NATIONAL MARINE FISHERIES SERVICE REPORT

Mr. Mark Helvey, of the National Marine Fisheries Service Southwest Region (NMFS SWR), will provide the Council a presentation on the February, 2010 NOAA Catch Shares Workshop. Dr. Gary Sakagawa, of the NMFS Southwest Fisheries Science Center (SWFSC), will present the report on the June, 2010 survey methods workshop, which included discussion of future stock assessment methods and planning. Dr. Russ Vetter, (NMFS SWFSC) will provide a brief presentation on the 2010 sardine survey results, ocean conditions, and how those results compare with recent years.

Council Task:

1. Discussion.

Reference Materials:

Agenda Item I.1.b, Attachment 1: *Workshop on Enhancing Stock Assessments of Pacific Sardine in the California Current through Cooperative Surveys*.

Agenda Order:

a.	Regulatory Activities	**Mark Helvey**
b.	Fisheries Science Center Activities	**Gary Sakagawa, Russ Vetter**
c.	Reports and Comments of Management Entities and Advisory Bodies	
d.	Public Comment	
e.	Council Discussion	

PFMC
10/18/10

Science, Service, Stewardship

Agenda Item I.1.a
Supplemental NMFS SWR PowerPoint (Helvey)
November 2010

Overview of the Coastal Pelagic Species Catch Share Workshop

February 2-4, 2010
San Francisco
California

November 7, 2010

NOAA FISHERIES SERVICE

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Workshop Purpose and Structure

- **Two-part purpose**
  - Educational
  - Information-sharing
- **Structure**
  - Educational
    - Background talks
    - Case study presentations
  - Information-sharing
    - Panel sessions
    - Full and small group discussion sessions

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Workshop Participation

- **57 total participants**
- **Catch shares experience**
  - Fishery managers
  - Academics
- **CPS fishery interests**
  - Fishermen (i.e., commercial, small landings, recreational, live bait)
  - Processors
  - Conservation groups
  - Federal and state fishery managers

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Background Talks

- **Mark Helvey**
  Significance of Catch Shares from a Policy Perspective
- **Monica Medina**
  NOAA Catch Shares Task Force
- **Sam Herrick**
  Conditions in the U.S. West Coast CPS Fishery
- **Jenny Sun**
  Price Response Analysis of the U.S. Pacific Sardine Fishery
- **Amber Morris**
  Rights-based Management Program Variety
- **Rognvaldur Hannesson**
  Catch Shares and Fisheries Management

Case Study Presentations

- **Jim Seger**
  U.S. West Coast Groundfish Trawl Rationalization
- **Julio Pena Torres**
  Rights-based Fishery Management in Chile
- **Rashid Sumaila**
  Namibian Fisheries Management and Individual Catch Quotas
- **Tim Ward**
  South Australian Sardine Fishery and Individual Transferable Quotas
- **Tracy Yandle**
  New Zealand Rock Lobster Experience with Property Rights
- **Glenn Merrill**
  Bering Sea Pollock Fishery Quota-based Catch Share Program

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Major Findings: Need for management changes

- **Overfishing is not a driver for change**
- **Under low biomass conditions, current management does not work well**
  - Fishery operates as a derby
  - Product continuity is reduced
- **Lack of consensus on urgency of improvements**
  - Short-term: reconsider season start dates; set capacity goals; reduce competition among sectors
  - Long-term: account for regional differences in resource availability and community values; generate value with product consistency, create transboundary agreements

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Major Findings: Catch share program concerns

- **Time requirements for design and implementation**
- **Ability to adequately assess community impacts**
- **Impacts to small landings operations and niche markets**
- **Effects of stock fluctuations on share values**
- **Deterrence of new entrants**
- **Controversy over initial allocation**
  - Assurance of equity across sectors of fishery
  - Access to adequate information and understanding of stock structure and movement

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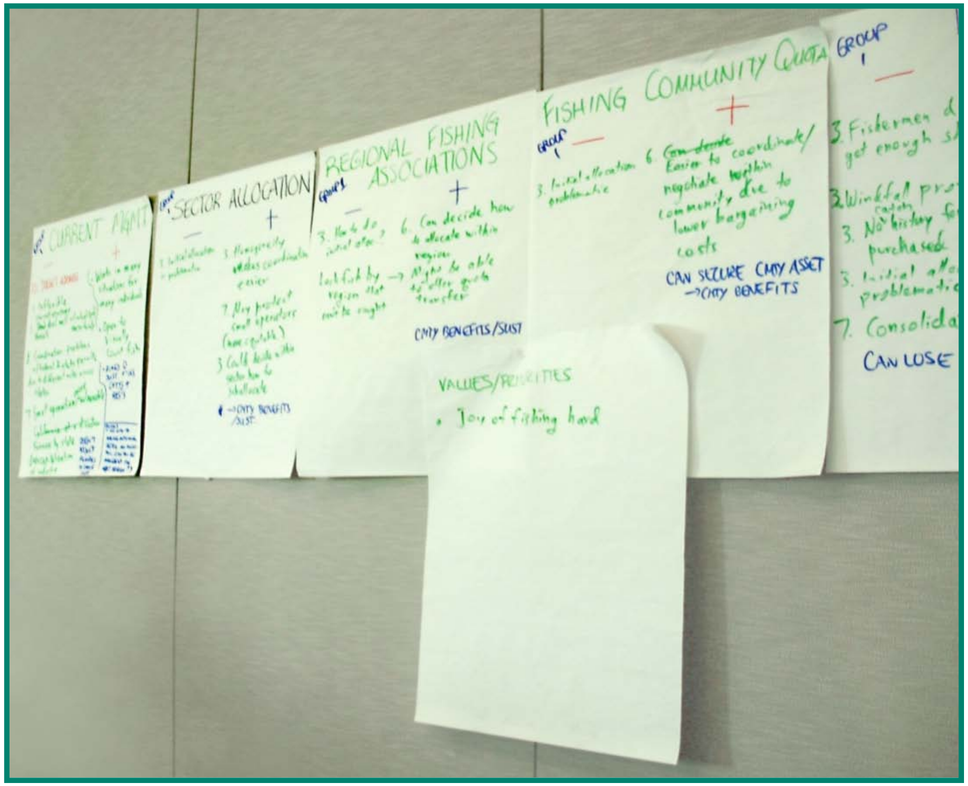
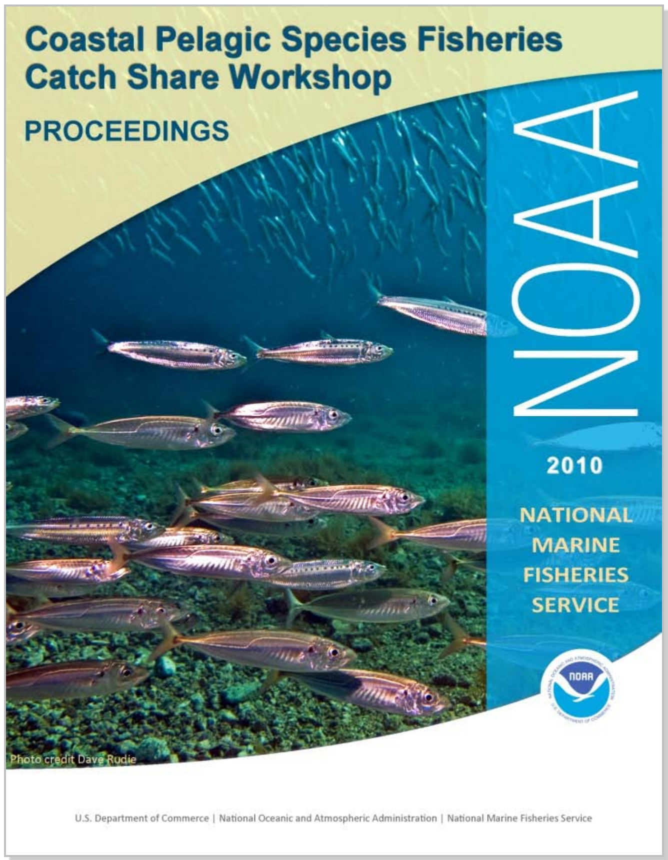
Major Findings: Allocation options considered

- **ITQs raised concerns**
- **Permit stacking got mixed reviews**
- **Regional, sector, and community allocations were more favorably considered**



NOAA FISHERIES SERVICE

Workshop Proceedings



- **Printed copies available, contact:**

Amber Morris

Southwest Regional Office

(562) 980-3231

Amber.Morris@noaa.gov

- **Electronic copies available online:**

http://swr.nmfs.noaa.gov/fmd/cps/2010-cs-workshop-proceedings.htm

WORKSHOP ON ENHANCING STOCK ASSESSMENTS OF PACIFIC SARDINE IN THE CALIFORNIA CURRENT THROUGH COOPERATIVE SURVEYS

JUNE 1-3, 2010
LA JOLLA, CALIFORNIA

WORKSHOP REPORT AVAILABLE

- In PFMC Nov. 2010 Briefing Book
- On SWFSC website (+documents)

ACKNOWLEDGEMENT

SPONSORS - SWFSC and NWFSC in partnership with stakeholders

STEERING TEAM - Kristen Koch, Mike Okoniewski, Diane Pleschner-Steele, Jerry Thon, Usha Varanasi, Gary Sakagawa

TECHNICAL TEAM - Bob Emmett, Tom Jagielo, Doyle Hanan, Russ Vetter, Gary Sakagawa, Sarah Shoffler

ACKNOWLEDGEMENT (Cont.)

CONTRIBUTORS - Jim Churnside, Dave Demer, Kevin Hill, Tom Jagielo, Nancy Lo, Bev Macewicz, Jake Schweigert, Dale Sweetnam

CRUCIAL SUPPORT - Gerard DiNardo, Don Hansen, Rose Sanford, Sarah Shoffler, Dawn Graham

Present Distribution
('northern subpopulation')
Summer
Feeding Habitat
Spring
Spawning Habitat
Nursery Habitat
British Columbia
Washington
Oregon
Monterey
San Pedro
Ensenada

WORKSHOP
TO ACHIEVE COMMON UNDERSTANDING ABOUT

- ADVANTAGES, LIMITATIONS AND CHALLENGES WITH SURVEY METHODS
- IDENTIFY CURRENT INVESTIGATORS AND USERS
- IDENTITY OPPORTUNITIES FOR COLLABORATION IN ADVANCING DEVELOPMENT

SURVEY METHODS REVIEWED

Method	Principal Sponsor
ACOUSTICS	SWFSC
AERIAL	Fishing industry
DAILY EGG PRODUCTION	SWFSC
Fishery-Dependent (LOGBOOK)	CDFG
LIDAR	NOAA, ESRL
SATELLITE Photography	Fishing industry
SWEPT AREA TRAWL	Canada-DFO

PROPOSED COLLABORATION ON SURVEYS FOR 2010 and 2011

	2010	2011
*ACOUSTICS	X	X
*AERIAL	X	?
LIDAR	X	?
SATELLITE IMAGES	X	?
ACOUSTICS	X	?
*DAILY EGG PRODUCTION	X	X
SATELLITE IMAGES	X	X
*SWEPT AREA TRAWL	X	X

EXPERIMENT NEEDED IN 2012

Objective: Compare and calibrate sardine survey methods under similar conditions (season, area, environment, sizes of sardine, etc.)

Develop a Plan:

1) SWFSC organize an Experimental Design Team (Team)
2) Team design experiment for small areas and short periods
3) Team use available information on stock structure, biology, etc.

EXPERIMENT NEEDED IN 2012 (Cont.)

Funding and Execution:

1) Experimental design available by March 2011
2) Experiment promoted for funding
3) Experiment executed in 2012

Questions

Agenda Item I.1.b
Supplemental NMFSSWFSCPowerPoint (Vetter)
November 2010

Research Update for:
Coastal Pelagic Species FMP
Southwest Fisheries Science Center

Russ Vetter, Director Fisheries Resources
Southwest Fisheries Science Center

November 7, 2010

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Science, Service, Stewardship

1. Sardine Habitat Models
2. Spring 2010 Sardine Biomass cruise results
3. Plans for STAR acoustic/trawl biomass estimation
4. New Capabilities: FSVs and new laboratory

November 7, 2010

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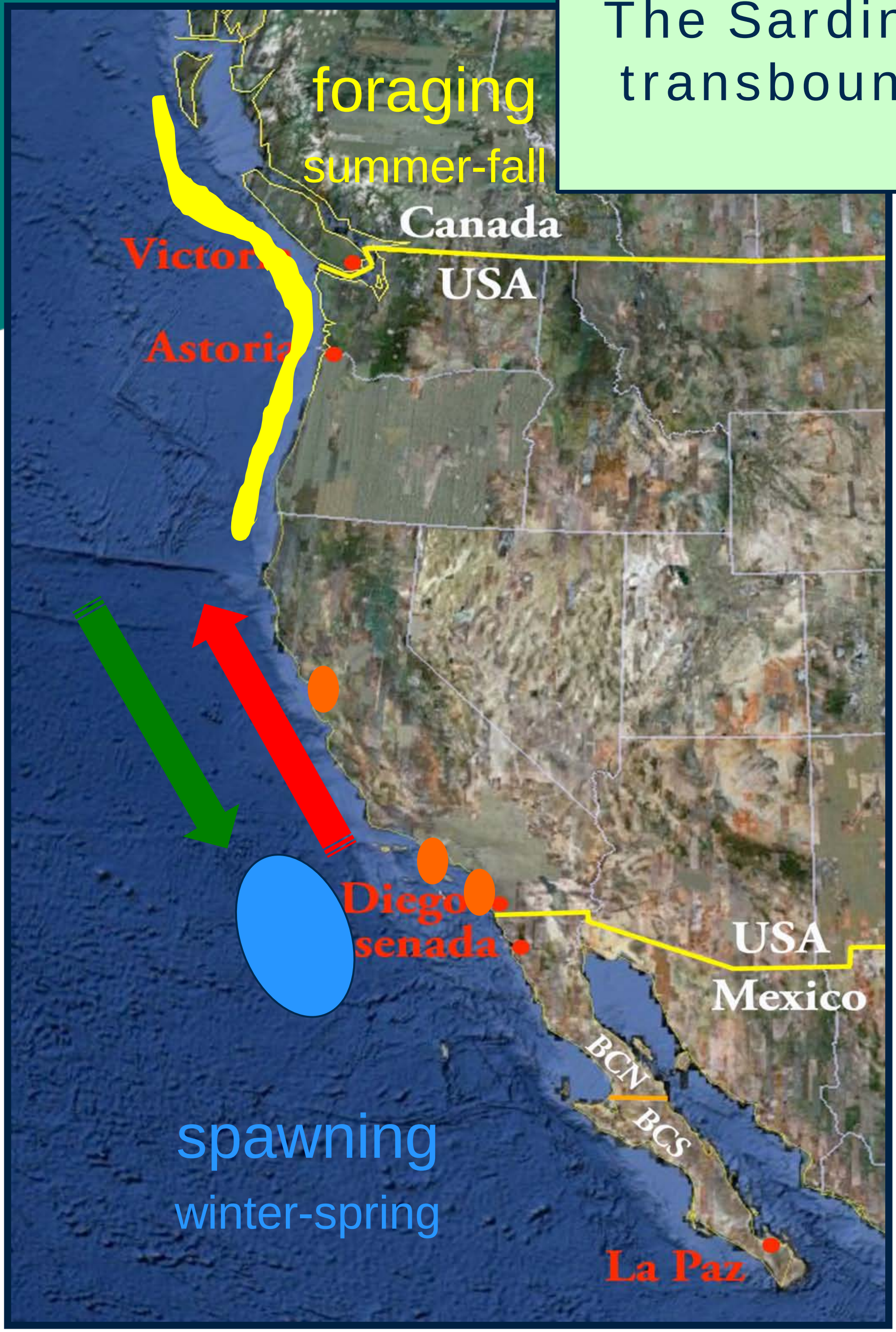
The Sardine/Hake Sampler's Dilemma: transboundary stocks with migration



Summer-Fall: compressed (+)
nearshore (+)
latitudinal apex (+)
transboundary (-) Canada

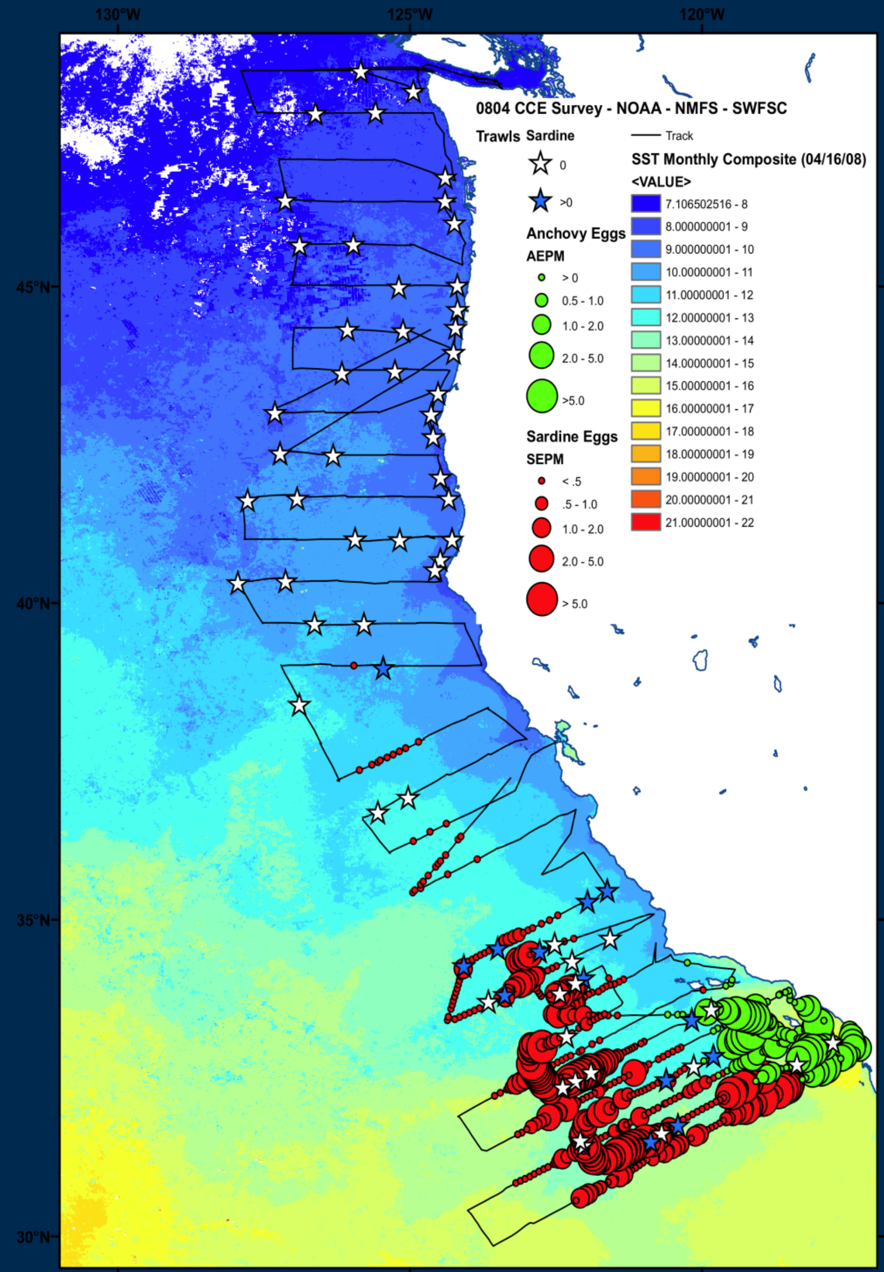
current hake survey

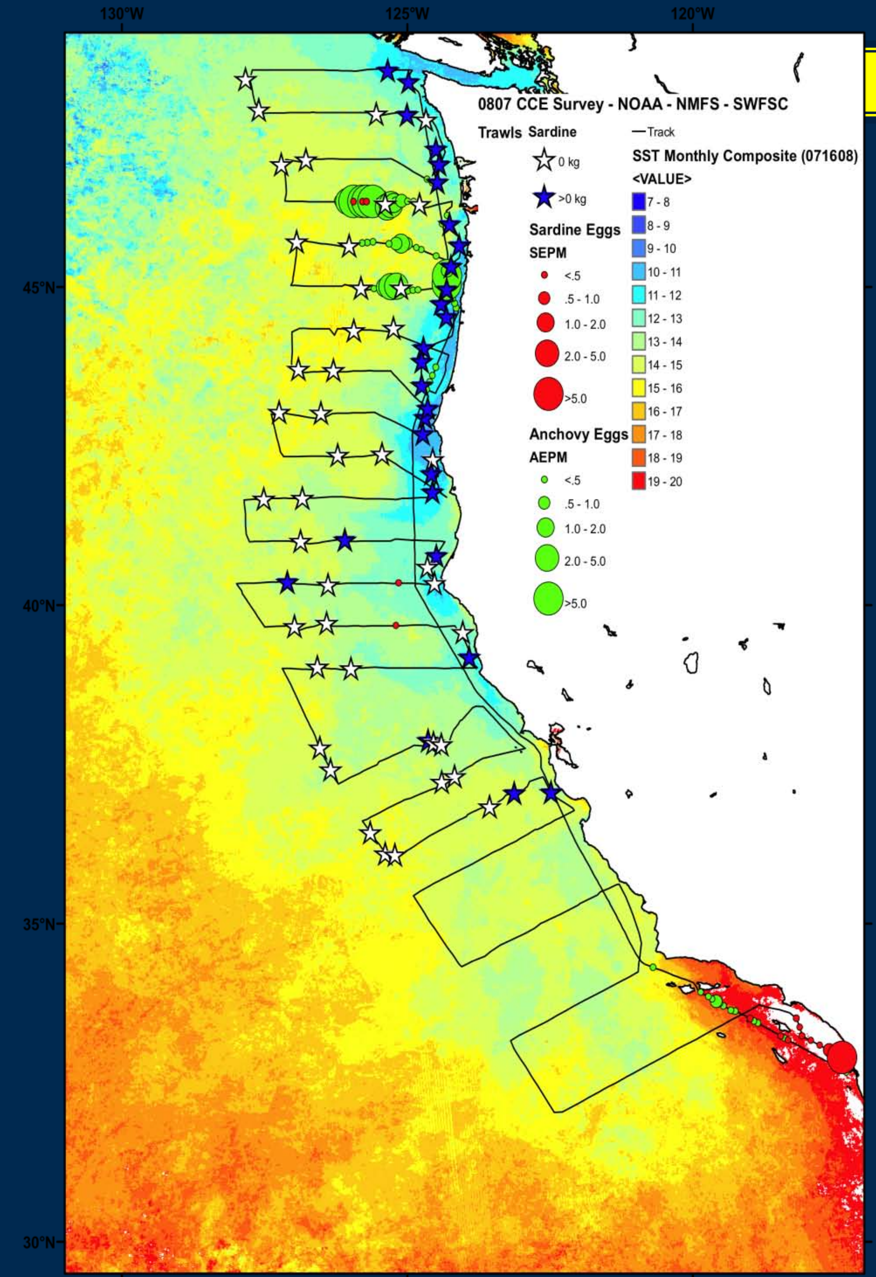
Fall-Winter: dispersed (-)
offshore (-)
migratory (-)
US EEZ (+)

Spring-Summer: dispersed (-)
nearshore (+)
migrating (-)
US EEZ (+)

Winter-Spring: compressed (+)
offshore (-)
latitudinal apex (+)
transboundary (-) Mexico

current sardine survey


130°W
125°W
120°W
45°N
40°N
35°N
30°N
0804 CCE Survey - NOAA - NMFS - SWFSC
Trawls Sardine
0
>0
Track
SST Monthly Composite (04/16/08)
<VALUE>
7.106502516 - 8
8.000000001 - 9
9.000000001 - 10
10.00000001 - 11
11.00000001 - 12
12.00000001 - 13
13.00000001 - 14
14.00000001 - 15
15.00000001 - 16
16.00000001 - 17
17.00000001 - 18
18.00000001 - 19
19.00000001 - 20
20.00000001 - 21
21.00000001 - 22
Anchovy Eggs
AEPM
> 0
0.5 - 1.0
1.0 - 2.0
2.0 - 5.0
>5.0
Sardine Eggs
SEPM
< .5
.5 - 1.0
1.0 - 2.0
2.0 - 5.0
> 5.0


130°W
125°W
120°W
45°N
40°N
35°N
30°N
0807 CCE Survey - NOAA - NMFS - SWFSC
Trawls Sardine
0 kg
>0 kg
Track
SST Monthly Composite (071608)
<VALUE>
7 - 8
8 - 9
9 - 10
10 - 11
11 - 12
12 - 13
13 - 14
14 - 15
15 - 16
16 - 17
17 - 18
18 - 19
19 - 20
Sardine Eggs
SEPM
<.5
.5 - 1.0
1.0 - 2.0
2.0 - 5.0
>5.0
Anchovy Eggs
AEPM
<.5
.5 - 1.0
1.0 - 2.0
2.0 - 5.0
>5.0

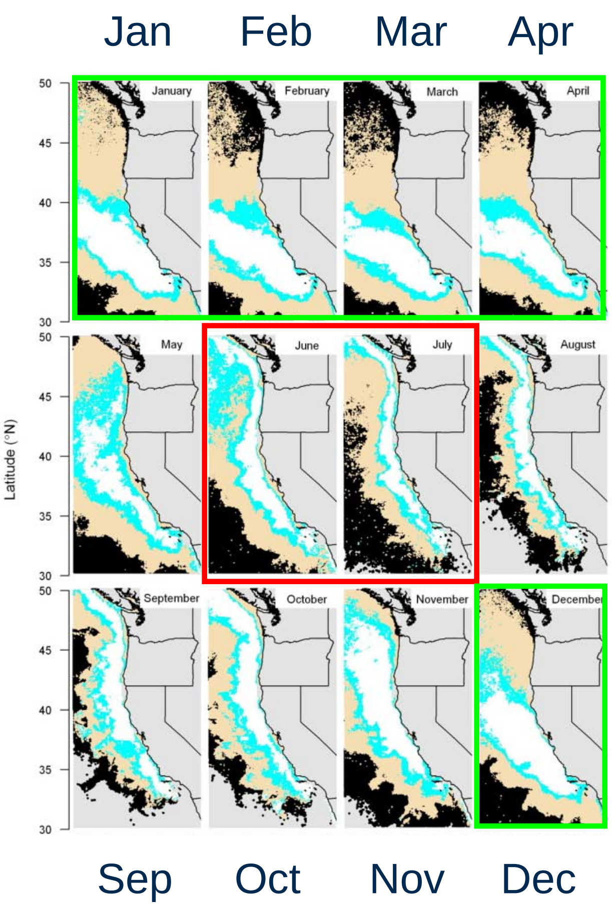
Zwolinski et. al. Sardine Habitat Model

Summary (June - August)

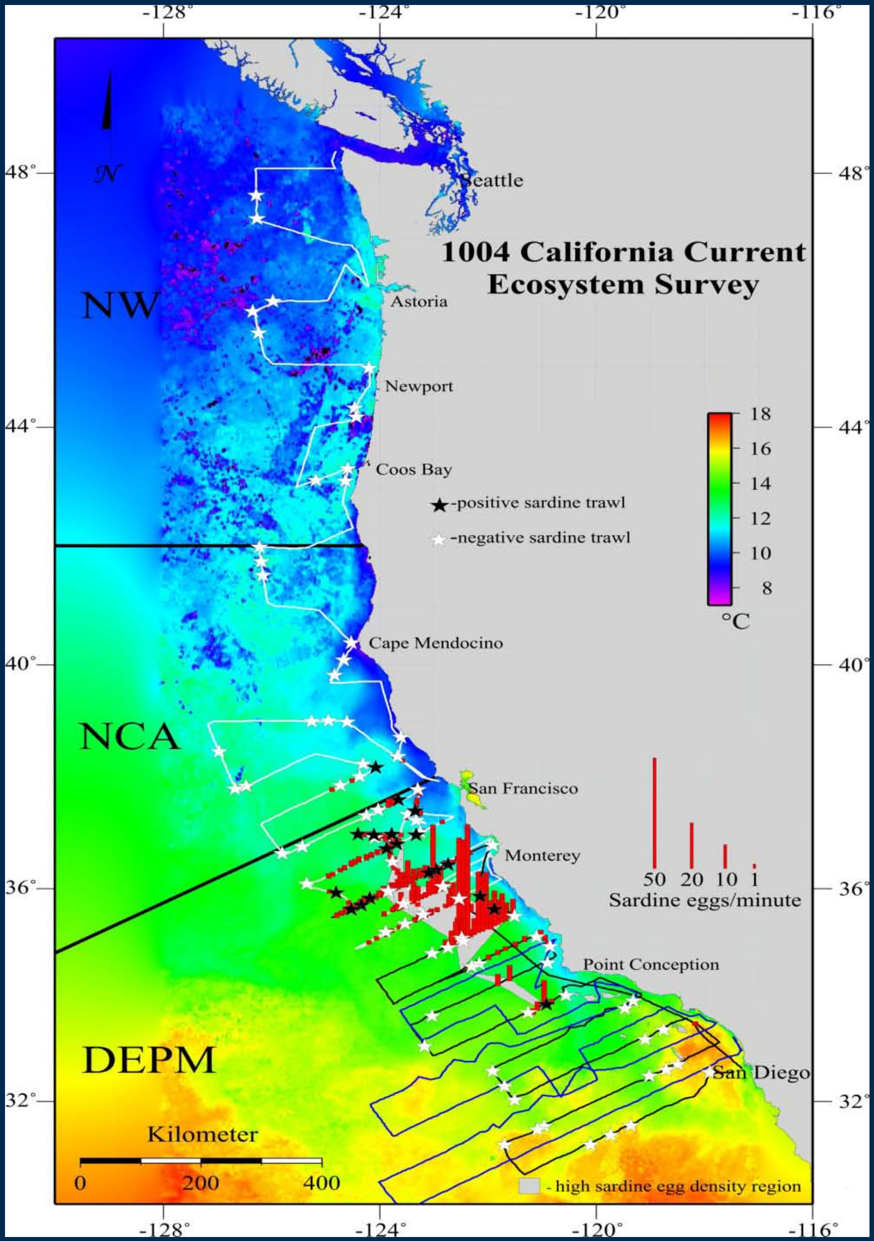
- Sardine compressed along coast

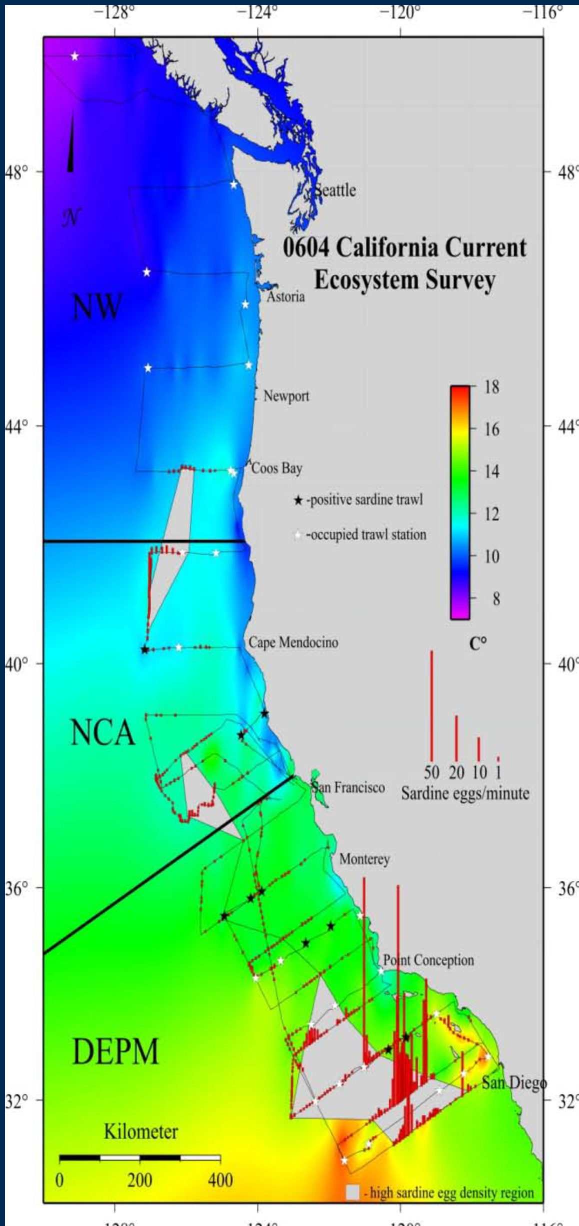
Spring (March- April)

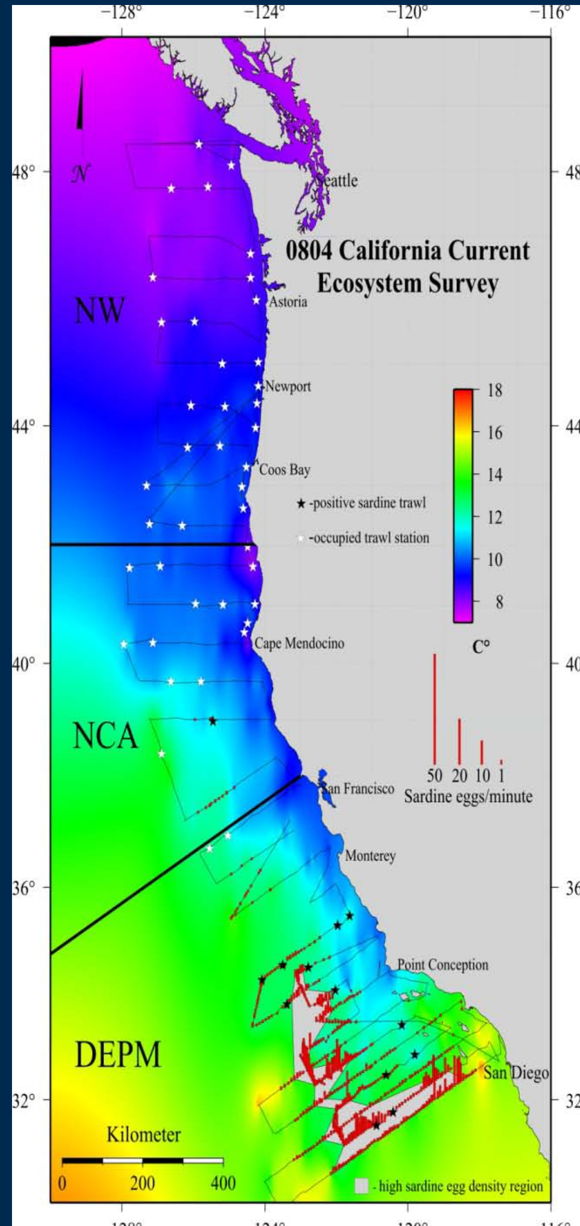
- Sardine spawn off California and Baja CA
  - CalCOFI surveys conducted every year
  - Potentially expand into Mexican EEZ



2. 2010 cruise results




0604 California Current
Ecosystem Survey
NW
NCA
DEPM
Seattle
Astoria
Newport
Coos Bay
Cape Mendocino
San Francisco
Monterey
Point Conception
San Diego
★ -positive sardine trawl
☆ -occupied trawl station
18
16
14
12
10
8
C°
50 20 10 1
Sardine eggs/minute
Kilometer
0 200 400
- high sardine egg density region
−128° −124° −120° −116°
48° 44° 40° 36° 32°


0804 California Current
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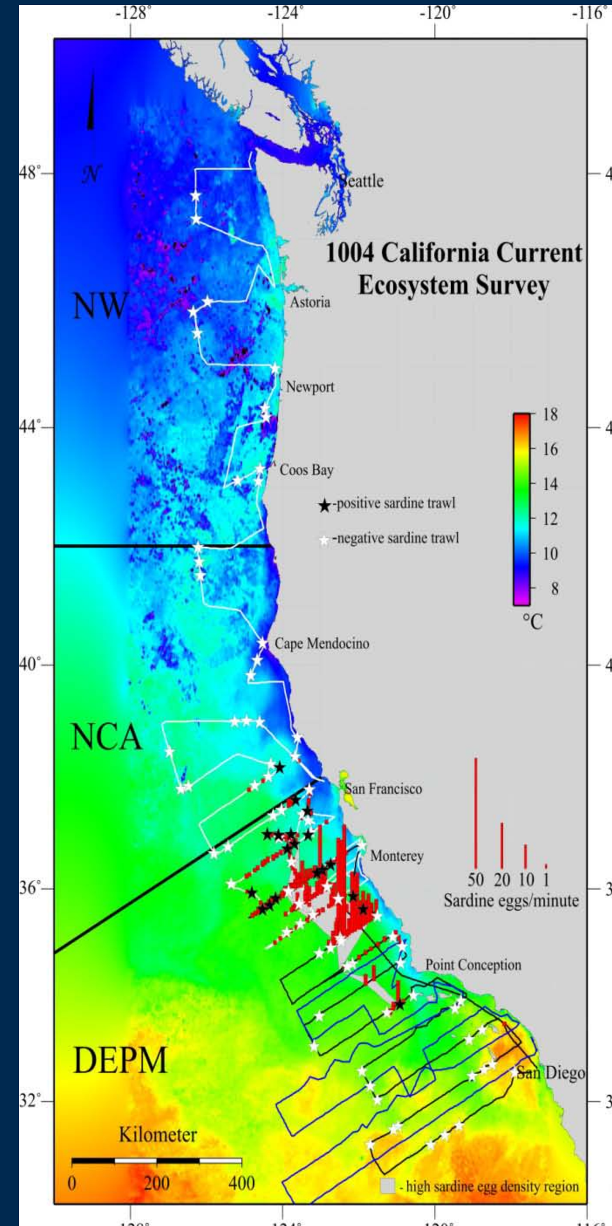
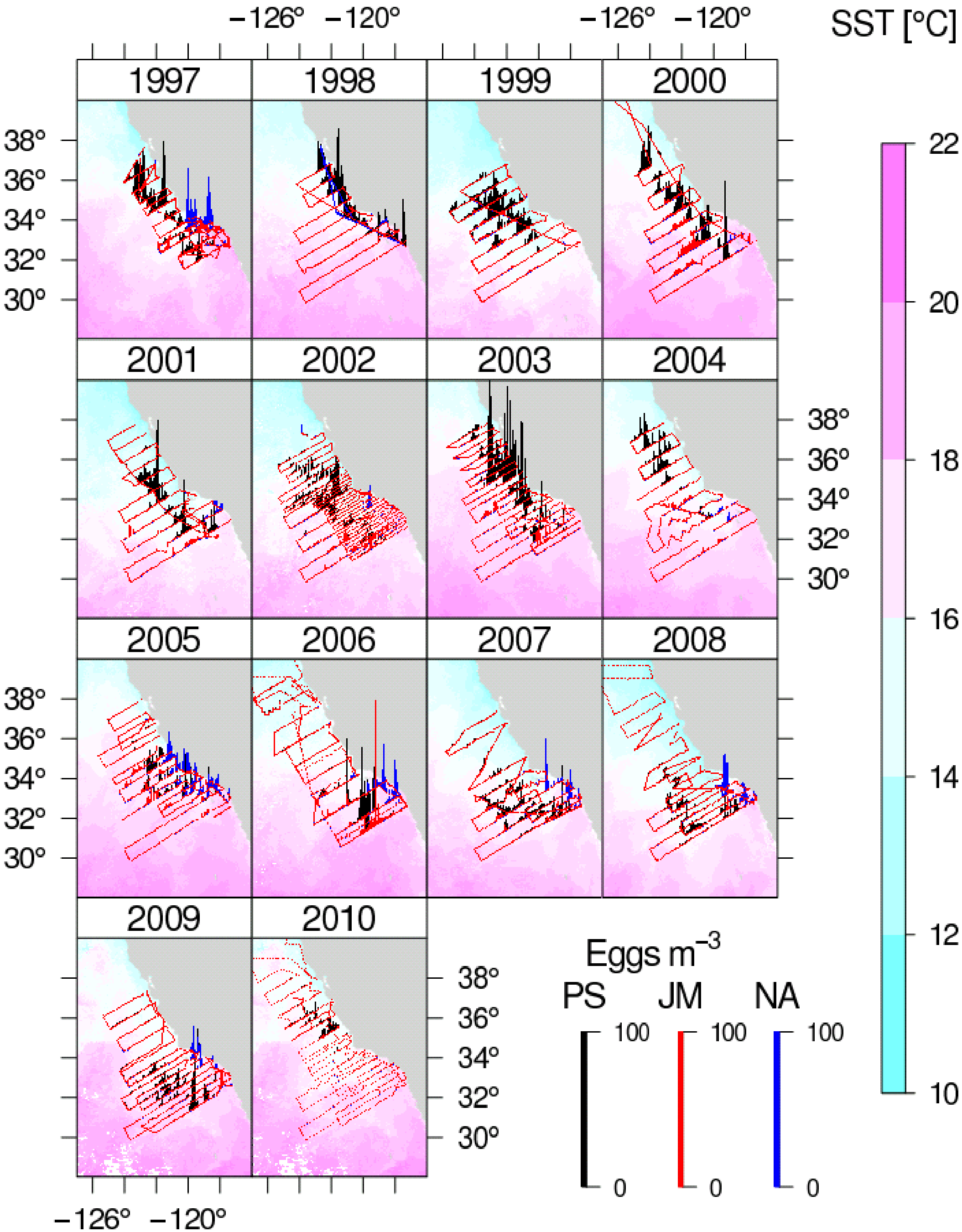

1004 California Current
Ecosystem Survey
NW
NCA
DEPM
Seattle
Astoria
Newport
Coos Bay
Cape Mendocino
San Francisco
Monterey
Point Conception
San Diego
★ -positive sardine trawl
☆ -negative sardine trawl
18
16
14
12
10
8
°C
50 20 10 1
Sardine eggs/minute
Kilometer
0 200 400
- high sardine egg density region
−128° −124° −120° −116°
48° 44° 40° 36° 32°

1. 2010 cruise results



Sardine (PS), anchovy (NA), jack mackerel (JM) eggs overlaid on satellite sea-surface temperatures.

Trends:

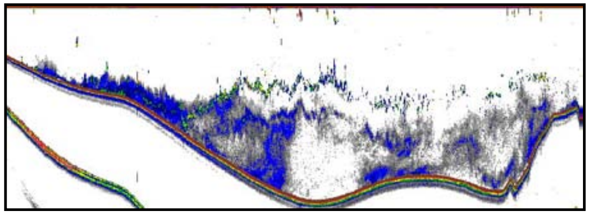
- Overall decline in sardine eggs
- Notably strong sardine spawning in 2003
- Sardine spawning off central California from 1997-2004
- Sardine spawning centered south of Pt. Conception from 2005-2009
- Return to central California spawning in 2010, but very low numbers

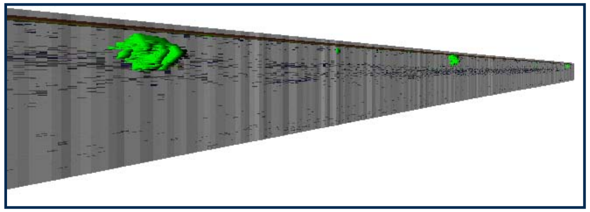
S.McClatchie & E.Weber,
SWFSC, NMFS

Acoustic-Trawl-DEPM Sardine Survey

Acoustic-Trawl Sampling

- EK 60s Multi-frequency echosounders:
    - —18, 38, 70, 120, & 200 kHz
- Surface trawls:
    - — length, weight, sex, age, & stomach
- CUFES & Calvet egg sampling
- Oceanography:
    - ADCP, CTD, XBT, TSG





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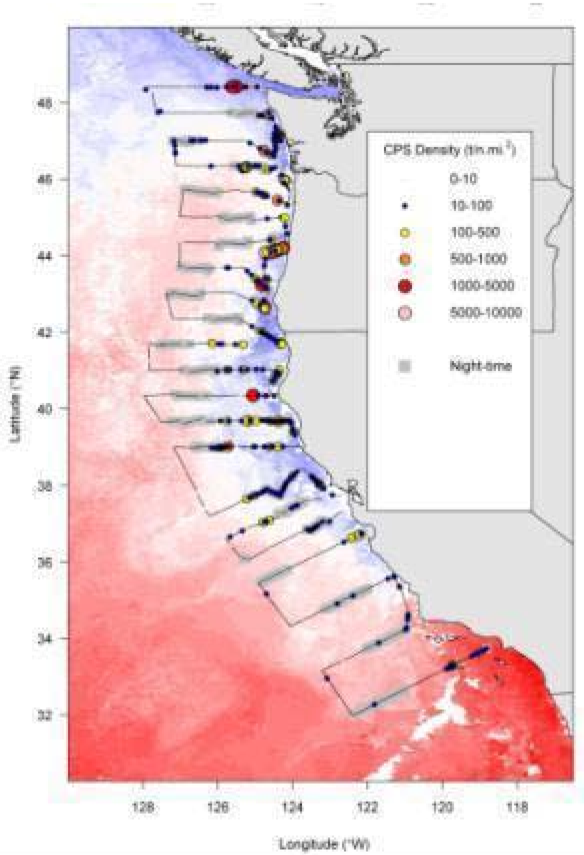
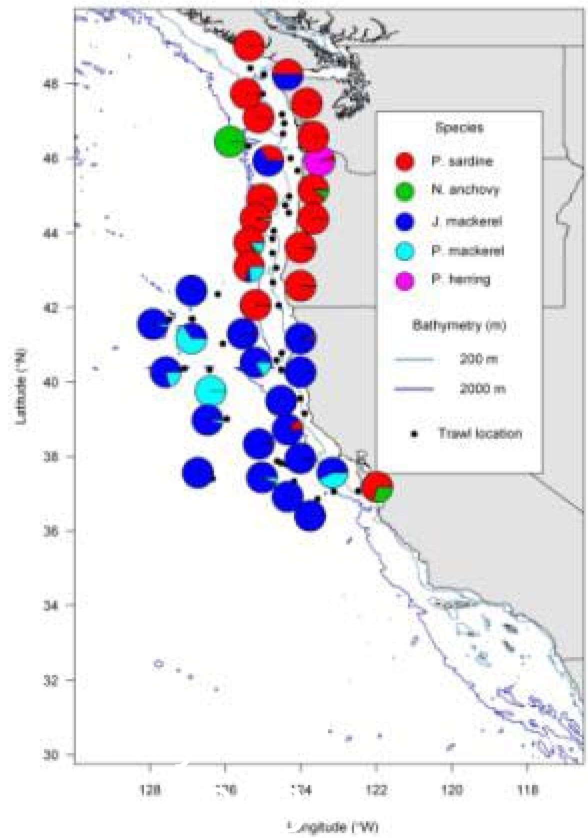
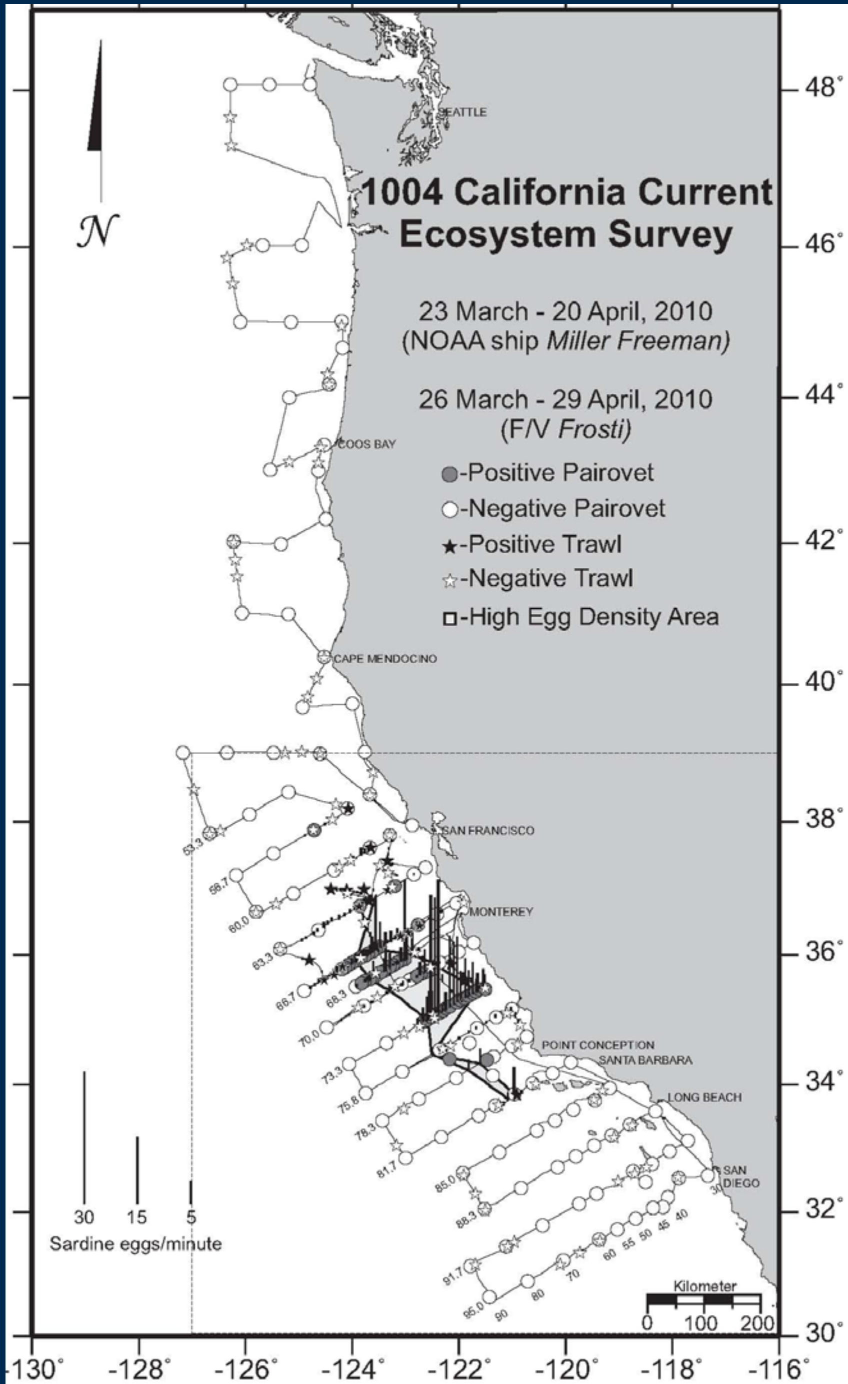
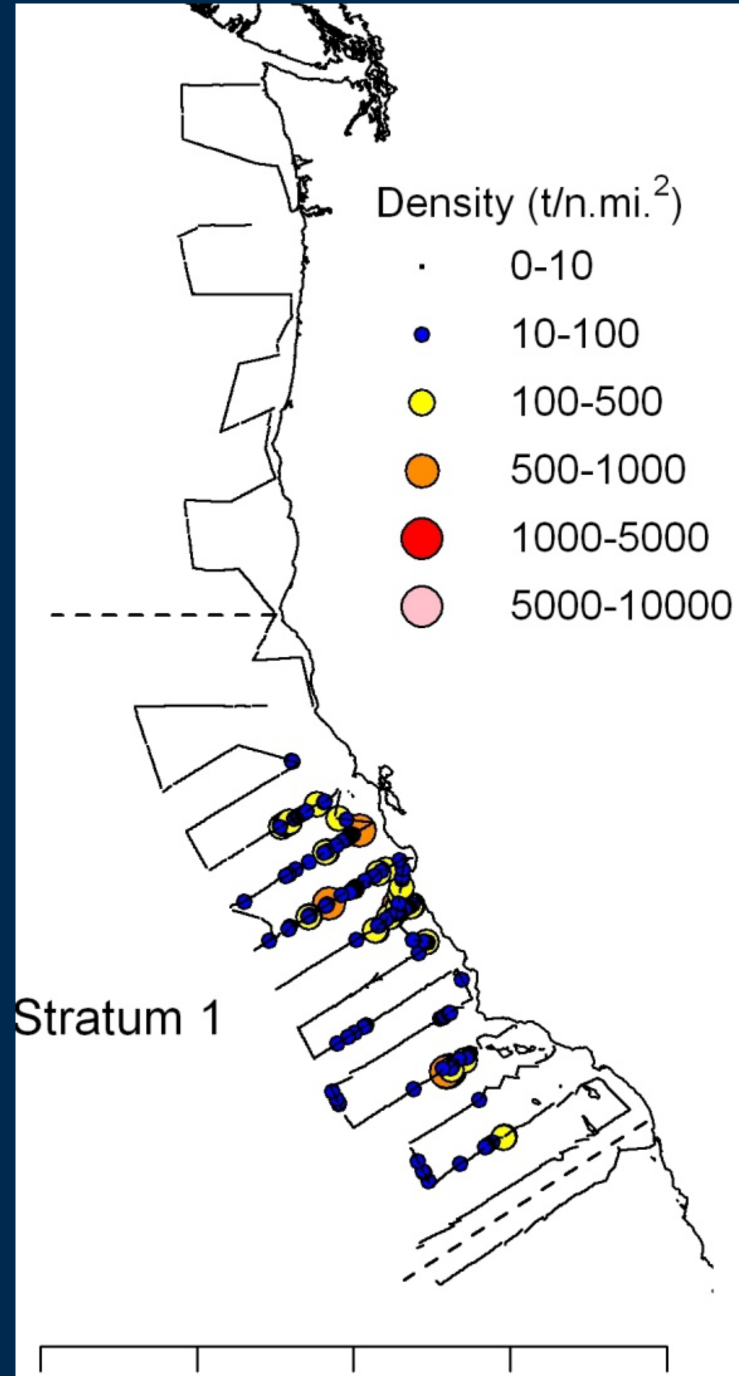
Summer Acoustic Trawl Survey of Pacific Sardine

- CPS mapped east of habitat boundary
- Night-time samples biased
- Species segregation
- No trawls south of Monterey






1004 California Current Ecosystem Survey
23 March - 20 April, 2010
(NOAA ship Miller Freeman)
26 March - 29 April, 2010
(F/V Frosti)
-Positive Pairovet
-Negative Pairovet
-Positive Trawl
-Negative Trawl
-High Egg Density Area
SEATTLE
COOS BAY
CAPE MENDOCINO
SAN FRANCISCO
MONTEREY
POINT CONCEPTION
SANTA BARBARA
LONG BEACH
SAN DIEGO
30 15 5
Sardine eggs/minute
Kilometer
0 100 200
48°
46°
44°
42°
40°
38°
36°
34°
32°
30°
-130° -128° -126° -124° -122° -120° -118° -116°

Density (t/n.mi.²)
0-10
10-100
100-500
500-1000
1000-5000
5000-10000
Stratum 1

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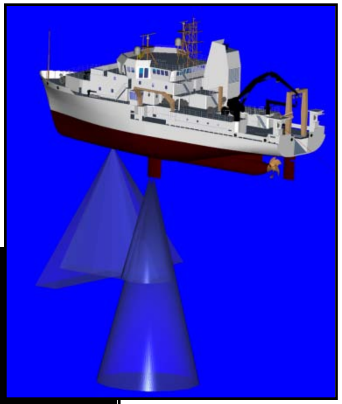
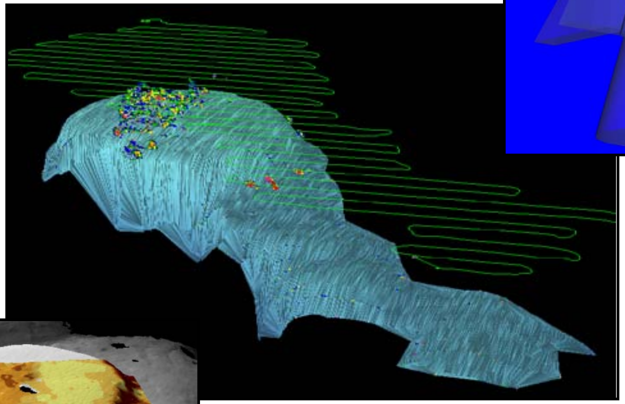
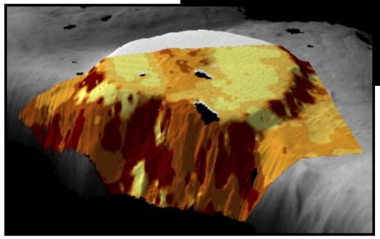
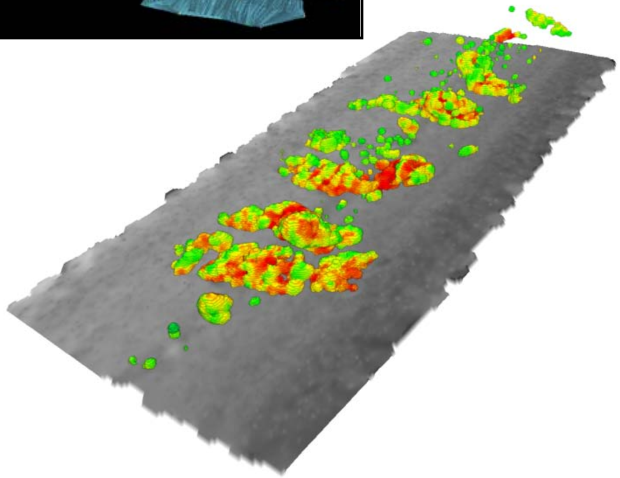
4. new CPS capabilities with FSV and new laboratory

Underway Mapping of Fish and their Habitat









Multi-frequency echosounders (EK60s)

- Map biology and their seabed habitats
- Observe single fish and their behaviors

Multi-beam Echosounder (ME70)

- Map fish distributions
- Measure school sizes and shapes
- Observe fish behaviors

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Advanced Survey Technologies
Southwest Fisheries Science Center

Science and Technology-Development Tank

- State-of-the-art tank facility, unmatched world-wide
- 10 m deep x 10 m wide x 20 m long (2 M liters)
- Thermohaline controlled (2 - 23°C; fresh to seawater)
- Saves valuable ship-time
- Development and Testing
  - Sensors: multi-frequency, and multibeam echosounders
  - Autonomous platforms: tags, landers, buoys, floats, moored arrays, and AUVs
- Science experiments
  - Mammals, turtles, fish, and invertebrates
- Resource for partnerships

Questions?

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Re-assessment of the stock–recruit and temperature–recruit relationships for Pacific sardine (*Sardinops sagax)*

Sam McClatchie, Ralf Goericke, Guillermo Auad, and Kevin Hill

Can J. Fish. Aquat. Sci. vol 67, 2010

Abstract: The harvest guideline for Pacific sardine (*Sardinops sagax) incorporates an environmental parameter based on* averaged surface temperatures at the Scripps Institution of Oceanography pier (SIO pier) in La Jolla, California, USA, which would be invoked after a series of cool years to reduce commercial catches using a precautionary decision rule. We revisit the stock–recruit and temperature–recruit relationships underpinning the currently used environmental parameter for sardine assessment and found that the temperature–recruit relationship no longer holds for the SIO pier when time series are updated with data from more recent years. The significance of the correlation between temperature and recruitment was also artificially increased by autocorrelation in the time series. In contrast, the stock–recruit relationship was still valid when recent data were added. SIO pier surface temperatures are warmer than 10 m-depth Southern California Bight (SCB) temperatures where the sardine spawn, and the difference has increased since the late 1970s. Sardine recruitment was also not related to offshore temperatures in the SCB. We demonstrate that the environmental proxy derived from SIO pier temperature, which has never affected the harvest guideline since its implementation, no longer predicts recruitment of Pacific sardine, and should be removed from sardine management.

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Advanced Survey Technologies
Southwest Fisheries Science Center

Underway Optical Fish Sampling

FasTowCam – Stereo Camera and environmental sampler

- Identifies acoustic scatterers
- Estimates fish sizes
- Environmental sampler (CTD + DO)
- Real-time display
- Tow speeds to 12 knots
- Tow depths to 500 m (nom. < 70 m)
- Developing automated detection and measuring software

Agenda Item I.1.b
Attachment 1
November 2010

WORKSHOP ON ENHANCING STOCK ASSESSMENTS OF PACIFIC SARDINE IN THE CALIFORNIA CURRENT THROUGH COOPERATIVE SURVEYS

June 1-3, 2010
La Jolla, California

Sponsored by NOAA Fisheries Southwest Fisheries Science Center and Northwest Fisheries Science Center.

ACKNOWLEDGMENT

Organizing and staging this Workshop on Enhancing Stock Assessments of Pacific Sardine in the California Current Through Cooperative Surveys took a lot of personal dedication and commitment on the part of a number of individuals. The sponsors wish to thank Robert Emmett, Doyle Hanan, Tom Jagielo, Gary Sakagawa, Sarah Shoffler and Russ Vetter for serving on the Steering Committee and Diane Pleschner-Steele and Mike Okoniewski for serving as sardine industry advisers to the Committee.

James Churnside, David Demer, Tom Jagielo, Dayle Hanan, Kevin Hill, Nancy Lo, Jake Schweigert, Dale Sweetnam and Jerry Thon graciously agreed to prepare and present working papers on different survey methods. Their contributions were appreciated.

Finally, the services of Bev Macewicz, Dawn Graham and Rose Sanford for various important tasks for smooth execution of the event were appreciated. A special thanks is owed to Gerard DiNardo for expertly facilitating the workshop to its objectives.

WORKSHOP ON ENHANCING STOCK ASSESSMENTS OF PACIFIC SARDINE IN THE CALIFORNIA CURRENT THROUGH COOPERATIVE SURVEYS

June 1-3, 2010
La Jolla, California

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LIST OF DOCUMENTS

Annex I List of Participants
Annex II Agenda
Document 1 Current Management and Fishery-Dependent Sampling of the U.S. Pacific Sardine Fishery *by D. Sweetnam, California Department of Fish and Game*
Document 2 Assessment of the Pacific Sardine Resource in 2009 for U.S. Management in 2010 *by K.T. Hill, N.C.H. Lo, B.J. Macewicz, P.R. Crone, and R. Felix*
Document 3 A Description of the West Coast Aerial Sardine Survey *by T. Jagielo and D. Hanan, West Coast Sardine Survey*
Document 4 Daily Egg Production Method Survey *by N.C.H. Lo and B. Macewicz*
Document 5 Acoustic-Trawl Surveys of Pacific Sardine (*Sardinops sagax*) in the California Current Ecosystem *by D.A. Demer, J.P. Zwolinski, K.A. Byers, G.R. Cutter, J.S. Renfree, and T.S. Sessions, NOAA Southwest Fisheries Science Center*
Document 6 Fishery Logbook Data for Pacific Sardine *by K.T. Hill, NOAA Southwest Fisheries Science Center*
Document 7 Airborne LIDAR for Pacific Sardine Surveys *by J. Churnside, NOAA Earth System Research Laboratory*
Document 8 Considerations Regarding the Use of Satellite Imagery for West Coast Sardine Surveys *by J. Thon, Northwest Sardine Survey*

Document 9 Pacific Sardine Trawl Surveys – Canada *by J. Schweigert, Department of Fisheries and Oceans Canada*

WORKSHOP ON ENHANCING STOCK ASSESSMENTS OF PACIFIC SARDINE IN THE CALIFORNIA CURRENT THROUGH COOPERATIVE SURVEYS

June 1-3, 2010
La Jolla, California

I. OPENING AND INTRODUCTION

The Southwest Fisheries Science Center (SWFSC) and Northwest Fisheries Science Center (NWFSC) of NOAA Fisheries, in partnership with stakeholders in the Pacific sardine (*Sardinops sagax caerulea*) fisheries of the United States, held the Sardine Workshop, June 1-3, 2010, in La Jolla, California. The objectives of this Workshop were 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; and (3) opportunities for collaboration. Participation was by invitation only.

The workshop began with participants introducing themselves (see Annex 1 Participants List). Usha Varanasi, Director of Science and Research at the NWFSC and Acting Director of the SWFSC welcomed the participants to the workshop. She noted that it was the first time stakeholders have met to discuss available sardine survey methods. She reiterated the objectives of the workshop and added that the workshop results should show who will work on each relevant survey method and indicate when results will be available. She thanked participants for making the workshop possible: those who traveled, the steering group, and others. She also extended a special thanks to Don Hansen who has been a proponent of collaboration among stakeholders and to the California Wetfish Producers Association (CWPA) for sponsoring the ice breaker reception.

II. ARRANGEMENTS AND PROCESS

Gary Sakagawa, Chair of the Sardine Workshop, reviewed the logistics and the role of facilitator. The facilitator, Gerard DiNardo, promoted constructive dialogue among all parties to ensure that various views were presented. He also ensured that presenters adhered to their allotted 15 minutes per presentation. The participants provided the content. The purpose of this forum was not to debate the merits and limitations of each method, but to promote a common understanding of the methods. The principal investigators for each method were invited to discuss their method, plans for their survey and explore opportunities for collaboration with other stakeholders. It was noted that for the purpose of this workshop collaborations are limited to surveys conducted in U.S. waters. Potential collaborations with foreign partners are necessary and will need review at a later date. Sarah Shoffler, with assistance from Beverly Macewicz, was appointed rapportuer.

The agenda (Annex 2) and general schedule were reviewed and accepted.

III. REVIEW OF THE FISHERIES AND STOCK ASSESSMENT MODEL REQUIREMENTS

1. Fisheries coast-wide (D. Sweetnam, Doc. 1)

Dale Sweetnam presented a review of: 1) the U.S Pacific sardine fishery; 2) recent changes in management of the sardine resource; 3) a description of the current sardine fleet; 4) an overview of fishery-dependent sampling techniques; and 5) the effect of harvest constraints on the fishery in 2008 and 2009.

The Pacific sardine fishery was the largest in North America in the 1930s and 1940s with peak landings of over 700,000 metric tons (t) in 1936. Then, in 1967, after approximately fifty years of fishing, a moratorium on fishing was imposed by the California Legislature. However, by the time the moratorium was imposed, most of the fisheries along the west coast of the U.S. had collapsed, even in southern California. In the early 1980s, sardine was once again observed with increasing regularity in other coastal pelagic species (CPS) and live bait fisheries. In 1986, the first directed fishery in 20 years was conducted with a 1,000 short ton quota, and, in 1999, the California Department of Fish and Game (CDFG) declared that the Pacific sardine resource was officially recovered. U.S. management responsibility of the Pacific sardine resource was transferred from CDFG to the National Marine Fisheries Service (NMFS) with the Coastal Pelagic Species Fishery Management Plan (CPS FMP) which was implemented by the Pacific Fishery Management Council (PFMC) in January 2000.

The majority of sardine on the Pacific coast are landed by vessels with roundhaul gear, primarily purse seines. In 2009, the federal CPS limited entry program in California consisted of 65 permits and 61 vessels; the state-managed Oregon limited-entry fleet consisted of 25 permits; and the Washington limited-entry program consisted of 16 permits and six active vessels.

All three states monitor the commercial Pacific sardine catch utilizing fishery-dependent port sampling programs. The goals of the sampling program are to: 1) provide age from otoliths and length data to NMFS for Pacific sardine and Pacific mackerel for use in stock assessment modeling; 2) determine sex and maturity; 3) estimate the species composition of the CPS catch; and 4) estimate by-catch and incidental catch.

In 2008, the U.S. harvest guideline (HG) was set at 89,093 t, a 42% decline from the 2007 HG of 152,564 t. However in 2007, the U.S. fishery landed 127,764 t of Pacific sardine, 43% larger than the projected 2008 HG, setting the stage for landings to be constrained by management restrictions for the first time since the 1999 recovery declaration. In California, as well as the Pacific Northwest, the potential for early closures during the allocation periods resulted in a derby style fishery in which there was a race to catch Pacific sardine. In 2008, the Pacific sardine fishery was open for 199 days (55%) and closed 166 days (45%), the amount landed per day roughly doubled in each allocation period, and number of landings per day increased. In 2009, the Pacific sardine fishery was only open for 78 days (21%) and closed 287 days (79%). Since 2008, the directed fishery has been closed from October-December, the peak harvest season in California.

Discussion

Sweetnam also mentioned a report by Hunter and Hanan, written in 2000, summarizing the results of the "Stock Assessment and Management Workshop" held at Scripps Institution of Oceanography May 23-25, 2000 that describes management and monitoring recommendations for enhancing the sardine stock assessment. It was pointed out that many of the issues outlined in the 2000 report persist today.

Several details about which landings are available and used in the assessment were discussed and clarified by Sweetnam: Port samples were based on tonnage of landings; CDFG currently samples about one in 10 landings. Oregon and Washington conduct similar sampling which has been assembled and used in the stock assessment model. Canadian samples have been available since the last assessment. That fishery was relatively small until 2008 and was 15,000 t in 2009. Accounting for the sizes of that catch is important and it is hoped that the Canadian data will be a regular contribution. As for Mexican data, updated length compositions series for 1989-2000 and new data for 2001-2009 were obtained earlier this year and are hoped to be incorporated in future assessments.

The length-frequency data show periods when the Pacific sardine enter the fishery. It was pointed out that it would be useful to the assessment to have consistency in who conducts the analyses and maintains the data.

2. Stock assessment model requirements and improvements (K. Hill, Doc. 2)

Kevin Hill reviewed the Pacific sardine stock assessment model and requirements currently implemented. The northern subpopulation of Pacific sardine is assessed each year to establish a harvest guideline for the U.S. fishery. The current assessment was conducted using the Stock Synthesis model. The model included landings and biological sample data from commercial fisheries in Ensenada (Mexico), southern California, central California, and the Pacific Northwest (1981 to present), and abundance estimates from three fishery-independent surveys. The daily egg production method (DEPM) and total egg production (TEP) indices of spawning stock biomass were based on the SWFSC's egg production survey conducted each spring from San Diego to San Francisco (1986 to 2009). The third index was an estimate of biomass from the 2009 aerial survey. The 2009 aerial survey observation was considerably higher than recent biomass from the DEPM and TEP surveys (e.g., 2006-2008), and this scaled the model estimates of biomass upward. Due to the contrast in scale among survey estimates, the base model was tuned without the aerial spotter estimate. The estimate was then included to derive final base model results. Stock biomass increased rapidly through the 1980s and 1990s, starting at 8,210 t in 1981 and peaking at 1.69 million t in 2000. Stock biomass has subsequently declined to the present, July 1, 2009, level of 702,024 t. Stock biomass from the 2009 final model, including the aerial survey estimate, was very similar to the results from the final 2007 assessment. Both the 2009 and 2007 final models were scaled higher than the 2008 update and the 2009 base model that excluded the aerial survey estimate. Based on results from the final 2009 model, the PFMC's 2010 HG for the U.S. fishery was set at 72,039 t. The total exploitation rate for the combined Pacific sardine fisheries is currently less than 16 %.

Discussion

It was noted that the biomass trajectory of the 2007 assessment was similar to that in the 2009 assessment with the aerial data and that the 2008 update model scaled considerably lower than both. Hill explained that the 2008 model trajectory was influenced by two changes: One was that there was a lower DEPM estimate of spawning biomass, and the other was that sample sizes for the combined Oregon and Washington fisheries were large, increasing the weight of the data in the model. There were no changes to the model structure, only changes to input data.

Variation in scale across different models was reflected by the catchability coefficients. Female spawning stock biomass was one of the model inputs. The catchability for the DEPM and TEP indices was much higher without the aerial survey data. It was pointed out that the Pacific sardine assessment is unique in that it starts with a severely depleted population, whereas most begin with an unexploited one. This means that the initial population in the stock assessment must be estimated by an additional parameter.

The current understanding of stock structure of the Pacific sardine population was discussed. Two stocks exist along the West Coast from outer Baja California, Mexico to Canada. Their degree of separation is unclear. The southern and northern stocks may mix in the Southern California Bight (SCB), but the degree to which the southern stock contributes to the southern California fishery or the assessment is unclear. It was noted that University of Washington was recently awarded California Sea Grant funding to develop a model accounting for the separation between southern and northern stocks, and to evaluate the importance of including spatial structure in the stock assessment model.

What can be done to improve surveys to address stock mixing issues and measure recruitment was discussed. Biological samples (tissues, otoliths) and oceanographic data can potentially be used to determine stock source, particularly for areas and times when there is a high likelihood of stock mixing. Some surveys have collected samples, but how to analyze them or work up data are not planned. Sampling of the live bait fishery catch could be another source for collecting biological samples and addressing questions about stock mixing.

Juvenile rockfish surveys being conducted by the SWFSC were discussed as a potential source of data on Pacific sardine abundance. The survey is conducted in May/June and uses a different gear from those used on sardine surveys, and catches some sardine. The group agreed it should explore the usefulness of this source of sardine data.

Some information regarding recruitment is obtained from the length composition and age composition data from the Pacific sardine fisheries. However, because the California fishery operates within a narrow band of coast relative to the entire region where recruitment occurs, data on recruits from this source are variable. Nonetheless, the data set could be improved upon by directing sampling on young-of-the-year (when present) by the fleet. It was noted that power plants impinge and entrain sardine during normal operations and may provide an additional source of recruitment data. However, the utility of recruitment data in the assessment model requires further investigation, particularly because these data normally exhibit high variability and surveys to collect sufficient data are expensive.

The live bait fishery, which targets both northern anchovy and Pacific sardine, could potentially provide samples for estimating recruitment abundance in a small local area. For the 0-age fish collected, birth date can be back-calculated with analysis of hard parts.

IV. REVIEW OF SURVEY METHODS CURRENTLY PROVIDING DATA FOR THE STOCK ASSESSMENT MODEL

1. Aerial survey (T. Jagielo, Doc. 3)

Tom Jagielo presented an overview of the survey design and methodologies of the aerial survey. He noted the industry's application for an exempted fishing permit of the PFMC in 2010 includes both a repeat of the summer aerial survey conducted in 2009, with an extension in 2010 into southern California, and a pilot project in the fall, in conjunction with the fall CalCOFI cruise, intended to test various assessment methodologies including LIDAR and acoustics both day and night, at a time when Pacific sardine are abundant in southern California.

He focused his presentation on the summer aerial survey, noting that the survey method was reviewed by the PFMC STAR Panels in both May and September of 2009, where it was concluded that the method provides a minimum estimate of absolute abundance, and should be included in the 2009 stock assessment of Pacific sardine. The chief advantage of the method over other techniques is that it provides a synoptic, direct estimate of abundance. It also makes use of the extensive "on the grounds" expertise of spotter pilots and fishermen. Uncertainty in the estimate of biomass was evaluated via the method of bootstrapping, which showed that at current sampling levels, the method can produce biomass coefficient of variation (CV) values within the range useful for stock assessment modeling.

Discussion

A number of points regarding why the method provides a minimum estimate, and perhaps an underestimate, of abundance were discussed. For instance, some schools are too deep below the ocean surface to be seen from the air. Also, factors that obscure the view of the ocean surface, such as sea state and glare (depending on weather conditions and time of day) can cause problems in detecting schools with the aerial survey method. Jagielo pointed out that one factor that could introduce a positive bias would be if schools of other species were mis-identified as sardine schools. In 2009, sardine were virtually the only species observed in the point set samples used to estimate the biomass of individual schools; however, it is possible that sampling in the future could result in multi-species school encounters where this issue could be of concern.

It was pointed out that airplanes can rapidly cover large areas of the ocean surface relative to vessels at sea, and satellites even more so. More discussion of satellites was tabled until the satellite survey methods presentation.

Jagielo noted that the project has been building a library of photographs for analysts to use to improve species identification skills. Additionally, double blind tests and similar methods are planned to evaluate and monitor photo-analyst performance.

Various methods for verifying school species identification were discussed, including: 1) conducting more synoptic point sets, and 2) conducting surface trawls.

The group also discussed issues related to school detection. The question was raised if reducing the plane altitude could be expected to improve school-species identification. It was noted that there is a tradeoff between survey altitude and the amount of area swept by the camera, not to mention safety considerations. To keep point set sampling representative of transect sampling, the STAR panel recommended that pilots first identify schools at 4,000 feet before the sets are made. Current procedure provides for pilots to identify schools at the nominal transect height, then descend, as necessary, to direct the set. To date, all of the schools selected for point-set sampling at an altitude of 4,000 feet were sardine schools.

Finally, it was noted that the fall 2010 aerial survey will use LIDAR, acoustics, and aerial photography both day and night, and also evaluate flying at 2,000 feet, to explore alternative methods that may facilitate improvements in aerial survey techniques.

3. Daily Egg Production Survey (N. Lo, Doc. 4)

Nancy Lo presented a summary of the DEPM. The DEPM was developed by the SWFSC in the early 1980s to estimate the absolute spawning biomass of northern anchovy off central and southern California and has been applied to anchovy, sardine, sprat, mackerel, horse mackerel, snapper, and hake in 16 locations around the world. The DEPM is suitable for multiple-spawning fishes with eggs distributed in the upper layers of the ocean and mature females for whom the spawning rates can be measured. Eggs are the preferred stage for sampling because they do not avoid the nets. However the patchy distribution of eggs requires a sound survey design, like adaptive sampling. Processing of adult reproductive specimens requires intensive laboratory work and a large number of trawl samples to achieve reliable estimates. A complication is that a small portion (<10%) of adults may reside and spawn north of the standard DEPM survey area, from San Diego to San Francisco in April.

The DEPM requires just a single survey conducted for at most a month, preferably during the peak spawning time. The cost of such a survey is about half million dollars. The cost would be double for a survey from San Diego to the US-Canadian border, expanded to 43°N and starting from the northern end of the survey area; this would enable sampling of that portion of the stock spawning in the northern area. If extra vessel time is needed, commercial fishing vessels are a potential source for collecting adult fish samples through the cooperative research funding as suggested by the May 2009 STAR panel. Long time series of spawning biomass, and biomass estimates from other survey methods, like acoustic and/or aerial surveys, can be used to compare with and calibrate DEPM results.

Discussion

Data indicate that the proportion of females spawning off the Pacific northwest in July is small (3% female per day) on a per day basis compared to off the Pacific southwest in April (13% of females per day). Because Pacific sardine are multiple spawners they continue to produce eggs, depending on the environment, food, and size of the fish over a period of time. They typically spawn in the south, off California, and travel northward. After about a month, they may spawn again off the Pacific northwest. Hence, those spawning off the Pacific northwest may be repeat spawners or they may be fish spawning only in the north. It is suspected, though, that primary spawning occurs in the south and a second spawning occurs in the north. Size at maturity is smaller in the southern range than off the Pacific northwest.

Lo noted that this northward movement pattern of Pacific sardine was determined years ago and should be investigated again with advanced tagging methods that are currently available. She suggested using acoustical archival tags such as those used for inshore salmon studies in the Pacific Northwest.

It was mentioned that the fishery caught about 16 t of Pacific sardine off Coos Bay in 2009. The fish averaged 90-200 g and 220-240 mm long. The smaller fish had low fat content and females had no eggs. The bigger fish were more mature and had more fat. If samples from this catch are available, the females could be analyzed for spawning activity by the SWFSC.

Lo noted that DEPM projects trends in spawning biomass. There are a few reproductive biology factors that could affect the estimate from this method. For example, the DEPM method assumes the survey covers the total spawning area, but migration and spawning outside of the survey area can contradict this assumption. In addition, more work is needed to update the temperature-dependent egg development relationships because temperature affects the rate of degeneration of post-ovulatory follicles, as well as the percentage of fish spawning.

It was pointed out that the timing and duration of the survey are important aspects of the current survey. The best survey time is during the peak spawning period because fewer samples (eggs and adults) are needed. However, if the area is large, it may take three weeks to survey the entire spawning area. Therefore a good survey design is necessary, and for a coast-wide survey, two vessels are needed.

The group discussed augmenting the DEPM with acoustics, swept-area trawls or other methods if the trawls are inefficient. It was pointed out that the swept-area trawl method has a different objective from the DEPM. Also pointed out was that acoustics have been used in combination with trawls to augment the DEPM in past surveys.

In response to questions on the Continuous Underway Fish Egg Sampler (CUFES), Lo responded that it effectively samples the top three meters only and gives a good indication of presence and absence of eggs. This is useful information for guiding adaptive sampling. Lo also noted that bongo net samples are also taken at fixed stations during the DEPM surveys.

V. REVIEW OF OTHER SURVEY METHODS OR POTENTIAL DATA SOURCES

1. Acoustics survey (D. Demer, Doc. 5)

David Demer described acoustic-trawl surveys. Acoustic-trawl methods have been used to survey Pacific sardine off the west coast of the U.S. for more than a half century. The methods provide estimates of biomass and distribution. They have also been used by France, Spain, Portugal, Peru, Chile, South Africa, Namibia, and other countries to estimate distributions and abundances of CPS in other ecosystems, and the operational methods and results have been reviewed and published extensively. The main benefits of acoustic sampling is that it can be conducted continuously while a survey vessel is underway; the sampling range, volume, and resolution are greater than those of alternative techniques; and the data provide quantitative information about the distributions, densities and interactions of the various species in a survey area. The challenges of acoustic-trawl surveys are to first survey the potential habitat of the target species; identify the target species' contribution to the total acoustic backscatter; estimate the mean acoustic backscatter per individual fish, and combine this information to estimate their biomass densities and total biomass. Total uncertainty, including random and systematic components of measurement and sampling error, is then estimated. Total biomass of sardine was estimated from the summer 2008 survey data as 0.8 million t with a CV of 29%. The biomass was located mostly off the coasts of Oregon and Washington as predicted in summer by a generalized additive model of Pacific sardine habitat. The model also indicates that surveys of sardine may be most efficiently conducted during the months of June and July when: (1) the habitat is compressed along the coasts of Oregon and Washington, (2) the fish are generally north of Point Conception and south of the Strait of Juan de Fuca, (3) daytime survey effort is maximum, and (4) the survey analysis can be augmented with fishery catch data from the same general time and place. Collecting these data as part of the NWFSC biennial hake survey, which is conducted in this time and place, may offer additional survey efficiencies. Further analyes are required to assess the utility of these data.

Discussion
In response to a question, Demer indicated that acoustic observations are best conducted during daylight because the Pacific sardine observed by echosounders are deeper and thus available to acoustic sampling.

Adidtional challenges to the method were also discussed: One challenge to acoustic sampling is that the fish may react to the ship. Pacific sardine and other coastal pelagics have been observed during the day in acoustical tracings at depths of between approximately 10 and 70 m with mean depth of 20 m. One possibility is that when the vessel approaches Pacific sardine schools, they dive and become more available to acoustic sampling. The depth distribution of Pacific sardine changes depending on their position relative to shore, the season, and the surface conditions (e.g. turbulence).

The Simrad MS70 sonar has the capability to create a three-dimensional image of a near-surface school within 500 m perpendicular to a vessel. This tool, slated to be installed on FSV6, may help to explain the vertical distributions of sardine schools and to quantify error associated with acoustically estimated biomasses of epi-pelagic fish.

Another challenge is attributing the acoustics data to other coastal pelagic species, given that some organisms may have similar frequency responses. There is also the possibility of underestimating diffuse aggregations or individual fish.

It was noted that the NWFSC has been conducting a regular hake survey using trawling and acoustics methods along the West Coast to estimate hake abundance. Data collected from that survey contain information on Pacific sardine. Demer suggested that the data be analyzed for possible use for measuring Pacific sardine abundance and the group agreed this would be a possible data source to explore.

Demer also explained that habitat modeling and acoustics sampling could be used to guide other Pacific sardine surveys. Acoustics and the habitat optimization model could be used to stratify and reduce variance in other surveys. Predicting the habitat reduces the number of zero observations in sampling and also reduces costs. His model was tested against data from CUFES, fishery landings, and scientific catches around the Columbia River mouth. The predicted habitat is consistent with historical records and recent observations.

Acoustics are best augmented with targeted-trawl sampling to determine species and to estimate their sizes. Fishery landings can also be used to obtain length data. Catch information can be used if it is spatially and temporally coincident with the acoustic sampling.

It was noted that CWPA has acquired a BioSonics scientific echosounder (a portable system) which will be used opportunistically to measure Pacific sardine schools (see Section VII). The goal is to use the system to measure the same school as the LIDAR and aerial camera.

In discussion of point sets (Doc. 3) used in aerial surveys to determine the relationship between surface area of observed Pacific sardine schools from aircrafts (photos) and the actual tonnage of the schools from capture (purse seine) of the observed schools, the concept of using acoustics to determine tonnage instead of capture was discussed. The concept was described as “virtual point-sets” and could increase the sample size for the surface area to tonnage relationship without capturing schools that are too large for available purse seine vessels to handle or schools that avoid the vessels.

2. Fishery-dependent (logbook) survey (K. Hill, Doc. 6)

Kevin Hill reviewed the use of logbook information for estimating an abundance index for Pacific sardine. Stock assessment scientists often use fishery logbook data to infer changes in population abundance over time. Before utilizing logbook or survey data in an assessment one must first ask: 1) does the survey/fishery sample a sufficient amount of the population to accurately represent overall trends; 2) do changes in the index represent changes in population size or just local availability; 3) is the catchability coefficient ‘*q*’ constant over time, or has it changed due to fishing practice or survey technique?; and 4) does *q* remain constant as population density changes? MacCall (1976) examined catch-per-unit-effort (CPUE) and abundance data from the historic Pacific sardine fishery and estimated that *q* was inversely proportional to population abundance, i.e., the catchability of sardine increased as the population declined. An inverse relationship between catchability and population size means that CPUE will most likely remain stable as the population declines. This phenomenon has been observed during collapse of other major coastal pelagic fish stocks such as Atlantic menhaden, Norwegian herring, and the Peruvian anchoveta. This is a highly undesirable characteristic for a stock assessment time series as it will result in misinformed management decisions. While logbook data may not provide useful time series for the current Pacific sardine stock assessment, there are other potential uses for the data, including: indices of local abundance for spatially-explicit research models; data for improving ongoing Pacific sardine habitat prediction models; optimizing survey design; economic data for PFMC or other regulatory analyses; documenting fishing grounds in the event that MPAs are proposed for those areas; improving Total Catch Accounting, including by-catch and discards.

Discussion

Hill reiterated that CPUE as a index of Pacific sardine abundance from logbooks is well known to be misleading as an indicator of abundance because CPUE tends to remain constant when abundance decreases because of increasing catchability. However, it was noted that because catchability is related to improvements in the fishing capability of a unit of fishing effort, after a period of efficiency improvements, efficiency stabilizes. For the sardine boats, this may already have occurred and hence, CPUE may be currently useful as a measure of local abundance, especially with the data stratified by small areas.

Hill noted that Oregon and Washington require logbook recording by the northwest sardine fishery, although the data requirements are not standardized, whereas California does not. Although logbook data might not be useful for measuring total population abundance, Hill reminded the group that logbook data are useful for tracking catch location, verifying landing information, estimating school size and monitoring expansion and contraction of the population. Other uses are for studying preferred habitat, economics of the fishery and by-catch in the fishery. The group agreed it would be worthwhile to establish a consistent logbook along the entire West Coast.

3. LIDAR survey (J. Churnside, Doc.7)

James Churnside reviewed the airborne LIDAR survey method for estimating biomass. Airborne LIDAR uses a laser to probe the upper ocean and readily detects schools of fish like Pacific sardine. The presentation described the results of experimental surveys of Pacific sardine in the Pacific northwest and menhaden in Chesapeake Bay. The main strengths of this technique are the high speed and low cost with which surveys can be performed. The main weaknesses are limitations to identification of species and limited depth penetration. These strengths and weaknesses were discussed.

Discussion
Churnside elaborated on limitations and advantages of the LIDAR method. He noted that the surface footprint of the LIDAR beam is five meters, an OSHA standard for occupational use of laser beams. There is some scattering of the beam's energy because of sea state and time of day. For example, the top two meters of the ocean is observed when sea state is rough. He noted that when it is rough, not many fish are found in the top two meters of the surface. Best depth penetration is during the night, but the day-night difference is not large.

4. Satellite (as augmentation to aerial surveys) (T. Jagielo, Doc. 8)

Tom Jagielo described use of satellite photography for assessing location, number, and size (area) of Pacific sardine schools. An example of satellite-derived photographsy collected for Pacific sardine school analysis off the southern Washington coast in August of 2009 was presented. Considerations of the advantages and limitations or challenges of using satellite photography for Pacific sardine school analysis were discussed.

Discussion
Satellite data may be used to assist in the planning and design of surveys employing other methods, or as a primary tool for estimating densities of schools throughout the Pacific sardine spatial distribution. Survey effort can be stratified before an acoustical or aerial survey using satellite information on school location and size.

It was pointed out that NASA or others should have powerful analytical tools to enhance satellite images to accurately detect schools in the images. GeoEye currently does visual imaging and is in the business of developing products for users. GeoEye might be approached to explore development of an inexpensive tool for enhancing current available images to more accurately identify Pacific sardine schools. Expertise in photo image enhancement is available at the SWFSC and it was suggested that that expertise should be consulted.

5. *Trawl survey (swept area) (J. Schweigert, Doc. 9)*

Jake Schweigert presented a summary of swept-area trawl surveys off Vancouver Island, Canada. Swept-area trawl surveys provide a method for estimating population abundance if the distribution and density of the target species can be estimated. It assumes unbiased and representative sampling of the population. Factors such as vessel avoidance and gear selectivity can result in biased sampling. Surveys employing mid-water trawls near the surface have been conducted on the west coast of Vancouver Island from 1997 to present to examine the distribution and relative abundance of sardine. Abundance estimates were calculated using representative trawl catches from the surface to 30 m depth, collected during surveys in late June, July, and August. The July surveys have generally been most indicative of the relative sardine biomass in Canadian coastal and offshore waters. Biomass estimates were calculated from data collected during cruises from 1997 to 2009. In general, the trawl surveys provide an empirical estimate of relative sardine abundance in Canadian waters. An issue that remains is describing the northerly extent of the annual feeding migration. A considerable portion of the fishery occurs in areas not surveyed north of Vancouver Island where an abundance of Pacific sardine is clearly present. Another issue is the abundance of Pacific sardine in inlets on Vancouver Island and in mainland inlets which are not surveyed routinely. The annual survey is constrained by the availability of survey vessels which has restricted the survey to key strata along the west coast of Vancouver Island that have historically contained the bulk of the Pacifric sardine. Some experimental trials have been conducted with aerial surveys but to date these have not been very successful. Nevertheless, aerial surveys could be used in future to augment trawl surveys in areas north of Vancouver Island. Similarly, there has been limited capacity to conduct acoustic surveys during the swept-area survey and this could be augmented in future.

Discussion

The group raised some questions regarding limitations and challenges the survey method faces: In response to a question, Schweigert indicated that the estimates from his survey reflect limits of the survey range. This issue is recognized and needs to be addressed. Regarding differences in performance owing to change from day to night trawling in 2006, Schweigert indicated that in 2005, Canada DFO conducted comparative day and night surveys The day catch was 21% greater than the night catch. Schweigert noted that the age composition of Pacific sardine from the 2009 survey is preliminary and the aging needs to be reviewed.

In response to a question about whether fishermen are involved in the survey, Schweigert indicated that Canadian fishermen have not yet been involved but they are interested in collaborating. The question being reviewed by DFO is how to conduct joint surveys with the involvement of the fishing fleet. Schweigert also explained that there is currently 10% observer coverage of the fishery.

Regarding how the Canadian trawl surveys differ from the SWFSC trawl sampling, it was indicated that the gears (especially the trawl doors) and trawling speed are different. A comparative survey to test the performances of the different gears would be useful.

Schweigert was asked whether his trawl survey has been combined with other survey technologies. Schweigert explained that satellite SST data have not been used to estimate the distribution of Pacific sardine. Also, while acoustic technology has not yet been used, he is interested in utilizing that technology to augment the trawl results.

Extending the U.S. aerial survey into Canada to cover the northern limits of the stock beyond the U.S. northwest was discussed. It was noted that there is interest in extending the survey but there is a lack of experienced pilots and the costs are prohibitive for such an extension; hence, future application of aerial methods is unknown.

VI. REVIEW OF PLANS AND PARTNERSHIP OPPORTUNITIES: 2010-2011

The group reviewed the advantages and limitations/challenges of each survey method particularly with respect to the current Pacific sardine stock assessment method; these are summarized in Table 1. The group also reviewed existing and proposed survey plans, which are summarized in Table 2.

Stock assessment of the Pacific sardine resource is regularly produced for the PFMC and is currently highly dependent on abundance information from two surveys, DEPM and aerial, that provide an estimate of total abundance and a minimum estimate of abundance, respectively. Plans for these surveys are in place for 2010 and 2011 with each planned for execution with overlap in area but not time. The 2010 surveys are underway with the SWFSC responsible for the DEPM survey and the Pacific northwest and California sardine industries responsible for the aerial survey. Plans for 2011 surveys are to repeat the 2010 survey designs. The group engaged in a useful discussion on various collaborative projects that can assist in minimizing the limitations and/or augment the objectives of these two surveys.

The group concluded that both 2010 and 2011 surveys should proceed as planned but should incorporate testing of other methods with the proviso that additional methods incorporated into the surveys should not distract from the objectives of the surveys. The group identified two immediate benefits from piggyback collaboration. One is increased efficiency in designing and executing the surveys by taking into account the dynamic seasonal changes in the preferred habitat of Pacific sardine through use of satellite data. The other is validation of tonnage, species composition and sizes of fish in observed schools from the aerial survey through augmentation with acoustics and LIDAR methods as well as with use of purse seine sets.

The group agreed that the following opportunities for collaboration should be pursued for the 2010 surveys:

1. Testing of acoustics and LIDAR methods in the “point sets” experiment (Doc. 3) in the Pacific northwest and southern California fishing areas during the aerial survey. Echosounders might be deployed aboard vessels used by the NWFSC on its annual NWFSC salmon juvenile cruise and by the sardine industry in the Pacific northwest. LIDAR should be deployed on an aircraft used in the Pacific northwest aerial survey.

   Similarly for the southern California fishing area, echosounders should be deployed on the SWFSC’s annual CalCOFI cruise. Plans by CWPA to deploy LIDAR are already in place for an aircraft to be used in the aerial survey in southern California. SWFSC (R. Vetter) will be responsible for arrangements for deploying acoustic instruments on the CalCOFI cruises; D. Hanan (CWPA) will be responsible for arrangements to deploy a portable Biosionics scientific echosounder opportunistically on targeted sardine schools during the fall aerial survey; and NOAA/ESRL (J. Churnside) will be responsible for deploying LIDAR in the fall aerial survey. D. Hanan (CWPA) will take the lead for the analyses.

2. Satellite imagery and data should be compiled and tested for estimating the preferred habitat of Pacific sardine, and for forecasting that habitat to optimize efficiencies in designing (optimum sample size) and operating (cost savings) of surveys. The SWFSC (R. Vetter) will take lead.

3. A budget of $10K was identified to serve as “challenge awards” to encourage collaboration, including work to analyze sardine data contained in records of the regularly conducted NWFSC hake acoustics-trawl survey. The SWFSC (K. Koch) will take lead on exploring whether this data can be used.

Similar opportunities for collaboration are available for the 2011 surveys. Because planning for the 2011 surveys is not yet in final form, collaborations should be more easily incorporated in the survey plans at the outset and thus, enable enhanced efficiencies. Priority should be given to replicating tests conducted in the 2010 surveys, but also to looking for opportunities for augmenting trawl sampling and increasing sample sizes for biological data. A budget of $625K was estimated as required for incorporating piggyback methods on the two surveys in 2011; this assumes that a 2011 EFP with similar provisions as the 2010 EFP (Doc. 3) will be approved.

VII. CLEARING OF REPORT AND COMMITMENTS FOR FOLLOW THROUGH

1. Commitments for follow through

During the review and discussion of available survey methods, it was evident that because of the characteristics of the methods or different areas where they have been deployed, they provide data that yield different estimates of abundance. The group concluded that this is troublesome and that the methods need to be tested and compared under similar conditions and standards. The group agreed that a technical design team should be organized to 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. The design team would draw upon available information on sardine stock structure and biology, information gained from the DEPM and aerial surveys conducted to date, and fishery information, to design the experiment for small areas and a short period. The experiment should be planned for 2012, to not disrupt existing survey plans for 2010 and 2011, and with consideration for the need to replicate in subsequent years. The SWFSC should take lead in organizing the team in consultation with stakeholders. The objective would be to have the team's design, budget estimate and plan for execution available by March 2011, for budget considerations and for execution in 2012.

2. Clearing of report.

Sections I-VI of the workshop report were reviewed and approved by the group before the close of the workshop. Sakagawa explained that notes for the remaining Sections VII-IX of the report would be used to draft those sections. The entire draft report would then be made available to participants for review and comments before finalizing. For this process, the group provided Sakagawa with the authority to make decisions on incorporating comments and to finalize the report as soon as possible.

VIII. CLOSE OF WORKSHOP

In closing, Gary Sakagawa thanked everyone for contributing to the workshop and expressed his opinion that the interactions were productive. He thanked the CWPA for sponsoring the social and participants, especially those who traveled long distances to be in La Jolla, for their contributions.

Usha Varanasi also thanked everyone for their participation, including the SWFSC support staff and acknowledged that this was a valuable effort by the stakeholders. She expressed her expectation that valuable collaborations and products would result from this meeting and the spirit of cooperation developed at this workshop will continue.

TABLE 1
SUMMARY OF ADVANTAGES AND LIMITATIONS & CHALLENGES* OF SURVEY METHODS

Aerial Survey

Advantages

- Provides an empirical estimate (fishery-independent) of minimum abundance
- Makes use of experienced spotter pilots and their observations
- Surveys are conducted in optimal weather conditions
- Could be used to provide estimates of other species, boats, etc.

Limitations and Challenges

- Speed at which the plane can fly
- Time – may take several days or even weeks to complete a "SET" due to prohibitive weather
- Species identification – need to confirm
- Schools extending outside of visual frame (edge effects)
- Conversion of aerially estimated school area to sardine biomass
- Probability of detection is affected by depth, school size, sea state, etc.

Daily Egg Production Method

Advantages

- Eggs are non-evasive,
- Provides estimates of egg production, egg mortality, reproductive parameters, and spawning biomass with the measurements of precision, e.g. the coefficient of variation (CV).
- A short cruise time
- Data of other species and oceanographic measurements, valuable for other coastal pelagic species
- Provides fishery-independent long-term time series of relative abundance for the stock assessment model

Limitations and Challenges

- Patchy distribution of eggs requires large number of net tows or a well-designed survey
- Adult samples require intensive lab work and a good number of trawls with mature fish
- Adult sardine migrate and spawning habitat can move outside current DEPM survey area biasing the abundance estimates
- Some biological parameters require regular updating

Acoustics

Advantages

- Estimates distribution and abundance of multiple species
- Conducted concomitant with other ship-based sampling
- Continuous sampling, depth and distance
- Refined methods accepted and used worldwide
- Multi-species observations - ecosystem surveys

- Can be conducted synoptically
- Pending review, ready for use in stock assessment

Limitations and Challenges

- Optimized sampling - define habitat and optimally allocate survey effort
- Animal behavior including avoidance
    - Horizontal migration
    - Vertical migration
    - Aggregation variation
- Species identification
- Target Strength estimation

Logbook

Advantages

- Catch location, quantity, and SST data provide input for habitat prediction models. This could be used to optimize survey design
- Important to document fishing ground utilization in event closures are proposed
- Improving Total Catch Accounting including bycatch and discards.
- Economic data for regulatory impact reviews and other analyses
- Potentially can provide index of local abundance for use in spatially-explicit research models.
- Oregon and Washington already have logbooks which are likely standardized
- Logbooks are collected in Canada

Limitations and Challenges

- Catchability coefficient is inversely proportional to population size; highly problematic for catch-per-unit effort (CPUE) time series in an assessment
- No logbooks currently exist for the directed commercial fishery in California
- No logbooks currently provide trip target data and detailed effort information
- Canadian and existing US logbooks are not standardized

LIDAR

Advantages

- Low platform cost (aircraft)
- No vessel avoidance
- Synoptic surveys
- Potentially estimates biomass
- Provides additional information on school density, shape and depth

Limitations and Challenges

- Target identification
- Target strength estimation
- Observational range (depth penetration)
- Narrow swath width
- Technology not yet commercially available

Satellite Photography (private)

Advantages

- Only pay for data used

- Specific ocean and weather conditions can be requested (i.e. % cloud cover, % water vapor, ocean surface conditions)
- Time – These satellites travel the entire coast in a matter of minutes
- Extensive synopticity
- Single platform reduces potential for equipment bias
- Reduced possibility of "double counting" of sardine schools
- Fewer personnel needed to acquire data

Limitations and Challenges

- Species identification
- Image processing
- Weather may preclude sampling at specific times
- Ground truthing

Trawl survey (swept area)

Advantages

- Simple to conduct
- Provides direct identification of targets and ground truthing of other methods
- Less weather dependent
- Provides critical biological information on the target population
- Widely accepted, provides ancillary data on other cohabiting species
- Can provide a direct biomass estimate

Limitations and Challenges

- Expensive, requires vessel and staff resources
- Data analysis can be complex (have to incorporate gear efficiency, etc.)
- Difficult to account for vessel and gear avoidance
- Generally not possible to confirm the entire spatial distribution of the target population
- Unable to sample some areas (nearshore, untrawlable areas, potential protected species interactions)

*Limitations and challenges common to all or most methods (such as mechanical problems) are not listed.

TABLE 2 (continued): EXISTING AND PROPOSED SURVEYS TO COLLECT DATA FOR STOCK ASSESSMENTS OF PACIFIC SARDINE IN THE CALIFORNIA CURRENT*									
Methods	**Objective: Primary (biomass/index)**	**Objective: Fish age group**	**Location**	**Duration in years**	**Time Period (length)**	**Platform**	**PI**	**Collaborators**	**Needs**
Aerial	Summer: Min.estimate of absolute abundance	Adults	Synoptic - Cape Flattery to southern California	2009, 2010	[during close of directed fishery]late July - Sep 14; 35 days)	4 Airplanes, 8 fishing vessels	NWSS/CWPA - T. Jagielo/D. Hanan	Industry, PFMC	Expedite expempted fishing permit mechanism, NOAA real time habitat estimates, Twin-engine plane[s]
	Fall: Evaluate alternate survey methods; i.e. aerial photogrammetry, lidar, acoustics, day vs. night	Adults in southern California	Southern California Bight, centered on Catalina Island to 75nm offshore	2010	Concurrent w/ fall CalCOFI - late Oct-Nov (10-14 days)	2 Airplanes, 4 purse-seine fishing vessels	CWPA - D. Hanan/J. Churnside	Industry, CalCOFI, SWFSC	Expedite exempted fishing permit mechanism, NOAA real time habitat estimates, Twin-engine plane[s]
Acoustic	Biomass and distribution of sardine, other CPS, and their zooplankton prey	Adults	San Diego to San Francisco	1986-present (most years) (1986-88 conducted by CDFG)	Late March to Early May (22 days)	NOAA research vessel, SIO RV, fishing vessel	SWFSC - David Demer	Industry	Trawl samplers, Fishery catch data, Lidar, aerial observations
	Biomass and distribution of sardine, other CPS, and their zooplankton prey	Adults	Predicted habitat - between Pt. Conception and Strait of Juan de Fuca	n/a	June-July	NOAA vessel and charters	SWFSC - David Demer	Industry	Trawl samplers, Fishery catch data, Lidar, aerial observations
Daily Egg Production	Spawning biomass	All ages of adult fish All eggs and yolk-sac larvae	San Diego to San Francisco	1986-present (most years) (1986-88 conducted by CDFG)	Late March to Early May (22 days)	NOAA research vessel, SIO RV, fishing vessel	SWFSC - Nancy Lo	CDF&G	Verify lab experiments of temperature dependent egg development rates
	Spawning biomass	All ages of adult fish; All eggs and yolk-sac larvae	coastwide survey from San Diego to US-Canada boarder	2006, 2008 (2), 2010	Late March, April, Early May; sometimes in July (35 days)	NOAA research vessel and chartered fishing vessel	SWFSC - Nancy Lo and Bev Macewicz	CDF&G, NWFSC	Verify lab experiments of temperature dependent egg development rates; semi-annual occurrence
	April 2011,basic area biomass	1+ years	US-Mexican Border to San Francisco, CA	n/a	Aprii 2011, basic area	NOAA vessel	SWFSC - Sam McClatchie	NWFSC, SIO	better adaptive sampling, better trawling, better lab expts, better coordination, better forward looking sonar, fast tow cam
	Apri 2012 coastwide-biomass	1+ years	Mexico to Canada		Apri 2012 coastwide	NOAA vessel	SWFSC - Sam McClatchie	NWFSC, SIO	better adaptive sampling, better trawling, better lab expts, better coordination, better forward looking sonar, fast tow cam
	July 2012 coastwide-biomass	1+ years	Mexico to Canada		July 2012 coastwide	NOAA Vessel	SWFSC - Sam McClatchie	NWFSC, SIO	better adaptive sampling, better trawling, better lab expts, better coordination, better forward looking sonar, fast tow cam

TABLE 2 (continued): EXISTING AND PROPOSED SURVEYS TO COLLECT DATA FOR STOCK ASSESSMENTS OF PACIFIC SARDINE IN THE CALIFORNIA CURRENT*									
Methods	**Objective: Primary (biomass/index)**	**Objective: Fish age group**	**Location**	**Duration in years**	**Time Period (length)**	**Platform**	**PI**	**Collaborators**	**Needs**
Fishery Independent	live bait log - California (voluntary after 1998) - Purpose: fishery monitoring	Commercial fish available in California livebait fishery	California	1933-present		commercial purse seines	CDFG		incorporated as part of federal CPS logbook; size sampling to provide potential recruitment index
LIDAR	biomass; feasibility studies; spatial distribution and env factor relationships	adult	Washington and Oregon	2003, 2005, 2006	July (03), Aug (05), May (06), (~14days)	light aircraft	NOAA ESRL - James Churnside	SWFSC (03), NWFSC, Uni W., OR state (05, 06), industry, U AK fairbanks	
	biomass; collaboration with aerial survey	adult	S. California		Oct. 2010 (~14 days)	light aircraft	NOAA ESRL - James Churnside	CWPA	
Satellite	Evaluate alternate survey methods (biomass)	0-3 years	Synoptic - Cape Flattery to southern California	n/a	consistent with aerial	Satellite, fishing vessels, planes	NWSS/CWPA-T. Jagielo/D. Hanan	Industry, PFMC, SWFSC, Can DFO, NESDIS	NASA? or private Satellite data
Trawl survey	Biomass	All, primarily >2 years	British Columbia	1997-present	July - Aug (~10days)	WE Ricker	Canada DFO - Jake Schweigert	Possibly Aerial, high seas salmon	Plane
	Biomass	All, primarily >2 years	British Columbia		July - Aug (~10days)	plane	Canada DFO - Jake Schweigert	trawl	Plane

*Proposed surveys are shaded

Acronyms	
Can DFO	Department of Fisheries and Oceans Canada
CDF&G	California Department of Fish and Game
CWPA	California Wetfish Producers Association
ESRL	NOAA Earth Systems Research Laboratory
NESDIS	NOAA Environmental Satellite, Data, and Information Service
NWFSC	NOAA Northwest Fishery Science Center
PFMC	Pacific Fishery Management Council
SIO	University of California, Scripps Institution of Oceanography
SWFSC	NOAA Southwest Fishery Science Center

Agenda Item I.2
Situation Summary
November 2010

PACIFIC SARDINE STOCK ASSESSMENT AND COASTAL PELAGIC SPECIES (CPS) MANAGEMENT MEASURES FOR 2011

At this meeting, the Council is scheduled to adopt harvest specifications and management measures for the 2011 Pacific sardine fishing season; and to adopt harvest specifications for monitored Coastal Pelagic Species (CPS) stocks (jack mackerel, northern anchovy, and market squid). The Council will also hear reports on the 2010 Pacific sardine stock assessment and the 2010 aerial sardine survey.

Full assessments for CPS stocks typically occur every two to three years. The intervening years employ updates based on the same methodology and assessment protocols used for the previous full assessment. 2010 was an update year, using essentially the same methodology that was approved by a Stock Assessment Review (STAR) Panel for the previous assessment year (2009). New abundance data from two survey methods were employed in the update assessment: The Southwest Fisheries Science Center's (SWFSC) Daily Egg Production Model, and the industry-led aerial sardine survey (Agenda Item I.2.b, Attachment 1). The Stock Assessment Team (STAT) incorporated data from both of these surveys in the *Assessment of the Pacific Sardine Resource in 2010 for U.S. Management in 2011* (Agenda Item I.2.b, Attachment 2). In October 2010, the results of both surveys and the updated stock assessment were reviewed by a panel consisting of members of the CPS subcommittee of the Scientific and Statistical Committee (SSC), the Coastal Pelagic Species Management Team (CPSMT), and a representative of the Coastal Pelagic Species Advisory Subpanel (CPSAS).

At the November Council meeting, the SSC will review aerial survey results, the Pacific sardine assessment, the SSC's CPS subcommittee report, and recommendations from the CPSMT before making its recommendations on harvest levels for the 2011 Pacific sardine fishery. The CPSMT and the CPSAS will also be in session at the November meeting and will provide recommendations on management measures for the 2011 Pacific sardine fishery, including harvest set-asides for incidental landings of Pacific sardine in other CPS fisheries, and for research activities conducted under an EFP.

The Council and NMFS are currently working on implementing Amendment 13 to the CPS Fishery Management Plan to address revised National Standard 1 guidelines. The Council is anticipated to adopt management measures, including annual catch limits, for Pacific sardine and monitored stocks per Amendment 13 at this meeting. Additionally, the Council is anticipated to consider status determination criteria and management measures for the northern subpopulation of northern anchovy per Amendment 13. Because Amendment 13 will not be finalized until the first quarter of 2011, NMFS and the CPSMT will likely recommend a management structure that will allow NMFS to regulate CPS fisheries in early 2011 in the absence of Amendment 13, until such time as Amendment 13 and the corresponding Federal regulations are approved.

A full assessment of sardine is scheduled for 2011, and may employ new survey methods. New methods will be considered under Agenda Item I.3, Terms of Reference for Stock Assessment and Methodology Review Panels. As part of the 2011 management measure process, the Council may set aside a portion of the allowable harvest of Pacific sardine for anticipated survey research to be conducted under an EFP in 2011. Formal review of such survey proposals will commence at the March 2011 Council meeting.

Council Action:

1. **Adopt Pacific Sardine Assessment, Harvest Specifications, and Monitored Stocks Management Measures for 2011, including consideration of set-asides for incidental landings and research.**
2. **Provide guidance on implementation of Amendment 13.**

Reference Materials:

1. Agenda Item I.2.b, Attachment 1: *West Coast Aerial Sardine Survey Sampling Results in 2010.*
2. Agenda Item I.2.b, Attachment 2: *Assessment of the Pacific Sardine Resource in 2010 for U.S. Management in 2011.* (Executive Summary, **for full document, see electronic files on the Briefing Book CD or Council website**).
3. Agenda Item I.2.c, CPSMT Report 1: *Management Measures for Monitored Stocks.*
4. Agenda Item I.2.c, Supplemental SSC Report.
5. Agenda Item I.2.c, Supplemental CPSMT Report 2.
6. Agenda Item I.2.c, Supplemental CPSAS Report.
7. Agenda Item I.2.d, Public Comment.

Agenda Order:

a. Agenda Item Overview — **Kerry Griffin**
b. Survey and Assessment Report — **Tom Jagielo, Kevin Hill**
c. Reports and Comments of Management Entities and Advisory Bodies
d. Public Comment
e. **Council Action**: Approve the Pacific Sardine Assessment and Final 2011 Management Measures for CPS

PFMC
10/15/10

West Coast Aerial Sardine Survey

Sampling Results in 2010

Prepared by

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October 15, 2010

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Introduction

Advisory bodies of the Pacific Fishery Management Council (PFMC), including the Coastal Pelagic Species Advisory Subpanel (CPSAS), Coastal Pelagic Species Management Team (CPSMT) and the Scientific and Statistical Committee (SSC), have recommended that additional fishery-independent indices of abundance be developed for the assessment of Pacific Sardine. Aerial survey methods have been used previously in S. Africa to assess sardine stock abundance (Misund et al. 2003), and Hill et al. (2007) described how aerial survey indices were developed from spotter pilot logs and a contracted line transect survey conducted in 2004 and 2005 for sardine in Southern California.

To meet the stated need for a credible comparative index, a coastwide aerial survey was developed by a consortium formed by the West Coast sardine industry and was conducted in the summer of 2009 as part of an Exempted Fishery Permit (EFP) granted by the National Marine Fisheries Service (NMFS). Results from the 2009 aerial sardine survey were incorporated into the sardine stock assessment model used to set harvests for the 2010 fishing year (Hill et al 2009). The survey was expanded further in scope and conducted again in 2010. This paper reports the results of the aerial sardine survey in 2010.

The aerial survey incorporates effort from both northern and southern industry components; the Northwest Sardine Survey (NWSS), and California Wetfish Producers Association (CWPA), respectively. The survey conducted in 2010 follows the same basic approach that was used in 2009 (Jagielo et al 2009). It incorporates methods that were initially developed through pilot study work conducted in the northwest in 2008 (Wespestad et al. 2008) and were subsequently reviewed at Stock Assessment Review (STAR) panels in May and September of 2009.

The survey employs a two-part approach, involving 1) quantitative photographs collected on planned, randomly sampled aerial transects to estimate sardine school surface areas, and 2) fishing vessels operating at sea to capture a sample of photographed and measured schools to determine the relationship between sardine school biomass and school surface area.

Materials and Methods

I. Survey Design

A two-stage survey sampling design was employed. Stage 1 consisted of aerial transect sampling to estimate the surface area (and ultimately the biomass) of individual sardine schools from quantitative aerial photogrammetry; Stage 2 involved at-sea sampling to quantify the relationship between individual school surface area and biomass. Sampling was coordinated on a coastwise basis. Pilots from both NWSS and CWPA participated in coast wide transects. Vessels from NWSS conducted point sets in the north, and vessels from CWPA conducted point sets in the south. Logistical details of the survey are provided in an Operational Plan document which is included as Appendix I of the of the 2010 EFP Application (Thon and Pleschner-Steele, 2010).

Stage 1: Aerial Transect Survey

Logistics

The aerial survey employs the belt transect method using systematic random sampling, with each transect comprising a single sampling unit (Elzinga et al. 2001). Three alternative fixed starting points five miles apart were established, and from these points, three SETs of transects were delineated for the survey in each study region (north and south). The order of conducting the three replicate SETs was chosen by randomly picking one SET at a time without replacement. The first SET chosen in 2010 was SET C, followed by SET A, and finally SET B. The starting and ending positions for these transects are given in the Operational Plan.

Survey transects were conducted in an east-west orientation, generally parallel to the gradient of sardine schools distributed along the coast. To fully encompass the expected westward (offshore) extent of the sardine school distribution, transects originated three miles from the shoreline and extended westward for 35 miles. Additionally, the segment from the coastline to the transect east end (3 miles offshore) was also photo-documented for future evaluation. The spatial coverage of the survey design extended from the Canadian border in the north to the southern California Bight area in the south. Transects were parallel and spaced 15 nautical miles apart. For each SET, a total of 66 transects were planned for the 2010 survey with 26 off Washington and Oregon, and 40 off California. Three replicate SETS, or 198 transects in total were planned. Six pilots participated in the 2010 survey; four operated single engine airplanes, and two operated twin engine airplanes (Table 1).

A transect SET was conducted as follows. Survey pilots within each region operated as a coordinated team. The prevailing conceptual model of west coast sardine movement holds that fish tend to move in a northward direction during summer. A “leap-frog” approach was taken such that southward progress was continually maintained. This approach enabled relatively rapid southward progress in order to avoid double counting of sardine schools, which were presumably travelling northward during the survey time period. It was acceptable to skip transects or portions of transects if conditions required it (e.g. if better weather was available to the south of an area), but transects could not be “made up” once skipped during the sampling of a transect SET.

Once begun, the goal was to cover the full number of transects in a SET within a region in as few days as possible. Transects were flown at the nominal survey altitude of 4,000 ft, and could be flown starting at either the east end or the west end. At the beginning of each potential survey day, the survey pilots conferred by telephone to jointly determine if conditions could permit safe and successful surveying that day. Factors taken into consideration included sea condition, the presence of cloud or fog cover, and other relevant factors as determined by the survey pilots. The goal was to conduct sampling on days when prevailing conditions could permit clear visibility of sardine schools on the ocean surface from an altitude of 4000 ft.

Data Collection and Reduction

Each of the six survey planes was equipped with the same Aerial Imaging Solutions photogrammetric aerial digital camera mounting system and data acquisition system as used in the 2008 and 2009 work (see Operational Plan). This integrated system was used to acquire digital images and to log transect data. The system recorded altitude, GPS position, and spotter observations, which were directly linked to the time stamped quantitative digital imagery. At the nominal survey altitude of 4000 feet, the approximate transect width-swept by the camera with a 24 mm lens was 1829 m (1.13 mi). Digital images were collected with 60% overlap to ensure seamless photogrammetric coverage.

A Transect Flight Log Form was kept during the sampling of each transect for the purpose of documenting the observations of the pilot and/or onboard observers. Key notations included observations of school species identification and documentation of any special conditions that could have an influence on interpreting transect photographs.

In order to provide ground truth information and a cross comparison between survey aircraft, digital imagery of certain objects of known size (e.g. airplane hangars, baseball field diamonds, and football fields) was collected at a series of altitudes ranging from 500 ft. to 4000 ft. The observed vs. actual sizes of the objects were subsequently compared to evaluate photogrammetric error.

Five analysts performed the tasks of locating and measuring sardine schools on the aerial transect digital photographs collected in 2010. The procedure for analyzing transects was as follows: 1) two analysts independently conducted a preliminary examination of all photographs on a transect and made note of the presence or absence of schools on each photograph, 2) a third analyst examined the findings of the first two analysts and resolved which pictures would be used for sardine school measurements, and 3) transect school measurement assignments were made using the photographs selected for analysis on the transect.

Digital images were analyzed to determine the number, size, and shape of sardine schools on each transect. Adobe *Photoshop Lightroom 3.0* software was used to bring the sardine schools into clear resolution and measurements of sardine school size (m^2) and shape (circularity) were made using Adobe *Photoshop CS5-Extended*. Transect width was determined from the digital images using the basic photogrammetric relationship:

$$\frac{I}{F} = \frac{GCS}{A}$$

and solving for *GCS*:

$$GCS = \frac{I}{F}A$$

where *I* = Image width of the camera sensor (e.g. 36 mm), *F* = the focal length of the camera lens (e.g. 24mm), *A* = altitude, and *GCS* = “ground cover to the side” or width of the field of view of the digital image. Transect width was obtained by taking the average of *GCS* for all images collected. Transect length was obtained from the distance between start and stop endpoints using the GPS data logged by the data acquisition system.

Stage 2: At-Sea Point Set Sampling

Logistics

Point sets were the means used to determine the relationship between individual school surface area (as documented with quantitative aerial photographs, described above) and the biomass of individual fish schools. Empirical measurements of biomass were obtained by conducting research hauls or "point sets" at sea. Four purse seine vessels participated in the survey in the north (Astoria - NWSS), and eight in the south (Monterey and S. California - CWPA) (Table 2).

For the purposes of the aerial survey, a point set was defined as a sardine school first identified by a survey pilot and subsequently captured in its entirety by a survey purse seine vessel. Pilots were instructed to first identify schools for point sets at an altitude of 4,000 ft -- which was also the nominal altitude specified for survey transects. The protocol for conducting point sets, and the specific criteria used for determining the acceptability of point sets for analysis of the school area-biomass relationship are given in the Operational Plan.

For fully captured schools, the 1) total weight of the school, 2) numbers per unit weight, and 3) species composition was determined, based on biological sampling of the point set hauls. Additionally, school height information was recorded from vessel sonar and down-sounder equipment.

The point set sampling design was based on school size, with the goals of 1) obtaining a range of sizes representative of schools photographed on the transects and 2) keeping within a size range consistent with the safe operation of the vessels participating in the survey. Thus, point sets were generally not attempted for schools larger than approximately 130 mt. Point set sampling was distributed between the northern and southern areas, with 2100 mt available for point sets for each area. A total of n = 54 schools were planned for the north, and 54 for the south.

Biological Sampling

Fish were collected at processing plants upon landing. Fishermen participating in the survey were instructed to keep the point set hauls in separate holds upon capture so the tonnage of each aerially photographed and measured haul could be determined separately upon landing. Samples were collected from the unsorted catch while being pumped from the vessels. Fish were taken systematically at the start, middle, and end of each delivery as it was pumped. The three samples were then combined and a random subsample of fish was taken from the pooled sample. Length, weight, sex, and maturity data were collected for each sampled fish. Sardine weights were taken using an electronic scale accurate to 0.5 gm; sardine lengths were taken using a millimeter length strip provided attached to a measuring board. Standard length was determined by measuring from sardine snout to the last vertebrae. Sardine maturity was documented by referencing maturity codes (female- 4 point scale, male- 3 point scale) supplied by Beverly Macewicz NMFS, SWFSC (Table 3).

II. Analytical Methods

<u>*Total Biomass*</u>

Estimation of total sardine biomass for the survey area was accomplished in a 3 step process, and required 1) measurements of individual school surface area on sampled transects, 2) estimation of individual school biomass (from measured school surface area and estimated school density), and 3) transect sampling design theory for estimation of a population total. The calculations described below were implemented using the R statistical programming language. The R programs used for the analysis are included as Appendix I.

Individual school surface area (a_i) was measured on the photo-documented transects using the measurement tool feature of *Adobe Photoshop*, and employed the photogrammetric relationships described above. Individual school density (d_i) is specific to school size and was determined from the empirical relationship between surface area and biomass obtained from Stage 2 (point set) sampling (described below). Individual school biomass (b_i) was estimated as the product of school density and surface area ($b_i = d_i a_i$). The sum of individual school biomass (b_u) was then determined for each transect (u). The mean sampled biomass for the study area ($\bar{b}$) was computed as

$$\bar{b} = \sum_{u=1}^{n} b_u \ / n \ ,$$

where n = the number of transects sampled. Total biomass for the study area $\left(\hat{B}\right)$ was estimated using the unbiased estimator for a population total (Stehman and Salzer 2000),

$$\hat{B} = N\bar{b} \ ,$$

where N = the total number of transects that could possibly be sampled in the survey area without overlap. In 2010, three replicate sets of transects (SET A, SET B, and SET C) were completed and thus three estimates of $\hat{B}$ were calculated: $\hat{B}_A$, $\hat{B}_B$, and $\hat{B}_C$, respectively. The point estimate of total biomass for the study area ($\hat{B}_T$) was obtained by averaging these three estimates of biomass.

Individual School Biomass

The biomass of individual schools observed on the transects (b_i) was calculated using 1) measurements of school surface area, and 2) the relationship between school surface area and biomass, obtained from point sets. The three parameter Michaelis-Menten (MM) model assuming log-normal error was used to describe the sardine surface area– density relationship

d_i = (yint * cc + asymp * a_i) / (cc + a_i)

where

d_i = school density (mt/m^2)
a_i = school area (m^2)
yint = y intercept
asymp = asymptote as x -> infinity
asymp/cc = slope at the origin .

As noted above, individual school biomass (b_i) was then estimated as the product of school density and surface area ($b_i = d_i a_i$).

Total Biomass Coefficient of Variation (CV) for the 2010 Survey

The CV of the total biomass estimate was obtained by employing a bootstrapping procedure implemented with the R statistical programming language (Appendix I). The intent of the procedure was to propagate error from the point of school density estimation forward -- to the ultimate goal of total biomass estimation from the three replicate sets of transect data. The steps of the procedure were:

1) The MM model was fit to the point set data.
2) A variance-covariance matrix was derived for the MM model fit to the data, using the R library “MSBVAR” .
3) A matrix of simulated MM parameters was derived from the MSBVAR output, using the R function “rmultnorm”.
4) For n = 100,000 bootstraps:
   a. One realization of the MM parameters was selected from the matrix of simulated parameters.
   b. The predicted MM curve was calculated.
   c. Total biomass for the study area was estimated for each of the three replicate transect sets.
   d. The three replicate estimates of total biomass were sampled with replacement.
   e. The mean of the sampled replicates was calculated, and stored as the bootstrap estimate of biomass.
5) The standard error (SE) was calculated from the stored bootstrap estimates of biomass (4e).
6) CV was calculated as CV = SE/$\hat{B}_T$.

Total Biomass Coefficient of Variation (CV) for the 2009 Survey

The 2009 survey did not collect replicate sets of transect data for analysis. Thus, the CV for the 2009 estimate of biomass was based on between-transect variability (see Appendix I – *bootsard3.r*). The steps were:

1) The MM model was fit to the point set data.
2) A variance-covariance matrix was derived for the MM model fit to the data, using the R library "MSBVAR" .
3) A matrix of simulated MM parameters was derived from the MSBVAR output, using the R function "rmultnorm".
4) For n = 100,000 bootstraps:
   a. One realization of the MM parameters was selected from the matrix of simulated parameters.
   b. The predicted MM curve was calculated.
   c. Biomass was estimated for the transects.
   d. The transects were randomly sampled with replacement.
   e. Total biomass for the study area was calculated from the sampled transects and stored as the bootstrap estimate of biomass.
5) The standard error (SE) was calculated from the stored bootstrap estimates of biomass (4e).
6) CV was calculated as CV = SE/$\hat{B}$.

Survey Results

Photogrammetric Evaluation

To evaluate photogrammetric error, a cross-comparison of the camera systems employed on the survey aircraft was conducted by analyzing photographs of known-size objects. Measurements of airplane hangars (or football fields) with known area (m^2) were obtained from photographs taken at altitudes ranging from 918 to 4482 ft. Average deviance ranged from 3.0% to 11.4% for five of the six camera systems employed in the study (area measurement data were not available for SP6) (Table 12).

In 2010, every transect photograph was examined by two photo analysts for the presence of sardine schools. The photo analysts worked independently during this phase of photograph analysis. A summary of the rate of agreement between photo analysts independently engaged in the activity of finding fish schools on photographs is given in Table 13. For the 22,878 photographs examined on the three replicate transect SETs, the average percent agreement per transect ranged from 97.0 to 98.5%.

Stage 1: Aerial Transect Survey

Transect sampling in 2010 was conducted from August 13th through September 9th and was successful in obtaining three replicate SETs, for a total of 182 transects sampled (Table 4). Three transects were not sampled on SET A (37, 48, and 49), seven on SET B (27, 28, 30, 31, 32, 33, and 34), and six on SET C (23, 32, 40, 41, 56, and 59). Transect detail data are presented in Tables 5a- 5f. Sardine schools were observed on 18 of 63 transects sampled for SET A, 13 of 59 sampled on SET B, and 20 of 60 sampled on SET C (Tables 5a-5f). The observed average biomass per transect was 200.0 mt for SET A, 96.9 for SET B, and 160.6 for SET C. The total number of transects possible (N) was 883 for SET A, 896 for SET B, and 945 for SET C. Fewer schools per transect were seen in 2010, compared with 2009 (Table 4). Schools sampled in 2010 tended to be smaller in size, on average, when compared with those sampled in 2009 (Figure 1), and schools observed in the south were smaller on average compared to schools in the north

(Figure 2). Maps showing the locations of sardine schools observed on transects in 2010 are given in Figure 11.

Stage 2: At-Sea Point Set Sampling

At-sea sampling in 2010 resulted in the landing of 71 point sets between August 9th and September 14th, which included 37 from the north (2,065 mt), and 34 from the south (1,248 mt). A summary of point sets landed by size is given in Table 14. Point set data detail is summarized in Table 6 for the north, and Table 7 for the south. Point set species composition averaged 99.5% sardine in the north, and 98.3% sardine in the south. Pacific mackerel was the predominant bycatch species. Point set locations are plotted in Figure 3 (north) and Figure 4 (south). Point set sampling was not successful in the Monterey area in 2010. Histograms of size frequency and maturity stage for all point sets landed in 2010 are given in Figures 9 and 10, respectively. Maps of point set locations, shown with respect to the location of sardine schools observed on transects in 2010, are given in Figure 12.

Area-Biomass Analysis
In 2010, 24 of 37 point sets qualified for the area-biomass analysis in the north (Table 8), and 17 of 34 point sets qualified in the south (Table 9). Specific reasons for not using point sets in the analysis are summarized in Table 6 (north) and Table 7 (south). Fits of the MM model to the data are shown in Figures 5 and 6.

Two likelihood ratio tests were conducted (Table 10). The first test evaluated pooling the new 2010 data from the north with the data collected previously in the north and used in the 2009 analysis (Table 10, top); the null hypothesis of no difference between model fits to the separate vs. pooled data was not rejected (P = 0.189). The second test evaluated pooling the new 2010 data from the south with all of the data from the north (Table 10, bottom); the null hypothesis was rejected at the 0.05 level of significance (P = 0.029). It is noteworthy that 1) fitting the model to the pooled data from the north resulted in the asymptote parameter becoming bound at the lower limit (0.001), and 2) fitting the model to the new 2010 data from the south resulted in the cc parameter becoming bound at the lower limit (100). It was concluded that the best model for the area-biomass analysis is the coastwide (all data pooled) model. Pooling data for this model was not rejected at the P = 0.01 level of significance, and fitting the model to the data did not result in any bound parameters.

Estimation of quantities for input to the sardine stock assessment

Total Biomass
Estimates of total biomass and associated CVs are summarized in Tables 11 and 11a. The point estimate for the coast wide survey in 2010 was 138,379 mt (CV = 0.30); this analysis used the coastwide pooled point set data (filename = *cdata2010nsp*).

Total biomass was also calculated separately using the point set data from each region; filenames *cdata2010np* (north) and *cdata2010s* (south), respectively. Analysis of the northern region yielded a point estimate of 105,738 mt, (CV = 0.44) with the asymptote bound at 0.001, and a point estimate of 108,851 (CV = 0.40) with the asymptote bound at 0.005. Analysis of the southern region resulted in 27,695 mt (CV = 0.72).

Total biomass was also re-calculated for 2009 using the transect data from that year with the updated point set data (Table 11). Using the pooled point set data from the north, total biomass was 794,159 mt (CV = 2.08) with the asymptote bound at 0.001, and 1,247,250 mt (CV = 1.12) when the asymptote was bound at 0.005. A third run using the coast wide pooled point set data resulted in 2,000,618 mt (CV = 0.66). By comparison, the biomass estimate using only the point set data from the 2009 analysis yielded a biomass estimate of 1,236,911 mt (CV = 1.12).

Weighted length composition
Vectors of weighted length frequency were also derived for input to the sardine stock assessment model. The raw length frequency data were weighted by the landed point set weights. Separate vectors were computed for the north, south, and coast as a whole. Length distributions differed noticeably with larger fish predominating in the north, as compared to the south (Figure 8).

Discussion

In 2010, we were successful in coordinating industry resources on a coast wide basis to achieve a second synoptic West Coast sardine survey. The results were strikingly different in 2010 compared to 2009.

Factors that can contribute to make the survey a minimum estimate of biomass were enumerated by the May 2009 STAR Panel and include incomplete detection due to: 1) schools too deep, 2) schools lost in glare, 3) marginal cloud cover – reduced visibility, 4) sea state, and 5) weather that is consistently prohibitive to sampling (limiting to full area coverage during the survey time window).

Weather again negatively impacted survey results in 2010. In the limited time available for the survey, we completed three replicate transect SETs, however, it was often not possible to sample during optimal conditions for sardine observation. As a result, sampling often occurred under sub-optimal conditions.

Monterey point sets in 2010 – Observations by Doyle Hanan
A question raised by this year's aerial survey is the presence of sardines in the aerial transects from the Monterey area but absence of point sets for determining the ratio of school surface area to school biomass. A primary objective of the 2010 summer survey was to accomplish, to the degree possible, three complete replicates of the aerial transects in order to establish a defensible CV. Although dense and persistent marine layer plagued the project in California during the entire month of August and early September, by chartering four pilots we were able to deploy planes strategically to capitalize on the few clear days available to fly, and three complete sets of 40 transects were flown successfully. During the few days that the marine layer lifted sufficiently to allow visibility from the air, the area around Monterey Bay was scouted (low altitude flights to look for sardine schools) by airplane and by fishing vessels participating in other fisheries and traversing to and from those fishing grounds. Specifically we were in

communication several times each day with both the pilot(s) and with the fishing vessels participating in the market squid fishery, which was active just north of Monterey Bay, and they reported no sardines visible. We also scouted the area up to the Farallon Islands with airplanes, as well as, areas to the south of Monterey Bay. Apparently those schools visible in the enhanced transect photographs were not visible to or seen by our pilots or fishermen in fishing vessels using various sonar gears. We did observe sardines in the northeast corner of Monterey Bay in shallow water, but we followed the guidelines recommended by the SSC and CPSMT and did not attempt to capture schools from this area as it was very close to shore within the three mile exclusion zone. Resulting from the inability to conduct point sets in Monterey Bay during the survey period, August to September 14, we were required to return 861 metric tons of the EFP set aside to the fall directed fishery. As EFP fish are sold at cost to cover research expenses, the inability to capture point sets in Monterey caused a significant budget shortfall in the California portion of the survey. Ironically, sardines became visible in the Bay both to pilots and fishermen after the fall directed fishery was closed for the year on September 23.

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Table 1. Pilot and aircraft information for the aerial sardine survey in 2010.

Region	Pilot ID	Pilot Name	Aircraft ID	Aircraft Type
North	Survey Pilot No.1 (SP1)	Frank Foode	N700AM	Cessna 336 Skymaster (twin engine)
North	Survey Pilot No.2 (SP2)	Merrill Danne	N18ZF	Piper Super Cub
South	Survey Pilot No.3 (SP3)	Eric Waxman	N2950A	Piper Seminole (twin engine)
South	Survey Pilot No.4 (SP4)	Allen Hewitt	N5210Y	Cessna 182 Turbo
South	Survey Pilot No.5 (SP5)	Geno Zandona	N735U	Cessna 182
South	Survey Pilot No.6 (SP6)	Devin Reed	N172JP	Cessna 172

Table 2 . Identification and gear configuration of participating vessels in 2010.

Vessel Name	Skipper	Owner	USGS/OR Reg#	CPS/Sardine Permit #	Length	GRT	Holds	Capacity (Tons)
Astoria								
Pacific Pursuit	Keith Omey	Pacific Pursuit, LLC	OR873ABY	30920	73'	86	4	80
Lauren L. Kapp	Ryan Kapp	Daryll Kapp	OR072ACX	57008	72'	74	4	60
Pacific Knight	Mike Hull	Dulcich, Inc.	OR155ABZ	57011	62'	53	4	50
Pacific Raider	Nick Jerkovich	Nick Jerkovich	972638	57010	58'	75	2	55
Monterey								
Sea Wave	Andy Russo	Sea Wave Corp-Sal Tringali	D951443	10	78'	206.9	2	75
King Philip	Anthony Russo	Sea Wave Corp-Sal Tringali	D1061827	9	79'	156.9	6	125
El Dorado	Frank Aliotti	Aliotti Brothers, Inc.	D690849	32	56'	54.9	3	40
Aliotti Bros.	Dominic Aliotti	Joseph D. Aliotti	D685870	48	67.6'	107	3	80
Southern CA								
Eileen	Nick Jurlin	South Sound Fisheries, Inc.	D252749	38	79.4'	119.9	2	85
Trionfo	Neil Guglielmo	Aniello Guglielmo	D625449	45	63.8'	79.2	3	60
Endurance	Vince Lauro	Vincent Lauro	D613302	35	49'	42	3	40
Maria T	Robert Terzoli	Vito Terzoli	D509632	25	57.3'	68.1	3	65

Table 3. Sardine maturity codes. Source: Beverly Macewicz NMFS, SWFSC.

Female maturity codes	Male maturity codes
1. Clearly immature- ovary is very small; no oocytes present	1. Clearly immature- testis is very small thin, knifed-shaped with flat edge
2. Intermediate- individual oocytes not visible but ovary is not clearly immature; includes maturing and regressed ovaries	2. Intermediate- no milt evident and is not a clear immature; includes maturing or regressed testis
3. Active- yolked oocytes visible; any size or amount as long as you can see them with the unaided eye in ovaries	3. Active- milt is present; either oozing from pore, in the duct, or when testis is cut with knife.
4. Hydrated oocytes present; yolked oocytes may be present	

Table 4. Transect summary results, 2009 and 2010.

Coastwide		**No. of Transects Sampled**	**No. of Schools**	**Avg. School Area (m2)**	**Total School Area (m2)**	**Total School Biomass (mt)**
2009		41	1,033	9,853	10,178,228	85,371
2010	Rep A	63	642	775	497,841	12,597
	Rep B	59	230	1,198	275,467	5,719
	Rep C	60	618	572	353,198	9,633
	2010 Total	182	1,490	756	1,126,506	27,949
North		**No. of Transects Sampled**	**No. of Schools**	**Avg. School Area (m2)**	**Total School Area (m2)**	**Total School Biomass (mt)**
2010	Rep A	26	504	868	437,607	10,698
	Rep B	26	177	1,348	238,645	4,818
	Rep C	25	281	902	253,482	6,235
	2010 Total	77	962	966	929,734	21,752
South		**No. of Transects Sampled**	**No. of Schools**	**Avg. School Area (m2)**	**Total School Area (m2)**	**Total School Biomass (mt)**
2010	Rep A	37	138	436	60,234	1,899
	Rep B	33	53	695	36,822	901
	Rep C	35	337	296	99,716	3,398
	2010 Total	105	528	373	196,772	6,198

Table 5a. Transect detail, 2010 – SET A (north).

Transect	No. of Schools	Area (m^2)	Biomass (mt)	Date	Pilot	Start Dec. Longitude	Start Dec. Latitude	End Dec. Longitude	End Dec. Latitude	Transect Avg. Width (m)	Transect Length (km)
1	14	5706.5	207.4	8/22/2010	SP1	-124.7162	48.3327	-125.4720	48.3341	1822.8	55.8
2	36	26176.3	738.1	8/22/2010	SP1	-125.4842	48.0824	-124.7358	48.0847	1830.9	55.6
3	13	7728.8	241.0	8/23/2010	SP1	-124.5352	47.8329	-125.2817	47.8336	1806.6	55.7
4	36	27976.6	708.7	8/23/2010	SP1	-125.1432	47.5832	-124.3985	47.5845	1791.2	55.8
5	98	53222.7	1572.6	8/23/2010	SP1	-124.3320	47.3357	-125.0750	47.3345	1794.0	56.0
6	39	8239.3	355.2	8/23/2010	SP1	-124.9523	47.0825	-124.2160	47.0829	1792.7	55.7
7	2	450.8	20.7	8/23/2010	SP1	-124.1499	46.8333	-124.8818	46.8337	1800.0	55.6
8	11	3508.4	139.5	8/23/2010	SP1	-124.8472	46.5831	-124.1164	46.5823	1809.2	55.8
9	111	176658.4	3540.5	8/23/2010	SP1	-124.8269	46.3343	-124.1003	46.3340	1801.6	55.7
10	19	33378.6	668.9	8/23/2010	SP1	-123.9831	46.0822	-124.7022	46.0843	1792.0	55.4
11	46	37345.9	886.2	8/23/2010	SP1	-124.7071	45.8341	-123.9956	45.8344	1795.3	55.1
12	75	55153.8	1548.7	8/23/2010	SP1	-123.9795	45.5844	-124.6962	45.5841	1783.2	55.7
13	1	836.7	24.1	8/23/2010	SP1	-124.7218	45.3334	-124.0159	45.3381	1779.6	55.1
14	1	378.7	15.0	8/24/2010	SP1	-124.7577	45.0837	-124.0475	45.0825	1822.0	55.7
15	0	0.0	0.0	8/24/2010	SP1	-124.1132	44.8349	-124.8231	44.8336	1814.5	55.9
16	2	845.3	31.5	8/24/2010	SP1	-124.8156	44.5821	-124.1115	44.5831	1821.0	55.7
17	0	0.0	0.0	8/24/2010	SP1	-124.1645	44.3347	-124.8614	44.3342	1822.1	55.4
18	0	0.0	0.0	8/24/2010	SP1	-124.8803	44.0838	-124.1772	44.0822	1824.6	56.1
19	0	0.0	0.0	8/24/2010	SP1	-124.2123	43.8342	-124.9057	43.8327	1820.8	55.6
20	0	0.0	0.0	8/24/2010	SP1	-124.9572	43.5837	-124.2613	43.5832	1822.4	56.0
21	0	0.0	0.0	8/24/2010	SP1	-124.4276	43.3338	-125.1171	43.3339	1805.2	55.7
22	0	0.0	0.0	8/24/2010	SP1	-125.1636	43.0843	-124.4779	43.0833	1816.1	55.6
23	0	0.0	0.0	8/24/2010	SP1	-124.5965	42.8348	-125.2769	42.8335	1840.0	55.4
24	0	0.0	0.0	8/24/2010	SP1	-125.1270	42.5840	-124.4457	42.5868	1826.6	55.7
25	0	0.0	0.0	8/24/2010	SP1	-124.4771	42.3334	-125.1544	42.3334	1812.9	55.6
26	0	0.0	0.0	8/24/2010	SP1	-125.0203	42.0849	-124.3417	42.0837	1819.2	56.0

Table 5b. Transect detail, 2010 – SET A (south).

Transect	No. of Schools	Area (m^2)	Biomass (mt)	Date	Pilot	Start Dec. Longitude	Start Dec. Latitude	End Dec. Longitude	End Dec. Latitude	Transect Avg. Width (m)	Transect Length (km)
27	0	0.0	0.0	8/24/2010	SP5	-124.2600	41.8347	-124.9327	41.8348	1989.3	55.7
28	0	0.0	0.0	8/24/2010	SP5	-124.8153	41.5823	-124.1422	41.5838	2006.9	55.9
29	0	0.0	0.0	8/24/2010	SP5	-124.1060	41.3391	-124.7814	41.3342	2459.3	56.3
30	0	0.0	0.0	8/24/2010	SP5	-124.8563	41.0881	-124.1915	41.0838	2010.1	55.7
31	0	0.0	0.0	8/24/2010	SP5	-124.2380	40.8349	-124.8908	40.8373	1847.6	54.9
32	0	0.0	0.0	8/24/2010	SP5	-125.0314	40.5868	-124.3861	40.5828	2000.0	54.5
33	0	0.0	0.0	8/25/2010	SP5	-124.3771	40.3319	-124.4514	40.3404	2053.2	6.4
34	0	0.0	0.0	8/25/2010	SP5	-124.5937	40.0828	-124.1042	40.0831	1882.6	41.6
35	0	0.0	0.0	8/25/2010	SP5	-123.8948	39.8333	-124.4937	39.8403	1958.5	51.1
36	0	0.0	0.0	8/25/2010	SP5	-124.4461	39.5791	-123.8001	39.5772	1963.1	55.3
37	Not Sampled										
38	0	0.0	0.0	8/24/2010	SP4	-123.7268	39.0861	-124.3726	39.0806	1901.5	55.7
39	0	0.0	0.0	8/24/2010	SP4	-124.2881	38.8261	-123.6428	38.8329	1920.2	55.9
40	5	1854.2	72.3	8/24/2010	SP4	-123.3941	38.5823	-124.0354	38.5795	1932.8	55.7
41	0	0.0	0.0	8/24/2010	SP4	-123.7544	38.3344	-123.1060	38.3328	1904.7	56.5
42	0	0.0	0.0	8/25/2010	SP4	-122.9920	38.0853	-123.6324	38.0853	1903.8	56.0
43	0	0.0	0.0	8/25/2010	SP4	-123.1811	37.8349	-122.5432	37.8331	1909.1	56.0
44	0	0.0	0.0	8/25/2010	SP4	-122.5385	37.5878	-123.1757	37.5886	1923.5	56.1
45	5	885.9	43.4	8/25/2010	SP4	-123.0570	37.3357	-122.4236	37.3323	1919.4	56.0
46	0	0.0	0.0	8/25/2010	SP4	-122.3089	37.0832	-122.9390	37.0868	1883.6	55.9
47	0	0.0	0.0	8/25/2010	SP4	-122.4545	36.8352	-122.2702	36.8360	1887.2	16.4
48	Not Sampled										
49	Not Sampled (No GPS data)										
50	0	0.0	0.0	8/24/2010	SP3	-122.2803	36.0828	-121.6514	36.0844	1829.4	56.5
51	0	0.0	0.0	8/24/2010	SP3	-121.4344	35.8317	-122.0610	35.8335	1832.8	56.4
52	0	0.0	0.0	8/24/2010	SP3	-121.8243	35.5798	-121.1551	35.5849	1837.7	60.5
53	0	0.0	0.0	8/24/2010	SP3	-120.9194	35.3345	-121.5384	35.3308	1791.5	56.1
54	0	0.0	0.0	8/24/2010	SP3	-121.2712	35.0842	-120.6525	35.0826	1878.8	56.3
55	0	0.0	0.0	8/24/2010	SP3	-120.6492	34.8360	-121.2660	34.8344	1800.9	56.3
56	0	0.0	0.0	8/24/2010	SP3	-121.3030	34.5828	-120.7460	34.5840	1861.4	51.0
57	128	57493.8	1783.6	8/29/2010	SP6	-119.4397	34.3321	-120.0521	34.3370	1848.4	56.2
58	0	0.0	0.0	8/29/2010	SP6	-120.3533	34.3338	-120.6295	34.3273	1839.2	25.4
59	0	0.0	0.0	8/29/2010	SP6	-119.6809	34.0816	-119.0732	34.0825	1862.9	55.9
60	0	0.0	0.0	8/29/2010	SP6	-120.5783	34.0850	-119.9835	34.0842	1875.2	54.7
61	0	0.0	0.0	8/30/2010	SP3	-119.0455	33.8343	-118.4404	33.8336	1741.4	55.9
62	0	0.0	0.0	8/30/2010	SP3	-119.9538	33.8314	-119.3441	33.8344	1813.6	56.3
63	0	0.0	0.0	8/30/2010	SP3	-117.8736	33.5802	-118.4776	33.5829	1875.0	55.9
64	0	0.0	0.0	8/30/2010	SP3	-118.7785	33.5808	-119.3816	33.5843	1815.7	55.8
65	0	0.0	0.0	8/30/2010	SP3	-118.1393	33.3348	-117.5385	33.3343	1834.0	55.8
66	0	0.0	0.0	8/30/2010	SP3	-119.0440	33.3320	-118.4423	33.3333	1846.4	55.9

Table 5c. Transect detail, 2010 – SET B (north).

Transect	No. of Schools	Area (m^2)	Biomass (mt)	Date	Pilot	Start Dec. Longitude	Start Dec. Latitude	End Dec. Longitude	End Dec. Latitude	Transect Avg. Width (m)	Transect Length (km)
1	0	0.0	0.0	8/28/2010	SP1	-124.7513	48.2514	-125.5041	48.2508	1784.8	55.7
2	0	0.0	0.0	8/28/2010	SP1	-125.4712	47.9979	-124.7180	48.0014	1795.9	56.0
3	0	0.0	0.0	9/2/2010	SP1	-124.4648	47.7504	-125.2193	47.7511	1832.4	56.4
4	23	8200.7	286.2	9/2/2010	SP1	-125.1312	47.5015	-124.3826	47.5015	1840.6	56.2
5	16	9077.7	269.4	9/2/2010	SP1	-124.2666	47.2510	-125.0064	47.2506	1829.1	55.8
6	51	124146.5	2095.1	9/2/2010	SP1	-124.9532	47.0013	-124.2143	46.9949	1819.2	56.0
7	35	43608.9	893.3	9/2/2010	SP1	-124.1478	46.7508	-124.8687	46.7500	1822.2	54.9
8	33	38619.3	859.7	9/2/2010	SP1	-124.8255	46.4999	-124.0978	46.4950	1801.9	55.7
9	5	6977.6	150.7	9/2/2010	SP1	-124.0815	46.2506	-124.8084	46.2515	1796.9	55.9
10	0	0.0	0.0	9/2/2010	SP1	-124.7085	46.0001	-123.9809	45.9999	1789.4	56.2
11	0	0.0	0.0	9/2/2010	SP1	-123.9951	45.7491	-124.7182	45.7510	1796.5	56.1
12	0	0.0	0.0	9/2/2010	SP1	-124.7208	45.4991	-123.9943	45.4984	1793.6	56.6
13	0	0.0	0.0	9/3/2010	SP1	-123.9973	45.2528	-124.5284	45.2506	1804.6	41.5
14	6	3156.8	107.1	9/3/2010	SP1	-124.7755	44.9972	-124.0623	45.0002	1817.2	56.0
15	8	4857.7	156.8	9/3/2010	SP1	-124.0980	44.7515	-124.4985	44.7493	1811.6	31.6
16	0	0.0	0.0	9/3/2010	SP1	-124.8196	44.4981	-124.1140	44.4981	1832.6	55.9
17	0	0.0	0.0	9/3/2010	SP1	-124.1442	44.2518	-124.8481	44.2497	1820.7	56.0
18	0	0.0	0.0	9/3/2010	SP1	-124.8823	43.9994	-124.1776	44.0008	1820.2	56.3
19	0	0.0	0.0	9/4/2010	SP1	-124.2279	43.7516	-124.9245	43.7503	1831.7	55.9
20	0	0.0	0.0	9/4/2010	SP1	-125.0061	43.4999	-124.3133	43.4994	1835.3	55.8
21	0	0.0	0.0	9/4/2010	SP1	-124.4427	43.2509	-125.1367	43.2499	1844.6	56.2
22	0	0.0	0.0	9/4/2010	SP1	-125.2030	43.0005	-124.5097	43.0008	1836.9	56.3
23	0	0.0	0.0	9/4/2010	SP1	-124.5606	42.7499	-125.2496	42.7499	1834.7	56.2
24	0	0.0	0.0	9/4/2010	SP1	-125.1466	42.5002	-124.4582	42.5016	1834.0	56.4
25	0	0.0	0.0	9/4/2010	SP1	-124.4438	42.2506	-125.1260	42.2501	1829.0	56.1
26	0	0.0	0.0	9/4/2010	SP1	-124.9218	42.0005	-124.2443	42.0005	1822.4	55.9

Table 5d. Transect detail, 2010 – SET B (south).

Transect	No. of Schools	Area (m^2)	Biomass (mt)	Date	Pilot	Start Dec. Longitude	Start Dec. Latitude	End Dec. Longitude	End Dec. Latitude	Transect Avg. Width (m)	Transect Length (km)
27	Not Sampled (No GPS data)			8/31/2010	SP3						
28	Not Sampled (No GPS data)			8/31/2010	SP3						
29	0	0.0	0.0	8/31/2010	SP3	-124.1416	41.2517	-124.4802	41.2470	1882.7	28.3
30	Not Sampled (No GPS data)			8/31/2010	SP3						
31	Not Sampled (No GPS data)			8/31/2010	SP3						
32	Not Sampled (No GPS data)			8/31/2010	SP3						
33	Not Sampled (No GPS data)			8/31/2010	SP3						
34	Not Sampled (No GPS data)			8/31/2010	SP3						
35	0	0.0	0.0	9/1/2010	SP3	-123.8597	39.7539	-124.5077	39.7495	1885.0	55.4
36	0	0.0	0.0	9/1/2010	SP3	-124.4518	39.5044	-123.8294	39.4927	1858.2	53.4
37	0	0.0	0.0	9/2/2010	SP3	-123.8258	39.2512	-124.4756	39.2504	1861.1	55.9
38	0	0.0	0.0	9/2/2010	SP3	-124.3721	39.0092	-123.7237	39.0003	1865.5	56.0
39	0	0.0	0.0	9/2/2010	SP3	-123.5565	38.7511	-124.2046	38.7495	1872.3	56.2
40	0	0.0	0.0	9/2/2010	SP3	-123.8849	38.5046	-123.2389	38.5000	1879.0	56.2
41	0	0.0	0.0	9/2/2010	SP3	-122.9905	38.2492	-123.6048	38.2488	1892.7	53.6
42	0	0.0	0.0	9/2/2010	SP3	-123.6457	38.0045	-123.0388	38.0011	1910.2	53.1
43	0	0.0	0.0	9/6/2010	SP3	-123.1607	37.7545	-122.5237	37.7508	1847.4	56.0
44	0	0.0	0.0	9/6/2010	SP3	-122.4882	37.5006	-123.1263	37.5004	1878.5	56.2
45	0	0.0	0.0	9/6/2010	SP3	-123.0578	37.2676	-122.4240	37.2511	1890.5	56.1
46	47	33142.3	784.5	9/6/2010	SP5	-122.2045	36.9874	-122.8383	36.9984	1803.3	56.3
47	0	0.0	0.0	9/6/2010	SP5	-122.4698	36.7505	-121.8362	36.7424	1873.6	56.4
48	0	0.0	0.0	9/6/2010	SP5	-121.9580	36.4977	-122.5739	36.4977	1878.8	55.0
49	0	0.0	0.0	9/6/2010	SP5	-122.4319	36.2484	-121.9224	36.2448	1814.2	45.7
50	0	0.0	0.0	9/6/2010	SP5	-121.7549	35.9943	-122.0724	35.9999	1895.6	28.5
51	0	0.0	0.0	9/9/2010	SP3	-121.7089	35.7464	-121.3584	35.7507	1802.8	31.6
52	0	0.0	0.0	9/9/2010	SP3	-121.0980	35.4961	-121.5557	35.4984	1876.5	41.4
53	0	0.0	0.0	9/9/2010	SP3	-121.2910	35.2530	-120.9206	35.2514	1798.8	33.6
54	0	0.0	0.0	9/9/2010	SP3	-120.6746	34.9932	-121.1157	34.9948	1806.3	40.2
55	2	890.7	33.1	9/9/2010	SP3	-120.9747	34.7507	-120.6626	34.7510	1839.2	28.5
56	0	0.0	0.0	9/9/2010	SP3	-121.1321	34.4988	-120.6405	34.4995	1821.5	45.0
57	1	735.5	22.4	9/9/2010	SP3	-119.9141	34.2501	-119.3046	34.2491	1785.8	56.0
58	0	0.0	0.0	9/9/2010	SP3	-120.8258	34.2532	-120.2165	34.2486	1794.1	56.0
59	0	0.0	0.0	9/9/2010	SP3	-118.8561	33.9976	-119.4626	33.9997	1850.5	55.9
60	0	0.0	0.0	9/9/2010	SP3	-119.7659	34.0006	-120.3702	34.0003	1830.6	55.7
61	2	871.5	31.0	9/9/2010	SP3	-119.0595	33.7503	-118.4537	33.7508	1797.7	56.0
62	0	0.0	0.0	9/9/2010	SP3	-119.9691	33.7507	-119.3635	33.7487	1846.5	56.0
63	0	0.0	0.0	9/9/2010	SP3	-117.7862	33.5004	-118.3942	33.5004	1851.5	56.3
64	0	0.0	0.0	9/9/2010	SP3	-118.6939	33.4985	-119.2976	33.4980	1833.3	55.9
65	1	1181.9	29.6	9/9/2010	SP3	-118.0722	33.2499	-117.4712	33.2508	1855.3	55.9
66	0	0.0	0.0	9/9/2010	SP3	-118.9734	33.2473	-118.3716	33.2509	1844.0	55.9

Table 5e. Transect detail, 2010 – SET C (north).

Transect	No. of Schools	Area (m^2)	Biomass (mt)	Date	Pilot	Start Dec. Longitude	Start Dec. Latitude	End Dec. Longitude	End Dec. Latitude	Transect Avg. Width (m)	Transect Length (km)
1	1	1194.3	29.7	8/13/2010	SP1	-124.7678	48.1683	-125.5197	48.1674	55.7	1899.5
2	26	39514.0	836.9	8/13/2010	SP1	-124.6660	47.9131	-125.4135	47.9156	55.7	1883.8
3	84	73401.7	1833.0	8/13/2010	SP1	-125.1616	47.6674	-124.4182	47.6663	55.6	1894.1
4	30	17194.1	507.3	8/13/2010	SP1	-124.3685	47.4153	-125.1081	47.4148	55.6	1888.9
5	44	15374.0	591.1	8/13/2010	SP1	-124.9724	47.1662	-124.2325	47.1650	55.9	1872.6
6	16	3605.8	158.0	8/13/2010	SP1	-124.1822	46.9168	-124.9160	46.9177	55.7	1888.2
7	0	0.0	0.0	8/13/2010	SP1	-124.8406	46.6679	-124.1148	46.6665	55.3	1857.3
8	7	6326.1	171.5	8/19/2010	SP1	-124.0978	46.4182	-124.8265	46.4153	55.8	1800.5
9	0	0.0	0.0	8/19/2010	SP1	-124.7412	46.1661	-124.0155	46.1668	55.8	1806.0
10	1	175.8	8.9	8/19/2010	SP1	-124.0128	45.9166	-124.7364	45.9161	55.9	1816.5
11	5	4052.2	107.8	8/20/2010	SP1	-123.9657	45.6679	-124.6831	45.6679	55.7	1802.1
12	50	74188.2	1570.8	8/20/2010	SP1	-124.7123	45.4165	-123.9973	45.4169	55.8	1813.4
13	9	13046.5	276.8	8/20/2010	SP1	-124.0141	45.1678	-124.7253	45.1686	55.7	1831.5
14	0	0.0	0.0	8/20/2010	SP1	-124.7695	44.9147	-124.0621	44.9157	55.7	1828.0
15	0	0.0	0.0	8/20/2010	SP1	-124.0969	44.6668	-124.8003	44.6676	55.6	1833.7
16	0	0.0	0.0	8/20/2010	SP1	-124.8236	44.4204	-124.1294	44.4159	55.1	1810.0
17	0	0.0	0.0	8/20/2010	SP1	-124.1606	44.1678	-124.8629	44.1688	56.0	1827.2
18	0	0.0	0.0	8/20/2010	SP1	-124.8929	43.9173	-124.1936	43.9159	56.0	1816.4
19	0	0.0	0.0	8/20/2010	SP1	-124.2479	43.6667	-124.9403	43.6692	55.7	1819.6
20	0	0.0	0.0	8/20/2010	SP1	-125.0545	43.4165	-124.3606	43.4184	56.0	1826.7
21	0	0.0	0.0	8/20/2010	SP1	-124.4600	43.1686	-125.1490	43.1638	55.8	1822.8
22	0	0.0	0.0	8/20/2010	SP1	-125.2454	42.9152	-124.5627	42.9146	55.6	1794.5
23	Not Sampled										
24	8	5409.1	143.5	8/22/2010	SP5	-124.4628	42.4170	-125.0160	42.4111	45.4	1965.7
25	0	0.0	0.0	8/22/2010	SP5	-125.0904	42.1664	-124.4101	42.1673	56.0	1909.1
26	0	0.0	0.0	8/22/2010	SP5	-124.2301	41.9171	-124.8615	41.9095	52.2	1879.8

Table 5f. Transect detail, 2010 – SET C (south).

Transect	No. of Schools	Area (m^2)	Biomass (mt)	Date	Pilot	Start Dec. Longitude	Start Dec. Latitude	End Dec. Longitude	End Dec. Latitude	Transect Avg. Width (m)	Transect Length (km)
27	0	0.0	0.0	8/22/2010	SP5	-124.8363	41.6735	-124.1600	41.6630	56.1	1921.4
28	0	0.0	0.0	8/22/2010	SP5	-124.0922	41.4193	-124.7642	41.4163	56.0	1826.7
29	0	0.0	0.0	8/22/2010	SP5	-124.7951	41.1686	-124.1725	41.1204	52.4	1823.0
30	0	0.0	0.0	8/22/2010	SP5	-124.1725	40.9196	-124.7212	40.9167	46.1	1941.8
31	0	0.0	0.0	8/22/2010	SP5	-124.7597	40.6691	-124.3256	40.6687	36.6	1844.7
32	Not Sampled										
33	0	0.0	0.0	8/23/2010	SP5	-124.2426	40.1669	-124.7294	40.1670	41.3	1950.9
34	0	0.0	0.0	8/23/2010	SP5	-124.6165	39.9298	-123.9577	39.9068	56.2	1826.6
35	0	0.0	0.0	8/23/2010	SP5	-123.8245	39.6671	-124.3395	39.6685	44.0	1942.8
36	0	0.0	0.0	8/23/2010	SP5	-124.3809	39.4194	-123.8406	39.4195	46.4	1834.5
37	0	0.0	0.0	8/23/2010	SP5	-123.7801	39.1647	-124.3114	39.1662	45.8	1902.9
38	0	0.0	0.0	8/23/2010	SP5	-124.2689	38.9207	-123.7401	38.9123	45.7	1950.0
39	0	0.0	0.0	8/23/2010	SP5	-123.4748	38.6624	-123.8826	38.6700	35.4	1539.3
40	Not Sampled										
41	Not Sampled										
42	3	3688.7	88.4	8/22/2010	SP3	-122.7565	37.9148	-123.3992	37.9194	56.3	1886.3
43	0	0.0	0.0	8/22/2010	SP3	-123.1619	37.6563	-122.5262	37.6679	55.9	1850.5
44	0	0.0	0.0	8/22/2010	SP3	-122.4594	37.4140	-123.0920	37.4151	55.8	1847.0
45	0	0.0	0.0	8/22/2010	SP3	-123.0386	37.1656	-122.4055	37.1669	56.1	1849.6
46	201	54185.8	1885.6	8/23/2010	SP4	-121.8914	36.9150	-122.5207	36.9085	55.9	1876.6
47	3	9220.5	163.4	8/23/2010	SP4	-122.4863	36.6597	-121.8563	36.6685	56.2	1870.5
48	0	0.0	0.0	8/23/2010	SP4	-121.9259	36.4088	-122.5466	36.4131	55.5	1875.3
49	24	1163.0	69.7	8/23/2010	SP4	-122.3150	36.1648	-121.6960	36.1686	55.5	1878.4
50	0	0.0	0.0	8/23/2010	SP4	-121.4898	35.9146	-122.1117	35.9176	56.0	1870.0
51	0	0.0	0.0	8/23/2010	SP4	-121.9471	35.6850	-121.3202	35.6636	56.6	1859.7
52	0	0.0	0.0	8/23/2010	SP4	-120.9070	35.4186	-121.5218	35.4159	55.7	1932.3
53	0	0.0	0.0	8/23/2010	SP4	-121.4219	35.1608	-120.8076	35.1624	55.8	1835.0
54	0	0.0	0.0	8/23/2010	SP4	-120.7067	34.9099	-121.3236	34.9117	56.2	1893.8
55	0	0.0	0.0	8/23/2010	SP3	-120.7229	34.6704	-121.2698	34.6667	50.0	1812.1
56	Not Sampled										
57	0	0.0	0.0	8/22/2010	SP6	-119.2694	34.1642	-119.8822	34.1798	56.4	1879.0
58	0	0.0	0.0	8/22/2010	SP6	-120.1807	34.1765	-120.7906	34.1666	56.1	1912.3
59	Not Sampled									17.9	1806.4
60	0	0.0	0.0	8/22/2010	SP6	-119.9869	33.9164	-119.3794	33.9148	14.6	546.0
61	27	14007.8	444.3	8/23/2010	SP3	-118.6439	33.6674	-118.0369	33.6685	56.0	1883.6
62	0	0.0	0.0	8/23/2010	SP3	-119.5534	33.6685	-118.9474	33.6614	56.1	1859.0
63	38	6760.1	319.5	8/23/2010	SP3	-117.6560	33.4152	-118.2569	33.4091	56.1	1830.0
64	0	0.0	0.0	8/23/2010	SP3	-118.5570	33.4105	-119.1608	33.4174	55.7	1831.6
65	17	6546.3	232.9	8/23/2010	SP6	-117.4074	33.1603	-118.0068	33.1729	56.0	1844.0
66	24	4143.9	194.1	8/23/2010	SP6	-118.3069	33.1681	-118.9040	33.1624	55.8	1891.1

Table 6. Point set data detail for the north in 2010.

Point Set No.	Date	Vessel	Additional Vessel Utilized	Fish Ticket No.	Survey Pilot	Dec. Latitude	Dec. Longitude	Total Sardine (lbs)	Total Pacific Mackerel (lbs)	Total Landed Wt. (lbs)	% Sardine	Area (m²)	Status
1	8/20/2010	Pacific Pursuit		4925269	SP2	46.5919	-124.4220	177,270	1405	178,675	99.2%	1867.5	Acceptable - Measured
2	8/20/2010	Lauren L Kapp		4925270	SP2	46.5788	-124.4133	168,281	207	168,488	99.9%	1987.6	Acceptable - Measured
3	8/21/2010	Pacific Pursuit		4925271	SP2	46.3801	-124.3364	155,218	1761	156,979	98.9%	2774.0	Flown at 1000 feet
4	8/21/2010	Pacific Knight		4925273	SP2	46.3522	-124.3502	113,295	363	113,658	99.7%	2135.8	Acceptable - Measured
5	8/21/2010	Lauren L Kapp		4925272	SP2	46.3580	-124.3366	70,069	241	70,310	99.7%	1840.5	Acceptable - Measured
6	8/21/2010	Lauren L Kapp		4925272	SP2	46.3393	-124.2927	61,603	385	61,988	99.4%	N/A	No approach photograph
7	8/22/2010	Pacific Pursuit	Lauren L Kapp	4925274	SP2	46.1269	-124.3272	249,646	1025	250,671	99.6%	2674.6	Acceptable - Measured
8	8/22/2010	Pacific Knight		4925276	SP2	46.1544	-124.4091	88,517	856	89,373	99.0%	N/A	Percent captured
9	8/22/2010	Lauren L Kapp		4925275	SP2	46.1704	-124.4191	35,950	659	36,609	98.2%	N/A	Not visible: clouds
10	8/23/2010	Pacific Pursuit		4925277	SP2	46.1452	-124.3410	132,025	3636	135,661	97.3%	2676.3	Acceptable - Measured
11	8/23/2010	Lauren L Kapp		4925278	SP2	46.1512	-124.3525	112,674	389	113,063	99.7%	2087.9	Acceptable - Measured
12	8/23/2010	Pacific Pursuit	Pacific Knight	4925277, 4925279	SP2	46.1481	-124.3432	132,317	1548	133,865	98.8%	1876.3	Acceptable - Measured
13	8/24/2010	Pacific Pursuit		4925280	SP2	46.1954	-124.5371	105,027	1958	106,985	98.2%	3660.7	Acceptable - Measured
14	8/24/2010	Lauren L Kapp		4925281	SP2	46.1888	-124.5485	101,036	491	101,527	99.5%	2570.5	Acceptable - Measured
15	8/26/2010	Pacific Pursuit		4925282	SP2	46.3584	-124.4748	115,460	245	115,705	99.8%	N/A	School not visible: mixed haul
16	8/26/2010	Lauren L Kapp		4925283	SP2	46.3672	-124.4742	166,046	209	166,255	99.9%	3892.2	Acceptable - Measured
17	8/26/2010	Pacific Knight		4925284	SP2	46.3026	-124.4822	85,619	1063	86,682	98.8%	2792.2	Acceptable - Measured
18	8/26/2010	Pacific Pursuit		4925282	SP2	46.2956	-124.4544	61,654	245	61,899	99.6%	1389.0	Measured: mixed haul
19	8/27/2010	Pacific Pursuit	Lauren L Kapp	4925285, 4925286	SP2	46.3205	-124.5086	307,174	197	307,371	99.9%	3167.2	Acceptable - Measured
20	8/27/2010	Pacific Knight		4925287	SP2	46.3061	-124.5076	72,201	28	72,229	100.0%	775.2	Acceptable - Measured
21	8/29/2010	Pacific Pursuit		4925288	SP2	46.6722	-124.4356	177,995	1301	179,296	99.3%	817.7	Acceptable - Measured
22	8/29/2010	Pacific Knight	Lauren L Kapp	4925290, 4925289	SP2	46.6776	-124.4353	180,429	269	180,698	99.9%	2044.2	Acceptable - Measured
23	8/29/2010	Lauren L Kapp		4925289	SP2	46.6637	-124.3964	70,528	0	70,528	100.0%	1112.9	Acceptable - Measured
24	8/30/2010	Pacific Knight		4925293	SP2	46.4264	-124.3645	99,123	165	99,288	99.8%	N/A	Not visible: clouds
25	8/30/2010	Lauren L Kapp		4925292	SP2	46.4980	-124.5095	167,643	87	167,730	99.9%	1764.6	Acceptable - Measured
26	8/30/2010	Pacific Pursuit		4925291	SP2	46.5232	-124.5292	88,814	116	88,930	99.9%	1792.1	Acceptable - Measured
27	8/30/2010	Pacific Pursuit		4925291	SP2	46.5201	-124.4582	68,459	246	68,705	99.6%	1528.7	Acceptable - Measured
28	9/1/2010	Lauren L Kapp		4925295	SP2	46.4363	-124.4109	118,491	87	118,578	99.9%	953.4	Acceptable - Measured
29	9/1/2010	Pacific Pursuit		4925294	SP2	46.4575	-124.3985	149,643	91	149,734	99.9%	1672.5	Acceptable - Measured
30	9/1/2010	Pacific Knight		4925296	SP2	46.4323	-124.4201	73,121	158	73,279	99.8%	1635.6	Acceptable - Measured
31	9/2/2010	Pacific Pursuit		4925297	SP2	46.6157	-124.2861	149,551	356	149,907	99.8%	7461.5	Acceptable - Measured
32	9/2/2010	Lauren L Kapp		4925298	SP2	46.6318	-124.2652	96,225	257	96,482	99.7%	N/A	Unable to determine school
33	9/4/2010	Pacific Pursuit		4925299	SP2	46.6111	-124.3237	91,829	205	92,034	99.8%	N/A	Unable to determine school
34	9/4/2010	Lauren L Kapp	Pacific Knight	4925300, 4925301	SP2	46.5819	-124.3235	213,613	229	213,842	99.9%	3470.3	Acceptable - Measured
35	9/6/2010	Lauren L Kapp		4925303	SP2	45.9297	-124.3302	77,336	100	77,436	99.9%	1870.1	Flown at 1000 feet
36	9/6/2010	Pacific Pursuit		4925302	SP2	45.9384	-124.3021	79,195	177	79,372	99.8%	1514.6	Flown at 1000 feet
37	9/14/2010	Pacific Knight	Lauren L Kapp	4925305, 4925304	SP2	46.4835	-124.4683	118,645	240	118,885	99.8%	N/A	No photos available

Table 7. Point set data detail for the south in 2010.

Point Set No.	Date	Vessel	Additional Vessel Utilized	Fish Ticket No.	Survey Pilot	Dec. Latitude	Dec. Longitude	Total Sardine (lbs)	Total Pacific Mackerel (lbs)	Other Species (lbs)	Total Landed Wt. (lbs)	% Sardine
1	8/9/2010	Eileen		W324597	SP6	34.2440	-119.3109	10,692	0	0	10,692	100.0%
2	8/12/2010	Trionfo		W317881	SP6	33.9667	-119.5833	88,584	0	0	88,584	100.0%
3	8/12/2010	Eileen		W325559	SP6	33.9668	-119.5833	56,750	0	0	56,750	100.0%
4	8/16/2010	Trionfo		W318964	SP6	34.1510	-119.5274	84,962	0	0	84,962	100.0%
5	8/17/2010	Maria T		W319004	SP6	33.3333	-118.4833	24,010	3222	0	27,232	88.2%
6	8/17/2010	Eileen		W325565	SP6	33.3167	-118.4500	22,286	2824	0	25,110	88.8%
7	8/18/2010	Maria T		W319007	SP6	33.4167	-118.6167	14,832	4	0	14,836	100.0%
8	8/18/2010	Eileen		W325567	SP6	33.4168	-118.5334	33,868	1338	0	35,206	96.2%
9	8/18/2010	Eileen		W325566	SP6	33.4333	-118.5668	32,986	5747	0	38,733	85.2%
10	8/18/2010	Maria T		W319006	SP6	33.4333	-118.5667	39,502	5387	0	44,889	88.0%
11	8/19/2010	Eileen		W325569	SP6	33.4627	-118.5958	6,269	0	0	6,269	100.0%
12	8/19/2010	Eileen		W325570	SP6	33.4621	-118.5995	21,198	0	0	21,198	100.0%
13	8/22/2010	Eileen		W325572	SP6	33.4178	-118.5056	32,747	0	0	32,747	100.0%
14	8/23/2010	Maria T		W319013	SP6	33.6708	-118.0711	23,675	0	0	23,675	100.0%
15	8/23/2010	Eileen		W325573	SP6	33.6912	-118.0577	44,162	0	0	44,162	100.0%
16	8/31/2010	Eileen		W317887	SP6	33.9846	-119.5952	129,430	0	0	129,430	100.0%
17	8/31/2010	Maria T		W318989	SP6	33.9802	-119.6465	96,899	0	0	96,899	100.0%
18	8/31/2010	Eileen	Maria T	W317885 W317886	SP6	33.9633	-119.6979	69,061	0	0	69,061	100.0%
19	9/1/2010	Eileen		W317890	SP6	34.0158	-119.5326	148,612	0	0	148,612	100.0%
20	9/1/2010	Maria T		W318993	SP6	34.0175	-119.5367	99,282	0	0	99,282	100.0%
21	9/7/2010	Eileen		W317892	SP6	34.0005	-119.5333	157,431	0	0	157,431	100.0%
22	9/8/2010	Eileen		W317893	SP6	34.0145	-119.5358	85,594	0	0	85,594	100.0%
23	9/8/2010	Maria T		W319000	SP6	34.0180	-119.5357	52,797	0	0	52,797	100.0%
24	9/9/2010	Eileen		W317894	SP6	34.0288	-119.6072	169,215	0	0	169,215	100.0%
25	9/9/2010	Maria T		W319126	SP6	34.0123	-119.5113	103,223	0	0	103,223	100.0%
26	9/10/2010	Maria T		W319127	SP6	34.0251	-119.6088	123,644	0	0	123,644	100.0%
27	9/10/2010	Eileen		W317895	SP6	34.0275	-119.6086	187,164	0	0	187,164	100.0%
28	9/12/2010	Maria T		W319128	SP6	34.0136	-119.5346	111,389	0	0	111,389	100.0%
29	9/12/2010	Eileen		W317896	SP6	34.0159	-119.5288	186,454	0	0	186,454	100.0%
30	9/13/2010	Eileen		W317898	SP6	34.0188	-119.5350	44,504	800	0	45,304	98.2%
31	9/13/2010	Maria T		W319132	SP6	34.0127	-119.5353	89,237	901	0	90,138	99.0%
32	9/13/2010	Eileen		W317898	SP6	34.0168	-119.5380	141,510	1000	0	142,510	99.3%
33	9/14/2010	Eileen		W320403	SP6	34.0167	-119.5317	162,478	0	66	162,544	100.0%
34	9/14/2010	Maria T		W319134	SP6	34.0167	-119.5167	35,040	715	0	35,755	98.0%

Table 8. Point set data from the 2010 survey used for the area-biomass analysis (north).

Point Set No.	Sardine wt (mt)	Area (m^2)	Density (mt/m^2)
1	80.4	1867.5	0.0431
2	76.3	1987.6	0.0384
4	51.4	2135.8	0.0241
5	31.8	1840.5	0.0173
7	113.2	2674.6	0.0423
10	59.9	2676.3	0.0224
11	51.1	2087.9	0.0245
12	60.0	1876.3	0.0320
13	47.6	3660.7	0.0130
14	45.8	2570.5	0.0178
16	75.3	3892.2	0.0194
17	38.8	2792.2	0.0139
19	139.3	3167.2	0.0440
20	32.7	775.2	0.0422
21	80.7	817.7	0.0987
22	81.8	2044.2	0.0400
23	32.0	1112.9	0.0287
25	76.0	1764.6	0.0431
26	40.3	1792.1	0.0225
27	31.1	1528.7	0.0203
28	53.7	953.4	0.0564
30	33.2	1635.6	0.0203
31	67.8	7461.5	0.0091
34	96.9	3470.3	0.0279

Table 9. Point set data from the 2010 survey used for the area-biomass analysis (south).

Point Set No.	Sardine wt (mt)	Area (m^2)	Density (mt/m^2)
1	4.8	546.0	0.0089
5	10.9	2033.3	0.0054
8	15.4	311.8	0.0493
9	15.0	1482.4	0.0101
10	17.9	127.6	0.1404
11	2.8	620.1	0.0046
12	9.6	799.6	0.0120
13	14.9	455.1	0.0326
14	10.7	2133.6	0.0050
15	20.0	2187.1	0.0092
16	58.7	2488.0	0.0236
17	44.0	673.2	0.0653
18	31.3	2144.3	0.0146
25	46.8	1787.1	0.0262
26	56.1	1828.9	0.0307
30	20.2	618.2	0.0327
31	40.5	1147.7	0.0353

Table 10. Likelihood ratio tests for MM model fits to the point set data.

Comparision of data from the north used in the 2009 analysis with the new 2010 data from the north:

Model Data	Data File Name	Model Name	Log Likelihood	df
(north 2008;2009 pooled)	cdata	mmfit	-28.26	33
(north 2010)	cdata2010n	mmfita	-11.46	21
(north 2008;2009;2010 pooled)	cdata2010np	mmfitb	-44.50	57
		LLcombined	-44.50	57
		LLseparate	-39.73	54

(LLseparate - LLcombined) =	4.76996845	
Chi Sq (df=3) P =	0.189	->Fail to reject H_o at 0.05 significance level.

Comparision of all data from the north (pooled) with the new 2010 data from the south:

Model Data	Data File Name	Model Name	Log Likelihood	df
(north 2008;2009;2010 pooled)	cdata2010np	mmfitb	-44.50	57
(south 2010)	cdata2010s	mmfitc	-19.75	14
(all data pooled)	cdata2010nsp	mmfitd	-73.28	74
		LLcombined	-73.28	74
		LLseparate	-64.24	71

(LLseparate - LLcombined) =	9.03413383	
Chi Sq (df=3) P =	0.029	->Reject H_o at 0.05 significance level.

Table 11. Estimates of total biomass and CV from the 2010 aerial sardine survey.

Region	Point Set Data File	Biomass Estimate (mt)		CV	Area-Biomass Calibration Parameters		
					asymp	yint	cc
Coastwide	cdata2010nsp	Total	138,379	0.30	0.0119	0.0707	338.0
		Rep A	176,561				
		Rep B	86,850				
		Rep C	151,726				
North (asymp = 0.001)	cdata2010np	Total	105,738	0.44	0.001 (bound)	0.0435	2375.5
		Rep A	157,749				
		Rep B	62,314				
		Rep C	97,150				
North (asymp = 0.005)	cdata2010np	Total	108,851	0.40	0.005 (bound)	0.0464	1649.4
		Rep A	161,448				
		Rep B	66,656				
		Rep C	98,450				
South	cdata2010s	Total	27,695	0.72	0.0061	0.1392	100.0 (bound)
		Rep A	21,511				
		Rep B	10,767				
		Rep C	50,806				
2009 (asymp = 0.001)	cdata2010np		794,159	2.08	0.001 (bound)	0.0435	2375.5
2009 (asymp = 0.005)	cdata2010np		1,247,250	1.12	0.005 (bound)	0.0464	1649.4
2009	cdata2010nsp		2,000,618	0.66	0.0119	0.0707	338.0
2009	cdata (2009)		1,236,911	1.12	0.0057	0.0455	1187.5

Table 11a. Estimates of total biomass and CV from the 2010 aerial sardine survey – Runs conducted at the STAR Panel meeting, 10-5-2010.

Region	**Point Set Data File**	**Biomass Estimate (mt)**		**CV**	**Area-Biomass Calibration Parameters**		
					asymp	**yint**	**cc**
Runs conducted at the STAR panel meeting 10-5-2010							
North	cdata2010n	Total	173,390	0.42	0.0057	0.2020	257.5
		Rep A	263,331				
		Rep B	100,626				
		Rep C	156,214				
South	cdata2010s	Total	27,695	0.56	0.0061	0.1392	100.0 (bound)
		Rep A	21,511				
		Rep B	10,767				
		Rep C	50,806				

Table 12. Results from the analysis of photographs of known-size objects, collected to evaluate photogrammetric error.

Pilot	No. of Photographs Analyzed	No. of Measurements Made	Average % Deviance	Min Altitude (ft)	Max Altitude (ft)
SP1	10	195	4.8%	1017	4022
SP2	12	240	7.5%	918	4026
SP3	2	40	11.4%	1423	1430
SP4	17	200	5.7%	1066	4482
SP5	11	55	3.0%	1086	4307
SP6			data not available		

Table 13. Rate of agreement between photo analysts engaged in the activity of finding fish schools on photographs (results from blind comparisons of independent measurements).

Transect Replicate	No. of Photographs	Average % Agreement (per transect)	Min. % Agreement (per transect)	Max. % Agreement (per transect)
SET A	7647	98.2%	86.8%	100.0%
SET B	7774	98.5%	88.9%	100.0%
SET C	7457	97.0%	76.4%	100.0%

Table 14. Summary of point sets landed in 2010, by size category.

Weight (mt)	No. Planned	North	South
3.8	8	0	1
10.6	8	0	3
17.0	8	1	6
26.5	8	0	6
51.9	8	19	9
70.5	8	7	4
82.1	8	7	3
95.0	0	0	2
115.0	0	2	0
140.0	0	1	0
	56	37	34

Figure 1. Histograms of school surface area (m^2) from 2009 and 2010 transect sampling.

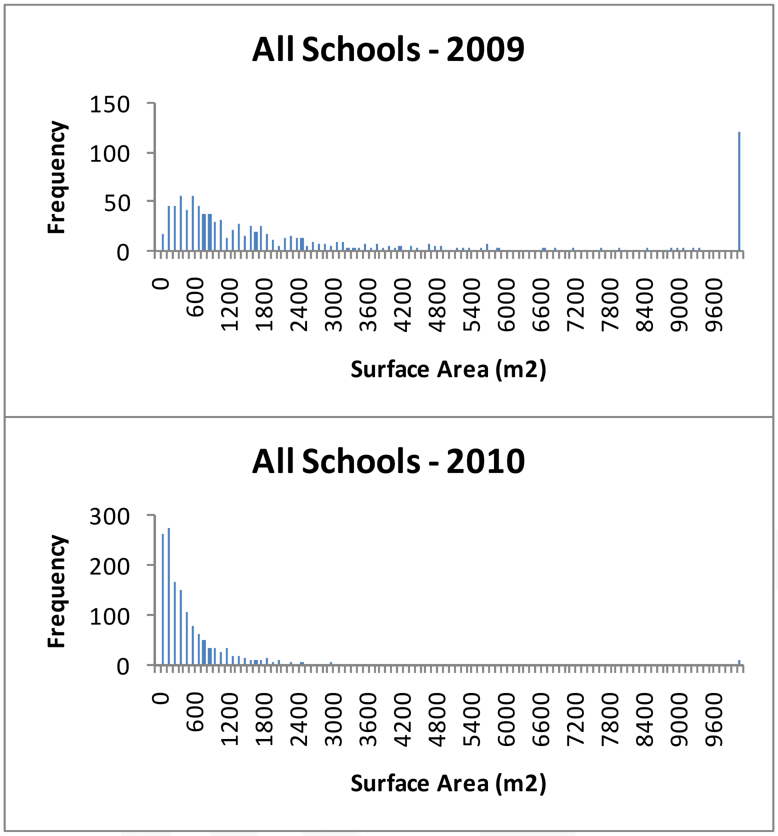


Figure 2. Histograms of school surface area (m^2) from transect sampling in 2010.

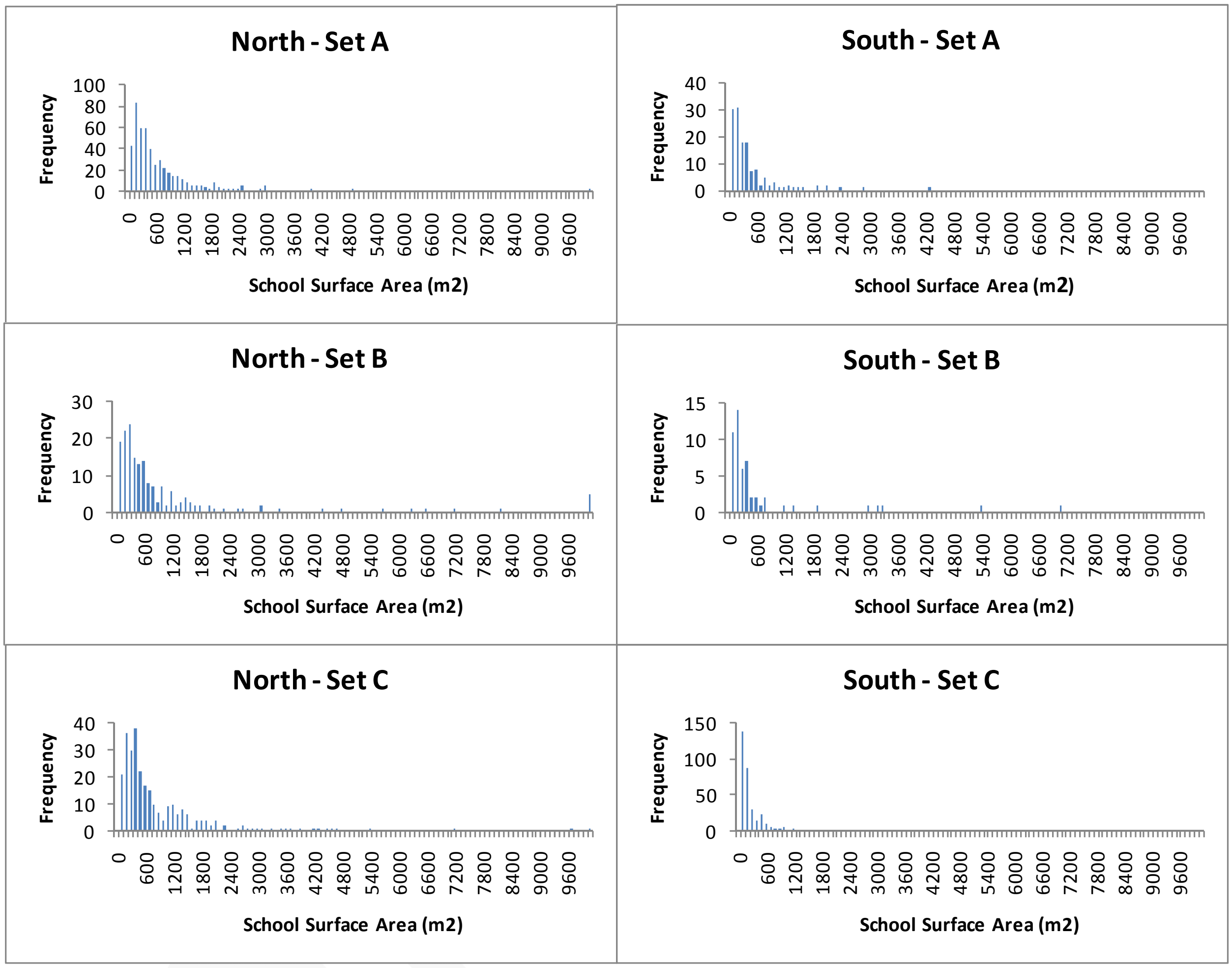


Figure 3. Location of point sets conducted in 2010 (north).

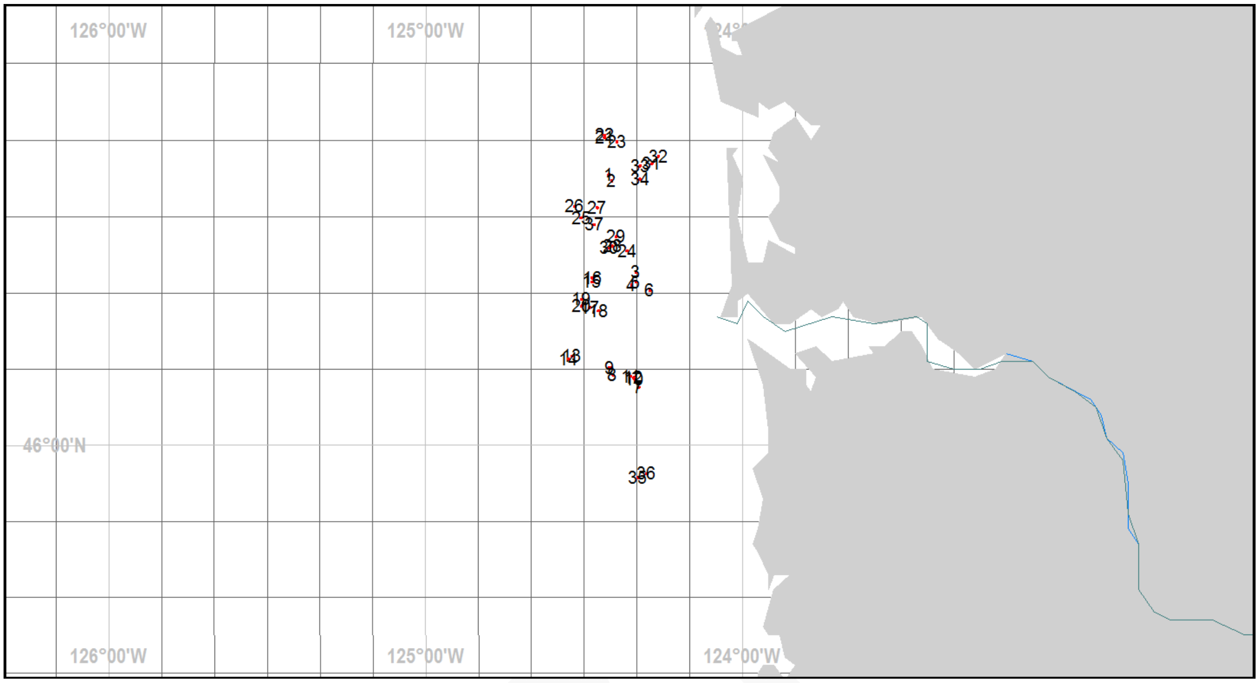


Figure 4. Location of point sets conducted in 2010 (south).

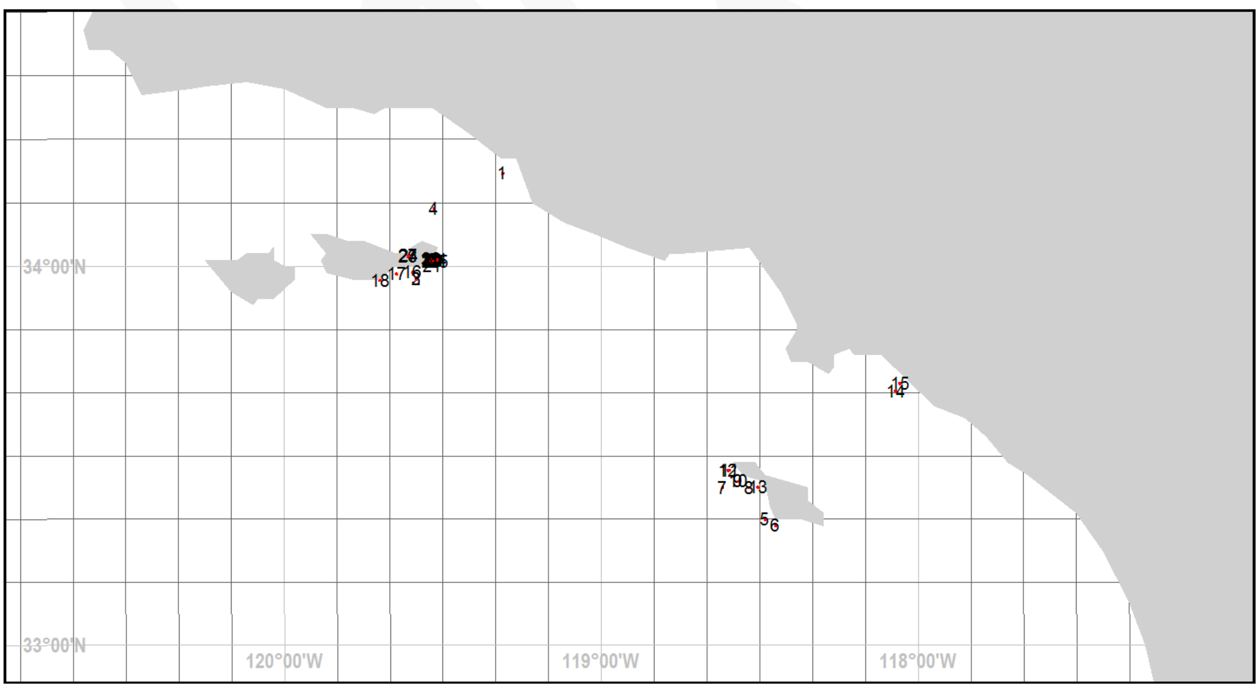


Figure 5. Plot of point set data used in the 2009 analysis (filename = cdata: blue points – solid line) and point set data from the north in 2010 (filename = cdata2010n: green points – dashed line). Likelihood ratio test P = 0.189; reject H_0 at the 0.05 significance level. Pooled data filename = cdata2010np.

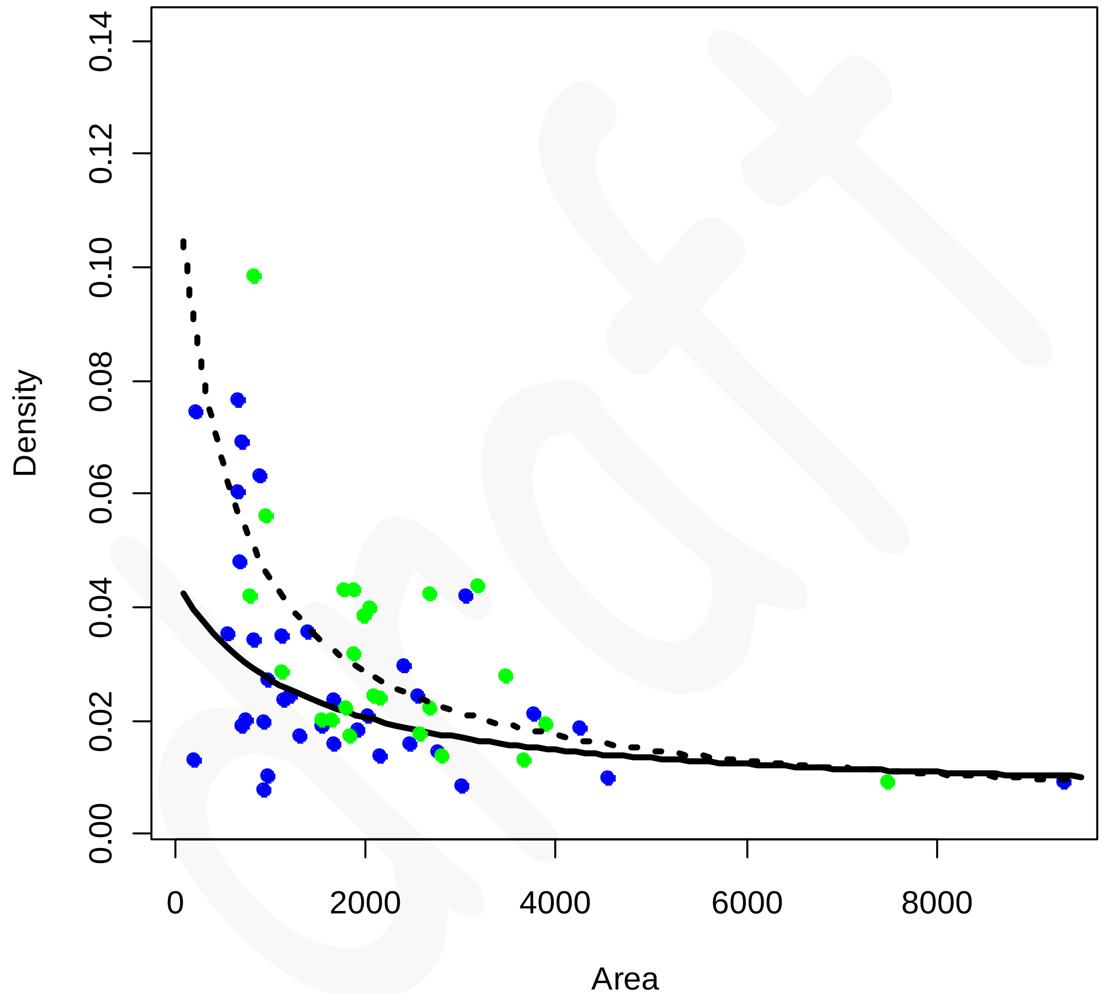


Figure 6. Plot of the pooled data from the north (filename = cdata2010np: blue points – solid line), and the new data from the south in 2010 (filename = cdata2010s: green points – dashed line). Likelihood ratio test P = 0.029; fail to reject H_0 at the 0.05 significance level.

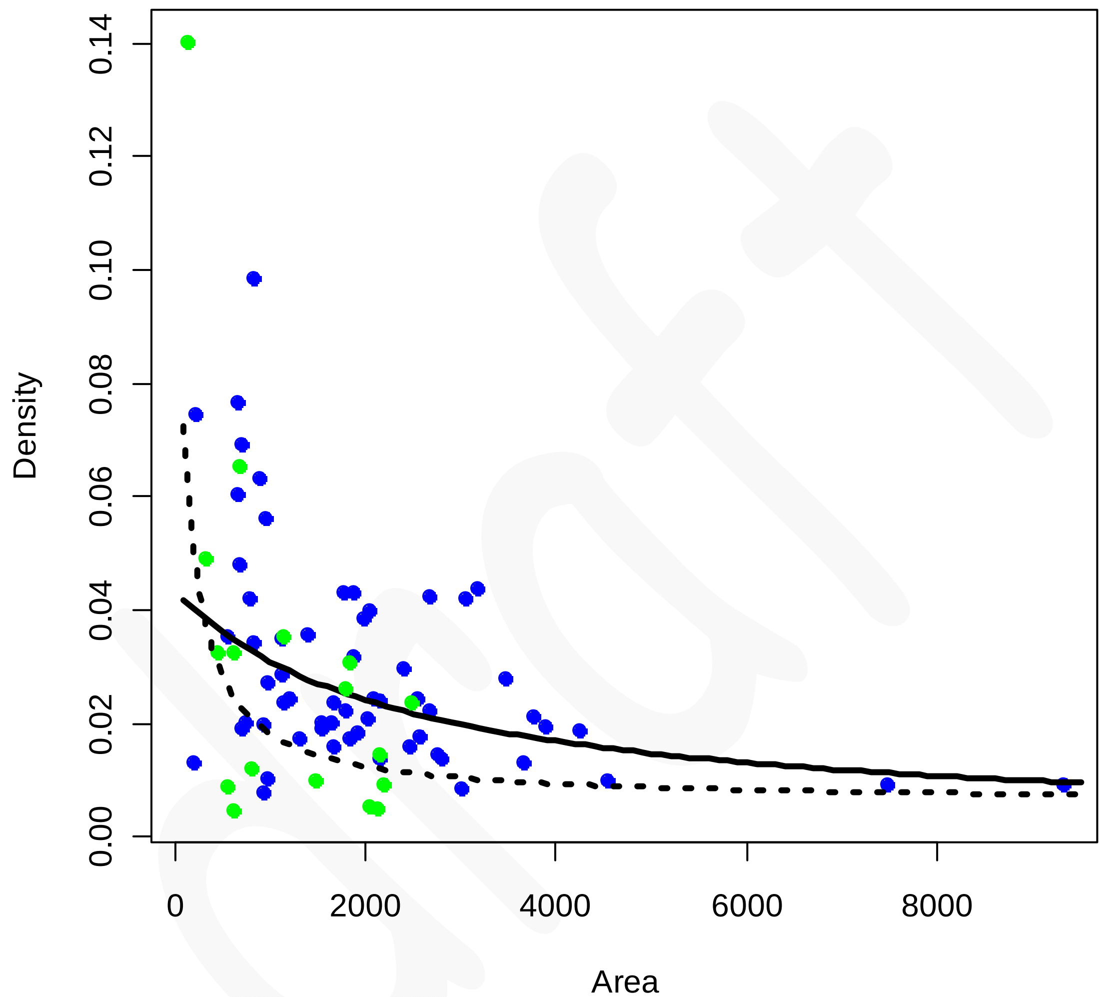


Figure 7. Plot of all data pooled (filename = cdata2010nsp).

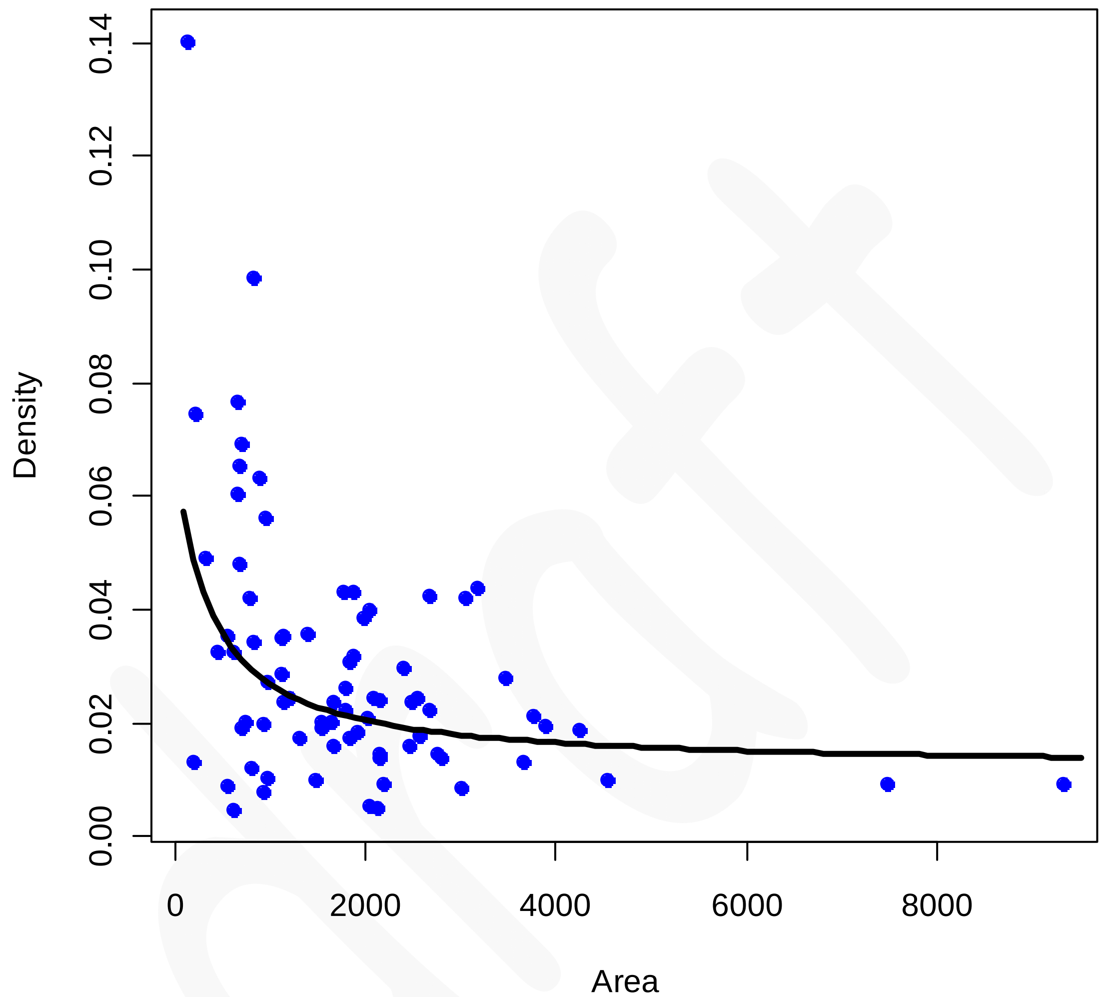
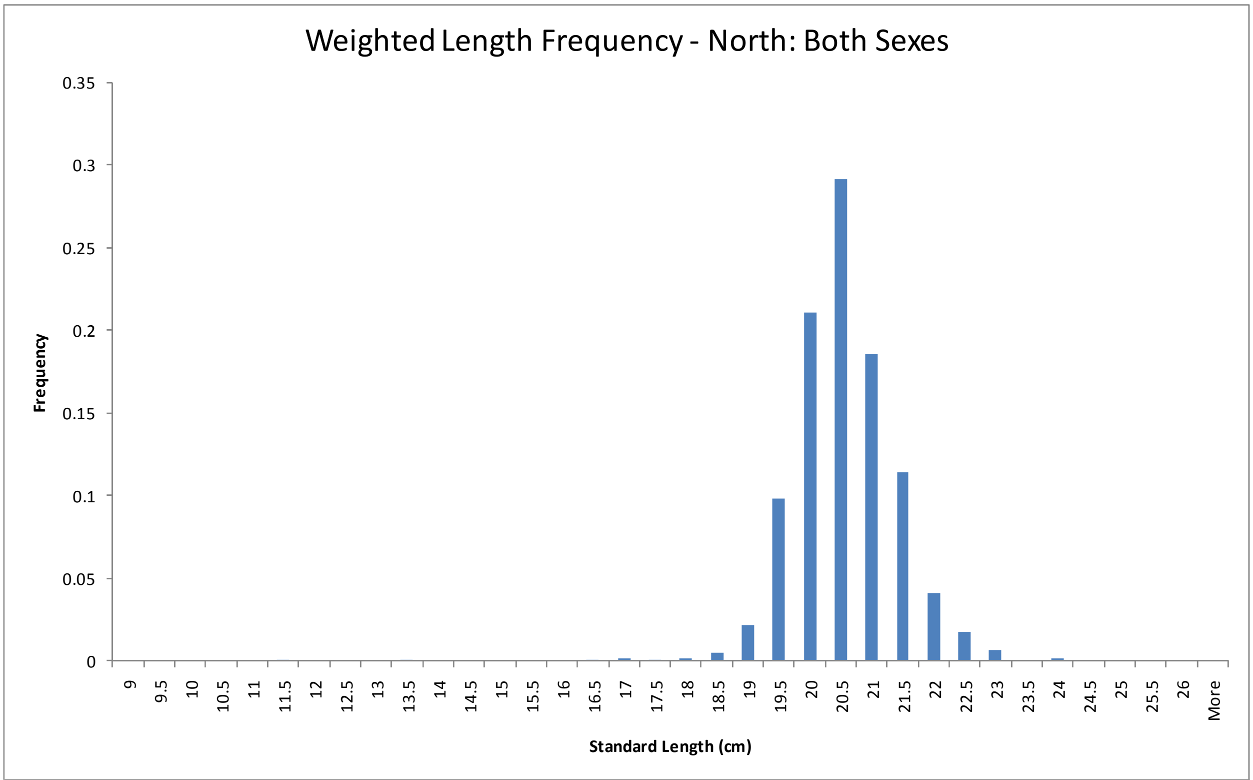


Figure 8. Weighted length frequencies from point sets used in the area-biomass analysis in 2010.



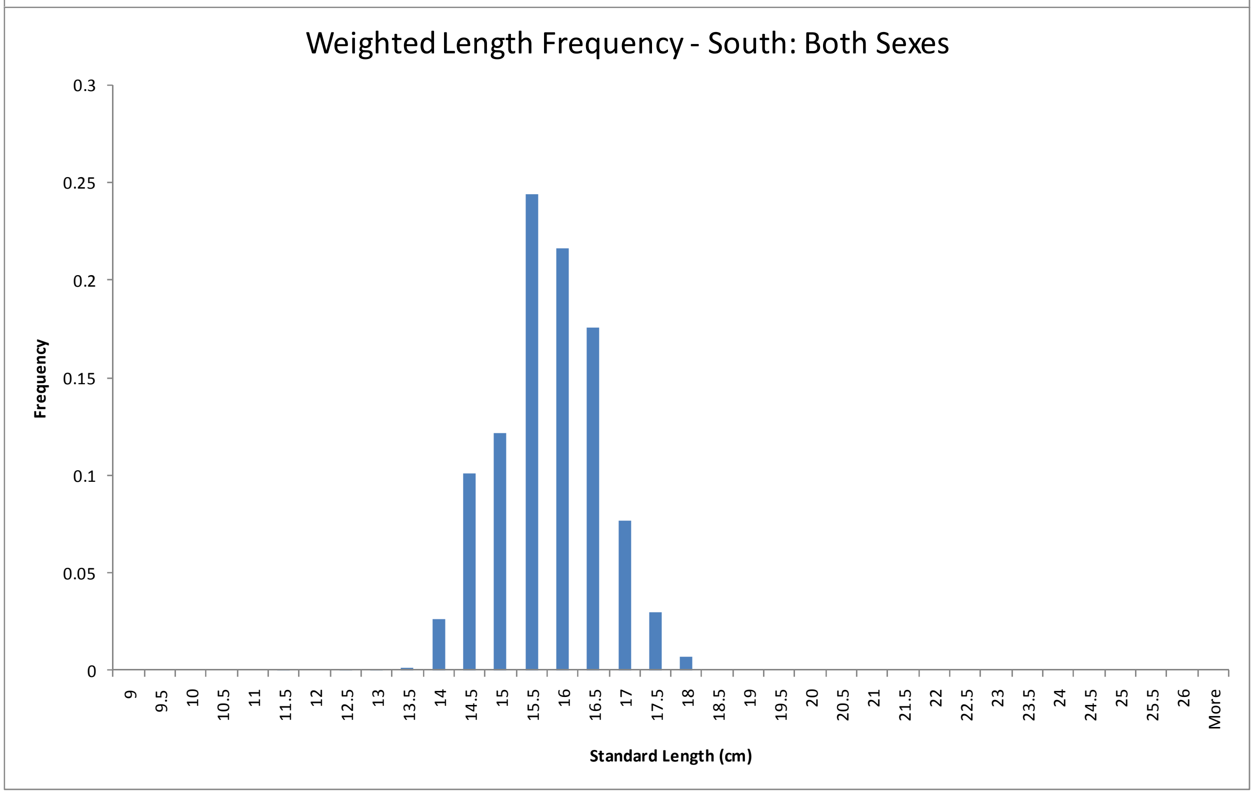


Figure 9. Histograms of length frequency for all point sets landed in 2010.

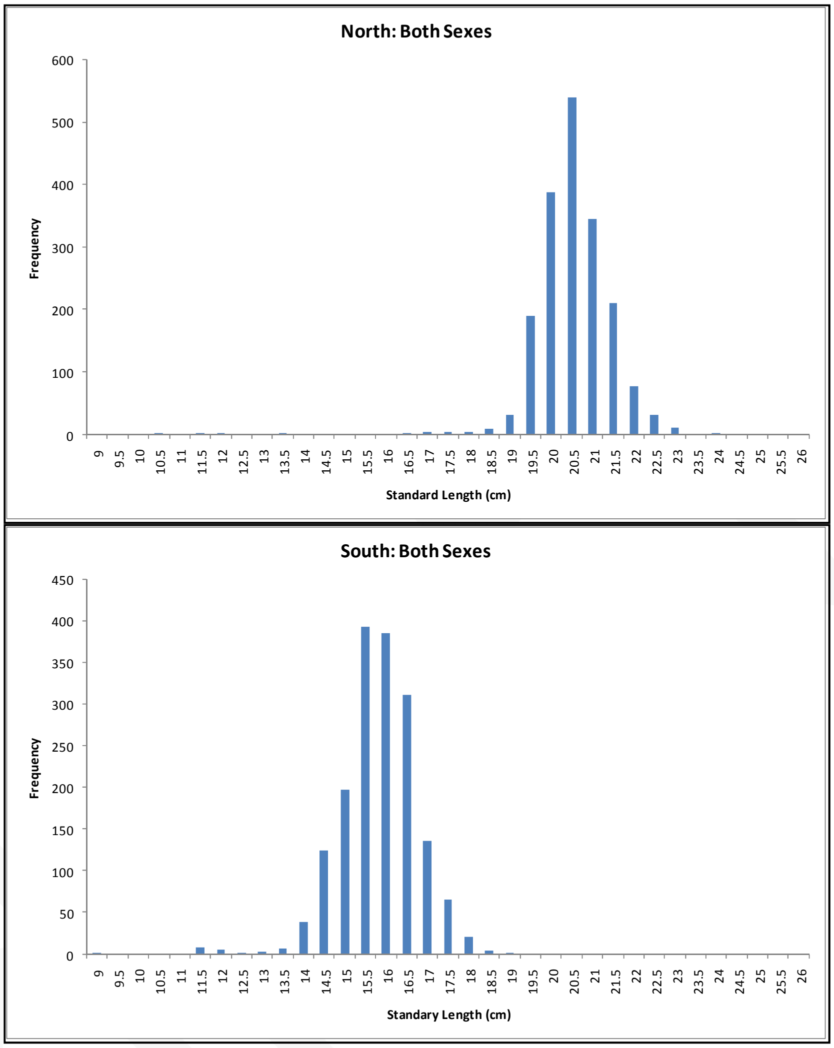
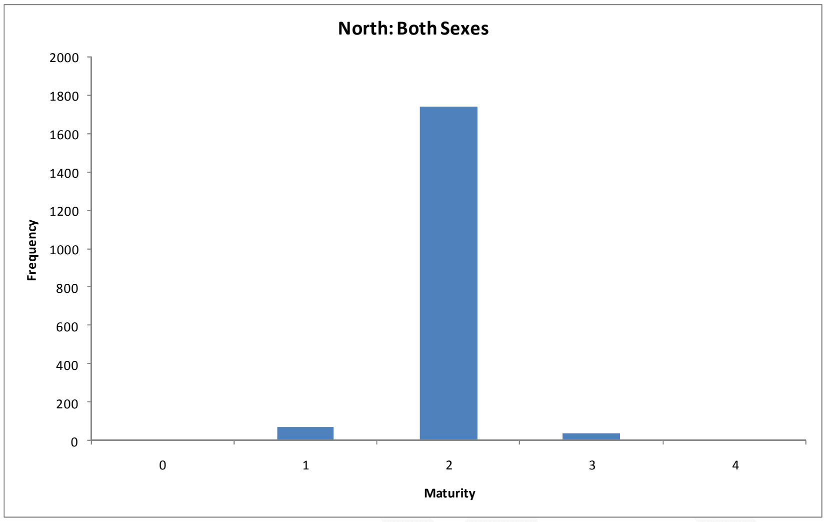


Figure 10. Histograms of maturity stage for all point sets landed in 2010.



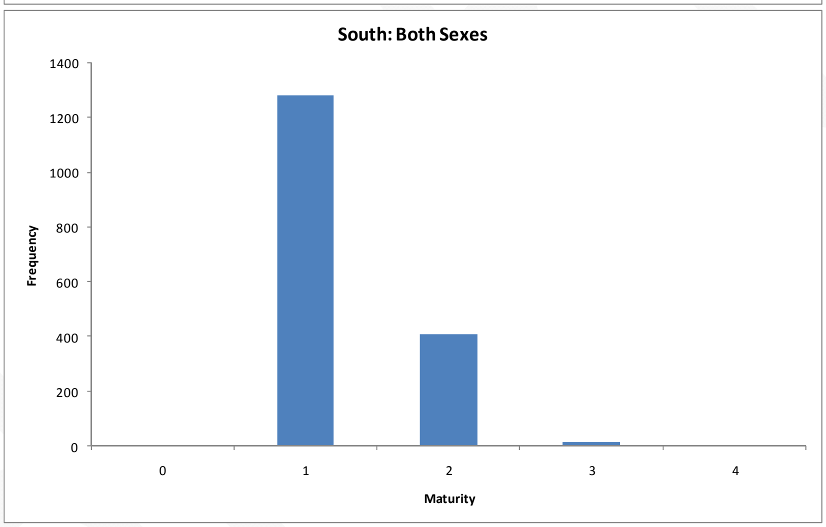


Figure 11. Maps showing the locations of sardine schools observed on transects in 2010. Top (north); bottom (south).

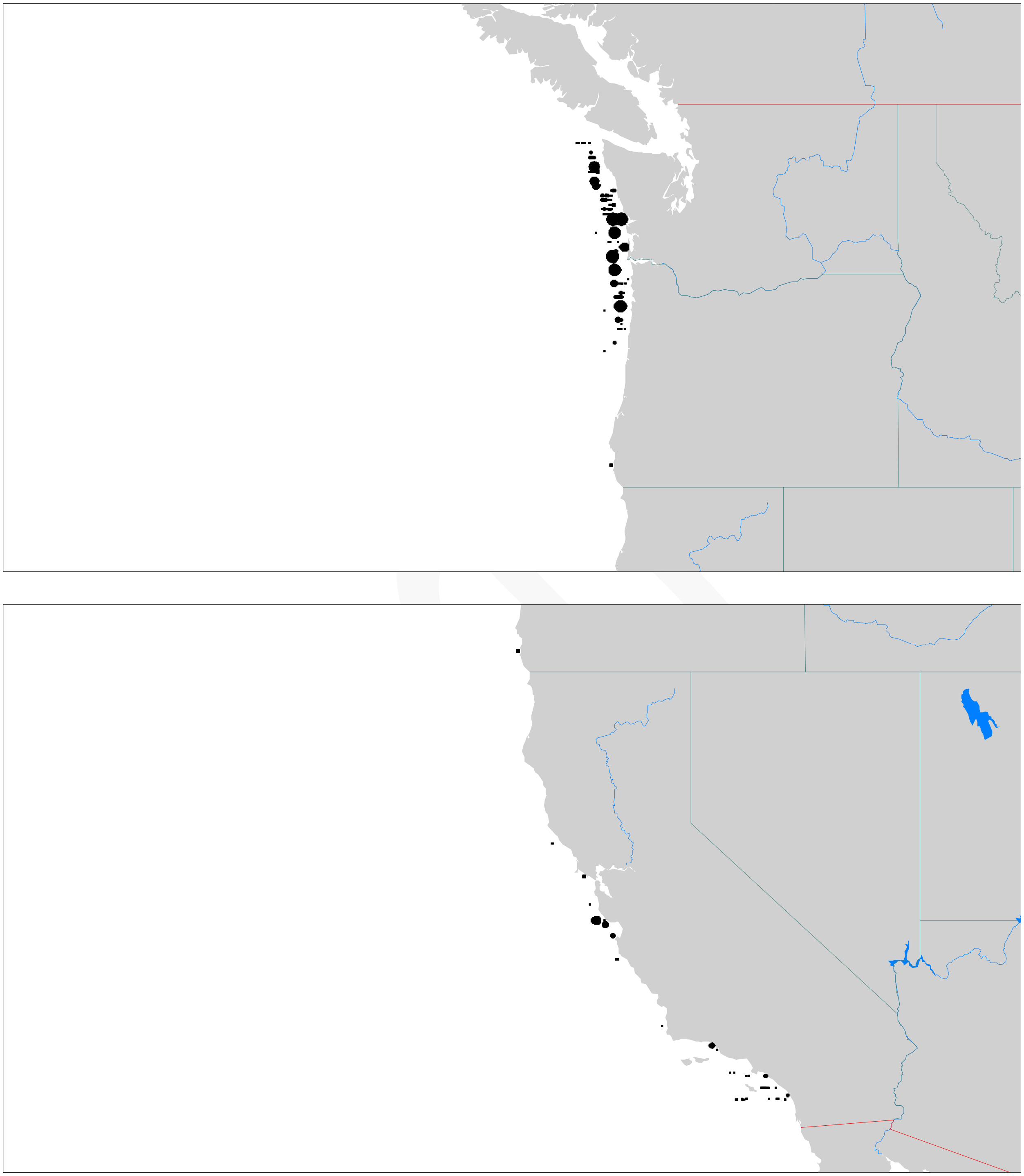


Figure 12. Locations of point sets (identified by number) with repect to sardine school locations observed on transects in 2010. Top (north); bottom (south).

Appendix I. R programs used for the 2010 survey.

```
# bscoast: computes biomass estimate and variance for north and south together
#  calculated from three replicate transect sets
#  Uses library 'MSVBAR' to simulate pointset variability
cdata <- read.csv(file="cdata2010nsp.csv")      #file of point set data (2008;2009;2010 north and south pooled)
tdata1 <- read.csv(file="transectdataCA.csv")   #file of transect surface area data for replicate A
tdata2 <- read.csv(file="transectdataCB.csv")   #file of transect surface area data for replicate B
tdata3 <- read.csv(file="transectdataCC.csv")   #file of transect surface area data for replicate C

  bscoast = function(nboots,cdata,tdata1,tdata2,tdata3){

  convert = function(yint, asymp, cc, x) {   #defines function to convert area to bms - yint = y intercept
    return((yint*cc+asymp*x)/(cc+x))}       #asymp = asymptote as x->infty, asymp/c = slope at orgin
  nls.control(maxiter = 5000,tol = 2e-6)     #control parameters for nonlinear fitting
  dimcdata <-  dim(cdata)
  larea <- log(cdata$Area) #logs of areas of point sets
  parea <- cdata$Area      #point set areas
  obs <- cdata$ObsDens
  lobs <- log(cdata$ObsDens) #log of observed densities of point sets
  #Fit Point Set Data
  mmfit <- nls(lobs~log(convert(exp(lyint),exp(lasymp),exp(lcc),parea)),
    start = list(lyint= log(0.045), lasymp= log(0.0057), lcc= log(1187)),
    upper=list(lyint= log(1.0), lasymp= log(0.1),lcc= log(10000)),
    lower=list(lyint= log(0.001), lasymp= log(0.001),lcc= log(100)),
    algorithm="port")  #fit point set data
  mmcoef <- coef(mmfit)
  yint <- exp(mmcoef[1])   #fitted coef a
  asymp <- exp(mmcoef[2])  #fitted coef b
  cc <- exp(mmcoef[3])     #fitted coef c
  print(paste("yint = ",yint),quote=F)
  print(paste("asymp = ",asymp),quote=F)
  print(paste("cc = ",cc),quote=F)
  windows()
  plot(ObsDens~Area,data = cdata,ylab="Density",pch=19) #plots point set data
  areas <- 100*(1:95)
  pdens0 <-  convert(yint,asymp,cc,areas)#predicted curve
  lines(pdens0~areas,lwd=3)  #plots predicted curve

# Estimated Biomass - replicate (SET A):
 Density1 <- convert(yint,asymp,cc,tdata1$sarea)
 tdata1$bms <- Density1*tdata1$sarea  #estimated bms of schools
 transectbms1 <- tapply(tdata1$bms,tdata1$transect,sum)#calc bms on transect by summing over schools
 tbmsrep1 <- 883*sum(transectbms1)/63  #calculate total bms
 # Note: SET A transects 37,48, and 49 not sampled; n = 63
 print(paste("Est bms Rep A = ",round(tbmsrep1)),quote=F)
# Estimated Biomass - replicate (SET B):
 Density2 <- convert(yint,asymp,cc,tdata2$sarea)
 tdata2$bms <- Density2*tdata2$sarea  #estimated bms of schools
 transectbms2 <- tapply(tdata2$bms,tdata2$transect,sum)#calc bms on transect by summing over schools
 tbmsrep2 <- 896*sum(transectbms2)/59  #calculate total bms
 # Note: SET B transects 27,28,30,31,32,33, and 34 not sampled; n = 59
```

```
print(paste("Est bms Rep B = ",round(tbmsrep2)),quote=F)
# Estimated Biomass - replicate (SET C):
Density3 <- convert(yint,asymp,cc,tdata3$sarea)
tdata3$bms <- Density3*tdata3$sarea  #estimated bms of schools
transectbms3 <- tapply(tdata3$bms,tdata3$transect,sum)#calc bms on transect by summing over schools
tbmsrep3 <- 945*sum(transectbms3)/60  #calculate total bms
# Note: transects 23,32,40,41,56 and 59 not sampled on SET C; n = 60
print(paste("Est bms Rep C = ",round(tbmsrep3)),quote=F)

# Overall biomass estimate
tbms0 <- (tbmsrep1+tbmsrep2+tbmsrep3)/3
print(paste("Est overall bms = ",round(tbms0)),quote=F)

 cof <- matrix(nrow=nboots,rep(0,3*nboots)) #set up bootstraps
 bms <- rep(0,nboots)
 library('MSBVAR')
 covmatrix <- vcov(mmfit)
 meanparams <- coef(mmfit)
 newcoef <- rmultnorm(nboots,vmat=covmatrix,mu=meanparams)
 for (i in 1:nboots){
   nyint <- exp(newcoef[i,1])
   nasymp <- exp(newcoef[i,2])
   nasymp <- min(nasymp,0.02)
   nc <- exp(newcoef[i,3])   #simulated coefficients
   if (i < 20){ #draw refitted lines on pointset plot
     pdens <- convert(nyint,nasymp,nc,areas)
     lines(pdens~areas,col=i,lwd=0.05)
      }
#   Replicate A:
   Density1 <- convert(nyint,nasymp,nc,tdata1$sarea)
   bms1 <- Density1*tdata1$sarea  #bms of schools
   transectbms1 <- tapply(bms1,tdata1$transect,sum) #bms on each transect
   tbms1 <- 883*sum(transectbms1)/63  #calculate total bms
#   Replicate B:
   Density2 <- convert(nyint,nasymp,nc,tdata2$sarea)
   bms2 <- Density2*tdata2$sarea  #bms of schools
   transectbms2 <- tapply(bms2,tdata2$transect,sum) #bms on each transect
   tbms2 <- 896*sum(transectbms2)/59  #calculate total bms
#   Replicate C:
   Density3 <- convert(nyint,nasymp,nc,tdata3$sarea)
   bms3 <- Density3*tdata3$sarea  #bms of schools
   transectbms3 <- tapply(bms3,tdata3$transect,sum) #bms on each transect
   tbms3 <- 945*sum(transectbms3)/60  #calculate total bms

#   Overall biomass estimate:
   repbms <- c(tbms1,tbms2,tbms3)
   ii <- sample(seq(from=1,to=3),size=3,replace=T)
   yy <- repbms[ii]
   bms[i] <- mean(yy)
  }
   windows()
   hist(bms,breaks=20,density=10,col='dark blue') #histogram of bootstrapped biomasses
```

```
   print(paste("SE = ",round(sd(bms,na.rm=TRUE))),quote=F)
   print(paste("CV = ",round(sd(bms,na.rm=TRUE))/tbms0), quote=F)
}
```

 # bsnorth: computes biomass estimate and variance for northern area

```
#  calculated from three replicate transect sets
#  Uses library 'MSVBAR' to simulate pointset variability
cdata <- read.csv(file="cdata2010n.csv")     #file of point set data (2010 north)
tdata1 <- read.csv(file="transectdataNA.csv")   #file of transect surface area data for replicate A
tdata2 <- read.csv(file="transectdataNB.csv")   #file of transect surface area data for replicate B
tdata3 <- read.csv(file="transectdataNC.csv")   #file of transect surface area data for replicate C

 bsnorth = function(nboots,cdata,tdata1,tdata2,tdata3){

 convert = function(yint, asymp, cc, x) {   #defines function to convert area to bms - yint = y intercept
   return((yint*cc+asymp*x)/(cc+x))}      #asymp = asymptote as x->infty, asymp/c = slope at orgin
 nls.control(maxiter = 5000,tol = 2e-6)     #control parameters for nonlinear fitting
 dimcdata <-  dim(cdata)
 larea <- log(cdata$Area) #logs of areas of point sets
 parea <- cdata$Area      #point set areas
 obs <- cdata$ObsDens
 lobs <- log(cdata$ObsDens) #log of observed densities of point sets
 #Fit Point Set Data
 mmfit <- nls(lobs~log(convert(exp(lyint),exp(lasymp),exp(lcc),parea)),
   start = list(lyint= log(0.045), lasymp= log(0.008), lcc= log(1187)),
   upper=list(lyint= log(1.0), lasymp= log(0.1),lcc= log(10000)),
   lower=list(lyint= log(0.001), lasymp= log(0.0057),lcc= log(100)),
   algorithm="port")  #fit point set data
 mmcoef <- coef(mmfit)
 yint <- exp(mmcoef[1])   #fitted coef a
 asymp <- exp(mmcoef[2])  #fitted coef b
 cc <- exp(mmcoef[3])     #fitted coef c
 print(paste("yint = ",yint),quote=F)
 print(paste("asymp = ",asymp),quote=F)
 print(paste("cc = ",cc),quote=F)
 windows()
 plot(ObsDens~Area,data = cdata,ylab="Density",pch=19) #plots point set data
 areas <- 100*(1:95)
 pdens0 <-  convert(yint,asymp,cc,areas)#predicted curve
 lines(pdens0~areas,lwd=3)  #plots predicted curve

# Estimated Biomass - replicate (SET A):
 Density1 <- convert(yint,asymp,cc,tdata1$sarea)
 tdata1$bms <- Density1*tdata1$sarea  #estimated bms of schools
 transectbms1 <- tapply(tdata1$bms,tdata1$transect,sum)#calc bms on transect by summing over schools
 tbmsrep1 <- 385*sum(transectbms1)/26  #calculate total bms
 print(paste("Est bms Rep A = ",round(tbmsrep1)),quote=F)
# Estimated Biomass - replicate (SET B):
 Density2 <- convert(yint,asymp,cc,tdata2$sarea)
 tdata2$bms <- Density2*tdata2$sarea  #estimated bms of schools
 transectbms2 <- tapply(tdata2$bms,tdata2$transect,sum)#calc bms on transect by summing over schools
 tbmsrep2 <- 383*sum(transectbms2)/26  #calculate total bms
```

```
print(paste("Est bms Rep B = ",round(tbmsrep2)),quote=F)
# Estimated Biomass - replicate (SET C):
Density3 <- convert(yint,asymp,cc,tdata3$sarea)
tdata3$bms <- Density3*tdata3$sarea  #estimated bms of schools
transectbms3 <- tapply(tdata3$bms,tdata3$transect,sum)#calc bms on transect by summing over schools
# Note: transect No. 23 not sampled on SET C; n = 25
tbmsrep3 <- 377*sum(transectbms3)/25  #calculate total bms
print(paste("Est bms Rep C = ",round(tbmsrep3)),quote=F)

# Overall biomass estimate
tbms0 <- (tbmsrep1+tbmsrep2+tbmsrep3)/3
print(paste("Est overall bms = ",round(tbms0)),quote=F)

 cof <- matrix(nrow=nboots,rep(0,3*nboots)) #set up bootstraps
 bms <- rep(0,nboots)
 library('MSBVAR')
 covmatrix <- vcov(mmfit)
 meanparams <- coef(mmfit)
 newcoef <- rmultnorm(nboots,vmat=covmatrix,mu=meanparams)
 for (i in 1:nboots){
   nyint <- exp(newcoef[i,1])
   nasymp <- exp(newcoef[i,2])
   nasymp <- min(nasymp,0.02)
   nc <- exp(newcoef[i,3])   #simulated coefficients
   if (i < 20){ #draw refitted lines on pointset plot
     pdens <- convert(nyint,nasymp,nc,areas)
     lines(pdens~areas,col=i,lwd=0.05)
      }
#   Replicate A:
    Density1 <- convert(nyint,nasymp,nc,tdata1$sarea)
    bms1 <- Density1*tdata1$sarea  #bms of schools
    transectbms1 <- tapply(bms1,tdata1$transect,sum) #bms on each transect
    tbms1 <- 385*sum(transectbms1)/26  #calculate total bms
#   Replicate B:
    Density2 <- convert(nyint,nasymp,nc,tdata2$sarea)
    bms2 <- Density2*tdata2$sarea  #bms of schools
    transectbms2 <- tapply(bms2,tdata2$transect,sum) #bms on each transect
    tbms2 <- 383*sum(transectbms2)/26  #calculate total bms
#   Replicate C:
    Density3 <- convert(nyint,nasymp,nc,tdata3$sarea)
    bms3 <- Density3*tdata3$sarea  #bms of schools
    transectbms3 <- tapply(bms3,tdata3$transect,sum) #bms on each transect
    tbms3 <- 377*sum(transectbms3)/25  #calculate total bms

#   Overall biomass estimate:
    repbms <- c(tbms1,tbms2,tbms3)
    ii <- sample(seq(from=1,to=3),size=3,replace=T)
    yy <- repbms[ii]
    bms[i] <- mean(yy)
   }
    windows()
    hist(bms,breaks=20,density=10,col='dark blue') #histogram of bootstrapped biomasses
```

```
    print(paste("SE = ",round(sd(bms,na.rm=TRUE))),quote=F)
    print(paste("CV = ",round(sd(bms,na.rm=TRUE))/tbms0), quote=F)
}
```

 # bssouth: computes biomass estimate and variance for southern area

```
#  calculated from three replicate transect sets
#  Uses library 'MSVBAR' to simulate pointset variability
cdata <- read.csv(file="cdata2010s.csv")       #file of point set data (2010 south)
tdata1 <- read.csv(file="transectdataSA.csv")   #file of transect surface area data for replicate A
tdata2 <- read.csv(file="transectdataSB.csv")   #file of transect surface area data for replicate B
tdata3 <- read.csv(file="transectdataSC.csv")   #file of transect surface area data for replicate C

  bssouth = function(nboots,cdata,tdata1,tdata2,tdata3){

  convert = function(yint, asymp, cc, x) {   #defines function to convert area to bms - yint = y intercept
    return((yint*cc+asymp*x)/(cc+x))}       #asymp = asymptote as x->infty, asymp/c = slope at orgin
  nls.control(maxiter = 5000,tol = 2e-6)     #control parameters for nonlinear fitting
  dimcdata <-  dim(cdata)
  larea <- log(cdata$Area) #logs of areas of point sets
  parea <- cdata$Area      #point set areas
  obs <- cdata$ObsDens
  lobs <- log(cdata$ObsDens) #log of observed densities of point sets
  #Fit Point Set Data
  mmfit <- nls(lobs~log(convert(exp(lyint),exp(lasymp),exp(lcc),parea)),
    start = list(lyint= log(0.045), lasymp= log(0.0057), lcc= log(1187)),
    upper=list(lyint= log(1.0), lasymp= log(0.1),lcc= log(10000)),
    lower=list(lyint= log(0.001), lasymp= log(0.005),lcc= log(100)),
    algorithm="port")  #fit point set data
  mmcoef <- coef(mmfit)
  yint <- exp(mmcoef[1])   #fitted coef a
  asymp <- exp(mmcoef[2])  #fitted coef b
  cc <- exp(mmcoef[3])     #fitted coef c
  print(paste("yint = ",yint),quote=F)
  print(paste("asymp = ",asymp),quote=F)
  print(paste("cc = ",cc),quote=F)
  windows()
  plot(ObsDens~Area,data = cdata,ylab="Density",pch=19) #plots point set data
  areas <- 100*(1:95)
  pdens0 <-  convert(yint,asymp,cc,areas)#predicted curve
  lines(pdens0~areas,lwd=3)  #plots predicted curve

# Estimated Biomass - replicate (SET A):
 Density1 <- convert(yint,asymp,cc,tdata1$sarea)
 tdata1$bms <- Density1*tdata1$sarea  #estimated bms of schools
 transectbms1 <- tapply(tdata1$bms,tdata1$transect,sum)#calc bms on transect by summing over schools
 # Note: SET A transects 37,48, and 49 not sampled; n = 37
 tbmsrep1 <- 498*sum(transectbms1)/37  #calculate total bms
 print(paste("Est bms Rep A = ",round(tbmsrep1)),quote=F)

# Estimated Biomass - replicate (SET B):
 Density2 <- convert(yint,asymp,cc,tdata2$sarea)
 tdata2$bms <- Density2*tdata2$sarea  #estimated bms of schools
```

```
transectbms2 <- tapply(tdata2$bms,tdata2$transect,sum)#calc bms on transect by summing over schools
# Note: SET B transects 27,28,30,31,32,33, and 34 not sampled; n = 33
tbmsrep2 <- 513*sum(transectbms2)/33  #calculate total bms
print(paste("Est bms Rep B = ",round(tbmsrep2)),quote=F)

# Estimated Biomass - replicate (SET C):
Density3 <- convert(yint,asymp,cc,tdata3$sarea)
tdata3$bms <- Density3*tdata3$sarea  #estimated bms of schools
transectbms3 <- tapply(tdata3$bms,tdata3$transect,sum)#calc bms on transect by summing over schools
# Note: transects 32,40,41,56 and 59 not sampled on SET C; n = 35
tbmsrep3 <- 568*sum(transectbms3)/35  #calculate total bms
print(paste("Est bms Rep C = ",round(tbmsrep3)),quote=F)

# Overall biomass estimate
tbms0 <- (tbmsrep1+tbmsrep2+tbmsrep3)/3
print(paste("Est overall bms = ",round(tbms0)),quote=F)

 cof <- matrix(nrow=nboots,rep(0,3*nboots)) #set up bootstraps
 bms <- rep(0,nboots)
 library('MSBVAR')
 covmatrix <- vcov(mmfit)
 meanparams <- coef(mmfit)
 newcoef <- rmultnorm(nboots,vmat=covmatrix,mu=meanparams)
 for (i in 1:nboots){
   nyint <- exp(newcoef[i,1])
   nasymp <- exp(newcoef[i,2])
   nasymp <- min(nasymp,0.02)
   nc <- exp(newcoef[i,3])   #simulated coefficients
   if (i < 20){ #draw refitted lines on pointset plot
     pdens <- convert(nyint,nasymp,nc,areas)
     lines(pdens~areas,col=i,lwd=0.05)
      }
#   Replicate A:
   Density1 <- convert(nyint,nasymp,nc,tdata1$sarea)
   bms1 <- Density1*tdata1$sarea  #bms of schools
   transectbms1 <- tapply(bms1,tdata1$transect,sum) #bms on each transect
   tbms1 <- 498*sum(transectbms1)/37  #calculate total bms
#   Replicate B:
   Density2 <- convert(nyint,nasymp,nc,tdata2$sarea)
   bms2 <- Density2*tdata2$sarea  #bms of schools
   transectbms2 <- tapply(bms2,tdata2$transect,sum) #bms on each transect
   tbms2 <- 513*sum(transectbms2)/33  #calculate total bms
#   Replicate C:
   Density3 <- convert(nyint,nasymp,nc,tdata3$sarea)
   bms3 <- Density3*tdata3$sarea  #bms of schools
   transectbms3 <- tapply(bms3,tdata3$transect,sum) #bms on each transect
   tbms3 <- 568*sum(transectbms3)/35  #calculate total bms

#   Overall biomass estimate:
   repbms <- c(tbms1,tbms2,tbms3)
   ii <- sample(seq(from=1,to=3),size=3,replace=T)
   yy <- repbms[ii]
```

```
    bms[i] <- mean(yy)
   }
    windows()
    hist(bms,breaks=20,density=10,col='dark blue') #histogram of bootstrapped biomasses
    print(paste("SE = ",round(sd(bms,na.rm=TRUE))),quote=F)
    print(paste("CV = ",round(sd(bms,na.rm=TRUE))/tbms0), quote=F)
}
```

#Bootsard3: Computes biomass and CV estimate for the 2009 Survey

```
# Covariance on point set data obtained from library 'MSVBAR'
cdata <- read.csv(file="cdata2010nsp.csv")            #file of point set data
transectdata <- read.csv(file="transectdata2009.csv") #file of transect surface area data

 bootsard3 = function(nboots,cdata,transectdata){
  convert = function(yint, asymp, cc, x) {   #defines function to convert area to bms - yint = y intercept
    return((yint*cc+asymp*x)/(cc+x))} #asymp = asymptote as x->infty, asymp/c = slope at orgin
  nls.control(maxiter = 5000,tol = 2e-6) #control parameters for nonlinear fitting
  ntransects <- 41
  dimcdata <-  dim(cdata)
  npdata <- dimcdata[1] #number of point sets
  larea <- log(cdata$Area) #logs of areas of point sets
  parea <- cdata$Area  #point set areas
  obs <- cdata$ObsDens
  lobs <- log(cdata$ObsDens) #log of observed densities of point sets
  mmfit <- nls(lobs~log(convert(exp(lyint),exp(lasymp),exp(lcc),parea)),
    start = list(lyint= log(0.045), lasymp= log(0.0057), lcc= log(1187)),
    upper=list(lyint= log(1.0), lasymp= log(0.1),lcc= log(10000)),
    lower=list(lyint= log(0.001), lasymp= log(0.005),lcc= log(100)),
    algorithm="port")  #fit point set data
  mmcoef <- coef(mmfit)
  yint <- exp(mmcoef[1])  #fitted coef a
  asymp <- exp(mmcoef[2])  #fitted coef b
  cc <- exp(mmcoef[3])  #fitted coef c
  predobs <- convert(yint,asymp,cc,cdata$Area)
  res <- predobs - obs  #residuals of point sets
  windows()
  plot(ObsDens~Area,data = cdata,ylab="Density",pch=19) #plots point set data
  areas <- 100*(1:95)
  pdens0 <-  convert(yint,asymp,cc,areas)#predicted curve
  lines(pdens0~areas,col='dark red',lwd=3)  #plots predicted curve
  Density <- convert(yint,asymp,cc,transectdata$sarea)
  transectdata$bms <- Density*transectdata$sarea  #estimated bms of schools
  transectbms1 <- tapply(transectdata$bms,transectdata$transect,sum)#calc bms on transect by summing over
schools
  tbms0 = 599*sum(transectbms1)/41  #calculate total bms
  print(paste("Est bms = ",round(tbms0)),quote=F)
  cof <- matrix(nrow=nboots,rep(0,3*nboots)) #set up bootstraps
  bms <- rep(0,nboots)
  library('MSBVAR')
  covmatrix <- vcov(mmfit)
  meanparams <- coef(mmfit)
  newcoef <- rmultnorm(nboots,vmat=covmatrix,mu=meanparams)
```

```
 for (i in 1:nboots){
   nyint <- exp(newcoef[i,1])
   nasymp <- exp(newcoef[i,2])
   nasymp <- min(nasymp,0.02)
   nc <- exp(newcoef[i,3])   #simulated coefficients
   if (i < 20){ #draw refitted lines on pointset plot
     pdens <- convert(nyint,nasymp,nc,areas)
     lines(pdens~areas,col=i,lwd=0.05)
      }
   Density <- convert(nyint,nasymp,nc,transectdata$sarea)
   bms1 <- Density*transectdata$sarea  #bms of schools
   transectbms <- tapply(bms1,transectdata$transect,sum) #bms on each transect
   tresample <- sample(1:ntransects,replace=T)  #sample the transect indicies
   retransect <- transectbms[tresample] #bootstrap of transects
   bms[i] <- 599*sum(retransect)/41  #calculated bms of this bootstrap
  }
  windows()
  hist(bms,breaks=20,density=10,col='dark blue') #histogram of bootstrapped biomasses
  print(paste("yint = ",yint),quote=F)
  print(paste("asymp = ",asymp),quote=F)
  print(paste("cc = ",cc),quote=F)
  print(paste("SE = ",round(sd(bms,na.rm=TRUE))),quote=F)
  print(paste("CV = ",round(sd(bms,na.rm=TRUE))/tbms0), quote=F)
}
```

 # fpsdata: fits and plots pointset data

```
cdata <- read.csv(file="cdata.csv")         #point set data: 2008 and 2009 pooled
cd2010n <- read.csv(file="cdata2010n.csv")   #point set data: 2010 (north)
cd2010np <- read.csv(file="cdata2010np.csv") #point set data: 2008; 2009; 2010 (north) pooled
cd2010s <- read.csv(file="cdata2010s.csv")   #point set data: 2010 (south)
cd2010nsp <- read.csv(file="cdata2010nsp.csv") #point set data: 2008; 2009; 2010 (north); 2010 (south) pooled

 fpsdata = function(cdata, cd2010n,cd2010np,cd2010s,cd2010nsp){
 convert = function(yint, asymp, cc, x) {   #defines function to convert area to bms - yint = y intercept
   return((yint*cc+asymp*x)/(cc+x))}       #asymp = asymptote as x->infty, asymp/c = slope at orgin
 nls.control(maxiter = 5000,tol = 2e-6)     #control parameters for nonlinear fitting

# fit pooled 2008 and 2009 pointset data (cdata.csv)
 larea <- log(cdata$Area) #logs of areas of point sets
 parea <- cdata$Area  #point set areas
 obs <- cdata$ObsDens
 lobs <- log(cdata$ObsDens) #log of observed densities of point sets
 mmfit <- nls(lobs~log(convert(exp(lyint),exp(lasymp),exp(lcc),parea)),
   start = list(lyint= log(0.045), lasymp= log(0.0056), lcc= log(1187)),
   upper=list(lyint= log(1.0), lasymp= log(0.1),lcc= log(10000)),
   lower=list(lyint= log(0.001), lasymp= log(0.001),lcc= log(100)),
   algorithm="port")  #fit point set data
 mmcoef <- coef(mmfit)
 yint <- exp(mmcoef[1])  #fitted coef a
 asymp <- exp(mmcoef[2])  #fitted coef b
 cc <- exp(mmcoef[3])  #fitted coef c
```

```
# fit 2010 pointset data (north - cdata2010n.csv)
larea2 <- log(cd2010n$Area) #logs of areas of point sets
parea2 <- cd2010n$Area  #point set areas
obs2 <- cd2010n$ObsDens
lobs2 <- log(cd2010n$ObsDens) #log of observed densities of point sets
mmfita <- nls(lobs2~log(convert(exp(lyint2),exp(lasymp2),exp(lcc2),parea2)),
  start = list(lyint2= log(0.045), lasymp2= log(0.0056), lcc2= log(1187)),
  upper=list(lyint2= log(1.0), lasymp2= log(0.1),lcc2= log(10000)),
  lower=list(lyint2= log(0.001), lasymp2= log(0.001),lcc2= log(100)),
  algorithm="port")  #fit point set data
mmcoef2 <- coef(mmfita)
yint2 <- exp(mmcoef2[1])  #fitted coef a
asymp2 <- exp(mmcoef2[2])  #fitted coef b
cc2 <- exp(mmcoef2[3])  #fitted coef c

# fit 2008; 2009 and 2010(north) pointset data - pooled  (cdata2010np.csv)
larea3 <- log(cd2010np$Area) #logs of areas of point sets
parea3 <- cd2010np$Area  #point set areas
obs3 <- cd2010np$ObsDens
lobs3 <- log(cd2010np$ObsDens) #log of observed densities of point sets
mmfitb <- nls(lobs3~log(convert(exp(lyint3),exp(lasymp3),exp(lcc3),parea3)),
  start = list(lyint3= log(0.045), lasymp3= log(0.0056), lcc3= log(1187)),
  upper=list(lyint3= log(1.0), lasymp3= log(0.1),lcc3= log(10000)),
  lower=list(lyint3= log(0.001), lasymp3= log(0.001),lcc3= log(100)),
  algorithm="port")  #fit point set data
mmcoef3 <- coef(mmfitb)
yint3 <- exp(mmcoef3[1])  #fitted coef a
asymp3 <- exp(mmcoef3[2])  #fitted coef b
cc3 <- exp(mmcoef3[3])  #fitted coef c

# fit 2010 pointset data(south - cdata2010s.csv)
larea4 <- log(cd2010s$Area) #logs of areas of point sets
parea4 <- cd2010s$Area  #point set areas
obs4 <- cd2010s$ObsDens
lobs4 <- log(cd2010s$ObsDens) #log of observed densities of point sets
mmfitc <- nls(lobs4~log(convert(exp(lyint4),exp(lasymp4),exp(lcc4),parea4)),
  start = list(lyint4= log(0.045), lasymp4= log(0.0056), lcc4= log(1187)),
  upper=list(lyint4= log(1.0), lasymp4= log(0.1),lcc4= log(10000)),
  lower=list(lyint4= log(0.001), lasymp4= log(0.001),lcc4= log(100)),
  algorithm="port")  #fit point set data
mmcoef4 <- coef(mmfitc)
yint4 <- exp(mmcoef4[1])  #fitted coef a
asymp4 <- exp(mmcoef4[2])  #fitted coef b
cc4 <- exp(mmcoef4[3])  #fitted coef c

# fit 2008;2009;2010 (north); 2010 (south) pooled (cdata2010nsp.csv)
larea5 <- log(cd2010nsp$Area) #logs of areas of point sets
parea5 <- cd2010nsp$Area  #point set areas
obs5 <- cd2010nsp$ObsDens
lobs5 <- log(cd2010nsp$ObsDens) #log of observed densities of point sets
mmfitd <- nls(lobs5~log(convert(exp(lyint5),exp(lasymp5),exp(lcc5),parea5)),
  start = list(lyint5= log(0.045), lasymp5= log(0.0056), lcc5= log(1187)),
```

```
   upper=list(lyint5= log(1.0), lasymp5= log(0.1),lcc5= log(10000)),
   lower=list(lyint5= log(0.001), lasymp5= log(0.001),lcc5= log(100)),
   algorithm="port")  #fit point set data
 mmcoef5 <- coef(mmfitd)
 yint5 <- exp(mmcoef5[1])  #fitted coef a
 asymp5 <- exp(mmcoef5[2])  #fitted coef b
 cc5 <- exp(mmcoef5[3])  #fitted coef c

#resmmfit <- residuals(mmfit)
#resmmfita <- residuals(mmfita)
#resmmfitb <- residuals(mmfitb)
#resids <- cbind(resmmfit,resmmfita,resmmfitb)
#write.csv(resids, file = "resids.csv")

 print(paste("yint = ",yint),quote=F)
 print(paste("asymp = ",asymp),quote=F)
 print(paste("cc = ",cc),quote=F)
 dfmmfit <- df.residual(mmfit)
 print(paste("df mmfit = ",dfmmfit),quote=F)
 llmmfit <- logLik(mmfit)
 print(paste("logLik mmfit = ",llmmfit),quote=F)

 print(paste("yint2 = ",yint2),quote=F)
 print(paste("asymp2 = ",asymp2),quote=F)
 print(paste("cc2 = ",cc2),quote=F)
 dfmmfita <- df.residual(mmfita)
 print(paste("df mmfita = ",dfmmfita),quote=F)
 llmmfita <- logLik(mmfita)
 print(paste("logLik mmfita = ",llmmfita),quote=F)

 print(paste("yint3 = ",yint3),quote=F)
 print(paste("asymp3 = ",asymp3),quote=F)
 print(paste("cc3 = ",cc3),quote=F)
 dfmmfitb <- df.residual(mmfitb)
 print(paste("df mmfitb = ",dfmmfitb),quote=F)
 llmmfitb <- logLik(mmfitb)
 print(paste("logLik mmfitb = ",llmmfitb),quote=F)

 print(paste("yint4 = ",yint4),quote=F)
 print(paste("asymp4 = ",asymp4),quote=F)
 print(paste("cc4 = ",cc4),quote=F)
 dfmmfitc <- df.residual(mmfitc)
 print(paste("df mmfitc = ",dfmmfitc),quote=F)
 llmmfitc <- logLik(mmfitc)
 print(paste("logLik mmfitc = ",llmmfitc),quote=F)

 print(paste("yint5 = ",yint5),quote=F)
 print(paste("asymp5 = ",asymp5),quote=F)
 print(paste("cc5 = ",cc5),quote=F)
 dfmmfitd <- df.residual(mmfitd)
 print(paste("df mmfitd = ",dfmmfitd),quote=F)
 llmmfitd <- logLik(mmfitd)
```

```
print(paste("logLik mmfitd = ",llmmfitd),quote=F)

windows()
plot(ObsDens~Area,data = cd2010nsp,ylab="Density",pch=19,col="blue",type="n")
  #sets the xy scale for plots to follow
points(ObsDens~Area,data = cdata,ylab="Density",pch=19,col="blue")
 #plots point set data for 2008 and 2009 pooled
areas <- 100*(1:95)
pdens2009 <-  convert(yint,asymp,cc,areas)
                 #predicted curve
lines(pdens2009~areas,col='black',lwd=3)
                  #plots predicted curve for 2008 and 2009 pooled

points(ObsDens~Area,data= cd2010n,pch=19,col="green")
         #plots point set data for 2010 north
pdens2010n <-  convert(yint2,asymp2,cc2,areas)
              #predicted curve
lines(pdens2010n~areas,col='black',lwd=3,lty="dotted")
        #plots predicted curve for 2010 north

windows()
plot(ObsDens~Area,data = cd2010nsp,ylab="Density",pch=19,col="blue",type="n")
  #sets the xy scale for plots to follow
points(ObsDens~Area,data = cd2010np,ylab="Density",pch=19,col="blue")
     #plots point set data for 2008;2009 and 2010-n  - all pooled
pdens2010np <-  convert(yint3,asymp3,cc3,areas)
                  #predicted curve
lines(pdens2010np~areas,col='black',lwd=3)
                     #plots predicted curve for pooled 2008;2009 and 2010 north data

points(ObsDens~Area,data= cd2010s,pch=19,col="green")
        #plots point set data for 2010 south
pdens2010s <-  convert(yint4,asymp4,cc4,areas)
             #predicted curve
lines(pdens2010s~areas,col='black',lwd=3,lty="dotted")
       #plots predicted curve for 2010 south

windows()
plot(ObsDens~Area,data = cd2010nsp,ylab="Density",pch=19,col="blue")  #plots point set data for 2008; 2009;
2010-n; 2010-s pooled
pdens2010nsp <-  convert(yint5,asymp5,cc5,areas)
lines(pdens2010nsp~areas,col='black',lwd=3)

}
```

Agenda Item I.2.b
Attachment 2
Pacific Sardine Assessment Update Report
November 2010

Full Report on Web/CD Only

ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2010 FOR U.S. MANAGEMENT IN 2011

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ACRONYMS, ABBREVIATIONS. AND DEFINITIONS

ABC	acceptable biological catch
ACL	annual catch limit
ACT	annual catch target
BC	British Columbia (Canada)
CA	State of California
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CalVET	California Vertical Egg Tow (ichthyoplankton net)
CCA	Central California fishery
CDFG	California Department of Fish and Game
CDFO	Canada Department of Fisheries and Oceans
CICIMAR	Centro Interdisciplinario de Ciencias Marinas
CONAPESCA	Comisión Nacional de Acuacultura y Pesca
CPS	Coastal Pelagic Species
CPSAS	Coastal Pelagic Species Advisory Subpanel
CPSMT	Coastal Pelagic Species Management Team
CV	coefficient of variation
DEPM	Daily egg production method
ENS	Ensenada (México) fishery
FMP	fishery management plan
HG	harvest guideline, as defined in the CPS-FMP
INP-CRIP	Instituto Nacional de la Pesca – Centro Regional de Invest. Pesquera
MLE	maximum likelihood estimate
Model Year	Annual model increment spans July 1 to June 30 of following year
mt	metric tons
mmt	million metric tons
MX	México
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OR	State of Oregon
ODFW	Oregon Department of Fish and Wildlife
OFL	overfishing limit
PFMC	Pacific Fishery Management Council
PNW	Pacific Northwest fishery (Oregon, Wash., and British Columbia)
S1 & S2	Season 1 (Jul-Dec) and Season 2 (Jan-Jun)
SCA	Southern California fishery
SS	Stock Synthesis version 3
SSB	spawning stock biomass
SSC	Scientific and Statistical Committee
SST	sea surface temperature
STAR	Stock Assessment Review
STAT	Stock Assessment Team
SWFSC	Southwest Fisheries Science Center
TEP	Total egg production
WA	State of Washington
WDFW	Washington Department of Fish and Wildlife

ACKNOWLEDGMENTS

The annual sardine assessment depends, in large part, on the diligent efforts of many colleagues and the timely receipt of their data products. Landings data from the Ensenada fishery were provided by Manuel Nevarrez (INP-Guaymas) and CONAPESCA. Port samples for the Ensenada, México fishery were collected by INP-CRIP (Ensenada) and aged by Roberto Felix-Uraga and Casimiro Quiñonez (CICIMAR, La Paz). Port samples and age data for the California fishery were provided by CDFG Marine Region personnel in Los Alamitos, Santa Barbara, San Diego, and Monterey, with special thanks to Dianna Porzio, Mandy Lewis, Bill Miller, Paul Ton, Santi Luangpraseut, Dale Sweetnam, Briana Brady, Ed Dunn, Sonia Torres, and Lou Zeidberg for long dockside and laboratory hours. Thanks also go to the dedicated staff that collected and processed biological samples from the fisheries off Oregon and Washington, including Jill Smith, Keith Matteson, Sheryl Manley, Kelly Corbet, and David Wolfe Wagman of ODFW, and Carol Henry of WDFW. Sandra Rosenfield and Jennifer Topping (WDFW) aged all Oregon and Washington otoliths. Monthly landings and size data for the British Columbia fishery were kindly provided by Jake Schweigert, Linnea Flostrand, and Jackie Detering of DFO-Canada. Numerous staff from SIO, NMFS, and CDFG assisted in the ongoing collection and identification of CalCOFI ichthyoplankton samples. Sea surface temperature data were provided by Melissa Carter of Scripps Institution of Oceanography's Shore Stations program, funded by the California Department of Boating and Motorways. We are indebted to Richard Methot (NWFSC) for developing and continuously improving the Stock Synthesis model, and to Ian Taylor (NWFSC) for maintaining the 'R' function to summarize SS outputs. Finally, we thank Jenny McDaniel (SWFSC) for providing valuable assistance in finalizing the assessment report and for meeting preparations.

EXECUTIVE SUMMARY

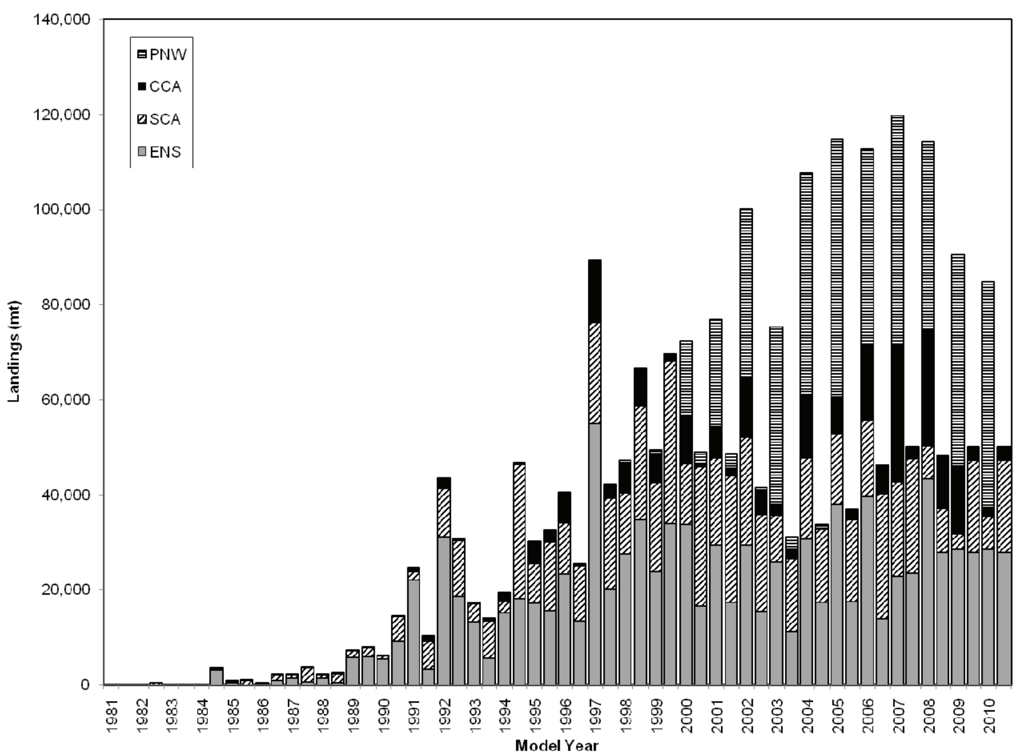
Stock

The Pacific sardine (*Sardinops sagax caerulea*) ranges from southeastern Alaska to the Gulf of California, México, and is thought to comprise three subpopulations. In this assessment, we model the northern subpopulation which ranges seasonally from northern Baja California, México, to British Columbia, Canada, and offshore as far as 300 nm. All U.S., Canada, and Ensenada (México) landings are assumed to be taken from a single northern stock (Table 1). Future modeling efforts will explore a scenario separating the catches in Ensenada and San Pedro into the respective northern and southern stocks based on objective criteria.

Catches

The assessment includes sardine landings from four commercial fisheries: Ensenada (México), Southern California (San Pedro to Santa Barbara), Central California (Monterey Bay region), and the Pacific Northwest (Oregon, Washington, and British Columbia), from 1981 to 2010.

Model Year	ENS	SCA	CCA	PNW
2001	46,948	44,939	8,042	25,683
2002	44,938	43,125	17,589	36,123
2003	37,040	25,141	4,508	39,861
2004	48,007	32,581	13,278	47,747
2005	55,600	31,991	9,857	54,254
2006	53,617	42,472	21,724	41,221
2007	46,353	43,982	31,284	48,237
2008	71,236	16,214	35,275	39,800
2009	56,357	22,730	16,841	44,841
2010	56,357	26,291	4,842	47,502



Data and assessment

This assessment update was conducted using 'Stock Synthesis' version 3.03a and utilizes fishery and survey data collected from mid-1981 through mid-2010. The model uses a July-June 'model year', with two semester-based seasons per year (S1=Jul-Dec and S2=Jan-Jun). Fishery data include catch and biological samples for the fisheries off Ensenada, Southern California, Central California, and the Pacific Northwest. Two indices of relative abundance are included in the base model: Daily Egg Production Method and Total Egg Production estimates of spawning stock biomass (1986-2010), both based on annual surveys conducted off California. Finally, the 'tuned' update model '10w' was run with the addition of aerial (northern region) survey estimates of absolute abundance from 2009 and 2010 (q=1) to derive population quantities for 2011 management.

Stock biomass and recruitment

Stock biomass, used for determining the HG, is defined as the sum of the biomass for sardines ages 1 and older. Biomass increased rapidly through the 1980s and 1990s, peaking at 1.57 mmt in 2000. Biomass has subsequently trended downward to the present (July 1, 2010) level of 537,173 mt.

Recruitment was modeled using the Ricker stock-recruitment relationship. The estimate of steepness was high (h=2.253). Virgin recruitment (R_0) was estimated at 4.62 billion age-0 fish for the base model. Recruitment increased rapidly through the mid-1990s, peaking at 17.156 billion fish in 1997, 19.743 billion in 1998, and 18.578 billion in 2003. Recruitments have been notably lower from 2006 to 2009.

Model Year	Stock biomass (ages 1+, mt)	Recruits (age-0, billions)
2000	1,570,120	2.928
2001	1,382,790	7.959
2002	1,211,880	0.804
2003	938,187	18.578
2004	1,049,690	9.617
2005	1,166,640	10.448
2006	1,248,410	3.277
2007	1,137,980	3.596
2008	919,328	2.674
2009	683,575	4.613
2010	537,173	---

Exploitation status

Exploitation rate is defined as calendar year catch divided by total mid-year biomass (July-1, ages 0+). Exploitation rate was relatively high during the early recovery period (mid-1980s) but declined and stabilized as the stock underwent the most rapid phase of recovery. Exploitation rate has subsequently increased in recent years as the stock has decreased in size. Based on the update model '10w', total coast-wide exploitation rate is currently ≈23%.

Calendar Year	ENS	SCA	CCA	PNW	Total
2000	4.3%	2.9%	0.7%	1.0%	8.9%
2001	3.2%	3.3%	0.5%	1.7%	8.7%
2002	3.8%	4.0%	1.2%	3.2%	12.2%
2003	3.7%	2.7%	0.7%	3.4%	10.6%
2004	3.7%	2.9%	1.3%	4.3%	12.2%
2005	4.4%	2.4%	0.6%	4.4%	11.8%
2006	4.5%	2.6%	1.4%	3.2%	11.7%
2007	3.1%	3.9%	3.0%	4.1%	14.2%
2008	7.1%	3.3%	2.8%	4.2%	17.4%
2009	7.8%	1.7%	3.5%	6.2%	19.2%
2010	9.4%	4.4%	0.8%	7.9%	22.5%

Management performance

Based on results from the update model '10w', the harvest guideline for the U.S. fishery in calendar year 2011 would be 50,526 mt. The HG is based on the control rule defined in the CPS-FMP:

$$HG_{2011} = (BIOMASS_{2010} - CUTOFF) \bullet FRACTION \bullet DISTRIBUTION;$$

where HG_{2011} is the total U.S. (California, Oregon, and Washington) harvest guideline in 2011, $BIOMASS_{2010}$ is the estimated July 1, 2010 stock biomass (ages 1+) from the assessment (537,173 mt), CUTOFF is the lowest level of estimated biomass at which harvest is allowed (150,000 mt), FRACTION is an environment-based percentage of biomass above the CUTOFF that can be harvested by the fisheries (see below), and DISTRIBUTION (0.87) is the average portion of BIOMASS assumed in U.S. waters. The following formula is used to determine the appropriate FRACTION value:

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

where T is the running average sea-surface temperature at Scripps Pier, La Jolla, California during the three preceding seasons (July-June). Based on the current (T_{2010}) SST estimate of 17.90 °C, the F_{msy} exploitation fraction should remain at 0.15. The new U.S. HG (50,526 mt) would be the lowest since management was initiated under the federal CPS-FMP:

Year	U.S. OFL	U.S. HG	U.S. Landings	Total OFL	Total Landings
2000	273,907	186,791	72,496	314,835	142,063
2001	204,816	134,737	78,520	235,421	125,857
2002	149,585	118,442	101,367	171,937	148,951
2003	165,826	110,908	74,599	190,604	116,918
2004	188,902	122,747	92,613	217,129	138,948
2005	206,730	136,179	90,130	237,621	148,684
2006	183,845	118,937	90,776	211,316	149,588
2007	228,478	152,564	127,695	262,618	166,065
2008	144,234	89,093	87,175	165,786	164,466
2009	114,820	66,932	67,084	131,976	138,775
2010	121,598	72,039	63,066	139,768	---

INTRODUCTION

The Pacific sardine resource is assessed each year in support of the Pacific Fishery Management Council (PFMC) process that, in part, establishes an annual harvest guideline ('HG') for the U.S. fishery. The following assessment update for 2011 management is based on data sources and methodologies described in detail by Hill et al. 2009 and Jagielo et al. (2009), and reviewed by a STAR Panel during September 2009 (STAR 2009). In this update, we append fishery-dependent and survey series with more recently available information, without changes to base model structure or parameterization.

A preliminary draft assessment was reviewed by the SSC's CPS-Subcommittee October 5-7, 2010, in La Jolla, California. Modifications to input data were incorporated during the course of that review, resulting in changes to population estimates and management-related quantities. The present report has been updated to reflect those changes.

ASSESSMENT

Fishery Data

Overview

Fishery data include commercial landings and biological samples from four regional fisheries: 1) Ensenada ('ENS', northern Baja California); Southern California ('SCA', San Pedro to Santa Barbara); 3) Central California ('CCA', Monterey Bay); and 4) the Pacific Northwest ('PNW': Oregon, Washington, and British Columbia). All fishery data (catch and composition) were compiled by model year (July-June) and semester (S1=Jul-Dec, S2=Jan-Jun) as described by Hill et al. (2009). Landings by model year and semester are provided in Table 2, and sample sizes (ESS) are provided in Table 3.

Updated Landings

Landings by model year, semester, and fishery are presented in Table 2 and Figure 4. The SS model includes landings from model years 1981 through 2010. Landings for model years 1981 through 2006 did not change for this update (see Hill et al. 2009). Recent landings for each fishery were updated as follows.

For the Ensenada fishery (ENS), we obtained final monthly catches from calendar year 2008 (CONAPESCA 2010) and new semester aggregate catches from calendar year 2009 (Dr. Manuel Nevarrez, INP-Guaymas, pers. comm.), resulting in updated landings for model years 2007, 2008, and 2009 (Table 2, Figure 4). Landings for the S2 of 2009 (i.e. Jan-Jun 2010) were unknown, so assumed identical to S2 of 2008. Landings for the final model year (S1 & S2 of 2010) were borrowed from model year 2009.

Landings for the two California fisheries (SCA & CCA) were updated for calendar year 2009 through the first half of 2010. This resulted in changes to landings for model years 2008 and 2009. Landings for S1 of 2010-11 were projected based on remaining available HG and the portions caught by these fisheries in the same allocation seasons of 2009. Landings for S2 of 2010-11 were assumed identical to that of S2 in 2009-10 (Table 2, Figure 4).

Final landings for the Pacific Northwest fishery (PNW) during 2008 and 2009 were obtained. Catch statistics for model year 2008 did not change for this update. The final PNW catch for 2009-S1 (44,841 mt) was 18,597 mt higher than the 26,244 mt value projected by Hill et al. (2009) (Table 2, Figure 4).

Updated Length and Conditional Age-at-Length Compositions

New biological sample data, collected from July 2009 to June 2010 (i.e. model year 2009), were obtained for the SCA, CCA, and PNW fisheries. All fishery length and conditional age-at-length compositions were compiled using methods described in detail by Hill et al. (2009). Length and conditional age-at-length compositions for each fishery and semester were the sums of weighted observations, with monthly landings within semester being the sampling unit. Updates to monthly catch, described above, resulted in trivial changes to weightings used to recompile fishery SCA and CCA compositions for model year 2008. ESS by model year, semester, and fishery are provided in Table 3. Length-compositions by fishery are displayed in Figures 5a-f. Implied ('ghost') age composition data are presented adjacent to corresponding length compositions in Figures 6a-f. Conditional age-at-length compositions for each fishery and semester are presented in Figures 7a-f. Fishery-specific ageing error vectors are displayed in Figure 8.

Fishery-Independent Data

Overview

Two fishery-independent time series were used in the most recent full assessment (Hill et al. 2009a,b), and both were based on the SWFSC's egg production survey that ranges from San Diego to San Francisco each spring (Table 4). The daily egg production method (DEPM) index of female SSB is used when adult daily-specific fecundity data are available from the survey. The total egg production (TEP) index of SSB is used when survey-specific fecundity data are unavailable. The DEPM series was updated for the following assessment. Both time series were treated as indices of relative SSB abundance, with the catchability coefficients (q) being estimated.

In addition to the egg production time series from California, the last full assessment incorporated results from the Aerial Sardine Survey of 2009 (Jagielo et al. 2009). The biomass and CV associated with the 2009 survey has since been re-estimated (Jagielo et al. 2010) using a bootstrap procedure recommended by the STAR in 2009. This change, particularly the increased CV, had a substantial impact on scaling within the updated assessment model. The aerial survey was repeated on a larger scale with replication during 2010, and the northern stratum estimate was included in the final update model this year. The aerial survey series was modeled as an index of absolute abundance (q=1) in the final base model.

Updated Daily Egg Production Method Survey

The SWFSC conducted a coastwide California Current Ecosystem (CCE) survey from March 23 to April 29, 2010 aboard the NOAA ship *Miller Freeman* and the F/V *Frosti*. The survey, which ranged from Cape Flattery, Washington to San Diego, California (Figure 9), employed all the usual methods for estimating sardine SSB via the DEPM (Lo et al. 2009). The survey included a complete sampling of the 'standard' area for the assessment models' DEPM time series, i.e. San Francisco to San Diego (Figure 10).

Only minor quantities of sardine (~3,300 mt) were estimated to be outside the standard DEPM area (Figures 9-10). The coast-wide female spawning biomass and total spawning biomass of the Pacific sardine was estimated by the DEPM to be 62,131 mt (CV = 0.37) and 108,280 mt (CV = 0.36), respectively, for an area of 477,092 km^2 between San Diego and Cape Flattery, primarily south of 37°N. For the overall survey area, the daily egg production estimate was 0.22/.05m^2 (CV = 0.23), although no eggs were collected in the area north of CalCOFI line 56.7, and only one positive trawl was observed north of CalCOFI line 60 at 38.2°N (Table 5, Figures 9-10). Preliminary analysis of acoustic backscatter data collected throughout the 2010 survey indicated sardine distributions similar to that inferred by sampled adults, eggs, and larvae (Figures 9 & 11; Drs. David Demer & Juan Zwolinski, pers. comm.).

The standard DEPM index area off California (San Diego to San Francisco; CalCOFI lines 95 to 60) was 271,773 km^2, and the egg production (P_0) estimate was 0.36/0.05m^2 (CV = 0.29). Female spawning biomass for the standard area was taken as the sum of female spawning biomass in regions 1 and 2 (Table 5). The female spawning biomass and total spawning biomass for the standard DEPM area was estimated to be 58,447 mt (CV = 0.42) and 105,200 mt (CV = 0.35), respectively. Adult reproductive parameters for the survey are presented in Table 6. The daily specific fecundity was calculated as 18.07 (number of eggs/population weight (g)/day) using the estimates of reproductive parameters from 313 mature females collected from 17 positive trawls, where: mean batch fecundity (F) was 39304 eggs/batch (CV = 0.11); fraction spawning (S) was 0.104 females spawning per day (CV = 0.22); mean female fish weight (W_f) was 129.5 g (CV = 0.02); and sex ratio of females by weight (R) was 0.574 (CV = 0.07). Since 2005, trawling has been conducted randomly or at CalCOFI stations, which resulted in sampling adult sardines in both high (Region 1) and low (Region 2) sardine egg density areas. During the 2010 survey, more positive tows were observed in region 2 than region 1.

In SS, the DEPM series was taken to represent female SSB (length selectivity option '30') in the middle of S2 (April). The latest DEPM estimate, based on eggs and adults collected during cruise 1004 (Spring of 2010; Figures 9-10), was 58,447 mt of female SSB (CV=0.42; SE≈0.40) (Table 5). The 2010 DEPM estimate is considerably lower than estimates from other recent years, but is consistent with the downward trend in relative abundance indicated by this survey.

Updated Aerial Sardine Survey

During summer 2009, the Pacific sardine industry funded an aerial survey ranging from Monterey, California to Cape Flattery, Washington (Figure 12). A description of methods and results may be found in Jagielo et al. (2009). The 2009 STAR panel reviewed and ultimately endorsed the 2009 survey estimate of 1,353,170 mt (CV=0.55) for use in the assessment (STAR 2009), but made a recommendation to use bootstrap methods for better calculating uncertainty

(CV) associated with the relationship between school surface area and biomass. Jagielo et al. (2010) subsequently re-estimated the 2009 aerial survey biomass and CV using the bootstrapping routine ‘MSBVAR’ (*R* statistical software library). Based on 100,000 bootstrap simulations, the 2009 aerial survey biomass is now 1,236,910 mt (down from 1,353,170 mt), with a CV of 1.12 (increased from 0.55) (Jagielo et al. 2010). The approximate standard error for this CV was calculated to be 0.90 for SS model runs, where $SE \approx sqrt(log_e(1+CV^2))$. This change was reviewed and endorsed by the SSC’s CPS-subcommittee and sardine STAT during October 2010, so was used for model runs in this report (Table 4).

The industry-funded aerial sardine survey was repeated during summer 2010, this time on a broader latitudinal scale and with replication. The 2010 survey methods and results are documented in Jagielo et al. (2010). The aerial survey team presented a range of scenarios for estimating abundance from the 2010 survey, including pooling of point set data (surface area to biomass relationship) across years and regions, as well as year- and region-specific estimates and variances (i.e. fully independent observations). A related issue was whether California point set data, collected exclusively in the Southern California Bight, should be taken to represent size and biomass of sardine schools from the Monterey Bay region, where 90% of the California biomass was observed. Each of the scenarios and issues has been documented either in Jagielo et al. (2010) or in the CPS Subcommittee report (Nov 2010 briefing book). The STAT ultimately chose not to include the California data due to uncertainties mentioned above. The STAT also chose to use 2009 and 2010 aerial estimates (northern region) based on point set data (surface-area to biomass) from each respective year rather than pooling parameters across years. Each survey observation could therefore be considered fully-independent, so autocorrelation problems within SS were avoided. Sensitivity of the model to various treatments of the 2010 aerial data is further addressed in the section titled ‘Uncertainty, Sensitivity, and Unresolved Issues’.

For the final update model ‘10w’, the sardine STAT chose to include only the northern portion of 2010 aerial data (‘Aerial_N’, i.e. Oregon-Washington), where the biomass (173,390 mt) and variance (SE≈0.40) was estimated using only 2010 point set data collected from this region. The 2009 and 2010 aerial estimates were treated as a single index (Table 4) with catchability coefficient (q) fixed to equal 1. Weighted length compositions for the surveys (Figure 13) were fit using the double-normal selectivity function, allowing selectivity to assume a domed shape, with a single shared selectivity function. The update (‘10w’) and alternative models (‘10t through ‘10x2’) were tuned prior to adding the aerial survey data.

Model Description

SS Version 3.03a, compiled 11 May 2009, was used for the last full assessment (Hill et al. 2009) and for this update. The reader is referred to Methot (2005, 2009) for a complete description of the SS model. The objective function for the base model included likelihood contributions from the DEPM, TEP, and Aerial surveys, contributions from the length-compositions and conditional age-at-length data from the four fisheries, a contribution from the deviations about the spawner-recruit relationship and minor contributions from parameter soft-bound penalties (Tables 7-8). Update model parameters and their asymptotic standard deviations are provided in Table 7.

The update model '10w' had the following specifications, per Hill et al (2009):

- Model Year based on the July 1 birth date assumption (July 1-June 30 time span);
- Assessment years 1981-2010; Two semesters per year (S1=Jul-Dec; S2=Jan-Jun);
- Four fisheries (ENS, SCA, CCA, PNW), with annual selectivity patterns for ENS and PNW and seasonal selectivity patterns for SCA and CCA (S1 & S2).
- Use of length-frequency and conditional age-at-length data for all fisheries;
- Length-based, double-normal selectivity with time-blocking:
    - ENS, SCA_S1, & SCA_S2: 1981-91, 1992-98, 1999-10;
    - CCA_S1 & CCA_S2: 1981-92, 1993-98, 1999-10;
    - PNW: 1981-03, 2004-10;
- M = 0.4yr^{-1} for all ages and years;
- Time-varying growth in two periods: 1981-90 and 1991-10;
- Ricker stock-recruitment relationship; $\sigma_R = 0.815$; Steepness estimated;
- Initial recruitment (R_1) estimated; recruitment devs estimated from 1975 to 2008;
- Hybrid-F fishing mortality option;
- DEPM and TEP measures of spawning biomass (1986, 1987, 1993, 2003, 2004, and 2006-2009 for DEPM, and 1987, 1995-2002 and 2005 for TEP) and aerial survey estimates of abundance from 2009 and 2010.
- Length-frequency data for the 2009 and 2010 aerial surveys, taken from point-set samples, fit with a single selectivity function (double-normal, dome-shaped).

Update Model '10w' Results

<u>Growth</u>
Growth parameters (size at age 0.5, size at age 15, von Bertalanffy growth rate '*K*') were estimated for two periods within the model: 1981-90, and 1991-10. For the 1981-90 period, sardines were estimated to grow to 9.78 cm SL by age 0.5, to 23.95 cm SL by age 15, with a growth rate (K) of 1.111 yr^{-1} For the 1991-10 period, sardines grew to 9.82 cm SL by age 0.5, to 24.02 cm SL by age 15, with a growth rate (K) of 0.370 yr^{-1}. Modeled length-at-age is displayed in Figure 2b and growth parameters and standard deviations are provided in Table 7.

The weight-at-length relationship, unchanged from Hill et al. (2009), is displayed in Figure 2a. Maturity and fecundity at length and age are displayed in Figure 3a-b. Parameters for these relationships are presented in Table 7.

<u>Selectivity estimates and fits to fishery composition data</u>
Selectivity estimates for each fishery and time period are displayed in Figures 14a-d. The ENS, SCA and CCA fisheries caught progressively smaller fish over time, but the shift was most pronounced for the SCA fishery, particularly SCA_S2 (Figure 14b). Selectivity for the PNW fishery shifted toward smaller fish after 2003 (Figure 14d).

Model fits to length frequencies and implied age-frequencies, along with associated Pearson residuals, are shown in Figures 15-26. Results are grouped by fleet so, for example, the reader can examine fits to length compositions, bubble plots of the input data, and bubble plots of Pearson residuals across facing pages. Corresponding fits to implied age compositions for the same fishery are subsequently found on the following two pages. Results indicate random residual patterns for most fleets. Some fisheries (e.g. SCA and PNW) displayed notable residuals patterns when the strongest year classes (e.g. 1997, 1998, and 2003) moved through each fishery.

Observed and effective sample sizes for length frequency and conditional age-at-length data are displayed in Figures 27-32. Input effective sample sizes for each fishery composition were iteratively reweighted (multiplicative constant) to match model estimates of variance.

Fits to DEPM and TEP Survey Indices

Fits to the DEPM and TEP series are displayed in Figures 33 and 34. Input CVs for each index were iteratively adjusted (additive constant) to match model estimates of variance. Catchability coefficient (q) for the DEPM series of female SSB was estimated to be 0.1715. The TEP series was best fitted with q=0.4568.

Fit to Aerial Survey Index

The northern aerial survey (Aerial_N) series was fit with q fixed at 1 and using dome-shaped selectivity, per Hill et al. (2009). The aerial survey observations of selected abundance were higher than biomass from the DEPM and TEP surveys, forcing population estimates to scale upward in the model. The update model estimate corresponding to the Aerial_N series of selected abundance was outside of the lower 95% confidence intervals for both survey estimates (Figure 35a). Fit to the aerial survey length composition, based on dome-shaped selectivity, is displayed in Figure 35b. Sensitivity of the update model to 2009 and 2010 aerial survey estimates, as well as to aerial selectivity assumptions, is further explored in the section 'Uncertainty, Sensitivity, and Unresolved Issues'.

Harvest and exploitation rates

Harvest rates (catch per selected biomass, 'continuous-*F*' method) by fishery for the base model are displayed in Figure 36.

Exploitation rates (calendar year catch/total mid-year biomass, ages 0+) by fishery and country for the update model '10w' are displayed in Figure 37. Total exploitation rate has trended upward since the decline in biomass commenced in 2001, reaching ≈23% in 2010.

Spawning stock biomass

Base model estimates of total SSB are presented in Tables 9-10 and Figure 38. Consistent with past assessments, biomass increased rapidly through the 1980s and 1990s, peaked at 1.3 mmt in 2000, and declines again to current low levels.

Recruitment

Time series of recruit (age-0) abundance are provided in Tables 9-10 and Figures 39-40. Recruitment increased rapidly through the mid-1990s, peaking at 17.156 billion fish in 1997, 19.743 billion in 1998, and 18.578 billion fish in 2003. Recruitments have been notably lower from 2006 to 2009.

Stock biomass (ages 1+) for PFMC management

Stock biomass, used for management purposes, is defined as the sum of the biomass for sardines ages 1 and older. Base model estimates of stock biomass are shown in Table 10 and Figure 40 (model '10s'). Stock biomass increased rapidly through the 1980s and 1990s, starting at 8,603 mt in 1981 and peaking at 1.57 mmt in 2000. Stock biomass has subsequently declined to the present (July 1, 2010) level of 537,173 mt.

Stock-recruitment

The Ricker stock-recruitment relationship for the base model is displayed in Figure 41a. The estimate of steepness (h) was 2.25301 for the base model (Table 7). Ricker model fit to the recruitment time series is shown in Figure 41b.

Recruitment deviations (main period) were estimated from 1981 through 2008. Recruitments for 2009 and 2010 were taken directly from the stock-recruitment curve. Sigma-R was fixed at 0.8153 in the final tuned model. Recruitment deviations and their asymptotic standard errors are shown in Figure 42a,b.

Uncertainty, Sensitivity, and Unresolved Issues

Retrospective analysis

Retrospective analyses for this update focused on the effect of each new data element on modeled likelihood components and derived quantities of interest (Table 8). Building from the final model of 2009 (Hill et al. 2009a,b), revised or updated data sources were incrementally added to the model: (1) first without advancing the range of years for estimating recruitment deviations, adjusting sigma-R, or adjusting variances (see Table 8, models '09a' through '10o'); and then (2) advancing recruitment devs by one year and tuning the model without Aerial data (models 10p and 10q), and (3) adding the revised Aerial 2009 and 2010 data in various combinations (Table 8, models '10t' through '10w').

Early analyses indicated a notable effect of the new CCA_S2 length composition on population scaling. Early runs without the 2009 CCA_S2 length composition scaled higher than when these data were included (compare models '10e', '10g' and '10h' in Table 8). However, this effect disappeared in later model runs which included all new data sources. The tuned model ('10t') was run again without the new CCA-S2 length composition (model '10t2'), and the opposite effect occurred, i.e. population estimates scaled lower when this length composition was excluded.

Sensitivity to revision of 2009 aerial estimate

Including the revised 2009 aerial biomass CV down-weighted this surveys' influence within the assessment model. Comparisons between the final 2009 model (Aerial-09 CV=0.55) , the 2009 model with the revised CV ('09a'), and the 2010 update model minus the 2010 aerial data ('10t') are made in Table 8 and Figure 43. As expected, stock biomass (Figure 43a) and recruitment (Figure 43b) estimates scaled substantially downward.

Sensitivity to addition of 2010 aerial survey estimates

The 2010 aerial survey estimates were examined in a number of ways through the course of the update review (see Jagielo 2010 and the CPS Subcommittee report). To examine the influence of the 2010 aerial data the STAT was asked to provide the following model runs, each described in Table 8:

1) Model '10t': the tuned update model including all new data minus Aerial 2010;
2) Model '10u': included separate 2010 aerial estimates from the north (Aerial-10N) and south (Aerial10S), each modeled with its own selectivity;
3) Model '10v': included only the northern aerial data (Aerial-10N), with length selectivity estimated separately from Aerial-09;
4) Update model '10w', northern aerial data from 2009 and 2010 modeled as a single series with shared selectivity.

Likelihoods and derived quantities for these models are presented in Table 8. Stock biomass and recruitment time series for these runs are presented in Figures 43a&b. All models incorporating at least some portion of 2010 aerial data ('10u', '10v', '10w') had population estimates scaling higher than the model omitting the 2010 data '10t' (Table 8, Figure 43). This result occurred despite the 2010 aerial estimate being only 14% of the value from 2009. This outcome is attributed to (1) the 2010 aerial CV being smaller than that estimated for 2009 (increasing influence of the 2010 estimate), (2) selectivity for the survey being dome-shaped, with modeled lengths representing a narrow size range of the population (~4 cm), and (3) sardine sizes in the north increased from 2009 to 2010 (see Figures 13and 35b). Model '10u', which included the California survey data from 2010, scaled slightly lower than the update model '10w'. This was due to the relatively small amount biomass observed off California in combination with smaller sized fish being selected, forcing the model to estimate lower numbers-at-size for that segment of the population.

Uncertainty regarding aerial survey selectivity assumptions

In the 2009 final and 2010 update models, length compositions from the aerial survey (northern region) were fit using dome-shaped selectivity assumptions. However, most of the biomass observed in the northern survey was in the same region where the Oregon and Washington fisheries operate. Length compositions from the PNW fishery are currently best fit using asymptotic selectivity (see Figure 14d). This modeling inconsistency was identified by the STAT and STAR panel as an unresolved issue in the 2009 assessment (Hill et al. 2009; STAR 2009). Altering the aerial selectivity function was deemed outside the bounds of change permitted in an assessment update, however, the SSC's CPS Subcommittee report (Nov 2010 briefing book) did recommend this as an area for further analysis prior to the 2011 STAR.

Subsequent to the October 2010 update review, the STAT ran alternative models '10x1' and 10x2', both variants of '10w', to explore this uncertainty:

(1) Model '10x1', where the aerial survey length compositions were fit to asymptotic selectivity function (estimating peak and ascending slope of the double-normal function, per the PNW fishery) with no other changes to the model;
(2) Model '10x2', where the variance associated with SS fit to aerial length data in '10x1' was adjusted (i.e. tuned) to match model estimates.

Selectivity ogives and model fits to the length data are compared in Figure 44a&b. Model fits to the aerial length data degraded when forced to fit to an asymptotic selectivity, although the lack of fit is no worse than fits estimated for some fisheries data in certain semesters.
Model fits to the aerial abundance estimates improved notably under asymptotic selectivity assumptions. As mentioned previously, the update model estimate corresponding to the Aerial_N series of selected abundance (domed-shape) was outside of the lower 95% confidence intervals for both survey estimates (Figure 45a). Models run with asymptotic selectivity ('10x1' & '10x2') both displayed reasonable fits within the 95% confidence limits of the observations (Figure 45b).

Likelihoods and derived quantities of interest for the alternative models are shown in Table 8. The likelihood for model '10x1' increased due to the loss of fit to the length composition data. Once model variances for these data were adjusted (model '10x2'), the total likelihood of the model matched that of the update model '10w' (Table 8).

Stock biomass and recruits for domed ('10w') versus asymptotic ('10x1' and '10x2') selectivity models are displayed in Figure 46. Population estimates for asymptotic selectivity models scaled considerably lower than the update model '10w'. This result highlights the importance of considering selectivity assumptions for this survey, particularly given that it is used as a measure of absolute population abundance with q=1.

HARVEST GUIDELINE FOR 2011

Based on results from the update model '10w', the harvest guideline (HG) for the U.S. fishery in calendar year 2011 would be 50,526 mt. Parameters used to determine this harvest guideline are discussed below and presented in Table 11. To calculate the harvest guideline for 2011, we used the maximum sustainable yield (MSY) control rule defined in Amendment 8 of the Coastal Pelagic Species-Fishery Management Plan, Option J, Table 4.2.5-1, PFMC (1998). This formula is intended to prevent Pacific sardine from being overfished and maintain relatively high and consistent catch levels over the long-term. The Amendment 8 harvest formula for sardines is:

$$HG_{2011} = (BIOMASS_{2010} – CUTOFF) \bullet FRACTION \bullet DISTRIBUTION;$$

where HG_{2011} is the total USA (California, Oregon, and Washington) harvest guideline in 2011, $BIOMASS_{2010}$ is the estimated July 1, 2010 stock biomass (ages 1+) from the assessment (537,173 mt), CUTOFF is the lowest level of estimated biomass at which harvest is allowed (150,000 mt), FRACTION is an environmentally-based percentage of biomass above the CUTOFF that can be harvested by the fisheries, and DISTRIBUTION (87%) is the average portion of BIOMASS assumed in U.S. waters.

The value for FRACTION in the harvest control rule for Pacific sardines is a proxy for F_{msy}. Given that F_{msy} and the productivity of the sardine stock have been shown to increase when relatively warm-ocean conditions persist, the following formula has been used to determine an appropriate (sustainable) FRACTION value:

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

where T is the running average sea-surface temperature at Scripps Pier, La Jolla, California during the three preceding seasons (July-June). Ultimately, under Option J (PFMC 1998), F_{msy} is constrained and ranges between 5% and 15%. Based on the T values observed throughout the period covered by this stock assessment (Figure 47), the appropriate exploitation fraction has consistently been 15%; and this remains the case under current conditions (T_{2010} = 17.90 °C). The HG for 2011 (50,526 mt) is ≈30% lower than the 2010 HG and is the lowest since onset management under the federal CPS-FMP (Table 12, Figure 1).

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Table 1. Pacific sardine landings for major fishing regions off the West Coast of North America, calendar years 1981-2010. The stock assessment includes northern subpopulation catches from Ensenada, México to British Columbia, Canada. \1

	MÉXICO					UNITED STATES					CANADA	
Calendar Year	Golfo de California\2*	Bahia Magdalena	Isla Cedros	Ensenada	México Total	So. Calif.	Cen. Calif.	Oregon	Wash.	U.S. Total	British Columbia	GRAND TOTAL
1981	93,989	10,557	1,705	0	106,251	6	0	0	0	6	0	106,256
1982	71,425	9,392	2,362	0	83,179	131	0	0	0	131	0	83,310
1983	111,526	2,386	1,580	274	115,766	352	0	0	0	352	0	116,119
1984	146,467	2,454	1,044	0	149,965	171	64	0	0	235	0	150,199
1985	160,391	10,979	1,429	3,722	176,521	559	34	0	0	593	0	177,114
1986	240,226	14,203	2,808	243	257,480	1,051	113	0	0	1,164	0	258,644
1987	272,574	8,599	2,856	2,432	286,461	2,056	39	0	0	2,095	0	288,556
1988	261,363	12,081	846	2,035	276,325	3,775	10	0	0	3,785	0	280,109
1989	294,095	7,746	2,344	6,224	310,410	3,443	238	0	0	3,681	0	314,091
1990	109,942	16,975	2,086	11,375	140,378	2,508	307	0	0	2,815	0	143,193
1991	113,631	15,893	551	31,392	161,468	6,774	976	0	0	7,750	0	169,217
1992	6,858	5,026	348	34,568	46,801	16,061	3,128	4	0	19,193	0	65,993
1993	7,594	7,671	1,505	32,045	48,814	15,488	705	0	0	16,192	0	65,007
1994	127,486	33,787	1,685	20,877	183,835	10,346	2,359	0	0	12,705	0	196,540
1995	174,951	34,541	0	35,396	244,888	36,561	4,928	0	0	41,489	23	286,400
1996	200,870	25,795	0	39,065	265,730	25,171	8,885	0	0	34,056	0	299,786
1997	203,529	14,656	0	68,439	286,624	32,837	13,361	0	0	46,198	71	332,893
1998	59,400	2,493	0	47,812	109,705	31,975	9,081	1	0	41,056	488	151,249
1999	51,266	11,795	0	58,569	121,630	42,863	13,884	775	0	57,522	24	179,177
2000	65,593	42,276	0	67,845	175,715	46,835	11,367	9,529	4,765	72,496	1,722	249,933
2001	190,862	40,572	0	46,071	277,505	47,662	7,241	12,780	10,837	78,520	1,266	357,292
2002	220,360	50,969	0	46,845	318,174	49,366	14,078	22,711	15,212	101,367	739	420,280
2003	198,757	53,862	0	41,342	293,961	30,289	7,448	25,258	11,604	74,599	977	369,537
2004	102,034	47,173	0	41,897	191,104	32,393	15,308	36,112	8,799	92,613	4,438	288,155
2005	94,341	40,000	0	55,323	189,664	30,253	7,940	45,008	6,929	90,130	3,232	283,025
2006	133,650	52,429	0	57,237	243,316	33,286	17,743	35,648	4,099	90,776	1,575	335,667
2007	178,205	55,550	0	36,847	270,602	46,199	34,782	42,052	4,663	127,695	1,522	399,820
2008	488,573	36,289	0	66,866	591,728	31,089	26,711	22,940	6,435	87,175	10,425	676,675
2009	---	---	0	56,357	---	12,565	25,012	21,481	8,026	67,084	15,334	---
2010	---	---	0	---	---	*26,291*	*4,842*	*19,240*	*12,928*	*63,301*	---	---

\1 U.S. landings are from the PacFIN database. U.S. landings for 2010 are incomplete. British Columbia landings were provided by the Canada Department of Fisheries and Oceans. Mexican landings for 2009 were presented by INP scientists during the MEXUS-Pacifico stock assessment workshop in Ensenada, Mexico (Feb 24-26, 2010).

\2 Gulf of California catch statistics are compiled by an Oct-Sep fishing season, e.g. the 2008 value represents landings between Oct. 2007 and Sep. 2008.

Table 2. Pacific sardine landings (mt) by model year, semester, and fishery for the base model.

Model Year	Sem	ENS	SCA	CCA	PNW
1981	1	0	6	0	0
1981	2	0	57	0	0
1982	1	0	74	0	0
1982	2	150	263	0	0
1983	1	124	89	0	0
1983	2	0	159	0	0
1984	1	0	12	64	0
1984	2	3,174	312	10	0
1985	1	548	247	24	0
1985	2	99	854	65	0
1986	1	143	197	48	0
1986	2	975	1,282	22	0
1987	1	1,457	773	17	0
1987	2	620	3,012	8	0
1988	1	1,415	763	3	0
1988	2	461	1,919	235	0
1989	1	5,763	1,524	3	0
1989	2	5,900	1,887	245	0
1990	1	5,475	621	62	0
1990	2	9,271	5,082	90	0
1991	1	22,121	1,692	885	0
1991	2	3,327	5,884	1,113	0
1992	1	31,242	10,177	2,014	4
1992	2	18,648	11,759	369	0
1993	1	13,397	3,729	335	0
1993	2	5,712	7,738	629	0
1994	1	15,165	2,607	1,730	0
1994	2	18,227	28,122	443	0
1995	1	17,169	8,439	4,485	23
1995	2	15,666	14,409	2,486	0
1996	1	23,399	10,762	6,399	0
1996	2	13,498	11,524	343	44
1997	1	54,941	21,313	13,018	27
1997	2	20,239	19,094	2,747	1
1998	1	27,573	12,881	6,334	488
1998	2	34,760	24,050	7,741	75
1999	1	23,810	18,813	6,143	725
1999	2	33,933	34,119	1,285	430
2000	1	33,912	12,716	10,082	15,586
2000	2	16,545	29,343	774	2,337
2001	1	29,526	18,318	6,467	22,547
2001	2	17,422	26,621	1,575	3,136
2002	1	29,424	22,745	12,503	35,526
2002	2	15,514	20,380	5,086	597
2003	1	25,827	9,909	2,363	37,242
2003	2	11,213	15,232	2,146	2,618
2004	1	30,684	17,161	13,163	46,731
2004	2	17,323	15,419	115	1,016
2005	1	38,000	14,834	7,825	54,153
2005	2	17,601	17,158	2,033	102
2006	1	39,636	16,128	15,711	41,221
2006	2	13,981	26,344	6,013	0
2007	1	22,865	19,855	28,769	48,237
2007	2	23,488	24,127	2,515	0
2008	1	43,378	6,962	24,196	39,800
2008	2	27,858	9,252	11,080	0
2009	1	28,499	3,313	13,932	44,841
2009	2	27,858	19,417	2,909	0
2010	1	28,499	6,874	1,933	47,502
2010	2	27,858	19,417	2,909	0

Table 3. Number of composition samples (input effective sample sizes) by model year, semester, and fishery.

Model Year	Sem	ENS	SCA	CCA	PNW
1981	1	0.00	7.00	0.00	0.00
1981	2	0.00	9.52	0.00	0.00
1982	1	0.00	14.44	0.00	0.00
1982	2	0.00	23.32	0.00	0.00
1983	1	0.00	12.16	0.00	0.00
1983	2	0.00	7.52	0.00	0.00
1984	1	0.00	0.00	0.00	0.00
1984	2	0.00	8.64	0.00	0.00
1985	1	0.00	15.00	0.00	0.00
1985	2	0.00	33.40	0.00	0.00
1986	1	0.00	20.20	0.00	0.00
1986	2	0.00	44.20	0.00	0.00
1987	1	0.00	29.40	0.00	0.00
1987	2	0.00	87.68	0.00	0.00
1988	1	0.00	22.76	0.00	0.00
1988	2	0.00	46.80	0.00	0.00
1989	1	3.88	45.76	0.00	0.00
1989	2	2.92	50.28	0.00	0.00
1990	1	9.96	14.56	4.00	0.00
1990	2	26.36	86.60	5.00	0.00
1991	1	49.64	18.88	20.00	0.00
1991	2	38.00	77.08	9.00	0.00
1992	1	19.24	95.48	0.00	0.00
1992	2	9.56	64.84	0.00	0.00
1993	1	4.96	22.12	0.00	0.00
1993	2	8.88	104.84	0.00	0.00
1994	1	10.56	25.92	0.00	0.00
1994	2	9.20	277.56	0.00	0.00
1995	1	12.68	58.52	0.00	0.00
1995	2	7.32	60.88	11.00	0.00

Model Year	Sem	ENS	SCA	CCA	PNW
1996	1	12.80	33.96	87.64	0.00
1996	2	6.32	59.00	2.00	0.00
1997	1	14.16	53.88	54.96	0.00
1997	2	5.24	59.80	5.00	0.00
1998	1	7.56	53.88	52.00	0.00
1998	2	13.92	60.56	14.00	0.00
1999	1	10.60	48.60	0.00	2.96
1999	2	11.52	58.28	0.00	4.16
2000	1	11.92	56.20	0.00	97.49
2000	2	8.56	67.96	4.00	10.56
2001	1	5.80	66.80	27.92	97.38
2001	2	8.68	64.84	12.96	17.92
2002	1	0.00	69.92	35.00	199.67
2002	2	0.00	70.00	19.00	4.96
2003	1	0.00	61.00	8.00	180.87
2003	2	0.00	67.28	8.00	10.92
2004	1	0.00	69.00	23.96	136.37
2004	2	0.00	70.96	0.00	5.00
2005	1	0.00	73.00	24.00	105.47
2005	2	0.00	67.00	32.00	3.00
2006	1	0.00	60.96	58.00	26.96
2006	2	0.00	73.84	46.96	0.00
2007	1	0.00	72.08	68.04	112.76
2007	2	0.00	52.64	14.80	0.00
2008	1	0.00	25.48	29.84	320.54
2008	2	0.00	19.88	19.88	0.00
2009	1	0.00	13.00	23.00	95.00
2009	2	0.00	62.00	37.00	0.00

Table 4. Fishery-independent indices of Pacific sardine relative abundance. Complete details regarding estimation of DEPM and TEP values can be found in Tables 5 and 6. In the SS model, indices had a lognormal error structure with units of standard error of $\log_e$(index). Variance of the observations was only available as a CV, so the S.E. was approximated as sqrt($\log_e(1+CV^2)$).

Model Year	DEPM	SE of ln(Index)	TEP	SE of ln(Index)	TEP_all	SE of ln(Index)	Aerial	SE of ln(Index)
1981	---	---	---	---	---	---	---	---
1982	---	---	---	---	---	---	---	---
1983	---	---	---	---	---	---	---	---
1984	---	---	---	---	---	---	---	---
1985	---	---	---	---	---	---	---	---
1986	4,061	0.60	---	---	11,220	0.73	---	---
1987-1	8,661	0.56	---	---	25,637	0.48	---	---
1987-2	---	---	17,266	0.35	17,266	0.35	---	---
1988	---	---	---	---	---	---	---	---
1989	---	---	---	---	---	---	---	---
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	69,065	0.29	---	---	73,374	0.21	---	---
1994	---	---	---	---	---	---	---	---
1995	---	---	97,923	0.40	97,923	0.40	---	---
1996	---	---	482,246	0.21	482,246	0.21	---	---
1997	---	---	369,038	0.33	369,038	0.33	---	---
1998	---	---	332,177	0.34	332,177	0.34	---	---
1999	---	---	1,252,539	0.39	1,252,539	0.39	---	---
2000	---	---	928,806	0.38	928,806	0.38	---	---
2001	---	---	236,660	0.17	236,660	0.17	---	---
2002	---	---	556,177	0.18	556,177	0.18	---	---
2003	145,274	0.23	---	---	307,795	0.24	---	---
2004	459,943	0.55	---	---	486,950	0.40	---	---
2005	---	---	651,994	0.25	651,994	0.25	---	---
2006	198,404	0.30	---	---	306,297	0.26	---	---
2007	66,395	0.27	---	---	128,118	0.21	---	---
2008	99,162	0.24	---	---	162,188	0.22	---	---
2009	58,447	0.40	---	---	97,838	0.29	1,236,910	0.90
2010	---	---	---	---	---	---	173,390	0.40

Table 5. Spawning biomass-related parameters: daily egg production/0.05m^2 (P_0),daily mortality rate (z), survey area (km^2), two daily specific fecundities: (RSF/W), and (SF/W); spawning biomass, female spawning biomass, total egg production (TEP) and sea surface temperature for 1986, 1987, 1994,2005 and 2007-2010.

Calendar year	Season	Region	[1]P_0/0.05m^2 (cv)	Z (CV)	[2]RSF/W based on S_1	[3]RSF/W based on S_{12}	[3]FS/W based on S_{12}	[4]Area (km^2)	[5]S. biomass (cv)	S. biomass females (cv)	S. biomass females (Sum of R1andR2) (cv)	total egg production (TEP)	Mean temper-ature (°C) for positive eggs	Mean temper-ature (°C) from Calvet
1986 (Aug)	1986	[6]S	1.48(1)	1.59(0.5)	38.31	43.96	72.84	6478	4362 (1.00)	2632 (1)		9587.44		
		N	0.32(0.25)		8.9	13.34	23.89	5333	2558 (0.33)	1429 (0.28)		1706.56		
		whole	0.95(0.84)		23.61	29.89	49.97	11811	7767 (0.87)	4491 (0.86)	4061 (0.66)	11220.45	18.7	18.5
1987 (July)	1987	1	1.11(0.51)	0.66(0.4)	38.79	37.86	57.05	22259	13050 (0.58)	8661 (0.56)		24707.49		
		2	0					15443	0	0		0		
		whole	0.66(0.51)		38.79	37.86	57.05	37702	13143 (0.58)	8723 (0.56)	8661 (0.56)	25637.36	18.9	18.1
1994	1993	1	0.42(0.21)	0.12(0.91)	11.57	11.42	21.27	174880	128664 (0.30)	69065 (0.30)		73449.6		
		2	0(0)	-				205295	0	0		0		
		whole	0.193(0.21)		11.57	11.42	21.27	380175	128531 (0.31)	68994 (0.30)	69065 (0.30)	73373.775	14.3	14.7
2004	2003	1	3.92(0.23)	0.25(0.04)	27.03	26.2	42.37	68204	204118 (0.27)	126209 (0.26)		267359.68		
		2	0.16(0.43)		-	-	-	252416	30833 (0.45)	19065 (0.44)		40386.56		
		whole	0.96(0.24)		27.03	26.2	42.37	320620	234958 (0.28)	145297 (0.27)	145274 (0.23)	307795.2	13.4	13.7
2005	2004	1	8.14(0.4)	0.58(0.2)	31.49	25.6	46.52	46203	293863 (0.45)	161685 (0.42)		376092.42		
		2	0.53(0.69)		3.76	3.2	7.37	207417	686168 (0.86)	298258 (0.89)		109931.01		
		whole	1.92(0.42)		15.67	12.89	27.11	253620	755657 (0.52)	359209 (0.50)	459943 (0.60)	486950.4	14.21	14.1
2007	2006	1	1.32(0.2)	0.13(0.36)	12.06	13.37	27.54	142403	281128 (0.42)	136485 (0.36)		187971.96		
		2	0.56(0.46)		24.48	23.41	38.94	213756	102998 (0.67)	61919 (0.62)		119703.36		
		whole	0.86(0.26)		15.68	16.17	31.52	356159	380601 (0.39)	195279 (0.36)	198404 (0.31)	306296.74	13.7	13.6
2008	2007	1	1.45(0.18)	0.13(0.29)	57.4	53.89	68.54	53514	29798 (0.20)	22642 (0.19)		77595.3		
		2	0.202(0.32)		13.84	12.6	22.57	244435	78359 (0.45)	43753 (0.42)		49375.87		
		whole	0.43(0.21)		21.82	20.31	32.2	297949	126148 (0.40)	79576 (0.35)	66395 (0.28)	128118.07	13.1	13.1
2009	2008	1	1.76(0.22)	0.25(0.19)	19.50	20.37	36.12	74966	129520 (0.31)	73048 (0.29)		131940.16		
		2	0.15(0.27)		14.25	14.34	22.97	199929	41816 (0.38)	26114 (0.38)		29989.35		
		whole	0.59(0.22)		17.01	17.53	29.11	274895	185084 (0.28)	111444 (0.27)	99162 (0.24)	162188.05	13.6	13.5
2010	2009	1	1.70(0.22)	0.33(0.23)	21.08	24.02	51.56	27462	38875 (0.34)	18111 (0.26)		46685.4		
		2	0.22(0.42)		14.55	16.20	26.65	244311	66345 (0.52)	40336 (0.52)		53748.42		
		whole	0.36(0.29)		16.08	18.07	31.49	271773	108280 (0.36)	62131 (0.37)	**58447 (0.42)**	97838.28	13.7	13.9

1: P_0 for the whole is the weighted average with area as the weight.

2. The estimates of adult parameters for the whole area were unstratified and RSF/W was based on original S_1 data of day-1 spawning females. For 2004, 27.03 was based on sex ratio= 0.618 while past biomass used RSF/W of 21.86 based on sex ratio = 0.5.(Lo et al. 2008)

3. The estimates of adult parameters for the whole area were unstratified. Batch fecundity was estimated with error term. For 1987 and 1994, estimates were based on S_1 using data of day-1 spawning females. For 2004, all trawls were in region 1 and value was applied to region 2,

4. Region 1, since 1997, is the area where the eggs/min from CUFES $\geq$1 and prior to 1997, is the area where the eggs/0.05m^2 >0 from CalVET tows

5: For the spawning biomasses, the estimates for the whole area uses unstratified adult parameters

Table 6. Pacific sardine female adult parameters for surveys conducted in the standard daily egg production method (DEPM) sampling area off California (1994 includes females from off northern Baja California).

		1994	1997	2001	2002	2004	2005	2006	2007	2008	2009	2010
Midpoint date of trawl survey		22-Apr	25-Mar	1-May	21-Apr	25-Apr	13-Apr	2-May	24-Apr	16-Apr	27-Apr	20-Apr
Beginning and ending dates of positive collections		04/15-05/07	03/12-04/06	05/01-05/02	04/18-04/23	04/22-04/27	03/31-04/24	05/01-05/07	04/19-04/30	04/13-04/27	04/17-05/06	04/12-04/27
N collections with mature females		37	4	2	6	16	14	7	14	12	29	17
N collection within Region 1		19	4	2	6	16	6	2	8	4	15	3
Average surface temperature (°C) at collection locations		14.36	14.28	12.95	12.75	13.59	14.18	14.43	13.6	12.4	12.93	13.62
Female fraction by weight	**R**	0.538	0.592	0.677	0.385	0.618	0.469	0.451	0.515	0.631	0.602	0.574
Average mature female weight (grams):												
with ovary	W_f	82.53	127.76	79.08	159.25	166.99	65.34	67.41	81.62	102.21	112.40	129.51
without ovary	W_{of}	79.33	119.64	75.17	147.86	156.29	63.11	64.32	77.93	97.67	106.93	121.34
Average batch fecundity[a] (mature females, oocytes estimated)	**F**	24283	42002	22456	54403	55711	17662	18474	21760	29802	29790	39304
Relative batch fecundity (oocytes/g)		294	329	284	342	334	270	274	267	292	265	303
N mature females analyzed		583	77	9	23	290	175	86	203	187	467	313
N active mature females		327	77	9	23	290	148	72	187	177	463	310
Spawning fraction of mature females[b]	**S**	0.074	0.133	0.111	0.174	0.131	0.124	0.0698	0.114	0.1186	0.1098	0.1038
Spawning fraction of active females[c]	S_a	0.131	0.133	0.111	0.174	0.131	0.155	0.083	0.134	0.1187	0.1108	0.1048
Daily specific fecundity	$\frac{RSF}{W}$	11.7	25.94	21.3	22.91	27.04	15.67	8.62	15.68	21.82	17.53	18.07

[a] 1994-2001 estimates were calculated using F_b = -10858 + 439.53 W_{of} (Macewicz et al. 1996), 2004 used F_b = 356.46W_{of}. (Lo and Macewicz 2004), 2005 used F_b = -6085 + 376.28 W_{of} (Lo and Macewicz 2006), 2006 used F_b = -396 + 293.39 W_{of} (Lo et al. 2007a); 2007 used F_b = 279.23W_{of} (Lo et al. 2007b), 2008 used F_b = 305.14W_{of} (Lo et al. 2008), 2009 used F_b = -4598 + 326.78W_{of} + e (Lo et al. 2009).
[b] Mature females include females that are active and those that are postbreeding (incapable of further spawning this season).
[c] Active mature females are capable of spawning and have ovaries containing oocytes with yolk or postovulatory follicles less than 60 hours old.

Table 7. Update model '10w' parameters and asymptotic standard deviations.

Parameter	Phase	Min	Max	Initial	Final Value	Std Dev
NatM	-3	0.3	0.7	0.4	0.4	_
L_at_Amin	-3	3	15	9.8	9.8	_
L_at_Amin_BLK_mult1981	3	-2	2	0.00215292	-0.0172376	0.0349086
L_at_Amin_BLK_mult1991	3	-2	2	-0.00305681	0.0191278	0.0142922
L_at_Amax	-3	20	30	24	24	_
L_at_Amax_BLK_mult1981	3	-2	2	-0.0463661	-0.0497648	0.00570444
L_at_Amax_BLK_mult1991	3	-2	2	0.0201076	0.0163254	0.00544525
VonBert_K	-3	0.05	0.99	0.5	0.5	_
VonBert_K_BLK_mult1981	3	-2	2	0.572263	0.610771	0.0459234
VonBert_K_BLK_mult1991	3	-2	2	-0.106793	-0.129712	0.0331108
CV_young	3	0.05	0.3	0.171502	0.169318	0.00544429
CV_old	3	0.01	0.1	0.032336	0.0359333	0.0018543
Wtlen_1	-3	-3	3	9.47212E-06	9.47212E-06	_
Wtlen_2	-3	-3	5	3.14752	3.14752	_
Mat50%	-3	9	19	16	16	_
Mat_slope	-3	-20	3	-0.7571	-0.7571	_
Eg/gm_inter	-3	0	10	1	1	_
Eg/gm_slope_wt	-3	-1	5	0	0	_
SR_R0	1	3	25	16	15.3469	0.175376
SR_R1_offset	2	-15	15	-4.15911	-4.04985	0.284419
SR_steep	6	0.2	3	2.36989	2.25301	0.179045
SR_sigmaR	-3	0	2	0.815314	0.815314	_
InitAgeComp_6	_	_	_	_	-1.19209	0.563149
InitAgeComp_5	_	_	_	_	-1.24113	0.552946
InitAgeComp_4	_	_	_	_	-1.04782	0.529335
InitAgeComp_3	_	_	_	_	-0.975371	0.491765
InitAgeComp_2	_	_	_	_	-0.807052	0.399894
InitAgeComp_1	_	_	_	_	0.270767	0.228329
RecrDev_1981	_	_	_	_	-0.881323	0.308318
RecrDev_1982	_	_	_	_	-0.16005	0.262364
RecrDev_1983	_	_	_	_	-0.493425	0.249459
RecrDev_1984	_	_	_	_	-0.877292	0.230923
RecrDev_1985	_	_	_	_	-0.207951	0.208757
RecrDev_1986	_	_	_	_	-0.134712	0.217857
RecrDev_1987	_	_	_	_	-0.135672	0.200846
RecrDev_1988	_	_	_	_	-0.668343	0.195423
RecrDev_1989	_	_	_	_	-0.231532	0.184987
RecrDev_1990	_	_	_	_	0.484353	0.171711
RecrDev_1991	_	_	_	_	0.106411	0.189568
RecrDev_1992	_	_	_	_	0.920741	0.154275
RecrDev_1993	_	_	_	_	0.868006	0.138001
RecrDev_1994	_	_	_	_	-0.199195	0.139571
RecrDev_1995	_	_	_	_	0.276566	0.132875
RecrDev_1996	_	_	_	_	1.39805	0.131966
RecrDev_1997	_	_	_	_	1.52258	0.115985
RecrDev_1998	_	_	_	_	-0.0153356	0.180581
RecrDev_1999	_	_	_	_	0.198351	0.252337
RecrDev_2000	_	_	_	_	1.36771	0.268626
RecrDev_2001	_	_	_	_	-1.18492	0.30457
RecrDev_2002	_	_	_	_	1.68366	0.157478
RecrDev_2003	_	_	_	_	0.808737	0.12857

Table 7 (cont'd). Update model '10w' parameters and asymptotic standard deviations.

Parameter	Phase	Min	Max	Initial	Final Value	Std Dev
RecrDev_2004	_	_	_	_	0.896903	0.123489
RecrDev_2005	_	_	_	_	-0.113255	0.187733
RecrDev_2006	_	_	_	_	0.0705939	0.224386
RecrDev_2007	_	_	_	_	-0.324432	0.250383
RecrDev_2008	_	_	_	_	0.0174666	0.297973
Q_base_7_DEPM	5	-3	3	-1.10601	-1.76344	0.263323
Q_base_8_TEP	5	-3	3	-0.374949	-0.783497	0.270047
Q_base_12_Aerial_N	-5	-3	3	0	0	_
SizeSel_1P_1_ENS_BLK_repl1981	4	10	26	23.8106	23.799	0.105235
SizeSel_1P_1_ENS_BLK_repl1992	4	10	26	16.5277	16.4842	0.294933
SizeSel_1P_1_ENS_BLK_repl1999	4	10	26	16.9992	16.9467	0.469745
SizeSel_1P_2_ENS_BLK_repl1981	-4	-5	3	-4.9	-4.9	_
SizeSel_1P_2_ENS_BLK_repl1992	4	-5	3	-0.51709	-0.511144	0.121436
SizeSel_1P_2_ENS_BLK_repl1999	4	-5	3	-1.68387	-1.72382	0.496769
SizeSel_1P_3_ENS_BLK_repl1981	4	-1	9	3.01542	3.06796	0.0876759
SizeSel_1P_3_ENS_BLK_repl1992	4	-1	9	0.940063	0.921007	0.26962
SizeSel_1P_3_ENS_BLK_repl1999	4	-1	9	1.44534	1.44304	0.368585
SizeSel_1P_4_ENS_BLK_repl1981	4	-4	9	-3.99421	-3.99572	0.138741
SizeSel_1P_4_ENS_BLK_repl1992	4	-1	9	0.145243	0.152359	0.57283
SizeSel_1P_4_ENS_BLK_repl1999	4	-1	9	0.928352	0.994362	0.48974
SizeSel_1P_5_ENS_BLK_repl1981	-4	-10	10	-10	-10	_
SizeSel_1P_5_ENS_BLK_repl1992	-4	-10	10	-10	-10	_
SizeSel_1P_5_ENS_BLK_repl1999	-4	-10	10	-10	-10	_
SizeSel_1P_6_ENS_BLK_repl1981	4	-10	10	-0.630716	-0.916343	0.741937
SizeSel_1P_6_ENS_BLK_repl1992	4	-10	10	-3.06322	-3.12107	1.10975
SizeSel_1P_6_ENS_BLK_repl1999	4	-10	10	-5.80902	-6.26152	5.58637
SizeSel_2P_1_SCA_S1_BLK_repl1981	4	10	26	21.3865	21.021	0.750232
SizeSel_2P_1_SCA_S1_BLK_repl1992	4	10	26	18.2913	18.2796	0.257138
SizeSel_2P_1_SCA_S1_BLK_repl1999	4	10	26	16.269	16.1859	0.176412
SizeSel_2P_2_SCA_S1_BLK_repl1981	4	-5	3	0.913317	1.02618	10.8157
SizeSel_2P_2_SCA_S1_BLK_repl1992	-4	-5	3	-5	-5	_
SizeSel_2P_2_SCA_S1_BLK_repl1999	-4	-5	3	-5	-5	_
SizeSel_2P_3_SCA_S1_BLK_repl1981	4	-1	9	2.55337	2.44029	0.388236
SizeSel_2P_3_SCA_S1_BLK_repl1992	4	-1	9	2.20117	2.22223	0.13489
SizeSel_2P_3_SCA_S1_BLK_repl1999	4	-1	9	2.09147	2.04976	0.118689
SizeSel_2P_4_SCA_S1_BLK_repl1981	4	-1	9	3.99209	4.02374	110.482
SizeSel_2P_4_SCA_S1_BLK_repl1992	4	-1	9	0.812195	0.829477	0.376594
SizeSel_2P_4_SCA_S1_BLK_repl1999	4	-1	9	1.02159	1.05565	0.186635
SizeSel_2P_5_SCA_S1_BLK_repl1981	-4	-10	10	-10	-10	_
SizeSel_2P_5_SCA_S1_BLK_repl1992	-4	-10	10	-10	-10	_
SizeSel_2P_5_SCA_S1_BLK_repl1999	-4	-10	10	-10	-10	_
SizeSel_2P_6_SCA_S1_BLK_repl1981	4	-10	10	-1.10102	-0.954895	187.836
SizeSel_2P_6_SCA_S1_BLK_repl1992	4	-10	10	-2.91214	-2.92458	0.553828
SizeSel_2P_6_SCA_S1_BLK_repl1999	4	-10	10	-6.07771	-6.14575	1.18754
SizeSel_3P_1_SCA_S2_BLK_repl1981	4	10	26	25.9884	25.0612	1.16172
SizeSel_3P_1_SCA_S2_BLK_repl1992	4	10	26	16.4992	16.5318	0.184207
SizeSel_3P_1_SCA_S2_BLK_repl1999	4	10	26	14.5503	14.5443	0.139026
SizeSel_3P_2_SCA_S2_BLK_repl1981	4	-5	3	-1.33524	-1.08509	8.69191
SizeSel_3P_2_SCA_S2_BLK_repl1992	-4	-5	3	-5	-5	_
SizeSel_3P_2_SCA_S2_BLK_repl1999	-4	-5	3	-5	-5	_
SizeSel_3P_3_SCA_S2_BLK_repl1981	4	-1	9	3.46286	3.37644	0.195683

Table 7 (cont'd). Update model ‘10w’ parameters and asymptotic standard deviations.

Parameter	Phase	Min	Max	Initial	Final Value	Std Dev
SizeSel_3P_3_SCA_S2_BLK_repl1992	4	-1	9	1.80316	1.82068	0.10778
SizeSel_3P_3_SCA_S2_BLK_repl1999	4	-1	9	1.38232	1.33359	0.122576
SizeSel_3P_4_SCA_S2_BLK_repl1981	4	-1	9	3.98324	-0.279104	19.9693
SizeSel_3P_4_SCA_S2_BLK_repl1992	4	-1	9	1.55826	1.49939	0.266445
SizeSel_3P_4_SCA_S2_BLK_repl1999	4	-1	9	1.77072	1.72	0.116462
SizeSel_3P_5_SCA_S2_BLK_repl1981	-4	-10	10	-10	-10	_
SizeSel_3P_5_SCA_S2_BLK_repl1992	-4	-10	10	-10	-10	_
SizeSel_3P_5_SCA_S2_BLK_repl1999	-4	-10	10	-10	-10	_
SizeSel_3P_6_SCA_S2_BLK_repl1981	4	-10	10	-1.32541	-3.56383	95.6702
SizeSel_3P_6_SCA_S2_BLK_repl1992	4	-10	10	-2.29699	-2.30161	0.340829
SizeSel_3P_6_SCA_S2_BLK_repl1999	4	-10	10	-5.58708	-5.59383	0.661343
SizeSel_4P_1_CCA_S1_BLK_repl1981	4	10	26	20.5704	20.5679	0.0745024
SizeSel_4P_1_CCA_S1_BLK_repl1993	4	10	26	18.7071	18.7181	0.240037
SizeSel_4P_1_CCA_S1_BLK_repl1999	4	10	26	16.7855	16.8847	0.167535
SizeSel_4P_2_CCA_S1_BLK_repl1981	-4	-5	3	-5	-5	_
SizeSel_4P_2_CCA_S1_BLK_repl1993	-4	-5	3	-5	-5	_
SizeSel_4P_2_CCA_S1_BLK_repl1999	-4	-5	3	-5	-5	_
SizeSel_4P_3_CCA_S1_BLK_repl1981	4	-1	9	1.00548	1.03493	0.32998
SizeSel_4P_3_CCA_S1_BLK_repl1993	4	-1	9	2.3574	2.37841	0.135078
SizeSel_4P_3_CCA_S1_BLK_repl1999	4	-1	9	1.39614	1.44165	0.187898
SizeSel_4P_4_CCA_S1_BLK_repl1981	4	-4	9	-3.98895	-3.98755	0.395433
SizeSel_4P_4_CCA_S1_BLK_repl1993	4	-1	9	0.256433	0.254065	0.434312
SizeSel_4P_4_CCA_S1_BLK_repl1999	4	-1	9	0.160941	0.0277991	0.313219
SizeSel_4P_5_CCA_S1_BLK_repl1981	-4	-10	10	-10	-10	_
SizeSel_4P_5_CCA_S1_BLK_repl1993	-4	-10	10	-10	-10	_
SizeSel_4P_5_CCA_S1_BLK_repl1999	-4	-10	10	-10	-10	_
SizeSel_4P_6_CCA_S1_BLK_repl1981	4	-10	10	-0.965405	-1.06231	0.607682
SizeSel_4P_6_CCA_S1_BLK_repl1993	4	-10	10	-3.52512	-3.47048	0.686946
SizeSel_4P_6_CCA_S1_BLK_repl1999	4	-10	10	-3.01732	-3.14081	0.222695
SizeSel_5P_1_CCA_S2_BLK_repl1981	4	10	26	17.0497	17.0617	1.03794
SizeSel_5P_1_CCA_S2_BLK_repl1993	4	10	26	17.7861	17.7602	1.14938
SizeSel_5P_1_CCA_S2_BLK_repl1999	4	10	26	17.7112	16.5967	0.45393
SizeSel_5P_2_CCA_S2_BLK_repl1981	-4	-5	3	-5	-5	_
SizeSel_5P_2_CCA_S2_BLK_repl1993	-4	-5	3	-5	-5	_
SizeSel_5P_2_CCA_S2_BLK_repl1999	-4	-5	3	-5	-5	_
SizeSel_5P_3_CCA_S2_BLK_repl1981	4	-1	9	0.0205592	0.0213744	1.5834
SizeSel_5P_3_CCA_S2_BLK_repl1993	4	-1	9	2.41869	2.44574	0.521009
SizeSel_5P_3_CCA_S2_BLK_repl1999	4	-1	9	3.94488	3.08316	0.314228
SizeSel_5P_4_CCA_S2_BLK_repl1981	4	-4	9	6.24069	6.61543	44.2646
SizeSel_5P_4_CCA_S2_BLK_repl1993	4	-1	9	2.93323	2.95518	1.50798
SizeSel_5P_4_CCA_S2_BLK_repl1999	4	-1	9	1.3935	1.9707	0.309841
SizeSel_5P_5_CCA_S2_BLK_repl1981	-4	-10	10	-10	-10	_
SizeSel_5P_5_CCA_S2_BLK_repl1993	-4	-10	10	-10	-10	_
SizeSel_5P_5_CCA_S2_BLK_repl1999	-4	-10	10	-10	-10	_
SizeSel_5P_6_CCA_S2_BLK_repl1981	4	-10	10	0.814964	-1.42285	14.6003
SizeSel_5P_6_CCA_S2_BLK_repl1993	4	-10	10	-2.98473	-2.89733	9.85348
SizeSel_5P_6_CCA_S2_BLK_repl1999	4	-10	10	-2.73732	-3.1637	0.486916
SizeSel_6P_1_PNW_BLK_repl1981	4	10	26	22.2464	22.3504	0.374987
SizeSel_6P_1_PNW_BLK_repl2004	4	10	26	20.0824	20.03	0.302473
SizeSel_6P_2_PNW_BLK_repl1981	-4	-5	3	1	1	_
SizeSel_6P_2_PNW_BLK_repl2004	-4	-5	3	1	1	_

Table 7 (cont'd). Update model '10w' parameters and asymptotic standard deviations.

Parameter	Phase	Min	Max	Initial Value	Final Value	Std Dev
SizeSel_6P_3_PNW_BLK_repl1981	4	-1	9	2.16289	2.22946	0.209262
SizeSel_6P_3_PNW_BLK_repl2004	4	-1	9	1.77802	1.69954	0.19762
SizeSel_6P_4_PNW_BLK_repl1981	-4	-1	9	1.6	1.6	_
SizeSel_6P_4_PNW_BLK_repl2004	-4	-1	9	1.6	1.6	_
SizeSel_6P_5_PNW_BLK_repl1981	-4	-10	10	-10	-10	_
SizeSel_6P_5_PNW_BLK_repl2004	-4	-10	10	-10	-10	_
SizeSel_6P_6_PNW_BLK_repl1981	-4	-10	10	10	10	_
SizeSel_6P_6_PNW_BLK_repl2004	-4	-10	10	10	10	_
SizeSel_12P_1_Aerial_N	4	10	26	19.3	19.719	0.552442
SizeSel_12P_2_Aerial_N	4	-5	3	-0.999933	-2.9872	1.93528
SizeSel_12P_3_Aerial_N	4	-1	9	4.00004	0.0963858	0.8218
SizeSel_12P_4_Aerial_N	4	-1	9	3.99994	0.061018	0.655126
SizeSel_12P_5_Aerial_N	-4	-10	10	-10	-10	_
SizeSel_12P_6_Aerial_N	4	-10	10	-0.000129392	-5.23815	2.36121

Table 8. Likelihood components and derived quantities for the final 2009 model and 2010 models with additional data. Update model is ‘10w’.

		ADDITION OF REVISED DATA:				ADDITION OF NEW DATA:						
DATA / PROCESS:	**09_FINAL**	**09a**	**09b**	**09c**	**09d**	**10a**	**10b**	**10c**	**10d**	**10e**	**10f**	**10g**
Revised 2008/09 Landings												
Revised 2008 Length Comps												
Revised 2008 Age Comps												
2010 Landings												
2009-10 length comp SCA1												
2009-10 length comp SCA2												
2009-10 length comp CCA1												
2009-10 length comp CCA2												
2009-10 length comp PNW												
2009-10 age comp SCA1												
2009-10 age comp SCA2												
2009-10 age comp CCA1												
2009-10 age comp CCA2												
2009-10 age comp PNW												
2010 DEPM survey												
Rdevs adv. one year (pre-tuning)												
Tune model (var. adj. & Sig-R)												
Aerial-09 Index (1.35mmt, SE=0.55)	domed slx											
Revised Aerial-09 Index (1.24mmt, SE=0.90)		domed slx	domed slx	domed slx	domed slx	domed slx	domed slx	domed slx	domed slx	domed slx	domed slx	domed slx
Aerial-10N												
Aerial-10S												
LIKELIHOOD COMPONENT:	**09_FINAL**	**09a**	**09b**	**09c**	**09d**	**10a**	**10b**	**10c**	**10d**	**10e**	**10f**	**10g**
DEPM Index	-1.138	-1.981	-1.840	-1.839	-1.851	-1.840	-1.637	-1.073	-1.422	-2.171	-1.093	-0.732
TEP Index	-0.765	-0.581	-0.619	-0.619	-0.482	-0.619	-0.663	-0.763	-0.701	-0.511	-0.668	-0.713
Aerial-09 Index	9.514	7.156	7.022	7.022	6.354	7.023	6.203	4.703	5.076	8.523	4.295	3.636
Aerial-10N Index	---	---	---	---	---	---	---	---	---	---	---	---
Aerial-10S Index	---	---	---	---	---	---	---	---	---	---	---	---
Survey Subtotal	**7.611**	**4.594**	**4.563**	**4.564**	**4.021**	**4.564**	**3.903**	**2.867**	**2.954**	**5.841**	**2.534**	**2.191**
ENS-len	361.71	361.45	361.45	361.44	360.73	361.44	361.55	361.78	361.44	361.42	362.16	362.14
SCA1-len	352.87	352.99	352.82	352.83	353.04	352.82	359.62	352.30	351.73	351.95	349.83	354.78
SCA2-len	426.60	428.11	427.96	428.05	428.97	428.04	427.71	441.83	424.39	431.09	423.83	435.21
CCA1-len	161.51	163.01	162.84	162.83	162.33	162.83	162.62	161.83	180.71	163.28	161.25	177.98
CCA2-len	191.53	191.98	192.20	191.94	191.72	191.93	191.71	191.54	192.54	242.24	193.36	194.04
PNW-len	190.87	186.45	186.47	186.47	187.22	186.47	187.44	190.26	189.92	187.06	222.95	222.05
Aerial09-len	1.28	0.42	0.41	0.41	0.39	0.41	0.37	0.32	0.33	0.47	0.33	0.33
Aerial10N-len	---	---	---	---	---	---	---	---	---	---	---	---
Aerial10S-len	---	---	---	---	---	---	---	---	---	---	---	---
Length Comp Subtotal	**1686.37**	**1684.41**	**1684.15**	**1683.97**	**1684.40**	**1683.96**	**1691.02**	**1699.85**	**1701.06**	**1737.50**	**1713.72**	**1746.53**
ENS-age	265.06	263.89	263.99	263.99	264.84	263.99	263.97	263.95	264.36	264.58	264.40	264.40
SCA1-age	223.17	223.25	223.29	223.29	222.73	223.29	223.30	222.93	223.38	221.30	222.60	222.53
SCA2-age	492.89	488.94	489.25	489.23	490.21	489.23	490.22	491.55	490.93	485.04	489.71	490.94
CCA1-age	108.88	109.09	109.11	109.11	109.20	109.11	108.93	108.36	109.29	109.33	109.35	109.35
CCA2-age	158.66	159.68	159.72	159.72	159.52	159.64	159.42	158.81	160.54	161.35	160.86	161.63
PNW-age	135.03	133.89	134.05	134.04	134.22	134.05	134.74	136.41	135.62	133.39	137.97	139.39
Age Comp Subtotal	**1383.69**	**1378.73**	**1379.40**	**1379.39**	**1380.73**	**1379.30**	**1380.58**	**1382.00**	**1384.12**	**1374.99**	**1384.89**	**1388.25**
Catch	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.63E-07	1.64E-07	1.64E-07
Recruitment	55.60	56.55	56.53	56.54	53.05	56.54	56.04	55.34	56.37	56.84	55.57	55.55
Parameter softbounds	0.0320	0.0328	0.0325	0.0325	0.0239	0.0325	0.0322	0.0317	0.0318	0.0340	0.0322	0.0322
Crash penalty	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Likelihood	**3133.29**	**3124.32**	**3124.68**	**3124.50**	**3122.23**	**3124.40**	**3131.57**	**3140.09**	**3144.54**	**3175.20**	**3156.74**	**3192.55**
DERIVED QUANTITIES:	**09_FINAL**	**09a**	**09b**	**09c**	**09d**	**10a**	**10b**	**10c**	**10d**	**10e**	**10f**	**10g**
SSB-virgin (mt)	1,034,580	752,356	774,876	774,965	849,118	774,840	794,057	840,174	847,756	710,223	790,923	796,365
Biomass (1+) peak - 2000	1,686,190	1,248,430	1,281,250	1,281,560	1,396,090	1,281,280	1,302,610	1,351,640	1,383,290	1,169,230	1,238,300	1,238,150
Biomass (1+) - 2009	702,024	348,967	365,773	365,850	423,296	365,745	413,885	550,089	492,500	280,969	512,883	587,573
HG-2010	72,039	25,965	28,158	28,168	35,665	28,155	34,437	52,212	44,696	17,091	47,356	57,103
Biomass (1+) - 2010	---	---	---	---	---	291,680	333,532	461,170	397,563	228,524	426,557	495,008
HG-2011	---	---	---	---	---	18,489	23,951	40,608	32,307	10,247	36,091	45,024

Table 8 (cont'd). Likelihood components and derived quantities for the final 2009 model and 2010 models with additional data. Update model is '10w'.

			ADDITION OF NEW DATA:								MODEL TUNING:	
DATA / PROCESS:	**09_FINAL**	**09a**	**10h**	**10i**	**10j**	**10k**	**10l**	**10m**	**10n**	**10o**	**10p**	**10q**
Revised 2008/09 Landings												
Revised 2008 Length Comps												
Revised 2008 Age Comps												
2010 Landings												
2009-10 length comp SCA1												
2009-10 length comp SCA2												
2009-10 length comp CCA1												
2009-10 length comp CCA2												
2009-10 length comp PNW												
2009-10 age comp SCA1												
2009-10 age comp SCA2												
2009-10 age comp CCA1												
2009-10 age comp CCA2												
2009-10 age comp PNW												
2010 DEPM survey												
Rdevs adv. one year (pre-tuning)												
Tune model (var. adj. & Sig-R)												
Aerial-09 Index (1.35mmt, SE=0.55)	domed slx											
Revised Aerial-09 Index (1.24mmt, SE=0.90)		domed slx	domed slx	domed slx	domed slx	domed slx	domed slx	domed slx	domed slx	domed slx	domed slx	
Aerial-10N												
Aerial-10S												
LIKELIHOOD COMPONENT:	**09_FINAL**	**09a**	**10h**	**10i**	**10j**	**10k**	**10l**	**10m**	**10n**	**10o**	**10p**	**10q**
DEPM Index	-1.138	-1.981	-1.750	-1.721	-1.260	-1.715	-1.877	-1.509	-0.905	-1.365	-2.039	-2.268
TEP Index	-0.765	-0.581	-0.498	-0.511	-0.616	-0.514	-0.464	-0.660	-0.784	-0.766	-0.671	-0.656
Aerial-09 Index	9.514	7.156	5.443	5.341	4.609	5.333	5.742	5.110	4.189	4.271	5.146	1.060
Aerial-10N Index	---	---	---	---	---	---	---	---	---	---	---	---
Aerial-10S Index	---	---	---	---	---	---	---	---	---	---	---	---
Survey Subtotal	**7.611**	**4.594**	**3.194**	**3.109**	**2.733**	**3.105**	**3.400**	**2.941**	**2.500**	**2.139**	**2.437**	**-2.924**
ENS-len	361.71	361.45	362.48	362.52	363.00	362.45	362.30	364.02	364.61	364.68	364.47	358.17
SCA1-len	352.87	352.99	354.87	354.82	355.11	354.85	354.81	358.27	358.18	358.09	357.93	352.98
SCA2-len	426.60	428.11	438.29	438.01	438.98	438.13	438.88	443.80	442.79	442.68	442.15	430.90
CCA1-len	161.51	163.01	182.02	181.70	182.46	181.69	181.73	182.57	182.16	182.22	182.90	172.86
CCA2-len	191.53	191.98	248.74	249.48	250.60	249.36	248.14	246.19	248.70	248.52	250.33	221.58
PNW-len	190.87	186.45	222.54	222.41	221.70	222.49	223.37	228.15	226.91	226.93	227.55	218.61
Aerial09-len	1.28	0.42	0.43	0.43	0.40	0.43	0.44	0.32	0.30	0.30	0.32	---
Aerial10N-len	---	---	---	---	---	---	---	---	---	---	---	---
Aerial10S-len	---	---	---	---	---	---	---	---	---	---	---	---
Length Comp Subtotal	**1686.37**	**1684.41**	**1809.36**	**1809.36**	**1812.24**	**1809.39**	**1809.68**	**1823.33**	**1823.63**	**1823.41**	**1825.66**	**1755.10**
ENS-age	265.06	263.89	264.83	264.90	264.44	264.95	265.06	268.21	268.04	268.05	268.20	268.69
SCA1-age	223.17	223.25	221.14	224.57	222.19	221.19	220.73	221.96	226.67	226.71	226.44	225.87
SCA2-age	492.89	488.94	486.25	486.21	498.13	486.25	485.11	487.28	502.71	502.95	500.28	538.97
CCA1-age	108.88	109.09	109.59	109.66	109.01	112.36	109.87	110.92	113.36	113.39	113.80	113.70
CCA2-age	158.66	159.68	162.32	162.31	160.10	162.23	166.99	159.26	162.60	162.61	163.95	163.22
PNW-age	135.03	133.89	137.38	137.26	137.63	137.25	137.22	186.31	188.79	188.84	185.65	183.82
Age Comp Subtotal	**1383.69**	**1378.73**	**1381.49**	**1384.91**	**1391.50**	**1384.24**	**1384.98**	**1433.94**	**1462.17**	**1462.54**	**1458.31**	**1494.27**
Catch	1.64E-07	1.64E-07	1.63E-07	1.63E-07	1.63E-07	1.63E-07	1.63E-07	1.64E-07	1.64E-07	1.63E-07	1.63E-07	1.63E-07
Recruitment	55.60	56.55	55.73	55.80	55.48	55.83	55.99	54.80	54.83	54.65	54.92	59.74
Parameter softbounds	0.0320	0.0328	0.0344	0.0344	0.0336	0.0344	0.0346	0.0344	0.0341	0.0341	0.0344	0.0300
Crash penalty	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Likelihood	**3133.29**	**3124.32**	**3249.81**	**3253.22**	**3261.99**	**3252.60**	**3254.09**	**3315.05**	**3343.16**	**3342.77**	**3341.36**	**3306.20**
DERIVED QUANTITIES:	**09_FINAL**	**09a**	**10h**	**10i**	**10j**	**10k**	**10l**	**10m**	**10n**	**10o**	**10p**	**10q**
SSB-virgin (mt)	1,034,580	752,356	692,644	694,979	718,637	697,694	686,337	793,233	826,265	816,518	790,300	688,646
Biomass (1+) peak - 2000	1,686,190	1,248,430	1,080,850	1,083,950	1,110,450	1,088,200	1,077,390	1,273,390	1,318,100	1,304,380	1,270,590	1,133,960
Biomass (1+) - 2009	702,024	348,967	378,335	383,382	472,558	385,453	351,985	448,169	560,288	547,226	446,464	354,325
HG-2010	72,039	25,965	29,798	30,456	42,094	30,727	26,359	38,911	53,543	51,838	38,689	26,664
Biomass (1+) - 2010	---	---	328,433	331,117	421,200	333,148	301,698	378,069	474,214	463,119	318,834	223,058
HG-2011	---	---	23,286	23,636	35,392	23,901	19,797	29,763	42,310	40,862	22,033	9,534

Table 8 (cont'd). Likelihood components and derived quantities for the final 2009 model and 2010 models with additional data. Update model is '10w'.

			REVIEW WEEK MODELS:					ALT MODELS:	
DATA / PROCESS:	**09_FINAL**	**09a**	**10t**	**10t2**	**10u**	**10v**	**10w**	**10x**	**10x2**
Revised 2008/09 Landings									
Revised 2008 Length Comps									
Revised 2008 Age Comps									
2010 Landings									
2009-10 length comp SCA1									
2009-10 length comp SCA2									
2009-10 length comp CCA1									
2009-10 length comp CCA2									
2009-10 length comp PNW									
2009-10 age comp SCA1									
2009-10 age comp SCA2									
2009-10 age comp CCA1									
2009-10 age comp CCA2									
2009-10 age comp PNW									
2010 DEPM survey									
Rdevs adv. one year (pre-tuning)									
Tune model (var. adj. & Sig-R)									
Aerial-09 Index (1.35mmt, SE=0.55)	domed slx								
Revised Aerial-09 Index (1.24mmt, SE=0.90)		domed slx	domed slx	domed slx	domed slx	domed slx	domed slx	asymp slx	asymp slx
Aerial-10N					domed slx	domed slx			
Aerial-10S					domed slx				
LIKELIHOOD COMPONENT:	**09_FINAL**	**09a**	**10t**	**10t2**	**10u**	**10v**	**10w**	**10x**	**10x2**
DEPM Index	-1.138	-1.981	-1.994	-2.016	-1.344	-1.221	-1.276	-1.777	-2.049
TEP Index	-0.765	-0.581	-0.731	-0.708	-0.834	-0.845	-0.838	-0.568	-0.665
Aerial-09 Index	9.514	7.156	5.275	5.453	3.737	3.505	3.921	0.332	0.194
Aerial-10N Index	---	---	---	---	1.35	0.89	---	---	---
Aerial-10S Index	---	---	---	---	-0.30	---	---	---	---
Survey Subtotal	**7.611**	**4.594**	**2.551**	**2.729**	**2.603**	**2.333**	**1.807**	**-2.012**	**-2.520**
ENS-len	361.71	361.45	357.79	357.40	357.48	357.51	357.52	359.27	358.30
SCA1-len	352.87	352.99	353.31	353.06	353.45	353.45	353.29	350.70	352.49
SCA2-len	426.60	428.11	430.84	428.92	429.96	429.94	429.59	428.14	430.07
CCA1-len	161.51	163.01	172.06	169.72	170.73	170.65	170.25	169.36	171.47
CCA2-len	191.53	191.98	222.04	171.97	222.73	222.22	223.39	222.40	221.70
PNW-len	190.87	186.45	218.50	219.13	218.67	218.67	218.85	221.29	218.85
Aerial09-len	1.28	0.42	0.33	0.33	0.27	0.27	9.52	49.81	16.36
Aerial10N-len	---	---	---	---	1.29	1.11			
Aerial10S-len	---	---	---	---	1.56	---	---	---	---
Length Comp Subtotal	**1686.37**	**1684.41**	**1754.86**	**1700.53**	**1756.14**	**1753.82**	**1762.41**	**1800.96**	**1769.24**
ENS-age	265.06	263.89	269.03	268.49	270.06	270.25	270.28	269.49	269.04
SCA1-age	223.17	223.25	225.75	225.61	225.59	225.62	225.49	224.93	225.56
SCA2-age	492.89	488.94	539.86	539.02	542.72	543.69	543.29	538.22	539.05
CCA1-age	108.88	109.09	113.57	113.31	113.47	113.44	113.50	113.93	113.72
CCA2-age	158.66	159.68	163.00	165.94	163.03	162.71	162.96	164.92	163.61
PNW-age	135.03	133.89	183.93	182.78	184.84	185.35	184.95	193.50	186.37
Age Comp Subtotal	**1383.69**	**1378.73**	**1495.13**	**1495.16**	**1499.71**	**1501.05**	**1500.47**	**1504.99**	**1497.35**
Catch	1.64E-07	1.64E-07	1.63E-07	1.08E-04	1.64E-07	1.64E-07	1.64E-07	1.63E-07	1.63E-07
Recruitment	55.60	56.55	59.67	60.61	59.14	59.02	59.03	59.08	59.43
Parameter softbounds	0.0320	0.0328	0.0327	0.0329	0.0464	0.0364	0.0315	0.0327	0.0325
Crash penalty	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Likelihood	**3133.29**	**3124.32**	**3312.24**	**3259.07**	**3317.64**	**3316.26**	**3323.74**	**3363.05**	**3323.52**
DERIVED QUANTITIES:	**09_FINAL**	**09a**	**10t**	**10t2**	**10u**	**10v**	**10w**	**10x**	**10x2**
SSB-virgin (mt)	1,034,580	752,356	750,942	730,817	938,037	977,257	966,884	651,230	699,647
Biomass (1+) peak - 2000	1,686,190	1,248,430	1,232,360	1,231,180	1,523,120	1,578,370	1,570,120	1,021,780	1,134,920
Biomass (1+) - 2009	702,024	348,967	429,143	409,160	650,585	698,692	683,575	389,668	389,324
HG-2010	72,039	25,965	36,428	33,820	65,326	71,604	69,632	31,277	31,232
Biomass (1+) - 2010	---	---	295,097	225,663	508,936	564,426	537,173	316,912	272,517
HG-2011	---	---	18,935	9,874	46,841	54,083	50,526	21,782	15,988

Table 9. Derived SSB (mt) and Recruits (1,000s of age-0 fish) and standard deviations from the update model '10w'. SSB estimates are calculated near the end of each model year, e.g. the 2010 value is SSB projected for spring of calendar year 2011. Recruits are age-0 fish calculated at the beginning of each subsequent model year so, for example, the 2003 year class (18.578 billion) is displayed in row 2002 since they were produced by the SSB of that year.

YEAR	SSB (mt)	SSB Std Dev	Recruits, year+1 (1,000s)	Recruits Std Dev
Virgin	966,880	171,750	4,624,800	811,070
Initial	16,848	5,632	80,586	26,643
1981	7,997	2,469	106,170	34,603
1982	9,978	3,006	271,210	76,258
1983	12,355	3,597	239,290	67,803
1984	20,693	5,572	267,750	70,954
1985	26,231	7,693	654,350	158,750
1986	33,536	9,303	884,960	207,330
1987	50,083	13,560	1,270,400	310,280
1988	77,598	19,821	1,083,700	277,930
1989	113,790	29,205	2,260,700	546,170
1990	140,030	37,450	5,354,400	1,098,200
1991	154,250	46,399	3,910,100	874,870
1992	192,520	58,539	10,078,000	1,906,000
1993	266,010	77,809	11,130,000	1,937,100
1994	421,420	107,720	4,222,600	801,780
1995	629,040	148,430	6,252,500	1,116,000
1996	756,100	171,260	17,156,000	2,821,600
1997	740,090	172,470	19,743,000	2,899,600
1998	883,660	191,640	3,624,200	611,600
1999	1,197,300	236,160	2,927,700	465,270
2000	1,307,800	253,150	7,959,500	1,003,400
2001	1,135,900	226,950	803,680	220,550
2002	936,170	193,670	18,578,000	2,572,900
2003	745,570	162,480	9,617,300	1,432,500
2004	750,930	158,560	10,448,000	1,326,400
2005	886,040	179,010	3,276,800	466,650
2006	958,950	190,380	3,596,300	521,470
2007	879,550	182,280	2,673,700	556,510
2008	684,820	157,020	4,612,900	1,362,700
2009	501,270	130,260	---	---
2010	376,250	116,020	---	---

Table 10. Pacific sardine biomass and population numbers-at-age (1,000s) by model year and semester for the update model '10w'.

Model Year	Sem	BIOMASS (mt) Total (0+)	Age 1+	SSB	POPULATION NUMBERS-AT-AGE (1,000s of fish) 0 (R)	1	2	3	4	5	6	7	8	9	10+
VIRG	1	1,114,720	1,073,750	_	4,624,760	3,100,070	2,078,040	1,392,950	933,723	625,893	419,549	281,232	188,515	126,366	256,932
VIRG	2	1,076,680	1,025,240	966,883	3,786,430	2,538,120	1,701,350	1,140,450	764,468	512,438	343,498	230,253	154,343	103,459	210,358
INIT	1	19,424	18,710	_	80,586	54,019	36,210	24,272	16,270	10,906	7,311	4,900	3,285	2,202	4,477
INIT	2	18,761	17,865	16,848	65,978	44,227	29,646	19,872	13,321	8,929	5,985	4,012	2,689	1,803	3,665
1981	1	9,274	8,603	_	75,772	50,791	11,587	6,564	4,092	2,261	1,592	4,900	3,285	2,202	4,477
1981	2	9,659	8,817	7,997	62,037	41,576	9,480	5,369	3,348	1,850	1,302	4,009	2,687	1,801	3,662
1982	1	11,603	10,662	_	106,168	50,786	33,933	7,710	4,360	2,716	1,500	1,056	3,252	2,180	4,432
1982	2	12,046	10,865	9,978	86,923	41,499	27,574	6,258	3,538	2,205	1,218	857	2,639	1,769	3,597
1983	1	15,583	13,180	_	271,209	71,122	33,338	21,680	4,876	2,748	1,710	944	665	2,046	4,160
1983	2	16,525	13,509	12,355	222,046	58,015	26,852	17,375	3,902	2,199	1,368	755	532	1,637	3,328
1984	1	23,162	21,042	_	239,294	181,758	47,225	21,715	14,009	3,143	1,770	1,101	608	428	3,995
1984	2	26,256	23,595	20,693	195,917	148,689	38,427	17,688	11,424	2,564	1,444	899	496	349	3,260
1985	1	30,132	27,760	_	267,750	160,016	111,252	25,993	11,519	7,357	1,645	926	576	318	2,312
1985	2	31,988	29,010	26,231	219,213	130,123	88,259	20,414	9,023	5,759	1,288	724	451	249	1,809
1986	1	41,269	35,472	_	654,354	179,357	104,477	69,497	15,938	7,023	4,477	1,001	563	350	1,598
1986	2	43,826	36,549	33,536	535,738	146,470	84,528	56,104	12,864	5,668	3,613	808	454	282	1,290
1987	1	60,651	52,811	_	884,962	438,177	116,112	64,651	42,279	9,645	4,242	2,702	604	340	1,176
1987	2	66,755	56,912	50,083	724,535	354,907	90,541	49,621	32,314	7,363	3,237	2,062	461	259	897
1988	1	91,781	80,527	_	1,270,380	592,462	280,312	68,661	36,965	23,916	5,437	2,388	1,521	340	852
1988	2	101,386	87,256	77,598	1,040,090	481,815	222,643	53,989	28,988	18,741	4,259	1,871	1,191	266	668
1989	1	132,448	122,847	_	1,083,700	851,059	387,611	176,129	42,404	22,709	14,668	3,332	1,463	932	730
1989	2	139,865	127,812	113,790	887,241	687,162	297,366	131,881	31,532	16,853	10,879	2,471	1,085	691	542
1990	1	172,063	152,035	_	2,260,680	725,673	542,702	226,021	98,766	23,506	12,545	8,094	1,838	807	917
1990	2	177,731	152,587	140,032	1,850,860	589,258	426,942	175,017	76,127	18,094	9,653	6,227	1,414	621	705
1991	1	250,476	203,039	_	5,354,410	1,513,110	458,798	314,310	126,007	54,417	12,903	6,878	4,435	1,007	944
1991	2	248,165	182,153	154,253	4,383,530	1,211,790	325,771	210,439	83,287	35,896	8,510	4,536	2,925	664	622
1992	1	315,475	280,834	_	3,910,090	3,586,780	968,592	249,130	157,951	62,176	26,755	6,340	3,379	2,179	958
1992	2	317,364	269,169	192,517	3,200,370	2,695,340	607,498	173,071	118,602	47,925	20,802	4,944	2,638	1,702	749
1993	1	421,171	331,890	_	10,077,600	2,588,300	1,944,390	439,926	133,361	93,811	38,220	16,635	3,958	2,113	1,963
1993	2	462,837	338,596	266,008	8,250,200	2,067,240	1,481,400	339,923	106,500	75,807	30,991	13,503	3,214	1,716	1,594
1994	1	639,233	540,625	_	11,130,400	6,718,940	1,616,770	1,160,660	272,050	86,232	61,577	25,196	10,982	2,614	2,693
1994	2	720,303	583,081	421,416	9,112,240	5,404,100	1,256,830	906,152	217,138	69,880	50,101	20,523	8,948	2,130	2,194
1995	1	831,686	794,277	_	4,222,550	7,382,700	4,045,280	945,831	705,192	173,190	56,347	40,506	16,605	7,242	3,501
1995	2	887,512	835,455	629,039	3,456,830	5,936,480	3,142,810	739,974	561,997	140,118	45,861	33,013	13,539	5,906	2,855
1996	1	965,185	909,793	_	6,252,460	2,816,370	4,649,880	2,460,480	588,448	451,853	113,540	37,282	26,860	11,019	7,130
1996	2	953,334	876,253	756,098	5,118,550	2,258,090	3,582,070	1,911,170	467,056	363,813	92,188	30,363	21,891	8,982	5,813
1997	1	1,102,810	950,812	_	17,156,400	4,171,460	1,774,670	2,818,260	1,526,240	376,608	294,945	74,975	24,723	17,831	12,053
1997	2	1,060,720	849,251	740,093	14,042,600	3,228,380	1,233,400	2,002,260	1,149,090	294,709	235,210	60,391	19,989	14,431	9,759
1998	1	1,305,240	1,130,330	_	19,743,000	11,401,900	2,455,630	939,005	1,565,280	914,302	236,844	189,961	48,909	16,207	19,621
1998	2	1,393,920	1,150,530	883,662	16,162,100	9,092,610	1,862,130	719,274	1,231,620	732,368	191,381	154,092	39,756	13,185	15,968
1999	1	1,540,890	1,508,780	_	3,624,210	13,138,200	6,948,620	1,415,240	559,325	975,962	587,235	154,389	124,666	32,218	23,648
1999	2	1,603,850	1,559,180	1,197,320	2,965,790	10,427,700	5,398,400	1,127,940	453,268	795,529	479,496	126,129	101,864	26,328	19,326

Table 10 (cont'd). Pacific sardine biomass and population numbers-at-age (1,000s) by model year and semester for the update model '10w'.

		BIOMASS (mt)			POPULATION NUMBERS-AT-AGE (1,000s of fish)										
Model Year	Sem	Total (0+)	Age 1+	SSB	0 (R)	1	2	3	4	5	6	7	8	9	10+
2000	1	1,596,060	1,570,120	_	2,927,690	2,370,610	7,868,440	4,212,710	905,714	368,481	649,370	391,880	103,122	83,296	37,335
2000	2	1,498,340	1,462,260	1,307,820	2,395,730	1,866,210	5,986,440	3,292,800	720,738	295,006	520,806	314,464	82,766	66,859	29,969
2001	1	1,453,300	1,382,790	_	7,959,450	1,865,520	1,329,770	4,624,040	2,645,740	585,540	240,397	424,762	256,541	67,528	79,005
2001	2	1,305,320	1,207,360	1,135,870	6,504,980	1,384,880	934,290	3,494,060	2,077,430	464,991	191,495	338,666	204,608	53,865	63,025
2002	1	1,219,000	1,211,880	_	803,681	4,995,310	937,177	697,288	2,765,320	1,677,710	377,844	155,887	275,851	166,694	95,241
2002	2	1,059,530	1,049,640	936,174	656,567	3,565,260	608,675	501,556	2,107,470	1,301,460	294,564	121,709	215,482	130,241	74,424
2003	1	1,102,780	938,186	_	18,578,400	509,900	2,469,450	454,018	396,020	1,702,510	1,059,180	240,260	99,344	175,934	167,127
2003	2	1,004,280	775,539	745,568	15,189,200	379,767	1,690,020	328,514	299,322	1,308,040	817,801	185,789	76,862	136,150	129,352
2004	1	1,134,890	1,049,690	_	9,617,320	12,068,400	278,727	1,287,200	260,270	241,550	1,062,190	665,354	151,250	62,588	216,223
2004	2	1,116,520	998,053	750,929	7,866,660	9,096,510	189,670	909,768	191,823	181,192	801,239	502,759	114,356	47,332	163,544
2005	1	1,259,200	1,166,640	_	10,447,900	6,355,640	7,054,470	149,344	731,465	155,889	147,802	654,329	410,727	93,436	172,313
2005	2	1,216,480	1,087,740	886,044	8,548,840	4,943,820	5,092,720	108,714	544,597	117,350	111,668	494,921	310,787	70,712	130,420
2006	1	1,277,440	1,248,410	_	3,276,770	6,873,530	3,803,550	4,015,910	87,659	443,459	95,871	91,319	404,862	254,265	164,565
2006	2	1,194,090	1,153,730	958,949	2,680,690	5,271,380	2,712,970	2,967,960	66,873	342,534	74,338	70,892	314,425	197,500	127,840
2007	1	1,169,840	1,137,980	_	3,596,270	2,117,220	3,886,410	2,110,870	2,387,290	54,412	279,681	60,760	57,963	257,118	266,064
2007	2	1,013,710	969,441	879,551	2,939,910	1,551,600	2,606,510	1,532,120	1,806,530	41,649	214,740	46,694	44,558	197,679	204,573
2008	1	943,015	919,328	_	2,673,680	2,254,190	1,036,890	1,920,800	1,206,960	1,459,630	33,923	175,319	38,152	36,417	328,811
2008	2	777,861	744,938	684,821	2,186,210	1,574,000	607,632	1,277,700	881,684	1,102,630	25,886	134,196	29,233	27,916	252,124
2009	1	724,442	683,575	_	4,612,910	1,687,490	1,012,560	412,904	960,841	699,422	891,174	21,043	109,297	23,827	228,370
2009	2	600,657	543,838	501,270	3,773,090	1,197,350	595,244	267,014	679,903	513,036	661,071	15,663	81,454	17,766	170,336
2010	1	600,034	537,173	_	7,095,450	2,825,960	684,061	376,896	195,173	534,674	413,835	537,386	12,765	66,443	153,546
2010	2	522,570	435,201	376,250	5,801,740	2,029,920	405,080	234,171	132,094	376,965	295,696	385,573	9,172	47,768	110,444

Table 11. Pacific sardine harvest control rules for the 2011 management year based on stock biomass (537,173 mt) estimated in the update model '10w'. See 'Harvest Guideline' section for methods used to derive the harvest guideline (HG). See PFMC (2010) for methods used to derive OFL, ABC, ACL, and associated buffer values.

Harvest Formula Parameters	Value			
BIOMASS (ages 1+, mt)	537,173			
Pstar (probability of overfishing)	0.45	0.40	0.30	0.20
$BUFFER_{Pstar}$	0.95217	0.90592	0.81504	0.72020
F_{MSY} (upper quartile SST)	0.1985			
FRACTION	0.15			
CUTOFF (mt)	150,000			
DISTRIBUTION (U.S.)	0.87			

Amendment 13 Harvest Formulas	MT
OFL = BIOMASS * F_{MSY} * DISTRIBUTION	92,767
$ABC_{0.45}$ = BIOMASS * $BUFFER_{0.45}$ * F_{MSY} * DISTRIBUTION	88,330
$ABC_{0.40}$ = BIOMASS * $BUFFER_{0.40}$ * F_{MSY} * DISTRIBUTION	84,040
$ABC_{0.30}$ = BIOMASS * $BUFFER_{0.30}$ * F_{MSY} * DISTRIBUTION	75,609
$ABC_{0.20}$ = BIOMASS * $BUFFER_{0.20}$ * F_{MSY} * DISTRIBUTION	66,811
ACL=LESS THAN OR EQUAL TO ABC	TBD
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION	50,526
ACT=EQUAL TO HG OR ACL, WHICHEVER VALUE IS LESS	TBD

Table 12. Sardine fishery performance since the onset of federal management. OFLs are limits are based on biomass and temperature-based F_{MSY}, but are not implemented or enforced through any international treaty. U.S. landings for 2010 are preliminary, and total coastwide catch for 2010 is not yet known.

Year	U.S. OFL	U.S. HG	U.S. Landings	Total OFL	Total Landings
2000	273,907	186,791	72,496	314,835	142,063
2001	204,816	134,737	78,520	235,421	125,857
2002	149,585	118,442	101,367	171,937	148,951
2003	165,826	110,908	74,599	190,604	116,918
2004	188,902	122,747	92,613	217,129	138,948
2005	206,730	136,179	90,130	237,621	148,684
2006	183,845	118,937	90,776	211,316	149,588
2007	228,478	152,564	127,695	262,618	166,065
2008	144,234	89,093	87,175	165,786	164,466
2009	114,820	66,932	67,084	131,976	138,775
2010	121,598	72,039	63,066	139,768	---

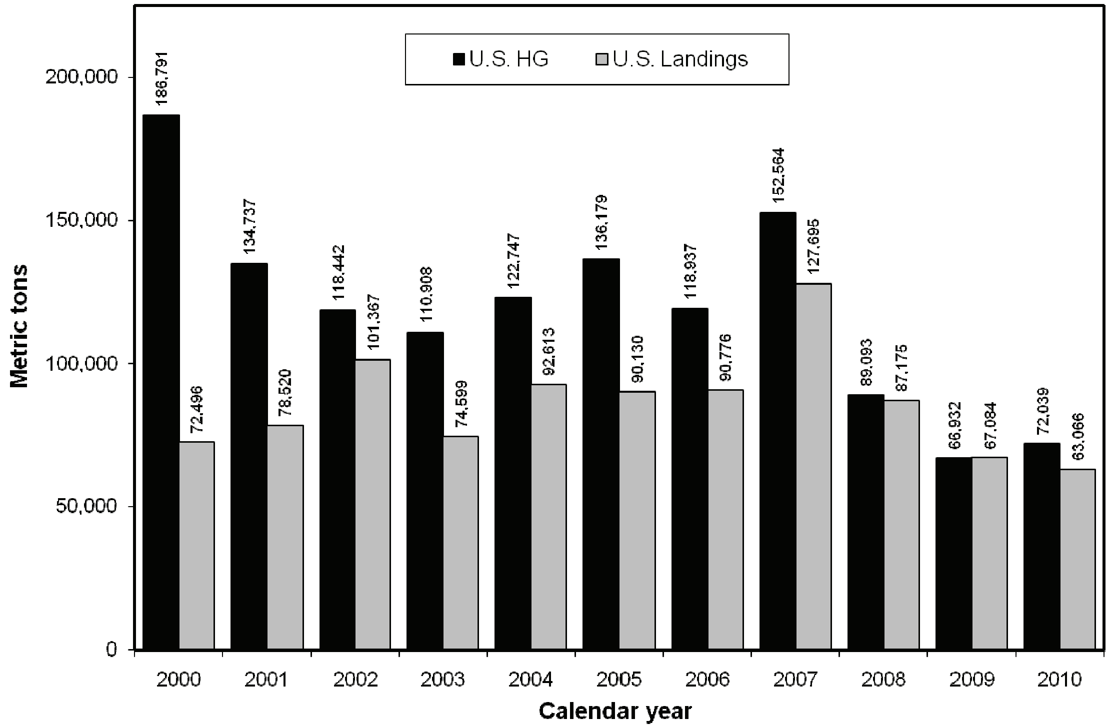


Figure 1a. U.S. harvest guidelines and landings since calendar year 2000.

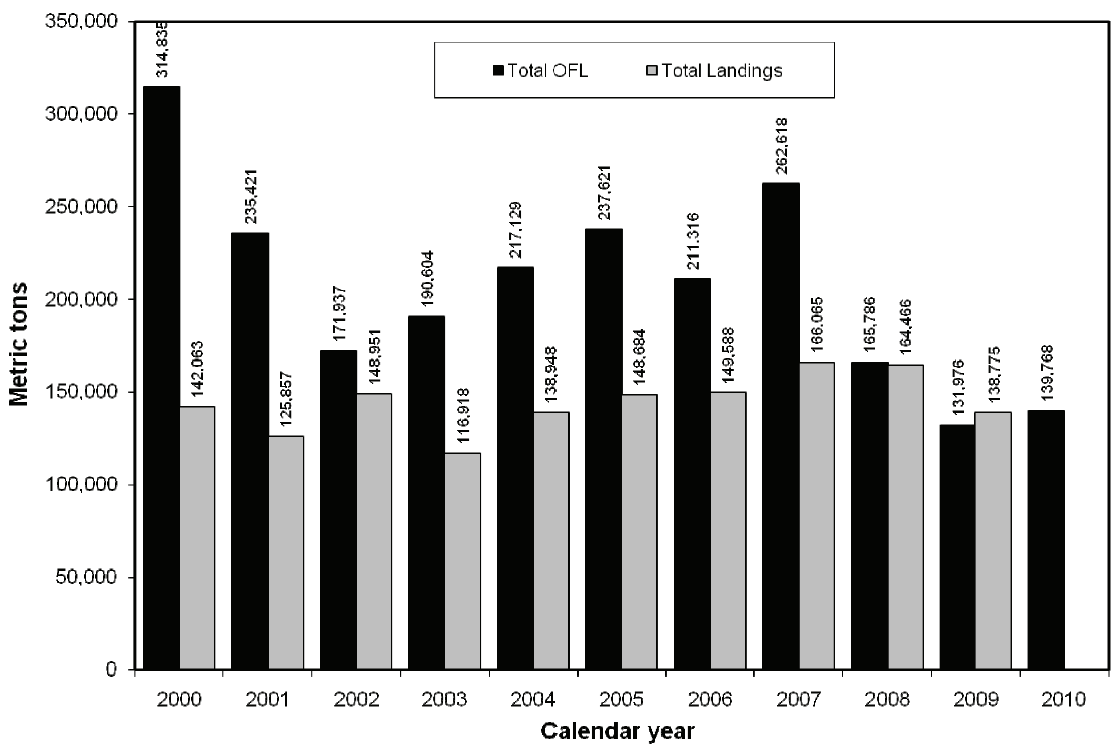


Figure 1b. Coast-wide OFLs and landings (Ensenada to British Columbia) since 2000.

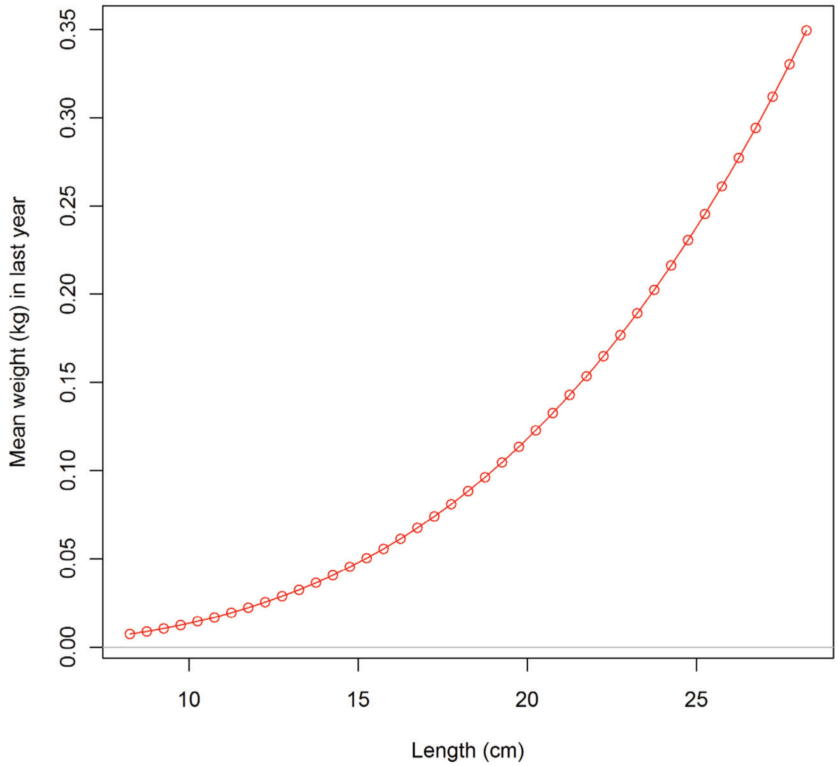


Figure 2a. Weight-at-length as applied in the base model (a = 9.47212e-06, b = 3.14752).

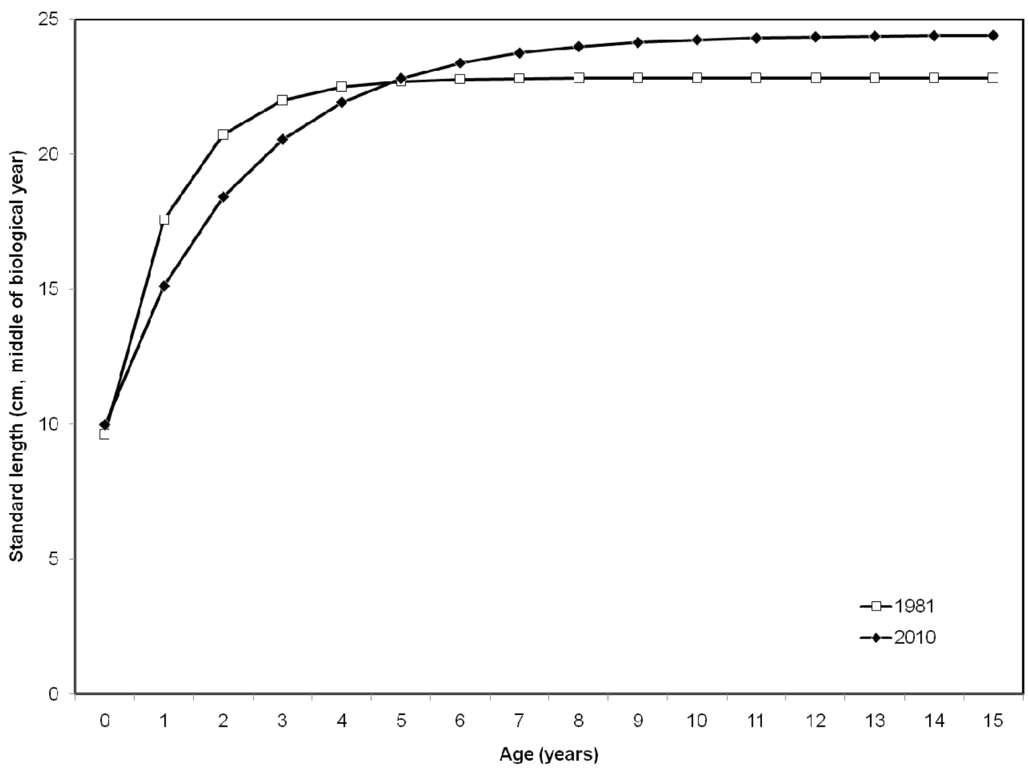


Figure 2b. Length-at-age as estimated in the base model (1981-90 period: $L_{0.5yr}$ = 9.78, L_{15yr}=23.95, K=1.111. 1991-10 period: $L_{0.5yr}$ = 9.82, L_{15yr}=24.02, K=0.370).

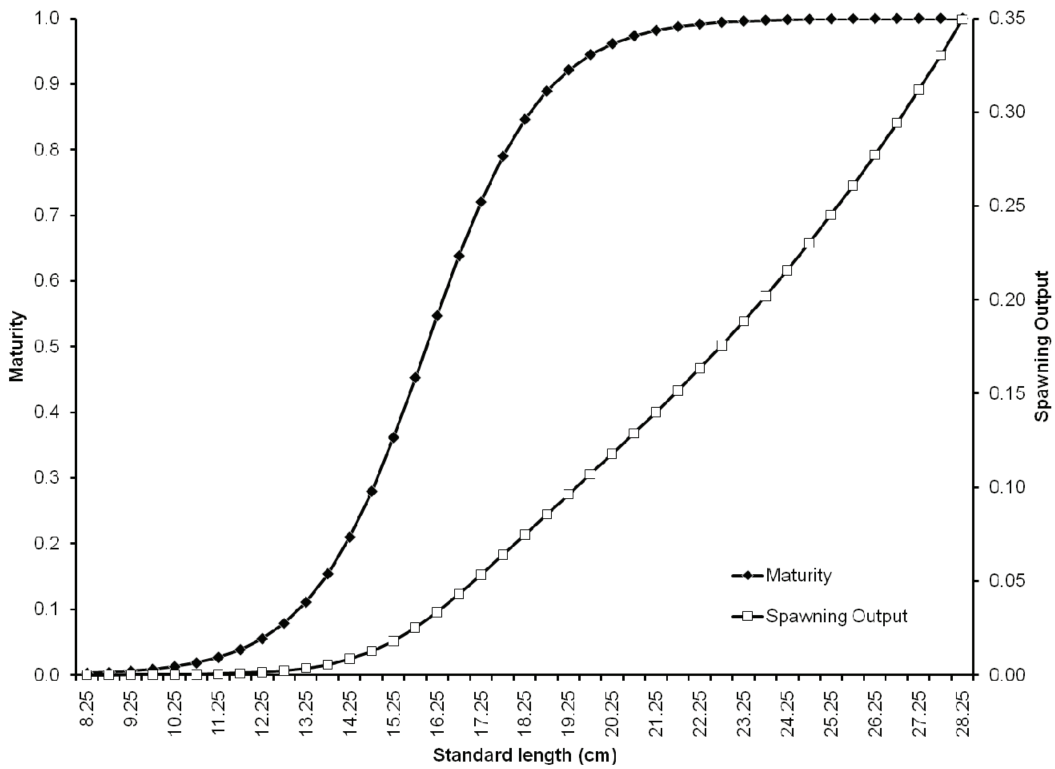


Figure 3a. Maturity (L_{50} = 16.0 cm) and spawning output as a function of length in base model.

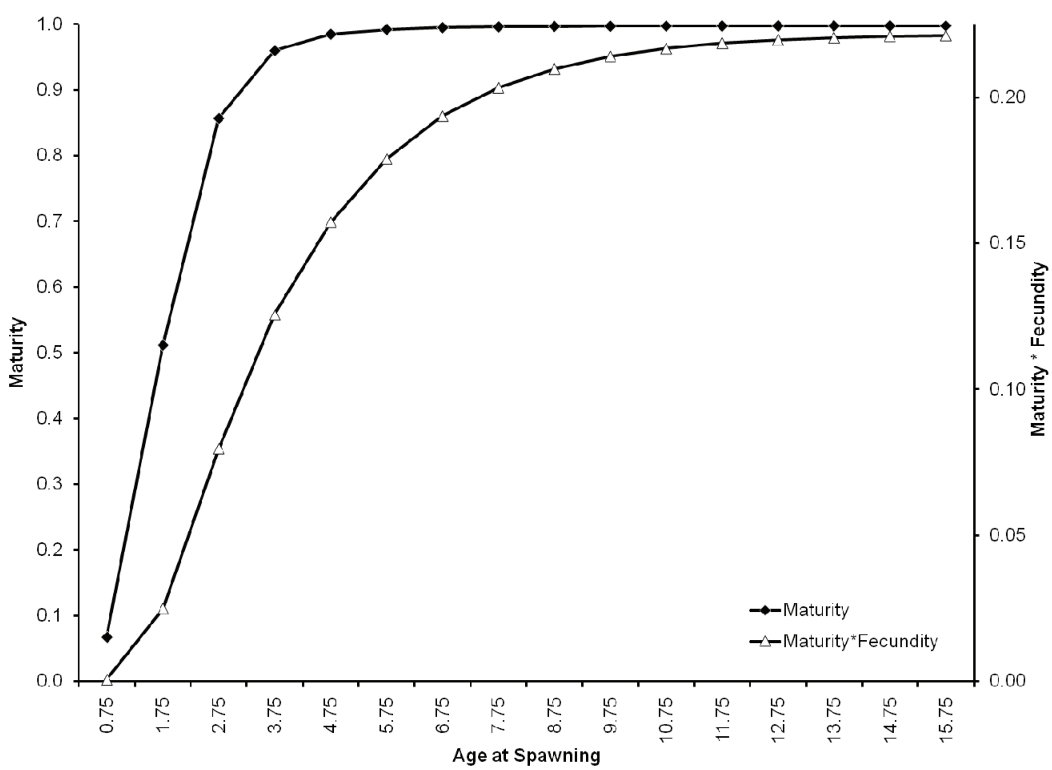


Figure 3b. Maturity and fecundity as a function of age, as derived from the base model.

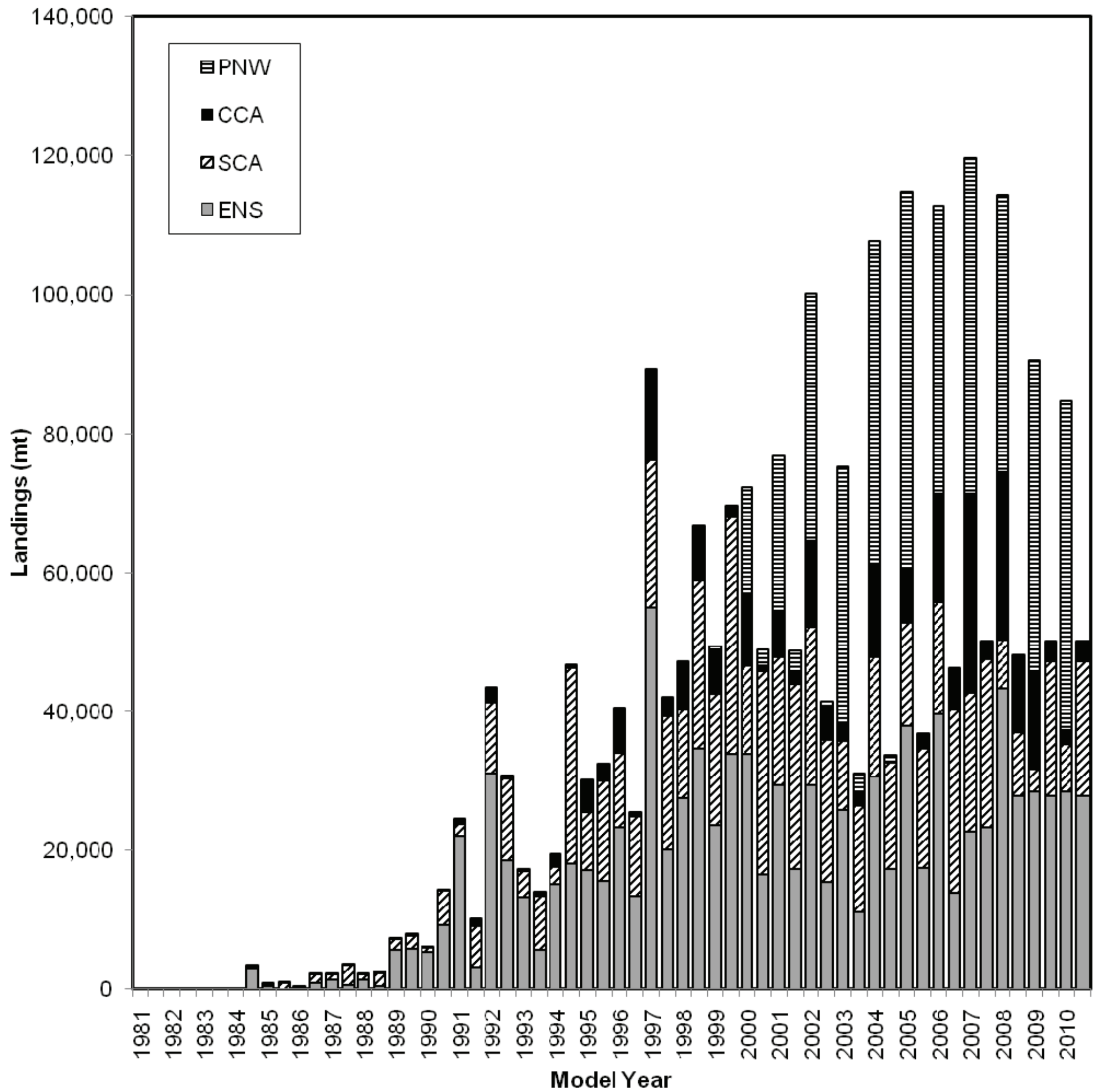


Figure 4. Pacific sardine landings (mt) by fishery, model year and semester as used in SS.

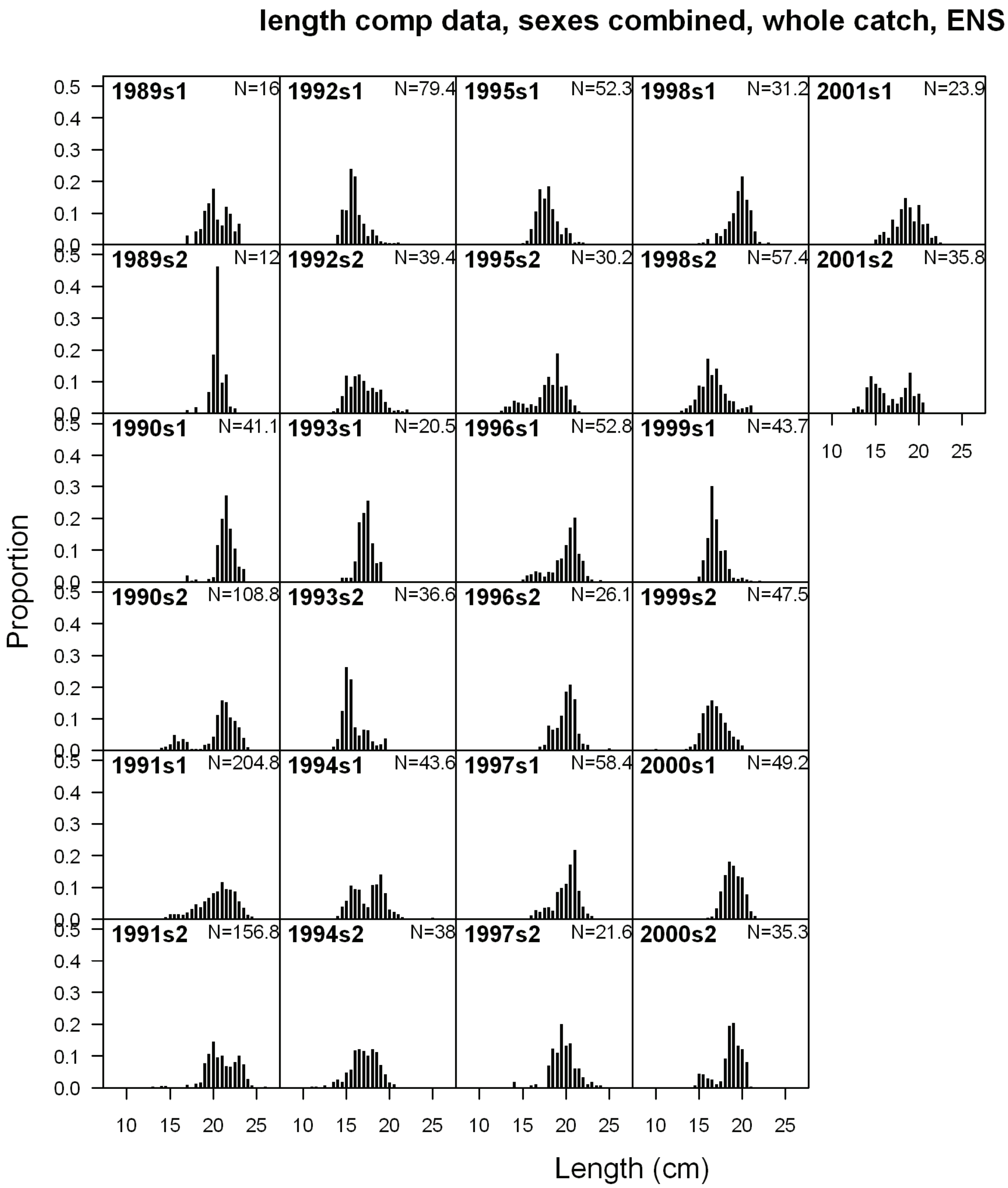


Figure 5a. Length-composition data for the ENS fishery.

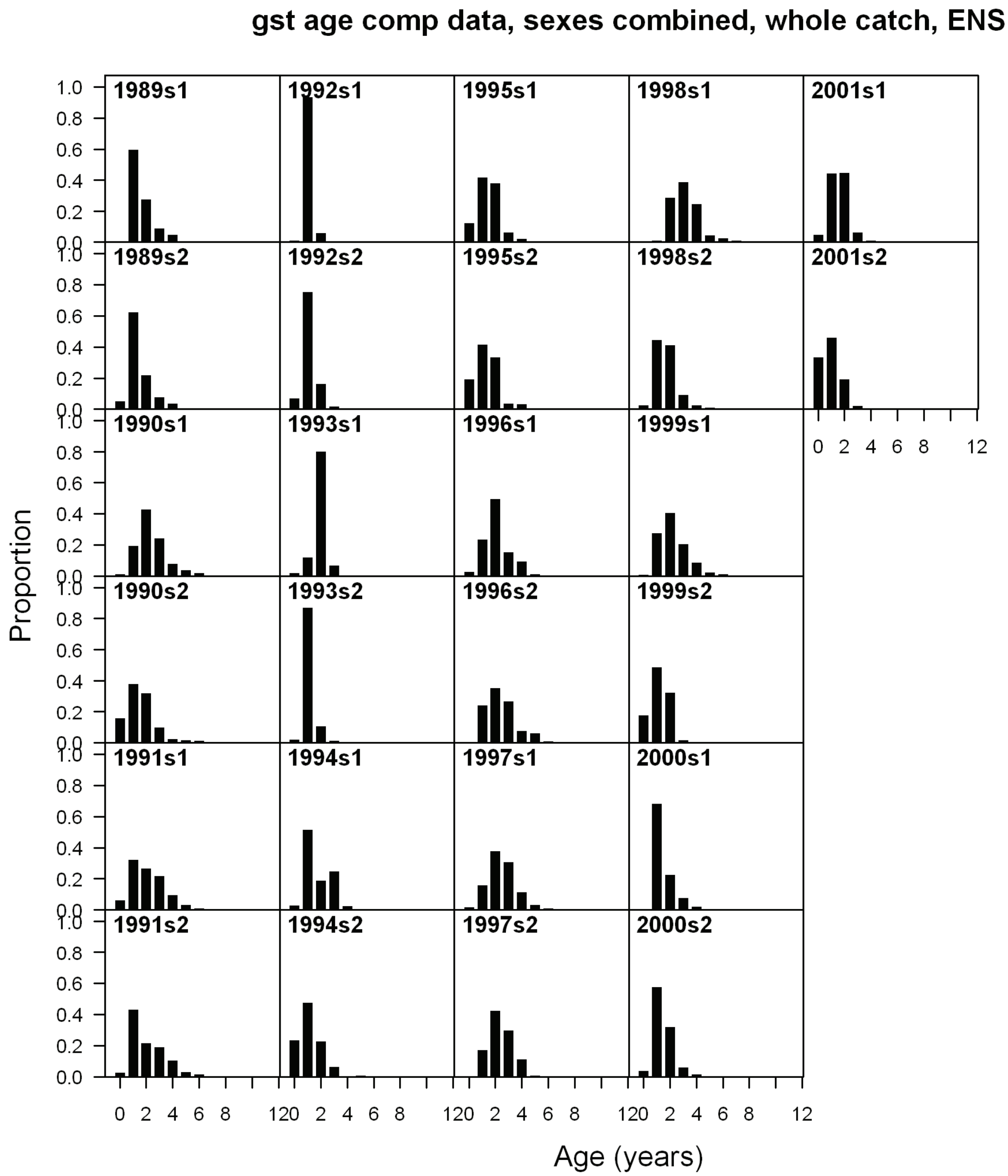


Figure 6a. Implied age-composition data for the ENS fishery.

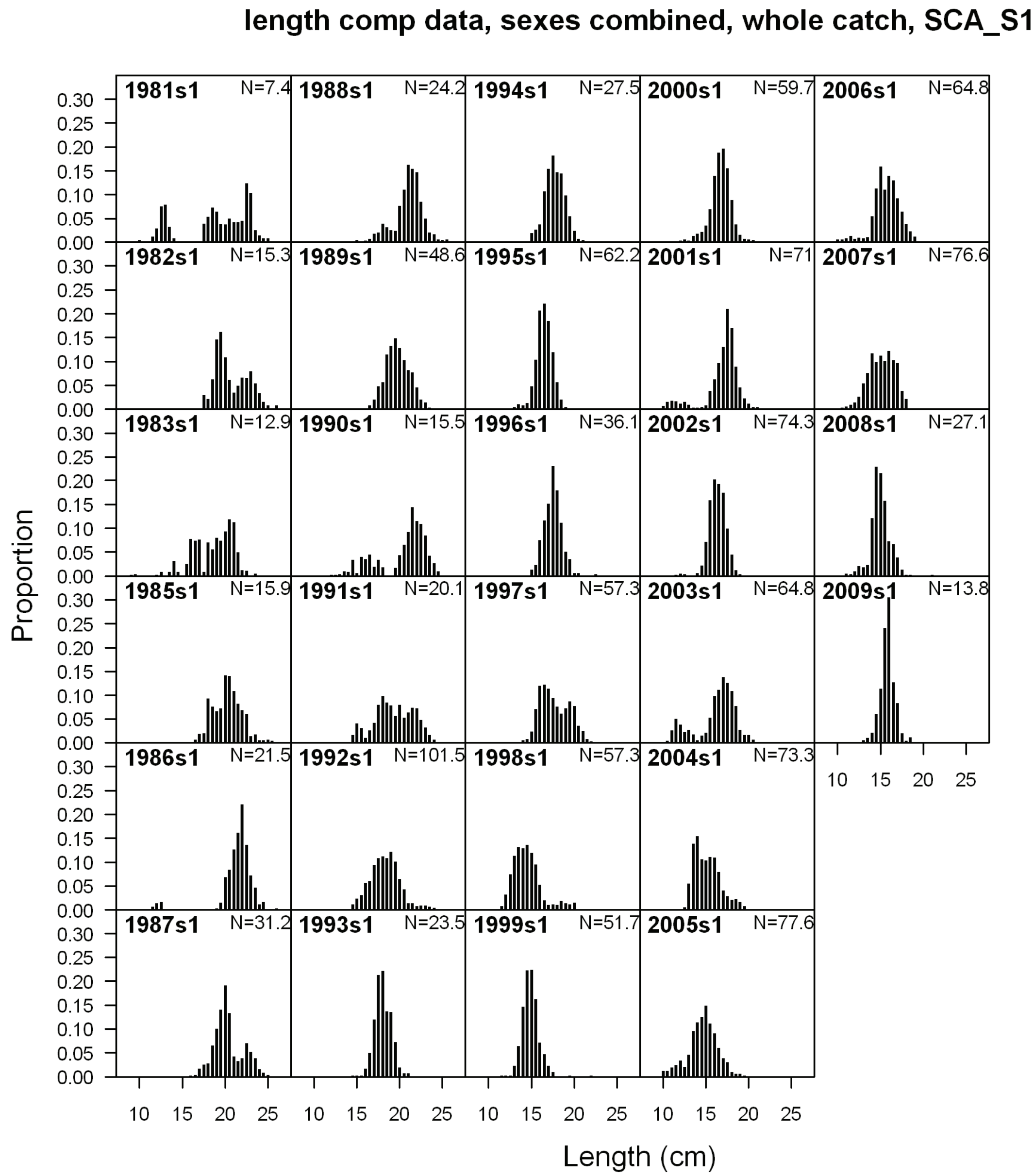


Figure 5b. Length-composition data for the SCA_S1 fishery.

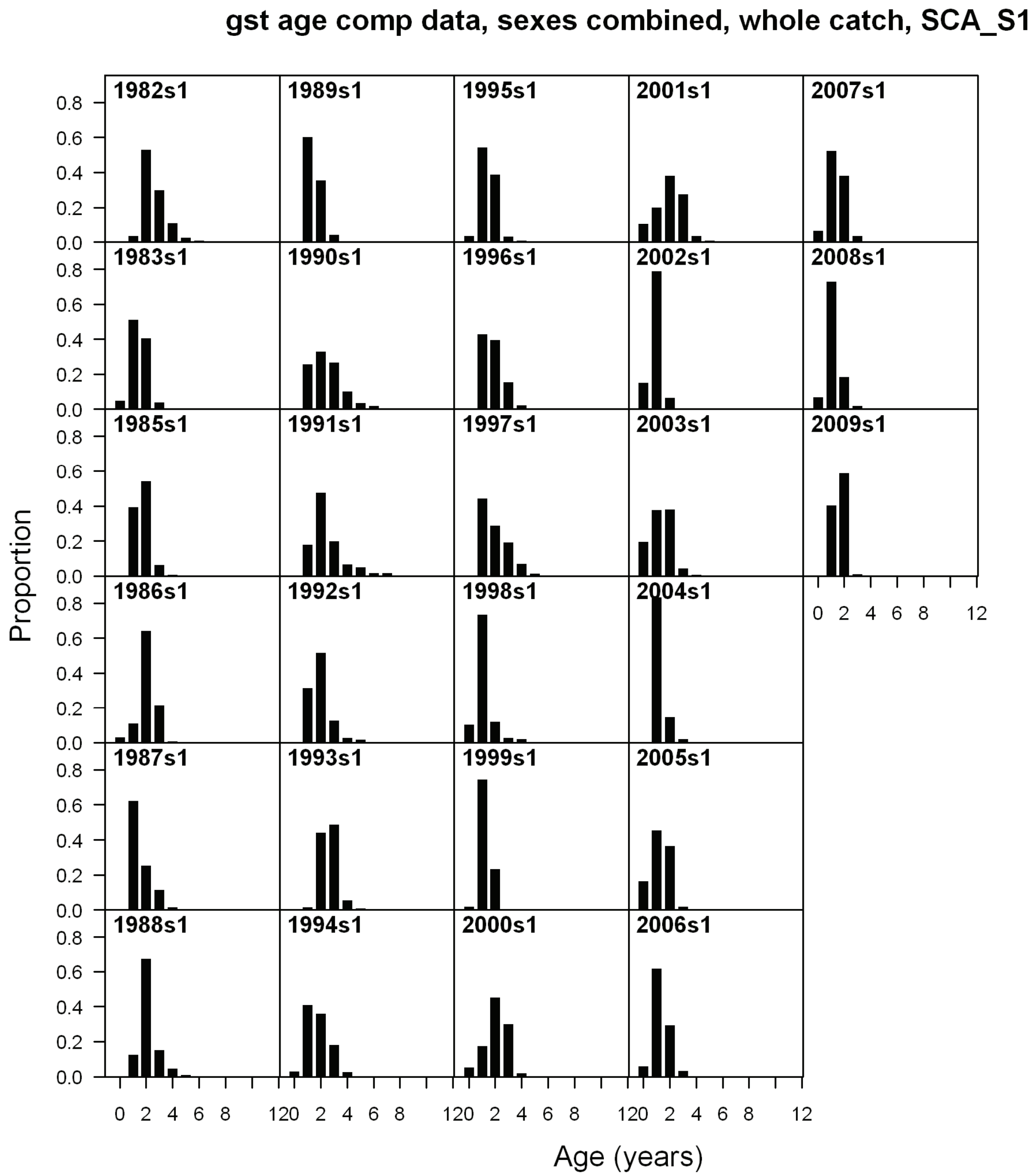


Figure 6b. Implied age-composition data for the SCA_S1 fishery.

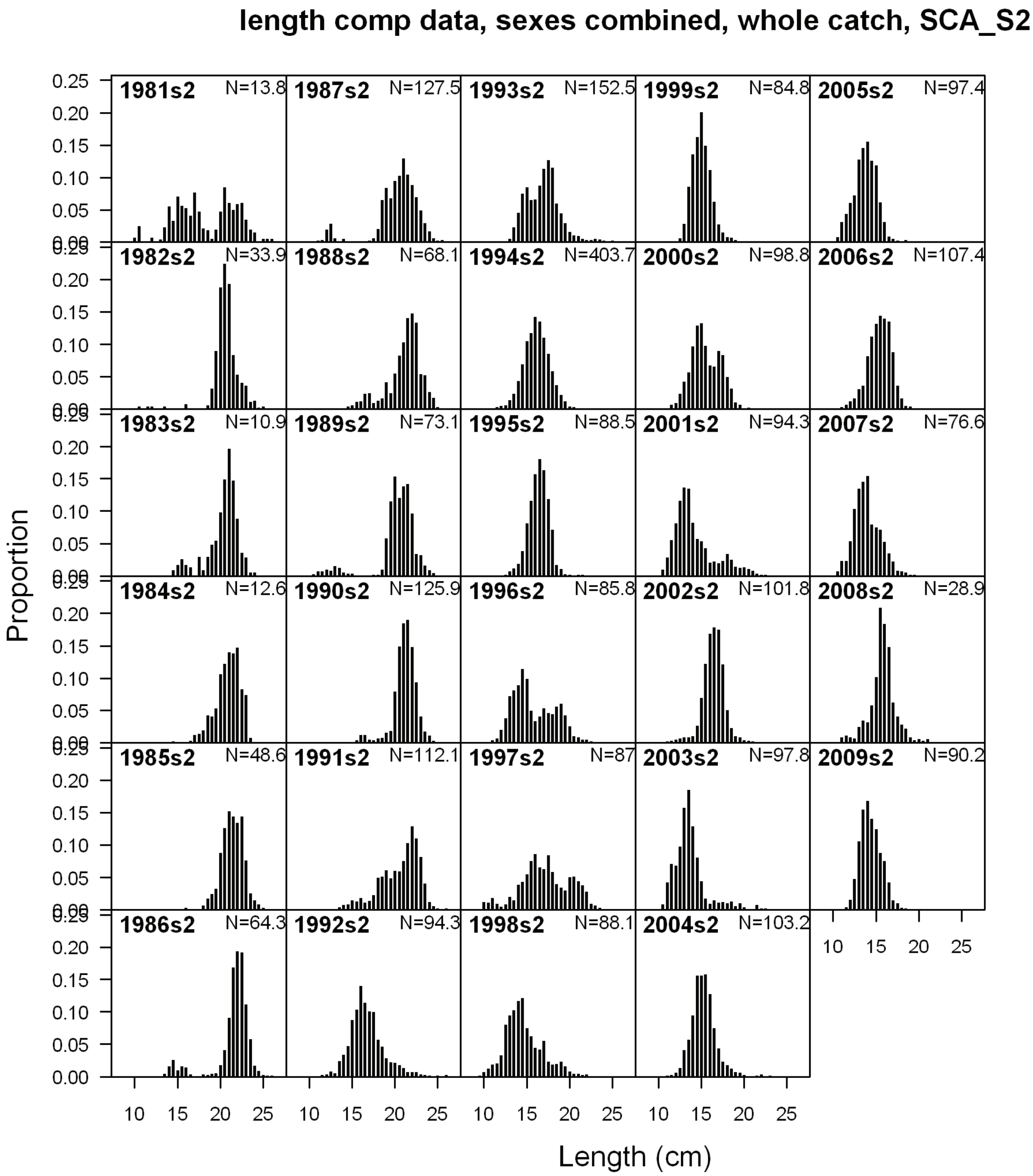


Figure 5c. Length-composition data for the SCA_S2 fishery.

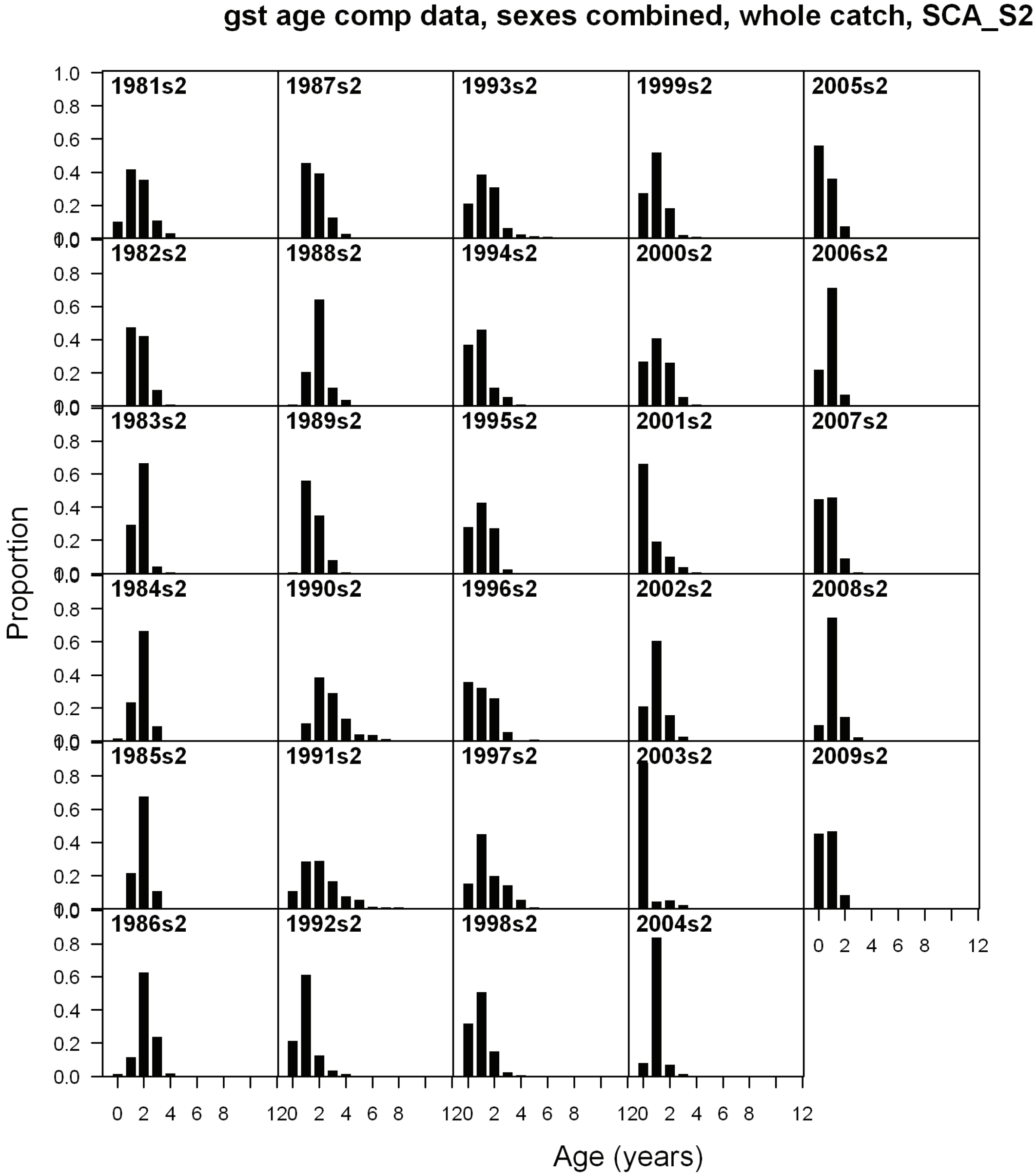


Figure 6c. Implied age-composition data for the SCA_S2 fishery.

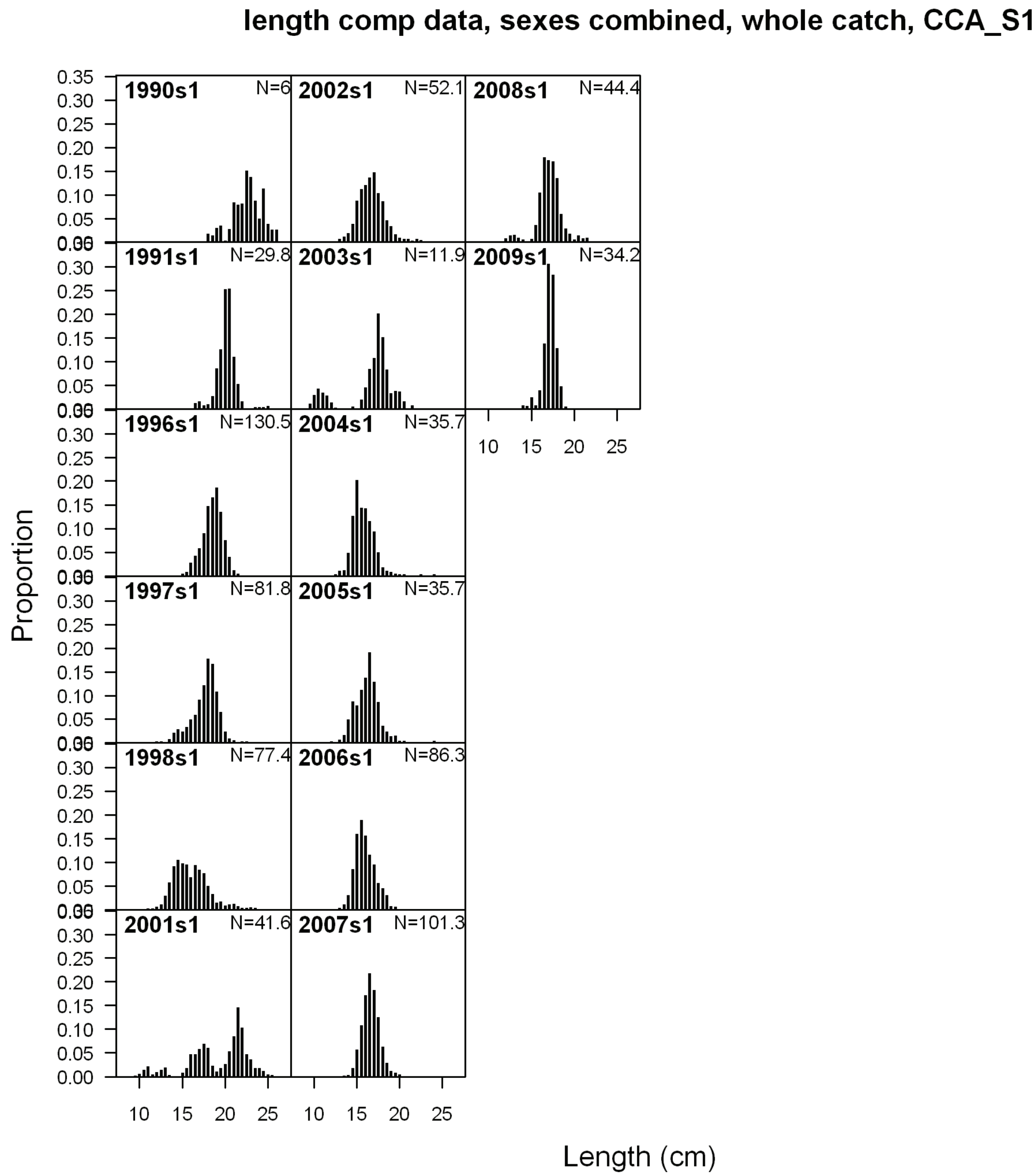


Figure 5d. Length-composition data for the CCA_S1 fishery.

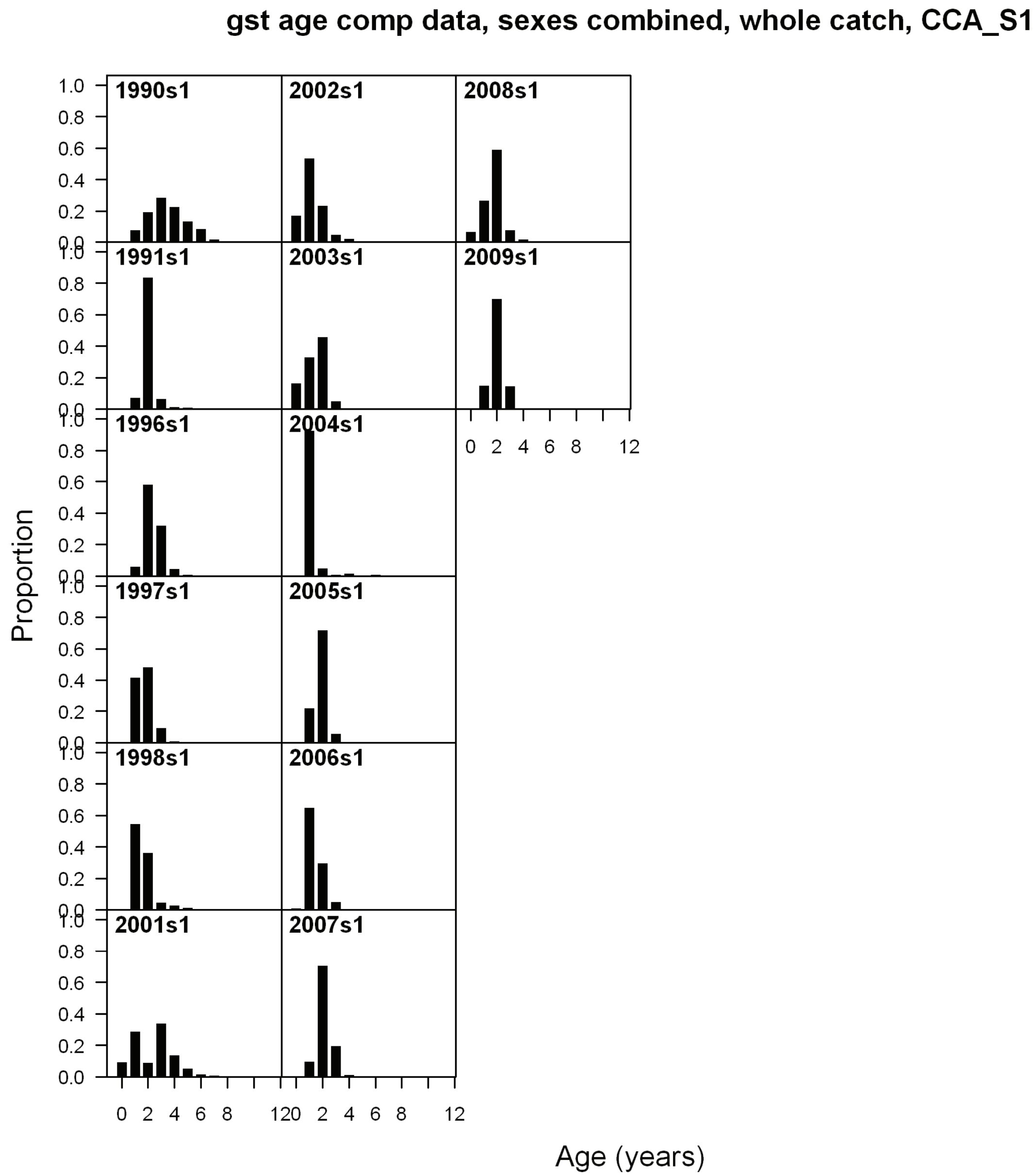


Figure 6d. Implied age-composition data for the CCA_S1 fishery.

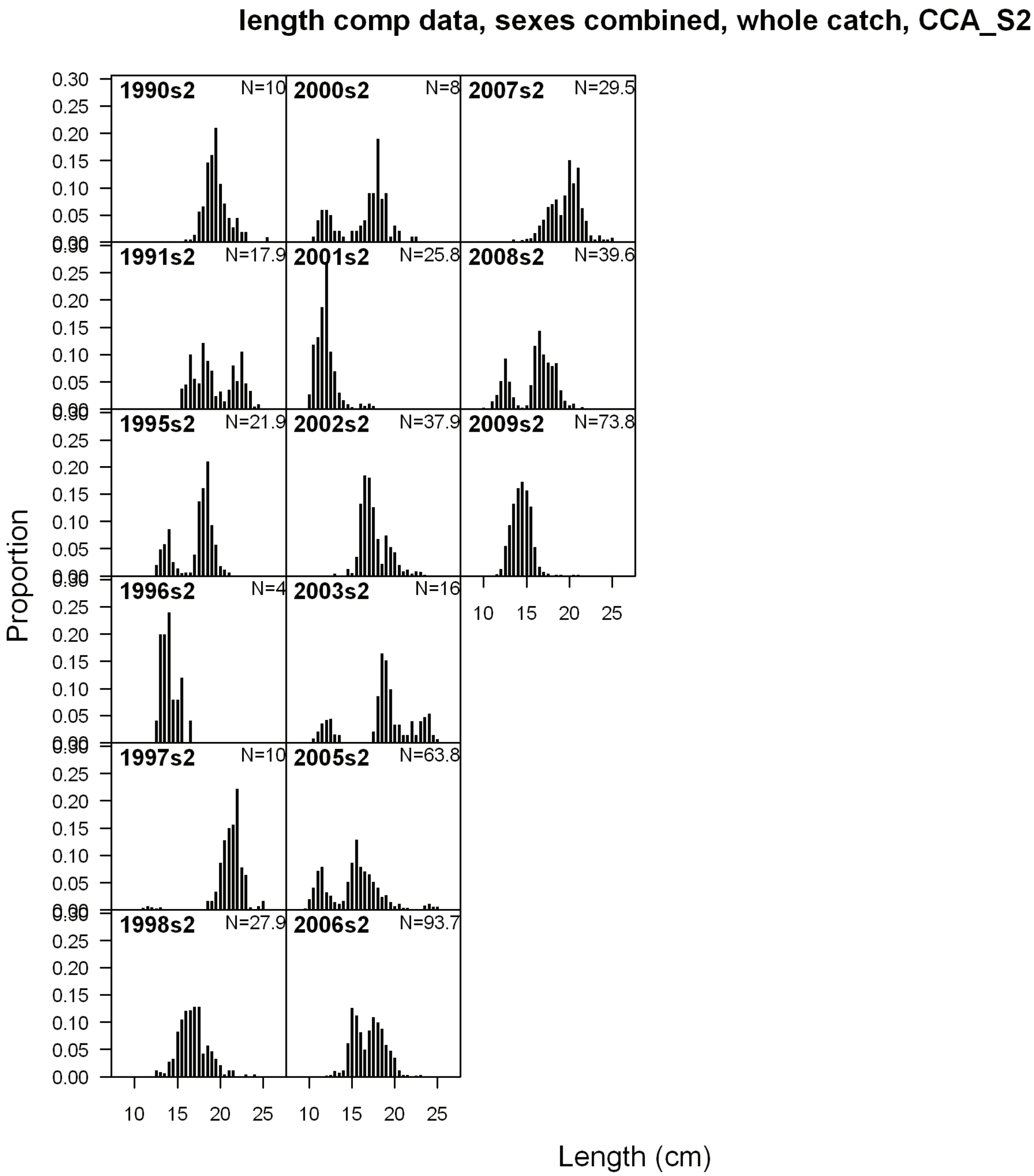


Figure 5e. Length-composition data for the CCA_S2 fishery.

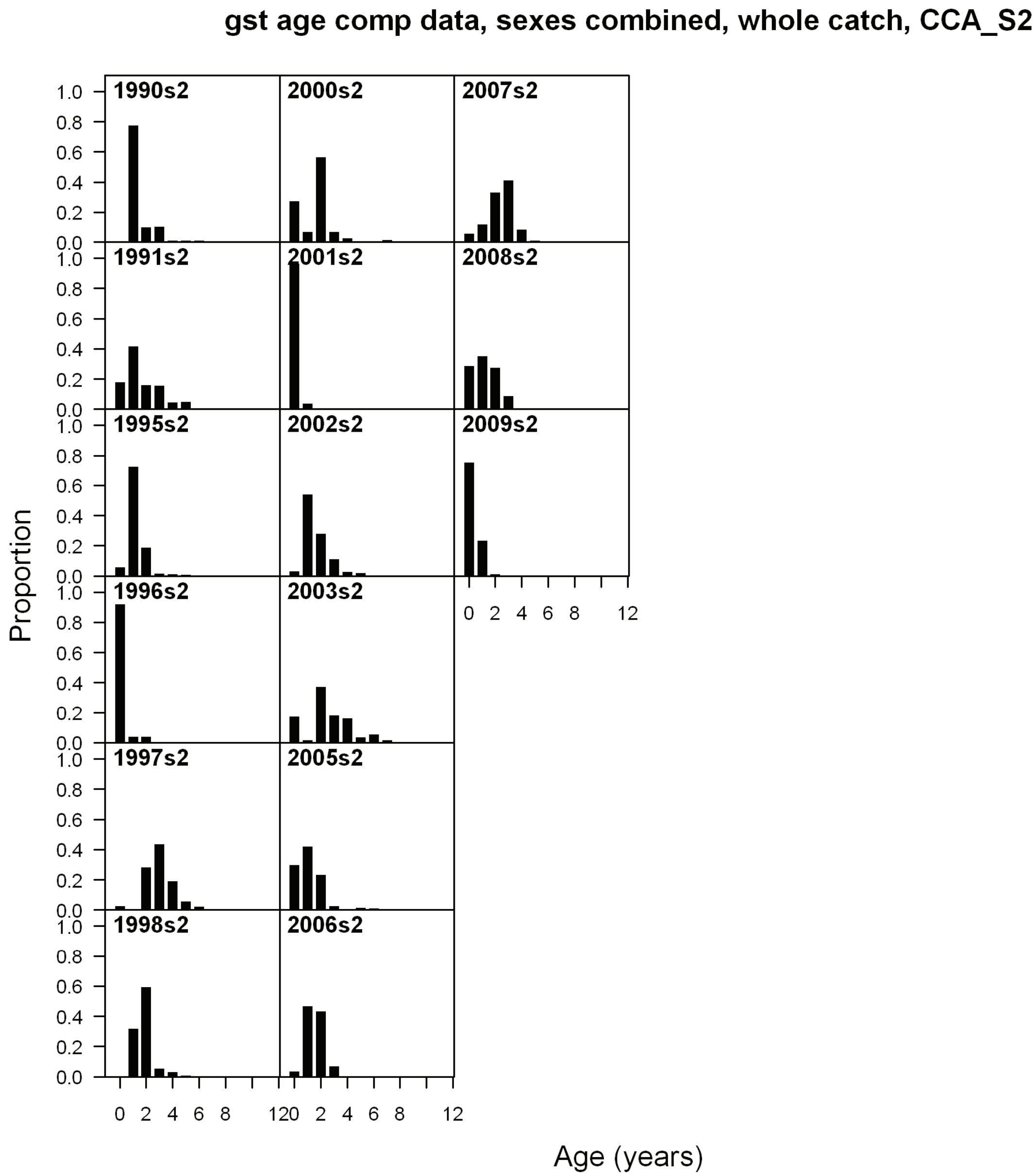


Figure 6e. Implied age-composition data for the CCA_S2 fishery.

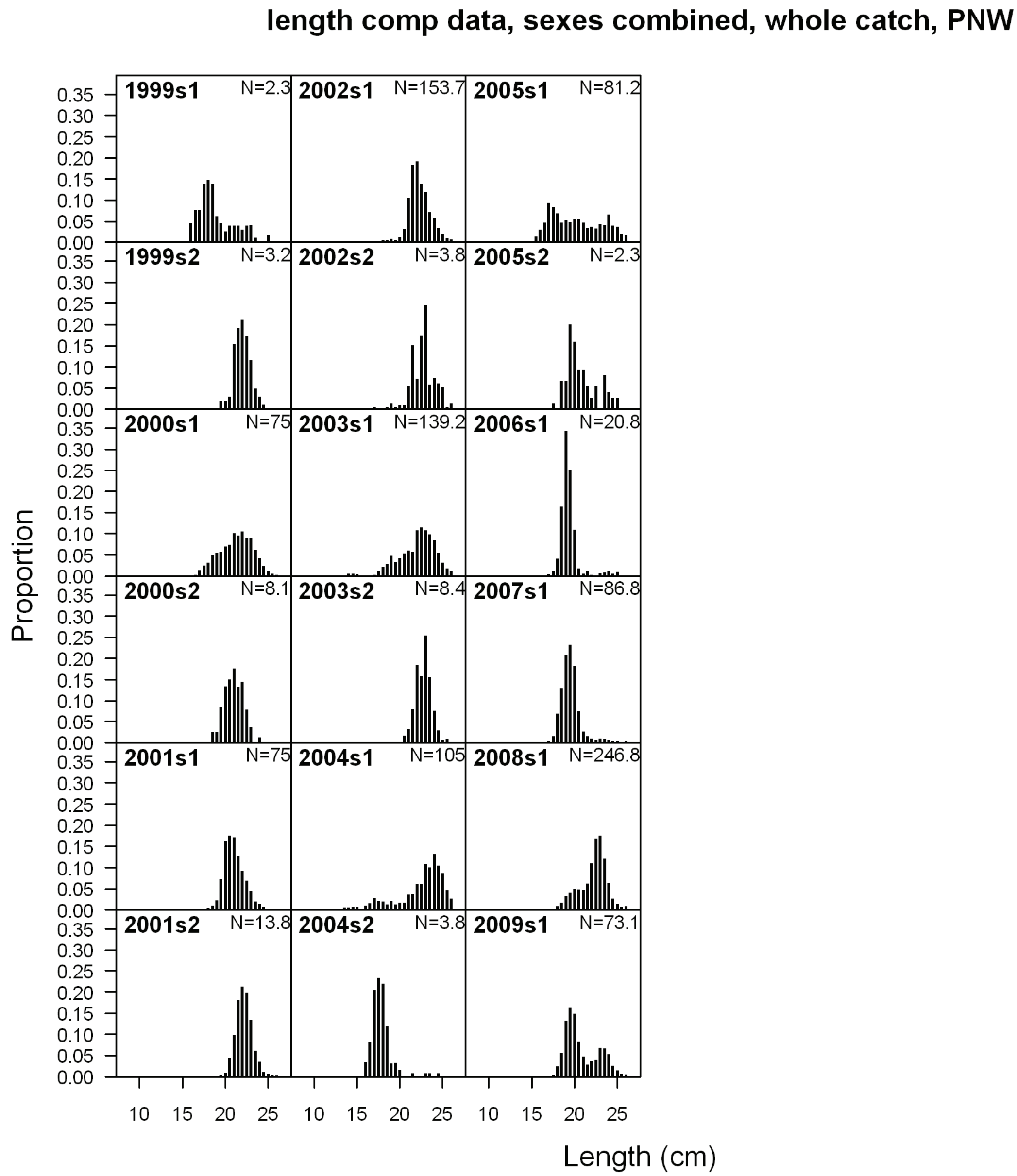


Figure 5f. Length-composition data for the PNW fishery.

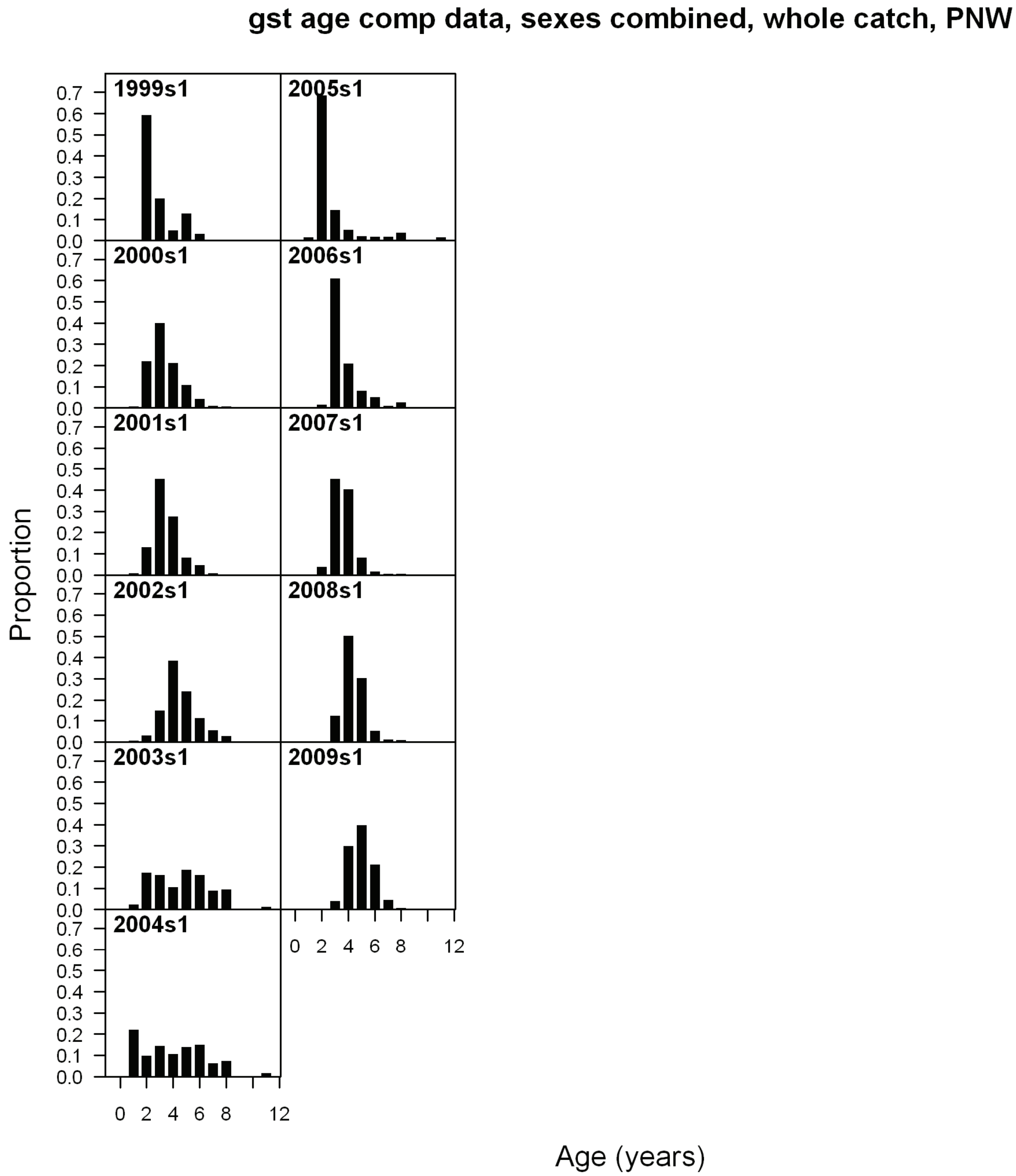


Figure 6f. Implied age-composition data for the PNW fishery.

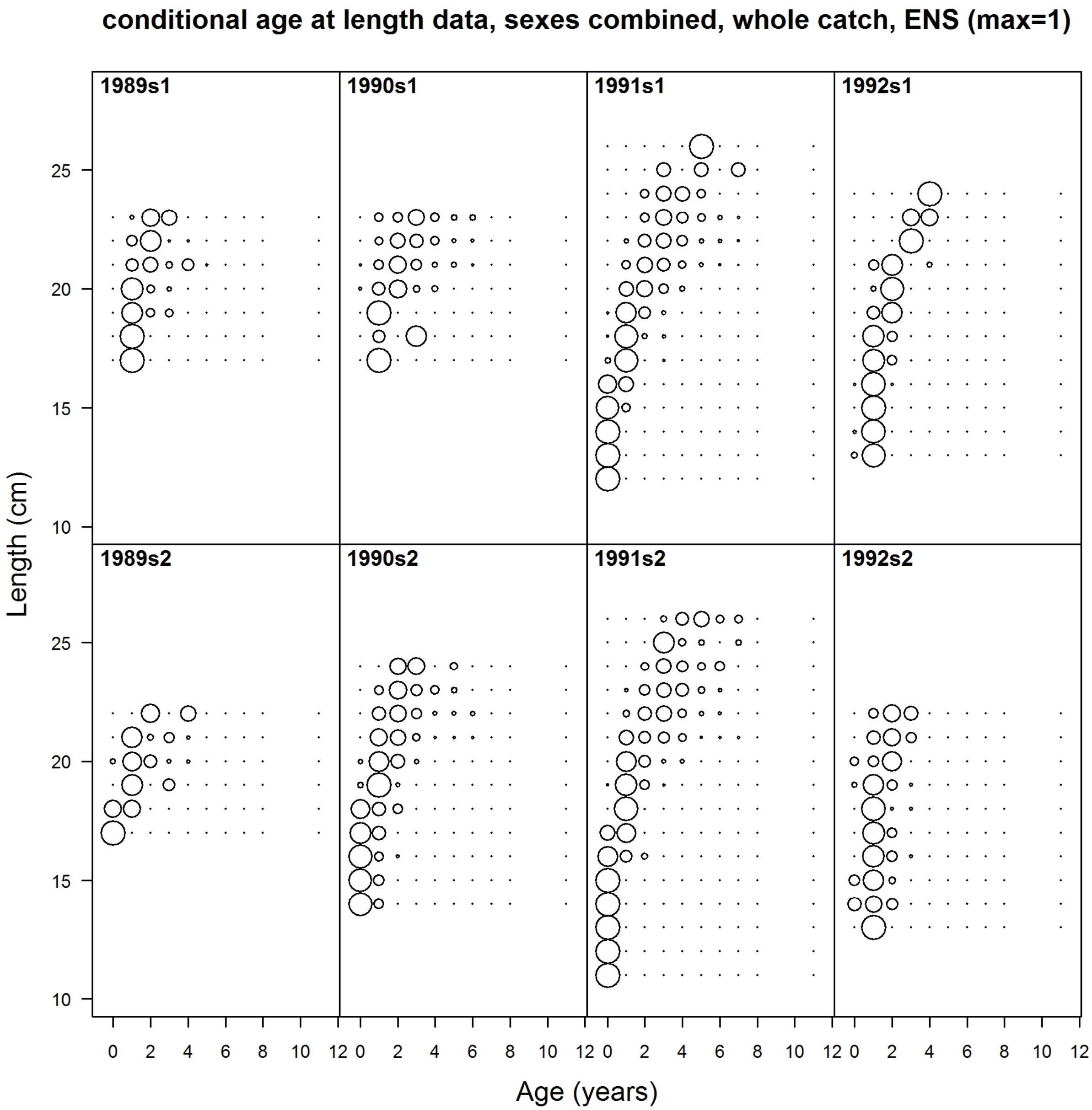


Figure 7a. Conditional age-at-length data for the ENS fishery, 1989-1992.

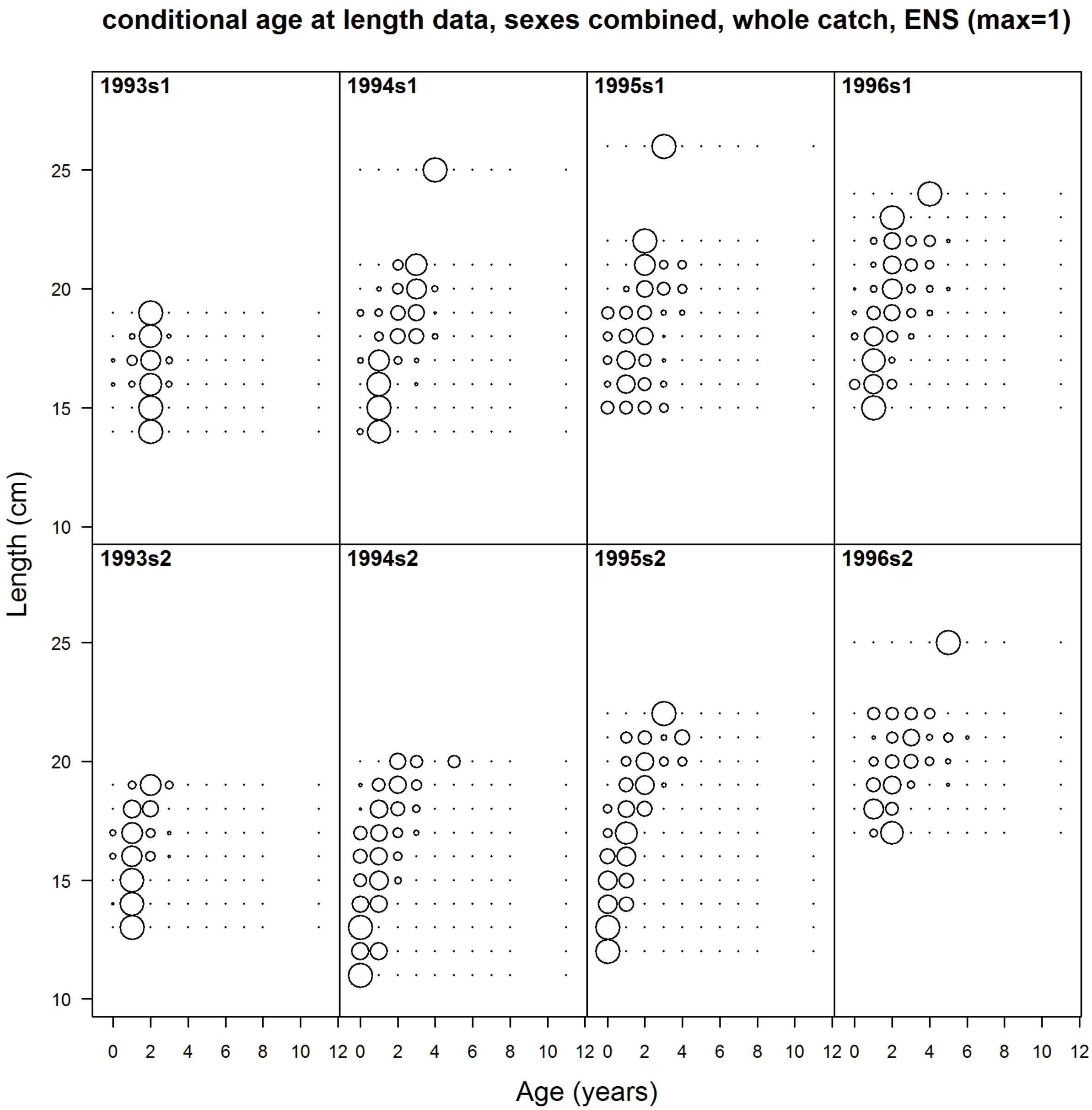


Figure 7a (cont'd). Conditional age-at-length data for the ENS fishery, 1993-1996.

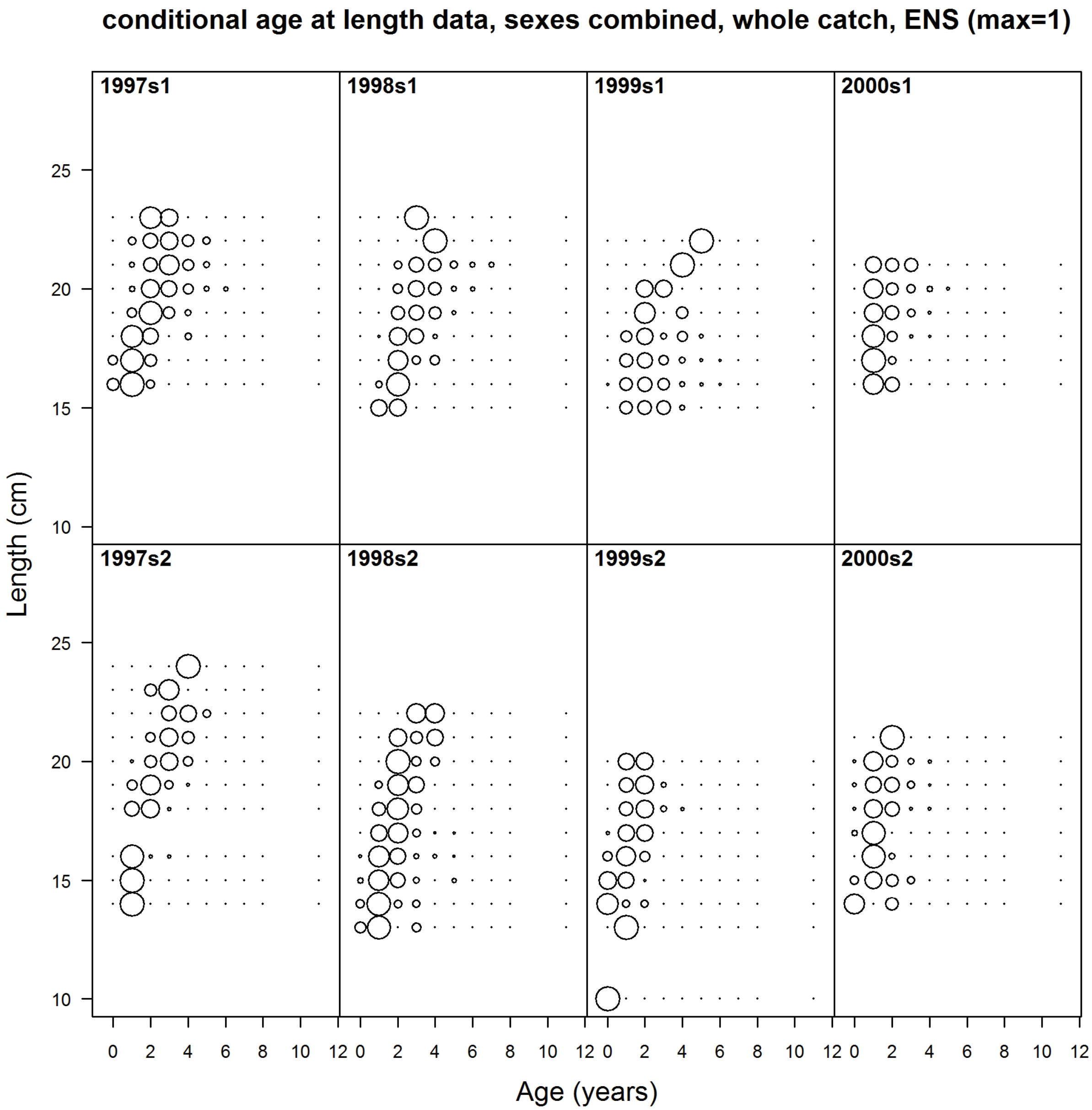


Figure 7a (cont'd). Conditional age-at-length data for the ENS fishery, 1997-2000.

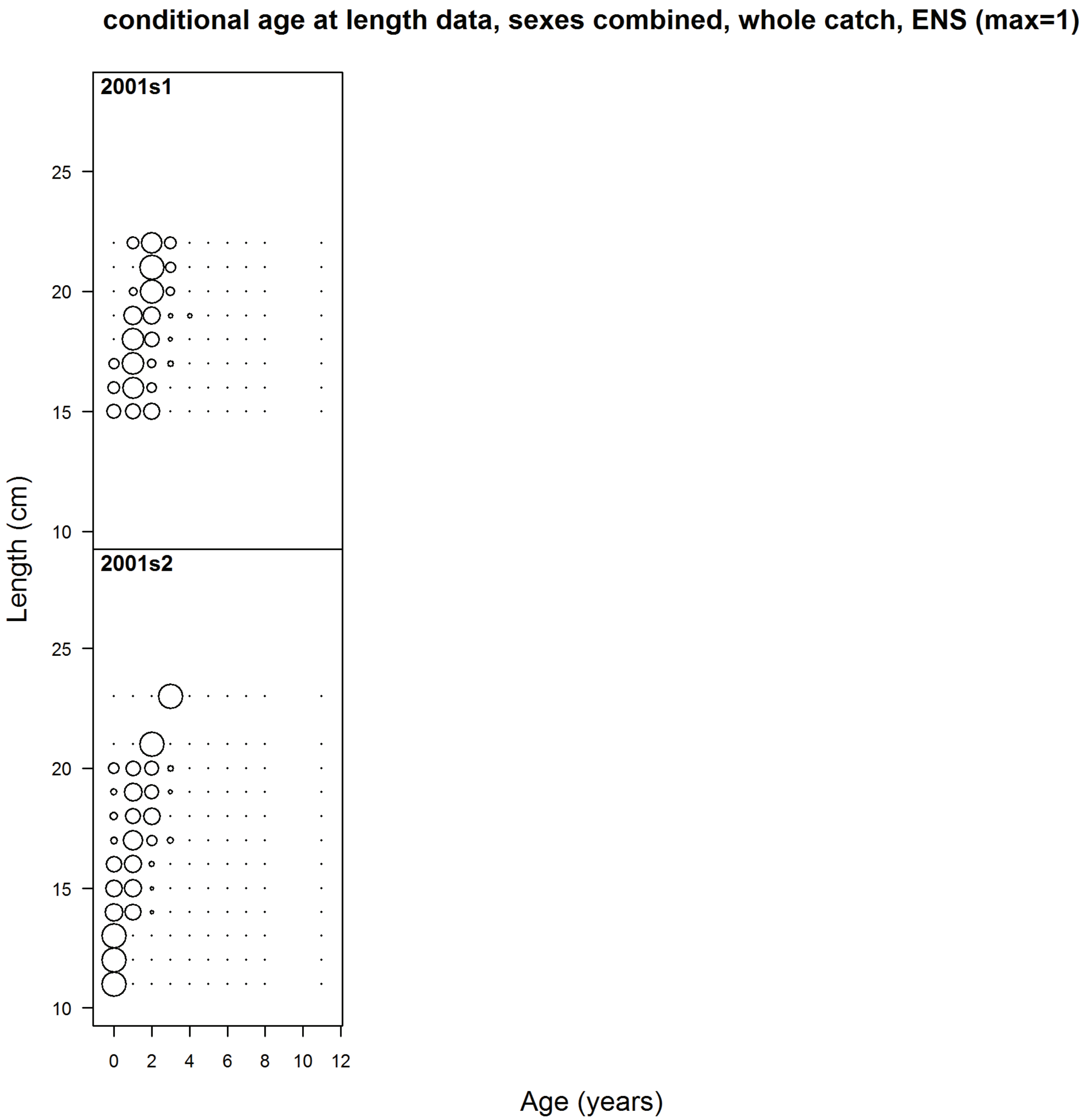


Figure 7a (cont'd). Conditional age-at-length data for the ENS fishery, 2001.

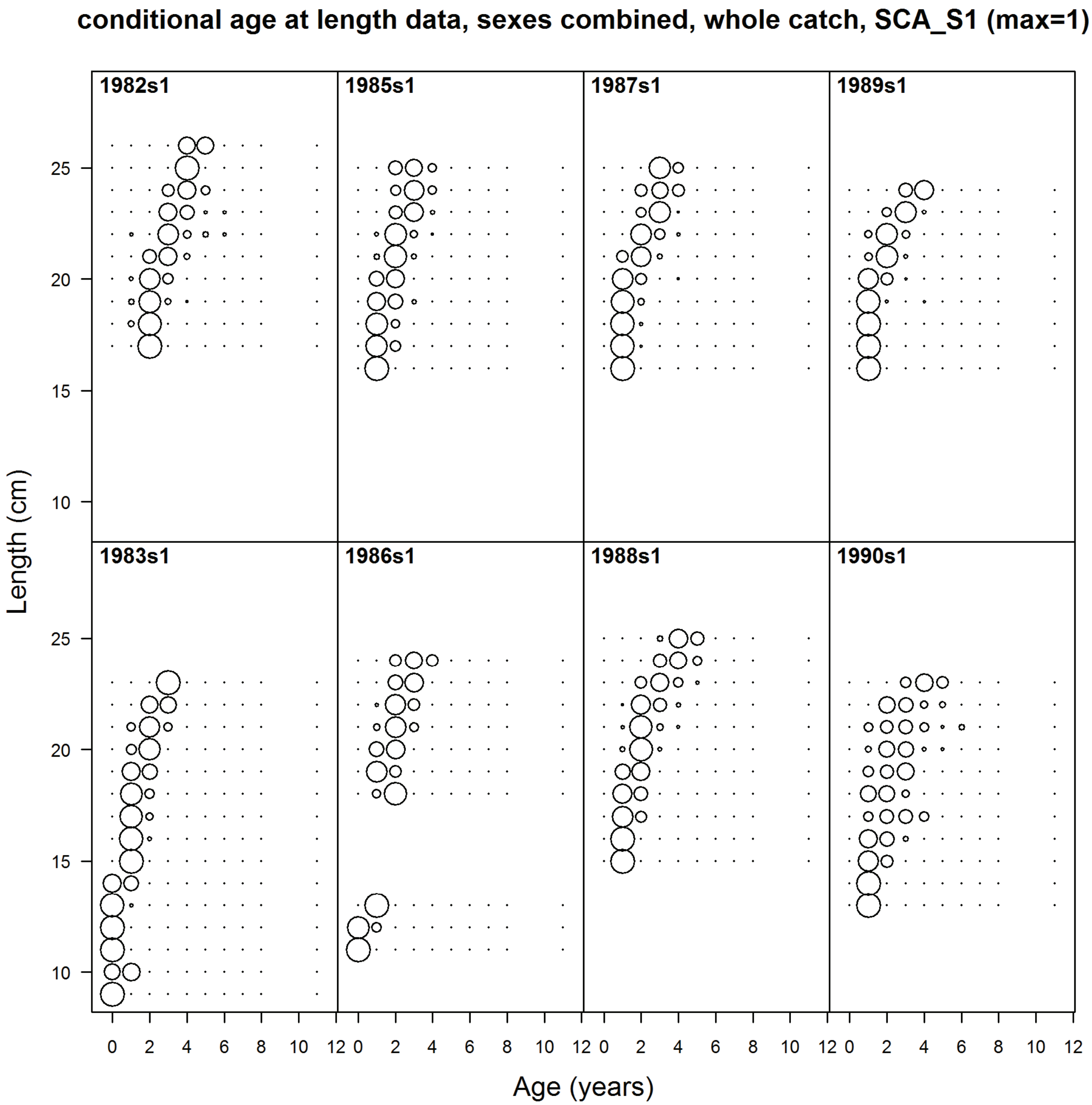


Figure 7b. Conditional age-at-length data for the SCA_S1 fishery, 1982-1990.

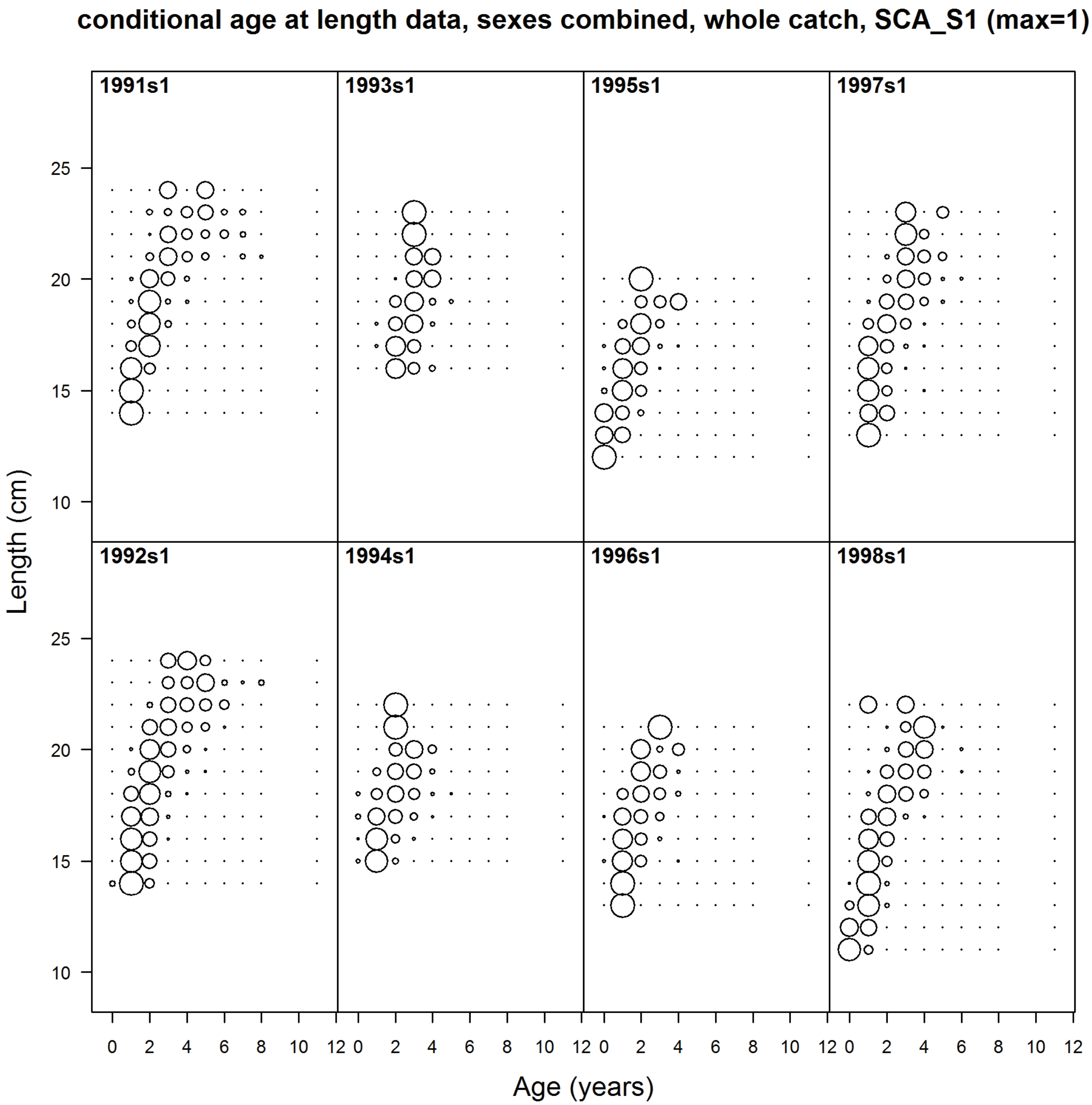


Figure 7b (cont'd). Conditional age-at-length data for the SCA_S1 fishery, 1991-1998.

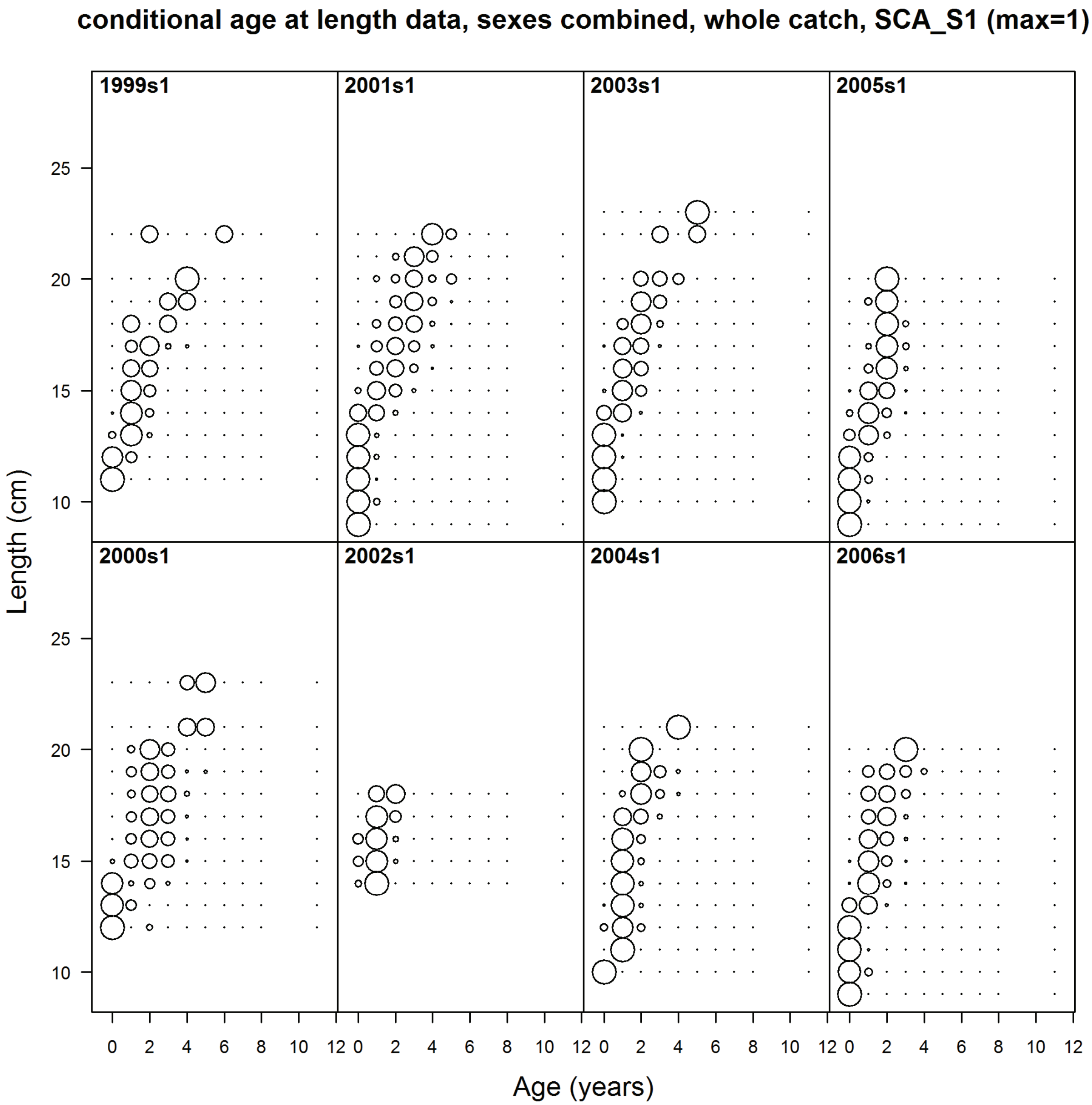


Figure 7b (cont'd). Conditional age-at-length data for the SCA_S1 fishery, 1999-2006.

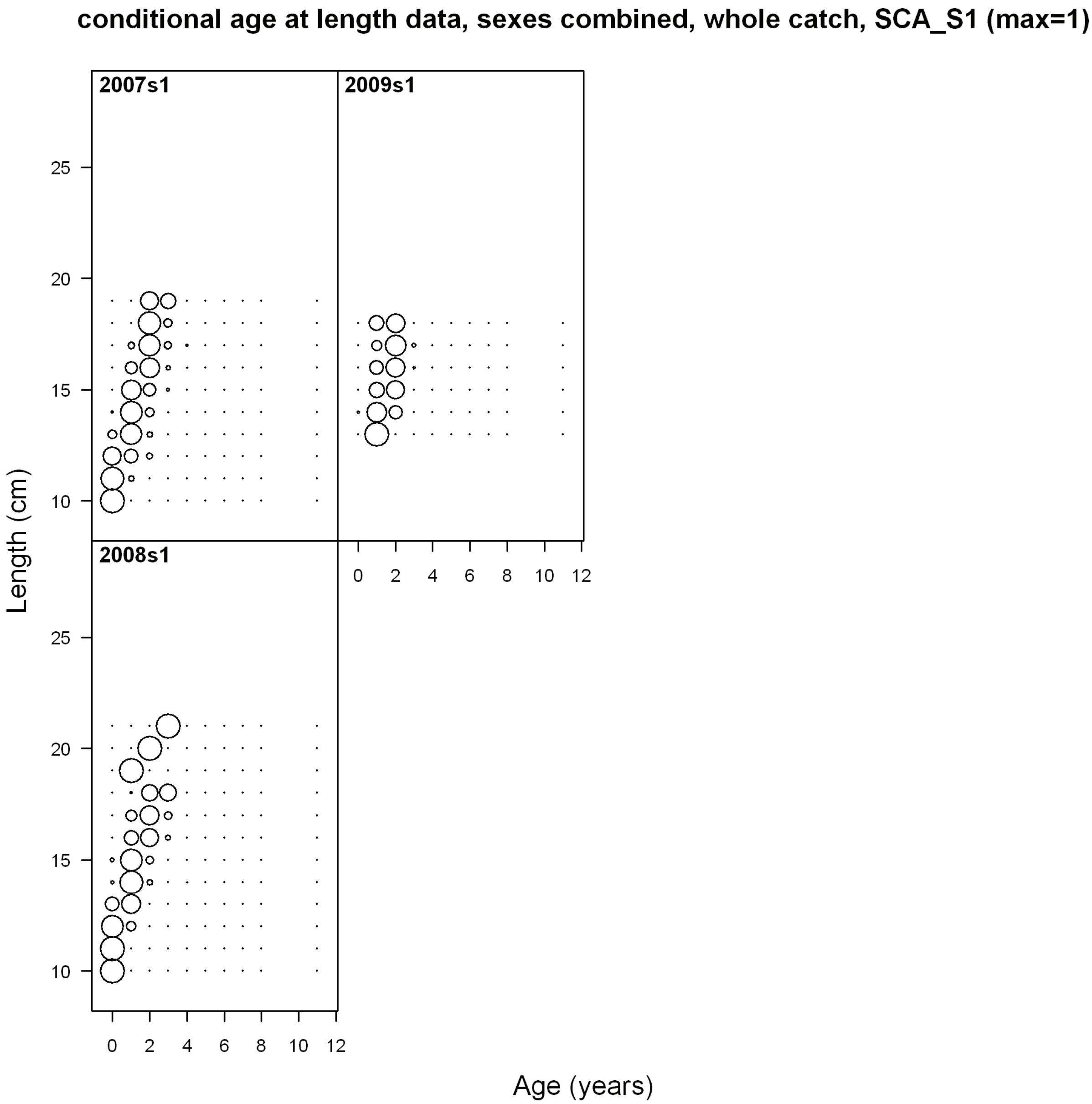


Figure 7b (cont'd). Conditional age-at-length data for the SCA_S1 fishery, 2007-2009.

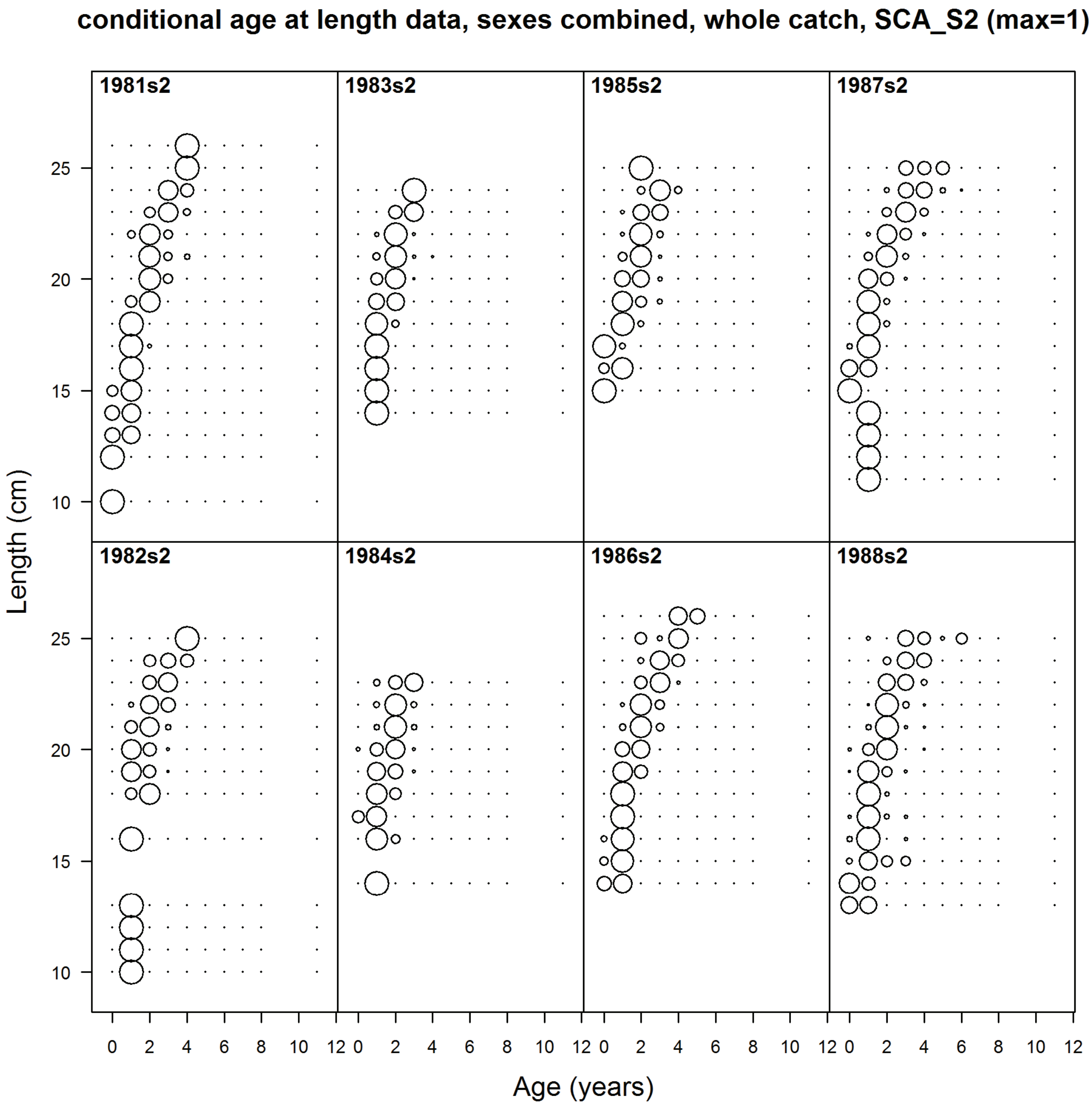


Figure 7c. Conditional age-at-length data for the SCA_S2 fishery, 1981-1988.

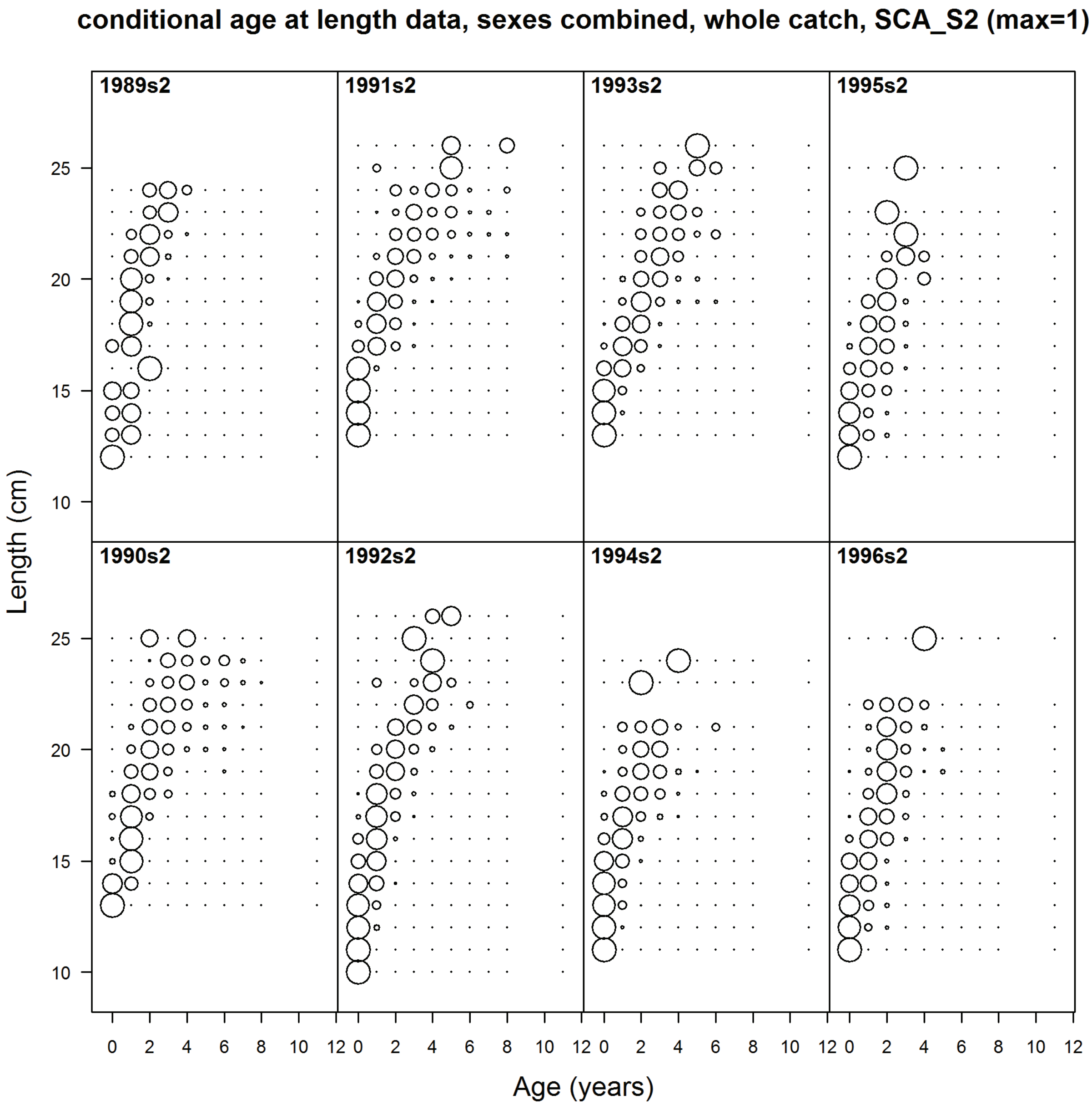


Figure 7c (cont'd). Conditional age-at-length data for the SCA_S2 fishery, 1989-1996.

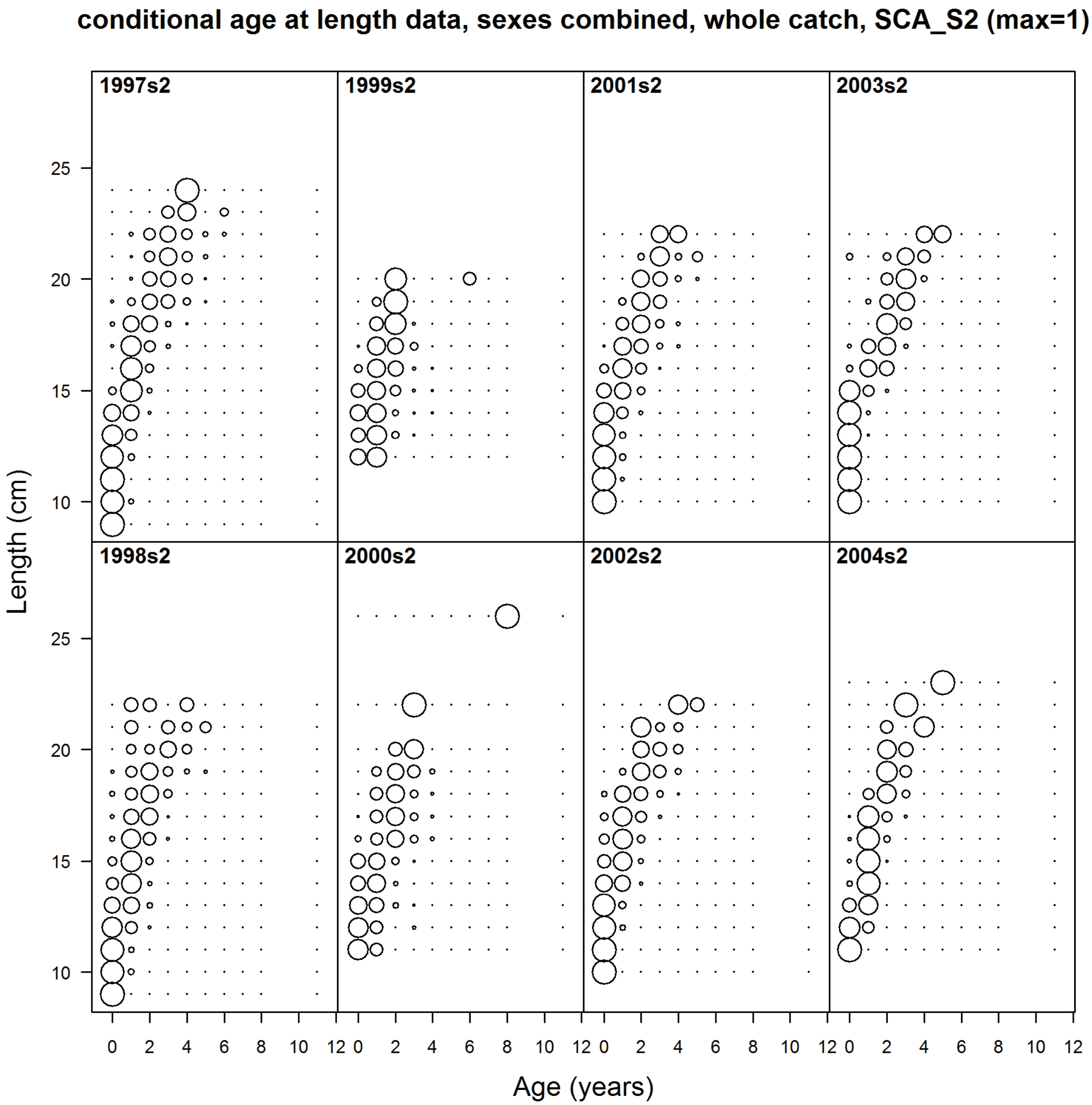


Figure 7c (cont'd). Conditional age-at-length data for the SCA_S2 fishery, 1997-2004.

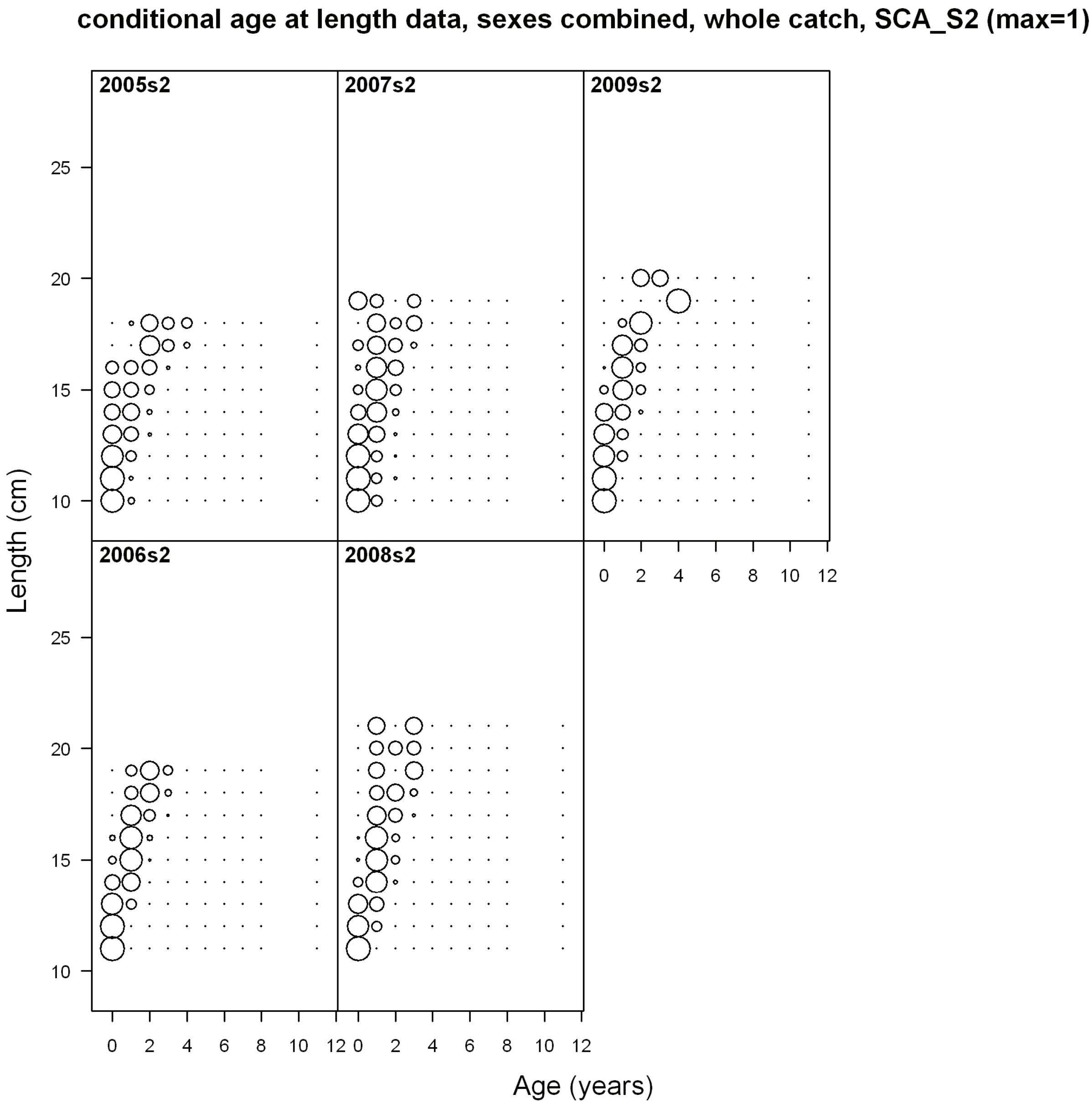


Figure 7c (cont'd). Conditional age-at-length data for the SCA_S2 fishery, 2005-2009.

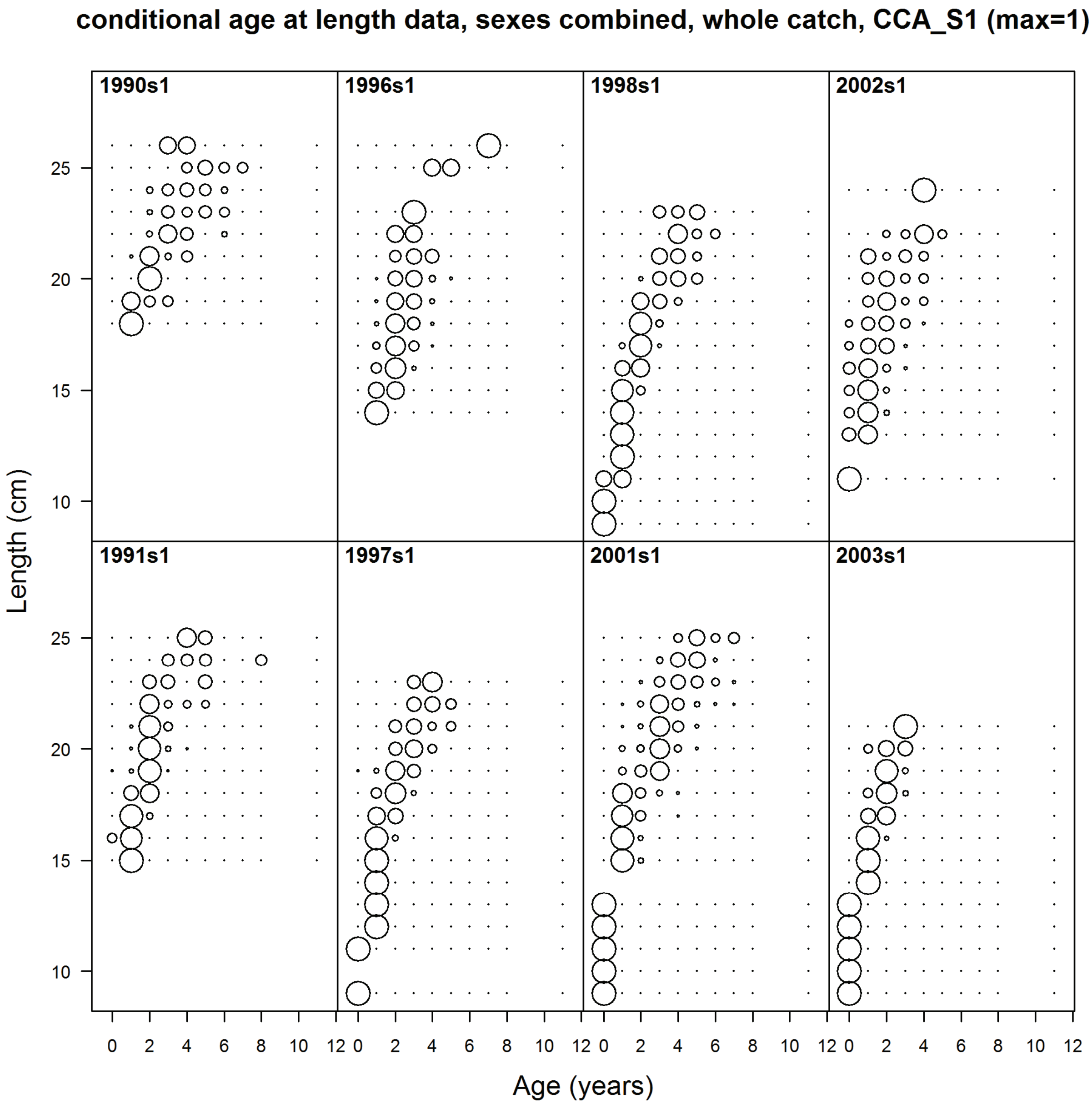


Figure 7d. Conditional age-at-length data for the CCA_S1 fishery, 1990-2003.

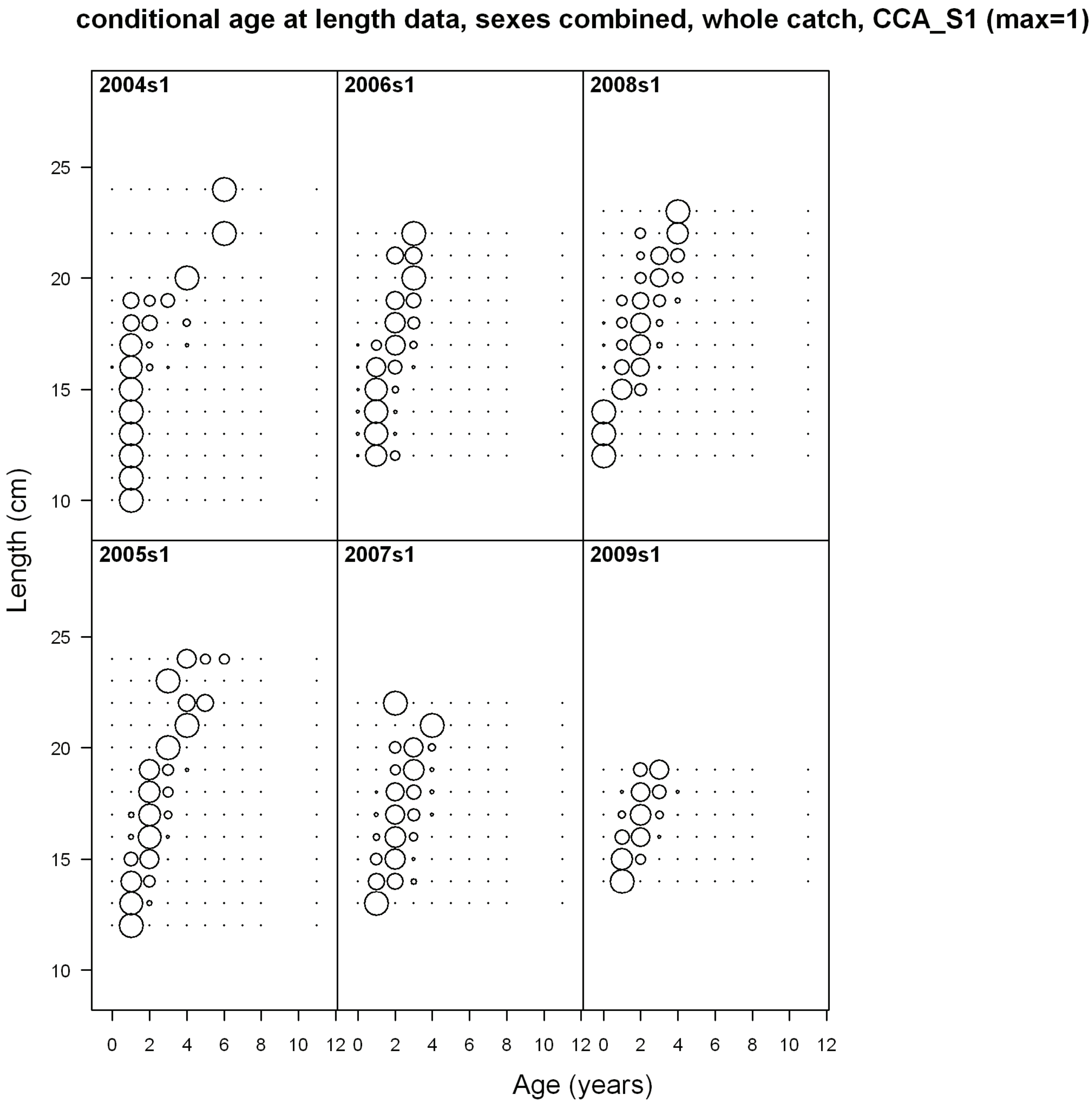


Figure 7d (cont'd). Conditional age-at-length data for the CCA_S1 fishery, 2004-2009.

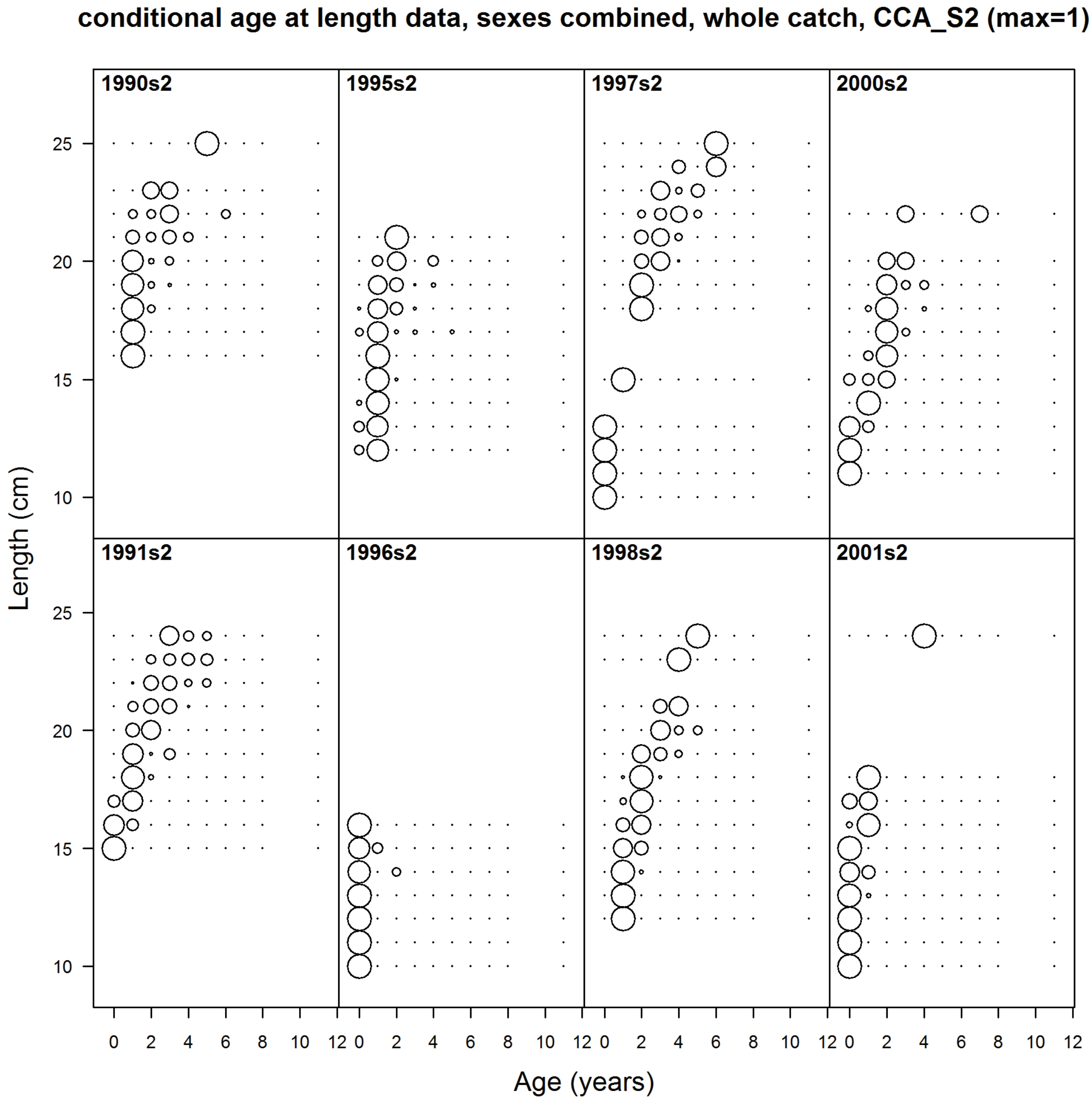


Figure 7e. Conditional age-at-length data for the CCA_S2 fishery, 1990-2001.

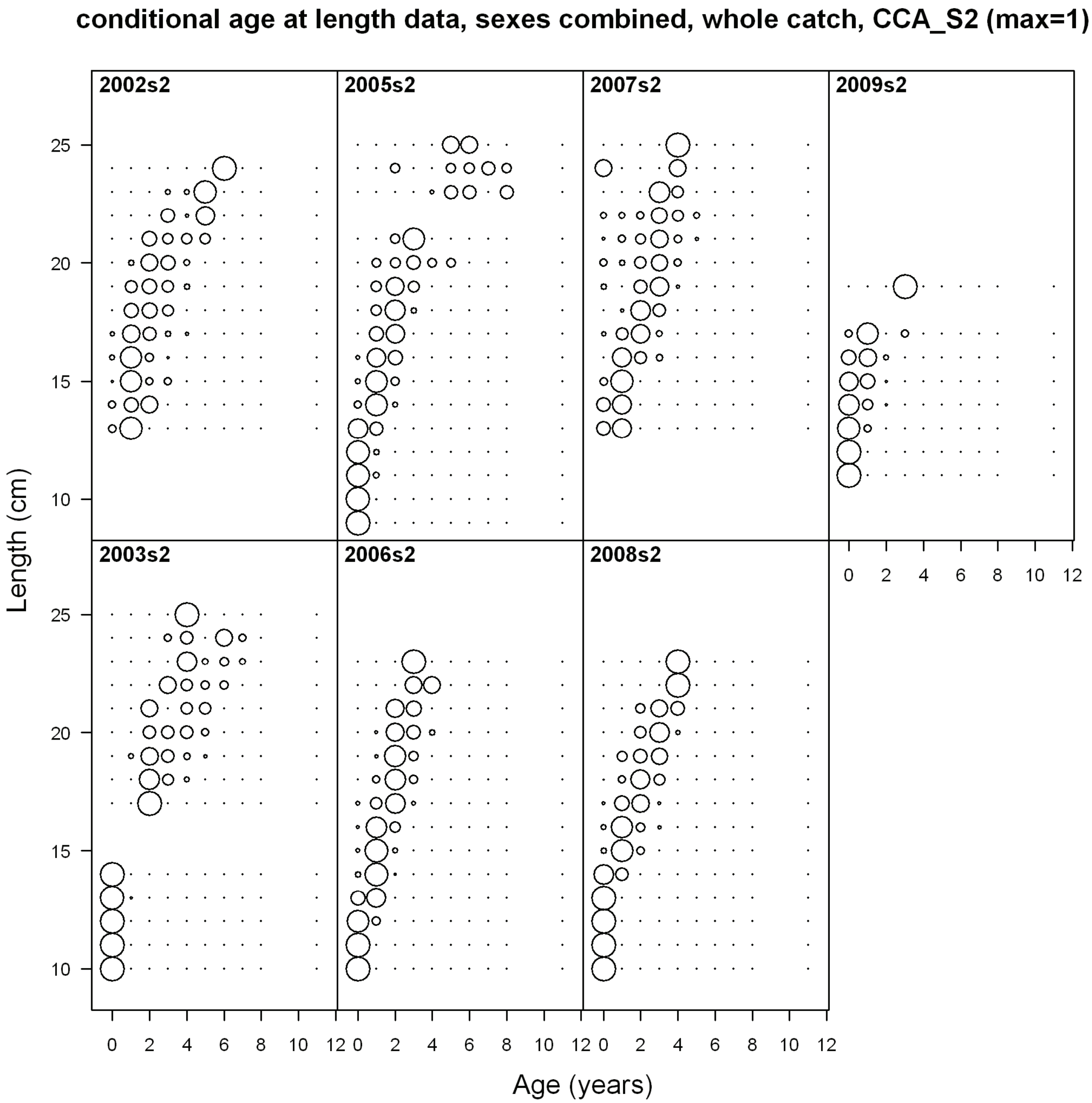


Figure 7e (cont'd). Conditional age-at-length data for the CCA_S2 fishery, 2002-2009.

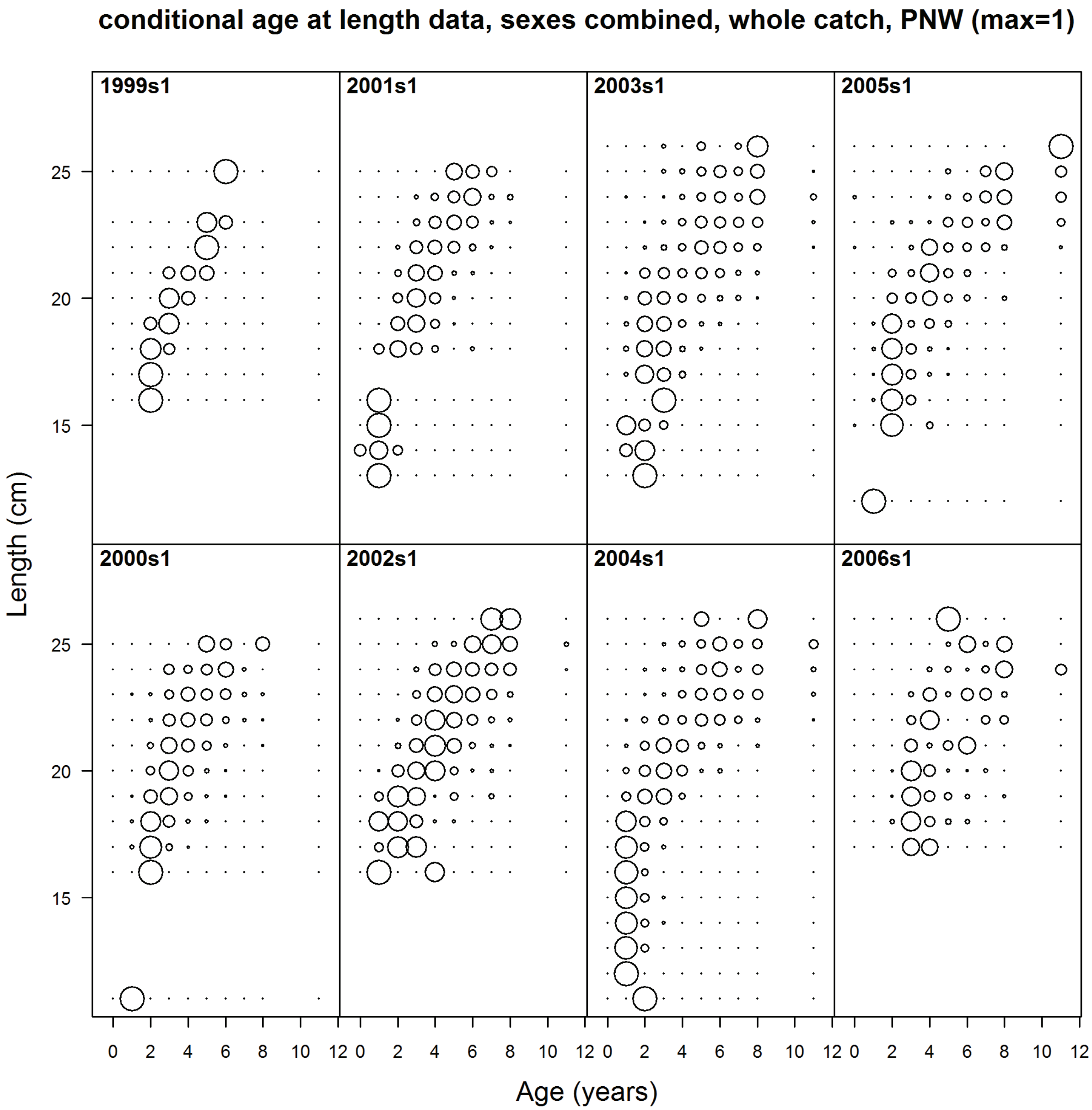


Figure 7f. Conditional age-at-length data for the PNW fishery, 1999-2006.

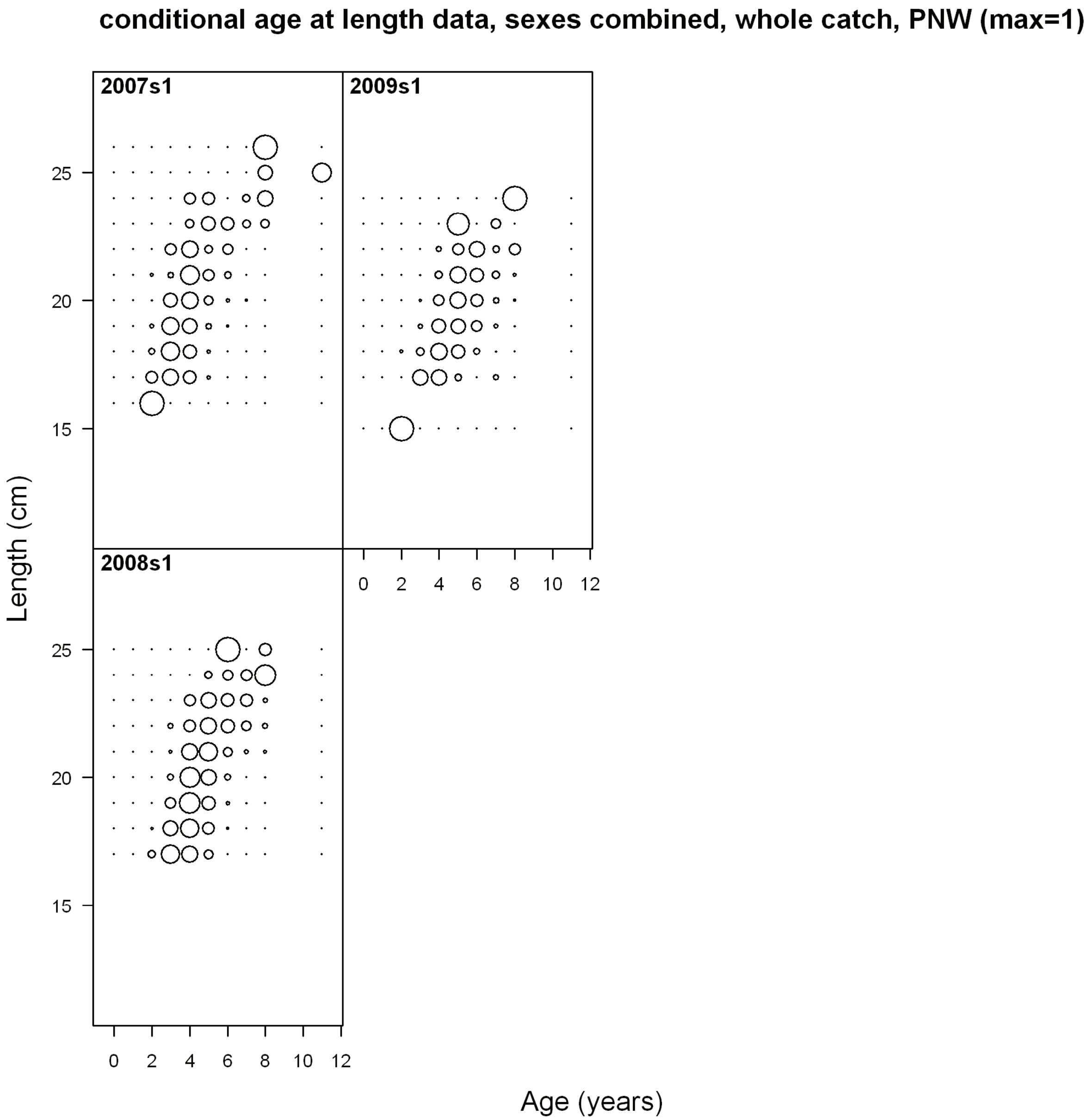


Figure 7f (cont'd). Conditional age-at-length data for the PNW fishery, 2007-2009.

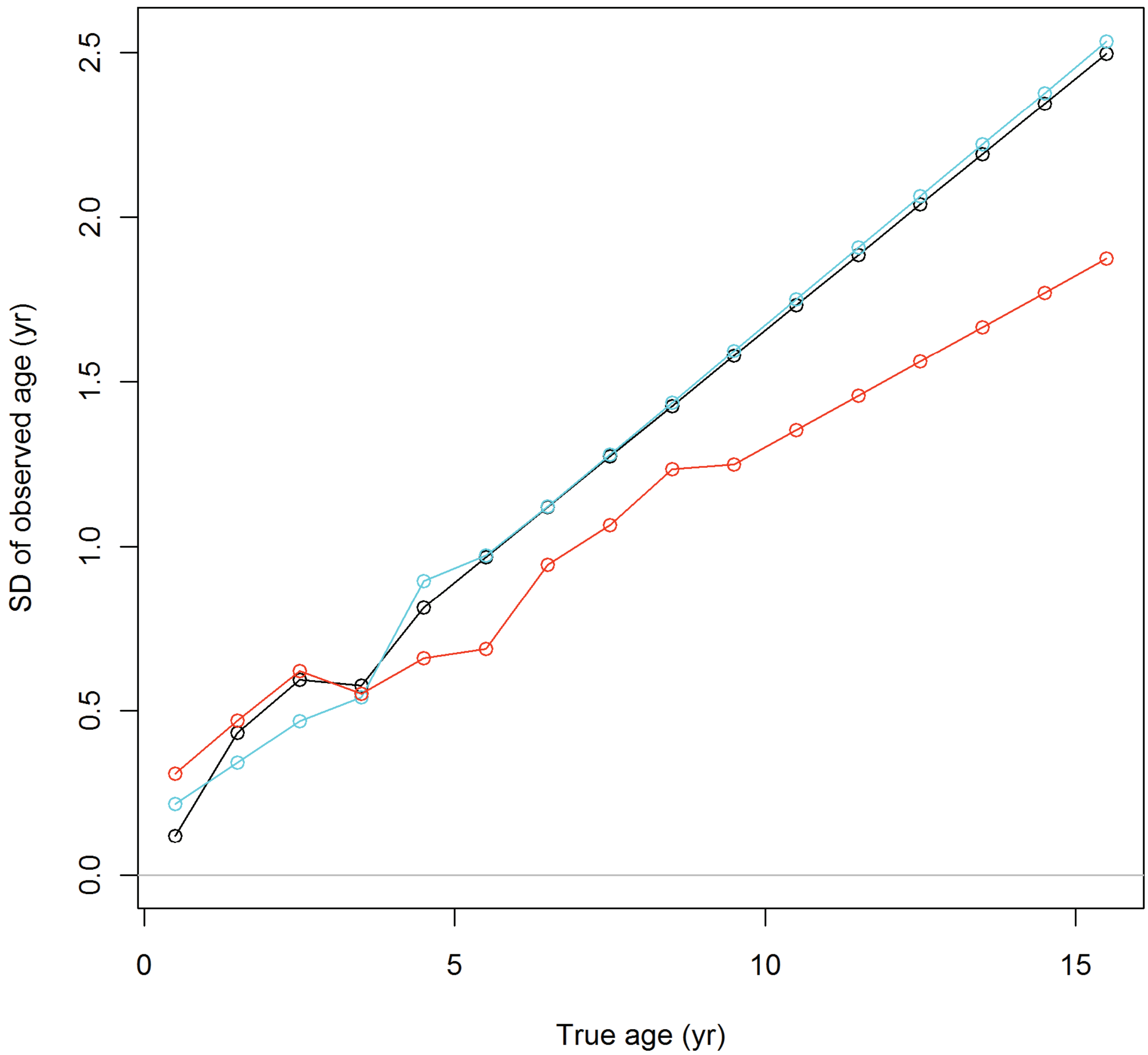


Figure 8. Fishery-specific ageing errors: black line is ENS, blue line is SCA and CCA, and red line is PNW.

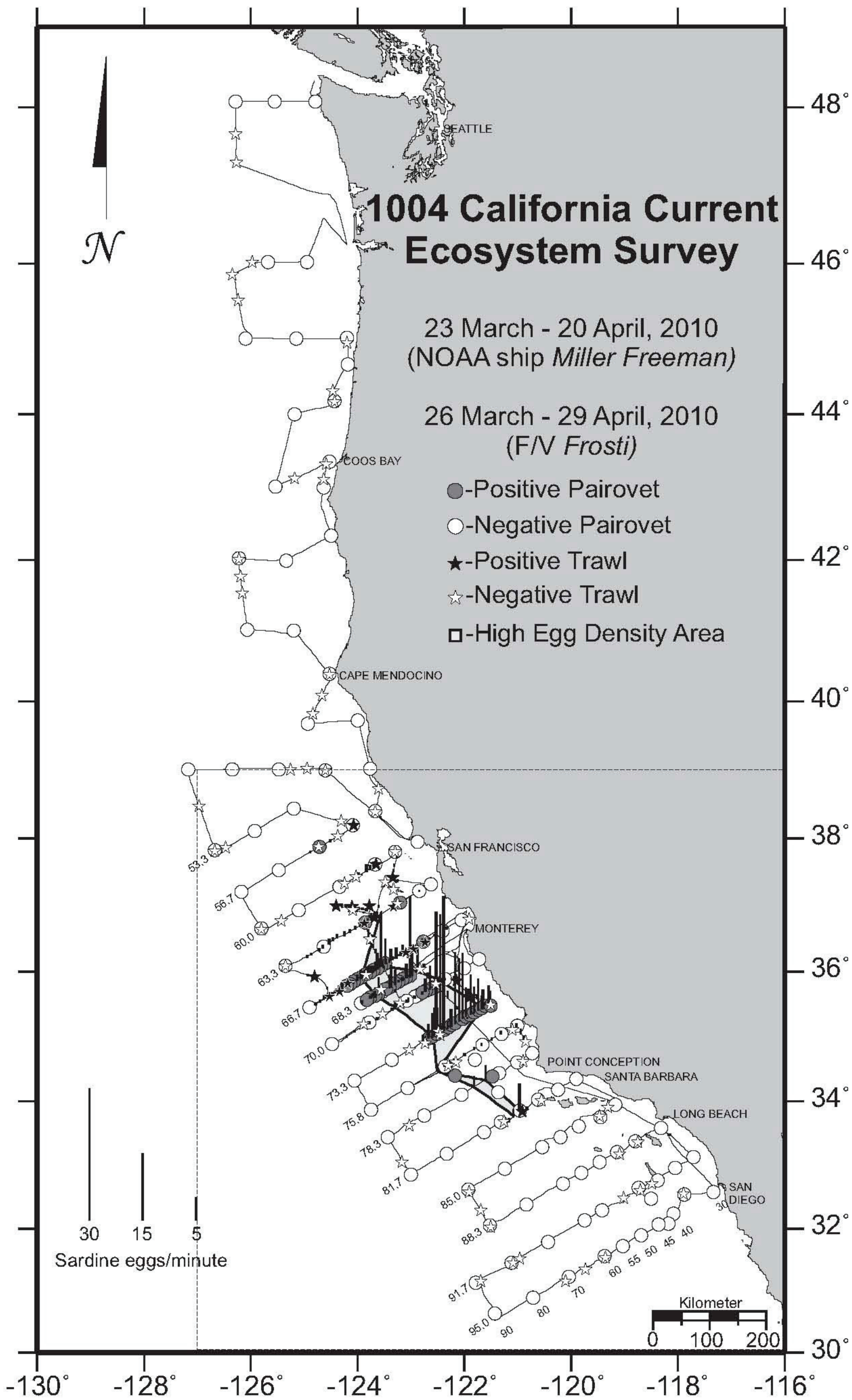


Figure 9. Distribution of CUFES and Pairovet ichthyoplankton collections, and adult trawl samples from the SWFSC 1004 sardine survey (coast-wide), conducted onboard the F/V *Frosti* and NOAA ship *Miller Freeman* during spring of 2010. Standard sampling area for the DEPM/TEP index (inset) is displayed on the following page.

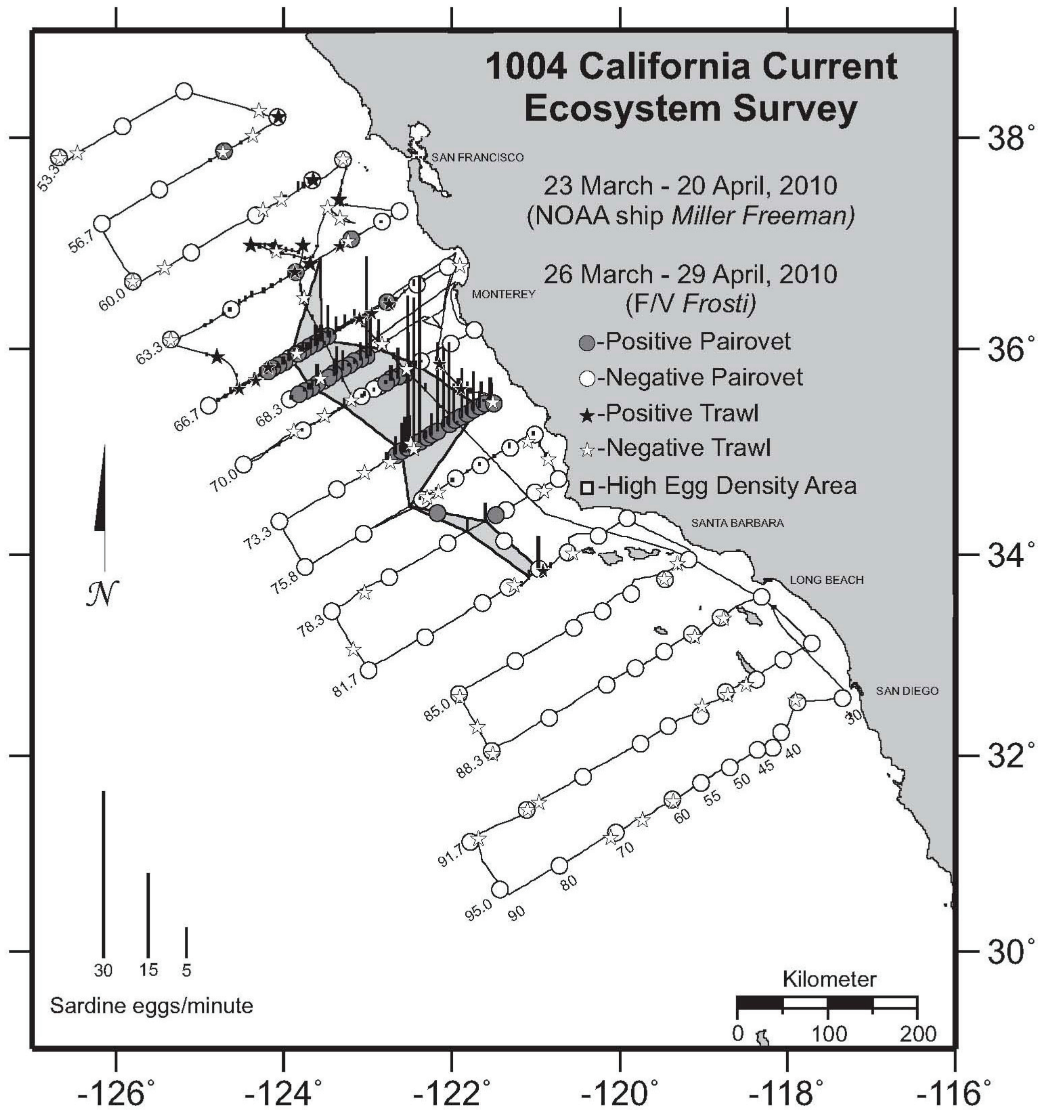


Figure 10. Distribution of CUFES and Pairovet ichthyoplankton collections, and adult trawl samples from the SWFSC 1004 sardine survey (standard sampling area for the DEPM index), conducted onboard the F/V *Frosti* and NOAA ship *Miller Freeman* during spring of 2010.

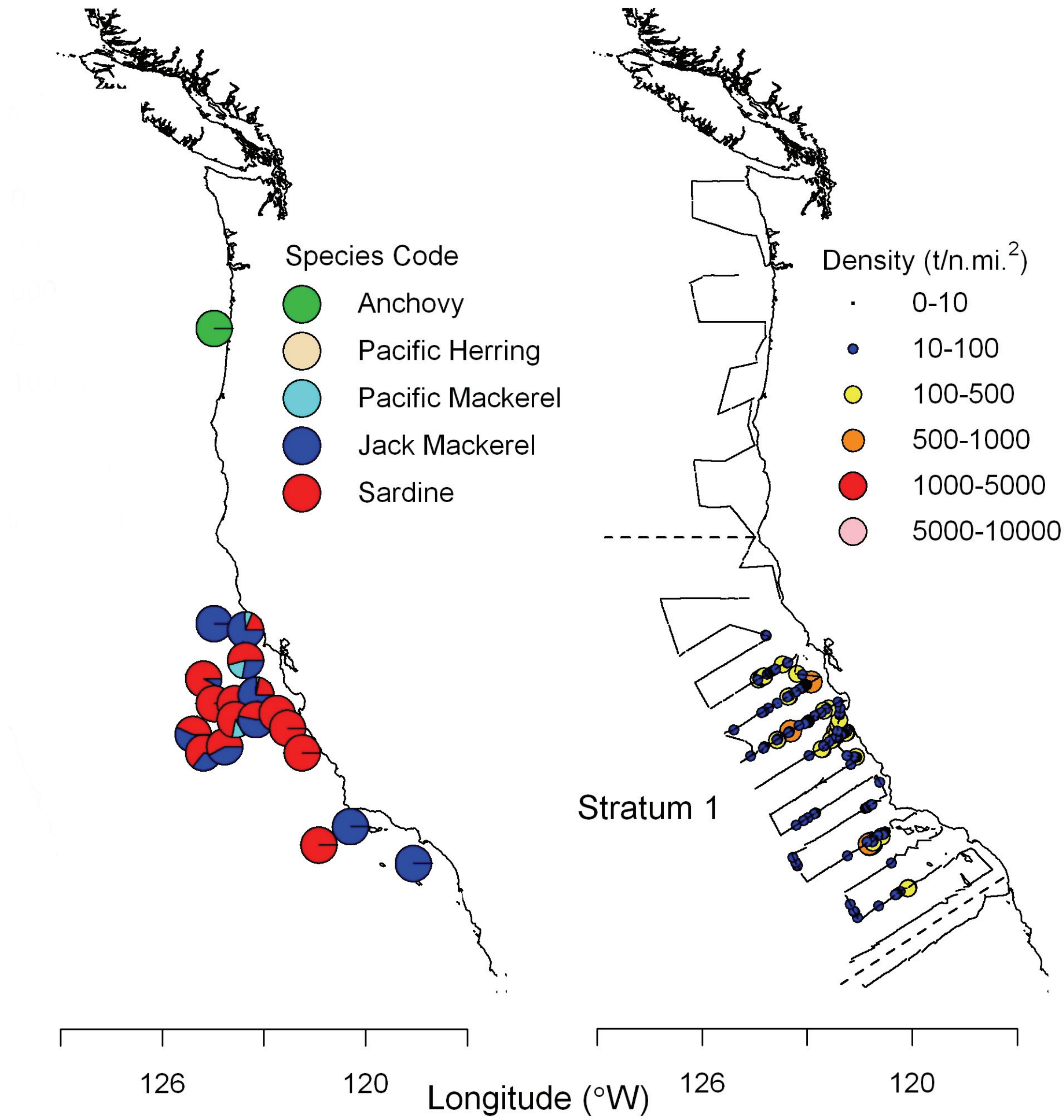


Figure 11. Trawl species composition (left) and Pacific sardine density (right) measured by acoustic backscatter during the SWFSC 1004 sardine survey (coast-wide), conducted onboard the F/V *Frosti* and NOAA ship *Miller Freeman* during spring of 2010. Maps provided by Drs. David Demer and Juan Zwolinski (SWFSC Advanced Survey Technologies).

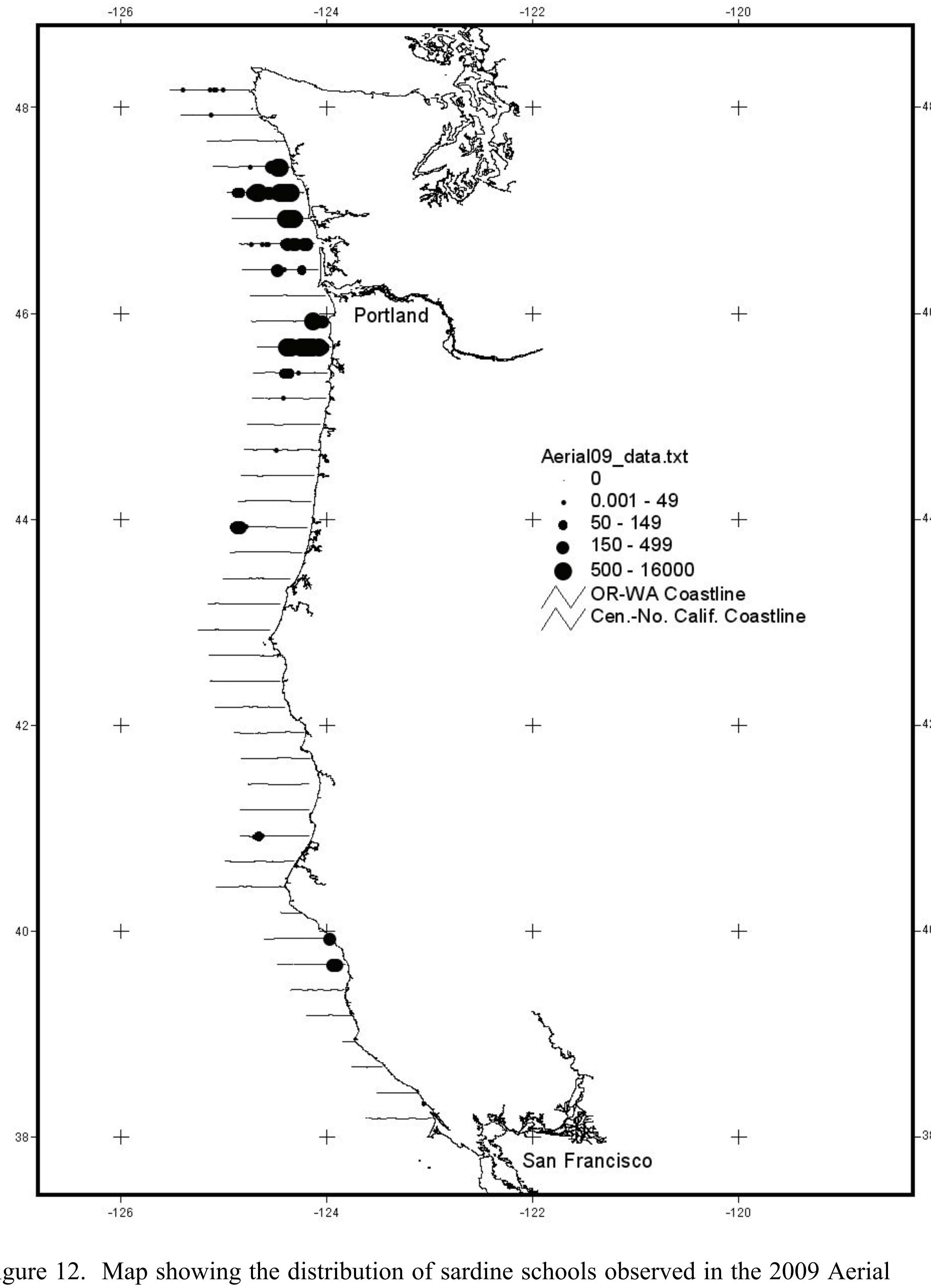


Figure 12. Map showing the distribution of sardine schools observed in the 2009 Aerial Sardine Survey (data from Jagielo 2009).

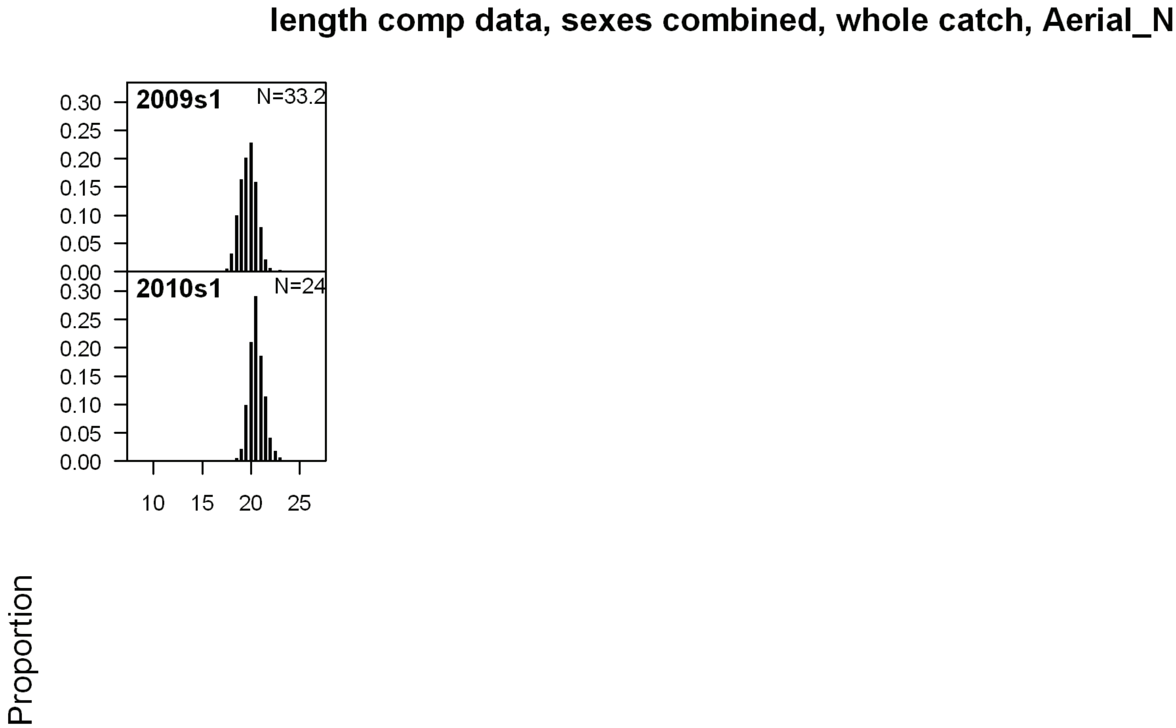


Figure 13. Length-composition data for the aerial survey.

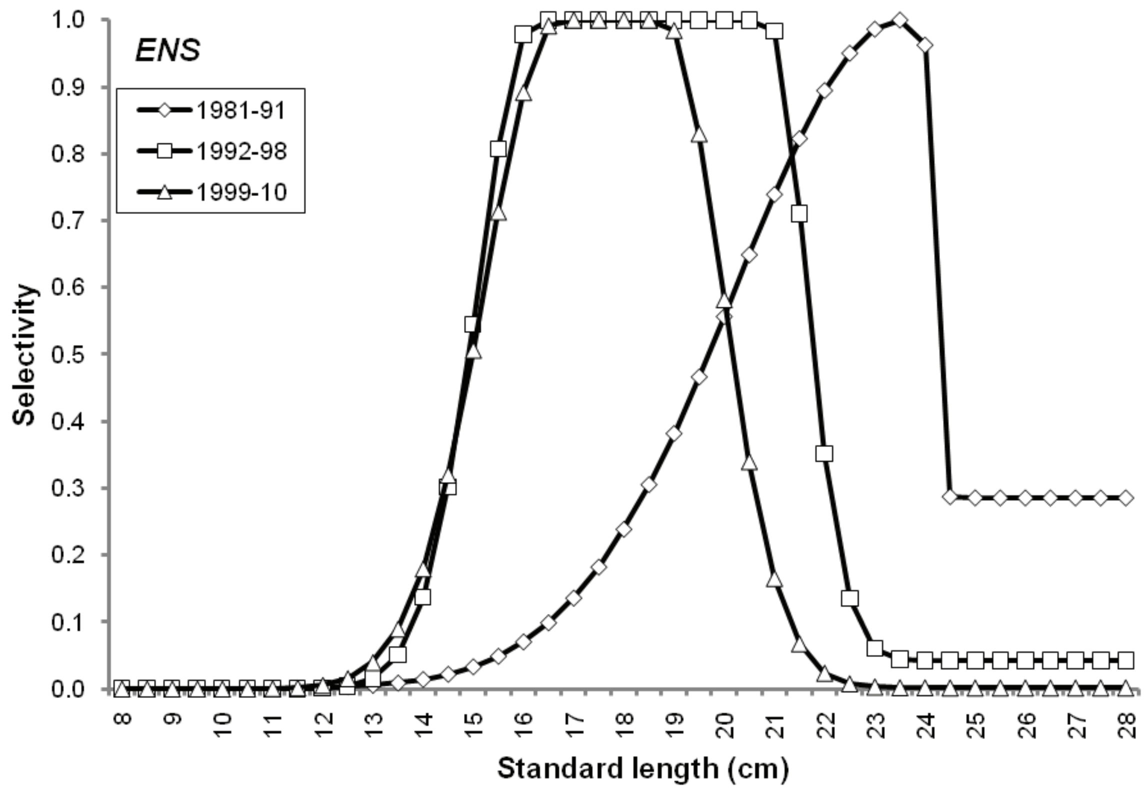


Figure 14a. Length-based selectivity for the ENS fleet by time block.

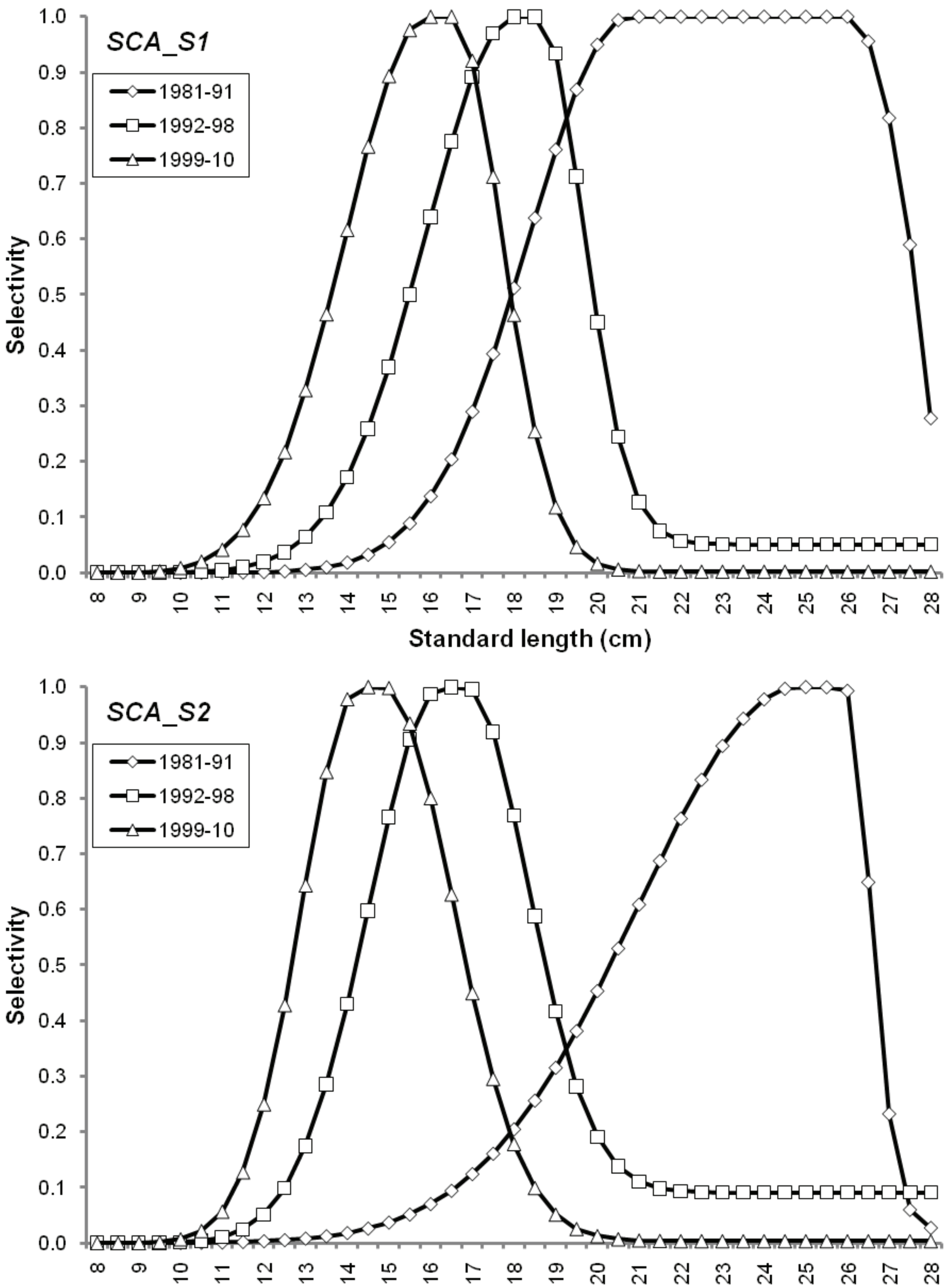


Figure 14b. Length-based selectivity for the SCA fleet by semester and time block.

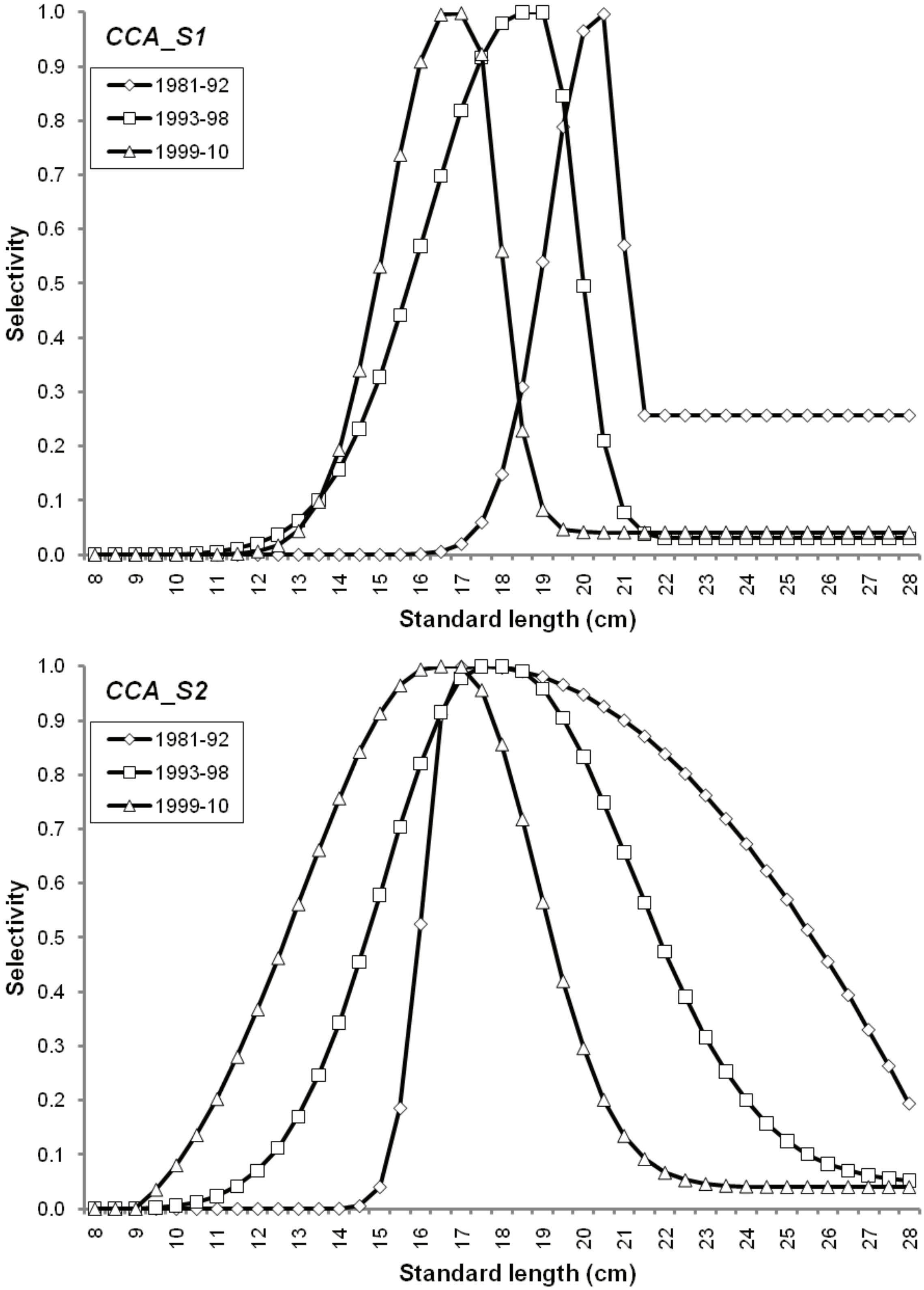


Figure 14c. Length-based selectivity for the CCA fleet by semester and time block.

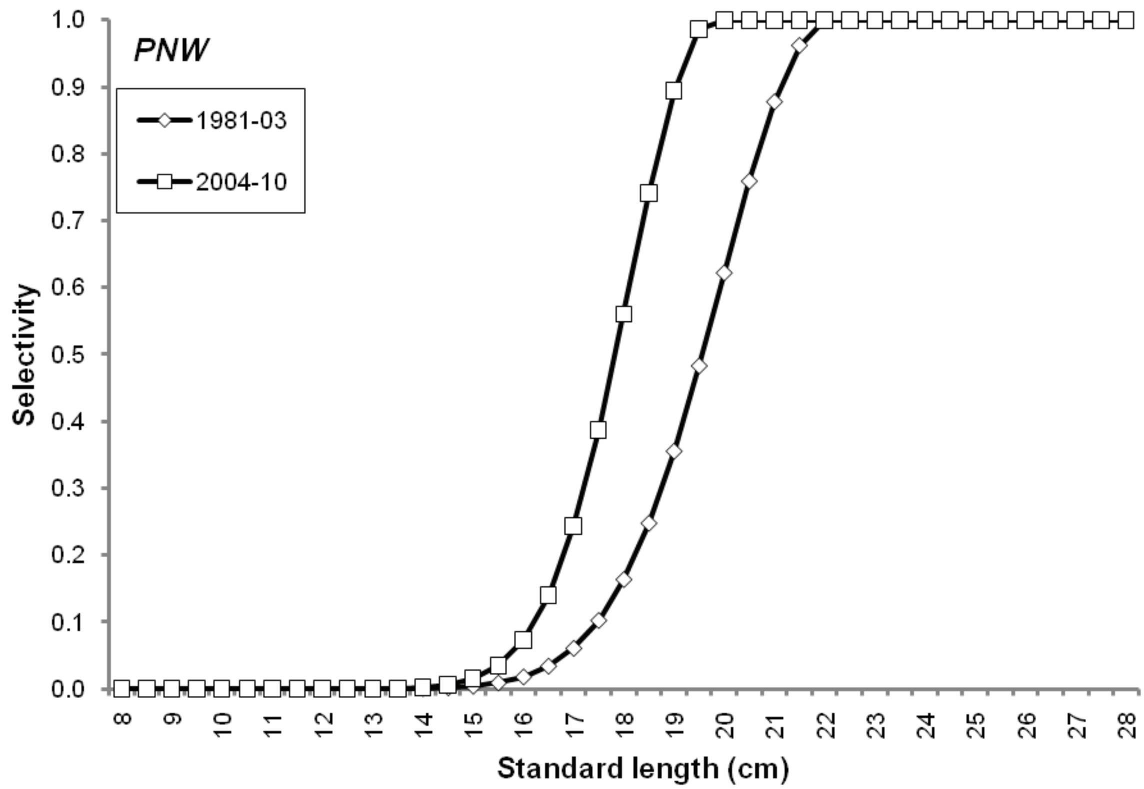


Figure 14d. Length-based selectivity for the PNW fleet by time block.

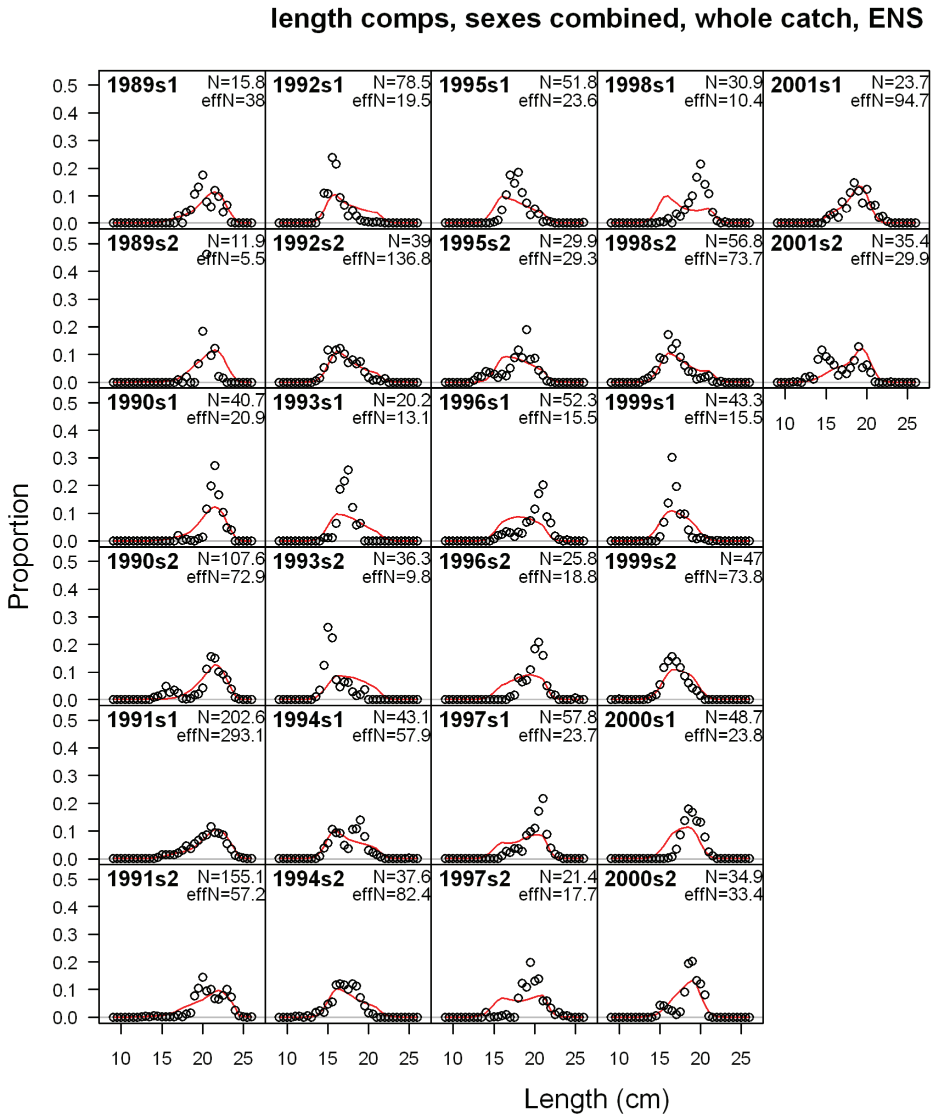


Figure 15a. Base model fits to length-frequency data for the ENS fishery.

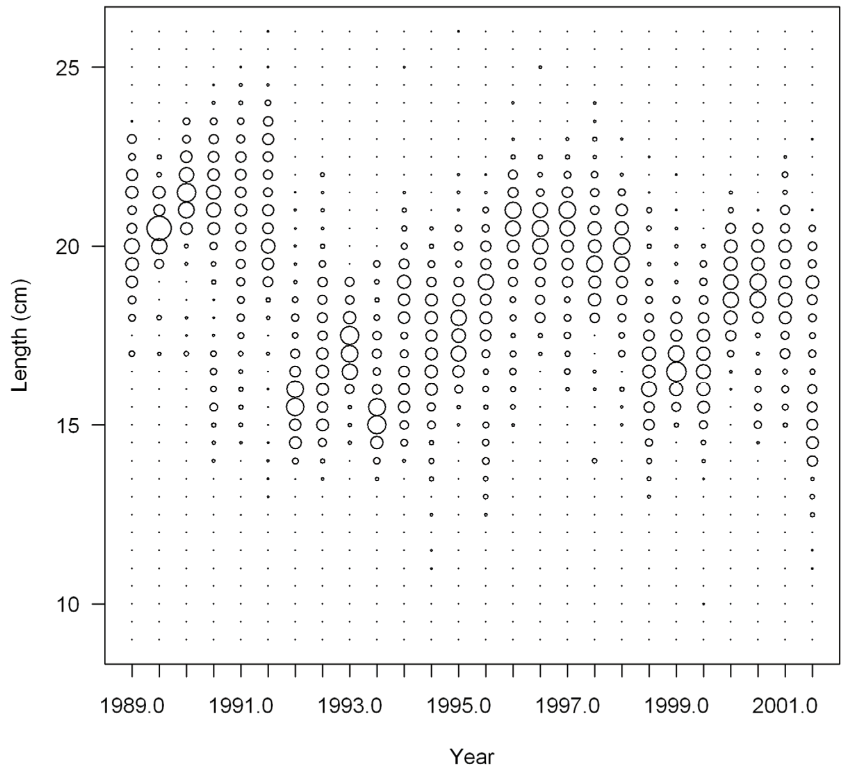


Figure 15b. Bubble plot of length-frequency data for the ENS fishery.

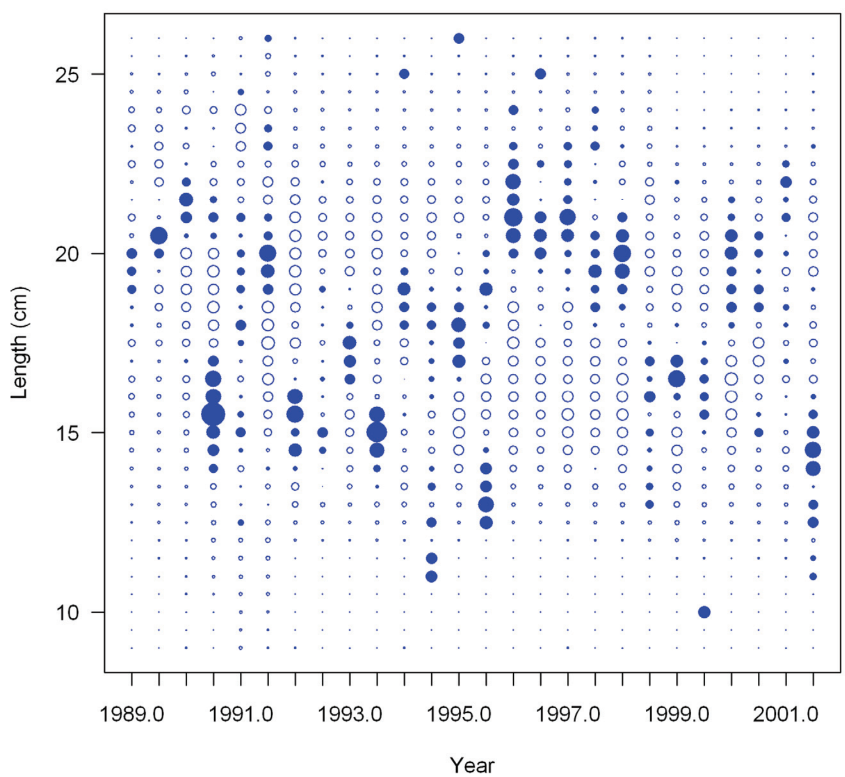


Figure 15c. Pearson residuals (max=7.82) for fit to length-frequency data for the ENS fishery.

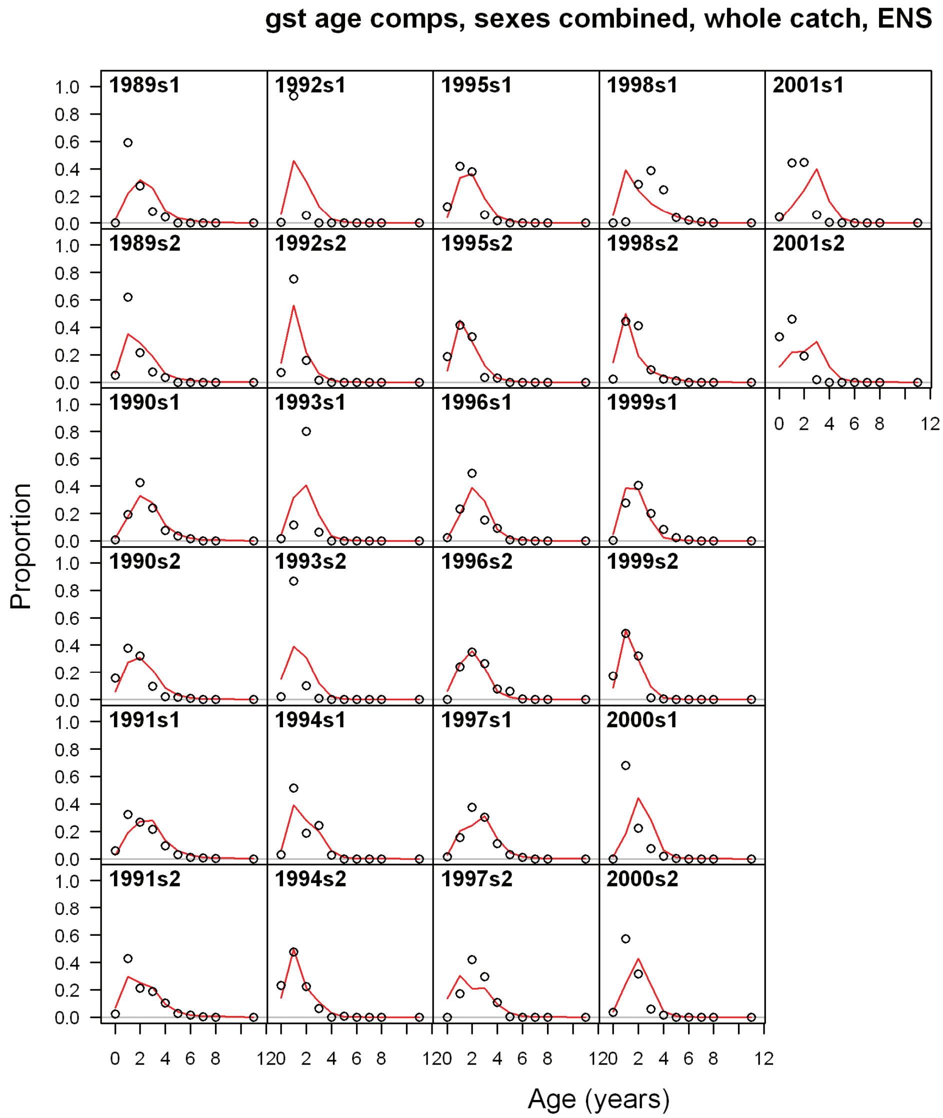


Figure 16a. Base model fits to implied age-frequency data for the ENS fishery.

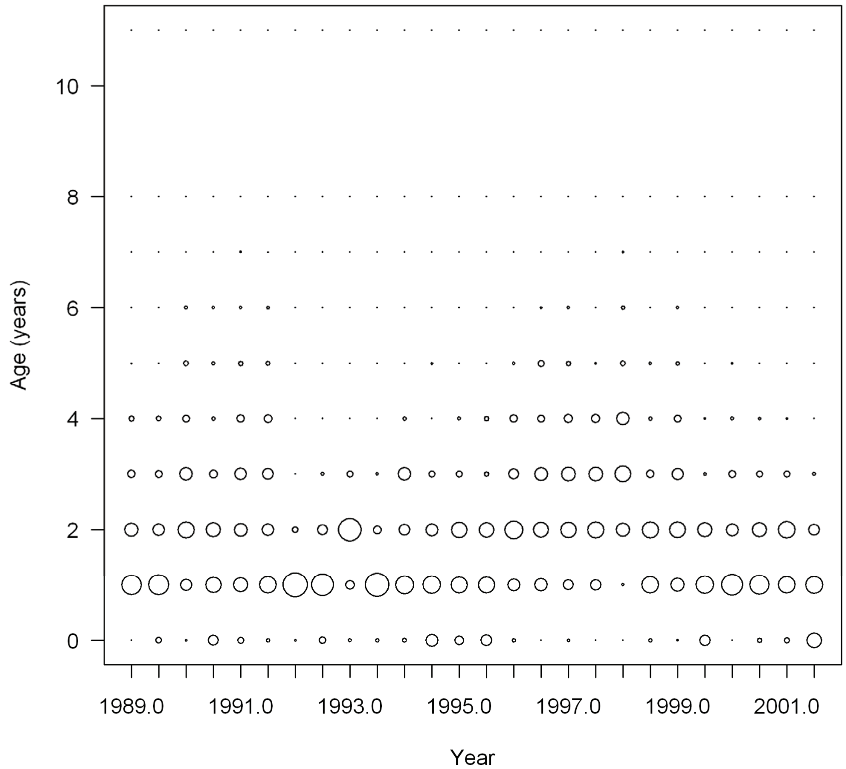


Figure 16b. Bubble plot of age-frequency data for the ENS fishery.

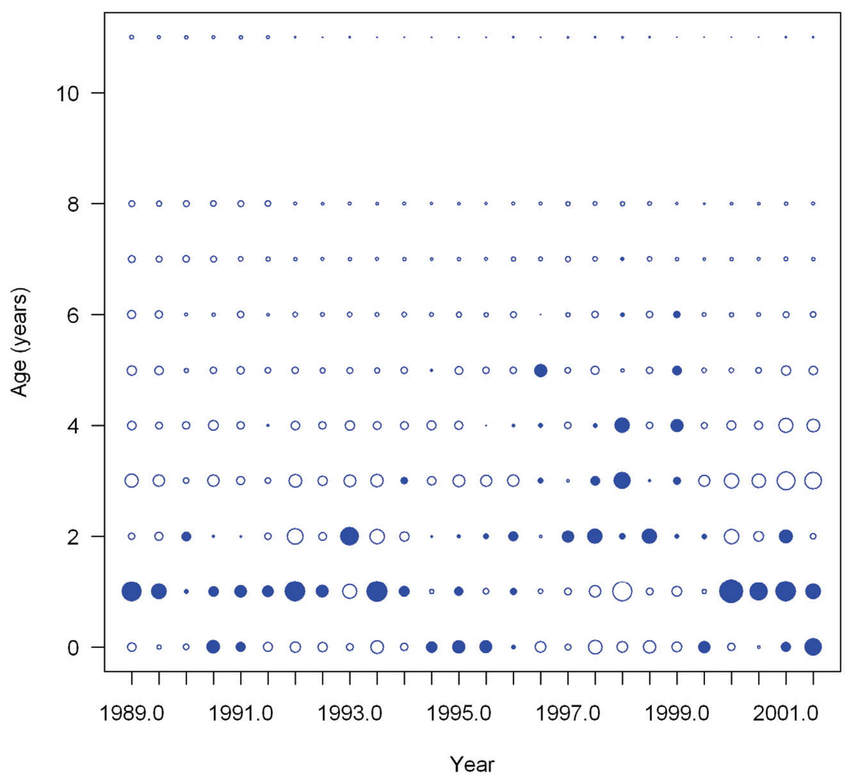


Figure 16c. Pearson residuals (max=1.28) for fit to implied age-frequency data for the ENS fishery.

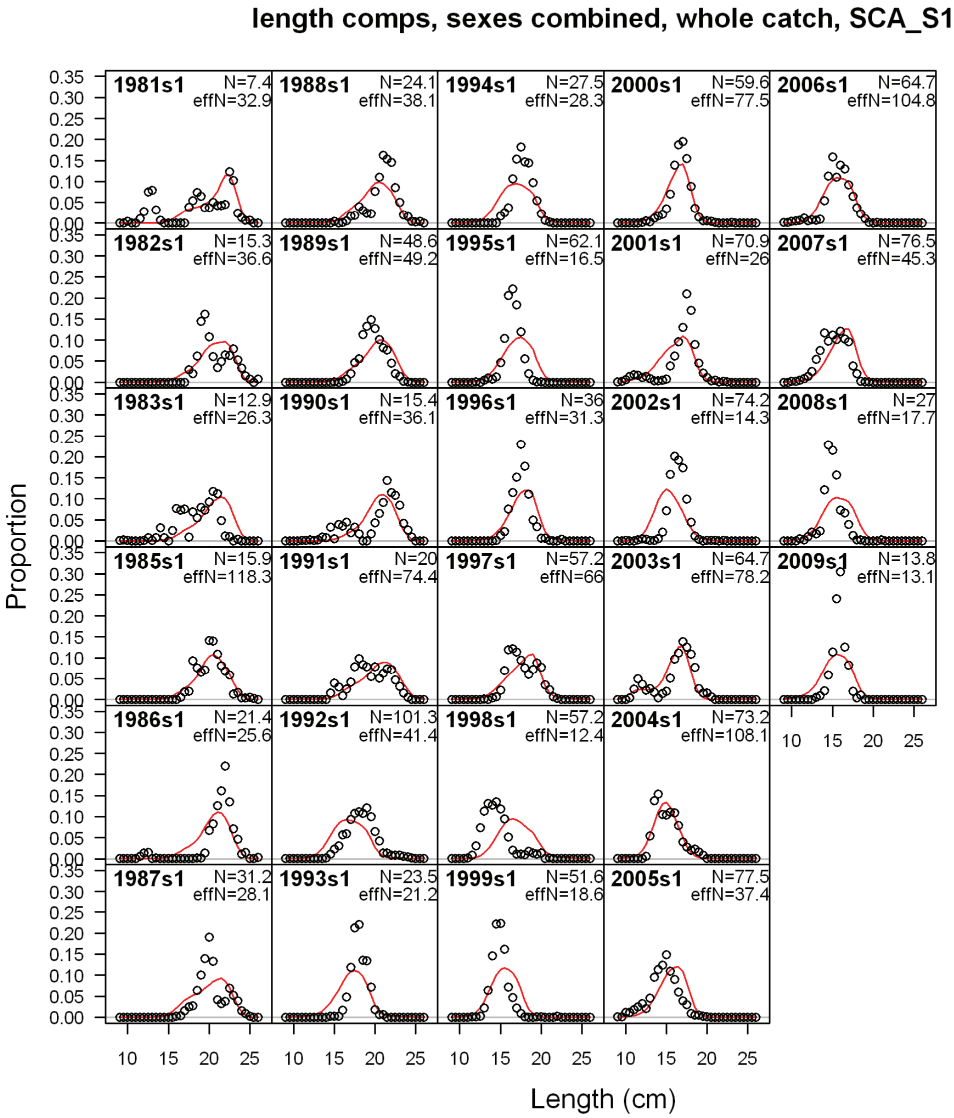


Figure 17a. Base model fits to length-frequency data for the SCA_S1 fishery.

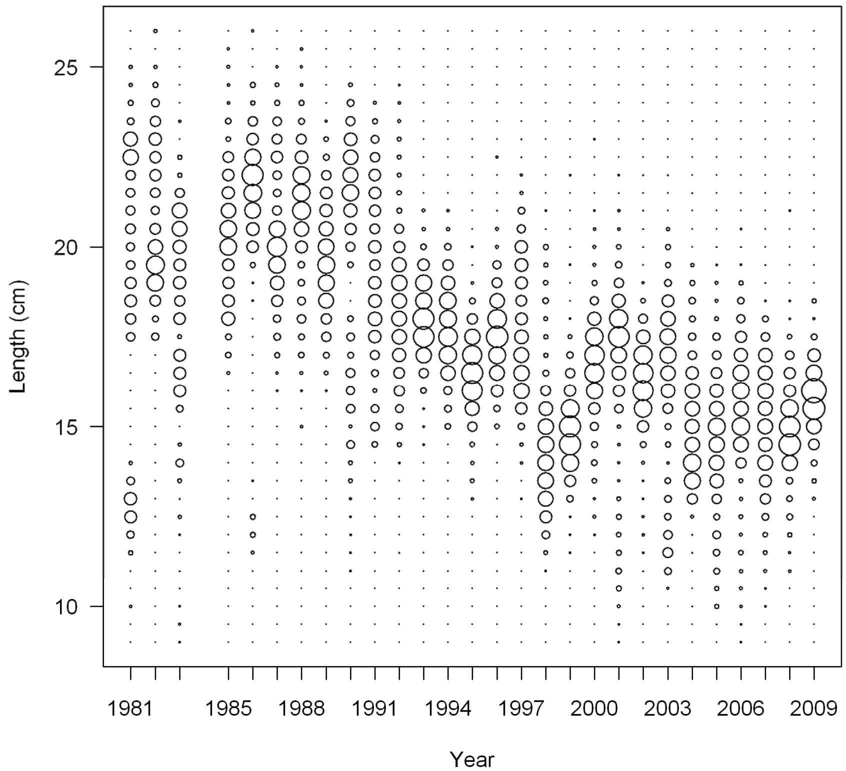


Figure 17b. Bubble plot of length-frequency data for the SCA_S1 fishery.

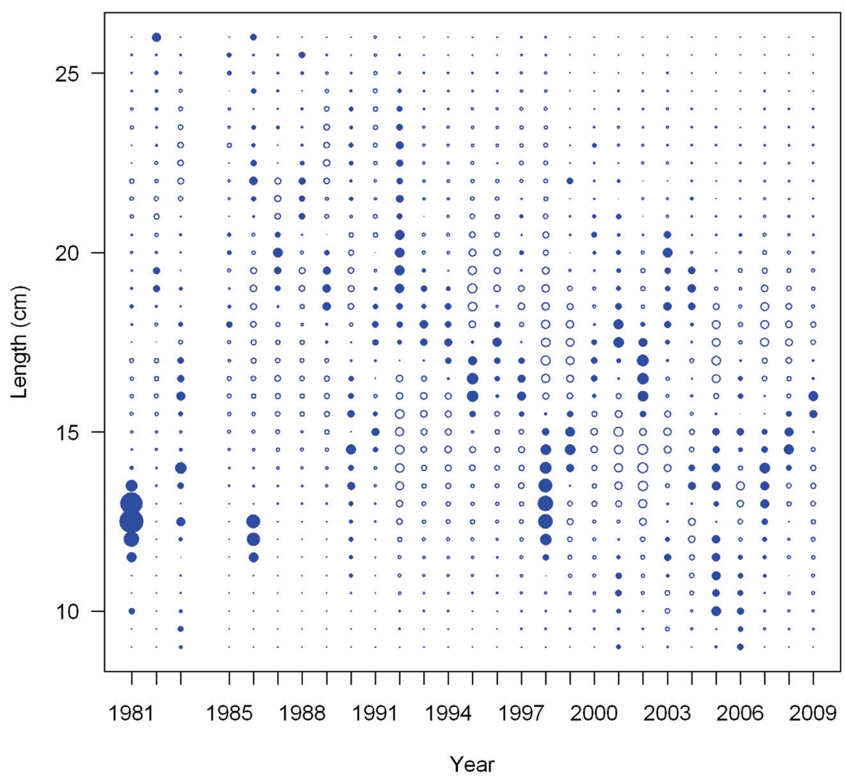


Figure 17c. Pearson residuals (max=15.68) for fit to length-frequency data for the SCA_S1 fishery.

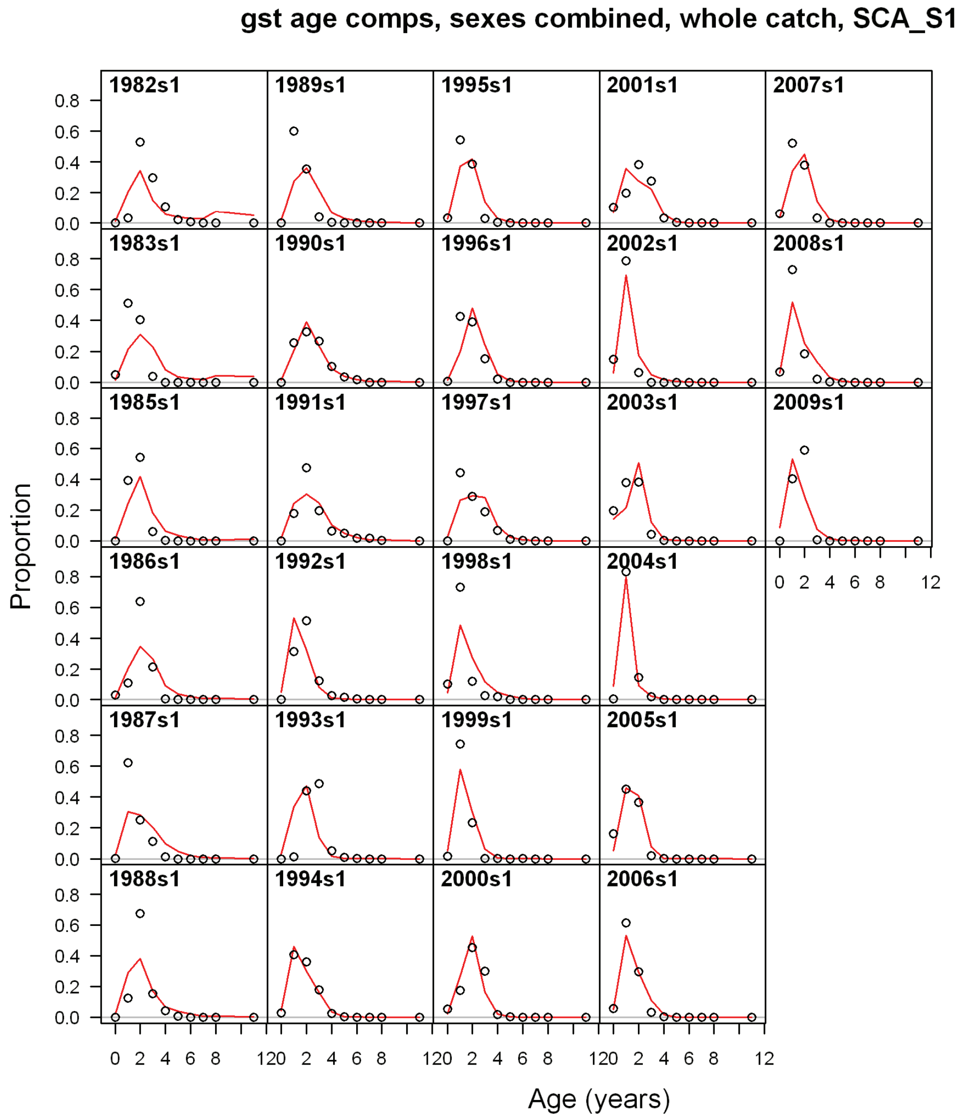


Figure 18a. Base model fits to implied age-frequency data for the SCA_S1 fishery.

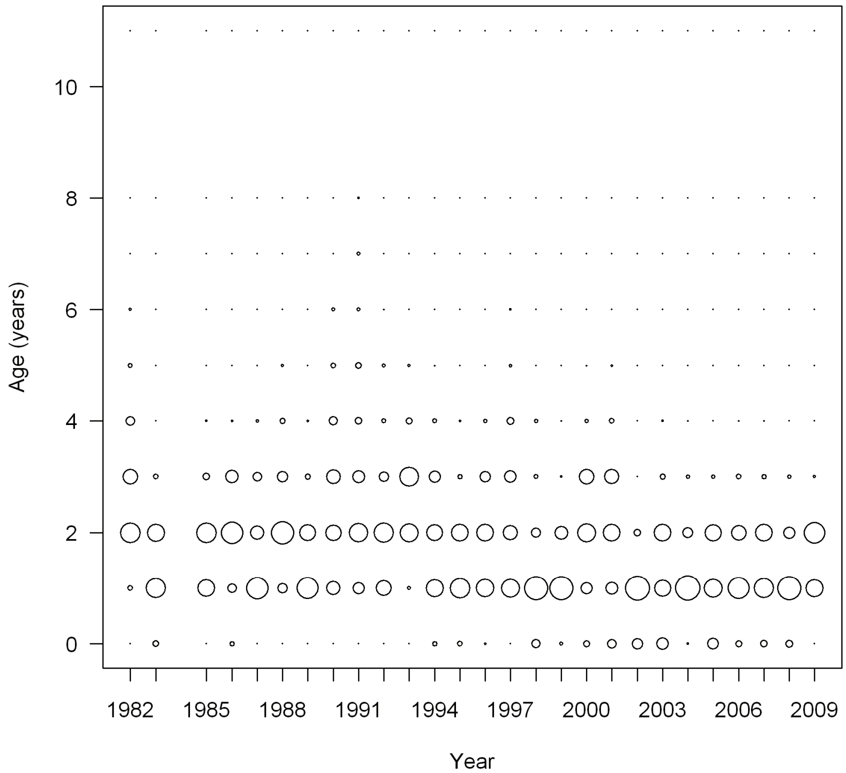


Figure 18b. Bubble plot of age-frequency data for the SCA_S1 fishery.

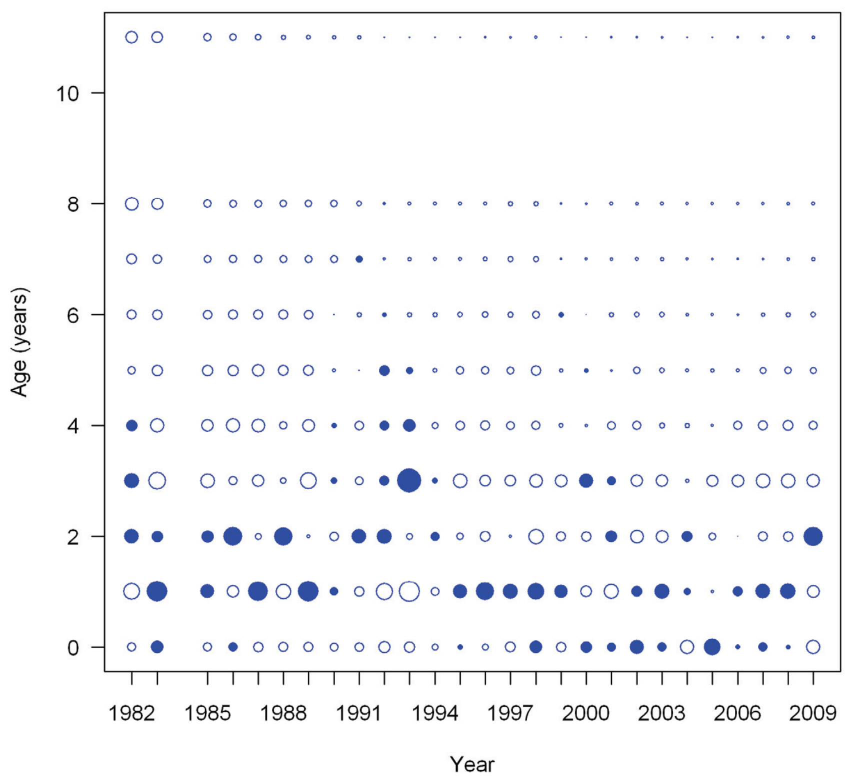


Figure 18c. Pearson residuals (max=1.01) for fit to implied age-frequency data for the SCA_S1 fishery.

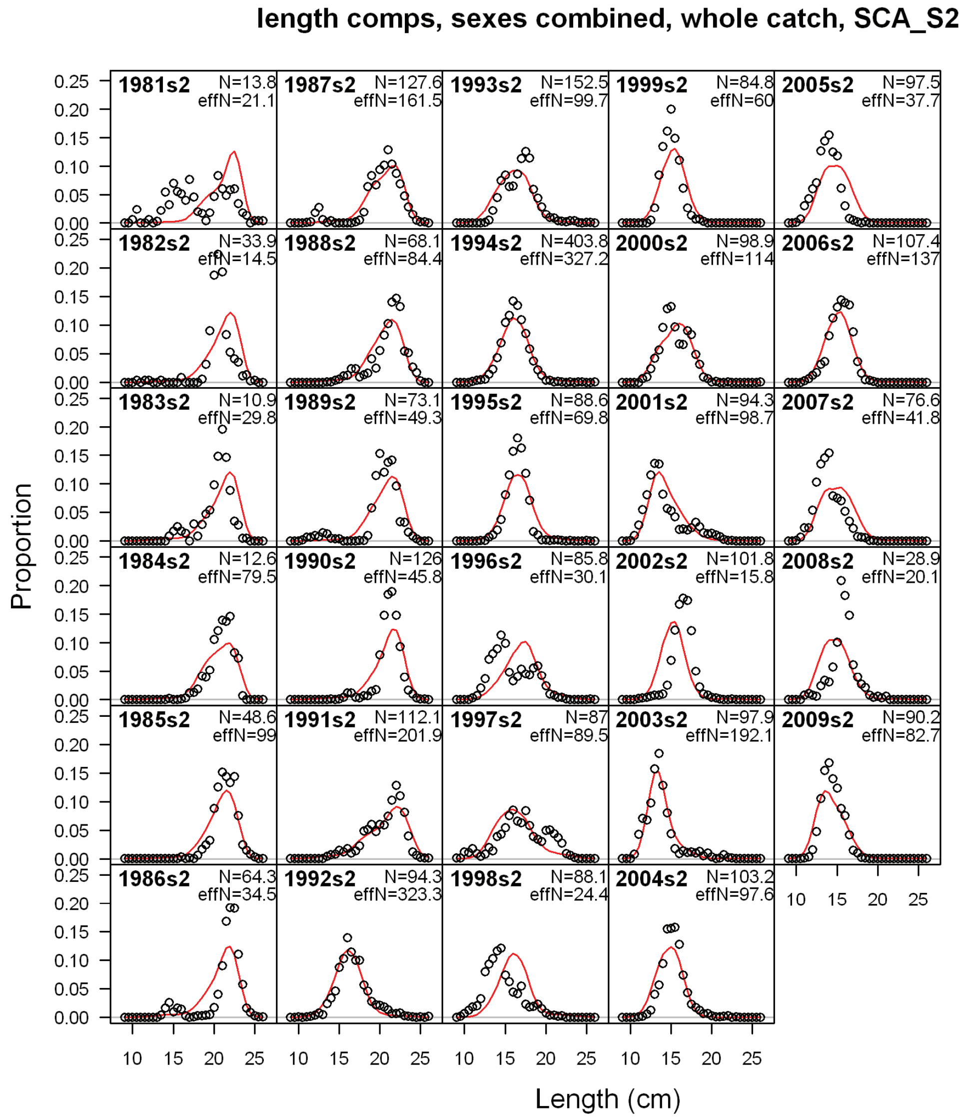


Figure 19a. Base model fits to length-frequency data for the SCA_S2 fishery.

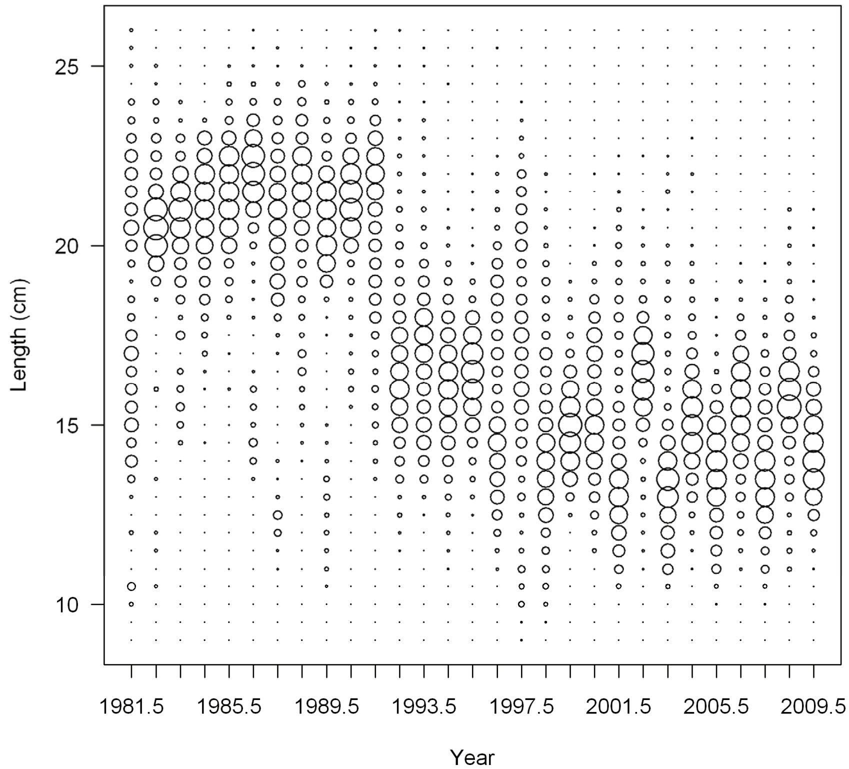


Figure 19b. Bubble plot of length-frequency data for the SCA_S2 fishery.

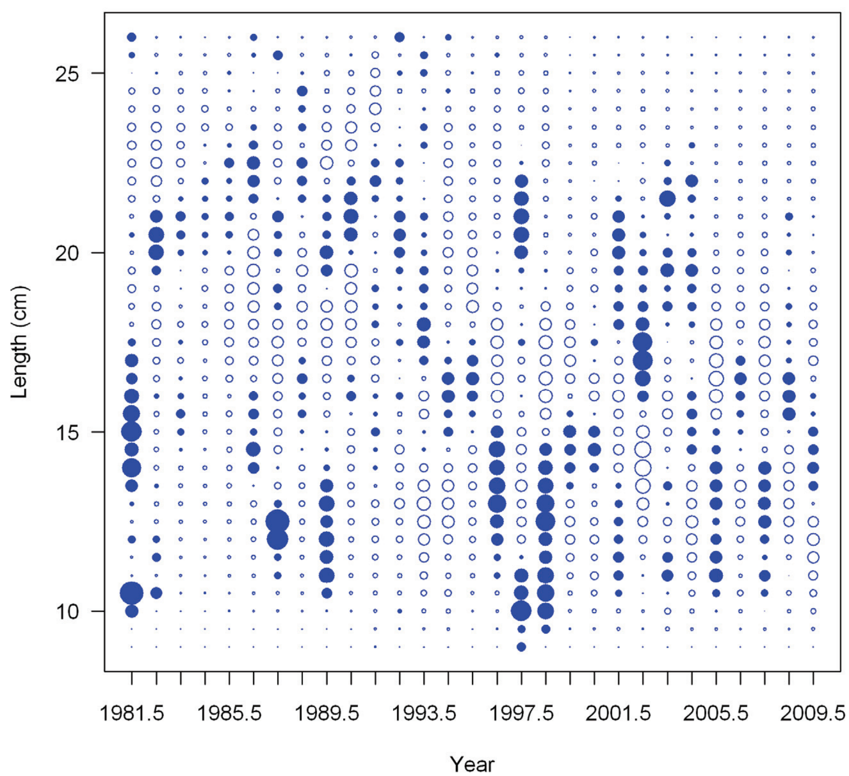


Figure 19c. Pearson residuals (max=6.76) for fit to length-frequency data for the SCA_S2 fishery.

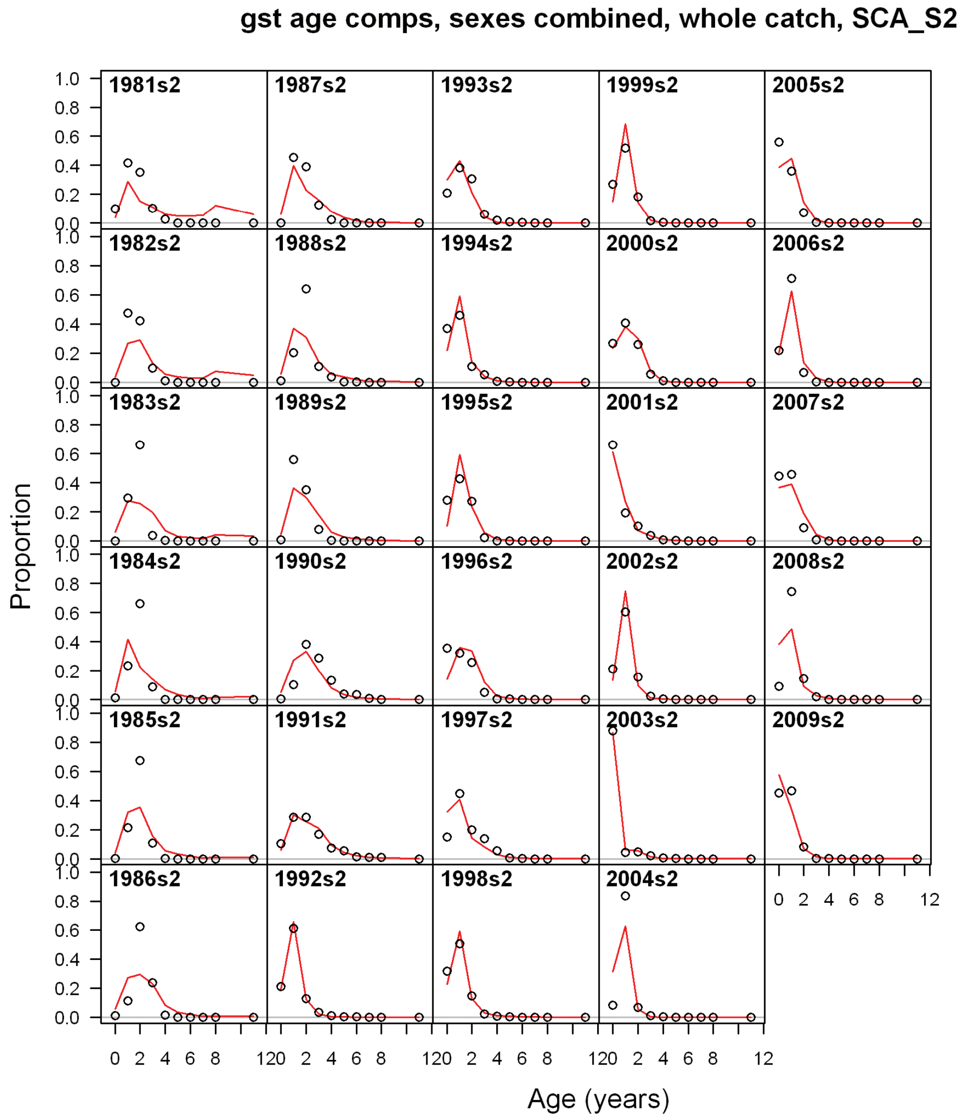


Figure 20a. Base model fits to implied age-frequency data for the SCA_S2 fishery.

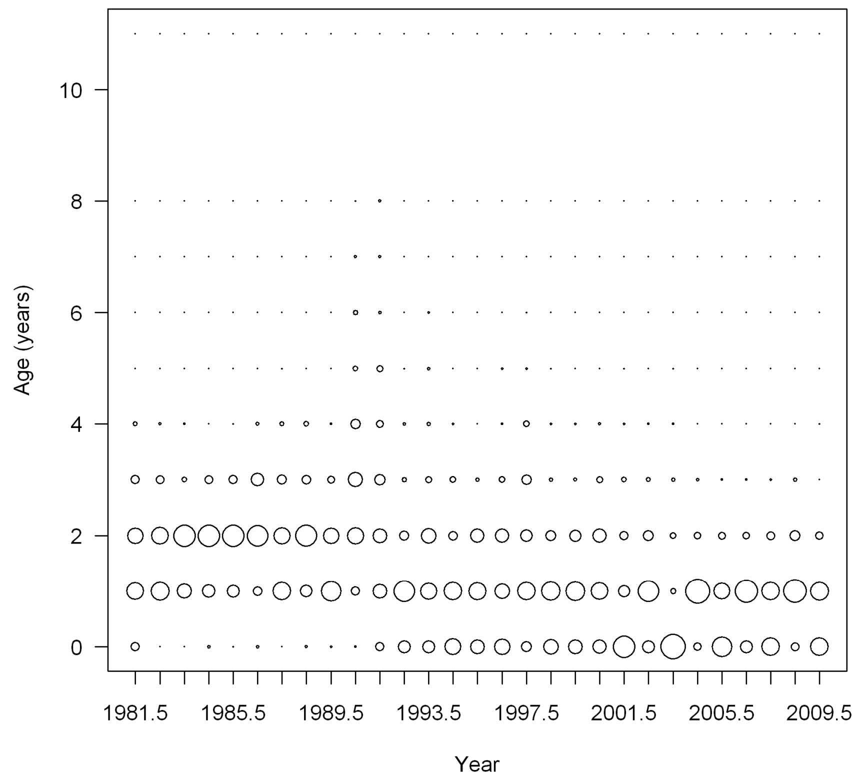


Figure 20b. Bubble plot of implied age-frequency data for the SCA_S2 fishery.

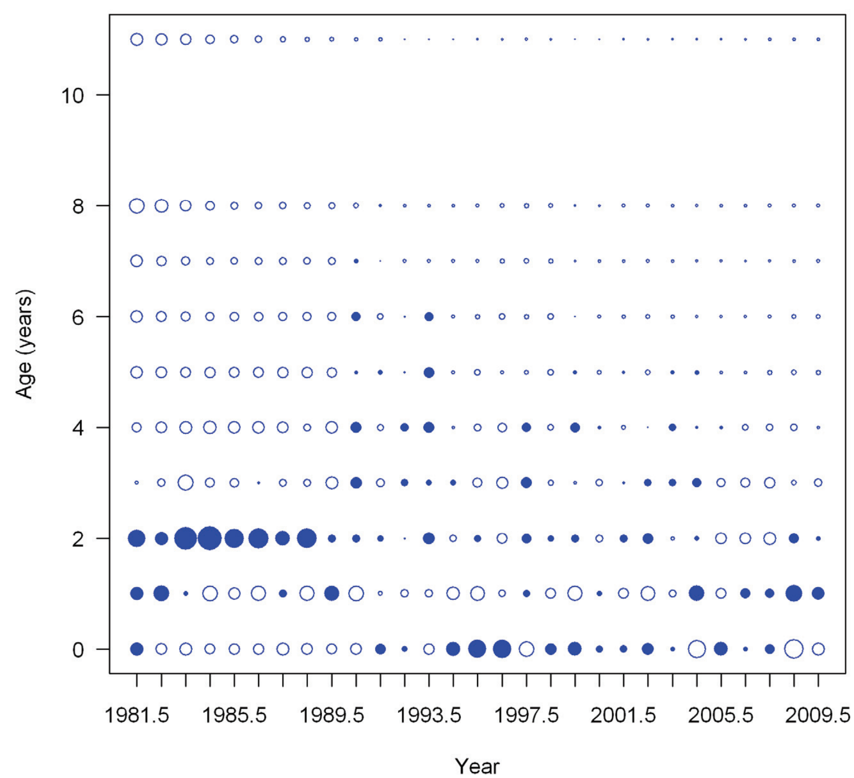


Figure 20c. Pearson residuals (max=1.04) for fit to implied age-frequency data for the SCA_S2 fishery.

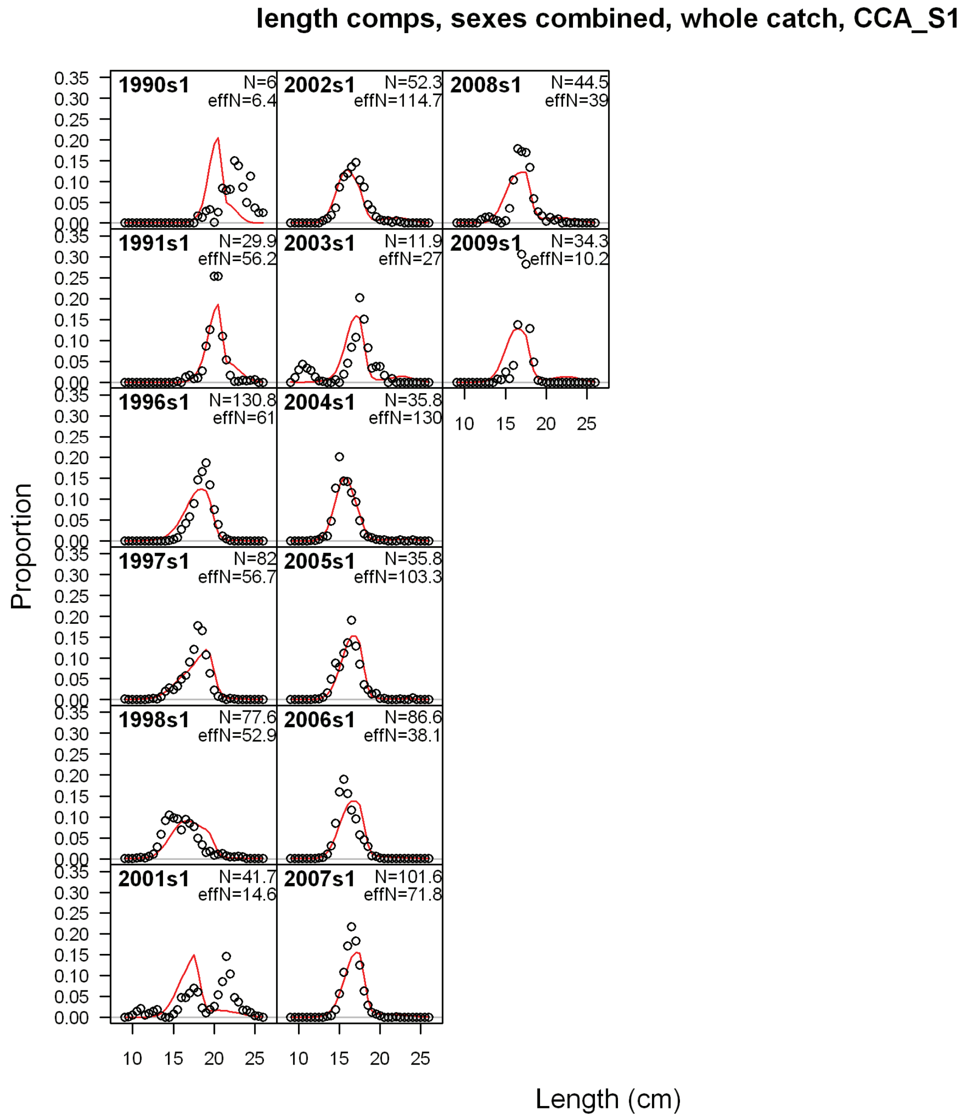


Figure 21a. Base model fits to length-frequency data for the CCA_S1 fishery.

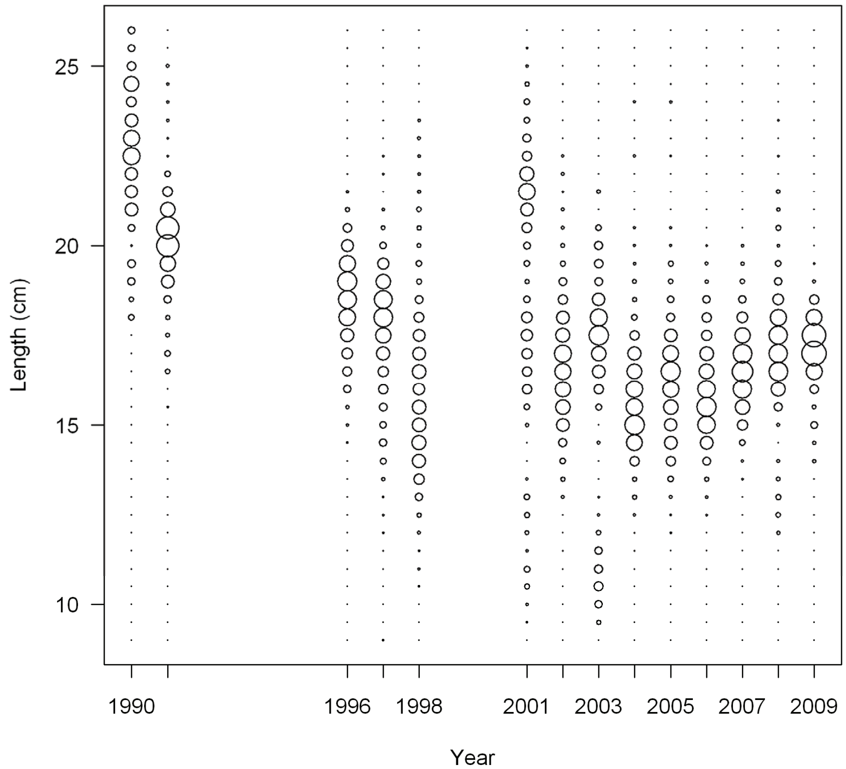


Figure 21b. Bubble plot of length-frequency data for the CCA_S1 fishery.

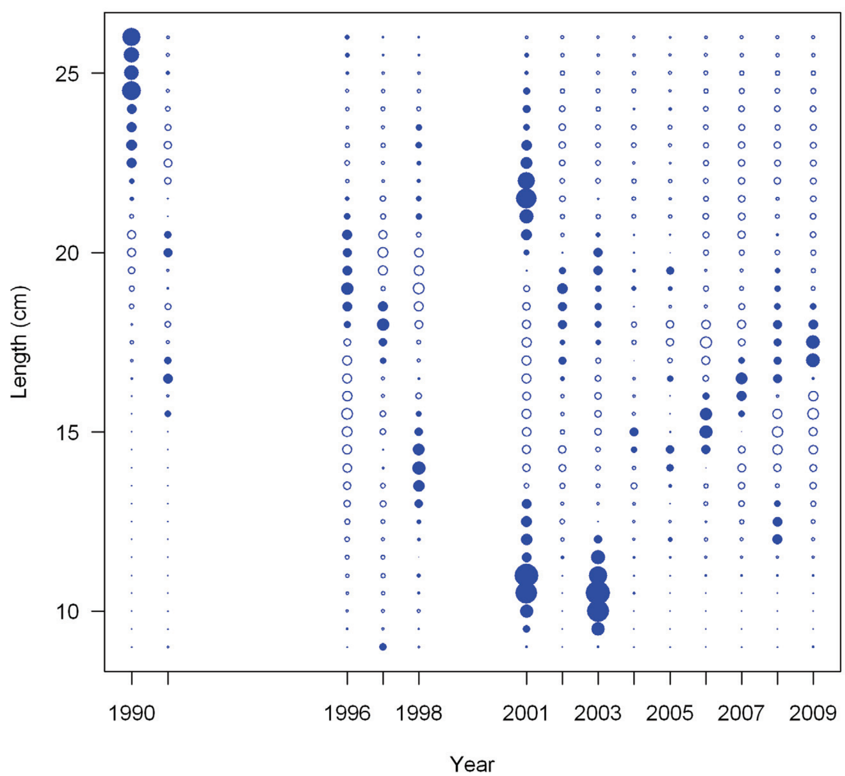


Figure 21c. Pearson residuals (max=9.64) for fit to length-frequency data for the CCA_S1 fishery.

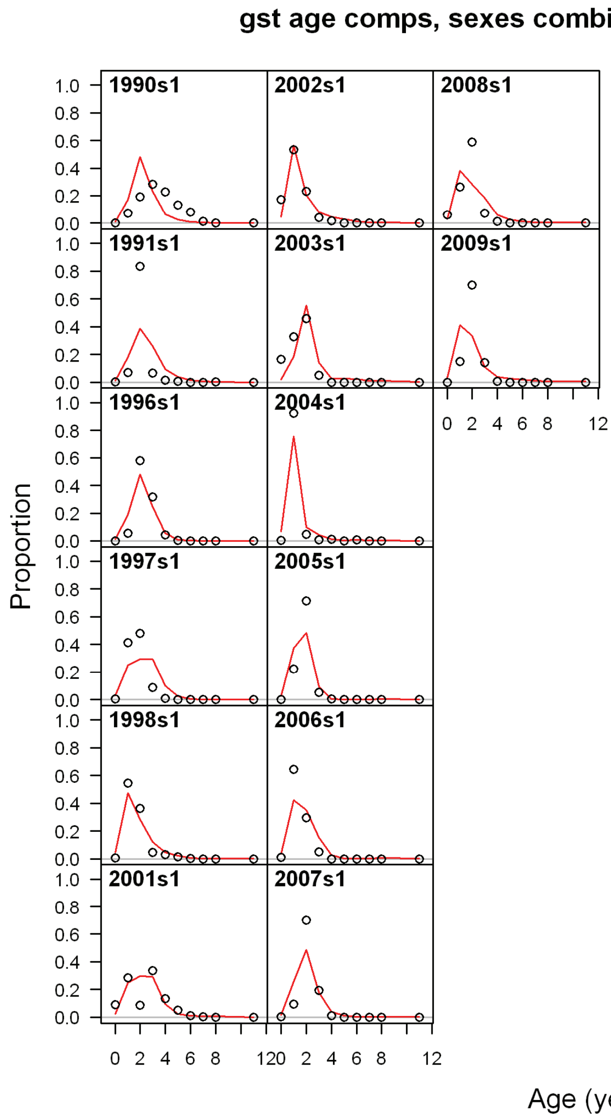


Figure 22a. Base model fits to implied age-frequency data for the CCA_S1 fishery.

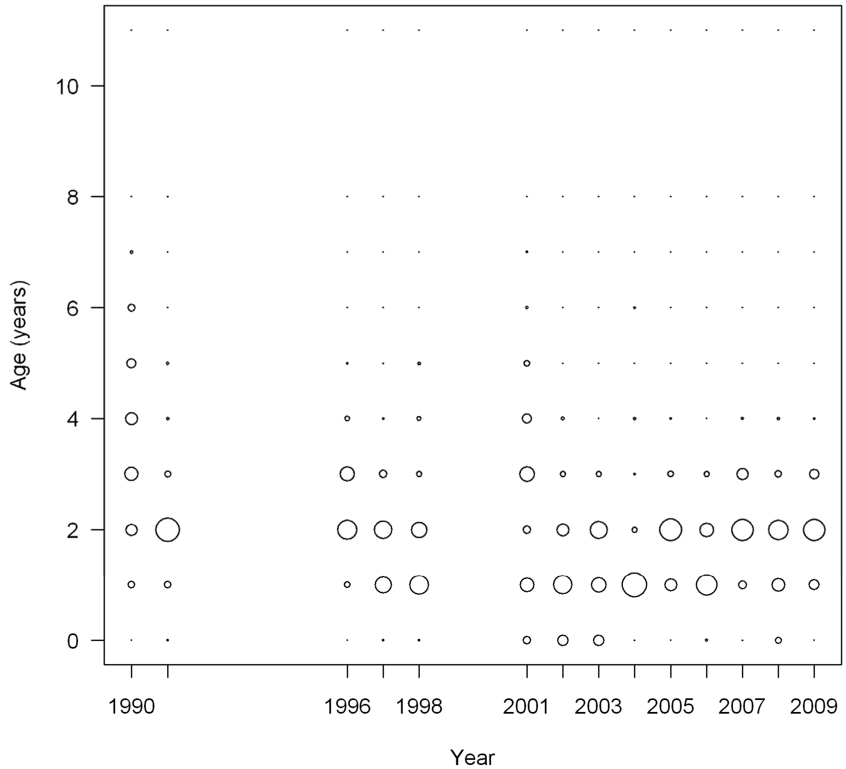


Figure 22b. Bubble plot of implied age-frequency data for the CCA_S1 fishery.

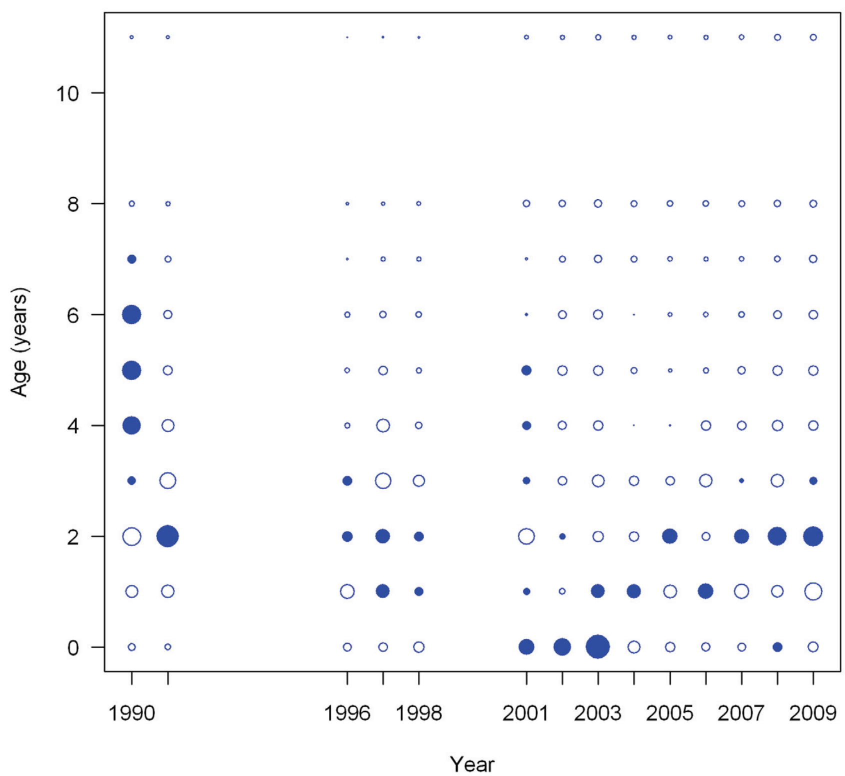


Figure 22c. Pearson residuals (max=1.09) for fit to implied age-frequency data for the CCA_S1 fishery.

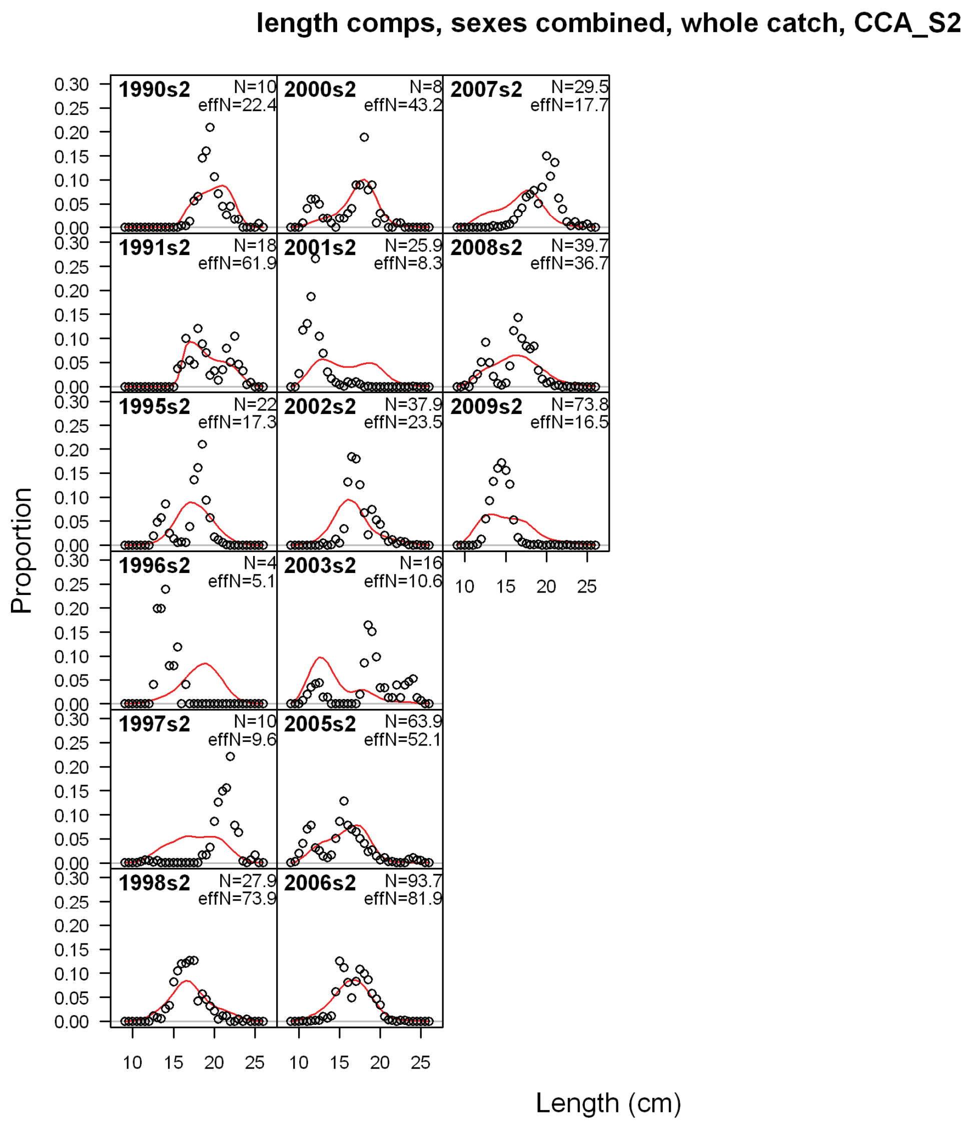


Figure 23a. Base model fits to length-frequency data for the CCA_S2 fishery.

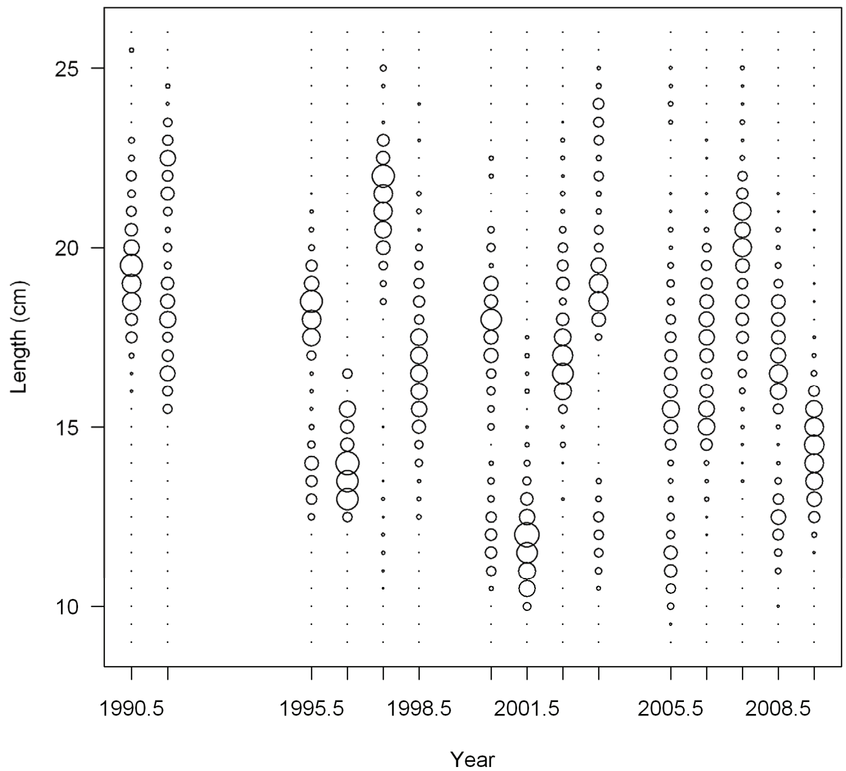


Figure 23b. Bubble plot of length-frequency data for the CCA_S2 fishery.

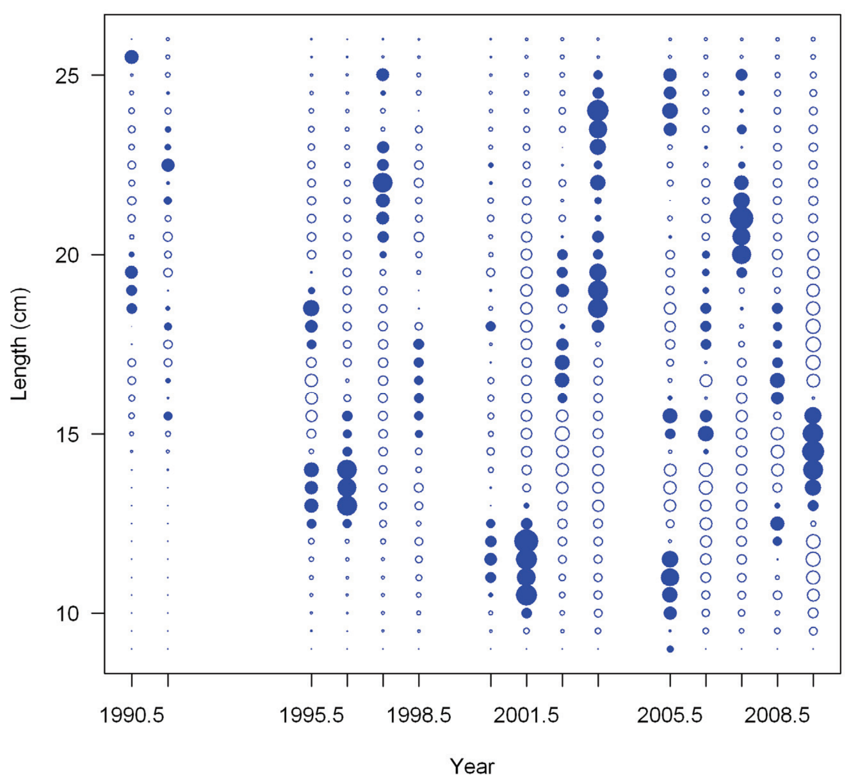


Figure 23c. Pearson residuals (max=5.08) for fit to length-frequency data for the CCA_S2 fishery.

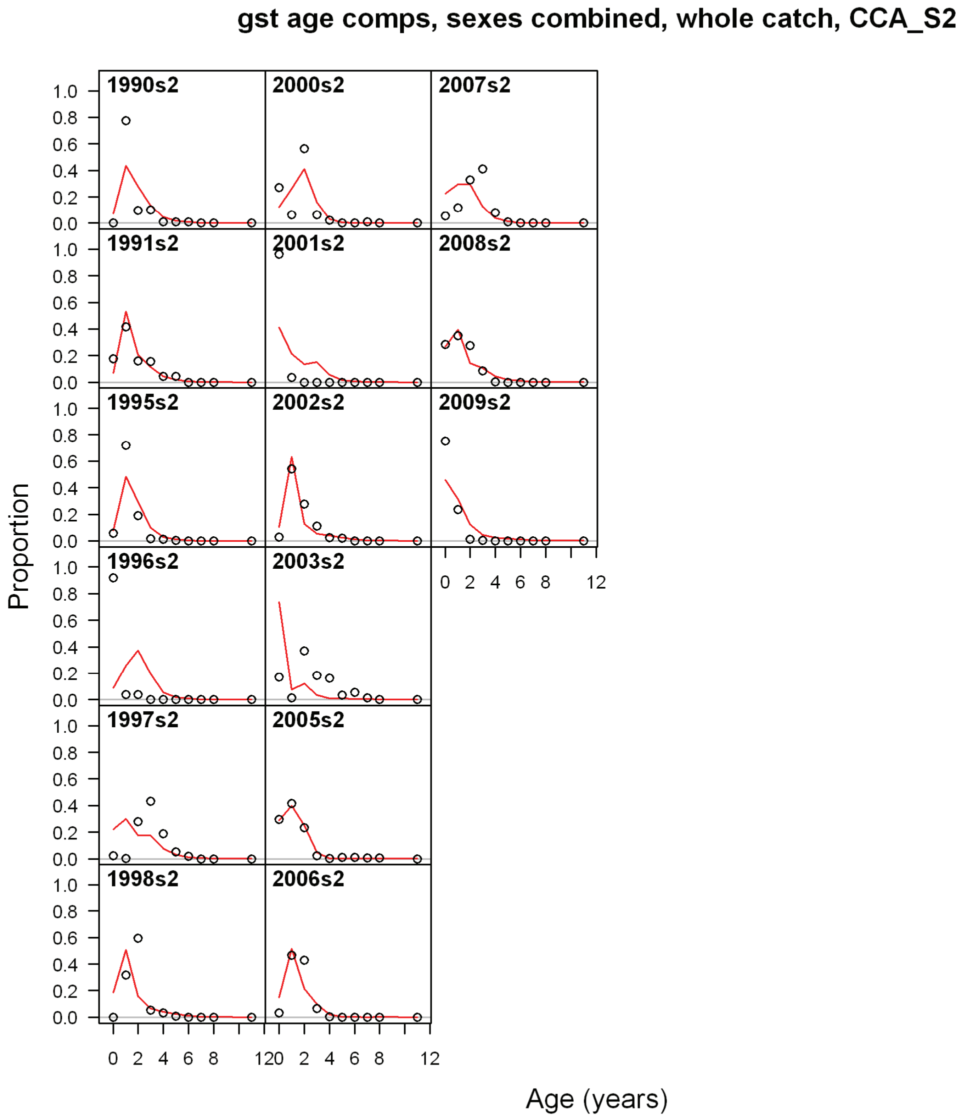


Figure 24a. Base model fits to implied age-frequency data for the CCA_S2 fishery.

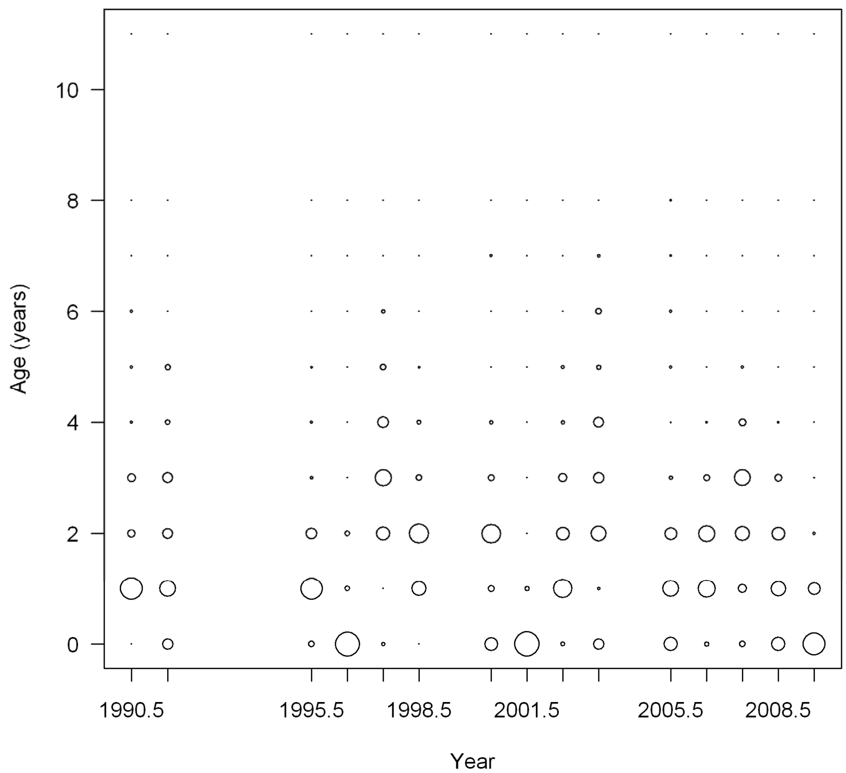


Figure 24b. Bubble plot of implied age-frequency data for the CCA_S2 fishery.

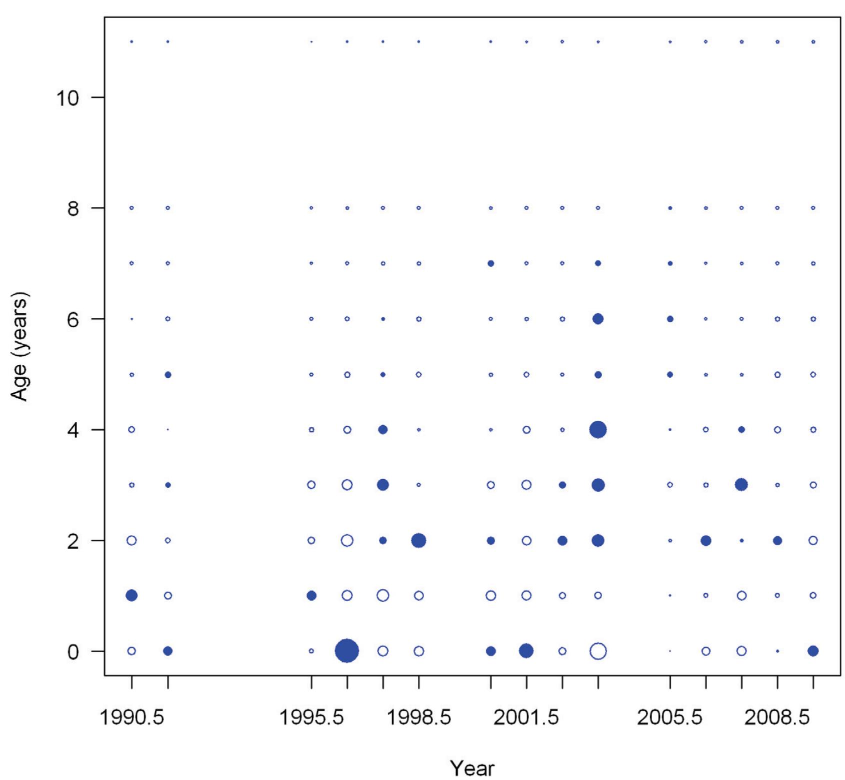


Figure 24c. Pearson residuals (max=2.95) for fit to implied age-frequency data for the CCA_S2 fishery.

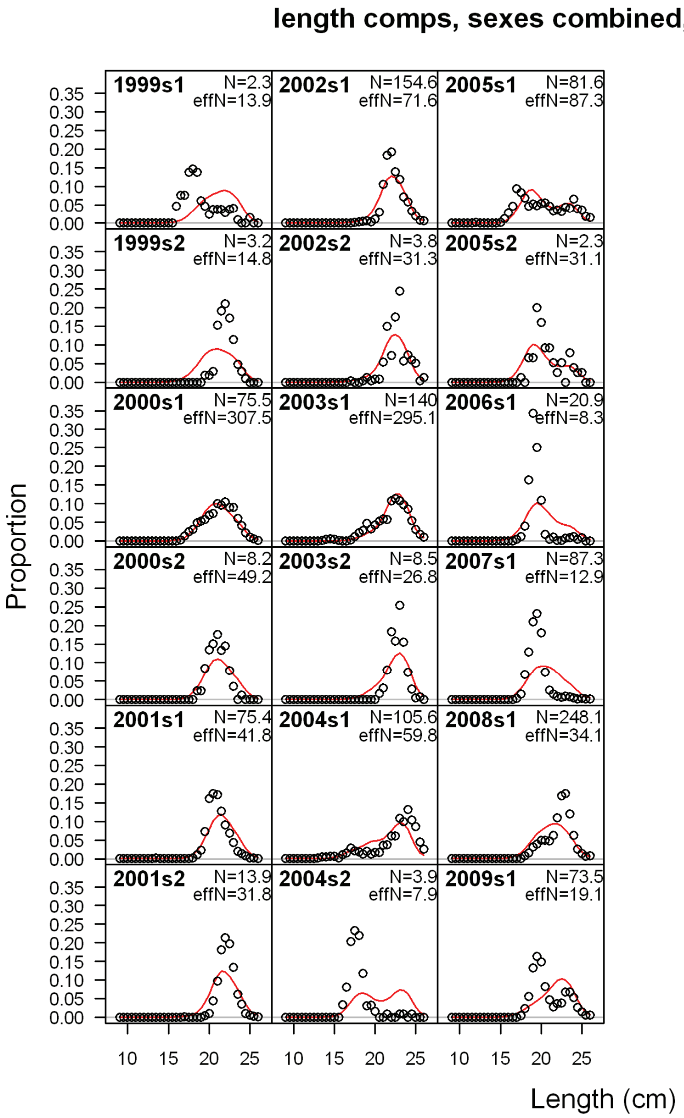


Figure 25a. Base model fits to length-frequency data for the PNW fishery.

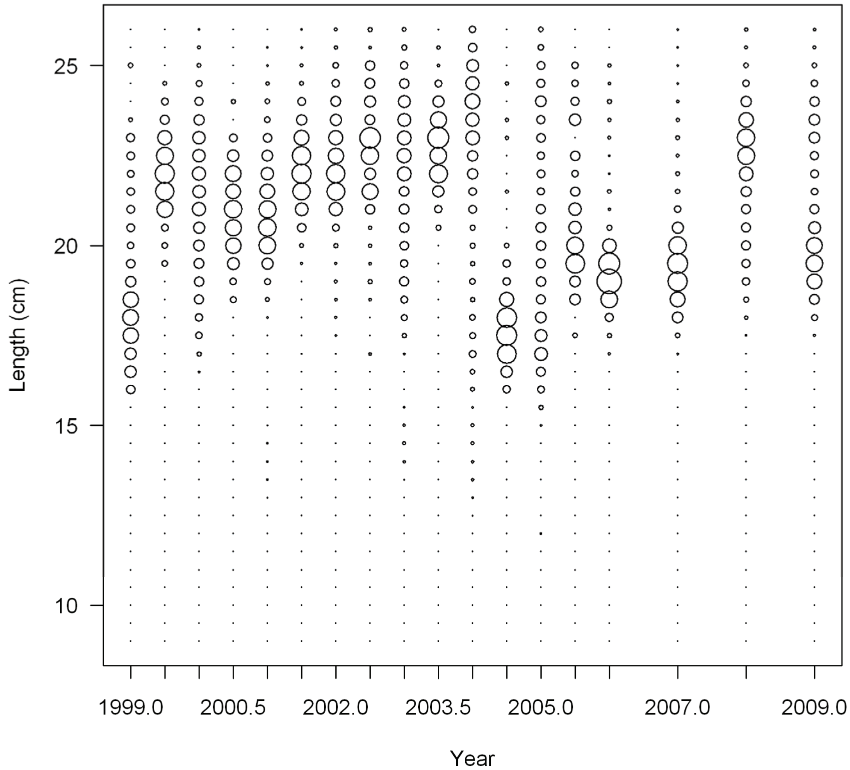


Figure 25b. Bubble plot of length-frequency data for the PNW fishery.

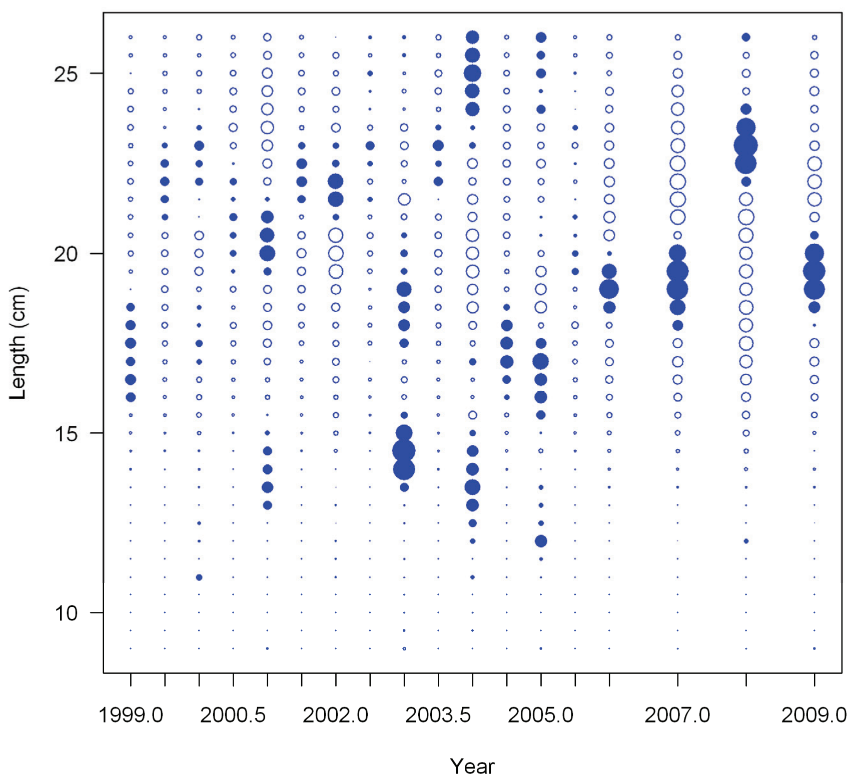


Figure 25c. Pearson residuals (max=5.8) for fit to length-frequency data for the PNW fishery.

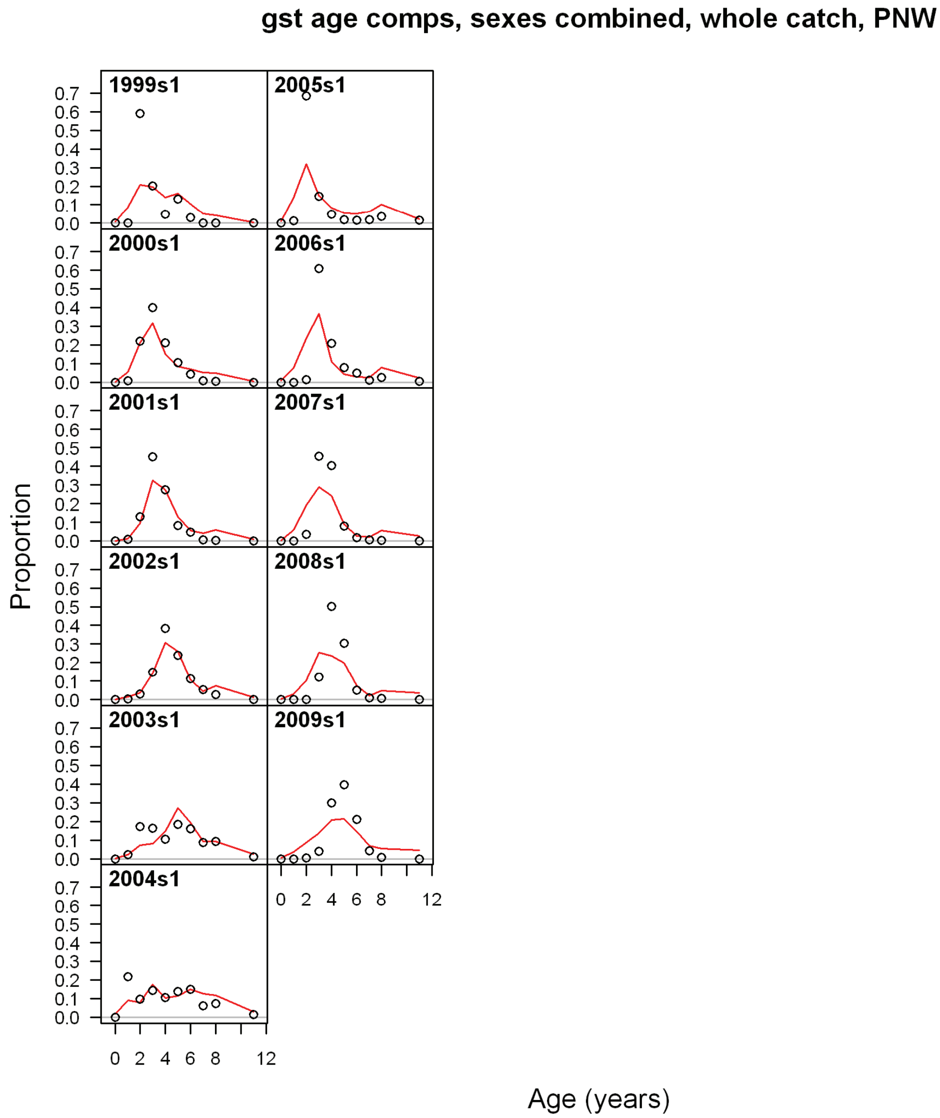


Figure 26a. Base model fits to implied age-frequency data for the PNW fishery.

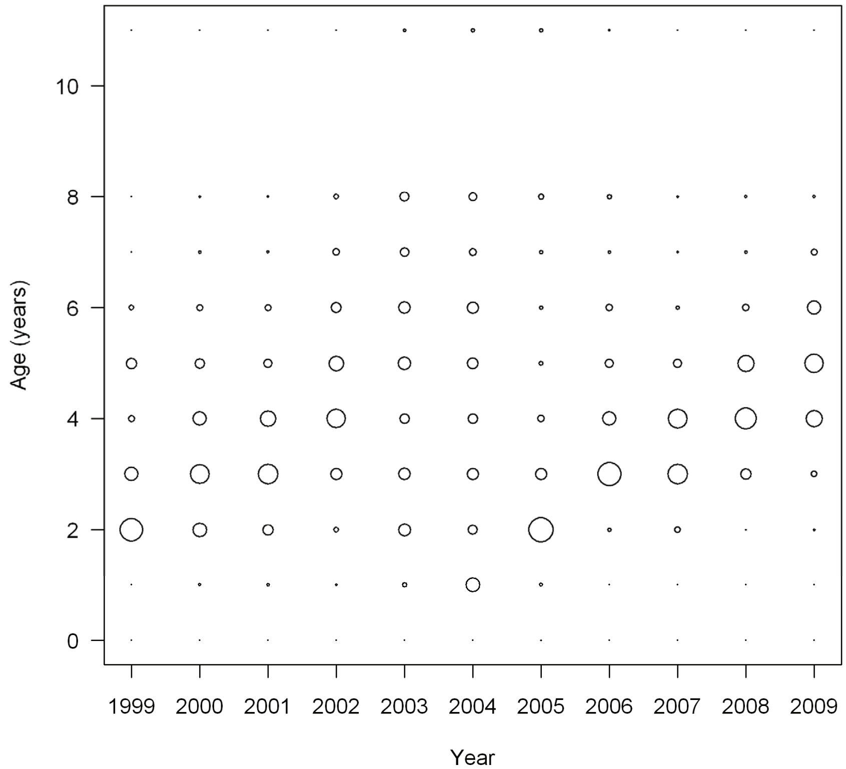


Figure 26b. Bubble plot of implied age-frequency data for the PNW fishery.

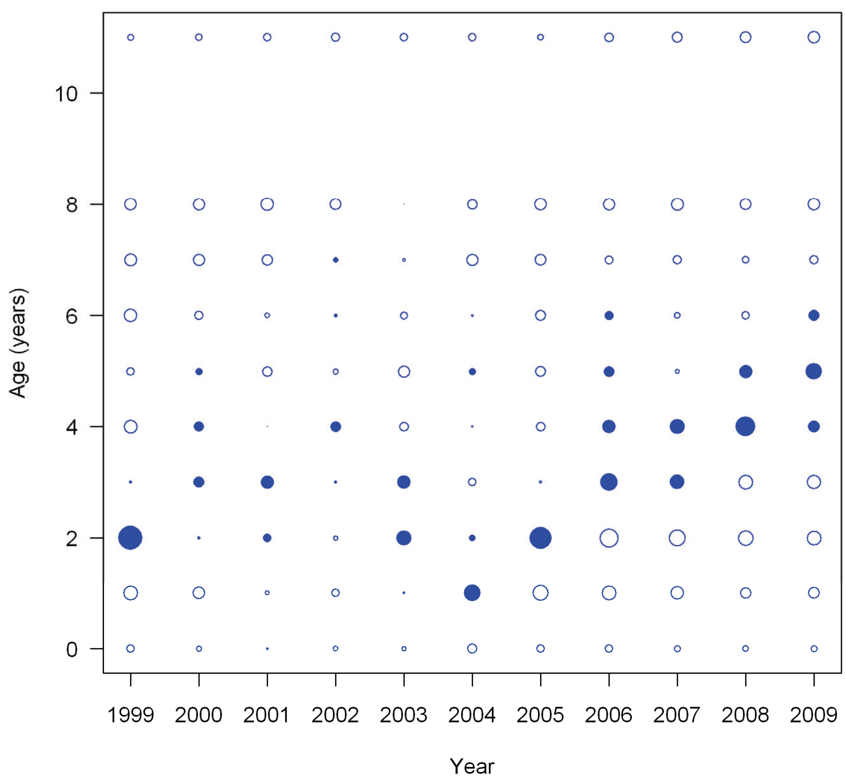


Figure 26c. Pearson residuals (max=0.94) for fit to implied age-frequency data for the PNW fishery.

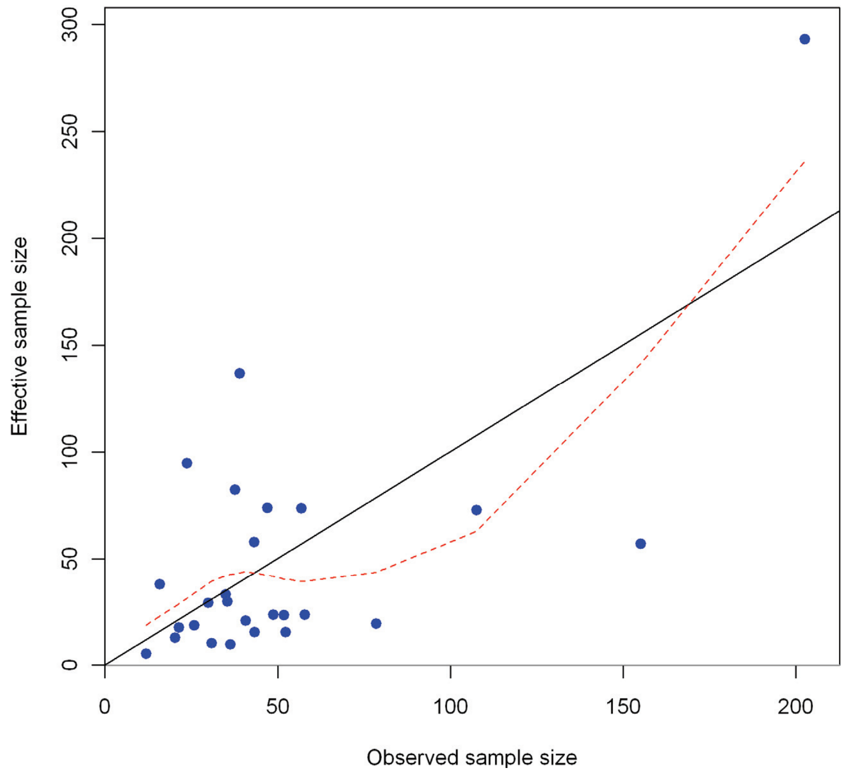


Figure 27a. Observed and effective sample sizes for the ENS fishery length-frequency data.

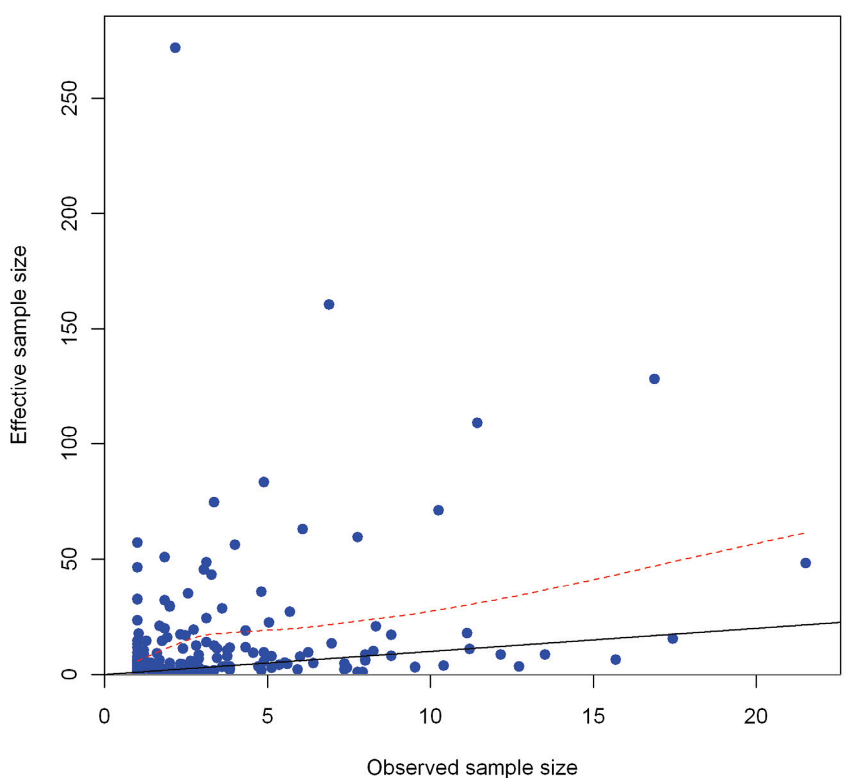


Figure 27b. Observed and effective sample sizes for the ENS fishery conditional age-at-length data.

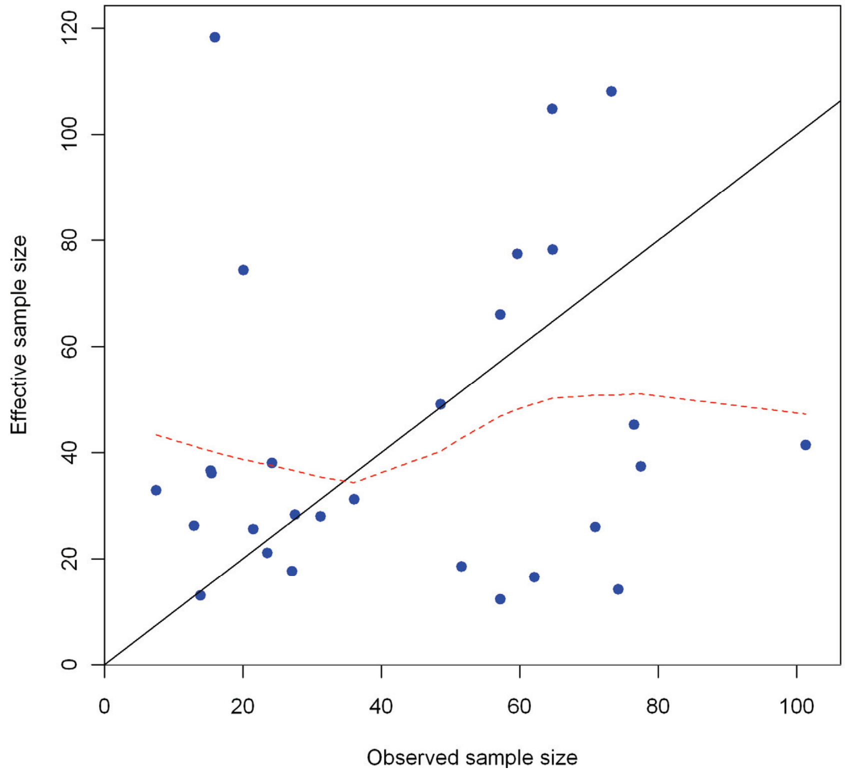


Figure 28a. Observed and effective sample sizes for the SCA_S1 fishery length-frequency data.

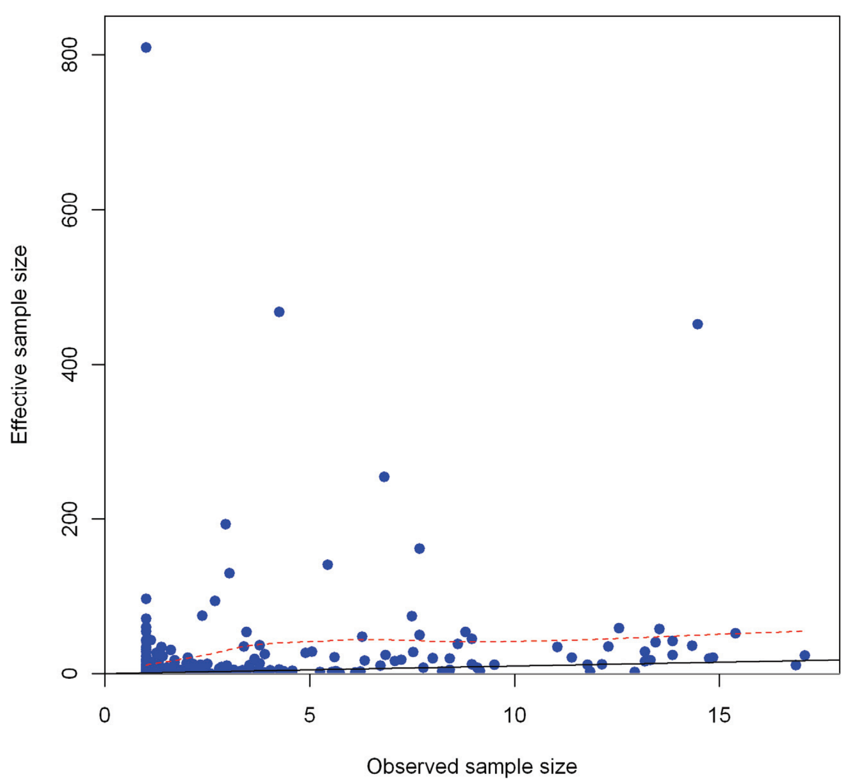


Figure 28b. Observed and effective sample sizes for the SCA_S1 fishery conditional age-at-length data.

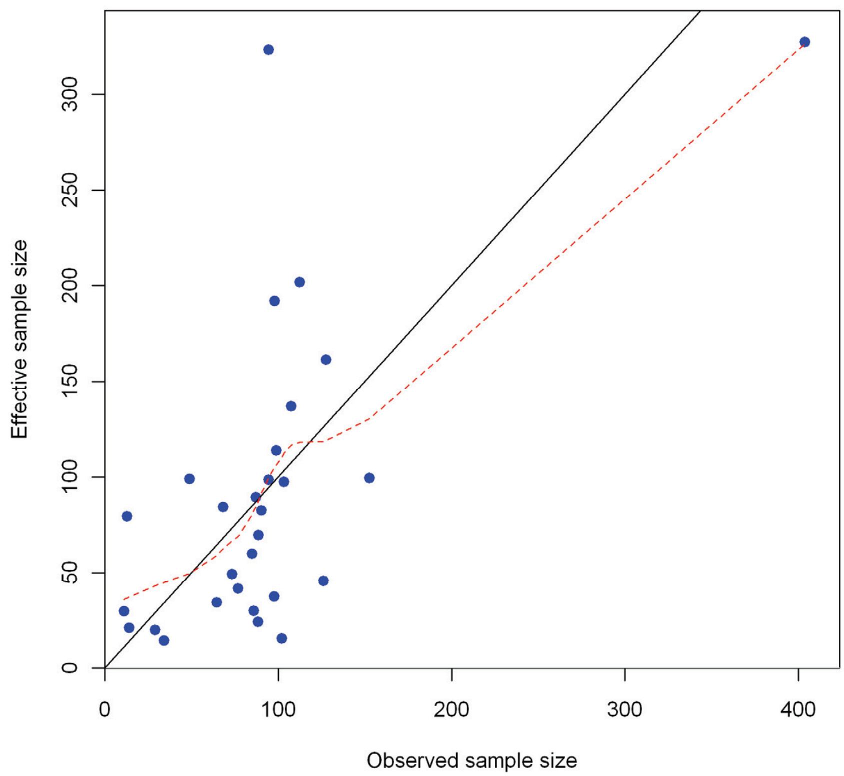


Figure 29a. Observed and effective sample sizes for the SCA_S2 fishery length-frequency data.

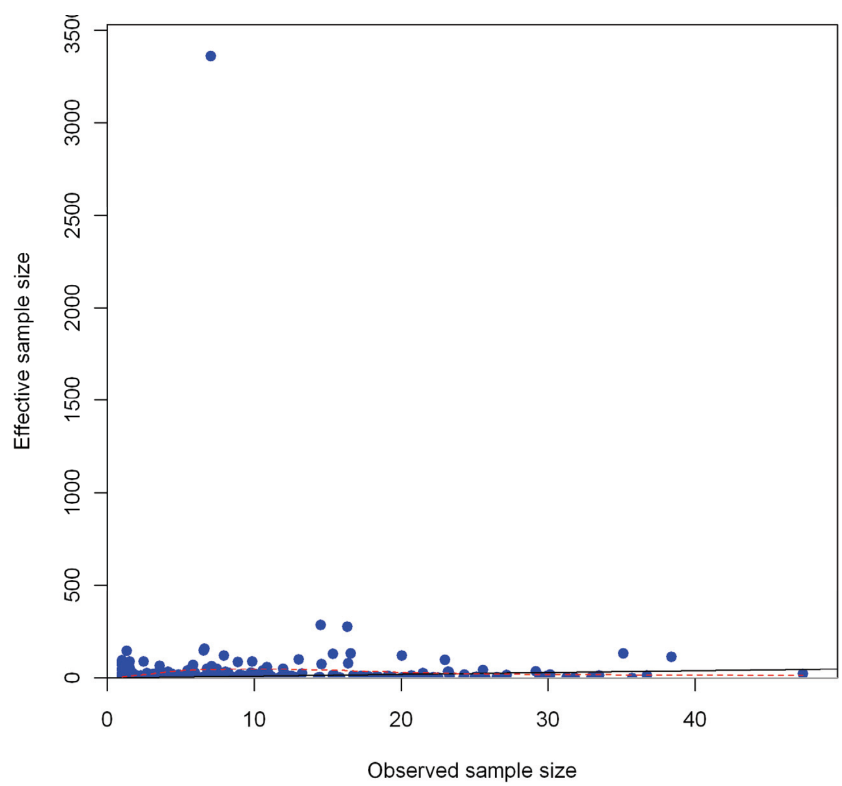


Figure 29b. Observed and effective sample sizes for the SCA_S2 fishery conditional age-at-length data.

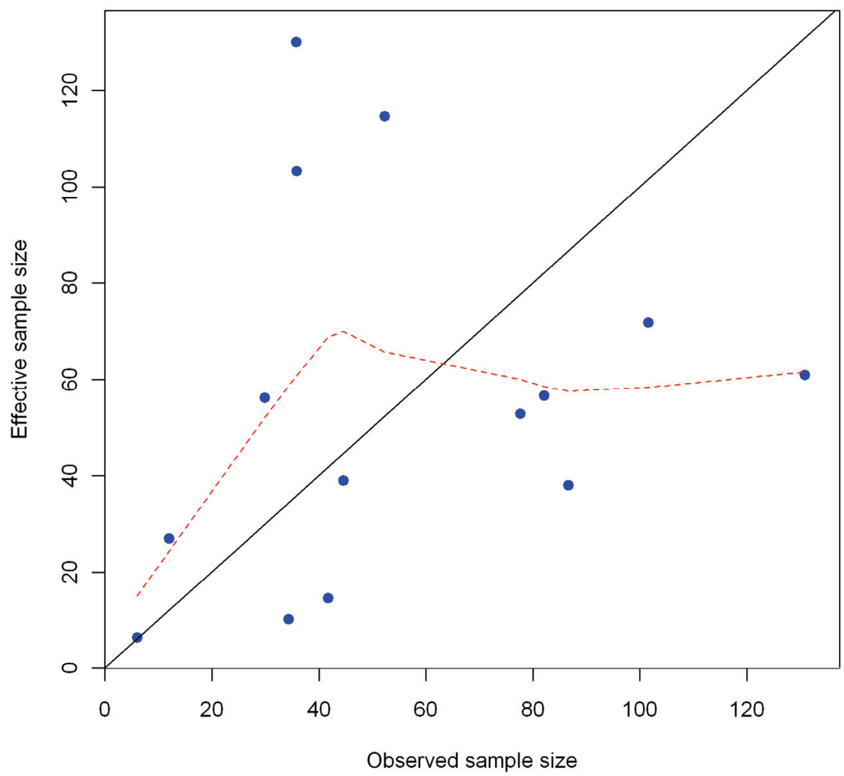


Figure 30a. Observed and effective sample sizes for the CCA_S1 fishery length-frequency data.

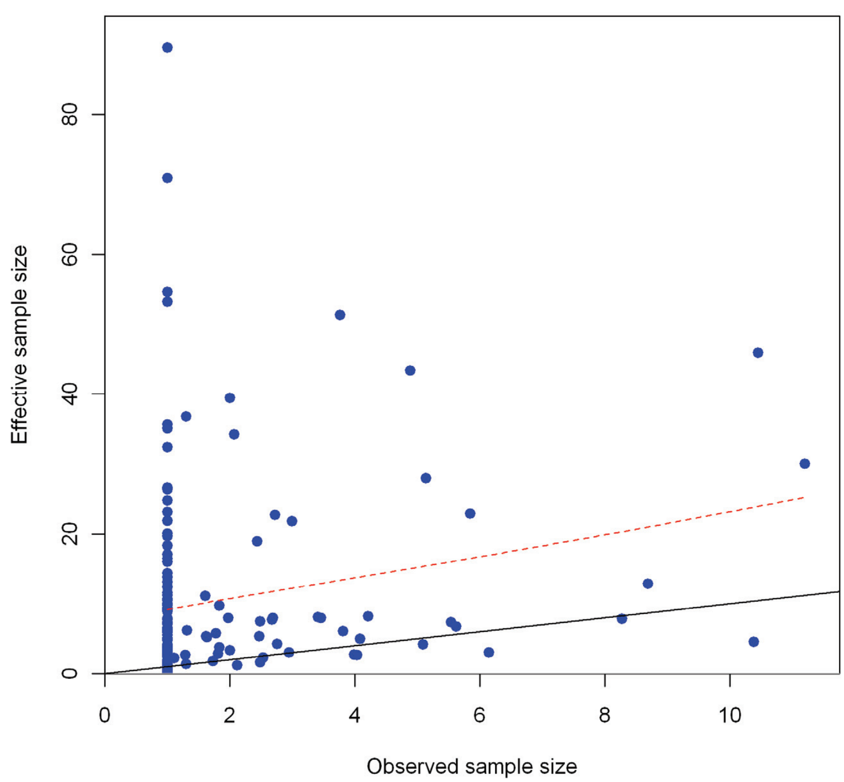


Figure 30b. Observed and effective sample sizes for the CCA_S1 fishery conditional age-at-length data.

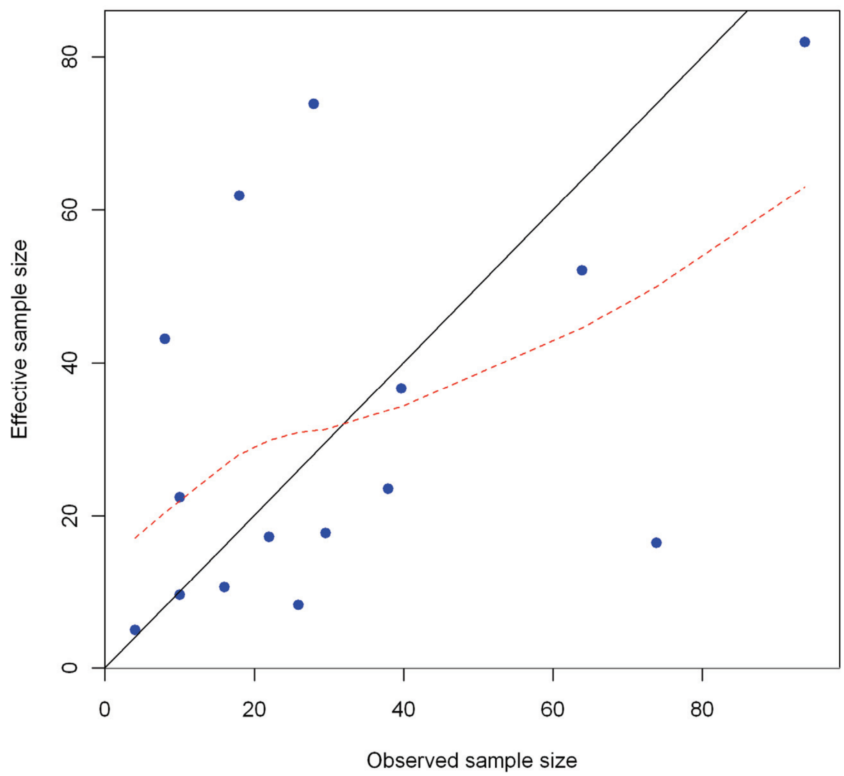


Figure 31a. Observed and effective sample sizes for the CCA_S2 fishery length-frequency data.

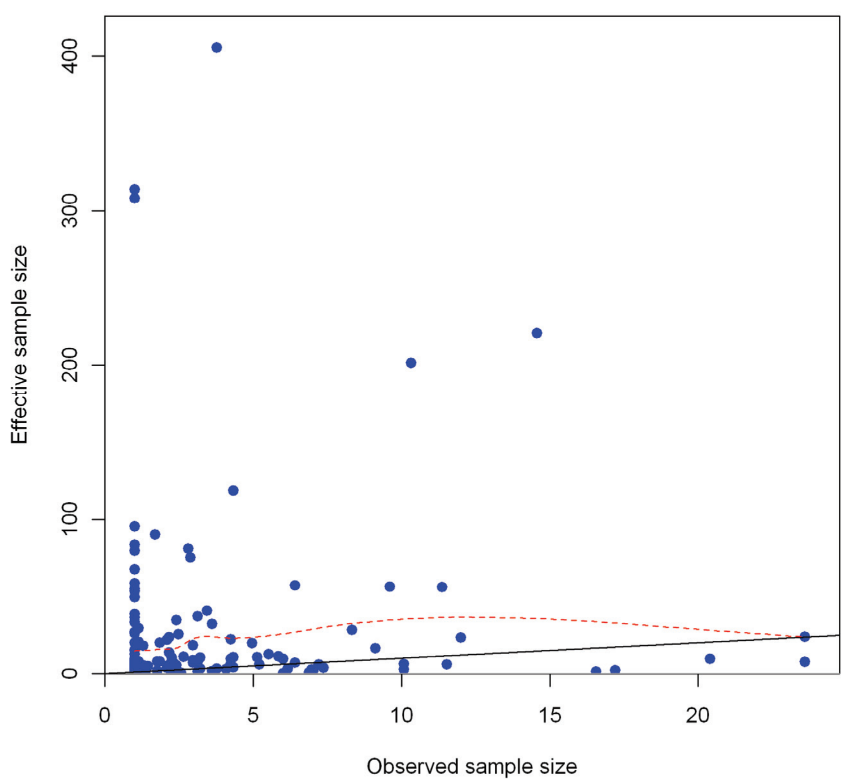


Figure 31b. Observed and effective sample sizes for the CCA_S2 fishery conditional age-at-length data.

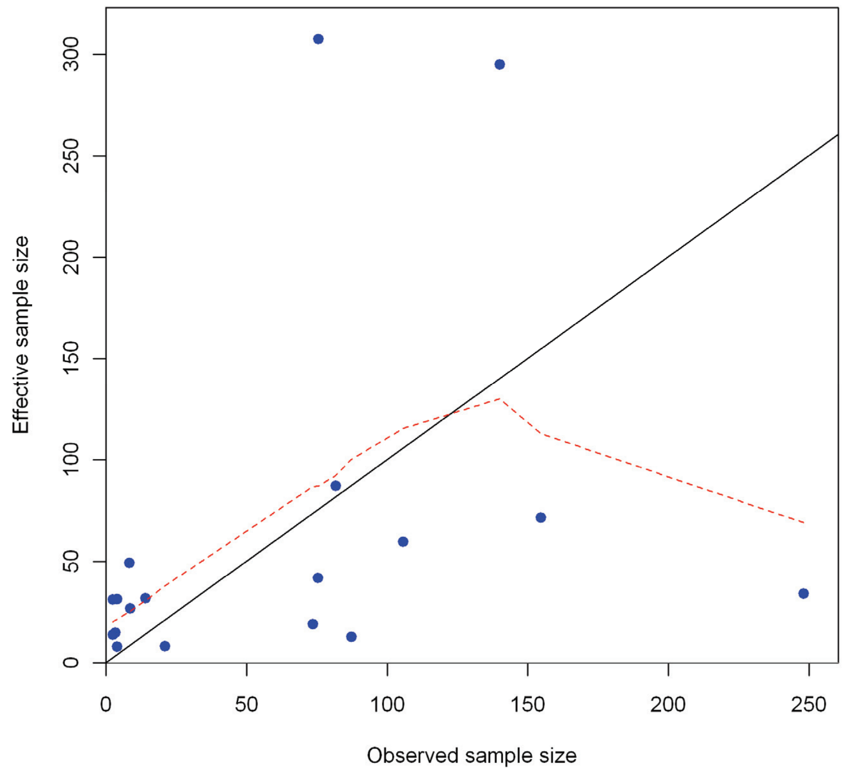


Figure 32a. Observed and effective sample sizes for the PNW fishery length-frequency data.

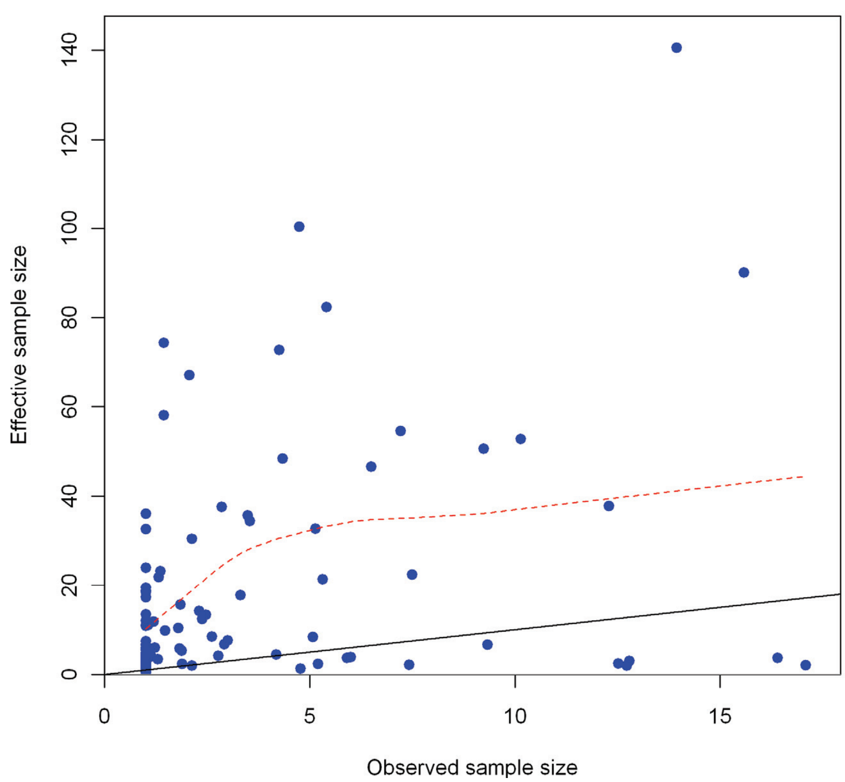


Figure 32b. Observed and effective sample sizes for the PNW fishery conditional age-at-length data.

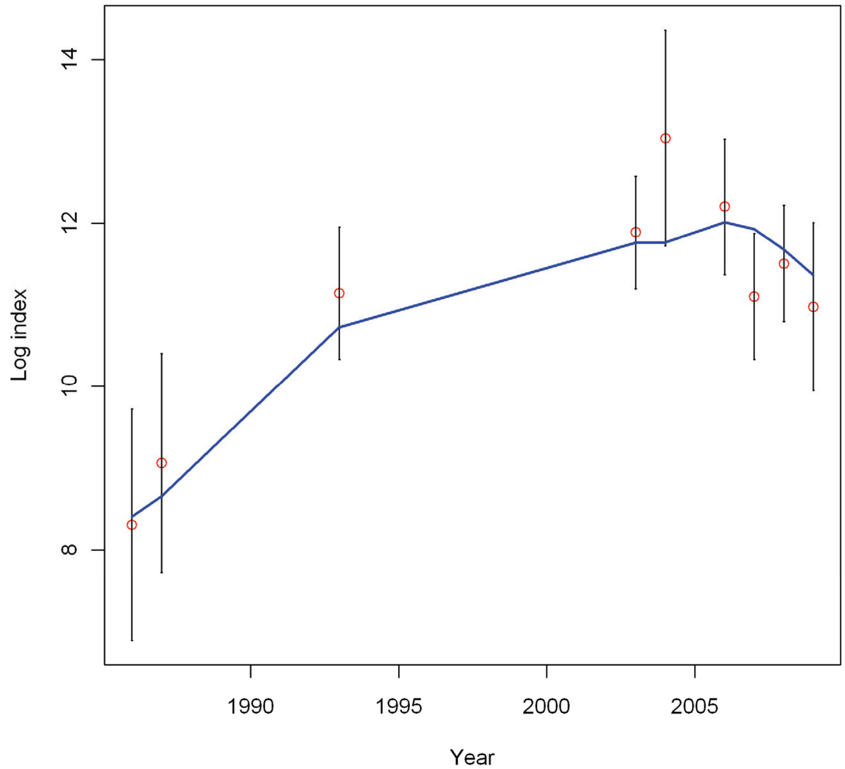


Figure 33a. Base model fit to the Daily Egg Production Method (DEPM) series of female spawning biomass (q=0.1715).

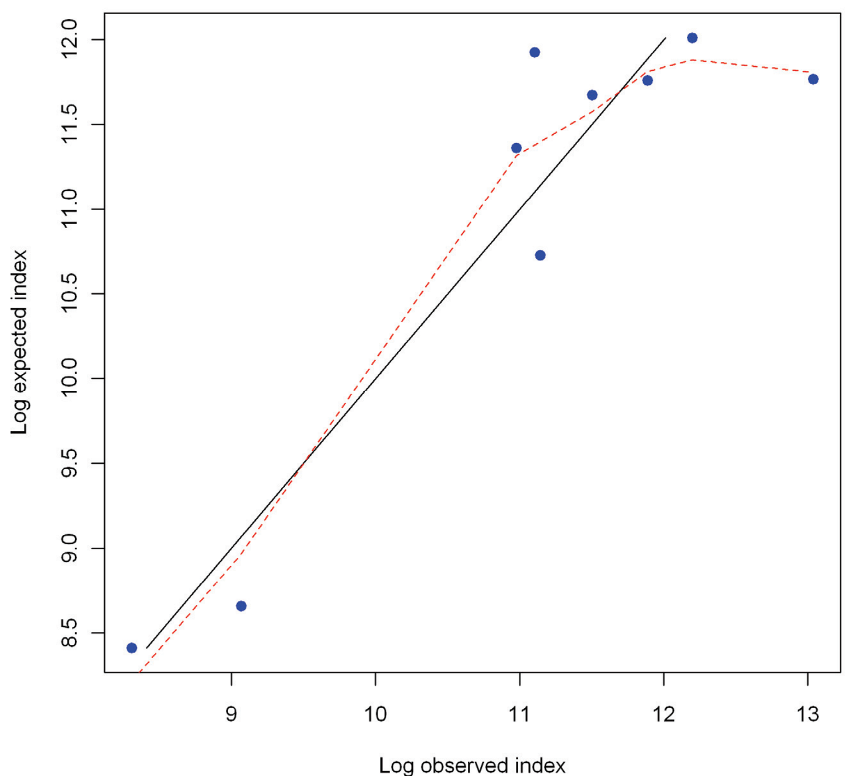


Figure 33b. Relationship between observed and expected values (log scale) for the DEPM survey (base model). Straight line is 1 to 1 relationship.

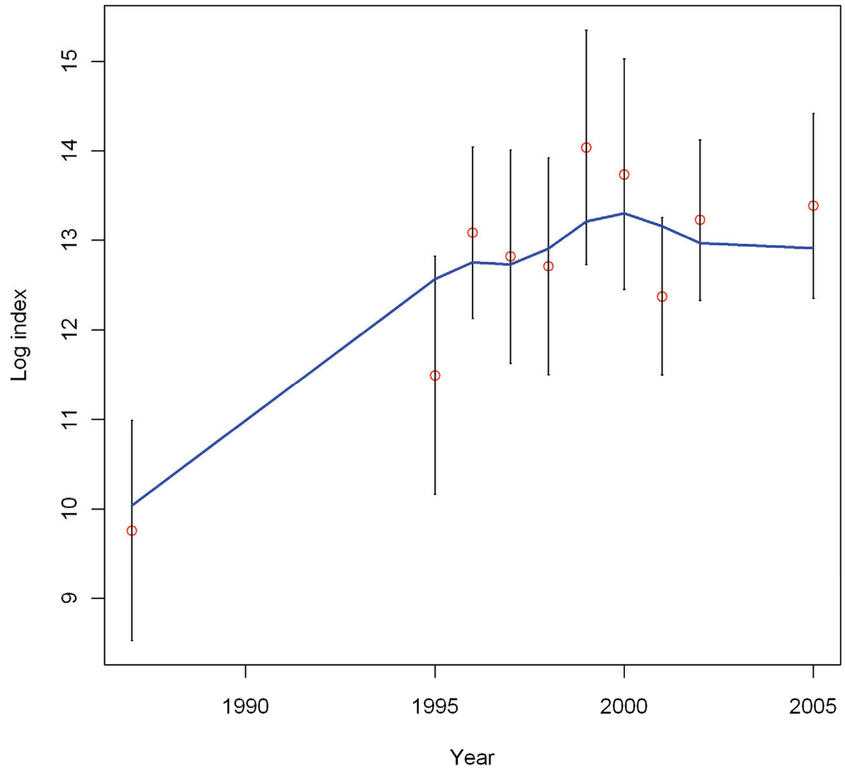


Figure 34a. Base model fit to the Total Egg Production (TEP) series of total spawning biomass (q=0.4568).

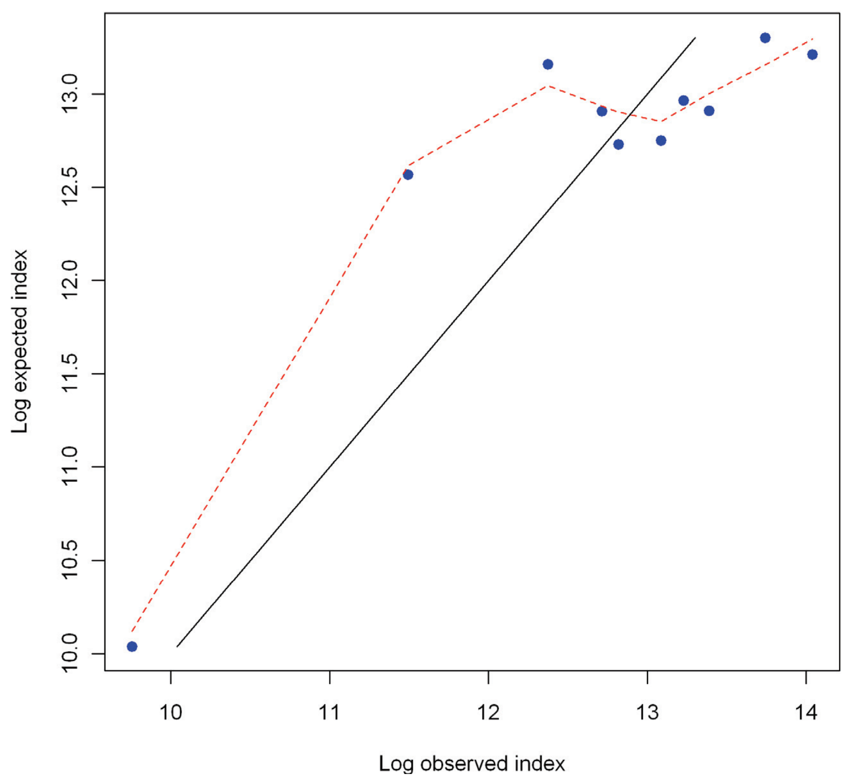


Figure 34b. Relationship between observed and expected values (log scale) for the TEP survey (base model). Straight line is 1 to 1 relationship.

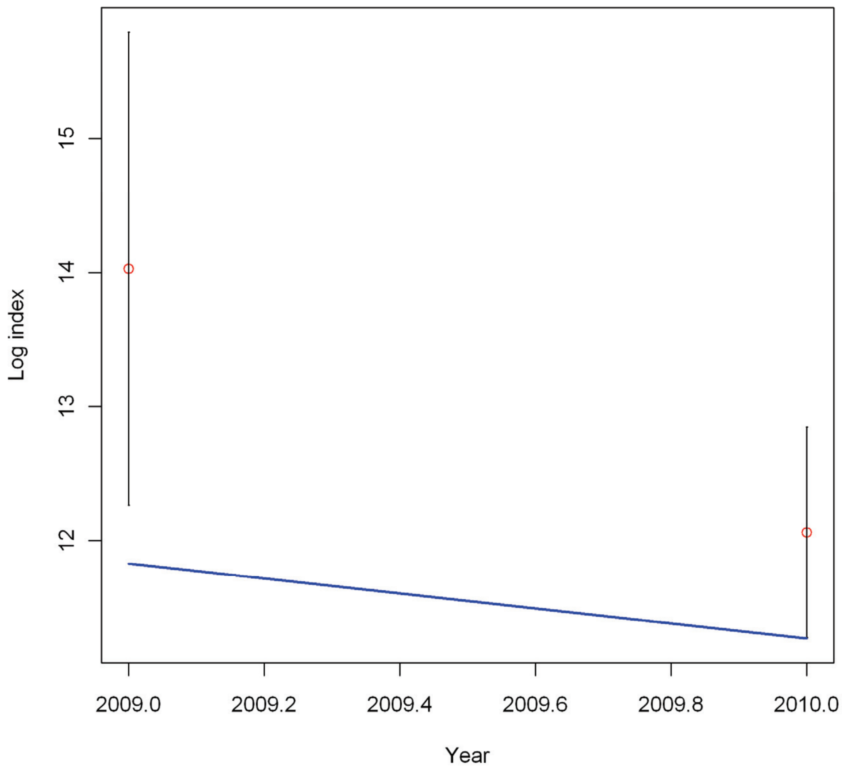
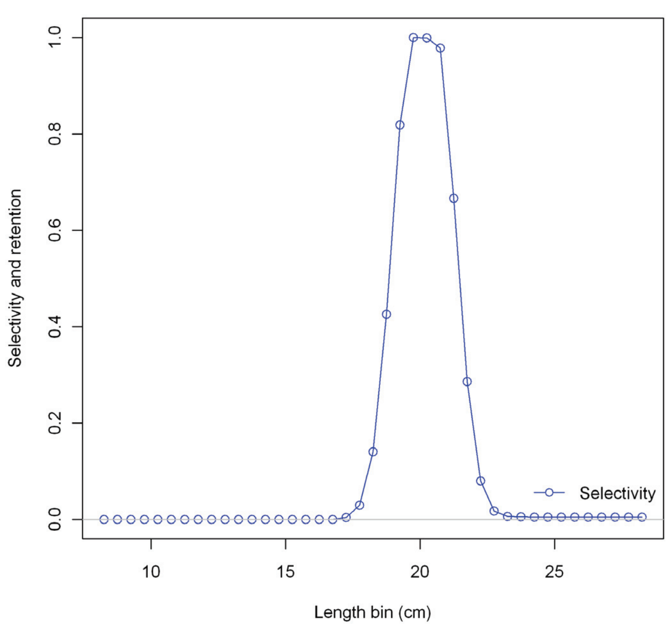


Figure 35a. Update model ‘10w’ fit to Aerial_N estimates of biomass (q fixed to 1). Base model fits length compositions using dome-shaped (double normal) selectivity.



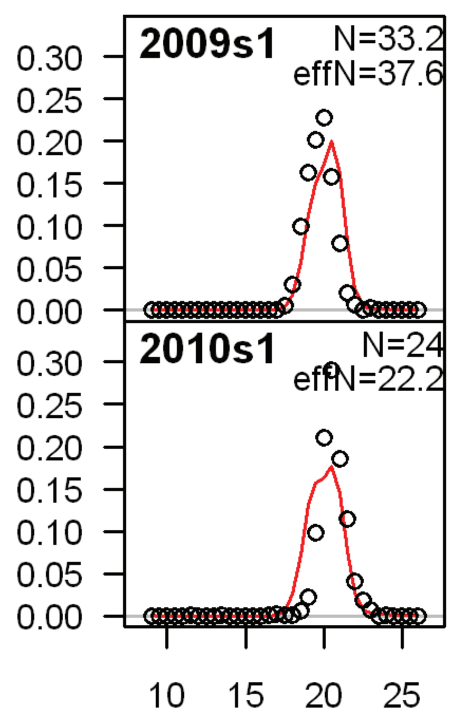


Figure 35b. Length-based selectivity (left panel; double-normal function) for the Aerial_N survey and corresponding model fit to length-frequency data (right panel).

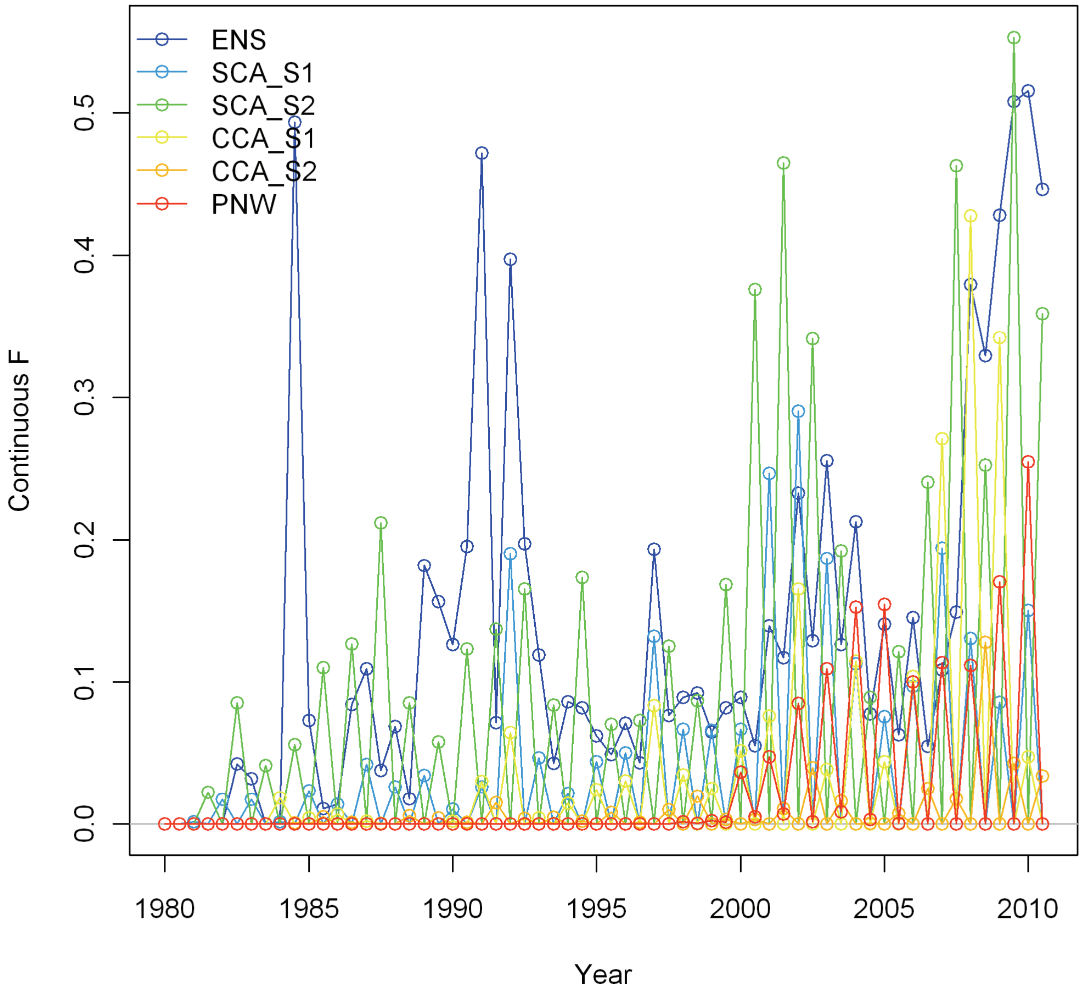


Figure 36. Harvest rate by fishery (Hybrid F-method) from the base model.

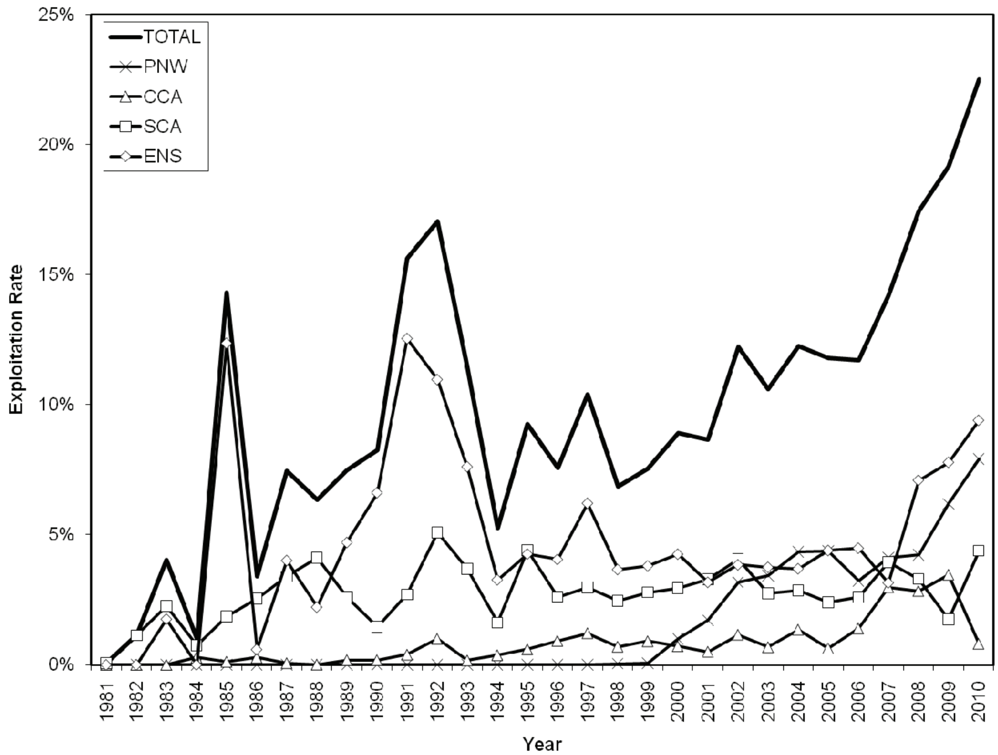


Figure 37a. Exploitation rate (CY landings / July total biomass) by fishery for the update model ('10w').

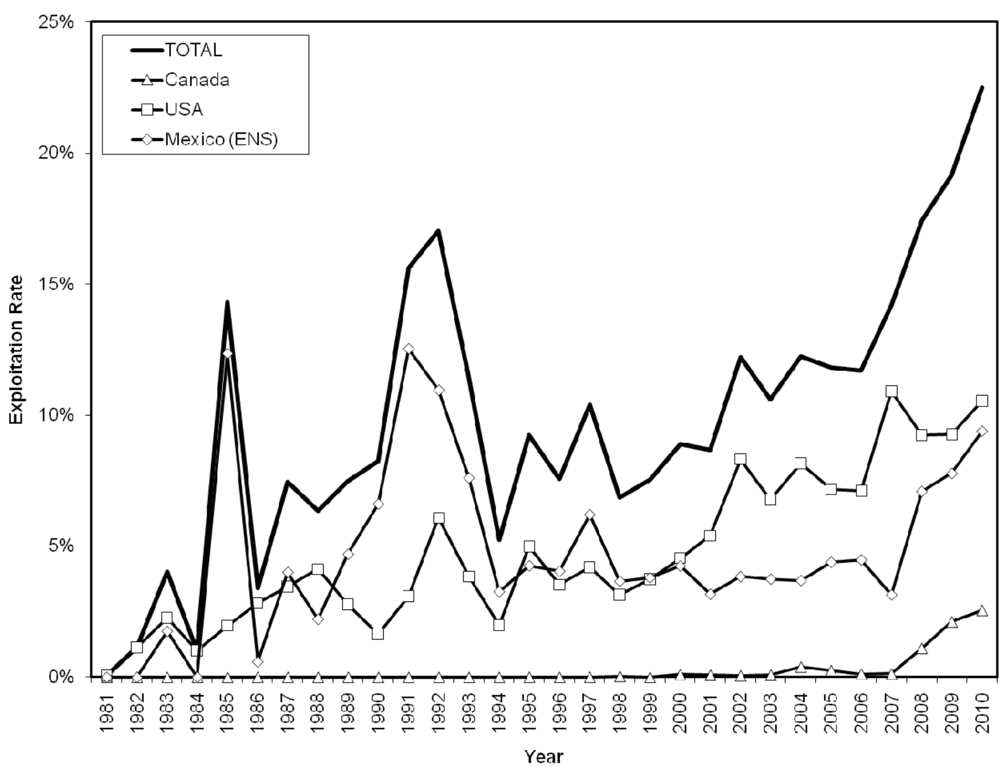


Figure 37b. Exploitation rate (CY landings / July total biomass) by country for the update model ('10w').

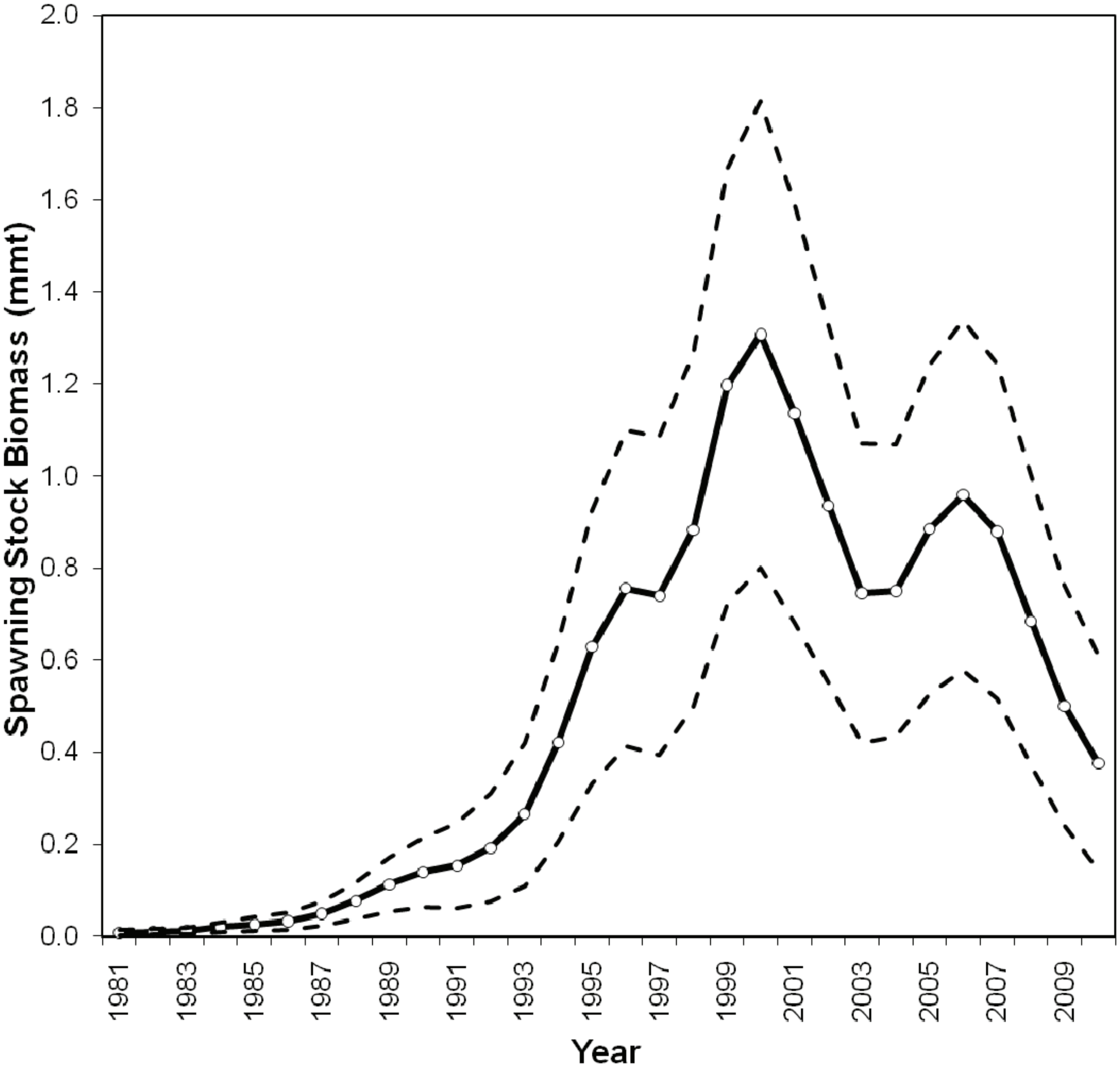


Figure 38. Spawning stock biomass with ~95% asymptotic confidence intervals from the update model '10w'.

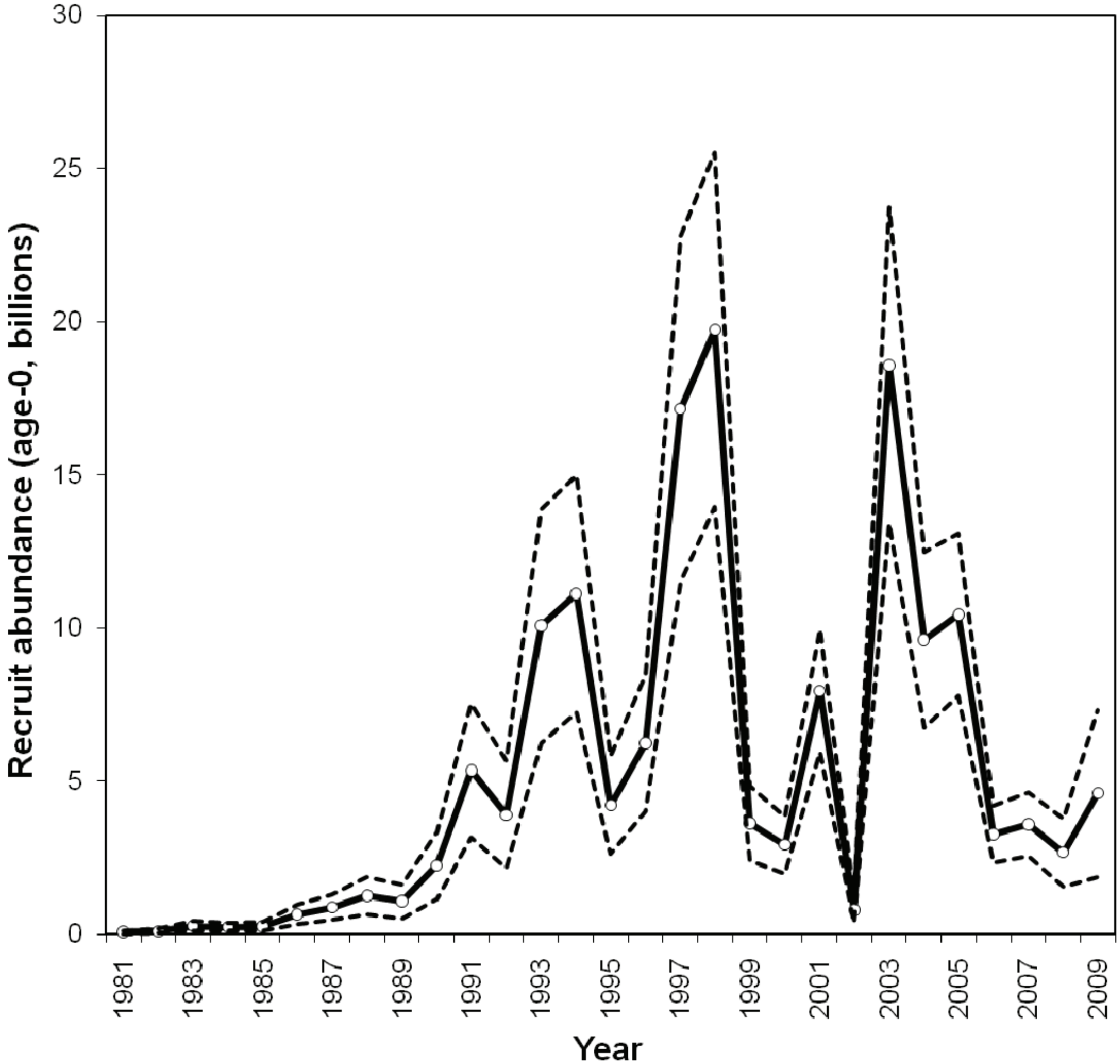


Figure 39. Year class abundance with ~95% asymptotic confidence intervals from the update model '10w'.

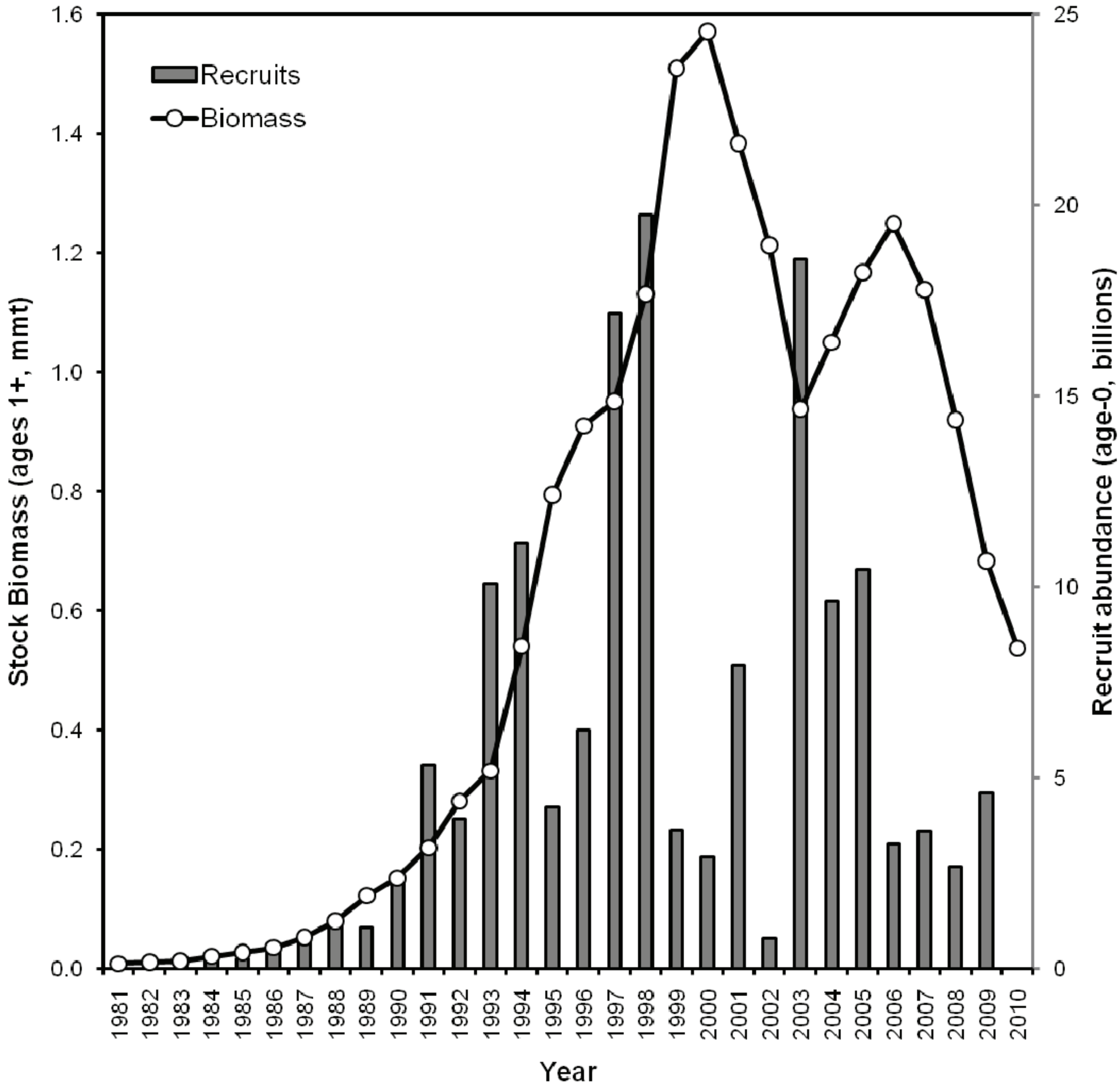


Figure 40. Pacific sardine stock biomass (ages 1+) and recruits (age 0) from the 2010 update model '10w'.

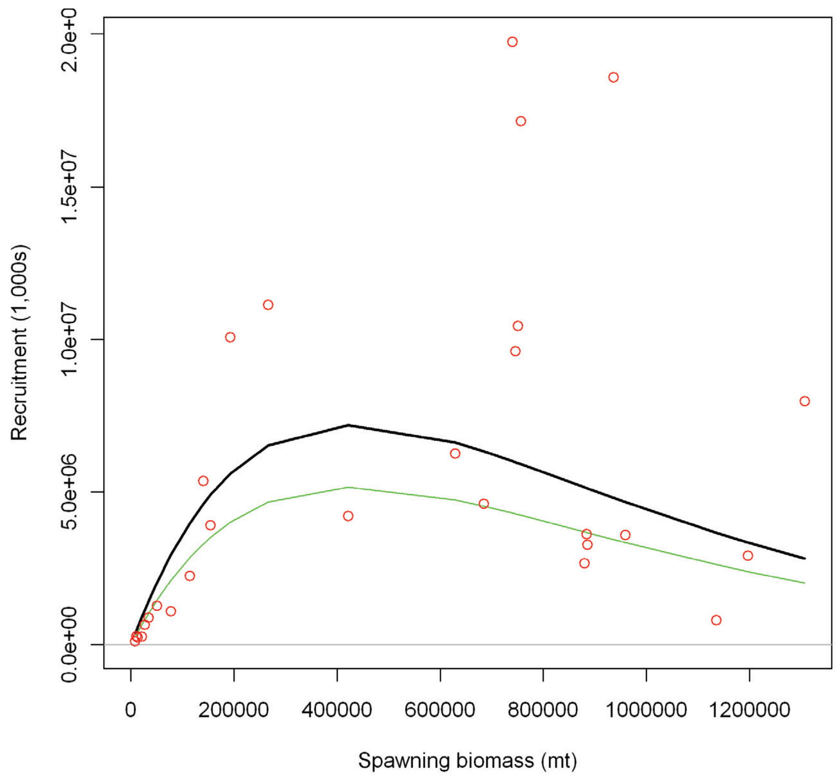


Figure 41a. Spawner-recruitment relationship for update model '10w', showing Ricker function fit with bias correction. Steepness (*h*) = 2.25301.

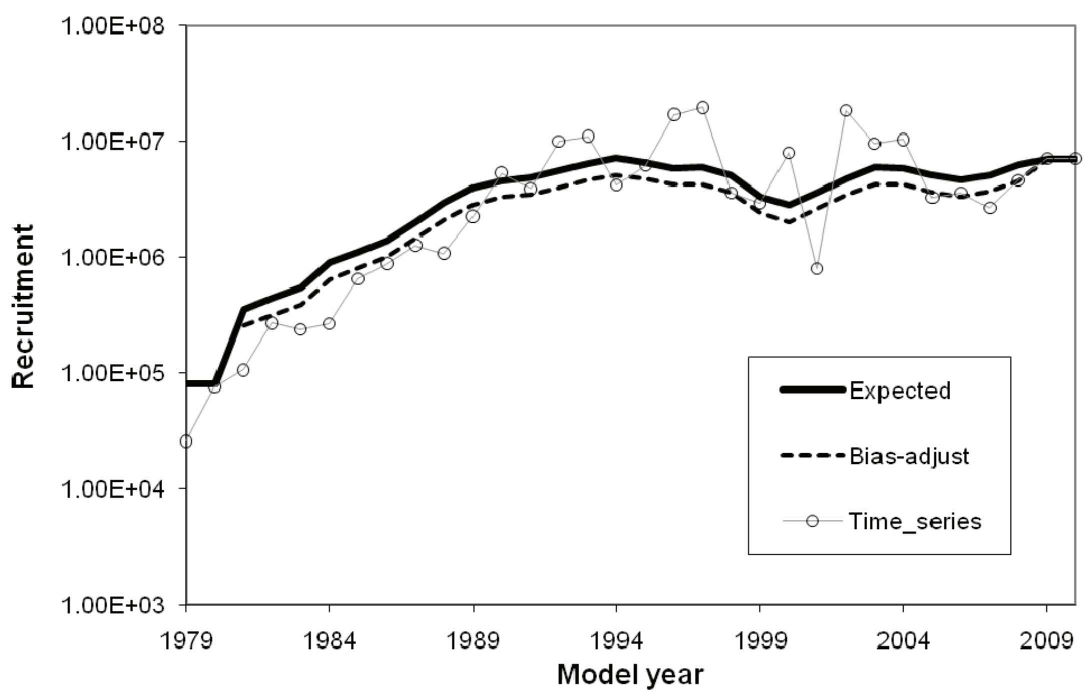


Figure 41b. Ricker model fit to the recruitment time series (model '10w').

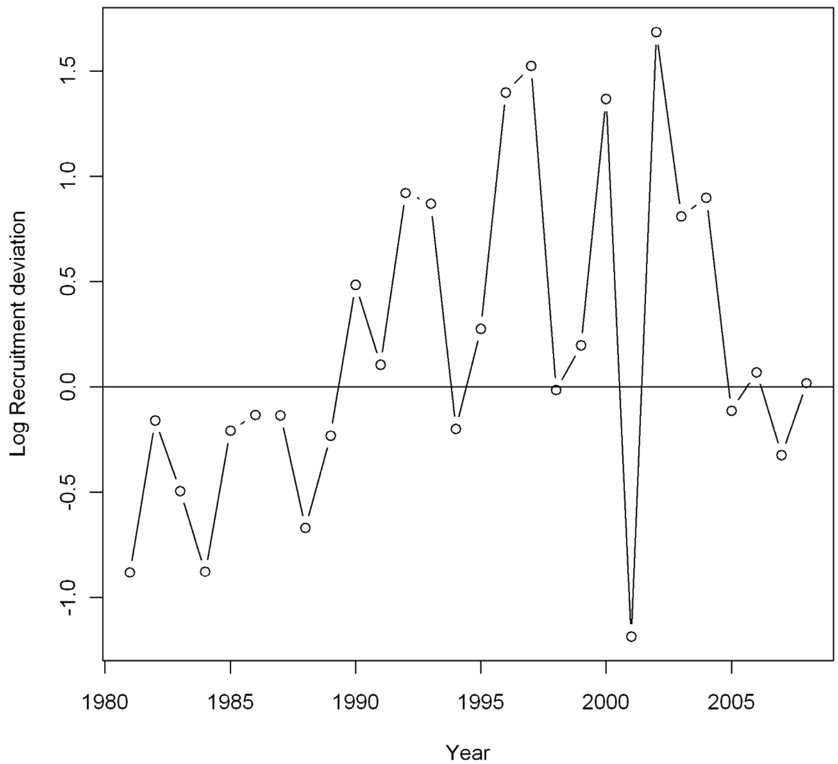


Figure 42a. Recruitment deviations estimated in the update model ‘10w’.

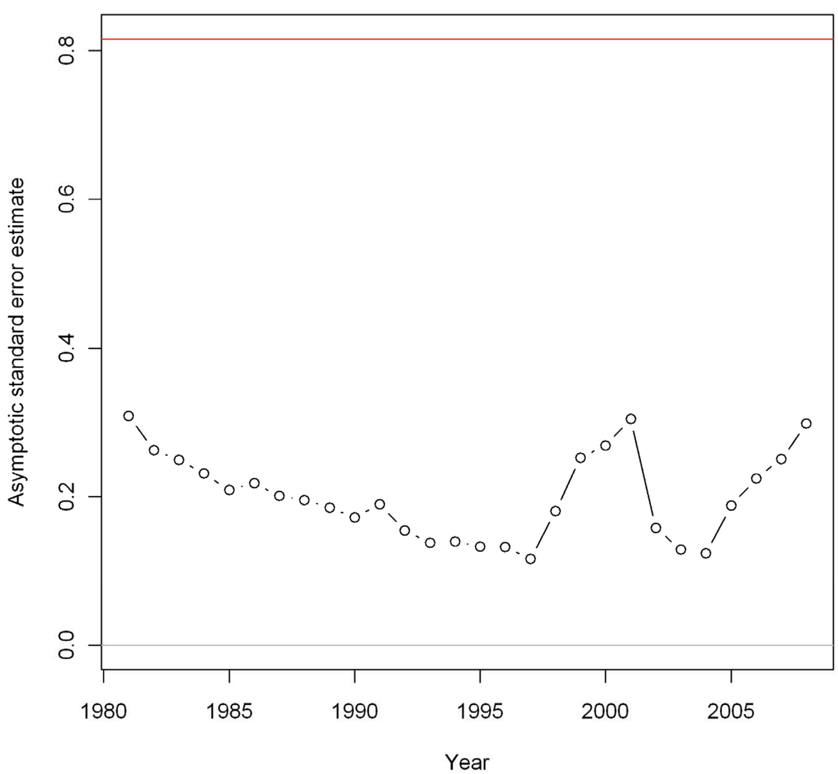


Figure 42b. Asymptotic standard errors for estimated recruitment deviations in the update model ‘10w’.

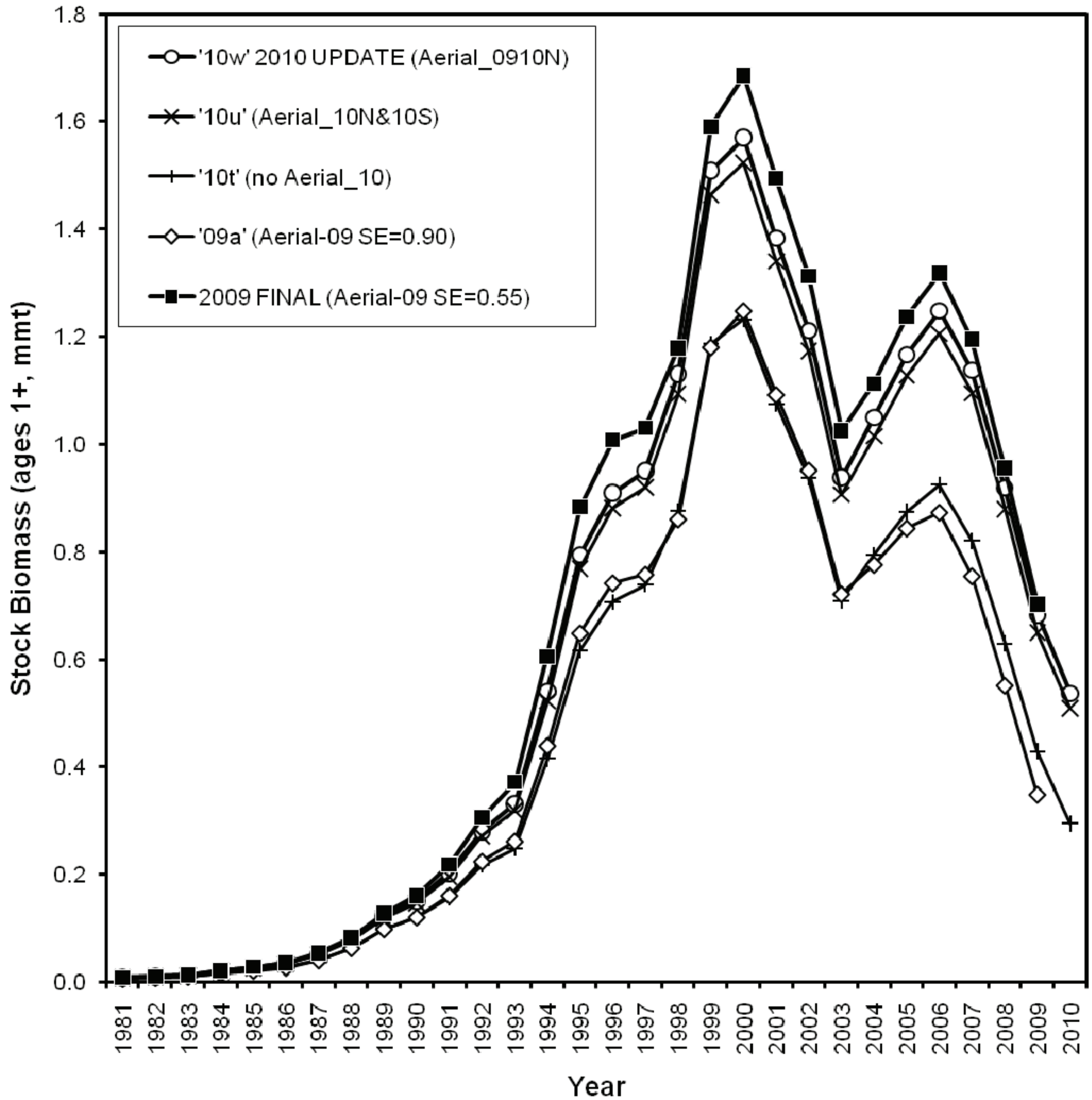


Figure 43a. Pacific sardine stock biomass (ages 1+) from the 2010 update model '10w' compared to: the 2009 final model (aerial SE=0.55); the 2009 model '09a' where aerial SE=0.90; the 2010 update without the 2010 aerial data ('10t'), and the 2010 update fit to both the northern and southern aerial estimates from 2010 ('10u'). See Table 8 for all model specifications.

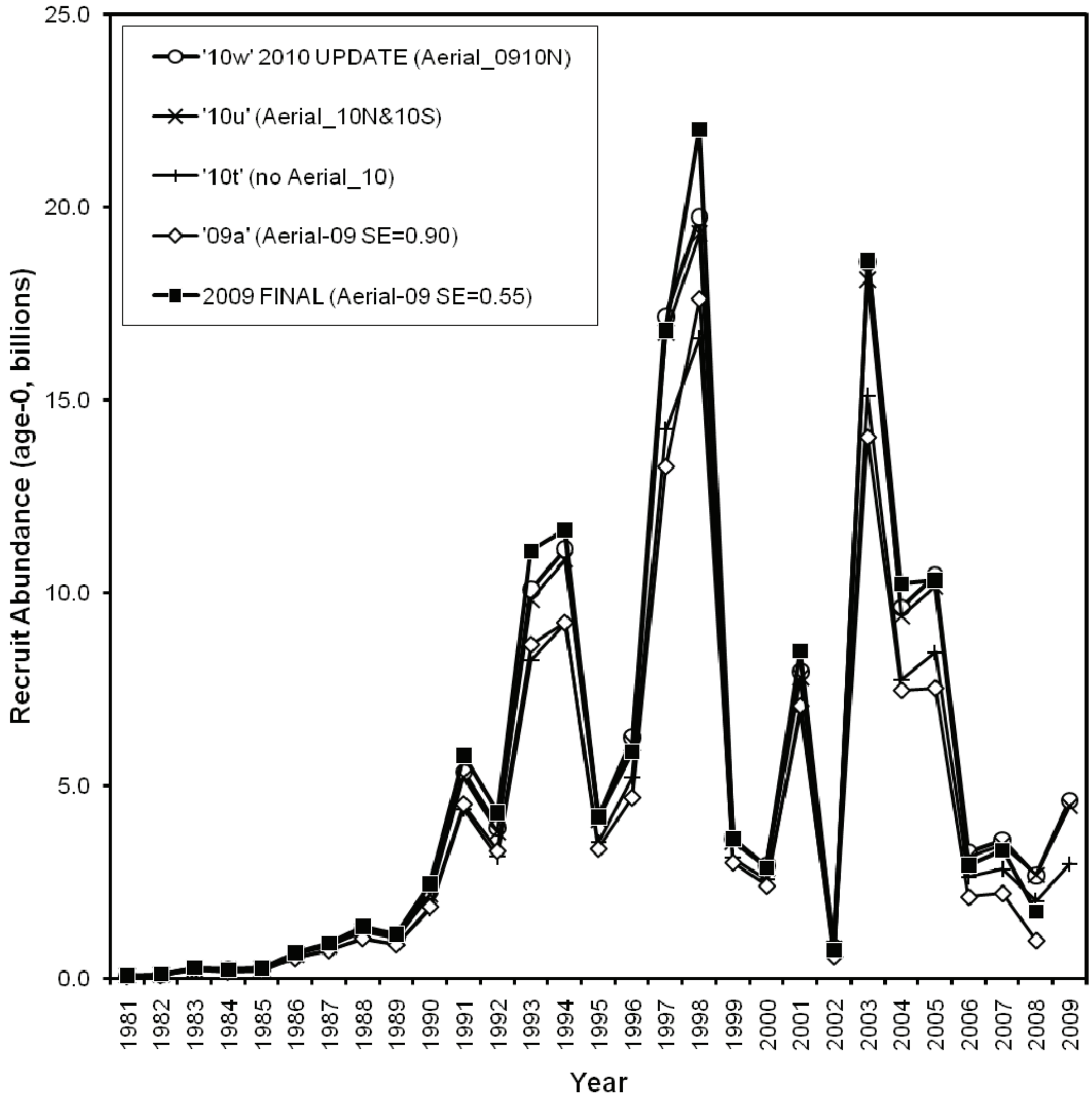


Figure 43b. Pacific sardine recruit (age-0) abundance from the 2010 update model '10w' compared to: the 2009 final model (aerial SE=0.55); the 2009 model '09a' where aerial SE=0.90; the 2010 update without the 2010 aerial data ('10t'), and the 2010 update fit to both the northern and southern aerial estimates from 2010 ('10u'). See Table 8 for all model specifications.

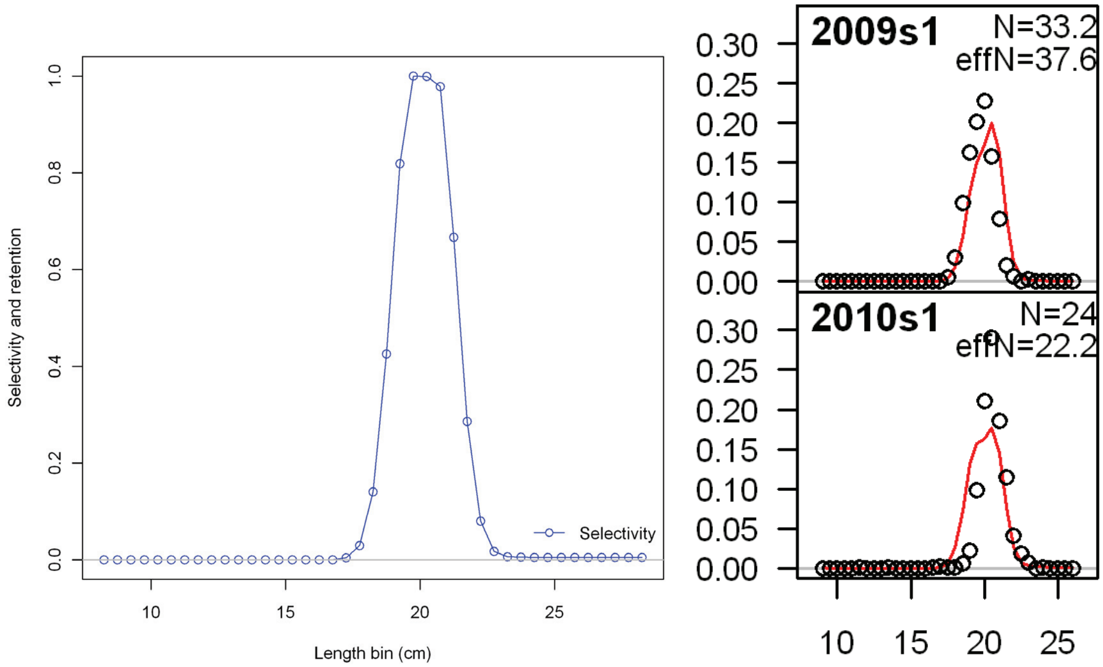


Figure 44a (from Figure 35b). Length-based selectivity ogive (left panel; double-normal function) for the Aerial_N survey and corresponding model '10w' fit to length-frequency data (right panel).

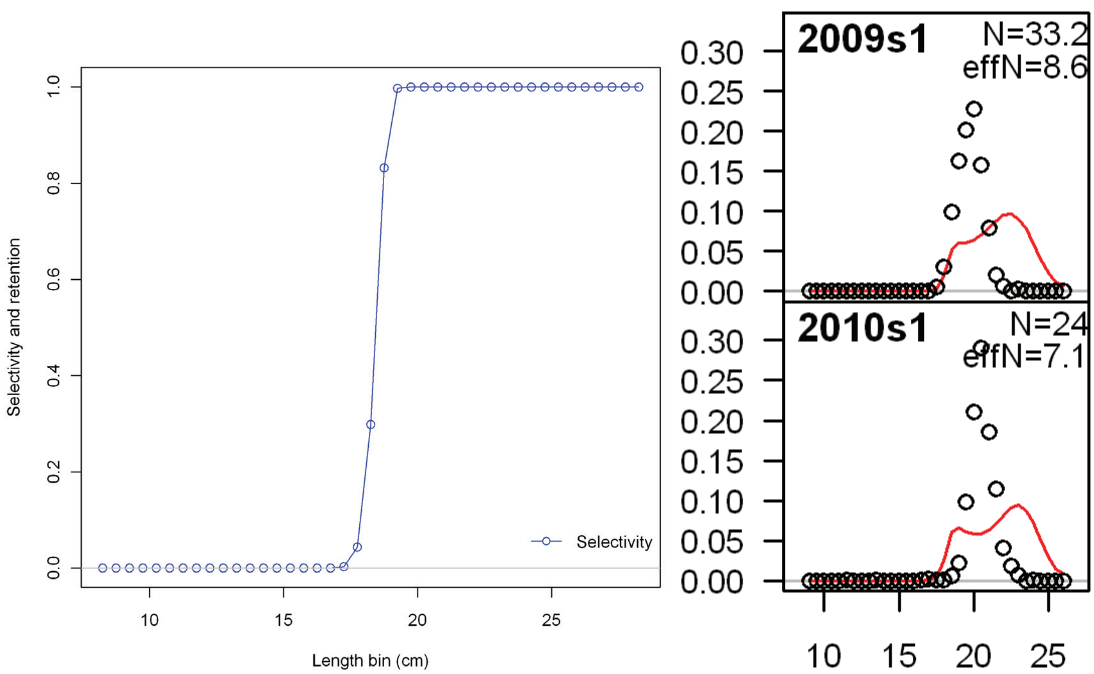


Figure 44b. Length-based selectivity ogive (double-normal forced to asymptotic shape; right panel) for the Aerial_N survey and corresponding model '10x1' fit to length-frequency data (right panel).

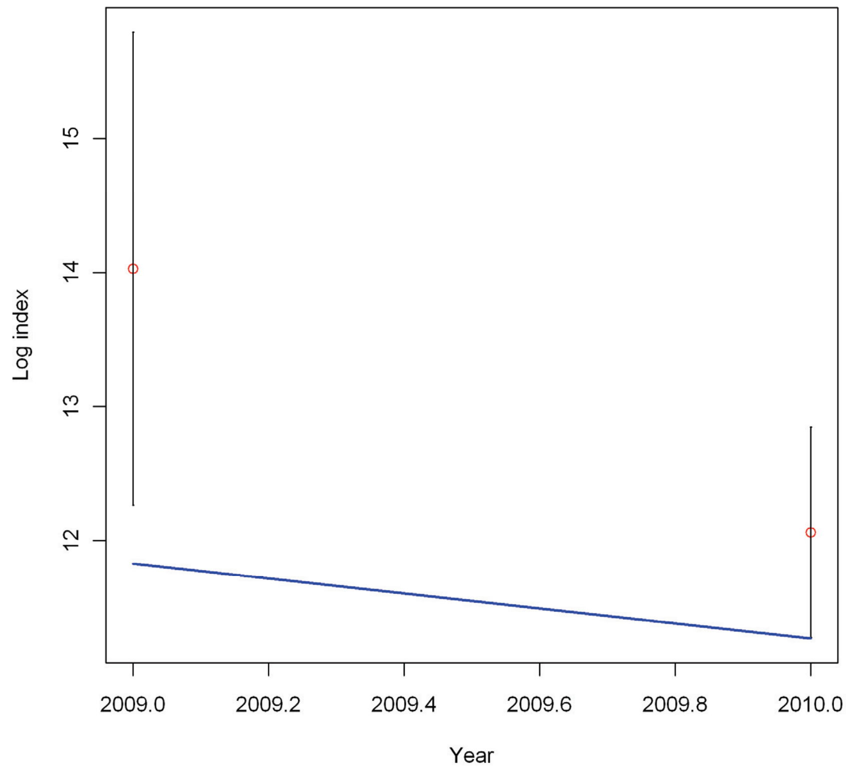


Figure 45a (from Figure 35a). Update model '10w' fit to Aerial_N estimates of biomass (q fixed to 1), where aerial survey lengths were fit using dome-shaped selectivity.

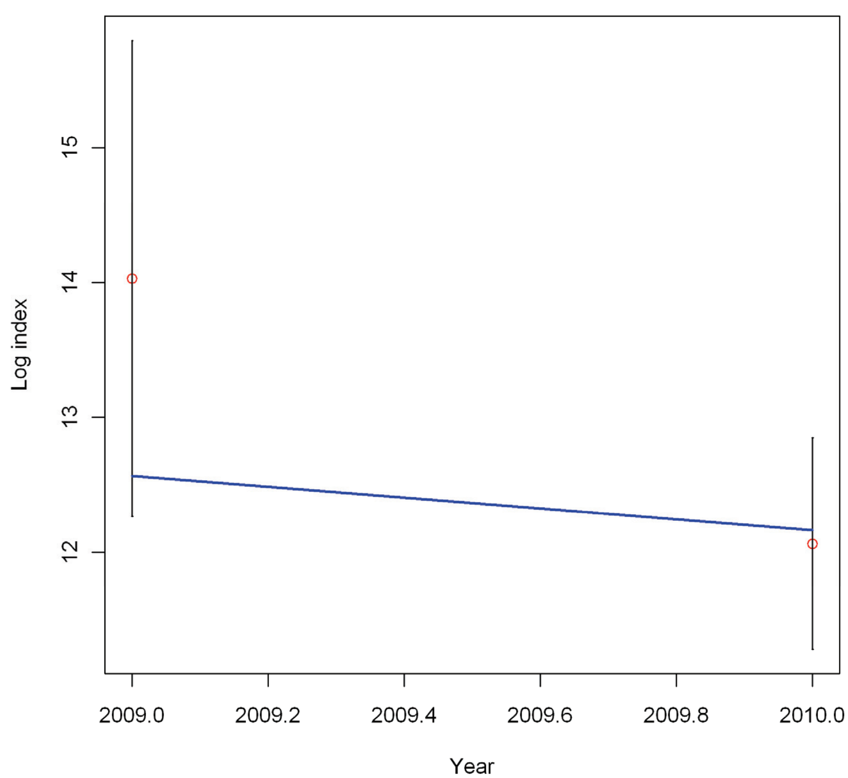


Figure 45b. Update model '10x1' fit to Aerial_N estimates of biomass (q fixed to 1), where aerial survey length compositions were fit using asymptotic selectivity.

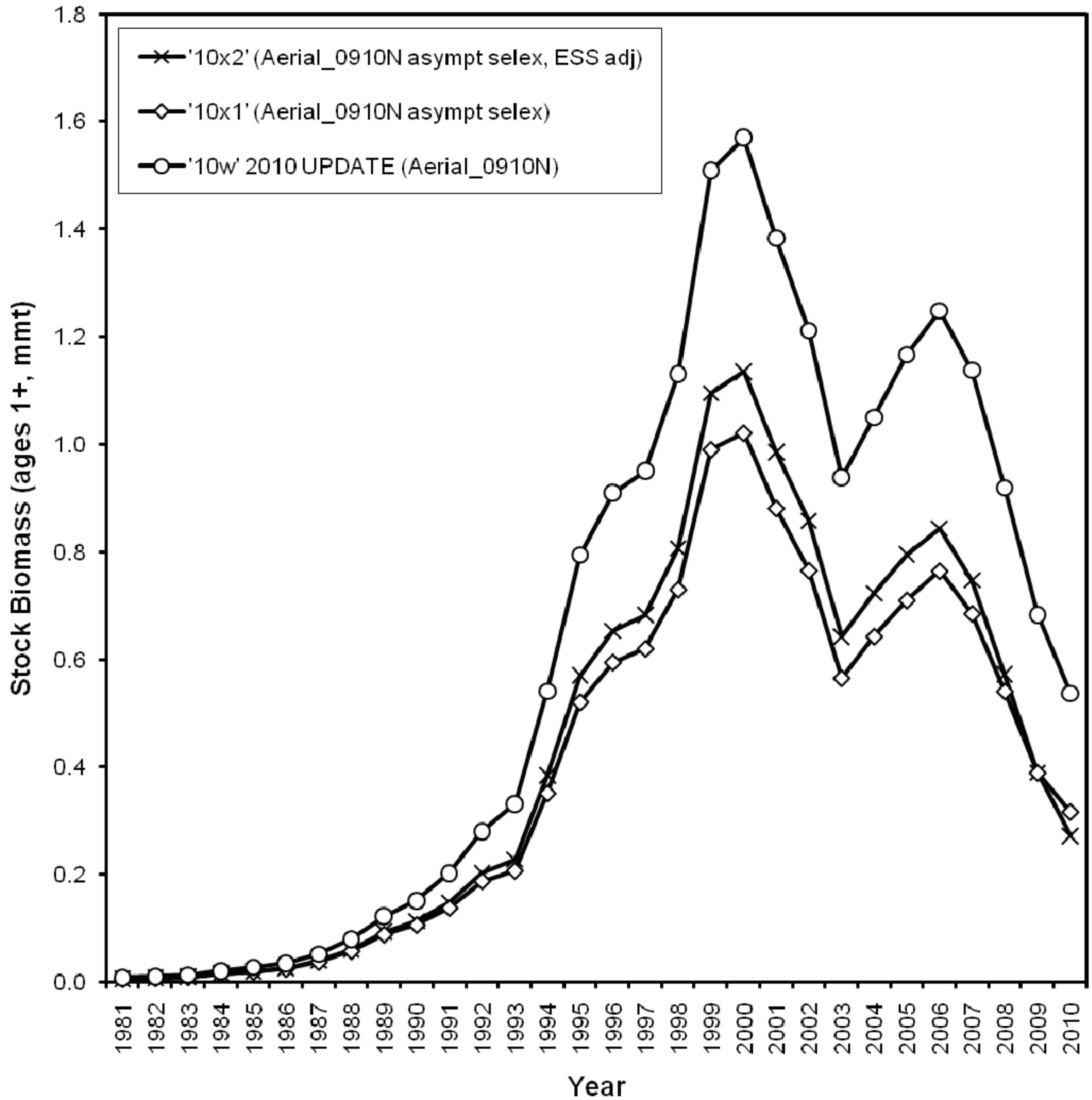


Figure 46a. Pacific sardine stock biomass (ages 1+) from the 2010 update model '10w' compared to models '10x1' and '10x2', where aerial survey length compositions were fit using asymptotic selectivities. Model 10x2 adjusts the aerial length composition variances to match model estimates from '10x1'. See Table 8 for model specifications.

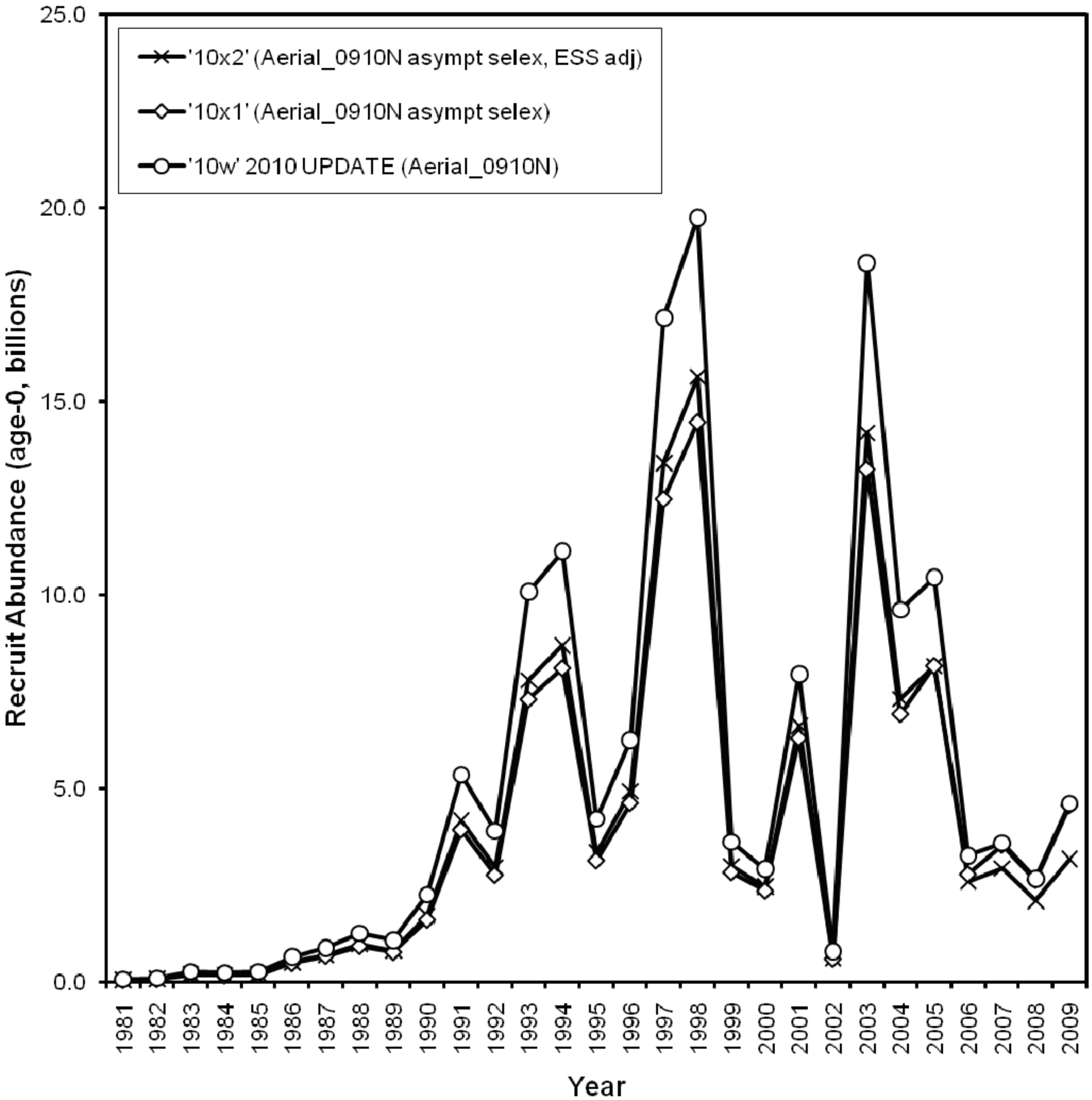


Figure 46b. Pacific sardine recruit (age-0) abundance from the 2010 update model '10w' compared to models '10x1' and '10x2', where aerial survey length compositions were fit using asymptotic selectivities. Model '10x2' adjusts the aerial length composition variances to match model estimates from '10x1'. See Table 8 for model specifications.

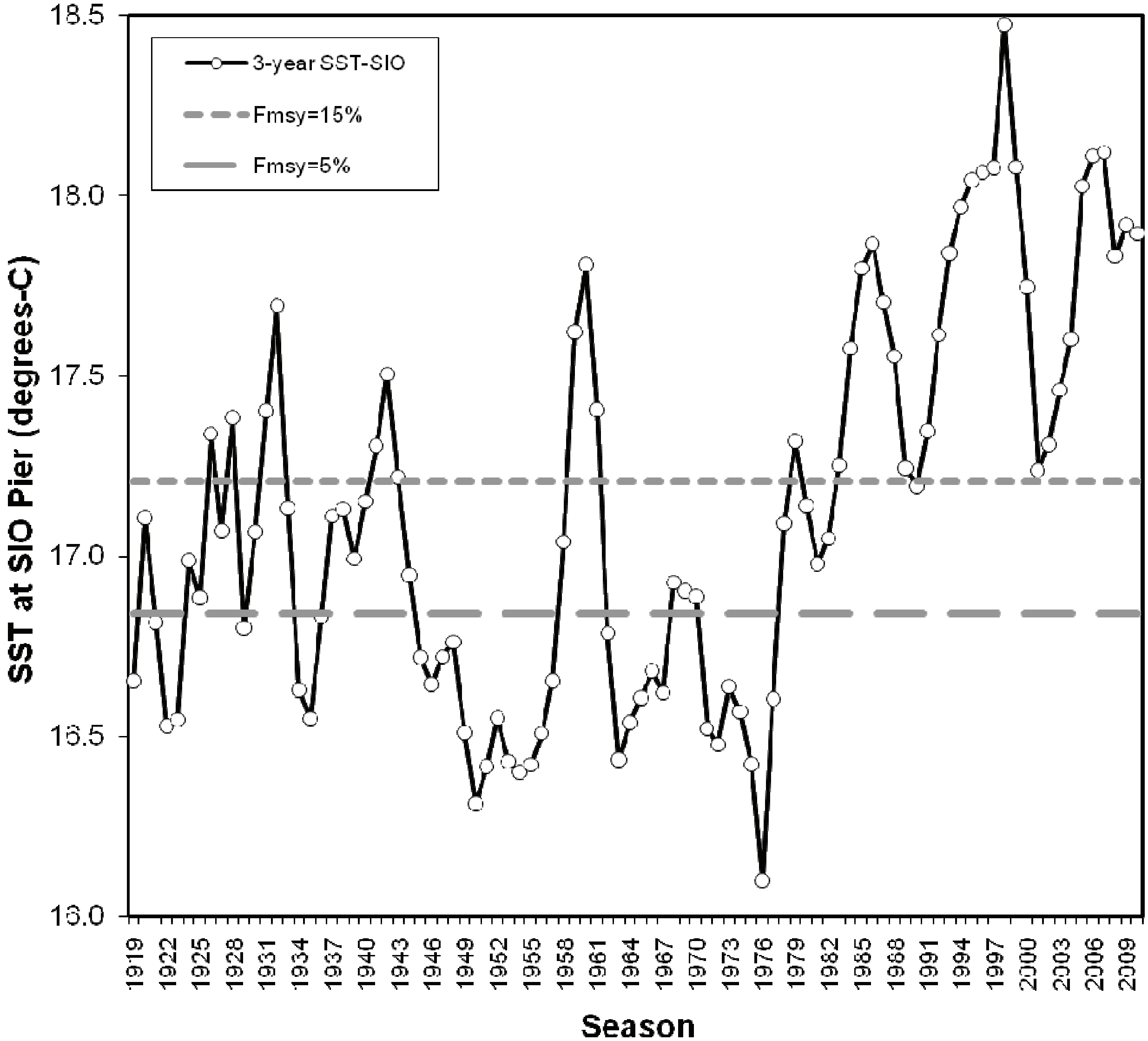


Figure 47. Three-season running average of sea surface temperature (SST) data collected daily at Scripps Institution of Oceanography pier since 1916. For any given season, SST is the running average temperature during the preceding three seasons (July-June), e.g. the 2010 estimate is the average from July 1, 2007 through June 30, 2010. The 2010 value used for management in 2011 was calculated to be 17.90 °C, so a 15% exploitation fraction (F_{msy}) should be applied in the harvest guideline control rule.

Agenda Item I.2.b
Supplemental Aerial Sardine PowerPoint (Jagielo)
November 2010

West Coast Aerial Sardine Survey

A Consortium of the Sardine Industry

Sampling Results in 2010

2010 EFP Components

- Summer Coastwide Aerial Sardine Survey

  Research “Set-Aside”:

  - 2,100 mt in Northern Region (WA/OR) - NWSS

  - 2,100 mt in Southern Region (CA) - CWPA

- Fall California Pilot Study

  Research “Set-Aside”:

  - 800 mt in S. CA Bight - CWPA

2010 Survey Design

- Stage 1 Sampling: Aerial Survey Transects

Systematic Random Sampling: Sampling Unit = Transect

Each Replicate SET: 26 Transects in Northern Region, 40 transects in Southern Region

Three SETs = 198 Planned Transects

Transects oriented E/W and spaced 15 nautical miles apart N/S

- Stage 2 Sampling: At-Sea Point Sets

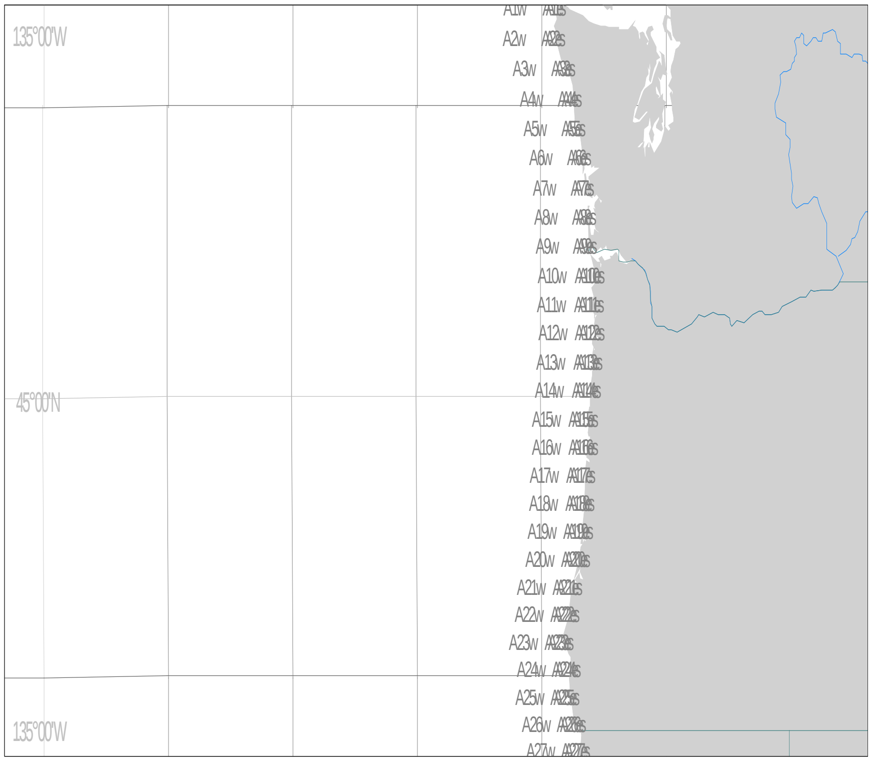
Distributed by Size: Size Bins Range from 100 m^2 to 10,000 m^2 (4-82 mt)

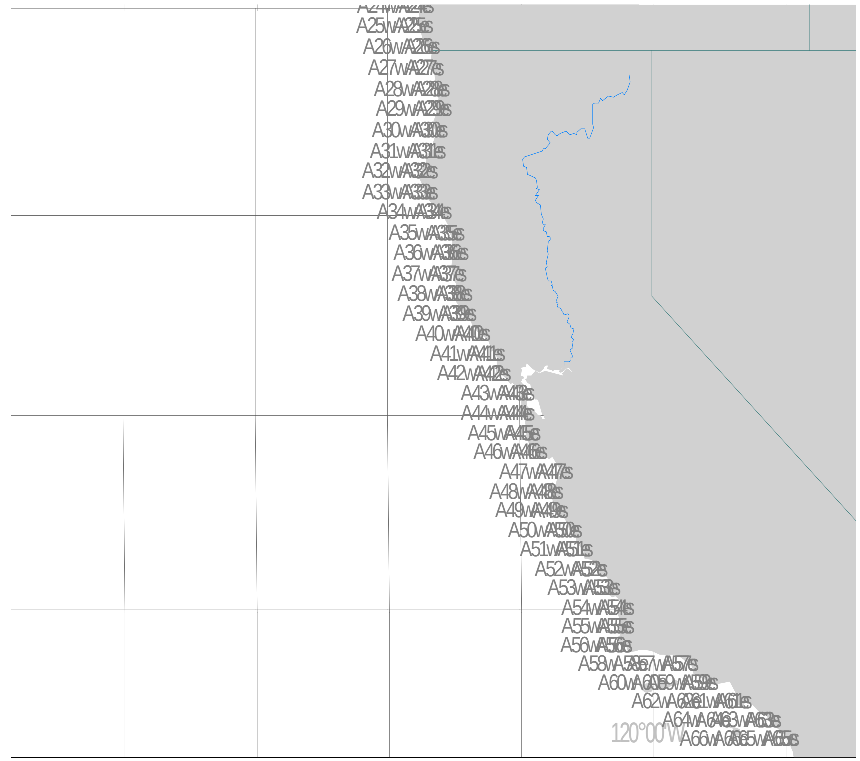
56 Planned Point Sets in Northern Region

56 Planned Point Sets in Southern Region

2010 Survey – Planned Transects

Cape Flattery to S.CA Bight – 66 Transects/SET





Northern Region (WA/OR) -- 26 Transects -- (NWSS)

Southern Region (CA) -- 40 Transects (CWPA)

Transect Logistics

At the nominal survey altitude of 4000 feet, the approximate width-swept by the camera with a 24 mm lens is about 1 mile.   Digital images are collected with 60% overlap to ensure seamless photogrammetric coverage of the transects.

Data Collection and Reduction

Aerial Survey
Data Acquisition

Manufacturer
Aerial Imaging Solutions
Don LeRoi

Canon EOS 1D Mark III
Digital AF/AE SLR
5616 x 3744 pixels
21 mega pixels
Lens 24mm

Laptop PC
Dell latitude D630

Acquires digital images at specified overlap rate (60%)
Logs: Altitude, GPS Position, Observer Comments

2010 Survey – Planned Point Sets

Size (m^2)	Weight (mt)	Total Weight	Number of Point Sets
100	3.8	31	8
500	10.6	85	8
1000	17.0	136	8
2000	26.5	212	8
4000	51.9	415	8
8000	70.5	564	8
10000	82.1	657	8
		2099	56

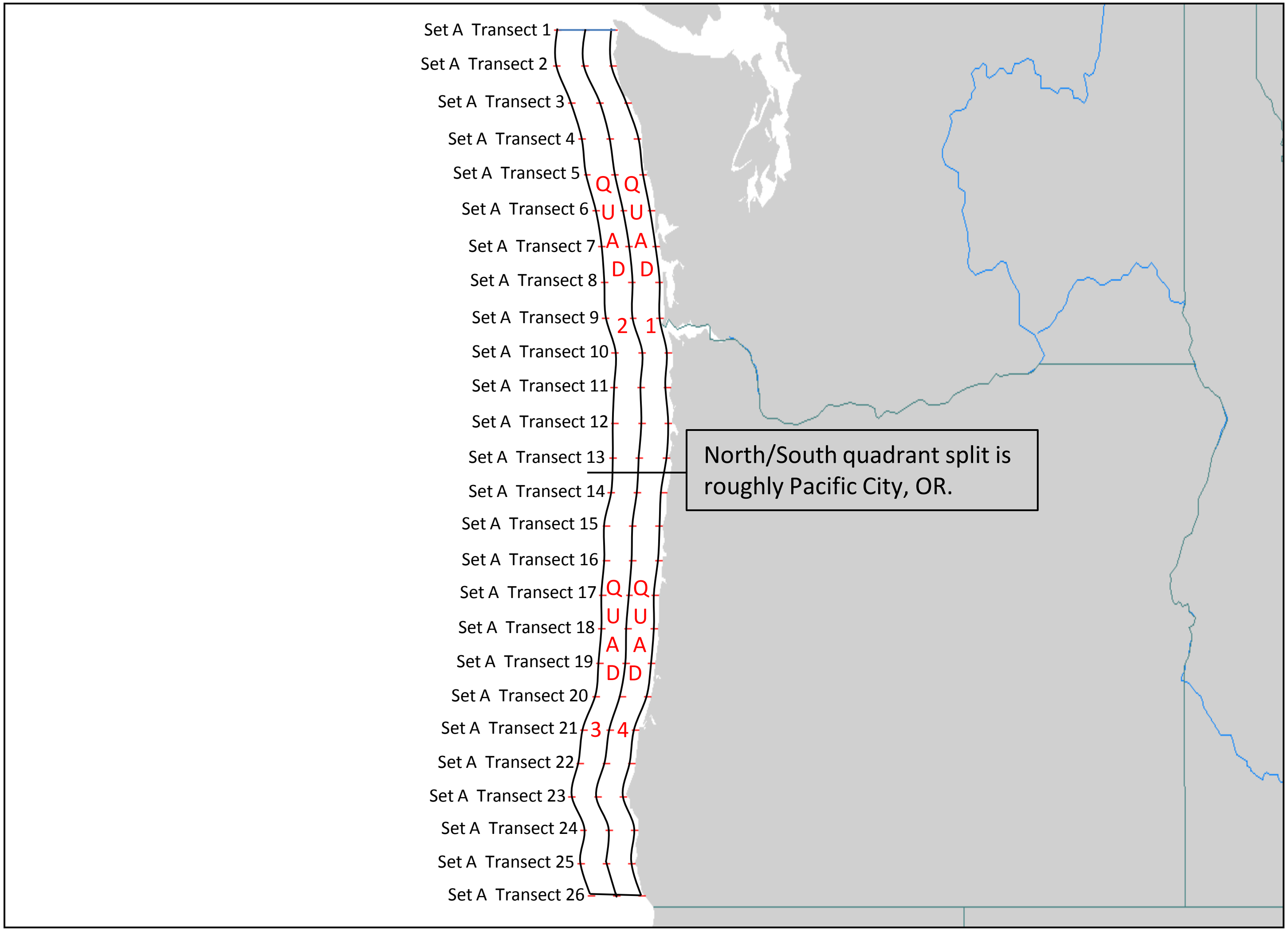


Table 1. Northern Region Point Set Quadrants – Set A

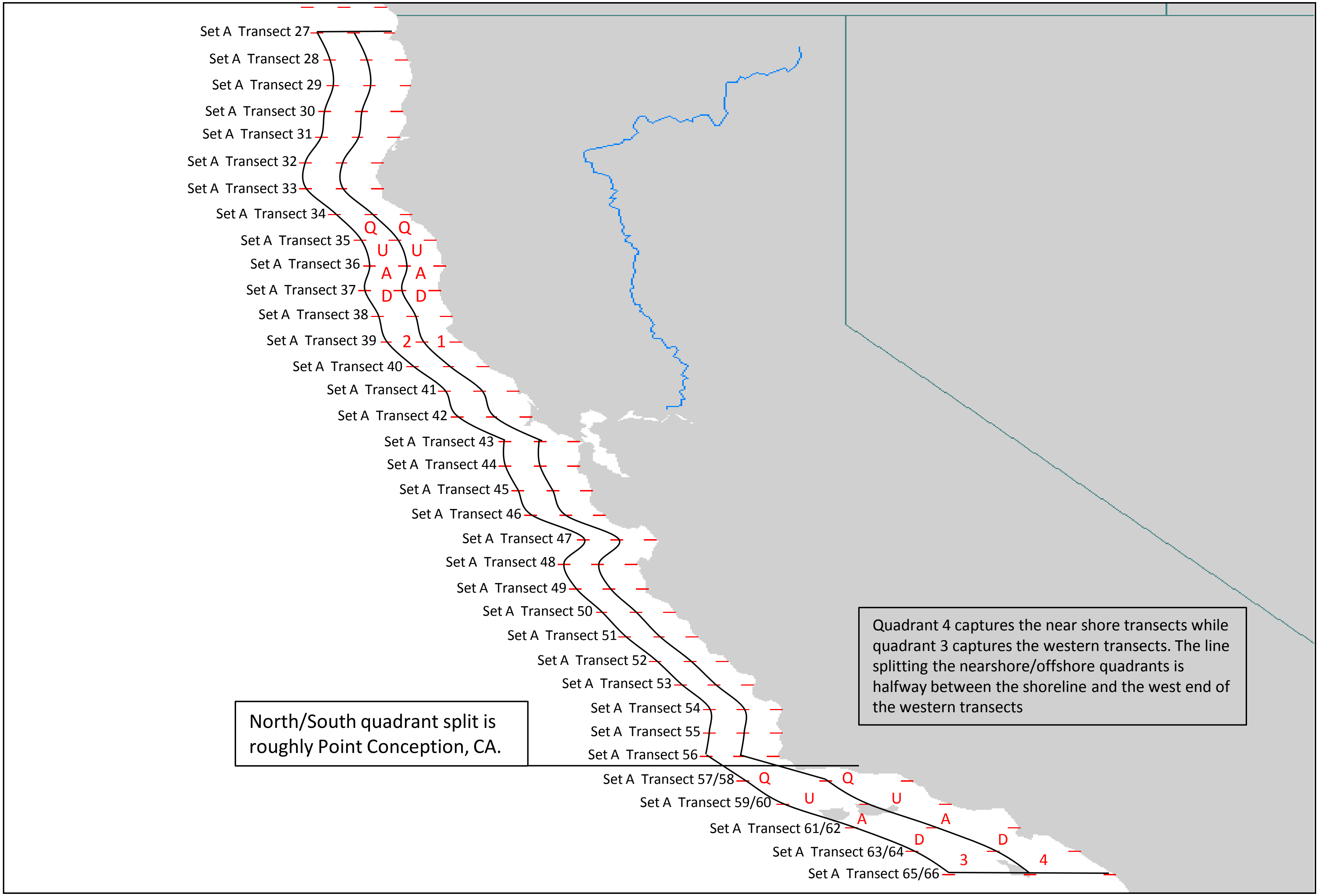


Table 2. Southern Region Point Set Quadrants – Set A

Analytical Methods

- Estimation of Biomass from Stage 1 and Stage 2 Sampling
- Estimation of Coefficient of Variation of Biomass Estimate (CV)

2010 Survey Results

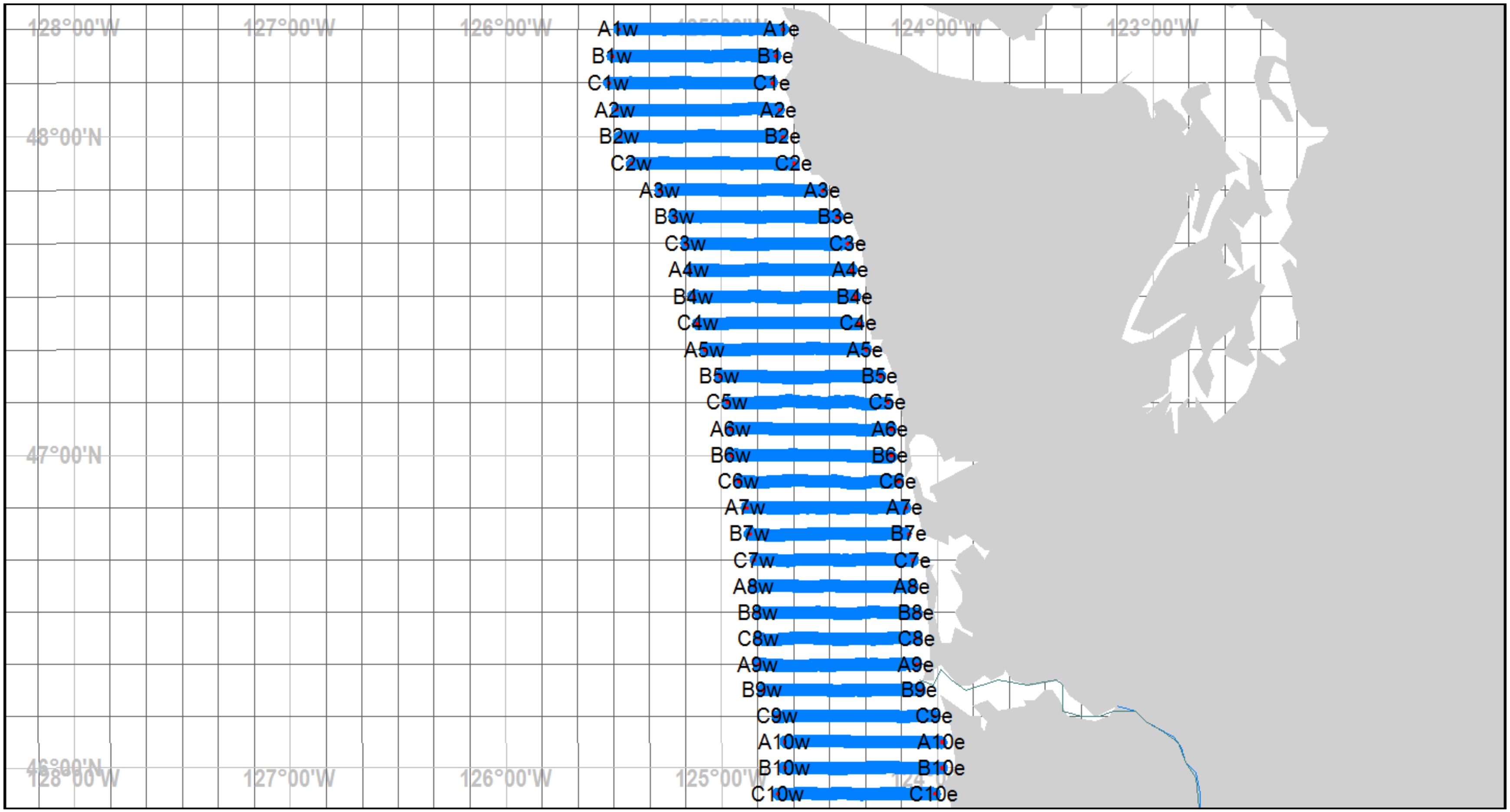
- Transects:

  Three Replicates – 182 Transects Sampled

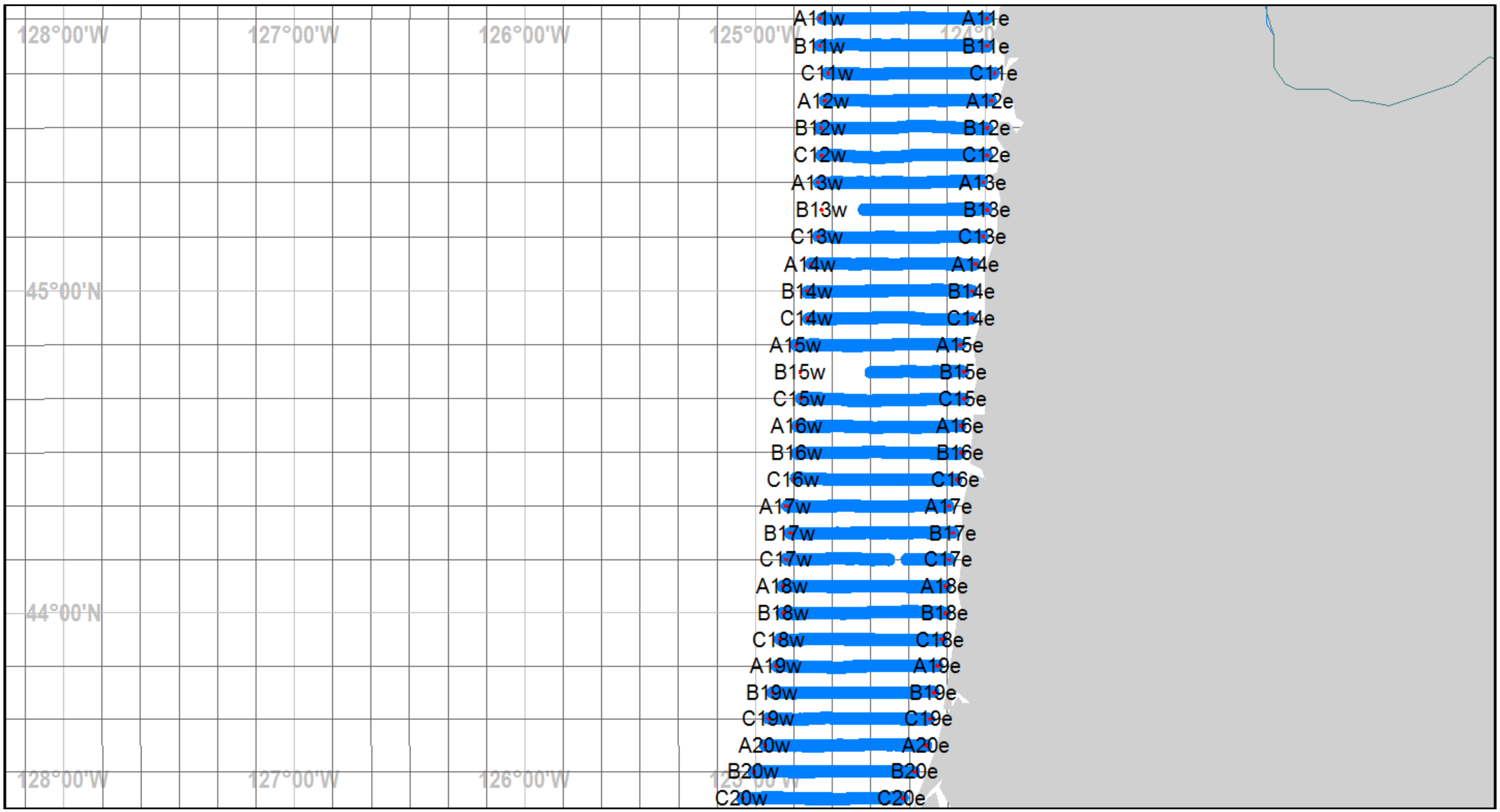
- Point Sets:

  71 Landed – 51 qualified for area-biomass analysis

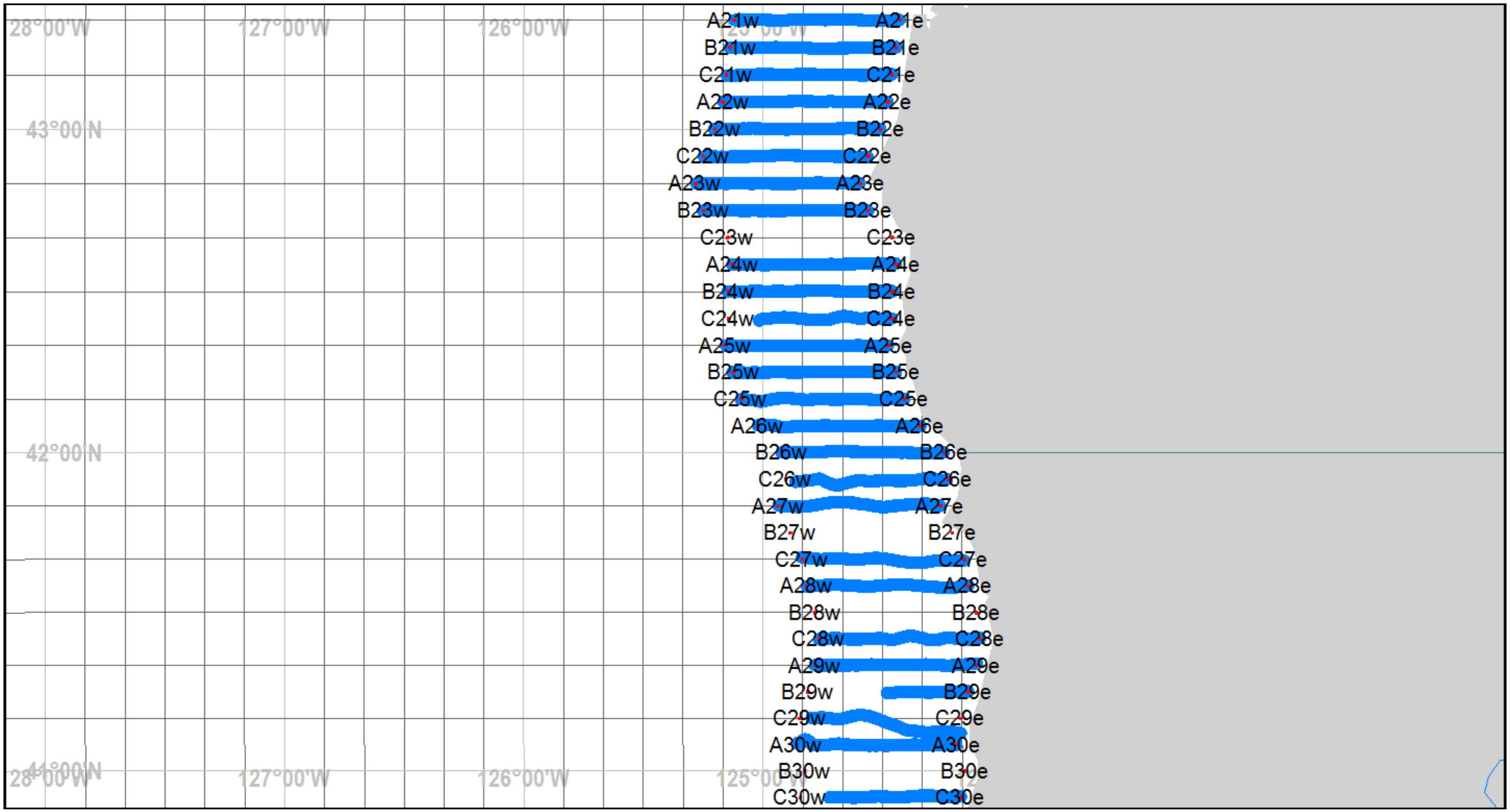
Transect SET A,B,C Transects 1-10



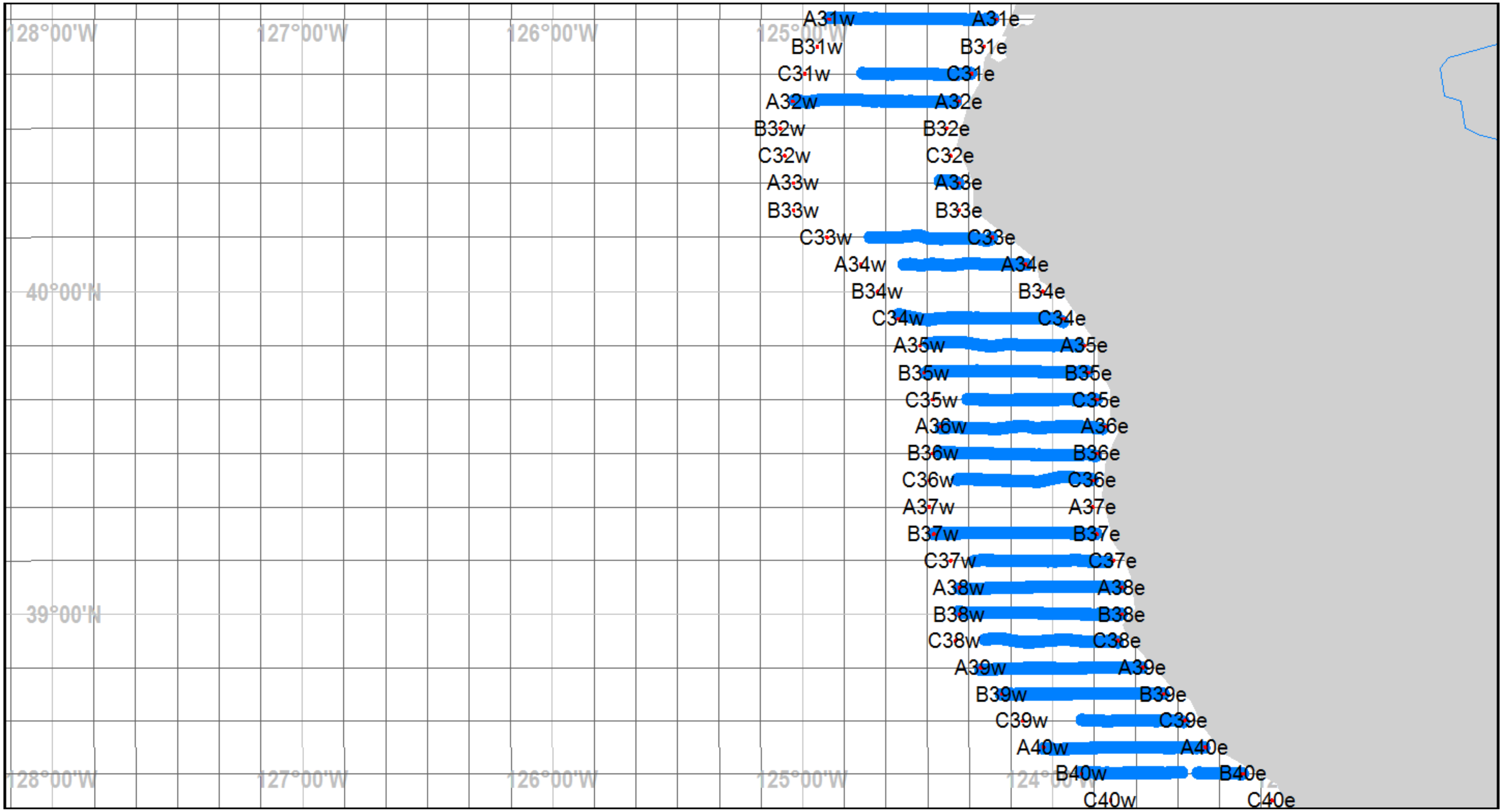
Transect SET A,B,C Transects 11-20



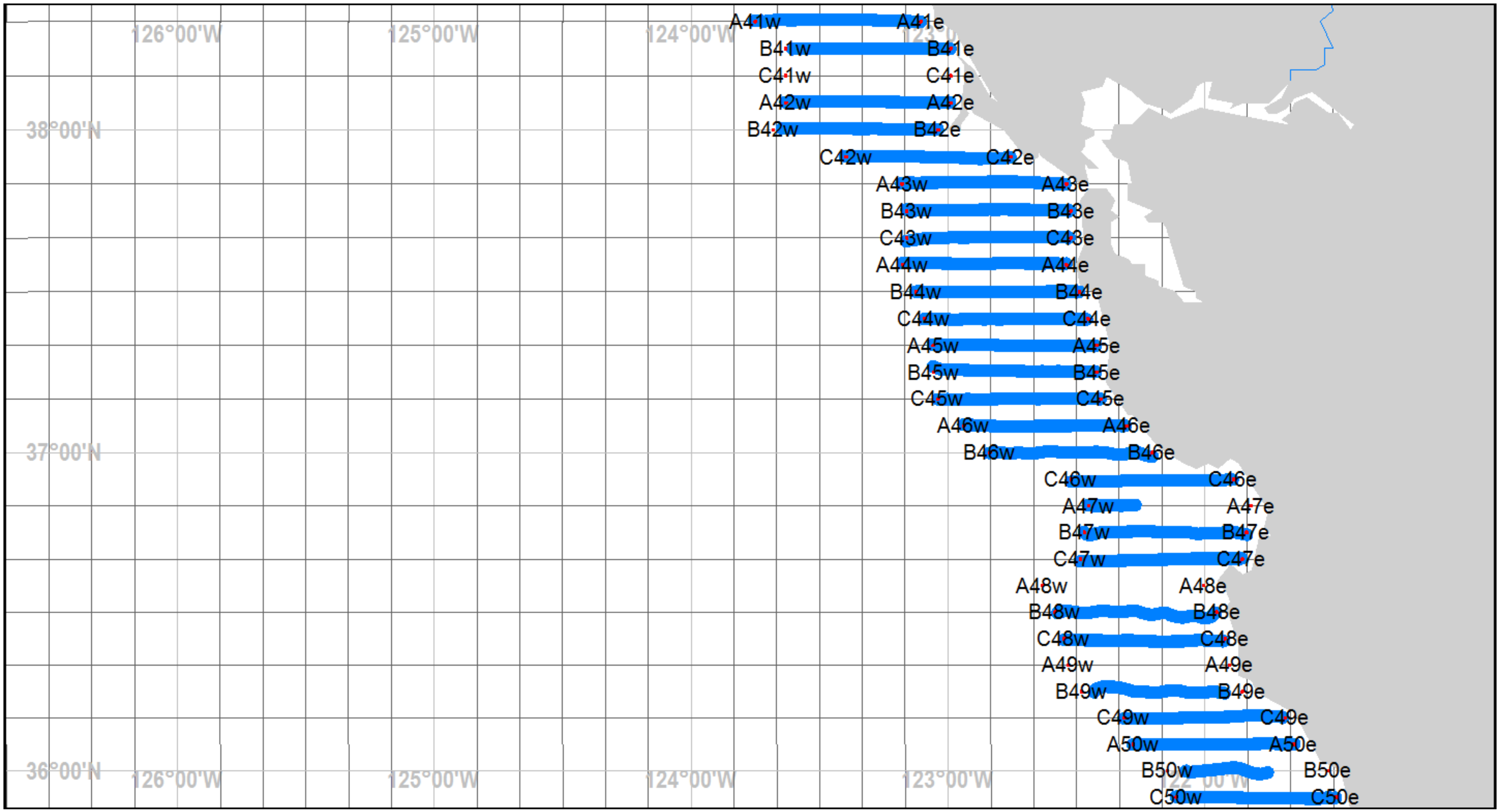
Transect SET A,B,C Transects 21-30



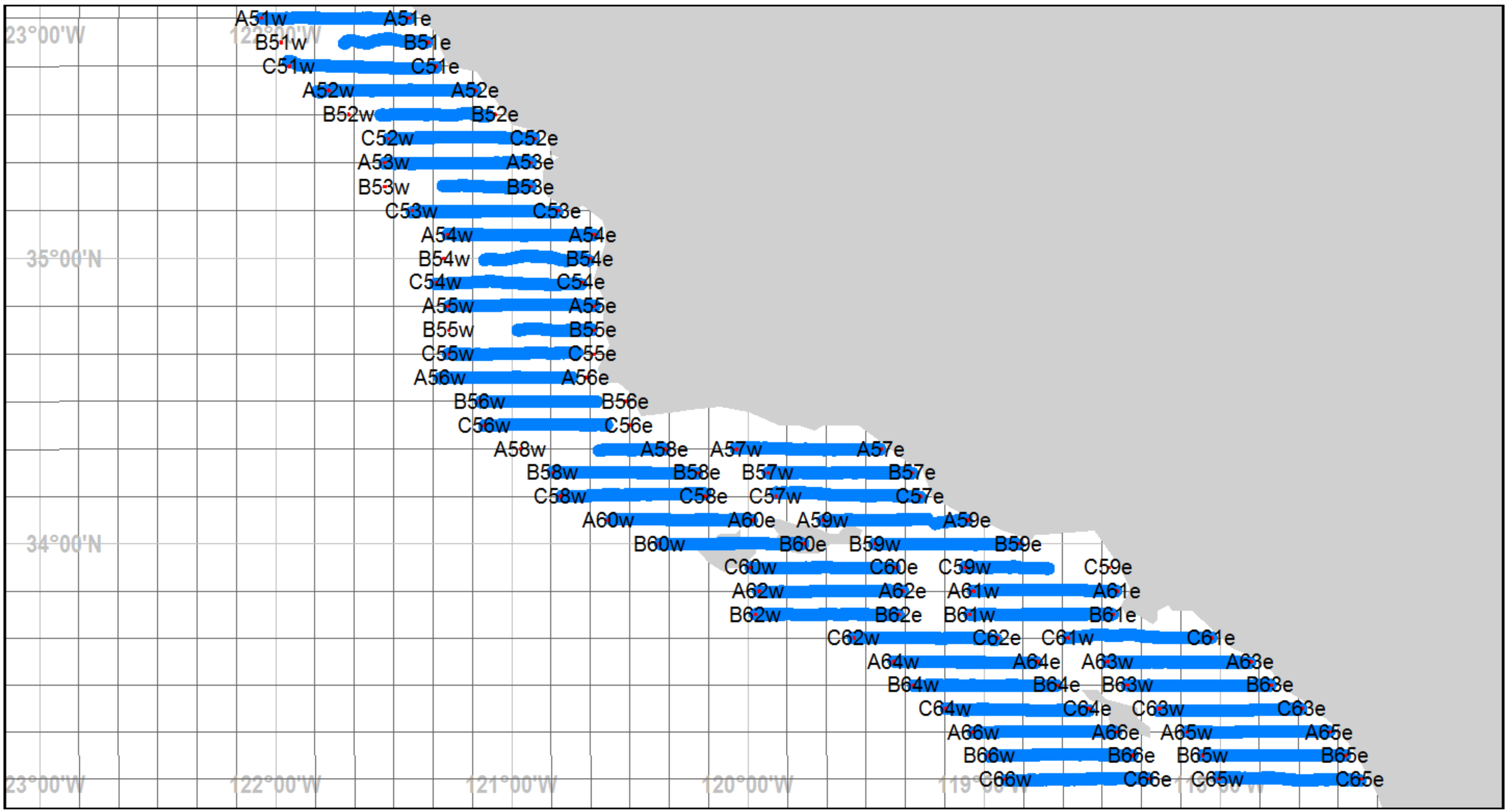
Transect SET A,B,C Transects 31-40



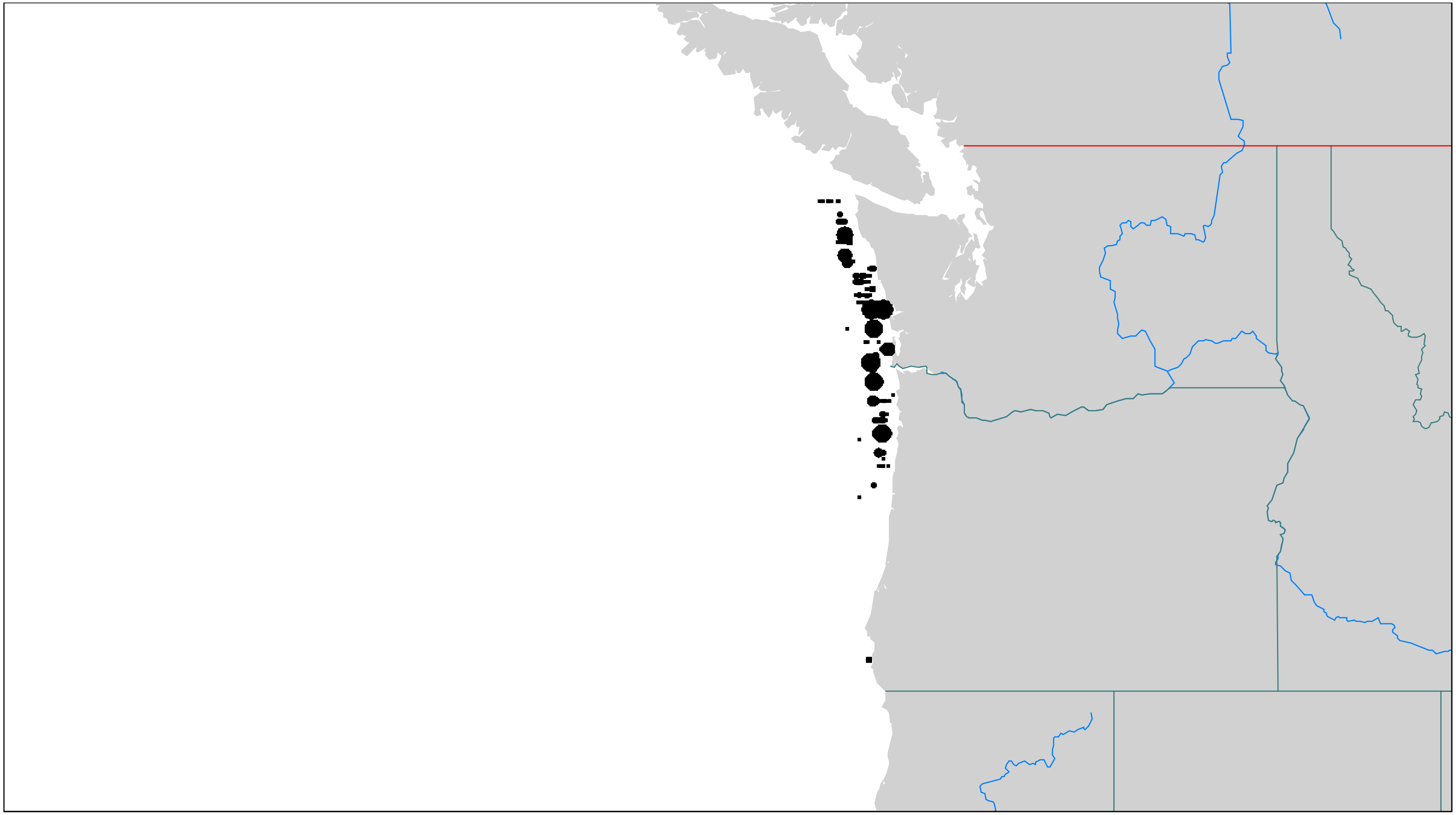
Transect SET A,B,C Transects 41-50



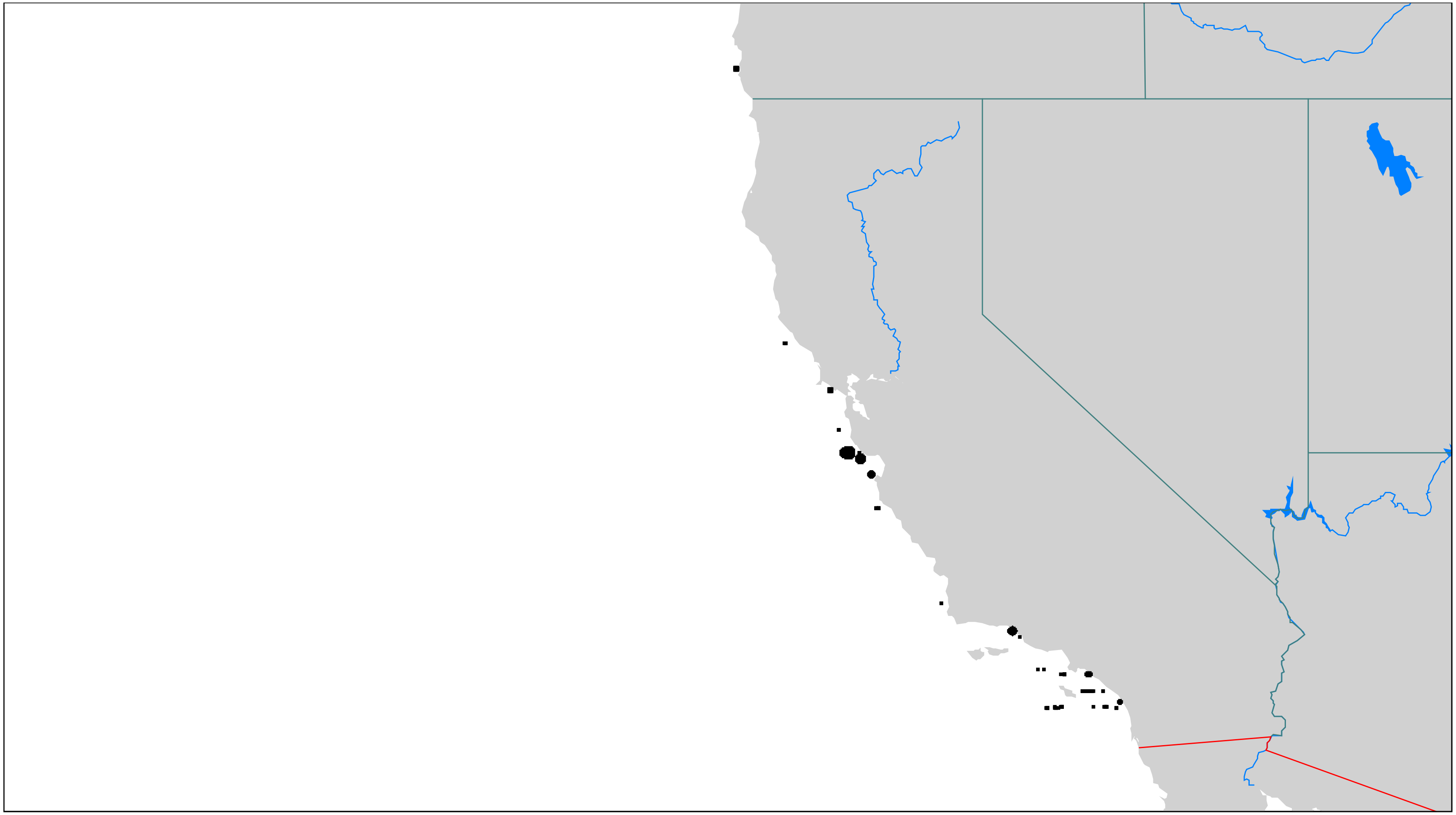
Transect SET A,B,C Transects 51-66



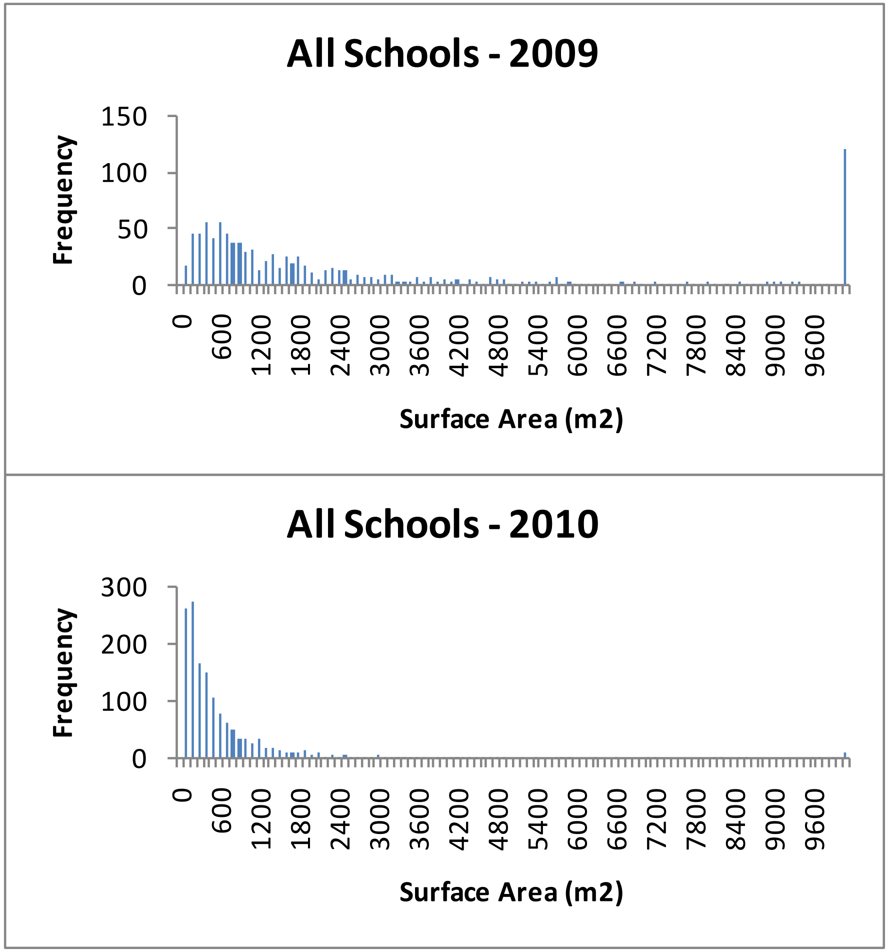
2010 School Locations - North



2010 School Locations - South



Size of Schools on Transects



Transect Summary Results

Coastwide		No. of Transects Sampled	No. of Schools	Avg. School Area (m2)	Total School Area (m2)	Total School Biomass (mt)
2009		41	1,033	9,853	10,178,228	85,371
2010	Rep A	63	642	775	497,841	12,597
	Rep B	59	230	1,198	275,467	5,719
	Rep C	60	618	572	353,198	9,633
	2010 Total	182	1,490	756	1,126,506	27,949

North		No. of Transects Sampled	No. of Schools	Avg. School Area (m2)	Total School Area (m2)	Total School Biomass (mt)
2010	Rep A	26	504	868	437,607	10,698
	Rep B	26	177	1,348	238,645	4,818
	Rep C	25	281	902	253,482	6,235
	2010 Total	77	962	966	929,734	21,752

South		No. of Transects Sampled	No. of Schools	Avg. School Area (m2)	Total School Area (m2)	Total School Biomass (mt)
2010	Rep A	37	138	436	60,234	1,899
	Rep B	33	53	695	36,822	901
	Rep C	35	337	296	99,716	3,398
	2010 Total	105	528	373	196,772	6,198

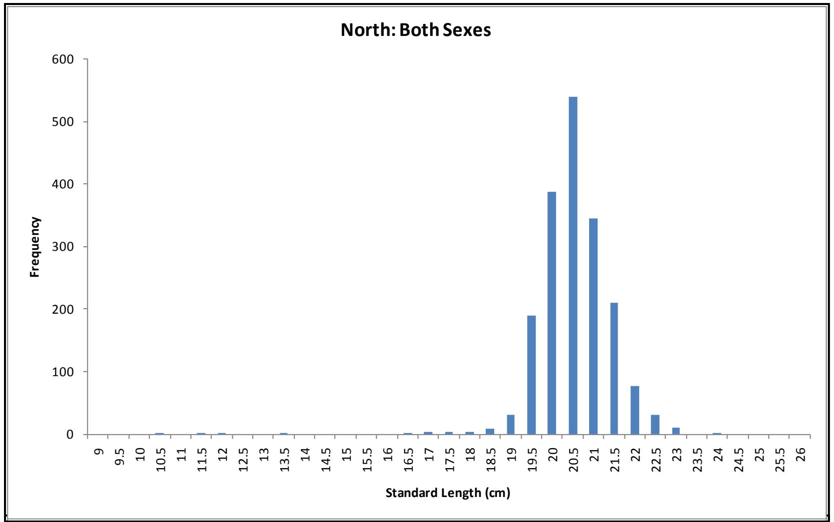
2010 Point Sets - North

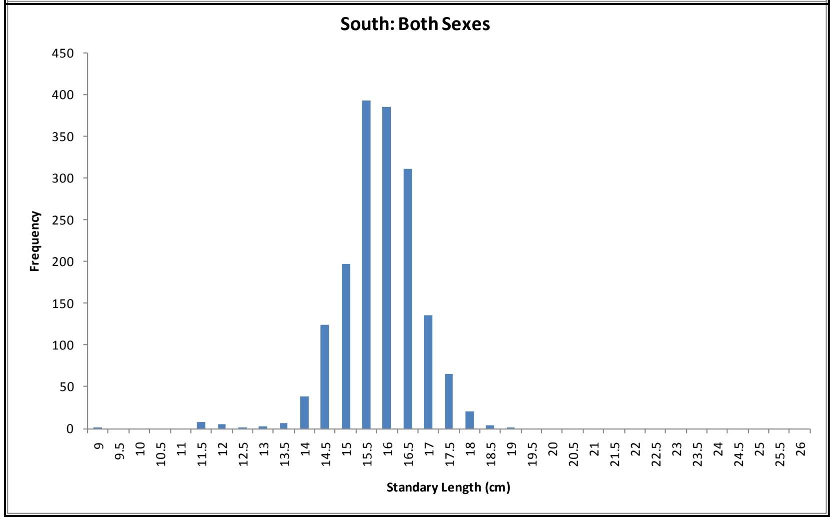
2010 Point Sets - South

Size of Point Sets Landed

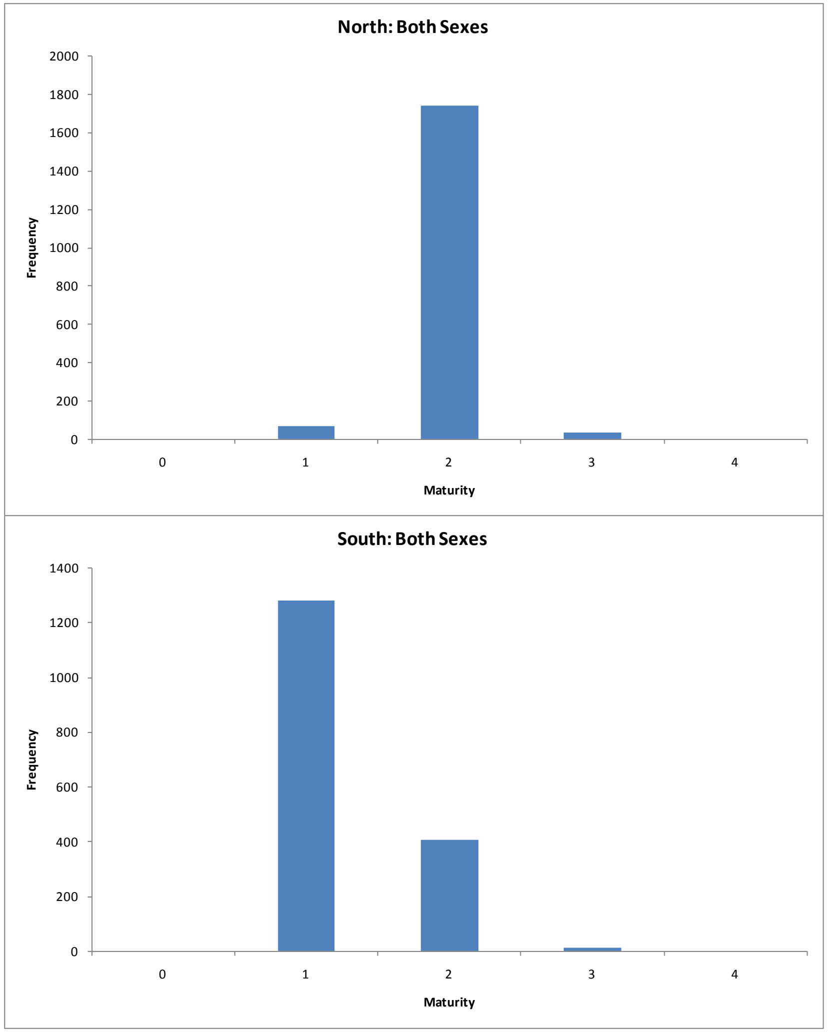
Weight (mt)	No. Planned	North	South
3.8	8	0	1
10.6	8	0	3
17.0	8	1	6
26.5	8	0	6
51.9	8	19	9
70.5	8	7	4
82.1	8	7	3
95.0	0	0	2
115.0	0	2	0
140.0	0	1	0
	56	37	34

Point Set Sampling – Length Frequency



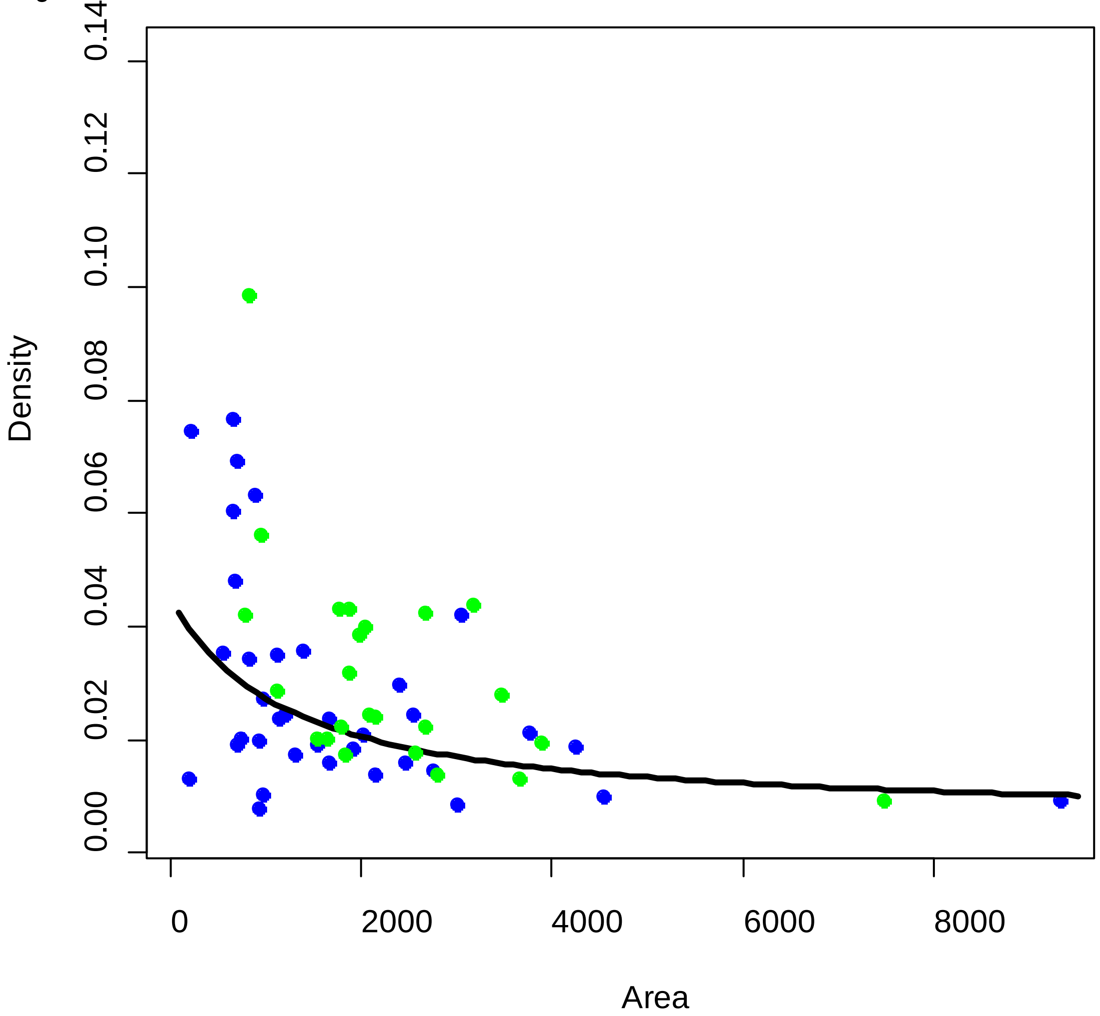


Point Set Sampling – Maturity



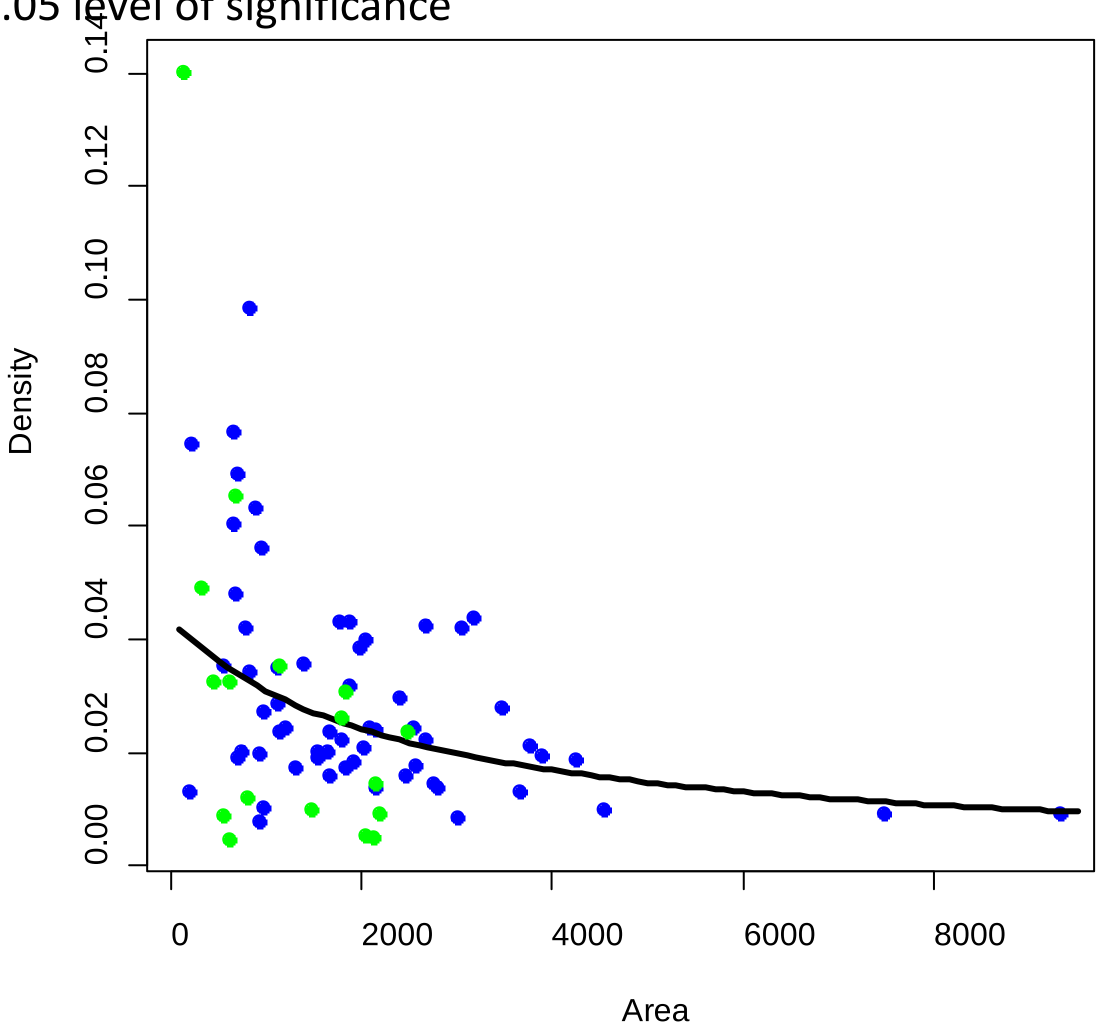
Plot of point set data – Density (mt/m^2) vs. Area (m^2):

- Data from the 2009 analysis (blue points – solid line)
- New data from the north in 2010 (green points – dashed line)
- Likelihood ratio test P = 0.189
- Fail to reject H_0 at 0.05 level of significance



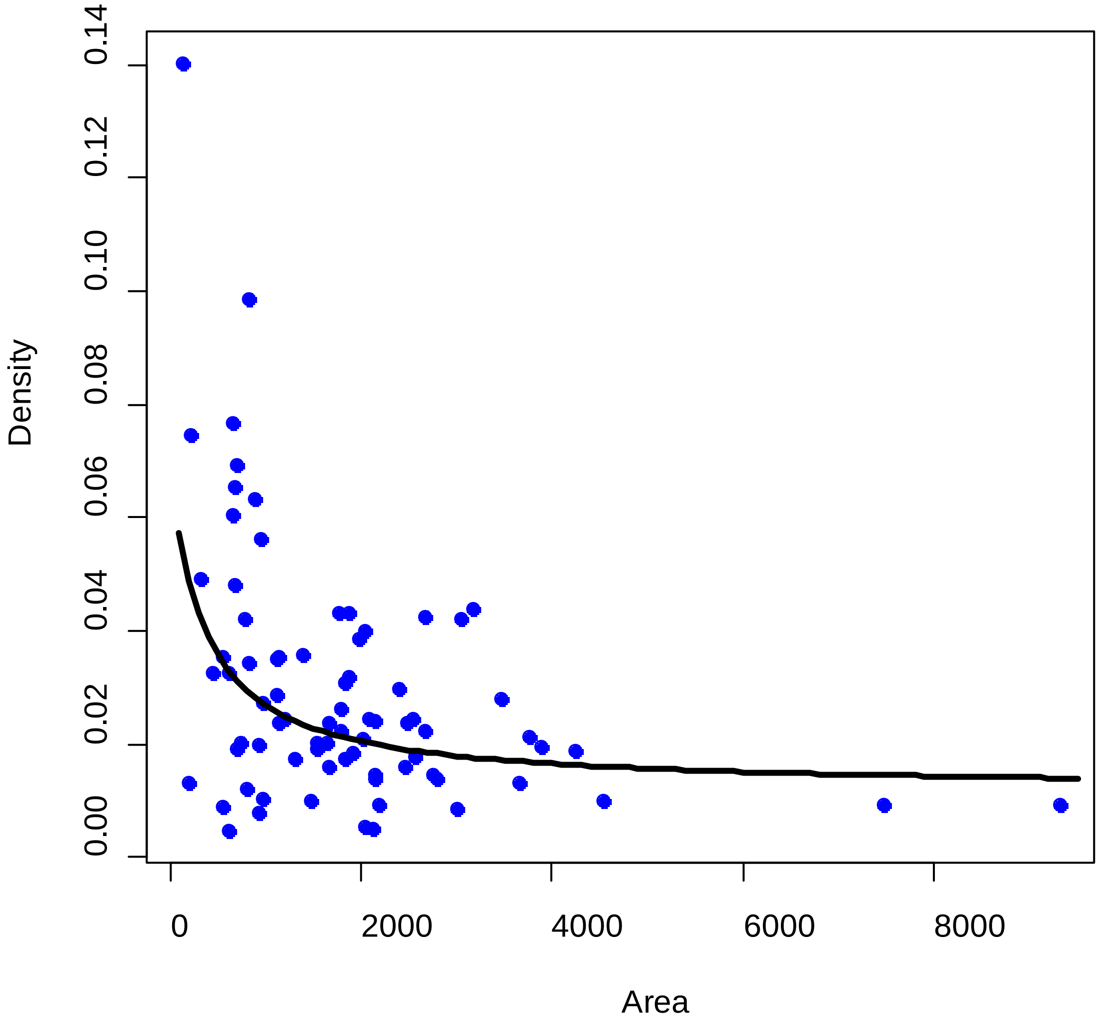
Plot of point set data – Density (mt/m^2) vs. Area (m^2):

- All years pooled from the north (blue points – solid line)
- New data from the south in 2010 (green points – dashed line)
- Likelihood ratio test P = 0.029
- Reject H_0 at 0.05 level of significance



Plot of point set data – Density (mt/m^2) vs. Area (m^2):

- All years and regions pooled



Biomass Estimates

Region	Point Set Data File	Biomass Estimate (mt)		CV	Area-Biomass Calibration Parameters		
					asymp	yint	cc
Runs conducted at the STAR panel meeting 10-5-2010							
North	cdata2010n	Total	173,390	0.42	0.0057	0.2020	257.5
		Rep A	263,331				
		Rep B	100,626				
		Rep C	156,214				
South	cdata2010s	Total	27,695	0.56	0.0061	0.1392	100.0 (bound)
		Rep A	21,511				
		Rep B	10,767				
		Rep C	50,806				

Estimation of School Density

Michaelis-Menten model with log-normal error

= (yint * cc + asymp *) / (cc +)

where

= school density (mt/m^2)
= school area (m^2)
yint = y intercept
asymp = asymptote as x -> infinity
asymp/cc = slope at the origin .

Estimation of Total Biomass

Where:
= school biomass (mt)
= school density (mt/m^2)
= school area (m^2)

Where:
= mean sampled biomass for the study area
= sum of school biomass on a transect
= number of transects sampled

Where:
= total biomass for the study area
N = total number of transects possible

Bootstrapping Procedure to Estimate CV

1) The MM model was fit to the point set data.
2) A variance-covariance matrix was derived for the MM model fit to the data, using the R library “MSBVAR” .
3) A matrix of simulated MM parameters was derived from the MSBVAR output, using the R function “rmultnorm”.
4) For n = 100,000 bootstraps:
   a. One realization of the MM parameters was selected from the matrix of simulated parameters.
   b. The predicted MM curve was calculated.
   c. Total biomass for the study area was estimated for each of the three replicate transect sets.
   d. One of the three replicate estimates of total biomass was selected at random and stored.
5) The standard error (SE) was calculated from the stored bootstrap estimates of biomass (4d).
6) CV was calculated as CV = SE/ .

Figure 4. NWSS point sets conducted during the Aerial Sardine Survey in 2010.

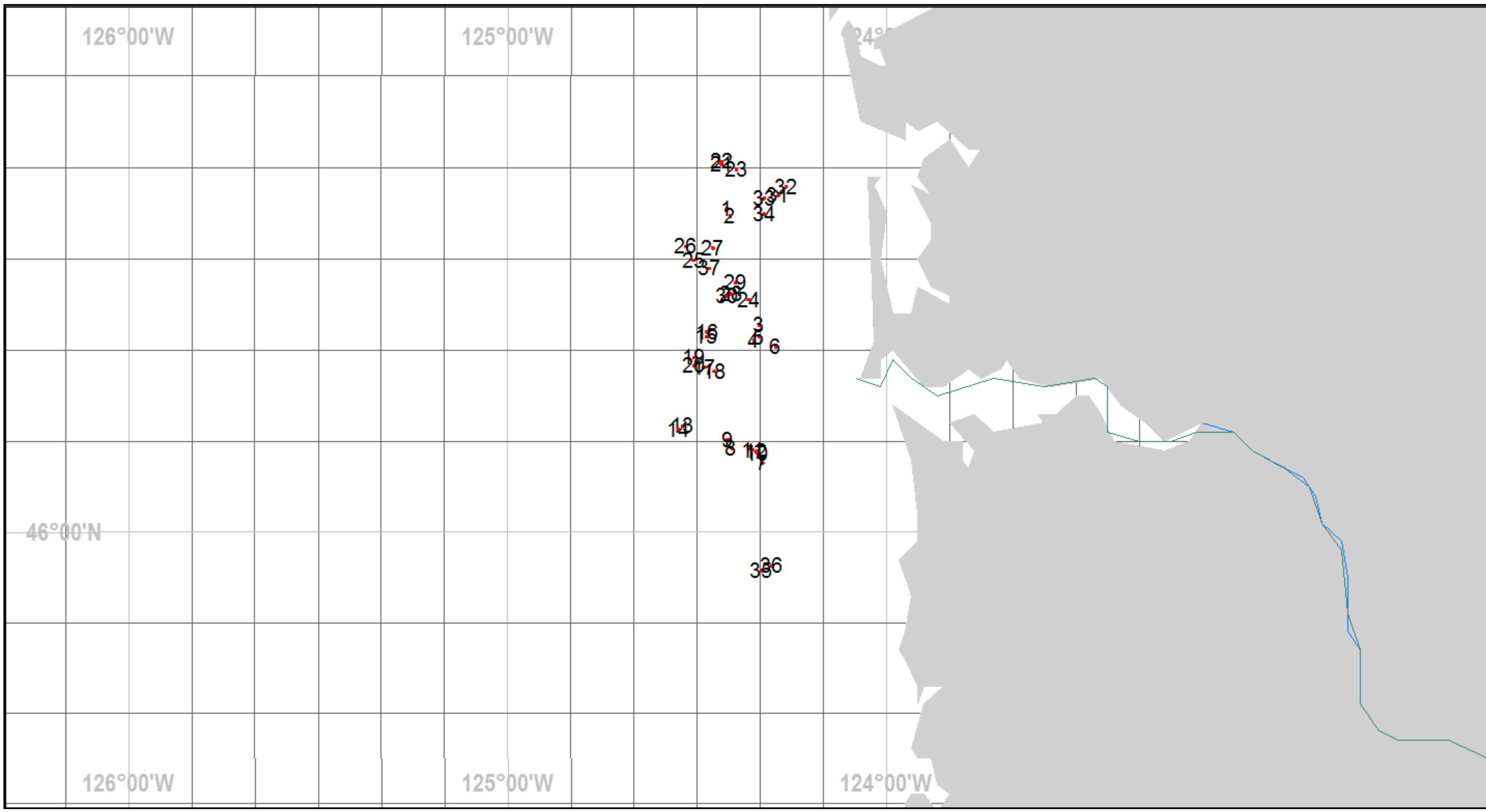
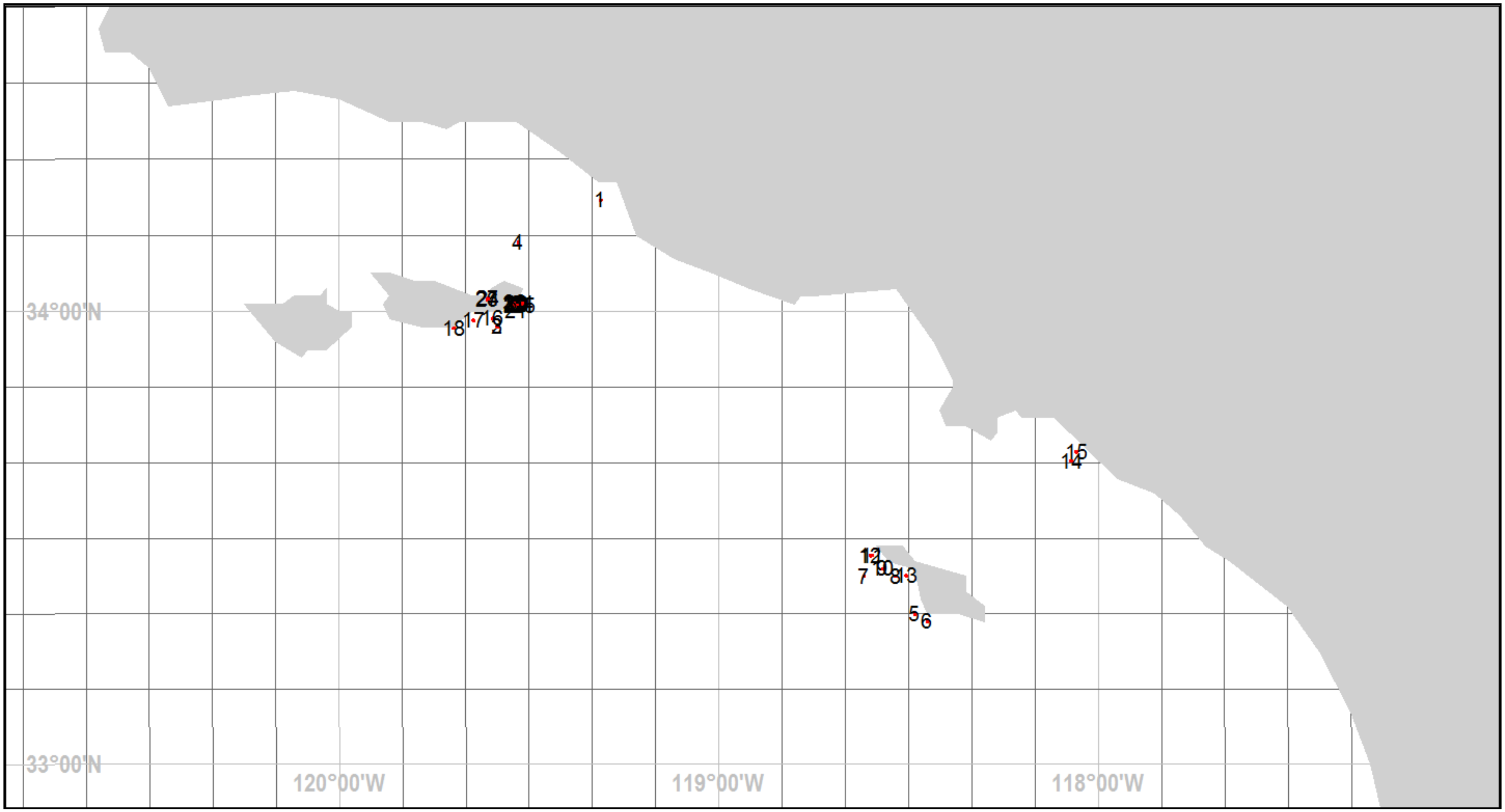


Figure 5. CWPA point sets conducted during the Aerial Sardine Survey in 2010.



Point Set Data - Likelihood Ratio Tests

Comparision of data from the north used in the 2009 analysis with the new 2010 data from the north:

Model Data	Data File Name	Model Name	Log Likelihood	df
(north 2008;2009 pooled)	cdata	mmfit	-28.26	33
(north 2010)	cdata2010n	mmfita	-11.46	21
(north 2008;2009;2010 pooled)	cdata2010np	mmfitb	-44.50	57
		LLcombined	-44.50	57
		LLseparate	-39.73	54

(LLseparate - LLcombined) =	4.76996845	
Chi Sq (df=3) P =	0.189	->Fail to reject H_o at 0.05 significance level.

Comparision of all data from the north (pooled) with the new 2010 data from the south:

Model Data	Data File Name	Model Name	Log Likelihood	df
(north 2008;2009;2010 pooled)	cdata2010np	mmfitb	-44.50	57
(south 2010)	cdata2010s	mmfitc	-19.75	14
(all data pooled)	cdata2010nsp	mmfitd	-73.28	74
		LLcombined	-73.28	74
		LLseparate	-64.24	71

(LLseparate - LLcombined) =	9.03413383	
Chi Sq (df=3) P =	0.029	->Reject H_o at 0.05 significance level.

Region	Point Set Data File	Biomass Estimate (mt)		CV	Area-Biomass Calibration Parameters		
					asymp	yint	cc
Coastwide	cdata2010nsp	Total	138,379	0.30	0.0119	0.0707	338.0
		Rep A	176,561				
		Rep B	86,850				
		Rep C	151,726				
North (asymp = 0.001)	cdata2010np	Total	105,738	0.44	0.001 (bound)	0.0435	2375.5
		Rep A	157,749				
		Rep B	62,314				
		Rep C	97,150				
North (asymp = 0.005)	cdata2010np	Total	108,851	0.40	0.005 (bound)	0.0464	1649.4
		Rep A	161,448				
		Rep B	66,656				
		Rep C	98,450				
South	cdata2010s	Total	27,695	0.72	0.0061	0.1392	100.0 (bound)
		Rep A	21,511				
		Rep B	10,767				
		Rep C	50,806				
2009 (asymp = 0.001)	cdata2010np		794,159	2.08	0.001 (bound)	0.0435	2375.5
2009 (asymp = 0.005)	cdata2010np		1,247,250	1.12	0.005 (bound)	0.0464	1649.4
2009	cdata2010nsp		2,000,618	0.66	0.0119	0.0707	338.0
2009	cdata (2009)		1,236,911	1.12	0.0057	0.0455	1187.5

Agenda Item I.2.b
Supplemental NMFS SWFSC PowerPoint (Hill)
November 2010

ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2010 FOR U.S. MANAGEMENT IN 2011

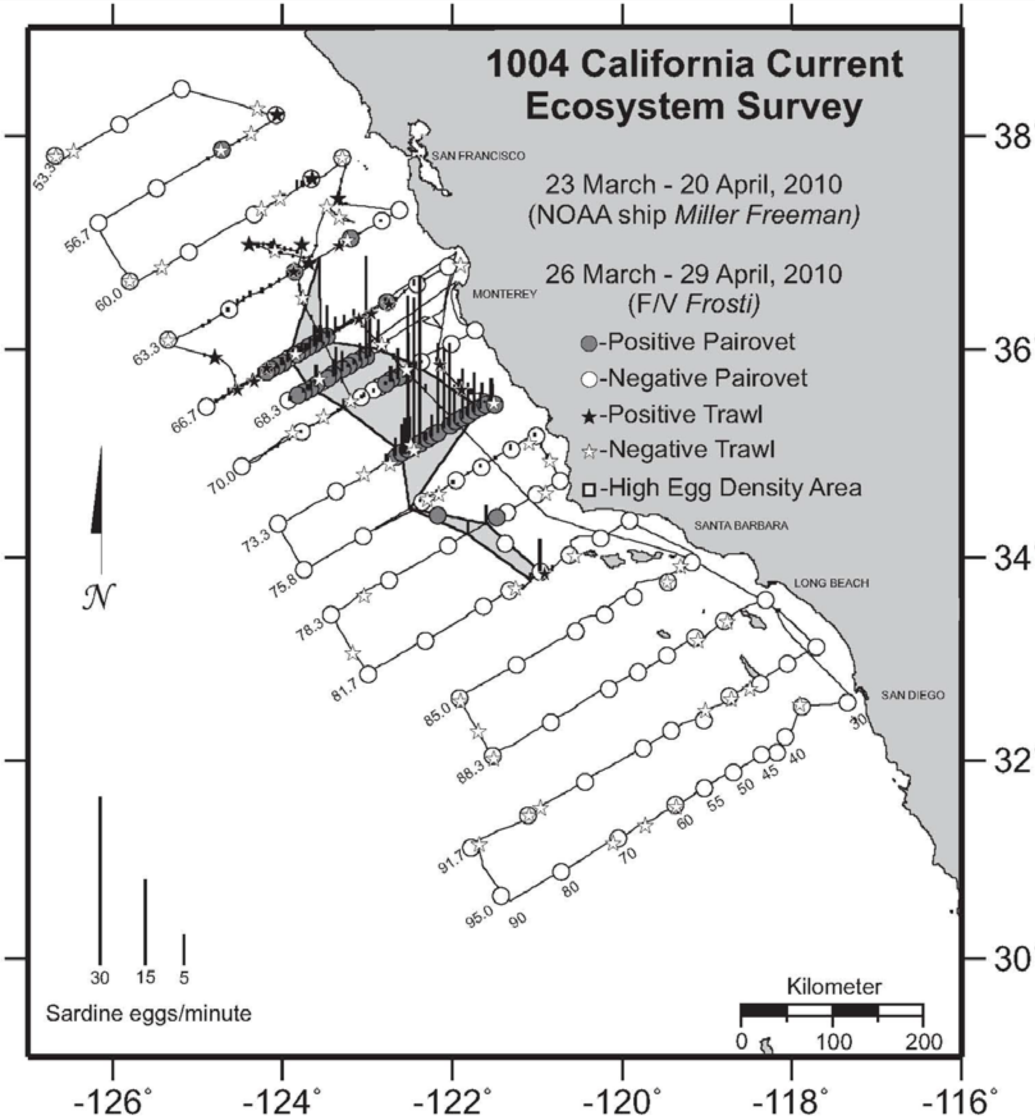
Kevin T. Hill, Nancy C. H. Lo, Beverly J. Macewicz, Paul R. Crone (SWFSC), and Roberto Felix-Uraga (CICIMAR-IPN)

Updated Data Sources

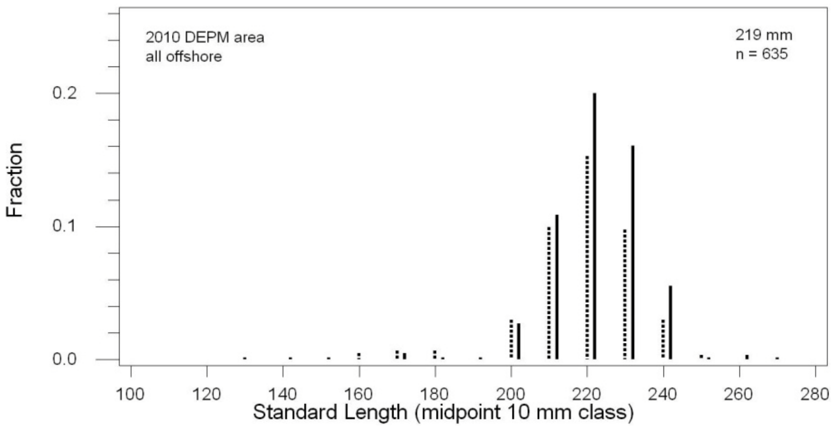
- Fishery Data:
  - Ensenada (ENS):
    - Catch 2008 & 2009
  - Southern California (SCA) & Central California (CCA):
    - Catch 2009 & 2010; Samples July-09 to June-10
  - Pacific Northwest (PNW):
    - Catch and samples 2009

- Fishery-Independent Data:
  - SWFSC's DEPM survey - Spring 2010;
  - West Coast Sardine Aerial Survey:
    - Revised estimate & CV from 2009
    - New survey in Summer 2010

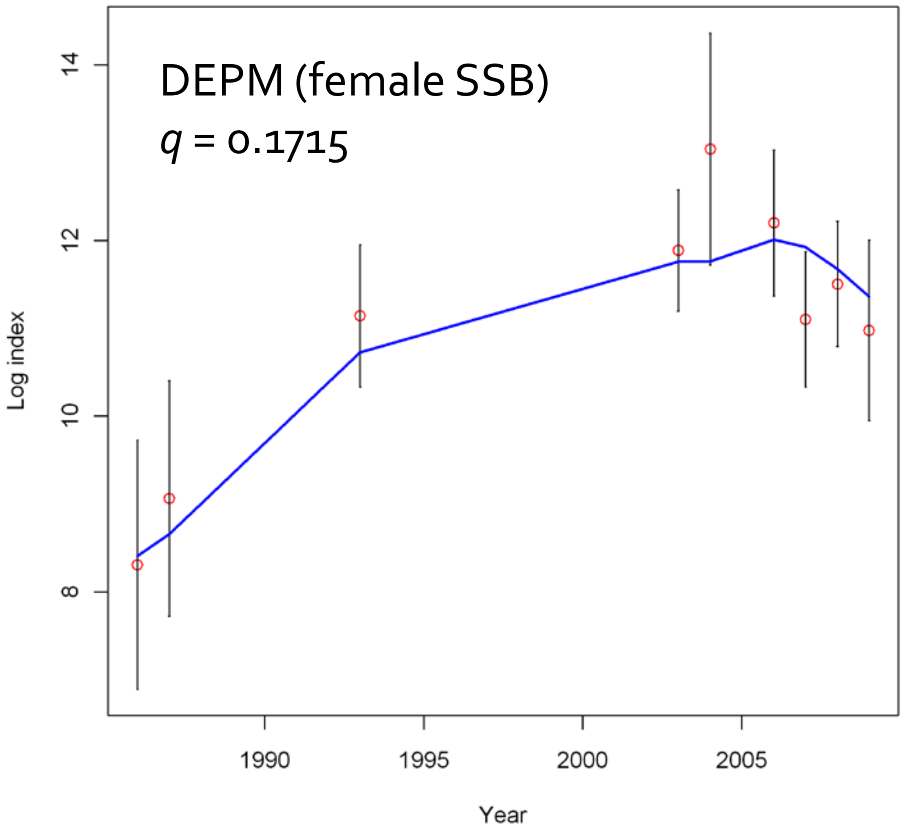
Standard DEPM Area – Spring 2010

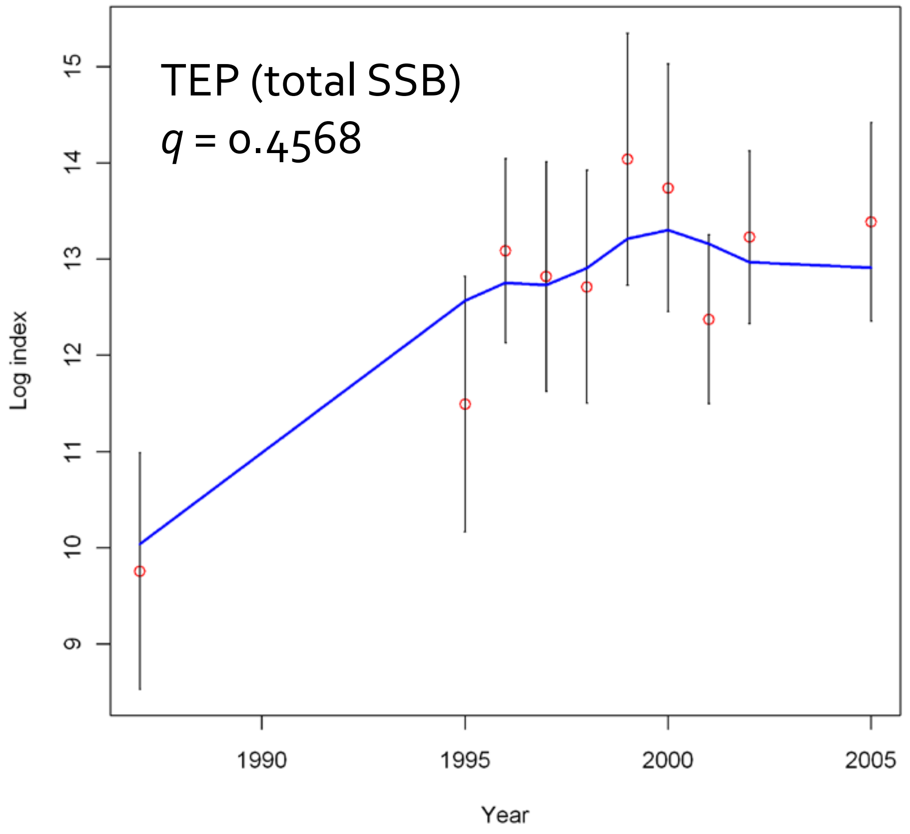


- Low egg density (P_o);
- Fraction of spawning females was 10% (≤avg);
- Females slightly larger;
- SSB_{total} = 105,220 mt;
- SSB_{female} = 58,447 mt (0.42);
- Lowest DEPM biomass estimate since mid-1990s



Model '10w' Fit to DEPM & TEP Series





Aerial Sardine Survey – Summer 2010

(Jagielo et al. 2010)

Figure 11. Maps showing the locations of sardine schools observed on transects in 2010. Top (north); bottom (south).

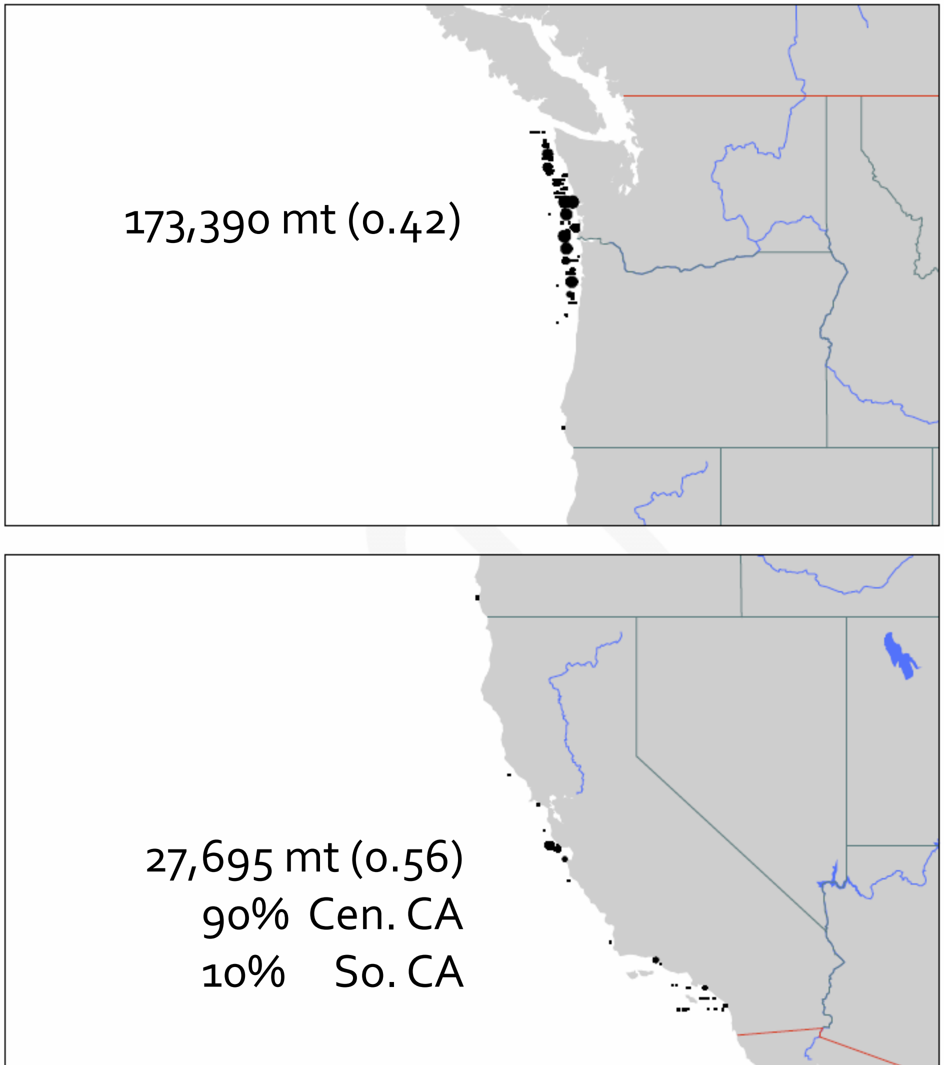
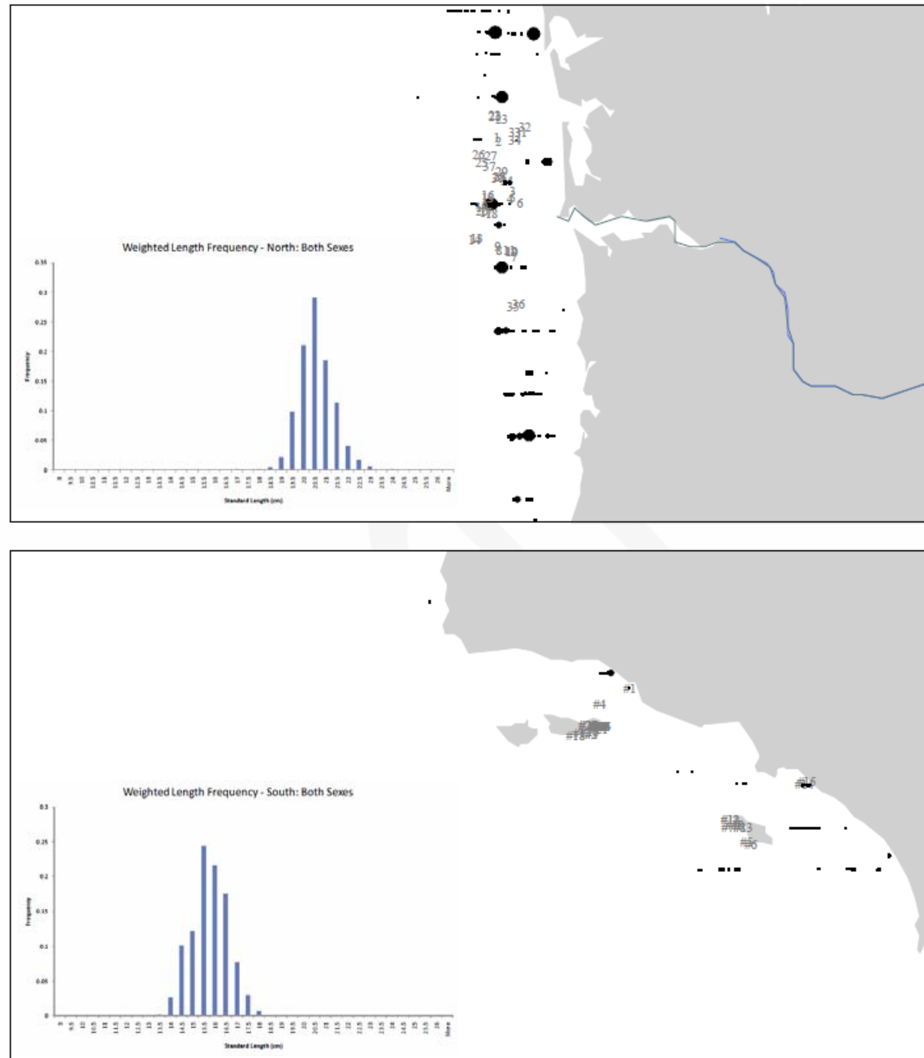
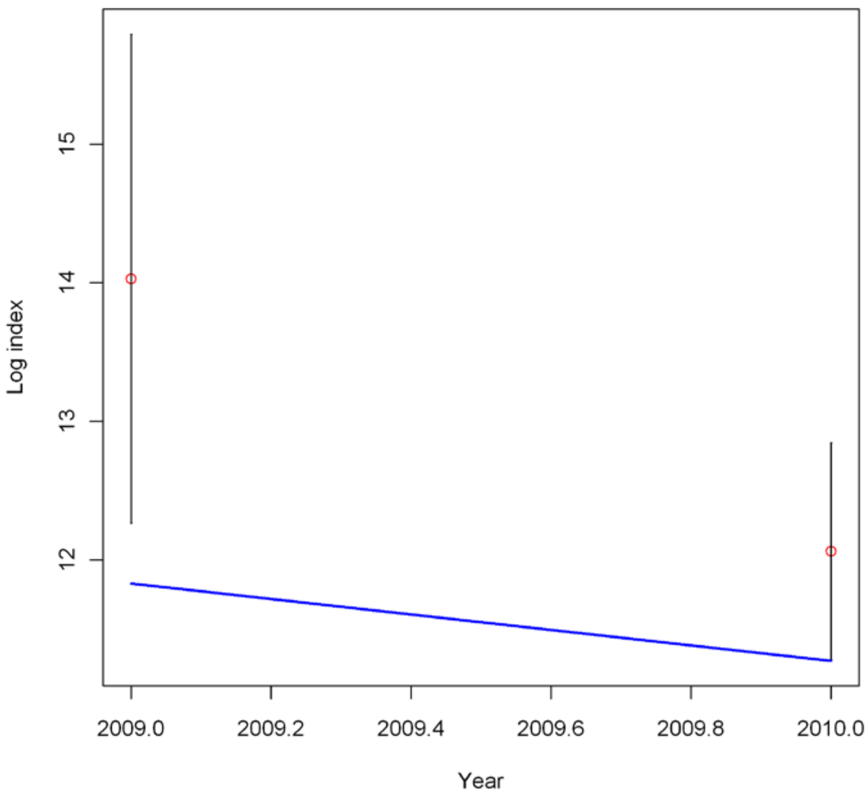


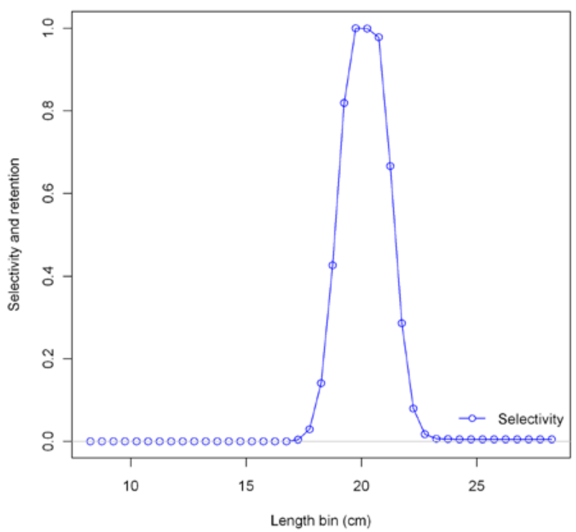
Figure 12. Locations of point sets (identified by number) with repect to sardine school locations observed on transects in 2010. Top (north); bottom (south).



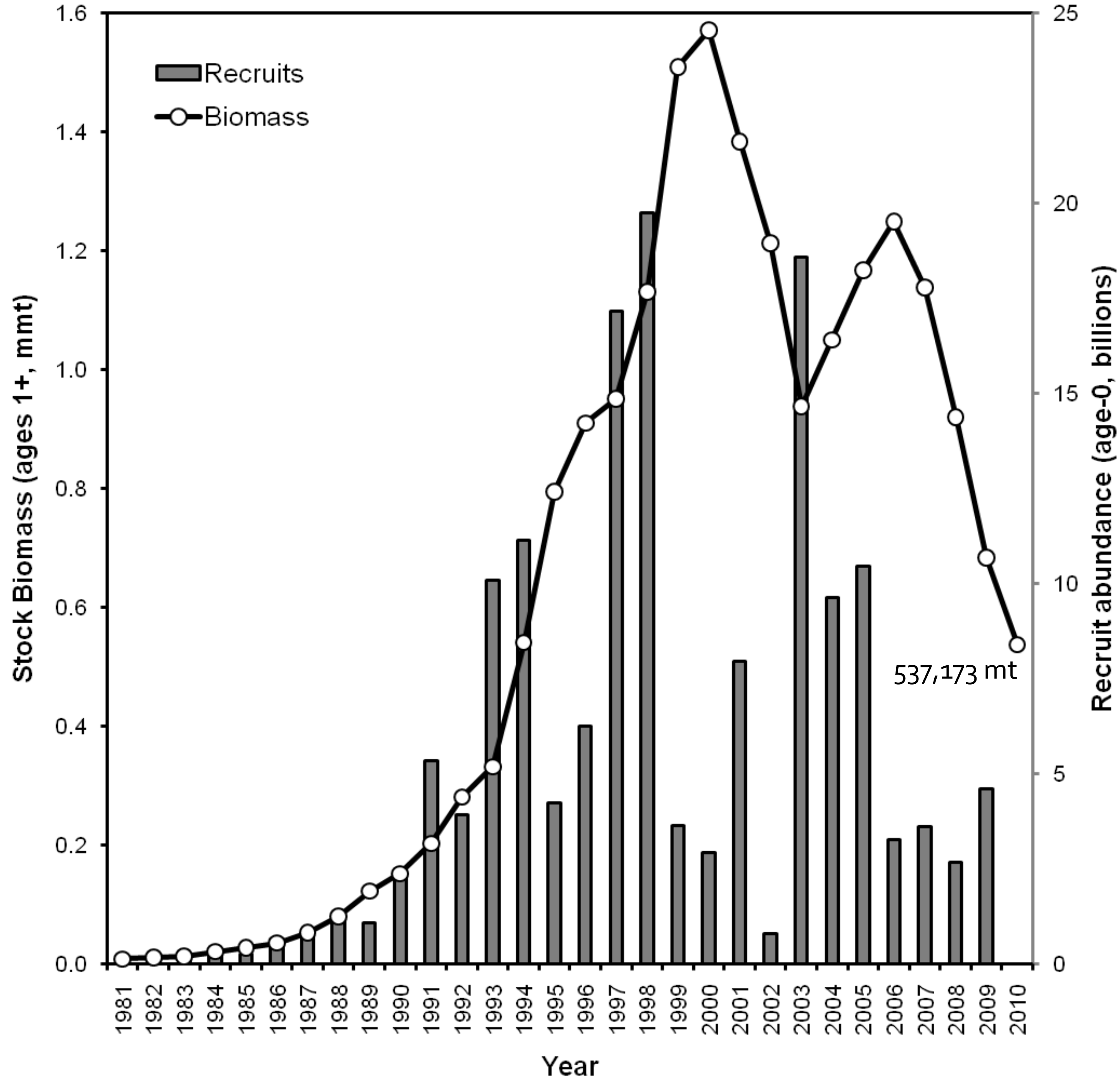
Model '10w' Fit to Sardine Aerial Survey



- Catchability fixed, q=1;
- SS model tuned prior to inclusion of aerial biomass estimates;
- Length comp fit with double-normal selectivity, domed shape;
- Selectivity assumption not explored during STAR, but is inconsistent with PNW fishery selectivity which is fit with asymptotic shape.

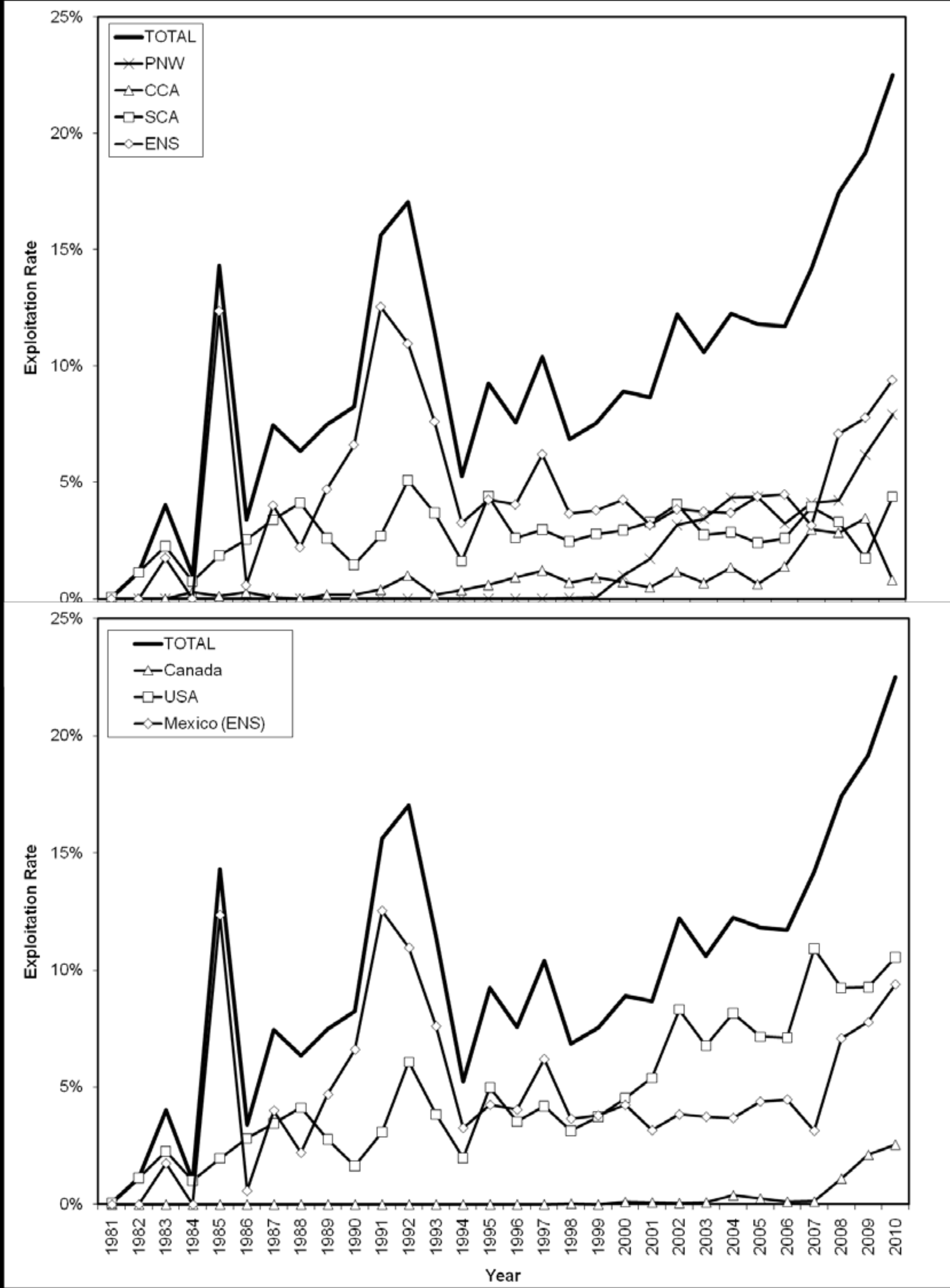


Stock Biomass (Ages 1+) and Recruits Model '10w'

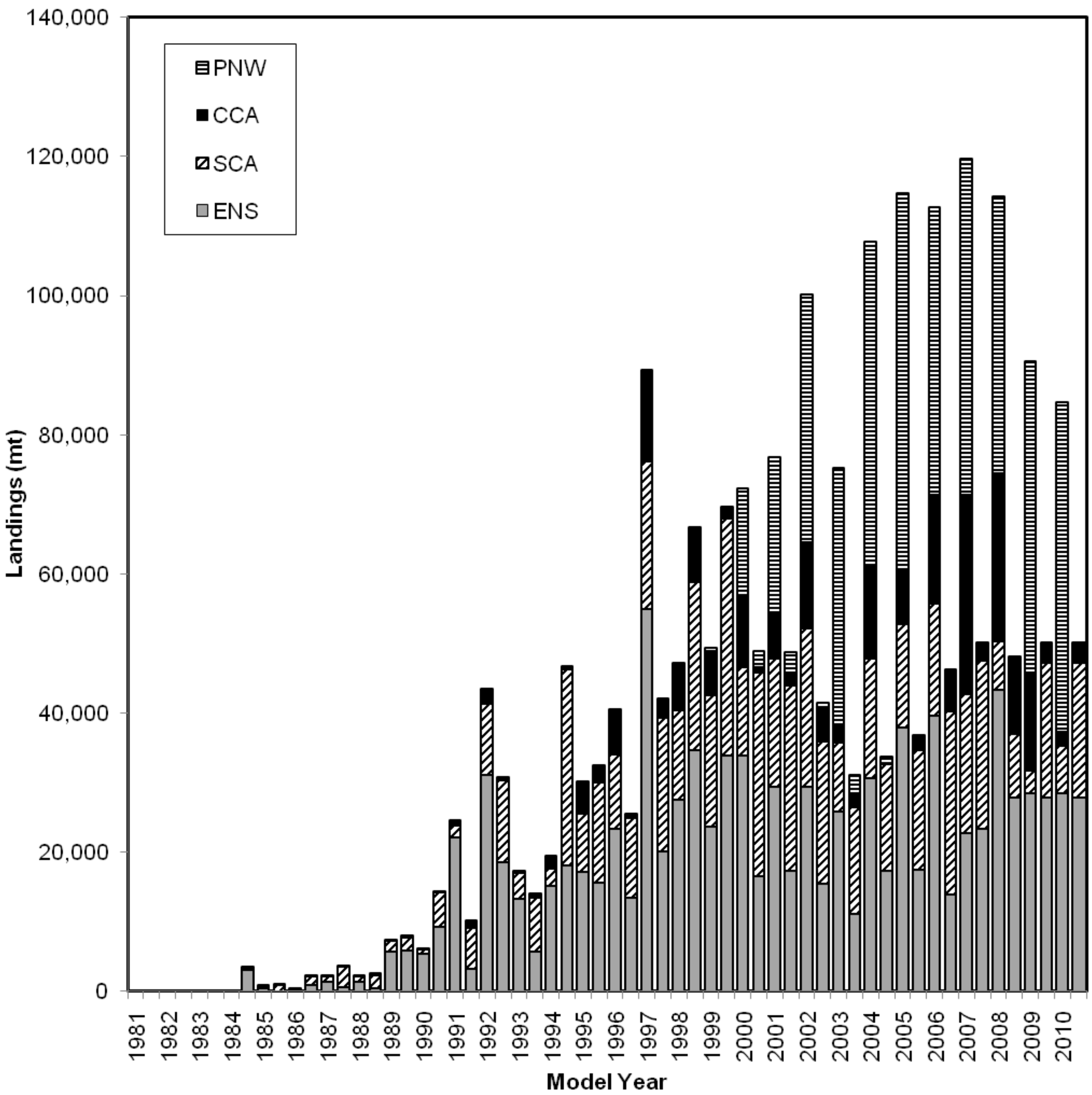


Exploitation Rate by Fishery and Country

(calendar year catch/total mid-year biomass)

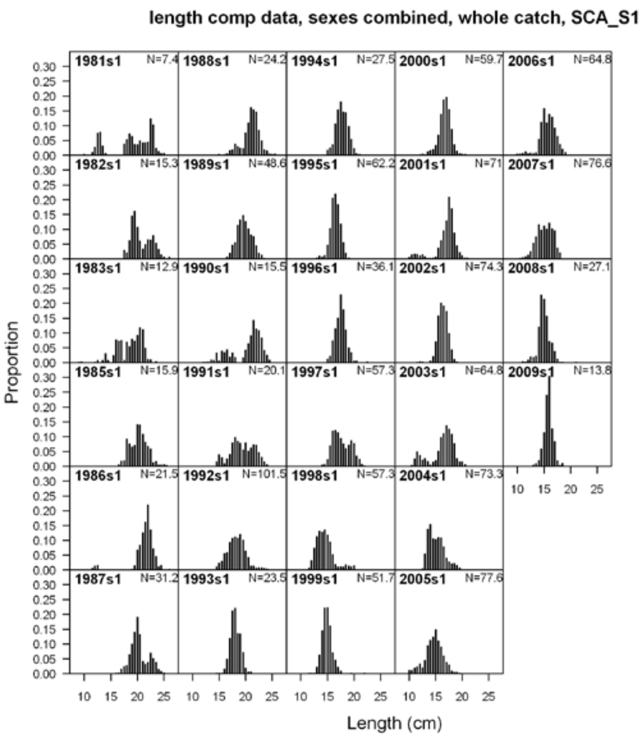


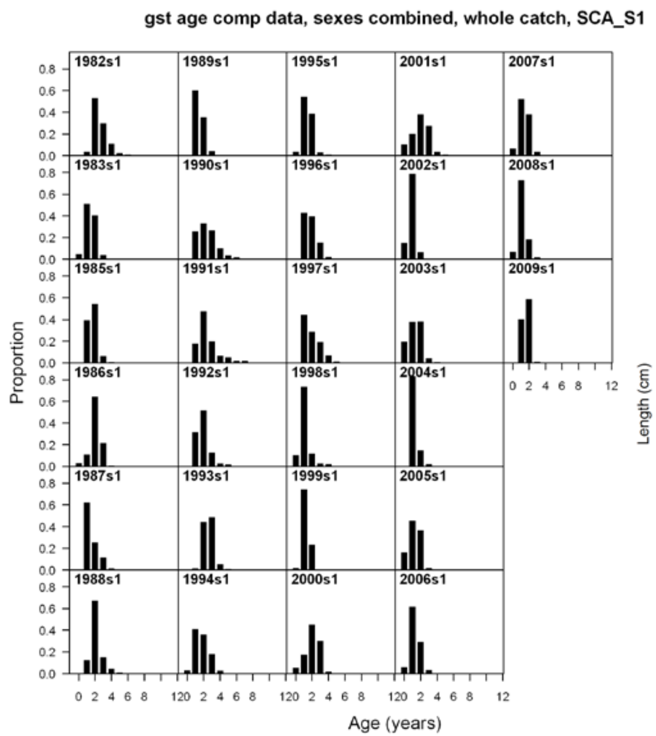
Landings

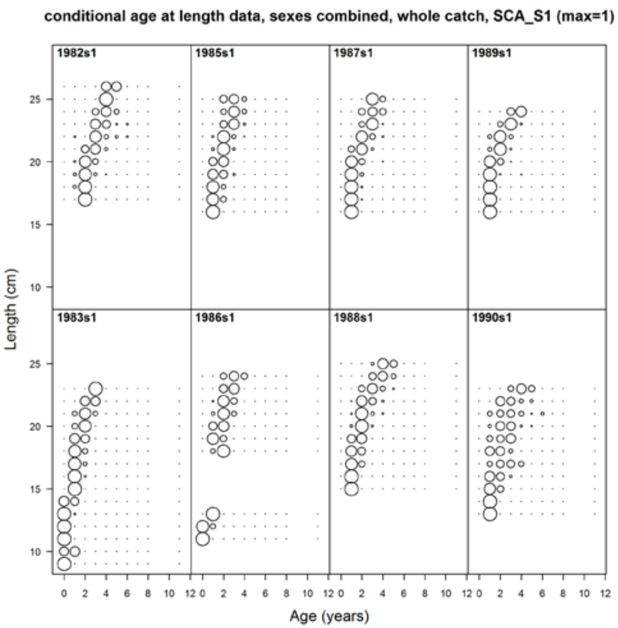


PNW
CCA
SCA
ENS
Landings (mt)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Model Year

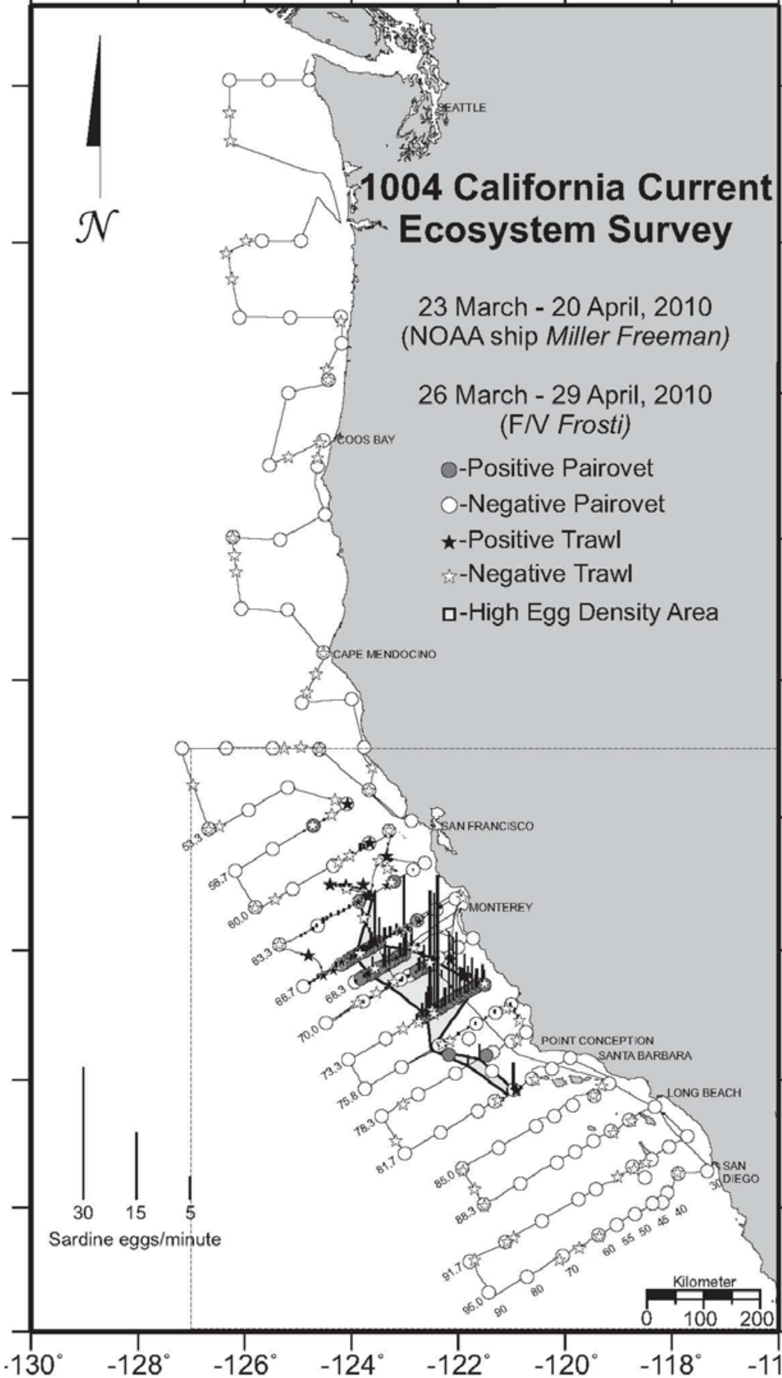
Length and Age Compositions

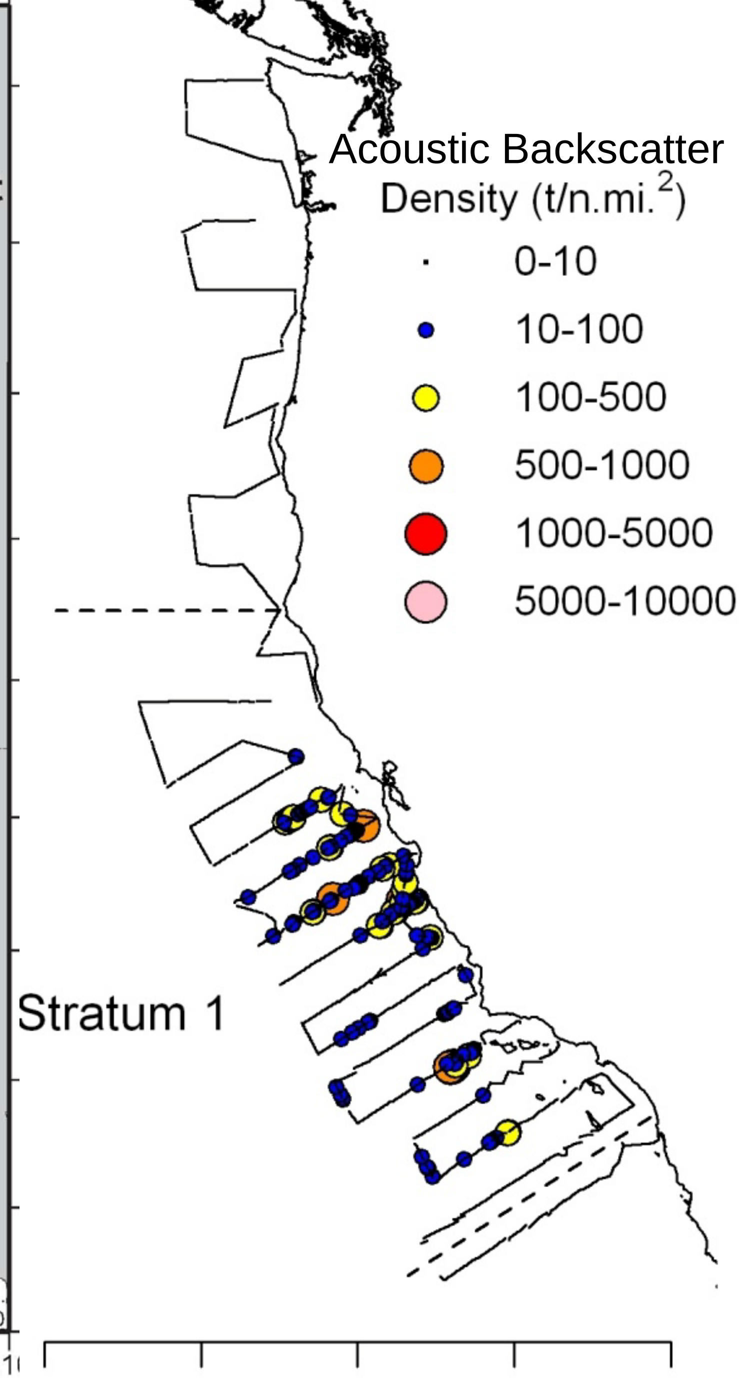






SWFSC CCES Spring 2010

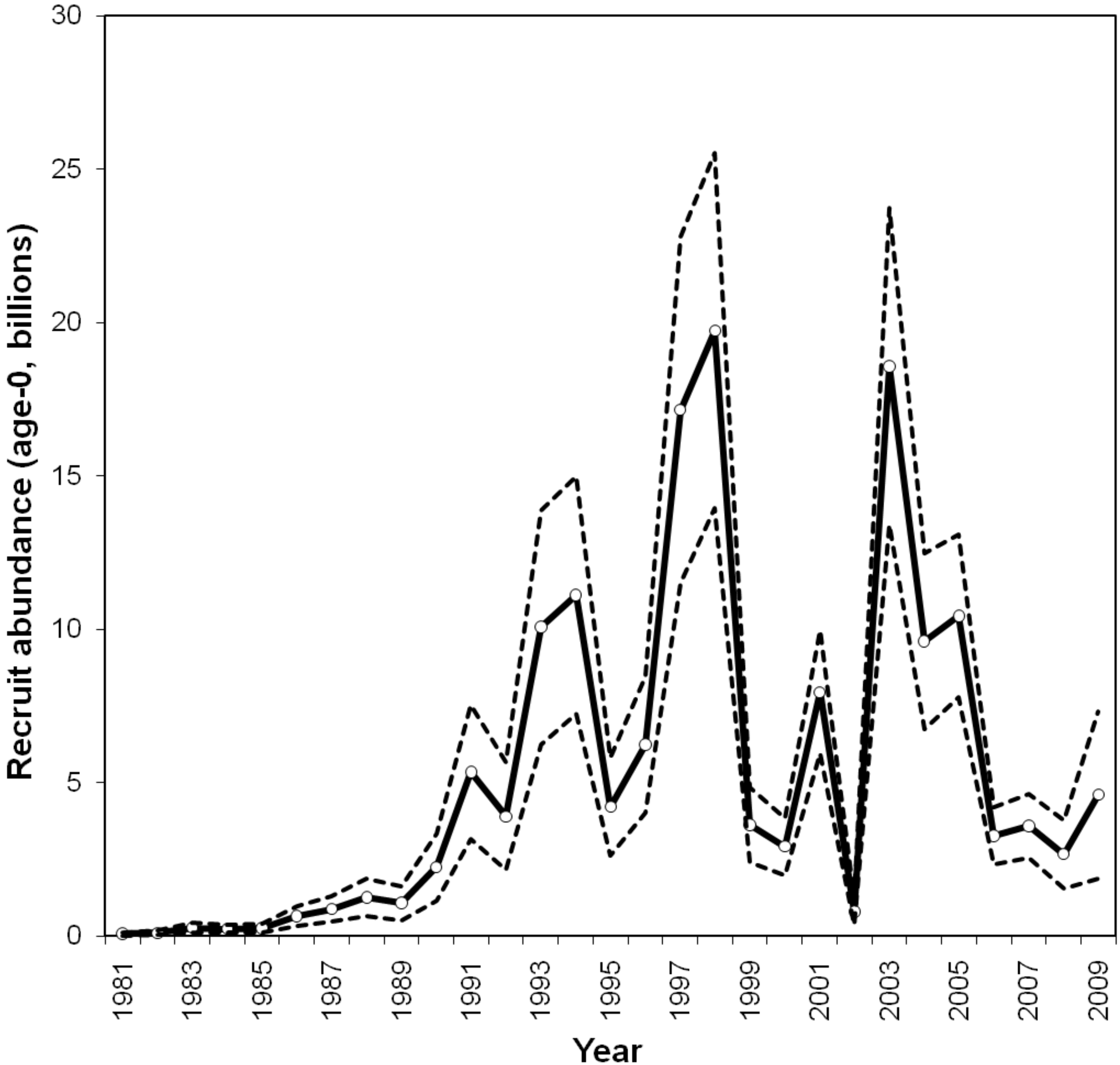




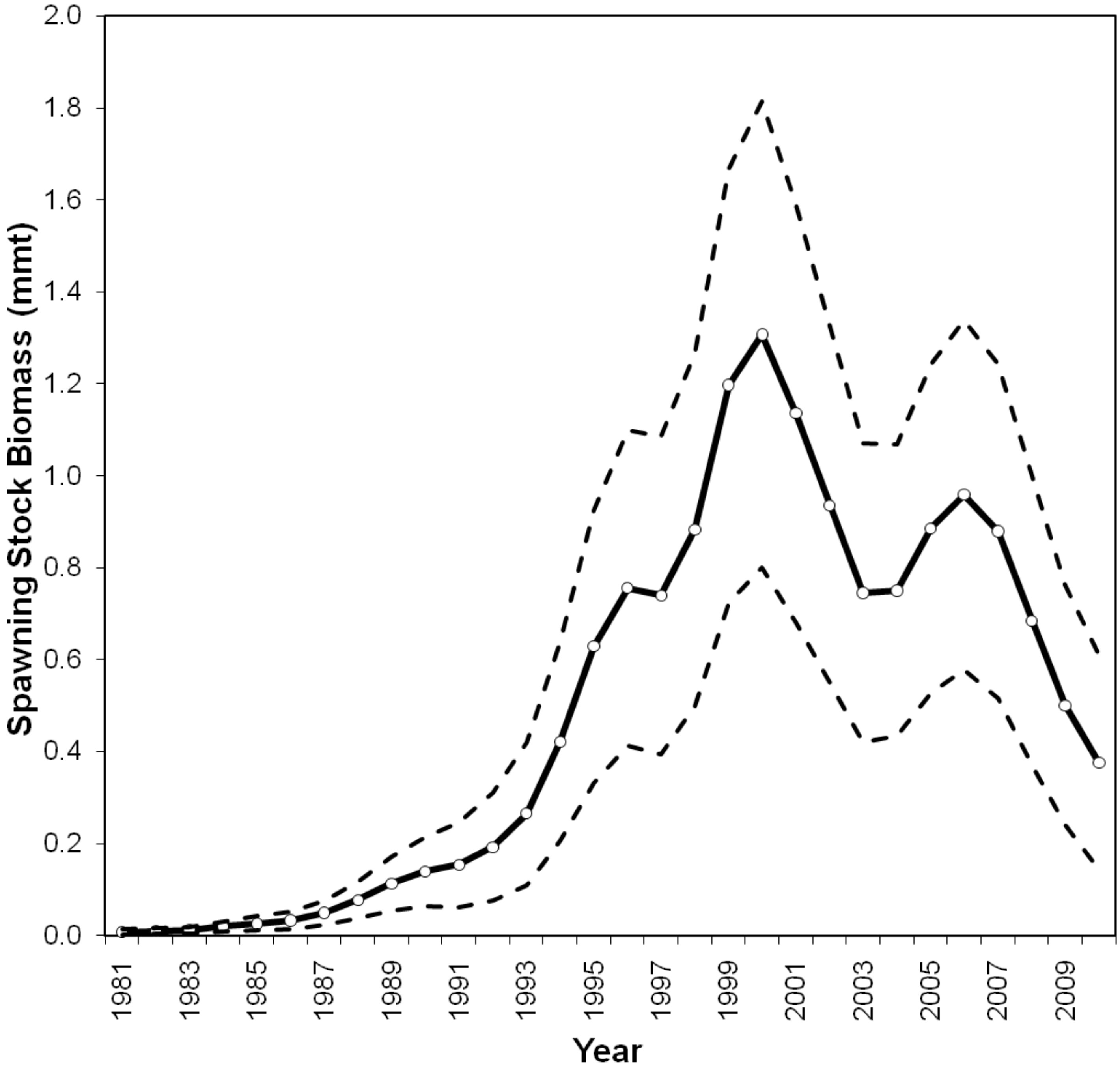
Update Model Specifications (10w)

- Stock Synthesis version 3.03a (11 May 2009);
- Model Year based on the July 1 birth date assumption (July 1-June 30 time span);
- Assessment years 1981-2010; Two semesters per year (S1=Jul-Dec; S2=Jan-Jun);
- Four fisheries (ENS, SCA, CCA, PNW), with annual selectivity patterns for ENS and PNW and seasonal selectivity patterns for SCA and CCA (S1 & S2);
- Use of length-frequency and conditional age-at-length data for all fisheries;
- Length-based, double-normal selectivity with time-blocking:
  - ENS, SCA_S1, & SCA_S2: 1981-91, 1992-98, 1999-10;
  - CCA_S1 & CCA_S2: 1981-92, 1993-98, 1999-10;
  - PNW: 1981-03, 2004-10;
- M = 0.4yr^{-1} for all ages and years;
- Time-varying growth in two periods: 1981-90 and 1991-10;
- Ricker stock-recruitment relationship; σ_R = 0.815; Steepness estimated;
- Initial recruitment (R_1) estimated; recruitment devs estimated from 1975 to 2008;
- Hybrid-F fishing mortality option;
- DEPM and TEP measures of spawning biomass (1986, 1987, 1993, 2003, 2004, and 2006-2009 for DEPM, and 1987, 1995-2002 and 2005 for TEP) and aerial survey estimates of abundance from 2009 and 2010;
- Length-frequency data for the 2009 and 2010 aerial surveys, taken from point-set samples, fit with a single selectivity function (double-normal, dome-shaped).

Recruits (Age-0)



Spawning Stock Biomass



Retrospective & Sensitivity Analyses

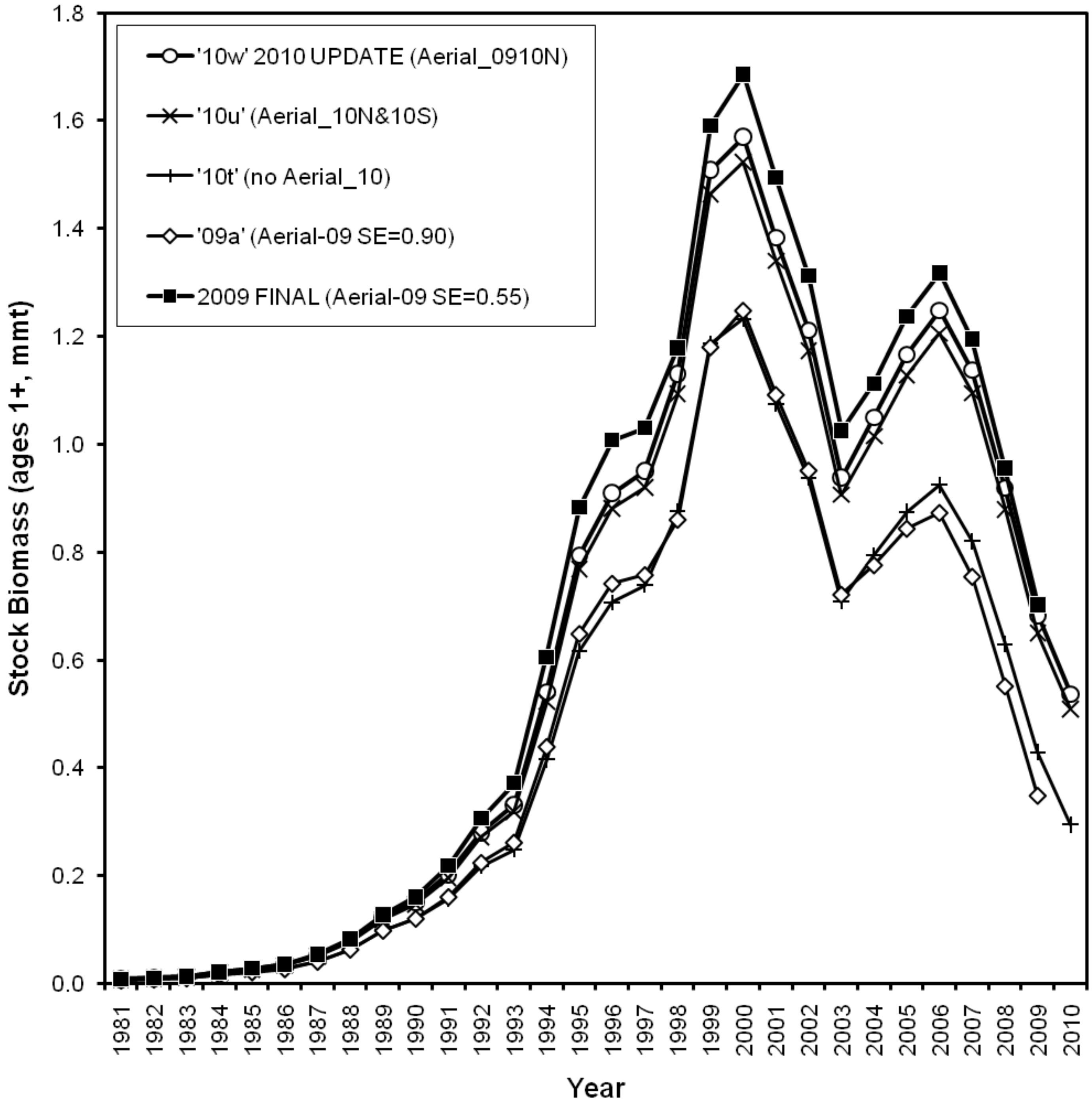
Retrospective:

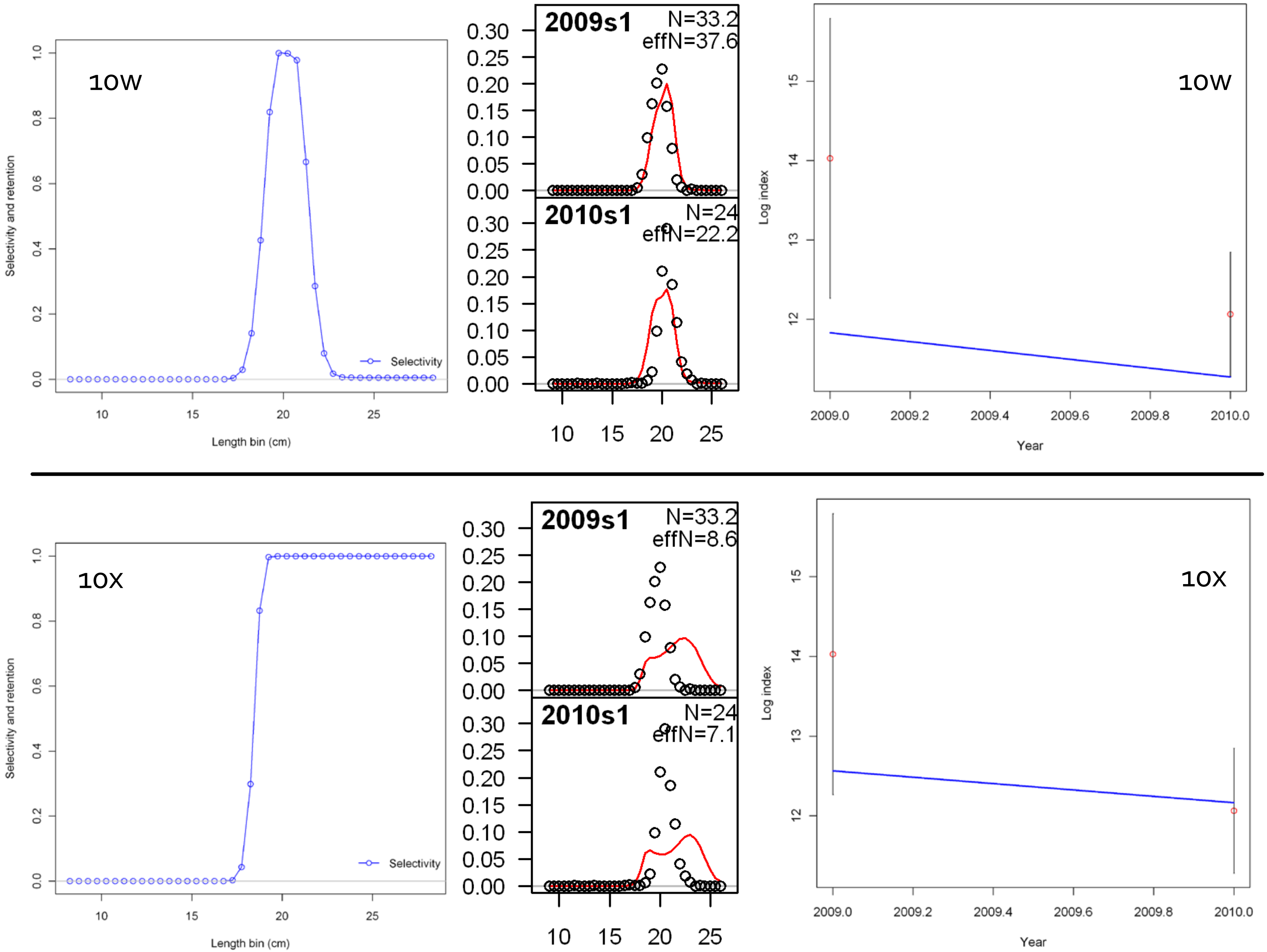
- addition of revised and new data elements (Table 8)

Sensitivity:

- revision of 2009 aerial estimate;
- addition of 2010 aerial estimate(s);
- aerial survey selectivity assumptions

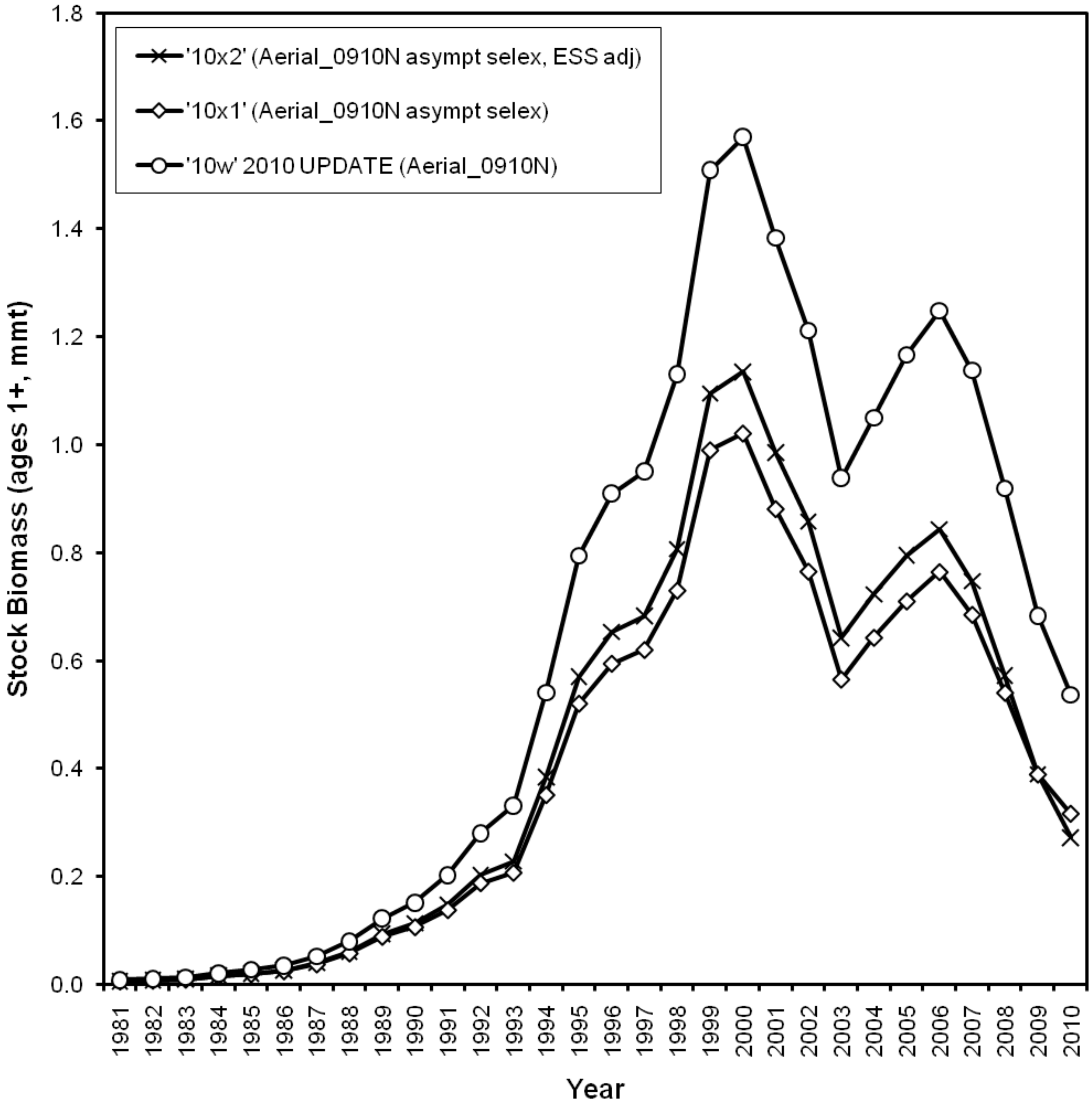
Stock Biomass (Ages 1+) Sensitivity to Aerial Survey Data



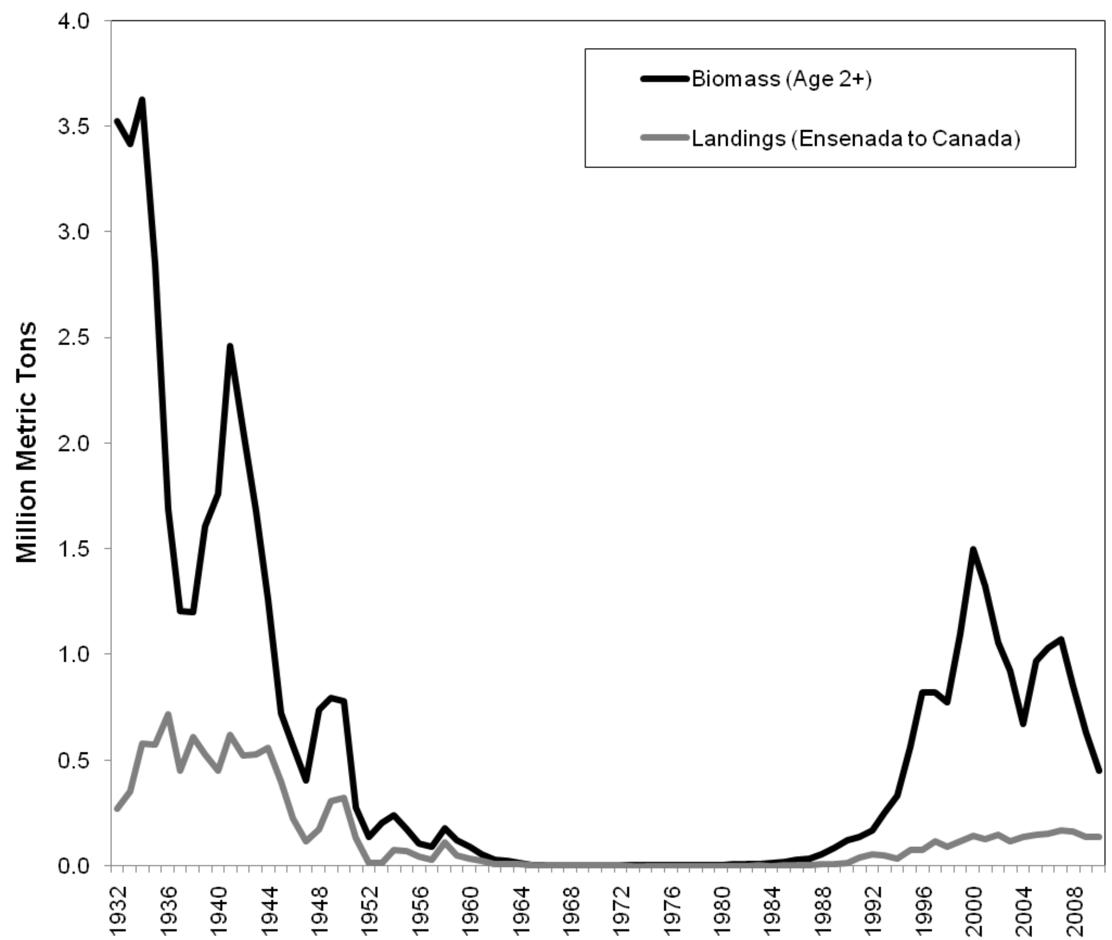


10W
Selectivity and retention
Length bin (cm)
Selectivity
2009s1
N=33.2
effN=37.6
2010s1
N=24
effN=22.2
Log index
Year
10X
2009s1
N=33.2
effN=8.6
2010s1
N=24
effN=7.1

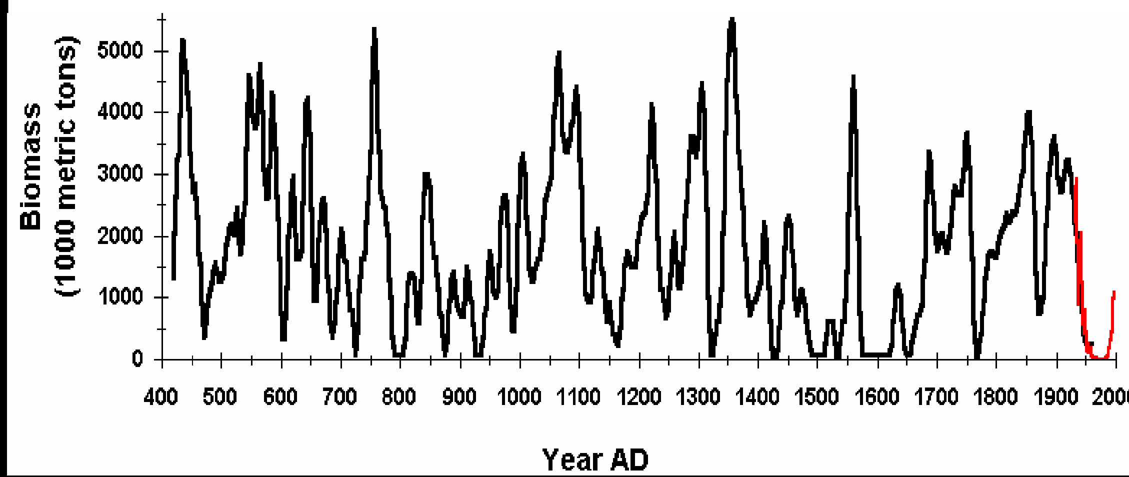
Stock Biomass (Ages 1+) Sensitivity to Aerial Survey Selectivity Function



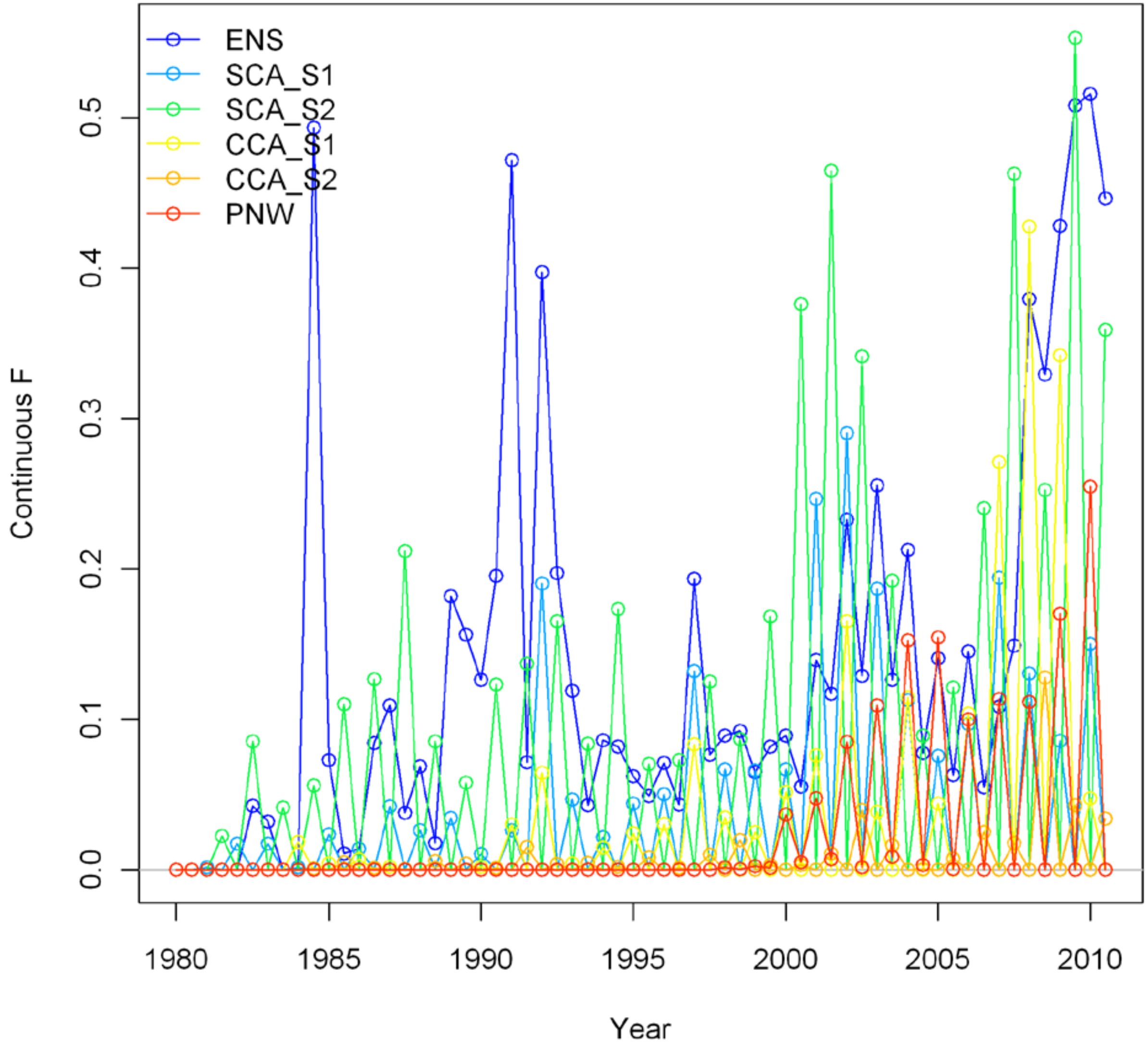
Historic sardine biomass (age 2+) from Murphy (1966) and the base model.



Millennial-scale variation from scale deposits in marine sediments
(courtesy Tim Baumgartner, CICESE)



Fishing Mortality Rate



Likelihoods and Derived Quantities (Table 8, p. 32)

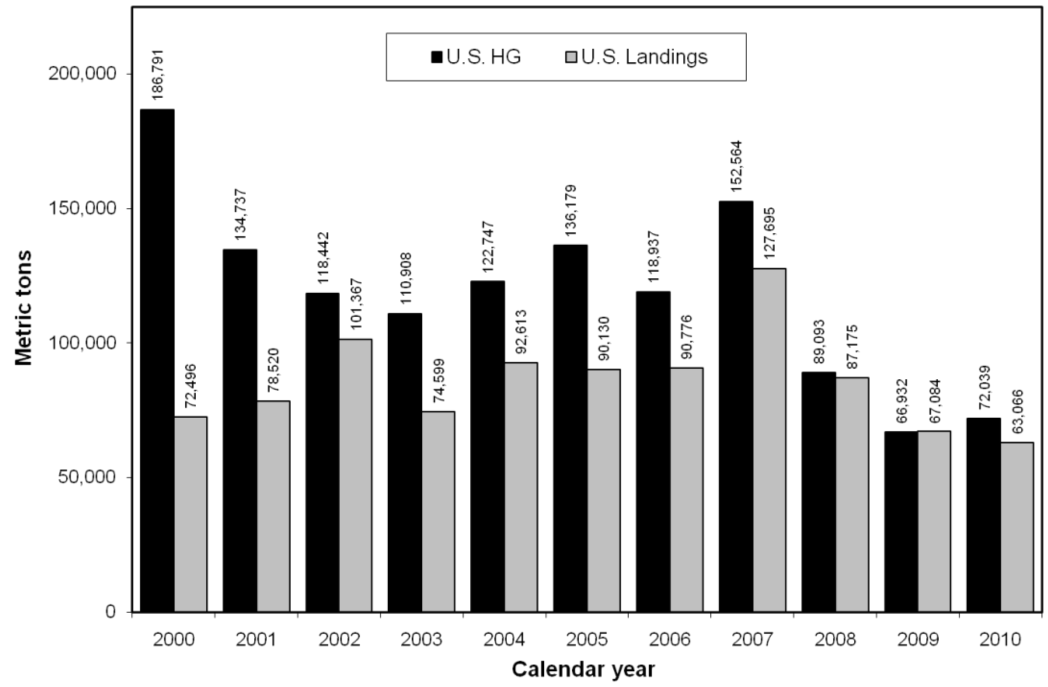
			REVIEW WEEK MODELS:					ALT MODELS:	
DATA / PROCESS:	**09_FINAL**	**09a**	**10t**	**10t2**	**10u**	**10v**	**10w**	**10x1**	**10x2**
Revised 2008/09 Landings									
Revised 2008 Length Comps									
Revised 2008 Age Comps									
2010 Landings									
2009-10 length comp SCA1									
2009-10 length comp SCA2									
2009-10 length comp CCA1									
2009-10 length comp CCA2									
2009-10 length comp PNW									
2009-10 age comp SCA1									
2009-10 age comp SCA2									
2009-10 age comp CCA1									
2009-10 age comp CCA2									
2009-10 age comp PNW									
2010 DEPM survey									
Rdevs adv. one year (pre-tuning)									
Tune model (var. adj. & Sig-R)									
Aerial-09 Index (1.35mmt, SE=0.55)	domed slx								
Revised Aerial-09 Index (1.24mmt, SE=0.90)		domed slx	domed slx	domed slx	domed slx	domed slx	domed slx	asymp slx	asymp slx
Aerial-10N					domed slx	domed slx			
Aerial-10S					domed slx				
LIKELIHOOD COMPONENT:	**09_FINAL**	**09a**	**10t**	**10t2**	**10u**	**10v**	**10w**	**10x1**	**10x2**
DEPM Index	-1.138	-1.981	-1.994	-2.016	-1.344	-1.221	-1.276	-1.777	-2.049
TEP Index	-0.765	-0.581	-0.731	-0.708	-0.834	-0.845	-0.838	-0.568	-0.665
Aerial-09 Index	9.514	7.156	5.275	5.453	3.737	3.505	3.921	0.332	0.194
Aerial-10N Index	---	---	---	---	1.35	0.89	---	---	---
Aerial-10S Index	---	---	---	---	-0.30	---	---	---	---
Survey Subtotal	**7.611**	**4.594**	**2.551**	**2.729**	**2.603**	**2.333**	**1.807**	**-2.012**	**-2.520**
ENS-len	361.71	361.45	357.79	357.40	357.48	357.51	357.52	359.27	358.30
SCA1-len	352.87	352.99	353.31	353.06	353.45	353.45	353.29	350.70	352.49
SCA2-len	426.60	428.11	430.84	428.92	429.96	429.94	429.59	428.14	430.07
CCA1-len	161.51	163.01	172.06	169.72	170.73	170.65	170.25	169.36	171.47
CCA2-len	191.53	191.98	222.04	171.97	222.73	222.22	223.39	222.40	221.70
PNW-len	190.87	186.45	218.50	219.13	218.67	218.67	218.85	221.29	218.85
Aerial09-len	1.28	0.42	0.33	0.33	0.27	0.27	9.52	49.81	16.36
Aerial10N-len	---	---	---	---	1.29	1.11			
Aerial10S-len	---	---	---	---	1.56	---	---	---	---
Length Comp Subtotal	**1686.37**	**1684.41**	**1754.86**	**1700.53**	**1756.14**	**1753.82**	**1762.41**	**1800.96**	**1769.24**
ENS-age	265.06	263.89	269.03	268.49	270.06	270.25	270.28	269.49	269.04
SCA1-age	223.17	223.25	225.75	225.61	225.59	225.62	225.49	224.93	225.56
SCA2-age	492.89	488.94	539.86	539.02	542.72	543.69	543.29	538.22	539.05
CCA1-age	108.88	109.09	113.57	113.31	113.47	113.44	113.50	113.93	113.72
CCA2-age	158.66	159.68	163.00	165.94	163.03	162.71	162.96	164.92	163.61
PNW-age	135.03	133.89	183.93	182.78	184.84	185.35	184.95	193.50	186.37
Age Comp Subtotal	**1383.69**	**1378.73**	**1495.13**	**1495.16**	**1499.71**	**1501.05**	**1500.47**	**1504.99**	**1497.35**
Catch	1.64E-07	1.64E-07	1.63E-07	1.08E-04	1.64E-07	1.64E-07	1.64E-07	1.63E-07	1.63E-07
Recruitment	55.60	56.55	59.67	60.61	59.14	59.02	59.03	59.08	59.43
Parameter softbounds	0.0320	0.0328	0.0327	0.0329	0.0464	0.0364	0.0315	0.0327	0.0325
Crash penalty	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Likelihood	**3133.29**	**3124.32**	**3312.24**	**3259.07**	**3317.64**	**3316.26**	**3323.74**	**3363.05**	**3323.52**
DERIVED QUANTITIES:	**09_FINAL**	**09a**	**10t**	**10t2**	**10u**	**10v**	**10w**	**10x1**	**10x2**
SSB-virgin (mt)	1,034,580	752,356	750,942	730,817	938,037	977,257	966,884	651,230	699,647
Biomass (1+) peak - 2000	1,686,190	1,248,430	1,232,360	1,231,180	1,523,120	1,578,370	1,570,120	1,021,780	1,134,920
Biomass (1+) - 2009	702,024	348,967	429,143	409,160	650,585	698,692	683,575	389,668	389,324
HG-2010	72,039	25,965	36,428	33,820	65,326	71,604	69,632	31,277	31,232
Biomass (1+) - 2010	---	---	295,097	225,663	508,936	564,426	537,173	316,912	272,517
HG-2011	---	---	18,935	9,874	46,841	54,083	50,526	21,782	15,988

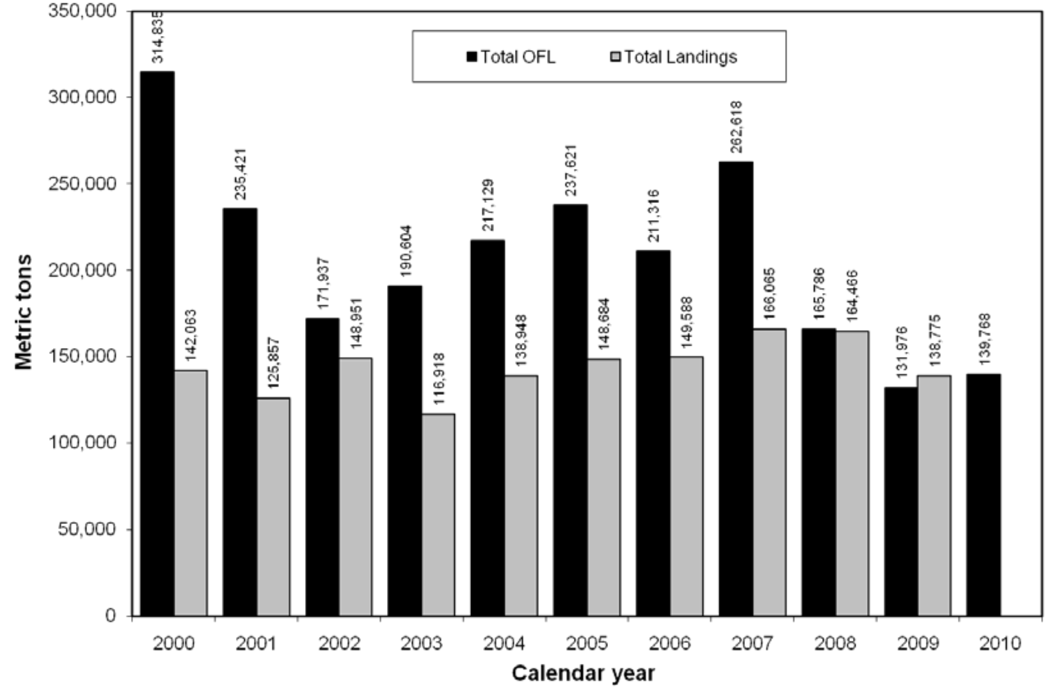
U.S. Harvest Levels - Update Model

Harvest Formula Parameters	Value			
BIOMASS (ages 1+, mt)	537,173			
Pstar (probability of overfishing)	0.45	0.40	0.30	0.20
$BUFFER_{Pstar}$ (Sigma=0.36)	0.95577	0.91283	0.82797	0.73861
F_{MSY} (upper quartile SST)	0.1985			
FRACTION	0.15			
CUTOFF (mt)	150,000			
DISTRIBUTION (U.S.)	0.87			

Amendment 13 Harvest Formulas	MT
OFL = BIOMASS * F_{MSY} * DISTRIBUTION	92,767
$ABC_{0.45}$ = BIOMASS * $BUFFER_{0.45}$ * F_{MSY} * DISTRIBUTION	88,664
$ABC_{0.40}$ = BIOMASS * $BUFFER_{0.40}$ * F_{MSY} * DISTRIBUTION	84,681
$ABC_{0.30}$ = BIOMASS * $BUFFER_{0.30}$ * F_{MSY} * DISTRIBUTION	76,808
$ABC_{0.20}$ = BIOMASS * $BUFFER_{0.20}$ * F_{MSY} * DISTRIBUTION	68,519
ACL=LESS THAN OR EQUAL TO ABC	TBD
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION	50,526
ACT=EQUAL TO HG OR ACL, WHICHEVER VALUE IS LESS	TBD

Management Performance: U.S. HGs & Coastwide OFLs





Agenda Item I.2.c
CPSMT Report 1
November 2010

Specifications and Management Measures for Monitored CPS Stocks

At its June 2010 meeting, the Pacific Fishery Management Council (Council) heard from its Coastal Pelagic Species (CPS) advisory bodies, the Scientific and Statistical Committee (SSC), and the public on the matter of establishing Overfishing Limits (OFLs), Acceptable Biological Catch (ABCs), and Annual Catch Limits (ACLs) for monitored stocks under Amendment 13 to meet the NS1 guidelines. After reviewing a range of alternatives, the Council adopted the following final action for monitored stocks under Amendment 13:

- Maintain the default harvest control rules for monitored stocks as modified to specify the new management reference points. ACLs would be specified for multiple years until such time as the species becomes actively managed or new scientific information becomes available. The value of 0.25 in the ABC control rule (a 75 % buffer) will remain in use until recommended for modification by the Scientific and Statistical Committee and approved by the Council.

  Control Rules for Monitored Species

OFL	STOCK SPECIFIC MSY PROXY
ABC	OFL * 0.25
ACL	Equal to ABC or reduced by OY considerations.

- The Council confirmed that status determination criteria for the CPS FMP are to remain as currently specified with the exception of the northern subpopulation of northern anchovy (for which no criteria currently exist). The Council is anticipated to adopt a maximum sustainable yield (MSY) proxy for this subpopulation through the annual management cycle at its November meeting.

The control rules and harvest policies for monitored CPS stocks may be more generic, precautionary, and simpler than those used for actively managed stocks. Under the FMP, any stock supporting catches approaching the ABC or MSY levels should be actively managed unless there is too little information or other practical problems. The main use of the control rules for a monitored stock is to help gauge the need for active management and to trigger consideration to move a stock to active management. The goal is to move the stock to active management before it is experiencing overfishing or if other concerns prompt a move to active management. While landings are low and the stock remains in the monitored category, its status is assessed infrequently making estimates of MSY or MSST difficult and impractical. MSY proxies for market squid, jack mackerel and the central subpopulation are currently in place. In Amendment 8 of the CPS FMP, the benchmarks for monitored finfish stocks were truncated at the nearest thousand mt when they were adopted, as it was recognized that the estimates were not precise and this would provide an additional precaution against overfishing. The benchmarks for these three stocks are listed in Table 1. Section 4.4 of Appendix B in Amendment 8 of the CPS FMP can be reviewed for details on the benchmarks for monitored finfish stocks. Details for market squid can be found in the market squid fishery management plan (CDFG 2005) and Amendment 10 of the CPS FMP (PFMC 2002).

Table 1. Management reference points for monitored stocks in the CPS FMP.

Jack Mackerel	Sources: MacCall and Stauffer (1983), Amendment 8 – Appendix B (PFMC 1998)	
OFL	Stock MSY proxy = 194,000mt	US Distribution MSY proxy = 126,000 mt
ABC	OFL x 0.25 = 48,000 mt	US ABC = 31,000 mt
Northern Anchovy, Central Subpop	Sources: Conrad (1991), Amendment 8 – Appendix B (PFMC 1998)	
OFL	Stock MSY proxy = 123,000mt	US Distribution MSY proxy = 100,000 mt
ABC	OFL x 0.25 = 31,000 mt	US ABC = 25,000 mt
Market Squid	Sources: CPS FMP Amendment 10 (PFMC 2002) and California Market Squid FMP (CDFG 2005)	
OFL	F_{MSY} proxy resulting in Egg Esc ≥ 30%	
ABC	245,348 mt	

At a joint meeting with the CPSMT October 5-7 in La Jolla, CA the CPS subcommittee of the SSC expressed interest in reviewing how the MSY proxies were derived and the data sources utilized. Details of how these proxies were derived can be found in the original sources, which are listed here to facilitate SSC review. The complete analyses done to derive these proxies are not repeated here and are beyond the scope of this summary document. However, the existing stock specific MSY proxies, their sources, the general method and date of their derivation are listed below. As was noted by the SSC in March and June 2010, these proxies are based on dated information and the 75% reduction buffer in the ABC control rule may need to be reevaluated. Consequently, major caveats of utilizing these proxies noted in the source documents, some of the key parameters utilized in their derivation, landings data for these stocks, and results of a vulnerability analysis for CPS stocks (Patrick et al. 2009) are summarized below to help evaluate if the application of the 75% reduction buffer is adequate to prevent overfishing. These finfish monitored stocks continue to experience limited targeted fishing pressure and relatively low levels of landings at this time.

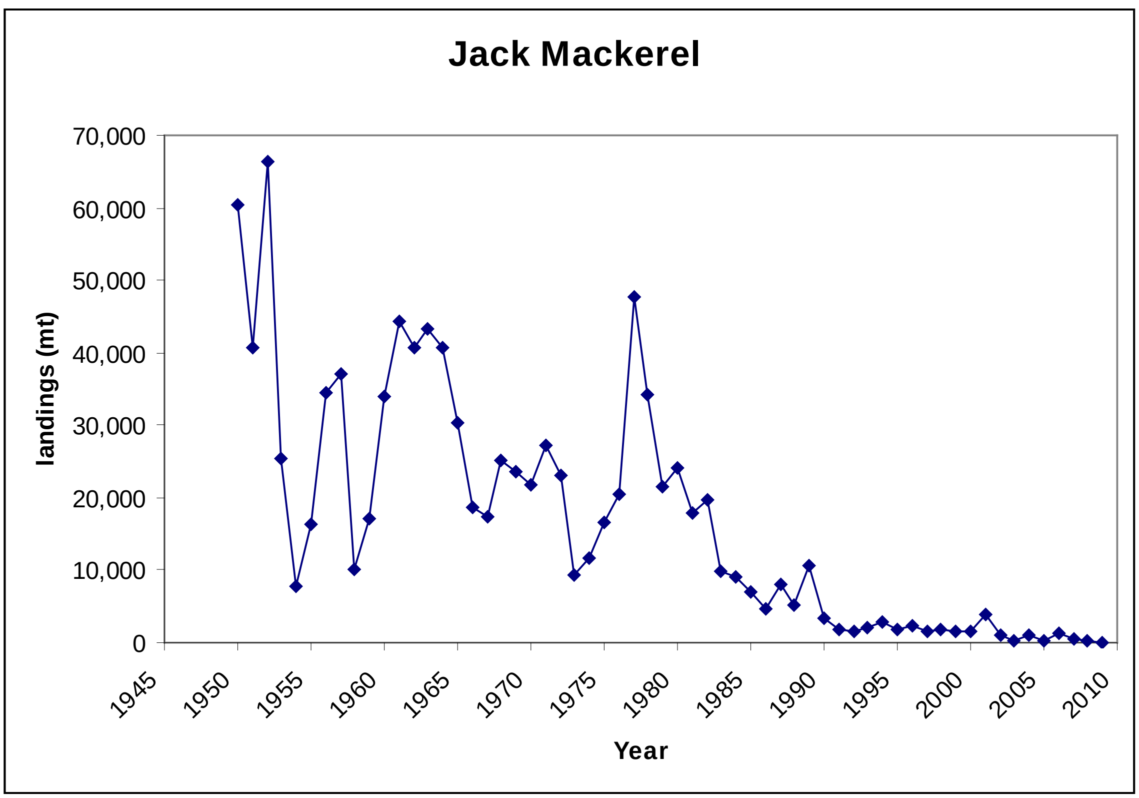
Distribution

Details of the analysis, available data, and discussion of the management issues for harvest levels for US fisheries with these transboundary finfish stocks can be found in section 4.1.3 of Appendix B to Amendment 8 on pages B-84 to B-89. The MSY proxies in Amendment 8 for jack mackerel and the central subpopulation of northern anchovy were based on the entire stock. It was recognized that these stocks did not reside entirely in US waters so a distribution term was utilized to account for the portion available to US fisheries. The best estimates of the portion of CPS stocks available in US waters were derived from CalCOFI egg and larvae collections (1951-1985) and aerial fish spotter data (1964-1992). The estimates represent an average of CalCOFI data for spring and summer and fish spotter data from summer through winter. Best estimates for the average distribution in US waters for monitored stocks of jack mackerel and the central subpopulation of northern anchovy were 65% and 82%, respectively. It was noted that it was unlikely that these estimates could be updated frequently, but that the estimate for jack mackerel should be updated if a significant fishery developed.

Jack Mackerel

The MSY proxy for jack mackerel was derived by MacCall and Staufer (1983) using a dynamic pool model with various assumptions about natural mortality and fecundity. Data collected in CalCOFI egg and larval surveys from 1951-1976 were utilized. Their estimates of initial total biomass ranged from 14,841,000 mt to 18,120,000 mt with potential yield ranging from 130,000 to 260,000 mt. The midpoint of potential yield, 194,000 mt was used as the MSY proxy for the entire stock of jack mackerel. The ABC was set to 48,000 mt for the entire stock and 31,000 mt for the portion available to fisheries in US waters based on the default MSY control rule.

Landings for this stock have declined substantially and have been relatively low since 1990 as effort and interest in targeting this species has declined.



Average jack mackerel landings (mt) for the last five decades with high and low values are given below.

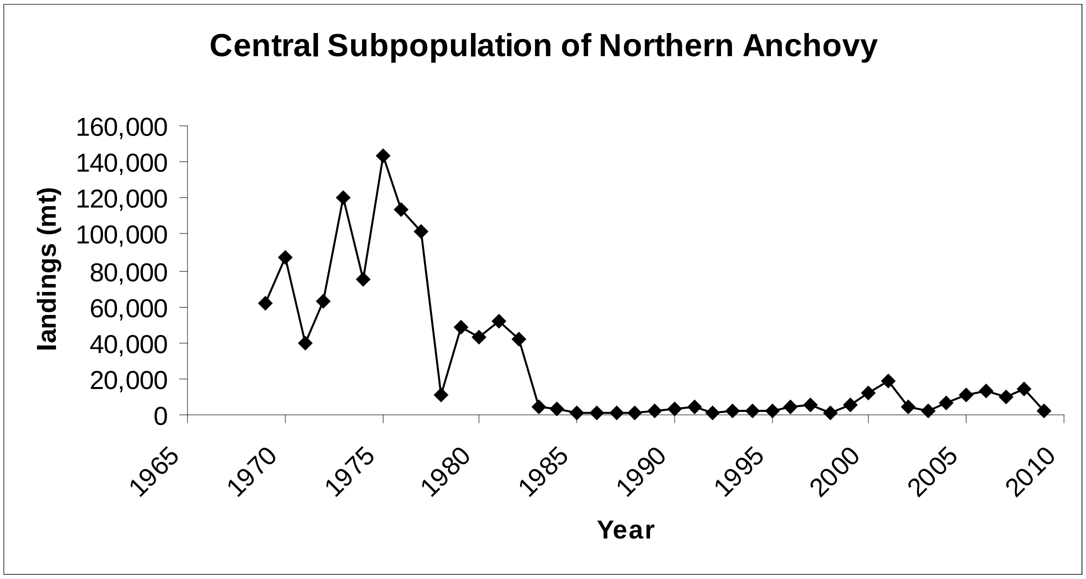
Time Period	Average landings	Highest landings	Lowest landings
1950 -1959	31,561	66,462	7,863
1960 -1969	31798	43,274	17,325
1970 - 1979	23,353	34,349	9,406
1980 - 1989	10,084	24,181	4,777
1990 - 1999	2,053	3,254	1,526
2000 -2009	1,027	3,839	121

Northern Anchovy - central subpopulation

The benchmarks for the central subpopulation of northern anchovy come from a bioeconomic model for the reduction fishery developed by Conrad (1991). Optimal biomass of ~733,000 mt and stock MSY of ~123,000 mt resulted from the modeled analysis. However, the author noted that the most recent (1990) biomass estimate was 299,410 mt (Jacobson and Lo 1991). The ABC was set to 31,000 mt for the stock and 25,000 mt for the portion available to fisheries in US waters based on the default MSY control rule.

There has been extensive work on biomass estimate modeling for this subpopulation with the most recent estimate of the spawning stock being 388,000 mt in 1995 (Jacobson et al. 1995). Jacobson et al. (1997) concluded that the abundance and biomass was at least as high in 1997 as it was in 1995 based on a qualitative analysis. Median biomass reported for this stock for the period 1953-1991 was 547,000 mt (Jacobson et al. 2001). Management options have also been examined (Jacobson and Thomson 1989).

Landings for this stock have declined substantially since the 1970s as the reduction fishery declined. The biomass of this stock also declined from the 1970s to the 1990s, which was probably related to environmental and ecological changes such as the Pacific Decadal Oscillation and/or the increase in the Pacific sardine biomass. However, mechanistic links between anchovy biomass and environmental and ecological changes are still poorly understood.



Average landings (mt) of central subpopulation of northern anchovy with high and low values for the last four decades are given below.

Time Period	Average landings	Highest landings	Lowest landings
1970 - 1979	80,349	120,327	11,439
1980 - 1989	15,320	52,308	1,390
1990 - 1999	3,076	5,718	1,124
2000 -2009	9,546	19,277	1,676

Market Squid

Market squid is a short-lived species that is exempt from ACLs under the NS1 guidelines. Current management establishes a threshold egg escapement of at least 30 percent as a proxy for MSY. The control rule for market squid and the MSY proxy are entirely different than for other monitored stocks. Details of the analysis and options examined are in Amendment 10 (PFMC 2002). The relationship between *F*msy and stock abundance is poorly understood. The biomass of the stock is unknown at this time. Although monitoring/modeling efforts to date provide useful descriptive statistics regarding population dynamics surrounding this species, further work would be necessary before implementing new methods for long-term management purposes. The substantial spatial and temporal variability in productivity of the population(s) off the central-southern California coast hinders the applicability methods to determine egg escapement in practical terms and ultimately, emphasizes the need for timely data collection, laboratory processing, and modeling, if any methods are to be employed formally in the future.The fishery takes place primarily in California and there is a state landing cap of 107,048 mt. The state landing cap is envisioned as a benchmark triggering reevaluation of the monitored status of this stock.

Management measures currently in place for market squid include:

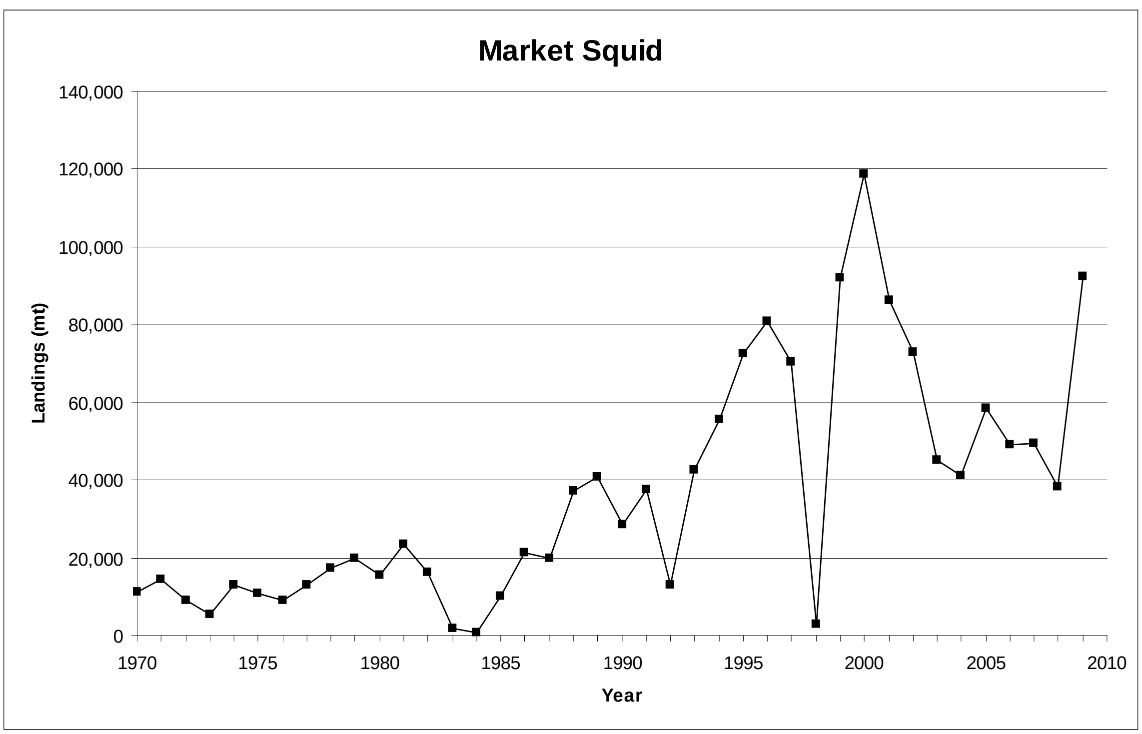
1. Temporal closures (weekend closures);

2. Spatial closures (marine protected areas, which include Channel Islands Marine Protection Areas (MPAs) and new and proposed MPAs under the California Marine Life Protection Act);
3. Gear closures (i.e., Santa Monica Bay, leeward side of Catalina, lighting restrictions in Gulf of the Farallones Marine Sanctuary);
4. Gear restrictions for light shields and wattage limits;
5. Continued monitoring programs used to evaluate the impact of the fishery on the resource;
6. Restricted access program designed to limit fleet participation in order to maintain a moderately productive and specialized fleet; and
7. State management framework (Marine Life Management Act), which provides specific guidelines for making management decisions.
8. State landing cap of 107,048 mt.

Other constraints that protect squid from overfishing include:

9. The population is utilized for commercial purposes within a fraction of the geographic range;
10. Fishing occurs within a limited portion of the depth range; and
11. Fishing pressure does not usually shift from traditional fishing areas to new areas when there is a decrease in availability of squid.

Landings for market squid have increased since the mid 1980s due to increased market demand and targeting of this species.



Average landings (mt) of market squid with high and low values for the last four decades are given below.

Time Period	Average landings	Highest landings	Lowest landings
1970 - 1979	12,300	19,982	5,471
1980 - 1989	18,725	40,893	564
1990 - 1999	49,563	91,950	2,895
2000 -2009	65,181	118,814	38,101

Northern Anchovy – northern subpopulation
No management benchmarks for this stock presently exist. This subpopulation ranges from Eureka, California to the Queen Charlotte Islands, British Columbia, Canada. Some key fishery independent data on this stock are summarized below:

- Egg and larvae surveys
    - Richardson (1981)
        - July 1975 – biomass 262,506 to 796,511 mt
        - July 1976 – biomass 144,654 to1,005,263 mt
        - July 1977 – acoustic estimate of 800,000 mt
        - Potential yield – 86,792 mt to 633,319 mt, lower if managed like central anchovy subpopulation
    - PFMC 1998 – CPS FMP Amendment 8 Appendix B
        - "Educated guess" correction factor reduces Richardson's spawning biomass estimates to a range of 87,000-116,000 mt
    - Emmett et al. (1997) in Forage Fish in Marine Ecosystems
        - No biomass estimate
        - Greatly reduced abundance and distribution of anchovy eggs and larvae in July 1994 and 1995 compared with Richardson's (1981) work in 1975 and 1976
        - Eggs present at only 1 station of 242 stations in 1994 (0.4%). Egg density 400/m^2
        - Max egg density in 1995 was 5,600/m^2 at 1 station
        - Larvae densities also lower and present at only 4% and 9% of stations in 1994 and 1995 compared with 47% and 57% presence in 1975 and 1976.

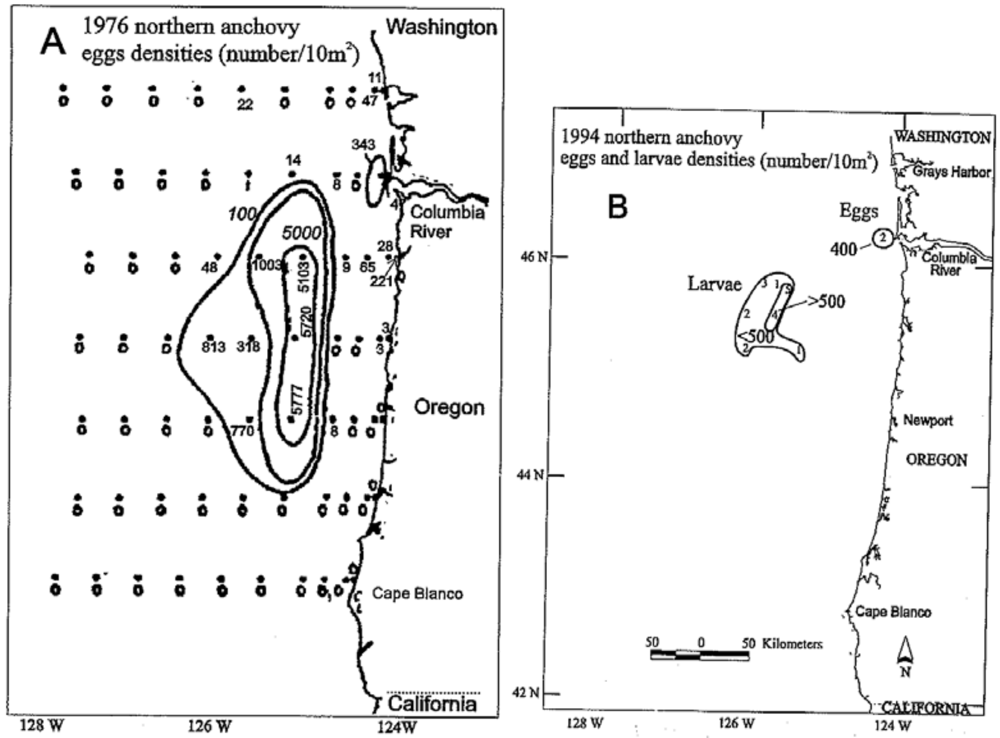
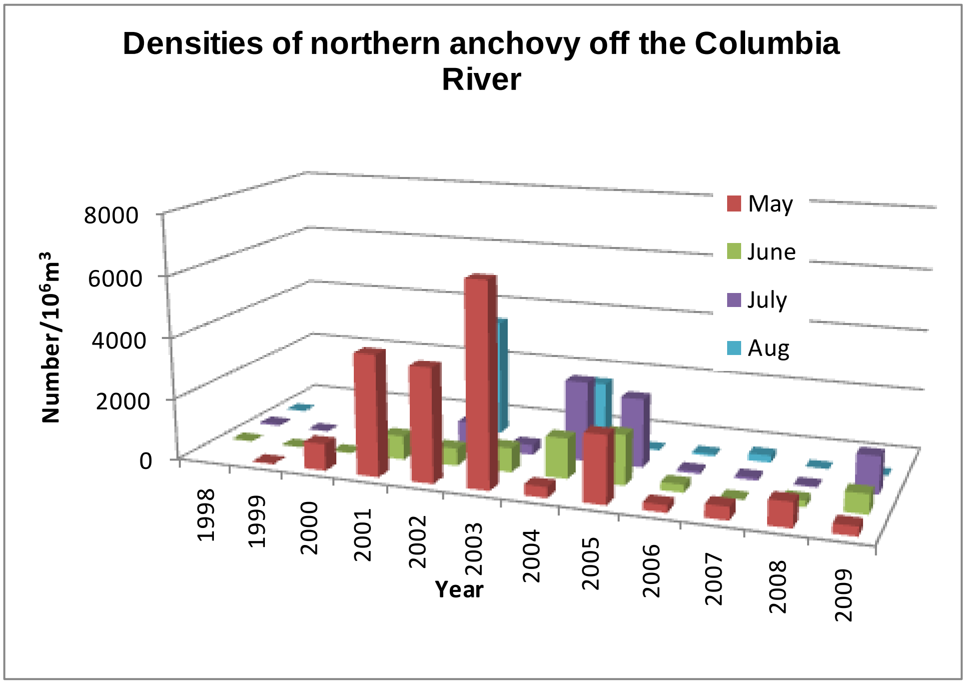


Figure 1. Location and density of northern anchovy eggs and larvae found in July 1976 (A) (from Richardson 1981) and July 1994 (B) from ichthyoplankton surveys off Oregon and southern Washington. Actual numbers of eggs and larvae captured in 1994 are shown in B. In 1994, larvae included some unidentified clupeid larvae that could have been northern anchovy or Pacific sardine.

Figure from Emmett et al. 1997.

- Acoustic estimate 2008
  - Zwolinski et al. (in prep.) SWFSC
    - 159,800 mt (CV >0.88)
    - Note: details of this estimate are not presently available for SSC review
- Relative index of abundance 1999-2009
  - Emmett (unpublished data in figure below, methods published in Emmett et al. 2001) found higher abundance in 2001 - 2005 than in 2006 - 2009

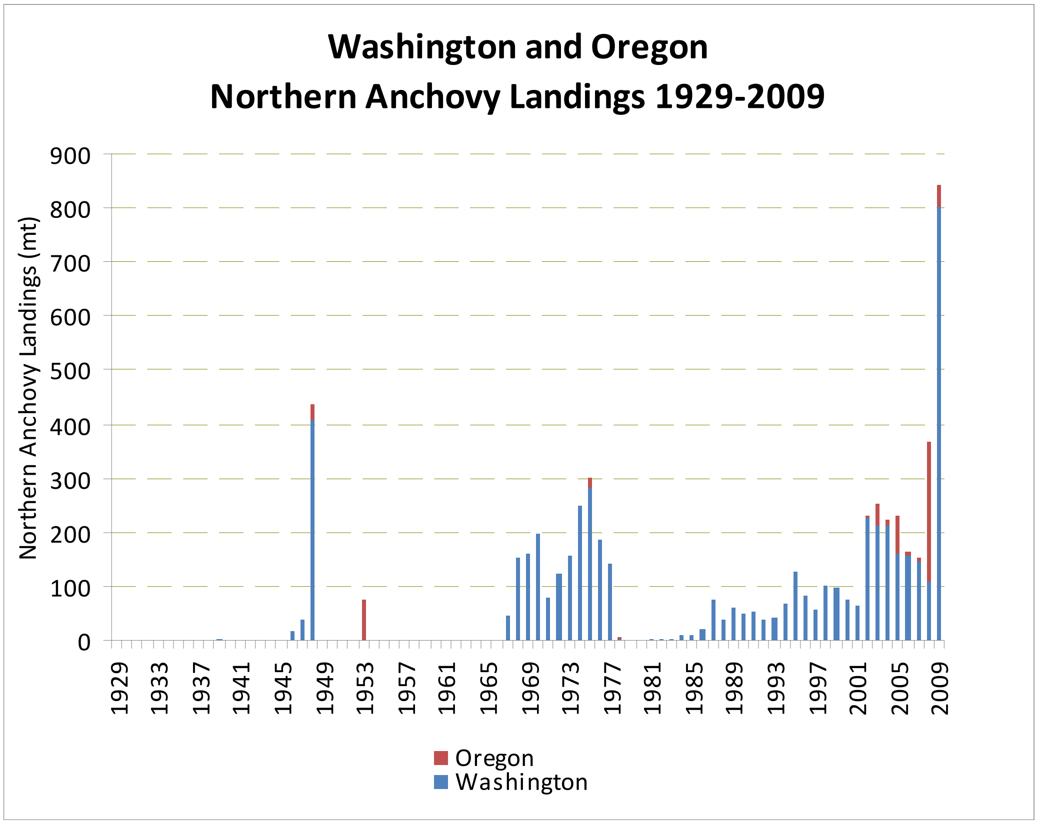


- Litz et al. (2008) examined ecology and distribution of the northern subpopulation
  - Recent population fluctuations likely related to timing of spring transition and abundance of cold water copepods
  - Strong year classes recruited earlier were caught in 2003 and 2004 and abundance decreased subsequently
  - Ages of anchovy sampled were 0-3 years

There are also substantial fishery data available for this stock from landings in Canada, Oregon, and Washington, which are summarized below:

- British Columbia, Canada landings
  - Stock Status report B6-08 (DFO 2002)
    - Max of 6,000 mt in 1941
    - Avg. 1939-1949 = 1,665.1 mt
    - Avg. 1950-1959 = 137.0 mt
    - Avg. 1960-1979 no data
    - Avg. 1980-1989 = 42.6 mt
    - Avg. 1990-1999 = 2.8 mt
    - Avg. 1997-2001 = 95.2 kg (range 0 – 272 kg)
    - Fishery closed in 2002

- Oregon and Washing landings combined



Average landings (mt) of northern subpopulation of northern anchovy with high and low values for the last six decades are given below.

Time Period	Average landings	Highest landings	Lowest landings
1950 -1959	8	76	0
1960 -1969	37	162	0
1970 - 1979	146	304	0.3
1980 - 1989	24	62	1
1990 - 1999	74	103	42
2000 -2009	262	845	68

Stock Vulnerability Considerations

The term “vulnerability” is referenced in sections of the NS1 guidelines that deal with 1) differentiating between “fishery” and “ecosystem component” stocks, 2) assembling and managing stock complexes, and 3) creating management control rules. Productivity and susceptibility indices were examined to determine stock vulnerability for California Current coastal pelagic species including both the actively managed and monitored stocks in the CPS FMP (Patrick et al. 2009). The vulnerability of a stock to become overfished is defined in this report as the potential for the productivity of the stock to be diminished by direct and indirect fishing pressure. Vulnerability is expected to differ among stocks based on life history characteristics and susceptibility to the fishery. Vulnerability includes two key elements: 1) stock productivity (a function of the stock's life-history characteristics); and 2) stock susceptibility, or the degree to which the fishery can negatively impact the stock. Data quality was also considered in the analysis. This definition differs from that often used in evaluation of species at risk of extinction, where the concern is the likelihood of recovering from a diminished abundance and the focus is placed upon the productivity of the stock. In our case, a stock with a low level of productivity would not be considered vulnerable to fishing unless there was also some susceptibility of the stock to a fishery. The interaction between the productivity of a species and its susceptibility to a fishery has a long history in fisheries science.

CPS vulnerability scores (scale 0 to 2.83)
Pacific sardine - 1.2
Pacific mackerel - 1.5
Northern anchovy - 1.2
Market squid - 1.4

- CPS are not classified as 'vulnerable' resources. These species' productivity is high, susceptibility to the fishery is moderate, and overall vulnerability low compared with other fisheries/species, (e.g., majority of the sharks, groundfishes, and other species evaluated in Patrick et al. 2009).
- CPS are not currently 'overfished' or subject to 'overfishing' practices.

Biology generally supports less precautionary harvest recommendations for CPS than for most of the other exploited species that inhabit the CA current. However, these species are subject to high interannual and interdecadal variability in recruitment, the causes of which are largely unknown. This variability tempers their higher productivity scores and should be recognized in management of fisheries for these species.

Using Recent Catch to Develop OFLs, ABCs, ACLs, and ACTs
A recent presentation by fishery scientist Dr. Rick Methot (NMFS Office of Science & Technology and the Northwest Fisheries Science Center) provided an overview of ABC control rules and scientific uncertainty. The presentation is available at:
http://www.fisheriesforum.org/documents/11181_May2010Forum_Methot.pdf

Catch for the monitored CPS finfish stocks best fit into the scenario presented for recent catch being "small", based on the vulnerability analysis and historical catch information. Dr. Methot suggests that ABC and ACL be set above historical catch, that ACT be set at historical catch levels, and an increase in ACT be allowed if accompanied by cooperative research and close monitoring.

Acoustic data that can be utilized to provide information on biomass has been collected on NMFS research cruises and a proposal for reviewing methods to estimate biomass from acoustic data has been submitted by the SWFSC (see Agenda Item I.3.a Attachment 2, Terms of Reference for methodology reviews). Landings of these stocks are closely monitored each year by state agencies. Thus, the monitored CPS finfish stocks may be good candidates for applying the methods suggested by Dr. Methot.

Options for Consideration

Option 1 - Adopt benchmarks for jack mackerel, northern anchovy (central population), and market squid based on existing stock specific MSY proxies from Table 1 and adopt benchmarks for northern anchovy (northern subpopulation) based on recent catch.

Option 2 – Adopt benchmarks for s based on MSY proxies from Table 1 with modifications suggested by SSC and adopt based benchmarks for northern anchovy (northern subpopulation) based on recent catch.

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COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON PACIFIC SARDINE STOCK ASSESSMENT AND MANAGEMENT MEASURES

The Coastal Pelagic Species Advisory Subpanel (CPSAS), along with the CPS Management Team (CPSMT), received presentations on the 2010 Pacific Coast Aerial Survey from Mr. Tom Jagielo, and the 2010 Pacific Sardine stock assessment from Dr. Kevin Hill. The CPSAS offers grateful thanks to Dr. Hill and the Stock Assessment Team for incorporating the point estimate for the 2010 summer aerial survey despite receiving the data only a few days prior to the stock assessment meeting.

The aerial survey data included the assessment resulted in a biomass (ages 1+) estimate of 537,173 mt. This is a significant reduction from the 702,024 mt in 2009. Applying the harvest control rule, the Harvest Guideline (HG) for the 2011 fishery is 50,526 MT, down from the 72,039 mt approved in 2010.

Discussing the outcome of the 2010 assessment, the CPSAS acknowledged the contradiction of the surveys with observations in the field:

- the Daily Egg Production Model (DEPM) index reflected the lowest egg deposition survey since the early 1990s;
- The 2010 aerial survey indicated a decline of biomass from that photographed in 2009.

However, the scientific advisor for the aerial survey noted that the 2010 survey results were likely reduced by chronic inclement weather conditions. With the exception of Monterey, fishers in the Pacific Northwest, southern California, and Canada all reported large and numerous sardine schools. Landings in Westport were at historic highs. Today, in November, Canadian fishers continue to harvest large volumes of sardines when weather permits.

Even with a reduced biomass estimate, the aerial survey scaled up model output significantly from the DEPM survey alone. The CPSAS supports the proposed improvements for the aerial survey.

The CPSAS acknowledges the new suite of requirements mandated by Amendment 13 of the CPS fishery management plan (FMP). The CPSAS notes that the low assignments of HG coupled with individual seasonal allocations of HG have resulted in a truncated season of every sardine season since 2008. The recommended low target HG for 2011 will result in seasons that are shorter unless some boats and plants choose not to operate. Given the economics, this is a real possibility.

Management Measures

The CPSAS recommends the following management measures for the 2011 sardine fishery:

(1) The HG for the 2011 sardine fishery be approved as derived from Dr. Hill's Model run 10W (50,526 mt).
(2) An aggregate total of 5000 mt be set aside for incidental catch (3000 mt) and a harvest buffer (2000 mt): (1000 mt of incidental allowance would be set aside for each of the three periods for non-sardine fisheries. For the first two periods any of the 1000 mt not utilized would roll into the next period's directed fishing.)
(3) An Exempted Fishing Permit (EFP) set aside of 4,200 mt be approved for industry-supported research, to be deducted from the HG before it is allocated (Table 1).

The CPSAS commends the effective in-season actions taken by the National Marine Fisheries Service (NMFS) to deal with surpluses or shortages in the directed and incidental seasonal allocations.

The CPSAS recommends that the non-sardine incidental landing allowance in 2011 be no more than 30 percent Pacific sardine by weight, as adopted in 2010. The CPSAS recommends that if the directed seasonal allocation and set-asides are reached, the retention of Pacific sardine be prohibited for the remainder of that sardine season.

Table 1. Allocation scheme for the 2011 Pacific Sardine Harvest Guideline

HG = 50,526 mt; Potential EFP set aside = 4,200 mt; Adjusted HG = 46,326 mt				
	Jan 1- Jun 30	Jul 1- Sep 14	Sep 15 – Dec 31	Total
Seasonal Allocation (mt)	16,214	18,530	11,582	46,326
Incidental Set Aside (mt)	1,000	1,000	1,000	
Management Uncertainty (mt)			2,000	
Adjusted Allocation (mt)	15,214	17,530	8,582	41,326

Research set aside and EFP Request

The CPSAS requests the Council approve an EFP set-aside of 4,200 mt to be allocated as follows:

- 2,100 mt for the Northwest Sardine Survey, under the direction of scientific advisor, Tom Jagielo. This will be utilized to repeat the summer aerial survey in the Pacific Northwest in 2011 and operate under established protocols.
- 2,100 mt for the California Wetfish Producers Association's (CWPA) Pilot Program under the direction of scientific advisor Dr. Doyle Hanan. This will be utilized to expand the pilot project presently underway. This involves approved aerial photographic

techniques with the addition of light detection and ranging (LIDAR), which is intended to enhance existing survey methods. LIDAR will provide density to surface area measurements, and these overlapping technologies can be used to develop an estimate of biomass when the weather is more conducive to such research and sardines are abundant in California.

- A detailed EFP application encompassing the two aerial survey projects, including methodology and operational plans, will be submitted to the Council prior to the March 2011 meeting. The Fall Pilot Program EFP request is subject to the Stock Assessment Review Panel (STAR) review of LIDAR and enhanced photographic methods, and tentatively scheduled for May 2011. If the methodology is not approved, the Fall Pilot Program EFP set aside would be added to the Fall directed allocation.

The CPSAS strongly recommends the Council support the EFP research and our request for STAR Methodology review panels as outlined in Agenda Item I.3.b. We encourage the NMFS to support and fund comprehensive coast-wide annual CPS research. This is necessary to improve understanding of the spawning biomass and migration patterns. We encourage similar cooperative surveys in Canada and Mexico.

We commend NMFS and the Council for their parts in arranging a Sardine Survey Methods Workshop in June of 2010. In particular, we would like to thank Dr. Varanasi and Dr. Sakagawa.

Monitored Stocks

The majority of the CPSAS generally concurs with the approach adopted by the CPSMT to deal with monitored stocks in Amendment 13.

Included are conservation representative comments:
The Magnuson-Stevens Fishery Conservation and Management Act (MSA) mandates that Fishery Management Plans (FMPs) must prevent overfishing.[1] The MSA further requires FMPs to include 'objective and measurable criteria for identifying when the fishery to which the plan applies is overfished' as well as an analysis of how the criteria were determined and the relationship of the criteria to the reproductive potential of stocks in that fishery.[2] The Specifications and Management Measures for Monitored CPS stocks do not include criteria for identifying when market squid, jack mackerel or northern anchovy are overfished. Market squid, jack mackerel and northern anchovy are "in the fishery" and are not exempt from Stock Determination Criteria.[3] Therefore, the Specifications and Management Measures for Monitored CPS Stocks do not meet the requirements of MSA, they are illegal and should not be approved by the Council and NMFS.

The CPSAS reiterates that coordinated international management of CPS fisheries is essential to understand the potential for coast wide overfishing. The CPSAS encourages the Council, NMFS

[1] 16 USC 1851 Sec. 301(a)(1).
[2] 16 USC 1853 Sec. 303(a)(10).
[3] While market squid is exempt from ACL and AM requirements because of its life history characteristics, "FMPs or FMP amendments for these stocks must have SDC, OY, ABC, and an ABC control rule." 74 FR 11 at 3210 (January 16, 2009).

and the State Department to continue their work to achieve the timely receipt of research and catch data from Mexico and Canada.

PFMC
11/07/10

Agenda Item I.2.c
Supplemental CPSMT Report 1 Addendum
November 2010

Addendum to CPSMT Report 1

<u>Summary</u>

The Council's Coastal Pelagic Species Management Team (CPSMT) submits this addendum to clarify two issues concerning 2011 management measures for monitored CPS stocks. The first pertains to the acceptable biological catch (ABC) for market squid. Table 1 of Agenda Item I.2.c (CPSMT Report 1) erroneously includes a market squid ABC of 245,348 mt. This value should be replaced with "F_{MSY} proxy resulting in Egg Escapement $\geq$ 30%," which was set in Amendment 10 to the CPS Fishery Management Plan (FMP).

The second issue pertains to the overfishing Limit (OFL)/maximum sustainable yield (MSY) proxy and ABC management benchmarks for the northern subpopulation of northern anchovy (NSNA). The CPSMT Report 1 contains background information on both species, with additional information (including suggested OFL/MSY proxy and ABCs) provided below.

<u>Market Squid</u>

Market squid have a less than one year life cycle, and have not been determined to be currently subject to overfishing. Therefore, market squid are exempt from annual catch limits (ACL) under National Standard 1 (NS1) guidelines. Amendment 10 to the CPS FMP established a minimum 30 percent egg escapement threshold as an F_{MSY} proxy, which is the ABC control rule. Results from egg escapement research provided general conclusions regarding this species' relatively high productivity and low vulnerability to fishing pressure, which support the above MSY-based management guidance. The CPSMT anticipates using the California state landings cap of 107,048mt (CDFG 2005) as a trigger for review of management measures for this species.

<u>Northern Subpopulation of Northern Anchovy</u>

The CPSMT is unable to determine an MSY proxy (equal to OFL for monitored CPS stocks) for the NSNA population because of the extremely limited information about current biomass or the variability of biomass over time. Therefore, the CPSMT does not recommend a specific OFL/MSY proxy at this time. However, the CPSMT suggests two potential OFL numbers to consider. Both are reasonable, based on the biology of the species, results of the vulnerability analysis for CPS stocks in the California Current ecosystem (Patrick et al. 2009), the relatively low recent catch for this subpopulation, and consistency with other CPS-monitored stock benchmarks.

The first is based on biomass estimates from the mid-1970s and from 2008. The midpoint of the revised biomass estimates from Richardson's work in the 1970s is 102,000 mt and the estimate from 2008 is 159,800 mt (Zwolinski et al, unpublished). Applying an 80 percent reduction (similar to other CPS stocks) to an approximate average biomass of 130,000 mt results in an OFL/MSY proxy of 26,000 mt. Applying the default monitored stock control rule (ABC=OFL*0.25) to this biomass estimate results in an ABC of 6,500 mt.

The second is based on recent catch, and assumes an ABC of 3,000. (This ABC, approximately six times the 10-year average catch and three times the 2009 catch, is a reasonable starting point.) Based on the default Harvest Control Rule for monitored stocks, this ABC would align with an OFL/MSY proxy of 12,000 mt. Regardless of the OFL/MSY proxy, the CPSMT anticipates recommending precautionary harvest specifications, at the November Council meeting.

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PFMC
11/03/10

COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON PACIFIC SARDINE STOCK ASSESSMENT AND COASTAL PELAGIC SPECIES (CPS) MANAGEMENT MEASURES FOR 2011

Pacific sardine

The Coastal Pelagic Species Management Team (CPSMT) received presentations from Dr. Kevin Hill concerning the Pacific sardine stock assessment conducted in 2010, and from Mr. Tom Jagielo regarding the results of the aerial survey conducted in 2010 that were incorporated into the stock assessment. The CPSMT recommends that the Pacific Fishery Management Council (Council) adopt the update assessment (model 10w) that resulted in a stock biomass (ages 1+) estimate of 537,173 mt, which results in a harvest guideline (HG) of 50,526. This represents a 23 percent decline in biomass from the previous stock assessment adopted by the Council (November 2009). The CPSMT notes that there are a number of factors indicating that the HG should not exceed 50,526 mt:

1. Total abundance of sardine has decreased in recent years:
    a. Recruitments have been low since 2006 (Agenda Item I.2.b, Attachment 2, Page 119 of stock assessment, Figure 40);
    b. Indices of abundance collectively indicate the population is currently lower than observed in previous years:
        i. Daily Egg Production Model (DEPM) data since 2006 (Agenda Item I.2.b, Attachment 2, page 23 of stock assessment, Table 4);
        ii. Aerial Survey (Agenda Item I.2.b, Attachment 2, page 12 of stock assessment, line 4 and paragraph 3, line 2):
            1. 2009 estimate: 1,236,910 mt;
            2. 2010 estimate: 173,390 mt;
    c. Additional data sources, not included in the assessment, also indicate that sardine abundance has declined in recent years:
        i. Southwest Fisheries Science Center hydroacoustic survey;
        ii. Canada Department of Fisheries and Oceans (swept area) trawl survey.
2. The combined international harvest has contributed to a recent increase in the total exploitation rate exerted on the population at large (Agenda Item I.2.b, Attachment 2, Page 116 of stock assessment, Figure 37b); however, the CPSMT notes that overfishing is currently not occurring in the US fishery.

Aerial Survey

In regards to the industry sponsored aerial survey, the CPSMT commends the Exempted Fishing Permit (EFP) applicants for their dedicated efforts in achieving a high degree of completion of the study design specifications. However, there were two inadequacies: 1) the previously specified range of school biomass was not fully sampled; 2) point sets were not located in the corresponding geographic area of observed biomass. The CPSMT understands that weather and other logistical limitations precluded these two aspects from occurring as designed. Because of the lack of representative point sets, the data provided in the south were not included in the stock assessment.

Harvest Specifications for 2011

Table 1 contains harvest formula parameters and a range of acceptable biological catch (ABC) values based on various P-Star (probability of overfishing) values. The CPSMT recognizes that the Council will select a P-Star. The CPSMT recommends that the annual catch limit (ACL) equal the ABC resulting from the Council's P-Star choice.

Table 1. Pacific sardine Amendment 13 Harvest Formulas Parameters

Harvest Formula Parameters	Value			
BIOMASS (ages 1+, mt)	537,173			
Pstar (probability of overfishing)	0.45	0.40	0.30	0.20
$BUFFER_{Pstar}$ (Sigma=0.36)	0.95577	0.91283	0.82797	0.73861
F_{MSY} (upper quartile SST)	0.1985			
FRACTION	0.15			
CUTOFF (mt)	150,000			
DISTRIBUTION (U.S.)	0.87			

Amendment 13 Harvest Formulas	MT
OFL = BIOMASS * F_{MSY} * DISTRIBUTION	92,767
$ABC_{0.45}$ = BIOMASS * $BUFFER_{0.45}$ * F_{MSY} * DISTRIBUTION	88,664
$ABC_{0.40}$ = BIOMASS * $BUFFER_{0.40}$ * F_{MSY} * DISTRIBUTION	84,681
$ABC_{0.30}$ = BIOMASS * $BUFFER_{0.30}$ * F_{MSY} * DISTRIBUTION	76,808
$ABC_{0.20}$ = BIOMASS * $BUFFER_{0.20}$ * F_{MSY} * DISTRIBUTION	68,519
ACL=LESS THAN OR EQUAL TO ABC	TBD
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION	50,526
ACT=EQUAL TO HG OR ACL, WHICHEVER VALUE IS LESS	50,526

The CPSMT recommends that the incidental catch for CPS fisheries in each of the three allocation periods should be set to 1,000 mt (Table 2). To account for management uncertainty, an additional 2,000 mt should be reserved in the third period. The CPSMT recommends that the incidental landing allowance for CPS fisheries be no more than 30 percent Pacific sardine by weight. The CPSMT recommends setting aside 4,200 mt for potential sardine EFPs.

Table 2. Allocation scheme for 2010 Pacific Sardine HG

HG = 50,526 mt; Potential EFP set aside = 4,200 mt; Adjusted HG = 46,326 mt				
	Jan 1- Jun 30	Jul 1- Sep 14	Sep 15 – Dec 31	Total
Seasonal Allocation (mt)	16,214	18,530	11,582	46,326
Incidental Set Aside (mt)	1,000	1,000	1,000	
Management Uncertainty (mt)			2,000	
Adjusted Allocation (mt)	15,214	17,530	8,582	41,326

Ecological considerations

In June 2010 the Council decided that it would include ecological considerations when adopting benchmarks of status determination criteria (SDCs), overfishing limits (OFLs), ABCs, and ACLs as part of implementing Amendment 13. Yet the Council did not provide the CPSMT guidance on the process for this provision. The CPSMT examined Pacific Coast Ocean Observing System (PACOOS) reports on the state of the California Current Large Marine Ecosystem (CCLME) and notes that following the El Nino event of 2008-2009 that a La Nina event is now underway. The North Pacific is also presently experiencing a negative Pacific Decadal Oscillation with cold water now along the Pacific Coast. How CPS stocks respond to these oceanographic conditions varies. The CPSMT examined stock assessment and population trend information available for a number of marine mammals and bird species from the following National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS) sources:

http://www.nmfs.noaa.gov/pr/sars/species.htm
http://www.fws.gov/pacific/migratorybirds/Seabird_Conservation_Plan_Document_pdf_files.htm

The CPSMT did not find evidence of upper trophic level forage limitations attributable to CPS stocks managed under the FMP (Fishery Management Plan). In general, marine mammal stocks have been increasing with many of the pinniped species reaching carrying capacity. Most seabird populations examined appear to stable or increasing.

The CPSMT notes that there is a large body of information available on the CCLME, and that other FMPs include ecological considerations clauses. A dedicated ecological modeling effort focused on the effects of various oceanographic conditions and management policies would be beneficial. Such an effort could be part of the Ecosystem Fishery Management Plan (E-FMP) that the Council is considering. The CPSMT recommends that the Council provide guidance on the process for taking additional ecological considerations not already incorporated into current management into account when setting benchmarks.

Monitored Stocks

At its June 2010 meeting, the Council heard from its CPS advisory bodies, the Scientific and Statistical Committee (SSC), and the public, on the matter of establishing OFLs, ABCs, and ACLs for monitored stocks under Amendment 13 to meet the National Standard 1 (NS1) guidelines. After reviewing a range of alternatives, the Council adopted the following final action for monitored stocks under Amendment 13 (Table 3):

- The Council confirmed that SDC for the CPS FMP are to remain as currently specified, with the exception of the northern subpopulation of northern anchovy.

- Maintain the default harvest control rules for monitored stocks as modified to specify the new management reference points. The ACLs would be specified for multiple years, until such time as the species becomes actively managed or new scientific information becomes available. The harvest rate of 0.25 in the ABC control rule (i.e., a precautionary buffer of 75 percent) will remain in use until recommended for modification by the SSC and approved by the Council.

Control rules for monitored species

OFL	Stock-specific MSY proxy
*AB*C	OFL * 0.25
ACL	Equal to ABC or reduced by OY considerations

The CPSMT notes that the SDC for market squid do not fit the default control rule and that overfishing is not occurring in the market squid fishery, which is also managed under an accepted state-based fishery management plan. The CPSMT provided information on current management measures in place for this species (Agenda Item I.2.c, CPSMT Report 1). The CPSMT notes that the market squid life cycle is less than one year and is not experiencing overfishing. Therefore, it is exempt from the requirement to establish ACLs.

The CPSMT met with the CPS subcommittee of the SSC in La Jolla, CA on October 5-7, 2010 to discuss the newly required reference points for monitored species noted above. In addition, most CPSMT members attended the full SSC's discussion of reference points at its November 5, 2010 meeting. Finally, the CPSMT supports the conclusion the SSC noted regarding inherent difficulties developing meaningful reference points for monitored CPS stocks, given the paucity data necessary to determine biomass.

Northern Anchovy-Northern Subpopulation

The CPSMT presented a review of available data for the Northern anchovy-northern subpopulation (Agenda Item I.2.c, Supplemental CPSMT Report 1 Addendum), which included two methods for determining total abundance. The SSC in its review of reference points for monitored stocks (Agenda Item I.2.c, supplemental SSC Report), proposes the reference points below. The CPSMT supports the conclusion from the SSC that anchovy productivity is very likely as high (or higher) than that currently assumed for species such as Pacific mackerel; and recommends that the Council adopt the reference points specified in Table 3 until substantial new information warrants revision.

OFL = 130,000 mt * 0.30 = 39,000 mt

ABC = 39,000 mt * 0.25 = 9,750 mt.

Table 3. OFL and ABC of monitored stocks

Stock	OFL	ABC	ACL
Jack mackerel	126,000 mt	31,000 mt	Equal to ABC
Northern anchovy, northern subpopulation	39,000 mt	9,750 mt	Equal to ABC
Northern anchovy, central subpopulation	100,000 mt	25,000 mt	Equal to ABC
Market squid	F_{msy} proxy resulting in Egg Esc ≥ 30%	F_{msy} proxy resulting in Egg Esc ≥ 30%	Exempt

Monitored Stock Fishing Seasons
The CPSMT recommends that the regulatory fishing seasons for monitored stocks be:

1. Finfish: Calendar Year
2. Market squid: April 1 to March 31 of the following year

Future work
The CPSMT has learned of a very recent publication by McClatchie et al. (Can. J. Fish. Aquat. Sci. 67: 1782–1790, November 2010), which re-evaluates the stock-recruit and temperature recruit relationships that determine fraction in the current Pacific sardine harvest control rule. This publication indicates that sea-surface temperature data collected from Scripps Pier are no longer a reliable predictor of sardine recruitment success. The CPSMT requests that this publication be reviewed by the SSC in the near future, and that the paper's principal author (Dr. Sam McClatchie, Southwest Fisheries Science Center-La Jolla) be present for the discussion.

The CPSMT recommends that the Council encourage NMFS to continue to fund comprehensive coastwide annual CPS research. The CPSMT continues to believe strongly that coordinated international management of CPS fisheries is essential to avoid the potential for coastwide overfishing. The CPSMT encourages the Council, NMFS, and the State Department to continue working to achieve timely receipt of biological research data from Mexico.

PFMC
11/7/10

Agenda Item I.2.c
Supplemental SSC Report
November 2010

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON
PACIFIC SARDINE STOCK ASSESSMENT AND COASTAL PELAGIC SPECIES
MANAGEMENT MEASURES FOR 2011

The Scientific and Statistical Committee (SSC) reviewed and discussed the assessment and resulting overfishing fishing limits (OFLs) and acceptable biological catches (ABCs) for Pacific sardine, and the OFLs and ABCs for monitored stocks. Mr. Tom Jagielo presented the 2010 aerial survey results. Dr. Kevin Hill, the lead member of the Stock Assessment Team (STAT), presented the results of the sardine stock assessment update. Dr. André Punt provided a summary of the review conducted on October 5-6, 2010 by members of the SSC Coastal Pelagic Species Subcommittee in a joint session with members of the CPS Management Team (CPSMT) and the CPS Advisory Subpanel (CPSAS). Mr. Greg Krutzikowsky presented the CPSMT's analysis and recommendations for OFLs and ABCs for monitored species, focusing on northern subpopulation of Northern anchovy.

The sardine assessment was an update to one that had undergone a full stock assessment review (STAR) in 2009. Updates are appropriate in situations where no alterations to a stock assessment model have occurred, other than to incorporate recent data from sources already used in the full assessment. In this case, the newly incorporated data included updated catch data coastwide, length composition data for all regions except Ensenada, the 2010 spawning stock biomass index (DEPM), and the 2010 aerial survey estimate. In addition, the assessment update included a new estimate of the coefficient of variation (CV) for the 2009 aerial survey, based on a corrected analysis requested by the 2009 STAR Panel.

As specified in the "2009 Terms of Reference for Coastal Pelagic Species Stock Assessment Review Process," the review focused on two central questions: (1) did the assessment carry forward its fundamental structure from a model that was previously reviewed and endorsed by a STAR Panel, and (2) are the new input data and model results sufficiently consistent with previous data and results that the updated assessment can form the basis for Council decision-making. The assessment model presented (denoted "10w" in the assessment document) satisfies the criteria for assessment updates and the SSC recommends adoption of it as the best available science for the management of Pacific sardine in 2011.

The estimated biomass of 537,173 (ages 1+, mt), an F_{MSY} of 0.1985 based on a relationship between temperature and F_{MSY}, and an estimated distribution of 87% of the stock in U.S. waters lead to an OFL (U.S. only) for 2011 of 92,767 mt. The SSC has recommended that scientific uncertainty (σ) be set to the maximum of the CV of the biomass estimate for the most recent year or a default value of 0.36. The model CV for 2010 sardine biomass was 0.31; therefore scientific uncertainty (σ) was set to the default value. The Amendment 13 ABC buffer depends on the probability of overfishing level determined by the Council (P*). The following table shows how the ABC varies according to P*:

Table 1. Allowable Biological Catch estimates for an illustrative range of probability of overfishing (P*) values.

OFL=92,767mt	***P*=0.5***	***P*=0.45***	***P*=0.4***	***P*=0.3***	***P*=0.2***
BUFFER	1.0	0.956	0.913	0.828	0.739
Allowable Biological Catch (ABC, mt)	92,767	88,664	84,681	76,808	68,519

Note: the selected value of P* must be less than 0.5 to assure that the ABC<OFL

The SSC noted a number of aspects of the assessment that the Council may wish to consider when choosing a P* for sardine and setting harvest specifications:

- There is a need to re-evaluate the assumption that selectivity for the aerial survey in the northern region is dome-shaped but the selectivity for the fishery in the same area is asymptotic. Assuming that survey selectivity is asymptotic and that survey catchability (q) is 1.0 leads to a more pessimistic appraisal of stock status. Changing the selectivity pattern for the survey selectivity is, however, outside of the CPS Terms of Reference for assessment updates and should be considered during the next full assessment in fall 2011.
- The estimate of absolute biomass from the assessment is sensitive to how the aerial survey data are included in the assessment.
- All model configurations examined in the assessment indicate a declining trend in abundance over recent years. Due to recent low recruitment, this decline is likely to continue.

The SSC also recommends that the full assessment in 2011 should examine how the CV for the 2009 survey is estimated based on results from the 2010 aerial survey and those of a 2011 aerial survey, if such a survey takes place. In addition, the 2011 assessment should examine the assumption that natural mortality, M, is constant and equal to $0.4 yr^{-1}$.

OFLs and ABCs for Monitored Species

Reference points for monitored CPS stocks are difficult to determine due to limited data to estimate biomass and productivity. The northern subpopulation of the northern anchovy is currently lightly fished, with inconsistent effort, making the time series of catch an unreliable indicator of stock status. The CPSMT compiled all the scientific information on northern anchovy and found only two estimates of biomass: egg and larval production estimates from the 1970s and a recent acoustic survey by researchers at the Southwest Fisheries Science Center. The average of these two estimates is approximately 130,000 mt. Following considerable discussion, the SSC recommended that the OFL be set by multiplying the biomass estimate of 130,000 mt by 0.3, the F_{MSY} value for Pacific mackerel. This was considered appropriate because anchovy are likely to be as productive as Pacific mackerel. With the established uncertainty buffer of 75%, this gives an OFL of 39,000 mt and an ABC of 9,750 mt. These estimates are uncertain because productivity is poorly known, the abundance estimates are dated, and the acoustic survey methodology has yet to be reviewed (see Item I.3). This OFL and ABC should be updated when new biomass estimates or information on productivity become available.

The SSC recommends the OFLs and ABCs developed by the CPSMT advice for the other monitored stocks (Table 2). The OFL and ABC for market squid is the F_{MSY} proxy of $\geq$ 30% egg escapement. Since this a fishing mortality rate, and not an annual catch amount, as required by NMFS guidelines, the SSC requests that the CPSMT provide justification or further analysis showing why it is considered appropriate. In addition, the ABC was set equal to the OFL, which is allowed under NMFS guidelines, but justification or further analysis is required to show why scientific uncertainty does not need to be taken into account when setting the ABC.

The SSC wishes to acknowledge the solid work done by the CPSMT and the Pacific Sardine Assessment Team.

Table 2. OFL and ABC for CPS Monitored species in U.S. waters.

Stock	OFL	ABC
Jack Mackerel	126,000 mt	31,000 mt
Northern Anchovy, Central Population	100,000 mt	25,000 mt
Market Squid	F_{MSY} proxy resulting in Egg Esc $\geq$ 30%	F_{MSY} proxy resulting in Egg Esc $\geq$ 30%
Northern Anchovy, Northern Population	39,000 mt	9,750 mt

PFMC
11/06/10

Agenda Item I.2.d
Public Comment
November 2010

NATIONAL COALITION FOR MARINE CONSERVATION
4 Royal Street, S.E., Leesburg, VA 20175

October 15, 2010

Mark Cedergreen, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, OR 97220

RE: Maintaining Pacific Sardine Biomass Above the B_{MSY} Level

Dear Council Members,

Throughout development of Amendment 13 to the Coastal Pelagic Species (CPS) Fishery Management Plan, the National Coalition for Marine Conservation (NCMC) has consistently recommended evaluating the CPS harvest control rules for actively managed species as to how well they achieve the goal of maintaining adequate forage (prey) for the ecosystem (predators including many piscivorous fish, seabirds and marine mammals). And throughout this process, the council has maintained that CPS, notably Pacific sardine, are conservatively managed with respect to ecological considerations.

To support this assertion, Amendment 13 as approved by the council in June features an expanded analysis of the purpose and intent of the sardine harvest control rule (taken from the 2009 SAFE Report), explaining that it seeks "to maintain the sardine stock biomass at levels well above those of a single species MSY-based management strategy" and that the primary focus is on biomass, rather than catch, because CPS are very important to the ecosystem as forage.[1]

[1] CPS SAFE Report June 2009, p. 15

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The assumption, then, is that if the inputs are conservative, so then will be the outputs. But in reviewing how the sardine HCR has performed compared to an MSY-based strategy since it was implemented in 2000, we find that it has fallen considerably short of its conservative goal; a goal that was reinforced by the 2009 NMFS National Standard 1 Guidelines which recommend that, in order "to maintain adequate forage for all components of the ecosystem", forage fish populations should be maintained above the B_{MSY} level.[2]

According to the stochastic simulations done by Dr. Richard Parrish in helping the council select the basis for the current sardine HCR from among a range of options, the MSY biomass was estimated to be 1,408,000 MT. As Amendment 13 reiterates, the HCR was chosen to achieve a long-term average biomass significantly above this level.

But according to Amendment 13, Table 4.3.1-4, the average sardine biomass from 2000-2010 – the biomass taken from stock assessments and used in the harvest guidelines – was 1,056,678 MT. That's well below the MSY biomass level. Either the HCR is not performing as intended, or the simulations used to select the harvest control rule were not realistic and should be recalculated. If the council agrees that recalculations are necessary, this should be made a priority and done through the Environmental Assessment that supports implementation of Amendment 13.

In the interim, the council should utilize the precaution built into the revised HCR approved in Amendment 13, which now contains a buffer for scientific uncertainty in setting the allowable biological catch (ABC), with that uncertainty primarily being around the estimate of biomass[3]. The amendment also specifies that the council should include ecological considerations when reviewing and/or adopting ABCs and ACLs.

If the sardine control rule has not been effectively maintaining biomass "at levels well above those of a single species MSY-based management strategy," as is the intent of Amendment 13 and is now national policy for forage fish, the council should:

a) Ensure that the uncertainty buffer used in setting the ABC is sufficient to ensure adequate biomass is maintained, above the MSY level; or,

---

[2] 50 CFR § 600.310(e)(3)(iv)(C)

[3] The formula generally uses the estimated biomass for the whole stock in one year (BIOMASS) to set harvest for the whole stock in the following year (H) although projections or estimates of BIOMASS, abundance index values or other data might be used instead. BIOMASS is an estimate only, it is never assumed that BIOMASS is a perfect measure of abundance. Efforts to develop a harvest formula must consider probable levels of measurement error in BIOMASS, which typically have coefficient of variations of about 50% for CPS. CPS SAFE Report June 2009 p. 16-17

b) Reduce the annual catch limit (ACL) sufficiently below the ABC level to achieve this goal.

We will be attending the November CPS meetings and look forward to learning the council's intent at that time.

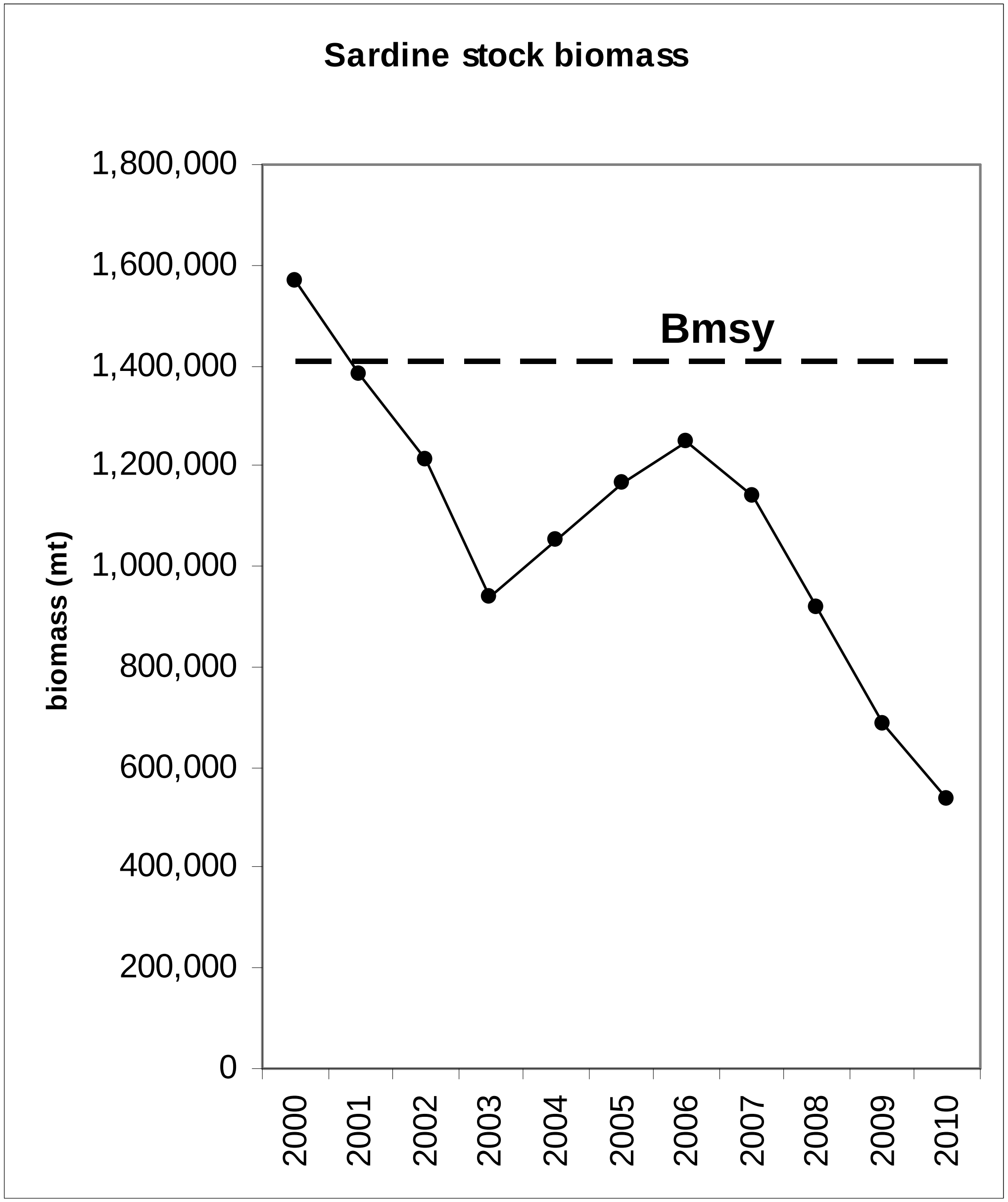
Sincerely,

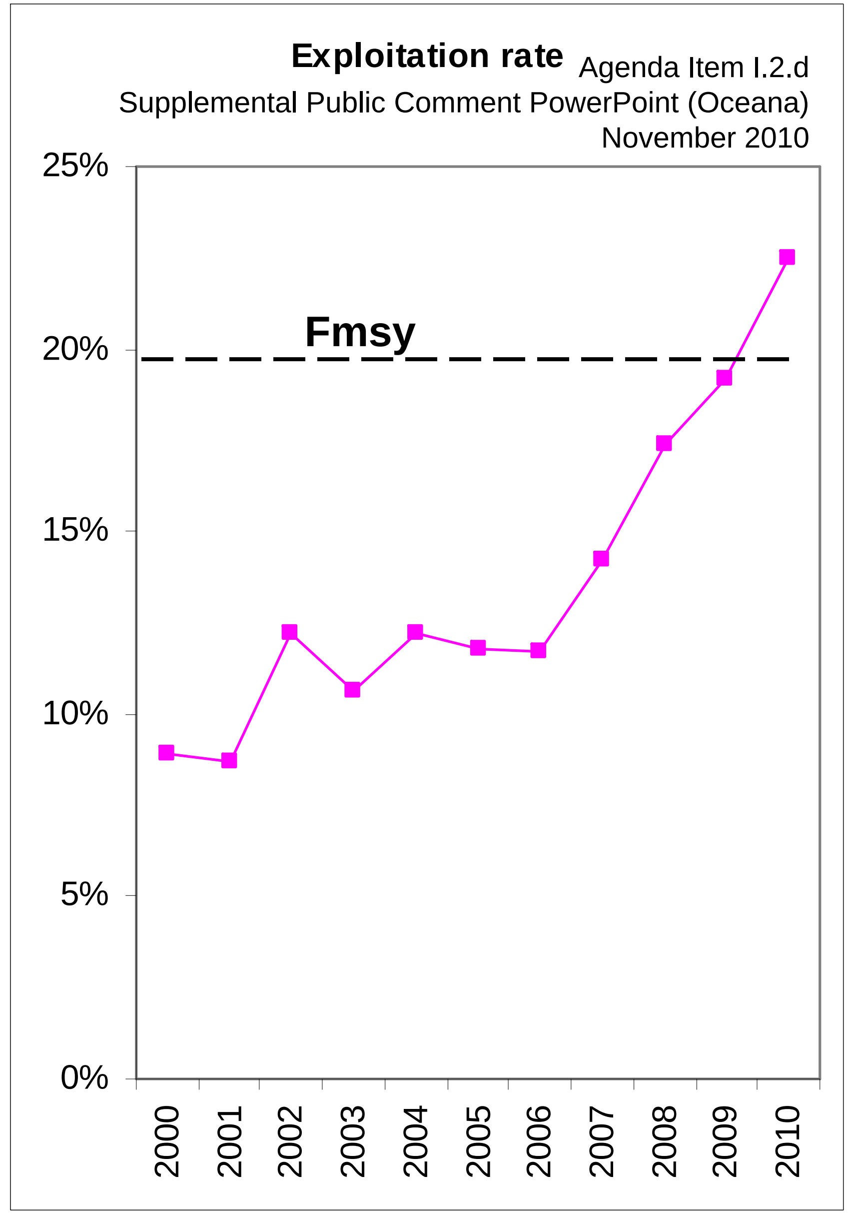
Ken Hinman

Ken Hinman
President

cc: Don McIsaac
Kerry Griffin
Mike Burner
Greg Krutzikowsky

Agenda Item I.2.d
Supplemental Public Comment PowerPoint (Oceana)
November 2010





Data from: Assessment of the Pacific Sardine Resource in 2010 for US Management in 2011 (Executive Summary). Agenda Item I.2.b Attachment 2

Agenda Item I.3
Situation Summary
November 2010

TERMS OF REFERENCE FOR STOCK ASSESSMENT AND METHODOLOGY REVIEW PANELS

Full assessments for Pacific sardine and Pacific mackerel typically occur every third year, although since 2007 they have occurred on a two-year cycle. Full assessments trigger the Coastal Pelagic Species (CPS) Stock Assessment Review (STAR) process. If entirely new, structurally changed or significantly revised assessments are developed in a full assessment, a STAR Panel must be convened to review the assessment prior to its use for setting harvest guidelines. Full stock assessment reports are developed and distributed following each STAR Panel review. Updated assessments are conducted during interim years and involve a less formal review process. Full assessments for Pacific sardine and Pacific mackerel are planned for 2011.

In addition, there are new surveys that have been proposed for inclusion in the next full assessment of Pacific sardine, including acoustic data from the Southwest Fisheries Science Center (SWFSC) coastwide surveys conducted during 2006, 2008, and 2010. New sources of information warrant a methodology review to discuss potential improvements in the survey designs and ways the data could be treated for inclusion in the 2011 full assessments.

To guide and coordinate stock assessment authors and reviewers, two draft documents were developed by the Scientific and Statistical Committee (SSC), with review by Council staff and the Coastal Pelagic Species Management Team (CPSMT). These are 1) the draft (revised from the 2009 version) *Terms of Reference for a Coastal Pelagic Species Stock Assessment Review Process* (Agenda Item J.1.a, Attachment 1); and 2) the draft *Terms of Reference for Coastal Pelagic Species Stock Assessment Methodology Review* (Agenda Item J.1.a, Attachment 2).

The Council considered these two draft documents at its September 2010 meeting, including comments by the Scientific and Statistical Committee (SSC), CPSMT, and Coastal Pelagic Species Advisory Subpanel (CPSAS). The Council directed staff to make changes to the TORs where there was agreement, and to work together at the November Council meeting to reconcile any remaining points of disagreement. Agenda Items I.3.a Attachment 1 and Attachment 2 incorporate Council direction from September 2010. Remaining points of disagreement are anticipated to be resolved, and will be reflected in supplemental statements by the SSC and the CPSMT.

The Council also directed staff to compile a list of proposed methods for review, based on suggestions from CPS advisory bodies, management entities, the SSC, and any interested parties; and submit those for consideration by the SSC for final approval at the November Council meeting. Four proposals were submitted (Agenda Item I.3.c, public comment), although two of the proposals (to use satellite imagery in conjunction with aerial photos and point sets) should be considered as a single proposal. The methodologies to be considered are 1) use of satellite imagery, 2) acoustic trawl surveys, and 3) LIDAR coupled with aerial photography.

Council Action:

1. Approve the Terms of Reference for Stock Assessment and Methodology Review Panels.

2. Approve CPS Stock Survey Methods to be Considered by the Methodology Review Panel.

Reference Materials:

1. Agenda Item I.3.a, Attachment 1: Draft Terms of Reference for a Coastal Pelagic Species Stock Assessment Review Process.
2. Agenda Item I.3.a, Attachment 2: Draft Terms of Reference for Coastal Pelagic Species Stock Assessment Methodology Review.
3. Agenda Item I.3.b, Supplemental SSC Report.
4. Agenda Item I.3.b, Supplemental CPSMT Report.
5. Agenda Item I.3.c, Public Comment.

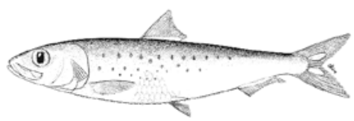
Agenda Order:

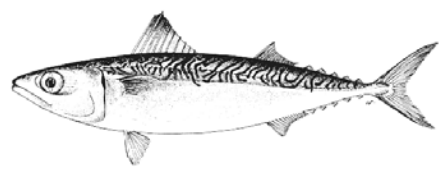
a. Agenda Item Overview **Kerry Griffin**
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. **Council Action**: Approve the Final Terms of Reference for Stock Assessment and Methodology Review Panels

PFMC
10/18/10

Agenda Item I.3.a
Attachment 1
November 2010

TERMS OF REFERENCE
FOR A
COASTAL PELAGIC SPECIES
STOCK ASSESSMENT REVIEW PROCESS





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NOVEMBER 2010

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TERMS OF REFERENCE FOR A COASTAL PELAGIC SPECIES
STOCK ASSESSMENT REVIEW PROCESS

November 2010

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Introduction

The purpose of this document is to outline the guidelines and procedures for the Pacific Fishery Management Council's (Council) coastal pelagic species (CPS) stock assessment review (STAR) process and to clarify expectations and responsibilities of the various participants. The STAR process has been designed to establish a procedure for peer review as referenced in the 2006 Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA), which states that "the Secretary and each Regional Fishery Management Council may establish a peer review process for that Regional Fishery Management Council for scientific information used to advise the Regional Fishery Management Council about the conservation and management of the fishery" (see MSRA 302(g)(1)(E)). If a peer review process is established, it should investigate the technical merits of stock assessments and other scientific information used by the Council's Scientific and Statistical Committee (SSC). The peer review process is not a substitute for the SSC and should work in conjunction with the SSC. This document will be included in the Council's Statement of Organization, Practices and Procedures as documentation of the review process that will underpin the scientific advice from the SSC.

Parties involved in implementing the peer review process described here are the Council members; Council staff; members of Council Advisory Bodies, including the SSC, the Coastal Pelagic Species Management Team (CPSMT), and the Coastal Pelagic Species Advisory Subpanel (CPSAS); the National Marine Fisheries Service (NMFS); state agencies; and interested persons. The STAR process is a key element in an overall process designed to review the technical merits of stock assessments and other relevant scientific information used by the SSC. This process will allow the Council to make timely use of new fishery and survey data, analyze and understand these data as completely as possible, provide opportunity for public comment, assure that the results are as accurate and error-free as possible, and provide the best available science for management decisions.

This current edition of the terms of reference reflects many recommendations from previous participants in the STAR process, including STAR Panel members, SSC members, stock assessment teams (STATs), Council staff, and Council advisory groups. Nevertheless, no set of guidelines can be expected to deal with every contingency, and all participants should anticipate the need to be flexible and address new issues as they arise.

Stock assessments for Pacific sardine and Pacific mackerel are typically conducted annually to assess the abundance, trends, and appropriate harvest levels for these species[1]. Assessments[2] use statistical population models to simultaneously analyze and integrate a combination of survey, fishery, and biological data. Since 2004, the CPS assessments have undergone an assessment cycle and peer

---

1/ Stock assessments are conducted for species "actively" managed under the Coastal Pelagic Species Fishery Management Plan (FMP). That is, fisheries for Pacific sardine and Pacific mackerel are actively managed via annual harvest guidelines and management specifications, which are based on current stock assessment information.

2/ In this document, the term "stock assessment" includes activities, analyses and reports, beginning with data collection and continuing through to scientific recommendations presented to the Council and its advisors. Stock assessments provide the fundamental basis for management decisions on CPS harvests. To best serve that purpose, stock assessments should attempt to identify and quantify major uncertainties, balance realism and parsimony, and make best use of the available data.

review process. There are two distinct types of assessments which are subject to different review procedures. “Full assessments” involve a re-examination of the underlying assumptions, data, and model parameters used to assess the stock, while “update assessments” maintain the model structure of the previous full assessment and are generally restricted to the addition of new data that have become available since the last assessment.

Full assessments for Pacific sardine and Pacific mackerel typically occur every third year, necessitating a three-year STAR Panel cycle. If entirely new, structurally changed or significantly revised assessments are developed, a STAR Panel must be convened to review the assessment prior to its use for setting Overfishing Limits (OFLs), Acceptable Biological Catches (ABCs), Harvest Guidelines (HGs), Annual Catch Limits (ACLs), and Annual Catch Targets (ACTs). Recommendations regarding OFLs and ABCs are an SSC responsibility. The Council identifies the risk policy that factors into setting ABC, and selects ACLs and ACTs given the HGs, ABCs and advice from its advisory bodies. Full stock assessment reports are developed and distributed following each STAR Panel review. Updated assessments are conducted during interim years and involve a less intensive review by the CPSMT and the SSC. Details from interim-year assessments are documented in executive summaries.

STAR Goals and Objectives

The goals and objectives for the CPS assessment and review process are to:

1. Ensure that CPS stock assessments are the "best available" scientific information and facilitate the use of this information by the Council. In particular, provide information that will allow the Council to adopt OFLs, ABCs, ACLs and ACTs.
2. Meet the Magnuson-Stevens Fisheries Conservation and Management Act (MSA) and other legal requirements.
3. Follow a detailed calendar and explicit responsibilities for all participants to produce required outcomes and reports.
4. Provide an independent external review of CPS stock assessments.
5. Increase understanding and acceptance of CPS stock assessments and peer reviews by all members of the Council family.
6. Identify research needed to improve assessments, reviews, and fishery management in the future.
7. Use assessment and review resources effectively and efficiently.

Responsibilities

Shared Responsibilities

All parties have a stake in ensuring adequate technical review of stock assessments. NMFS, as the designee of the Secretary of Commerce, must determine that the best scientific advice has been used when it approves fishery management recommendations made by the Council. The Council uses statements from the SSC to determine whether the information on which it will base its recommendation is the "best available" science. Fishery managers and scientists providing technical documents to the Council for use in management need to ensure the work is technically correct.

Program reviews, in-depth external reviews, and peer-reviewed scientific publications are used by federal and state agencies to provide quality assurance for the basic scientific methods used to produce stock assessments. However, the time-frame for this sort of review is not suited to the routine examination of assessments that are, generally, the primary basis for harvest recommendations. The review of current stock assessments requires a routine, dedicated effort that simultaneously meets the needs of NMFS, the Council, and others. Leadership, in the context of the stock assessment review process for CPS means consulting with all interested parties to plan, prepare terms of reference, and develop a calendar of events and a list of deliverables. Coordination means organizing and carrying out review meetings, distributing documents in a timely fashion, and making sure that assessments and reviews are completed according to plan. Leadership and coordination involve costs, both monetary and time, which have not been calculated, but are likely substantial.

The Council, NMFS, and the Secretary of Commerce share primary responsibility to create and foster a successful STAR process. The Council will oversee the process and involve its standing advisory committees, especially the SSC. The chair of the SSC CPS subcommittee will coordinate, oversee, and facilitate the process. Together NMFS and the Council will consult with all interested parties to plan, prepare terms of reference, and develop a calendar of events and a list of deliverables for final approval by the Council. NMFS and the Council will share fiscal and logistical responsibilities and both parties should ensure that there are no conflicts of interest in the process[3].

The CPS STAR process is sponsored by the Council, because the Federal Advisory Committee Act (FACA) limits the ability of NMFS to establish advisory committees. FACA specifies a procedure for convening advisory committees that provide consensus recommendations to the federal government. The intent of FACA was three-fold: to limit the number of advisory committees; to ensure that advisory committees fairly represent affected parties; and to ensure that advisory committee meetings, discussions, and reports are carried out and prepared in full public view. Under FACA, advisory committees must be chartered by the Department of Commerce through a rather cumbersome process. However, the Sustainable Fisheries Act exempts the Council from FACA per se, but requires public notice and open meetings similar to those under FACA.

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3 The proposed NS2 guidelines state: "Peer reviewers who are federal employees must comply with all applicable federal ethics requirements. Peer reviewers who are not federal employees must comply with the following provisions. Peer reviewers must not have any real or perceived conflicts of interest with the scientific information, subject matter, or work product under review, or any aspect of the statement of work for the peer review. For purposes of this section, a conflict of interest is any financial or other interest which conflicts with the service of the individual on a review panel because it: (A) Could significantly impair the reviewer's objectivity; or (B) Could create an unfair competitive advantage for a person or organization. (C) Except for those situations in which a conflict of interest is unavoidable, and the conflict is promptly and publicly disclosed, no individual can be appointed to a review panel if that individual has a conflict of interest that is relevant to the functions to be performed. Conflicts of interest include, but are not limited to, the personal financial interests and investments, employer affiliations, and consulting arrangements, grants, or contracts of the individual and of others with whom the individual has substantial common financial interests, if these interests are relevant to the functions to be performed. Potential reviewers must be screened for conflicts of interest in accordance with the procedures set forth in the NOAA Policy on Conflicts of Interest for Peer Review subject to OMB's Peer Review Bulletin."

CPS STAR Coordination (Full Assessments)

The SSC CPS subcommittee chair will work with the Council, Council staff, other agencies, and groups or interested persons that carry out assessment work to coordinate and organize STATs, STAR Panels, and reviews of assessment updates. The objective is to make sure that work is carried out in a timely fashion according to the calendar and terms of reference.

The SSC CPS Subcommittee chair, in consultation with the SSC and the NMFS Southwest Fisheries Science Center (SWFSC), will coordinate the selection (including number) of external reviewers. Criteria for reviewer qualifications, nomination, and selection will be established by the SWFSC in consultation with the SSC, and will be based principally on a candidate's knowledge of stock assessment science and methods, preferably with CPS. Expertise in the ecological role of CPS in the California Current is also desirable for reviewers. The public is welcome to nominate qualified reviewers. The majority of panelists should be experienced stock assessment scientists, i.e., individuals who have conducted stock assessments using current methods (generally statistical age- and or length-structured assessment models). It is, however, recognized that the pool of qualified reviewers is limited, and that staffing of STAR Panels is subject to constraints that may make it difficult to achieve the ideal, and some diversity of expertise may be desirable.

Following any modifications to the stock assessments resulting from STAR Panel reviews and prior to distribution of stock assessment documents and STAR Panel reports, the SSC CPS subcommittee chair will ensure that the stock assessments and Panel reports are reviewed for consistency with the terms of reference, especially completeness. If inconsistencies are identified, authors will be requested to make appropriate revisions in time to meet the deadline for distributing documents for the CPSMT meeting at which ACL and ACT recommendations are developed.

Individuals (employed by NMFS, state agencies, or other entities) that conduct assessments or technical work in connection with CPS stock assessments are responsible for ensuring their work is technically sound, complete, and delivered in a timely manner. The Council's review process is the principal means for review of complete stock assessments, although additional in-depth technical review of data utilized in the stock assessment and the methods utilized to collect those data is desirable. Stock assessments must be completed and reviewed in full accordance with the terms of reference (Appendices A and B).

CPSMT Responsibilities

The CPSMT is responsible for identifying and evaluating potential management actions based on the best available scientific information. In particular, the CPSMT makes ACL and ACT recommendations to the Council based on OFL, ABC and HG control rules. The CPSMT will use stock assessments, STAR Panel reports, and other information, including ecological factors, in making their ACL, ACT, or HG recommendations. Preliminary ACL and ACT recommendations will be developed by the CPSMT according to the management process defined in the CPS Fishery Management Plan and Council Operating Procedures.

A representative of the CPSMT will be appointed by the CPSMT chair and will serve as a liaison to each assessment update review meeting (in most cases, the entire CPSMT participates in assessment update reviews) or full assessment STAR Panel, and will participate in review discussions. The

CPSMT representative will not serve as a member of a STAR Panel. The CPSMT representative should be prepared to advise the STAT and STAR Panel on changes in fishing regulations or practices that may influence data used in the assessment and the nature of the fishery in the future. The CPSMT will not seek revision or additional review of stock assessments after they have been reviewed by a STAR Panel. However, the CPSMT can request additional model projections in order to develop a full evaluation of potential management actions. The CPSMT chair will communicate any unresolved issues to the SSC for consideration. Successful separation of scientific (i.e., STATs and STAR Panels) from management (i.e., CPSMT) work depends on completion of stock assessment documents and STAR reviews prior to the time the CPSMT meets to discuss preliminary ACL and ACT levels.

CPSAS Responsibilities

It is the responsibility of the CPSAS representative to ensure that CPSAS concerns regarding the adequacy of data being used by the STAT are expressed at an early stage in the process. The chair of the CPSAS will appoint a representative to track each assessment and participate at the assessment update review meeting or STAR Panel meeting. The CPSAS representative will serve as an advisor to the STAT and STAR Panel. It is especially important that the CPSAS representative be included in the STAT's discussion and review of all the data sources being used in the assessment, prior to development of the stock assessment model. This coordination should first occur via telephone or email. Council-funded travel for coordination between the STAT and the CPSAS representative requires advanced approval by the Council or the Council Executive Director. The CPSAS representative will participate in review discussions as an advisor to the STAR Panel, in the same capacity as the CPSMT advisor. The CPSAS representative may provide appropriate data and advice to the assessment update review meeting, STAR Panel, and CPSMT, and will report to the CPSAS on STAR Panel and other meeting proceedings.

The CPSAS representative will attend the CPSMT meeting at which preliminary ACL and ACT recommendations are developed. The CPSAS representative will also attend subsequent CPSMT, Council, and other necessary meetings.

SSC Responsibilities

The SSC will participate in the stock assessment review process and provide the CPSMT and Council with technical advice related to stock assessments and the review process. The SSC is also responsible for making OFL and ABC recommendations to the CPSMT and the Council.

The SSC will assign at least two (ideally three) members from its CPS subcommittee to each assessment update review meeting. The SSC representatives at the review meeting will prepare a meeting summary and present it to the full SSC at its next regular meeting. The SSC will review any additional analytical work required or carried out by the CPSMT after the stock assessments have been reviewed at the update review meeting.

The SSC will assign at least one member from its CPS subcommittee to each STAR Panel for reviewing full assessments. This member will chair the STAR Panel and will be expected to attend the assigned STAR Panel meeting, the CPSMT meeting at which ACL, and ACT recommendations are made, and the Council meetings when the STAR Panel reviewed stock assessment is discussed.

The SSC will review the outcomes of additional analytical work (e.g. additional projections using the agreed base model) requested by the CPSMT after the stock assessments have been reviewed by the STAR Panels.

The SSC, during their normally scheduled meetings, will serve as arbitrator to resolve disagreements between the STAT and,the STAR Panel.. The STAT and the STAR Panel (CPS subcommittee in the case of update reviews) may disagree on technical issues regarding an assessment. Estimates and projections representing all sides of the disagreement need to be presented, reviewed, and commented on by the SSC.

Council Staff Responsibilities

A Council staff officer will be assigned to coordinate, monitor and document the STAR process. The Council staff officer will be responsible for timely issuance of meeting notices and distribution of stock assessment documents, stock summaries, meeting minutes, and other appropriate documents. The Council staff officer will monitor compliance with the most recent version of the terms of reference for the CPS STAR process adopted by the Council. The Council staff officer will coordinate materials and presentations for Council meetings relevant to final Council adoption of CPS stock assessments. Council staff will also collect and maintain file copies of reports from each STAR Panel (containing items specified in the STAR Panel terms of reference), the outline for CPS stock assessment documents, Scientific and Statistical Committee (SSC), Coastal Pelagic Species Management Team (CPSMT), and Coastal Pelagic Species Advisory Subpanel (CPSAS) comments and reports, letters from the public, and any other relevant information. At a minimum, the stock assessments (assessment documents, STAR Panel reports, and stock summaries) should be published and distributed in the Council annual stock assessment and fishery evaluation (SAFE) document.

A primary role for the Council staff officer assigned to the STAR process will be to monitor STAR Panel and SSC activities to ensure compliance with these terms of reference. The Council staff officer will attend all STAR Panels to ensure continuity and adherence to these terms of reference. The Council staff officer will identify inconsistencies with the terms of reference that occur during STAR Panels and work with the STAR Panel chair to develop solutions and to correct them. The Council staff officer will coordinate with the STAR Panel chair and the NMFS in a review of STAT documents to assure they are received on time, are consistent with the terms of reference, and are complete. The Council staff officer will review the Executive Summary for consistency with the terms of reference. If the STAT materials are not in compliance with the terms of reference, the Council staff officer will return the materials to STAT with either a list of deficiencies, a notice that the deadline has expired, or both. Inconsistencies will be identified and the authors requested to make appropriate revisions in time for the appropriate SSC, CPSMT, and CPSAS meetings, when an assessment is considered. The Council staff officer will also coordinate and monitor SSC review of stock assessments and STAR Panel reports to ensure compliance with these terms of reference and the independent review requirements of Council Operating Procedure 4 (roles, responsibilities, and functions of the SSC).

National Marine Fisheries Service Responsibilities

NMFS Southwest Fisheries Science Center (SWFSC) will provide staff to work with the Council, other agencies, groups, or interested persons that carry out assessment work to assist in organizing the STAT and STAR Panels. Since most assessments are conducted by NMFS STATs, the SWFSC will work with STATs to develop a draft list of assessments to be considered by the Council. The SWFSC also will develop a draft STAR Panel schedule for review by the Council. The SWFSC will identify independent STAR panelists following criteria for reviewer qualifications. The costs associated with these reviewers will be borne by NMFS. The SWFSC will coordinate with the STATs to facilitate delivery of materials by scheduled deadlines and in compliance with other requirements of these terms of reference, to the extent possible and with the assistance of the assigned Council staff officer and the STAR Panel chair.

Following any modifications to the stock assessments resulting from STAR Panel reviews and prior to SSC review, the SWFSC will assist the Council staff officer in reviewing the Executive Summary for consistency with the terms of reference. The STAT will be requested to make appropriate revisions in time for the appropriate SSC, CPSMT, and CPSAS meetings when inconsistencies are identified.

Terms of Reference for STAR Panels and Meetings (Full Assessments)

The objective of the STAR Panel is to complete a detailed evaluation of a stock assessment to advance the best available scientific information to the Council. The responsibilities of the STAR panel include:

1. review draft stock assessment documents, data inputs, and analytical models along with other pertinent information (e.g., previous assessments and STAR Panel reports, when available);
2. discuss the technical merits and deficiencies of the input data and analytical models during the Panel meeting and work with the STATs to correct deficiencies;
3. document meeting discussions; and
4. provide complete STAR Panel reports for all reviewed species.

The STAR Panel chair has, in addition, the responsibility to:

5. review revised stock assessment documents and STAR Panel reports before they are forwarded to the SSC.

CPS STAR Panels normally include a chair (who is a member of the SSC CPS subcommittee), at least one "external" member (i.e., outside the Council family and not involved in management or assessment of West Coast CPS, typically designated by the Center for Independent Experts [CIE]), and two additional members. The total number of STAR Panel members should be at least "n+3" where n is the number of stock assessments. Selection of STAR panelists should aim for balance between outside expertise, in-depth knowledge of CPS fisheries, data sets available for those fisheries, and modeling approaches applied to CPS. Expertise in ecosystem models and the role of CPS in the ecosystem may also be desirable. Reviewers should not have financial or personal conflicts of interest, either current to the meeting, within the previous year (at minimum), or anticipated. The majority of panelists should be experienced stock assessment scientists (i.e., individuals who have done stock assessments using current methods). STAR panelists should be knowledgeable about the specific modeling approaches being reviewed, which in most cases will be statistical age- and/or length-structured assessment models. In addition to Panel members, STAR meetings will include CPSMT and CPSAS advisory representatives with responsibilities as laid out in their terms of reference and a Council staff member to help advise the STAR Panel and assist in recording meeting discussions and results.

STAR Panels normally meet for one week. The number of assessments reviewed per Panel should not exceed two. Contested assessments, in which alternative assessments are brought forward by competing STATs using different modeling approaches, will typically require additional time (and/or panel members) to review adequately, and should be scheduled accordingly. While contested assessments are likely to be rare, they can be accommodated in the STAR Panel review process. STAR Panels should thoroughly evaluate each analytical approach, comment on the relative merits of each, and, when conflicting results are obtained, identify the reasons for the differences. STAR Panels are charged with selecting a preferred base model, which will be more difficult when there are several modeling approaches from which to choose.

The STAR Panel chair is responsible for: 1) developing an agenda, 2) ensuring that STAR Panel members and STATs follow the terms of reference, 3) participating in the review of the assessment, 4) guiding the STAR Panel and STAT to mutually agreeable solutions, 5) coordinating review of final assessment documents, and 6) providing Council staff with a camera ready and suitable electronic version of the Panel's report for inclusion in the annual SAFE report. The STAR Panel, STAT, the CPSMT and CPSAS representatives, and the public are legitimate meeting participants that should be accommodated in discussions. It is the STAR Panel chair's responsibility to manage discussions and public comment so that work can be completed.

The STAR Panel is responsible for determining if a stock assessment document is sufficiently complete according to Appendix A. It is the Panel's responsibility to identify assessments that cannot be reviewed or completed for any reason. The Panel's decision that an assessment is complete should be made by consensus. If a Panel cannot reach agreement, then the nature of the disagreement must be described in the Panel's report.

The STAR Panel's terms of reference solely concern technical aspects of stock assessment work. It is therefore important that the Panel strive for a risk neutral perspective in its reports and deliberations. Assessment results based on model scenarios or data that have a flawed technical basis, or are questionable on other grounds, should be identified by the Panel and excluded from consideration in developing management advice. It is recognized that no model scenario or data set will be perfect or issue free. Therefore, a broad range of results should be reported to better define the scope of the accepted model results. The STAR Panel should comment on the degree to which the accepted model describes and quantifies the major sources of uncertainty. Confidence intervals of indices and model outputs, as well as other measures of uncertainty that could affect management decisions, should be provided in completed stock assessments and the reports prepared by STAR Panels. The STAR Panel may also provide qualitative comments on the probability of various model results, especially if the Panel does not think that the probability distributions calculated by the STAT capture all major sources of uncertainty. However, as a scientific peer review body, the STAR Panel should avoid matters of policy.

Recommendations and requests to the STAT for additional or revised analyses must be clear, explicit, and in writing. STAR Panel recommendations and requests to the STAT should reflect the consensus opinion of the entire Panel and not the minority view of a single individual or individuals on the Panel. A written summary of discussion on significant technical points and lists of all STAR Panel requests and recommendations and requests to the STAT are required in the STAR Panel's report, which should be completed (at least in draft form) prior to the end of the Panel meeting. It is the chair and Panel's responsibility to carry out any follow-up review of work that is required.

The STAR Panel's primary duty is to conduct a peer review of an assessment that is presented by a STAT; STAR Panel meetings are not workshops. In the course of this review, the Panel may ask for a reasonable number of additional runs, additional details of existing assessments, or similar items from the STAT. It would not be unusual for this evaluation to result in a change to the initial base model, provided both the STAR Panel and the STAT agree that the change(s) lead to a better assessment. STAR Panels are expected to be judicious in their requests of the STATs, recognizing that some issues uncovered during review are best flagged as research priorities, and dealt with more effectively and comprehensively between assessments. The STAR Panel may also request additional analysis based on an alternative approach. However, the STAR Panel is not authorized to conduct an alternative assessment representing its own views that are distinct from those of the STAT, nor can it impose an alternative assessment on the STAT. Similarly, the Panel should not require their preferred methodologies when such is a matter of professional opinion. Rather, if the Panel finds that an assessment is inadequate, it should document and report that opinion and, in addition, suggest remedial measures that could be taken by the STAT to rectify whatever perceived shortcomings may exist.

Large changes in data (such as wholesale removal of large data sets) or analytical methods recommended by the STAR Panel, even if accepted by the STAT, will often result in such great changes to the assessment that it cannot adequately be reviewed during the course of the STAR Panel meeting. Therefore caution should be exercised in making such changes, and in many cases those changes should be relegated to future research recommendations. If the STAR Panel feels the changes are necessary and the assessment is not otherwise acceptable, it may decide to recommend that the last reviewed model be used for management purposes until the necessary work (which could be reviewed during a methodology review or a regularly scheduled SSC meeting) is complete. Similarly, if the STAR Panel believes that the results of the stock assessment strongly indicate the need to review a current control rule or one of its parameters, it should identify further analysis needed to support a change, in its report.

STATs and STAR Panels are required to make an honest attempt to resolve any areas of disagreement during the review meeting. Occasionally, fundamental differences of opinion remain between the STAR Panel and STAT that cannot be resolved by discussion. In such cases, the STAR Panel must document the areas of disagreement in its report. In exceptional circumstances, the STAT may choose to submit a supplemental report supporting its view, but in the event that such a step is taken, an opportunity must be given to the STAR Panel to prepare a rebuttal. These documents will then be appended to STAR Panel report as part of the record of the review meeting. STAR Panel members may have fundamental disagreements that cannot be resolved during the STAR Panel meeting. In such cases, STAR Panel members may prepare a minority report that will become part of the record of the review meeting. The SSC will then review all information pertaining to STAR Panel or STAR Panel/STAT disputes, and issue its recommendations, which may include recommendations for issues to be addressed during the next full assessment. SSC members involved during the STAR

Panel as reviewers or assessment authors will recuse themselves when the SSC draws conclusions regarding minority reports.

Additional analyses required by the STAR Panel should be completed by the STAT during the STAR Panel meeting. It is the obligation of the STAR Panel chair, in consultation with other panel members, to prioritize requests for additional analyses and make the requests as explicit as possible. Moreover, in situations where a STAT arrives with a well-considered, thorough assessment, it may be that the Panel can conclude its review early (i.e., early dismissal of a STAT is an option for well-constructed assessments). If follow-up work by the STAT is required after the review meeting, then it is the Panel's responsibility to track STAT progress. In particular, the chair is responsible for communicating with the STAT (by phone, e-mail, or any convenient means) to determine if the revised stock assessment and documents are complete and ready to be used by managers. If stock assessments and reviews are not complete at the end of the STAR Panel meeting, then the work must be completed a week prior to the CPSMT meeting where the assessments and preliminary ACL and ACT levels are discussed. Any post-STAR drafts of the stock assessment must be reviewed by the STAR Panel or the chair if delegated that authority by the STAR Panel. Assessments cannot be given to Council staff for distribution unless they are endorsed by the STAR Panel chair and accompanied by a complete and approved STAR Panel report. Likewise, the final draft that is published in the Council's SAFE document must also be approved by the STAR Panel chair prior to being accepted by Council staff.

Suggested Template for STAR Panel Report

- Summary of the STAR Panel meeting, containing:
  - names and affiliations of STAR Panel members;
  - list of analyses requested by the STAR Panel, the rationale for each request, and a brief summary the STAT responses to each request; and
  - description of base model.
- Comments on the technical merits and/or deficiencies in the assessment and recommendations for remedies.
- Areas of disagreement regarding STAR Panel recommendations:
  - among STAR Panel members (including concerns raised by the CPSMT and CPSAS representatives), and
  - between the STAR Panel and STAT(s).
- Unresolved problems and major uncertainties, e.g., any special issues that complicate scientific assessment, questions about the best model scenario.
- Management, data or fishery issues raised during the STAR Panel by the public, the CPSMT and/or the CPSAS representatives.
- Prioritized recommendations for future research and data collection.

Terms of Reference for CPS STATs

The STAT will carry out its work according to these terms of reference for full assessments.

Each STAT will appoint a representative to coordinate work with the STAR Panel and attend the

STAR Panel meeting.

The STAT shall include in both the STAR Panel draft and final assessment all data sources that include the species being assessed, identify which are used in the assessment, and provide the rationale for data sources that are excluded. The STAT is obliged to keep the CPSAS representative informed of the specific data being used in the stock assessment. The STAT is expected to initiate contact with the CPSAS representative at an early stage in the process, and to be prepared to respond to concerns about the data that might be raised. The STAT should also contact the CPSMT representative for information about changes in fishing regulations that may influence data used in the assessment.

Each STAT will appoint a representative who will attend the CPSMT, CPSAS, and Council meetings where preliminary harvest levels are discussed. In addition, a representative of the STAT should attend the CPSMT and Council meeting where final ACL and ACT recommendations are developed, if requested or necessary. At these meetings, the STAT member shall be available to give a presentation of the assessment and answer questions about the STAT report.

The STAT is responsible for preparing three versions of the stock assessment document:

1) a "draft", including an executive summary, for discussion at the STAR Panel meeting;
2) a “revised draft" for distribution to the CPSMT, CPSAS, SSC, and Council for discussions about preliminary harvest levels; and
3) a "final" version to be published in the SAFE report. Other than authorized changes, only editorial and other minor changes should be made between the "revised draft" and "final" versions. Post-STAR Panel drafts must be reviewed by the Panel chair prior to being submitted to Council staff, but these reviews are limited to editorial issues, verifying that the required elements are included according to the terms of reference, and confirming that the document reflects the discussions and decisions made during the STAR Panel.

The STAT will distribute "draft" assessment documents to the STAR Panel, Council staff, and the CPSMT and CPSAS representatives at least two weeks prior to the STAR Panel meeting. Complete, fully-developed assessments are critical to the STAR Panel process. Draft assessments will be evaluated for completeness prior to the STAR Panel meeting, and assessments that do not satisfy minimum criteria will not be reviewed. The STAR Panel chair will make an initial recommendation, which will then be reviewed by the SSC CPS subcommittee members and Council staff if the chair determines that the draft assessment is not sufficiently complete. The draft document should include all elements listed in Appendix A except a) the point-by-point responses to current STAR Panel recommendations, and 2) acknowledgements. Incomplete assessments will be postponed to the next assessment cycle.

The STAT is responsible for bringing data in digital format and model files to the review meeting so that they can be analyzed on site. STATs should have several models ready to present to the STAR Panel and be prepared to discuss the merits of each. The STAT also should identify a candidate base model, fully-developed and well-documented in the draft assessment, for STAR Panel review.

In most cases, the STAT should produce a complete draft of the assessment within three weeks of the end of the STAR Panel meeting (including any internal agency review). In any event, the STAT must finalize the assessment document at least one week before the CPSMT meeting at which harvest recommendations are discussed.

The STAT and the STAR Panel may disagree on technical issues regarding an assessment, but a complete stock assessment must include a point-by-point response by the STAT to each of the STAR Panel recommendations. Assessment model estimates and the results of applying control rules representing all sides of any disagreements need to be presented, reviewed by, and commented on by the SSC.

Electronic versions of final assessment documents, parameter files, data files, and key output files must be provided to Council staff by the STATs. Any tabular data that are inserted into the final documents in an object format should also be submitted in alternative forms (e.g., spreadsheets), which allow selection of individual data elements.

If there are competing STATs, STATs whose models are not chosen as the base model by a STAR panel should provide those draft assessments (corrected as necessary, in consultation with the STAR Panel) to the Council prior to the briefing book deadline."

Terms of Reference for Stock Assessment Updates

The STAR process is designed to provide a comprehensive, independent review of a stock assessment. However, when a model has already been critically examined and is simply updated by incorporating the most recent data, a less intensive review is required. For CPS, this typically occurs during two years out of every three because that is the default cycle for CPS assessments. In this context, a model refers not only to the population dynamics model *per se*, but also to the particular data sources that are used as inputs to the model, the statistical framework for fitting the model to the data, and the analytical treatment of model outputs used in providing management advice, including reference points and the basis for the OFL, ABC, ACL, ACT and/or HG. These terms of reference establish a procedure for a limited, but still rigorous, review for stock assessments that fall into this latter category. However, it is recognized that even simple updates may in practice result in situations (e.g., what seem like minor changes to data leading to large changes in estimated biomass and hence a change in stock status) that are impossible to resolve in an abbreviated process. These terms of reference allow for the possibility of limited modifications to an existing model. However, a full assessment and review might still be necessary if an updated assessment could not be accomplished without incorporating major structural changes to the model. A full assessment would then be scheduled for the next year.

Qualification

The SSC will determine whether a stock assessment qualifies as an update under these terms of reference. To qualify, a stock assessment must carry forward its fundamental structure from a model that was previously reviewed and endorsed by a STAR Panel. In practice this means similarity in: (a) the particular sources of data used, (b) the software used in programming the assessment, (c) the assumptions and structure of the population dynamics model underlying the stock assessment, (d) the statistical framework for fitting the model to the data and determining goodness of fit, and (e) the analytical treatment of model outputs in determining management reference points. A stock assessment update is appropriate in situations where no significant change in these five factors has occurred. In general, the only changes to a previously reviewed and endorsed assessment would be that the data time series is extended using the most recent information. However, changes to: (a) the analytical methods used to summarize data prior to input to the model, such has how the compositional data are pooled across sampling strata, (b) the weighting of the various data components (including the use of methods for tuning the variances of the data components), and (c) how selectivity is modeled, such as the time periods for the selectivity blocks, are acceptable as long the update assessment clearly documents and justifies the changes. There will always be valid reasons for altering a model, although, in the interests of stability, such changes should be resisted as much as possible in assessment updates. Substantial changes to the model should be reserved for full assessment years, when they can be fully evaluated through the STAR Panel process.

Composition of the Review Panel

The CPS subcommittee of the SSC will conduct the review of stock assessment updates. A lead reviewer for each updated assessment will be designated by the chair of the CPS subcommittee from among the membership of this subcommittee, and it will be the lead reviewer's responsibility to ensure the review is completed properly and that a written report of the proceedings is produced. In addition, the CPSMT and one designee from the CPSAS will participate in the review in an advisory capacity.

Review Format

Stock assessment updates will be reviewed during a single 2-3-day meeting of the SSC CPS Subcommittee, although there may be situations where the update review could take place in less time, i.e., early dismissal of a STAT is an option. The review process will be as follows. The STAT preparing the update will distribute the updated stock assessment to the review panelists at least two weeks prior to the review meeting. In addition, Council staff will provide the participants in the update review with a copy of the last stock assessment reviewed under the full STAR process, as well as the previous STAR Panel report. Review of stock assessment updates is not expected to require extensive analytical requests or model runs during the meeting. The review will focus on two crucial questions: (1) has the assessment complied with the terms of reference for stock assessment updates and (2) can the results from the updated assessment form the basis of Council decision-making. If either of these criteria is not met, then a full stock assessment will be required in the next year. If the review meeting concludes that it is not possible to update the stock assessment, the SSC will consider all the model runs examined during the review meeting and will provide fishing level recommendations to the Council. Recommendations for modifications to the assessment should be recorded in the CPS Subcommittee's report for consideration by the STAT during the next full assessment.

STAT Deliverables

It is the STATs responsibility to provide the review panel with a completed update at least two weeks prior to the review meeting. To streamline the review process, the STAT can reference whatever material it chooses, including that presented in the previous stock assessment (e.g., a description of methods, data sources, stock structure, etc.). However, it is essential that any new information that is incorporated in the assessment is presented in enough detail for the review panel to determine whether the update satisfactorily meets the Council's requirement to use the best available scientific information. There must be a retrospective analysis showing the performance of the model with and without the updated data streams. Similarly, if any changes to the "model" structure are adopted, above and beyond updating specific data streams, the impact of this needs to be documented. The

STAT is required to present key assessment outputs in tabular form. The final update document should include the following:

- title page and list of preparers;
- Executive Summary (see Appendix B);
- introduction;
- documentation of updated data sources;
- short description of overall model structure;
- base-run results, including a time series of total, 1+, and spawning biomass (and/or spawning output), recruitment and fishing mortality or exploitation rate estimates (table and figures); and
- uncertainty analysis, including retrospective analysis.

Review Panel Report

The SSC subcommittee members will issue a report that will include the following items:

- Name and affiliation of panelists
- Comments on the technical merits and/or deficiencies of the update
- List of analyses requested by the review panel, the rationale for each request, and a brief summary the STAT responses to each request
- Explanation of areas of disagreement between the panel and STAT
- Recommendation regarding the adequacy of the updated assessment for use in management

Appendix A: Outline for CPS Stock Assessment Documents

This is an outline of items that should be included in stock assessment reports for CPS managed by the Pacific Fishery Management Council. The outline is a working document meant to provide assessment authors with flexible guidelines about how to organize and communicate their work. All items listed in the outline may not be appropriate or available for each assessment. Items flagged by asterisks (*) are optional for draft assessment documents prepared for STAR Panels, but should be included in the final assessment document. In the interest of clarity and uniformity of presentation, stock assessment authors and reviewers are encouraged (but not required) to use the same organization and section names as in the outline. It is important that time trends of catch, abundance, harvest rates, recruitment and other key quantities be presented in tabular form to facilitate full understanding and follow-up work.

1. Title page and list of preparers - the names and affiliations of the stock assessment team (STAT), either alphabetically or as first and secondary authors

2. Executive Summary (see attached template in Appendix B). This also serves as the STAT summary included in the SAFE)

3. Introduction
   a. Scientific name, distribution, the basis for the choice of stock structure, including differences in life history or other biological characteristics that should form the basis for management units
   b. A map depicting the scope of the assessment and identifying boundaries for fisheries or data collection strata.
   c. Important features of life history that affect management (e.g., migration, sexual dimorphism, bathymetric demography)
   d. Important features of the current fishery and relevant history of fishery
   e. Summary of management history (e.g., changes in management measures, harvest guidelines, or other management actions that may have significantly altered selection, catch rates or discards)
   e. Management performance - a table or tables comparing annual biomass, harvest guidelines, and landings for each management subarea and year

4. Assessment
   a. Data
      i. Landings by year and fishery, catch-at-age, weight-at-age, survey and catch-per-unit-effort (CPUE) data, data used to estimate biological parameters (e.g., growth rates, maturity schedules, and natural mortality) with coefficients of variation (CVs) or variances if available. Include complete tables and figures (if practical) and date of extraction.
      ii. Sample size information for length and age composition data by area, year, gear, market category, etc. including the number of trips and fish sampled.
      iii. All data sources that include the species being assessed, which are used in the assessment, and provide the rationale for data sources that are excluded

b. History of modeling approaches used for this stock - changes between current and previous assessment models
    i. Response to STAR Panel recommendations from the last assessment
    ii. Report of consultations with CPSAS and CPSMT representatives regarding the use of various data sources in the stock assessment.

c. Model description
    i. Complete description of any new modeling approaches
    ii. Definitions of fleets and areas
    iii. Assessment program with last revision date (i.e., date executable program file was compiled)
    iv. List and description of all likelihood components in the model
    v. Constraints on parameters, selectivity assumptions, natural mortality, treatment of age reading bias/imprecision, and other fixed parameters
    vi. Description of stock-recruitment constraints or components
    vii. Description of how the first year that is included in the model was selected and how the population state at that time is defined (e.g. B_0, stable age-structure)
    viii. Critical assumptions and consequences of assumption failures

d. Model selection and evaluation
    i. Evidence of search for balance between model realism and parsimony
    ii. Comparison of key model assumptions, include comparisons based on nested models (e.g., asymptotic vs. domed selectivities, constant vs. time-varying selectivities)
    iii. Summary of alternative model configurations that were tried, but rejected
    iv. Likelihood profile for the base-run (or proposed base-run model for a draft assessment undergoing review) configuration over one or more key parameters (e.g. M, h, q) to show consistency among input data sources.
    v. Residual analysis for the base-run (or proposed base-run model for a draft assessment undergoing review) configuration, e.g., residual plots, time series plots of observed and predicted values, or other approaches. Note that model diagnostics *are* required in draft assessments undergoing review.
    vi. Convergence status and convergence criteria for base-run model (or proposed base-run model)
    vii. Randomization run results or other evidence of search for global best estimates
    viii. Evaluation of model parameters. Do they make sense? Are they credible?

e. Point-by-point response to the STAR Panel recommendations*

f. Base-run(s) results
    i. Table listing all explicit parameters in the stock assessment model used for base runs, their purpose (e.g., recruitment parameter, selectivity parameter) and whether or not the parameter was actually estimated in the stock assessment model
    ii. Time-series of total 1+ and spawning biomass (or spawning output),depletion relative to B_0, recruitment and fishing mortality or exploitation rate estimates (table and figures)
    iii. Selectivity estimates (if not included elsewhere)

v. Stock-recruitment relationship
vi. OFL, ABC and ACL (and/or ABC, ACT and HG) for recent years
vii. Clear description of units for all outputs

g. Information on ecological factors pertinent to the species, if available.

h. Uncertainty and sensitivity analyses. i.The best approach for describing uncertainty and range of probable biomass estimates in CPS assessments may depend on the situation. Possible approaches include:

A. Parameter uncertainty (variance estimation conditioned on a given model, estimation framework, data set choice, and weighting scheme), including likelihood profiles of important assessment parameters (e.g., natural mortality). This also includes expressing uncertainty in derived outputs of the model and estimating CVs by an appropriate method (e.g., bootstrap, asymptotic methods, Bayesian approaches, such as MCMC). Include the CV of spawning biomass in the first year for which an OFL has not been specified (typically end year +1 or +2).

B. Sensitivity analyses (tables or figures) that show ending biomass levels or likelihood component values obtained while systematically varying emphasis factors for each type of data in the model

C. Sensitivity to assumptions about model structure, i.e., model specification uncertainty

D. Retrospective analysis, where the model is fitted to a series of shortened input data sets, with the most recent years of data input being dropped.

E. Historic analysis (plot of actual estimates from current and previous assessments)

F. Subjective appraisal of magnitude and sources of uncertainty

G. If a range of model runs (e.g., based on CVs or alternate assumptions about model structure or recruitment) is used to depict uncertainty, then it is important that some qualitative or quantitative information about relative probability be included. If no statements about relative probability can be made, then it is important to state that all scenarios (or all scenarios between the bounds depicted by the runs) are equally likely

H. If possible, ranges depicting uncertainty should include at least three runs: (a) one judged most probable; (b) at least one that depicts the range of uncertainty in the direction of lower current biomass levels; and (c) one that depicts the range of uncertainty in the direction of higher current biomass levels.

5. <u>Harvest Control Rules</u>[4]

The OFL, ABC and HG harvest control rules for actively managed species apply to the U.S. (California, Oregon, and Washington) harvest recommended for the next fishing year and are defined as follows:

- OFL = BIOMASS * F_{MSY} * U.S. DISTRIBUTION
- ABC = BIOMASS * BUFFER * F_{MSY} * U.S. DISTRIBUTION
- ACL LESS THAN OR EQUAL TO ABC
- HG = (BIOMASS-CUTOFF)* FRACTION * DISTRIBUTION

4 Not yet adopted by the Council at the time of writing.

- ACT EQUAL TO HG OR ACL, WHICHEVER VALUE IS LESS

where F_{MSY} is the fishing mortality rate that maximizes catch biomass in the long-term.

Implementation for Pacific Sardine

1. BIOMASS is the estimated stock biomass (ages 1+) at the start of the next year from the current assessment,

2. CUTOFF (150,000 mt) is the lowest level of estimated biomass at which harvest is allowed,

3. FRACTION is an environment-based percentage of biomass above the CUTOFF that can be harvested by the fisheries. Given that the productivity of the sardine stock has been shown to increase during relatively warm-water ocean conditions, the following formula has been used to determine an appropriate (sustainable) FRACTION value:

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

   where T is the running average sea-surface temperature at Scripps Pier, La Jolla, California during the three preceding years. Under the harvest control rule, FRACTION is constrained and ranges between 5% and 15% depending on the value of T.

4. U.S. DISTRIBUTION is the percentage of BIOMASS in U.S. waters (87%).

Implementation for Pacific Mackerel

1. BIOMASS is the estimated stock biomass (ages 1+) at the start of the next year from the current assessment,

2. CUTOFF (18,200 mt) is the lowest level of estimated biomass at which harvest is allowed,

3. FRACTION (30%) is the fraction of biomass above CUTOFF that can be taken by fisheries, and

4. STOCK DISTRIBUTION (70%) is the average fraction of total BIOMASS in U.S. waters.

The CUTOFF and FRACTION values applied in the Council's harvest policy for mackerel are based on simulations published by MacCall et al. in 1985.

6. <u>Management Recommendations</u>

7. <u>Research Needs</u> (prioritized)

8. <u>Acknowledgments</u> (include STAR Panel members and affiliations as well as names and

affiliations of persons who contributed data, advice, or information but were not part of the assessment team)*

9. Literature Cited

10. An appendix with the complete parameter and data in the native code of the stock assessment program. (For a draft assessment undergoing review, these listings can be provided as text files or in spreadsheet format.)

Appendix B: Template for Executive Summaries Prepared by STATs

Stock: species/area, including an evaluation of any potential biological basis for regional management

Catches: trends and current levels - include table for last ten years and graph with long-term data

Data and assessment: date of last assessment, type of assessment model, data available, new information, and information lacking

Unresolved problems and major uncertainties: any special issues that complicate scientific assessment, questions about the best model scenario, etc.

Stock biomass: trends and current levels relative to virgin or historic levels, description of uncertainty - include table for last 10 years and graph with long-term estimates

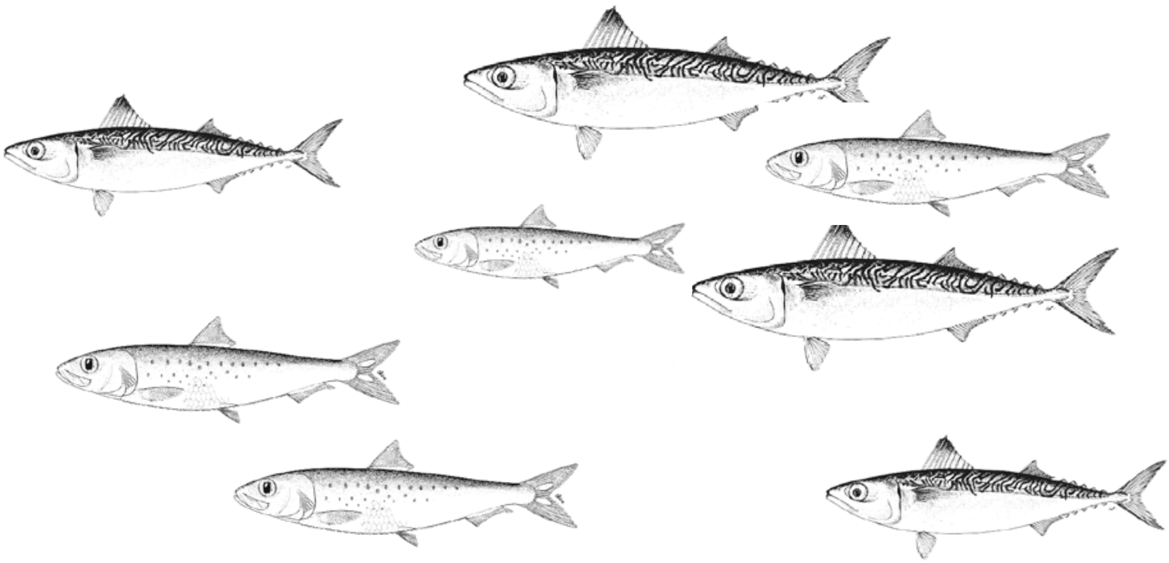
Recruitment: trends and current levels relative to virgin or historic levels - include table for last 10 years and graph with long-term estimates

Exploitation status: exploitation rates (i.e., total catch divided by exploitable biomass) – include a table with the last 10 years of data and a graph showing the trend in total fishing mortality relative to the target (y-axis) plotted against the trend in biomass relative to the target (x-axis).

Management performance: catches in comparison to the OFL, ABC, ACL/HG values for the most recent 10 years (when available), actual catch and discard.

Research and data needs: identify information gaps that seriously impede the stock assessment

TERMS OF REFERENCE
FOR A
COASTAL PELAGIC SPECIES



STOCK ASSESSMENT
METHODOLOGY REVIEW PROCESS

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Introduction

The purpose of this document is to outline the guidelines and procedures for conducting methodology reviews related to coastal pelagic species (CPS) stock assessments and management for the Pacific Fishery Management Council, and to clarify the expectations and responsibilities of the various participants.

The methodology review process provides for peer review as referenced in the 2006 Reauthorization of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA), which states that "the Secretary and each Regional Fishery Management Council may establish a peer review process for that Regional Fishery Management Council for scientific information used to advise the Regional Fishery Management Council about the conservation and management of the fishery" (MSRA section 302(g)(1)(E)). If a peer review process is established, it should investigate the technical merits of stock assessments and other scientific information used by the Council's Scientific and Statistical Committee (SSC). The peer review process is not a substitute for the SSC and should work in conjunction with the SSC. This document will be included in the Council's Statement of Organization, Practices and Procedures as documentation of the review process that will underpin the scientific advice from the SSC.

Parties involved in implementing the peer review process described here are the Pacific Fishery Management Council members (Council); Council staff; members of Council Advisory Bodies, including the SSC, the Coastal Pelagic Species Management Team (CPSMT), and the Coastal Pelagic Species Advisory Subpanel (CPSAS); the National Marine Fisheries Service (NMFS); state agencies; and interested persons (including external reviewers).

Unlike Stock Assessment Review (STAR) Panels and assessment update review panels, methodology review panels do not occur on a regular timetable, but are instead established by the Council to provide peer and in-depth review of major changes to the methodology on which CPS stock assessments are based. Consequently, the outcomes from a methodology review do not include stock assessment results, but rather recommendations regarding whether a particular methodology can be applied in future stock assessments, along perhaps with recommendations on how it should be modified if it is to be used in future stock assessments. Existing methodologies could also be reviewed especially if they are key to CPS stock assessments and have not been reviewed for many years (particularly if incremental changes in how the methodology is applied have occurred).

There are no explicit guidelines for what topics can be covered during a methodology review, but typical examples would be evaluation of: (a) proposed major new data types which if included in an assessment could change its outcomes markedly (e.g. the aerial survey for Pacific sardine), (b) proposed changes to the design of existing surveys, (c) proposed changes to stock assessment models, (d) existing data inputs to assessments which have not been reviewed in depth by a Council-sponsored peer-review Panel for many years (e.g. the egg production method for Pacific sardine), (e) data or model results that contribute to ecosystem-based management of CPS stocks, and (f) proposed major changes to the stock assessment methods that fall outside the scope of what a STAR panel would be expected to review as part of its normal activities (for example, a change to the stock assessment modelling platform such as from ASAP to the Stock Synthesis).

This current edition of the terms of reference reflects how previous methodology reviews have been undertaken. Nevertheless, no set of guidelines can be expected to deal with every contingency, and all participants should anticipate the need to be flexible and address new issues as they arise.

Review Panel Goals and Objectives

The goals and objectives for the methodology review process are to:

1. Ensure that research surveys, data collection, data analyses and other scientific techniques in support of CPS stock assessments are the best available scientific information and facilitate the use of this information by the Council.
2. Provide recommendations regarding whether, and if so, how a particular methodology can be applied in future stock assessments.
3. Meet the MSRA and other legal requirements.
4. Follow a detailed calendar and explicit responsibilities for all participants to produce required outcomes and reports.
5. Provide an independent external review of survey and analytical methods used to develop data to inform CPS stock assessment models.
6. Increase understanding and acceptance of CPS research methodologies and review work by all members of the Council family.
7. Identify research needed to improve assessments, reviews, surveys, analyses, and fishery management in the future.

Responsibilities

Shared Responsibilities

All parties have a stake in ensuring adequate technical review of stock assessments and the information on which they are based. The National Marine Fisheries Service (NMFS), as the designee of the Secretary of Commerce, must determine that the best scientific advice has been used when it approves fishery management recommendations made by the Council. The Council uses statements from the SSC to determine whether the information on which it will base its recommendation represents the "best available" science. Fishery managers and scientists providing technical documents to the Council for use in management need to ensure the work is technically correct.

The Council, NMFS, and the Secretary of Commerce share primary responsibility to create and foster a successful peer review process. The Council will oversee the process and involve its standing advisory committees, especially the SSC. The chair of the SSC CPS subcommittee will coordinate, oversee, and facilitate the process for CPS. Together, NMFS and the Council will consult with all interested parties to plan, prepare terms of reference, and develop a calendar of events for each methodology review and a list of deliverables for final approval by the Council. NMFS and the Council will share fiscal and logistical responsibilities and both should ensure that there are no conflicts of interest in the process[1].

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1 The proposed NS2 guidelines state: "Peer reviewers who are federal employees must comply with all applicable federal ethics requirements. Peer reviewers who are not federal employees must comply with the following provisions. Peer reviewers must not have any real or perceived conflicts of interest with the scientific information, subject matter, or work product under review, or any aspect of the statement of work for the peer review. For purposes of this section, a conflict of interest is any financial or other interest which conflicts with the service of the individual on a review Panel because it: (A) Could significantly impair the reviewer's objectivity; or (B) Could create an unfair competitive advantage for a person or organization. (C) Except for those situations in which a conflict of interest is unavoidable, and the conflict is promptly and publicly disclosed, no individual can be appointed to a review Panel if that individual has a conflict of interest that is relevant to the functions to be performed. Conflicts of interest include, but are not limited to, the personal financial interests and investments, employer affiliations, and consulting arrangements, grants, or contracts of the individual and of others with whom the individual has substantial common financial interests, if these interests are relevant to the functions to be performed. Potential reviewers must be screened for conflicts of interest in accordance with the procedures set forth in the NOAA Policy on Conflicts of Interest for Peer Review subject to OMB's Peer Review Bulletin."

The CPS peer-review process is sponsored by the Council, because the Federal Advisory Committee Act (FACA) limits the ability of NMFS to establish advisory committees. FACA specifies a procedure for convening advisory committees that provide consensus recommendations to the federal government. The intent of FACA was to limit the number of advisory committees; ensure that advisory committees fairly represent affected parties; and ensure that advisory committee meetings, discussions, and reports are carried out and prepared in full public view. Under FACA, advisory committees must be chartered by the Department of Commerce through a rather cumbersome process. However, the Sustainable Fisheries Act exempts the Council from FACA per se, but requires public notice and open meetings similar to those under FACA.

Coordination of CPS Review Panels

The SSC CPS subcommittee chair will work with the Council, Council staff, other agencies, groups or interested persons that carry out data collection, management, and assessment work to coordinate and organize methodology reviews. The objective is to make sure that work is carried out in a timely fashion according to an agreed schedule and these terms of reference.

The SSC CPS subcommittee chair will develop terms of reference for methodology reviews, in consultation with the SSC, the Council and those whose work is being reviewed. The SSC CPS subcommittee chair, in consultation with the SSC and the Southwest Fisheries Science Center (SWFSC), will also coordinate the selection (including number) of external reviewers. Criteria for reviewer qualifications, nomination, and selection will be established by the SWFSC in consultation with the SSC, and will be based principally on a candidate's knowledge of the topic being reviewed and ideally West Coast CPS fisheries. The public is welcome to nominate qualified reviewers. It is, however, recognized that the pool of qualified reviewers is limited, and that staffing of Methodology Panels is subject to constraints that may make it difficult to achieve the ideal.

Individuals that provide information to the review are responsible for ensuring their work is technically sound and complete.

CPSMT Responsibilities

The CPSMT is responsible for identifying and evaluating potential management actions based on the best available scientific information. In particular, the CPSMT makes Annual Catch Limit (ACL) and Annual Catch Target (ACT) recommendations to the Council based on Overfishing Limit (OFL), Acceptable Biological Catch (ABC) and Harvest Guideline (HG) control rules.

A representative of the CPSMT may be appointed by the CPSMT chair and, if appointed, will serve as a liaison to the methodology review meeting, and will participate in review discussions. The CPSMT representative will not serve as a member of the Panel. The CPSMT representative should be prepared to advise the Panel on fishing regulations or practices that may influence data used in assessment and the nature of the fishery in the future (this will be more relevant for some of the topics which are considered by methodology reviews than others).

CPSAS Responsibilities

It is the responsibility of the CPSAS representative to ensure that CPSAS concerns regarding the issue being reviewed are conveyed to the Panel. The chair of the CPSAS may appoint a representative to participate at a methodology review. If appointed, the CPSAS representative will serve as an advisor to the review meeting. The CPSAS representative will participate in review discussions as an advisor to the Panel, in the same capacity as the

CPSMT advisor. The CPSAS representative may provide appropriate data and advice to the review meeting, and will report to the CPSAS on the meeting.

SSC Responsibilities

The SSC will assign at least one member from its CPS subcommittee to each methodology review. This member will chair the review meeting, and attend the Council meetings when the outcomes from the review meeting are discussed. The SSC representative on the review Panel will present the report of the meeting at SSC and Council meetings. The SSC will review any additional analytical work arising from the review meeting, will serve as arbitrator to resolve disagreements that arose during the review meeting, and will make recommendations to the Council (e.g. that the methodology that was reviewed provides the "best available science" and hence could be used during the next full assessment).

Council Staff Responsibilities

A Council staff officer will be assigned to coordinate, monitor and document the review process. The Council staff officer will be responsible for timely issuance of meeting notices and distribution of appropriate documents. The Council staff officer will monitor compliance with the most recent version of the terms of reference for methodology reviews adopted by the Council. The Council staff officer will coordinate materials and presentations for Council meetings relevant to Council decision making. Council staff will also collect and maintain file copies of reports from each methodology review, the documents considered during the review, SSC, CPSMT, and CPSAS comments and reports, letters from the public, and any other relevant information.

A primary role for the Council staff officer assigned to each methodology review will be to monitor review meetings and SSC activities to ensure compliance with these terms of reference. The Council staff officer will attend the review meeting to ensure continuity and adherence to these terms of reference. The Council staff officer will identify inconsistencies with the terms of reference that occur during review meetings and work with the Panel chair to develop solutions and to correct them. The Council staff officer will coordinate with the Panel chair and NMFS to assure that all documents are received on time, and are complete.

National Marine Fisheries Service Responsibilities

NMFS Southwest Fisheries Science Center (SWFSC) will provide staff to work with the Council, other agencies, groups, or interested persons that carry out assessment work to assist in organizing methodology reviews. The SWFSC will identify independent panellists following criteria for reviewer qualifications. The costs associated with these reviewers will be borne by NMFS. The SWFSC will coordinate with those whose work is being reviewed to facilitate delivery of materials by scheduled deadlines and in compliance with other requirements of these terms of reference, to the extent possible and with the assistance of the assigned Council staff officer and the Panel chair.

Terms of Reference for Methodology Reviews and Meetings

The objective of a methodology review is to complete a detailed evaluation of a topic selected by the Council and which could have a major impact on stock assessments for CPS and make a recommendation regarding whether the methodology represents the best available scientific information for the Council. The responsibilities of the Panel include:

1. review documents pertinent to the topic under consideration;
2. discuss the technical merits and deficiencies of the proposed method(s) during the Panel meeting and work with the proponents to correct deficiencies;

3. provide recommendations for alternative methods or modifications to proposed methods, or both, as appropriate during the Panel meeting;
4. provide recommendations on future application of collected information to the stock assessment and/or management process;
5. document meeting discussions; and
6. provide complete Panel reports.

The Panel chair has, in addition, the responsibility to:

7. review revised documents and Panel reports before they are forwarded to the SSC.

Methodology review panels normally include a chair (who is a member of the SSC CPS subcommittee), at least one "external" member (i.e., outside the Council family and not involved in management or assessment of West Coast CPS, typically designated by the Center for Independent Experts [CIE]), and two additional members. Selection of the external and independent panelists should aim for balance between outside expertise of the topic being reviewed, in-depth knowledge of CPS fisheries, data sets available for those fisheries, and modeling approaches applied to CPS. Reviewers should not have financial or personal conflicts of interest, either current to the meeting, within the previous year (at minimum), or anticipated. Panelists should be knowledgeable about the specific approaches being reviewed. In addition to Panel members, methodology review meetings will include a Council staff member to help advise the Panel and assist in recording meeting discussions and results and may include CPSMT and CPSAS advisory representatives with responsibilities as laid out in their terms of reference. The length of a methodology review meeting will be selected by the SSC and could range one to five days.

The Panel chair is responsible for: 1) developing an agenda, 2) ensuring that the Panel follows the terms of reference, 3) participating in the review of the methodology, 4) guiding the participants in the review (proponents and Panel) to mutually agreeable solutions, 5) coordinating review of documents, and 6) providing Council staff with a camera ready and suitable electronic version of the Panel's report. The Panel, those proposing the methodology, the CPSMT and CPSAS representatives, and the public are legitimate meeting participants that should be accommodated during discussions. It is the Panel chair's responsibility to manage discussions and public comment so that work can be completed.

The Panel's terms of reference solely concern technical aspects. It is therefore important that the Panel strive for a risk neutral perspective in its reports and deliberations. Methods or results that have a flawed technical basis, or are questionable on other grounds, should be identified by the Panel and a recommendation made that they should excluded from consideration in developing management advice. The Panel should comment on the degree to which the uncertainty associated with the method being reviewed is quantified (e.g. through confidence intervals) because uncertainty is taken into account during the management process.

Recommendations and requests to the proponents for additional or revised analyses must be clear, explicit, and in writing. Panel recommendations and requests to the proponents should reflect the consensus opinion of the entire Panel and not the minority view of a single individual or individuals on the Panel. A written summary of discussion on significant technical points and lists of all Panel requests and recommendations and requests to the proponents are required in the Panel's report, which should be completed (at least in draft form) prior to the end of the review meeting. It is the chair and Panel's responsibility to carry out any follow-up review of work that is required.

The Panel's primary duty is to conduct a peer review of the proposed methodology. Methodology Panel meetings are not workshops, although the involvement of the Panel in shaping the methodology is greater during methodology reviews than during STAR Panels. This is particularly the case when the outside reviewers have considerably more experience with a given methodology than the proponents and the reviewers from within the Council family. In the course of this review, the Panel may ask for a reasonable number of additional analyses, as well as for additional details of the proposed methodology. It would not be unusual for this evaluation to result in a change to the initial methodology, provided both the Panel and the proponents agree. Panels are expected to be judicious in their requests of the proponents, recognizing that some issues uncovered during a review are best flagged as research priorities (and use of the methodology deferred until those issues are resolved). The Panel should not impose as a requirement their preferred methodologies when such is a matter of professional opinion. Rather, if the Panel finds that a method is inadequate, it should document and report that opinion.

Panels and proponents are required to make an honest attempt to resolve any areas of disagreement during the review meeting. Occasionally, fundamental differences of opinion remain between the Panel and the proponents that cannot be resolved by discussion. In such cases, the Panel must document the areas of disagreement in its report. In exceptional circumstances, the proponents may choose to submit a supplemental report supporting its view, but in the event that such a step is taken, an opportunity must be given to the Panel to prepare a rebuttal. These documents will then be appended to Panel report as part of the record of the review meeting. Panel members may have fundamental disagreements that cannot be resolved during the meeting. In such cases, Panel members may prepare a minority report that will become part of the record of the review meeting. The SSC will then review all information pertaining to Panel or Panel/proponent disputes, and issue a recommendation.

Additional analyses required by the Panel should be completed by the proponents during the review meeting. It is the obligation of the Panel chair, in consultation with other Panel members, to prioritize requests for additional analyses. If follow-up work by the proponents is required after the review meeting, then it is the Panel's responsibility to track progress. In particular, the chair is responsible for communicating with proponents (by phone, e-mail, or any convenient means) to determine if the revised analyses and documents are complete and ready to be presented to the SSC.

Suggested Template for Methodology Panel Report

- Summary of the Methodology Panel meeting, containing:
    - names and affiliations of Panel members;
    - topic(s) being reviewed; and
    - list of analyses requested by the Panel, the rationale for each request, and a brief summary the responses to each request.
- Comments on the technical merits and/or deficiencies of the methodology and recommendations for remedies.
- Areas of disagreement regarding Panel recommendations:
    - among Panel members (including concerns raised by the CPSMT and CPSAS representatives); and
    - between the Panel and proponents.
- Unresolved problems and major uncertainties, e.g., any issues that could preclude use of the methodology.
- Management, data or fishery issues raised by the public and CPSMT and CPSAS representatives during the Panel.

- Prioritized recommendations for future research and data collection.

Terms of Reference for Proponents of Methodology

The proponents will appoint a representative to coordinate work with the Panel and attend the Panel meeting. A representative of the proponents should attend the SSC meeting at which the outcomes from the Panel are discussed.

The proponents are responsible for preparing two versions of the methodology review document:

1) a "draft", including an executive summary, for discussion during the review meeting; and
2) a "final" version for presentation to the SSC, the Council, the CPSMT, and the CPSAS.

The proponents will distribute "draft" documents outlining the methodology to the Panel, Council staff, and the CPSMT and CPSAS representatives at least two weeks prior to the review meeting. The proponents are responsible for bringing analysis methods and relevant data (in digital format) to the review meeting so that data can be analyzed on site and sensitivity analyses conducted. In most cases, the proponents should produce a revised document outlining the methodology (and preliminary results / responses to the Panel recommendations) three weeks after the end of the Panel meeting (including any internal agency review).

The proponents and the Panel may disagree on technical issues, but “final” documents must include a point-by-point response by the proponents to each of the Panel recommendations. Where time allows, the Panel and proponents should be provided the opportunity to prepare rebuttals.

Agenda Item I.3.b
Supplemental CPSAS Report
November 2010

COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON TERMS OF REFERENCE FOR STOCK ASSESSMENT AND METHODOLOGY REVIEW PANELS

The Coastal Pelagic Species Management Team (CPSMT) and the Coastal Pelagic Species Advisory Subpanel (CPSAS) discussed draft terms of reference (TOR) for both the Coastal Pelagic Species Stock Assessment and Survey Methodology reviews. The CPSAS has also reviewed the draft Scientific and Statistical Committee (SSC) statement. The CPSAS generally supports the recommendations of the SSC and CPSMT.

We note the need for at least three Stock Assessment Review (STAR) panels in 2011 to review new data sources from three surveys, which are developed, or are developing:

The first is the Acoustics Survey conducted by the Southwest Fisheries Science Center (SWFSC) since 2006. This will be ready for STAR review in February 2011.

The second is Satellite imagery. The Satellite photos can overlap and greatly enhance the present photographic technique in of the Aerial Survey. The principals believe this will be ready for full review at the February STAR. The SSC has offered to give guidance on the potential development of Satellite Imagery at that STAR.

The third is the California Wetfish Producers Association's (CWPA's) Light Detection and Ranging (LIDAR) and Aerial Survey are presently being conducted in Southern California. This survey will be ready for review at the May Pacific mackerel STAR.

The CPSAS strongly supports STAR Panel review of all three of these surveys. Further, we believe that Satellite Imagery can be overlapped with the 2011 Aerial Survey photography to amplify the photographic data to a superior level. We believe this could be incorporated with the Aerial Survey 2011 data and be ready for full review at the September STAR Panel.

The CPSAS notes that once approved, these other surveys may be used singularly or jointly to ground-truth and enhance present survey methodology.

Some of the short and long-term benefits include:
[1] Improved scientific understanding of the sardine resource and their migratory patterns;
[2] Improved synoptic data collection via the use of coast wide satellite imagery;
[3] A reduction in the coefficient of variation;
[4] A significant increase in the economic benefits to the sardine industry and coastal communities;
[5] Decreased pilot risk in the Aerial Survey when transecting remote areas of the coast.

PFMC
11/07/10

COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON TERMS OF REFERENCE FOR STOCK ASSESSMENT AND METHODOLOGY REVIEW PANELS

The Coastal Pelagics Management Team (CPSMT) considered the Terms of Reference (TOR) documents for Stock Assessment Review (STAR) and Methodology Review Panels. In addition, the CPSMT considered three proposals to be included in next year's methodology review workshop, tentatively scheduled for the first week in February 2011.

The Council considered draft TORs at the September meeting. Regarding the STAR TOR, the Council, noting that there were some areas of agreement and some areas yet unresolved, directed the CPSMT and Scientific and Statistical Committee (SSC) to resolve remaining concerns at the November meeting. The STAR TOR in the briefing book (Agenda Item I.3.a Attachment 1) reflects the agreed-upon changes. The Methodology TOR in the briefing book (Agenda Item I.3.a Attachment 2) still has two edits yet to be incorporated. The CPSMT recommends approval of the two TORs, with the addition of the edits to the Methodology TOR as stated in the Supplementary SSC Report (Agenda Item I.3.b).

The CPSMT also considered the three proposed methodologies to be reviewed in 2011: 1) the use of satellite imagery during aerial photographic surveys, 2) acoustic trawl surveys, and 3) calibration of aerial photographic surveys using Light Detection and Ranging (LIDAR). The CPSMT supports the recommendation of the SSC to review all three.

PFMC
11/7/10

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON TERMS OF REFERENCE FOR STOCK ASSESSMENT AND METHODOLOGY REVIEW PANELS

The Scientific and Statistical Committee (SSC) addressed two issues under this agenda item: 1) it identified a list of potential methods to be reviewed at the methodology reviews scheduled for 2011, and 2) it provided a final review of the Terms of Reference (TOR) for the coastal pelagic species (CPS) stock assessments and methodology reviews.

Potential methods for review during 2011

Three proposals were presented to the SSC for consideration for methodology review during 2011: 1) the use of satellite imagery during aerial photographic surveys, 2) the use of acoustic and (associated trawl) surveys for abundance estimation, and 3) calibration of aerial photographic surveys using lidar and acoustics. A trawl survey for Pacific sardine in Canadian waters had originally been mentioned as potentially being reviewed for use in the September 2011 assessment. However, no proposal related to this survey was presented to the SSC. The SSC considered what information would be available for a Panel to review, and how the methodology could be used in stock assessments and when specifying overfishing limits.

(1) Methodology Panel 1 (early 2011)

The SSC recommends that this Panel focus on reviewing the coastwide acoustic (and associated trawl) surveys conducted by the Southwest Fisheries Science Center (SWFSC) in 2006, 2008, and 2010. These surveys have the potential to provide estimates of abundance for Pacific sardine, jack mackerel, Northern anchovy, and Pacific mackerel. This Panel should also allocate time to provide recommendations for how a pilot study related to the use of satellite imagery could be conducted. The SSC considers the use of satellite imagery as being sufficiently promising that time spent on this topic would be beneficial. However, this methodology is not currently sufficiently well developed that results could be included in the September 2011 assessment of Pacific sardine. Experts in satellite imagery and analysis would be members of the Review Panel.

(2) Methodology Panel 2 (May 2011)

The SSC notes that there is an opportunity to conduct a methodology review in parallel with the STAR Panel for Pacific mackerel and suggests that this review consider the aerial photographic surveys being conducted off southern California at present. Analysis of the data from these surveys will not be completed by the first methodology panel. Delaying the review until May 2011 should allow sufficient time for initial analyses to be conducted.

The SSC re-emphasizes the importance of the availability of complete documentation and data during the methodology reviews to allow a thorough review of the methodologies and to permit analyses to be conducted during the Panel meeting. Following Council decisions regarding which methodology will be reviewed during 2011, the chair of the SSC Coastal Pelagic Species (CPS) Subcommittee will coordinate with Council staff, SWFSC staff and the proponents of the various methodologies to organize agendas, and arrange SSC members of the Panel.

Terms of Reference for CPS

All remaining issues relating to the TORs for CPS stock assessment review process and methodology review have been resolved between the SSC and the Coastal Pelagic Species Management Team (CPSMT). In the stock assessment TOR, the present draft includes all changes, specifically language relating to the qualifications of review panel members, the procedure for bringing forward ecological considerations, and review of harvest control rules. The SSC endorses these changes.

Changes to the methodology review TOR were agreed between the SSC and the CPSMT, but the document has not yet been updated. The following outlines the issues that were resolved and changes that will be made. The SSC also endorses these changes.

- Methodological reviews are appropriate when a major new data source is introduced into a stock assessment or when a major change in the stock assessment modelling is contemplated. In both cases, a methodological review is needed when the change(s) from how assessments have been conducted in the past are deemed to be more than what a STAR Panel can reasonably be expected to handle. For example, the introduction of a new survey will generally require a methodological review; as will a change to a new stock assessment model platform. However, changes to the structure of a previously reviewed assessment model (e.g., changes in selectivity year-blocking) fall within the scope of what a STAR Panel would be expected to review as part of its normal activities.
  This change will be addressed be removing c) on page 3, next to last paragraph.
- Some aspects of changes to the control rules could also be considered by a methodological review. In this case, however, care must be taken to separate the scientific analysis supporting the change (e.g. the structure and technical aspects of simulation studies used to compare a revised control rule against the *status quo*) and the management objectives used to measure performance (e.g. minimize year-to-year catch variance, maximize long-term average catch, etc.). The former are amenable to methodological review (provided adequate background analyses have been completed), but the latter are management decisions – not well suited to a methodological review.
  This paragraph will be included above the last paragraph on page 3.

PFMC
11/06/10

NORTHWEST SARDINE SURVEY
12 Bellwether Way, Suite 209
Bellingham, Washington 98225

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

SATELLITE IMAGING

Improvements for Sardine Stock Assessments

The fishing industry has been providing scientific research for the purpose of improving the understanding of the abundance of sardines on the Pacific Coast. It has been through these efforts that recent harvest quotas have provided sufficient quantities to allow some commercial fishing at limited levels. Without the industry sponsored surveys and data collection the sardine fishery would not exist. This economic disaster has been avoided to some degree, up until now.

The aerial survey was first conducted as a desperate action to show a more realistic sardine abundance than the current science provided. It was not expected to be the final answer in sardine research. The project has provided accurate data for use in the sardine stock assessment model, however it falls short in validating anything close to the real sardine population.

The NW Sardine Survey LLC has been conducting a pilot project using satellite imaging for two years. This effort has clearly shown the potential for this technology to be a vast improvement over the current survey methods.

In 2009 Satellite images were used to identify sardine schools. This proved that images from satellites would be adaptable for use in a sardine survey. In 2010 another image was taken in a similar area off the Southern Coast of Washington State. This image was overlaid with aerial survey photos taken on the same day that contained known sardine schools. The characteristics of the identified sardine schools were transferred to the satellite image. From this, computer software can measured sardine schools in the entire satellite image.

The results were remarkable. In an ocean area of less than 25 square kilometers, 22,582 metric tons of sardines were located. By comparison, the sardine volume seen in the aerial photos was far less.

It is essential that satellite imaging be used to determine sardine stock abundance in order for science to reflect reality and to ensure the economic stability of fishing communities on the entire West Coast.

Jerry Thon
NW Sardine Survey

Staff Note: This methodology proposal is paired with the proposal submitted by Mr. Tom Jagielo (Agenda Item I.3.c public comment). They represent a single methodology proposal.

SATELLITE IMAGING

Improvements for Sardine Stock Assessments

2010

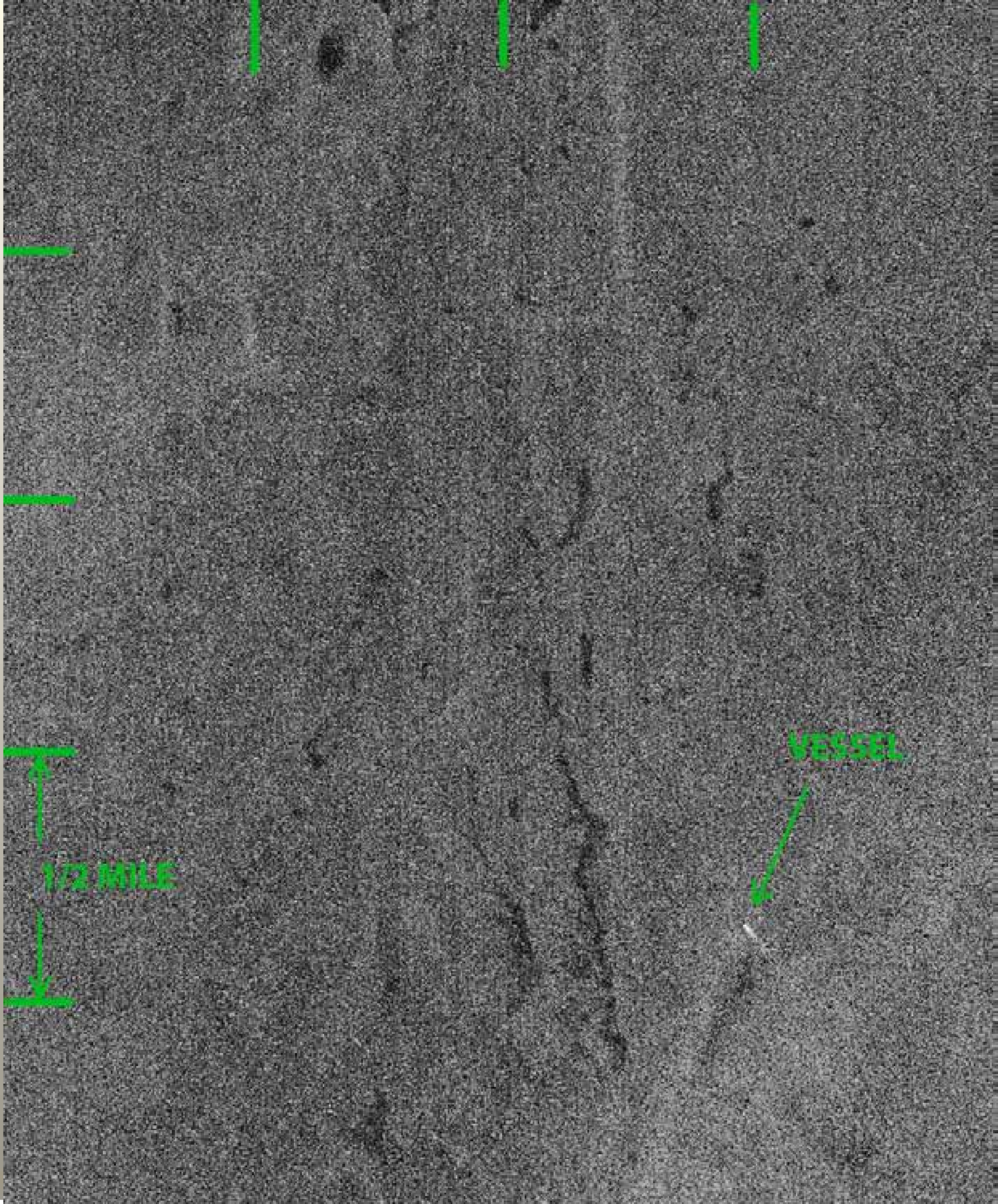
NW Sardine Survey LLC

1^{st} Year

2009 Okonos Satellite Image

Concept Proven

Sardine Schools Identified in Black



2nd Year

Rapid Eye Satellite Image

August 23, 2010
10:30 AM PST

Large Area Multi-Spectral Images

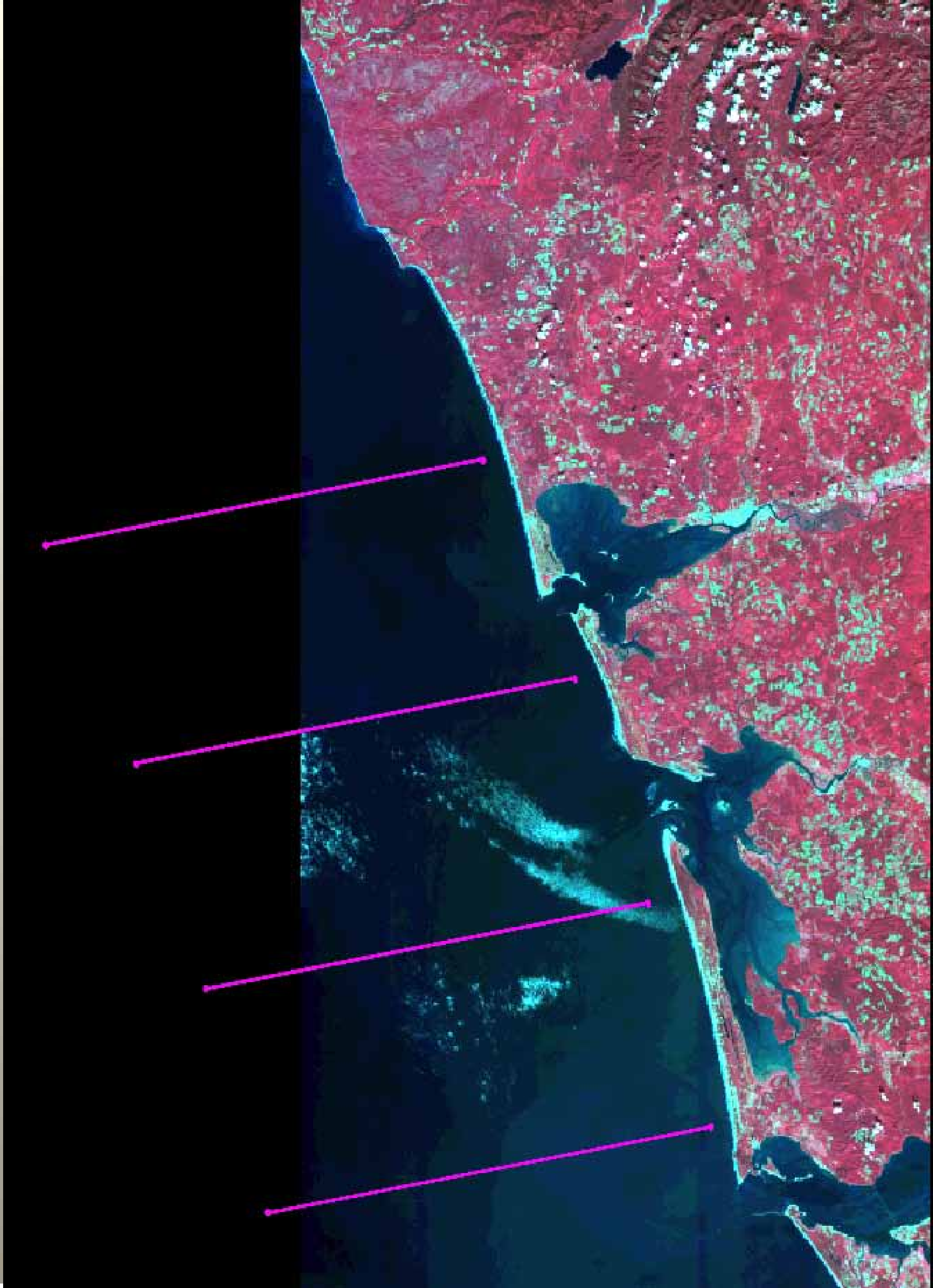
5 Band Sensor Camera
- Blue
- Green
- Red
- Red Near Edge
- Infrared

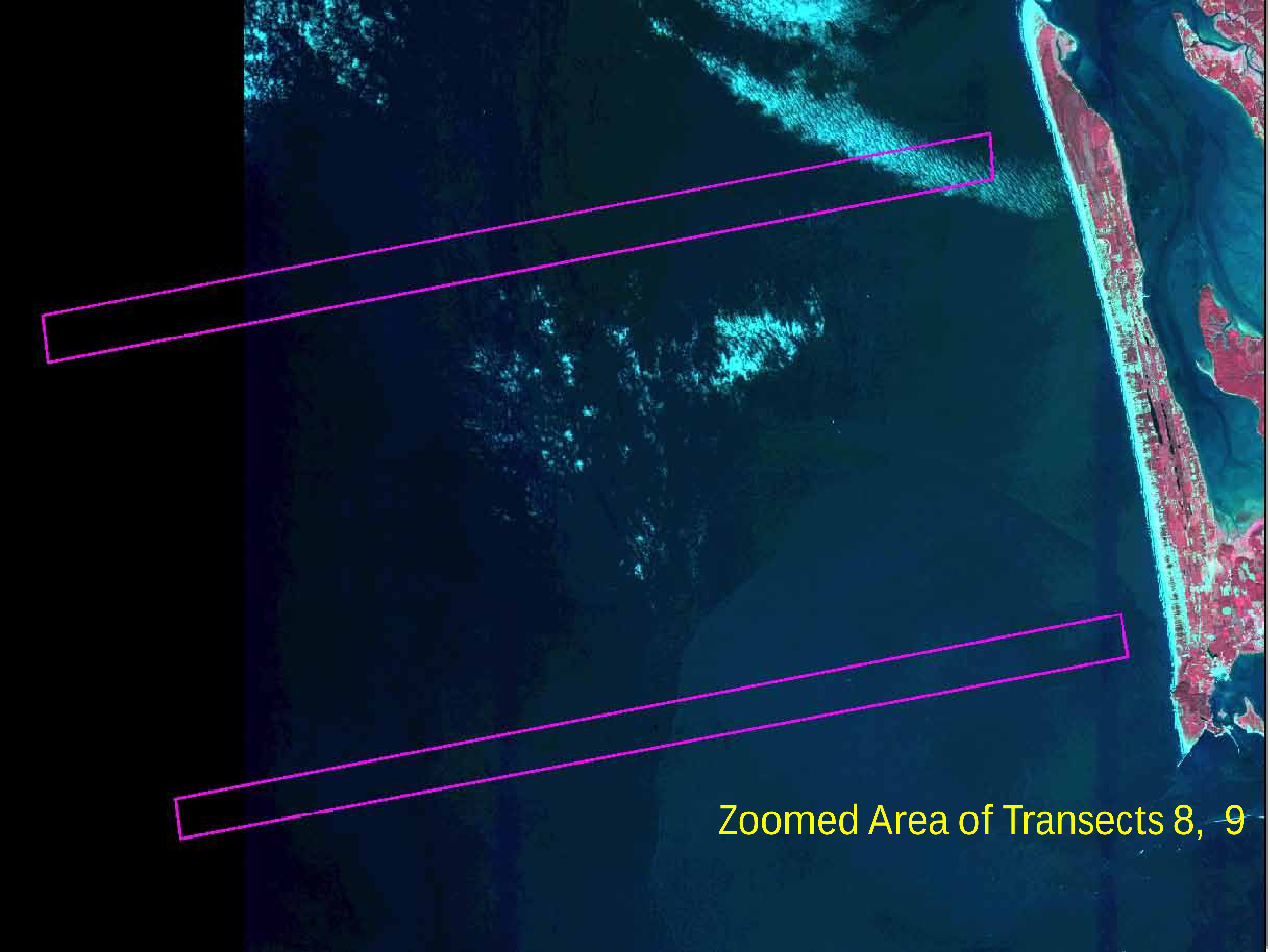
2010 Aerial Survey Transects Overlaid

Set A # 6, 7, 8, 9

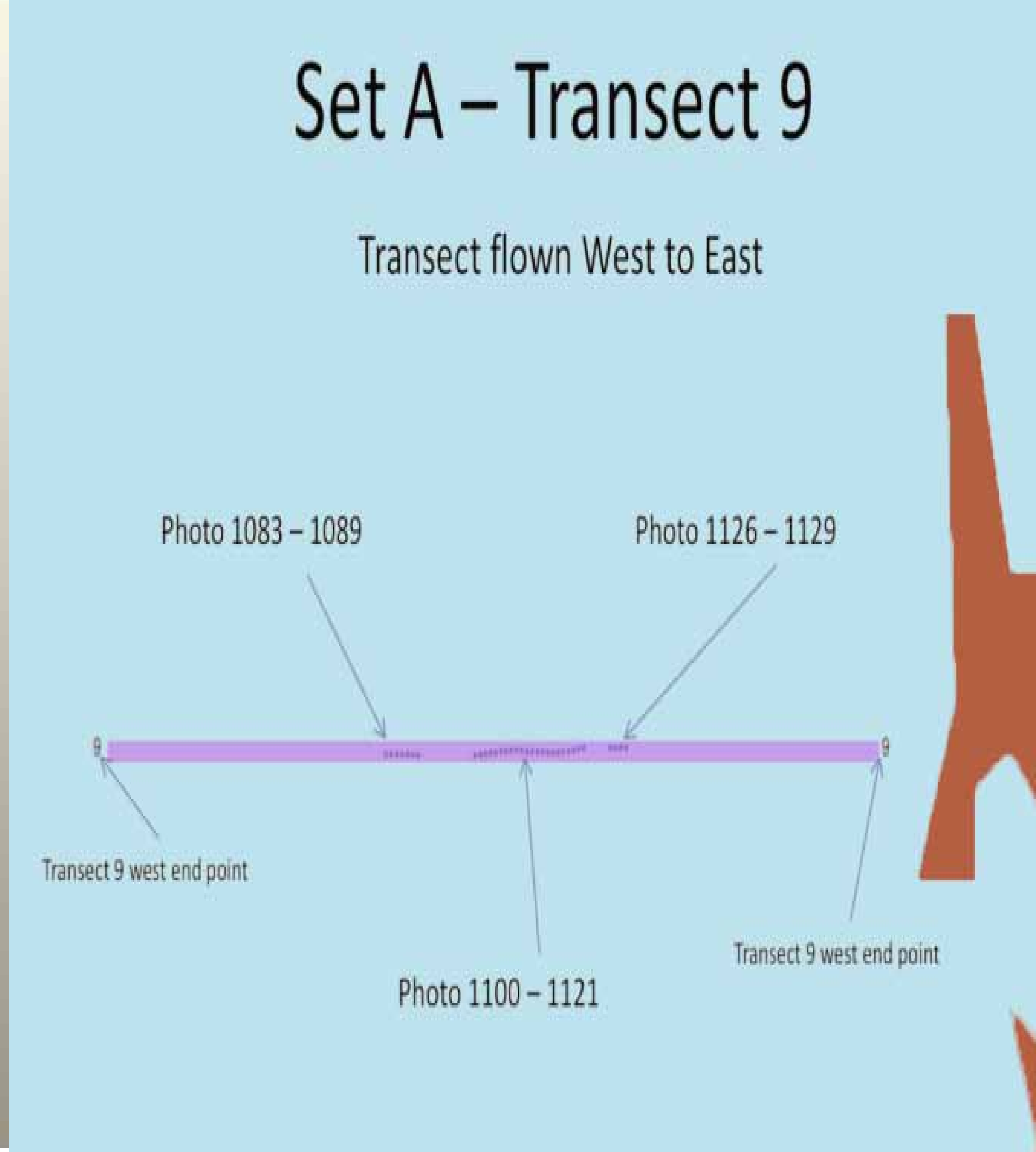
Transect length 35 miles

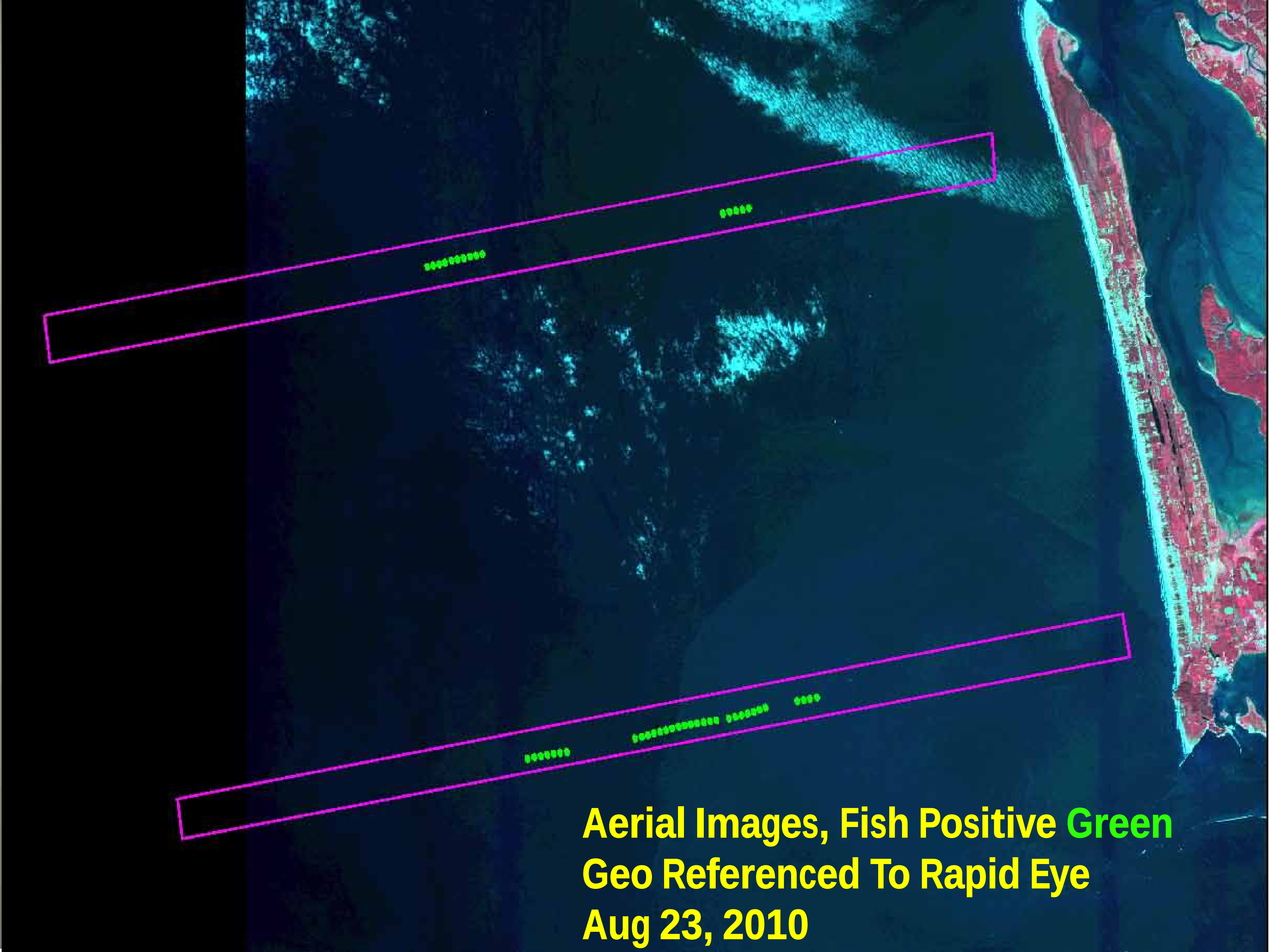
Transect width 1 mile



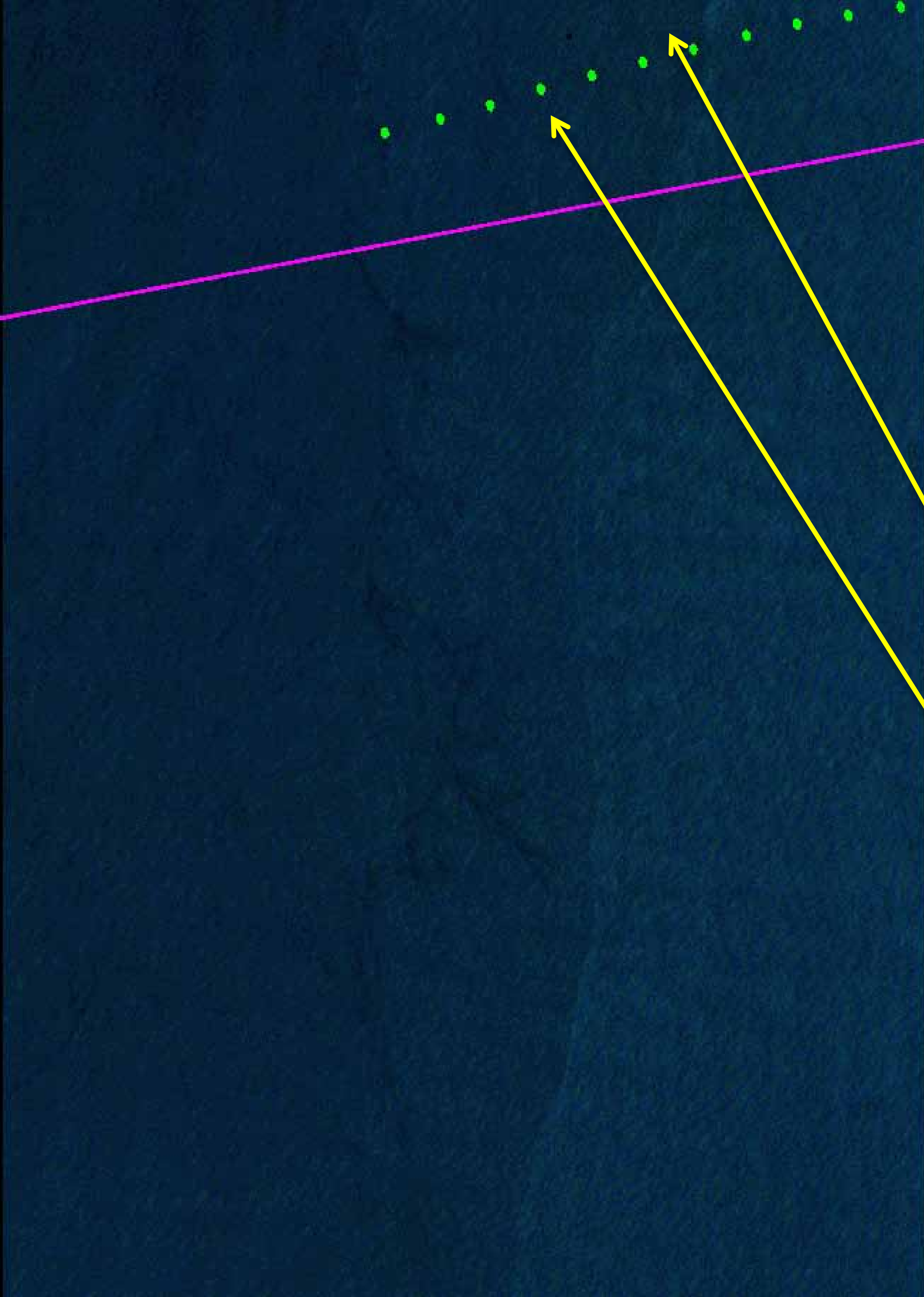

Zoomed Area of Transects 8, 9

Fish Positive Aerial Photos





Aerial Images, Fish Positive Green
Geo Referenced To Rapid Eye
Aug 23, 2010



Aerial Photos Positions On Satellite Image

August 23, 2010

Image 3P3Q1105

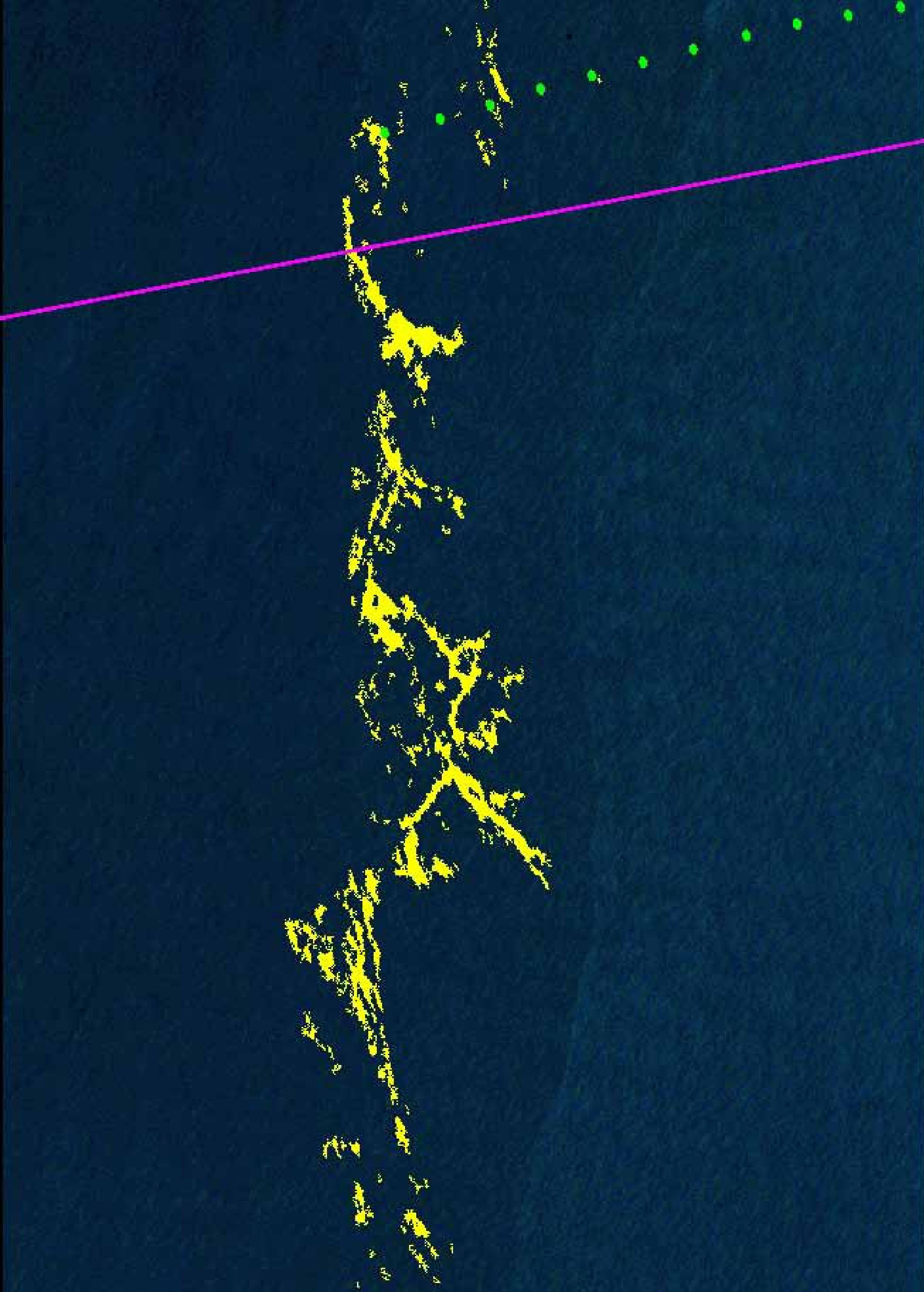
Image 3P3Q1103

Transect 9 Set A Image 3P3Q1103

Transect 9 Set A Image 3P3Q1103

Transect 9 Set A Image 3P3Q1105

Transect 9 Set A Image 3P3Q1105



Satellite/Aerial Image Hybrid

Determine Characteristics of Sardine Schools From Aerial Images

Assign Sardine Photo Properties To Satellite Image

Map Similarities on Satellite Image W/ Automated Classification Software

Colored in Yellow = Sardine

Measured Surface Area In This Region
279 Acres **1,129,113 SQ Meters**

22,582 Metric Tons of Sardine

Satellite Imagery Benefits

- Provides Accurate Data for the Sardine Assessment Model
  Reduced extrapolation of data because of greater area coverage

- Advanced Software Available for Image Enhancement
  Automates and improves image calculations and species identification

- Obtain Optimum Harvest Yield
  With no risk of over fishing… no guessing, real time observations

- Social and Economic Impacts Avoided
  Quotas determined by complete coastal surveys… won't miss fish

- Improved Understanding of Complex Biological Systems
  Ocean conditions (water temps, plankton concentrations) overlaid with sardine concentrations for future study

Agenda Item I.3.c
Public Comment

Title: Use of Satellite Imagery to Complement Aerial Survey Estimates of Sardine Abundance

Name of proposers: Northwest Sardine Survey, LLC – Jerry Thon, Principal; Science advisor: Tom Jagielo Consulting

How the proposed methodology will improve assessment and management for CPS species:
The aerial sardine survey has now contributed information that has been used in two assessments of Pacific sardine. Experience gained in conducting the aerial survey, together with the results from a satellite-imagery pilot project conducted in 2009 and 2010, have resulted in the identification of ways that satellite imagery can be used to improve the aerial sardine survey.

Incorporating satellite-image estimates of sardine abundance will augment the existing aerial sardine survey by 1) improving sampling logistics to optimize observational parameters, and 2) substantially increasing the area of the ocean surface sampled, and thus potentially reducing the uncertainty of the biomass estimate. The current aerial survey employs small aircraft to fly three pre-designated replicate transect sets (a total of 182 transects were flown in 2010). This method is time consuming and puts pilots at risk (portions of the transects extend beyond thirty-five miles from the shoreline). Also, because of survey time constraints, transects cannot always be flown during optimal conditions for observing sardine schools. This was a noteworthy problem in 2010, when a persistent coast-wide marine layer delayed the sampling effort starting time in early summer. As a result, numerous transects were flown throughout the summer 1) with over 50% cloud cover, 2) under windy conditions, and 3) at sub-optimal times-of-day for glare and other considerations. By contrast, satellite imagery can capture the entire coast in a matter of minutes, and is thus virtually instantaneous from a sampling perspective. We have been working with a vendor (Spatial Solutions, Inc.) who provides satellite imagery specifically tailored to our project's needs. For example, we can control for parameters that influence the visibility of sardine schools at the ocean surface, such as 1) percent cloud cover, and 2) atmospheric moisture levels. Incorporating satellite imagery into the aerial survey approach will improve the likelihood of capturing multiple replicate observations, under conditions optimal for observation. From the perspective of survey sampling design statistics, satellite imagery can provide a a virtual census of the coast -- with less need for statistical extrapolation, as from transect sampling. Thus, estimates of abundance can potentially be obtained with less sampling uncertainly.

Outline of methods:
1) Pre-stratification. Examination of NOAA satellite coverages showing "real-time" distribution of chlorophyll *a*, temperature, etc. will be used for pre-stratification.

2) Selection of target coverage area. The area to be covered by the satellite imagery (to be purchased from the vendor) is selected.

3) Spatial allocation of transects for aerial photography. The approach will be to conduct adaptive sampling based on a combination of 1) the distribution of sardines found in previous year's aerial sardine survey results, and 2) "real time" information from satellite pre-stratification data (above).

4) Satellite survey of target area – three replicate images, collected under optimal observational parameter settings.

5) Aerial transect survey of target area – three replicate transect sets (using the currently approved methodology).

6) Ground-truthing of satellite imagery. This will be accomplished by 1) one to one comparisons of aerial photographs with sardine schools and satellite images from the same day/time, and 2) in-situ jigging by fishermen to confirm the sardine signature on the satellite image.

7) Analytical methods:

Aerial survey. Estimates of abundance will follow the methods currently used. Point sets will be conducted to establish the area-biomass relationship of sardine schools in the target area.

Satellite survey. Estimates of sardine school surface area will be obtained using 1) the sardine signature developed from ground-truthing (item 6, above), and classification algorithms developed using ERDAS software.

Logistics and Funding:
This project will be managed logistically by the Northwest Sardine Survey. Scientific leadership will be provided by Tom Jagielo, Consulting. Funding will potentially come from multiple sources including 1) the sale of fish under an EFP research set-aside program, and 2) federal funding sources, as available.

Submitted October 14, 2010 for review at the November, 2010 Council meeting.

Staff Note: This methodology proposal is paired with the proposal submitted by Mr. Jerry Thon (Agenda Item I.3.c public comment). They represent a single methodology proposal.

Agenda Item I.3.c
Public comment
November 2010

Proposed Survey Method for Consideration by Methodology Review Panel

*** Title: Acoustic-trawl surveys of coastal pelagic fish species (CPS) in the California Current**

The following is a succinct proposal for an acoustic-trawl method for surveying CPS. The NMFS SWFSC is the principal proponent.

Name of proposers: David Demer, Juan Zwolinski, Randy Cutter, Kyle Byers, and Josiah Renfree (participants in the review; and analysts during that review).

Expectations for improvement of assessment and management for CPS species: Acoustic-trawl surveys provide estimates of abundances (CVs ~0.2 to 0.3) and distributions of multiple CPS species (e.g., Pacific sardine, jack mackerel, anchovy and Pacific mackerel), perhaps multiple times per year, each year, contributing to biomass time-series.

Outline of methods (field and analytical): Acoustic surveys are conducted during daylight hours using multiple frequency echosounders (18, 38, 70, 120, and 200 kHz; Simrad EK60s) along parallel, randomly-spaced track lines, running approximately perpendicular to the coastline. Using backscattering spectra, these acoustic data are ascribed to CPS and other scatterers. Surface-trawl samples are taken along the same transects during night-time hours to sample the CPS species and their sizes. The CPS backscatter data is apportioned to CPS species using the trawl data and the fish length information is used to estimate their acoustic target strengths which allow estimations of biomass by species. Random-sampling error is estimated from a bootstrap analysis of the acoustic and trawl samples.

PFMC Agenda Item I.3.c
Public Comment
November 2010

California Wetfish Producers Association
PO Box 1951 • Buellton, CA 93427 • Office: (805) 963-5430 • Mobile: (805) 350-3231 • Fax: (805) 686-9312 • www.californiawetfish.org

Mr. Mark Cedergreen, Chair
Dr. Don McIsaac, Executive Director
Pacific Fishery Management Council
7700 NE Ambassador Place #200
Portland OR 97220-1384

RE: Agenda Item I.3.c **Terms of Reference for Stock Assessment and Methodology Review Panels**

Dear Mr. Cedergreen, Dr. McIsaac and Council members,

The California Wetfish Producers Association (CWPA) represents the majority of active wetfish fishermen and processors from both Monterey and southern California. We appreciate this opportunity to present the following comments supporting our request for consideration re: the TOR for STAR and Methodology Review Panels.

As noted elsewhere in this Briefing Book, California dedicated substantial effort and funding to participate in a synoptic summer (August-early September) aerial survey in 2009 and 2010. Both the SSC and CPS Management Team found the survey methods followed the protocol described in the operational plan (to the extent Mother Nature allowed.) However, in light of the severe and persistent summertime marine fog pattern that plagued us in both years, and which is predicted to increase in the future, coupled with the urgency to analyze and present aerial survey data prior to October, as required by the current stock assessment schedule, we believe the best use of our research budget in the future is to focus efforts toward developing and improving survey methods to measure the resource in the fall, when sardines are abundant in California and weather conditions are more cooperative.
.
As the Council also is aware, we have invested significant resources, supported in part by a small (800 mt) EFP allocation this year, to assess the variance between and among several methods to measure sardine: day vs. nighttime photography following the same techniques as in the summer aerial survey, coupled with the addition of LIDAR (Light Detecting and Range), which can 'see' 50 meters underwater (far deeper than the cameras now employed in the aerial survey), and hydroacoustics. As part of our research plan this fall, we will be conducting point sets to calibrate and compare all these survey methods, working in communication and cooperation with the SW Fisheries Science Center to conduct point sets on schools measured with acoustics. Our fall pilot is timed to coincide with the CalCOFI survey, underway concurrently with the November Council meeting. This study will be completed on or before November 30, 2010. A brief description of methods and evaluation of the three components of this survey, supplied at the request of the SSC, is appended to this letter.

Results from this fall project will form the basis for an EFP application to be submitted in early January, as outlined in the Recommendations for Research Set Asides n 2011.

We understand the Council will approve a list of prioritized methods for STAR panel review in 2011, beginning with a review of acoustic technology requested by the SW Fisheries Science Center, which then could be incorporated in the 2011 sardine stock assessment. We request Council support to include the results from CWPA's fall pilot for STAR panel review in 2011 also. The acoustic element described in our final report is intended to calibrate the acoustic methods presented by the SW Fisheries Science Center. If time is an issue, we ask that the LIDAR / photographic elements be considered for review in conjunction with the May Pacific Mackerel STAR panel.

Peer-reviewed papers by NOAA's Dr. James Churnside et al have already been published, comparing LIDAR and acoustics as well as LIDAR and aerial photogrammetry (specifically video). The CWPA research project will draw on these published works to expand and improve aerial survey and acoustic techniques to measure sardine abundance. Our goals in this work are to utilize one or more methods to measure the sardine population when abundant in California, as well as to improve existing survey methods for potential future synoptic use to investigate sardine migration patterns.

We would appreciate the Council's support for 2011 STAR panel review of the data produced in CWPA's fall pilot study. Thank you very much for your consideration.

Best regards,

Diane Pleschner-Steele

Diane Pleschner-Steele
Executive Director

Attachment: CWPA Methods Description

PFMC Agenda Item 1.3.c
Public Comment
November 2010
Attachment to CWPA cover letter

CWPA Methods Description

Prepared for

Pacific Fisheries Management Council

October 15, 2010

Title:

CWPA Methods Review Proposal: aerial photographic surveys with lidar and hydroacoustic components for calibration.

Names of Proposers:

California Wetfish Producers Association
Diane Pleschner-Steele
Doyle Hanan
James Churnside
David Demer
Don LeRoi

How proposed methodology will improve assessment and management for CPS species.

Current aerial sardine assessment techniques for estimation of biomass photographed are dependent on capture of sardine schools that have been photographed immediately prior to capture by purse seine (termed a point set in this survey). School surface areas (m^2) are regressed against the landing weights (biomass in mt) for all schools captured to develop an expected relationship. Only those schools captured and meeting stringent criteria (>90% of school captured, series of pictures that delineate or identify the school captured) are used in the analysis. During the 2009 and 2010 aerial surveys, a total of 69 “acceptable” purse seine sets were made, but they represented a very small portion (3%) of the total schools photographed and measured (2,523). For the California portion of the two surveys, only 17 of 81 sets were qualified for use in the regression and in Oregon/Washington 52 of 70 were used. Because of these issues as well as others, this point set method of determining school density is difficult to accomplish, varies by location, and is expensive.

We are proposing the use of additional methods to enhance measurements of school density and to calibrate these techniques for use with aerial surveys. The methods we propose (lidar and hydroacoustics) have been tested in numerous studies and have demonstrated their effectiveness for providing quantifiable results. There are advantages and disadvantages to each method, but either method, or both, should yield results superior to the point set method alone. Lidar provides a third dimension (actual thickness of schools) and hydroacoustics also provides that third dimension, which is missing in the aerial survey utilizing surface photogrammetry alone (hydroacoustic sound return gives a 3-D view/analysis of schools). Lidar can be run simultaneously from the same airplane that conducts the photographic survey; therefore all schools sampled by lidar will also have corresponding photographs. Schools found near the ocean surface sampled by hydroacoustics can also be photographed.

Better estimates of density for large numbers of schools during photographic surveys will be very useful for improving sardine assessment and management. Sampling by airplane, or multiple planes, can cover large areas of the sardine habitat relatively quickly, but weather, clouds and fog can seriously hamper aerial surveys, Ships and hydroacoustics can cover areas further offshore and can sample when airplanes are restricted by weather.

Airplanes are less expensive for the area surveyed and much faster; therefore, we are proposing a coordinated survey utilizing all three techniques.

We are also proposing that this survey be conducted in the fall (October-November) when the marine layer, low clouds, and fog, that greatly restricted the aerial survey for the past two years in California during the summer, are less prevalent. Fall is also a season when the seas tend to be calmer and clearer, thus allowing better photographic conditions. This time period is also a season when sardines have returned to California from the PNW, and there will be a greater chance of sampling the stock with reduced variability using the combined techniques discussed above. When combined with the summer aerial survey, hydroacoustics, and DEPM, a fall survey should contribute significantly to our understanding of Pacific sardine abundance, migratory patterns and trends. Based on result from this pilot project we will be submitting an EFP application to be submitted in early January, as outlined in the Recommendations for Research Set Asides in 2011.

Outline of methods (field and analytical).

We are proposing a survey method that utilizes aerial survey methodology that has already been approved by the Council. To this methodology we will add simultaneous lidar use in the transect airplanes. We also plan point sets on targeted sardine schools to calibrate with CalCOFI and SWFSC shipboard hydroacoustics, which will augment and enhance the aerial survey by comparison with those hydroacoustic surveys.

LIDAR FIELD LOGISTICS AND ANALYSIS:

Use of Lidar Resource

We will be incorporating and following closely assessment methods developed by Dr. Jim Churnside for comparison of lidar to photogrammetric techniques (high definition video[1]) and acoustics (BioSonics 208 kHz splitbeam transducer[2]). In the video study, Dr. Churnside counted fish schools for analysis, but we intend to measure surface area and density of fish schools for comparison to the photographs we will collect, adopting and expanding his survey methods to correspond with our existing STAR panel approved photographic analysis. We expect to use lidar gear, techniques, and settings very similar to (Churnside, et al., 2001): “frequency-doubled, Q-switched Nd:YAG laser that produced 120 mJ of green (532 nm), linearly polarized light in a 12 nsec pulse at a rate of

[1] Churnside, J. H., A. F Sharov, R. Richter. (Submitted for publication). Aerial Surveys of Fish in estuaries: A Case Study in Chesapeake Bay. 27 pages.

[2] Churnside, J. H., Demer, D. A., and Mahmoudi, B. 2003. A comparison of lidar and echosounder measurements of fish schools in the Gulf of Mexico. ICES Journal of Marine Science, 60:147–154.

30 pulses per second. The beam from the laser will be diverged, using a lens in front of the laser, to be eye-safe at the surface (laser spot diameter of approximately 8 m) from the flight altitude of 600 m. The diverged beam will be directed by a pair of mirrors to be parallel to the axes of the two receiver telescopes, which collected the two orthogonal polarizations of the backscattered light. The first receiver channel uses a 7 cm diameter refracting telescope with a polarizer aligned with the laser polarization to measure the co-polarized lidar return. The other channel uses a 17 cm diameter telescope with a polarizer oriented perpendicular to the laser polarization to measure the cross-polarized lidar return. Each of the telescopes collects light onto an interference filter to reject background light. An aperture at the focus of the primary lens also limits background light by limiting the field of view of the telescope to match the divergence of the transmitted laser beam. A photomultiplier behind each telescope converts the lidar return into an electronic signal, which is passed through a logarithmic amplifier to improve the dynamic range. This signal is digitized at a rate of 109 samples per second during the return from each laser pulse. The computer records the digitized returns, along with the position and time from a GPS receiver, and displays the data to the operator. Sardine schools will be identified by visual examination of the photographs and lidar data and then lidar data will be plotted in grey scale. Return from water near the school will be estimated and subtracted from the sardine school returns to account for water scattering between fish. This return will also be used to estimate lidar attenuation and the signal will be corrected by multiplying with the inverse of attenuation. In addition, the penetration depth of lidar will be estimated as the depth at which the lidar signal reaches the same level as from background light in the absence of sardine schools. Length of each school along the flight track will be estimated from the number of lidar pulses across the school, the time between pulses, and the speed of the aircraft. The school area will then be estimated by assuming the measurement passes through the center of a circular school. Average distance between sea surface and maximum lidar return within schools is assumed to be a measure of school depth for calculating school volume."

The following steps will be applied to processing of the lidar data:

1. Identify fish schools by visual inspection of the data.

2. Measure the optical properties of the water near the schools. The important properties are the lidar attenuation, α, and the volume backscatter function, β_w. The lidar signal in homogenous water has the form

$$S_w = C\beta_w \exp(-2\alpha z), \tag{1}$$

where C is the calibration constant of the lidar, S_w is the lidar signal near the school, and z is depth. A is obtained from a laboratory calibration and the other two parameters are found from the lidar signal at several depths using Eq. (1).

3. Calculate the corrected volume backscatter from the school according to the following equation

$$\beta_f \;=\; (CS - \beta_w)\exp(2\alpha z), \tag{2}$$

where β_f is the volume backscatter coefficient of fish within the school.

4. Estimate the density of fish within the school using the equation

$$N \;=\; \frac{\beta_f}{\sigma}, \tag{3}$$

where σ is the backscatter cross section of a single fish. The average backscatter cross section of a collection of 480 sardines was measured in a tank (Churnside et al., 1997), with the result

$$\sigma \;=\; (9.7 \pm 0.9)\times 10^{-3} A, \tag{4}$$

where A is the cross sectional area of a single fish as seen from above. The area is generally proportional to length squared, and a linear relationship between backscatter cross section and length squared is also used in fisheries hydroacoustics. For sardines, we expect the area to be about 0.1 times the length squared. If lidar to be used as an absolute measure of biomass, more work will be needed to refine the relationship between backscatter cross section and fish length.

5. Estimate the total number of fish in the school from the product of the number density and the total volume. School volume will be estimated in two different ways. The first will use the thickness of the school inferred from the lidar and the area from the camera images. The other will use the length of the school along the lidar track to estimate its area under the assumption of a circular school. This technique worked very well in estimating the area of menhaden schools in Chesapeake Bay (Churnside et al., 2010), but it is not clear yet how well it will work for sardines.

6. Perform a regression analysis comparing the lidar results with hydroacoustics, point sets, and images. This will involve binning of the data to account for time differences between observations. The spatial scale of that binning will be determined during processing, based on the scales of variability in the data.

References

Churnside, J. H., J. J. Wilson, and V. V. Tatarskii (1997) Lidar profiles of fish schools, Appl. Opt. **36**, 6011-6020.

Churnside, J. H., A. F. Sharov, and R. A. Richter (2010) Aerial surveys of fish in estuaries: a case study in Chesapeake Bay, ICES J. Mar. Sci. doi: 10.1093/icesjms/fsq138

HYDROACOUSTICS FIELD LOGISTICS AND ANALYSIS:

Methods

Aerial surveys are to be conducted for schools of sardine. The remote observations of near-surface fish schools will be used to estimate fish abundance. These estimates are to be validated by purse-seine capture of a number of schools. Here we propose to augment these measurements with active-hydroacoustic measurements made with a multi-frequency split-beam echosounder system (Simrad EK60), and a single-frequency multi-beam sonar (Kongsberg-Mesotech SM20/2000). After a fish school is spotted, and before it is netted, a vessel equipped with hydroacoustic instrumentation will drive around the school to hydroacoustically estimate the size and shape of the school; a subset of schools will be measured by driving over the school multiple times to hydroacoustically estimate the fish density. Schools measured by sonar will also be photographed and observed to evaluate fish avoidance behavior during these transects.

EK60 multi-frequency echosounder

Throughout the survey, volume backscattering strengths (S_v; dB re 1 m) and *in-situ* target strengths (*TS*; dB 1 m^2) will be measured continuously by four calibrated Simrad EK60 split-beam echosounders operating at frequencies of 38, 70, 120, and 200 kHz. The echosounders will be configured with Simrad ES38-12, ES70-7C, ES120-7C, and ES200-7C transducers. The four split-beam transducers will be pole mounted on the side of the ship's hull, and positioned approximately 2m beneath the water surface. Synchronized pulses of 1024 µs will be transmitted downward every 0.5 seconds, received with bandwidths of 0.8745, 1.6375, 2.3435, 2.7785, and 2.986 kHz, respectively, digitized to a range of 150 m, and stored in .raw-data format. Except for the EK60 sounders being used for these surveys, all other echo sounders and sonars operating at or near the survey frequencies will be secured.

SM20/SM2000 Multi-beam sonar

A Kongsberg-Mesotech SM2000 200 kHz multi-beam sonar (180 degree-head with a nominal 155 degree usable swath) and an SM20 processor will be used. The system forms 128 beams that insonify a 180 degree swath. The SM2000 has two transducers: a cylindrical array that can be used to both transmit and receive when operating in imaging mode; and a long stave that can be used as the transmitter, when operated in echosounding mode, with receiving on the cylindrical array. This survey will be conducted in echosounding mode only. The SM2000 sonar head will also be mounted on a pole, attached at an angle of 30 degrees off vertical at a depth of approximately 2 m below the mean water surface.

Triggering

One of the EK60s and the SM2000 both operate at 200 kHz. Therefore, the EK60s and the SM20 processor surface telemetry board (STB) will be triggered using a multiplexer unit. Triggering will be synchronous for all EK60s, and asynchronous (alternating) between the EK60s and the SM20 to prevent interference. That is, a trigger pulse will be sent to the EK60s every second; one-half second after the pulse is sent to the EK60s, a pulse will be sent to the SM20.

AERIAL SURVEY FIELD LOGISTICS AND ANALYSIS:

I. Aerial Transect Survey

Overall Aerial Survey Design

The 2010 California Aerial Sardine Survey design consists of 36 (?) aerial transects spanning the area from 15 miles north of CalCOFI line 86.7 in the north to 15 miles south of CalCOFI line 90 in the southern California Bight (Figures 1 and 2). These transects will extend on or parallel to the CalCOFI lines and run from shore to 75 miles offshore. Each 6-transect series will be conducted as a SET, and will make up one replicate. We intend to fly these transects during both day and night to determine optimum observation time for sardines. The survey will strive to complete three replicate SETS, or 18 transects in total, to the degree possible.

Location of Transects

Transects and corresponding shoreline positions are mapped in Figure 2. The transects start at shore and extend westward for 75 statute miles in length; they are spaced approximately 15 nautical miles (15 minutes) apart in latitude.

Aerial Resources Available

The airplane used for this survey will be equipped with a Canon EOS 1Ds camera with laptop control computer and Lidar equipment ((1) laser and beam-control optics, 2) receiver optics and detector, and 3) data collection and display computer))[3] to survey the transects. The camera will be mounted in an *Aerial Imaging Solutions* FMC mount system installed inside the fuselage and utilizing one of the downward ports (belly port). The Lidar will use a 2nd downward viewing port. Experimental photography of nighttime bioluminescence also will be attempted with a Nikon D700 camera and intensifier, which offers an extremely high ISO along with larger pixel size to reduce noise. It may be sensitive enough to capture usable images at a reasonable shutter speed (1/10th)

[3] Churnside, J. H., J. J. Wilson, and V. V. Tatarskii. 2001. Airborne lidar for fisheries applications. Opt. Eng. 40:406-414.

Use of Aerial Resources
The survey pilot will begin with the most northward transect, flying to the off shore end then move to the next transect and survey to shore. The pilot will repeat this pattern until each transect is surveyed. The pilot will repeat this patter three times thus will attempt to fly a total of 18 transect lines both day and night.

Hydroacoustic Resources Available
Drs. David Demer and Sam McClatchie, NMFS, SWFSC, will direct the hydroacoustic portion of this research project. We propose to augment these measurements with active-hydroacoustic measurements made with a multi-frequency split-beam echosounder system (Simrad EK60), and single-frequency multi-beam sonar (Kongsberg-Mesotech SM20/2000). After a fish school is spotted, and before it is netted, a vessel equipped with the hydroacoustic instrumentation will drive around the school to hydroacoustically estimate the size and shape of the school to hydroacoustically estimate the fish density.

Use of Hydroacoustic Resources
We propose to estimate a function which relates aerially-observed fish school area to fish biomass, including error bounds; and estimate the target strength of sardine (and perhaps other fish species) versus hydroacoustic frequency and fish length, including error bounds.

Conditions Acceptable for Aerial Surveying
At the beginning of each potential survey day, the survey pilot will confer with Dr. Doyle Hanan, Co-principal Investigator, and will jointly judge if conditions will permit safe and successful surveying that day. Considering local conditions, they will also jointly determine the optimal time of day for surveying the area slated for coverage that day. Factors will include sea condition, time of day for best sardine visibility, presence of cloud or fog cover, and other relevant criteria as determined by the survey pilot and Dr. Hanan.

Transect Sampling
Prior to beginning a survey flight, the Pre-Flight Survey Checklist will be completed. This will ensure that the camera system settings and Lidar equipment are fully operational for data collection. For example, it is important to have accurate GPS information in the log file. It is also crucial that the photograph number series is re-set to zero.

The decision of when to start a new SET of transects will be determined jointly by the pilot and the principal investigator. Transects will be flown at the nominal survey altitude of 1,500 – 2,000 ft if possible. If conditions require a lower altitude for acceptable ocean surface visibility, transects (or portions of transects) may be flown at a lower altitude, when necessary. Transects may be flown starting at either the east end or the west end.

A Transect Flight Log Form will be kept during the sampling of each transect for the purpose of documenting the observations of the pilot and/or onboard observers. Key notations will include observations of school species ID and documentation of any special conditions that could have an influence on interpreting photographs taken during transects.

It will be acceptable to skip portions of transects as conditions require (e.g. fog covering a small transect portion). The goal is to cover a full 6-transect SET in one day and two replicate SETS of transects in as few days as possible.

Data Transfer
Photographs and FMC camera log files will be downloaded and forwarded for analysis and archival as soon as practicable. Dr. Hanan will collect photographic data and provide to Zachary Hanan to analyze and archive, with supervision by Don LeRoi. Dr. Hanan will also coordinate collection of the Lidar data and provide to Dr. Churnside to archive and analyze.

II. Point Set Sampling

Location of Point Sets
Point sets are the actual capture of fish by purse seiners approved and permitted for this research. Each set by a purse seiner will be directed by the spotter pilot. Attempts will be made to conduct point sets over as wide an area as feasible; however, point sets may occur in any area covered by aerial transects that are not restricted to purse seine fishing and where sardine schools of the desired size are found.

Aerial Photography of Point Sets
Sardine schools to be captured for point sets will be first selected by the spotter pilot and photographed at the nominal survey altitude of 1,500 – 2,000 ft. Following selection, the spotter pilot will descend to a lower altitude to better photograph the approach of the seiner to the school and set the seiner for capture of the school. The camera system will be running during the whole point set thus allowing photographs before and during the vessels approach to the school for the point set capture. Each school selected by the spotter pilot and photographed for a potential point set will be logged on the spotter pilot's Point Set Flight Log Form. The species identification of the selected school will be verified by the captain of the purse seine vessel conducting the point set and will be logged on the Fisherman's Log Form. These records will be used to determine the rate of school mis-identification by the spotter pilot in the field and by analysts viewing photographs taken.

Vessel Point Set Capture
The purse seine vessel will encircle (wrap) and fully capture the school selected by the spotter pilot for the point set. Any schools not "fully" captured will not be considered a valid point set for analysis. If a school is judged to be "nearly completely" captured (i.e. over 90% captured), it will be noted as such and will be included for analysis. Both the spotter pilot and the purse seine captain will independently make note of the "percent captured" on their survey log forms for this purpose. Upon capture, sardine point sets

will be held in separate holds for separate weighing and biological sampling of each set after landing.

Biological Sampling

Biological samples of individual point sets will be collected at the landing docks or at the fish processing plants upon landing. Fish will be systematically taken at the start, middle, and end of a delivered set. The three samples will then be combined and a random subsample of fish will be taken. The sample size will be n = 50 fish for each point set haul.

Length, weight, maturity, and otoliths will be sampled for each point set haul and will be documented on the Biological Sampling Form. Sardine weights will be taken using an electronic scale accurate to 0.5 gm. Sardine lengths will be taken using a millimeter length strip attached to a measuring board. Standard length will be determined by measuring from sardine snout to the last vertebrae. Sardine maturity will be established by referencing maturity codes (female- 4 point scale, male- 3 point scale) supplied by Beverly Macewicz NMFS, SWFSC. Otolith samples will be collected from n = 25 fish selected at random from each n = 50 fish point set sample for future age reading analysis.

Hydroacoustic Sounding of School Height

School height will be measured for each point set. This may be obtained by using either the purse seine or other participating research vessels' hydroacoustic gear. The school height measurements to be recorded on the Fisherman's Log Form are: 1) depth in the water column of the top of the school, and 2) depth in the water column of the bottom of the school.

Number and Size of Point Sets

Point sets will be conducted for a range of school sizes (Table 1). Each day, the spotter pilot will operate with an updated list of remaining school sizes needed for analysis. The spotter pilot will use his experience to judge the biomass of sardine schools from the air, and will direct the purse seine vessel to capture schools of appropriate size. Following landing of the point sets at the dock, the actual school weights will be determined and the list of remaining school sizes needed from Table 1 will be updated accordingly for the next day of fishing. If schools are not available in the designated size range, point sets will be conducted on schools as close to the designated range as possible. Dr. Hanan will oversee the gathering of point set landing data and will update the list daily. The total landed weight of point sets sampled will not exceed **800 mt**. The number of point set samples needed for the Southern California pilot sardine aerial survey in 2010 (Table 1), were distributed to obtain adequate data points for the area-biomass regression in the region between 2,000 and 10,000 m^2 of school surface area (Figure 3).

Landing Reporting Requirements

Cumulative point set landings will be maintained and updated by Ms. Diane Pleschner-Steele or Dr. Hanan and will be reported daily to NMFS, as per the terms of the Exempted Fishing Permit. Also included in this daily report will be an estimate of the weight of all by-catch by species.

Other EFP Reporting Requirements
Ms. Pleschner-Steele or Dr. Hanan will be responsible for providing the other required reporting elements (as specified in the EFP permit) to NMFS. For example, a daily notice will be provided for enforcement giving 24 hour notice of vessels to be conducting point sets on any given day and will include vessel name, area to be fished, estimated departure time, estimated return time.

III. Calibration and Validation

Aerial Measurement Calibration
A series of photographs have been collected from both participating planes, depicting a feature of known size (e.g. a football field or tennis court) on the ground, from the altitudes of 1,000 ft, 1,500, and 2,000 ft. For each altitude series, an aerial pass was made to place the target onto the right, middle, and left portions of the photographic image.

Aerial Photographs and Sampling for Species Validation
A set of reference photographs will be compiled which will be taken at the nominal survey altitude of 1,500 – 2,000 ft for the purpose of species identification. The spotter pilot will find and photograph schooling fish other than sardine (e.g. mackerel, herring, smelt, anchovy, etc). For the actual schools photographed, a vessel at sea will collect a jig sample to document the species identification. This set of reference photographs will be used by the photograph analysts to learn how to discern between sardine and other species as they appear on the aerial transect photographs.

IV. Photograph Data Reduction and Analysis

Digital images will be analyzed by Zachary Hanan, under the supervision of Don LeRoi, to determine the number, size, and shape of sardine schools on each transect. Adobe *Photoshop Lightroom 3.0* software will be used to bring the sardine schools into clear resolution and measurements of sardine school size (m^2) and shape (circularity) will be made using Adobe *Photoshop CS5-Extended*. Transect width will be determined from the digital images using the basic photogrammetric relationship:

$$\frac{I}{F} = \frac{GCS}{A}$$

and solving for *GCS*:

$$GCS = \frac{I}{F}A$$

where I = Image width of the camera sensor (e.g. 36 mm), F = the focal length of the camera lens (e.g. 24mm), A = altitude, and GCS = “ground cover to the side” or width of the field of view of the digital image. Transect width will be obtained by taking the average of GCS for all images collected on the transect. Transect length will be obtained from the distance between start and stop endpoints using the GPS data logged by the data acquisition system.

V. Data Analysis

Total Biomass

Principal Investigator, Dr. Hanan, assisted by Tom Jagielo, will estimate total sardine biomass for the survey area with a 3 step process, and requiring 1) measurements of individual school surface area on sampled transects, 2) estimation of individual school biomass (from measured school surface area and estimated school density), and 3) transect sampling design theory for estimation of a population total. The calculations described below will be implemented using the R statistical programming language.

Individual school surface area (a_i) will be measured on the photo-documented transects using the measurement tool feature of *Adobe Photoshop*, and employed the photogrammetric relationships described above. Individual school density (d_i) will be specific to school size and will be determined from the empirical relationship between surface area and biomass obtained from Stage 2 (point set) sampling (described below). Individual school biomass (b_i) will be estimated as the product of school density and surface area ($b_i = d_i a_i$). The sum of individual school biomass (b_u) will then be determined for each transect (u). The mean sampled biomass for the study area ($\bar{b}$) will be computed as

$$\bar{b} = \sum_{u=1}^{n} b_u \ / n \ ,$$

where n = the number of transects sampled. Total biomass for the study area $(\hat{B})$ will be estimated using the unbiased estimator for a population total (Stehman and Salzer 2000),

$$\hat{B} = N\bar{b} \ ,$$

where N = the total number of transects that could possibly be sampled in the survey area without overlap. In 2011, we intend to fly three replicate sets of transects (SET A, SET B, and SET C) and thus three estimates of $\hat{B}$ will be calculated: $\hat{B}_A$, $\hat{B}_B$, and $\hat{B}_C$, respectively. The point estimate of total biomass for the study area ($\hat{B}_T$) will be obtained by averaging these three estimates of biomass.

Individual School Biomass

The biomass of individual schools observed on the transects (b_i) will be calculated using 1) measurements of school surface area, and 2) the relationship between school surface area and biomass, obtained from point sets. The three parameter Michaelis-Menten (MM) model assuming log-normal error will be used to describe the sardine surface area–density relationship

d_i = (yint * cc + asymp * a_i) / (cc + a_i)

where

d_i = school density (mt/m^2)
a_i = school area (m^2)
yint = y intercept
asymp = asymptote as x -> infinity
asymp/cc = slope at the origin .

As noted above, individual school biomass (b_i) will then be estimated as the product of school density and surface area ($b_i = d_i a_i$).

Total Biomass Coefficient of Variation (CV) for the 2010 PILOT Survey
The CV of the total biomass estimate will be obtained by employing a bootstrapping procedure implemented with the R statistical programming language (Appendix I). The intent of the procedure will be to propagate error from the point of school density estimation forward -- to the ultimate goal of total biomass estimation from the three replicate sets of transect data. The steps of the procedure are:

1) The MM model will be fit to the point set data.
2) A variance-covariance matrix will be derived for the MM model fit to the data, using the R library "MSBVAR" .
3) A matrix of simulated MM parameters will be derived from the MSBVAR output, using the R function "rmultnorm".
4) For n = 100,000 bootstraps:
   a. One realization of the MM parameters will be selected from the matrix of simulated parameters.
   b. The predicted MM curve will be calculated.
   c. Total biomass for the study area will be estimated for each of the three replicate transect sets.
   d. The three replicate estimates of total biomass will be sampled with replacement.
   e. The mean of the sampled replicates will be calculated, and stored as the bootstrap estimate of biomass.
5) The standard error (SE) will be calculated from the stored bootstrap estimates of biomass (4e).
6) CV will be calculated as CV = SE/$\hat{B}_T$.

Table 1. Size and Number of Point Sets needed during 2010 EFP survey for the Southern California Pilot Sardine Survey area. Total landed weight of point sets will not exceed 800 mt.

Surface Area (m2/set)	mt/set	Number of point sets	Total mt
100	3.8	3	11.4
500	10.6	4	42.4
1000	17	5	85
2000	26.5	6	159
4000	51.9	4	207.6
8000	70.5	3	211.5
10000	82.1	1	82.1
Total		26	799

Figure 1. Transects

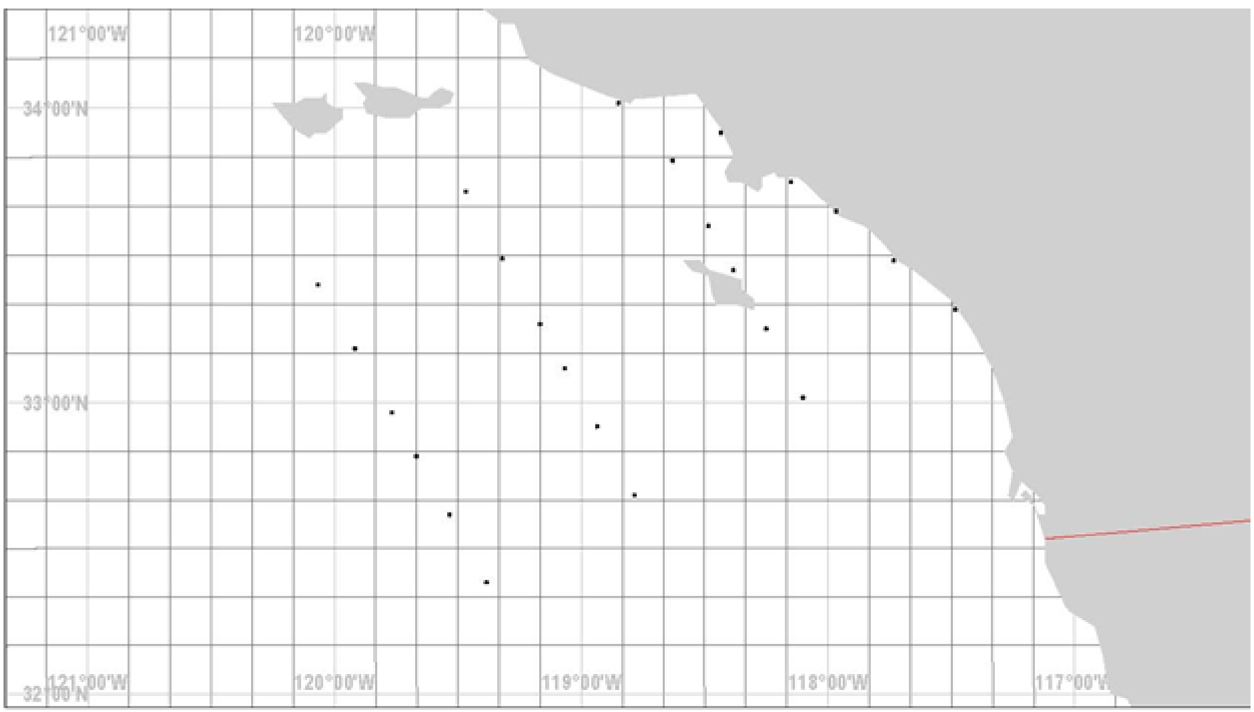
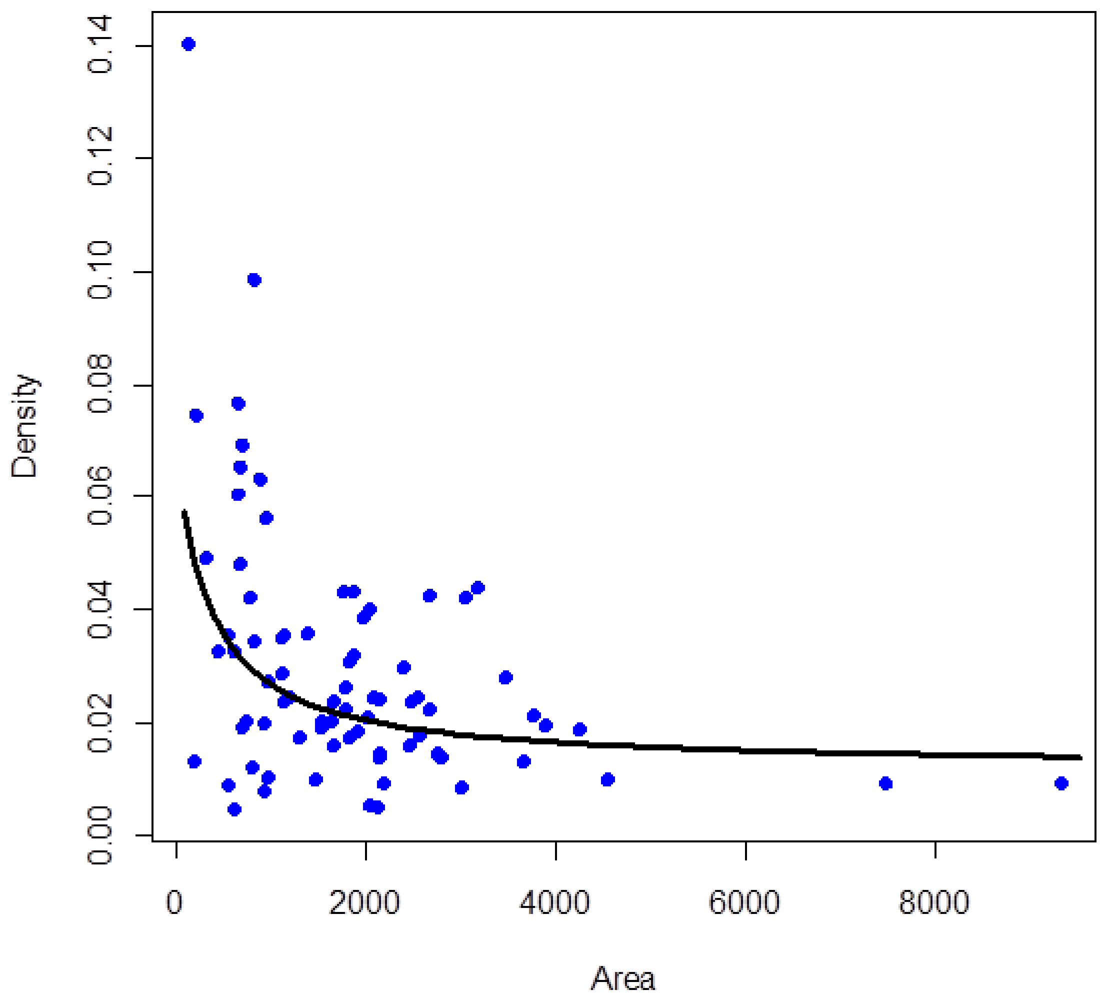


Figure 2. Relationship of surface area (m^2) (x axis) vs. density (y axis) determined from point sets sampled in 2008, 2009, and 2010 (From: West Coast Aerial Sardine Survey Sampling Results in 2010, Jagielo, et al, 2010).



Agenda Item I.3.c
Supplemental Public Comment PowerPoint (Thon)
November 2010

SATELLITE IMAGING

Improvements for Sardine Stock Assessments

2011

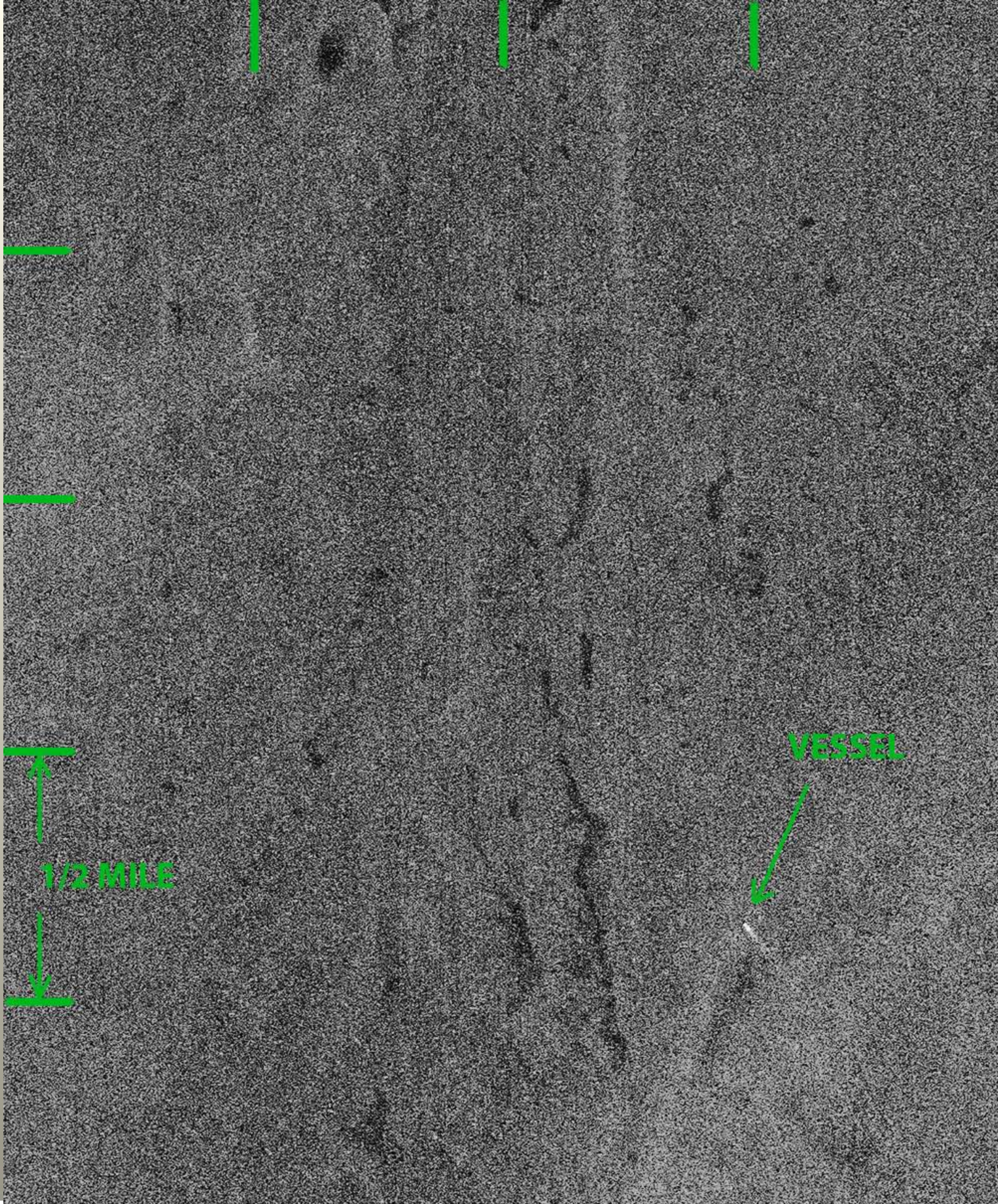
NW Sardine Survey LLC

1st Year

2009 Okonos Satellite Image

Concept Proven

Sardine Schools Identified in Black



2nd Year

Rapid Eye Satellite Image

August 23, 2010
10:30 AM PST

Large Area Multi-Spectral Images

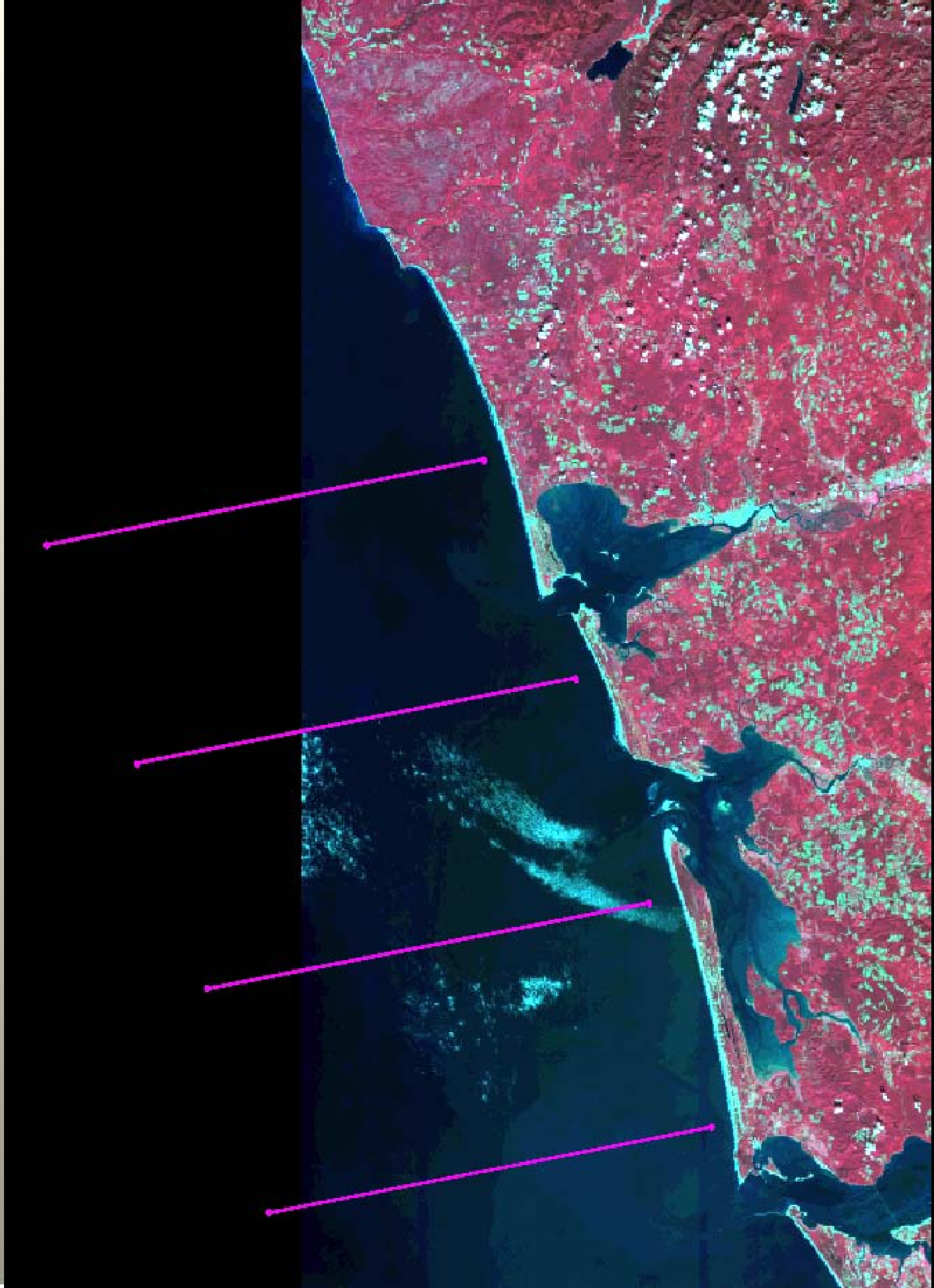
5 Band Sensor Camera
- Blue
- Green
- Red
- Red Near Edge
- Infrared

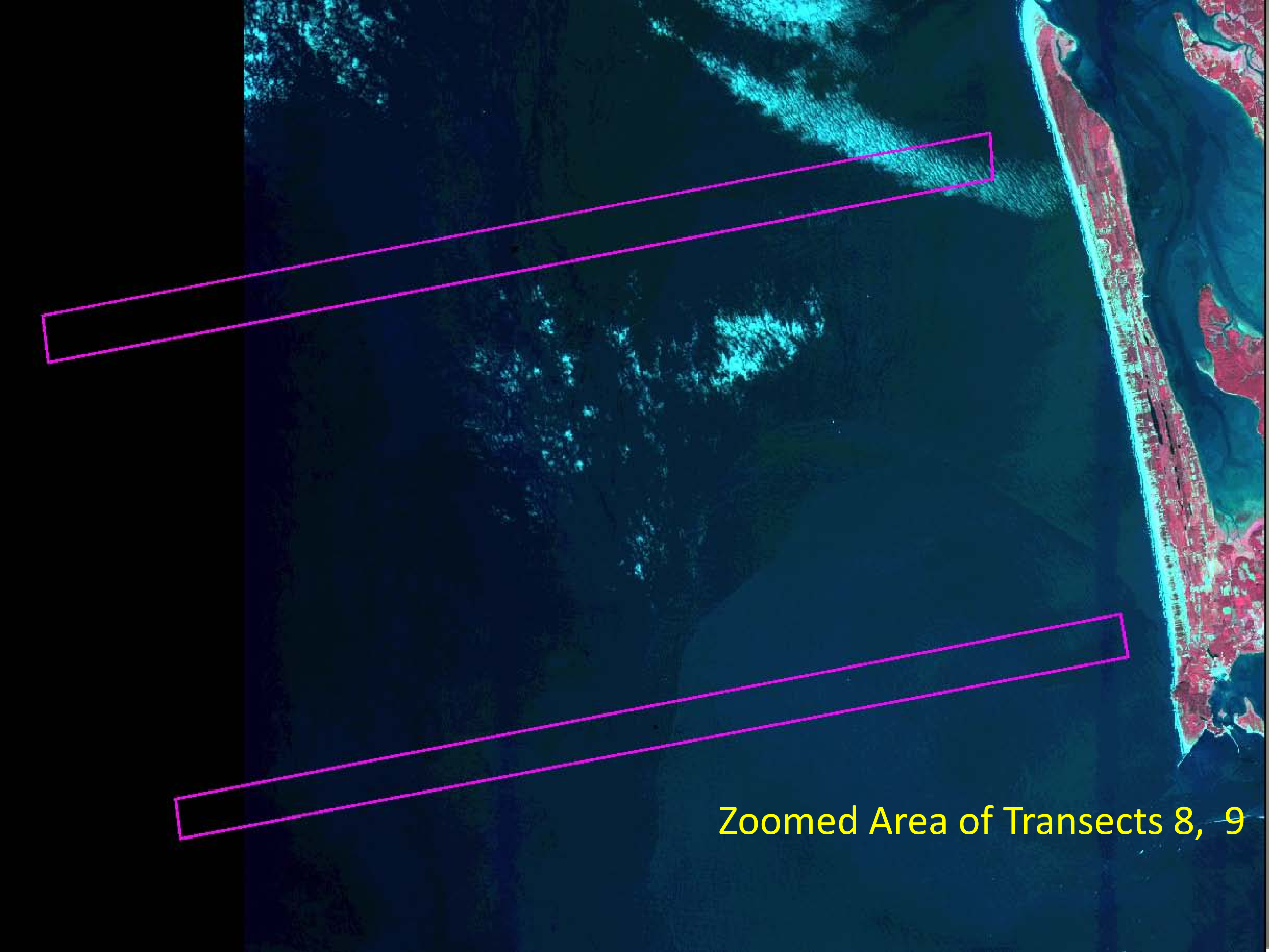
2010 Aerial Survey Transects Overlaid

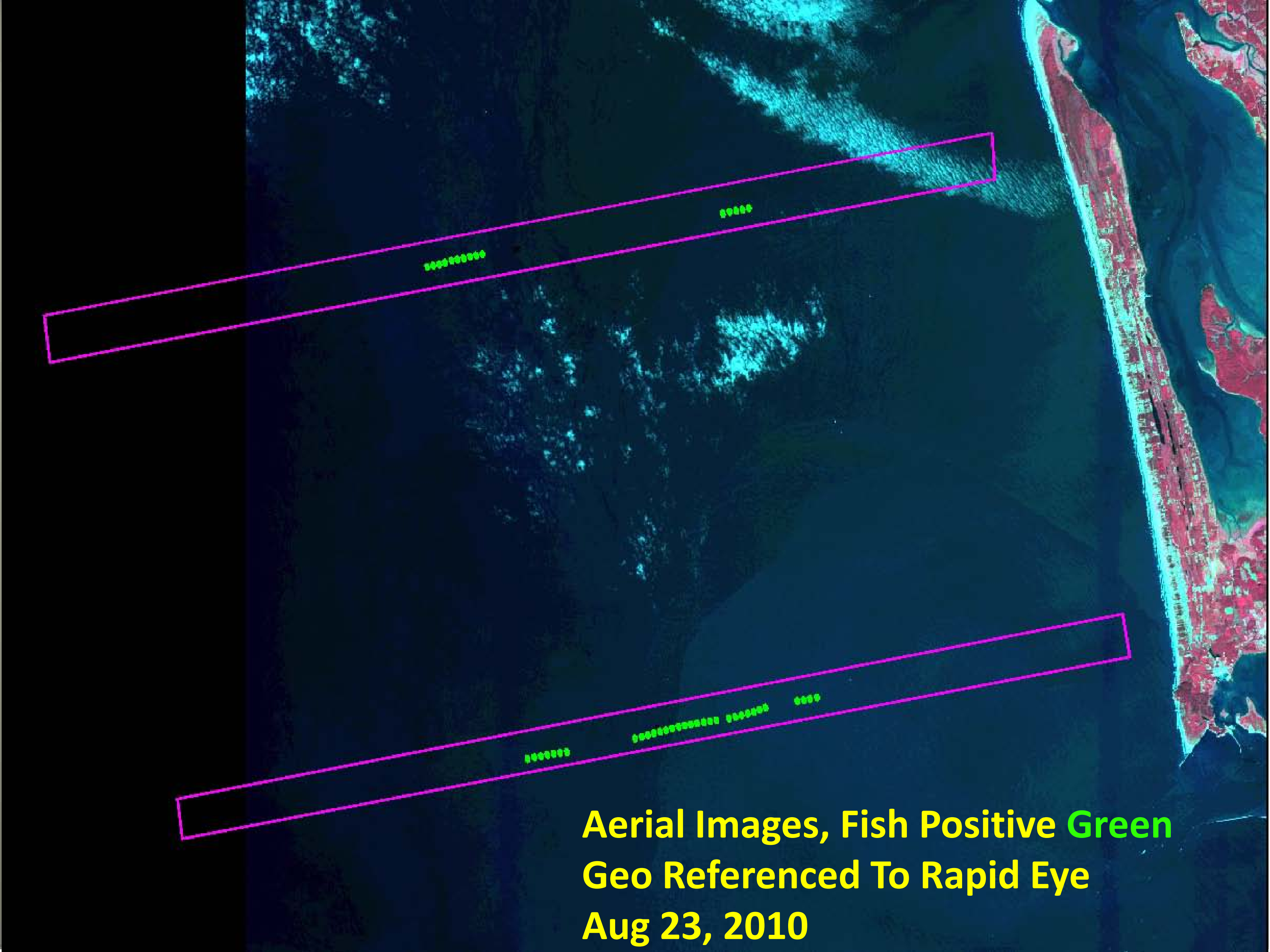
Set A   # 6, 7, 8, 9

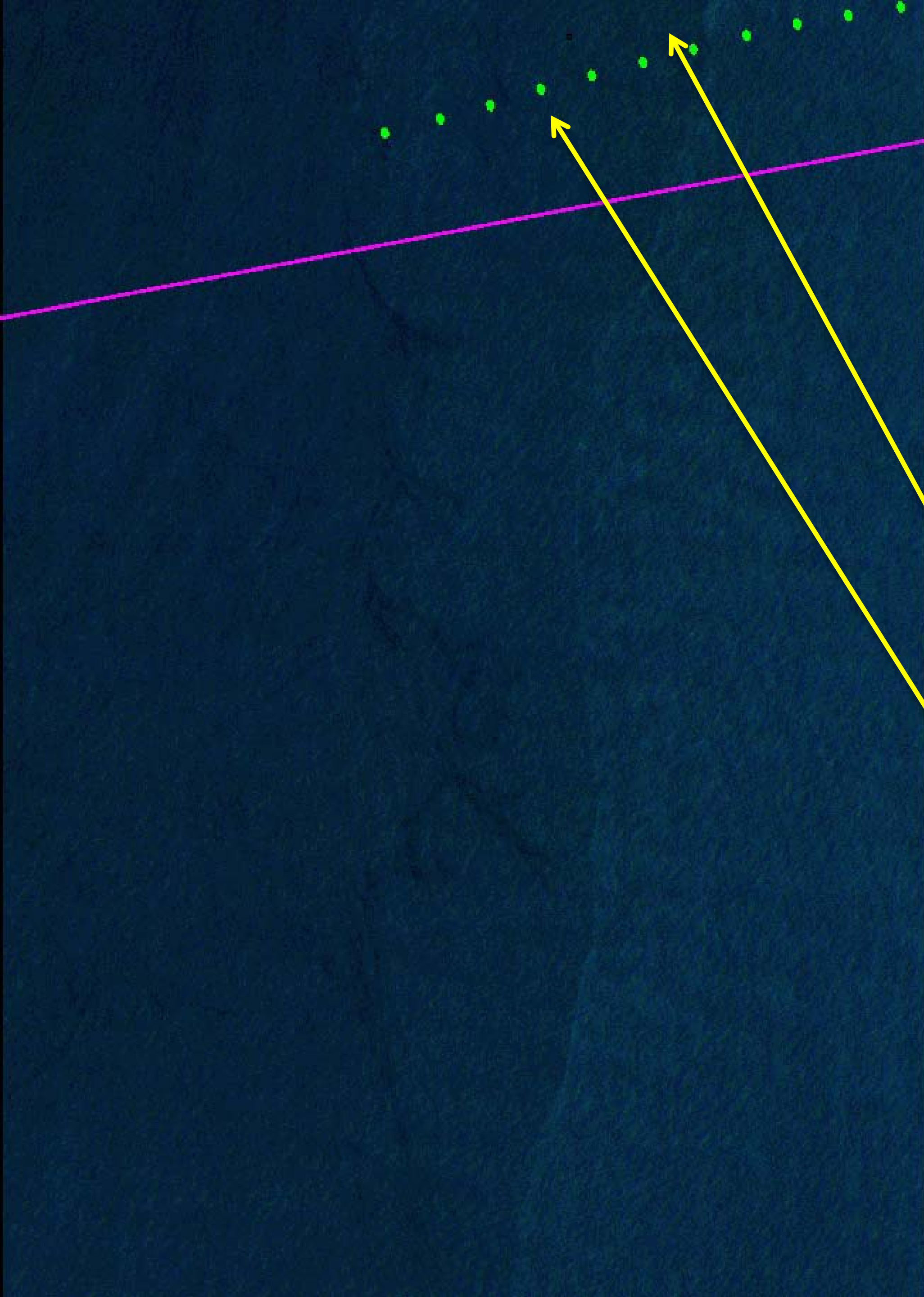
Transect length 35 miles

Transect width 1 mile




Zoomed Area of Transects 8, 9


Aerial Images, Fish Positive Green
Geo Referenced To Rapid Eye
Aug 23, 2010



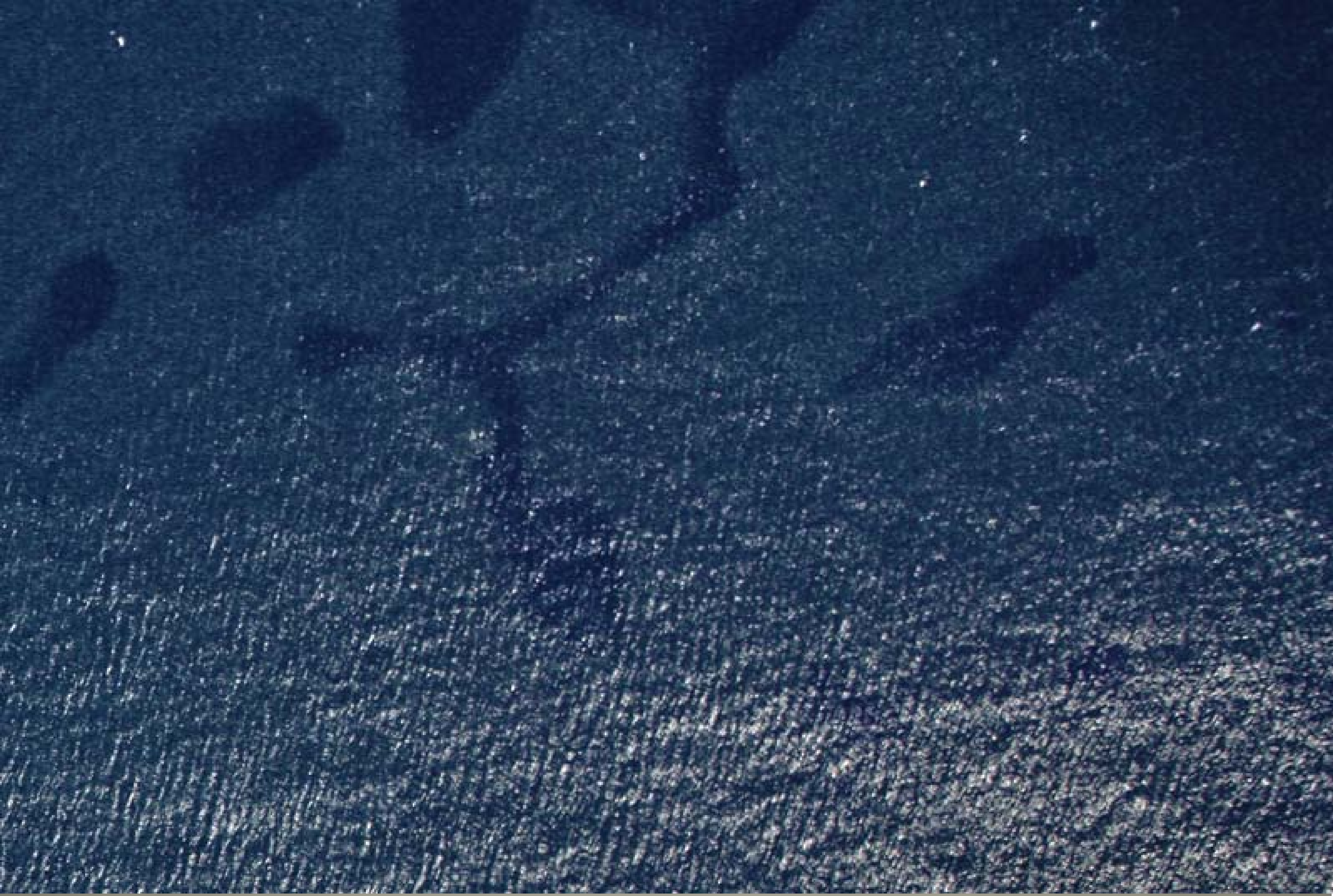
Aerial Photos Positions On Satellite Image

August 23, 2010

Image 3P3Q1105

Image 3P3Q1103

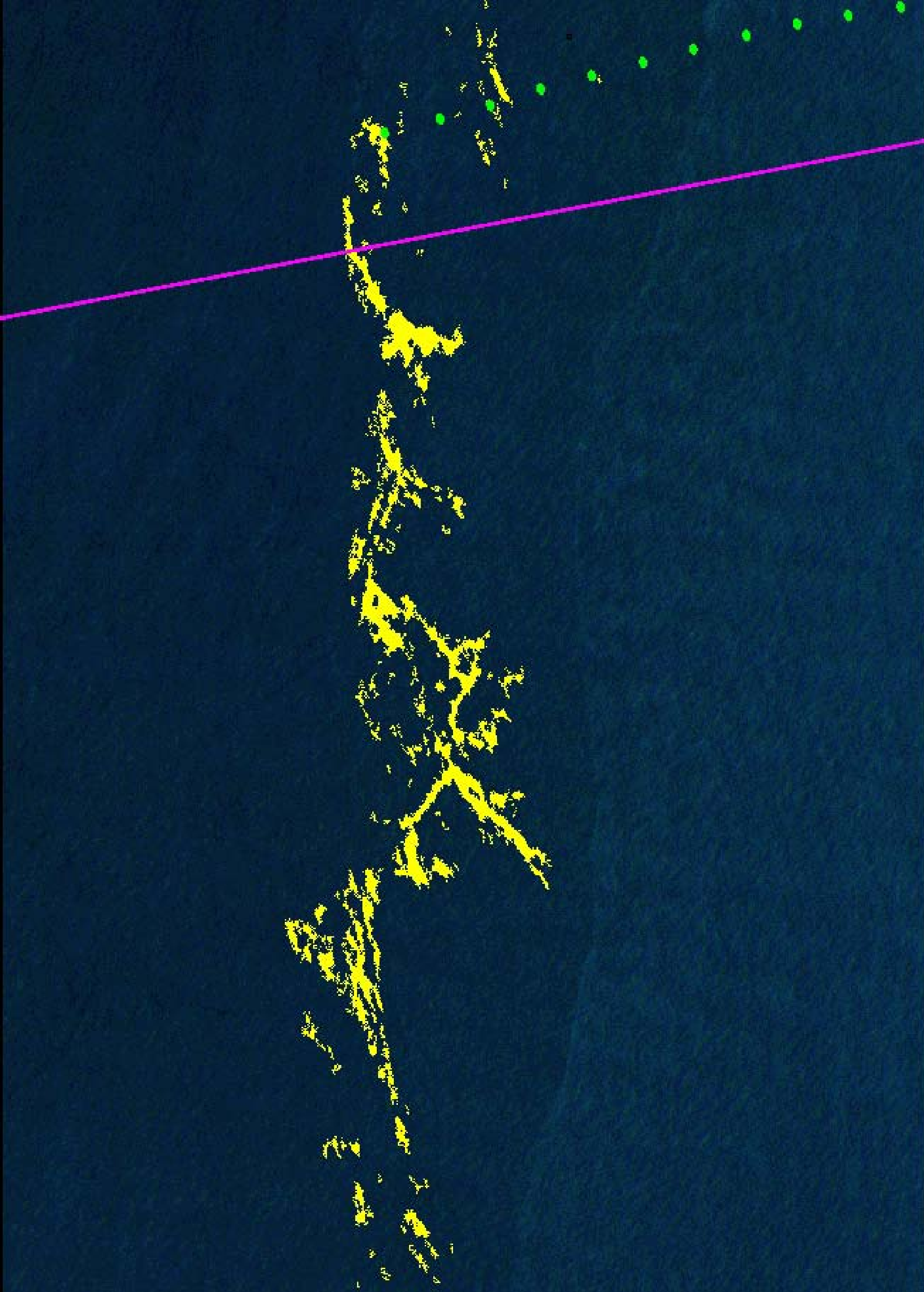
Transect 9 Set A Image 3P3Q1103



Transect 9 Set A Image 3P3Q1103

Transect 9 Set A Image 3P3Q1105

Transect 9 Set A Image 3P3Q1105



Satellite/Aerial Image Hybrid

Determine Characteristics of Sardine Schools From Aerial Images

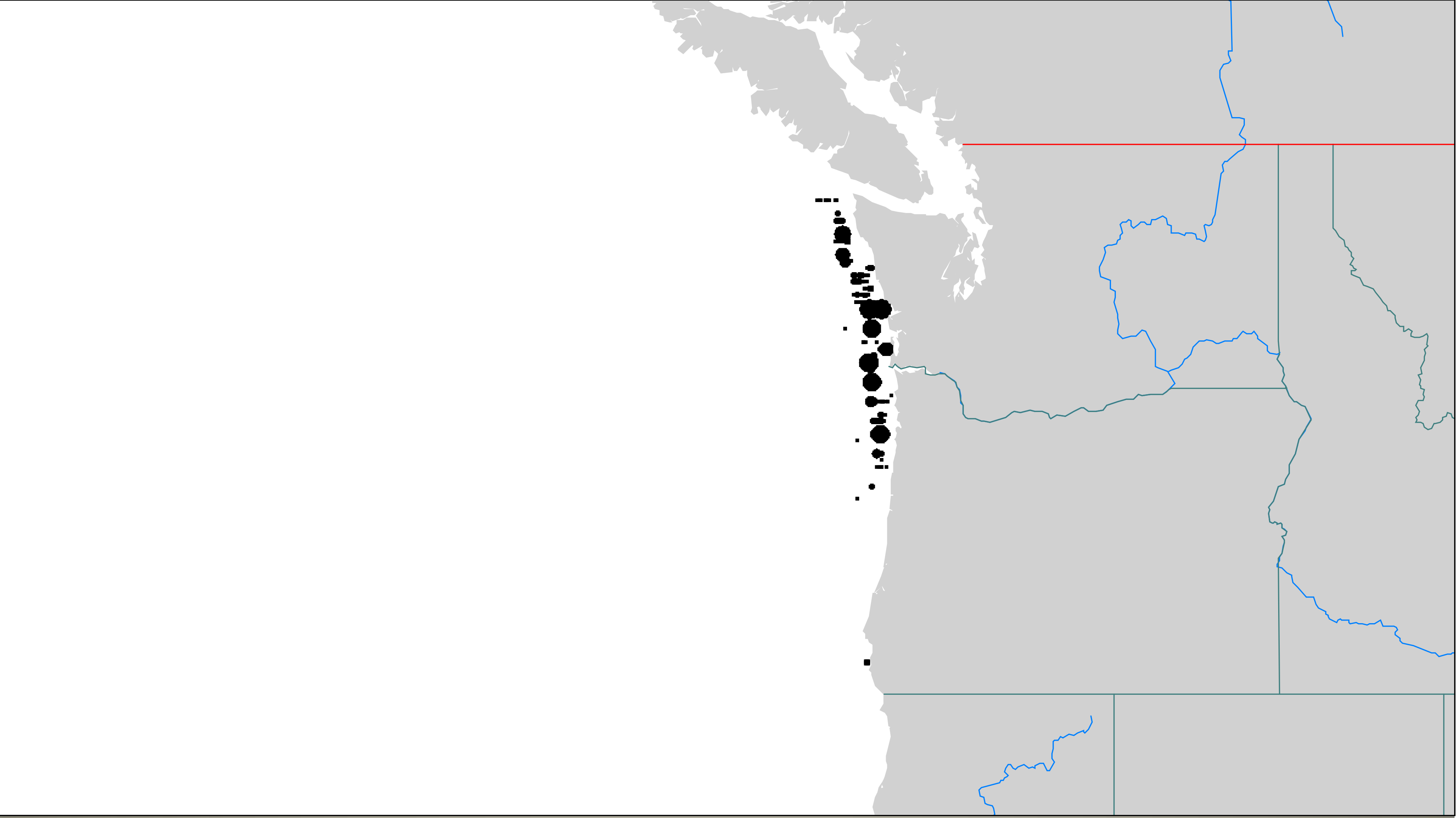
Assign Sardine Photo Properties To Satellite Image

Map Similarities on Satellite Image W/ Automated Classification Software

Colored in Yellow = Sardine

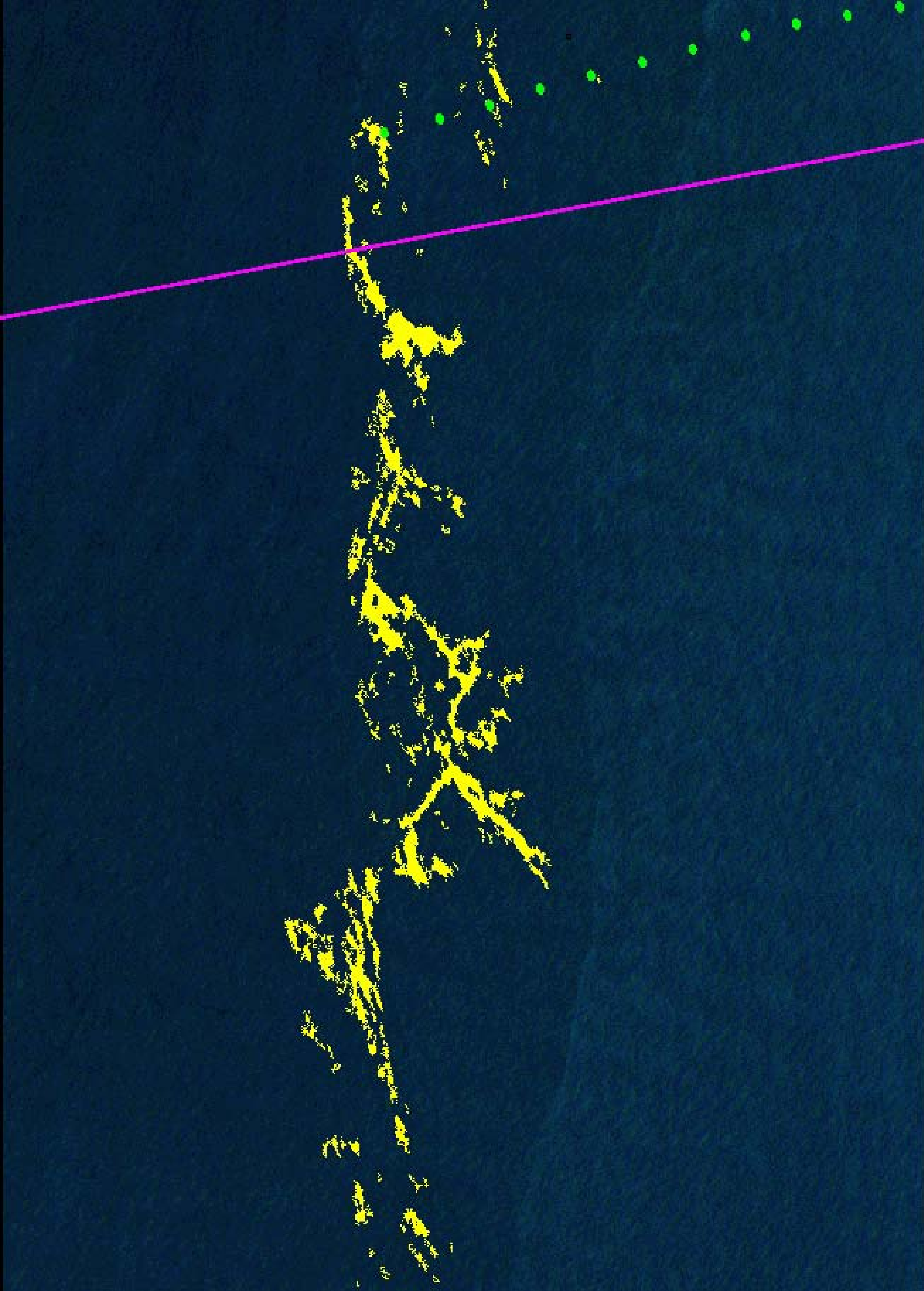
Measured Surface Area In This Region
279 Acres **1,129,113 SQ Meters**

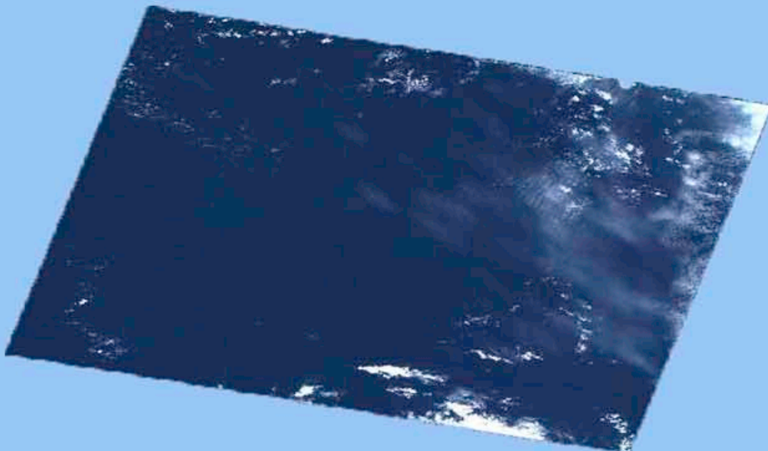
22,582 Metric Tons of Sardine



Distribution of Sardine 2010


Sept 20th Photo 200,000 M/T ESTIMATE





RapidEye Satellite Images 8/22, 8/23

CWPA Methods Description

Prepared for

Pacific Fisheries Management Council

October 15, 2010

Title:

CWPA Methods Review Proposal: aerial photographic surveys with lidar and hydroacoustic components for calibration.

Names of Proposers:

California Wetfish Producers Association
Diane Pleschner-Steele
Doyle Hanan
James Churnside
David Demer
Don LeRoi

How proposed methodology will improve assessment and management for CPS species.

Current aerial sardine assessment techniques for estimation of biomass photographed are dependent on capture of sardine schools that have been photographed immediately prior to capture by purse seine (termed a point set in this survey). School surface areas (m^2) are regressed against the landing weights (biomass in mt) for all schools captured to develop an expected relationship. Only those schools captured and meeting stringent criteria (>90% of school captured, series of pictures that delineate or identify the school captured) are used in the analysis. During the 2009 and 2010 aerial surveys, a total of 69 "acceptable" purse seine sets were made, but they represented a very small portion (3%) of the total schools photographed and measured (2,523). For the California portion of the two surveys, only 17 of 81 sets were qualified for use in the regression and in Oregon/Washington 52 of 70 were used. Because of these issues as well as others, this point set method of determining school density is difficult to accomplish, varies by location, and is expensive.

We are proposing the use of additional methods to enhance measurements of school density and to calibrate these techniques for use with aerial surveys. The methods we propose (lidar and hydroacoustics) have been tested in numerous studies and have demonstrated their effectiveness for providing quantifiable results. There are advantages and disadvantages to each method, but either method, or both, should yield results superior to the point set method alone. Lidar provides a third dimension (actual thickness of schools) and hydroacoustics also provides that third dimension, which is missing in the aerial survey utilizing surface photogrammetry alone (hydroacoustic sound return gives a 3-D view/analysis of schools). Lidar can be run simultaneously from the same airplane that conducts the photographic survey; therefore all schools sampled by lidar will also have corresponding photographs. Schools found near the ocean surface sampled by hydroacoustics can also be photographed.

Better estimates of density for large numbers of schools during photographic surveys will be very useful for improving sardine assessment and management. Sampling by airplane, or multiple planes, can cover large areas of the sardine habitat relatively quickly, but weather, clouds and fog can seriously hamper aerial surveys, Ships and hydroacoustics can cover areas further offshore and can sample when airplanes are restricted by weather.

Airplanes are less expensive for the area surveyed and much faster; therefore, we are proposing a coordinated survey utilizing all three techniques.

We are also proposing that this survey be conducted in the fall (October-November) when the marine layer, low clouds, and fog, that greatly restricted the aerial survey for the past two years in California during the summer, are less prevalent. Fall is also a season when the seas tend to be calmer and clearer, thus allowing better photographic conditions. This time period is also a season when sardines have returned to California from the PNW, and there will be a greater chance of sampling the stock with reduced variability using the combined techniques discussed above. When combined with the summer aerial survey, hydroacoustics, and DEPM, a fall survey should contribute significantly to our understanding of Pacific sardine abundance, migratory patterns and trends. Based on result from this pilot project we will be submitting an EFP application to be submitted in early January, as outlined in the Recommendations for Research Set Asides in 2011.

Outline of methods (field and analytical).

We are proposing a survey method that utilizes aerial survey methodology that has already been approved by the Council. To this methodology we will add simultaneous lidar use in the transect airplanes. We also plan point sets on targeted sardine schools to calibrate with CalCOFI and SWFSC shipboard hydroacoustics, which will augment and enhance the aerial survey by comparison with those hydroacoustic surveys.

LIDAR FIELD LOGISTICS AND ANALYSIS:

Use of Lidar Resource

We will be incorporating and following closely assessment methods developed by Dr. Jim Churnside for comparison of lidar to photogrammetric techniques (high definition video[1]) and acoustics (BioSonics 208 kHz splitbeam transducer[2]). In the video study, Dr. Churnside counted fish schools for analysis, but we intend to measure surface area and density of fish schools for comparison to the photographs we will collect, adopting and expanding his survey methods to correspond with our existing STAR panel approved photographic analysis. We expect to use lidar gear, techniques, and settings very similar to (Churnside, et al., 2001): "frequency-doubled, Q-switched Nd:YAG laser that produced 120 mJ of green (532 nm), linearly polarized light in a 12 nsec pulse at a rate of

[1] Churnside, J. H., A. F Sharov, R. Richter. (Submitted for publication). Aerial Surveys of Fish in estuaries: A Case Study in Chesapeake Bay. 27 pages.

[2] Churnside, J. H., Demer, D. A., and Mahmoudi, B. 2003. A comparison of lidar and echosounder measurements of fish schools in the Gulf of Mexico. ICES Journal of Marine Science, 60:147–154.

30 pulses per second. The beam from the laser will be diverged, using a lens in front of the laser, to be eye-safe at the surface (laser spot diameter of approximately 8 m) from the flight altitude of 600 m. The diverged beam will be directed by a pair of mirrors to be parallel to the axes of the two receiver telescopes, which collected the two orthogonal polarizations of the backscattered light. The first receiver channel uses a 7 cm diameter refracting telescope with a polarizer aligned with the laser polarization to measure the co-polarized lidar return. The other channel uses a 17 cm diameter telescope with a polarizer oriented perpendicular to the laser polarization to measure the cross-polarized lidar return. Each of the telescopes collects light onto an interference filter to reject background light. An aperture at the focus of the primary lens also limits background light by limiting the field of view of the telescope to match the divergence of the transmitted laser beam. A photomultiplier behind each telescope converts the lidar return into an electronic signal, which is passed through a logarithmic amplifier to improve the dynamic range. This signal is digitized at a rate of 109 samples per second during the return from each laser pulse. The computer records the digitized returns, along with the position and time from a GPS receiver, and displays the data to the operator. Sardine schools will be identified by visual examination of the photographs and lidar data and then lidar data will be plotted in grey scale. Return from water near the school will be estimated and subtracted from the sardine school returns to account for water scattering between fish. This return will also be used to estimate lidar attenuation and the signal will be corrected by multiplying with the inverse of attenuation. In addition, the penetration depth of lidar will be estimated as the depth at which the lidar signal reaches the same level as from background light in the absence of sardine schools. Length of each school along the flight track will be estimated from the number of lidar pulses across the school, the time between pulses, and the speed of the aircraft. The school area will then be estimated by assuming the measurement passes through the center of a circular school. Average distance between sea surface and maximum lidar return within schools is assumed to be a measure of school depth for calculating school volume."

The following steps will be applied to processing of the lidar data:

1. Identify fish schools by visual inspection of the data.

2. Measure the optical properties of the water near the schools. The important properties are the lidar attenuation, α, and the volume backscatter function, β_w. The lidar signal in homogenous water has the form

$$S_w = C\beta_w \exp(-2\alpha z), \tag{1}$$

where C is the calibration constant of the lidar, S_w is the lidar signal near the school, and z is depth. A is obtained from a laboratory calibration and the other two parameters are found from the lidar signal at several depths using Eq. (1).

3. Calculate the corrected volume backscatter from the school according to the following equation

$$\beta_f = (CS - \beta_w)\exp(2\alpha z), \tag{2}$$

where β_f is the volume backscatter coefficient of fish within the school.

4. Estimate the density of fish within the school using the equation

$$N = \frac{\beta_f}{\sigma}, \tag{3}$$

where σ is the backscatter cross section of a single fish. The average backscatter cross section of a collection of 480 sardines was measured in a tank (Churnside et al., 1997), with the result

$$\sigma = (9.7 \pm 0.9) \times 10^{-3} A, \tag{4}$$

where A is the cross sectional area of a single fish as seen from above. The area is generally proportional to length squared, and a linear relationship between backscatter cross section and length squared is also used in fisheries hydroacoustics. For sardines, we expect the area to be about 0.1 times the length squared. If lidar to be used as an absolute measure of biomass, more work will be needed to refine the relationship between backscatter cross section and fish length.

5. Estimate the total number of fish in the school from the product of the number density and the total volume. School volume will be estimated in two different ways. The first will use the thickness of the school inferred from the lidar and the area from the camera images. The other will use the length of the school along the lidar track to estimate its area under the assumption of a circular school. This technique worked very well in estimating the area of menhaden schools in Chesapeake Bay (Churnside et al., 2010), but it is not clear yet how well it will work for sardines.

6. Perform a regression analysis comparing the lidar results with hydroacoustics, point sets, and images. This will involve binning of the data to account for time differences between observations. The spatial scale of that binning will be determined during processing, based on the scales of variability in the data.

References

Churnside, J. H., J. J. Wilson, and V. V. Tatarskii (1997) Lidar profiles of fish schools, Appl. Opt. **36**, 6011-6020.

Churnside, J. H., A. F. Sharov, and R. A. Richter (2010) Aerial surveys of fish in estuaries: a case study in Chesapeake Bay, ICES J. Mar. Sci. doi: 10.1093/icesjms/fsq138

HYDROACOUSTICS FIELD LOGISTICS AND ANALYSIS:

Methods

Aerial surveys are to be conducted for schools of sardine. The remote observations of near-surface fish schools will be used to estimate fish abundance. These estimates are to be validated by purse-seine capture of a number of schools. Here we propose to augment these measurements with active-hydroacoustic measurements made with a multi-frequency split-beam echosounder system (Simrad EK60), and a single-frequency multi-beam sonar (Kongsberg-Mesotech SM20/2000). After a fish school is spotted, and before it is netted, a vessel equipped with hydroacoustic instrumentation will drive around the school to hydroacoustically estimate the size and shape of the school; a subset of schools will be measured by driving over the school multiple times to hydroacoustically estimate the fish density. Schools measured by sonar will also be photographed and observed to evaluate fish avoidance behavior during these transects.

EK60 multi-frequency echosounder

Throughout the survey, volume backscattering strengths (S_v; dB re 1 m) and *in-situ* target strengths (*TS*; dB 1 m^2) will be measured continuously by four calibrated Simrad EK60 split-beam echosounders operating at frequencies of 38, 70, 120, and 200 kHz. The echosounders will be configured with Simrad ES38-12, ES70-7C, ES120-7C, and ES200-7C transducers. The four split-beam transducers will be pole mounted on the side of the ship's hull, and positioned approximately 2m beneath the water surface. Synchronized pulses of 1024 µs will be transmitted downward every 0.5 seconds, received with bandwidths of 0.8745, 1.6375, 2.3435, 2.7785, and 2.986 kHz, respectively, digitized to a range of 150 m, and stored in .raw-data format. Except for the EK60 sounders being used for these surveys, all other echo sounders and sonars operating at or near the survey frequencies will be secured.

SM20/SM2000 Multi-beam sonar

A Kongsberg-Mesotech SM2000 200 kHz multi-beam sonar (180 degree-head with a nominal 155 degree usable swath) and an SM20 processor will be used. The system forms 128 beams that insonify a 180 degree swath. The SM2000 has two transducers: a cylindrical array that can be used to both transmit and receive when operating in imaging mode; and a long stave that can be used as the transmitter, when operated in echosounding mode, with receiving on the cylindrical array. This survey will be conducted in echosounding mode only. The SM2000 sonar head will also be mounted on a pole, attached at an angle of 30 degrees off vertical at a depth of approximately 2 m below the mean water surface.

Triggering
One of the EK60s and the SM2000 both operate at 200 kHz. Therefore, the EK60s and the SM20 processor surface telemetry board (STB) will be triggered using a multiplexer unit. Triggering will be synchronous for all EK60s, and asynchronous (alternating) between the EK60s and the SM20 to prevent interference. That is, a trigger pulse will be sent to the EK60s every second; one-half second after the pulse is sent to the EK60s, a pulse will be sent to the SM20.

AERIAL SURVEY FIELD LOGISTICS AND ANALYSIS:

I. Aerial Transect Survey

Overall Aerial Survey Design
The 2010 California Aerial Sardine Survey design consists of 36 (?) aerial transects spanning the area from 15 miles north of CalCOFI line 86.7 in the north to 15 miles south of CalCOFI line 90 in the southern California Bight (Figures 1 and 2). These transects will extend on or parallel to the CalCOFI lines and run from shore to 75 miles offshore. Each 6-transect series will be conducted as a SET, and will make up one replicate. We intend to fly these transects during both day and night to determine optimum observation time for sardines. The survey will strive to complete three replicate SETS, or 18 transects in total, to the degree possible.

Location of Transects
Transects and corresponding shoreline positions are mapped in Figure 2. The transects start at shore and extend westward for 75 statute miles in length; they are spaced approximately 15 nautical miles (15 minutes) apart in latitude.

Aerial Resources Available
The airplane used for this survey will be equipped with a Canon EOS 1Ds camera with laptop control computer and Lidar equipment ((1) laser and beam-control optics, 2) receiver optics and detector, and 3) data collection and display computer))[3] to survey the transects. The camera will be mounted in an *Aerial Imaging Solutions* FMC mount system installed inside the fuselage and utilizing one of the downward ports (belly port). The Lidar will use a 2nd downward viewing port. Experimental photography of nighttime bioluminescence also will be attempted with a Nikon D700 camera and intensifier, which offers an extremely high ISO along with larger pixel size to reduce noise. It may be sensitive enough to capture usable images at a reasonable shutter speed (1/10th)

[3] Churnside, J. H., J. J. Wilson, and V. V. Tatarskii. 2001. Airborne lidar for fisheries applications. Opt. Eng. 40:406-414.

Use of Aerial Resources
The survey pilot will begin with the most northward transect, flying to the off shore end then move to the next transect and survey to shore. The pilot will repeat this pattern until each transect is surveyed. The pilot will repeat this patter three times thus will attempt to fly a total of 18 transect lines both day and night.

Hydroacoustic Resources Available
Drs. David Demer and Sam McClatchie, NMFS, SWFSC, will direct the hydroacoustic portion of this research project. We propose to augment these measurements with active-hydroacoustic measurements made with a multi-frequency split-beam echosounder system (Simrad EK60), and single-frequency multi-beam sonar (Kongsberg-Mesotech SM20/2000). After a fish school is spotted, and before it is netted, a vessel equipped with the hydroacoustic instrumentation will drive around the school to hydroacoustically estimate the size and shape of the school to hydroacoustically estimate the fish density.

Use of Hydroacoustic Resources
We propose to estimate a function which relates aerially-observed fish school area to fish biomass, including error bounds; and estimate the target strength of sardine (and perhaps other fish species) versus hydroacoustic frequency and fish length, including error bounds.

Conditions Acceptable for Aerial Surveying
At the beginning of each potential survey day, the survey pilot will confer with Dr. Doyle Hanan, Co-principal Investigator, and will jointly judge if conditions will permit safe and successful surveying that day. Considering local conditions, they will also jointly determine the optimal time of day for surveying the area slated for coverage that day. Factors will include sea condition, time of day for best sardine visibility, presence of cloud or fog cover, and other relevant criteria as determined by the survey pilot and Dr. Hanan.

Transect Sampling
Prior to beginning a survey flight, the Pre-Flight Survey Checklist will be completed. This will ensure that the camera system settings and Lidar equipment are fully operational for data collection. For example, it is important to have accurate GPS information in the log file. It is also crucial that the photograph number series is re-set to zero.

The decision of when to start a new SET of transects will be determined jointly by the pilot and the principal investigator. Transects will be flown at the nominal survey altitude of 1,500 – 2,000 ft if possible. If conditions require a lower altitude for acceptable ocean surface visibility, transects (or portions of transects) may be flown at a lower altitude, when necessary. Transects may be flown starting at either the east end or the west end.

A Transect Flight Log Form will be kept during the sampling of each transect for the purpose of documenting the observations of the pilot and/or onboard observers. Key notations will include observations of school species ID and documentation of any special conditions that could have an influence on interpreting photographs taken during transects.

It will be acceptable to skip portions of transects as conditions require (e.g. fog covering a small transect portion). The goal is to cover a full 6-transect SET in one day and two replicate SETS of transects in as few days as possible.

Data Transfer
Photographs and FMC camera log files will be downloaded and forwarded for analysis and archival as soon as practicable. Dr. Hanan will collect photographic data and provide to Zachary Hanan to analyze and archive, with supervision by Don LeRoi. Dr. Hanan will also coordinate collection of the Lidar data and provide to Dr. Churnside to archive and analyze.

II. Point Set Sampling

Location of Point Sets
Point sets are the actual capture of fish by purse seiners approved and permitted for this research. Each set by a purse seiner will be directed by the spotter pilot. Attempts will be made to conduct point sets over as wide an area as feasible; however, point sets may occur in any area covered by aerial transects that are not restricted to purse seine fishing and where sardine schools of the desired size are found.

Aerial Photography of Point Sets
Sardine schools to be captured for point sets will be first selected by the spotter pilot and photographed at the nominal survey altitude of 1,500 – 2,000 ft. Following selection, the spotter pilot will descend to a lower altitude to better photograph the approach of the seiner to the school and set the seiner for capture of the school. The camera system will be running during the whole point set thus allowing photographs before and during the vessels approach to the school for the point set capture. Each school selected by the spotter pilot and photographed for a potential point set will be logged on the spotter pilot's Point Set Flight Log Form. The species identification of the selected school will be verified by the captain of the purse seine vessel conducting the point set and will be logged on the Fisherman's Log Form. These records will be used to determine the rate of school mis-identification by the spotter pilot in the field and by analysts viewing photographs taken.

Vessel Point Set Capture
The purse seine vessel will encircle (wrap) and fully capture the school selected by the spotter pilot for the point set. Any schools not "fully" captured will not be considered a valid point set for analysis. If a school is judged to be "nearly completely" captured (i.e. over 90% captured), it will be noted as such and will be included for analysis. Both the spotter pilot and the purse seine captain will independently make note of the "percent captured" on their survey log forms for this purpose. Upon capture, sardine point sets

will be held in separate holds for separate weighing and biological sampling of each set after landing.

Biological Sampling
Biological samples of individual point sets will be collected at the landing docks or at the fish processing plants upon landing. Fish will be systematically taken at the start, middle, and end of a delivered set. The three samples will then be combined and a random subsample of fish will be taken. The sample size will be n = 50 fish for each point set haul.

Length, weight, maturity, and otoliths will be sampled for each point set haul and will be documented on the Biological Sampling Form. Sardine weights will be taken using an electronic scale accurate to 0.5 gm. Sardine lengths will be taken using a millimeter length strip attached to a measuring board. Standard length will be determined by measuring from sardine snout to the last vertebrae. Sardine maturity will be established by referencing maturity codes (female- 4 point scale, male- 3 point scale) supplied by Beverly Macewicz NMFS, SWFSC. Otolith samples will be collected from n = 25 fish selected at random from each n = 50 fish point set sample for future age reading analysis.

Hydroacoustic Sounding of School Height
School height will be measured for each point set. This may be obtained by using either the purse seine or other participating research vessels' hydroacoustic gear. The school height measurements to be recorded on the Fisherman's Log Form are: 1) depth in the water column of the top of the school, and 2) depth in the water column of the bottom of the school.

Number and Size of Point Sets
Point sets will be conducted for a range of school sizes (Table 1). Each day, the spotter pilot will operate with an updated list of remaining school sizes needed for analysis. The spotter pilot will use his experience to judge the biomass of sardine schools from the air, and will direct the purse seine vessel to capture schools of appropriate size. Following landing of the point sets at the dock, the actual school weights will be determined and the list of remaining school sizes needed from Table 1 will be updated accordingly for the next day of fishing. If schools are not available in the designated size range, point sets will be conducted on schools as close to the designated range as possible. Dr. Hanan will oversee the gathering of point set landing data and will update the list daily. The total landed weight of point sets sampled will not exceed **800 mt**. The number of point set samples needed for the Southern California pilot sardine aerial survey in 2010 (Table 1), were distributed to obtain adequate data points for the area-biomass regression in the region between 2,000 and 10,000 m^2 of school surface area (Figure 3).

Landing Reporting Requirements
Cumulative point set landings will be maintained and updated by Ms. Diane Pleschner-Steele or Dr. Hanan and will be reported daily to NMFS, as per the terms of the Exempted Fishing Permit. Also included in this daily report will be an estimate of the weight of all by-catch by species.

Other EFP Reporting Requirements

Ms. Pleschner-Steele or Dr. Hanan will be responsible for providing the other required reporting elements (as specified in the EFP permit) to NMFS. For example, a daily notice will be provided for enforcement giving 24 hour notice of vessels to be conducting point sets on any given day and will include vessel name, area to be fished, estimated departure time, estimated return time.

III. Calibration and Validation

Aerial Measurement Calibration

A series of photographs have been collected from both participating planes, depicting a feature of known size (e.g. a football field or tennis court) on the ground, from the altitudes of 1,000 ft, 1,500, and 2,000 ft. For each altitude series, an aerial pass was made to place the target onto the right, middle, and left portions of the photographic image.

Aerial Photographs and Sampling for Species Validation

A set of reference photographs will be compiled which will be taken at the nominal survey altitude of 1,500 – 2,000 ft for the purpose of species identification. The spotter pilot will find and photograph schooling fish other than sardine (e.g. mackerel, herring, smelt, anchovy, etc). For the actual schools photographed, a vessel at sea will collect a jig sample to document the species identification. This set of reference photographs will be used by the photograph analysts to learn how to discern between sardine and other species as they appear on the aerial transect photographs.

IV. Photograph Data Reduction and Analysis

Digital images will be analyzed by Zachary Hanan, under the supervision of Don LeRoi, to determine the number, size, and shape of sardine schools on each transect. Adobe *Photoshop Lightroom 3.0* software will be used to bring the sardine schools into clear resolution and measurements of sardine school size (m^2) and shape (circularity) will be made using Adobe *Photoshop CS5-Extended*. Transect width will be determined from the digital images using the basic photogrammetric relationship:

$$\frac{I}{F} = \frac{GCS}{A}$$

and solving for *GCS*:

$$GCS = \frac{I}{F}A$$

where I = Image width of the camera sensor (e.g. 36 mm), F = the focal length of the camera lens (e.g. 24mm), A = altitude, and GCS = “ground cover to the side” or width of the field of view of the digital image. Transect width will be obtained by taking the average of *GCS* for all images collected on the transect. Transect length will be obtained from the distance between start and stop endpoints using the GPS data logged by the data acquisition system.

V. Data Analysis

Total Biomass

Principal Investigator, Dr. Hanan, assisted by Tom Jagielo, will estimate total sardine biomass for the survey area with a 3 step process, and requiring 1) measurements of individual school surface area on sampled transects, 2) estimation of individual school biomass (from measured school surface area and estimated school density), and 3) transect sampling design theory for estimation of a population total. The calculations described below will be implemented using the R statistical programming language.

Individual school surface area (a_i) will be measured on the photo-documented transects using the measurement tool feature of *Adobe Photoshop,* and employed the photogrammetric relationships described above. Individual school density (d_i) will be specific to school size and will be determined from the empirical relationship between surface area and biomass obtained from Stage 2 (point set) sampling (described below). Individual school biomass (b_i) will be estimated as the product of school density and surface area ($b_i = d_i a_i$). The sum of individual school biomass (b_u) will then be determined for each transect (u). The mean sampled biomass for the study area ($\bar{b}$) will be computed as

$$\bar{b} = \sum_{u=1}^{n} b_u \ / n \ ,$$

where n = the number of transects sampled. Total biomass for the study area $(\hat{B})$ will be estimated using the unbiased estimator for a population total (Stehman and Salzer 2000),

$$\hat{B} = N\bar{b} \ ,$$

where N = the total number of transects that could possibly be sampled in the survey area without overlap. In 2011, we intend to fly three replicate sets of transects (SET A, SET B, and SET C) and thus three estimates of $\hat{B}$ will be calculated: $\hat{B}_A$, $\hat{B}_B$, and $\hat{B}_C$, respectively. The point estimate of total biomass for the study area ($\hat{B}_T$) will be obtained by averaging these three estimates of biomass.

Individual School Biomass

The biomass of individual schools observed on the transects (b_i) will be calculated using 1) measurements of school surface area, and 2) the relationship between school surface area and biomass, obtained from point sets. The three parameter Michaelis-Menten (MM) model assuming log-normal error will be used to describe the sardine surface area–density relationship

d_i = (yint * cc + asymp * a_i) / (cc + a_i)

where

d_i = school density (mt/m^2)
a_i = school area (m^2)
yint = y intercept
asymp = asymptote as x -> infinity
asymp/cc = slope at the origin .

As noted above, individual school biomass (b_i) will then be estimated as the product of school density and surface area ($b_i = d_i a_i$).

Total Biomass Coefficient of Variation (CV) for the 2010 PILOT Survey
The CV of the total biomass estimate will be obtained by employing a bootstrapping procedure implemented with the R statistical programming language (Appendix I). The intent of the procedure will be to propagate error from the point of school density estimation forward -- to the ultimate goal of total biomass estimation from the three replicate sets of transect data. The steps of the procedure are:

1) The MM model will be fit to the point set data.
2) A variance-covariance matrix will be derived for the MM model fit to the data, using the R library “MSBVAR” .
3) A matrix of simulated MM parameters will be derived from the MSBVAR output, using the R function “rmultnorm”.
4) For n = 100,000 bootstraps:
   a. One realization of the MM parameters will be selected from the matrix of simulated parameters.
   b. The predicted MM curve will be calculated.
   c. Total biomass for the study area will be estimated for each of the three replicate transect sets.
   d. The three replicate estimates of total biomass will be sampled with replacement.
   e. The mean of the sampled replicates will be calculated, and stored as the bootstrap estimate of biomass.
5) The standard error (SE) will be calculated from the stored bootstrap estimates of biomass (4e).
6) CV will be calculated as CV = SE/$\hat{B}_T$.

Table 1. Size and Number of Point Sets needed during 2010 EFP survey for the Southern California Pilot Sardine Survey area. Total landed weight of point sets will not exceed 800 mt.

Surface Area (m2/set)	mt/set	Number of point sets	Total mt
100	3.8	3	11.4
500	10.6	4	42.4
1000	17	5	85
2000	26.5	6	159
4000	51.9	4	207.6
8000	70.5	3	211.5
10000	82.1	1	82.1
Total		26	799

Figure 1. Transects

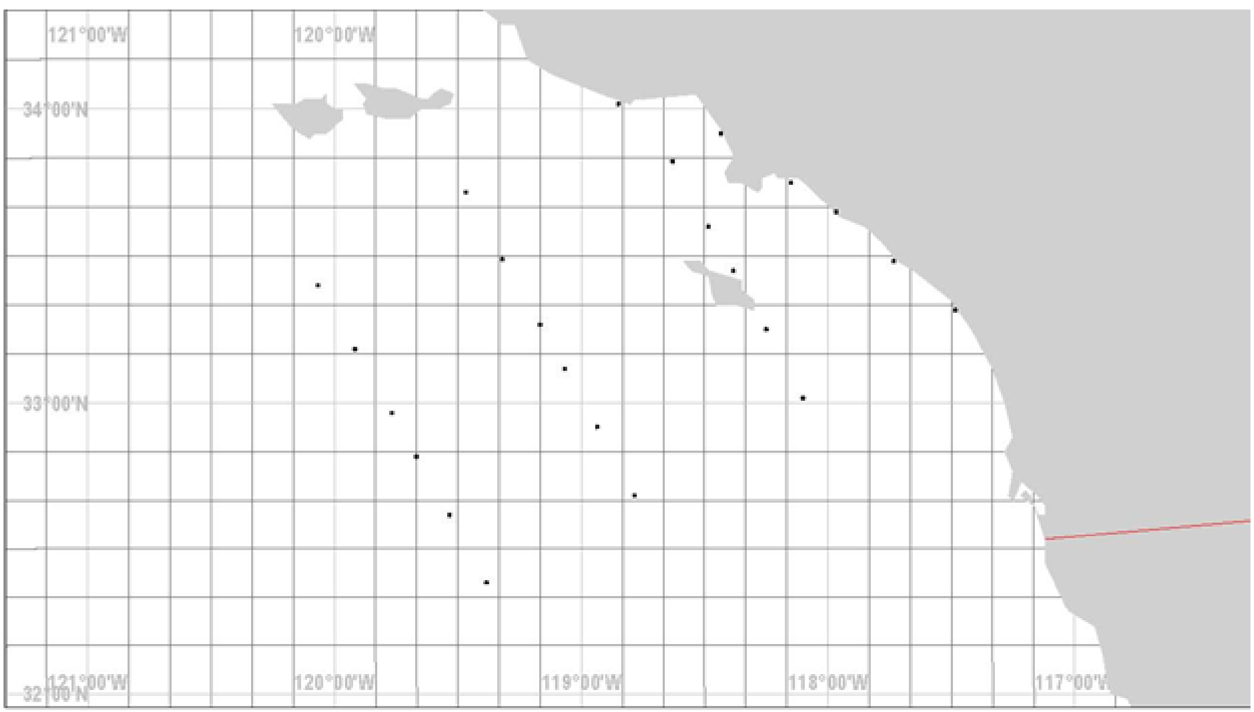
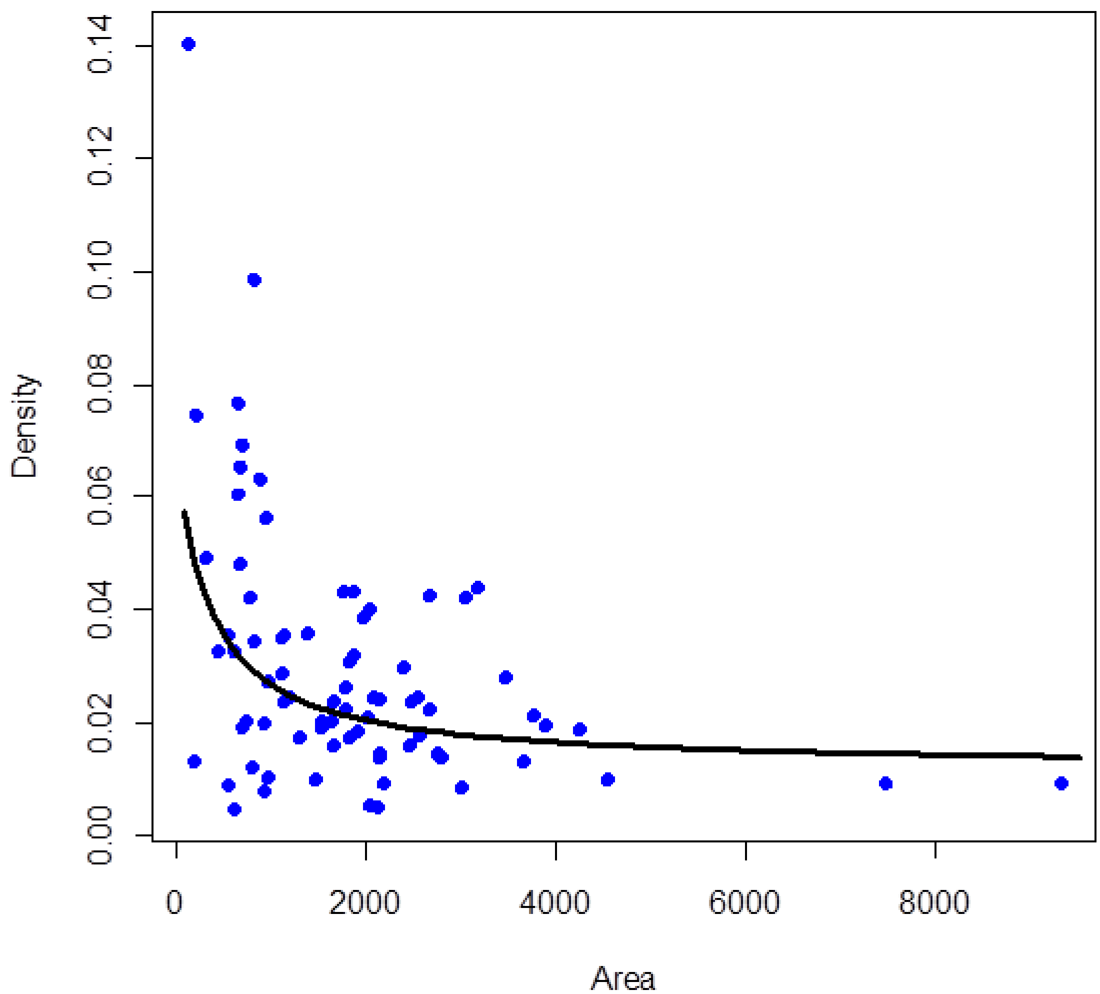


Figure 2. Relationship of surface area (m^2) (x axis) vs. density (y axis) determined from point sets sampled in 2008, 2009, and 2010 (From: West Coast Aerial Sardine Survey Sampling Results in 2010, Jagielo, et al, 2010).



CPS ESSENTIAL FISH HABITAT FIVE YEAR REVIEW

The Pacific Fishery Management Council (Council) is scheduled to consider the Essential Fish Habitat (EFH) Review for Coastal Pelagic Species (CPS). The Magnuson-Stevens Fishery Conservation and Management Act (MSA) requires periodic reviews of EFH descriptions and potential impacts from fishing and non-fishing activities. EFH for CPS species was established in 1998, as Appendix D of Amendment 8 to the CPS FMP, and was reviewed in 2005. The Council determined that the new information considered did not warrant any changes to CPS EFH.

EFH reviews are effectively a two-stage process. First, the entity conducting the review (the CPSMT in this case) works with NMFS to search for and review relevant information that was not available previously. Relevant information can include published literature, unpublished data, public comment, and other information. The review team reports its findings to the Council, which then determines if the new information warrants a change to existing EFH. If the Council's decision is to make changes to existing EFH, the second stage commences. The second stage may involve an FMP amendment, depending on the magnitude and type of change chosen by the Council.

The CPSMT initiated a review of relevant literature and other information in January 2010, and presented a preliminary report at the June 2010 Council meeting. The Council directed the CPSMT to solicit information and comments from interested parties, and to continue developing a report. No comments were received during the open comment period that ended September 19, 2010. The CPSMT report on the CPS EFH five year review (Agenda Item I.4.a, Attachment 1) concludes the CPSMT's review, in accordance with the National Marine Fisheries Service's regulatory guidance.

<u>Council Action</u>:

1. Approve CPS Essential Fish Habitat review; provide direction for any further action.

<u>Reference Materials</u>:
1. Agenda Item I.4.a, Attachment 1: *CPSMT Report on Review of Essential Fish Habitat for Coastal Pelagic Species.*
2. Agenda Item I.4.a, Attachment 2: *Appendix D to the CPS FMP (EFH descriptions).*
3. Agenda Item I.4.a, Attachment 3: *Excerpt from Amendment 12 to the CPS FMP (EFH description for krill species).*
4. Agenda Item I.4.b, Supplemental CPSMT Report.
5. Agenda Item I.4.b, Supplemental SSC Report.
6. Agenda Item I.4.b, Supplemental HC Report.

Agenda Order:

a. Agenda Overview **Kerry Griffin**
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. **Council Action:** Approve Essential Fish Habitat Review

PFMC
10/18/10

ESSENTIAL FISH HABITAT PERIODIC REVIEW OF COASTAL PELAGIC SPECIES

Coastal Pelagic Species Management Team report to the Pacific Fishery Management Council

Recognizing the importance of fish habitat to the productivity and sustainability of U.S. marine fisheries, in 1996 Congress added new habitat conservation provisions to the Magnuson-Stevens Act (MSA), the federal law that governs U.S. marine fisheries management. The re-named Magnuson-Stevens Act mandated the identification of Essential Fish Habitat (EFH) for managed species as well as measures to conserve and enhance the habitat necessary to fish to carry out their life cycles. The MSA requires cooperation among the National Marine Fisheries Service (NMFS), the Councils, fishing participants, Federal and state agencies, and others in achieving EFH protection, conservation, and enhancement. Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 U.S.C. 1802(10)). The EFH guidelines under 50 *CFR* 600.10 further interpret the EFH definition as follows:

> *"Waters include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; substrate includes sediment, hard bottom, structures underlying the waters, and associated biological communities; necessary means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle."*

The Councils and NMFS are expected to periodically review the EFH components of FMPs. Each FMP EFH identification recommendation and amendment should include a provision to review and update EFH information and prepare a revised FMP amendment if newly-available information warrants revision of EFH. The schedule for this review should be based on an assessment of the quality of both the existing data and expectations when new data will be available. Such a review of information should be conducted at least once every five years (62 *FR* 66531, December 19, 1997).

Process for five-year Review of CPS EFH

The review process was initiated at a meeting of the Coastal Pelagic Species Management Team (CPSMT) in January, 2010, in La Jolla, California, with a discussion of the existing EFH, habitat needs, and new information. The team subsequently compiled publications (see References) relevant to CPS habitat needs and associations. The CPSMT discussed CPS EFH at its April 27-30, 2010 meeting in Portland, Oregon; and during the June 13-14, 2010 Council meeting. In addition, the CPS Subcommittee of the SSC, the CPSMT, and some members of the Coastal

Pelagic Species Advisory Subpanel (CPSAS) attended the sardine assessment meeting in October, 2010 in La Jolla, CA, which included discussion of CPS EFH.

The Council's Habitat Committee (HC), Scientific and Statistical Committee (SSC), and the CPSAS considered the issue during the June, 2010 Council meeting in Foster City, California. The full Council also considered CPS EFH at that meeting, and added it to the November, 2010 Council meeting agenda in Costa Mesa, California, scheduled for final action.

In August, 2010, Council staff issued a request for comments, via an email to the Council's HC, CPSMT, CPSAS, and the CPS subcommittee of the SSC, requesting comments on CPS EFH. These advisory and management groups of the Council include representatives from the NMFS Northwest and Southwest Fisheries Science Centers; the NMFS Northwest and Southwest Regions; state agencies of California, Oregon, and Washington; commercial and recreational fishing interests; conservation interests; a port representative; and a tribal representative. No comments were received in response to that request.

The CPSMT considered new information, comments and discussion with Council advisory bodies, and best professional judgment to review CPS EFH in the context of three primary questions:

1. Does new information indicate that existing CPS EFH should be revised?
2. Does new information suggest establishing Habitat Areas of Particular Concern (HAPC)?
3. Are there emerging threats that could adversely affect CPS EFH?

Description of Existing EFH

The CPS fishery includes four finfish species, market squid, and krill:

- Pacific sardine (*Sardinops sagax*)
- Pacific (chub) mackerel (*Scomber japonicus*)
- Northern anchovy (*Engraulis mordax*)
- Jack mackerel (*Trachurus symmetricus*)
- Market squid (*Loligo opalescens*)
- Krill (*Euphasiid spp*.)

CPS finfish inhabit the water column and are not associated with substrate, and generally occur above the thermocline in the upper mixed layer. For the purposes of EFH, the four CPS finfish species are treated as a single species complex, because of similarities in their life histories and similarities in the habitat requirements. Market squid inhabit the water column, but are also associated with bottom substrate during spawning events and egg development. Squid are treated in the same complex as CPS finfish because they are similarly fished above spawning aggregations (PFMC 1998).

Unless the Council and NMFS conclude that there are reasons to substantiate a change to the definition of CPS EFH at this time, the description of EFH will remain the same as that identified in Amendment 8 to the FMP (PFMC, 1998). A detailed description of existing EFH for CPS can be found in Appendix D of that document. In determining EFH for CPS, the estuarine and marine habitats necessary to provide sufficient production to support maximum sustainable yield and a healthy ecosystem were considered.

Using presence/absence data, EFH is "based on a thermal range bordered within the geographic area where a managed species occurs at any life stage, where the species has occurred historically during periods of similar environmental conditions, or where environmental conditions do not preclude colonization by the species" (PFMC 1998). The specific description and identification of EFH for CPS finfish accommodates the fact that the geographic range of all species varies widely over time in response to the temperature of the upper mixed layer of the ocean, particularly in the area north of 39° N latitude. For example, an increase in sea surface temperature since the 1970s has led to a northerly expansion of the Pacific sardine resource. With an environment favorable to Pacific sardine, this species can now be found in significant quantities from Mexico to Canada. Adult CPS finfish are generally not found at temperatures colder than 10° C or warmer than 26° C. Preferred temperatures (including minimum spawning temperatures) are generally above 13° C. Spawning is most common at 14° C to 16° C.

Essential Fish Habitat for West Coast CPS species was established in December, 1998, with the issuance of Appendix D to Amendment 8 of the Northern Anchovy Fishery Management Plan. Appendix D contains the identification and description of CPS EFH; information on life history and habitat needs; fishing and non-fishing effects on CPS EFH; and potential conservation and enhancement measures. CPS EFH is linked to ocean temperatures, which shift temporally and spatially, providing a dynamic definition of EFH. This definition is as follows:

> *The east-west geographic boundary of EFH for each individual CPS finfish and market squid is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the exclusive economic zone (EEZ) and above the thermocline where sea surface temperatures range between $10^{0}C$ to $26^{0}C$. The southern boundary of the geographic range of all CPS finfish is consistently south of the US-Mexico border, indicating a consistency in SSTs below $26^{0}C$, the upper thermal tolerance of CPS finfish. Therefore, the southern extent of EFH for CPS finfish is the US-Mexico maritime boundary. The northern boundary of the range of CPS finfish is more dynamic and variable due to the seasonal cooling of the SST. The northern EFH boundary is, therefore, the position of the $10^{0}C$ isotherm which varies both seasonally and annually.*

Krill species were added to the CPS FMP in 2006, and EFH for krill was issued in 2008. The two most prevalent species of krill are *Euphausia pacifica* and *Thysanoessa spinifera*, although six other krill species are also included in the FMP. All are prohibited from harvest on the U.S. West Coast. The two species (*E. pacifica* and *T. spinifera*) form large aggregations of moderate density, while the other species are typically more dispersed. EFH is identified individually for *E. pacifica* and *T. spinifera*, and then collectively for the other krill species. The following descriptions are taken from Amendment 12 to the CPS FMP (PFMC 2006).

Euphausia pacifica EFH

Larvae, juveniles and adults: From the baseline from which the shoreline is measured seaward to the 1000 fm (1,829 m) isobath, from the U.S.- Mexico north to the U.S.-Canada border, from the surface to 400 m deep, from the U.S.- Mexico north to the U.S.-Canada border. Highest concentrations occur within the inner third of the EEZ, but can be advected into offshore waters in phytoplankton-rich upwelling jets that are known to occur seaward to the outer boundary of the EEZ and beyond.

Thysanoessa spinifera EFH
Larvae, juveniles and adults: From the baseline from which the shoreline is measured to the 500 fm (914 m) isobath, from the U.S.- Mexico north to the U.S.-Canada border, from the surface to 100 m deep. Largest concentrations in waters less than 200 m deep, although individuals, especially larvae and juveniles, can be found far seaward of the shelf, probably advected there by upwelling jets.

Other krill species EFH
Larvae, juveniles and adults: From the baseline from which the shoreline is measured seaward to the 1000 fm (1,829 m) isobath, from the U.S.- Mexico north to the U.S.-Canada border, from the surface to 400 m deep, from the U.S.- Mexico north to the U.S.-Canada border. Amendment 12 concluded that no biological, social or economic impacts are expected beyond administrative costs of reviewing federally regulated projects for potential impacts on this habitat, where krill and krill predators concentrate.

New Information

Existing EFH descriptions for CPS are based largely on presence/absence data and upon a thermal range within the broader geographic area in which CPS stocks occur. The 1998 EFH identification and descriptions also base EFH on historical presence or "where environmental conditions do not preclude colonization by the CPS" (PFMC 1998). Although temperature associations among individual species and life stages within the CPS complex exhibit some variation, the temperature range that describes existing EFH is sufficiently representative of habitat associations. This temperature range is between 10°-26° C, although CPS can be found at temperatures outside that range. The CPSMT considered information contained in several recent publications relevant to CPS (see References). The new information does not present any significant change in existing documented habitat associations, including temperature.

Because krill EFH was only recently established (under Amendment 12, finalized in 2008), the CPSMT did not invest significant effort in reviewing information on which EFH designations for krill are based. However, this periodic review offers an opportunity to synchronize the timing of krill with the other CPS stocks, for future EFH reviews.

Habitat Areas of Particular Concern (HAPCs)

The implementing regulations for the EFH provisions of the MSA (50 CFR part 600) encourage the Fishery Management Councils to identify specific types or areas of habitat within EFH as "habitat areas of particular concern" (HAPC), based on one or more of the following considerations: (1) the importance of the ecological function provided by the habitat; (2) the extent to which the habitat is sensitive to human-induced environmental degradation; (3) whether, and to what extent, development activities are, or will be, stressing the habitat type; and (4) the rarity of the habitat type. The intended goal of identifying such habitats as HAPCs is to provide additional focus for conservation efforts. While the HAPC designation does not add any specific regulatory process, it highlights certain habitat types as ecologically very important. This designation is manifested in EFH consultations, in which a consulting NMFS biologist can call attention to a HAPC, in developing conservation recommendations to the action agency.

Habitat Areas of Particular Concern were not considered in Appendix D of Amendment 8, for CPS. HAPCs for krill species were considered under Amendment 12, but were not adopted. Amendment 12 noted that "all the prospective high quality areas identified in the literature review and meetings with scientists would be included in the proposed designations of EFH." A similar situation exists for other CPS, i.e., all likely HAPC candidates are already protected as EFH. Therefore, there are no HAPCs identified for any CPS stocks at this time. CPS finfish and market squid are highly mobile, and generally associated with a range of thermal conditions rather than fixed physical habitat. This creates a challenge in proposing HAPCs, especially in open ocean waters where CPS stocks are found.

Emerging Threats

Climate Change

Fluctuating oceanographic conditions are known to have significant effects on the abundance of CPS in the Pacific Ocean and worldwide. Ocean temperatures, which are known to have direct effects on CPS recruitment, distribution, and abundance, have increased worldwide and (Domingues et al. 2008). The California Current (CC), the dominant large scale oceanographic feature along the US west coast, is known to fluctuate significantly at annual and longer time scales. At short time scales the El Niño/Southern Oscillation (ENSO) (http://www.esrl.noaa.gov/psd/people/klaus.wolter/MEI/mei.html) is a short-term cooling or warming of the ocean at the equator caused by altering wind patterns. Climate change is expected to alter ENSO frequencies and duration but the levels are still impossible to predict. El Niño periods can produce considerable warming and reductions in primary and secondary production in the CC and reduce some CPS abundances. Many CPS and other fishes show significant alterations in their coastal distributions during strong El Niño or warm ocean periods (Phillips et al. 2007). For example, jellyfish blooms appear to be having significant effects on fisheries all over the world. Recently Brodeur et al. (2008) indicated that that jellyfish may compete directly with CPS in the California Current. The CC recently moved from an El Niño condition to a La Niña or cold condition this summer. The PACOOS program (http://www.pacoos.org/Default.htm) is presently tracking many oceanographic (physical and biological) indices that are revealing how oceanographic fluctuations affect marine resources, including some CPS.

Recent research has also shown that the entire North Pacific oscillates (Pacific Decadal Oscillation PDO) between hot and cold states at decadal scales, with significant effects on living marine resources (both benthic and pelagic) (Mantua et al. 1997; Hare et al. 1999; Beamish et al. 2000; Hare and Mantua 2000; Hollowed et al. 2001; Kar et al. 2001; and Brinton and Townsend 2003). Sardines appear to become abundant during warm PDO periods and anchovy during cool PDO periods. However, the time series is short and the mechanisms involved are still uncertain.

The "source water" for the California Current appears to fluctuate depending on the status of the PDO and ENSO (DFO. 2010). This has significant effects on CPS and other species in the CC.

In 2008, the North Pacific Current was very strong, as was the amount of water that split south from this current to become the CC. When the southern split is strong, much nutrient rich North Pacific waters enter the CC and appear to enhance primary and secondary productivity (DFO 2010; http://www.pac.dfo-mpo.gc.ca/science/oceans-eng.htm). In 2009 and spring 2010 North Pacific flows to the CC were reduced, which decreased overall productivity.

The most significant local feature along the west coast is wind induced upwelling (Bakun 1996). Upwelling is responsible for bringing nutrient rich waters from depth to the surface, thus enhancing primary production. Future climate change scenarios indicate much uncertainty as to whether winds and ocean conditions will be more conducive to upwelling or not, but Bakun (1990) thought that upwelling related winds would intensify because of higher pressure differentials between ocean and land. There is also concern that the phenology (i.e., timing of upwelling relative to the evolved life histories of various species) might be affected by alterations or changes in the seasonality and timing of upwelling periods along the west coast (Bograd et al. 2008).

One of the most significant impacts of climate change comes directly from the increased concentrations of carbon dioxide dissolving into the oceans and leading to decreased pH or ocean acidification. Lower ocean pH levels will have significant consequences on calcifying organisms many of which are prey for sardines and other CPS (Feely et al. 2004; 2008; Kerr 2010).

Recently, periods of hypoxia, or very low levels of oxygen were observed on the continental shelf off Washington and Oregon and expected to occur more often in the future (Grantham et al. 2004; Chan et al. 2008). Hypoxia appears to be related to changes and wind and currents directly tied to climate change.

The last few years (Field 2008), and particularly in 2009, large numbers of Humboldt squid (*Dosidicus gigas*) were observed in the CC from Canada to Mexico. It is unknown if the unusual abundance of this species in the CC was related to climate change or some other oceanographic condition. However, their occurrence does appear to be related to the recent abundance of the hypoxia area off the west coast (Gilly et al. 2006). Humboldt squid are very efficient predators that have some of the highest growth rates of any species. They can consume significant numbers of CPS and other species and may affect their abundance.

Finally, harmful algal blooms (HABs) have been observed more frequently in recently years and expected to be more common in the future. The effects of various HAB on CPS is unknown at this time.

Ocean Energy Development

At this time there is a lot of interest in developing renewable ocean energy projects in the CC. Possible energy projects include wave, wind, tidal, ocean currents, and thermal gradient. All of these will have structures that may affect benthic and pelagic environments. Unfortunately, the environmental effects of these projects needs study (Boehlert et al. 2008; Boehlert and Gill 2010). Some energy structures may act as fish aggregating devices (FADs) for CPS or their predators. Very few studies have been done to look at the effects of electromagnetic effects on migrations/movements of CPS. As these energy projects become initiated, it will be important to identify how they interact with CPS.

Conclusions

After review of recently-published literature, discussion and presentation at several Council-related meetings, and based on the opportunity provided for public comment; the CPSMT makes the following conclusions:

- Although new information is likely to help inform EFH consultations, and provides additional background on CPS habitat; it does not warrant changes to the existing description of CPS EFH.
- The fishing impacts and non-fishing impacts sections of Appendix D to Amendment 8 sufficiently describe those adverse impacts as well as conservation measures to mitigate those impacts.
- New information on climate change and ocean energy development should be added to body of information on potential impacts to CPS EFH. This should be published in the 2011 SAFE document, to remain available for use in EFH consultations and for future EFH reviews.
- The timing of the periodic review of krill EFH should be synchronized with the future reviews of CPS EFH.

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APPENDIX D
DESCRIPTION AND IDENTIFICATION OF ESSENTIAL FISH HABITAT FOR THE COASTAL PELAGIC SPECIES FISHERY MANAGEMENT PLAN

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This document contains the identification and description of essential fish habitat (EFH) for the coastal pelagic species (CPS) fishery management plan (FMP) of the Pacific Fishery Management Council (Council). This document also contains fishing and nonfishing threats and potential conservation and enhancement measures to preserve EFH of CPS as specified in the interim final rule to implement the EFH provisions of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), 50 CFR 600 (added by the interim final rule published at 62 Fed. Reg. 66531; December 19, 1997).

1.0 INTRODUCTION

The 1996 amendments to the Magnuson-Stevens Act established new requirements for describing and identifying EFH in federal FMPs. The amendments (16 U. S. C. 1801 *et. seq.*) also require consultation between the National Marine Fisheries Service (NMFS) and federal agencies on activities that may adversely impact EFH for those species managed under FMPs. The amended Magnuson-Stevens Act requires Fishery Management Councils to amend all of their FMPs to describe and identify EFH for the fishery based on guidelines established by NMFS, to minimize to the extent practicable adverse effects on such habitat caused by fishing, and to identify other actions to encourage the conservation and enhancement of EFH. NMFS guidelines on EFH requirements for FMPs were published as an interim final rule in the *Federal Register* on December 19, 1997 (62 FR 66531). These guidelines were used in the description and identification of EFH for the CPS Fishery.

The Magnuson-Stevens Act defines "essential fish habitat" as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." To clarify this definition, the following interpretations are made: "waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers the full life cycle of a species. The definition of EFH may include habitat for an individual species or an assemblage of species, whichever is appropriate to the FMP.

The CPS fishery includes four finfish (Pacific sardine, Pacific (chub) mackerel, northern anchovy, and jack mackerel) and the invertebrate, market squid. CPS finfish are pelagic (in the water column near the surface and not associated with substrate), because they generally occur above the thermocline in the upper mixed layer. For the purposes of EFH, the four CPS finfish are treated as a single species complex, because of similarities in their life histories and similarities in their habitat requirements. Market squid are also treated in this same complex because they are similarly fished above spawning aggregations.

2.0 DESCRIPTION AND IDENTIFICATION OF ESSENTIAL FISH HABITAT FOR THE COASTAL PELAGIC SPECIES FISHERY

In determining EFH for the CPS, including CPS finfish (northern anchovy, Pacific sardine, Pacific (chub) mackerel, and jack mackerel) and market squid, the estuarine and marine habitat necessary to provide sufficient CPS production to support a maximum sustained yield (MSY) CPS fishery and a healthy ecosystem was considered. Using Level 1 information, (i.e., presence/absence distribution data) EFH for CPS is based upon a thermal range bordered within the geographic area where a CPS species occurs at any life stage, where the CPS species has occurred historically during periods of similar environmental conditions, or where environmental conditions do not preclude colonization by the CPS species. EFH for CPS species is derived from distributional (presence/absence) data, oceanographic data (e.g., sea surface temperatures), relationships between oceanographic variables (e.g., temperature), and other published information. Specific EFH boundaries (i.e., the habitat necessary to provide sufficient CPS production) are based on best available scientific information. Sufficient Level 1 information exists to describe and identify EFH in a more precise manner for CPS finfish than for market squid.

The specific description and identification of EFH for CPS finfish accommodates the fact that the geographic range of all CPS finfish varies widely over time in response to the temperature of the upper mixed layer of the ocean, particularly in the area north of Point Arena, California (39° N latitude). This generalization is probably also true for market squid but few data are available. Adult CPS finfish are generally not found at temperatures colder than 10°C or warmer than 26°C and preferred temperatures and minimum spawning temperatures are generally above 13°C (see Figures 2-1 through 2-4). Spawning is most common at 14°C to 16°C.

The east-west geographic boundary of EFH for each individual CPS finfish and market squid is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the exclusive economic zone (EEZ) and above the thermocline where sea surface temperatures range between 10°C to 26°C. The southern boundary of the geographic range of all CPS finfish is consistently south of the US-Mexico border, indicating a consistency in sea surface temperatures at below 26°C, the upper thermal tolerance of CPS finfish. Therefore, the southern extent of EFH for CPS finfish is the United States-Mexico maritime boundary. The northern boundary of the range of CPS finfish is more dynamic and variable due to the seasonal cooling of the sea surface temperature. The northern EFH boundary is, therefore, the position of the 10°C isotherm which varies both seasonally and annually. EFH for CPS species is summarized in Table 2-1.

Sea surface temperatures and habitat boundaries for CPS finfish vary seasonally and from year to year (Figures 2-1 through 2-4). Year to year variation in temperature and habitat boundaries is most pronounced during the summer. Additionally, variation in the boundaries of preferred habitat are more pronounced than variation in the boundaries of thermal tolerance. These relationships mean that highly mobile mackerels and sardine are seasonally much more abundant in the Oregon to Alaska region during the summer and warm water years (e.g., El Niño) than during the winter and cold water years due to increased habitat availability (Pearcy et al. 1985).

In years with cold winter sea surface temperatures, the position of the 10°C isotherm (a rough estimate of the lower thermal and northern geographic bound for CPS finfish) during February is near Cape Mendocino along the coast (about 40° N latitude) and at about 43° N latitude further offshore (Figures 2-1 through 2-4). In warm years, the 10°C isotherm during February is further north along the coast but still at about 43° N latitude offshore. The 14°C isotherm (a rough measure of the location of preferred temperatures) during February is near the U.S.-Mexico border (about 31° N latitude) in cold years and near Point Arena (about 39° N latitude) in warm years.

Sea surface temperatures and habitat boundaries for CPS finfish extend farther to the north during the summer than during the winter (Figures 2-1 through 2-4). The position of the 10°C isotherm during August is off Canada and Alaska in years with both cold and warm summer sea surface temperatures. The 14°C isotherm during August is off Cape Flattery (about 43° N latitude) in cold years and off Canada above 53° N latitude in warm years. As described above, sea surface temperatures of 14°C to 16°C are generally preferred for spawning. The 16°C isotherm, and preferred spawning habitat for CPS finfish, is south of the 14°C isotherm, but shows the same patterns of variability.

Differences between spawning habitat (14°C to 16°C) and geographic range (>10°C) mean that sardine and Pacific (chub) mackerel tend to move north to feed during summer and south to spawn during winter. Abundance and biomass are probably both related to the geographic extent of spawning. Pacific (chub) mackerel and sardine in particular may have increased reproductive success during warm decades (i.e., the 1930s, 1980s, and 1990s) and it is likely the carrying capacity for CPS is larger during warm water years, because the maximum preferred habitat is larger.

Information regarding the distribution, habitat, life history, abundance, and fishery utilization are available in Section 6.0 of this Appendix. Average February (winter) and August (summer) sea surface temperatures (°C) in the California Current within the EEZ during warm winters, cold winters, warm summers and cold summers from the Comprehensive Ocean Atmosphere Data Set database. Warm winter data are averages for 1958, 1981, and 1983 (years with the warmest temperatures during January through March within a band two degrees Celsius wide along the coast from central Baja California to the Queen Charlotte Islands during 1950 to 1995). Cold winter data are averages for 1950, 1971, and 1972 (years with the coldest January through March sea surface temperatures). Warm summer data are averages for 1983, 1990, and 1992 (years with the warmest July through September sea surface temperatures). Cold summer data are averages for 1952, 1950, and 1955 (years with the coldest July through September sea surface temperatures).

TABLE 2.0. Summary of distribution and essential fish habitat for Pacific CPS including finfish (northern anchovy, Pacific sardine, Pacific (chub) mackerel, jack mackerel) and market squid. CPS are most common in the upper mixed layer of the ocean (above the thermocline) in a broad band (up to hundreds of miles wide) along the coast. CPS may occur in shallow embayments and brackish water, but do not depend on these habitats to any significant degree. In general, older and larger individuals occur further north and offshore. The northern extent of the distribution and essential fish habitat for CPS depends on temperature and biomass. Northern areas tend to be used most extensively when water temperatures are warm and abundance is high. Adult CPS prefer water temperatures in the range 10°C to 26°C. Spawning and successful reproduction occurs at about 14°C to 16°C . "??" indicates unavailable information.

Common Name (Scientific Name)	Lifestage	Punta Baja - Pt. Conception	Pt. Conception - Cape Blanco	Cape Blanco - Queen Charlotte Islands	Queen Charlotte Is. - Western Aleutian Islands	Benthic Association
Northern anchovy (*Engraulis mordax*)	Eggs/Larvae/ Juveniles	yes	yes	yes	no	no
	Adults	yes	yes	yes	no	no
Pacific sardine (*Sardinops sagax*)	Eggs/Larvae/ Juveniles	yes	yes (warm environ. / high abund.)	yes (warm environ. / high abund.)	yes (warm environ. / high abund.)	no
	Adults	yes	yes (warm environ. / high abund.)	yes (warm environ. / high abund.)	yes (warm environ. / high abund.)	no
Pacific (chub) mackerel (*Scomber japonicus*)	Eggs/Larvae/ Juveniles	yes	yes	yes (warm environ. / high abund.)	yes (warm environ. / high abund.)	no
	Adults	yes	yes	yes (warm environ. / high abund.)	yes (warm environ. / high abund.)	no
Jack mackerel (*Trachurus symmetricus*)	Eggs/Larvae/ Juveniles	yes	yes	no	no	no
	Adults	yes	yes	yes	yes	no
Market squid (*Loligo opalescens*)	Eggs/Larvae/ Juveniles	yes	yes	??	??	yes
	Adults	yes	yes	yes	yes	yes

Figure 2-1. February sea surface temperatures (coldest three winters).

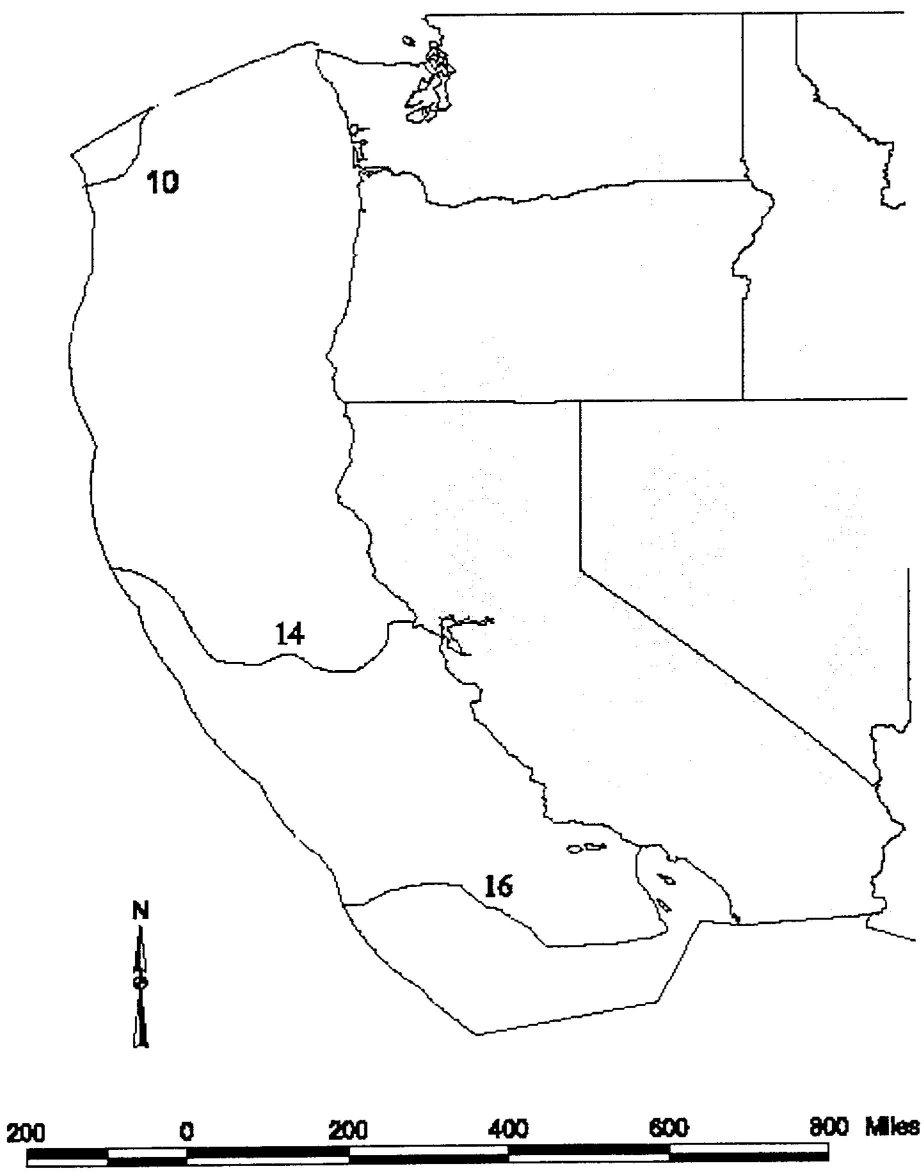

Figure 2-2. February sea surface temperatures (warmest three winters).

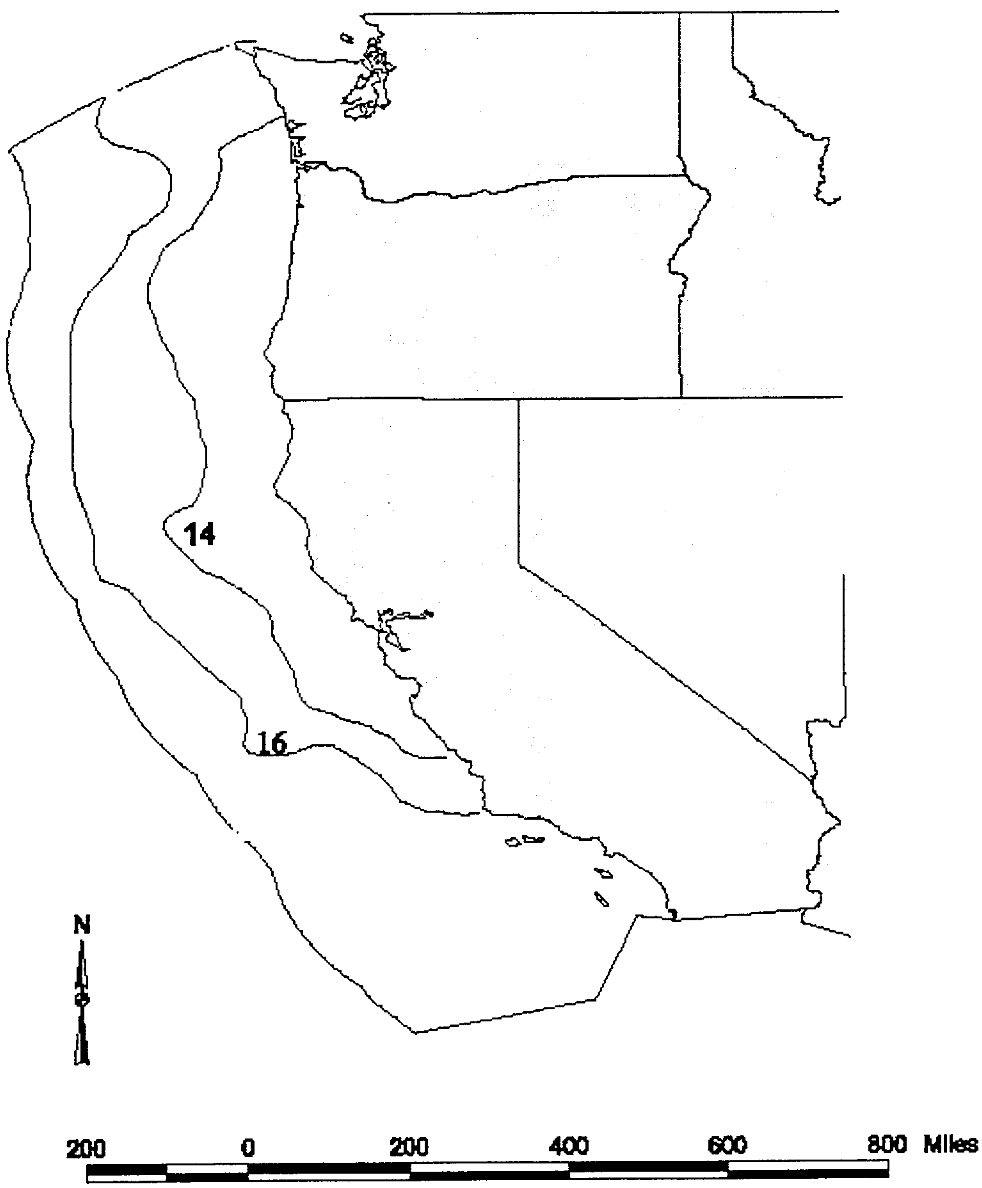

Figure 2-3. August sea surface temperatures (coldest three summers).

Figure 2-4. August sea surface temperatures (warmest three summers).

3.0 FISHING EFFECTS AND CONSERVATION MEASURES ON COASTAL PELAGIC SPECIES ESSENTIAL FISH HABITAT

3.1 Background

Section 600.815 (a) (3) of the interim final rule lists the mandatory contents of FMPs regarding fishing activities that may adversely affect EFH. The adverse effects from fishing activities may include physical, chemical, or biological alterations of the substrate, and loss of, or injury to, benthic organisms, prey species and their habitat, and other components of the ecosystem. FMPs must include management measures that minimize adverse effects on EFH from fishing, to the extent practicable, and identify conservation and enhancement measures. They must also contain an assessment of the potential adverse effects of all fishing activities in waters described as EFH. This assessment should consider the relative impacts of all fishing equipment types used in EFH on different types of habitat found within EFH. In completing this assessment, Councils should use the best scientific information available, as well as other appropriate information sources, as available. The assessment should also consider the establishment of research closure areas and other measures to evaluate the impact of any fishing activity that alters EFH.

Councils must act to prevent, mitigate, or minimize any adverse effects from fishing activities, to the extent practicable, if there is evidence that a fishing activity is having an identifiable adverse effect on EFH. In determining whether it is practicable to minimize an adverse effect from fishing, Councils should consider whether, and to what extent, the fishing activity is adversely impacting EFH, including the fishery; the nature and extent of the adverse effect on EFH; and whether the management measures are practicable, taking into consideration the long and short-term costs and benefits to the fishery and EFH, along with other appropriate factors, consistent with national standard 7 (conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication).

Fishery management options to prevent, mitigate, or minimize adverse effects from fishing activities may include, but are not limited to:

Fishing gear restrictions: Seasonal and areal restrictions on the use of specified gear; gear modifications to allow escapement of particular species or particular life stages (e.g., juveniles); prohibitions on the use of explosives and chemicals; prohibitions on anchoring or setting gear in sensitive areas; and prohibitions on fishing activities that cause significant physical damage in EFH.

Time/area closures: Closing areas to all fishing or specific gear types during spawning, migration, foraging, and nursery activities; and designating zones for use as marine protected areas to limit adverse effects of fishing practices on certain vulnerable or rare areas/species/life history stages, such as those areas designated as habitat areas of particular concern.

Harvest limits: Limits on the take of species that provide structural habitat for other species assemblages or communities, and limits on the take of prey species.

3.2 Impacts

With the exception of harvesting prey species, fishing for CPS finfish has little effect on CPS EFH because CPS finfish are pelagic at all life stages. Contact between roundhaul gear and substrate is rare in fishing for CPS finfish, because fishing usually occurs in water deeper than the height of the net. Thus, the only opportunity for damage to benthos or EFH for any species in fishing for CPS finfish is from lost gear. There is potential for fishing to impact squid spawning grounds because market squid attach their egg cases to the bottom substrate at spawning sites that include shallow, nearshore areas. Such damage is not believed to be extensive and is transitory with regard to the habitat.

CPS are planktivores at all or most life stages and utilize forage that is not affected by fishing. Pacific (chub) mackerel, jack mackerel, and market squid are piscivorous as adults, however, with diets that include northern anchovy, Pacific (chub) mackerel, young salmon (possibly when water temperatures are warm and pelagic fish are common off the Pacific northwest) and other species of commercial interest. Thus, overfishing of northern anchovy, Pacific sardine, market squid, or other species could adversely affect EFH for Pacific (chub) mackerel, jack mackerel, and market squid. Harvest policies used to manage northern anchovy and Pacific sardine should be taken into consideration while recognizing the importance of these species as forage in the ecosystem as a whole.

Although there are presumably few, if any, direct effects from mid-water trawling on EFH for CPS finfish, other fishery operations may alter species complexity in the water column. Off the Pacific coast, there is a large mid-water trawl fishery for Pacific whiting, primarily occurring north of 39° N latitude. Discharge of offal and processing slurry may affect EFH for CPS. Prolonged offal discards from some large-scale fisheries have redistributed prey food away from mid-water and bottom feeding organisms to surface-feeding organisms like CPS finfish, usually resulting in scavenger and seabird population increases (Hill and Wassenberg 1990, Evans et al. 1994). Offal discards in low-current environments can collect and decompose on the ocean floor, creating anoxic bottom conditions that may affect CPS. Pacific coast marine habitat is generally characterized by strong current and tide conditions, but there may be either undersea canyons affected by at-sea discard, or bays and estuaries affected by discard from shoreside processing plants. As with bottom trawling off the Pacific coast, little is known about the environmental effects of mid-water trawling and processing discards on habitat conditions.

3.3 Conservation Measures to Mitigate Fishing Effects on Coastal Pelagic Species Essential Fish Habitat

There is a growing body of research on the effects of fishing activities on marine habitat and general conclusions about the effects of some gear types on marine habitat may be drawn from this body of research (Auster and Langton, 1998). However, it has been noted above that there has been little research on Pacific coast fisheries EFH and into the fishing effects on such habitat, especially market squid EFH. Implementing measures to mitigate gear impacts on habitat may require research that specifically describes the effects of the fishing gear used in Pacific coast fisheries on marine habitat utilized by market squid. The Council may weigh the magnitude of this potential impact and develop appropriate recommendations for addressing them.

In addition to suggesting measures to restrict fishing gears and methods, NMFS' regulatory guidance on EFH also suggests time/area closures as possible habitat protection measures. These measures might include, but would not be limited to: closing areas to all fishing or specific equipment types during spawning, migration, foraging, and nursery activities; and designating zones for use as marine protected areas to limit adverse effects of fishing practices on certain vulnerable or rare areas/species/life history stages. Some of these closures may already exist, such as the exclusion of trawling within three miles of the California coastline and areas closed to commercial fishing (e.g., Santa Monica Bay). The Council may examine whether such opportunities exist for CPS and make appropriate recommendations for addressing them.

Beyond protecting natural reserves and areal closures for particular species, the Council may consider creating habitat reserves closed to all fishing. Several no-fishing zones have been created by the North Pacific Fishery Management Council for the waters off Alaska, generally for the purposes of protecting either crabs or marine mammal rookeries.

3.4 References

Auster, P. J. and R. W. Langton. The indirect effects of fishing. Draft document prepared for National Marine Fisheries Service, Office of Habitat Conservation, Silver Spring, MD.

4.0 NONFISHING EFFECTS ON COASTAL PELAGIC SPECIES ESSENTIAL FISH HABITAT

4.1 Background

Section 600.815 (a) (5) of the draft interim EFH regulations pertains to identifying nonfishing related activities that may adversely affect EFH. The section states that FMPs must identify activities that have the potential to adversely affect, directly or cumulatively, EFH quantity or quality, or both. Broad categories of activities which can adversely affect EFH include, but are not limited to: dredging, fill, excavation, mining, impoundment, discharge, water diversions, thermal additions, actions that contribute to nonpoint source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. FMPs should describe the EFH most likely to be adversely affected by these or other activities. For each activity, FMPs should describe known and potential adverse impacts to EFH. The descriptions should explain the mechanisms or processes that may cause adverse effects and how these may affect habitat function. A geographical information system (GIS) or other mapping system should be used to support analyses of data and to present these data in an FMP in order to geographically depict impacts identified in this paragraph.

The Magnuson-Stevens Act requires federal agencies undertaking, permitting or funding activities that may adversely affect EFH to consult with NMFS. Under section 305 (b)(4) of the Magnuson-Stevens Act, NMFS is required to provide EFH conservation and enhancement recommendations to federal and state agencies for actions that adversely affect EFH. However, state agencies and private parties are not required to consult with NMFS. EFH consultations will be combined with existing interagency consultations and environmental review procedures that may be required under other statutes such as the Endangered Species Act, Clean Water Act, the National Environmental Policy Act, the Fish and Wildlife Coordination Act, the Federal Power Act, or the Rivers and Harbors Act.

EFH consultation may be at either a broad programmatic level or project-specific level. Programmatic is defined as "broad" in terms of process, geography, or policy (e.g., "national level" policy, a "batch" of similar activities at a "landscape level", etc.) Where appropriate, NMFS will use a programmatic approach designed to reduce redundant paperwork and to focus on the appropriate level of analysis whenever possible. The approach would permit project activities to proceed at broad levels of resolution so long as they conform to the programmatic consultation. The wide variety of development activities over the extensive range of EFH, and the Magnuson-Stevens Act requirement for a cumulative effects analysis warrants this programmatic approach.

4.2 Nonfishing Effects

The following is a general description of nonfishing related activities that may directly or cumulatively, temporarily or permanently, threaten the physical, chemical and biological properties of the habitat utilized by CPS and/or their prey. The direct result of these threats is that EFH may be eliminated, diminished or disrupted. The list includes common activities with known or potential impacts to EFH. The list is not prioritized nor is it to be considered all-inclusive. The potential adverse effects described below, however, do not necessarily apply to the described activities in all cases, as the specific circumstances of the proposed activity or project must be carefully considered on a case-by-case basis. Furthermore, some of the activities described below may also have beneficial effects on habitat, which need to be considered in any analysis of an action's net effect by agencies conducting adverse effects analysis.

Nonfishing related effects on EFH for CPS finfish (northern anchovy, Pacific sardine, Pacific (chub) mackerel, or jack mackerel) may not be as adverse relative to other EFH types, because adults and juveniles are mobile, and all life stages are pelagic (in the water column near the surface and not associated with substrate) and dispersed in a wide band along the west coast of north America. However, impacts to CPS finfish prey are conceivable. Nonfishing adverse impacts on EFH may be more important for market squid that attach their egg cases to the substrate at spawning sites that include shallow, near shore areas. Table 4.0-1 summarizes the potential adverse impacts of these nonfishing activities and conservation/enhancement measures to minimize those effects.

4.2.1 Dredging

Dredging navigable waters has a periodic impact on benthic and adjacent habitats during construction and operation of marinas, harbors and ports. Periodic dredging is required to maintain or create ship (e.g., ports) and boat (e.g., marinas) access to docking facilities. Dredging is also used to create deepwater navigable channels or to maintain existing channels that periodically fill with sediments from rivers or transported by wind, wave, and tidal processes. In the process of dredging, large quantities and qualities of the seafloor are removed, disturbed, and resuspended and the biological characteristics of the seafloor are changed. Turbidity plumes may arise.

4.2.1.1 Adverse Impacts

Dredging events using certain types of dredging equipment can result in greatly elevated levels of fine-grained mineral particles, usually smaller than silt, and organic particles in the water column habitat utilized by CPS finfish. These turbidity plumes of suspended particulates may reduce light penetration and lower the rate of photosynthesis (e.g., adjacent eelgrass beds) and the primary productivity of an aquatic area if suspended for variable periods of time. CPS finfish may suffer reduced feeding ability if suspended particulates persist. The contents of the suspended material may react with the dissolved oxygen in the water and result in short-term oxygen depletion to aquatic resources. Toxic metals and organics, pathogens, and viruses absorbed or adsorbed to fine-grained particulates in the material may become biologically available to organisms either in the water column or through food chain processes.

Dredging as well as the equipment used in the process such as pipelines may damage or destroy spawning, nursery habitat and other sensitive habitats important to market squid. Within bays and harbors, dredging may also modify current patterns and water circulation of the habitat by changing the direction or velocity of water flow, water circulation, or otherwise changing the dimensions of the water body potentially utilized by CPS finfish.

4.2.1.2 References

Collins, M. A. 1995. Dredging-induced near-field resuspended sediment concentration and source strengths. Miscellaneous Paper D-95-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A299 151.

Farnworth, E.G., M. C. Nichols, C.N. Vann, L. G. Wolfson, R. W. Bosserman, P. R. Hendrix, F. B. Golley, and J. L. Cooley. 1979. Impacts of sediment and nutrients on biota in surface waters of the United States. EPA; Athens, GA (USA)., Oct 1979., 331 p., Ecol. Res. Series U. S. Environ. Protect. Agency.

LaSalle, M. W., Clarke, D. G., Homziak, J., Lunz, J. D., and Fredette, T. J. (1991). A framework for assessing the need for seasonal restrictions on dredging and disposal operations. Technical Report D-91-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A240 567.

Port of Long Beach, California, Port of Los Angeles, California, Department of the Army, Corps of Engineers, Department of the Interior, Fish and Wildlife Service; Department of Commerce, National Oceanic and Atmospheric Administration. 1990. Phase I 2020 Plan and Feasibility Study, Los Angeles and Long Beach Harbors, San Pedro Bay, California. EPA No.: 900342D, 987 pages and maps, September 10, 1990.

4.2.2 Dredge Material Disposal/Fills

The discharge of dredged materials subsequent to dredging operations or the use of fill material in the construction/development of harbors results in sediments (e.g., dirt, sand, mud) covering or smothering existing submerged substrates. Usually these covered sediments are of a soft-bottom nature as opposed to rock or hard-bottom substrates.

4.2.2.1 Adverse Impacts

The disposal of dredged or fill material can result in varying degrees of change in the physical, chemical, and biological characteristics of the substrate. Direct discharges may adversely alter the habitat of benthic organisms such as market squid. Subsequent erosion, slumping, or lateral displacement of surrounding bottom of such deposits can also adversely affect substrate outside the perimeter of the disposal site by changing or destroying benthic habitat. The bulk and composition of the discharged material and the location, method, and timing of discharges may all influence the degree of impact on potential market squid EFH. The discharged material can also change the chemistry of the receiving water at the disposal site by introducing chemical constituents in suspended or dissolved form.

The discharge of dredged or fill material can result in greatly elevated levels of fine-grained mineral particles, usually smaller than silt, and organic particles in the water column thereby affecting CPS finfish. These suspended particulates may reduce light penetration and lower the rate of photosynthesis and the primary productivity of an aquatic area if suspended for lengthy intervals. CPS finfish may suffer reduced feeding ability leading to limited growth and lowered resistance to disease if high levels of suspended particulates persist. The contents of the suspended material may react with the dissolved oxygen in the water and result in oxygen depletion. Toxic metals and organics, pathogens, and viruses absorbed or adsorbed to fine-grained particulates in the material may become biologically available to organisms either in the water column or through food chain processes.

4.2.2.2 References

Peddicord, R.K. and J. B. Herbich (ed.). 1979. Impacts of open-water dredged material discharge. Proceedings of the eleventh dredging seminar., Publ. by: TAMU; College Station, TX (USA)., Oct 1979., p. 24-40., Rep. Tex. A and M Univ. Sea Grant Program

National Oceanic and Atmospheric Administration. 1991. National Status and Trends Program for marine environmental quality. Progress report on secondary summary of data on chemical contaminants in sediments from the National Status and Trends Program. Tech. Mem. NOS OMA 59. NOAA, NOS, Silver Spring, MD. 29pp.

4.2.3 Oil/Gas Exploration/Production

Oil exploration/production occurs in a wide range of water depths and usually over soft-bottom substrates although hard-bottom habitats may be present in the general vicinity. Oil exploration/production areas are vulnerable to an assortment of physical, chemical, and biological disturbances as oil and gas deposits are located using high energy seismic surveys. EFH may be disrupted by the use and/or installation of anchors, chains, drilling templates, dredging, pipes, and platform legs. During actual operations, chemical contaminants may also be released into the aquatic environment.

4.2.3.1 Adverse Impacts

The impacts of oil exploration-related seismic energy release may interrupt and cause CPS finfish to disperse. Available data indicates that sensitive egg and larval stages within a few meters of the sources of seismic energy releases are not affected, however, disruption to CPS finfish feeding is possible.

Exploratory activities may also result in resuspension of fine-grained mineral particles, usually smaller than silt in the water column. These suspended particulates may reduce light penetration and lower the rate of photosynthesis and the primary productivity of the aquatic area especially if suspended for lengthy intervals. The contents of the suspended material may react with the dissolved oxygen in the water and result in oxygen depletion.

The discharge of oil drilling muds can change the chemistry and physical characteristics of the receiving water at the disposal site by introducing toxic chemical constituents thereby potentially impacting market squid EFH. Changes in the clarity and the addition of contaminants can reduce or eliminate the suitability of water bodies for habituation of fish species and their prey.

4.2.3.2 References

Battelle Ocean Sciences. 1988. The Effects of Seismic Energy Releases on the Zoeal Larvae Of the Dungeness Crab *(Cancer magister)*. Submitted by: Battelle Memorial Institute, Marine Research Laboratory, 439 W. Sequim Bay Road, Sequim, Washington to State of California Department of Fish and Game 1416 Ninth Street, Sacramento, California 95814. Contract Number 6c-194398-382

Coats, D. A. 1994. Deposition of drilling particulates off Point Conception, California. Mar. Environ. Res. 37:95-127.

Hyland, J., D. Hardin, M. Steinhauer, D. Coats, R. Green, and J. Neff. 1994. Environmental impact of offshore oil development on the outer continental shelf and slope off Point Arguello, California. Mar. Environ. Res. 37:195-229.

MEC Analytical Systems. 1995. Disturbance of deep-water reef communities by exploratory oil and gas operations in the Santa Maria Basin and Santa Barbara Channel. U.S. DOI, Minerals Management Service, Camarillo, CA. OCS Study MMS 95-0030

4.2.4 Water Intake Structures

The withdraw of ocean water by offshore water intakes structures is a common coastwide occurrence. Water may be withdrawn for providing sources of cooling water for coastal power generating stations or as a source of potential drinking water as in the case of desalinization plants. If not properly designed, these structures may create unnatural and vulnerable conditions to various fish life stages and their prey.

4.2.4.1 Adverse Impacts

The withdrawal of seawater can create unnatural habitat conditions to the EFH for all life stages of CPS finfish as well as their prey. Various life stages of CPS can be affected by water intake operations such as entrapment through water withdrawal, impingement on intake screens, and entrainment through the heat-exchange systems or discharge plumes of both heated and cooled effluent.

4.2.4.2 References

Helvey, M. 1985. Behavioral factors influencing fish entrapment at offshore cooling-water intake structures in southern California. Marine Fisheries Review 47(1) 18-26.

4.2.5 Aquaculture

The culture of estuarine, marine, and freshwater species in coastal areas can reduce or degrade habitats used by native stocks. The location and operation of these facilities will determine the level of impact on the marine environment.

4.2.5.1 Adverse Impacts

A major concern of aquaculture operations is the discharge of organic waste from the farms. Wastes are composed primarily of feces and excess feed and the buildup of waste products into the receiving waters will depend on water depths and circulation patterns. The release of these wastes may introduce nutrients or organic materials into the surrounding water body and lead to a high biochemical oxygen demand (BOD) which may reduce dissolved oxygen, thereby potentially affecting the survival of many aquatic organisms in the area. Net effects to CPS may be either positive or negative.

Aquaculture operations also have the potential to release high levels of antibiotics, disease, as well as allowing cultured organisms to escape into the environment. These events have unknown but potential adverse impacts on fish habitat.

4.2.5.2 References

British Columbia Minist. of Environment, Victoria, (Canada). Water Management Branch. 1990. Environmental management of marine fish farms. 28 pp NTIS Order No.: MIC-91-00496/GAR.

4.2.6 Wastewater Discharge

The discharge of point and nonpoint source wastewater from activities including municipal wastewater treatment plants, power generating stations, industrial plants (e.g., pulp mills, desalination plants) and storm drains into open ocean waters, bay or estuarine waters can introduce pollutants detrimental to estuarine and marine habitats. These pollutants include pathogens, nutrients, sediments, heavy metals, oxygen demanding substances, hydrocarbons and other toxics. Historically, wastewater discharges have been one of the largest sources of contaminants into coastal waters. However, whereas wastewater discharges have been regulated under increasingly more stringent requirements over the last 25 years, non-point source/ stormwater runoff has not, and continues to be a significant remaining source of pollution to the coastal areas and ocean. Outfall-related changes in community structure and function, health and abundance may result. Many of these changes can be long-lasting.

4.2.6.1 Adverse Impacts

Wastewater effluent and non-point source/ stormwater discharges may affect the growth and condition of fish associated with wastewater outfalls should high contaminant levels (e.g., chlorinated hydrocarbons; pesticides; herbicides) be discharged. In addition, the high nutrient levels downcurrent of these outfalls may also be a concern. If contaminants are present, they may become bioavailable by absorption across the gills or bioaccumulate as a result of consuming contaminated prey. This is especially true for benthic-feeding fish frequenting wastewater discharge outfalls. Due to bioturbation, diffusion, and other upward transport mechanisms, buried contaminants may migrate to surface layers and become bioavailable.

Prager and MacCall (1993) detected possible effects of contaminant loadings in the ocean off southern California on reproductive success of Pacific sardine but not for northern anchovy or Pacific (chub) mackerel. Contaminant loadings were measured using a synthetic variable that included data from a wide variety of sources along the coast of southern California. The study was meant to generate rather than test hypotheses, however, and results were not definite.

Localized sources of pollution may effect CPS in bays and harbors along the coast but likely may not affect CPS stocks as a whole because CPS are distributed over large areas of the open coast and respond quickly to adverse changes in their environment by moving away. It is known however, that growth and survival of Pacific sardine adults can be affected by low level exposure to paper and cardboard pulp suspended in the water and ingested while feeding. Data are limited for most CPS, but information available for northern anchovy (see below) is probably applicable to other CPS species.

There is relatively little information regarding the water quality requirements and preferences of northern anchovy except for studies in the Los Angeles area concerning environmental problems corrected decades ago. Oxygen depletion due to die-off of massive dinoflagellate blooms caused occasional fish kills in both Santa Cruz Harbor and Fish Harbor (1973 to 1974) at Terminal Island, Los Angeles. Prior to regulatory control, oxygen depletion due to excessive dumping of high oxygen demand wastes into waters with reduced circulation caused episodes of fish kills as well, but such areas provided attractive food supplies preliminary to the oxygen depletion events. Anchovy tended to congregate around areas of sewage outfall, such as White's Point off Palos Verdes Peninsula, and prior to regulatory control, around the outfalls of the Terminal Island fish processors and sewage treatment plant.

Impacts of cannery and sewage waste on anchovy have been studied extensively only in the Los Angeles Harbor area during the 1980s and earlier. At the time of the studies, anchovy reduction processing was only one of the various fishery products that contributed to cannery effluent. Cannery wastes for many years were dumped into Inner Fish Harbor along with pumpings from boat holds and human wastes. The waters were frequently anoxic and the debris laden bottom was devoid of benthic macro organisms. In 1964, two cannery discharges were relocated intertidally outside Fish Harbor in Los Angeles Harbor not far from the sewage treatment outfall (Soule and Oguri, 1973). The Way Street Station outfall received wastes from various canneries and the other discharges effluent from only Starkist canneries. The discharge of cannery wastes was most critical during the fall of the year when seasonal die-off of biota from late summer and early fall plankton blooms and water column turnover placed a heavy natural oxygen demand on the receiving waters (Chamberlain 1975). Soule and Oguri (1976) report that "under (then) present conditions, a small zone within approximately 200 feet of the outfalls exists where numbers of species are low. Adjacent to this zone is a zone of enrichment which extends through most of the outer harbor. Beyond that, conditions return to average coastal populations. The regulations of waste loadings and control of pollutants in the past six-year period has brought the harbor ecosystem from a depauperate biota to a moderately rich one in the immediate outfalls zone, with a very rich biota in the adjacent outer harbor area."

Soule and Oguri (1973) reported that "Nothing is known about the distance traveled by individual anchovies within the harbor, nor about the degree to which they move in and out of the harbor. Catches by the bait boats, presently being surveyed, indicate that there may be an area of inhibition in the immediate vicinity of the cannery outfalls. There are indications that the anchovies move away from the area when the oxygen is low and also when it is excessively high, during plankton blooms. Weather conditions may exert influence as well, for anchovies apparently disappeared from harbor catches prior to heavy winter storms and subsequent rainwater runoff. They also were not caught in the harbor near the end of the season when the Davidson Current brought warmer southerly waters into the area, but reappeared just after water temperatures dropped."

Turbid waters with high densities of edible fine particulate matter apparently made harbor waters an excellent habitat for larval and juvenile fishes. Fish productivity began to decrease when dissolved air flotation treatment (DAF) was installed on the cannery waste streams in 1975, even though esthetically the harbors were improved. The installation of secondary waste treatment at the Terminal Island Treatment Plant and the subsequent connecting of cannery waste streams to the treatment plant in 1977 to 1978 resulted in a dramatic decrease in harbor biota and, in particular, in anchovies (Soule and Oguri 1979; 1980). Benthic populations decreased three-to four-fold in the outer harbor between 1973 and 1978, and the fish populations, sampled by otter trawl, also dropped four-fold. Trawl catches of anchovy in the outer harbor decreased about ten-fold between 1973 and 1974 continued to decrease at a slower rate through 1978 (Soule and Oguri 1980). The offshore anchovy population increased from 1973 to 1974 then decreased about five-fold through 1978 and recovered in 1979. Anchovy and other fish have been attracted to the harbor during episodes when the treatment plant malfunctioned and released high biological oxygen demand floc and wastes, and when dredging created high levels of turbidity and resuspended edible particulates and microbiota. Fish catches by commercial party boats decreased dramatically off the Orange County Sanitation District outfall after conversion to a deep water outlet (Soule and Oguri 1982).

The use of biocides (e.g., chlorine; heat treatments) to prevent biofouling or the discharge of brine as a byproduct of desalinization may reduce the suitability of water bodies for populations of fish species and their prey in the general vicinity of the discharge pipe. The impacts of chlorination and heat treatments, if any, are minimized due to their intermittent use and regulation pursuant to state and/or federal national pollutant discharge elimination system (NPDES) permit requirements. These compounds may change the chemistry and the physical characteristics of the receiving water at the disposal site by introducing chemical constituents in suspended or dissolved form. In addition to chemical and thermal effects, discharge sites may adversely impact sensitive areas such as emergent marshes, seagrasses, and kelp beds if located improperly.

High discharge velocities may cause scouring at the discharge point as well as entrainment of particulates with resulting turbidity plumes. Turbidity plumes may reduce light penetration and lower the rate of photosynthesis and the primary production in an area if suspension persists. Fish may suffer reduced feeding ability especially if suspended particulates persist. The contents of the suspended material may react with the dissolved oxygen in the water and result in oxygen depletion.

A significant portion of impacts to coastal waters may also be caused by nonpoint source pollution. Major sources in coastal waters include agriculture and urban runoff. Other significant sources include faulty septic systems, forestry, marinas and recreational boating, physical changes to stream channels, and habitat degradation, especially the destruction of wetlands and vegetated areas near streams. Runoff can include heavy metals, pesticides, fertilizers, synthetic and petroleum hydrocarbons, and pet droppings. Unless proper management measures are incorporated, these contaminants can find their way into the food web through benthic infaunal communities and subsequently bioaccumulate in numerous fish species.

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4.2.7 Discharge of Oil or Release of Hazardous Substances

The discharge of oil or release of a hazardous substance into estuarine and marine habitats, or exposure to a product of reactions resulting from the discharge of oil or release of a hazardous substance can have both acute and chronic effects on fish resources and their prey.

4.2.7.1 Adverse Impacts

Exposure to petroleum products and hazardous substances from spills or other unauthorized releases can have both acute and chronic effects on fish resources and their prey, and also potentially reduce the marketability of target species. Direct physical contact with discharged oil or released hazardous substances (e.g., toxics; oil dispersants, mercury) or indirect exposure resulting from food chain processes can produce a number of biological responses in fish resources and their prey. These responses can occur in a variety of habitats including the water column, seafloor, bays, and estuaries. Chronic and large oil spills have a significant impact on fishery populations.

Other issues related to the category include efforts to cleanup spills or releases that in themselves can create serious harm to the habitat. For example, the use of potentially toxic dispersants to break up an oil spill may adversely effect the egg, larval, and adult stages of CPS finfish.

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4.2.8 Coastal Development Impacts

Coastal development involves changes in land use by the construction of urban, suburban, commercial, and industrial centers and the corresponding infrastructure. Vegetated and open forested areas are removed by cut-and-fill activities for enhancing the development potential of the land. Portions of the natural landscape are converted to impervious surfaces resulting in increased runoff volumes. Runoff from these developments include heavy metals, sediments, nutrients and organics, including synthetic and petroleum hydrocarbons, yard trimmings, litter, debris, and pet droppings. As residential, commercial, and industrial growth continues, the demand for water escalates. As ground water resources become depleted or contaminated, greater demands are placed on surface water through dam and reservoir construction or other methods of freshwater diversion. The consumptive use of redistribution of significant volumes of surface freshwater causes reduced river flows that can affect salinity regimes as saline waters intrude further upstream.

4.2.8.1 Adverse Impacts

Development activities within watersheds and in coastal marine areas may impact fish habitat on both long-term and short term scales. Runoff of toxics reduces the quality and quantity of water column and benthic EFH for CPS by the introduction of pesticides, fertilizers, petrochemicals, construction chemicals (e.g., concrete byproducts, seals and paints).

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5.0 CONSERVATION AND ENHANCEMENT MEASURES

5.1 Background

Section 600.815 (a) (7) of the EFH regulations states that FMPs must describe options to avoid, minimize, or compensate for the adverse effects and promote the conservation and enhancement of EFH. Generally, nonwater dependent actions should not be located in EFH if such actions may have adverse impacts on EFH. Activities that may result in significant adverse affects on EFH, should be avoided where less environmentally harmful alternatives are available. If there are no alternatives, the impacts of these actions should be minimized. Environmentally sound engineering and management practices should be employed for all actions which may adversely affect EFH. Disposal or spillage of any material (dredge material, sludge, industrial waste, or other potentially harmful materials) which would destroy or degrade EFH should be avoided. If avoidance or minimization is not possible, or will not adequately protect EFH, compensatory mitigation to conserve and enhance EFH should be recommended. FMPs may recommend proactive measures to conserve or enhance EFH. When developing proactive measures, the Council may develop a priority ranking of the recommendations to assist federal and state agencies undertaking such measures.

5.2 Measures

Established policies and procedures of the Council and the NMFS provide the framework for conserving and enhancing essential fish habitat. Components of this framework include adverse impact avoidance and minimization; provision of compensatory mitigation whenever the impact is significant and unavoidable; and incorporation of enhancement. New and expanded responsibilities contained in the Magnuson-Stevens Act will be met through appropriate application of these policies and principles. In assessing the potential impacts of proposed projects, the Council and NMFS are guided by the following general considerations:

- The extent to which the activity would directly and indirectly affect the occurrence, abundance, health, and continued existence of fishery resources.
- The extent to which the potential for cumulative impacts exists.
- The extent to which adverse impacts can be avoided through project modification, alternative site selection or other safeguards.
- The extent to which the activity is water dependent if loss or degradation of EFH is involved.
- The extent to which mitigation may be used to offset unavoidable loss of habitat functions and values.

The following activities have been identified as potentially, directly or indirectly, affecting the habitat utilized by all or some CPS: dredging, fills/dredge material disposal, oil/gas exploration/production, water intake structures, aquaculture, wastewater discharge, discharge of oil or release of hazardous substances, and coastal development. The following measures are suggested in an advisory, not mandatory, capacity as proactive conservation measures that would aid in minimization or avoidance of the adverse effects of these nonfishing activities on essential fish habitat.

5.2.1 Dredging

1. To the maximum extent practicable, new, as opposed to maintenance dredging, should be avoided. Activities that require dredging (such as placement of piers, docks, marinas, etc.) should be sited in deep water areas or designed in such a way as to alleviate the need for maintenance dredging. Projects should be permitted only for water dependent purposes, when no feasible alternatives are available.

2. Where the dredge equipment employed could cause significant long term impacts due to entrainment of prey species, dredging in estuarine waters shallower than 20 feet in depth should be performed during the time frame when prey species are least likely to be entrained.

3. All dredging permits should reference latitude-longitude coordinates of the site so information can be incorporated into GIS for tracking cumulative impacts. Inclusion of aerial photos may also be required to help geo-reference the site and evaluate impacts over time.

4. Sediments should be tested for contaminants as per the Environmental Protection Agency and U.S. Army Corps of Engineers requirements to determine proper removal and disposal procedures.

5. The cumulative impacts of past and current dredging operations on EFH should be considered and described by federal, state, and local resource management and permitting agencies and considered in the permitting process.

6. Where a dredging equipment type is used that is expected to create significant turbidity (e.g., clamshell), dredging should be conducted using adequate control measures to minimize turbidity.

5.2.2 Fills/Dredge Material Disposal

1. Upland dredge disposal sites should be considered as an alternative to offshore disposal sites. Fills should not be allowed in areas with subaquatic vegetation or other areas of high productivity. Survey should be undertaken to identify least productive areas prior to disposal. Use of clean dredge material meeting Army Corps of Engineers and state water quality requirements for beach replenishment and other beneficial uses (e.g., creation of eelgrass beds) is encouraged.

2. The cumulative impacts of past and current fill operations on EFH should be addressed by federal, state, and local resource management and permitting agencies and considered in the permitting process.

3. Any disposal of dredge material in EFH should meet applicable state and/or federal quality standards for such disposal.

4. When reviewing open water disposal permits for dredged material, state and federal agencies should identify the direct and indirect impacts such projects may have on EFH. Benthic productivity should be determined by sampling prior to any discharge of fill material. Sampling design should be developed with input from state and federal resource agencies.

5. The areal extent of the disposal site should be minimized. However, in some cases, thin layer disposal may be less deleterious. All non-avoidable, adverse impacts (other than insignificant impacts) should be fully mitigated.

6. All spoil disposal permits should reference latitude-longitude coordinates of the site so information can be incorporated into GIS systems. Inclusion of aerial photos may also be required to help geo-reference the site and evaluate impacts over time.

5.2.3 Oil/Gas Exploration/Production

1. Benthic productivity should be determined by sampling prior to any exploratory operations. Areas of high productivity should be avoided to the maximum extent possible. Sampling design should be developed with input from state and federal resource agencies.

2. Mitigation should be fully addressed for impacts.

3. Containment equipment and sufficient supplies to combat spills should be on site at all facilities that handle oil or hazardous substances.

4. Each facility should have a "Spill Contingency Plan" and all employees should be trained in how to respond to a spill.

5. To the maximum extent practicable, storage of oil and hazardous substances should be located in an area that would prevent spills from reaching the aquatic environment.

5.2.4 Water Intake Structures

1. New facilities that rely on surface waters for cooling should be located in areas of low productivity or areas not prone to congregating CPS and their prey. New discharge points should be located in areas that have low concentrations of living marine resources, or they should incorporate cooling towers that employ sufficient safeguards to ensure against release of blow-down pollutants into the aquatic environment in concentrations that exceed state and/ or federal limits established pursuant to state and/ or federal NPDES regulations.

2. All intake structures should be designed to minimize entrainment or impingement of prey species. Power plant intake structures should be designed to meet the "best technology available" requirements as developed pursuant to Section 316b of the Clean Water Act.

3. Discharge temperatures (both heated and cooled effluent) should comply with applicable temperature limits established pursuant to state and/ or federal NPDES regulations.

5.2.5 Aquaculture Facilities

1. Facilities should be located in upland areas as often as possible. Tidally influenced wetlands should not be enclosed or impounded for mariculture purposes. This includes hatchery and grow-out operations. Siting of facilities should also take into account the size of the facility, the presence or absence of submerged aquatic vegetation, proximity of wild fish stocks, migratory patterns, and competing uses. Areas of high productivity should be avoided to the maximum extent possible.

2. Water intakes should be designed to avoid entrainment and impingement of fish species.

3. Water discharge should be treated to avoid contamination of the receiving water, and should be located only in areas having good mixing characteristics.

4. Where cage mariculture operations are undertaken, water depths and circulation patterns should be investigated and should be adequate to preclude the buildup of waste products, excess feed, and chemical agents.

5. Any net pen structure should have small enough webbing to prevent entanglement by prey species.

6. Measures should be taken to avoid escapement of farmed animals.

7. Mitigation should fully address all impacts.

5.2.6 Wastewater Discharge

1. New outfall structures should be placed offshore sufficiently far enough to prevent discharge water from impacting productive areas. Discharges should be managed to comply with applicable state and/or federal NPDES permit requirements, including compliance with applicable technology-based and water quality-based effluent limits.

2. The establishment of management programs to address non-point source/stormwater pollution water quality issues on a watershed basis is supported and encouraged.

5.2.7 Discharge of Oil or Release of Hazardous Substances

1. Containment equipment and sufficient supplies to combat spills should be on-site at all facilities that handle oil or hazardous substances.

2. Facilities should have a "Spill Contingency Plan", where required by applicable local, state, or federal requirements, and employees identified in the plan as having responsibility for responding to a spill should receive appropriate training.

3. To the maximum extent practicable, storage of oil and hazardous substances should be located in an area that would prevent spills from reaching the aquatic environment.

5.2.8 Coastal Development Impacts

1. Prior to installation of any piers or docks benthic productivity should be determined and areas with high productivity avoided. Sampling design should be developed with input from state and federal resource agencies.

2. Fueling facilities should be equipped with all necessary safeguards to prevent spills. A spill response plan should be developed and gear necessary for combating spills should be located on sight.

3. Filling of any aquatic areas should be curtailed as much as reasonably possible.

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TABLE 4.0-1 Adverse nonfishing activities, impacts and conservation/enhancement measures for CPS EFH.

ACTIVITY	IMPACTS (Potential)	CONSERVATION MEASURES (Advisory)
1. Dredging	• Bottom-dwelling organisms • Turbidity plumes • Bioavailability of toxics • Damage to sensitive habitats	• Curtail/minimize new dredging activities as practicable • Take actions to prevent impacts to flora/fauna • Geo-reference all dredge sites • Contaminant assays • Address cumulative impacts • Minimize turbidity
2. Dredge Material Disposal/fills	• Bottom-dwelling organisms • Turbidity plumes • Toxics becoming biologically available • Damage sensitive habitats • Loss of habitat function	• Place dredge spoils upland if possible;avoid fills in productive areas • Address cumulative impacts • Meet applicable quality requirements for disposal of dredge material in EFH • Identify direct and indirect impacts on EFH • Minimize areal extent of the disposal site • Geo-reference the site
3. Oil/gas Exploration/ production	• Seismic energy release • Discharge of exploratory drill muds and cuttings • Resuspension of fine-grained mineral particles • Composition of the substrate altered	• Avoid areas of high productivity • Provide mitigation • On-site containment equipment • Maintain "spill contingency plan" • Keep oil and hazardous substances from reaching the Aquatic environment
4. Water Intake Structures	• Entrapment, impingement, and entrainment • Loss of prey species	• Locate new facilities away from productive areas • Minimize entrainment or impingement of prey species per CWA 316(b). • Discharge temperatures to meet applicable discharge Limits
5. Aquaculture	• Discharge of pollutants from the facility • Escapement	• Minimize water/habitat quality impacts • Avoid entrainment and impingement losses • Treat and mix water discharges • Preclude waste product buildups • Prevent entanglement of prey species • Prevent escapement • Mitigate impacts
6. Wastewater Discharge	• Wastewater effluent with high contaminant levels • High nutrient levels downcurrent of outfall • Biocides to prevent biofouling • Thermal effects • Turbidity plumes • Stormwater runoff	• Avoid areas of high productivity with new discharge points • Watershed management programs
7. Oil Discharge/ Hazardous Substances Release	• Direct physical contact • Indirect exposure resulting • Cleanup	• Maintain on-site containment equipment and supplies • On-site "Spill Contingency Plan" • Prevent spills from reaching the aquatic environment.
8. Coastal Development Impacts	• Contaminant runoff • Sediment runoff • Filling of aquatic areas	• Shoreline construction should avoid productive areas • Prevent fuel spillage • Curtail fills in estuaries, wetlands, and bay

6.0 COASTAL PELAGIC SPECIES HABITAT/LIFE HISTORY DESCRIPTIONS

6.1 Northern Anchovy

6.1.1 Distribution and Habitat

Northern anchovy are distributed from the Queen Charlotte Islands, British Columbia, to Magdalena Bay, Baja California and anchovy have recently colonized the Gulf of California. The population is divided into northern, central and southern subpopulations, or stocks. The southern subpopulation is entirely within Mexican waters. The central subpopulation, which supports significant commercial fisheries in the U.S. and Mexico, ranges from approximately San Francisco, California, to Punta Baja, Baja California. The bulk of the central subpopulation is located in the Southern California Bight, a 20,000-square-nautical-mile area bounded by Point Conception, California, in the north and Point Descanso, Mexico, (about 40 miles south of the U.S.-Mexico boarder) in the south.

Northern anchovy in the central subpopulation are typically found in waters that range from 12°C to 21.5°C; however, laboratory defined lethal temperatures occur at seven degrees Celsius and 29°C (Brewer 1976). There is a great deal of regional variation in age composition and size, with older and larger anchovy found farther offshore and to the north (Parrish et al. 1985). The pattern is accentuated in warm years and during the summer (Methot 1989).

There is a great deal of regional variation in age composition and size with older and larger individuals further offshore and to the north (Parrish et al. 1985). These patterns are accentuated during warm years such as El Niño and when abundance is high (Methot 1989). The geographic distribution of northern anchovy has been more consistent over time and is more nearshore than the geographic distribution of Pacific sardine. In the Oregon to Vancouver Island region northern anchovy must overwinter in upper mixed layer temperatures as low as eight degrees Celsius to nine degrees Celsius; short term laboratory lethal temperatures for northern anchovy are seven degrees Celsius (Brewer 1976).

Eggs and larvae are found near the surface, generally at depths of less than 50 meters and in the same areas as spawning adults. Anchovy eggs are most abundant at about 14°C. All life stages are found in the surface waters of the EEZ.

Methot found that near shore habitat areas (<90 meters) between Pt. Conception, California and Pt. Banda, Baja California represented 23% of the available habitat for central stock juvenile northern anchovy . Densities of juvenile anchovy in near shore areas were about ten times higher than in other habitat areas. He concluded that near shore habitats supported at least 70% of the juvenile anchovy population (Methot 1981, Smith 1985).

6.1.2 Life History

Northern anchovy are small, short-lived fish typically found in schools near the surface. Northern anchovy rarely exceed four years of age and 18 cm total length, although individuals as old as seven years and 23 cm have been recorded. Natural mortality is thought to be M = 0.6 to 0.8 $year^{-1}$, which means that 45% to 55% of the total stock would die each year of natural causes if no fishing occurred. Northern anchovy eat phytoplankton and zooplankton by either filter feeding or biting, depending on the size of the food.

Anchovy spawn during every month of the year, but spawning increases in late winter and early spring and peaks from February to April. Preferred spawning temperature is 14°C and eggs are most abundant at temperatures of 12°C to 16°C. Females spawn batches of eggs throughout the spawning season at intervals as short as seven to ten days. The eggs, found near the surface, are typically ovoid and translucent and require two to four days to hatch, depending on water temperatures. Both the eggs and larvae are found near the surface. Anchovy in the central subpopulation are all sexually mature at age two. The fraction of one-year-olds that is sexually mature in a given year depends on water temperature and has been observed to range from 47% to 100% (Methot 1989). This phenomenon affects estimates of spawning population.

6.1.3 Fisheries

Northern anchovy in the central subpopulation are harvested by commercial fisheries in California and Mexico for reduction, human consumption, live bait, dead bait, and other nonreduction commercial uses. Anchovy landed in Mexico are used primarily for reduction, although small amounts are probably used as bait.

The northern subpopulation supports a small bait fishery (one to four boats) off Oregon and Washington. The small quantities of the northern subpopulation are taken for use as bait.

Anchovy landed by the reduction fisheries are converted to meal, oil, and soluble protein products sold mainly as protein supplements for poultry food and also as feed for pigs, farmed fish, fur-producing animals, laboratory animals, and household pets. Meal obtained from anchovy is about 65% protein (meal from other fishes is 50% to 55% protein).

Anchovy harvested by the live bait fishery in California are not landed but are kept alive for sale to anglers as bait and chum (in contrast anchovy sold as "live" bait off Oregon and Washington may be killed at time of sale). Transactions between buyers and sellers of live bait take place either at sea or at bait wells tied up at docks. Bait dealers generally supply party boats on a contract basis and receive a percentage of the fees paid by passengers. Bait is also sold by the scoop to anglers in private vessels.

Anchovy landed by the nonreduction (other than live bait) fishery are used as dead frozen bait, fresh fish for human consumption, canned fish for human consumption, animal food, and anchovy paste.

6.1.4 Relevant Trophic Information

Northern anchovy are subject to natural predation throughout all life stages. Eggs and larvae fall prey to an assortment of invertebrate and vertebrate planktivores. As juveniles, anchovy are vulnerable to a wide variety of predators, including many recreationally and commercially important species of fish. As adults, anchovy are fed upon by endangered salmon stocks, endangered birds (California brown pelican *Pelecanus occidentalis californicus* and least tern *Sterna albifrons browni)* numerous fishes (some of which have recreational and commercial value) mammals, and birds. Links between brown pelican breeding success and anchovy abundance have been documented (Anderson et al. 1980, 1982; Jacobson and Thomson 1989).

6.2 Jack Mackerel

Biological information about jack mackerel is available in MacCall et al. (1980), MacCall and Stauffer (1983), and in references cited below.

6.2.1 Distribution and Habitat

Jack mackerel are a pelagic schooling fish that ranges widely throughout the northeastern Pacific, from the Pacific coast to an offshore limit approximated by a line running from Cabo San Lucas, Baja California, to the eastern Aleutian Islands, Alaska. Much of the range lies outside the 200-mile U.S. EEZ (MacCall and Stauffer 1983).

Small jack mackerel (10 cm to 30 cm FL and up to six years of age) are most abundant in the Southern California Bight, where they are often found near the mainland coast and islands and over shallow rocky banks. Older, larger fish (50 cm to 60 cm FL and 16 years to 30 years) range from Cabo San Lucas, Baja California, to the Gulf of Alaska, where they are generally found offshore in deep water and along the coastline to the north of Point Conception. Large fish rarely appear in southern inshore waters. Fish of intermediate lengths (30 cm to 50 cm TL; nine years to 20 years of age) were found in considerable numbers during the spring of 1991 around the 200-mile limit of the U.S. EEZ off southern California; fish off five years to nine years of age were the most numerous and fish ten years to 20 years old were common (Nebenzahl 1997).

Jack mackerel sampled over several years by trawl surveys off Oregon and Washington ranged from 30 cm to 62 cm and four years to 36 years old. More than half of the fish sampled were greater than 20 years old and fish greater than 30 years old were common (Nebenzahl 1997). As with other CPS finfish, older and larger fish are most common further north and offshore. Jack mackerel differ from the other CPS species in that they are quite long lived and more commonly found offshore. Jack mackerel older than 30 years are common in the northern portion of their range (Nebenzahl 1997). Spawning occurs farther offshore than for other CPS (Jacobson et al. 1997).

Jack mackerel off southern California move inshore and offshore as well as north and south. They are more available on offshore banks in late spring, summer and early fall than during the remainder of the year. In southern California waters, jack mackerel schools are often found over rocky banks, artificial reefs, and shallow rocky coastal areas. They remain near the bottom or under kelp canopies during daylight and venture into deeper surrounding areas at night. Young juvenile fish sometimes form small schools beneath floating kelp and debris in the open sea.

6.2.2 Life History

Jack mackerel grow to about 60 cm and live 35 years or longer. Estimates of natural mortality are uncertain, but the natural mortality rate (M) averaged over the life span of a typical fish is probably less than 0.20 year to 0.25 year^{-1}. This means that about 18% to 22% of the total stock would die each year of natural causes if no fishing occurred.

Small jack mackerel taken off southern California and northern Baja California eat large zooplankton (copepods, pteropods, and euphausiids), juvenile squid, and anchovy. Larvae feed almost entirely on copepods.

Although immature jack mackerel can be found off southern California at all times of the year, 50% or more of all females reach sexual maturity during their first year of life. Older jack mackerel, in samples taken about 200 miles offshore from Southern California, spawned about every five days and the average female may spawn as many as 36 times per year Macewicz and Hunter (1993).

The spawning season for jack mackerel off California extends from February to October, with peak activity from March to July (MacCall and Prager 1988). Young spawners off southern California begin spawning later in the year than older spawners. Little is known of the maturity cycle of large fish offshore, but peak spawning appears to occur later in more northerly waters.

Large predators like tunas and billfish eat jack mackerel, but except as young-of-the-year and yearlings, jack mackerel are probably a minor forage source for smaller predators. Older jack mackerel probably do not contribute significantly to food supplies of marine birds, because they are too large to be eaten by most bird species and school inaccessibly deep. Little information is available on predation of jack mackerel by marine mammals. Jack mackerel are not often eaten by California sea lions, *Zalophus californianus*, or northern fur seals, *Callorhinus ursinus*.

6.2.3 Fishery Utilization

The southern California segment of the stock has been fished since the late 1940s, when jack mackerel served as a substitute for the failing sardine fishery. Purse seiners prefer Pacific (chub) mackerel, because jack mackerel tend to occur further from port and over rocky bottoms where there is increased risk of damage to nets. Mason (1991) describes the history of management for the jack mackerel fishery off southern California.

Offshore, large adult jack mackerel are sometimes taken incidentally in trawls for Pacific whiting. During the 1970s, foreign trawl fisheries may have caught 1,000 mt to 2,000 mt annually, but catches by foreign and joint-venture fishers in the 1980s ranged from nil to about 100 mt.

6.3 Pacific Sardine

Biological information about Pacific sardine *Sardinops sagax caerulea* is available in Frey (1971), Clark and Marr (1955), Ahlstrom (1960), Murphy (1966), MacCall (1979), and in the references cited below. Other common names for Pacific sardine include California pilchard, pilchard (in the northern part of its range), and sardina monterey (in the southern part of its range).

6.3.1 Distribution and Habitat

Sardines as a group of species are small pelagic schooling fish that inhabit coastal subtropical and temperate waters. The genus *Sardinops* is found in eastern boundary currents of the Atlantic and Pacific, and in western boundary currents of the Indo-Pacific oceans. Recent studies indicate that sardines in the Alguhas, Benguela, California, Kuroshio, and Peru currents, and off New Zealand and Australia are a single species (*Sardinops sagax*, Parrish et al. 1989) but stocks in different areas of the globe may be different at the subspecies level (Bowen and Grant 1997).

Pacific sardines are pelagic at all life history stages. They occur in estuaries, but are most common in the near shore and offshore domains along the coast. Pacific sardine are highly mobile and move seasonally along the coast (Radovich 1983). Older adults may move from spawning grounds in southern California and northern Baja California to feeding grounds off the Pacific northwest and Canada. Younger adults (ages two to four) appear to migrate to feeding grounds primarily in central and northern California. Juveniles occur in near shore waters off of northern Baja California and southern California (Clark 1940). Eggs and larvae occur nearly everywhere adults are found and eggs are most abundant between 14°C and 15°C (Lluch-Belda et al. 1991; Lo et al. 1994). When abundance is high, eggs and larvae may be concentrated 50 km to 150 km offshore of the area north of Point Conception with lesser quantities found in the region offshore of the Channel Islands. When abundance is low, eggs and larvae may be concentrated nearer shore and further south. These patterns probably depend on both sea surface temperatures and sardine abundance because they are accentuated during warm years and when abundance is high.

Sardine have at times been the most abundant fish species in the California Current (Barnes et al. 1992). When abundance is high and environmental conditions are favorable, Pacific sardine are distributed from the tip of Baja California (23° N latitude) to southeastern Alaska, and throughout the Gulf of Mexico. When abundance is low, as during the late 1960s and 1970s, sardine are not found in commercial quantities north of Point Conception and may be restricted to waters off southern and central Baja California. Dramatic changes in distribution, depending on environmental conditions and abundance (which are tightly linked) occur in sardine populations around the world (Lluch-Belda et al. 1989).

It is generally accepted that sardine off the West Coast of North America form three subpopulations or stocks. A northern subpopulation (northern Baja California to Alaska), a southern subpopulation (off Baja California), and a Gulf of California subpopulation were distinguished on the basis of serological techniques (Vrooman 1964). A recent electrophoretic study (Hedgecock et al. 1989) showed, however, no genetic variation among sardines from central and southern California, the Pacific coast of Baja California or the Gulf of California. A fourth, far northern, subpopulation has also been postulated (Radovich 1982). Although the ranges of the northern and southern subpopulations overlap, the stocks may move north and south at similar times and not overlap significantly. The northern stock is exploited by U.S. fisheries and is included in this FMP.

Pacific sardine probably migrated extensively during historical periods when abundance was high, moving north as far as British Columbia in the summer and returning to southern California and northern Baja California in the fall. Tagging studies (Clark and Janssen 1945) indicate that the older and larger fish moved farther north. Migratory patterns were probably complex and the timing and extent of movement were affected by oceanographic conditions (Hart 1973) and stock biomass. During the 1950s to 1970s, a period of reduced stock size and unfavorably cold sea surface temperatures, the stock apparently abandoned the northern portion of its range. At present, the combination of increased stock size and warmer sea surface temperatures are causing the stock to reoccupy grounds off northern California, Oregon, Washington, and British Columbia. Abandonment and recolonization of the higher latitude portion of their range has been associated with changes in abundance of sardine populations around the world (Parrish et al. 1989).

6.3.2 Life History

Pacific sardines may reach 41 cm, but are seldom longer than 30 cm. They may live as long as 13 years, but individuals in historical and current California commercial catches are usually younger than five years. In contrast, the most common ages in the historical Canadian sardine fishery were six years to eight years. There is a good deal of regional variation in size at age and size at age increases from south to north (Phillips 1948). Size and age at maturity may decline with a decrease in biomass, but latitude and temperature also are important (Butler 1987). At low biomass levels, sardines appear to be fully mature at age one, whereas at high biomass levels only some of the two-year-olds are mature (MacCall 1979).

Age-specific mortality estimates are available for the entire suite of life history stages (Butler et al. 1993). Mortality is high at the egg and yolk sac larvae stages (instantaneous rates in excess of 0.66 d^{-1}). Adult natural mortality rates has been estimated to be M=0.4.$year^{-1}$ (Murphy 1966; MacCall 1979) and 0.51 $year^{-1}$ (Clark and Marr 1955). A natural mortality rate of $M = 0.4$ $year^{-1}$ means that 33% of the sardine stock would die each year of natural causes if there were no fishery.

Pacific sardines spawn in loosely aggregated schools in the upper 50 meters of the water column. Spawning occurs year-round in the southern stock and peaks April through August between Point Conception and Magdalena Bay, and January through April in the Gulf of California (Allen et al. 1990). Off California, sardine eggs are most abundant at sea surface temperatures of 14°C to 16°C and larvae are most abundant at 13°C to 16° C. Temperature requirements are apparently flexible, however, because eggs are most common at 17°C to 21°C and in the Gulf of California and at 22°C to 25°C off Southern Baja (Lluch-Belda et al. 1991).

The spatial and seasonal distribution of spawning is influenced by temperature. During periods of warm water, the center of sardine spawning shifts northward and spawning extends over a longer period of time (Butler 1987; Ahlstrom 1960). Recent spawning has been concentrated in the region offshore and north of Point Conception (Lo et al. 1996). Historically, spawning may also have been fairly regular off central California. Spawning was observed off Oregon, and young fish were seen in waters off British Columbia in the early fishery (Ahlstrom 1960) and during recent years (Hargreaves et al. 1994). The main spawning area for the historical population off the U.S. was between Point Conception and San Diego, California, out to about 100 miles offshore, with evidence of spawning as far as 250 miles offshore (Hart 1973)

Sardines are oviparous multiple-batch spawners with annual fecundity that is indeterminate and highly age or size dependent. Butler et al. (1993) estimate that two year old sardines spawn on average six times per year whereas the oldest sardines spawn 40 times per year. Both eggs and larvae are found near the surface. Sardine eggs are spheroid, have a large perivitelline space, and require about three days to hatch at 15°C.

Sardine are planktivores that consume both phytoplankton and zooplankton. When biomass is high, Pacific sardine may consume a significant proportion of total organic production in the California Current system. Based on an energy budget for sardine developed from laboratory experiments and estimates of primary and secondary production in the California Current, Lasker (1970) estimated that annual energy requirements of the sardine population would have been about 22% of the annual primary production and 220% of the secondary production during the 1932 to 1934, a period of high sardine abundance.

6.3.3 Fishery Utilization

The sardine fishery first developed in response to demand for food during World War I. Landings increased from 1916 to 1936, and peaked at over 700,000 mt. The Pacific sardine supported the largest fishery in the western hemisphere during the 1930s and 1940s, with landings along the coast in British Columbia, Washington, Oregon, California, and Mexico. The fishery declined, beginning in the late 1940s and with some short-term reversals, to extremely low levels in the 1970s. There was a southward shift in the catch as the fishery decreased, with landings ceasing in the northwest in 1947 to 1948, and in San Francisco in 1951 to 1952. Sardines were primarily used for reduction to fish meal and oil and as canned food, with small quantities taken for live bait. An extremely lucrative dead bait market developed in central California in the 1960s.

In the early 1980s, sardine began to be taken incidentally with Pacific (chub) mackerel and jack mackerel in the southern California mackerel fishery and primarily canned for pet food, although some were canned for human consumption. As sardine continued to increase in abundance, a directed fishery was reestablished. Sardine landed in the directed sardine fisheries off southern and central California are mostly canned for human consumption and sold overseas, with minor amounts sold fresh for human consumption and animal food. Small quantities are harvested for dead bait and live bait. Sardines landed in Mexico are used primarily for reduction.

6.3.4 Relevant Trophic Information

Pacific sardines are taken by a variety of predators throughout all life stages. Sardine eggs and larvae are consumed by an assortment of invertebrate and vertebrate planktivores. Although it has not been demonstrated in the field, anchovy predation on sardine eggs and larvae was postulated as a possible mechanism for increased larval sardine mortality from 1951 to 1967 (Butler 1987). There have been few studies about sardine as forage, but juvenile and adult sardines are consumed by a variety of predators, including commercially important fish (e.g., yellowtail, barracuda, bonito, tuna, marlin, mackerel, hake, salmon, and sharks), seabirds (pelicans, gulls, and cormorants) and marine mammals (sea lions, seals, porpoises, and whales). In all probability, sardine are fed on by the same predators (including endangered species) that utilize anchovy (Table 1.1.2-1). It is also likely that sardines will become more important as prey as their numbers increase. For example, while sardine were abundant during the 1930s, they were a major forage species for both coho and chinook salmon off Washington (Chapman 1936).

6.4 Pacific (Chub) Mackerel

Pacific (chub) mackerel (*Scomber japonicus*) found off the Pacific coast of the U.S. are often called "blue" or "chub" mackerel and are the same species as mackerel of various names found elsewhere in the Pacific, Atlantic and Indian oceans (Collett and Nauen 1983). A synopsis of the biology of Pacific (chub) mackerel is available in Schaefer (1980) and references cited below. The northeastern Pacific stock (see below) is included in this fishery management plan.

6.4.1 Distribution and Habitat

Pacific (chub) mackerel in the northeastern Pacific range from Banderas Bay, Mexico, to southeastern Alaska, 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. Pacific (chub) mackerel usually occur within 20 miles of shore but have been taken as far offshore as 250 miles (Fitch 1969; Frey 1971; Allen et al. 1990; MBC 1987).

There are three spawning stocks along the Pacific coasts of the U.S. and Mexico: one in the Gulf of California, one in the vicinity of Cabo San Lucas, and one extending along the Pacific coast north of Punta Abreojos, Baja California (Collette and Navem 1983; Allen et al. 1990; MBC 1987). The latter "northeastern Pacific" stock is harvested by fishers in the U.S. and Mexico and included in this FMP.

Pacific (chub) mackerel adults are found in water ranging from 10°C to 22.2°C (MBC 1987), and larvae may be found in water around 14°C (Allen et al. 1990). As adults, Pacific (chub) mackerel may move north in summer and south in winter between Tillamook, Oregon, and Magdalena Bay, Baja California. Northerly movement in the summer peaks 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 (chub) 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 depths of 300 meters (Allen et al. 1990). Pacific (chub) mackerel often school with other pelagic species, particularly jack mackerel and Pacific sardine.

6.4.2 Life History

The largest recorded Pacific (chub) mackerel was 63 cm long and weighed 2.8 kg, but Pacific (chub) mackerel taken by commercial fishing seldom exceed 40 cm or one kg (Hart 1973; Roedel 1938). The oldest recorded age for a Pacific (chub) mackerel was 11 years, but most caught commercially are less than four years old (Fitch 1951). Some Pacific (chub) mackerel mature as one-year-olds, and all are sexually mature by age four (Prager and MacCall 1988). The annual rate of natural mortality (M) is thought to be about 0.5 $year^{-1}$, which means that 39% of the stock would die each year of natural causes in the absence of fishing (Parrish and MacCall 1978).

Pacific (chub) mackerel larvae eat copepods and other zooplankton including fish larvae (Collette and Nauen 1983; MBC 1987). Juveniles and adults feed on small fishes, fish larvae, squid and pelagic crustaceans such as euphausids (Clemens and Wilby 1961; Turner and Sexsmith 1967; Fitch 1969; Fitch and Lavenberg 1971; Frey 1971; Hart 1973; Collette and Nauen 1983).

Pacific (chub) mackerel in the northeastern Pacific stock spawn from Eureka, California, south to Cabo San Lucas in Baja California (Frey 1971; MBC 1987) between three and 320 km from shore. They seldom spawn north of Point Conception (Fritzsche 1978; MBC 1987) although young of year mackerel have been recently reported as far north as Oregon and Washington due, perhaps, to current warm sea surface temperatures. Spawning peaks from late April to July (MacCall and Prager 1988). Like most CPS, Pacific (chub) mackerel have indeterminate fecundity and seem to spawn whenever sufficient food is available and appropriate environmental conditions prevail. Actively spawning fish appear capable of spawning every day or every other day (Dickerson et al. 1992).

Pacific (chub) mackerel larvae are subject to predation from a number of invertebrate and vertebrate planktivores. Juveniles and adults are eaten by larger fishes, marine mammals, and seabirds. Predators include porpoises, California sea lions (*Zalophus californianus*), brown pelican (*Pelecanus occidentalis*), striped marlin (*Terapturus audax*), black marlin (*Makaira indca*), sailfish (*Istiophorus platypterus*), bluefin tuna (*Thunnus thynnus*), white sea bass *(Atractoscion nobilis)*, yellowtail (*Seriola dorsalis*), giant sea bass (*Stereolepis gigas*), and various sharks (MBC 1987). Although consumed in significant numbers by a wide variety of predators, Pacific (chub) mackerel are likely not as important as forage than Pacific sardine or northern anchovy which are smaller in size (i.e., available to a wider variety of predators) and often more abundant.

6.4.3 Fishery Utilization

Pacific (chub) mackerel in the northeastern Pacific are harvested by commercial fisheries in California and Mexico; some recreational harvest also occurs. Pacific (chub) mackerel are sold as fresh fish, canned for human consumption and pet food, and reduced to fish meal and oil.

Pacific (chub) mackerel are often taken by anglers and in considerable numbers, though seldom as a target species (Allen et al. 1990). During 1980 to 1989, the recreational catch averaged 1,330 mt per year (Wolf 1989) and Pacific (chub) mackerel was numerically the most important species taken in the California commercial passenger fishing boat fleet during the period of 1978 to 1989.

6.5 Market Squid

Market squid (*Loligo opalescens)* along the west coast of North America were studied extensively during 1960 through 1980 (Recksiek and Frey 1978; Symposium of the 1978 CalCOFI Conference[1]), but little research applicable to fisheries management has been carried out since then. Recent increases in squid landings (see below) have stimulated a variety of new research projects but results have not yet been published.

6.5.1 Distribution and Habitat

Adult and juvenile market squid (Dickerson and Leos 1992) are distributed throughout the California and Alaska current systems from the southern tip of Baja California, Mexico (23° N latitude) to southeastern Alaska (55° N latitude). They are most abundant between Punta Eugenio, Baja California and Monterey Bay, central California. Market squid are harvested near the surface and generally considered pelagic, but are actually found over the continental shelf from the surface to depths of at least 800 meters. They prefer

1/ See papers by various authors published during 1979 *in*: Calif. Coop. Oceanic Fish. Invest. Rep. 20: 21-71.

oceanic salinities and are rarely found in bays, estuaries, or near river mouths (Jefferts 1983). Adults and juveniles are most abundant between temperatures of ten degrees Celsius and 16°C (Roper et al. 1984).

Spawning squid concentrate in dense schools near spawning grounds, but habitat requirements for spawning are not well understood. Spawning occurs over a wide depth range, but the extent and significance of spawning in deep water is unknown. Known major spawning areas are shallow semi-protected near shore areas with sandy or mud bottoms adjacent to submarine canyons where fishing occurs. In these locations, egg deposition is between five meters (Jefferts 1983) and 55 meters (Roper and Sweeney 1984), and most common between 20 meters and 35 meters. Off California, squid and squid eggs have been taken in bottom trawls at depths of about 800 meters near Monterey (Bob Leos, California Department of Fish and Game, pers. comm.) and have been observed at 180 meters near the Channel Islands (Roper and Sweeney 1984). Factors that determine spawning grounds have not been precisely identified. Hatchlings (called "paralarvae") are presumably dispersed by currents. Their distribution after leaving the spawning areas is largely unknown.

Attempts to differentiate squid stocks using anatomical and genetic characters have been inconclusive. Thus, the number of market squid stocks or subpopulations along the Pacific coast is unknown.

6.5.2 Life History

Market squid are small short-lived molluscs reaching a maximum size of 30 cm total length, including arms (Roper and Sweeney 1984). Age and growth studies suggest than some individuals may live up to two years, but most mature and spawn when about one year old (Spratt 1979). In the laboratory squid have been reared to maturity and spawned at six months of age. Histological examination of squid testes and ovaries using electron microscopy suggests that squid spawn once over a short time period before dying (Greib 1978; Knipe 1978), although this is a topic of current research and some debate.

Spawning occurs year-round (Jefferts 1983). Peak spawning usually begins in southern California during the fall-spring season. Off central California, spawning normally begins in the spring-fall season. Squid spawning has been observed off Oregon during May through July. Off Washington and Canada, spawning normally begins in late summer. Year-round spawning likely reduces effects of poor temporary local conditions for survival of eggs or hatchlings. Year-round spawning suggests that stock abundance is not dependent on spawning success during a single short season or a single spawning area.

Males on spawning grounds are larger than females. Males reach 19 cm dorsal mantle length, a maximum weight of 130 grams and have larger heads and thicker arms than females. Females reach 17 cm dorsal mantle length and a maximum weight of 90 grams. Mating has been observed on spawning grounds just prior to spawning, but may also occur before squid move to the spawning grounds. Males deposit spermatophores into the mantle cavity of females and eggs are fertilized as they are extruded (Hurley 1977). Females produce 20 egg to 30 egg capsules and each capsule contains 200 eggs to 300 eggs that are suspended in a gelatinous matrix within the capsule. Females attach each egg capsule individually to the substrate. As spawning continues, mounds of egg capsules covering more than 100 m^2 may be formed.

Spawning is continuous and eggs of varying developmental stages may be present at one site. Eggs take three months to hatch at seven degrees Celsius to eight degrees Celsius, one month at 13°C and 12 days to 23 days at ten degrees Celsius (Jefferts 1983). Newly hatched squid (called "para larvae") are about 2.5 mm to three mm in length and resemble miniature adults. Hatchlings are dispersed by currents and their distribution after leaving the spawning areas is largely unknown.

Few organisms eat squid eggs although bat stars and sea urchins have been observed doing so (Jefferts 1983). Like northern anchovy and Pacific sardine (Table 1.1.2-1), market squid are probably important as forage to a long list of fish, birds, and mammals including threatened, endangered, and depleted species (Morejohn et al. 1978). Some of the more important squid predators are king salmon, coho salmon, lingcod, rockfish, harbor seals, California sea lions, sea otters, elephant seals, Dall's porpoise, sooty shearwater, Brandt's cormorant, rhinoceros auklet, and common murre.

Squid feed on copepods as juveniles gradually changing to euphausiids, other small crustaceans, small fish, and other squid as they grow (Karpov and Cailliet 1978).

6.5.3 Fishery Utilization

Market squid are harvested commercially primarily off southern and central California although some catch occurs throughout their range. Fishing occurs on spawning grounds and occurs during the spawning season. Peak catches occur off southern California during the winter, off Central California during the late spring and summer, and later in the summer off Oregon to Alaska.

Commercial squid fishing vessels use purse seines primarily, although scoop nets are also used in the southern California fishery. Lights are usually used to bring the squid schools up near the surface where they are more easily captured by seine or scoop net. Purse seines used for squid typically do not hang as deep as purse seines used for other species so contact with the bottom is reduced. However, squid eggs are occasionally observed in purse seines when the seines contact the bottom. Egg mortality associated with purse seining for squid has not been quantified.

The California squid fishery accounts for most of the coast wide landings. Minor amounts of market squid are landed in Canada, Washington, and Oregon . The size of the Mexican fishery is unknown but is thought to be minor. The California annual squid catch set records of 56, 70, and 80 thousand mt during 1994 to 1996.

In California, most squid marketed for human consumption is frozen, but minor amounts are canned or sold fresh. Historically, the domestic demand for frozen squid has been relatively small, and most of the increased production from California during 1994 to 1996 was frozen and exported to Europe, Spain, and China. Squid is also frozen for bait and supplied to domestic commercial and sport fishers and is an important source of live bait for the California sport fishing industry.

6.6 References

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TABLE 6.1 Summary of habitat information for northern anchovy.

Life Stage	Diet	Season	Location	Water Column	Oceanographic Features
Eggs and larvae	Yolk sac and planktivorous	Year-round, peaks from Feb. to April	Surface waters of the EEZ	Near surface, < 50m	12°C to 21.5°C
Adults	Phytoplankton, zooplankton	Year-round	Surface waters of the EEZ	Near surface, < 50m	12° C to 21.5°C

TABLE 6.2 Summary of habitat information for jack mackerel.

Life Stage	Diet	Season	Location	Water Column	Oceanographic Features
Eggs and larvae	Yolk sac; larvae consume copepods	Feb. to Oct.with peak from March to July	Pelagic, schooling	Pelagic	10°C to 26°C
Juveniles	N/A	Year-round	Sometimes in small schools under floating kelp and debirs	Pelagic	10° C to 26°C
Adults	Zooplankton (copepods, pteropods and euphausids, juvenile squid, and northern anchovy	Year-round	Inshore and offshore; sometimes over rocky bottoms	Pelagic	10°C to 26°C

TABLE 6.3 Summary of habitat information for Pacific sardine.

Life Stage	Diet	Season	Location	Water Column	Oceanographic Features
Eggs and larvae	Yolk sac and planktivorous	Year-round, with peak in April-August	Pelagic, 50-150 km offshore	Upper 50 m	Eggs: 14°C to 16°C Larvae: 14°C to 16°C
Juveniles	Planktivorous	Year-round	Pelagic	Above thermocline	10° to 26°C
Adults	Phytoplankton and zooplankton	Year-round	Pelagic, sometimes in estuaries	Above theromcline	10° C to 26°C

TABLE 6.4 Summary of habitat information for Pacific (chub) mackerel.

Life Stage	Diet	Season	Location	Water Column	Oceanographic Features
Eggs and larvae	Yolk sac; copepods and fish larvae	Peaks from late April to July	N/A	Surface	14°C
Juveniles	Small fishes, fish larvae, squid, and pelagic crustaceans such as euphausids	Inshore-offshore migration off CA July to Nov.; increased offshore abundance March to May	Off sandy beaches, around kelp beds, and in open bays	N/A	10°C to 26°C
Adults	Small fishes, fish larvae, squid, and pelagic crustaceans such as euphausids	Inshore-offshore migration off CA July to Nov.; increased offshore abundance March to May	Usually within 20 miles of shore, but as far as 250 miles offshore; near shallow banks	Surface to 300 m	10°C to 22.2°C

TABLE 6.5 Summary of habitat information for market squid, continued.

Life Stage	Diet	Season	Location	Water Column	Oceanographic Features
Eggs and para larvae (newly hatched squid)	N/A	Year-round	Shallow semi-protected nearshore areas with sandy or mud bottoms adjacent to submarine canyons; distribution of paralarvae is largely unknown		10°C to 26°C
Juvenile	Copepods	N/A	N/A	N/A	10°C to 26°C
Adult	Euphausiids and other small crustaceans, small fish and other squid	Spawn year	Rarely found in bays, estuaries or near river mouths	Surface to 800 m	10°C to 26°C

7.0 RESEARCH NEEDS

Research in general needs to address additional life history information, nonfishing impacts and the potential for conservation and enhancement measures. In addition, because potential overfishing of northern anchovy, Pacific sardine, market squid, or other species could adversely affect the EFH for other species such as Pacific (chub) mackerel, jack mackerel, and market squid; the dynamics of predator-prey relationships within the context of an ecosystem perspective should be investigated.

Studies on effects of fishing activities (e.g., mid-water trawling, processing discards) on the EFH of CPS should be considered.

Consideration should be given to research necessary to describe, identify, and map EFH based on at least level 2 and level 3 information, and ideally, level 4 information. More specific information on the preferred habitats of CPS is needed for more narrowly identifying areas of EFH (not the whole EEZ).

Review and revision of the EFH components of this FMP should be undertaken as necessary. Part of this review should address the specific research needs identified below for each species:

7.1 Northern Anchovy

Northern anchovy is a well studied species and no areas of concern or important research gaps related to EFH have been identified.

7.2 Jack Mackerel

Migrations for feeding and spawning are not well known. Adult jack mackerel may migrate southwards into California during the winter to spawn, however it is also possible that many older jack mackerel overwinter in the region north of 39° N latitude, particularly in offshore regions. Better information on the seasonal distribution and migratory behavior of jack mackerel would be useful. There is no evidence of stock structure in jack mackerel along the West Coast.

7.3 Pacific Sardine

No areas of concern or important research gaps related to EFH have been identified for Pacific sardine with the exception of the debate over how many sardine stocks exist along the West Coast during periods of high and low abundance.

7.4 Pacific (Chub) Mackerel

No areas of concern or important research gaps related to EFH have been identified for Pacific (chub) mackerel.

7.5 Market Squid

Market squid are poorly understood, relative to CPS finfish. As described above, impacts on EFH are most likely during fishing which occurs almost entirely on spawning aggregations in shallow water. There are two areas of potential concern that have not been quantified: damage to substrate used to attach eggs, and damage to egg masses.

Information about how squid spawning grounds are distributed with depth and their locations along the coast is required; information on spawning grounds in deep water and to the north of central California is particularly meager. In addition, information about egg survival and paralarvae production per unit area in different types of spawning habitats is needed for understanding potential impacts of fishing in shallow water.

Dispersal of adults and paralarvae along the West Coast (i.e., stock structure) is required for determining how local impacts might be mitigated by recruitment from other areas in this short lived species.

Egg mortality associated with purse seining for squid has not been quantified.

Factors that determine spawning grounds have not been precisely identified.

MANAGEMENT OF KRILL AS AN ESSENTIAL COMPONENT OF THE CALIFORNIA CURRENT ECOSYSTEM

AMENDMENT 12 TO THE COASTAL PELAGIC SPECIES FISHERY MANAGEMENT PLAN

ENVIRONMENTAL ASSESSMENT, REGULATORY IMPACT REVIEW & REGULATORY FLEXIBILITY ANALYSIS

SUBMITTED BY:
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IN CONJUNCTION WITH:
DEPARTMENT OF COMMERCE
NATIONAL MARINE FISHERIES SERVICE
SOUTHWEST REGION

FEBRUARY 2008

3.3 Essential Fish Habitat

3.3.1 MSA Requirements

Section 303(a)(7) of the MSA requires that FMPs describe and identify EFH, minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat. The MSA provides the following definition:

> "The term 'essential fish habitat' means those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." (16 U.S.C. § 1802 (10)).

NMFS has published regulations for implementation of the EFH requirements. These regulations (at 50 C.F.R. 600 Subpart J) provide additional interpretation of the definition of essential fish habitat:

> "'Waters' include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include aquatic areas historically used by fish where appropriate; 'substrate' includes sediment, hard bottom, structures underlying the waters, and associated biological communities; 'necessary' means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and 'spawning, breeding, feeding, or growth to maturity' covers a species' full life cycle."

The NMFS guidelines intended to assist councils in implementing the EFH provision of the M-SA set forth the following four broad tasks:

- Identify and describe EFH for all species managed under an FMP;
- Describe adverse impacts to EFH from fishing activities;
- Describe adverse impacts to EFH from non-fishing activities; and
- Recommend conservation and enhancement measures to minimize and mitigate the adverse impacts to EFH resulting from fishing and non-fishing related activities.

In sum, the EFH regulations require that EFH be described and identified within the U.S. EEZ for all life stages of each species in a fishery management unit if they occur within that zone. FMPs must describe EFH in text and/or tables and figures which provide information on the biological requirements for each life history stage of the species. An initial inventory of available environmental and fisheries data sources should be taken to compile information necessary to describe and identify EFH and to identify major species-specific habitat data gaps. The EFH regulations also suggest that where possible, FMPs should identify Habitat Areas of Particular Concern (HAPCs) within EFH for habitats which satisfy the criteria of being 1) sensitive or vulnerable to environmental stress, 2) are rare, or are 3) particularly important ecologically.

The Council proposes that EFH be established consistent with option 2 below. The following discussion is provided to summarize the alternatives considered and presented to the public to solicit public comment.

3.3.2 Data Sources and Methods

Data and information to describe krill EFH were obtained primarily from the scientific literature, as well as through consultation with krill researchers (Appendix A) and examination of data on geographic catch densities off California for the years 1950-2002 provided by E. Brinton and A. Townsend, SIO, Pelagic Invertebrates Collection (pers. comm., La Jolla, CA 6/6/2005). The majority of these data are level 1 data, where all that is known is where a species occurs based on distribution data for all or part of the geographic range of the species (presence/absence). Some preliminary data are also available on aerial densities of relative abundance (Level 2, see SIO reference above). Little is known of growth, reproduction or survival rates within habitats (Level 3); or habitat-dependent production rates quantified by habitat quantities, qualities and specific locations (Level 4).

3.3.3 Description and Analysis of EFH Alternatives: Proposed Action and Options Considered

Option 1. Status Quo. Do not designate EFH.

Because Amendment 12 incorporated krill as a MUS in the CPS FMP; the option of not identifying EFH is not acceptable. The MSA requires designation of EFH for all MUS in FMPs.

Option 2. Adopt EFH as described below (Proposed Action)

The designation of essential habitat for krill is based on information about EFH for the two principal species. It was not possible at the time that this amendment was being developed to discern consistent differences in distribution of the various life stages, other than coastwide, the larvae of both species tend to occur closer to shore, often over the shelf. It is recommended that these designations be updated on final analysis and publication of the SIO 50-year time series of maps showing spatial densities of these and other euphausiid species in the CalCOFI sampling area (E. Brinton, SIO, unpub. data, personal commun. 6/8/05).

Isobaths (depth contours) are used below as outer boundaries of EFH, but only because they roughly approximate the outer bounds of reported densest concentrations of the populations, and because static boundaries are preferred for the legal definition of EFH. These contours also roughly form the outer boundaries of some of the major upwelling areas (though perhaps not some of the larger offshore jets), within which consistently high concentrations of phytoplankton occur (Fig. 15). The boundaries are not meant to imply the strict association of these highly dynamic macroplanktonic species with fixed bottom topography.

A review of the literature and available data on krill aggregating areas and reproductive swarms, with high densities of predators such as salmon, seabirds and large baleen whales, revealed certain krill-rich upwelling areas to be especially important. Dense krill swarms and predator aggregations are reported most consistently within the ocean boundaries of the following NOAA National Marine Sanctuaries (NMS): Olympic Coast NMS off Washington (Calambokidis 2004) and Cordell Bank NMS, Gulf of the Farallones NMS (Chess et al 1988; Smith and Adams 1988; Kieckhefer 1992; Schoenherr 1991; Adams 2001; Howard 2001) and Channel Islands NMS in California (Armsrong and Smith 1997; Fiedler et al. 1998; Croll et al 1998). (Fig. 14). Additionally, the following other high-density krill and krill predator areas have been reported: Heceta Bank and Cape Blanco areas, Oregon (Ainley et al. 2005; Ressler 2005; Tynan et al 2005) and Bodega Canyon (Howard 2001). A confluence within these areas of rich, upwelled unstratified water and topological features such as submarine canyons, banks, and island shelves may not only provide rich feeding areas for krill, but may also contain features necessary for krill patches to be exploited by baleen whales, fish and seabirds, by concentrating and trapping krill over the shelf as they attempt to descend to the depths during the day (Chess et al. 1988; Fieldler et al. 1998; Ressler et al. 2005)

After considering this information, the Council agreed to propose the following designations of EFH for krill.

Euphausia pacifica EFH (Fig. 16)

Larvae, juveniles and adults: From the baseline from which the shoreline is measured seaward to the 1000 fm (1,829 m) isobath, from the U.S.- Mexico north to the U.S.-Canada border, from the surface to 400 m deep, from the U.S.- Mexico north to the U.S.-Canada border (Fig. 16). Highest concentrations occur within the inner third of the EEZ, but can be advected into offshore waters in phytoplankton-rich upwelling jets (Fig. 15) that are known to occur seaward to the outer boundary of the EEZ and beyond.

Thysanoessa spinifera EFH (Fig. 17)

Larvae, juveniles and adults: From the baseline from which the shoreline is measured to the 500 fm (914 m) isobath, from the U.S.- Mexico north to the U.S.-Canada border, from the surface to 100 m deep. Largest concentrations in waters less than 200 m deep, although individuals, especially larvae and juveniles, can be found far seaward of the shelf, probably advected there by upwelling jets (Figs. 15, 17).

Other krill species

Larvae, juveniles and adults: From the baseline from which the shoreline is measured seaward to the 1000 fm (1,829 m) isobath, from the U.S.- Mexico north to the U.S.-Canada border, from the surface to 400 m deep, from the U.S.- Mexico north to the U.S.-Canada border. No biological, social or economic impacts are expected beyond administrative costs of reviewing federally regulated projects for potential impacts on this habitat, where krill and krill predators concentrate.

Option 3: Designate the full EEZ as EFH

There is little statistical basis for designating EFH beyond the areas identified above. However, it is conceivable that krill exist throughout the EEZ even if not in concentrations that support a forage role or that support reproduction or other life stages.

3.3.4 Habitat Areas of Particular Concern (HAPCs)

The Council considered the following HAPC options:

HAPC Option 1. Status Quo–Do not designate HAPCs

HAPC Option 2. Designate HAPC to consist of the ocean area within the boundaries of Cordell Bank, Gulf of the Farallones, Monterey Bay, Channel Islands, and Olympic Coast NMS. These sanctuaries encompass the most important consistently krill-rich areas around California islands as well as important submarine canyons, bank, shelf and slope areas (e.g., Gulf of the Farallones, Pescadero Canyon, Ascension Canyon, Monterey Bay Canyon area, Channel Islands).

HAPC Option 3. Designate HAPC for krill to consist of the ocean area within the boundaries of Cordell Bank, Gulf of the Farallones, Monterey Bay, Channel Islands and Olympic Coast NMS, and Heceta Bank area (east of longitude 125˚ 30’ W Long, between 43˚50’ and 44˚ 50’ Lat), off Cape Blanco (east of longitude 125˚ 30’ between 42˚20’ and 43˚ 000’ Lat), and the Bodega Canyon area as HAPCs. This is similar to Option 2, but also includes three additional known important krill areas outside of Sanctuary boundaries.

HAPC Option 4. Designate HAPC for krill to consist of the ocean area within the boundaries of Cordell Bank, Gulf of the Farallones, Monterey Bay, Channel Islands and Olympic Coast NMS as HAPCs and all other waters of the EEZ Federal coastal and island waters off Washington, Oregon and California out to 60 nm from shore. This would cover all the areas Option 1, the highest krill density areas in Option 2, and add other inshore island, shelf, bank and slope areas along the coast suspected of supporting high densities of krill and krill predators within the EEZ.

In the process of reviewing the literature and available data on habitat use and preferences of krill, an effort was made to determine specific areas within U.S. West Coast EEZ EFH that satisfied the criteria of being 1) sensitive or vulnerable to environmental stress, 2) rare, or 3) particularly important ecologically. As noted above, this included a review of the literature and available data on krill aggregating areas and reproductive swarms, with high densities of predators such as salmon, seabirds and large baleen whales, revealed certain krill-rich upwelling areas to be especially important.

The Council concluded that it was not necessary at this time to propose designation of any specific HAPC. All the prospective high quality areas identified in the literature review and meetings with scientists would be included in the proposed designations of EFH.

COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON CPS ESSENTIAL FISH HABITAT FIVE-YEAR REVIEW

The Coastal Pelagic Species Management Team (CPSMT) and the Coastal Pelagic Species Advisory Subpanel (CPSAS) discussed the CPS Essential Fish Habitat (EFH) Five-Year Review. The general consensus supported by both groups recommend approving the five-year review substantially as written, with the following modifications:

- Synchronize the EFH review schedule for CPS and krill;
- Include information recently made available, e.g. market squid habitat information, in the 2011 CPS SAFE document;
- Review and revise, if necessary, EFH for all CPS including krill at the time of the next krill EFH review.

PFMC
11/07/10

Agenda Item I.4.b
Supplemental CPSMT Report 2
November 2010

COASTAL PELAGIC SPECIES (CPS) REPORT ON CPS ESSENTIAL FISH HABITAT FIVE-YEAR REVIEW

The Coastal Pelagic Species Management Team (CPSMT) initiated a review of Essential Fish Habitat (EFH) for CPS in January, 2010, and concluded its review at the November 2010 Council meeting. The CPSMT Report on EFH (Agenda Item I.4.a, Attachment 1) contains information on the process, including opportunities for public comment.

The EFH for CPS was initially described in Appendix D of Amendment 8 to the CPS Fishery Management Plan (FMP) in 1998, and was last reviewed in 2005. Krill EFH was established in 2008, and was not part of this review.

The CPSMT notes there are areas for improvement in the identification and description of CPS EFH contained in Appendix D of Amendment 8, particularly regarding emerging threats, the identification of benthic habitats where squid spawn, and non-fishing gear effects.

Regarding squid spawning areas, the CPSMT notes that a new publication is pending that will likely provide information on squid spawning behavior and benthic habitat associations. However, this manuscript has not been published. The CPSMT also notes that significant squid spawning areas are in protected marine reserves established under the California Marine Life Protection Act as well as in the Channel Islands National Marine Sanctuary.

Recent information will help inform EFH consultations and provide additional background on CPS habitat, but does not warrant changes to the existing description of CPS EFH at this time.

The CPSMT recommends the following:

- Amend the EFH review report to include:
    - A section documenting that fishing effects have not changed significantly since gear effects were documented in Appendix D of Amendment 8;
    - A clearer explanation of why Habitat Areas of Particular Concern were not recommended;
    - New reference on squid spawning habitat (Zeidberg et al., unpublished report);
- Incorporate the CPSMT's CPS EFH Report (Agenda Item I.4.a, Attachment 1), including the recommended additions above, into the 2011 CPS Stock Assessment Fishery Evaluation document. This will add to the body of information, available for National Marine Fisheries Service biologists when conducting EFH consultations, and will provide information for use in future CPS EFH reviews;
- Adding more description of how new information compares with Appendix D of Amendment 8;
- Synchronize the next CPS EFH review with the pending five-year review of krill EFH by 2013.

PFMC
11/07/10

Agenda Item I.4.b
Supplemental HC Report
November 2010

HABITAT COMMITTEE REPORT ON COASTAL PELAGIC SPECIES ESSENTIAL FISH HABITAT FIVE-YEAR REVIEW

The Habitat Committee (HC) received an overview and history of the Coastal Pelagic Species Management Team (CPSMT) report on the CPS essential fish habitat (EFH) five-year review (Agenda Item I.4.a, Attachment 1) from Mr. Kerry Griffin, Council staff. Based on the information provided in the overview and in the report, the HC believes a thorough review of new information was conducted by the CPSMT and concurs with the conclusions made in the report. In particular, the HC agrees that the new information regarding CPS habitat associations still supports the strong linkage between their distribution and sea surface temperature, and therefore, does not warrant any changes to the existing CPS EFH descriptions.

The HC supports the CPSMT plan to document the review process more thoroughly in the 2011 Stock Assessment Fishery Evaluation (SAFE) report. For instance, the new information related to habitat associations for CPS should be summarized in the SAFE report to more fully support the conclusions. New information about state actions to establish Marine Protected Areas (MPAs), in part to protect squid spawning areas, should also be acknowledged. In addition, the report should document the CPSMT's conclusion that fishing activities and fishing gear impacts to EFH have not changed substantially since the last time they were analyzed, and are adequately addressed in the fishery management plan. The HC believes that adding this new information (e.g., climate change) to the 2011 SAFE Report is an integral step in documenting the review process.

The decision to not designate habitat areas of particular concern (HAPCs) for CPS should be based primarily on their strong association with thermal conditions that are inherently spatially variable. Even though HAPCs are not recommended for designation in this CPS EFH review because of the substantial uncertainty associated with identifying their spatial extent, there are topographic features or geomorphic areas important to CPS species. As noted in the krill management plan (Amendment 12), these topographic features create unique areas of high productivity where krill and predatory species (including other CPS species, salmon, groundfishes, seabirds, and whales) congregate. Such areas would be important to identify and incorporate into an ecosystem plan, allowing for more effective and comprehensive management of ecosystem resources, and should be considered for HAPC designation in future CPS EFH reviews.

Therefore, the HC recommends that the Council consider the CPS EFH five-year review process, including the gathering and evaluation of new information, to be complete, but suggests the further documentation recommended by the CPSMT.

PFMC
11/04/10

Agenda Item I.4.b
Supplemental SSC Report
November 2010

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON CPS ESSENTIAL FISH HABITAT FIVE-YEAR PLAN

Mr. Kerry Griffin summarized the Coastal Pelagic Species (CPS) Essential Fish Habitat (EFH) five-year review process, along with the options considered for possible amendment to the CPS Fishery Management Plan (FMP). The CPS Management Team's (CPSMT) review included a literature review on the distribution and ocean habitat characteristics for CPS species, the possibility of a distinct EFH designation for market squid (currently grouped with fish species) based on identification of benthic spawning grounds, and identification of broad-scale threats to EFH that were not included in the previous EFH designation for CPS (climate change and ocean acidification). The CPSMT recommends that the Stock Assessment and Fishery Evaluation be expanded to include the new information, but no changes be made in EFH designation for CPS. The SSC concurs with the CPSMT recommendations.

However, the SSC notes that market squid may not be dealt with effectively in the current EFH FMP because – unlike the other CPS – successful squid spawning is dependent on the benthic habitat. This is unavoidable at present because the location and quantity of the benthic habitat used for squid spawning is unknown. The SSC notes that recent research (yet to be reviewed) may considerably improve our understanding of the market squid spawning habitat, and may be incorporated in the next review of EFH designation for CPS.

PFMC
11/06/10