NATIONAL MARINE FISHERIES SERVICE REPORT

Mr. Mark Helvey, of the National Marine Fisheries Service Southwest Region (NMFS SWR), will provide the Council with a regulatory update. Dr. Russ Vetter, NMFS Southwest Fisheries Science Center, will provide a presentation on an alternative stock assessment schedule for Coastal Pelagic Species, and an update on the summer research survey.

Council Task:

1. Discussion.

Reference Materials:

None.

Agenda Order:

a.	Agenda Item Overview	Kerry Griffin
b.	Regulatory Activities	Mark Helvey
c.	Fisheries Science Center Activities	Russ Vetter
d.	Reports and Comments of Management Entities and Advisory Bodies	
e.	Public Comment	
f.	Council Discussion	

PFMC
10/13/11

Agenda Item F.1.c
Supplemental SWFSC PowerPoint
November 2011

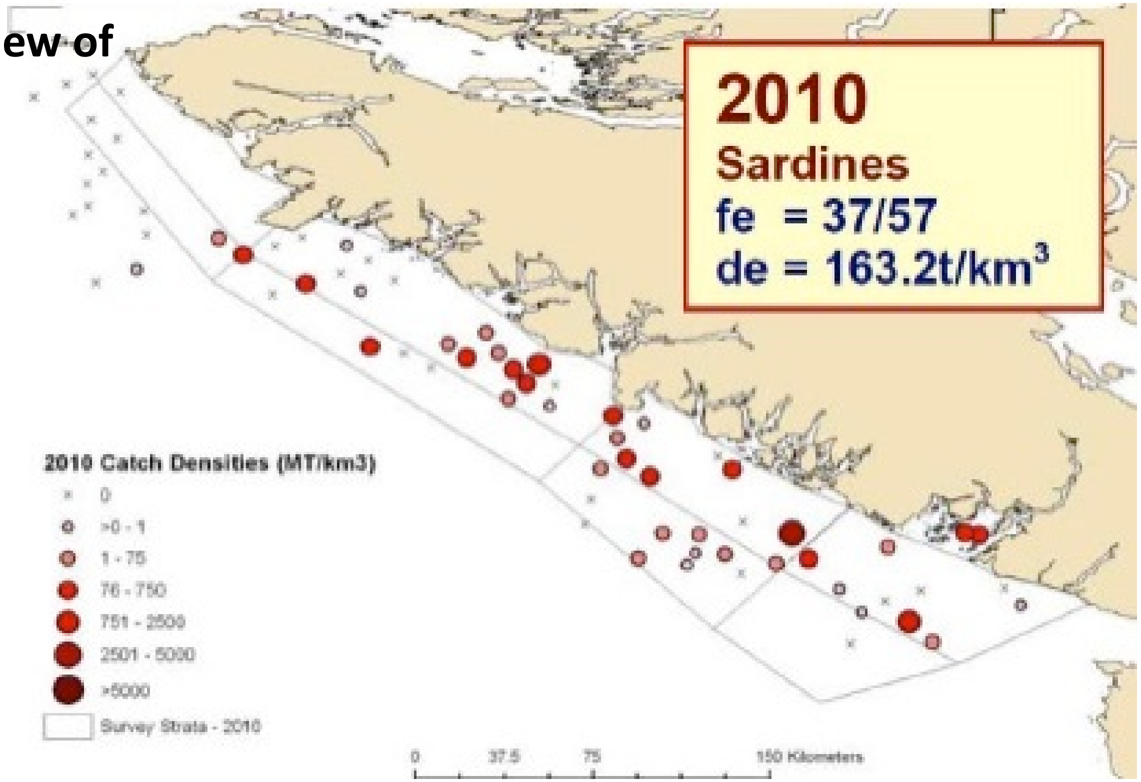
NOAA SWFSC Council Report: November 4, 2011 Costa Mesa, CA

A. Canadian Survey Review

B. Coastwide Summer Survey

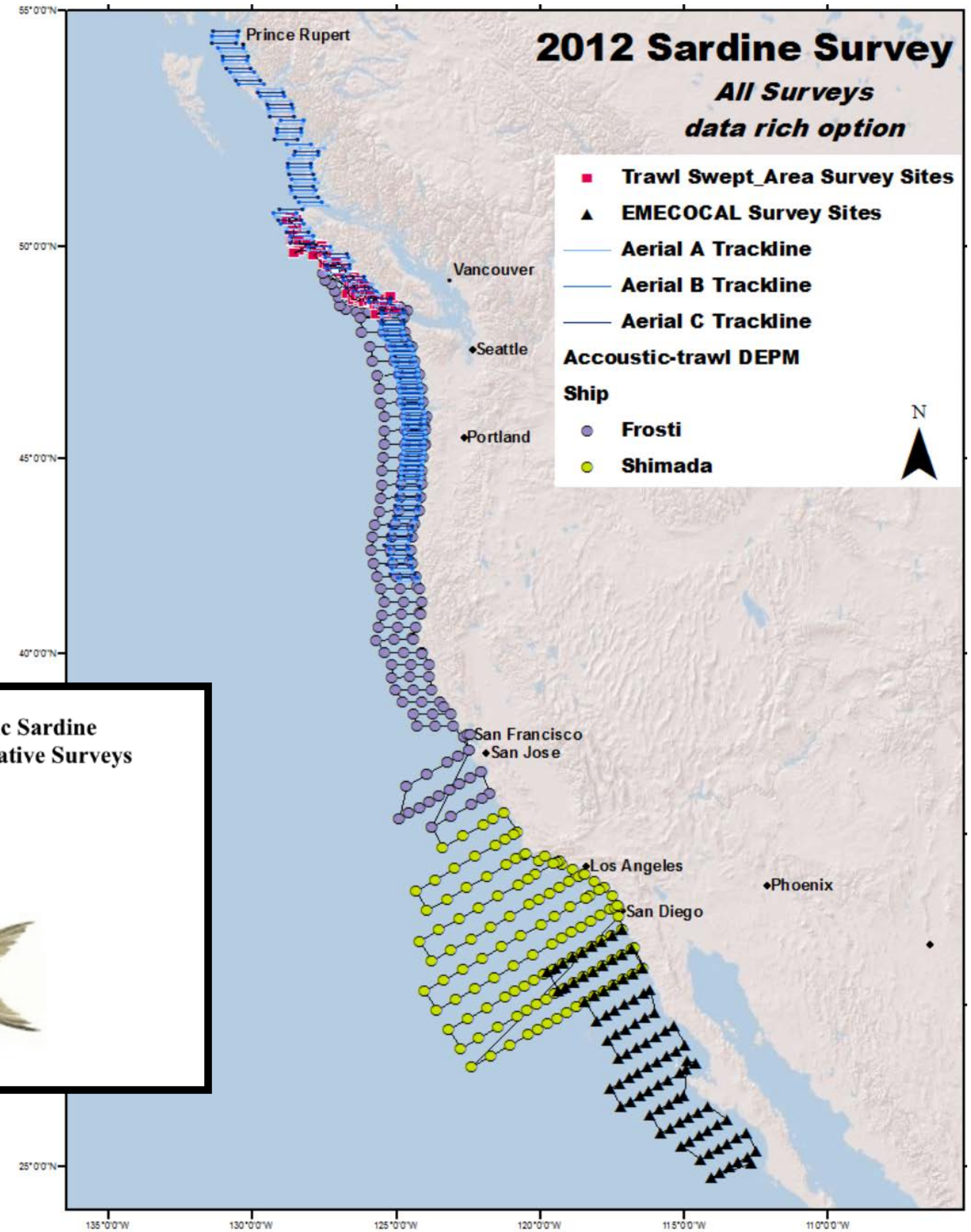
C. Revisiting CPSFMP: needs priorities, timing

Topic A. Planned Review of Canadian Survey



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

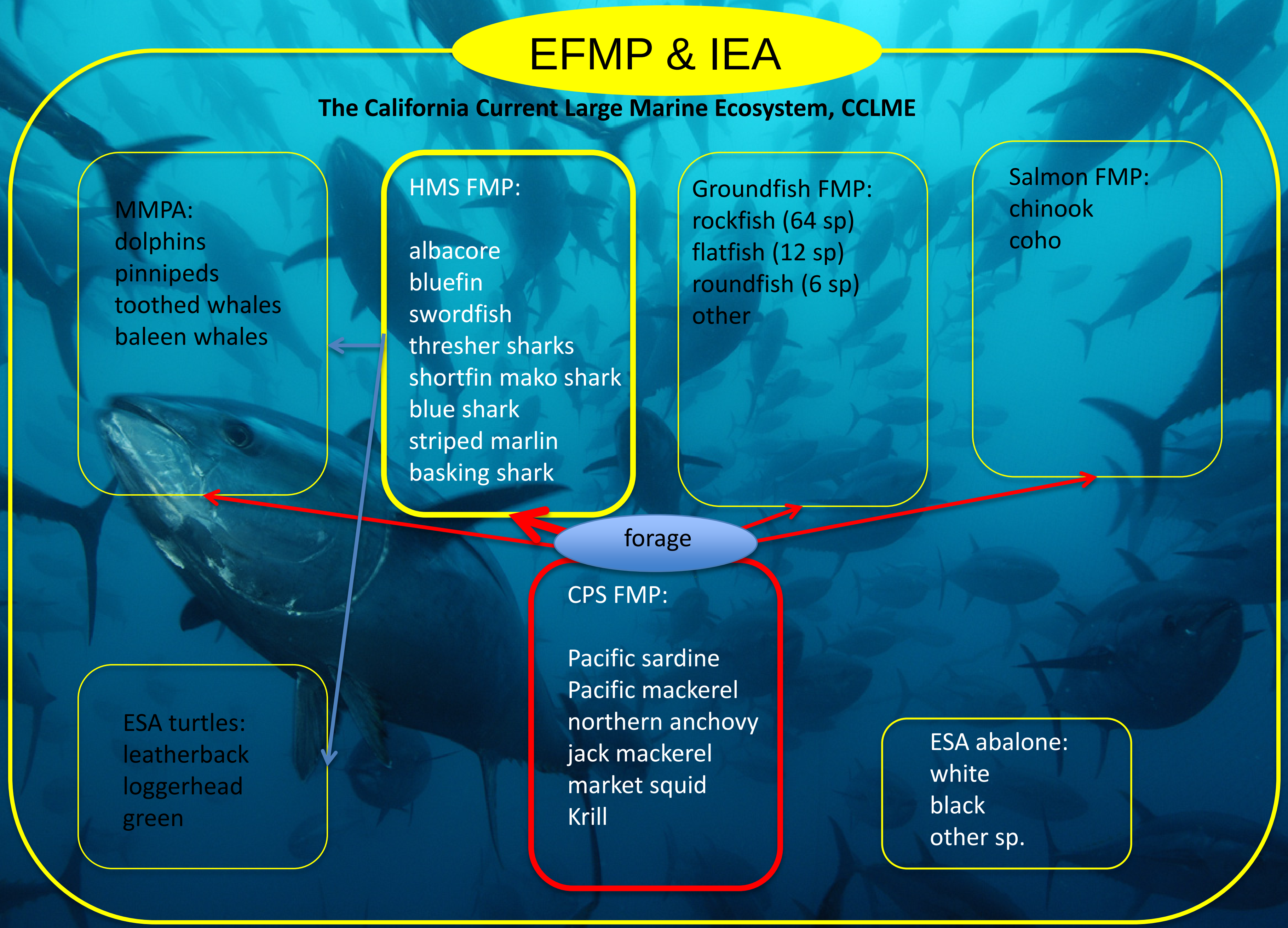
Topic B: 2012 CPS Spring and Summer Coastwide Survey Plans



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

May 23-24, 2011
La Jolla, California

C. NOAA's Ecosystem Based Fisheries Management: The Role of CPSFMP



New Drivers for CPS FMP:

Single species:

1. FSSI Report Card to Congress & ACLs of monitored stocks
2. Regional Allocations: international, state, tribe
3. Climate Variation and CPS

Integrated:

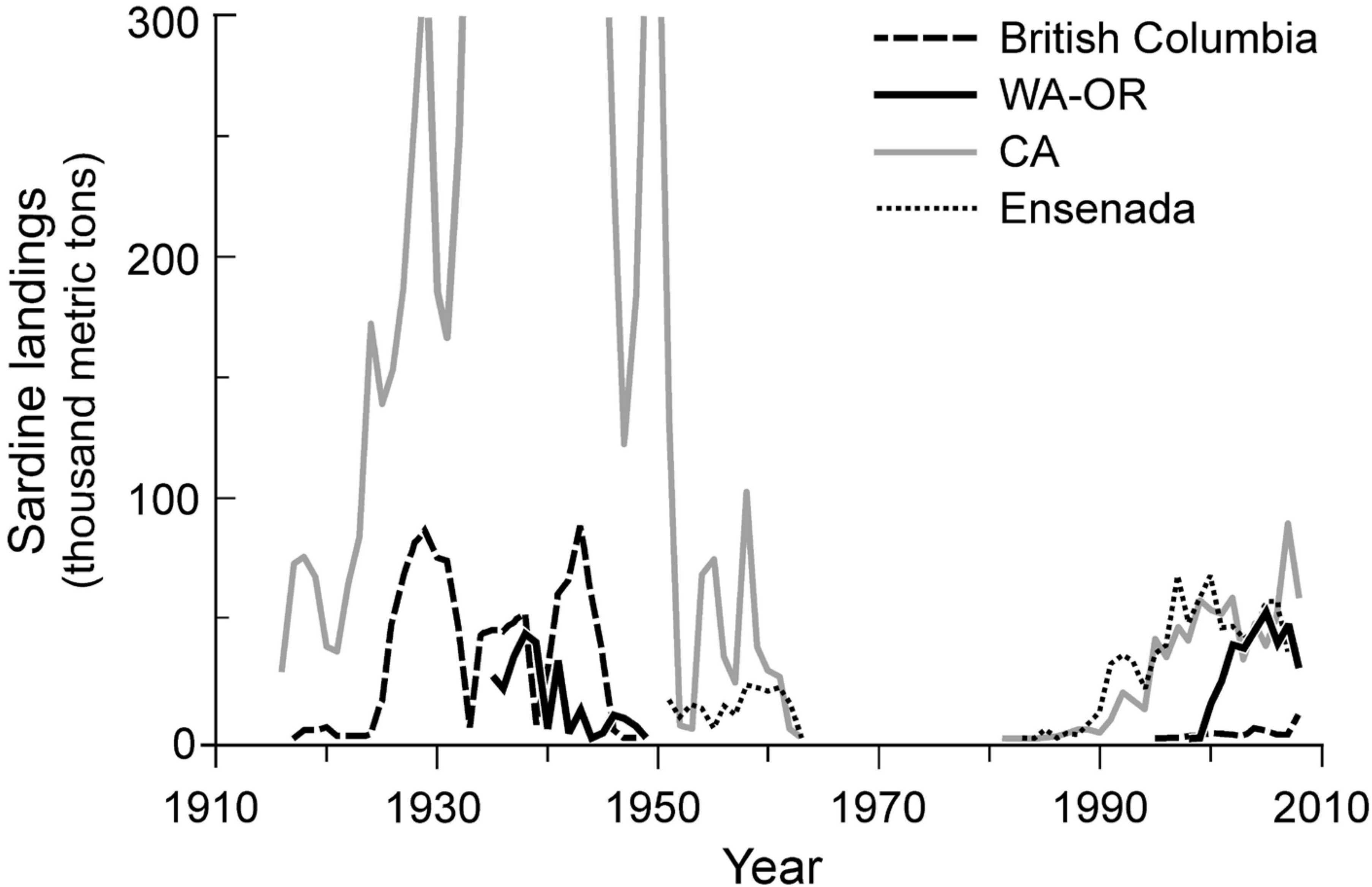
4. Forage Set Asides and Natural Mortality
5. Ecosystem Based Fishery Management Plan (EFMP)
6. Integrated Ecosystem Assessments (IEA)

1. FSSI Report Card to Congress & ACLs for Monitored Species

NOAA Fish Stock Sustainability Index (FSSI): NOAA website updates quarterly

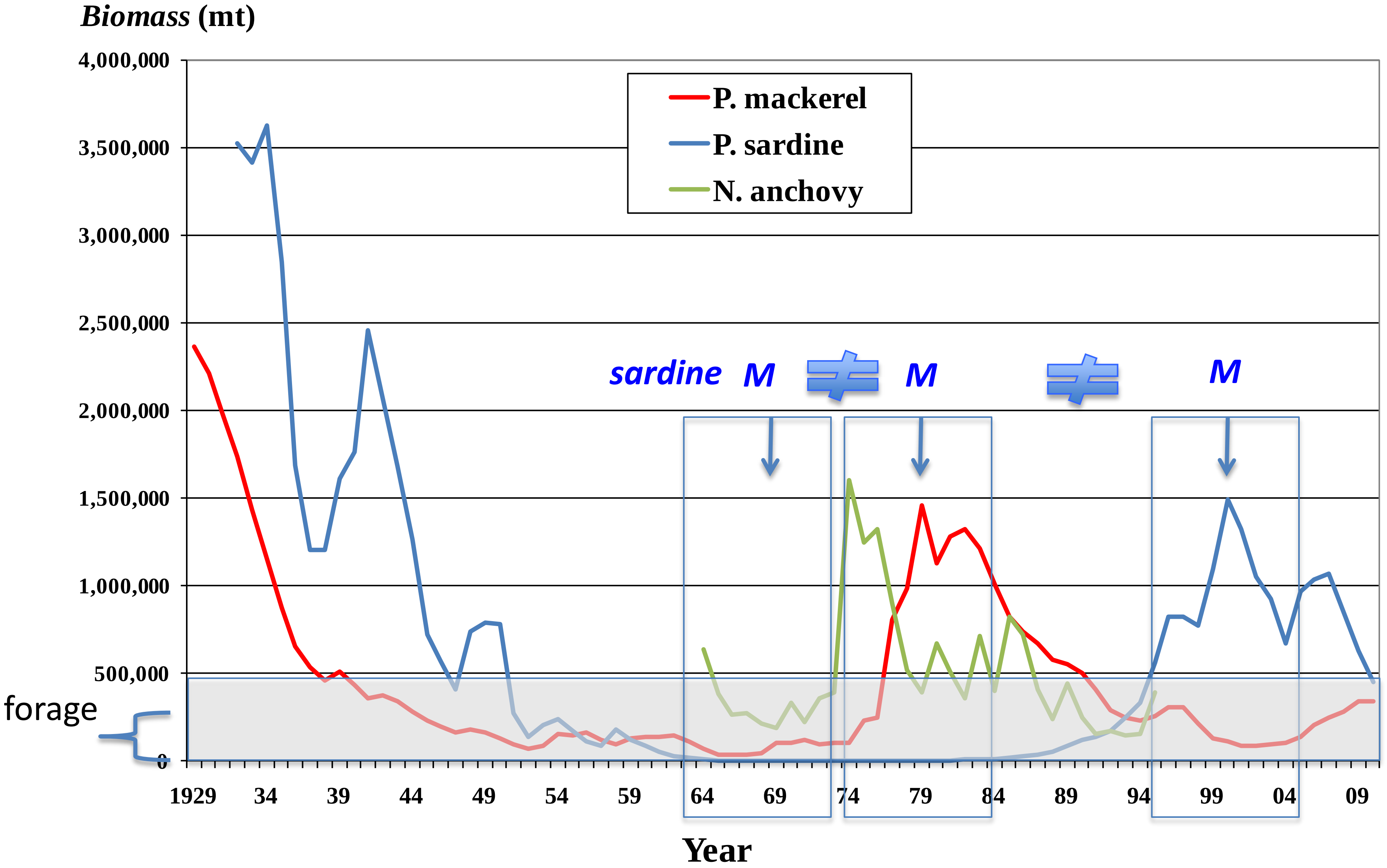
FMP	Stock	Last Asmt	Level - SEE LEVEL TAB	Currently Adequate?	Next Planned Asmt Year	Next Planned Asmt Month	Next Planned Asmt Level
Coastal Pelagic Species	Jack mackerel - Pacific Coast	1983.12	0	0			
Coastal Pelagic Species	Northern anchovy - Northern Pacific Coast	1995.12	0	0			
Coastal Pelagic Species	Northern anchovy - Southern Pacific Coast	1995.12	0	0			
Coastal Pelagic Species	Opalescent inshore squid - Pacific Coast	2006.10	2	0			
Coastal Pelagic Species	Pacific chub mackerel - Pacific Coast	2011.6	4	1			
Coastal Pelagic Species	Pacific sardine - Pacific Coast	2011.10	4	1			

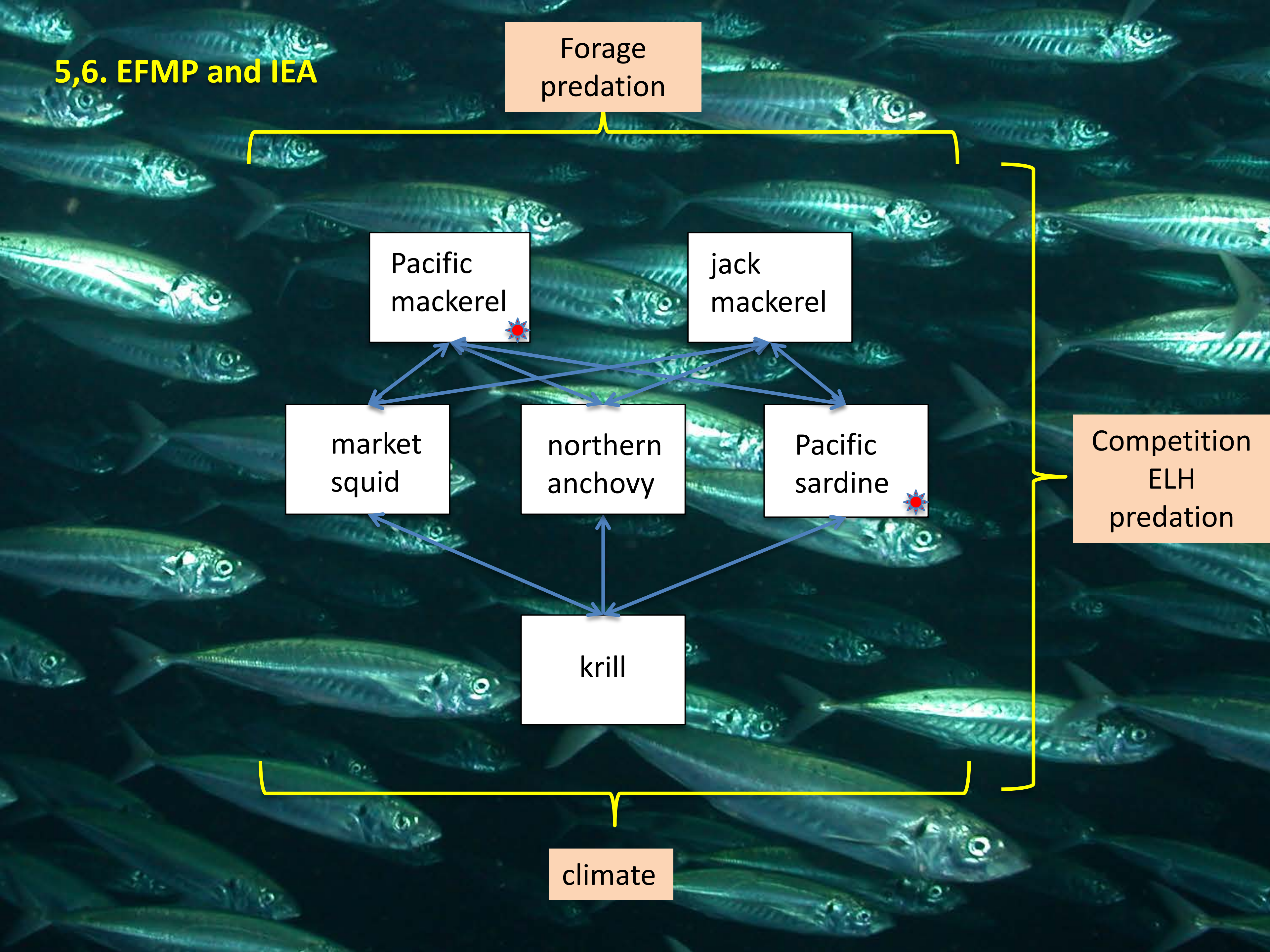
2,3. Regional Allocations & Climate:



4. Forage Set Aside
& Natural Mortality *M=0.4*

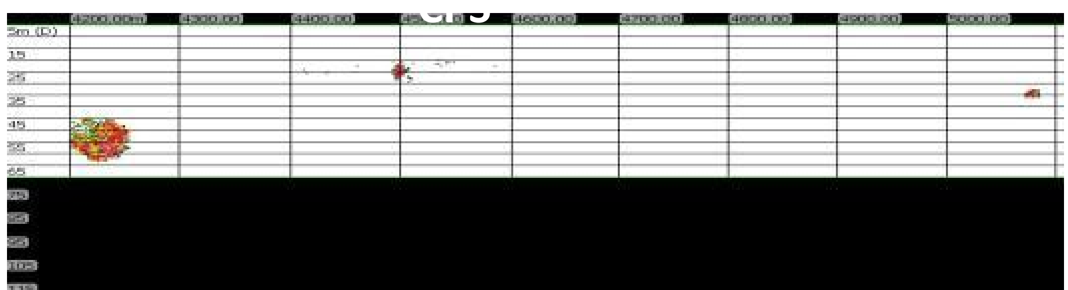
CPS Biomass Time Series

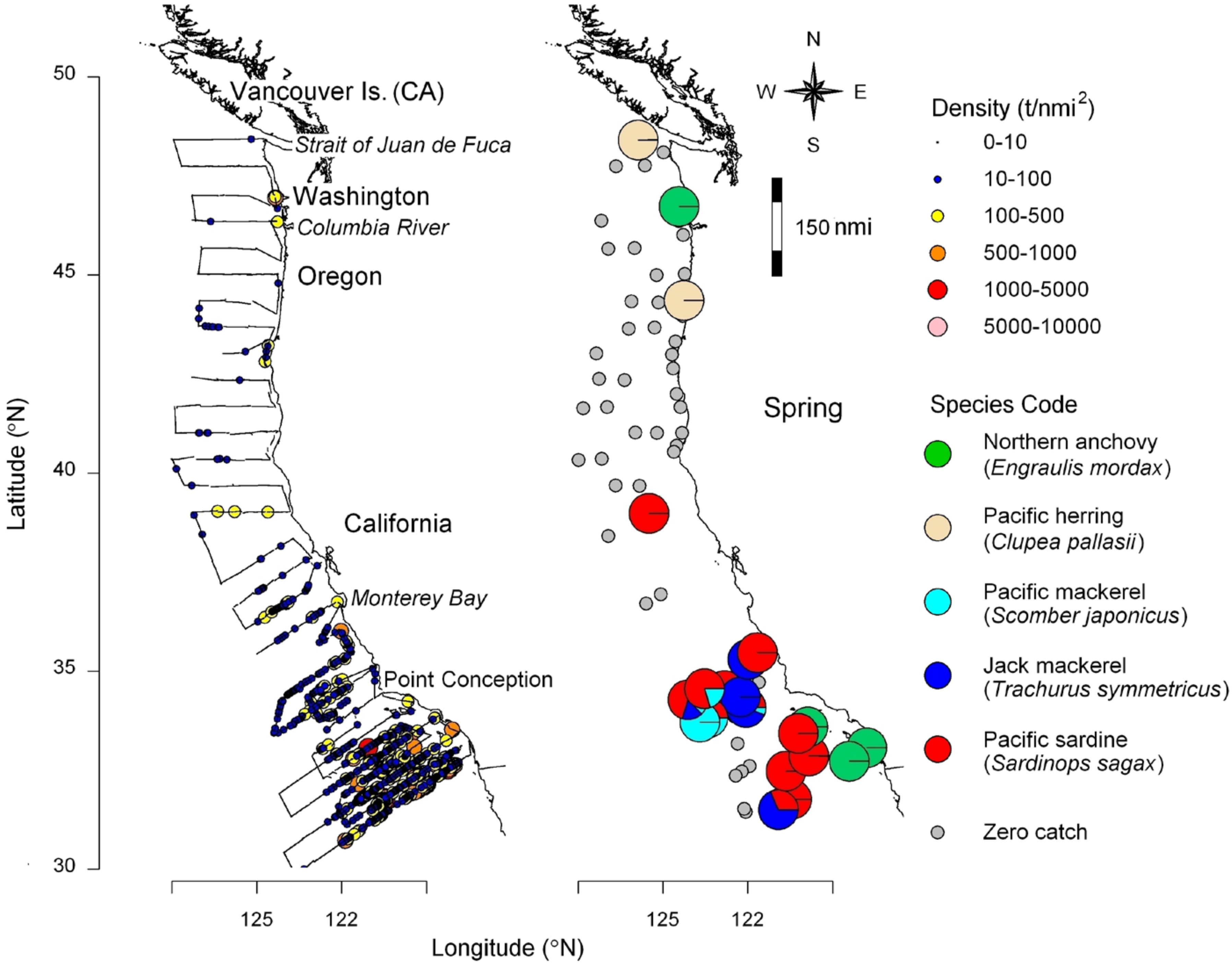


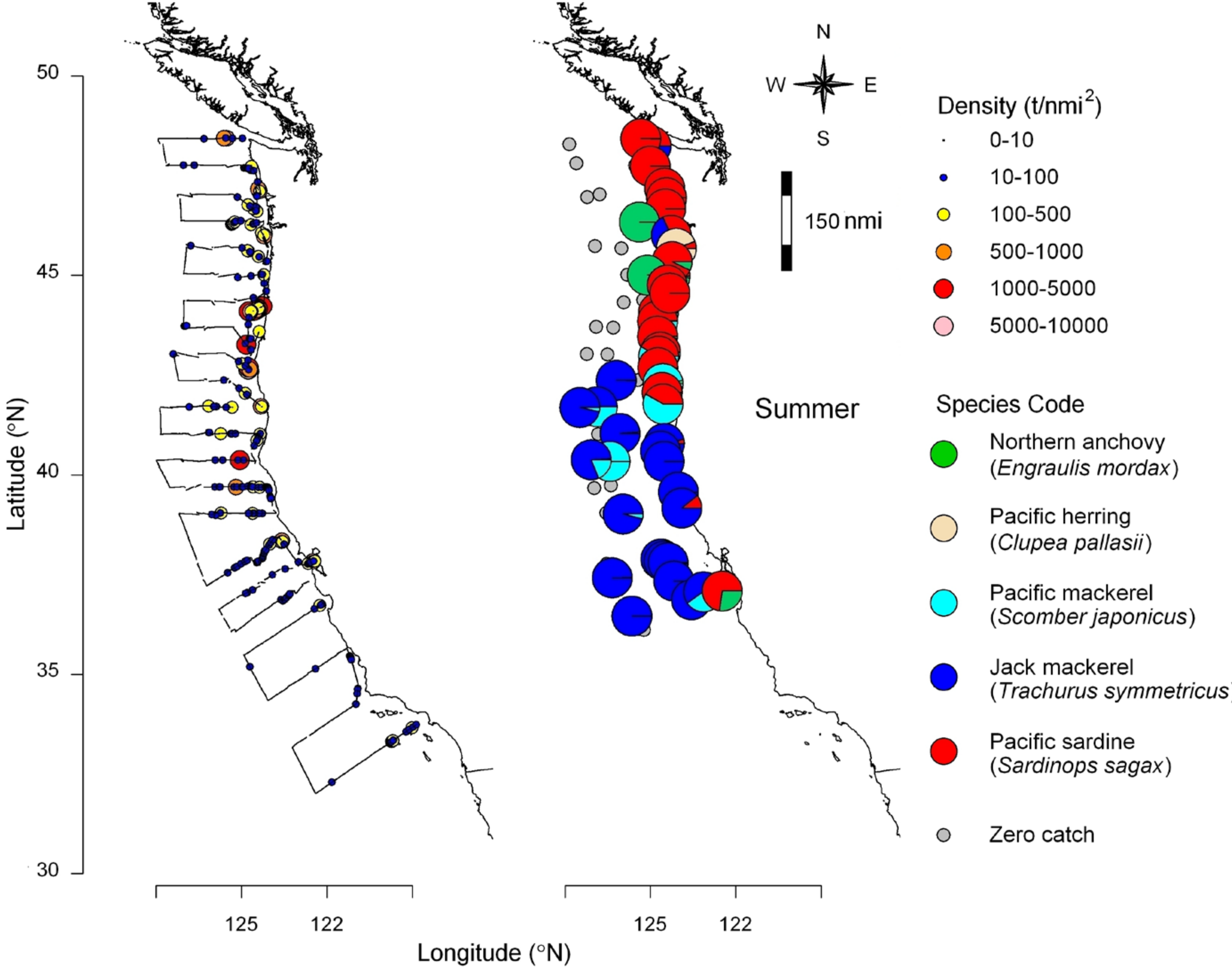

5,6. EFMP and IEA
Forage predation
Pacific mackerel
jack mackerel
market squid
northern anchovy
Pacific sardine
krill
Competition ELH predation
climate

Acoustic Trawl Survey of CPS

Multi-frequency acoustic target identification



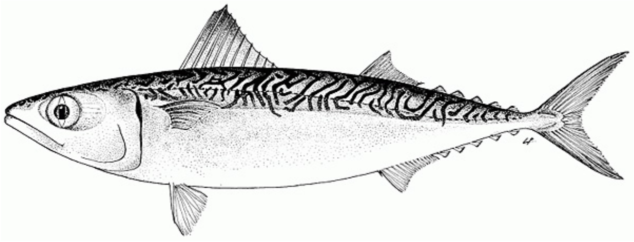

Vancouver Is. (CA)
Strait of Juan de Fuca
Washington
Columbia River
Oregon
California
Monterey Bay
Point Conception
N
W
E
S
150 nmi
Spring
Density (t/nmi^2)
0-10
10-100
100-500
500-1000
1000-5000
5000-10000
Species Code
Northern anchovy (*Engraulis mordax*)
Pacific herring (*Clupea pallasii*)
Pacific mackerel (*Scomber japonicus*)
Jack mackerel (*Trachurus symmetricus*)
Pacific sardine (*Sardinops sagax*)
Zero catch
Latitude (°N)
50
45
40
35
30
125
122
125
122
Longitude (°N)



50
45
40
35
30
Latitude (°N)
125
122
125
122
Longitude (°N)
N
W
E
S
150 nmi
Summer
Density (t/nmi²)
0-10
10-100
100-500
500-1000
1000-5000
5000-10000
Species Code
Northern anchovy (Engraulis mordax)
Pacific herring (Clupea pallasii)
Pacific mackerel (Scomber japonicus)
Jack mackerel (Trachurus symmetricus)
Pacific sardine (Sardinops sagax)
Zero catch

Topic 3:

Assessment and Research Schedule for Coastal Pelagic Species of the Northeast Pacific Ocean: an Adaptive Approach



Southwest Fisheries Science Center / Southwest Region
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

June 2011

Agenda Item F.2
Situation Summary
November 2011

PACIFIC SARDINE STOCK ASSESSMENT AND COASTAL PELAGIC SPECIES (CPS) MANAGEMENT MEASURES FOR 2012

At this meeting, the Council will hear a report on the 2011 Pacific sardine stock assessment, adopt harvest specifications and management measures for the 2012 Pacific sardine fishing season, and be prepared to consider a proposal for reviewing a new sardine survey method.

A full stock assessment for Pacific sardine was completed in 2011. Full assessments for CPS stocks typically occur every two to three years, with updates conducted in the intervening years, based on the same methodology and assessment protocols used for the previous full assessment. The 2011 Pacific sardine assessment (Agenda Item F.2.b, Attachment 1), conducted by the National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center (SWFSC), utilized new abundance data from three survey methods: The SWFSC's Daily Egg Production Model (Agenda Item F.2.b, Attachment 2), the industry-led aerial sardine survey (Agenda Item F.2.b, Attachment 3), and the SWFSC's acoustic-trawl survey (Agenda Item F.2.b, Attachment 4).

In October 2011, the results of the surveys and the full stock assessment were reviewed by a Stock Assessment Review (STAR) Panel consisting of two Scientific and Statistical Committee (SSC) members, a Northeast Fisheries Science Center scientist, and an independent reviewer provided by the Council of Independent Experts (CIE). The STAR Panel produced a report on the assessment (Agenda Item F.2.b, Attachment 5), and the CIE reviewer will submit a separate report (Agenda Item F.2.b, Supplemental Attachment 7). Representatives of the Coastal Pelagic Species Management Team (CPSMT) and the Coastal Pelagic Species Advisory Subpanel (CPSAS), although not members of the STAR Panel, attended in an advisory capacity to the Panel.

At the November Council meeting, the SSC will review the Pacific sardine assessment and make an Overfishing Limit (OFL) recommendation on which to base management measures. The Council will consider a range of Acceptable Biological Catch (ABC) levels associated with various P* alternatives, and will establish harvest measures, including an Annual Catch Limit (ACL) and possibly an Annual Catch Target (ACT). The CPSMT and the CPSAS will also be in session at the November meeting and will provide recommendations to the Council on 2012 sardine management measures, including harvest set-asides for incidental landings of Pacific sardine in other CPS fisheries, and for research activities conducted under an EFP.

Amendment 13 to the CPS Fishery Management Plan (FMP) to address revised National Standard 1 guidelines was recently approved by the Secretary of Commerce. Therefore, the Council should adopt management measures, including ACLs that are consistent with Amendment 13.

The Council will also consider a proposal for reviewing a new sardine survey method for use in future stock assessments (Agenda Item F.2.b Attachment 6). The Canadian West Coast Vancouver Island Swept Area Trawl Survey has not in the past been included in U.S. Pacific sardine stock assessments. The review and approval procedure for any new survey method would follow the Council's Terms of Reference for CPS Methodology Review Panels.

In a letter dated August 31, 2011, the Quinault Indian Nation provided notice of their intent to participate in the 2012 sardine fishery, with an anticipated allocation need of 9,000 mt. (Agenda Item F.2.a, Attachment 1). The letter and its implications were discussed briefly at the September Council meeting where a number of questions were posed as to how such an allocation would mesh with the CPS Fishery Management Plan provisions, including such matters as whether the allocation would be subtracted from the total ACL and how any uncaught remainder might be treated. Agenda Item F.2.a, Attachment 2 provides a listing of hypothetical questions and the relevant excerpts from the CPS FMP regarding mandated or flexible procedures that address the questions. During the Council discussion in September, NMFS expressed the intent to informally discuss, prior to the November meeting, information associated with Federal, Council, State, and Tribal processes in place to address treaty tribe fishing rights for Pacific sardines.

Council Action:

1. **Approve the Pacific Sardine Assessment and Pacific sardine OFL.**
2. **Select P*, ABC, ACL and, if appropriate, ACT Specifications and Management Measures; Including Consideration of a Quinault Tribal Allocation.**
3. **Consider a Review Process for a New Sardine Survey Method.**

Reference Materials:

1. Agenda Item F.2.a, Attachment 1: August 31, 2011 letter from Ed Johnstone, Quinault Fisheries Policy Spokesperson, regarding the Quinault Indian Nation's intent to establish a tribal allocation and to enter the 2012 Pacific sardine fishery.
2. Agenda Item F.2.a, Attachment 2: Management questions and relevant CPS FMP excerpt regarding the Quinault Indian Nation's intents for 2012.
3. Agenda Item F.2.b, Attachment 1: *Assessment of the Pacific Sardine Resource in 2011 for U.S. Management in 2012, Executive Summary.*
4. Agenda Item F.2.b, Attachment 2: Southwest Fisheries Science Center's (SWFSC) Daily Egg Production Model Survey Report. **(*Electronic only*).**
5. Agenda Item F.2.b, Attachment 3: Northwest Aerial Sardine Survey – Sampling Results in 2011. **(*Electronic only*).**
6. Agenda Item F.2.b, Attachment 4: SWFSC's Acoustic-Trawl Survey Report, 2011. **(*Electronic only*).**
7. Agenda Item F.2.b, Attachment 5: 2011 Pacific Sardine STAR Panel Report.
8. Agenda Item F.2.b, Attachment 6: Proposal to Review Canadian Swept Area Trawl Survey Methodology.
9. Agenda Item F.2.b, Supplemental Attachment 7: CIE Independent STAR Panel Report.
10. Agenda Item F.2.d, Public Comment.

Agenda Order:

a. Agenda Item Overview — Kerry Griffin
b. Survey and Assessment Report — Kevin Hill
c. Reports and Comments of Advisory Bodies and Management Entities
d. Public Comment
e. **Council Action**: Approve the Pacific Sardine Assessment and Final 2012 Management Measures for CPS; and Consider Methodology Review Proposal

PFMC
10/14/11

Quinault Indian Nation

POST OFFICE BOX 189 □ TAHOLAH, WASHINGTON 98587 □ TELEPHONE (360) 276-8211

Mr. Rod McInnis
Regional Administrator
Southwest Region, NMFS
501 W. Ocean Blvd. Suite 4200
Long Beach, CA 90802

August 31, 2011

Dear Mr. McInnis,

Per Title 50 of the Code of Federal Regulations (CFR), part 660, the Quinault Indian Nation intends to exercise its treaty right to enter into the Pacific Sardine fishery in 2012.

§ 660.518 **Pacific Coast Treaty Indian Rights**
(a) Pacific Coast treaty Indian tribes have treaty rights to harvest CPS in their usual and accustomed fishing areas in U.S. waters.
(b) For the purposes of this section, "Pacific Coast treaty Indian tribes" and their "usual and accustomed fishing areas" are described at §660.324(b) and (c). **[NOTE: the updated, current citation for the "usual and accustomed fishing areas" is § 660.50(c)]**
(c) Boundaries of a tribe's fishing area may be revised as ordered by a Federal court.
(d) *Procedures.* The rights referred to in paragraph (a) of this section will be implemented in accordance with the procedures and requirements of the framework contained in Amendment 9 to the FMP and in this Subpart.
(1) The Secretary, after consideration of the tribal request, the recommendation of the Council, and the comments of the public, will implement Indian fishing rights.
(2) The rights will be implemented either through an allocation of fish that will be managed by the tribes or through regulations that will apply specifically to the tribal fisheries.
(3) An allocation or a regulation specific to the tribes shall be initiated by a written request from a Pacific Coast treaty Indian tribe to the NMFS Southwest Regional Administrator at least 120 days prior to the start of the fishing season as specified at §660.510 and will be subject to public review according to the procedures in §660.508(d).
(4) The Regional Administrator will announce the annual tribal allocation at the same time as the annual specifications.
(e) The Secretary recognizes the sovereign status and co-manager role of Indian tribes over shared Federal and tribal fishery resources. Accordingly, the Secretary will develop tribal allocations and regulations in consultation with the affected tribe(s) and, insofar as possible, with tribal consensus.
[66 FR 44987, Aug. 27, 2001]

Accordingly, Quinault anticipates a total of three treaty fishing vessels participating in the 2012 Sardine Fishery. At this time Quinault seeks 3,000 metric tonnes per vessel for a total of 9,000 metric tonnes to meet the needs of our fishers. However, this does not set precedent for determination of our treaty share of Pacific Sardines in the Quinault Indian

Nation's Usual and Accustomed (U&A) marine fishing area which we believe to be 50% of the harvestable tonnage of fish available in any given year in our U&A. We anticipate the majority of our harvest will occur in the late spring and summer of 2012.

The Quinault Department of Fisheries will regulate our fishery and we look forward to working with NMFS to facilitate our entry into the Sardine fishery in an orderly manner consistent with Pacific Fisheries Management Council (PFMC) and NMFS management. We thank you for your assistance and stand ready to answer any questions you may have. Please contact me directly if you need further information at 360-276-8215 ext. 368.

Sincerely,

Ed Johnstone

Ed Johnstone,
Quinault Fisheries Policy Spokesperson

c.c. Dan Wolford, Chair, Pacific Fisheries Management Council
Phil Anderson, Director, Washington Department of Fish and Wildlife
Mark Helvey, Asst. Regional Administrator for Sustainable Fisheries
Judson Feder, Regional Counsel, Southwest Region

Agenda Item F.2.a
Attachment 2
November 2011

MANAGEMENT QUESTIONS AND RELEVANT CPS FMP EXCERPT REGARDING THE QUINAULT INDIAN NATION'S INTENTS FOR 2012

Treaties between the United States and Pacific Northwest Indian Tribes reserve the rights of the Tribes to take fish at usual and accustomed fishing grounds. The Pacific Fishery Management Council's Coastal Pelagic Species Fishery Management Plan (CPS FMP), as amended by Amendment 9 and codified in National Marine Fisheries Service (NMFS) regulations (50 CFR 660.518), outline a process for the Council and NMFS to consider and implement tribal allocation requests for CPS. The Quinault Indian Nation has expressed their intent to take 9,000 metric tons (mt) for the 2012 fishing season. The Council is scheduled to make recommendations on the allocation request at its November 2011 meeting. Following is a key excerpt from the CPS FMP:

> **Procedures**. The rights…will be implemented by the Secretary, after consideration of the tribal request, the recommendation of the Council, and the comments of the public. The rights will be implemented either through an allocation of fish that will be managed by the tribes, or through regulations that will apply specifically to the tribal fisheries. An allocation or a regulation specific to the tribes shall be initiated by a written request from a Pacific Coast treaty Indian tribe to the NMFS Southwest Regional Administrator, at least 120 days prior to the start of the fishing season as specified at 50 CFR 660.510, and will be subject to public review according to the procedures in 50 CFR 660.508(d). The Regional Administrator generally will announce the annual tribal allocation at the same time as the annual specifications. The Secretary recognizes the sovereign status and co-manager role of Indian tribes over shared federal and tribal fishery resources. Accordingly, the Secretary will develop tribal allocations and regulations in consultation with the affected tribe(s) and, insofar as possible, with tribal consensus.

At the September, 2011 Council meeting, several questions were posed as to how a tribal sardine fishery in 2012 would be managed according to the CPS FMP and other applicable law or regulations. Towards a goal of assisting in the understanding of what matters are mandated or flexible according the CPS FMP, the Council staff has developed draft responses to the following hypothetical questions.

- **How is the 50 percent entitlement for tribal fisheries calculated?** Is the 9,000 mt level brought forward by the Quinault Indian Nation greater than a 50 percent entitlement?
    - The CPS FMP does not contain formulaic procedures for calculating an amount of sardines applicable to the tribal fishing right in usual and accustomed fishing areas. This is a matter brought to the Council from the NMFS, when applicable. The NMFS Southwest Region and Southwest Fisheries Science Center are analyzing available data on migration patterns and population dynamics, relative to this question.
- **Where would the tribal allocation come from**? Would a tribal allocation be accounted for as part of the directed fishery allocation, i.e., part of the Harvest Guideline/Annual

Catch Target (HG/ACT)? Alternatively, would it be considered a separate allocation and not a portion of the directed fishery allocation?

  - The FMP does not provide guidance on this issue. It appears there may be flexibility on how to source a tribal allocation. One way would be to consider it a part of the directed fishery HG/ACT, similar to the way that Exempted Fishing Permit fish are accounted for. It is unclear whether a tribal allocation could be accounted for between the ACL and the ACT. However, under all scenarios, the Council and NMFS would have to account for all sources of mortality and avoid overfishing, by managing to not exceed the ACL.

- **Would any unharvested tribal allocation be "rolled" back into the non-tribal directed fishery, prior to the close of the fishing season?**
  - The FMP does not provide guidance on this issue. This scenario would likely be more feasible if a tribal allocation were to be allocated as a portion of the directed fishery HG/ACT, and if sufficient time remained in the non-treaty fishing season to access any uncaught tribal allocation (similar to the way Pacific Whiting are managed). Historically, rollover provisions in CPS fisheries have applied only to sectors fishing under the directed fisheries harvest guideline. Rollover provisions between sectors operating under separate harvest specifications would have to be further explored.

- **What regulations would the Tribe follow in prosecuting a fishery under a tribal allocation?**
  - The FMP states that the tribal allocation of fish "…*will be managed by the tribes, or through regulations that will apply specifically to the tribal fisheries*." This provides flexibility for the Council to recommend specific regulations.

- **Would management measures implemented for 2012 set a precedent for future tribal allocation of sardine or other CPS?**
  - The FMP does not provide guidance on establishing long-term management for tribal CPS allocations. The Quinault Indian Nation indicated that the 9,000 mt catch level should not be considered as setting any precedent for future considerations.

PFMC
10/18/2011

ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2011 FOR U.S. MANAGEMENT IN 2012

Kevin T. Hill, Paul R. Crone, Nancy C. H. Lo, Beverly J. Macewicz,
Emmanis Dorval, Jennifer D. McDaniel, and Yuhong Gu

NOAA National Marine Fisheries Service
Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, California, USA 92037

October 13, 2011

Disclaimer: This information is distributed solely for the purpose of pre-dissemination peer review under applicable information quality guidelines. It has not been formally disseminated by NOAA-National Marine Fisheries Service. It does not represent and should not be construed to represent any agency determination or policy.

EXECUTIVE SUMMARY

Stock

Pacific sardine (*Sardinops sagax caerulea*) range from southeastern Alaska to the Gulf of California, México, and are thought to comprise three subpopulations. In this assessment, we presumed to model the northern subpopulation which ranges seasonally from northern Baja California, México, to British Columbia, Canada, and up to 300 nm offshore. All U.S., Canada, and México (Ensenada) landings were assumed to be taken from a single northern stock. Future modeling efforts may explore a scenario where Ensenada and San Pedro catches are parsed into the northern and southern stocks using some objective criteria.

Catches

The assessment includes sardine landings from six major fishing regions: Ensenada, southern California, central California, Oregon, Washington, and British Columbia.

Calendar year	ENS	SCA	CCA	OR	WA	BC	Total
2000	67,845	46,835	11,367	9,529	4,765	1,721	142,063
2001	46,071	47,662	7,241	12,780	10,837	1,266	125,857
2002	46,845	49,366	14,078	22,711	15,212	739	148,952
2003	41,342	30,289	7,448	25,258	11,604	978	116,919
2004	41,897	32,393	15,308	36,112	8,799	4,438	138,948
2005	55,323	30,253	7,940	45,008	6,929	3,232	148,684
2006	57,237	33,286	17,743	35,648	4,099	1,575	149,588
2007	36,847	46,199	34,782	42,052	4,663	1,522	166,065
2008	66,866	31,089	26,711	22,940	6,435	10,425	164,466
2009	55,911	12,561	25,015	21,482	8,025	15,334	138,328
2010	56,821	29,382	4,306	20,853	12,381	22,223	145,965

Data and assessment

This assessment was conducted using 'Stock Synthesis' version 3.21d and includes fishery and survey data collected from mid-1993 through mid-2011. The model uses a July-June 'model year', with two semester-based seasons per year (S1=Jul-Dec and S2=Jan-Jun). Catches and biological samples for the fisheries off Ensenada, southern California, central California were pooled into a single 'MexCal' fleet, in which selectivity was modeled separately for each season (S1 & S2). Catches and biological samples from Oregon, Washington, and British Columbia were modeled as a single 'PacNW' fleet. Four indices of relative abundance were included in the base model: daily egg production method and total egg production estimates of spawning stock biomass off California (1994-2011), aerial survey estimates of biomass off Oregon and Washington (2009-2011), and acoustic estimates of biomass observed from California to Washington (2006-2011). Catchability coefficient (q) for the acoustic survey was fixed at 1 in the base model. All other survey qs were freely estimated.

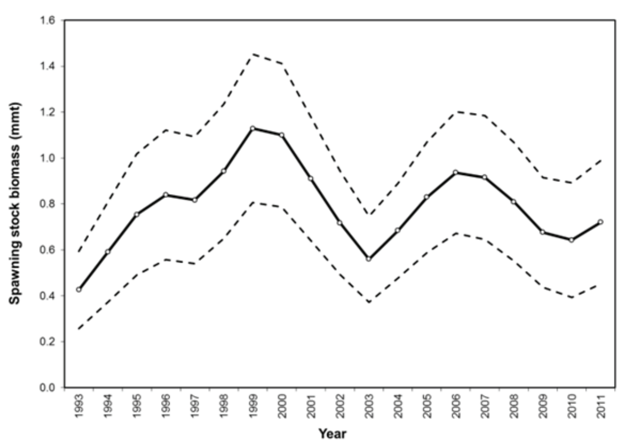
Unresolved problems and major uncertainties

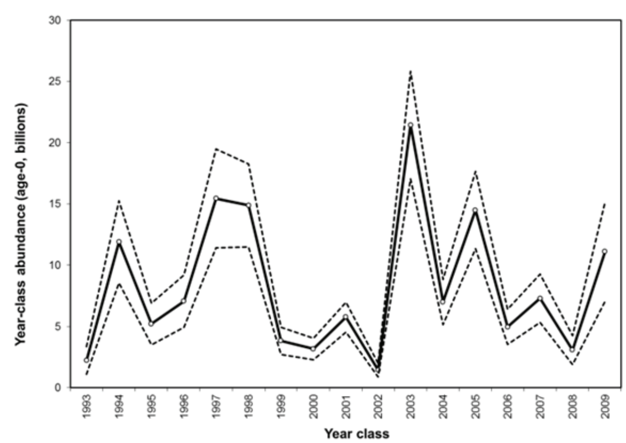
As in the past, the sardine model can be sensitive with regard to scaling of population estimates. While model likelihoods were robust to large changes in scale (i.e., flat likelihood surface), some model scenarios (e.g. extended time series, or treating Canadian fishery separately) resulted in implausibly high fishing mortality rates at the start and/or end of the modeled time series. In the 2009 and 2010 assessments, the scaling problem was addressed by fixing the aerial survey catchability coefficient (*q*) to equal 1. For the current assessment, model scaling and stability was improved, in part, by simplifying overall model structure (e.g. fewer time-varying elements and fleets) and reducing the number of estimated parameters. Final base model stability was further improved by fixing *q* for the acoustic time series to equal 1. The acoustic biomass survey was chosen due to the more synoptic nature and longer time series available for the survey. A more detailed listing of modeling issues and uncertainties may be found in the body of this report as well as the STAR (2011) panel report.

Spawning Stock Biomass and Recruitment

Recruitment was modeled using the Ricker stock-recruitment relationship (σ_R=0.62). The estimate of steepness was high (*h*=2.96), and virgin recruitment (R_0) was estimated to be 6.2 billion age-0 fish. Virgin SSB was estimated to be 0.969 mmt. Spawning stock biomass (SSB) increased throughout the 1990s, with peaks at 1.13 mmt in 1999 and 0.936 mmt in 2006. Recruitment (year-class abundance) peaked at 15.5 billion fish in 1997, 14.9 billion in 1998, 21.4 billion in 2003, and 14.5 billion in 2005. The 2009 year class was estimated to be 11.1 billion fish, higher than the recent average.

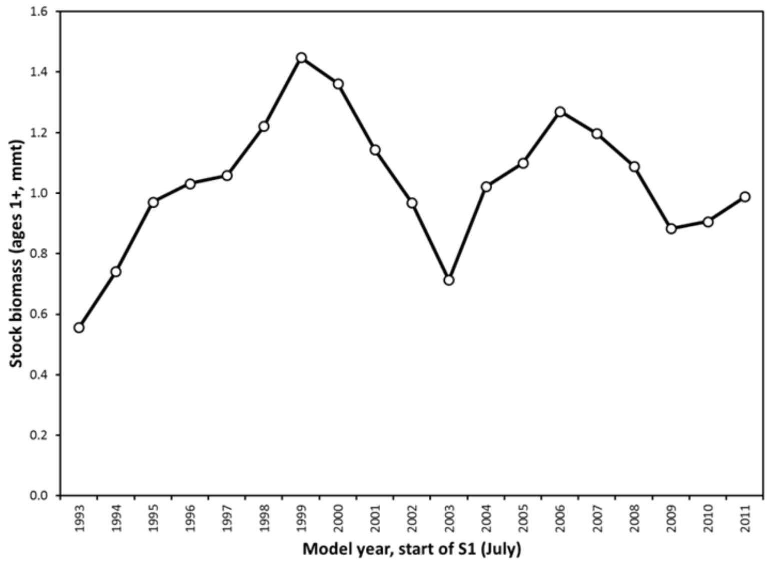
Model year	SSB (mt)	SSB Std Dev	Year class abundance (billions)	Recruits Std Dev
2000	1,099,300	156,590	3.176	0.441
2001	910,030	134,710	5.774	0.611
2002	717,380	112,480	1.453	0.280
2003	559,170	93,958	21.444	2.198
2004	683,570	103,390	7.007	0.927
2005	828,760	120,630	14.502	1.573
2006	936,130	132,590	4.968	0.714
2007	915,230	134,720	7.299	0.987
2008	809,350	128,620	3.081	0.584
2009	675,810	119,320	11.107	2.028
2010	642,830	124,630	---	---
2011	720,420	134,540	---	---





Stock biomass

Stock biomass, used for calculating harvest specifications, is defined as the sum of the biomass for sardine ages 1 and older. Biomass increased rapidly throughout the 1990s, peaking at 1.45 mmt in 1999 and 1.27 mmt in 2006. Stock biomass was estimated to be 988,385 mt as of July 2011.



Exploitation status

Exploitation rate is defined as calendar year catch divided by total mid-year biomass (July-1, ages 0+). U.S. exploitation rate has averaged 7.6% since 2000 and is currently about 6.6%. Total coast-wide exploitation rate has averaged 12.8% since 2000 is currently about 14.5%.

Calendar year	U.S. rate	Total rate
2000	5.20%	10.19%
2001	6.54%	10.48%
2002	10.32%	15.16%
2003	8.08%	12.67%
2004	8.50%	12.75%
2005	7.26%	11.98%
2006	6.88%	11.34%
2007	10.06%	13.09%
2008	7.79%	14.70%
2009	6.77%	13.95%
2010	6.62%	14.45%

Harvest Specifications

Harvest Guideline for 2012

Using results from the final base model ('X5'), the harvest guideline for the U.S. fishery in calendar year 2012 would be 109,409 mt. To calculate the HG for 2012, we used the harvest control rule defined in Amendment 8 of the Coastal Pelagic Species-Fishery Management Plan (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 guideline for sardine is calculated:

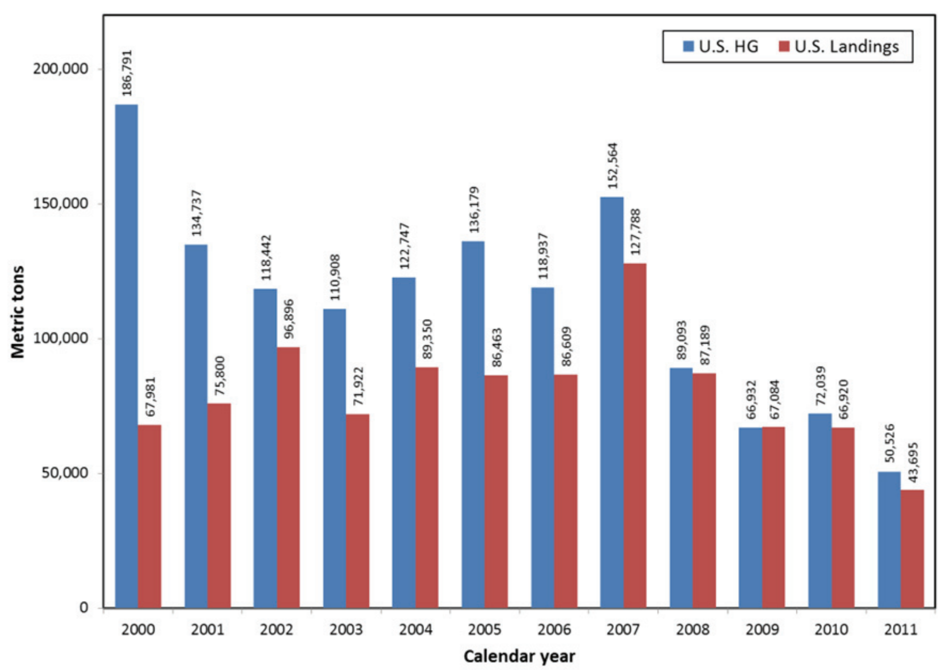
$$HG_{2012} = (BIOMASS_{2011} – CUTOFF) \bullet FRACTION \bullet DISTRIBUTION;$$

where HG_{2012} is the total U.S. (California, Oregon, and Washington) harvest guideline for 2012, $BIOMASS_{2011}$ is the estimated July 1, 2011 stock biomass (ages 1+) from the assessment (988,385 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 following formula has been used to determine FRACTION value:

$$FRACTION = 0.248649805(T^2) – 8.190043975(T) + 67.4558326;$$

where T is the running average sea-surface temperature at Scripps Pier, La Jolla, California during the three preceding seasons (July-June). Under Option J (PFMC 1998), F_{MSY} is constrained and ranges between 5% and 15%. Based on T values observed throughout the period covered by this stock assessment, the appropriate exploitation fraction has consistently been 15%; and this remains the case under current conditions (T_{2011} = 17.7 °C). U.S. harvest guidelines and catches since 2000 are displayed below.



OFL and ABC

The Magnuson-Stevens Reauthorization Act requires fishery managers to define an overfishing limit (OFL), allowable biological catch (ABC), and annual catch limit (ACLs) for species managed under federal FMPs. By definition, ABC and ACL must always be lower than the OFL based on uncertainty in the assessment approach. The PFMC's SSC recommended the 'P*' approach for buffering against scientific uncertainty when defining ABC, and this approach was adopted under Amendment 13 to the CPS-FMP.

The estimated biomass of 988,385 (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 results in a U.S. OFL of 170,689 mt for 2012. For Pacific sardine, the SSC has recommended that scientific uncertainty (σ) be set to the maximum of either (1) the CV of the biomass estimate for the most recent year or (2) a default value of 0.36, which was based on uncertainty across full sardine assessment models. Model CV for the terminal year biomass was equal to 0.187 (σ =0.185); therefore scientific uncertainty (σ) was set to the default value of 0.36. The Amendment 13 ABC buffer depends on the probability of overfishing level chosen by the Council (P*). Uncertainty buffers and ABCs associated with a range of discreet P* values are presented in the table below.

Harvest Formula Parameters	Value			
BIOMASS (ages 1+, mt)	988,385			
P* (probability of overfishing)	0.45	0.40	0.30	0.20
BUFFER_{P*} (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			

Harvest Control Rules	MT
OFL = BIOMASS * F_{MSY} * DISTRIBUTION	170,689
$\mathrm{ABC}_{0.45}$ = BIOMASS * $\mathrm{BUFFER}_{0.45}$ * F_{MSY} * DISTRIBUTION	163,140
$\mathrm{ABC}_{0.40}$ = BIOMASS * $\mathrm{BUFFER}_{0.40}$ * F_{MSY} * DISTRIBUTION	155,810
$\mathrm{ABC}_{0.30}$ = BIOMASS * $\mathrm{BUFFER}_{0.30}$ * F_{MSY} * DISTRIBUTION	141,325
$\mathrm{ABC}_{0.20}$ = BIOMASS * $\mathrm{BUFFER}_{0.20}$ * F_{MSY} * DISTRIBUTION	126,073
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION	109,409

**SPAWNING BIOMASS OF PACIFIC SARDINE (*Sardinops sagax*)
OFF U.S. IN 2011**

Nancy C.H. Lo, Beverly J. Macewicz, and David A. Griffith

National Oceanic & Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center
Fisheries Resources Division
8604 La Jolla Shores Drive
La Jolla, CA 92037-1508
Nancy.Lo@NOAA.GOV

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SUMMARY

The spawning biomass of the Pacific sardine (*Sardinops sagax*) in April 2011 was estimated using the daily egg production method (DEPM) calculated by two methods: 1) the traditional method where the egg production (P_0) was a weighted mean while each adult parameter was an unstratified estimate, and 2) a stratified procedure where the estimate of total spawning biomass is the sum of the estimated spawning biomass in each of two regions representing high and low spawning activity. Thus the two estimates of the spawning biomass were 383,286 mt (CV = 0.32) and 373,348 mt (CV = 0.28) respectively for the standard DEPM survey area of 314,480.69 km^2 off the west coast of North America from San Diego, California to north of San Francisco, California (CalCOFI line 60.0). The daily egg production estimate (P_0, a weighted average with area as the weight) was 1.16/.05m^2 (CV = 0.26). In the standard DEPM area, the estimates of female spawning biomass calculated by the two methods were 225,155 mt (CV = 0.32) and 219,386 mt (CV = 0.28). Even though a small area close to Astoria, Oregon (47.1° - 45.9°N) was sampled, no eggs and only 2 immature sardine were collected in this area north of CalCOFI line 62.2. Hence, coastwide estimates of sardine spawning biomass and female spawning biomass were not calculated.

The estimated daily specific fecundity was 19.04 (number of eggs/population weight (g)/day) using the following estimates of reproductive parameters from 244 mature female Pacific sardines collected from 30 positive trawls: *F*, mean batch fecundity, 38369 eggs/batch (CV = 0.07); *S*, fraction spawning per day, 0.1078 females spawning per day (CV = 0.18); W_f, mean female fish weight, 127.6 g (CV = 0.05); and *R*, sex ratio of females by weight, 0.587 (CV = 0.06). 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 2011 survey, the number of tows positive for mature female sardine was similar in Regions 1 and 2 (14 and 16 respectively), while four additional tows in Region 2 contained solely immature sardines.

The estimates of spawning biomass of the Pacific sardine off California in 1994 – 2011 based on the traditional method are: 127,000 mt, 80,000 mt, 83,000 mt, 410,000 mt, 314,000 mt, 282,000 mt, 1.06 million mt, 791,000 mt, 206,000 mt, 485,000 mt, 300,000 mt, 600,000 mt, 837,000 mt, 392,000 mt, 117,000 mt, 185,000, 108,000mt and 383,000 mt (for the standard DEPM area), respectively. These estimates of spawning biomass indicate that there has been considerable fluctuation during this time (the peaks occurred in 2000 and 2006) and that biomass has declined in the recent three years and increased in 2011. The time series of spawning biomass was one of the fishery-independent inputs to the annual stock assessment of the Pacific sardine from 1985 – 2008. Since 2009, the time series of spawning biomass was replaced by female spawning biomass for years when sufficient trawl samples were available and the total egg production for other years as inputs to the stock assessment of Pacific sardine.

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INTRODUCTION

The spawning biomass of the Pacific sardine (*Sardinops sagax*) was estimated using the daily egg production method (DEPM: Lasker 1985) in 1986 (Scannel et al. 1996), 1987 (Wolf 1988a), 1988 (Wolf 1988b), 1994 (Lo et al. 1996), and 1996 (Barnes et al. 1997). The DEPM estimates spawning biomass by 1) calculating the daily egg production from ichthyoplankton survey data, 2) estimating the reproductive parameters of females from adult fish samples, and 3) calculating the biomass of spawning adults. Before 1996, sardine egg production was estimated from CalVET plankton net samples. Adult fish were sampled in various ways prior to 1996 to obtain specimens for batch fecundity, spawning fraction, sex ratio, and average female fish weight (Wolf 1988a, 1988b; Scannell et al. 1996; Macewicz et al. 1996; Lo et al. 1996).

Since 1996, in addition to CalVET and Bongo nets, the Continuous Underway Fish Egg Sampler (CUFES; Checkley, et al. 1997) has been used as a routine sampler for fish eggs, and data on sardine eggs collected with CUFES have been incorporated in various ways into the estimation procedures of the daily egg production. In the 1997 sardine egg survey (Hill et al. 1998, Lo et al. 2001), CUFES was used to allocate CalVET tows in an adaptive sampling plan. From 1998 to 2000, data on sardine eggs collected with both CalVET and CUFES during each April California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruise were used to estimate daily egg production (Hill et al. 1999). Use of the full data sets from both samplers in the DEPM can be time consuming. Furthermore, the CUFES samples are exclusively from 3 m depth and it is not clear whether sardine egg stages from CUFES samples are representative of the entire vertical distribution of stages. Use of the CUFES data also requires an estimated conversion factor from eggs/min to eggs/0.05m^2. Starting with the 1999 April CalCOFI survey, an adaptive allocation survey design similar to the 1997 survey was implemented. In this design, CalVET tows are added in areas where they were not pre-assigned if sardine egg densities in CUFES collections were high.

Since 2001, a cost-effective alternative has been adopted to calculate the DEPM index that reduces effort in calculation and egg staging of the CUFES collections. This revised DEPM index only uses CalVET samples of eggs and yolk-sac larvae and Bongo samples of yolk-sac larvae, all from the high density area (Region 1), to provide an estimate of P_0, the variance of which may be large due to small sample size (fewer than 100 plankton tows). Adult samples were collected sporadically in 1997, 2001, and 2002 (Lo et al. 2005).

Starting in 2004, full-scale surveys have been conducted for collection of Pacific sardine eggs, larvae, and adults to better estimate the spawning biomass in the area off California between San Diego and San Francisco (Lo and Macewicz 2004; Lo et al. 2005; Lo and Macewicz 2006; Hill et al. 2006 a, b; Lo et al. 2007a, b, 2008, Lo et al. 2009, 2010b). In 2004 the adult samples were taken primarily in the high density area, but beginning in 2005 adult Pacific sardine samples for reproductive output were taken in both high and low sardine egg density areas. The ichthyoplankton samples taken during regular April CalCOFI cruises were also included in the spawning biomass computation. During 2006, 2008 and 2010, the survey area was extended north to the US-Canadian border, and spawning biomass was computed for both the whole survey area and the standard DEPM survey area, i.e. from San Diego to San

Francisco. For 2011, even though the eggs and adults were observed in the area between CalCOFI line 62.2 and 91.7, the daily egg production (P_0) was estimated for the standard DEPM survey area between CalCOFI lines 60.0 and 95.0.

Since 2009, in addition to the estimates of spawning biomass based on the past procedure where P_0 was weighted by the size (km^2) of each region and the adult parameters were estimated from all trawl samples in the entire survey area, an alternative estimator based on stratified sampling for each parameter was also included (Hill et al. 2009) for years when adequate adult samples were available (1986, 1987, 1994, 2004, 2005, 2007 – present). As such, the original time series of spawning biomass may not be comparable due to slightly different estimation procedures and the refined survey designs over time. This alternative method was also used to estimate the female spawning biomass that is now used as a data time series for stock assessment computations. Here, we report the time series of spawning biomass, female spawning biomass, and total egg production based on both the traditional method and the stratified estimates.

MATERIALS AND METHODS

Data

The spring 2011 California Current Ecosystem (CCE) survey was conducted aboard one NOAA research vessel and a chartered fishing vessel. The NOAA ship *Bell M. Shimada* (March 23-April 27) covered the area off of the west coast of US from Cape Flattery, Washington to San Diego, California with most of the stations off California located within the area from San Francisco to San Diego (CalCOFI lines 63.3 to 93.3 from March 27 to April 25). The F/V *Frosti* (March 26-April 28) covered the area from San Francisco to San Diego, California (CalCOFI lines 61.7 to 95, data collected April 1-26). Within the CCE survey the *Shimada* occupied the primary CalCOFI lines, 76.7 to 93.3, from April 10 to 25 for the spring CalCOFI cruise. During the CCE and the CalCOFI surveys, CalVET tows, Bongo tows, CUFES and trawls were conducted aboard both vessels. Data from both CCE and CalCOFI surveys were included in the estimation of spawning biomass of Pacific sardines.

In addition to sardine eggs and yolk-sac larvae collected with the CalVET net, yolk-sac larvae collected with the Bongo net have been included to model the sardine embryonic mortality curve since 2000. Beginning in 2001 (Lo 2001), CUFES data from the ichthyoplankton surveys have been used only to map the spatial distribution of the sardine spawning population with the survey area post-stratified into high-density (Region 1) and low-density (Region 2) areas according to the sardine egg density from CUFES collections. Staged eggs from CalVET tows and yolk-sac larvae from CalVET and Bongo tows in the high-density area have been used to model embryonic mortality in the high density area and later converted to the daily egg production, P_0, for the whole survey area.

During the 2011 CCE survey, twenty six distinct transects were occupied by the vessels. The *Shimada* occupied 13 out of 36 planned lines and the *Frosti* occupied 14 lines. CalCOFI line 76.7 was occupied once by the *Frosti* sampling with CUFES and trawls and then again by *Shimada* during the April CalCOFI survey using the standard sampling protocol of ichthyoplankton tows and trawling. For the CCE survey, CalVET tows were taken at 4-nm intervals on each line after the egg density from each of two consecutive CUFES samples exceeded 1 egg/min, and CalVET tows were stopped after the egg density from each of two consecutive CUFES samples was less than 1 egg/min. The threshold of 1 egg/min was reduced from the number used in years prior to 2002 (2 eggs/min) to increase the area identified as the high-density area and, subsequently, to increase the number of CalVET samples. One egg/min is equivalent to two to thirteen eggs/CalVET tow, depending on the degree of water mixing. This adaptive allocation sampling was similar to that used in the 1997 survey (Lo et al. 2001). Because the threshold changed in 2002, caution should be taken when comparing the size of the area of Region 1.

The entire survey area was mostly south of CalCOFI line 60.0 (line 61.7 was the northern line occupied by *Frosti*) of 314,481 km^2 compared to 271,773 km^2 south of CalCOFI line 60.0 (37.94°N latitude) in 2010. This area, considered to be the standard DEPM survey area, was used to estimate the initial P_0, even though no eggs were observed north of CalCOFI line 63.3, only two CUFES collections included sardine eggs north of CalCOFI line 63.3 (63.1 and 63.2 aboard *Shimada*). This area was post-stratified into two regions: Region 1 (high sardine egg density) and Region 2 (low egg density). Region 1 encompassed the area where the egg density in CUFES collections was at least 1 egg per minute which happened to bebetween CalCOFI line 63.3 and 85.0 (Figure 1). The total area between CalCOFI line 63.3 and 86.7 is termed the sub-DEPM area. The sizes of Region 1 and the standard DEPM survey area were calculated using the formula for a trapezoid area based on the distance between CalCOFI lines and the distance between CalCOFI stations. Region 1 was 41,878 km^2 (13.6% of the standard DEPM area) and Region 2 was 272,603 km^2. Over the years, although the standard DEPM survey area has varied in size, it has been approximately between CalCOFI line 60 (near San Francisco) and line 95 (near San Diego). In 2011 the spawning biomass estimated in the standard DEPM area was considered to be the spawning biomass for the entire survey area.

A total of 923 CUFES samples were collected from the *Frosti* (513) and *Shimada* (410) cruises over the whole survey area. For the DEPM area (CalCOFI line 60.0 to 95), 823 CUFES samples were taken by the *Shimada* (310) and *Frosti* (513). CUFES sampling intervals ranged from 1 to 121 minutes with a mean of 37.41 minutes and median of 30 minutes. The total number of CalVET tows was 154 for the entire survey area, with 151 in the standard DEPM survey area. A total of 46 CalVET samples caught at least one egg (Table 1). Egg densities from each CalVET sample and from the CUFES samples taken within an hour before and after the CalVET tow were paired and used to derive a conversion factor (*E*) from eggs/min of CUFES sample to CalVET catch (eggs/tow). We used a regression estimator to compute the ratio of mean eggs/min from CUFES to mean eggs/tow from CalVET: $E = \mu_y / \mu_x$ where y is eggs/min and x is eggs/tow.

For adult samples, the survey plan was to use the *Shimada* and the *Frosti* to conduct 3 – 5 trawls a night either near regular CalCOFI stations or at random sites on the survey line regardless of the presence of sardine eggs in CUFES collections. In addition, it was planned to conduct some directed trawls in the daytime on acoustic targets to verify potential sardine schools. At night a Nordic 264 rope trawl with 3.0 m^2 foam core doors was towed for 30 minutes at the surface (0 – 11 meters). The trawl was modified for surface trawling with Polyform floats attached to the head rope and trawl wings. The trawl was modified with a marine mammal extruder device placed midsection just forward of the codend. In addition on the *Frosti*, the first trawl of the night (about a half hour after sunset) was towed without the Polyform floats to depths of 15 to 20 meters to potentially catch fish that might still be moving up toward the surface from daytime depths since dark had not fully descended. For the whole CCE survey trawling occurred from March 23 to April 25, 2011 and 37 of the 105 trawls conducted at night were positive for Pacific sardines. A single trawl off Astoria, Oregon collected 2 immature sardine. The other 36 trawls with sardines were located in the south below latitude 37.4°N (Figure 1).

Up to 50 sardines were randomly sampled from each positive trawl with more than 75 fish, or all were sampled if less than 75 fish were captured (Table 2). After the random subsample, additional mature females were randomly processed, if necessary, from the trawl catch to obtain 25 mature females per trawl for reproductive parameters or to obtain females for use in estimating batch fecundity. Each fish was sexed, standard length (mm) and weight (g) were measured, otoliths were removed for aging, tissue was preserved in 95% ethanol for genetics, and, for females, ovaries were removed and preserved in 10% neutral buffered formalin. Each preserved ovary was blotted and weighed to the nearest milligram in the laboratory. Ovary wet weight was calculated as preserved ovary weight times 0.78 (unpublished data, CDFG 1986). A piece of each ovary was removed and prepared as hematoxylin and eosin (H&E) histological slides. All slides were analyzed for oocyte development, atresia, and postovulatory follicle age to assign female maturity and reproductive state (Macewicz et al. 1996).

Daily egg production (P_0)

Because no eggs or adults were collected north of latitude 37.5°N (CalCOFI line 61.7), the spawning biomass was most likely distributed in the survey area south of San Francisco, the standard DEPM survey area. The estimate of the P_0, thus spawning biomass for the standard DEPM survey area (i.e., the area between CalCOFI line 60.0 and 95) was also used for the entire survey area, different from some of the previous years, such as 2006. Appropriate parameter estimates required by the DEPM were obtained for each area.

Similar to the 2001 – 2005 procedure (Lo 2001), we used a net tow as the sampling unit. Sardine eggs from CalVET tows and sardine yolk-sac larvae from both CalVET and Bongo tows in Region 1 were used to compute egg production, primarily based on data from 13 transects (Figure 1). In Region 1, a total of 35 out of 48 CalVET samples contained at least 1 sardine egg; these eggs were examined for their developmental stages (Figure 2 and Table 1). In the total Region 2 (North plus DEPM), 11 out to 107 CalVET tows caught sardine eggs.

Based on aboard-ship counts of sardine eggs in CUFES samples, 333 of the 923 collections were positive for sardine eggs over the entire survey area. For the DEPM area (south of CalCOFI line 60.0), 333 of 823 collections caught sardine eggs. In Region 1, there were 131 positive CUFES collections out of 161 total collections. In the DEPM Region 2, 202 of the total 762 collections were positive. None of CUFES samples taken north of CalCOFI line 60.0 were positive (Table 1).

To model the embryonic mortality curve, we included yolk-sac larvae (preserved larvae ≤ 5 mm notochord length) assuming that the mortality rate of yolk-sac larvae was the same as that of eggs (Lo 1986). Yolk-sac larval production was computed as the number of yolk-sac larvae/0.05m^2 divided by the duration of the yolk-sac stage (number of larvae/0.05m^2/day). Duration was computed based on the temperature-dependent growth curve (Table 3 of Zweifel and Lasker 1976) for each tow. For yolk-sac larvae caught by the Bongo net, larval abundance was further adjusted for size-specific extrusion from 0.505 mm mesh (Table 7 of Lo 1983) and for the percent of each sample that was sorted. The adjusted yolk-sac larvae/0.05 m^2 was then computed for each tow and was termed daily larval production/0.05 m^2.

In the whole survey area, 32 of 154 CalVET and 49 of 132 Bongo samples had at least one yolk-sac larva (Table 1). In Region 1 (Figure 3), 18 of 48 CalVET and 10 of 11 Bongo samples were positive for yolk-sac larvae (all within the DEPM area), and in the total Region 2, 14 of 106 CalVET and 39 of 121 Bongo samples were positive for yolk-sac larvae. In the DEPM survey area (area south of CalCOFI line 60), 32 out of 151 Calvet and 49 out of 129 Bongo samples had at least one yolk-sac larvae. In Region 1, 18 of 48 CalVET and 10 of 11 Bongo samples were positive for yolk-sac larvae, and in Region 2, 14 of 106 CalVET and 39 of 121 Bongo samples were positive for yolk-sac larvae (Table 1).

Daily egg production for the whole survey area (29.87°N – 47.80°N)

Because no eggs were collected in the area north of CalCOFI line 61.7 (lat 37.5 ^{o}N) (Figure 1), and majority of stations were south of CalCOFI line 61.7, only the overall P_0 (daily egg production/0.05m^2) was computed for the area south of CalCOFI line 60.0, the standard DEPM survey area.

Daily egg production in Region 1 ($P_{0,1}$) for the standard DEPM survey area (south of CalCOFI line 60.0)

Sardine eggs and yolk-sac larvae and their ages were used to construct an embryonic mortality curve (Lo et al. 1996). Sardine egg density for each developmental stage was computed based on CalVET samples (Figure 2). The distribution of overall density of eggs by egg development stage in 2011, with peak at stage 3, was different from those in recent years when stage 6 or stages 6-9 had the highest density (Lo et al. 2009 and 2010b). The average sea surface temperature for CalVET tows with ≥1 egg in this DEPM survey area was 13.5°C, which is lower than recent years (Lo et al. 2010b). A temperature-dependent stage-to-age model (Lo et. al. 1996) was used to assign age to each stage. Sardine eggs and estimated ages were used directly in nonlinear regression. Eggs ≤ 3h old and eggs older than 2.5 days were excluded because of possible bias. The average sea surface temperature for all CalVET tows from *Frosti* was 13.5°C, while from the *Shimada* it was 13.9°C for the tows in the standard DEPM survey area.

The sardine embryonic mortality curve was modeled by an exponential decay curve (Lo et al. 1996):

$$P_t = P_0 e^{-zt} \quad [1]$$

where P_t is either eggs/0.05m^2/day from CalVET tows or yolk-sac-larvae/0.05m^2/day from CalVET and Bongo tows, and t is the age (days) of eggs or yolk-sac larvae from each tow. A weighted nonlinear regression was used to estimate two parameters in equation (1) where the weights were 1/SD. The standard deviation (SD) of eggs was 10.25, 3.26, and 2.55, for day-one, day-two and day-three age groups from CalVET samples, respectively, and the SD for yolk-sac larvae was 0.45 and 0.89 from CalVET and Bongo samples .

A simulation study (Lo 2001) indicated that $P_{0,1}$ computed from a weighted nonlinear regression based on the original data points has a relative bias (RB) of -0.04 of the estimate, where the RB = (mean of 1,000 estimates - true value)/mean of 1,000 estimates. Therefore the bias-corrected estimate of egg production in Region 1 is calculated as $P_{0,1,c} = P_{0,1}$ * (1- RB) = $P_{0,1}$ *(1.04), and SE ($P_{0,1,c}$) = SE($P_{0,1}$) * 1.04.

Daily egg production in Region 2 ($P_{0,2}$) for the standard DEPM survey area

Although 104 CalVET samples were taken in Region 2, only 11 tows had sardine eggs ≥ 1, ranging from 1 to 39 eggs per tow (Table 1). Therefore, we estimated daily egg production in Region 2 ($P_{0,2}$) as the product of the bias-corrected egg production in Region 1 ($P_{0,1,c}$) and the ratio (q) of egg density in Region 2 to Region 1 from CUFES samples, assuming the catch ratio of eggs/min from CUFES to eggs/tow from CalVET was the same for the whole survey area:

$$P_{0,2} = P_{0,1,c}\, q \quad [2]$$

$$q = \frac{\sum_i \frac{\bar{x}_{2,i}}{\bar{x}_{1,i}} m_i}{\sum_i m_i} \quad [3]$$

$$\mathrm{var}(q) = \frac{[n/(n-1)]\sum_i m_i^2 (q_i - q)^2}{\left(\sum_i m_i\right)^2}$$

where q is the ratio of eggs/min between the low density and high density areas, m_i was the total CUFES time (minutes) in the ith transect, $\bar{x}_{j,i}$ is eggs/min of the ith transect in the jth Region, and $q_i = \frac{\bar{x}_{2,i}}{\bar{x}_{1,i}}$ is the catch ratio in the ith transect. The estimates of q were computed from a total of 7 transect lines occupied by both the *Frosti* and the *Shimada* in Region 1. The ratio,q, was computed from the sub-DEPM area (187,287 km^2), between Calcofi line 63.3 to 86.7 to obtain the initial daily egg production in Region 2 (145,389 km^2), because only two CUFES collections had sardine eggs ranging from 0.01 to 0.12 egg/minutes south of CalCOFI line 86.7. The area north of the sub-area: between CalCOFI line 60.0- 63.3 (6,859 km^2) and the area south of the sub

DEPM area (120,335 km^2) were added to the region 2 in the sub DEPM area as the total area of the Region 2 (272,603 km^2) in the standard DEPM survey area (314,481 km^2) (Figure 1). $P_{0,2}$ for the standard DEPM area, from CalCOFI lines 60.0 - 95, was prorated from the sub area.

Daily egg production (P_0) for the standard DEPM survey area

P_0 was computed as the weighted average of $P_{0,1}$ and $P_{0,2}$:

$$
\begin{aligned}
P_0 &= \frac{P_{0,1,c}A_1 + P_{0,2}A_2}{A_1 + A_2} \\
&= P_{0,1,c}w_1 + P_{0,2}w_2 \\
&= P_{0,1,c}[w_1 + qw_2]
\end{aligned}
\qquad [4]
$$

and

$$mse(P_0) = mse(P_{0,1,c})(w_1 + w_2 q)^2 + P_{0,1,c}^2 w_2^2 V(q) - mse(P_{0,1,c}) w_2^2 V(q)$$

(Goodman 1960) where *mse* ($P_{0,1,c}$) = v($P_{0,1}$) + bias^2 = v($P_{0,1}$) + ($P_{0,1}$ RB)^2

and $w_i = \dfrac{A_i}{A_1 + A_2}$, and A_i is the area size for i = 1 or 2 for the DEPM survey area.

The above P_0 was computed for the DEPM area: $P_{0,DEPM} = \sum P_{0,i,\ DEPM} W_{i,DEPM}$ where the weights are $W_{i,DEPM} = A_{i,DEPM} / A_{DEPM}$ for i = 1, or 2. $A_{DEPM} = A_{1,DEPM} + A_{2,\ DEPM}$ where $A_{i,DEPM}$ is the area for the ith region in the standard survey area (41,878 km^2). For Region 1, $P_{0,1,DEPM} = P_{0,1}$. For Region 2, $P_{0,2,DEPM} = P_{0,2}$ x $A_{2,\ sub\ DEPM}$ / $A_{2,\ DEPM}$ = $P_{0,I,c}$ x q x (145,389/272,603) where $A_{2,\ sub\text{-}DEPM}$ is the area between CalCOFI line 63.3 and 86.7 and $A_{2,\ DEPM}$ is the area of the DEPM Region 2. CV ($P_{0,DEPM}$)= se ($P_{0,DEPM}$)/ $P_{0,DEPM}$ where se ($P_{0,DEPM}$) = sqrt [(se ($P_{0,1}$) * $W_{1,DEPM}$)^2 + (se ($P_{0,2,DEPM}$) * $W_{2,DEPM}$)^2]. The area of Region 1 for the whole survey area ($A_{1,DEPM}$) is equal to Region 1 in the DEPM survey area (A_1) and CV($P_{0,2,DEPM}$) = CV($P_{0,2}$) . The size of the standard DEPM survey area (area between CalCOFI lines 60.0 and 95.0) is 314,481 km^2 (41,878 km^2 + 272,603 km^2).

Adult parameters

Four adult parameters are needed for estimation of spawning biomass: 1) daily spawning fraction or the number of spawning females per mature female per day (*S*), 2) the average batch fecundity (*F*), 3) the proportion of mature female fish by weight (sex ratio, *R*), and 4) the average weight of mature females (g, W_f). Population values for *S*, *R*, *F* and W_f were estimated using the methods of Picquelle and Stauffer (1985). Daily specific fecundity (number of eggs per population weight (g) per day) is $(RSF)/W_f$. The parameters were estimated for the whole and DEPM areas and separately for sardine females caught in each egg-density region. Correlations among all pairs of adult parameters were calculated for computing the variance of the estimate of spawning biomass (Parker 1985). In the past, the predicted batch fecundity for each female fish was calculated as y = a + bx where x is the female weight (without ovary) and y is the predicted value. In reality, most of the batch fecundities we estimated gravimetrically are scattered around the regression line and not on it. Therefore, to account for the deviation of batch fecundity from the regression line, we added an error term to the predicted value as y = a + bx + *e* where error term *e* was a random number generated from a normal distribution with mean zero and a variance of the error terms from the regression analysis. An MS[1] Visual Basic program (Chen et al. 2003) was modified to more accurately describe batch fecundity variance and was used summarize the trawl adult parameters, calculate adult parameter correlations and covariance, and to estimate spawning biomass and its coefficient of variation.

Spawning fraction (S). In total, 244 mature female sardines were analyzed and considered to be a random sample of the population in the area. Histological criteria can be used to identify four different spawning nights: postovulatory follicles aged 44 – 54 hours old indicated spawning two nights before capture (A), postovulatory follicles aged about 20 – 30 hours old indicated spawning the night before capture (B), hydrated oocytes or new (without deterioration) postovulatory follicles indicated spawning the night of capture (C), and early stages of migratory-nucleus oocytes indicated that spawning would have occurred the night after capture (D). The daily spawning fraction can be estimated using the number of females spawning on one night, an average of several nights, or all nights. We used the average of the number of females identified as having spawned the night before capture (B) and those having spawned two nights before capture (A) and the adjusted number of mature females caught in each trawl (Table 2) to estimate the 2011 population spawning fraction (S_{12}) and variance (Picquelle and Stauffer 1985, Hill et al. 2009).

Batch fecundity (F). Batch fecundity (number of oocytes per spawn) was considered to be the number of migratory-nucleus-stage oocytes or the number of hydrated oocytes in the ovary (Hunter et al., 1985). We used the gravimetric method (Macewicz et al. 1996; Hunter et al. 1985, 1992) to estimate mean batch fecundity for 52 females caught during the April 2011 survey. The relationship of batch fecundity (F_b) to female weight (without ovary, W_{of}), as determined by simple linear regression, was $F_b = -2252 + 347.6W_{of}$, where $r^2 = 0.678$, variance of the slope was 1146.5, and W_{of} ranged from 68 to 180 g (Figure 4); the intercept did not differ from zero ($P = 0.582$). We used the equation $F_b = -2252 + 347.6W_{of} + e$ where the error term, *e*, was generated from a normal distribution with mean zero and variance of 53,584,146 to estimate batch fecundity for each of the 244 mature Pacific sardine females that were analyzed to estimate spawning frequency.

Female weight (W_f). The observed female weight was adjusted downward for females with hydrated ovaries, because their ovary weights were temporarily inflated. We obtained the adjusted female weight by the linear equation $W_f = -0.59 + 1.07W_{of}$ where W_f is wet weight and W_{of} is ovary-free wet weight based on data from non-hydrated females taken during the April 2011 CCE survey.

Sex ratio (R). The female proportion by weight was determined for each trawl (or each collection). The average weight of males and females (calculated from the first 10 males and 25 females) was multiplied by the number of males or females in the collection of randomly selected fish to calculate total weight by sex in each collection. Thus, the female proportion by

[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

weight in each collection (Table 2) was calculated as estimated total female weight divided by estimated total weight in the sample. The estimate of the population's sex ratio by weight was also calculated (Picquelle and Stauffer, 1985).

Spawning biomass (B_s)

The spawning biomass was computed:

$$B_s = \frac{P_0 AC}{RSF/W_f} \qquad [5]$$

where A is the survey area in units of 0.05m^2, S is the fraction of mature females spawning per female per day, F is the batch fecundity (number of eggs per mature female released per spawning), R is the fraction of mature female fish by weight (sex ratio), W_f is the average weight of mature females (g), and C is the conversion factor from grams (g) to metric tons (mt). P_0A is the total daily egg production in the survey area, and the denominator (RSF/W_f) is the daily specific fecundity (number of eggs/population weight (g)/day).

The variance of the spawning biomass estimate $\left(\hat{B}_s\right)$ was computed using Taylor expansion and in terms of the coefficient of variation (CV) for each parameter estimate and covariance for adult parameter estimates (Parker 1985):

$$VAR\left(\hat{B}_s\right) = \hat{B}_s^{\,2}\left[CV\left(\hat{P}_0\right)^2 + CV\left(\hat{W}_f\right)^2 + CV\left(\hat{S}\right)^2 + CV\left(\hat{R}\right)^2 + CV\left(\hat{F}\right)^2 + 2COVS\right] \qquad [6]$$

The last term, involving the covariance term, on the right-hand side is

$$COVS = \sum_i \sum_{i<j} sign \frac{COV\left(x_i, x_j\right)}{x_i x_j}$$

where x's are the adult parameter estimates, and subscripts i and j represent different adult parameters; e.g., $x_i = F$ and $x_j = W_f$. The sign of any two terms is positive if they are both in the numerator of B_S or denominator of B_S (equation 5); otherwise, the sign is negative. The covariance term is

$$\text{cov}(x_{i,} x_j) = \frac{[n/(n-1)]\sum_k m_k (x_{i,k} - x_i) g_k (x_{j,k} - x_j)}{\left(\sum_k m_k\right)\left(\sum_k g_k\right)}$$

where k refers to k^{th} tow, and k = 1,…,n. The terms of m_k and g_k are sample sizes and $x_{i,k}$ and $x_{j,k}$ are sample means from the k^{th} tow for x_i and x_j respectively.

The survey area was post-stratified into two regions based on the presence of sardine eggs: Region 1 (high-density area) and Region 2 (low-density area). Thus, equation (5) can be applied to the whole survey area and/or to each of the two regions depending on the availability of data. For the female spawning biomass (fs.biomass), one of the inputs to the stock assessment, the sex ratio (R), was excluded from equations (5) and (6). The estimate of female spawning biomass was the sum of the estimate from each of the two regions, which is referred to as the stratified procedure. The traditional method is to obtain a weighted mean for P_0 (equation 4) while each of the adult parameter was an unstratified estimate.

RESULTS

Daily egg production (P_0) for the standard DEPM survey area and the whole survey area

In Region 1, the initial daily egg production ($P_{0,1}$) from the mortality curve was 5.366/0.05 m^2/day (CV = 0.24; equation 1 and Figure 5). The bias-corrected egg production, ($P_{0,1,c}$) was 5.57 (CV = 0.24) (Table 3) for an area of 41,878 km^2 (south of CalCOFI line 61.7). The ratio (q) of egg density between Region 2 and Region 1 from CUFES samples was 0.164 (CV = 0.23) (equation 3). The egg production ($P_{0,2}$) in Region 2 of the sub-DEPM surey area, was 0.914 /0.05 m^2/day (CV = 0.5) for an area of 187,287 km^2 (54,722 nm^2) and 0.487 eggs/0.05m2 for the Region 2 area (272,603 km^2) in the standard DEPM survey area. Egg mortality (0.51 (CV = 0.14)) was higher than many years (Table 4). The P_0 for the standard DEPM survey area was 1.16/0.05 m^2 (CV = 0.26) (equation 4) for 314,481 km^2 (91,866 nm^2) (Table 3).

Catch ratio between CUFES and CalVET (E)

Although this ratio is no longer needed in the current estimation procedure, we computed it for comparison purposes. The catch ratio of eggs/min to eggs/tow (eggs/min = E * eggs/0.05 m^2) was computed from 46 pairs of CalVET tows and CUFES collections from the *Frosti* and *Shimada* cruises (Figure 6). The eggs/min corresponding to each positive CalVET tow was the mean of all CUFES collections taken from one hour before to one hour after each positive CalVET tow. The catch ratio was 0.0589 (CV = 0.21) in comparison to the 2010 estimate of 0.077(CV = 0.14. A ratio of 0.058 means that one egg/tow from a CalVET tow was equivalent to approximately 0.058 egg/min from a CUFES sample, or one egg/minute from the CUFES was equivalent to 17.24 eggs/tow from the CalVET sample.

The ratio of egg densities of two regions from pump samples (q)

The q value (ratio of eggs/min in Region 1 to eggs/min in Region 2) serves as the calibration factor to estimate $P_{0,2}$ in Region 2 (equation 2), because low abundance of eggs observed in Region 2 prevents us from using the egg mortality curve to directly estimate $P_{0,2}$. For the 2011 survey, q was obtained from 7 transect lines between CalCOFI lines 81.7 and 70.0: The estimate was 0.164 (CV = 0.23).

Adult parameters

Over the whole survey area trawled (31.3° – 46.74°N) during the April 2011 CCE survey, only one tow caught sardines north of CalCOFI line 60 at 46.04°N. Since both of the sardines caught that single tow were immature (sizes were 146 and 147 mm SL) and no sardine eggs were found, a coastwide spawning biomass was not estimated. In the standard DEPM survey area off California (from CalCOFI lines 95 to 60), Pacific sardine were found in 36 tows: mature female sardines were found in 30 tows, 4 tows contained immature females, and 2 tows had only a single male (Table 2). Standard length (SL), of the randomly obtained sardine in each trawl ranged from 153 to 248 mm for 292 males and from 155 to 268 mm for 374 females. The smallest mature female was 173 mm SL. Since 104 immature female sardines (size range 146 to 196 mm SL) were captured during the 2011 survey, the length at which 50% of females are mature (ML_{50}) was calculated as 186.47 mm (Figure 7) using logistic regression (Macewicz et al. 1996, Lo et al. 2005).

The DEPM survey area off California in 2011 was 314,481 km^2. Estimates of reproductive parameters of 244 mature female sardines (up to 25 mature analyzed per trawl) for the individual trawls are given in Table 2. The mature female Pacific sardine reproductive parameters in the standard DEPM survey area, estimated from 30 positive trawls (Table 2) and 244 mature females, were: F, mean batch fecundity, 38,369 eggs/batch (CV = 0.07); S, fraction spawning per day, 0.1078 females spawning per day (CV = 0.18); W_f, mean female fish weight, 127.6 g (CV = 0.05); and R, sex ratio of females by weight, 0.587 (CV = 0.06) (Table 5). The average interval between spawning (spawning frequency) was about 9 days (inverse of spawning fraction or 1/0.1078), and the daily specific fecundity was 19.04 eggs/population weight (g)/day (Table 5). The correlation matrix for the adult parameter estimates for the DEPM Region 1 and Region 2, and the whole DEPM area is shown in Table 5. We also provided estimates of each adult parameter in each region (Table 5), primarily because they are used to compute female spawning biomass which is an input to stock assessment.

Spawning biomass (B_s)

The final estimate of spawning biomass of Pacific sardine in 2011 using the traditional method (equation 1 and 4, Table 3 and 4) was 383,286 mt (CV = 0.32) or 421,615 short tons (st) (= mt x 1.1) for the standard DEPM survey area of 314,480.98 km^2 (91,886 nm^2) off California. The point estimate of spawning biomass of Pacific sardine off California in 1994 – 2011 are, respectively, 127,102;79,997; 83,176; 409,579; 313,986; 282,248; 1,063,837; 790,925; 206,333; 485,121; 281,639; 621,657; 837,501; 392,492, 117,426, 185,084, 108,280 and 383,286 mt (Table 4). Based on the stratified procedure, the estimate of the 2011 spawning biomass was 373,348 mt (CV = 0.28) (Table 3 and 6).

The estimate of the female spawning biomass for the DEPM survey area was 219,386 mt (CV = 0.28) and 225,155 mt (CV = 0.32) based on the stratified procedure and the traditional method respectively. The former with estimates of previous years was used as one input time series to the Pacific sardine stock assessment (Table 6).

DISCUSSION

Sardine eggs

Sardine eggs in April 2011 were concentrated in the area between CalCOFI lines 63.3 and 83.3 up to offshore CalCOFI station 100.0 in an area of close to 42,000 km^2 (Figure 1), larger than the area in 2010 when eggs were distributed between CalCOFI lines 63.3 and 73.3 while in 2009 when eggs were distributed south between CalCOFI lines 81.7 and 95.0 (Lo et al. 2010b and 2009). The change in distribution of eggs in 2010 and 2011 from previous years could be due to low water temperature or other environmental conditions. Similar to 2010, the area north of CalCOFI line 60.0 had zero eggs, and as eggs were observed north of CalCOFI line 63.1. The daily egg production rate of 5.57/0.05m^2 in the high-density area was much higher than those in previous years in 2007-2010. However, the high-density area was only 13% of the standard DEPM survey area, much lower than in previous years (e.g., 27% in 2009). The high overall P_0 of 1.16/0.05 m^2 for the standard DEPM survey area was similar to that in 2004. The spawning area has been in the southern part of California waters since 2006 even though a few eggs were observed in Mexican surveys, i.e. IMECOCAL. In the past, eggs were concentrated north of Point Conception were 1999, 2004 and 2005. The relatively small size of Region 1 in 2011 and its northern location (between CalCOFI line 63.3 and 83.3) has been extended more south compared to 2010, which again could be due to minor La Niña phenomena. Moreover, in 2006 CCE survey, eggs were observed around latitudes 40 – 43^{o}N, which was not true for the 2008 and the 2011 CCE surveys.

The adaptive allocation sampling procedure was used aboard the *Frosti* and the *Shimada*. (including April CalCOFI survey). A total of 151 CalVET tows was taken in the standard DEPM survey area. This was higher than many previous years: 129 in 2010, 136 in 2009, 84 in 2007, 123 in 2006, 74 in 2005, and 124 tows in 2004, but smaller than in other recent years: 217 in 2002, 192 in 2003 and the same in 2008. Unlike the previous years, adaptive sampling was used during the April CalCOFI survey this year. Due to the low egg densities south of CalCOFI line 83.3, no extra CalVET tows were taken. We still highly recommend that adaptive allocation sampling be applied aboard the research vessel that conducts during the spring (March – April) routine CalCOFI survey in the future to enhance the quality of the estimate of the spawning biomass.

Embryonic mortality curve

The estimates of the daily egg production at age 0 (P_0/0.05 m^2=5.366 with CV=0.24) and the daily embryonic mortality (0.51, CV=0.14) from the mortality curve in Region 1 were much higher than recent years from 2007-2010, similar to those in 2006. The high value of P_0 was partially caused by the distribution of egg developmental stages (Figure 2). In many past years, the peak egg developmental stage was stage 6. In 2011, the peak egg development stage was stage 3. Another extreme case was in 2010, when the peak densities spread from stage 6 to 9 (Lo et al. 2010b). The latter phenomenon is not understood and needs thorough investigation. The overall P_0 in the DEPM (1.16 eggs/0.05m^2) was higher than previous years (Table 3 and 4), despite of the relatively small area of high density area (Figure 1). The spatial distribution of yolk-sac larvae was broader than 2010, in particular in the 2011 southern CalCOFI lines (Figure 3). This could be due to the survey time aboard *Shimada* was toward the end of April. Those yolk-sac larvae in Region 2 were not used in the computation of spawning biomass.

Catch ratio between CUFES and CalVET (E)

The 2011 catch ratio between CUFES and CalVET (0.058) computed from data obtained from the *Frosti* and *Shimada* appeared to be lowest among all years: 2010 (0.077), 2009 (0.15), 2008 (0.14), 2007 (0.15), 2006 (0.32(CV = 0.12)), 2005 (0.18 (CV = 0.28)), 2004 (0.22 (CV = 0.09)), 2003 (0.39 (CV = 0.11)), 2002 (0.24 (CV = 0.06)), 2001 (0.145 (CV = 0.026)), 2000 (0.27), 1999 (0.34), and 1998 (0.32). This low catch ratio in 2011 indicated that relatively fewer eggs were in the upper 3 meters of the water column, possibly due to weakly mixed ocean water. Again, the current catch ratio is different from the 1996 estimate of 0.73. This could be because the 1996 CalVET samples were taken only in the southern area near San Diego (routine CalCOFI survey area) while after 1997 CalVET samples were taken in a larger area extending far north of San Diego (Lo et al. 2005). It would be informative to examine the relationship between the catch ratio and the degree of water mixing over the years (Lo et al. 2001).

The ratio of egg densities of two regions from pump samples (q)

The *q* value (ratio of eggs/min in Region 1 to eggs/min in Region 2) (equation 2) was 0.164 (CV=0.23), slightly higher than 2010's estimate: 0.128 (CV = 0.37) for the standard DEPM sampling area. This value, even though lower than that of 2007 (0.48), was higher than those of previous years. The q values have ranged from 0.036 to 0.065 from 2001-2006 with an increasing trend. If this trend continues, it may mean that the spatial distribution of the sardine eggs is becoming less aggregated.

Adult parameters

The April 2011 CCE survey again covered a large area off the west coast of the U.S. from Cape Flattery, WA to San Diego, CA. Previous trawling was conducted in the spring off the whole west coast during 2006, 2008, and 2010 (Lo et al. 2007a, 2008, 2010b). We examined the range of sea temperatures at 3m depth, recorded during trawl operations, in three subareas off the coast: Washington and Oregon, northern California, and the standard DEPM area (Table 7). Although only five trawls were conducted off Washington-Oregon (9.4 – 9.5^{o}C), two immature sardines (mean of 146.5mm and 31g) were caught off Astoria, Oregon. The last time we caught sardines in a survey off Washington and Oregon was in March of 2004 and 2005 when a majority of the sardines were small, immature, and found in cooler waters (average about 10.2°C) than mature female sardines (Lo et al. 2010a). No trawls were conducted off northern California, due to weather and time constraints. Temperatures recorded during CUFES sampling (9.9 – 11.9^{o}C) were similar to previous surveys indicating that sardines may have been caught off northern CA if trawling had occurred. In the standard DEPM area during 2011 (9.9 – 16.3^{o}C) sardine adults and eggs were collected as in past surveys. Although, during 2006-2010 the size of sardines caught increased, and the size of Region 1 (high sardine egg density) and P_0 (daily egg production) decreased, during 2011 average sardine was smaller and P_0 and the area of Region 1 increased, indicating possible improvement of recruitment.

During the April 2011 survey in the standard DEPM survey area, we were again able to collect some trawl samples (Table 2) in areas of high (Region 1) and low (Region 2) sardine egg density to yield a better estimate of Pacific sardine spawning biomass for the whole population in the large oceanic area from San Diego to San Francisco. We found that the average mature female weight (W_f) was similar in both regions (128.4 grams (SE = 4.16) in Region 1 and 126.9 grams (SE = 11.27) in Region 2, Table 5) while the fraction of females spawning per day, S_{12}, (based on the average of females that spawned the night before capture and 2 night before capture or "average of day 1+day 2") was higher in Region 1 (0.136 females/day (CV = 0.18)) than Region 2 (0.084 females/day (CV = 0.35)). This regional difference in the fraction of females spawning (high in 1 and lower in 2) was similar to that in past DEPM surveys in 2005, 2006 (Lo and Macewicz 2006, Lo et al. 2007a), 2007 (when one unusual trawl is removed, Lo et al. 2007b), 2008, 2009, and 2010 (Lo et al. 2008, 2009, 2010). Although there were more trawls conducted in Region 2 (78) than in Region 1 (22), about the same number of trawls contained mature females (Table 5) and when trawls with only males or immatures are included there were slightly more positive in Region 2 (21) than Region 1 (15). Many trawls taken in Region 2 did not catch any sardine. In the future, we may reduce number of trawls in Region 2 when the egg density is zero or consistently less than 1 egg/min. Because more females were spawning per day in Region 1 than Region 2, it is necessary to continue to trawl in both regions to ensure an unbiased estimate of spawning biomass for the whole population.

In 2011 the CV (0.18) of the spawning fraction estimate in the DEPM area was higher than that in 2009 (CV = 0.15) but lower than that in 2010 (CV = 0.22) and those in earlier years (CVs of 0.33 in 2007 and 0.31 in 2005 and 2008) (Lo et al. 2006, 2007b, 2008, 2009, and 2010b). The high CVs in previous years were most likely due to the low number of sardine positive trawls (12 – 14) and high variability of spawning (Table 8). In 2011, as in 2010 and 2009, a factor in improvement of the CV was the change in the calculation of daily spawning fraction. In the past (1994, 1997, 2004, 2005, 2007, and 2008), calculation of the original daily spawning fraction (S_1) was based on the number of females that spawned the night before capture (night B, "day1") and followed the procedure for Northern anchovy (Picquelle and Hewitt, 1983) to replace the number of females spawning the night of capture (night C, "day0") with the number of night B spawning females to adjust the number of total mature females. By contrast, since 2009 we calculated the daily spawning fraction (S_{12}) using the mean number of night B and night A (two nights before capture, "day2") spawning females for each trawl and replaced the night C females by this mean to adjust the number of total mature females. Another factor for the lower CV of the 2011 and 2009 spawning fraction estimate was an increase in the number of trawls with sardine (30 in 2011 and 29 in 2009), while 2010 had fewer sardine positive trawls (17) and slightly higher CV (0.22) (Table 8). Therefore for continued improvement of spawning fraction precision, we recommend using S_{12} to calculate daily spawning fraction and that at least 17 trawl samples need to be obtained or the number of trawls sampled be increased, in both high and low egg density areas, for future biomass surveys.

We estimated that 50% of the female sardines were mature (ML_{50}) at 186.47 mm during April 2011 (Figure 7). The April 2011 estimate of ML_{50} is between the 2004 value (193 mm) and the 1997 value (171 mm), and higher than the estimates from 2007(153 mm), 2005 (152 mm) and 1994 (159 mm) (Lo et al. 2005 and 2007b, Lo and Macewicz 2006). The variation in ML_{50} could be real due to change in maturity or it may be the result of sample bias from one or more of the following: a) sardines were from the high egg density area only, b) all or a majority of the sardines were from offshore, c) all or a majority of the sardines were from inshore or near islands, d) migration of sardine subpopulations, and e) age and length relationship. We recommend continued evaluation of maturity to eliminate any biases.

We examined the relative frequency of length of sardines taken in 2011 and compared them to those taken during a similar period in the standard DEPM area in previous years (Figure 8 and 9). The mean size of sardines (male and females) was slightly smaller than the recent three years (2008-2010), slightly larger than 2005-2007, and much smaller than 2004 (Figure 9). The length distribution of sardine caught during 2011 shows two size modes: one peaking about 185 mm and the other about 230 mm with a severe dip in the 210 mm length class (Figure 8). The smaller size mode was almost absent in 2010 and low in quantity in 2008 and 2009 surveys while the larger lengths are consistent with increasing size of an aging fish population during 2008-2010. 67% of the females caught between 155mm and 194 mm standard length were immature in 2010. We believe that the most likely explanation for the smaller fish is good recruitment of the 2010 year class. It could possibly also be due to 1) conducting trawls and capturing sardines inshore (6 trawls with sardine in 2011, 0 during 2008-2010) where sardines are known to be small relative to offshore (Lo et al. 2007a), or 2) movement of smaller sizes slightly farther offshore since 43% of offshore sardine were less than 195 mm standard length. We recommend that to improve the whole population adult parameter analyses more trawls should continued to be added in the inshore areas to obtain spawning and maturity information on smaller fish to avoid possible bias against smaller fish.

Spawning biomass

In the DEPM survey area, the 2011 estimate of spawning biomass using the traditional method was 383,286 mt, based on the egg production of 1.16 eggs/0.05m$^{2/}$day, and the daily specific fecundity of 19.04 eggs/g/day. This production was primarily in the area between CalCOFI line 70.0 and 83.3 (35.5 °N and 34.16 °N). The spawning biomass was considerably higher than for most previous years (Table 4). The high spawning biomass is primarily due to the high egg production in the high-density area (Table 3) and an average adult reproductive output (Table 3). Note that the egg production rate of 5.57 eggs/0.05m^2 in the high-density area was higher than 2010: 1.70 eggs/0.05m2, and 2009: 1.69 eggs/.05m^2 (Lo et al. 2009). The overall daily egg production, 1.16 eggs/0.05m2, is much higher than most recent years: 0.36 eggs/0.05m^2/day in 2010, 0.59 in 2009, 0.43 in 2008, 0.864 in 2007, and lower than 1.936 in 2006, and 1.916 eggs/0.05m^2 in 2005. The area of Region 1 of 41,000 km^2 was larger than 27,462 km^2 in 2010 and smaller than other years. The adult daily reproductive output (daily specific fecundity) was similar to that in the previous year. The higher values in early years were due to the fact that trawl samples were taken in the high-density area only. Since 2005, trawl samples have been taken in both Region 1 and Region 2. The high daily egg production rate and the daily specific fecundity (19.04) similar to 2010 estimate (18.07), indicate that the spawning biomass is increasing. The difference between the estimates of spawning biomasses between 2010 and 2011 was statistically significant (t = 2.6). The significant difference of spawning biomass indicated that the spawning biomass of Pacific sardine has not been declining from 2010 to 2011. For the stock assessment, we provided the estimates of female spawning biomass for years where adequate adult samples were available (Table 6).

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Table 1. Number of positive tows of sardine eggs from CalVET, yolk-sac larvae from CalVET and Bongo, eggs from CUFES and positive sardine trawls[a] in Region 1 (eggs/min ≥ 1), Region 2 (eggs/min < 1) for *Frosti* , and *Shimada* cruises of 2011 April CCE survey. Both *Shimada* and *Frosti* occupied part of the standard DEPM survey area: *Shimada* occupied the area from from Cape Flattery, Washington to CalCOFI line 93.3, with most stations between CalCOFI lines 93.3 to 63.3. *Frosti* occupied the area from San Francisco to San Diego (CalCOFI line 61.7 to 95.0). The area north of CalCOFI line 60.0 is referred to as 'North' and the standard DEPM survey area is CalCOFI lines 95.0 – 60.0. (note: I did change 61.7 to 60.0 for 2011)

		Region 1			**Region 2**			**Grand Total**		
		Total	North	DEPM	Total	North	DEPM	Total	North	DEPM
CalVET Eggs	Positive	35	0	35	11	0	11	46	0	46
	Total	48	0	48	107	3	104	154	3	151
CalVET Yolk-sac	Positive	18	0	18	14	0	14	32	0	32
	Total	48	0	48	107	3	104	154	3	151
Bongo Yolk-sac	Positive	10	0	10	39	0	39	49	0	49
	Total	11	0	11	121	3	118	132	3	129
CUFES Eggs	Positive	131	0	131	202	0	202	333	0	333
	Total	161	0	161	762	100	662	923	100	823
Trawls	Positive	15	--	15	22	1	21	37	1	36
	Total	22	--	22	83	5	78	105	5	100

[a] All sardines were captured at night.

Table 2. Sardine egg density region, individual trawl information, sex ratio[a], and parameters for mature female sardine, *Sardinops sagax*, used in the estimation of the April 2011 west coast spawning biomass. Collection 2740 is north of CalCOFI line 60 and the other 36 trawls are in the standard DEPM sampling area off California.

COLLECTION INFORMATION									MATURE FEMALES							
				Location										Number spawning		
Region 1=high 2=low	No.	Month-Day	Time	Latitude °N	Longitude °W	Surface Temp. °C	No. of fish	Sex Ratio	No. anal-yzed	Body weight (g) Ave.	Weight without ovary (g) Ave.	Batch Fecundity Ave.	Adj. No.[b]	Night of capture	Night before capture	2 Nights before capture
2	2740	3-24	19:39	46.041	124.320	09.4	2	0.484	0	0.00	0.00	0	0.0	0	0	0
2	2656	4-02	00:46	37.398	122.800	12.6	1	1.000	0	0.00	0.00	0	0.0	0	0	0
2	2743	3-27	19:41	37.233	122.786	12.1	5	0.821	0	0.00	0.00	0	0.0	0	0	0
2	2744	3-27	23:07	37.168	122.933	11.7	26	0.722	1	91.00	83.34	30431	1.0	0	0	0
2	2745	3-28	01:52	37.086	122.801	12.2	8	0.597	1	78.00	73.87	18197	1.0	0	0	0
2	2658	4-03	21:33	36.815	122.244	12.6	4	0.571	0	0.00	0.00	0	0.0	0	0	0
2	2746	3-28	19:33	36.575	124.239	13.0	5	0.878	3	131.50	120.76	35301	3.0	0	0	0
2	2747	3-28	21:43	36.506	124.413	12.9	50	0.702	25	136.82	126.33	40763	24.5	1	0	1
2	2748	3-29	01:15	36.285	124.412	12.7	50	0.516	25	163.76	150.57	50777	23.0	3	1	1
2	2752	4-04	23:59	35.813	124.200	12.7	69	0.627	6	139.17	131.97	38622	6.0	0	0	0
2	2679	4-14	19:08	35.520	123.127	12.8	5	0.637	2	161.44	153.06	41578	1.0	1	0	0
2	2695	4-17	22:36	35.447	121.583	11.6	4	0.728	0	0.00	0.00	0	0.0	0	0	0
2	2680	4-14	21:10	35.428	123.303	12.9	6	0.701	4	139.20	129.76	37063	3.0	1	0	0
1	2754	4-05	22:27	35.371	123.515	12.9	1	0.000	0	0.00	0.00	0	0.0	0	0	0
2	2689	4-15	01:22	35.333	123.048	13.0	6	0.522	3	140.17	131.75	47061	3.0	0	0	0
1	2688	4-14	23:03	35.250	123.238	12.9	1	1.000	1	150.00	142.71	36424	1.5	0	0	1
1	2693	4-16	22:46	34.700	123.211	13.4	13	0.717	8	118.94	112.12	37308	10.0	0	0	4
1	2786	4-25	21:40	34.593	121.841	13.5	21	0.254	5	83.07	78.10	21996	2.0	3	0	0
2	2662	4-08	19:20	34.572	122.746	13.1	2	1.000	2	143.00	132.38	39833	2.0	0	0	0
1	2785	4-25	19:30	34.505	122.027	13.6	2	0.574	1	109.00	101.02	29675	1.0	0	0	0
1	2670	4-10	19:47	34.492	121.293	13.3	83	0.705	25	135.81	127.00	40704	14.5	12	2	1
2	2663	4-08	21:21	34.487	122.891	13.2	36	0.474	14	88.10	81.70	24603	13.5	1	0	1
1	2672	4-11	01:35	34.420	121.432	13.3	4	0.800	3	108.17	102.49	29675	4.5	0	1	2
1	2665	4-09	01:22	34.394	122.653	13.3	50	0.527	25	139.76	130.50	40402	27.0	1	1	5
1	2671	4-10	21:52	34.364	121.145	13.5	7	0.427	3	112.00	105.59	31492	2.0	1	0	0
1	2664	4-08	23:18	34.343	122.812	13.4	40	0.659	23	121.19	112.65	37323	23.5	1	3	0
1	2696	4-18	19:52	34.342	122.343	13.4	27	0.194	5	136.03	128.80	47040	1.5	4	0	1
1	2699	4-19	01:55	34.339	122.215	13.5	2	1.000	2	154.75	147.09	51371	3.0	0	0	2
2	2691	4-16	00:58	34.242	124.213	12.5	50	0.516	18	78.64	75.13	24217	20.0	2	2	6
1	2698	4-18	23:50	34.208	122.236	13.5	7	0.778	5	125.20	118.33	41500	4.5	1	0	1
1	2697	4-18	21:45	34.183	122.381	13.5	8	0.758	6	134.42	127.41	40662	7.0	0	1	1
2	2692	4-16	03:43	34.167	124.369	12.9	52	0.512	16	125.88	119.20	38672	15.0	3	1	3
2	2667	4-09	21:07	33.748	122.840	13.3	4	0.388	1	128.01	120.19	43448	0.0	1	0	0
2	2668	4-09	23:10	33.616	122.754	13.4	1	1.000	1	136.00	131.07	37564	0.0	1	0	0
1	2704	4-20	21:37	33.545	121.576	13.6	3	1.000	3	125.33	120.36	43017	4.5	0	3	0
2	2669	4-10	01:08	33.512	122.870	13.5	11	0.704	7	135.14	130.79	41775	9.5	0	4	1
2	2716	4-24	22:41	32.375	118.908	14.7	1	0.000	0	0.00	0.00	0	0.0	0	0	0
									244				232.0	37	19	31

[a] Sex ratio, proportion of females by weight, based on average weights from subsamples and number of fish sampled in each trawl(Picquelle and Stauffer 1985).
[b] Mature adjusted by the average number of females spawning the night before capture and females spawning 2 nights before capture

Table 3. Egg production (P_0) of the Pacific sardine in 2011 based on egg data from CalVET and yolk-sac larval data from CalVET and Bongo in Region 1 (eggs/min ≥ 1) and Region 2 (eggs/min < 1) from *Frosti* (April 1- 27), and *Shimada* (March 23-April 27) cruises, adult parameters from positive trawls (April 3 – 25), and 2011 spawning biomass estimates.

Parameter	Region 1	Region 2		DEPM Area
		North	DEPM	
CUFES samples	161	100	662	**823**
CalVET samples	47	3	104	**151**
P_0 / 0.05m^2	5.57 [a]	0	0.49	**1.16**
CV	0.24	--	0.33	**0.26**
Area (km^2)	41,878	—	272,603	**314,481**
% Whole coast	—	—	—	**—**
% DEPM area	13	--	87	**100**
Year of adult samples	2011	2011	2011	**2011**
Female fish wt (W_f)	128.36	30.5 [b]	126.92	**127.59**
Batch fecundity (F)	38805	--	37980	**38369**
Spawning fraction (S)	0.136	--	0.084	**0.1078**
Sex ratio (R)	0.589	--	0.586	**0.587**
(RSF)/W_f	24.26	--	14.67	**19.04**
Spawning biomass (mt) Traditional method [c]		--		**383,286**
CV				**0.32**
Spawning biomass (mt) Stratified procedure [d]	192,332	--	181,016	**373,348**
CV	0.31		0.48	**0.28**
Daily mortality (Z)	0.51			
CV	0.14			
eggs/min	1.66		0.23	**0.45**
CV	0.21		0.28	**0.36**
q = eggs/min in Reg.2 / eggs/min in Reg.1				**0.164**
CV				**0.37**
E = (eggs/min)/(eggs/tow)				**0.058**
CV				**0.24**
Bongo samples	11	3	118	**129**
Area in nm^2	12,236	--	79,650	**91,886**
Spawning biomass (short ton) (need to do)	211,565	--	199,118	**410,683**

[a] 5.57 was corrected for bias of P_0.
[b] single immature female and no eggs collected in North, no biomass estimated for this area
[c] biomass was computed from estimates of parameters in each column, e.g., DEPM area is an average of adult parameters from Region 1 and DEPM Region 2.
[d] biomass was computed by the stratified procedure, i.e., total spawning biomass = the sum of the estimates of spawning biomass in Region 1 and Region 2: 373,348 = 192,332 + 181,016.

Table 4. Estimates of daily egg production (P_0)[a] for the DEPM survey area, daily instantaneous mortality rates (Z) from high-density area (Region 1), daily specific fecundity (RSF/W), spawning biomass of Pacific sardines using the traditional method and average sea surface temperature for the years 1994 to 2011.

Year	P_0 (CV)	Z (CV)	Area (km^2) (Region 1)	RSF[h]/W	Spawning biomass (mt) (CV)[b]	Mean Temp. for positive egg or yolk-sac samples	Mean temperature all CalVETs
1994	0.193 (0.210)	0.120 (0.91)	380,175 (174,880)	11.38	127,102 (0.32)	14.3	14.7
1995	0.830 (05)	0.400 (0.4)	113,188.9 (113188.9)	23.55[c]	79,997 (0.6)	15.5	14.7
1996	0.415 (0.42)	0.105 (4.15)	235,960 (112,322)	23.55	83,176 (0.48)	14.5	15.0
1997	2.770 (0.21)	0.350 (0.14)	174,096 (66,841)	23.55[d]	409,579 (0.31)	13.7	13.9
1998	2.279 (0.34)	0.255 (0.37)	162,253 (162,253)	23.55	313,986 (0.41)	14.38	14.6
1999	1.092 (0.35)	0.100 (0.6)	304,191 (130,890)	23.55	282,248 (0.42)	12.5	12.6
2000	4.235 (0.4)	0.420 (0.73)	295,759 (57,525)	23.55	1,063,837 (0.67)	14.1	14.4
2001	2.898 (0.39)	0.370 (0.21)	321,386 (70,148)	23.55	790,925 (0.45)	13.3	13.2
2002	0.728 (0.17)	0.400 (0.15)	325,082 (88,403)	22.94	206,333 (0.35)	13.6	13.6
2003	1.520 (0.18)	0.480 (0.08)	365,906 (82,578)	22.94	485,121 (0.36)	13.7	13.8
2004	0.960 (0.24)	0.250 (0.04)	320,620 (68,234)	21.86[e]	281,639 (0.3)	13.4	13.7
2005	1.916 (0.417)	0.579 (0.20)	253,620 (46,203)	15.67	621,657 (0.54)	14.21	14.1
2006	1.936 (0.256)	0.31 (0.25)	336,774 (98,034)	15.57[f]	837,501[f] (0.46)	14.95	14.5
2007	0.864 (0.256)	0.133 (0.36)	356,159 (142,403)	15.68	392,492 (0.45)	13.7	13.6
2008[g]	0.43 (0.21)	0.13 (0.29)	297,949 (53,514)	21.82	117,426 (0.43)	13.3	13.1
2009	0.59 (0.22)	0.25 (0.19)	274895 (74,966)	17.53	185,084 (0.28)	13.6	13.5
2010[i]	0.36 (0.40)	0.33 (0.23)	271,773 (27,462)	18.07	108,280 (0.46)	13.7	13.9
2011	1.16 (0.26)	0.51 (0.14)	314,481 (41,878)	19.04	383,286 (0.32)	13.5	13.6

a weighted non-linear regression on original data and bias correction of 1.04, except in 1994 and 1997 when grouped data and a correction factor of 1.14 was used (appendix Lo 2001).

b $CV(B_s) = (CV^2(P_0) + \text{allotherCOV}^2)^{1/2} = (CV^2(P_0)+0.054)^{1/2}$. For years 1995 – 2001 allotherCOV^2 was from 1994 data (Lo et al. 1996). For year 2003, allotherCOV was from 2002 data (Lo and Macewicz 2002)

c 23.55 was from computation for 1994 based on S = 0.149 (the average spawning fraction (day 0 + day 1) of active females from 1986 – 1994; Macewicz et al. 1996).

d is 25.94 when calculated from parameters in 1997 (table 9) and estimated spawning biomass is 371,725 mt with CV = 0.36

e uses R = 0.5 (Lo and Macewicz 2004); if use actual R = 0.618, then value is 27.0 and biomass is estimated at 227,746 mt

f value for standard DEPM sampling area off California when calculated using S = 0.126, the average of females spawning the night before capture ("day 1") from 1997, 2004, 2005, and 2007. When 2006 survey S of 0.0698 was previously used (Lo et al. 2007a), the 2006 DEPM spawning biomass was estimated as 1,512,882 mt (CV 0.46) and the 2006 coast-wide spawning biomass was estimated as 1,682,260 mt

g standard DEPM sampling area off California from San Diego to CalCOFI line 66.7 whole 2008 survey area off west coast of North America from about 31°N to 48.47°N latitude, spawning biomass was estimated as 135,301 mt(CV=0.43)

h RSF/W from 2009 is based on S_{12},:average of day1 and day2 females.

i The whole survey area was 477,092 km^2 from San Diego, CA to Cape Flattery,Wa. .Very few sardine eggs were observed north of the DEPM survey area (CalCOFI line 60.0 is the northern boundary of the DEPM area)

Table 5. Estimated 2011 adult parameters and correlations for each region[a] in the DEPM area outputted from the EPM program (Appendix II Chen et al. 2003).

Region 1 DEPM area

Statistic Results:

	Average	Variance
Whole Body Weight	128.3571636	17.3317798261
Gonad Fee Weight	120.342368696	15.0403107045
Batch fecundity	38805.1157582	3809719.74811
Spawners, Day 0	0.2	0.00782387669
Spawners ave (day1+day2)	0.13615015493	0.00059430486
Sex Ratio	0.58929453354	0.00428845086
Daily specific fecundity	24.2560134095	
Number of Sets	14	

CORRELATIONS

Parameter	W	F	S	R
Whole - Body Weight (W)		0.87548224	0.01666435	0.13641787
Batch Fecundity (F)			0.1349069	0.10537435
Fraction Spawning (S)				-0.1250504
Sex Ratio (R)				

Region 2 DEPM area

Statistic Results:

	Average	Variance
Whole Body Weight	126.916043473	127.105383264
Gonad Fee Weight	118.520213178	101.432781818
Batch fecundity	37980.8817397	17112443.7393
Spawners, Day 0	0.10852713178	0.00055716306
Spawners ave (day1+day2)	0.08366522311	0.00088167375
Sex Ratio	0.58584137154	0.00096508963
Daily specific fecundity	14.6680887637	
Number of Sets	16	

CORRELATIONS

Parameter	W	F	S	R
Whole - Body Weight (W)		0.99116278	-0.569925	0.07617438
Batch Fecundity (F)			-0.496786	0.00035832
Fraction Spawning (S)				-0.2911582
Sex Ratio (R)				

DEPM area

Statistic Results:

	Average	Variance
Whole Body Weight	127.595259926	38.1929626883
Gonad Fee Weight	119.379015984	30.7762408932
Batch fecundity	38369.3526910	7082578.4693
Spawners, Day 0	0.15163934426	0.00200223903
Spawners ave (day1+day2)	0.10775852155	0.00036635926
Sex Ratio	0.5874331229	0.00115467504
Daily specific fecundity	19.0353114374	
Number of Sets	30	

CORRELATIONS

Parameter	W	F	S	R
Whole - Body Weight (W)		0.98160171	-0.4288243	0.07873889
Batch Fecundity (F)			-0.3770331	0.03661725
Fraction Spawning (S)				-0.1127607
Sex Ratio (R)				

[a] Area of Region 1 is 41,878 km^2, Region 2 DEPM area is 272,603 km^2, and the DEPM area is 314,481 km^2

Table 6. The 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); s. biomass, female spawning biomass, total egg production (TEP) and sea surface temperature for 1986, 1987, 1994, 2004, 2005 and 2007-2011

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 (0.44)	18111 (0.39)		46685.4		
		2	0.22(0.42)		14.55	16.20	26.65	244311	66345 (0.58)	40336 (0.58)		53748.42		
		whole	0.36(0.29)		16.08	18.07	31.49	271773	108280 (0.46)	62131 (0.46)	58447 (0.42)	97838.28	13.7	13.9
2011	2010	1	5.57(0.24)	0.51(0.14)	19.03	24.26	41.16	41878	192332 (0.31)	113340 (0.30)		233260.5		
		2	0.487(0.33)		11.40	14.67	25.04	272603	181016 (0.48)	106046 (0.49)		132757.7		
		whole	1.16(0.26)		14.85	19.04	32.40	314481	383286 (0.32)	225155 (0.32)	219386 (0.28)	364798.0	13.5	13.6

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 2007 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

6. Within southern and northern area, the survey area was stratified as Region 1 (eggs/0.05m2>0 with embedded zero) and Region 2 (zero eggs)

Table 7. Temperature range (3m depth) and presence (+) of Pacific sardine eggs collected in CUFES samples and adults taken in trawls during the spring 2006, 2008, and 2010 surveys off the west coast of the United States.

Survey Information	**April 2006**	**April 2008**	**April 2010**	**April 2011**
Washington – Oregon: 48.5° – 42°N				
Sea Temperature Range	9.1-11.8°C	8.2-10.1 °C	9.5-11.4°C	9.4-9.5
Mean °C of sardine positive trawls	na	na	na	9.4
Number positive trawls (total)	0 (9)	0 (25)	0 (12)	1 (5)
Number of sardine sampled	-	-	-	2
Mean body weight (g)	-	-	-	31g
Eggs, Region 1	+	-	-	-
Eggs, Region 2	+	-	-	-
Northern California: 42°N – CalCOFI line 60				
Sea Temperature Range	10.8-12.2°C	7.8-11.6°C *	9.6-13.2°C	-
Mean °C of sardine positive trawls	11.4°C	11.5°C	13.2°C	-
Number positive trawls (total)	3 (4)	1 (15)	1 (17)	0
Number of sardine sampled	101	1	50	-
Mean body weight (g)	91g	148g	152g	-
Eggs, Region 1	+	-	-	-
Eggs, Region 2	+	+	+	-
standard DEPM: CalCOFI lines 60 – 95 (San Francisco – San Diego)				
Sea Temperature Range	13.3-16.6°C	11.2-15.5°C	12.1-15.9°C	9.9-16.3°C
Mean °C of sardine positive trawls	14.4°C	12.4°C	13.6°C	13.1°C
Number positive trawls (total)	7 (22)	12 (31)	18 (68)	36 (100)
Number of sardine sampled	194	353	635	666
Mean body weight (g)	67g	105g	127g	108g
Eggs, Region 1 (area, km^2)	+ (98034)	+ (53514)	+ (27462)	+ (41878)
Eggs, Region 2	+	+	+	+
Whole DEPM area P_0	1.96	0.43	0.36	1.16

* a single negative offshore trawl at 38.4°N recorded 13.2°C

Table 8. Pacific sardine female adult parameters for surveys conducted in the standard daily egg production method (DEPM) sampling area off California (1994 includes females from off Mexico).

		1994	1997	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011
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	8-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	03/23-04/25
N collections with mature females		37	4	2	6	16	14	7	14	12	29	17	30
N collection within Region 1		19	4	2	6	16	6	2	8	4	15	3	14
Average surface temperature (°C) at collection locations		14.36	14.28	12.95	12.75	13.59	14.18	14.43	13.3	12.4	12.93	13.62	13.12
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	0.587
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	127.59
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	119.38
Average batch fecundity[a] (mature females, oocytes estimated)	**F**	24283	42002	22456	54403	55711	17662	18474	21760	29802	29790	39304	38369
Relative batch fecundity (oocytes/g)		294	329	284	342	334	270	274	267	292	265	303	301
N mature females analyzed		583	77	9	23	290	175	86	203	187	467	313	244
N active mature females		327	77	9	23	290	148	72	187	177	463	310	244
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	0.1078
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	0.1078
Daily specific fecundity	$\frac{\mathbf{RSF}}{\mathbf{W}}$	11.7	25.94	21.3	22.91	27.04	15.67	8.62	15.68	21.82	17.53	18.07	19.04

[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), and 2010 used F_b = 5136 + 287.37W_{of} + e (Lo et al. 2010b).

[b] Mature females include females that are active and those that are postbreeding (incapable of further spawning this season). S_1 was used for years prior to 2009 and S_{12} was used staring in 2009.

[c] Active mature females are capable of spawning and have ovaries containing oocytes with yolk or postovulatory follicles less than 60 hours old.

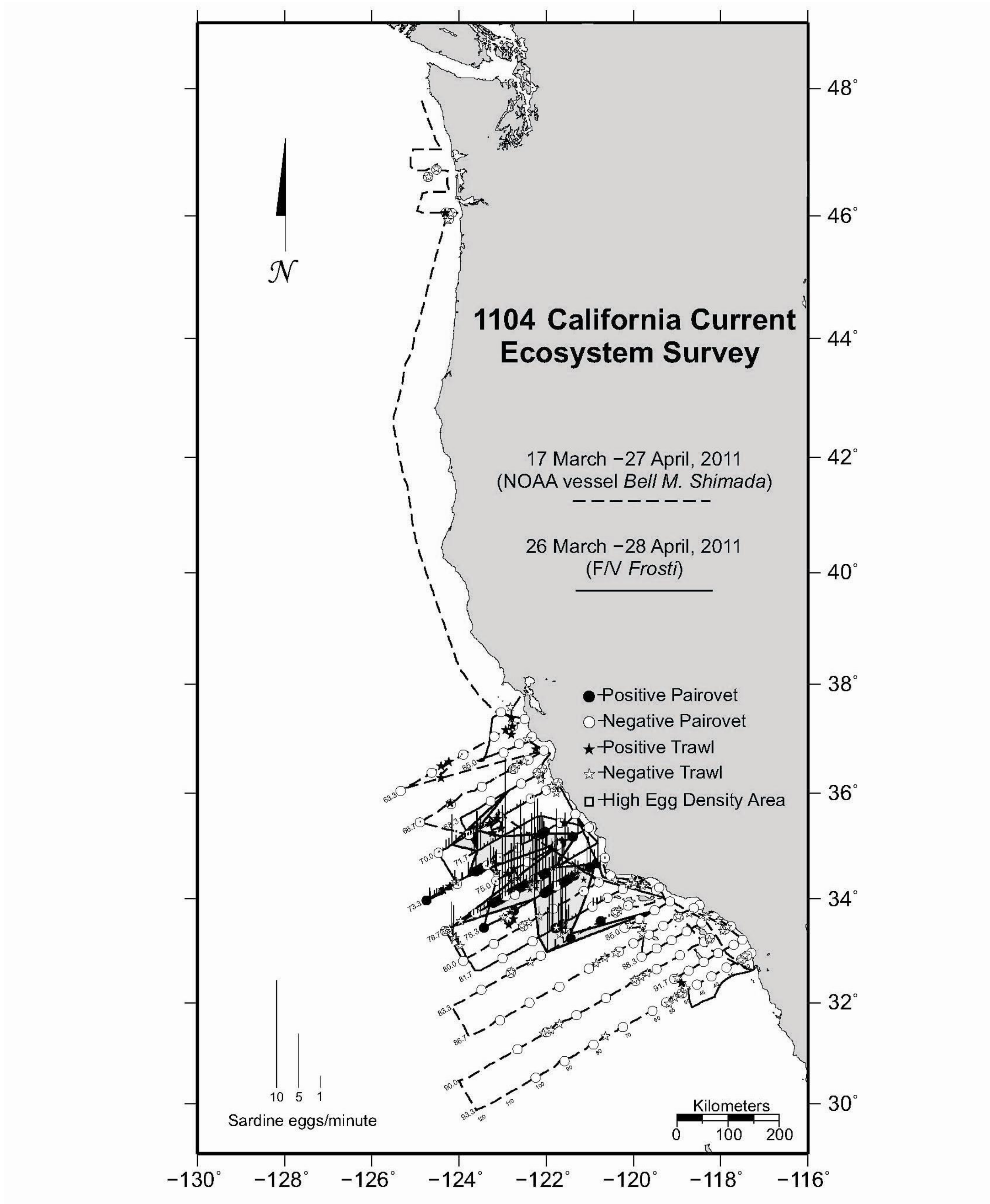

Figure 1. Location of sardine eggs collected from CalVET, a.k.a. Pairovet; (solid circle is a positive catch and open circle is zero catch) and from CUFES (stick denotes positive collection), and trawl locations (solid star is catch with sardine adults and open star is catch without sardines) during the 2011 survey aboard two vessels: F/V *Frosti* (solid line) and R/V *Shimada* (dash line). Shaded area is Region 1, the high egg-density area, and the rest of survey area is Region 2.

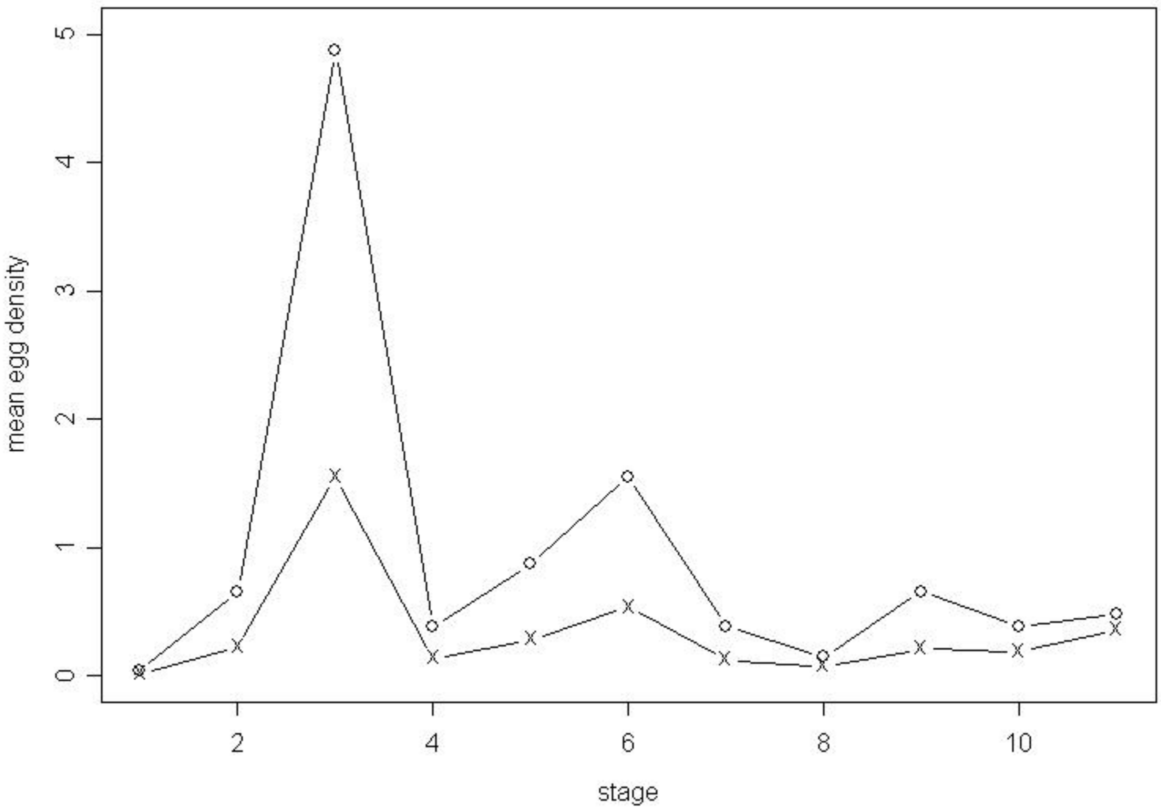

Figure 2. Mean sardine egg density (eggs per 0.05 m^2) for each developmental stage within each area for April 2011. Symbols: o = Region 1 and x = DEPM survey area (CalCOFI line 95 to 60).

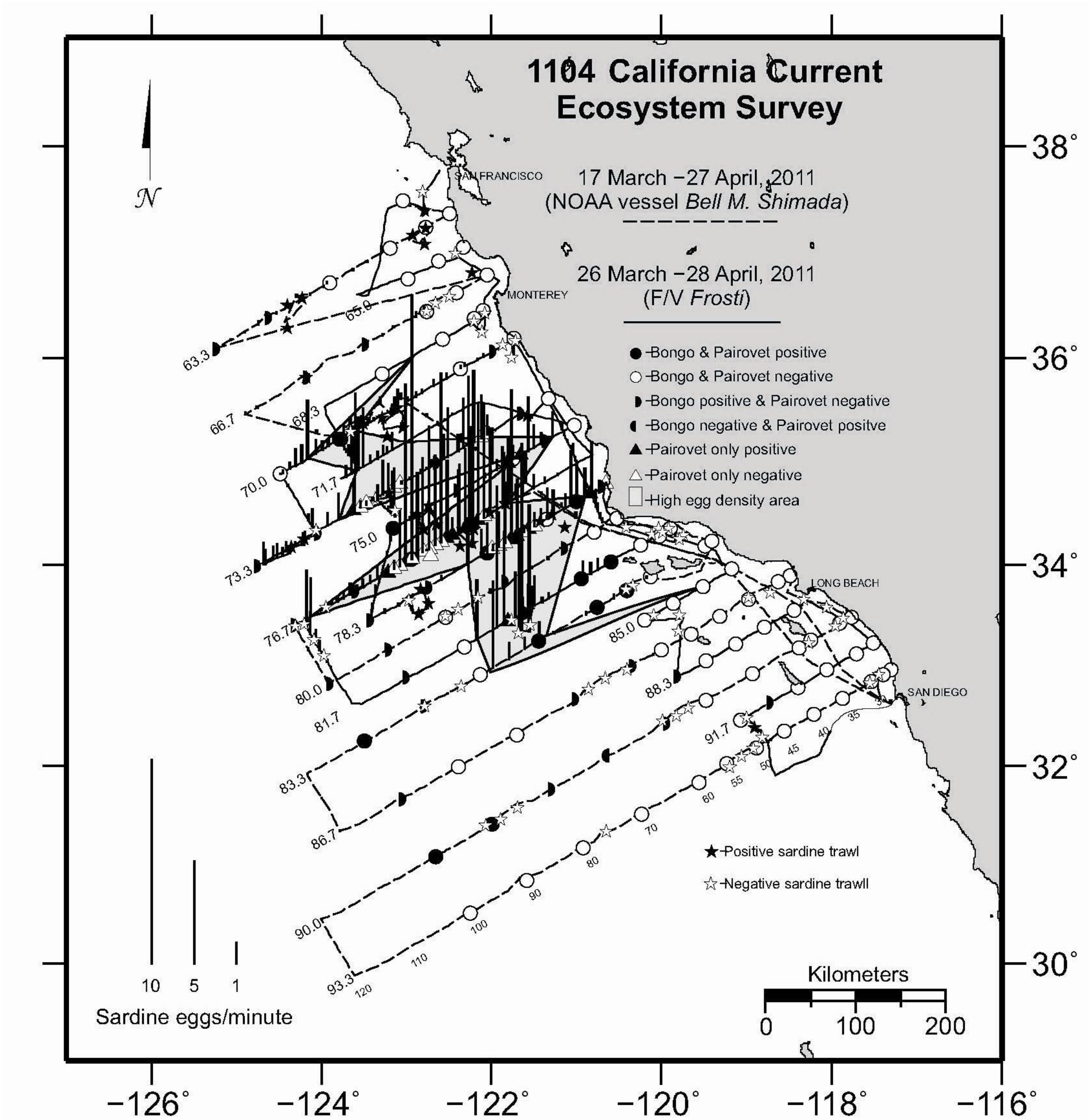

Figure 3. Location of sardine trawls (star), yolk-sac larvae collected from CalVET (or Pairovet; circle and triangle) and from Bongo (circle and square) during the 2011 survey aboard two vessels: F/V *Frosti* (solid line) and R/V *Shimada* (dash line). Solid symbols are positive and open symbols are zero catch. Few yolk-sac larvae were caught north of CalCOFI line 60.0. The shaded area is Region 1: the high egg-density area. Region 2 in the standard DEPM area includes the rest of the survey area shown between CalCOFI line 95.0 and 60.0.

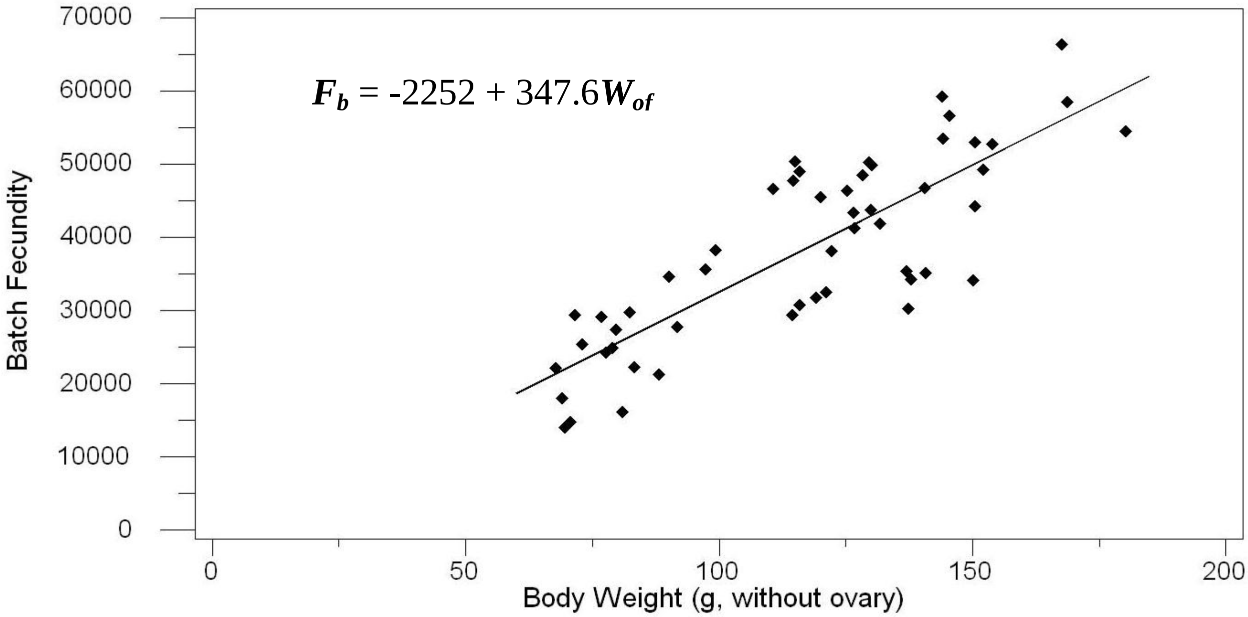

Figure 4. Batch fecundity (F_b) of *Sardinops sagax* as a function of female body weight (W_{of}, without the ovary) for 52 females taken onboard the *Shimada* and *Frosti* during April 2011. The batch was estimated from the number of hydrated or migratory-nucleus-stage oocytes.

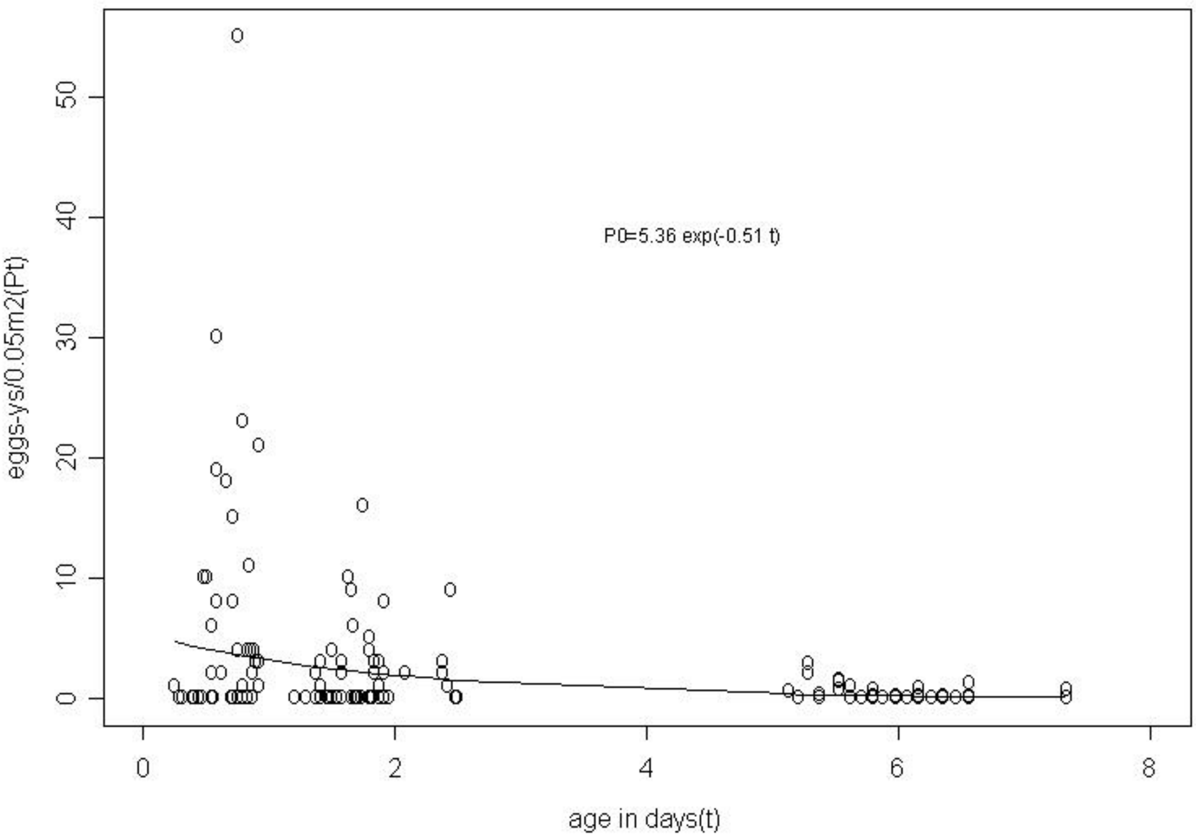

Figure 5. Embryonic mortality curve of Pacific sardines. Staged egg data were from CalVET and yolk-sac larval data were from CalVET and Bongo during April 2011, onboard *Shimada* and *Frosti*. The number, 5.36, is the estimate of daily egg production at age 0 (P_0) before correction for bias.

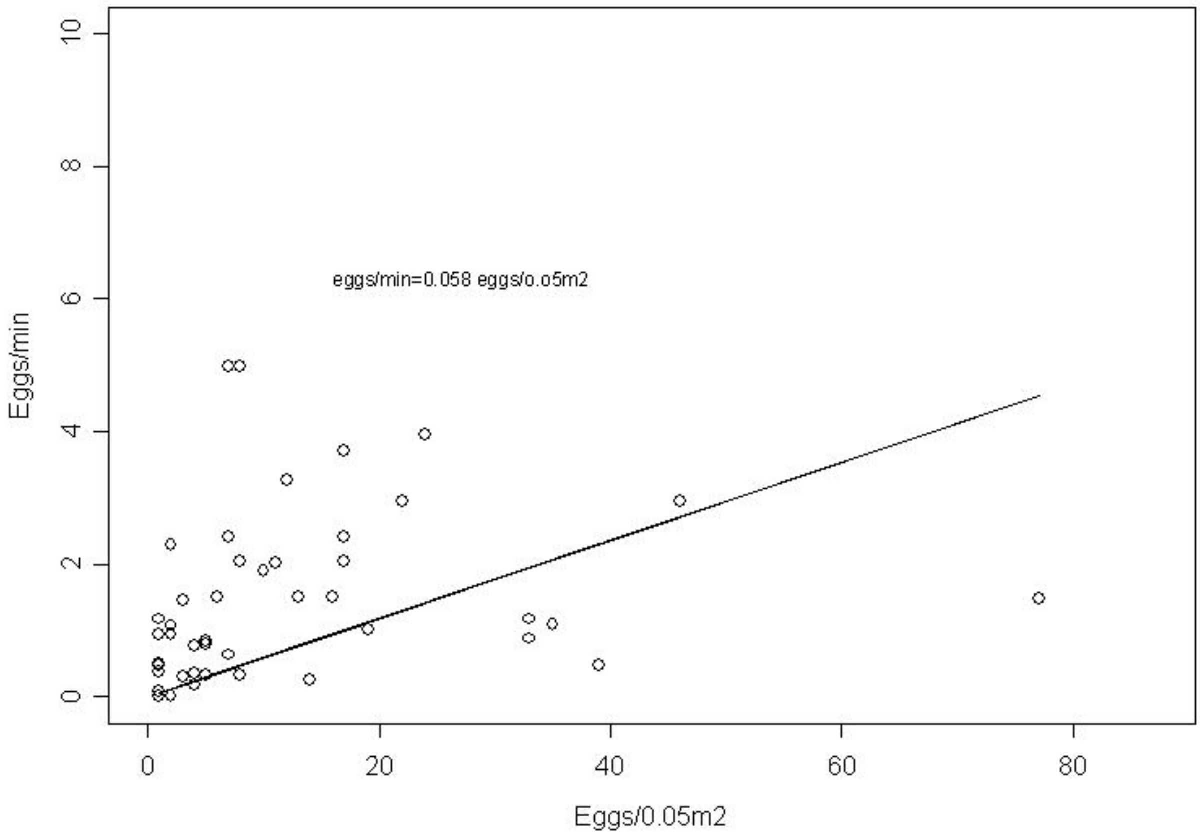

Figure 6. Catch ratio of eggs/min from CUFES to eggs/0.05m^2 from CalVET during April 2011 from *Frosti* and *Shimada* collections.

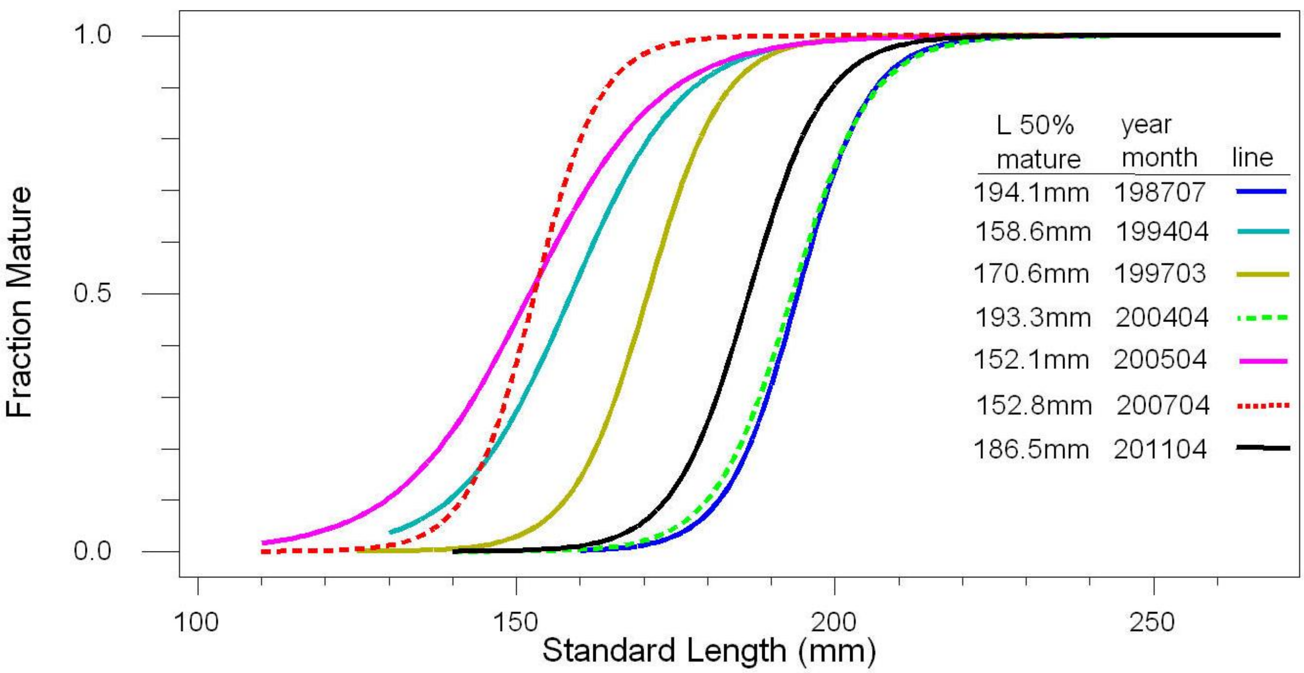

Figure 7. Fraction of Pacific sardine females randomly sampled during seven DEPM sardine surveys that were sexually mature as a function of standard length. The length at 50% maturity from the April 2011 survey was the third largest at 186.5 mm. Insufficient immature females were collected during 2002, 2008, 2009, and 2010 DEPM surveys to calculate length at 50% mature.

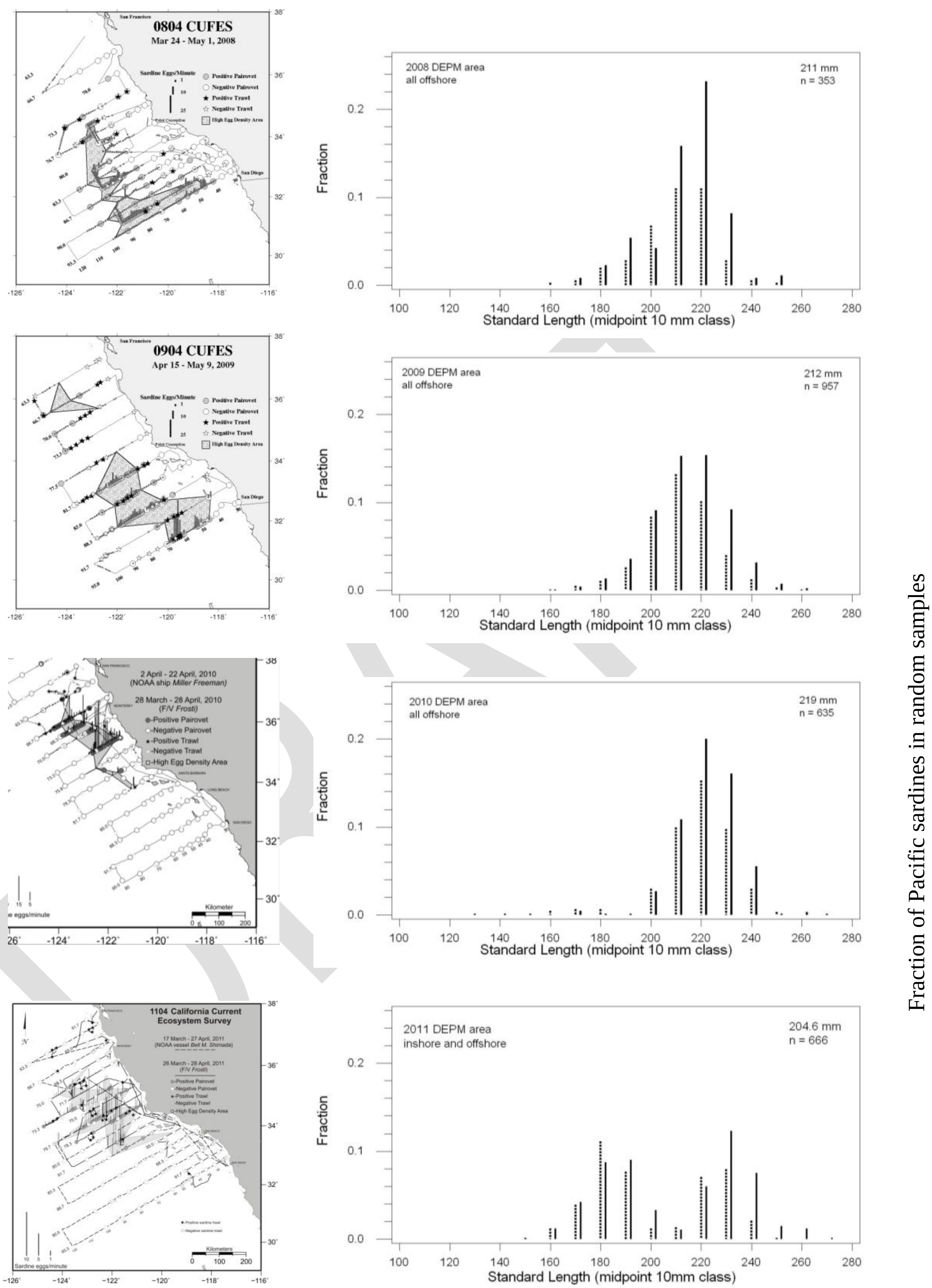

Figure 8. Trawl-egg map, length distribution and mean length of Pacific sardines caught in the 2008, 2009, 2010, and 2011 DEPM survey areas. Males indicated by dotted bars and females by solid bar.

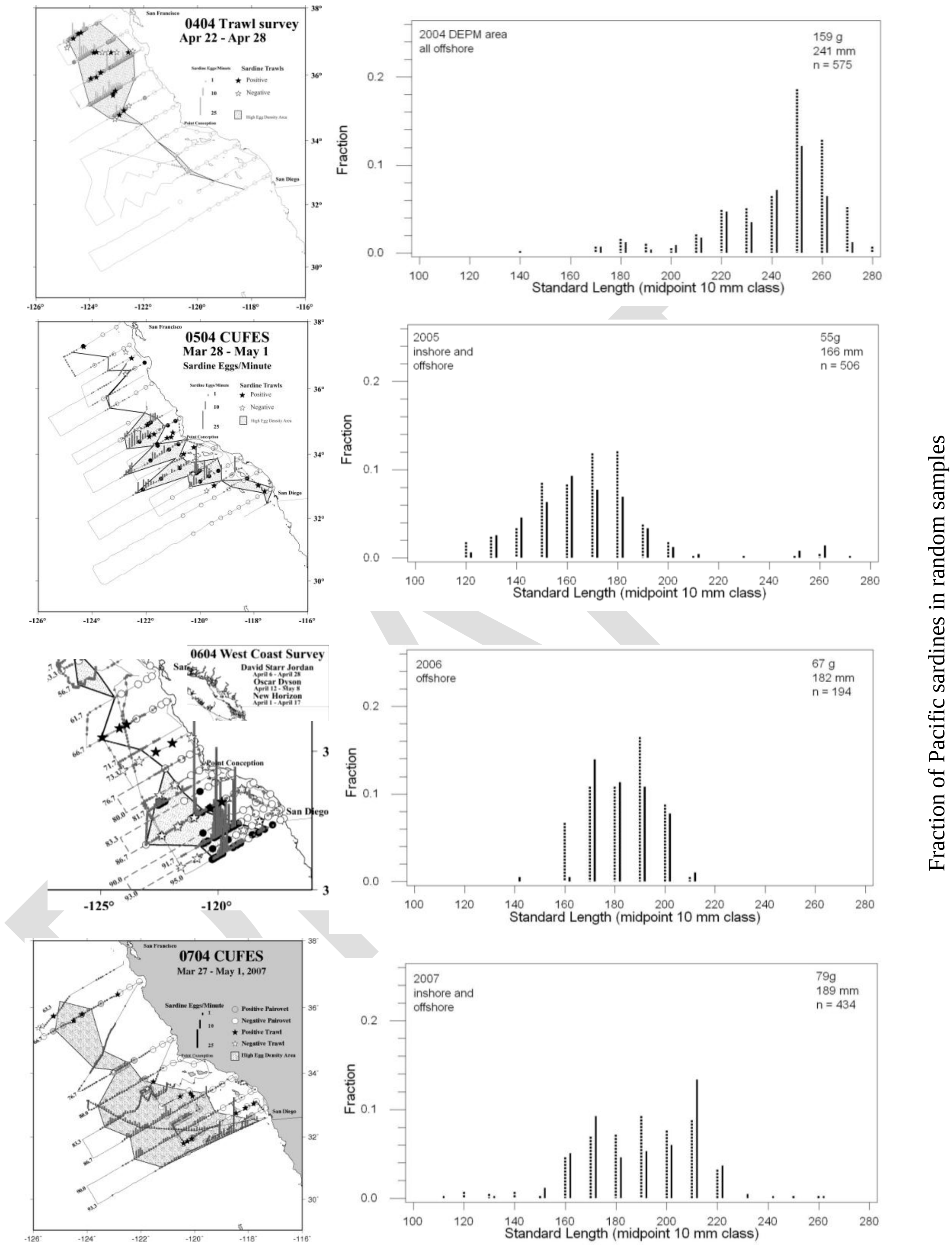

Figure 9. Trawl-egg map, length distribution and mean length and weight of Pacific sardines caught in the 2004, 2005, 2006 and 2007 DEPM survey areas. Males indicated by dotted bars and females by solid bar.

Northwest Aerial Sardine Survey

Sampling Results in 2011

Prepared by

Tom Jagielo[1]
Ryan Howe
and
Meghan Mikesell

for

Northwest Sardine Survey, LLC
c/o Jerry Thon, Principal
12 Bellwether Way, Suite 209
Bellingham, Washington 98225

October 13, 2011

[1] Tom Jagielo Consulting (TomJagielo@msn.com)

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 (Northwest Sardine Survey, LLC - NWSS). The methods employed by this survey were initially developed through pilot study work conducted in the northwest in 2008 (Wespestad et al. 2008) and were reviewed at Stock Assessment Review (STAR) panels in May and September of 2009. Full-scale surveys were subsequently performed by NWSS and the California Wetfish Producers Association (CWPA) in the coastal waters off Washington, Oregon, and California in the summers of 2009 and 2010 under Exempted Fishery Permits (EFPs) approved by PFMC and granted by the National Marine Fisheries Service (NMFS). Results from the 2009 and 2010 aerial sardine surveys were incorporated into the Pacific sardine stock assessment models used to set harvests for the 2010 and 2011 fishing years (Hill et al 2009; 2010).

Survey work in 2011 was again conducted off the coasts of Washington and Oregon by NWSS, using the same basic approach that was used in 2009 and 2010 (Jagielo et al 2009; 2010). 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. Additional logistical details of the survey are provided in a Field Operational Plan document (Appendix I).

Stage 1: Aerial Transect Survey

Transect 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. 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 2011 was Set A, followed by Set B, and finally Set C. The starting and ending positions for these transects are given in the Field Operational Plan (Appendix I).

Survey transects were parallel and were aligned in an east-west orientation. 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 Oregon/California border in the south. Two strata were established for sampling: 1) a northern zone from Cape Flattery, WA to the Newport, OR area, and 2) a southern zone from the Newport area to the Oregon/California border. Transects were spaced 7.5 nautical miles apart in the northern stratum (n = 31 transects); spacing was 15 nautical miles apart in the southern stratum (n = 10 transects) (Appendix I Tables 1a-1c).

Three pilots participated in the 2011 survey; two operated single engine airplanes, and one operated a twin engine airplane (Appendix I; Adjunct 3b, page 37). The prevailing conceptual model of West Coast sardine movement holds that fish tend to move in a northward direction during summer. Thus, the transect sets were conducted as follows. Two survey pilots operated as a coordinated team. 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 observation conditions were 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 the set 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 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.

Each survey plane was again equipped with the same Aerial Imaging Solutions photogrammetric aerial digital camera mounting system and data acquisition system as used in the 2008, 2009, and 2010 work (Appendix I, page 21). 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). In previous years, digital images were collected with 60% overlap to ensure seamless photogrammetric coverage; in 2011 we increased the overlap to 80%.

Transect Data Collection and Reduction

Photogrammetric calculations. 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* software. 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.

Photogrammetric Calibration. 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 at the Astoria, OR airport) was collected at a series of altitudes ranging from 1000 ft. to 4000 ft. The observed vs. actual sizes of the objects were subsequently compared to evaluate photogrammetric error. Measurements were made by 6 photograph analysts (PA1-PA6), for calibration flights made by 3 survey pilots (SP1-SP3). Average deviation ranged from -0.059 to 0.074 for the three camera systems employed in the study (Appendix II). Deviations generally tended to increase with altitude, as expected.

Transect Photograph Analysis. The procedure for analyzing the transect photographs involved three steps: 1) preliminary analysis, 2) school measurement, and 3) analysis of between-reader differences.

In the first step (preliminary analysis), a review of all transect photographs was conducted by a well seasoned member of the analysis team. The presence or absence of schools was noted for each transect photograph for the purpose of determining which photographs would be used for collecting sardine school measurements. Classification of transects according to readability criteria (described below) was also performed at this time.

In the second step (school measurement), transect photographs were assigned to two separate analysts for independent school detection and measurement. The two individuals worked independently (double-blind) and did not confer with each other regarding their work.

Finally, in the third step (analysis of between-reader differences), the two sets of transect school measurement readings were examined side-by-side to evaluate variability in the detection and measurement of schools. For the transects showing the largest deviation in total school surface area, the two readings were compared on a school-by-school basis (a process we called transect resolution). The object of this exercise was to identify where 1) schools were not detected by one of the analysts (i.e. they were missed and should be added to the set of readings), 2) objects (e.g. cloud shadows) were mistakenly measured as schools, and should be subtracted or 3) schools were inadvertently double-counted, and one of the measurements should be subtracted. Following transect resolution, we determined what portion of the area measurement differences could be attributed to either 1) school detection and identification, or 2) measurement of school areas.

Transect Readability. Transects were classified using a three point scoring system to characterize the overall readability of the photographs used in the analysis. For each transect, all photos were reviewed and transects were assigned a single readability value of either: 1 (for few impediments to readability), 2 (for moderate impediments), or 3 (for substantial impediments). Specific conditions were also documented, which included: 1) cloud cover, 2) water turbidity, 3) sea-surface chop, and 4) excessive glare. Detailed comments were also recorded to further document transect-specific conditions.

School Species Identification. We relied on real-time observations made by experienced fishery spotter pilots for the species identification of schools on the transects. The spotter pilots recorded their observations on a Transect Flight Log Form (Appendix I, page 28). The pilots also documented general conditions to aid in the subsequent interpretation of the transect photographs, including factors such as sea state, weather, and sea surface anomalies (e.g. tidal rips, bodies of fresh water or turbidity plumes).

Stage 2: At-Sea Point Set Sampling

<u>Point Set Logistics</u>

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 2011 (Appendix I; Adjunct 3, page 37).

Point sets were defined as sardine schools first identified by a survey pilot and subsequently captured in their entirety by a survey purse seine vessel. Spotter 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 Field Operational Plan (Appendix I, page 38).

The point set sampling design was stratified by school size, with the goals of obtaining 1) a range of sizes representative of schools photographed on the transects (keeping within a size range consistent with the safe operation of the vessels participating in the survey) and 2) a geographic distribution of schools that would be representative of schools found on the transects (to the extent logistically possible given operational constraints). Point sets were generally not attempted for schools larger than approximately 130 mt. Using the EFP set-aside amount of 2,700 mt, a total of n = 76 point sets were planned for 2011 (Appendix I; Table 2, page 12).

Point Set Data Collection and Reduction

School height information was collected at sea using purse-seine vessel sonar and down-sounder equipment, and was recorded by vessel skippers on a Point Set Vessel Log Form (Appendix I, page 31). The total weight of the school was determined from measurements made at the dock of landed weight.

School Surface Area. The method used to obtain measurements of surface areas for the point set schools was the same as that described above for measuring on transect photographs. For each point set, a series of photographs was taken to document the target school prior to the approach of the fishing vessel. Point set school size measurements were made using the best quality image available, prior to any observable influence by the vessel during the process of school capture. Observations by the spotter pilot were recorded on the Point Set Flight Log Form (Appendix I, page 30).

Biological Sampling. Species composition of the point sets and sardine biological parameters were determined from sampling the landings at the dock. 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 (Appendix I; Table 3, page 12). Observations were recorded on the Biological Sampling Form (Appendix I, page 29)

II. Analytical Methods

Total Biomass

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 the estimated surface area – biomass relationship), 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 III.

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 surface area 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 surface area 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 $(\hat{B})$ 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.

The school measurement process described above was conducted by two independent readers; thus two estimates of total biomass were obtained. The two separate estimates of biomass were then averaged to obtain the final biomass estimate.

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 – biomass relationship:

$$d_i = (yz + xa_i)/(z + a_i)$$

where

d_i = school surface area density (mt/m^2)
a_i = school surface area (m^2)
y = y intercept
x = asymptote as x approaches infinity
x/z = slope at the origin.

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

Total Biomass - Coefficient of Variation (CV)

The CV of the total biomass estimate was obtained by employing a bootstrapping procedure implemented with the R statistical programming language (Appendix III). The intent of the procedure was to propagate error through the entire process of biomass estimation, incorporating variability due to error in: 1) the surface area - biomass relationship, 2) reader measurements, and 3) transect random sampling. 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 j = 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 (Reading 1 and Reading 2).
   d. For each of the n transects, either Reading 1 or Reading 2 was selected at random.
   e. The set of selected transects was randomly sampled with replacement.
   f. 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

I. Aerial Transect Sampling

Transect Coverage in 2011

Transect sampling in 2011 was conducted from July 4th through August 26th. Sampling proceeded as follows. On July 4th, transects 1 through 8a of Set A were flown. Fish were observed on 14 of the 16 transects sampled. Subsequent weather conditions did not permit resumption of sampling for the next 13 days. Due to the amount of elapsed time, sampling resumed with transect Set B. Sampling of set B began with transect 1 on July 18th and ended with transect 26 on August 12th; a complete set was obtained (Figures 1a-f). Fish were observed on 21 out of 22 transects in the northern stratum, ranging from transects 1 through 11a. Subsequently, no fish were observed on transects 12 through 16 of the northern stratum, nor were any fish observed in the southern stratum of Set B (transects 17 through 26).

At that point two logistical considerations were apparent: 1) it was unlikely that three full replicate sets could be flown during the time remaining for the survey (as had been proposed in the Field Operational Plan (Appendix I)), and 2) most of the sardine biomass available to the survey was residing in the northern sampling stratum, as had been anticipated. Thus, in the remaining time available, we decided to attempt one additional transect set -- focusing on the northern stratum, with still-closer (5 mile) transect spacing. This transect set was dubbed “Set HD” for “high density”. Sampling of the Set HD transects began on August 23rd and ended on August 26th. A total of 14 transects were completed; fish were observed on 12 of the 14 transects. Unfortunately, subsequent conditions did not permit completion of the Set HD transects during the survey season.

In summary, we were successful in completing one full transect set (Set B) for biomass estimation in 2011. Our estimate of biomass was limited to the northern sampling stratum (transects 1 through 16), because fish were not found in the southern stratum (transects 17-26).

Transect Readability

Readability classifications for Set B transects 1- 26 are given in Table 1. For the 31 transects of the northern stratum, impediments to readability were judged to minor for 13 transects, moderate for 11 transects, and substantial for 7 transects. Clouds were a factor on 15 transects (distributed throughout the range), turbidity was present on 1 transect (8a), and sea-surface chop was noteworthy on 10 transects (at the southern end of the range).

Transect Measurements

Measurements of individual sardine schools were completed by two photo analysts for each of the 21 transects on Set B where sardine schools were observed. Schools were not observed on transect 5a nor on transects 12 through 16 of the northern stratum. Transect total school areas ranged from 2960 m^2 to 245,482 m^2 (Table 2). A comparison of frequency histograms of individual school size measurements (surface area in m^2) are given in Figure 2 for sampling in 2009-2011. The shape of the distribution of school sizes in 2011 was similar to that observed in 2010, with a slightly shorter tail on the right side (relatively fewer larger schools in 2011). The geographic (spatial) distribution of schools observed on the transects is shown in Figures 3a-d.

Between Reader Differences in School Measurements

We examined between-reader differences in school measurements on a school-by-school basis (transect resolution) for six transects (6, 9a, 6a, 1a, 3a, and 5). Collectively, these six transects accounted for 65% of the total difference in area observed between readers across all transects. We found that most of the differences between transect area readings could be accounted for by school detection or school identification issues (61%); the remaining differences between readers could be accounted for by differences in school measurements (39%) (Table 3). A total of 201 schools measurements were added to the pre-resolution readings because they were missed, and a total of 22 school measurements were subtracted because they were judged to be either: 1) mis-identified cloud shadows (18), or 2) they were inadvertently double counted (4). A difference of 5 schools remained between readings after resolution. This resulted from several occasions where one reader made two measurements (while the other chose to make one measurement) for a partially fragmented school image. The process of resolution for the six transects resulted in reducing the total between-reader differences by 74,492 m^2. Before resolution, transect differences ranged from 54,973 m^2 to 4 m^2; afterward the range was from 26,960 m^2 to 4 m^2 (Figure 4).

Transect School Species Observations

Other than sardine, anchovy were the only other schooling species reported by the spotter pilots on flight logs in 2011. Pilots documented the occurrence of anchovy in the nearshore (0-3 mile segments) of transects 1, 1a, 2, 2a, 3, 3a, 4, 4a, 5a, 7, 7a, and 8a; additionally, one occurrence of anchovy was recorded further offshore (on transect 7a) (Figure 5).

III. Point Set Sampling

Point Set Coverage

At-sea sampling in 2011 resulted in the landing of 35 useable point sets between July 20th and September 12th (Table 4a); for comparison, data from 2009 and 2010 are given in Tables 4b and 4c, respectively). An additional 18 point sets were conducted but were not acceptable for analysis (Table 5). Reasons for unacceptability included: 1) flown at an altitude of less than 4000 ft. (9 point sets), 2) less than 90% of the school was captured (3 point sets), 3) the school was not discrete (3 point sets), and 4) no useable photograph was taken of the school (3 point sets). A map of the useable point set locations, shown with respect to the locations of sardine schools observed on transects in 2011, is given in Figure 6. Spatially, the point sets ranged from 47° 30.0′ N in the north, to 45º 53.9′ in the south, and covered the majority of the latitudinal range where fish schools were observed in 2011. Sardine schools were observed as far north as transect 1 and as far south as transect 11a; point sets ranged from the vicinity of transect 4 in the north to transect 10a in the south. Point sets were conducted at ocean depths ranging from 23 to 68 fm and at ocean temperatures ranging from 55 to 61 degrees F (Table 4a).

Point Set School Characteristics

Vertically, schools ranged from approximately 1 to 5 fm from the surface and averaged approximately 2 fm in height (Table 4a). Point set species composition averaged 99.9% sardine; Pacific mackerel dominated the remainder of the landings. The distribution of maturity stage for female and male sardine is shown in Figure 7. Stage 2 (intermediate) maturity was most prominent for both sexes, followed by Stage 1 (immature). A small number of females were classified as Stage 3 (active) and Stage 4 (showing hydrated oocytes), and a small number of males were classified as Stage 3 (active). The distribution of weight (g) for female and male sardine is shown in Figure 8. Female sardine averaged 167g; males averaged 162 g.

Sardine School Surface Area - Biomass Relationship

A plot of the sardine school surface area - biomass relationship for the full set of useable point sets collected from 2008-2011 is shown in Figure 9. Point sets collected in 2011 are shown by open black squares, for comparison with the other years. Fits of the MM model to 1) all of the data from 2011-2011 (solid black line) and 2) only the 2011 data (dashed black line) are shown in Figure 10. A likelihood ratio test was performed to evaluate pooling the 2011 data with the pooled data from 2008-2010. The null hypothesis (H_o: No difference between the fit of pooled point set data vs. point set data from 2011 alone) was not rejected (P =0.147; Chi-Sq $_{df = 3,\ \alpha = 0.05}$) (Table 6).

IV. Quantities for Input to the Pacific Sardine Stock Assessment

Weighted Length Composition

Vectors of weighted length frequency were derived for input to the sardine stock assessment model. The raw length frequency data were weighted by the landed point set weights. The weighted length distributions differed from 2009-2011 with sequentially larger modes evident over the three year period (Figure 11).

Total Biomass

Sardine biomass was estimated for the area from Cape Flattery, WA to Newport, OR in 2011 (fish schools were not observed from south of Newport to the California border). The data collected on Set B transects 1-16 (n = 31 transects) was used for biomass estimation. The total number of transects possible (N) was 230 for this stratum. Estimates of sardine biomass by transect are given in Table 7. Estimates of total biomass and associated CVs were computed two ways: 1) by using only the point set data from 2011 (Figure 12), and 2) by using the full set of point set data from 2008-2011 (Figure 13). The estimate of sardine biomass was 201,888 mt (CV = 0.3012) using the 35 point sets from 2011 alone, and 249,865 mt (CV = 0.2727) using the full set of 95 point sets from 2008-2011.

V. Material prepared at the request of the October 4-7 STAR panel

The following information was prepared and presented in response to requests made during the Pacific Sardine Assessment STAR panel, held October 4-7, 2011 in La Jolla, CA:

A. For the aerial survey, examine the effect (on biomass estimates) of incorporating complete point sets observed from altitudes less than 4,000 feet. Rationale: A considerable amount of potentially useful data are not being used in biomass estimation currently because of the operating constraint that requires the 4000 foot altitude.
Response: See Appendix IV, Figure 1.

B. For the aerial survey, modify Table 7 (p.43) to include the sum the biomass for each column, and do a paired t-test on the reading effect. Rationale: The Panel wanted to get a better understanding of the possible effects from the two independent readers.
Response: See Appendix IV, Figure 2.

C. For the aerial survey, compute the autocorrelation function among positive transects. Rationale: To examine the assumption of independence among transects.
Response: See Appendix IV, Figure 3.

D. For the aerial survey, compute the mean length of fish in each school (from the point sets) and plot by latitude. Do separately for each year. Rationale: To examine whether the size data from point sets are representative of the sardine population in the Pacific Northwest. In particular, whether the shift (to the right) in length comps over 2009-11 (Figure 11) may be an artifact of latitude at which the point sets were made.
Response: See Appendix IV, Figure 4.

E. For the aerial survey, plot mt vs. area for 2011 point sets with a fitted line. Rationale: This relationship may be an alternative to the mt/area vs. area relationship.
Response: See Appendix IV, Figure 5.

Discussion

Our survey effort in 2011 focused primarily on the area from Cape Flattery, WA to Newport OR, with transects spaced at a wider interval south of Newport to the California border. This distribution of survey effort turned out to be a good one; it allowed us to again document the southward extent of schools for comparison with previous years, but also placed most of our effort where the fish were most available to our survey method - in the north. Our initial intent was to conduct three replicate sets of transects and to use the average biomass of the three sets to obtain an estimate of biomass and it's CV for 2011. We found instead that a better approach was to conduct one or two sets of transects, and to strive for sampling under only the best of conditions possible.

When computing the variability of biomass estimates among transects for the northern stratum, our transect spacing of 7.5 miles yielded CVs for the total biomass estimate in the range of 0.27-0.30, depending on the number of point sets used in the analysis. This was an improvement over the 2010 results (when CV's were in the range of 0.40-0.44). Biomass estimates in 2011 were higher than those observed in 2010, but were still substantially lower than those observed in 2009. Biomass in 2010 also differed considerably depending on which collection of point sets was used in the analysis (2008-2011 vs. 2011 only). Clearly, variability in the surface area – biomass relationship is an important factor to consider when using our survey method to estimate sardine biomass.

Reasons for the variability observed in the point set school surface area – biomass data are poorly understood. It is clear, however, that a certain amount of scatter in the relationship will always persist simply because surface area is a poor proxy for volume (i.e. we are measuring a dynamic, three dimensional feature in only two dimensions). Our collective results from 2008-2011 support the notion that the school surface area – biomass relationship can vary substantially with school size, and the relationship appears to be curvilinear in log space, with biomass per unit surface area declining as school surface area increases. Likelihood ratio tests, conducted incrementally with new annual data sets to evaluate data pooling across years, have supported pooling the data; however, sample sizes are small and statistical power is likely not high (Jagielo et al 2010; present analysis). It is possible to make a case for using only year-specific data (e.g. in order to preserve the independence of observations and to capture a year-effect, if it exists); alternately, a compelling case can also be made that the overall variability in the surface area – biomass relationship is high and the full data set (with a larger sample size) may best capture the true relationship. In preliminary work, for example, we have monitored the surface area of individual schools over short periods of time and have observed that surface area measurements for the same school can often vary well over 10% in a matter of several seconds.

As we gain more experience with this survey method, it has become apparent that monitoring the readability of transect photographs is critical. By giving immediate feedback to the pilots, and also by taking heed of the pilot's advice regarding conditions that they can observe (but may not always be evident on the photographs), we have become more selective about when to conduct transect sampling. Being more selective about acceptable survey conditions can result in completing substantially fewer transects over the course of the survey season, but can potentially yield more representative sampling.

Another lesson learned in 2011 was that conducting repeat readings of all transect measurements is an important component of a rigorous QA/QC protocol for this survey method. We found that the process of reviewing the differences between readings can afford the opportunity to improve the quality of the data and can also provide feedback to the analysts to improve future performance.

Acknowledgements

This work is the result of the diligent efforts put forth by members of the sardine industry (Northwest Sardine Survey - Jerry Thon, Principal) operating under an EFP and harvest set-aside approved by PFMC and granted by NMFS.

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Figure 1a. Map of transect Set B, flown in 2011 (Transects 1 through 4a).

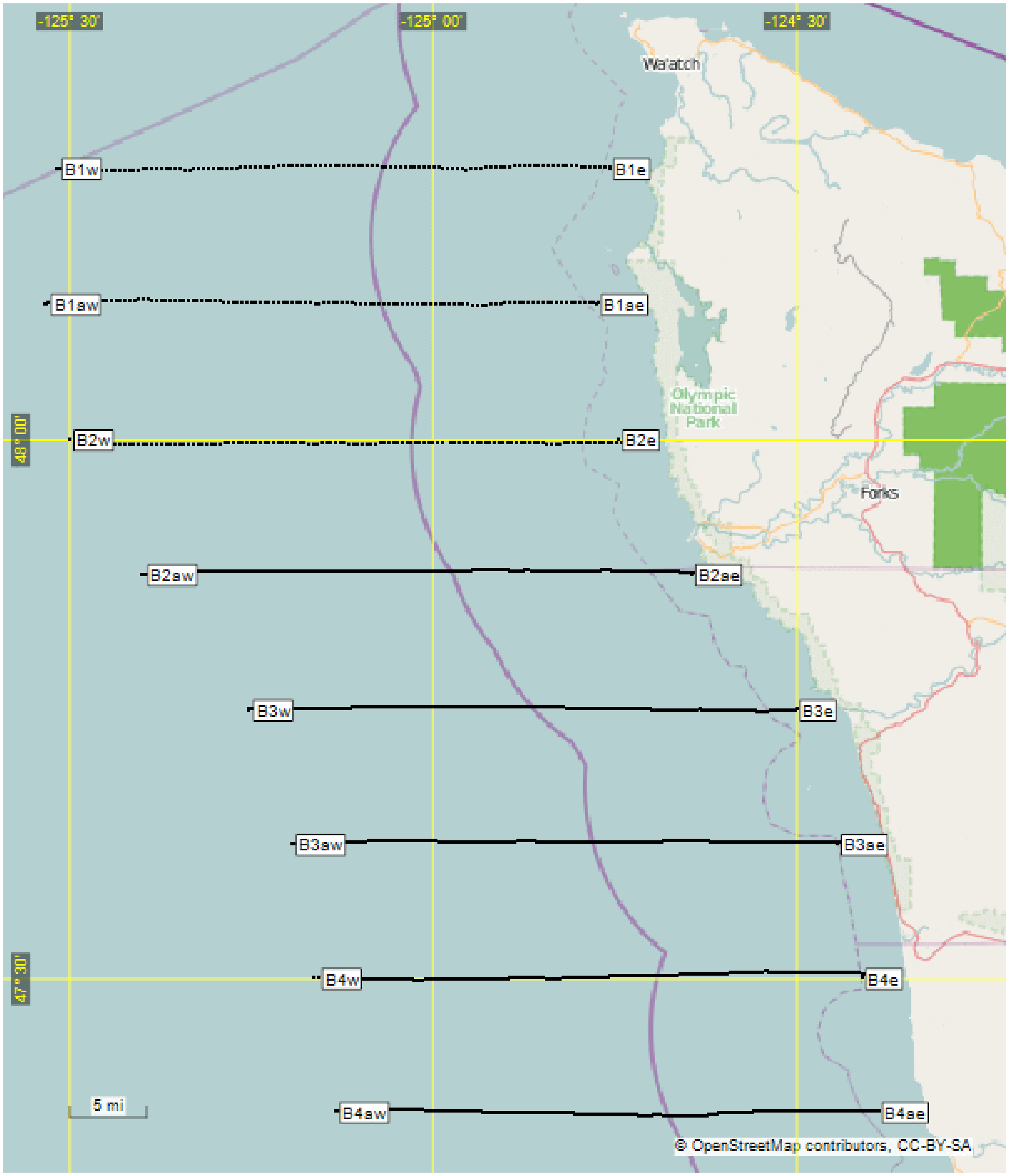


Figure 1b. Map of transect Set B, flown in 2011 (Transects 5 through 9).

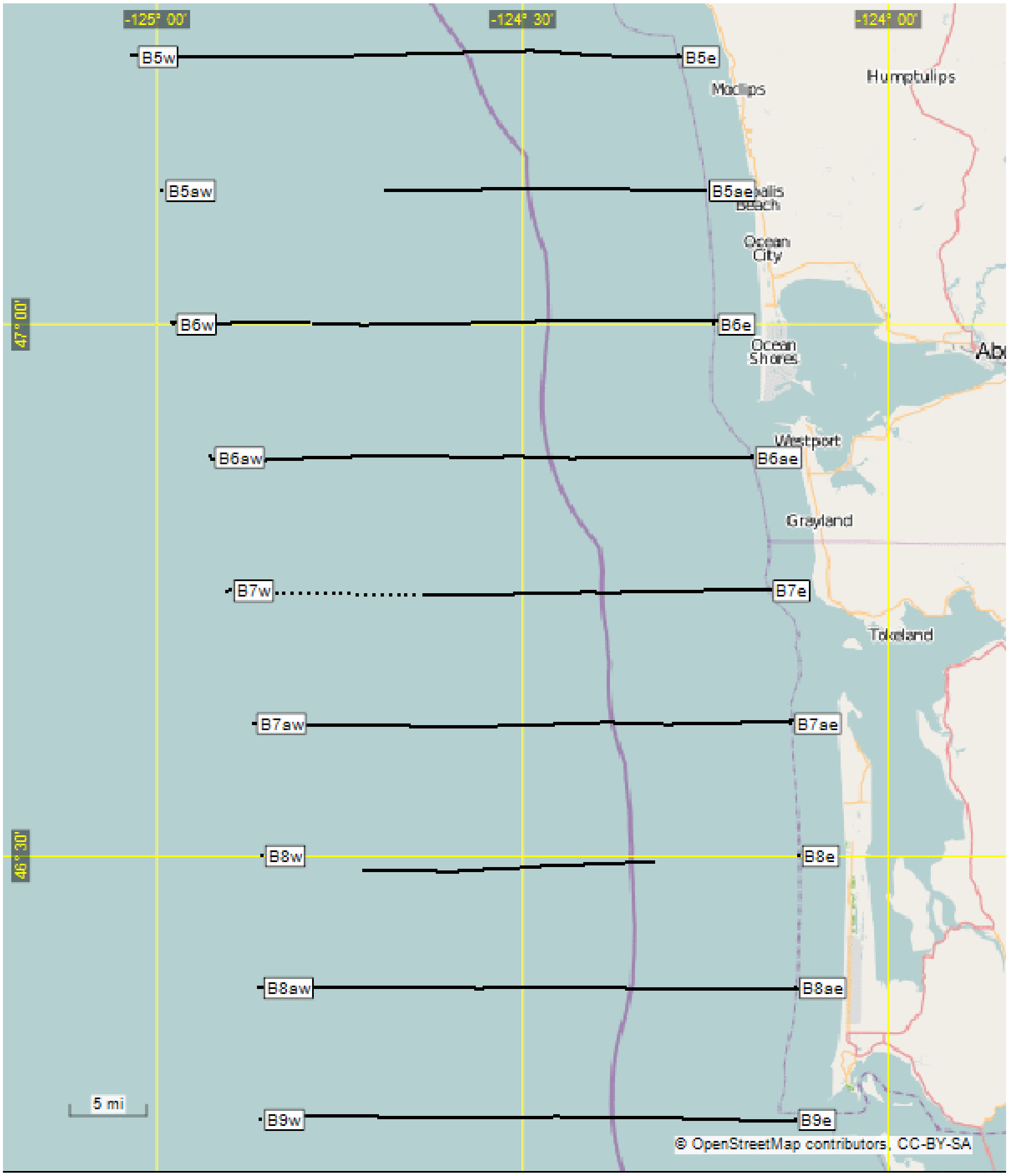


Figure 1c. Map of transect Set B, flown in 2011 (Transects 9a through 13a).

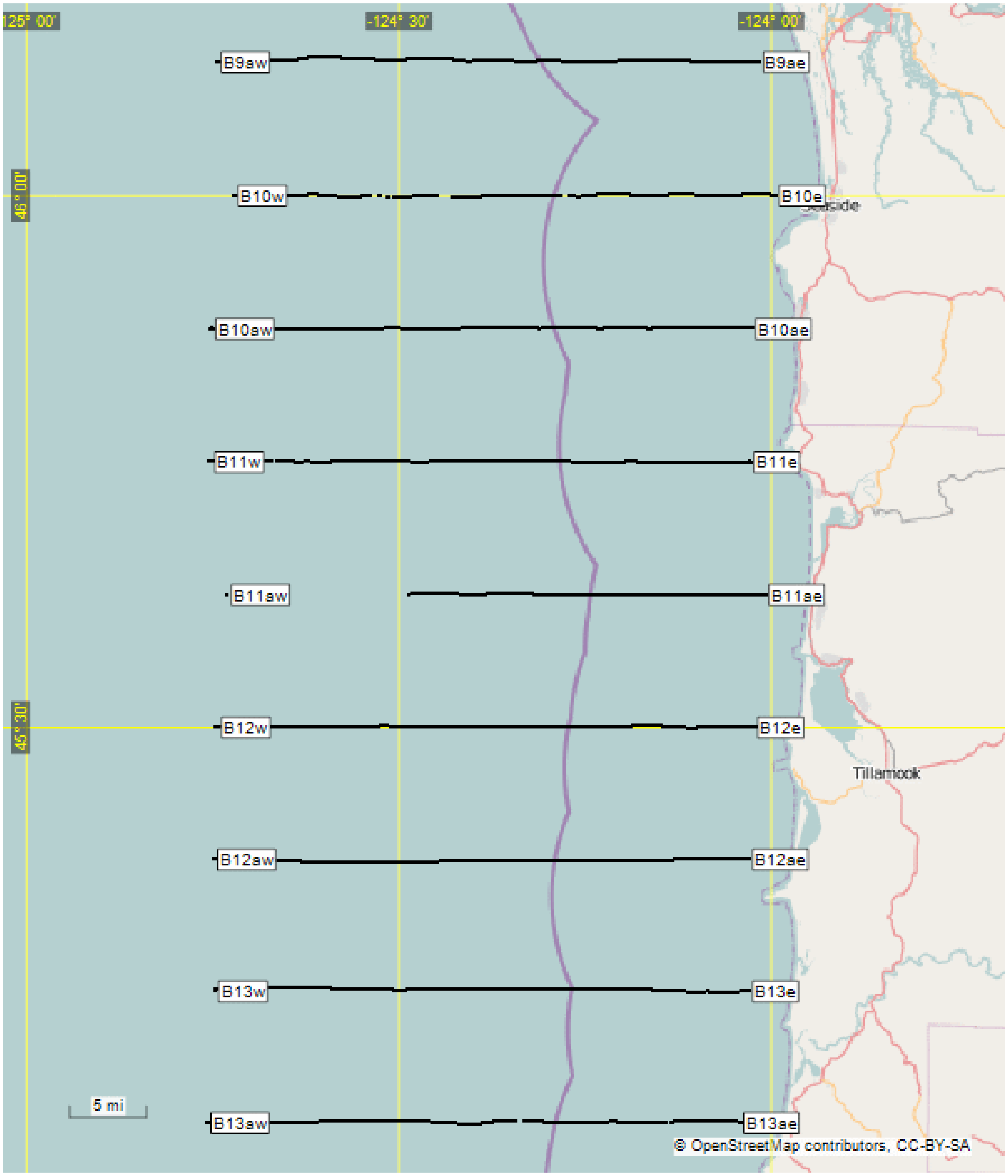


Figure 1d. Map of transect Set B, flown in 2011 (Transects 14 through 18).

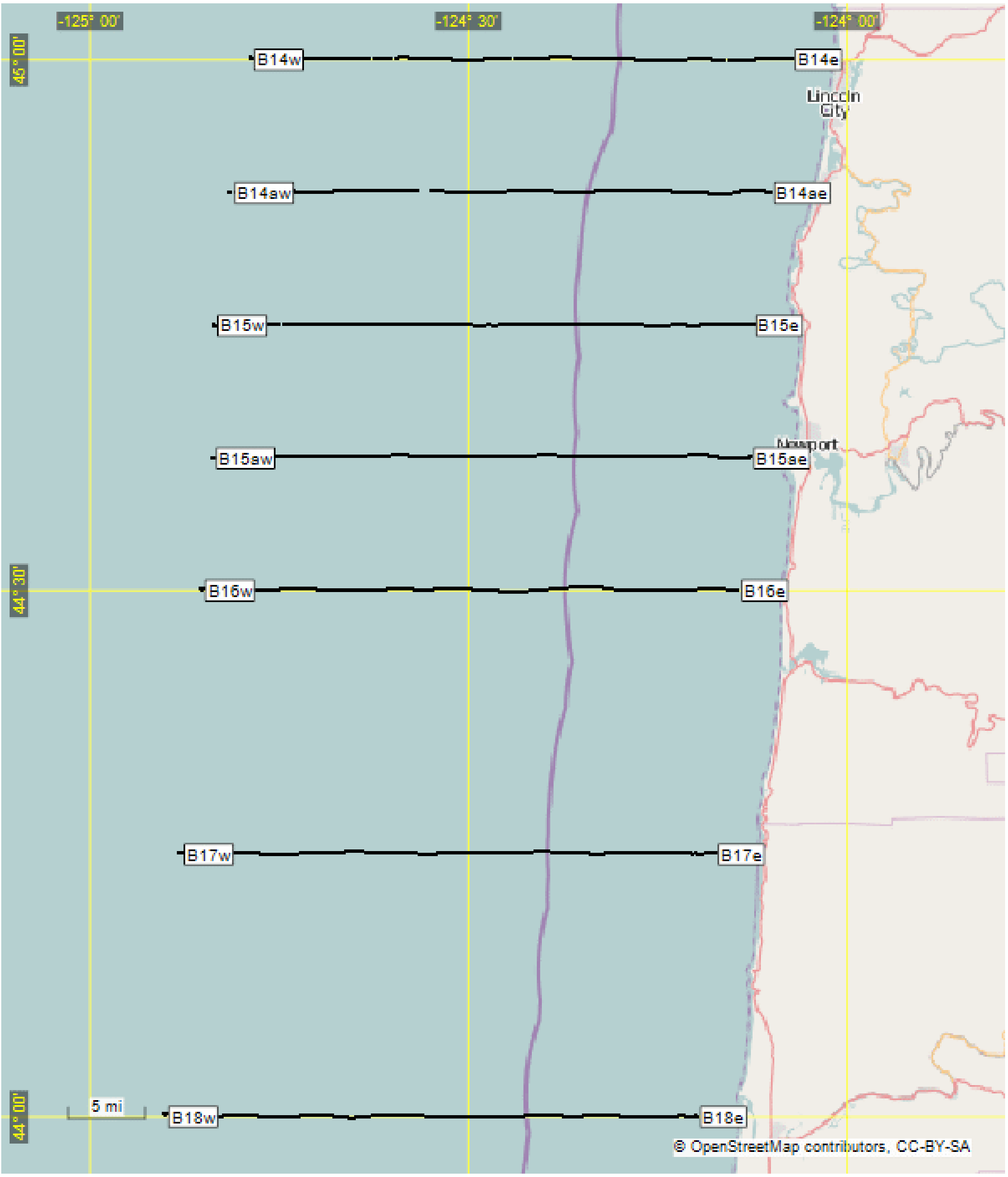


Figure 1e. Map of transect Set B, flown in 2011 (Transects 19 through 23).

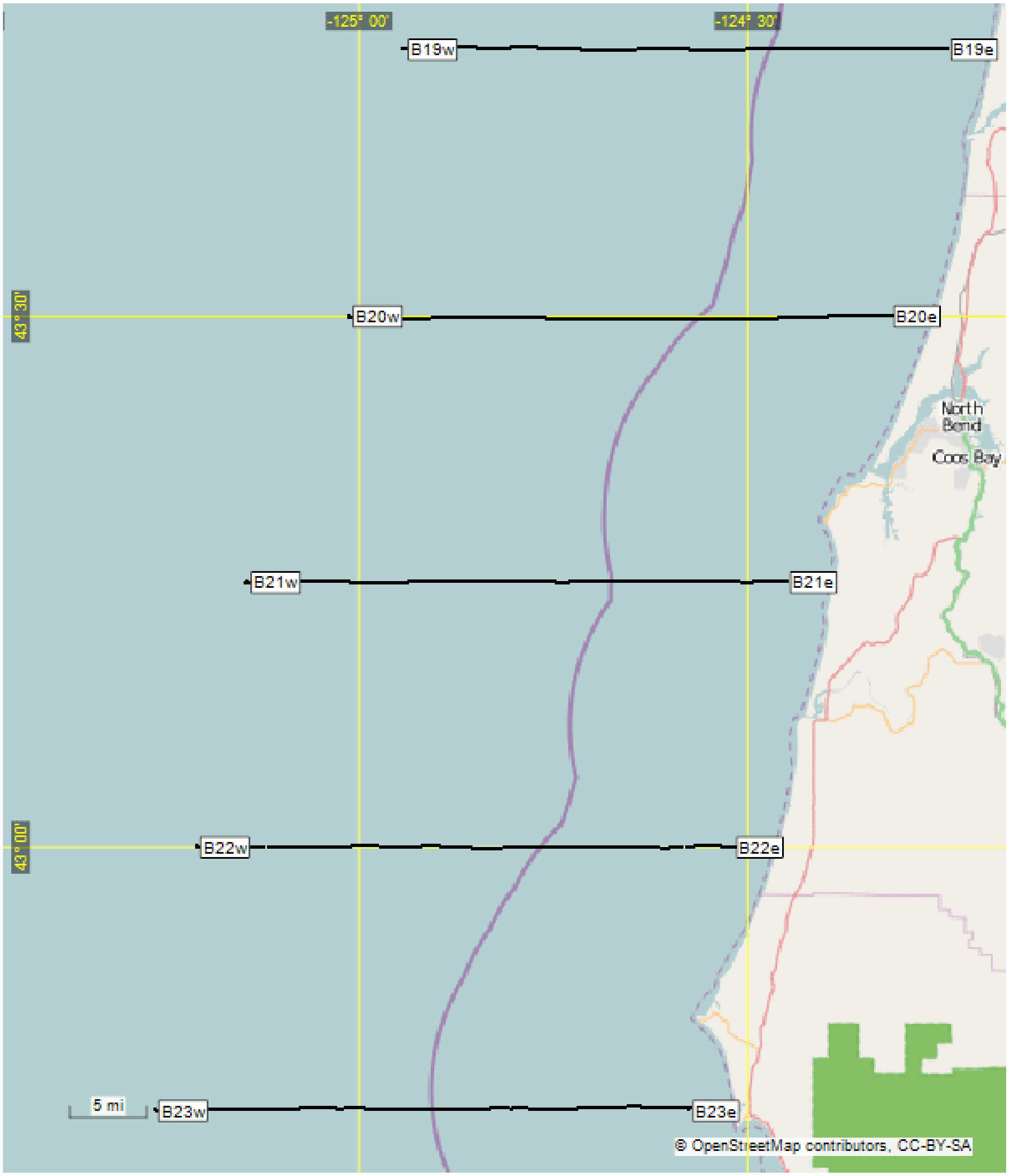


Figure 1f. Map of transect Set B, flown in 2011 (Transects 24 through 26).

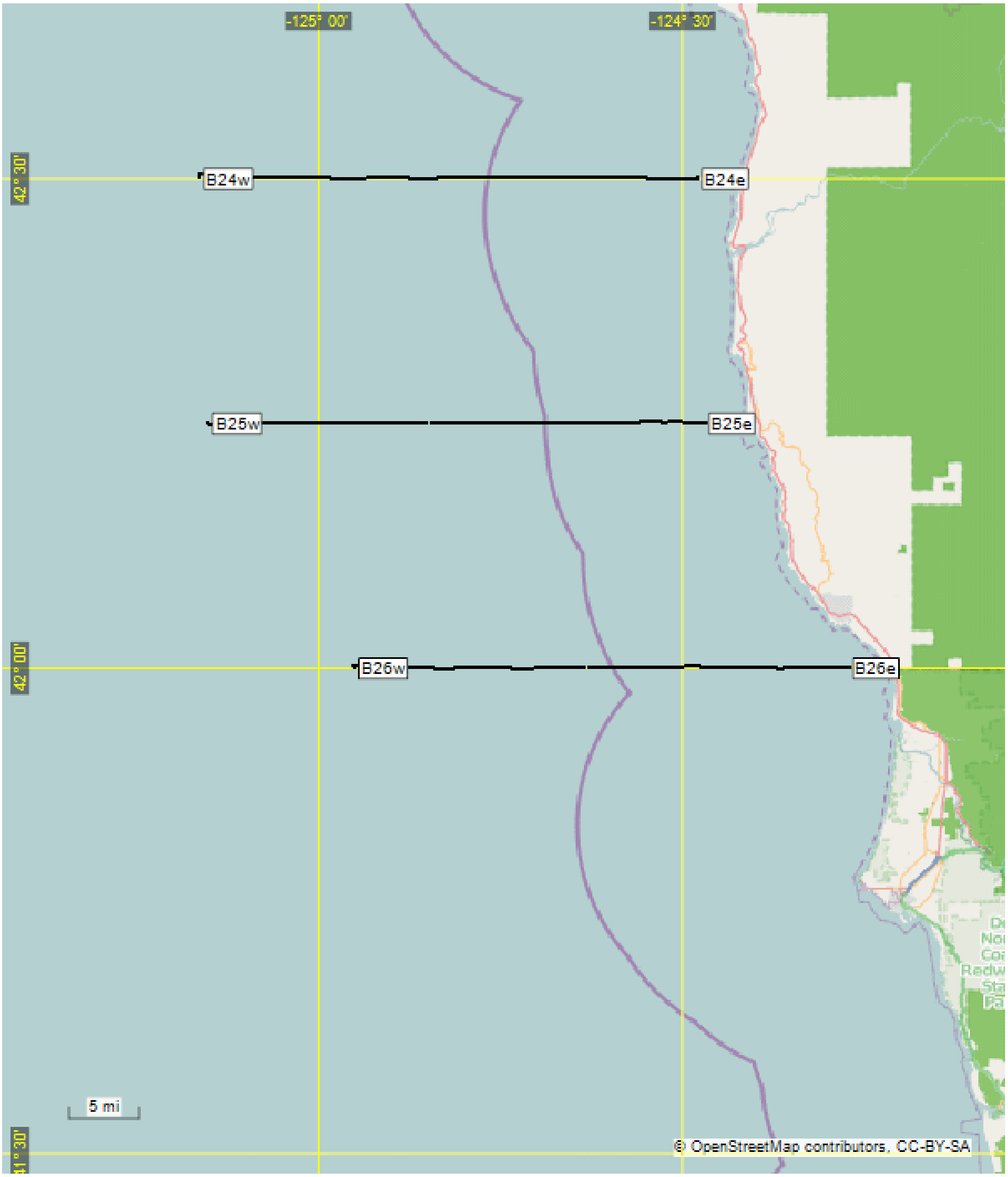


Figure 2. Size distribution of individual schools (surface area in m^2) sampled on transects, 2009-2011.

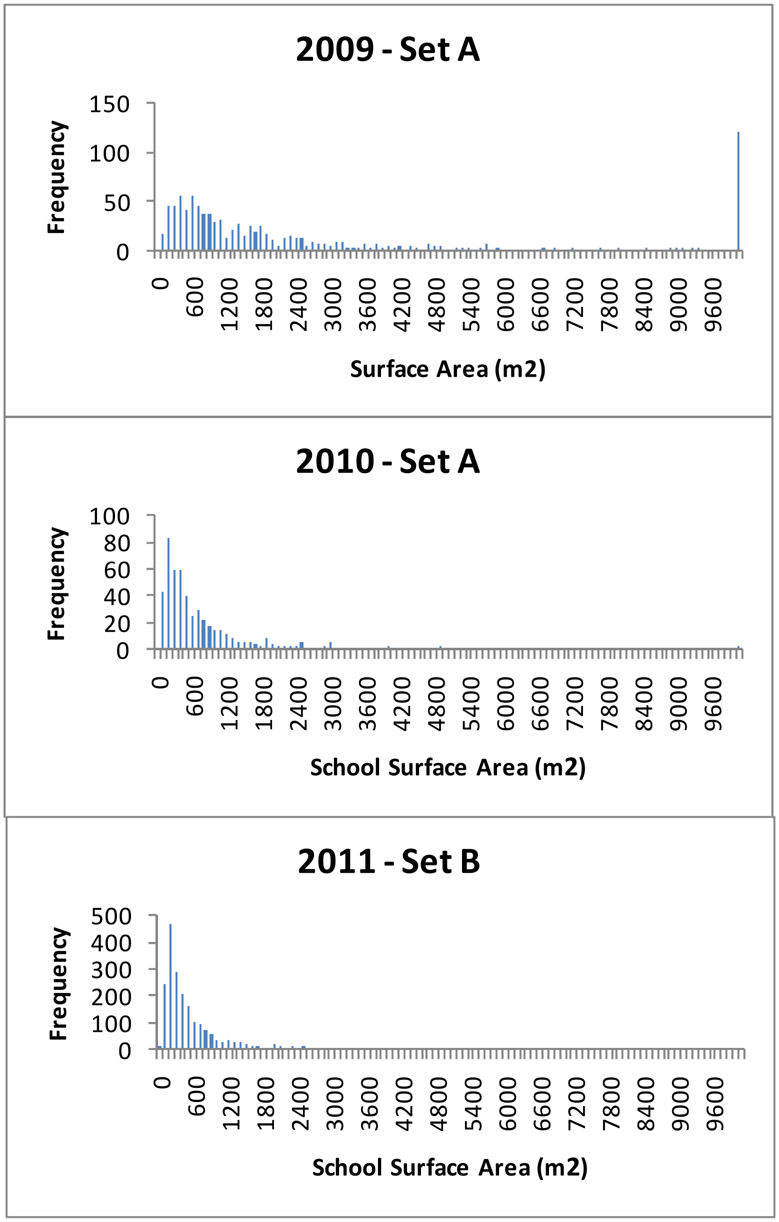


Figure 3a. Map showing locations of sardine schools: Transects 1-3. Circle sizes are proportional to sardine school surface area.

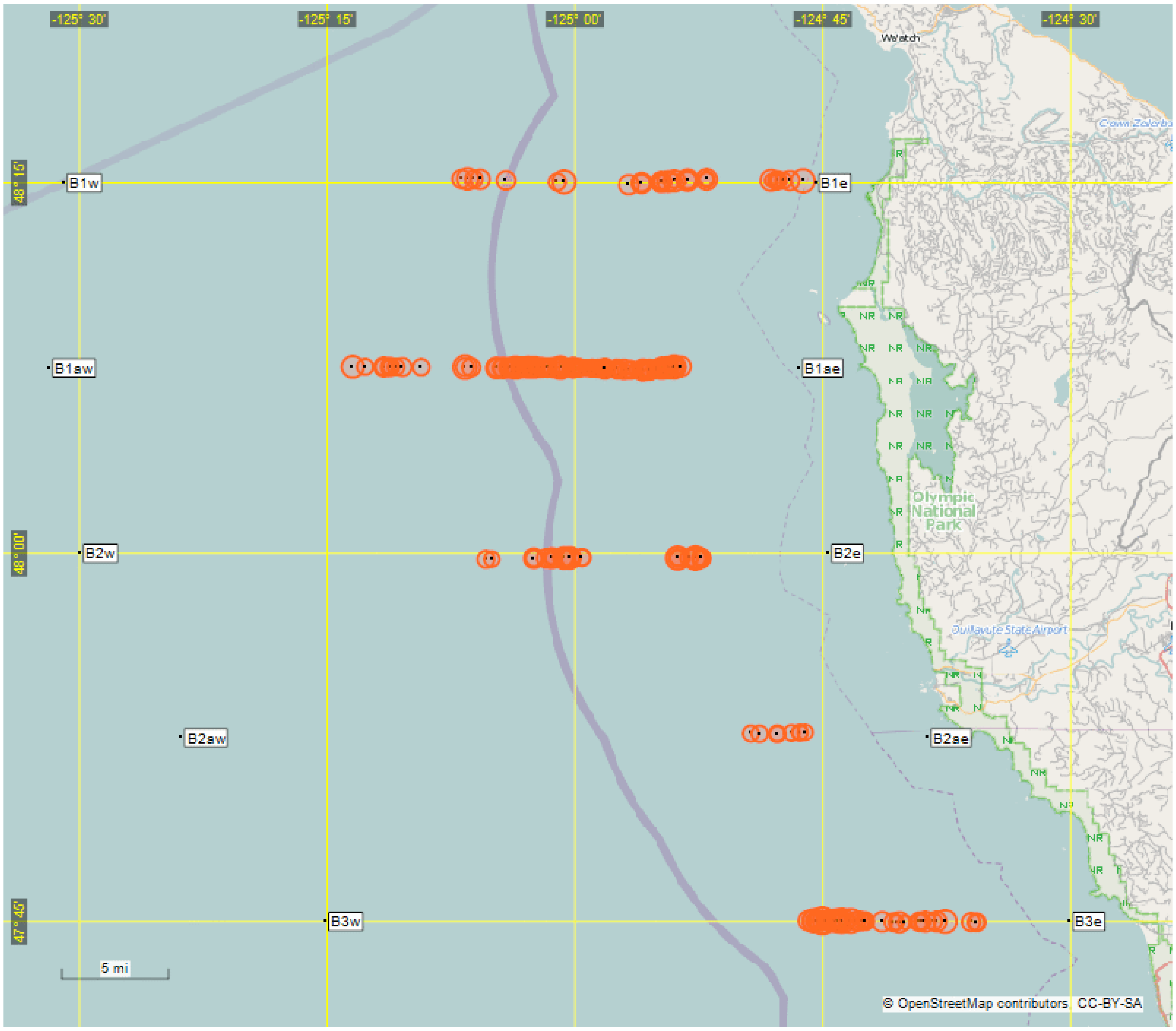


Figure 3b. Map showing locations of sardine schools: Transects 3a-5a. Circle sizes are proportional to sardine school surface area.

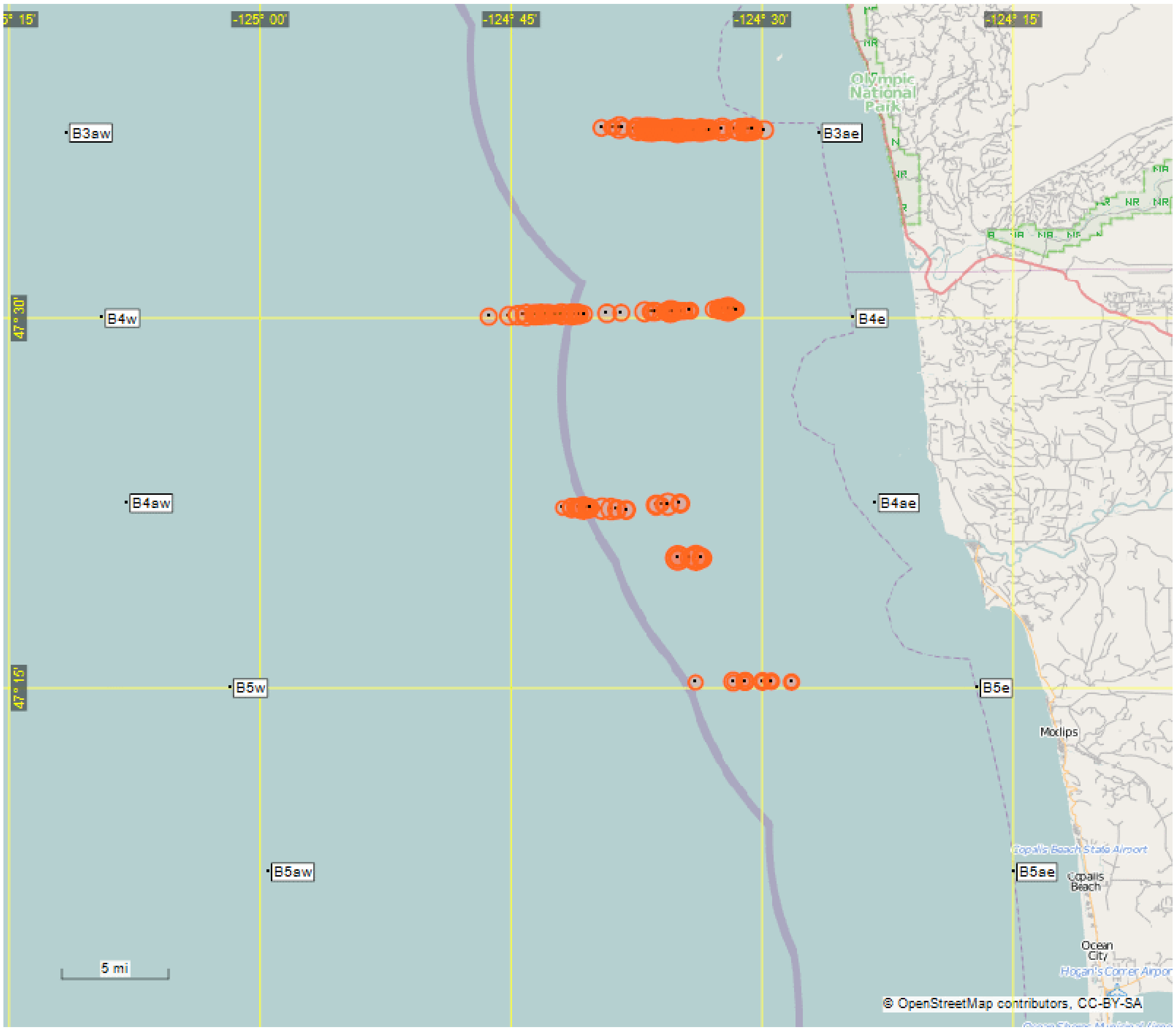


Figure 3c. Map showing locations of sardine schools: Transects 6-8. Circle sizes are proportional to sardine school surface area.

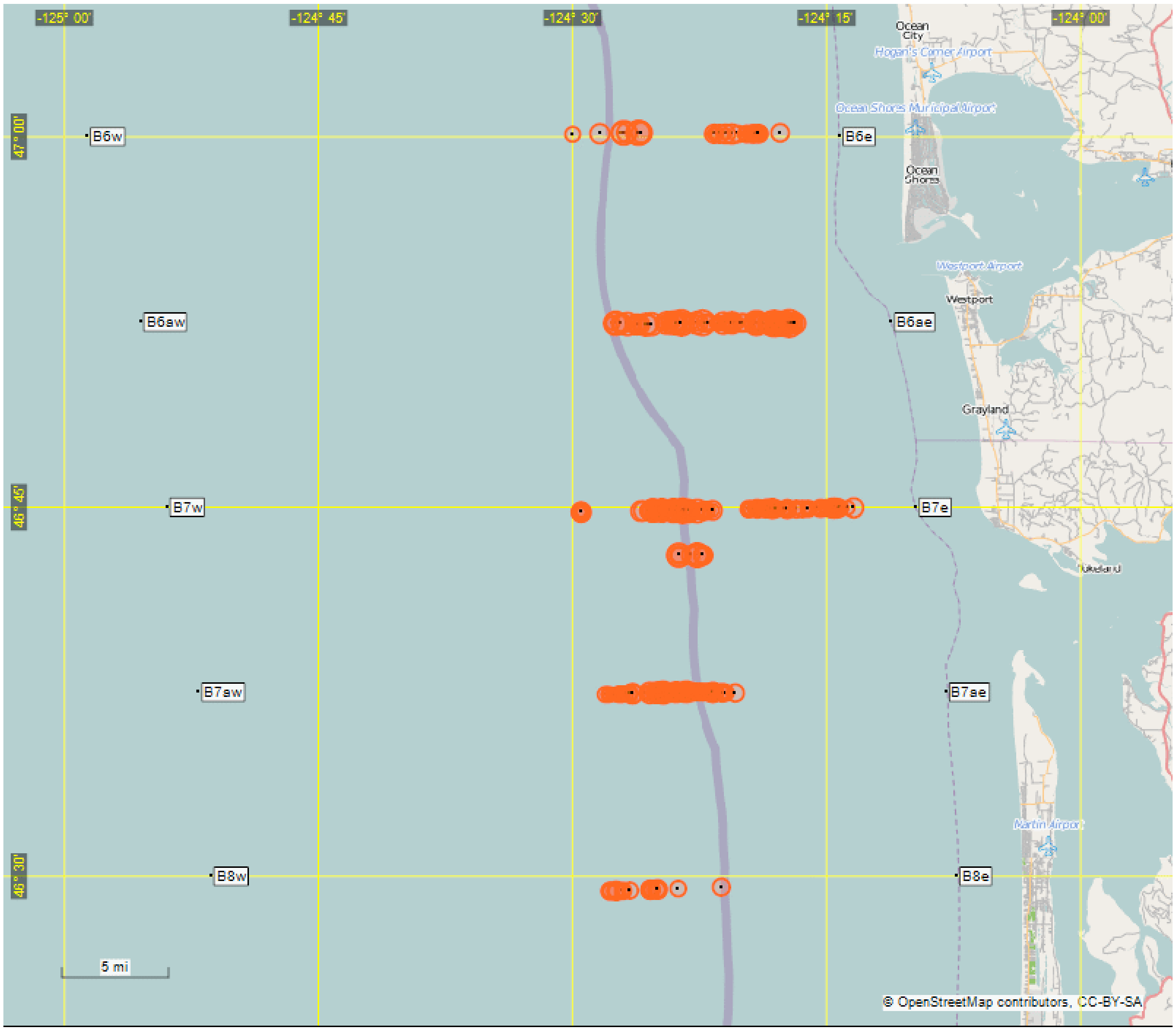


Figure 3d. Map showing locations of sardine schools: Transects 8a-11a. Circle sizes are proportional to sardine school surface area.

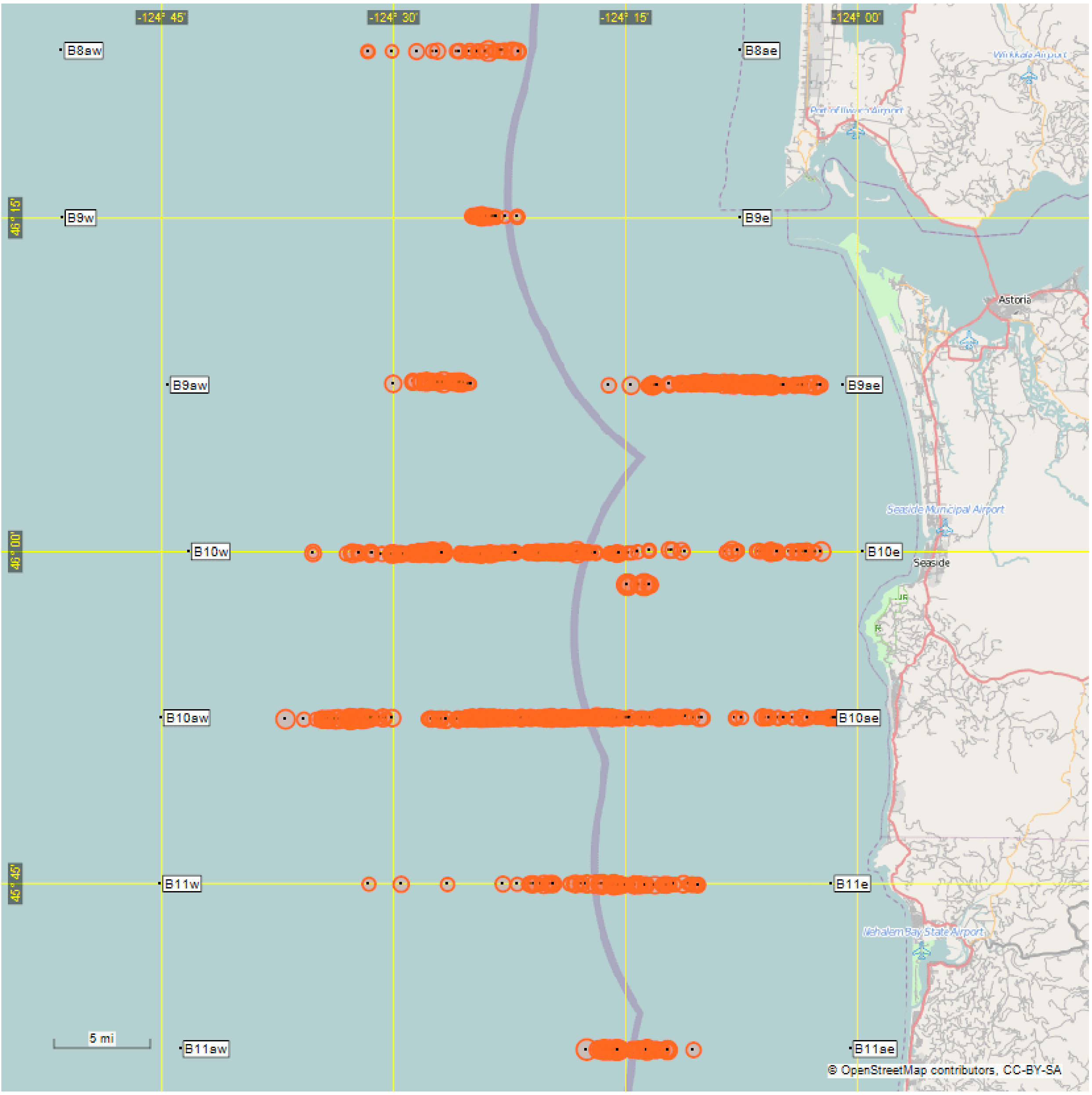


Figure 4. Between-reader differences in transect total surface area measurements. Top: difference prior to resolution of six transects; bottom: difference after transect resolution.

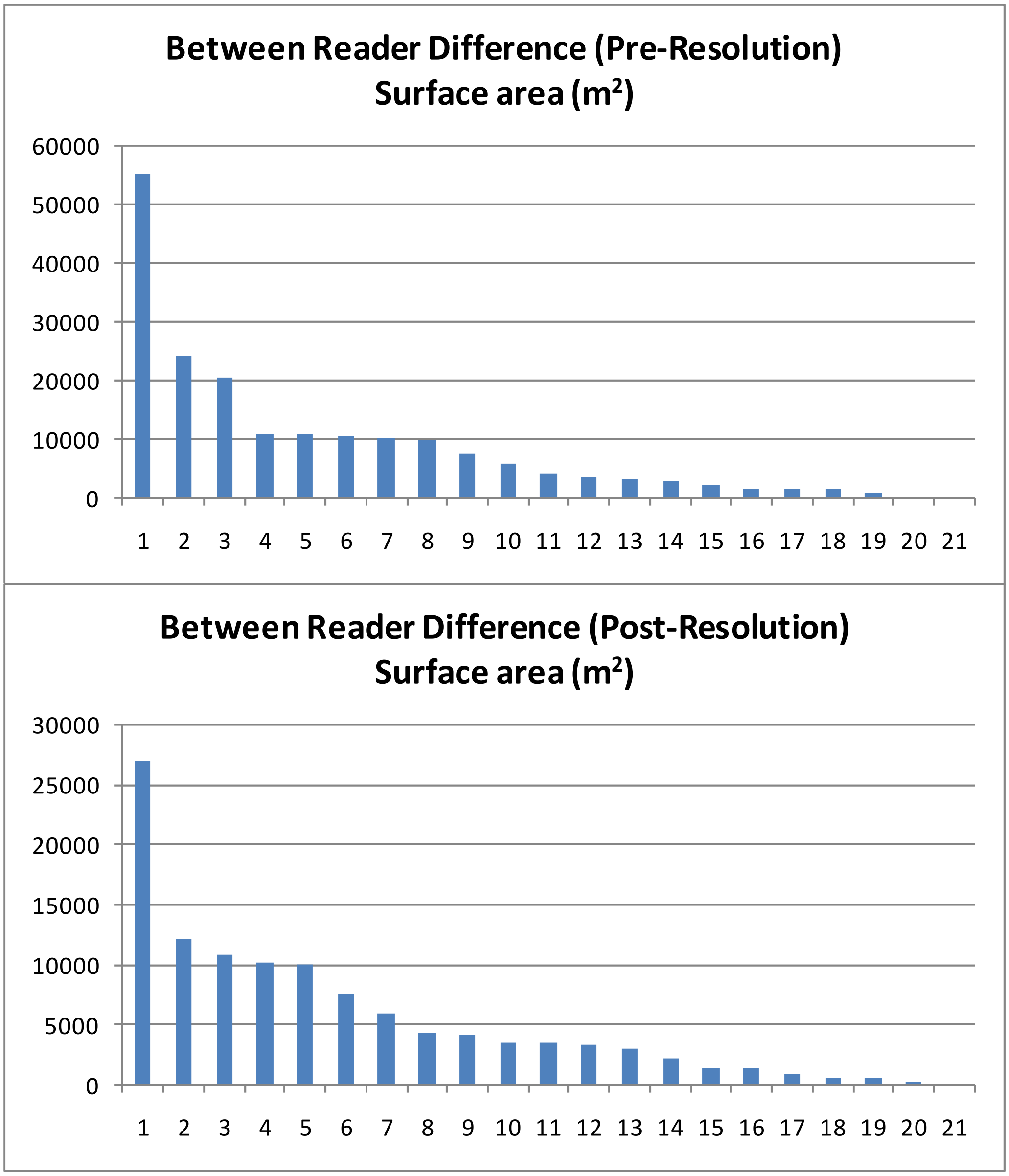


Figure 5. Locations of anchovy schools as reported on spotter pilot flight logs in 2011.

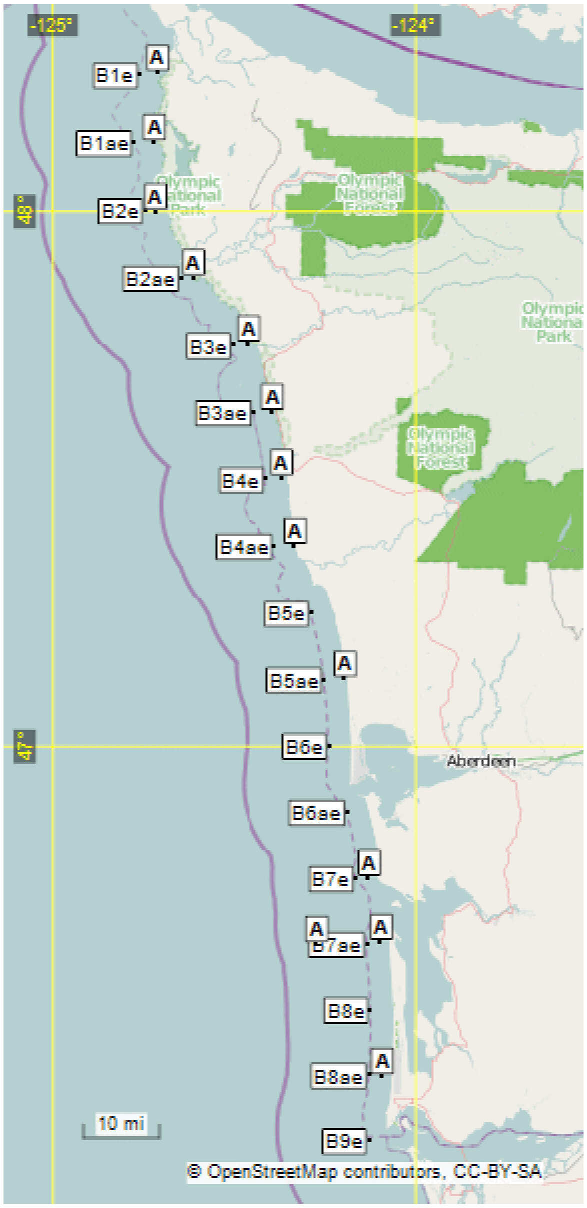


Figure 6. Map showing locations of point sets with respect to fish school locations on transects (2009-2011).

2009 2010 2011

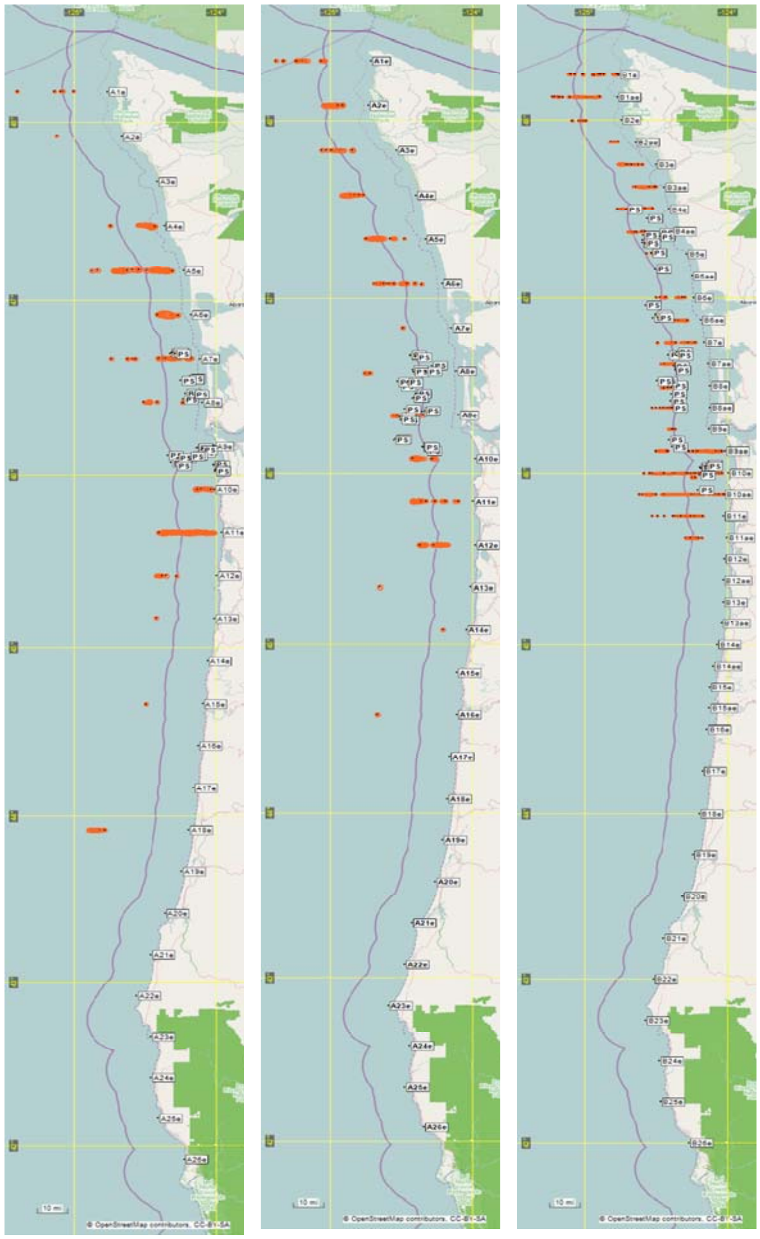
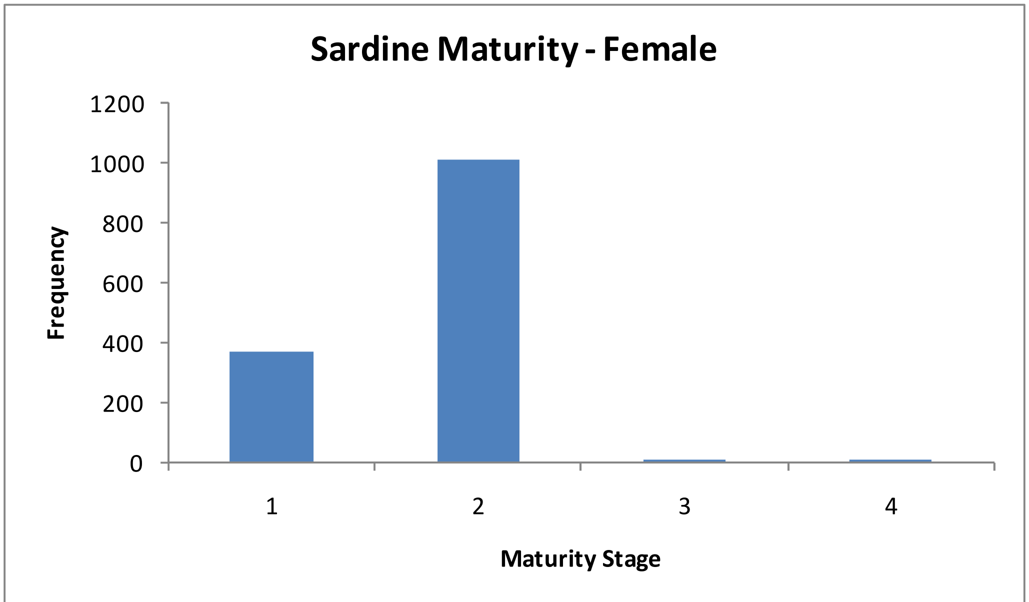


Figure 7. Frequency distribution of female and male sardine maturity stage sampled from point sets in 2011. Definitions of the maturity stages are summarized in Appendix I, Table 3, page 12).



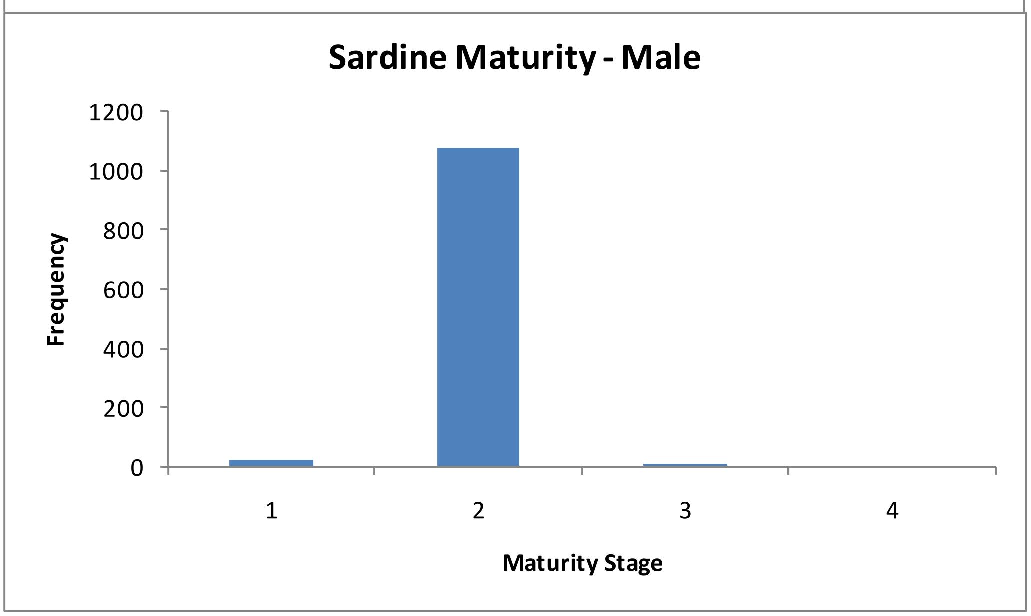


Figure 8. Frequency distribution of female and male sardine weight (g) sampled from point sets in 2011.

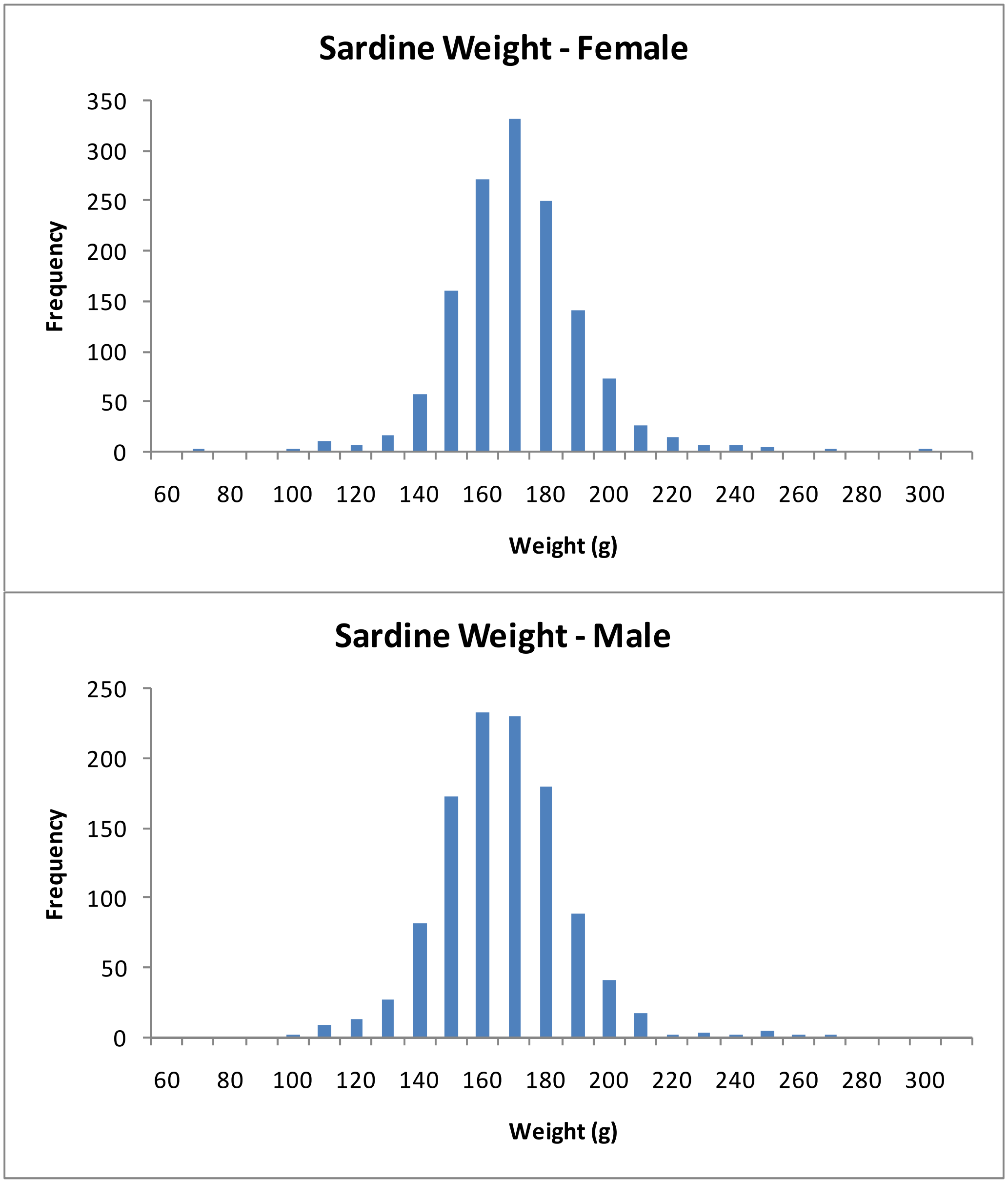


Figure 9. Plot showing sardine point set surface area-biomass relationship (mt/m^2 vs m^2), 2008-2011. Red – 2008; Green – 2009; Blue – 2010; Black (open squares) – 2011.

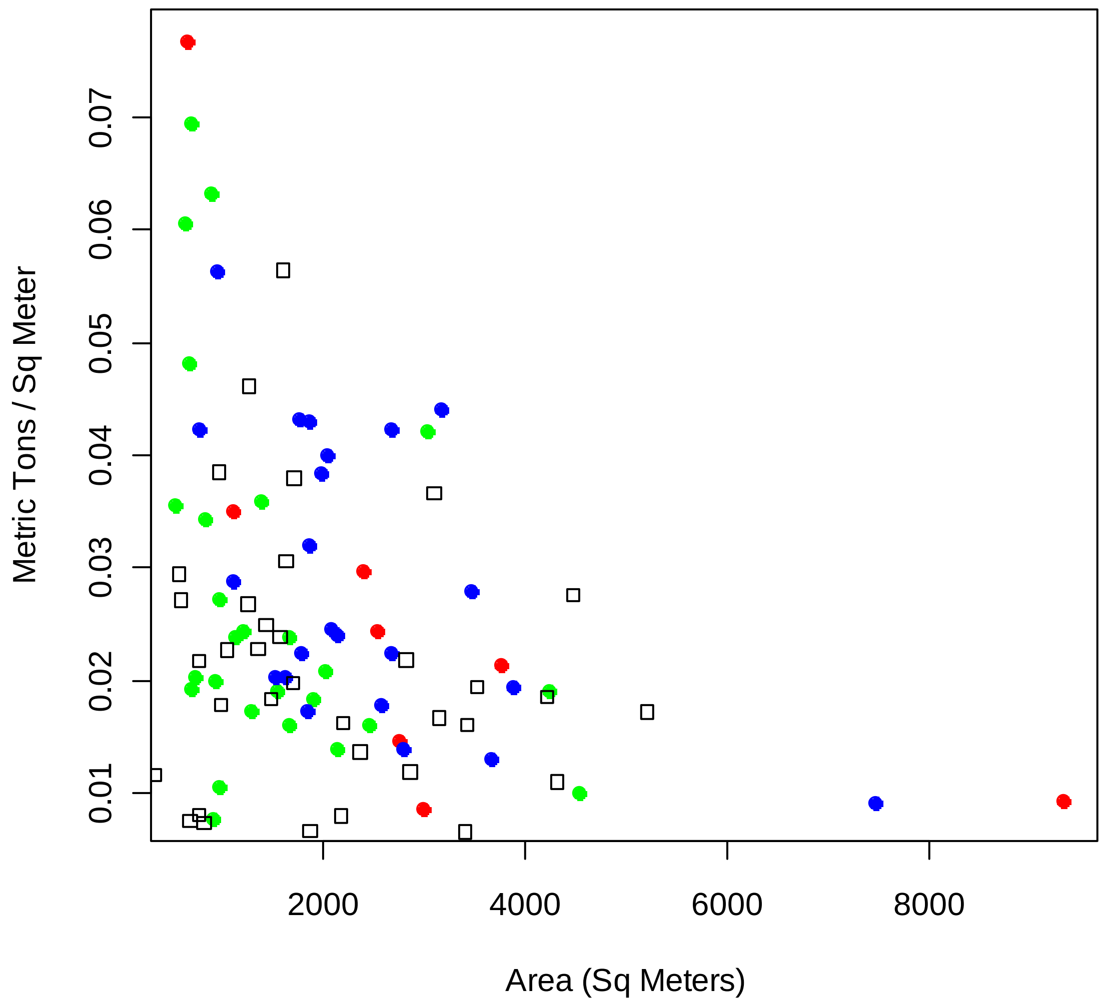


Figure 10. Plot showing fit of MM curve to point set data. 2008-2011 data pooled (green dots; solid black line). 2011 data alone (black squares; dashed black line).

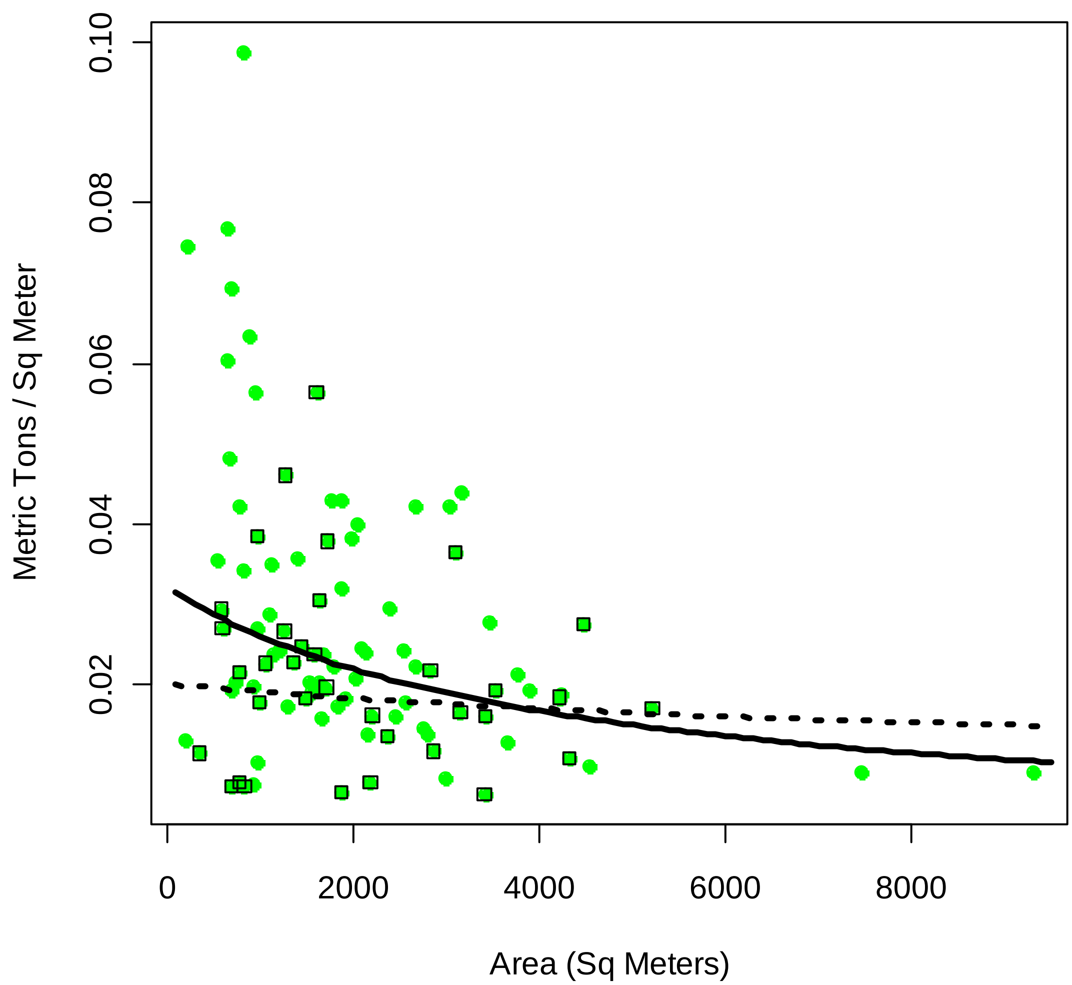


Figure 11. Weighted length frequency of sardine sampled from point sets (sexes combined), 2009-2011.

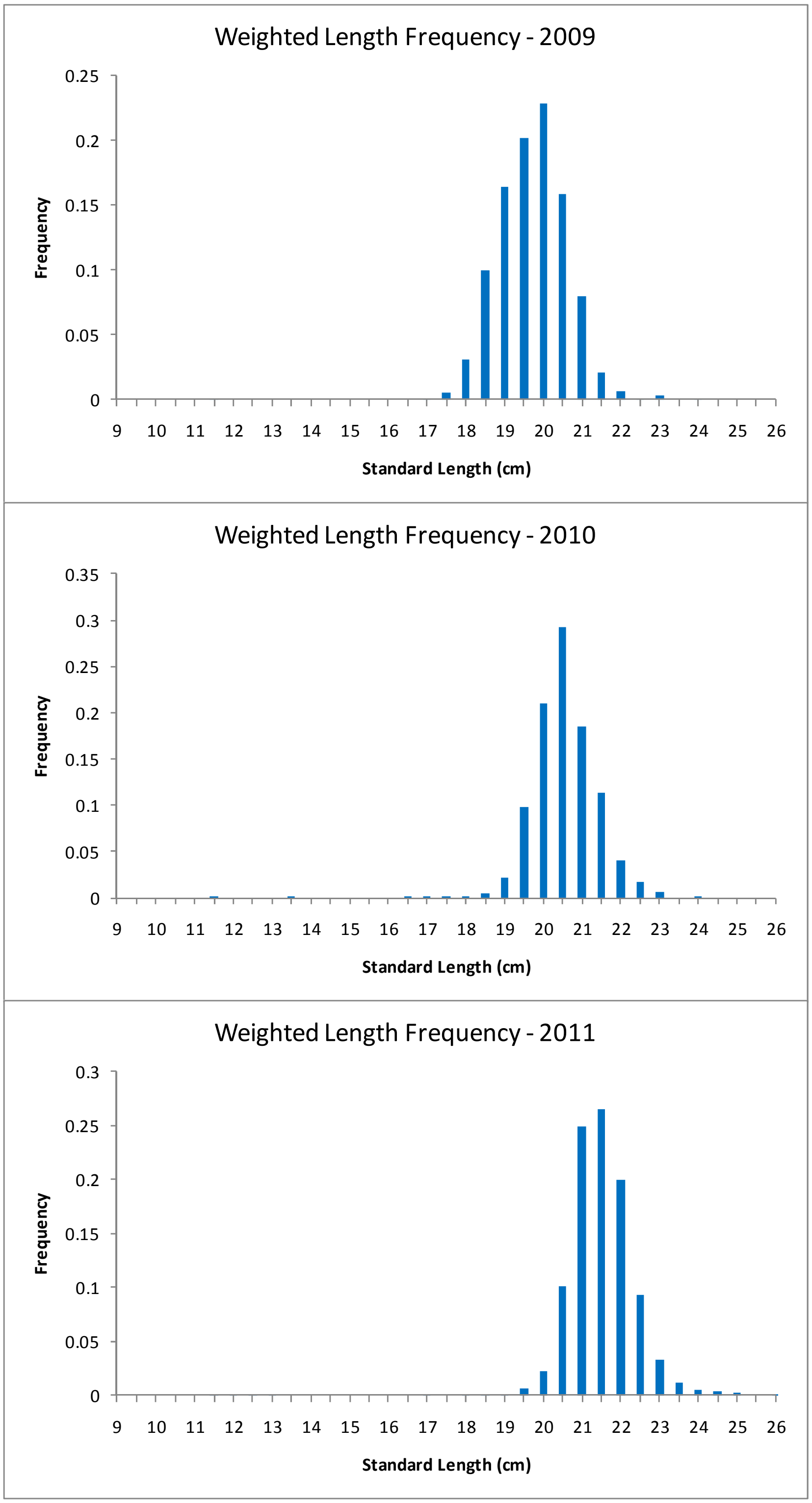
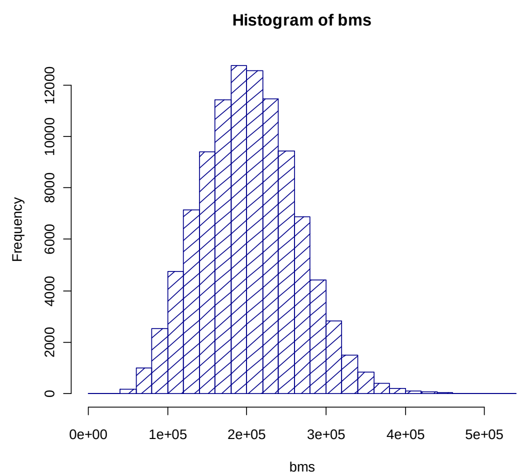


Figure 12. Sardine biomass estimate using 2011 point set data only.

n=35 pointsets (cdata2011)
n=31 transects (SetB 1-16); N = 230.
> setb2011(100000,cdata,transectdata,transectdata2)

[1] Est bms = 201888
[1] yint (y) = 0.0200260752562909
[1] asymp (x) = 0.002
[1] cc (z) = 20552.2555443797
[1] SE = 60819
[1] CV = 0.301251453374665



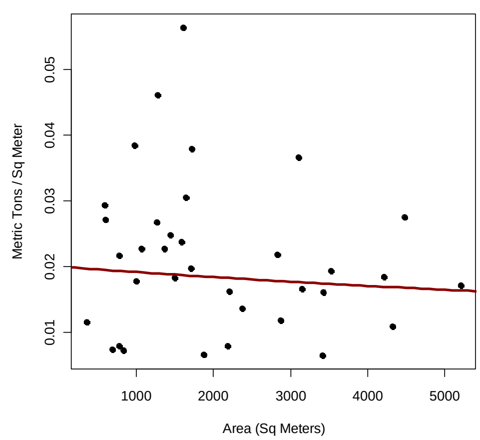
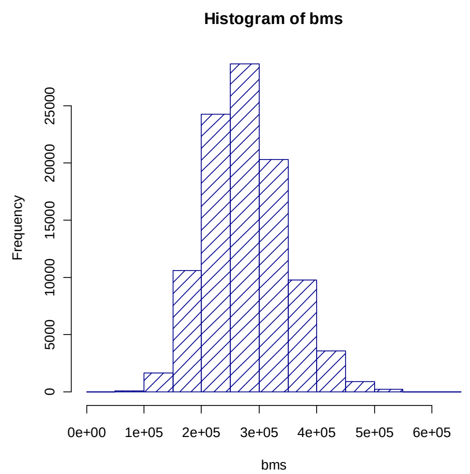


Figure 13. Sardine biomass estimate using all point set data (2008-2011).

n=95 pointsets (cdataALL)
n=31 transects (SetB 1-16); N = 230.
> setb2011(100000,cdata,transectdata,transectdata2)

[1] Est bms = 249865
[1] yint (y) = 0.0324969001322648
[1] asymp (x) = 0.002
[1] cc (z) = 3786.38133185203
[1] SE = 68163
[1] CV = 0.272799417331195



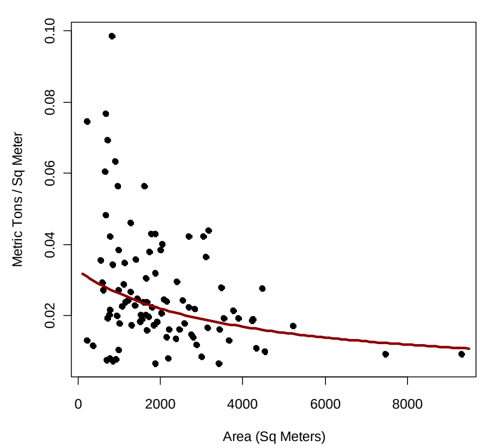


Table 1. Transect readability classifications: Set B 2011.

2011 Set B						
Transect	Classification	Impediment Codes				
Number	Code	Clouds	Turbidity	Chop	Glare	Notes
1	*1*	*x*				Cloud and cloud shadows photos 19-33
1a	*2*	*x*				Cloud and cloud shadows photo 290-303, 367-411
2	*3*	*x*				Cloud and cloud shadows photos 419-490
2a	*1*					
3	*1*					
3a	*1*					
4	*1*					
4a	*1*					
5	*1*					
5a	*1*					
6	*3*	*x*				Clouds above and below airplane casting shadows on ocean surface (marbling), photo 128-293
6a	*3*	*x*				Cloud and cloud shadows on ocean surface, photo 591-602, 624-816
7	*2*	*x*				Cloud and cloud shadows photo 1233-1254, 1278-1285, 1312-1315,
7a	*1*					
8	2	x				Approx 1/3rd of transect not flown due to clouds. Of the portion flown, approx 20 photos with clouds.
8a	*2*	*x*	*x*			Clouds on 377-398; Turbidity on 365-375.
9	*2*	*x*				Cloud and cloud shadows photo 453-492
9a	*1*					
10	*1*					
10a	*1*					
11	*1*					
11a	*2*	x		*x*		Cloud and cloud shadowing photos 130-188. Surface chop, Pilot indicated it was blowing 15-20
12	*2*	x		*x*		Clouds 200-206. Surface chop
12a	*2*			*x*		Surface chop
13	*2*			*x*		Surface chop
13a	*3*	x		*x*		Low clouds and cloud shadowing photo 148-242 with gaps, surface chop
14	*3*	x		*x*		Clouds and cloud shadowing photo 246-287, photo 299-306, photo 316-363, surface chop
14a	*3*	*x*		*x*		Cloud and cloud shadows photo 624-743, surface chop
15	*3*	*x*		*x*		Cloud and cloud shadows photos 756-780, 803-822, 878-890, surface chop.
15a	*2*			*x*		Surface chop
16	*2*			*x*		Surface chop
17	*2*			*x*		Surface chop
18	*2*			*x*		Surface chop
19	*1*					
20	*1*					
21	*2*	*x*		*x*		Cloud and cloud shadows photo 1536-1577, surface chop
22	*1*					
23	*1*					
24	*1*			*x*		Surface chop
25	*1*					
26	*2*	*x*				Cloud and cloud shadows photo 1231-1255

Table 2. Transect total school area measurements (m^2): Set B 2011.

Transect	Date Flown	Reading 1	Reading 2
1	7/18/2011	43477	39228
1a	7/18/2011	114921	118502
2	7/18/2011	44348	42194
2a	7/23/2011	2964	2960
3	7/23/2011	118951	112903
3a	7/23/2011	98517	94217
4	7/23/2011	44870	41350
4a	7/23/2011	18704	19603
5	7/23/2011	4063	3495
5a	7/30/2011	0	0
6	8/10/2011	42510	41915
6a	8/10/2011	218523	245482
7	8/10/2011	102564	112529
7a	8/10/2011	53313	60883
8	8/10/2011	10765	9320
8a	8/10/2011	12176	13626
9	8/10/2011	12185	11975
9a	8/10/2011	134435	146664
10	8/10/2011	106639	116839
10a	8/10/2011	180091	190927
11	8/10/2011	44853	47833
11a	8/11/2011	76085	79471
12	8/11/2011	0	0
12a	8/11/2011	0	0
13	8/11/2011	0	0
13a	8/11/2011	0	0
14	8/11/2011	0	0
14a	8/11/2011	0	0
15	8/11/2011	0	0
15a	8/11/2011	0	0
16	8/11/2011	0	0

Table 3. Summary of between-reader differences in sardine school measurements for 6 transects from Set B in 2011.

Transect ID	Reading ID	Schools Measured (pre-resolution)		Schools measured (post-resolution)		Schools Added (missed)		Schools Subtracted (not a school)		Schools Subtracted (double counted)	
		Count	Area (m^2)	Count	Area (m^2)	Count	Area (m^2)	Count	Area (m^2)	Count	Area (m^2)
	1	30	39833	34	42510	4	2677	0	0	0	0
6	2	41	94806	34	41915	6	6769	13	59660	0	0
	Difference	11	54973	0	595			13			
	1	290	134420	289	134435	3	969	3	849	1	105
9a	2	176	110288	285	146664	112	37092	0	0	3	716
	Difference	114	24132	4	12229						
	1	83	215020	86	218523	3	3503	0	0	0	0
6a	2	92	194602	86	245482	24	50880	0	0	0	0
	Difference	9	20418	0	26960						
	1	125	114385	128	114921	3	536	0	0	0	0
1a	2	98	103430	128	118502	31	18702	1	3629	0	0
	Difference	27	10955	0	3582						
	1	101	98993	101	98517	1	80	1	556	0	0
3a	2	90	88402	100	94217	10	5815	0	0	0	0
	Difference	11	10590	1	4299						
	1	13	4016	14	4063	1	47	0	0	0	0
5	2	11	2361	14	3495	3	1134	0	0	0	0
	Difference	2	1655	0	567						
Total		1150	1200558	1299	1263245	201	128204	18	64695	4	822
Total Difference :		174	122723	5	48232						
Area Difference due to detection/ID:				74492	61%						
Area difference due to measurement only:				48232	39%						

Table 4. Summary of point sets planned, and accomplished in 2011, by size category.

Weight (mt)	No. Planned	No. Completed	No. Successful
3.8	12	5	4
10.6	12	3	3
17.0	11	6	5
26.5	11	22	12
51.9	10	11	6
70.5	10	2	1
82.1	10	3	2
95.0	-	1	1
115.0	-	1	1
140.0	-	0	0
	76	54	35

Table 4a. Summary of useable point sets in 2011.

Point Set ID	Photo Id	Time	Latitude	Longitude	Depth to Top of School (fm)	Depth to Bottom of School (fm)	Ocean Depth (fm)	Ocean Temp. (°F)	Sardine (mt)	Pacific Mackerel (mt)	TOTAL Delivery (mt)	% Sardine	% Pacific Mackerel	Surface Area (m²)
PJ_07202011_1	SP2_0032	3:15pm	47.4999	-124.7069	2	4	43	61	33.89	0.08	33.97	99.8%	0.2%	2866.56
PP_07232011_1	SP2_0050	5:15pm	47.4486	-124.5631	2	4	29	61	68.39	0.02	68.41	100.0%	0.0%	3531.40
LLK_07242011_1	SP2_0145	10:45am	47.3669	-124.4855	2	5	25	60	113.61	0.01	113.62	100.0%	0.0%	3102.61
EM_07242011_1	SP2_0294	12:15pm	47.3438	-124.4788	2	3	23	59	16.81	0.00	16.81	100.0%	0.0%	776.01
PP_07262011_1	SP2_0022	11:50am	47.3241	-124.5952	2	3	42	59	22.17	0.00	22.18	100.0%	0.0%	3413.86
PP_07262011_2	SP2_0293	1:10pm	47.3523	-124.5881	2	3	37	59	35.78	0.01	35.79	100.0%	0.0%	2205.35
LLK_07262011_1	SP2_0526	1:30pm	47.3089	-124.5963	2	5	42	60	89.35	0.02	89.37	100.0%	0.0%	5210.05
EM_07262011_1	SP2_0683	1:45pm	47.3075	-124.5791	2	4	36	61	32.22	0.01	32.22	100.0%	0.0%	2369.12
PP_07272011_1	SP2_0005	1:10pm	47.2559	-124.5352	2	5	33	58	77.81	0.01	77.82	100.0%	0.0%	4213.81
PP_07292011_1	SP2_0716	2:10pm	46.8891	-124.5202	2	4	50	59	65.36	0.01	65.37	100.0%	0.0%	1723.21
EM_07292011_1	SP2_1474	3:30pm	46.9038	-124.4984	2	4	46	55	12.44	0.02	12.46	99.8%	0.2%	1877.04
LLK_07292011_1	SP2_1755	3:55pm	46.8898	-124.4869	3	4.5	45	55	55.01	0.00	55.01	100.0%	0.0%	3422.88
PP_07312011_2	SP2_1348	5:45pm	46.6738	-124.4182	2	4	38	60	33.76	0.04	33.80	99.9%	0.1%	1711.25
EM_08012011_1	SP2_0063	2:05pm	46.691	-124.3533	2	4	38	55	52.52	0.01	52.53	100.0%	0.0%	3151.31
PP_08022011_1	SP2_0036	1:35pm	46.6714	-124.3517	2	4	44	59	47.35	0.01	47.36	100.0%	0.0%	4321.34
EM_08102011_1	SP2_0059	9:50am	46.6111	-124.3767	2	4	45	58	50.19	0.03	50.22	99.9%	0.1%	1641.26
PP_08102011_1	SP2_0442	10:15am	46.5882	-124.3663	4.5	6	48	59	31.14	0.03	31.16	99.9%	0.1%	1366.46
PP_08112011_1	SP2_0340	3:45pm	46.0328	-124.1934	2	4	48	60	6.13	0.00	6.13	100.0%	0.0%	832.24
LLK_08112011_1	SP2_0602	4:10pm	46.0368	-124.1893	1	3	46	56	5.14	0.00	5.14	99.9%	0.1%	689.51
PP_08112011_2	SP2_1046	4:40pm	46.0279	-124.1843	2	4	48	60	4.05	0.00	4.05	100.0%	0.0%	349.93
LLK_08112011_2	SP2_1351	5:40pm	46.0502	-124.1462	1	3	43	56	6.20	0.01	6.21	99.9%	0.1%	776.83
PP_08122011_1	SP2_0795	1:15pm	46.5016	-124.3889	3	6	52	61	24.02	0.02	24.04	99.9%	0.1%	1058.69
EM_08122011_1	SP2_1771	3:40pm	46.4547	-124.3934	2	4	46	61	37.58	0.06	37.64	99.8%	0.2%	976.01
LLK_08122011_1	SP2_2271	4:25pm	46.4128	-124.3986	2	5	55	60	61.60	0.01	61.61	100.0%	0.0%	2826.79
PP_08122011_2	SP2_2670	4:55pm	46.3739	-124.3895	3	6	58	61	27.36	0.02	27.37	99.9%	0.1%	1491.76
EM_08162011_1	SP2_0064	12:40pm	45.8985	-124.2050	2	3	57	61	17.22	0.04	17.27	99.7%	0.3%	585.23
EM_08182011_1	SP2_0716	1:05pm	45.9881	-124.1956	2	5	49	61	17.68	0.00	17.68	100.0%	0.0%	992.37
EM_08182011_2	SP2_1568	2:50pm	46.0413	-124.1554	2	4	43	61	16.25	0.00	16.25	100.0%	0.0%	598.57
LLK_08182011_1	SP2_1802	3:05pm	46.0400	-124.1442	2	4	43	58	35.90	0.00	35.90	100.0%	0.0%	1443.56
LLK_08242011_1	SP2_0324	12:30pm	46.1477167	-124.38775	1	4	64	59	37.69	0.00	37.69	100.0%	0.0%	1581.73
LLK_08242011_2	SP2_0672	2:40pm	46.1872	-124.40825	1	3	63	59	17.39	0.31	17.70	98.2%	1.8%	2184.47
LLK_08272011_1	SP2_0196	4pm	46.9572	-124.5754	2	5	51	57	123.65	0.28	123.93	99.8%	0.2%	4479.56
LLK_08302011_1	SP2_0119	10:45am	47.16585	-124.50432	2	8	33	56	58.80	0.20	59.00	99.7%	0.3%	1274.77
LLK_09012011_1	SP2_1275	2pm	46.5266	-124.4624	2	7	68	58	90.77	0.09	90.85	99.9%	0.1%	1608.91
EM_09012011_1	SP2_1656	2:20pm	46.5259	-124.4964	2	4	52	58	33.77	0.12	33.88	99.7%	0.3%	1261.87

Table 4b. Summary of useable point sets in 2009.

Point Set ID	Photo Id	Time	Latitude	Longitude	Depth to Top of School (fm)	Depth to Bottom of School (fm)	Ocean Depth (fm)	Ocean Temp. (°F)	Sardine (mt)	Pacific Mackerel (mt)	TOTAL Delivery (mt)	% Sardine	% Pacific Mackerel	Surface Area (m²)
PP_07282009_1	3A8K0249	1210	46.0558	-124.0209	3	6	19	58	29.42	0.00	29.43	100.0%	0.0%	1546.51
LLK_07282009_1	3A8K0285	1230	46.0578	-124.0165	2	6	20	55.8	22.41	0.00	22.41	100.0%	0.0%	1297.34
PP_07282009_2	3A8K0604	1330	46.0261	-124.0084	3	6	20	58	19.36	0.00	19.36	100.0%	0.0%	544.53
LLK_07282009_2	3A8K0703	1430	46.0205	-124.0094	2	6	19	55.6	34.98	0.00	34.98	100.0%	0.0%	1914.62
PP_08132009_1	SP1_0079	1145	46.1127	-124.3428	2	9	60	62	127.40	0.75	128.15	99.4%	0.6%	3038.96
LLK_08132009_1	SP2_0991	1530	46.0694	-124.3162	0	2	61	62	2.68	0.00	2.68	100.0%	0.0%	204.53
PP_08142009_1	SP1_0033	1150	46.0940	-124.2540	3	7	54	62	49.78	0.32	50.10	99.4%	0.6%	2020.14
LLK_08142009_1	SP1_0107	1200	46.0998	-124.2734	0	3	53	61	41.94	0.06	42.00	99.9%	0.1%	1396.40
PP_08142009_2	SP1_0030	1406	46.0509	-124.2836	3	7	55	62	32.48	0.09	32.57	99.7%	0.3%	675.41
LLK_08162009_1	SP1_0106	1300	46.4331	-124.2359	1	6	27	61	57.74	0.51	58.25	99.1%	0.9%	891.43
PP_08162009_1	SP1_0475	1440	46.4708	-124.2153	1	6	27	62	27.24	0.01	27.25	100.0%	0.0%	1145.93
PP_08222009_1	77	1202	46.6997	-124.3003			37	60	7.11	0.05	7.15	99.3%	0.7%	923.00
PP_08222009_2	197	1310	46.6980	-124.3254			38	60	26.56	0.00	26.56	100.0%	0.0%	1666.02
LLK_08222009_1	411	1330	46.6981	-124.3118	2	4	33	60	10.17	0.00	10.17	100.0%	0.0%	970.65
PP_08222009_3	456	1450	46.7030	-124.3054			37	60	15.75	0.11	15.87	99.3%	0.7%	212.81
LLK_08222009_2	506	1530	46.6942	-124.2900	2	5	30	60	39.10	0.05	39.14	99.9%	0.1%	647.05
PP_08232009_1	335	1230	46.5554	-124.1867			20	62	18.60	0.19	18.78	99.0%	1.0%	931.16
LLK_08232009_1	422	1230	46.5495	-124.1998	0	2.5	20	60	13.55	0.11	13.65	99.2%	0.8%	702.06
LLK_08232009_2	508	1430	46.5477	-124.1954	2	6	20	60	48.90	0.41	49.31	99.2%	0.8%	704.35
PP_08232009_2	615	1450	46.5512	-124.1968			20	62	15.08	0.31	15.39	98.0%	2.0%	743.67
PP_08242009_1	143	1500	46.4638	-124.1607	2	4	25	58	26.40	0.02	26.42	99.9%	0.1%	972.39
LLK_08242009_1	961	1300	46.5429	-124.2523	2	4	25	59	28.55	0.01	28.56	100.0%	0.0%	832.26
PP_09012009_1	297	930	46.1562	-124.1360			33	58	29.85	0.06	29.91	99.8%	0.2%	2148.96
LLK_09012009_1	389	1000	46.1570	-124.1332	2	6	27	55	39.40	0.05	39.45	99.9%	0.1%	2451.53
LLK_09012009_2	574	1230	46.1294	-124.1131	2	6	28	55	39.85	0.04	39.89	99.9%	0.1%	1671.78
PP_09012009_2	998	1230	46.1443	-124.1023			23	58	45.03	0.08	45.12	99.8%	0.2%	4543.25
PP_09022009_1	137	1000	46.1109	-124.1712			45	59	80.43	0.06	80.49	99.9%	0.1%	4243.20
LLK_09022009_1	252	1130	46.1071	-124.1886	1	3	40	58	29.31	0.01	29.32	100.0%	0.0%	1205.97

Table 4c. Summary of useable point sets in 2010.

Point Set ID	Photo Id	Time	Latitude	Longitude	Depth to Top of School (fm)	Depth to Bottom of School (fm)	Ocean Depth (fm)	Ocean Temp. (^{o}F)	Sardine (mt)	Pacific Mackerel (mt)	TOTAL Delivery (mt)	% Sardine	% Pacific Mackerel	Surface Area (m²)
PP_08202010_1	SP2_0064	12:45	46.5919	-124.4220	2.5	7.5	54		80.41	0.64	81.05	99.2%	0.8%	1867.48
LLK_08202010_1	SP2_0184	13:20	46.5788	-124.4133	2.5	7	52		76.33	0.09	76.43	99.9%	0.1%	1987.65
PK_08212010_1	SP2_0343	14:45	46.3522	-124.3502			50		51.39	0.16	51.56	99.7%	0.3%	2135.80
LLK_08212010_1	SP2_0462	15:30	46.3580	-124.3366	2	4.5	48		31.78	0.11	31.89	99.7%	0.3%	1840.49
PP_08222010_1	SP2_0657	11:15	46.1269	-124.3272	3	9	58		113.24	0.46	113.70	99.6%	0.4%	2674.60
PP_08232010_1	SP2_0021	10:30	46.1452	-124.3410	2	6	60		59.89	1.65	61.54	97.3%	2.7%	2676.29
LLK_08232010_1	SP2_0348	13:00	46.1512	-124.3525	2	5	60		51.11	0.18	51.29	99.7%	0.3%	2087.87
PP_08232010_2	SP2_0437	12:30	46.1481	-124.3432	2	6	63		60.02	0.70	60.72	98.8%	1.2%	1876.28
PP_08242010_1	SP2_0008	10:35	46.1954	-124.5371	3	6	77	59.3	47.64	0.89	48.53	98.2%	1.8%	3660.70
LLK_08242010_1	SP2_0084	11:00	46.1888	-124.5485	2	4	82		45.83	0.22	46.05	99.5%	0.5%	2570.49
LLK_08262010_1	SP2_0257	14:20	46.3672	-124.4742	2	5	70		75.32	0.09	75.41	99.9%	0.1%	3892.22
PK_08262010_1	SP2_0352	15:00	46.3026	-124.4822	2	8	170		38.84	0.48	39.32	98.8%	1.2%	2792.20
PP_08272010_1	SP2_0002	11:43	46.3205	-124.5086	3	6	75	59	139.33	0.09	139.42	99.9%	0.1%	3167.16
PK_08272010_1	SP2_0131	12:30	46.3061	-124.5076	2	4	75		32.75	0.01	32.76	100.0%	0.0%	775.22
PP_08292010_1	SP2_0057	11:30	46.6722	-124.4356	3	6	48	57.7	80.74	0.59	81.33	99.3%	0.7%	817.69
PK_08292010_1	SP2_0139	11:50	46.6776	-124.4353	2	9	54		81.84	0.12	81.96	99.9%	0.1%	2044.20
LLK_08292010_1	SP2_0515	15:00	46.6637	-124.3964	2	5	44		31.99	0.00	31.99	100.0%	0.0%	1112.89
LLK_08302010_1	SP2_0148	12:54	46.4980	-124.5095	2	6	115		76.04	0.04	76.08	99.9%	0.1%	1764.58
PP_08302010_1	SP2_0259	13:17	46.5232	-124.5292	3	6	126	59.1	40.29	0.05	40.34	99.9%	0.1%	1792.15
PP_08302010_2	SP2_0361	15:00	46.5201	-124.4582	3	6	64	59.1	31.05	0.11	31.16	99.6%	0.4%	1528.72
LLK_09012010_1	SP2_0004	12:10	46.4363	-124.4109	2	4.5	52		53.75	0.04	53.79	99.9%	0.1%	953.44
PP_09012010_1	SP2_0111	12:40	46.4575	-124.3985	3	6	52	58.9	67.88	0.04	67.92	99.9%	0.1%	1672.51
PK_09012010_1	SP2_0183	13:30	46.4323	-124.4201	2	8	57	57	33.17	0.07	33.24	99.8%	0.2%	1635.58
PP_09022010_1	SP2_0474	12:52	46.6157	-124.2861	2	4	34	58	67.84	0.16	68.00	99.8%	0.2%	7461.48
LLK_09042010_1	SP2_0497	15:00	46.5819	-124.3235	2	7	37		96.90	0.10	97.00	99.9%	0.1%	3470.27

Table 5. Summary of point sets not useable in 2011.

Vessel	Point Set ID	Time	Latitude	Longitude	Depth to Top of School (fm)	Depth to Bottom of School (fm)	Ocean Depth (fm)	Ocean Temp.	Sardine (mt)	Pacific Mackerel (mt)	TOTAL Delivery (mt)	% Sardine	% Pacific Mackerel	Surface Area (m^2)	Comments
Pacific Pursuit	PP_07202011_1	3:45pm	47.5307	-124.7050	4	5	43	61	34.126	0.044	34.170	99.9%	0.1%	1878.33	100% Capture - Camera Malfunction
Lauren L Kapp* **	LLK_07222011_1	11:50am	47.4524	-124.5755	2	5	30	60	93.937	0.000	93.937	100.0%	0.0%	2912.54	90% Capture - Flown @ 2000'
Evermore	EM_07222011_1	12:10pm	47.4627	-124.5620	2	4	30	61	33.275	0.000	33.275	100.0%	0.0%	2484.01	90% Capture - Flown @ 2000'
Pacific Pursuit	PP_07222011_1	1:20pm	47.4599	-124.5866	2	5	30	61	56.299	0.009	56.308	100.0%	0.0%	2186.66	100% Capture - Flown @ 3000'
Lauren L Kapp	LLK_07302011_1	3:15pm	46.7737	-124.4454	3	5	45	56	36.752	0.043	36.794	99.9%	0.1%	Not Measured	< 90% Captured
Pacific Pursuit	PP_07302011_1	3:40pm	46.7949	-124.4658	2	4	48	59	46.831	0.011	46.843	100.0%	0.0%	Not Measured	No Purse Photograph
Pacific Pursuit No. 1	PP_07312011_1	3:00pm	46.6927	-124.3842	2	4	42	60	49.358	0.055	49.414	99.9%	0.1%	Not Measured	School Not Discrete
Lauren L Kapp	LLK_07312011_1	3:40pm	46.7119	-124.3923	2	4	43	56	68.456	0.183	68.639	99.7%	0.3%	Not Measured	School Not Discrete
Lauren L Kapp	LLK_08012011_1	4:35pm	46.7378	-124.4243	0	4	43	55	9.077	0.008	9.086	99.9%	0.1%	Not Measured	<90% Captured
Evermore	EM_08022011_1	1:50pm	46.7145	-124.403	2	4	47	58	37.500	0.000	37.500	100.0%	0.0%	1227.29	95% Capture - Flown between 3,000 - 3,500 ft
Pacific Pursuit No.2	PP_08022011_2	3:00pm	46.7336	-124.4167	2	4	44	59	25.682	0.082	25.764	99.7%	0.3%	652.01	100% Capture - Flown between 3,000 - 3,500 ft
Pacific Pursuit	PP_08092011_1	12:50pm	46.6816	-124.4168	3	6	49	58	71.959	0.004	71.963	100.0%	0.0%	2150.55	98% Capture - Flown @ 2000'
Lauren L Kapp	LLK_08102011_1	11:35pm	46.5914	-124.4157	3	6	50	56	61.233	0.048	61.280	99.9%	0.1%	Not Measured	Camera Malfunction (no purse photo)
Pacific Pursuit No.2	PP_08102011_2	1:35pm	46.6126	-124.4532	5	6	55	59	44.077	0.033	44.109	99.9%	0.1%	1067.80	95% Capture - Flown @ 2000'
Pacific Pursuit	PP_08132011_1	12:25pm	46.1411	-124.3002	3	6	54	59	62.769	0.005	62.774	100.0%	0.0%	4726.19	100% Capture - Flown @ 3,000'
Lauren L Kapp	LLK_08132011_1	2:50pm	46.1041	-124.2507	2	5	50	57	32.642	0.000	32.642	100.0%	0.0%	1915.10	100% Capture - Flown @ 3,000'
Evermore	EM_08132011_1	3:15pm	46.0910	-124.2537	2	4	52	61	28.283	0.000	28.283	100.0%	0.0%	Not Measured	95% Capture - Flown @ 3,000' - School not discrete
Lauren L Kapp	LLK_09042011_1	10:10am	47.0117	-124.5517	2	7	42	56	66.210	0.019	66.228	100.0%	0.0%	Not Measured	60% Capture

Table 6. Likelihood ratio test results: H_o: No difference between fit of pooled point set data vs. point set data from 2011 alone; H_a: Difference in fit between models.

Comparision of MM model fits to pooled data from 2008-2010 with the new data from 2011:

Point Set Data	Data File Name	Model Name	Log Likelihood	df
(2008-2010)	cdataALLsans2011	mmfitb	-44.50	57
(2011)	cdata2011	mmfita	-29.10	32
(2008-2011)	cdataALL	mmfit	-78.96	92
		LLcombined	-78.96	92
		LLseparate	-73.60	89

(LLseparate - LLcombined) =	5.367	
Chi Sq (df=3) P =	0.147	->Fail to reject H_o at 0.05 significance level.

Table 7. Estimates of sardine biomass on Set B transects in 2011.

Transect	Estimates using 2011 Point Set Data Sardine Biomass (mt)		Estimates using 2008-2011 Point Set Data Sardine Biomass (mt)	
	Reading 1	Reading 2	Reading 1	Reading 2
1	780.2	699.1	905.8	791.1
1a	2125.9	2180.5	2670.9	2717.1
2	775.1	734.0	854.8	792.6
2a	58.4	58.5	88.0	89.5
3	1750.0	1691.4	1659.4	1647.3
3a	1812.0	1744.1	2239.1	2189.6
4	849.2	788.2	1137.0	1074.9
4a	355.9	370.9	477.2	489.1
5	79.8	69.0	119.4	104.8
5a	0.0	0.0	0.0	0.0
6	722.3	719.3	777.5	778.3
6a	3452.3	3804.7	3398.4	3661.9
7	1878.6	2064.2	2322.8	2546.7
7a	1020.1	1167.5	1409.9	1620.1
8	210.1	182.3	305.8	267.7
8a	229.6	259.4	308.4	353.5
9	234.8	229.7	328.8	318.7
9a	2560.5	2727.3	3483.2	3554.5
10	2053.0	2252.0	2895.0	3186.7
10a	3460.1	3653.7	4833.9	5057.5
11	854.2	907.3	1156.7	1214.6
11a	1394.3	1462.6	1696.2	1830.5
12	0.0	0.0	0.0	0.0
12a	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0
13a	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0
14a	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0
15a	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0

Appendix I

West Coast Aerial Sardine Survey

2011

Field Operational Plan

Industry Coordinator:

Northwest Sardine Survey, LLC
(Jerry Thon, Principal)

Science Advisor:

Tom Jagielo
Tom Jagielo, Consulting

Scientific Field Project Leader:

Ryan Howe

July 5th, 2011

Aerial Transect Survey

Overall Aerial Survey Design

Mr. Jerry Thon will oversee the day to day logistic activities of the survey, including deployment of vessels and aircraft as needed to accomplish the projects objectives. To ensure clear communications among participants and other interested parties, the Single Point of Contact (SPC) person for 2011 survey field work will be Mr. Chris Cearns (NWSS), working under the direction of Mr. Thon.

Scientific field work will be conducted in Washington and Oregon by Mr. Ryan Howe with oversight from Mr. Tom Jagielo. Mr. Howe will lead the digital photograph analysis team and will archive all photographic and biological data.

Mr. Jagielo will be responsible for analyzing the survey data and will report the results to Dr. Kevin Hill, NMFS, SWFSC, in a form suitable for input to the stock assessment model. Mr. Howe will be available to help with data analysis as requested.

The 2011 aerial survey design consists of 41 transects spanning the area from Cape Flattery in the north to the Oregon-California border in the south (Table 1, Figure 1). Each 41-transect series will be conducted as a SET, and will make up one survey replicate. The 2011 survey will strive to complete three replicate SETS, or 123 transects in total. Survey coverage could potentially be extended northward into Canada -- if Canadian governmental approvals can be obtained.

Location of Transects
The east and west endpoints of each transect and corresponding shoreline position are given in Tables 1a-c and are mapped in Figures 1a-c for each of the three replicates (SET A, SET B, and SET C, respectively). Transects start at 3 miles from shore and extend westward for 35 statute miles in length. Transect spacing differs in the north (7.5 nautical miles) compared to the south (15 nautical miles) of the survey area. In addition to the 35 statute mile transect, the 3 statute mile segment directly eastward of each transect to the shore will be flown and photographed. Survey biomass will be estimated from the 35 statute mile transect data. Photographs from the shoreward segment will be used primarily to evaluate the need for future modification of the survey design.

Aerial Resources
Two Piper Super Cubs and one Cessna 337 will be used to conduct survey transects and point sets. Survey airplanes will be equipped with a Canon EOS 1Ds in an Aerial Imaging Solutions FMC mount system (Adjunct 1), installed inside the fuselage of the plane.

Use of Aerial Resources
Aerial resources will be coordinated by Mr. Thon (NWSS). To conduct a SET, survey pilots will begin with transect number 1 at Cape Flattery in the north and will proceed to the southernmost transect off the southern Oregon coast. When operating together as a team, pilots will communicate via radio or cell phone. They will take a “Leap-Frog” approach: for example --

plane 1 will fly transects 1-5 while plane 2 is flying transects 6-10; then plane 1 will fly transects 11-15 while plane 2 flies Transects 16-20, and so on. The actual number of transects flown in a day by each plane will be determined jointly by the survey pilots and Mr. Thon and may be more or less than the example of five per plane given above.

Conditions Acceptable for Surveying

At the beginning of each potential survey day, the survey pilots will confer with Mr. Thon 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.

Transect Sampling

Prior to beginning a survey flight, the Pre-Flight Survey Checklist (Adjunct 2) will be completed for each aircraft. This will ensure that the camera system settings are fully operational for data collection. For example, it is crucial to have accurate GPS information in the log file. It is also crucial that the photograph number series is re-set to zero. Transects flown without the necessary survey data are not valid and cannot be analyzed.

The decision of when to start a new SET of transects will be determined by Mr. Thon with input from Mr. Jagielo and/or others as requested. Transects will be flown at the nominal survey altitude of 4,000 ft whenever possible. Transects may be flown starting at either the east end or the west end.

A Transect Flight Log Form (Adjunct 2) 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.

Sardine are believed to migrate from California, northward during the summer. Thus, to avoid the possibility of “double counting”, it is important that transects are conducted in a North-to-South progression. Once a transect (or a portion of a transect) has been flown, neither that transect, nor any transects to the north of that transect, may be flown again during that transect SET in progress. It will be acceptable to skip transects or portions of transects if conditions require it (e.g. if better weather is available to the south of an area), but transects may not be “made up” once skipped during the sampling of a transect SET. Once begun, the goal is to cover the full 41-transect SET in as few days as possible.

Data Transfer

Photographs and FMC log files will be downloaded and forwarded for analysis and archival at the end of each survey day. At the end of each flight, the Scientific Field Project Leader (Mr. Howe) will verify that the camera and data collection system operated properly and that images collected are acceptable for analysis. Mr. Howe will collect data from the pilots and will coordinate the transfer and archival of all aerial survey data.

I. Point Set Sampling

Location, Number, and Size of Point Sets
Point sets are fully captured sardine schools landed by purse seiners approved and permitted for this research. Each set by a purse seiner will be directed by one of the survey pilots. Point sets will be made over as wide an area as feasible within the survey area, in order to distribute the sampling effort spatially. We anticipate that point sets will be landed into both Washington and Oregon ports in 2011.

Point sets will be collected over a range of sizes, as set out in Table 2. The goal is to obtain 76 valid point sets.

Aerial Photography of Point Sets
The detailed protocol for point set sampling is given in Adjunct 4. Sardine schools to be captured for point sets will be first selected by the survey pilot and photographed at the nominal survey altitude of 4,000 ft. Following a discrete school selection, the 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. Photographs will be taken before and during the vessels approach to the school for the point set capture. Each school selected by the pilot and photographed for a potential point set will be logged on the survey pilot's Point Set Flight Log Form (Adjunct 2). 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 (Adjunct 2). These records will be used to determine the rate of school mis-identification by spotter pilots in the field and by analysts viewing photographs taken at the nominal survey altitude of 4,000 ft.

Vessel Point Set Capture
The purse seine vessel will encircle (wrap) and fully capture the school selected by the survey pilot for the point set. Any school 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 survey 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 (Adjunct 2). 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. A subsample of 25 fish from each point set sample will be individually bagged, identified with sample number and frozen with other fish in the subsample, clearly identified as to point set number, vessel, and location captured and retained for collection of otoliths.

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. Simrad ES-60 sounders will be installed on two purse seine vessels. Data collected by the ES-60 sounders will be backed-up daily and archived onshore.

Number and Size of Point Sets to be Captured
Point sets will be conducted for a range of school sizes (Table 2). Point sets will be targeted working in general from the smallest size category to the largest. Each day, spotter pilots will operate with an updated list of remaining school sizes needed for analysis. Each 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. Every effort will be made to ensure, as soon as possible, that successfully landed point sets were also successfully photographed. This will in general be at the end of each fishing day or sooner. After verification of point set acceptability, the list of remaining school sizes needed from Table 2 will be updated accordingly for ongoing 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. Pumping large sets onto more than one vessel should be avoided, and should only be done in the accidental event that school size was grossly underestimated. Mr. Howe 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 2,700 mt.

Spatial Distribution of Point Sets
In order to distribute point sets spatially, sampling will occur both north and south of the Columbia River. This will be facilitated by landing point sets in both Washington and Oregon ports in 2011. Efforts will be made to distribute the point sets offshore vs. nearshore, as well. Quadrants have been identified to facilitate spatial distribution of the point sets (Figure 2).

Landing Reporting Requirements
Cumulative point set landings will be updated by Mr. Chris Cearns (NWSS), who will report the running total 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
To ensure clear communications among participants and other interested parties, the single point of contact (SPC) person during 2011 survey field work will be Mr. Chris Cearns.

Mr. Cearns (under the direction of Mr. Thon) will also 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.

II. Calibration and Validation

Aerial Measurement Calibration
Each survey year, routine calibration is conducted to verify aerial measurements. A series of photographs will again be collected from a feature of known size (e.g., a football field or tennis court) on the ground, from the altitudes of 1,000 ft, 2,000 ft, 3,000 ft, and 4,000 ft. For each altitude series, an aerial pass will be made to place the target onto the right, middle, and left portions of the photographic image.

Aerial Photographs and Sampling for Species Validation
The collection of reference photographs is updated each survey year, for the purpose of species identification. These photographs are used by the team of photograph analysts to continue to learn how to discern between sardine and other species as they appear on the aerial transect photographs.

Reference photographs will be taken at the nominal survey altitude of 4,000 ft for the purpose of species identification. The spotter pilots 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 (typically a small, relatively fast boat) will collect a jig sample to document the species identification. This sampling will most likely occur in June, prior to commencement of the summer fishery opening.

Tables 1a -1i Transect SETs A, B, and C.

Table 1a. SET A

	Survey	Transect	Transect Latitude		West End			East End			Shoreline		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Washington	N	A1	48	20.000	125	29.30	A1w	124	43.71	A1e	124	39.81	A1s
Washington	N	A1a	48	12.500	125	30.98	A1aw	124	45.51	A1ae	124	41.61	A1as
Washington	N	A2	48	5.000	125	30.99	A2w	124	45.63	A2e	124	41.74	A2s
Washington	N	A2a	47	57.500	125	29.48	A2aw	124	44.24	A2ae	124	40.36	A2as
Washington	N	A3	47	50.000	125	21.05	A3w	124	35.91	A3e	124	32.04	A3s
Washington	N	A3a	47	42.500	125	13.82	A3aw	124	28.79	A3ae	124	24.93	A3as
Washington	N	A4	47	35.000	125	10.89	A4w	124	25.96	A4e	124	22.11	A4s
Washington	N	A4a	47	27.500	125	9.13	A4aw	124	24.30	A4ae	124	20.46	A4as
Washington	N	A5	47	20.000	125	5.89	A5w	124	21.17	A5e	124	17.33	A5s
Washington	N	A5a	47	12.500	125	0.98	A5aw	124	16.37	A5ae	124	12.54	A5as
Washington	N	A6	47	5.000	124	59.07	A6w	124	14.57	A6e	124	10.76	A6s
Washington	N	A6a	46	57.500	124	58.70	A6aw	124	14.30	A6ae	124	10.50	A6as
Washington	N	A7	46	50.000	124	54.58	A7w	124	10.28	A7e	124	6.49	A7s
Washington	N	A7a	46	42.500	124	52.93	A7aw	124	8.73	A7ae	124	4.95	A7as
Washington	N	A8	46	35.000	124	51.75	A8w	124	7.66	A8e	124	3.88	A8s
Washington	N	A8a	46	27.500	124	51.41	A8aw	124	7.42	A8ae	124	3.65	A8as
Washington	N	A9	46	20.000	124	51.77	A9w	124	7.87	A9e	124	4.11	A9s
Washington	N	A9a	46	12.500	124	47.63	A9aw	124	3.83	A9ae	124	0.08	A9as
Oregon	N	A10	46	5.000	124	43.80	A10w	124	0.10	A10e	123	56.36	A10s
Oregon	N	A10a	45	57.500	124	45.71	A10aw	124	2.11	A10ae	123	58.38	A10as
Oregon	N	A11	45	50.000	124	44.99	A11w	124	1.50	A11e	123	57.77	A11s
Oregon	N	A11a	45	42.500	124	43.65	A11aw	124	0.25	A11ae	123	56.53	A11as
Oregon	N	A12	45	35.000	124	44.22	A12w	124	0.91	A12e	123	57.20	A12s
Oregon	N	A12a	45	27.500	124	45.16	A12aw	124	1.95	A12ae	123	58.25	A12as
Oregon	N	A13	45	20.000	124	45.10	A13w	124	1.99	A13e	123	58.29	A13s
Oregon	N	A13a	45	12.500	124	44.94	A13aw	124	1.92	A13ae	123	58.23	A13as
Oregon	N	A14	45	5.000	124	46.96	A14w	124	4.03	A14e	124	0.36	A14s
Oregon	N	A14a	44	57.500	124	47.76	A14aw	124	4.93	A14ae	124	1.26	A14as
Oregon	N	A15	44	50.000	124	49.86	A15w	124	7.12	A15e	124	3.45	A15s
Oregon	N	A15a	44	42.500	124	49.95	A15aw	124	7.31	A15ae	124	3.65	A15as
Oregon	N	A16	44	35.000	124	50.38	A16w	124	7.83	A16e	124	4.18	A16s
Oregon	N	A17	44	20.000	124	52.00	A17w	124	9.63	A17e	124	6.00	A17s
Oregon	N	A18	44	5.000	124	53.44	A18w	124	11.25	A18e	124	7.63	A18s
Oregon	N	A19	43	50.000	124	55.46	A19w	124	13.45	A19e	124	9.84	A19s
Oregon	N	A20	43	35.000	124	58.98	A20w	124	17.14	A20e	124	13.55	A20s
Oregon	N	A21	43	20.000	125	7.59	A21w	124	25.92	A21e	124	22.35	A21s
Oregon	N	A22	43	5.000	125	11.18	A22w	124	29.67	A22e	124	26.12	A22s
Oregon	N	A23	42	50.000	125	18.75	A23w	124	37.41	A23e	124	33.87	A23s
Oregon	N	A24	42	35.000	125	8.28	A24w	124	27.11	A24e	124	23.59	A24s
Oregon	N	A25	42	20.000	125	10.20	A25w	124	29.20	A25e	124	25.68	A25s
Oregon	N	A26	42	5.000	125	3.86	A26w	124	23.02	A26e	124	19.52	A26s

Table 1b. SET B

	Survey	Transect	Transect Latitude		West End			East End			Shoreline		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Washington	N	B1	48	15.000	125	30.91	B1w	124	45.40	B1e	124	41.50	B1s
Washington	N	B1a	48	7.500	125	31.79	B1aw	124	46.39	B1ae	124	42.50	B1as
Washington	N	B2	48	0.000	125	29.92	B2w	124	44.64	B2e	124	40.75	B2s
Washington	N	B2a	47	52.500	125	23.80	B2aw	124	38.62	B2ae	124	34.75	B2as
Washington	N	B3	47	45.000	125	15.09	B3w	124	30.02	B3e	124	26.16	B3s
Washington	N	B3a	47	37.500	125	11.56	B3aw	124	26.60	B3ae	124	22.74	B3as
Washington	N	B4	47	30.000	125	9.43	B4w	124	24.58	B4e	124	20.73	B4s
Washington	N	B4a	47	22.500	125	7.95	B4aw	124	23.20	B4ae	124	19.37	B4as
Washington	N	B5	47	15.000	125	1.78	B5w	124	17.13	B5e	124	13.31	B5s
Washington	N	B5a	47	7.500	124	59.49	B5aw	124	14.95	B5ae	124	11.13	B5as
Washington	N	B6	47	0.000	124	58.62	B6w	124	14.19	B6e	124	10.38	B6s
Washington	N	B6a	46	52.500	124	55.48	B6aw	124	11.15	B6ae	124	7.35	B6as
Washington	N	B7	46	45.000	124	53.93	B7w	124	9.70	B7e	124	5.91	B7s
Washington	N	B7a	46	37.500	124	52.05	B7aw	124	7.92	B7ae	124	4.14	B7as
Washington	N	B8	46	30.000	124	51.33	B8w	124	7.31	B8e	124	3.54	B8s
Washington	N	B8a	46	22.500	124	51.46	B8aw	124	7.53	B8ae	124	3.77	B8as
Washington	N	B9	46	15.000	124	51.41	B9w	124	7.59	B9e	124	3.83	B9s
Washington	N	B9a	46	7.500	124	44.62	B9aw	124	0.89	B9ae	123	57.14	B9as
Oregon	N	B10	46	0.000	124	43.24	B10w	123	59.61	B10e	123	55.87	B10s
Oregon	N	B10a	45	52.500	124	45.05	B10aw	124	1.51	B10ae	123	57.78	B10as
Oregon	N	B11	45	45.000	124	45.10	B11w	124	1.67	B11e	123	57.94	B11s
Oregon	N	B11a	45	37.500	124	43.78	B11aw	124	0.44	B11ae	123	56.73	B11as
Oregon	N	B12	45	30.000	124	44.58	B12w	124	1.34	B12e	123	57.63	B12s
Oregon	N	B12a	45	22.500	124	44.90	B12aw	124	1.76	B12ae	123	58.06	B12as
Oregon	N	B13	45	15.000	124	44.81	B13w	124	1.76	B13e	123	58.07	B13s
Oregon	N	B13a	45	7.500	124	45.43	B13aw	124	2.48	B13ae	123	58.79	B13as
Oregon	N	B14	45	0.000	124	47.23	B14w	124	4.36	B14e	124	0.69	B14s
Oregon	N	B14a	44	52.500	124	48.78	B14aw	124	6.01	B14ae	124	2.34	B14as
Oregon	N	B15	44	45.000	124	50.13	B15w	124	7.46	B15e	124	3.80	B15s
Oregon	N	B15a	44	37.500	124	50.24	B15aw	124	7.66	B15ae	124	4.01	B15as
Oregon	N	B16	44	30.000	124	51.11	B16w	124	8.62	B16e	124	4.97	B16s
Oregon	N	B17	44	15.000	124	52.78	B17w	124	10.47	B17e	124	6.84	B17s
Oregon	N	B18	44	0.000	124	54.02	B18w	124	11.88	B18e	124	8.27	B18s
Oregon	N	B19	43	45.000	124	56.45	B19w	124	14.49	B19e	124	10.90	B19s
Oregon	N	B20	43	30.000	125	0.71	B20w	124	18.92	B20e	124	15.34	B20s
Oregon	N	B21	43	15.000	125	8.59	B21w	124	26.92	B21e	124	23.35	B21s
Oregon	N	B22	43	0.000	125	12.51	B22w	124	31.07	B22e	124	27.52	B22s
Oregon	N	B23	42	45.000	125	15.75	B23w	124	34.46	B23e	124	30.93	B23s
Oregon	N	B24	42	30.000	125	9.74	B24w	124	28.63	B24e	124	25.11	B24s
Oregon	N	B25	42	15.000	125	9.03	B25w	124	28.08	B25e	124	24.57	B25s
Oregon	N	B26	42	0.000	124	56.96	B26w	124	16.17	B26e	124	12.67	B26s

Table 1c. SET C

	Survey	Transect	Transect Latitude		West End			East End			Shoreline		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Washington	N	C1	48	10.000	125	33.23	C1w	124	47.80	C1e	124	43.91	C1s
Washington	N	C1a	48	2.500	125	30.14	C1aw	124	44.81	C1ae	124	40.93	C1as
Washington	N	C2	47	55.000	125	27.35	C2w	124	42.14	C2e	124	38.27	C2s
Washington	N	C2a	47	47.500	125	17.80	C2aw	124	32.70	C2ae	124	28.83	C2as
Washington	N	C3	47	40.000	125	12.56	C3w	124	27.57	C3e	124	23.71	C3s
Washington	N	C3a	47	32.500	125	10.08	C3aw	124	25.18	C3ae	124	21.34	C3as
Washington	N	C4	47	25.000	125	8.72	C4w	124	23.94	C4e	124	20.10	C4s
Washington	N	C4a	47	17.500	125	2.94	C4aw	124	18.26	C4ae	124	14.43	C4as
Washington	N	C5	47	10.000	125	0.13	C5w	124	15.56	C5e	124	11.73	C5s
Washington	N	C5a	47	2.500	124	58.74	C5aw	124	14.26	C5ae	124	10.45	C5as
Washington	N	C6	46	55.000	124	57.35	C6w	124	12.98	C6e	124	9.18	C6s
Washington	N	C6a	46	47.500	124	53.97	C6aw	124	9.71	C6ae	124	5.91	C6as
Washington	N	C7	46	40.000	124	52.16	C7w	124	8.00	C7e	124	4.21	C7s
Washington	N	C7a	46	32.500	124	51.45	C7aw	124	7.39	C7ae	124	3.61	C7as
Washington	N	C8	46	25.000	124	51.33	C8w	124	7.37	C8e	124	3.60	C8s
Washington	N	C8a	46	17.500	124	52.19	C8aw	124	8.33	C8ae	124	4.57	C8as
Washington	N	C9	46	10.000	124	45.89	C9w	124	2.13	C9e	123	58.38	C9s
Washington	N	C9a	46	2.500	124	43.18	C9aw	123	59.52	C9ae	123	55.78	C9as
Oregon	N	C10	45	55.000	124	45.64	C10w	124	2.08	C10e	123	58.35	C10s
Oregon	N	C10a	45	47.500	124	45.21	C10aw	124	1.74	C10ae	123	58.02	C10as
Oregon	N	C11	45	40.000	124	43.51	C11w	124	0.14	C11e	123	56.43	C11s
Oregon	N	C11a	45	32.500	124	44.06	C11aw	124	0.79	C11ae	123	57.08	C11as
Oregon	N	C12	45	25.000	124	44.58	C12w	124	1.40	C12e	123	57.70	C12s
Oregon	N	C12a	45	17.500	124	44.67	C12aw	124	1.59	C12ae	123	57.90	C12as
Oregon	N	C13	45	10.000	124	44.93	C13w	124	1.94	C13e	123	58.26	C13s
Oregon	N	C13a	45	2.500	124	46.84	C13aw	124	3.94	C13ae	124	0.27	C13as
Oregon	N	C14	44	55.000	124	48.17	C14w	124	5.37	C14e	124	1.70	C14s
Oregon	N	C14a	44	47.500	124	50.64	C14aw	124	7.93	C14ae	124	4.27	C14as
Oregon	N	C15	44	40.000	124	49.91	C15w	124	7.30	C15e	124	3.65	C15s
Oregon	N	C15a	44	32.500	124	50.65	C15aw	124	8.12	C15ae	124	4.48	C15as
Oregon	N	C16	44	25.000	124	51.18	C16w	124	8.74	C16e	124	5.11	C16s
Oregon	N	C17	44	10.000	124	52.90	C17w	124	10.64	C17e	124	7.02	C17s
Oregon	N	C18	43	55.000	124	54.64	C18w	124	12.56	C18e	124	8.95	C18s
Oregon	N	C19	43	40.000	124	57.85	C19w	124	15.95	C19e	124	12.35	C19s
Oregon	N	C20	43	25.000	125	3.13	C20w	124	21.40	C20e	124	17.82	C20s
Oregon	N	C21	43	10.000	125	9.61	C21w	124	28.05	C21e	124	24.48	C21s
Oregon	N	C22	42	55.000	125	14.93	C22w	124	33.55	C22e	124	30.00	C22s
Oregon	N	C23	42	40.000	125	10.57	C23w	124	29.34	C23e	124	25.81	C23s
Oregon	N	C24	42	25.000	125	10.24	C24w	124	29.18	C24e	124	25.66	C24s
Oregon	N	C25	42	10.000	125	6.07	C25w	124	25.18	C25e	124	21.67	C25s
Oregon	N	C26	41	55.000	124	56.53	C26w	124	15.80	C26e	124	12.31	C26s

Table 1g. SET A Canadian Transects

	Survey	Transect	Transect Latitude		West End			East End			Shoreline		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Canada	CN	cnA1	48	35.000	125	30.02	cnA1w	124	44.22	cnA1e	124	40.29	cnA1s
Canada	CN	cnA2	48	50.000	126	9.18	cnA2w	125	23.15	cnA2e	125	19.20	cnA2s
Canada	CN	cnA3	49	5.000	126	42.25	cnA3w	125	55.98	cnA3e	125	52.02	cnA3s
Canada	CN	cnA4	49	20.000	127	4.75	cnA4w	126	18.25	cnA4e	126	14.26	cnA4s
Canada	CN	cnA5	49	35.000	127	31.47	cnA5w	126	44.73	cnA5e	126	40.73	cnA5s
Canada	CN	cnA6	49	50.000	127	54.49	cnA6w	127	7.51	cnA6e	127	3.48	cnA6s
Canada	CN	cnA7	50	5.000	128	40.48	cnA7w	127	53.26	cnA7e	127	49.21	cnA7s
Canada	CN	cnA8	50	20.000	128	50.05	cnA8w	128	2.58	cnA8e	127	58.51	cnA8s
Canada	CN	cnA9	50	35.000	129	5.73	cnA9w	128	18.01	cnA9e	128	13.92	cnA9s
Canada	CN	cnA10	50	50.000	129	4.71	cnA10w	128	16.74	cnA10e	128	12.63	cnA10s
Canada	CN	cnA11	51	5.000	128	31.37	cnA11w	127	43.13	cnA11e	127	39.00	cnA11s
Canada	CN	cnA12	51	20.000	128	39.13	cnA12w	127	50.63	cnA12e	127	46.48	cnA12s
Canada	CN	cnA13	51	35.000	129	0.41	cnA13w	128	11.65	cnA13e	128	7.47	cnA13s
Canada	CN	cnA14	51	50.000	129	9.27	cnA14w	128	20.24	cnA14e	128	16.03	cnA14s
Canada	CN	cnA15	52	5.000	129	15.18	cnA15w	128	25.88	cnA15e	128	21.66	cnA15s
Canada	CN	cnA16	52	20.000	129	38.12	cnA16w	128	48.54	cnA16e	128	44.29	cnA16s
Canada	CN	cnA17	52	35.000	130	2.84	cnA17w	129	12.98	cnA17e	129	8.71	cnA17s
Canada	CN	cnA18	52	50.000	130	16.03	cnA18w	129	25.88	cnA18e	129	21.58	cnA18s
Canada	CN	cnA19	53	5.000	130	38.77	cnA19w	129	48.34	cnA19e	129	44.01	cnA19s
Canada	CN	cnA20	53	20.000	131	4.57	cnA20w	130	13.84	cnA20e	130	9.49	cnA20s
Canada	CN	cnA21	53	35.000	131	28.20	cnA21w	130	37.17	cnA21e	130	32.80	cnA21s
Canada	CN	cnA22	53	50.000	131	36.53	cnA22w	130	45.20	cnA22e	130	40.80	cnA22s
Canada	CN	cnA23	54	5.000	131	33.54	cnA23w	130	41.90	cnA23e	130	37.48	cnA23s
Canada	CN	cnA24	54	20.000	131	26.95	cnA24w	130	35.00	cnA24e	130	30.55	cnA24s
Canada	CN	cnA25	54	35.000	132	2.78	cnA25w	131	10.51	cnA25e	131	6.03	cnA25s

Table 1h. SET B Canadian Transects

	Survey	Transect	Transect Latitude		West End			East End			Shoreline		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Canada	CN	cnB1	48	30.000	125	33.41	cnB1w	124	47.68	cnB1e	124	43.76	cnB1s
Canada	CN	cnB2	48	45.000	125	57.61	cnB2w	125	11.65	cnB2e	125	7.71	cnB2s
Canada	CN	cnB3	49	0.000	126	30.47	cnB3w	125	44.28	cnB3e	125	40.32	cnB3s
Canada	CN	cnB4	49	15.000	126	56.32	cnB4w	126	9.90	cnB4e	126	5.92	cnB4s
Canada	CN	cnB5	49	30.000	127	24.28	cnB5w	126	37.62	cnB5e	126	33.62	cnB5s
Canada	CN	cnB6	49	45.000	127	49.17	cnB6w	127	2.27	cnB6e	126	58.25	cnB6s
Canada	CN	cnB7	50	0.000	128	10.98	cnB7w	127	23.84	cnB7e	127	19.80	cnB7s
Canada	CN	cnB8	50	15.000	128	39.58	cnB8w	127	52.20	cnB8e	127	48.14	cnB8s
Canada	CN	cnB9	50	30.000	129	0.01	cnB9w	128	12.38	cnB9e	128	8.29	cnB9s
Canada	CN	cnB10	50	45.000	129	15.83	cnB10w	128	27.94	cnB10e	128	23.84	cnB10s
Canada	CN	cnB11	51	0.000	128	24.13	cnB11w	127	35.99	cnB11e	127	31.86	cnB11s
Canada	CN	cnB12	51	15.000	128	38.03	cnB12w	127	49.62	cnB12e	127	45.47	cnB12s
Canada	CN	cnB13	51	30.000	128	58.26	cnB13w	128	9.59	cnB13e	128	5.42	cnB13s
Canada	CN	cnB14	51	45.000	129	0.72	cnB14w	128	11.78	cnB14e	128	7.59	cnB14s
Canada	CN	cnB15	52	0.000	129	7.13	cnB15w	128	17.92	cnB15e	128	13.70	cnB15s
Canada	CN	cnB16	52	15.000	129	18.98	cnB16w	128	29.49	cnB16e	128	25.25	cnB16s
Canada	CN	cnB17	52	30.000	129	53.92	cnB17w	129	4.15	cnB17e	128	59.89	cnB17s
Canada	CN	cnB18	52	45.000	130	11.91	cnB18w	129	21.86	cnB18e	129	17.57	cnB18s
Canada	CN	cnB19	53	0.000	130	35.44	cnB19w	129	45.10	cnB19e	129	40.79	cnB19s
Canada	CN	cnB20	53	15.000	130	58.66	cnB20w	130	8.02	cnB20e	130	3.68	cnB20s
Canada	CN	cnB21	53	30.000	131	21.16	cnB21w	130	30.23	cnB21e	130	25.86	cnB21s
Canada	CN	cnB22	53	45.000	131	22.07	cnB22w	130	30.84	cnB22e	130	26.45	cnB22s
Canada	CN	cnB23	54	0.000	131	36.01	cnB23w	130	44.47	cnB23e	130	40.05	cnB23s
Canada	CN	cnB24	54	15.000	131	21.17	cnB24w	130	29.32	cnB24e	130	24.88	cnB24s
Canada	CN	cnB25	54	30.000	131	55.50	cnB25w	131	3.34	cnB25e	130	58.87	cnB25s

Table 1i. SET C Canadian Transects

	Survey	Transect	Transect Latitude		West End			East End			Shoreline		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Canada	CN	cnC1	48	25.000	125	33.09	cnC1w	124	47.44	cnC1e	124	43.52	cnC1s
Canada	CN	cnC2	48	40.000	125	40.56	cnC2w	124	54.67	cnC2e	124	50.74	cnC2s
Canada	CN	cnC3	48	55.000	126	18.86	cnC3w	125	32.75	cnC3e	125	28.80	cnC3s
Canada	CN	cnC4	49	10.000	126	51.29	cnC4w	126	4.95	cnC4e	126	0.97	cnC4s
Canada	CN	cnC5	49	25.000	127	25.40	cnC5w	126	38.82	cnC5e	126	34.83	cnC5s
Canada	CN	cnC6	49	40.000	127	43.17	cnC6w	126	56.35	cnC6e	126	52.34	cnC6s
Canada	CN	cnC7	49	55.000	128	3.03	cnC7w	127	15.97	cnC7e	127	11.94	cnC7s
Canada	CN	cnC8	50	10.000	128	42.20	cnC8w	127	54.90	cnC8e	127	50.84	cnC8s
Canada	CN	cnC9	50	25.000	128	48.14	cnC9w	128	0.59	cnC9e	127	56.51	cnC9s
Canada	CN	cnC10	50	40.000	129	12.56	cnC10w	128	24.76	cnC10e	128	20.66	cnC10s
Canada	CN	cnC11	50	55.000	128	52.06	cnC11w	128	4.00	cnC11e	127	59.88	cnC11s
Canada	CN	cnC12	51	10.000	128	39.54	cnC12w	127	51.22	cnC12e	127	47.08	cnC12s
Canada	CN	cnC13	51	25.000	128	48.18	cnC13w	127	59.60	cnC13e	127	55.43	cnC13s
Canada	CN	cnC14	51	40.000	129	2.29	cnC14w	128	13.44	cnC14e	128	9.26	cnC14s
Canada	CN	cnC15	51	55.000	129	8.30	cnC15w	128	19.18	cnC15e	128	14.97	cnC15s
Canada	CN	cnC16	52	10.000	129	24.51	cnC16w	128	35.11	cnC16e	128	30.88	cnC16s
Canada	CN	cnC17	52	25.000	129	40.03	cnC17w	128	50.36	cnC17e	128	46.10	cnC17s
Canada	CN	cnC18	52	40.000	130	8.07	cnC18w	129	18.11	cnC18e	129	13.83	cnC18s
Canada	CN	cnC19	52	55.000	130	26.33	cnC19w	129	36.09	cnC19e	129	31.78	cnC19s
Canada	CN	cnC20	53	10.000	130	52.13	cnC20w	130	1.60	cnC20e	129	57.27	cnC20s
Canada	CN	cnC21	53	25.000	131	15.43	cnC21w	130	24.60	cnC21e	130	20.24	cnC21s
Canada	CN	cnC22	53	40.000	131	18.96	cnC22w	130	27.83	cnC22e	130	23.45	cnC22s
Canada	CN	cnC23	53	55.000	131	39.54	cnC23w	130	48.10	cnC23e	130	43.69	cnC23s
Canada	CN	cnC24	54	10.000	131	45.12	cnC24w	130	53.38	cnC24e	130	48.94	cnC24s
Canada	CN	cnC25	54	25.000	131	44.31	cnC25w	130	52.25	cnC25e	130	47.79	cnC25s

Table 2. Distribution of point set sizes proposed for the 2011 Aerial Sardine Survey. Total Weight is in metric tons.

Size (m^2)	Weight (mt)	Total Weight (mt)	Number of point sets
100	3.8	45.6	12
500	10.6	127.2	12
1000	17	187	11
2000	26.5	291.5	11
4000	51.9	519	10
8000	70.5	705	10
10000	82.1	821	10
		2696.3	76

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	

Figure 1a. Maps showing locations of transects comprising Replicate SET A

SET A: Transects 1-8

SET A: Transects 9-16

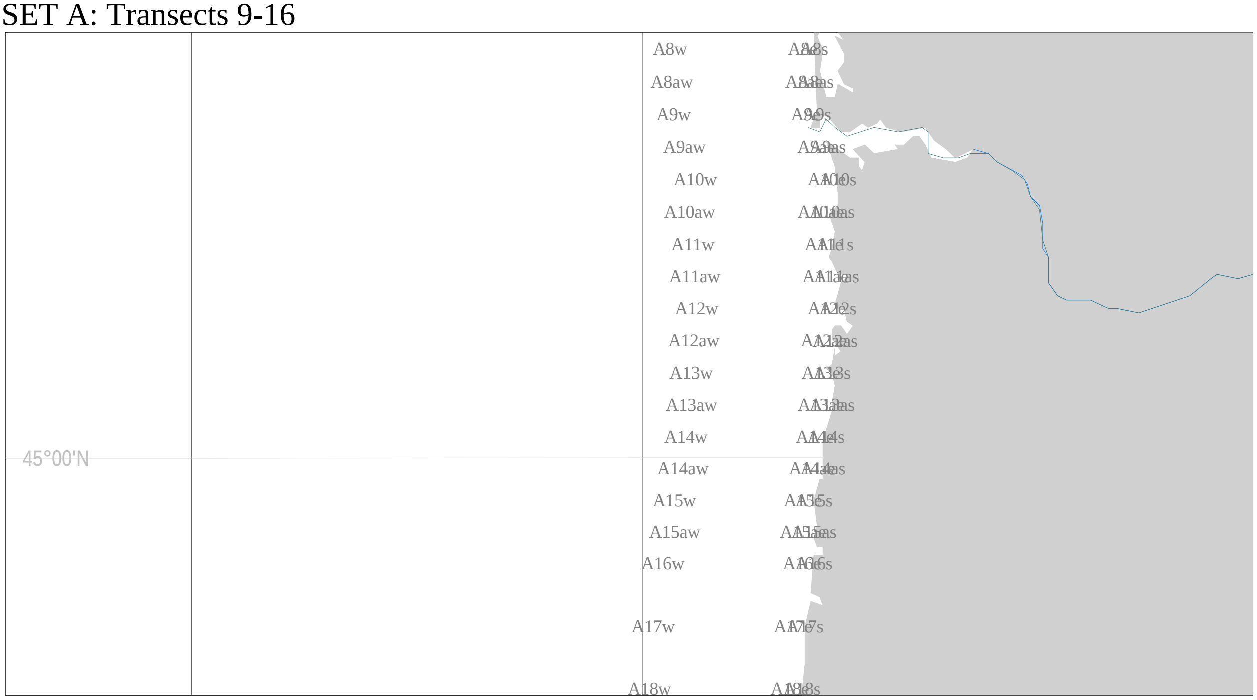


Figure 1a, Continued. Maps showing locations of transects comprising Replicate SET A

SET A: Transects 17-26

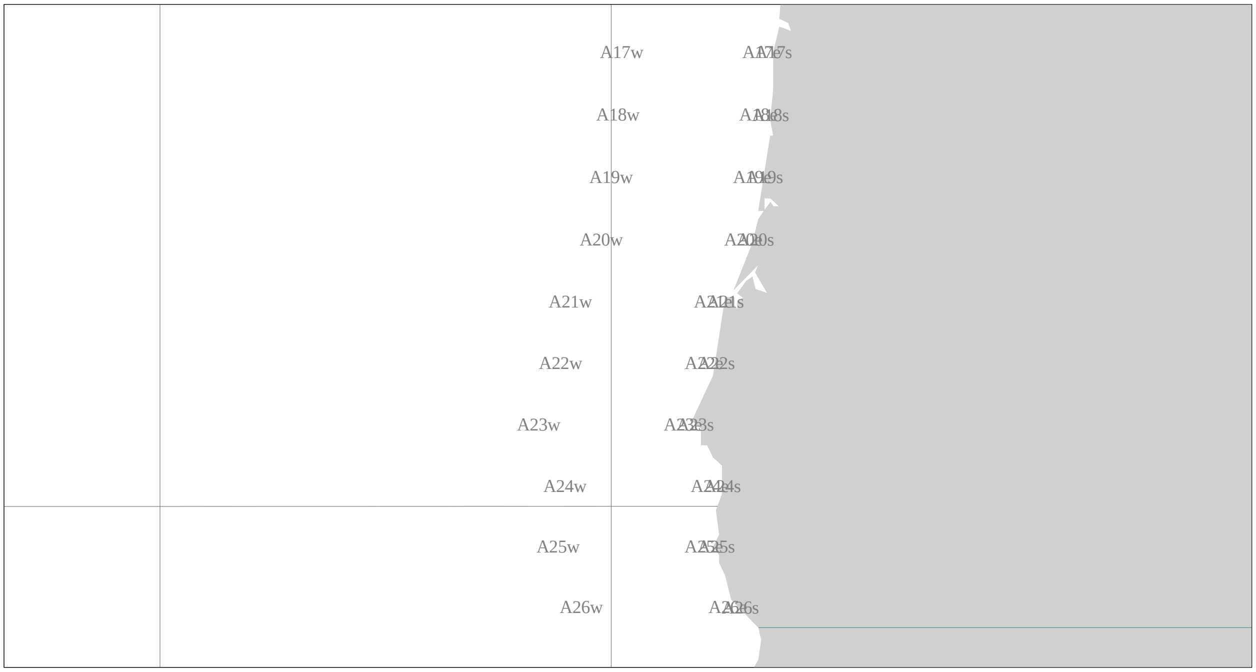


Figure 1b. Maps showing locations of transects comprising Replicate SET B

SET B: Transects 1-8

SET B: Transects 9-16

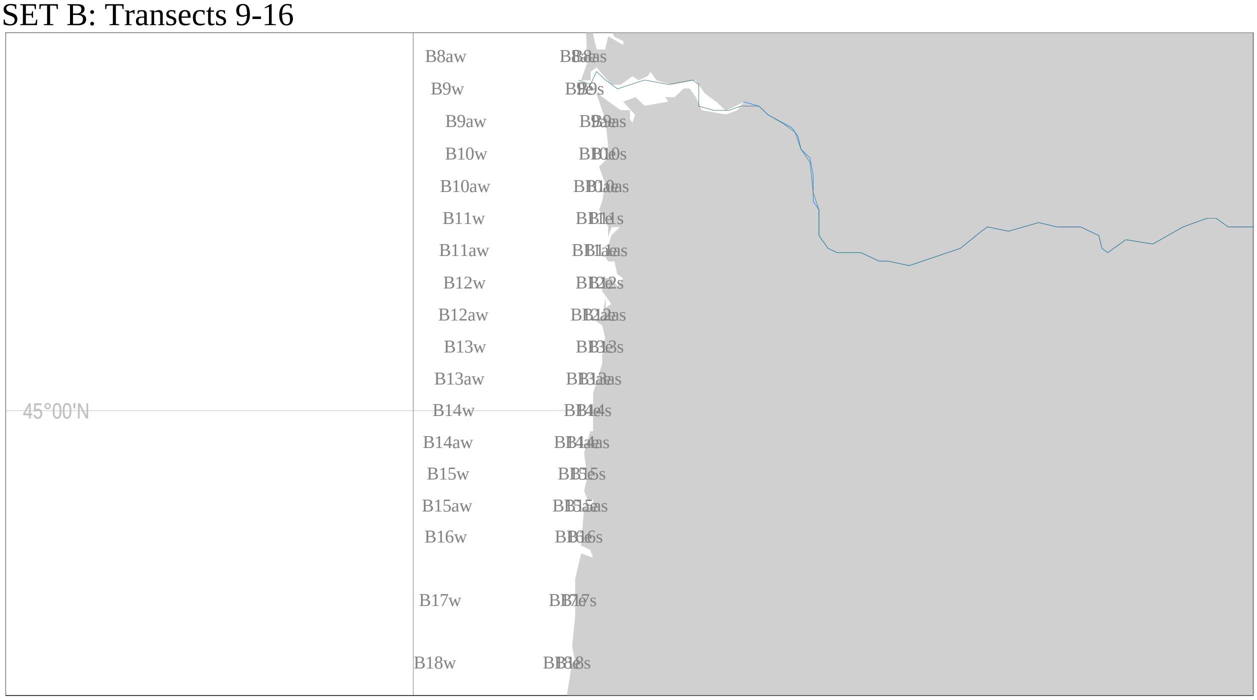


Figure 1b, Continued. Maps showing locations of transects comprising Replicate SET B

SET B: Transects 17-26

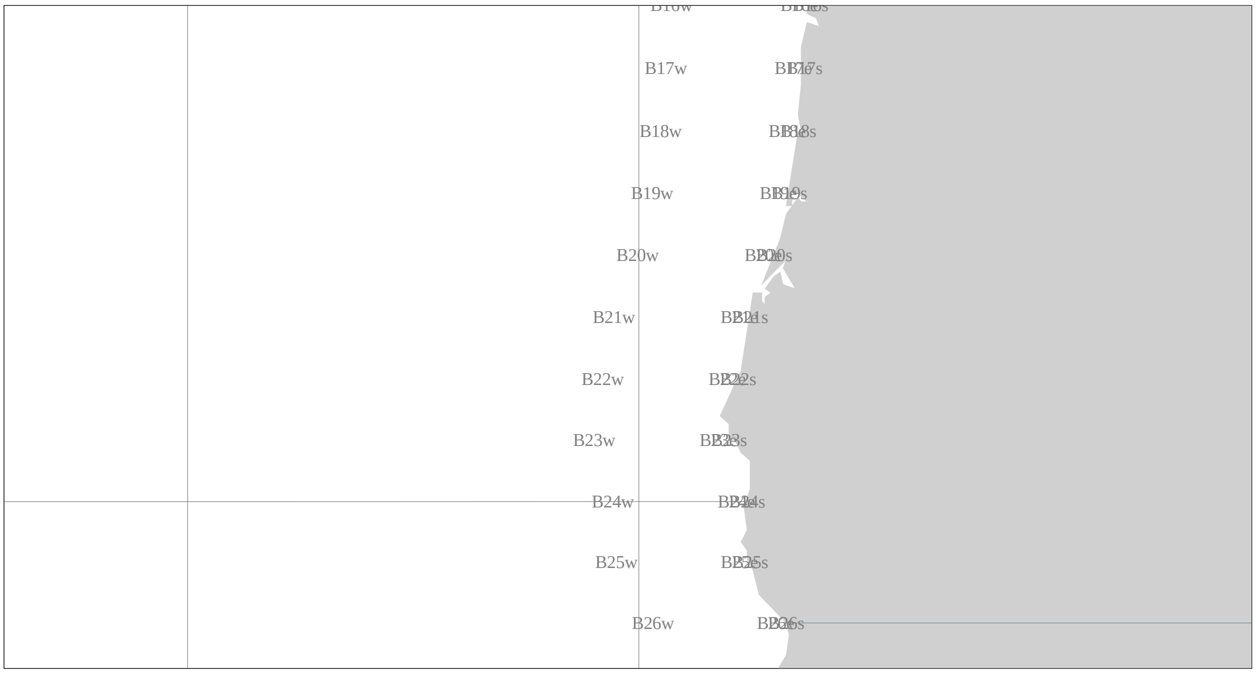
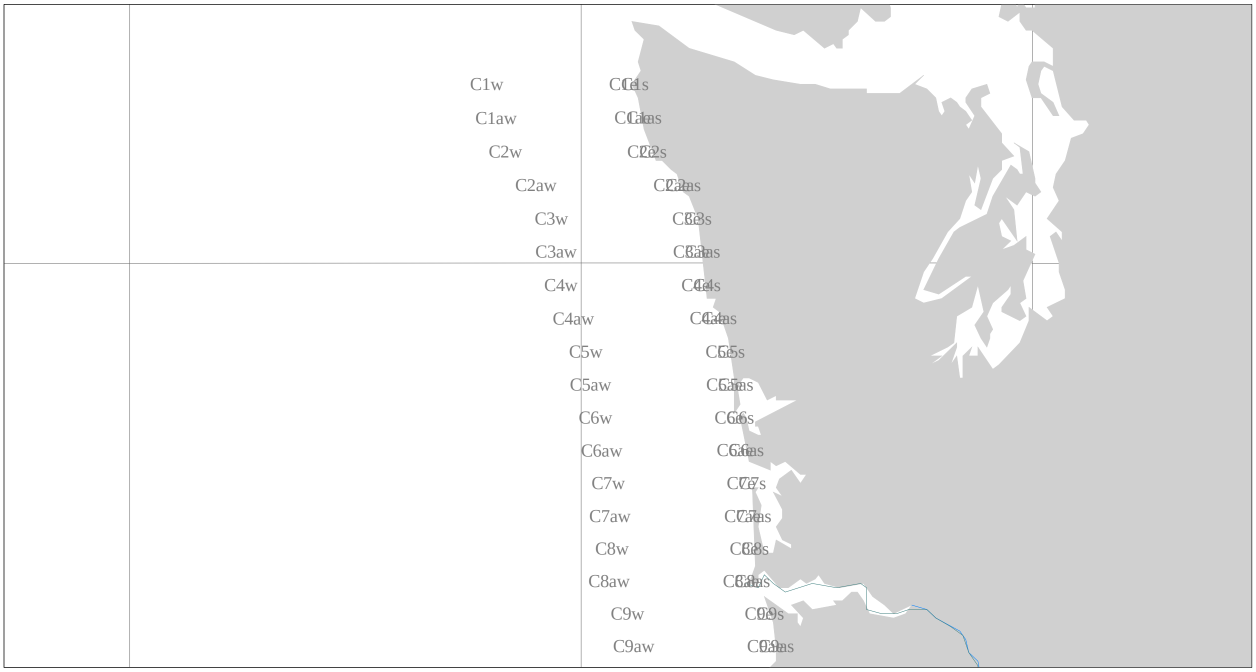


Figure 1c. Maps showing locations of transects comprising Replicate SET C

SET C: Transects 1-8



SET C: Transects 9-16

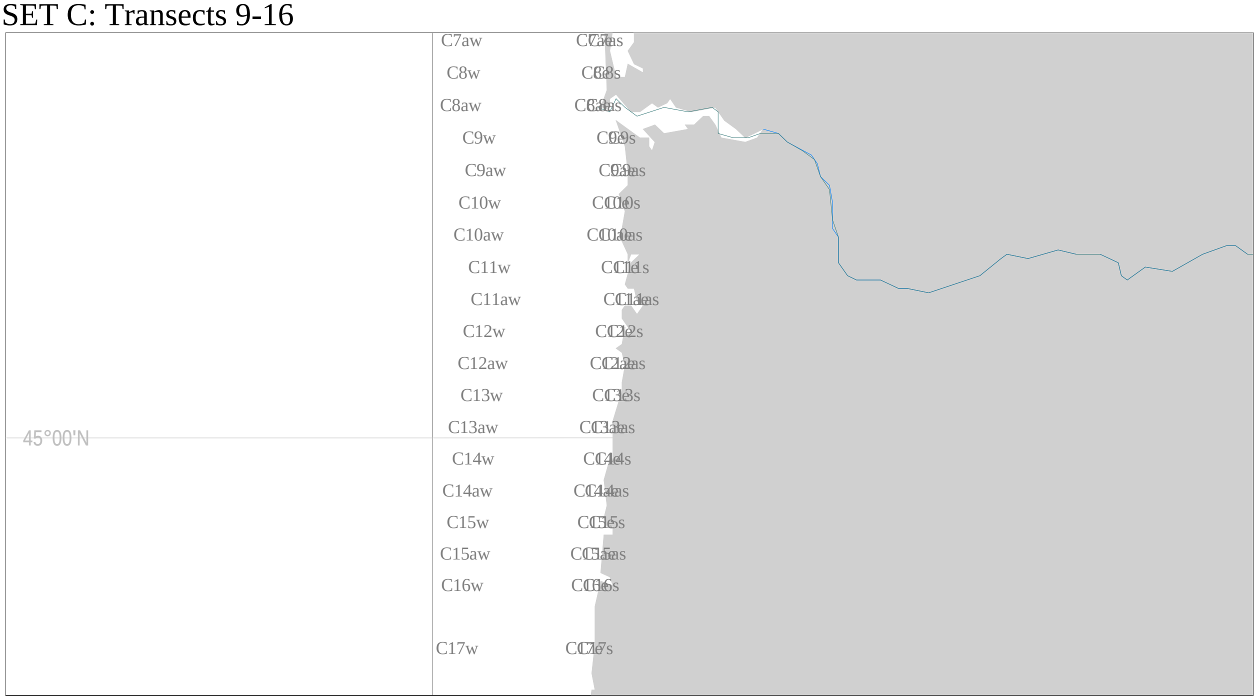


Figure 1c, Continued. Maps showing locations of transects comprising Replicate SET C

SET C: Transects 17-26

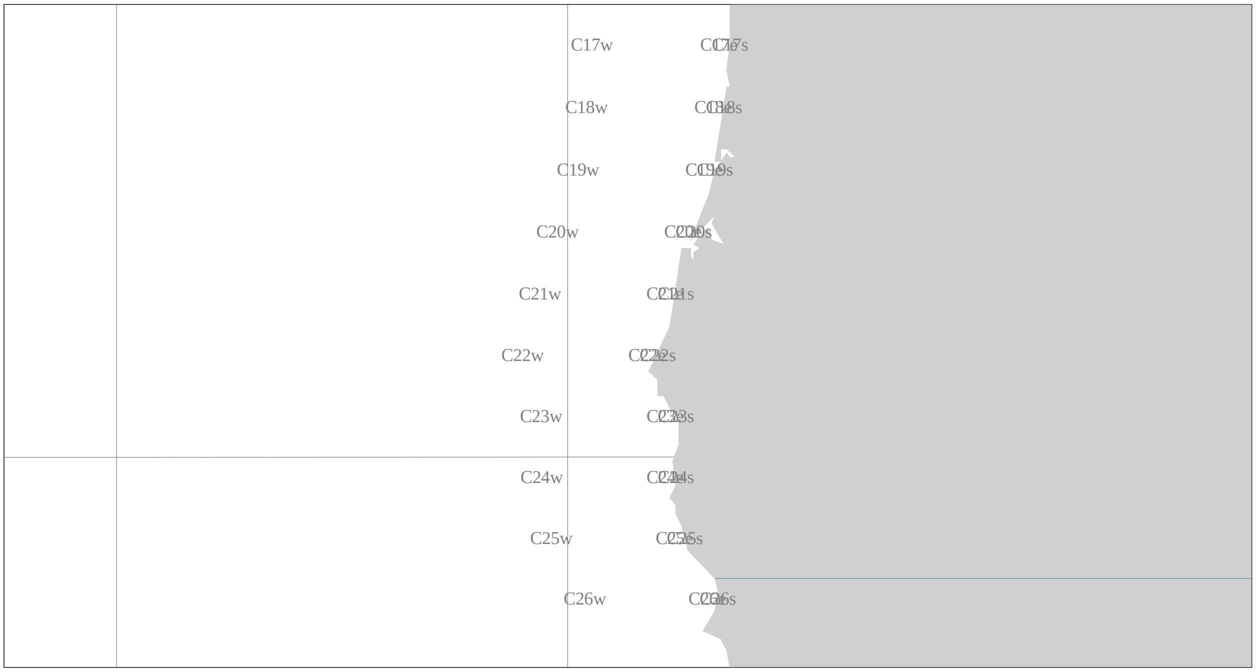
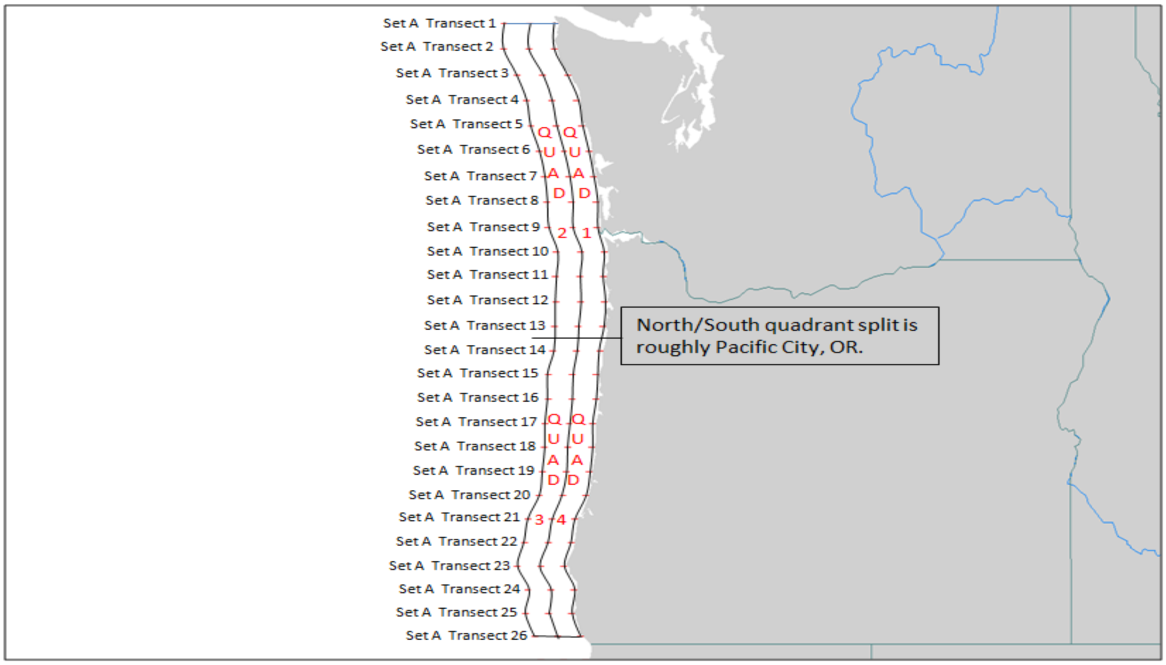
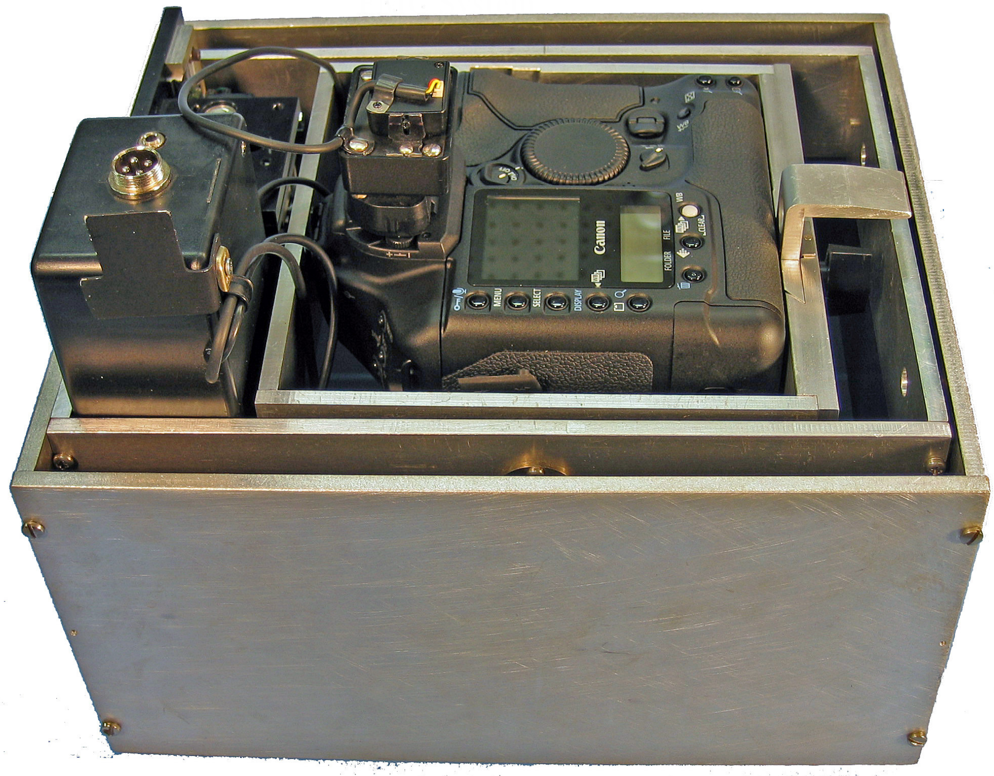


Figure 2. Maps showing quadrants for spatial distribution of point sets.



Appendix I, Adjunct 1. FMC Aerial Photography - Data Logging System

AERIAL IMAGING SOLUTIONS
FMC MOUNT SYSTEM



DESCRIPTION

An aerial mount system for digital cameras that reduces image blur caused by the forward motion of the aircraft while the shutter is open. The mount and camera are connected to, and remotely controlled by, a program running on a customer-supplied (Windows-based) computer. Flight and camera parameters entered by the computer's operator determine the required forward motion compensation (FMC) and camera firing interval. The system also takes inputs from the customer-supplied GPS and radar altimeter and will, optionally, use these data to automatically determine the required FMC and firing interval. The system includes a remote viewfinder that displays the image seen through the camera's eyepiece on a small monitor to permit the computer operator to observe camera operation to ensure successful coverage of sites. It also includes a data acquisition system that interfaces with the camera, GPS, radar altimeter, and computer to record position and altitude readings as each frame is collected.

Appendix I, Adjunct 2. Field Data Forms

West Coast Sardine Survey

Camera Settings for 1Ds Mark III (Bigger Camera)

1. Press the MENU button located in the upper left corner of the camera, just above the LCD monitor.

    a. Turn the dial on the top right of the camera, near the shutter button, to scroll left though the menu tabs at the top of the monitor.

    b. Under the Shooting 1 tab, ensure that the White balance is set to "AWB" and that the Picture style is set to "Standard."

    c. Scroll right and select the Shooting 2 tab. Under the Shooting 2 tab, set the image size to "L."

    d. Scroll right and select the Set-up 1 tab. Set Auto power off to "Off".

    e. Set File numbering to "Auto Reset".

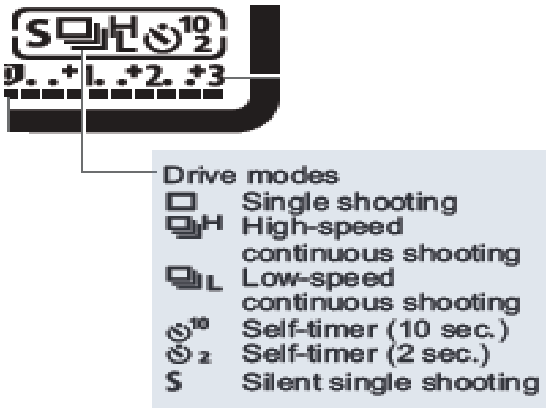
    f. Select Record Function+media/folder sel. and set the camera to "Auto switch media." Set the camera to record first to the CF memory card (card number 1).

    g. Select Live View function settings. Select Live View shoot. Select "Disable".

    h. Finally, select File name setting and change the User 1 setting to read "SP3_" for survey pilot 3, "SP4_ " for survey pilot 4, and so forth. Photos will now be numbered SPx_001, SPx_002, and so on.

2. Set the lens focus mode switch located on the side of the lens to "M" and move the focusing ring toward the camera to engage it.

3. Press the AF DRIVE button located on the top left corner of the camera. Turn the scroll wheel to set the camera to "Single Shot". The icon is a single rectangle, not "S". "S" is silent mode, which will ruin your day! See below:



4. Press the MODE button located above the AF DRIVE button and rotate the scroll wheel to set the camera to "M." Wait for the AF drive display to time out, then turn the scroll wheel to set the Aperture to "4.0." Turn the dial to set the Shutter speed to "2000."

5. Press the ISO button located adjacent to the dial and turn the scroll wheel to set the ISO Speed to "400."

6. Ensure that the 3 cables plugged into the side of the camera are securely connected. The 3 connectors are: flash sync, remote, and mini USB.

   - The flash sync connector screws in. Make sure that it is screwed in all the way. It is ok to use long nosed pliers to tighten it if your fingers are too stubby. Just be gentle.

   - The remote connector is a push-pull locking connector. Press on the top rubber part to engage it. Pull on the silver outer ring to disengage it.

   - The mini USB simply plugs in.

West Coast Sardine Survey

Camera Settings for 5D Mark II (Smaller Camera)

1. Press the MENU button located in the upper left corner of the camera, just above the LCD monitor.

    a. Turn the dial on the top right of the camera, near the shutter button, to scroll left though the menu tabs at the top of the monitor.

    b. Ensure that the White balance is set to “AWB” and that the Picture style is set to “Standard.”

    c. Set the image size to “L.”

    d. Set Auto power off to “Off”.

    e. Set File numbering to “Auto Reset”.

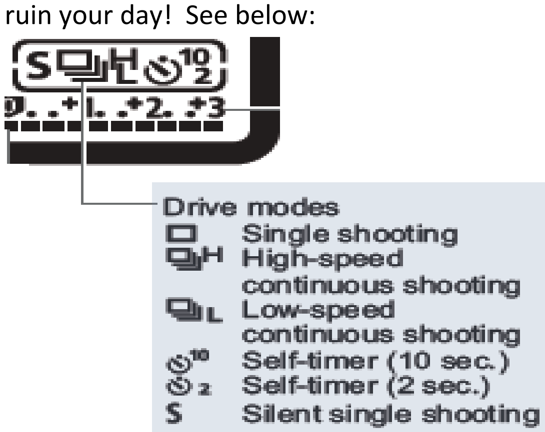
    f. Select Record Function+media/folder sel. and set the camera to “Auto switch media.” Set the camera to record first to the CF memory card (card number 1).

    g. Select Live View function settings. Select Live View shoot. Select “Disable”.

    h. Disable “Silent Mode” shooting.

2. Set the lens focus mode switch located on the side of the lens to “M” and move the focusing ring toward the camera to engage it.

3. Press the AF DRIVE button located on the top left corner of the camera. Turn the scroll wheel to set the camera to “Single Shot”. The icon is a single rectangle, not “S”. “S” is silent mode, which will ruin your day! See below:



4. Press the MODE button located above the AF DRIVE button and rotate the scroll wheel to set the camera to “M.” Wait for the AF drive display to time out, then turn the scroll wheel to set the Aperture to “4.0.” Turn the dial to set the Shutter speed to “2000.”
5. Press the ISO button located adjacent to the dial and turn the scroll wheel to set the ISO Speed to “400.”

6. Ensure that the 3 cables plugged into the side of the camera are securely connected. The 3 connectors are: flash sync, remote, and mini USB.

   - The flash sync connector screws in. Make sure that it is screwed in all the way. It is ok to use long nosed pliers to tighten it if your fingers are too stubby. Just be gentle.

   - The remote connector is a push-pull locking connector. Press on the top rubber part to engage it. Pull on the silver outer ring to disengage it.

   - The mini USB simply plugs in.

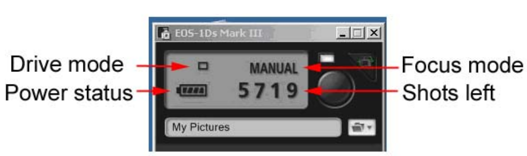
Pilot Checklist

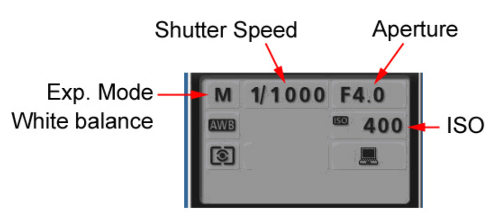
Pre-Flight

1. Check/clean the camera window
2. Check that batteries are fully charged.
3. Ensure that memory cards are installed and have sufficient space.
4. Ensure that a copy of the transect waypoint document is aboard aircraft.
5. Check GPS reading and enter waypoints if necessary.
6. Ensure that all mount system cables are properly connected.
7. Turn on camera, notebook computer, power inverter, and control unit.
8. Ensure the laptop sleep setting is set to "never."
9. Start FMC Mount, Remote Viewfinder, and EOS Utility programs on notebook computer.

   Note: make sure only one window is open for each of the previous programs, having more than one of any program open will cause problems with the camera system.
10. Adjust FMC Mount program settings, as necessary:
    - Altitude: TBD
    - Speed: TBD
    - Overlap: 60%
    - FMC: On
    - Frame count: 0 (Admin->Frame Count->ENTER "0")
11. Ensure that GPS/IMU is functioning.

    Note: the first time the GPS is used in a new location, it may take up to 25 minutes for the GPS to initialize.
12. Ensure that the camera viewfinder is displayed in the Remote Viewfinder window.
13. Check the camera settings using the EOS Utility. See below:





- Look for the rectangle for Drive mode and "MANUAL" for the Focus mode, to verify that the camera is in "Single Shot" mode and is set to manual focus.

- Verify that the Exp. Mode is "M" for manual exposure control and that the Shutter Speed, Aperture and ISO are set for proper exposure - normally, 1/2000, F4.0, and 400, respectively.

- Press "F9" in the FMC Mount program and verify that the camera fires. The frame counter in the FMC program should advance and that the Shots left indicator in the EOS Utility should subtract.

  WARNING: If the Shots left indicator in EOS Utility doesn't change when the camera fires, it indicates that the images are not being saved to the memory card in the camera. Go to "Preferences -> Remote Shooting", in EOS Utility and check the box "Save also on camera's memory card".

14. *The following may be unnecessary:*

    i. *Power OFF the mount system so that power does not spike when the airplane is started.*
    ii. *Start the airplane.*
    iii. *Power ON the mount system.*
    iv. *Verify that the on-screen GPS positions approximately match the pilot's GPS.*
    v. *Press "F9" to take a single photo and verify that all systems are working properly.*

Mid-Flight

Upon approaching the beginning of a transect/point set, press "F5" (AUTO) to begin recording. Occasionally compare the Mount System GPS positions with the pilot's GPS. Also, remember to adjust the Mount System altitude and speed settings as necessary.

Post-Flight

After landing, the survey photos and FMC datalog will need to be downloaded. Please contact Mr. Ryan Howe to coordinate the download and archive for each survey day.

West Coast Aerial Sardine Survey 2011

Transect Flight Log Form

Date:___________ **Set:**__________ **Pilot:**___________ **Observer:**______________ **Plane:**_________________

Transect No.	Time	Start Photo No.	Latitude/Longitude	Altitude (ft)	Species Observed	Est. Tonnage (mt)	End Photo No.

Cloud Cover code	Glare code	Beaufort Wind Scale

Comments:____

____

Transect No.	Time	Start Photo No.	Latitude/Longitude	Altitude (ft)	Species Observed	Est. Tonnage (mt)	End Photo No.

Cloud Cover code	Glare code	Beaufort Wind Scale

Comments:____

____

Transect No.	Time	Start Photo No.	Latitude/Longitude	Altitude (ft)	Species Observed	Est. Tonnage (mt)	End Photo No.

Cloud Cover code	Glare code	Beaufort Wind Scale

Comments:____

____

Transect No.	Time	Start Photo No.	Latitude/Longitude	Altitude (ft)	Species Observed	Est. Tonnage (mt)	End Photo No.

Cloud Cover code	Glare code	Beaufort Wind Scale

Comments:____

____

____

Cloud Cover code: **1**- Clear, **2**- Cloud Coverage <50%, **3**- Cloud Coverage >50%, **4**- No Visibility

Glare code: **1**- No glare, **2**- glare <50%, **3**- glare >50%, **4**- Cloud shadows <50%, **5**- Cloud shadows >50%, **6**- No visibility

Beaufort Wind Scale: Refer to attached Beaufort Wind Scale (0-12) to quantify sea state

West Coast Aerial Sardine Survey 2011

Biological Sampling Form

Date Landed:__________ Vessel:______________________ Sample No.___________ Point Set No.__________

Date Sampled:_________ Sampler:_____________________ Processor:___________ Sample Wt (kg):_______

Fish No.	Weight (g)	Std. Length (mm)	Sex (M/F)	Maturity Code	Otolith Vial No.
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					

Fish No.	Weight (g)	Std. Length (mm)	Sex (M/F)	Maturity Code	Otolith Vial No.
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					
45					
46					
47					
48					
49					
50					

Comments:

West Coast Aerial Sardine Survey 2011

Point Set Flight Log Form

Date:________________ Pilot:_________________________ Plane:________________________

Processor:_________________________ Observer:______________________

Point Set No.	Time	Photo No.	Latitude/Longitude	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)

Comments:

Point Set No.	Time	Photo No.	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)

Comments:

Point Set No.	Time	Photo No.	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)

Comments

Point Set No.	Time	Photo No.	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)

Comments:

Point Set No.	Time	Photo No.	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)

Comments:

Point Set No.	Time	Photo No.	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)

Comments:

West Coast Aerial Sardine Survey 2011

Vessel Point Set Log

Date:_____________________________ **Captain:**_____________________________

Vessel:_____________________________ **Processor:**_____________________________

Hydroacoustic Gear

Type	Manufact.	Model	Frequency
Sounder			
Sonar			

Net Dimensions

Net Length (fath)	Net Depth (fath)	Mesh Size

School and Ocean Data

Point Set No.	Time	Latitude	Longitude	Depth to Top of School (fath)	Depth to Bottom of School (fath)	Ocean Depth (fath)	Temp.	Weather Condition

Captains Estimate and Delivery Information / Office Use Only

Point Set No.	Species Observed	% of school captured	Est. School Tonnage (mt)	Fish Hold (FP, FS, MP, MS, AP, AS)	Other Vessel utilized: Name, est. weight, fish hold	*Delivered Weight (mt)	*Fish Ticket Number

Comments: ____

____

____

____

____

West Coast Aerial Sardine Survey 2011

Survey Data Form Overview

The purpose of this document is to help guide us through each of the 2011 sardine survey data forms. If you are still unclear of what a field within a form is asking, please contact Mr. Ryan Howe for further clarification. Please have all survey forms completed and submitted to Mr. Howe by the end of each survey day.

Transect Flight Log Form

Aerial survey pilots will complete the Transect Flight Log Forms for each transect flown for each survey day. The information recorded on this form will help the photo analyst identify fish schools during the transect survey photo processing period, so be as detailed as possible while recording notes. *If a transect is skipped or aborted due to poor visibility or some other factor, please make a note of it on the Transect Flight Log Form and also let Mr. Howe know as early as possible.

Heading Information

- **Date** – Record the date that the transect is flown
- **Set** – Record which replicate SET is being flown
- **Pilot** – Name of pilot flying the transect
- **Observer** – Name of observer on board if any
- **Plane** – Type of aircraft flying the transect

Transect Data

- **Transect No.** – Record the transect number that is flown
- **Time** – Pilots are asked to log the time a fish school is observed along the survey transect
- **Start Photo No.** – Pilots are asked to log the photo number that corresponds with the school identified on that transect.
- **Latitude/Longitude** – Record the latitude and longitude of the school observed while flying the survey transect.
- **Altitude (ft)** – Record the altitude of the plane as it passes over the school observed
- **Species Observed –** Record the species observed on each transect. Use comments section for additional writing space as needed.
- **Estimated Tonnage (mt)** – Pilots are to estimate the observed tonnage of fish schools identified along the survey transect. If there are too many schools to estimate tonnage for each individual school, estimate the schools as a whole.
- **End Photo No**. – Pilots are asked to log the photo number that corresponds with the last school observed on that transect.

- **Cloud Cover code** – Pilots are asked to record the current cloud cover conditions while flying transects, using the following cloud cover scale: **1**- Clear, **2**- Cloud Coverage <50%, **3**- Cloud Coverage >50%, **4**- No Visibility
- **Glare code** – Pilots are asked to record the current glare conditions on the surface of the water using the following glare scale: **1**- No glare, **2**- glare <50%, **3**- glare >50%, **4**- Cloud shadows <50%, **5**- Cloud shadows >50%, **6**- No visibility
- **Beaufort Wind Scale**: Pilots are asked to refer to the Beaufort Wind Scale (0-12) to quantify sea state conditions during transect flights.
- **Comments** – Please write any additional information or notes in this section

Biological Sampling Form

During the 2011 West Coast Aerial Sardine Survey, biological samples will be taken from landed point sets to collect individual fish data. This form is to be filled out by the person/s working up the biological sample. Please contact Mr. Howe with any questions or for further clarification.

Heading Information

- **Date Landed**– Record the date the point set was landed at the processing plant
- **Vessel** – Record the vessel name that delivered the point set catch
- **Sample No.** – Record the sample number consecutively as they occur during the 2011 season
- **Point Set No.** – Record the point set number that the biological sample corresponds to
- **Date Sampled** – Record the date the biological sample was worked up
- **Sampler** – Record the name of the person/s processing the biological sample
- **Processor** – Name of the fish processing plant the sample was collected at
- **Sample Wt. (kg)** – Record the total biological sample weight in kilograms

Biological Data

- **Weight (g)** – Record the individual fish weights using an electronic scale accurate to 0.5 gm
- **Standard (Std.) Length (mm)** – Record the length of each individual fish. Standard length is measured from the tip of fish snout to last vertebrae in millimeters.
- **Sex** – Record the sex of each individual fish (M = male ; F = female)
- **Maturity Code** – Record the maturity code that closely matches the maturity of the fish. Refer to Table. 3 of the Operational Plan for detailed sardine maturity codes.
- **Otolith vial No.** - The otolith vial number is determined by the following information: the point set number, fish number and the year date the otolith was collected. This information allows for easy reference to the individual fish information as needed.
  Example: Point set number 23 is being offloaded. You collect your biological sample from the processing plant. You have already determined which fish will be the otolith fish. It is a good idea to pre-label the capsules before working up the sample. So our otolith capsule would read **PS23F37-11** which again refers to **P**oint **S**et **23** and **F**ish number **37** of 50 collected in 20**11**.

- **Comments** – Please write any additional information or notes in this section.

Point Set Flight Log Form

During the 2011 West Coast Aerial Sardine Survey, pilots are asked to record important point set information that will be used in the photo enhancement process. Each pilot is asked to fill out a new Point Set Flight Log Form each day point sets are attempted. The Point Set Flight Log Form allows for six point sets to be recorded on each form. Use additional Point Set Flight Log Forms as needed. Also on the form is a comments section for the pilot to include any other important details or notes.

Heading Information

- **Date** – Record the date the point sets are completed
- **Pilot** – Name of pilot setting the vessel for point sets
- **Plane** – Type of aircraft flying for point sets
- **Processor** – Name of the fish processing plant that the catch will be delivered to
- **Observer** – Name of observer onboard airplane if any

Point Set Flight Log Data

- **Point Set No.** – Number the point sets consecutively as they occur during the 2011 season
- **Time** – Record the time when the point set is attempted
- **Photo No.** - Pilots are asked to log the photo number that corresponds with the point set school that is identified and being targeted
- **Latitude/Longitude** - Record the latitude and longitude of the school being targeted for the point set
- **Altitude(ft)** – Record the altitude of the airplane for which species identification was made
- **Vessel** – Record the name of the vessel being set during each point set
- **Species Observed** – Record the species observed for each point set. Use comment section for additional writing space
- **% of School Captured** – Pilots are to estimate a percentage of point set school capture. Pilots estimated percent capture should be independent of captain's vessel estimate.
- **Estimated School Tonnage (mt)** – Pilots are to estimate the tonnage of the targeted fish school prior to setting on it.
- **Comments** – Please write any additional information or notes in this section.

Vessel Point Set Log Form

During the 2011 West Coast Aerial Sardine Survey, vessel captains participating in the capture of point sets are asked to record important fish school data, ocean data, catch estimates and delivery information. Additional vessels may be utilized during point set operations, so be sure to include this information in the '**Other Vessel utilized**' field under the Captains Estimate and Delivery Information heading. If additional vessels are used to land a point set, please contact Mr. Howe.

Heading Information

- **Date** – Record the date the point set is completed
- **Vessel** – Name of the vessel participating in the point set operations (also include any additional vessels that were utilized during a point set landing)
- **Captain** – Name of the person operating the vessel
- **Processor** –Name of the processing plant the point set catch will be delivered to

Vessel Log Data

Hydro acoustic Gear

- **Manufacturer –** Record the manufacturer name of the sounder and sonar being used during point set operations
- **Model –** Record the model number or series number of the sounder and sonar being used during point set operations
- **Frequency –** Record the frequency used for both the sounder and sonar during point-set operations

Net Dimensions

- **Net Length –** Record the length of the net (in fathoms) being used during point set operations
- **Net Depth –** Record the depth of the net (in fathoms) being used during point set operations
- **Mesh size –** Record the size of the net mesh (in inches) being used during point set operations

School and Ocean Data

- **Point Set No. –** Number the point sets consecutively as they occur during the 2011 season
- **Time –** Record the time the skiff was deployed from the vessel for point set capture
- **Latitude/Longitude –**Record the positional information related to the targeted point set school
- **Depth to Top of School (fath) –** Record the distance from the water surface to the top of the targeted point set school
- **Depth to Bottom of School (fath) –** Record the distance from the water surface to the bottom of the targeted point set school
- **Ocean Depth (fath) –** Record the ocean depth at which the point set occurred
- **Temperature –** Record the temperature of the water that the point set occurred in

- **Weather Condition –** Refer to the key at the bottom of the Vessel Point Set Log form for weather codes: **1**- calm, clear, **2** - light wind, good visibility, **3** - moderate wind, fair visibility, **4 -** poor fishing conditions.

Captains Estimate and Delivery Information

- **Species Observed** – Record the species observed for each point set
- **% of School captured** – Record the percentage of school captured. The captain's estimate will be independent of the pilot's estimated percent capture.
- **Estimated School Tonnage (mt)** – Record the estimated landed weight (mt)of the targeted point set
- **Fish Hold** – Record the fish hold that the point set is being held in for delivery. Below are abbreviations to be used for identifying which hold a specific point set is being held. Of course not all vessels will have six fish holds, use the fish hold code that best represents your vessels.

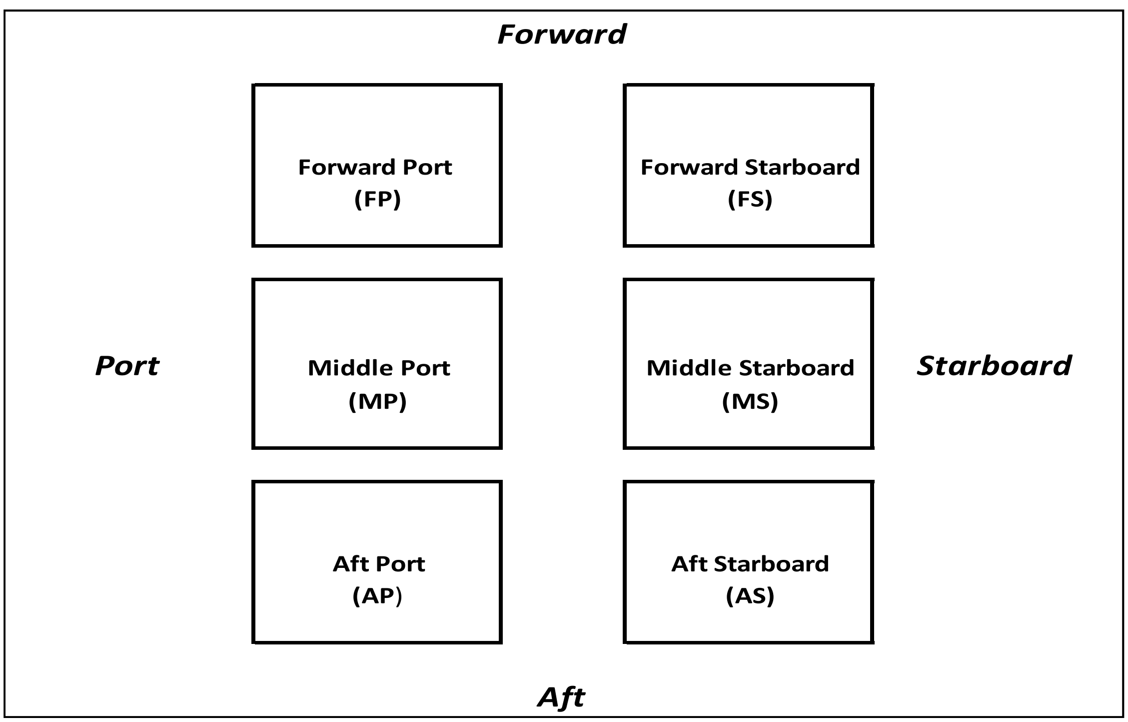


Diagram of fish hold abbreviations to be used on Fisherman's Log Form

- **Other Vessel utilized** – If an additional vessel is utilized to land a point set school, record the vessels name, estimated weight (mt) and in what holds the fish are being held. Use the comments section at the bottom of the form to report any additional information.
- ***Delivered Weight** (Office Use Only) – Leave this field blank. After the delivery is completed, the regional field coordinators will acquire this information from the processing plant manager.
- ***Fish Ticket Number** (Office Use Only) – Leave this field blank. The regional field coordinator will acquire this information from the processing plant manager.
- **Comments** – Please write any additional information or notes in this section.

Appendix I, Adjunct 3. Identification and gear configuration of participating vessels

Vessel Name	Skipper	Owner	USGS/OR Reg#	CPS/Sardine Permit #	Length	GRT	Holds	Capacity (Tons)
Pacific Pursuit	Keith Omey	Pacific Pursuit, LLC	OR873ABY	30920	73'	86	4	80
Lauren L. Kapp	Ryan Kapp	Mt. Hood Holdings LLC	OR072ACX	57008	72'	74	4	70
Evermore	Arnold Burke	Gulf Vessel Management	248555	57009	82'	120	4	50
Pacific Journey	Leaf Nelson	Stan Nelson	OR661ZK	36106	71'	98	4	78

Appendix I, Adjunct 3a. Identification of participating sardine processors

In Washington and Oregon, participating fish processors were established by a bid process using the same procedure as in 2010. Processors for 2011 will be Ocean Gold (Westport, WA), and Astoria Holdings (Astoria, OR).

Appendix I, Adjunct 3b. Identification of survey pilots and aircraft

2011 Survey Pilot Information

Pilot ID	Pilot Name	Aircraft ID	Aircraft Type
Survey Pilot No.1 (SP1)	Frank Foode	N700AM	Cessna 336 Skymaster (twin engine)
Survey Pilot No.2 (SP2)	Merrill Danna	N18ZF	Piper PA18 Super Cub
Survey Pilot No.3 (SP3)	Pat Miller	N31B	Cessna 180

Appendix I, Adjunct 3c. Identification of photograph analysts

Photo Analyst ID	Name
PA1	Sarah Stolar
PA2	Ryan Howe
PA3	Jason Tobin
PA4	Meghan Mikesell
PA5	Karen Lindsay
PA6	Lucas Edens

Appendix I, Adjunct 4. Aerial Survey Point Set Protocol

1) Sardine schools to be captured for point sets will first be selected by the spotter pilot and photographed at the nominal survey altitude of 4,000 ft. After selection, the pilot may descend to a lower altitude to continue photographing the school and setting the fishing vessel.
2) It is essential that any school selected for a point set is a discrete school and is of a size that can be captured in its entirety by the purse seine vessel; point set schools may not be a portion of a larger aggregation of fish.
3) To ensure standardization of methodology, the first set of point sets taken by each participating pilot will be reviewed to ascertain that they meet specified requirements. From that point forward, point set photos will be reviewed routinely to ensure that requirements are met.
4) A continuous series of photographs will be taken before and during the vessels approach to the school to document changes in school surface area before and during the process of point set capture. The photographs will be collected automatically by the camera set at 60% overlap.
5) Each school selected by the spotter pilot and photographed for a potential point set will be logged on the spotter pilots' 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 Fishermans' Log Form. These records will be used to determine the rate of school mis-identification by spotter pilots in the field and by analysts viewing photographs taken at the nominal survey altitude of 4,000 ft.
6) The purse seine vessel will 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.
7) 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 vessel captain will independently make note of the "percent captured" on their survey log forms for this purpose.
8) Upon capture, sardine point sets will be held in separate holds for separate weighing and biological sampling at the dock.
9) Biological samples of individual point sets will be collected at fish processing plants upon landing. Samples will be collected from the unsorted catch while being pumped from the vessels. Fish will be systematically taken at the start, middle, and end of a delivery as it is pumped. The three samples will then be combined and a random subsample of fish will be taken. The sample size will be n = 50 fish for each point set haul.
10) Length, weight, maturity, and age structures 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 provided attached to a measuring board. Standard length will be determined by measuring from sardine snout to the last vertebrae. Sardine maturity will be established by referencing maturity codes (female- 4 point scale, male- 3 point scale). 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. Alternatively, the 25 fish subsample

may be frozen (with individual fish identified as to sample number, point set, vessel and location captured, to link back to biological data) and sampled for otoliths at a later date.

11) 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 Fishermans' 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. Simrad ES-60 sounders will be installed on two purse seine vessels. Data collected by the ES-60 sounders will be backed-up daily and archived onshore.
12) Point sets will be conducted for a range of school sizes. Point sets will be targeted working in general from the smallest size category to the largest. The field director will oversee the gathering of point set landing data and will update the list of point sets needed (by size) daily for use by the spotter pilot. 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 surface area of sardine schools from the air, and will direct the purse seine vessel to capture schools of the 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 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. Pumping large sets onto more than one vessel should be avoided, and should only be done in the accidental event that school size was grossly underestimated.
13) The Scientific Field Project Leader will also oversee the spatial distribution of point set sampling, to ensure adequate dispersal of point set data collection.
14) Photographs and FMCdatalogs of point sets will be forwarded from the field to Mr. Howe daily.
15) The total landed weight of point sets taken will not exceed the EFP allotment.
16) The following criteria will be used to exclude point sets from the density analysis (reasons used to deem a point set "unacceptable"). Mr. Howe will make the final determination of point set acceptability in the lab. A preliminary judgment will be made in the field, generally at the end of each day (or sooner), to ensure ongoing sampling is being properly accomplished.

1	Percent captured	School is judged to be less than 90% captured
2	No photograph -1	No photograph of vessel was documented (camera off)
3	No photograph -2	No photograph of vessel was documented (camera on)
4	No photograph -3	Photograph available, but late (vessel is already pursing the catch)
5	School not discrete	Sardine captured was only a portion of a larger school ("cookie cutter")
6	Mixed hauls	Multiple point sets were mixed in one hold

Appendix II. Aerial Survey Calibration Flight Results in 2011.

Nominal Altitude:	4000 ft.						
Pilot	SP3						
Average of % Deviation	**Column Labels**						
Row Labels	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	**PA6**	**Grand Total**
Hanger 1	0.065	0.064	0.081	0.080	0.050	0.076	0.069
Hanger 2	0.061	0.048	0.070	0.064	0.032	0.077	0.058
Hanger 3	0.064	0.051	0.067	0.060	0.036	0.081	0.060
Hanger 4	0.113	0.111	0.115	0.113	0.089	0.113	0.109
Grand Total	**0.076**	**0.068**	**0.083**	**0.079**	**0.052**	**0.087**	**0.074**

Nominal Altitude:	3000 ft.						
Pilot	SP3						
Average of % Deviation	**Column Labels**						
Row Labels	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	**PA6**	**Grand Total**
Hanger 1	0.096	0.086	0.108	0.097	0.079	0.106	0.095
Hanger 2	0.059	0.047	0.074	0.048	0.038	0.078	0.057
Hanger 3	0.057	0.048	0.074	0.049	0.044	0.086	0.060
Hanger 4	0.082	0.081	0.087	0.081	0.067	0.092	0.082
Grand Total	**0.073**	**0.066**	**0.086**	**0.069**	**0.057**	**0.090**	**0.073**

Nominal Altitude:	2000 ft.						
Average of % Deviation	**Column Labels**						
Row Labels	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	**PA6**	**Grand Total**
Hanger 1	0.041	0.041	0.044	0.043	0.016	0.046	0.038
Hanger 2	0.023	0.023	0.027	0.027	0.002	0.030	0.022
Hanger 3	0.026	0.025	0.031	0.030	0.011	0.036	0.027
Hanger 4	0.076	0.080	0.083	0.081	0.065	0.083	0.078
Grand Total	**0.041**	**0.042**	**0.046**	**0.045**	**0.023**	**0.049**	**0.041**

Nominal Altitude:	1000 ft.						
Pilot	SP3						
Average of % Deviation	**Column Labels**						
Row Labels	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	**PA6**	**Grand Total**
Hanger 1	-0.004	-0.004	-0.002	-0.004	-0.017	0.006	-0.004
Hanger 2	-0.026	-0.025	-0.015	-0.025	-0.037	-0.005	-0.022
Hanger 3	-0.015	-0.015	-0.015	-0.014	-0.026	0.009	-0.012
Hanger 4	0.028	0.030	0.030	0.030	0.019	0.030	0.028
Grand Total	**-0.004**	**-0.003**	**0.000**	**-0.003**	**-0.015**	**0.010**	**-0.003**

Appendix II. Aerial Survey Calibration Flight Results in 2011, Continued.

Nominal Altitude:	4000ft.						
Pilot	SP1						
Average of % Deviation	**Column Labels**						
Row Labels	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	**PA6**	**Grand Total**
Hanger 1	-0.032	-0.032	-0.038	-0.033	-0.052	-0.029	-0.036
Hanger 2	-0.072	-0.069	-0.071	-0.070	-0.070	-0.067	-0.070
Hanger 3	-0.073	-0.071	-0.073	-0.072	-0.081	-0.071	-0.073
Hanger 4	-0.058	-0.056	-0.055	-0.056	-0.066	-0.055	-0.058
Grand Total	**-0.059**	**-0.057**	**-0.059**	**-0.058**	**-0.067**	**-0.056**	**-0.059**

Nominal Altitude:	3000ft.						
Pilot	SP1						
Average of % Deviation	**Column Labels**						
Row Labels	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	**PA6**	**Grand Total**
Hanger 1	0.008	0.010	0.011	-0.011	-0.013	-0.007	0.000
Hanger 2	-0.007	-0.006	-0.005	-0.006	-0.013	-0.006	-0.007
Hanger 3	-0.006	-0.005	-0.004	-0.005	0.007	0.012	0.000
Hanger 4	0.030	0.033	0.033	0.053	0.027	0.033	0.035
Grand Total	**0.006**	**0.008**	**0.009**	**0.008**	**0.002**	**0.008**	**0.007**

Nominal Altitude:	2000ft.						
Pilot	SP1						
Average of % Deviation	**Column Labels**						
Row Labels	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	**PA6**	**Grand Total**
Hanger 1	0.043	0.044	0.045	0.044	0.039	0.045	0.043
Hanger 2	0.016	0.017	0.017	0.017	0.011	0.017	0.016
Hanger 3	0.018	0.020	0.020	0.020	0.014	0.020	0.018
Hanger 4	0.058	0.059	0.059	0.059	0.052	0.059	0.057
Grand Total	**0.034**	**0.035**	**0.035**	**0.035**	**0.029**	**0.035**	**0.034**

Nominal Altitude:	1000ft.						
Pilot	SP1						
Average of % Deviation	**Column Labels**						
Row Labels	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	**PA6**	**Grand Total**
Hanger 1	-0.054	-0.054	-0.054	-0.054	-0.060	-0.054	-0.055
Hanger 2	-0.052	-0.052	-0.052	-0.052	-0.056	-0.052	-0.053
Hanger 3	-0.051	-0.051	-0.051	-0.051	-0.055	-0.051	-0.052
Hanger 4	0.009	0.009	0.009	0.009	0.005	0.009	0.009
Grand Total	**-0.037**	**-0.037**	**-0.037**	**-0.037**	**-0.042**	**-0.037**	**-0.038**

Appendix II. Aerial Survey Calibration Flight Results in 2011, Continued.

Nominal_Altitude (ft)	4000					
Pilot	SP2					
Average of % Deviation	**Column Labels**					
Row Labels	**PA1**	**PA3**	**PA4**	**PA5**	**PA6**	**Grand Total**
Hanger 1	0.034	0.096	0.093	0.082	0.097	0.080
Hanger 2	0.014	0.069	0.065	0.056	0.067	0.054
Hanger 3	0.012	0.074	0.071	0.064	0.074	0.059
Hanger 4	0.045	0.091	0.089	0.085	0.096	0.081
Grand Total	**0.027**	**0.083**	**0.079**	**0.072**	**0.083**	**0.069**

Nominal_Altitude (ft)	3000					
Pilot	SP2					
Average of % Deviation	**Column Labels**					
Row Labels	**PA1**	**PA3**	**PA4**	**PA5**	**PA6**	**Grand Total**
Hanger 1	0.019	0.067	0.066	0.094	0.068	0.063
Hanger 2	-0.009	0.025	0.025	0.017	0.023	0.016
Hanger 3	-0.010	0.030	0.029	0.012	0.018	0.016
Hanger 4	-0.012	0.032	0.032	0.004	0.046	0.021
Grand Total	**-0.003**	**0.038**	**0.038**	**0.032**	**0.039**	**0.029**

Nominal_Altitude (ft)	2000					
Pilot	SP2					
Average of % Deviation	**Column Labels**					
Row Labels	**PA1**	**PA3**	**PA4**	**PA5**	**PA6**	**Grand Total**
Hanger 1	0.015	0.050	0.031	0.025	0.037	0.031
Hanger 2	-0.011	0.023	0.019	0.014	0.031	0.015
Hanger 3	-0.010	0.007	0.006	0.001	0.015	0.004
Hanger 4	0.022	0.033	0.050	0.042	0.055	0.040
Grand Total	**0.004**	**0.028**	**0.026**	**0.021**	**0.034**	**0.022**

Nominal_Altitude (ft)	1000					
Pilot	SP2					
Average of % Deviation	**Column Labels**					
Row Labels	**PA1**	**PA3**	**PA4**	**PA5**	**PA6**	**Grand Total**
Hanger 1	0.022	0.037	0.037	0.033	0.039	0.034
Hanger 2	-0.029	-0.029	-0.030	-0.034	-0.029	-0.030
Hanger 3	-0.058	-0.055	-0.058	-0.062	-0.055	-0.058
Hanger 4	-0.060	-0.057	-0.057	-0.062	-0.054	-0.058
Grand Total	**-0.031**	**-0.026**	**-0.027**	**-0.031**	**-0.025**	**-0.028**

Appendix III. R-code used to compute survey biomass and CV

```
#SetB2011: Computes biomass and CV estimate for Set B of the 2011 Survey (Transects 1-16).
# Bootstraps two readings of school size
# Covariance on pointset data obtained from library 'MSVBAR'
cdata <- read.csv(file="cdata2011.csv")              #file of point set data
transectdata <- read.csv(file="transectdata2011setbR1.csv")  #file of transect surface area data , reading 1
transectdata2 <- read.csv(file="transectdata2011setbR2.csv") #file of transect surface area data , reading 2

 setb2011 = function(nboots,cdata,transectdata,transectdata2){
  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 <- 31
  xpanfactor  <- 230
  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(100000)),
     lower=list(lyint= log(0.001), lasymp= log(0.002),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$sarea)
  Density2 <- convert(yint,asymp,cc,transectdata2$sarea)
  transectdata$bms <- Density*transectdata$sarea       #estimated bms of schools - reading 1
  transectdata2$bms <- Density2*transectdata2$sarea    #estimated bms of schools - reading 2

  transectbms1 <- tapply(transectdata$bms,transectdata$transect,sum)
    #calc bms on transect by summing over schools reading1
  transectbms1R2 <- tapply(transectdata2$bms,transectdata2$transect,sum)
   #calc bms on transect by summing over schools reading2

  tbmsR1 = xpanfactor*sum(transectbms1)/ntransects  #calculate total bms - reading 1
  tbmsR2 = xpanfactor*sum(transectbms1R2)/ntransects  #calculate total bms - reading 2
  tbms0 = (tbmsR1+tbmsR2)/2
  print(paste("Est bms = ",round(tbms0)),quote=F)

  bms <- rep(0,nboots) #set up bootstraps
```

```
library('MSBVAR')
covmatrix <- vcov(mmfit)
meanparams <- coef(mmfit)
newcoef <- rmultnorm(nboots,vmat=covmatrix,mu=meanparams)
Rselect <- transectbms1
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$sarea)
  Density2 <- convert(nyint,nasymp,nc,transectdata2$sarea)

  transectdata$bms <- Density*transectdata$sarea       #estimated bms of schools - reading 1
  transectdata2$bms <- Density2*transectdata2$sarea    #estimated bms of schools - reading 2

  transectbms1 <- tapply(transectdata$bms,transectdata$transect,sum)
   #calc bms on transect by summing over schools reading1
  transectbms1R2 <- tapply(transectdata2$bms,transectdata2$transect,sum)
   #calc bms on transect by summing over schools reading2

  #randomly select reading 1 or reading 2 for each transect
  readings <- matrix(nrow=ntransects,c(transectbms1,transectbms1R2))
  ii <- sample(seq(from=1,to=2),size=ntransects,replace=T)
   for (j in 1:ntransects){
    Rselect[j] <- readings[j,ii[j]]
     }

  tresample <- sample(1:ntransects,replace=T)  #sample the transect indicies
  retransect <- Rselect[tresample] #bootstrap of transects

  bms[i] <- xpanfactor*sum(retransect)/ntransects  #calculated bms of this bootstrap
  }

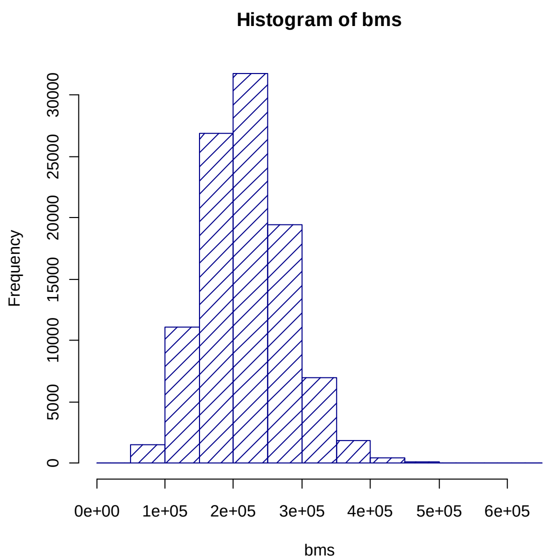
  windows()
  hist(bms,breaks=20,density=10,col='dark blue') #histogram of bootstrapped biomasses
  print(paste("yint = ",yint),quote=F)
  print(paste("asymp = ",asymp),quote=F)
  print(paste("cc = ",cc),quote=F)
  print(paste("SE = ",round(sd(bms,na.rm=TRUE))),quote=F)
  print(paste("CV = ",round(sd(bms,na.rm=TRUE))/tbms0), quote=F)

}
```

Appendix IV. Response to requests made at the October 4-7, 2011 STAR panel.

Figure 1. Biomass estimate results when nine additional point sets (flown at altitudes < 4,000 ft) are included in the analysis.

Aerial Survey Biomass Estimate (N = 44 Point Sets): 215,075 mt; CV = 0.28



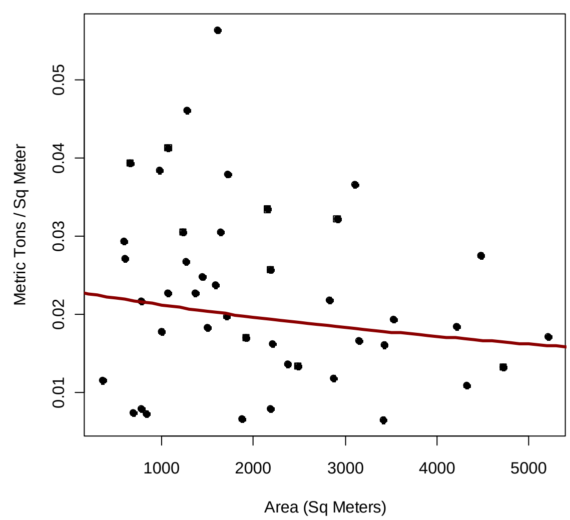


Figure 2. Sum of transect biomass estimates by reader and results of paired two-sample t-Test.

	Estimates using 2011 Point Set Data		Estimates using 2008-2011 Point Set Data	
Transect	Sardine Biomass (mt)		Sardine Biomass (mt)	
	Reading 1	Reading 2	Reading 1	Reading 2
1	780.2	699.1	905.8	791.1
1a	2125.9	2180.5	2670.9	2717.1
2	775.1	734.0	854.8	792.6
2a	58.4	58.5	88.0	89.5
3	1750.0	1691.4	1659.4	1647.3
3a	1812.0	1744.1	2239.1	2189.6
4	849.2	788.2	1137.0	1074.9
4a	355.9	370.9	477.2	489.1
5	79.8	69.0	119.4	104.8
5a	0.0	0.0	0.0	0.0
6	722.3	719.3	777.5	778.3
6a	3452.3	3804.7	3398.4	3661.9
7	1878.6	2064.2	2322.8	2546.7
7a	1020.1	1167.5	1409.9	1620.1
8	210.1	182.3	305.8	267.7
8a	229.6	259.4	308.4	353.5
9	234.8	229.7	328.8	318.7
9a	2560.5	2727.3	3483.2	3554.5
10	2053.0	2252.0	2895.0	3186.7
10a	3460.1	3653.7	4833.9	5057.5
11	854.2	907.3	1156.7	1214.6
11a	1394.3	1462.6	1696.2	1830.5
	26656.5	27765.5	33068.4	34286.5

t-Test: Paired Two Sample for Means		
	Variable 1	*Variable 2*
Mean	859.8857348	895.6605494
Variance	1086324.407	1239167.803
Observations	31	31
Pearson Correlation	0.998171071	
Hypothesized Mean Dif	0	
df	30	
t Stat	-2.068550466	
P(T<=t) one-tail	0.023650941	
t Critical one-tail	1.697260851	
P(T<=t) two-tail	0.047301882	
t Critical two-tail	2.042272449	

Figure 3. Transect autocorellation function (ACF) analysis.

bms1				bms2			
780.2429	0.246188	N =	22	699.1442	0.2598	N =	22
2125.941		lag =	1	2180.483		lag =	1
775.1225				733.9543			
58.37225				58.49498			
1750.029				1691.401			
1812.03				1744.07			
849.1662				788.1812			
355.909				370.8975			
79.83483				68.95598			
0				0			
722.3427				719.282			
3452.281				3804.719			
1878.59				2064.158			
1020.108				1167.54			
210.0593				182.2927			
229.5764				259.3576			
234.7863				229.6728			
2560.482				2727.269			
2053.004				2252.022			
3460.07				3653.697			
854.2059				907.26			
1394.304				1462.623			

Figure 4. Plot of mean fish length by latitude from point set samples, 2009-2011.

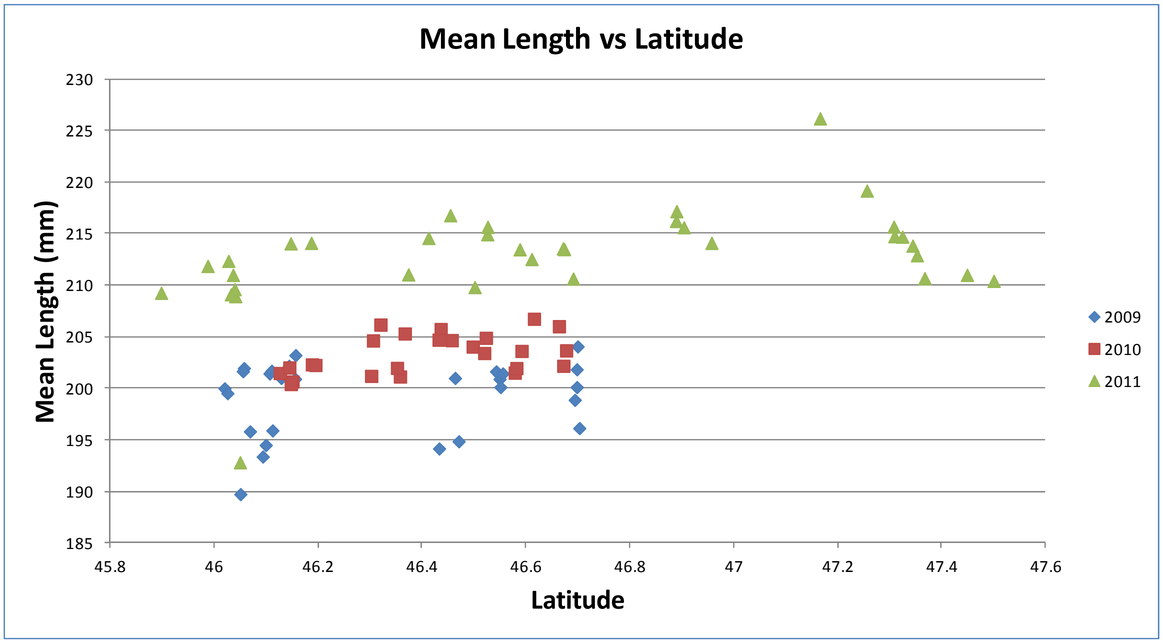
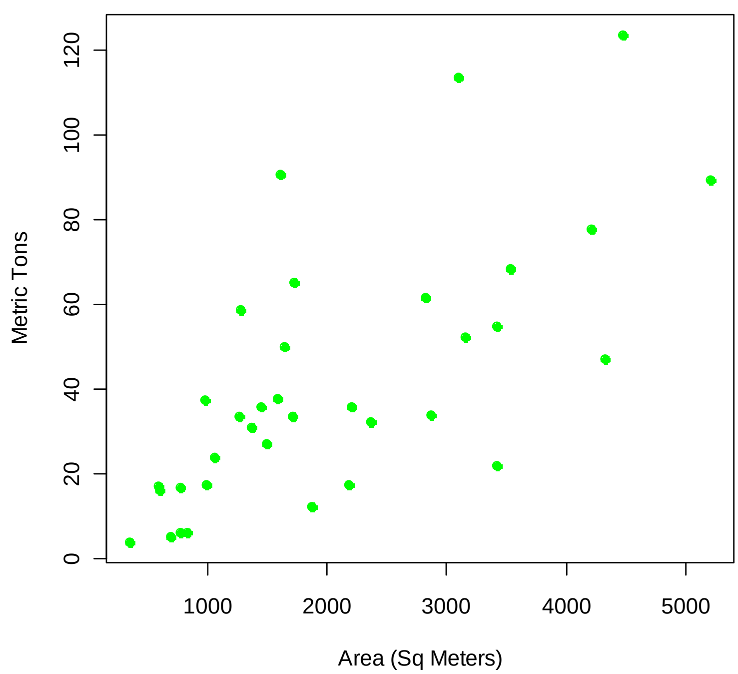


Figure 5. Plot of metric tons vs. area for point sets sampled in 2011.



Pacific sardine (*Sardinops sagax*) abundances estimated using an acoustic-trawl survey method

David A. Demer, Juan P. Zwolinski, Kyle A. Byers, George R. Cutter Jr., Thomas S. Sessions, and Beverly J. Macewicz

NOAA / National Marine Fisheries Service
Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, CA, 92037

Abstract

The "northern" stock of Pacific sardine (*Sardinops sagax)* in the California Current have been surveyed by the Advanced Survey Technologies Program at the Southwest Fisheries Science Center during spring 2006, 2008, 2010, and 2011, and summer 2008, using acoustic-trawl (ATM) methods (Demer et al., in press; Zwolinski et al., in review). Here, the methods and results are briefly summarized. Multi-frequency echosounders are used to map acoustic backscatter from coastal pelagic fish species (CPS); the proportions of species in trawl catches, weighted by their length-dependent acoustic target strength (*TS*) values, are used to apportion the CPS backscatter to species; and the total backscatter from sardine is converted to biomass using estimates of sardine *TS* and survey area. The sardine biomass has been declining since 2006 as the last large cohort, spawned in 2003, diminishes. The sardine-length distributions from the trawl samples clearly track the 2003 cohort through 2011. The reduction in biomass from 2006 to 2010 indicates a total-mortality, exponential-decay rate of 0.66. These internally consistent fisheries-independent estimates can be used as absolute estimates of sardine distribution and abundance (PFMC, 2011). The surveys spanned the entirety of the potential sardine habitat (Zwolinski et al., 2011; Demer et al., in press; Zwolinski et al., in review) and thus sampled the entire northern stock. The coefficient of variation (*CV*) values ranged from a maximum of 43.3% in spring 2010 to only 9% in spring 2008; the latter resulted from high-density sampling of a coalesced spring-spawning aggregation.

Introduction

Acoustic-trawl method (ATM)

During spring 2006, 2008, 2010, and 2011, and summer 2008, the Southwest Fisheries Science Center (SWFSC) used the acoustic-trawl method (ATM) (Demer et al., in press; Zwolinski et al., in review), to survey the "northern" stock of Pacific sardine (*Sardinops sagax*) and other coastal pelagic fish species (CPS) off the west coast of the United States of America (US), from the US-Mexican to US-Canadian borders. The ATM uses ship-based, multiple-frequency echosounders to map the distribution of CPS; and trawl catches to apportion the echo energy to species, map their densities, and estimate their abundances. Details of the method and results of the 2006 to 2010 ATM surveys may be found in Demer et al. (in press) and Zwolinski et al. (in review). A synopsis of the 2006 to 2011 ATM survey methods and results is presented here.

Methods

Sampling equipment and platforms

ATM surveys of CPS in the California Current Ecosystem (CCE) were conducted from NOAA Fisheries Survey Vessels (FSVs) and contract fishing vessels (FVs) during spring 2006, 2008, 2010, and 2011, and summer 2008. Each ship was configured with multi-frequency split-beam echosounders (Simrad EK60s) configured with hull- or retractable-keel-mounted transducers (Simrad ES18-11, ES38B, ES70-7C, ES120-7C, and ES200-7C), operating at 38, 70, 120, and 200 kHz (FSV *David Starr Jordan* and F/V *Frosti*) and 18, 38, 70, 120, and 200 kHz (FSVs *Oscar Dyson* and *Bell M. Shimada*). Surface trawls were conducted using a midwater trawl (Nordic 264) with foam-filled doors and floats on the headline.

Sampling design

Parallel-line transects, perpendicular to the coast, extending from the US-Mexican to US-Canadian borders, were surveyed acoustically at a nominal speed of 10 kts. At night, the vessels trawled near the sea surface. Survey transects were planned with considerations to requisite California Cooperative Oceanic and Fisheries Investigations (CalCOFI) sampling in the Southern California Bight (SCB), and, during the latter portion of the time-series, sardine habitat predicted from satellite-sensed oceanographic conditions (Zwolinski *et al*., 2011).

Acoustic and trawl sampling

Measurements of echo power (p_r; W) and interferometric-phase angle were sampled continuously throughout the surveys. To minimize potential bias from diel vertical migration of CPS, only the daytime data were included in the following analysis. At nighttime, during the same periods as above, when CPS are generally near to the sea surface and more dispersed compared to daytime, fish species and their lengths were sampled with the surface trawl at a minimum of two stations per night, from each vessel.

Acoustic-trawl analysis

Measurements of volume backscattering strength (S_v; dB re 1 m^{-1}), target strength (TS; dB re 1 m^2), and nautical-area backscattering coefficients (s_A; m^2 n.mi.$^{-2}$) were derived from the echosounder power and angle data. Three-frequency (38, 120, and 200 kHz) S_v data were used to map CPS and estimate biomasses for sardine. To identify acoustic backscatter from CPS, differences in measured S_v values were compared to empirical predictions: $-17 \le S_{v70} - S_{v38} \le 10$; $-17 \le S_{v120} - S_{v38} \le 14$; and $-14 \le S_{v200} - S_{v38} \le 5$ dB. The s_A values attributed to CPS, averaged along two-kilometer-long intervals, were mapped throughout the survey region.

The s_A at 38 kHz corresponding to CPS (s_{A_CPS}) in the 100-m-long cells were apportioned to j species present using the catch proportions in the nearest (space and time) trawl samples (Nakken and Domasnes, 1975):

$$s_{A_i} = \frac{w_i \times 10^{(\langle TS_i \rangle/10)}}{\sum_j w_i \times 10^{(\langle TS_i \rangle/10)}} s_{A\_\mathrm{CPS}} \tag{1}$$

where w_i is the proportion of the mass of the catch (kg) for the i-th species, and $<TS_i>$ is its length-weighted mean target strength (TS; dB re 1 m^2/kg). Thus, each $<TS_i>$ is a mean TS, weighted in the linear domain by the distribution of total length (TL; cm) of the sampled fish of that species. The TS relationships employed are:

$$TS = -14.90 \times \log(TL) - 13.21, \text{ for sardine;} \tag{2}$$

$$TS = -12.15 \times \log(TL) - 21.12, \text{ for anchovy; and} \tag{3}$$

$$TS = -15.44 \times \log(TL) - 7.75, \text{ for mackerel.} \tag{4}$$

These relationships were originally estimated for anchovy (*Engraulis capensis*), sardine (*Sardinops ocelatus*), and horse mackerel (*Trachurus trachurus*), based on the combination of backscatter-versus-length and mass-versus-length measurements of *in situ* fish (Barange *et al.*, 1996). Because jack mackerel and Pacific mackerel have similar TS (Peña, 2008), equation (4) was used for both of these species. For each species, the s_{A_i} values were converted to fish-biomass density (ρ_i; kg/n.mi.^{2}) using:

$$\rho_i = \frac{s_{A_i}}{4\pi 10^{(\langle TS_i \rangle/10)}} . \tag{5}$$

The estimated densities of Pacific sardine along two-kilometer-long intervals were mapped throughout the survey region (see Demer et al., in press; Zwolinski et al., in review).

Post-survey strata were defined based on the inter-transect spacing, the species composition in the trawls, and the spatial distribution of acoustic backscatter. With confirmed independence between the mean biomasses of the east-west transects, unbiased estimates were derived for the survey mean (Jolly and Hampton, 1990), and its variance (Efron, 1981). For each species, the point estimate of abundance was obtained by raising the stratum-mean biomass density to the stratum area. The stratum-mean biomass density was calculated as the average of the biomass density for each transect, using only daytime samples, weighted by the correspondent daytime-transect lengths.

The sampling variances and confidence intervals were estimated using bootstrap because it provides better statistical inference than traditional methods for data with unknown statistical distributions and small sample sizes (Efron 1981). The 95% confidence intervals for the mean biomass densities were estimated as the 0.025- and 0.975-quantiles of the distribution of 1,000 bootstrap survey-mean biomass densities. Coefficient of variation (CV) values were obtained by dividing the bootstrapped standard errors by the bootstrapped arithmetic means (Efron 1981). Given that the data within each transect are serially correlated, but the samples are independent between transects (confirmed via correlation analysis; Demer et al., in press), bootstrap resampling of the transect means provided unbiased estimates of the variance for the survey mean, even when there are several levels of variability nested at the intratransect level (Williams 2000).

Results

The acoustic-trawl sampling spanned the extent of the potential sardine habitat. During each spring, acoustically- and trawl-sampled sardine densities were largest offshore of southern and central California (**Fig. 1**). During summer 2008, sardine densities were highest nearshore, principally along the coasts of Oregon and Washington (**Fig. 1**). The biomass of sardine declined precipitously between 2006 and 2010 (**Table 1** and **Fig. 2**), corresponding to the mortality and growth of the strong 2003 cohort (**Figs. 3 and 4**). In spring 2011, a new, relatively small cohort was present (**Fig. 4**), which contributed to a slight increase in the total sardine biomass (**Table 1** and **Fig. 2**).

Tables

Table 1. The acoustic-trawl method (ATM) estimates of Pacific sardine biomasses for the 2011 survey. The second biomass estimate for summer 2008 (in parentheses) includes an extrapolated estimate of biomass (0.169 Mt) in the region (2,848 n.mi.^{2}) between the eastern ends of the transects and the coast (details in Demer et al., in press).

Surveys	Biomass (Mt)	CI_{95} (Mt)	CV (%)
2006 spring	1.947	0.897 – 3.139	30.4
2008 spring	0.751	0.611 – 0.870	9.2
2008 summer	0.632 (0.801)	0.303 – 1.098	30.9
2010 spring	0.357	0.094 – 0.690	43.3
2011 spring	0.494	0.221 – 0.816	30.4

Figures

Figure 1. Relative sardine biomass densities averaged over 2 km intervals off the west coast of the US during spring 2006, 2008, 2010, and 2011, and summer 2008.

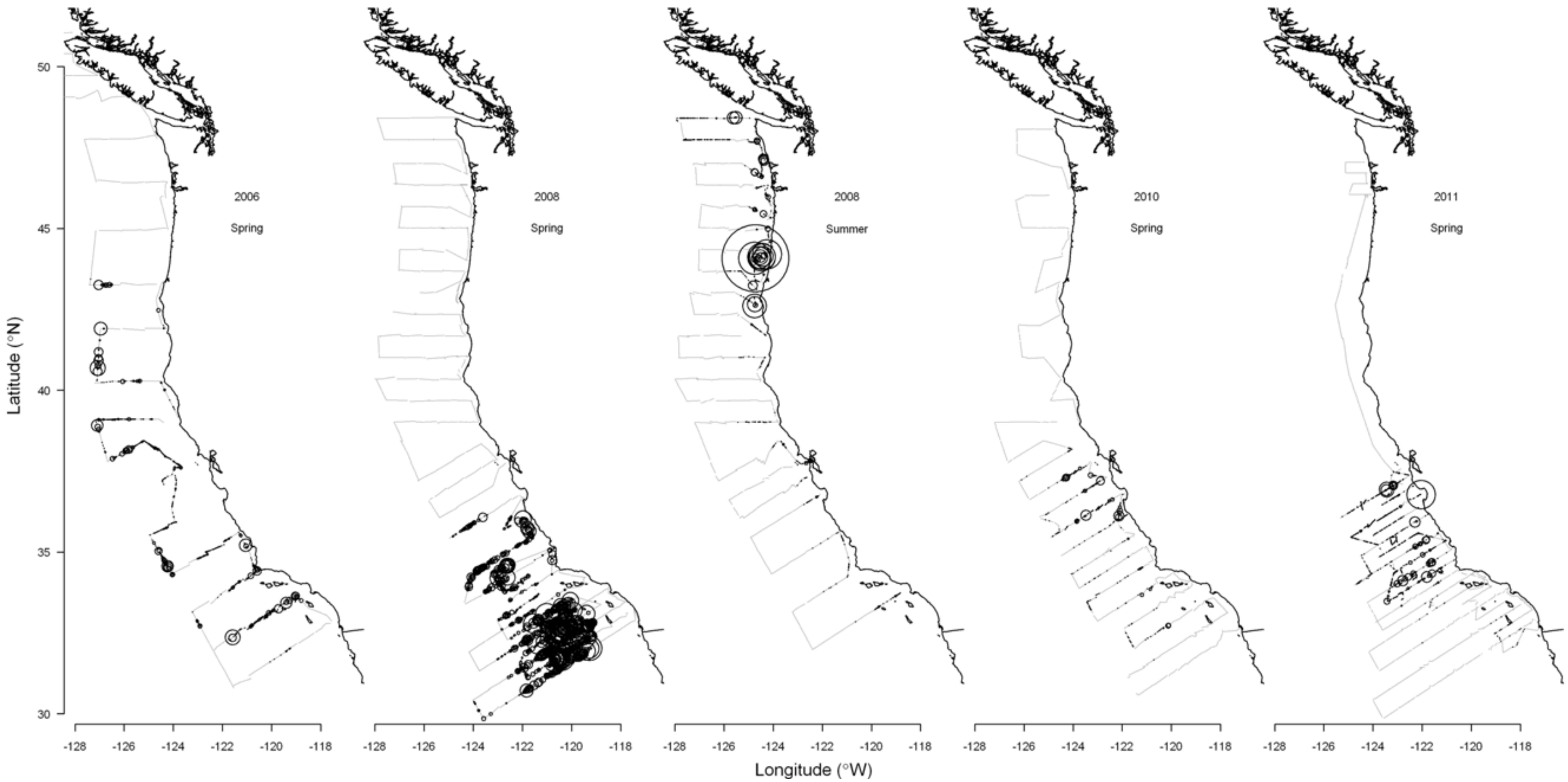


Figure 2. Total-sardine biomass off the west coast of the US surveyed during spring 2006, 2008, 2010, and 2011, and summer 2008, estimated from the acoustic-trawl survey (red); the age 1+ biomass estimated from the *preliminary* stock assessment model (Hill *et al.,* 2011; blue). In 2011, the trajectories of both the total-sardine biomass (solid red) and the biomass of the 2003 cohort are indicated (dashed red).

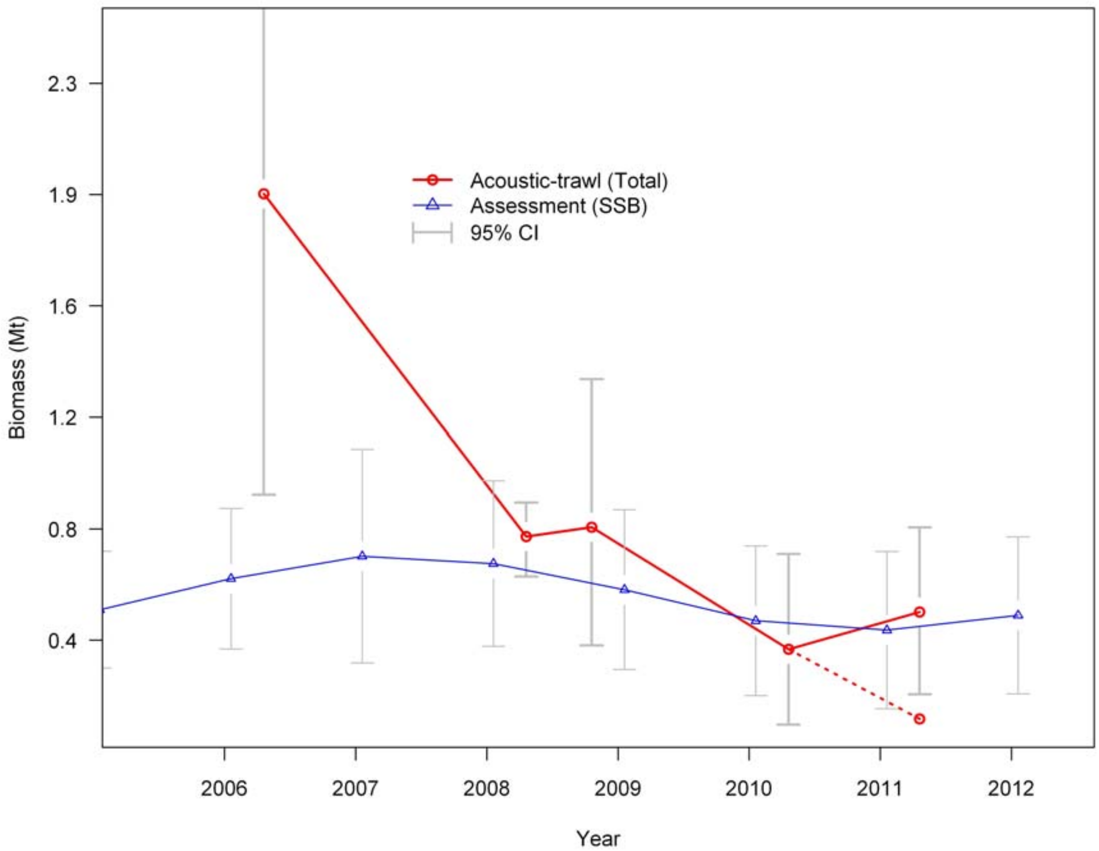


Figure 3. Decay rate of the Pacific sardine population, comprised mainly from one cohort, estimated from the acoustic-trawl estimates of biomass from 2006, 2008, 2010, and 2011. The 2003 cohort, which dominated in spring 2006, is clearly tracked through 2011 (**Figs. 2-4**). In spring 2011, the sardine biomass was dominated by a new, but small, cohort (**Figs. 2 and 4**).

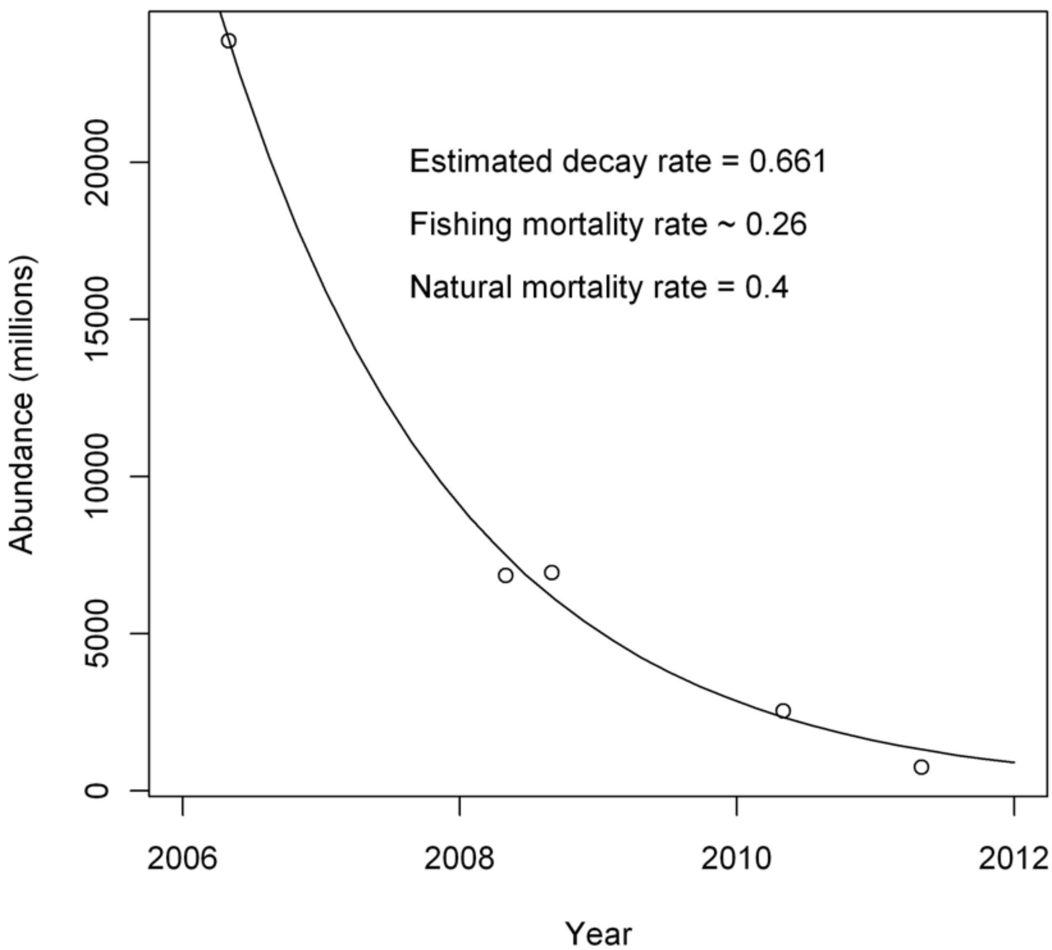
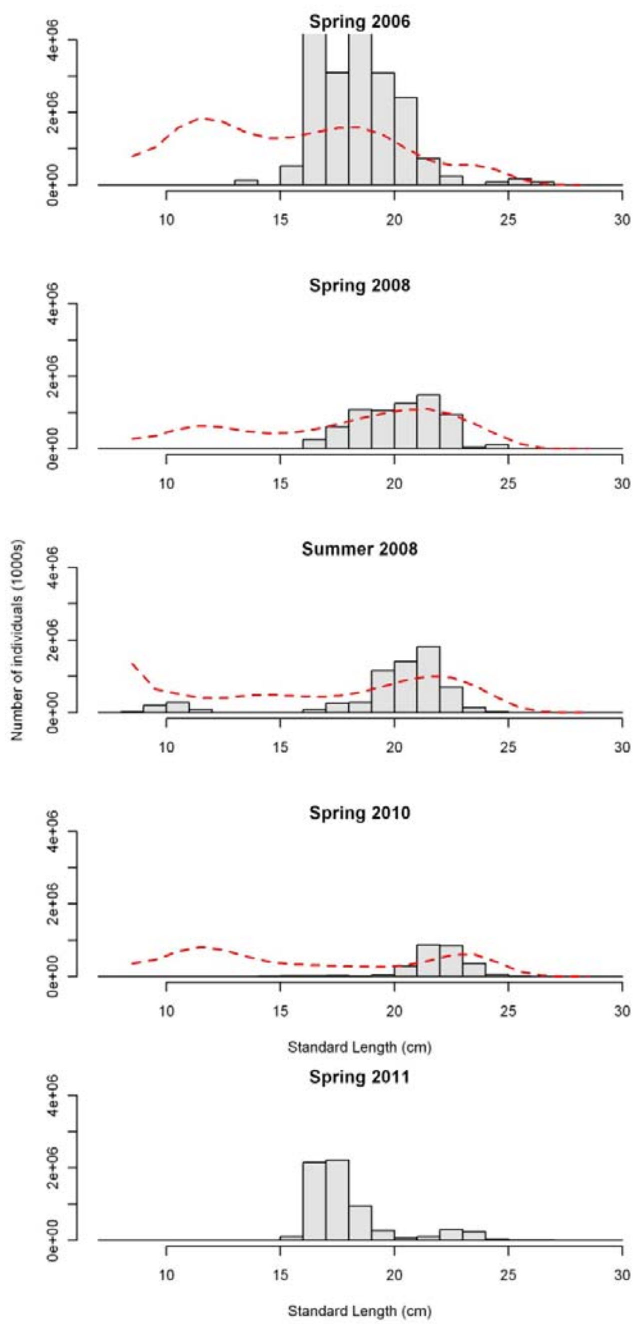


Figure 4. Lengths of Pacific sardine from trawl samples during the 2006, 2008, 2010, and 2011 surveys of CPS off the US west coast (bars) and those estimated from the stock assessment model (dashed line; Hill *et al.,* 2010). The 2003 cohort, which dominated in spring 2006, is clearly tracked through 2011. The rate of decline for this cohort throughout this period is approximately 0.66 (**Fig. 3**). In spring 2011, the sardine biomass was dominated by a new, but small, cohort (see also **Fig. 2**). The smaller fish indicated by the assessment model (dashed red lines in 2006 to 2010) might result from the inclusion of summer landings data from the Californian and Mexican fisheries. These fish likely represent the "southern" stock of Pacific sardine and their inclusion appears to confound the assessment.



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Pacific Sardine

STAR Panel Meeting Report

NOAA / Southwest Fisheries Science Center
La Jolla, California
October 4-7, 2011

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
Ray Conser, SSC, Southwest Fisheries Science Center (SWFSC)
Larry Jacobson, External Reviewer, Northeast Fisheries Science Center
Chris Francis, Center for Independent Experts (CIE)

Pacific Fishery Management Council (Council) Representatives:
Lorna Wargo, Coastal Pelagic Species Management Team (CPSMT)
Mike Okoniewski, Coastal Pelagic Species Advisory Subpanel (CPSAS)
Kerry Griffin, Council Staff

Pacific Sardine Stock Assessment Team:
Kevin Hill, NOAA / SWFSC
Paul Crone, NOAA / SWFSC
Nancy Lo, NOAA / SWFSC
Beverly Macewicz, NOAA / SWFSC
Emmanis Dorval, NOAA / SWFSC
Jennifer McDaniel, NOAA / SWFSC
Yuhong Gu, NOAA / NWFSC

Acoustic- Trawl Survey Team
David Demer, NMFS, SWFSC
Juan Zwolinski, NMFS, SWFSC

Aerial Survey Team
Tom Jagielo, Tom Jagielo Consulting

1) Overview

The Pacific Sardine Stock Assessment and Review (STAR) Panel (Panel) met at the Southwest Fisheries Science Center, La Jolla, CA Laboratory from October 4-7, 2011 to review a draft assessment by the Stock Assessment Team (STAT) for Pacific Sardine. Introductions were made (see list of attendees, Appendix 1), the agenda was adopted, and Kerry Griffin reviewed the Terms of Reference (TOR) for CPS assessments with respect to how the Panel would be conducted. A draft assessment document and background materials were provided to the Panel in advance of the meeting on a SWFSC FTP site. The Chair, André Punt, noted that the assessment report included analyses related to estimating F_{MSY}, but that reviewing this analysis was beyond the scope of the TOR for the Panel.

Kevin Hill presented the assessment methodology and the results from a draft assessment utilizing the Stock Synthesis Assessment Tool, Version 3.21d (SS3) to the Panel. The model on which the draft assessment was based differed from that on which the 2009 assessment was based in several respects. The draft assessment included: (a) two rather than four fleets, (b) a later start-date for the assessment (1993 rather than 1981), (c) fewer time-blocks for selectivity, (d) no time-blocking for growth, (e) inclusion of the indices of abundance from the acoustic-trawl surveys, (f) revised age-reading error matrices, and (g) the aerial (and acoustic-trawl) surveys were assumed to be relative rather than absolute indices of abundance. The draft assessment benefited from a number of improvements to the abundance data and an improved understanding of the precision of the age data for sardine. The assessment was also based on other updated data streams, in particular additional age and length data for the Ensenada fishery.

David Demer, Nancy Lo, and Tom Jagielo respectively presented aspects of the methodology and results for the acoustic-trawl, Daily Egg Production Method (DEPM), and aerial surveys. The Panel agreed that the current approach of calculating spawning fraction for DEPM estimates should be continued and no futher work related to a Bayesian analysis of spawning fraction was required. The Panel noted, and was particularly appreciative of, the efforts made by the STAT to respond to the recommendations from past panels and the SSC.

The review and subsequent explorations of the assessment through sensitivity analyses were motivated primarily by the reasons for the changes from the last assessment, the poor residual patterns for some of the fits, understanding the best way to weight the various data sources, the considerable sensitivity of the estimate of current 1+ biomass to what would seem to be minor changes to the specifications of the assessment (see, for example request U below), and the assumptions related to catchability for the aerial and acoustic-trawl surveys. The Panel supported the effort by the STAT to simplify the assessment; with the aim of finding a more stable assessment (likelihood profiles presented to the Panel indicated that even though the assessment includes many data points, these are largely uninformative regarding current 1+ biomass).

The Panel noted that the approach to computing effective Ns in Appendix 2 differs from that used in most assessments of west coast coastal pelagic and groundfish species. This approach accounts for correlations among residuals within years, unlike the conventional method of McAllister & Ianelli (1997), which is used in SS3 to calculate 'output' effective sample sizes. These correlations are often substantial (those shown in Figure 2 of Appendix 2 are typical). The SSC should consider whether the approach of Appendix 2 should be used regularly when conducting stock assessments for Council-managed stocks.

The STAR Panel thanked the STAT for their hard work and willingness to respond to Panel requests, and the staff at the SWFSC La Jolla laboratory for their exceptional support and provisioning during the STAR meeting.

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

Tuesday AM

A. Tabulate and plot the annual mean size-at-age in the catch by fishery (Mexico, California and Oregon/Washington) for semester 1; and superimpose the growth curve estimated in the model and, if possible, growth curves from the literature. ***Rationale***: To determine if there is evidence in the data for differences in growth by fishery and over time (mean size-at-age by fishery is not reported in the assessment document). These diagnostics may also provide some insight into possible model misspecification, and allow an evaluation of whether the estimated growth curve is biologically realistic. ***Response***: Mean size-at-age (averaged over years) was plotted for the various regions along the west coast. Mean size-at-age increased with latitude but decreased over time within region. The reduction in mean size-at-age over time was most apparent in the Pacific Northwest (PacNW) region, but most of the change occurred before 1991 (the assessment modeling begins in 1993).
B. Smooth the ageing error standard deviation (SD) relationship for California ages in 2007 (Figure 8 of the assessment report). ***Rationale***: Ageing error data are very noisy for fish older than 3.5 yr. The ageing error SD for age 4.5 is clearly an artifact. ***Response***: The spike in SD at age 4.5 was eliminated and linear extrapolation was used for all older ages. This change led to no changes in the 1+ biomass and became part of the base case for all subsequent model runs.
C. Conduct a run that does not use the ageing error matrix, or downweights the ageing error to near zero. ***Rationale***: To determine whether ageing error has an important effect on key assessment results. ***Response***: This change smoothed the recruitment estimates, but did not cause an appreciable change in the time-series of 1+ biomass.
D. Add the recommendations from the September 2010 SSC CPS Subcommittee review and the November 2010 SSC report to the recommendation list from the 2009 STAR Panel (see 2010 assessment document, p 135+). ***Rationale***: This will complete the assessment review history of requests and actions taken. ***Response***: This request could not be completed before the end of the Panel meeting and was added to the list of changes that need to be made to the final document.

Tuesday PM

E. Progressively estimate fewer recruitment deviations (2007-11) at the end of the time series. Carry out retrospective analyses (2007-11) to ascertain if estimating fewer recruitment deviations improves the retrospective pattern. Determine the appropriate number of recruitment deviations to estimate using this analysis. Keep the number of recruitment deviations not estimated constant. ***Rationale***: There are few data near the end of the time series to inform estimation of annual recruitment. ***Response***: Changing the number of year classes forced to fall on the S/R curve near the end of the time series led to fairly large changes in 1+ biomass, especially near the end of the time series. The retrospective pattern seen in the base case generally persisted.

F. Check the estimate of biomass from the acoustic-trawl survey for summer 2008 and the CVs of these biomass estimates for all years. ***Rationale***: Values in Table 5 of the assessment document appear to differ from those shown in the acoustic-trawl survey presentation. ***Response***: The values were corrected. This change led to no difference in the estimates of 1+ biomass and the revised estimate of abundance became part of the base case for all subsequent runs.

G. Conduct a sensitivity run which replaces the CV for the spring 2008 acoustic-trawl survey with the average CV from the other acoustic-trawl surveys. ***Rationale***: The CV for the spring 2008 acoustic-trawl survey (9.2%) appears to be too small given the CVs for the other acoustic-trawl surveys and the sampling issues experienced during the 2008 survey. ***Response***: The CV was changed to the average value (CV=33%). This change led to no appreciable difference to the 1+ biomass.

H. Examine the effect on the biomass estimates from the aerial survey of using complete point sets observed from altitudes less than 4000 feet when fitting the density vs. school area relationship. ***Rationale***: A considerable amount of potentially useful data are currently not being used in biomass estimation because of the operating constraint that requires the 4000 foot altitude. ***Response***: The biomass estimate increased less than 10% and the CV decreased slightly. There was no appreciable change to the fitted curve to the density vs school size data.

I. Modify Table 7 (p.43) of the aerial survey report to include the sum of the biomass for each column, and do a paired t-test on the effect of different readers. ***Rationale***: The Panel wanted to get a better understanding of the possible effects from the two independent readers. ***Response***: While the paired t-test showed a difference at the α=0.05 level of significance, the biomass estimates from the two readers were quite similar. There appears to be no practical difference between the two readers.

J. Compute the autocorrelation function among positive transects from the 2011 aerial survey. ***Rationale***: Strong autocorrelation will violate the assumption of independence among transects on which method used to calculate the CV for the 2011 aerial survey is based. ***Response***: The correlation was 0.25 at lag 1; similar or smaller correlations were found for lags greater than 1. The transects appear to be sufficiently independent for application of the chosen method of variance estimation.

K. Compute the mean length of fish in each school from the point sets from the 2009, 2010 and 2011 aerial surveys, and plot by latitude. ***Rationale***: To examine whether the size data from the point sets are representative of the sardine population in the Pacific Northwest; in particular, to determine whether the shift (to the right) in length compositions over 2009-11 (Figure 11 of the aerial survey assessment report) are an artifact of the latitude at which the point sets were made. ***Response***: There are clearly year effects in mean length-at-age from the point sets, and some trend with latitude, but not enough to explain the misfitting of the length compositions in the assessment.

L. Plot catch weight vs. school area for the 2011 point sets and add a fitted line. ***Rationale***: This relationship may be an alternative to the density vs. school area relationship. ***Response***: The plot of catch weight vs. school area showed large variance and confirmed that density vs. school area is more likely to produce a useful predictive relationship.

M. Create a likelihood profile for q for the acoustic-trawl survey (q = 0.25 - 1.75). Tabulate the likelihood components for each discrete value of q used in the profile. ***Rationale***: To determine the key likelihood components over a range of biomass scalings. ***Response***: The total likelihood was flat across all values of acoustic-trawl q (less than 2 units difference over the entire range). The likelihood components for the indices of abundance and the age compositions favoured q at the high end of the range profiled (other than the PacNW age-at-length data), but the length compositions favored q at the low end of the range. However, the overall difference in likelihood units was small (~ 5 units) for all individual components over the full range of q ($0.25 \rightarrow 1.75$).

N. Conduct a run with initial F set to zero and continue to estimate the recruitment deviations starting in 1987. ***Rationale***: The initial F estimate in the base case model is not credible (F=4 yr^{-1}), and the estimated recruitment deviations are not significantly different from zero. Setting F=0 may result in better recruitment deviation estimates as a means of initializing the model, i.e. creating numbers-at-age at the start of 1993. ***Response***: This run led to a trend in 1+ biomass that was nearly identical to that for the base case, but overall 1+ biomass was approximately 50% greater than for the base case. The recruitment trend was also similar, but recruitment was ~30% larger than for the base case. Some of the later early deviations became significantly different from zero and R_0 increased approximately 35% compared to the base case. Early recruitment deviations were negative rather the zero as for the base case, indicating lower than average recruitment during late 1980s. The q estimates were more reasonable (all less than 1.0). The Panel and STAT agreed that this run (which also reflects the modifications from Requests B and F, above) was more plausible than the base case in the assessment document, and should serve as the base case for all subsequent runs.

O. Conduct a run with one vector of recruitment deviations, i.e. do not model early and main recruitment deviations separately. ***Rationale***: It was not clear to the Panel why the early and main recruitment deviations need to be modeled separately. ***Response***: This run was not carried out due to lack of time and the low priority given to it by the Panel.

P. Plot the sex ratio by length for each fishery. ***Rationale***: The model is not sex-specific. This plot will help to assess whether the data support a single-sex model. ***Response***: The sex ratios were plotted by length bin and region. The proportion of males decreases appreciably above the 21 cm size bin in all regions. It was also noted that the sex ratio data by weight from the DEPM surveys also showed that the percentage of females in the spawning population is consistently greater than 50%. Future modeling may wish to consider sex explicitly (see research recommendations, below).

Q. Do a profile over S/R variability (σ_R) using the base case in the assessment document. Show the 1+ biomass trend for each σ_R. ***Rationale***: σ_R from the base case (σ_R=0.622) may be smaller than is typical for a small pelagics. ***Response***: As σ_R increases from σ_R=0.622, the 2011 1+ biomass increases considerably through σ_R=1.0, but 1+ biomass decreases markedly when σ_R>1.

R. Do a sensitivity run dropping the TEP index. ***Rationale***: The DEPM time series is now much longer that when the TEP index was first introduced. It may not be necessary to continue to use the TEP index which ignores variation among years in biological parameters. ***Response***: Removing the TEP index had little effect on the time series of 1+ biomasses.

Based on the requests, above, the Panel and STAT considered the run from Request N to be the candidate base case subject to the additional requests, below.

Wednesday

S. Create a separate Canadian fishery with selectivity mirrored to the USA portion of the PacNW fishery. Present length and conditional age-at-length residuals by fishery. If possible, keep the annual effective sample sizes the same as in the base case model. ***Rationale***: While this change should not affect model fitting and results greatly, it will provide additional diagnostics for understanding the poor fits to the length compositions from the PacNW fishery and to assess whether it is justified to pool data for Oregon, Washington and Canada. ***Response***: The residual pattern for the Canadian fishery is quite different than that for the USA PacNW fishery (the former has many more positive residuals at the larger sizes). The next stock assessment should consider establishing a separate Canadian fishery.

T. Create a separate Mexican fishery with selectivity mirrored to the USA portion of the MexCal fishery. Present length and conditional age-at-length residuals by fishery. If possible, keep the annual effective sample sizes the same as in the base case model. ***Rationale***: While this change should not affect model fitting and results greatly, it will assist the Panel examine whether it is justified to pool data across Mexico and California. ***Response***: The residual pattern for the Mexican fishery is somewhat different than that for the USA portion of the MexCal fishery (the former has more positive residuals at the larger sizes, particularly during semester 2). The next stock assessment should consider re-establishing a separate Mexican fishery.

U. Drop the 2008-10 conditional age-at-length data for the PacNW fishery. ***Rationale***: The age readings from these years appear to be quite different from all other years. ***Response***: The trend in 1+ biomass is similar to the base case (run N), but the average biomass is much reduced - current 1+ biomass is ~20% less that for run N.

V. Reduce the multipliers for the effective sample sizes for the length composition data using the Francis vector (Appendix 2 of this report) and reduce the multipliers for the effective sample sizes for the conditional age-length data by 90%. ***Rationale***: Considerable among-length / -age correlation is evident in both the length composition and conditional age-at-length residuals, but the method used to infer effective sample sizes in SS3 assumes independence among residuals. Hence, the presence of strong correlation, combined with the method used in SS3 to compute downweighting factors, effectively over-weights the age and length data. ***Response***: The trend in 1+ biomass differed from that for the base case (run N) and all other runs examined to date. The average 1+ biomass was lower than for run N, but closer to that run than to the average biomass from run U. The fit to the indices were similar to those seen in all earlier runs.

W. Apply a model that fits predominately to age-based data. Use the age composition data rather than the combination of length and conditional age-at-length data, whenever available; do not use length data whenever acceptable age data are available; fix growth using the base case (run N) parameter estimates; continue using length-based selectivity for the fisheries (as in the base case); and use the effective sample sizes and lambda multipliers for the length data from the base case for the age data. ***Rationale***: The sardine assessment is unusual in that a large proportion of the sampled fish are aged. The additional information from length compositions may be marginal, and the model has difficulty fitting the length compositions. This should be considered an exploratory model, i.e. not one that is likely to be used as a base case for this year's assessment. ***Response***: Selectivity at length did not differ greatly from for the base case run (some selectivity curves were steeper at small sizes, but had similar points of inflection). The recruitment deviations for recent years differed markedly from those for run N (all were highly positive). Fits to indices of abundance were generally similar; as were fits to the age compositions. The trend in 1+ biomass differed from that for run N (two roughly equally high peaks) and the average 1+ biomass was slightly lower than for run N. The next stock assessment should consider an approach similar to the one explored here.

Thursday

X. Conduct six additional model runs based on the current base-case model (run N):

1. fix DEPM survey q=0.5 and retain length and conditional age-at-length composition weighting as in run N;
2. fix DEPM survey q=0.5 and weight the length and conditional age-at-length composition data as in run V;
3. fix aerial survey q=1 and retain length and conditional age-at-length composition weighting as in run N;
4. fix aerial survey q=1 and weight the length and conditional age-at-length composition data as in run V;
5. fix acoustic-trawl survey q=1 and retain length and conditional age-at-length composition weighting as in run N;
6. fix acoustic-trawl survey q=1 and weight the length and conditional age-at-length composition data as in run V.

Rationale: The results of these runs are needed to address two issues: (i) the scale of biomass in the assessment is not well determined; fixing q=1, one survey at a time, should better inform the scale issue; and (ii) the length and conditional age-at-length data appear to be over-weighted relative to the indices of abundance (see Request V, above), but the full impact of alternative weighting needs to be more fully examined. ***Response***: The estimate of 2011 1+ biomass (used in the PFMC control rule) was greater in run N than in any of runs X.1 through X.6. The trend in 1+ biomass was similar in runs X.1, X.3 and X.5 to that for run N, but those for runs X.2, X.4, X.6 (when the age and length data were further down-weighted relative to the indices) differed from that for run N. The fits to the indices of abundance were similar across all runs. Biomass scaling differed most from run N for runs X.1, X.2, and X.6. The realized S/R variability was noticeable smaller for run X.6 (σ_R=0.39). The estimated q's for the aerial and acoustic-trawl surveys were most plausible for runs X.3 through X.6 (i.e., except when the DEPM indices were assumed to be absolute).

Y. Use run X.5 (above) as the reference run (i.e. a candidate for a new base case) and conduct six additional runs:
    1. drop the conditional age-at-length data from the PacNW fishery for 2008-10 (analogous to run V);
    2. constrain only the last recruitment such that it falls on the S/R curve;
    3. constrain the last three recruitments such that they fall on the S/R curve;
    4. fix σ_R = 0.4;
    5. fix σ_R = 0.8; and
    6. fix σ_R = 1.0.

    Rationale: Run N has been the candidate base case, but it exhibited some instabilities – particularly in biomass scale (see Requests E, Q, and U, above). The q for the acoustic-trawl survey was fixed (q=1) in run X.5 in an effort to provide more stability. This set of runs was designed to examine the stability of run X.5 relative to the stability of run N. ***Response***: Run Y.1 showed the largest effect on biomass scaling (relative to run X.5), but the amount of change in biomass scaling was much less than was seen for the comparable sensitivity run based on run N (*cf.* Request U). The biomass scaling effect was not greatly different for Run Y.2 than that for the comparable runs based on the base case in the assessment document (*cf.* Request E). However, runs Y.5 and Y.6 did show improved stability in biomass scale relative to the comparable sensitivity runs based on run N (*cf.* Request Q). The biomass series for runs Y.3 and Y.4 differed from that for run X.5, but SS3 failed to converge for these runs so the Panel could not draw conclusions regarding stability.

Z. Consider run X.5 to be the new base case and make a final set of sensitivity runs:
    1. jitter to the 10% level; for each jitter, present total likelihood, q for all surveys, terminal year 1+ biomass and exploitation rate;
    2. create a likelihood profile on M [0.25-0.75yr^{-1}; step size 0.125yr^{-1}]; for each M, present total likelihood, q for all surveys, terminal year 1+ biomass and exploitation rate;

3. create a likelihood profile on the q for the acoustic-trawl survey [0.25-2.00; step size 0.25]; for each q, present total likelihood, q for all surveys, terminal year 1+ biomass and exploitation rate;
4. conduct a retrospective analysis over the last 5 years (2007-11); for each terminal year, present time-series of 1+ biomass and recruitment;
5. conduct a prospective analysis over the first 5 years (1993-97); for each initial year, present time series of 1+ biomass and recruitment.

Rationale: Additional runs are needed for the candidate base case (run X.5) to check for local minima; to identify the major axis of uncertainty and to quantify same; and to check for retrospective and prospective patterns. ***Response***:

1. **Run Z.1** (test for local minima). The full jitter was not completed, but will be included in the final assessment document. A few runs with R_0 changed converged to the same minimum as run X.5.
2. **Run Z.2** (*M* profile) showed that the total likelihood and the conditional age-at-length likelihood tend to strongly favor higher natural mortality rates than assumed in the base case; the length compositions favored a somewhat higher *M*. Increasing *M* reduces 2011 1+ biomass and increases the exploitation rate. The *M* profile is quite similar to the corresponding profile from the 2010 assessment.
3. **Run Z.3** (*q* profile) indicated that the length compositions do not inform the choice of acoustic-trawl *q*, but the conditional age-at-length data do have some influence. Overall, however, the likelihood surface is quite flat (even after fixing the acoustic-trawl *q*) – the profile showed a difference of only 2 units over the entire range of *q* (0.25 - 1.75). As expected, terminal year biomass and *F* were greatly affected by *q*.
4. **Run X.4** (retrospective analysis) showed an appreciable retrospective variability (up to 400,000 t changes among years in terminal biomass), but no systematic effect (i.e. the pattern is mixed - some high some low).
5. **Run X.5** (prospective analysis) showed modest changes in early year biomass estimates (and no systematic pattern), but virtually no change in 2011 biomass.

3) Technical Merits and/or Deficiencies of the Assessment

During its deliberations (see Section 2 of this report) the Panel identified a number of issues which should be explored for the assessment of Pacific sardine (see Section 6) including (a) further downweighting of the age and length data; (b) use of age-compositions rather than the combination of length-compositions and conditional age-at-length data, given within-year growth and among-region variation in growth; (c) additional fleets; and (d) inclusion of spatial- and sex-structure. Several analyses were conducted by the STAT to examine whether such changes warrant consideration in future. However, the STAT stated that major changes to the structure of the assessment should not be made without full and careful analyses of model structure and weights. The Panel agreed with the STAT that making these types of changes was not feasible in the time available and therefore focused on model configurations with two fleets and no spatial- or sex-structure. Some of these suggested changes may lead to more complicated models that cannot be supported by available, largely uninformative, data, and which may exhibit the types of undesirable behaviours seen in previous assessments. These changes should therefore only be implemented if there are clear benefits to the assessment and management of the stock.

Although trends in 1+ biomass do not change much given changes to the specifications to the assessment (although not necessarily to marked changes in data weighting), absolute biomass is poorly determined. The STAT and Panel therefore agreed that an appropriate way to increase stability in the assessment was to fix the *q* for one of the surveys. This is not an ideal approach, and the Panel recommends that the next full assessment include the development of informative priors for the *q* parameters for the DEPM, aerial and acoustic-trawl surveys. Development of informative priors is a non-trivial task and should involve people in addition to the STAT, in particular the surveys teams; therefore this task should start before the analytical work on the assessment itself, perhaps in the form of a workshop. The STAT and Panel agreed to impose the assumption q=1 for the acoustic-trawl survey because (a) there are more estimates of abundance for this series than for the aerial survey, (b) the acoustic-trawl survey is more synoptic than the aerial survey, (c) the estimates are generally more precise than those for the aerial survey, and (d) the assumption q=1 for the DEPM survey leads to unrealistic values of *q* for the aerial and acoustic-trawl surveys (>1.8). While the SSC recommended that strong evidence is needed to assume q=1 for any survey, the STAT and Panel agree that in this instance it is best available science to make this assumption. The use of q=1 for this assessment is, however, ***not*** an endorsement of this assumption for future assessments. Rather it is preference of the STAT and Panel to use informative *q* priors in future. However, this is not feasible at present.

The STAT and Panel strongly agreed that it would be better in principle to downweight the age and length data using an approach such as that of Appendix 2 of this report. However, runs with the downweighted data led to lower than expected values for the root mean square error of the recruitment deviations (0.391 for the acoustic-trawl q=1 run), and to a growth curve which did not match the size-at-age data well. Further work on models with downweighted age and length data should form part of the next full assessment, but there was insufficient time during the Panel to find a model configuration which downweighted the data and did not exhibit poor behaviour in other respects.

The final base model incorporates the following specifications:

- two seasons (Jul-Dec and Jan-Jun) (assessment years 1993 to 2011);
- sex is ignored;
- two fleets (MexCal, PacNW), with an annual selectivity pattern for the PacNW fleet, and seasonal selectivity patterns for the MexCal fleet;
- length-based, double-normal selectivity with time-blocking (1993-1998, 1999-2011) for the MexCal fleet; asymptotic length-selectivity for the PacNW fleet;
- Ricker stock-recruitment relationship with estimated “steepness”;
- M = 0.4 yr^{-1}; σ_R = 0.622 (tuned value);
- initial recruitment estimated; recruitment residuals estimated for 1987-2009;
- length-frequency and conditional age-at-length data for all fisheries;
- virgin (R_0) and initial recruitment offset (R_1) were estimated;
- initial *F*s set to 0 for all fleets;

- DEPM and TEP measures of spawning biomass; *q* estimated;
- aerial survey biomass, 2009-2011, *q* estimated, domed selectivity; and
- acoustic-trawl survey biomass, 2006-2011, *q*=1, asymptotic selectivity.

The Panel agrees that the final base model represents the best available science regarding the status of the northern subpopulation of Pacific sardine.

It is difficult to fully characterize uncertainty in the assessment. However, estimates of 1+ biomass from sensitivity analyses about run N, including runs with *q*=1 for each survey (Figure 1 of this report), are a crude depiction of the underlying uncertainties.

An important uncertainty not addressed elsewhere stems from the differences in biomass scale and trend indicated by the acoustic, DEPM and aerial surveys (see Figure 15 in the assessment report). In trying to fit all of the surveys, the final base case model estimates an average trend that does not match the trends in any of the individual surveys. In particular, the final model does not match or explain the relatively substantial and consistent decline in the acoustic-trawl survey during 2007-2011. In future assessments, it would be advisable to examine models that may better fit the trend in each of the individual surveys.

4) Areas of Disagreement

There were no major areas of disagreement between the STAT and Panel, nor among members of the Panel.

5) Unresolved Problems and Major Uncertainties

1. The ongoing uncertainties, in particular regarding absolute biomass, are likely to persist until the information content of the data increases substantially.
2. The Panel wishes to highlight that the level of variation in terminal biomass evident from the retrospective pattern (on the order of 100,000s of tons from one year to the next; Figure 2 of this report) is not unexpected, and changes in terminal 1+ biomass estimates of this extent may occur when the 2012 assessment update occur.
3. The indices of abundance do not exhibit consistent trends even after allowing for the differences in their respective selectivities, and remain in conflict even when the age and length data are greatly down-weighted.
4. The data set is able to estimate general trends in abundance fairly robustly, but the likelihood is flat over a wide range of current biomass levels, which means that relatively small changes to the data set or assumptions can lead to marked changes in current abundance. The current assessment has somewhat reduced the influence of this lack of information by fixing survey catchability. Ultimately, it is only through further data collection (or the development of informative priors for survey catchability) that these uncertainties may be overcome.
5. The STAT evaluated a large number of model configurations to identify a more stable model that fits the data better. However, the residual patterns for the composition data and indices remain unsatisfactory. Furthermore, attempts to split the data by fleet to reduce some of these patterns led to unrealistic results (e.g. Fs > $2yr^{-1}$ in recent years for the MexCal fishery). The Panel identified the need to consider models with sex-

and spatial-structure, but there was insufficient time to develop, test, and evaluate such models during the Panel meeting.

6. Further downweighting the age and length data is warranted given the analyses in Appendix 2 of this report. However, time is needed to find a model configuration that does not lead to undesirable diagnostics (such as a low value for the root mean square error for the recruitment deviations, or a poor fit to the size-at-age data, as found in initial models examined during the meeting).
7. The period covered by the current assessment starts in 1993 (rather than in 1981 as in past assessments). This change was necessary because of a variety of factors, including lack of precise abundance estimates for the years 1981-92, lack of age and length data for the Ensenada fishery (only three years of data), and the fact that the age and length data for southern California were collected from an incidental fishery for sardine for much of this period. In addition, the growth data for these years is inconsistent with the later growth data and was one reason for the previous assessment invoking the assumption of time-varying growth. While the Panel supports the change in start year, dropping the early data means that it is no longer possible to assess the state of the stock prior to 1993, which adds to uncertainty about the dynamics of this population and current biomass levels.
8. The scarcity of old and large sardines in the data relative to model estimates is a fundamental tension in the assessment that may be due to assumptions about, for example, growth, selectivity, natural mortality, and data weighting.

6) Issues raised by the CPSMT and CPSAS representatives during the meeting

a) CPSMT issues

The CPSMT representative commends the Panel and STAT for the significant amount of work accomplished prior to and during the meeting, and for a conducting a well-run review. The CPSMT representative notes that poor fitting of age data from fisheries in the Pacific Northwest by the model was identified as potentially an age reading issue and encourages efforts to evaluate whether or not this is the case, or if there is another reason. The upcoming ageing workshop in December 2011 offers an excellent opportunity to pursue future exchanges of otoliths for comparison among readers in the various laboratories. Previous recommendations have called for new indices to be incorporated into the sardine stock assessment. The CPSMT representative is encouraged to see the acoustic-trawl survey and aerial survey as recent additions, and notes that another survey (Canadian trawl survey) may be under consideration as well. The CPSMT representative suggests that in addition to considering new surveys in the next assessment, that a comparable effort to further refine and improve all data sources should be made to ensure these data are as informative as possible.

The Panel’s consensus is that the model is very sensitive to relatively minor changes in parameters and data, and thus the biomass estimate is subject to significant variations of several hundred thousand metric tons. Given this uncertainty inherit in the model, the CPSMT representative suggests careful consideration of this fact when establishing sardine harvest management measures.

b) CPSAS issues

The CPSAS representative commends the Panel and STAT for integrating a new acoustic-trawl survey into the SS3 model. Previous Panels, the CPS Advisory Bodies, and the SSC have remarked that additional work was needed in the areas of surveys to enrich the data sources that are use when fitting the model.

Industry wants to see a sustainable resource that is not in danger of being overfished. Overfishing makes a poor platform for economic investment. That said, the CPSAS representative does not believe there is any immediate danger that overfishing is taking place at present. Anecdotal reports from Ensenada to the Queen Charlottes suggest that the sardine biomass is larger at this point in the expansion cycle than at any time since the last expansion. Boats in Westport Washington and Monterey California were often able to do "daily doubles" when there was sufficient processing capacity during the brief fishing periods this summer. Canadian vessels now report a "solid wall" of fish in October the entire length of West Vancouver Island.

The CPSAS representative does not have concerns about the model work, but it is very complex. The model demands data to function rationally. Slight tweaks to data and assumptions can lead to huge swings in outputs, particularly for the original base model. The model cannot operate effectively without robust data. The acoustic-trawl survey is a welcome tool, but when strictly coupled with the habitat model, migration theory, and certain assumptions on vessel avoidance we believe that this survey capacity is not fully utilized. The 2011 Sardine Workshop recommended utilization of the acoustic-trawl survey with application of a powerful sonar during the height of the summer feeding season, when the sardines are in peak abundance simultaneously in the Northwest and Canada. These stocks should be surveyed in Canada to the northern end of their range.

It is now known that the Canadian swept-trawl survey CV reported previously was an over-estimate. A recommendation of the 2009 STAR Panel was to consider possible use of the Canadian data in the stock assessment. One reason for not doing so in the current assessment was the high CV. The CPSAS representative recommends that this important data source be utilized as soon as feasible, and believes that there well may be, an older, and as large a biomass in Canada at peak season as inhabits the Northwest at the same time. None of this information is presently available for the modeling platform. To advance use of the Canadian survey data will require a methodology review for the swept trawl survey. This should be undertaken in 2012.

The CPSAS representative would like to thank the STAT, the SWFSC, the survey teams, and the Panel, along with the public for their hard work, dedication, and time.

7) Research Recommendations (not in priority order)

A. Continue to explore possible additional fishery-independent data sources. As noted by previous Panels, there would be value in attempting to include the data from the mid-water trawl surveys off the west coast of Vancouver Island (see Appendix 3 of this report for an overview) in the assessment. However, inclusion of a substantial new data source would likely require review which would not be easily accomplished during a standard STAR Panel meeting so would likely need to be reviewed during a

Council-sponsored Methodology Panel. Similarly, the information provided on presence of sardine in the SWFSC juvenile rockfish survey should be explored further for possible inclusion in the future assessment.

B. The Panel continues to support expansion of coast-wide sampling of adult fish for use when estimating parameters in the DEPM method (and when computing biomass from the acoustic-trawl surveys). It also encourages sampling in Mexican and Canadian waters (aerial and acoustic-trawl surveys).
C. Temperature at catch could provide insight into stock structure and the appropriate catch stream to use for assessments, because the southern subpopulation is thought to prefer warmer water. Conduct sensitivity tests to alternative assumptions regarding the fraction of the MexCal catch that comes from the northern subpopulation
D. The assessment would benefit not only from data from Mexico and Canada, but also from joint assessment, which includes assessment team members from these countries.
E. Conduct additional studies on stock structure - otolith and microchemistry studies are useful tools for this purpose.
F. The relationship between environmental correlates and abundance should be examined. In particular, the relationship between environmental covariates and overall recruitment levels as well as recruitment deviations should be explored further.
G. Consider spatial models for Pacific sardine, which can be used to explore the implications of regional recruitment patterns and region-specific biological parameters. These models could be used to identify critical biological data gaps as well as better represent the latitudinal variation in size-at-age.
H. Explore models which consider a much longer time-period (e.g. 1931 onwards) to determine whether it is possible to model the entire period and determine whether this leads to a more informative assessment and to provide a broader context for evaluating changes in productivity.
I. Modify Stock Synthesis so that the standard errors of the logarithms of 1+ biomass can be reported. These biomasses are used when computing the Overfishing Level, the Acceptable Biological catch, and the Harvest Level, but the CV used when applying the ABC control rule is currently that associated with spawning biomass and not 1+ biomass.
J. In relation to the aerial survey: (a) provide the otoliths collected from the point sets to the SWFSC for possible ageing, (b) explore different functional forms for the mean relationship between school density and area (e.g. splines) as well as the variation about the mean curve (e.g. gamma), and (c) consider possible covariates (e.g. average fish size) in the relationship between catch weight and area.
K. Modify the r4ss package to include a plot of correlations among the residuals for the length and data data, as well as the fit of the model to the mean length or age in each composition (see Appendix 2 of this report).
L. Consider a model which explicitly models the sex-structure of the population and the catch.
M. Consider a model which has separate fleets for Mexico, California, Oregon-Washington and Canada.

N. Develop a relationship between egg production and age which accounts for the duration of spawning, batch fecundity, etc. by age.
O. Consider model configurations which use age-composition rather than length-composition and conditional age-at-length data given evidence for time- and spatially-varying growth.
P. Further explore methods to reduce between-reader ageing bias. In particular, consider comparisons among laboratories and assess whether the age-reading protocol can be improved to reduce among-ager variation.
Q. The reasons for the discrepancy between the observed and expected proportions of old animals in the length and age compositions should be explored further. Possible factors to consider in this investigation include ageing error / ageing bias and the way dome-shaped selectivity has been modeled.
R. Any future management strategy evaluation work to compare control rules should focus on alternatives which are as robust as possible to uncertainty regarding absolute abundance.
S. Profiles on key parameters should be included in future draft assessment to facilitate initial review.

Suggestions for modifications to the assessment report

A. Add a section on ‘data sources considered but not used.’
B. Add a description of the derivation of the acoustic-trawl estimates in an appendix to the assessment report.
C. Add text to the report to explain why selectivity blocking was changed. Discuss whether the resulting selectivity patterns are consistent with auxiliary information on the behaviour of sardine and the fishery.
D. Add an update to Table 5a from the previous aerial survey report to the current report, and add the intended and achieved distribution of point sets by weight.
E. Document how the reweighting of the model was done (including changes in effective Ns for the age and length data and extra CVs for the abundance indices)
F. Add the recommendations from the September 2010 SSC CPS Subcommittee review and the November 2010 SSC review to the recommendation list from the 2009 STAR Panel (see 2010 assessment document, p 135+).
G. Include profiles and prospective and retrospective analyses for the final base model and the full range of sensitivity tests, including those in which the age and length data are downweighted, and each survey is assumed to be an absolute index of abundance, in the final report.

Reference

McAllister, M.K., and Ianelli, J.N. 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. *Can. J. Fish. Aquat. Sci.* 54: 284–300.

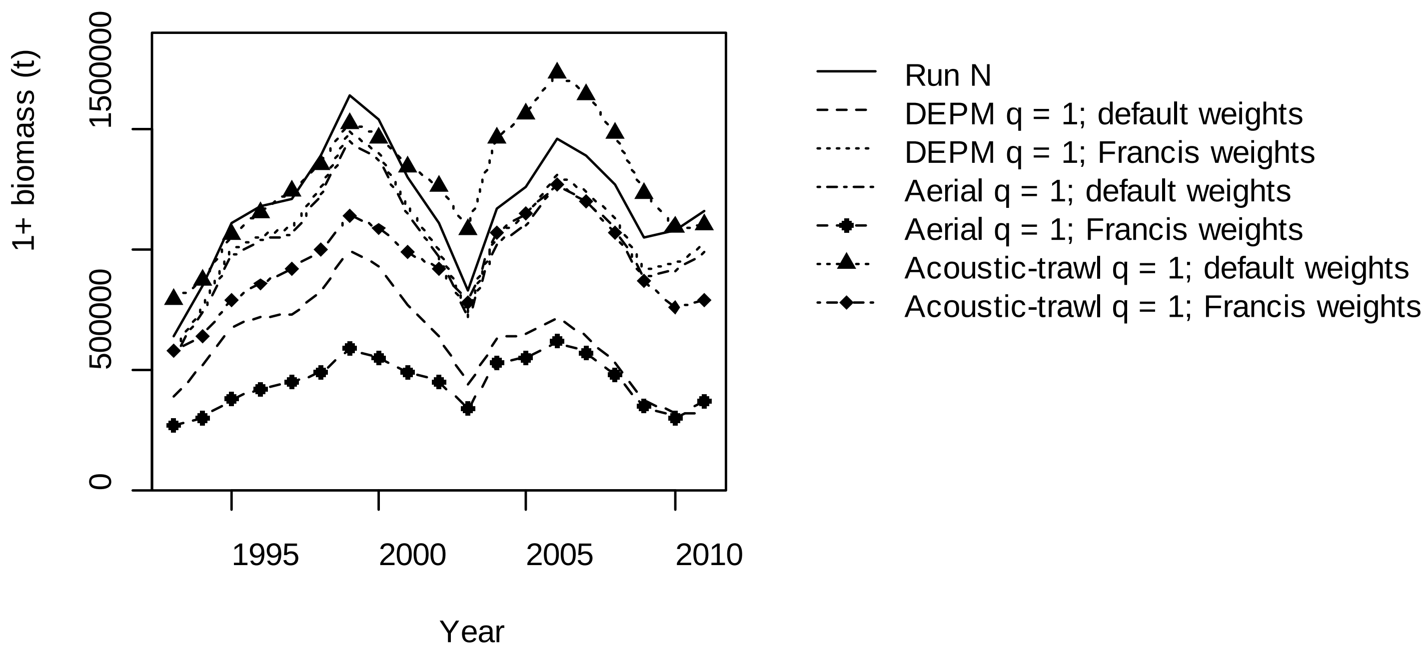

Figure 1. Time-trajectories of 1+ biomass from run N and six variants of this run in which each of three survey series are assumed to be absolute indices of abundance and the weights assigned to the age and length data are set to the default values and reduced as in run X.

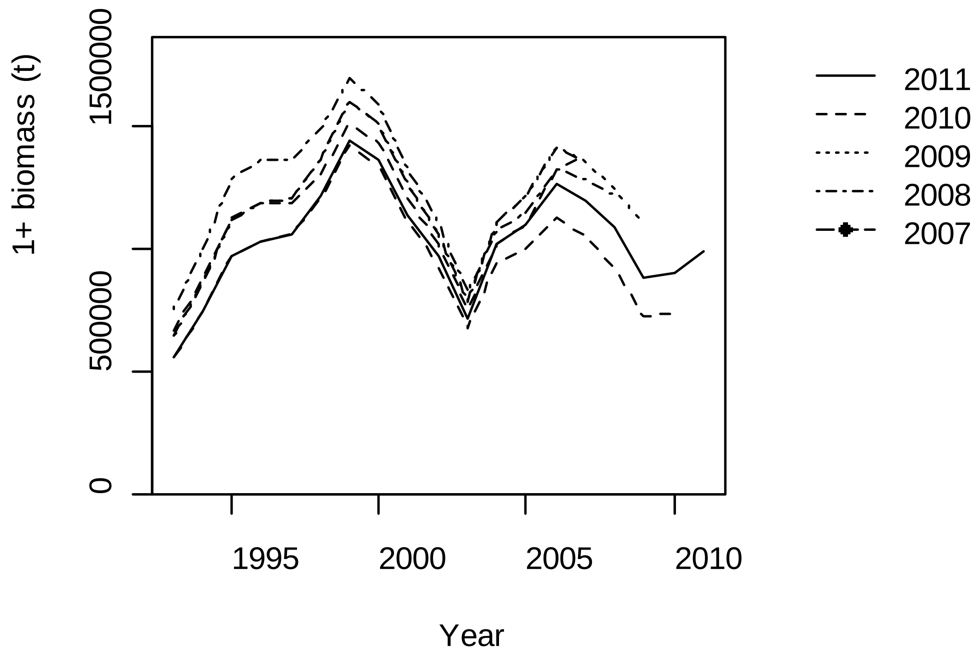

Figure 2. Results of the retrospective analysis based on the final base model.

Appendix 1
2011 Pacific Sardine STAR Panel Meeting Attendees

STAR Panel Members
André Punt (Chair), University of Washington
Ray Conser, NOAA Southwest Fisheries Science Center
Chris Francis, New Zealand National Institute of Water & Atmospheric Research
Larry Jacobson, NOAA Northeast Fisheries Science Center

Other Attendees
Mike Okoniewski, CPSAS Rep to STAR Panel
Lorna Wargo, CPSMT Rep to STAR Panel
Kevin Hill, NOAA Southwest Fisheries Science Center (SWFSC)
Kerry Griffin, Council Staff
Jenny McDaniel, SWFSC
Nancy Lo, SWFSC
Beverly Macewicz, SWFSC
Paul Crone, SWFSC
David Demer, SWFSC
Greg Krutzikowsky, ODFW
Steve Marx, Pew Charitable Trusts
Piera Carpi, UMass, Dartmouth
Sandy McFarlane, Canadian DFO & Canadian Pacific Sardine Association
Linnea Flostrand, Canadian DFO
Bob Seidel, Commercial fishing
Kirk Lynn, CDFG
Jerry Thon, Northwest Aerial Sardine Survey (NWSS)
Tom Jagielo, NWSS
Dale Sweetnam, SWFSC
Erin Reed, SWFSC
Sam Herrick, SWFSC
Diane Pleschner-Steele, CA Wetfish Producers Association
Ryan Howe, NWSS
Richard Carroll, Ocean Gold Seafood
Ed Weber, SWFSC
David Haworth, Commercial fishing
Fabio Campanella, SWFSC
Josh Lindsay, NMFS SWR
Christina Show, SWFSC
Russ Vetter, SWFSC
Emmanis Dorval, SWFSC
Kristen Koch, SWFSC
Briana Brady, CPSMT

Appendix 2
Comments on Weighting of Composition Data
Chris Francis

The composition data in many stock assessment models are given too much weight because most approaches to assigning weight to this type of data ignore the strong correlations in these data (and also in the associated residuals). A useful way to highlight this problem is to plot observed and expected mean lengths (or ages), as in done in Figure 1 for the base model length comps. The fact that the expected mean lengths in this plot are often outside the confidence intervals for the observations indicates that the data are over-weighted. Down-weighting these data (by decreasing the multinomial sample sizes) would increase the width of the plotted confidence intervals.

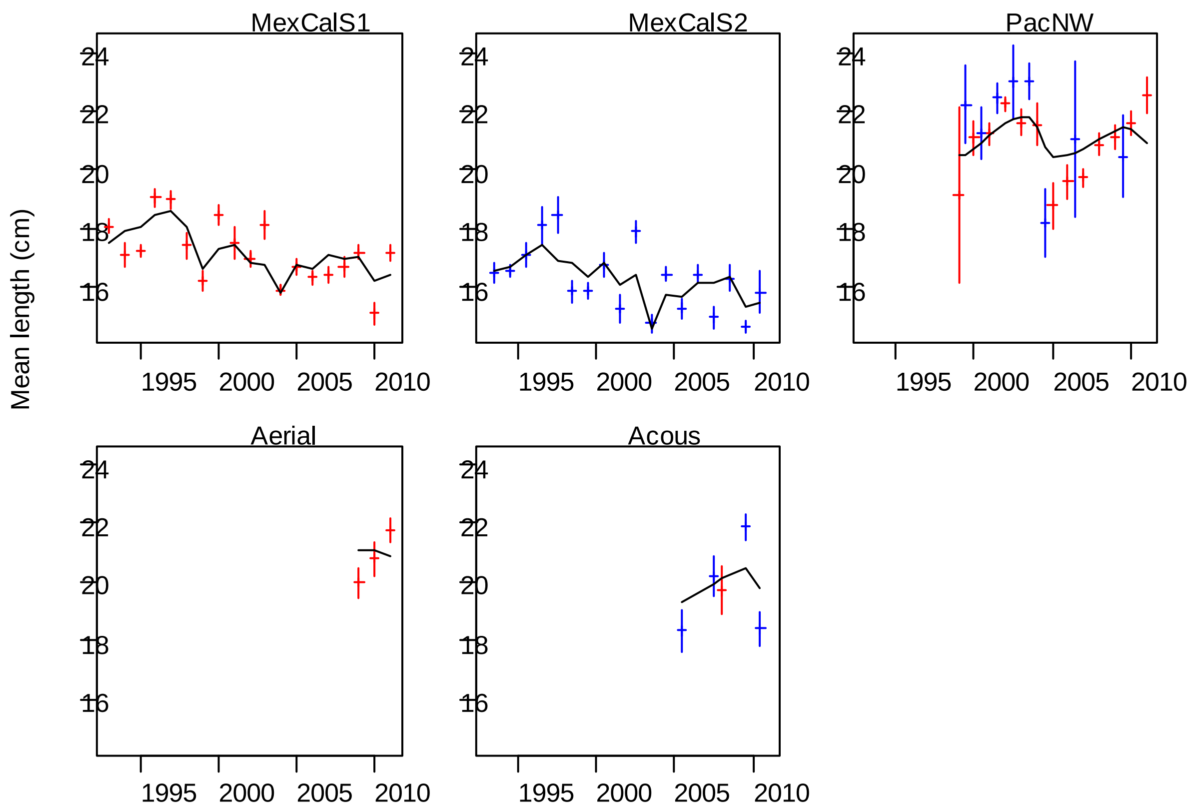

Figure 1: Observed ('+', with 95% confidence intervals shown as vertical lines) and expected (lines) mean lengths for all length composition data in the base model. The plotting colour of the observed values indicates the semester (red for semester 1, blue for semester 2). The confidence intervals were calculated using the multinomial sample sizes assumed for the base model (i.e., the products of the initial sample sizes and effN_mult_Lencomp values in Tables 4 and 9 of the assessment report).

The method of iteratively reweighting composition data in Stock Synthesis implicitly assumes that the residuals associated with one length (or age) bin are uncorrelated with those in another bin. In fact, correlations between composition residuals are often strong, and show a characteristic pattern like that in Figure 2.

One way of avoiding over-weighting composition data (by ignoring these correlations) is to base the re-weighting calculations on the residuals of mean length (or age), rather than on residuals of individual proportions. When this was done for the length composition data in the base model it suggested that the multinomial sample sizes for these data should be smaller by a factor of 0.06 – 0.1 (Table 1).

Full details about this method of re-weighting composition data are given in Francis (2011) [see method TA1.8 in Table A1; the w_j in that table is the same as the N_multipler in Table 1 below].

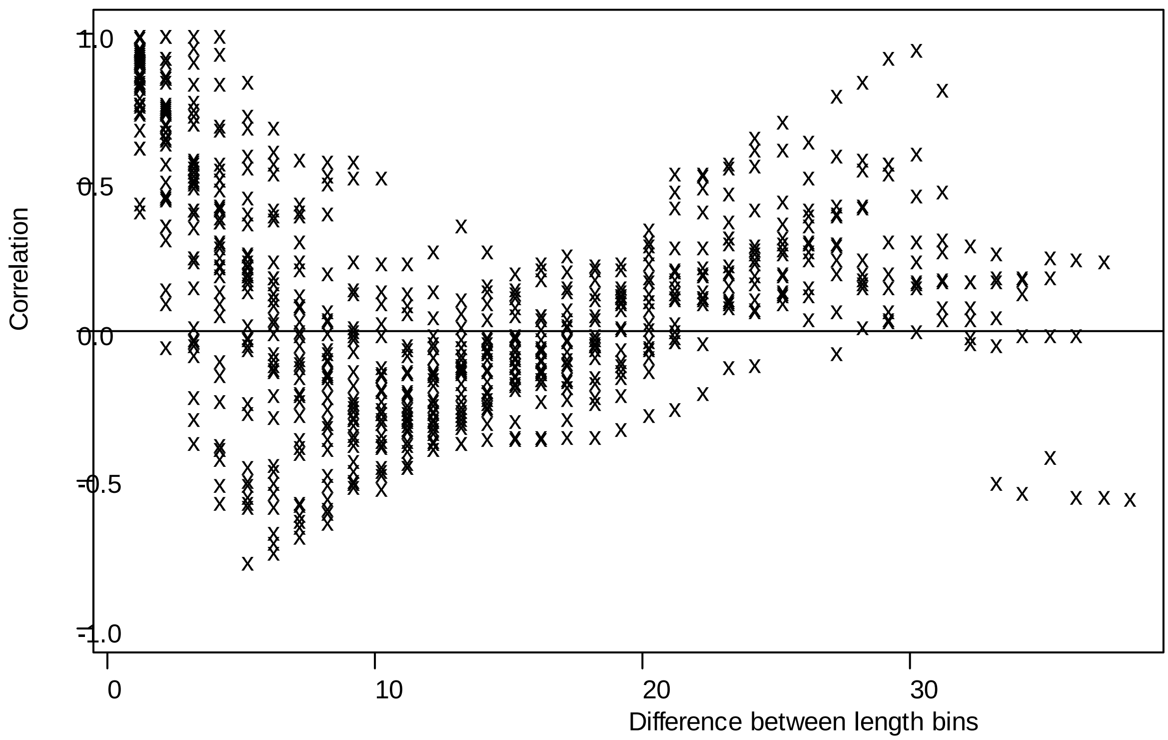

Figure 2: Correlations amongst the residuals from the MexCal_S1 length comps in the base model. Each plotted point represents a correlation between the vector of residuals for one length bin and that for a different length bin; the x-axis shows the difference (number of bins) between the two length bins.

Table 1: Suggested reweighting of the length composition data from the base model, showing the median sample sizes assumed for each data set in the base model (N_base), an N multiplier calculated from the mean length residuals, and the suggested median sample sizes (N_new), which are the product of N_base and the multiplier. Because of small sample sizes (i.e., few years of observations), the N_multiplier for the aerial and acoustic-trawl surveys was calculated by combing these two series.

Data set	Median N_base	N_multiplier	Median N_new
MexCalS1	135.9	0.058	7.9
MexCalS2	117.7	0.061	7.2
PacNW	40.9	0.104	4.3
Aerial	14.8	0.067	1.0
Acous	43.5	0.067	2.9

Reference

Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences* **68**: 1124–1138.

Appendix 3
West coast of Vancouver Island sardine trawl survey

Provided by L. Flostrand and J. Schweigert
Department of Fisheries & Oceans Canada
Pacific Biological Station, 3190 Hammond Bay Rd. Nanaimo, BC V9T 6N7

Summer surveys directed at collecting information on sardines off the West coast of Vancouver Island (WCVI) started in 1997. Fishing is conducted in surface waters ($\leq$ 30 m) using a mid water trawl towed at average speeds approximating 4-5 knots. Since 2006, sampling has been conducted at night. Biomass estimates are based on extrapolating the average sardine catch density (metric ton /km^3) by stratum over an estimate of the stratum's spatial size (km^3) and then summing across strata. The core area of the survey region is approximately 16,740 km^2 and catch densities are assumed to represent sardine distributions in the top 30m of the region, therefore the region's surface volume is estimated at ~ 502.2 km^3 (see Figure below). Recent regional estimates of sardine catch density and seasonal biomass in the WCVI core survey region from night sampling in 2006 and 2008 to 2010 (no survey was conducted in 2007) show a declining trend, whereas the 2011 estimates are approximately double the 2010 estimates (see Table below).

The current Canadian harvest control rule is based on the U.S. assessment of coastwide adult biomass and the migration rate of sardines into Canadian waters (Ware 1999, Schweigert et al 2009, DFO 2009), upon which a harvest rate equivalent to the U.S. rate is established (a 15% harvest rate has been in place since 2002; DFO 2010). More information on the provision of science advice and the harvest control rule is reported in the 2011 Science Advisory Report on the *Evaluation of Pacific sardine stock assessment and harvest guidelines in British Columbia* (http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2011/2011_016-eng.pdf, DFO 2011)

Table. Summary information and statistics associated with West Coast Vancouver Island (WCVI) trawl survey sardine catch densities and biomass estimates. For 95% confidence interval, LL= lower limit and UL= upper limit.

YEAR	2006	2008	2009	2010	2011 *
WCVI SAMPLING					
Tows with sardines / total number of tows	42/45	44/71	53/109	40/72	41/68
Core survey region					
Tows with sardines/ total number of tows	41/44	40/60	47/95	37/57	41/68
SARDINE DENSITY (mt/km^3)					
Mean	759.9	420	378.3	163.2	~300.0
95% LL	461.6	196.5	220.2	57.6	Not available
95% UL	1,105.60	736.4	557.8	309.7	Not available
CV **	0.23	0.33	0.23	0.39	~0.28
BIOMASS (mt)					
Mean	381,617	210,924	189,977	81,964	~150,000
95% LL	231,816	98,682	110,589	28,927	Not available
95% UL	555,232	369,820	280,127	155,541	Not available

* 2011 estimates are preliminary and have not been reviewed

** CVs presented above have been corrected from previously reported estimates (reported to have ranged from ~ 1-3).

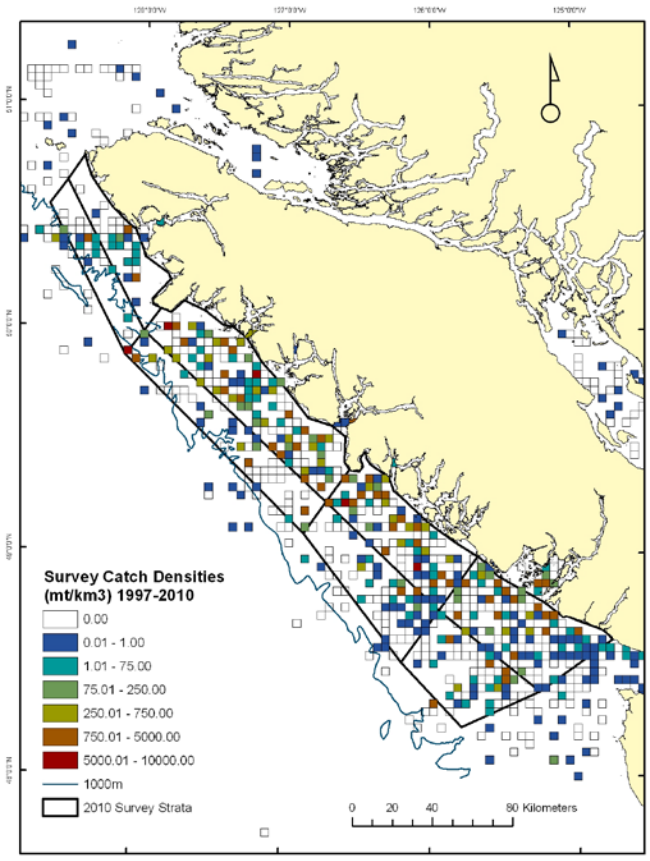

Figure. Mean sardine densities for all 1997-2010 sardine survey trawl tows based on 4x4 km sized grid cells. Outer boundaries define the core WCVI survey region. Also shown are sub-regional boundaries as they pertain to future work interests for stratification schemes.

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DFO. 2009. Proceedings of the Pacific Scientific Advice Review Committee (PSARC) meeting for the assessment of scientific information to estimate Pacific sardine seasonal migration into Canadian waters. DFO Can.Sci. Advis.Sec. Proceed. Ser. 2009/034.

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Schweigert, J., McFarlane, G.A., and Hodes, V. 2009. Pacific sardine (*Sardinops sagax*) biomass and migration rates in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/088. 14p.

Ware, D.M. 1999. Life history of Pacific sardine and a suggested framework for determining a B.C. catch quota. DFO Can. Sci. Advis. Sec. Res. Doc. 1999/204.

Proposal for Methodology Review of the Canadian Swept-Area Trawl Survey conducted along the West Coast of Vancouver Island for Inclusion into the Pacific Sardine Stock Assessment

1. Title: Canadian West Coast Vancouver Island Trawl Survey (WCVI).
2. Name of proposers:
   a. Fisheries and Oceans Canada (DFO Canada): Jake Schweigert, Linnea Flostrand, DFO
   b. NOAA Fisheries/Southwest Fisheries Science Center will act as sponsor.
3. How the proposed methodology will improve assessment and management for CPS species: Both the 2009 and 2011 Pacific Sardine Stock Assessment Review Panels recommended the addition of the WCVI survey as an additional fishery-independent data set, stating that the data set is potentially valuable since it provides abundance information for a large area within Canadian waters. Inclusion of the Canadian survey would also provide valuable insights into the northern most extension of the population, the largest size classes, and the timing and extent of migration during different years. There is also interest in expanding scientific data exchange and cooperation.
4. Outline of methods (field and analytical): The time series for the summer WCVI surface trawl survey has a combination of sample designs (see attached summary). From 1997-2004, fishing was conducted during day time periods along transects and at ad hoc sites between transects lines, where transect locations often varied between years. In 2005, some daytime and night time comparisons were made and sampling coverage was relatively limited. From 2006 to 2011, all fishing was conducted between dusk and dawn periods and line transects in combination with random spot sites were applied in 2006-2009, whereas in 2010 and 2011 the use of line transects was abandoned and fishing was planned at randomly selected sites of a ~ 10x10km grid plan, at approximately equal sampling intensity throughout the survey region. The surface trawls generally fished at depths $\leq$ 25 m.

PACIFIC SARDINE WEST COAST OF VANCOUVER ISLAND TRAWL SURVEYS – CANADA

I. Introduction and Background of Survey Method

Surveys of marine fish populations are generally undertaken to obtain estimates of absolute or relative abundance of the species of interest as well as obtaining data on their distribution and biological attributes (length, weight, sex, age, maturity, etc.). The general theory behind trawl survey sampling methods is that if one assumes that the population is randomly distributed within the area of the survey then it is reasonable to expect that conducting a number of trawl sets in the area will provide an unbiased estimate of the average density of the species in the area of interest and then the mean density can be expanded to the entire distribution of the species to estimate the total population size. However, there are a number of considerations that will impact the ability to conduct this survey in a manner that will provide an accurate (unbiased) estimate of population size.

Possibly the most difficult variable to assess is the total area of the population distribution. The ocean is pretty big and so it is not a simple task to cover the area of possible distribution and confirm that there are no additional schools outside the survey area. Missing schools will impact the estimate of total population abundance and result in an inaccurate estimate (biased low).

Another factor that affects the accuracy of trawl surveys is vessel and gear avoidance. In particular, sardine are surface oriented so that they will be easily disturbed by an approaching noisy vessel and move away from the trawl path, similarly larger fish may have a higher ability to avoid approaching nets. Again the result would be to underestimate sardine density (biased low).

Perhaps the most critical assumption in a trawl survey program is that the population is randomly distributed while we know that fish are generally in schools and that the schools are distributed in patches. As a result attempts to make ‘random’ sets within a survey area will provide a biased estimate of fish density. A huge statistical literature exists on determining the correct distribution of the population from trawl surveys and how to either transform the data prior to analysis or assume a different sampling distribution for the data than the usual normal distribution. The effect of this assumption is really to alter the estimate of variability around the abundance estimate depending on sampling distribution that one assumes. It generally does not impact the estimate of average population density and total abundance.

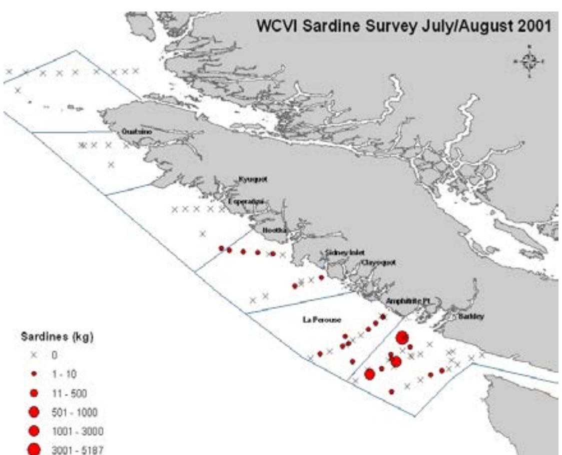
The output of the trawl survey can be an estimate of the total population if there is good evidence that the entire distribution of the species of interest has been sampled or it can provide an index of population abundance that can be used to monitor trends in abundance and as such could feed directly into a stock assessment model such as a catch-age analysis.

The major advantage of the trawl survey is that it is empirical so that if one conducts enough trawl sets it is possible to determine whether the population is increasing, decreasing, or stable. The biggest disadvantage is that it is expensive and difficult to cover the entire distribution of sardine in a reasonable time frame. It also requires a lot staff to support the survey and analyse the data.

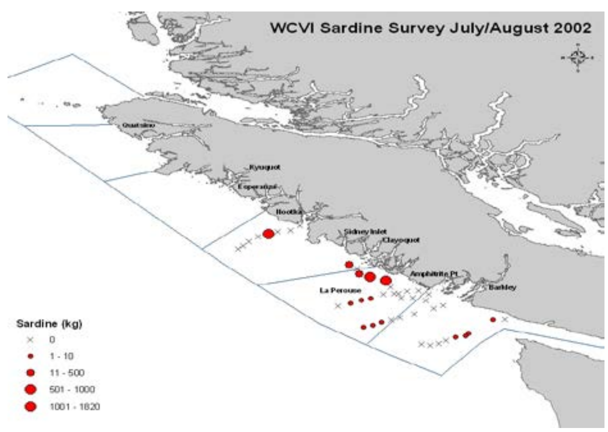
Methods and Results

Summer surveys employing mid-water trawls near the surface have been conducted on the west coast of Vancouver Island from the mid-1990s to present to examine the distribution and relative abundance of sardines (McFarlane et al 2005; Schweigert et al 2009). The surveys were generally conducted during the last week of July or first week of August assuming that the northerly migration of fish into Canadian waters had peaked. Prior to 2006, sampling occurred during the day, subsequently all surveys are conducted from dawn to dusk. Prior to 2010, sampling applied a combination of transect lines and spot sampling configured to represent up to 6 strata, each varying in part by latitude and orientation to shore. For 2010 and 2011, random sampling was conducted at night but based on random selection of sites within a 10x 10km grid, rather than applying transect lines. Examples of survey coverage and catch densities are depicted in the figures below.

Abundance estimates for the region or by sub-region (stratum) have been calculated using sardine catch densities (weight/volume) from surface trawls representing the surface to 30 m depth and sardine densities have been extrapolated across the represented area's size and surface volume. Surveys have generally been conducted over 5-16 day (or night) periods and the number of fishing tows generally range from 40-109. There was a survey in 1997 but no surveys occurred in 1998 and 2007 and some of the earlier years had limited sampling coverage. Regional estimates of abundance from surveys conducted during 1997- 2005 range from ~ 25,000 to 125,000 metric tons and regional estimates of abundance from surveys conducted during 2006-2011 range from ~380,000 to ~150,000 metric tons (Schweigert et al 2009; DFO 2011).



2001



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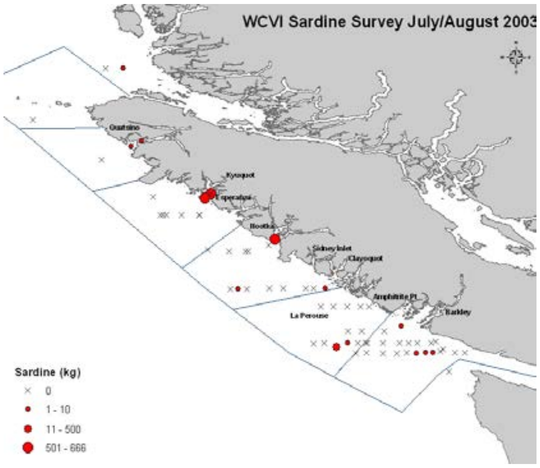
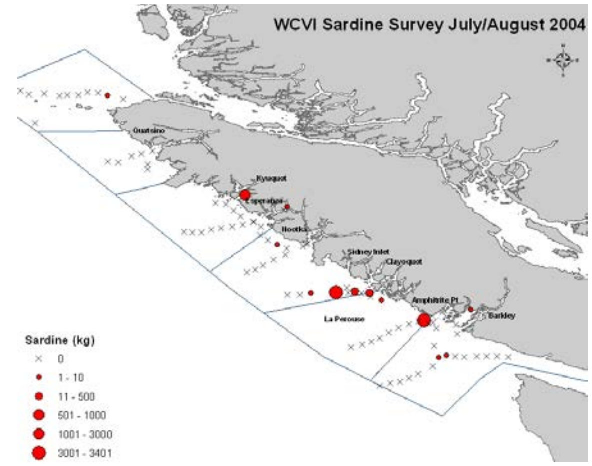
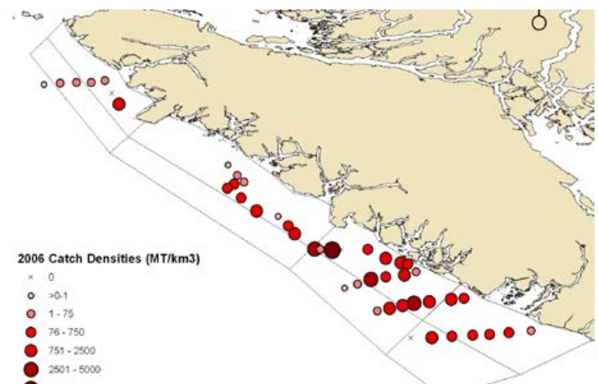




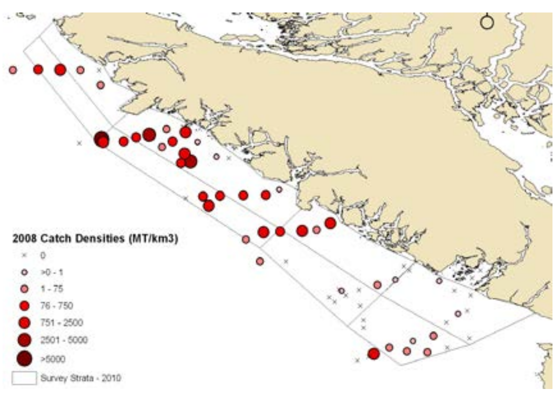
2003 2004

Above figures represent day surveys (2001-2004) with transects and spot sampling. Note units are kg, not standardized by catch density.

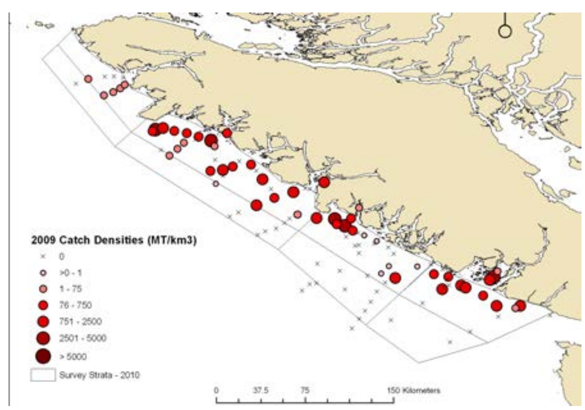


2006

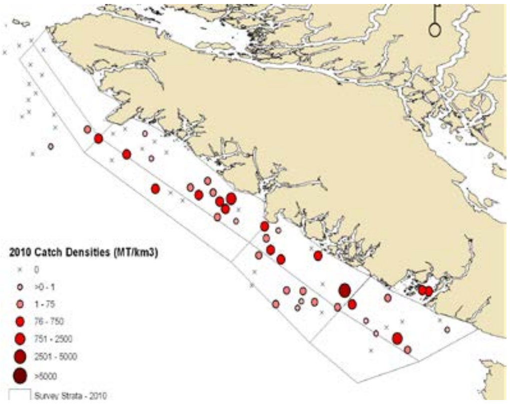
No survey in 2007

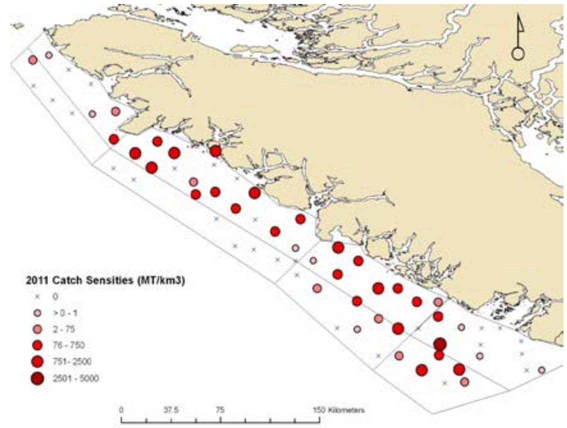


2008



2009





2010 2011

Above figures represent night surveys (2006-2011) with transects and spot sampling (2006, 2008, 2009) and random grid sampling (2010, 2011). Note units are standardized by catch density (metric ton/ km^3).

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McFarlane, G.A., Schweigert, J., MacDougall, L., and Hrabok, C. 2005. Distribution and biology of Pacific sardines (*Sardinops sagax*) off British Columbia, Canada. CalCOFI Sci. Rep. 46: 144-160.

Schweigert, J., McFarlane, G.A., and Hodes, V. 2009. Pacific sardine (*Sardinops sagax*) biomass and migration rates in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/088. 14p.

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NIWA
Taihoro Nukurangi

Report on the 2011 assessment of Pacific sardine

Prepared for The Center for Independent Experts
Northern Taiga Ventures, Inc.

October 2011

Authors/Contributors:
R.I.C.C. Francis

For any information regarding this report please contact:

R.I.C.C. Francis
Principal Scientist

+64-4-386 0525
c.francis@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
301 Evans Bay Parade, Greta Point
Wellington 6021
Private Bag 14901, Kilbirnie
Wellington 6241
New Zealand

Phone +64-4-386 0300
Fax +64-4-386 0574

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Report date:	October 2011
NIWA Project:	NTV120301

Contents

Reviewed by

Andy McKenzie

Andrew McKenzie

Approved for release by

Julie Hall

Dr Julie Hall

Executive summary

A STAR Panel met 4-7 October 2011 at the Southwest Fisheries Science Center in La Jolla, California to review the 2011 draft assessment of Pacific sardine. The assessment, and some additional analyses, were presented and discussed. Some modifications to the assessment were agreed to, and the Panel wrote its report.

I conclude that the modified assessment, though characterised by a high degree of uncertainty, constitutes the best available science. The analytic methodology used was generally sound but methods of data weighting could be improved. The review process was excellently run.

With regard to data weighting I recommend consideration be given to

- adopting the approach proposed by Francis (2011) in future assessments, and
- improving the Stock Synthesis documentation related to this topic.

To reduce uncertainty in future assessments I recommend particular attention be paid to

- reducing relative bias in age estimates,
- producing priors on survey catchabilities, and
- resolving uncertainty about survey selectivities.

For future assessments I also recommend that

- age compositions be used, rather than the combination of length compositions and conditional age-at-length data,
- the methodology of the Canadian trawl survey be reviewed so that these data might be used if found suitable,
- an attempt be made to reduce the lack of model fit for older fish, and
- in considering whether to change model structural assumptions concerning sex and the number of fisheries, the STAT be cautious about unnecessarily complicating the model structure.

For future CIE reviews I recommend that attention be given to the way that Statements of Work specify the structure of the reviewer's report.

1 Background

This report reviews, at the request of the Center for Independent Experts (see Appendix 2), the 2011 assessment of the stock of Pacific sardine (*Sardinops sagax*) which is fished off the west coast of North America, from northern Mexico to Canada. The author was provided with various documents (Appendix 1), and participated both in the meeting which considered the assessment, and in the writing of the Panel Report from that meeting.

2 Review activities

The stock assessment review (STAR) Panel met 4-7 October 2011 at the Southwest Fisheries Science Center of NOAA/NMFS in La Jolla, California. Those attending the meeting included four Panel members, three representatives of the Pacific Fishery Management Council (PFMC), the teams responsible for the stock assessment and associated surveys, and other interested parties from both the fishing industry and the research community (Appendix 3). The assessment and related material were presented to the Panel, and numerous additional analyses requested by the Panel were carried out and discussed. The Panel, in consultation with the STAT (the stock assessment team), agreed on some modifications to the assessment, and further analyses were carried out to evaluate the modified assessment. The Panel drafted their report.

3 Summary of findings

For reasons given below (in Section 3.6), neither this section nor the next is structured according to the Terms of Reference for the review, as was required by my Statement of Work (Appendix 1). Instead, I have grouped my findings in a way that seemed natural.

3.1 Best available science

I believe that the Pacific sardine assessment, as produced by the STAT, with some modifications developed during the STAR Panel meeting, constitutes the best available science, and does a reasonable job of estimating the status of the stock and quantifying the considerable uncertainty about that status. The assessment used state of the art software (Stock Synthesis), which was applied professionally and diligently by the STAT.

Much of the uncertainty in this assessment stems from the fact that, although it is relatively data-rich, it is still information-poor. In particular, although four separate time series of abundance were available (Total Egg Production [TEP], Daily Egg Production Method [DEPM], trawl-acoustic, and aerial) these were not in agreement about biomass trends.

One consequence of this uncertainty was that the assessment model was quite unstable. That is, small changes in the data or model assumptions sometimes produced large changes in estimated stock status. This instability imposed a considerable constraint on both the STAT and the STAR Panel by making the process of evaluating alternative model assumptions very time-consuming. Thus some possible model improvements could not be evaluated in the time available. In particular it was not possible to seek model configurations that better fitted the abundance time series.

3.2 Analytic methodology

The analytic methodology used in this assessment – implemented in Stock Synthesis (Methot 2005, 2011) – followed standards that have been established in other assessments within the PFMC jurisdiction. I believe Stock Synthesis to be excellent software, which has been thoroughly tested and is widely used – both within and outside the PFMC jurisdiction.

In general I approve of the standard methodology, but I think there is one aspect that could be improved in the next assessment: data weighting.

3.2.1 Data weighting

Stock assessment results are often sensitive to the weight (or emphasis) given to different data sets. A data set can be given more weight by decreasing coefficients of variation (c.v.s) (in the case of abundance data) or increasing effective sample sizes (in the case of age or length composition data). The approach I suggest considering for the next assessment is that proposed by Francis (2011). I will not repeat the arguments advanced in that paper, but will discuss two components of the proposed approach in the context of the sardine assessment, and then make some comments about data weighting in Stock Synthesis.

The first component is the need to down-weight length and/or age composition data to account for correlations. A useful way to illustrate this need is to plot observed and expected mean lengths (or ages), as is done in Figure 1 for the length composition data in the draft base model. The fact that the expected mean lengths in this plot are often outside the confidence intervals for the observations indicates that the length composition data were over-weighted. Down-weighting these data (by decreasing the multinomial sample sizes) would increase the width of the plotted confidence intervals.

Most methods of iteratively reweighting composition data (including that used in Stock Synthesis) implicitly assume that the residuals associated with one length (or age) bin are uncorrelated with those from another bin. In fact, correlations between composition residuals are often strong, and show a characteristic pattern like that in Figure 2.

Francis (2011) suggested that one way to avoid over-weighting composition data is to base the re-weighting calculation on the residuals of mean length (or age), rather than on residuals of individual proportions. Application of this approach to the length composition data in the base model suggested that the multinomial sample sizes for these data should be smaller by a factor of 0.06 – 0.1 (Table 1).

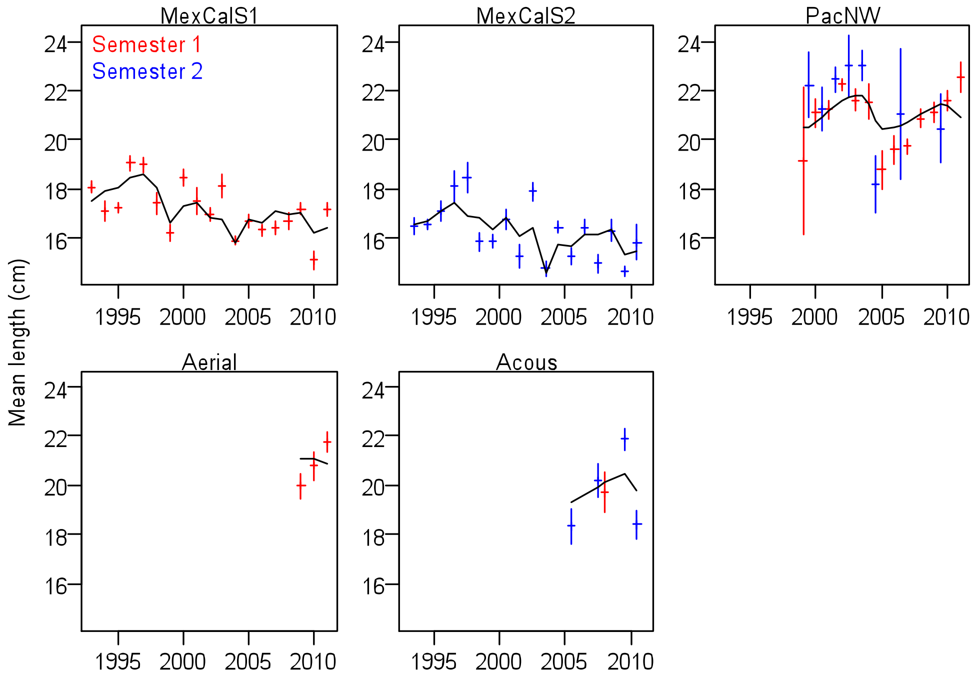

Figure 1: Observed ('+') and expected (lines) mean lengths for all length composition data in the base model. Confidence intervals (shown as vertical lines) were calculated using the multinomial sample sizes assumed for the base model (i.e., the products of the initial sample sizes and effN_mult_Lencomp values in tables 4 and 9 of Hill et al. 2011).

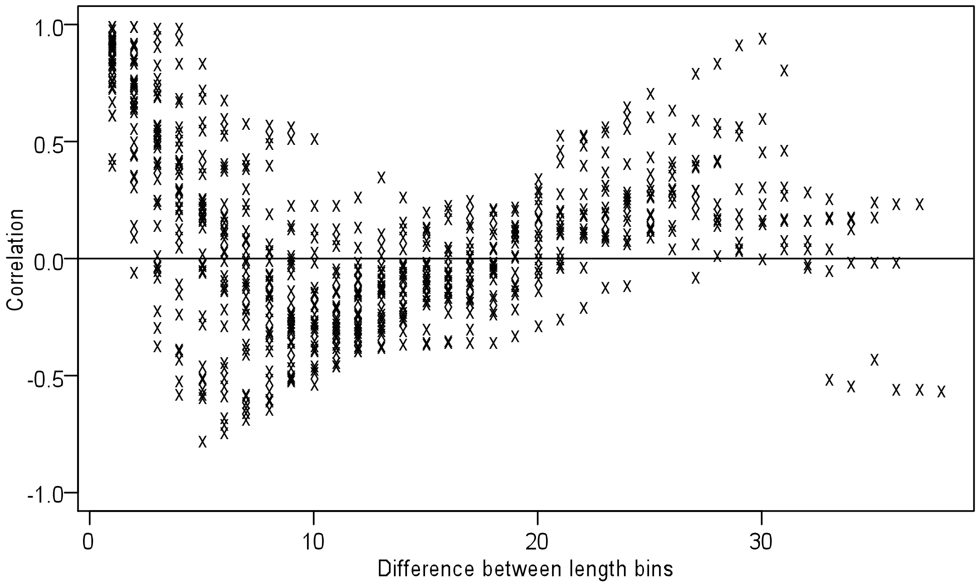

Figure 2: Correlations amongst residuals from the MexCal_S1 length composition data in the base model. Each plotted point represents a correlation between the vectors of residuals for two length bins; the x-axis shows the distance (number of bins) between the two length bins.

Table 1: Suggested reweighting of the length composition data from the base model in the draft assessment report (Hill et al. 2011). The suggested sample sizes, N_new, are the product of the sample sizes assumed in the base model, N_base, and a multiplier, N multiplier.

Data set	Median N_base	N_multiplier[1]	Median N_new
MexCalS1	135.9	0.058	7.9
MexCalS2	117.7	0.061	7.2
PacNW	40.9	0.104	4.3
Aerial	14.8	0.067[2]	1.0
Acous	43.5	0.067[2]	2.9

[1]Calculated using method TA1.8 of Francis (2011, Appendix A, in which N_multiplier is denoted w_j)
[2] Because of small sample sizes (i.e., few years of observations), the N_multiplier for the aerial and acoustic-trawl surveys was calculated by combing these two series

Another component of the data weighting approach proposed by Francis (2011) is the importance of fitting abundance indices well. A striking feature of both the draft and final assessments was that none of the four abundance indices was well fitted. One possible reason for this is that the three indices that overlap (DEPM, trawl-acoustic, and aerial) show quite different trends. All indicate that the biomass dropped substantially, but they disagree about the years over which this occurred (2004-2007 for DEPM; 2005-2009 for trawl-acoustic; and 2009-2010 for aerial). Schnute & Hilborn (1993) pointed out that when two data sets are contradictory it is a mistake to include both in an assessment model. It is better to consider two alternative assessments: one without the first data set, and one without the second. If there are no grounds for preferring one data set over the other then the difference between the two alternative assessments serves as a measure of the uncertainty about stock status. In jurisdictions in which a STAT is required to provide only one assessment they will be forced to choose which of two contradictory data sets is more plausible. One fact in support of choosing the trawl-acoustic survey is its similarity in trend to the Canadian trawl survey (see Section 3.4.2 below).

Sometimes the year-to-year changes in an abundance index are so large that the index cannot be well fitted by any plausible model. In this case, the appropriate response is to discard the index, on the grounds that it cannot be representative of the population. This might be the case with the TEP index, which jumped up by a factor of almost 4 in 1999, and then dropped by a factor of more than 5 over the next 2 years. I wonder if the spawning biomass of sardines can change so rapidly.

Finally, I offer some comments on the iterative reweighting of abundance indices as is commonly done (including in this assessment) with Stock Synthesis. This involves adding to the initial survey standard errors (labelled 'S.E. ln(index)' in table 5 of Hill et al. 2011), variance adjustment terms (labelled 'index_extra_cv' in table 9 of Hill et al. 2011) which have been calculated from an earlier model run without any variance adjustment. This approach has the apparent merit of being objective, but Francis (2011) argued that full objectivity is not possible in data weighting. A perverse consequence of this approach in the sardine assessment was that it assigned slightly more weight to TEP than to DEPM (the median final standard errors for the two series were 0.62 and 0.66, respectively), even though the consensus of attendees at the STAR Panel seemed to be that DEPM was likely to be superior to TEP as an index of spawning biomass (that consensus opinion – partly subjective – was not used in the stock assessment). I note also that I could not find in the Stock

Synthesis documentation provided (Methot 2005,2011) either a description of how these variance adjustments were calculated, or a justification for simply adding them to the initial standard errors (the conventional approach is to sum standard errors as squares: s.e.[final]^2 = s.e.[initial]^2 + s.e.[extra]^2). My attempts to replicate the calculation of the variance adjustments, using what seemed to me to be the appropriate approach, were not successful. Whatever the method of calculation, it cannot be considered very reliable because it is analogous to estimating a variance from a very small sample (sample sizes [i.e., numbers of years] were 8, 9, 3, and 5 for the DEPM, TEP, aerial, and trawl-acoustic surveys, respectively).

3.3 Sources of uncertainty

Two types of factor contributed to the uncertainty in this assessment: those that were largely unavoidable; and those that are potentially reducible.

Some important unavoidable factors are the wide area traversed by this stock (from northern Mexico to Canada); the substantial movements (both ontogenetic and annual) that it undertakes; and the fact that the nature and extent of these movements (primarily north-south, but also inshore-offshore) will vary from year to year in a way that is inherently difficult to measure. A consequence of these factors is that there may be substantial variation in the portion of the stock that is vulnerable to capture or sampling (either by the fishery or by surveys) at a given place and time. This variation is likely to be responsible for much of the year-to-year changes in mean lengths (and ages) in the fishery catches, and possibly also in the survey samples (see Figure 1). It also leads to uncertainty about the extent to which we can be sure that each survey is indexing the same portion of the population in each year.

Potentially reducible sources of uncertainty include sampling error (e.g., survey c.v.s), stock structure, ageing error, and survey catchabilities (*q*s) and selectivities. It is obviously sensible to try to reduce uncertainty from all these sources, but I think special emphasis should be given to the last three, which I now discuss in turn.

3.3.1 Ageing error

In my view ageing error could well be a serious problem for this assessment, and my concern is more with (relative) bias, than with precision. Between-reader bias was sometimes very substantial (see plots labelled ‘Age bias plot’ in Dorval et al. 2011), to the point that I wondered how bad such bias would need to be before the age estimates were deemed unusable in the stock assessment. I don’t mean to imply incompetence on the part of age readers. Some species’ otoliths are inherently very difficult to read, and Pacific sardine appears to be one such species. However, I am aware that the consistency of ageing has been significantly improved for *some* species by the development of strict ageing protocols and regular inter-agency comparisons. This is not a simple task, and it will not be achieved quickly.

3.3.2 Survey catchabilities

There are three approaches to dealing with survey catchabilities (commonly referred to as *q*s) in stock assessment models. First, we can tell the model we know nothing about the catchabilities, as was done for all surveys in the draft assessment. Because the survey biomass indices showed no consistent trends, this approach made the model unstable in terms of absolute biomass. That is, slightly different model configurations sometimes estimated biomass trajectories that were similar in trend, but greatly different in level. In order to reduce this type of instability the STAR Panel meeting decided to adopt a second approach – for the trawl-acoustic survey alone – which was to tell the model that catchability was known exactly (it was fixed to 1). I approve of this decision as a short-term measure, because it will tend to reduce year-to-year changes in stock status (and in particular, in the estimate of current 1+ biomass, which is important for management purposes). However, I recommend that the third approach, which is intermediate between the first two, be adopted for future assessments if possible. This is to provide the model with a summary of what is known about each survey catchability in the form of a prior distribution for this parameter.

I note that the task of generating survey catchability priors should not be the responsibility of the STAT. This task is often addressed by the combination of a Bayesian statistician (whose expertise relates to the function of a prior distribution in a model) and subject experts (the survey teams, whose expertise is in understanding all the factors that contribute to catchability for their type of survey [e.g., target strength for acoustic surveys, proportion spawning for egg surveys, etc]). In Bayesian parlance the statistician is said to 'elicit' the prior from the experts.

3.3.3 Survey selectivities

The assessment model was unable to fit the considerable year-to-year changes in length compositions for both the trawl-acoustic and aerial surveys. There was a similar problem with age compositions for the acoustic survey.

There are three alternative explanations for this lack of fit. One possibility is that the survey selectivity is changing substantially from year to year. This would be of concern because it would undermine the value of these surveys, since they would be surveying a substantially different portion of the population each year.

In both of the other two explanations the survey selectivity does not vary significantly from year to year, but there are different reasons for the lack of fit. One reason would be that the composition data from these surveys were not representative of the portion of the population being surveyed. This would be of concern because it would mean that the survey selectivity was poorly estimated in the assessment. Thus, in fitting the survey biomass index the observed biomass would be compared by the model to the wrong expected biomass. Alternatively, it could be that the composition data *are* representative, but the model has estimated the wrong parameters (particularly those for growth and recruitment). It may be that with different parameter values the model would achieve a much better fit to the survey composition data.

This last explanation may be correct for the aerial surveys, where an upward trend in mean length is consistent with a similar trend from the catches in the PacNW fishery (in a similar area), and neither trend was fitted by the model (see Figure 1). An upward trend in mean length suggests the population in that area is dominated by one or more year classes. This could be checked if the otoliths from the aerial survey were aged.

3.4 Model data and structure

3.4.1 Use of age and length data

Both age and length composition data were available for most years for the three fisheries (MexCal in semesters 1 and 2, and PacNW), and for three of the five years for the trawl-acoustic survey. I suggest that it is a mistake in this situation to include both the length composition (LC) and the conditional age-at-length data (CA@L) in the model. It is better to include just the age compositions (ACs), omitting the other data types.

I acknowledge that this suggestion is counter-intuitive. It seems obvious that there is more information in the combination of LC and CA@L, than there is in AC alone. While this is true in general, it is *not* true for the type of model used in this assessment, because this model is age-structured. That is to say, the model's accounting system is age-based: it reconstructs the history of the sardine population by keeping track of the number of fish of each age in each time step in each year. The model deals with length data (and with selectivities that are functions of length) only by converting back and forth between length and age, using its growth parameters. In particular, to calculate a likelihood for an observed LC the model converts its expected AC to an expected LC using information about the relationship between length and age that is contained in its growth parameters. The problem is that these growth parameters are the same for all years and all areas, whereas we know, from the CA@L data that the relationship between length and age varies, both from year to year, and from south to north. Thus, it is better to use the time and area-varying information we have in the CA@L data to convert our LCs to ACs outside the model, and then to include only these ACs in the model.

3.4.2 Canadian survey

The 2009 STAR Panel recommended that the fishery-independent mid-water trawl survey series off the west coast of Vancouver Island should be considered for inclusion in the current assessment. The STAT rightly argued that this series would be of limited utility because of (*inter alia*) very high c.v.s (1.5 – 3.0). During the STAR Panel meeting a Canadian representative reported that there had been an error in the calculation of these c.v.s, and the correct values were much smaller (0.23 – 0.39 [see Appendix 3 of the STAR Panel report]).

Another important characteristic of this survey, not noticed during the STAR Panel meeting (at least by me), is that it estimates a biomass trend very similar to that from the U.S. trawl-acoustic survey (Figure 3). Since these surveys were carried out independently, and in different areas, this similarity in trend provides strong support to both surveys as being representative of actual changes in the sardine population.

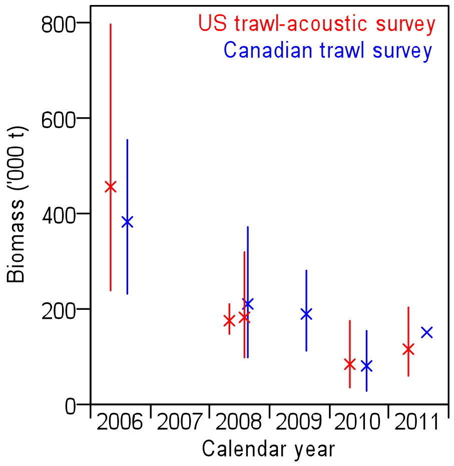

Figure 3: Comparison of biomass estimates from Canadian trawl surveys and US trawl-acoustic surveys. To aid comparison the US estimates have been scaled to have the same mean as the Canadian ones. Vertical bars are 95% confidence intervals.

3.4.3 Lack of fit to old fish

A systematic lack of fit to the conditional age-at-length data indicated that fewer old fish were observed – in surveys and catches – than was expected by the model. This lack of fit is most easily seen in the plots of residuals to the implied age frequencies: most of the residuals for the older age classes were negative. As a consequence, a profile on natural mortality, M, had its minimum at M = 0.625 y^{-1}: higher than was considered plausible, and much higher than the value assumed in the assessment (M = 0.4 y^{-1}).

It would be good to try to remove this systematic lack of fit in future assessments. This might be done by introducing age-dependent natural mortality, or changing the form of the selectivities. The danger is that the model might compromise the fit to the abundance indices in an attempt to find combinations of parameters that slightly reduce the lack of fit at older ages.

3.4.4 Sex and fishery structure

During the STAR Panel meeting, evidence emerged that suggested that two of the STAT's decisions on model structure – to ignore sex, and to have only two fisheries – may need to be reconsidered. Proportion female in fishery catches was shown to exceed 0.5 in bigger fish, and female spawning biomass was estimated to be more than half of total spawning biomass in 7 of the 8 DEPM surveys. Also, splitting the length composition data from the two model fisheries showed that Canadian fish tended to be larger than those from Oregon and Washington, and Mexican fish were larger than those from California.

I support the suggestion that these structural decisions be reconsidered, but urge caution. Changes to these structures will increase model complexity (and parameter numbers), and increased complexity makes it harder for the modeller to understand what is driving the model. I point out that the aim of stock assessment modelling is to inform fishery management, not to build the most realistic model possible.

For example, consider the decision as to whether to include sex in the model. The evidence cited above makes it clear that including sex would make the model more realistic. But realism isn't the point. I suggest the questions to ask are (a) does including sex materially change the estimated stock status? and (b) if so, is the change in estimated status plausible? Sex should be included in the model only if the answers to both questions are 'yes'. If in doubt, err on the side of simplicity.

3.5 Review process

The review process was excellently run by PFMC, with support from SWFSC staff. Before the meeting I was particularly aware of contributions from Kerry Griffin, Nancy Lo, and Jennifer McDaniell, and of course Kevin Hill, who lead the considerable effort required to get the draft assessment report ready in time. I was especially pleased to see the Stock Synthesis input files included in this report because that allowed me to check on some of the technical details that can be important. During the meeting, both the STAT and survey teams went out of their way to respond to queries and requests from the Panel. The Panel was very ably chaired, and all participants showed a constructive approach to the review.

3.6 Terms of Reference

The present review raised a problem that I think needs to be considered when Statements of Work (SOWs) are prepared for future reviews. The problem concerns the Terms of Reference (ToRs) within the SOW (Appendix 1).

These ToRs were used in two distinct ways within the SOW. The first way, which posed no problems for me, was to direct the activities of the CIE reviewer before (ToR 1) and during (ToRs 2-6) the review meeting (e.g., on p. 3 of the SOW: "The CIE reviewer shall … participate in … the meeting review panel, and … shall be focused on the ToRs …"). The second way was to structure the CIE reviewer's report (e.g., Annex 1 of the SOW says the report shall include "Summary of Findings for each ToR", and this is underlined under **Acceptable Performance Standards** where it says "the CIE report shall address each ToR").

This latter use of the ToRs has not been a problem for me in previous reviews because the ToRs for those reviews have referred to aspects of the assessment being reviewed (e.g., "Comment on quality of data used in the assessment" and "Evaluate and comment on analytic methodologies"). However, the ToRs in the present SOW refer to activities of the panel members, rather than aspects of the assessment. It would not make sense for me to include in my report findings for each of these ToRs. For example, ToR 2 is "Working with STAT Teams to ensure assessments are reviewed as needed", and ToR 3 is "Documenting meeting discussions". If I were to present findings related to these ToRs I would be reviewing the panel activities rather than the sardine assessment.

I discussed this problem with Manoj Shivlani (CIE) before the review meeting and he agreed that, for this review, I need not take literally the requirement to structure my report around the ToRs.

4 Conclusions and recommendations

4.1 Best available science

I conclude that the assessment, as modified during the STAR Panel meeting, constitutes the best available science.

4.2 Analytic methodology

The analytic methodology used in this assessment was generally sound but methods of data weighting could be improved.

I recommend consideration be given to

- adopting the data-weighting approach proposed by Francis (2011), and
- improving the Stock Synthesis documentation relating to data weighting.

4.3 Sources of uncertainty

This assessment was characterised by a high degree of uncertainty.

To reduce uncertainty in future assessments I recommend particular attention be paid to

- reducing relative bias in age estimates,
- producing priors on survey catchabilities, and
- resolving uncertainty about survey selectivities.

4.4 Model data and structure

For future assessments I recommend that

- age compositions be used, rather than the combination of length compositions and conditional age-at-length data,
- the methodology of the Canadian trawl survey be reviewed so that these data might be used if found suitable,
- an attempt be made to reduce the lack of model fit for older fish, and
- in considering whether to change assumptions concerning sex and the number of fisheries, the STAT be cautious about unnecessarily complicating the model structure.

4.5 Review process

The review process was excellently run, with great support from PFMC and SWFSC staff, and enthusiastic cooperation from both STAT and survey teams.

4.6 Terms of Reference

The STAR Panel's Terms of Reference were suitable for guiding the reviewer's activities during the Panel meeting, but not for structuring this report.

For future CIE reviews I recommend that attention be given to the way that Statements of Work specify the structure of the reviewer's report.

5 References

Dorval, E.; McDaniell, J.; Hill, K. (2011). An evaluation of the consistency of age-determination of Pacific sardine (*Sardinops sagax*) collected from Mexico to Canada. Appendix 2 in the draft assessment report.

Hill, K.T.; Crone, P.R.; Lo, N.C.H.; Macewicz, B.J.; Dorval, E.; McDaniel, J.D.; Gu, Y. (2011). Assessment of the Pacific sardine resource in 2011 for U.S. management in 2012. Draft assessment report.

Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences* **68**: 1124–1138.

Methot, R.D. (2005). Technical Description of the Stock Synthesis II Assessment Program Version 1.17

Methot, R.D. (2011). User manual for Stock Synthesis model version 3.21d. Updated May 8, 2011

Schnute, J.T.; Hilborn, R. (1993). Analysis of contradictory data sources in fish stock assessment. Can. J. Fish. Aquat. Sci. 50(9): 1916–1923.

Appendix 1. Materials provided for the review

The reviewer was provided with access to the following documents on an ftp website (ftp://swfscftp.noaa.gov/users/jmcdaniel/Pacific Sardine STAR 202011/)

1. The draft assessment report (Hill et al. 2011)
2. User Manual and Technical Documentation for Stock Synthesis (Methot 2005, 2011)
3. Background documents on the three surveys series (egg, acoustic, and aerial)
4. 2011 SAFE (Stock Assessment And Fishery Evaluation) document
5. Reports from previous assessments, 2007-2010

Appendix 2. Statement of work

This appendix contains the Statement of Work that formed part of the consulting agreement between the Center for Independent Experts and the author.

External Independent Peer Review by the Center for Independent Experts

STAR Panel Review of Pacific Sardine Stock Assessment

October 4-7, 2011

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: The CIE reviewer will serve on a Stock Assessment Review (STAR) Panel and will be expected to participate in the review of Pacific sardine stock assessment. The Pacific sardine stock is assessed regularly (currently, every 1-2 years) by SWFSC scientists, and the Pacific Fishery Management Council (PFMC) uses the resulting biomass estimate to establish an annual harvest guideline (quota). The stock assessment data and model are formally reviewed by a Stock Assessment Review (STAR) Panel once every three years, with a coastal pelagic species subcommittee of the SSC reviewing updates in interim years. Independent peer review is required by the PFMC review process. The STAR Panel will review draft stock assessment documents and any other pertinent information for Pacific sardine, work with the stock assessment teams to make necessary revisions, and produce a STAR Panel report for use by the PFMC and other interested persons for developing management recommendations for the fishery. The PFMC's Terms of Reference (ToRs) for the STAR Panel review are attached in **Annex 2**. The tentative agenda of the Panel review meeting is attached in **Annex 3**. Finally, a Panel summary report template is attached as **Annex 4**.

Requirements for CIE Reviewer: One CIE reviewer shall participate during a panel review meeting in La Jolla, California during 4-7 October, and shall conduct an impartial and independent peer review accordance with the SoW and ToRs herein. The CIE reviewer shall have the expertise as listed in the following descending order of importance:

- The CIE reviewer shall have expertise in the application of fish stock assessment methods, particularly, length/age-structured modeling approaches, e.g., 'forward-simulation' models (such as Stock Synthesis, SS) and it is desirable to have familiarity in 'backward-simulation' models (such as Virtual Population Analysis, VPA).
- The CIE reviewer shall have expertise in the life history strategies and population dynamics of coastal pelagic fishes.
- It is desirable for the CIE reviewer to be familiar with the design and execution of fishery-independent surveys for coastal pelagic fishes.
- It is desirable for the CIE reviewer to be familiar with the design and application of fisheries underwater acoustic technology to estimate fish abundance for stock assessment.
- It is desirable for the CIE reviewer to be familiar with the design and application of aerial surveys to estimate fish abundance for stock assessment.

The CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review process.

Location/Date of Peer Review: The CIE reviewer shall conduct an independent peer review during the STAR Panel review meeting at NOAA Fisheries, Southwest Fisheries Science Center, 8604 La Jolla Shores, La Jolla, California from October 4-7, 2011.

Statement of Tasks: The CIE reviewer shall complete the following tasks in accordance with the SoW, ToRs and Schedule of Milestones and Deliverables specified herein.

<u>Prior to the Peer Review</u>: Upon completion of the CIE reviewer selection by the CIE Steering committee, the CIE shall provide the CIE reviewer information (name, affiliation, and contact details) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewer. The NMFS Project Contact is responsible for providing the CIE reviewer with the background documents, reports, foreign national security clearance, and information concerning other pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

<u>Foreign National Security Clearance</u>: When CIE reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE reviewers who are non-US citizens. For this reason, the CIE reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html

<u>Pre-review Background Documents</u>: Two weeks before the peer review, the NMFS Project Contact will send by electronic mail or make available at an FTP site to the CIE reviewer all necessary background information and reports for the peer review. In the case where the

documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. The CIE reviewer shall read all documents in preparation for the peer review, for example:

- Recent stock assessment documents since 2009;
- STAR Panel- and SSC-related documents pertaining to reviews of past assessments;
- CIE-related summary reports pertaining to past assessments; and
- Miscellaneous documents, such as ToR, logistical considerations.

Pre-review documents will be provided up to two weeks before the peer review. Any delays in submission of pre-review documents for the CIE peer review will result in delays with the CIE peer review process, including a SoW modification to the schedule of milestones and deliverables. Furthermore, the CIE reviewer is responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein.

Panel Review Meeting: The CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs. **Modifications to the SoW and ToR cannot be made during the peer review, and any SoW or ToR modification prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** The CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified in the contract SoW.

Respective roles of the CIE reviewer and STAR Panel chair are described in Annex 2 (see p. 6-8). The CIE reviewer will serve a role that is equivalent to the other panelists, differing only in the fact that he/she is considered an 'external' member (i.e., outside the Pacific Fishery Management Council family and not involved in management or assessment of West Coast CPS). The CIE reviewer will serve at the behest of the STAR Panel Chair, adhering to all aspects of the PFMC's ToR as described in Annex 2. The STAR Panel chair is responsible for: 1) developing an agenda, 2) ensuring that STAR Panel members (including the CIE reviewer), and STAT Teams follow the Terms of Reference, 3) participating in the review of the assessment (along with the CIE reviewer), 4) guiding the STAR Panel (including the CIE reviewer) and STAT Team to mutually agreeable solutions.

The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: The CIE reviewer shall complete an independent peer review report in accordance with the SoW. The CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. The CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Other Tasks – Contribution to Summary Report: The CIE reviewer will assist the Chair of the panel review meeting with contributions to the Summary Report. The CIE reviewer is not required to reach a consensus, and should instead provide a brief summary of their views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

Specific Tasks for CIE Reviewer: The following chronological list of tasks shall be completed by the CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review;
2) Participate during the panel review meeting in La Jolla, California during October 4-7, 2011 as called for in the SoW, and conduct an independent peer review in accordance with the ToRs (Annex 2);
3) No later than October 21, 2011, the CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and Dr. David Die, CIE Regional Coordinator, via email to ddie@rsmas.miami.edu. The CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in Annex 2.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

August 22, 2011	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
September 20, 2011	NMFS Project Contact sends the CIE Reviewer the pre-review documents
October 4-7, 2011	The reviewer participates and conducts an independent peer review during the panel review meeting
October 21, 2011	CIE reviewer submits draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
November 4, 2011	CIE submits CIE independent peer review reports to the COTR
November 11, 2011	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be made through the Contracting Officer's Technical Representative (COTR) who submits the modification for approval to the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the CIE within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and Terms of Reference (ToR) of the SoW as long as the role and ability of the CIE reviewer to complete the SoW deliverable in accordance with the ToRs and deliverable schedule are not adversely impacted. The SoW and ToRs cannot be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (the CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards: (1) the CIE report shall have the format and content in accordance with Annex 1, (2) the CIE report shall address each ToR as specified in Annex 2, (3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon notification of acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the approved CIE reports to the NMFS Project Contact and regional Center Director.

Support Personnel:

William Michaels, Program Manager, COTR
NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
William.Michaels@noaa.gov Phone: 301-713-2363 ext 136

Manoj Shivlani, CIE Lead Coordinator
Northern Taiga Ventures, Inc.
10600 SW 131st Court, Miami, FL 33186
shivlanim@bellsouth.net Phone: 305-427-8155

Roger W. Peretti, Executive Vice President
Northern Taiga Ventures, Inc. (NTVI)
22375 Broderick Drive, Suite 215, Sterling, VA 20166
RPerretti@ntvifederal.com Phone: 571-223-7717

Key Personnel:

Nancy Lo, **NMFS Project Contact**
Fisheries Resources Division, Southwest Fisheries Science Center,
8604 La Jolla Shores Dr., La Jolla, CA 92037
Lo.Nancy@noaa.gov Phone: 858-546-7123

Dr. Russ Vetter, Director, FRD,
Fisheries Resources Division, Southwest Fisheries Science Center,
8604 La Jolla Shores Dr., La Jolla, CA 92037
Russ.Vetter@noaa.gov Phone: 858-546-7125

Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewer should describe in their own words the review activities completed during the panel review meeting, including providing a detailed summary of findings, conclusions, and recommendations.

   b. Reviewer should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewer should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewer shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the proceedings and findings of the meeting, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include as separate appendices as follows:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Annex 2: Terms of Reference for the Peer Review of the Pacific sardine stock assessment

The CIE reviewer is one of the four equal members of the STAR panel. The principal responsibilities of the STAR Panel are to review stock assessment data inputs, analytical models, and to provide complete STAR Panel reports.

Along with the entire STAR Panel, the CIE Reviewer's duties include:
1. Reviewing draft stock assessment and other pertinent information (e.g.; previous assessments and STAR Panel reports);
2. Working with STAT Teams to ensure assessments are reviewed as needed;
3. Documenting meeting discussions;
4. Reviewing summaries of stock status (prepared by STAT Teams) for inclusion in the Stock Assessment and Fishery Evaluation (SAFE) document;
5. Recommending alternative methods and/or modifications of proposed methods, as appropriate during the STAR Panel meeting, and;
6. The STAR Panel's terms of reference concern technical aspects of stock assessment work. The STAR Panel should strive for a risk neutral approach in its reports and deliberations.

The STAR Panel, including the CIE Reviewer, is responsible for determining if a stock assessment or technical analysis is sufficiently complete. It is their responsibility to identify assessments that cannot be reviewed or completed for any reason. The decision that an assessment is complete should be made by Panel consensus. If agreement cannot be reached, then the nature of the disagreement must be described in the Panels' and CIE Reviewer's reports.

The review solely concerns technical aspects of stock assessment. It is therefore important that the Panel strive for a risk neutral perspective in its reports and deliberations. Assessment results based on model scenarios that have a flawed technical basis, or are questionable on other grounds, should be identified by the Panel and excluded from the set upon which management advice is to be developed. The STAR Panel should comment on the degree to which the accepted model scenarios describe and quantify 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.

Recommendations and requests to the STAT Team for additional or revised analyses must be clear, explicit, and in writing. A written summary of discussion on significant technical points and lists of all STAR Panel recommendations and requests to the STAT Team are required in the STAR Panel's report. This should be completed (at least in draft form) prior to the end of the meeting. It is the chair and Panel's responsibility to carry out any follow-up review of work that is required.

DRAFT AGENDA: CPS STAR PANEL

Tuesday 4 October

08h30	Call to Order and Administrative Matters	
	Introductions	Punt
	Facilities, e-mail, network, etc.	Lo
	Work plan and Terms of Reference	Griffin
	Report Outline and Appointment of Rapporteurs	Punt
09h00	Pacific Sardine assessment presentation	Hill
10h00	Break	
10h30	Pacific Sardine assessment presentation	Hill
11h30	Acoustic and trawl survey	Zwolinski
12h30	Bayesian estimates of spawning fraction	Lo
12h30	Lunch	
13h30	Pacific Sardine assessment presentation(continue)	Hill
14h30	Panel discussion and analysis requests	Panel
15h00	Break	
15h30	Public comments and general issues	
17h00	Adjourn	

Wednesday and Thursday 5-6 October

08h00.	Assessment Team Responses	Hill
10h30	Break	
11h00.	Discussion and STAR Panel requests	Panel
12h30	Lunch	
13h30	Report drafting	Panel
15h00	Break	
15h30	Assessment Team Responses	Hill
16h30	Discussion and STAR Panel requests	
17h00	Adjourn	

Friday, 7 October, 2011

08h00	Assessment Team Responses	Hill
09h00	Finalize STAR Panel Report	Panel
10h30	Break	
11h00	Finalize STAR Panel Report	Panel
13h00	Adjourn	

Annex 4: STAR Panel Summary Report (Template)

- 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
- Comments on the technical merits and/or deficiencies in the assessment and recommendations for remedies
- Explanation of areas of disagreement regarding STAR Panel recommendations
  - Among STAR Panel members (including concerns raised by the CPSMT and CPSAS representatives)
  - Between the STAR Panel and STAT Team
- Unresolved problems and major uncertainties, e.g., any special issues that complicate scientific assessment, questions about the best model scenario, etc.
- Management, data or fishery issues raised by the public and CPSMT and CPSAS representatives during the STAR Panel
- Prioritized recommendations for future research and data collection

Appendix 3. STAR panel attendees

STAR Panel Members

André Punt (Chair)	Scientific and Statistical Committee (SSC), Univ of Washington
Ray Conser	SSC, Southwest Fisheries Science Center
Larry Jacobson	External Reviewer, Northeast Fisheries Science Center
Chris Francis	Center for Independent Experts (CIE)

Pacific Fishery Management Council (Council) Representatives

Lorna Wargo	Coastal Pelagic Species Management Team (CPSMT)
Mike Okoniewski	Coastal Pelagic Species Advisory Subpanel (CPSAS)
Kerry Griffin	Council Staff

Pacific Sardine Stock Assessment Team

Kevin Hill	NOAA / SWFSC
Paul Crone	NOAA / SWFSC
Nancy Lo	NOAA / SWFSC
Beverly Macewicz	NOAA / SWFSC
Emmanis Dorval	NOAA / SWFSC
Jennifer McDaniel	NOAA / SWFSC
Yuhong Gu	NOAA / NWFSC

Acoustic-Trawl Survey Team

David Demer	NMFS, SWFSC
Juan Zwolinski	NMFS, SWFSC

Aerial Survey Team

Tom Jagielo	Tom Jagielo Consulting

Other attendees

Greg Krutzikowsky	ODFW
Steve Marx	Pew Charitable Trusts
Piera Carpi	UMass, Dartmouth
Sandy McFarlane	Canadian DFO & Canadian Pacific Sardine Association
Linnea Flostrand	Canadian DFO
Bob Seidel	Commercial fishing
Kirk Lynn	CDFG
Jerry Thon	Northwest Aerial Sardine Survey (NWSS)
Dale Sweetnam	SWFSC
Erin Reed	SWFSC
Sam Herrick	SWFSC
Diane Pleschner-Steele	CA Wetfish Producers Association
Ryan Howe	NWSS
Richard Carroll	Ocean Gold Seafood
Ed Weber	SWFSC
David Haworth	Commercial fishing
Fabio Campanella	SWFSC
Josh Lindsay	NMFS SWR
Christina Show	SWFSC
Russ Vetter	SWFSC
Kristen Koch	SWFSC

ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2011 FOR U.S. MANAGEMENT IN 2012

Kevin T. Hill, Paul R. Crone, Nancy C. H. Lo, Beverly J. Macewicz,
Emmanis Dorval, Jennifer D. McDaniel, and Yuhong Gu

NOAA National Marine Fisheries Service
Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, California, USA 92037

October 25, 2011

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TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

ABC	acceptable biological catch
ACL	annual catch limit
ACT	annual catch target
ALK	age-length key
BC	British Columbia (Canada) fishery
CA	California fishery
CalCOFI	California Cooperative Oceanic Fisheries Investigations
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 (México's National Commission of Aquaculture and Fishing)
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
INAPESCA	Instituto Nacional de la Pesca (México's National Fisheries Institute)
Model Year	July 1 (year) to June 30 (year+1)
mt	metric tons
mmt	million metric tons
MexCal	southern 'fleet' based on ENS, SCA, and CCA fishery data
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
ODFW	Oregon Department of Fish and Wildlife
OFL	overfishing limit
OR	Oregon fishery
PacNW	northern 'fleet' based on OR, WA, and BC fishery data
PFMC	Pacific Fishery Management Council
S1 & S2	Model Season 1 (Jul-Dec) and Season 2 (Jan-Jun)
SCA	Southern California fishery
SS	Stock Synthesis
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	Washington fishery
WDFW	Washington Department of Fish and Wildlife

PREFACE

The Pacific sardine resource is assessed each year in support of the Pacific Fishery Management Council (PFMC) process that, in part, establishes annual harvest specifications for the U.S. fishery. The following assessment was conducted using the 'Stock Synthesis 3' (SS3) model, and includes fishery and survey data from updated and new sources. A draft assessment was reviewed by a STAR Panel 4-7 October, 2011, in La Jolla, California. Modifications to input data and model parameterization were incorporated during the course of the STAR, resulting in changes to population estimates and the implied management outcomes. This final report reflects changes made during the STAR process, and will be reviewed by the PFMC and its advisory bodies in November 2011. The outcome of those reviews may form the basis for U.S. Pacific sardine management in 2012.

EXECUTIVE SUMMARY

Stock

Pacific sardine (*Sardinops sagax caerulea*) range from southeastern Alaska to the Gulf of California, México, and are thought to comprise three subpopulations. In this assessment, we presumed to model the northern subpopulation which ranges seasonally from northern Baja California, México, to British Columbia, Canada, and up to 300 nm offshore. All U.S., Canada, and México (Ensenada) landings were assumed to be taken from a single northern stock. Future modeling efforts may explore a scenario where Ensenada and San Pedro catches are parsed into the northern and southern stocks using some objective criteria.

Catches

The assessment includes sardine landings from six major fishing regions: Ensenada, southern California, central California, Oregon, Washington, and British Columbia.

Calendar year	ENS	SCA	CCA	OR	WA	BC	Total
2000	67,845	46,835	11,367	9,529	4,765	1,721	142,063
2001	46,071	47,662	7,241	12,780	10,837	1,266	125,857
2002	46,845	49,366	14,078	22,711	15,212	739	148,952
2003	41,342	30,289	7,448	25,258	11,604	978	116,919
2004	41,897	32,393	15,308	36,112	8,799	4,438	138,948
2005	55,323	30,253	7,940	45,008	6,929	3,232	148,684
2006	57,237	33,286	17,743	35,648	4,099	1,575	149,588
2007	36,847	46,199	34,782	42,052	4,663	1,522	166,065
2008	66,866	31,089	26,711	22,940	6,435	10,425	164,466
2009	55,911	12,561	25,015	21,482	8,025	15,334	138,328
2010	56,821	29,382	4,306	20,853	12,381	22,223	145,965

Data and assessment

This assessment was conducted using 'Stock Synthesis' version 3.21d and includes fishery and survey data collected from mid-1993 through mid-2011. The model uses a July-June 'model year', with two semester-based seasons per year (S1=Jul-Dec and S2=Jan-Jun). Catches and biological samples for the fisheries off Ensenada, southern California, central California were pooled into a single 'MexCal' fleet, in which selectivity was modeled separately for each season (S1 & S2). Catches and biological samples from Oregon, Washington, and British Columbia were modeled as a single 'PacNW' fleet. Four indices of relative abundance were included in the base model: daily egg production method and total egg production estimates of spawning stock biomass off California (1994-2011), aerial survey estimates of biomass off Oregon and Washington (2009-2011), and acoustic estimates of biomass observed from California to Washington (2006-2011). Catchability coefficient (q) for the acoustic survey was fixed at 1 in the base model. All other survey qs were freely estimated.

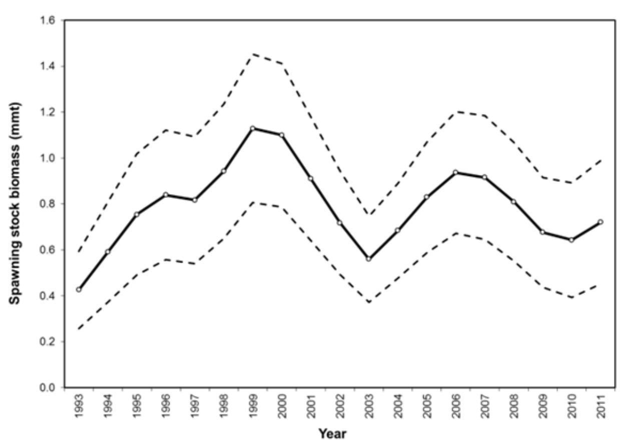
Unresolved problems and major uncertainties

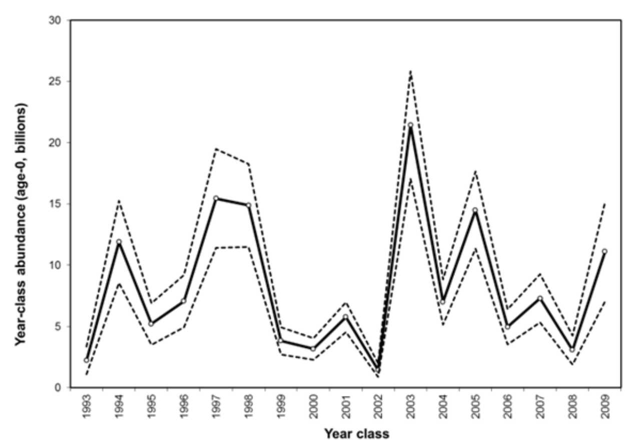
As in the past, the sardine model can be sensitive with regard to scaling of population estimates. While model likelihoods were robust to large changes in scale (i.e., flat likelihood surface), some model scenarios (e.g. extended time series, or treating Canadian fishery separately) resulted in implausibly high fishing mortality rates at the start and/or end of the modeled time series. In the 2009 and 2010 assessments, the scaling problem was addressed by fixing the aerial survey catchability coefficient (q) to equal 1. For the current assessment, model scaling and stability was improved, in part, by simplifying overall model structure (e.g. fewer time-varying elements and fleets) and reducing the number of estimated parameters. Final base model stability was further improved by fixing q for the acoustic time series to equal 1. The acoustic biomass survey was chosen due to the more synoptic nature and longer time series available for the survey. A more detailed listing of modeling issues and uncertainties may be found in the body of this report as well as the STAR (2011) panel report.

Spawning Stock Biomass and Recruitment

Recruitment was modeled using the Ricker stock-recruitment relationship (σ_R=0.62). The estimate of steepness was high (h=2.96), and virgin recruitment (R_0) was estimated to be 6.2 billion age-0 fish. Virgin SSB was estimated to be 0.969 mmt. Spawning stock biomass (SSB) increased throughout the 1990s, with peaks at 1.13 mmt in 1999 and 0.936 mmt in 2006. Recruitment (year-class abundance) peaked at 15.5 billion fish in 1997, 14.9 billion in 1998, 21.4 billion in 2003, and 14.5 billion in 2005. The 2009 year class was estimated to be 11.1 billion fish, higher than the recent average.

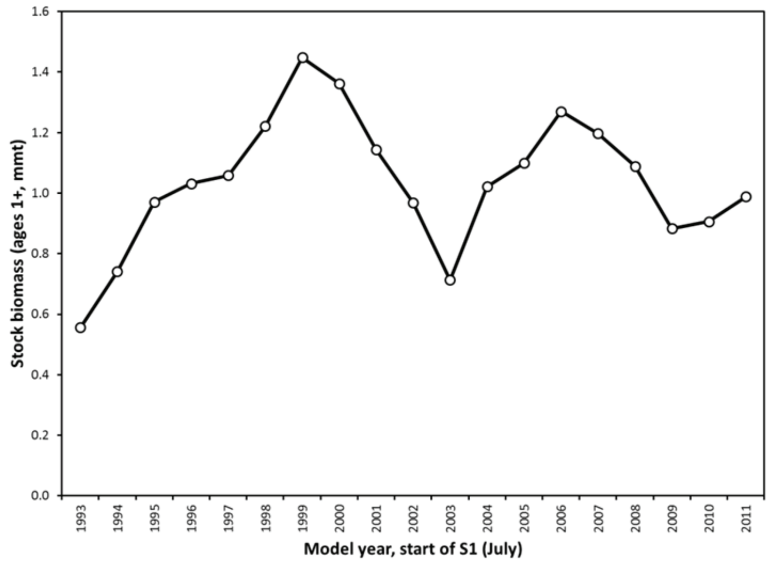
Model year	SSB (mt)	SSB Std Dev	Year class abundance (billions)	Recruits Std Dev
2000	1,099,300	156,590	3.176	0.441
2001	910,030	134,710	5.774	0.611
2002	717,380	112,480	1.453	0.280
2003	559,170	93,958	21.444	2.198
2004	683,570	103,390	7.007	0.927
2005	828,760	120,630	14.502	1.573
2006	936,130	132,590	4.968	0.714
2007	915,230	134,720	7.299	0.987
2008	809,350	128,620	3.081	0.584
2009	675,810	119,320	11.107	2.028
2010	642,830	124,630	---	---
2011	720,420	134,540	---	---





Stock biomass

Stock biomass, used for calculating harvest specifications, is defined as the sum of the biomass for sardine ages 1 and older. Biomass increased rapidly throughout the 1990s, peaking at 1.45 mmt in 1999 and 1.27 mmt in 2006. Stock biomass was estimated to be 988,385 mt as of July 2011.



Exploitation status

Exploitation rate is defined as calendar year catch divided by total mid-year biomass (July-1, ages 0+). U.S. exploitation rate has averaged 7.6% since 2000 and is currently about 6.6%. Total coast-wide exploitation rate has averaged 12.8% since 2000 is currently about 14.5%.

Calendar year	U.S. rate	Total rate
2000	5.20%	10.19%
2001	6.54%	10.48%
2002	10.32%	15.16%
2003	8.08%	12.67%
2004	8.50%	12.75%
2005	7.26%	11.98%
2006	6.88%	11.34%
2007	10.06%	13.09%
2008	7.79%	14.70%
2009	6.77%	13.95%
2010	6.62%	14.45%

Harvest Specifications

Harvest Guideline for 2012

Using results from the final base model ('X5'), the harvest guideline for the U.S. fishery in calendar year 2012 would be 109,409 mt. To calculate the HG for 2012, we used the harvest control rule defined in Amendment 8 of the Coastal Pelagic Species-Fishery Management Plan (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 guideline for sardine is calculated:

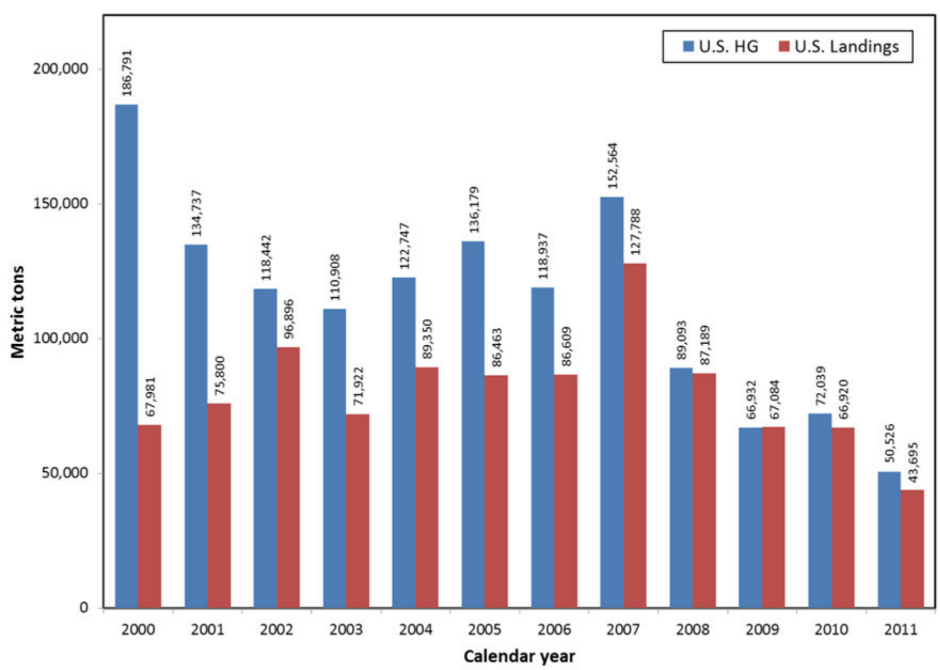
$$HG_{2012} = (BIOMASS_{2011} – CUTOFF) \cdot FRACTION \cdot DISTRIBUTION;$$

where HG_{2012} is the total U.S. (California, Oregon, and Washington) harvest guideline for 2012, $BIOMASS_{2011}$ is the estimated July 1, 2011 stock biomass (ages 1+) from the assessment (988,385 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 following formula has been used to determine FRACTION value:

$$FRACTION = 0.248649805(T^2) – 8.190043975(T) + 67.4558326;$$

where T is the running average sea-surface temperature at Scripps Pier, La Jolla, California during the three preceding seasons (July-June). Under Option J (PFMC 1998), F_{MSY} is constrained and ranges between 5% and 15%. Based on T values observed throughout the period covered by this stock assessment, the appropriate exploitation fraction has consistently been 15%; and this remains the case under current conditions (T_{2011} = 17.7 °C). U.S. harvest guidelines and catches since 2000 are displayed below.



OFL and ABC

The Magnuson-Stevens Reauthorization Act requires fishery managers to define an overfishing limit (OFL), allowable biological catch (ABC), and annual catch limit (ACLs) for species managed under federal FMPs. By definition, ABC and ACL must always be lower than the OFL based on uncertainty in the assessment approach. The PFMC's SSC recommended the '*P**' approach for buffering against scientific uncertainty when defining ABC, and this approach was adopted under Amendment 13 to the CPS-FMP.

The estimated biomass of 988,385 (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 results in a U.S. OFL of 170,689 mt for 2012. For Pacific sardine, the SSC has recommended that scientific uncertainty (σ) be set to the maximum of either (1) the CV of the biomass estimate for the most recent year or (2) a default value of 0.36, which was based on uncertainty across full sardine assessment models. Model CV for the terminal year biomass was equal to 0.187 (σ =0.185); therefore scientific uncertainty (σ) was set to the default value of 0.36. The Amendment 13 ABC buffer depends on the probability of overfishing level chosen by the Council (*P**). Uncertainty buffers and ABCs associated with a range of discreet *P** values are presented in the table below.

Harvest Formula Parameters	**Value**			
BIOMASS (ages 1+, mt)	988,385			
*P** (probability of overfishing)	0.45	0.40	0.30	0.20
BUFFER_{P^*} (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			

Harvest Control Rules	**MT**
OFL = BIOMASS * F_{MSY} * DISTRIBUTION	170,689
$\mathrm{ABC}_{0.45}$ = BIOMASS * $\mathrm{BUFFER}_{0.45}$ * F_{MSY} * DISTRIBUTION	163,140
$\mathrm{ABC}_{0.40}$ = BIOMASS * $\mathrm{BUFFER}_{0.40}$ * F_{MSY} * DISTRIBUTION	155,810
$\mathrm{ABC}_{0.30}$ = BIOMASS * $\mathrm{BUFFER}_{0.30}$ * F_{MSY} * DISTRIBUTION	141,325
$\mathrm{ABC}_{0.20}$ = BIOMASS * $\mathrm{BUFFER}_{0.20}$ * F_{MSY} * DISTRIBUTION	126,073
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION	109,409

INTRODUCTION

Distribution, Migration, Stock Structure, Management Units

Information regarding Pacific sardine (*Sardinops sagax caerulea*) biology is available in Clark and Marr (1955), Ahlstrom (1960), Murphy (1966), MacCall (1979), Leet et al. (2001), and in references cited below.

The Pacific sardine has at times been the most abundant fish species in the California Current. When the population is large it is abundant from the tip of Baja California (23^{o} N latitude) to southeastern Alaska (57^{o} N latitude) and throughout the Gulf of California. Occurrence tends to be seasonal in the northern extent of its range. When sardine abundance is low, as during the 1960s and 1970s, sardines do not occur in commercial quantities north of Baja California.

It is generally accepted that sardines off the West Coast of North America consists of three subpopulations or 'stocks'. A northern subpopulation (northern Baja California to Alaska), a southern subpopulation (outer coastal Baja California to southern California), and a Gulf of California subpopulation were distinguished on the basis of serological techniques (Vrooman 1964) and in a study of temperature-at capture (Felix-Uraga et al., 2004; 2005). An 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. Although the ranges of the northern and southern subpopulations overlap, the adult spawning stocks may move north and south in synchrony and do not overlap significantly. The northern subpopulation is exploited by fisheries off Canada, the U.S., and northern Baja California and is included in the Coast Pelagic Species Fishery Management Plan (CPS-FMP; PFMC 1998).

Pacific sardines 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 indicate that the older and larger fish moved farther north (Janssen 1938, Clark & Janssen 1945). 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 apparently caused the stock to abandon the northern portion of its range. In recent decades, the combination of increased stock size and warmer sea surface temperatures resulted in the stock re-occupying areas off Central California, Oregon, Washington, and British Columbia, as well as distant-offshore areas off California. During a cooperative U.S.-U.S.S.R. research cruise for jack mackerel in 1991, several tons of sardines were collected 300 nm west of the Southern California Bight (Macewicz and Abramenkoff 1993). Resumption of seasonal movement between the southern spawning habitat and the northern feeding habitat has been inferred by presence/absence of size classes in focused regional surveys (Lo et al. 2011).

Life History Features Affecting Management

Pacific sardines may reach 41 cm in length, but are seldom longer than 30 cm. They may live up to 15 years, but fish in California commercial catches are usually younger than five years. Sardine are typically larger and two to three years older in regions off the Pacific northwest. There is evidence for regional variation in size-at-age, with size increasing from south to north and from inshore to offshore (Phillips 1948, Hill 1999). Size- and age-at-maturity may decline with a decrease in biomass, but latitude and temperature are also likely important (Butler 1987). At relatively low biomass levels, sardines appear to be fully mature at age one, whereas at very high biomass levels only some of the two-year-olds are mature (MacCall 1979).

Sardine ages three and older were fully recruited to the fishery until 1953 (MacCall 1979). Recent fishery data indicate that sardines begin to recruit at age zero and are fully recruited to the southern California fishery by age two. Age-dependent availability to the fishery likely depends upon the location of the fishery; young fish are unlikely to be fully available to fisheries located in the north and old fish are less likely to be fully available to fisheries south of Point Conception.

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 rate has been estimated to be M=0.4 yr^{-1} (Murphy 1966; MacCall 1979) and 0.51 yr^{-1} (Clark and Marr 1955). A natural mortality rate of M=0.4 yr^{-1} means that 33% of the adult sardine stock would die each year of natural causes if there were no fishery.

Pacific sardine spawn in loosely aggregated schools in the upper 50 meters of the water column. Northern subpopulation spawning activity begins in January off northern Baja California and ends by August off the Pacific northwest, typically peaking off California in April. Sardine eggs are most abundant at sea surface temperatures of 13^{o}C to 15^{o}C and larvae are most abundant at 13^{o}C to 16^{o}C. 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 & 2005). Sardines are oviparous, multiple-batch spawners with annual fecundity that is indeterminate and age- or size-dependent (Macewicz et al. 1996).

Abundance, Recruitment, and Population Dynamics

Extreme natural variability is characteristic for clupeoid stocks such as Pacific sardine (Cushing 1971). Estimates of sardine abundance from the years 300 through 1970 have been reconstructed from the deposition of fish scales in sediment cores from the Santa Barbara basin off southern California (Soutar and Issacs 1969, 1974; Baumgartner et al. 1992). Significant sardine populations existed throughout the period with biomass levels varying widely. Both sardine and anchovy populations tend to vary over periods of roughly 60 years, although sardines have varied more than anchovies. Sardine population declines were characterized as lasting an average of 36 years; recoveries lasted an average of 30 years. Biomass estimates inferred from scale-depositions in the 19th and 20th centuries suggest that the biomass peaked at about six mmt in 1925 (Soutar and Isaacs 1969; Smith 1978).

Sardine spawning biomass estimated from catch-at-age analysis averaged 3.5 million mt from 1932 through 1934, fluctuated from 1.2 to 2.8 million mt over the next ten years, then declined steeply from 1945 to 1965, with some short-term reversals following periods of particularly successful recruitment (Murphy 1966, MacCall 1979). During the 1960s and 1970s, spawning biomass levels were thought to be less than about five thousand to ten thousand mt (Barnes et al. 1992). The sardine stock began to increase by an average rate of 27% per annum in the early 1980s (Barnes et al. 1992).

Pacific sardine recruitment is highly variable. Analyses of the sardine stock recruitment relationship have been controversial, with some studies showing a strong density-dependent relationship (production of young sardines declining at high levels of spawning biomass) and others finding no relationship (Clark and Marr 1955; Murphy 1966; MacCall 1979). Jacobson and MacCall (1995) found both density-dependent and environmental factors to be important.

Relevant History of the Fishery

The sardine fishery was first developed in response to demand for food during World War I. Landings increased from 1916 to 1936, peaking at over 700,000 mt. Pacific sardines supported the largest fishery in the western hemisphere during the 1930s and 1940s, with landings in British Columbia, Washington, Oregon, California, and México. The population and 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 catch as the fishery collapsed, with landings ceasing in the Pacific Northwest in 1947 through 1948, and in San Francisco in 1951 through 1952. Sardines were primarily used for reduction to fish meal, oil, and as canned food, with small quantities taken for bait.

In the early 1980s, sardine were taken incidentally with Pacific and jack mackerel in the southern California mackerel fishery. As sardines continued to increase in abundance, a directed purse-seine fishery was reestablished. The sardine incidental fishery ended in 1991. Besides San Pedro and Monterey, California, substantial Pacific sardine landings are now made in the Pacific northwest and in Baja California, México. Total annual harvest by the Mexican fishery is not regulated by quotas, but there is a minimum legal size limit.

Recent Management Performance

In January 2000, management authority for the U.S. Pacific sardine fishery was transferred to the Pacific Fishery Management Council. The Pacific sardine was one of five species included in the federal CPS-FMP (PFMC 1998). The CPS-FMP includes a maximum sustainable yield (MSY) control rule intended to prevent Pacific sardines from being overfished and to maintain relatively high and consistent catch levels over a long-term horizon. The harvest formula for sardines is provided at the end of this report ('Harvest Guideline for 2012' section). A thorough description of PFMC management actions for sardines, including harvest guidelines, may be found in the most recent CPS SAFE document (PFMC 2011). U.S. harvest guidelines and resultant landings since calendar year 2000 are displayed in Table 1 and Figure 1a. Coast-wide harvests for major fishing regions from Ensenada to British Columbia are provided in Table 2 and Figure 1b.

ASSESSMENT

Data

<u>Biological Parameters</u>

Stock structure

For purposes of this assessment, we model the northern subpopulation ('cold stock') that ranges from northern Baja California, México to British Columbia, Canada and extends up to 300 nm offshore (Macewicz and Abramenkoff 1993). Specifically, all landings, biological samples, and survey data collected between Ensenada (Mexico) and Vancouver Island (British Columbia, Canada) are assumed to be taken from a single stock. Future modeling scenarios may consider an alternative case that separates the catches in Ensenada and San Pedro into the respective northern ('cold') and southern ('temperate') stocks using temperature-at-catch and otolith morphometric criteria proposed by Felix-Uraga et al. (2004, 2005). Subpopulation differences in growth, maturation, and natural mortality would also be taken into account.

Growth

The weight-length relationship for Pacific sardines (combined sexes) was modeled using fishery samples collected from 1981 to 2011 and the standard power function:

$$W = a\ (L^b);$$

where W is weight (kg) at length L (cm), and a and b are regression coefficients. The estimated coefficients were a = 1.68384e-05 and b = 2.94825 (corrected R^2 = 0.928; n = 155,814). Coefficients a and b were fixed parameters in all models (Figure 2a).

The largest recorded Pacific sardine was 41.0 cm long (Eschmeyer et al. 1983), but the largest Pacific sardine taken by commercial fishing since 1981 was 29.7 cm long. The heaviest sardine weighed 0.323 kg. The oldest recorded age is 15 years, but commercially-caught sardines are typically less than seven years old.

Sardine otolith ageing methods were first described by Walford and Mosher (1943) and further clarified by Yaremko (1996). Pacific sardines are routinely aged by fishery biologists in México, California, and the Pacific Northwest using annuli enumerated in whole sagittae. A birth date of July 1 is assumed when assigning year class. Lab-specific ageing errors were calculated and applied as described in 'Conditional age-at-length compositions' and in Appendix 2.

Sardine growth was first estimated outside the SS model to provide initial parameter values and CVs for length at Age_{min} (0.5 yrs), length at Age_{max} (15 yrs), and the growth coefficient K. An analysis of size-at-age from fishery samples (1993-2010) revealed no evidence for sexual dimorphism (Figure 2b), so a single-sex model was applied in SS.

During the 2009 STAR panel, examination of residuals for the age- and length-composition data revealed that growth was apparently not constant over time. Specifically, there was evidence for a shift in growth rates in 1991. To address this in past assessments, growth parameters were modeled in two time blocks: 1981-1990 and 1991-2009 (Hill et al. 2009, 2010). It is still unclear whether this shift in growth rate was due to density-dependence (compensatory growth) during the early stages of population recovery or some other explanation. For example, the early difference in size-at-age could have been due to size-selective schooling, as many of these sardine were sampled from incidental catches (mixed with larger mackerel). Uncertainty around growth and representativeness of early samples was one of several reasons for starting the model in a later period (base model currently begins 1993).

Maturity

Maturity-at-length was estimated using sardines sampled from survey trawls conducted from 1986 to 2011. Reproductive state was primarily established through histological examination although some immature individuals were simply identified through gross visual examination. Maturity parameters were estimated over two blocks of time to match different SS model scenarios. The full range of available samples was included for models beginning in the early 1980s, resulting in an inflexion = 16.05 cm and slope = -0.78849. A subset of survey samples (1994 to 2011) was used to parameterize maturity in abbreviated SS models (i.e. base case), where inflexion = 15.88 cm and slope = -0.90461. Parameters for the logistic maturity function were fixed in SS, where:

$$\text{Maturity} = 1/(1+\exp(slope*L-L_{\text{inflexion}})))$$

Fecundity was fixed at 1 egg/gram body weight. Resultant maturity and fecundity-at-size and age during the spawning season derived from the final base model are presented in Figure 3.

Natural mortality

Adult natural mortality rate has been estimated to be M=0.4 yr^{-1} (Murphy 1966; MacCall 1979) and 0.51 yr^{-1} (Clark and Marr 1955). A natural mortality rate of M=0.4 yr^{-1} means that 33% of the stock would die of natural causes each year if there were no fishery. Consistent with all previous sardine assessments, the base-case value for the instantaneous rate of natural mortality was taken as 0.4 yr^{-1} for all ages and years (Murphy 1966, Deriso et al. 1996, Hill et al. 1999).

<u>Fishery Data</u>

Overview

Available fishery data include commercial landings and biological samples from six regional fisheries: Ensenada (ENS), Southern California (SCA), Central California (CCA), Oregon (OR), Washington (WA), and British Columbia (BC). Standard biological samples include individual weight (kg), standard length (cm), sex, maturity, and otoliths for age determination (most but not all cases). A complete list of available landings and port sample data by fishing region, model year, and season is provided in Table 3.

Ensenada sardine samples have been collected by INAPESCA since 1989. Sampling has been comparable to that of the U.S. with respect to randomness, frequency, and types of biological data. INAPESCA has collected approximately 10 random samples of 25 fish per month for size, sex, and reproductive condition, with a random subset being aged using otoliths (Table 3). Our previous sardine assessments have used the subset data for both length and conditional age-at-length compositions as provided by Dr. Roberto Felix-Uraga (CICIMAR-IPN), since the full complement of sample data were not available from INAPESCA. For this assessment, we include newly-available length compositions (catch-weighted aggregates provided by INAPESCA) representing the full set of INAPESCA samples collected from mid-1988 through mid-2009. INAPESCA also provided a full series of conditional age-at-length compositions, however, those data were not included this year due to unresolved issues.

CDFG currently collects 12 random port samples (25 fish per sample) per month from each region. CDFG has collected sardine samples on a regular basis since 1981 (Table 3). ODFW has collected port samples since 1999, and WDFW since 2000 (Table 3). Oregon and Washington fishery samples are typically collected more frequently due to a compressed fishing season, but each sample contains 25 fish.

CDFO has sampled the BC sardine fishery since 1998. CDFO collects 100 fish per sample and requires 100% observer coverage, so most of the BC loads are sampled. CDFO's protocol does include collection of otoliths, however, their ageing efforts have primarily focused on survey samples, so no fishery ages were available for this assessment.

All fishery catches and compositions were compiled based on the sardine's biological year ('model year') to match the July-1 birth date assumption used in age assignments. Each model year is labeled with the first of two calendar years spanned (e.g. model year '1993' includes data from July 1, 1993 through June 30, 1994). Further, each model year had two six-month seasons, where 'S1'=Jul-Dec and 'S2'=Jan-Jun. For the final base model, major fishery regions were pooled to represent a southern 'MexCal' fleet (ENS+SCA+CCA) and a northern 'PacNW' fleet (OR+WA+BC), where the MexCal fleet was treated with semester-based selectivities ('MexCal_S1' and 'MexCal_S2'). Rationale for this design is provided in the 'Model Description' section.

Landings

Ensenada monthly landings, 1981 to 2002, were compiled using the 'Boletín Anual' series previously produced by INAPESCA's Ensenada office (e.g. Garcia and Sánchez, 2003). Monthly landings from 2003 to 2010 were taken from CONAPESCA's web archive of Mexican fishery yearbook statistics (CONAPESCA 2011). Ensenada catch for 2011 was unavailable, so was assumed identical to the catch of 2010.

California (SCA & CCA) commercial landings were obtained from CDFG. CDFG catch data are based on dealer landings receipts which, in some cases, were augmented with special sampling for mixed-load portions. During California's incidental sardine fishery (1981 through 1990), many processors reported sardines as mixed with jack or Pacific mackerel, but in some cases sardines were not accurately reported on landing receipts. For these years, sardine landings data were augmented by CDFG with shore-side 'bucket' sampling of mixed-load fish bins to estimate species portions by weight and track compliance with incidental allowance regulations. CDFG reported these landings statistics in 'Wetfish Tables', which are still distributed by the

Department on a monthly basis. These tables are considered more accurate than PacFIN for California CPS statistics so were used for this assessment.

Oregon (OR) and Washington (WA) landings were obtained from the PacFIN database. British Columbia monthly landing statistics, 1999 to 2010, were provided by CDFO (Jake Schweigert, pers. comm.). Catch data for 2011 were unavailable, so was assumed identical to 2010.

The current SS base model includes landings from 1993 to 2011, and aggregates regional fisheries into a southern 'MexCal' fleet and a northern 'PacNW' fleet (see Model Desciption section for rationale). Landings by model year, semester, and fleet are presented in Table 4 and Figure 4.

Length composition
Length compositions for each fishery and semester were the sums of catch-weighted length observations, with monthly landings within semester being the sampling unit. Length compositions were comprised of 0.5-cm bins ranging from 9 cm to 28 cm standard length (39 bins total). The 9-cm bin reflects all fish $\leq$9.49 cm, the 28-cm bin reflects all fish $\geq$28 cm, and all other bins (9.5 to 27.5 cm) reflect the lower end of the respective 0.5-cm interval (e.g., the 9.5-cm bin includes fish ranging 9.5 to 9.99 cm).

Total numbers of lengths observed in each fishery-semester stratum were divided by the typical number of fish collected per sampled load (25 fish per sample for most regions, 100 fish per sample in Canada) to calculate effective sample sizes (ESS). Compositions having fewer than two samples per semester were omitted from the model. Length-compositions were input as proportions. While raw sample data were not available from the ENS and BC regional fisheries, catch weighted length distributions, assembled per above, were made available by INAPESCA and CDFO. Once the decision was made to pool ENS with SCA-CCA data (='MexCal'), and to combine BC with OR-WA data (='PacNW'), the respective length distributions and effective sample sizes were weighted by catch from each region at the semester level. Landings and ESS by model year, semester, and fleet are provided in Table 4. Length-compositions by fleet are displayed in Figures 5a-c.

Age composition
Implied ('ghost') age compositions were compiled based on the same fishery samples and weighting methods described above in 'Length composition'. Implied age-compositions were included as model inputs with effective sample sizes set to "-1". Inclusion of these input data facilitated comparison of model predictions of age-composition to the inferred values through examination of model residual patterns. Implied age composition data are presented adjacent to corresponding length compositions in Figures 6a-c.

Conditional age-at-length compositions were constructed from the same fishery samples and weighting methods described above. Age bins included 0, 1, 2, 3, 4, 5, 6, 7, 8-10, 11-15 (10 bins total). The age 11-15 bin served as an accumulator allowing growth to approach L_∞. Age-compositions were input as proportions of fish in 1-cm length bins. As per the length-compositions, the number of individuals comprising each bin was divided by number of fish per sample to set the initial effective sample size. In most cases, age data were available for every length observation. Conditional age-at-length compositions for each fishery are presented in Figures 7a-c.

Ageing error
Ageing error vectors (std. dev. by age, Figure 8) were calculated and linked to fishery-specific conditional age-at-length compositions following methods recommended during the 2009 STAR panel. The past four stock assessments of Pacific sardine (i.e., Hill 2007-2010) relied on traditional methods to estimate and include age-reading precisions in the Stock Synthesis 3 model. The traditional methods assumed that all agers were unbiased and computed standard deviation-at-age (SDa) by averaging across all fish that were assigned a given age a by one or more readers. In addition these estimates of SDa were limited because: (1) they were based solely on age-readings from a 2004 Tri-national workshop, including agers from Mexico, the US and Canada, and thus they were a snap shot in time; and (2) they did not account for difference in age estimation from different fisheries and laboratories. As age-reading errors can impact the performance of stock assessment models, and with the advent of new statistical models that can simultaneously estimate bias and precision, the 2009 Pacific sardine Stock Assessment Review Panel recommended that: new analyses should be conducted to allow for better estimation and integration of age-reading errors in future Pacific sardine assessment models.

In this assessment, we estimated SD for three fisheries (Ensenada, California, Pacific Northwest) and the DEPM survey. Age-reading data sets (i.e., sets of otoliths that were aged by the same set of agers) were built by fishery and date of fish collection. These data were produced by four ageing laboratories: CICIMAR-IPN (Baja California Sur, Mexico); CDFG (CA, US); SWFSC (CA, US); and WDFW (WA, US). For each fishery and the DEPM survey, we compared SD estimated from the traditional method and the Age-Reading Error Matrix Estimator (Agemat model), a statistical model developed by Punt et al. (2008). The Agemat model uses the maximum likelihood method to estimate ageing errors, and typically compute SD by age-reader. However, age data and age-reading errors cannot be included in the Stock Synthesis 3 model by ager. As an alternative, we defined various model scenarios, comparing models that assumed equal or unequal SD among agers for each fishery and the DEPM survey. Then, we used AICc (Akaike Information Criterion with a correction for finite sample sizes) to select the best model; and thus determined whether there was enough evidence to support the assumption of equality of SD among agers for the age-reading data sets considered in a given model. We refer the reader to Appendix 2 for more details regarding age-reading data sets, model development and assumptions.

Estimates of standard deviation-at-age from the traditional method and the Agemat model were different. Estimates from the Agemat model were derived from models that assumed equality of SD among agers. These models were selected because they had the lowest AICc when compared to models that did not assume equality of SD among agers (Appendix 2, Table 8).

Final model runs of the Stock Synthesis model were based on SD estimated from the Agemat model (Figure 8). Although SDs estimated for the Ensenada and the PNW fisheries were based on single year of fish collection; time-series of age data used in this assessment for these two fisheries were produced by the same agers. Thus we could assume that for the Ensenada and the PNW fisheries age-reading errors did not change over time. In contrast for the California fishery and the DEPM survey multiple readings of otolith samples were performed on a yearly basis, but there was turnover among agers. Therefore, in this assessment we used time-varying estimates of SDa for the California fishery and the DEPM survey.

Fishery-Independent Data

Overview

This assessment includes four time series obtained from fishery-independent surveys: 1) Daily Egg Production Method (DEPM) estimates of female spawning biomass; 2) Total Egg Production (TEP) estimates of total spawning biomass; 3) Aerial photogrammetric surveys of biomass; and 4) Acoustic-trawl surveys of biomass. The DEPM, TEP, and Aerial surveys and estimation methods were previously reviewed and included in recent sardine assessments. The SWFSC acoustic-trawl time series of biomass is new to this assessment model, and the survey and estimation approach was rigorously reviewed in February 2011. All surveys were initially treated as time series of relative abundance in the base model (pre-STAR model 'Ld'). Following recommendations of the 2011 STAR Panel, the acoustic survey series is now modeled with a catchability coefficient (q) of 1 to provide further stability in scaling population estimates. Survey estimates and standard errors are presented in Table 5.

Daily egg production method spawning biomass

DEPM and TEP estimates of SSB were based on SWFSC ship-based surveys conducted each April between San Diego and San Francisco. The 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 and TEP series have been used for sardine stock assessment since the 1990s, and the surveys and estimation method were reviewed by a STAR Panel in May 2009. Both time series are treated as indices of relative SSB, with catchability coefficients (q) being estimated (Figure 15).

The SWFSC conducted a coastwide California Current Ecosystem (CCE) survey from March 23 to April 29, 2011 aboard the NOAA ship *Bell M. Shimada* and the F/V *Frosti*. The survey, which ranged from Cape Flattery, Washington to San Diego, California (Figure 9a) including the primary CalCOFI area (CalCOFI lines 76.7 to 93.3), employed all the usual methods for estimating sardine SSB via the DEPM (Lo et al. 2010). 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 9b).

The standard DEPM index area off California (San Diego to San Francisco; CalCOFI lines 95 to 60) was 314,481 km^2, and the egg production (P_0) estimate was 1.16/0.05m^2 (CV = 0.29)(Lo et al. 2011). Even though a small area close to Astoria, Washington (47.1° - 45.9° N) was sampled by the *Bell M. Shimada*, no eggs and only two immature sardines were collected in the area north of CalCOFI line 63.3. Female spawning biomass for the standard area was taken as the sum of female spawning biomass in regions 1 and 2 (Table 6). The female spawning biomass and total spawning biomass (sum) for the standard DEPM area was estimated to be 219,386 mt (CV = 0.28) and 373,348 mt (CV = 0.28), respectively (Table 6). Adult reproductive parameters for the survey are presented in Table 7. The daily specific fecundity was calculated as 19.04 (number of eggs/population weight (g)/day) using the estimates of reproductive parameters from 244 mature females collected from 30 positive trawls, where: mean batch fecundity (F) was 38369 eggs/batch (CV = 0.07); fraction spawning (S) was 0.1078 females spawning per day (CV = 0.18); mean female fish weight (W_f) was 127.6 g (CV = 0.05); and sex ratio of females by weight (R) was 0.587 (CV = 0.06). 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 2011 survey, the number of tows positive for mature female sardine was similar in Regions 1 and 2 (14 and 16 respectively), while four additional tows in Region 2 contained solely immature sardines (Lo et al. 2011).

In SS, the DEPM series was taken to represent female SSB (length selectivity option '30') in the middle of S2 (April). Since 2009, the time series of spawning biomass was replaced by female spawning biomass for years when sufficient trawl samples were available and the total egg production for other years as inputs to the stock assessment of Pacific sardine. The 2011 DEPM estimate is considerably higher than previous few years, primarily due to the relative high egg production (Tables 5 & 6; Figure 15).

Total egg production spawning biomass

Adult sardine samples are needed to calculate daily specific fecundity for true DEPM estimates. Sardine trawls were not always conducted during the egg production surveys. Beginning in 2007, we chose to include these data as a Total Egg Production (TEP) series, which is simply the product of egg density (P_0) and spawning area (km^2). Calculated TEP values are provided in Table 5 & 6, and displayed in Figure 15. TEP was also taken to represent relative SSB (length selectivity option '30') in the model, but in this case the female fraction was unknown (Tables 5 & 6; Figure 15).

Aerial survey

The Pacific sardine industry has funded aerial photogrammetric surveys of sardine abundance off the coast of Oregon and Washington, beginning with a pilot survey in summer 2008. The 2008 survey methodology and results were reviewed by a STAR in May 2009. Full surveys were subsequently conducted during summers of 2009, 2010, and 2011 (Jagielo et al. 2009-2011).

The Aerial survey employs two sampling elements: 1) high-resolution photographs collected by spotter planes to estimate the number and surface area of sardine schools, and 2) using fishing vessels to conduct point sets on schools to determine the relationship between surface area and biomass and to determine size composition of the schools. Maps of the 2009 and 2010 biomass distributions and point set locations are displayed in Figure 10 and 11. Weighted length compositions from the three surveys are displayed in Figure 12. A complete description of the methods and results can be found in Jagielo et al. (2009-2011).

The past two assessments (Hill et al. 2009 & 2010) have treated the aerial biomass estimates as absolute (q=1), with length selectivity being dome-shaped. The current assessment continued using domed-selectivity but now treats the time series as relative (Figure 15), i.e. catchability (q) is now estimated.

Acoustic survey

The Acoustic-trawl time series is based on SWFSC surveys conducted coast-wide (most years) between San Diego and Cape Flattery, Washington since 2006. The acoustic-trawl surveys and estimation methods were reviewed during an independent review panel in February 2011. Following the methodology review, recommended revisions were made and additional survey data (April 2011) were incorporated (Demer et al. 2011; Zwolinski et al. 2011a,b).

Sardine size and age composition data were available from survey trawls. Survey length compositions were based on biomass-weighted length distributions from each haul (Demer et al. 2011; Zwolinski et al. 2011a,b) (Figure 14a). Conditional age-at-length compositions were available for surveys conducted in spring of 2006, 2008, and 2010 (Figure 14b). Survey-specific ageing error vectors were also included in the model (Figure 8). Acoustic trawl biomass estimates were treated as absolute (q = 1), with asymptotic length selectivity assumptions (Figure 15).

Data Sources Considered But Not Used
Pacific sardine are routinely collected during two additional surveys: 1) CDFO's swept area trawl survey for sardine, conducted each summer along the west coast of Vancouver Island (Canada), and 2) the SWFSC's juvenile rockfish mid-water trawl survey, conducted during late spring along the central and southern California coast. CDFO's trawl survey was described by MacFarlane et al. (2005), and has been proposed for potential methodology review during 2012 (Schweigert & Flostrand 2011). The SWFSC juvenile rockfish survey was described by Sakuma et al. (2006) and Field et al. (2010), and a preliminary analysis of sardine CPUE and size data has been summarized by Crone (2011) in Appendix 3 of this report. As noted in the 2011 STAR panel report, any substantial new data source would likely need to be reviewed during a Council-sponsored Methodology Review Panel before it could be included in the sardine stock assessment.

History of modeling approaches

The Pacific sardine population (pre-collapse) was first modeled by Murphy (1966). MacCall (1979) refined Murphy's VPA analysis using additional data and prorated portions of Mexican landings to exclude the southern subpopulation. Deriso et al. (1996) modeled the recovering population (1982 forward) using CANSAR, a modification of Deriso's (1985) CAGEAN model. CANSAR was subsequently modified by Dr. Larry Jacobson (NOAA) into a *quasi* two-area model 'CANSAR-TAM' to account for net losses from the core model area. CANSAR and CANSAR-TAM were used for annual stock assessments and management advice from 1996 through 2004 (e.g. Hill et al. 1999, Conser et al. 2003). In 2004, a STAR panel endorsed use of the ASAP model for routine assessments. ASAP was used for sardine assessment and management advice for calendar years 2005 to 2007 (Conser et al. 2003 & 2004, Hill et al. 2006a,b). In 2007, a STAR panel reviewed and endorsed an assessment using 'Stock Synthesis 2' (Methot 2005, 2007), and the results were adopted for management in 2008 (Hill et al. 2007) as well as an update for 2009 management (Hill et al. 2008). The sardine model was transitioned to Stock Synthesis version 3.03a in 2009 (Methot 2009), and was again used for an updated assessment in 2010 (Hill et al. 2009 & 2010).

Responses to 2009 STAR Panel and 2010 SSC CPS-Subcommittee Recommendations

A. Future assessments should consider the fishery-independent mid-water trawl surveys off the west coast of Vancouver Island. This data set is potentially valuable as it provides abundance information for a large area within Canadian waters. However, it needs to be analyzed further before it can be included in a future assessment. The STAT should confer with the lead investigator for the WCVI survey to obtain further information, including raw data. If necessary, the lead investigator should be invited to attend the next STAR Panel to present results for this time series.
STAT Response: The PFMC reviewed a number of requests for CPS survey methodology reviews during 2011 (SWFSC's Acoustic survey, Southern California Aerial-LIDAR Survey, and Pacific NW Satellite Imagery Survey), however, CDFO's swept area trawl survey was not formally proposed for review. From the STAT's perspective, CDFO's swept area trawl survey would be of limited utility in the assessment for two reasons: (1) spatial coverage is limited to areas off Vancouver Island, the northern tail of the stock's distribution, and (2) CDFO's biomass estimates (nighttime trawls, 2006-2010) have large CVs (1.5~3.0), so the survey would not be an informative time series within an assessment model.

B. Further review the sampling protocols and analysis methods for other potential indices of abundance (such as the SWFSC juvenile rockfish survey and the acoustic surveys, which have been conducted in conjunction with egg surveys since 2003) and consider inclusion of such data in future assessments.
STAT Response: The STAT (Crone) has conferred with the lead scientist for the SWFSC's Pelagic Juvenile Rockfish Survey (Dr. John Field) regarding potential use of sardine data as a time series in the assessment. A delta-GLM model was used to generate a time series of sardine abundance for the core and broader survey areas. Raw (i.e. un-weighted) length distributions were also developed. A summary analysis is provided in Appendix 3 of this report (Crone 2011). Overall, the STAT concludes that this survey will require further evaluation, and potentially a methodology review, before adopting as an index in an ongoing assessment for sardine.

C. Density-dependent changes in growth or reproduction have not been identified nor evaluated. Maturity at length is variable from year to year, although adult sampling has not been consistent, and young fish may be under-represented. Available maturation ogives could be compared to biomass estimates to identify possible density-dependent effects, although environmental variation is likely to be a major factor in growth and maturation so inference may be weak.
STAT Response: Length-at-maturity (L_{50}) can change considerably among survey years, likely due to a combination of sampling bias and movement. This recommendation suggests looking for density-dependence, but this will be difficult unless sources of potential bias are identified and addressed. Smaller, immature fish are under-represented in the regressions.

D. Fecundity at age is based on weight and does not account for the total number of batches of eggs produced during a season (annual fecundity). While the spawning frequency during the peak season does not appear to be age-dependent, the length of the spawning season may be longer in older fish. This may affect the stock-recruitment relationship. Whether visual

estimates of activity (presence of developed gonads) from port-collected samples can be used to estimate length-specific timing and duration of spawning across the stock's range should be explored.
STAT Response: The STAT examined visual maturity data available from port-samples collected 1981 to 2010 (CA, OR, WA), and found some evidence for size-dependence in duration of spawning season (Figure 3c). Data from the SWFSC's egg production surveys (not presented here) also indicate a size-dependence in spawning frequency. Given this preliminary evidence for size-dependence in annual fecundity, it is not entirely clear how this relationship should best be modeled in SS. That is, should this information by captured in the fecundity equation (eggs/gram), or should an age-specific fecundity vector be applied? Time did not permit further exploration of this problem prior to the conclusion of this draft.

E. There continues to be uncertainty in the DEPM survey as a key indicator of spawning stock biomass trends coastwide. Expand coastwide sampling of adult fish to further refine the estimate of the proportion spawning.
STAT Response: The SWFSC continues to pursue coast-wide surveys as frequently as possible. The most recent coast-wide survey, conducted in 2010, and found little evidence of sardine (ichthyoplankton, trawled adults, or acoustic backscatter) outside of the standard DEPM area (Figure 9b). Plans are underway to conduct a synoptic survey in 2012.

F. Temperature at catch could provide insight in stock structure and the appropriate catch stream to use for assessments, because the southern subpopulation is thought to prefer warmer water. Conduct sensitivity tests to alternative assumptions regarding the fraction of the ENS and SCA catch that comes from the northern subpopulation.
STAT Response: This is a potentially important research exercise, but not one that will soon translate into model for management advice. Felix et al. (2004, 2005) used course grid (2-degree) SST data from the Hadley Centre (U.K.). Additional work is needed to look at the best oceanographic data and spatial scope for parsing the catch and comp data. This topic is currently being studied by a graduate student at CICIMAR-La Paz.

G. The assessment would benefit not only from data from Mexico and Canada, but also from a joint assessment, which includes assessment team members from these countries.
STAT Response: A joint INP-NMFS sardine assessment workshop was held in La Paz during September, 2010. The workshop resulted in exchange of information regarding the SS modeling platform, as well as standardized data sets for the respective fisheries off Mexico and the U.S.

H. Re-evaluate the magnitude of discards in each fishery, and account for discards in future assessments.
STAT Response: No extensive work has been undertaken on this topic. In general, the small purse seine fisheries are relatively 'clean' with regard to discards, given the nature of the fishing procedure (i.e. purse contents being pumped into the hold) and the practical difficulties incurred by dumping entire loads. Under-reporting on landing receipts has been documented by enforcement agents, however, it would be problematic to apply some expansion factor to the entire catch.

I. Otolith and microchemistry studies are useful tools for evaluating stock structure. Results should be evaluated to determine if the spatial distribution is purely age-dependent or due to an alternate life history strategy. These evaluations could be combined with a traditional tagging study (which has not been done since the 1940s) to provide useful information about fish migration and distribution.
STAT Response: No data were available.

J. The relationship between environmental correlates and abundance should be examined. In particular, the relationship between environmental covariates and recruitment deviations should be explored further.
STAT Response: This is a currently-funded project under the FATE program, however, no new time series is yet available.

K. Further evaluate the appropriate form of stock-recruitment relationship for Pacific sardine, including appropriate environmental covariates.
STAT Response: The STAT has explored alternative S-R functions in SS (e.g. Beverton-Holt, CAA), however, all have resulted in poorer overall fits to the data, with worsening trends in the recruitment deviations. McClatchie et al. (2010) have raised doubts regarding applicability of SST data collected at the SIO pier. No alternative environmental covariate has been identified.

L. Consider spatial models for Pacific sardine, which can be used to explore the implications of regional recruitment patterns and region-specific biological parameters. These models could be used to identify critical biological data gaps.
STAT Response: This is the focus of a current Washington SeaGrant project (PI: Andre Punt), and is been being studied intensively by Dr. Punt's graduate student, Felipe Hurtado.

M. Re-estimate age-reading error matrices and include them in updated assessments.
STAT Response: This item has been addressed and fully documented in Appendix 2 (Dorval et al. 2011).

N. During the May 2009 STAR Panel review of the DEPM survey, the panel recommended applying Bayesian hierarchical models to estimate adult spawning fraction in years when survey collections are less than adequate. This request has been studied by Lo et al. (2011) and is attached as Appendix 5.

O. During the SSC CPS-Subcommittee review of the 2010 assessment update (October 2010), the subcommittee made a recommendation to "Explore model configurations in which the selectivity pattern for the aerial survey in the north is asymptotic, as is the case for the fishery, rather than dome-shaped." The subcommittee's recommendation was based on the STAT's analysis of selectivity assumptions (asymptotitc vs. domed) presented during the update review and further summarized in the 2010 update report (Hill et al. 2010). Selectivity shape can be quite important when an index is taken to represent absolute abundance (e.g. aerial survey q=1), as was demonstrated in the 2010 assessment update (Hill et al. 2010). The aerial survey was not modeled with q = 1 during the 2011 assessment, so this recommendation was not explored further.

Model Description

Assessment program with last revision date

Stock Synthesis version 3.21d (Methot 2005, 2011) is based on the AD Model Builder software environment (Otter Research 2001). The SS model framework allows the integration of both size and age structure. The general estimation approach used in the SS model accounts for most relevant sources of variability and expresses goodness of fit in terms of the original data, potentially allowing final estimates of model precision to capture most relevant sources of uncertainty.

The SS model comprises three sub-models: 1) a population dynamics sub-model, where abundance, mortality and growth patterns are incorporated to create a synthetic representation of the true population; 2) an observation sub-model that defines various processes and filters to derive expected values for the different type of data; and 3) a statistical sub-model that quantifies the difference between observed data and their expected values and implement algorithms to search for the set of parameters that maximizes the goodness of fit. These sub-models are fully integrated, and the SS model uses forward-algorithms, which begin estimation prior to or in the first year of available data and continues forward up to the last year of data (Methot 2005, 2011).

Definitions of fleets and areas

Data from major fishing regions are aggregated to represent southern and northern fleets. The southern 'MexCal' fleet includes data from three major fishing areas at the southern end of the stock's distribution: northern Baja California (Ensenada, Mexico), southern California (Los Angeles to Santa Barbara), and central California (Monterey Bay). Fishing can occur throughout the year in the southern region, however, availability-at-size/age changes due to migration. Selectivity for the southern 'MexCal' fleet was therefore modeled separately for seasons 1 and 2 ('S1' & 'S2').

The 'PacNW' fleet includes data from the northern range of the stock's distribution, where sardine are typically abundant between late spring and early fall. The PacNW fleet includes aggregate data from Oregon, Washington, and Vancouver Island (British Columbia, Canada). Majority of fishing in the northern region typically occurs between July and October (S1).

Likelihood components and model parameters

A complete list of model parameters is provided in Table 8. The objective function for the base model included likelihood contributions from: 1) fits to catch, 2) fits to the DEPM, TEP, Aerial, and Acoustic surveys; 3) fits to length compositions from the three fleets, Aerial and Acoustic surveys; 4) fits conditional age-at-length data from the three fleets and the Acoustic survey; 5) deviations about the spawner-recruit relationship; and 6) minor contributions from parameter soft-bound penalties (Table 9).

The final base model (X5) incorporates the following specifications:

- model year spans July 1-June 30 (July 1 birth date assumption);
- two seasons (S1=Jul-Dec and S2=Jan-Jun) (assessment years 1993 to 2011);
- sex is ignored;

- two fleets (MexCal, PacNW), with an annual selectivity pattern for the PacNW fleet, and seasonal selectivity patterns for the MexCal fleet;
- length-frequency and conditional age-at-length data for all fisheries;
- length-based, double-normal selectivity with time-blocking (1993-1998, 1999-2011) for the MexCal fleet; asymptotic length-selectivity for the PacNW fleet;
- Ricker stock-recruitment relationship with estimated "steepness"; σ_R = 0.622 (tuned);
- virgin (R_0) and initial recruitment offset (R_1) were estimated;
- spawning occurs in S2 and recruitment in S1;
- initial recruitment estimated; recruitment residuals estimated for 1987-2009;
- initial *F*s set to 0 for all fleets;
- hybrid-*F* fishing mortality (option 3);
- $M = 0.4$ yr^{-1} for all ages;
- DEPM and TEP measures of spawning biomass; *q* estimated;
- aerial survey biomass, 2009-2011, *q* estimated, domed selectivity; and
- acoustic survey biomass, 2006-2011, *q*=1, asymptotic selectivity.

Selectivity assumptions

Length data from the MexCal and PacNW fleets were fit using a length-based selectivity. The MexCal fleet was fit using the domed selectivity (double-normal function), as we assumed that not all larger sardine were available to the Baja California and California fisheries from 1993 onward. At that stage in the population's recovery, large spawning events were observed off central California (Lo et al. 1996), and sardines were captured in trawls 300 nm off the California coast (Macewicz and Abramenkoff 1993). Selectivity for the MexCal fleet was estimated by season and in two time blocks (1993-1998, 1999-2011) to better account for both seasonal- and decadal-scale shifts in sardine availability to the southern region.

PacNW fleet lengths were fit using asymptotic selectivity (simple logistic). Large sardine are typically found in the northern region, and it is assumed the largest sardine are best able to migrate to northern feeding habitats in summer. The 2007 STAR recommended fitting PacNW lengths over two time blocks (break at 2003/2004) to better fit a decrease in length observed following the large 2003 recruitment event. While the additional time block had resulted in slightly better fit to the PacNW lengths (Hill et al. 2007), we decided to remove this time block from the current base model as there was no theoretical basis for its application.

Stock-recruitment constraints and components

Pacific sardines are believed to have a broad spawning season, beginning in January off northern Baja California and ending by July off the Pacific Northwest. The SWFSC's annual egg production surveys are timed to capture (as best is possible) the peak of spawning activity off the central and southern California coast during April. In our semester-based model, we calculated SSB at the beginning of S2. Recruitment was specified to occur in Semester-1 of the following model year (consistent with the July-1 birth date assumption).

As per past assessments (Hill et al. 2007, 2009), we explored models fit with Ricker and Beverton-Holt S-R functions. Models based on the Ricker function were ultimately more stable and improved the trend in recruitment deviations. Jacobson and MacCall (1995) found that

Pacific sardines were best modeled using Ricker assumptions, and past assessments using CANSAR and CANSAR-TAM included a modified Ricker S-R function (e.g. Deriso et al. 1996, Hill et al. 1999, Conser et al. 2003).

Virgin recruitment (R_0), initial recruitment offset (R_1), and steepness (h) were all freely estimated. Recruitment variability (σ_R) was initially set at a high value (0.9), and later fixed at 0.622 to match the model RMSE. Recruitment deviations were estimated as separate vectors for the early and main data periods. Early recruitment deviations for the initial population were estimated from beginning in 1987 (start year minus 6). A recruitment bias adjustment ramp was applied to the early period (Figure 32d).

The last year for the main recruitment deviations was set at 2008, which means that the 2009 year class freely estimated from the data and the 2010 and 2011 year classes were derived from the Ricker curve. This is a change from past assessments, which estimated recruitments until end year minus one. Our rationale for this change is that there is very little information on recent recruitment available from the last two years of data. Implied age-selectivities (product of length selectivity and the age-length key) from the fisheries and surveys are displayed in Figures 18b and 25b. The Acoustic survey is about ~85% selected by age-2, and other surveys are selected at older ages (Figure 25b). The MexCal_S2 fleet (1999-2011 block) is fully selected by age-1, but these fish are approaching their second birthday. The MexCal_S1 fleet (same block) is fully selected at age-2.

<u>Selection of first modeled year and treatment of initial population</u>
Recent assessments started the model in 1981 (Hill et al. 2007-2010), however, we chose begin the base model in 1993. This year was chosen for several reasons: 1) as stated previously, there is some uncertainty regarding representativeness of the early (1981-1990) composition data, which was a mixture of samples from incidental and directed fisheries (Table 3); 2) egg production surveys of the mid-1980s were conducted between June and August within the Southern California Bight (Table 5), so they covered a smaller geographic range and might have sampled summer spawning of the southern subpopulation; 3) scaling problems encountered in models using the full time series may be exacerbated by starting the population at a such low levels (1,000s of tons) relative to 'recovered' conditions (>1 mmt).

The initial population was calculated by estimating early recruitment deviations from 1987-1992, six years prior to the model start year. In the pre-STAR assessment model ('Ld'), initial F was estimated for the MexCal_S1 fleet, fixed at low values for the MexCal_S2 and PacNW fleets, and non-equilibrium conditions were assumed (i.e. lambdas for equilibrium catch were set to zero). The initial F parameter for MexCal_S1 was consistently estimated at F=4 yr^{-1}, a value that was not credible. Moreover, the fishery selectivity used to calculate initial F appeared to be taken from a later time block (1999-2011) instead of the early period (1993-1998), indicating a potential SS coding error. To address this problem, the STAR panel recommended starting the model with all initial F parameters set to zero (STAR 2011; request 'N'). The new model had a trend in biomass that was nearly identical, scaled 40-50% higher, and had survey q estimates that were more reasonable than model 'Ld'.

The implications of assuming initial F=0 yr^{-1} (as opposed to some value >0) were not explored during the STAR, but the STAT did note there was a fishery occurring during initial modeled period (late 1980s and early 1990s). Following the STAR, the STAT tested a model where initial F for MexCal_S1 was fixed at a moderate level (F=0.5 yr^{-1}). The terminal year stock biomass for that model scaled lower by a minor amount (3%) relative to the base model ('X5') where initial F=0.

Convergence criteria and status

The iterative process for determining numerical solutions in the model was continued until the difference between successive likelihood estimates was <0.0001. Final gradient for the base model was 0.00003444.

Base model changes made during the 2011 STAR panel

The STAT explored a wide range of model designs and parameterizations and conducted suites of sensitivity analyzes throughout the 2011 STAR panel (see STAR 2011 for complete details). Resultant changes from the preliminary model (pre-STAR model 'Ld') to the final STAR base model ('X5') were as follows:

1) Smooth the ageing error vector for CA-2007 (STAR request 'B');
2) Minor correction to the summer 2008 acoustic biomass estimate (changed from 783,740 mt to 801,000 mt) (STAR request 'F');
3) Set the Initial-F parameters to 0 (STAR request 'N');
4) Acoustic survey q fixed to equal 1(STAR request 'X.5')

The first two changes (requests 'B' and 'F') were trivial corrections to model inputs and had no detectable effect on population estimates or model fits. The third change (request N), which resulted in upward scaling of population estimates, was discussed above in the section 'Selection of first modeled year and treatment of initial population' and in the STAR (2011) report. The fourth change (request 'X5') was incorporated to provide scaling stability to the final base model (STAR 2011).

Base Model Results

Parameter estimates and errors

Base model parameter estimates and standard errors are presented in Table 8. Most model parameters were within a reasonable range of bounds and had relatively small standard errors.

Growth

Modeled length-at-age and is displayed in Figure 16. Length at age 0.5 was estimated to be 11.2 cm SL, L_∞ was 24.0 cm, and the growth coefficient K was 0.399. Standard deviations for the growth parameters are provided in Table 8. Fits to fleet and survey conditional age-at-length data are shown in Figures 17a-d. Most conditional age-at-length compositions fit reasonably well, with the exceptions of MexCal_S1 in 1993 and 2002-2003 (Figure 17a), and PacNW in 2008-2010 (Figure 17c).

Selectivity estimates and fits to composition data

Length selectivity estimates for each fleet and time period are displayed in Figure 18a. Implied age selectivities (product of length selectivity and the age-length key) for each fleet and period are shown in Figure 18b. The MexCal fleets (S1 & S2) captured progressively smaller fish between the early and latter time blocks (Figure 18a).

Model fits to fleet length frequencies, implied age-frequencies, Pearson residuals, and observed and effective samples sizes, are displayed in Figures 19-24. 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 data and fleets. The PacNW fleet displayed notable residuals patterns for strong year classes (1997, 1998, 2003) moving through the fishery (Figure 23c,d).

Length selectivity estimates for each survey are displayed in Figure 25a, and implied age selectivities are shown in Figure 25b. Model fits to Aerial and Acoustic survey compositions, Pearson residuals, and observed and effective samples sizes, are displayed in Figures 26-28. A clear trend is evident in the residual pattern for the Aerial length data (Figure 26a,d). Fits to the Acoustic-trawl survey length and age data are likewise less than optimal (Figures 27-28).

Fits to indices

Model fits to the DEPM, TEP, Aerial and Acoustic survey time series are displayed in Figure 29a-d. Model expected values all fit within error bounds of the observed data. The acoustic survey series showed evidence for under-fitting at the start (2006) and over-fitting at the end (2010-2011) (Figure 29d). Runs in residuals for the acoustic survey are difficult to interpret due to the abbreviated nature of this time series. Catchability coefficient (q) for the DEPM series of female SSB was estimated at 0.18. The TEP series was best fit with q=0.49. The Aerial best fit with q=0.89.

Spawning stock biomass

Base model estimates of total SSB are presented in Tables 10-11 and Figure 31a. SSB increased throughout the 1990s, peaking at 1.13 mmt in 1999 (=Jan of calendar year 2000) and at 0.936 mmt in 2006. Virgin SSB was approximately 0.969 mmt.

Recruitment

Time series of recruit (age-0) abundance are provided in Tables 10-11 and Figure 31b. Virgin recruitment (R_0) was estimated at 6.2 billion age-0 fish. Recruitment increased rapidly through the mid-1990s, peaking at 15.4 billion fish in 1997, 14.9 billion in 1998, and 21.4 billion fish in 2003. The 2009 year-class was estimated to be 11.1 billion fish (Figure 31b).

Stock-recruitment relationship

The Ricker stock-recruitment relationship for the base model is displayed in Figure 32a. The estimate of steepness (h) was 2.96 for the base model (Table 8). Recruitment deviations (main period) were estimated from 1993 through 2008 (2009 Year Class). There was no evidence for trend in the recruitment deviations over time (Figure 32b). Recruitments for 2010 and 2011 were drawn from the stock-recruitment curve. Sigma-R was fixed at 0.622 in the final tuned model. Recruitment deviations and their asymptotic standard errors are shown in Figure 32b,c.

Stock biomass (ages 1+) for PFMC management

Stock biomass, used for setting management specifications, is defined as the sum of the biomass for ages 1 and older. Base model estimates of stock biomass are provided in Table 11 and displayed in Figure 33. Stock biomass increased rapidly through the 1990s, peaking at 1.45 mmt in 1999 and 1.27 mmt in 2006. Stock biomass was estimated at 988,385 mt as of July 1, 2011.

Harvest and exploitation rates

Harvest rates (catch per selected biomass, 'continuous-*F*') by fleet are displayed in Figure 30a. *F* estimates were all within a plausible range of values, and most were less than 0.6 in any given season.

Exploitation rates (calendar year catch/total mid-year biomass, ages 0+) for the U.S. and total fisheries are displayed in Figure 30b. The U.S. exploitation rate trended upwards from 3% in 1993 to approximately 10% in 2007. Total exploitation rate has trended upward since 2001, reaching 14.5% in 2010.

Uncertainty and Sensitivity Analyses

Profile on recruitment variance (σ_R)

The base model (X5) had been tuned with σ_R = 0.622, a value considered by some to be low for a small pelagic species. Sensitivity of base model to recruitment variability was examined by profiling across σ_R values ranging from 0.4 to 1.0 (STAR 2011, requests Y.4-Y.6). Biomass estimates for the range of σ_R values are displayed in Figure 34. Biomass scaling did not differ greatly between the base case and runs having higher σ_R values. The model with σ_R = 0.4 scaled appreciably lower than the others (Figure 34).

Sensitivity to survey *q* and data weighting assumptions

During the 2011 STAR, the panel requested a series of model runs to address two issues: 1) scale of the biomass in the assessment, which was not well-determined, and 2) the weighting of length and conditional age-at-length data relative to the survey indices of abundance. Variants of STAR model N (all survey *q*'s estimated; default data weighting) were run by sequentially fixing *q*=1 for each of three indices (DEPM, Aerial, Acoustic), and applying the default versus Francis data weighting methods to each of the variants (STAR 2011, requests X.1-X.6). Biomass trajectories for these models are displayed in Figure 35. Survey *q* estimates for models N and X.1-X.6 are provided in Table 12.

The estimate of terminal year (2011) stock biomass was higher for model N (all *q*s estimated) than for models X.1-X.6. Biomass trends were similar for models N, X.1, X.3, and X.5, in which default data weightings were used, but biomass scaling differed widely among runs that fixed survey *q*=1. Biomass trajectories were similar across models using down-weighted composition data (Francis wtg; models X.2, X.4, X.6), but the trend differed from default weighting runs, in that the second biomass peak was higher than the first (Figure 35). The estimated q's for the aerial and acoustic surveys were most plausible for runs X.3 through X.6, but were implausibly high for runs that treated DEPM as absolute (q's ranged 2.32-4.74; Table 12).

Likelihood profile on M

Natural mortality (M) was profiled for the base model (X5, M=0.4) using values ranging from 0.25 yr^{-1} to 0.75 yr^{-1} in 0.125 yr^{-1} increments (STAR 2011, request Z.2). Model component likelihoods, terminal year (2011) stock biomass, and the 2010 exploitation rate are summarized in Table 13. Likelihood profiles for key model components (surveys, lengths, ages, and total) are displayed in Figure 36. The total likelihood, length likelihoods, and conditional length-at-age likelihoods all favored higher natural mortality rates than the base model. The survey likelihoods indicated overall better fits with M's equal to or lower than the base model (Figure 36). Results were consistent with the M profiles conducted for the 2007 and 2009 assessments (Hill et al. 2007, 2009).

Likelihood profile on acoustic survey q

Acoustic survey q was profiled for the base model (X5; q=1) using q values ranging from 0.25 to 2.00 in 0.25 increments (STAR 2011, request Z.3). Model component likelihoods, terminal year (2011) stock biomass, the 2010 exploitation rate, and q's for the DEPM, TEP, and Aerial surveys are summarized in Table 14. Likelihood profiles for key model components (surveys, lengths, ages, and total) are displayed in Figure 37. The profile on acoustic q indicated that the length compositions were not informative to the choice of q, but the conditional age-at-length data did favor q's in the range of 0.75-1.50 (Figure 37). The overall likelihood surface was quite flat, changing by only 2-3 units across the modeled range of q's (Figure 37).

Retrospective analysis

Retrospective analysis can provide another means of examining model properties and characterizing uncertainty. A retrospective analysis of the base model (X5) was performed, where data were incrementally removed from the end year back to 2007 (STAR 2011, request Z.4). Stock biomass and recruitment series from these analyses are displayed in Figure 38. The model displayed no systematic pattern of under- or over-estimation, however there was appreciable variability, with changes of up to 377,000 mt from one year to the next (e.g. 2010 to 2009 end years; Figure 38).

Prospective analysis

A prospective analysis was conducted over the first five years of the base model (1993-97; STAR 2011, request Z.5). Stock biomass and recruitment time series are displayed in Figure 39. The model showed only modest changes in early period biomass estimates, minimal changes in terminal year biomass estimates, and no systematic pattern was evident (Figure 39).

Historical analysis

Base model estimates of stock biomass and recruitment were compared to recent assessment models (Figures 40a,b). Full and updated models from Hill et al. (2007-2010) were included in the comparison, in addition to alternative models where aerial survey estimates (q fixed at 1) were either excluded or de-emphasized. Trends in biomass and recruitment were generally comparable among models, with some departure in scale and trajectory of the current base model (X5) for the final few years.

HARVEST CONTROL RULES

Harvest Guideline for 2012

Using results from the final base model ('X5'), the harvest guideline for the U.S. fishery in calendar year 2012 would be 109,409 mt. To calculate the HG for 2012, we used the harvest control rule defined in Amendment 8 of the Coastal Pelagic Species-Fishery Management Plan (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 guideline for sardine is calculated:

$$HG_{2012} = (BIOMASS_{2011} - CUTOFF) \bullet FRACTION \bullet DISTRIBUTION;$$

where HG_{2012} is the total U.S. (California, Oregon, and Washington) harvest guideline for 2012, $BIOMASS_{2011}$ is the estimated July 1, 2011 stock biomass (ages 1+) from the assessment (988,385 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 following formula has been used to determine FRACTION value:

$$FRACTION = 0.248649805(T^2) - 8.190043975(T) + 67.4558326;$$

where T is the running average sea-surface temperature at Scripps Pier, La Jolla, California during the three preceding seasons (July-June). Under Option J (PFMC 1998), F_{MSY} is constrained and ranges between 5% and 15%. Based on T values observed throughout the period covered by this stock assessment, the appropriate exploitation fraction has consistently been 15%; and this remains the case under current conditions (T_{2011} = 17.7 °C). U.S. harvest guidelines and catches since 2000 are displayed in Figure 1a.

OFL and ABC

The Magnuson-Stevens Reauthorization Act requires fishery managers to define an overfishing limit (OFL), allowable biological catch (ABC), and annual catch limit (ACLs) for species managed under federal FMPs. By definition, ABC and ACL must always be lower than the OFL based on uncertainty in the assessment approach. The PFMC's SSC recommended the '*P**' approach for buffering against scientific uncertainty when defining ABC, and this approach was adopted under Amendment 13 to the CPS-FMP.

The estimated biomass of 988,385 (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 results in a U.S. OFL of 170,689 mt for 2012. For Pacific sardine, the SSC has recommended that scientific uncertainty (σ) be set to the maximum of either (1) the CV of the biomass estimate for the most recent year or (2) a default value of 0.36, which was based on uncertainty across full sardine assessment models. Model CV for the terminal year biomass was equal to 0.187 (σ

=0.185); therefore scientific uncertainty (σ) was set to the default value of 0.36. The Amendment 13 ABC buffer depends on the probability of overfishing level chosen by the Council (P^*). Uncertainty buffers and ABCs associated with a range of discreet P^* values are presented in Table 15a. Table 15b provides complementary OFL and ABC values using an alternative estimate of F_{MSY} (0.18) that is independent of the SIO-SST environmental time series (see Hill 2011; Appendix 4 of this report).

RESEARCH AND DATA NEEDS

The following research recommendations are excerpted from 2011 STAR Panel Report:

A. Explore additional fishery-independent data sources for possible inclusion in the assessment, e.g. CDFO's mid-water trawl survey off Vancouver Island and the SWFSC's juvenile rockfish survey. Inclusion of a substantial new data source would likely require review during a Council-sponsored Methodology Panel.
B. Continue expansion of coast-wide sampling of adult fish for use when estimating parameters in the DEPM method and when computing biomass from the acoustic-trawl surveys. Pursue collaborative survey sampling in Mexican and Canadian waters.
C. Temperature-at-catch could provide insight into stock structure and the appropriate catch stream to use for assessments, because the southern subpopulation is thought to prefer warmer water. Conduct sensitivity tests to alternative assumptions regarding the fraction of the MexCal (in particular, Ensenada and Southern California) catch that comes from the northern subpopulation.
D. The assessment would benefit not only from data from Mexico and Canada, but also from joint assessment, which includes assessment team members from these countries.
E. Conduct additional studies on stock structure – otolith morphometry and microchemistry studies are potential tools for this purpose.
F. The relationship between environmental correlates and abundance should be examined. In particular, the relationship between environmental covariates and overall recruitment levels as well as recruitment deviations should be explored further.
G. Consider spatial models for Pacific sardine, which can be used to explore the implications of regional recruitment patterns and region-specific biological parameters. These models could be used to identify critical biological data gaps as well as better represent the latitudinal variation in size-at-age.
H. Explore models which consider a much longer time-period (e.g. 1931 onwards) to determine whether it is possible to model the entire period and determine whether this leads to a more informative assessment and to provide a broader context for evaluating changes in productivity.
L. Consider a model which explicitly models the sex-structure of the population and the catch.
M. Reconsider a model which has separate fleets for Mexico, California, Oregon-Washington and Canada.
N. Develop a relationship between egg production and age which accounts for the duration of spawning, batch fecundity, etc. by age.
O. Consider model configurations which use age-composition rather than length-composition and conditional age-at-length data given evidence for time- and spatially-varying growth.

P. Further explore methods to reduce between-reader ageing bias. In particular, consider comparisons among laboratories and assess whether the age-reading protocol can be improved to reduce among-ager variation.
Q. Reasons for the discrepancy between the observed and expected proportions of old animals in the length and age compositions should be explored further. Possible factors to consider in this investigation include ageing error / ageing bias and the way dome-shaped selectivity has been modeled.

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TABLES

Table 1. Sardine harvest guidelines and U.S. landings since the onset of federal management. Landings for 2011 are provisional.

Year	HG (mt)	Landings (mt)
2000	186,791	67,981
2001	134,737	75,800
2002	118,442	96,896
2003	110,908	71,922
2004	122,747	89,350
2005	136,179	86,463
2006	118,937	86,609
2007	152,564	127,788
2008	89,093	87,189
2009	66,932	67,084
2010	72,039	66,920
2011	50,526	*43,695*

Table 2. Pacific sardine landings (mt) for major fishing regions off northern Baja California (Mexico), the United States, and Canada, calendar years 1981 to 2010[\1].

Calendar year	ENS	SCA_Inc	SCA_Dir	CCA	OR	WA	BC	Grand Total
1981	0.0	5.8	0.0	0.0	0.0	0.0	0.0	5.8
1982	0.0	131.1	0.0	0.0	0.0	0.0	0.0	131.1
1983	273.6	352.4	0.0	0.0	0.0	0.0	0.0	626.0
1984	0.0	170.6	0.0	63.9	0.0	0.0	0.0	234.5
1985	3,722.3	558.6	0.0	34.4	0.0	0.0	0.0	4,315.2
1986	242.6	721.1	330.1	112.9	0.0	0.0	0.0	1,406.7
1987	2,431.6	1,691.8	363.9	38.9	0.0	0.0	0.0	4,526.2
1988	2,034.9	2,790.3	984.3	10.2	0.0	0.0	0.0	5,819.7
1989	6,224.2	2,605.1	838.2	237.7	0.0	0.0	0.0	9,905.2
1990	11,375.3	1,266.1	1,241.9	306.6	0.0	0.0	0.0	14,189.9
1991	31,391.8	1,174.9	5,599.1	975.7	0.0	0.0	0.0	39,141.5
1992	34,568.2	0.0	16,061.0	3,127.6	3.9	0.0	0.0	53,760.7
1993	32,044.9	0.0	15,487.7	704.5	0.2	0.0	0.0	48,237.3
1994	20,877.0	0.0	10,345.9	2,359.0	0.0	0.0	0.0	33,581.9
1995	35,396.2	0.0	36,561.4	4,927.9	0.0	0.0	22.7	76,908.1
1996	39,064.7	0.0	25,170.9	8,885.1	0.0	0.0	0.0	73,120.7
1997	68,439.0	0.0	32,836.8	13,360.8	0.0	0.0	70.8	114,707.3
1998	47,812.2	0.0	31,974.6	9,080.8	1.0	0.0	488.1	89,356.7
1999	58,569.4	0.0	42,863.0	13,884.0	775.1	0.0	24.5	116,115.9
2000	67,845.3	0.0	46,834.8	11,367.3	9,529.0	4,765.4	1,721.3	142,063.1
2001	46,071.3	0.0	47,661.7	7,241.4	12,780.0	10,837.0	1,265.9	125,857.3
2002	46,845.3	0.0	49,365.9	14,077.8	22,711.0	15,212.1	739.4	148,951.5
2003	41,341.8	0.0	30,289.1	7,448.3	25,258.0	11,603.9	977.7	116,918.7
2004	41,896.9	0.0	32,393.4	15,308.3	36,111.8	8,799.4	4,438.0	138,947.9
2005	55,322.5	0.0	30,252.6	7,940.1	45,008.1	6,929.0	3,231.8	148,684.2
2006	57,236.9	0.0	33,285.8	17,743.1	35,648.2	4,099.0	1,575.4	149,588.4
2007	36,846.8	0.0	46,198.6	34,782.1	42,052.3	4,662.5	1,522.3	166,064.6
2008	66,866.1	0.0	31,089.3	26,711.0	22,939.9	6,435.2	10,425.0	164,466.4
2009	55,911.2	0.0	12,561.1	25,015.0	21,481.6	8,025.2	15,334.3	138,328.4
2010	56,820.9	0.0	29,381.5	4,305.9	20,852.6	12,381.1	22,223.1	145,965.0

[\1] Southern and central California landings (incidental and directed) are from CDFG's monthly 'Wetfish' tables, which included bucket sampling of mixed loads to account for incidental catches not included on landing receipts. OR and WA landings were obtained from the PacFIN database. British Columbia landings were provided by the Canada Department of Fisheries and Oceans. Ensenada (Mexico) landings were obtained from INAPESCA annual reports, INAPESCA scientists, and CONAPESCA (2005-2010).

Table 3. Pacific sardine landings (mt) and corresponding number of fish sampled (available length and/or age data) for major fishing regions off northern Baja California (Mexico), the United States, and Canada, by model year and season, 1981 to 2011[\1]. Base model begins 1993-1.

Model year	Model sem	ENS mt	ENS N_len	ENS N_age	SCA Inc mt	SCA Inc N_fish	SCA Dir mt	SCA Dir N_fish	CCA mt	CCA N_fish	OR mt	OR N_fish	WA mt	WA N_fish	BC mt	BC N_len
1981	1	0	0	0	6	179	0	0	0	0	0	0	0	0	0	0
1981	2	0	0	0	57	204	0	0	0	0	0	0	0	0	0	0
1982	1	0	0	0	74	361	0	0	0	0	0	0	0	0	0	0
1982	2	150	0	0	263	580	0	0	0	0	0	0	0	0	0	0
1983	1	124	0	0	89	411	0	0	0	0	0	0	0	0	0	0
1983	2	0	0	0	159	188	0	0	0	0	0	0	0	0	0	0
1984	1	0	0	0	12	0	0	0	64	0	0	0	0	0	0	0
1984	2	3,174	0	0	312	214	0	0	10	0	0	0	0	0	0	0
1985	1	548	0	0	247	371	0	0	24	0	0	0	0	0	0	0
1985	2	99	0	0	530	482	325	297	65	0	0	0	0	0	0	0
1986	1	143	0	0	191	447	5	14	48	0	0	0	0	0	0	0
1986	2	975	0	0	918	767	364	289	22	0	0	0	0	0	0	0
1987	1	1,457	0	0	773	728	0	0	17	0	0	0	0	0	0	0
1987	2	620	0	0	2,028	1,365	984	762	8	0	0	0	0	0	0	0
1988	1	1,415	0	0	763	562	0	0	3	0	0	0	0	0	0	0
1988	2	461	34	34	1,081	810	838	262	235	0	0	0	0	0	0	0
1989	1	5,763	97	97	1,524	1,018	0	0	3	0	0	0	0	0	0	0
1989	2	5,900	73	69	645	556	1,242	588	245	0	0	0	0	0	0	0
1990	1	5,475	395	94	621	350	0	0	62	92	0	0	0	0	0	0
1990	2	9,271	1,216	303	601	441	4,481	1,514	90	113	0	0	0	0	0	0
1991	1	22,121	1,073	242	574	0	1,118	412	885	495	0	0	0	0	0	0
1991	2	3,327	469	139	0	0	5,884	912	1,113	221	0	0	0	0	0	0
1992	1	31,242	1,195	356	0	0	10,177	2,098	2,014	0	4	0	0	0	0	0
1992	2	18,648	853	239	0	0	11,759	1,585	369	0	0	0	0	0	0	0
1993	1	13,397	2,068	124	0	0	3,729	363	335	0	0	0	0	0	0	0
1993	2	5,712	816	222	0	0	7,738	785	629	0	0	0	0	0	0	0
1994	1	15,165	913	264	0	0	2,607	644	1,730	0	0	0	0	0	0	0
1994	2	18,227	958	230	0	0	28,122	3,024	443	0	0	0	0	0	0	0
1995	1	17,169	1,283	317	0	0	8,439	863	4,485	0	0	0	0	0	23	0
1995	2	15,666	665	183	0	0	14,409	1,492	2,486	271	0	0	0	0	0	0
1996	1	23,399	1,065	320	0	0	10,762	837	6,399	2,182	0	0	0	0	0	0
1996	2	13,498	534	158	0	0	11,524	1,441	343	49	0	0	0	0	44	0
1997	1	54,941	1,250	354	0	0	21,313	1,325	13,018	1,374	0	0	0	0	27	0
1997	2	20,239	458	131	0	0	19,094	1,482	2,747	124	1	0	0	0	0	0
1998	1	27,573	1,034	189	0	0	12,881	1,315	6,334	1,286	0	0	0	0	488	175
1998	2	34,760	1,461	348	0	0	24,050	1,514	7,741	348	50	31	0	0	24	165
1999	1	23,810	1,014	265	0	0	18,813	1,215	6,143	0	725	76	0	0	0	290
1999	2	33,933	1,156	288	0	0	34,119	1,457	1,285	0	205	106	62	0	162	0

Table 3. (cont'd). Pacific sardine landings (mt) and corresponding number of fish sampled (available length and/or age data) for major fishing regions off northern Baja California (Mexico), the United States, and Canada, by model year and season, 1981 to 2011[\1]. Base model begins 1993-1

Model year	Model Sem	ENS mt	ENS N_len	ENS N_age	SCA Inc mt	SCA Inc N_fish	SCA Dir mt	SCA Dir N_fish	CCA mt	CCA N_fish	OR mt	OR N_fish	WA mt	WA N_fish	BC mt	BC N_len
2000	1	33,912	1,281	298	0	0	12,716	1,405	10,082	0	9,324	796	4,703	899	1,559	2,909
2000	2	16,545	1,145	214	0	0	29,343	1,699	774	92	2,288	168	49	100	0	648
2001	1	29,526	720	145	0	0	18,318	1,670	6,467	690	10,492	702	10,789	1,350	1,265	1,206
2001	2	17,422	930	217	0	0	26,621	1,621	1,575	302	2,724	250	412	419	1	300
2002	1	29,424	891	55	0	0	22,745	1,153	12,503	758	19,987	1,249	14,800	3,113	739	9,323
2002	2	15,514	460	0	0	0	20,380	1,739	5,086	471	503	25	94	186	0	300
2003	1	25,827	1,036	0	0	0	9,909	1,511	2,363	195	24,755	943	11,510	2,726	977	9,227
2003	2	11,213	5,028	0	0	0	15,232	1,669	2,146	197	2,204	124	235	298	180	0
2004	1	30,684	5,113	0	0	0	17,161	1,715	13,163	563	33,908	872	8,564	1,578	4,258	6,689
2004	2	17,323	4,191	0	0	0	15,419	1,756	115	23	692	50	324	147	0	0
2005	1	38,000	2,885	0	0	0	14,834	1,810	7,825	587	44,316	349	6,605	1,348	3,231	6,451
2005	2	17,601	1,336	0	0	0	17,158	3,322	2,033	1,530	102	0	0	0	0	0
2006	1	39,636	1,154	0	0	0	16,128	1,517	15,711	1,446	35,547	300	4,099	375	1,575	0
2006	2	13,981	553	0	0	0	26,344	1,789	6,013	1,138	0	75	0	0	0	0
2007	1	22,865	1,138	0	0	0	19,855	1,802	28,769	1,701	42,052	1,999	4,663	250	1,522	2,336
2007	2	23,488	1,080	0	0	0	24,127	1,318	2,515	370	0	0	0	0	0	0
2008	1	43,378	2,074	0	0	0	6,962	637	24,196	746	22,940	2,000	6,435	360	10,425	22,894
2008	2	25,783	1,251	0	0	0	9,251	497	11,080	497	0	0	0	0	0	0
2009	1	30,128	0	0	0	0	3,310	325	13,935	575	21,482	2,050	8,025	300	15,334	28,527
2009	2	12,989	0	0	0	0	19,457	1,550	2,909	925	437	84	511	50	0	200
2010	1	43,832	0	0	0	0	9,925	625	1,397	325	20,416	1,599	11,870	200	22,223	28,689
2010	2	12,989	0	0	0	0	12,515	549	2,643	275	0	0	0	0	0	0
2011	1	43,832	0	0	0	0	3,173	300	9,070	301	12,779	0	11,252	0	21,801	0

[\1] Southern and central California landings (incidental and directed) are from CDFG's monthly 'Wetfish' tables, which included bucket sampling of mixed loads to account for incidental catches not included on landing receipts. OR and WA landings were obtained from the PacFIN database. British Columbia landings were provided by the Canada Department of Fisheries and Oceans. Ensenada (Mexico) landings were obtained from INAPESCA annual reports, INAPESCA scientists, and CONAPESCA (2005-2010).

Table 4. Pacific sardine landings (mt) and effective sample sizes (ESS) by model year, semester, and fishery for the base model. The base model begins in 1993-1.

Model year	Model sem	MexCal mt	MexCal ESS	PacNW mt	PacNW ESS
1981	1	5.8	7.16	0.0	0.00
1981	2	57.2	9.52	0.0	0.00
1982	1	73.9	14.44	0.0	0.00
1982	2	412.8	23.32	0.0	0.00
1983	1	213.2	16.84	0.0	0.00
1983	2	159.1	7.52	0.0	0.00
1984	1	75.4	0.00	0.0	0.00
1984	2	3,495.8	8.64	0.0	0.00
1985	1	819.4	15.00	0.0	0.00
1985	2	1,019.0	33.40	0.0	0.00
1986	1	387.7	20.20	0.0	0.00
1986	2	2,278.9	44.32	0.0	0.00
1987	1	2,247.3	29.40	0.0	0.00
1987	2	3,639.8	87.72	0.0	0.00
1988	1	2,179.9	22.76	0.0	0.00
1988	2	2,614.8	46.80	0.0	0.00
1989	1	7,290.5	12.65	0.0	0.00
1989	2	8,031.5	15.49	0.0	0.00
1990	1	6,158.4	16.11	0.0	0.00
1990	2	14,443.5	64.03	0.0	0.00
1991	1	24,698.0	42.48	0.0	0.00
1991	2	10,323.5	64.38	0.0	0.00
1992	1	43,433.3	61.18	3.9	0.00
1992	2	30,776.4	46.21	0.2	0.00
1993	1	17,460.8	68.60	0.0	0.00
1993	2	14,078.9	75.58	0.0	0.00
1994	1	19,503.0	34.15	0.0	0.00
1994	2	46,792.1	184.41	0.0	0.00
1995	1	30,093.3	54.40	22.7	0.00
1995	2	32,561.2	50.12	0.0	0.00
1996	1	40,559.5	76.02	0.0	0.00
1996	2	25,364.6	39.90	43.5	0.00

Model year	Model sem	MexCal mt	MexCal ESS	PacNW Mt	PacNW ESS
1997	1	89,272.0	72.64	27.2	0.00
1997	2	42,079.7	42.44	0.8	0.00
1998	1	46,787.9	67.85	488.5	0.00
1998	2	66,550.5	66.15	74.4	0.00
1999	1	48,765.8	44.67	725.1	3.04
1999	2	69,337.6	52.39	429.6	4.24
2000	1	56,709.8	53.24	15,586.2	63.93
2000	2	46,662.7	62.74	2,336.6	10.72
2001	1	54,311.7	58.90	22,546.0	78.15
2001	2	45,617.1	62.32	3,137.2	26.75
2002	1	64,671.9	73.64	35,525.7	172.79
2002	2	40,979.6	62.30	597.3	8.44
2003	1	38,099.6	50.43	37,242.3	145.33
2003	2	28,590.6	124.63	2,618.4	16.88
2004	1	61,008.2	149.06	46,730.8	95.17
2004	2	32,857.3	122.39	1,016.3	7.88
2005	1	60,658.0	108.68	54,152.6	67.68
2005	2	36,791.2	77.23	101.7	0.00
2006	1	71,474.7	78.73	41,220.9	27.00
2006	2	46,338.3	91.44	0.0	3.00
2007	1	71,489.2	109.86	48,237.1	87.86
2007	2	50,130.3	56.13	0.0	0.00
2008	1	74,536.0	71.40	39,800.1	129.64
2008	2	46,113.9	45.51	0.0	0.00
2009	1	47,373.4	36.00	44,841.2	159.41
2009	2	35,354.6	99.08	948.1	5.36
2010	1	55,153.7	38.00	54,508.8	159.59
2010	2	28,147.9	32.96	0.0	0.00
2011	1	56,074.7	24.04	45,832.8	73.60
2011	2	12,989.1	0.00	0.0	0.00

Table 5. Fishery-independent indices of Pacific sardine relative abundance. Complete details regarding estimation of DEPM and TEP values can be found in Tables 6 and 7. 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($\log_e(1+CV^2)$). The current base model begins in 1993.

Model year	DEPM	S.E. ln(index)	TEP	S.E. ln(index)	TEP_full	S.E. ln(index)	Aerial	S.E. ln(index)	Acoustic	S.E. ln(index)
1981	---	---	---	---	---	---	---	---	---	---
1982	---	---	---	---	---	---	---	---	---	---
1983	---	---	---	---	---	---	---	---	---	---
1984	---	---	---	---	---	---	---	---	---	---
1985	---	---	---	---	---	---	---	---	---	---
1986	4,061	0.60	---	---	11,220	0.73	---	---	---	---
1987-1	8,661	0.56	---	---	24,883	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	---	---	369,775	0.33	369,775	0.33	---	---	---	---
1998	---	---	332,177	0.34	332,177	0.34	---	---	---	---
1999	---	---	1,252,539	0.39	1,252,539	0.39	---	---	---	---
2000	---	---	931,377	0.38	931,377	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	---	---	1,947,063	0.30
2006	198,404	0.30	---	---	306,297	0.26	---	---	---	---
2007	66,395	0.27			128,118	0.21	---	---	751,075	0.09
2008-1	---	---	---	---	---	---	---	---	801,000	0.30
2008-2	99,162	0.24	---	---	162,188	0.22	---	---	---	---
2009	58,447	0.40	---	---	97,838	0.39	1,236,911	0.90	357,006	0.41
2010	219,386	0.27	---	---	364,798	0.26	173,390	0.40	493,672	0.30
2011	---	---	---	---	---	---	201,888	0.29	---	---

Table 6. The 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); s. biomass, female spawning biomass, total egg production (TEP) and sea surface temperature for 1986, 1987, 1994, 2004, 2005 and 2007-2011.

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 (0.44)	18111 (0.39)		46685.4		
		2	0.22(0.42)		14.55	16.20	26.65	244311	66345 (0.58)	40336 (0.58)		53748.42		
		whole	0.36(0.29)		16.08	18.07	31.49	271773	108280 (0.46)	62131 (0.46)	58447 (0.42)	97838.28	13.7	13.9
2011	2010	1	5.57(0.24)	0.51(0.14)	19.03	24.26	41.16	41878	192332 (0.31)	113340 (0.30)		233260.5		
		2	0.487(0.33)		11.40	14.67	25.04	272603	181016 (0.48)	106046 (0.49)		132757.7		
		whole	1.16(0.26)		14.85	19.04	32.40	314481	383286 (0.32)	225155 (0.32)	219386 (0.28)	364798.0	13.5	13.6

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 ≥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

6. Within southern and northern area, the survey area was stratified as Region 1 (eggs/0.05m2>0 with embedded zero) and Region 2 (zero eggs)

Table 7. Pacific sardine female adult parameters for surveys conducted in the standard daily egg production method (DEPM) sampling area off California (1994 includes females from off Mexico).

		1994	1997	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011
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	8-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	03/23-04/25
N collections with mature females		37	4	2	6	16	14	7	14	12	29	17	30
N collection within Region 1		19	4	2	6	16	6	2	8	4	15	3	14
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	13.12
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	0.587
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	127.59
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	119.38
Average batch fecundity[a] (mature females, oocytes estimated)	**F**	24283	42002	22456	54403	55711	17662	18474	21760	29802	29790	39304	38369
Relative batch fecundity (oocytes/g)		294	329	284	342	334	270	274	267	292	265	303	301
N mature females analyzed		583	77	9	23	290	175	86	203	187	467	313	244
N active mature females		327	77	9	23	290	148	72	187	177	463	310	244
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	0.1078
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	0.1078
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	19.04

[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), and 2010 used $F_b = 5136 + 287.37W_{of} + e$ (Lo et al. 2010).
[b] Mature females include females that are active and those that are postbreeding (incapable of further spawning this season). S_1 was used for years prior to 2009 and S_{12} was used staring 2009.
[c] Active mature females are capable of spawning and have ovaries containing oocytes with yolk or postovulatory follicles less than 60 hours old.

Table 8. Base model parameters and asymptotic standard deviations.

Parameter	Phase	Min	Max	Initial Value	Final Value	Std Dev
NatM_p_1_Fem_GP_1	-3	0.3	0.7	0.4	0.400000	_
L_at_Amin_Fem_GP_1	3	3	15	10	11.205900	0.176972
L_at_Amax_Fem_GP_1	3	20	30	25	23.956000	0.206533
VonBert_K_Fem_GP_1	3	0.05	0.99	0.40	0.398582	0.019772
CV_young_Fem_GP_1	3	0.05	0.3	0.14	0.150130	0.005995
CV_old_Fem_GP_1	3	0.01	0.1	0.05	0.054534	0.003000
Wtlen_1_Fem	-3	-3	3	1.68384E-05	0.000017	_
Wtlen_2_Fem	-3	-3	5	2.94825	2.948250	_
Mat50%_Fem	-3	9	19	15.88	15.880000	_
Mat_slope_Fem	-3	-20	3	-0.90461	-0.904610	_
Eggs/kg_inter_Fem	-3	0	10	1.00	1.000000	_
Eggs/kg_slope_wt_Fem	-3	-1	5	0.00	0.000000	_
SR_LN(R0)	1	3	25	16.00	15.644400	0.127072
SR_Ricker	6	0.2	4	2.50	2.959450	0.661916
SR_sigmaR	-3	0	2	0.622	0.622000	_
SR_R1_offset	2	-15	15	0.00	-1.026230	0.206755
Early_InitAge_6	_	_	_	_	-0.711711	0.476840
Early_InitAge_5	_	_	_	_	-0.775153	0.462862
Early_InitAge_4	_	_	_	_	-0.756781	0.458298
Early_InitAge_3	_	_	_	_	0.053468	0.365529
Early_InitAge_2	_	_	_	_	0.728308	0.253221
Early_InitAge_1	_	_	_	_	1.427700	0.202966
Main_RecrDev_1993	_	_	_	_	-0.039491	0.347683
Main_RecrDev_1994	_	_	_	_	-0.664052	0.250149
Main_RecrDev_1995	_	_	_	_	-0.104942	0.168600
Main_RecrDev_1996	_	_	_	_	0.830296	0.126283
Main_RecrDev_1997	_	_	_	_	0.751775	0.113416
Main_RecrDev_1998	_	_	_	_	-0.366219	0.157222
Main_RecrDev_1999	_	_	_	_	-0.164342	0.259925
Main_RecrDev_2000	_	_	_	_	0.371005	0.233258
Main_RecrDev_2001	_	_	_	_	-1.397970	0.185927
Main_RecrDev_2002	_	_	_	_	0.943127	0.104668
Main_RecrDev_2003	_	_	_	_	-0.409594	0.216045
Main_RecrDev_2004	_	_	_	_	0.496969	0.117325
Main_RecrDev_2005	_	_	_	_	-0.323344	0.146036
Main_RecrDev_2006	_	_	_	_	0.267517	0.214102
Main_RecrDev_2007	_	_	_	_	-0.636362	0.252510
Main_RecrDev_2008	_	_	_	_	0.445624	0.212131
InitF_1MexCal_S1	-1	0	4	0.00	0.000000	_
InitF_2MexCal_S2	-1	0	4	0.00	0.000000	_
InitF_3PacNW	-1	0	4	0.00	0.000000	_
Q_base_4_DEPM	5	-3	3	-1.39	-1.727120	0.284961
Q_base_5_TEP	5	-3	3	-0.69	-0.695249	0.239106
Q_base_7_Aerial	5	-3	3	0.00	-0.114855	0.462752
Q_base_8_Acoustic	-5	-3	3	0.00	0.000000	_

Table 8 (cont'd). Base model parameters and asymptotic standard deviations.

Parameter	Phase	Min	Max	Initial Value	Final Value	Std Dev
SizeSel_1P_1_MexCal_S1	4	10	28	18.00	18.997800	0.344970
SizeSel_1P_2_MexCal_S1	4	-5	3	3.00	-3.362570	1.579730
SizeSel_1P_3_MexCal_S1	4	-1	9	2.50	2.376110	0.138967
SizeSel_1P_4_MexCal_S1	4	-1	9	4.00	1.056540	0.391492
SizeSel_1P_5_MexCal_S1	-4	-10	10	-10.00	-10.000000	_
SizeSel_1P_6_MexCal_S1	4	-10	10	10.00	-5.566430	4.552130
SizeSel_1P_1_MexCal_S1_BLK1repl_1999	4	10	28	18.00	16.831400	0.125793
SizeSel_1P_2_MexCal_S1_BLK1repl_1999	-4	-5	3	-5.00	-5.000000	_
SizeSel_1P_3_MexCal_S1_BLK1repl_1999	4	-1	9	2.50	2.121320	0.075526
SizeSel_1P_4_MexCal_S1_BLK1repl_1999	4	-1	9	4.00	1.552330	0.124518
SizeSel_1P_5_MexCal_S1_BLK1repl_1999	-4	-10	10	-10.00	-10.000000	_
SizeSel_1P_6_MexCal_S1_BLK1repl_1999	4	-10	10	10.00	-3.903470	0.401022
SizeSel_2P_1_MexCal_S2	4	10	28	18.00	16.503800	0.231807
SizeSel_2P_2_MexCal_S2	-4	-5	3	-4.90	-4.900000	_
SizeSel_2P_3_MexCal_S2	4	-1	9	2.50	1.820640	0.143881
SizeSel_2P_4_MexCal_S2	4	-1	9	4.00	2.374640	0.233013
SizeSel_2P_5_MexCal_S2	-4	-10	10	-10.00	-10.000000	_
SizeSel_2P_6_MexCal_S2	4	-10	10	10.00	-2.693700	0.721403
SizeSel_2P_1_MexCal_S2_BLK1repl_1999	4	10	28	18.00	15.217400	0.145741
SizeSel_2P_2_MexCal_S2_BLK1repl_1999	-4	-5	3	-5.00	-5.000000	_
SizeSel_2P_3_MexCal_S2_BLK1repl_1999	4	-1	9	2.50	1.651470	0.115971
SizeSel_2P_4_MexCal_S2_BLK1repl_1999	4	-1	9	4.00	2.240940	0.117707
SizeSel_2P_5_MexCal_S2_BLK1repl_1999	-4	-10	10	-10.00	-10.000000	_
SizeSel_2P_6_MexCal_S2_BLK1repl_1999	4	-10	10	10.00	-3.647030	0.389847
SizeSel_3P_1_PacNW	4	10	28	18.00	18.623100	0.175019
SizeSel_3P_2_PacNW	4	1	16	4.00	2.181730	0.203663
SizeSel_7P_1_Aerial	4	10	28	18.00	20.974100	0.458331
SizeSel_7P_2_Aerial	4	-5	3	3.00	-4.909180	2.734450
SizeSel_7P_3_Aerial	4	-1	9	2.50	0.889258	0.477407
SizeSel_7P_4_Aerial	4	-1	9	4.00	0.228393	0.924095
SizeSel_7P_5_Aerial	-4	-10	10	-10.00	-10.000000	_
SizeSel_7P_6_Aerial	4	-10	10	10.00	-3.341490	1.915570
SizeSel_8P_1_Acoustic	4	10	28	18.00	17.452300	0.448059
SizeSel_8P_2_Acoustic	-4	-5	3	3.00	3.000000	_
SizeSel_8P_3_Acoustic	4	-1	9	2.50	0.219768	0.630375
SizeSel_8P_4_Acoustic	-4	-1	9	4.00	4.000000	_
SizeSel_8P_5_Acoustic	-4	-10	10	-10.00	-10.000000	_
SizeSel_8P_6_Acoustic	-4	-10	10	10.00	10.000000	_

Table 9. Likelihood components and input variance adjustments for the base model.

COMPONENT	-log(L)	MexCal_S1	MexCal_S2	PacNW	DEPM	TEP	Aerial	Acoustic
Catch	2.98E-10	1.50E-15	1.38E-15	2.98E-10	---	---	---	---
Survey	-1.31068	---	---	---	0.372788	-0.0280109	0.0325582	-1.68802
Length comp	1060.54	399.058	318.83	233.857	---	---	19.1359	89.6555
Age comp	712.701	267.064	231.061	182.407	---	---	0.000	32.1695
Recruitment	11.0596							
Parm softbounds	0.00990076							
TOTAL	1783							

INPUT VARIANCE ADJUSTMENTS	MexCal_S1	MexCal_S2	PacNW	DEPM	TEP	Aerial	Acoustic
Index_extra_CV	---	---	---	0.377	0.288	0.274	0.171
effN_mult_Lencomp	2.003	1.882	0.64	---	---	0.445	2.416
effN_mult_Agecomp	0.8	0.8	0.25	---	---	---	0.25

Table 10. Derived SSB (mt) and recruits (year-class abundance, billions of age-0 fish) for the base model. SSB estimates are calculated at the beginning of Season 2 of each model year, e.g. the 2011 value is SSB January 2012. Recruits are age-0 fish calculated at the beginning of each model year (July).

Model year	SSB (mt)	SSB Std Dev	Year class abundance (billions)	Recruits Std Dev
Virgin	968,740	125,630	6.227	0.791
1993	425,720	84,036	2.232	0.563
1994	590,020	108,710	11.904	1.671
1995	753,910	132,160	5.217	0.850
1996	839,030	140,980	7.067	1.068
1997	816,720	138,010	15.450	2.020
1998	941,340	146,640	14.884	1.689
1999	1,128,200	161,320	3.833	0.555
2000	1,099,300	156,590	3.176	0.441
2001	910,030	134,710	5.774	0.611
2002	717,380	112,480	1.453	0.280
2003	559,170	93,958	21.444	2.198
2004	683,570	103,390	7.007	0.927
2005	828,760	120,630	14.502	1.573
2006	936,130	132,590	4.968	0.714
2007	915,230	134,720	7.299	0.987
2008	809,350	128,620	3.081	0.584
2009	675,810	119,320	11.107	2.028
2010	642,830	124,630	---	---
2011	720,420	134,540	---	---

Table 11. Pacific sardine biomass and population numbers-at-age (1,000s) by model year and semester for the base model.

		BIOMASS (mt)			POPULATION NUMBERS-AT-AGE (1,000s of fish)										
Model year	Sem	Total (0+)	Stock (Age 1+)	SSB	0 (R)	1	2	3	4	5	6	7	8	9	10+
VIRG	1	1,221,710	1,160,880		6,227,090	4,174,140	2,798,010	1,875,560	1,257,230	842,745	564,909	378,670	253,830	170,147	345,951
VIRG	2	1,204,900	1,091,000	968,738	5,098,310	3,417,500	2,290,820	1,535,580	1,029,330	689,981	462,508	310,028	207,818	139,305	283,241
INIT	1	437,807	416,007		2,231,510	1,495,830	1,002,680	672,118	450,534	302,002	202,438	135,698	90,961	60,973	123,974
INIT	2	431,782	390,967	347,153	1,827,010	1,224,680	820,927	550,284	368,866	247,259	165,742	111,100	74,473	49,921	101,501
1993	1	636,749	556,488		8,215,490	5,507,000	1,880,430	658,056	201,122	135,695	99,357	135,698	90,961	60,973	123,974
1993	2	705,515	555,274	425,724	6,725,220	4,432,750	1,466,180	511,248	158,561	108,499	80,147	109,995	73,928	49,630	101,060
1994	1	857,328	741,032		11,903,900	5,468,340	3,526,510	1,169,150	411,659	128,486	88,203	65,259	89,637	60,273	122,911
1994	2	951,388	733,686	590,016	9,745,020	4,422,540	2,787,330	921,696	327,980	103,415	71,445	53,045	73,001	49,139	100,315
1995	1	1,021,880	970,915		5,216,830	7,838,350	3,363,010	2,132,290	722,954	261,490	83,136	57,672	42,911	59,123	121,185
1995	2	1,053,020	957,615	753,914	4,270,610	6,324,070	2,639,760	1,668,510	572,906	209,753	67,196	46,810	34,909	48,160	98,841
1996	1	1,100,960	1,031,920		7,066,960	3,459,990	4,956,230	2,076,150	1,331,850	461,741	169,885	54,556	38,053	28,398	119,667
1996	2	1,091,820	962,588	839,033	5,785,000	2,783,620	3,858,690	1,610,430	1,048,810	368,935	136,976	44,209	30,920	23,111	97,537
1997	1	1,209,670	1,058,730		15,449,900	4,692,820	2,192,960	3,049,340	1,289,310	846,837	299,177	111,315	35,967	25,171	98,280
1997	2	1,211,710	929,243	816,715	12,644,300	3,678,870	1,584,830	2,183,570	958,478	652,626	235,811	88,835	28,899	20,302	79,597
1998	1	1,366,710	1,221,290		14,884,200	10,192,700	2,823,250	1,222,630	1,721,860	766,688	525,842	190,686	71,970	23,437	81,110
1998	2	1,448,270	1,176,090	941,344	12,183,800	8,165,990	2,171,410	935,787	1,342,560	608,606	422,125	154,026	58,331	19,031	66,005
1999	1	1,485,630	1,448,190		3,832,790	9,800,370	6,210,650	1,661,290	734,018	1,070,340	489,234	340,724	124,589	47,238	68,955
1999	2	1,466,790	1,396,750	1,128,220	3,135,230	7,717,000	4,811,090	1,316,220	591,856	869,557	398,587	277,904	101,668	38,557	56,295
2000	1	1,393,700	1,362,670		3,176,150	2,459,280	5,740,310	3,718,690	1,049,870	478,317	706,196	324,336	226,329	82,835	77,311
2000	2	1,272,840	1,214,820	1,099,280	2,596,930	1,897,830	4,301,540	2,864,790	827,767	380,965	564,634	259,716	181,356	66,397	61,986
2001	1	1,200,600	1,144,190		5,774,400	2,022,800	1,389,310	3,290,080	2,271,510	666,260	308,361	458,048	210,898	147,339	104,342
2001	2	1,076,030	970,655	910,035	4,716,920	1,497,940	979,706	2,434,840	1,749,760	522,259	243,321	362,383	167,042	116,765	82,726
2002	1	982,277	968,081		1,453,050	3,599,100	1,046,910	728,400	1,904,630	1,398,010	420,592	196,573	293,169	135,230	161,581
2002	2	823,587	797,106	717,378	1,185,370	2,512,270	674,334	504,687	1,403,580	1,058,410	321,708	150,969	225,555	104,131	124,498
2003	1	922,867	713,370		21,443,900	894,507	1,713,610	494,805	393,178	1,121,080	853,304	260,328	122,365	182,967	185,577
2003	2	960,865	569,837	559,167	17,503,600	640,051	1,137,220	345,612	287,695	837,488	642,533	196,644	92,558	138,490	140,536
2004	1	1,090,130	1,021,680		7,006,860	13,880,100	487,492	889,470	276,312	232,120	678,030	520,909	159,519	75,106	226,468
2004	2	1,090,860	962,917	683,573	5,726,900	10,505,600	346,512	634,204	199,559	168,784	494,392	380,253	116,502	54,866	165,466
2005	1	1,241,230	1,099,550		14,502,000	4,593,010	8,210,540	275,654	511,927	162,065	137,385	402,785	309,919	94,972	179,645
2005	2	1,247,560	982,667	828,757	11,857,300	3,534,740	5,985,820	200,139	374,152	118,929	100,992	296,300	228,056	69,897	132,229
2006	1	1,319,000	1,270,470		4,968,080	9,470,290	2,737,810	4,740,590	161,422	304,073	96,929	82,403	241,881	186,217	165,079
2006	2	1,254,380	1,163,660	936,129	4,061,170	7,227,040	1,993,700	3,508,050	121,693	231,241	73,964	62,965	184,934	142,416	126,281
2007	1	1,268,830	1,197,530		7,298,760	3,218,250	5,500,340	1,562,600	2,816,530	98,690	188,234	60,297	51,365	150,912	219,320
2007	2	1,162,560	1,029,310	915,233	5,964,450	2,421,040	3,921,630	1,140,210	2,105,970	74,626	142,959	45,874	39,108	114,943	167,093
2008	1	1,118,830	1,088,740		3,080,490	4,647,930	1,774,760	3,005,530	906,300	1,699,550	60,567	116,289	37,353	31,859	229,852
2008	2	979,231	923,037	809,353	2,515,410	3,382,720	1,210,780	2,147,670	675,049	1,289,430	46,277	89,101	28,655	24,455	176,515
2009	1	991,425	882,913		11,107,100	1,940,100	2,423,240	915,249	1,696,580	543,139	1,044,610	37,593	72,467	23,319	163,642
2009	2	930,980	728,307	675,809	9,072,280	1,429,020	1,673,660	653,181	1,250,820	406,405	786,114	28,355	54,713	17,615	123,666
2010	1	1,010,480	906,627		10,630,300	7,090,560	1,054,220	1,286,570	519,367	1,008,670	329,457	638,608	23,056	44,508	114,984
2010	2	979,318	785,315	642,833	8,684,180	5,253,580	727,402	902,167	372,597	731,661	240,026	466,075	16,840	32,521	84,045
2011	1	1,097,640	**988,385**		11,183,300	6,933,440	4,065,910	575,853	727,585	302,826	596,374	195,869	380,525	13,752	95,217
2011	2	1,092,010	887,795	720,421	9,141,400	5,275,290	2,924,950	416,984	534,247	223,933	442,261	145,420	282,656	10,218	70,760

Table 12. Survey catchability coefficient (q) estimates for STAR models N, X1-X6.

Model	DEPM	TEP	Aerial	Acoustic
N (default wtg)	0.15	0.43	0.73	0.81
X1 (default wtg)	1 (fixed)	0.79	3.29	2.32
X2 (Francis wtg)	1 (fixed)	1.36	4.74	2.91
X3 (default wtg)	0.17	0.48	1 (fixed)	0.92
X4 (Francis wtg)	0.12	0.42	1 (fixed)	0.67
X5 (default wtg)	0.18	0.49	0.89	1 (fixed)
X6 (Francis wtg)	0.18	0.59	1.5	1 (fixed)

Table 13. Likelihood profile for a range of natural mortality rates (*M*) in the base model.

Natural Mortality Rate (*M*):	**0.250**	**0.375**	**0.400**	**0.500**	**0.625**	**0.750**
TOTAL LIKELIHOOD	1840.27	1788.75	1783.00	1768.68	1762.43	1793.14
SURVEY Likelihoods	2.5228	-1.2864	-1.3107	0.4542	2.5333	0.2692
DEPM	0.5409	0.3958	0.3728	1.3500	2.3474	0.4486
TEP	-0.2147	-0.0967	-0.0280	2.0087	3.2330	0.4158
Aerial	0.0517	0.0405	0.0326	-0.1388	-0.1734	0.1391
Acoustic	2.1449	-1.6259	-1.6880	-2.7657	-2.8737	-0.7343
LENGTH Likelihoods	1068.45	1060.81	1060.54	1051.49	1057.70	1089.06
MexCal_S1	404.61	399.41	399.06	392.96	394.06	387.66
MexCal_S2	319.33	318.66	318.83	314.70	318.10	313.66
PacNW	235.26	233.96	233.86	235.09	235.67	275.41
Aerial	18.77	19.04	19.14	18.80	19.42	18.65
Acoustic	90.48	89.74	89.66	89.94	90.44	93.67
AGE Likelihoods	748.35	717.20	712.70	704.43	689.56	696.12
MexCal_S1	281.21	268.96	267.06	263.84	256.71	264.16
MexCal_S2	247.37	233.24	231.06	228.20	219.55	227.68
PacNW	186.02	182.54	182.41	179.84	182.12	175.82
Acoustic	33.75	32.47	32.17	32.55	31.19	28.47
DERIVED QUANTITIES						
DEPM *Q*	0.308	0.190	0.178	0.154	0.131	0.050
TEP *Q*	0.966	0.546	0.499	0.270	0.192	0.140
Aerial *Q*	1.447	0.931	0.891	1.338	1.376	0.263
Acoustic *Q* (fixed)	1.000	1.000	1.000	1.000	1.000	1.000
Exploitation rate (2010)	0.246	0.154	0.144	0.202	0.202	0.024
Biomass_ages_1+ (2011)	570,437	923,087	988,385	574,765	644,435	5,527,460

Table 14. Likelihood profile for a range of acoustic survey qs.

Acoustic survey *q*:	**0.25**	**0.50**	**0.75**	**1.00**	**1.25**	**1.50**	**1.75**	**2.00**
TOTAL LIKELIHOOD	1784.74	1783.36	1782.88	1783.00	1783.46	1784.11	1784.84	1785.56
SURVEY Likelihoods	-0.8050	-0.9983	-1.2050	-1.3107	-1.3238	-1.2829	-1.2191	-1.0890
DEPM	0.3630	0.3729	0.3750	0.3728	0.3702	0.3756	0.4079	0.4941
TEP	-0.0428	-0.0540	-0.0536	-0.0280	0.0108	0.0697	0.1607	0.2797
Aerial	0.1047	0.0797	0.0557	0.0326	0.0083	-0.0196	-0.0538	-0.0920
Acoustic	-1.2299	-1.3970	-1.5821	-1.6880	-1.7131	-1.7086	-1.7339	-1.7709
LENGTH Likelihoods	1060.69	1060.27	1060.40	1060.54	1060.66	1060.58	1060.09	1059.17
MexCal_S1	394.21	396.55	398.10	399.06	399.67	399.99	400.00	399.72
MexCal_S2	320.23	319.66	319.28	318.83	318.37	317.82	317.09	316.22
PacNW	236.52	234.96	234.15	233.86	233.82	233.96	234.22	234.52
Aerial	18.53	18.76	18.96	19.14	19.29	19.42	19.54	19.62
Acoustic	91.20	90.34	89.90	89.66	89.51	89.38	89.24	89.08
AGE Likelihoods	715.02	713.81	712.96	712.70	712.71	712.99	713.62	714.57
MexCal_S1	267.60	267.33	267.13	267.06	267.09	267.21	267.48	267.89
MexCal_S2	232.35	231.77	231.31	231.06	230.94	230.96	231.17	231.56
PacNW	182.13	182.09	182.16	182.41	182.64	182.83	182.97	183.06
Acoustic	32.95	32.62	32.36	32.17	32.04	31.98	32.00	32.07
DERIVED QUANTITIES								
DEPM *Q*	0.050	0.099	0.142	0.178	0.209	0.237	0.263	0.289
TEP *Q*	0.156	0.298	0.412	0.499	0.566	0.616	0.652	0.675
Aerial *Q*	0.225	0.460	0.684	0.891	1.096	1.314	1.573	1.878
Acoustic *Q* (fixed)	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
Exploitation rate (2010)	0.043	0.083	0.116	0.144	0.170	0.196	0.226	0.261
Biomass_ages_1+ (2011)	3,277,040	1,710,860	1,223,820	988,385	839,514	724,772	620,323	524,737

Table 15a. Pacific sardine harvest control rules for the 2012 management year based on stock biomass estimated in the base model 'X5' and temperature-dependent F_{MSY} per Amendment 8 to the CPS-FMP (PFMC 1998).

Harvest Formula Parameters	Value			
BIOMASS (ages 1+, mt)	988,385			
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			

Harvest Formulas	MT
OFL = BIOMASS * F_{MSY} * DISTRIBUTION	170,689
$ABC_{0.45}$ = BIOMASS * $BUFFER_{0.45}$ * F_{MSY} * DISTRIBUTION	163,140
$ABC_{0.40}$ = BIOMASS * $BUFFER_{0.40}$ * F_{MSY} * DISTRIBUTION	155,810
$ABC_{0.30}$ = BIOMASS * $BUFFER_{0.30}$ * F_{MSY} * DISTRIBUTION	141,325
$ABC_{0.20}$ = BIOMASS * $BUFFER_{0.20}$ * F_{MSY} * DISTRIBUTION	126,073
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION	109,409

Table 15b. Pacific sardine harvest control rules for the 2012 management year based on stock biomass estimated in the base model 'X5' and stochastic F_{MSY} per Hill (2011; see Appendix 4).

Harvest Formula Parameters	Value			
BIOMASS (ages 1+, mt)	988,385			
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} (stochastic, SST-independent)	0.18			
FRACTION	0.15			
CUTOFF (mt)	150,000			
DISTRIBUTION (U.S.)	0.87			

Harvest Formulas	MT
OFL = BIOMASS * F_{MSY} * DISTRIBUTION	154,781
$ABC_{0.45}$ = BIOMASS * $BUFFER_{0.45}$ * F_{MSY} * DISTRIBUTION	147,935
$ABC_{0.40}$ = BIOMASS * $BUFFER_{0.40}$ * F_{MSY} * DISTRIBUTION	141,289
$ABC_{0.30}$ = BIOMASS * $BUFFER_{0.30}$ * F_{MSY} * DISTRIBUTION	128,153
$ABC_{0.20}$ = BIOMASS * $BUFFER_{0.20}$ * F_{MSY} * DISTRIBUTION	114,323
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION	109,409

FIGURES

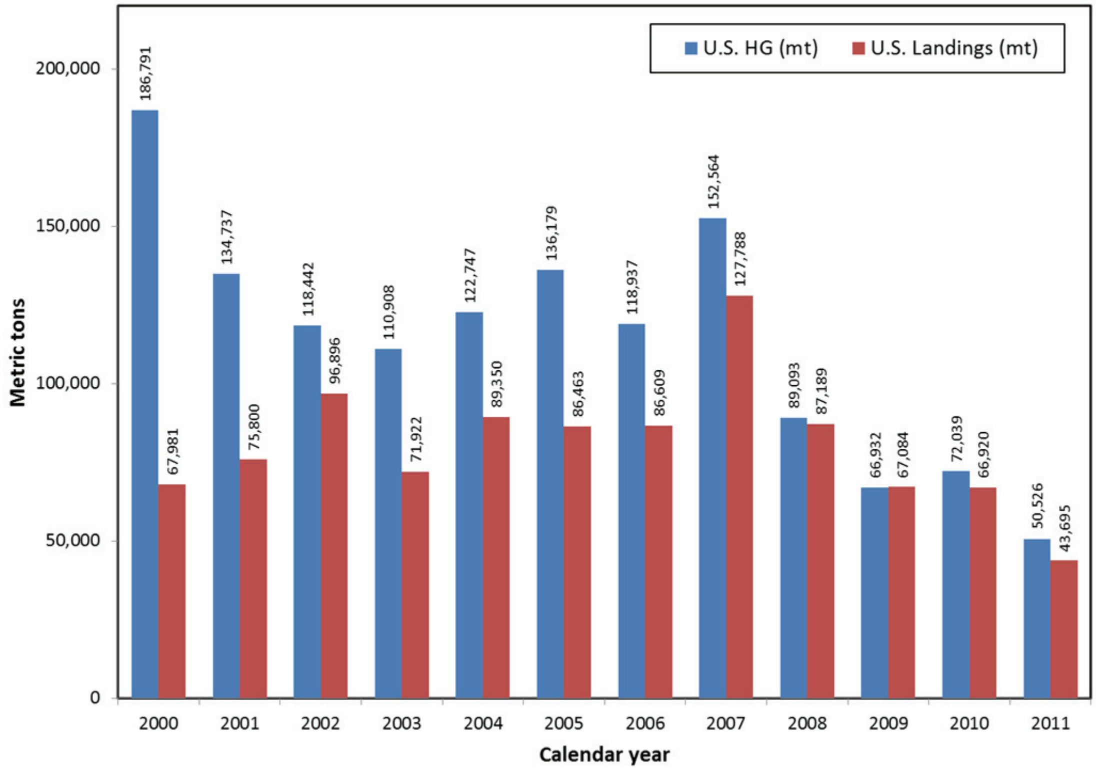


Figure 1a. U.S. harvest guidelines and landings since calendar year 2000.

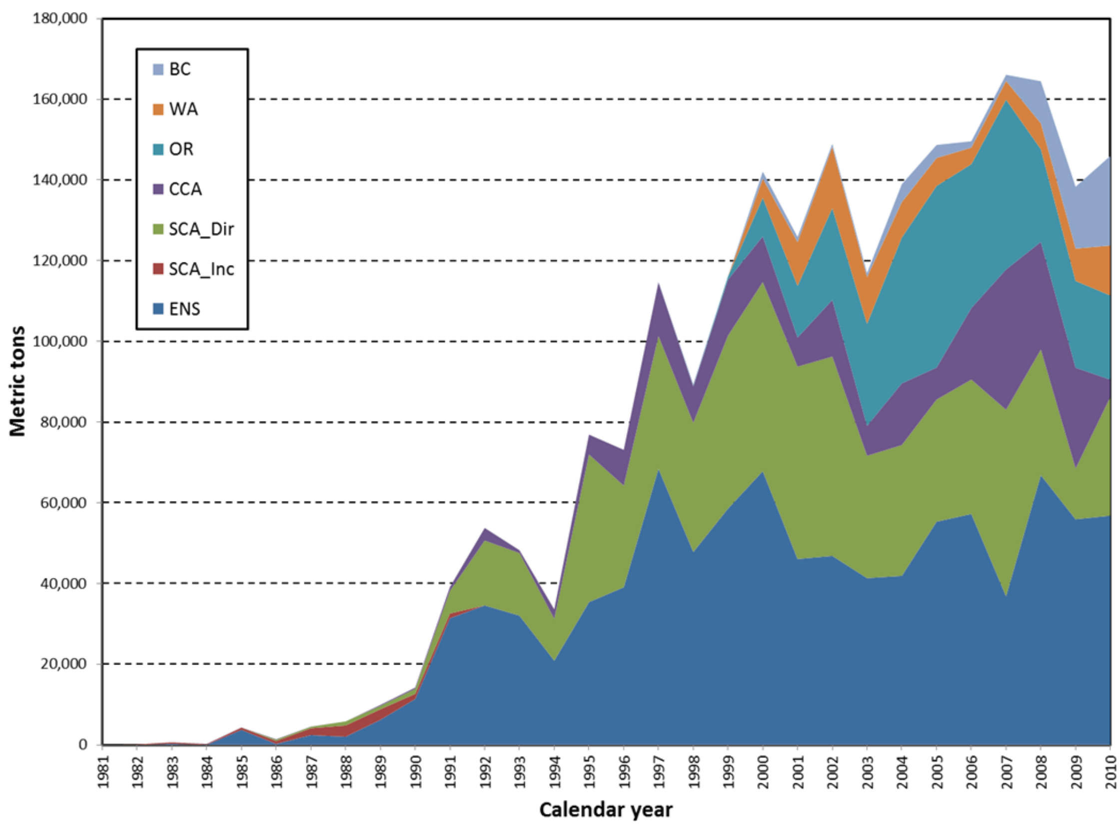


Figure 1b. Pacific sardine landings (mt) by major fishing region and calendar year.

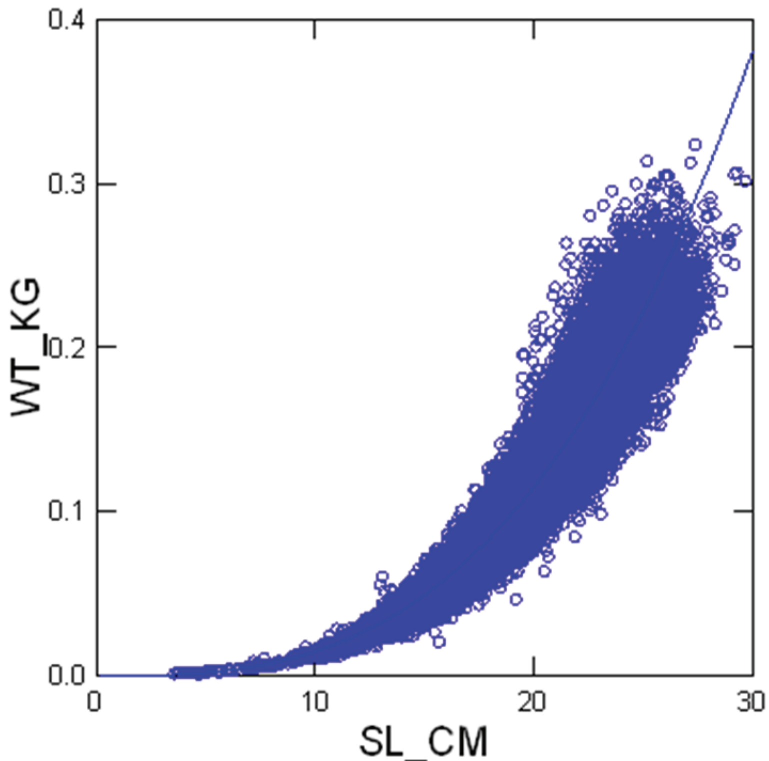


Figure 2a. Weight-at-length regression from fishery samples as applied in the base model, where: a = 1.68384E-05 and b = 2.94825 (n=155,814, R^2 = 0.928).

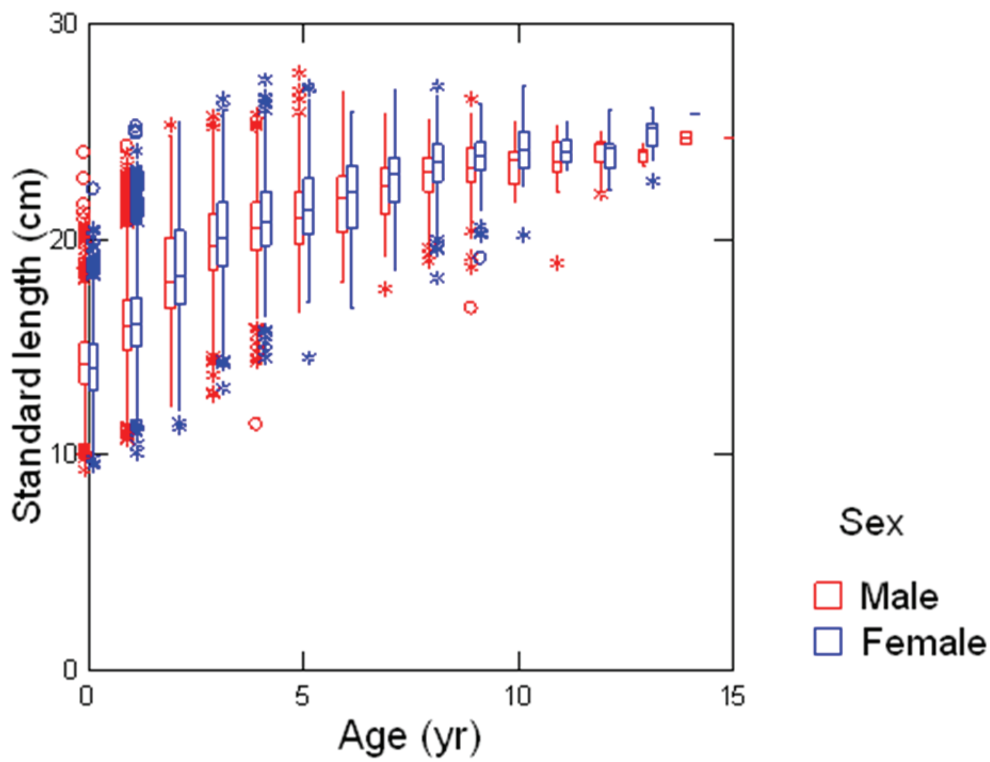


Figure 2b. Length-at-age by sex from fishery samples. Box symbols indicate median and quartile ranges for the raw data. The SS base model is based on pooled sexes.

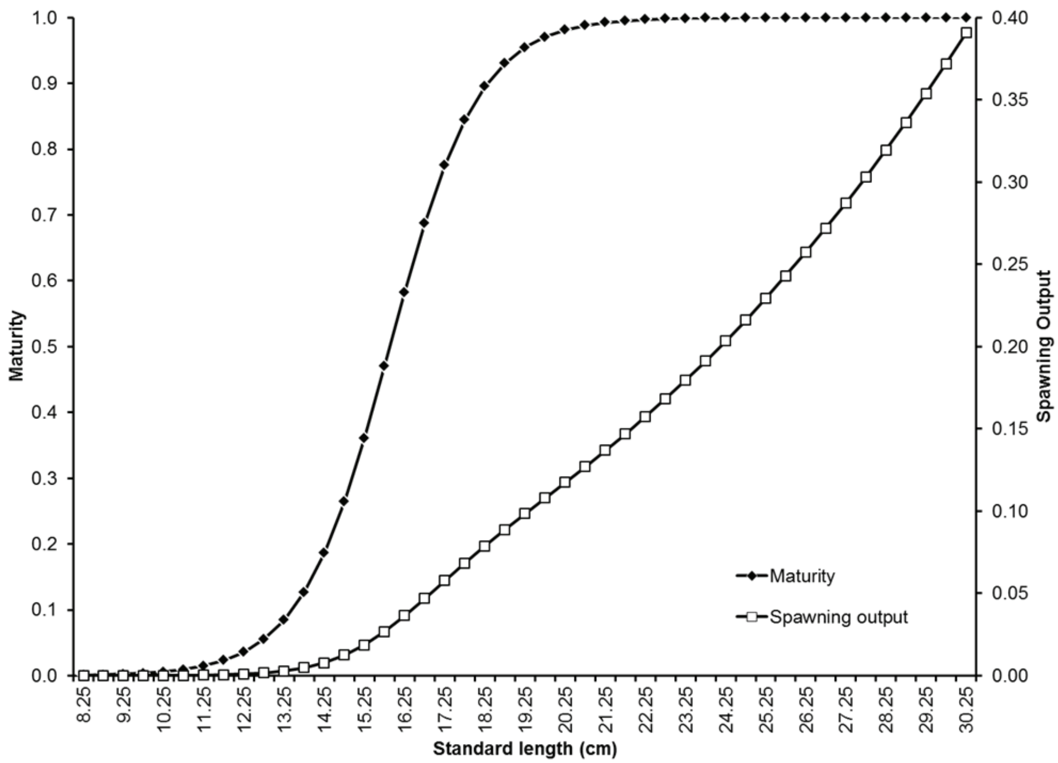


Figure 3a. Maturity (L_{50} = 15.88 cm) and spawning output as a function of length in base model.

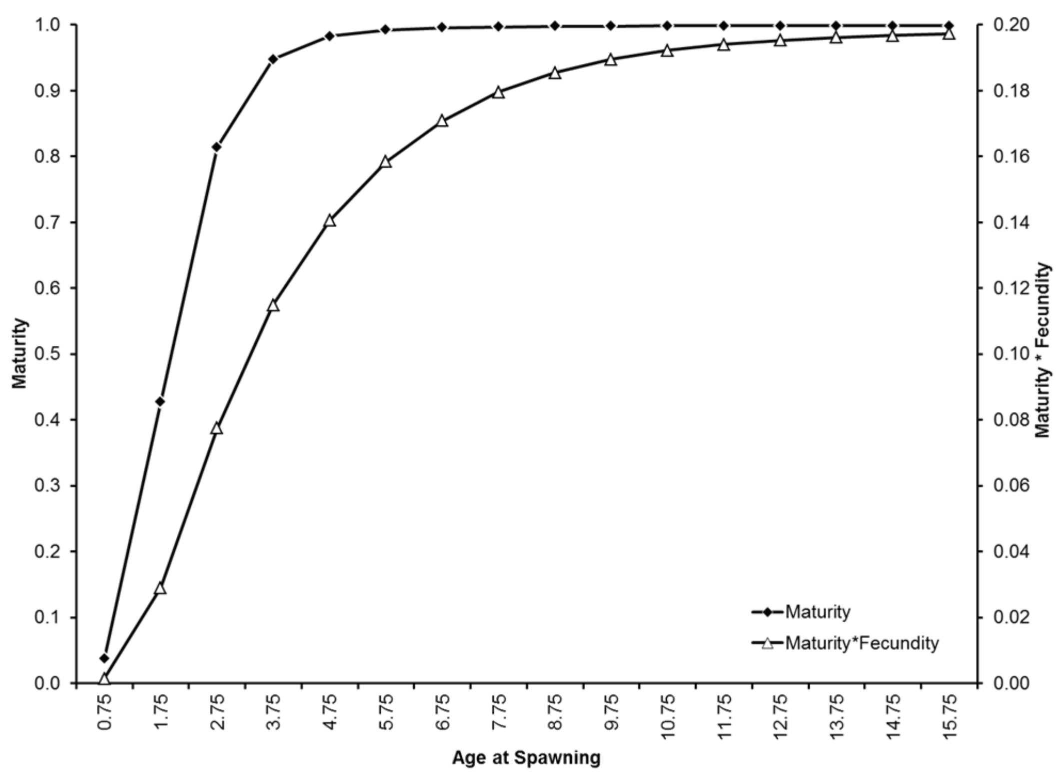


Figure 3b. Maturity and fecundity as a function of age, as derived from the base model.

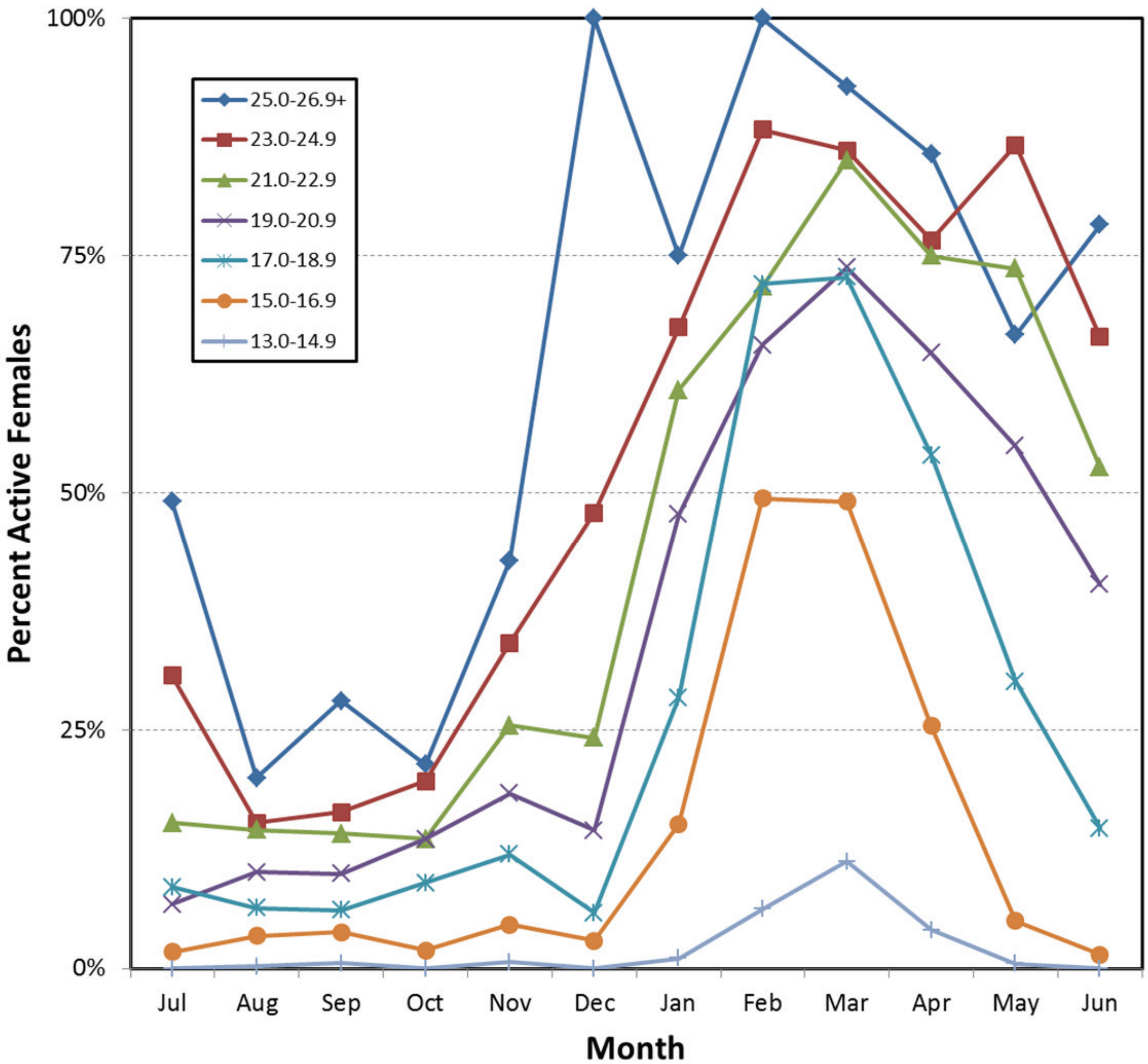


Figure 3c. Spawning activity by size (2-cm categories) and month based on visual inspection of gonads collected from U.S. port samples, 1981-2010.

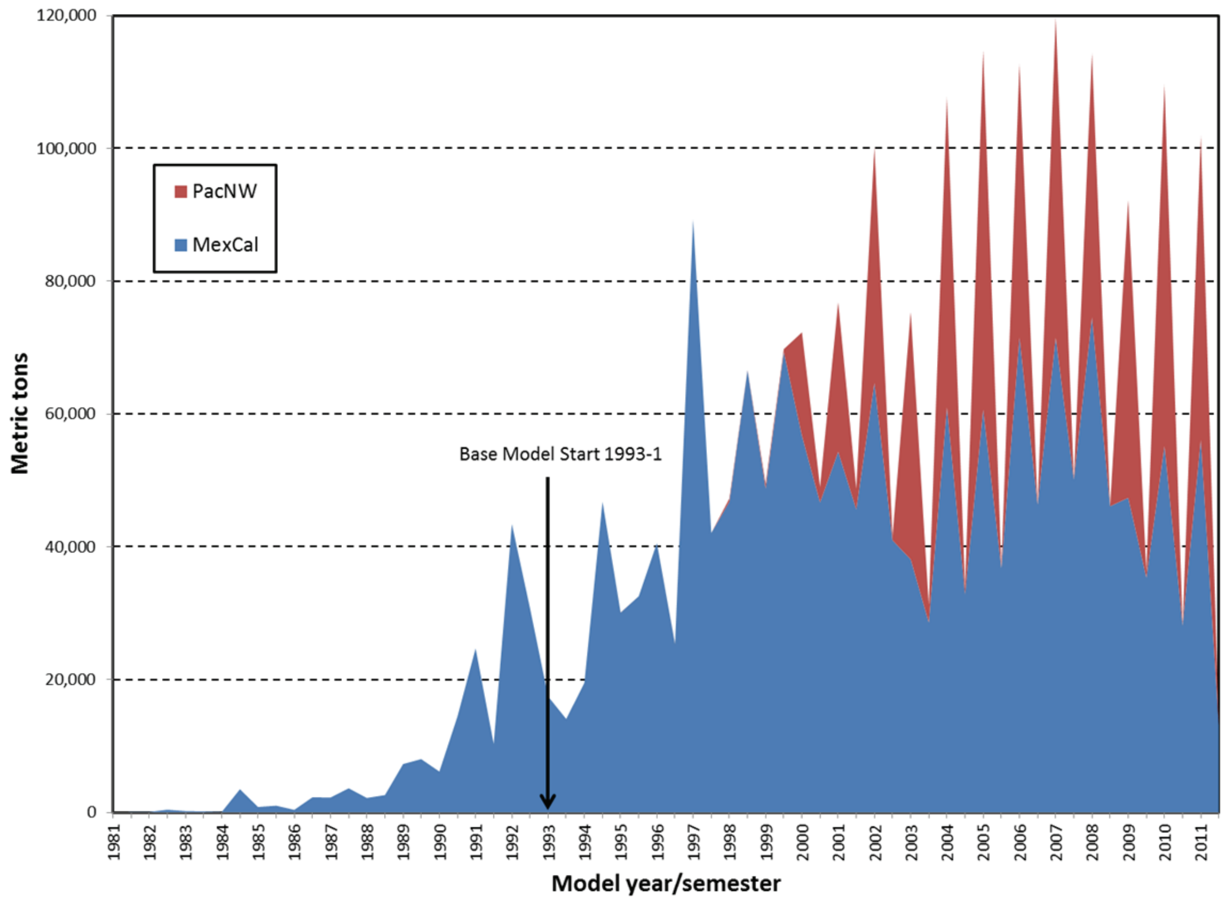


Figure 4. Pacific sardine landings (mt) by fishery, model year and semester as used in SS. The base model begins in 1993-1.

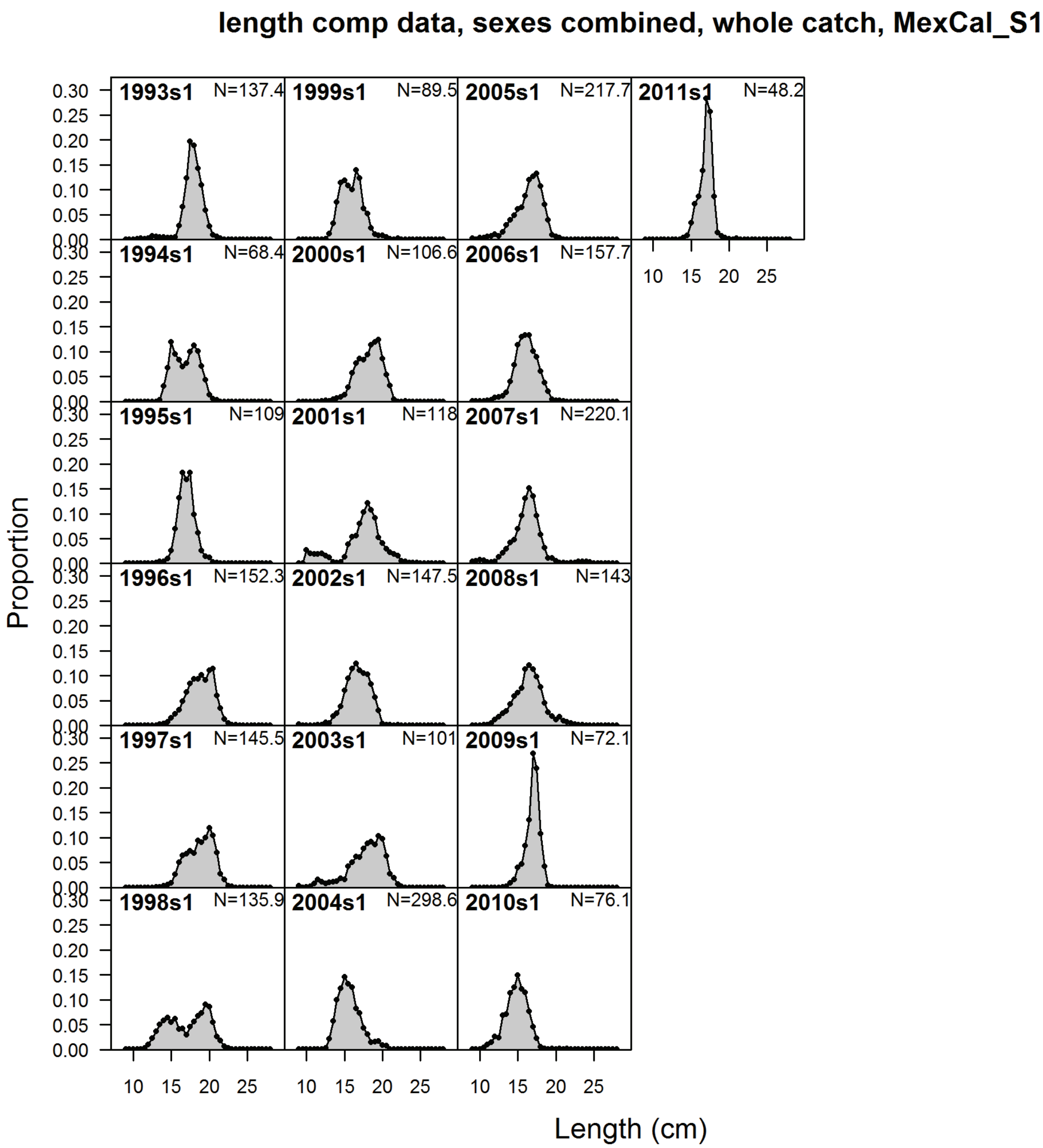


Figure 5a. Length-composition and effective sample size data for the MexCal_S1 fishery.

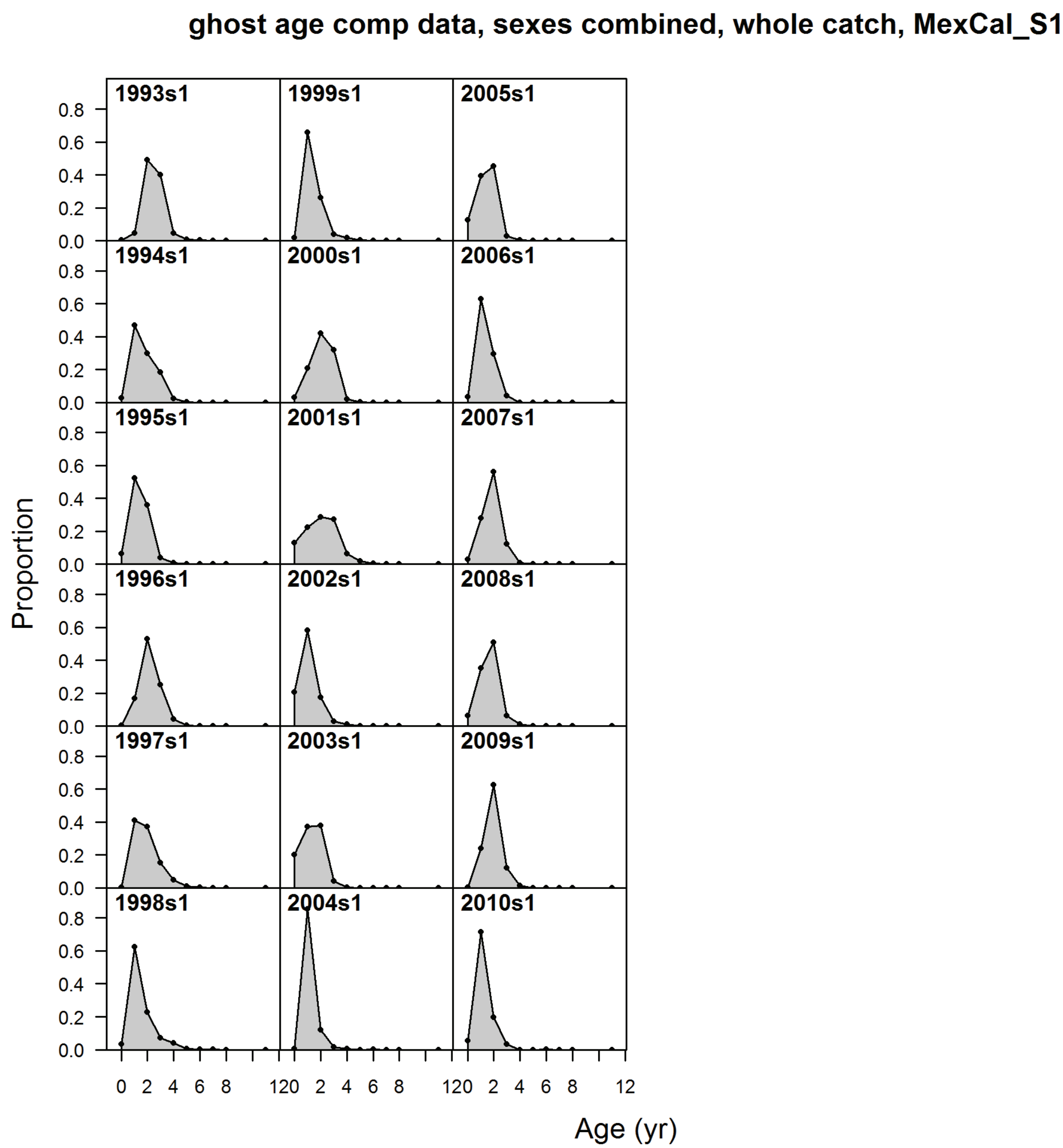


Figure 6a. Implied age-composition data for the MexCal-S1 fishery.

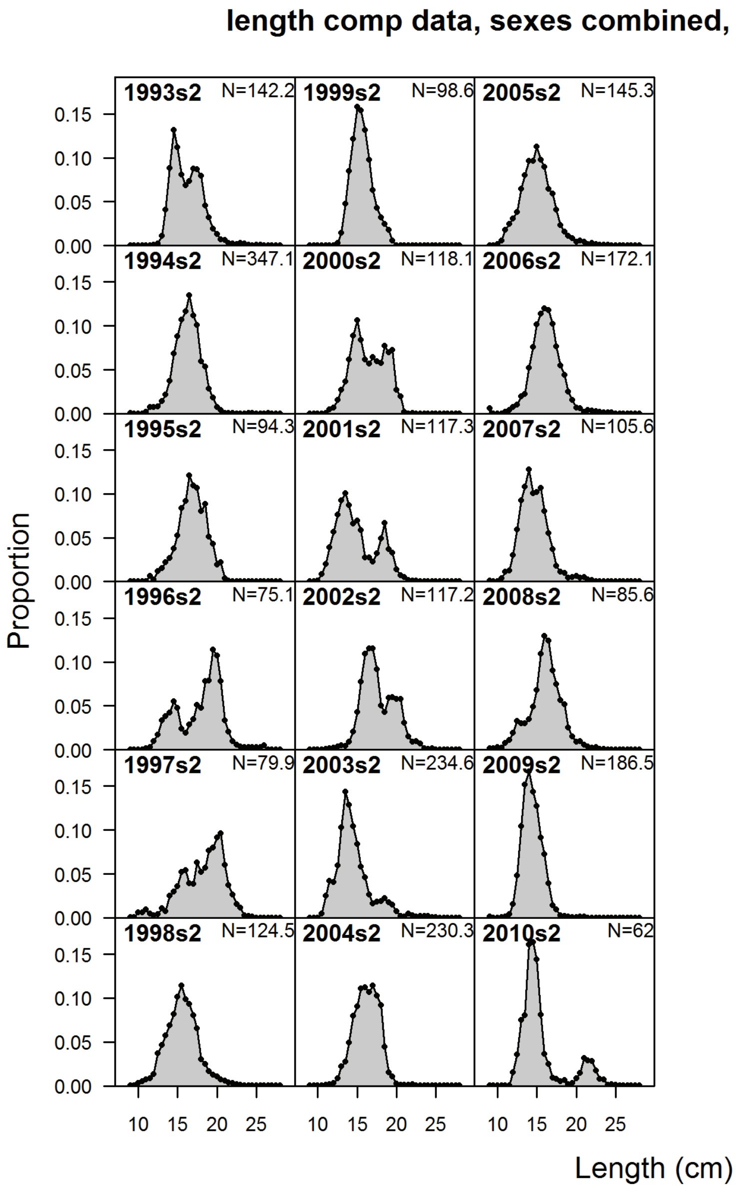


Figure 5b. Length-composition data and effective sample size for the MexCal_S2 fishery.

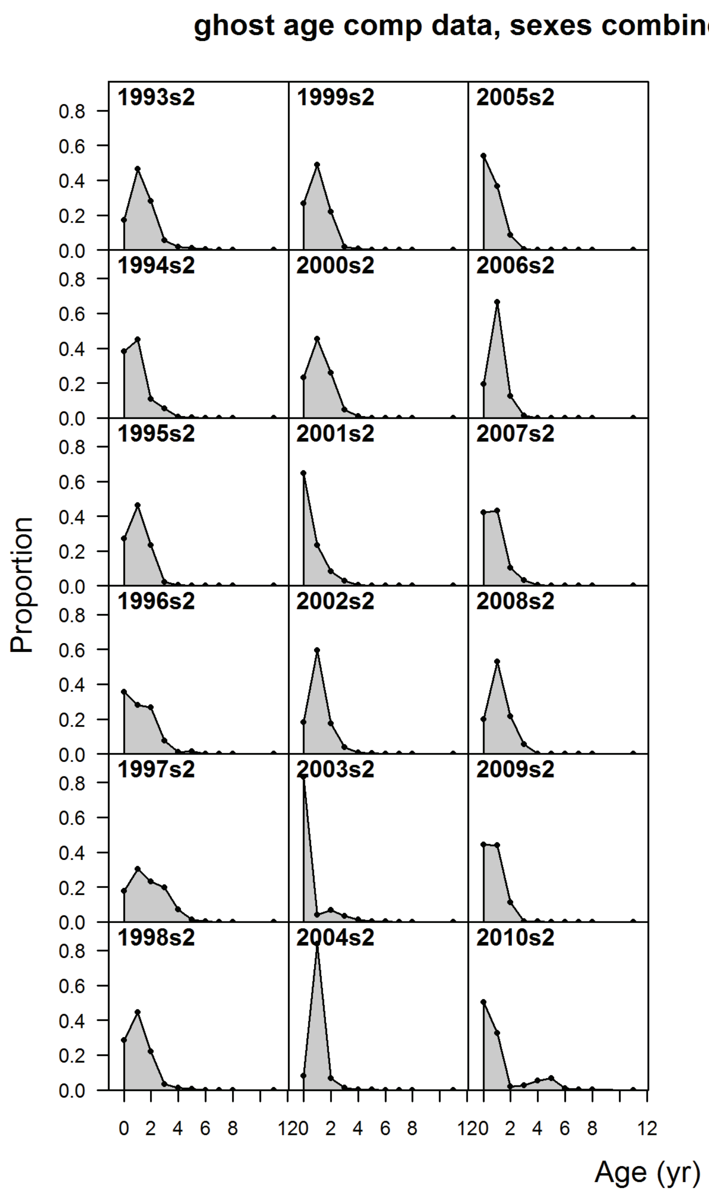


Figure 6b. Implied age-composition data for the MexCal_S2 fishery.

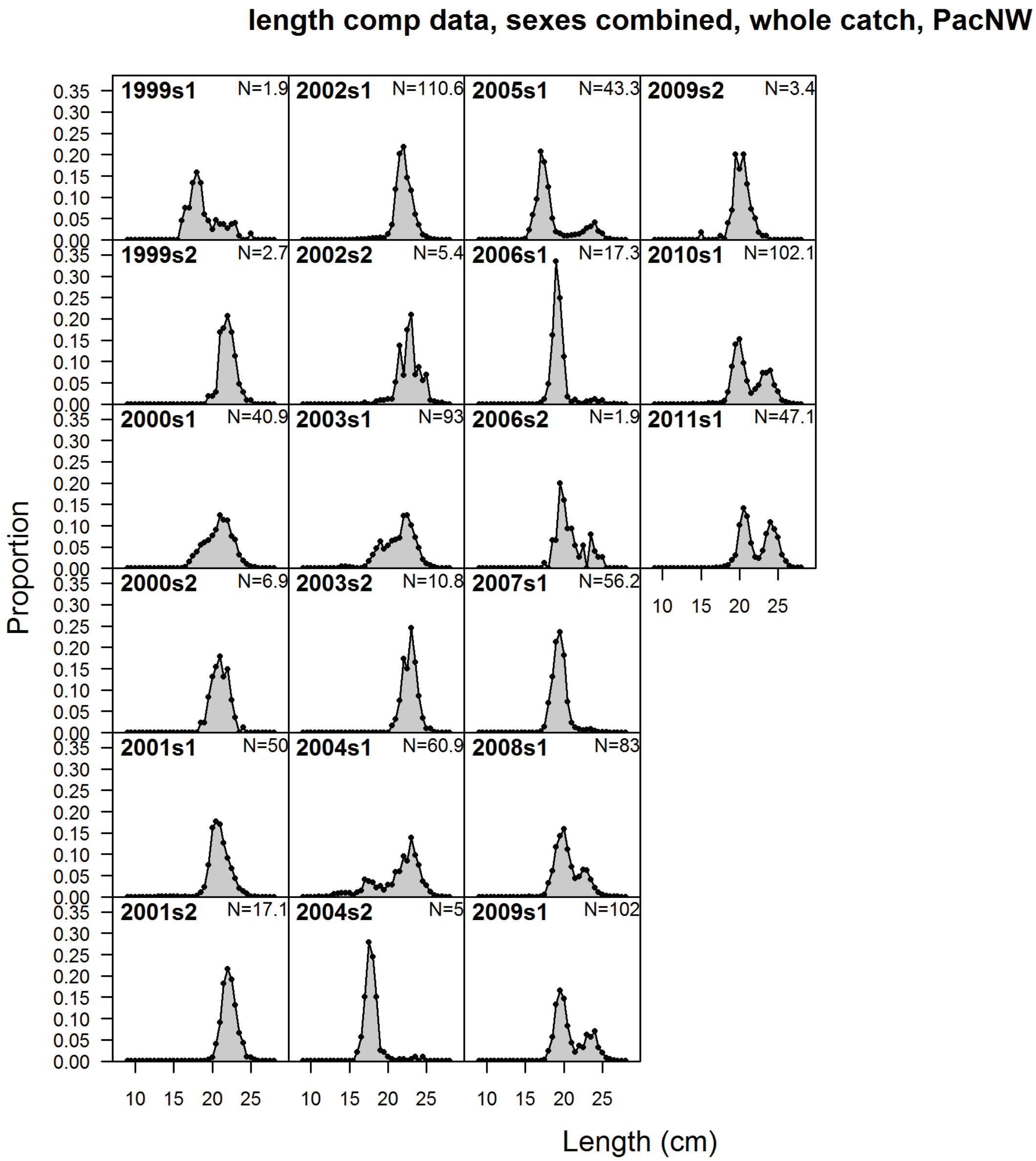


Figure 5c. Length-composition and effective sample size data for the PacNW fishery.

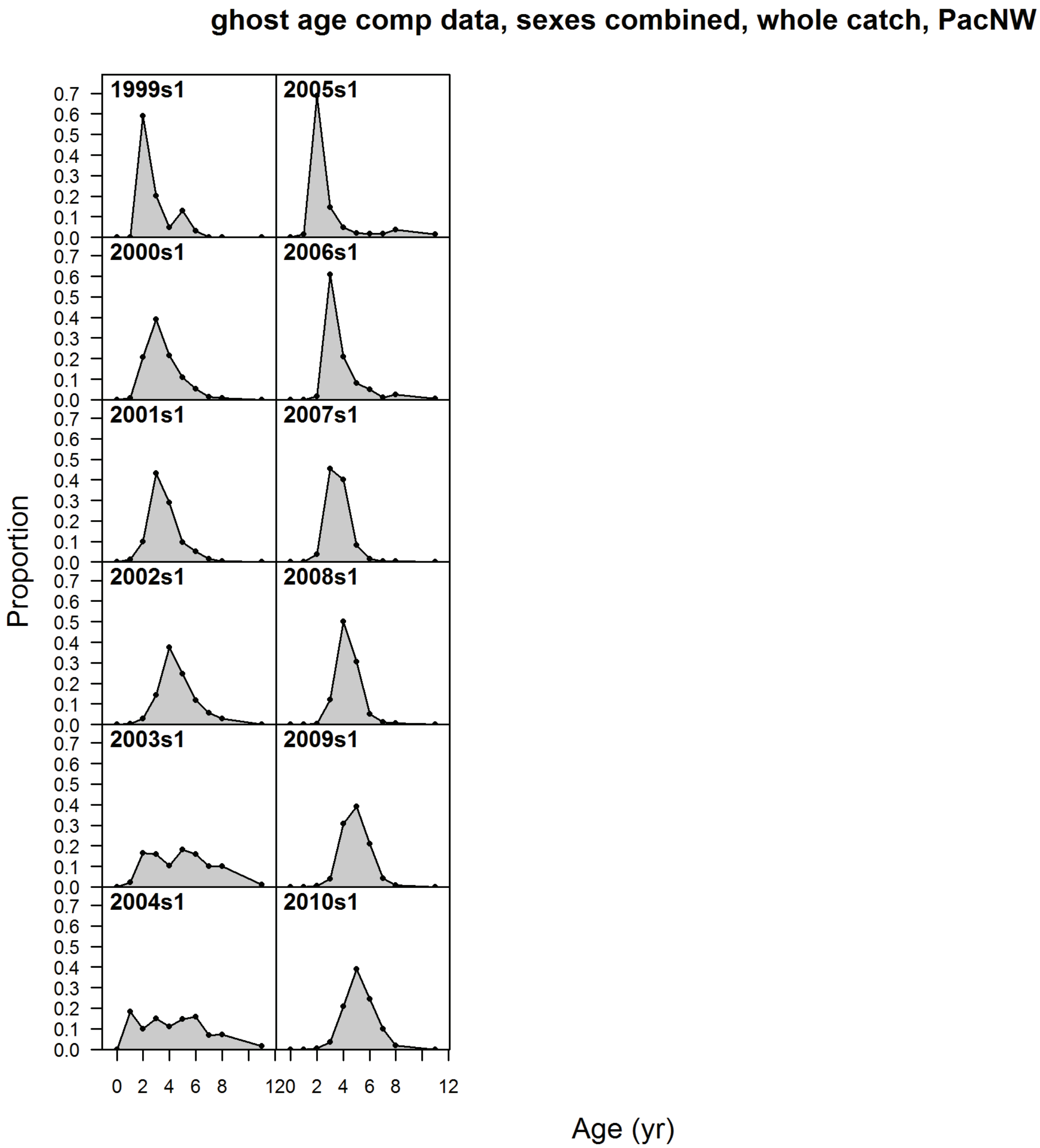


Figure 6c. Implied age-composition data for the PacNW fishery.

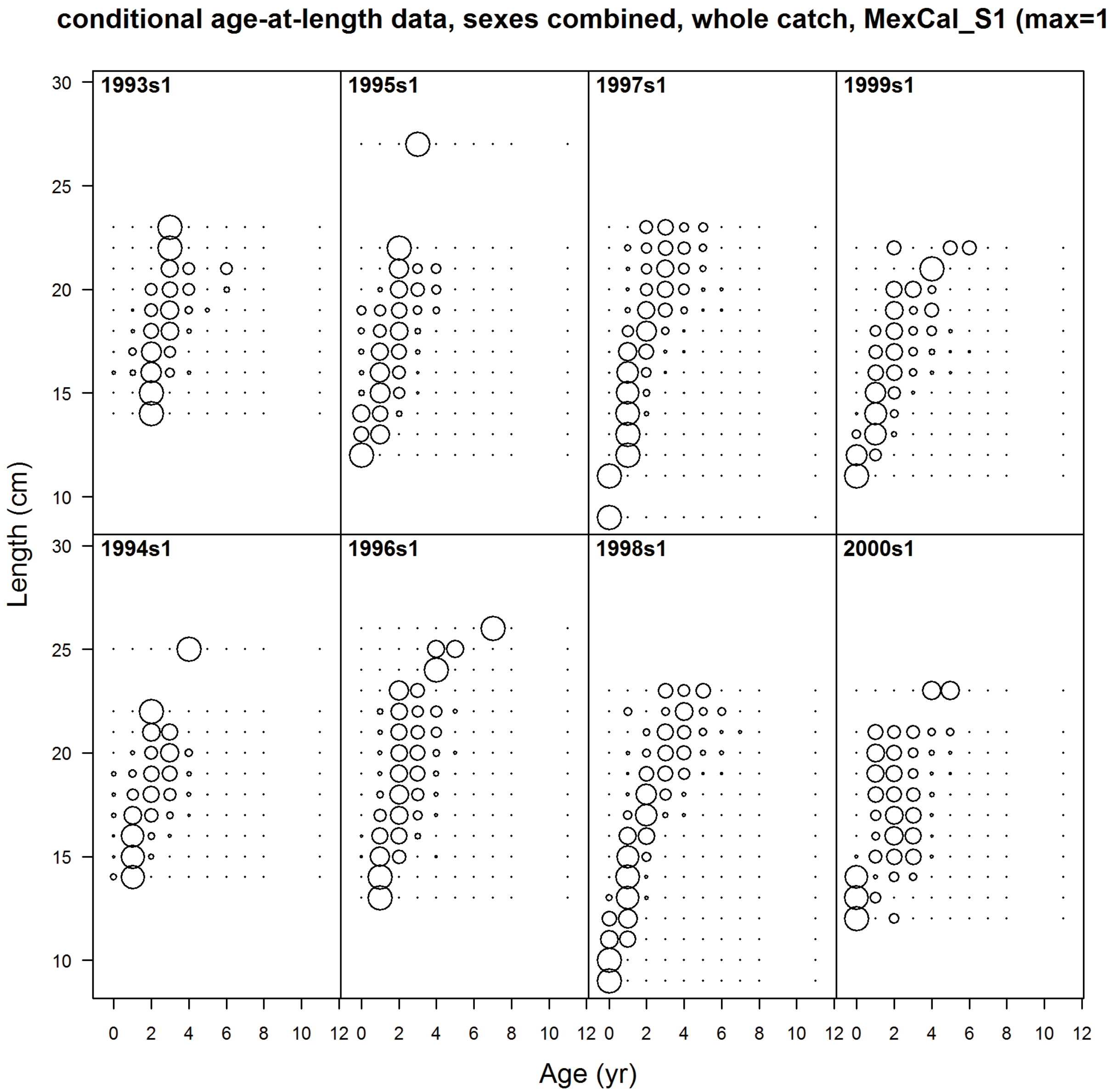


Figure 7a. Conditional age-at-length data for the MexCal_S1 fishery, 1993-2000.

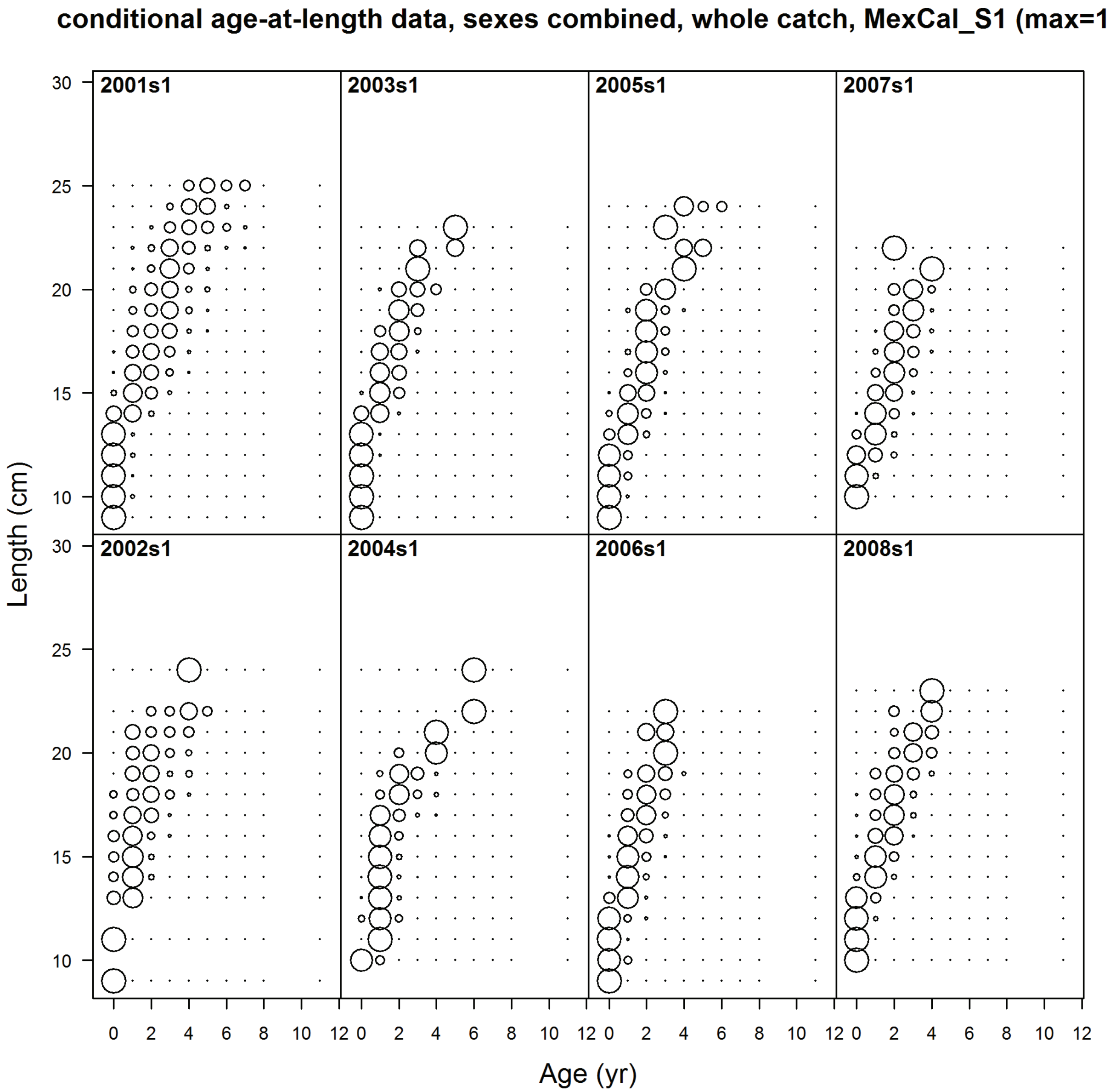


Figure 7a (cont'd). Conditional age-at-length data for the MexCal_S1 fishery, 2001-2008.

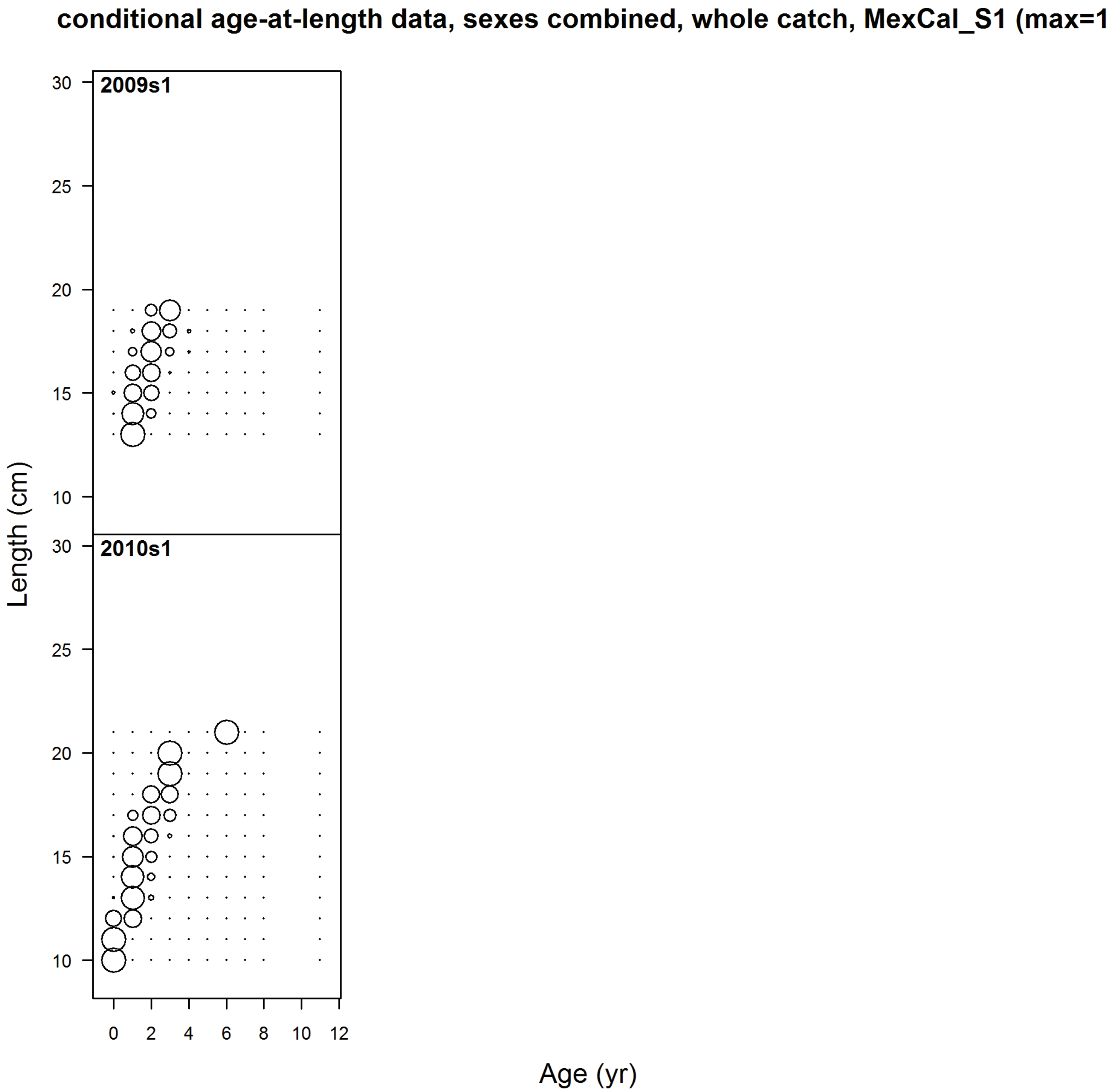


Figure 7a (cont'd). Conditional age-at-length data for the MexCal_S1 fishery, 2009-2010.

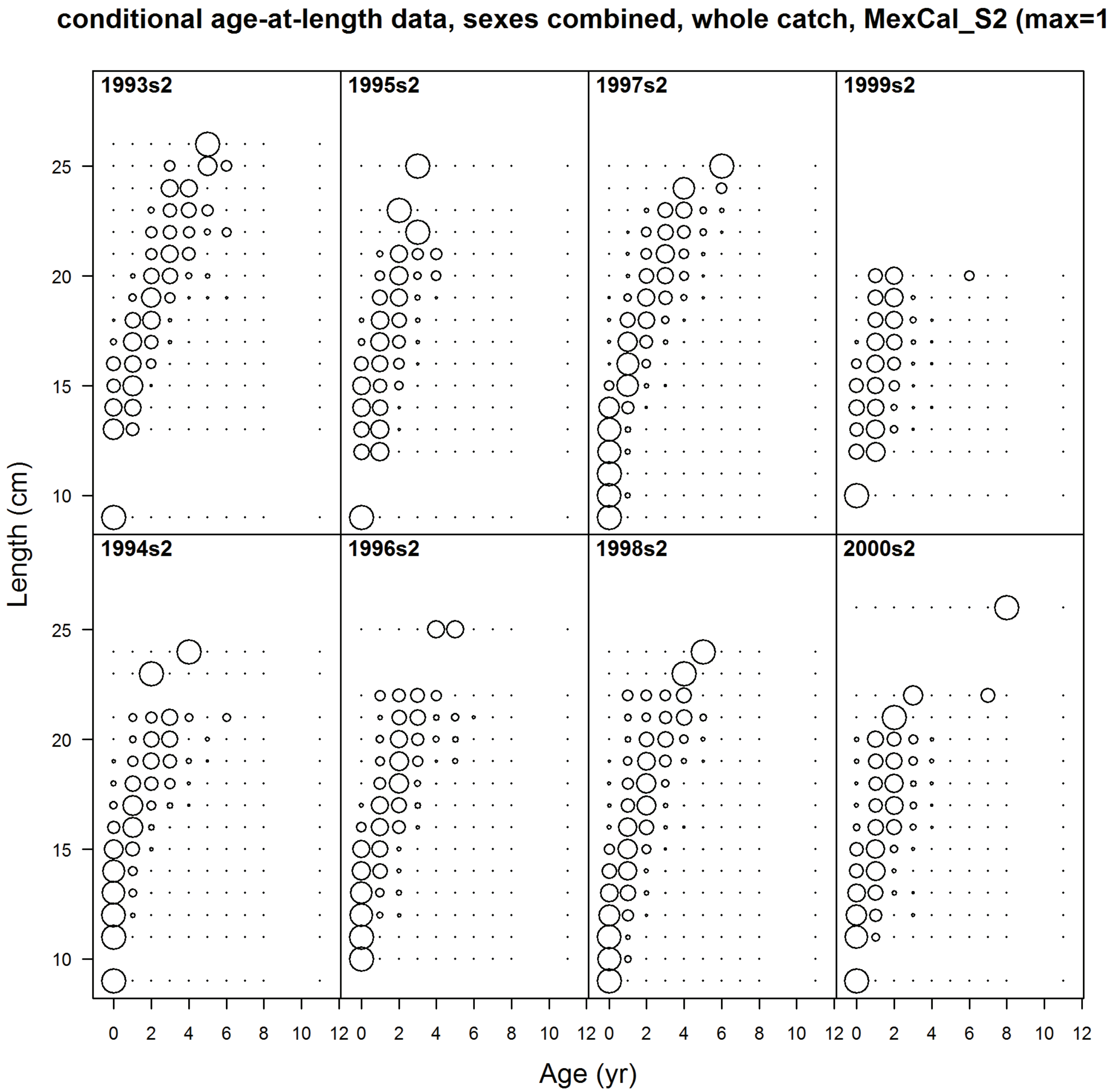


Figure 7b. Conditional age-at-length data for the MexCal_S2 fishery, 1993-2000.

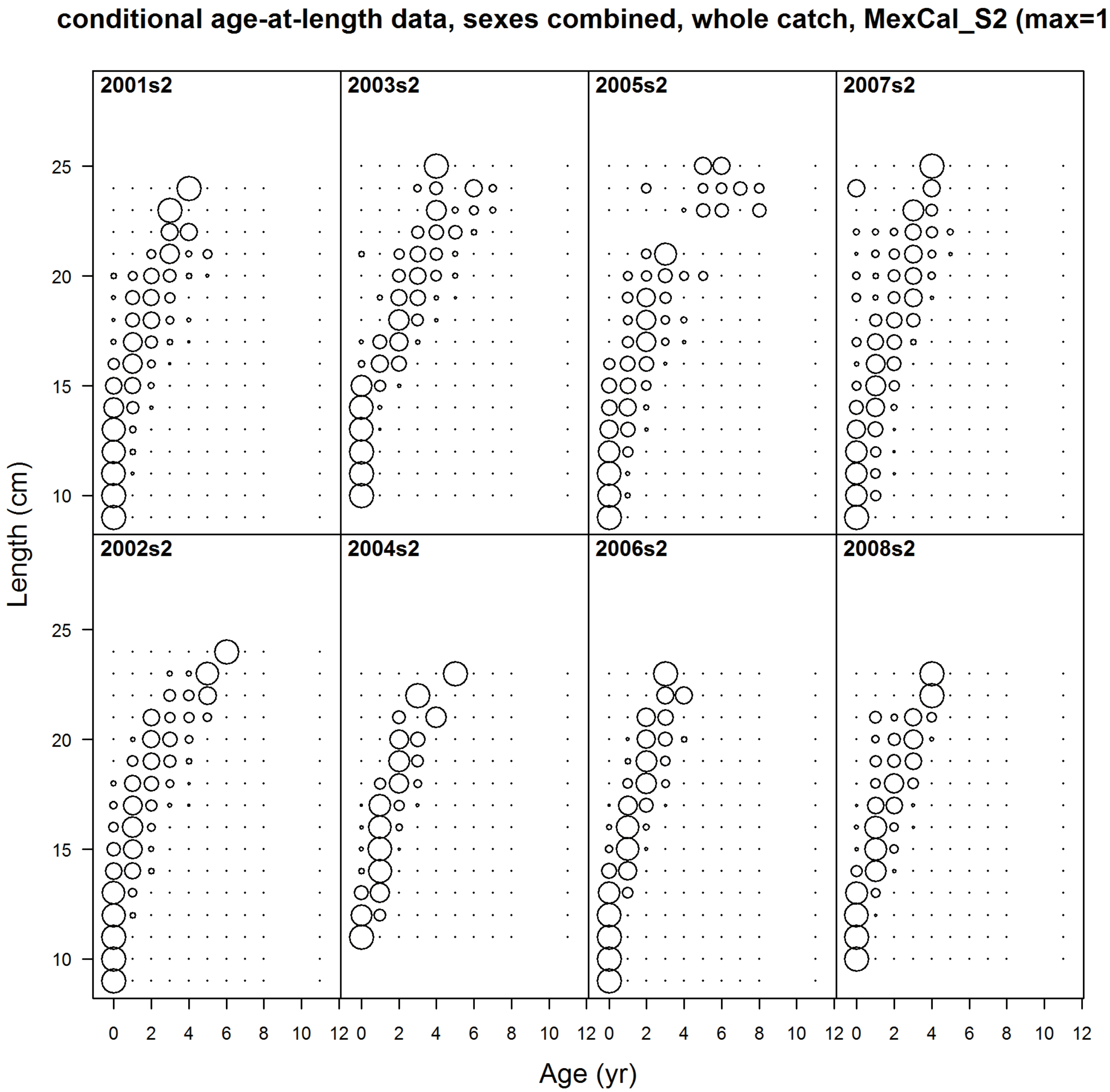


Figure 7b (cont'd). Conditional age-at-length data for the MexCal_S2 fishery, 2001-2008.

conditional age-at-length data, sexes combined, whole catch, MexCal_S2 (max=1)

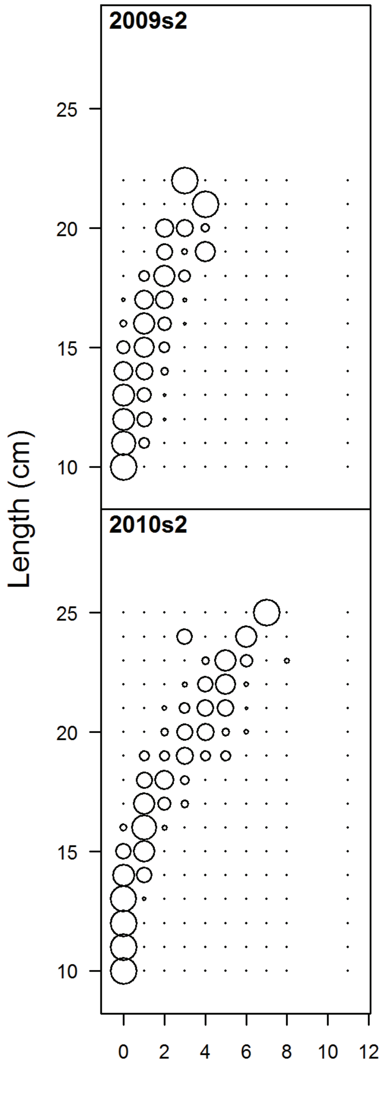


Figure 7b (cont'd). Conditional age-at-length data for the MexCal_S2 fishery, 2009-2010.

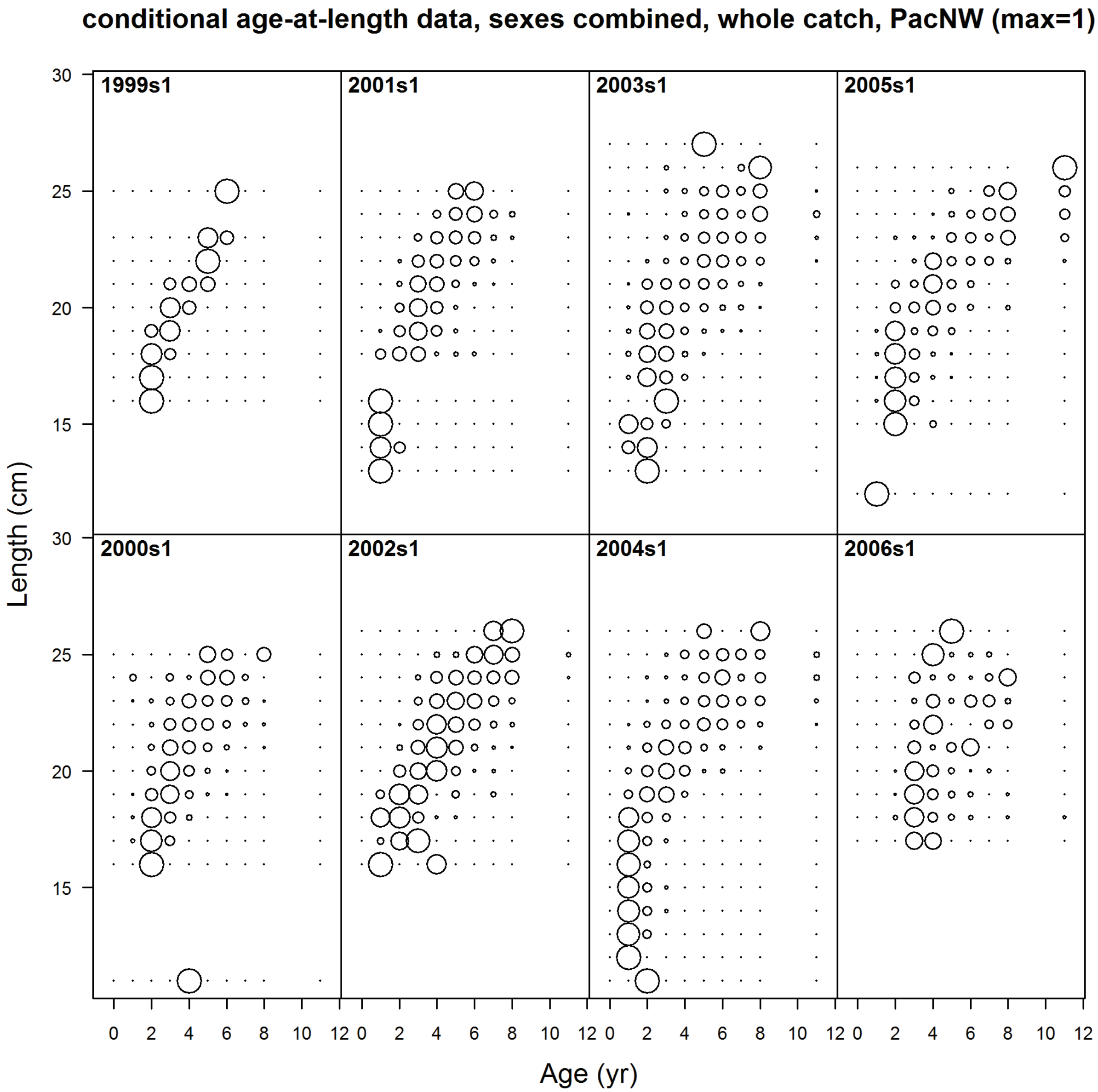


Figure 7c. Conditional age-at-length data for the PacNW fishery, 1999-2006.

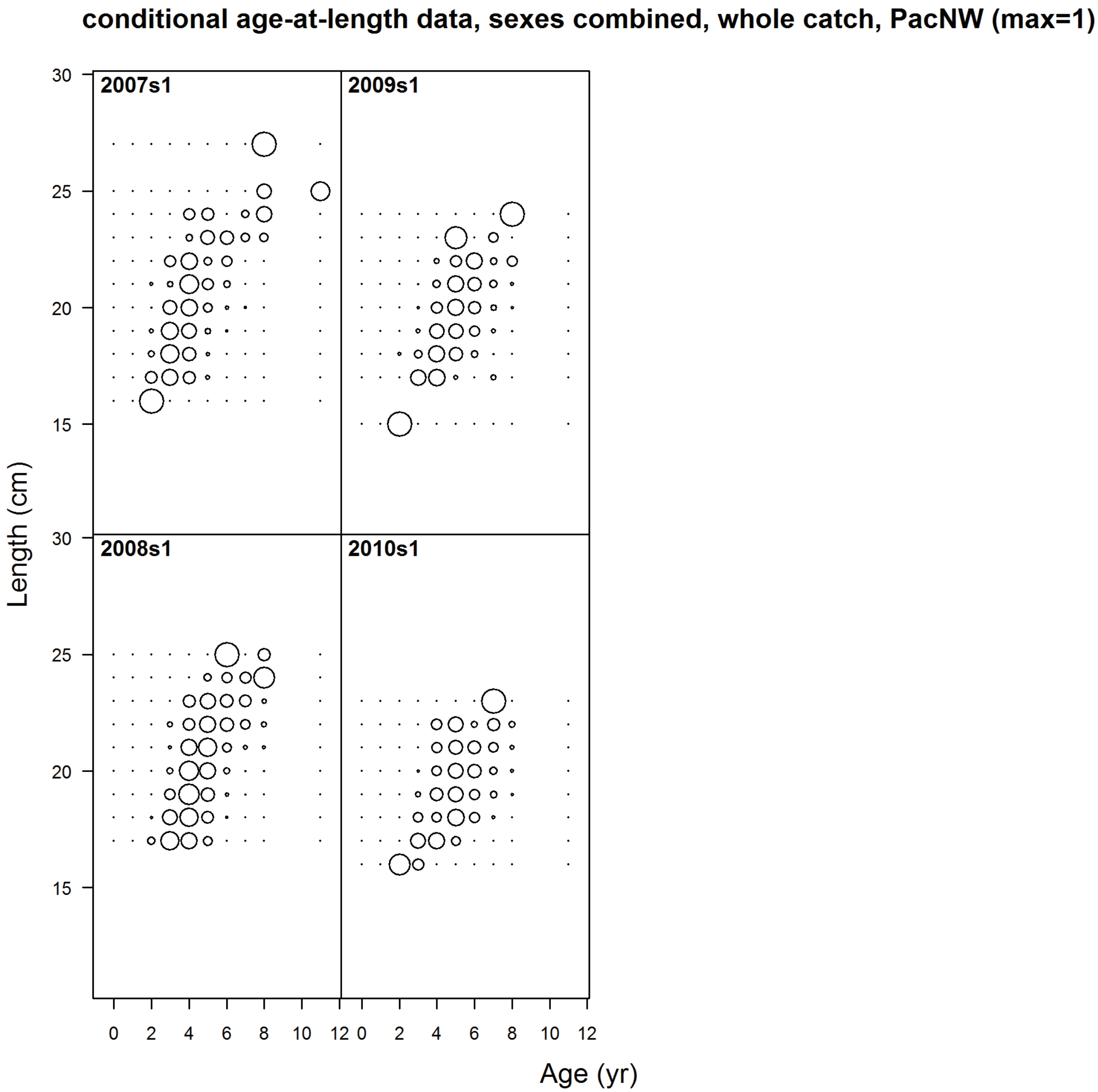


Figure 7c (cont'd). Conditional age-at-length data for the PacNW fishery, 2007-2010.

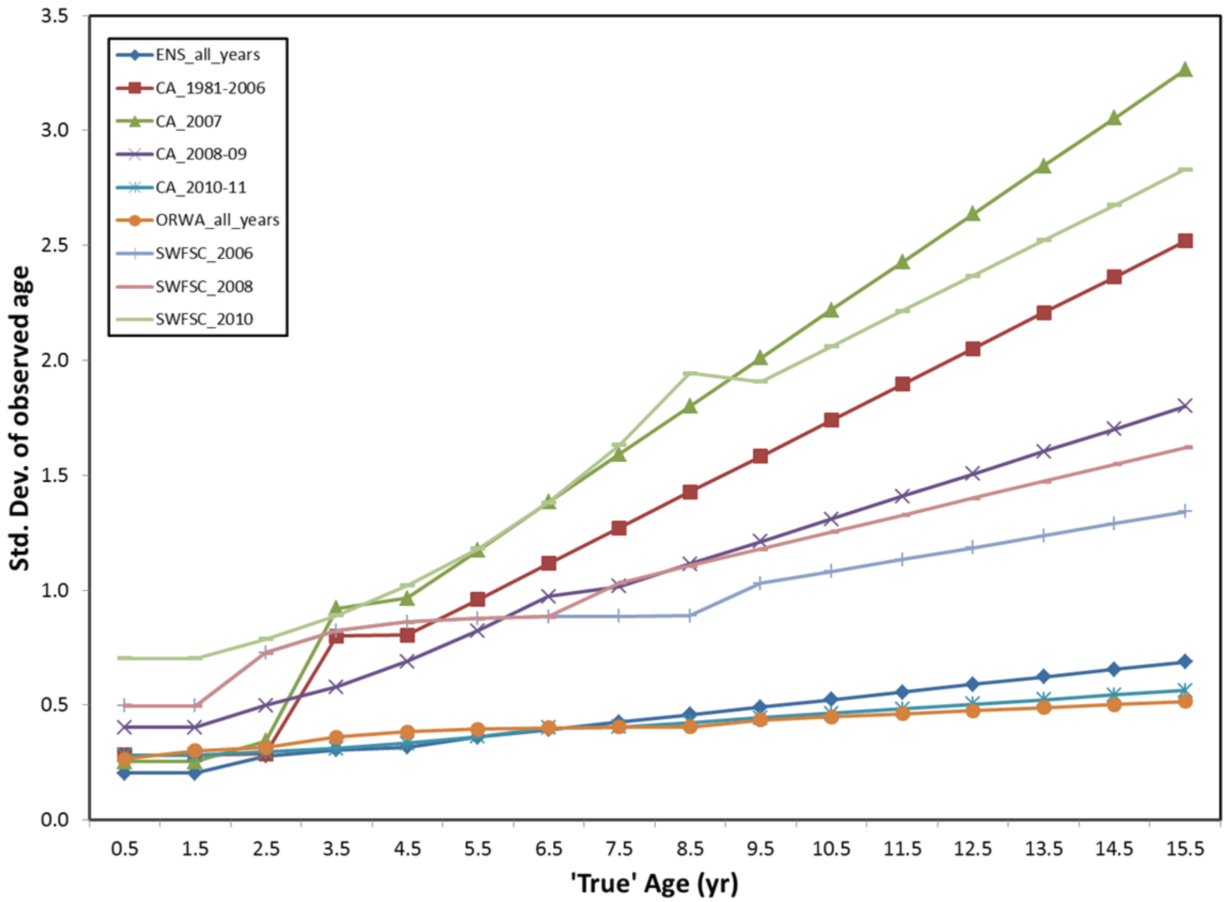


Figure 8. Laboratory- and year-specific ageing errors.

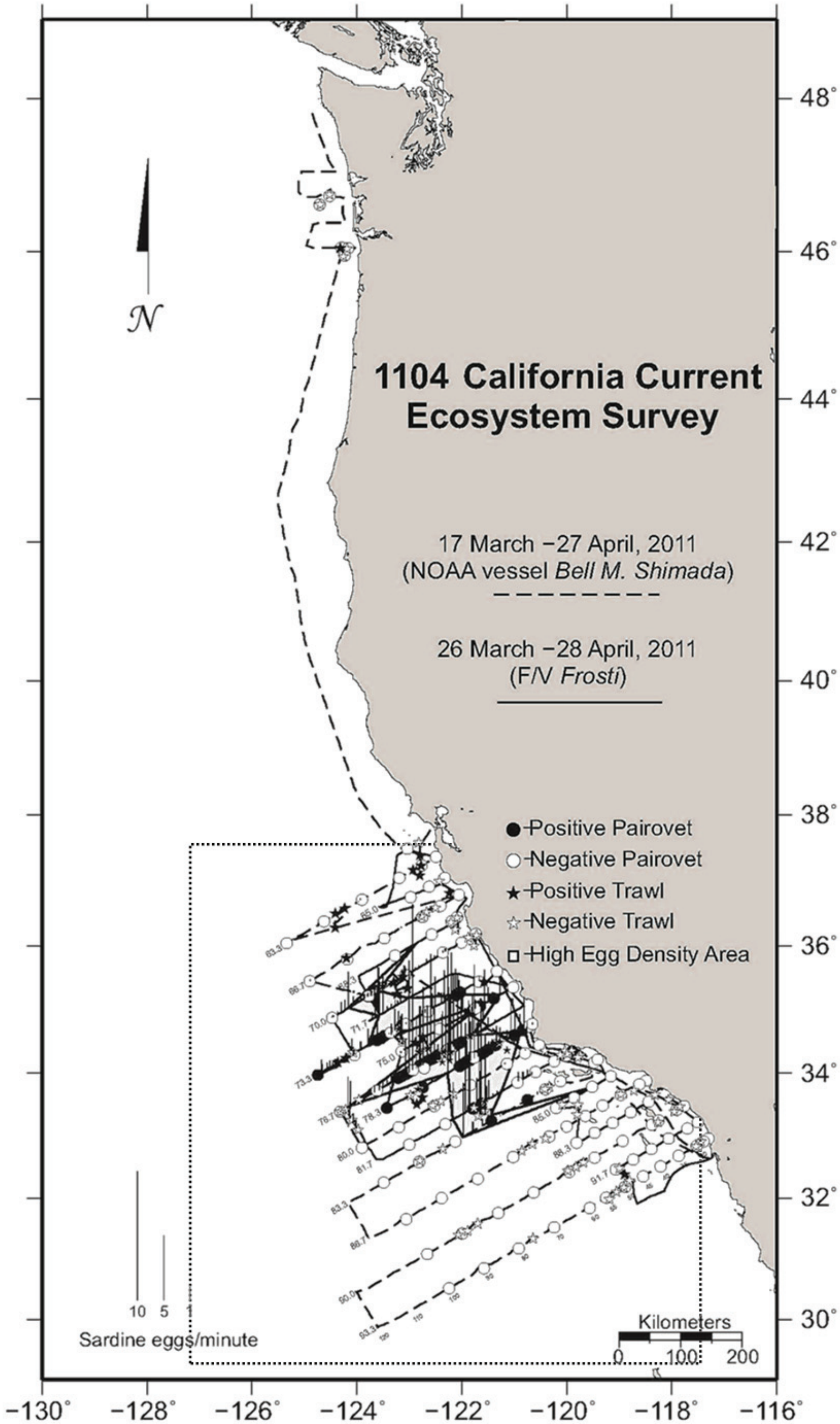


Figure 9a. Distribution of CUFES, Pairovet and Bongo ichthyoplankton collections, and adult trawl samples from the SWFSC 1104 sardine survey (coast-wide), conducted onboard the F/V *Frosti* and NOAA ship *Bell M. Shimada* during spring of 2011. Standard sampling area for the DEPM/TEP index (inset) is displayed on the following page.

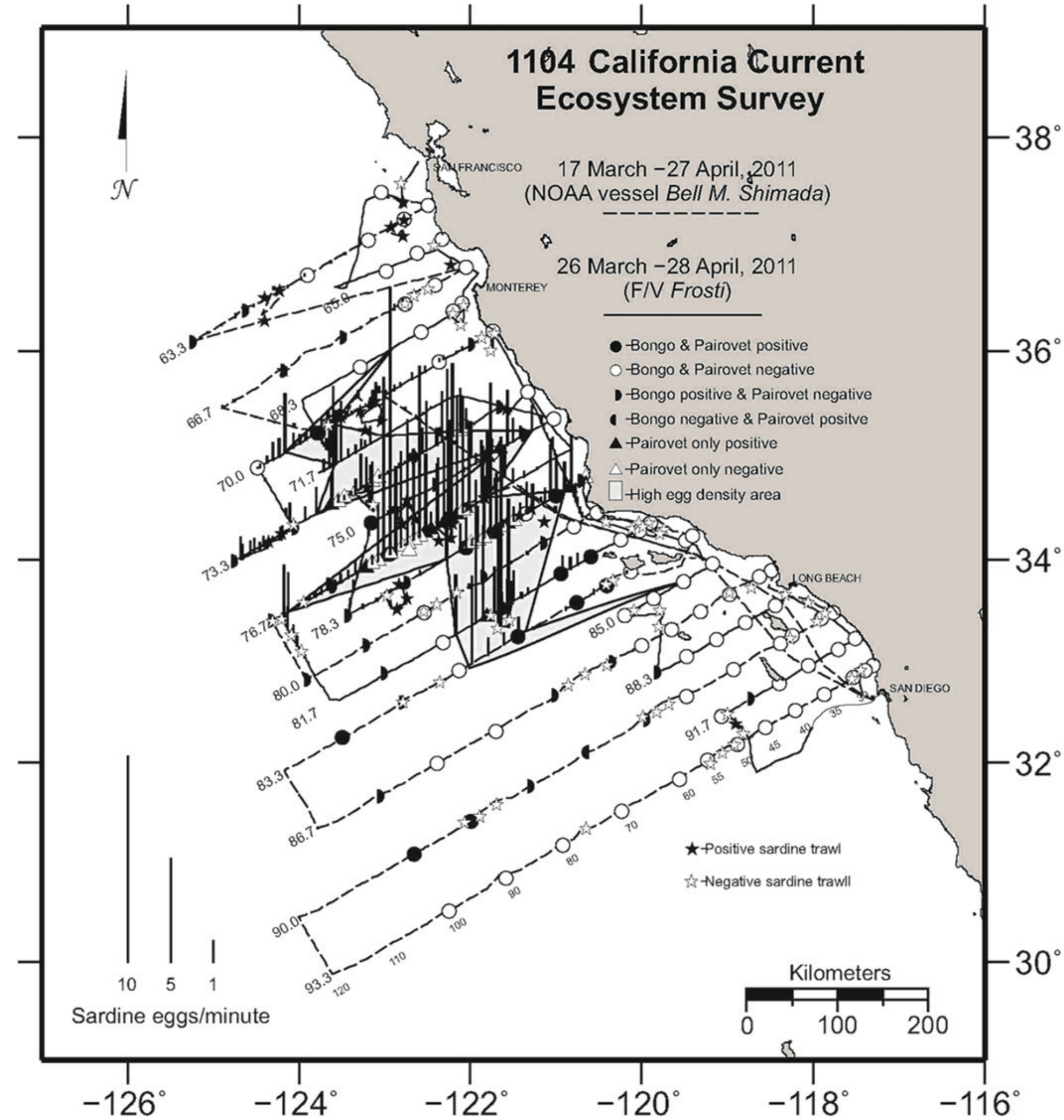


Figure 9b. Distribution of CUFES, Pairovet, and Bongo collections, and adult trawl samples from the SWFSC 1104 sardine survey in the standard sampling area for the DEPM index, conducted onboard the F/V *Frosti* and the NOAA ship *Bell M. Shimada* during spring 2011.

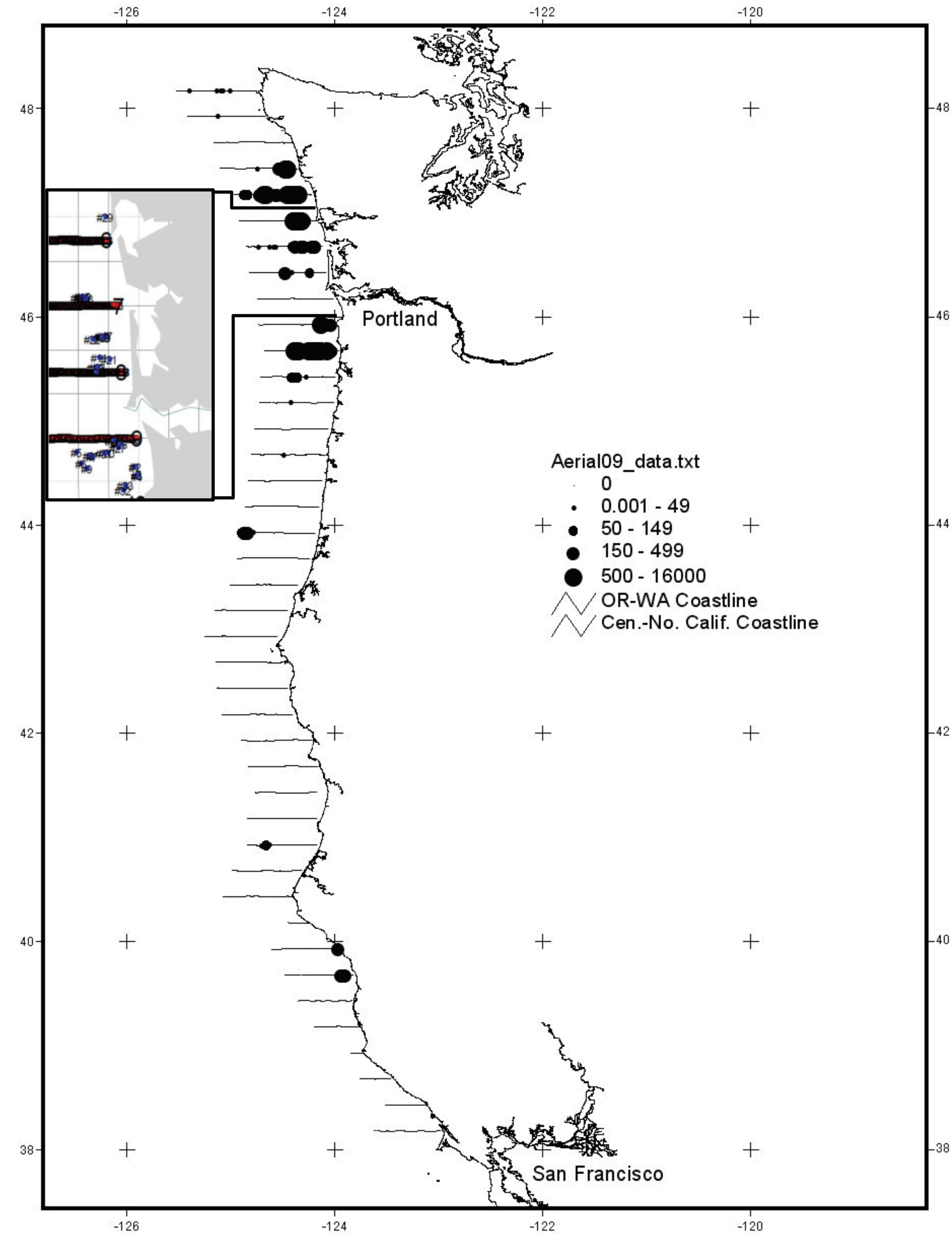


Figure 10. Distribution of sardine schools observed in the 2009 Aerial Sardine Survey (data from Jagielo et al. 2009).

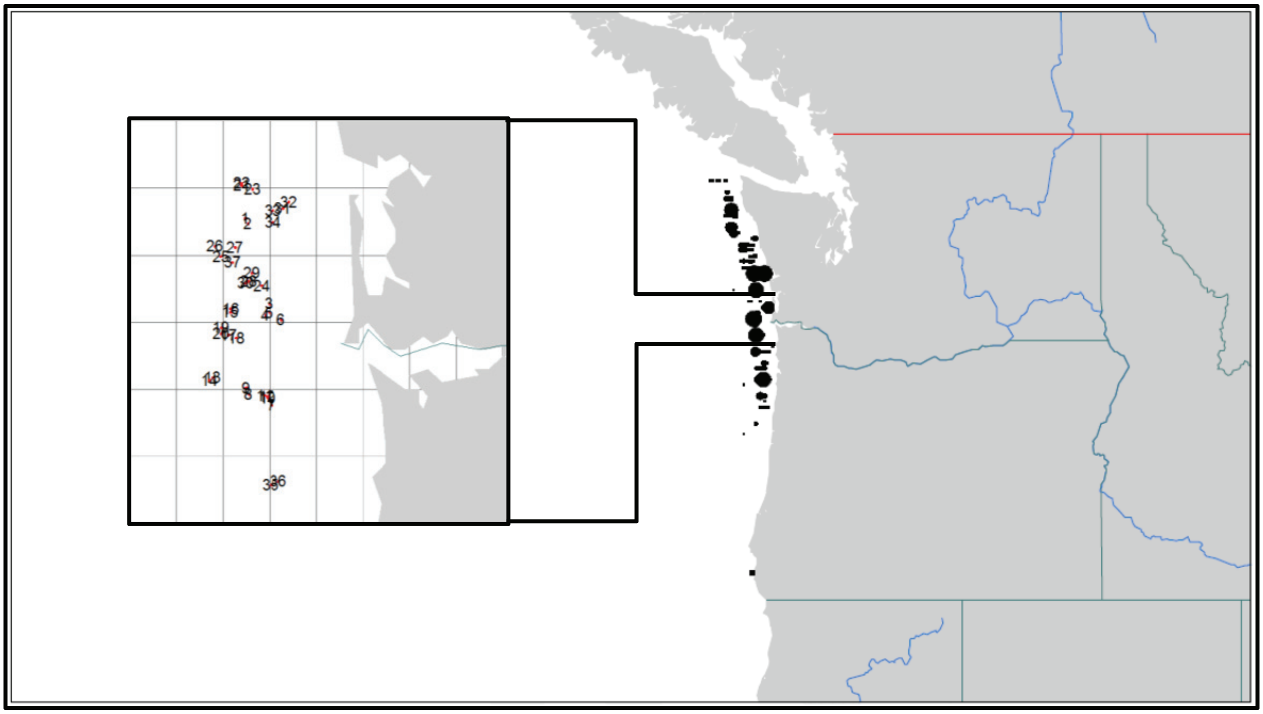


Figure 11. Distribution of sardine schools observed in the 2010 Aerial Sardine Survey (from Jagielo et al. 2010). Inset displays distribution of point sets to determine surface area to biomass relationship and length composition.

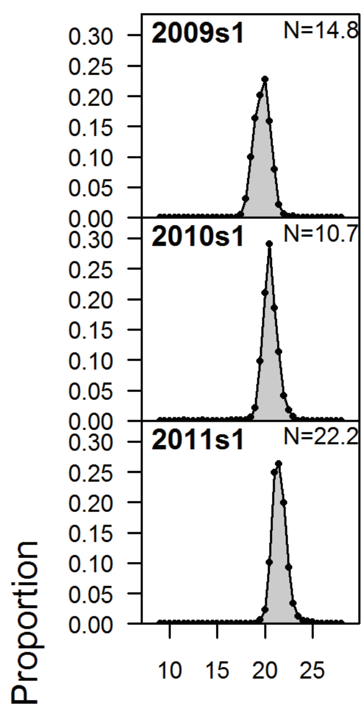


Figure 12. Length-composition data (SL-cm) for the aerial survey.

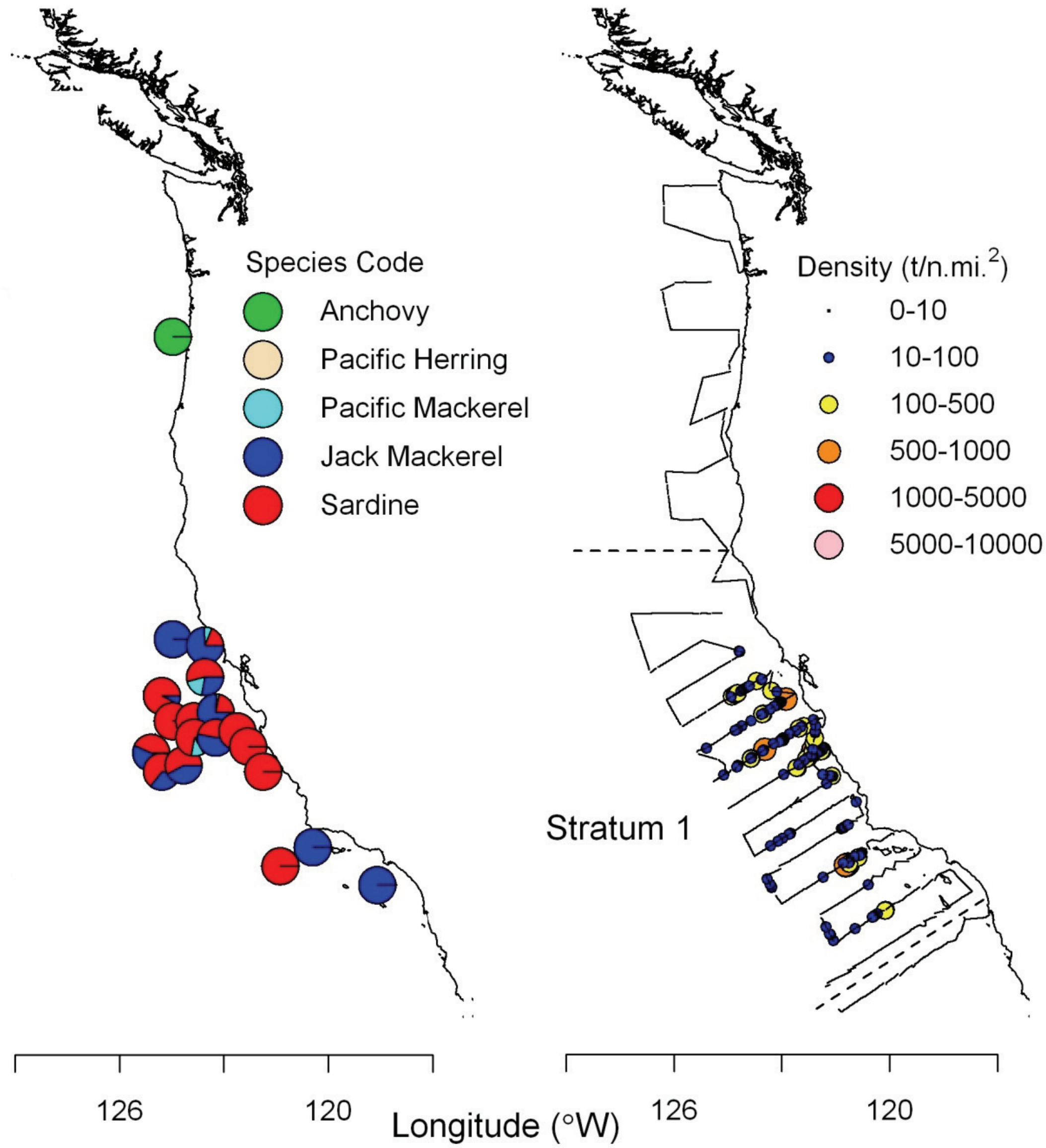


Figure 13. Trawl species composition (left) and Pacific sardine density (right) measured by acoustic backscatter during the SWFSC 1004 sardine survey (coast-wide), conducted onboard the F/V *Frosti* and NOAA ship *Miller Freeman* during spring of 2010. Maps provided by Drs. David Demer and Juan Zwolinski (SWFSC Advanced Survey Technologies).

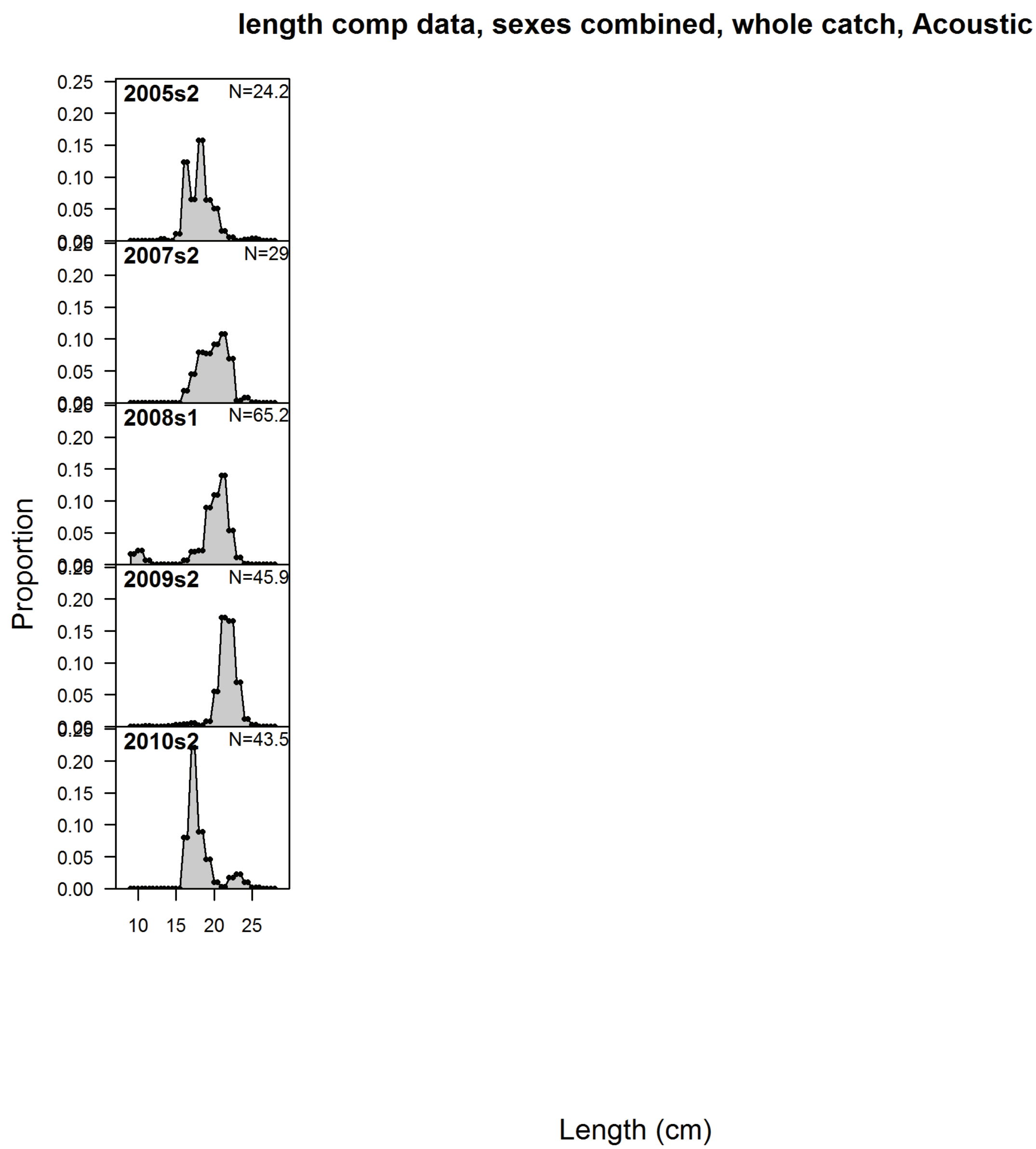


Figure 14a. Length-composition data (1-cm resolution) for the acoustic survey, 2005-2010.

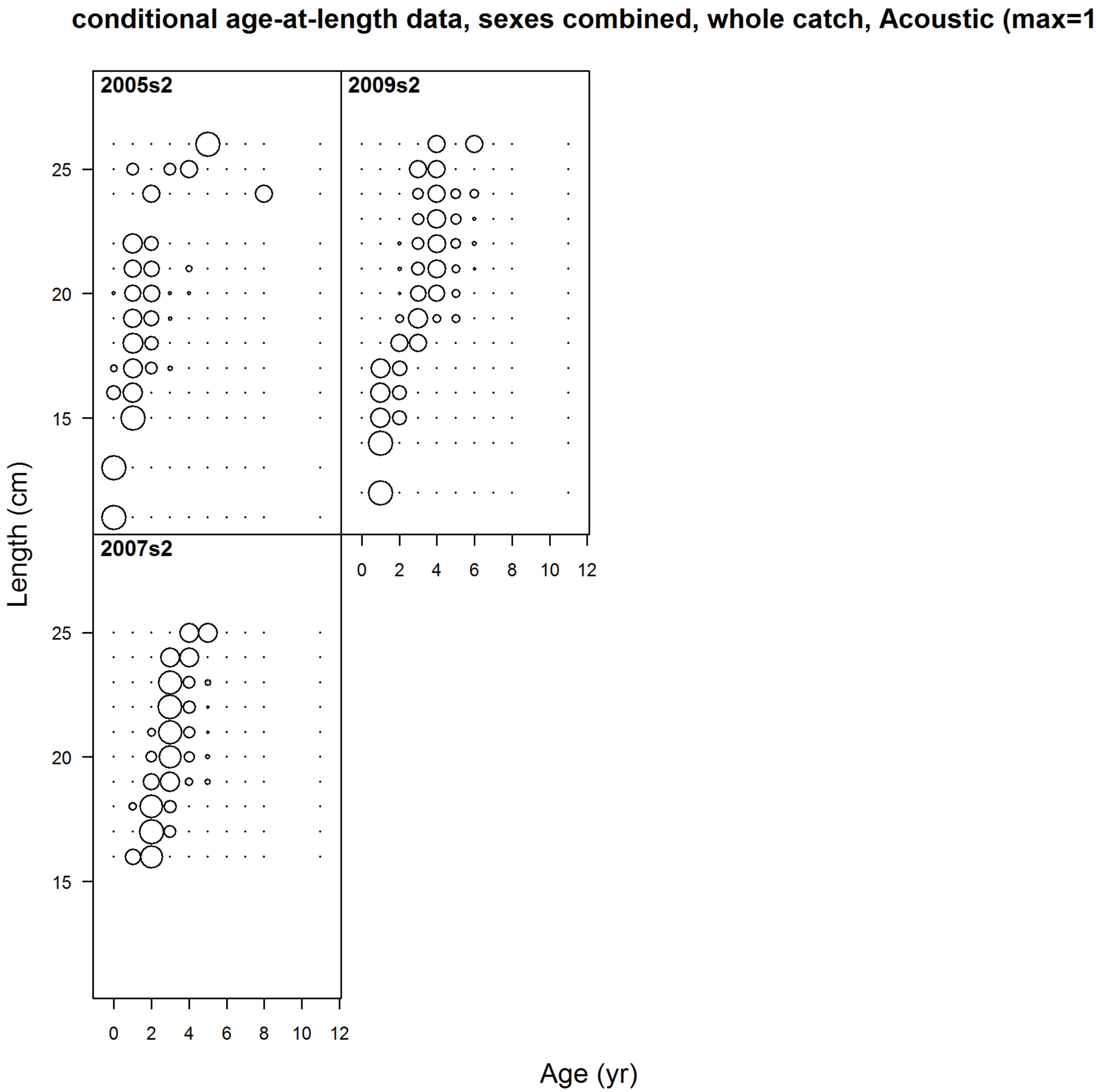


Figure 14b. Conditional age-at-length data for the Acoustic-trawl survey, 2005-2009.

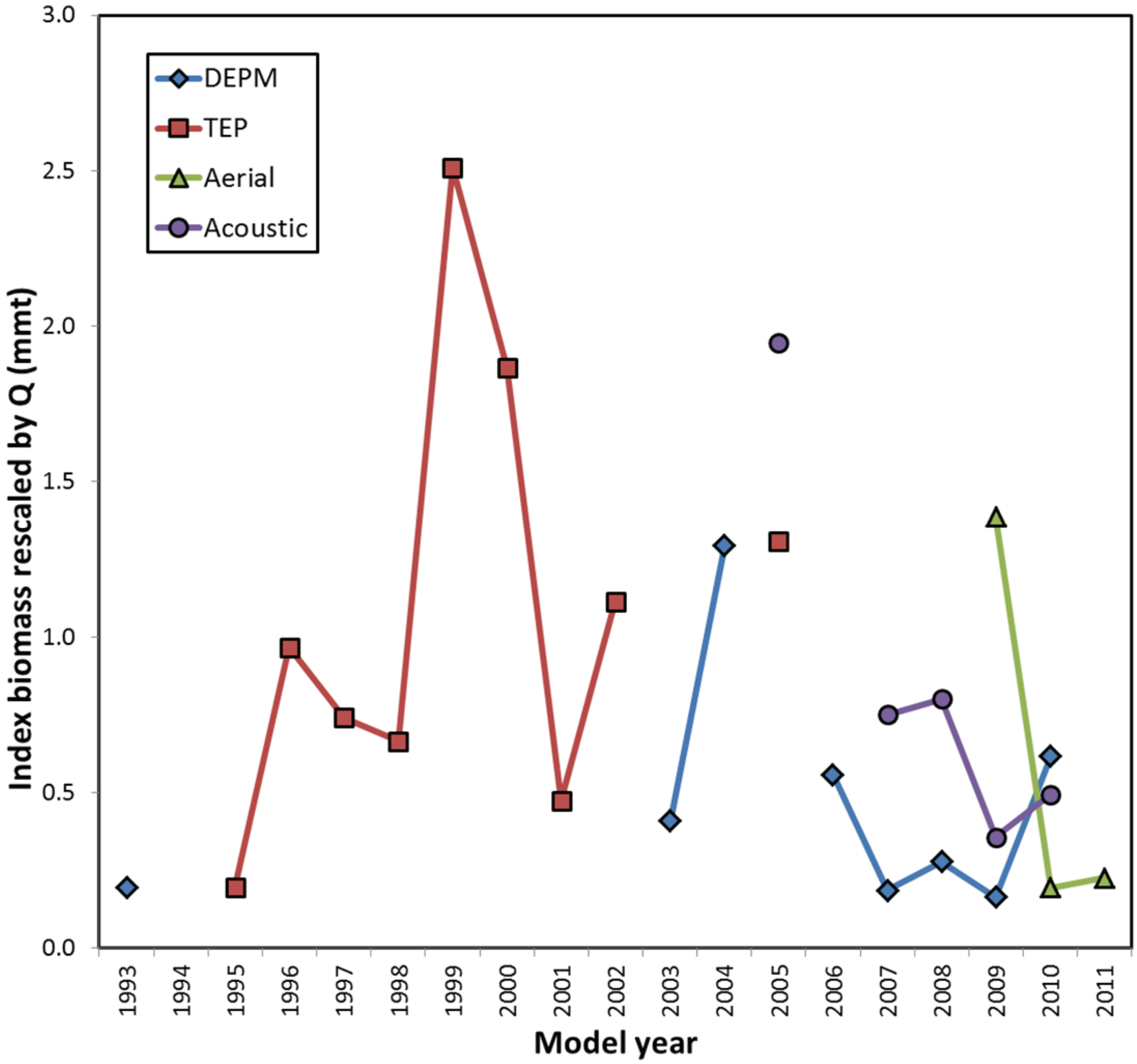


Figure 15. Survey indices of relative abundance standardized by base model estimates of q for each survey.

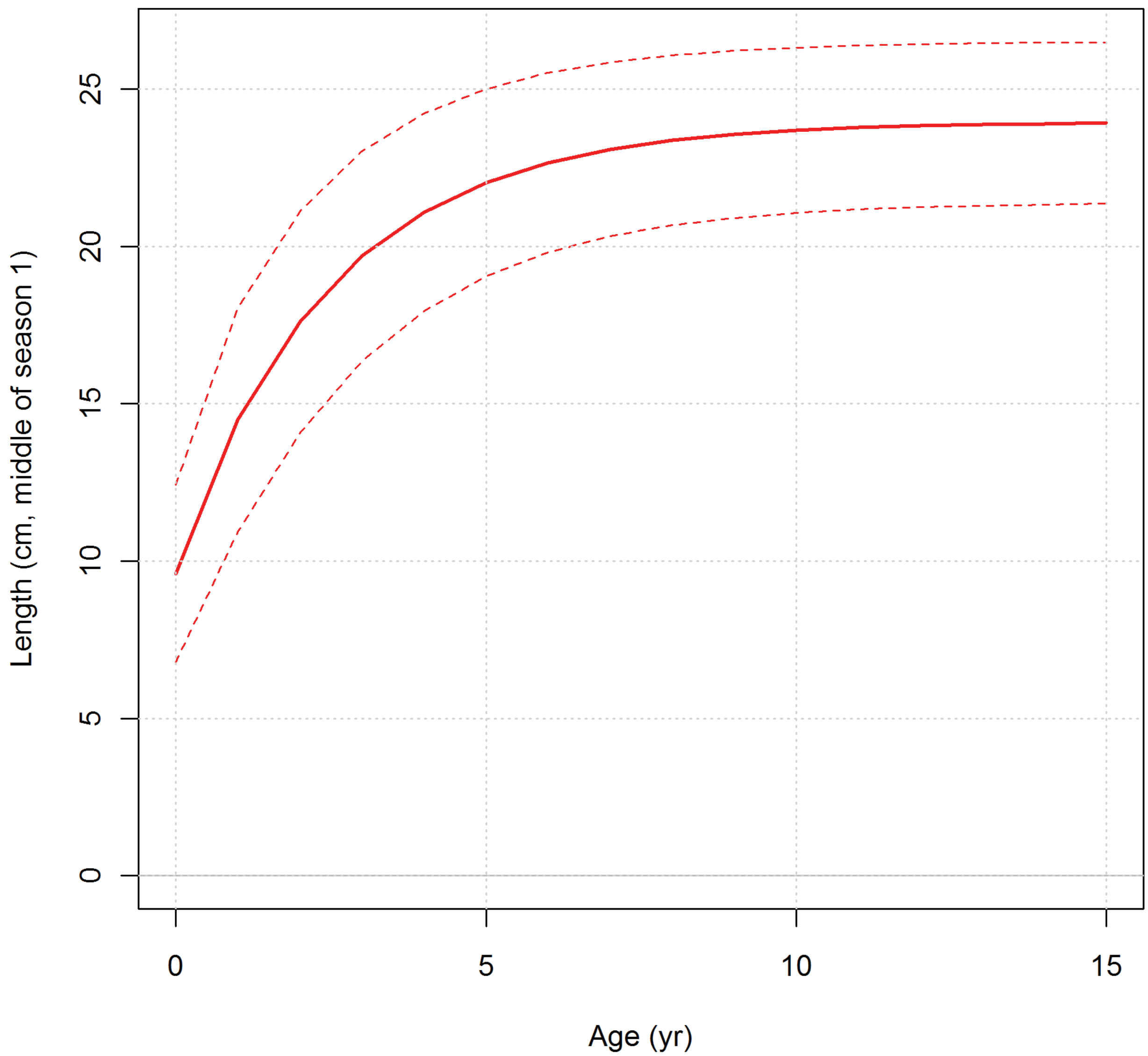


Figure 16. Length-at-age as estimated in the base model ($L_{0.5yr}$ = 11.2, L_{∞} = 24.0, K = 0.399).

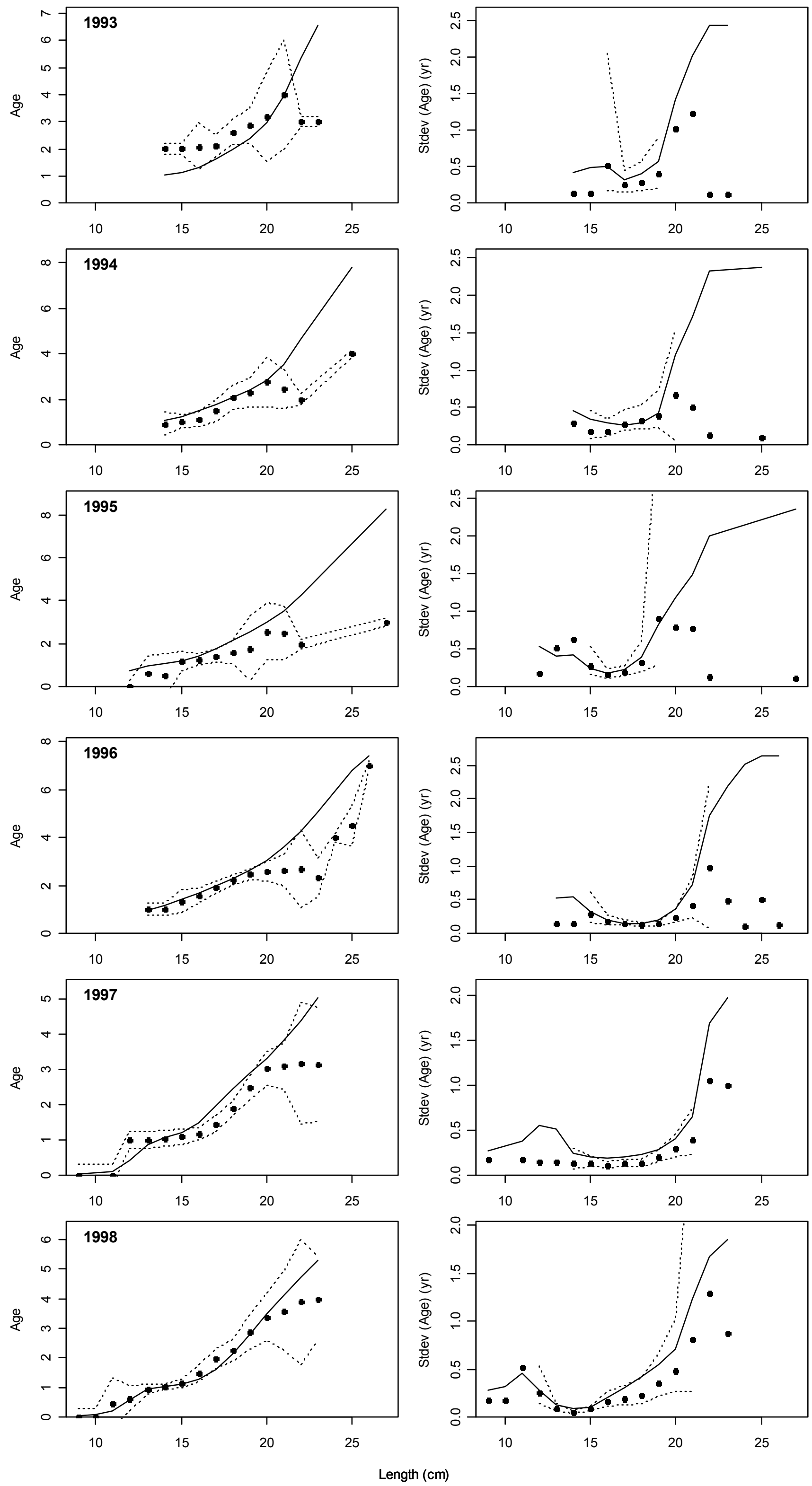


Figure 17a. Fit to conditional age-at-length data, MexCal_S1, 1993-1998.

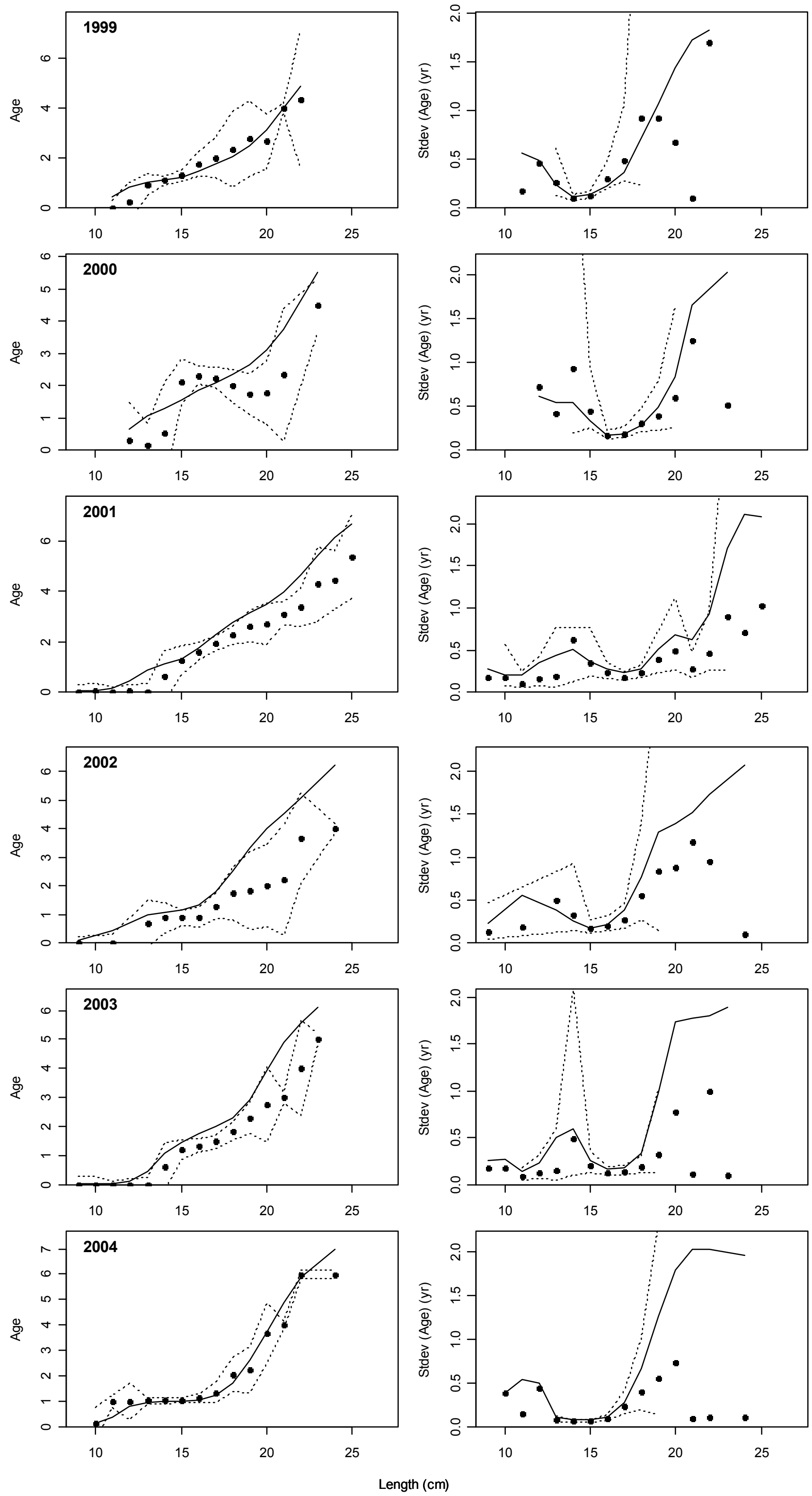


Figure 17a (cont'd). Fit to conditional age-at-length data, MexCal_S1, 1999-2004.

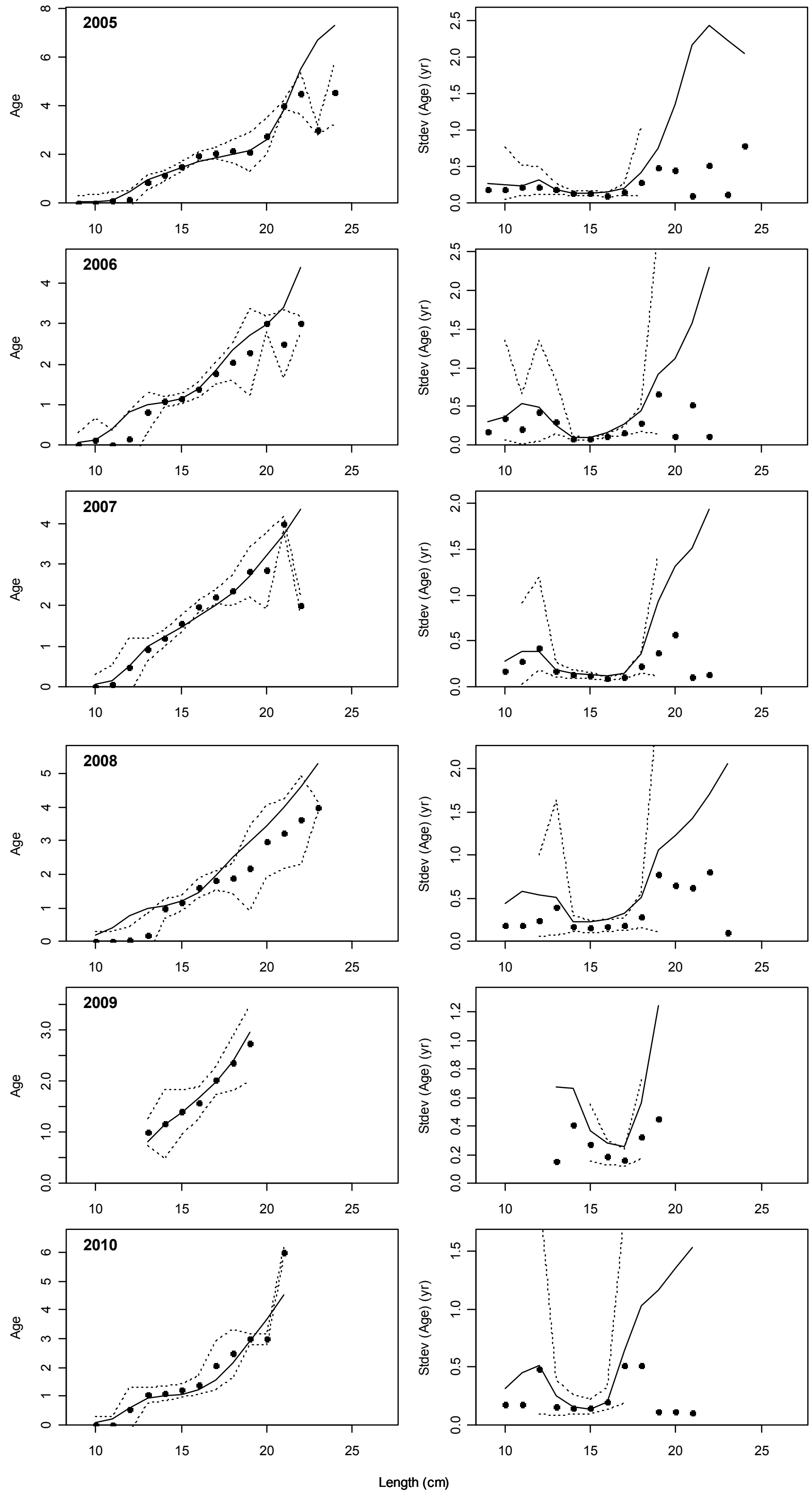


Figure 17a (cont'd). Fit to conditional age-at-length data, MexCal_S1, 2005-2010.

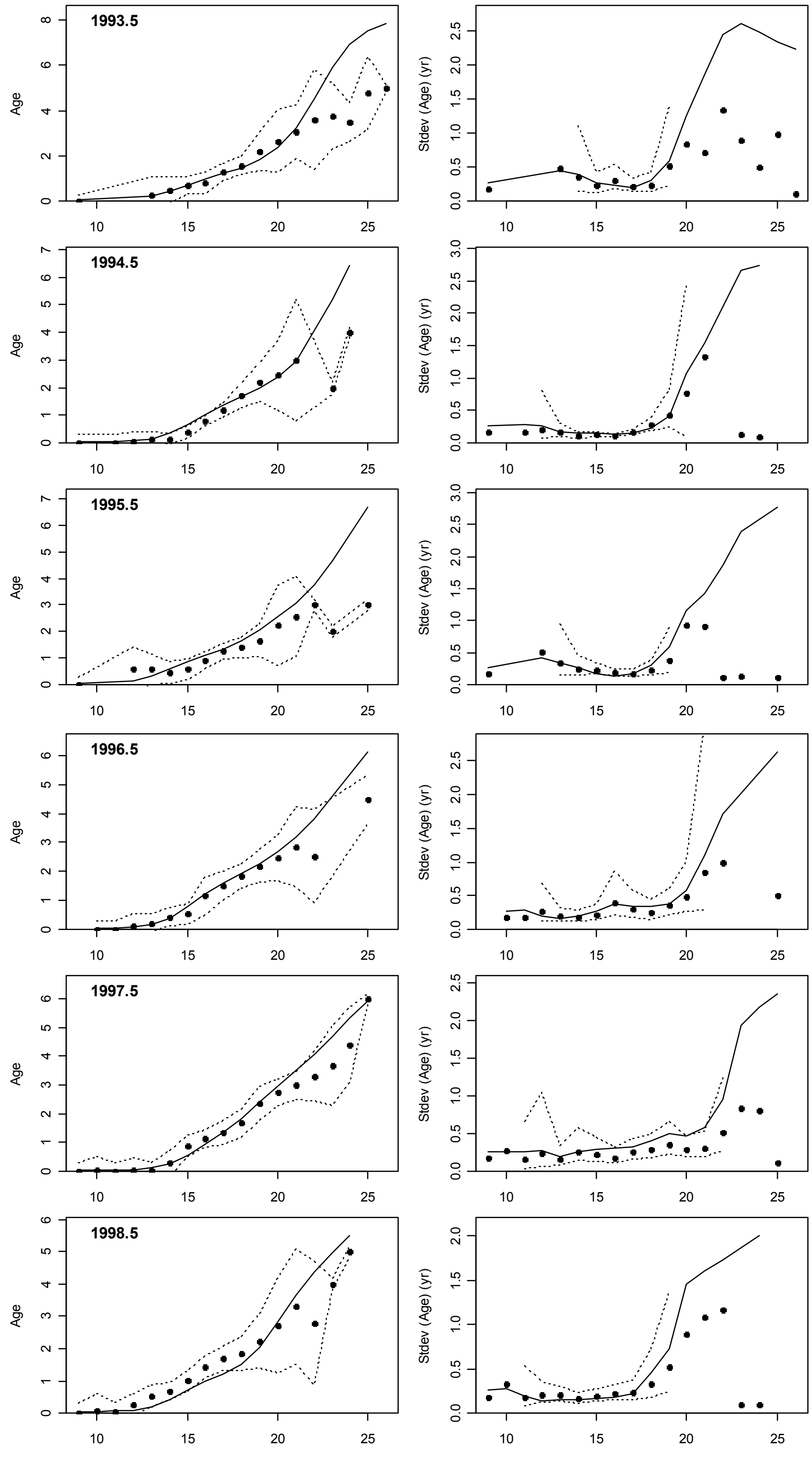


Figure 17b. Fit to conditional age-at-length data, MexCal_S2, 1993-1998.

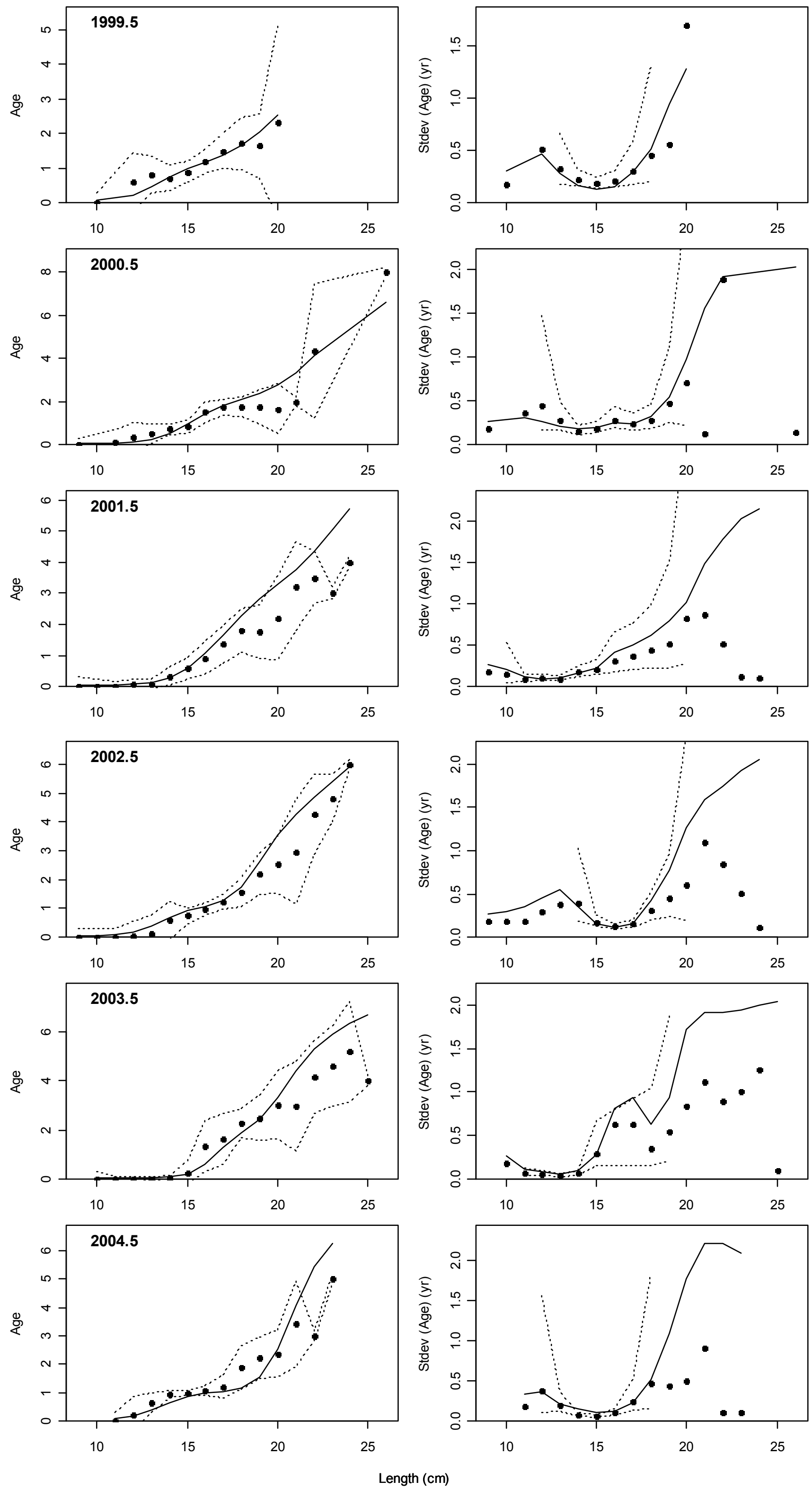


Figure 17b (cont'd). Fit to conditional age-at-length data, MexCal_S2, 1999-2004.

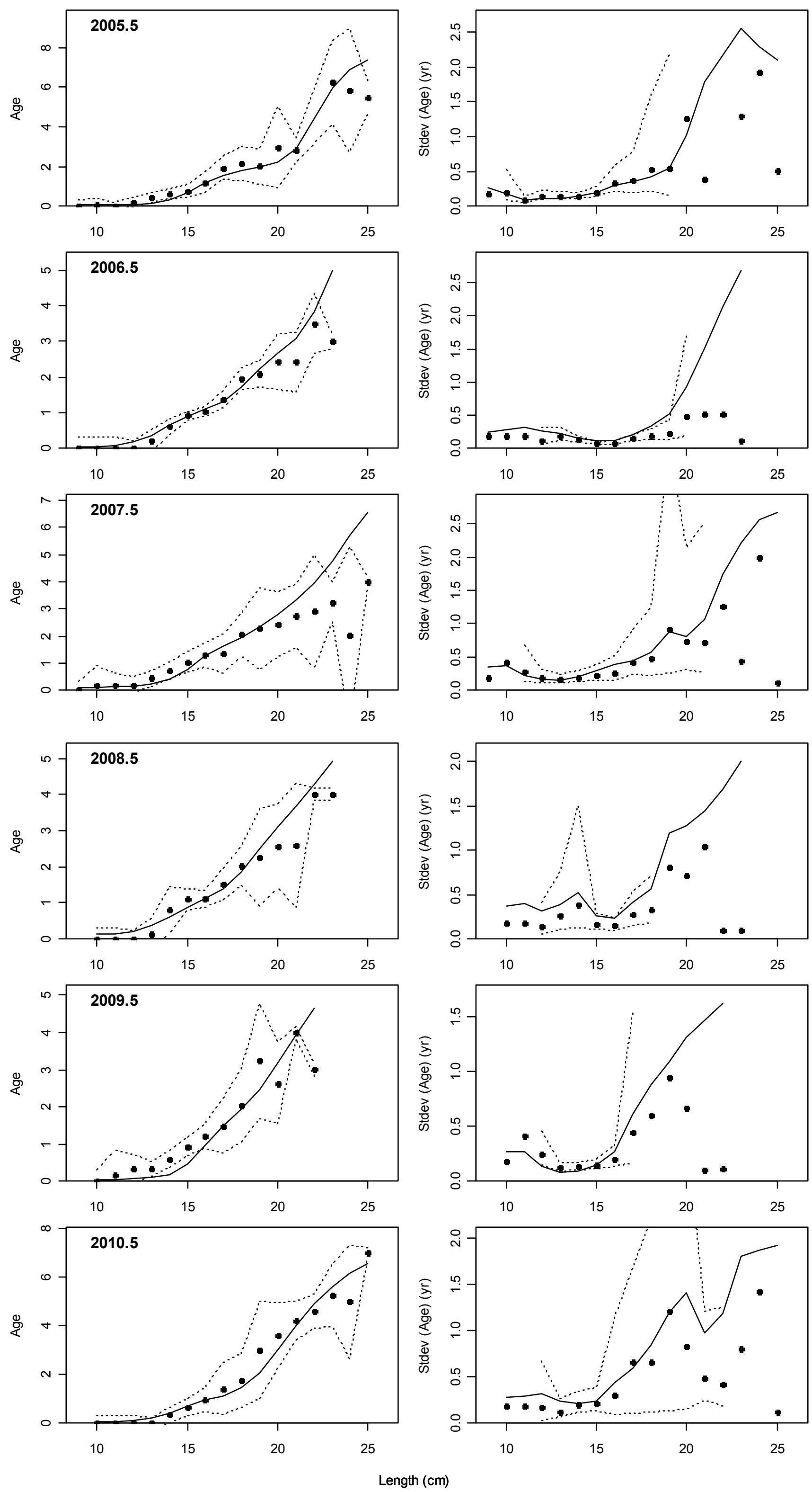


Figure 17b (cont'd). Fit to conditional age-at-length data, MexCal_S2, 2005-2010.

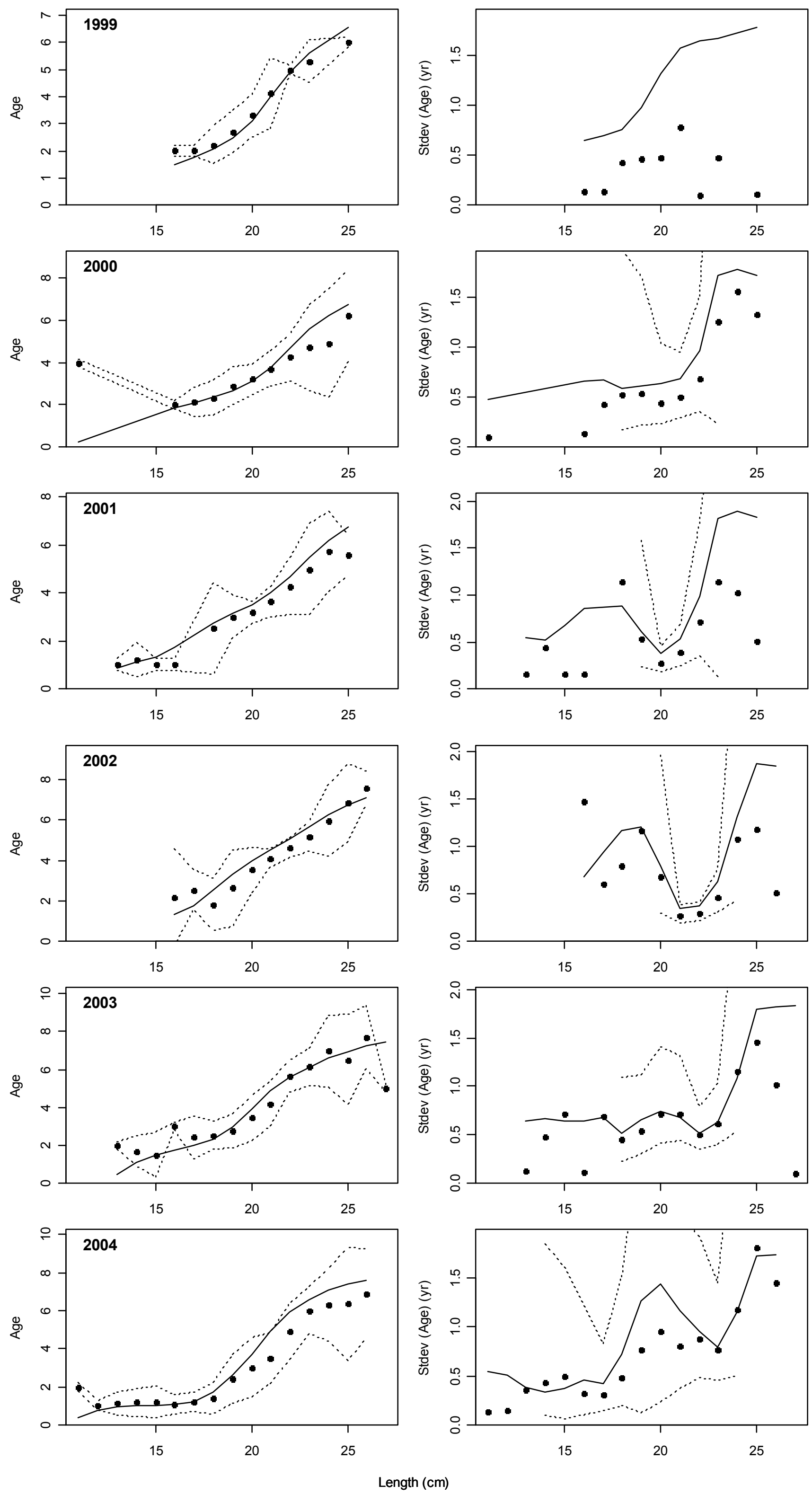


Figure 17c. Fit to conditional age-at-length data, PacNW, 1999-2004.

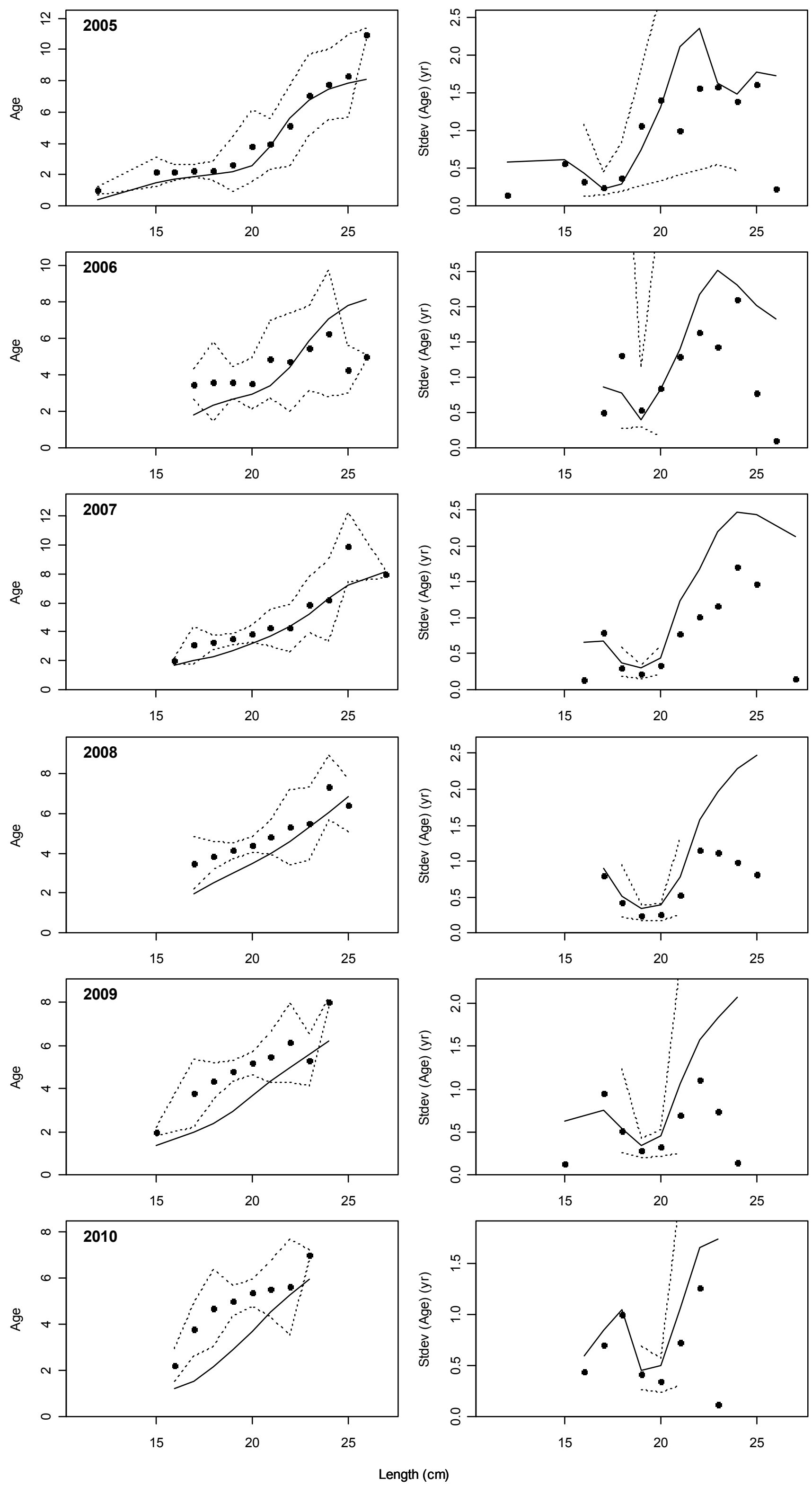


Figure 17c (cont'd). Fit to conditional age-at-length data, PacNW, 2005-2010.

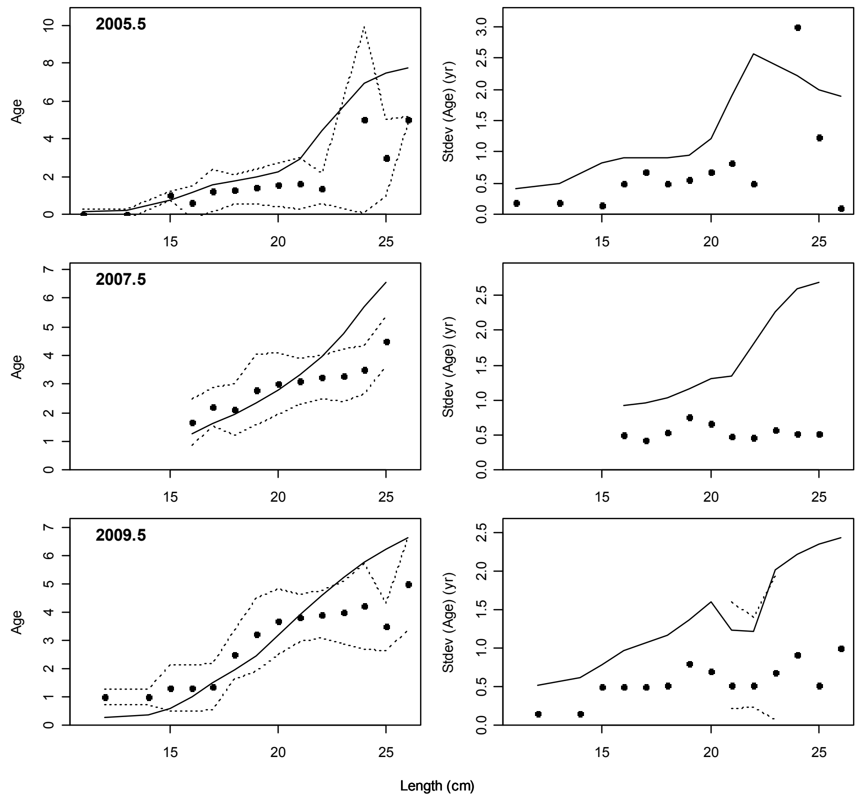


Figure 17d. Fit to conditional age-at-length data, Acoustic survey, 2005-2009.

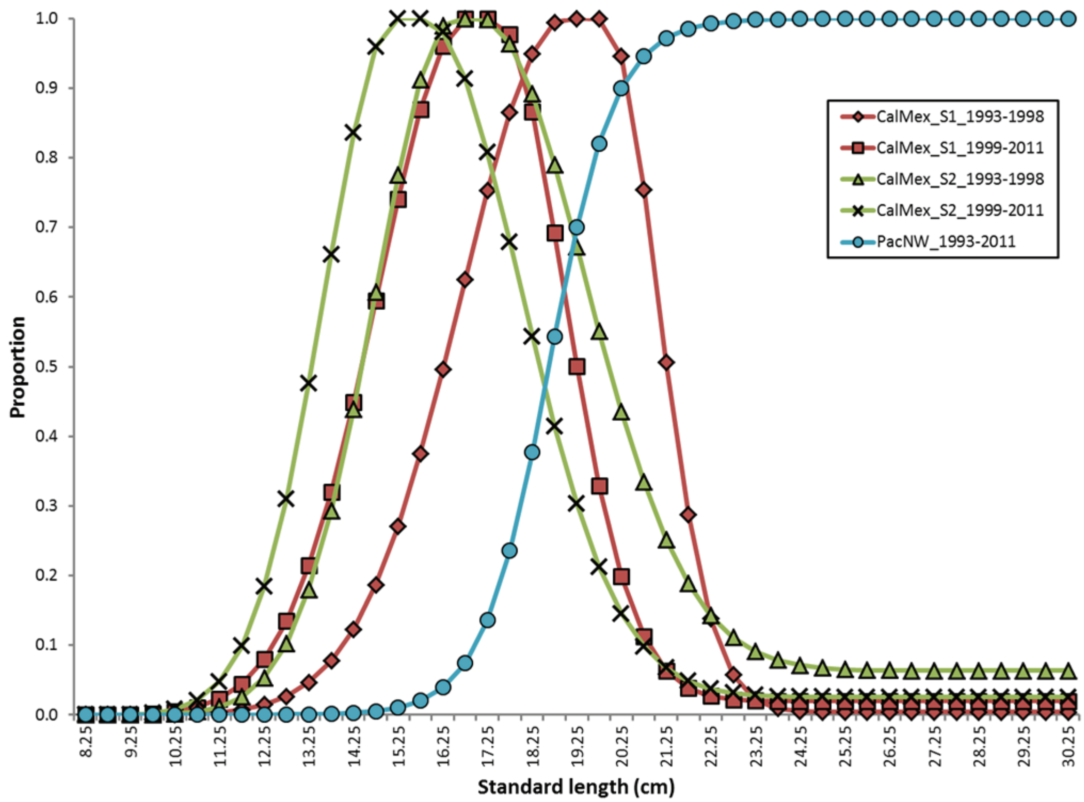


Figure 18a. Fishery length selectivities estimated by SS.

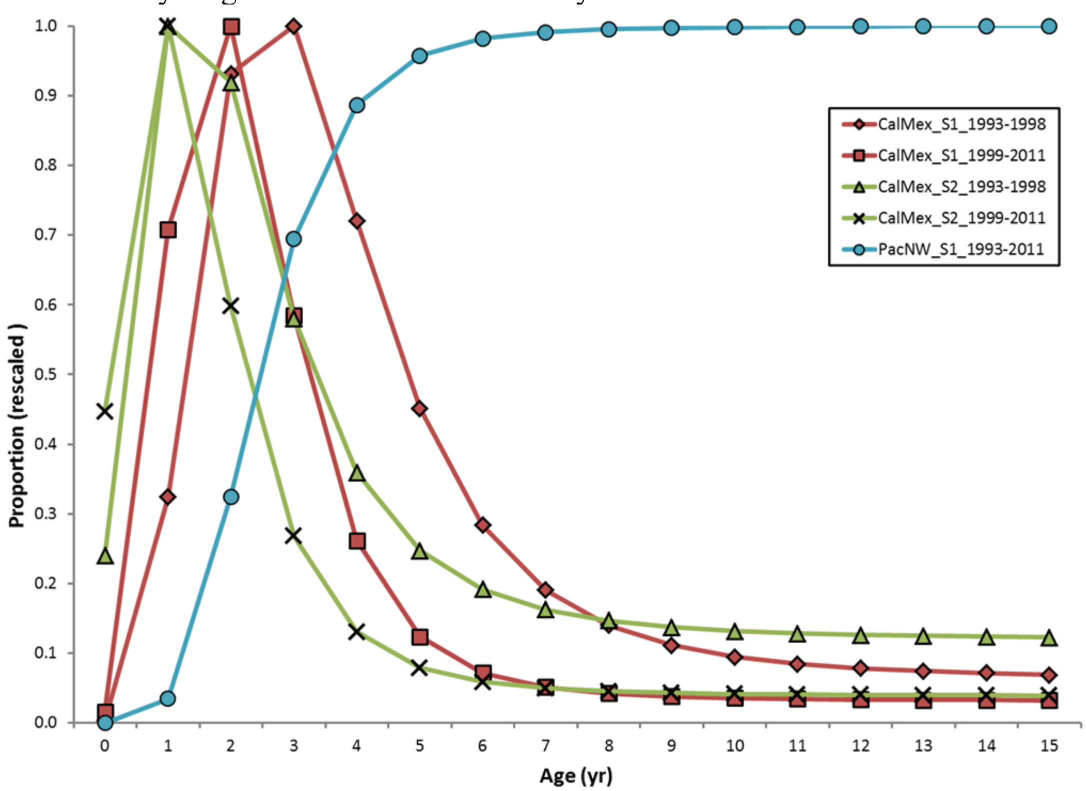


Figure 18b. Fishery age selectivities as implied by the product of length selectivity and the ALK.

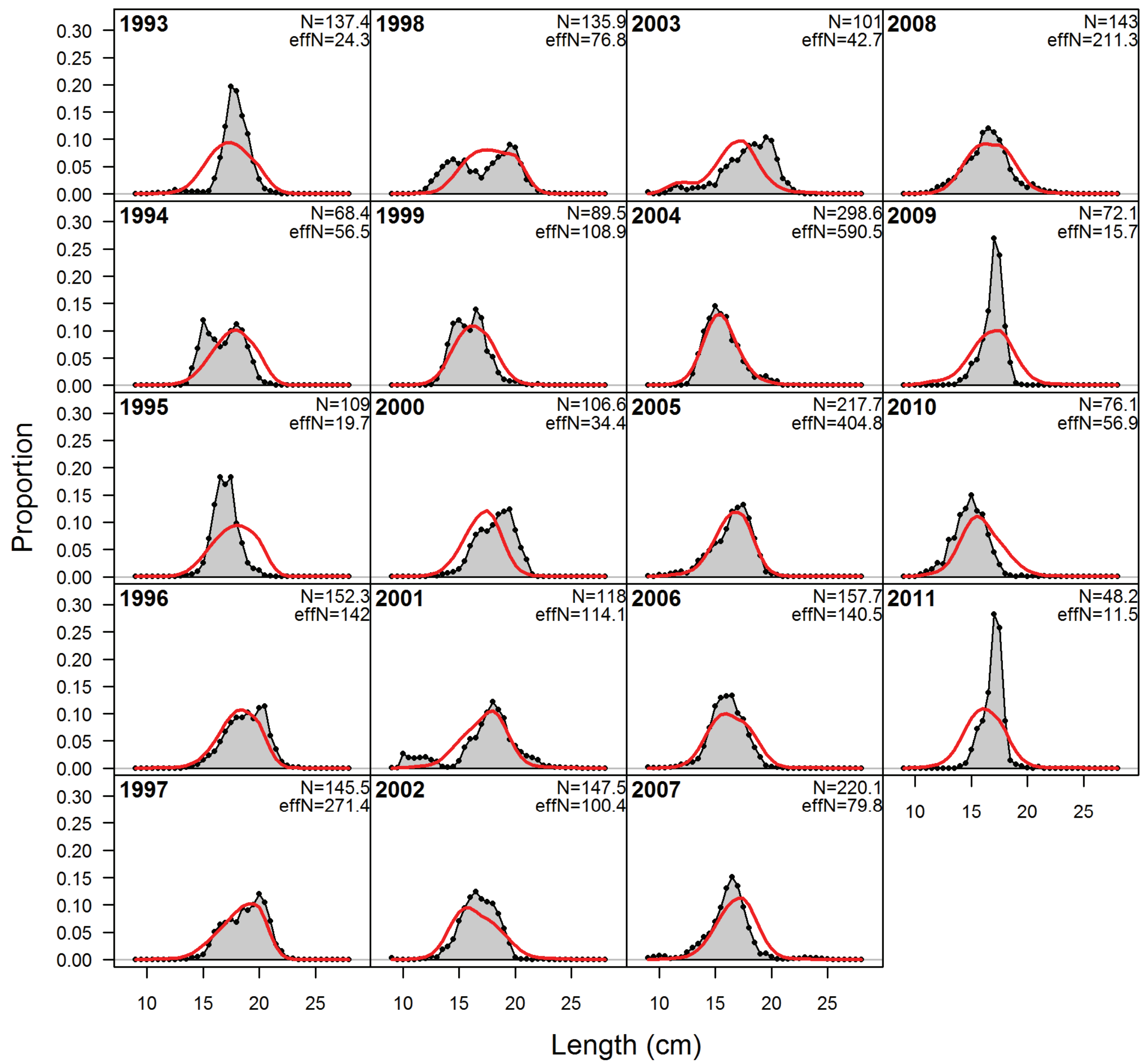


Figure 19a. Base model fits to MexCal_S1 length-frequency data (Season 1).

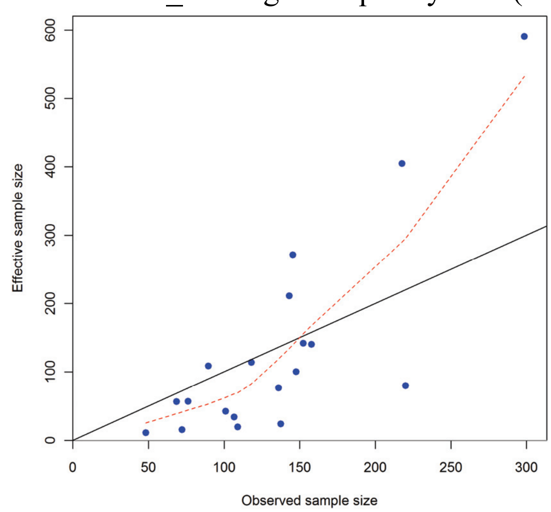


Figure 19b. Observed and effective sample sizes for MexCal_S1 fishery length-frequency data.

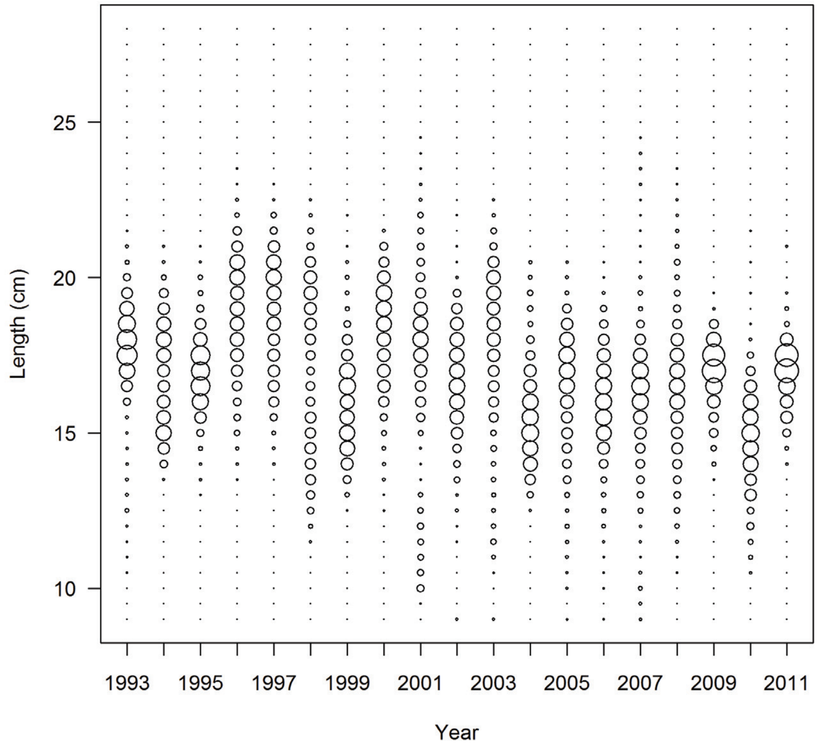


Figure 19c. Bubble plot of MexCal_S1 length-frequency data (Season 1).

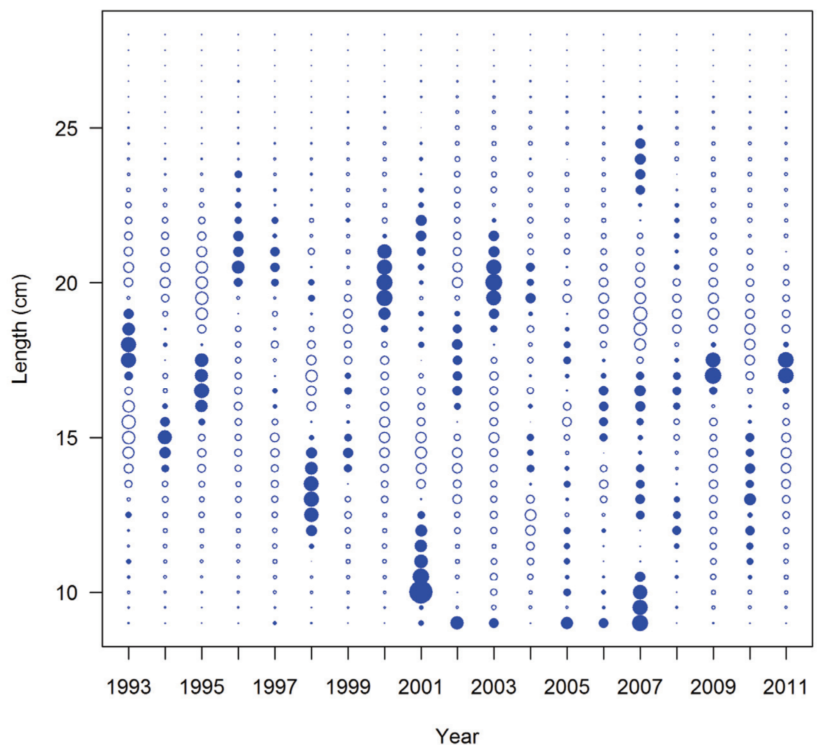


Figure 19d. Pearson residuals (max=9.19) for fit to MexCal_S1 length-frequency data.

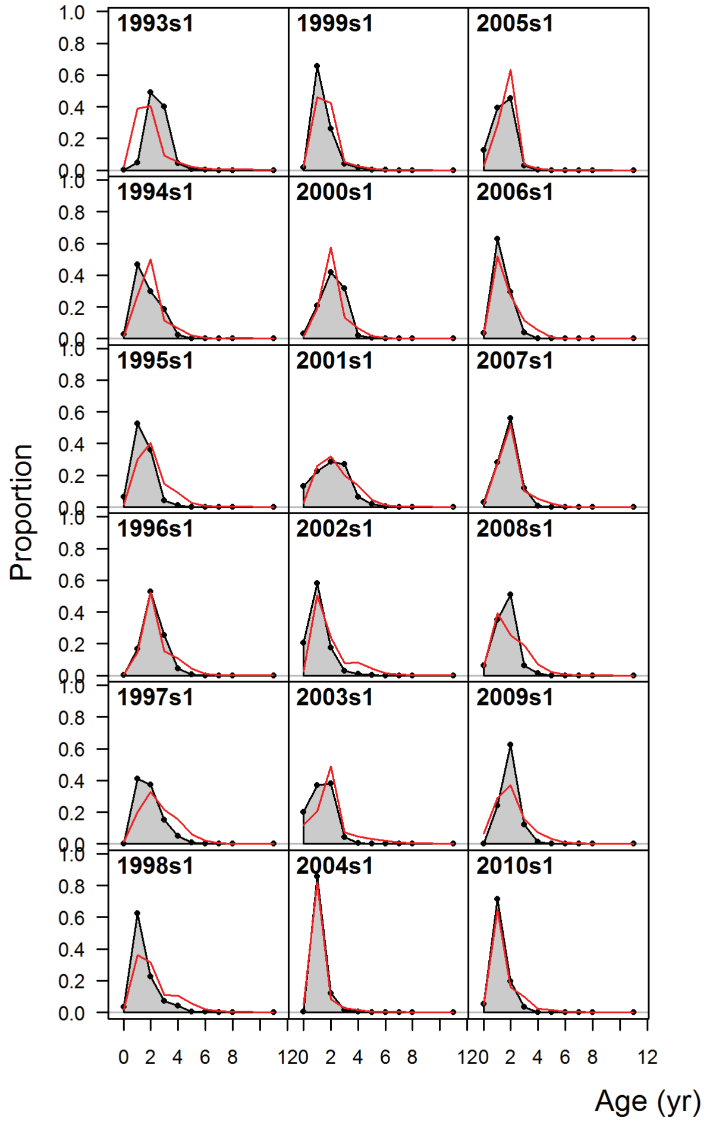


Figure 20a. Base model fits to MexCal_S1 implied age-frequency data (Season 1).

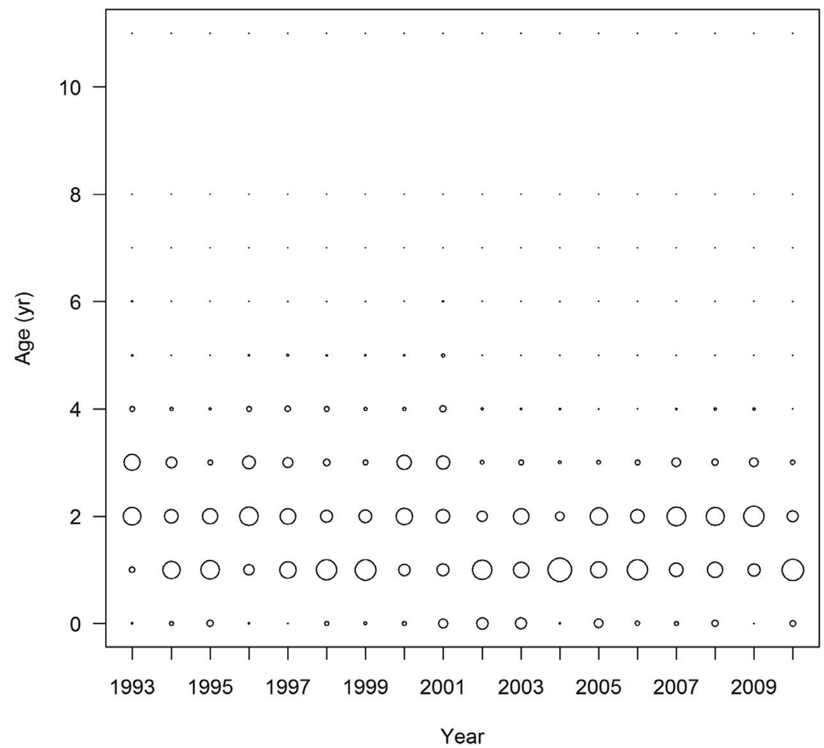


Figure 20b. Bubble plot of MexCal_S1 implied age-frequency data (Season 1).

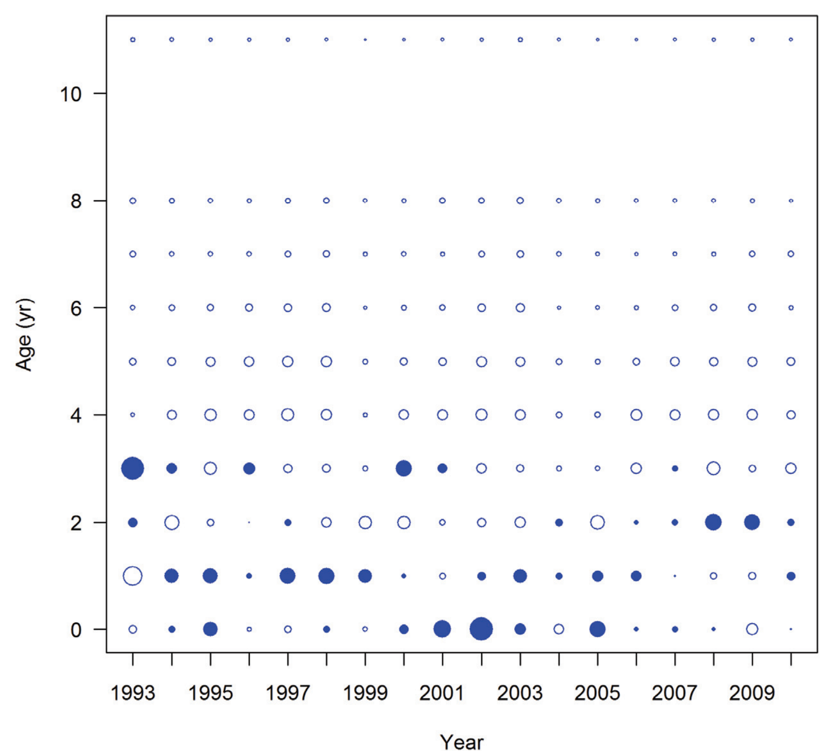


Figure 20c. Pearson residuals (max=1.13) for fit to MexCal_S1 implied age-frequency data.

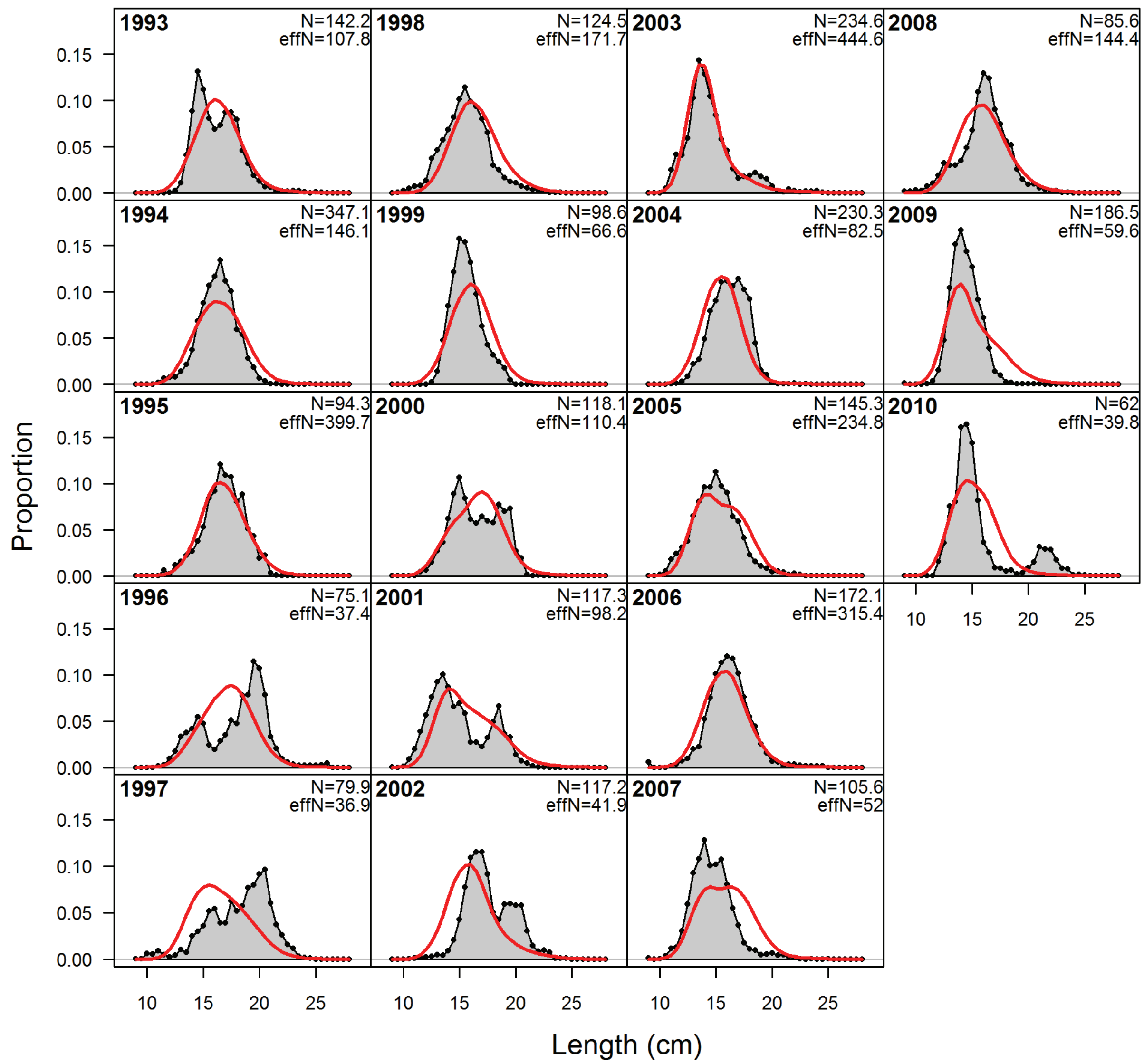


Figure 21a. Base model fits to MexCal_S2 length-frequency data (Season 2).

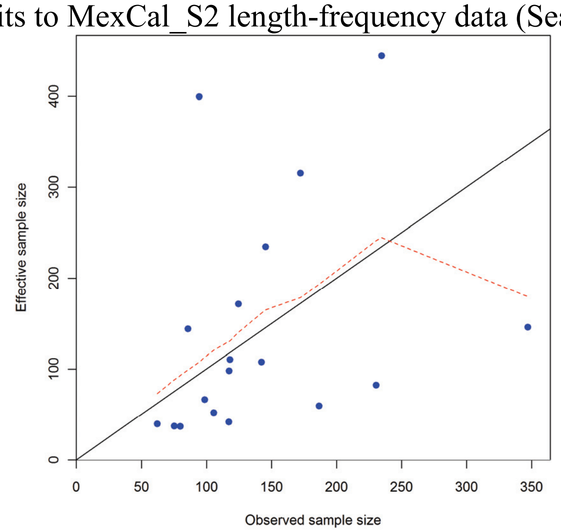


Figure 21b. Observed and effective sample sizes for MexCal_S2 fishery length-frequency data.

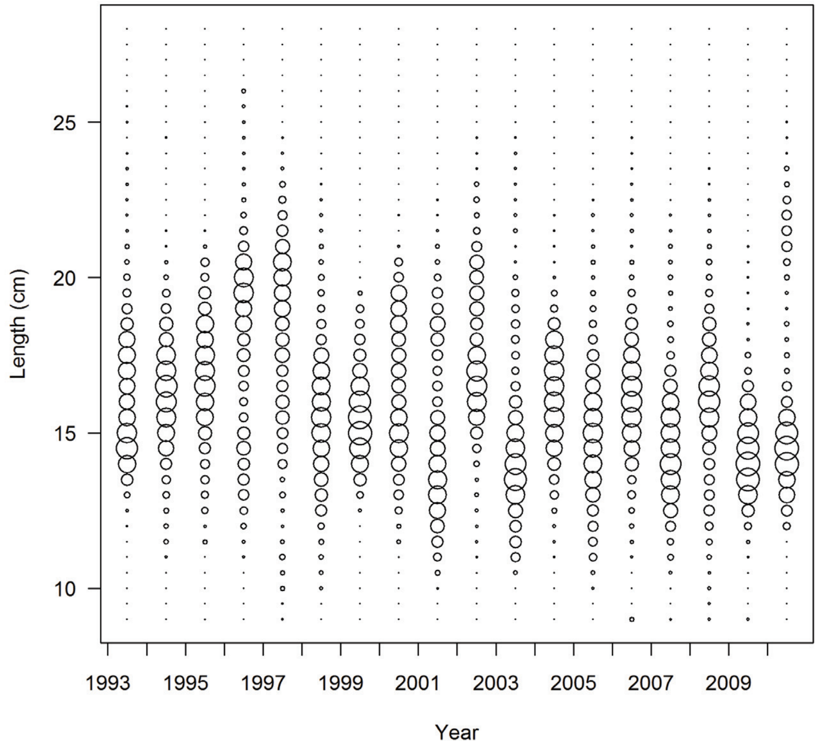


Figure 21c. Bubble plot of MexCal_S2 length-frequency data (Season 2).

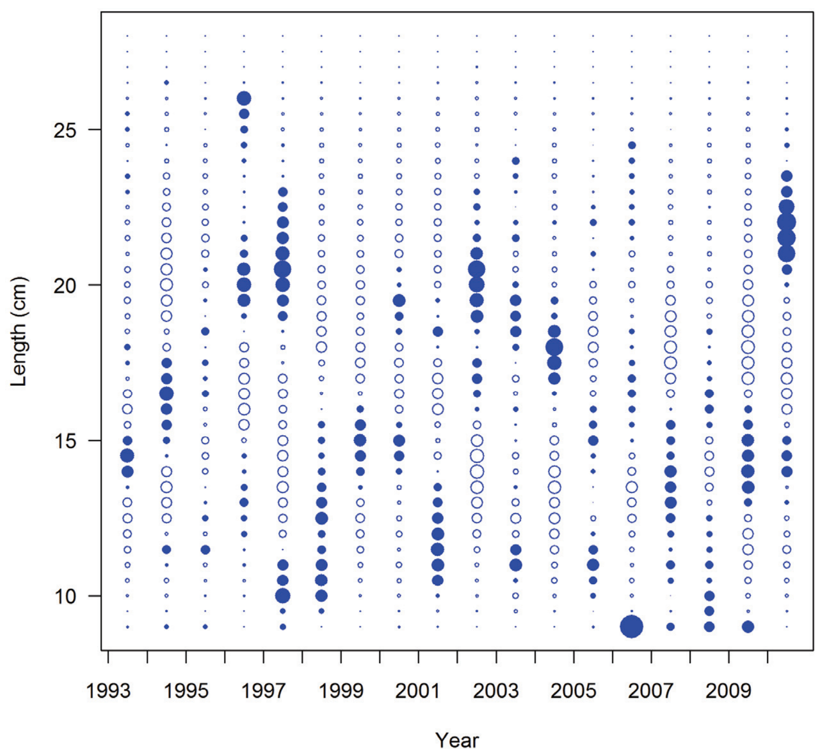


Figure 21d. Pearson residuals (max=7.62) for fit to MexCal_S2 length-frequency data.

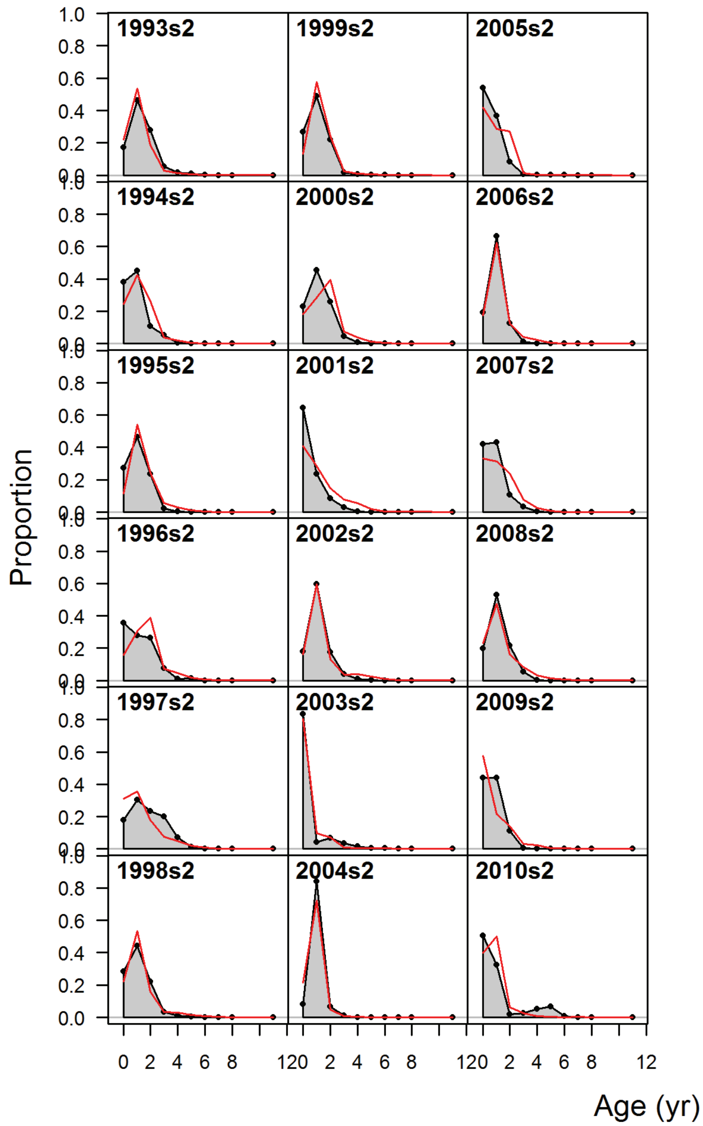


Figure 22a. Base model fits to MexCal_S2 implied age-frequency data (Season 2).

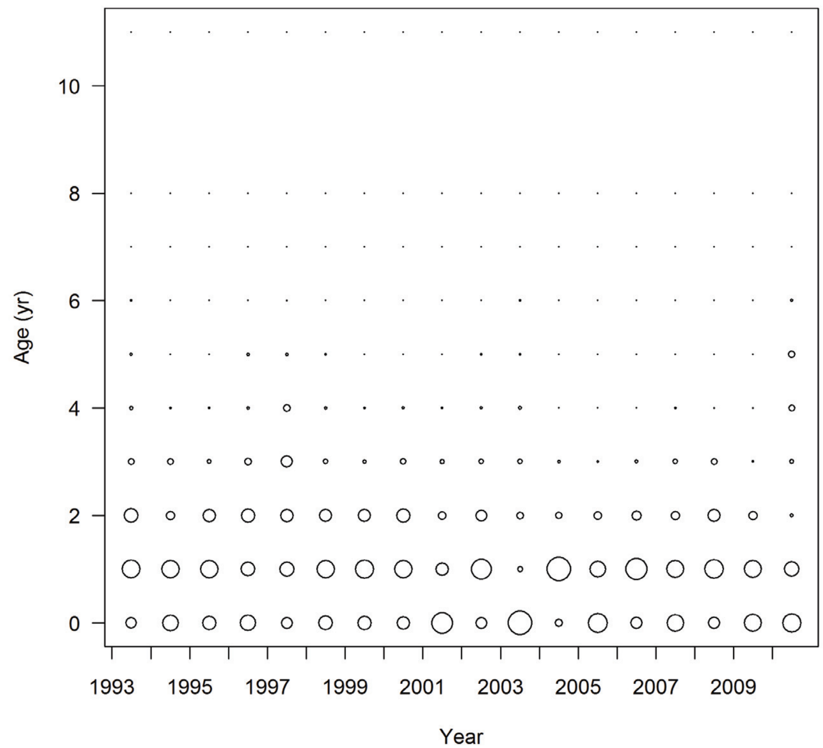


Figure 22b. Bubble plot of MexCal_S2 implied age-frequency data (Season 2).

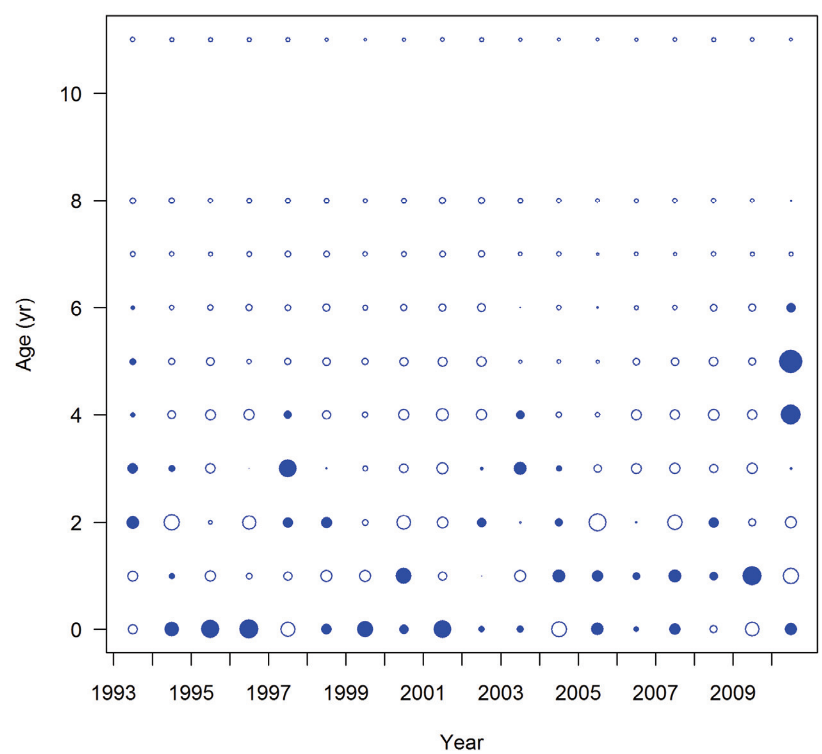


Figure 22c. Pearson residuals (max=0.81) for fit to MexCal_S2 implied age-frequency data.

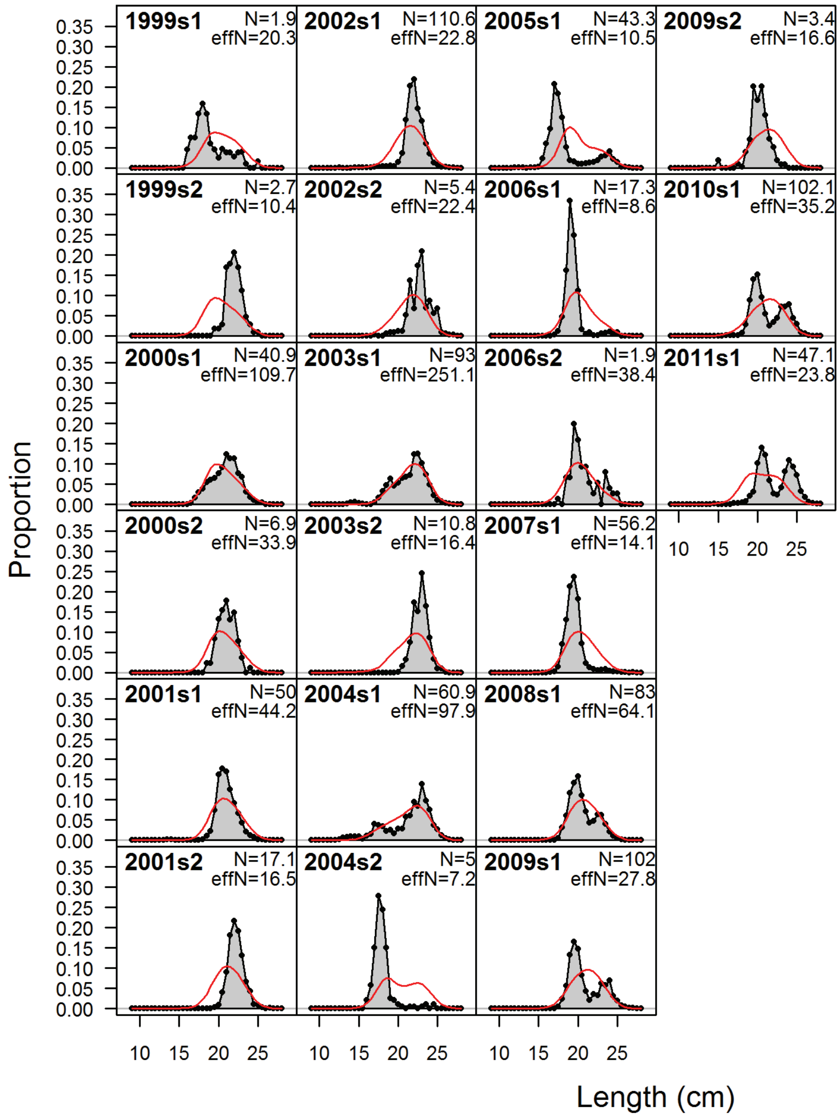


Figure 23a. Base model fits to PacNW length-frequency data.

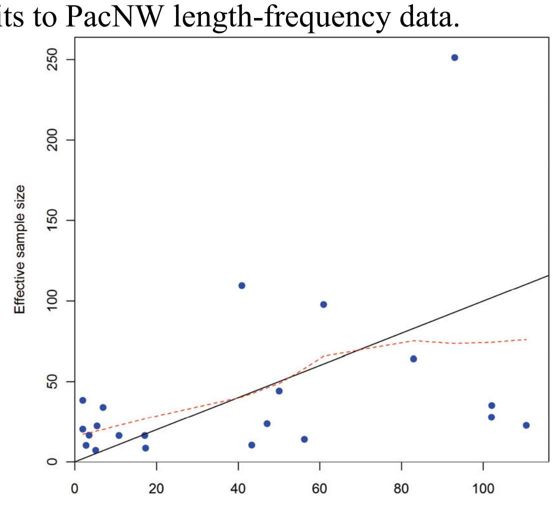


Figure 23b. Observed and effective sample sizes for PacNW fishery length-frequency data.

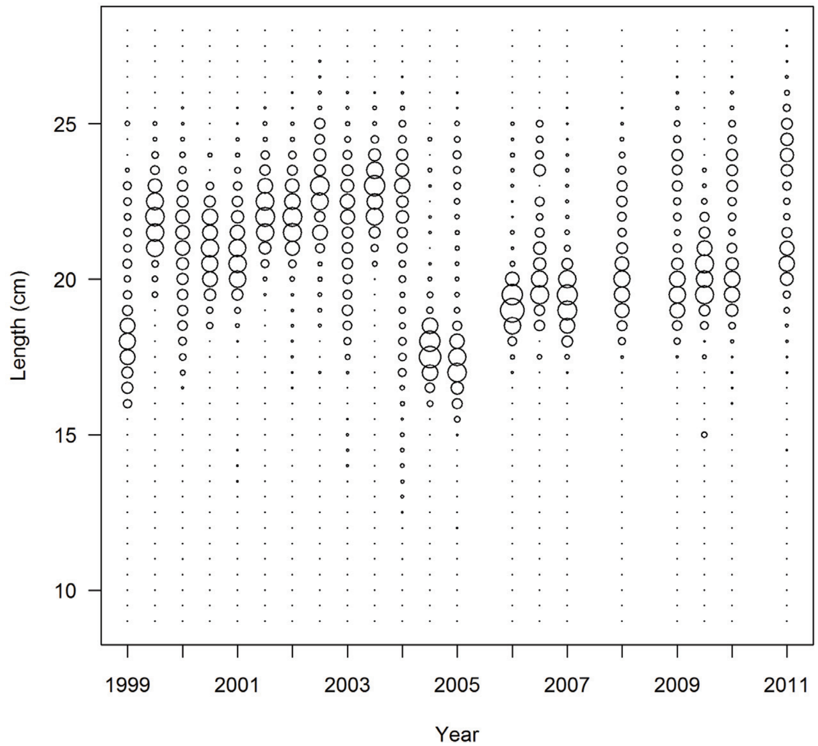


Figure 23c. Bubble plot of PacNW length-frequency data.

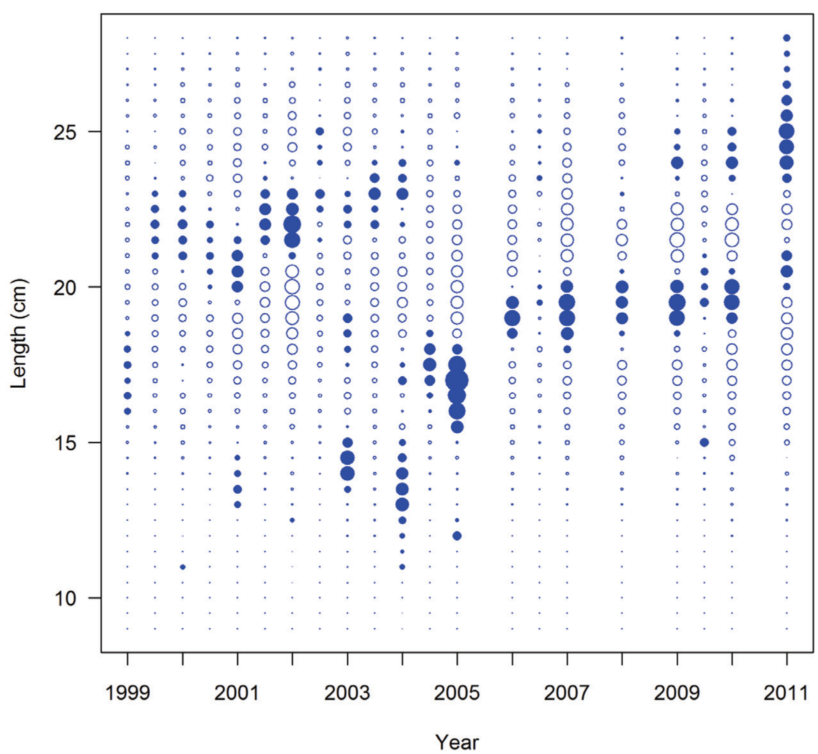


Figure 23d. Pearson residuals (max=6.72) for fit to PacNW length-frequency data.

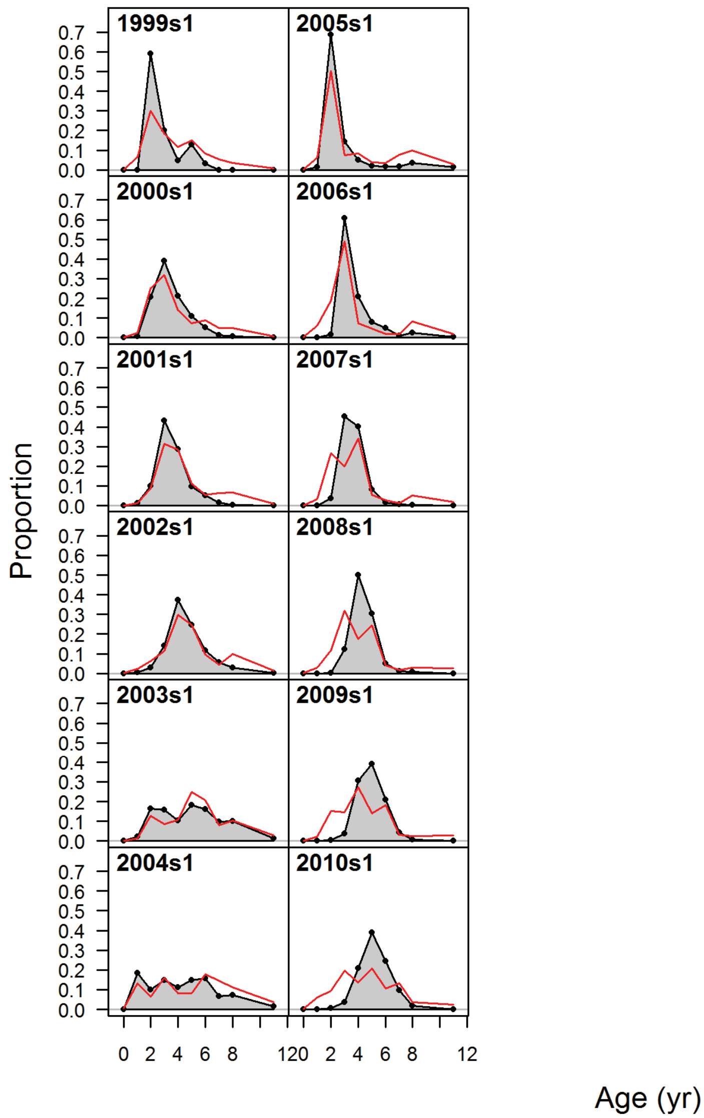


Figure 24a. Base model fits to implied age-frequency data for the PacNW fishery.

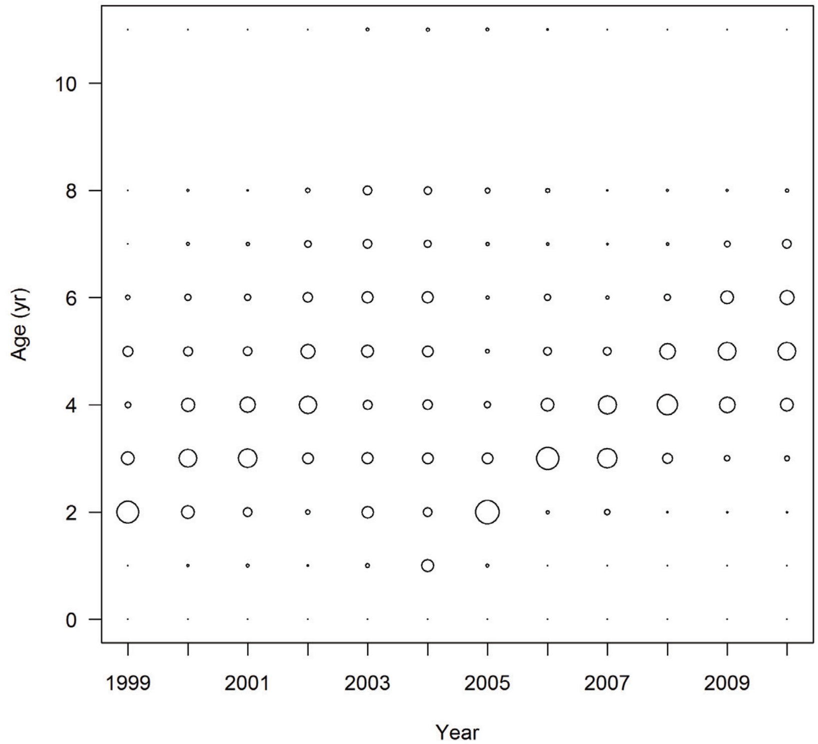


Figure 24b. Bubble plot of PacNW implied age-frequency data.

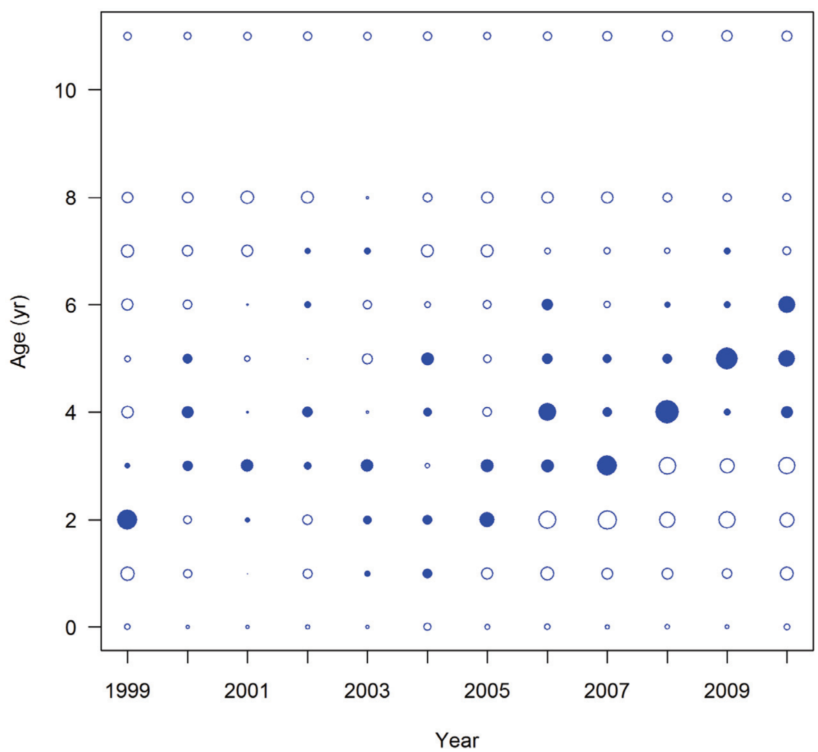


Figure 24c. Pearson residuals (max=0.86) for fit to PacNW implied age-frequency data.

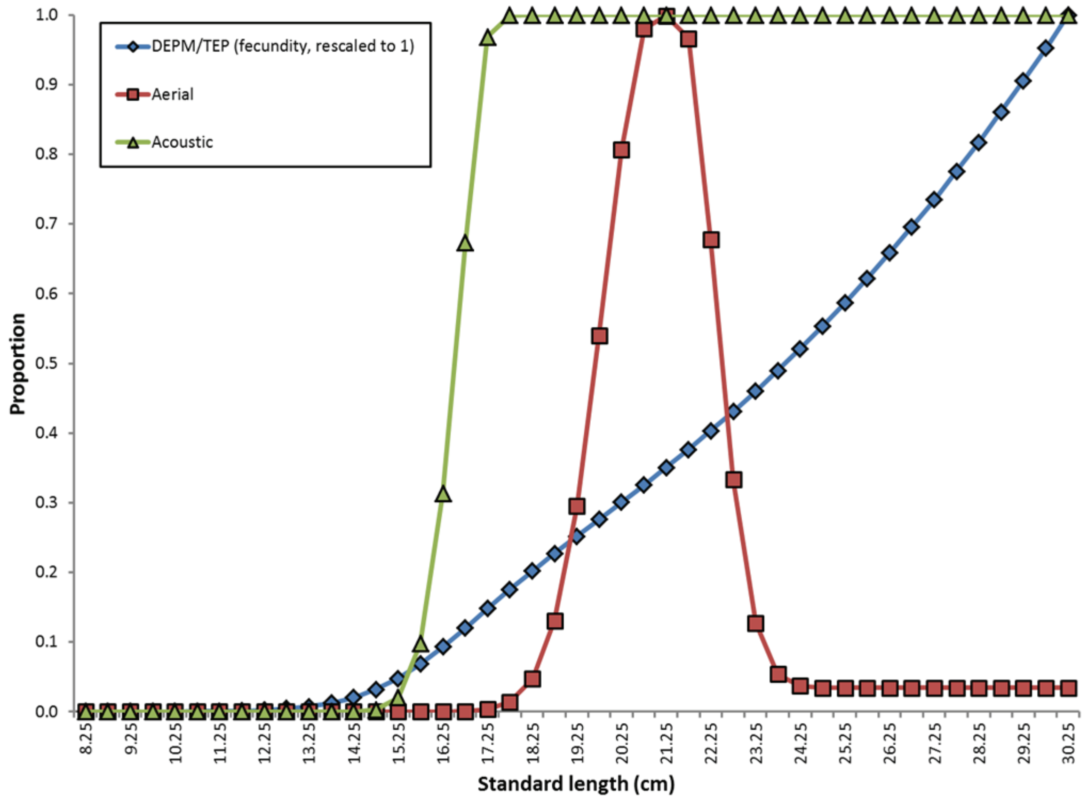


Figure 25a. Survey length selectivities estimated by SS.

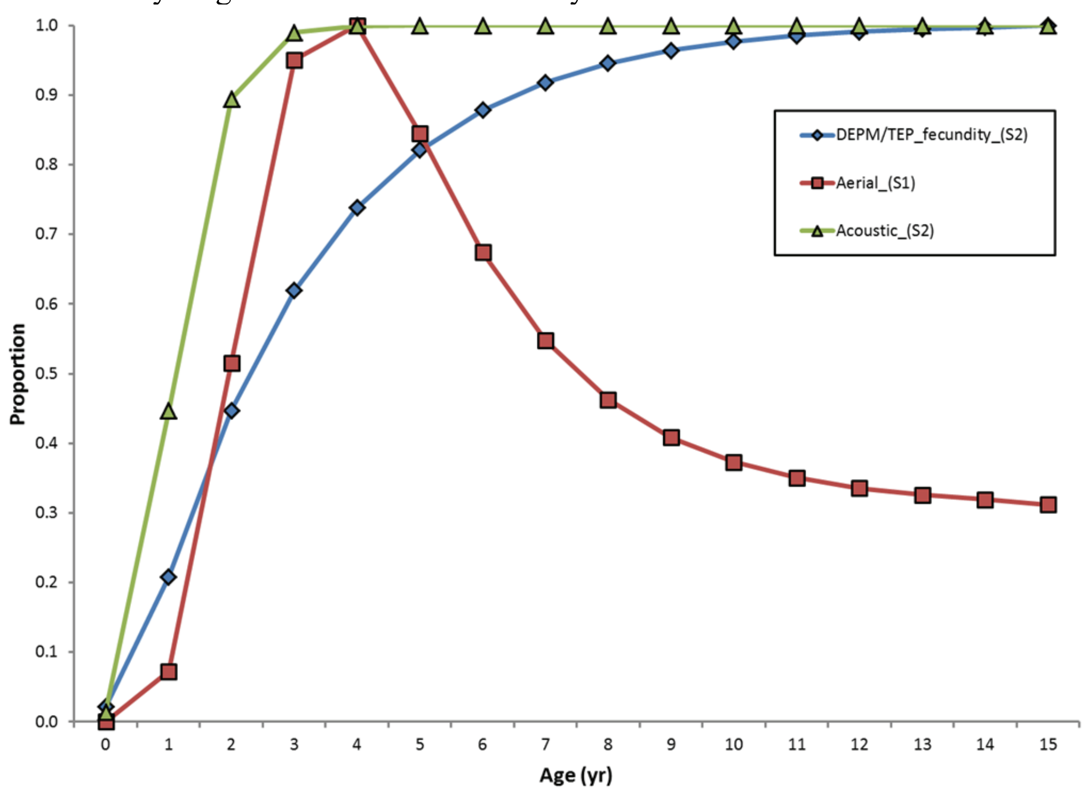


Figure 25b. Survey age selectivities as implied by the product of length selectivity and the ALK.

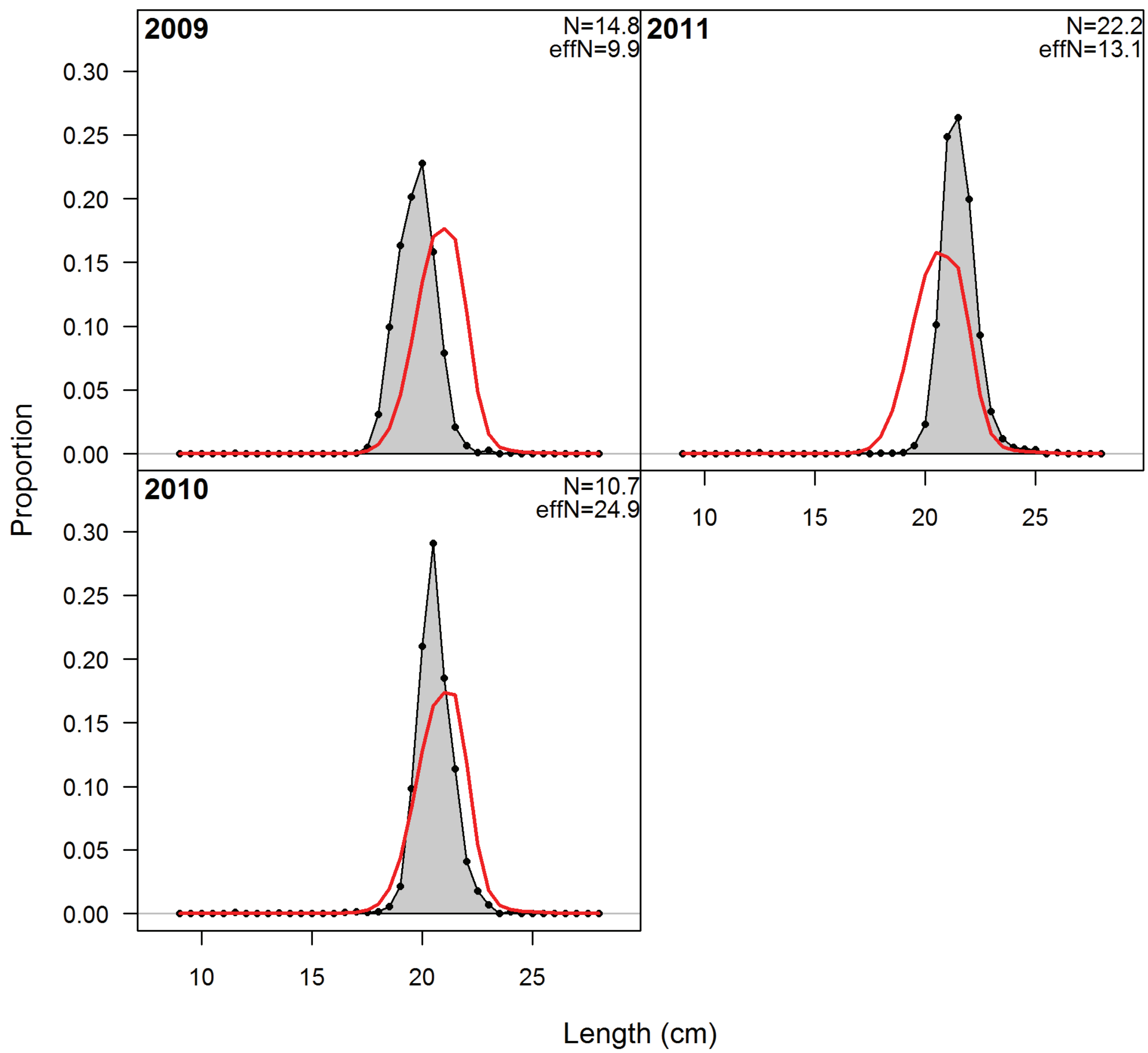


Figure 26a. Base model fits to Aerial survey length-frequency data.

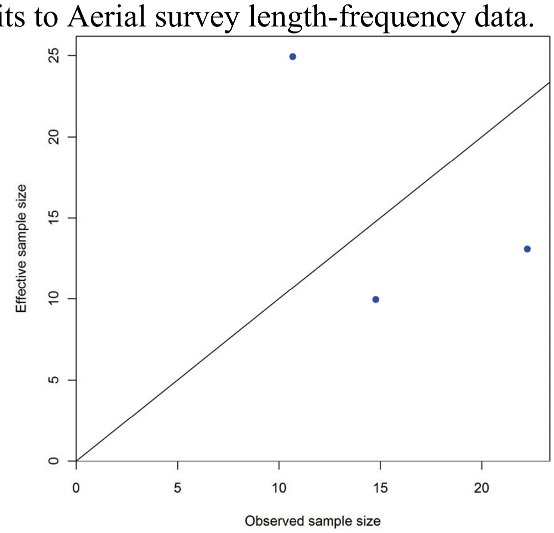


Figure 26b. Observed and effective sample sizes for Aerial survey fishery length-frequency data.

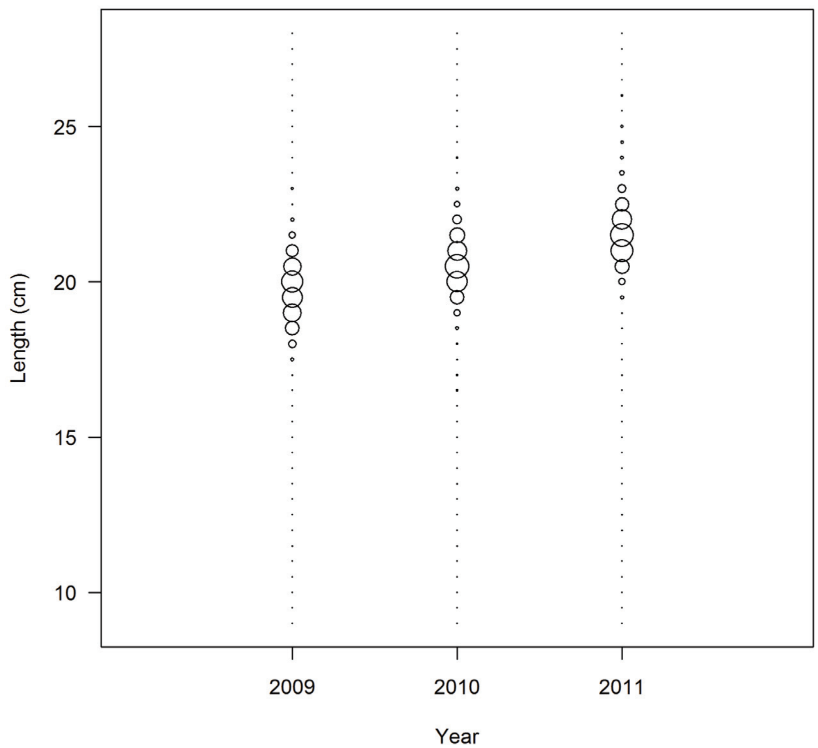


Figure 26c. Bubble plot of Aerial survey length-frequency data.

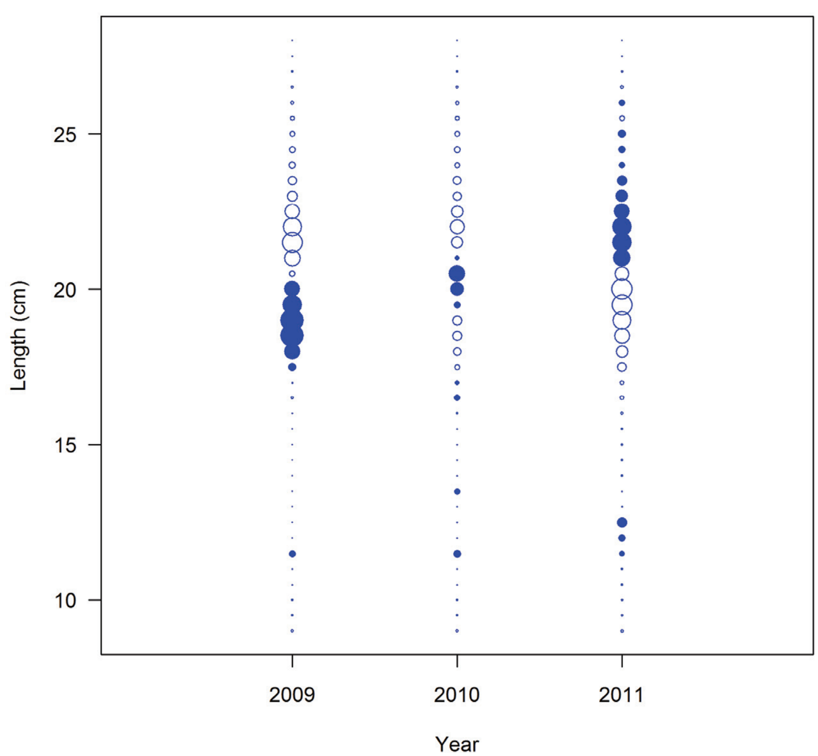


Figure 26d. Pearson residuals (max=2.19) for fit to Aerial survey length-frequency data.

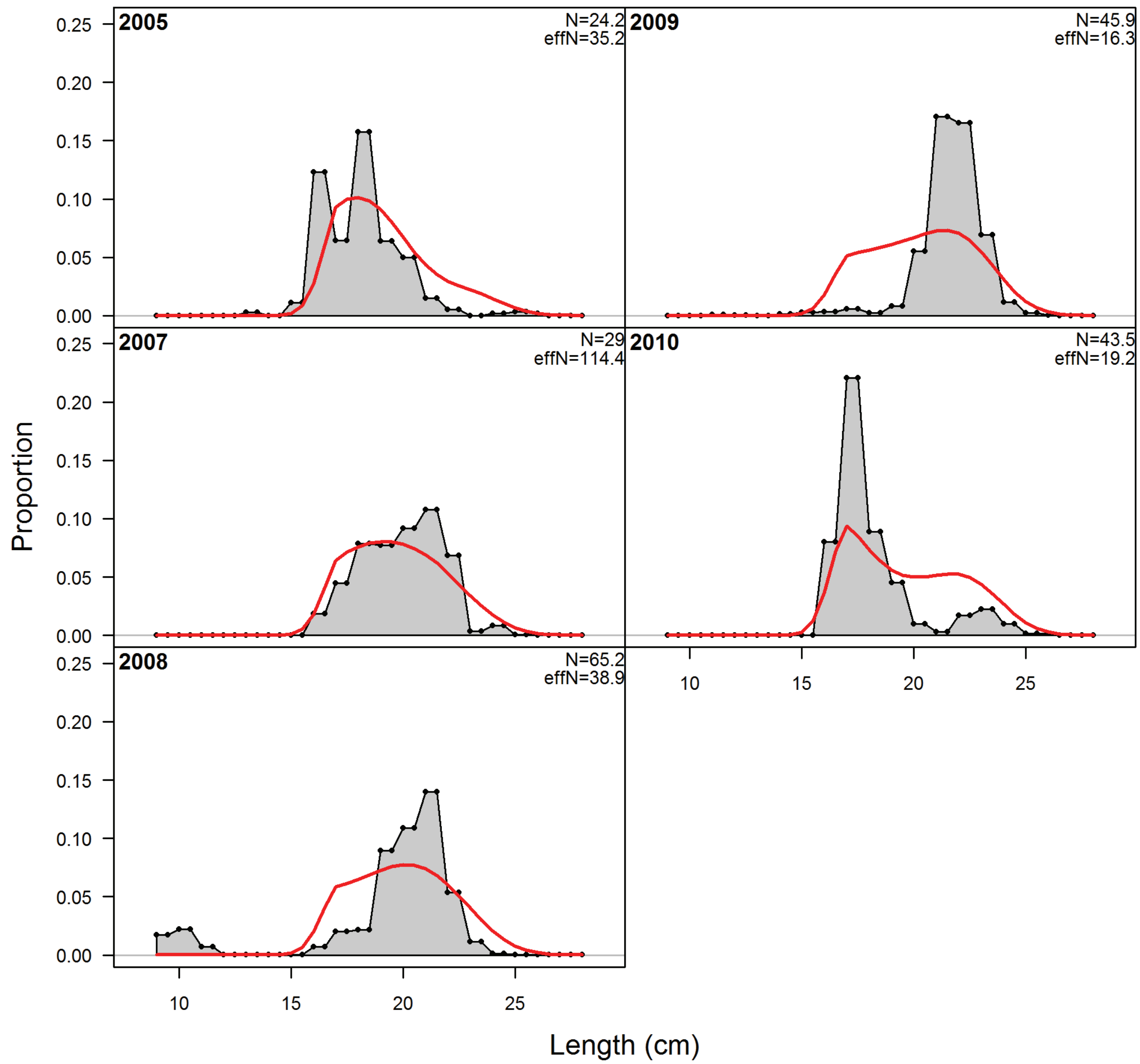


Figure 27a. Base model fits to Acoustic survey length-frequency data.

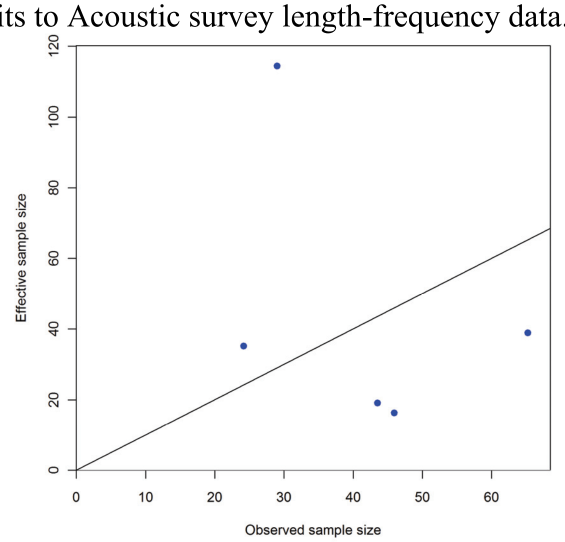


Figure 27b. Observed and effective sample sizes for Acoustic survey fishery length data.

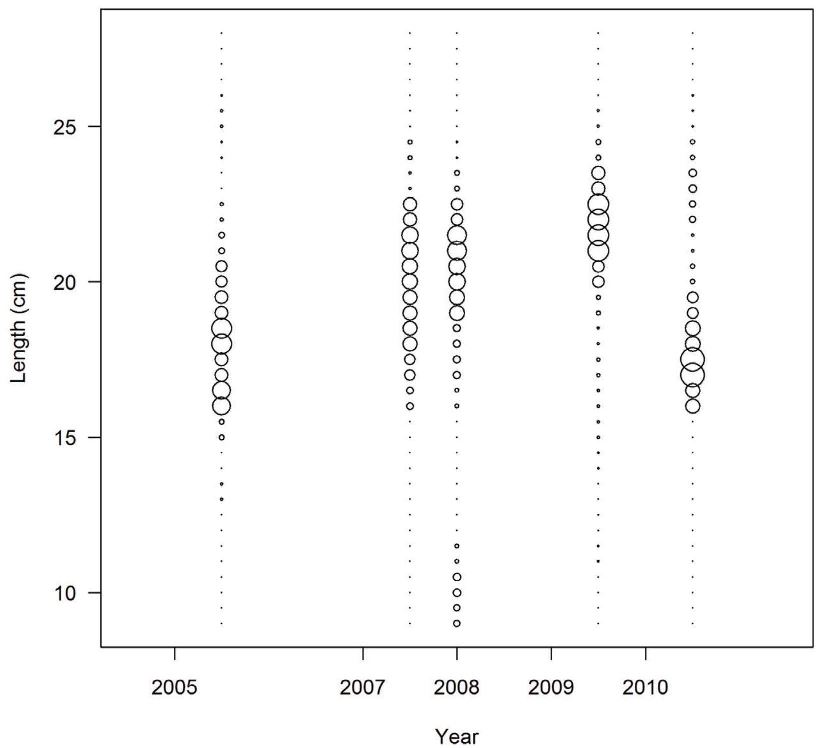


Figure 27c. Bubble plot of Acoustic survey length-frequency data.

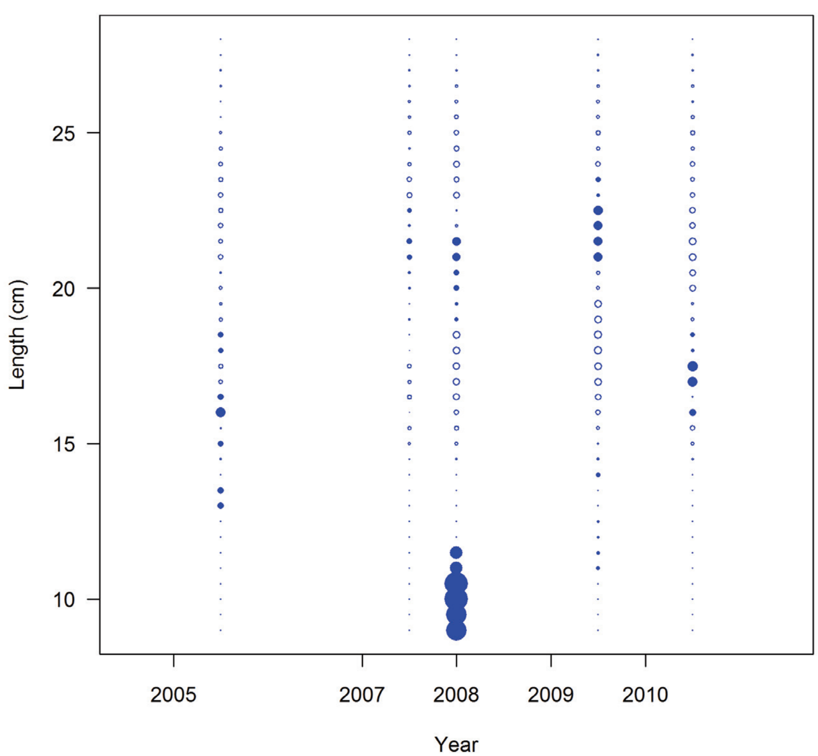


Figure 27d. Pearson residuals (max=17.62) for fit to Acoustic survey length-frequency data.

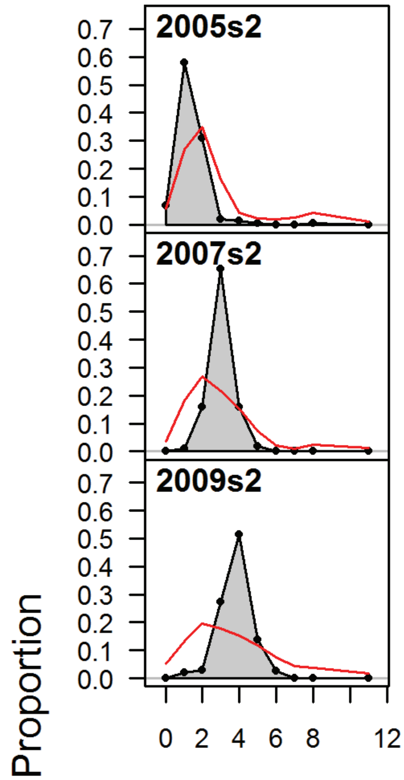


Figure 28a. Base model fits to Acoustic survey implied age-frequency data.

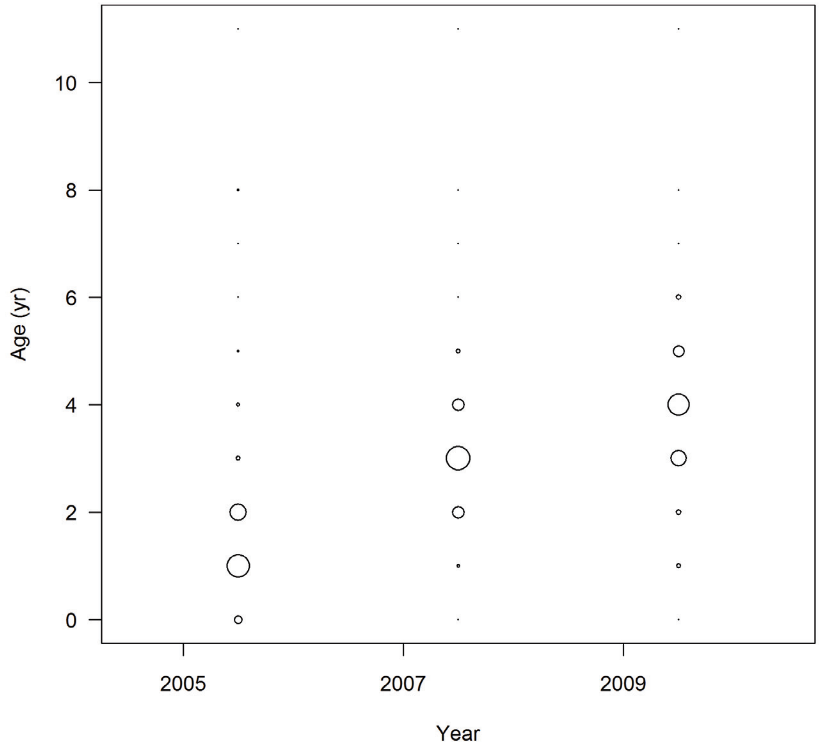


Figure 28b. Bubble plot of Acoustic survey implied age-frequency data.

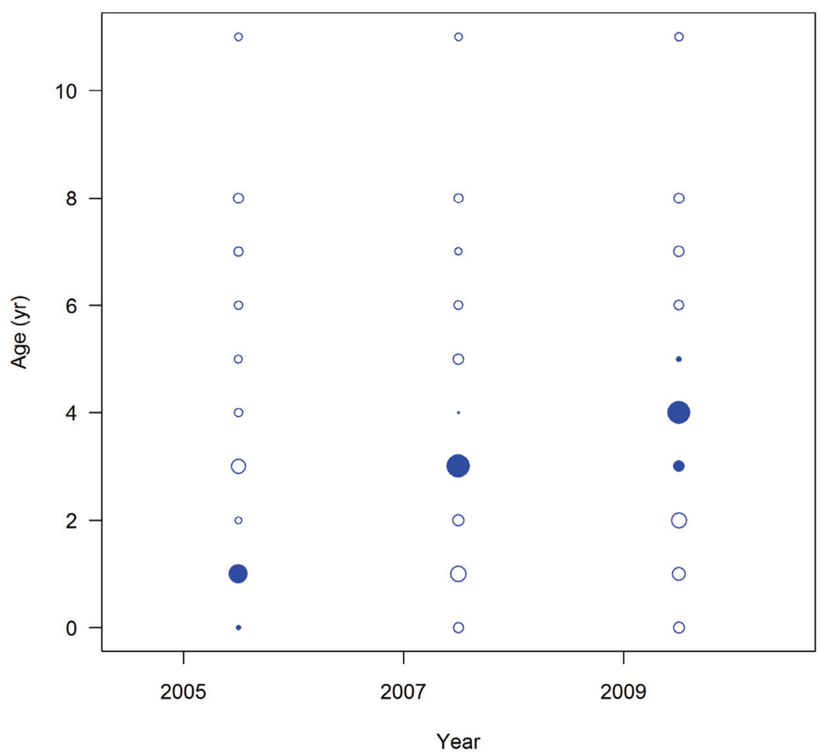


Figure 28c. Pearson residuals (max=1.07) for fit to Acoustic survey implied age-frequency data.

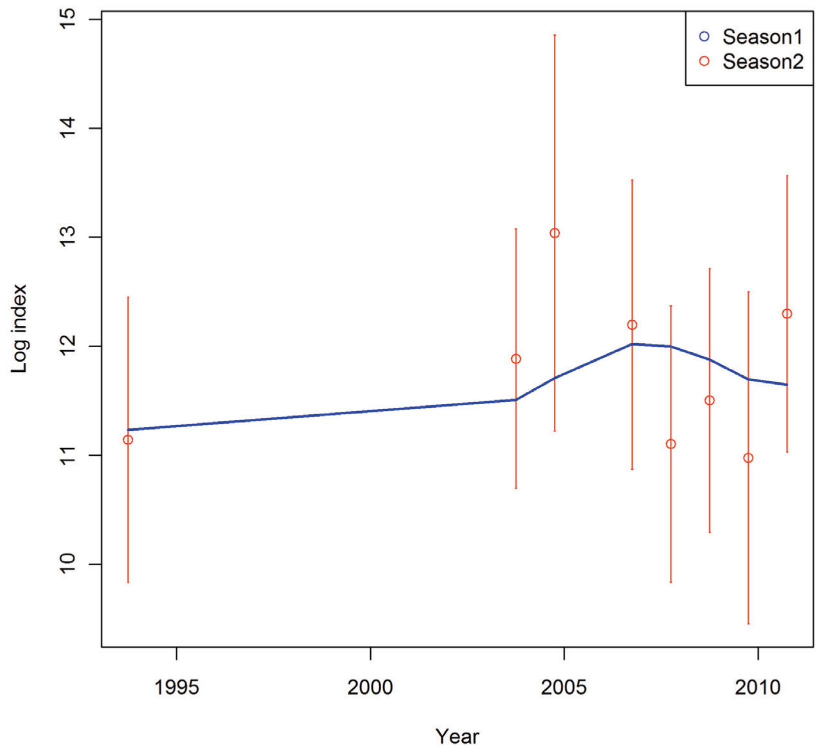


Figure 29a. Base model fit to the Daily Egg Production Method (DEPM) series of female SSB (q=0.18).

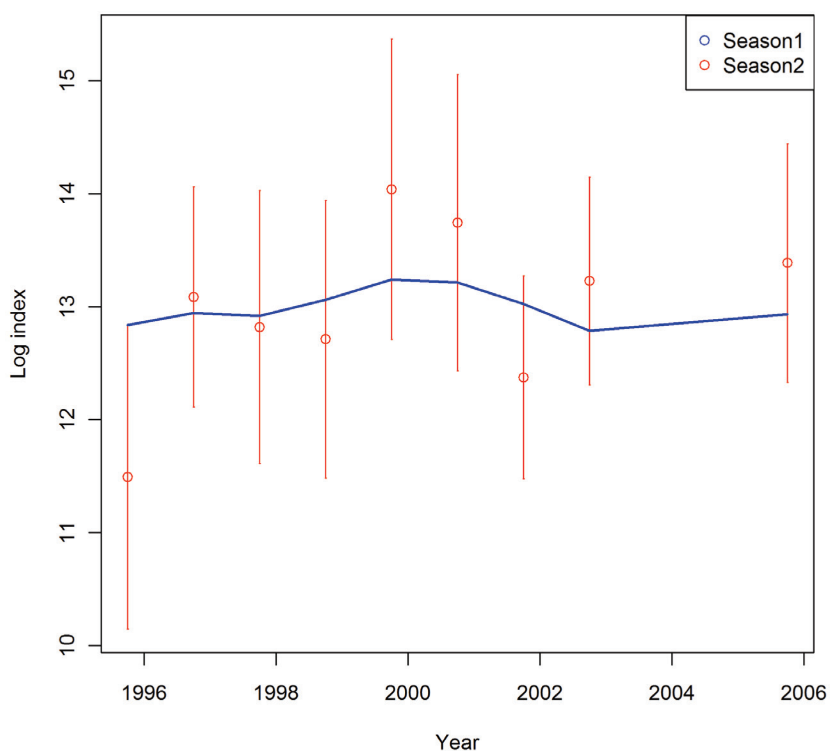


Figure 29b. Base model fit to the Total Egg Production (TEP) series of total SSB (q=0.49).

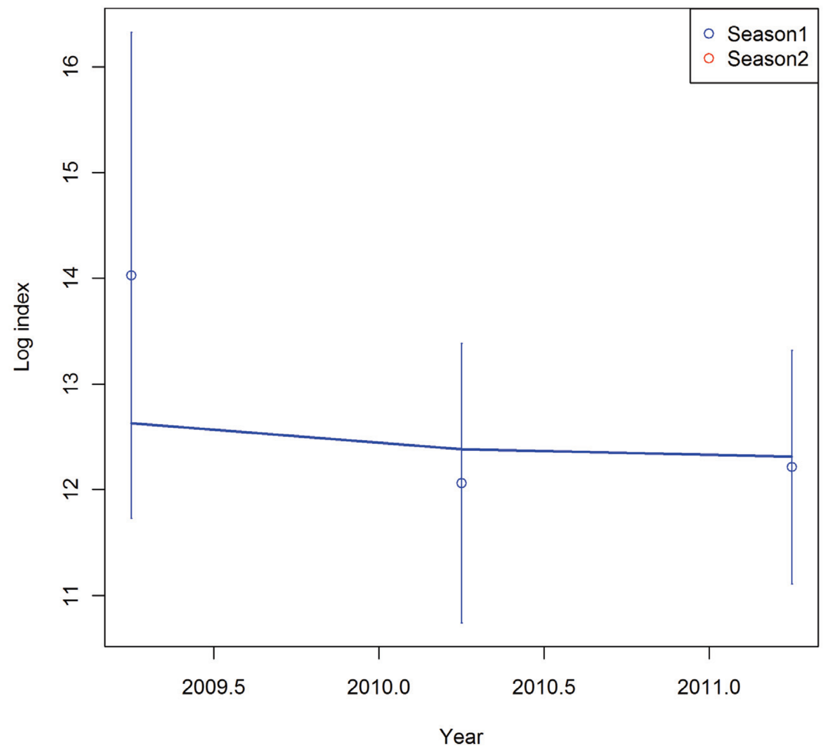


Figure 29c. Base model fit to Aerial survey estimates of biomass (q = 0.89).

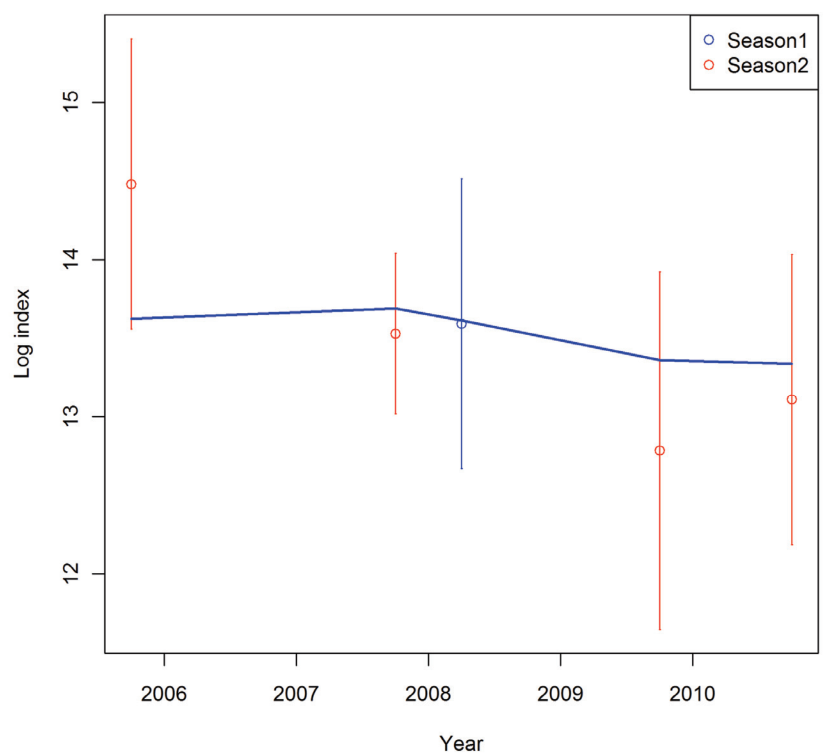


Figure 29d. Base model fit to the Acoustic survey biomass series (q = 1; fixed).

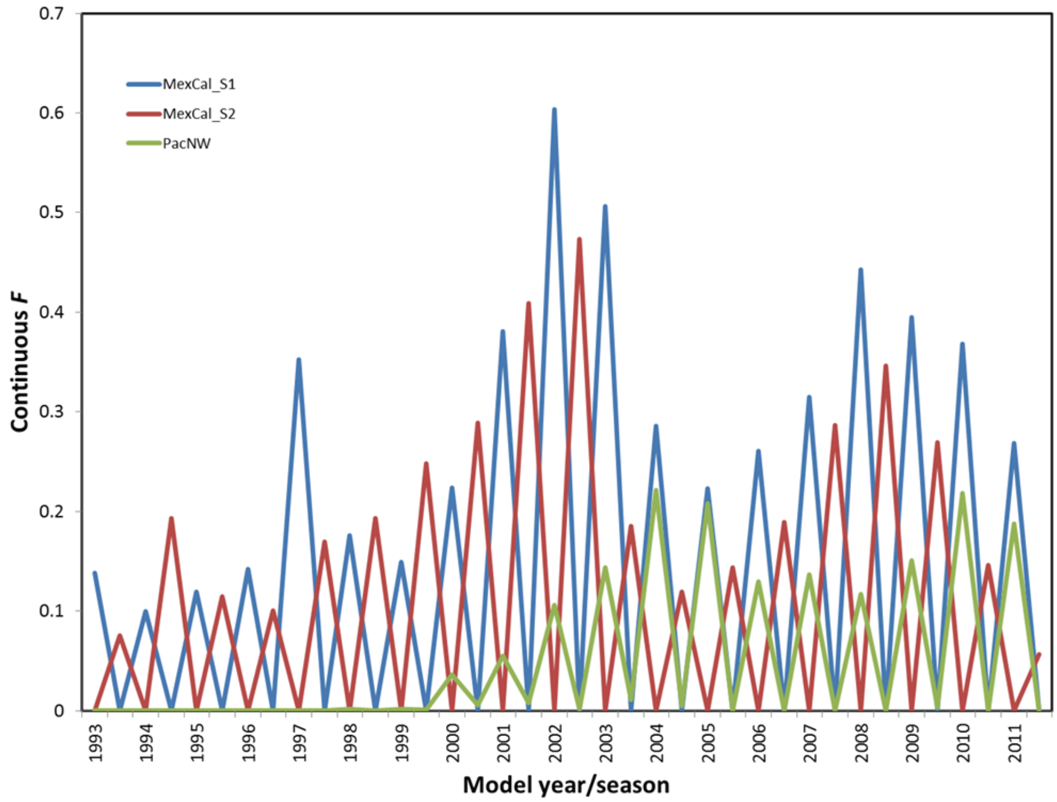


Figure 30a. Base model fishing mortality rate (continuous *F*; SS method 3) by fishery.

Figure 30b. Exploitation rate (CY landings / July total biomass) for the base model.

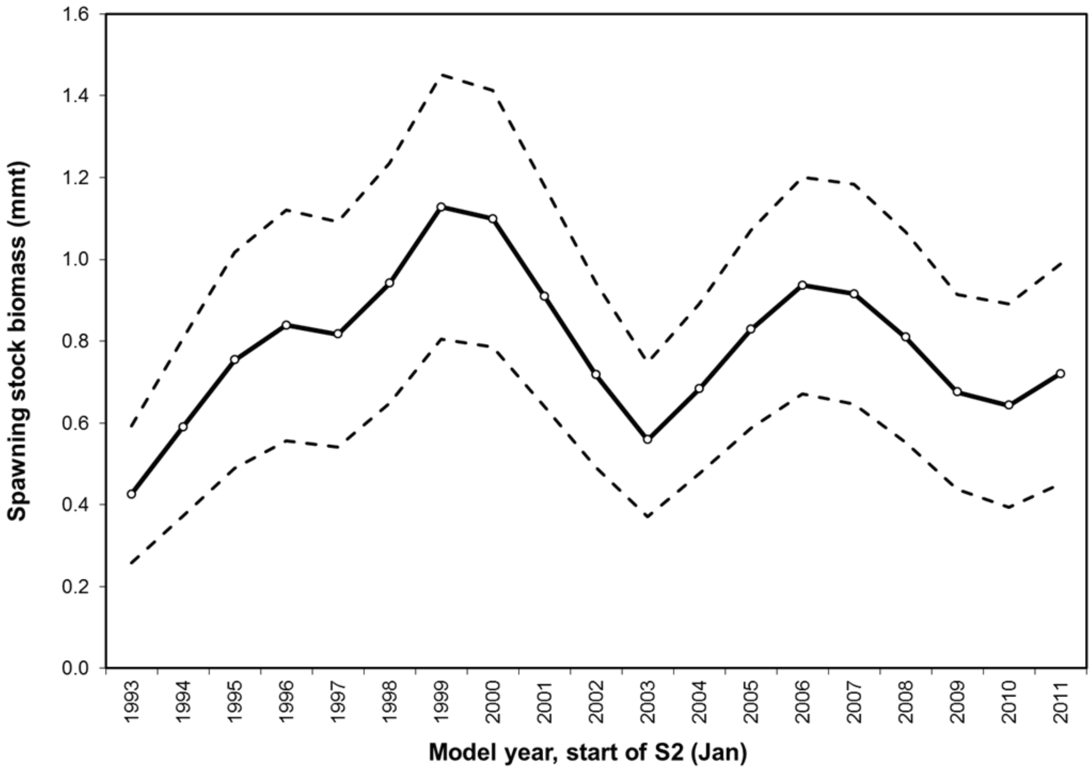


Figure 31a. Base model spawning stock biomass with ~95% asymptotic confidence intervals.

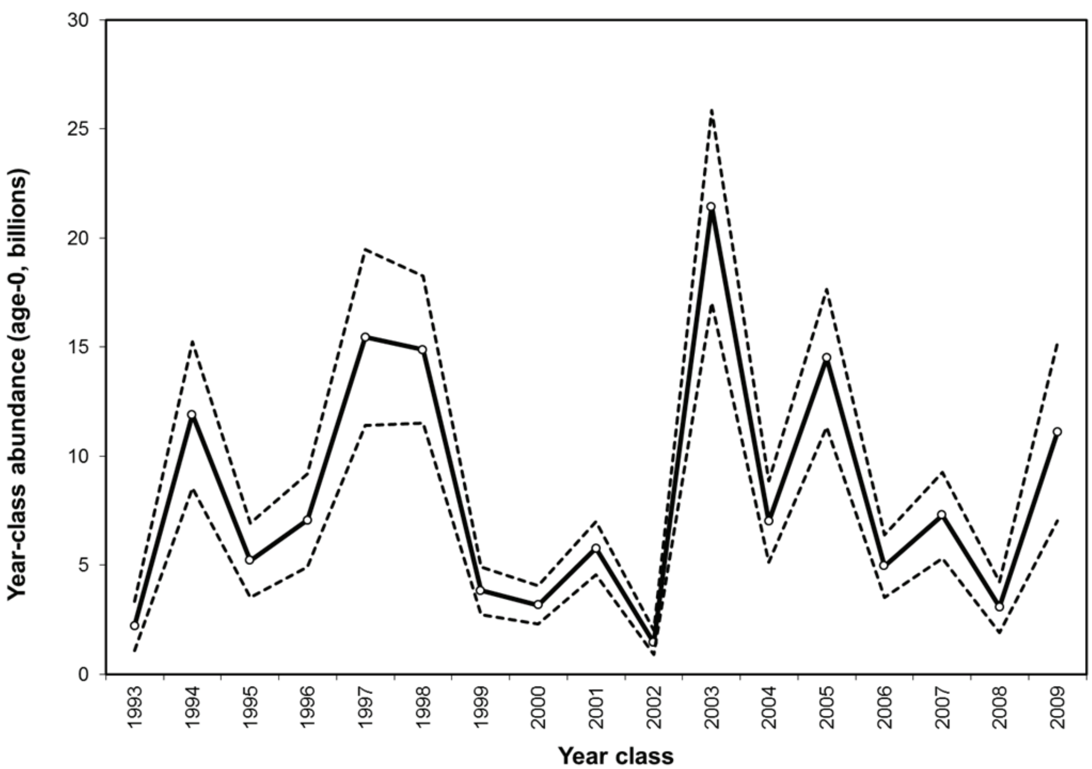


Figure 31b. Base model year-class abundance with ~95% asymptotic confidence intervals.

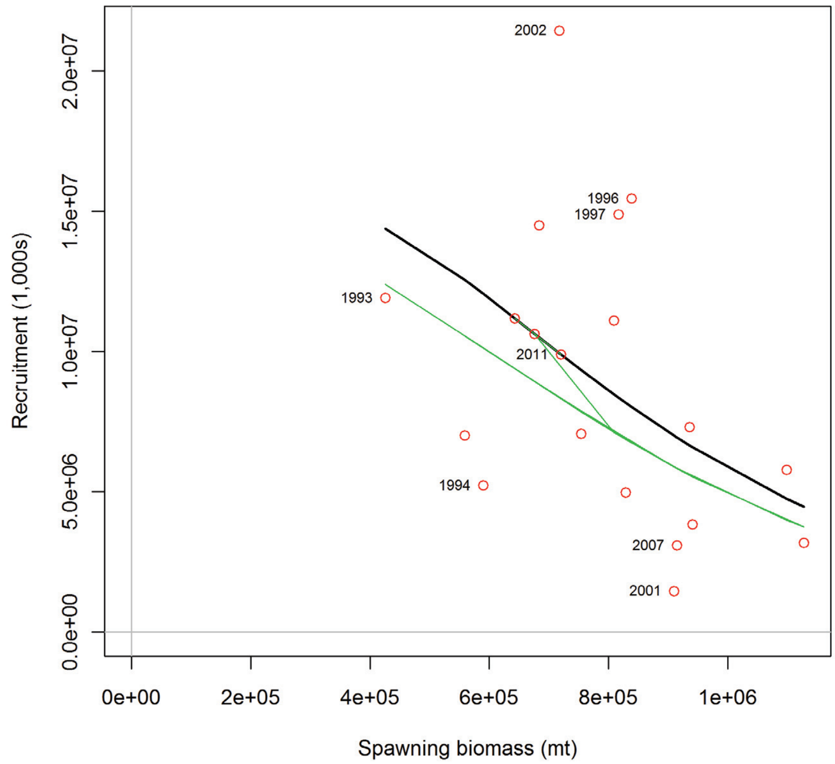


Figure 32a. Spawner-recruitment relationship for the base model, showing Ricker function fit with bias correction. Steepness (*h*) = 2.96, R_0 = 6.23 billion age-0 fish, and σ_R = 0.622. Year labels indicate year of spawning season (S2) prior to recruitment season in the following S1, e.g. '1996' is season prior to production of the 1997 year-class.

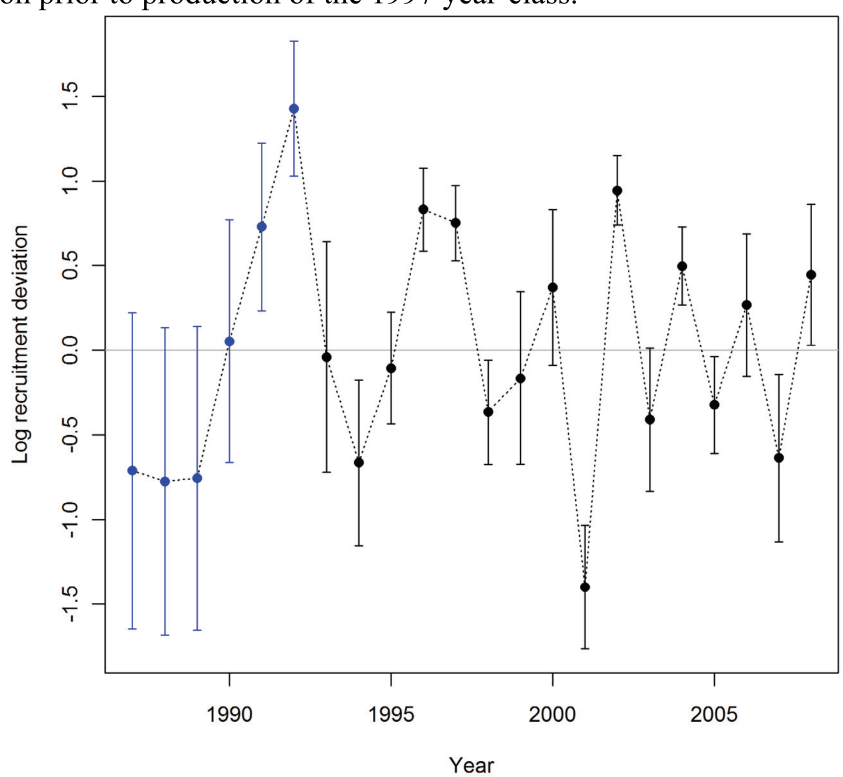


Figure 32b. Recruitment deviations and standard errors estimated in the base model (σ_R = 0.622).

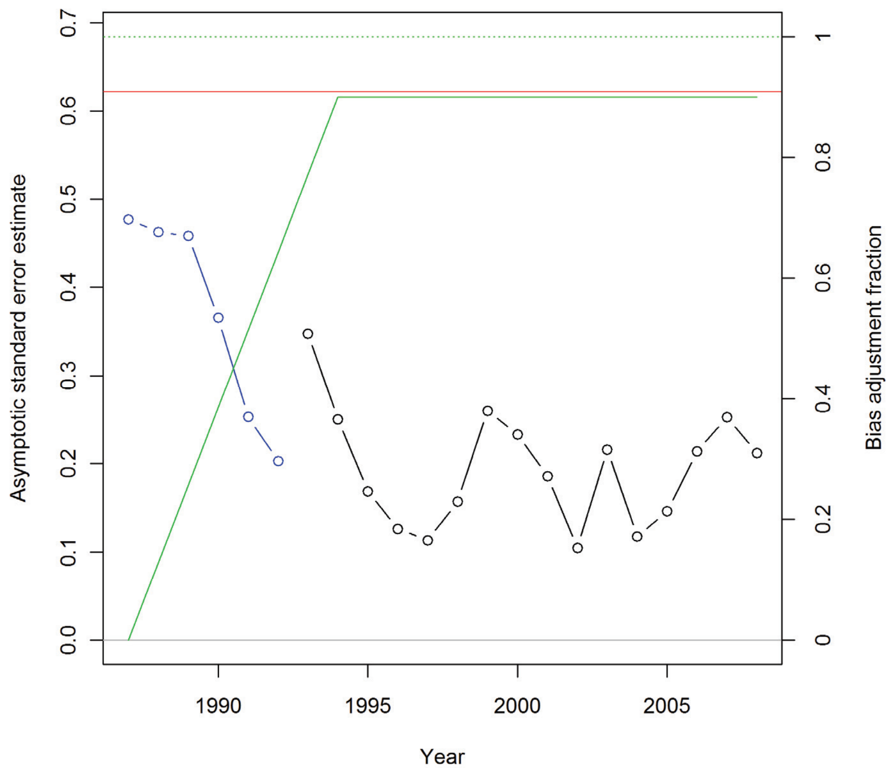


Figure 32c. Asymptotic standard errors for estimated recruitment deviations in the base model.

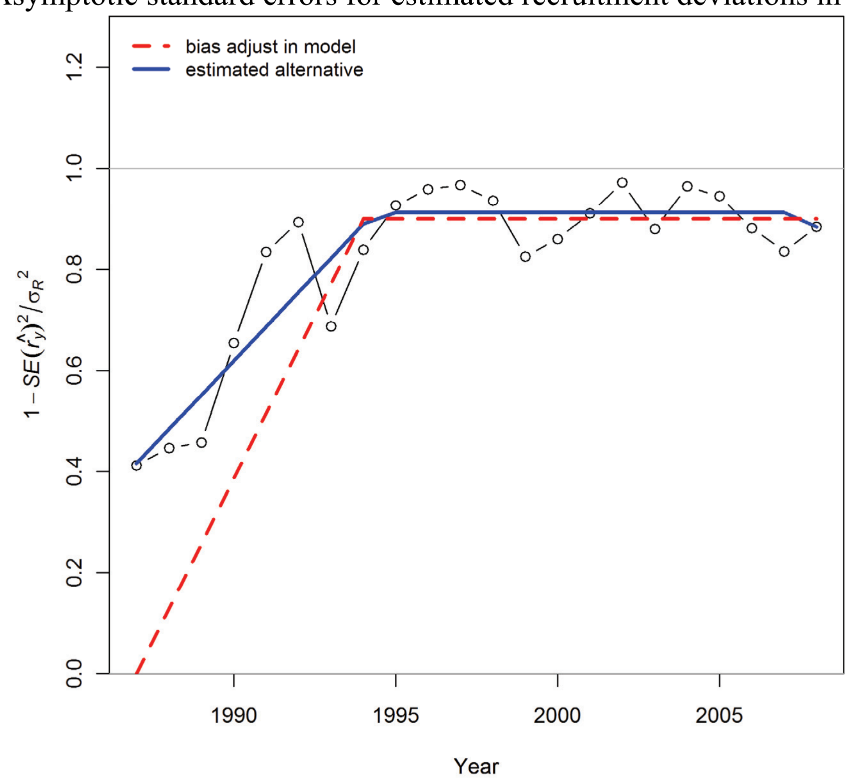


Figure 32d. S-R bias adjustment ramp applied in the base model.

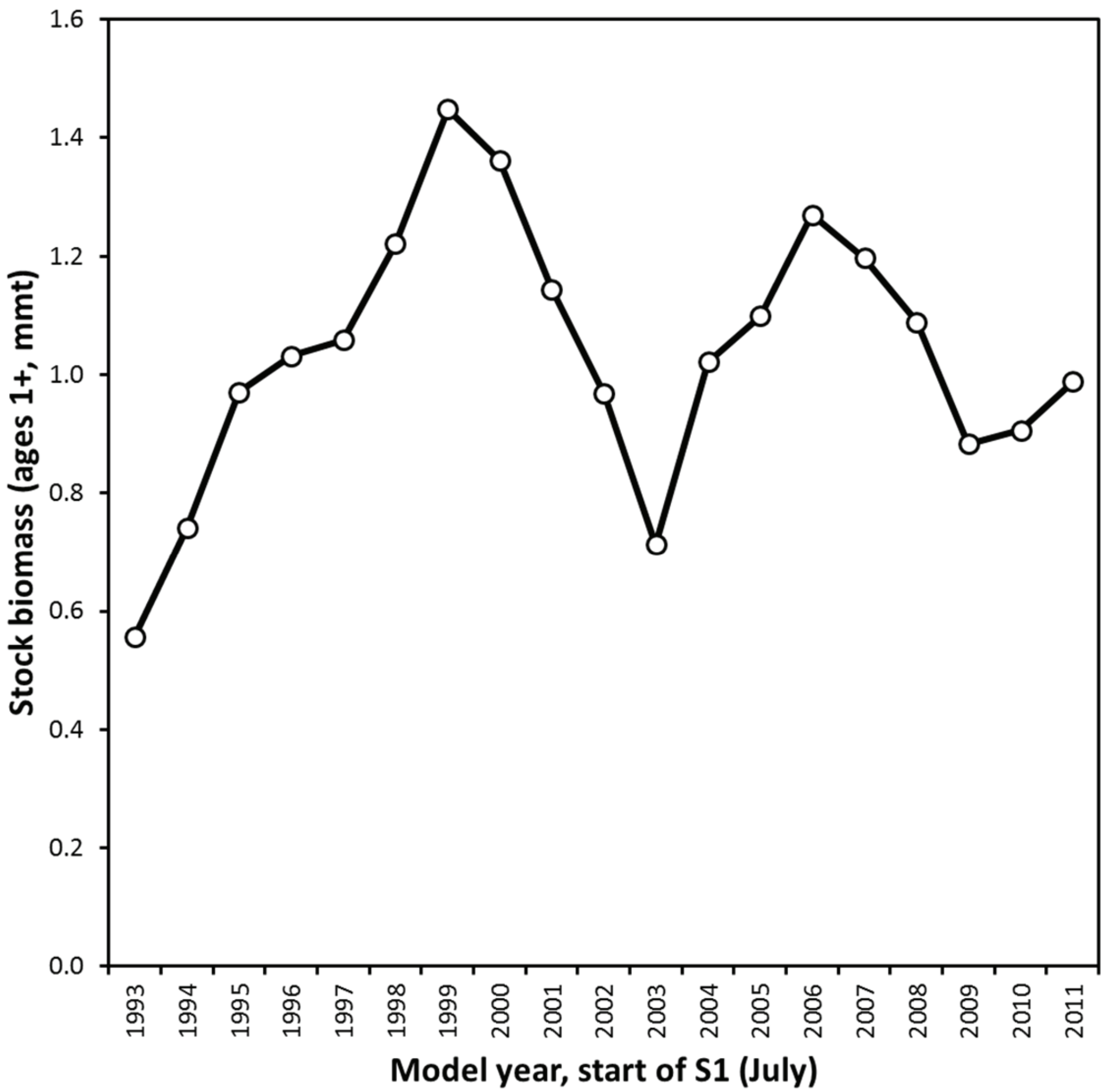


Figure 33. Base model stock biomass (ages 1+) used for annual management measures. Stock biomass was estimated to be 988,385 mt on July 1, 2011.

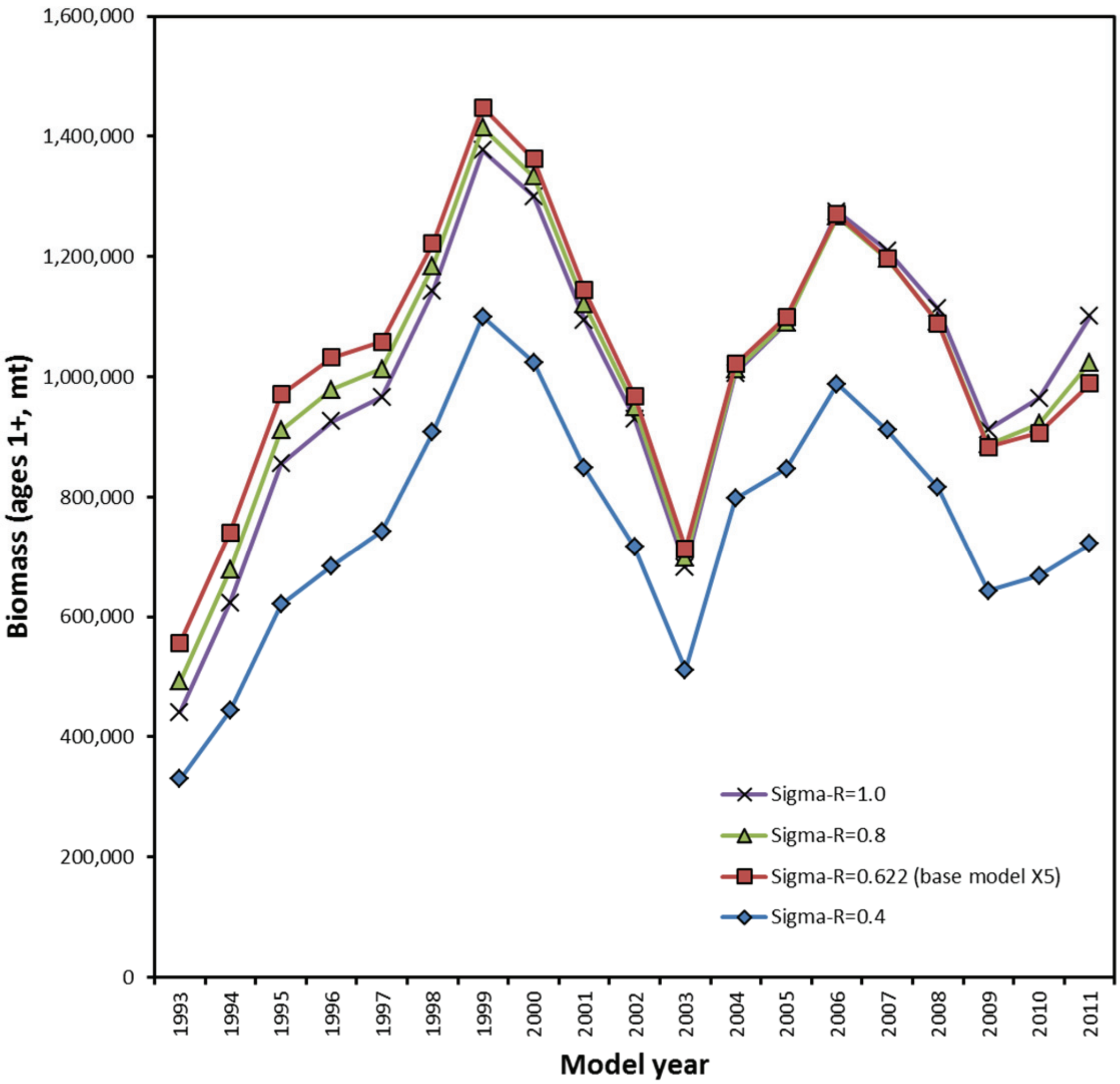


Figure 34. Base model stock biomass (ages 1+) series over a range of σ_R values.

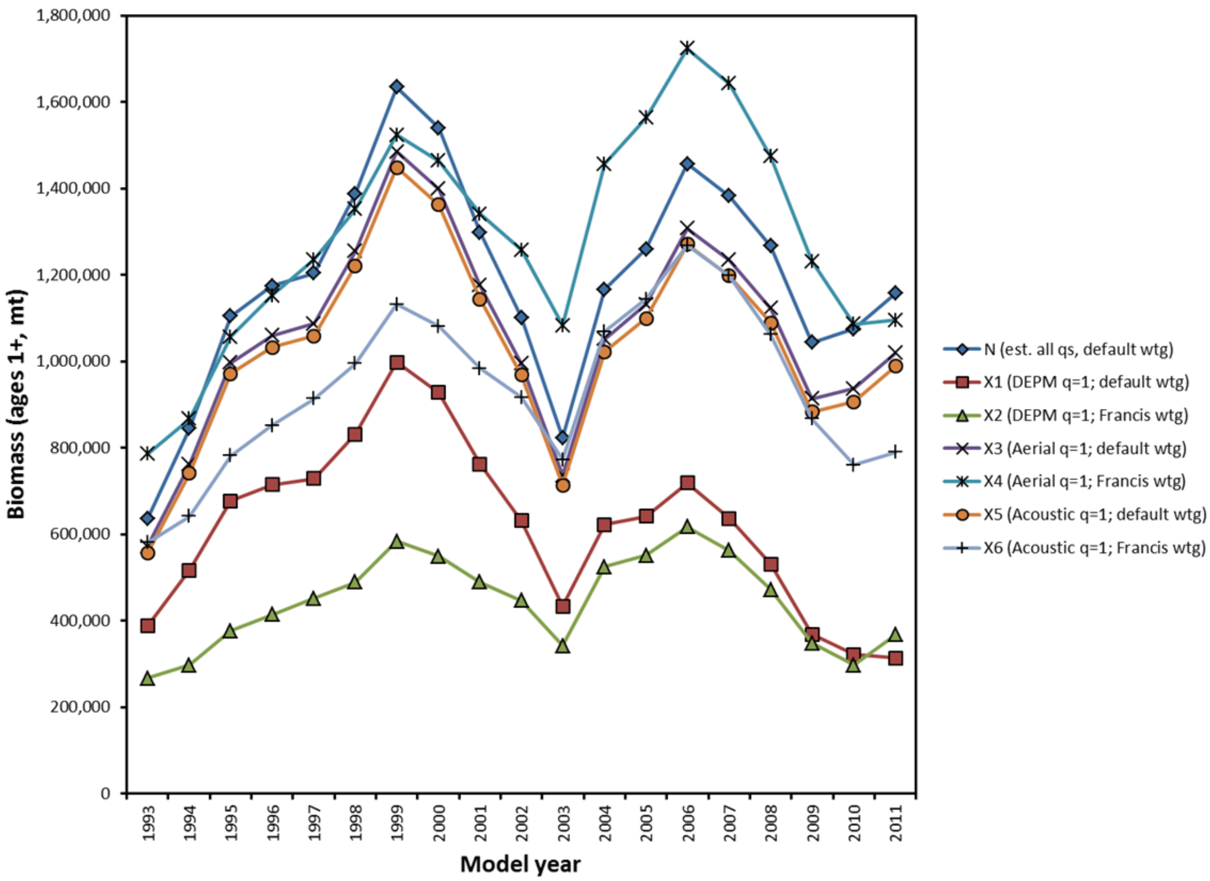


Figure 35. Base model stock biomass (ages 1+) estimates from STAR model N and six model variants (X.1-X.6) in which three survey series (DEPM, Aerial, and Acoustic) are assumed to be indices of absolute abundance (q=1) and weights assigned to the age and length data are set to default values and reduced per the 'Francis method' in STAR request X.

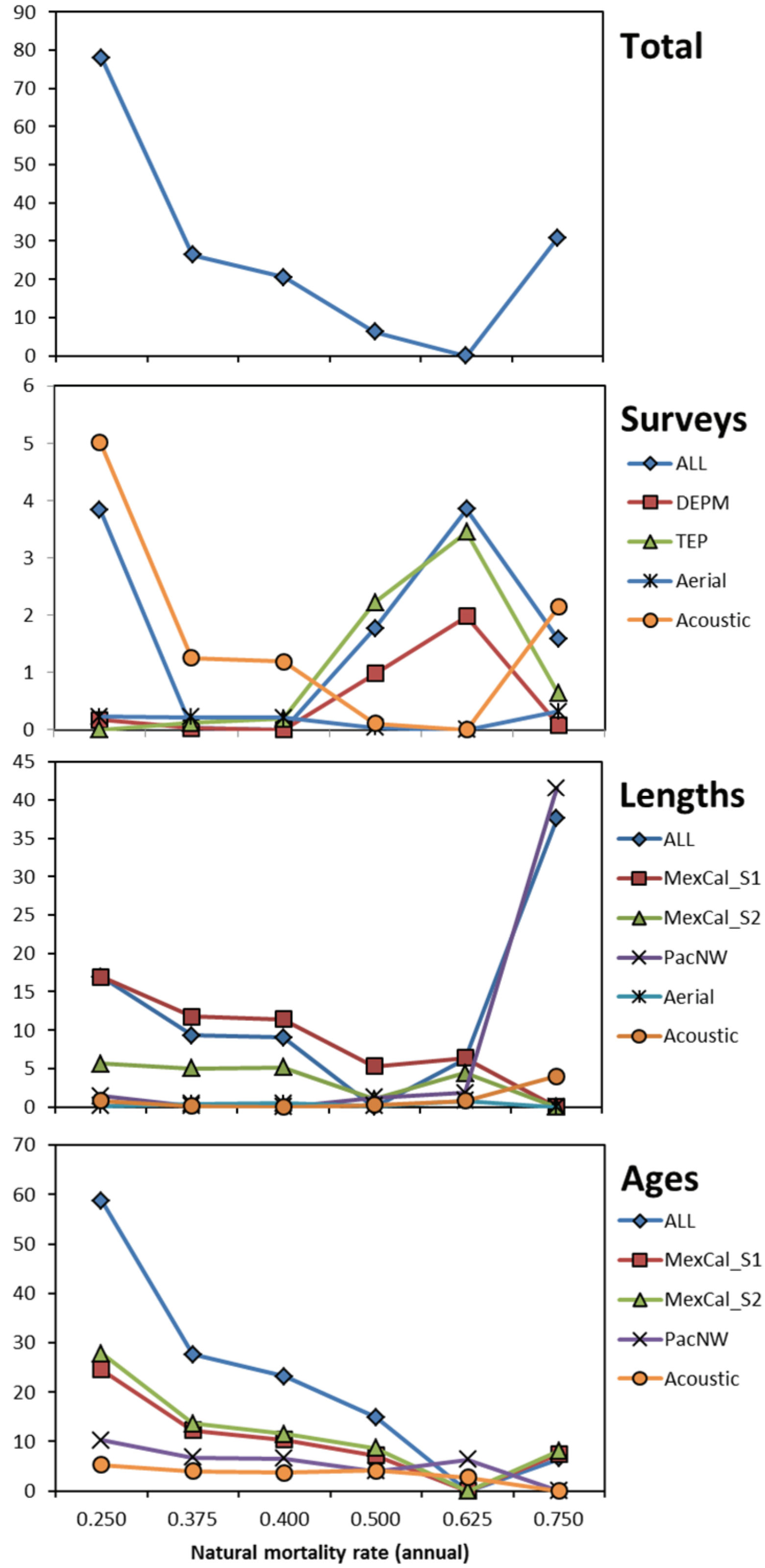


Figure 36. Profiles of key likelihood components for a range of *M* values (rescaled to the minimum value of each component).

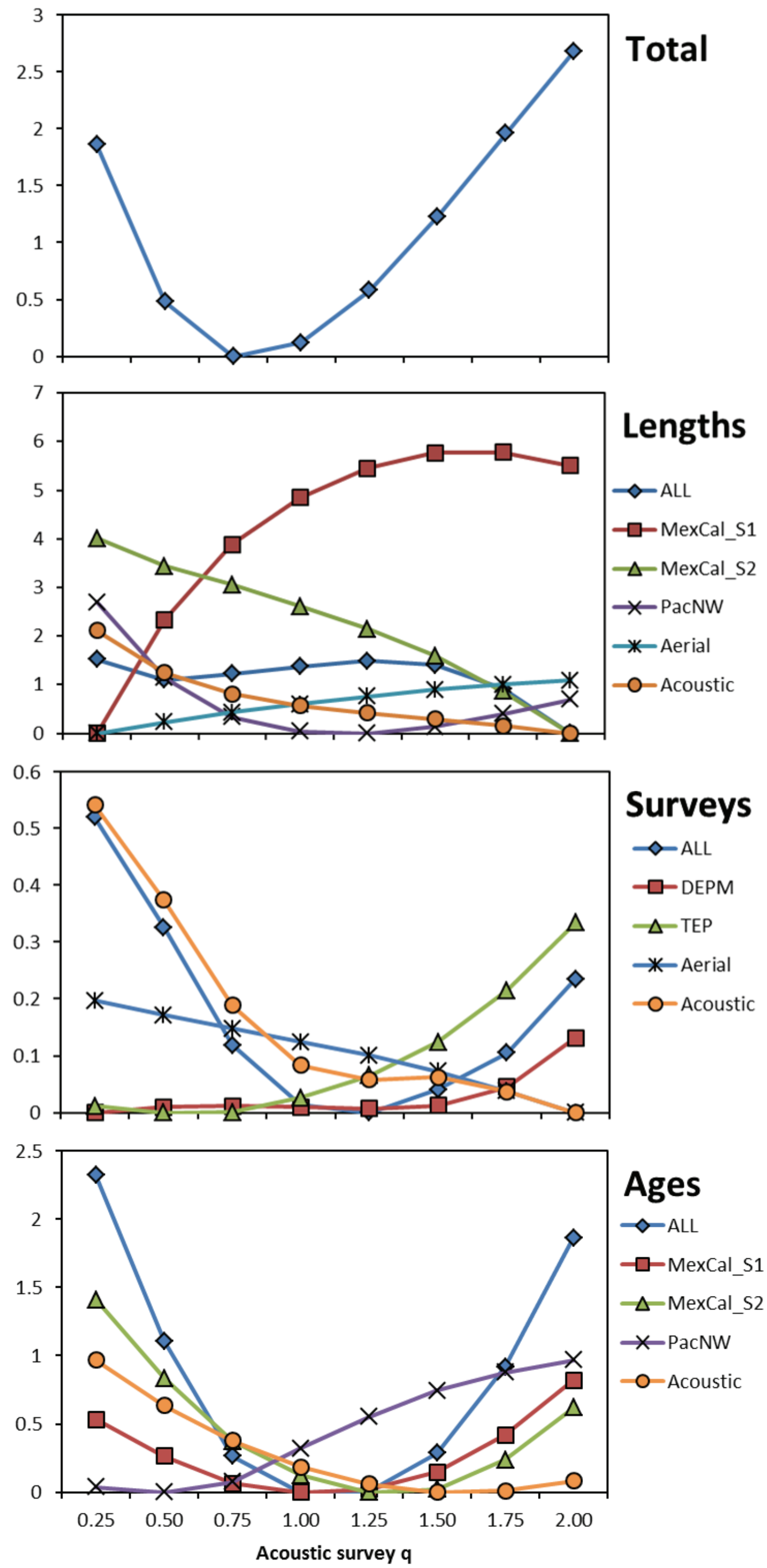


Figure 37. Profiles of key likelihood components over a range of acoustic survey *q*'s (rescaled to the minimum value of each component).

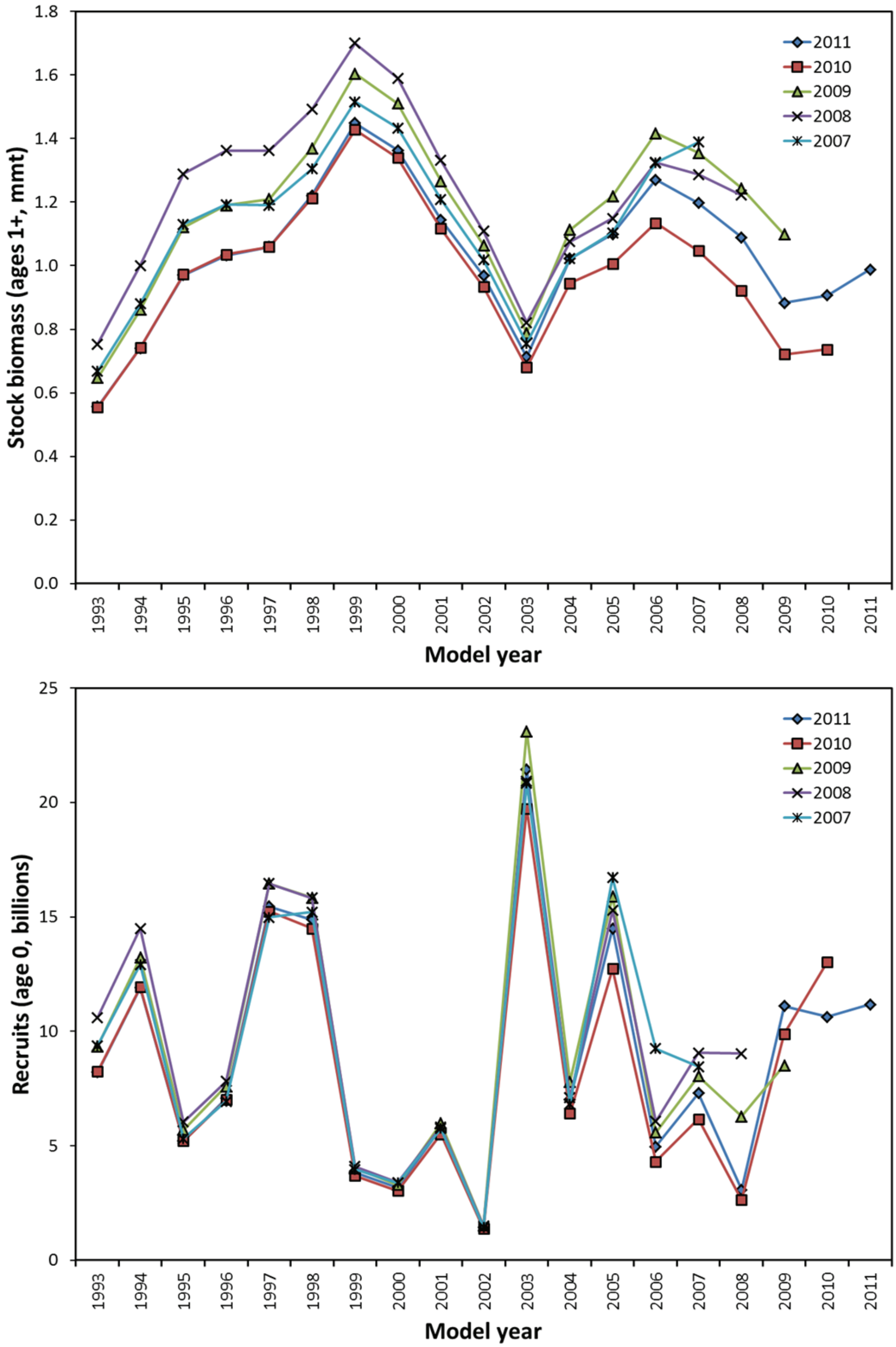
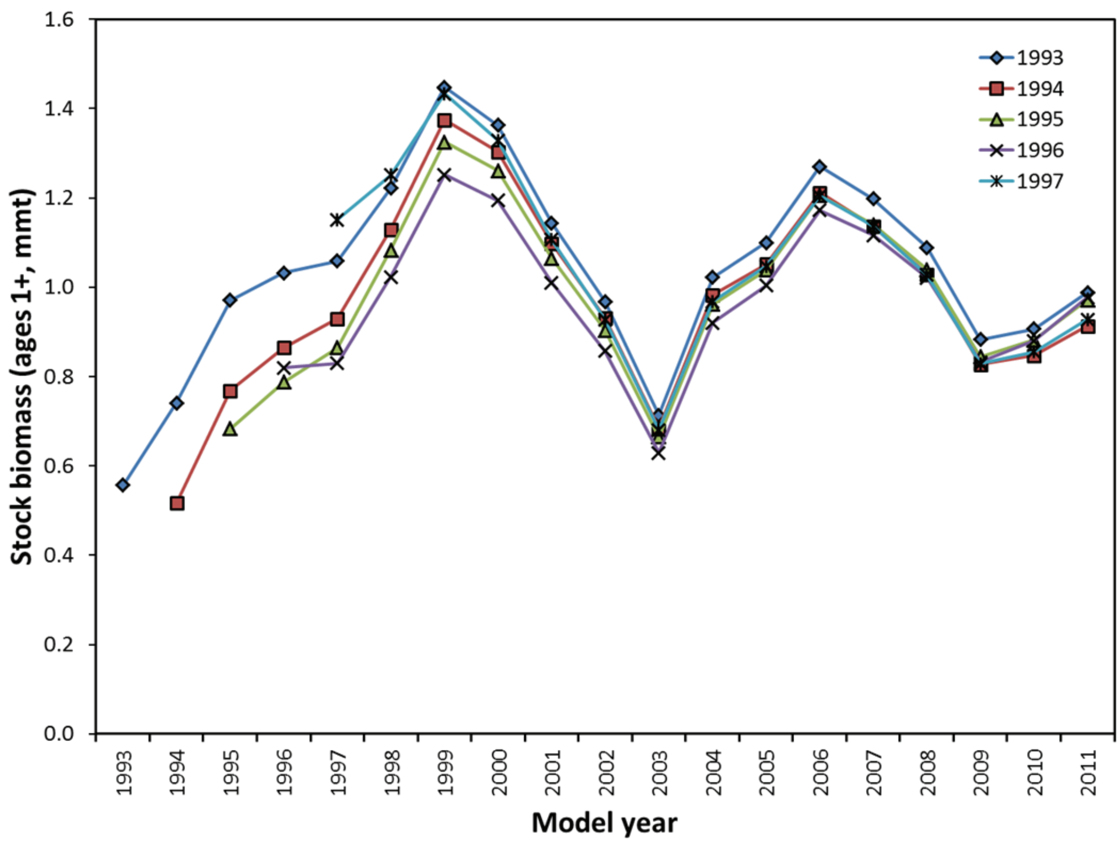


Figure 38. Retrospective analysis of stock biomass and recruitment from base model X5.



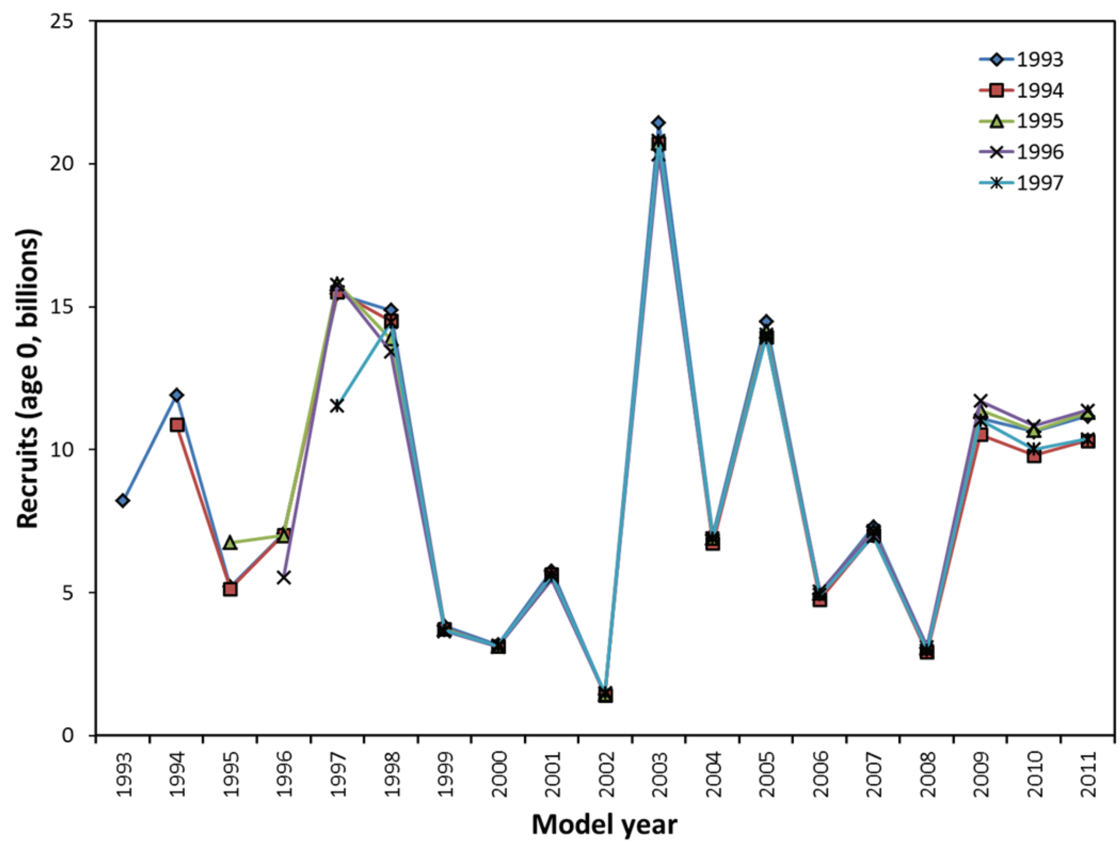


Figure 39. Prospective analysis of stock biomass and recruitment.

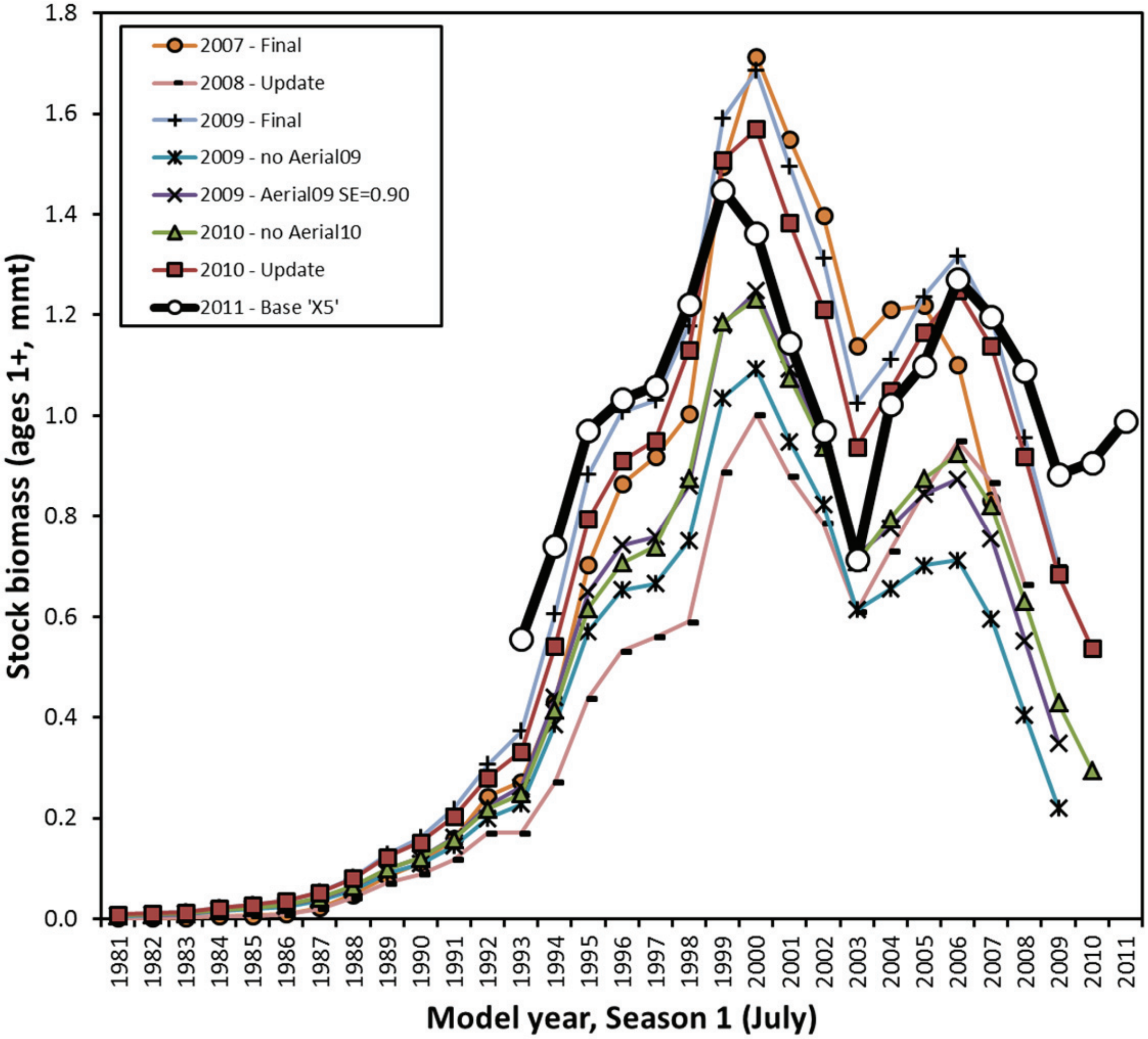


Figure 40a. Pacific sardine stock biomass (ages 1+) from the base model compared to range of models from the past four assessments.

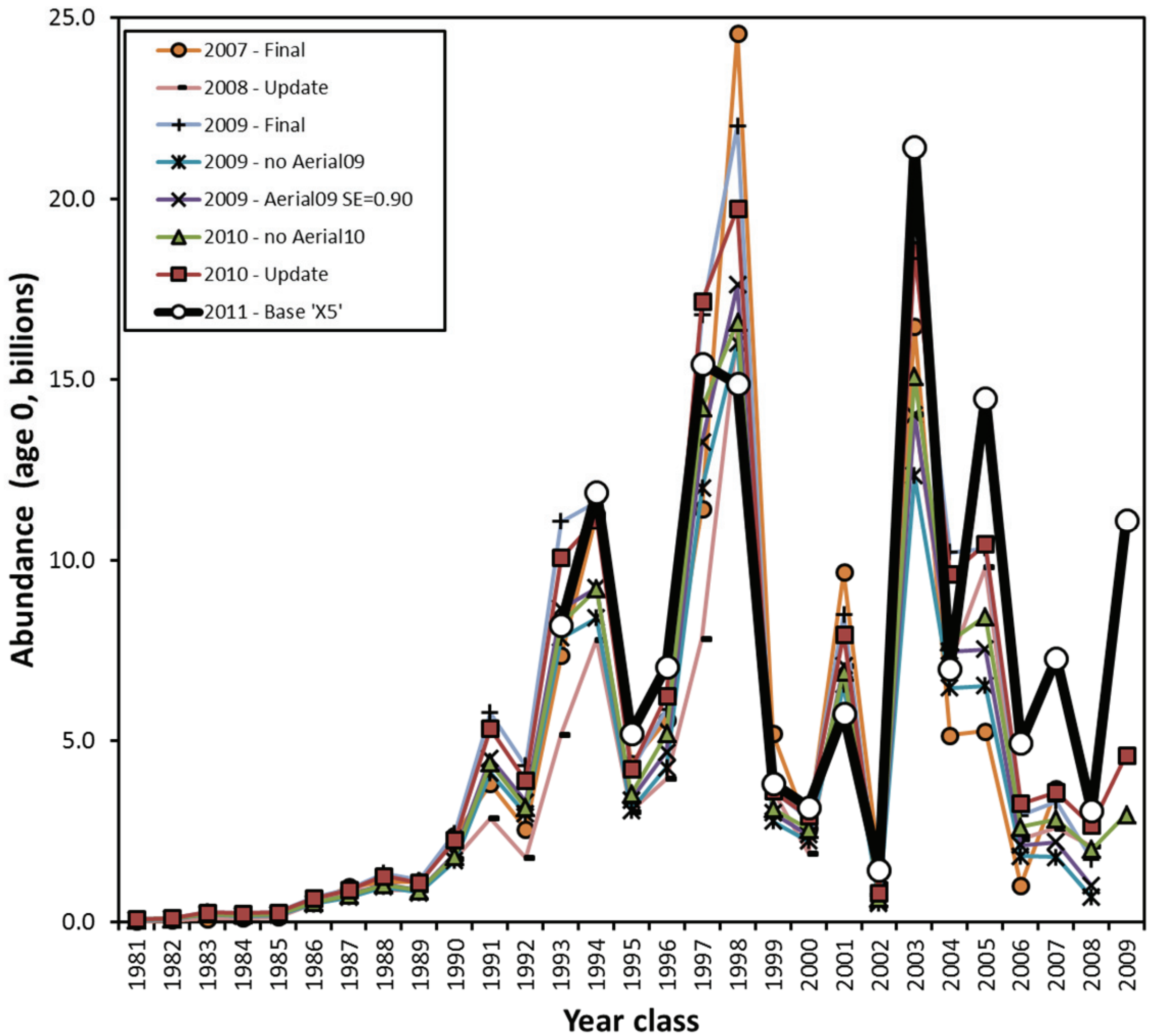


Figure 40b. Pacific sardine recruit (age-0) abundance from the base model compared to range of models from the past four assessments.

APPENDICES

Appendix 1. SS inputs for the base model (PS11_X5).

Appendix 2. An Evaluation of the Consistency of Age-determination of Pacific Sardine (*Sardinops sagax*) Collected from Mexico to Canada. E. Dorval, J. McDaniel, and K. Hill

Appendix 3. SWFSC Juvenile Rockfish Survey (1983-11). P. R. Crone

Appendix 4. Re-evaluation of F_{MSY} for Pacific sardine in the absence of an environmental covariate. K. T. Hill

Appendix 5. Spawning fraction using Bayesian hierarchical (random effect) model for years in 1986-2011. N. C. H. Lo, Y. Gu, and B. Macewicz

Appendix 1 – SS inputs for the base model (PS11_X5)

STARTER.SS

```
#V3.21a-win64
#C - Pacific Sardine Assessment 2011 - model L
PS11_X5.DAT
PS11_X5.CTL
0 # 0=use init values in control file; 1=use ss3.par
1 # run display detail (0,1,2)
2 # detailed age-structured reports in REPORT.SSO (0,1,2)
0 # write detailed checkup.sso file (0,1)
3 # write parm values to ParmTrace.sso (0=no,1=good,active; 2=good,all; 3=every_iter,all_parms;
4=every,active)
2 # write to cumreport.sso (0=no,1=like&timeseries; 2=add survey fits)
0 # Include prior_like for non-estimated parameters (0,1)
1 # Use Soft Boundaries to aid convergence (0,1) (recommended)
1 # Number of datafiles to produce: 1st is input, 2nd is estimates, 3rd and higher are bootstrap
10 # Turn off estimation for parameters entering after this phase
10 # MCeval burn interval
2 # MCeval thin interval
0 # jitter initial parm value by this fraction
-1 # min yr for sdreport outputs (-1 for styr)
-1 # max yr for sdreport outputs (-1 for endyr; -2 for endyr+Nforecastyrs
0 # N individual STD years
#vector of year values
0.00001 # final convergence criteria
0 # retrospective year relative to end year (e.g. -4)
1 # min age for calc of summary biomass
1 # Depletion basis:  denom is: 0=skip; 1=rel X*B0; 2=rel X*Bmsy; 3=rel X*B_styr
1 # Fraction (X) for Depletion denominator (e.g. 0.4)
1 # SPR_report_basis:  0=skip; 1=(1-SPR)/(1-SPR_tgt); 2=(1-SPR)/(1-SPR_MSY); 3=(1-SPR)/(1-
SPR_Btarget); 4=rawSPR
1 # F_report_units: 0=skip; 1=exploitation(Bio); 2=exploitation(Num); 3=sum(Frates); 4=true F for
range of ages
#COND 10 15 #_min and max age over which average F will be calculated with F_reporting=4
1 # F_report_basis: 0=raw; 1=F/Fspr; 2=F/Fmsy ; 3=F/Fbtgt
999 # check value for end of file
```

FORECAST.SS

```
#V3.21a-win64
# for all year entries except rebuilder; enter either: actual year, -999 for styr, 0 for endyr,
neg number for rel. endyr
1 # Benchmarks: 0=skip; 1=calc F_spr,F_btgt,F_msy
2 # MSY: 1= set to F(SPR); 2=calc F(MSY); 3=set to F(Btgt); 4=set to F(endyr)
0.4 # SPR target (e.g. 0.40)
0.4 # Biomass target (e.g. 0.40)
#_Bmark_years: beg_bio, end_bio, beg_selex, end_selex, beg_relF, end_relF (enter actual year, or
values of 0 or -integer to be rel. endyr)
 0 0 0 0 0 0
#  2010 2010 2010 2010 2010 2010 # after processing
1 #Bmark_relF_Basis: 1 = use year range; 2 = set relF same as forecast below
#
0 # Forecast: 0=none; 1=F(SPR); 2=F(MSY) 3=F(Btgt); 4=Ave F (uses first-last relF yrs); 5=input
annual F scalar
0 # N forecast years
0 # F scalar (only used for Do_Forecast==5)
#_Fcast_years:  beg_selex, end_selex, beg_relF, end_relF  (enter actual year, or values of 0 or -
integer to be rel. endyr)
 9.09362e+223 1.9911e+209 6.21814e+175 2.28885e+243
#  1180631052 1667592815 7631713 1936290657 # after processing
0 # Control rule method (1=catch=f(SSB) west coast; 2=F=f(SSB) )
0 # Control rule Biomass level for constant F (as frac of Bzero, e.g. 0.40); (Must be > the no F
level below)
0 # Control rule Biomass level for no F (as frac of Bzero, e.g. 0.10)
0 # Control rule target as fraction of Flimit (e.g. 0.75)
14 #_N forecast loops (1=OFL only; 2=ABC; 3=get F from forecast ABC catch with allocations
applied)
```

```
0 #_First forecast loop with stochastic recruitment
0 #_Forecast loop control #3 (reserved for future bells&whistles)
0 #_Forecast loop control #4 (reserved for future bells&whistles)
0 #_Forecast loop control #5 (reserved for future bells&whistles)
0  #FirstYear for caps and allocations (should be after years with fixed inputs)
0 # stddev of log(realized catch/target catch) in forecast (set value>0.0 to cause active
impl_error)
0 # Do West Coast gfish rebuilder output (0/1)
0 # Rebuilder:  first year catch could have been set to zero (Ydecl)(-1 to set to 1999)
0 # Rebuilder:  year for current age structure (Yinit) (-1 to set to endyear+1)
1 # fleet relative F:  1=use first-last alloc year; 2=read seas(row) x fleet(col) below
# Note that fleet allocation is used directly as average F if Do_Forecast=4
0 # basis for fcast catch tuning and for fcast catch caps and allocation  (2=deadbio;
3=retainbio; 5=deadnum; 6=retainnum)
# Conditional input if relative F choice = 2
# Fleet relative F:  rows are seasons, columns are fleets
#_Fleet:  ENS SCA_S1 SCA_S2 CCA_S1 CCA_S2 ORWA BC
#  0 0 0 0 0 0 0
#  0 0 0 0 0 0 0
# max totalcatch by fleet (-1 to have no max) must enter value for each fleet

# max totalcatch by area (-1 to have no max); must enter value for each fleet

# fleet assignment to allocation group (enter group ID# for each fleet, 0 for not included in an
alloc group)

#_Conditional on >1 allocation group
# allocation fraction for each of: 0 allocation groups
# no allocation groups
0 # Number of forecast catch levels to input (else calc catch from forecast F)
0 # basis for input Fcast catch:  2=dead catch; 3=retained catch; 99=input Hrate(F) (units are
from fleetunits; note new codes in SSV3.20)
# Input fixed catch values
#Year Seas Fleet Catch(or_F)
#
999 # verify end of input
```

PS11 X5.CTL:

```
#V3.21d-win64
#C - Sardine 2011 Model X5_tuned
#_SS-V3.21d-safe-win64;_04/23/2011;_Stock_Synthesis_by_Richard_Methot_(NOAA)_using_ADMB
1 #_N_Growth_Patterns
1 #_N_Morphs_Within_GrowthPattern
#_Cond 1 #_Morph_between/within_stdev_ratio (no read if N_morphs=1)
#_Cond  1 #vector_Morphdist_(-1_in_first_val_gives_normal_approx)
#
1 # number of recruitment assignments (overrides GP*area*seas parameter values)
0 # recruitment interaction requested
# GP seas area for each recruitment assignment
1 1 1
#
#_Cond 0 # N_movement_definitions goes here if N_areas > 1
#_Cond 1.0 # first age that moves (real age at begin of season, not integer) also cond on
do_migration>0
#_Cond 1 1 1 2 4 10 # example move definition for seas=1, morph=1, source=1 dest=2, age1=4,
age2=10
#
2 #_Nblock_Patterns
1 1 #_blocks_per_pattern 3 2 2
# begin and end years of blocks
1999 2011 #_MexCal_selex
#
0.5 #_fracfemale
0 #_natM_type:_0=1Parm; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
  #_no additional input for selected M option; read 1P per morph
1 # GrowthModel: 1=vonBert with L1&L2; 2=Richards with L1&L2; 3=not implemented; 4=not
implemented
0.5 #_Growth_Age_for_L1
999 #_Growth_Age_for_L2 15 (999 to use as Linf)
```

```
0 #_SD_add_to_LAA (set to 0.1 for SS2 V1.x compatibility)
0 #_CV_Growth_Pattern:  0 CV=f(LAA); 1 CV=F(A); 2 SD=F(LAA); 3 SD=F(A); 4 logSD=F(A)
1 #_maturity_option:  1=length logistic; 2=age logistic; 3=read age-maturity matrix by
growth_pattern; 4=read age-fecundity; 5=read fec and wt from wtatage.ss
#_placeholder for empirical age-maturity by growth pattern
0 #_First_Mature_Age
1 #_fecundity option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b; (4)eggs=a+b*L;
(5)eggs=a+b*W
0 #_hermaphroditism option:  0=none; 1=age-specific fxn
1 #_parameter_offset_approach (1=none, 2= M, G, CV_G as offset from female-GP1, 3=like SS2 V1.x)
1 #_env/block/dev_adjust_method (1=standard; 2=logistic transform keeps in base parm bounds;
3=standard w/ no bound check)
#
#_growth_parms
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block
Block_Fxn
0.3     0.7     0.4     0       -1      99      -3      0       0       0       0       0       0
        0       #       NatM_p_1_Fem_GP_1
3       15      10      0       -1      99      3       0       0       0       0       0       0
        0       #       L_at_Amin_Fem_GP_1
20      30      25      0       -1      99      3       0       0       0       0       0       0
        0       #       L_at_Amax_Fem_GP_1
0.05    0.99    0.4     0       -1      99      3       0       0       0       0       0       0
        0       #       VonBert_K_Fem_GP_1
0.05    0.3     0.14    0       -1      99      3       0       0       0       0       0       0
        0       #       CV_young_Fem_GP_1
0.01    0.1     0.05    0       -1      99      3       0       0       0       0       0       0
        0       #       CV_old_Fem_GP_1
-3      3       1.68E-05        0       -1      99      -3      0       0       0       0       0
        0       0       #       Wtlen_1_Fem
-3      5       2.948247        0       -1      99      -3      0       0       0       0       0
        0       0       #       Wtlen_2_Fem
9       19      15.88   0       -1      99      -3      0       0       0       0       0       0
        0       #       Mat50%_Fem
-20     3       -0.90461        0       -1      99      -3      0       0       0       0       0
        0       0       #       Mat_slope_Fem
0       10      1       0       -1      99      -3      0       0       0       0       0       0
        0       #       Eggs/kg_inter_Fem
-1      5       0       0       -1      99      -3      0       0       0       0       0       0
        0       #       Eggs/kg_slope_wt_Fem
-4      4       0       0       -1      99      -3      0       0       0       0       0       0
        0       #       RecrDist_GP_1
-4      4       1       0       -1      99      -3      0       0       0       0       0       0
        0       #       RecrDist_Area_1
-4      4       1       0       -1      99      -3      0       0       0       0       0       0
        0       #       RecrDist_Seas_1
-4      4       0       0       -1      99      -3      0       0       0       0       0       0
        0       #       RecrDist_Seas_2
1       1       1       0       -1      99      -3      0       0       0       0       0       0
        0       #       CohortGrowDev
#_seasonal_effects_on_biology_parms
 0 0 0 0 0 0 0 0 0 0 #_femwtlen1,femwtlen2,mat1,mat2,fec1,fec2,Malewtlen1,malewtlen2,L1,K
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no seasonal MG parameters
#
#_Cond -4 #_MGparm_Dev_Phase
#
#_Spawner-Recruitment
2 #_SR_function: 1=B-H_flattop; 2=Ricker; 3=std_B-H; 4=CAA; 5=Hockey; 6=Shepard_3Parm
#_LO HI INIT PRIOR PR_type SD PHASE
3       25      16      0       -1      99      1       #       SR_R0
0.2     4       2.5     0       -1      99      6       #       SR_steep
0       2       0.622   0       -1      99      -3      #       SR_sigmaR
-5      5       0       0       -1      99      -3      #       SR_envlink
-15     15      0       0       -1      99      2       #       SR_R1_offset
0       0       0       0       -1      99      -3      #       SR_autocorr
0 #_SR_env_link
0 #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness
1 #do_recdev:  0=none; 1=devvector; 2=simple deviations
1993 # first year of main recr_devs; early devs can preceed this era  (styear-6; was 1975)
2008 # 2009 last year of main recr_devs; forecast devs start in following year
1 #_recdev phase
```

```
1 # (0/1) to read 13 advanced options
-6 # -6 _recdev_early_start (0=none; neg value makes relative to recdev_start)
2 # 2 _recdev_early_phase
0 # 0 _forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)
1 # 1 _lambda for Fcast_recr_like occurring before endyr+1
1987 # 1988 _last_early_yr_nobias_adj_in_MPD
1994 # 1993 _first_yr_fullbias_adj_in_MPD
2008 # 2009 _last_yr_fullbias_adj_in_MPD
2009 # 2009 _first_recent_yr_nobias_adj_in_MPD
0.9 # 1 0.9 _max_bias_adj_in_MPD (-1 to override ramp and set biasadj=1.0 for all estimated
recdevs)
0 #_period of cycles in recruitment (N parms read below)
-5 #min rec_dev
5 #max rec_dev
0 #_read_recdevs
#_end of advanced SR options
#_placeholder for full parameter lines for recruitment cycles
# read specified recr devs
#_Yr Input_value
#Fishing Mortality info
0.1 # F ballpark for tuning early phases
-2006 # F ballpark year (neg value to disable)
3 # F_Method:  1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)
4 # max F or harvest rate, depends on F_Method
10  # N iterations for tuning F in hybrid method (recommend 3 to 7)
#_initial_F_parms
#_LO HI INIT PRIOR PR_type SD PHASE
0       4       0       0       -1      99      -1      #       InitF_1MexCal_S1
0       4       0       0       -1      99      -1      #       InitF_2MexCal_S2
0       4       0       0       -1      99      -1      #       InitF_3PacNW
#_Q_setup
# Q_type options:  <0=mirror, 0=median_float, 1=mean_float, 2=parameter, 3=parm_w_random_dev,
4=parm_w_randwalk, 5=mean_unbiased_float_assign_to_parm
#_Den-dep  env-var  extra_se  Q_type
0       0       0       0       #       1       MexCal_S1
0       0       0       0       #       2       MexCal_S2
0       0       0       0       #       3       PacNW
0       0       0       2       #       4       DEPM
0       0       0       2       #       5       TEP
0       0       0       2       #       6       TEP_all
0       0       0       2       #       7       Aerial
0       0       0       2       #       8       Acoustic
#
#_Cond 0 #_If q has random component, then 0=read one parm for each fleet with random q; 1=read a
parm for each year of index
#_Q_parms(if_any)
# LO HI INIT PRIOR PR_type SD PHASE
-3      3       -1.39   0       -1      99      5       #       Q_base_8_DEPM
-3      3       -0.69   0       -1      99      5       #       Q_base_9_TEP
-3      3       -0.69   0       -1      99      5       #       Q_base_9_TEP_all
-3      3       0       0       -1      99      5       #       Q_base_10_Aerial
-3      3       0       0       -1      99      -5      #       Q_base_11_Acoustic
#_size_selex_types
#_Pattern Discard Male Special
24      0       0       0       #       1       MexCal_S1
24      0       0       0       #       2       MexCal_S2
1       0       0       0       #       3       PacNW
30      0       0       0       #       4       DEPM
30      0       0       0       #       5       TEP
30      0       0       0       #       6       TEP_full
24      0       0       0       #       7       Aerial
24      0       0       0       #       8       Acoustic
#_age_selex_types
#_Pattern ___ Male Special
11      0       0       0       #       1       MexCal_S1
11      0       0       0       #       2       MexCal_S2
11      0       0       0       #       3       PacNW
11      0       0       0       #       4       DEPM
11      0       0       0       #       5       TEP
11      0       0       0       #       6       TEP_full
11      0       0       0       #       7       Aerial
```

```
11      0       0       0       #       8       Acoustic
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block
Block_Fxn
#_MexCal_S1_Baseline_Selex
10      28      18      0       -1      99      4       0       0       0       0       0       1
        2       #       SizeSel_2P_1_MexCal_S1
-5      3       3       0       -1      99      4       0       0       0       0       0       1
        2       #       SizeSel_2P_2_MexCal_S1
-1      9       2.5     0       -1      99      4       0       0       0       0       0       1
        2       #       SizeSel_2P_3_MexCal_S1
-1      9       4       0       -1      99      4       0       0       0       0       0       1
        2       #       SizeSel_2P_4_MexCal_S1
-10     10      -10     0       -1      99      -4      0       0       0       0       0       1
        2       #       SizeSel_2P_5_MexCal_S1
-10     10      10      0       -1      99      4       0       0       0       0       0       1
        2       #       SizeSel_2P_6_MexCal_S1
#_MexCal_S2_Baseline_Selex
10      28      18      0       -1      99      4       0       0       0       0       0       1
        2       #       SizeSel_2P_1_MexCal_S2
-5      3       -4.9    0       -1      99      -4      0       0       0       0       0       1
        2       #       SizeSel_2P_2_MexCal_S2
-1      9       2.5     0       -1      99      4       0       0       0       0       0       1
        2       #       SizeSel_2P_3_MexCal_S2
-1      9       4       0       -1      99      4       0       0       0       0       0       1
        2       #       SizeSel_2P_4_MexCal_S2
-10     10      -10     0       -1      99      -4      0       0       0       0       0       1
        2       #       SizeSel_2P_5_MexCal_S2
-10     10      10      0       -1      99      4       0       0       0       0       0       1
        2       #       SizeSel_2P_6_MexCal_S2
#_PacNW_Baseline_Selex
10      28      18      0       -1      99      4       0       0       0       0       0       0
        0       #       SizeSel_6P_1_PacNW_logistic
1       16      4       0       -1      99      4       0       0       0       0       0       0
        0       #       SizeSel_6P_2_PacNW_logistic
#_Aerial_Baseline_Selex
10      28      18      0       -1      99      4       0       0       0       0       0       0
        0       #       SizeSel_2P_1_Aerial
-5      3       3       0       -1      99      4       0       0       0       0       0       0
        0       #       SizeSel_2P_2_Aerial
-1      9       2.5     0       -1      99      4       0       0       0       0       0       0
        0       #       SizeSel_2P_3_Aerial
-1      9       4       0       -1      99      4       0       0       0       0       0       0
        0       #       SizeSel_2P_4_Aerial
-10     10      -10     0       -1      99      -4      0       0       0       0       0       0
        0       #       SizeSel_2P_5_Aerial
-10     10      10      0       -1      99      4       0       0       0       0       0       0
        0       #       SizeSel_2P_6_Aerial
#_Acoustic_Baseline_Selex
10      28      18      0       -1      99      4       0       0       0       0       0       0
        0       #       SizeSel_8P_1_Acoustic
-5      3       3       0       -1      99      -4      0       0       0       0       0       0
        0       #       SizeSel_8P_2_Acoustic
-1      9       2.5     0       -1      99      4       0       0       0       0       0       0
        0       #       SizeSel_8P_3_Acoustic
-1      9       4       0       -1      99      -4      0       0       0       0       0       0
        0       #       SizeSel_8P_4_Acoustic
-10     10      -10     0       -1      99      -4      0       0       0       0       0       0
        0       #       SizeSel_8P_5_Acoustic
-10     10      10      0       -1      99      -4      0       0       0       0       0       0
        0       #       SizeSel_8P_6_Acoustic
#_Age_Selex_Basline
0       15      0       0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_2P_1_MexCal_S1
0       15      15      0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_2P_2_MexCal_S1
0       15      0       0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_3P_1_MexCal_S2
0       15      15      0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_3P_2_MexCal_S2
0       15      0       0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_6P_1_PacNW
```

```
0       15      15      0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_6P_2_PacNW
0       15      0       0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_8P_1_DEPM
0       15      15      0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_8P_2_DEPM
0       15      0       0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_9P_1_TEP
0       15      15      0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_9P_2_TEP
0       15      0       0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_9P_1_TEP_full
0       15      15      0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_9P_2_TEP_full
0       15      0       0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_10P_1_Aerial
0       15      15      0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_10P_2_Aerial
0       15      0       0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_11P_1_Acoustic
0       15      15      0       -1      99      -4      0       0       0       0       0       0
        0       #       AgeSel_11P_2_Acoustic
#
#_Cond 0 #_custom_sel-env_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no enviro fxns
1 #_custom_sel-blk_setup (0/1)
#_MexCal_S1_Block_2_Selex
10      28      18      0       -1      99      4       #       SizeSel_1P_1_MexCal_S1_BLK2repl_1999
-5      3       -5      0       -1      99      -4      #       SizeSel_1P_2_MexCal_S1_BLK2repl_1999
-1      9       2.5     0       -1      99      4       #       SizeSel_1P_3_MexCal_S1_BLK2repl_1999
-1      9       4       0       -1      99      4       #       SizeSel_1P_4_MexCal_S1_BLK2repl_1999
-10     10      -10     0       -1      99      -4      #       SizeSel_1P_5_MexCal_S1_BLK2repl_1999
-10     10      10      0       -1      99      4       #       SizeSel_1P_6_MexCal_S1_BLK2repl_1999
#_MexCal_S2_Block_2_Selex
10      28      18      0       -1      99      4       #       SizeSel_2P_1_MexCal_S2_BLK2repl_1999
-5      3       -5      0       -1      99      -4      #       SizeSel_2P_2_MexCal_S2_BLK2repl_1999
-1      9       2.5     0       -1      99      4       #       SizeSel_2P_3_MexCal_S2_BLK2repl_1999
-1      9       4       0       -1      99      4       #       SizeSel_2P_4_MexCal_S2_BLK2repl_1999
-10     10      -10     0       -1      99      -4      #       SizeSel_2P_5_MexCal_S2_BLK2repl_1999
-10     10      10      0       -1      99      4       #       SizeSel_2P_6_MexCal_S2_BLK2repl_1999
#_Cond No selex parm trends
#_Cond -4 # placeholder for selparm_Dev_Phase
1 #_env/block/dev_adjust_method (1=standard; 2=logistic trans to keep in base parm bounds;
3=standard w/ no bound check)
#
# Tag loss and Tag reporting parameters go next
0  # TG_custom:  0=no read; 1=read if tags exist
#_Cond -6 6 1 1 2 0.01 -4 0 0 0 0 0 0 0  #_placeholder if no parameters
#
1 #_Variance_adjustments_to_input_values
#_fleet: 1 2 3 4 5 6 7 8
0       0       0       0.377   0.288   0       0.274   0.171   #_add_to_survey_CV
0       0       0       0       0       0       0       0       #_add_to_discard_stddev
0       0       0       0       0       0       0       0       #_add_to_bodywt_CV
2.003   1.882   0.64    1       1       1       0.445   2.416   #_mult_by_lencomp_N
0.8     0.8     0.25    1       1       1       1       0.25    #_mult_by_agecomp_N
1       1       1       1       1       1       1       1       #_mult_by_size-at-age_N
#
1 #_maxlambdaphase
1 #_sd_offset
#
17 # number of changes to make to default Lambdas (default value is 1.0)
# Like_comp codes:  1=surv; 2=disc; 3=mnwt; 4=length; 5=age; 6=SizeFreq; 7=sizeage; 8=catch;
# 9=init_equ_catch; 10=recrdev; 11=parm_prior; 12=parm_dev; 13=CrashPen; 14=Morphcomp; 15=Tag-
comp; 16=Tag-negbin
#like_comp fleet/survey  phase  value  sizefreq_method
1       4       1       1       1       #_DEPM
1       5       1       1       1       #_TEP
1       6       1       0       1       #_TEP_full
1       7       1       1       1       #_Aerial
1       8       1       1       1       #_Acoustic
```

```
4       1       1       1       1       #_MexCal-S1_lengths
4       2       1       1       1       #_MexCal-S2_lengths
4       3       1       1       1       #_PacNW_lengths
4       7       1       1       1       #_Aerial_lengths
4       8       1       1       1       #_Acoustic_lengths
5       1       1       1       1       #_MexCal-S1_CondAL
5       2       1       1       1       #_MexCal-S2_CondAL
5       3       1       1       1       #_PacNW_CondAL
5       8       1       1       1       #_Acoustic_CondAL
9       1       1       0       1       #_init_equ_catch_MexCal-S1
9       2       1       0       1       #_init_equ_catch_MexCal-S2
9       3       1       0       1       #_init_equ_catch_PacNW
#
0 # (0/1) read specs for more stddev reporting
 # 0 1 -1 5 1 5 1 -1 5 # placeholder for selex type, len/age, year, N selex bins, Growth pattern, 
N growth ages, NatAge_area(-1 for all), NatAge_yr, N Natages
 # placeholder for vector of selex bins to be reported
 # placeholder for vector of growth ages to be reported
 # placeholder for vector of NatAges ages to be reported
999
```

PS11 X5.DAT:

```
#V3.21d-win64
#_SS-V3.21d-safe-win64;_04/23/2011;_Stock_Synthesis_by_Richard_Methot_(NOAA)_using_ADMB
#_Start_time: Mon May 09 12:25:15 2011
#_Number_of_datafiles: 1
#C Stock Synthesis 3.21d (R. Methot)
#C Pacific sardine stock assessment for 2011 (K. Hill)
#C PS11L.DAT
#_observed data:
1993 #_styr (July '93)
2011 #_endyr
2 #_nseas
6 6 #_months/season
2 #_spawning_season (Spring semester)
3 #_N_fleets
5 #_N_surveys
1 #_N_areas
MexCal_S1%MexCal_S2%PacNW%DEPM%TEP%TEP_full%Aerial%Acoustic
0.5 0.5 0.5 0.58 0.58 0.58 0.2 0.58 #_surveytiming_in_season
1 1 1 1 1 1 1 1 #_area_assignments_for_each_fishery_and_survey
1 1 1 #_units of catch:  1=bio; 2=num
0.05 0.05 0.05 #_se of log(catch) only used for init_eq_catch and for Fmethod 2 and 3
1 #_Ngenders
15 #_Nages
0  0  0  #_init_equil_catch_for_each_fishery (lambda=0)
62 #_N_lines_of_catch_to_read
#_catch_biomass(mtons):_columns_are_fisheries,year,season
5.78    0.00    0.00    1981    1
0.00    57.15   0.00    1981    2
73.94   0.00    0.00    1982    1
0.00    412.76  0.00    1982    2
213.19  0.00    0.00    1983    1
0.00    159.12  0.00    1983    2
75.39   0.00    0.00    1984    1
0.00    3495.80 0.00    1984    2
819.44  0.00    0.00    1985    1
0.00    1018.99 0.00    1985    2
387.70  0.00    0.00    1986    1
0.00    2278.90 0.00    1986    2
2247.30 0.00    0.00    1987    1
0.00    3639.76 0.00    1987    2
2179.91 0.00    0.00    1988    1
0.00    2614.75 0.00    1988    2
7290.45 0.00    0.00    1989    1
0.00    8031.52 0.00    1989    2
6158.41 0.00    0.00    1990    1
0.00    14443.49        0.00    1990    2
24698.02        0.00    0.00    1991    1
```

```
0.00	10323.52	0.00	1991	2
43433.31	0.00	3.90	1992	1
0.00	30776.37	0.18	1992	2
17460.78	0.00	0.00	1993	1
0.00	14078.85	0.00	1993	2
19503.00	0.00	0.00	1994	1
0.00	46792.12	0.00	1994	2
30093.29	0.00	22.68	1995	1
0.00	32561.24	0.00	1995	2
40559.48	0.00	0.00	1996	1
0.00	25364.55	43.54	1996	2
89272.03	0.00	27.22	1997	1
0.00	42079.67	0.82	1997	2
46787.92	0.00	488.45	1998	1
0.00	66550.51	74.39	1998	2
48765.83	0.00	725.10	1999	1
0.00	69337.59	429.59	1999	2
56709.77	0.00	15586.16	2000	1
0.00	46662.67	2336.60	2000	2
54311.70	0.00	22545.99	2001	1
0.00	45617.11	3137.24	2001	2
64671.88	0.00	35525.69	2002	1
0.00	40979.60	597.29	2002	2
38099.55	0.00	37242.26	2003	1
0.00	28590.55	2618.43	2003	2
61008.15	0.00	46730.80	2004	1
0.00	32857.28	1016.32	2004	2
60658.00	0.00	54152.62	2005	1
0.00	36791.15	101.70	2005	2
71474.68	0.00	41220.90	2006	1
0.00	46338.25	0.00	2006	2
71489.22	0.00	48237.10	2007	1
0.00	50130.29	0.00	2007	2
74536.03	0.00	39800.10	2008	1
0.00	46113.91	0.00	2008	2
47373.39	0.00	44841.15	2009	1
0.00	35354.56	948.10	2009	2
55153.70	0.00	54508.77	2010	1
0.00	28147.86	0.00	2010	2
56074.68	0.00	45832.84	2011	1
0.00	12989.06	0.00	2011	2
#
48 #_N_cpue_and_surveyabundance_observations
#_Units:  0=numbers; 1=biomass; 2=F
#_Errtype:  -1=normal; 0=lognormal; >0=T
#_Fleet Units Errtype
1 1 0 # MexCal_S1
2 1 0 # MexCal_S2
3 1 0 # PacNW
4 1 0 # DEPM
5 1 0 # TEP
6 1 0 # TEP_full
7 1 0 # Aerial_N
8 1 0 # Acoustic
#_year seas index obs err
1986	1	4	4061	0.60	#_DEPM_8608
1987	1	4	8661	0.56	#_DEPM_8707
1993	2	4	69065	0.29	#_DEPM_9404
2003	2	4	145274	0.23	#_DEPM_0404
2004	2	4	459943	0.55	#_DEPM_0504
2006	2	4	198404	0.30	#_DEPM_0704
2007	2	4	66395	0.27	#_DEPM_0804
2008	2	4	99162	0.24	#_DEPM_0905
2009	2	4	58447	0.40	#_DEPM_1004
2010	2	4	219386	0.27	#_DEPM_1104
1987	2	5	17266	0.35	#_TEP_8805
1995	2	5	97923	0.40	#_TEP_9604
1996	2	5	482246	0.21	#_TEP_9704
1997	2	5	369775	0.33	#_TEP_9804
1998	2	5	332177	0.34	#_TEP_9904
1999	2	5	1252539	0.39	#_TEP_0004
```

```
2000   2      5      931377  0.38    #_TEP_0104
2001   2      5      236660  0.17    #_TEP_0204
2002   2      5      556177  0.18    #_TEP_0304
2005   2      5      651994  0.25    #_TEP_0604
1986   1      6      11220   0.73    #_TEPall_8608
1987   1      6      24883   0.48    #_TEPall_8707
1987   2      6      17266   0.35    #_TEPall_8805
1993   2      6      73374   0.21    #_TEPall_9404
1995   2      6      97923   0.40    #_TEPall_9604
1996   2      6      482246  0.21    #_TEPall_9704
1997   2      6      369775  0.33    #_TEPall_9804
1998   2      6      332177  0.34    #_TEPall_9904
1999   2      6      1252539 0.39    #_TEPall_0004
2000   2      6      931377  0.38    #_TEPall_0104
2001   2      6      236660  0.17    #_TEPall_0204
2002   2      6      556177  0.18    #_TEPall_0304
2003   2      6      307795  0.24    #_TEPall_0404
2004   2      6      486950  0.40    #_TEPall_0504
2005   2      6      651994  0.25    #_TEPall_0604
2006   2      6      306297  0.26    #_TEPall_0704
2007   2      6      128118  0.21    #_TEPall_0804
2008   2      6      162188  0.22    #_TEPall_0904
2009   2      6      97838   0.39    #_TEPall_1004
2010   2      6      364798  0.26    #_TEPall_1104
2009   1      7      1236911 0.90    #_Aerial_09N
2010   1      7      173390  0.40    #_Aerial_10N
2011   1      7      201888  0.29    #_Aerial_11N
2005   2      8      1947063 0.30    #_Acoustic_0604
2007   2      8      751075  0.09    #_Acoustic_0804
2008   1      8      801000  0.30    #_Acoustic_0807
2009   2      8      357006  0.41    #_Acoustic_1004
2010   2      8      493672  0.30    #_Acoustic_1104
#
0 #_N_fleets_with_discard
#_discard_units (1=same_as_catchunits(bio/num); 2=fraction; 3=numbers)
#_discard_errtype:  >0 for DF of T-dist(read CV below); 0 for normal with CV; -1 for normal with
se; -2 for lognormal
#Fleet Disc_units err_type
0 #N discard obs
#_year seas index obs err
#
0 #_N_meanbodywt_obs
100 #_DF_for_meanbodywt_T-distribution_like
#
2 # length bin method: 1=use databins; 2=generate from binwidth,min,max below; 3=read vector
0.5 # binwidth for population size comp
8 # minimum size in the population (lower edge of first bin and size at age 0.00)
30 # maximum size in the population (lower edge of last bin)
#
-0.0001 #_comp_tail_compression
0.0001 #_add_to_comp
0 #_combine males into females at or below this bin number
39 #_N_LengthBins
 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15 15.5 16 16.5 17 17.5 18 18.5 19 19.5 20 20.5 21
21.5 22 22.5 23 23.5 24 24.5 25 25.5 26 26.5 27 27.5 28
89 #_N_Length_obs
#Yr Seas Flt/Svy Gender Part Nsamp datavector(female-male)
1981   1      1      0      0      7.16    0.014850       0.000000       0.003712
       0.000000       0.000000       0.010595       0.027531       0.073623       0.077878
       0.031243       0.006883       0.000000       0.000000       0.000000       0.000000
       0.000000       0.000000       0.038144       0.053144       0.072163       0.063356
       0.036924       0.036349       0.049662       0.042237       0.042237       0.044860
       0.121757       0.101109       0.024212       0.013765       0.006883       0.006883
       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000
1982   1      1      0      0      14.44   0.000000       0.000000       0.000000
       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000
       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000
       0.000000       0.000000       0.029296       0.021078       0.062474       0.145519
       0.161921       0.108544       0.061647       0.034477       0.049395       0.065545
       0.064364       0.078843       0.053783       0.033650       0.014817       0.007324
       0.000000       0.007324       0.000000       0.000000       0.000000       0.000000
```

1983	1 1	0 0	16.84 0.000100	0.001878	0.000751	
	0.000376	0.000376	0.000125	0.001127	0.005525	0.000391
	0.005680	0.022394	0.005555	0.000250	0.017534	0.054939
	0.052128	0.053965	0.006025	0.049484	0.039604	0.057124
	0.052170	0.066392	0.084218	0.080405	0.034818	0.008141
	0.007403	0.000125	0.002922	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1985	1 1	0 0	15.00 0.000000	0.000000	0.000000	
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.005515	0.018111	0.019377	0.093897	0.075785	0.065500
	0.071040	0.142121	0.141013	0.109065	0.081894	0.068232
	0.059663	0.013687	0.017131	0.004700	0.004285	0.005851
	0.003133	0.000000	0.000000	0.000000	0.000000	0.000000
1986	1 1	0 0	20.20 0.000000	0.000000	0.000000	
	0.000000	0.000000	0.006163	0.013867	0.015408	0.000000
	0.001541	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000213	0.001541	0.002345
	0.014175	0.067847	0.083715	0.126750	0.161270	0.220701
	0.135881	0.071980	0.046496	0.011572	0.015408	0.000000
	0.000000	0.003128	0.000000	0.000000	0.000000	0.000000
1987	1 1	0 0	29.40 0.000000	0.000000	0.000000	
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.002360
	0.003307	0.015751	0.024324	0.027775	0.064364	0.099968
	0.139844	0.191449	0.133004	0.041213	0.032414	0.037585
	0.069647	0.051579	0.038567	0.015637	0.008293	0.002919
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	1 1	0 0	22.76 0.000000	0.000000	0.000000	
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.003951	0.000000	0.001958
	0.005910	0.017625	0.019107	0.039478	0.030792	0.023926
	0.023330	0.076430	0.110504	0.162587	0.154245	0.146449
	0.085467	0.050050	0.019970	0.015623	0.004519	0.003559
	0.004519	0.000000	0.000000	0.000000	0.000000	0.000000
1989	1 1	0 0	12.65 0.000000	0.000000	0.000000	
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000049	0.000000	0.000370
	0.001667	0.026277	0.009898	0.043862	0.061970	0.112096
	0.135223	0.166573	0.084054	0.065568	0.110924	0.087230
	0.036419	0.055513	0.002127	0.000183	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1990	1 1	0 0	16.11 0.000000	0.000000	0.000000	
	0.000049	0.000148	0.000148	0.000221	0.000172	0.000295
	0.001049	0.000902	0.003626	0.000570	0.004269	0.003802
	0.004845	0.002086	0.006415	0.018809	0.011279	0.014124
	0.010356	0.018768	0.142194	0.091751	0.150873	0.161789
	0.130339	0.099539	0.055362	0.039552	0.006803	0.005699
	0.002862	0.011254	0.000024	0.000024	0.000000	0.000000
1991	1 1	0 0	42.48 0.000086	0.000000	0.000000	
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.001044	0.001044	0.001992	0.015909	0.020662	0.028711
	0.032315	0.011543	0.026949	0.042753	0.061528	0.059733
	0.059129	0.075783	0.081491	0.092243	0.088192	0.156331
	0.063401	0.036361	0.025117	0.014075	0.003323	0.000287
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	1 1	0 0	61.18 0.000000	0.000000	0.000000	
	0.000000	0.000000	0.000182	0.000000	0.000000	0.000000
	0.000752	0.010293	0.037792	0.080330	0.112393	0.120486
	0.123700	0.114211	0.089003	0.069941	0.060366	0.054391
	0.046258	0.027985	0.022356	0.009227	0.006012	0.004527
	0.003876	0.002501	0.001757	0.001131	0.000530	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1993	1 1	0 0	68.60 0.000000	0.000000	0.000000	
	0.000928	0.001856	0.000928	0.002783	0.007422	0.005567
	0.004639	0.004175	0.003735	0.003271	0.005126	0.028021
	0.066029	0.123349	0.197066	0.188812	0.143559	0.109763
	0.059052	0.026514	0.009434	0.005642	0.001860	0.000464
	0.000005	0.000005	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

1994	1 1	0 0	34.15 0.000000	0.000000	0.000000	
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.003200	0.030933	0.068266	0.120232	0.095225	0.083914
	0.070584	0.076933	0.100247	0.112729	0.101358	0.070868
	0.043075	0.013565	0.005760	0.002962	0.000075	0.000000
	0.000075	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1995	1 1	0 0	54.40 0.000000	0.000000	0.000000	
	0.000000	0.000000	0.000000	0.000135	0.000000	0.001898
	0.004101	0.004176	0.009878	0.025299	0.069670	0.132279
	0.183127	0.169360	0.183165	0.098559	0.061397	0.025728
	0.014663	0.012118	0.002780	0.001112	0.000556	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	1 1	0 0	76.02 0.000000	0.000000	0.000000	
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.002094	0.003448	0.006561	0.015096	0.023171	0.031032
	0.048107	0.067165	0.084056	0.093164	0.093388	0.102063
	0.091071	0.110929	0.114026	0.059566	0.034854	0.012377
	0.004724	0.001354	0.001449	0.000000	0.000000	0.000102
	0.000102	0.000000	0.000102	0.000000	0.000000	0.000000
1997	1 1	0 0	72.64 0.000307	0.000000	0.000000	
	0.000000	0.000000	0.000085	0.000229	0.000299	0.000556
	0.000886	0.003593	0.005131	0.008741	0.026647	0.051093
	0.063877	0.067670	0.074096	0.068533	0.094399	0.090619
	0.100394	0.119879	0.104534	0.070381	0.027853	0.015770
	0.002865	0.001478	0.000085	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1998	1 1	0 0	67.85 0.000000	0.000047	0.000000	
	0.000185	0.000732	0.002543	0.009411	0.022722	0.035773
	0.049703	0.057779	0.063782	0.054665	0.061802	0.040712
	0.041858	0.029271	0.045642	0.055677	0.067969	0.073375
	0.090870	0.085642	0.055078	0.026356	0.018064	0.006293
	0.002711	0.000764	0.000573	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1999	1 1	0 0	44.67 0.000000	0.000000	0.000000	
	0.000000	0.000000	0.000595	0.000595	0.001086	0.011159
	0.032540	0.074890	0.113985	0.119258	0.108611	0.100978
	0.139682	0.124076	0.062958	0.051763	0.022877	0.010234
	0.007987	0.007710	0.004816	0.001204	0.000602	0.002394
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	1 1	0 0	53.24 0.000000	0.000000	0.000000	
	0.000000	0.000000	0.000000	0.000849	0.002046	0.001125
	0.004749	0.006904	0.008446	0.013623	0.028049	0.057074
	0.077376	0.086447	0.083974	0.094618	0.114409	0.119602
	0.123812	0.086044	0.053555	0.032143	0.004667	0.000000
	0.000000	0.000488	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	1 1	0 0	58.90 0.000572	0.000952	0.027129	
	0.019833	0.018743	0.019354	0.020284	0.015051	0.012432
	0.002324	0.002025	0.002578	0.012867	0.038050	0.053442
	0.055914	0.080320	0.102973	0.122124	0.107547	0.091623
	0.052195	0.040876	0.029596	0.022617	0.019207	0.015089
	0.005060	0.003788	0.001805	0.001811	0.001140	0.000416
	0.000259	0.000000	0.000000	0.000000	0.000000	0.000000
2002	1 1	0 0	73.64 0.002665	0.000000	0.000259	
	0.000000	0.000196	0.001112	0.001764	0.005839	0.004543
	0.018753	0.024079	0.037655	0.070101	0.094662	0.114295
	0.124723	0.110974	0.105531	0.103205	0.083759	0.056809
	0.030472	0.004064	0.001205	0.001184	0.000329	0.001184
	0.000506	0.000000	0.000000	0.000000	0.000132	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2003	1 1	0 0	50.43 0.002780	0.000158	0.000421	
	0.001718	0.008330	0.015618	0.011645	0.007644	0.009932
	0.011847	0.012806	0.018353	0.015909	0.042276	0.050086
	0.062188	0.061051	0.078334	0.088647	0.091874	0.086325
	0.103707	0.097823	0.063573	0.027836	0.019762	0.006777
	0.002456	0.000125	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

2004	1	1	0	0	149.06	0.000000	0.000000	0.000246
	0.000041		0.000041		0.000375	0.000589	0.002638	0.021356
	0.057128		0.099392		0.122562	0.145713	0.131569	0.125546
	0.082819		0.072825		0.043637	0.030076	0.014641	0.015061
	0.016709		0.008448		0.007113	0.000328	0.000399	0.000000
	0.000374		0.000000		0.000000	0.000374	0.000000	0.000000
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
2005	1	1	0	0	108.68	0.001935	0.000225	0.003231
	0.003046		0.005884		0.007342	0.009982	0.006443	0.014565
	0.029433		0.039148		0.048148	0.061427	0.065013	0.087550
	0.120444		0.127016		0.132825	0.107498	0.069921	0.039190
	0.008945		0.005718		0.004080	0.000271	0.000074	0.000000
	0.000147		0.000074		0.000000	0.000353	0.000074	0.000000
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	78.73	0.001266	0.000381	0.001026
	0.001133		0.001644		0.003224	0.007389	0.009410	0.011514
	0.017665		0.040559		0.073952	0.114217	0.129565	0.133074
	0.133431		0.101687		0.090060	0.060436	0.038090	0.020712
	0.004586		0.002392		0.001691	0.000699	0.000099	0.000099
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
2007	1	1	0	0	109.86	0.003421	0.005131	0.007440
	0.005875		0.002273		0.002893	0.004462	0.012989	0.021376
	0.028985		0.041855		0.048109	0.069259	0.095969	0.130362
	0.151932		0.135074		0.096284	0.057900	0.031398	0.010292
	0.011239		0.004927		0.001136	0.001136	0.001026	0.001864
	0.001710		0.003763		0.003421	0.003421	0.002395	0.000684
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
2008	1	1	0	0	71.40	0.000000	0.000351	0.000351
	0.001433		0.001769		0.004771	0.012218	0.016937	0.024198
	0.028756		0.043208		0.058505	0.065684	0.075270	0.112669
	0.120940		0.113497		0.098252	0.077311	0.044701	0.026574
	0.018577		0.011694		0.017714	0.008961	0.006572	0.004357
	0.002717		0.001052		0.000964	0.000000	0.000000	0.000000
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
2009	1	1	0	0	36.00	0.000000	0.000000	0.000000
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000822
	0.001644		0.009428		0.015366	0.039907	0.047117	0.083946
	0.136304		0.270089		0.239552	0.107839	0.041994	0.004537
	0.001455		0.000000		0.000000	0.000000	0.000000	0.000000
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	38.00	0.000000	0.000000	0.000000
	0.004395		0.009888		0.014283	0.025586	0.023109	0.068357
	0.071257		0.114000		0.125375	0.149905	0.121419	0.114315
	0.077246		0.045191		0.022349	0.005227	0.002024	0.000845
	0.002024		0.000000		0.001601	0.000000	0.001601	0.000000
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
2011	1	1	0	0	24.04	0.000000	0.000000	0.000000
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
	0.000000		0.003447		0.008617	0.033605	0.072138	0.086918
	0.138418		0.283650		0.258043	0.087082	0.014041	0.007390
	0.003325		0.000862		0.000000	0.002463	0.000000	0.000000
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	9.52	0.000000	0.000000	0.006064
	0.024255		0.000000		0.000000	0.006064	0.000000	0.003686
	0.022115		0.055286		0.033172	0.070802	0.056446	0.052492
	0.040900		0.077104		0.047083	0.020480	0.017478	0.004369
	0.018726		0.047261		0.084535	0.060993	0.049936	0.058853
	0.060993		0.035044		0.018637	0.014119	0.000000	0.004369
	0.004369		0.004369		0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	23.32	0.000000	0.000000	0.000000
	0.003935		0.000000		0.003935	0.003935	0.000000	0.000000
	0.003935		0.000000		0.000000	0.000000	0.000000	0.007870
	0.000000		0.000000		0.000000	0.000000	0.005678	0.031542
	0.089996		0.187715		0.224677	0.193622	0.083601	0.052876
	0.040658		0.035774		0.011064	0.013144	0.002110	0.003935
	0.000000		0.000000		0.000000	0.000000	0.000000	0.000000

1983	2	2	0	0	7.52	0.000000	0.000000	0.000000	
	0.000000		0.000000		0.000000		0.000000	0.000000	0.000000
	0.000000		0.000000		0.008428		0.016857	0.025285	0.016857
	0.013165		0.000000		0.029407		0.008428	0.028760	0.047463
	0.054168		0.098094		0.148723		0.196770	0.146815	0.088310
	0.034943		0.028053		0.004737		0.004737	0.000000	0.000000
	0.000000		0.000000		0.000000		0.000000	0.000000	0.000000
1984	2	2	0	0	8.64	0.000000	0.000000	0.000000	
	0.000000		0.000000		0.000000		0.000000	0.000000	0.000000
	0.000000		0.000000		0.001886		0.000000	0.000000	0.001139
	0.002848		0.011710		0.012874		0.018784	0.041612	0.040002
	0.052357		0.106126		0.122135		0.140128	0.138143	0.146951
	0.082833		0.073648		0.006824		0.000000	0.000000	0.000000
	0.000000		0.000000		0.000000		0.000000	0.000000	0.000000
1985	2	2	0	0	33.40	0.000000	0.000000	0.000000	
	0.000000		0.000000		0.000000		0.000000	0.000000	0.000000
	0.000000		0.000000		0.000000		0.000596	0.000000	0.002930
	0.000000		0.001318		0.000102		0.006694	0.017110	0.024155
	0.032687		0.087814		0.126262		0.152217	0.143861	0.133935
	0.144089		0.075907		0.024816		0.014497	0.007928	0.003083
	0.000000		0.000000		0.000000		0.000000	0.000000	0.000000
1986	2	2	0	0	44.32	0.002410	0.000000	0.000000	
	0.000000		0.000000		0.000000		0.000000	0.000000	0.000000
	0.004016		0.015796		0.025256		0.009460	0.015624	0.014115
	0.002774		0.000000		0.000635		0.002953	0.002388	0.003535
	0.004631		0.017000		0.040132		0.090145	0.168191	0.192720
	0.191083		0.110550		0.057719		0.016222	0.008234	0.002161
	0.001160		0.000181		0.000454		0.000454	0.000000	0.000000
1987	2	2	0	0	87.72	0.000805	0.000000	0.000000	
	0.000000		0.001610		0.002415		0.018516	0.028177	0.005635
	0.000805		0.004505		0.000000		0.000000	0.000175	0.000175
	0.000351		0.002050		0.005086		0.019853	0.064866	0.084206
	0.068216		0.094739		0.102463		0.129387	0.104192	0.088407
	0.069647		0.048689		0.029229		0.015836	0.005375	0.001883
	0.002527		0.000000		0.000180		0.000000	0.000000	0.000000
1988	2	2	0	0	46.80	0.000000	0.000000	0.000000	
	0.000000		0.000000		0.000000		0.000000	0.000000	0.000000
	0.000195		0.000781		0.003490		0.005585	0.010950	0.011830
	0.023613		0.024090		0.009582		0.012837	0.016158	0.041302
	0.024608		0.055205		0.082781		0.103236	0.140703	0.147367
	0.133137		0.054189		0.052161		0.026467	0.017157	0.002580
	0.000000		0.000000		0.000000		0.000000	0.000000	0.000000
1989	2	2	0	0	15.49	0.000000	0.000000	0.000000	
	0.000569		0.001707		0.001707		0.002560	0.002133	0.003923
	0.003271		0.001280		0.000937		0.000878	0.000084	0.000084
	0.000000		0.007162		0.000269		0.014677	0.002566	0.015325
	0.079172		0.177012		0.372683		0.107560	0.127596	0.040629
	0.020333		0.008557		0.004085		0.002159	0.001083	0.000000
	0.000000		0.000000		0.000000		0.000000	0.000000	0.000000
1990	2	2	0	0	64.03	0.000000	0.000000	0.000000	
	0.000000		0.000000		0.000000		0.000000	0.000000	0.000050
	0.000222		0.000243		0.002751		0.004847	0.011895	0.020598
	0.019397		0.016070		0.005814		0.006993	0.004525	0.010096
	0.010986		0.037681		0.077013		0.103777	0.153705	0.158034
	0.135714		0.084959		0.064094		0.035987	0.020168	0.008835
	0.004224		0.001319		0.000000		0.000000	0.000000	0.000000
1991	2	2	0	0	64.38	0.000000	0.000000	0.000000	
	0.000000		0.000000		0.000000		0.000000	0.000000	0.002578
	0.007888		0.015169		0.018982		0.025407	0.020630	0.022543
	0.012965		0.013142		0.018770		0.039027	0.036031	0.044608
	0.043464		0.062686		0.065341		0.074440	0.081531	0.109866
	0.095440		0.080602		0.056393		0.028770	0.012553	0.008233
	0.001743		0.001197		0.000000		0.000000	0.000000	0.000000
1992	2	2	0	0	46.21	0.000000	0.000000	0.000245	
	0.000000		0.000245		0.000736		0.001267	0.003103	0.002808
	0.012862		0.025718		0.037861		0.087770	0.099213	0.116302
	0.116070		0.111534		0.092665		0.059823	0.051823	0.049999
	0.037880		0.028712		0.020277		0.014052	0.006907	0.007917
	0.006302		0.003740		0.001677		0.001351	0.000000	0.000462
	0.000000		0.000218		0.000245		0.000000	0.000218	0.000000

1993	2 2	0 0	75.58 0.000099	0.000000	0.000000	
	0.000000	0.000000	0.000000	0.000621	0.002340	0.010980
	0.040808	0.088672	0.131779	0.112035	0.080980	0.068931
	0.073152	0.087587	0.087219	0.079264	0.045659	0.031650
	0.019192	0.012961	0.006905	0.006012	0.002440	0.001769
	0.001516	0.002449	0.002206	0.000953	0.000153	0.000906
	0.000660	0.000000	0.000099	0.000000	0.000000	0.000000
1994	2 2	0 0	184.41 0.000174	0.000000	0.000000	
	0.000000	0.001735	0.006987	0.007448	0.008158	0.014166
	0.021731	0.037195	0.068769	0.087983	0.107261	0.116769
	0.134859	0.111859	0.101310	0.059562	0.053800	0.028406
	0.018420	0.006945	0.003993	0.000506	0.000701	0.000202
	0.000000	0.000091	0.000000	0.000221	0.000528	0.000000
	0.000000	0.000000	0.000221	0.000000	0.000000	0.000000
1995	2 2	0 0	50.12 0.000331	0.000000	0.000000	
	0.000000	0.000000	0.006331	0.002139	0.011995	0.015520
	0.022247	0.026844	0.037423	0.052884	0.084154	0.091996
	0.121070	0.109392	0.107146	0.080676	0.088582	0.051062
	0.043209	0.019286	0.022310	0.003597	0.000760	0.000426
	0.000000	0.000310	0.000000	0.000000	0.000000	0.000310
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	2 2	0 0	39.90 0.000000	0.000000	0.000000	
	0.000000	0.001536	0.003017	0.009326	0.017311	0.033639
	0.037845	0.041986	0.054786	0.047630	0.024027	0.019090
	0.028685	0.034975	0.050976	0.047417	0.078157	0.078669
	0.114601	0.107664	0.078522	0.033363	0.020424	0.009334
	0.005635	0.003696	0.002464	0.002464	0.002464	0.002464
	0.002906	0.004928	0.000000	0.000000	0.000000	0.000000
1997	2 2	0 0	42.44 0.000565	0.000565	0.006218	
	0.005658	0.009259	0.004822	0.002245	0.004177	0.010364
	0.007253	0.025158	0.029778	0.035906	0.051944	0.054388
	0.038954	0.038856	0.062911	0.052211	0.057149	0.076851
	0.079941	0.091753	0.096512	0.060414	0.037167	0.026114
	0.015638	0.011329	0.002730	0.001721	0.001351	0.000098
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1998	2 2	0 0	66.15 0.000000	0.000478	0.002667	
	0.004847	0.007371	0.008141	0.013182	0.037230	0.046507
	0.057548	0.068718	0.082140	0.101691	0.114244	0.099175
	0.093664	0.080174	0.065382	0.030140	0.024923	0.016488
	0.012237	0.010762	0.007189	0.005594	0.003382	0.002883
	0.001787	0.000727	0.000447	0.000280	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1999	2 2	0 0	52.39 0.000000	0.000000	0.000000	
	0.000000	0.000000	0.000000	0.000000	0.002803	0.013954
	0.047865	0.085181	0.121801	0.158236	0.154086	0.132039
	0.097971	0.063073	0.043164	0.031698	0.024594	0.017816
	0.005291	0.000321	0.000107	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2 2	0 0	62.74 0.000103	0.000000	0.000000	
	0.000052	0.000207	0.004595	0.006264	0.015185	0.027244
	0.036256	0.061835	0.088702	0.106683	0.083819	0.061452
	0.057073	0.064202	0.059857	0.057682	0.077487	0.069800
	0.072861	0.027024	0.019339	0.001548	0.000000	0.000573
	0.000052	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000103	0.000000	0.000000	0.000000
2001	2 2	0 0	62.32 0.000086	0.000000	0.000967	
	0.008720	0.020138	0.038937	0.056557	0.076552	0.092967
	0.100591	0.087478	0.066011	0.069411	0.058438	0.027432
	0.027380	0.022600	0.032229	0.049091	0.066681	0.036636
	0.032945	0.013638	0.006822	0.004744	0.001763	0.000588
	0.000588	0.000000	0.000000	0.000012	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2 2	0 0	62.30 0.000029	0.000000	0.000000	
	0.000310	0.000930	0.001550	0.002157	0.003087	0.004677
	0.003980	0.009187	0.020745	0.042643	0.077442	0.109215
	0.115644	0.115443	0.091496	0.050570	0.042569	0.058989
	0.059885	0.057942	0.058080	0.030420	0.014651	0.008624
	0.009536	0.006932	0.001157	0.001032	0.001079	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

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2003   2     2      0     0      124.63  0.000000      0.000000      0.000000
       0.004836     0.024900     0.041747     0.040940     0.059498     0.102846
       0.143817     0.129061     0.104544     0.084170     0.058191     0.045825
       0.026450     0.016042     0.017837     0.019166     0.022279     0.017689
       0.015080     0.007090     0.001584     0.001328     0.004556     0.002713
       0.001414     0.001595     0.001861     0.002127     0.000532     0.000266
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
2004   2     2      0     0      122.39  0.000000      0.000000      0.000000
       0.000000     0.000851     0.001390     0.003292     0.008546     0.022293
       0.027333     0.049014     0.079615     0.090950     0.111045     0.112157
       0.106740     0.114667     0.102874     0.092278     0.044648     0.015402
       0.010574     0.002185     0.000929     0.000719     0.000720     0.001347
       0.000000     0.000431     0.000000     0.000000     0.000000     0.000000
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
2005   2     2      0     0      77.23   0.000086      0.000117      0.001398
       0.005107     0.017957     0.024140     0.030889     0.037777     0.064883
       0.080334     0.096487     0.096321     0.112933     0.097793     0.089993
       0.064652     0.059271     0.041117     0.023153     0.015733     0.010544
       0.008228     0.004302     0.005390     0.004165     0.001468     0.002685
       0.001343     0.000459     0.000342     0.000456     0.000250     0.000228
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
2006   2     2      0     0      91.44   0.005852      0.000000      0.000000
       0.000059     0.001594     0.003695     0.007183     0.009823     0.019775
       0.022291     0.052327     0.075917     0.101604     0.113838     0.120053
       0.117874     0.102179     0.076536     0.054851     0.044279     0.025198
       0.015565     0.006694     0.005998     0.001722     0.003707     0.003413
       0.002219     0.001659     0.001365     0.001365     0.001365     0.000000
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
2007   2     2      0     0      56.13   0.000910      0.000000      0.000420
       0.003380     0.011232     0.012584     0.030352     0.059333     0.092629
       0.108317     0.128226     0.101101     0.102325     0.107334     0.080524
       0.055080     0.036845     0.017677     0.011160     0.009734     0.004499
       0.005294     0.006498     0.004443     0.004913     0.002250     0.001425
       0.000413     0.000138     0.000413     0.000138     0.000138     0.000275
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
2008   2     2      0     0      45.51   0.001666      0.001666      0.002909
       0.002221     0.007303     0.010603     0.019147     0.032675     0.029694
       0.030193     0.035028     0.048775     0.067995     0.109292     0.129573
       0.124315     0.090484     0.074640     0.056167     0.051841     0.025380
       0.014964     0.008953     0.009710     0.005355     0.003525     0.002221
       0.002408     0.000555     0.000742     0.000000     0.000000     0.000000
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
2009   2     2      0     0      99.08   0.001463      0.000000      0.000000
       0.000330     0.000986     0.003632     0.015228     0.048031     0.104670
       0.151941     0.167060     0.143772     0.127564     0.091907     0.072428
       0.039165     0.013929     0.009646     0.002593     0.001642     0.000954
       0.000534     0.000656     0.000890     0.000901     0.000000     0.000000
       0.000078     0.000000     0.000000     0.000000     0.000000     0.000000
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
2010   2     2      0     0      32.96   0.000000      0.000000      0.000000
       0.000003     0.000010     0.000000     0.015370     0.035526     0.075211
       0.080295     0.161158     0.164426     0.144231     0.081373     0.036557
       0.025042     0.008798     0.008022     0.005019     0.006459     0.001896
       0.003236     0.008708     0.014737     0.031483     0.028804     0.028134
       0.017416     0.008038     0.007368     0.000670     0.001340     0.000670
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
1999   1     3      0     0      3.04    0.000000      0.000000      0.000000
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
       0.000000     0.000000     0.000000     0.000001     0.000006     0.044838
       0.074723     0.074726     0.134488     0.158714     0.134484     0.059770
       0.044828     0.024229     0.046430     0.037147     0.037156     0.027872
       0.037163     0.039185     0.009291     0.000003     0.000001     0.014943
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
1999   2     3      0     0      4.24    0.000000      0.000000      0.000000
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
       0.018868     0.018868     0.028302     0.169811     0.179245     0.207547
       0.169811     0.113208     0.047170     0.028302     0.009434     0.009434
       0.000000     0.000000     0.000000     0.000000     0.000000     0.000000
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2000   1     3     0     0     63.93  0.000000     0.000000     0.000000
       0.000000    0.000542    0.000000    0.000034    0.000065    0.000000
       0.000034    0.000000    0.000034    0.000000    0.000000    0.000637
       0.003089    0.015709    0.028986    0.038236    0.054959    0.060933
       0.065604    0.076649    0.091046    0.124481    0.113589    0.113161
       0.076089    0.067536    0.031636    0.018147    0.010180    0.004288
       0.003651    0.000601    0.000031    0.000040    0.000000    0.000012
2000   2     3     0     0     10.72  0.000000     0.000000     0.000000
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000125
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000000
       0.000000    0.000000    0.000000    0.000000    0.023512    0.023761
       0.083164    0.131807    0.154198    0.178832    0.130813    0.148947
       0.077170    0.035774    0.000008    0.011885    0.000002    0.000001
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000000
2001   1     3     0     0     78.15  0.000000     0.000000     0.000000
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000870
       0.001566    0.001218    0.001159    0.000602    0.000464    0.000000
       0.000464    0.000000    0.000000    0.002618    0.010241    0.023236
       0.074672    0.163004    0.177386    0.169962    0.126699    0.091581
       0.066939    0.042932    0.020731    0.012758    0.007586    0.001565
       0.001589    0.000111    0.000046    0.000000    0.000000    0.000000
2001   2     3     0     0     26.75  0.000000     0.000000     0.000000
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000000
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000000
       0.000483    0.000483    0.000001    0.000000    0.000000    0.000000
       0.003672    0.008793    0.040104    0.090451    0.181972    0.217069
       0.191869    0.131393    0.066064    0.043253    0.010753    0.008805
       0.002902    0.000484    0.000967    0.000483    0.000000    0.000000
2002   1     3     0     0     172.79 0.000000     0.000000     0.000000
       0.000003    0.000006    0.000006    0.000006    0.000315    0.000009
       0.000006    0.000014    0.000315    0.000625    0.000312    0.000946
       0.001362    0.001747    0.003172    0.003616    0.004448    0.005364
       0.004218    0.013819    0.035660    0.118577    0.203111    0.219145
       0.146527    0.115716    0.060206    0.035433    0.012562    0.007773
       0.002410    0.001648    0.000333    0.000544    0.000019    0.000024
2002   2     3     0     0     8.44   0.000000     0.000000     0.000000
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000000
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000000
       0.000000    0.003124    0.000000    0.000000    0.006247    0.009371
       0.009373    0.012494    0.012497    0.052211    0.137895    0.067854
       0.174318    0.210082    0.069991    0.087587    0.056318    0.068754
       0.009384    0.006247    0.003126    0.003124    0.000000    0.000004
2003   1     3     0     0     145.33 0.000000     0.000000     0.000000
       0.000000    0.000000    0.000004    0.000000    0.000004    0.000004
       0.000814    0.004032    0.005145    0.003386    0.001414    0.000020
       0.000297    0.004555    0.016617    0.032166    0.047167    0.063808
       0.046116    0.053689    0.065377    0.067425    0.072089    0.123671
       0.124741    0.102149    0.073617    0.047979    0.021472    0.010950
       0.006870    0.003056    0.000714    0.000627    0.000013    0.000012
2003   2     3     0     0     16.88  0.000000     0.000000     0.000000
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000000
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000000
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000000
       0.000000    0.000685    0.016262    0.031838    0.074705    0.173461
       0.150967    0.245610    0.165543    0.086041    0.034079    0.010279
       0.009159    0.001371    0.000000    0.000000    0.000000    0.000000
2004   1     3     0     0     95.17  0.000016     0.000016     0.000000
       0.000000    0.000561    0.000280    0.000618    0.001474    0.006190
       0.007703    0.009384    0.008862    0.009291    0.003363    0.011186
       0.014509    0.040745    0.037235    0.033800    0.022246    0.025481
       0.016250    0.028075    0.028902    0.058170    0.060385    0.095333
       0.084282    0.139844    0.097784    0.075070    0.037032    0.027036
       0.012349    0.004252    0.001317    0.000550    0.000171    0.000240
2004   2     3     0     0     7.88   0.000000     0.000000     0.000000
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000000
       0.000000    0.000000    0.000000    0.000000    0.000000    0.021317
       0.056924    0.150803    0.279200    0.245884    0.150382    0.024951
       0.020637    0.009980    0.004990    0.000000    0.004990    0.004990
       0.000000    0.004990    0.009980    0.000000    0.009980    0.000000
       0.000000    0.000000    0.000000    0.000000    0.000000    0.000000
```

2005	1 3	0 0	67.68	0.000000	0.000000	0.000000
	0.000000	0.000006	0.000014	0.001595	0.000394	0.000208
	0.000041	0.000208	0.000203	0.002701	0.022918	0.059250
	0.096167	0.207278	0.183288	0.124437	0.050976	0.018772
	0.015158	0.009988	0.009429	0.010806	0.012437	0.013475
	0.018913	0.028061	0.031101	0.040826	0.021083	0.014480
	0.002821	0.002493	0.000274	0.000147	0.000027	0.000027
2006	1 3	0 0	27.00	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.003855	0.011516	0.047824	0.162951	0.336029
	0.249862	0.112435	0.017377	0.004662	0.009944	0.001930
	0.001226	0.006868	0.008264	0.011352	0.004870	0.008650
	0.000000	0.000000	0.000386	0.000000	0.000000	0.000000
2006	2 3	0 0	3.00	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.013333	0.000000	0.066667	0.066667
	0.200000	0.160000	0.093333	0.093333	0.053333	0.026667
	0.053333	0.000000	0.080000	0.040000	0.026667	0.026667
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	1 3	0 0	87.86	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000007	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000016
	0.000619	0.002556	0.014423	0.070113	0.131612	0.213838
	0.237077	0.182199	0.072210	0.022876	0.013073	0.007999
	0.005563	0.006845	0.008026	0.004104	0.002152	0.002146
	0.001155	0.000719	0.000110	0.000501	0.000013	0.000045
2008	1 3	0 0	129.64	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000041	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000419	0.000000
	0.000000	0.000583	0.004608	0.031939	0.061327	0.117159
	0.142707	0.159212	0.111180	0.071091	0.043395	0.047645
	0.064097	0.062095	0.040864	0.021478	0.010396	0.004509
	0.002537	0.001063	0.000595	0.000562	0.000277	0.000221
2009	1 3	0 0	159.41	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000007
	0.000000	0.000000	0.000368	0.000368	0.000000	0.000000
	0.000007	0.000022	0.003787	0.023832	0.056195	0.133178
	0.165416	0.147245	0.082555	0.042626	0.021331	0.035813
	0.032583	0.061578	0.057204	0.069956	0.031626	0.019305
	0.007933	0.004396	0.001357	0.000843	0.000237	0.000232
2009	2 3	0 0	5.36	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.017982	0.000000	0.000001
	0.000000	0.000000	0.009260	0.002153	0.039681	0.070320
	0.201066	0.167201	0.201652	0.131568	0.072393	0.050747
	0.017991	0.008993	0.008992	0.000000	0.000001	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1 3	0 0	159.59	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000014	0.000000	0.000014	0.000014
	0.000014	0.000458	0.000000	0.000014	0.000000	0.001794
	0.002011	0.001592	0.002523	0.007358	0.028022	0.089093
	0.140431	0.152296	0.096692	0.054984	0.025309	0.034573
	0.044765	0.073213	0.073300	0.078991	0.044765	0.029546
	0.009798	0.005620	0.001807	0.000564	0.000193	0.000230
2011	1 3	0 0	73.60	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.001206	0.000000	0.000650	0.000039
	0.000158	0.002344	0.002290	0.004626	0.006907	0.019899
	0.030293	0.101541	0.140899	0.121872	0.059071	0.025929
	0.023605	0.041356	0.081663	0.108839	0.092595	0.072887
	0.032651	0.017025	0.006538	0.002458	0.001352	0.001306
2009	1 7	0 0	33.20	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000528	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000576	0.004958	0.031030	0.099600	0.163745
	0.202198	0.228388	0.158862	0.079160	0.020953	0.006153
	0.000865	0.002586	0.000000	0.000396	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

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2010	1	7	0	0	24.00	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000802	0.000000	0.000000	0.000000
	0.000519	0.000000	0.000000	0.000000	0.000000	0.000000
	0.001019	0.001444	0.000686	0.001323	0.005190	0.021500
	0.098531	0.210714	0.291734	0.185741	0.114178	0.040929
	0.017702	0.006693	0.000000	0.001294	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2011	1	7	0	0	50.00	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000324	0.000488	0.000903	0.000048
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000677	0.000000	0.000175	0.000583	0.000816
	0.006391	0.022915	0.101584	0.249394	0.264604	0.200251
	0.093287	0.033275	0.011906	0.004779	0.003640	0.002944
	0.000000	0.001018	0.000000	0.000000	0.000000	0.000000
2005	2	8	0	0	10.00	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.002709
	0.002709	0.000000	0.000000	0.011009	0.011009	0.123534
	0.123534	0.064539	0.064539	0.157732	0.157732	0.064270
	0.064270	0.050097	0.050097	0.015162	0.015162	0.005054
	0.005054	0.000000	0.000000	0.001685	0.001685	0.003369
	0.003369	0.001685	0.000000	0.000000	0.000000	0.000000
2007	2	8	0	0	12.00	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.018711
	0.018711	0.044561	0.044561	0.078855	0.078855	0.077210
	0.077210	0.091963	0.091963	0.108039	0.108039	0.068818
	0.068818	0.003212	0.003212	0.008259	0.008259	0.000373
	0.000373	0.000000	0.000000	0.000000	0.000000	0.000000
2008	1	8	0	0	27.00	0.017005	0.017005	0.022107
	0.022107	0.006802	0.006802	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.006802
	0.006802	0.020097	0.020097	0.021648	0.021648	0.089515
	0.089515	0.109393	0.109393	0.140293	0.140293	0.053859
	0.053859	0.011184	0.011184	0.001294	0.001294	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	8	0	0	19.00	0.000000	0.000000	0.000000
	0.000000	0.000719	0.000719	0.000362	0.000362	0.000000
	0.000000	0.001215	0.001215	0.002653	0.002653	0.003321
	0.003321	0.005555	0.005555	0.002244	0.002244	0.008334
	0.008334	0.055063	0.055063	0.171078	0.171078	0.165809
	0.165809	0.069541	0.069541	0.011538	0.011538	0.002430
	0.002430	0.000273	0.000000	0.000000	0.000000	0.000000
2010	2	8	0	0	18.00	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000004	0.000004	0.000000
	0.000000	0.000000	0.000000	0.000151	0.000151	0.080206
	0.080206	0.221360	0.221360	0.089188	0.089188	0.045352
	0.045352	0.009572	0.009572	0.002872	0.002872	0.017106
	0.017106	0.022393	0.022393	0.009604	0.009604	0.001399
	0.001399	0.001586	0.000000	0.000000	0.000000	0.000000
#
10 #_N_age_bins
0 1 2 3 4 5 6 7 8 11
9  #_N_ageerror_definitions
0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5
	13.5	14.5	15.5	#_1_ENS_all_years
0.2043	0.2043	0.2792	0.3067	0.3169	0.3606	0.3933	0.4261	0.4589	0.4916	0.5244	0.5571	0.5899
	0.6227	0.6554	0.6882	#_1_ENS_all_years
0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5
	13.5	14.5	15.5	#_2_CA_1981-2006
0.2832	0.2832	0.289	0.8009	0.8038	0.9597	1.1156	1.2715	1.4274	1.5833	1.7392	1.8951	2.051
	2.2069	2.3627	2.5186	#_2_CA_1981-2006
0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5
	13.5	14.5	15.5	#_3_CA_2007
0.2539	0.2539	0.3434	0.9205	0.9653	1.1743	1.3832	1.5922	1.8011	2.0101	2.2190	2.4280	2.6369
	2.8459	3.0548	3.2638	#_3_CA_2007
0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5
	13.5	14.5	15.5	#_4_CA_2008-09
0.4032	0.4032	0.4995	0.58	0.6902	0.8246	0.9727	1.0165	1.1144	1.2123	1.3102	1.4082	1.5061
	1.604	1.702	1.7999	#_4_CA_2008-09
0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5
	13.5	14.5	15.5	#_5_CA_2010-11
```

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0.2825  0.2825  0.2955  0.3125  0.3347  0.3637  0.4017  0.4046  0.4245  0.4445  0.4645  0.4844  0.5044
        0.5243  0.5443  0.5643  #_5_CA_2010-11
0.5     1.5     2.5     3.5     4.5     5.5     6.5     7.5     8.5     9.5     10.5    11.5    12.5
        13.5    14.5    15.5    #_6_ORWA_all_years
0.26655 0.30145 0.3149  0.3615  0.3847  0.3961  0.4018  0.4047  0.4061  0.4352  0.4487  0.4622  0.4756
        0.4891  0.5026  0.516   #_6_ORWA_all_years
0.5     1.5     2.5     3.5     4.5     5.5     6.5     7.5     8.5     9.5     10.5    11.5    12.5
        13.5    14.5    15.5    #_7_SWFSC_1_2006_DataSetA
0.4972  0.4972  0.7284  0.8233  0.8622  0.8782  0.8847  0.8874  0.8885  1.0305  1.0823  1.134   1.1857
        1.2374  1.2892  1.3409  #_7_SWFSC_1_2006_DataSetA
0.5     1.5     2.5     3.5     4.5     5.5     6.5     7.5     8.5     9.5     10.5    11.5    12.5
        13.5    14.5    15.5    #_8_SWFSC_2_2008_DataSetB
0.4972  0.4972  0.7284  0.8233  0.8622  0.8782  0.8847  1.0328  1.1063  1.1798  1.2533  1.3268  1.4004
        1.4739  1.5474  1.6209  #_8_SWFSC_2_2008_DataSetB
0.5     1.5     2.5     3.5     4.5     5.5     6.5     7.5     8.5     9.5     10.5    11.5    12.5
        13.5    14.5    15.5    #_9_SWFSC_3_2010_CalCOFI_A_Reader12
0.7043  0.7043  0.7875  0.8912  1.0205  1.1816  1.3823  1.6324  1.944   1.9073  2.061   2.2147  2.3684
        2.5222  2.6759  2.8296  #_9_SWFSC_3_2010_CalCOFI_A_Reader12
#
1028 #_N_Agecomp_obs
3 #_Lbin_method: 1=poplenbins; 2=datalenbins; 3=lengths
-1 #_combine males into females at or below this bin number
#Yr Seas Flt/Svy Gender Part Ageerr Lbin_lo Lbin_hi Nsamp datavector(female-male)
1981    1       1       0       0       2       9       9.5     0.16    1       0       0       0
        0       0       0       0       0       0
1982    1       1       0       0       2       17      17.5    0.32    0.000000        0.000000
        1.000000        0.000000        0.000000        0.000000        0.000000        0.000000
        0.000000        0.000000
1982    1       1       0       0       2       18      18.5    1.08    0.000000        0.070693
        0.929307        0.000000        0.000000        0.000000        0.000000        0.000000
        0.000000        0.000000
1982    1       1       0       0       2       19      19.5    4.24    0.000000        0.061532
        0.858657        0.073498        0.006312        0.000000        0.000000        0.000000
        0.000000        0.000000
1982    1       1       0       0       2       20      20.5    2.92    0.000000        0.033912
        0.764204        0.201884        0.000000        0.000000        0.000000        0.000000
        0.000000        0.000000
1982    1       1       0       0       2       21      21.5    1.48    0.000000        0.000000
        0.330981        0.598596        0.070422        0.000000        0.000000        0.000000
        0.000000        0.000000
1982    1       1       0       0       2       22      22.5    1.76    0.000000        0.028189
        0.000000        0.770590        0.116654        0.056378        0.028189        0.000000
        0.000000        0.000000
1982    1       1       0       0       2       23      23.5    1.88    0.000000        0.000000
        0.000000        0.589261        0.355515        0.027612        0.027612        0.000000
        0.000000        0.000000
1982    1       1       0       0       2       24      24.5    0.60    0.000000        0.000000
        0.000000        0.270194        0.578692        0.151115        0.000000        0.000000
        0.000000        0.000000
1982    1       1       0       0       2       25      25.5    0.08    0.000000        0.000000
        0.000000        0.000000        1.000000        0.000000        0.000000        0.000000
        0.000000        0.000000
1982    1       1       0       0       2       26      26.5    0.08    0.000000        0.000000
        0.000000        0.000000        0.500000        0.500000        0.000000        0.000000
        0.000000        0.000000
1983    1       1       0       0       2       9       9.5     5.64    1.000000        0.000000
        0.000000        0.000000        0.000000        0.000000        0.000000        0.000000
        0.000000        0.000000
1983    1       1       0       0       2       10      10.5    0.36    0.444444        0.555556
        0.000000        0.000000        0.000000        0.000000        0.000000        0.000000
        0.000000        0.000000
1983    1       1       0       0       2       11      11.5    0.16    1.000000        0.000000
        0.000000        0.000000        0.000000        0.000000        0.000000        0.000000
        0.000000        0.000000
1983    1       1       0       0       2       12      12.5    0.40    1.000000        0.000000
        0.000000        0.000000        0.000000        0.000000        0.000000        0.000000
        0.000000        0.000000
1983    1       1       0       0       2       13      13.5    0.32    0.976858        0.023142
        0.000000        0.000000        0.000000        0.000000        0.000000        0.000000
        0.000000        0.000000
```

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1983   1     1      0     0      2     14      14.5   0.48   0.594077      0.405923
       0.000000     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1983   1     1      0     0      2     15      15.5   0.32   0.000000      1.000000
       0.000000     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1983   1     1      0     0      2     16      16.5   1.64   0.000000      0.970271
       0.029729     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1983   1     1      0     0      2     17      17.5   0.96   0.000000      0.903736
       0.096264     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1983   1     1      0     0      2     18      18.5   1.04   0.000000      0.836300
       0.163700     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1983   1     1      0     0      2     19      19.5   1.36   0.000000      0.576903
       0.423097     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1983   1     1      0     0      2     20      20.5   2.08   0.000000      0.189042
       0.810958     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1983   1     1      0     0      2     21      21.5   1.76   0.000000      0.128381
       0.741184     0.130435     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1983   1     1      0     0      2     22      22.5   0.24   0.000000      0.000000
       0.515671     0.484329     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1983   1     1      0     0      2     23      23.5   0.08   0.000000      0.000000
       0.000000     1.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1985   1     1      0     0      2     16      16.5   0.08   0.000000      1.000000
       0.000000     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1985   1     1      0     0      2     17      17.5   0.56   0.000000      0.789354
       0.210646     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1985   1     1      0     0      2     18      18.5   2.28   0.000000      0.865189
       0.134811     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1985   1     1      0     0      2     19      19.5   2.44   0.000000      0.574083
       0.384296     0.041621     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1985   1     1      0     0      2     20      20.5   3.52   0.000000      0.406997
       0.593003     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1985   1     1      0     0      2     21      21.5   2.68   0.000000      0.066383
       0.879878     0.053739     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1985   1     1      0     0      2     22      22.5   2.16   0.000000      0.033946
       0.852013     0.104924     0.009117      0.000000      0.000000      0.000000
       0.000000     0.000000
1985   1     1      0     0      2     23      23.5   0.80   0.000000      0.000000
       0.318208     0.644424     0.037368      0.000000      0.000000      0.000000
       0.000000     0.000000
1985   1     1      0     0      2     24      24.5   0.24   0.000000      0.000000
       0.174363     0.697451     0.128186      0.000000      0.000000      0.000000
       0.000000     0.000000
1985   1     1      0     0      2     25      25.5   0.24   0.000000      0.000000
       0.348726     0.523088     0.128186      0.000000      0.000000      0.000000
       0.000000     0.000000
1986   1     1      0     0      2     11      11.5   0.16   1.000000      0.000000
       0.000000     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1986   1     1      0     0      2     12      12.5   0.76   0.833333      0.166667
       0.000000     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
1986   1     1      0     0      2     13      13.5   0.04   0.000000      1.000000
       0.000000     0.000000     0.000000      0.000000      0.000000      0.000000
       0.000000     0.000000
```

1986	1	1	0	0	2	18	18.5	0.08	0.000000	0.121228	0.878772	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	1	1	0	0	2	19	19.5	0.32	0.000000	0.764282	0.235718	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	1	1	0	0	2	20	20.5	2.76	0.000000	0.384953	0.615047	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	1	1	0	0	2	21	21.5	5.76	0.000000	0.080288	0.768470	0.151242	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	1	1	0	0	2	22	22.5	7.16	0.000000	0.024934	0.732598	0.242468	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	1	1	0	0	2	23	23.5	2.36	0.000000	0.000000	0.399245	0.600755	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	1	1	0	0	2	24	24.5	0.76	0.000000	0.000000	0.235106	0.529789	0.235106	0.000000	0.000000	0.000000	0.000000	0.000000
1987	1	1	0	0	2	16	16.5	0.16	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	1	1	0	0	2	17	17.5	1.96	0.000000	0.987442	0.012558	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	1	1	0	0	2	18	18.5	4.28	0.005194	0.967892	0.026914	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	1	1	0	0	2	19	19.5	7.72	0.000000	0.914667	0.085333	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	1	1	0	0	2	20	20.5	7.20	0.000000	0.775097	0.217577	0.000000	0.007326	0.000000	0.000000	0.000000	0.000000	0.000000
1987	1	1	0	0	2	21	21.5	1.84	0.000000	0.252523	0.698943	0.048534	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	1	1	0	0	2	22	22.5	3.04	0.000000	0.000000	0.774087	0.197804	0.028110	0.000000	0.000000	0.000000	0.000000	0.000000
1987	1	1	0	0	2	23	23.5	2.52	0.000000	0.000000	0.183408	0.810340	0.006252	0.000000	0.000000	0.000000	0.000000	0.000000
1987	1	1	0	0	2	24	24.5	0.60	0.000000	0.000000	0.260189	0.480765	0.259046	0.000000	0.000000	0.000000	0.000000	0.000000
1987	1	1	0	0	2	25	25.5	0.08	0.000000	0.000000	0.000000	0.808417	0.191583	0.000000	0.000000	0.000000	0.000000	0.000000
1988	1	1	0	0	2	15	15.5	0.08	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	1	1	0	0	2	16	16.5	0.16	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	1	1	0	0	2	17	17.5	0.76	0.000000	0.785801	0.214199	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	1	1	0	0	2	18	18.5	1.44	0.000000	0.650911	0.349089	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	1	1	0	0	2	19	19.5	1.00	0.000000	0.434231	0.565769	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	1	1	0	0	2	20	20.5	4.20	0.000000	0.053131	0.912030	0.034838	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

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1988   1     1      0     0      2     21     21.5   7.12   0.000000      0.025100
       0.871801     0.083306     0.019792     0.000000      0.000000      0.000000
       0.000000     0.000000
1988   1     1      0     0      2     22     22.5   5.36   0.000000      0.008668
       0.638614     0.309369     0.043349     0.000000      0.000000      0.000000
       0.000000     0.000000
1988   1     1      0     0      2     23     23.5   1.72   0.000000      0.000000
       0.244582     0.567611     0.162532     0.025274      0.000000      0.000000
       0.000000     0.000000
1988   1     1      0     0      2     24     24.5   0.64   0.000000      0.000000
       0.000000     0.321603     0.526483     0.151914      0.000000      0.000000
       0.000000     0.000000
1988   1     1      0     0      2     25     25.5   0.28   0.000000      0.000000
       0.000000     0.066034     0.621211     0.312755      0.000000      0.000000
       0.000000     0.000000
1989   1     1      0     0      2     16     16.5   0.20   0.000000      1.000000
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1989   1     1      0     0      2     17     17.5   0.56   0.000000      1.000000
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1989   1     1      0     0      2     18     18.5   2.16   0.000000      1.000000
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1989   1     1      0     0      2     19     19.5   3.72   0.000000      0.913978
       0.064516     0.010753     0.010753     0.000000      0.000000      0.000000
       0.000000     0.000000
1989   1     1      0     0      2     20     20.5   5.28   0.000000      0.636364
       0.340909     0.022727     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1989   1     1      0     0      2     21     21.5   5.04   0.000000      0.182540
       0.674603     0.095238     0.039683     0.007937      0.000000      0.000000
       0.000000     0.000000
1989   1     1      0     0      2     22     22.5   2.16   0.000000      0.074074
       0.814815     0.092593     0.018519     0.000000      0.000000      0.000000
       0.000000     0.000000
1989   1     1      0     0      2     23     23.5   0.52   0.000000      0.076923
       0.230769     0.615385     0.076923     0.000000      0.000000      0.000000
       0.000000     0.000000
1989   1     1      0     0      2     24     24.5   0.12   0.000000      0.000000
       0.000000     0.333333     0.666667     0.000000      0.000000      0.000000
       0.000000     0.000000
1990   1     1      0     0      2     13     13.5   0.04   0.000000      1.000000
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1990   1     1      0     0      2     14     14.5   0.24   0.000000      1.000000
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1990   1     1      0     0      2     15     15.5   0.56   0.000000      0.785714
       0.214286     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1990   1     1      0     0      2     16     16.5   1.56   0.000000      0.538462
       0.410256     0.051282     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1990   1     1      0     0      2     17     17.5   0.48   0.000000      0.416667
       0.250000     0.250000     0.083333     0.000000      0.000000      0.000000
       0.000000     0.000000
1990   1     1      0     0      2     18     18.5   0.60   0.000000      0.733333
       0.066667     0.200000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1990   1     1      0     0      2     19     19.5   0.76   0.000000      0.473684
       0.263158     0.263158     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1990   1     1      0     0      2     20     20.5   2.44   0.016393      0.163934
       0.442623     0.262295     0.098361     0.016393      0.000000      0.000000
       0.000000     0.000000
1990   1     1      0     0      2     21     21.5   6.64   0.012048      0.126506
       0.379518     0.277108     0.120482     0.060241      0.024096      0.000000
       0.000000     0.000000
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1990   1      1       0      0       2      22      22.5   4.64    0.000000        0.043103
       0.284483       0.405172       0.189655       0.051724       0.025862        0.000000
       0.000000       0.000000
1990   1      1       0      0       2      23      23.5   2.20    0.000000        0.018182
       0.109091       0.381818       0.218182       0.181818       0.090909        0.000000
       0.000000       0.000000
1990   1      1       0      0       2      24      24.5   0.48    0.000000        0.000000
       0.083333       0.250000       0.333333       0.250000       0.083333        0.000000
       0.000000       0.000000
1990   1      1       0      0       2      25      25.5   0.20    0.000000        0.000000
       0.000000       0.000000       0.200000       0.400000       0.200000        0.200000
       0.000000       0.000000
1990   1      1       0      0       2      26      26.5   0.04    0.000000        0.000000
       0.000000       1.000000       0.000000       0.000000       0.000000        0.000000
       0.000000       0.000000
1990   1      1       0      0       2      27      27.5   0.04    0.000000        0.000000
       0.000000       0.000000       1.000000       0.000000       0.000000        0.000000
       0.000000       0.000000
1991   1      1       0      0       2      9       9.5    0.04    1.000000        0.000000
       0.000000       0.000000       0.000000       0.000000       0.000000        0.000000
       0.000000       0.000000
1991   1      1       0      0       2      12      12.5   0.08    1.000000        0.000000
       0.000000       0.000000       0.000000       0.000000       0.000000        0.000000
       0.000000       0.000000
1991   1      1       0      0       2      13      13.5   0.12    1.000000        0.000000
       0.000000       0.000000       0.000000       0.000000       0.000000        0.000000
       0.000000       0.000000
1991   1      1       0      0       2      14      14.5   0.80    0.300000        0.700000
       0.000000       0.000000       0.000000       0.000000       0.000000        0.000000
       0.000000       0.000000
1991   1      1       0      0       2      15      15.5   3.48    0.344828        0.655172
       0.000000       0.000000       0.000000       0.000000       0.000000        0.000000
       0.000000       0.000000
1991   1      1       0      0       2      16      16.5   2.00    0.360000        0.580000
       0.060000       0.000000       0.000000       0.000000       0.000000        0.000000
       0.000000       0.000000
1991   1      1       0      0       2      17      17.5   4.60    0.034783        0.669565
       0.286957       0.008696       0.000000       0.000000       0.000000        0.000000
       0.000000       0.000000
1991   1      1       0      0       2      18      18.5   8.32    0.004808        0.586538
       0.365385       0.043269       0.000000       0.000000       0.000000        0.000000
       0.000000       0.000000
1991   1      1       0      0       2      19      19.5   12.92   0.009288        0.371517
       0.578947       0.037152       0.003096       0.000000       0.000000        0.000000
       0.000000       0.000000
1991   1      1       0      0       2      20      20.5   20.92   0.000000        0.173996
       0.678776       0.118547       0.028681       0.000000       0.000000        0.000000
       0.000000       0.000000
1991   1      1       0      0       2      21      21.5   16.00   0.000000        0.100000
       0.487500       0.282500       0.080000       0.032500       0.005000        0.007500
       0.005000       0.000000
1991   1      1       0      0       2      22      22.5   10.28   0.000000        0.031128
       0.268482       0.389105       0.190661       0.066148       0.042802        0.011673
       0.000000       0.000000
1991   1      1       0      0       2      23      23.5   4.72    0.000000        0.000000
       0.161017       0.347458       0.254237       0.161017       0.050847        0.025424
       0.000000       0.000000
1991   1      1       0      0       2      24      24.5   1.16    0.000000        0.000000
       0.068966       0.448276       0.310345       0.137931       0.000000        0.000000
       0.034483       0.000000
1991   1      1       0      0       2      25      25.5   0.24    0.000000        0.000000
       0.000000       0.166667       0.333333       0.333333       0.000000        0.166667
       0.000000       0.000000
1991   1      1       0      0       2      26      26.5   0.04    0.000000        0.000000
       0.000000       0.000000       0.000000       1.000000       0.000000        0.000000
       0.000000       0.000000
1992   1      1       0      0       2      13      13.5   0.32    0.125000        0.875000
       0.000000       0.000000       0.000000       0.000000       0.000000        0.000000
       0.000000       0.000000
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1992	1	1	0	0	2	14	14.5	4.24	0.018868	0.924528	0.056604	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	1	1	0	0	2	15	15.5	9.84	0.000000	0.849594	0.150407	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	1	1	0	0	2	16	16.5	14.76	0.002710	0.745257	0.246612	0.005420	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	1	1	0	0	2	17	17.5	20.60	0.000000	0.533981	0.450485	0.015534	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	1	1	0	0	2	18	18.5	18.48	0.000000	0.350649	0.601732	0.041126	0.006494	0.000000	0.000000	0.000000	0.000000	0.000000
1992	1	1	0	0	2	19	19.5	17.88	0.000000	0.078300	0.706935	0.192394	0.017897	0.004474	0.000000	0.000000	0.000000	0.000000
1992	1	1	0	0	2	20	20.5	9.72	0.000000	0.020576	0.596708	0.316872	0.057613	0.008230	0.000000	0.000000	0.000000	0.000000
1992	1	1	0	0	2	21	21.5	3.24	0.000000	0.012346	0.370370	0.358025	0.148148	0.098765	0.012346	0.000000	0.000000	0.000000
1992	1	1	0	0	2	22	22.5	2.20	0.000000	0.000000	0.054545	0.418182	0.309091	0.145455	0.072727	0.000000	0.000000	0.000000
1992	1	1	0	0	2	23	23.5	1.48	0.000000	0.000000	0.000000	0.216216	0.270270	0.351351	0.108108	0.027027	0.027027	0.000000
1992	1	1	0	0	2	24	24.5	0.36	0.000000	0.000000	0.000000	0.333333	0.444444	0.222222	0.000000	0.000000	0.000000	0.000000
1993	1	1	0	0	2	14	14.5	0.04	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1993	1	1	0	0	2	15	15.5	0.08	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1993	1	1	0	0	2	16	16.5	1.84	0.021739	0.065217	0.739130	0.152174	0.021739	0.000000	0.000000	0.000000	0.000000	0.000000
1993	1	1	0	0	2	17	17.5	6.88	0.005814	0.093023	0.674419	0.226744	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1993	1	1	0	0	2	18	18.5	5.64	0.000000	0.021277	0.382979	0.553191	0.042553	0.000000	0.000000	0.000000	0.000000	0.000000
1993	1	1	0	0	2	19	19.5	4.12	0.000000	0.009709	0.281553	0.582524	0.097087	0.029126	0.000000	0.000000	0.000000	0.000000
1993	1	1	0	0	2	20	20.5	0.64	0.000000	0.000000	0.250000	0.437500	0.250000	0.000000	0.062500	0.000000	0.000000	0.000000
1993	1	1	0	0	2	21	21.5	0.16	0.000000	0.000000	0.000000	0.500000	0.250000	0.000000	0.250000	0.000000	0.000000	0.000000
1993	1	1	0	0	2	22	22.5	0.04	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1993	1	1	0	0	2	23	23.5	0.04	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1994	1	1	0	0	2	14	14.5	0.60	0.066667	0.933333	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1994	1	1	0	0	2	15	15.5	3.32	0.012048	0.939759	0.048193	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

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1994   1     1      0     0      2     16     16.5   6.32    0.006329      0.886076
       0.088608     0.018987     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1994   1     1      0     0      2     17     17.5   9.32    0.042918      0.549356
       0.304721     0.090129     0.012876     0.000000      0.000000      0.000000
       0.000000     0.000000
1994   1     1      0     0      2     18     18.5   8.96    0.026786      0.218750
       0.455357     0.263393     0.031250     0.004464      0.000000      0.000000
       0.000000     0.000000
1994   1     1      0     0      2     19     19.5   6.08    0.039474      0.098684
       0.421053     0.401316     0.039474     0.000000      0.000000      0.000000
       0.000000     0.000000
1994   1     1      0     0      2     20     20.5   1.28    0.000000      0.031250
       0.281250     0.593750     0.093750     0.000000      0.000000      0.000000
       0.000000     0.000000
1994   1     1      0     0      2     21     21.5   0.36    0.000000      0.000000
       0.555556     0.444444     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1994   1     1      0     0      2     22     22.5   0.04    0.000000      0.000000
       1.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1994   1     1      0     0      2     25     25.5   0.04    0.000000      0.000000
       0.000000     0.000000     1.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1995   1     1      0     0      2     12     12.5   0.04    1.000000      0.000000
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1995   1     1      0     0      2     13     13.5   0.20    0.400000      0.600000
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1995   1     1      0     0      2     14     14.5   0.68    0.529412      0.411765
       0.058824     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1995   1     1      0     0      2     15     15.5   5.48    0.065693      0.700730
       0.218978     0.014599     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1995   1     1      0     0      2     16     16.5   15.92   0.045226      0.653266
       0.283920     0.015075     0.002513     0.000000      0.000000      0.000000
       0.000000     0.000000
1995   1     1      0     0      2     17     17.5   15.00   0.048000      0.512000
       0.400000     0.037333     0.002667     0.000000      0.000000      0.000000
       0.000000     0.000000
1995   1     1      0     0      2     18     18.5   6.64    0.078313      0.301205
       0.554217     0.060241     0.006024     0.000000      0.000000      0.000000
       0.000000     0.000000
1995   1     1      0     0      2     19     19.5   1.88    0.148936      0.212766
       0.425532     0.127660     0.085106     0.000000      0.000000      0.000000
       0.000000     0.000000
1995   1     1      0     0      2     20     20.5   1.04    0.000000      0.038462
       0.500000     0.307692     0.153846     0.000000      0.000000      0.000000
       0.000000     0.000000
1995   1     1      0     0      2     21     21.5   0.24    0.000000      0.000000
       0.666667     0.166667     0.166667     0.000000      0.000000      0.000000
       0.000000     0.000000
1995   1     1      0     0      2     22     22.5   0.04    0.000000      0.000000
       1.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1995   1     1      0     0      2     27     27.5   0.04    0.000000      0.000000
       0.000000     1.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1996   1     1      0     0      2     13     13.5   0.04    0.000000      1.000000
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1996   1     1      0     0      2     14     14.5   0.28    0.000000      1.000000
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
1996   1     1      0     0      2     15     15.5   4.68    0.008547      0.658120
       0.324786     0.000000     0.008547     0.000000      0.000000      0.000000
       0.000000     0.000000
```

1996	1	1	0	0	2	16	16.5	14.68	0.013624	0.465940	0.460490	0.059946	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	1	1	0	0	2	17	17.5	26.60	0.001504	0.267669	0.560902	0.151880	0.016541	0.001504	0.000000	0.000000	0.000000	0.000000
1996	1	1	0	0	2	18	18.5	36.60	0.003279	0.088525	0.612022	0.262295	0.031694	0.002186	0.000000	0.000000	0.000000	0.000000
1996	1	1	0	0	2	19	19.5	30.32	0.001319	0.031662	0.513193	0.395778	0.052770	0.005277	0.000000	0.000000	0.000000	0.000000
1996	1	1	0	0	2	20	20.5	13.72	0.002915	0.032070	0.475219	0.384840	0.084548	0.020408	0.000000	0.000000	0.000000	0.000000
1996	1	1	0	0	2	21	21.5	5.08	0.000000	0.039370	0.456693	0.322835	0.181102	0.000000	0.000000	0.000000	0.000000	0.000000
1996	1	1	0	0	2	22	22.5	1.28	0.000000	0.062500	0.468750	0.218750	0.218750	0.031250	0.000000	0.000000	0.000000	0.000000
1996	1	1	0	0	2	23	23.5	0.12	0.000000	0.000000	0.666667	0.333333	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	1	1	0	0	2	24	24.5	0.04	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	1	1	0	0	2	25	25.5	0.08	0.000000	0.000000	0.000000	0.000000	0.500000	0.500000	0.000000	0.000000	0.000000	0.000000
1996	1	1	0	0	2	26	26.5	0.04	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000
1997	1	1	0	0	2	9	9.5	0.08	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1997	1	1	0	0	2	11	11.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1997	1	1	0	0	2	12	12.5	0.16	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1997	1	1	0	0	2	13	13.5	0.76	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1997	1	1	0	0	2	14	14.5	4.48	0.000000	0.955357	0.044643	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1997	1	1	0	0	2	15	15.5	9.28	0.000000	0.909483	0.086207	0.000000	0.004310	0.000000	0.000000	0.000000	0.000000	0.000000
1997	1	1	0	0	2	16	16.5	19.28	0.004149	0.817427	0.172199	0.006224	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1997	1	1	0	0	2	17	17.5	25.20	0.003175	0.566667	0.403175	0.020635	0.006349	0.000000	0.000000	0.000000	0.000000	0.000000
1997	1	1	0	0	2	18	18.5	24.64	0.000000	0.212662	0.683442	0.095779	0.008117	0.000000	0.000000	0.000000	0.000000	0.000000
1997	1	1	0	0	2	19	19.5	18.80	0.002128	0.046809	0.521277	0.336170	0.078723	0.008511	0.006383	0.000000	0.000000	0.000000
1997	1	1	0	0	2	20	20.5	11.76	0.000000	0.017007	0.258503	0.465986	0.210884	0.027211	0.020408	0.000000	0.000000	0.000000
1997	1	1	0	0	2	21	21.5	6.20	0.000000	0.025806	0.180645	0.516129	0.206452	0.070968	0.000000	0.000000	0.000000	0.000000

1997	1	1	0	0	2	22	22.5	1.16	0.000000	0.068966	0.172414	0.379310	0.275862	0.103448	0.000000	0.000000	0.000000	0.000000
1997	1	1	0	0	2	23	23.5	0.28	0.000000	0.000000	0.285714	0.428571	0.142857	0.142857	0.000000	0.000000	0.000000	0.000000
1998	1	1	0	0	2	9	9.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1998	1	1	0	0	2	10	10.5	0.08	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1998	1	1	0	0	2	11	11.5	0.72	0.555556	0.444444	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1998	1	1	0	0	2	12	12.5	4.92	0.373984	0.626016	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1998	1	1	0	0	2	13	13.5	15.76	0.071066	0.906091	0.022843	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1998	1	1	0	0	2	14	14.5	25.24	0.003170	0.977813	0.019017	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1998	1	1	0	0	2	15	15.5	23.56	0.001698	0.850594	0.147708	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1998	1	1	0	0	2	16	16.5	11.36	0.000000	0.510563	0.489437	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1998	1	1	0	0	2	17	17.5	8.52	0.000000	0.122066	0.812207	0.046948	0.018779	0.000000	0.000000	0.000000	0.000000	0.000000
1998	1	1	0	0	2	18	18.5	7.40	0.000000	0.016216	0.729730	0.221622	0.032432	0.000000	0.000000	0.000000	0.000000	0.000000
1998	1	1	0	0	2	19	19.5	6.56	0.000000	0.006098	0.359756	0.402439	0.219512	0.006098	0.006098	0.000000	0.000000	0.000000
1998	1	1	0	0	2	20	20.5	4.88	0.000000	0.024590	0.114754	0.426230	0.352459	0.049180	0.032787	0.000000	0.000000	0.000000
1998	1	1	0	0	2	21	21.5	1.92	0.000000	0.000000	0.083333	0.458333	0.312500	0.104167	0.020833	0.020833	0.000000	0.000000
1998	1	1	0	0	2	22	22.5	0.36	0.000000	0.111111	0.000000	0.111111	0.555556	0.111111	0.111111	0.000000	0.000000	0.000000
1998	1	1	0	0	2	23	23.5	0.32	0.000000	0.000000	0.000000	0.375000	0.250000	0.375000	0.000000	0.000000	0.000000	0.000000
1999	1	1	0	0	2	11	11.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1999	1	1	0	0	2	12	12.5	0.16	0.750000	0.250000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1999	1	1	0	0	2	13	13.5	3.80	0.136842	0.810526	0.052632	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1999	1	1	0	0	2	14	14.5	17.32	0.013857	0.866051	0.120092	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1999	1	1	0	0	2	15	15.5	20.16	0.000000	0.720238	0.261905	0.015873	0.001984	0.000000	0.000000	0.000000	0.000000	0.000000
1999	1	1	0	0	2	16	16.5	10.52	0.003802	0.429658	0.429658	0.095057	0.026616	0.011407	0.003802	0.000000	0.000000	0.000000

1999	1	1	0	0	2	17	17.5	4.68	0.000000	0.307692	0.478632	0.136752	0.059829	0.008547	0.008547	0.000000	0.000000	0.000000
1999	1	1	0	0	2	18	18.5	1.64	0.000000	0.195122	0.487805	0.121951	0.170732	0.024390	0.000000	0.000000	0.000000	0.000000
1999	1	1	0	0	2	19	19.5	0.36	0.000000	0.000000	0.555556	0.111111	0.333333	0.000000	0.000000	0.000000	0.000000	0.000000
1999	1	1	0	0	2	20	20.5	0.36	0.000000	0.000000	0.444444	0.444444	0.111111	0.000000	0.000000	0.000000	0.000000	0.000000
1999	1	1	0	0	2	21	21.5	0.04	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1999	1	1	0	0	2	22	22.5	0.12	0.000000	0.000000	0.333333	0.000000	0.000000	0.333333	0.333333	0.000000	0.000000	0.000000
2000	1	1	0	0	2	12	12.5	0.28	0.857143	0.000000	0.142857	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	1	1	0	0	2	13	13.5	0.72	0.833333	0.166667	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	1	1	0	0	2	14	14.5	1.48	0.756757	0.027027	0.135135	0.081081	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	1	1	0	0	2	15	15.5	4.72	0.016949	0.245763	0.355932	0.364407	0.016949	0.000000	0.000000	0.000000	0.000000	0.000000
2000	1	1	0	0	2	16	16.5	21.20	0.001887	0.094340	0.498113	0.394340	0.009434	0.000000	0.001887	0.000000	0.000000	0.000000
2000	1	1	0	0	2	17	17.5	19.80	0.002020	0.151515	0.460606	0.367677	0.016162	0.002020	0.000000	0.000000	0.000000	0.000000
2000	1	1	0	0	2	18	18.5	10.96	0.000000	0.354015	0.339416	0.266423	0.036496	0.003650	0.000000	0.000000	0.000000	0.000000
2000	1	1	0	0	2	19	19.5	5.40	0.000000	0.444444	0.392593	0.140741	0.014815	0.007407	0.000000	0.000000	0.000000	0.000000
2000	1	1	0	0	2	20	20.5	3.00	0.000000	0.480000	0.333333	0.133333	0.040000	0.013333	0.000000	0.000000	0.000000	0.000000
2000	1	1	0	0	2	21	21.5	0.48	0.000000	0.333333	0.250000	0.250000	0.083333	0.083333	0.000000	0.000000	0.000000	0.000000
2000	1	1	0	0	2	23	23.5	0.08	0.000000	0.000000	0.000000	0.000000	0.500000	0.500000	0.000000	0.000000	0.000000	0.000000
2001	1	1	0	0	2	9	9.5	0.40	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	1	1	0	0	2	10	10.5	2.48	0.967742	0.032258	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	1	1	0	0	2	11	11.5	4.32	0.990741	0.009259	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	1	1	0	0	2	12	12.5	3.24	0.962963	0.037037	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	1	1	0	0	2	13	13.5	1.80	0.977778	0.022222	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	1	1	0	0	2	14	14.5	0.64	0.437500	0.500000	0.062500	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

2001	1 1	0 0	2 15	15.5 4.24	0.066038	0.632075
	0.273585	0.028302	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2001	1 1	0 0	2 16	16.5 12.68	0.009464	0.485804
	0.397476	0.097792	0.009464	0.000000	0.000000	0.000000
	0.000000	0.000000				
2001	1 1	0 0	2 17	17.5 25.36	0.012618	0.296530
	0.463722	0.200315	0.025237	0.001577	0.000000	0.000000
	0.000000	0.000000				
2001	1 1	0 0	2 18	18.5 19.28	0.002075	0.226141
	0.331950	0.392116	0.041494	0.006224	0.000000	0.000000
	0.000000	0.000000				
2001	1 1	0 0	2 19	19.5 6.16	0.000000	0.110390
	0.279221	0.506494	0.090909	0.012987	0.000000	0.000000
	0.000000	0.000000				
2001	1 1	0 0	2 20	20.5 4.20	0.000000	0.085714
	0.295238	0.495238	0.076190	0.047619	0.000000	0.000000
	0.000000	0.000000				
2001	1 1	0 0	2 21	21.5 7.56	0.000000	0.010582
	0.105820	0.661376	0.195767	0.026455	0.000000	0.000000
	0.000000	0.000000				
2001	1 1	0 0	2 22	22.5 4.92	0.000000	0.016260
	0.089431	0.520325	0.284553	0.065041	0.016260	0.008130
	0.000000	0.000000				
2001	1 1	0 0	2 23	23.5 1.80	0.000000	0.000000
	0.022222	0.222222	0.355556	0.266667	0.111111	0.022222
	0.000000	0.000000				
2001	1 1	0 0	2 24	24.5 0.96	0.000000	0.000000
	0.000000	0.083333	0.416667	0.458333	0.041667	0.000000
	0.000000	0.000000				
2001	1 1	0 0	2 25	25.5 0.20	0.000000	0.000000
	0.000000	0.000000	0.200000	0.400000	0.200000	0.200000
	0.000000	0.000000				
2002	1 1	0 0	2 9	9.5 2.20	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2002	1 1	0 0	2 11	11.5 0.04	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2002	1 1	0 0	2 13	13.5 0.64	0.312500	0.687500
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2002	1 1	0 0	2 14	14.5 2.84	0.169014	0.774648
	0.056338	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2002	1 1	0 0	2 15	15.5 10.64	0.184211	0.755639
	0.060150	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2002	1 1	0 0	2 16	16.5 12.36	0.223301	0.663430
	0.093851	0.019417	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2002	1 1	0 0	2 17	17.5 8.36	0.105263	0.516746
	0.358852	0.019139	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2002	1 1	0 0	2 18	18.5 3.40	0.094118	0.270588
	0.458824	0.152941	0.023529	0.000000	0.000000	0.000000
	0.000000	0.000000				
2002	1 1	0 0	2 19	19.5 1.40	0.000000	0.400000
	0.457143	0.057143	0.085714	0.000000	0.000000	0.000000
	0.000000	0.000000				
2002	1 1	0 0	2 20	20.5 0.52	0.000000	0.307692
	0.461538	0.153846	0.076923	0.000000	0.000000	0.000000
	0.000000	0.000000				
2002	1 1	0 0	2 21	21.5 0.20	0.000000	0.400000
	0.200000	0.200000	0.200000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2002	1 1	0 0	2 22	22.5 0.24	0.000000	0.000000
	0.166667	0.166667	0.500000	0.166667	0.000000	0.000000
	0.000000	0.000000				

2002	1 1	0 0	2 24	24.5 0.04	0.000000	0.000000
	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 9	9.5 0.40	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 10	10.5 0.96	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 11	11.5 5.16	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 12	12.5 3.40	0.987913	0.012087
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 13	13.5 1.96	0.993234	0.006766
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 14	14.5 1.52	0.387138	0.592611
	0.020251	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 15	15.5 7.12	0.025488	0.744644
	0.229868	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 16	16.5 17.32	0.001409	0.640280
	0.356403	0.001909	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 17	17.5 17.44	0.005991	0.513980
	0.464421	0.015608	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 18	18.5 10.24	0.000000	0.225967
	0.690454	0.083579	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 19	19.5 2.56	0.000000	0.000000
	0.710027	0.289973	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 20	20.5 1.08	0.000000	0.015152
	0.396441	0.395445	0.192962	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 21	21.5 0.04	0.000000	0.000000
	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 22	22.5 0.08	0.000000	0.000000
	0.000000	0.484197	0.000000	0.515804	0.000000	0.000000
	0.000000	0.000000				
2003	1 1	0 0	2 23	23.5 0.04	0.000000	0.000000
	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000
	0.000000	0.000000				
2004	1 1	0 0	2 10	10.5 0.08	0.857242	0.142758
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2004	1 1	0 0	2 11	11.5 0.20	0.000000	1.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2004	1 1	0 0	2 12	12.5 0.64	0.080480	0.827431
	0.092089	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2004	1 1	0 0	2 13	13.5 12.52	0.009563	0.951229
	0.039208	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2004	1 1	0 0	2 14	14.5 21.76	0.003591	0.957393
	0.034665	0.004351	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2004	1 1	0 0	2 15	15.5 25.40	0.000000	0.940914
	0.057428	0.000000	0.001658	0.000000	0.000000	0.000000
	0.000000	0.000000				
2004	1 1	0 0	2 16	16.5 19.40	0.002030	0.860910
	0.131929	0.005132	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				

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2004   1     1      0     0      2     17     17.5   7.68   0.000000      0.699242
       0.260609     0.031090     0.009060     0.000000      0.000000      0.000000
       0.000000     0.000000
2004   1     1      0     0      2     18     18.5   3.40   0.000000      0.151869
       0.688190     0.121458     0.038483     0.000000      0.000000      0.000000
       0.000000     0.000000
2004   1     1      0     0      2     19     19.5   1.64   0.000000      0.072078
       0.620498     0.283693     0.023730     0.000000      0.000000      0.000000
       0.000000     0.000000
2004   1     1      0     0      2     20     20.5   0.12   0.000000      0.000000
       0.158647     0.000000     0.841353     0.000000      0.000000      0.000000
       0.000000     0.000000
2004   1     1      0     0      2     21     21.5   0.04   0.000000      0.000000
       0.000000     0.000000     1.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2004   1     1      0     0      2     22     22.5   0.04   0.000000      0.000000
       0.000000     0.000000     0.000000     0.000000      1.000000      0.000000
       0.000000     0.000000
2004   1     1      0     0      2     24     24.5   0.04   0.000000      0.000000
       0.000000     0.000000     0.000000     0.000000      1.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     9      9.5    0.56   1.000000      0.000000
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     10     10.5   1.76   0.980531      0.019469
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     11     11.5   3.56   0.889902      0.110098
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     12     12.5   4.08   0.849889      0.150111
       0.000000     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     13     13.5   12.08  0.228183      0.692650
       0.079167     0.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     14     14.5   23.44  0.067330      0.750525
       0.169934     0.007326     0.004884     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     15     15.5   23.28  0.009396      0.497928
       0.483032     0.009644     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     16     16.5   16.52  0.000000      0.106273
       0.860285     0.033442     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     17     17.5   8.56   0.000000      0.057952
       0.846003     0.096044     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     18     18.5   2.04   0.000000      0.000000
       0.866497     0.133503     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     19     19.5   1.16   0.000000      0.040981
       0.813455     0.130208     0.015356     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     20     20.5   0.12   0.000000      0.000000
       0.254068     0.745932     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     21     21.5   0.04   0.000000      0.000000
       0.000000     0.000000     1.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     22     22.5   0.08   0.000000      0.000000
       0.000000     0.000000     0.500000     0.500000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     23     23.5   0.04   0.000000      0.000000
       0.000000     1.000000     0.000000     0.000000      0.000000      0.000000
       0.000000     0.000000
2005   1     1      0     0      2     24     24.5   0.12   0.000000      0.000000
       0.000000     0.000000     0.655097     0.172451      0.172451      0.000000
       0.000000     0.000000
```

2006	1	1	0	0	2	9	9.5	0.96	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	10	10.5	1.40	0.887011	0.112989	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	11	11.5	1.32	0.985682	0.014318	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	12	12.5	1.32	0.880060	0.100527	0.019413	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	13	13.5	3.00	0.219400	0.761610	0.018989	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	14	14.5	21.32	0.013041	0.903589	0.078513	0.004858	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	15	15.5	37.72	0.010951	0.842539	0.140332	0.006177	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	16	16.5	28.40	0.006112	0.635835	0.336831	0.021222	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	17	17.5	15.56	0.004501	0.278671	0.644209	0.071729	0.000891	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	18	18.5	6.36	0.000000	0.168012	0.620276	0.209659	0.002052	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	19	19.5	1.48	0.000000	0.115973	0.517469	0.330871	0.035688	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	20	20.5	0.32	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	21	21.5	0.08	0.000000	0.000000	0.500000	0.500000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1	1	0	0	2	22	22.5	0.04	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	1	1	0	0	3	10	10.5	0.32	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	1	1	0	0	3	11	11.5	1.32	0.942872	0.057128	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	1	1	0	0	3	12	12.5	2.92	0.593846	0.333487	0.072668	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	1	1	0	0	3	13	13.5	9.68	0.145024	0.798335	0.056641	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	1	1	0	0	3	14	14.5	15.92	0.006176	0.809159	0.172511	0.012154	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	1	1	0	0	3	15	15.5	25.12	0.003832	0.466219	0.509896	0.020053	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	1	1	0	0	3	16	16.5	42.60	0.000212	0.139640	0.751980	0.106242	0.001926	0.000000	0.000000	0.000000	0.000000	0.000000
2007	1	1	0	0	3	17	17.5	31.44	0.002212	0.048805	0.703183	0.229064	0.016737	0.000000	0.000000	0.000000	0.000000	0.000000
2007	1	1	0	0	3	18	18.5	8.40	0.000000	0.010985	0.640391	0.320140	0.028485	0.000000	0.000000	0.000000	0.000000	0.000000

2007	1 1	0 0	3 19	19.5 1.92	0.000000	0.000000
	0.205755	0.766149	0.028096	0.000000	0.000000	0.000000
	0.000000	0.000000				
2007	1 1	0 0	3 20	20.5 0.40	0.000000	0.000000
	0.242391	0.662392	0.095216	0.000000	0.000000	0.000000
	0.000000	0.000000				
2007	1 1	0 0	3 21	21.5 0.04	0.000000	0.000000
	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2007	1 1	0 0	3 22	22.5 0.04	0.000000	0.000000
	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 10	10.5 0.04	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 11	11.5 0.36	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 12	12.5 1.60	0.958623	0.041377
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 13	13.5 1.44	0.809699	0.190301
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 14	14.5 8.04	0.083525	0.858719
	0.054734	0.000000	0.003022	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 15	15.5 10.60	0.022286	0.809042
	0.168671	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 16	16.5 13.44	0.013146	0.397069
	0.574898	0.014887	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 17	17.5 12.08	0.014438	0.209510
	0.715053	0.061000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 18	18.5 5.24	0.011516	0.194375
	0.703336	0.090773	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 19	19.5 1.36	0.000000	0.199815
	0.492115	0.258353	0.049717	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 20	20.5 0.60	0.000000	0.000000
	0.219690	0.584693	0.195617	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 21	21.5 0.40	0.000000	0.000000
	0.107282	0.570871	0.321847	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 22	22.5 0.08	0.000000	0.000000
	0.196456	0.000000	0.803544	0.000000	0.000000	0.000000
	0.000000	0.000000				
2008	1 1	0 0	4 23	23.5 0.04	0.000000	0.000000
	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2009	1 1	0 0	4 13	13.5 0.12	0.000000	1.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2009	1 1	0 0	4 14	14.5 1.24	0.005966	0.828273
	0.165760	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2009	1 1	0 0	4 15	15.5 5.04	0.017040	0.564000
	0.418960	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2009	1 1	0 0	4 16	16.5 10.16	0.000000	0.434445
	0.552971	0.012584	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2009	1 1	0 0	4 17	17.5 14.96	0.000000	0.136592
	0.725561	0.123291	0.014555	0.000000	0.000000	0.000000
	0.000000	0.000000				

2009	1	1	0	0	4	18	18.5	4.28	0.000000	0.031333	0.607668	0.332941	0.028057	0.000000	0.000000	0.000000	0.000000	0.000000
2009	1	1	0	0	4	19	19.5	0.20	0.000000	0.000000	0.250740	0.749260	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	5	10	10.5	0.16	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	5	11	11.5	0.88	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	5	12	12.5	1.48	0.461679	0.538321	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	5	13	13.5	3.68	0.008054	0.944988	0.046958	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	5	14	14.5	7.24	0.001790	0.891454	0.102104	0.004652	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	5	15	15.5	11.84	0.003125	0.784405	0.212470	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	5	16	16.5	10.12	0.004472	0.615199	0.348205	0.032124	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	5	17	17.5	2.12	0.000000	0.186069	0.554301	0.259630	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	5	18	18.5	0.24	0.000000	0.000000	0.500000	0.500000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	5	19	19.5	0.16	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	5	20	20.5	0.04	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	1	0	0	5	21	21.5	0.04	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	10	10.5	0.20	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	12	12.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	13	13.5	0.28	0.428571	0.571429	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	14	14.5	0.96	0.388889	0.611111	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	15	15.5	1.48	0.221984	0.778016	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	16	16.5	0.92	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	17	17.5	1.20	0.000000	0.969413	0.030587	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	18	18.5	0.36	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	19	19.5	0.24	0.000000	0.233333	0.766667	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

1981	2	2	0	0	2	20	20.5	1.16	0.000000	0.000000	0.844647	0.155353	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	21	21.5	0.96	0.000000	0.000000	0.814226	0.128870	0.056904	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	22	22.5	1.00	0.000000	0.108347	0.747994	0.143660	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	23	23.5	0.48	0.000000	0.000000	0.220238	0.682540	0.097222	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	24	24.5	0.12	0.000000	0.000000	0.000000	0.690526	0.309474	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	25	25.5	0.08	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1981	2	2	0	0	2	26	26.5	0.04	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	10	10.5	0.04	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	11	11.5	0.04	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	12	12.5	0.04	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	13	13.5	0.04	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	16	16.5	0.08	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	18	18.5	0.16	0.000000	0.246358	0.753642	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	19	19.5	3.64	0.000000	0.703234	0.288088	0.008679	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	20	20.5	10.32	0.000000	0.676891	0.307575	0.015534	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	21	21.5	5.56	0.000000	0.290965	0.645768	0.063268	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	22	22.5	2.04	0.000000	0.045746	0.592992	0.361262	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	23	23.5	0.96	0.000000	0.000000	0.346134	0.653866	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	24	24.5	0.36	0.000000	0.000000	0.257971	0.414907	0.327122	0.000000	0.000000	0.000000	0.000000	0.000000
1982	2	2	0	0	2	25	25.5	0.04	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1983	2	2	0	0	2	14	14.5	0.04	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1983	2	2	0	0	2	15	15.5	0.20	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1983	2	2	0	0	2	16	16.5	0.16	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

1983	2	2	0	0	2	17	17.5	0.16	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1983	2	2	0	0	2	18	18.5	0.24	0.000000	0.901572	0.098428	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1983	2	2	0	0	2	19	19.5	0.72	0.000000	0.467314	0.532686	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1983	2	2	0	0	2	20	20.5	1.80	0.000000	0.265700	0.724828	0.009472	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1983	2	2	0	0	2	21	21.5	2.80	0.000000	0.094092	0.867590	0.024531	0.013787	0.000000	0.000000	0.000000	0.000000	0.000000
1983	2	2	0	0	2	22	22.5	1.12	0.000000	0.038432	0.942600	0.018968	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1983	2	2	0	0	2	23	23.5	0.24	0.000000	0.000000	0.341460	0.658540	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1983	2	2	0	0	2	24	24.5	0.04	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1984	2	2	0	0	2	14	14.5	0.04	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1984	2	2	0	0	2	16	16.5	0.28	0.000000	0.857143	0.142857	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1984	2	2	0	0	2	17	17.5	0.64	0.277559	0.722441	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1984	2	2	0	0	2	18	18.5	1.04	0.000000	0.753081	0.246919	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1984	2	2	0	0	2	19	19.5	0.80	0.000000	0.587314	0.392262	0.020424	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1984	2	2	0	0	2	20	20.5	1.56	0.030252	0.314522	0.638500	0.016726	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1984	2	2	0	0	2	21	21.5	2.08	0.000000	0.059169	0.874837	0.065994	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1984	2	2	0	0	2	22	22.5	1.68	0.000000	0.071168	0.853023	0.075809	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1984	2	2	0	0	2	23	23.5	0.52	0.000000	0.084795	0.339178	0.576027	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1985	2	2	0	0	2	15	15.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1985	2	2	0	0	2	16	16.5	0.08	0.203547	0.796453	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1985	2	2	0	0	2	17	17.5	0.08	0.928434	0.071566	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1985	2	2	0	0	2	18	18.5	0.76	0.000000	0.933240	0.066760	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1985	2	2	0	0	2	19	19.5	1.96	0.000000	0.737046	0.212553	0.050401	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1985	2	2	0	0	2	20	20.5	7.68	0.000000	0.441147	0.516183	0.042670	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

1985	2	2	0	0	2	21	21.5	10.36	0.000000	0.148912	0.822914	0.028174	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1985	2	2	0	0	2	22	22.5	8.12	0.000000	0.030642	0.883803	0.085555	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1985	2	2	0	0	2	23	23.5	3.40	0.000000	0.033355	0.484629	0.482016	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1985	2	2	0	0	2	24	24.5	0.80	0.000000	0.000000	0.120609	0.782344	0.097047	0.000000	0.000000	0.000000	0.000000	0.000000
1985	2	2	0	0	2	25	25.5	0.12	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	9	9.5	0.12	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	14	14.5	1.76	0.375000	0.625000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	15	15.5	1.00	0.129944	0.870056	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	16	16.5	0.68	0.075908	0.924092	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	17	17.5	0.08	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	18	18.5	0.28	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	19	19.5	0.40	0.000000	0.681252	0.318748	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	20	20.5	2.96	0.000000	0.408311	0.587475	0.004214	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	21	21.5	12.28	0.000000	0.082157	0.795232	0.118145	0.004465	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	22	22.5	16.24	0.000000	0.030906	0.797495	0.170341	0.000629	0.000629	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	23	23.5	7.04	0.000000	0.000000	0.291231	0.687536	0.021233	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	24	24.5	1.00	0.000000	0.000000	0.068952	0.641163	0.289885	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	25	25.5	0.16	0.000000	0.000000	0.246846	0.054607	0.698547	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	26	26.5	0.08	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1986	2	2	0	0	2	27	27.5	0.04	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	9	9.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	11	11.5	0.20	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	12	12.5	2.32	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

1987	2	2	0	0	2	13	13.5	0.32	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	14	14.5	0.24	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	15	15.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	16	16.5	0.12	0.500000	0.500000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	17	17.5	0.64	0.056957	0.943043	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	18	18.5	6.08	0.000000	0.922278	0.077722	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	19	19.5	12.92	0.000000	0.925999	0.074001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	20	20.5	17.52	0.000000	0.659310	0.323347	0.017344	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	21	21.5	20.24	0.000000	0.126381	0.796871	0.075947	0.000801	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	22	22.5	14.64	0.001575	0.032590	0.693310	0.251577	0.020949	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	23	23.5	8.76	0.000000	0.000000	0.160663	0.715791	0.123546	0.000000	0.000000	0.000000	0.000000	0.000000
1987	2	2	0	0	2	24	24.5	2.96	0.000000	0.000000	0.046988	0.430694	0.450117	0.063032	0.009169	0.000000	0.000000	0.000000
1987	2	2	0	0	2	25	25.5	0.64	0.000000	0.000000	0.000000	0.377132	0.316232	0.306637	0.000000	0.000000	0.000000	0.000000
1988	2	2	0	0	2	13	13.5	0.08	0.500000	0.500000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	2	2	0	0	2	14	14.5	0.72	0.611111	0.388889	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	2	2	0	0	2	15	15.5	1.56	0.333333	0.589744	0.051282	0.025641	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	2	2	0	0	2	16	16.5	2.12	0.150943	0.830189	0.000000	0.018868	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	2	2	0	0	2	17	17.5	2.24	0.017857	0.892857	0.071429	0.017857	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	2	2	0	0	2	18	18.5	1.84	0.000000	0.913043	0.086957	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	2	2	0	0	2	19	19.5	2.56	0.015625	0.828125	0.140625	0.015625	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1988	2	2	0	0	2	20	20.5	5.48	0.014599	0.350365	0.620438	0.007299	0.007299	0.000000	0.000000	0.000000	0.000000	0.000000
1988	2	2	0	0	2	21	21.5	9.56	0.000000	0.058577	0.920502	0.016736	0.004184	0.000000	0.000000	0.000000	0.000000	0.000000
1988	2	2	0	0	2	22	22.5	10.56	0.000000	0.018939	0.867424	0.090909	0.018939	0.003788	0.000000	0.000000	0.000000	0.000000

1988	2 2	0 0	2 23	23.5 5.00	0.000000	0.016000
	0.496000	0.416000	0.056000	0.008000	0.008000	0.000000
	0.000000	0.000000				
1988	2 2	0 0	2 24	24.5 2.28	0.000000	0.017544
	0.157895	0.438596	0.368421	0.017544	0.000000	0.000000
	0.000000	0.000000				
1988	2 2	0 0	2 25	25.5 0.24	0.000000	0.166667
	0.000000	0.333333	0.166667	0.166667	0.166667	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 12	12.5 0.04	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 13	13.5 0.44	0.363636	0.636364
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 14	14.5 0.40	0.400000	0.600000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 15	15.5 0.32	0.625000	0.375000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 16	16.5 0.04	0.000000	0.000000
	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 17	17.5 0.16	0.500000	0.500000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 18	18.5 1.56	0.025641	0.923077
	0.051282	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 19	19.5 8.56	0.000000	0.920561
	0.074766	0.004673	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 20	20.5 14.52	0.005510	0.826446
	0.148760	0.016529	0.002755	0.000000	0.000000	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 21	21.5 12.20	0.000000	0.354098
	0.580328	0.062295	0.003279	0.000000	0.000000	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 22	22.5 6.08	0.000000	0.151316
	0.723684	0.111842	0.013158	0.000000	0.000000	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 23	23.5 1.88	0.000000	0.000000
	0.404255	0.595745	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1989	2 2	0 0	2 24	24.5 0.28	0.000000	0.000000
	0.285714	0.571429	0.142857	0.000000	0.000000	0.000000
	0.000000	0.000000				
1990	2 2	0 0	2 13	13.5 1.00	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1990	2 2	0 0	2 14	14.5 1.92	0.812500	0.187500
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1990	2 2	0 0	2 15	15.5 4.16	0.519231	0.480769
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1990	2 2	0 0	2 16	16.5 8.92	0.197309	0.793722
	0.008969	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1990	2 2	0 0	2 17	17.5 3.56	0.247191	0.707865
	0.044944	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1990	2 2	0 0	2 18	18.5 2.64	0.151515	0.681818
	0.136364	0.030303	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1990	2 2	0 0	2 19	19.5 4.96	0.016129	0.629032
	0.274194	0.064516	0.008065	0.000000	0.008065	0.000000
	0.000000	0.000000				

1990	2 2	0 0	2 20	20.5 20.80	0.013462	0.228846
	0.492308	0.182692	0.038462	0.026923	0.013462	0.003846
	0.000000	0.000000				
1990	2 2	0 0	2 21	21.5 31.48	0.000000	0.141042
	0.424396	0.266836	0.099111	0.035578	0.024142	0.007624
	0.001271	0.000000				
1990	2 2	0 0	2 22	22.5 21.40	0.000000	0.072897
	0.364486	0.310280	0.179439	0.033645	0.033645	0.003738
	0.001869	0.000000				
1990	2 2	0 0	2 23	23.5 6.88	0.000000	0.075581
	0.267442	0.244186	0.273256	0.058140	0.052326	0.023256
	0.005814	0.000000				
1990	2 2	0 0	2 24	24.5 1.16	0.000000	0.000000
	0.206897	0.344828	0.172414	0.103448	0.137931	0.034483
	0.000000	0.000000				
1990	2 2	0 0	2 25	25.5 0.12	0.000000	0.000000
	0.333333	0.000000	0.333333	0.333333	0.000000	0.000000
	0.000000	0.000000				
1991	2 2	0 0	2 11	11.5 0.08	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1991	2 2	0 0	2 12	12.5 0.12	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1991	2 2	0 0	2 13	13.5 0.44	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1991	2 2	0 0	2 14	14.5 1.32	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1991	2 2	0 0	2 15	15.5 2.64	1.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1991	2 2	0 0	2 16	16.5 3.04	0.868421	0.118421
	0.013158	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1991	2 2	0 0	2 17	17.5 3.64	0.318681	0.615385
	0.054945	0.010989	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1991	2 2	0 0	2 18	18.5 8.04	0.084577	0.776119
	0.134328	0.004975	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1991	2 2	0 0	2 19	19.5 12.64	0.009494	0.784810
	0.177215	0.025316	0.003165	0.000000	0.000000	0.000000
	0.000000	0.000000				
1991	2 2	0 0	2 20	20.5 13.76	0.000000	0.578488
	0.345930	0.052326	0.020349	0.002907	0.000000	0.000000
	0.000000	0.000000				
1991	2 2	0 0	2 21	21.5 11.52	0.000000	0.229167
	0.420139	0.246528	0.072917	0.010417	0.010417	0.003472
	0.006944	0.000000				
1991	2 2	0 0	2 22	22.5 12.52	0.000000	0.041534
	0.313099	0.348243	0.185304	0.076677	0.015974	0.012780
	0.006390	0.000000				
1991	2 2	0 0	2 23	23.5 10.04	0.000000	0.015936
	0.155378	0.406375	0.211155	0.163347	0.023904	0.023904
	0.000000	0.000000				
1991	2 2	0 0	2 24	24.5 2.40	0.000000	0.000000
	0.116667	0.300000	0.350000	0.150000	0.066667	0.000000
	0.016667	0.000000				
1991	2 2	0 0	2 25	25.5 0.24	0.000000	0.166667
	0.000000	0.166667	0.166667	0.333333	0.000000	0.166667
	0.000000	0.000000				
1991	2 2	0 0	2 26	26.5 0.36	0.000000	0.000000
	0.000000	0.111111	0.444444	0.333333	0.000000	0.000000
	0.111111	0.000000				
1991	2 2	0 0	2 27	27.5 0.28	0.000000	0.000000
	0.000000	0.000000	0.142857	0.428571	0.285714	0.142857
	0.000000	0.000000				

1991	2	2	0	0	2	28	28.5	0.12	0.000000	0.000000	0.000000	0.000000	0.000000	0.666667	0.000000	0.333333	0.000000	0.000000
1992	2	2	0	0	2	10	10.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	11	11.5	0.16	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	12	12.5	0.64	0.937500	0.062500	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	13	13.5	1.60	0.850000	0.150000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	14	14.5	5.00	0.568000	0.400000	0.032000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	15	15.5	12.80	0.328125	0.656250	0.015625	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	16	16.5	17.64	0.170068	0.770975	0.056689	0.002268	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	17	17.5	15.04	0.029255	0.795213	0.167553	0.007979	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	18	18.5	8.68	0.004608	0.774194	0.184332	0.036866	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	19	19.5	4.88	0.008197	0.442623	0.475410	0.073770	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	20	20.5	3.20	0.012500	0.187500	0.612500	0.137500	0.050000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	21	21.5	1.48	0.000000	0.054054	0.459459	0.351351	0.108108	0.027027	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	22	22.5	1.24	0.000000	0.032258	0.096774	0.612903	0.193548	0.000000	0.064516	0.000000	0.000000	0.000000
1992	2	2	0	0	2	23	23.5	0.28	0.000000	0.142857	0.000000	0.142857	0.571429	0.142857	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	24	24.5	0.08	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	25	25.5	0.08	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	26	26.5	0.08	0.000000	0.000000	0.000000	0.000000	0.500000	0.500000	0.000000	0.000000	0.000000	0.000000
1992	2	2	0	0	2	27	27.5	0.04	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000
1993	2	2	0	0	2	9	9.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1993	2	2	0	0	2	13	13.5	0.28	0.714286	0.285714	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1993	2	2	0	0	2	14	14.5	2.60	0.523077	0.476923	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1993	2	2	0	0	2	15	15.5	6.12	0.313725	0.679739	0.006536	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

1993	2	2	0	0	2	16	16.5	7.04	0.352273	0.482955	0.159091	0.005682	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1993	2	2	0	0	2	17	17.5	11.12	0.075540	0.589928	0.309353	0.021583	0.003597	0.000000	0.000000	0.000000	0.000000	0.000000
1993	2	2	0	0	2	18	18.5	7.04	0.011364	0.414773	0.551136	0.022727	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1993	2	2	0	0	2	19	19.5	3.04	0.000000	0.105263	0.671053	0.184211	0.013158	0.013158	0.013158	0.000000	0.000000	0.000000
1993	2	2	0	0	2	20	20.5	1.04	0.000000	0.038462	0.423077	0.423077	0.076923	0.038462	0.000000	0.000000	0.000000	0.000000
1993	2	2	0	0	2	21	21.5	0.56	0.000000	0.000000	0.214286	0.500000	0.285714	0.000000	0.000000	0.000000	0.000000	0.000000
1993	2	2	0	0	2	22	22.5	0.52	0.000000	0.000000	0.230769	0.307692	0.230769	0.076923	0.153846	0.000000	0.000000	0.000000
1993	2	2	0	0	2	23	23.5	0.52	0.000000	0.000000	0.076923	0.307692	0.384615	0.230769	0.000000	0.000000	0.000000	0.000000
1993	2	2	0	0	2	24	24.5	0.16	0.000000	0.000000	0.000000	0.500000	0.500000	0.000000	0.000000	0.000000	0.000000	0.000000
1993	2	2	0	0	2	25	25.5	0.20	0.000000	0.000000	0.000000	0.200000	0.000000	0.600000	0.200000	0.000000	0.000000	0.000000
1993	2	2	0	0	2	26	26.5	0.04	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	9	9.5	0.08	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	11	11.5	0.80	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	12	12.5	1.96	0.959184	0.040816	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	13	13.5	6.84	0.877193	0.116959	0.005848	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	14	14.5	15.40	0.849351	0.148052	0.002597	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	15	15.5	24.88	0.633441	0.339228	0.025723	0.001608	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	16	16.5	33.84	0.261229	0.677305	0.056738	0.003546	0.000000	0.001182	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	17	17.5	25.28	0.099684	0.678797	0.153481	0.061709	0.006329	0.000000	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	18	18.5	13.84	0.046243	0.421965	0.320809	0.190751	0.017341	0.002890	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	19	19.5	5.56	0.021583	0.172662	0.438849	0.309353	0.050360	0.007194	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	20	20.5	1.32	0.000000	0.090909	0.424242	0.454545	0.000000	0.030303	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	21	21.5	0.36	0.000000	0.111111	0.222222	0.444444	0.111111	0.000000	0.111111	0.000000	0.000000	0.000000

1994	2	2	0	0	2	23	23.5	0.04	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1994	2	2	0	0	2	24	24.5	0.04	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	9	9.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	12	12.5	0.48	0.416667	0.583333	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	13	13.5	3.04	0.421053	0.565789	0.013158	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	14	14.5	6.24	0.557692	0.429487	0.012821	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	15	15.5	12.64	0.553797	0.313291	0.129747	0.003165	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	16	16.5	21.60	0.331481	0.446296	0.207407	0.014815	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	17	17.5	18.68	0.089936	0.578158	0.301927	0.027837	0.000000	0.002141	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	18	18.5	9.48	0.042194	0.556962	0.358650	0.042194	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	19	19.5	3.72	0.000000	0.408602	0.526882	0.053763	0.010753	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	20	20.5	1.24	0.000000	0.161290	0.580645	0.096774	0.161290	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	21	21.5	0.56	0.000000	0.071429	0.500000	0.214286	0.214286	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	22	22.5	0.08	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	23	23.5	0.04	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1995	2	2	0	0	2	25	25.5	0.04	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	2	2	0	0	2	10	10.5	0.40	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	2	2	0	0	2	11	11.5	0.64	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	2	2	0	0	2	12	12.5	3.32	0.903614	0.072289	0.024096	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	2	2	0	0	2	13	13.5	9.28	0.818966	0.133621	0.047414	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	2	2	0	0	2	14	14.5	11.28	0.595745	0.375887	0.028369	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	2	2	0	0	2	15	15.5	8.12	0.502463	0.467980	0.029557	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	2	2	0	0	2	16	16.5	4.40	0.163636	0.527273	0.281818	0.027273	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

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1996   2     2      0     0      2     17      17.5   6.08    0.032895        0.500000
       0.401316     0.065789     0.000000      0.000000       0.000000        0.000000
       0.000000     0.000000
1996   2     2      0     0      2     18      18.5   6.84    0.000000        0.251462
       0.666667     0.076023     0.005848      0.000000       0.000000        0.000000
       0.000000     0.000000
1996   2     2      0     0      2     19      19.5   7.80    0.005128        0.138462
       0.610256     0.189744     0.010256      0.046154       0.000000        0.000000
       0.000000     0.000000
1996   2     2      0     0      2     20      20.5   4.96    0.000000        0.104839
       0.500000     0.266129     0.072581      0.056452       0.000000        0.000000
       0.000000     0.000000
1996   2     2      0     0      2     21      21.5   2.04    0.000000        0.039216
       0.372549     0.411765     0.058824      0.098039       0.019608        0.000000
       0.000000     0.000000
1996   2     2      0     0      2     22      22.5   0.68    0.000000        0.176471
       0.294118     0.352941     0.176471      0.000000       0.000000        0.000000
       0.000000     0.000000
1996   2     2      0     0      2     25      25.5   0.08    0.000000        0.000000
       0.000000     0.000000     0.500000      0.500000       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     9       9.5    0.08    1.000000        0.000000
       0.000000     0.000000     0.000000      0.000000       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     10      10.5   0.88    0.954545        0.045455
       0.000000     0.000000     0.000000      0.000000       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     11      11.5   1.40    1.000000        0.000000
       0.000000     0.000000     0.000000      0.000000       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     12      12.5   1.60    0.950000        0.050000
       0.000000     0.000000     0.000000      0.000000       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     13      13.5   4.28    0.943925        0.056075
       0.000000     0.000000     0.000000      0.000000       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     14      14.5   4.40    0.718182        0.272727
       0.009091     0.000000     0.000000      0.000000       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     15      15.5   5.72    0.160839        0.790210
       0.041958     0.006993     0.000000      0.000000       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     16      16.5   6.68    0.011976        0.850299
       0.131737     0.005988     0.000000      0.000000       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     17      17.5   7.96    0.020101        0.643216
       0.286432     0.045226     0.005025      0.000000       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     18      18.5   7.84    0.015306        0.408163
       0.469388     0.096939     0.010204      0.000000       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     19      19.5   6.56    0.006098        0.103659
       0.500000     0.310976     0.067073      0.012195       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     20      20.5   9.48    0.000000        0.025316
       0.375527     0.438819     0.147679      0.012658       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     21      21.5   7.52    0.000000        0.015957
       0.207447     0.579787     0.170213      0.026596       0.000000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     22      22.5   3.84    0.000000        0.010417
       0.166667     0.427083     0.302083      0.083333       0.010417        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     23      23.5   1.00    0.000000        0.000000
       0.040000     0.400000     0.440000      0.080000       0.040000        0.000000
       0.000000     0.000000
1997   2     2      0     0      2     24      24.5   0.20    0.000000        0.000000
       0.000000     0.000000     0.800000      0.000000       0.200000        0.000000
       0.000000     0.000000
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1997	2	2	0	0	2	25	25.5	0.04	0.000000	0.000000
	0.000000		0.000000		0.000000		0.000000		1.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	9	9.5	0.08	1.000000	0.000000
	0.000000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	10	10.5	1.00	0.920000	0.080000
	0.000000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	11	11.5	2.76	0.956522	0.043478
	0.000000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	12	12.5	7.20	0.761111	0.227778
	0.011111		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	13	13.5	11.84	0.533784	0.418919
	0.043919		0.003378		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	14	14.5	16.68	0.362110	0.597122
	0.035971		0.004796		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	15	15.5	16.16	0.183168	0.655941
	0.146040		0.009901		0.000000		0.004951		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	16	16.5	12.60	0.028571	0.568254
	0.368254		0.022222		0.009524		0.003175		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	17	17.5	10.04	0.027888	0.318725
	0.605578		0.039841		0.003984		0.003984		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	18	18.5	4.40	0.018182	0.218182
	0.663636		0.100000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	19	19.5	3.20	0.012500	0.125000
	0.550000		0.250000		0.050000		0.012500		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	20	20.5	1.24	0.000000	0.064516
	0.354839		0.419355		0.129032		0.032258		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	21	21.5	0.92	0.000000	0.086957
	0.130435		0.260870		0.434783		0.086957		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	22	22.5	0.20	0.000000	0.200000
	0.200000		0.200000		0.400000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	23	23.5	0.04	0.000000	0.000000
	0.000000		0.000000		1.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1998	2	2	0	0	2	24	24.5	0.04	0.000000	0.000000
	0.000000		0.000000		0.000000		1.000000		0.000000	0.000000
	0.000000		0.000000							
1999	2	2	0	0	2	10	10.5	0.04	1.000000	0.000000
	0.000000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1999	2	2	0	0	2	12	12.5	0.20	0.400000	0.600000
	0.000000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1999	2	2	0	0	2	13	13.5	5.00	0.304000	0.592000
	0.096000		0.008000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1999	2	2	0	0	2	14	14.5	15.12	0.420635	0.484127
	0.074074		0.010582		0.007937		0.002646		0.000000	0.000000
	0.000000		0.000000							
1999	2	2	0	0	2	15	15.5	23.12	0.337370	0.458478
	0.185121		0.013841		0.005190		0.000000		0.000000	0.000000
	0.000000		0.000000							
1999	2	2	0	0	2	16	16.5	16.28	0.162162	0.515971
	0.297297		0.017199		0.007371		0.000000		0.000000	0.000000
	0.000000		0.000000							

1999	2	2	0	0	2	17	17.5	5.92	0.027027	0.513514	0.412162	0.040541	0.006757	0.000000	0.000000	0.000000	0.000000	0.000000
1999	2	2	0	0	2	18	18.5	2.76	0.000000	0.391304	0.521739	0.072464	0.014493	0.000000	0.000000	0.000000	0.000000	0.000000
1999	2	2	0	0	2	19	19.5	1.12	0.000000	0.392857	0.571429	0.035714	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1999	2	2	0	0	2	20	20.5	0.24	0.000000	0.333333	0.500000	0.000000	0.000000	0.000000	0.166667	0.000000	0.000000	0.000000
2000	2	2	0	0	2	9	9.5	0.08	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2	2	0	0	2	11	11.5	0.72	0.888889	0.111111	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2	2	0	0	2	12	12.5	2.28	0.719298	0.263158	0.000000	0.017544	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2	2	0	0	2	13	13.5	6.56	0.560976	0.390244	0.042683	0.006098	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2	2	0	0	2	14	14.5	15.56	0.329049	0.632391	0.035990	0.002571	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2	2	0	0	2	15	15.5	17.84	0.309417	0.567265	0.103139	0.017937	0.002242	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2	2	0	0	2	16	16.5	11.08	0.090253	0.422383	0.397112	0.075812	0.014440	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2	2	0	0	2	17	17.5	12.00	0.033333	0.320000	0.546667	0.090000	0.010000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2	2	0	0	2	18	18.5	8.12	0.019704	0.315271	0.586207	0.059113	0.019704	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2	2	0	0	2	19	19.5	3.92	0.040816	0.357143	0.448980	0.122449	0.030612	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2	2	0	0	2	20	20.5	1.88	0.042553	0.446809	0.340426	0.148936	0.021277	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2	2	0	0	2	21	21.5	0.08	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	2	2	0	0	2	22	22.5	0.12	0.000000	0.000000	0.000000	0.666667	0.000000	0.000000	0.000000	0.333333	0.000000	0.000000
2000	2	2	0	0	2	26	26.5	0.04	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000
2001	2	2	0	0	2	9	9.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	10	10.5	2.00	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	11	11.5	7.68	0.984375	0.015625	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	12	12.5	14.60	0.936986	0.060274	0.000000	0.002740	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	13	13.5	16.96	0.912736	0.082547	0.004717	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

2001	2	2	0	0	2	14	14.5	13.28	0.698795	0.274096	0.024096	0.003012	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	15	15.5	11.84	0.483108	0.445946	0.067568	0.003378	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	16	16.5	4.84	0.223141	0.652893	0.115702	0.008264	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	17	17.5	4.80	0.050000	0.616667	0.266667	0.058333	0.008333	0.000000	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	18	18.5	4.12	0.019417	0.339806	0.495146	0.116505	0.029126	0.000000	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	19	19.5	2.76	0.028986	0.347826	0.449275	0.173913	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	20	20.5	1.96	0.061224	0.142857	0.428571	0.285714	0.061224	0.020408	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	21	21.5	0.56	0.000000	0.000000	0.142857	0.642857	0.071429	0.142857	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	22	22.5	0.08	0.000000	0.000000	0.000000	0.500000	0.500000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	23	23.5	0.04	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	2	2	0	0	2	24	24.5	0.04	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	9	9.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	10	10.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	11	11.5	0.32	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	12	12.5	0.60	0.940902	0.059098	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	13	13.5	1.20	0.867764	0.132236	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	14	14.5	3.20	0.482026	0.458611	0.059363	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	15	15.5	14.36	0.313630	0.630478	0.052288	0.003605	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	16	16.5	27.68	0.159687	0.715093	0.119107	0.005887	0.000000	0.000000	0.000000	0.000000	0.000226	0.000000
2002	2	2	0	0	2	17	17.5	26.04	0.102380	0.627070	0.230761	0.033456	0.006333	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	18	18.5	8.36	0.048244	0.461079	0.367265	0.112334	0.011078	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	19	19.5	4.40	0.000000	0.198016	0.469194	0.266720	0.066071	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	20	20.5	1.88	0.000000	0.037990	0.501652	0.354019	0.106338	0.000000	0.000000	0.000000	0.000000	0.000000

2002	2	2	0	0	2	21	21.5	0.40	0.000000	0.000000	0.496981	0.189946	0.179346	0.133727	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	22	22.5	0.28	0.000000	0.000000	0.000000	0.253270	0.205115	0.541616	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	23	23.5	0.20	0.000000	0.000000	0.000000	0.055178	0.055178	0.889644	0.000000	0.000000	0.000000	0.000000
2002	2	2	0	0	2	24	24.5	0.04	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	10	10.5	0.52	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	11	11.5	7.52	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	12	12.5	11.24	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	13	13.5	26.12	0.992160	0.007840	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	14	14.5	15.68	0.970741	0.029259	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	15	15.5	3.96	0.765334	0.212624	0.022043	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	16	16.5	1.24	0.082075	0.513778	0.404147	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	17	17.5	1.24	0.033966	0.346894	0.577620	0.041520	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	18	18.5	2.68	0.000000	0.000000	0.740758	0.235709	0.023534	0.000000	0.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	19	19.5	2.24	0.000000	0.053839	0.462090	0.426586	0.043113	0.014371	0.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	20	20.5	0.64	0.000000	0.000000	0.280117	0.469312	0.196017	0.054553	0.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	21	21.5	0.64	0.066159	0.000000	0.188860	0.422168	0.277137	0.045676	0.000000	0.000000	0.000000	0.000000
2003	2	2	0	0	2	22	22.5	0.60	0.000000	0.000000	0.000000	0.259670	0.362446	0.312967	0.064917	0.000000	0.000000	0.000000
2003	2	2	0	0	2	23	23.5	0.52	0.000000	0.000000	0.000000	0.000000	0.692308	0.076923	0.153846	0.076923	0.000000	0.000000
2003	2	2	0	0	2	24	24.5	0.40	0.000000	0.000000	0.000000	0.100000	0.300000	0.000000	0.500000	0.100000	0.000000	0.000000
2003	2	2	0	0	2	25	25.5	0.04	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2004	2	2	0	0	2	11	11.5	0.24	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2004	2	2	0	0	2	12	12.5	1.76	0.765543	0.234457	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2004	2	2	0	0	2	13	13.5	7.48	0.347232	0.652768	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

2004	2	2	0	0	2	14	14.5	17.64	0.057036	0.937344	0.005620	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2004	2	2	0	0	2	15	15.5	22.36	0.030395	0.958223	0.011382	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2004	2	2	0	0	2	16	16.5	14.52	0.026025	0.882873	0.091102	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2004	2	2	0	0	2	17	17.5	4.92	0.006256	0.795525	0.178539	0.019679	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2004	2	2	0	0	2	18	18.5	1.88	0.000000	0.220908	0.667868	0.111224	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2004	2	2	0	0	2	19	19.5	0.72	0.000000	0.000000	0.763696	0.236304	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2004	2	2	0	0	2	20	20.5	0.16	0.000000	0.000000	0.628300	0.371700	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2004	2	2	0	0	2	21	21.5	0.12	0.000000	0.000000	0.286989	0.000000	0.713011	0.000000	0.000000	0.000000	0.000000	0.000000
2004	2	2	0	0	2	22	22.5	0.12	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2004	2	2	0	0	2	23	23.5	0.04	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	9	9.5	0.28	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	10	10.5	2.92	0.946660	0.053340	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	11	11.5	10.96	0.965307	0.034693	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	12	12.5	10.60	0.812888	0.187112	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	13	13.5	18.48	0.598983	0.378692	0.022326	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	14	14.5	21.16	0.424068	0.523731	0.052201	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	15	15.5	17.36	0.400380	0.438371	0.161249	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	16	16.5	7.40	0.213452	0.389809	0.379019	0.017720	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	17	17.5	4.36	0.001445	0.226919	0.643857	0.100399	0.027380	0.000000	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	18	18.5	2.60	0.000000	0.140908	0.647482	0.136705	0.074905	0.000000	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	19	19.5	1.80	0.000000	0.197417	0.585080	0.217503	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	20	20.5	0.40	0.000000	0.153752	0.185406	0.353338	0.153752	0.153752	0.000000	0.000000	0.000000	0.000000
2005	2	2	0	0	2	21	21.5	0.16	0.000000	0.000000	0.157731	0.842269	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

2005	2	2	0	0	2	23	23.5	0.16	0.000000	0.000000	0.000000	0.000000	0.032060	0.322647	0.322647	0.000000	0.322647	0.000000
2005	2	2	0	0	2	24	24.5	0.32	0.000000	0.000000	0.161323	0.000000	0.000000	0.161323	0.193384	0.322647	0.161323	0.000000
2005	2	2	0	0	2	25	25.5	0.08	0.000000	0.000000	0.000000	0.000000	0.000000	0.500000	0.500000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	9	9.5	0.60	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	10	10.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	11	11.5	1.00	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	12	12.5	3.16	0.996187	0.003813	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	13	13.5	7.20	0.800386	0.199614	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	14	14.5	17.76	0.398312	0.597281	0.004407	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	15	15.5	28.84	0.102933	0.881599	0.015468	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	16	16.5	26.64	0.054470	0.875804	0.069726	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	17	17.5	17.44	0.008450	0.629472	0.350310	0.011768	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	18	18.5	10.32	0.000000	0.169512	0.718938	0.111549	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	19	19.5	5.88	0.000000	0.065488	0.778272	0.156240	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	20	20.5	2.16	0.000000	0.016751	0.594470	0.331235	0.057544	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	21	21.5	0.20	0.000000	0.000000	0.582262	0.417738	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	22	22.5	0.08	0.000000	0.000000	0.000000	0.500000	0.500000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	2	2	0	0	3	23	23.5	0.08	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	9	9.5	0.08	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	10	10.5	0.52	0.811614	0.188386	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	11	11.5	3.56	0.817489	0.169487	0.013023	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	12	12.5	7.96	0.807898	0.185434	0.006667	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	13	13.5	13.60	0.584438	0.400780	0.014783	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

2007	2	2	0	0	4	14	14.5	12.40	0.352394	0.579095	0.068511	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	15	15.5	8.40	0.139621	0.674462	0.185917	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	16	16.5	5.72	0.042656	0.609694	0.344559	0.003091	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	17	17.5	4.52	0.139080	0.440352	0.354548	0.066020	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	18	18.5	3.24	0.000000	0.258828	0.419177	0.321995	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	19	19.5	1.72	0.132304	0.049361	0.247871	0.547532	0.022932	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	20	20.5	2.76	0.103361	0.059064	0.251021	0.483193	0.103361	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	21	21.5	2.16	0.019199	0.095996	0.179739	0.563725	0.115196	0.026145	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	22	22.5	0.56	0.074840	0.074840	0.101915	0.449043	0.224521	0.074840	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	23	23.5	0.16	0.000000	0.000000	0.000000	0.750000	0.250000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	24	24.5	0.08	0.500000	0.000000	0.000000	0.000000	0.500000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	2	2	0	0	4	25	25.5	0.08	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	10	10.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	11	11.5	0.84	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	12	12.5	2.80	0.985579	0.014421	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	13	13.5	2.80	0.854595	0.145405	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	14	14.5	1.92	0.218530	0.754046	0.027424	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	15	15.5	7.56	0.026493	0.846759	0.124338	0.002410	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	16	16.5	11.56	0.031258	0.833041	0.123576	0.012125	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	17	17.5	5.56	0.013430	0.475284	0.492383	0.018903	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	18	18.5	4.44	0.003808	0.157939	0.636617	0.201636	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	19	19.5	1.24	0.000000	0.225957	0.285173	0.488870	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	20	20.5	0.60	0.000000	0.092864	0.273216	0.602148	0.031772	0.000000	0.000000	0.000000	0.000000	0.000000

2008	2	2	0	0	4	21	21.5	0.32	0.000000	0.246744	0.084419	0.500000	0.168837	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	22	22.5	0.04	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2	2	0	0	4	23	23.5	0.04	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	10	10.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	11	11.5	0.44	0.836891	0.163109	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	12	12.5	5.88	0.683630	0.304458	0.011912	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	13	13.5	22.88	0.688897	0.299091	0.012012	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	14	14.5	31.40	0.501500	0.410386	0.088114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	15	15.5	24.72	0.245217	0.583337	0.171088	0.000357	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	16	16.5	10.56	0.068292	0.660148	0.259199	0.012361	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	17	17.5	2.20	0.015835	0.503008	0.455195	0.025962	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	18	18.5	0.48	0.000000	0.155933	0.650239	0.193828	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	19	19.5	0.16	0.000000	0.000000	0.358705	0.052638	0.588657	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	20	20.5	0.12	0.000000	0.000000	0.473005	0.424390	0.102605	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	21	21.5	0.08	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	2	2	0	0	5	22	22.5	0.04	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	2	2	0	0	5	10	10.5	0.04	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	2	2	0	0	5	11	11.5	0.12	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	2	2	0	0	5	12	12.5	1.40	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	2	2	0	0	5	13	13.5	4.36	0.979379	0.020621	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	2	2	0	0	5	14	14.5	7.96	0.671570	0.328430	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	2	2	0	0	5	15	15.5	6.84	0.348898	0.651102	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	2	2	0	0	5	16	16.5	1.92	0.074299	0.882992	0.042709	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

2010	2	2	0	0	5	17	17.5	0.72	0.000000	0.666458
	0.248247		0.085294		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2010	2	2	0	0	5	18	18.5	0.48	0.000000	0.368473
	0.514804		0.116723		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2010	2	2	0	0	5	19	19.5	0.32	0.000000	0.146394
	0.146394		0.414425		0.146394		0.146394		0.000000	0.000000
	0.000000		0.000000							
2010	2	2	0	0	5	20	20.5	1.40	0.000000	0.000000
	0.085714		0.371429		0.428571		0.085714		0.028571	0.000000
	0.000000		0.000000							
2010	2	2	0	0	5	21	21.5	3.60	0.000000	0.000000
	0.033333		0.155556		0.400000		0.400000		0.011111	0.000000
	0.000000		0.000000							
2010	2	2	0	0	5	22	22.5	2.72	0.000000	0.000000
	0.000000		0.044118		0.338235		0.588235		0.029412	0.000000
	0.000000		0.000000							
2010	2	2	0	0	5	23	23.5	0.92	0.000000	0.000000
	0.000000		0.000000		0.086957		0.652174		0.217391	0.000000
	0.043478		0.000000							
2010	2	2	0	0	5	24	24.5	0.12	0.000000	0.000000
	0.000000		0.333333		0.000000		0.000000		0.666667	0.000000
	0.000000		0.000000							
2010	2	2	0	0	5	25	25.5	0.04	0.000000	0.000000
	0.000000		0.000000		0.000000		0.000000		0.000000	1.000000
	0.000000		0.000000							
1999	1	3	0	0	6	16	16.5	0.32	0.000000	0.000000
	1.000000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1999	1	3	0	0	6	17	17.5	0.56	0.000000	0.000000
	1.000000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1999	1	3	0	0	6	18	18.5	0.80	0.000000	0.000000
	0.785193		0.214807		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1999	1	3	0	0	6	19	19.5	0.28	0.000000	0.000000
	0.285714		0.714286		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
1999	1	3	0	0	6	20	20.5	0.28	0.000000	0.000000
	0.000000		0.697394		0.302606		0.000000		0.000000	0.000000
	0.000000		0.000000							
1999	1	3	0	0	6	21	21.5	0.32	0.000000	0.000000
	0.000000		0.250000		0.375000		0.375000		0.000000	0.000000
	0.000000		0.000000							
1999	1	3	0	0	6	22	22.5	0.28	0.000000	0.000000
	0.000000		0.000000		0.000000		1.000000		0.000000	0.000000
	0.000000		0.000000							
1999	1	3	0	0	6	23	23.5	0.16	0.000000	0.000000
	0.000000		0.000000		0.000000		0.691625		0.308375	0.000000
	0.000000		0.000000							
1999	1	3	0	0	6	25	25.5	0.04	0.000000	0.000000
	0.000000		0.000000		0.000000		0.000000		1.000000	0.000000
	0.000000		0.000000							
2000	1	3	0	0	6	11	11.5	0.04	0.000000	0.000000
	0.000000		0.000000		1.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2000	1	3	0	0	6	16	16.5	0.24	0.000000	0.000000
	1.000000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2000	1	3	0	0	6	17	17.5	3.16	0.000000	0.029710
	0.815682		0.154608		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2000	1	3	0	0	6	18	18.5	6.28	0.000000	0.016637
	0.697788		0.223840		0.057871		0.000000		0.003863	0.000000
	0.000000		0.000000							
2000	1	3	0	0	6	19	19.5	7.88	0.000000	0.010035
	0.266311		0.579188		0.115951		0.020759		0.007756	0.000000
	0.000000		0.000000							

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2000   1     3     0     0     6     20     20.5   12.44   0.000000    0.000000
       0.121329    0.620616    0.195788     0.049219       0.011680    0.000000
       0.001368    0.000000
2000   1     3     0     0     6     21     21.5   18.92   0.000000    0.000000
       0.073019    0.436890    0.288734     0.136640       0.050367    0.003948
       0.010402    0.000000
2000   1     3     0     0     6     22     22.5   13.52   0.000000    0.003760
       0.044215    0.240783    0.316392     0.250168       0.096557    0.032497
       0.015628    0.000000
2000   1     3     0     0     6     23     23.5   4.56    0.000000    0.009961
       0.028533    0.119035    0.339240     0.198430       0.210973    0.081155
       0.012672    0.000000
2000   1     3     0     0     6     24     24.5   0.60    0.000000    0.086043
       0.000000    0.095533    0.035490     0.355977       0.355977    0.070981
       0.000000    0.000000
2000   1     3     0     0     6     25     25.5   0.16    0.000000    0.000000
       0.000000    0.000000    0.000000     0.440690       0.214153    0.000000
       0.345157    0.000000
2001   1     3     0     0     6     13     13.5   0.56    0.000000    1.000000
       0.000000    0.000000    0.000000     0.000000       0.000000    0.000000
       0.000000    0.000000
2001   1     3     0     0     6     14     14.5   0.44    0.000000    0.785266
       0.214734    0.000000    0.000000     0.000000       0.000000    0.000000
       0.000000    0.000000
2001   1     3     0     0     6     15     15.5   0.16    0.000000    1.000000
       0.000000    0.000000    0.000000     0.000000       0.000000    0.000000
       0.000000    0.000000
2001   1     3     0     0     6     16     16.5   0.04    0.000000    1.000000
       0.000000    0.000000    0.000000     0.000000       0.000000    0.000000
       0.000000    0.000000
2001   1     3     0     0     6     18     18.5   1.12    0.000000    0.180512
       0.336145    0.374834    0.036102     0.042805       0.029602    0.000000
       0.000000    0.000000
2001   1     3     0     0     6     19     19.5   8.60    0.000000    0.019260
       0.212665    0.542250    0.196623     0.029202       0.000000    0.000000
       0.000000    0.000000
2001   1     3     0     0     6     20     20.5   29.88   0.000000    0.004228
       0.144369    0.540046    0.274000     0.033653       0.003704    0.000000
       0.000000    0.000000
2001   1     3     0     0     6     21     21.5   24.20   0.000000    0.005268
       0.054389    0.442968    0.358040     0.096638       0.027184    0.013860
       0.001654    0.000000
2001   1     3     0     0     6     22     22.5   11.32   0.000000    0.000000
       0.027393    0.277091    0.312453     0.204495       0.140915    0.033704
       0.003948    0.000000
2001   1     3     0     0     6     23     23.5   4.20    0.000000    0.000000
       0.000000    0.099383    0.261740     0.296962       0.255222    0.065471
       0.021223    0.000000
2001   1     3     0     0     6     24     24.5   1.36    0.000000    0.000000
       0.000000    0.000000    0.114003     0.296533       0.411512    0.113250
       0.064703    0.000000
2001   1     3     0     0     6     25     25.5   0.20    0.000000    0.000000
       0.000000    0.000000    0.000000     0.426327       0.573673    0.000000
       0.000000    0.000000
2002   1     3     0     0     6     16     16.5   0.32    0.000000    0.610794
       0.000000    0.000000    0.389206     0.000000       0.000000    0.000000
       0.000000    0.000000
2002   1     3     0     0     6     17     17.5   1.00    0.000000    0.053971
       0.337198    0.608831    0.000000     0.000000       0.000000    0.000000
       0.000000    0.000000
2002   1     3     0     0     6     18     18.5   2.40    0.000000    0.366922
       0.477941    0.133078    0.011029     0.011029       0.000000    0.000000
       0.000000    0.000000
2002   1     3     0     0     6     19     19.5   2.64    0.000000    0.081242
       0.447446    0.378318    0.003519     0.060968       0.000000    0.028507
       0.000000    0.000000
2002   1     3     0     0     6     20     20.5   8.84    0.000000    0.000968
       0.160285    0.290775    0.433370     0.088986       0.009744    0.015871
       0.000000    0.000000
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2002   1      3      0      0      6      21     21.5   54.32  0.000000      0.001384
       0.034230      0.202056      0.457164      0.231062      0.054866      0.015221
       0.004017      0.000000
2002   1      3      0      0      6      22     22.5   64.20  0.000000      0.001200
       0.007695      0.109576      0.405415      0.266606      0.132283      0.052513
       0.023910      0.000801
2002   1      3      0      0      6      23     23.5   30.20  0.000000      0.000275
       0.003044      0.070141      0.230022      0.308959      0.225169      0.116585
       0.045805      0.000000
2002   1      3      0      0      6      24     24.5   8.00   0.000000      0.000000
       0.000000      0.030318      0.153967      0.226058      0.195935      0.183646
       0.203080      0.006997
2002   1      3      0      0      6      25     25.5   1.92   0.000000      0.000000
       0.000000      0.000000      0.034118      0.034118      0.294865      0.380815
       0.228928      0.027155
2002   1      3      0      0      6      26     26.5   0.36   0.000000      0.000000
       0.000000      0.000000      0.000000      0.000000      0.000000      0.401760
       0.598240      0.000000
2003   1      3      0      0      6      13     13.5   0.08   0.000000      0.000000
       1.000000      0.000000      0.000000      0.000000      0.000000      0.000000
       0.000000      0.000000
2003   1      3      0      0      6      14     14.5   0.72   0.000000      0.298588
       0.701412      0.000000      0.000000      0.000000      0.000000      0.000000
       0.000000      0.000000
2003   1      3      0      0      6      15     15.5   0.36   0.000000      0.625000
       0.250000      0.125000      0.000000      0.000000      0.000000      0.000000
       0.000000      0.000000
2003   1      3      0      0      6      16     16.5   0.08   0.000000      0.000000
       0.000000      1.000000      0.000000      0.000000      0.000000      0.000000
       0.000000      0.000000
2003   1      3      0      0      6      17     17.5   2.96   0.000000      0.028899
       0.593881      0.299955      0.077265      0.000000      0.000000      0.000000
       0.000000      0.000000
2003   1      3      0      0      6      18     18.5   11.68  0.000000      0.046161
       0.480164      0.395415      0.057706      0.020554      0.000000      0.000000
       0.000000      0.000000
2003   1      3      0      0      6      19     19.5   15.92  0.000000      0.042405
       0.426503      0.362830      0.094365      0.042939      0.021084      0.009873
       0.000000      0.000000
2003   1      3      0      0      6      20     20.5   17.92  0.000000      0.017174
       0.297973      0.313883      0.133961      0.119094      0.058012      0.053303
       0.006600      0.000000
2003   1      3      0      0      6      21     21.5   20.92  0.000000      0.009540
       0.173881      0.210664      0.166575      0.204436      0.153824      0.054870
       0.026209      0.000000
2003   1      3      0      0      6      22     22.5   35.72  0.000000      0.004340
       0.021395      0.052615      0.101559      0.299392      0.261001      0.140538
       0.110454      0.008706
2003   1      3      0      0      6      23     23.5   27.04  0.000000      0.000000
       0.005814      0.036069      0.097599      0.222995      0.228554      0.200157
       0.185049      0.023763
2003   1      3      0      0      6      24     24.5   10.20  0.000000      0.009009
       0.001937      0.005762      0.045551      0.150182      0.203686      0.120177
       0.381845      0.081851
2003   1      3      0      0      6      25     25.5   2.60   0.000000      0.000000
       0.000000      0.033116      0.051151      0.149500      0.277747      0.132687
       0.348257      0.007541
2003   1      3      0      0      6      26     26.5   0.48   0.000000      0.000000
       0.000000      0.041303      0.000000      0.000000      0.000000      0.082606
       0.876091      0.000000
2003   1      3      0      0      6      27     27.5   0.08   0.000000      0.000000
       0.000000      0.000000      0.000000      1.000000      0.000000      0.000000
       0.000000      0.000000
2004   1      3      0      0      6      11     11.5   0.12   0.000000      0.000000
       1.000000      0.000000      0.000000      0.000000      0.000000      0.000000
       0.000000      0.000000
2004   1      3      0      0      6      12     12.5   0.44   0.000000      1.000000
       0.000000      0.000000      0.000000      0.000000      0.000000      0.000000
       0.000000      0.000000
```

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2004   1     3    0     0    6     13    13.5   2.60   0.000000   0.873254
       0.126746   0.000000   0.000000   0.000000   0.000000   0.000000
       0.000000   0.000000
2004   1     3    0     0    6     14    14.5   4.84   0.000000   0.827849
       0.146100   0.026052   0.000000   0.000000   0.000000   0.000000
       0.000000   0.000000
2004   1     3    0     0    6     15    15.5   4.24   0.000000   0.825249
       0.146346   0.024900   0.003505   0.000000   0.000000   0.000000
       0.000000   0.000000
2004   1     3    0     0    6     16    16.5   3.52   0.000000   0.915284
       0.084716   0.000000   0.000000   0.000000   0.000000   0.000000
       0.000000   0.000000
2004   1     3    0     0    6     17    17.5   10.12  0.000000   0.829120
       0.138110   0.032770   0.000000   0.000000   0.000000   0.000000
       0.000000   0.000000
2004   1     3    0     0    6     18    18.5   8.08   0.000000   0.705903
       0.183800   0.110297   0.000000   0.000000   0.000000   0.000000
       0.000000   0.000000
2004   1     3    0     0    6     19    19.5   4.44   0.000000   0.128497
       0.381799   0.420074   0.069630   0.000000   0.000000   0.000000
       0.000000   0.000000
2004   1     3    0     0    6     20    20.5   5.16   0.000000   0.067646
       0.227188   0.436327   0.205137   0.021234   0.042468   0.000000
       0.000000   0.000000
2004   1     3    0     0    6     21    21.5   10.08  0.000000   0.025073
       0.143171   0.401196   0.276653   0.081434   0.047374   0.000000
       0.025100   0.000000
2004   1     3    0     0    6     22    22.5   14.36  0.000000   0.013394
       0.073340   0.132515   0.127002   0.297820   0.206311   0.092164
       0.050261   0.007192
2004   1     3    0     0    6     23    23.5   19.20  0.000000   0.000000
       0.012716   0.044613   0.102141   0.220988   0.275935   0.153989
       0.158268   0.031350
2004   1     3    0     0    6     24    24.5   8.68   0.000000   0.000000
       0.016987   0.015802   0.051250   0.187655   0.404002   0.081292
       0.184503   0.058510
2004   1     3    0     0    6     25    25.5   1.84   0.000000   0.000000
       0.000000   0.025329   0.136455   0.149119   0.258451   0.207161
       0.157986   0.065499
2004   1     3    0     0    6     26    26.5   0.28   0.000000   0.000000
       0.000000   0.000000   0.000000   0.366231   0.000000   0.000000
       0.633769   0.000000
2005   1     3    0     0    6     12    12.5   0.08   0.000000   1.000000
       0.000000   0.000000   0.000000   0.000000   0.000000   0.000000
       0.000000   0.000000
2005   1     3    0     0    6     15    15.5   1.48   0.000000   0.000000
       0.918822   0.000000   0.081178   0.000000   0.000000   0.000000
       0.000000   0.000000
2005   1     3    0     0    6     16    16.5   7.36   0.000000   0.021172
       0.815695   0.158072   0.005061   0.000000   0.000000   0.000000
       0.000000   0.000000
2005   1     3    0     0    6     17    17.5   21.56  0.000000   0.006430
       0.783571   0.167511   0.034379   0.007326   0.000783   0.000000
       0.000000   0.000000
2005   1     3    0     0    6     18    18.5   13.36  0.000000   0.021428
       0.742551   0.185720   0.039205   0.007702   0.001344   0.000000
       0.002050   0.000000
2005   1     3    0     0    6     19    19.5   2.92   0.000000   0.018192
       0.641587   0.086551   0.167119   0.086551   0.000000   0.000000
       0.000000   0.000000
2005   1     3    0     0    6     20    20.5   1.32   0.000000   0.000000
       0.186444   0.211596   0.374785   0.112625   0.077642   0.000000
       0.036909   0.000000
2005   1     3    0     0    6     21    21.5   1.92   0.000000   0.000000
       0.108432   0.098211   0.573464   0.141124   0.078769   0.000000
       0.000000   0.000000
2005   1     3    0     0    6     22    22.5   3.16   0.000000   0.000000
       0.000000   0.030691   0.474579   0.151475   0.136797   0.125279
       0.062640   0.018539
```

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2005   1    3    0    0    6    23   23.5  6.56   0.000000   0.000000
       0.022707  0.015802  0.019418  0.162243    0.187714   0.097411
       0.378528  0.116176
2005   1    3    0    0    6    24   24.5  6.36   0.000000   0.000000
       0.000000  0.000000  0.013100  0.061901    0.120528   0.256460
       0.374074  0.173937
2005   1    3    0    0    6    25   25.5  1.48   0.000000   0.000000
       0.000000  0.000000  0.000000  0.050499    0.000000   0.201997
       0.522754  0.224750
2005   1    3    0    0    6    26   26.5  0.20   0.000000   0.000000
       0.000000  0.000000  0.000000  0.000000    0.000000   0.000000
       0.000000  1.000000
2006   1    3    0    0    6    17   17.5  0.24   0.000000   0.000000
       0.000000  0.517044  0.482956  0.000000    0.000000   0.000000
       0.000000  0.000000
2006   1    3    0    0    6    18   18.5  4.80   0.000000   0.000000
       0.043472  0.639661  0.164816  0.076025    0.040621   0.000000
       0.017702  0.017702
2006   1    3    0    0    6    19   19.5  14.92  0.000000   0.000000
       0.007279  0.640615  0.203558  0.083083    0.046459   0.000000
       0.019006  0.000000
2006   1    3    0    0    6    20   20.5  4.60   0.000000   0.000000
       0.012048  0.629248  0.245566  0.077579    0.006123   0.029435
       0.000000  0.000000
2006   1    3    0    0    6    21   21.5  0.72   0.000000   0.000000
       0.000000  0.281990  0.052866  0.156881    0.508263   0.000000
       0.000000  0.000000
2006   1    3    0    0    6    22   22.5  0.32   0.000000   0.000000
       0.000000  0.143805  0.611568  0.000000    0.000000   0.122314
       0.122314  0.000000
2006   1    3    0    0    6    23   23.5  0.52   0.000000   0.000000
       0.000000  0.051028  0.326323  0.051028    0.270812   0.245298
       0.055511  0.000000
2006   1    3    0    0    6    24   24.5  0.64   0.000000   0.000000
       0.000000  0.228810  0.047598  0.075579    0.023799   0.095196
       0.529018  0.000000
2006   1    3    0    0    6    25   25.5  0.20   0.000000   0.000000
       0.000000  0.000000  0.858254  0.044634    0.044634   0.052477
       0.000000  0.000000
2006   1    3    0    0    6    26   26.5  0.04   0.000000   0.000000
       0.000000  0.000000  0.000000  1.000000    0.000000   0.000000
       0.000000  0.000000
2007   1    3    0    0    6    16   16.5  0.04   0.000000   0.000000
       1.000000  0.000000  0.000000  0.000000    0.000000   0.000000
       0.000000  0.000000
2007   1    3    0    0    6    17   17.5  2.16   0.000000   0.000000
       0.237405  0.457802  0.276181  0.028613    0.000000   0.000000
       0.000000  0.000000
2007   1    3    0    0    6    18   18.5  18.64  0.000000   0.000000
       0.076835  0.575884  0.318022  0.026264    0.002994   0.000000
       0.000000  0.000000
2007   1    3    0    0    6    19   19.5  41.36  0.000000   0.000000
       0.030797  0.508917  0.393423  0.057622    0.006368   0.002874
       0.000000  0.000000
2007   1    3    0    0    6    20   20.5  23.40  0.000000   0.000000
       0.004374  0.329216  0.485827  0.143448    0.027008   0.007732
       0.002394  0.000000
2007   1    3    0    0    6    21   21.5  2.84   0.000000   0.000000
       0.017903  0.062489  0.606746  0.229746    0.083116   0.000000
       0.000000  0.000000
2007   1    3    0    0    6    22   22.5  0.44   0.000000   0.000000
       0.000000  0.219434  0.484781  0.109717    0.186068   0.000000
       0.000000  0.000000
2007   1    3    0    0    6    23   23.5  0.64   0.000000   0.000000
       0.000000  0.000000  0.090441  0.342360    0.311131   0.121670
       0.134398  0.000000
2007   1    3    0    0    6    24   24.5  0.28   0.000000   0.000000
       0.000000  0.000000  0.230263  0.261462    0.000000   0.092670
       0.415604  0.000000
```

2007	1	3	0	0	6	25	25.5	0.12	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.370935	0.629065
2007	1	3	0	0	6	27	27.5	0.04	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000
2008	1	3	0	0	6	17	17.5	0.88	0.000000	0.000000	0.080767	0.450034	0.356832	0.112366	0.000000	0.000000	0.000000	0.000000
2008	1	3	0	0	6	18	18.5	13.12	0.000000	0.000000	0.011848	0.320436	0.465292	0.195478	0.006947	0.000000	0.000000	0.000000
2008	1	3	0	0	6	19	19.5	32.20	0.000000	0.000000	0.000884	0.155359	0.576934	0.245631	0.018594	0.002598	0.000000	0.000000
2008	1	3	0	0	6	20	20.5	32.60	0.000000	0.000000	0.000000	0.058600	0.529805	0.347787	0.058123	0.002462	0.003223	0.000000
2008	1	3	0	0	6	21	21.5	10.96	0.000000	0.000000	0.000000	0.014751	0.360630	0.472976	0.109267	0.026327	0.016049	0.000000
2008	1	3	0	0	6	22	22.5	2.84	0.000000	0.000000	0.000000	0.037660	0.195012	0.360911	0.245838	0.122919	0.037660	0.000000
2008	1	3	0	0	6	23	23.5	1.28	0.000000	0.000000	0.000000	0.000000	0.213003	0.331888	0.228689	0.194014	0.032407	0.000000
2008	1	3	0	0	6	24	24.5	0.40	0.000000	0.000000	0.000000	0.000000	0.000000	0.074804	0.141732	0.179134	0.604330	0.000000
2008	1	3	0	0	6	25	25.5	0.08	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.791208	0.000000	0.208792	0.000000
2009	1	3	0	0	6	15	15.5	0.04	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	1	3	0	0	6	17	17.5	0.68	0.000000	0.000000	0.000000	0.428044	0.483143	0.033714	0.000000	0.055099	0.000000	0.000000
2009	1	3	0	0	6	18	18.5	11.80	0.000000	0.000000	0.020507	0.120375	0.463656	0.310610	0.080183	0.004669	0.000000	0.000000
2009	1	3	0	0	6	19	19.5	42.12	0.000000	0.000000	0.002269	0.035905	0.367415	0.373249	0.188276	0.029531	0.003354	0.000000
2009	1	3	0	0	6	20	20.5	31.76	0.000000	0.000000	0.002196	0.013425	0.214221	0.439131	0.259994	0.060784	0.010249	0.000000
2009	1	3	0	0	6	21	21.5	6.84	0.000000	0.000000	0.002125	0.005687	0.103187	0.447778	0.319858	0.102805	0.018562	0.000000
2009	1	3	0	0	6	22	22.5	0.56	0.000000	0.000000	0.000000	0.000000	0.048937	0.226954	0.460756	0.085502	0.177851	0.000000
2009	1	3	0	0	6	23	23.5	0.12	0.000000	0.000000	0.000000	0.000000	0.000000	0.838889	0.000000	0.161111	0.000000	0.000000
2009	1	3	0	0	6	24	24.5	0.04	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000
2010	1	3	0	0	6	16	16.5	0.60	0.000000	0.000000	0.769348	0.230652	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2010	1	3	0	0	6	17	17.5	0.68	0.000000	0.000000	0.000000	0.384674	0.461303	0.154023	0.000000	0.000000	0.000000	0.000000
2010	1	3	0	0	6	18	18.5	4.00	0.000000	0.000000	0.000000	0.167883	0.167971	0.469677	0.176775	0.017695	0.000000	0.000000

2010	1	3	0	0	6	19	19.5	26.64	0.000000	0.000000
	0.000000		0.048963		0.278756		0.386970		0.183333	0.089920
	0.012058		0.000000							
2010	1	3	0	0	6	20	20.5	30.28	0.000000	0.000000
	0.000000		0.010165		0.161805		0.404276		0.307602	0.095725
	0.020427		0.000000							
2010	1	3	0	0	6	21	21.5	8.44	0.000000	0.000000
	0.000000		0.000000		0.173464		0.353081		0.280132	0.162247
	0.031076		0.000000							
2010	1	3	0	0	6	22	22.5	1.04	0.000000	0.000000
	0.000000		0.000000		0.201114		0.392385		0.070103	0.266295
	0.070103		0.000000							
2010	1	3	0	0	6	23	23.5	0.16	0.000000	0.000000
	0.000000		0.000000		0.000000		0.000000		0.000000	1.000000
	0.000000		0.000000							
2005	2	8	0	0	7	11	11.5	0.04	1.000000	0.000000
	0.000000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2005	2	8	0	0	7	13	13.5	0.04	1.000000	0.000000
	0.000000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2005	2	8	0	0	7	15	15.5	0.12	0.000000	1.000000
	0.000000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2005	2	8	0	0	7	16	16.5	1.60	0.350000	0.650000
	0.000000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2005	2	8	0	0	7	17	17.5	1.80	0.088889	0.622222
	0.244444		0.044444		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2005	2	8	0	0	7	18	18.5	2.40	0.000000	0.683333
	0.316667		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2005	2	8	0	0	7	19	19.5	3.24	0.000000	0.567901
	0.407407		0.024691		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2005	2	8	0	0	7	20	20.5	1.92	0.020833	0.458333
	0.479167		0.020833		0.020833		0.000000		0.000000	0.000000
	0.000000		0.000000							
2005	2	8	0	0	7	21	21.5	0.56	0.000000	0.500000
	0.428571		0.000000		0.071429		0.000000		0.000000	0.000000
	0.000000		0.000000							
2005	2	8	0	0	7	22	22.5	0.12	0.000000	0.666667
	0.333333		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2005	2	8	0	0	7	24	24.5	0.08	0.000000	0.000000
	0.500000		0.000000		0.000000		0.000000		0.000000	0.000000
	0.500000		0.000000							
2005	2	8	0	0	7	25	25.5	0.16	0.000000	0.250000
	0.000000		0.250000		0.500000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2005	2	8	0	0	7	26	26.5	0.04	0.000000	0.000000
	0.000000		0.000000		0.000000		1.000000		0.000000	0.000000
	0.000000		0.000000							
2007	2	8	0	0	8	16	16.5	0.12	0.000000	0.333333
	0.666667		0.000000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2007	2	8	0	0	8	17	17.5	0.40	0.000000	0.000000
	0.800000		0.200000		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2007	2	8	0	0	8	18	18.5	0.96	0.000000	0.083333
	0.708333		0.208333		0.000000		0.000000		0.000000	0.000000
	0.000000		0.000000							
2007	2	8	0	0	8	19	19.5	1.00	0.000000	0.000000
	0.360000		0.520000		0.080000		0.040000		0.000000	0.000000
	0.000000		0.000000							
2007	2	8	0	0	8	20	20.5	2.84	0.000000	0.000000
	0.169014		0.661972		0.140845		0.028169		0.000000	0.000000
	0.000000		0.000000							

2007	2 8	0 0	8 21	21.5 4.96	0.000000	0.000000
	0.088710	0.733871	0.169355	0.008065	0.000000	0.000000
	0.000000	0.000000				
2007	2 8	0 0	8 22	22.5 3.40	0.000000	0.000000
	0.000000	0.776471	0.211765	0.011765	0.000000	0.000000
	0.000000	0.000000				
2007	2 8	0 0	8 23	23.5 0.80	0.000000	0.000000
	0.000000	0.750000	0.200000	0.050000	0.000000	0.000000
	0.000000	0.000000				
2007	2 8	0 0	8 24	24.5 0.24	0.000000	0.000000
	0.000000	0.500000	0.500000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2007	2 8	0 0	8 25	25.5 0.08	0.000000	0.000000
	0.000000	0.000000	0.500000	0.500000	0.000000	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 12	12.5 0.04	0.000000	1.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 14	14.5 0.04	0.000000	1.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 15	15.5 0.12	0.000000	0.666667
	0.333333	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 16	16.5 0.24	0.000000	0.666667
	0.333333	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 17	17.5 0.32	0.000000	0.625000
	0.375000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 18	18.5 0.16	0.000000	0.000000
	0.500000	0.500000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 19	19.5 0.36	0.000000	0.000000
	0.111111	0.666667	0.111111	0.111111	0.000000	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 20	20.5 2.72	0.000000	0.000000
	0.014706	0.411765	0.455882	0.117647	0.000000	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 21	21.5 8.12	0.000000	0.000000
	0.024631	0.295567	0.546798	0.118227	0.014778	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 22	22.5 9.72	0.000000	0.004115
	0.016461	0.251029	0.539095	0.156379	0.032922	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 23	23.5 4.16	0.000000	0.000000
	0.000000	0.221154	0.586538	0.173077	0.019231	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 24	24.5 0.96	0.000000	0.000000
	0.000000	0.208333	0.500000	0.166667	0.125000	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 25	25.5 0.08	0.000000	0.000000
	0.000000	0.500000	0.500000	0.000000	0.000000	0.000000
	0.000000	0.000000				
2009	2 8	0 0	9 26	26.5 0.16	0.000000	0.000000
	0.000000	0.000000	0.500000	0.000000	0.500000	0.000000
	0.000000	0.000000				
1982	1 1	0 0	2 9	28 -1	0.000000	0.034257
	0.528746	0.298514	0.109186	0.021972	0.007324	0.000000
	0.000000	0.000000				
1983	1 1	0 0	2 9	28 -1	0.323071	0.363497
	0.287600	0.025831	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000				
1985	1 1	0 0	2 9	28 -1	0.000000	0.392718
	0.542185	0.060441	0.004656	0.000000	0.000000	0.000000
	0.000000	0.000000				
1986	1 1	0 0	2 9	28 -1	0.030002	0.108060
	0.639928	0.215811	0.006200	0.000000	0.000000	0.000000
	0.000000	0.000000				

1987	1	1	0	0	2	9	28	-1	0.000477	0.622456
	0.252337		0.111946		0.012785		0.000000		0.000000	0.000000
	0.000000		0.000000							
1988	1	1	0	0	2	9	28	-1	0.000000	0.125056
	0.672795		0.151319		0.043426		0.007404		0.000000	0.000000
	0.000000		0.000000							
1989	1	1	0	0	2	9	28	-1	0.000000	0.546559
	0.370445		0.060729		0.020243		0.002024		0.000000	0.000000
	0.000000		0.000000							
1990	1	1	0	0	2	9	28	-1	0.005736	0.193117
	0.302103		0.281071		0.128107		0.061185		0.026769	0.001912
	0.000000		0.000000							
1991	1	1	0	0	2	9	28	-1	0.031731	0.260383
	0.438171		0.164256		0.064396		0.026132		0.008866	0.004666
	0.001400		0.000000							
1992	1	1	0	0	2	9	28	-1	0.001552	0.413887
	0.441427		0.098914		0.026377		0.013576		0.003491	0.000388
	0.000388		0.000000							
1993	1	1	0	0	2	9	28	-1	0.004107	0.047228
	0.492813		0.400411		0.045175		0.006160		0.004107	0.000000
	0.000000		0.000000							
1994	1	1	0	0	2	9	28	-1	0.027533	0.468062
	0.297357		0.183921		0.022026		0.001101		0.000000	0.000000
	0.000000		0.000000							
1995	1	1	0	0	2	9	28	-1	0.065254	0.524576
	0.359322		0.040678		0.010169		0.000000		0.000000	0.000000
	0.000000		0.000000							
1996	1	1	0	0	2	9	28	-1	0.003594	0.166816
	0.529200		0.252770		0.042528		0.004792		0.000000	0.000299
	0.000000		0.000000							
1997	1	1	0	0	2	9	28	-1	0.002620	0.411399
	0.373076		0.151982		0.049132		0.008844		0.002948	0.000000
	0.000000		0.000000							
1998	1	1	0	0	2	9	28	-1	0.032247	0.623074
	0.226442		0.069867		0.039771		0.005733		0.002508	0.000358
	0.000000		0.000000							
1999	1	1	0	0	2	9	28	-1	0.016216	0.657432
	0.262162		0.039865		0.018243		0.004054		0.002027	0.000000
	0.000000		0.000000							
2000	1	1	0	0	2	9	28	-1	0.031122	0.208456
	0.419260		0.318262		0.018790		0.003523		0.000587	0.000000
	0.000000		0.000000							
2001	1	1	0	0	2	9	28	-1	0.129689	0.224661
	0.285714		0.271748		0.063847		0.019553		0.003591	0.001197
	0.000000		0.000000							
2002	1	1	0	0	2	9	28	-1	0.206157	0.581157
	0.174440		0.027052		0.010261		0.000933		0.000000	0.000000
	0.000000		0.000000							
2003	1	1	0	0	2	9	28	-1	0.200160	0.371544
	0.380207		0.042800		0.004531		0.000759		0.000000	0.000000
	0.000000		0.000000							
2004	1	1	0	0	2	9	28	-1	0.003646	0.855330
	0.118615		0.015499		0.005375		0.000000		0.001535	0.000000
	0.000000		0.000000							
2005	1	1	0	0	2	9	28	-1	0.124701	0.392210
	0.452770		0.027341		0.002382		0.000398		0.000199	0.000000
	0.000000		0.000000							
2006	1	1	0	0	2	9	28	-1	0.035620	0.629630
	0.293614		0.040420		0.000715		0.000000		0.000000	0.000000
	0.000000		0.000000							
2007	1	1	0	0	3	9	28	-1	0.028525	0.281681
	0.561104		0.121745		0.006945		0.000000		0.000000	0.000000
	0.000000		0.000000							
2008	1	1	0	0	4	9	28	-1	0.062788	0.353708
	0.509380		0.061812		0.012313		0.000000		0.000000	0.000000
	0.000000		0.000000							
2009	1	1	0	0	4	9	28	-1	0.001640	0.241193
	0.624792		0.120679		0.011696		0.000000		0.000000	0.000000
	0.000000		0.000000							

```
2010   1      1      0      0      5      9      28     -1     0.053293     0.714652
       0.197234      0.033200      0.000000      0.000000      0.001621     0.000000
       0.000000      0.000000
1981   2      2      0      0      2      9      28     -1     0.098755     0.417995
       0.352364      0.103727      0.027158      0.000000      0.000000     0.000000
       0.000000      0.000000
1982   2      2      0      0      2      9      28     -1     0.000000     0.474273
       0.420444      0.096278      0.009005      0.000000      0.000000     0.000000
       0.000000      0.000000
1983   2      2      0      0      2      9      28     -1     0.000000     0.293665
       0.662163      0.039434      0.004737      0.000000      0.000000     0.000000
       0.000000      0.000000
1984   2      2      0      0      2      9      28     -1     0.013710     0.234339
       0.663874      0.088077      0.000000      0.000000      0.000000     0.000000
       0.000000      0.000000
1985   2      2      0      0      2      9      28     -1     0.002707     0.214279
       0.675366      0.106117      0.001531      0.000000      0.000000     0.000000
       0.000000      0.000000
1986   2      2      0      0      2      9      28     -1     0.013347     0.113393
       0.621308      0.235757      0.015474      0.000721      0.000000     0.000000
       0.000000      0.000000
1987   2      2      0      0      2      9      28     -1     0.001817     0.453467
       0.391106      0.127436      0.023484      0.002508      0.000182     0.000000
       0.000000      0.000000
1988   2      2      0      0      2      9      28     -1     0.033454     0.263110
       0.564195      0.101266      0.032550      0.003617      0.001808     0.000000
       0.000000      0.000000
1989   2      2      0      0      2      9      28     -1     0.016351     0.586919
       0.327883      0.064544      0.004303      0.000000      0.000000     0.000000
       0.000000      0.000000
1990   2      2      0      0      2      9      28     -1     0.074495     0.258349
       0.325505      0.195596      0.091009      0.027156      0.021284     0.005505
       0.001101      0.000000
1991   2      2      0      0      2      9      28     -1     0.110577     0.361538
       0.227404      0.158654      0.080288      0.042308      0.009615     0.006731
       0.002885      0.000000
1992   2      2      0      0      2      9      28     -1     0.174890     0.628838
       0.144737      0.036732      0.011513      0.002193      0.001096     0.000000
       0.000000      0.000000
1993   2      2      0      0      2      9      28     -1     0.171627     0.464286
       0.278770      0.053571      0.017857      0.009921      0.003968     0.000000
       0.000000      0.000000
1994   2      2      0      0      2      9      28     -1     0.381757     0.450246
       0.108108      0.052518      0.005835      0.001229      0.000307     0.000000
       0.000000      0.000000
1995   2      2      0      0      2      9      28     -1     0.272727     0.463790
       0.234720      0.023626      0.004623      0.000514      0.000000     0.000000
       0.000000      0.000000
1996   2      2      0      0      2      9      28     -1     0.354976     0.279126
       0.265777      0.074636      0.011529      0.013350      0.000607     0.000000
       0.000000      0.000000
1997   2      2      0      0      2      9      28     -1     0.177893     0.304548
       0.233161      0.198618      0.071963      0.011514      0.002303     0.000000
       0.000000      0.000000
1998   2      2      0      0      2      9      28     -1     0.285068     0.444344
       0.221267      0.033937      0.011312      0.004072      0.000000     0.000000
       0.000000      0.000000
1999   2      2      0      0      2      9      28     -1     0.266476     0.487679
       0.220057      0.018338      0.006304      0.000573      0.000573     0.000000
       0.000000      0.000000
2000   2      2      0      0      2      9      28     -1     0.230194     0.454908
       0.260090      0.045840      0.007972      0.000000      0.000000     0.000498
       0.000498      0.000000
2001   2      2      0      0      2      9      28     -1     0.646729     0.234579
       0.084579      0.028037      0.004673      0.001402      0.000000     0.000000
       0.000000      0.000000
2002   2      2      0      0      2      9      28     -1     0.180987     0.595442
       0.174335      0.037623      0.008158      0.003300      0.000077     0.000000
       0.000077      0.000000
```

```
2003    2     2     0     0     2     9     28    -1    0.833516    0.041170
        0.069308    0.033003    0.014688    0.003897    0.003535    0.000884
        0.000000    0.000000
2004    2     2     0     0     2     9     28    -1    0.080608    0.839148
        0.066600    0.011405    0.001316    0.000923    0.000000    0.000000
        0.000000    0.000000
2005    2     2     0     0     2     9     28    -1    0.539884    0.366314
        0.085027    0.005007    0.001290    0.000885    0.000708    0.000443
        0.000443    0.000000
2006    2     2     0     0     3     9     28    -1    0.192884    0.666349
        0.126485    0.013726    0.000557    0.000000    0.000000    0.000000
        0.000000    0.000000
2007    2     2     0     0     4     9     28    -1    0.421212    0.433120
        0.105717    0.033905    0.005434    0.000611    0.000000    0.000000
        0.000000    0.000000
2008    2     2     0     0     4     9     28    -1    0.198622    0.528342
        0.215326    0.055587    0.002123    0.000000    0.000000    0.000000
        0.000000    0.000000
2009    2     2     0     0     5     9     28    -1    0.441884    0.439656
        0.112942    0.003728    0.001789    0.000000    0.000000    0.000000
        0.000000    0.000000
2010    2     2     0     0     5     9     28    -1    0.504132    0.325277
        0.017494    0.025992    0.052903    0.065270    0.007558    0.000687
        0.000687    0.000000
1999    1     3     0     0     6     9     28    -1    0.000000    0.000000
        0.591516    0.200744    0.047586    0.129523    0.030632    0.000000
        0.000000    0.000000
2000    1     3     0     0     6     9     28    -1    0.000000    0.006618
        0.206591    0.391442    0.213536    0.109620    0.051579    0.012920
        0.007696    0.000000
2001    1     3     0     0     6     9     28    -1    0.000000    0.013198
        0.098825    0.433216    0.288073    0.096507    0.052477    0.014445
        0.003258    0.000000
2002    1     3     0     0     6     9     28    -1    0.000000    0.003766
        0.028886    0.141731    0.374978    0.245978    0.117474    0.056901
        0.029503    0.000783
2003    1     3     0     0     6     9     28    -1    0.000000    0.021023
        0.164251    0.158119    0.103102    0.182732    0.160233    0.098922
        0.099759    0.011858
2004    1     3     0     0     6     9     28    -1    0.000000    0.183211
        0.099132    0.148552    0.111072    0.146719    0.157173    0.067842
        0.071207    0.015092
2005    1     3     0     0     6     9     28    -1    0.000000    0.013560
        0.687544    0.144999    0.049115    0.020779    0.016360    0.017819
        0.035419    0.014405
2006    1     3     0     0     6     9     28    -1    0.000000    0.000000
        0.014971    0.608733    0.209052    0.079847    0.049039    0.009855
        0.024774    0.003730
2007    1     3     0     0     6     9     28    -1    0.000000    0.000000
        0.036842    0.453916    0.402431    0.081052    0.016571    0.004644
        0.003667    0.000878
2008    1     3     0     0     6     9     28    -1    0.000000    0.000000
        0.002384    0.122038    0.501659    0.304301    0.051440    0.011142
        0.007035    0.000000
2009    1     3     0     0     6     9     28    -1    0.000000    0.000000
        0.004977    0.038350    0.306740    0.390956    0.208582    0.042790
        0.007605    0.000000
2010    1     3     0     0     6     9     28    -1    0.000000    0.000000
        0.004864    0.035563    0.207821    0.390646    0.245312    0.098145
        0.017649    0.000000
2005    2     8     0     0     7     9     28    -1    0.069307    0.580858
        0.310231    0.019802    0.013201    0.003300    0.000000    0.000000
        0.003300    0.000000
2007    2     8     0     0     8     9     28    -1    0.000000    0.008108
        0.159459    0.654054    0.159459    0.018919    0.000000    0.000000
        0.000000    0.000000
2009    2     8     0     0     9     9     28    -1    0.000000    0.020588
        0.027941    0.273529    0.514706    0.136765    0.026471    0.000000
        0.000000    0.000000
#
0 #_N_MeanSize-at-Age_obs
```

```
#Yr Seas Flt/Svy Gender Part Ageerr Ignore datavector(female-male)
#samplesize(female-male)
0 #_N_environ_variables
0 #_N_environ_obs
0 # N sizefreq methods to read
#
0 # no tag data
#
0 # no morphcomp data
#
999
#
ENDDATA
```

Appendix 2

An Evaluation of the Consistency of Age-determination of Pacific Sardine (*Sardinops sagax*) Collected from Mexico to Canada

By

E. Dorval, J. McDaniel, K. Hill

NOAA FISHERIES
Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, CA 92037, USA

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1. Introduction

Since the 1990's Pacific sardine (*Sardinops sagax*) stocks have been assessed using age-structured models (Deriso et al. 1996, Conser et al. 2004, Hill et al. 2007, 2009). Although many of these models could include age-reading errors, a systematic estimation of these errors has never been conducted for sardine samples collected from both fishery dependent and independent surveys. Butler et al. (1996) used traditional methods (i.e., Beamish and Fournier 1981, Chang 1982) to assess age-reading imprecisions for fish collected during the 1994 Daily Egg Production Method (DEPM) survey, however these estimates could not be applied to fishery age-data time series used in past assessment models. Hill et al. (2007, 2009) also used traditional methods to compute the mean standard deviation-at-age (SD_a) for all agers that participated in a 2004 Tri-national sardine ageing workshop (i.e., involving age-readers from Mexico, the US and Canada). These estimates were included in Hill et al. (2007, 2009) assessment models, but they represented a snap shop in time and did not account for differences in age estimation between fisheries or laboratories. A major problem with using traditional methods is that these methods generally focused on computing either precision (i.e. Beamish and Fournier 1981, Chang 1982) or bias (Campana et al. 1995, Morison et al. 1998), but not on both. Thus, these methods are not appropriate to develop age-reading error matrices for use in stock assessment models (Punt et al. 2008).

The Pacific sardine 2009 Stock Assessment Review (STAR) Panel recommended that more systematic age-reading comparisons should be conducted in each of the major sardine ageing laboratories and that new analyses should be conducted to allow for better estimation and integration of age-reading errors in future assessment models. These recommendations were made based on two main reasons: (1) Age-reading errors can impact the performance of stock assessment models, smoothing out estimates of recruitment and total allowable catch (Reeves 2003), and potentially masking important stock-recruit relationship and the effects of environmental factors on year-class strength (Fournier and Archibald 1982, Richards et al. 1992); (2) New statistical models that can take account of both bias and precisions in estimating age-reading error matrices are now available (eg., Richards et al. 1992, Punt et al. 2008). These newer methods can estimate the true age distribution of a population, based on multiple age-readings of individual fish. Age-reading errors are represented using classification matrices that quantify the probability of a fish of true age a to be assigned an age a or some other age a', $P(a'|a)$. These models can estimate the parameters of various functions that can be used to determine the relationship between true age and estimated age. Because these statistical models are based on the maximum likelihood method, they can allow for considerable flexibility in the relationship between true age and the expectation and imprecision of the estimated age (Richards et al. 1992, Punt et al. 2008).

The otolith is the primary hard part used for ageing Pacific sardines collected in Mexico, the US and Canada. A methodology for determining age of Pacific sardine from whole (i.e., un-sectioned) otoliths was established by Yaremko (1996), and is currently used in ageing laboratories of Mexico and the US, although with slight variations among laboratories (see section 2.2. below). The method is straightforward and generally recommends that: (1) the age reader immerses the otolith in distilled water for about three minutes; and (2) the age reader counts the number of annuli observed on the proximal side of the otolith using a light microscope. An annulus is defined as the interface between an inner translucent growth increment and the successive outer opaque growth increment (Fitch 1951, Yaremko 1996). The method assumes a July 1 birthdate for all individual fish hatched in US waters within a calendar year. Pacific sardine have a prolonged spawning season, but in the early 1990s the majority of spawning used to occur in summer, justifying the assumption of a July 1 birthdate for the population off the west coast of the United States. Age assignment by readers is based on the capture date and the interpretation of the most distal pair of increments:

(1) Fish caught in the first semester of a calendar year have not yet reached their July 1 birth date; therefore their most distal pair of opaque and translucent increments should not be counted, even if exhibiting the early beginning of a second opaque increment (Yaremko 1996, Page 12).
(2) Fish caught in the second semester of a calendar year have completed a year since their last birthdate; therefore their age is equal to the number of annuli counted in their otolith.
(3) The marginal increment is categorized as opaque or translucent, wide or narrow, allowing a confidence rating to be assigned to the age determination.

The California Fish and Game (CDFG), the Washington Department of Fish and Wildlife (WDFW) and the Southwest Fisheries Science Center (SWFSC) have used this method for annual production ageing of Pacific sardine samples collected from the California, Oregon and Washington commercial fisheries, and from the DEPM survey since the 1990s. However, McFarlane et al. (2010) proposed an alternative method to age fish older than 1 collected in British Columbia waters. McFarlane et al. (2010) method consists in:

(1) Fixing the otolith on a microscope slide (sulcus side down) using the thermal resin Crystalbond^{TM} ;
(2) Polish the otolith using fine sand paper (600-800 grit);
(3) Age the otolith under a microscope using reflected light.

Comparing their method to Yaremko (1996)' otolith surface ageing, McFarlane et al. (2010) found that the polished otolith method could improve the identification of the first and the second annulus. In addition fish aged from the polished otolith method were found to be 1 to 3 years older than when aged from surface ageing. However, the polished otolith method is not currently being used for ageing fish collected off British Columbia (BC), because the method needs further evaluation particularly for fish collected in US and Mexico waters. Hence, the otolith surface ageing remains the primary method used for production ageing at the Pacific Biological Station (PBS, Nanaimo-BC).

The general goal of this paper was to summarize Pacific sardine age-reading works that have been conducted since 2004 in various ageing laboratories, and to estimate age-reading errors matrices that are suitable to be integrated in current assessment models. In particular we had three main objectives:

1) Estimate ageing-error matrices for the major fisheries and surveys of Pacific sardine. More specifically we compared ageing precision estimated from traditional methods to estimates derived from the Age-reading Error Matrix Estimator developed by Punt et al. (2008, here and thereafter referred as the Agemat model).
2) Determine which sets of ageing error matrices to be used in the 2011 stock assessment, given age data reporting from different laboratories and Stock Synthesis 3 model configurations.

3) Identify potential issues in the current ageing process and determine future research needs for improving the consistency of age determination of Pacific sardines.

2. Method

2.1. Sample Collection

Pacific sardines were collected from the DEPM survey and from port sampling of commercial fishery landings from Mexico to Canada. DEPM samples were collected during the 2004-2010 April surveys from San Diego to San Francisco (CA). Port sampling data were collected using various designs (Hill et al. 2009), but were assumed to be representative of four major fisheries: Ensenada (ENS, Mexico), California (CA, including the southern and central California fisheries), the Pacific Northwest (PNW, including Oregon, Washington) and British the Columbia (BC) fisheries. For details about the surveys and port samplings we refer the readers to Nancy et al. (2009), Hill et al. (2009), and McFarlane et al. (2010).

2.2. *Age-reading Data*

Pacific sardines were aged from otoliths by agers located at five ageing laboratories: (1) The Centro Interdisciplinario de Ciencas Marinas-Instituto Politécnico Nacional (CICIMAR-IPN, Baja California Sur, Mexico); (2) The California Department of Fish and Game (CDFG, CA, US); (3) The Southwest Fisheries Science Center (SWFSC, CA, US); (4) The Washington Department of Fish and Wildlife (WDFW, WA, US); and (5)The Pacific Biological Station (PBS) of the Department of Fisheries and Ocean (DFO, BC, Canada). All laboratories used the conventional technique of otolith age-readings described in Yaremko (1996) with slight variations. Age-reading data from each fishery and survey were organized in data sets, which were defined as sets of otoliths that were aged by the same set of agers. Each ager was provided with a unique identification number, and the number of readers per data set is presented in Table 1. All agers used in this study were certified agers, but with varying degree of experience.

2.2.1. ENS Fishery Age-readings

Pacific sardines samples were collected in Magdalena Bay during the 2005 fishing season. Fish collected in the Magdalena and Ensenada fisheries were aged by a single age reader (Ager 13), and thus we assumed that age-reading errors for Magdalena fish can be applied to the Ensenada fishery. Whole sardine otoliths were fixed on glass slides (sulcus side down) using glue. Otoliths were first read on December 2006 and then double-read on June 2011. A summary of the age-reading data, along with frequency of observations, is presented in Table 2. Ager 13 reported the final age assigned to an individual fish based on the number of annuli counted, and thus no birthdates were assumed.

2.2.2. CA Fishery Age-readings

Pacific sardines samples were collected from port landings of the southern California fishery (San Pedro to Santa Barbara) and central California fishery (Monterey Bay region) from 2005 to 2011. Whole otoliths were immersed in distilled water and then read multiple times from the distal side. Depending on the year of collection 3 to 5 CDFG agers participated in the age reading process. Data sets were built based on time of collection (one to two years) using only complete reported age-readings among agers (i.e., observations containing one or more missing values were discarded). The CA age-reading data sets, including frequency of observations, are summarized in Table 3. Each ager reported the final age assigned to an individual fish caught in California based on the capture date and a July 1 birthdate.

2.2.3. PNW Fishery Age-readings
Pacific sardines samples were collected from port landings in Oregon. Landings were sampled in July and September of 2009. Whole otoliths were immersed in alcohol and then read from the distal side using a light microscope. All otoliths were read by two WDFW age readers (Ager 8 and 9). The PNW age-reading data set, including frequency of observations, is presented in Table 4. Agers 8 and 9 reported the final age assigned to an individual fish based on the capture date and a July 1 birthdate.

2.2.4. *BC fishery Age-readings*
British Columbia samples were collected from July to September of 2007. Whole otoliths were first read separately by two age readers (Ager 10 and 11). Then, each otolith was re-read again simultaneously by both agers to estimate a best/resolved age (RA). Age data from these three readings, including frequency of observations, are presented in Table 5. Final age was assigned to individual fish based on the capture date and a January 1 birthdate. Finally, in this paper we assumed that the resolved age was more likely to be unbiased.

2.2.5. DEPM Survey Age-readings
Pacific sardine samples were collected during the April DEPM cruises from 2004 to 2011. Otoliths were extracted either at sea or in the laboratory, dried and then stored in conical vials. Whole otoliths were immersed in distilled water and then read from the distal side, using a light microscope. Age determinations were done by Agers 1 and 2 from CDFG and Ager 12 from the SWFSC. Two data sets containing the age readings from the three readers, including frequency of observations, are presented in Table 6. All three agers assigned a final age to individual fish based on the capture date and an assumed July 1 birthdate.

2.3. Ageing Error Estimation
2.3.1. *Traditional methods*
Pairwise comparisons of age readings were performed using age bias plots between readers (Campana et al. 1995). These graphs consist in plotting the mean age estimated by an ager against the single predicted age for a group of fish reported by the most experienced ager (*i.e.*, assumed to be more likely unbiased). These plots may allow detecting both systematic and non-systematic bias between agers. These plots were also used as exploratory tools to determine a potential relationship between true age and age-reading precisions.
Further, from each dataset we computed the standard deviation of ages estimated for an individual fish *j*, following Equation 1:

$$SD_j = \sqrt{\sum_{i=1}^{R} \frac{(a_{i,j} - a_j)^2}{R-1}}, \quad (1)$$

where *R* is the number of readers, a_{ij} the age reported by reader *i* for fish *j;* and a_j is the mean age estimated for fish *j*. Similarly as in previous sardine stock assessment (i.e., Hill et al. 2007, 2009), the *SD* at age *a* (SD_a) reported in a given data set was estimated by Equation 2.

(2) $$SD_a = \frac{\sum_{j=1}^{n} SD_j}{n},$$

where n is the number of fish that was assigned an age a at least by one reader.

2.3.2. *Statistical Model*

We used the Agemat model developed by Punt et al. (2008) to estimate age-reading error matrices by reader. The model computed ageing error matrices based on otoliths that have been aged multiple times by one or more agers, while assuming that: (1) ageing bias depends on ager and the true age of a fish; (2) the age-reading error standard deviation depends on ager and true age; and (3) age-reading error is normally distributed around the expected age. Hence, the probability to assign an age *a*' to a fish of true age *a* is computed following Equation 3 (see also Punt: Agemat user manual):

(3) $$P^i(a'|a,\emptyset) = \int_{a'}^{a'+1} \frac{1}{\sqrt{2\pi\sigma_a^i(\emptyset)}} \exp\left[\frac{-\left(a' - b_a^i(\emptyset)\right)^2}{2\left(\sigma_a^i(\emptyset)\right)^2}\right] da',$$

where b_a^i is the expected age when ager *i* determines the age of a fish of true age a, σ_a^i is the standard deviation for ager *i* of the age reading error for fish whose true age is a, and ϕ is the vector of parameters that determines the age reading error matrices. The values for these parameters are estimated by maximizing the following likelihood function, assuming there was some set of *J* ageing structures that were read by all readers:

(4) $$L(A|\beta,\emptyset) = \prod_{j=i}^{J} \sum_{a=L}^{H} \beta_a \prod_{i=1}^{I} P^i\,(a_{i,j}|a,\emptyset)$$

where a_{ij} is the age assigned by ager *i* to the j^{th} ageing structure; *L* and *H* are respectively the minimum and the maximum ages, and *A* is the entire data set of age-readings. The βs are nuisance parameters that can be interpreted as the relative frequency of fish of true age *a* in the sample.

For the purpose of this study we were mostly interested in estimating the *SD*s for the different fisheries and surveys. Agemat model typically estimates ageing errors by reader, however, age data input and precisions cannot be included in Stock Synthesis 3 by ager. As an alternative we defined various model scenarios, comparing models that assumed equal or unequal *SD*s among agers for each fishery and the survey. Then, we used AICc (Akaike Information Criterion with a correction for finite sample sizes) to select the best model, and determine whether there was enough evidence to support the assumption of equality of *SD*s among agers for the age-reading data sets considered in a given model.

We assumed that the functional form of random ageing error precisions followed either Equation 5 or 6 below.

(5) $$\sigma_a = \sigma_L + (\sigma_H - \sigma_L)\frac{1-\exp(-\delta(a-1))}{1-\exp(-\delta(a_{max}-1))}$$

where, σ_L and σ_H are respectively the standard deviation of the minimum and the maximum age in a given data set, and δ is a parameter that determines the extent of linearity between age and the age-reading standard deviation.

(6) $$CV_a = CV_L + (CV_H - CV_L)\frac{1-\exp(-\delta(a-1))}{1-\exp(-\delta(a_{max}-1))}$$

where CV_L and CV_H are respectively the coefficient of variation of the minimum and the maximum age in a given data set.
For the DEPM survey, the PNW and BC fisheries we also performed model runs where bias was estimated. In these cases, the most experienced agers were assumed to be unbiased, whereas the functional form for ageing bias for all other readers was assumed to follow Equation 7:

(7) $$E_a = E_L + (E_H - E_L)\frac{1-\exp(-\beta(a-1))}{1-\exp(-\beta(a_{max}-1))}$$

where E_a is the expected age of a fish of age a, E_L and E_H are respectively the minimum and the maximum ages in a given data set; a_{max} is a pre-specified maximum age; and β is a parameter that determines the extent of linearity between age and the expected age.
For all model runs the maximum expected age for sardine was set to be 15. Further, the maximum *SD* allowed in model runs was 100.

3. Results:

3.1. ENS Age-reading Errors

Pairwise comparison of age-reading 1 and 2 performed by Ager 13 for the ENS fishery, showed no bias in estimating age 0 through age 3. However, the second reading slightly underestimated age 4 compared to the first reading (Figure 1).
No bias was estimated from the Agemat model for the ENS fishery, but *SD* was estimated assuming that Ager 13 had equal *SD* in both readings. Estimates of *SD* from the ENS model are compared to traditional method's estimates in Table 7. Model fits to the ENS age-reading data set are presented in Figure 2.

3.2. CA Fishery Age-reading Errors

The CA fishery age-reading errors were estimated by date of sample collection. Both the number of readers involved in the age-reading process varied over time. In general there was little bias among readers from ages 0 to 2, except for Ager 5 for the 2007 and 2008-2009 data sets. Bias among readers was more significant for the age 3-6 group which occurs at a lower frequency in the CA data sets. Age bias plots and Agemat model fits to the CA age-reading data sets are presented in Figures 3 to 11.
No bias was estimated from the Agemat model for the CA fishery age-reading data sets. Model comparisons for the different time periods are presented in Table 8. In each of the time period considered, the models that assumed equal *SD* among agers had lower *AICc* than the models that assumed different *SD*s. In Table 7 we compare *SD*s estimated from the traditional method to estimates from the Agemat model that assumed equal *SD* among agers. Note that both model CA_0809 A and CA_0809_B did not fit well to the age-reading data set # 4, but changing the assumption on the functional form of the random ageing error precision could not improve these fits.

3.3. PNW Fishery Age-reading Errors

Pairwise comparison of age-reading showed that Ager 9 overestimated age 2, but underestimated age 7 compared to reader 8 (Figure 12). Agemat models with bias and no bias estimation are compared in Table 8. The model PNW_C that assumed no bias but equal *SD* between the two agers had the lowest *AICc* value. *SD*s estimated from model PNW_C are compared to traditional method estimates in Table 7. Model fits to the age-reading data set are presented in Figure 13.

3.4. BC Fishery Age-reading Errors
From age 2 to 5 Agers 10 and 11 showed no bias compared to the resolved age (RA) between these two readers. However, both readers underestimated age 6 to age 8 compared to the RA (Figure 8). Agemat model with bias and no bias estimation are compared in Table 8 for this fishery. The model BC_C that assumed no bias but equal *SD* had the lowest *AICc*. The *SD*s estimated from model BC_C are compared to *SD*s from the traditional method in Table 7. Model fits for the different data sets are presented in Figure 15.

3.5. DEPM Survey Age-reading Errors
Bias in the DEPM age-readings appeared to be non-systematic, *i.e.* Ager 12 over-estimated ages 0 to 3 but under-estimated ages 5 to 8 compared to Agers 1 and 2 (Figure 9). Agemat models with bias and no bias estimation are compared in Table 8. In Table 7, the *SD*s estimated from model DEPM_C are compared to estimates from the traditional method. Model fits to the two age-reading data sets are presented in Figure 17. Note that the model DEPM_C did not fit well to the the age-reading data sets, but changing the assumption on the functional form of the random ageing error precision could not improve these fits.

4. Discussion

4.1. Age-reading precision
Estimates of age-reading precision from the traditional method and the Agemat models were different. The traditional method estimation of standard deviation-at-age involved averaging across all fish that were assigned a given age *a* by one or more readers. Hence, this method assumed that all agers were unbiased, but without a mean to determine whether this assumption was appropriate. In contrast, with the Agemat model we assumed that all agers had equal standard deviation, but used an information criterion (*AICc*) to determine whether there was enough evidence in the age-reading data sets to support this assumption (i.e., when compared to alternative models). Although the Agemat model typically estimates age-reading precision by ager, the assumption of equality of standard deviation among agers was needed because ageing errors cannot be included by ager in the Stock Synthesis 3 model. The application of the Agemat model in this study provides a good example of the type of flexibility allowed by a statistical model compared to traditional method of estimating age-reading precision.
In general, estimates of standard deviation from the Agemat models that assumed equality of standard deviation among agers are within the range of expectation, and thus can be applied to the stock assessment model. Note that although we estimated ageing errors for the BC fishery, these estimates cannot be used in the 2011 stock assessment model because no age data were provided for the British Columbia fishery.

4.2. Age-reading accuracy

Although, the estimation of bias was not the primary focus of this study, we conducted Agemat model runs that estimated bias for the PNW and the BC fisheries and the DEPM survey. However, models that estimated bias were not selected because they had higher AICc values than those that assumed equal or unequal standard deviation among readers.

Most of the concerns regarding bias remain with ageing fish older than four years-old (i.e., the age 5^+- group). This age group is more frequent in the PNW and BC fisheries, and the DEPM survey. Interpreting increments at the edge of otoliths was challenging for all agers, because when ageing from whole otolith it is often difficult to differentiate a check mark from an annulus. For example, in the first year of life a wide opaque increment near the focus followed by a fine translucent ring can be interpreted as a check mark; whereas the same mark present in a more distal area of the otolith may be considered as an annulus (Yaremko 1996). The polished otolith method (McFarlane et al. 2010) may be an alternative method to reduce the level of bias currently observed among agers.

Regardless of the method used, a fundamental problem with ageing Pacific sardine is that there are no known-aged fish to determine age-reading accuracy. CDFG has established a Training Set of Otoliths (*TSO*) that has been used to train and certify new age readers. However, the *TSO* does not include any fish whose ages were validated, and thus cannot be used to directly address issues concerning ageing bias. The periodicity of sardine growth increments have been validated in juvenile fish (Butler 1987, Barnes and Foreman 1994), but to our knowledge validation of annulus in older mature fish has never been conducted. Validation of increments in young fish cannot be applied to older fish. In the absence of known age fish, the lack of verification of increment formation in each and every age group can lead to systematic bias in age determination (Campana 2011). Such systematic bias cannot be accounted by statistical models and need to be addressed via field/laboratory experiments.

5. Recommendations

- Final Stock Synthesis model runs for the 2011 Pacific sardine assessment can be based on estimates of standard deviation-at-age from the Agemat models that assumed equality of standard deviation among agers. These models had the lowest AICc values when compared to models that did not assumed equality of standard-deviation among agers, and thus were selected as the best models for the age-reading data sets considered in this study.

- Although estimates of standard deviation-at-age for the Ensenada and the PNW fishery were based on single year of collection, these errors can be applied to the entire time series of age data input for each fishery in the Stock Synthesis 3 model. These time series of age data were produced by the same agers in each fishery, and thus it can be assumed that ageing-errors did not vary over time for the Ensenada and the PNW fishery.

- Use time-varying estimates of standard deviation-at-age for the California fishery and the DEPM survey. These estimates account for turnover among readers and adjustments in age determination made by the CDFG and the SWFSC ageing laboratories.

6. Research needs

Several measures can be taken to improve both bias and precision of age determination of Pacific sardine:

- As ageing error can vary over time, and because of turnover among readers within laboratory, there is need for each ageing laboratory to conduct multiple readings of otolith samples on a yearly basis, similarly as being done by CDFG.

- Conduct growth experiment in the laboratory toward understanding the deposition of growth increment and check marks in both young and old Pacific sardines.

- Conduct a study to compare the surface and the polished otolith methods for Pacific sardine caught in Mexico and US waters.

- Develop an exchange program of otolith age-reading comparison between the different laboratories toward the standardization of the ageing method of Pacific sardine.

- Resolving the problem of bias in age determination of Pacific sardines would require mark-recapture data. In the last tagging experiment conducted by Clark and Jansen (1945) otoliths were not extracted or preserved. Any repeat of this experiment in the future can provide valuable data for the validation of sardine ages.

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Table 1. Summary of number of Pacific sardine otoliths (N) aged by reader and by year for each fishery or survey. **N** is the sample size, number of otoliths with age readings reported by all agers.

Ageing Laboratory	Fishery/Survey	Data set #	Collection Year	Number of Agers	Ager ID	Number of readings	N
CICIMAR-INP	ENS	1	2005	1	13	2	240
CDFG	CA	1	2005	3	1,2,3	3	219
		2	2007	4	2,4,5,6	4	148
		3	2008-2009	5	2,4,5,6,7	5	507
		4	2008-2009	4	2,5,6,7	4	145
		5	2010-2011	3	2,5,6	3	266
WDFG	PNW	1	2009	2	8,9	2	711
PBS	BC	1	2007	2	10,11	3	283
CDFG-SWFSC	DEPM	1	2004, 2006	2	1,12	2	360
		2	2006, 2008, 2009	2	2,12	2	360

Table 2. Age readings data reported by ager 13 for the Ensenada fishery. **n** is the frequency of observed otoliths for each unique age-reading combination.

			Age assigned from	
Fishery	**Data set**	**n**	**Reading 1**	**Reading 2**
ENS	1	19	0	0
		1	1	0
		150	1	1
		3	1	2
		4	2	1
		24	2	2
		5	3	2
		28	3	3
		3	4	3
		3	4	4

Table 3. Age readings data reported by agers and data set for Pacific sardines samples collected in the California fishery from 2005 to 2011. **n** is the frequency of observed otoliths for each unique age-reading combination.

				Age assigned by						
Fishery	**Collection Year**	**Data set #**	**n**	**Ager 1**	**Ager 2**	**Ager 3**	**Ager 4**	**Ager 5**	**Ager 6**	**Ager 7**
CA	2005	1	26	0	0	0				
			2	0	0	1				
			6	1	0	0				
			1	1	0	1				
			4	1	1	0				
			82	1	1	1				
			2	1	1	2				
			2	1	2	1				
			1	1	2	2				
			9	2	1	1				
			7	2	1	2				
			1	2	1	3				
			6	2	2	1				
			65	2	2	2				
			2	2	3	2				
			1	3	2	2				
			2	3	3	2				
	2007	2	1		1		1	1	0	
			57		1		1	1	1	
			8		1		1	1	2	
			4		1		1	2	1	
			1		1		1	2	2	
			2		1		1	3	1	
			1		2		1	1	2	
			3		2		1	2	1	
			1		2		2	1	2	
			8		2		2	2	1	
			48		2		2	2	2	
			6		2		2	2	3	
			1		2		2	3	1	
			2		2		2	3	2	
			1		2		2	4	2	
			1		3		2	2	1	
			1		3		2	3	1	
			1		3		2	3	2	
			1		3		2	3	3	

Table 3 Continued.

				Age assigned by						
Fishery	**Collection Year**	**Data set #**	**n**	**Ager 1**	**Ager 2**	**Ager 3**	**Ager 4**	**Ager 5**	**Ager 6**	**Ager 7**
CA	2008-2009	3	1		2		1	2	2	2
			1		2		2	0	1	1
			11		2		2	1	1	1
			3		2		2	1	2	1
			4		2		2	1	2	2
			1		2		2	1	4	1
			4		2		2	2	1	1
			2		2		2	2	1	2
			15		2		2	2	2	1
			33		2		2	2	2	2
			2		2		2	2	3	1
			7		2		2	2	3	2
			1		2		2	2	3	3
			1		2		2	2	4	2
			1		2		2	3	2	0
			5		2		2	3	2	1
			15		2		2	3	2	2
			2		2		2	3	2	3
			1		2		2	3	3	0
			9		2		2	3	3	1
			9		2		2	3	3	2
			1		2		2	4	3	1
			2		2		2	4	3	2
			1		2		2	4	3	3
			1		2		2	4	4	2
			1		2		3	1	1	1
			4		2		3	1	2	2
			5		2		3	1	3	2
			2		2		3	2	2	2
			1		2		3	2	3	2
			3		2		3	3	2	1
			3		2		3	3	2	2
			1		2		3	3	3	1
			1		2		3	3	3	2
			2		2		3	4	2	1
			2		2		3	4	3	1
			2		2		3	4	3	2
			1		2		3	4	4	1
			1		2		3	4	4	2
			1		2		3	4	5	2
			2		2		3	5	3	2
			1		2		3	5	4	2
			3		2		4	4	3	2
			1		2		4	5	3	2
			1		2		4	6	3	2
			1		3		2	2	3	2
			2		3		3	2	4	3
			1		3		3	3	2	2
			1		3		3	4	3	3
			2		3		4	4	3	2
			1		4		4	5	4	2

Table 3. Continued.

				Age assigned by						
Fishery	**Collection Year**	**Data set #**	**n**	**Ager 1**	**Ager 2**	**Ager 3**	**Ager 4**	**Ager 5**	**Ager 6**	**Ager 7**
			29		0		0	0	0	0
			2		0		0	0	1	0
			28		0		0	1	0	0
			1		0		0	1	0	1
			20		0		0	1	1	0
			5		0		0	1	1	1
			4		0		0	1	2	0
			1		0		0	1	2	1
			6		0		0	2	0	0
			5		0		0	2	1	0
			1		0		0	2	1	1
			5		0		1	1	0	0
			1		0		1	1	1	0
			1		0		1	2	0	0
			2		0		1	2	1	0
			1		1		0	0	1	0
			9		1		0	1	0	0
			6		1		0	1	1	0
			1		1		0	1	1	1
			2		1		0	1	2	1
			2		1		0	2	1	0
			1		1		1	0	1	1
			5		1		1	1	0	0
			10		1		1	1	0	1
			18		1		1	1	1	0
CA	2008-2009	3	81		1		1	1	1	1
			2		1		1	1	1	2
			2		1		1	1	2	0
			10		1		1	1	2	1
			3		1		1	2	1	0
			8		1		1	2	1	1
			2		1		1	2	1	2
			4		1		1	2	2	1
			1		1		1	2	2	2
			13		1		2	1	1	1
			5		1		2	1	2	1
			3		1		2	2	1	1
			7		1		2	2	2	1
			2		1		2	2	3	1
			2		1		2	3	2	1
			1		1		2	3	3	2
			1		1		2	4	3	1
			1		1		3	3	1	0
			1		1		3	3	4	1
			1		1		3	4	4	1
			3		2		1	1	0	1
			1		2		1	1	1	0
			5		2		1	1	1	1
			1		2		1	1	2	2
			1		2		1	2	2	0
			1		2		1	2	2	1

Table 3. Continued.

Fishery	Collection Year	Data set #	n	Age assigned by Ager 1	Ager 2	Ager 3	Ager 4	Ager 5	Ager 6	Ager 7
CA	2008-2009	4	17		1			1	1	1
			11		1			2	1	1
			4		1			2	2	1
			2		1			3	1	1
			3		2			1	1	1
			2		2			1	2	1
			1		2			1	2	2
			1		2			2	1	1
			4		2			2	1	2
			9		2			2	2	1
			43		2			2	2	2
			2		2			2	2	3
			2		2			2	3	2
			13		2			3	2	2
			4		2			3	3	3
			2		2			4	2	3
			1		3			1	2	1
			1		3			1	2	2
			1		3			2	2	1
			4		3			2	2	2
			1		3			2	2	3
			1		3			2	3	1
			1		3			2	3	2
			4		3			3	2	2
			2		3			3	2	3
			1		3			3	3	2
			3		3			3	3	3
			1		4			3	3	2
			1		4			3	3	4
			2		4			4	3	2
			1		4			4	3	3
	2010-2011	5	81		0			0	0	
			7		0			0	1	
			5		0			1	0	
			9		1			0	0	
			10		1			1	0	
			97		1			1	1	
			3		1			2	1	
			1		2			1	0	
			1		2			1	2	
			3		2			2	1	
			17		2			2	2	
			1		3			2	2	
			3		3			3	2	
			7		3			3	3	
			1		3			3	4	
			1		4			3	3	
			3		4			4	4	
			2		5			4	4	
			1		5			4	5	
			4		5			5	4	
			8		5			5	5	
			1		6			6	5	

Table 4. Age readings data reported by agers 8 and 9 for the PNW fishery. Pacific sardines samples were collected in 2009 from port landings in Oregon. **n** is the frequency of observed otoliths for each unique age-reading combination.

			Age assigned by	
Fishery	**Data set #**	**n**	**Reader 8**	**Reader 9**
PNW	1	3	2	3
		1	2	4
		16	3	3
		29	3	4
		1	3	5
		4	4	3
		178	4	4
		82	4	5
		2	4	6
		3	5	3
		33	5	4
		199	5	5
		42	5	6
		1	5	7
		2	6	4
		31	6	5
		67	6	6
		4	6	7
		1	6	8
		8	7	6
		3	7	7
		1	7	8

Table 5. Age reading data reported by agers 10 and 11 for the BC fishery. Pacific sardines samples were collected off British Columbia in 2007. **n** is the frequency of observed otoliths for each unique age-reading combination. Resolved age (RA) was assigned after both agers re-read an otolith together and agreed on a final age.

			Age assigned by		
Fishery	**Data set #**	**n**	**Reader 10**	**Reader 11**	**RA**
BC	1	10	3	3	3
		1	3	3	4
		1	3	3	5
		1	3	4	3
		12	3	4	4
		5	3	4	5
		1	3	5	3
		3	3	5	4
		4	3	5	5
		1	4	3	3
		2	4	3	4
		1	4	3	5
		87	4	4	4
		1	4	4	5
		1	4	4	6
		1	4	4	7
		1	4	4	8
		13	4	5	4
		19	4	5	5
		4	4	5	6
		2	4	6	4
		3	4	6	5
		1	4	6	6
		25	5	4	4
		2	5	4	6
		1	5	5	4
		34	5	5	5
		1	5	6	4
		7	5	6	5
		6	5	6	6
		1	5	6	7
		1	5	6	8
		1	5	7	5
		1	5	7	6
		2	5	7	7
		2	5	8	5
		1	5	8	7
		1	6	4	4
		1	6	4	5
		2	6	5	5
		5	6	5	6
		1	6	5	7
		6	6	6	6
		1	6	6	7
		1	6	7	7
		1	7	7	4
		1	7	7	7
		1	7	7	8
		2	8	8	8

Table 6. Age readings data reported by agers 1, 2, and 12 for the DEPM survey. Pacific sardines samples were collected in the April DEPM survey in 2004, 2006, 2008, 2009, and 2010. **n** is the frequency of observed otoliths for each unique age-reading combination.

				Age assigned by		
Survey	**Collection Year**	**Data set #**	**n**	**Ager 1**	**Ager 2**	**Ager 12**
DEPM	2004 ,2006	1	8	0		0
			7	0		1
			2	0		2
			2	0		3
			14	1		1
			20	1		2
			11	1		3
			4	1		4
			2	2		1
			63	2		2
			29	2		3
			8	2		4
			1	2		5
			2	3		2
			11	3		3
			3	3		4
			2	3		5
			12	4		3
			22	4		4
			11	4		5
			1	4		6
			2	5		2
			7	5		3
			24	5		4
			26	5		5
			6	5		6
			4	6		3
			9	6		4
			18	6		5
			8	6		6
			2	6		7
			4	7		3
			6	7		4
			2	7		5
			3	7		6
			2	7		7
			1	8		6
			1	8		7
	2006, 2008, 2009	2	3		0	0
			5		0	1
			2		0	2
			2		1	0
			27		1	1
			86		1	2
			26		1	3
			2		1	4
			1		2	1
			20		2	2
			28		2	3
			2		2	4
			5		3	2
			44		3	3
			21		3	4
			8		3	5
			1		3	6
			1		4	1
			3		4	2
			8		4	3
			11		4	4
			7		4	5
			2		4	6
			1		5	2
			7		5	3
			15		5	4
			9		5	5
			6		5	6
			3		5	7
			1		6	4
			1		6	5
			2		6	6

Table 7. Estimation of standard deviation- at-age by fishery / survey and dataset based on the traditional method and the Agemat model. Note that estimation of *SD* from Agemat was based on the assumptions that all agers had equal standard deviation.

				Estimation	
				Traditonal method	Agemat model
Fishery / Survey	Collection Year	Data set #	Age	Mean SD	SD
ENS		1	0	0.04	0.20
			1	0.04	0.20
			2	0.24	0.28
			3	0.16	0.31
			4	0.35	0.32
CA	2005	1	0	0.19	0.28
			1	0.23	0.28
			2	0.21	0.29
			3	0.65	0.80
	2007	2	0	0.50	0.25
			1	0.21	0.25
			2	0.25	0.34
			3	0.48	0.92
			4	1.00	4.64
	2008-2009	3	0	0.49	0.40
			1	0.47	0.40
			2	0.58	0.50
			3	0.76	0.58
			4	1.05	0.69
			5	1.24	0.82
			6	1.67	0.97
	2008-2009	4	1	0.42	0.40
			2	0.37	0.50
			3	0.54	0.58
			4	0.83	0.69
	2010-2011	5	0	0.17	0.28
			1	0.18	0.28
			2	0.84	0.30
			3	0.34	0.31
			4	0.43	0.33
			5	0.29	0.36
			6	0.58	0.40
PNW	2009	1	2	0.88	0.31
			3	0.55	0.36
			4	0.34	0.38
			5	0.36	0.40
			6	0.43	0.40
			7	0.59	0.40
			8	1.06	0.41
BC	2007	1	3	0.62	0.23
			4	0.42	0.37
			5	0.69	0.59
			6	0.74	0.94
			7	1.11	1.48
			8	1.26	2.32
DEPM	2004, 2006	1	0	0.63	0.50
			1	0.83	0.50
			2	0.57	0.73
			3	0.98	0.82
			4	1.36	0.86
			5	0.72	0.88
			6	0.86	0.88
			7	1.56	0.89
			8	1.06	0.89
	2006, 2008, 2009	2	0	0.65	0.50
			1	0.72	0.50
			2	0.65	0.73
			3	0.63	0.82
			4	0.74	0.86
			5	0.84	0.88
			6	0.84	0.88

Table 8. Summary of Agemat model assumption and comparison for each Pacific sardine fishery and survey.

Fishery/Survey	Number of dataset	Dataset #	Model	Bias estimation	Ager SD assumption	N	Input Eff N	Model Eff N	Eff N Ratio	Total likelihood	Number of parameters	AICc
ENS	1		ENS_1	No	Readings 1 = 2	240	240	1333.71	5.56	322.78		
CA	1	1	CA_05_A	No	Ager 1 ≠ 2 ≠ 3	219	219	299.156	1.37	416.504	13	15.71
	1	1	CA_05_B	No	Ager 1 = 2 = 3	219	219	253.677	1.16	423.874	7	2.43
	1	1	CA_07_A	No	Ager 1 ≠ 2 ≠ 3	148	148	235.321	1.59	315.986	17	27.20
	1	1	CA_07_B	No	Ager 1 = 2 = 3	148	148	76.786	0.52	337.979	8	5.39
	2	1	CA_0809_A	No	Ager 2 ≠ 4 ≠ 5 ≠ 6 ≠ 7	507	100	69.497	0.69	862.471	27	49.27
		2				145	100	22.108	0.22			
	2	1	CA_0809_B	No	Ager 2 = 4 = 5= 6 =7	507	100	75.316	0.75	855.52	15	19.11
		2				145	100	25.02	0.25			
	1	1	CA_1110_A	No	Ager 2 ≠ 5 ≠ 6	266	160	159.21	1.00	342.139	15	21.66
	1	1	CA_1110_B	No	Ager 2 = 5 = 6	266	160	146.29	0.91	346.32	9	7.51
	1	1	PNW_A	Ager 8 unbiased	Ager 8 ≠ 9	711	700	2992.13	4.27	1476.56	16	18.20
PNW	1	1	PNW_B	No	Ager 8 ≠ 9	711	700	254.03	0.36	1494.12	13	11.91
	1	1	PNW_C	No	Ager 8 = 9	711	700	206.54	0.30	1502.38	10	5.69
BC	1	1	BC_A	RA unbiased	RA ≠ Ager 10 ≠ 11	283	260	221.32	0.85	798.38	21	32.52
	1	1	BC_B	No	RA ≠ Ager 10 ≠ 11	283	260	47.64	0.18	878.85	15	18.41
	1	1	BC_C	No	RA = Ager 10 = 11	283	260	69.21	0.27	839.69	9	5.25
DEPM	2	1	DEPM_A	Ager 1 unbiased	Ager 1≠ 2≠ 12	360	100	97.38	0.97	890.628	27	45.97
		2				360	200	186.65	0.93			
	2	1	DEPM_B	No	Ager 1≠ 2≠ 12	360	100	66.7	0.67	951.39	21	31.61
		2				360	200	23.67	0.12			
	2	1	DEPM_C	No	Ager 1= 2= 12	360	100	73.77	0.74	966.169	15	17.94
		2				360	200	18.7	0.09			

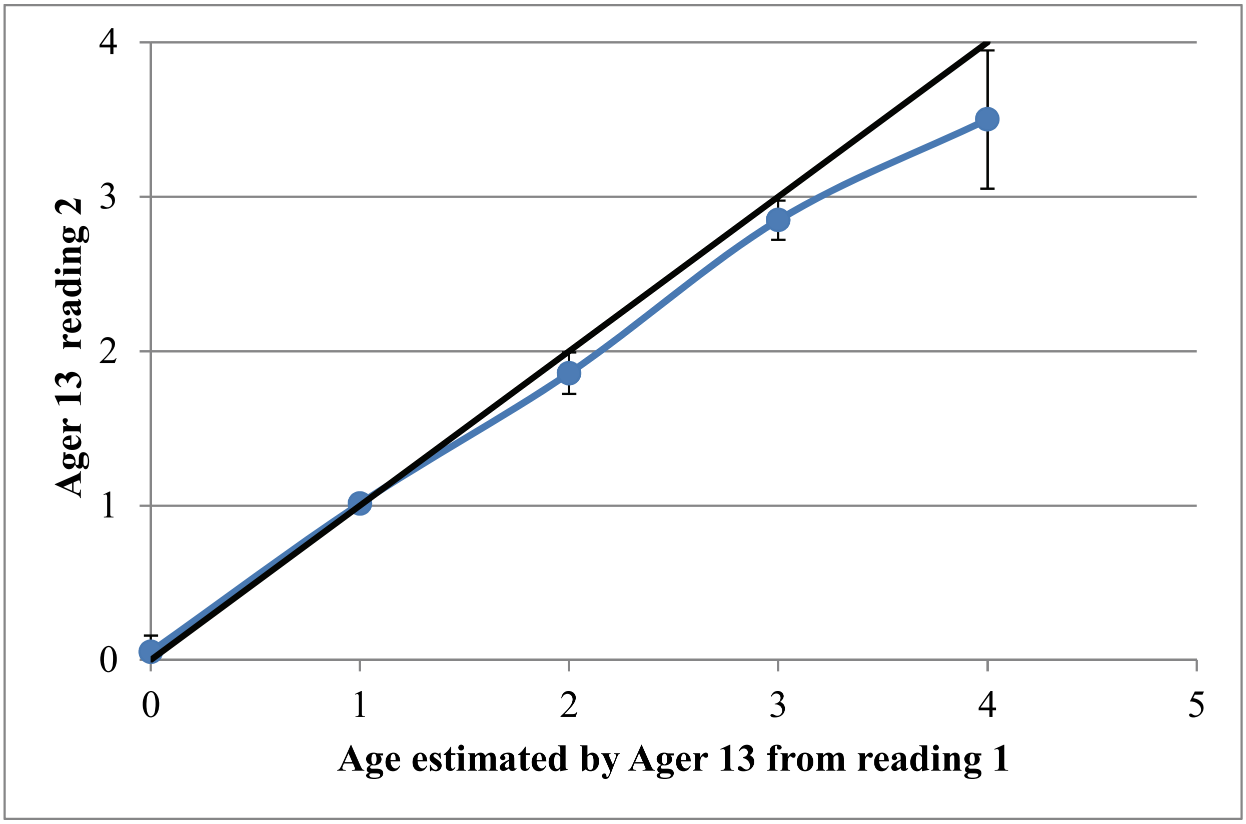


Figure 1. Age bias plot for the pairwise age comparison presented in Table 2 for the ENS fishery. Each error bar represents the 2*SE around the mean age assigned by ager 13 in the second reading for all fish assigned a given age in the first reading. The 1:1 equivalence (solid black line) is also shown on the plot.

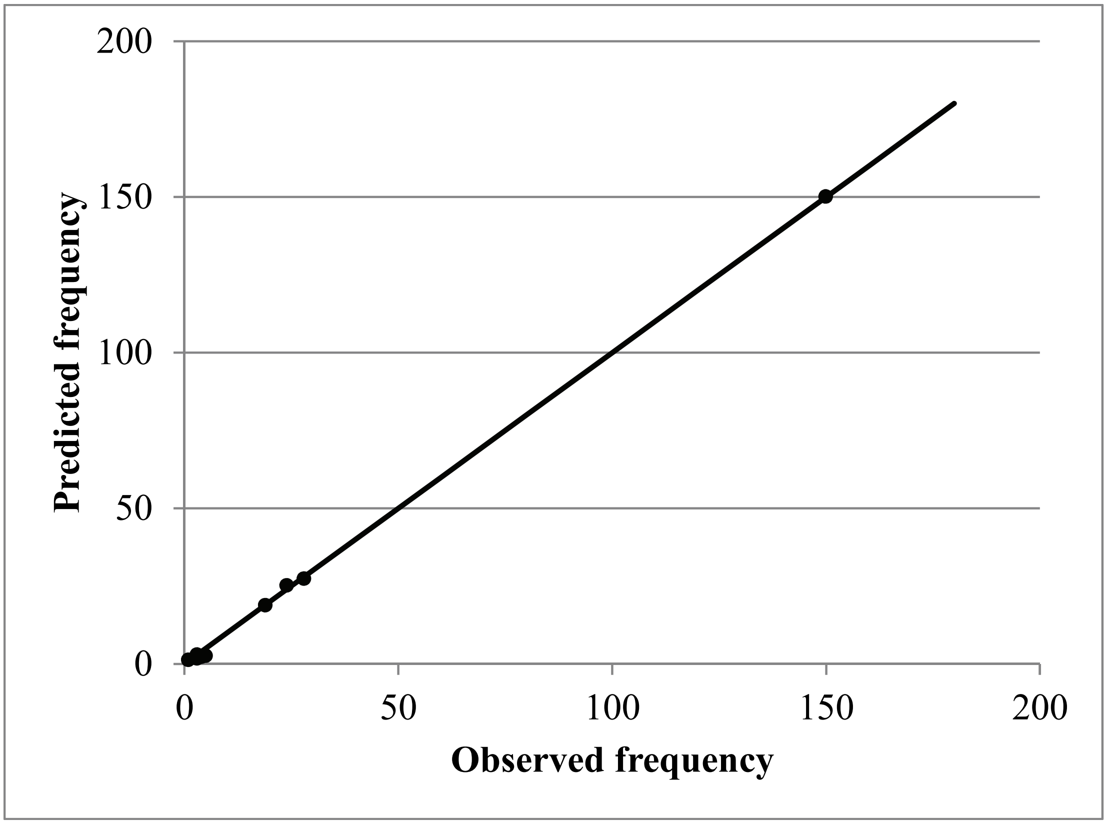
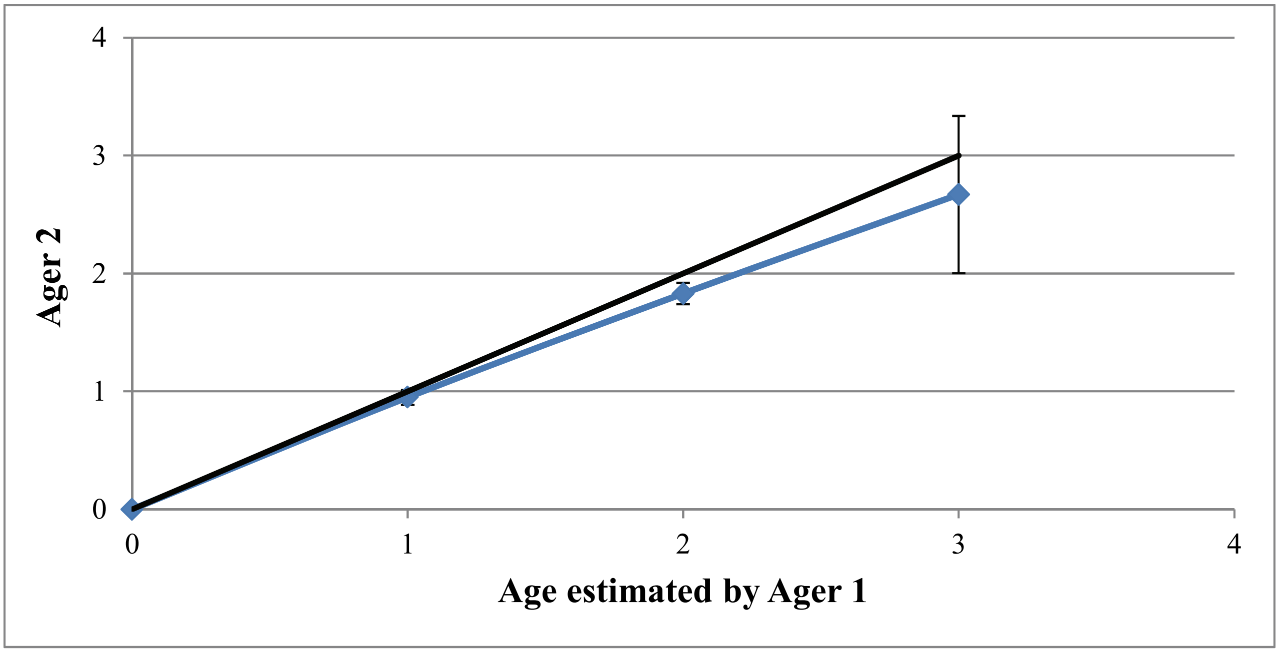


Figure 2. Predicted and observed frequency for the ENS fishey age-reading data. Predicted frequency was estimated from the ENS_1 Agemat model (see Table 8 for model assumptions). The 1:1 equivalence (solid black line) is also shown on each plot.



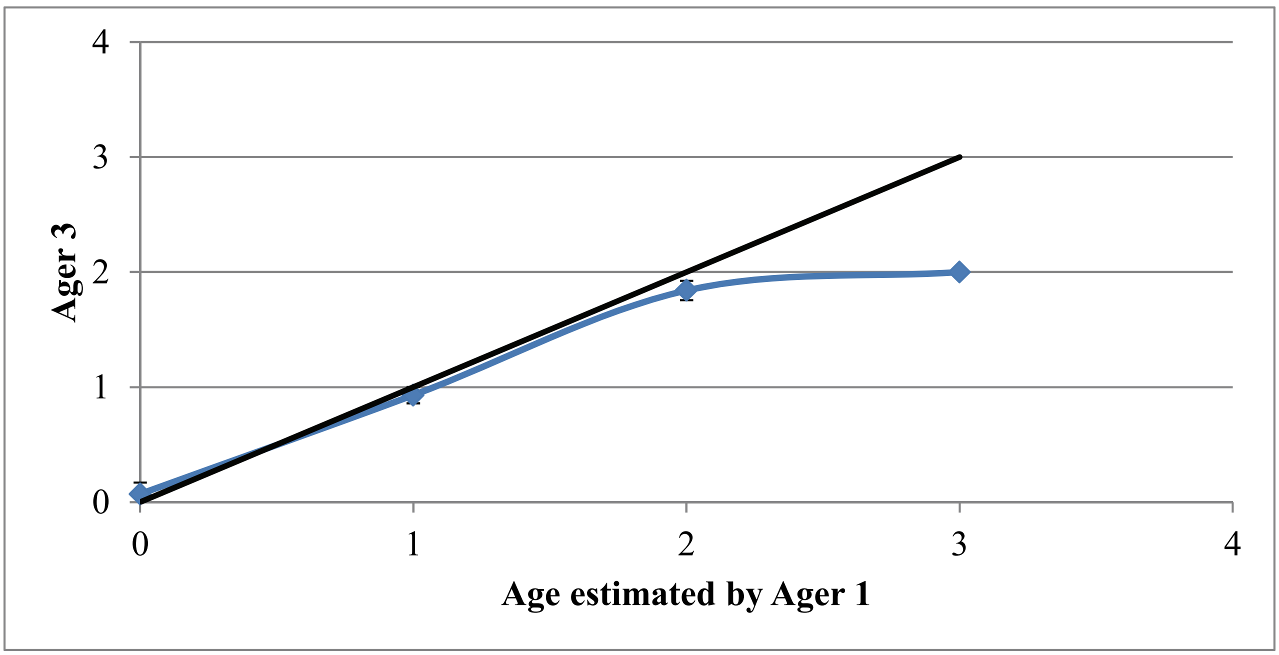


Figure 3. Age bias plots for each of the two pairwise age comparisons for fish collected in 2005 from landings of the CA fishery (Table 3, Data set # 1). Each error bar represents 2*SE around the mean age assigned by one ager for all fish assigned a given age by Ager 1. The 1:1 equivalence (solid black line) is also shown on each plot.

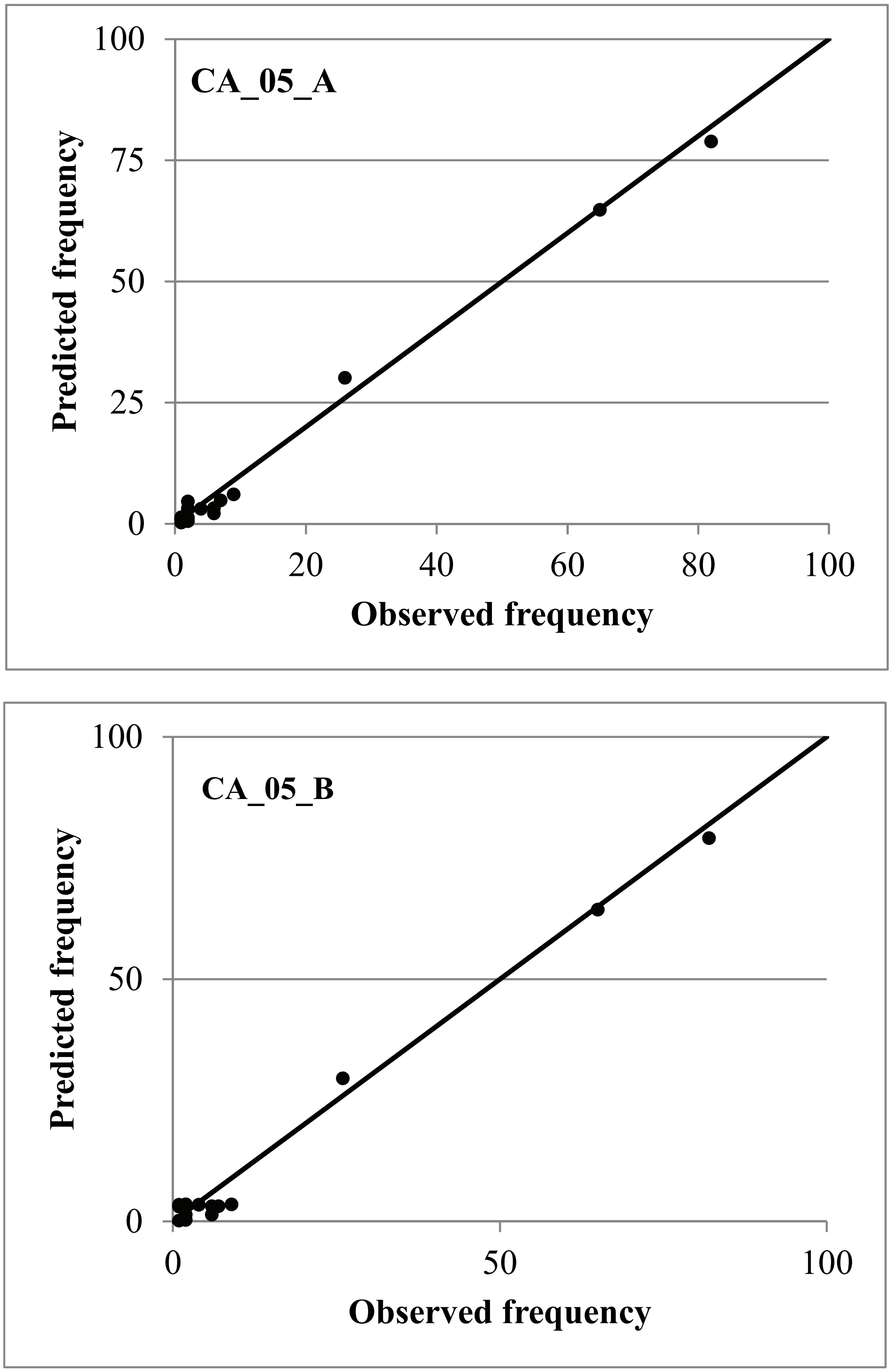


Figure 4. Predicted and observed frequency for the 2005 CA fishery age-reading data set. Predicted frequency was computed from two different Agemat models, CA_05_A and CA_05_B (see Table 8 for model assumptions). The 1:1 equivalence (solid black line) is also shown on each plot.

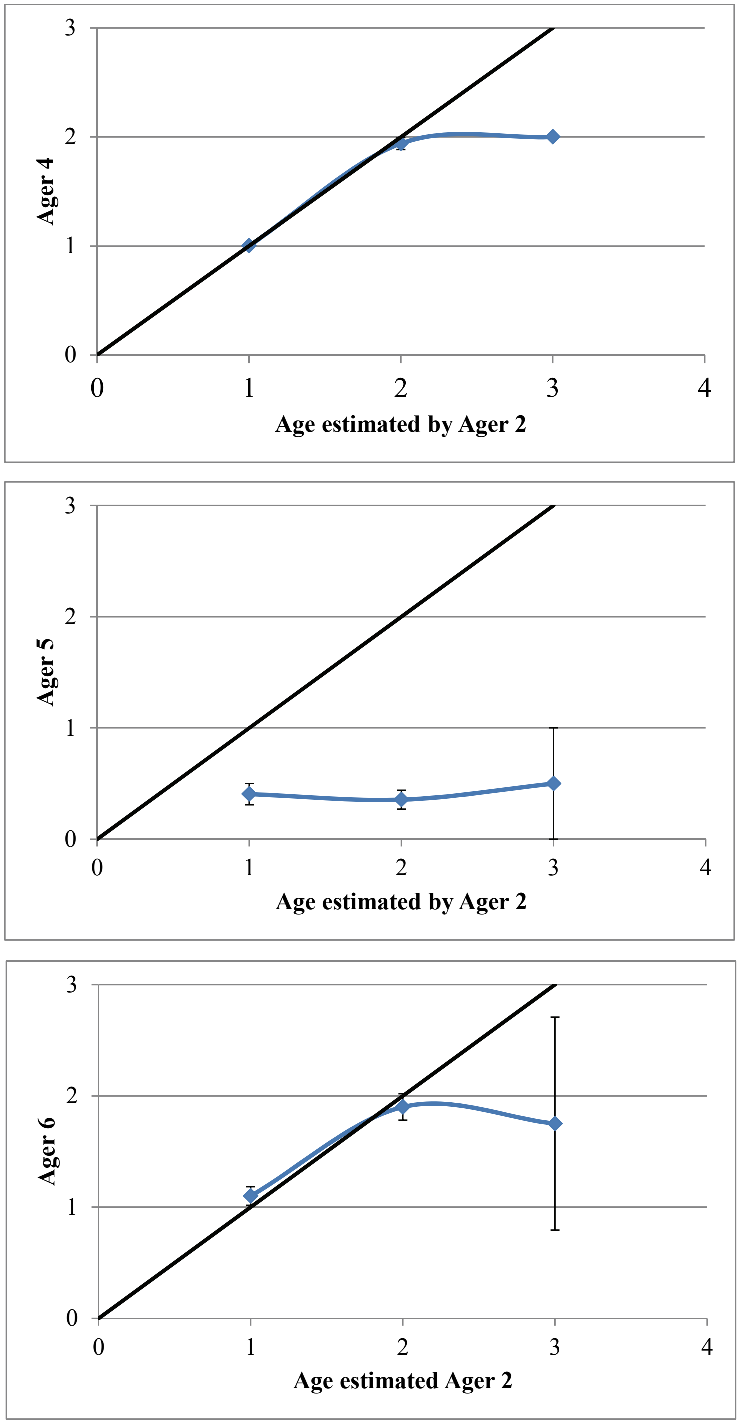
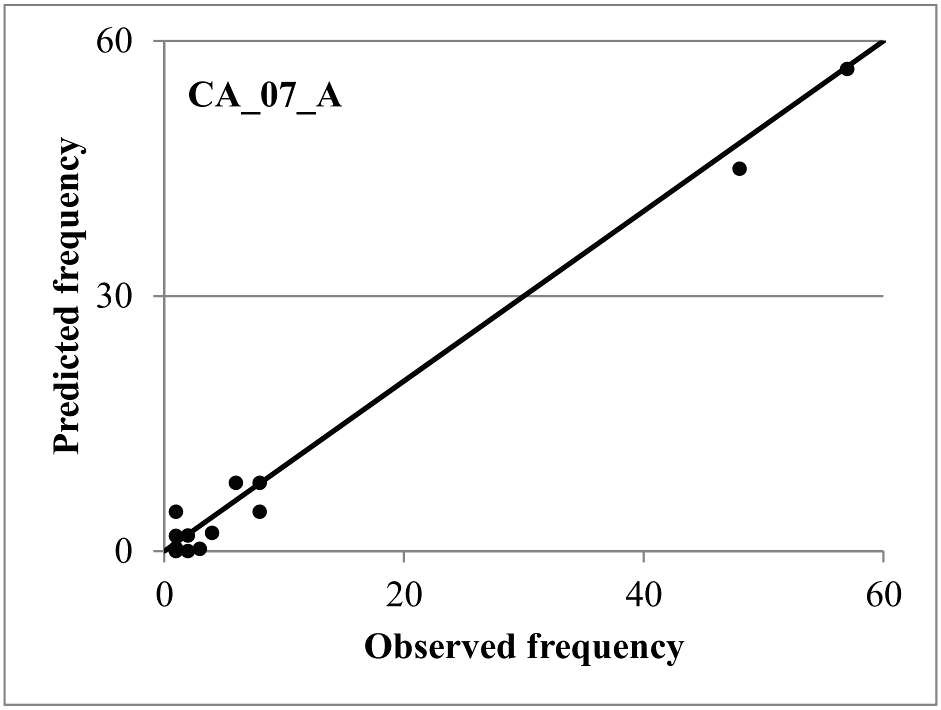


Figure 5. Age bias plots for each of the three pairwise age comparisons for fish collected in 2007 from landings of the CA fishery (Table 3, Data set # 2). Each error bar represents 2*SE around the mean age assigned by one ager for all fish assigned a given age by Ager 2. The 1:1 equivalence (solid black line) is also shown on each plot.



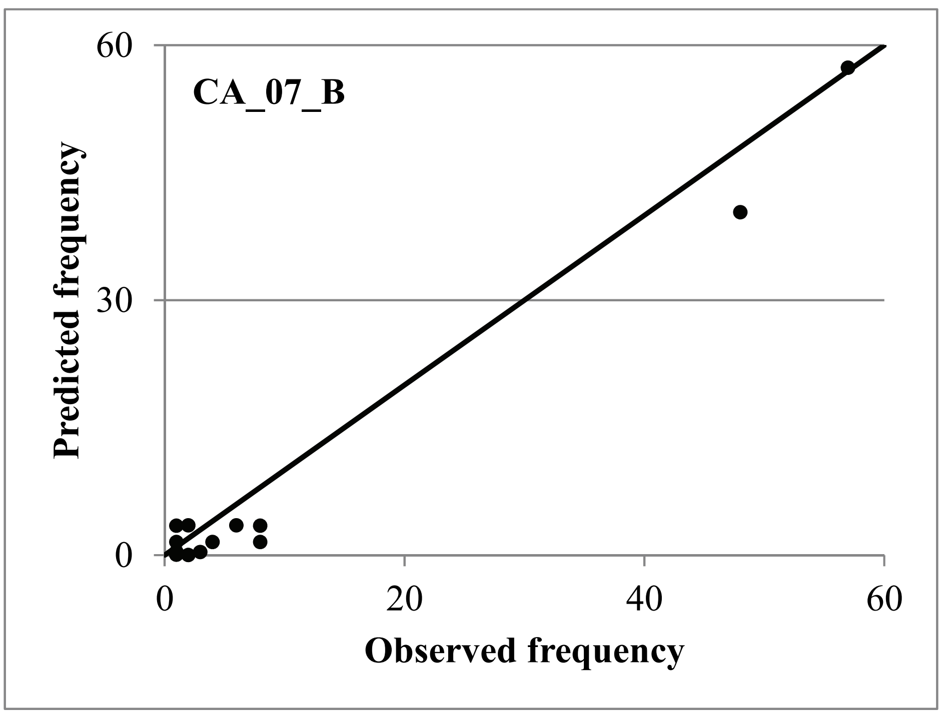


Figure 6. Predicted and observed frequency for the 2007 CA fishery age-reading data set. Predicted frequency was computed from two different Agemat models, CA_07_A and CA_07_B (see Table 8 for model assumptions). The 1:1 equivalence (solid black line) is also shown on each plot.

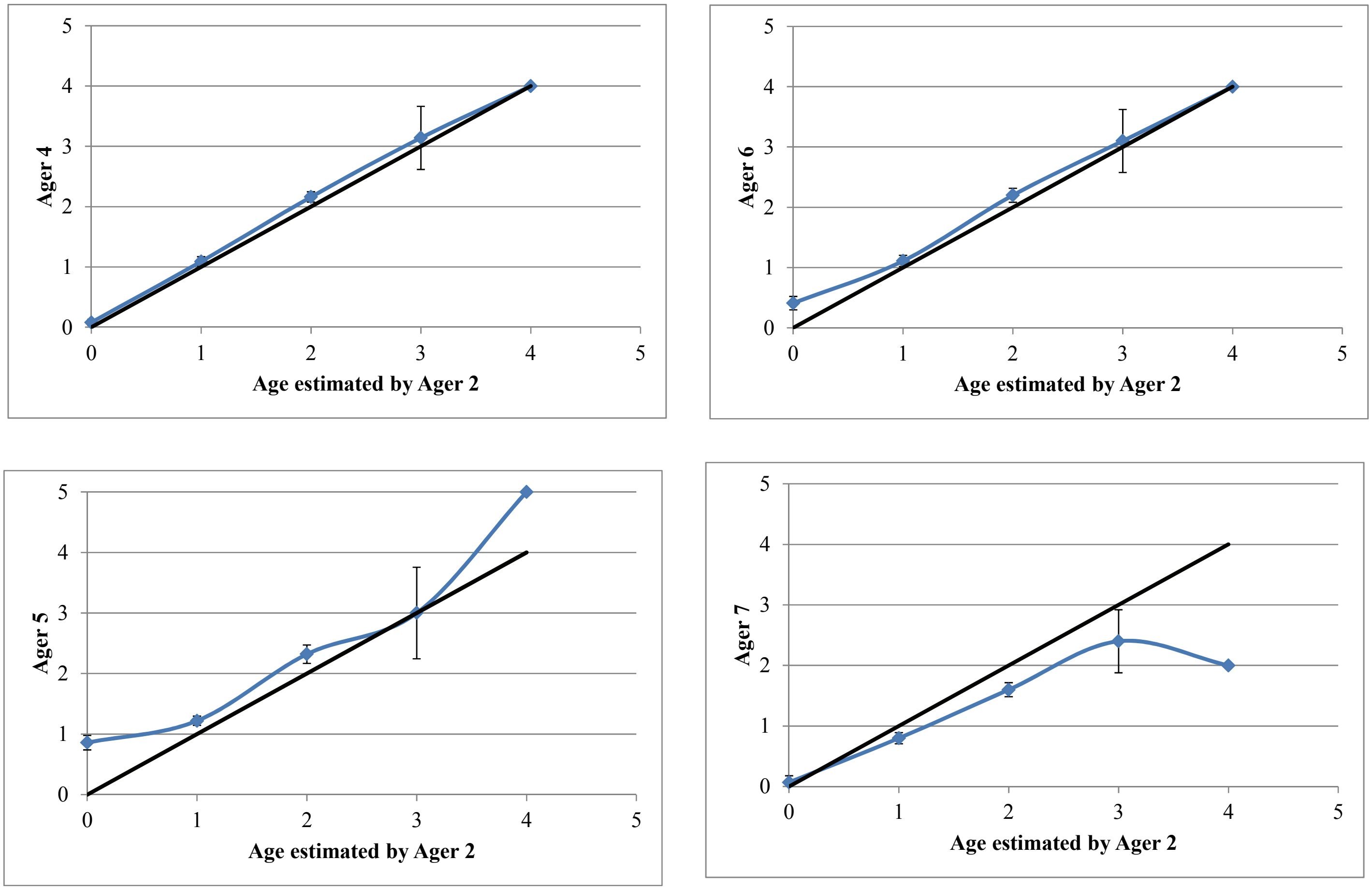


Figure 7. Age bias plots for each of the four pairwise age comparisons for fish collected in 2008 and 2009 from landings of the CA fishery (Table 3, Data set # 3). Each error bar represents 2*SE around the mean age assigned by one ager for all fish assigned a given age by Ager 2. The 1:1 equivalence (solid black line) is also shown on each plot.

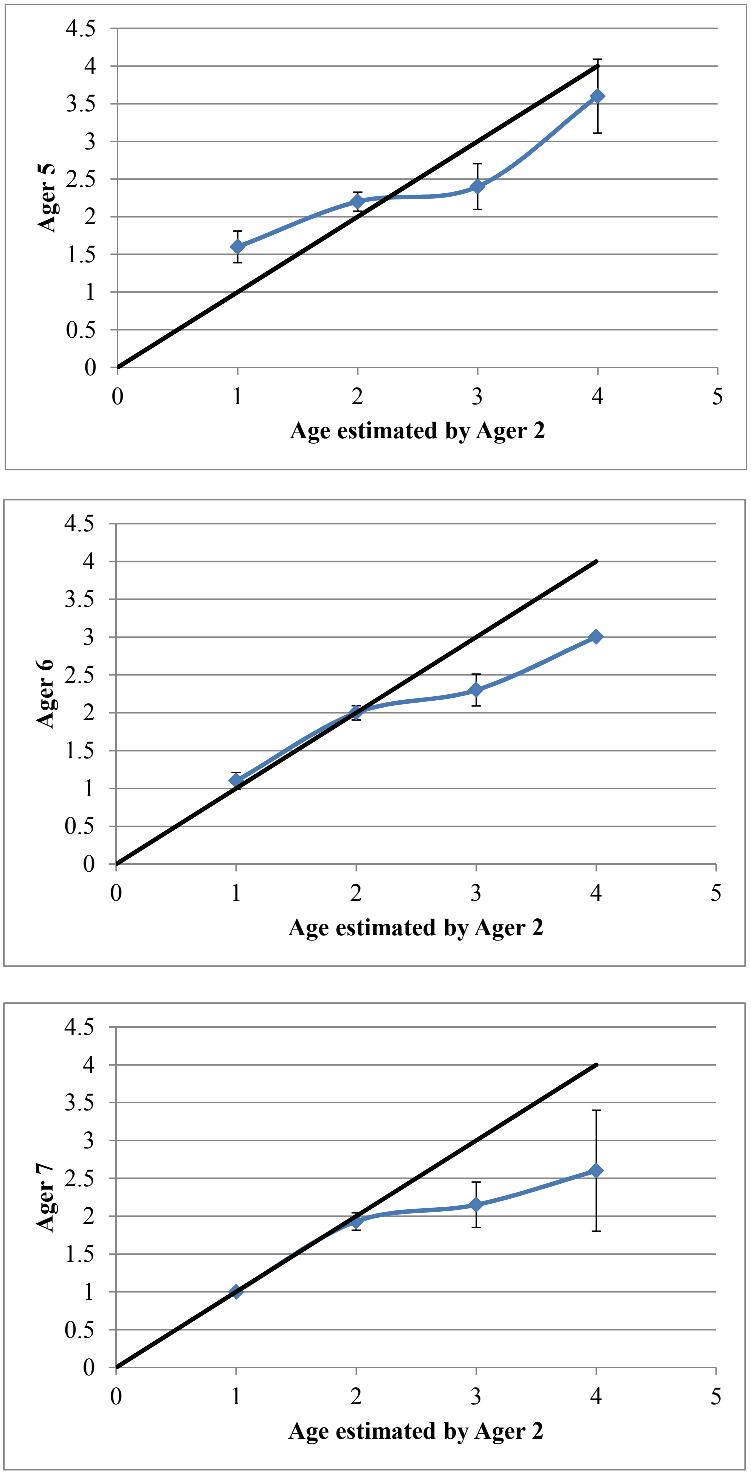


Figure 8. Age bias plots for each of the three pairwise age comparisons for fish collected in 2008 and 2009 from landings of the CA fishery (Table 3, Data set # 4). Each error bar represents 2*SE around the mean age assigned by one ager for all fish assigned a given age by Ager 2. The 1:1 equivalence (solid black line) is also shown on each plot.

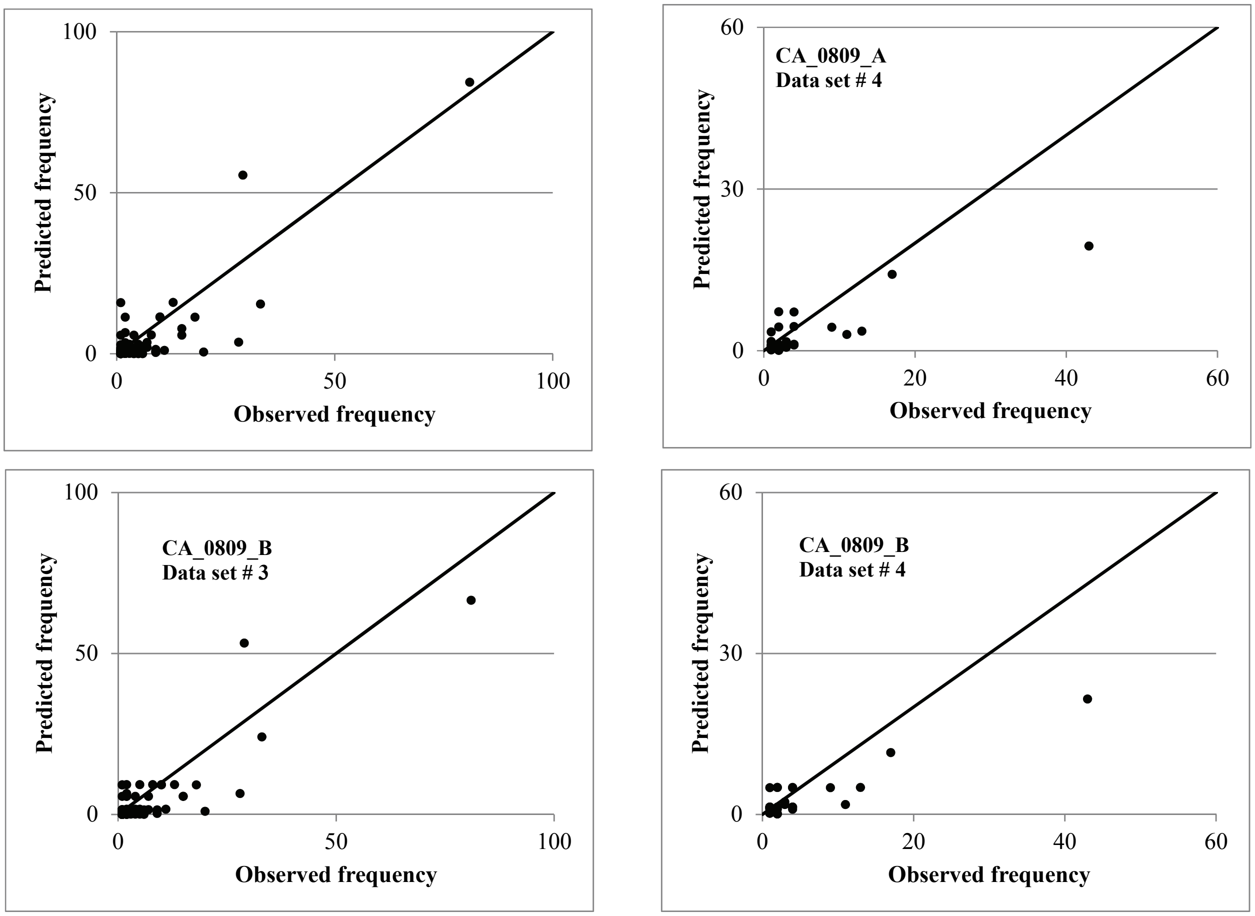
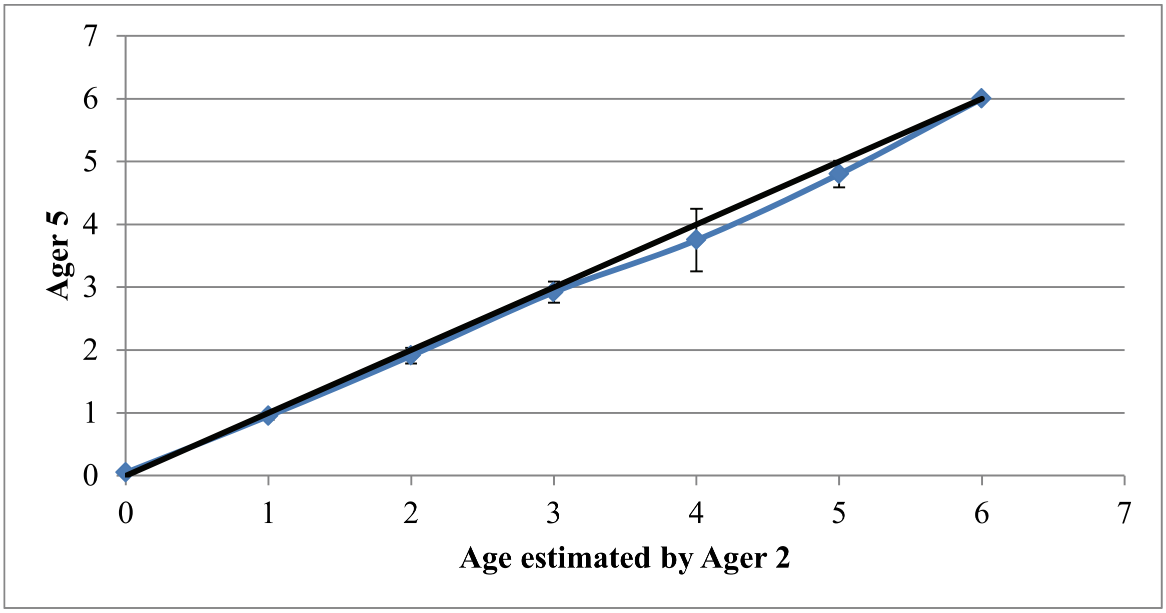


Figure 9. Predicted and observed frequency for the 2008-2009 CA fishery age-reading data sets (#3 and 4). Predicted frequency was computed from two different Agemat models, CA_0809_A and CA_0809_B (see Table 8 for model assumptions). We refer the reader to Table 3 for a summary of data sets #3 and 4. The 1:1 equivalence (solid black line) is also shown on each plot.



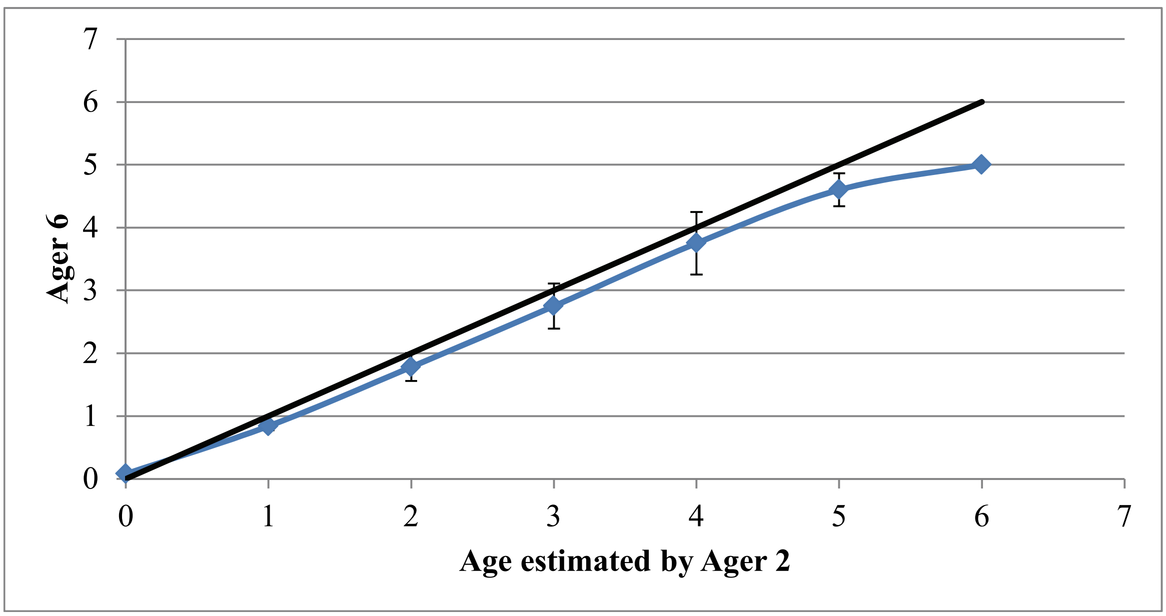


Figure 10. Age bias plots for each of the two pairwise age comparisons for fish collected in 2010 and 2011 from landings of the CA fishery. Each error bar represents 2*SE around the mean age assigned by on ager for all fish assigned a given age by Ager 2. The 1:1 equivalence (solid black line) is also shown on each plot.

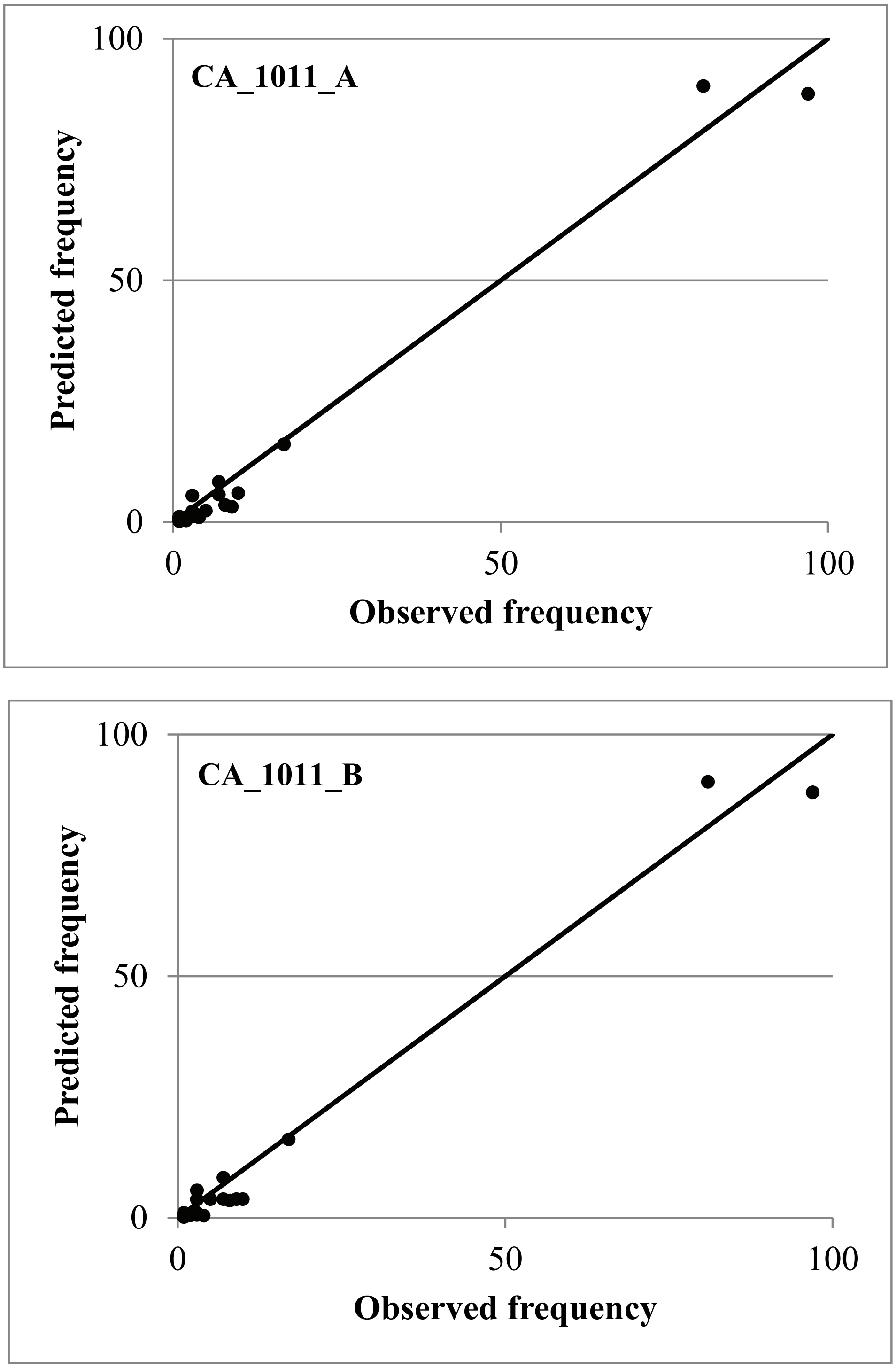


Figure 11. Predicted and observed frequency for the 2010-2011 CA fishery age-reading data set. Predicted frequency was computed from two different Agemat models, CA_1011_A andCA_1011_B (see Table 8 for model assumptions). The 1:1 equivalence (solid black line) is also shown on each plot.

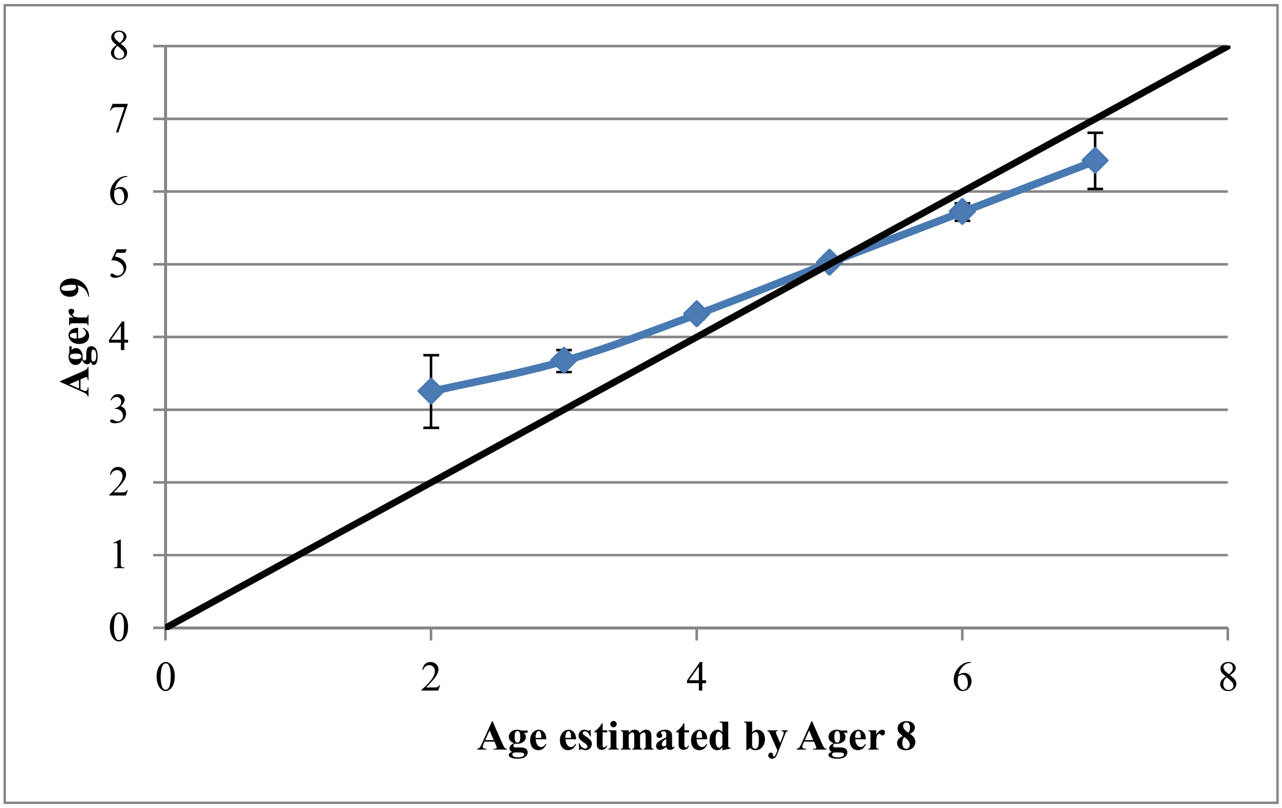


Figure 12. Age bias plot for the pairwise age comparison presented in Table 4 for the PNW fishery. Each error bar represents the 2*SE around the mean age assigned by ager 9 for all fish assigned a given age by ager 8. The 1:1 equivalence (solid black line) is also shown on the plot.

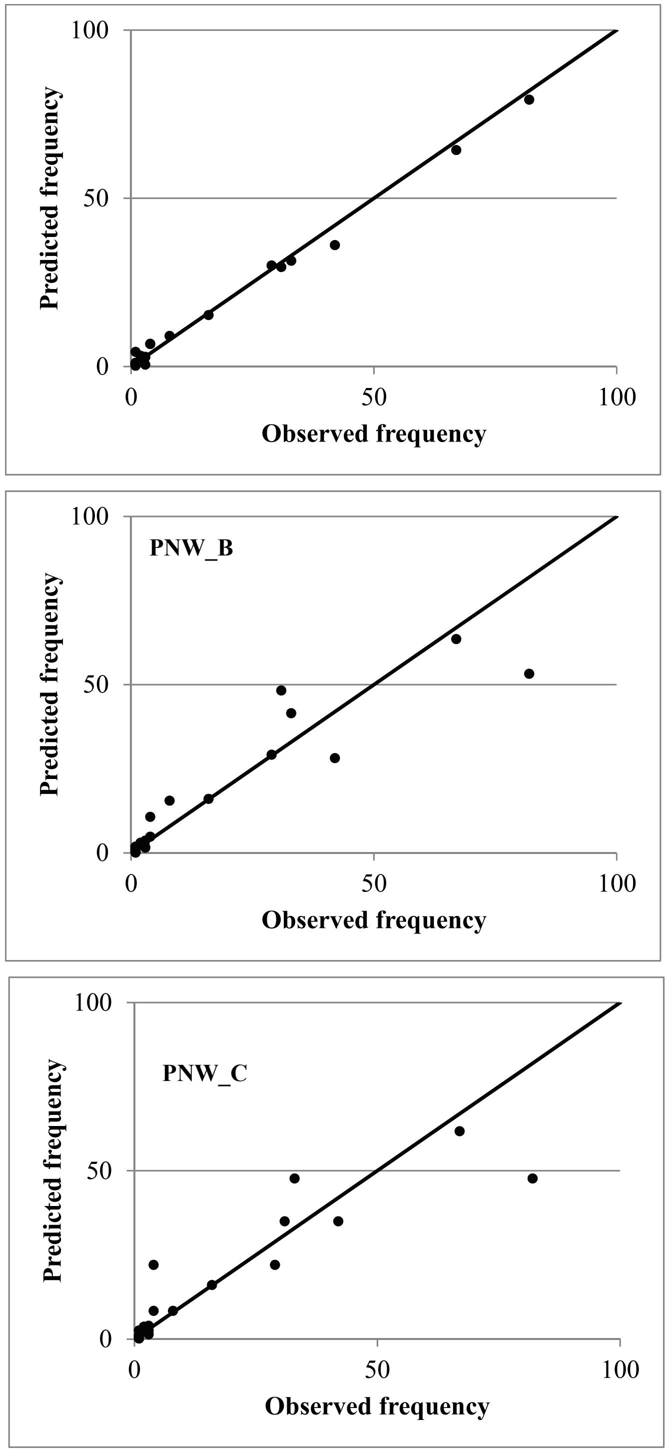


Figure 13. Predicted and observed frequency for the PNW fishery age-reading data set. Predicted frequency was computed from three different Agemat models, PNW_A, PNW_B and PNW_C (see Table 8 for model assumptions). The 1:1 equivalence (solid black line) is also shown on each plot.

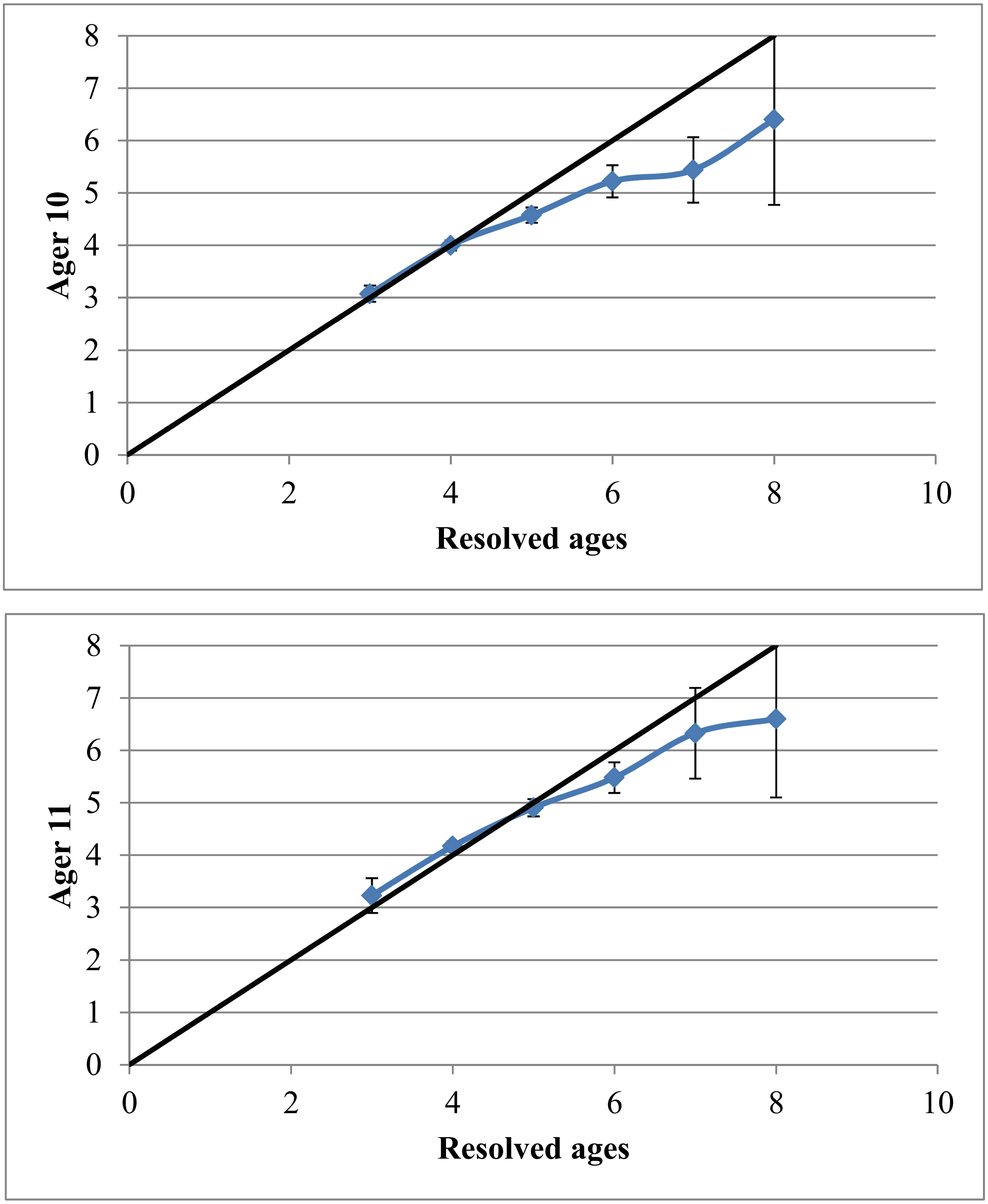


Figure 14. Age bias plot for the two pairwise age comparisons presented in Table 5 for the BC fishery. Each error bar represents the 2*SE around the mean age assigned by one ager for all fish assigned a given resolved age. The 1:1 equivalence (solid line) is also shown on the plot.

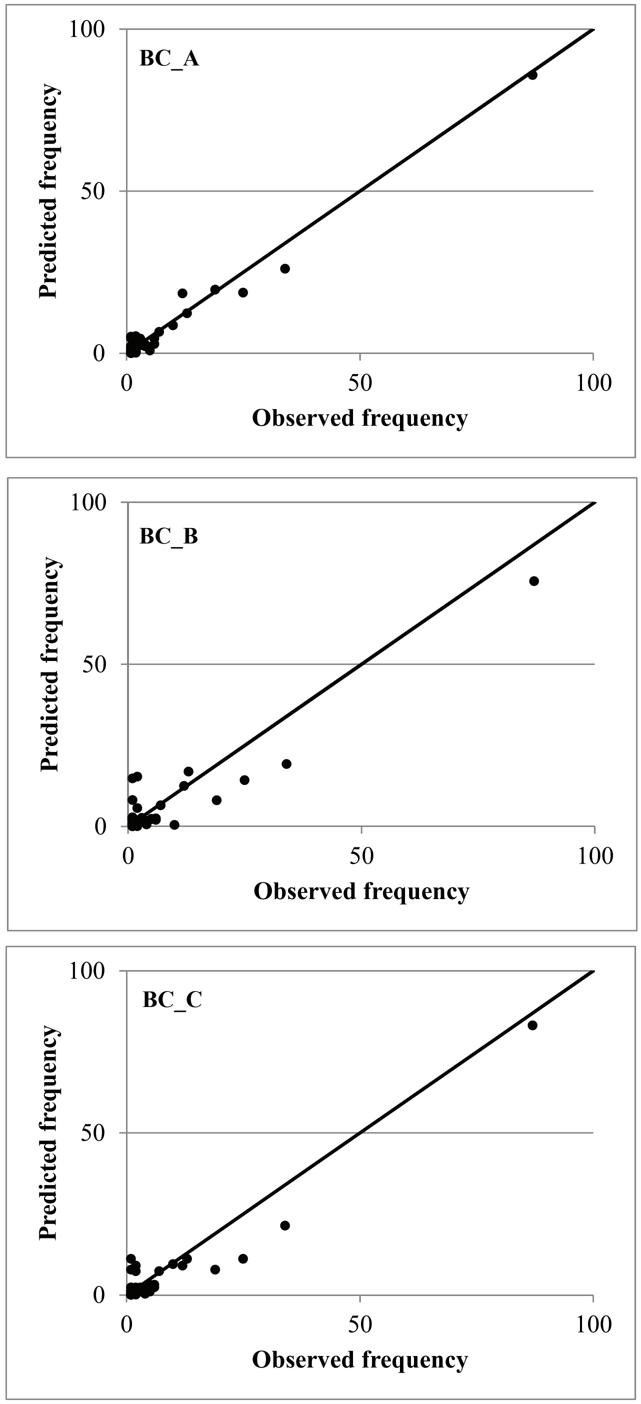
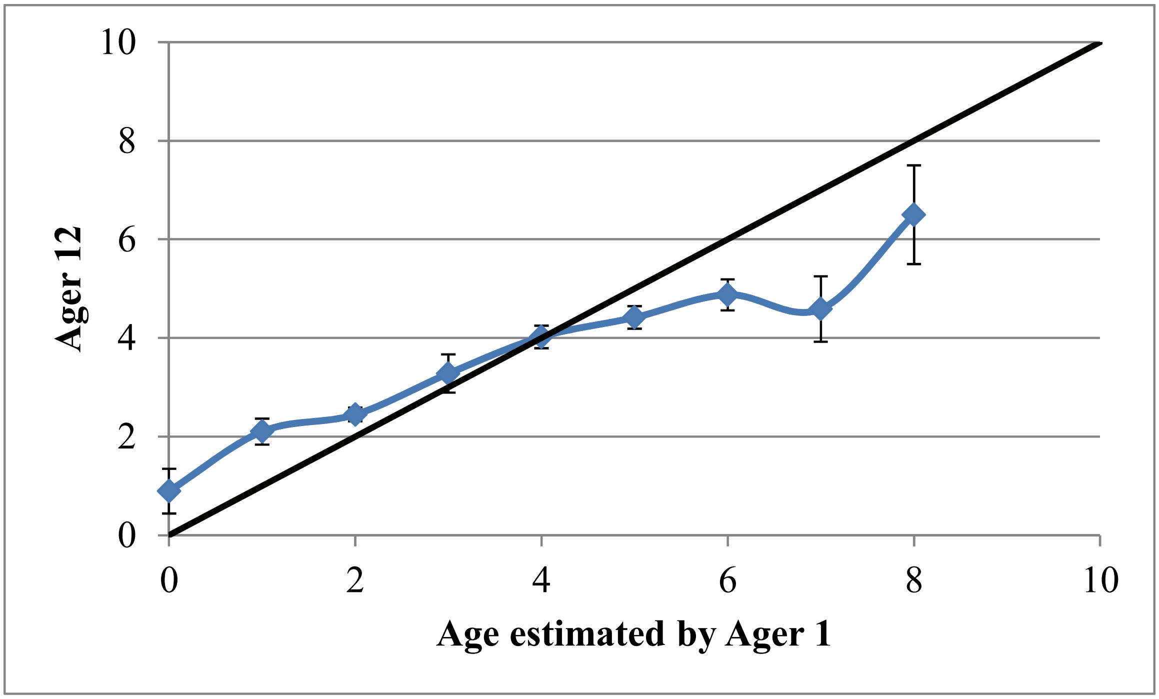


Figure 15. Predicted and observed frequency for the BC fishery age-reading data set. Predicted frequency was computed from three different Agemat models, BC_A, BC_B and BC_C (see Table 8 for model assumptions). The 1:1 equivalence (solid black line) is also shown on each plot.



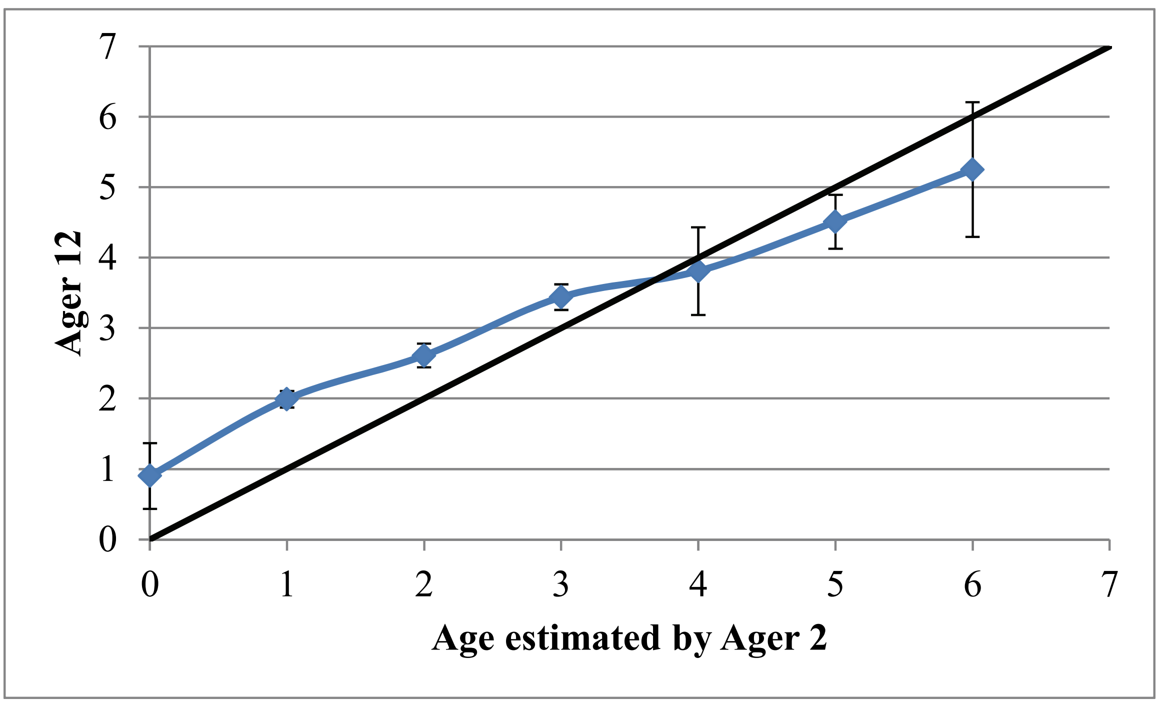


Figure 16. Age bias plot for the two pairwise age comparisons presented in Table 6 for the DEPM survey. Each error bar represents the 2*SE around the mean age assigned by ager 12 for all fish assigned a given by ager 1 or 2.The 1:1 equivalence (solid line) is also shown on the plot.

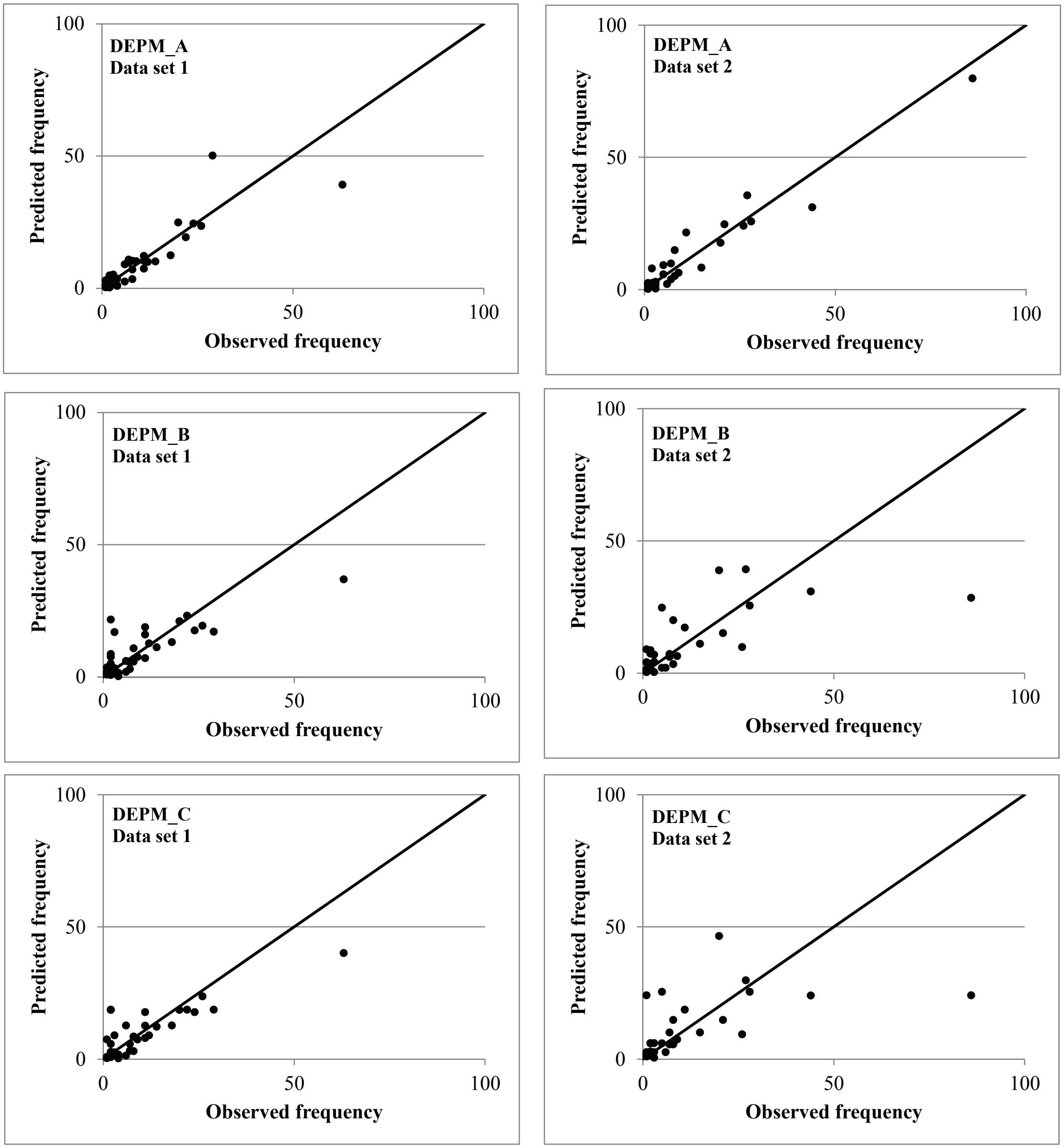


Figure 17. Predicted and observed frequency for the DEPM survey age-reading data sets (# 1 and 2).Predicted frequency was computed from three different Agemat models, DEPM _A, DEPM _B, and DEPM _C (see Table 8 for model assumptions). We refer the readers to Table 6 for a summary of DEPM data set # 1 and 2. The 1:1 equivalence (solid black line) is also shown on each plot.

APPENDIX 3

SWFSC Juvenile Rockfish Survey (1983-11)

P. R. Crone
September 2011

Overview

Since 1983, NOAA Fisheries (Southwest Fisheries Science Center, Santa Cruz Laboratory) has conducted annual midwater trawl surveys designed to estimate the distribution and abundance of pelagic juvenile rockfishes (*Sebastes* spp.) along the central California coast (Ralston and Howard 1995; Sakuma et al. 2006; Field et al. 2010). Research cruises associated with the pelagic juvenile rockfish survey (JRS) were conducted onboard the *RV* David Starr Jordan and other cooperating vessels during May to June when the approximately 100-day old juveniles are most susceptible to capture by midwater trawling gear. The primary goal of the JRS is to collect density/abundance and biological data applicable to rockfish species inhabiting California waters. The JRS typically encounters other species in addition to rockfishes, including coastal pelagic species (CPS) such as Pacific sardine. Consequently, an index of relative abundance for sardines was developed from these survey data in efforts to evaluate the potential utility of these survey data to the ongoing stock assessment for this species.

Sampling stations for the JRS are at fixed locations, with typically five to six stations along a transect line that traverses the continental shelf break (although some stations are clustered); most stations are occupied two to three times per research cruise. From 1983 through 2003, a cruise included roughly 40 stations in central California, i.e., defined as the JRS 'core' area that spanned from southern Monterey Bay to just north of Point Reyes, i.e., about 2 degrees of latitude). Beginning in 2004, the survey grid was expanded to include a series of transects from the U.S./Mexico border to just south of Cape Mendocino (see Sakuma et al. 2006 for details). Comparable surveys have been conducted by the NWFSC and Pacific Whiting Conservation Cooperative (PWCC) since 2001. The cruises employ a modified Cobb midwater trawl, with a 26-m headrope and 9.5-mm codend liner. The research cruises employ a modified 26x26 m Cobb midwater trawl, with a cod-end liner of 1.27-cm stretched mesh. At each station, a 15-min nighttime trawl (tow) sample was taken at a standard depth (30 m where possible, 10 m at shallow stations), and catches were identified, enumerated, and (for most species) measured (standard length; Figure 1). Ageing structures are typically only collected for juvenile rockfish, although ad-hoc collections for other species have been conducted at times. Since 2004, the number of tows in the core area has averaged approximately 75, with as many typically conducted in the expanded survey area. On average, approximately 25% of the tows have one or more sardines, although this percentage varies substantially from year to year.

From 1983 through 2008, cruises took place on the *RV* David Starr, but since 2009, a series of cooperating vessels has been utilized. Specifically, in 2011, the cruise was conducted by the *FV* Excalibur Jordan (the ship used for the NWFSC/PWCC surveys) and had limited temporal and spatial coverage relative to the post-2003 period. Although the JRS has sampled a greater spatial area from 2004 onward, the time series of abundance presented here for Pacific sardine is based on the core survey and begins in 1990 (start of consistent sampling for non-rockfish species of interest), given this spatial/temporal combination represented the most informative index of relative abundance for this species.

It is important to note that at this time, the index of relative abundance for Pacific sardine estimated from data collected in the JRS is intended as a preliminary time series, requiring further evaluation before adopting as a final index to be included in the ongoing assessment for this species, given: (1) the survey (core area) design represents a limited spatial area in relation to this species' overall biology and movement dynamics; and (2) the survey was not designed to accurately sample coastal pelagic species in general, which exhibit highly variable depth distributions and overall availabilities to a survey/fishery due largely to prevailing oceanographic conditions (e.g., no sardines were observed in 2010 or 2011). Specifically, the prevailing interpretation of the survey data is that Pacific sardine (and other CPS) are typically more abundant in the core area during oceanographic regimes of low productivity and/or low upwelling (J. Field, personal communication, SWFSC (Santa Cruz Laboratory), September 2011).

Index of relative abundance

A delta general linear model (GLM) was used to develop a relative index of abundance for Pacific sardine, based on a binomial model (using a logit link) for tow-specific presence/absence information,

$$\log\left(\frac{\pi_i}{1-\pi_i}\right) = \mathbf{x}_i{}^T\beta, \qquad (1)$$

where π_i is the predicted value of the binomial probability for ith observation, $\mathbf{x}_i$ is the vector specifying the explanatory variables for the ith value of the response variable, and $\boldsymbol{\beta}$ is the vector of the regression coefficients for the binomial model. The mean (μ) of positive tows was modeled with a normal linear model for the log-transformed data ($y_{i,}$, in number of fish),

$$\begin{aligned} &\mu_i = \log(y_i) - \varepsilon_i = \mathbf{x_j}{}^T\gamma, where \\ &\varepsilon \approx N(0,\sigma^2) \end{aligned} \qquad (2)$$

and γ is the vector of coefficients for the positive models. A gamma distribution was assumed for the positive observations in this standardization approach, which varied little from a model that used a lognormal distribution. The product of the year effects of the two models ($\pi\mu$) represented the final index of relative abundance for sardine (Figure 2), and a jackknife routine was utilized to provide an estimate of error (the average estimated CV for the data series in which year effects could be estimated was 0.80, ranging from 0.41 to 1.28). This delta-GLM approach for treating/standardizing the data is highly consistent with the approaches typically taken in stock assessments for developing fishery-independent indices of abundance for marine species (Dick 2004, Maunder and Punt 2004). Finally, a nominal index of relative abundance, based on the simple mean of log-transformed catch rates ($y_{i,}$+ 1) resulted in a similar estimated time series of abundance as the delta-GLM above.

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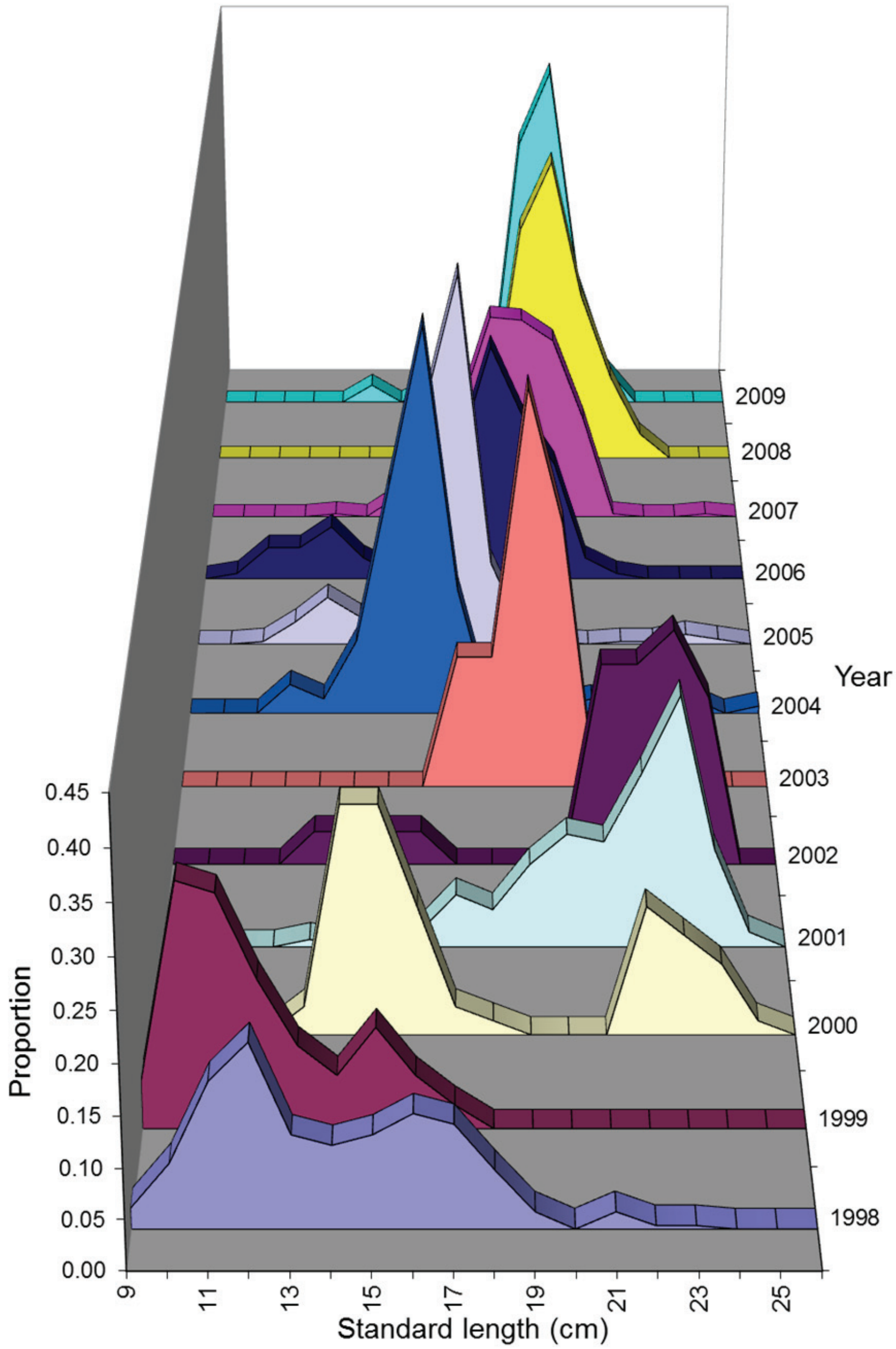

Figure 1. Pacific sardine length distributions (raw sample data, i.e. not catch-weighted) from the Juvenile Rockfish Survey, 1998-2009.

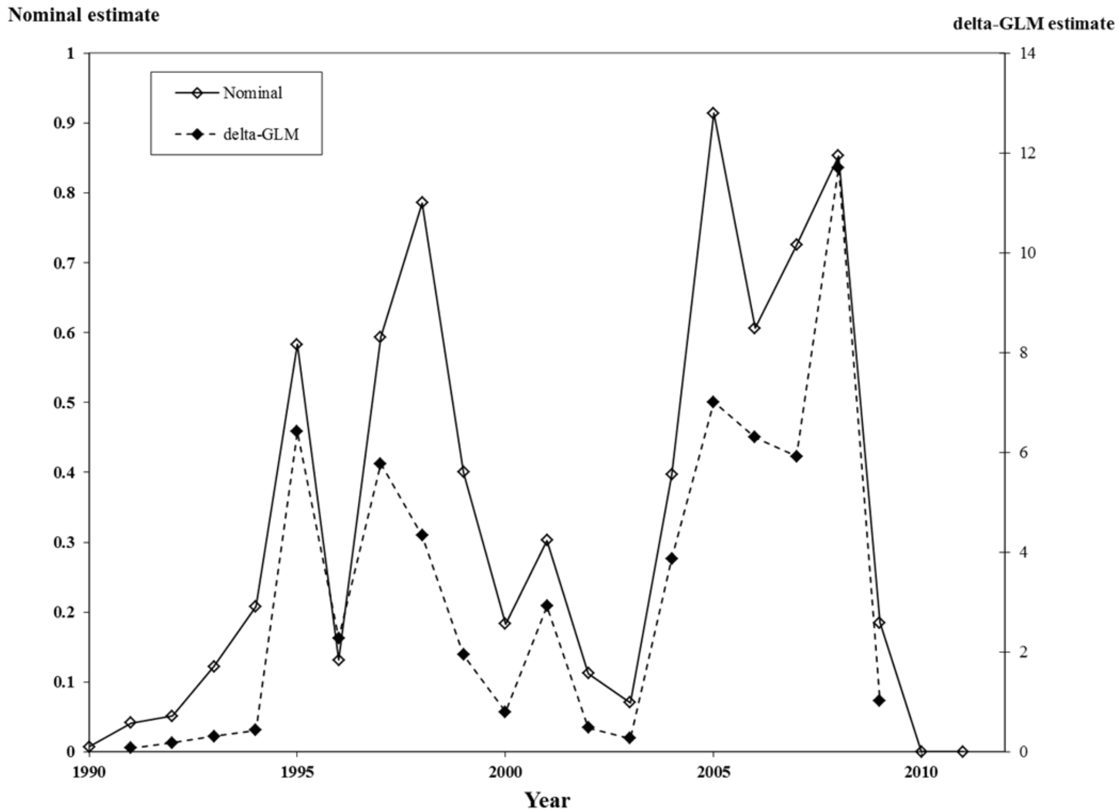

Figure 2. Pacific sardine relative abundance (nominal and delta-GLM estimates) from the Juvenile Rockfish Survey, 1990-2009.

APPENDIX 4

RE-EVALUATION OF F_{MSY} FOR PACIFIC SARDINE IN THE ABSENCE OF AN ENVIRONMENTAL COVARIATE

Kevin T. Hill

NOAA National Marine Fisheries Service
Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, California, USA 92037

September 15, 2011

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INTRODUCTION

The harvest control rule (HCR) implemented for U.S. management of Pacific sardine is unique in that it includes an environmentally-dependent harvest FRACTION based on the three-year running average of sea surface temperature (SST) at Scripps Institution of Oceanography (SIO) pier (PFMC 1998). This feature was based on the theory that: (1) sardine reproductive success was positively correlated with prevailing temperature in the California Current System (CCS); (2) temperature in the CCS could be indexed at SIO pier; and (3) a relationship between SST and F_{MSY} could be linked to surplus production and an appropriate removal rate (Jacobson & MacCall 1995, PFMC 1998). Under the current HCR, harvest FRACTION is bracketed between F_{MSY} values of 5% and 15%. The SST at SIO has been warmer than average for the past decade, so the FRACTION has remained at 15% since implementation of this rule in 2000. More recently, the temperature-F_{MSY} relationship was used to provide a potential range of overfishing limits (OFL) for the 2011 sardine management measures and during scoping for Amendment 13 to the CPS-FMP (PFMC 2010). For that analysis, F_{MSY} was limited to the lower and upper quartiles of SIO-SST observed since 1916, with F_{MSY} ranging 2.00% to 19.85%).

A recent study by McClatchie et al. (2010) re-assessed the relationship between SST and sardine recruitment success. Spawning biomass (*S*), recruitment (*R*), and sea-surface temperature (*T*) data used in Jacobson and MacCall (1995) and CPS Amendment 8 (PFMC 1998) were updated with more recent information, which resulted in a weaker relationship between SST and sardine productivity that was no longer statistically significant (McClatchie et al. 2010). The analysis also indicated that SST at SIO and SST off of southern-central California had diverged and therefore, SIO-SST was no longer representative of low-frequency SST variability in the sardine's core spawning habitat. McClatchie et al. (2010) did not infer that there was no relationship between sardine productivity and the environment, but their analysis does bring into question the current management approach (i.e. Harvest Control Rule 'FRACTION' based on SIO-SST) given the re-evaluation with updated time series. Finally, although research regarding sardine ecology is ongoing, a new environmental index has yet to be developed.

In light of McClatchie et al's. (2010) findings, there exists an interim need to estimate a static F_{MSY} value for sardine (i.e., one that is independent of environmental data) for the purpose of specifying OFL and ABC in the annual management process. Amendment 8 to the CPS-FMP analyzed a broad range of HCR options, including an estimate of 'Stochastic F_{MSY},' (where CUTOFF=0 and MAXCAT=infinite; PFMC 1998). Unfortunately, all of the simulations used to analyze HCRs in Amendment 8 also included the SIO temperature term in spawner-recruit (S-R) calculations, regardless of whether the harvest FRACTION was fixed or temperature-dependent:

$$[1] \qquad \ln(R/S) = \alpha + \beta_1 T + \beta_2 S + \epsilon$$

where R = recruits, S = spawning biomass, and T = SST at SIO (Jacobson and MacCall 1995). Therefore, in strict terms, 'Stochastic F_{MSY}' estimates from Amendment 8 should be considered outdated and potentially misleading. Moreover, S-R parameters from Jacobson and MacCall (1995) and PFMC (1998) were based on historic population estimates (Murphy 1966; MacCall 1979) and included only five years of data from the early stages of the population recovery (Barnes et al. 1992)and thus, were outdated by 23 years. Any new estimate of sardine F_{MSY} should include data from all available years, including the most recent stock assessment (Hill et al. 2010). In the present work, biomass and recruitment time series are appended, spawner-recruit parameters are re-calculated, and the simulation model from Amendment 8 is used to estimate F_{MSY} in a stochastic model (independent of SST or other HCR parameters). The purpose of this study is to update parameters used for the current management model, which is intended to be used as an interim measure, and not to explore a full management strategy evaluation (MSE) for sardine.

MATERIALS AND METHODS

Data

Analyses conducted in Jacobson and MacCall (1995) and Amendment 8 (PFMC 1998) were based on biomass and recruitment estimates from Murphy (1996), MacCall (1979), and Barnes et al. (1992). Population biomass (1,000s mt) for ages two and older was assumed a close proxy for spawning stock biomass, and recruitment was taken as abundance of fish at age 2 (millions) (Table 1, Figure 1). The original analysis lagged biomass (ages 2+) and recruitment (age 2) by three years (Jacobson and MacCall 1995).

The most recent sardine stock assessment, spanning 1981-2010, was used to append the historic series (Table 1, Figures 1 & 2). The five years of data from Barnes et al. (1992), included in the original analysis, were replaced with data from the current assessment model (Hill et al. 2010). The assessment provided estimates of SSB and age 2+ biomass, so both series were used to examine recruitment success and estimate stochastic F_{MSY}. The sardine assessment uses a semester (6 month) time step and SSB is calculated in the middle of the biological year and thus, biomass and recruitment were lagged by 2.5 years. For example, the abundance of age-2 sardine in July 2010 were produced by SSB (or age 2+ biomass) in January 2007 (Table 1).

The updated series of biomass and recruits (Table 1) was used to estimate new intercept (α) and slope (β) parameters for the linearized Ricker (1975) S-R relationship originally applied by Jacobson and MacCall (1995) and PFMC (1998), with the temperature term removed:

$$[2] \qquad \ln(R/S) = \alpha + \beta S$$

Simulation model

The simulation model used for this analysis is generally described in Appendix B of Amendment 8 (PFMC 1998). The model was based on a simple, age-aggregated biomass dynamic model described in detail by Jacobson et al. (1994). The original simulation model, using the 'SAS' statistical platform, was provided by Drs. Larry Jacobson (NEFSC-Woods Hole) and Richard Parrish (SWFSC-retired) for this analysis. Prior to modification, the simulation was tested to confirm reproducibility of HCR outputs (performance measures) summarized in Tables 4.2.3.3-1 and 4.2.5-1 of Amendment 8 (see Tables 5 and 6 of this report).

The primary goal of the analysis was to estimate $F_{\mathrm{MSY},}$ based on an updated time series of biomass and recruits and independent of the temperature covariate. While it would have been possible to update other model parameters (e.g., instantaneous growth rate '*G*', recruitment and biomass variances), a decision was made to keep these parameters consistent with Amendment 8 analyses for ease of comparison. Future efforts for a full MSE should revisit all model parameters in addition to addressing the PMFC's management goals.

Following is a summary of some key model elements and constraints that remained unchanged from the original simulation (PFMC 1998):

- Begin with estimated stock biomass in 1996 (463,000 mt);
- Random numbers affecting errors in simulated biomass and recruitment were unchanged;
- Instantaneous natural mortality (*M)* was 0.4 yr^{-1} and instantaneous growth (*G)* was 0.1 yr^{-1};
- Recruitment variability was addressed by assuming log-normally distributed random errors in the S-R relationship, with a standard deviation = 0.91;
- Biomass estimates from stock assessments had CVs = 50%;
- 'Quota' = (BIOMASS - CUTOFF) * FRACTION;
- 'Quota' catch was assumed to be taken entirely, except when biomass fell to such a low level that a fishing mortality rate(*F*) >1.0 yr^{-1} would have been required;
- In addition to 'Quota' catch, 2,000 mt of sardine per year were assumed to be taken as live bait as long as the estimated stock biomass was >50,000 mt (overfished level); and
- Biomass was never allowed to fall below 5,000 mt, and recruitment was never allowed to exceed ~30 billion two-year old fish.

Current changes to the simulation model included:

- S-R intercept (α) and slope (β_2) parameters were set per models (3) and (4) in Table 3;
- Slope (β_1) for the temperature term was set to 0, disabling SST effects on S-R calculations;
- CUTOFF = 0;
- Maximum allowable catch (MAXCAT) was unlimited;
- Harvest FRACTION was varied to range from 0% to 60%, in 1% increments; and
- Number of simulation years (iterations) was increased in orders of magnitude from 1K to 10M years to examine stability of simulation results, with final results based on models simulated over 100K years.

In Amendment 8 and for purposes of this study, 'Stochastic F_{MSY}' was defined as the value of FRACTION that maximizes average catch (i.e., equilibrium yield) in a stochastic simulation model when CUTOFF is equal to zero and MAXCAT is unlimited. Stochastic MSY was calculated by determining the average catch over 100K years for a series of constant FRACTION values between 0% and 60%, in 1% increments. The FRACTION level with the highest average catch was the annual harvest rate (vs. instantaneous *F*) associated with $F_{MSY.}$

RESULTS & DISCUSSION

The relationship between recruitment success and biomass was modeled with linear regression for both the original (Jacobson & MacCall 1995) and updated time series (SSB and age 2+ biomass) in the absence of SST data. Regression statistics for the original management model (Jacobson & MacCall 1995, PFMC 1998) are displayed in the lower half of Table 2 and in Table 3 (model 1). Regression slopes for biomass (β_2) from the original data series were not significant for models that either included or excluded SST (models 1 & 2 in Table 3; Figure 3a). Addition of 23 years of data improved fit to the regression slope, with β_2 being significant for models using SSB (model 3; p=0.0024) or age 2+ biomass (model 4; p=0.0016). Both updated regression models (3 & 4) had lower R^2 values and higher variances than the original management model, however, the intercept and slope parameters for the updated models were all significant (Table 3; Figures 3b,c).

The HCR analyses presented in Amendment 8 (PFMC 1998, Appendix B) were based on simulations iterated over 1,000 years. To examine the effect of simulation years on stability of model results, the update model based on SSB (model 3) was run for 1K, 10K, 100K, 1M, and 10M years. Average catch-at-fraction results are displayed in Figure 4. Stochastic F_{MSY} was equal to 18% in all simulation runs. Simulations run for 10K years or more had higher average biomasses and catches than the model run for 1K years. Simulations run for 100K years or more had similar scales of average biomass and catch, so are more appropriate when considering other biological reference points, such as B_{MSY} or B_0 (Figure 4).

Two 'stochastic F_{MSY}' estimates were presented in analyses for Amendment 8 -- one in Table 4.2.3.3-1 and the other in Table 4.2.5-1 (Appendix B; PFMC 1998). These Tables are reproduced in Tables 5 and 6 of this report and are also summarized in Table 4 (see columns 1 & 2). While the stochastic F_{MSY} estimates in Tables 4.2.3.3-1 and 4.2.5-1 were identical (12%), and both were supposedly based on the same model parameterization, the HCR performance measures (e.g., average catch and biomass) differed among the two tables. The stochastic F_{MSY} model based on the older data and parameters was re-run for this study (see Table 4, 'Amendment 8 Stochastic F_{MSY} Redux'). The model based on 1K year simulation had a F_{MSY} equal to 0.11 in addition to having different HCR performance measures (Table 4, column 4), however, the HCR measures associated with FRACTION=0.12 were identical to values presented in Table 4.2.3.3-1 of Amendment 8 (see Table 4, columns 2 & 3). Nonetheless, analysis of the same data and control rule over 100K years resulted in an F_{MSY} estimate of 12%, which is consistent with estimates from Amendment 8 (Table 4, column 5).

The sardine simulation model was revised using updated S-R parameters based on either SSB or age 2+ biomass (Table 3, models 3 & 4), and the model was run over 100K years for the range of FRACTION values. Both simulations resulted in stochastic F_{MSY} estimates of **18%**, with only minor differences in HCR performance measures (Table 4, columns 6 & 7; Figure 5). Average biomass for F_{MSY} (0.18) ranged from 980,000 to 1,005,000 mt.

For comparative purposes, the PFMC's current HCR (where CUTOFF=150,000, MAXCAT=200,000, and FRACTION is fixed at 15%; no SST) was simulated over 100K years using the updated S-R parameters. Average biomass was 50% higher than the updated stochastic F_{MSY} models, and the percent of years with biomass greater than 400,000 was 98% (Table 4, column 8).

The final goal of this analysis was to use the revised F_{MSY} estimate to calculate OFL and ABCs for a range of biomass levels and compare these to HGs from the current HCR. Uncertainty buffers for a range of overfishing probabilities (P^*) (for σ=0.36) are displayed in Figure 6. OFLs, buffered ABCs (for P^*=0.20-0.45), and HGs for a range of sardine biomass are presented in Figure 7. In most cases, HG from the current HCR is lower than buffered ABCs, with the only exception being ABC for P^*=0.20 when biomass ranges ~1.3 to 1.7 million mt (Figure 7).

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Table 1. Biomass (1,000 mt), recruits (millions), and ln(*R/S*) as published in Jacobson and MacCall (1995) and used in Amendment 8 analyses (left), and as appended from Hill et al. (2010)(right).

Jacobson & MacCall (1995) and Amendment 8:

Year (y)	SSB(y-3)	R-age2(y)	ln(*R/SSB*)
1935	3,526	4,098	0.150
1936	3,417	2,821	-0.192
1937	3,628	5,383	0.395
1938	2,847	6,940	0.891
1939	1,689	6,763	1.387
1940	1,207	11,808	2.281
1941	1,202	14,442	2.486
1942	1,609	6,152	1.341
1943	1,761	3,268	0.618
1944	2,459	3,720	0.414
1945	2,066	2,385	0.144
1946	1,679	1,625	-0.033
1947	1,261	1,667	0.279
1948	720	3,875	1.683
1949	566	4,261	2.019
1950	405	3,690	2.209
1951	740	290	-0.937
1952	793	397	-0.692
1953	780	972	0.220
1954	277	1,197	1.464
1955	136	382	1.033
1956	202	264	0.268
1957	239	588	0.900
1958	170	1,586	2.233
1959	108	905	2.126
1960	90	288	1.163
1961	177	111	-0.467
1962	122	74	-0.500
1963	88	56	-0.452
1986	5	88	2.868
1987	18	57	1.153
1988	24	212	2.179
1989	33	161	1.585
1990	56	238	1.447

Appended 1983 onward from Hill et al. (2010):

Year (y)	SSB(y-3)	B-age2+(y-3)	R-age2(y)	ln(R/SSB)	ln(R/B2+)
1935	3,526	3,526	4,098	0.150	0.150
1936	3,417	3,417	2,821	-0.192	-0.192
1937	3,628	3,628	5,383	0.395	0.395
1938	2,847	2,847	6,940	0.891	0.891
1939	1,689	1,689	6,763	1.387	1.387
1940	1,207	1,207	11,808	2.281	2.281
1941	1,202	1,202	14,442	2.486	2.486
1942	1,609	1,609	6,152	1.341	1.341
1943	1,761	1,761	3,268	0.618	0.618
1944	2,459	2,459	3,720	0.414	0.414
1945	2,066	2,066	2,385	0.144	0.144
1946	1,679	1,679	1,625	-0.033	-0.033
1947	1,261	1,261	1,667	0.279	0.279
1948	720	720	3,875	1.683	1.683
1949	566	566	4,261	2.019	2.019
1950	405	405	3,690	2.209	2.209
1951	740	740	290	-0.937	-0.937
1952	793	793	397	-0.692	-0.692
1953	780	780	972	0.220	0.220
1954	277	277	1,197	1.464	1.464
1955	136	136	382	1.033	1.033
1956	202	202	264	0.268	0.268
1957	239	239	588	0.900	0.900
1958	170	170	1,586	2.233	2.233
1959	108	108	905	2.126	2.126
1960	90	90	288	1.163	1.163
1961	177	177	111	-0.467	-0.467
1962	122	122	74	-0.500	-0.500
1963	88	88	56	-0.452	-0.452
1983	17	6	33	0.682	1.665
1984	8	8	47	1.776	1.731
1985	10	10	111	2.411	2.413
1986	12	13	104	2.135	2.098
1987	21	21	116	1.725	1.733
1988	26	27	280	2.369	2.327
1989	34	33	388	2.447	2.464
1990	50	54	543	2.383	2.313
1991	78	84	459	1.777	1.694
1992	114	119	969	2.141	2.095
1993	140	134	1,944	2.631	2.674
1994	154	168	1,617	2.350	2.264
1995	193	250	4,045	3.045	2.782
1996	266	329	4,650	2.861	2.648
1997	421	562	1,775	1.438	1.150
1998	629	821	2,456	1.362	1.095
1999	756	820	6,949	2.218	2.137
2000	740	772	7,868	2.364	2.322
2001	884	1,096	1,330	0.409	0.194
2002	1,197	1,496	937	-0.245	-0.467
2003	1,308	1,324	2,469	0.636	0.623
2004	1,136	1,055	279	-1.405	-1.331
2005	936	922	7,054	2.020	2.035
2006	746	670	3,804	1.630	1.736
2007	751	967	3,886	1.644	1.391
2008	886	1,032	1,037	0.157	0.004
2009	959	1,071	1,013	0.054	-0.056
2010	880	848	684	-0.251	-0.215

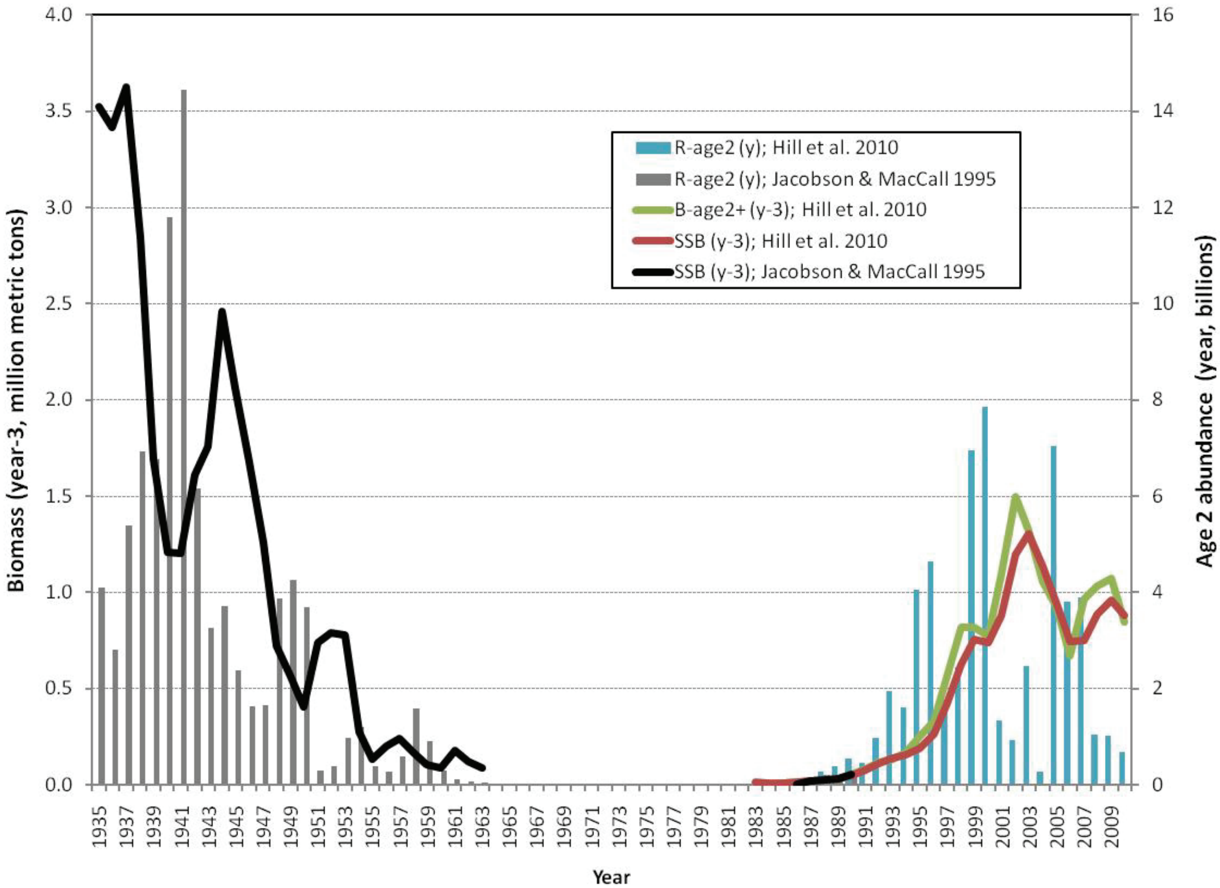


Figure 1. Biomass (yr-3) and recruits (age-2, yr) from Jacobson & MacCall (1995) and Hill et al. (2010).

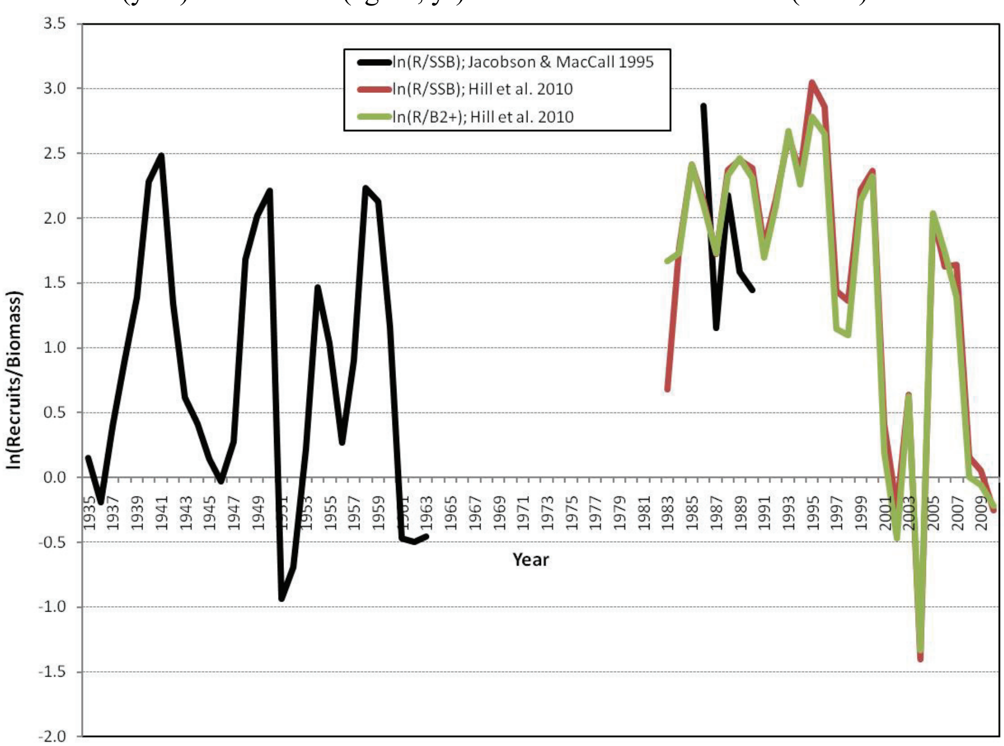


Figure 2. Recruitment success from Jacobson & MacCall (1995) and Hill et al. (2010).

Table 2. Regression statistics published in Table 5 of Jacobson & MacCall (1995). The second model served as the basis for Amendment 8 simulations (PFMC 1998).

Table 5. Summary statistics for management models [2] fit to log reproductive success data for sardine.

Parameter	Estimate	Standard error	t value	p value
Management model with temperature only				
$\ln(R/S) = \alpha + \beta T$				
α	−16.45	6.077	−2.71	0.011
β_1 (temperature)	1.025	0.358	2.86	0.007
(R^2 = 20%, Var(ε) = 0.87)				
Management model with temperature and spawning biomass				
$\ln(R/S) = \alpha + \beta_1 T + \beta_2 S$				
α	−15.12	5.99	−2.53	0.017
β_1 (temperature)	0.961	0.352	2.73	0.010
β_2 (spawning biomass)	−0.0002331	0.0001441	−1.62	0.116
(R^2 = 27%, Var(ε) = 0.83)				

Table 3. Summary statistics for models fit to log reproductive success data for Pacific sardine. Regression model: $\ln(R/S) = \alpha + \beta_1 T + \beta_2 S$, where R is age-2 abundance in year y, S is spawning biomass in y-3, and T is sea surface temperature at SIO pier, included model (1) only. See Figure 3 for scatter plots and modeled regressions.

Model/Parameter	Estimate	Standard error	t value	p value
(1) Model in J&M 1995 and Amendment 8 (R^2 = 27%, Var(ϵ) = 0.83, n = 34)				
α	-15.1220	5.99000	-2.530	1.700E-02
β_1	0.9609	0.35200	2.730	1.000E-02
β_2	-0.00023310	0.00014	-1.620	1.160E-01
(2) J&M 1995 model without SST (R^2 = 9%, Var(ϵ) = 0.99, n = 34)				
α	1.2097	0.23258	5.201	1.107E-05
β_1	0	---	---	---
β_2	-0.00027762	0.00016	-1.768	8.652E-02
(3) Updated model using SSB and no SST (R^2 = 15%, Var(ϵ) = 1.07, n = 57)				
α	1.5414	0.18548	8.310	2.733E-11
β_1	0	---	---	---
β_2	-0.00047896	0.00015	-3.175	2.454E-03
(4) Updated model using Age 2+ Biomass and no SST (R^2 = 17%, Var(ϵ) = 1.03, n = 57)				
α	1.5405	0.18457	8.346	2.385E-11
β_1	0	---	---	---
β_2	-0.00049010	0.00015	-3.311	1.648E-03

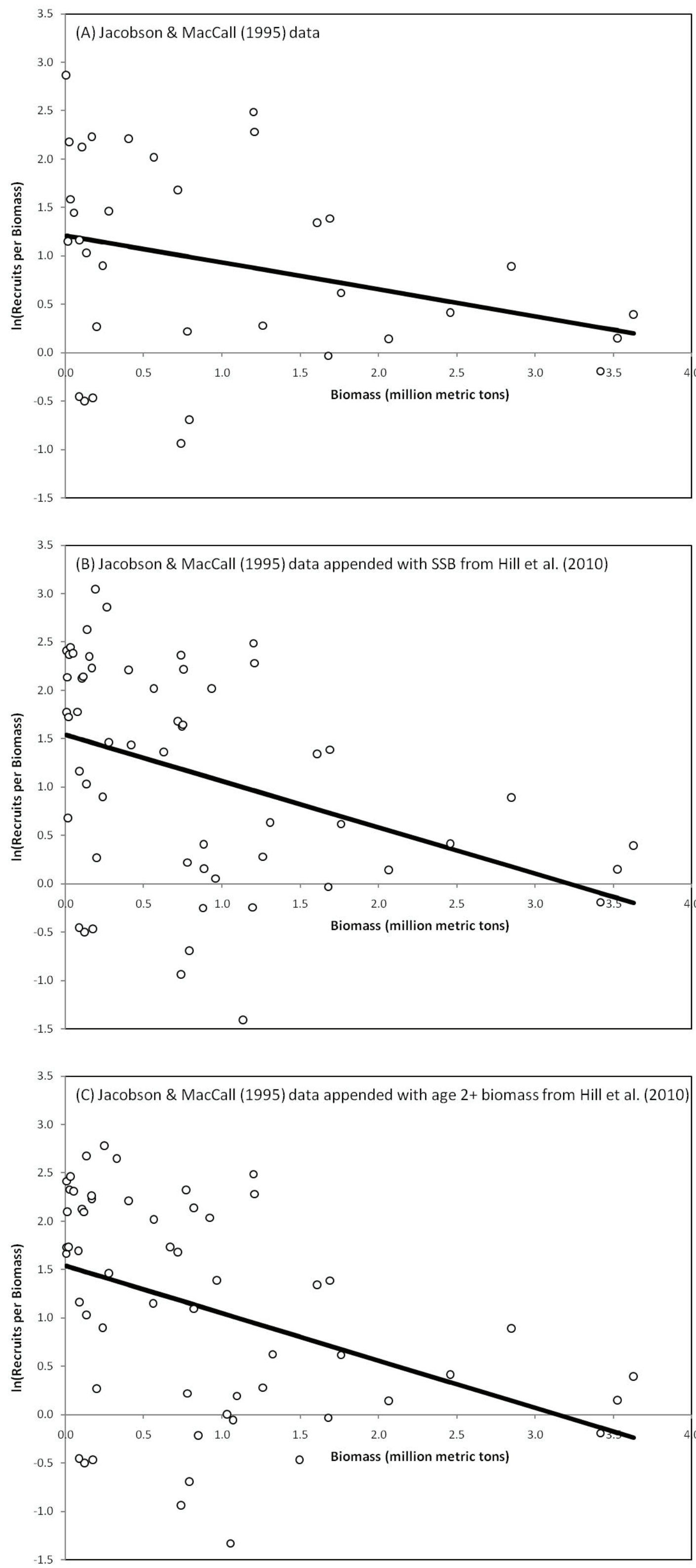


Figure 3. Plot of regressions for old (minus SST) and new data. See Table 3 for all regression statistics.

Table 4. Simulation parameters and performance measures for HCR from Amendment 8 and the updated analyses.

	Amendment 8 Stochastic F_{MSY}		Amendment 8 Stochastic F_{MSY} Redux			Updated Stochastic F_{MSY}		Current HCR:
	A8 Table 4.2.5-1	**A8 Table 4.2.3.3-1**	**Fraction=12%**	**Actual F_{MSY}**	**100K Years**	**Using SSB**	**Using 2+ Biomass**	**new SSB, 100K yrs**
Data Source / S-R parameters:	JM95 & A8	JM95 & A8	JM95 & A8	JM95 & A8	JM95 & A8	JM95+2010	JM95+2010	JM95+2010
$\ln(R/S) = \alpha + \beta_1 T + \beta_2 S$								
α	-15.1220	-15.1220	-15.1220	-15.1220	-15.1220	1.5414	1.5405	1.5414
β_1 (temperature)	0.9609	0.9609	0.9609	0.9609	0.9609	0	0	0
β_2 (spawning biomass)	-0.00023310	-0.00023310	-0.00023310	-0.00023310	-0.00023310	-0.00047896	-0.00049010	-0.00047896
Control Rule Parameters:								
Number of Simulation Years	1,000	1,000	1,000	1,000	100,000	100,000	100,000	100,000
Range of FRACTION Simulated	0-60%	0-60%	12%	0-60%	0-60%	0-60%	0-60%	15%
F_{MSY}	12%	12%	---	11%	12%	18%	18%	---
CUTOFF	0	0	0	0	0	0	0	150
MAXCAT	infinite	infinite	infinite	infinite	infinite	infinite	infinite	200
HCR Performance Measures:								
Average Catch	180	176	176	178	209	201	196	152
Std. Dev. Catch	180	180	180	173	218	175	171	59
Average Biomass	1,408	1,332	1,332	1,468	1,544	1,005	980	1,530
Std. Dev. Biomass	39	38	38	40	7	3	3	2
Average Log Catch	4.72	4.66	4.66	4.74	4.84	4.99	4.96	4.90
Average Log Biomass	6.89	6.76	6.76	6.94	6.93	6.69	6.66	7.20
Percent Years Biomass>400	84%	80%	80%	85%	84%	84%	84%	98%
Percent Years No Catch	0%	0%	0%	0%	0%	0%	0%	0.2%
Median Catch	128	123	123	127	139	148	144	180
Median Biomass	1,500	1,049	1,049	1,199	1,199	849	848	1,398

Table 5. Table 4.2.3.3-1 from Amendment 8 to the CPS-FMP. Stochastic F_{MSY} model is shown in the last column.

TABLE 4.2.3.3-1. Performance variables for various MSY control rules with constant FRACTION values. Biomass values are in thousand mt. All control rules except deterministic equilibrium F_{MSY} were evaluated in a stochastic model (see Table 4.2.5-1).

	Maximum Average Catch Policy ("Pulse Fishery")	Maximum Average Log Catch Policy	Maximum Median Catch Policy	Minimum Percent Years With No Catch Policy	Status Quo Policy	Deterministic Equilibrium F_{MSY} Policy in a Deterministic Model (Unrealistic)	Stochastic F_{MSY} Policy
MSY Control Rule Parameter							
FRACTION	45%	10%	100%	many	20%	8.8%	12%
CUTOFF	1,000	0	975	many	50	0	0
MAXCAT	1,000	300	300	many	400	Infinite	Infinite
Performance Variable							
Average Catch	208	159	173	many	151	170	176
Standard Deviation Catch	306	98	142	many	137	153	180
Average Biomass	1,307	1,754	1,675	many	936	1,756	1,332
Std. Dev. Biomass	15	45	30	many	27	44	38
Average Log Catch	3.19	4.79	3.74	many	4.33	4.78	4.66
Average Log Biomass	6.97	7.17	7.16	many	6.24	7.21	6.76
Percent Years With Biomass >400K mt	94%	91%	94%	many	61%	93%	80%
Percent Years With No Catch	47%	0%	37%	0%	5%	0%	0%
Median Catch	16	142	298	many	103	127	123
Median Biomass	1,049	1,449	1,324	many	598	1,499	1,049

Table 6. Table 4.2.5-1 from Amendment 8 to the CPS-FMP. Stochastic F_{MSY} model is Option L.

TABLE 4.2.5-1. MSY control rule options for Pacific Sardine. All options evaluated in a stochastic model.

	Option A (Status Quo)	Option B	Option C	Option D	Option E	Option F	Option G	Option H	Option I	Option J	Option K	Option L (Stochastic F_{MSY})	Option M (Determ. Equil. F_{MSY} in a Stochastic Model)
Overfishing Definitions													
Overfishing Rate	Catch> ABC	Catch> ABC	Catch> ABC	Catch> ABC	Catch> ABC	Catch> ABC	Catch> ABC	Catch> ABC	Catch> ABC	Catch> ABC	Catch> ABC	Catch> ABC	Catch> ABC
Overfished Threshold (mt)	50	50	50	50	50	50	50	50	50	50	50	50	50
Control Rule Parameters													
FRACTION	20%	F_{MSY} (10-30%)	20%	F_{MSY} (10-30%)	F_{MSY} (10-30%)	F_{MSY} (5-25%)	F_{MSY} (5-15%)	F_{MSY} (5-15%)	F_{MSY} (5-25%)	F_{MSY} (5-15%)	F_{MSY} (10-30%)	12%	8.8%
CUTOFF	50	50	100	100	100	100	100	100	100	150	50	0	0
MAXCAT	400	400	400	400	300	400	400	300	300	200	200	Infinite	Infinite
Performance Measure													
Average Catch	151	159	165	171	165	177	179	169	169	145	141	180	170
Std. Dev. Catch	137	140	140	143	113	143	133	105	112	67	72	180	153
Mean Biomass	936	964	1,073	1,091	1,280	1,216	1,543	1,665	1,400	1,952	1,516	1,408	1,784
StdDev Biomass	27	27	29	28	34	32	39	42	37	49	43	39	43
Mean Log Catch	4.33	4.46	4.44	4.54	4.64	4.62	4.77	4.80	4.70	4.76	4.65	4.72	4.77
Mean Log Biom	6.24	6.37	6.50	6.59	6.75	6.74	7.06	7.15	6.89	7.34	6.87	6.89	7.24
Percent Years Biomass>400	61%	64%	70%	73%	79%	81%	90%	92%	84%	96%	79%	84%	93%
Percent Years No Catch	5%	2%	7%	4%	3%	2%	1%	0%	1%	0.5%	1%	0%	0%
Median Catch	103	104	119	121	148	131	140	156	158	182	188	128	127
Median Biomass	598	600	700	748	898	850	1,248	1,349	1,048	1,648	1,099	1,500	1,049

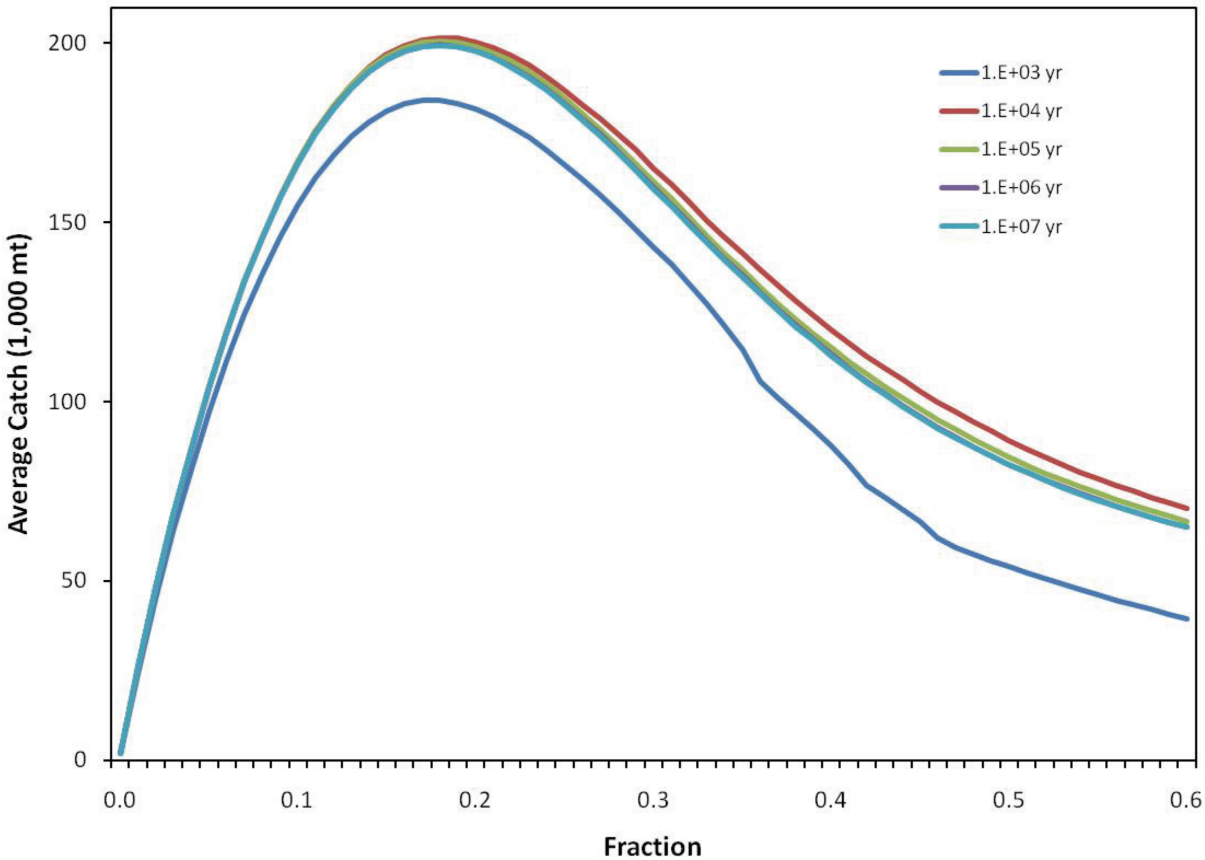
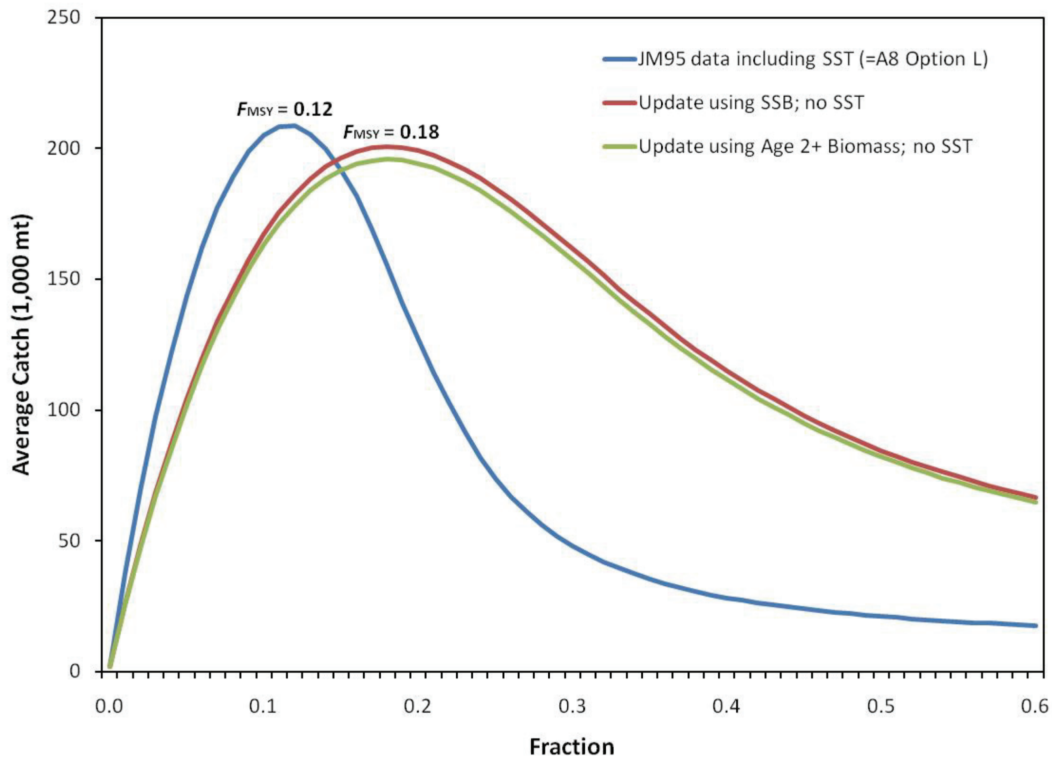


Figure 4. Average catch- at- fraction for the updated model and simulations ranging from 1,000 to 10 million iterations.



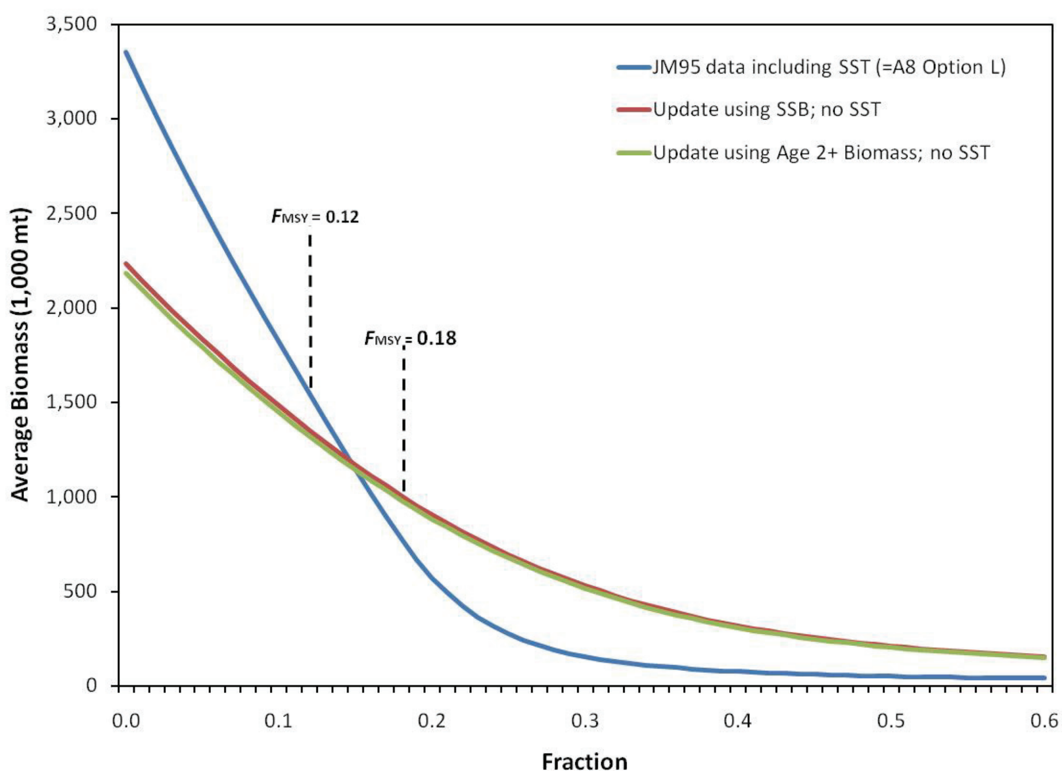


Figure 5. Average catch (upper panel) and average biomass (lower panel) for the updated 'Stochastic F_{MSY}' models for a range of harvest fraction values, each simulated over 100K iterations.

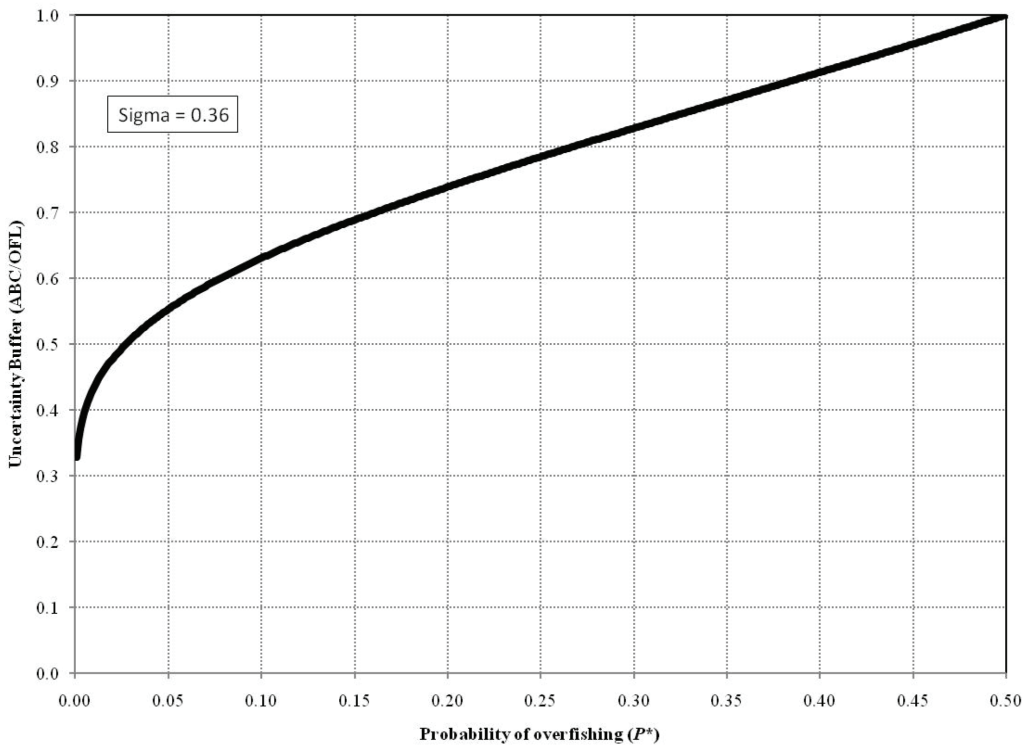


Figure 6. Uncertainty buffer for a range of P* values where Sigma = 0.36.

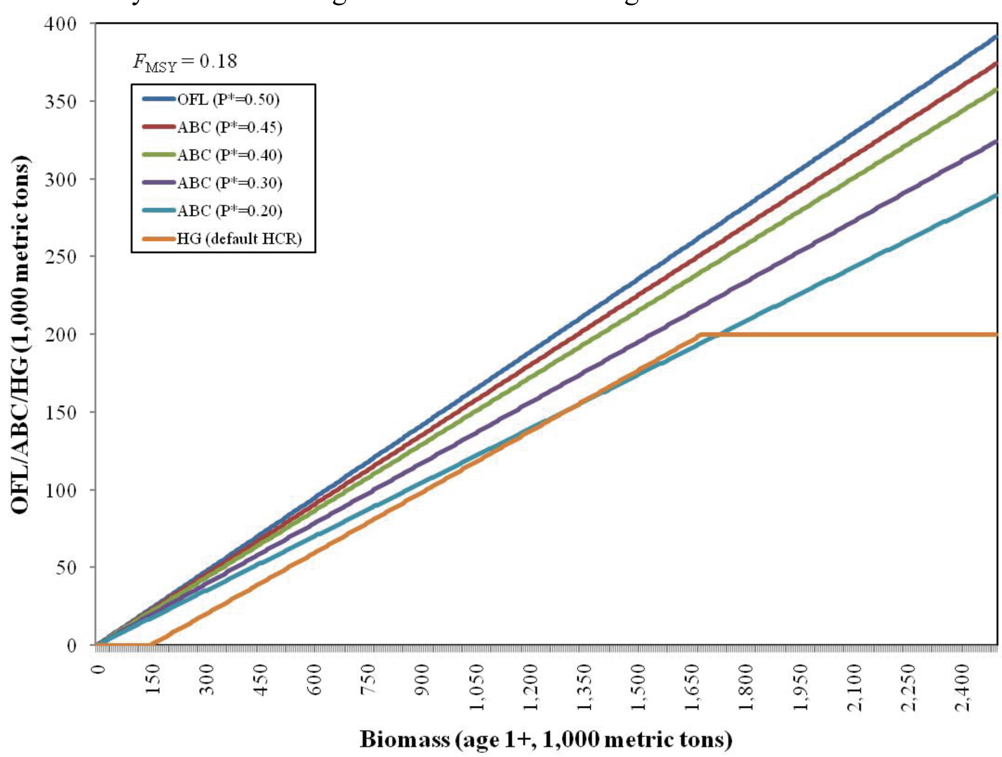


Figure 7. The OFL and ABC for a range of Pacific sardine biomasses, where F_{MSY} = 0.18 and Sigma = 0.36

APPENDIX 5

Spawning fraction using Baysian hierarchical (Random effect) model for years in 1986-2011

Nancy C H Lo, Yuhong Gu and Beverly Macewicz

Abstract

Spawning fraction (S), the proportion of mature female fish that spawn per day, is one of the adult reproductive parameters used in the daily egg production method to estimate the spawning biomass. This parameter is one of the most difficult parameters to estimate with relative large coefficient of variation (CV). Since 2004, number of trawls for Pacific sardine ichthyoplankton-trawl surveys has increased. To fully utilize trawl data from all years, a Bayesian hierarchical model (BHM) was investigated, as recommended by the May 2009 STAR panel[1]. The BHM was used for each of two regions (region1: high density area and region 2: low density area) when data of that region were available. For both regions, the point estimates from the original estimates and the BHM were similar. The CVs of the BHM estimates were lower than those from the original method in most years. In recent year, the CV of estimates from these two methods were similar for region 1, but the CV of BHM estimates were much lower than those of the original estimates for region 2. One of the reasons for the similarities of two estimators in recent years is due to the large sample sizes. We choose to continue using the original method for following reasons: 1). The shrinkage effect is small for future years when sample size is large, thus the gain from the BHM is minimum. 2). In many years (e.g. 1987, 1997, 2001, 2002 and 2004), when trawls were taken only in region 1 but not in region 2, the mean of the posterior predictive distribution for region 2 was used. The BHM is also needed for other adult parameters like fecundity, female weight and sex ratio Extensive computer programming is needed to incorporate the BHM estimates of adult samples and egg samples to compute the spawning biomass. 3). The current practice is for years when no adult samples were available in any one or both regions, the total egg production (TEP) time series was obtained and used in the stock assessment.

Introduction

The spawning biomass of Pacific sardine has been estimated using the daily egg production method (DEPM) (Piquelle and Stauffer 1985) since 1986 (Hill et al. 2009). Data were collected from ichthyoplankton-trawl surveys off California in most years and off the west coast of US in recent years (Lo et al. 2010). Although the icthyoplankton survey was conducted yearly, trawl samples were collected only in 1986-1988, 1994,

[1] Star Panel Report 2009, Daily Egg Production Methods for Pacific Sardine Report of STAR Panel Meeting. NOAA / Southwest Fisheries Science Center La Jolla, California, May 4-8, 2009 Star Panel Agenda Item H.2.a Attachment 4 (http://www.pcouncil.org/bb/2009/0609/H2a_ATT4_0609.pdf)

1997, 2001, 2002, and 2004-present. Further, the number of trawls was small during 1997, 2001 and 2002 when all the trawls were opportunistic collections. To compute the spawning biomass prior to 2009, for years when trawls samples were lacking or small, (e.g. 1995–2001), an overall average of the spawning fraction during 1986–94 and estimates of other adult parameters in 1994 were once used to estimate daily specific fecundity (number of eggs/gram weight). In 2003, when no trawls were taken, the estimates of adult reproductive parameters from 2002 were also once used. Since 2004, a full-scale survey has been conducted to estimate the spawning biomass of Pacific sardine (Lo et al. 2005). Starting in 2009, a stratified sampling scheme was used where the spawning biomass was estimated for each of two regions for years when trawls were available for both regions. Otherwise, the total egg production (TEP) was computed to form another time series for the stock assessment.

The spawning fraction (S), the proportion of mature female fish that spawn per day, is one of the most difficult parameters to estimate and typically has relative large coefficient of variation (CV) (see below). In recent years, number of trawls has been increased while in most of early years, prior to 2004, number of trawls was low. To fully utilize trawl data from all years, a Bayesian hierarchical model (a.k.a. random effects model) was recommended by the May 2009 STAR panel for the sardine survey (STAR panel report 2009). In this report, we provide Bayesian estimates of spawning fraction for the years between 1986 and 2011 when adult samples were available in at least in one of the two regions.

Material and method

Spawning biomass for Pacific sardine off California was estimated using DEPM for the survey area south of CalCOFI line 60 (DEPM survey area) during the spring DEPM survey even during some years, e.g. 2006, 2008, 2010, and 2011 when the survey also covered area off the Washington and Oregon coast (Figure 1). The survey area was post stratified into two regions based on egg density from the continuous underway egg sampler (CUFES) (Checkley et al. 1977, Lo et al 2001): region 1 (high density area: eggs/minute >=1) and region 2 (low density area: eggs/minutes<1) (Figure 1). The spawning biomass was computed for each of the two areas in the DEPM area and the sum of the two estimates was used to estimate the total spawning biomass. For stock assessment, we have provided the female spawning biomass since 2009 (Hill et al. 2009).

The spawning biomass was computed as:

$$B_s = \frac{P_0 AC}{RSF / W_f} \qquad (1)$$

where P_0 is the daily egg production per 0.05m^2, A is the survey area in units of 0.05m^2, S is the fraction of mature females spawning per female per day, F is the batch fecundity (number of eggs per mature female released per spawning), R is the fraction of mature female fish by weight (sex ratio), W_f is the average weight of mature females (g), and C is the conversion factor from grams (g) to metric tons (mt). P_0A is the total daily egg production in the survey area, and the denominator (RSF/W_f) is the daily specific fecundity (number of eggs/population weight (g)/day).

The variance of the spawning biomass estimate $\left(\hat{B}_s\right)$ was computed using Taylor expansion and in terms of the coefficient of variation (CV) for each parameter estimate and covariance for adult parameter estimates (Parker 1985):

$$VAR\left(\hat{B}_s\right) = \hat{B}_s^{\,2}\left[CV\left(\hat{P}_0\right)^2 + CV\left(\hat{W}_f\right)^2 + CV\left(\hat{S}\right)^2 + CV\left(\hat{R}\right)^2 + CV\left(\hat{F}\right)^2 + 2COVS\right] \quad (2)$$

The last term, involving the covariance term, on the right-hand side is

$$COVS = \sum_i \sum_{i<j} sign \frac{COV\left(x_i, x_j\right)}{x_i x_j}$$

where x's are the adult parameter estimates, and subscripts i and j represent different adult parameters; e.g., $x_i = F$ and $x_j = W_f$. The sign of any two terms is positive if they are both in the numerator of B_S or denominator of B_S (equation 1); otherwise, the sign is negative. The covariance term is

$$\text{cov}(x_{i,} x_j) = \frac{[n/(n-1)]\sum_k m_k (x_{i,k} - x_i) g_k (x_{j,k} - x_j)}{\left(\sum_k m_k\right)\left(\sum_k g_k\right)}$$

where k refers to k^{th} tow, and k = 1,…,n. The terms of m_k and g_k are sample sizes and $x_{i,k}$ and $x_{j,k}$ are sample means from the k^{th} tow for x_i and x_j respectively.

For the female spawning biomass, the parameter, sex ratio (R), was excluded from equations 1 and 2.

DEPM trawl samples

Adult Pacific sardines were collected from the entire survey area, e.g. 2011 survey (Figure 1), onboard a NOAA research vessel using either a high-speed mid- water trawl or a Nordic 264 midwater trawl, or in recent years, onboard the chartered commercial vessel F/V *Frosti,* using a Nordic 264 midwater trawl. Allocation of trawls was based on evidence of schools on echo-sounder or sardine eggs in CUFES samples in the early years. From 2006 on, trawls have been taken either at the pre-determined stations or randomly along survey transects. Collections of sardines were taken at night between 18:00 and 05:00 hours. Up to 50 randomly sampled fish from each collection were sexed and standard length was measured to the nearest millimeter. All females sampled were individually weighed to the nearest gram. After the random subsample, additional fish were processed following procedures used in 1994 (Macewicz et al. 1996) if necessary, to obtain 25 mature females per trawl to be used to calculate reproductive parameters. In the laboratory, each preserved ovary was processed (Hunter and Macewicz 1985). We analyzed oocyte development, atresia, and postovulatory follicle age to assign female maturity and reproductive state (Macewicz et al. 1996).

Annual number of mature female sardines analyzed ranged from 9 (2001) to 746 (1988) between 1986-2011 for the standard DEPM area (south of CalCOFI line 60, close to San Francisco, to CalCOFI line 95, close to San Diego), and was considered to be a random sample of the population in the area trawled. Histological criteria can be used to identify four different spawning nights: postovulatory follicles aged 44-54 hours old indicated spawning two nights before capture (day-2 female) postovulatory follicles aged about 20-30 hours old indicated spawning the night before capture (day-1 female); hydrated oocytes or new (without deterioration) postovulatory follicles indicated spawning the night of capture (day-0 female); and early stages of migratory-nucleus oocytes indicated that spawning would have occurred the night after capture (mn-female). The daily spawning fraction can be estimated using the number of females spawning on one night, an average of several nights, or average of all nights (Macewicz et al. 1996). Prior to 2009, number of day-1 females was used to replace day-0 females because of possible over representation of day-0 female during the spawning time (Picquelle and Stauffer 1985). Since 2009, we have used the average of number of day-1 female and number of day-2 female, and the adjusted number of mature females caught in each trawl to estimate the population spawning fraction (S_{12}) and its variance (Picquelle and Stauffer 1985, Hill et al. 2009). This pooled estimate of spawning fraction based on day-1 and day-2 females was used for Peruvian anchovy (Alheit et al. 1984), sardine off Spain (Garcia et al. 1992) and Portugal (Cunha et al. 1992). The spawning fraction was estimated for each region and the spawning biomass (and thus female spawning biomass) was the sum of the estimates, from both low and high density regions.

Bayesian hierarchical model (BHM)

The Bayesian hierarchical model (BHM) (Sahai 1975, Casella 1995, 2001, Clark 2007) has been used widely in ecological studies in recent years (Helser and Lai, 2004, Clark et al. 2005, Eguchi and Gerrodette 2009). Because the egg production method requires estimates of each parameter, for years when the sample size was small, the BHM can utilize data from other years to shrink the estimates, in particular for spawning fraction. The Bayesian estimates of the spawning fraction in each year were computed as follows.

The number of females spawned in the random sample of a maximum of 25 mature females (N_{ij}) from the j^{th} trawl in the i^{th} year (n_{ij}) follows the binomial distribution: $B(N_{ij}, S_{ij})$ where S_{ij} is the spawning fraction . The ratio of n_{ij} / N_{ij} is an estimate of S_{ij}. The prior distribution of logit (S_{ij}) was modeled by a logistic regression, and logit (S_{ij})

follows normal distribution: $\ln(\frac{S_{ij}}{(1-S_{ij})}) \sim N(\mu_{ij}, 1/\tau)$ where μ_{ij}, the mean, is a function of temperature, region, time block where the latter two independent variables are categorical variables and τ ($=1/\sigma^2$) is a measure of precision (equation 3). Before the implementation of the Bayesian hierarchical model (BHM), we conducted regression analyses to determine which independent variables to be included in the logistic equation. The independent variables considered were temperature, fish weight, region, season and time block where time block 1 included the years up to 2006, and time block 2 included years after 2006. Our regression analyses indicated that the effects of the fish weight and season were not significant, and thus were not included in the BHM.

$$\mu_{ij} = \alpha_i + \beta_{i1}(t_{ij} - \bar{t}_i) + \beta_{i2}x_{ij2} + \beta_{i3}x_{ij3} \quad (3)$$

where t_{ij} is the temperature of the j^{th} tow in the year i

x_{ij2} =1 for region 1 and =0 for region 2

x_{ij3} =1 for time block 2: years >2006 and =0 for time block 1: for years<=2006.

Note that α_i is the mean of $\ln(\frac{S_{ij}}{(1-S_{ij})})$ for average temperature in year i in region 2 and year is 2006 or earlier (<=2006).

The spawning fraction for the year i (S_i) was computed as a ratio estimator (Picquelle and Stauffer 1985):

$$S_i = \frac{\sum_j S_{ij} N_{ij}}{\sum_j N_{ij}} \quad (4)$$

The priors for parameters: The random effect was assumed for each of the regression coefficients for the ith year:

$$\alpha_i \sim normal(\alpha_c, \tau_\alpha) \quad (5)$$

$$\beta_{ik} \sim normal(\beta_{ck}, \tau_{\beta_{ck}}) \quad (6)$$

$$\tau \sim gamma(0.001, 0.001) \quad (7)$$

where k = 1,2, and 3 for temperature, region and time block.

Using the vague non-informative hyper priors, we have

$\alpha_c \sim normal(0,1.0E-6)$

$\tau_\alpha \sim gamma(0.001,0.001)$

Similarly, we have

$\beta_{ck} \sim normal(0,1.0E-6)$

$\tau_{\beta_{ck}} \sim gamma(0.001,0.001)$

For k = 1, 2 and 3 for temperature, region and time block.

If the survey was not post stratified, the equation (3) would include temperature and time block as the independent variables. Estimates of S_i (equation 4) and other parameter were obtained using program WINBUGS [2].

In years, when no trawls were taken in region 2 (Table 1), we obtained an overall estimate of the spawning fraction $S_i = \frac{e^{\mu_i}}{1+e^{\mu_i}}$ from its posterior predictive distribution where $\mu_i = \alpha_c + \beta_{c2}$ and $\mu_i = \alpha_c$ for region 1 and 2 respectively at the average temperature for years<= 2006 (equation 3) for example. The posterior distributions of BHM β_{c1} and β_{c2}, β_{c3}, and α_c (intercept) and thus μ_i plus the posterior predictive distribution of spawning fraction (S_i) for each of two regions and time blocks were obtained to estimate their mean(e.g. posterior.α_c and posterior.β_{ck}), standard deviation, and 95% confidence.

The posterior mean of spawning fraction in years<=2006 is

$$posterior.\,S_1 = \exp(posterior.\alpha_c + posterior.\beta_{ck})/(1+\exp(posterior.\alpha_c + posterior.\beta_{ck})$$ for region 1

and

$$posterior.\,S_2 = \exp(posterior.\alpha_c)/(1+\exp(posterior.\alpha_c)$$ for region 2

In practice, n_{ij} was replaced by n_{aij}, the adjusted total number of mature females by replacing number of day-0 (n_0) by either number of day-1 female ($n_{1,ij}$), or the average of number of day-1 and day-2 females ($n_{12,ij}$). For the latter, one would have the adjusted total number of mature females as $N_{aij}=n_{12.ij}+n_{1,ij}+n_{2,ij}+$others and $S_{aij} = n_{12,ij} / N_{aij}$. For years 1987, 1994 and 2002, only the number of day-1 female was available, and thus day-1 females were used in the analysis. We used WINBUGS program (http://www.stat.uiowa.edu/~gwoodwor/ BBIText/AppendixBWinbugs.pdf) to obtain the

[2] http://www.mrc-bsu.cam.ac.uk/bugs/winbugs/manual14.pdf

posterior distributions of all the parameters, because the Gibbs sampler usually produces chains with smaller autocorrelation than other MCMC samplers (Draper,1995, 2000[3] (http://www.bath.acx.uk/~masdd), Walsh 2004). To reduce possible autocorrelation,

we used 1000 burn-in samples, took every 10th output for a total of 30,000 iterations

Results

The summary statistics for the Bayesian estimates of parameters: α_c τ_α β_{ck} , τ and S for region 1 and region 2 are given in Table 2. The estimates of the spawning fractions and their coefficient of variation (CV) for each region in each year are given in Figures 2 and 3. The BHM point estimates and the original estimates were similar while the CV of the BHM estimates were lower than those of the traditional estimates for most years, except for 1986, 2005, 2008 and 2010 for region 1 estimates and 1986 and 1988 for region 2 estimate (Figures 2 and 3). For years when no trawls were taken in region 2, the estimates of spawning fraction were based on the mean of the posterior predictive distribution: 0.045 (Table 1 and 2, Figure 3). Note that the BHM estimate was close to the estimate using equation 3 with the Bayesian estimates of regression coefficients: 0.055.

Table 1. Number of positive trawls taken in years from 1986-2011 in the DEPM area

Year	86	87	88	94	97	01	02	04	05	06	07	08	09	l0	11
Total	11	13	19	22 [a]	**4**	**2**	**6**	16	13 [b]	7	14	12	28 [c]	17	28 [d]
Region 1	5	13	14	18	4	2	6	16	5	2	8	4	14	3	14
Region 2	6	**0**	5	4	**0**	**0**	**0**	**0**	8	5	6	8	14	14	14

[a] total trawls was 24, a trawl from region 1 and region 2 lacked SST and was not used in analysis
[b] total trawls was 14, a trawl from region 1 had only day-0 female and was not used in analysis
[c] total trawls was 29, a trawl from region 1 had only day-0 female and was not used in analysis
[d] total trawls was 30, 2 trawls from region 2 had only day-0 female and was not used in analysis

[3] Draper, David. 2000. *Bayesian Hierarchical Modeling*.

Table 2. Summary statistics of the Bayesian estimates of the parameters of the hyper priors of each regression coefficient: the intercept (α_c), coefficient for temperature (β_{c1}), and coefficient for region effect (β_{c2}), time block (β_{c3})and the precision ($\tau=1/\sigma^2$) of the logit (S_{ij}) (equations 3-6)) and spawning fraction estimates from the posterior predictive distribution: S_1 and S_2 are for years<=2006 and S_3 and S_4 are for years in 2007-2011 in region 1 and 2 respectively.

Parameters	mean	sd	CV	2.50%	median	97.50%	start	sample
α_c (intercept)	-3.118	0.217	-0.070	-3.560	-3.115	-2.703	1001	3000
β_{c1}(temperature)	0.499	0.116	0.232	0.290	0.495	0.740	1001	3000
β_{c2} (region)	0.815	0.212	0.259	0.407	0.811	1.255	1001	3000
β_{c3} (timeblock)	0.436	0.225	0.516	-0.052	0.430	0.950	1001	3000
$\tau=1/\sigma^2$	0.847	0.090	0.107	0.682	0.841	1.039	1001	3000
S_1(spawning fraction in region 1 for years<=2006)	0.098	0.032	0.330	0.038	0.091	0.208	1001	3000
S_2(spawning fraction in region 2 for years<=2006)	0.045	0.017	0.371	0.022	0.043	0.084	1001	3000
S_3(spawning fraction in region 1 for years>2006)	0.202	0.094	0.466	0.053	0.185	0.480	1001	3000
S_4 (spawning fraction in region 2 for years>2006)	0.098	0.033	0.338	0.039	0.091	0.209	1001	3000

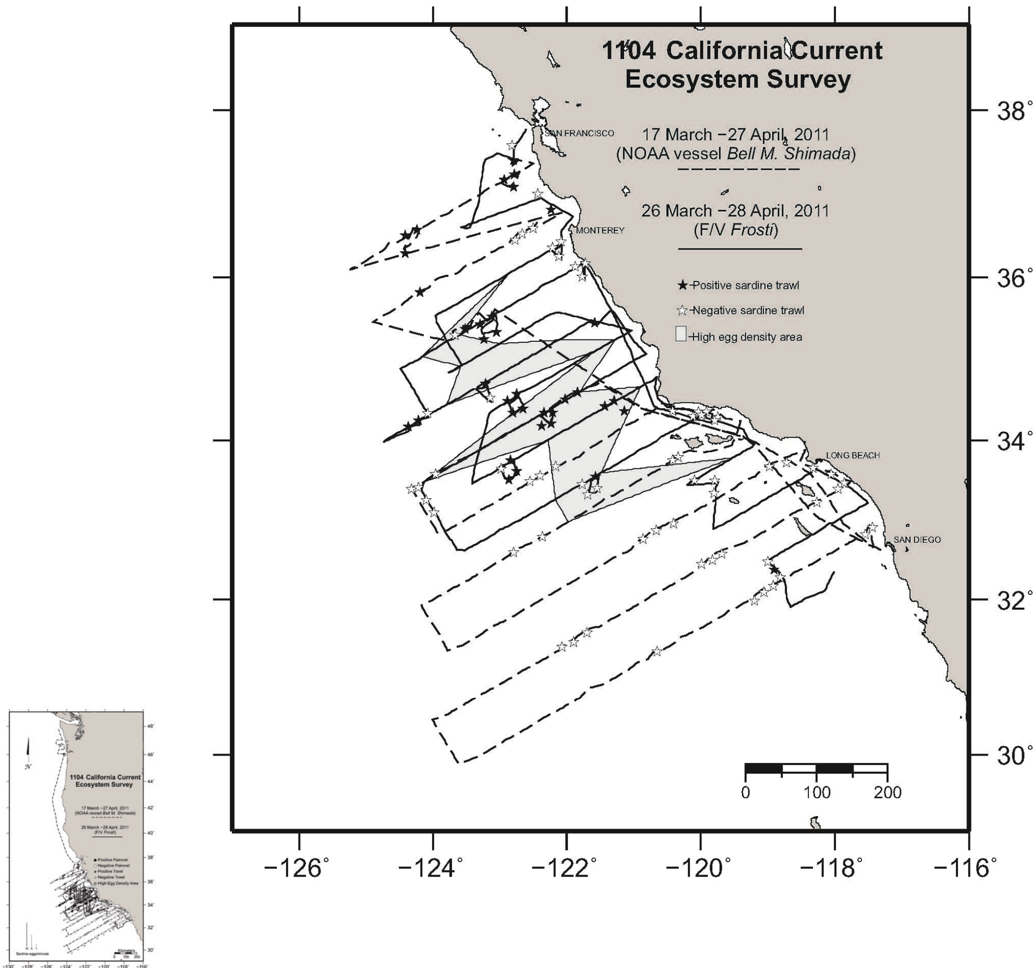
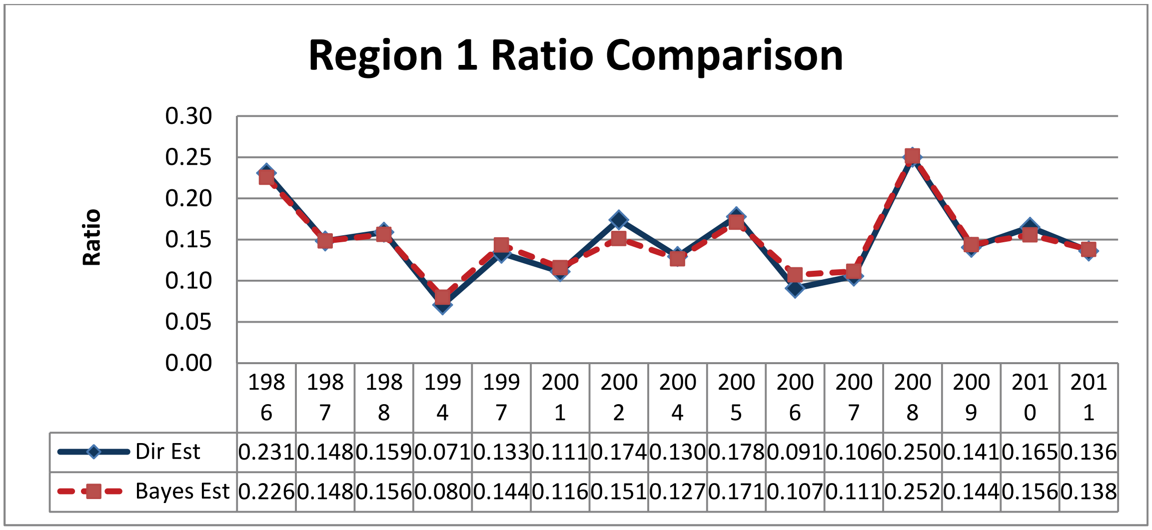
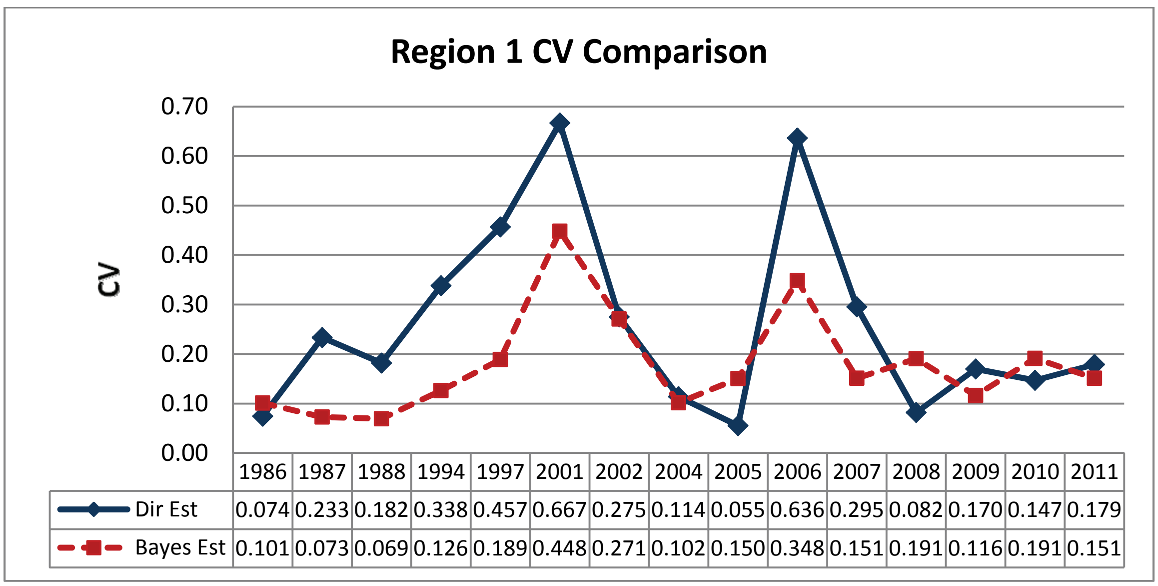


Figure 1. Trawl locations (solid star is catch with sardine adults and open star is catch without sardines) during the 2011 survey aboard two vessels: F/V *Frosti* (solid line) and R/V *Shimada* (dash line). Shaded area is Region 1, the high egg-density area, and the rest of survey area is Region 2 in the DEPM survey area. Some of the positive trawls had only immature females. The whole survey area was shown in the small graph.

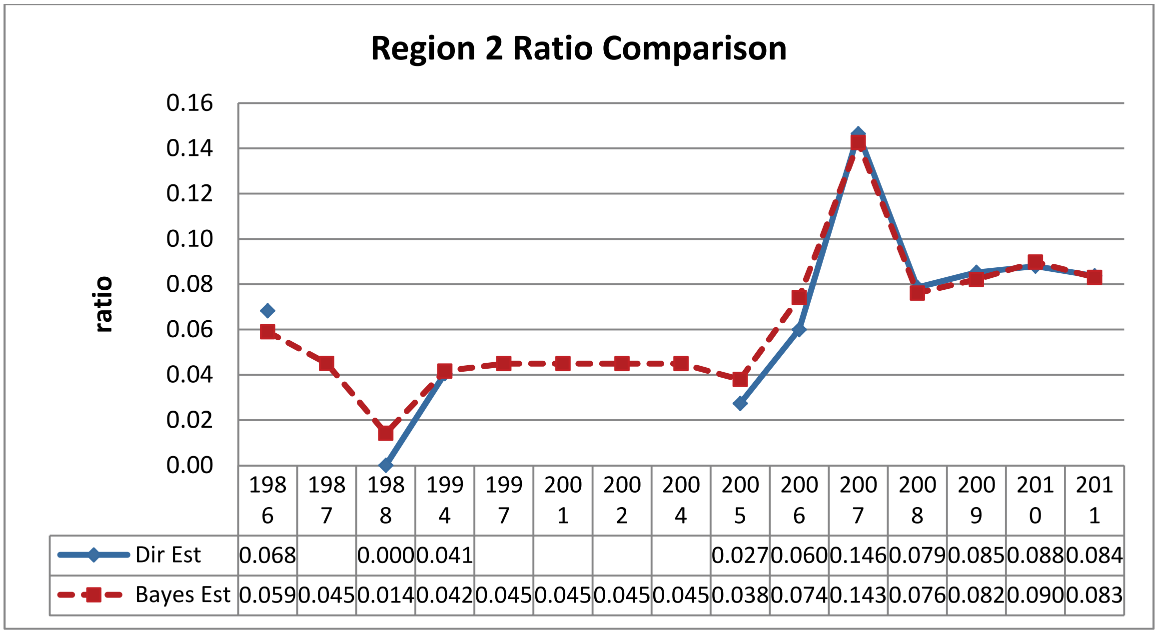


	1986	1987	1988	1994	1997	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011
Dir Est	0.231	0.148	0.159	0.071	0.133	0.111	0.174	0.130	0.178	0.091	0.106	0.250	0.141	0.165	0.136
Bayes Est	0.226	0.148	0.156	0.080	0.144	0.116	0.151	0.127	0.171	0.107	0.111	0.252	0.144	0.156	0.138



	1986	1987	1988	1994	1997	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011
Dir Est	0.074	0.233	0.182	0.338	0.457	0.667	0.275	0.114	0.055	0.636	0.295	0.082	0.170	0.147	0.179
Bayes Est	0.101	0.073	0.069	0.126	0.189	0.448	0.271	0.102	0.150	0.348	0.151	0.191	0.116	0.191	0.151

Figure 2: Point estimates (above) and CV (below) of the spawning fraction (S_{12}) in region 1 based on the average of day-1 and day-2 female from original (diamond and solid line) and HM estimates (square and dash line) from 1986-2011.



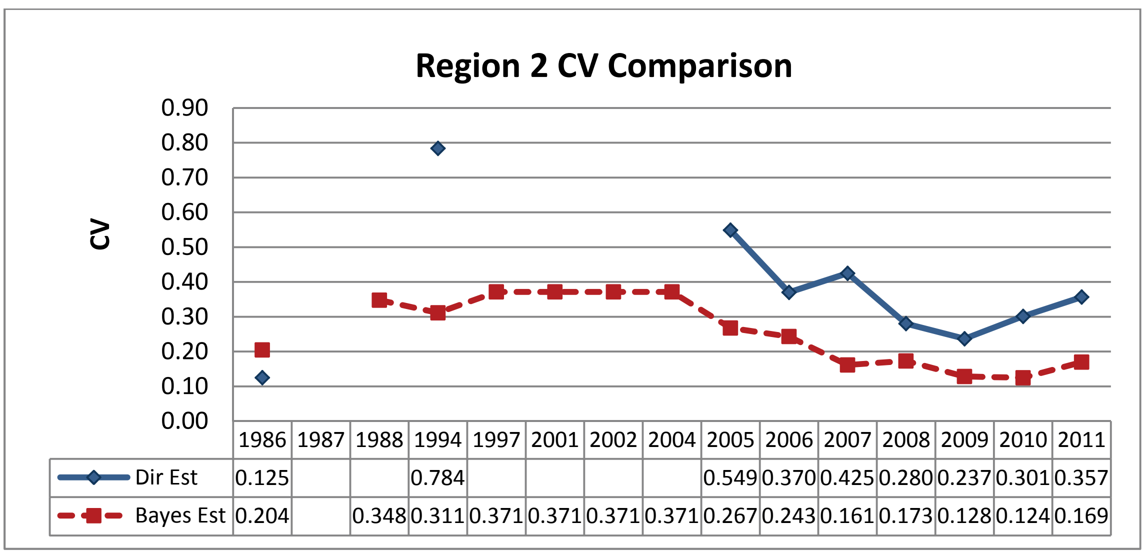


Figure 3: Point estimates (above) and CV (below) of the spawning fraction (S_{12}) in region 2 based on the average of day-1 and day-2 female from original (diamond and solid line) and BHM estimates (square and dash line) from 1986-2011: point estimate (above) and CV (below). For years 1987,1997,2001,2002 and 2004, only Bayesian estimate was obtained.

Conclusions

For the Pacific sardine, improvements have been made for adult parameter estimates, primarily for the spawning fraction (S) and spawning biomass since 2009. The estimates of spawning fraction (S_{12}) based on the average numbers of day-1 and day-2 females to replace the number of day-0 female have lower CVs than those from the original ratio estimate (Hill et al. 2010). The CV of spawning fraction from the Bayesian hierarchical model was further reduced from the CV of original estimates while the point estimates of BHM and the original method were similar for both regions. In many years, when no trawls were taken in region 2, (1987, 1997, 2001-2004) (Table 2), an overall estimate from the posterior predictive distribution for years <=2006 was used for all those years. The same estimate for many years may not be desirable for the stock assessment procedure, as experienced for years 1995-2001 and 2003. For years when no trawls were taken at all, (1996, 1998, 1999, 2000 and 2003), the estimates of total egg production (TEP) are used.

This BHM for the spawning fraction is a good exercise to seek alternative estimators for the spawning fraction. We chose not to use the BHM estimate after our analysis due to the following reasons:

1). The shrinkage effect from the Bayesian approach is small for future years when sample sizes are large, which we believe will continue. The reduction of CV of spawning biomass in region 2 does not have much effect on the CV of overall spawning biomass as the majority of spawning biomass was in region 1, in particular for recent years. Therefore the gain from the BHM is small and not be needed for the future years.

2). In many years, (1987, 1997, 2001, 2002 and 2004), no data were collected in region 2. All other adult parameters, (like fecundity, fish weight and sex ratios) were not available either and needed to be estimated by the HBM, which is not practical. If each of the other adult parameters was estimated by the mean of its posterior predictive distribution, the contribution of the change of the biomass in region 2 would be primarily due to the egg production and not the adult parameters as the estimates of adult parameters would be constant. Extensive computer programming is necessary to apply the BHM for all adult parameters in region 2 for years when no trawls were taken in region 2, which is not possible to implement right now.

and

3). The BHM requires the recalculation of estimates each year and the recalculation of yearly estimates are likely to be similar, which was demonstrated by the Bayesian estimates of spawning biomass up to 2010 and up to 2011(not shown in this report). Currently, for years when no adult samples were taken in both regions or in region 2, the total egg production (TEP) time series was obtained once for all and no recalculation is needed.

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ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2011 FOR U.S. MANAGEMENT IN 2012

K. T. Hill, P. R. Crone, N. C. H. Lo, B. J. Macewicz, E. Dorval, J. D. McDaniel, and Y. Gu

Fisheries Resources Division
Southwest Fisheries Science Center
NOAA National Marine Fisheries Service

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CDFO: Jake Schweigert, Linnea Flostrand, Jackie Detering

NWFSC: Richard Methot, Ian Taylor, Bob Emmett

WDFW: Carol Henry, Sandra Rosenfield, Jennifer Topping

ODFW: Jill Smith, Keith Matteson, Sheryl Manley, Kelly Corbet, David Wolfe Wagman

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CDFG: Dianna Porzio, Mandy Lewis, Bill Miller, Paul Ton, Santi Luangpraseut, Briana Brady, Ed Dunn, Sonia Torres, Lou Zeidberg

SWFSC: Dave Griffith, Amy Hays, Dimitry Abramenkoff, Sue Manion, Bill Watson, Elaine Acuña, Andrew Thompson, Sherri Charter, Sarah Zao, Noelle Bowlin, David Demer, Juan Zwolinski, Randy Cutter, Kyle Byers, Josiah Renfree, Steve Sessions, John Field

IATTC: Mark Maunder

INAPESCA: Manuel Nevarrez (Guaymas) and Ensenada field staff

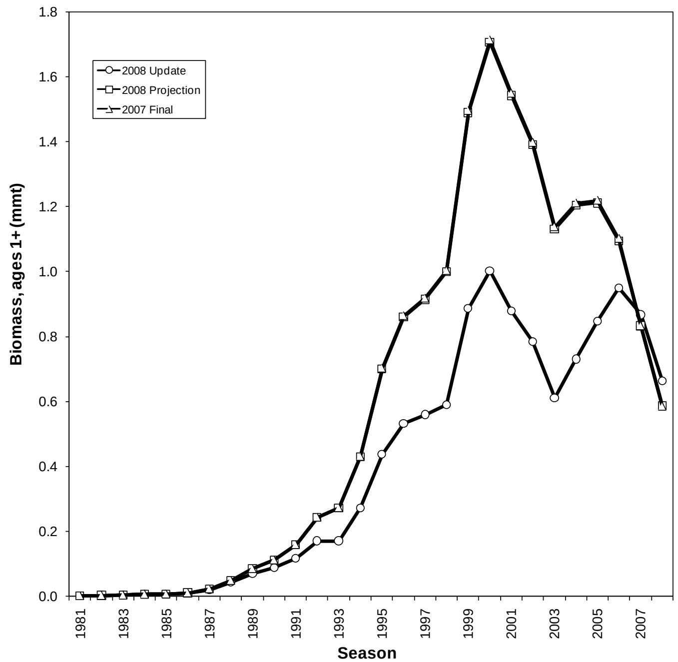
CICIMAR: Roberto Felix-Uraga and Casimiro Quiñonez

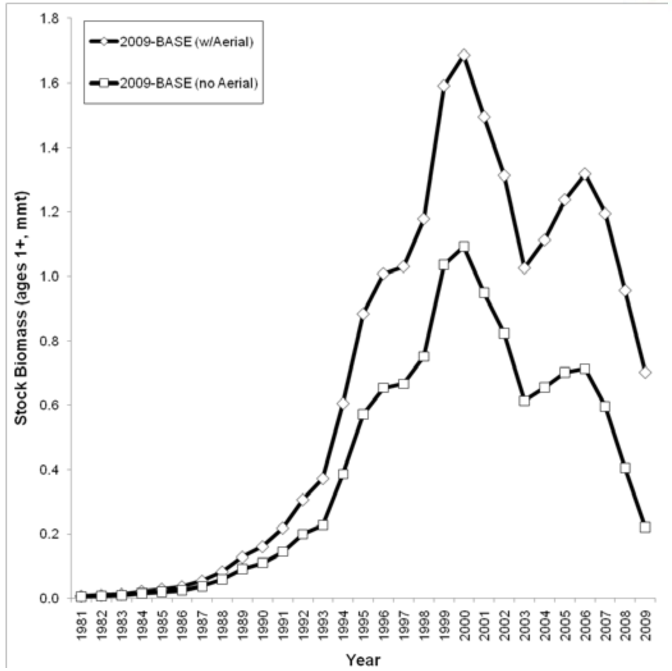
STAR Panel: Andre Punt, Ray Conser, Larry Jacobson, Chris Francis, Mike Okoniewski, and Lorna Wargo

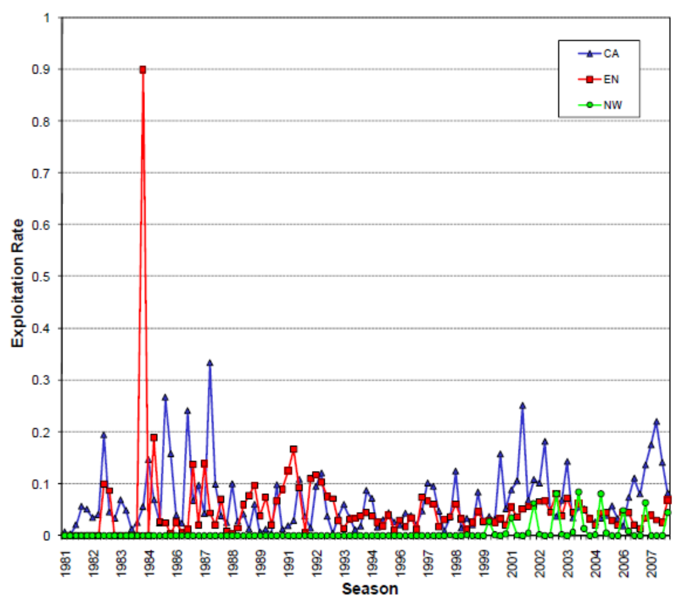
Ongoing Sardine Modeling Issues

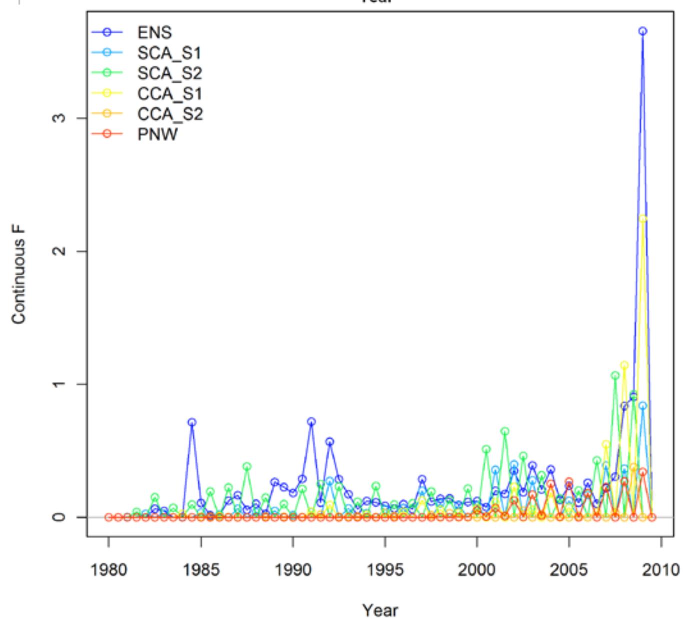
- Scaling population from low to high (CANSAR, ASAP) to lower levels again (SS);
- Sensitivity to new data (e.g. SS model 2008);
- Implausibly high *F* estimates (SS models 2009-2010):
  - fixed 'q=1' for Aerial Survey;
- Recent models had many selectivity parameters and time-varying elements resulting in some model instability (i.e. over-parameterized).

2008 Assessment Update || 2009 Full Assessment









Changes from Previous Assessments

NEW MODEL STRUCTURE:

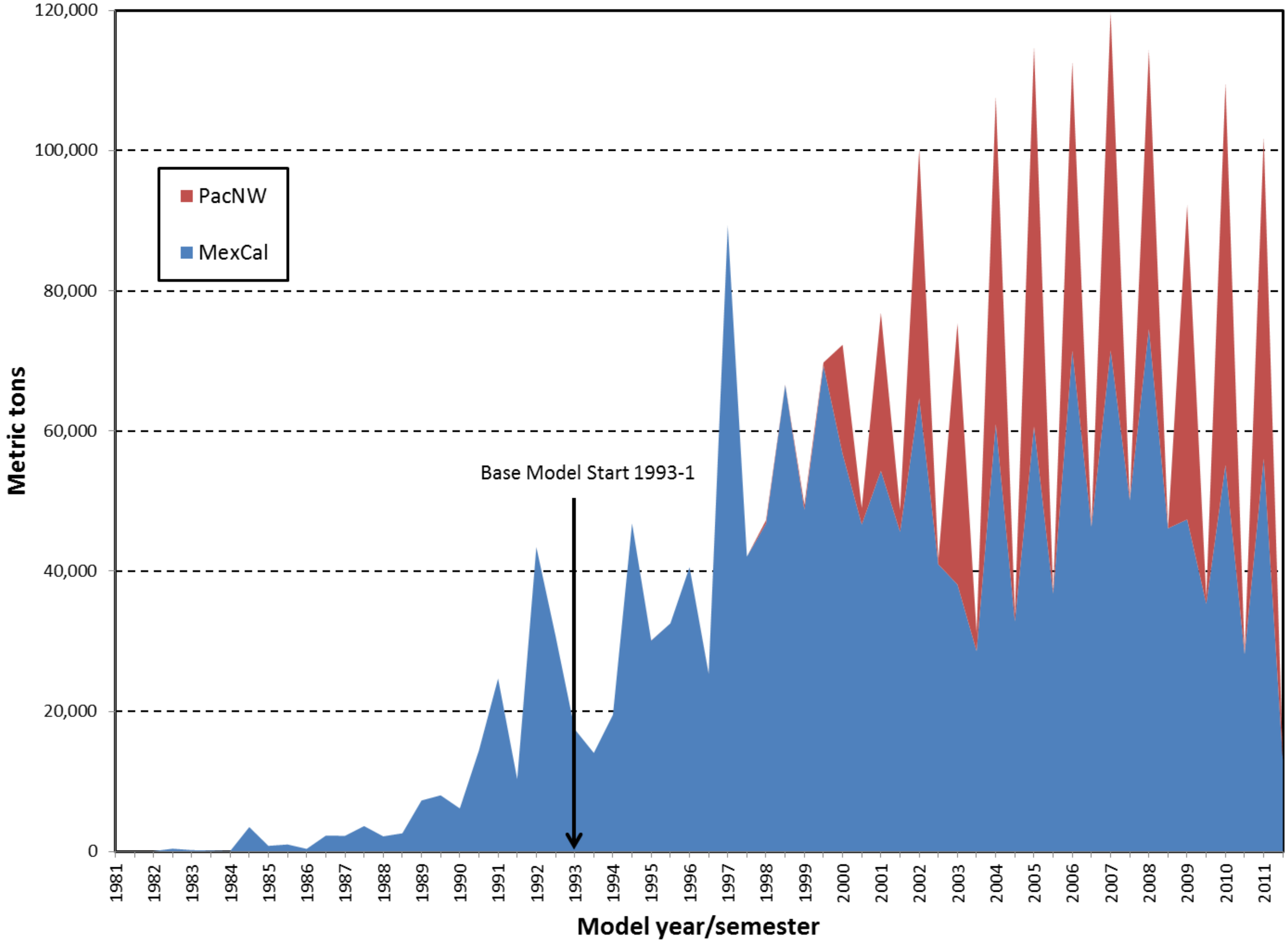
Goal: build more parsimonious model; robust to data/scaling; plausible *F* estimates;

- Regional fisheries aggregated to MexCal and PacNW 'fleets';
- Truncated time series (1993 start year);
- Fewer time-varying elements (selectivity and growth);
- Number of estimated parameters reduced from 132 to 61

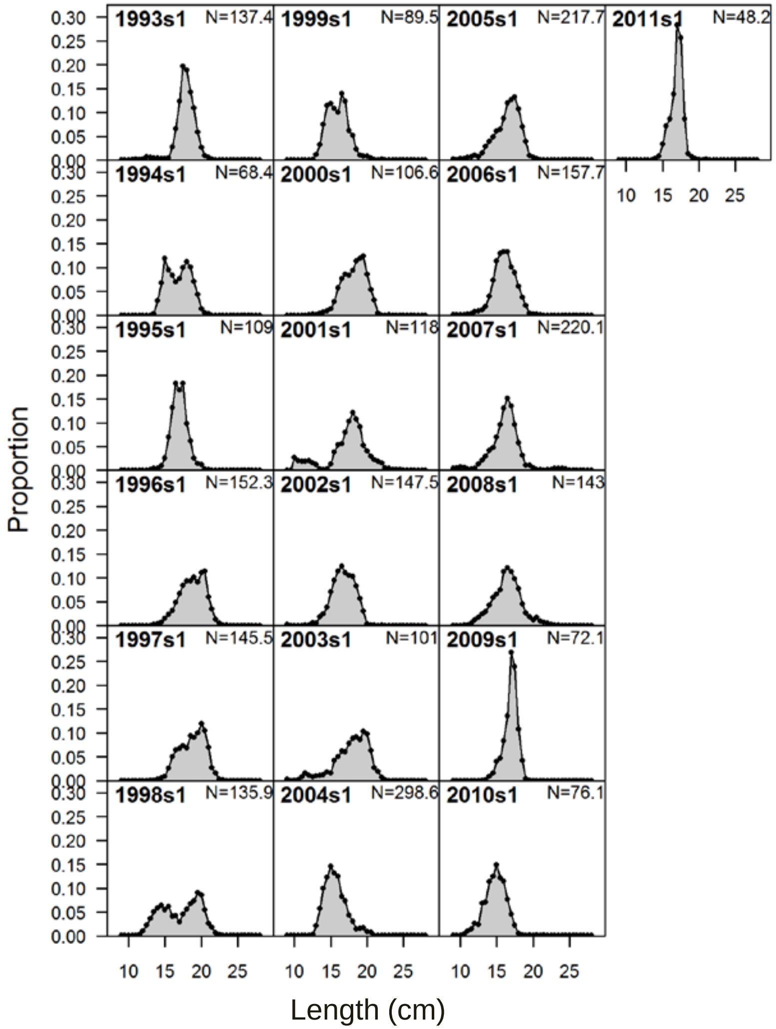
NEW DATA SOURCES:

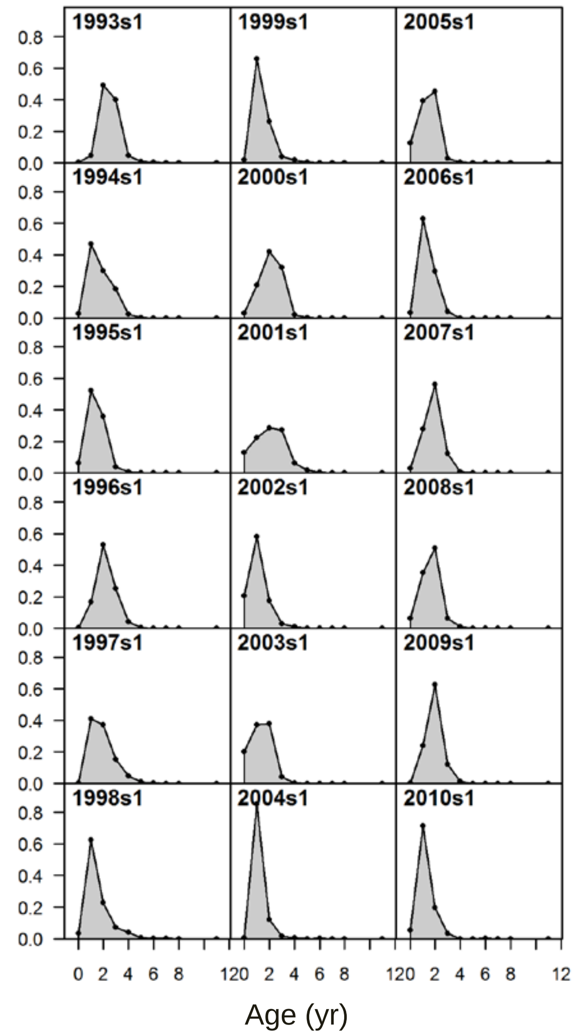
- SWFSC Acoustic survey time series
- Ensenada fishery lengths, 1989-2009

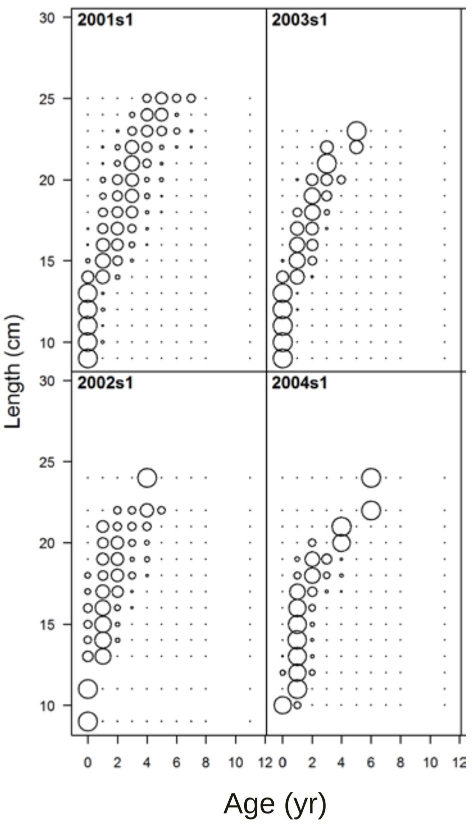
Landings by Fleet and Season



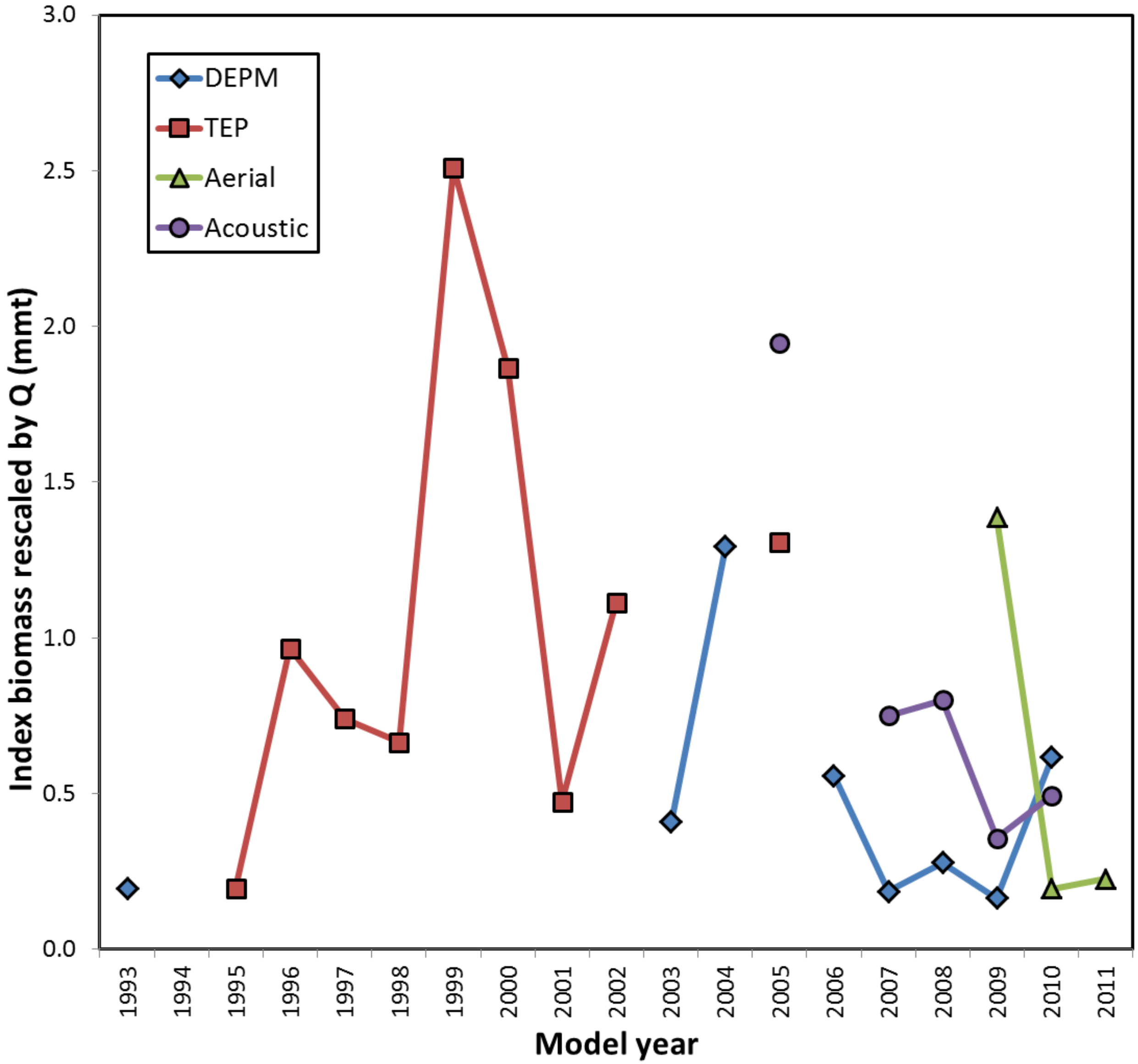
Length & Age Composition – MexCal_S1 Fleet



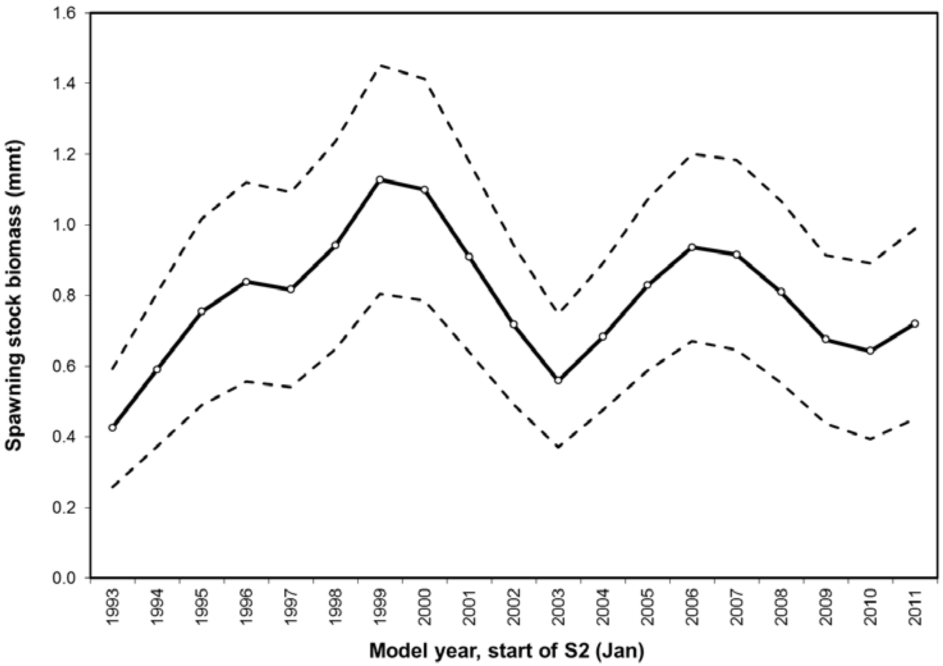


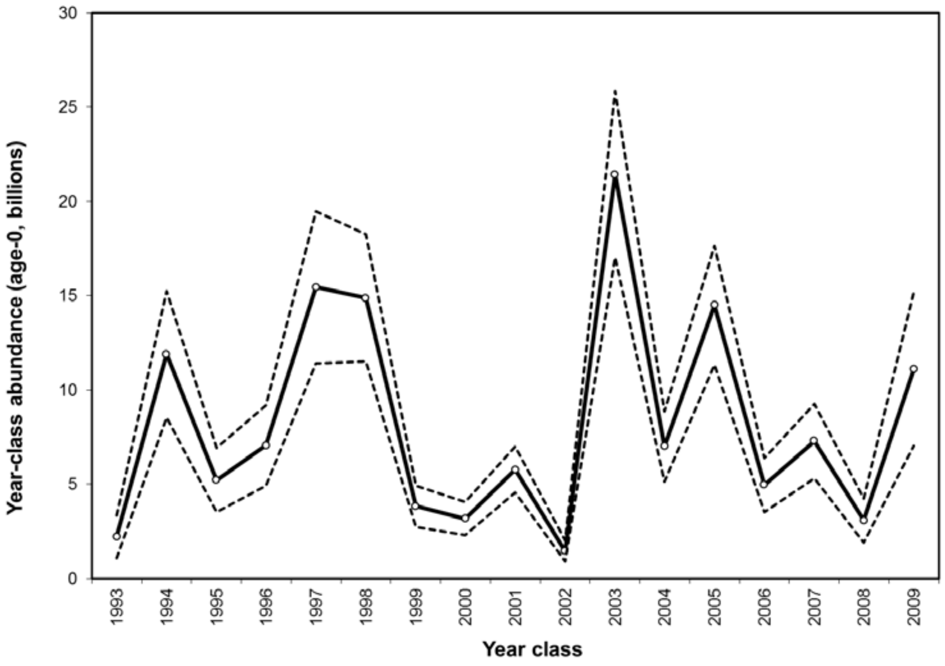


Survey Indices of Biomass

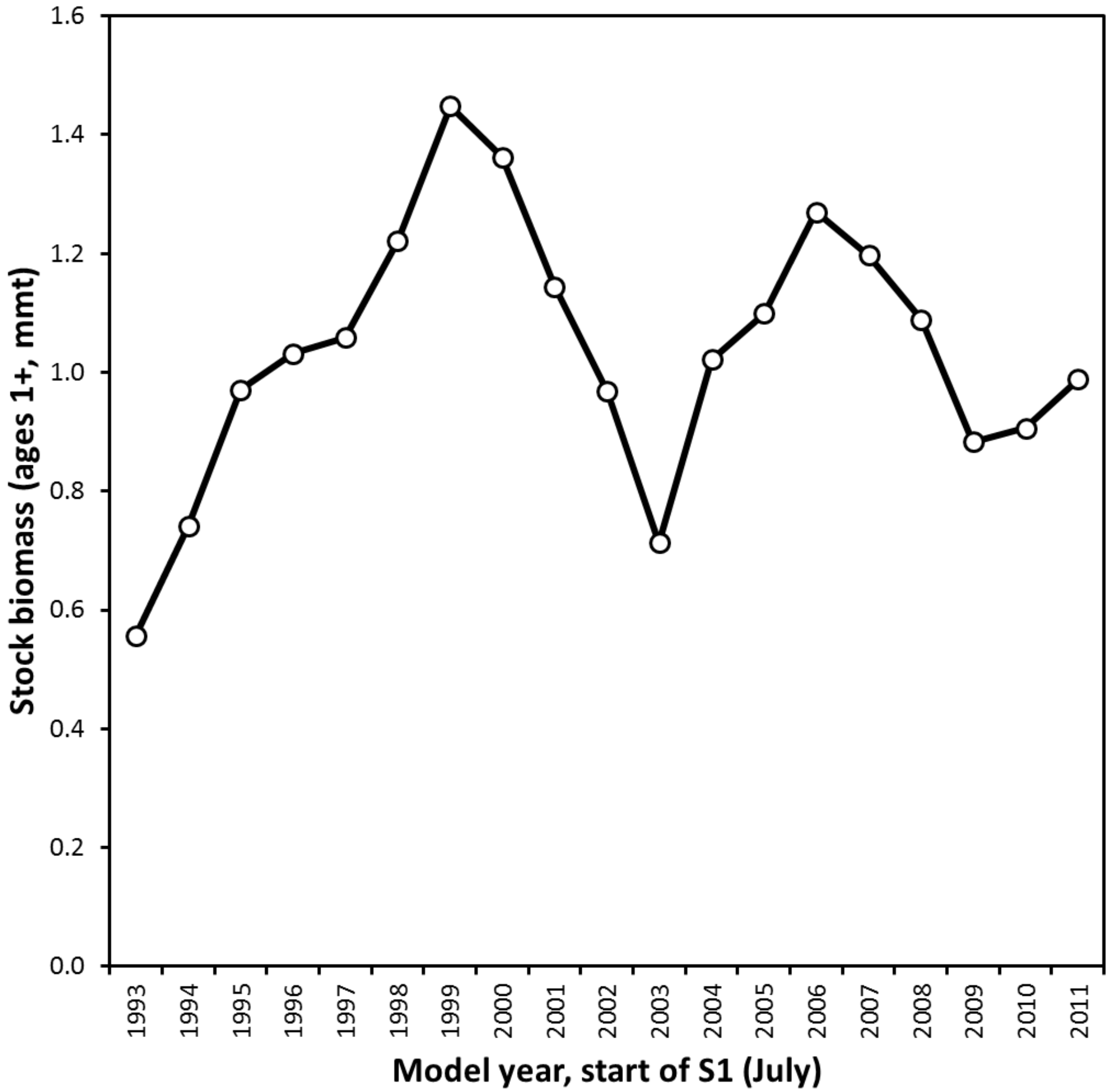


SSB and Recruitment Estimates



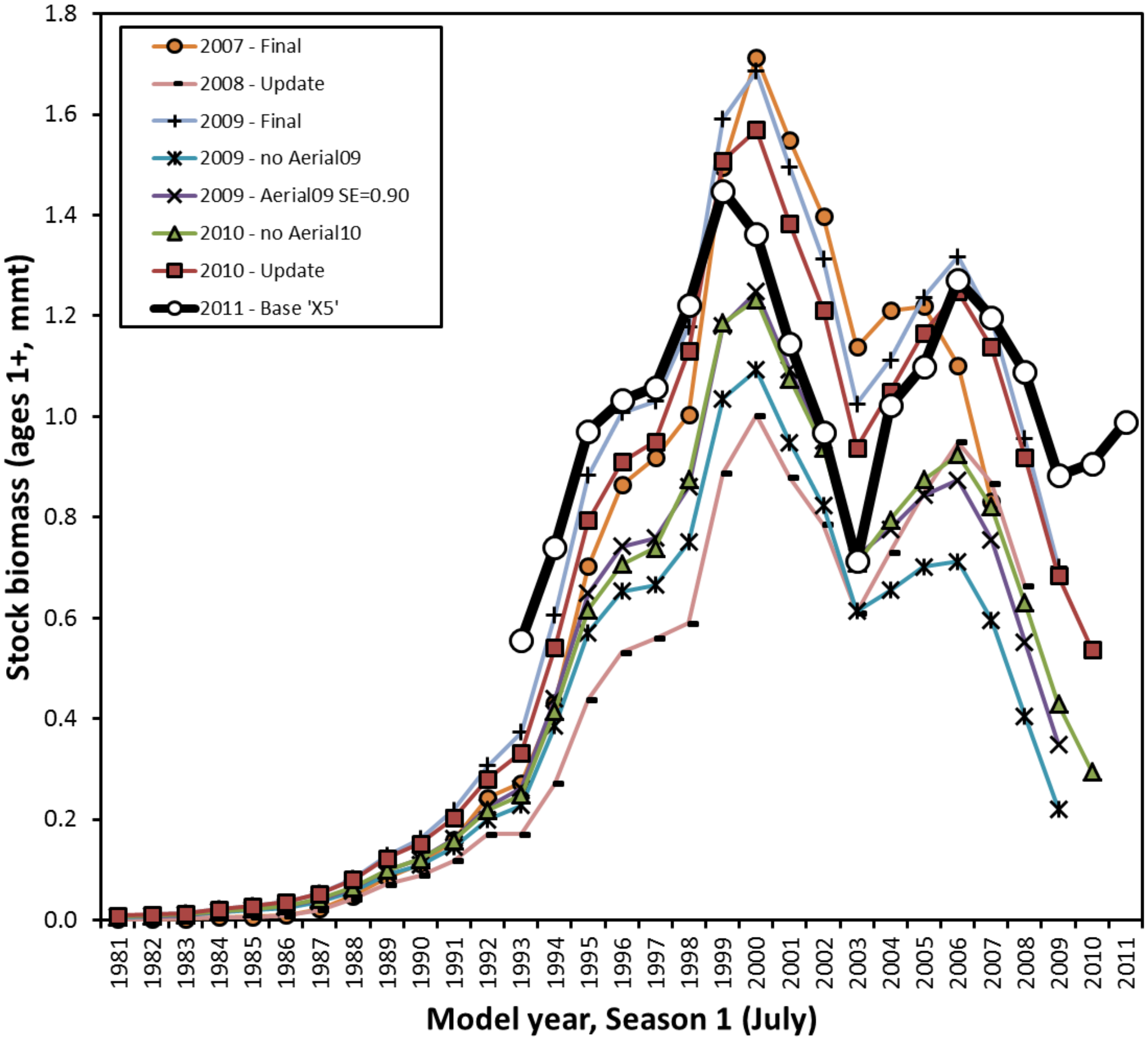


Estimated Stock Biomass Series from Base Model

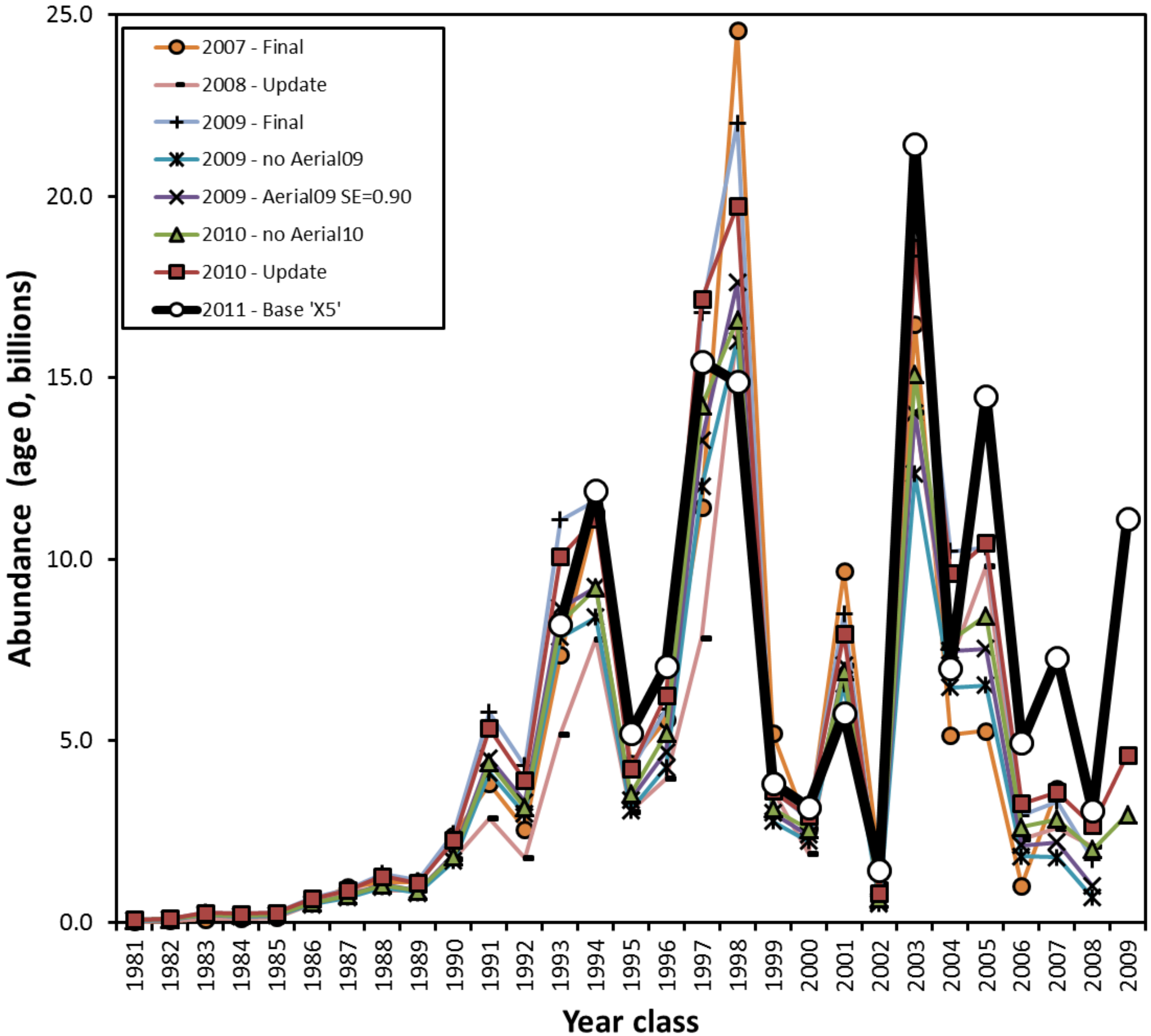


988,385 mt

Estimated Stock Biomass Series from Base Model



Estimated Recruitment Series from Base Model



OFL, ABC, and HG for 2012

Harvest Formula Parameters	Value			
BIOMASS (ages 1+, mt)	988,385			
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} (stochastic, SST-independent)	0.18			
FRACTION	0.15			
CUTOFF (mt)	150,000			
DISTRIBUTION (U.S.)	0.87			
Amendment 13 Harvest Formulas	**MT**			
OFL = BIOMASS * F_{MSY} * DISTRIBUTION	154,781			
$ABC_{0.45}$ = BIOMASS * $BUFFER_{0.45}$ * F_{MSY} * DISTRIBUTION	147,935			
$ABC_{0.40}$ = BIOMASS * $BUFFER_{0.40}$ * F_{MSY} * DISTRIBUTION	141,289			
$ABC_{0.30}$ = BIOMASS * $BUFFER_{0.30}$ * F_{MSY} * DISTRIBUTION	128,153			
$ABC_{0.20}$ = BIOMASS * $BUFFER_{0.20}$ * F_{MSY} * DISTRIBUTION	114,323			
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION	109,409			

Agenda Item F.2.c
Supplemental CPSAS Report
November 2011

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

The Coastal Pelagic Species Advisory Subpanel (CPSAS), along with the Coastal Pelagic Species Management Team (CPSMT), received a presentation on the Pacific Sardine stock assessment from Dr. Kevin Hill. The CPSAS commends Dr. Hill and the Stock Assessment Team for its significant body of work and effort to address Stock Assessment Review (STAR) Panel requests. The CPSAS concurs with the STAR Panel and Scientific and Statistical Committee (SSC) that the 2011 sardine stock assessment represents the best available science. The CPAS points out that the harvest guideline (HG) produced by the Harvest Control Rule is significantly more precautionary than all potential P* policy figures included in the stock assessment document.

Management Measures

The CPSAS recognizes the tribal right to harvest sardine, and we welcome cooperation in areas of research and data sharing. We would appreciate National Marine Fisheries Service (NMFS) working with the Quinault Indian Nation to consider developing a mechanism to allow any unharvested portion of the tribal allocation to be rolled into the directed fishery for the third and final harvest period. This would ensure full utilization of the harvest guideline. We also suggest that the CPSAS be expanded to include tribal representation.

A majority of the CPSAS recommends the following management measures for the 2012 sardine fishery:

(1) An HG/annual catch target (ACT) of 109,409 mt should be approved as derived from Dr. Hill's model run X5, based on an age 1+ biomass estimate of 988,385 mt.
(2) Harvest parameters for the 2012 fishery:

Biomass	988,385 mt
Overfishing Limit (OFL)	154,781 mt
Acceptable Biological Catch $(ABC)_{0.45}$	147,935 mt
$ABC_{0.40}$	141,289 mt
$ABC_{0.30}$	128,153 mt
$ABC_{0.20}$	114,323 mt
Annual Catch Limit (ACL)	Equal to ABC
HG/ACT	109,409 mt

The conservation representative of the CPSAS has serious concerns with the application of the Pacific sardine harvest control rule (HCR) given that, while potentially innovative, the HCR has serious flaws (see Agenda Item F.2.d, Public Comment).

Incidental Set Aside

The CPSAS supports an aggregate total of 3,000 mt to be set aside for incidental catch in non-sardine fisheries (1,000 mt of incidental allowance would be set aside for each of the three fishing periods. For the first two periods, any of the 1,000 mt not utilized would roll into the next period's directed fishing. Any incidental set aside not utilized in the third period would be foregone.)

The CPSAS recommends that the non-sardine incidental landing allowance in 2012 be no more than 30 percent Pacific sardine by weight, as adopted in 2011. The CPSAS recommends that if the directed seasonal allocation and set-asides are reached in any fishing period, the retention of Pacific sardine be prohibited for the remainder of that period.

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

Season Start Date

The CPSAS discussed the letter submitted by Mr. Ryan Kapp about season start date (Agenda Item F.2.d, Supplemental Public Comment). CPSAS members and members of the public representing industry also gave various opinions in support and in opposition to changing the start date. After further discussion among CPSAS members, no consensus was achieved. A majority of the CPSAS would like to discuss this issue further with industry participants to gauge support for a change of start dates in the future.

Exempted Fishing Permits

The CPSAS unanimously supports an Exempted Fishing Permit (EFP) set aside of 3,000 mt to be approved for Pacific Northwest industry-supported research, to be deducted from the HG before it is allocated to fishing periods. Any EFP set aside not included in an EFP, as well as any EFP fish allocated but not utilized in research, should be re-allocated to the third period directed fishery.

Members of the public representing industry also expressed support for the continuation of the aerial survey to be conducted under an EFP. A detailed EFP application encompassing the aerial survey project, including methodology and operational plans, will be submitted to the Council prior to the March 2012 meeting. The CPSAS thanks the Council for its support of EFP research.

Coastwide Research

The CPSAS continues to voice strong support for the recommendations produced in the sardine survey methods workshop that took place in June 2011 (see June 2011 Agenda Item G.1.b, Supplemental Sardine Workshop Report), and further thanks the Council for its letter of support. We encourage the NMFS to fully fund the "Cadillac" version of the synoptic survey in 2012, and to cooperate with Canadian and Mexican participants to ensure full coverage of the coast-wide population. This is necessary to improve understanding of the spawning biomass and migration patterns.

Methodology Review

The CPSAS strongly supports a methods review of the Canadian swept trawl survey for inclusion into the Sardine Stock Assessment. The CPSAS believes this will be a valuable source of data and will provide access to information about sardine biomass and habitat that is not available in the USA surveys.

International Research and Management

The CPSAS reiterates that coordinated international management of CPS fisheries is essential to safeguard against the potential for coast-wide overfishing. The CPSAS again strongly urges the Council, NMFS and the State Department to continue their work to promote international management of CPS stocks and to achieve the timely receipt of research and catch data from Mexico and Canada.

CPSAS Minority Statement

The conservation rep supports a full management strategy evaluation that includes the objective of providing sufficient forage for dependent marine predators in the California Current ecosystem, and economic considerations that account for the needs of other businesses, and fisheries where the target fish (e.g. salmon and tuna) depend on Pacific sardine as prey (see Hannesson and Herrick 2010).

Hannesson, R. and S.F. Herrick. 2010. The value of Pacific sardine as forage fish. Marine Policy. 34: 935-942

PFMC
11/04/11

COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON PACIFIC SARDINE STOCK ASSESSMENT AND COASTAL PELAGIC SPECIES (CPS) MANAGEMENT MEASURES FOR 2012

The Coastal Pelagic Species Management Team (CPSMT) received a presentation from Dr. Kevin Hill concerning the Pacific sardine stock assessment conducted in 2011. The CPSMT recommends that the Pacific Fishery Management Council (Council) adopt the full assessment (model X5) for management of the 2012 sardine fishery. Based upon the 988,385 mt age 1+ biomass estimate from this assessment, the harvest control rule produces a harvest guideline (HG) of 109,409 mt (Table 1 below). The 2011 biomass estimate represents an 84 percent increase from the update stock assessment previously adopted by the Council in November, 2010. The CPSMT notes a number of factors including new data and new sources of data that influence the increase in the biomass estimate, including a relatively large 2009 year class is now evident in the fishery and survey data, the daily egg production method exhibited an increase, and the addition of the Southwest Fisheries Science Center (SWFSC) Acoustic Survey as another index of abundance. The final model has less than half of the number of estimated parameters compared to the previous assessment.

Dr. Kevin Hill undertook a re-evaluation of F_{msy} for Pacific sardine in the absence of an environmental covariate for use in the overfishing limit (OFL) and acceptable biological catch (ABC) calculations (see Appendix 4 of Stock Assessment, Agenda Item F.2.b Supplemental Attachment 8). An updated value of F_{msy} estimated independently of temperature was presented to the Scientific and Statistical Committee (SSC). The SSC endorsed the use of the temperature-independent F_{msy} as an interim measure, and the CPSMT agrees.

The CPSMT acknowledges that the temperature relationship underlying FRACTION in the harvest control rule needs to be revised. For 2012, the CPSMT is confident that FRACTION of 15 percent adequately protects the stock and points out that it is less than the F_{msy} of 18 percent. It is clear that sardine reproductive success is related to environmental conditions. The CPSMT anticipates research relative to environmental covariates may take time to provide conclusive information.

Harvest Specifications for 2012

Table 1 (below) contains harvest formula parameters and a range of ABC values based on various P* (probability of overfishing) values. The CPSMT recognizes that the Council will select a P*. The CPSMT recommends that the annual catch limit (ACL) equal the ABC resulting from the Council's P* choice, and that the HG/ACT be set equal to 109,409 mt.

The CPSMT discussed the Quinault Indian Nation request for an allocation of Pacific sardine. Acknowledging that the final allocation is yet to be determined, Table 2 incorporates the requested allocation of 9,000 mt. In addition, 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). The CPSMT recommends setting aside 3,000 mt for potential sardine Exempted Fishing Permits (EFP). Any EFP set aside not included in an EFP, as well as any EFP fish allocated but not utilized in research, should be re-allocated to the third period directed fishery. The CPSMT recommends that the incidental landing allowance for CPS fisheries be no more than 30 percent Pacific sardine by weight.

Table 1. Pacific sardine Amendment 13 Harvest Formulas Parameters

Harvest Formula Parameters	Value			
BIOMASS (ages 1+, mt)	988,385			
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}	0.18			
FRACTION	0.15			
CUTOFF (mt)	150,000			
DISTRIBUTION (U.S.)	0.87			

Amendment 13 Harvest Formulas	MT
OFL = BIOMASS * F_{MSY} * DISTRIBUTION	154,781
$ABC_{0.45}$ = BIOMASS * $BUFFER_{0.45}$ * F_{MSY} * DISTRIBUTION	147,935
$ABC_{0.40}$ = BIOMASS * $BUFFER_{0.40}$ * F_{MSY} * DISTRIBUTION	141,289
$ABC_{0.30}$ = BIOMASS * $BUFFER_{0.30}$ * F_{MSY} * DISTRIBUTION	128,153
$ABC_{0.20}$ = BIOMASS * $BUFFER_{0.20}$ * F_{MSY} * DISTRIBUTION	114,323
ACL = EQUAL TO ABC	
ACT=HG=(BIOMASS-CUTOFF)*FRACTION*DISTRIBUTION	109,409

Table 2. Preliminary Allocation scheme for 2011 Pacific Sardine ACT

HG = 109,409 mt; Tribal Allocation = 9,000 mt; Potential EFP set aside = 3,000 mt
Adjusted HG = 97,409 mt

	Jan 1- Jun 30	Jul 1- Sep 14	Sep 15 – Dec 31	Total
Seasonal Allocation (mt)	34,093 (35%)	38,964 (40%)	24,352 (25%)	97,409
Incidental Set Aside (mt)	1,000	1,000	1,000	3,000
Adjusted Allocation (mt)	33,093	37,964	23,352	94,409

Finally, the CPSMT supports a methodology review of the Canadian West Coast Vancouver Island Swept Area Trawl Survey as a potential new source of abundance data to inform the next full sardine stock assessment.

PFMC
11/4/11

Summary of the Oregon Fishery
for
Pacific Sardine
(*Sardinops sagax*)

Oregon Department of Fish and Wildlife
Marine Resources Program
2040 SE Marine Science Drive
Newport, OR 97365

November, 2011

Background

In September 2011, the Pacific Fishery Management Council received a letter from the Quinault Indian Nation expressing their intent to have three treaty fishing vessels participating in the coastal sardine fishery beginning in 2012 and requested a tribal set aside of 9,000 mt to accommodate the needs of those fishing vessels. The request raised questions about the nature of the sardine fishery off the Oregon and Washington coast. In response, the Oregon Department of Fish and Wildlife (ODFW) prepared this summary report to provide information about the directed sardine fishery in Oregon. Fishing activities conducted under the federal exempted fishing permits issued from 2009 to 2011 are not included in this report.

Fishery Management

Pacific Sardine (*Sardinops sagax*) management has been transformed over the recent decades because of biological and industry changes in the directed sardine industry coast wide. The Pacific sardine fishery off Oregon started in 1935, but there are recorded landings of sardine in Oregon dating back to 1928. The catch dropped off in the 1940s with 1948 being the last year of directed fishery landings until 1999 when the fishery was revived. From 1999 to 2005, the Oregon sardine fishery was managed through ODFW's Developmental Fisheries Program (DEVO), which limited the number of harvest permits. In December 2005, the Oregon Fish and Wildlife Commission (Commission) moved the Pacific sardine fishery from a developmental fishery to a state sponsored limited entry fishery system. Since 2005, a number of revisions have been made to the limited entry permit system including number of permits and renewal requirements. The number of vessels participating in the sardine fishery has not exceeded 22 (Table 1). Currently there are 25 state limited entry fishery permits for Pacific sardine. If the number of permits drops below 24, a lottery may be held the following year, but the total number of permits issued shall not exceed 26 permits. It is worth noting that some of the vessels permitted in Oregon also hold federal and/or Washington state permits.

ODFW gathers information on the sardine fishery and collects biological samples to improve the coast-wide stock assessment of sardines, document the extent of by-catch in the fishery, and document the where fishing occurs.

Oregon Fishery Summary

The sardine fishery is prosecuted with purse seine vessels. Off the Pacific Northwest, weather events such as storms, heavy fog, or high seas are major factors in the success rate of catching sardines. These types of events make it difficult to predict how many pounds of sardines will be delivered during any given day. Another variable that can affect Oregon based fishermen is the quality of the sardines. Belly thickness, quantity of food in the stomach tissues, average size of the fish, and oil content can all influence the quality of the fish. All of these factors can affect the ex vessel price paid to the fishermen. Sardines caught in the summer months in the area of Oregon and Washington are feeding in productive nutrient rich waters. During this time, the fish are increasing their oil content or "fat". High oil content is important in the palatability for human consumption. The peak oil content for sardine off Oregon and Washington generally occurs in August and September, which coincided with the peak months of sardine landings in Oregon from 2005 – 2007. The federal coastwide harvest guideline was not a limiting factor for the fishery until 2008, when all three allocation periods were closed before the period ended because the allocation was reached. Lower estimates of biomass and the resultant lower HGs since 2008 have led to a derby style fishery and changed the timing of the fishery off Oregon and Washington with peak catch occurring in July during recent years for Oregon vessels (Figure 1).

Over the years, Astoria has been the main port of landing for Oregon permitted sardine vessels although there are landings in several other ports. Processing capabilities for sardines are also are centered in Astoria. Processing capacity may have been a limiting factor during the early years of the fishery. Sardine is a daytime fishery in the Pacific Northwest. When possible, spotter aircraft are used to assist fishing vessel captains in locating schools of fish. The spotter plane pilots and the vessel captains work as a team to increase the efficiency in catching sardines. Thus, a standard a unit of fishing effort is difficult to quantify. When fishermen are successful at rounding up their catch, distances to processors can be a factor. Tides, currents, and contending with the Columbia River affect costs for fuel and produce challenges for the sardine fishery. All of these components along with the distribution of fish are factors in determining where sardine fishermen set their nets. Most offloads begin in the mid to late afternoon and/or at night. It is rare for a fisherman to make more then one landing in a twenty four hour period.

The average landing size has varied from approximately 27.3 to 57.6 mt (Table 1). During the early years of the fishery, there was a greater disparity among the annual catch of individual vessels. To some degree, the disparity has lessened over time. Summary statistics for individual vessels participating in the fishery in recent years indicate that annual landings still vary among vessels in any given year (Table 2). Factors such as vessel, skipper and crew ability, weather and ocean conditions, availability of spotter planes, and proximity to harvestable sardine to port may factor into these differences. Season length and period closures also factor into annual vessel landings after 2007.

Fishing in the Quinault Tribe Usual & Accustomed Fishing Area

The Quinault usual and accustomed fishing area (U & A) is defined in **§ 660.50(c)(4)** as “That portion of the Fishery Management Area between 47°40.10' N. lat. (Destruction Island) and 46°53.30' N. lat. (Point Chehalis) and east of 125°44' W. long.” Preliminary examination of logbook data from 2000 through 2010 indicates that vessels landing sardine in Oregon fish infrequently in that area. Although there is variation among years, no more than 7% of the sets with location information recorded were made in the U & A in any given year and exceeded 5% in only two of eleven years (Table 1). Complete data for 2011 is not yet available.

Non Target Species

Oregon’s sardine permit rule stipulates that an at sea observer is required to be allowed on the vessel, when requested by ODFW. Currently ODFW does not have personnel dedicated to observe on sardine vessels. The state requires the use of a grate over the intake of the hold to sort out larger species of fish. The grate size spacing can be no larger then 2-3/8 inches between bars.

Information on non-target species catch is compiled each year. Oregon limited entry sardine permit rules require fishermen to report incidental catch including salmonids and other species in their logbook. Salmon may not be retained and are released live whenever possible. In addition to logbook information, landing receipts for vessels prosecuting the sardine fishery is another source of information on incidental catch. Non-target species caught in the sardine fishery consists mainly of other coastal pelagic species but also includes several other species. Tables 3 and 4 summarize recent and historical non-target species catch for the Oregon sardine fishery.

Table 1. Summary of Oregon sardine fishery. The federal Harvest Guideline, number of Oregon permitted vessels participating, annual Oregon landings, number of landings, average landing, the number of sets with recorded locations in logbooks, and the number of sets and percentage of sets in the U & A are shown for 2000 - 2011. Complete logbook data for 2011 is not yet available.

Year	HG (mt)	# of vessels	OR catch (mt)	# of landings	Avg. landing (mt)	# sets	# set in U&A	% of sets in U&A
2011*	50,526	17	8,291	144	57.6	-------	-------	-------
2010	72,039	20	18,826	372	50.6	568	31	5.5%
2009	66,932	20	20,290	371	54.7	607	6	1.0%
2008	89,093	22	22,949	471	48.7	884	62	7.0%
2007	152,564	22	42,151	877	48.1	1,132	12	1.1%
2006	118,936	16	35,648	766	46.5	1,014	12	1.2%
2005	136,179	16	45,111	1090	41.4	1,499	63	4.2%
2004	122,747	20	36,111	939	38.5	1,447	31	2.1%
2003	110,908	19	25,258	712	35.5	850	21	2.5%
2002	118,442	17	22,711	657	34.6	929	4	0.4%
2001	134,747	18	12,798	453	28.3	620	5	0.8%
2000	186,791	14	9,528	349	27.3	529	0	0.0%

*Preliminary data

Table 2. Summary statistics for annual landings (mt) for vessels participating in the Oregon sardine fishery 2005 - 2010.

	2010	**2009**	**2008**	**2007**	**2006**	**2005**
Number of vessels	20	20	22	22	16	21
Lower quartile	609	704	510	877	1,661	841
Mean	941	1,015	1,043	1,915	2,229	2,148
Median	889	850	947	1,821	2,276	2,205
Upper quartile	1,232	1,266	1,355	2,873	2,763	2,740

Table 3. Salmonid bycatch in Pacific sardine fisheries in Oregon 2000-2010.

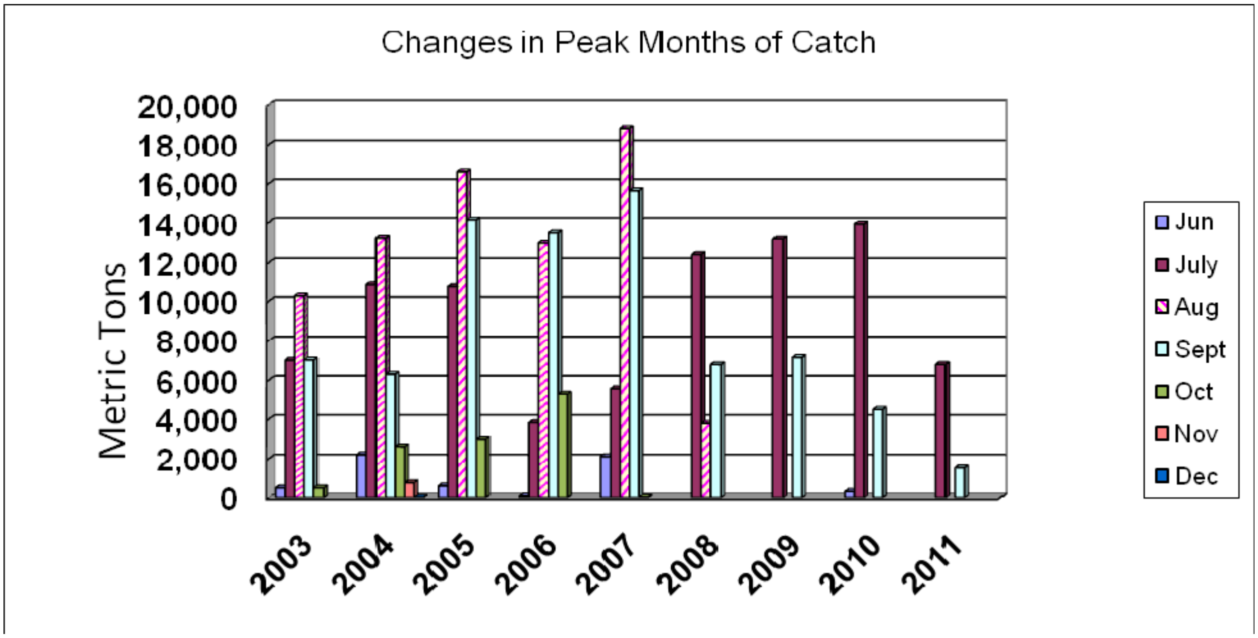
Year	Chinook (live)	Chinook (dead)	Coho (live)	Coho (dead)	Pink (live)	Unid (live)	Unid (dead)	Total (live)	Total (dead)	Grand Total
2010[1]								110	76	186
2009[1]								126	115	241
2008[1]								123	75	198
2007[1]								349	170	519
2006[1]								164	93	257
2005[1]								411	176	587
2004[1]								518	305	823
2003[1]								315	185	500
2002[1]								199	81	280
2001[2]	45	45	201	134	22	45	0	313	179	492
2000[2]	43	72	159	43	0	303	43	505	158	663

[1] Salmon bycatch data 2002-2010 are from logbooks
[2] Salmon bycatch data 2000-2001 are expanded from a bycatch rate of salmon/trip based on vessel observation program

Table 4. Incidental catch (mt) recorded on fish receipts for Oregon sardine fishery 2001 – 2010.

	2010	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**
Pacific Mackerel	52.8	126.3	158.3	161.5	316.1	665	699.7	56.8	49.5	39.2
Jack Mackerel	1.2	0.3	3.2	24.1	3.6	1.4	8	1.6	2.0	<0.01
Pacific Herring	-	3.3	-	10.3	0.1	1.2	-	55.8	-	-
Northern anchovy	-	0.2	-	1.0	68.4	8.6	<0.001	2.4	<0.001	1.2
American shad	-	0.3	-	1.2	-	0.44	-	0.3	0.003	-
Pacific hake	-	-	0.1	-	-	0.002	-	0.005	<0.001	-
Pacific sanddab	-	-	-	-	-	<0.001	0.002	-	-	-
Dover sole	-	-	-	-	-	-	0.002	-	-	-
Sablefish	-	-	-	-	-	0.01	-	-	-	-
Sharks	-	-	0.3	0.3	0.4	0.16	0.14	0.01	1.1	-
Squid	-	-	-	13.9	-	-	-	-	0.003	-
Jellyfish	-	-	-	5.5	-	-	-	-	<0.001	-

Figure 1. Oregon landings for the months of June through December from 2003 to 2011



SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON PACIFIC SARDINE ASSESSMENT AND COASTAL PELAGIC SPECIES MANAGEMENT MEASURES FOR 2012

Dr. Kevin Hill presented the 2011 assessment of the northern subpopulation of Pacific sardine and Dr. André Punt reported on the Stock Assessment Review (STAR) Panel that convened on October 4-7, 2011.

The 2011 assessment uses four survey indices: two egg production indices and an aerial index, which have been the primary abundance data series in previous assessments, and an acoustic survey, which had not been previously used. The acoustic survey was reviewed by a methodology review panel earlier this year and endorsed by the Scientific and Statistical Committee (SSC) for use in the assessment model. Additional length data from the Mexican fishery were also included. The current assessment model has many fewer parameters than the 2009 assessment (61 vs. 132). This was accomplished by reducing the number of fisheries modeled, reducing time blocking of fisheries selectivity, and shortening the assessment time period. In addition, during the STAR Panel the initial fishing mortality (F) was set to zero and catchability (q) in the acoustic trawl survey was set to one.

The SSC notes that there are contradictory trends in the three recent survey indices, which introduce substantial uncertainty into sardine biomass estimates. The new model estimated a higher sardine biomass than previous assessments for recent years, and the SSC was advised that this was likely due to increases of varying magnitude in all of the survey indices and recent data suggesting strong recruitment.

The SSC endorses the 2011 assessment as the best available science for management of the northern subpopulation of Pacific sardine in 2012.

Dr. Hill also briefed the SSC on a re-estimation of F_{MSY} in which the Amendment 8 analysis was duplicated with two differences: the Scripps Institute of Oceanography (SIO) Pier temperature index was removed from the stock-recruit relationship, and recent stock and recruitment information was used. The F_{MSY} harvest rate of 0.18 is very similar, but slightly lower than the previous F_{MSY} estimate of 0.1985. The SSC notes that temperature, or another correlated environmental variable, may be important in sardine recruitment, but that the SIO index is not reflective of the temperature in the area of greatest sardine spawning activity and is no longer correlated with sardine productivity.

The SSC recommends that the updated F_{MSY} be used for management in 2012, but that this should be considered strictly an interim measure. The SSC further endorses an overfishing limit (OFL) of 154,781 that arises from this updated F_{MSY}. To set acceptable biological catch (ABC) for sardine, SSC again recommends use of the P* approach, in which the buffer between OFL and ABC is determined by the value of sigma, representing scientific uncertainty and established by the SSC, and the Council's choice of a P* to express its policy decision on acceptable risk. The default value of sigma (0.36) for category 1 stocks was considered appropriate for Pacific sardine.

The SSC further recommends that a workshop be convened within the next year to design a simulation analysis similar to Amendment 8 analysis but employs current modeling approaches provide estimates of F_{MSY} and updated parameters for the harvest control rule. The SSC further recommends that a full management strategy evaluation be performed for the northern subpopulation of Pacific sardine as soon as time and resources permit.

PFMC
11/04/11

Agenda Item F.2.c
Supplemental WDFW Report
November 2011

Summary of the Washington Purse Seine Fishery for Pacific Sardine (*Sardinops sagax*)

Washington Department of Fish and Wildlife
48 Devonshire Road
Montesano, Washington 98563

October 2011

Washington Sardine Purse Seine Fishery

The Washington Department of Fish and Wildlife (WDFW) has managed a Pacific sardine fishery off our coast since 2000. In September 2011, the Pacific Fishery Management Council received a letter from the Quinault Indian Nation expressing their intent to have three treaty fishing vessels participating in the coastal sardine fishery beginning in 2012 and requested a tribal set aside of 9,000 mt to accommodate the needs of those fishing vessels. The Council had some discussion about the request and raised questions about the nature of the sardine fishery off the Washington coast. In response, WDFW has prepared this summary report, which will hopefully address some, if not all, of the questions raised.

Fishery Background

From 2000 through 2009, participation in the sardine fishery was managed under Washington's Emerging Commercial Fishery Act (ECFA), which provides for the harvest of a newly classified species or harvest of a classified species in a new area or by new means. The ECFA prohibits the transfer or sale of an emerging commercial fishery license. In 2009, new legislation created a license limitation program specifically for the harvest and delivery of Pacific sardines into the state. In addition to establishing 16 permanent licenses, the rules provide criteria for the issuance of temporary annual permits at the discretion of the WDFW Director. In combination, the number of permanent and temporary annual licenses cannot exceed 25. In recent years, even though 16 or more permits have been issued, the number of active participants each year has been five to eight (Table 1). Permanent sardine licenses can be transferred.

The Washington sardine fishery opens annually on April 1. In past years, when the coastwide sardine harvest guideline was not attained and did not therefore constrain the fishery, fishing in Washington in April and May was usually limited by poor weather and ocean conditions. The annual coastwide harvest guideline is released in periodic increments (January 1: 35%; July 1: 40%; and September 15: 25%) and in more recent years, as a result of lower coastwide harvest guidelines, the first period of the fishery has closed prior to April 1. A complete description of the Washington state regulations for the sardine fishery is provided at the end of this report.

Washington annual and monthly landing information is presented in Tables 1 and 2, and Figure 1 below.

Table 1. Description of annual landings (metric tons), number of landings and number of active vessels in the Washington sardine purse seine fishery, 2004-2011.

	2011*	2010	2009	2008	2007	2006	2005	2004
No. of Vessels	7	8	8	5	6	7	11	14
Total Landings (mt)	7,918	12,379	8,009	6,432	4,663	4,362	6,714	8,911
No. of Landings	126	232	173	150	106	108	207	236
Average Landing (mt)	63	53	46	43	44	39	32	37

*Preliminary

In reviewing landings data from the five vessels with the highest landings from 2000-2011, it appears that individual vessel landings averaged about 1,400 mt per year (Table 2). Season length, weather and ocean conditions, sardine abundance relative to proximity to port, processing capacity and skipper experience were likely all contributing factors.

Prior to 2008, the fishery did not attain the periodic allocation quotas or the annual coastwide harvest guideline. However, since then, as a result of a reduction in the coastwide harvest guideline, the fishery has since experienced closures between periods. In Washington, weather and ocean conditions are typically most favorable from May through October. Processor capacity does limit the number and size of deliveries; however, upgrades have increased facility capabilities compared to earlier years of the fishery.

Table 2. Annual landings (mt) for five vessels with the highest landings, ranked from highest to lowest for each year, 2000-2011.

Vessel	2011*	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
1	1,655	3,036	2,192	1,762	1,152	1,953	1,901	2,689	3,307	4,056	2,702	1,920
2	1,276	1,913	1,519	1,636	952	668	1,745	2,504	2,393	2,164	1,902	1,800
3	1,267	1,707	1,296	1,291	797	664	1,480	986	2,258	1,735	1,218	542
4	1,218	1,510	1,141	1,249	734	534	927	775	1,167	1,338	925	264
5	992	1,372	1,005	494	610	452	248	580	1,080	1,331	887	133

*Preliminary

In reviewing the vessel-specific harvest data for recent years (2009-2011), the vessels that produced the higher landings exerted a fair amount of effort in a relatively short period of time, making multiple landings per day—most of them made two landings per day and some made up to three. During this same time period, the Washington vessel activity was also compressed to just a few weeks in July and about one week in September.

WDFW also examined the Washington coastal sardine fishery logbook data to compare fishery set locations from 2008 through 2011 with the northern and southern boundaries of the Quinault Indian Nation's usual and accustomed fishing grounds (Figure 2). Set location data are for Washington licensed fishers only.

Figure 1. Washington sardine landings by month and allocation release periods, 2005-2011.

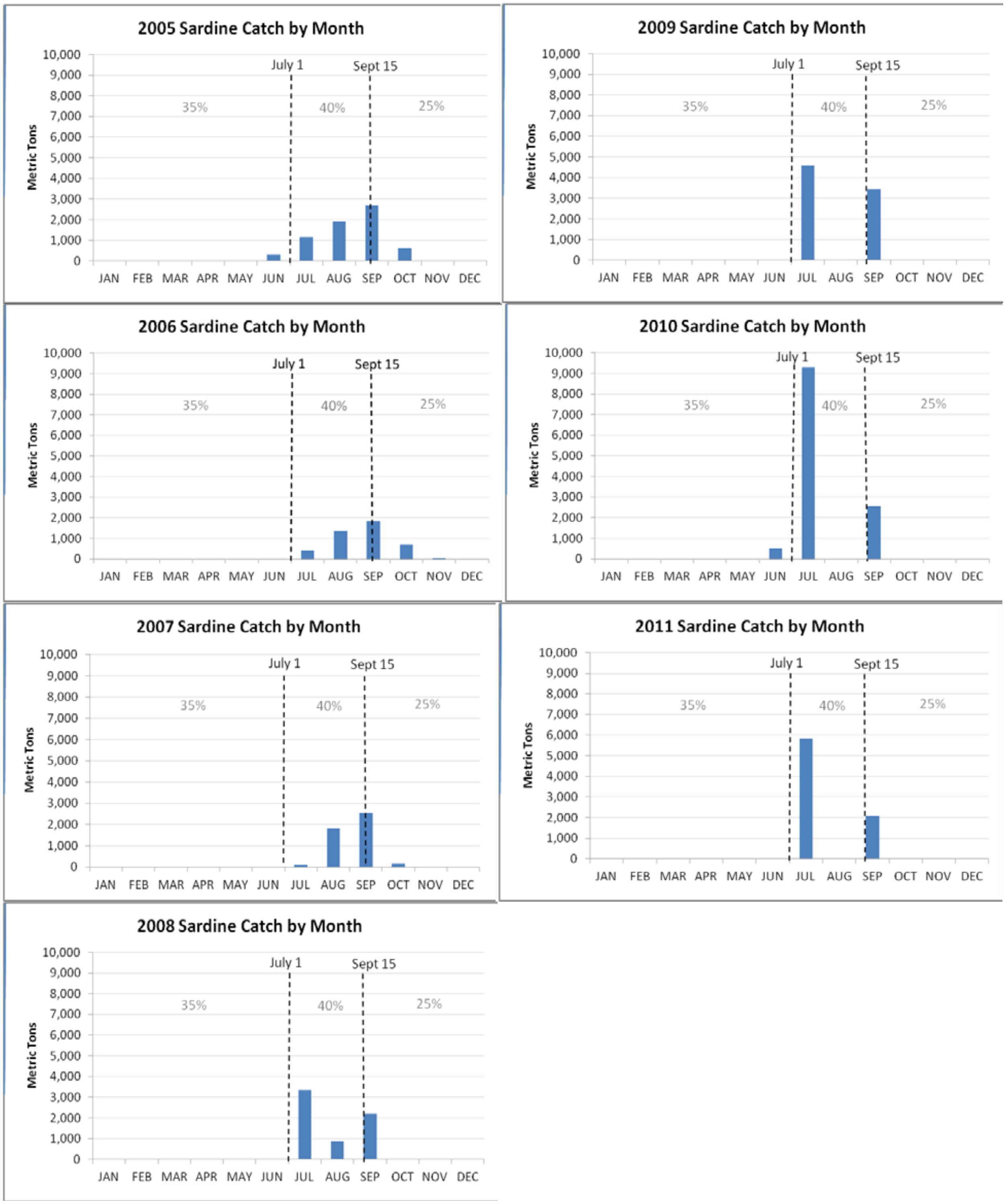
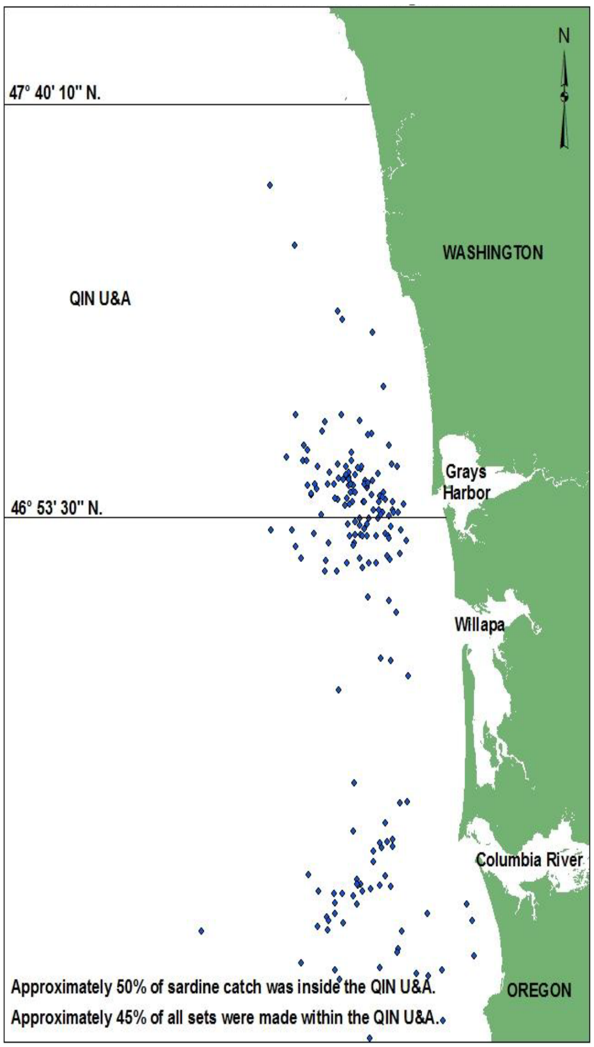


Figure 2. Washington licensed sardine set locations from logbook data, 2008-2011 with the northern and southern boundaries of the Quinault Indian Nation (QIN) Usual and Accustomed (U&A) fishing grounds.

2008



2009

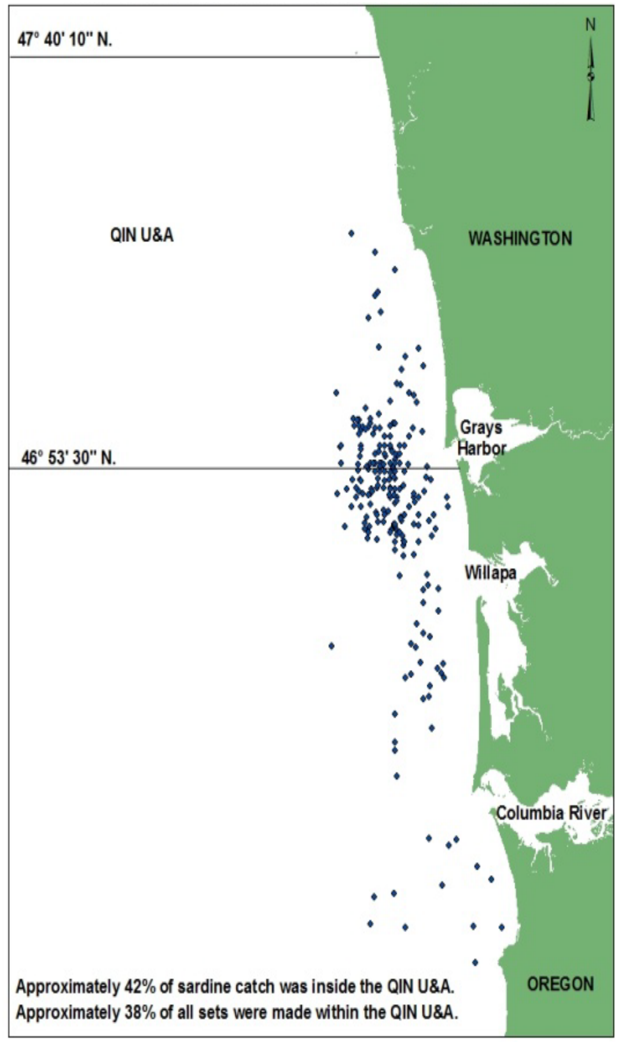
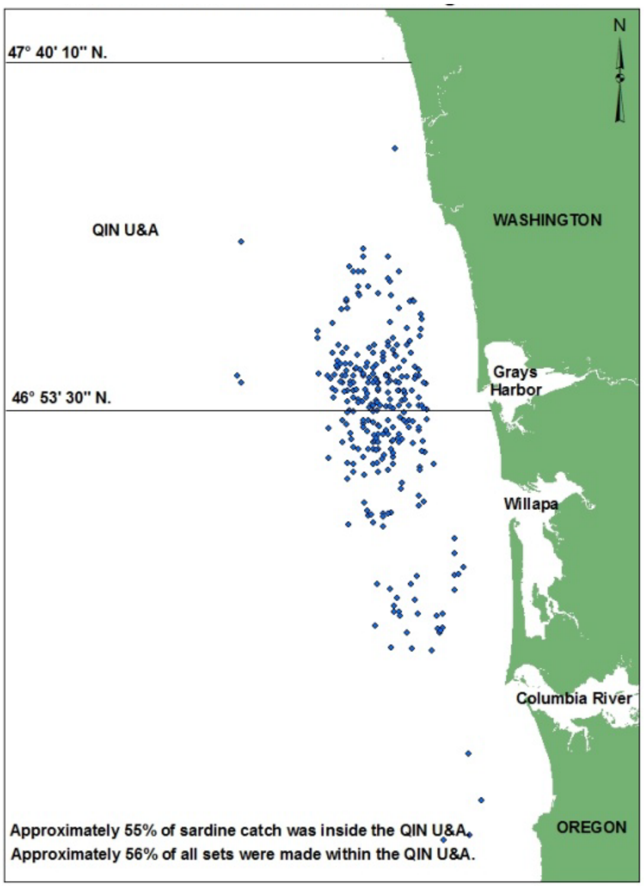
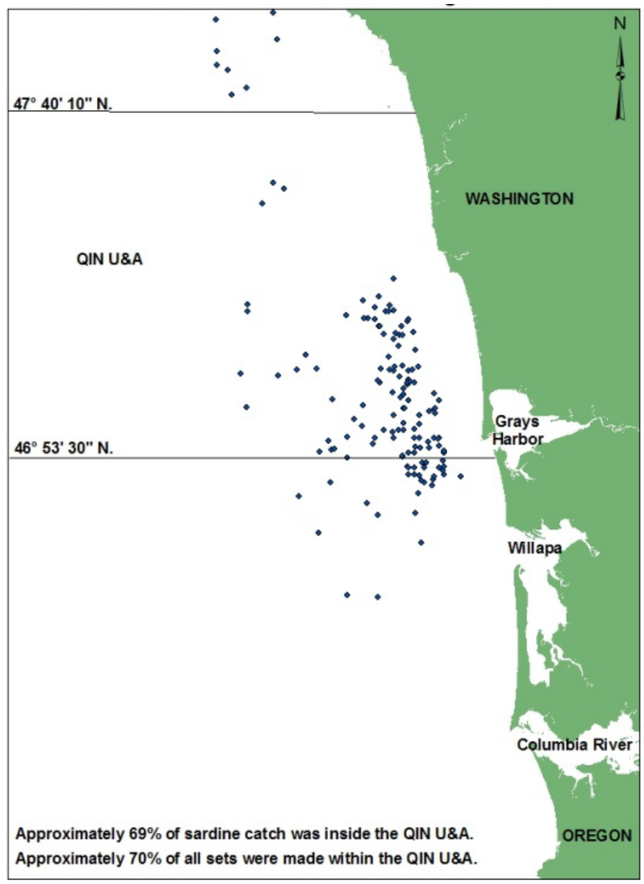


Figure 2. Washington licensed sardine set locations from logbook data, 2008-2011 with the northern and southern boundaries of the Quinault Indian Nation (QIN) Usual and Accustomed (U&A) fishing grounds.

2010



2011



Bycatch Evaluation of the Washington Sardine Purse Seine Fishery

From 2000 through 2004, WDFW required fishers to carry at-sea observers, as well as provide financial support for this observer effort. Bycatch information was collected in terms of species, amount, and condition; observers noted whether the fish were released or landed, and whether alive, dead, or in poor condition. During the five-year period of the program, overall observer coverage averaged over 25 percent of both total landed catch and number of landings made.

Based on observer data, the bycatch of non-targeted species in the Washington sardine fishery was relatively low. A comparison of logbook and observer data from 2000 to 2004 indicated that logbook data, in general, tended to under report bycatch by 20 to 80 percent (Culver and Henry, 2006). For this reason, salmon bycatch in the Washington sardine fishery for years subsequent to the observer program is calculated by multiplying total sardine catch and the observed 5-year average bycatch rates. Bycatch and mortality estimates of incidentally captured salmon by year and species are shown in Table 3. Incidental species caught and reported on Washington fish tickets are shown in Table 4. Mackerel, both Pacific and jack, comprise the majority of non-target catch in the sardine fishery.

Table 3. Expanded salmonid bycatch in Pacific sardine fisheries in Washington, 2000-2010.

	Chinook		Coho		Pink	Unidentified		Total		Grand
	Live	Dead	Live	Dead	Live	Live	Dead	Live	Dead	Total
2010	87	288	53	328						756
2009	56	186	34	212						488
2008	45	149	27	170						391
2007	33	108	20	124				53	232	285
2006	31	101	19	116				50	217	267
2005	47	156	29	178				76	334	410
2004[1/]	35	225	19	105	0	39	0	93	330	423
2003[1/]	92	262	81	231	0	173	0	346	493	839
2002[1/]	150	356	61	765	0	200	0	411	1211	1532
2001[1/]	449	170	571	504	0	80	0	1100	674	1774
2000[1/]	38	3	276	116	0	7	0	321	119	440

1/ Totals calculated from observed 2000-2004 observed bycatch rates.

Table 4. Incidental catch (mt) in Washington sardine fishery, 2000-2010 (from fish landing receipts).

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Mackerel	4.32	272.44	259.32	52.40	22.34	19.04	40.61	35.73	6.32	4.31	2.09
Pacific Herring			0.02						4.69		
Misc				0.34			1.37			2.34	
Northern Anchovy						1.81					
American Shad			0.18						<0.01		
Sharks	0.10	0.01							<0.01	<0.01	
Chinook		<0.01		<0.01							
Coho	<0.01										
Starry Flounder	<0.01										

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

Washington Sardine Fishery Regulations

RCW 77.70.480 Pacific sardines — Purse seine fishery license or temporary annual fishery permit required.
RCW 77.70.490 Pacific sardines — Purse seine fishery license — Adoption of rules regarding bycatch.

WAC 220-44-095 Coastal sardine purse seine fishery — Harvest, landing, and reporting requirements — Gear.
WAC 220-69-240 Duties of commercial purchasers and receivers.

Revised Code of Washington 77.70.480 Pacific sardines — Purse seine fishery license or temporary annual fishery permit required.

(1) A Washington sardine purse seine fishery license or temporary annual fishery permit is required to use purse seine gear to fish for or possess Pacific sardines in offshore waters. This requirement does not affect persons authorized to fish for or possess sardines in offshore waters under a valid Oregon or California license or permit.

(2) A Washington sardine purse seine fishery license or temporary annual fishery permit is required to deliver Pacific sardines into the state.

(3) Washington sardine purse seine fishery licenses and temporary annual fishery permits require vessel designation under RCW 77.65.100.

(4) Pacific sardines may not be taken or retained in state waters except for incidental harvest authorized by rule of the department.

Revised Code of Washington 77.70.490 Pacific sardines — Purse seine fishery license — Adoption of rules regarding bycatch.

(1) A Washington Pacific sardine purse seine fishery license:

> (a) May only be issued to a person that held a coastal pilchard experimental fishery permit in 2008, except as otherwise provided in this section;
>
> (b) Must be renewed annually to remain active; and
>
> (c) Subject to the restrictions of subsections (6) and (7) of this section and RCW 77.65.040, is transferable.

(2) A Washington Pacific sardine purse seine fishery license may be issued to any person that held a coastal pilchard experimental fishery permit in 2005, 2006, or 2007 and is precluded from qualifying under subsection (1) of this section because the vessel designated on the permit sank prior to 2008.

(3) Beginning in 2010, after taking into consideration the status of the Pacific sardine population, the impact of removal of sardines and other forage fish to the marine ecosystem, including the effect on endangered marine species, and the market for Pacific sardines in the state, the director may issue:

> (a) A Washington Pacific sardine purse seine fishery license to any person provided that the issuance would not raise the number of licenses beyond the number initially issued in 2009;

(b) A Washington Pacific sardine purse seine temporary annual fishery permit to any person if the combined number of active Washington Pacific sardine purse seine fishery licenses and annual temporary permits already issued during the year is less than twenty-five.

(4) The annual fee for a Washington Pacific sardine purse seine fishery license is one hundred eighty-five dollars for residents and two hundred ninety-five dollars for nonresidents.

(5) The fee for a Washington Pacific sardine purse seine temporary annual fishery permit is one hundred eighty-five dollars for residents and two hundred ninety-five dollars for nonresidents. A temporary annual fishery permit expires at the end of the calendar year in which the permit is issued.

(6) Only a person who owns or operates the vessel designated on the license or permit may hold a Washington Pacific sardine purse seine fishery license or temporary annual fishery permit.

(7) A person may not own or hold an ownership interest in more than two Washington Pacific sardine purse seine fishery licenses.

(8) The director shall adopt rules that require a person fishing under a Washington Pacific sardine purse seine fishery license or a temporary annual permit to minimize bycatch, and to the extent bycatch cannot be avoided, to minimize the mortality of such bycatch.

Washington Administrative Code 220-44-095 Coastal sardine purse seine fishery — Harvest, landing, and reporting requirements — Gear.

(1) (a) It is unlawful to possess, transport through the waters of the state, or deliver into any Washington port, Pacific sardine (Sardinops sagax) or other coastal pelagic species taken in violation of gear requirements and other rules published in Title 50, Part 660, Subpart I of the Code of Federal Regulations (CFR). These federal regulations govern commercial fishing for coastal pelagic species in the Exclusive Economic Zone off the coasts of Washington, Oregon, and California. Where the federal regulations refer to the fishery management area, that area is interpreted to include Washington state waters coterminous with the Exclusive Economic Zone. Updates to the federal regulations are published in the Federal Register. Discrepancies or errors between the CFR and Federal Register will be resolved in favor of the Federal Register. This chapter incorporates the CFR by reference and is based, in part, on the CFR. A copy of the federal rules may be obtained by contacting Lori Preuss at 360-902-2930, or going to the U.S. Government Printing Office's GPO Access web site (www.gpoaccess.gov). State regulations that are more restrictive than the federal regulations will prevail.

(b) The coastal sardine fishery season is open to purse seine fishing each year only from April 1st through December 31st. It is unlawful to take Pacific sardine in state waters except for the incidental take authorized by the coastal baitfish regulations.

(c) It is unlawful to retain any species that is taken incidental to sardine, except for anchovy, mackerel, and market squid (Logligo opalescens). Any salmon encircled in the purse seine must be released prior to completion of the set, and no salmon may be landed on the fishing vessel.

(d) It is unlawful to transfer sardine catch from one fishing vessel to another.

(e) It is unlawful to fail to have legal purse seine gear aboard the vessel making a sardine landing.

(f) It is unlawful to fail to deliver sardine landings to a shore-side processing facility.

(g) Once a delivery has commenced at a processing plant, all fish on board the vessel must be offloaded at that plant.

(h) It is unlawful to deliver more than fifteen percent cumulative weight of sardines for the purposes of conversion into fish flour, fish meal, fish scrap, fertilizer, fish oil, other fishery products, or by-products, for purposes other than human consumption or fishing bait used during the sardine fishery season.

(2) License owners must designate a vessel upon issuance or renewal of the license and must be identified as either the vessel owner or primary license operator.

(3) Persons fishing under a Washington sardine purse seine fishery license or temporary annual fishery permit must:

(a) Carry an observer on board for any sardine fishing trip if requested by the department;

(b) Surrender up to five hundred sardines per vessel per trip if requested by department samplers for biological information; and

(c) Complete a department-issued logbook each month in which fishing activity occurs, and submit it to the department by the 15th day of the following month.

(4) Violation of reporting requirements under this section is punishable pursuant to RCW 77.15.280.

(5) Violation of gear, harvest, or landing requirements under this section is punishable pursuant to RCW 77.15.520.

Washington Administrative Code 220-69-240 Duties of commercial purchasers and receivers.

(6) Forage fish: It is unlawful for any person receiving forage fish to fail to report the forage fish on fish receiving tickets initiated and completed on the day the forage fish are delivered. Herring are also required to be reported on herring harvest logs. The harvested amount of forage fish must be entered upon the fish ticket when the forage fish are off-loaded from the catcher vessel. An estimate of herring, candlefish, anchovy, or sardine caught but not sold due to mortality must be included on the fish ticket as "loss estimate." In the coastal sardine fishery, the amount of sardine, by weight, purchased for the purposes of conversion into fish flour, fishmeal, fish scrap, fertilizer, fish oil, other fishery products, or by-products for purposes other than human consumption or fishing bait, must be included on the fish ticket as "reduction." In any forage fish fishery, the amount of anchovy, by weight, purchased for the purposes of conversion into fish flour, fishmeal, fish scrap, fertilizer, fish oil, other fishery products, or by-products for purposes other than human consumption or fishing bait, must be included on the fish ticket as "reduction."

Violation of this subsection is a gross misdemeanor, punishable under RCW 77.15.640.

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831.643.9266
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October 13, 2011

Mr. Dan Wolford, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, OR 97220-1384

RE: Agenda Item F.2. Pacific sardine harvest specifications for 2012

Dear Chairman Wolford and members of the Council:

Thank you for this opportunity to comment on the 2012 Pacific sardine specifications. As sardines are an extremely important forage fish in the California Current Large Marine Ecosystem and the West Coast ocean-based economy, we urge the Council to take the utmost precaution in managing this stock. Although the results of the 2012 STAR panel review and Pacific sardine stock assessment are not publically available at this time, we continue to have serious concerns regarding the stock status of Pacific sardines, the harvest control rule used to develop the U.S. harvest guideline, and the lack of international cooperation in managing this transboundary stock. In this letter we detail those concerns and provide recommendations for addressing them.

1. Background explanation of the Pacific Sardine Harvest Control Rule (HCR)

Sardine management currently takes place through an innovative framework that could potentially serve as a model for ecosystem-based fishery management for targeted forage fish stocks.

HARVEST GUIDELINE = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION

Pending approval of Amendment 13 to CPS FMP:

OFL = BIOMASS * *F*MSY * DISTRIBUTION

ABC = BIOMASS * BUFFER(P*) * *F*MSY * DISTRIBUTION

ACT= EQUAL TO HG OR ACL (≤ABC), WHICHEVER VALUE IS LESS

In the current framework, a minimum cutoff (CUTOFF) biomass is "set-aside" such that fishing quotas are set on a percentage of the estimated BIOMASS (ages 1+) above the cutoff and the fishery is closed if the total population drops below CUTOFF. The current cutoff for Pacific sardine is 150,000 metric tons (MT). The percentage (FRACTION) of the remaining biomass that can be fished increases (to 15%) in warmer ocean conditions where the population is thought to be more productive and decreases (to 5%) in cooler, less favorable conditions. DISTRIBUTION (87%) is the percentage of BIOMASS assumed to be in U.S. waters. Finally, there is a maximum catch value (MAXCAT) that cannot be exceeded regardless of how large the population becomes which prevents overcapitalization and provides a level of precaution when stock assessments are uncertain. The Pacific sardine control rule currently employs MAXCAT of 200,000 metric tons. Other targeted forage species do not have this important control in place.

2. The simulation model used to establish the parameters used in the Pacific Sardine HCR was never fully documented, is therefore not transparent, and is outdated

While the framework for sardine management is innovative, we have serious concerns with the parameters going into the framework to determine the harvest guideline. The current harvest rule for Pacific sardines was first established in 1998 through CPS FMP Amendment 8 and reaffirmed in 2011 in the proposed Amendment 13 to the CPS FMP. It is based on results from a simulation model developed by Larry Jacobsen and Richard Parrish, which at the time was presumably determined to represent the best available science. According to Amendment 8, the simulation model used to evaluate MSY control rules was described in a publication that was "in prep"; therefore the Amendment only included "a summary of its essential features" in Appendix B to Amendment 8 of the CPS FMP.[1] While the simulation model itself is available, its formulation, assumptions, functioning, and full suite of model runs have never been adequately explained and the model has not been published.

As a result, there is no public transparency as to the fundamental basis for sardine management decisions. Some additional details of the model simulations not included in Amendment 8 have since been provided by Richard Parrish as Public Comment to the PFMC,[2] but without additional documentation, there can be no legitimate public analysis or peer review. Considering the importance of this stock to the ecosystem, growing public interest in proper management of this important public resource, and the inability of experts to undertake a peer review of a model that has never been made public, we request that the simulation model be fully disclosed and properly documented immediately.

In fact, the PFMC and management bodies have been aware for years that the HCR is outdated and in desperate need of a formal review. As stated in 2008 CPS SAFE document, "…the harvest control rules in the CPS FMP are dated and in need of review and potential revision. Review of the harvest control rules in the CPS FMP has been characterized as a high priority research and data need by the Council and its advisory bodies."[3]

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[1] PFMC. 1998. CPS FMP Amendment 8, Appendix B, p. B-92.
[2] PFMC. Agenda Item G.1.d. Public Comment. June 2008. and PFMC Agenda Item H.1.c Public Comment, June 2011.
[3]PMFC 2008. SAFE. June 2008, at 46. and see PFMC 2011. Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches. Stock Assessment and Fishery Evaluation. June 2011, at 68.

3. The HCR Uses a Temperature-Recruitment Relationship that is not based on the Best Available Science

A peer review of the model as well as a detailed analysis of sardine management is of utmost importance as information that has become readily available after 1998 clearly demonstrates that both the model formulation (as summarized in CPS FMP Amendment 8) and the parameters used in the current HCR are not accurate. For example, in the description of the simulation model, Amendment 8 stated that

> *The simulation model used a Ricker (1975) recruitment model based on sardine spawning biomass and mean sea surface temperatures at Scripps Pier, California (Jacobsen and MacCall 1995).... Temperature data and reproductive success in the simulations were related functionally and autocorrelated so that years of good and bad recruitment success occurred in regimes of approximately a decade.*[4]

Most recently, McClatchie et al.[5] published a re-analysis of the temperature-recruitment relationship for Pacific sardine that found "the temperature–recruit relationship no longer holds for the SIO [Scripps Institute of Oceanography] pier when time series are updated with data from more recent years", meaning that the relationship between temperature and reproductive success used in the simulation models are not valid. In addition, this also invalidates the temperature-based F_{MSY} calculation and thus the calculation of Overfishing Limit (OFL). The fact that temperature no longer predicts the recruitment of sardines represents a fundamental invalidation of the entire harvest guideline, which was built around the temperature-recruit relationship. This relationship was also used to justify the FRACTION in the HCR allowing higher exploitation rates in "favorable" regimes. Since the McClatchie et al. paper found that temperature does not predict favorable regimes, it is inappropriate and not in accordance with the best available science to continue using temperature as the basis for the FRACTION parameter in the control rule. While we encourage the development of a new, robust environmental indicator, it would be irresponsible to continue to use one that is known not to hold.

4. The DISTRIBUTION factor does not reflect current catch or stock distribution and international overfishing is occurring

A further flaw with the harvest guidelines is that the DISTRIBUTION parameter was intended to reflect the proportion of the available Pacific sardine stock that occurred in the U.S. versus other nations (Mexico and Canada), with the assumption that each nation is entitled to catch that proportion out of the overall coastwide catch. This was based on Summer-Fall fish spotter surveys conducted two decades ago during a period of low sardine abundance and has been used to justify the assumption that 87% of the stock is in U.S. waters while 13% of the stock is in Mexico waters.[6] This results in a much greater estimate of the proportion of Pacific sardine in

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[4] CPS FMP Amendment 8, Appendix B, p. B-92.
[5] McClatchie, S., R. Goericke, G. Auad, K. Hill. 2010. Re-assessment of the stock-recruit and temperature-recruit relationships for Pacific sardine (*Sardinops sagax*). Can. J. Fish. Aquat. Sci. 67(11): 1782-1790.
[6] CPS FMP Amendment 8, Appendix B, p. B-87-88.

U.S. waters than the State of California was using to set quotas in 1998 (59%, based on both CalCOFI data and fish spotter data).[7]

Species	United States	Mexico
Pacific (Chub) Mackerel	84%	16%
Jack Mackerel	75%	25%
Pacific Sardine	87%	13%
Northern Anchovy	98%	2%

Table. Fish Spotter (Summer-Fall) Distribution.
From Amendment 8 to the CPS FMP, Appendix B. p. B-88

According to the current distribution, we would expect that the U.S. would land approximately 87%, Mexico would land 13%, and Canada would land 0% of the total coastwide sardine landings. In fact, according to this estimate there should be no portion of the overall Pacific sardine stock in Canada at all.

Recent catch levels, however, indicate the use of an 87% estimate for U.S. waters is seriously flawed. For example in 2010, U.S. catch levels were only 46% of total catch (66,922 MT) as Mexico and Canada caught 39% and 15% respectively. The fact that Canada has any catch is evidence alone that the current DISTRIBUTION parameter does not accurately reflect the proportion of the stock in the respective waters of all three countries.

Pacific sardines are a particularly vulnerable international fish stock because unlike Pacific halibut, Pacific hake, and the highly migratory tunas, there is no international agreement governing the proportion of the stock to which each country is entitled. The fundamental problem is that neither Mexico nor Canada ever agreed that the U.S. is entitled to 87% of the coastwide catch. Therefore, each of the three countries is fishing the perceived portion of the stock to which each country believes they are entitled, and these proportions add up to far greater than 100%.

This lack of international coordination severely undermines any HCR that the U.S. establishes and jeopardizes the health of the stock. For example, under the current HCR, the CUTOFF parameter should prevent the total exploitation rate from exceeding 12% and should decrease the exploitation rate as the stock declines. In every year since the HCR was established, however, the total exploitation rate has exceeded 13% (including the current rate of approximately 20%), and the exploitation rate has increased as the stock has declined. Therefore, even if the U.S. follows its own HCR, the actual coastwide catch undermines any precaution or ecological consideration present in the HCR.

As per the Magnuson-Stevens Act and the NS1 guidelines, immediate action must be taken if

> *…a fishery is overfished or approaching a condition of being overfished due to excessive international fishing pressure, and for which there are no management*

[7] PFMC. CPS FMP, Amendment 8, Appendix B, p. B-88. December 1998.

> *measures (or no effective measures) to end overfishing under an international agreement to which the United States is a party…* [8]

Within one year of making this determination, the Council must then develop recommendations for addressing the relative impact of U.S. fishing vessels on the stock and submit recommendations to the Secretary of State for international actions to end overfishing.

Therefore, the critical determination is whether overfishing is occurring. The NS1 guidelines define F_{MSY} as "the fishing mortality rate that, if applied over the long term, would result in MSY".[9] For the case where fishing mortality is applied at a constant rate over the long term, the analysis in Amendment 8 to the CPS FMP determined the F_{MSY} (stochastic) to be 12%.[10] The NS1 guidelines define MSY stock size (B_{MSY}) as "the long-term average size of the stock or stock complex, measured in terms of spawning biomass or other appropriate measure of the stock's reproductive potential that would be achieved by fishing at F_{MSY}".[11] The analysis in CPS FMP Amendment 8 determined the average biomass of Pacific sardine to be 1,408,000 metric tons when fished at the F_{MSY} of 12%.[12] According to the current coastwide exploitation rate on Pacific sardines of 20% (in serious excess of the 12%), it is clear that $F > F_{MSY.}$ Therefore overfishing is occurring on sardines at the international level.

In addition, based on the NS1 guidelines, the stock of Pacific sardines should be considered overfished. According to the NS1 guidelines:

> *To the extent possible, the MSST [Minimum Stock Size Threshold] should equal whichever of the following is greater: One-half the MSY stock size, or the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years, if the stock or stock complex were exploited at the MFMT [Maximum Fishing Mortality Threshold] specified under paragraph (e)(2)(ii)(A)(1) of this section. Should the estimated size of the stock or stock complex in a given year fall below this threshold, the stock or stock complex is considered overfished.*[13]

Therefore, it is possible using the sardine simulations from the CPS Amendment 8, Appendix B to derive an MSST (overfished threshold) for Pacific sardines based on one half the MSY stock size (704,000 MT) as required in the NS1 final rule.[14] This is in stark contrast to the MSST value of 50,000 MT established in the CPS FMP. While the 2011 STAR panel assessment is not yet available, last year's assessment indicated that the stock was below 704,000 MT since

[8] 50 C.F.R. § 600.310 (k)
[9] 50 C.F.R. § 600.310 (e)(1)(i)(B).
[10] PFMC. CPS FMP, Amendment 8, Appendix B, p. B-94. December 1998.
[11] 50 C.F.R. § 600.310 (e)(1)(i)(C).
[12] PFMC. CPS FMP, Amendment 8, Appendix B, p. B-94. December 1998.
[13] 50 C.F.R. § 600.310(e)(2)(ii)(B).
[14] 50 C.F.R. § 600.310(e)(2)(ii)(B).

2009.[15] Based on the metric described by the NS1 final rule, the Pacific sardine stock is at an overfished level.

However, regardless of whether overfishing is occurring at the international level, Mexico and Canada are together catching far more than the 13% of the total harvest guideline as specified in current sardine management. This alone is grounds for a revision of the DISTRIBUTION parameter and/or international engagement with Mexico and Canada to address the discrepancy. Such international engagement could build on or be modeled off existing international fishing agreements the U.S. currently has with those countries.

5. The Current Management Structure Fails to Achieve Optimum Yield

Even if the Parrish and Jacobsen Pacific sardine simulation model used in CPS Amendment 8 continues to be used as the basis for the formulation of the harvest control rule, substantial changes to the harvest control rule are necessary to ensure the HCR meets the Magnuson-Stevens Act mandate of achieving Optimum Yield on an ongoing basis.

A recent study published in the journal Science concluded that fishing at MSY levels on low trophic level species (i.e. forage species) has widespread ecological consequences in all ecosystems assessed to date.[16] To maintain high catch levels while greatly reducing these ecological impacts, the study recommended setting exploitation rates for low trophic level species to below one half of MSY levels and establish B75% as a target. Based on the current stochastic MSY exploitation rate for Pacific sardines (12%), applying this approach to Pacific sardines would require reducing the coastwide exploitation rate to below 6%.

Regardless of the CUTOFF, FRACTION, and MAXCAT parameters of the harvest rule, recent coastwide exploitation rates have been on the order of 20%. Interestingly, based on the simulation model used in the current harvest rule and the current coastwide exploitation rate of 20%, an exploitation rate of 6% would actually yield greater average harvest levels than the status quo (approx 130,000 MT) (see figure below). At the same time, average sardine biomass would increase approximately 4 fold (from 500,000 MT up to over 2,200,000 MT) to levels approaching B75%. Such an increase in sardine biomass would result in a much greater amount of forage available to sardine predators throughout the California Current ecosystem, as well as greatly increased catch per unit effort of sardines in the fishery (hence lower fishing costs and increased profits associated with any given level of catch). This is shown in the graph below, which was derived from the same Pacific sardine simulation model used as the basis for the current HCR. While the figure does not include variability, and other tools such as MAXCAT and CUTOFF, it does provide a general indication of long-term averages, which are the basis of Optimum Yield. Notably, an exploitation rate of 6% would lead to similar average catches and higher average biomass that the current harvest control rule (Option J estimated to have an average biomass of 1,952 in Amendment 8). Furthermore, one of the performance indicators in

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[15] Hill et al. Assessment of the Pacific Sardine Resource in 2010 for U.S. Management in 2011. NOAA Tech Memo NMFS SWFSC 469.
[16] Smith et al. 2011. Impacts of Fishing Low-Trophic Level Species on Marine Ecosystems. *Science*. www.sciencemag.org July 21, 2011.

Amendment 8 was the percentage of years with a biomass above 400,000 MT, however there was no justification for how this threshold was selected, particularly in relation to providing adequate forage.

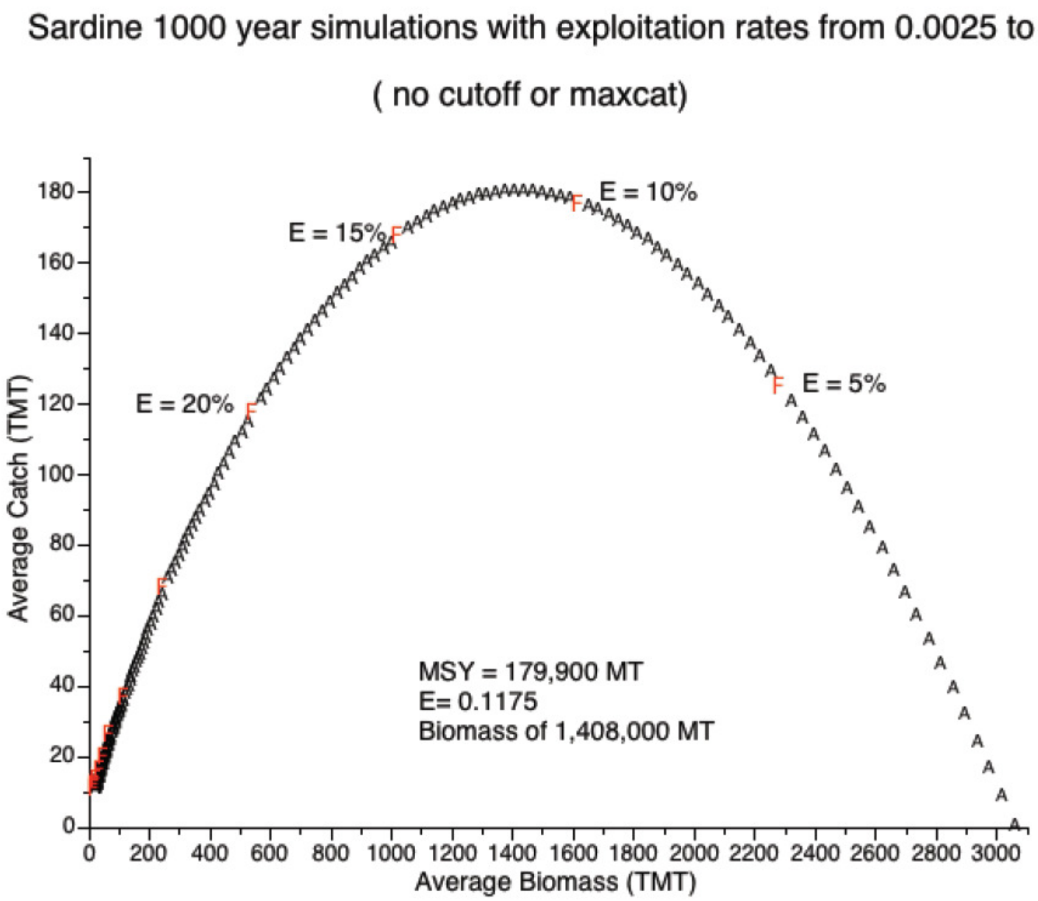

Figure from Parrish' May 11, 2008 letter.
PFMC Agenda Item G1d. Public Comment. June 2008 Briefing Book.

6. The Current Management Structure Fails to consider Adverse Impacts to Essential Fish Habitat for other Council-managed species.

Pacific sardines comprise a significant component of the diets of several Council-managed species in the Groundfish, Salmon, and Highly Migratory Species FMPs, and they are a major prey item which makes Pacific sardines essential fish habitat for those species.[17] As such, the Council and NMFS must consider the extent to which Council-authorized specifications for Pacific sardines reduce their availability as major prey for those species, which could constitute adverse impacts on EFH. The Council and NMFS must consider whether the overly aggressive Pacific sardine harvest rates constitute adverse impacts to EFH and, if adverse impacts exist, minimize them.

[17] As defined in EFH Final Rule. 16 U.S.C. 1853 §303(a)(7)

7. CUTOFF Does Not Adequately Include Forage Considerations

The original documentation for the harvest control rule in CPS FMP Amendment 8, Appendix B did not contain a justification for the use of a 150,000 MT CUTOFF. Later documents explain that "The purpose of CUTOFF is to protect the stock when biomass is low" and "CUTOFF provides a buffer of spawning stock that is protected from fishing and available for use in rebuilding if a stock becomes overfished."[18] In 2008, however, Richard Parrish submitted a letter to the PFMC describing that the approach was used to determine the forage set aside. The letter explains that

> *[t]he approach taken by the CPSMT was to use the general ecological rule that it takes ten gms. of food to produce one gm. of weight. This point occurs at an annual average catch of 147 thousand tons or an exploitation rate of 0.065. Using this approach the exploitation rate should not exceed the rate where an increase in catch results in a tenfold decrease in average biomass. In other words the set aside for forage by other species was determined by setting the exploitation rate at the level where the weight of the last mt of catch equaled the increase in biomass that would occur if the resulting ten mt. average biomass were left in the ocean.*[19]

We do not agree with the logic behind this approach and have great concern that it was neither published nor adequately peer-reviewed. First, rather than identify the predator populations that consume sardines and use information on actual consumption levels or conversion ratios, the approach simply relied on a general estimate of a 10:1 conversion. Second, this assumes that the value of the predators by weight is equal to the value of sardines by weight. This is clearly incorrect—for example, a pound of Chinook salmon is far more valuable than a pound of sardines.

Furthermore, even if one accepts these assumptions, the goal of the approach was to derive a harvest rate that should not be exceeded, which according to Dr. Parrish's letter was 0.065. However, rather than setting a maximum harvest rate, the corresponding catch at an exploitation rate of 0.065 (i.e., 147,000 MT) became the CUTOFF, not the maximum harvest rate. There is therefore a serious disconnect as the analysis was used to determine a harvest rate, but was instead then used to create the CUTOFF. Since the combination of the CUTOFF and the FRACTION together determine the actual harvest rate (which generally exceeds 0.065 in the current harvest control rule), the harvest control rule actually exceeds the rate where an increase in catch results in a tenfold decrease in biomass, violating the objective of the forage set aside as described in Dr. Parrish's letter.

This is of great concern as the coastwide exploitation rate has exceeded the harvest control rule every year since the HCR was implemented. Therefore, not only do the exploitation rates

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[18] PFMC 2011. Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches. Stock Assessment and Fishery Evaluation. June 2011, at 21.
[19] PFMC Agenda Item G1d. Public Comment. June 2008.

produced by the current HCR exceed the levels necessary to provide adequate forage, but the HCR itself is being exceeded.

8. Summary and Conclusions:

As detailed above, there are several fundamental flaws in the current harvest control rule used to develop harvest specifications for Pacific sardine.

These include:

- Use of a simulation model to derive the harvest control rule that has yet to be fully documented, is not transparent, and is clearly out of date;

- Use of flawed logic to justify a "forage set aside", thereby failing to meet optimum yield requirements;

- Use of a temperature-F_{MSY} relationship now known to be inaccurate;

- Failure to analyze the extent to which Pacific sardine harvest may adversely impact prey availability as a component of EFH for other Council-managed species;

- Failure to account for or coordinate management of Pacific sardine in Mexico and Canada.

The result is excessive fishing pressure on Pacific sardines that threatens the stock itself, the fishing communities that rely on long-term consistent sardine harvest, and populations of natural predators of sardines and their associated economic sectors. The PFMC and CPSMT have been aware for years that the harvest control rule needs to be revised. In fact, a formal review of the harvest control rule has been repeatedly identified as one of the highest priority research needs by the CPSMT and the Council. Given the gravity of these flaws, we realize that remedying the current situation is beyond the scope of what the Council can accomplish at the November 2011 meeting.

Therefore, we suggest the following:

1. The Council immediately task the CPSMT and SSC to re-evaluate and revise the harvest rule based on best available information, including providing adequate forage (for example, as per the recommendations in the Smith et al. *Science* study[20]) and fully documenting the simulation approach used, and to conduct a full management strategy evaluation;

[20] Smith et al. 2011. Impacts of Fishing Low-Trophic Level Species on Marine Ecosystems. *Science*. www.sciencemag.org July 21, 2011.

2. Request that NMFS and the US State Department engage in international discussions with Mexico and Canada to prevent overfishing;

3. Consider management measures that would expeditiously rebuild the Pacific sardine stock to levels exceeding $B_{MSY.}$

Once the results of the STAR panel review and stock assessment are available, we will provide more specific recommendations regarding the 2012 Annual Catch Limit. Thank you for your time and consideration of these comments.

Sincerely,

Geoffrey Shester, PhD
California Program Director, Oceana

cc: Rodney McGinnis; NMFS Regional Administrator, Southwest Region

California Wetfish Producers Association
PO Box 1951 • Buellton, CA 93427 • Office: (805) 693-5430 • Mobile: (805) 350-3231 • Fax: (805) 686-9312 • www.californiawetfish.org

Mr. Dan Wolford, Chair
And Members of the Pacific Fishery Management Council
7700 NE Ambassador Place #200
Portland OR 97220-1384

RE: Agenda Item F.2.d Pacific sardine harvest specifications for 2012

Dear Mr. Wolford and Council members,

The California Wetfish Producers Association (CWPA) represents the majority of coastal pelagic species 'wetfish' fishermen and processors in California. We present these comments in clarification and correction of the public comment letters submitted by Oceana and others, regarding sardine harvest management for 2012.

In a continuing pattern, the coast-wide overfishing allegations claimed in Oceana's letter and others of like tenor, as well as a substantial number of the demands made, are based on data that have been misrepresented or misunderstood – especially considering the latest stock assessment, which is characterized as 'best available science'.

In light of the challenges these allegations pose to CPS fisheries, and specifically the sardine fishery, we again asked Dr. Richard Parrish to review and comment on these letters, in the context of the 2011 sardine stock assessment and other background documents. As you're aware, Dr. Parrish was the co-author of the original Coastal Pelagic Species Fishery Management Plan and sardine harvest control rule, and is a respected, knowledgeable scientist and participant in the evolution of the Council's management of fisheries.

I am attaching Dr. Parrish's report for reference, and will summarize here some key points and recommendations.

• The rationale for the CPSMTs recommended harvest control rule (HCR) was dominated by a concern for maintaining the sardine stock at population levels well above that which would occur with a single-species, MSY-based management strategy. **The principal basis for the present sardine rule was to maintain a larger population of sardine, due to their importance as forage, than would occur with a MSY strategy**. All four components of the control rule contributed to the balanced strategy seen in the comparison of HCR performance measures in Amendment 8, Table 4.2.5-1. <u>The principal performance measure concerning the importance of the stock for forage is the mean biomass or in more modern terms the mean depletion.</u> Mean depletion with the current HCR is predicted to be 0.64. [Mean depletion from the 2011 stock assessment is 0.81].

- The model used to develop the sardine control rule did not include distribution. This allocation feature was added to the management of sardine by others and it played no role in the decision to pick Option J as the preferred science option. **International aspects of the sardine fishery are clearly external to the HCR.**

Recent total coast-wide catches from the so-called northern stock of sardine – including Mexico and Canada, which increased its harvest in the last few years – have exceed those calculated with the present control rule. Questions on stock structure further complicate management as an unknown portion of the so-called southern stock is landed in Ensenada and southern California, but for the purpose of the U.S. stock assessment, these landings are attributed to the northern stock and included in the stock assessment and harvest control rule calculations.

- **The harvest guideline produced by the HCR is more precautionary than any developed with the Council's new P* formula, predicting the probability of overfishing.**
  - the revised Fmsy estimate is considerably larger than the Fmsy estimate in Amendment 8;
  - the surplus production rates since 1993 are much larger than those simulated in the assessments leading to the adoption of the current HCR, and
  - the mean spawning stock depletion (i.e. mean biomass) is much higher than that predicted for the current HCR.

- **If the current HCR is "flawed", the latest 'best available science' suggests that the flaw caused the HCR to produce annual quotas much smaller than those that would occur with the 'best available science'**.

- Dr. Parrish disagrees with comments that the present control rule is invalid. However, he notes that the principal weakness of the analyses used to develop the present HCR is that **annual fecundity in sardine is known to be heavily age/size dependent. Future analyses, including both stock assessments and harvest management analyses, should include this important life history trait.**
  - He strongly recommends developing a new management assessment model that includes any potential environmental relationships and that **also includes the full 1935-2011 time series** for biomass and recruitment for the northern stock of sardine.

- Dr. Parrish agrees with the need to seek international management cooperation of this transboundary resource. **He also notes that the current coast-wide exploitation rates included in the 2011 sardine stock assessment DO NOT reflect overfishing.**

- The international effort to mount a synoptic summer survey extending into both Mexico and Canada is planned in 2012, and further plans to conduct a methods review to consider incorporating the Canadian swept-trawl sardine survey into future stock assessments are positive steps to better understand the coast-wide distribution of Pacific sardine.

- Oceana misrepresented the Smith et al study in Science. In fact, the Smith et al study found "…**impacts of fishing both species [sardine and anchovy] were low in the south east Australian and California Current ecosystems."**

- **The results from the Science study are almost identical to the strategy utilized with the present sardine control rule.**
  - **Depending upon the definition of MSY, (stochastic MSY or maximum long-term yield) the present control rule is either extremely close to the policy recommended by Smith et al (2011) or considerably more conservative than their recommendation.**

• Dr. Kevin Hill's reanalysis of the spawner-recruit relationship (Appendix 4 of the sardine stock assessment) shows that the sardine stock is considerably more productive than was predicted by the analyses in Amendment 8.

- **Fmsy with the new information occurs at a FRACTION of 18% whereas the older data suggested a value of only 12%.**

• An additional source of information concerning the recent productivity of Pacific sardines can be derived from calculations of surplus production based the information from the 2011 sardine stock assessment (Hill et al (2011).

- **Importantly, the mean production rate (14.5%) was considerably higher than the mean harvest rate (10.6%); as a result the age 1+ biomass increased from 636 TMT in 1993 to 1,097 TMT.**
- It is clear that the productivity of sardine during the recent period was considerably higher than that predicted by the original sardine simulations in Amendment 8.

• Oceana claims that the CUTOFF does not adequately include forage considerations, but their comments show they do not understand how this conversion rule was used. Dr. Parrish points out that the general 10:1 trophic conversion rule produced almost exactly the same result as the strategy recently proposed by Smith et al. (2011).

• Parrish further recommends that the relative values of the different trophic levels need to be assessed in a full ecosystem model, not by picking out some particular animal (i.e. salmon, which consume a minor part of the sardine population). About one third of the forage provided by the sardine stock consists of eggs, larvae and early juveniles. Zooplankton is a principal consumer of this forage, but have no monetary value.

• The very recent revision of this analysis by Hill et al 2011 should solve many of Oceana's problems associated with the current HCR. They should be happy to find that the 'best available science' now shows that the principal problem with the current HCR is that it results in a considerable under-estimation of the productivity of the stock.

• Dr. Parrish concurs with the Pew recommendation to incorporate a variable natural mortality rate into the stock assessment. Annual fecundity in sardine is known to be heavily age/size dependent.

- **Future analyses, including both stock assessment and harvest management analyses, should include this important life history trait, and high priority should be placed on developing a new and more complete assessment of the sardine control rule.**

• It is important to investigate the full range and distribution of Pacific sardine as a high priority in the coming year, and to initiate a new management strategy evaluation and assessment model that includes any new potential environmental relationships. The assessment should include the full 1935-2011 time series for developing both spawner-recruit and environment- recruit relationships.

Dr. Parrish concludes: "… **the 'best available science' shows that the sardine stock is considerably more productive than the 'outdated science' in Amendment 8; it also shows that the current HCR is very conservative and very robust and [he] recommends that it not be changed until a complete re-analysis of sardine management is accomplished."**

Thanks very much for considering these comments. We support Dr. Parrish's recommendations.

Best regards,

Diane Pleschner-Steele
Executive Director

Attachment: A Review of public comment letters on sardine management measures
By Richard Parrish, Ph.D

A REVIEW OF PUBLIC COMMENT LETTERS ON SARDINE MANAGEMENT MEASURES

Richard H. Parrish
Fisheries Biologist October 31, 2011

I am writing this letter in response to concerns about current sardine management, and the importance of sardine with respect to providing adequate forage for other species (Oceana F2d PC NOV1011bb.pdf) (Pew Environment Group, F2d_Supp_Pub_Comment).
First I will address the Oceana letter. Extracts from that letter appear in italics, followed by my response.

1. Background explanation of the Pacific Sardine Harvest Control Rule (HCR)
Sardine management currently takes place through an innovative framework that could potentially serve as a model for ecosystem-based fishery management for targeted forage fish stocks.
HARVEST GUIDELINE = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION
Pending approval of Amendment 13 to CPS FMP:
*OFL = BIOMASS * FMSY * DISTRIBUTION*
*ABC = BIOMASS * BUFFER(P*) * FMSY * DISTRIBUTION*
ACT= EQUAL TO HG OR ACL (_ABC), WHICHEVER VALUE IS LESS
In the current framework, a minimum cutoff (CUTOFF) biomass is "set-aside" such that fishing quotas are set on a percentage of the estimated BIOMASS (ages 1+) above the cutoff and the fishery is closed if the total population drops below CUTOFF. The current cutoff for Pacific sardine is 150,000 metric tons (MT). The percentage (FRACTION) of the remaining biomass that can be fished increases (to 15%) in warmer ocean conditions where the population is thought to be more productive and decreases (to 5%) in cooler, less favorable conditions.
DISTRIBUTION (87%) is the percentage of BIOMASS assumed to be in U.S. waters. Finally, there is a maximum catch value (MAXCAT) that cannot be exceeded regardless of how large the population becomes which prevents overcapitalization and provides a level of precaution when stock assessments are uncertain. The Pacific sardine control rule currently employs MAXCAT of 200,000 metric tons. Other targeted forage species do not have this important control in place.

The existing sardine control rule was developed using a model designed by Larry Jacobson, and I did the evaluations of model output that resulted in the original CPS Management Team's recommended harvest rule (Option J) that was accepted by the Pacific Council.

As I stated in my 11 May, 2008 letter to the CPS Advisory Subpanel and Management Team, in response to another Oceana public comment, the rationale for the CPSMTs recommended harvest control rule (HCR) was dominated by a concern for maintaining the sardine stock at population levels well above that which would occur with a single-species, MSY-based management strategy. In fact, the principal basis for the present sardine rule was to maintain a larger population of sardine, due to their importance as forage, than would occur with a MSY strategy. All four components of the control rule contributed to the balanced strategy seen in the comparison of HCR performance measures in Amendment 8 Table 4.2.5-1. I will point out again that the principal performance measure concerning the importance of the stock for forage is the mean biomass or in more modern terms the mean depletion. Mean depletion with the current HCR is predicted to be 0.64.

2. The simulation model used to establish the parameters used in the Pacific Sardine HCR was never fully documented, is therefore not transparent, and is outdated.

Unfortunately, Larry Jacobson transferred to the Northeast Fisheries Research Center shortly after the sardine harvest rule was enacted, and I was unable to secure the travel budget needed for me to travel to the east coast to organize a paper with Larry, describing the modeling work. Therefore the basis and results for the sardine harvest rule were never published. However, the simulation model itself is readily available, as Oceana acknowledged in its recent public comment letter.

The model used to develop the sardine control rule did not include distribution. This allocation feature was added to the management of sardine by others and it played no role in the decision to pick Option J as the preferred science option. **International aspects of the sardine fishery are clearly external to the HCR.** Recent total coast-wide catches from the so-called northern stock of sardine – including Mexico and Canada, which increased its harvest in the last few years – have exceed those calculated with the present control rule. Questions on stock structure further complicate management as an unknown portion of the so-called southern stock is landed in Ensenada and southern California, but for the purpose of the U.S. stock assessment, these landings are attributed to the northern stock and included in the stock assessment and harvest control rule calculations.

I note that an international effort to mount a synoptic summer survey extending into both Mexico and Canada is planned in 2012, and this effort should be fully supported by everyone interested in the Pacific sardine resource.

I also point out the results extracted from the 2011 stock assessment:

Harvest Control Rules MT
OFL = BIOMASS * *F*MSY * DISTRIBUTION 170,689
ABC0.45 = BIOMASS * BUFFER0.45 * *F*MSY * DISTRIBUTION 163,140
ABC0.40 = BIOMASS * BUFFER0.40 * *F*MSY * DISTRIBUTION 155,810
ABC0.30 = BIOMASS * BUFFER0.30 * *F*MSY * DISTRIBUTION 141,325
ABC0.20 = BIOMASS * BUFFER0.20 * *F*MSY * DISTRIBUTION 126,073
HG = (BIOMASS - CUTOFF) FRACTION *DISTRIBUTION 109,409

Note the harvest guideline produced by the HCR is more precautionary than any developed with the Council's new P* formula, predicting the probability of overfishing. As will be shown later the revised Fmsy estimate is considerably larger than the Fmsy estimate in Amendment 8; the surplus production rates since 1993 are much larger than those simulated in the assessments leading to the adoption of the current HCR, and the mean spawning stock depletion is much higher than that predicted for the current HCR.

If the current HCR is "flawed", the latest 'best available science' suggests that the flaw caused the HCR to produce annual quotas much smaller than those that would occur with the 'best available science'.

3. The HCR Uses a Temperature-Recruitment Relationship that is not based on the Best Available Science

A considerable amount of information is available since the present control rule was developed, and it is certainly time to either update the analyses or to develop a new management assessment methodology. However, I do not agree that the SST portion of the control rule has been "proven" to not be valid. The logic of adding additional warm years to a time series and then saying that the information from the warm years proves that sardine do not have depressed recruitment in cold years completely escapes me.

There had to be a reason for the fact that sardine abandoned the Pacific Northwest and Canada for three decades, and it is difficult to imagine any environmental factor other than lethal winter SST in the Pacific Northwest, and the southern displacement of the principal spawning grounds that would cause this to occur. However, whether or not the relationship between SST and reproductive success in sardine is valid, the Jacobson and MacCall (1995) and McClatchie et al (2010) spawner/recruit relationships are biased. The longer data series used by McClatachie et al. (Figure 1) is potentially more biased towards higher recruitment than the earlier study, which has a large proportion of its source data during the poor recruitment cold regime.

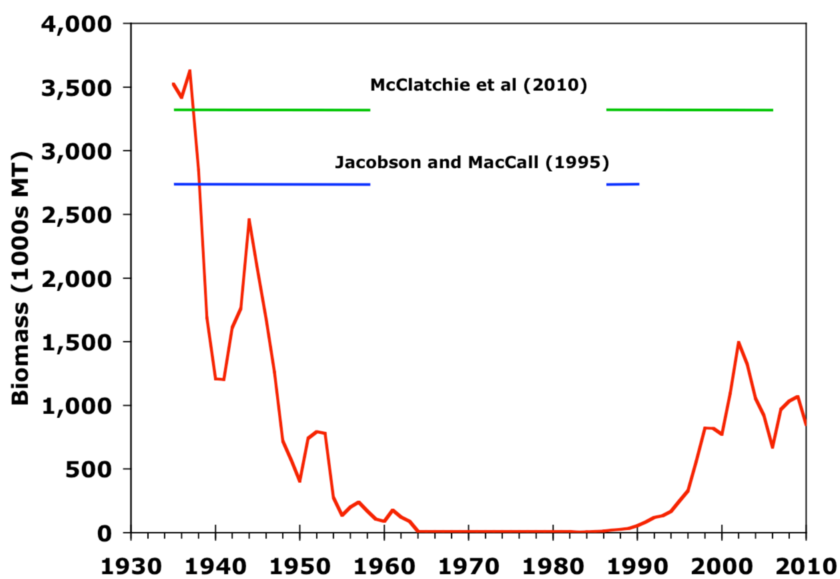

Figure 1. Time series of sardine biomass and periods included in two studies of the spawner-recruit relationship.

Although I disagree with comments that the present control rule is invalid, I strongly agree that it is time to develop a new management assessment model that includes any potential environmental relationships and that <u>also includes the full 1935-2011 time series</u> for biomass and recruitment for the northern stock of sardine.

Any re-analysis of the extremely important recruitment model should include the long series of cold-water years with extremely poor recruitment that occurred during the 1960s and early 1970s. It does not pay to ignore history.

In my opinion, the principal weakness of the analyses used to develop the present control rule is that annual fecundity in sardine is known to be heavily age/size dependent. Future analyses, including both stock assessments and harvest management analyses, should include this important life history trait, and I agree that a very high priority should be placed on developing a new and more complete assessment of the sardine control rule.

4. The DISTRIBUTION factor does not reflect current catch or stock distribution and international overfishing is occurring

I strongly agree with the need to seek international management cooperation for the sardine resource. I would also note that current coast-wide exploitation rates included in the 2011 stock assessment **do not reflect overfishing**. Moreover, it is unlikely that the Council would, or should, greatly reduce the U.S. catch in an attempt to keep the total catch from exceeding the projected coast-wide harvest level based on a 'flawed' HCR. I note that in the last three years the combined Mexican and Canadian landings exceeded the HCR values. The Mexican landings are particularly difficult to assess as they include an unknown proportion of sardines from the 'southern' sardine stock. Presently these landings are attributed to the northern stock.

The international effort to mount a synoptic summer survey extending into both Mexico and Canada is planned in 2012, and further plans to conduct a methods review to consider incorporating the Canadian swept-trawl sardine survey into future stock assessments are positive steps to better understand the coast-wide distribution of Pacific sardine.

5. The Current Management Structure Fails to Achieve Optimum Yield and
6. The Current Management Structure Fails to consider Adverse Impacts to Essential Fish Habitat for other Council-managed species.

According to the Oceana letter, the Smith et al (2011) study in Science stated *'A recent study published in the journal Science concluded that fishing at MSY levels on low trophic level species (i.e. forage species) has widespread ecological consequences in all ecosystems assessed to date.16'* (emphasis added)

In fact, the Smith et al (2011) study stated "For example harvesting anchovy had high impacts and harvesting sardine had low impacts in the northern Humboldt ecosystem, but in the southern Benguela ecosystem harvesting sardines had the larger impact, **while the impacts of fishing both species were low in the south east Australian and California Current ecosystems."**

Further the Smith study states that fishing low-trophic level species at MSY levels can have large impacts on other components of the ecosystem and they recommend that harvest levels should be set to achieve 80% of MSY **The results from the Science study are almost identical to the strategy utilized with the present sardine control rule.** For example, the yield policy with the highest average long-term yield produced an average yield of 208,000 MT (Table 4.2.3.3.1) and option L the stochastic model was 180,000 MT (Table 4.2.5-1)**.** The present harvest rule has an average yield of 145,000 MT; thus the present control rule has a harvest that is 80.6% of the stochastic MSY and only 67.7% of the maximum long-term yield.

In other words, depending upon the definition of MSY, (stochastic MSY or maximum long-term yield) the present control rule is either extremely close to the policy recommended by Smith et al (2011) or considerably more conservative than their recommendation.

A re-analysis of the spawner-recruit relationship in the context of the original sardine simulation model was carried out by Hill et al (2011 i.e. F2b SUP ATT8 2011 Pacific Sardine Assessment FINAL Draft1.pdf Appendix 4) Table 4 of this re-analysis compares the stochastic Fmsy and current sardine control rule simulations from Amendment 8 with new simulations run with a new spawner-recruit model that omits the SST relationship and is fitted to an updated time series that includes 23 more years of data than the original simulations.

This analysis shows that the sardine stock is considerably more productive than was predicted by the analyses in Amendment 8. Fmsy with the new information occurs at a FRACTION of 18% whereas the older data suggested a value of only 12%. The revised simulation using the current harvest control rule (Option J) has an average biomass more than 500,000 MT higher than that occurring with the revised Fmsy policy**. Demonstrating the robustness of the original control rule, this same difference (500,000+ MT) occurred in the simulations used in Amendment 8 (i.e. Table 4.2.5-1)**

An additional source of information concerning the recent productivity of the sardine can be derived from calculations of surplus production based the information from the 2011 sardine stock assessment (Hill et al (2011). Based on the first semester age 1+ biomass estimates and total landings in Hill et al (2011) the mean exploitation rate for the 1993-2010 period was 10.6% and the mean surplus production was 14.5% (Figure 2). **Total catch and annual surplus production show the typical pattern seen in well managed fisheries for CPS species; highly variable recruitment resulting in wide swings in the annual surplus production and quite stable annual landings that spread out the variability in the productivity of the stock (Figure 2).**

Importantly the mean production rate (14.5%) was considerably higher than the mean harvest rate (10.6%); as a result the <u>age 1+ biomass increased from 636 TMT in 1993 to 1,097 TMT.</u>

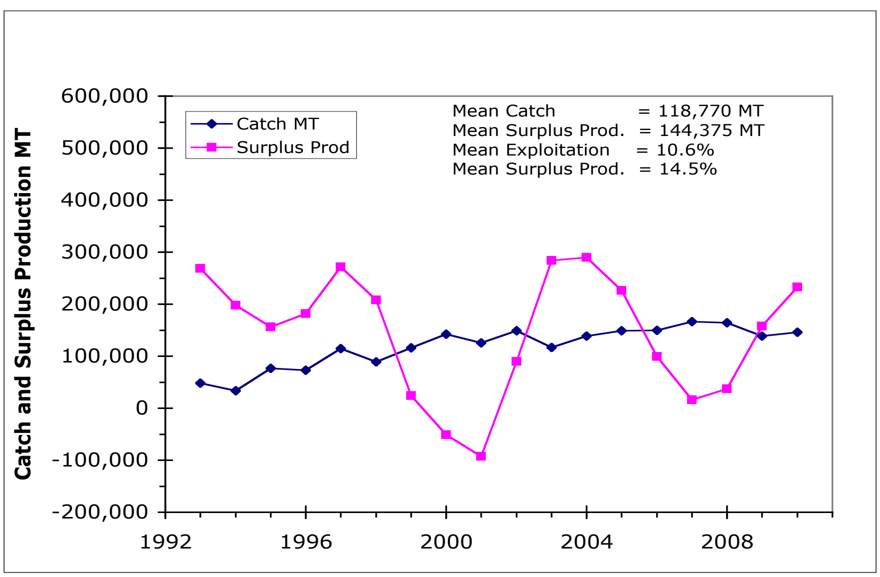

Figure 2. Sardine catch and surplus production (1993-2010 : calculated from data in Tables 2 and 11, 2011 stock assessment, Hill et al 2011).

A second test of recent management is to assess the depletions occurring in the most recent stock assessment. There were two peaks in the depletion pattern (Figure 3), each following one of the multi-year surges in surplus production (Figure 2). Average spawning stock depletion for the 1993-2011 period was 0.81 based on the stock assessments estimate of virgin spawning biomass (968,738 MT). The average depletion of age 1+ biomass predicted by the current control rule is 0.64, much less than the average 1993 to 2011 depletion. It is clear that the productivity of sardine during the recent period was considerably higher than that predicted by the original sardine simulations in Amendment 8.

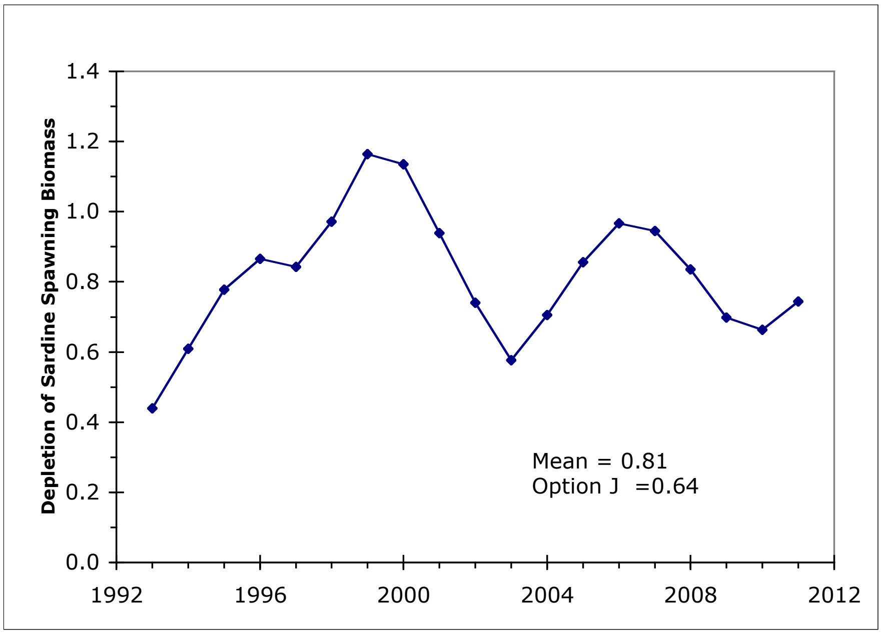

Figure 2. Depletion of Sardine Spawning Biomass,(data from Table 10. 2011 stock assessment Hill et al 2011).

7. CUTOFF Does Not Adequately Include Forage Considerations

The original documentation for the harvest control rule in CPS FMP Amendment 8, Appendix B did not contain a justification for the use of a 150,000 MT CUTOFF. Later documents explain that "The purpose of CUTOFF is to protect the stock when biomass is low" and "CUTOFF provides a buffer of spawning stock that is protected from fishing and available for use in rebuilding if a stock becomes overfished."[18] In 2008, however, Richard Parrish submitted a letter to the PFMC describing that the approach was used to determine the forage set aside. The letter explains that [t]he approach taken by the CPSMT was to use the general ecological rule that it takes ten gms. of food to produce one gm. of weight. This point occurs at an annual average catch of 147 thousand tons or an exploitation rate of 0.065. Using this approach the exploitation rate should not exceed the rate where an increase in catch results in a tenfold decrease in average biomass. In other words the set aside for forage by other species was determined by setting the exploitation rate at the level where the weight of the last mt of catch equaled the increase in biomass that would occur if the resulting ten mt. average biomass were left in the ocean.[19]

We do not agree with the logic behind this approach and have great concern that it was neither published nor adequately peer-reviewed. First, rather than identify the predator populations that consume sardines and use information on actual consumption levels or conversion ratios, the approach simply relied on a general estimate of a 10:1 conversion.

Second, this assumes that the value of the predators by weight is equal to the value of sardines by weight. This is clearly incorrect—for example, a pound of Chinook salmon is far more valuable than a pound of sardines. Furthermore, even if one accepts these assumptions, the goal of the approach was to derive a harvest rate that should not be exceeded, which according to Dr. Parrish's letter was 0.065. However, rather than setting a maximum harvest rate, the corresponding catch at an exploitation rate of 0.065 (i.e., 147,000 MT) became the CUTOFF, not the maximum harvest rate. There is therefore a serious disconnect as the analysis was used to determine a harvest rate, but was instead then used to create the CUTOFF. Since the combination of the CUTOFF and the FRACTION together determine the actual harvest rate (which generally exceeds 0.065 in the current harvest control rule), the harvest control rule actually exceeds the rate where an increase in catch results in a tenfold decrease in biomass, violating the objective of the forage set aside as described in Dr. Parrish's letter. This is of great concern as the coastwide exploitation rate has exceeded the harvest control rule every year since the HCR was implemented. Therefore, not only do the exploitation rates produced by the current HCR exceed the levels necessary to provide adequate forage, but the HCR itself is being exceeded.

I will again point out that the current harvest control rule has to be taken as a whole and the principal performance measure that predicts the effect of the HCR on the value of sardine as forage is the mean biomass level or the mean depletion.

Oceana's comments above show that they do not understand how the 10:1 conversion was used. The 147,000 MT mean catch had absolutely no relationship to the determination of the CUTOFF. The 147,000 MT mean catch became a criterion that we would not exceed and there were a large number of HCRs that would meet the criteria including some with a CUTOFF of zero. What I did was search for a policy that had approximately 147,000 MT mean catch and the highest mean biomass level that did not have significant problems with other performance measures. There were policies with catch near 147,000 MT and higher mean biomass levels than Option J but most of them tended towards a pulse fishery where the median catch was considerably lower than the mean catch. In contrast, Option J has a median catch much higher than the mean catch, a very desirable feature that is primarily caused by where you set MAXCAT.

I note that the general 10:1 trophic conversion rule produced almost exactly the same result as the strategy recently proposed by Smith et al. (2011). That is an average yield equal to 80% of MSY. Since the Oceana letter cited this report I assume they know if the 80% recommendation in this report has been peer-reviewed.

Salmon consume a very minor part of the sardine population. But if the absolute difference in commercial value is the stick we want to use to measure the trophic conversion ratio, a grander example would be bluefin tuna which are at least 10 times as valuable as salmon. I note that about 1/3 of the forage provided by the sardine stock consists of eggs, larvae and early juveniles. Zooplankton are the principal consumer of this component of the sardine forage and zooplankton have no monetary value. Marine mammals also consume considerable amounts of sardine and the last time I checked we were not harvesting marine mammals. Obviously the relative values of the different trophic levels need to be assessed in a full ecosystem model, not by picking out some particular animal as done by Oceana.

Oceana states that the sardine control rule was not peer reviewed. I note that the 10:1 conversion rate was presented by me to the full Council and was therefore available for anyone to review. Below is one such peer review from the Monterey Herald January 14, 1999.

Fishing laws may change

Environmentalists on the alert

By JUDIE MARKS
Herald Staff Writer

Changes in nationwide fishing laws to protect marine fish stocks and habitat will be complete by this summer, the National Marine Fisheries Service announced this week.

But a coalition of environmental groups is calling on Secretary of Commerce William Daley to reject some of the changes, saying stronger fishery management plans are needed.

"The administration made a pledge for sustainable fisheries at the Year of the Ocean conference (held in Monterey in June), but this is where it really counts," said Karen Garrison, senior policy analyst with the Natural Resources Defense Council.

If the Clinton administration is serious, Garrison said, "then we need to send back parts of that groundfish plan and make sure we have sustainable fisheries in practice, not just on paper."

She said the approach of the Pacific Fisheries Management Council, one of eight regional management councils around the country, has been "a lot of talk and little action. That's just not good enough."

While blasting the council for too-lenient measures in the groundfish fishery and for not completing the Pacific salmon plan, she praised proposed changes in the coastal pelagic portions of the council's plan, which cover fish such as sardines, anchovies and mackerel.

That portion of the plan, Garrison said, limits the number of boats that can enter the fishery and also allocates a part of the catch to fish, birds and marine mammals that also eat sardines, anchovies and mackerel.

"That's a pretty innovative provision that takes into account the role these fish play in the ecosystem," she said.

"Bycatch" or unintended catch, is not a problem with the sardines, anchovies and mackerel because they are not mixed in with other

Please see **Fishing page B3**

Apparently Oceana and the Natural Resources Defense Council have differing views.

Oceana has clearly stated their objections to the present control rule and many of the methods associated with its development. The very recent revision of this analysis by Hill et al 2011 should solve many of Oceana's problems associated with the current HCR. I am sure they will be happy to find that **the 'best available science' now shows that the principal problem with the current HCR is that it results in a considerable under-estimation of the productivity of the stock.**

In response to the Pew Environment Group letter, I note the Pew report suggests that a variable natural mortality rate be incorporated in the stock assessment methodology, and I agree with this suggestion. As stated above, in my opinion the principal weakness of the analyses used to develop the present control rule is that annual fecundity in sardine is known to be heavily age/size dependent. Future analyses, including both stock assessment and harvest management analyses, should include this important life history trait, and I agree that a very high priority should be placed on developing a new and more complete assessment of the sardine control rule.

It is important to investigate the full range and distribution of Pacific sardine as a high priority in the coming year, and to initiate a new management strategy evaluation and assessment model that includes any new potential environmental relationships. The assessment should include the full 1935-2011 time series for developing both spawner-recruit and environment- recruit relationships. Omitting the cold-regime period when sardine recruitment was extremely low will result in overestimates of recruitment.

The Pew report suggests a temporary 3% reduction in the FRACTION from 15% to 12%. until a new harvest rule study is made. I note that if Pew believes that the current control rule is no longer valid, the logic of proposing the 12% stochastic MSY is very poor, as the same temperature relationship was used to drive recruitment in the stochastic MSY simulation as in the simulation for the current control rule. If the present 'outdated' HCR were valid there would be merit in the Pew suggestion.

However, based on the new update of the spawner-recruit relationship that deletes the SST term and the re-analysis of stochastic Fmsy (i.e. FRACTION =18%) the PEW report's logic would suggest that FRACTION be increased from 15% to 18%.

CONCLUSION:

It would appear that the 'best available science' shows that the sardine stock is considerably more productive than the 'outdated science' in Amendment 8; it also shows that the current HCR is very conservative and very robust and I recommend that it not be changed until a complete re-analysis of the sardine management is accomplished. This reanalysis should pay particular attention to the mean depletion produced by various management strategies; however, the full suite of performance measures used in Amendment 8 should be used to achieve an optimum balance between the various factors.

Richard Parrish
Fisheries Biologist

References:

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Ryan D. Kapp
955 Colony Ct. Bellingham, WA 98229
(360)-714-0882 (360)961-6722 cell kappjr@comcast.net

October 31, 2011

Mr. Dan Wolford, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, OR 97220-1384

Re: Season start dates for the pacific sardine fishery

Mr. Chairman and Council Members,

I am writing today to ask for a change in the management measures for the pacific sardine fishery. When Amendment 11 to the CPS FMP was implemented the start dates did not seem problematic but some adjustment to these dates could improve the fishery. I am requesting that the Council consider modifying the season start dates for both the July 1^{st} and September 15^{th} fishery periods.

The basis of this request is simple: Weekends and Holidays. The July 1^{st} start is difficult because the Independence Day holiday is so close that many companies have difficulty acquiring a sufficient workforce because many who could work choose to celebrate a National holiday. Last year the container yard longshoremen took July 5^{th} off too which made shipping more difficult. Additionally, opening on a Friday or weekend makes shipping logistics difficult and more costly for processors to acquire shipping containers.

I propose moving the season start dates for the last two harvest guideline releases to the second Monday in July and the second Monday in September. Doing this would alleviate any concern over starting operations on a weekend and would also eliminate the difficulty of attempting to operate on one of our Nation's most important holidays.

I do not feel this suggestion would significantly alter the structure or prosecution of the fishery nor would it give any advantage or disadvantage to any particular user group or region. It is just a simple suggestion which would alleviate a lot of industry headache and help the fishery to operate more smoothly and predictably which would benefit all participants.

Thank you for your consideration of this matter.
Regards,

Ryan Kapp

THE PEW ENVIRONMENT GROUP

October 24, 2011

Mr. Dan Wolford, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, OR 97220-1384

RE: 2012 Conservation and Management Measures for Pacific Sardine

Dear Chair Wolford and Council Members:

Thank you for the opportunity to provide public comments regarding conservation and management measures for the 2012 Pacific sardine fishery.

In the interest of preserving a sustainable Pacific sardine fishery, maintaining healthy populations of those species that depend on Pacific sardine as forage and the overall health of the California Current ecosystem, we formally request that the Pacific Fishery Management Council (Council) take the following action:

1) Initiate a Management Strategy Evaluation to revise the flawed parameters in the harvest control rule for Pacific sardine.
2) Re-evaluate and revise the assumption of a constant natural mortality rate in the stock assessment methodology for Pacific sardine, as recommended by the Council's Scientific and Statistical Committee.
3) Explicitly list and incorporate relevant social, economic and ecological factors into the annual specifications process for the Coastal Pelagic Species Fishery Management Plan (CPS FMP).

Taking this action will bring the fishery into compliance with the Magnuson-Stevens Fishery Conservation and Management Act (MSA) and National Standard 1 (NS1) Guidelines, and will help to ensure a healthy ecosystem able to support valuable west coast fisheries and coastal economies.

During the 2011 Pacific sardine management cycle, the Pew Environment Group offered public comment to express concerns regarding the harvest control rule used to determine the annual harvest guideline.[1] We have also submitted public comment on Amendment 13 to the CPS FMP to establish science based annual catch limits (ACLs) intended to prevent overfishing while achieving optimum yield from the fishery.[2] For the 2012 management cycle, we further wish to register our concern regarding the assumption of natural mortality in the stock assessment methodology for Pacific sardine. These concerns and our corresponding requests are summarized below.

Harvest Control Rule

There are four parameters in the harvest control rule for Pacific sardine that is used to determine the annual harvest guideline for the fishery: BIOMASS, CUTOFF, FRACTION and DISTRIBUTION. While BIOMASS is determined through the annual stock assessment and update process, the CUTOFF, FRACTION and DISTRIBUTION parameters are either fixed or fixed within a range as the result of a policy determination made by the Council with advice from the relevant advisory bodies and the Council's Science and Statistical Committee (SSC). Our primary concerns with each of these parameters are described below.

<u>Define a CUTOFF Parameter That Provides Sufficient Forage and Rebuilding Stock</u>

In the harvest control rule for actively managed coastal pelagic species, the CUTOFF parameter is the biomass level below which direct harvest is not permitted. Should overfishing occur, CUTOFF is intended to set aside a buffer of spawning stock that is protected from fishing and available for use in rebuilding if the stock becomes overfished.[3] For Pacific sardine, the CUTOFF value is fixed at 150,000 metric tons (mt) and is subtracted off the top from the overall biomass available to the fishery. Accordingly, harvest levels determined by the rule will decline as overall biomass declines until it reaches the CUTOFF, at which point the harvest guideline would be zero.

There is a lack of transparency regarding how the CUTOFF value was derived and what its purpose is within the harvest control rule. For Pacific sardine, CUTOFF is set at three times the Minimum Stock Size Threshold (MSST) of 50,000 mt. According to the NS1 guidelines, MSST is defined as the greater of ½ B_{MSY} or the minimum stock size at which rebuilding to the Maximum Sustainable Yield (MSY) level would be expected to occur in 10 years if the stock was fished at the Maximum Fishing Mortality Threshold (MFMT).

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[1] See Pew Public Comment Letter Regarding 2011 Harvest Guideline for Pacific Sardine. (RIN 0648-XA109) Available at http://www.pewenvironment.org/campaigns/pacific-fish-conservation-campaign/id/85899360413/resources/

[2] See Pew Public Comment letter to the National Marine Fisheries Service on Amendment 13 to the Coastal Pelagic Species Fishery Management Plan. Available at http://www.pewenvironment.org/campaigns/pacific-fish-conservation-campaign/id/85899360413/resources/

[3] PFMC. Amendment 13 to the Coastal Pelagic Species FMP, Draft Environmental Assessment. Page 23.

This approach to defining MSST and therefore CUTOFF is problematic for two reasons. First, the National Marine Fisheries Service (NMFS) maintains that B_{MSY} is not used as a MSY reference point for Pacific sardine due to its cyclical nature of abundance.[4] This means that managers are left to define MSST according to the second option articulated in the NS1 guidelines – the minimum stock size at which rebuilding to the MSY level would be expected to occur in 10 years if the stock was fished at the MFMT. According to Amendment 13 to the CPS FMP, MFMT for Pacific sardine is not a fixed value (as is MSST and CUTOFF), but is defined as catch exceeding the Allowable Biological Catch (ABC), determined annually by the ABC control rule.[5] This should make establishing a value for MSST and CUTOFF an annual exercise. We therefore question why MSST is set at a fixed value of 50,000 mt and whether that is an adequate threshold for determining if the stock is overfished.

The Council should eliminate this confusion regarding how CUTOFF is defined and its purpose within the context of the harvest control rule. If CUTOFF is intended to provide a "forage set aside" as has been claimed by some observers including one of the authors of the harvest control rule,[6] we request that the Council transparently define a variable that both adequately accounts for rebuilding needs and provides sufficient forage for other marine species in the ecosystem by maintaining Pacific sardine's relative contribution to the California Current forage base. We believe this can be done most effectively through a Management Strategy Evaluation for the harvest control rule and an annual specifications process that properly incorporates ecological considerations.

<u>Revise FRACTION Parameter According to Stochastic F_{MSY} of 12%</u>

The FRACTION parameter in the harvest control rule is a proxy for F_{MSY}.[7] This parameter specifies the amount of Pacific sardine available to the fishery when BIOMASS exceeds CUTOFF and is based on average sea-surface temperature at the Scripps Pier in La Jolla, CA. A scientific study was conducted in 2010 to re-evaluate the stock-recruit and temperature-recruit relationships that are used to determine FRACTION.[8] This study shows that the sea-surface temperature data collected at Scripps Institute of Oceanography Pier is an unreliable predictor of sardine recruitment success. Despite this new information, the current harvest control rule continues to utilize this proxy to determine the harvest rate. Furthermore, whereas the Council established a range in harvest rate (FRACTION) of 5% - 15%, the chosen rate for the U.S. fishery

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[4] See Response to Public Comments. Federal Register, May 25, 2011. Vol. 76, No. 101. Final rule: Fisheries Off West Coast; Coastal Pelagic Species Fisheries, Annual Specifications. (RIN 0648-XA109)
[5] PFMC. Amendment 13 to the Coastal Pelagic Species FMP, Draft Environmental Assessment. Page 22.
[6] PFMC Agenda Item G1d. Public Comment. June 2008.
[7] PFMC. Amendment 13 to the Coastal Pelagic Species FMP, Draft Environmental Assessment.
[8] McClatchie, S., Goericke, R., Auad, G., and Hill, K. 2010. Re-assessment of the Stock-Recruit and Temperature-Recruit Relationships for Pacific Sardine (Sardinops sagax). 2010. Canadian Journal of Fisheries and Aquatic Sciences 67:1782-1790.

has been set at 15% since implementation of the harvest control rule began in 2000 due to relatively warm temperatures.

While an accurate and reliable replacement for this recruitment proxy may not be readily available, we believe that the National Marine Fisheries Service (NMFS) is making progress toward this end and has the tools it needs to further understand Pacific sardine recruitment. In particular, we are aware of recent studies looking at the effects of zooplankton abundance as well as mesoscale features on the spawning and recruitment variability of Pacific sardine.[9] We encourage continued focus on this effort. However, until the harvest control rule is corrected with an F_{MSY} proxy that accurately reflects recruitment success, we believe NMFS should act with more precaution than it currently has in determining harvest guidelines by setting a maximum harvest rate of 12%, which was determined to be the F_{MSY} (stochastic) through the analysis in Amendment 8 to the CPS FMP.[10]

Revise DISTRIBUTION Parameter to Accurately Reflect Actual Distribution of Pacific Sardine

The current Pacific sardine harvest control rule sets the portion of the fishery available in U.S. waters at 87%, implying that 13% is available in Mexican and Canadian waters. There is also broad agreement that this DISTRIBUTION parameter is inaccurate as recent catch history from Mexico and Canada show catch levels exceeding 13% of the total harvest guideline by a factor of four. In fact, landings data show that total coast-wide landings exceeded the total overfishing level in 2009.[11]

We request that the Council and NMFS revise this variable of the Pacific sardine harvest control rule to accurately reflect actual distribution within the fishery. We also encourage the Council, NMFS and the U.S. State Department to continue to explore avenues that will expand cooperation with Canada and Mexico on scientific research and coordinated international management of the fishery to prevent overfishing and provide sufficient forage in the ecosystem.

The current lack of coordinated transboundary management for Pacific sardine jeopardizes the long term health of the stock. Regardless of how precautionary an approach is being taken in U.S. waters, our efforts to maintain an ecologically sustainable fishery will be for naught if total exploitation rates for Pacific sardine continue to rise, as is currently the trend.

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[9] McClatchie, S. February 2011. Presentation on temperature-recruit relationship for Pacific sardine. Coastal Pelagic Species Management Team meeting. La Jolla, CA.
[10] PFMC. CPS FMP, Amendment 8, Appendix B, p. B-94. December 1998.
[11] Hill et al. 2010. Assessment of the Pacific sardine resource in 2010 for U.S. management in 2011. NOAA National Marine Fisheries Service Southwest Fisheries Science Center. Pacific Fishery Management Council. Agenda Item I.2.b Attachment 2. p. 7

Re-evaluate Assumption of Constant Natural Mortality in Stock Assessment Methodology

Annual stock assessments and updates for Pacific sardine are conducted out of the National Marine Fisheries Service's Southwest Fisheries Science Center. The current Stock Synthesis model used to determine biomass incorporates data from several different surveys conducted within the California Current ecosystem to arrive at a statistically defensible estimate of the total harvestable biomass of Pacific Sardine. In order to conduct this assessment, several assumptions are made regarding the life history and strategy for the species. One of these assumptions is the natural mortality rate (M) experienced by Pacific sardine, which for assessment purposes is constant and set at 0.4 yr-1, meaning that 33% of the Pacific sardine stock would die of natural causes, including predation, each year if there were no fishery.[12]

We are concerned with the assumption of a constant natural mortality rate of 0.4 yr-1 for all ages and all years. This assumption disregards studies finding that natural mortality due to predation is not only ontogenetically variable but also temporally variable, and especially for forage species, generally higher than assumed in traditional single species stock assessments.[13] Tyrrell et al. demonstrate that biological reference points generated by explicitly incorporating predation mortality into population dynamic models are generally more conservative (e.g., recommend higher standing biomass) than those produced using traditional assessment methods.[14]

Our concern over the assumed natural mortality rate utilized in the stock assessment methodology is also shared by the SSC. In its review of the 2010 Pacific sardine assessment, the SSC recommended an examination of this assumption and its appropriateness for use in the 2011 assessment.[15] Despite this recommendation, the assumption remains a fixed parameter in the Stock Synthesis model. As the Council endeavors to incorporate ecosystem science into the management of fisheries, the assumption of a constant natural mortality rate for critical forage species like Pacific sardine must be adapted to better account for predation mortality.

Explicitly Incorporate All Relevant Factors in the Determination of Optimum Yield

The MSA mandates that Fishery Management Plans (FMPs) seek to achieve Optimum Yield (OY) in order to provide the greatest overall benefit to the Nation, particularly with respect to food

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[12] Hill et al. 2008. Assessment of the Pacific sardine resource in 2008 for U.S. management in 2009. NOAA National Marine Fisheries Service, Southwest Fisheries Science Center.

[13] Dickey-Collas, M., R.D.M Nash, T. Brunel, C.J.G. van Damme, C.T. Marshall, , M. R. Payne, A. Corten, A.J. Geffen, M.A. Peck, E.M.C. Hatfield, N.T. Hintzen, K. Enberg, L.T. Kell and E. Simmonds. 2010. Lessons learned from stock collapse and recovery of North Sea herring: a review. *ICES Journal of Marine Science* 67: 1875–1886.

[14] Tyrrell, M.C., J.S. Link and H. Moustahfid. 2011. The importance of including predation in fish population models: Implications for biological reference points. *Fisheries Research* 108:1-8.

[15] Scientific and Statistical Committee Report on Pacific sardine stock assessment and coastal pelagic species management measures for 2011. PFMC Agenda ItemI.2.c. November 2010.

production, recreational opportunities and protecting marine ecosystems.[16] Under the MSA, OY is defined as MSY reduced by relevant social, economic and ecological factors.[17] The incorporation of economic and ecological factors into the determination of catch levels is thus a requirement of FMPs.[18] Moreover, the benefits of ecosystem protection required include "maintaining adequate forage for all components of the ecosystem."[19] The revised NS1 guidelines go even further by directing that in FMPs, "consideration should be given to managing forage stocks for higher biomass than B_{MSY} to enhance and protect the marine ecosystem."[20] Despite this clear mandate and specific guidelines, the CPS FMP does not explicitly incorporate any consideration of ecological factors, and the consideration of economic factors ignores the value of Pacific sardine as forage to commercially and recreationally important species.

We believe that there are practical ways to incorporate ecological and economic factors into the management of Pacific sardine and we look forward to working with the Council and relevant advisory bodies on this issue. Section 4.82 of the CPS FMP lists the various factors currently considered in making annual specifications and provides an ideal vehicle for explicitly listing economic and ecological factors.

Ecological considerations under this section should include among others: the relative contribution of each CPS (in this case Pacific sardine) to the diets of key predators in response to population trends and ocean conditions, identification of oceanographic features that correlate with high relative densities of CPS and their predators, and the results of modeling analyses to identify the potential ecological effects of alternative harvest strategies.

If managers are to maximize the economic benefit to our nation, economic considerations for Pacific sardine should include recent studies evaluating the relative economic value of forage species as forage for commercially and recreationally important marine species.[21] For Pacific sardine, Hanneson and Herrick find that the value of commercially caught predators and the efficiency by which they convert sardines to exploitable biomass were the most important factors in determining the viability of the sardine fishery.[22] Economic and social OY adjustments should also be carefully designed so that they do not overlook the possible negative impacts of forage fish depletion on commercial and recreational fisheries for marine predators in higher-trophic levels.

[16] 16 U.S.C. 1851 § 301(a)(1)
[17] 16 U.S.C. 1802 § 3(33)(B).
[18] 50 C.F.R. § 600.310(e)(3)(iv)(C).
[19] 50 C.F.R. § 600.310(e)(3)(iii)(C).
[20] 50 C.F.R. § 600.310(e)(3)(iv)(C).
[21] Hannesson, R., & Herrick JR, S. (2010). The value of Pacific sardine as forage fish. *Marine Policy*, *34*(5), 935-942. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0308597X10000254
[22] *Ibid.*

In light of the special emphasis on OY considerations for forage stocks, and the fact that the CPS plan manages forage species, the omission of relevant ecological and economic considerations is problematic. Recently published scientific findings show that directed fishing on lower-trophic level species can have significant negative effects on the ecosystem, as well as other valuable commercial fisheries.[23] Because of the important role these species play in the marine ecosystem by transferring production from plankton to larger predators, removing them in large quantities from the ecosystem has disproportionate effects up and down the food web. Smith et al report that even reducing the population of important forage species by a small amount (i.e., biomass reduced by a quarter, to 75% of the biomass without fishing, B_0) can have severe impacts on some predator populations, resulting in biomass declines of 60% or more for the predator.

Amendment 13 to the CPS FMP acknowledges the requirement to incorporate OY considerations through the addition of language explaining that the Council will consider ecological factors in specifying Status Determination Criteria, ACLs, and Annual Catch Targets for CPS species.[24] Amendment 13 also states that "the Council did not provide explicit guidance on the application of this provision," therefore it will only be implemented through subsequent actions (e.g. annual specifications).[25] This is not an adequate justification for the decision to defer consideration of ecological factors to subsequent specifications packages, as outlined in the proposed changes to the FMP.[26] We also note that "explicit guidance" on consideration of ecological factors, while not provided by the Council, is outlined in great detail in the NS1 Guidelines.

Conclusion

Pacific sardine is a critical forage species in the California Current ecosystem, preyed upon throughout its life cycle by a wide variety of commercially and recreationally valuable fish, domestic and migratory seabirds and marine mammals. Several of the species that depend on Pacific sardine as an important source of life sustaining protein are listed under the Endangered Species Act and are currently being managed under recovery plans.[27] Pacific sardine also supports a major commercial fishery on the west coast that has averaged ~85,600 mt with an

[23] Smith et al. 2011. Impacts of Fishing Low-Trophic Level Species on Marine Ecosystems. *Science*. www.sciencemag.org July 21, 2011.
[24] PFMC, Amendment 13 to the Coastal Pelagic Species FMP, Draft Environmental Assessment, at 9
[25] Ibid, at 27
[26] PFMC, Coastal Pelagic Species Fishery Management Plan, as Amended Through Amendment 13, Proposed Draft, January 2011 at A-45
[27] For a detailed list of threatened and endangered Pacific salmon species, see http://www.nwr.noaa.gov/ESA-Salmon-Listings/upload/1-pgr-8-11.pdf

ex-vessel value of $11,879,000 over the past 10 years.[28] As the Council sets conservation and management measures for the commercial harvest of Pacific sardine, it is essential that enough Pacific sardine is left in the ocean to maintain the ecological role they play in the California Current ecosystem to support sustainable fisheries, a productive ecosystem and strong coastal communities.

The Pew Environment Group has previously expressed concern regarding the management of forage fisheries on the west coast, including the Pacific sardine harvest control rule and Amendment 13 to the CPS FMP. We have also included in these comments our concern regarding the assumption of natural mortality used in the stock assessment. These concerns remain, and the Pacific sardine fishery continues to be managed according to the status quo. For these reasons, we request that the Council take immediate action to initiate a Management Strategy Evaluation to revise the harvest control rule, revise the assumption of a constant natural mortality rate, and explicitly incorporate the consideration of all relevant social, economic and ecological considerations in making annual specifications.

We look forward to working with the Council and all stakeholders to maintain healthy oceans and sustainable fisheries.

Sincerely,

Steve Marx
Pew Environment Group

[28] Pacific Fishery Management Council. Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches. Stock Assessment and Fishery Evaluation. June 2011

Agenda Item F.2.d
Supplemental Public Comment PowerPoint
November 2011

Comments Pacific Sardine Management in 2012

Geoff Shester, Ph.D.

11-4-11

OCEANA

Temperature-Recruit Relationship

- *“We demonstrate that the environmental proxy derived from SIO pier temperature … no longer predicts recruitment of Pacific sardine, and should be removed from sardine management.”*
  - McClatchie et al. 2010.
- “*The SIO index … is no longer correlated with sardine productivity*”
  - SSC Statement
- “*The temperature relationship underlying FRACTION in the harvest control rule needs to be revised*”
  - CPSMT Statement

DISTRIBUTION

From CPS FMP Amendment 8:

Estimates of the average distribution of CPS between the U.S. and Mexico based fish spotter data for 1964 through 1992 are given below. Fish spotters seldom enter Mexican waters during the winter and spring when CPS are most abundant in southern areas and search effort in Mexican waters has been limited in recent years. Portions in the table are, therefore, best thought of as summer-fall estimates.

Fish Spotter (Summer-Fall) Distribution

Species	United States	Mexico
Pacific (Chub) Mackerel	84%	16%
Jack Mackerel	75%	25%
Pacific Sardine	87%	13%
Northern Anchovy	98%	02%

Pacific sardine catches in 2010 as % of total (From Draft 2011 Assessment)

United States	Mexico	Canada
46%	39%	15%

International Management

- Mexican and Canadian catch undermine objectives of control rule and ability to achieve OY, and risk coastwide overfishing

- Council should ask NMFS to engage with US State Department to pursue international management agreement
  - (e.g., tunas, whiting)

Bryde's whale inhales a mouthful of Pacific sardine

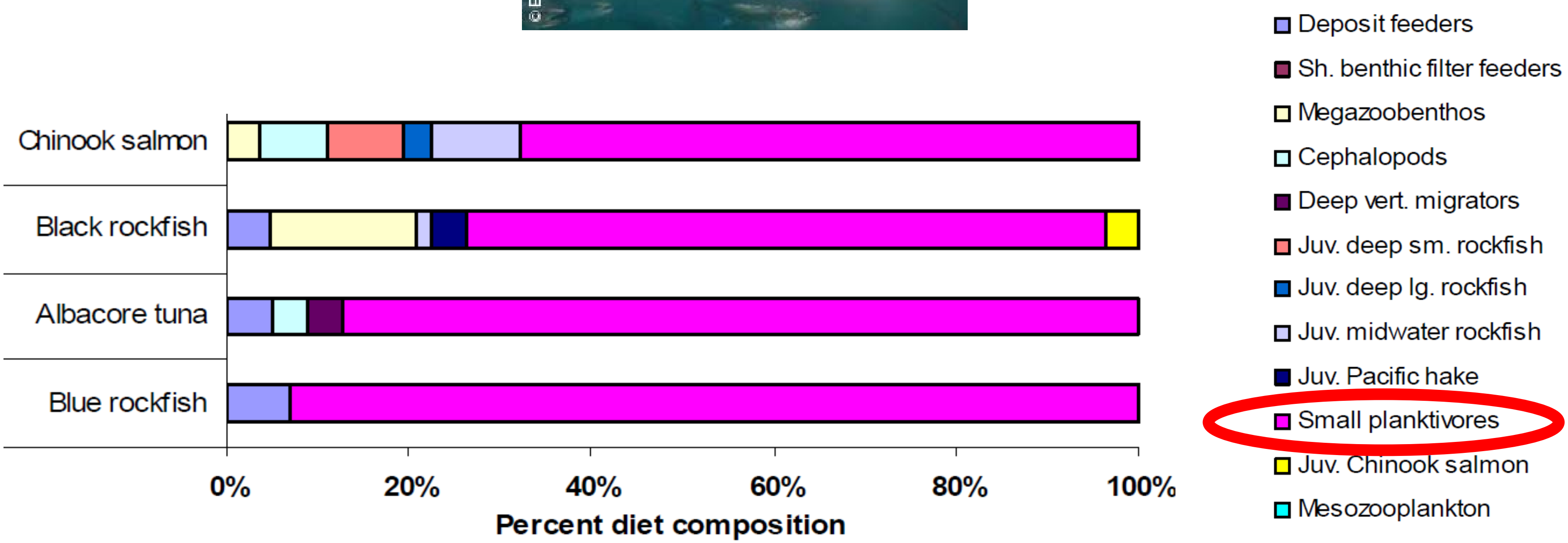
A Synthesis of Diets and Trophic Overlap of Marine Species in the California Current

Table C-51. Diet composition by weight for yelloweye rockfish, a member of feeding guild H in Figure 11.

Prey	Percent
Small planktivores	0.3273
Deposit feeders	0.1913
Miscellaneous nearshore fish	0.1450
Small flatfish	0.1267
Benthic herbivorous grazers	0.0900
Juv. midwater rockfish	0.0508
Midwater rockfish	0.0382
Juv. shallow large rockfish	0.0077
Cephalopods	0.0066
Juv. shallow small rockfish	0.0060
Shallow large rockfish	0.0058
Shallow small rockfish	0.0045
Large zooplankton	0.0001

Small Planktivores:

1. Pacific sardine
2. Northern anchovy
3. Pacific herring



CUTOFF

- Important safeguard when sardine abundance declines; higher cutoffs mean fewer years of low biomass

- Post-hoc “forage set-aside” justifications are flawed
  - No analysis of sardine predators, their consumption of sardines, or their economic value
  - No assessment of whether 150,000 MT cutoff ensures adequate forage

Summary

- Temp-Fmsy relationship used in the sardine HCR calculations is not best available science
- The current HG is still based on the Amendment 8 analysis
- Forage is not clearly accounted for
- There is major uncertainty in Fmsy, yet this is not reflected in σ
- Use of an 87% distribution without an international agreement results in chronically exceeding the HCR

Request Council Set Low P* for 2012

- Recognized flaws with current HG parameters
- Updated Fmsy is be “strictly interim” (SSC)
  - Uncertainty in Fmsy not accounted for
- “Substantial uncertainty” in 2011 stock assessment (SSC)
- Importance of Pacific sardines as forage in CCLME

Set more conservative ACL

Smith et al. 2011 Recommendations	½ Fmsy	Btarget = B75%
Amend 8 Original	6%	~2,300 TMT
Amend 8 Revised	9%	~1,700 TMT

Workshop Objectives

1. Update/document the Amendment 8 simulation model

2. Remove temperature relationship from HCR

3. Re-evaluate CUTOFF to provide adequate forage (make forage considerations explicit and transparent)

4. Re-evaluate DISTRIBUTION

5. Evaluate a range of harvest control rules