.00104 | 0.489547 |
| Main_RecrDev_1984 | _ | _ | _ | 0.366911 | 0.296722 |
| Main_RecrDev_1985 | _ | _ | _ | 0.337156 | 0.279371 |
| Main_RecrDev_1986 | _ | _ | _ | 0.759464 | 0.264261 |
| Main_RecrDev_1987 | _ | _ | _ | -1.03251 | 0.37629 |
| Main_RecrDev_1988 | _ | _ | _ | 1.68254 | 0.195281 |
| Main_RecrDev_1989 | _ | _ | _ | -0.836794 | 0.413652 |
| Main_RecrDev_1990 | _ | _ | _ | 0.420333 | 0.233331 |
| Main_RecrDev_1991 | _ | _ | _ | 0.334561 | 0.228476 |
| Main_RecrDev_1992 | _ | _ | _ | -0.759672 | 0.321362 |
| Main_RecrDev_1993 | _ | _ | _ | 0.731879 | 0.164942 |
| Main_RecrDev_1994 | _ | _ | _ | 0.242322 | 0.186322 |

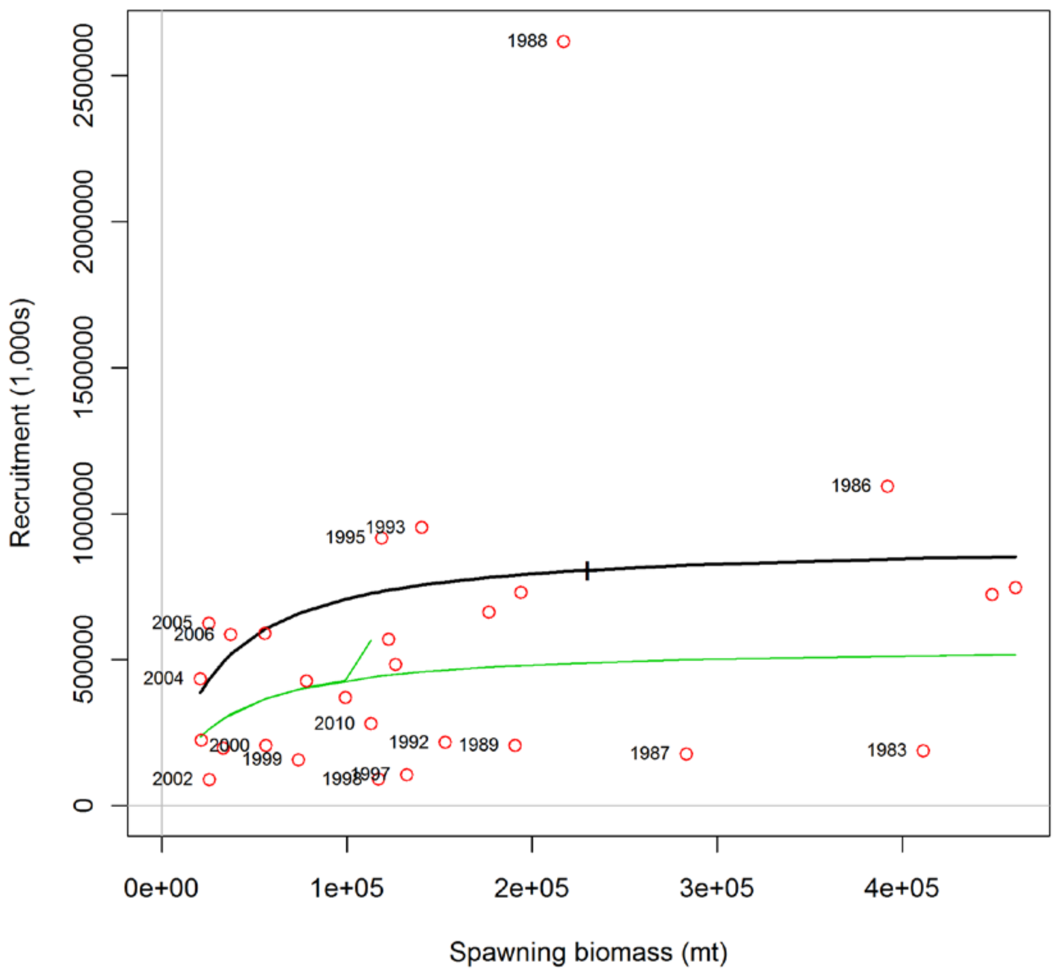
| Parameter | Min_Value | Max_Value | Init_Value | Fin_Value | SD |
|---|---|---|---|---|---|
| Main_RecrDev_1995 | _ | _ | _ | 0.723032 | 0.151321 |
| Main_RecrDev_1996 | _ | _ | _ | 0.0728743 | 0.19468 |
| Main_RecrDev_1997 | _ | _ | _ | -1.44384 | 0.362163 |
| Main_RecrDev_1998 | _ | _ | _ | -1.5808 | 0.306414 |
| Main_RecrDev_1999 | _ | _ | _ | -0.924772 | 0.200919 |
| Main_RecrDev_2000 | _ | _ | _ | -0.577272 | 0.211409 |
| Main_RecrDev_2001 | _ | _ | _ | -0.412906 | 0.338449 |
| Main_RecrDev_2002 | _ | _ | _ | -1.06413 | 0.443654 |
| Main_RecrDev_2003 | _ | _ | _ | -0.0524016 | 0.458841 |
| Main_RecrDev_2004 | _ | _ | _ | 0.614432 | 0.457423 |
| Main_RecrDev_2005 | _ | _ | _ | 0.869945 | 0.397333 |
| Main_RecrDev_2006 | _ | _ | _ | 0.621383 | 0.293877 |
| Main_RecrDev_2007 | _ | _ | _ | 0.476419 | 0.219778 |
| Main_RecrDev_2008 | _ | _ | _ | 0.0534656 | 0.236146 |
| Main_RecrDev_2009 | _ | _ | _ | -0.144445 | 0.289408 |
| Late_RecrDev_2010 | _ | _ | _ | -0.699974 | 0.699216 |
| ForeRecr_2011 | _ | _ | _ | 0 | 1 |
| Impl_err_2011 | _ | _ | _ | 0 | _ |
| InitF_1COM | 0.0001 | 5 | 0.1 | 0.0144242 | 0.0897996 |
| InitF_2REC | 0.00001 | 5 | 0.001 | 0.001 | _ |
| AgeSel_1P_1_COM | -20 | 15 | 1 | 0.0576732 | 2.81372 |
| AgeSel_1P_2_COM | -20 | 15 | -5 | -5 | _ |
| AgeSel_1P_3_COM | -20 | 15 | 4 | -7.37128 | 121.562 |
| AgeSel_1P_4_COM | -20 | 15 | 1.5 | 1.5 | _ |
| AgeSel_1P_5_COM | -20 | 20 | -1 | 0.104554 | 24.0497 |
| AgeSel_1P_6_COM | -20 | 20 | 15 | 15 | _ |
| AgeSel_2P_1_REC | -10 | 15 | 2 | 2.00031 | 0.320612 |
| AgeSel_2P_2_REC | -10 | 15 | -4 | -2.3412 | 3.39767 |
| AgeSel_2P_3_REC | -15 | 15 | -1 | -0.940619 | 0.654569 |
| AgeSel_2P_4_REC | -20 | 15 | -4 | -2.09116 | 22.7202 |
| AgeSel_2P_5_REC | -25 | 15 | -5 | -15.9471 | 104.601 |
| AgeSel_2P_6_REC | -20 | 15 | -2 | -0.426842 | 0.341071 |
| AgeSel_4P_1_CRFS | -10 | 15 | 2 | 0.505643 | 0.404807 |
| AgeSel_4P_2_CRFS | -10 | 15 | -4 | -8.49388 | 30.5612 |
| AgeSel_4P_3_CRFS | -15 | 15 | -1 | 3.69201 | 128.658 |
| AgeSel_4P_4_CRFS | -20 | 15 | -4 | -4.27335 | 70.9969 |
| AgeSel_4P_5_CRFS | -25 | 15 | -5 | -13.2365 | 131.22 |
| AgeSel_4P_6_CRFS | -20 | 15 | -2 | -12.6752 | 91.1591 |

# Pacific Mackerel Stock Assessment (2011) – Parameter Estimates (Model *XA*)

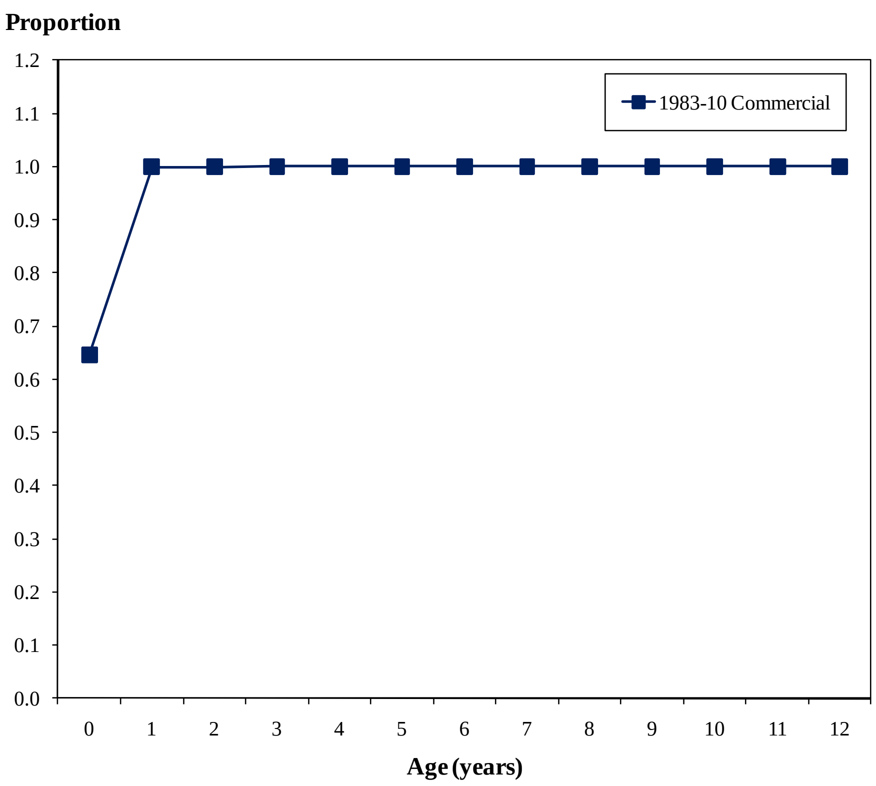
| Sensitivity run | Model | *B* (2011) | *B* (2011) - Peak | *-ln L* (Total) | *-ln L* (CPFV) | *-ln L* (CRFS) |
|---|---|---|---|---|---|---|
| Base case | XA | 211,126 | 1,065,990 | 842.5 | -6.4 | -5.3 |
| 2x $\lambda$ (CPFV index) | XA1 | 219,896 | 1,123,910 | 830.4 | -16.3 | -6.2 |
| 2x $\lambda$ (CRFS index) | XA2 | 200,383 | 1,073,720 | 836.4 | -7.6 | -6.6 |
| 2x $\lambda$ (Recreational length distribution) | XA3 | 287,442 | 1,025,710 | 1,029.7 | -5.8 | -3.9 |
| 2x $\lambda$ (Commercial age distribution) | XA4 | 178,682 | 981,870 | 1,188.6 | 10.8 | -1.5 |
| 2x $\lambda$ (Length-at-age distribution) | XA5 | 210,748 | 1,103,060 | 864.1 | -5.9 | -5.6 |
| Omit CRFS data (inclusive) | XA6 | 251,550 | 1,047,730 | 785.2 | -0.5 | na |
| $M = 0.3\ yr^{-1}$ | XA7 | 95,667 | 323,656 | 853.9 | 4.4 | -4.8 |
| $M = 0.4\ yr^{-1}$ | XA8 | 130,857 | 444,452 | 860.2 | -1.8 | -3.4 |
| $M = 0.6\ yr^{-1}$ | XA9 | 606,752 | 3,676,670 | 840.3 | -8.6 | -5.9 |
| $M = 0.7\ yr^{-1}$ [a] | XA10 | ** | ** | 839.3 | -6.7 | -5.9 |
| Start in 1978 | XA11 | 171,415 | 1,080,300 | 1,231.6 | -1.1 | -5.2 |
| Start in 1981 | XA12 | 190,897 | 1,096,960 | 1,007.1 | -4.3 | -5.0 |
| Start in 1990 | XA13 | 217,789 | 556,043 | 455.0 | -9.9 | -4.9 |
| Length-at-age max - estimate CV | XA14 | 226,929 | 1,082,290 | 851.5 | -8.4 | -4.3 |
| Sigma r = 0.8 | XA15 | 210,172 | 1,053,200 | 841.4 | -6.9 | -5.4 |
| Sigma r = 1.2 | XA16 | 211,258 | 1,071,720 | 845.0 | -6.2 | -5.3 |

**Biomass estimate from sensitivity run was essentially infinite and hessian may not be positive definite.

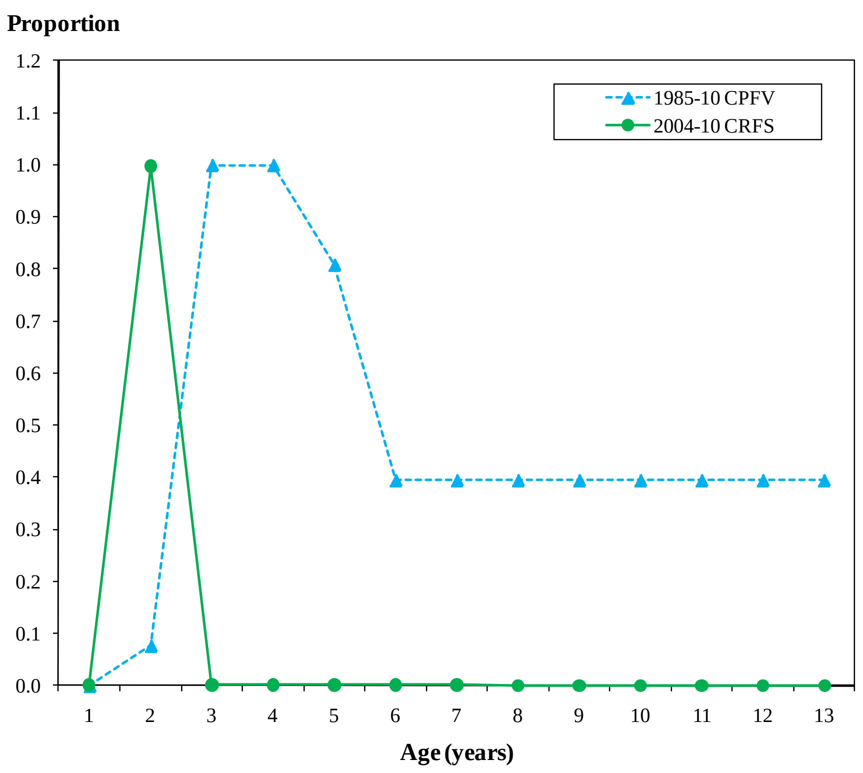
# Stock-Recruitment Relationship – Model *XA*



# Selectivity – Model *XA*

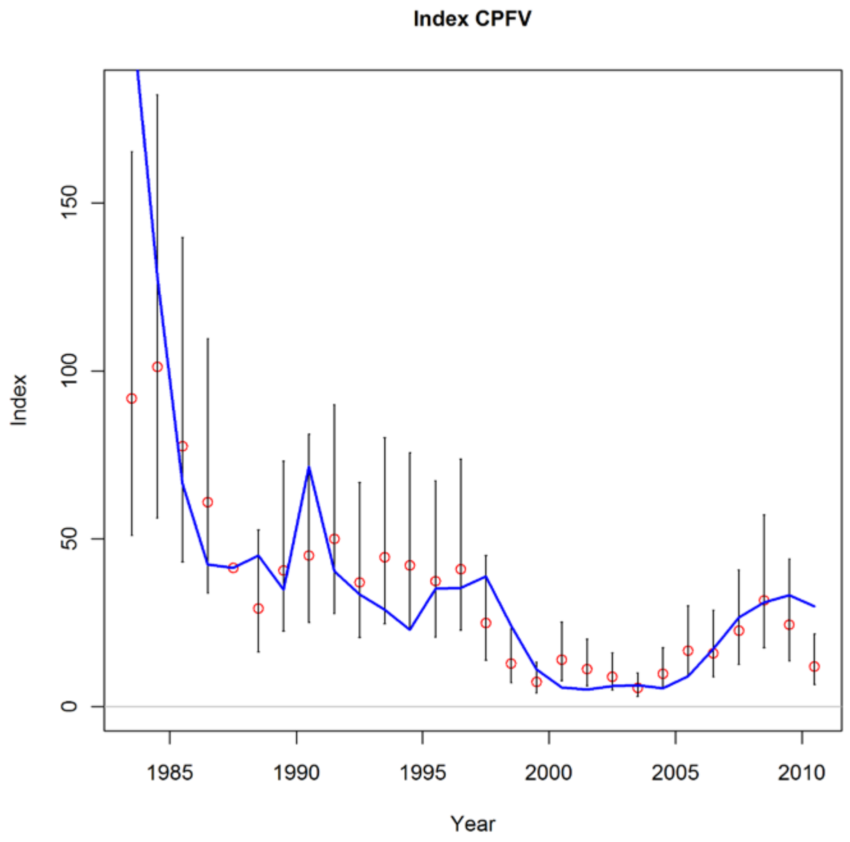


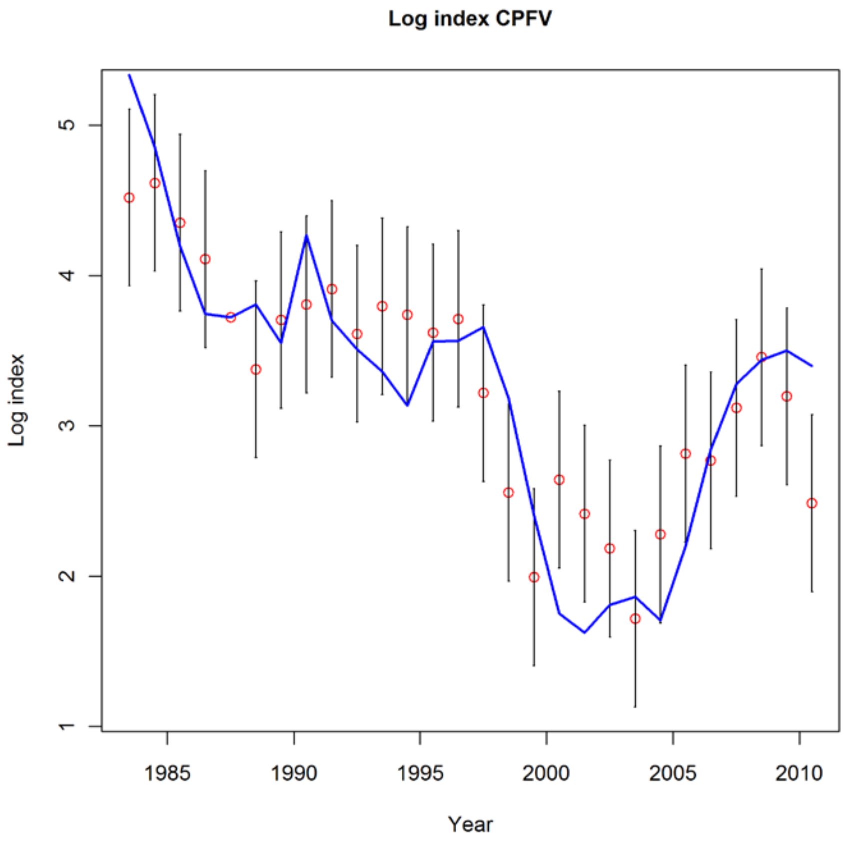

Commercial fishery



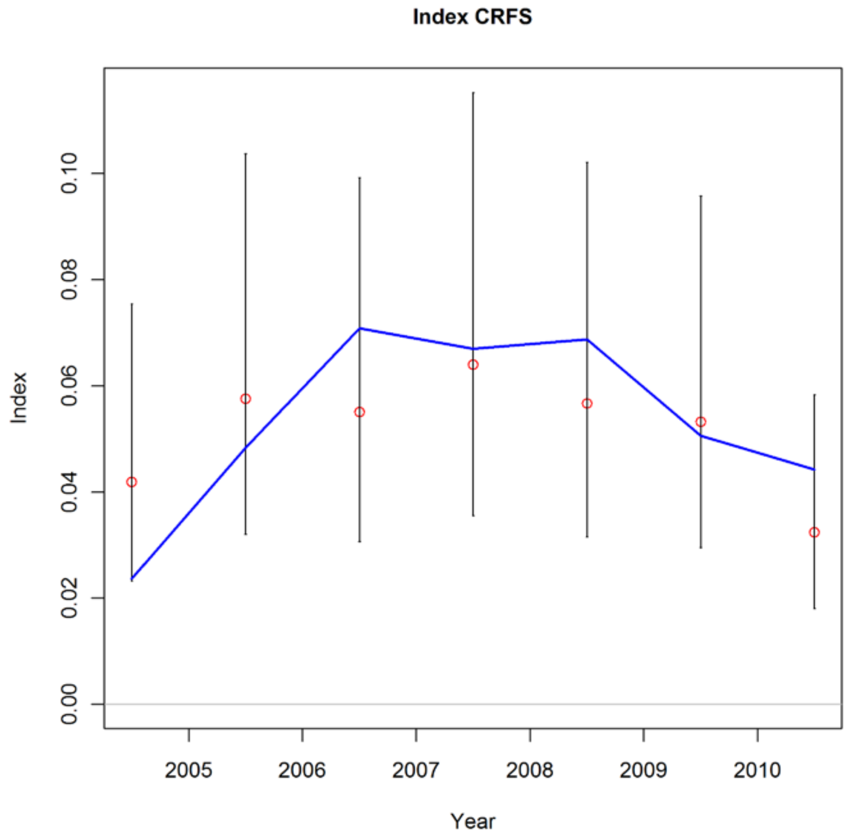

Recreational fishery

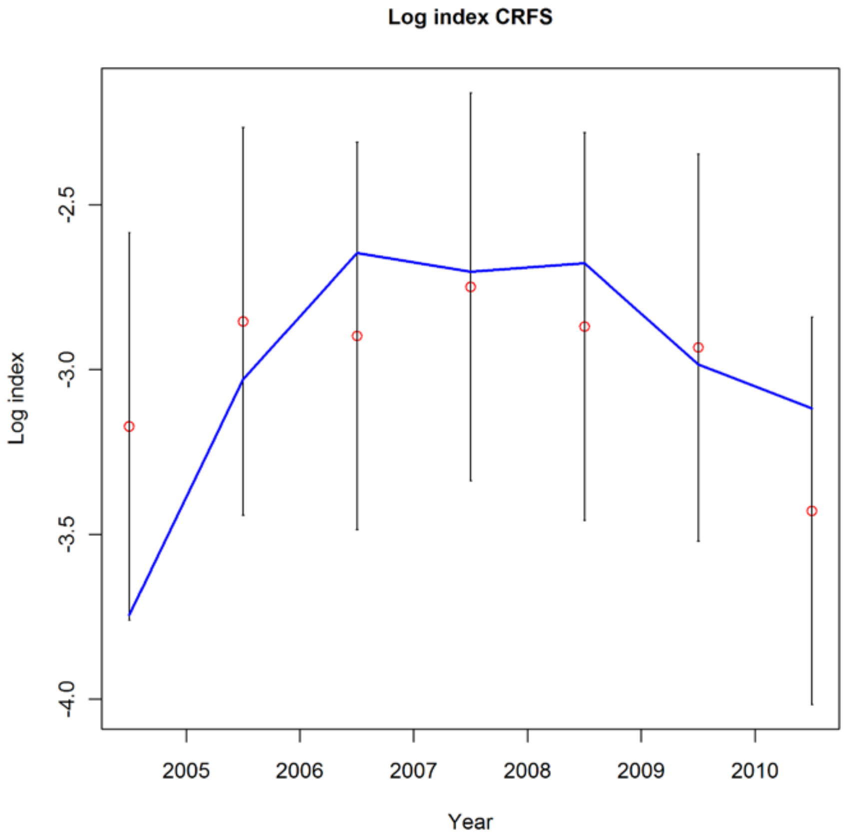
# CPFV Index of Abundance – Model *XA* fits



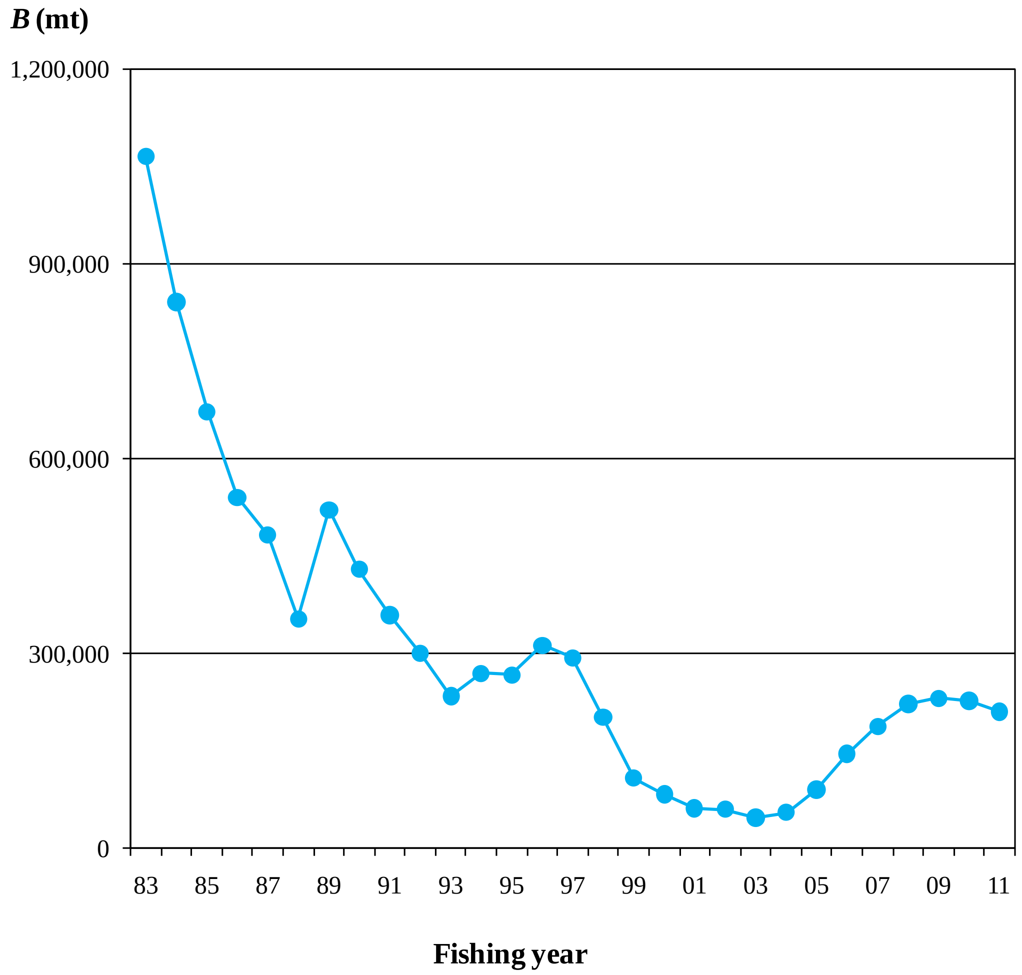



# CRFS Index of Abundance – Model *XA* fits

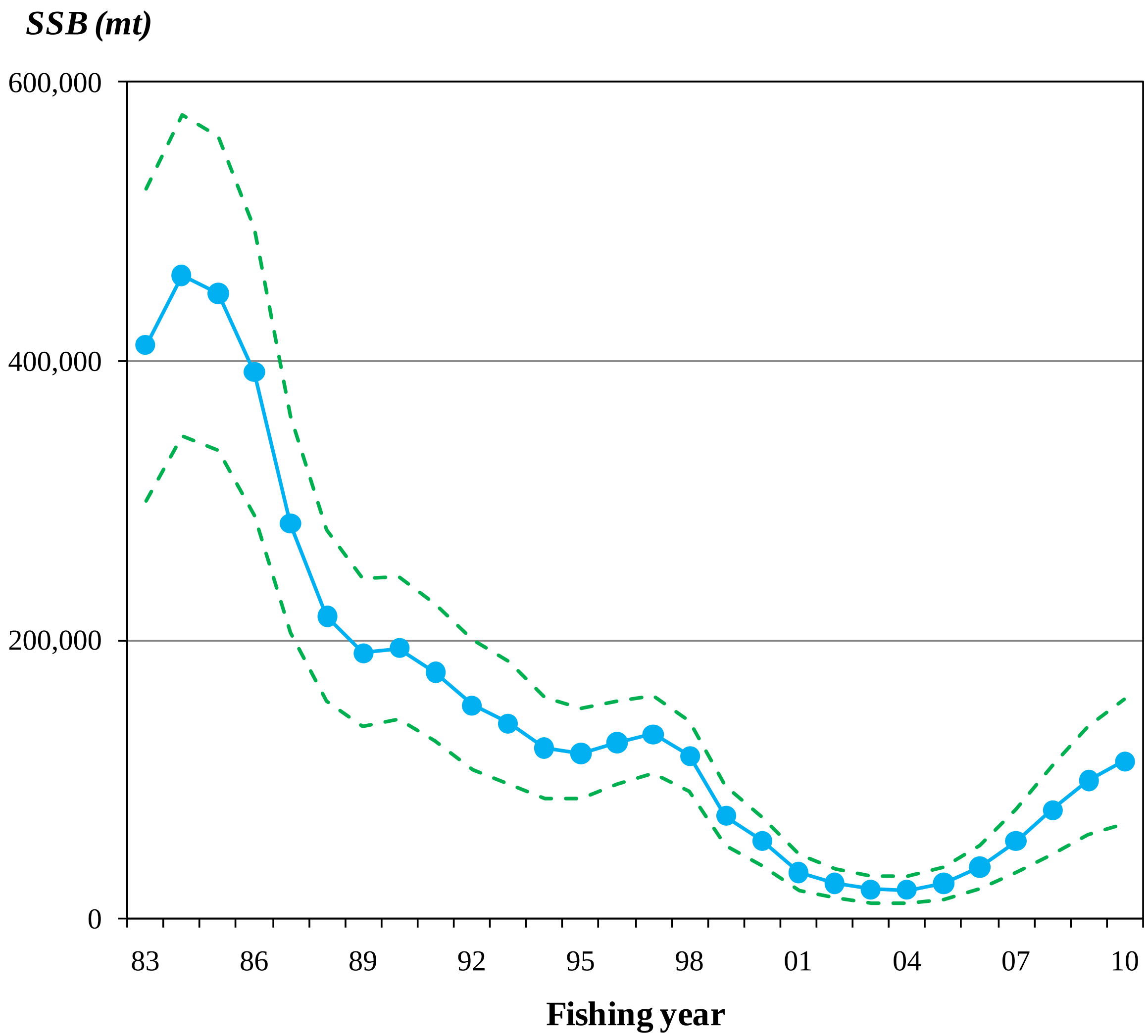


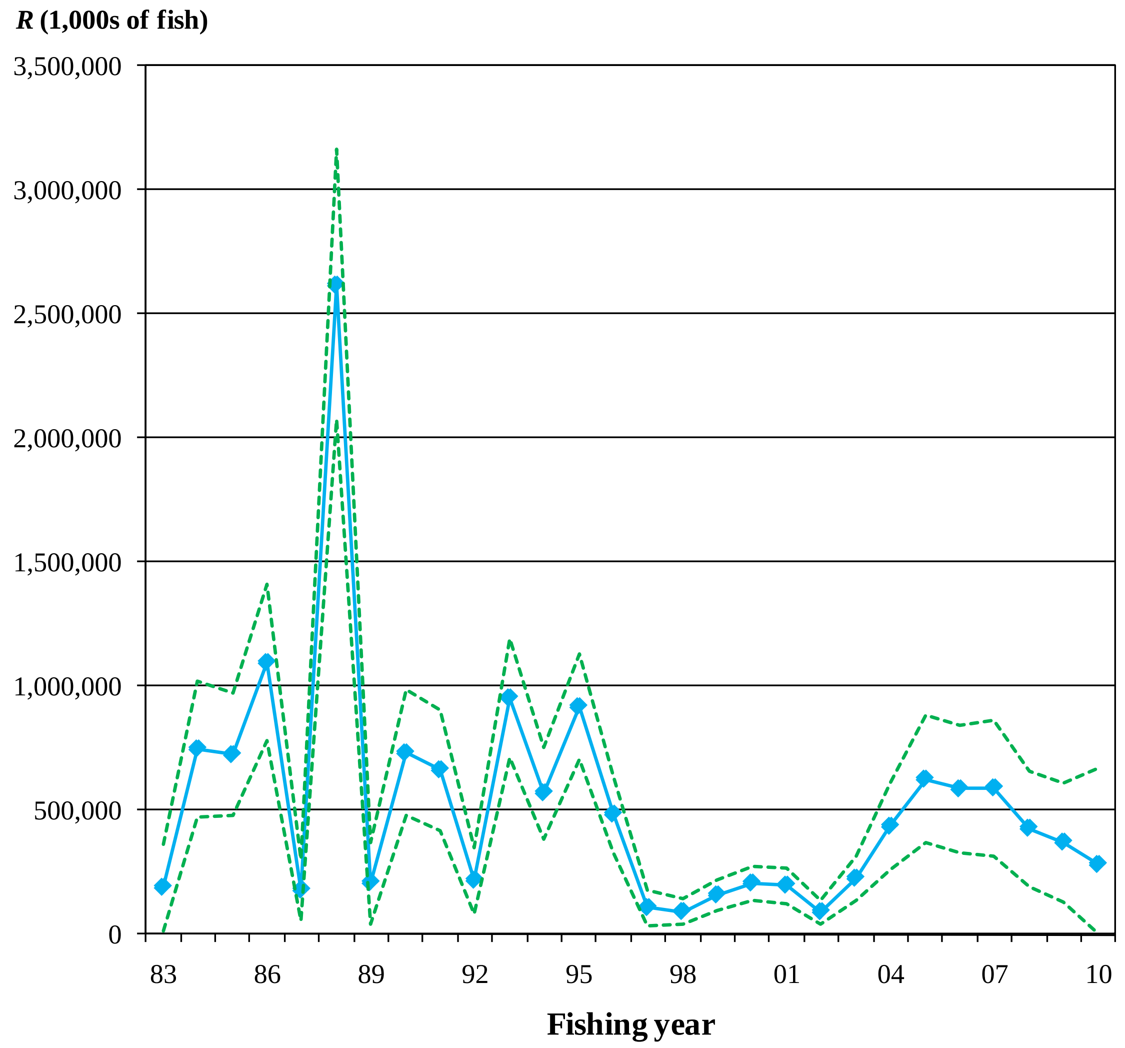
# Estimated Biomass Time Series – Model *XA*



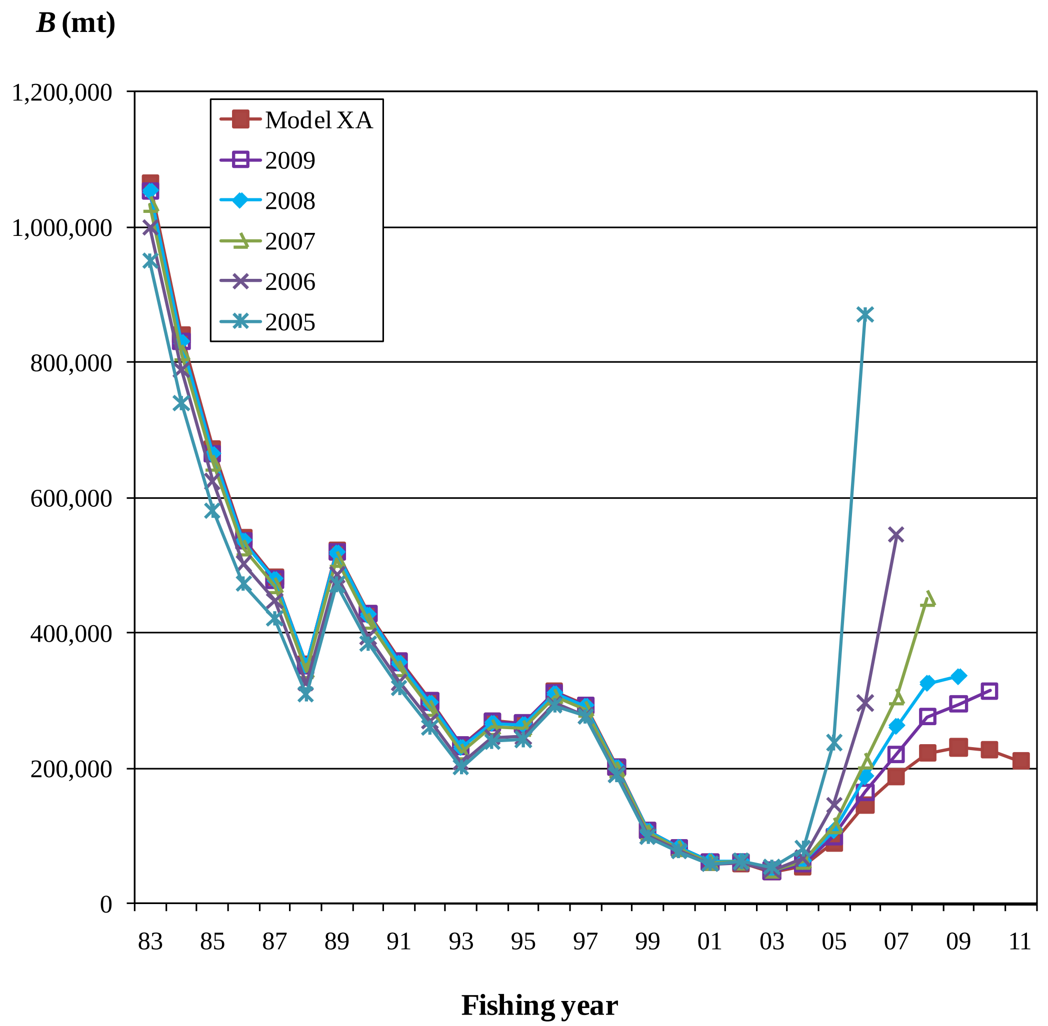
# Estimated Spawning Stock Biomass Time Series – Model *XA*



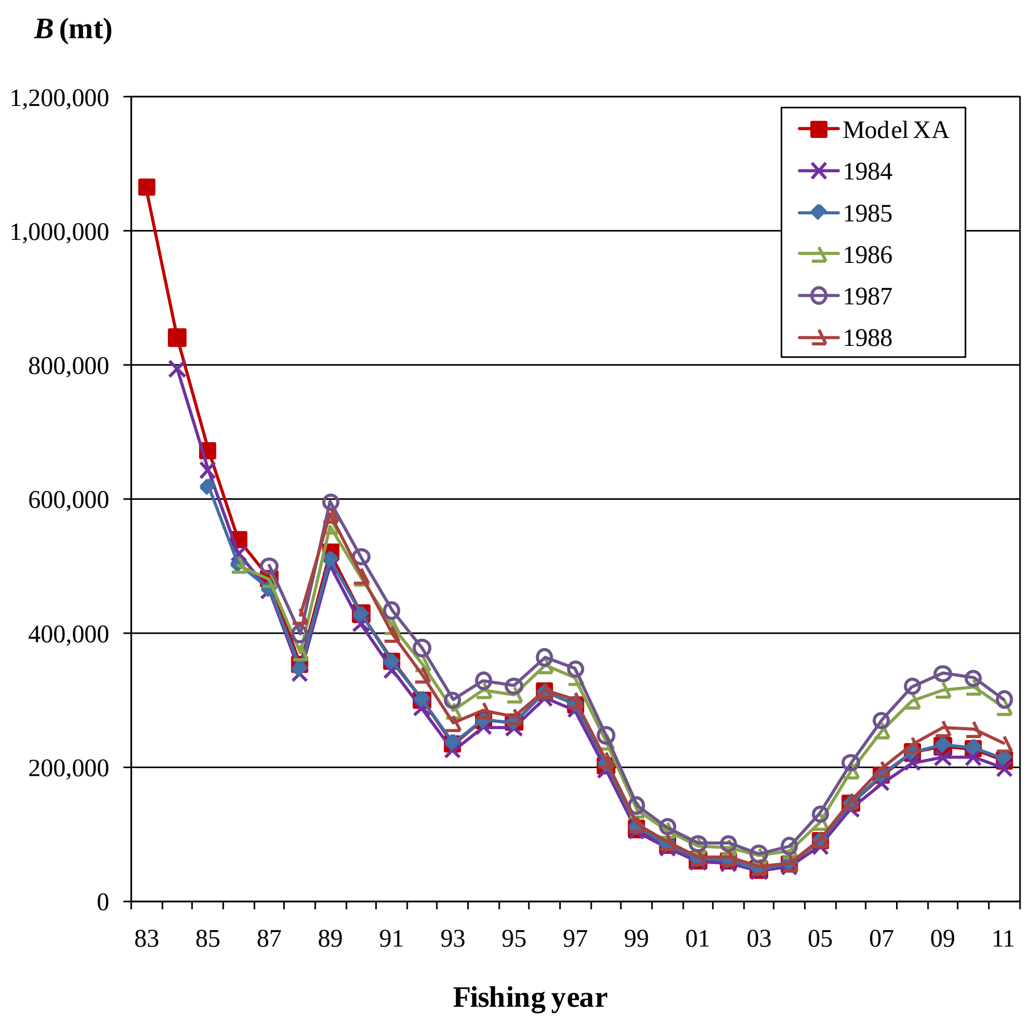
# Estimated Recruitment Time Series – Model *XA*



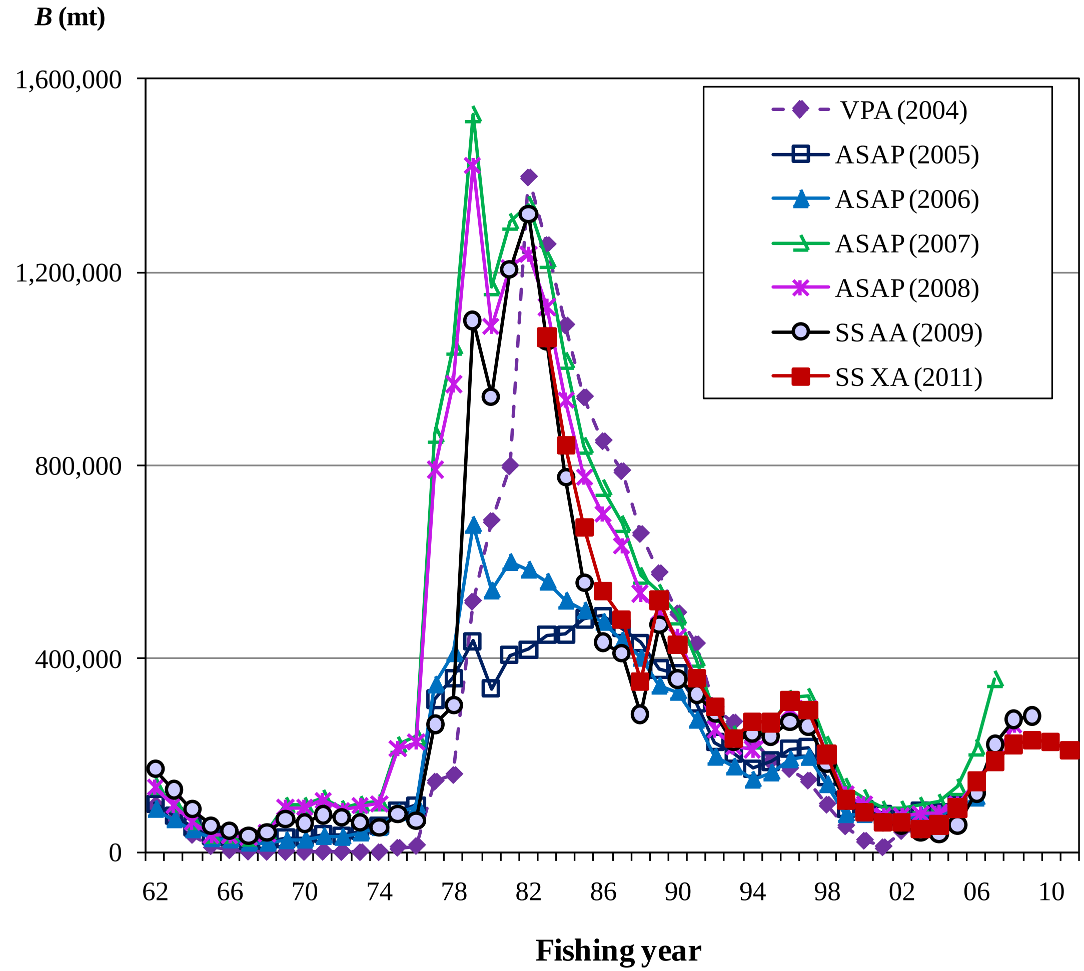
# Estimated Biomass Time Series - Retrospective



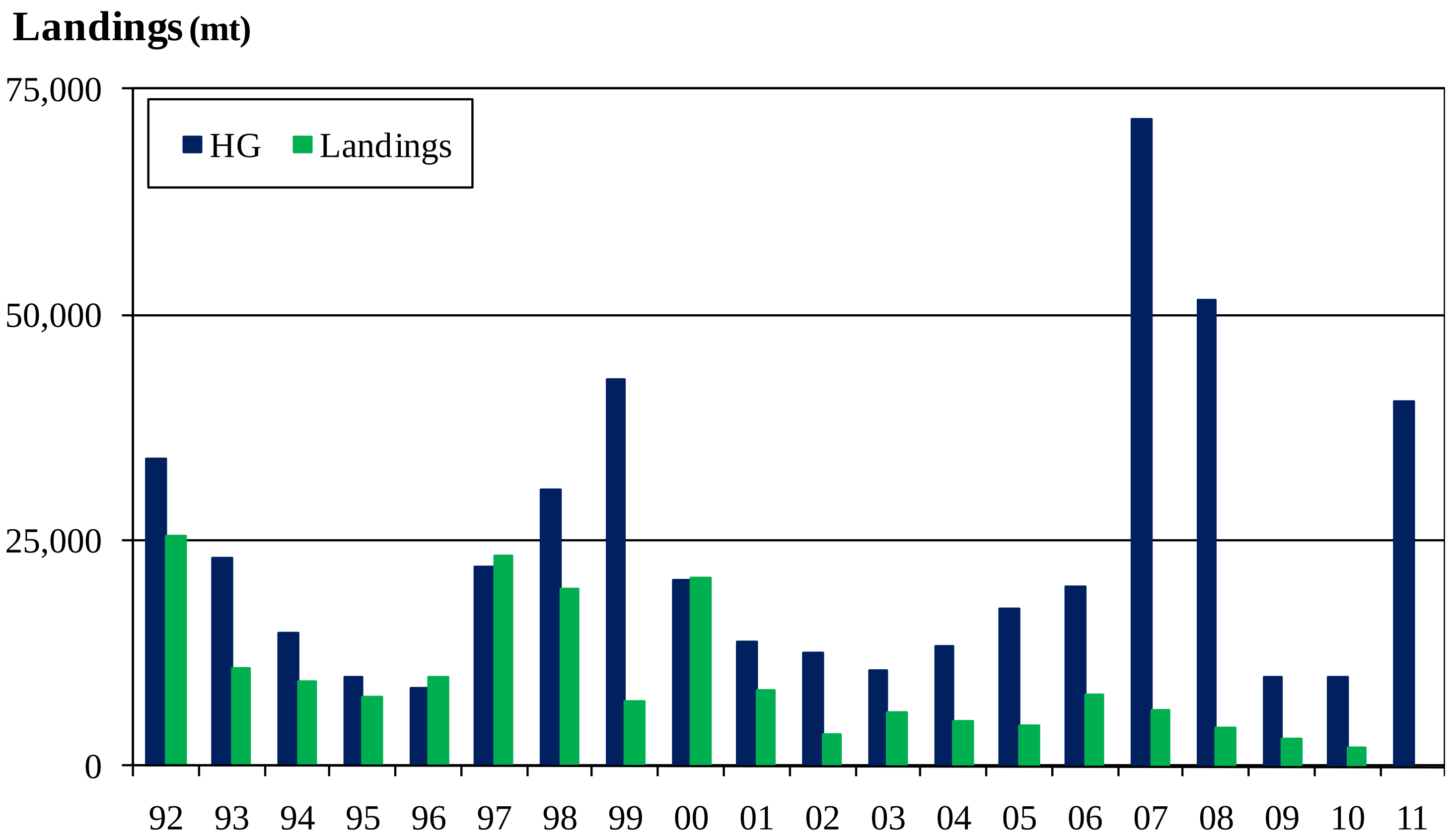
# Estimated Biomass Time Series - Prospective



# Estimated Biomass Time Series
# Historical Assessment Period (2004-11)

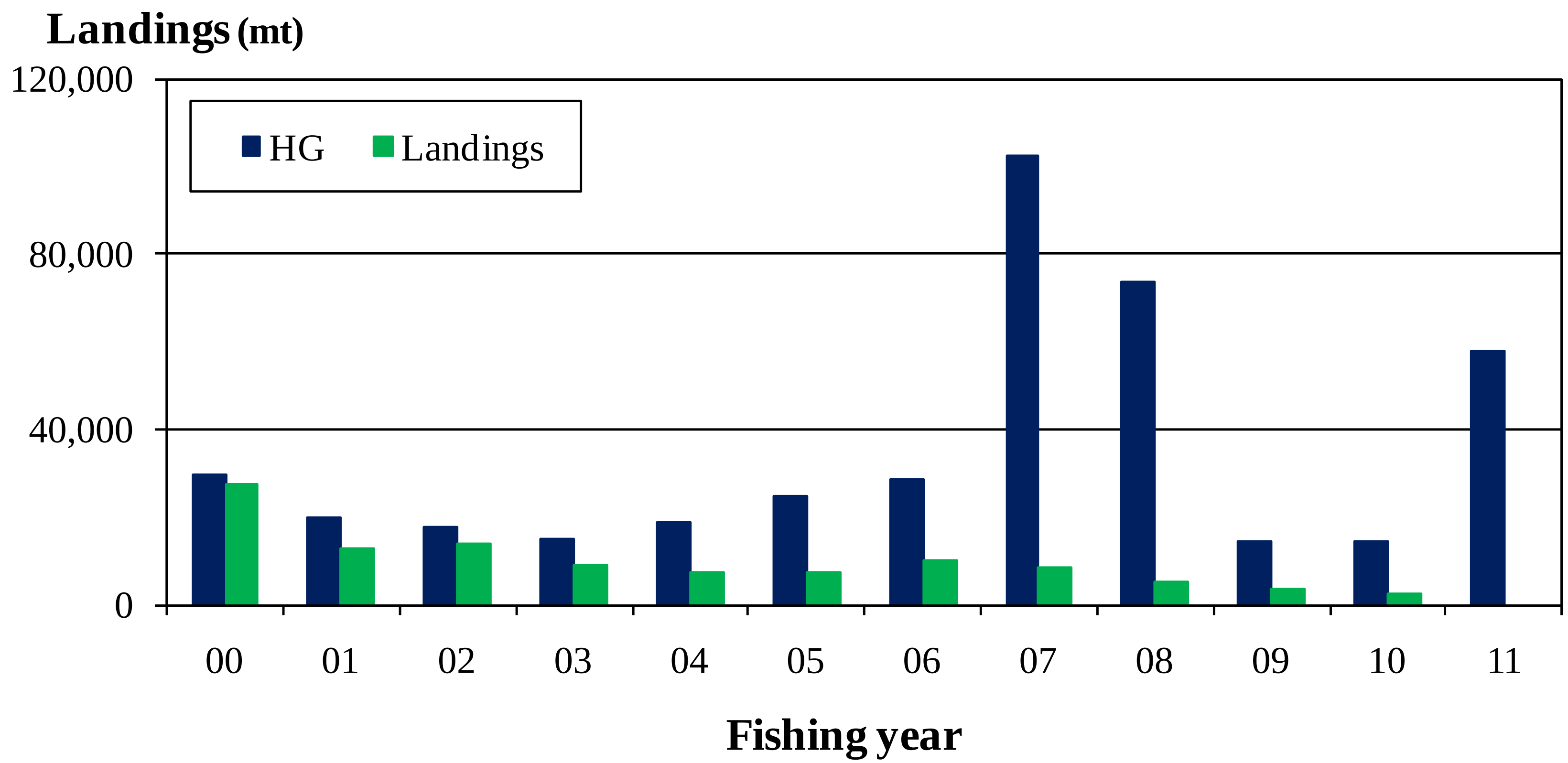


# Harvest Guideline




**Total Landings (mt) and hypothetical quotas based on no USA 'Distribution' parameter in the Harvest Control Rule**

# Harvest Guideline[1]




**[1]Total Landings (mt) and hypothetical quotas based on no USA 'Distribution' parameter in the Harvest Control Rule**

# Pacific Mackerel Stock Assessment (2011)

## Research and Data Needs … *p.* 30

- Improved collaboration with fishery researchers from Mexico and Canada
- Fishery-independent (‘survey’) index is lacking and needed
- Support marine recreational angler sampling programs currently underway (CRFS and CPFV logbook)
- Increased support of current port sampling/laboratory analysis programs underway for CPS (CDFG/NOAA Fisheries joint projects)
- Continued support of maturity study underway currently
- Begin formal research on related CPS to address ‘ecosystem’ component

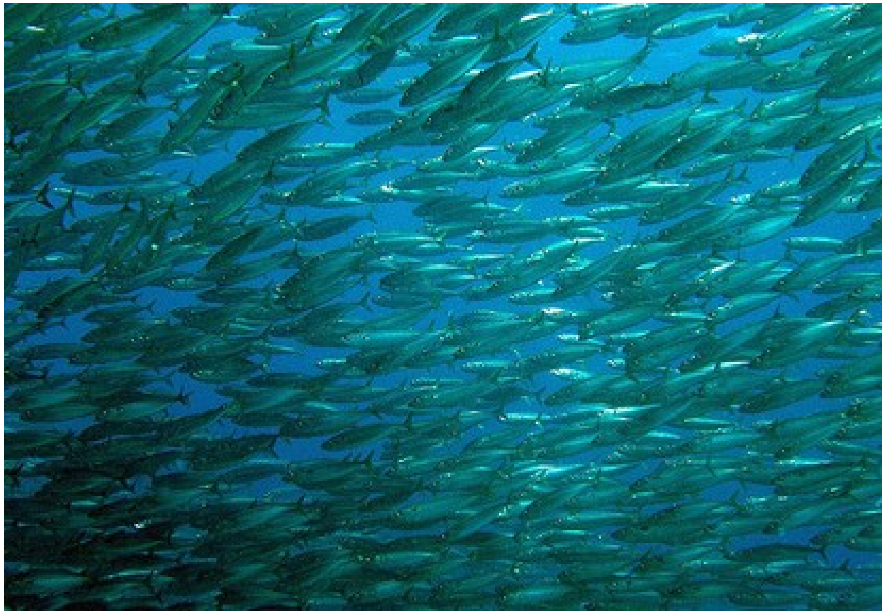
# Pacific Mackerel Stock Assessment (2011)

## Conclusions … see Assessment uncertainty (*p*. 28)

- Stock status determination at this time
  - Based on general information/expert consensus accumulated over time
  - Based on the fish stock assessment conducted recently and presented here

**“First and foremost, the population’s reproductive potential has been only lightly impacted from fishing pressure over the last decade, i.e., the estimated *SPR* time series, blah, blah, blah …”**

Pacific mackerel – California Current Ecosystem



Brown bears – Cabinet Yaak Ecosystem

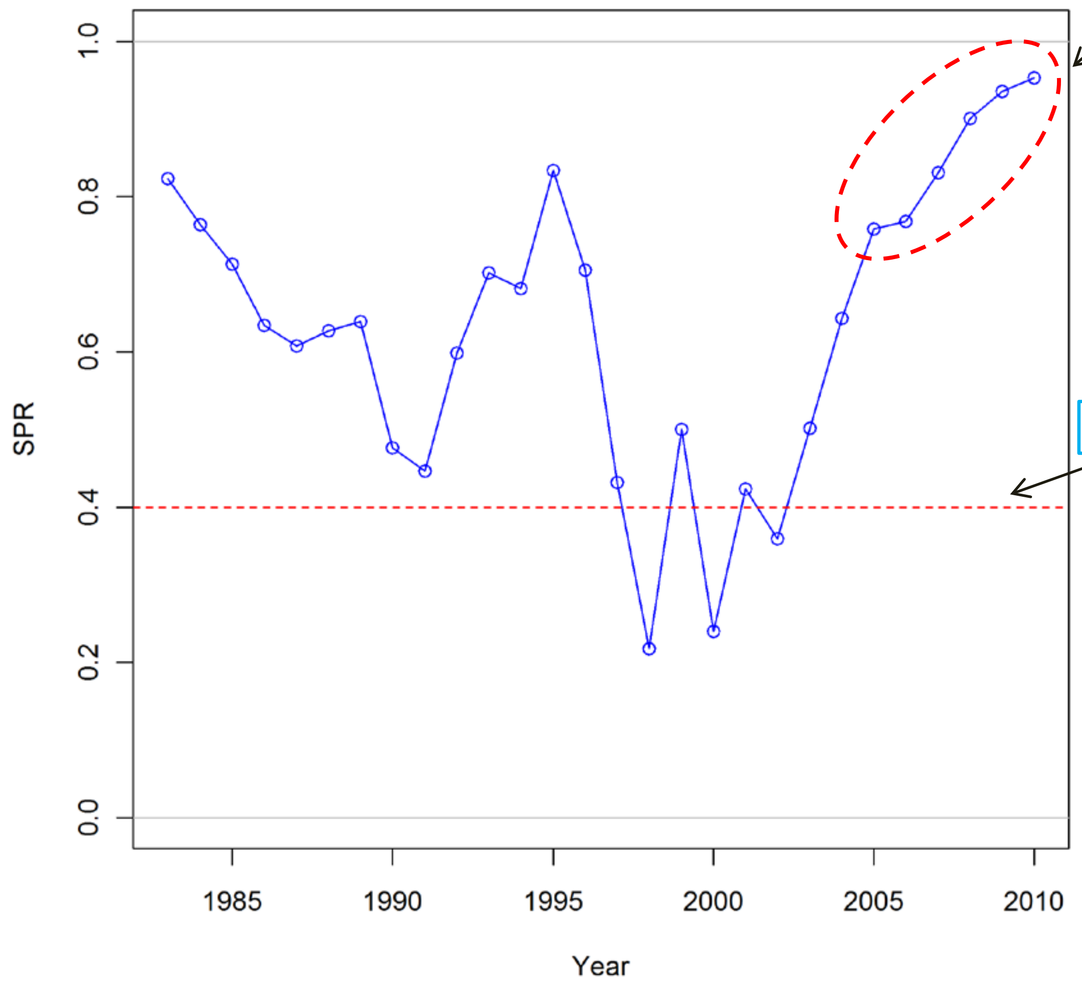
California condors – So. CA Coastal Mountain Range Ecosystem

Pacific bluefin tuna – North Pacific Ocean Ecosystem

# Spawning Potential Ratio Time Series – Model *XA*

Reeeally conservative benchmarks say …

Real conservative benchmark say …



# Pacific Mackerel Stock Assessment (2011)

## Acknowledgements … *p.* 31

- 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 (especially, David), CPSMT folks (especially, Briana), and Council staff (especially, Kerry)
- Time series development / modeling
  - Mark, Alex, Kevin, Vardis, HuiHua, Rick, and Ian[2]
- Review process (STAR contingent)
  - Andre, Jonathan, and John

# COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON PACIFIC MACKEREL MANAGEMENT FOR 2011-2012

The Coastal Pelagic Species Advisory Subpanel (CPSAS) heard a presentation of the Pacific mackerel stock assessment at a meeting of the Science and Statistical Committee, and met jointly with the Coastal Pelagic Species Management Team (CPSMT) to discuss Pacific mackerel management measures and the harvest guideline (HG) for the 2011-2012 season. Dr. Paul Crone presented an analysis of scientific uncertainty. The CPSAS thanks and commends Dr. Crone and the Pacific Mackerel Assessment Team for their dedication and hard work in developing the 2011 stock assessment.

The CPSAS notes that Pacific mackerel are subject to periodic outbreaks in biomass and landings, as occurred in the 2000-2001 season. This unexpected event led to the premature closure of the directed mackerel fishery. California fishermen have reported an increase in mackerel sightings. Under current management measures, an unanticipated spike in mackerel abundance could trigger the closure of other fisheries such as market squid. In addition an artificially low harvest guideline would prevent economic opportunity for our fishing communities.

The CPSAS recommends that the Council adopt the 2011-2012 stock assessment developed by the Stock Assessment Team (STAT) as best available science. Table 6(B), page 46 of the Pacific mackerel stock assessment document, outlines recommended Amendment 13 harvest formulas.

The CPSAS recommends that the Council adopt an acceptable biological catch (ABC)/annual catch limit (ACL) of 40,472 mt.

In adopting management measures for 2011-2012 the Council should consider the following:

- A rapid increase in Pacific mackerel biomass and catches, as occurred in 2000-2001, could create negative impacts to the directed fishery and other fisheries.
- There is no incentive to invest in spotter pilots or increase vessel fuel expenses in order to prospect and explore traditional offshore fishing grounds when harvest guidelines are at low levels.
- Recent year observations indicate an increase in Pacific mackerel. Fishermen and processors can only build viable business plans when there is a sufficient harvest guideline to justify the associated expenses.

We recommend setting an incidental set-aside of 25 percent of the ABC/ACL, but not less than 5,000 mt, to protect other fisheries. An increase in the directed fishery for Pacific mackerel will provide flexibility for the fleet to target mackerel when they become available to the fishery. This will help mitigate severe economic impacts if sardine and other CPS fisheries are at low harvest thresholds.

The CPSAS further recommends the following in the event the directed fishery closes:

- A 45 percent incidental catch is allowed when Pacific mackerel are landed with other coastal pelagic species; and

- Up to 1 mt of Pacific mackerel could be landed without landing any other CPS.

The CPSAS recommends an inseason review of the 2011-2012 Pacific mackerel fishery at the April 2012 Council meeting, if needed, to consider releasing a portion of the incidental set-aside to the directed fishery.

PFMC
06/10/11

# COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON PACIFIC MACKEREL MANAGEMENT IN 2011-2012

The Coastal Pelagic Species Management Team (CPSMT) met concurrently with the Scientific and Statistical Committee (SSC) and the Coastal Pelagic Species Advisory Subpanel (CPSAS) on June 9, 2011 to review the latest stock assessment of Pacific mackerel. In May 2011, a full stock assessment for Pacific mackerel was reviewed by a Stock Assessment Review (STAR) Panel in La Jolla, CA. The CPSMT supports conclusions from the Pacific mackerel stock assessment and STAR Panel. The CPSMT commends the Stock Assessment Team (STAT) on their overall work efforts, including: (1) identifying additional data sources for inclusion in the stock assessment model, e.g., biological and index of abundance information from the marine recreational fishery; and most importantly, (2) developing a sound population model that can be used to assess the status of the Pacific mackerel stock and provide appropriate management advice on sustainable exploitation strategies for this species. The CPSMT agrees with the research and data needs identified by the STAT and STAR Panel; in particular, the need for fishery-independent surveys that are well-supported and encompass the geographic range of the stock.

For the 2011-2012 management season, the CPSMT recommends the annual catch limit (ACL) be equal to the Harvest Guideline (HG, 40,514 mt) associated with the harvest control rule, which falls within the range of the acceptable biological catch (ABC) values. The table below provides the result from the harvest control rule and a range for ABC options. For the range of $P^*$ values presented, the team recognizes that if the Council selects a $P^*$ value less than 0.45, then the CPSMT-recommended ACL would exceed the ABC, and a different ACL would need to be selected. The CPSMT concludes that the range of ABC values is not likely to jeopardize the long-term sustainability of the stock. In addition, the CPSMT supports the CPSAS statement regarding incidental catch (i.e., an annual catch target (ACT) would be 75 percent of the ACL; 45 percent incidental catch allowance; 1 mt landing allowance) as this would be enough set-aside to support the indirect fishery and other sources of fisheries mortality.

In summary, this species has received very little fishing pressure over the last several years, with annual landings below the established HGs for the directed U.S. fishery and more importantly, its general biology is to produce only moderate recruitment success over long timeframes, with very high productivity produced infrequently and likely over short timeframes. The CPSMT recommends that the next formal stock assessment for this species be scheduled tentatively for 2013.

Table 6 from the stock assessment (page 46) shows the harvest control rule information for the Pacific mackerel fishery (2011-12) based on Model *XA*.

| ***B*** **(Age 1+, mt)** | **Cutoff (mt)** | **Fraction** | **Distribution** | **HG (mt)** |
|---|---|---|---|---|
| 211,126 | 18,200 | 30% | 70% | **40,514** |

| **Harvest Formula Parameters** | **Value** | | | |
|---|---|---|---|---|
| BIOMASS (ages 1+, mt) | 211,126 | | | |
| Pstar (probability of overfishing) | 0.45 | 0.4 | 0.3 | 0.2 |
| $BUFFER_{Pstar}$ | 0.95577 | 0.91283 | 0.82797 | 0.73861 |
| $F_{MSY}$ | 0.3 | | | |
| FRACTION | 0.3 | | | |
| CUTOFF (mt) | 18,200 | | | |
| DISTRIBUTION (U.S.) | 0.7 | | | |

| **Amendment 13 Harvest Formulas** | **MT** |
|---|---|
| OFL = BIOMASS * $F_{MSY}$ * DISTRIBUTION | 44,336 |
| $ABC_{0.45}$ = BIOMASS * BUFFER0.45 * $F_{MSY}$ * DISTRIBUTION | 42,375 |
| $ABC_{0.40}$ = BIOMASS * BUFFER0.40 * $F_{MSY}$ * DISTRIBUTION | 40,472 |
| $ABC_{0.30}$ = BIOMASS * BUFFER0.30 * $F_{MSY}$ * DISTRIBUTION | 36,709 |
| $ABC_{0.20}$ = BIOMASS * BUFFER0.20 * $F_{MSY}$ * DISTRIBUTION | 32,747 |
| ACL=LESS THAN OR EQUAL TO ABC | TBD |
| HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION | 40,514 |
| ACT=EQUAL TO HG OR ACL, WHICHEVER VALUE IS LESS | TBD |

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06/10/11

Agenda Item G.2.c
Supplemental SSC Report
June 2011

# SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON PACIFIC MACKEREL MANAGEMENT FOR 2011-12

Dr. Paul Crone from the Southwest Fisheries Science Center (SWFSC) presented the results of the Pacific mackerel stock assessment for the 2011-12 fishing year, and Dr. Ray Conser of the Scientific and Statistical Committee (SSC) presented a report on the Pacific mackerel Stock Assessment Review Panel that convened at the SWFSC in La Jolla, CA on May 2-5, 2011.

The assessment model was a modification of the Stock Synthesis-based model used in the previous assessment in 2009. It used commercial fishery age composition data and abundance indices developed from Commercial Passenger Fishing Vessel (CPFV) logbooks and the California Recreational Fishery Survey (CRFS) catch and effort data. The current model shows a strong retrospective pattern, which could be indicative of model overestimation of biomass.

The SSC endorses the updated assessment as best scientific information available for management of Pacific mackerel. The SSC further endorses the overfishing limit (44,336 mt), and ABC alternatives outlined in the assessment for the upcoming fishing season. The acceptable biological catch (ABC) alternatives depend on the Council's risk policy as reflected in the choice of P*.

The SSC highlights several critical data and research needs. Both the SSC and the Stock Assessment Team emphasize the importance of a fishery-independent survey, preferably as part of a multi-species coastal pelagic survey. There was general consensus that the acoustic trawl methodology is well-suited for such a survey, but would need to be expanded to encompass Mexican waters, and ideally Canadian waters as well, to be useful for Pacific mackerel assessment.

The current $F_{MSY}$ value used for Pacific mackerel has not been recently updated and appears to be based at least partly on qualitative considerations. The SSC recommends that $F_{MSY}$ be reevaluated using more current information and analytical approaches.

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06/10/11