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

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NOAA-TM-NMFS-SWFSC-469

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

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ACRONYMS, ABBREVIATIONS. AND DEFINITIONS

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

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

EXECUTIVE SUMMARY

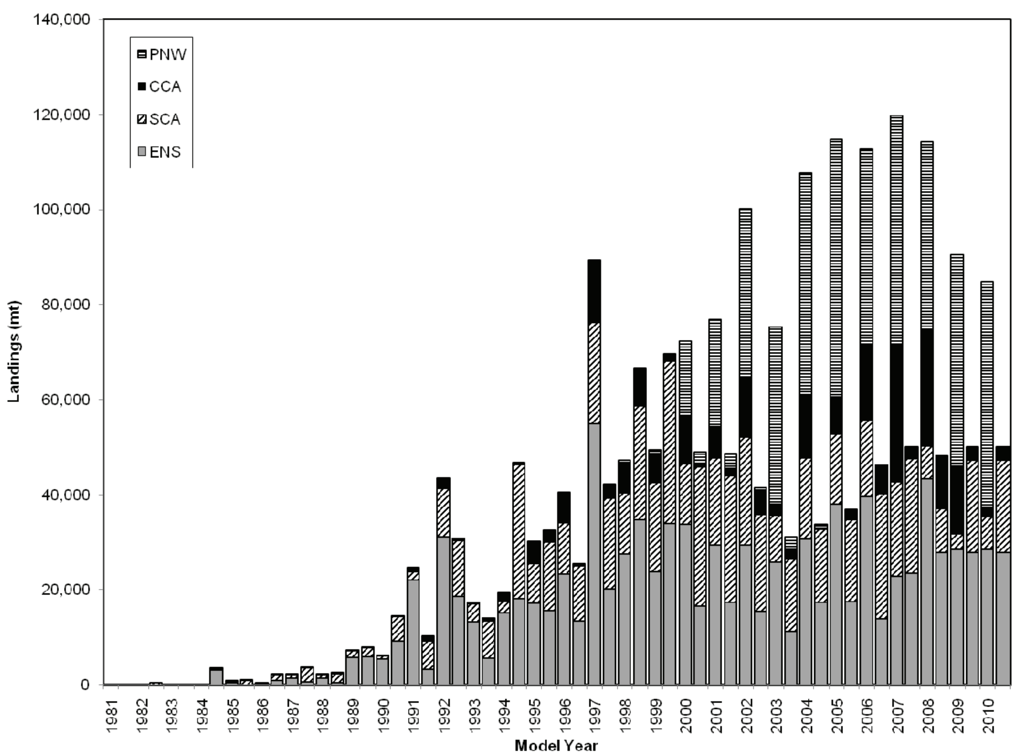
Stock

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

Catches

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

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



Data and assessment

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

Stock biomass and recruitment

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

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

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

Exploitation status

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

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

Management performance

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

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

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

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

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

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

INTRODUCTION

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

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

ASSESSMENT

Fishery Data

Overview

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

Updated Landings

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

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

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

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

Updated Length and Conditional Age-at-Length Compositions

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

Fishery-Independent Data

Overview

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

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

Updated Daily Egg Production Method Survey

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

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

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

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

Updated Aerial Sardine Survey

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

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

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

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

Model Description

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

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

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

Update Model '10w' Results

Growth

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

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

Selectivity estimates and fits to fishery composition data

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

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

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

Fits to DEPM and TEP Survey Indices

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

Fit to Aerial Survey Index

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

Harvest and exploitation rates

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

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

Spawning stock biomass

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

Recruitment

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

Stock biomass (ages 1+) for PFMC management

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

Stock-recruitment

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

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

Uncertainty, Sensitivity, and Unresolved Issues

Retrospective analysis

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

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

Sensitivity to revision of 2009 aerial estimate

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

Sensitivity to addition of 2010 aerial survey estimates

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

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

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

Uncertainty regarding aerial survey selectivity assumptions

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

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

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

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

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

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

HARVEST SPECIFICATIONS FOR 2011

Harvest Guideline

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

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

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

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

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

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

OFL, ABC, and ACL

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 incorporated in Amendment 13 to the CPS-FMP.

The estimated biomass of 537,173 (ages 1+, mt), an F_{MSY} of 0.1985 based on a relationship between temperature and F_{MSY}, and an estimated distribution of 87% of the stock in U.S. waters lead to an OFL (U.S. only) for 2011 of 92,767 mt. 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. During SSC review of this assessment update, it was determined that the model CV for the terminal year biomass was equal to 0.31; 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 determined by the Council (P*). Uncertainty buffers and ABCs associated with a range of discreet P* values are presented in Table 11.

At their November 2010 meeting, the Council adopted this assessment update and the stock biomass estimate of 537,173 metric tons (mt). For the 2011 Pacific sardine fishery, the Council adopted an Overfishing Limit (OFL) of 92,767 mt, a P* value of 0.40, and a corresponding Acceptable Biological Catch (ABC) of 84,681 mt. The Council set an Annual Catch Limit (ACL) equal to the ABC of 84,681 mt, and adopted a harvest guideline of 50,526 mt.

LITERATURE CITED

CONAPESCA. 2010. Anuario Estadístico de Acuacultura y Pesca. http://www.conapesca.sagarpa.gob.mx/wb/cona/cona_anuario_estadistico_de_pesca

Hill, K. T., N. C. H. Lo, P. R. Crone, B. J. Macewicz, and R. Felix-Uraga. 2009a. Assessment of the Pacific sardine resource in 2009 for USA management in 2010. Pacific Fishery Management Council, Nov 2009 Briefing Book, Agenda Item I.1.b. Attachment 2. 241 p. http://www.pcouncil.org/wp-content/uploads/bb_2009_11_I1b_ATT2_1109.pdf

Hill, K. T., N. C. H. Lo, P. R. Crone, B. J. Macewicz, and R. Felix-Uraga. 2009b. Assessment of the Pacific sardine resource in 2009 for USA management in 2010. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-452. 182 p. http://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-452.pdf

Jagielo, T., D. Hanan, and R. Howe. 2009. West coast aerial sardine survey: sampling results in 2009. PFMC, November 2009 Briefing Book, Agenda Item I.1.b., Attachment 1. 319 p. http://www.pcouncil.org/wp-content/uploads/bb_2009_11_I1b_ATT1_1109.pdf

Jagielo, T., D. Hanan, R. Howe, and M. Mikesell. 2010. West coast aerial sardine survey: sampling results in 2010. PFMC, November 2010 Briefing Book, Agenda Item I.2.b.

Lo, N. C. H., B. J. Macewicz, and D. A. Griffith. 2009. Spawning biomass of Pacific sardine (*Sardinops sagax*) off California in 2009. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-449. 31 pp. http://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-449.pdf

Methot, R. 2009. User manual for Stock Synthesis. Model version 3.03a. May 11, 2009. NOAA Fisheries, Seattle, WA. 143 p. http://nft.nefsc.noaa.gov/nft/SS3.html

PFMC. 1998. Amendment 8 (to the northern anchovy fishery management plan) incorporating a name change to: the coastal pelagic species fishery management plan. Pacific Fishery Management Council, Portland, OR. http://www.pcouncil.org/wp-content/uploads/a8fmp.pdf

PFMC. 2010. Measures for integrating new provisions of the Magnuson-Stevens Fishery Conservation and Management Act and National Standard 1 Guidelines into coastal pelagic species management. Amendment 13 to the Coastal Pelagic Species Fishery Management Plan. Partial Draft Environmental Assessment. Pacific Fishery Management Council, Portland, Oregon. June 2010 Briefing Book. Agenda Item F.2.a, Attachment 1. 51 p. http://www.pcouncil.org/wp-content/uploads/F2a_ATT1_DRAFT_EA_JUNE2010BB.pdf

Stock Assessment Review (STAR) Panel. 2009. Pacific sardine STAR panel meeting report. André Punt (chair) and members Selina Heppell, Dvora Hart, and John Wheeler. NOAA Fisheries, Southwest Fisheries Science Center, La Jolla CA, September 21-25, 2009. 27 p. http://www.pcouncil.org/wp-content/uploads/bb_2009_11_I1c_STAR_1109.pdf

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

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

\1 U.S. landings are from the PacFIN database. U.S. landings for 2010 are incomplete. British Columbia landings were provided by the Canada Department of Fisheries and Oceans. Mexican landings for 2009 were presented by INP scientists during the MEXUS-Pacifico stock assessment workshop in Ensenada, Mexico (Feb 24-26, 2010).
\2 Gulf of California catch statistics are compiled by an Oct-Sep fishing season, e.g. the 2008 value represents landings between Oct. 2007 and Sep. 2008.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

[a] 1994-2001 estimates were calculated using $F_b = -10858 + 439.53\ W_{of}$ (Macewicz et al. 1996), 2004 used $F_b = 356.46W_{of}$. (Lo and Macewicz 2004), 2005 used $F_b = -6085 + 376.28\ W_{of}$ (Lo and Macewicz 2006), 2006 used $F_b = -396 + 293.39\ W_{of}$ (Lo et al. 2007a); 2007 used $F_b = 279.23W_{of}$ (Lo et al. 2007b), 2008 used $F_b = 305.14W_{of}$ (Lo et al. 2008), 2009 used $F_b = -4598 + 326.78W_{of} + e$ (Lo et al. 2009).

[b] Mature females include females that are active and those that are postbreeding (incapable of further spawning this season).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

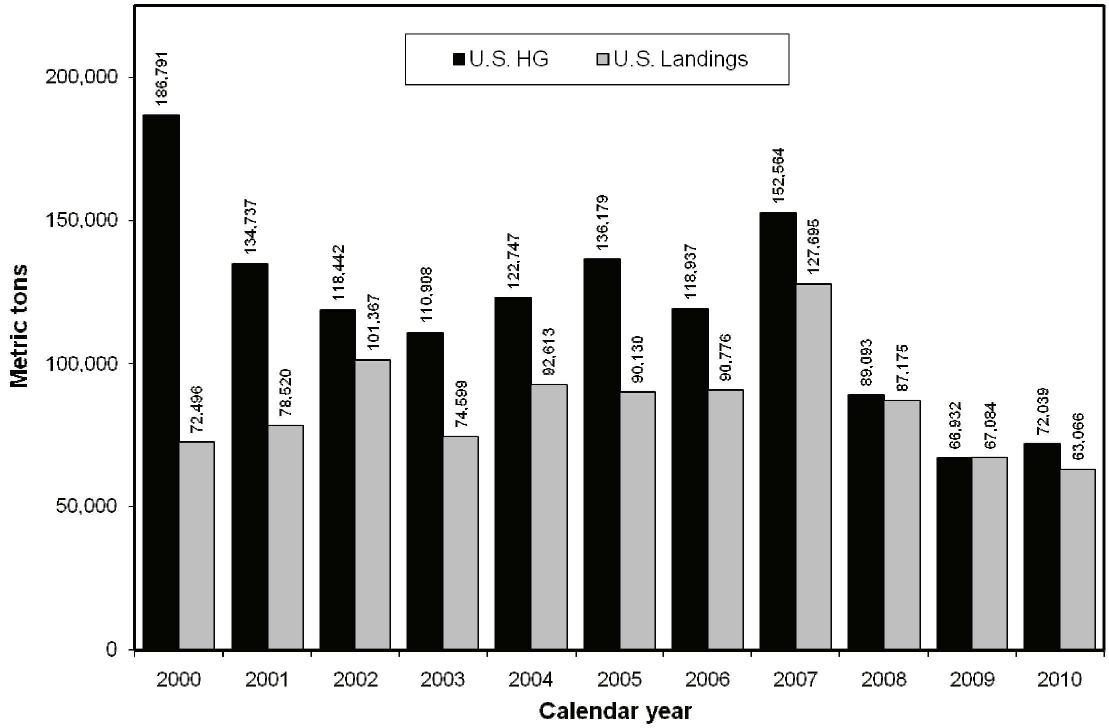


Figure 1a. U.S. harvest guidelines and landings since calendar year 2000.

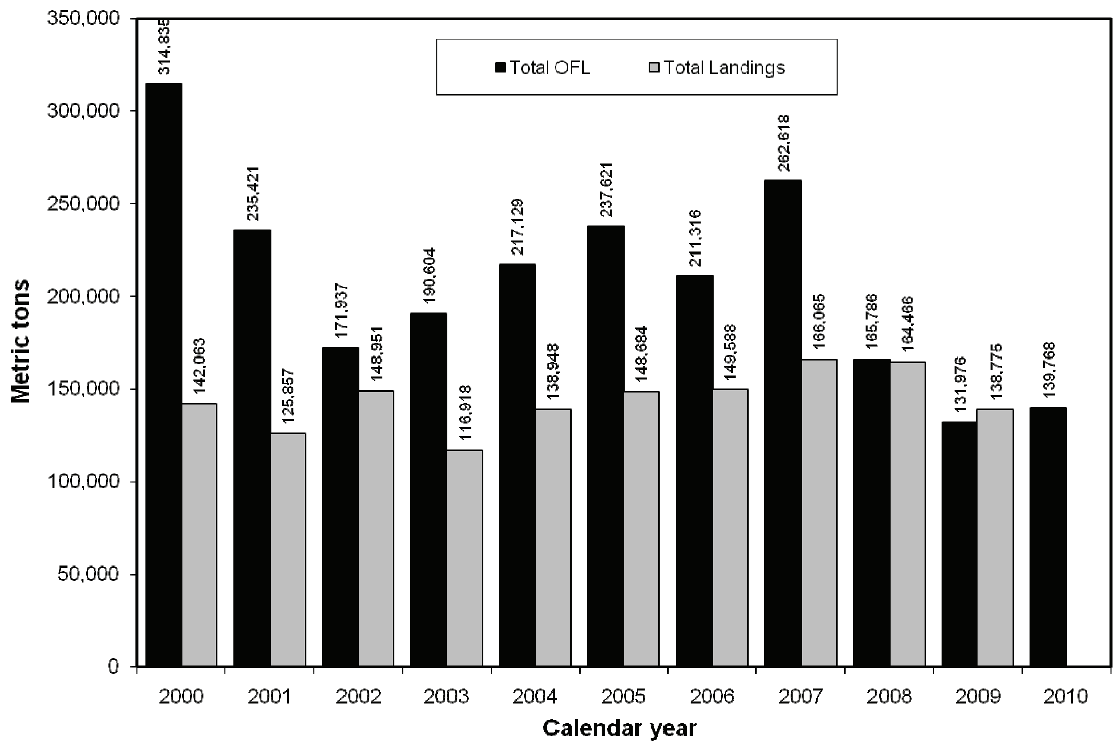


Figure 1b. Coast-wide OFLs and landings (Ensenada to British Columbia) since 2000.

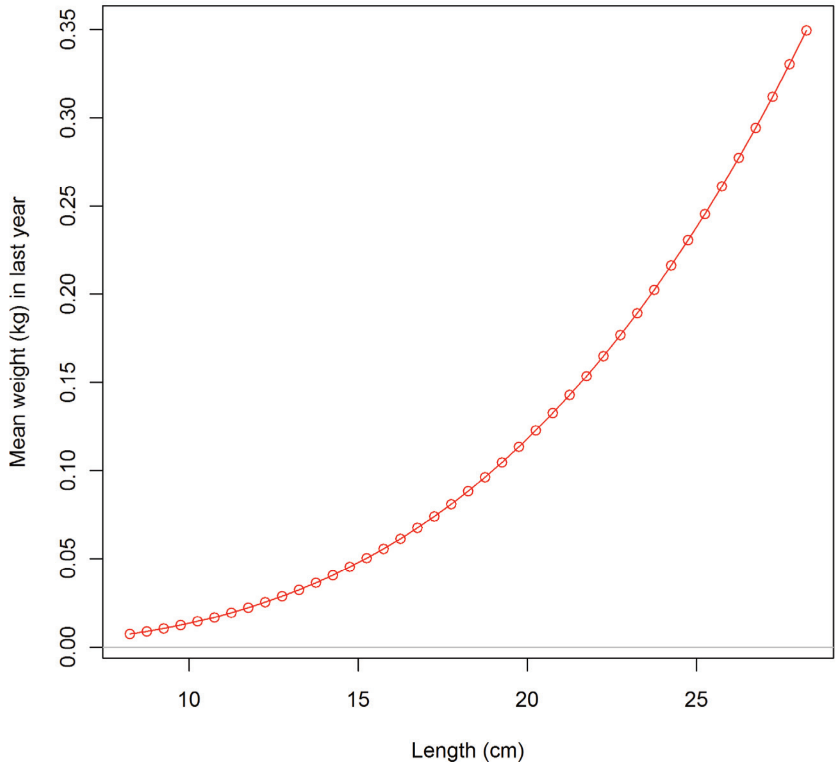


Figure 2a. Weight-at-length as applied in the base model (a = 9.47212e-06, b = 3.14752).

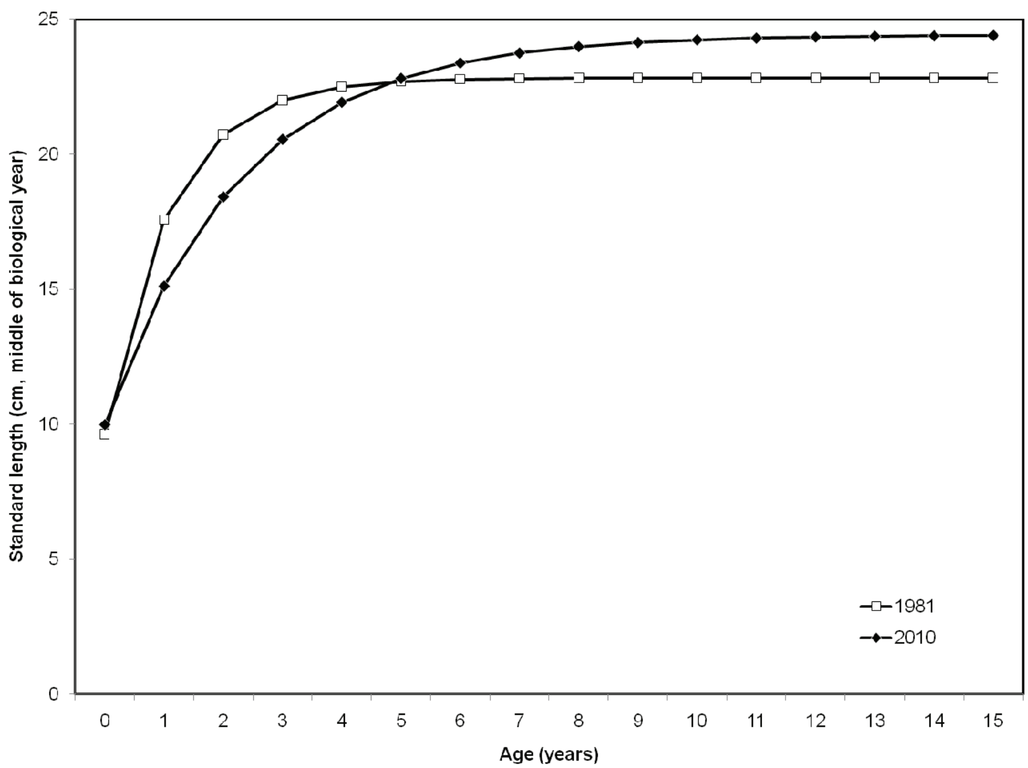


Figure 2b. Length-at-age as estimated in the base model (1981-90 period: $L_{0.5yr}$ = 9.78, L_{15yr}=23.95, K=1.111. 1991-10 period: $L_{0.5yr}$ = 9.82, L_{15yr}=24.02, K=0.370).

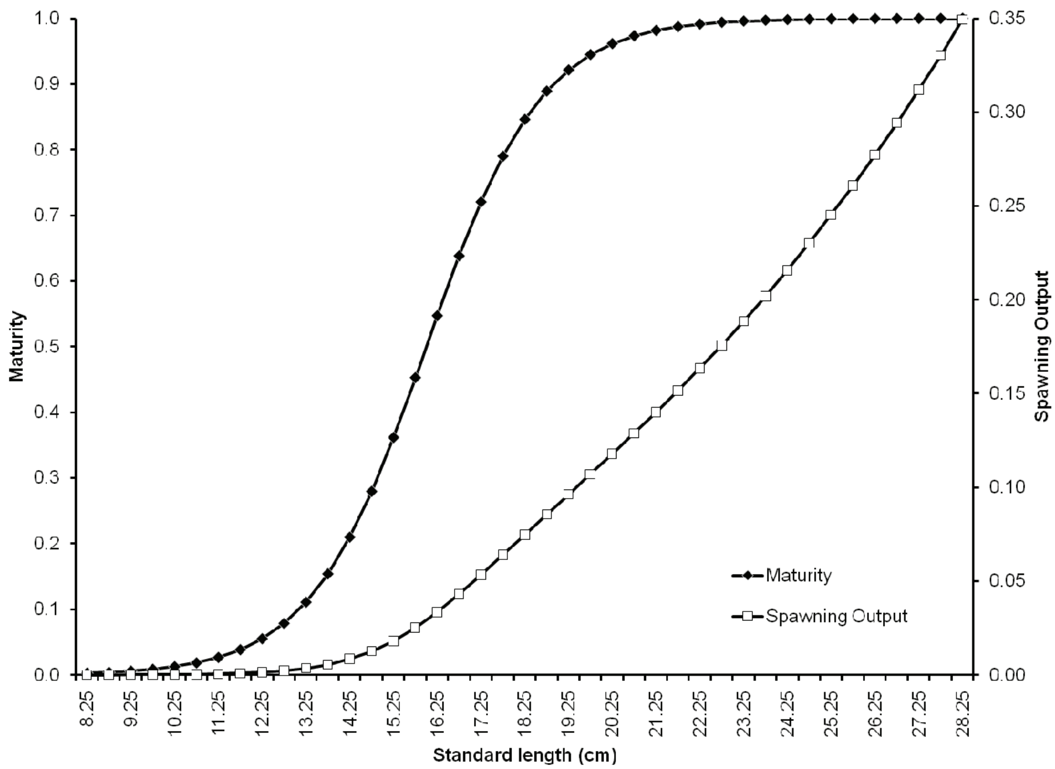


Figure 3a. Maturity (L_{50} = 16.0 cm) and spawning output as a function of length in base model.

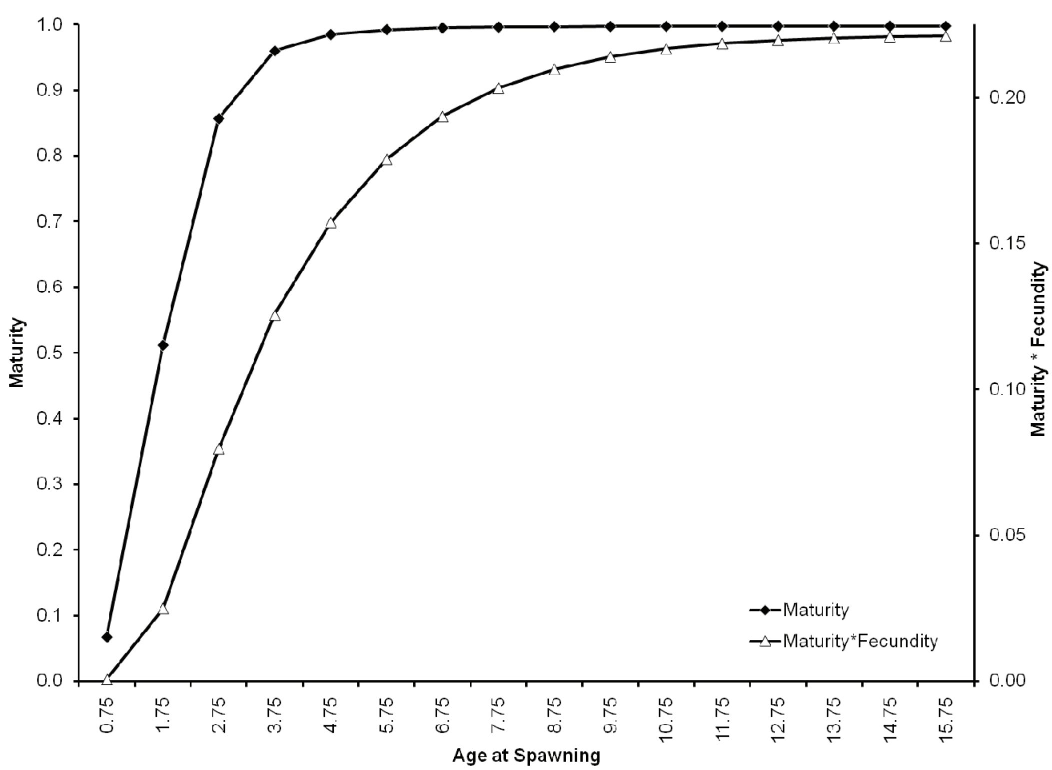


Figure 3b. Maturity and fecundity as a function of age, as derived from the base model.

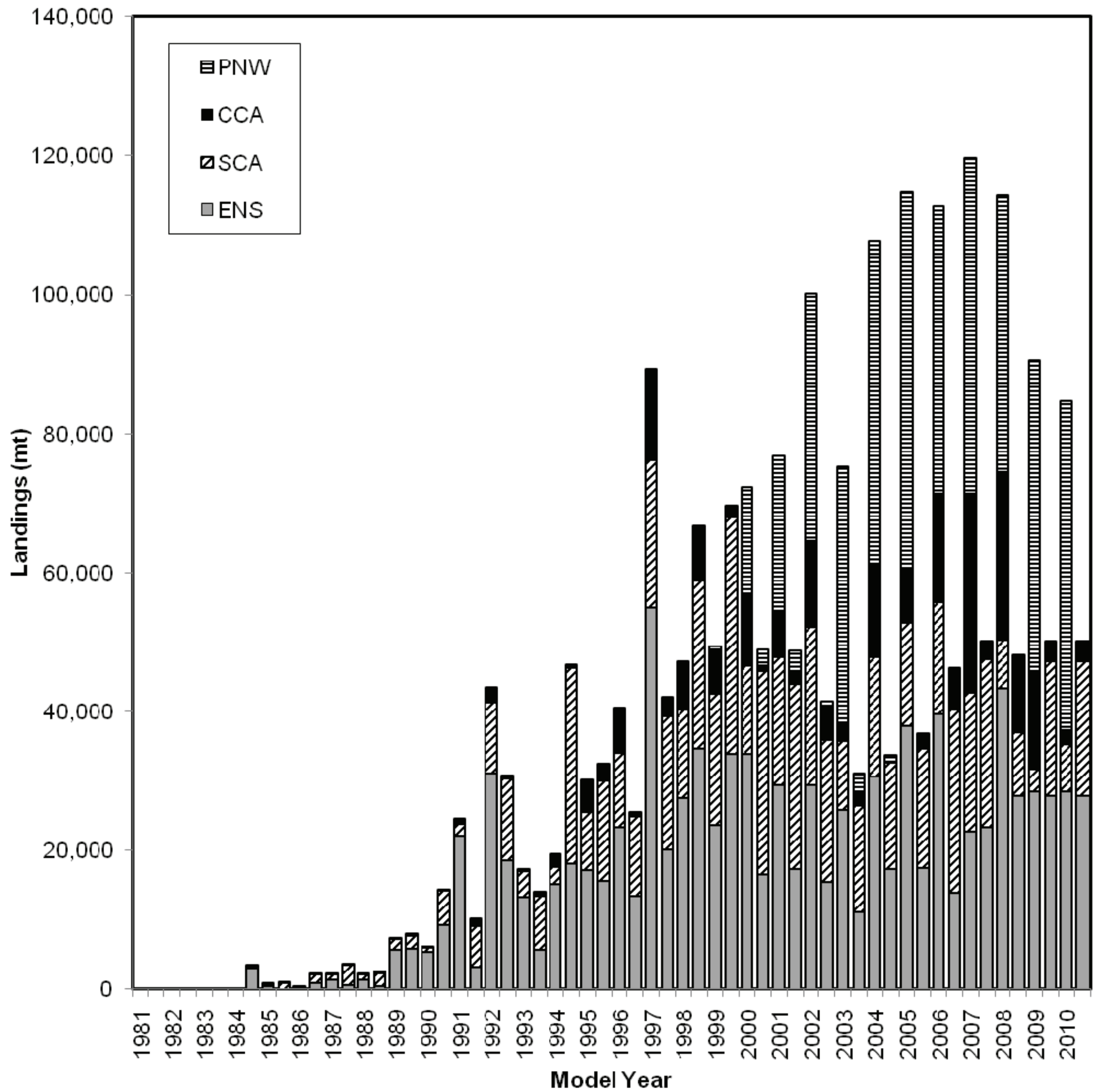


Figure 4. Pacific sardine landings (mt) by fishery, model year and semester as used in SS.

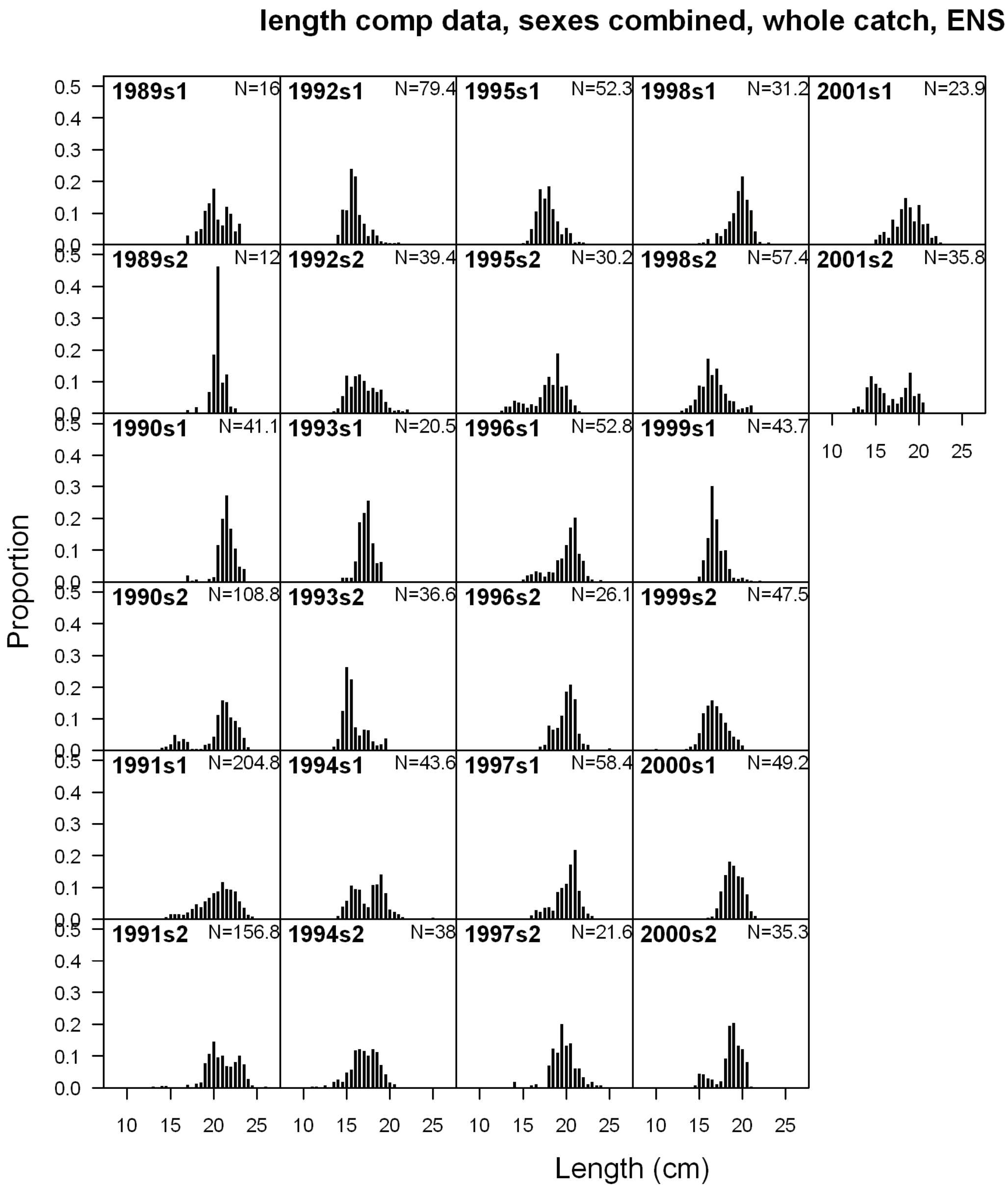


Figure 5a. Length-composition data for the ENS fishery.

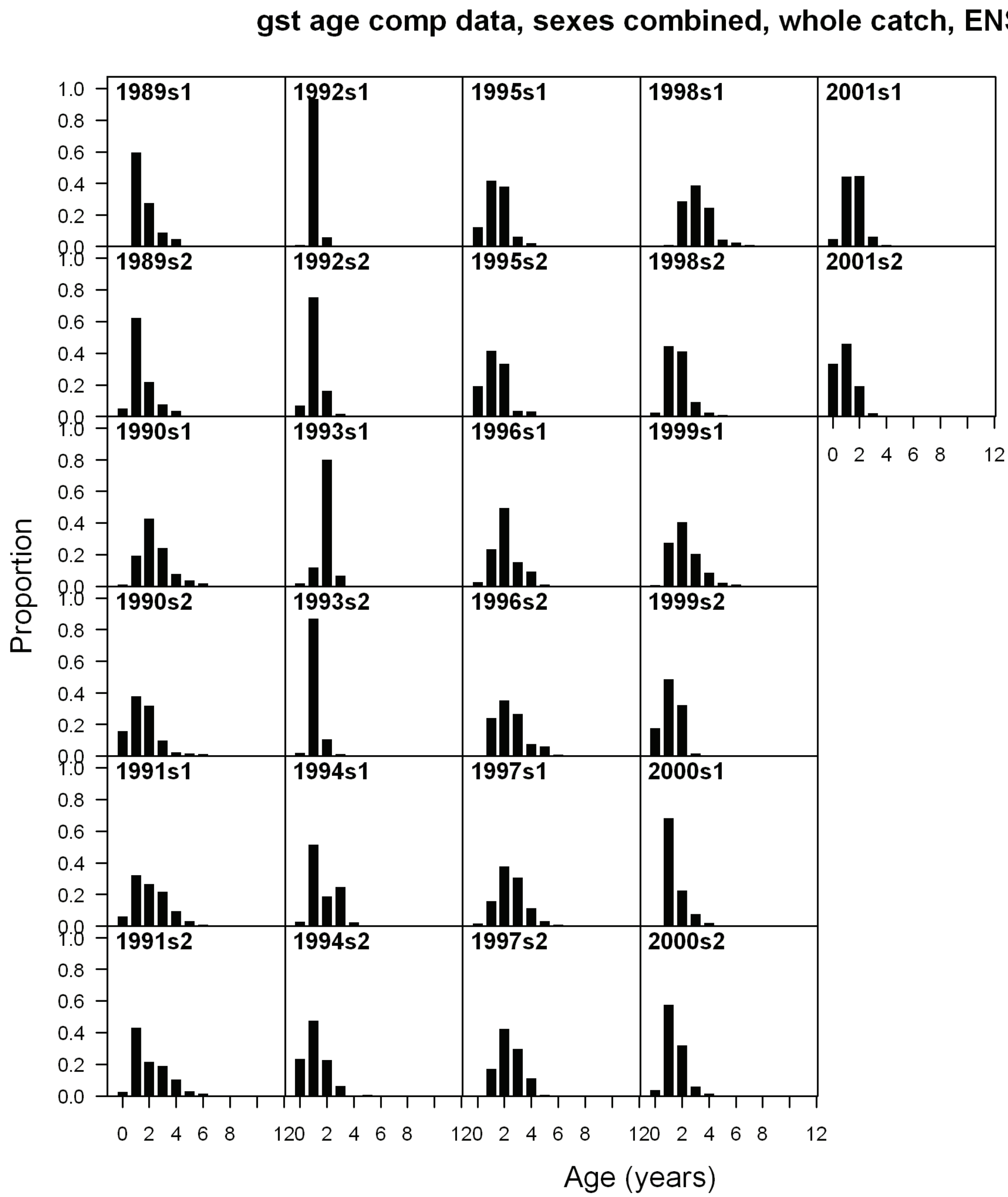


Figure 6a. Implied age-composition data for the ENS fishery.

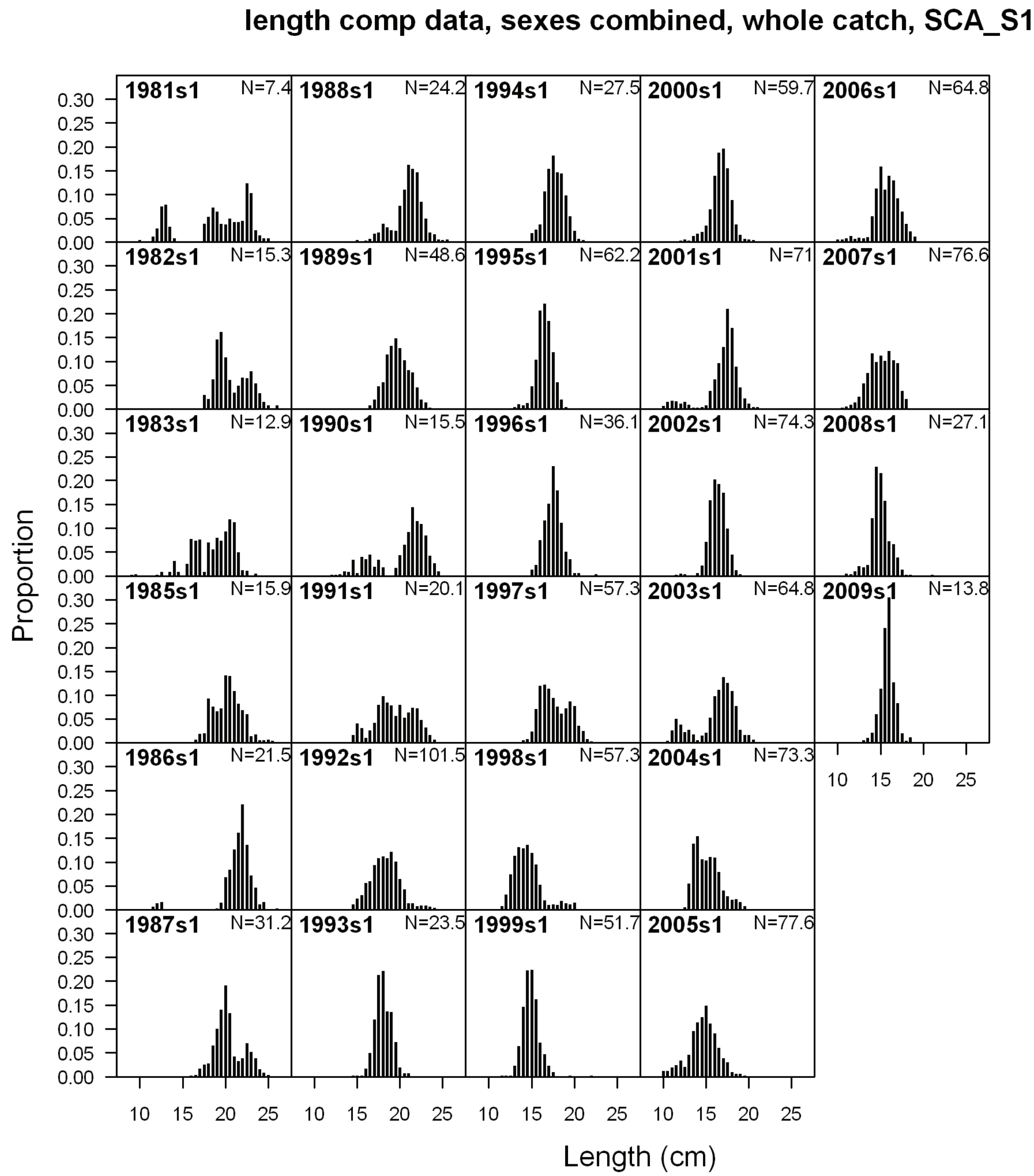


Figure 5b. Length-composition data for the SCA_S1 fishery.

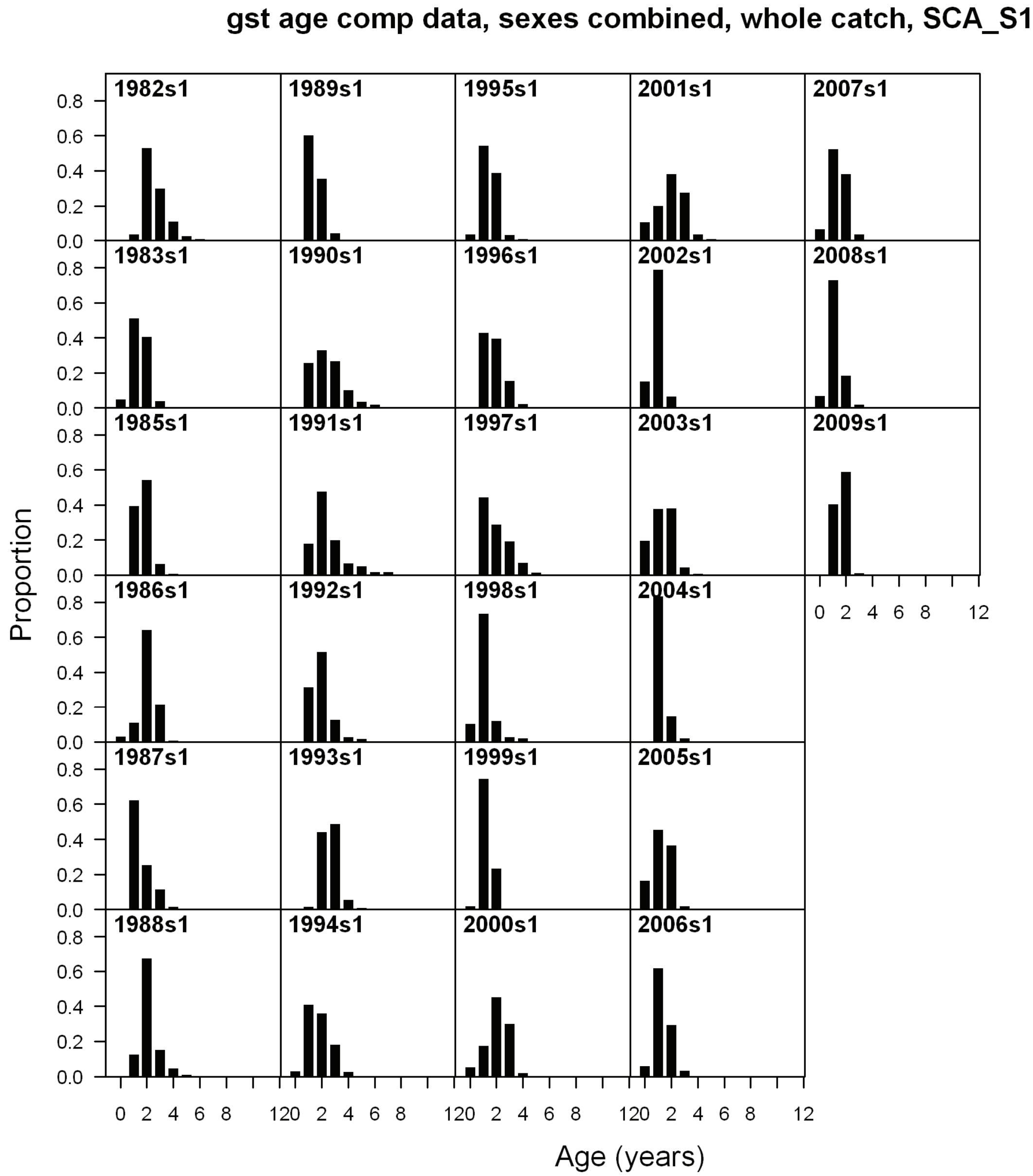


Figure 6b. Implied age-composition data for the SCA_S1 fishery.

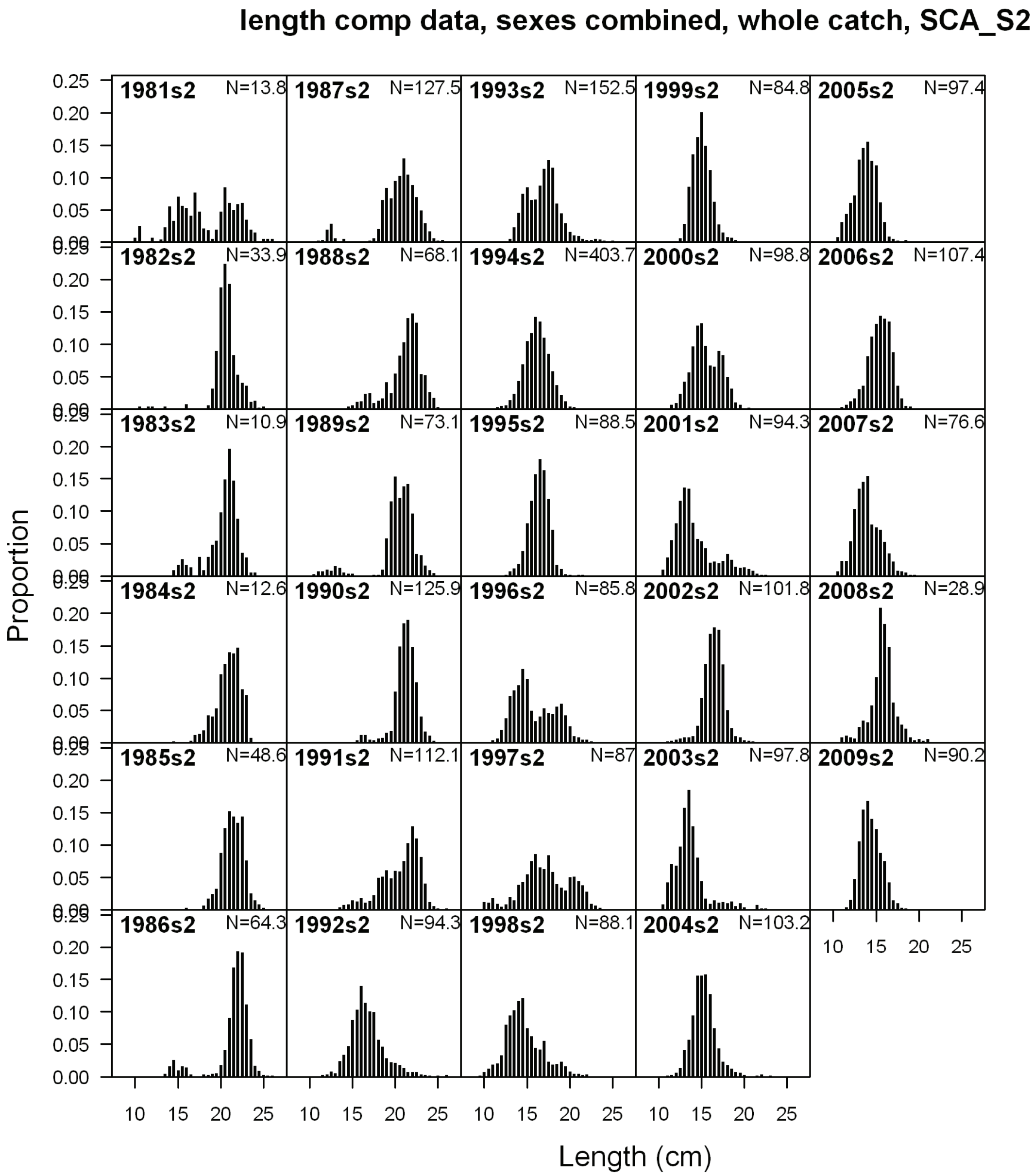


Figure 5c. Length-composition data for the SCA_S2 fishery.

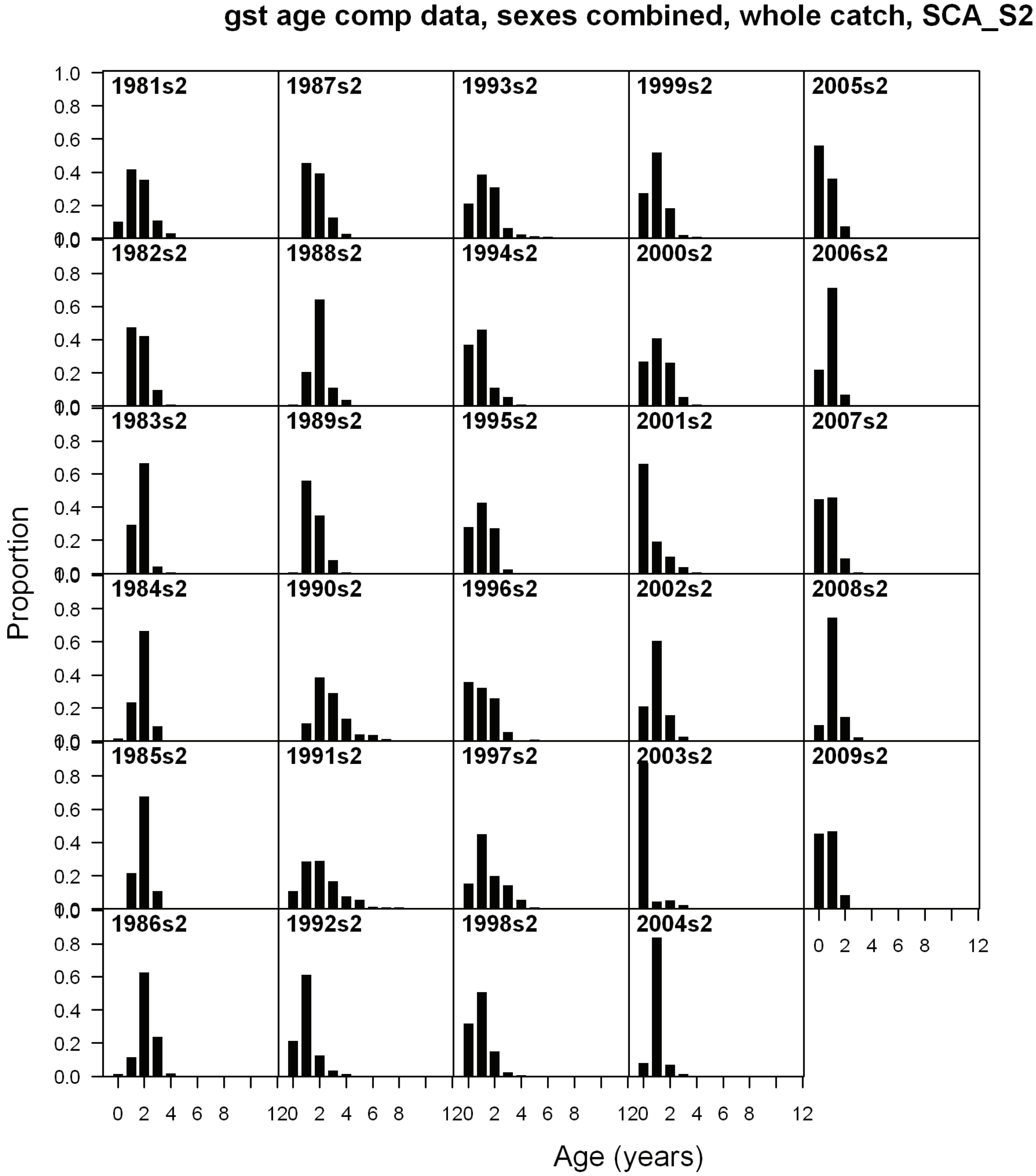


Figure 6c. Implied age-composition data for the SCA_S2 fishery.

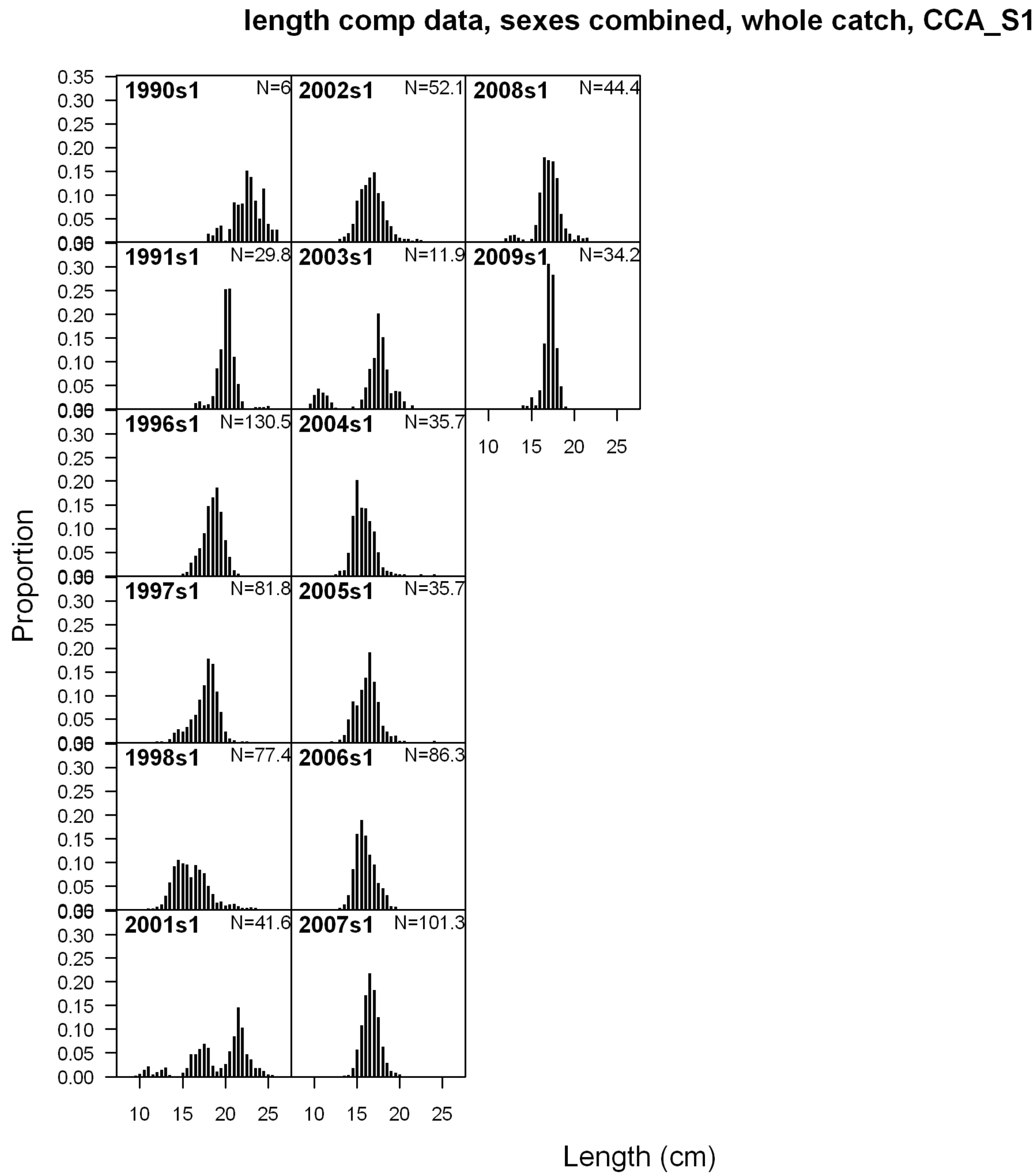


Figure 5d. Length-composition data for the CCA_S1 fishery.

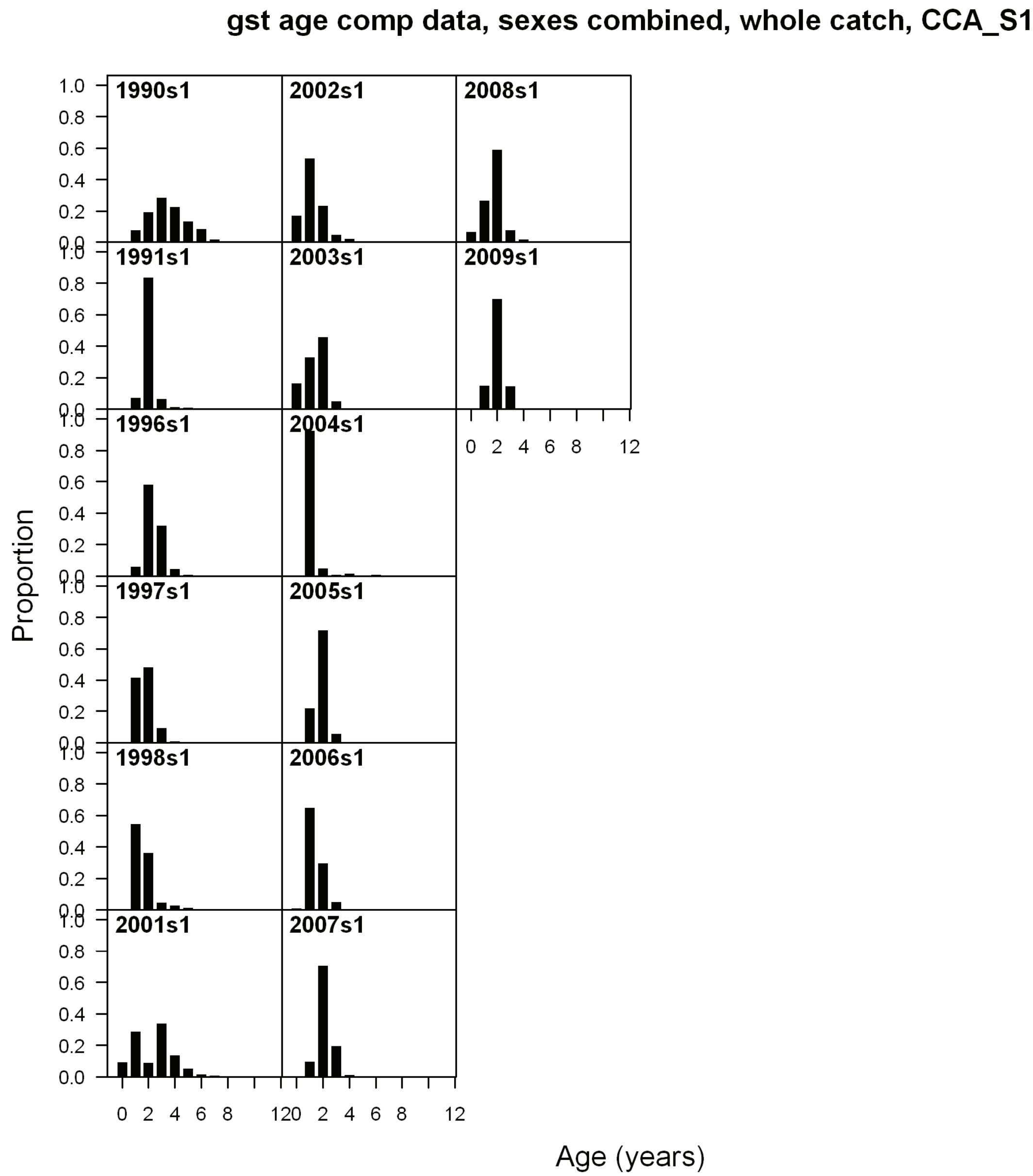


Figure 6d. Implied age-composition data for the CCA_S1 fishery.

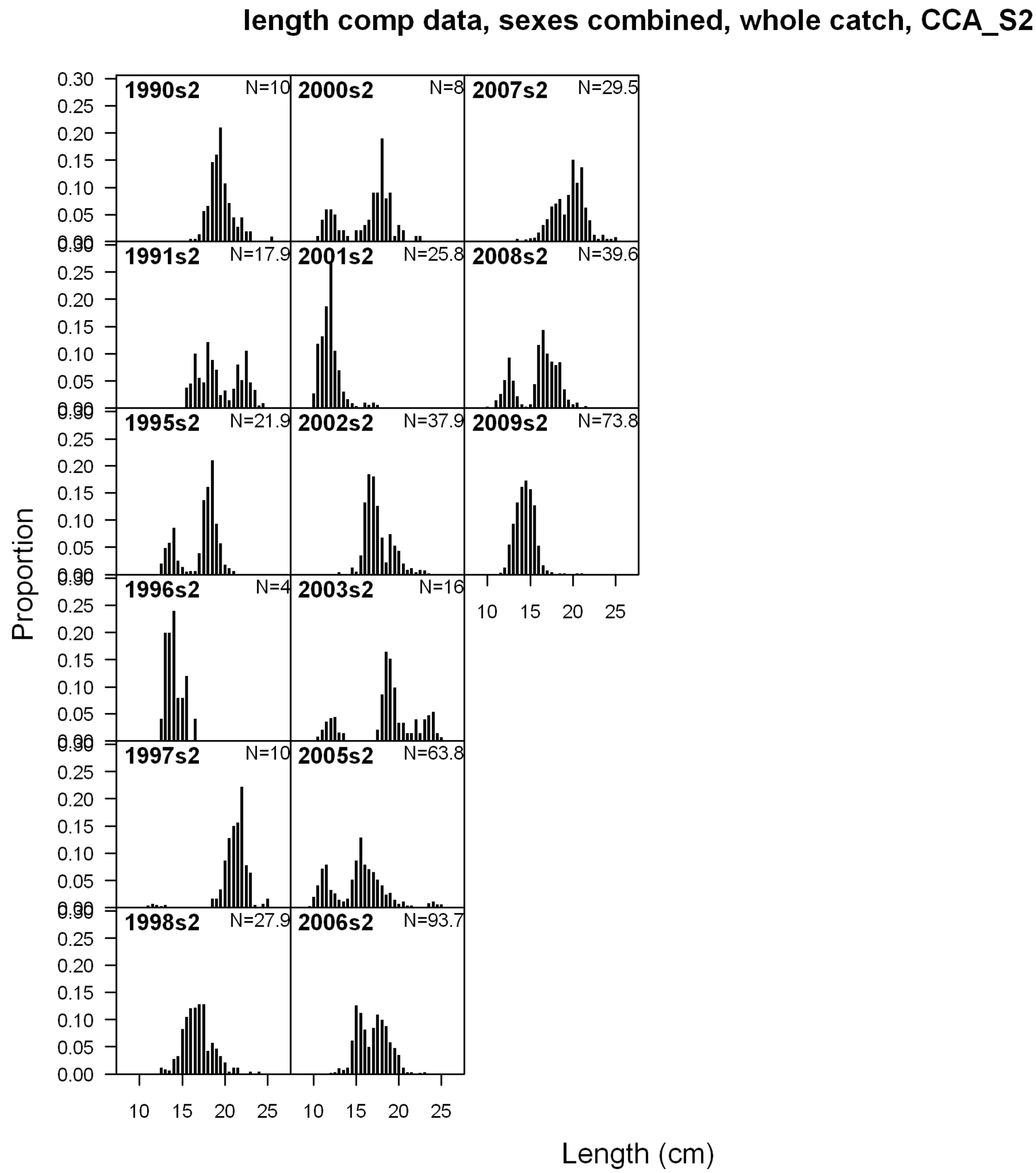


Figure 5e. Length-composition data for the CCA_S2 fishery.

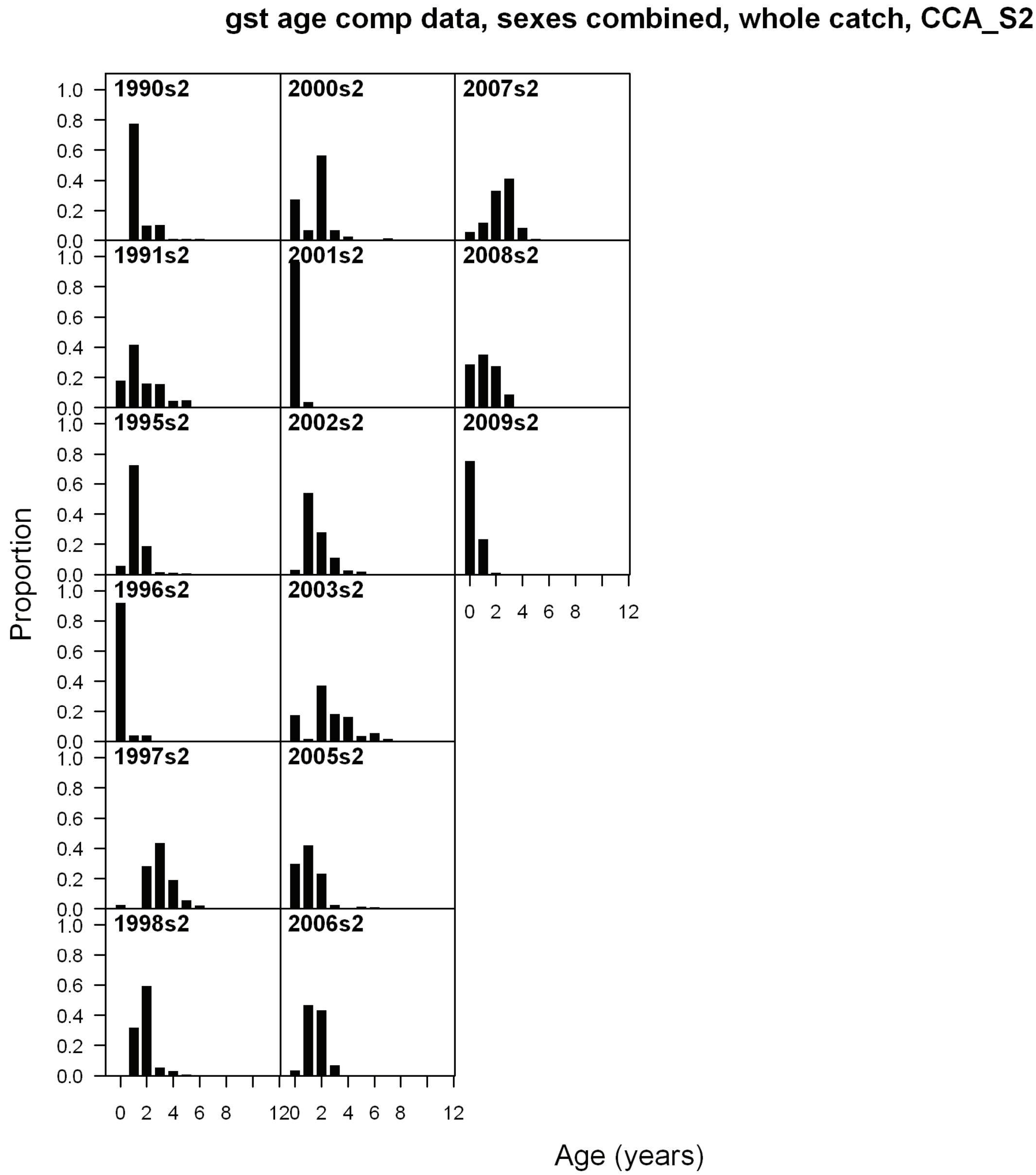


Figure 6e. Implied age-composition data for the CCA_S2 fishery.

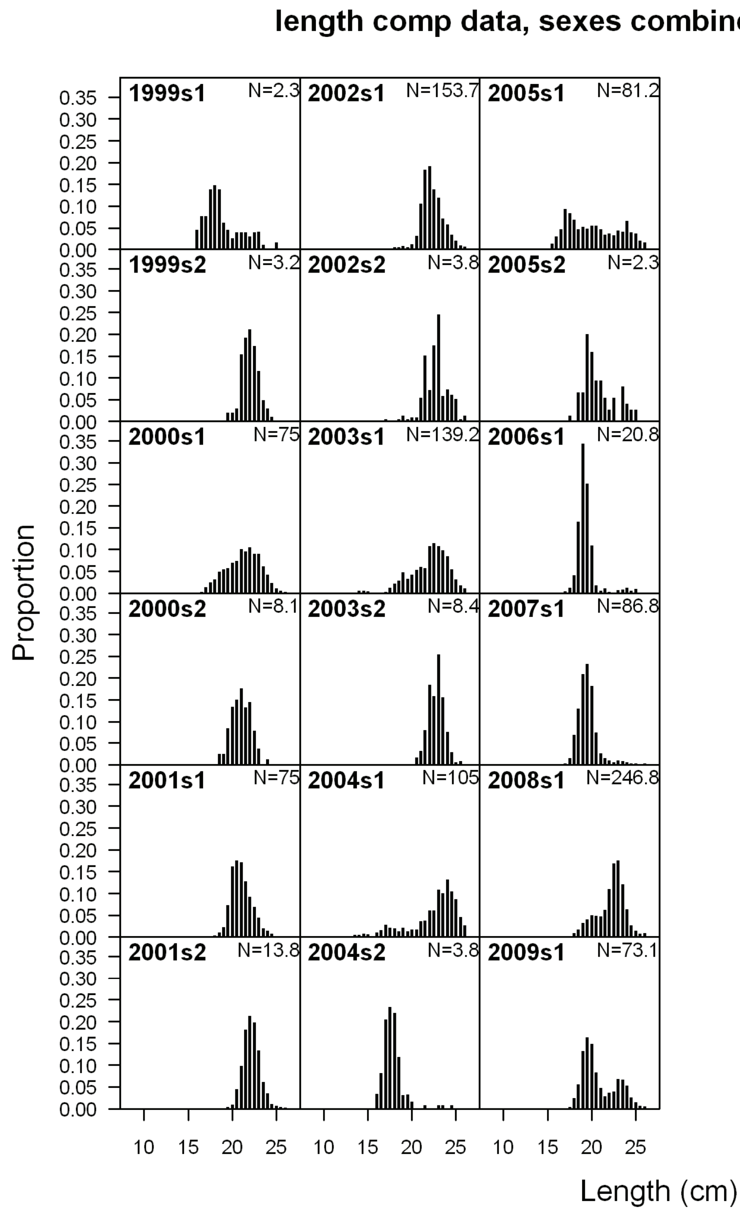


Figure 5f. Length-composition data for the PNW fishery.

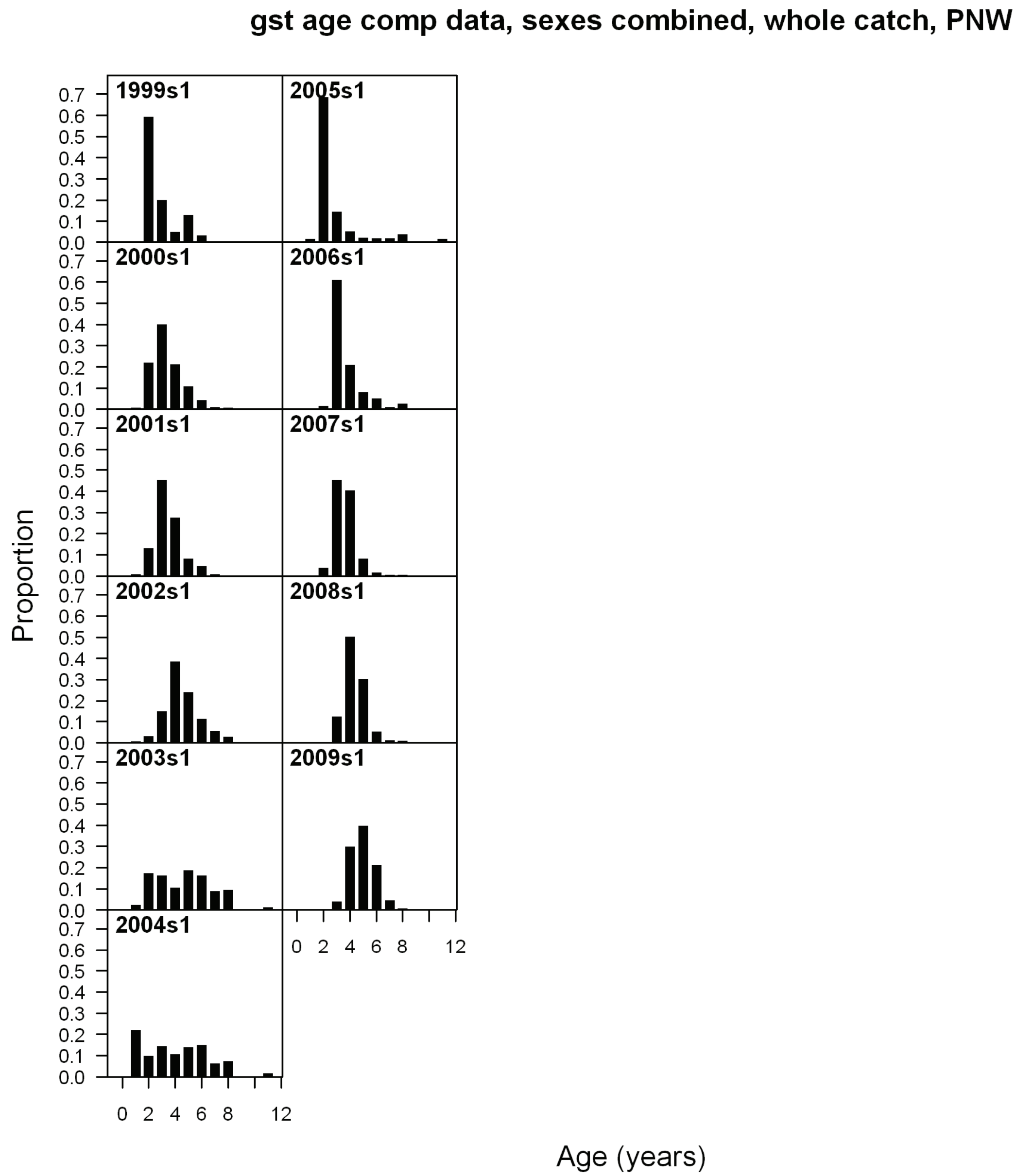


Figure 6f. Implied age-composition data for the PNW fishery.

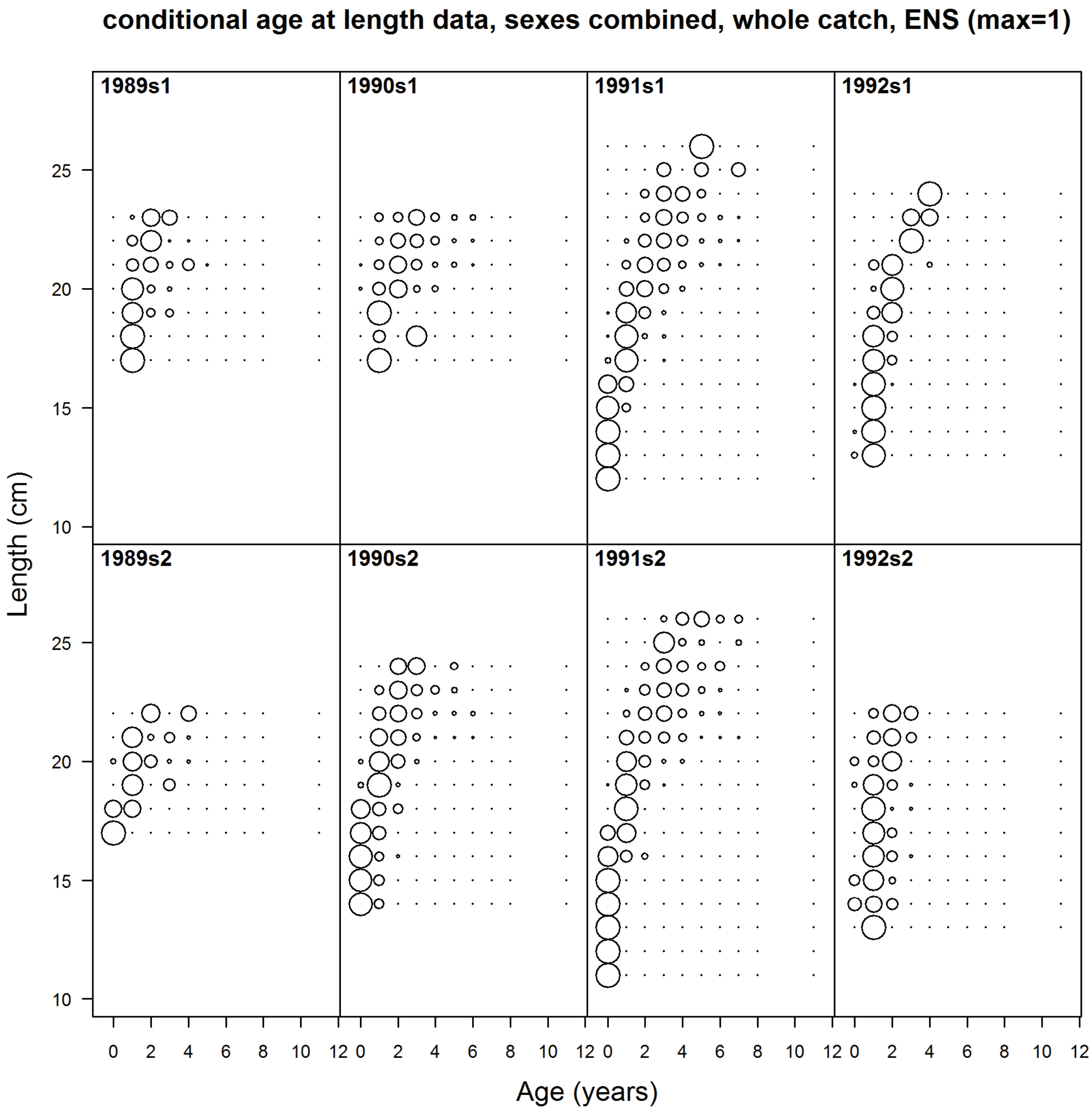


Figure 7a. Conditional age-at-length data for the ENS fishery, 1989-1992.

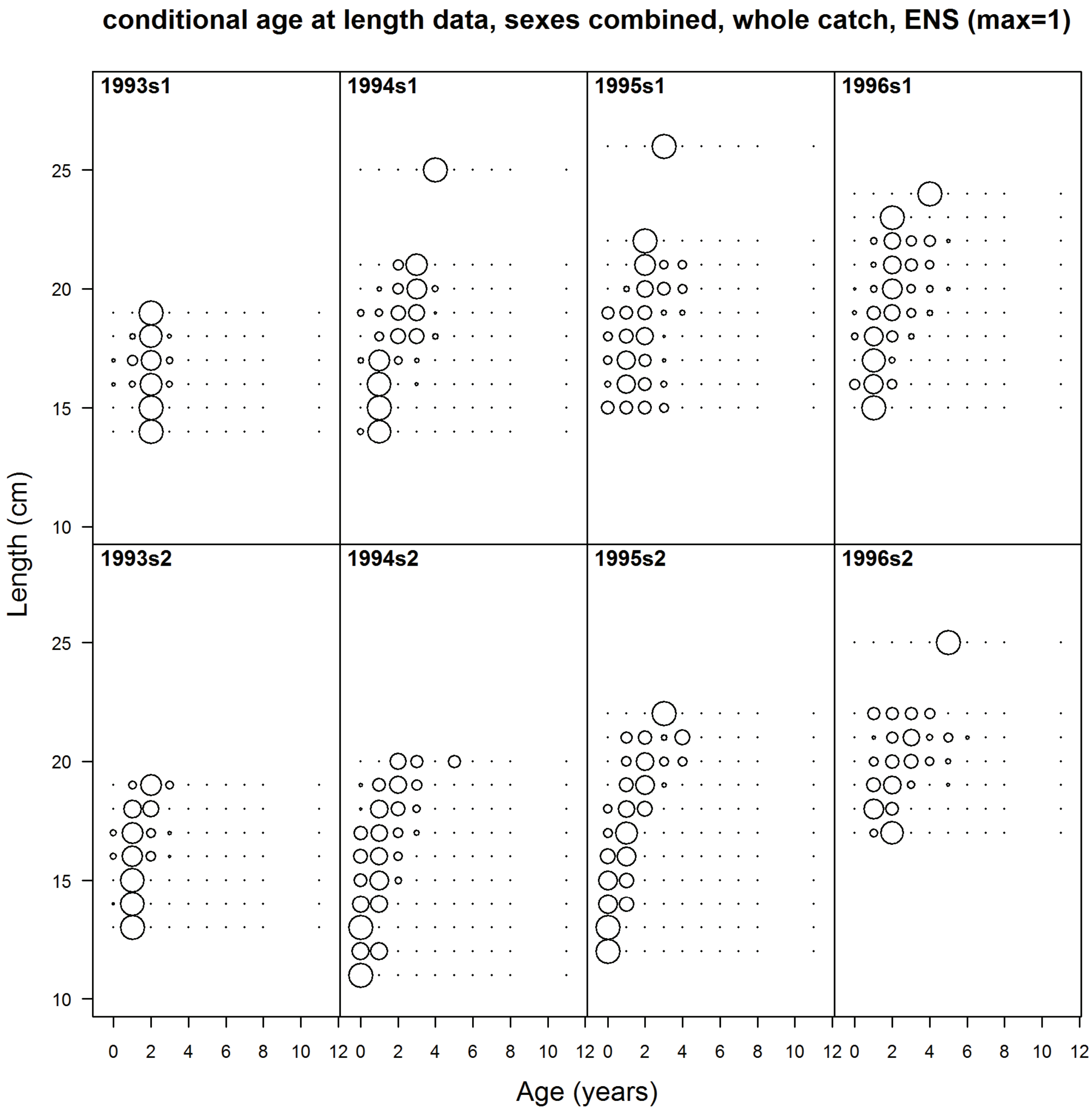


Figure 7a (cont'd). Conditional age-at-length data for the ENS fishery, 1993-1996.

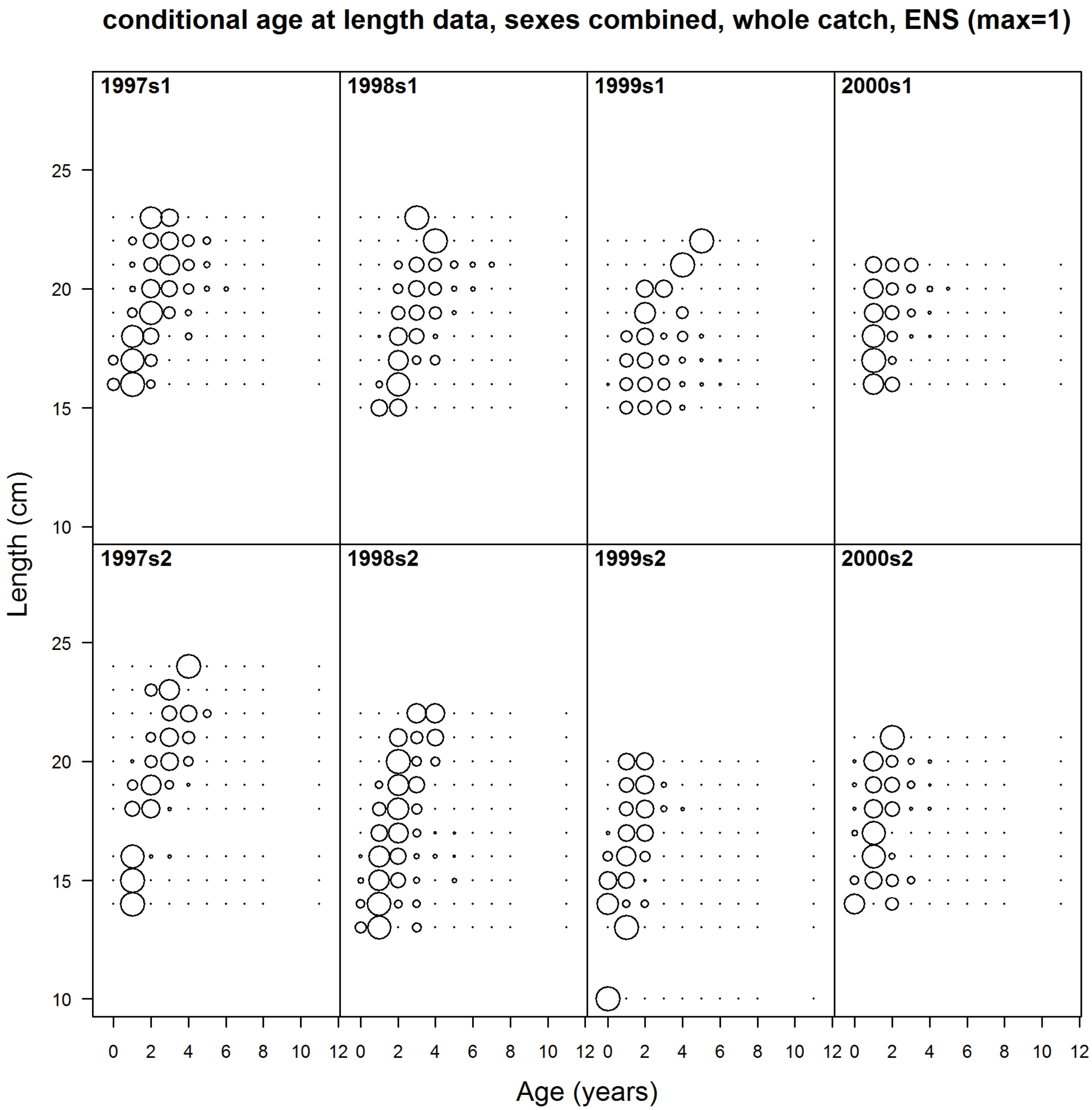


Figure 7a (cont'd). Conditional age-at-length data for the ENS fishery, 1997-2000.

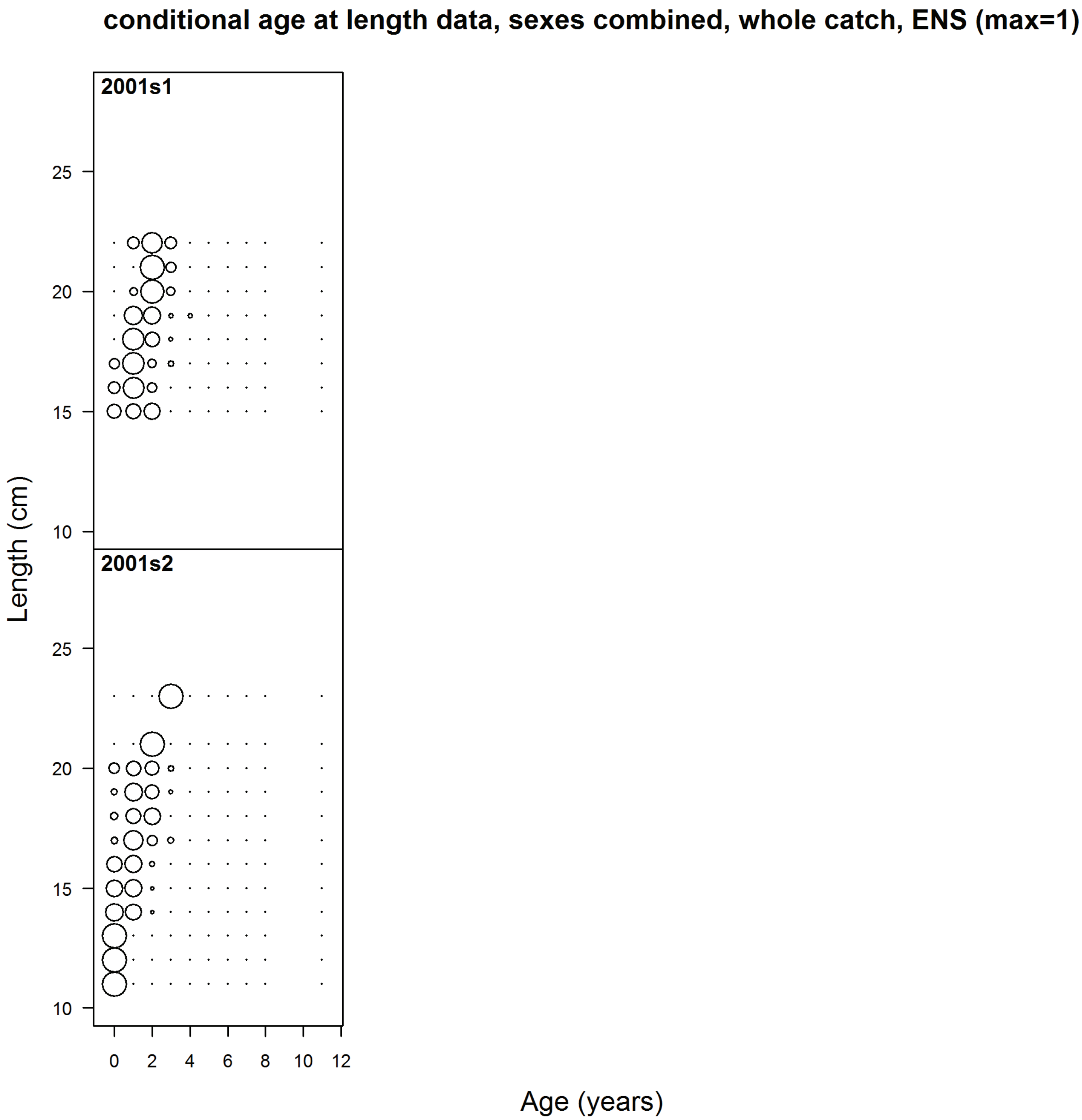


Figure 7a (cont'd). Conditional age-at-length data for the ENS fishery, 2001.

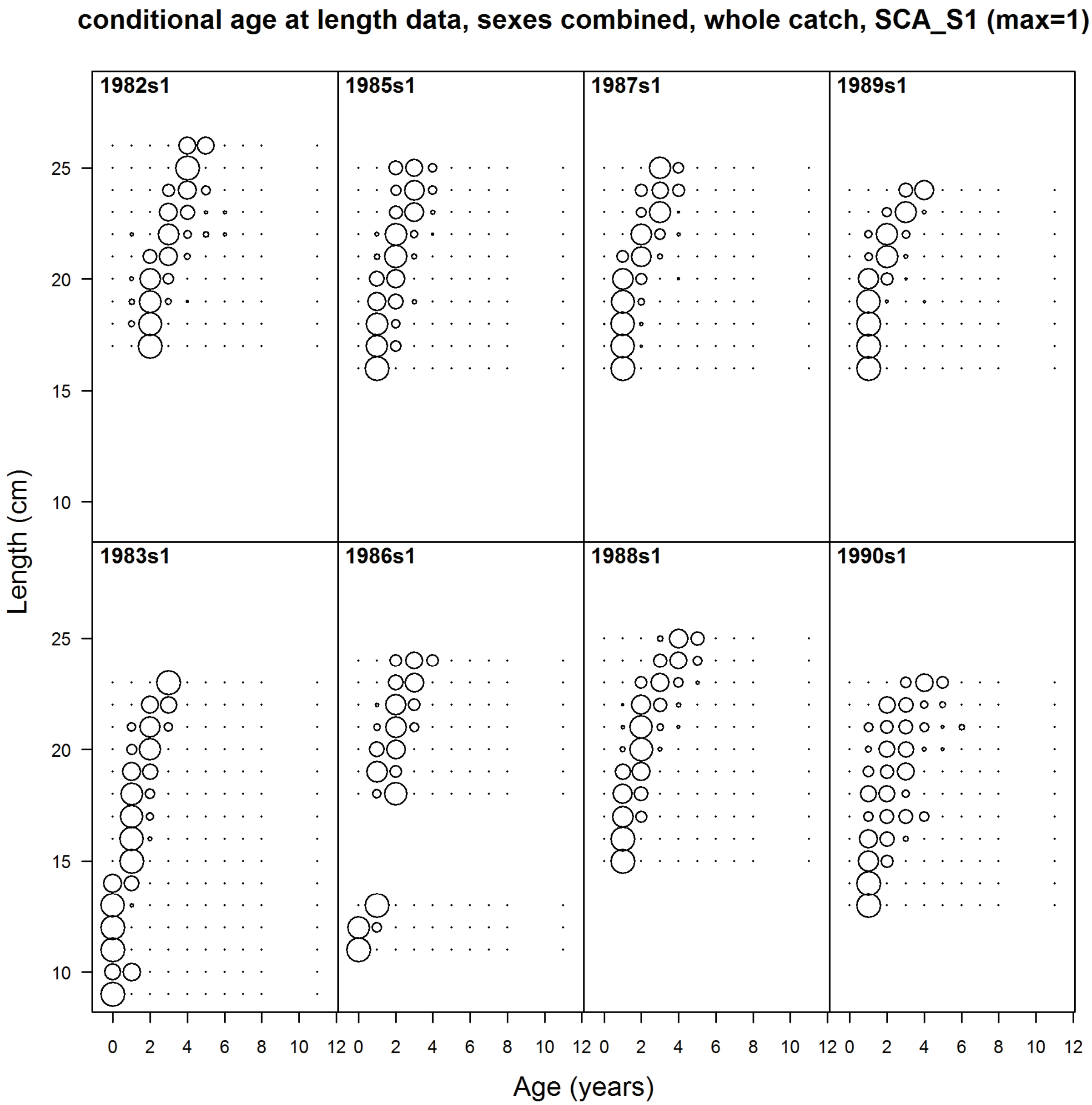


Figure 7b. Conditional age-at-length data for the SCA_S1 fishery, 1982-1990.

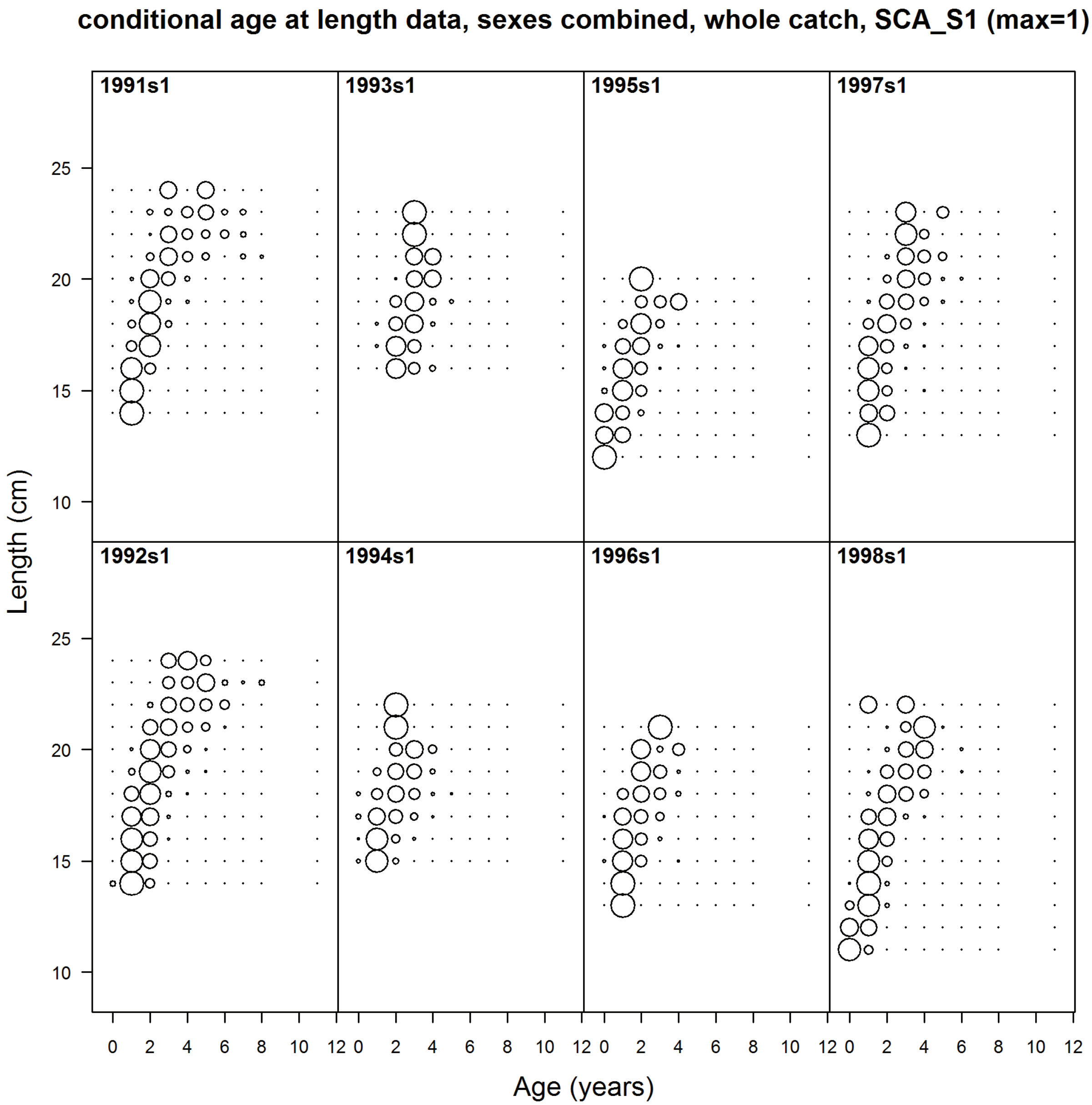


Figure 7b (cont'd). Conditional age-at-length data for the SCA_S1 fishery, 1991-1998.

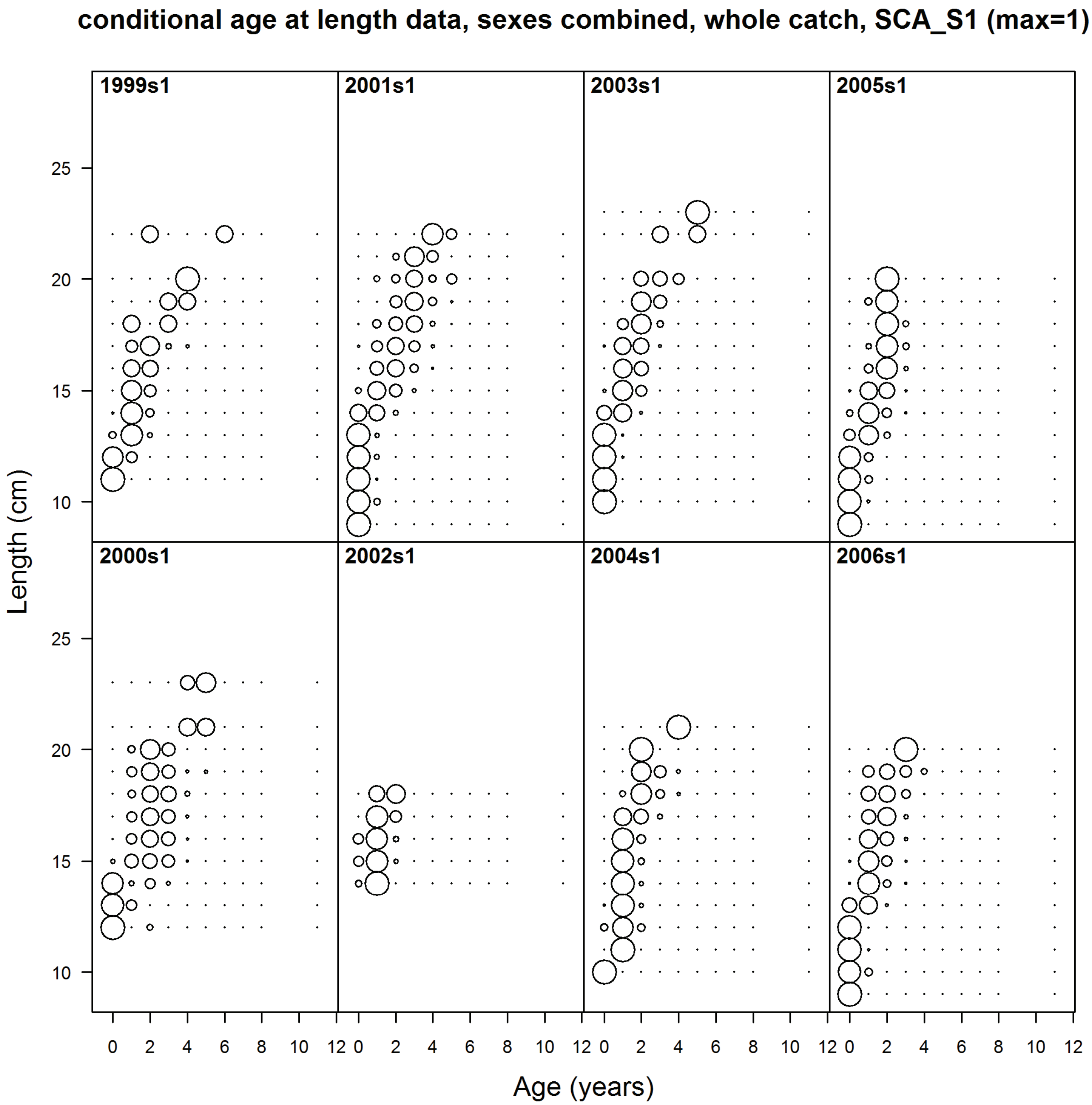


Figure 7b (cont'd). Conditional age-at-length data for the SCA_S1 fishery, 1999-2006.

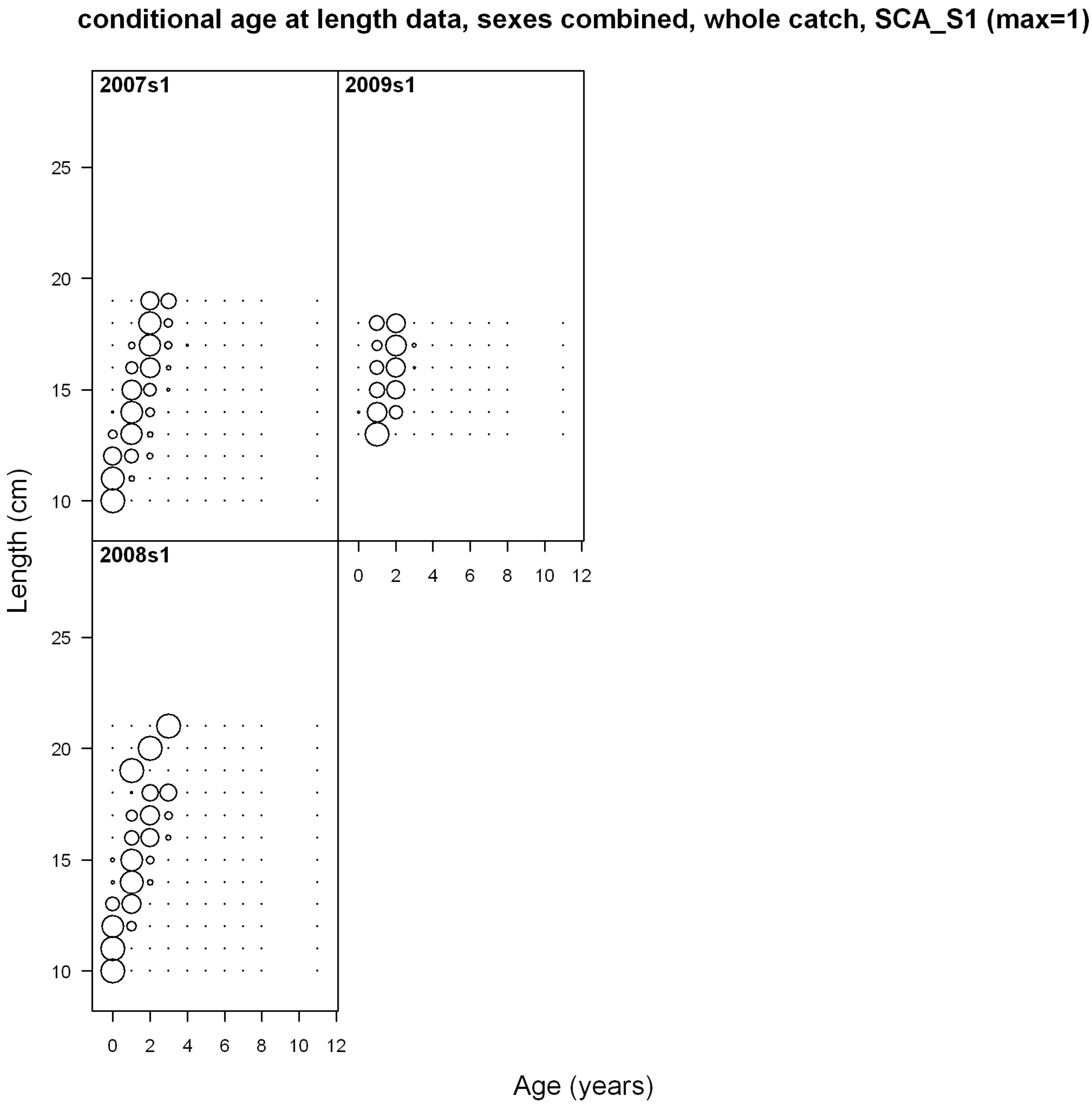


Figure 7b (cont'd). Conditional age-at-length data for the SCA_S1 fishery, 2007-2009.

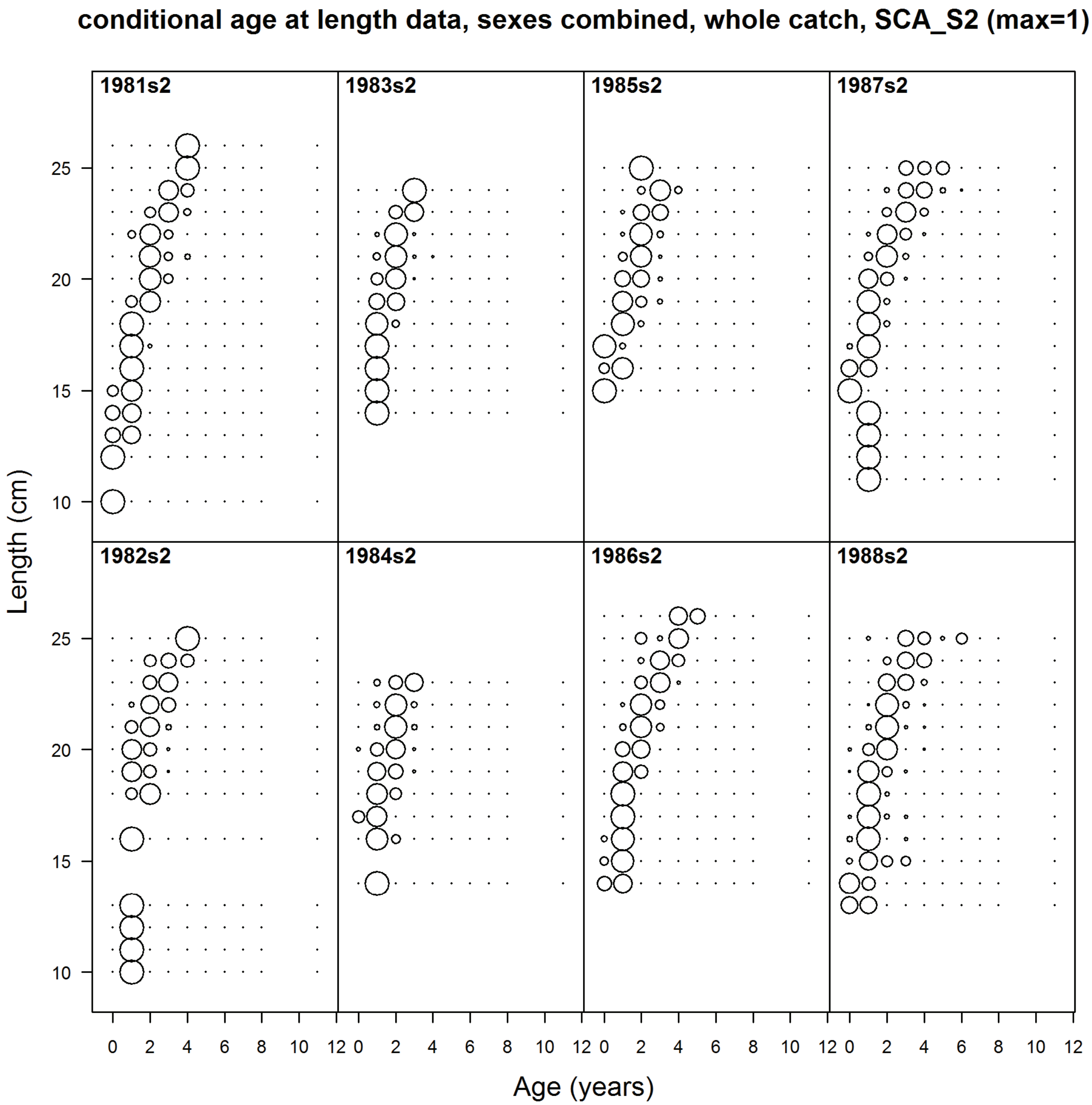


Figure 7c. Conditional age-at-length data for the SCA_S2 fishery, 1981-1988.

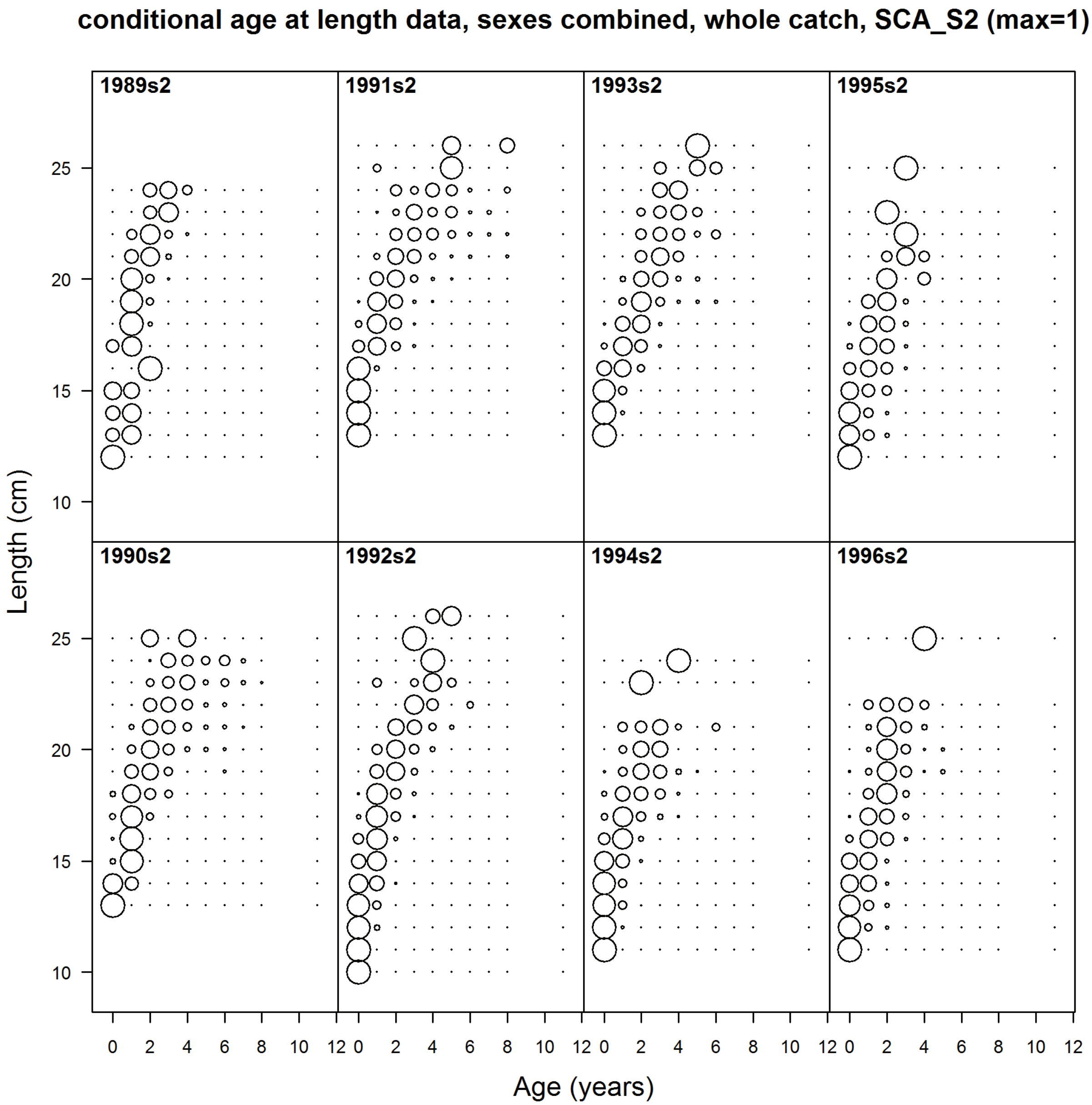


Figure 7c (cont'd). Conditional age-at-length data for the SCA_S2 fishery, 1989-1996.

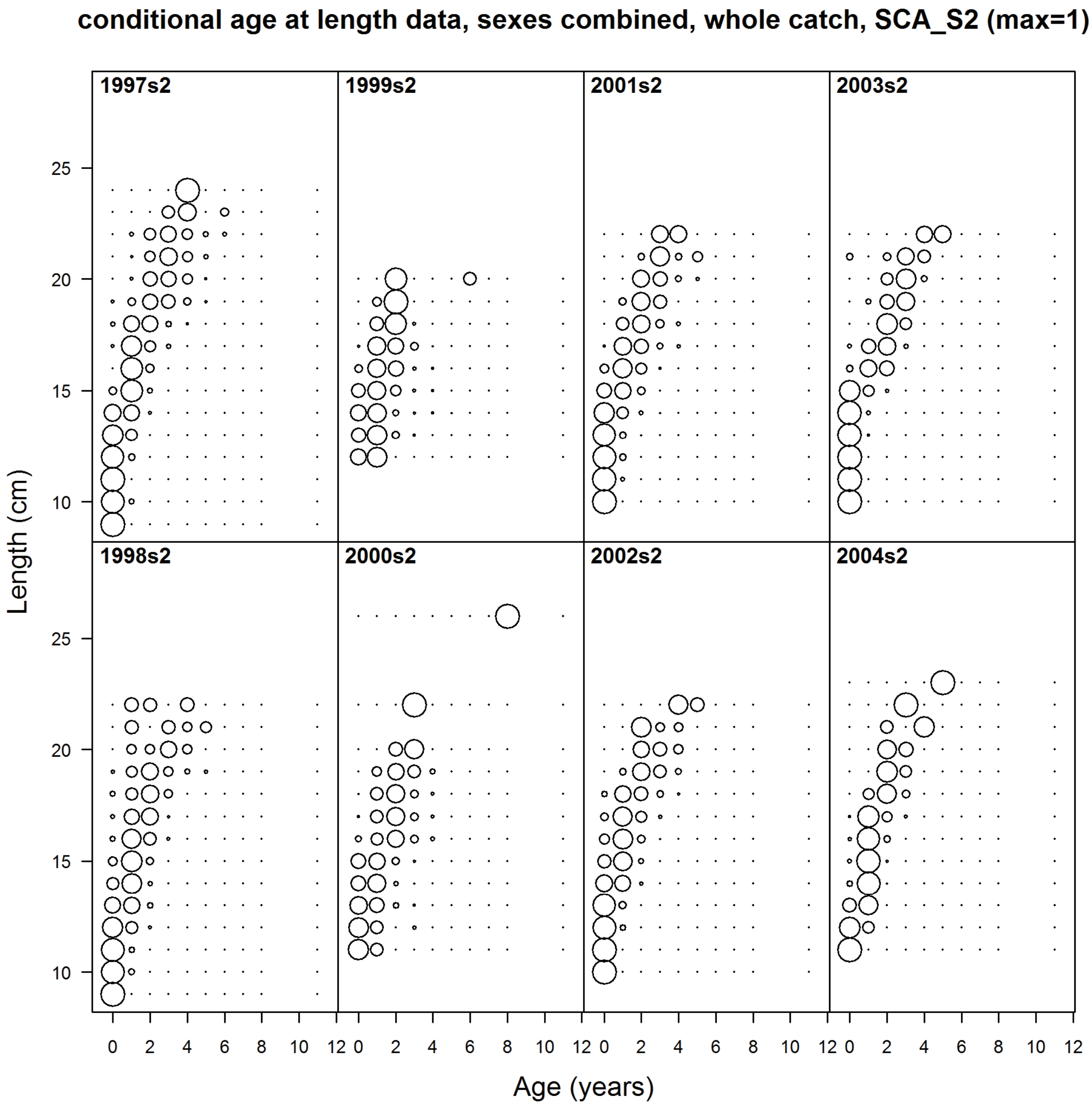


Figure 7c (cont'd). Conditional age-at-length data for the SCA_S2 fishery, 1997-2004.

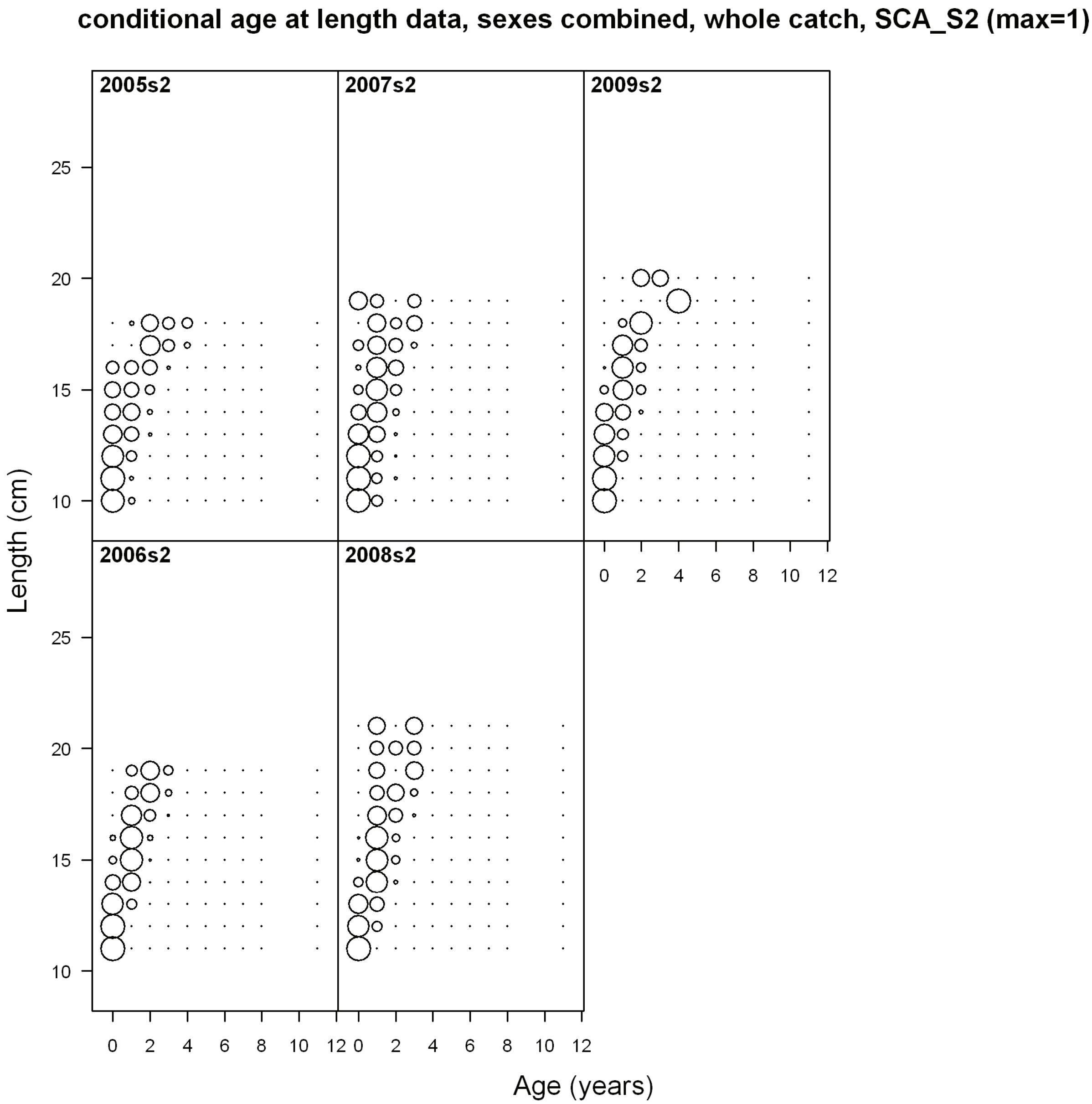


Figure 7c (cont'd). Conditional age-at-length data for the SCA_S2 fishery, 2005-2009.

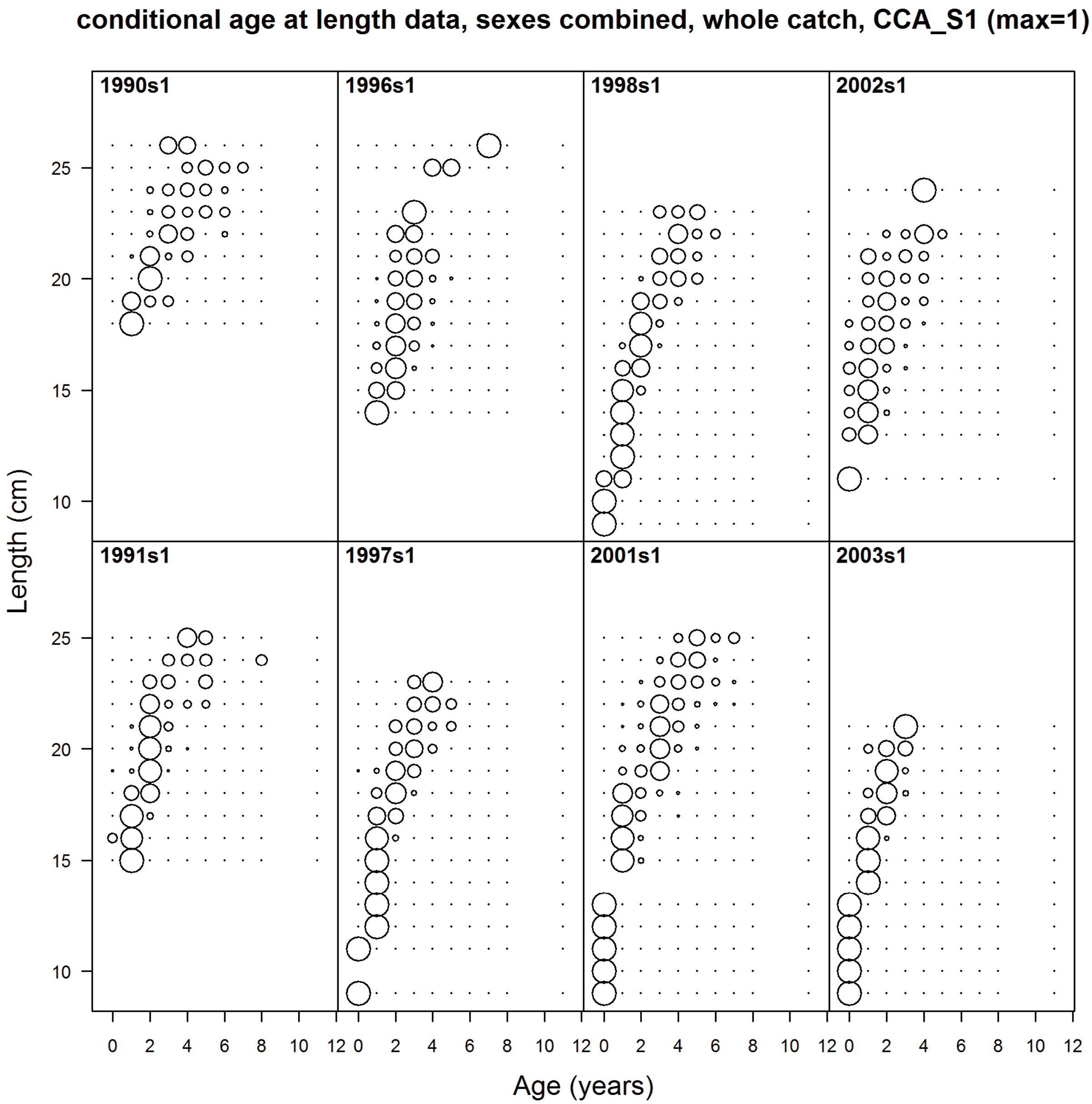


Figure 7d. Conditional age-at-length data for the CCA_S1 fishery, 1990-2003.

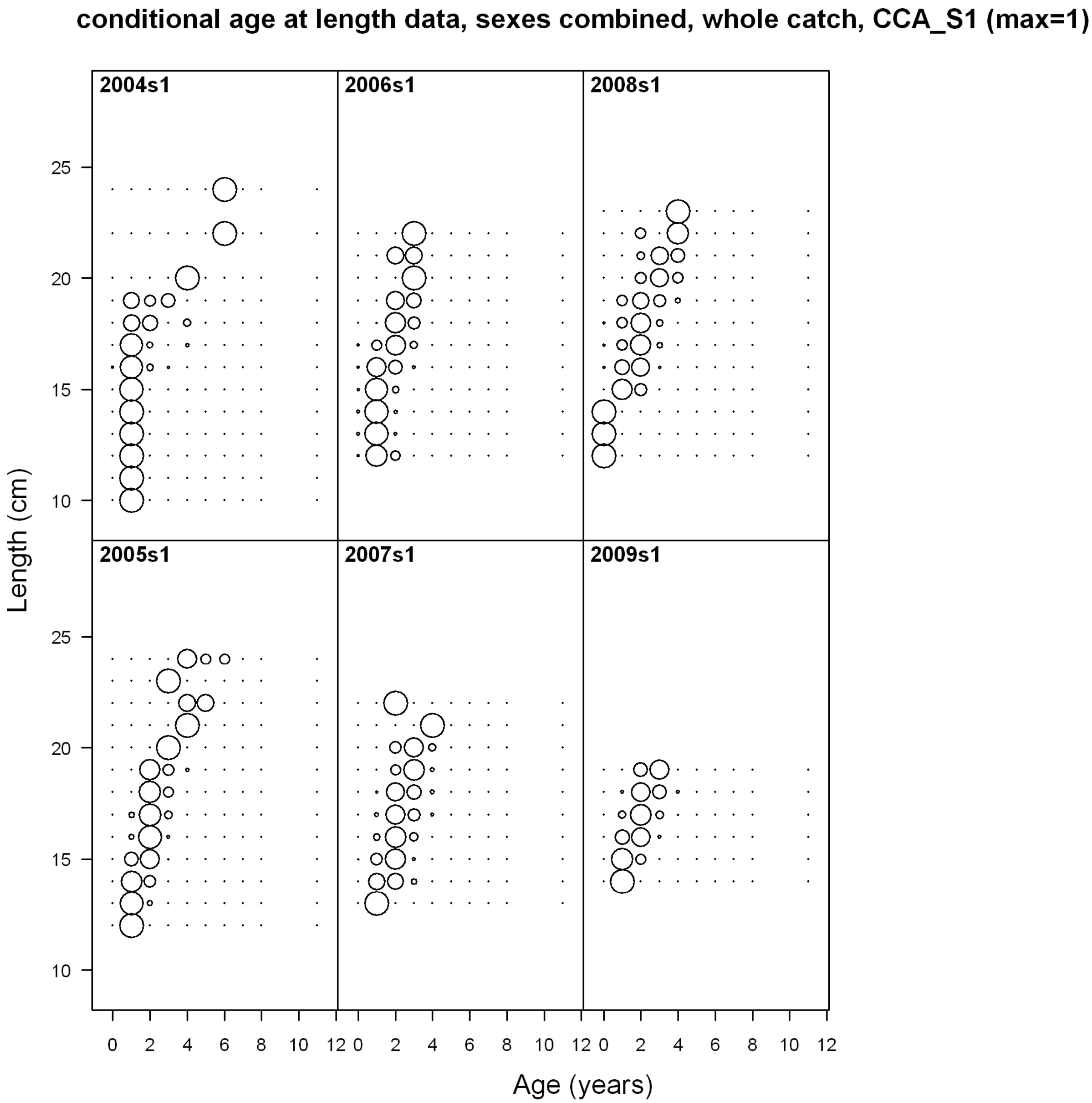


Figure 7d (cont'd). Conditional age-at-length data for the CCA_S1 fishery, 2004-2009.

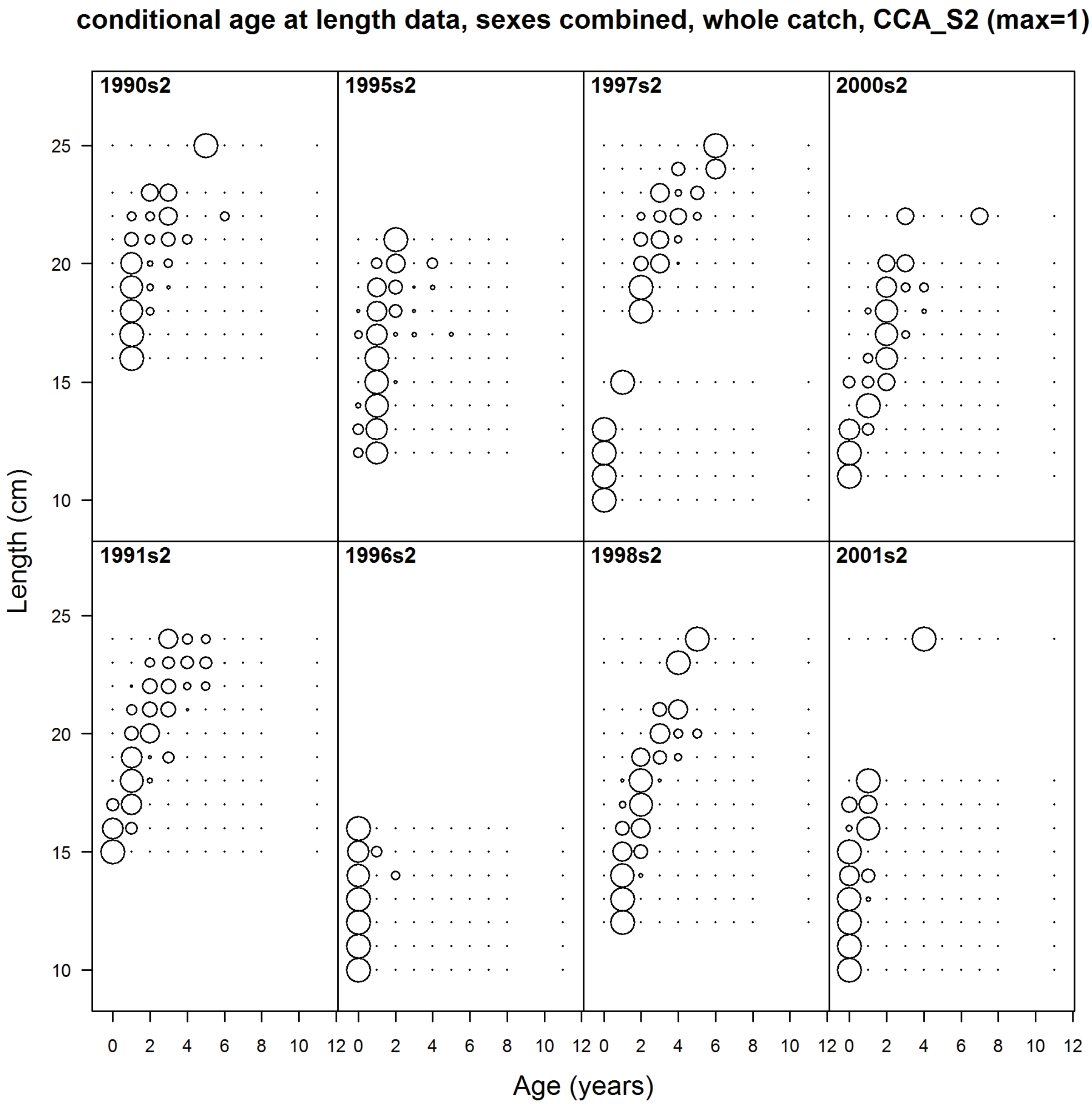


Figure 7e. Conditional age-at-length data for the CCA_S2 fishery, 1990-2001.

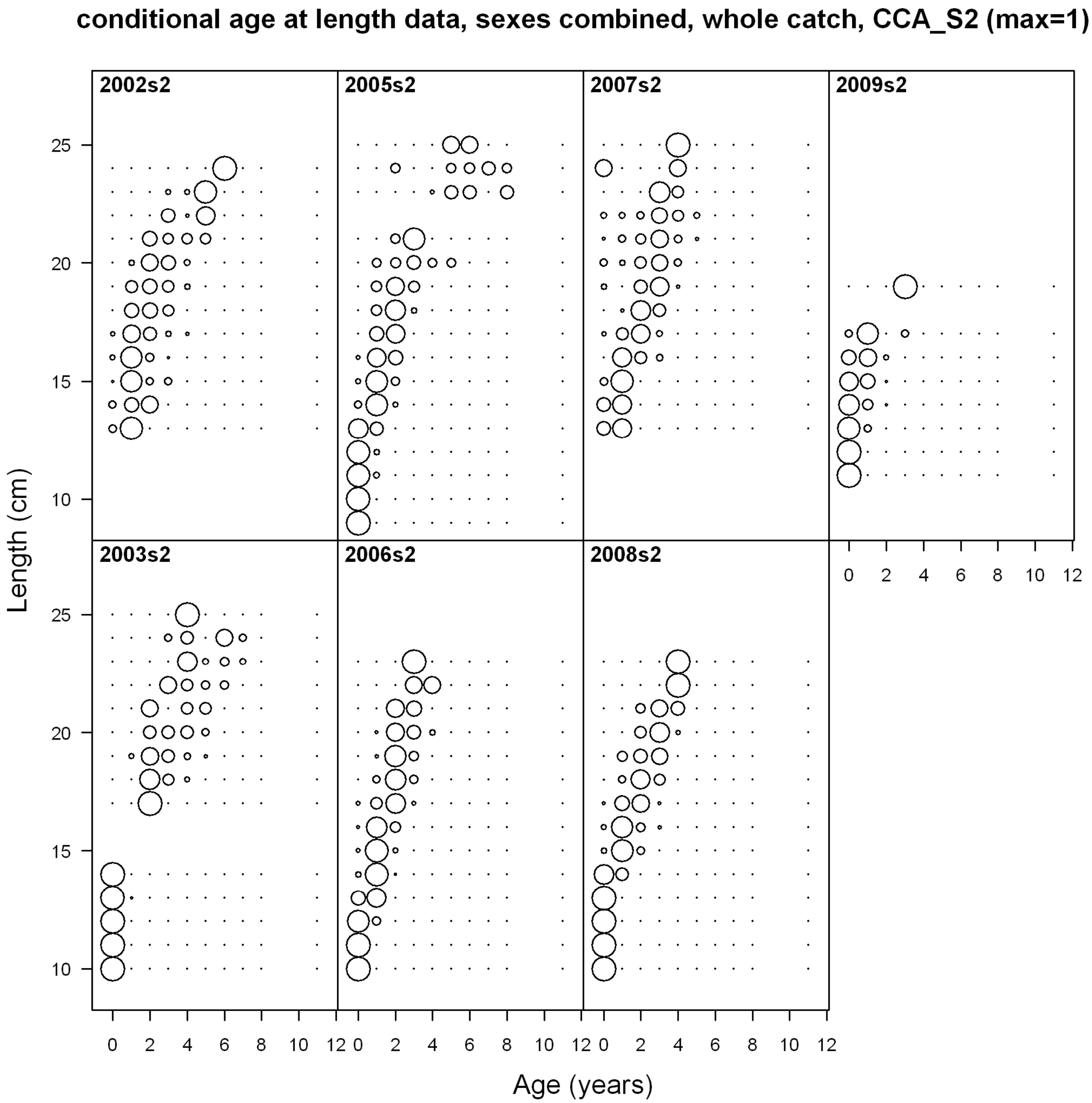


Figure 7e (cont'd). Conditional age-at-length data for the CCA_S2 fishery, 2002-2009.

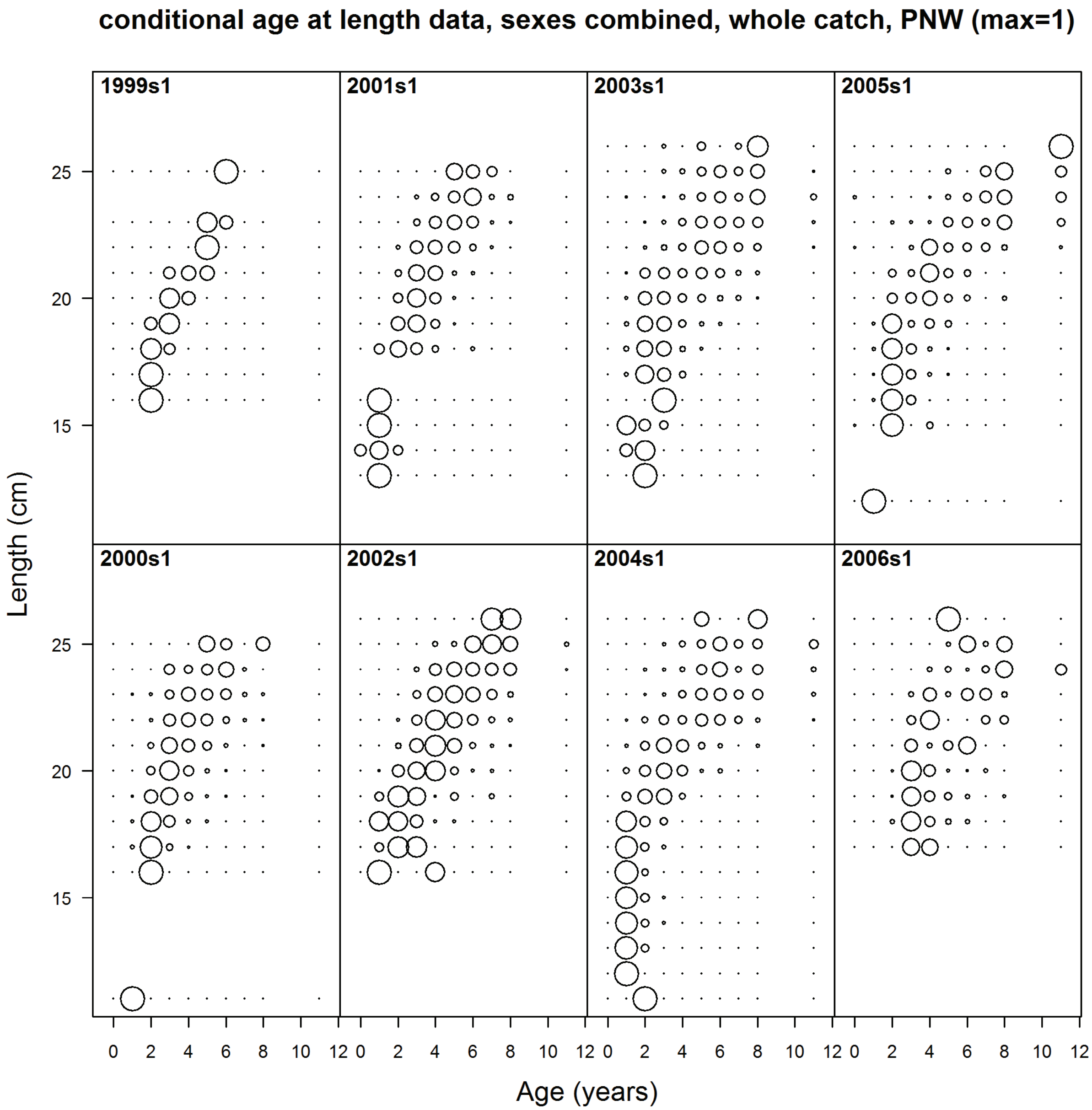


Figure 7f. Conditional age-at-length data for the PNW fishery, 1999-2006.

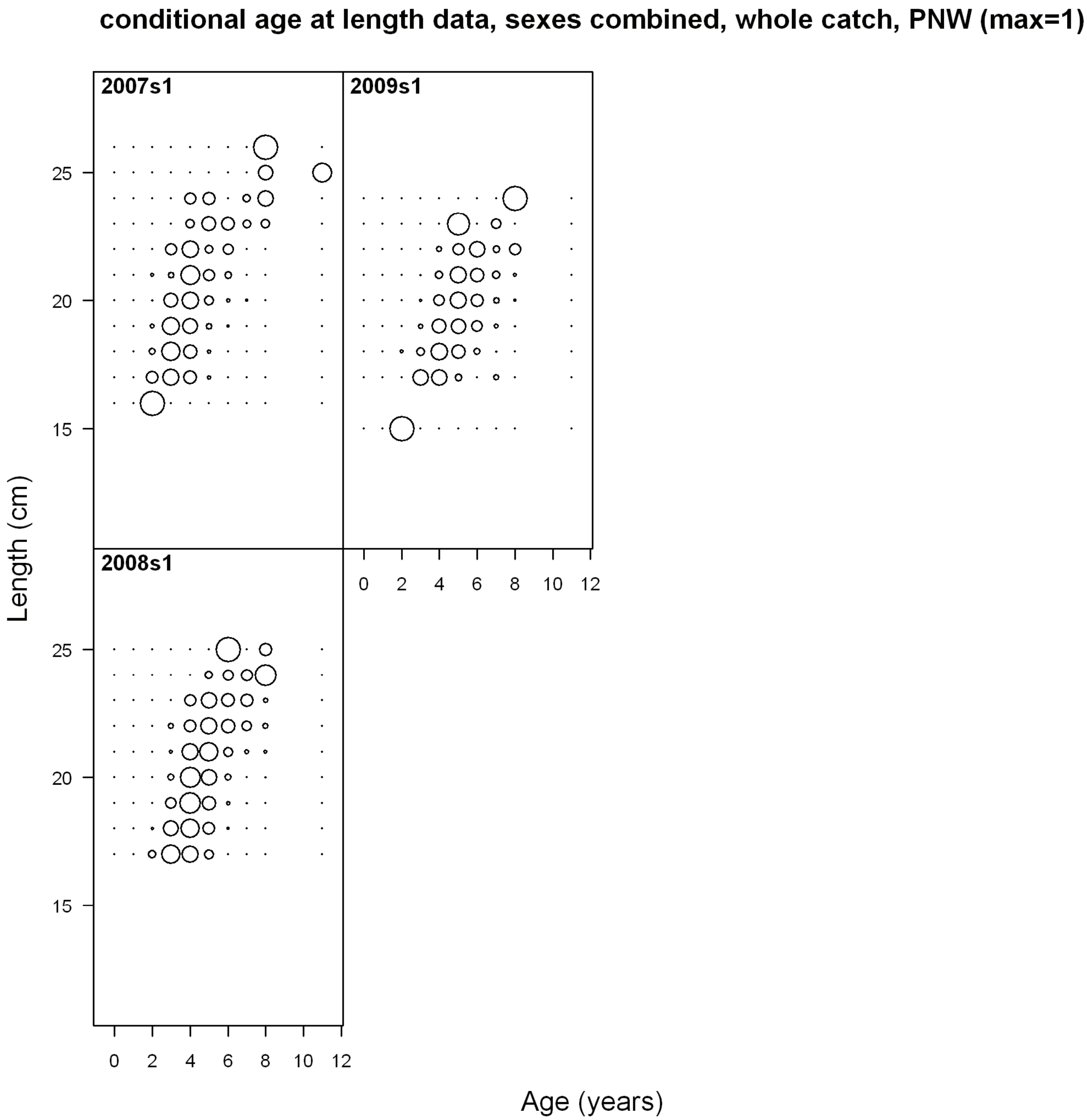


Figure 7f (cont'd). Conditional age-at-length data for the PNW fishery, 2007-2009.

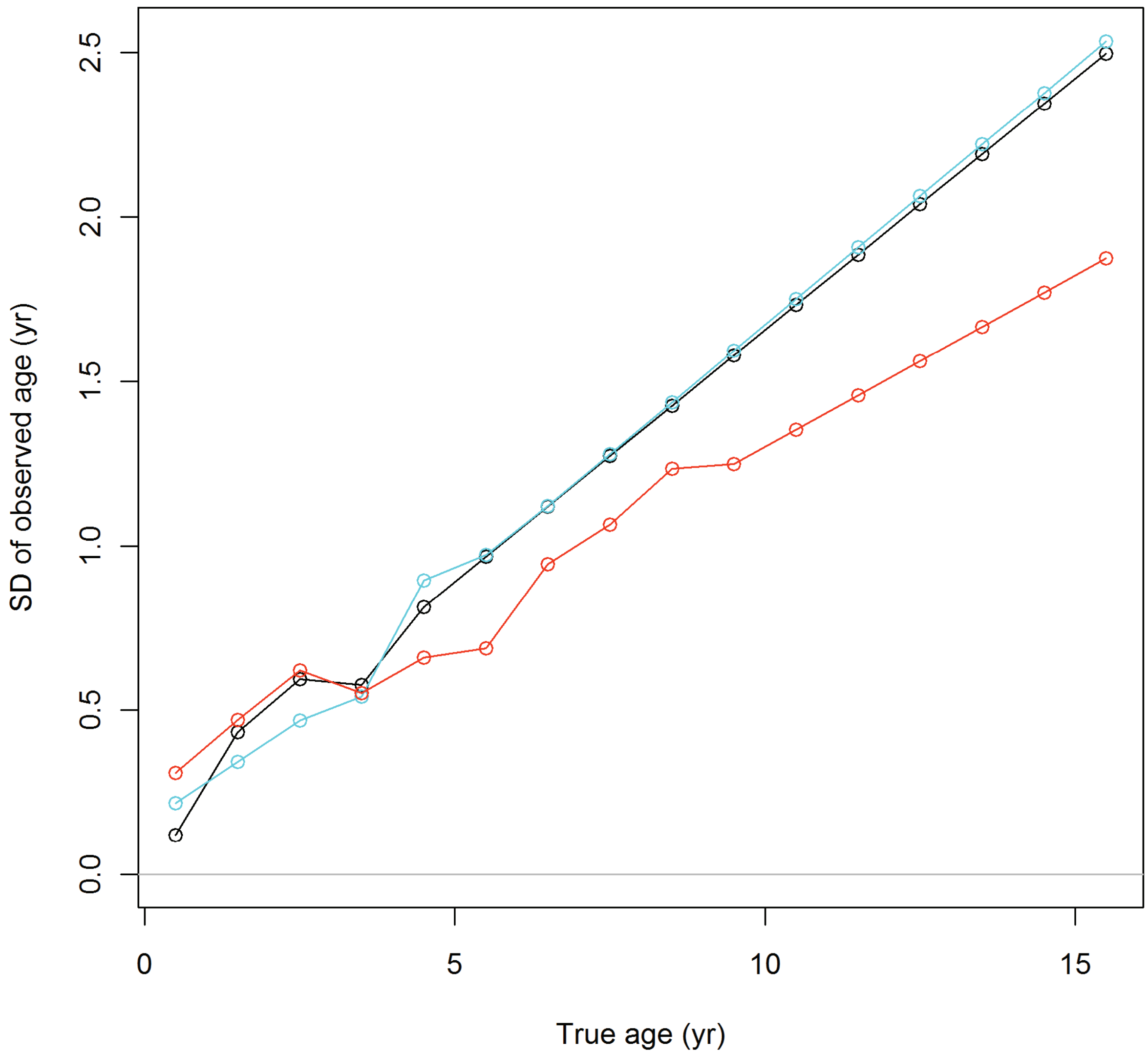


Figure 8. Fishery-specific ageing errors: black line is ENS, blue line is SCA and CCA, and red line is PNW.

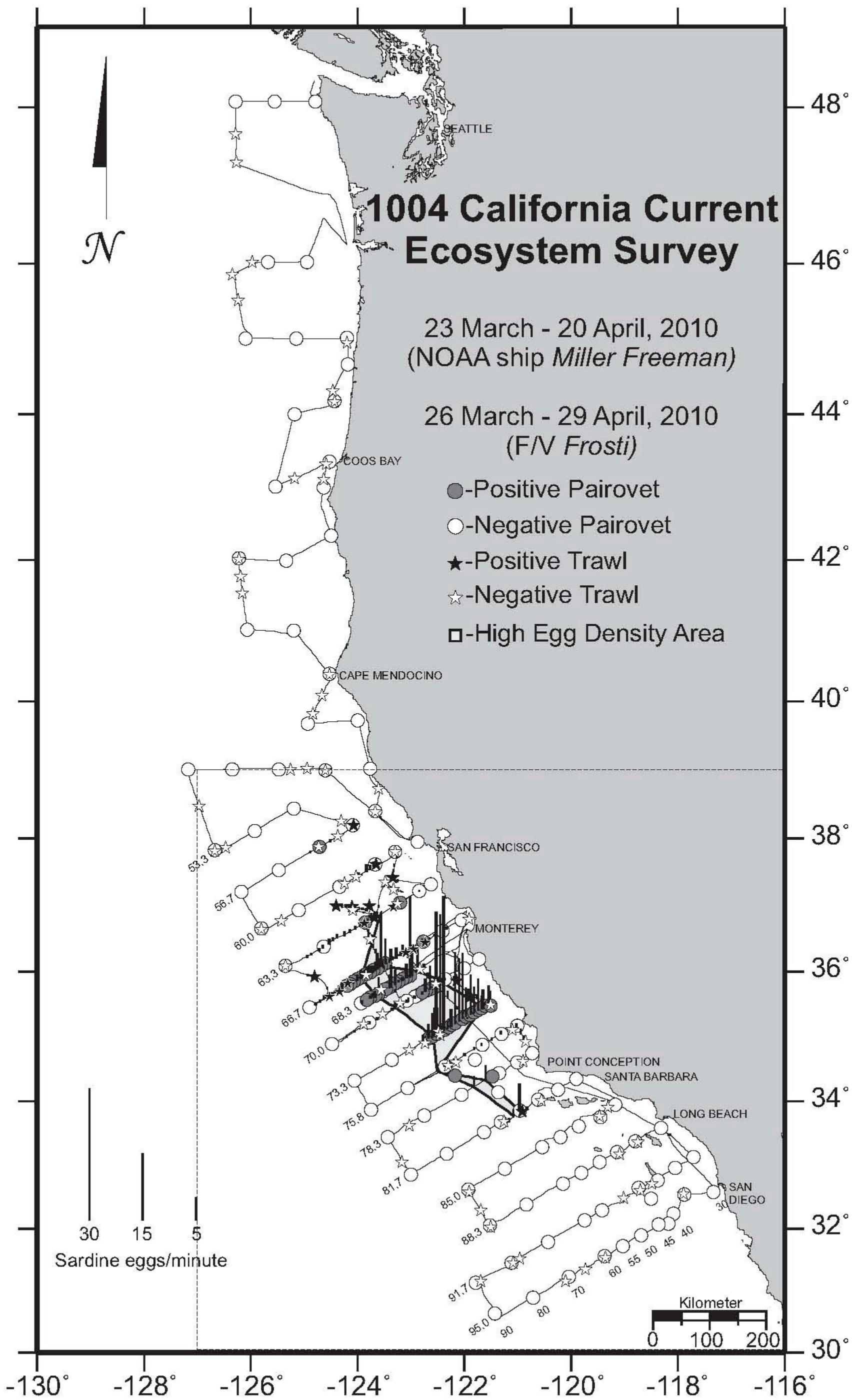


Figure 9. Distribution of CUFES and Pairovet ichthyoplankton collections, and adult trawl samples from the SWFSC 1004 sardine survey (coast-wide), conducted onboard the F/V *Frosti* and NOAA ship *Miller Freeman* during spring of 2010. Standard sampling area for the DEPM/TEP index (inset) is displayed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

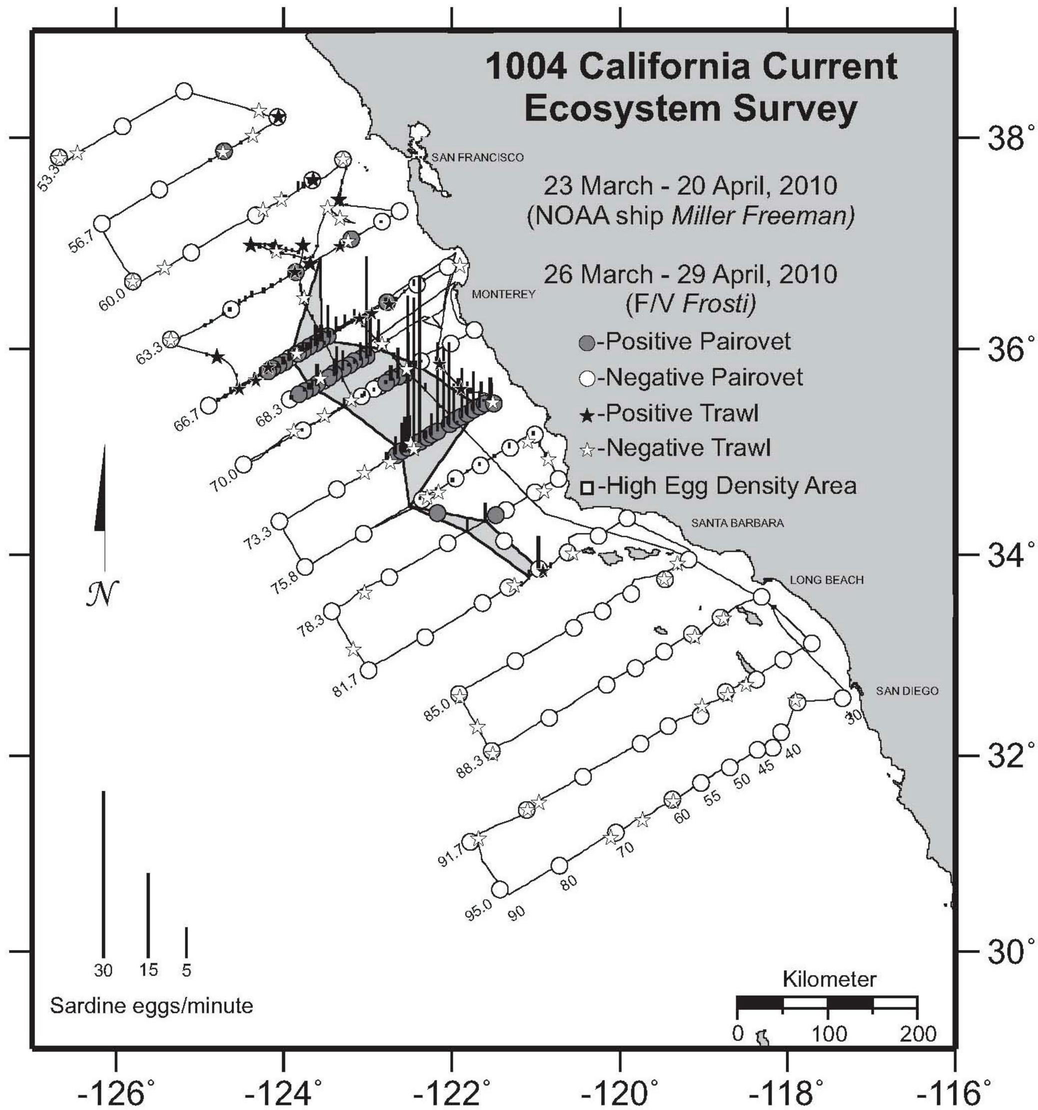


Figure 10. Distribution of CUFES and Pairovet ichthyoplankton collections, and adult trawl samples from the SWFSC 1004 sardine survey (standard sampling area for the DEPM index), conducted onboard the F/V *Frosti* and NOAA ship *Miller Freeman* during spring of 2010.

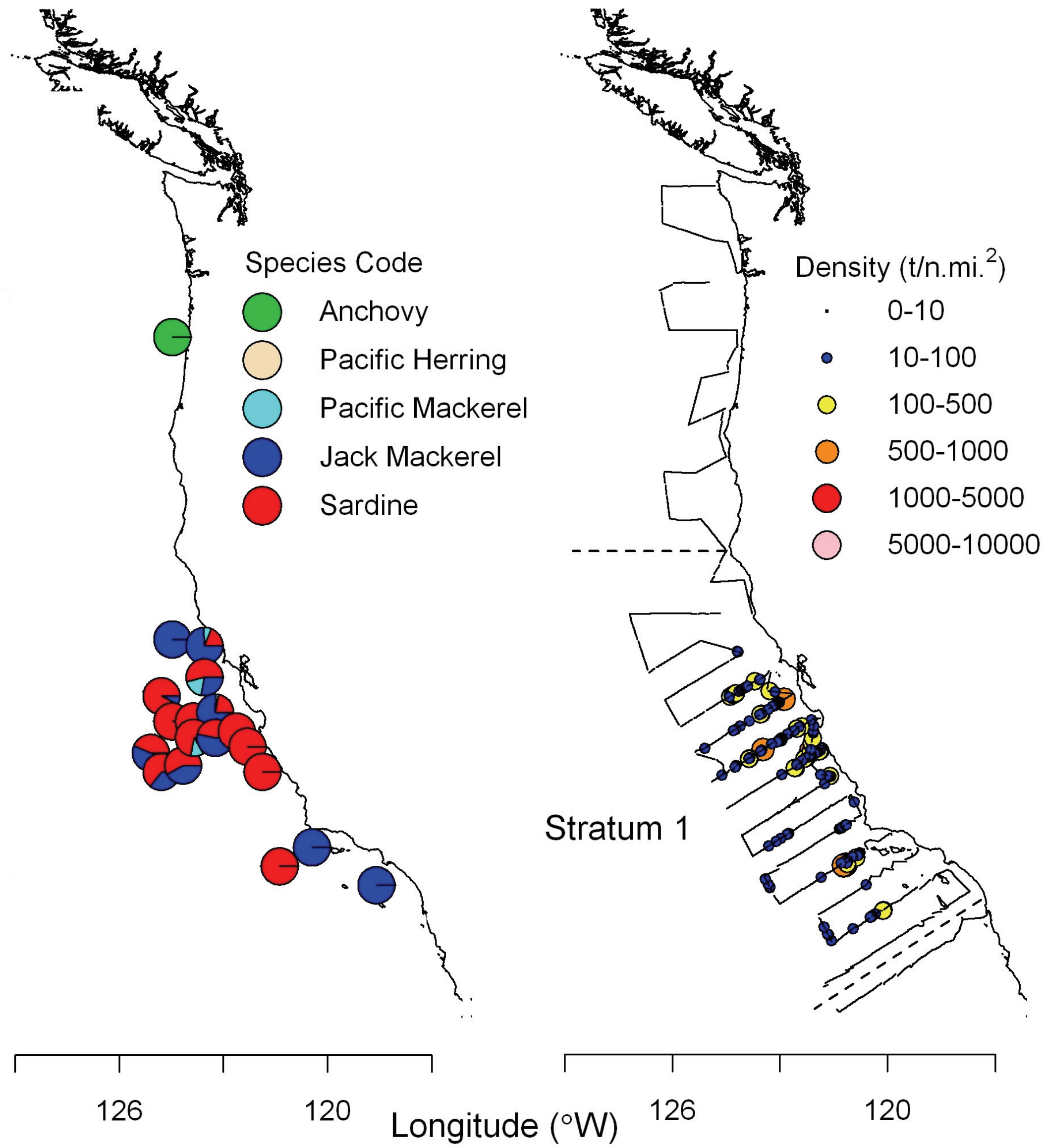


Figure 11. Trawl species composition (left) and Pacific sardine density (right) measured by acoustic backscatter during the SWFSC 1004 sardine survey (coast-wide), conducted onboard the F/V *Frosti* and NOAA ship *Miller Freeman* during spring of 2010. Maps provided by Drs. David Demer and Juan Zwolinski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

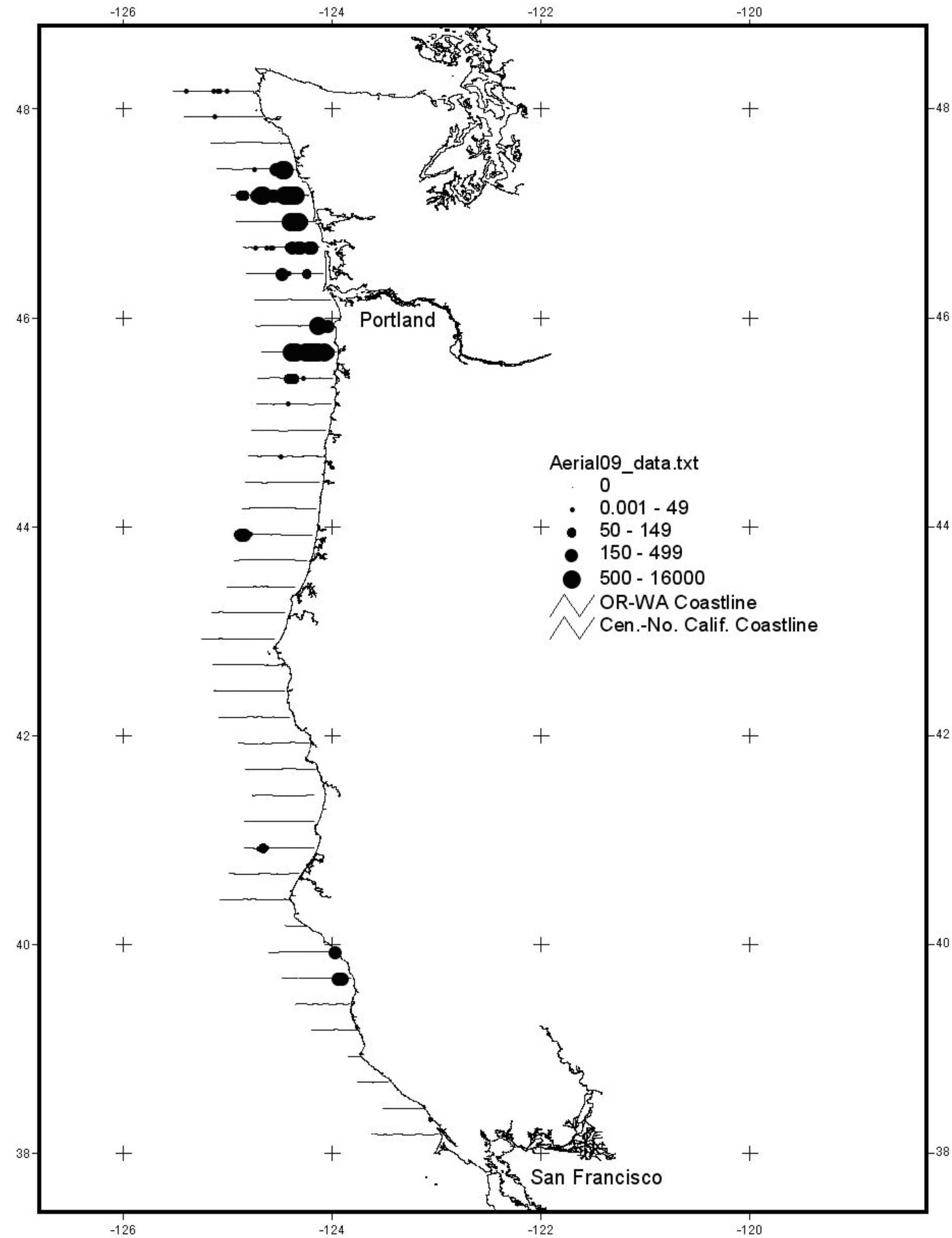


Figure 12. Map showing the distribution of sardine schools observed in the 2009 Aerial Sardine Survey (data from Jagielo 2009).

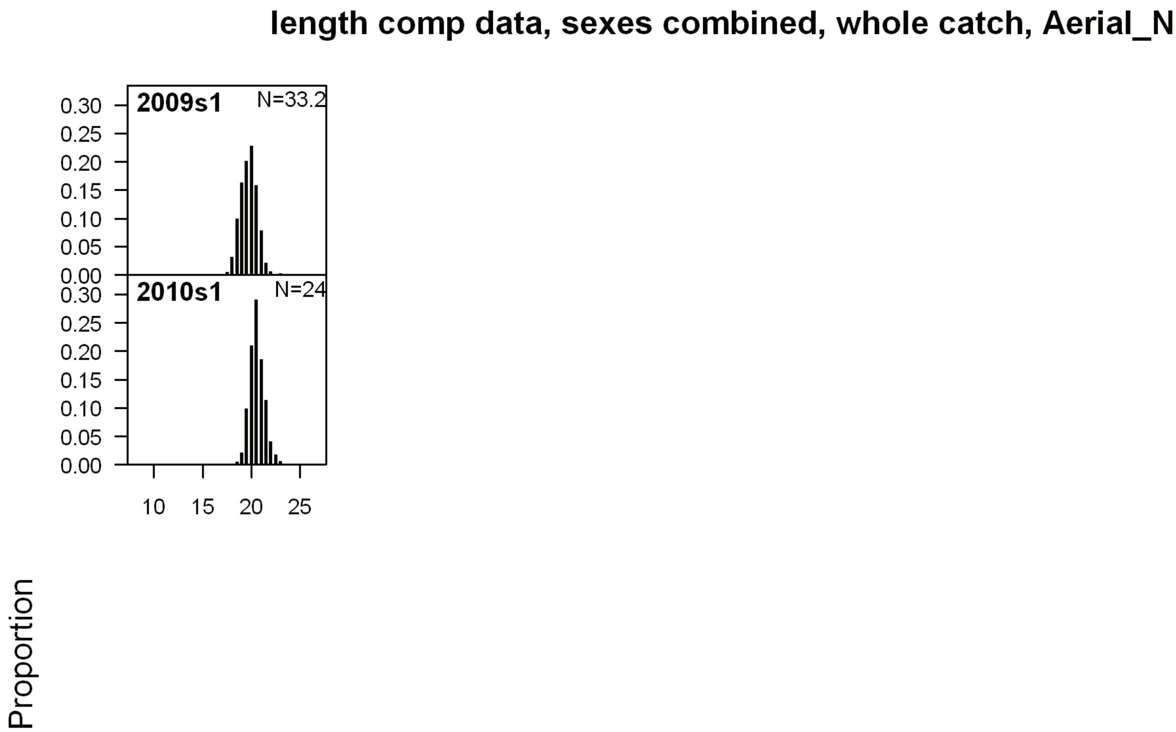


Figure 13. Length-composition data for the aerial survey.

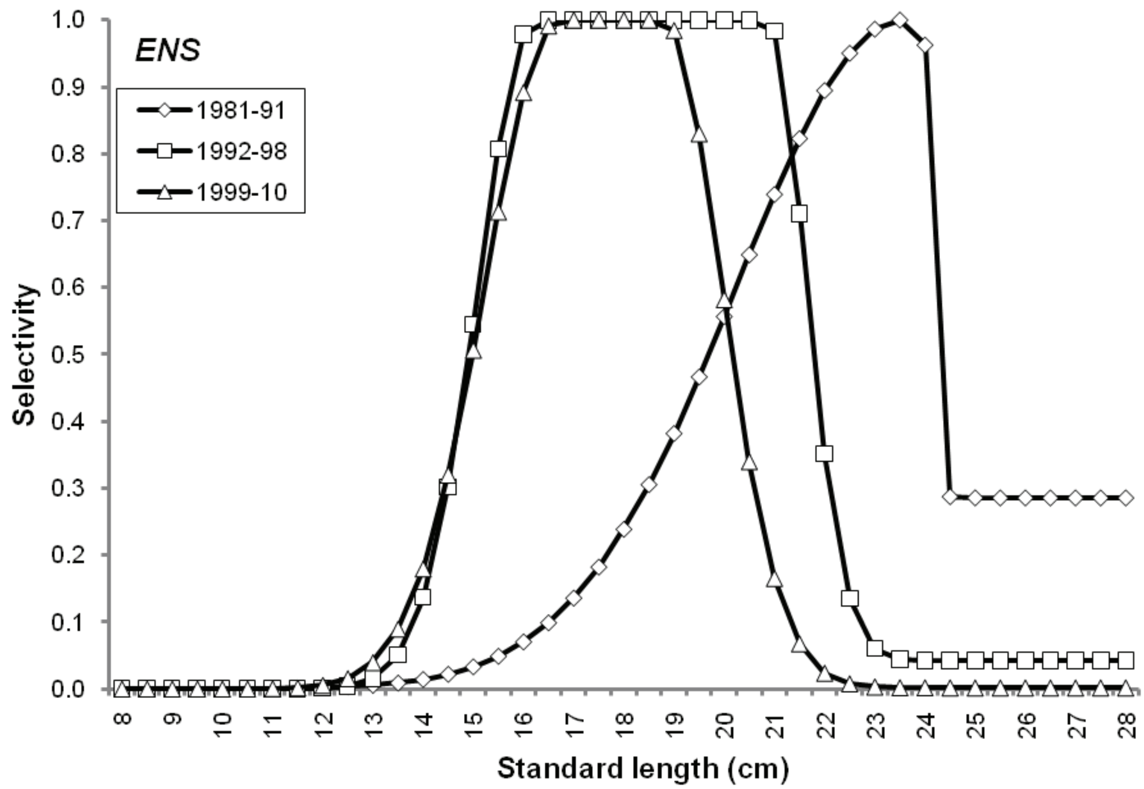


Figure 14a. Length-based selectivity for the ENS fleet by time block.

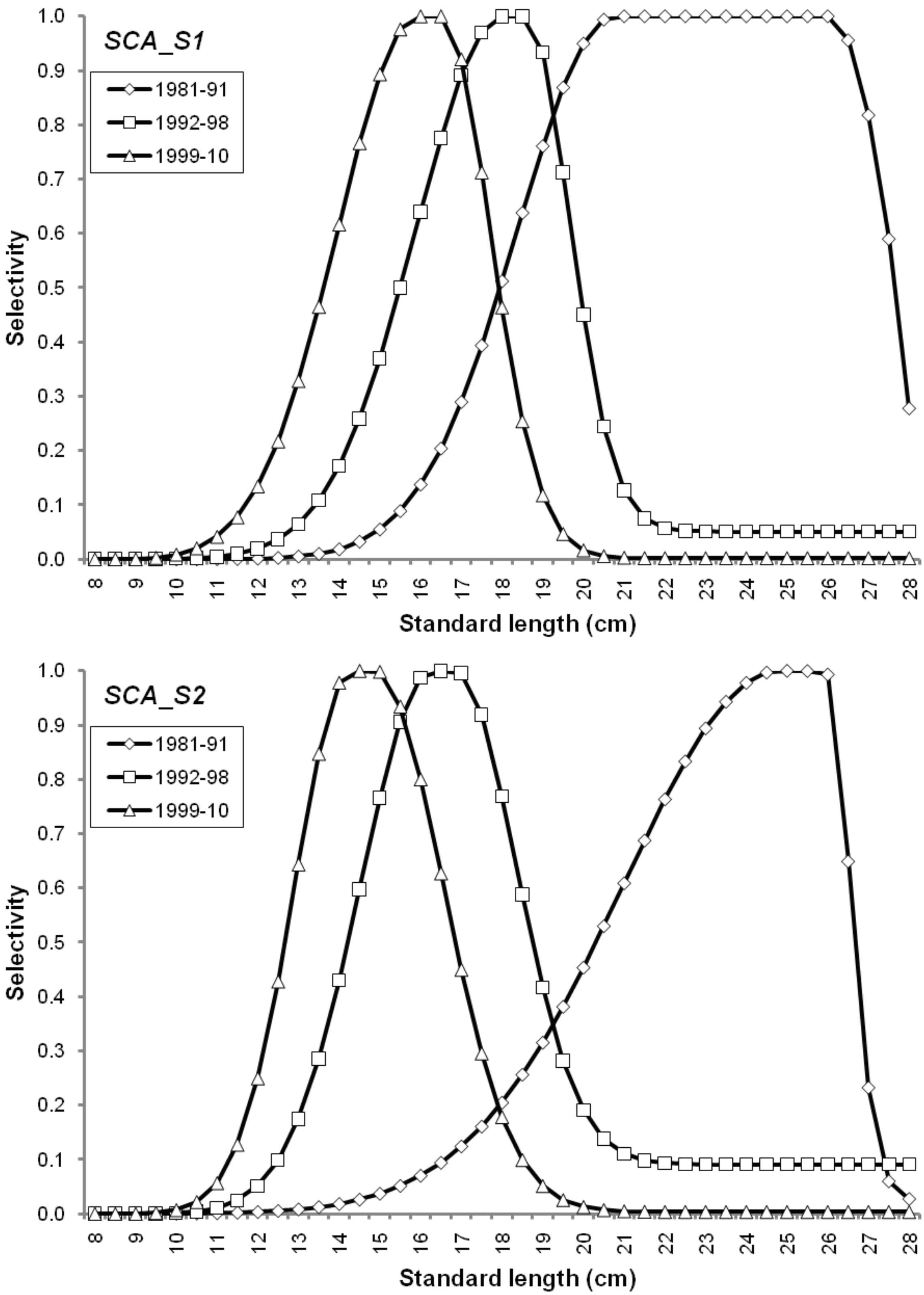


Figure 14b. Length-based selectivity for the SCA fleet by semester and time block.

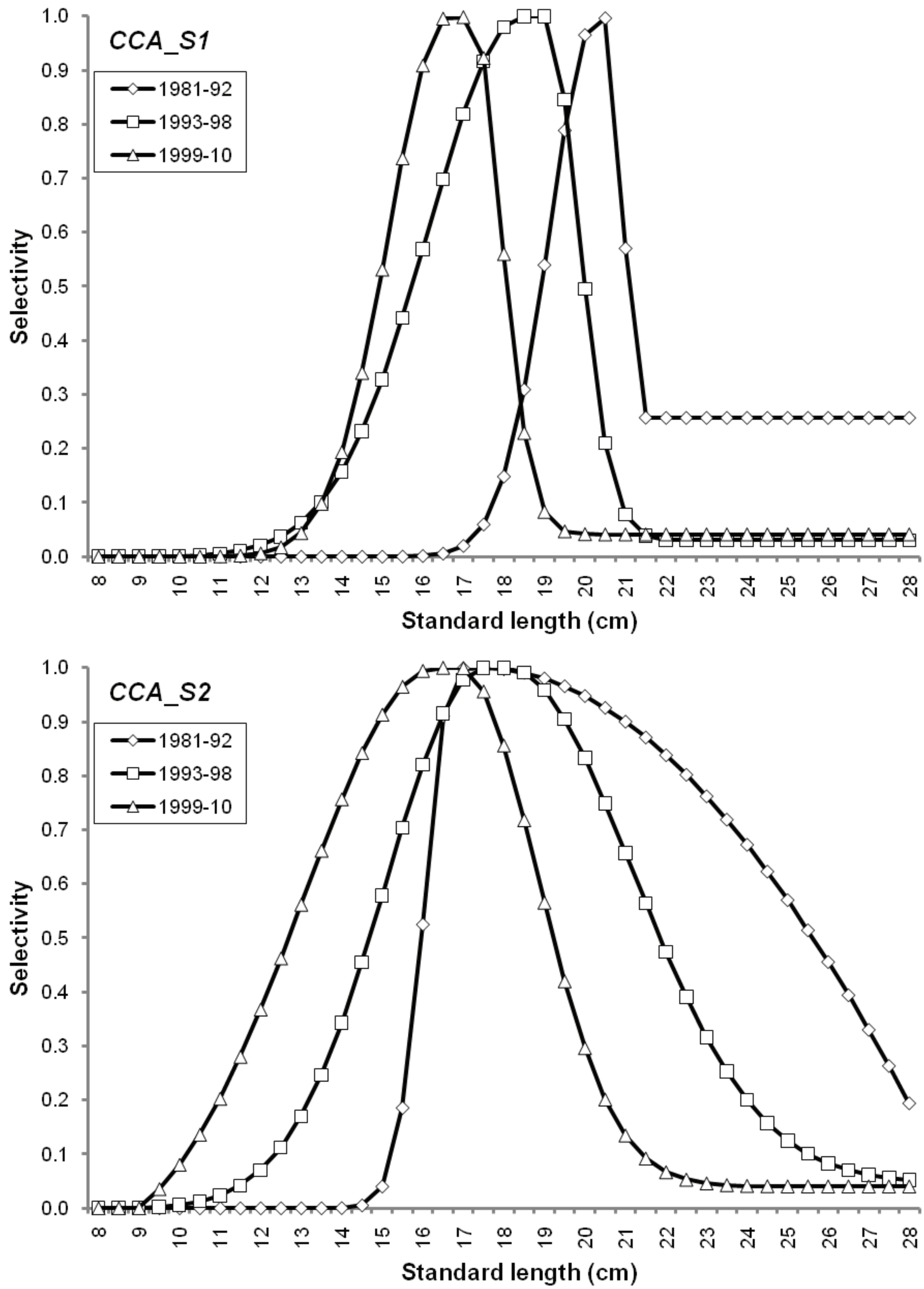


Figure 14c. Length-based selectivity for the CCA fleet by semester and time block.

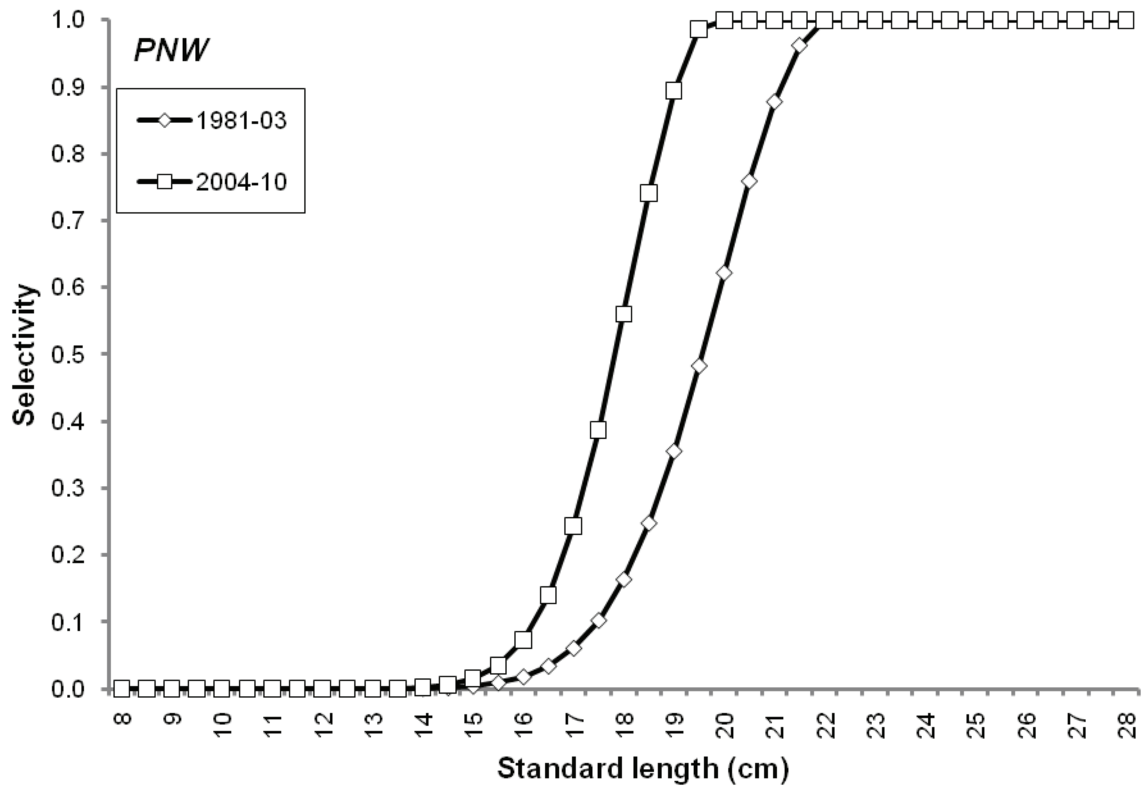


Figure 14d. Length-based selectivity for the PNW fleet by time block.

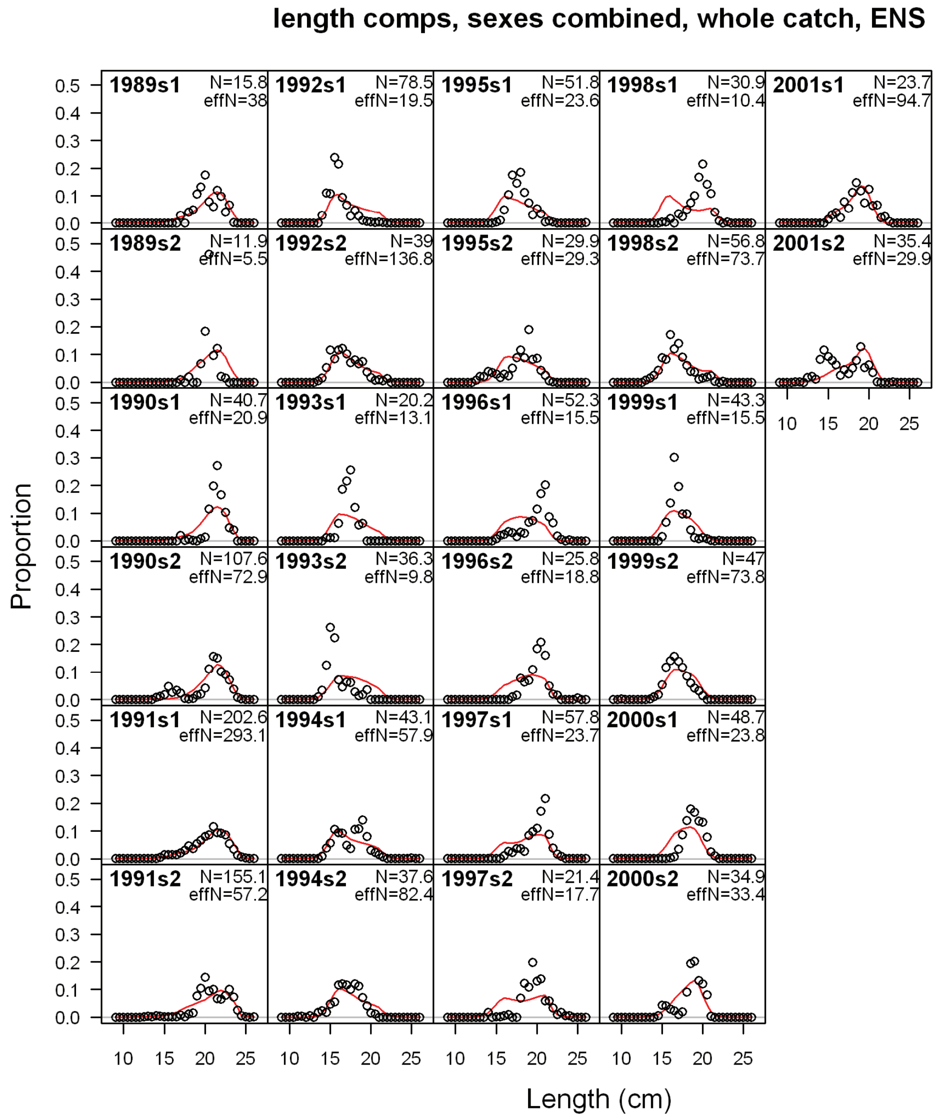


Figure 15a. Base model fits to length-frequency data for the ENS fishery.

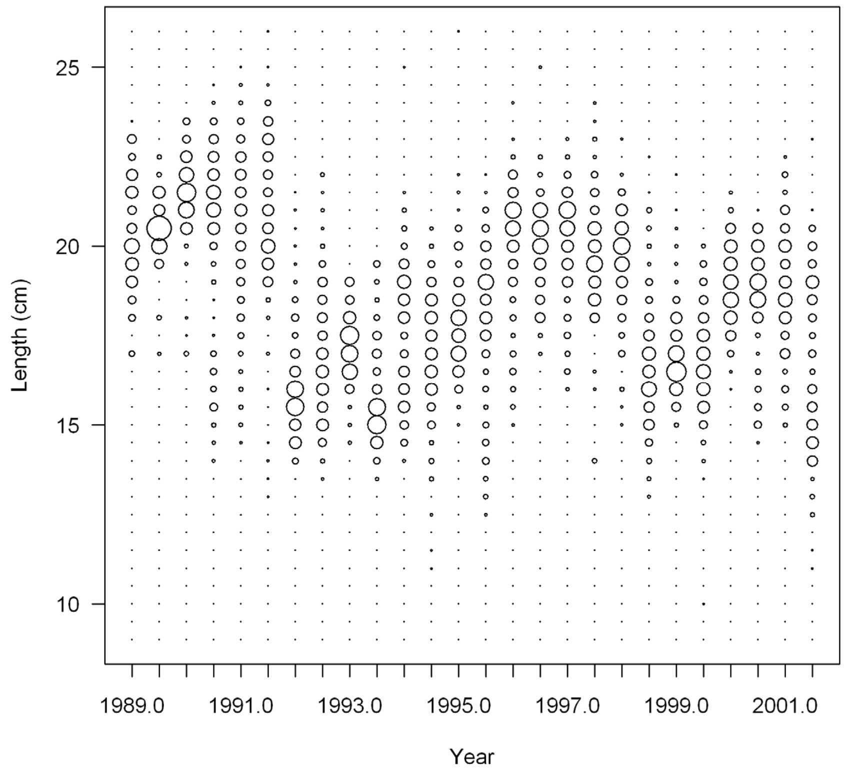


Figure 15b. Bubble plot of length-frequency data for the ENS fishery.

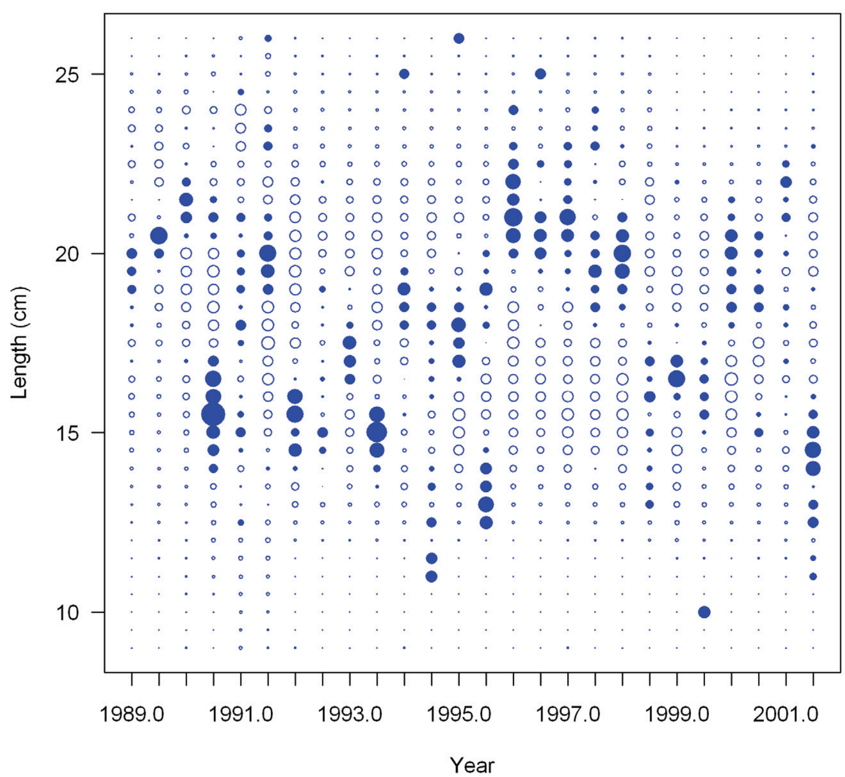


Figure 15c. Pearson residuals (max=7.82) for fit to length-frequency data for the ENS fishery.

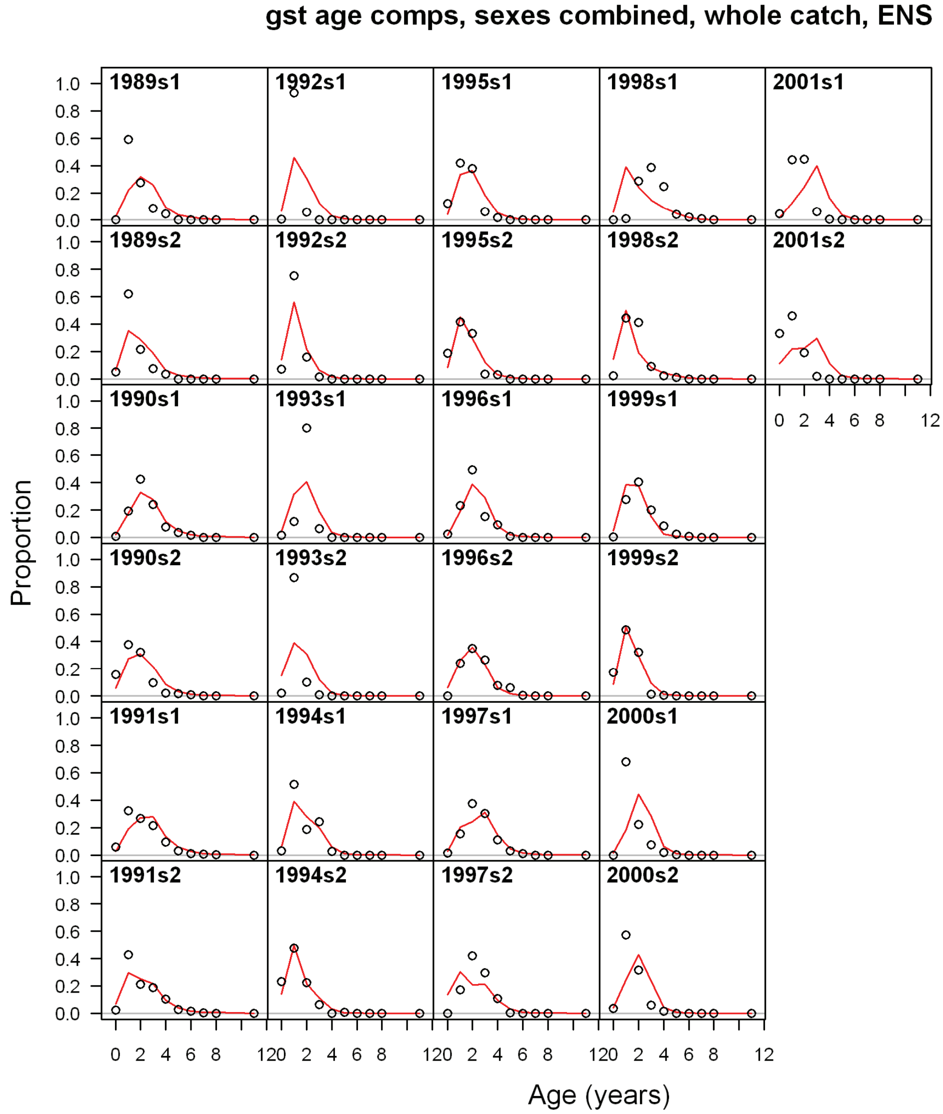


Figure 16a. Base model fits to implied age-frequency data for the ENS fishery.

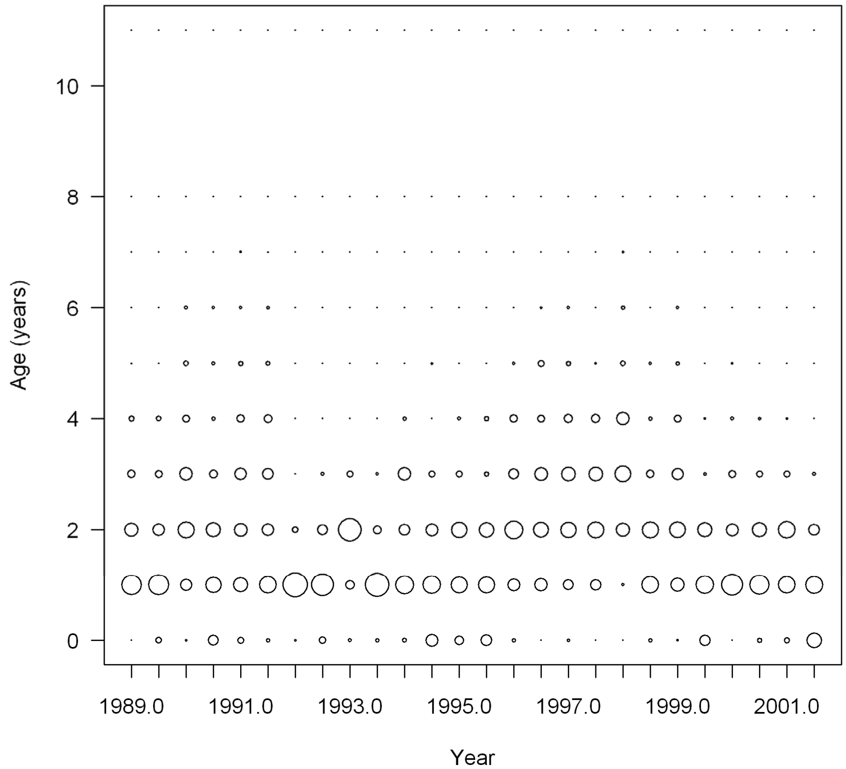


Figure 16b. Bubble plot of age-frequency data for the ENS fishery.

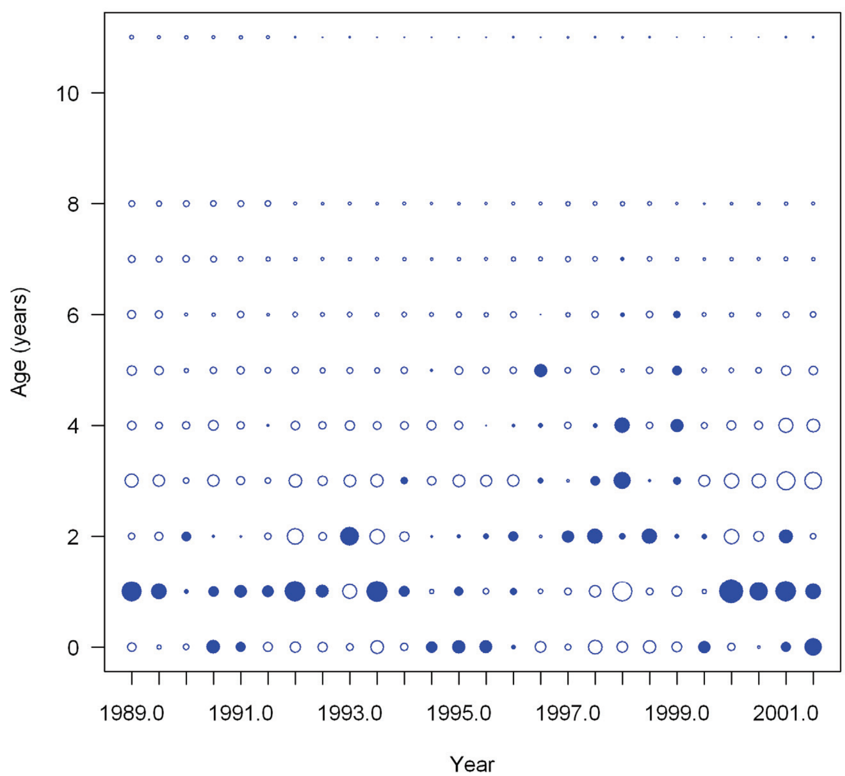


Figure 16c. Pearson residuals (max=1.28) for fit to implied age-frequency data for the ENS fishery.

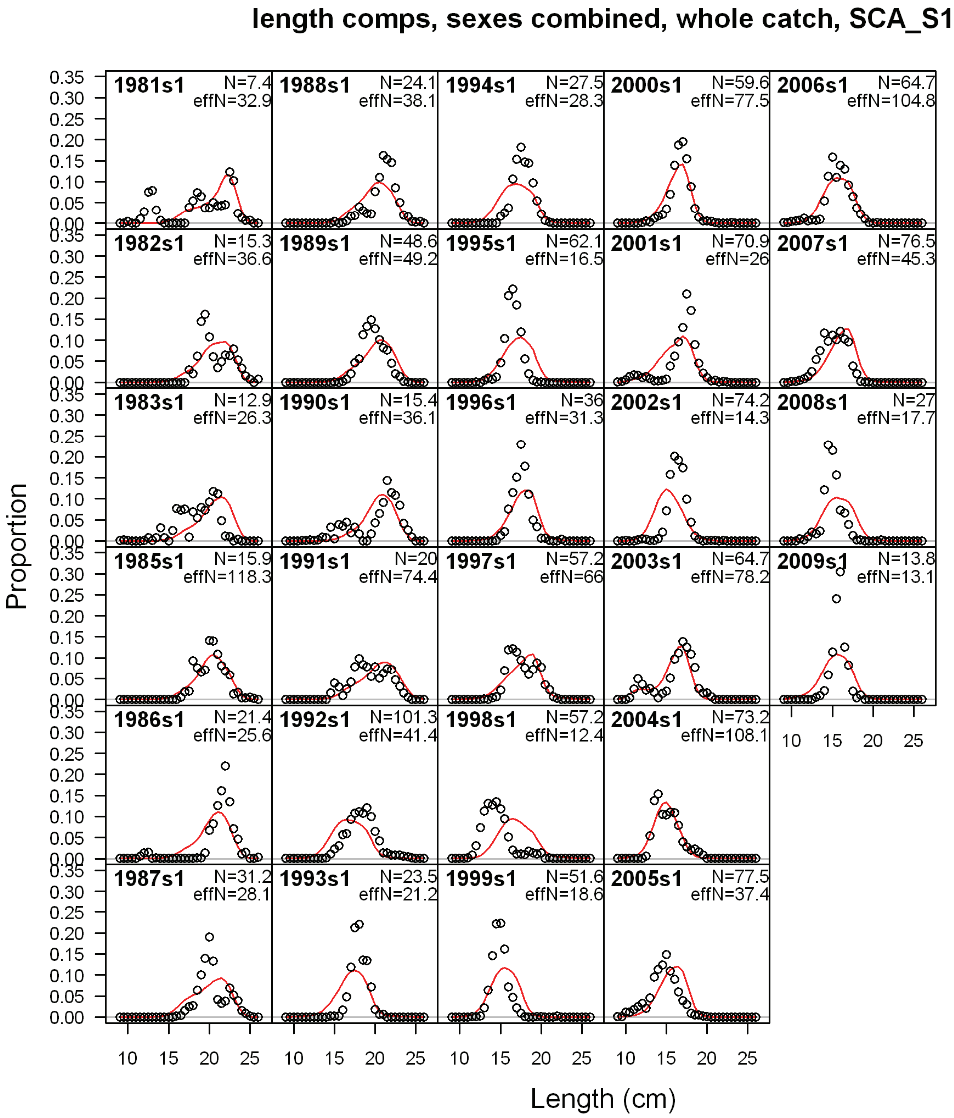


Figure 17a. Base model fits to length-frequency data for the SCA_S1 fishery.

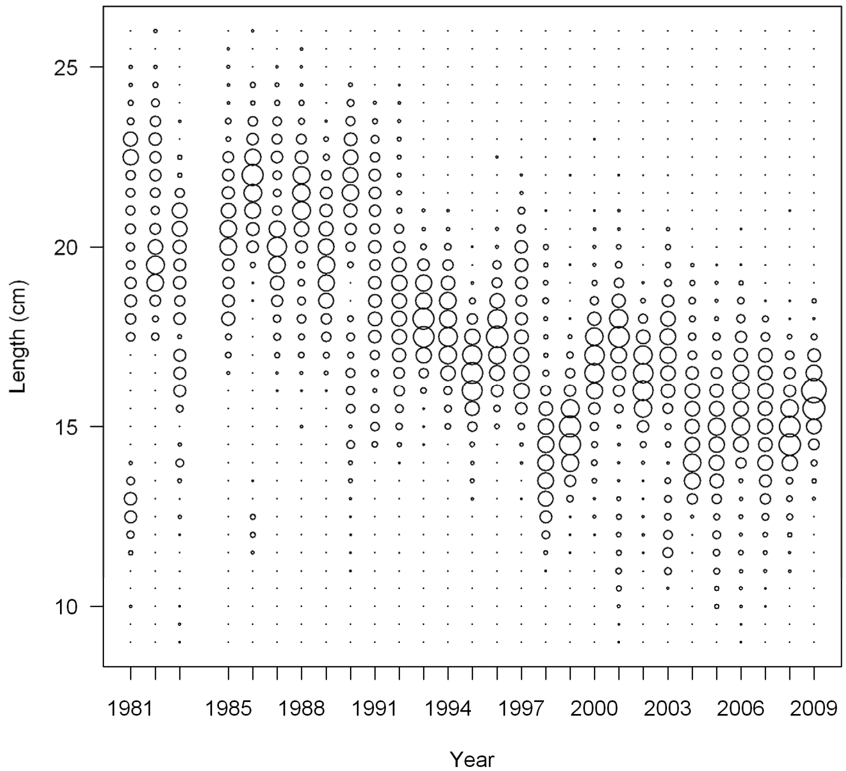


Figure 17b. Bubble plot of length-frequency data for the SCA_S1 fishery.

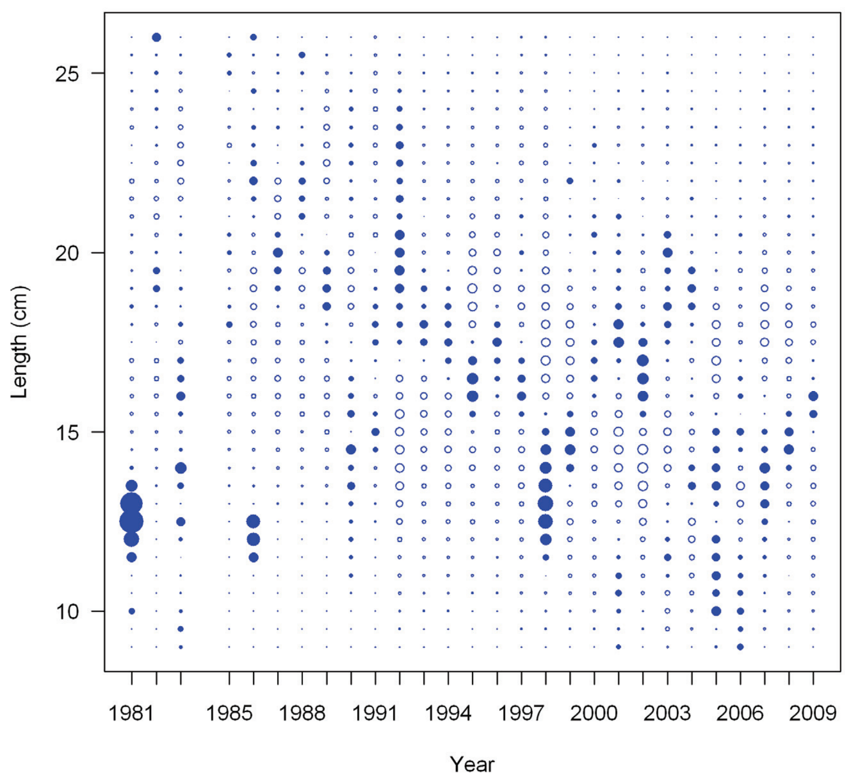


Figure 17c. Pearson residuals (max=15.68) for fit to length-frequency data for the SCA_S1 fishery.

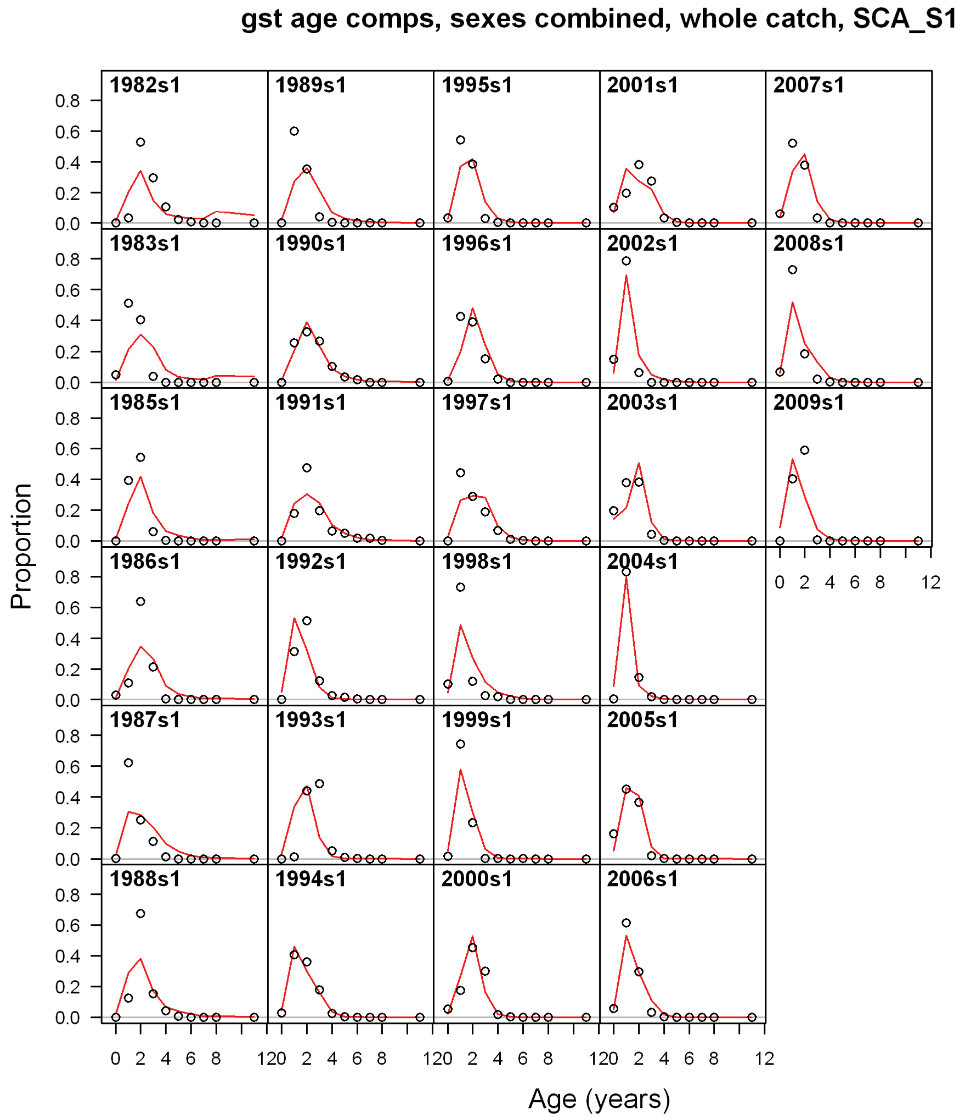


Figure 18a. Base model fits to implied age-frequency data for the SCA_S1 fishery.

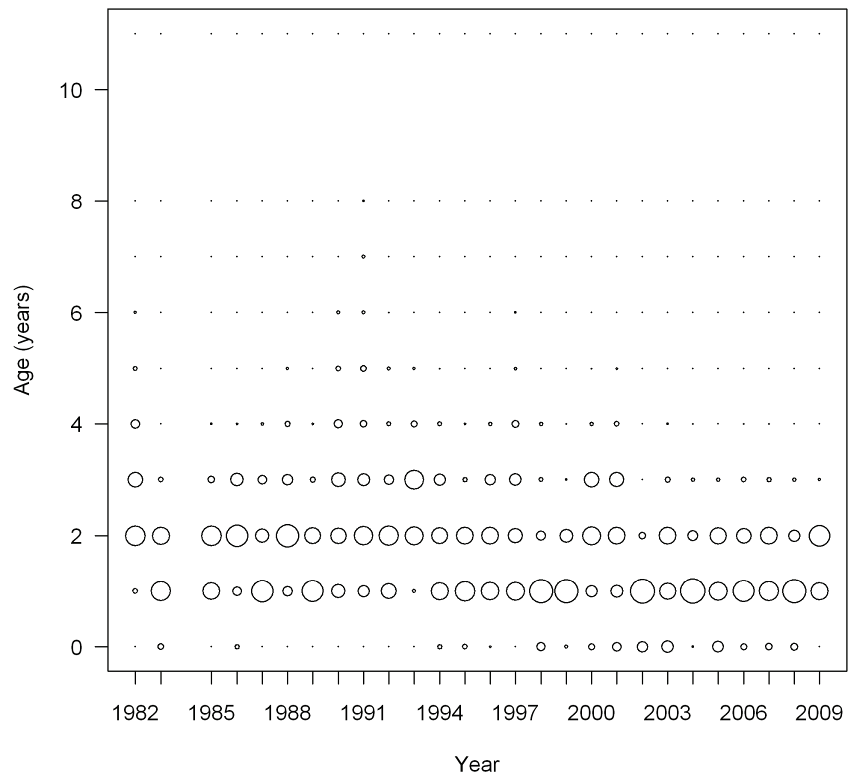


Figure 18b. Bubble plot of age-frequency data for the SCA_S1 fishery.

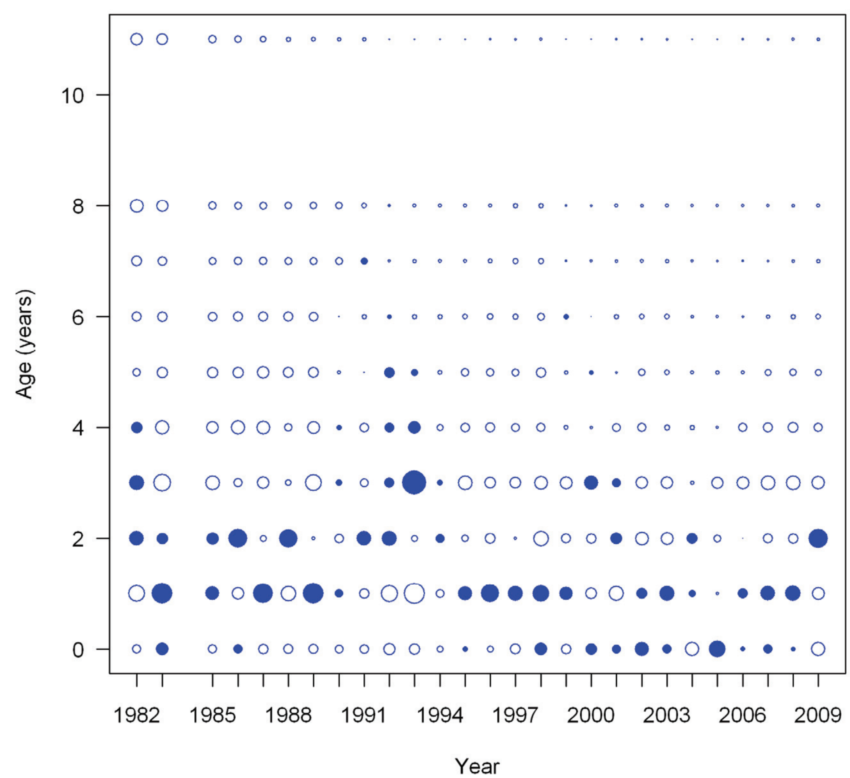


Figure 18c. Pearson residuals (max=1.01) for fit to implied age-frequency data for the SCA_S1 fishery.

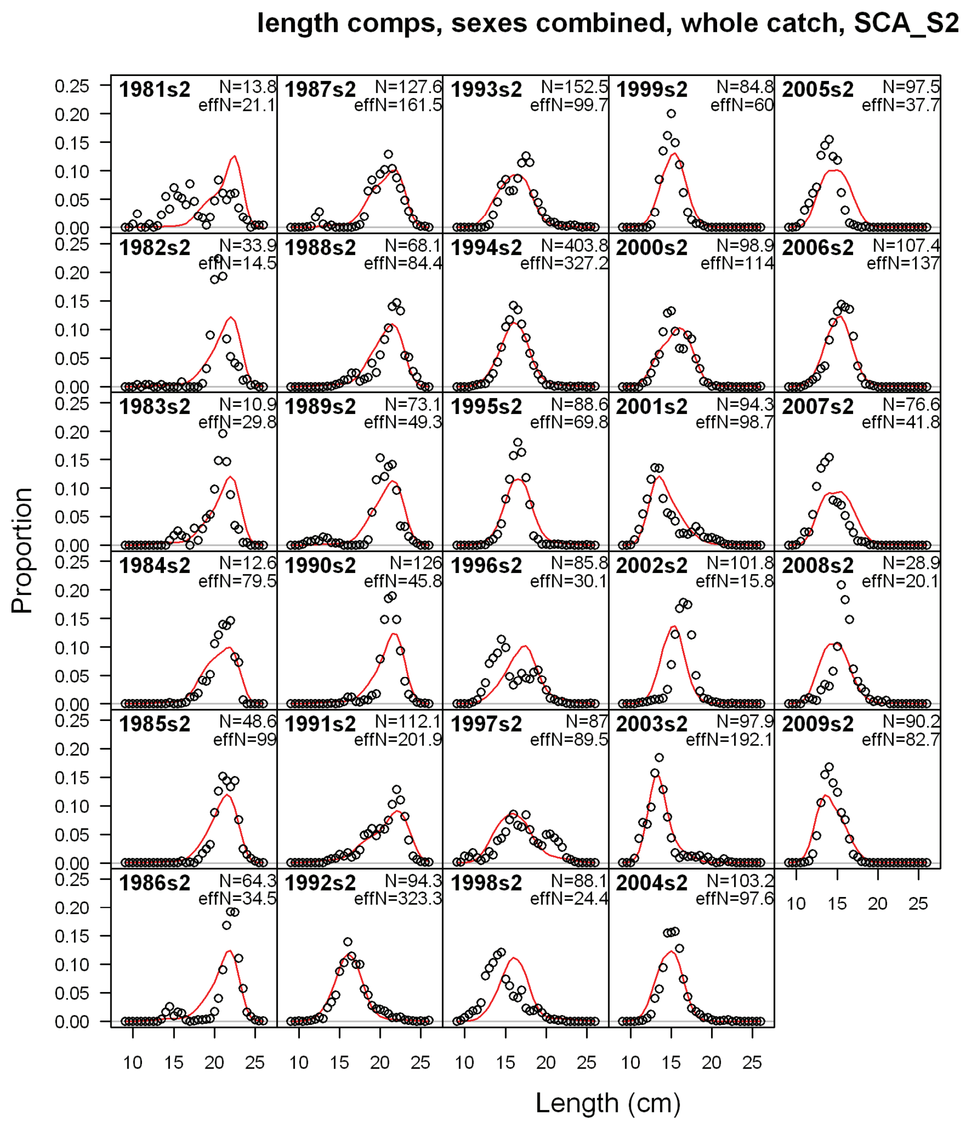


Figure 19a. Base model fits to length-frequency data for the SCA_S2 fishery.

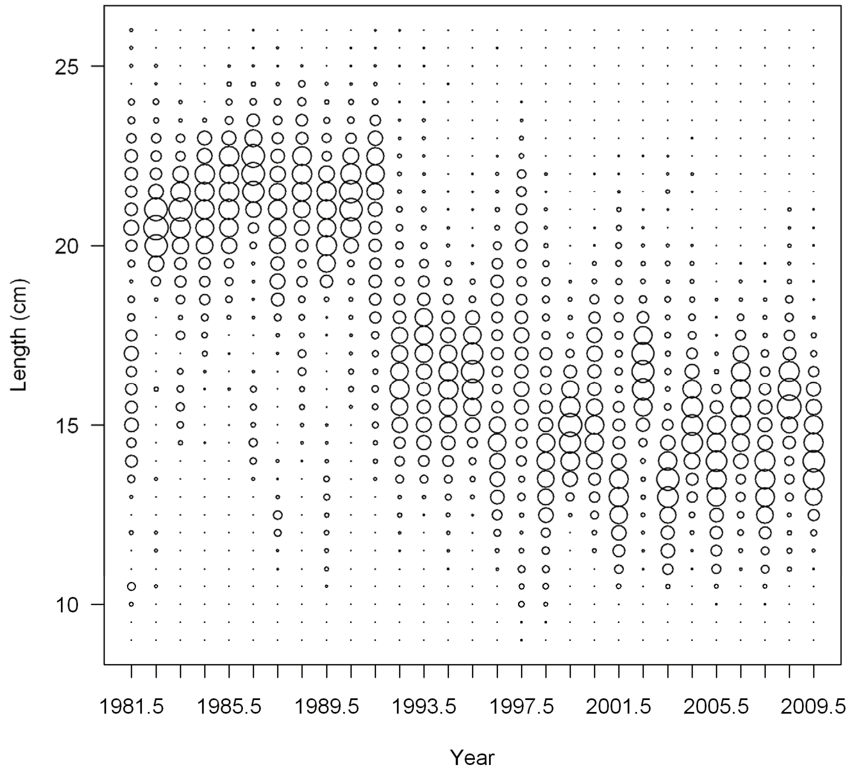


Figure 19b. Bubble plot of length-frequency data for the SCA_S2 fishery.

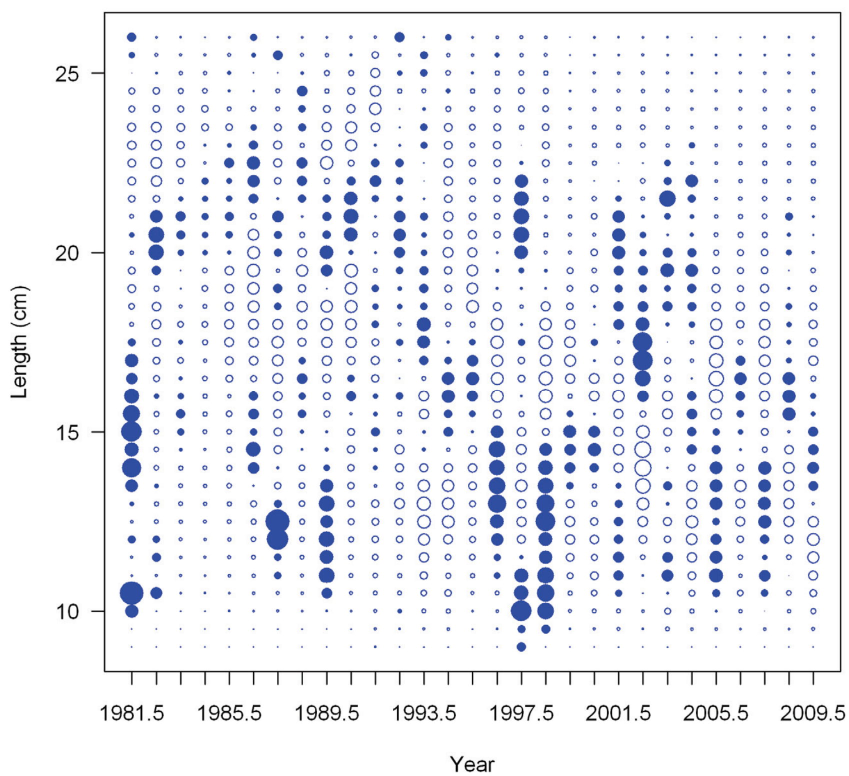


Figure 19c. Pearson residuals (max=6.76) for fit to length-frequency data for the SCA_S2 fishery.

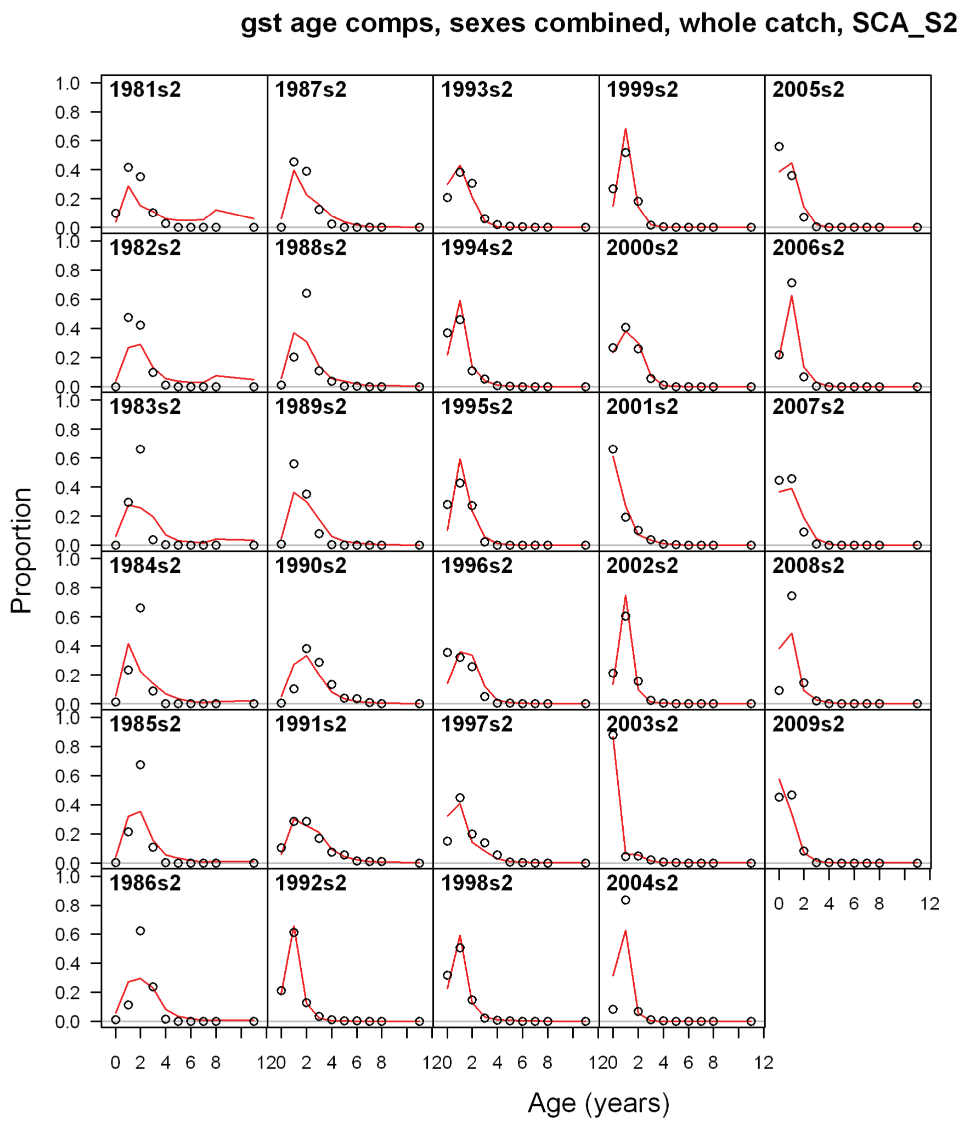


Figure 20a. Base model fits to implied age-frequency data for the SCA_S2 fishery.

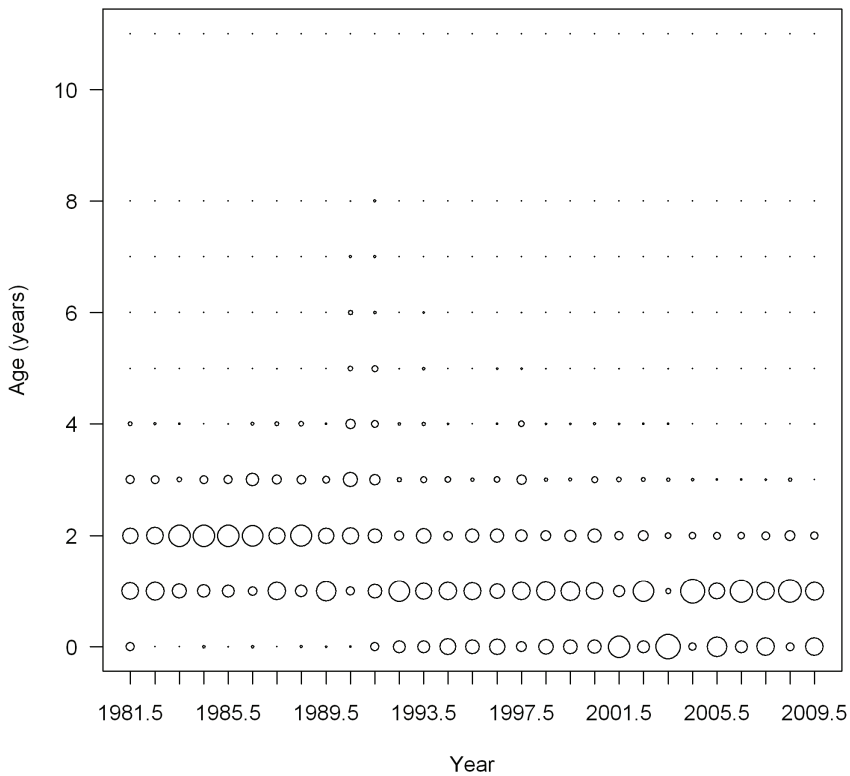


Figure 20b. Bubble plot of implied age-frequency data for the SCA_S2 fishery.

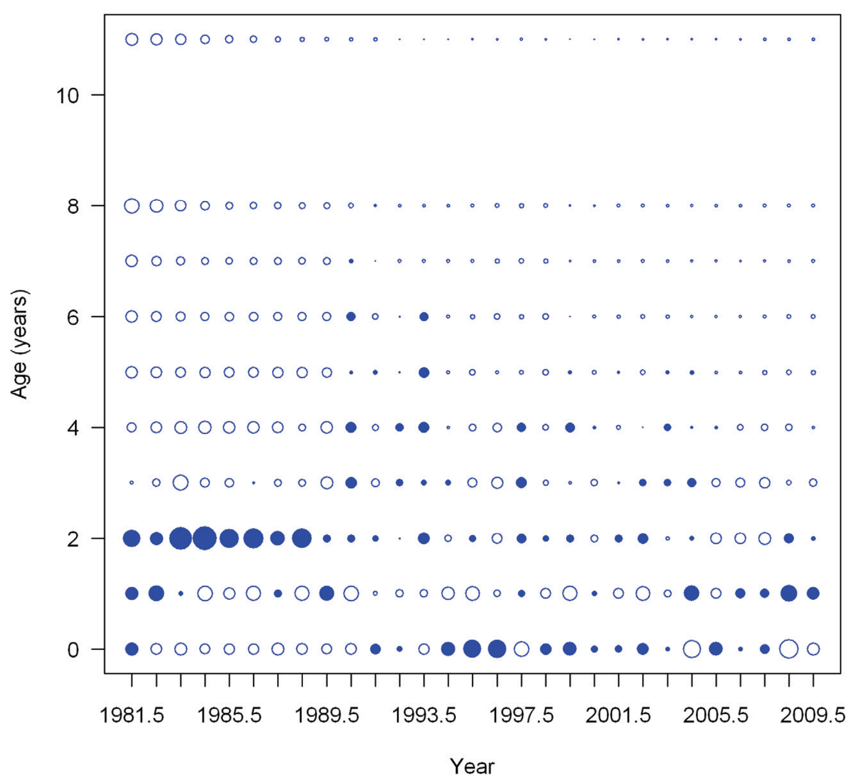


Figure 20c. Pearson residuals (max=1.04) for fit to implied age-frequency data for the SCA_S2 fishery.

length comps, sexes combined, whole catch, CCA_S1

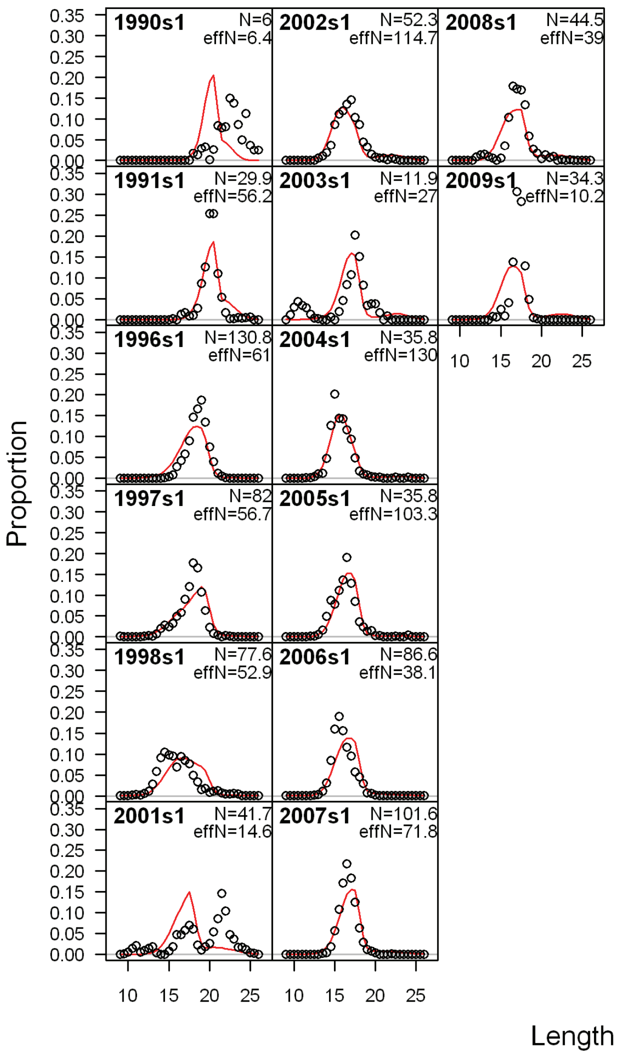


Figure 21a. Base model fits to length-frequency data for the CCA_S1 fishery.

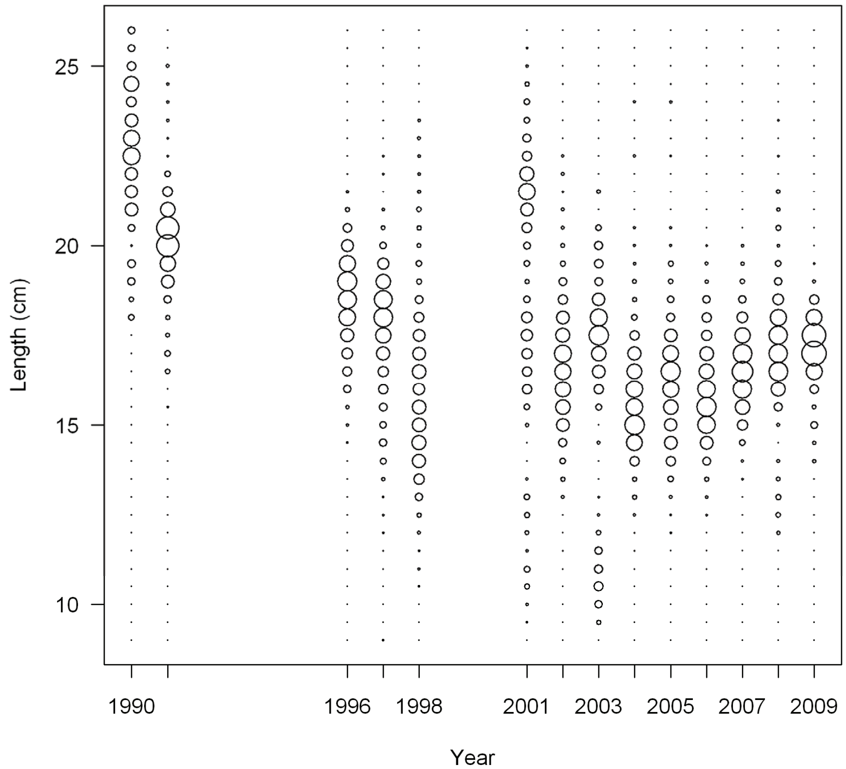


Figure 21b. Bubble plot of length-frequency data for the CCA_S1 fishery.

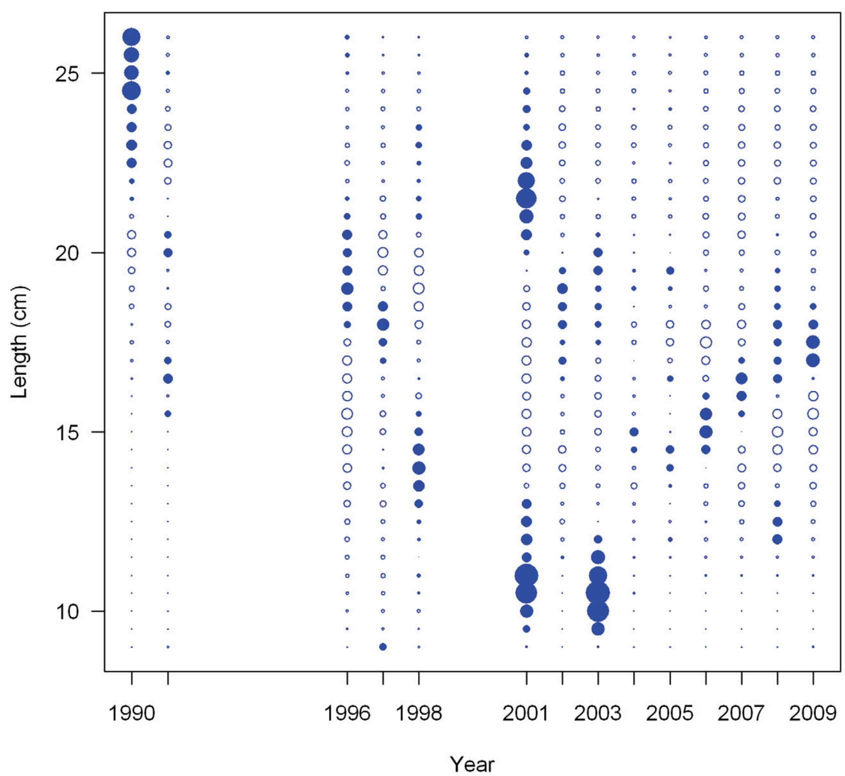


Figure 21c. Pearson residuals (max=9.64) for fit to length-frequency data for the CCA_S1 fishery.

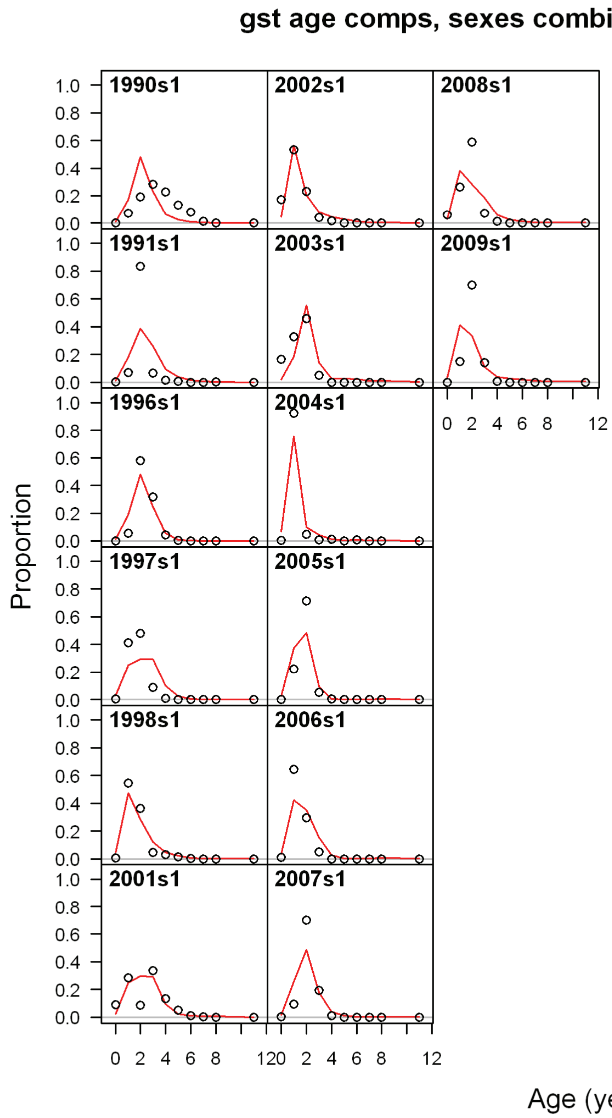


Figure 22a. Base model fits to implied age-frequency data for the CCA_S1 fishery.

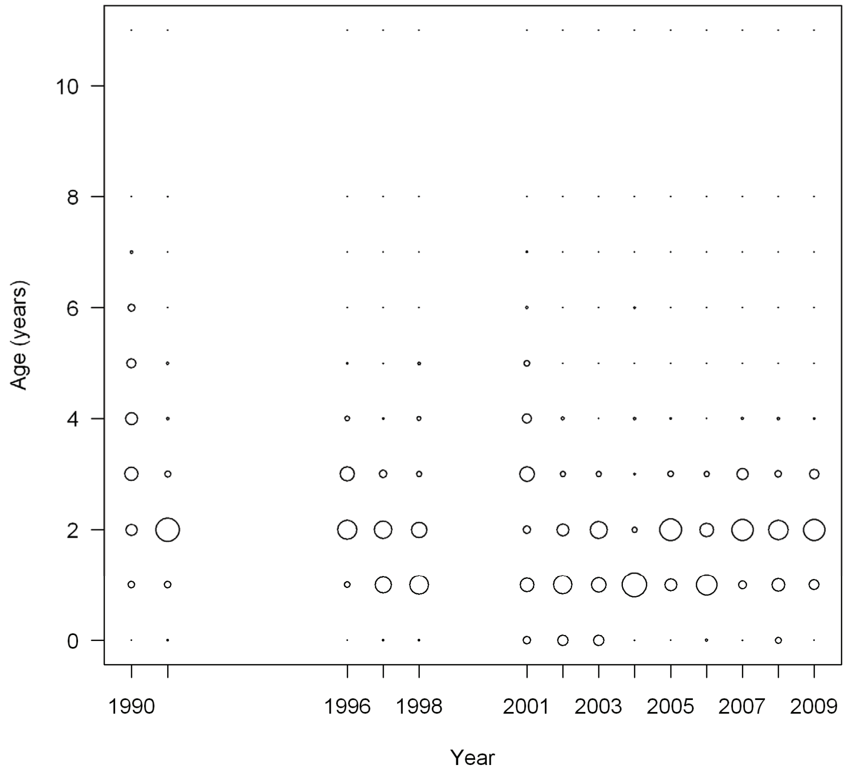


Figure 22b. Bubble plot of implied age-frequency data for the CCA_S1 fishery.

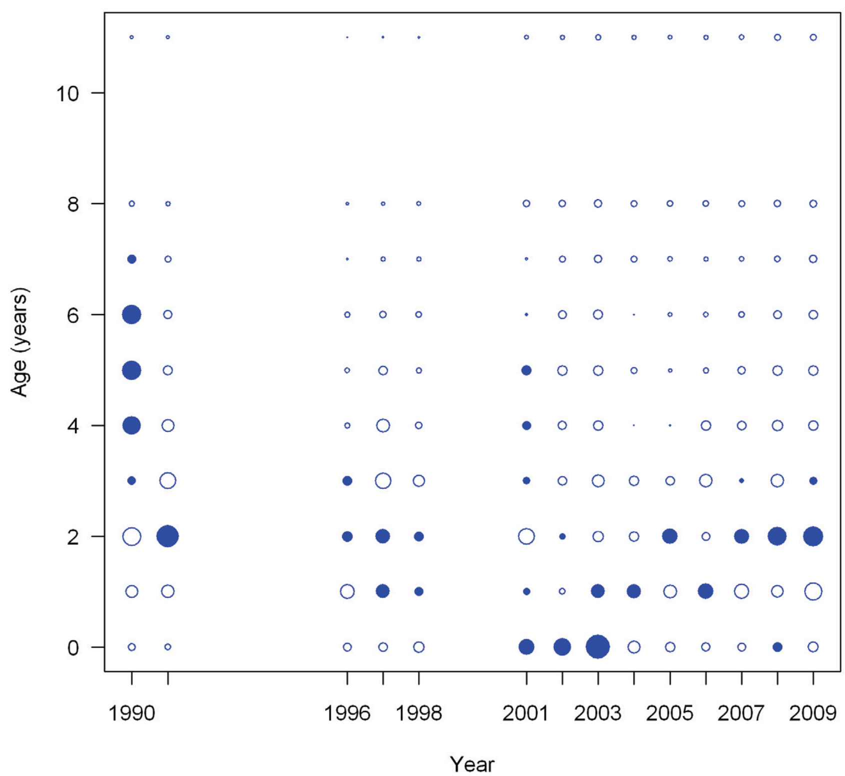


Figure 22c. Pearson residuals (max=1.09) for fit to implied age-frequency data for the CCA_S1 fishery.

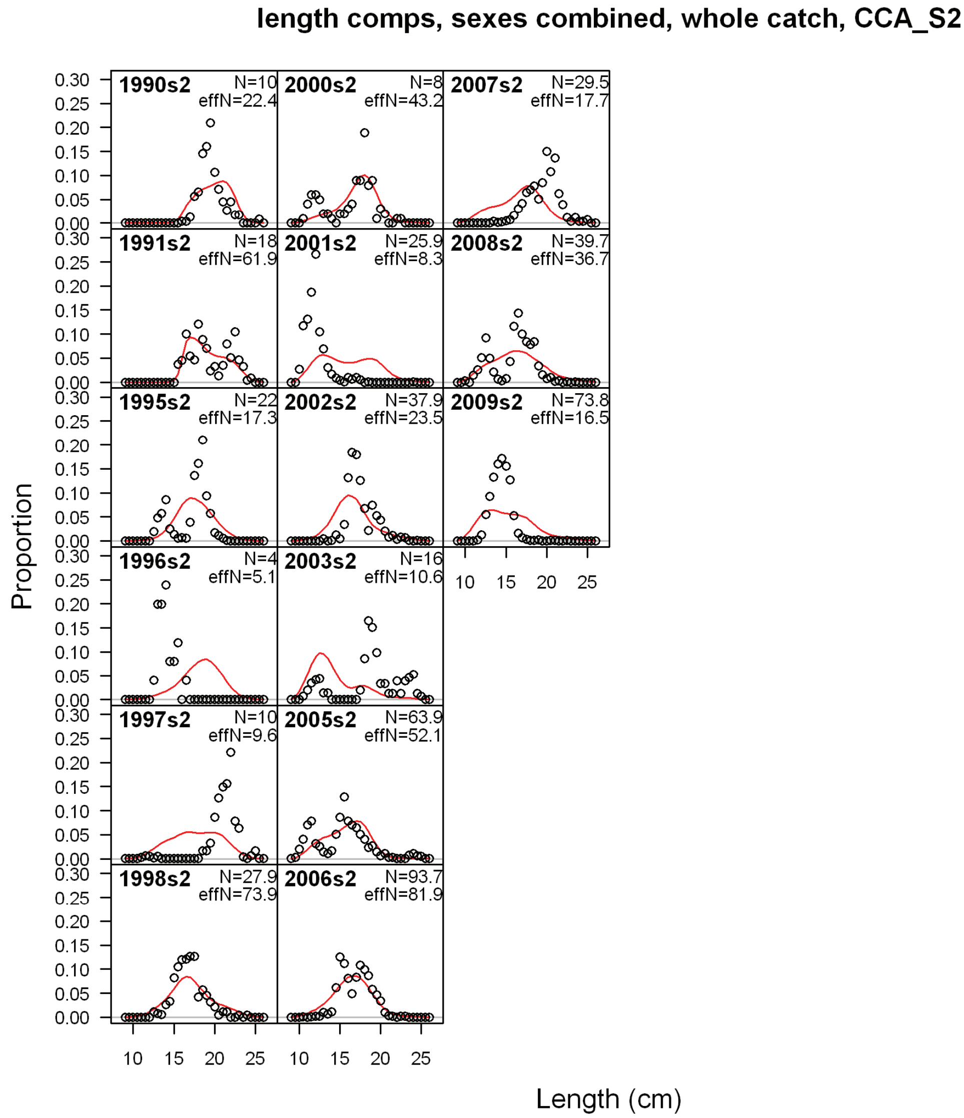


Figure 23a. Base model fits to length-frequency data for the CCA_S2 fishery.

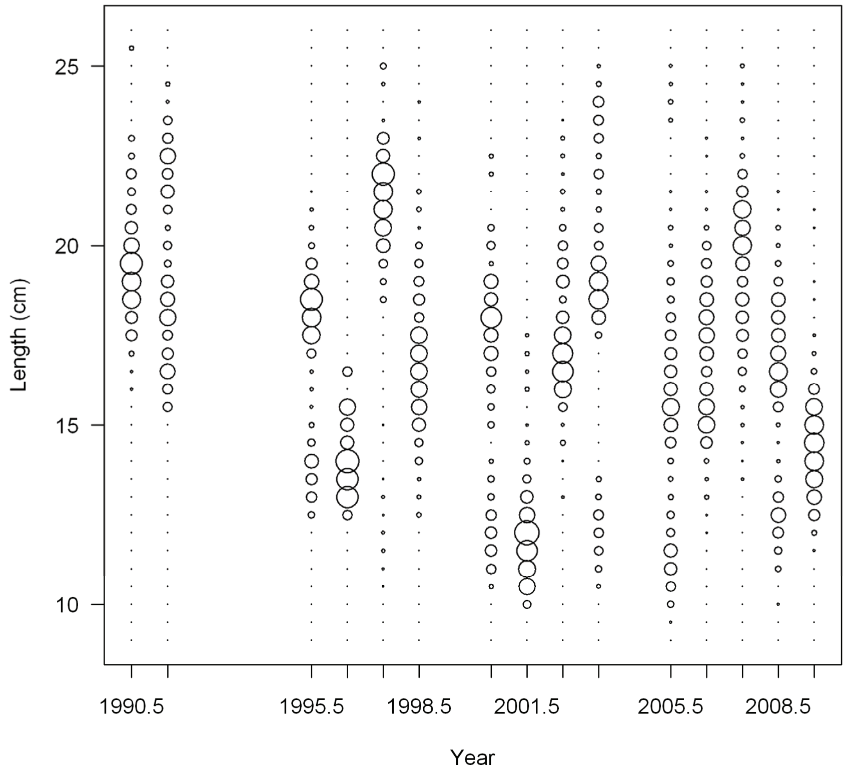


Figure 23b. Bubble plot of length-frequency data for the CCA_S2 fishery.

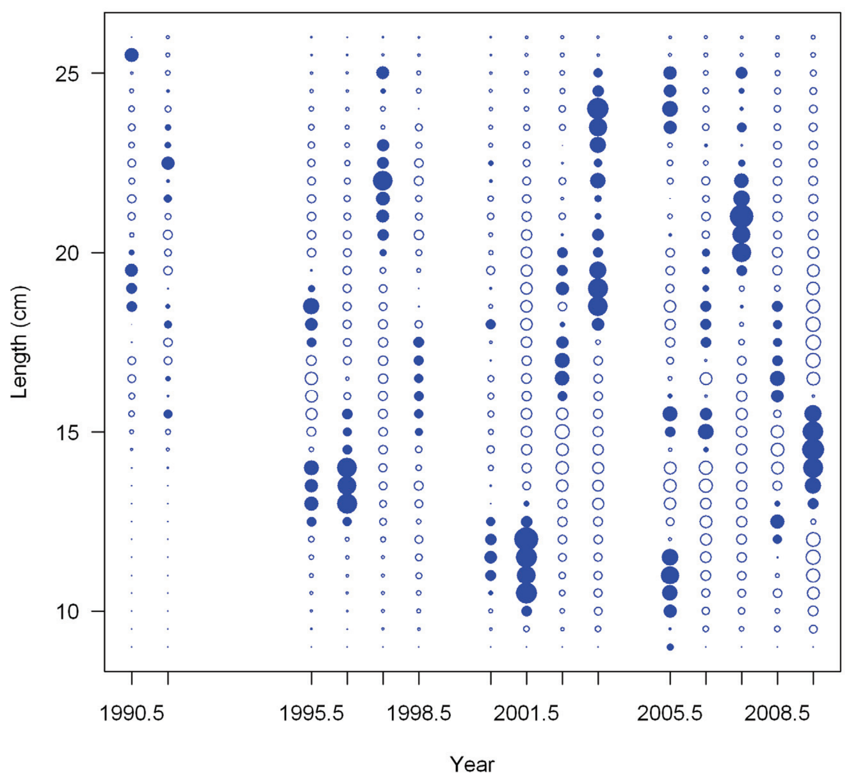


Figure 23c. Pearson residuals (max=5.08) for fit to length-frequency data for the CCA_S2 fishery.

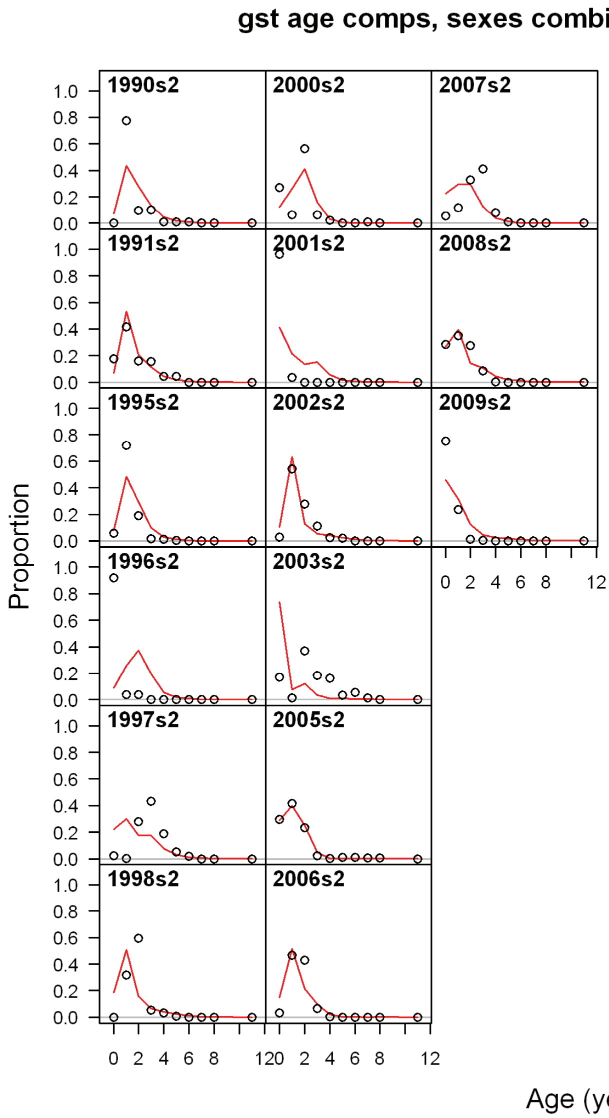


Figure 24a. Base model fits to implied age-frequency data for the CCA_S2 fishery.

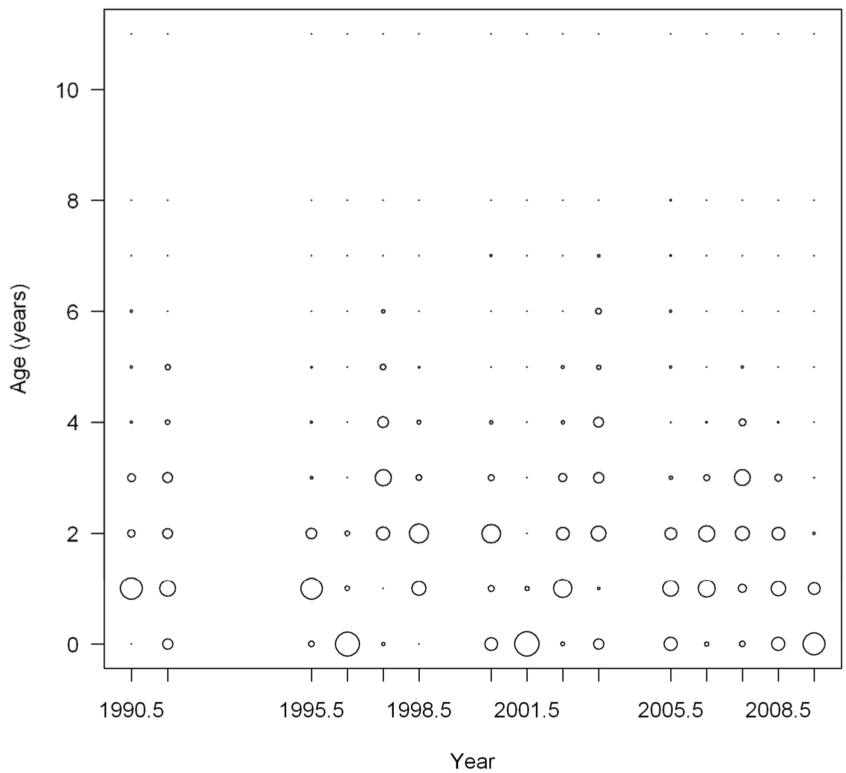


Figure 24b. Bubble plot of implied age-frequency data for the CCA_S2 fishery.

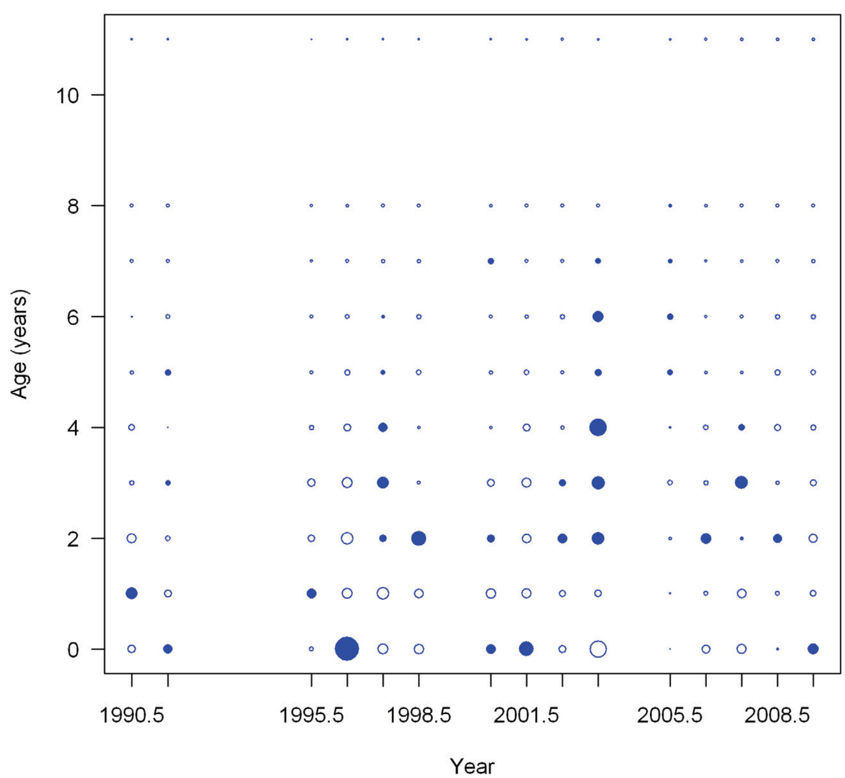


Figure 24c. Pearson residuals (max=2.95) for fit to implied age-frequency data for the CCA_S2 fishery.

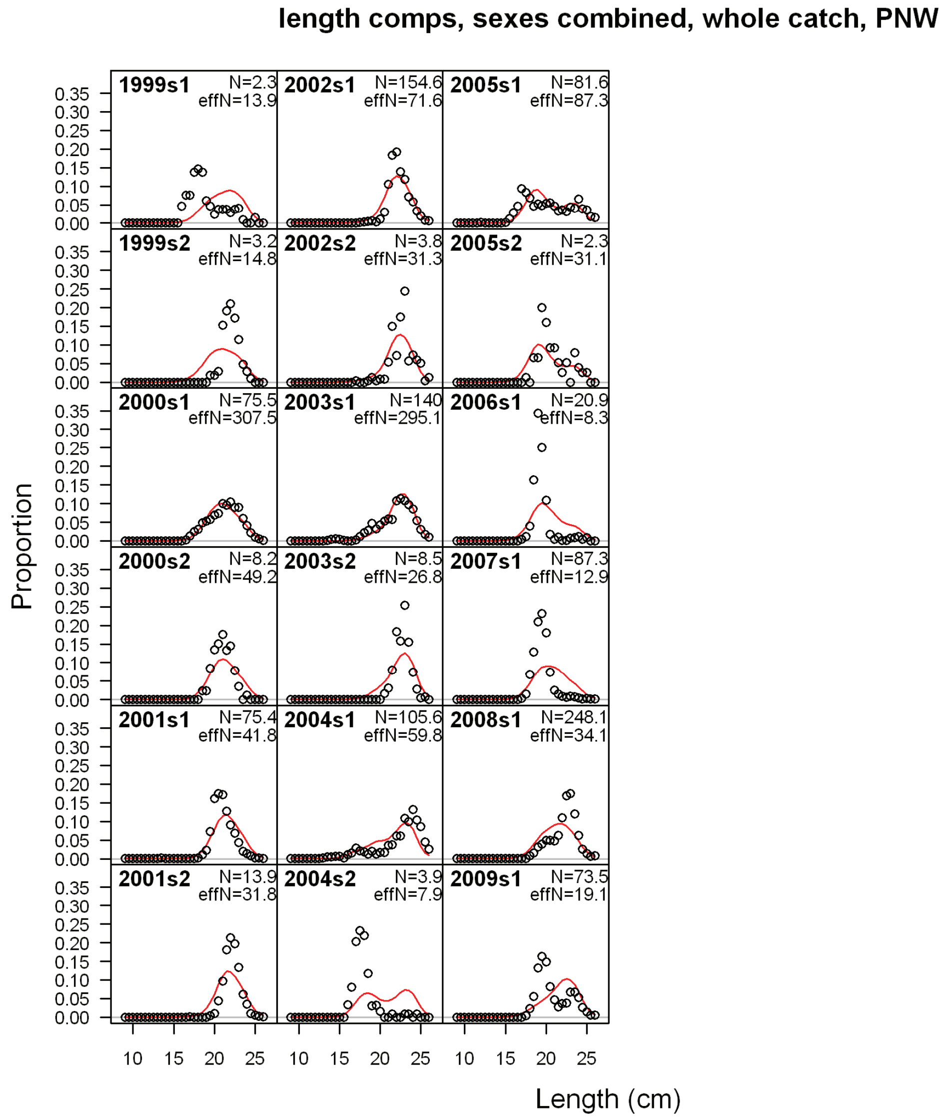


Figure 25a. Base model fits to length-frequency data for the PNW fishery.

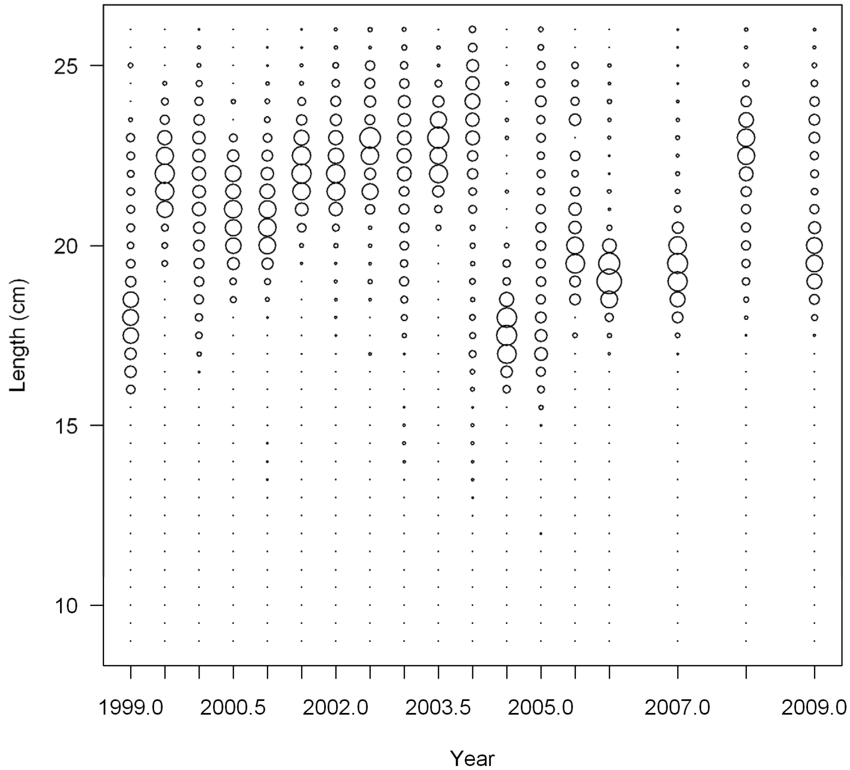


Figure 25b. Bubble plot of length-frequency data for the PNW fishery.

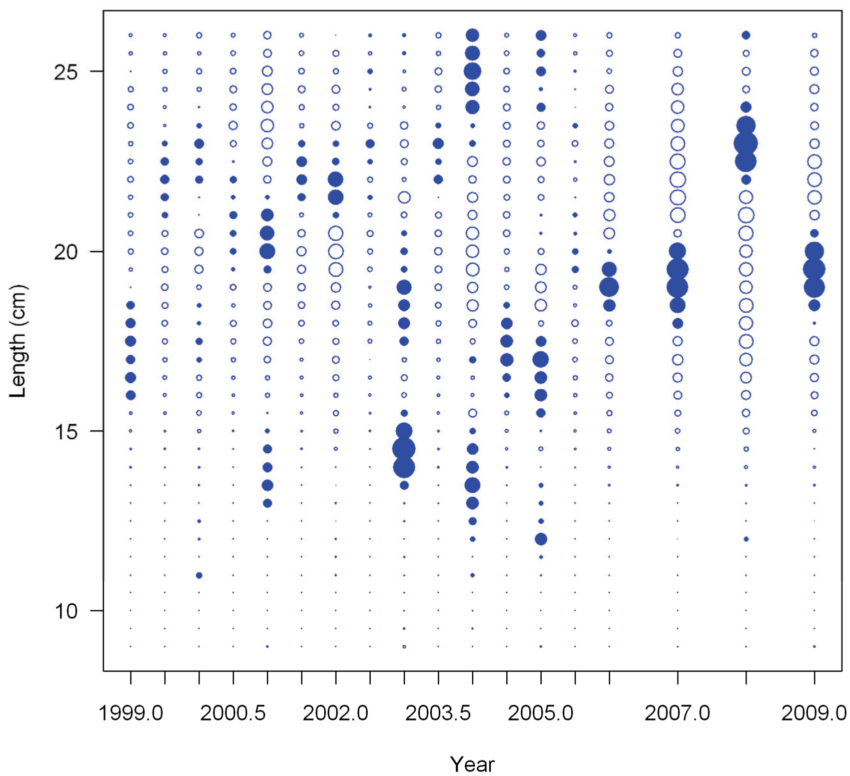


Figure 25c. Pearson residuals (max=5.8) for fit to length-frequency data for the PNW fishery.

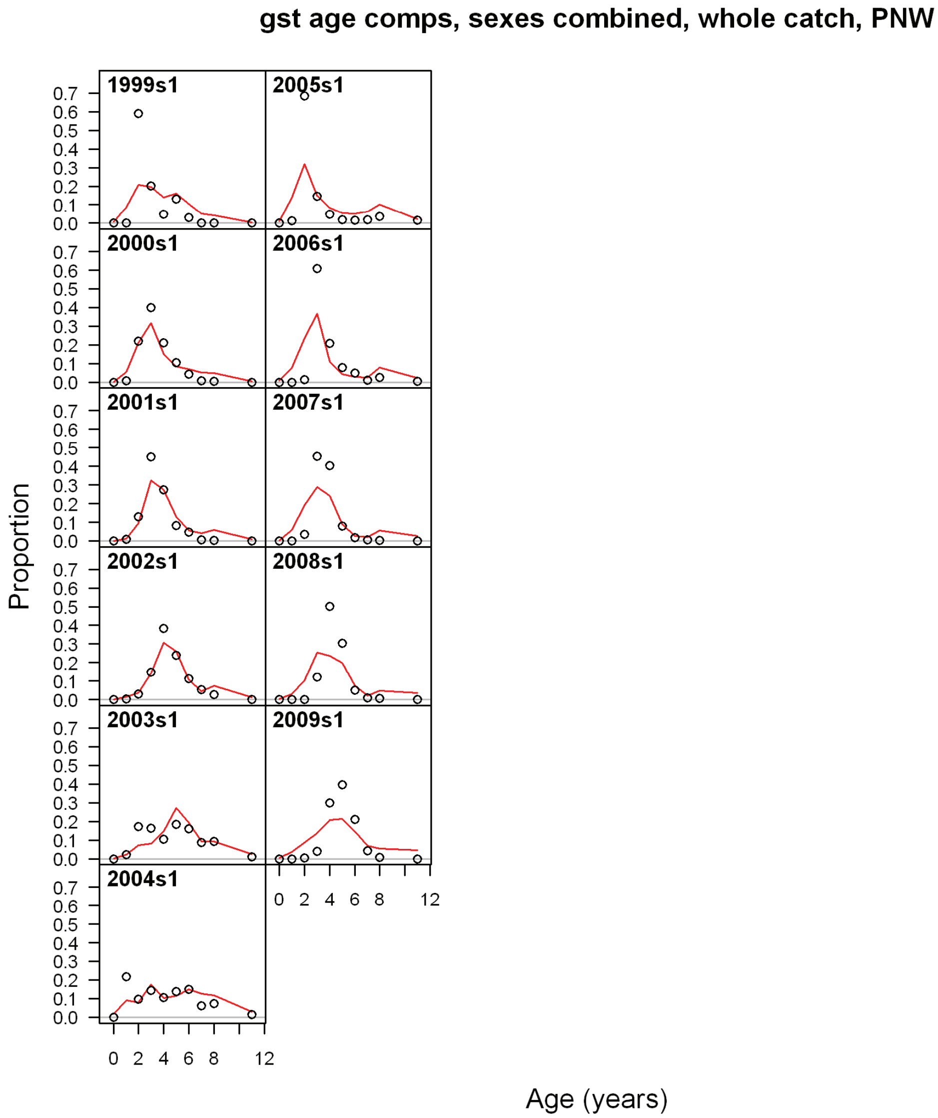


Figure 26a. Base model fits to implied age-frequency data for the PNW fishery.

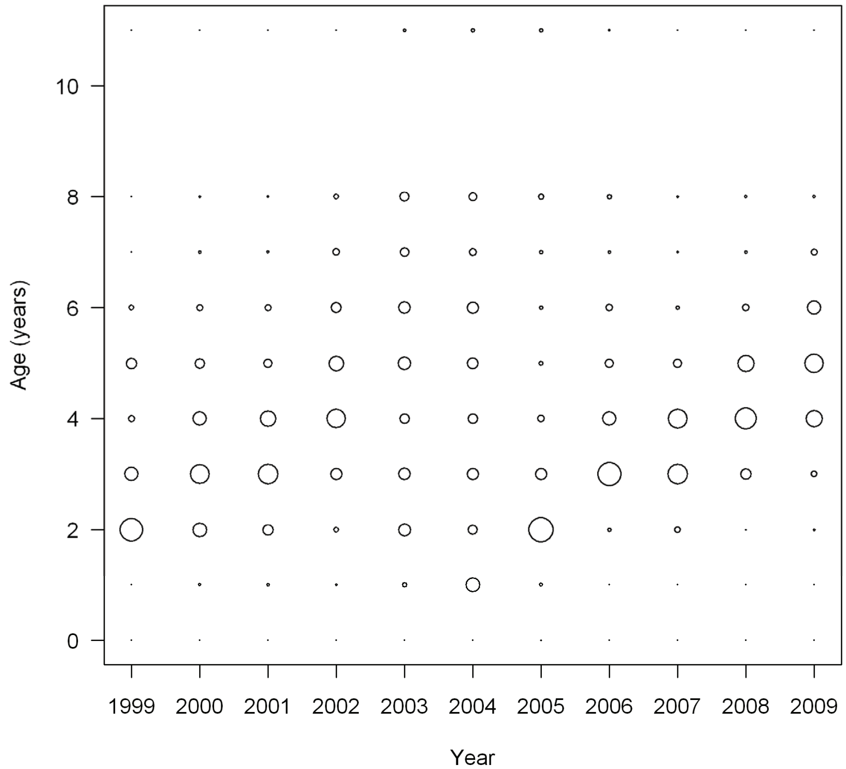


Figure 26b. Bubble plot of implied age-frequency data for the PNW fishery.

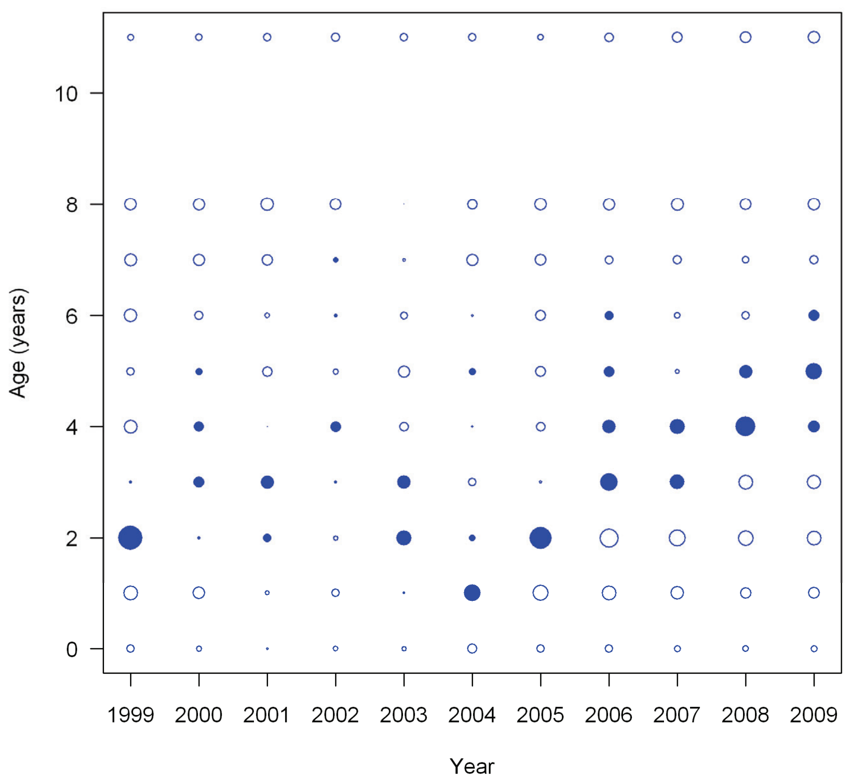


Figure 26c. Pearson residuals (max=0.94) for fit to implied age-frequency data for the PNW fishery.

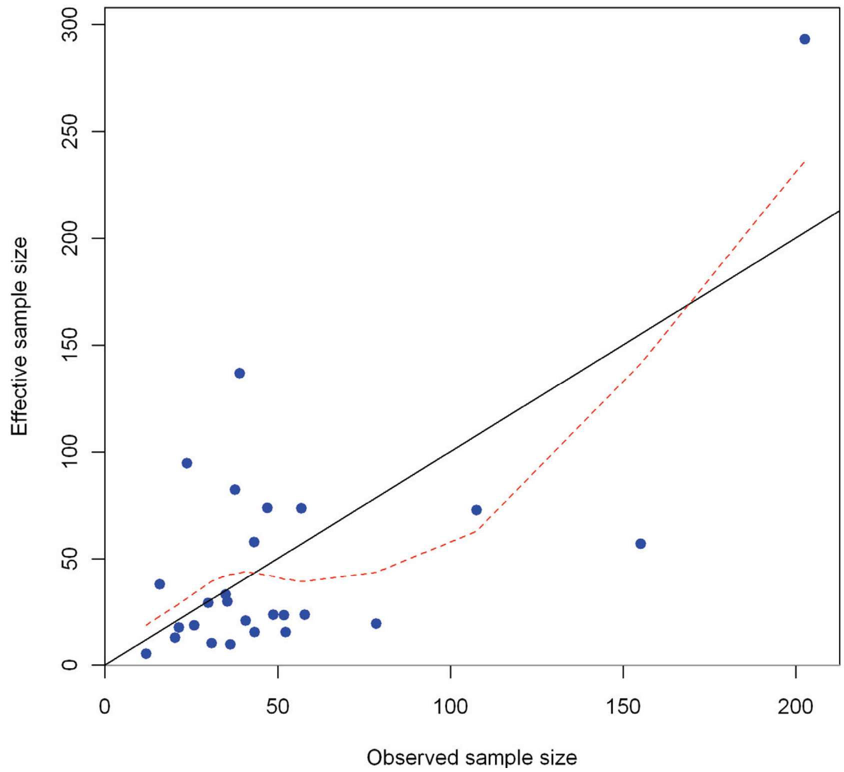


Figure 27a. Observed and effective sample sizes for the ENS fishery length-frequency data.

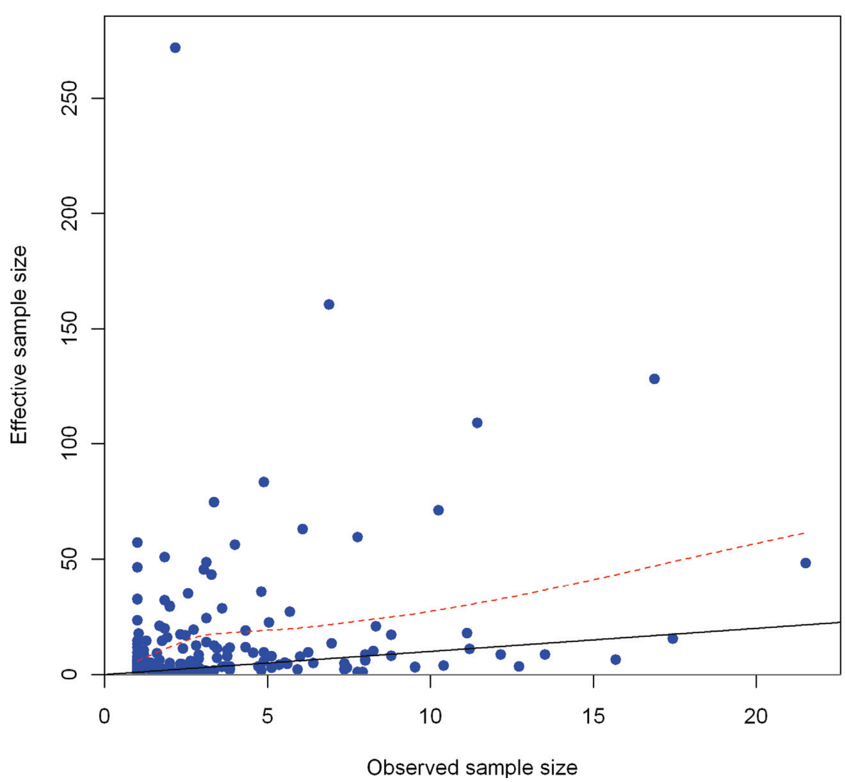


Figure 27b. Observed and effective sample sizes for the ENS fishery conditional age-at-length data.

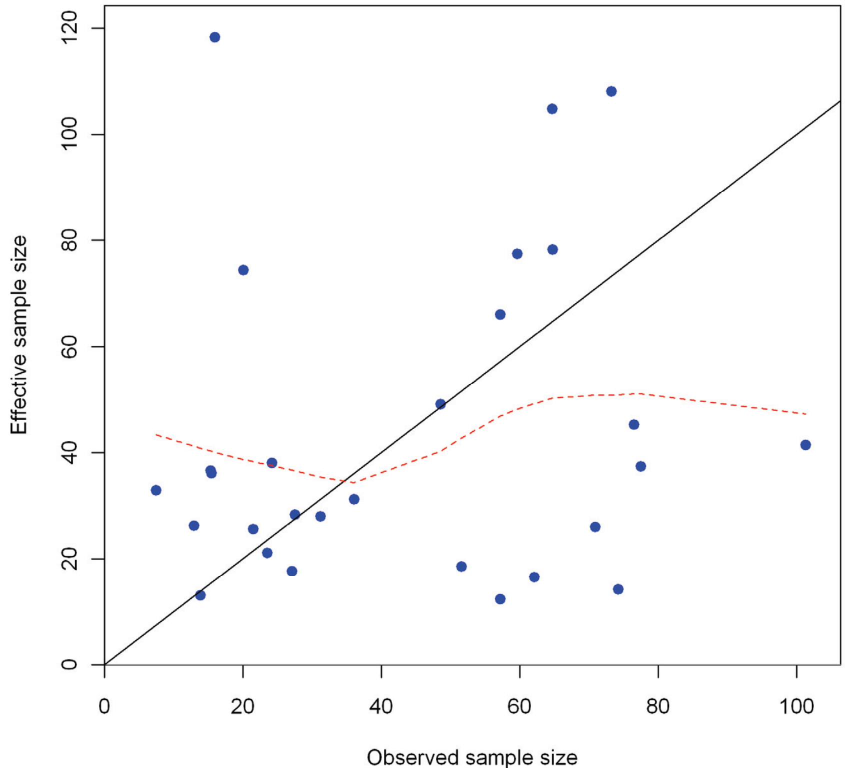


Figure 28a. Observed and effective sample sizes for the SCA_S1 fishery length-frequency data.

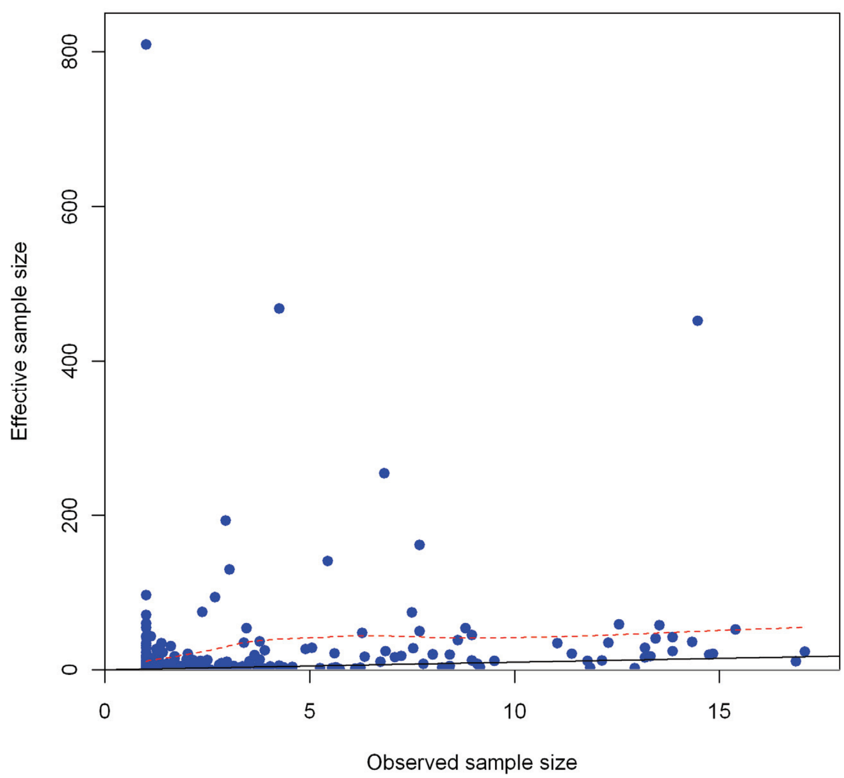


Figure 28b. Observed and effective sample sizes for the SCA_S1 fishery conditional age-at-length data.

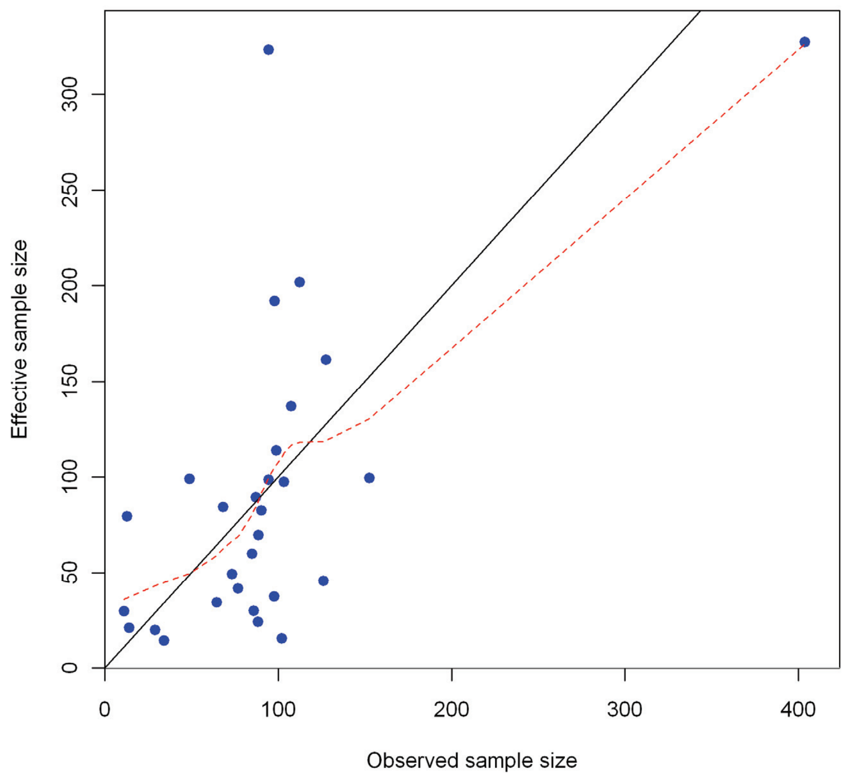


Figure 29a. Observed and effective sample sizes for the SCA_S2 fishery length-frequency data.

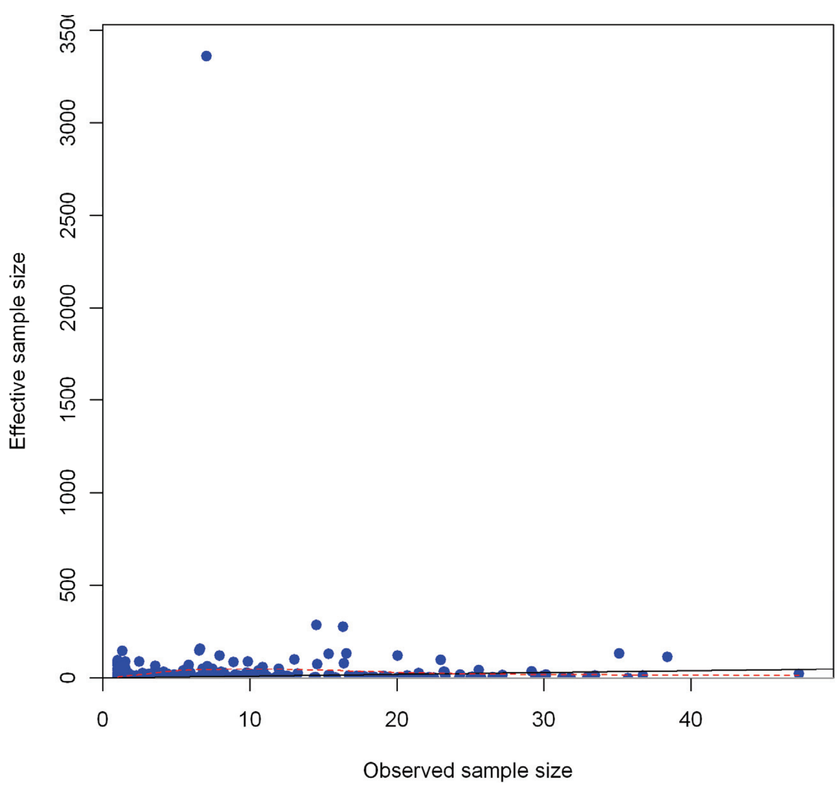


Figure 29b. Observed and effective sample sizes for the SCA_S2 fishery conditional age-at-length data.

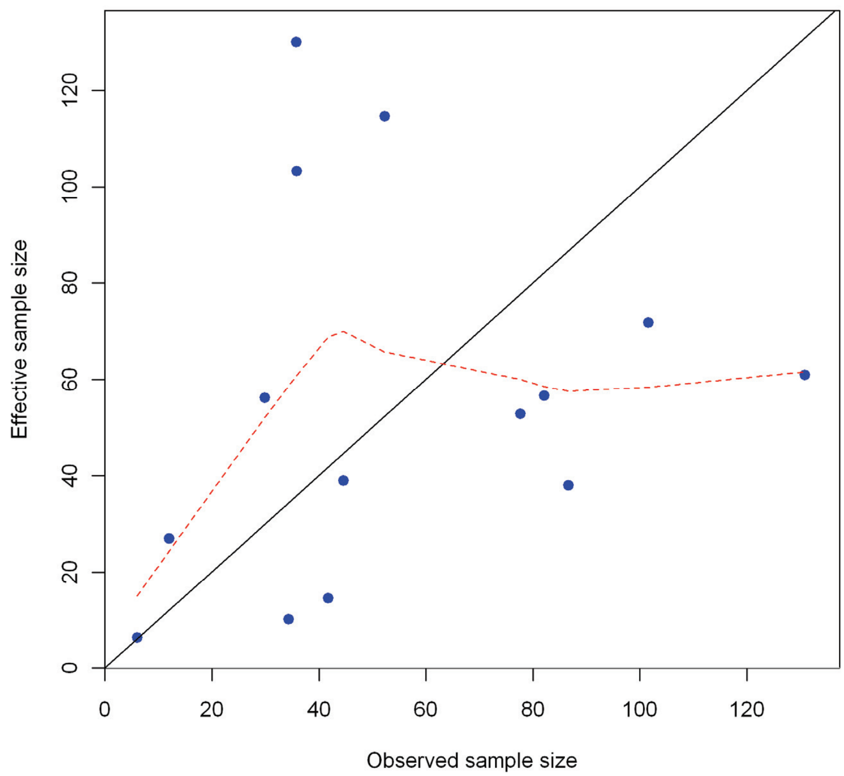


Figure 30a. Observed and effective sample sizes for the CCA_S1 fishery length-frequency data.

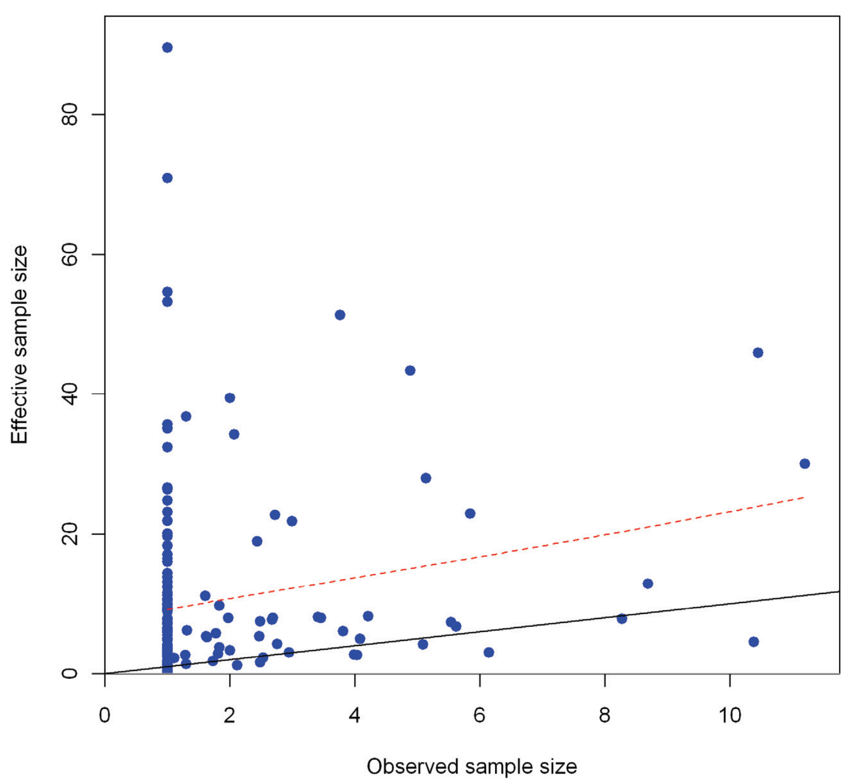


Figure 30b. Observed and effective sample sizes for the CCA_S1 fishery conditional age-at-length data.

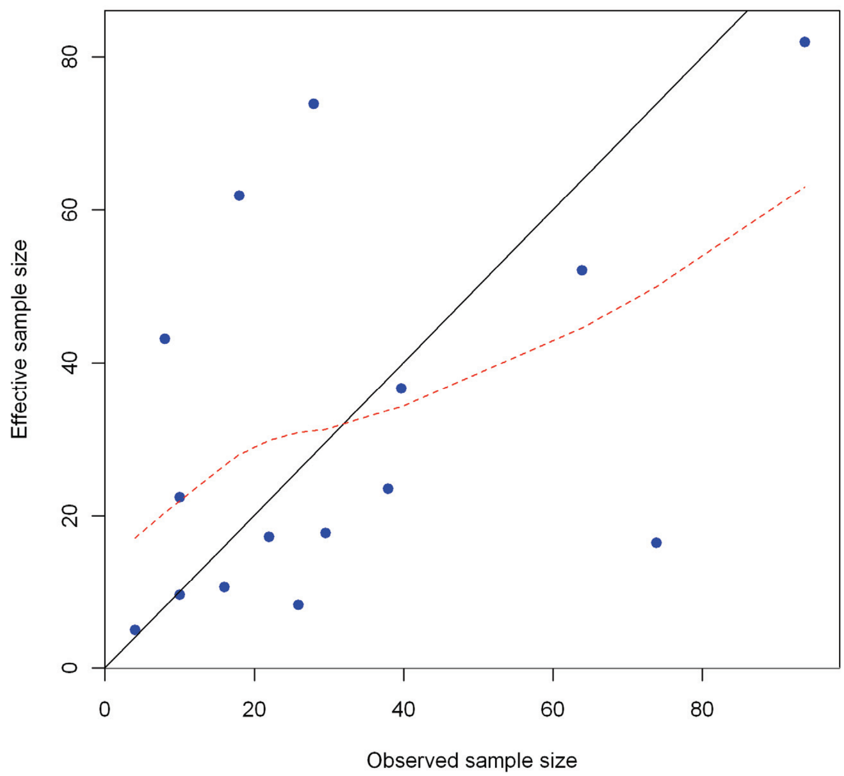


Figure 31a. Observed and effective sample sizes for the CCA_S2 fishery length-frequency data.

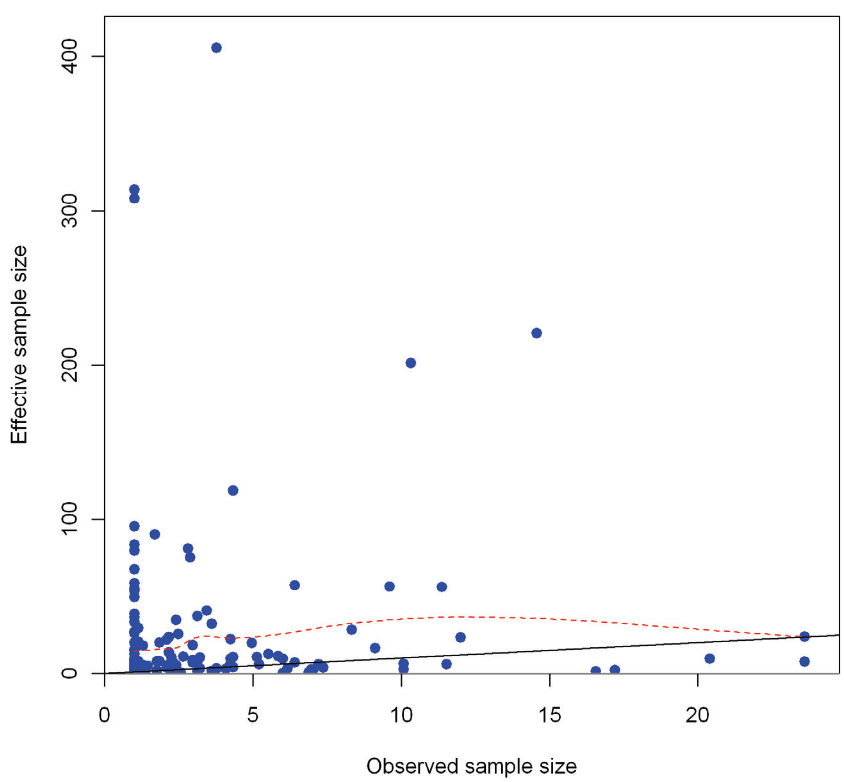


Figure 31b. Observed and effective sample sizes for the CCA_S2 fishery conditional age-at-length data.

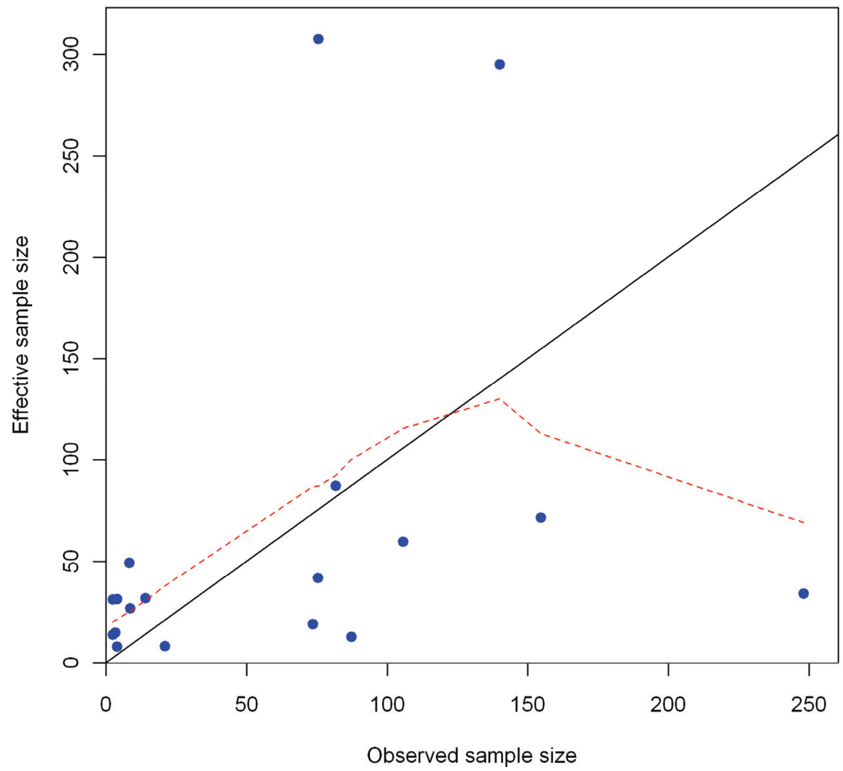


Figure 32a. Observed and effective sample sizes for the PNW fishery length-frequency data.

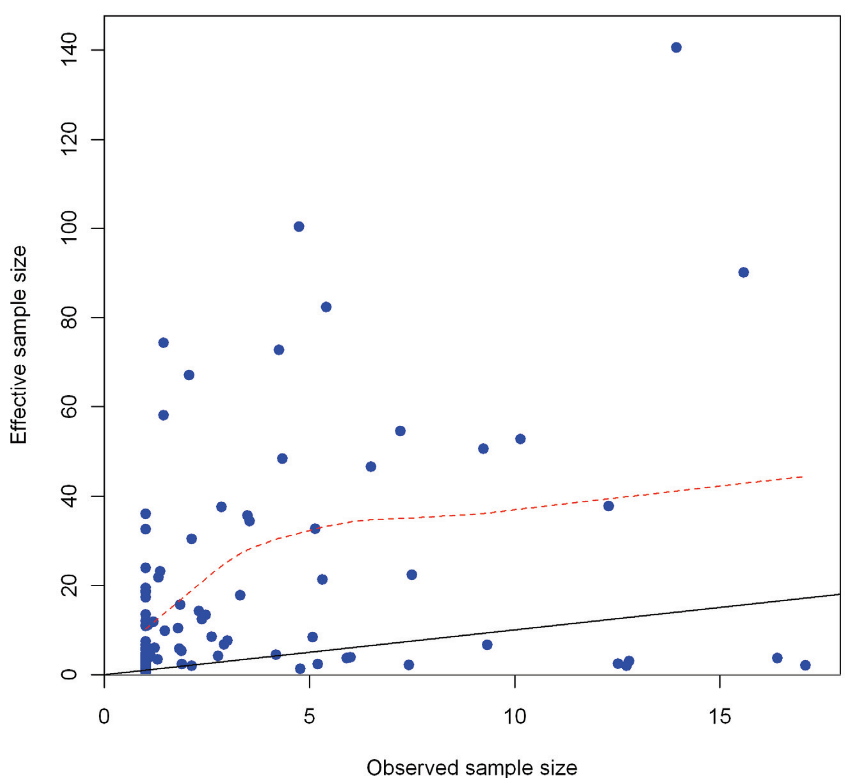


Figure 32b. Observed and effective sample sizes for the PNW fishery conditional age-at-length data.

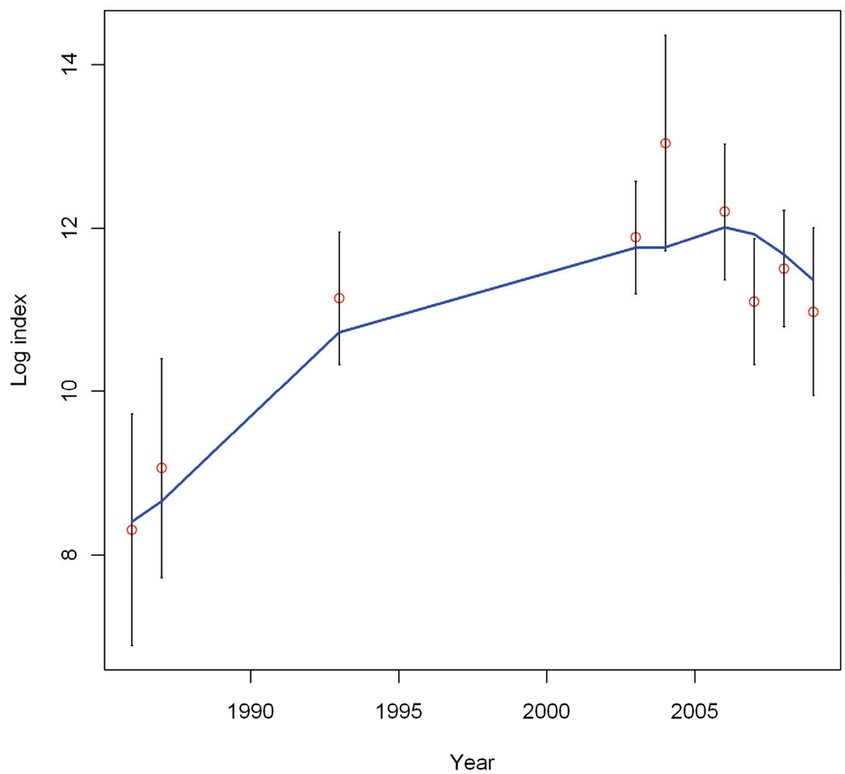


Figure 33a. Base model fit to the Daily Egg Production Method (DEPM) series of female spawning biomass (q=0.1715).

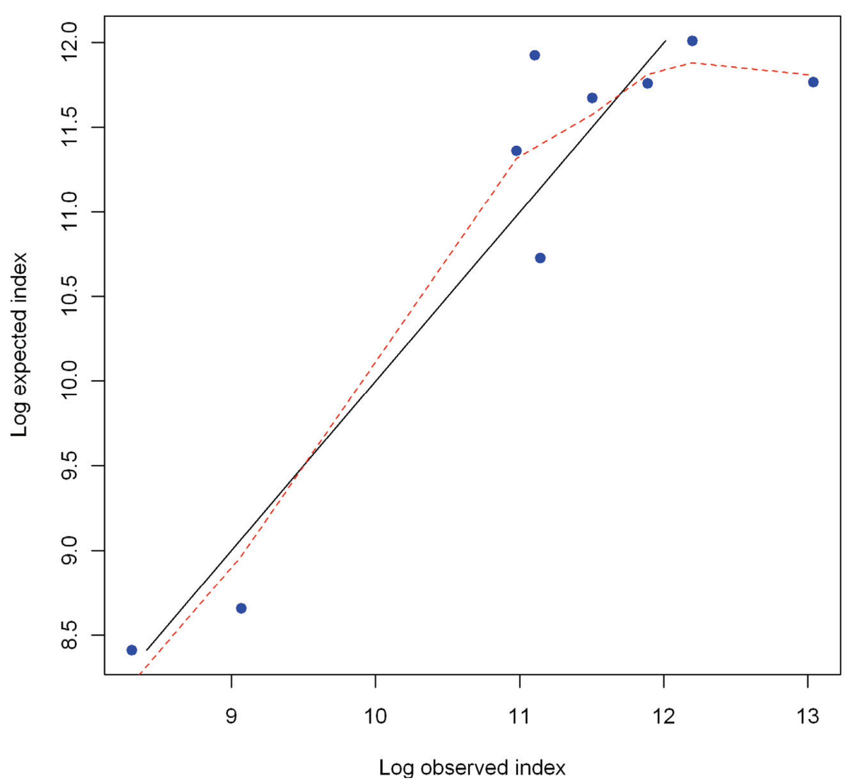


Figure 33b. Relationship between observed and expected values (log scale) for the DEPM survey (base model). Straight line is 1 to 1 relationship.

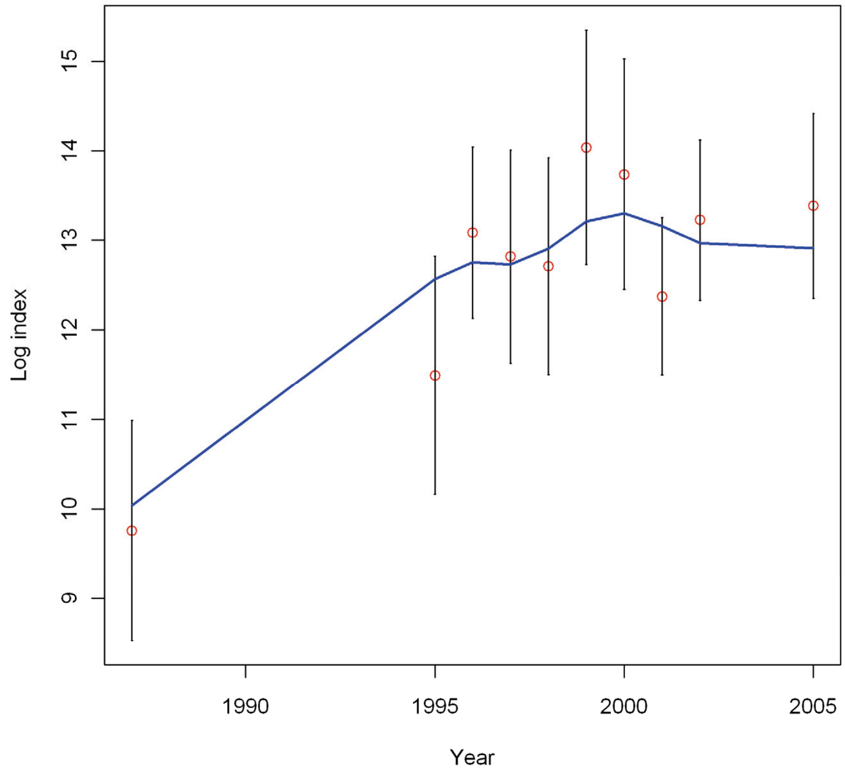


Figure 34a. Base model fit to the Total Egg Production (TEP) series of total spawning biomass (*q*=0.4568).

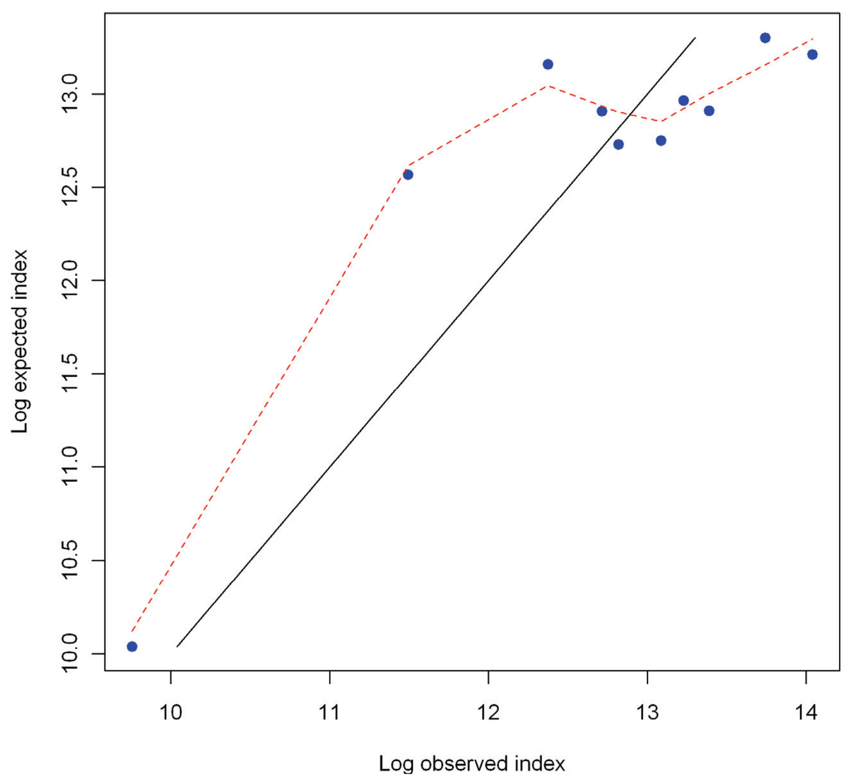


Figure 34b. Relationship between observed and expected values (log scale) for the TEP survey (base model). Straight line is 1 to 1 relationship.

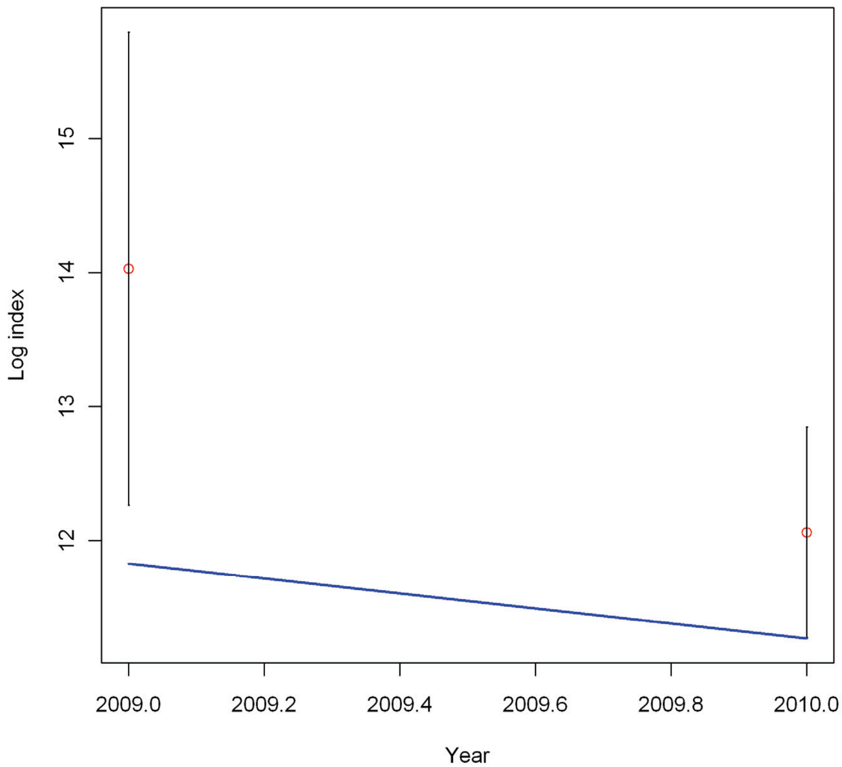
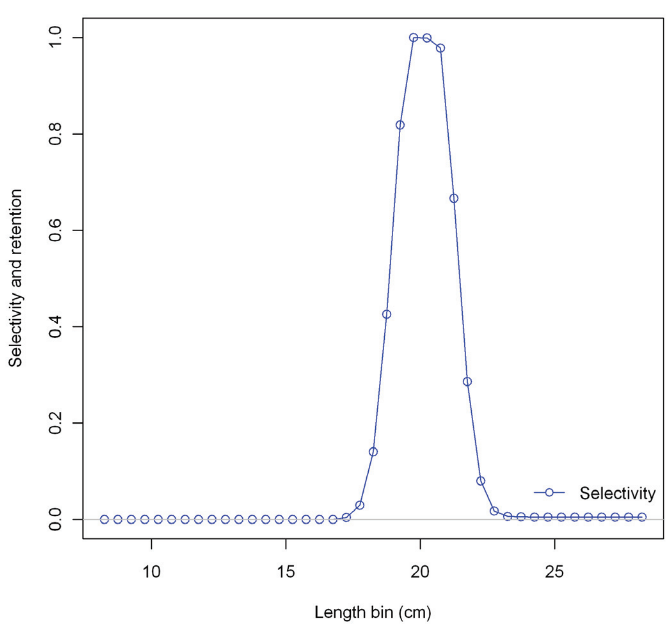


Figure 35a. Update model '10w' fit to Aerial_N estimates of biomass (q fixed to 1). Base model fits length compositions using dome-shaped (double normal) selectivity.



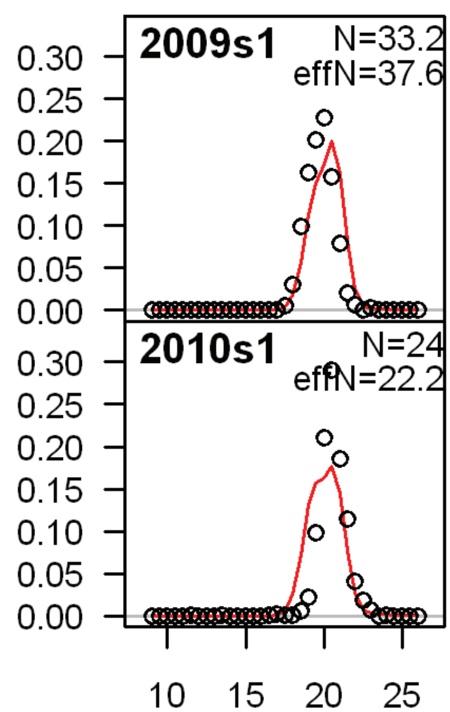


Figure 35b. Length-based selectivity (left panel; double-normal function) for the Aerial_N survey and corresponding model fit to length-frequency data (right panel).

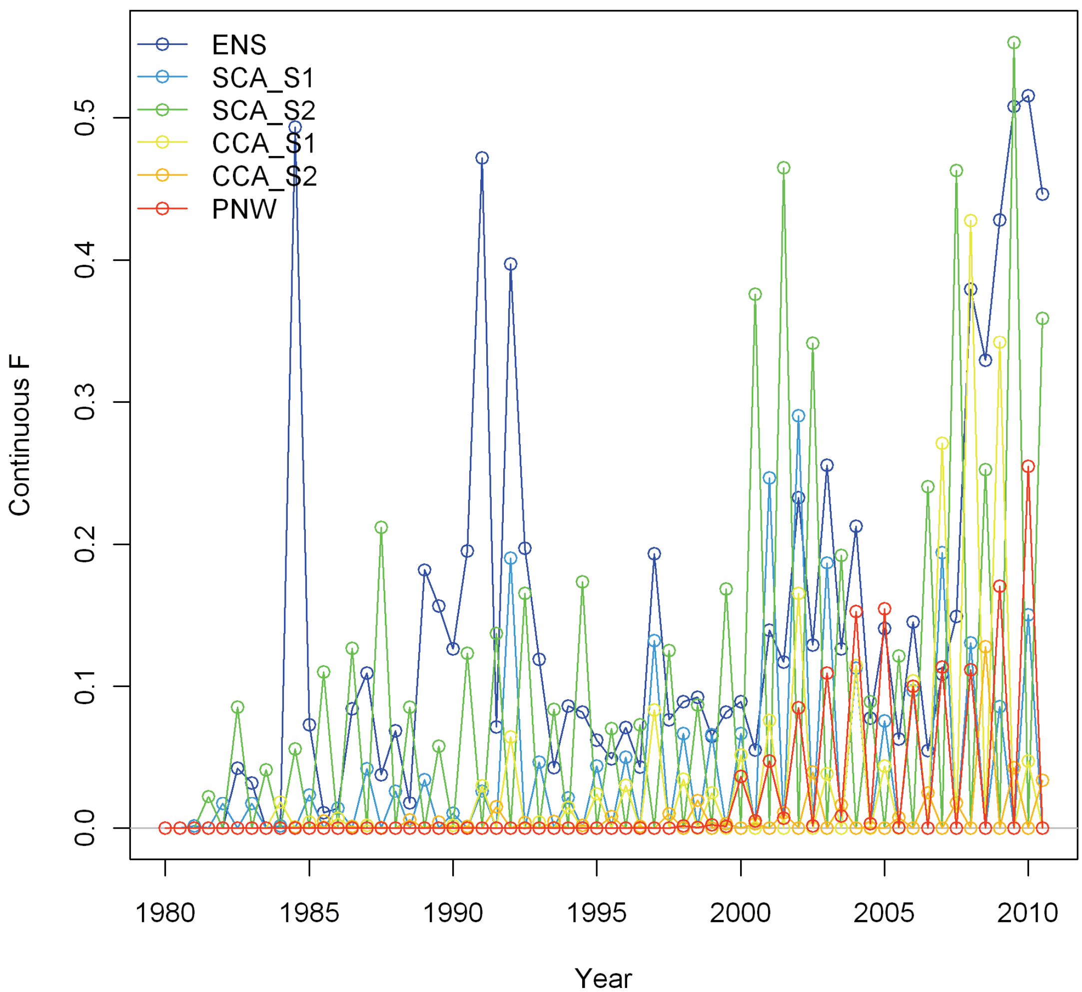


Figure 36. Harvest rate by fishery (Hybrid F-method) from the base model.

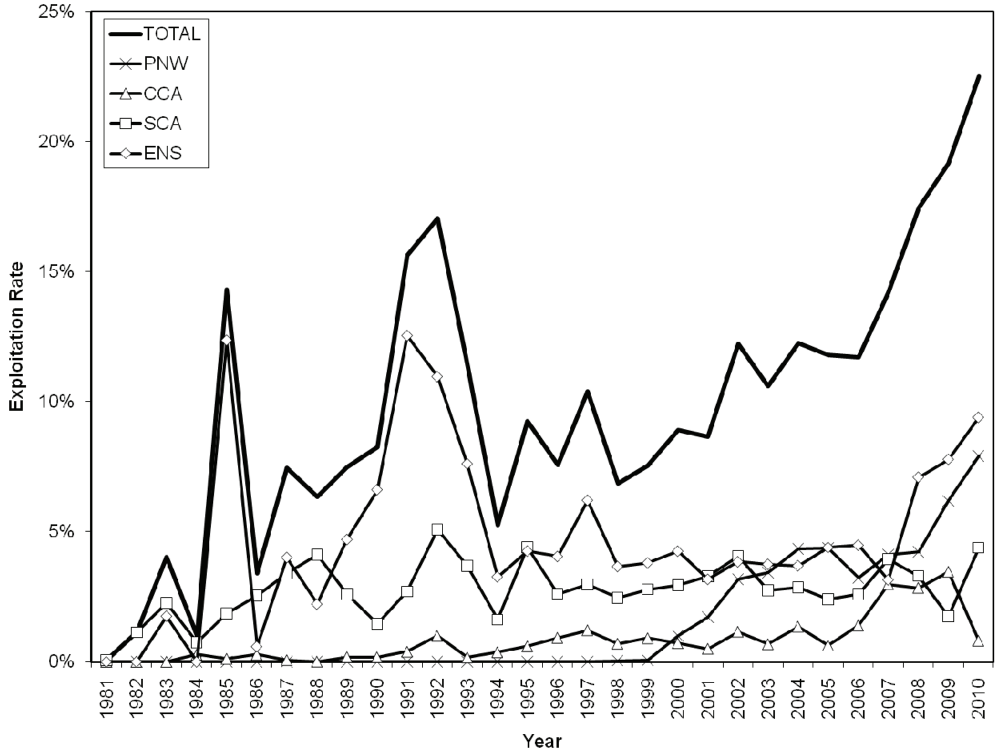


Figure 37a. Exploitation rate (CY landings / July total biomass) by fishery for the update model ('10w').

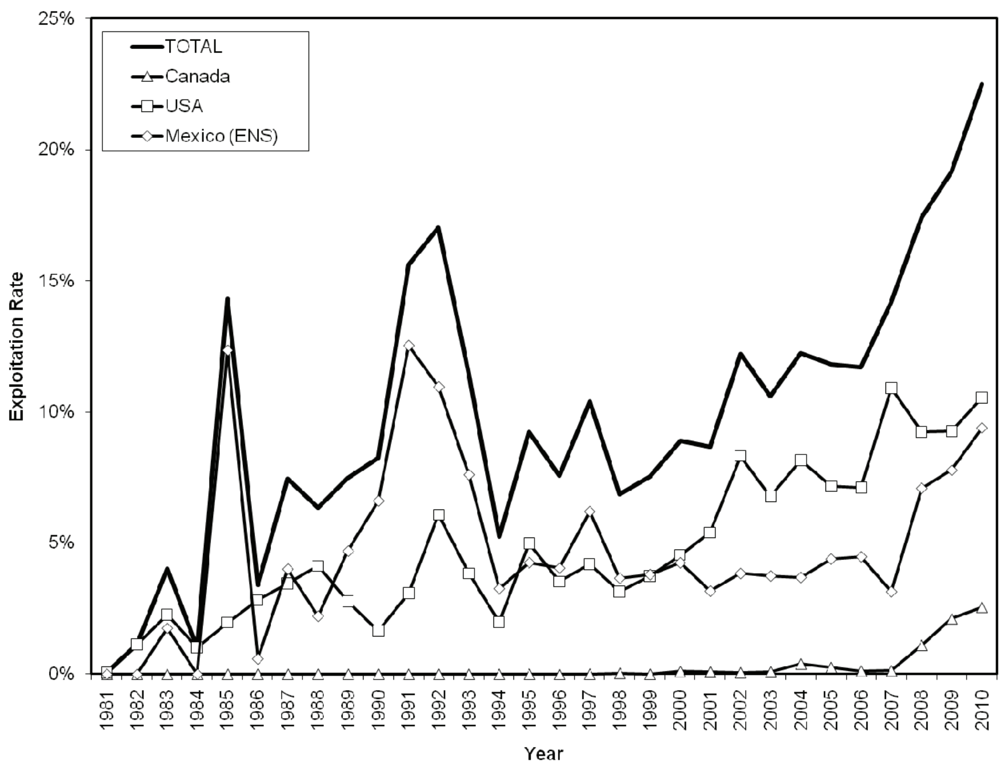


Figure 37b. Exploitation rate (CY landings / July total biomass) by country for the update model ('10w').

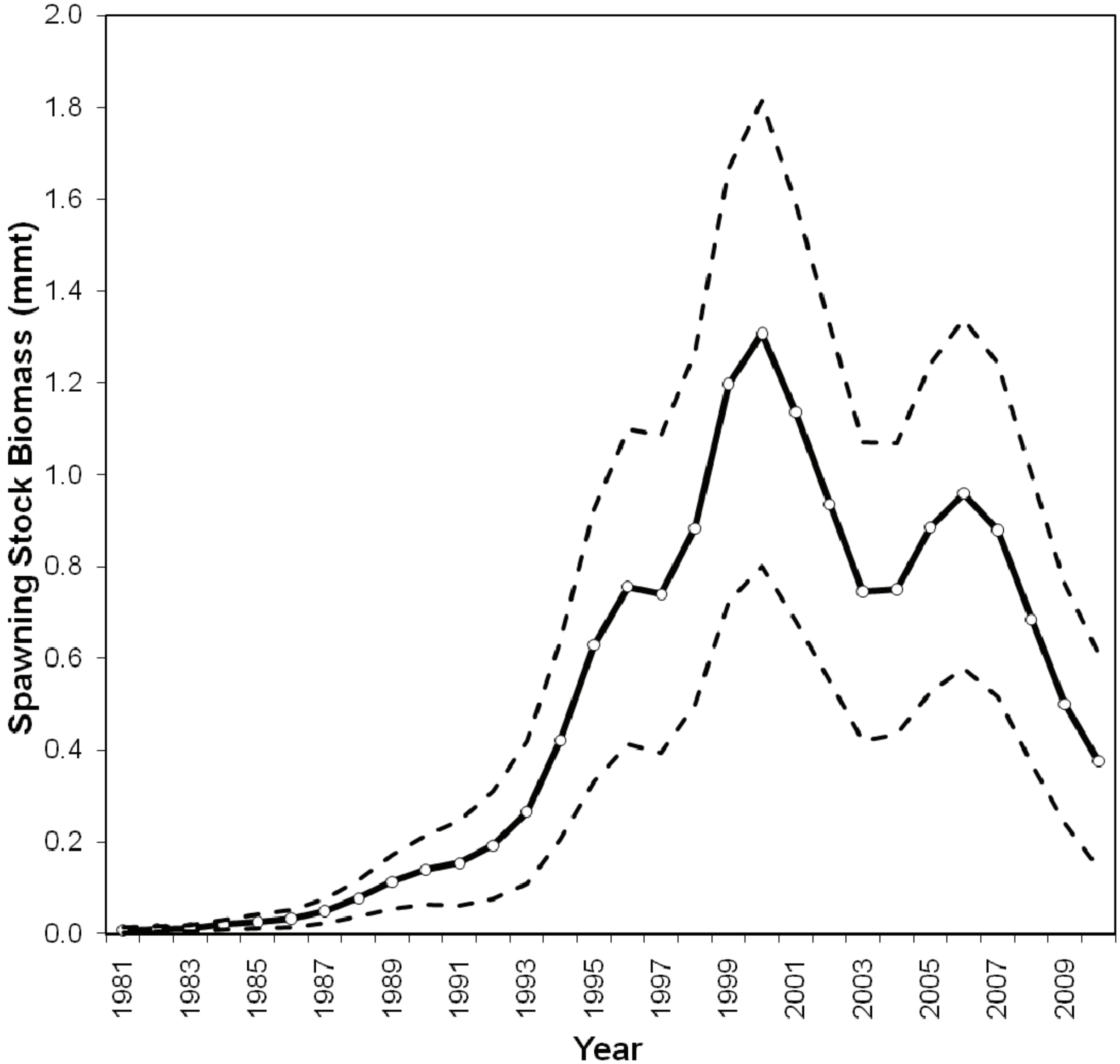


Figure 38. Spawning stock biomass with ~95% asymptotic confidence intervals from the update model '10w'.

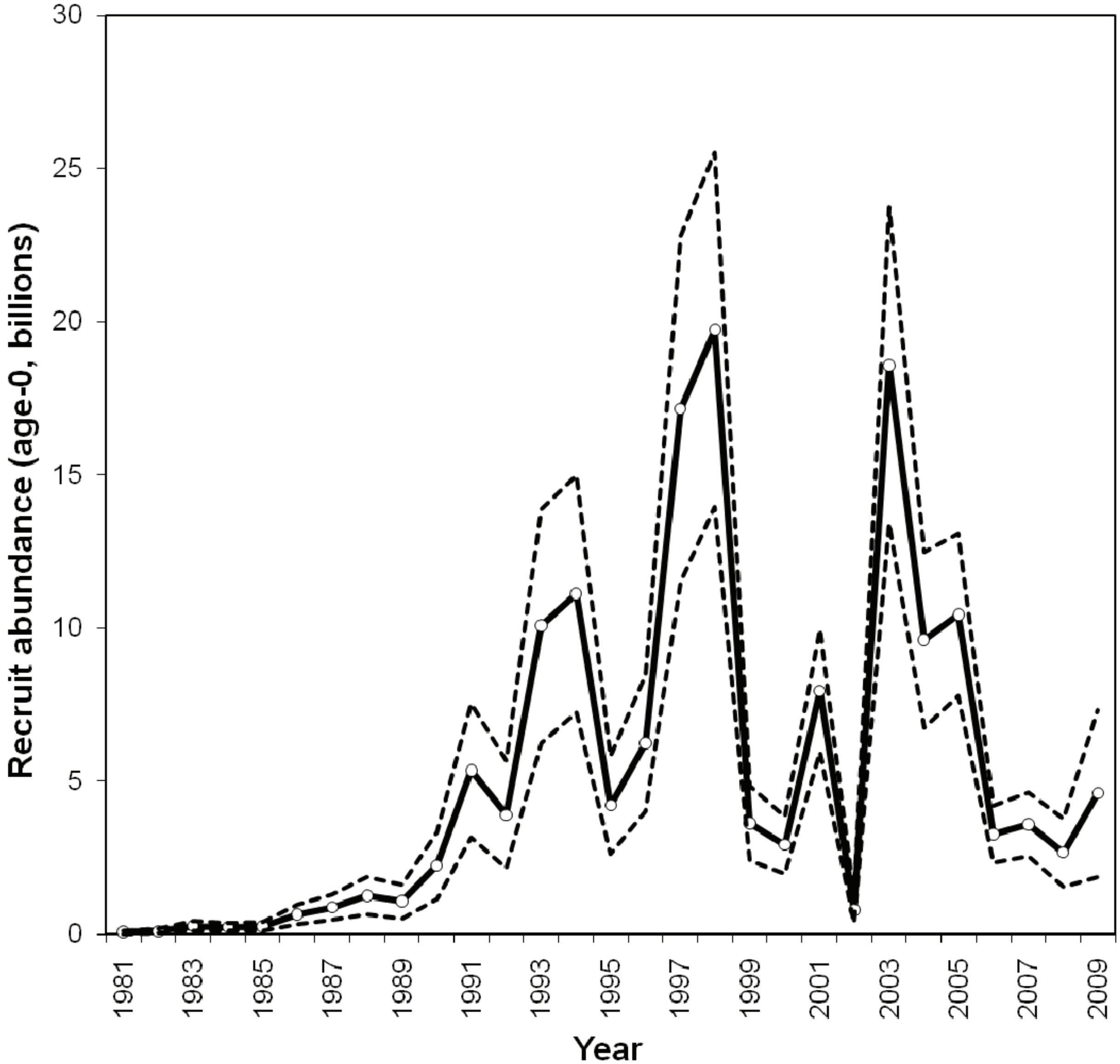


Figure 39. Year class abundance with ~95% asymptotic confidence intervals from the update model ‘10w’.

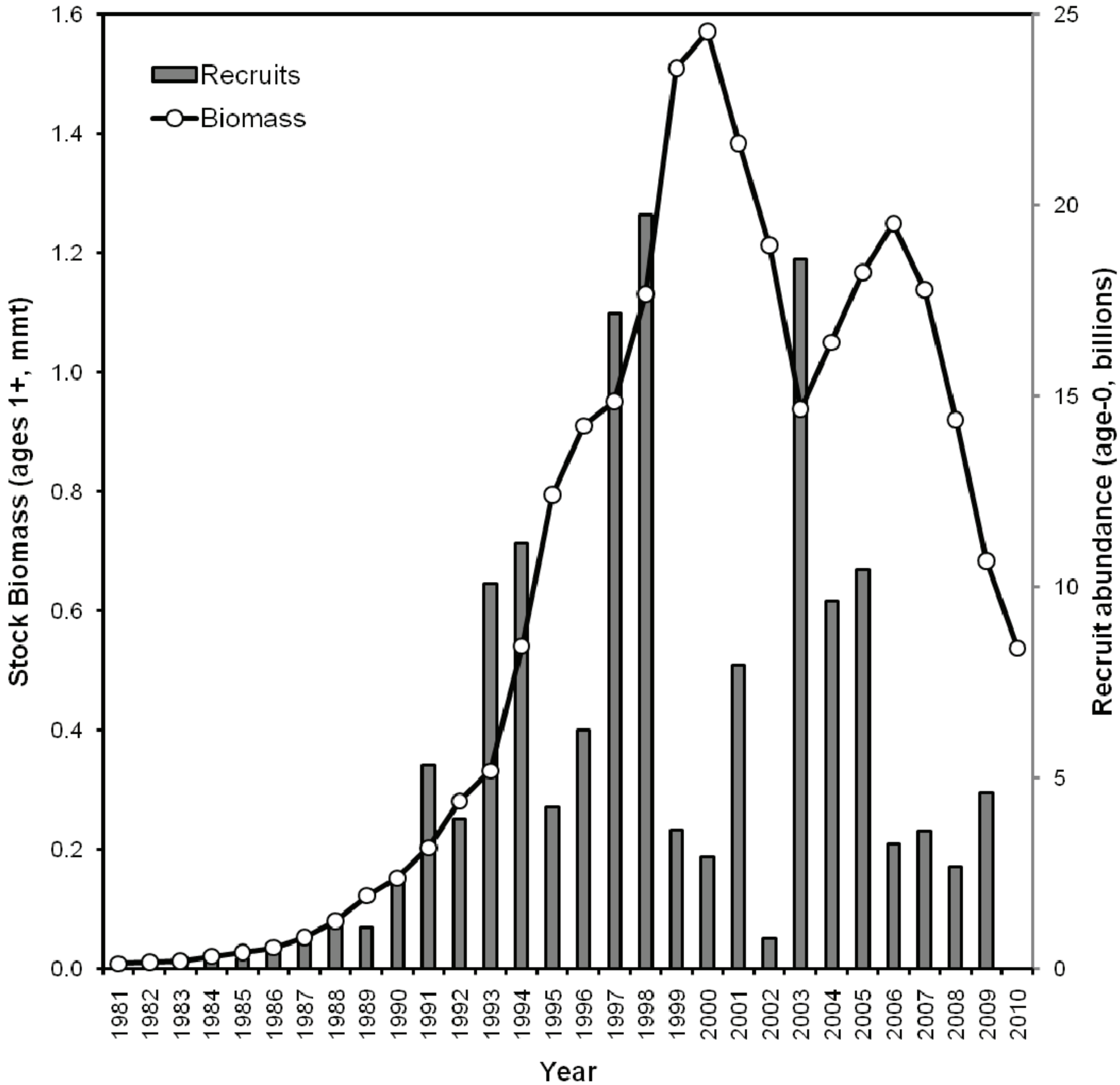


Figure 40. Pacific sardine stock biomass (ages 1+) and recruits (age 0) from the 2010 update model '10w'.

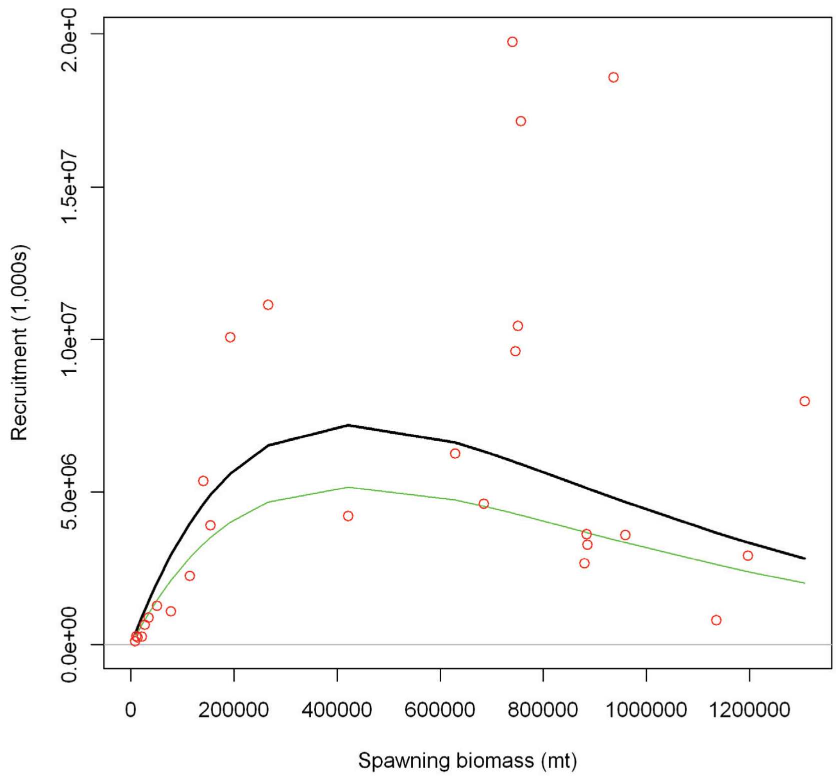


Figure 41a. Spawner-recruitment relationship for update model '10w', showing Ricker function fit with bias correction. Steepness (*h*) = 2.25301.

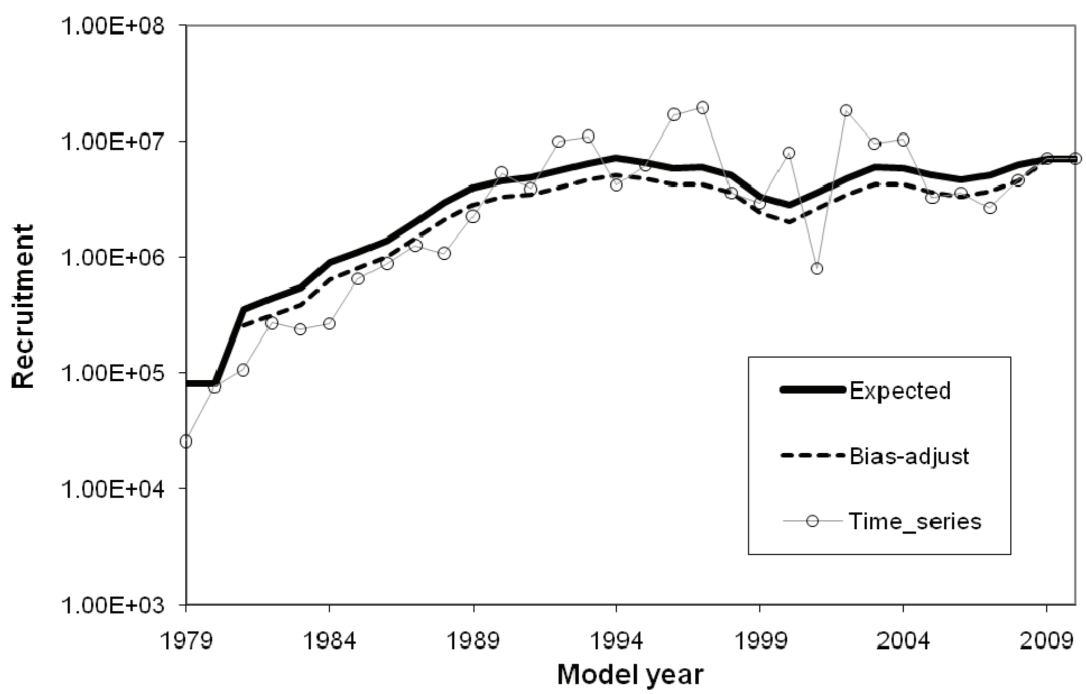


Figure 41b. Ricker model fit to the recruitment time series (model '10w').

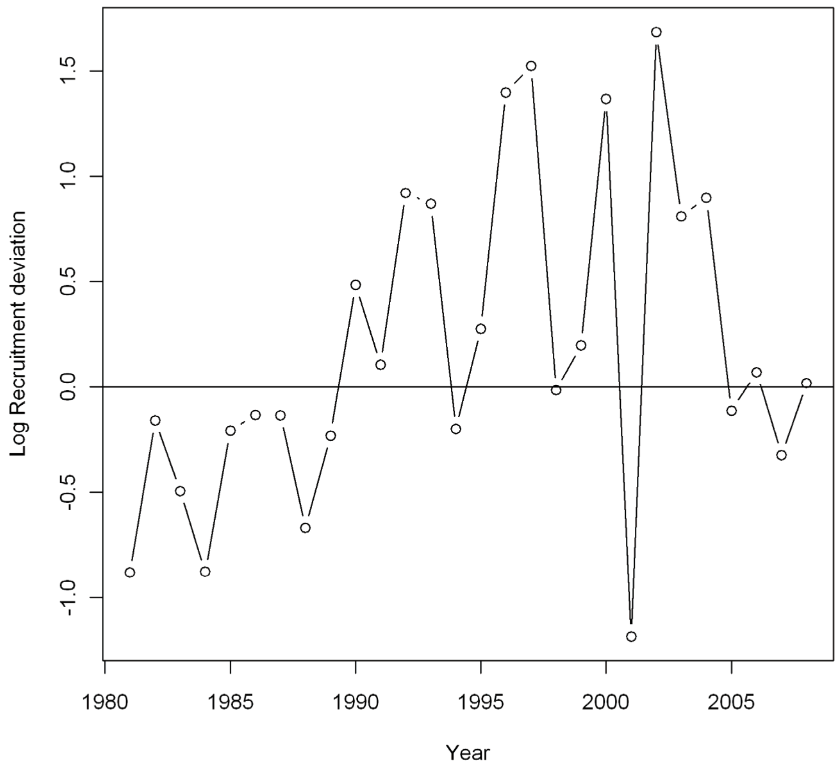


Figure 42a. Recruitment deviations estimated in the update model ‘10w’.

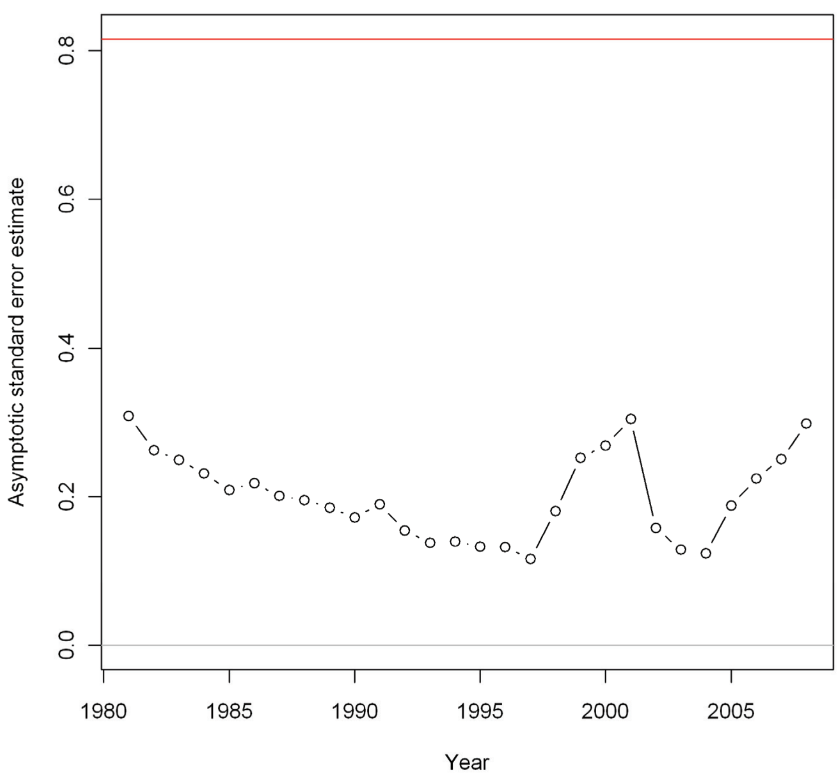


Figure 42b. Asymptotic standard errors for estimated recruitment deviations in the update model ‘10w’.

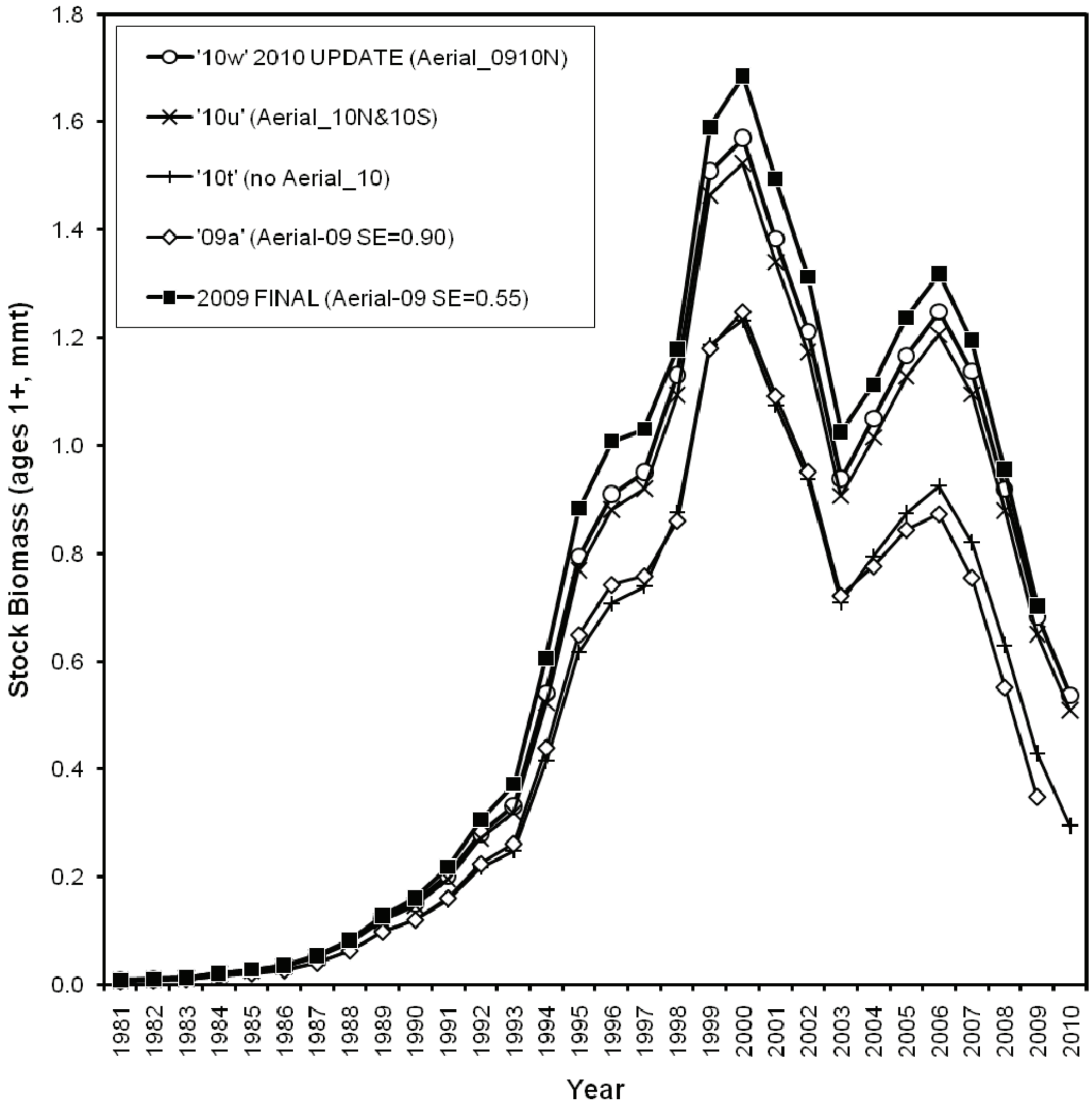


Figure 43a. Pacific sardine stock biomass (ages 1+) from the 2010 update model '10w' compared to: the 2009 final model (aerial SE=0.55); the 2009 model '09a' where aerial SE=0.90; the 2010 update without the 2010 aerial data ('10t'), and the 2010 update fit to both the northern and southern aerial estimates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

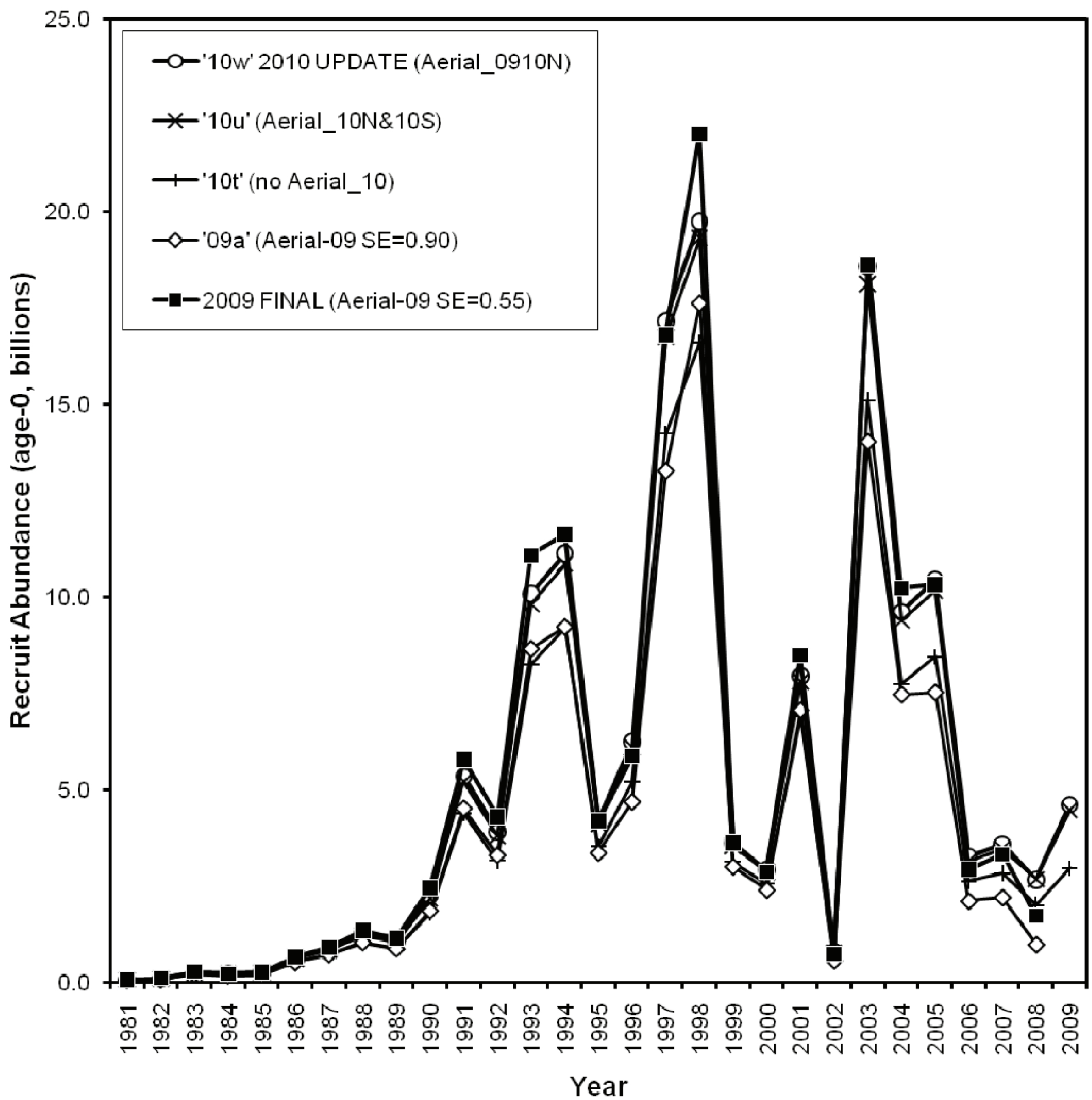


Figure 43b. Pacific sardine recruit (age-0) abundance from the 2010 update model '10w' compared to: the 2009 final model (aerial SE=0.55); the 2009 model '09a' where aerial SE=0.90; the 2010 update without the 2010 aerial data ('10t'), and the 2010 update fit to both the northern and southern aerial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

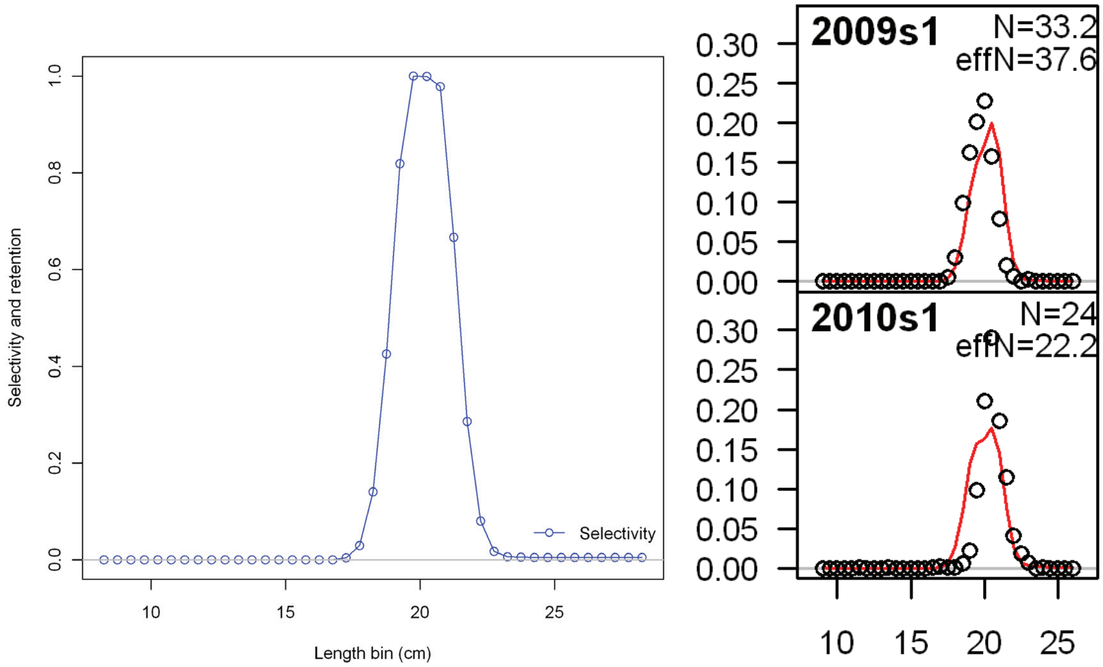


Figure 44a (from Figure 35b). Length-based selectivity ogive (left panel; double-normal function) for the Aerial_N survey and corresponding model ‘10w’ fit to length-frequency data (right panel).

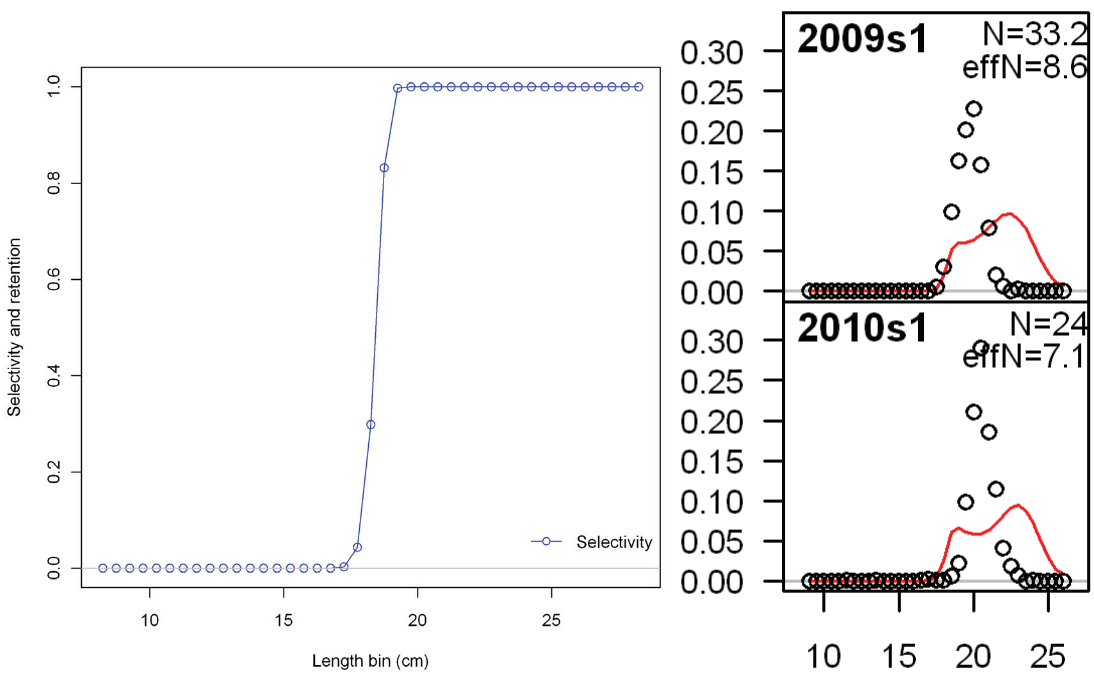


Figure 44b. Length-based selectivity ogive (double-normal forced to asymptotic shape; right panel) for the Aerial_N survey and corresponding model ‘10x1’ fit to length-frequency data (right panel).

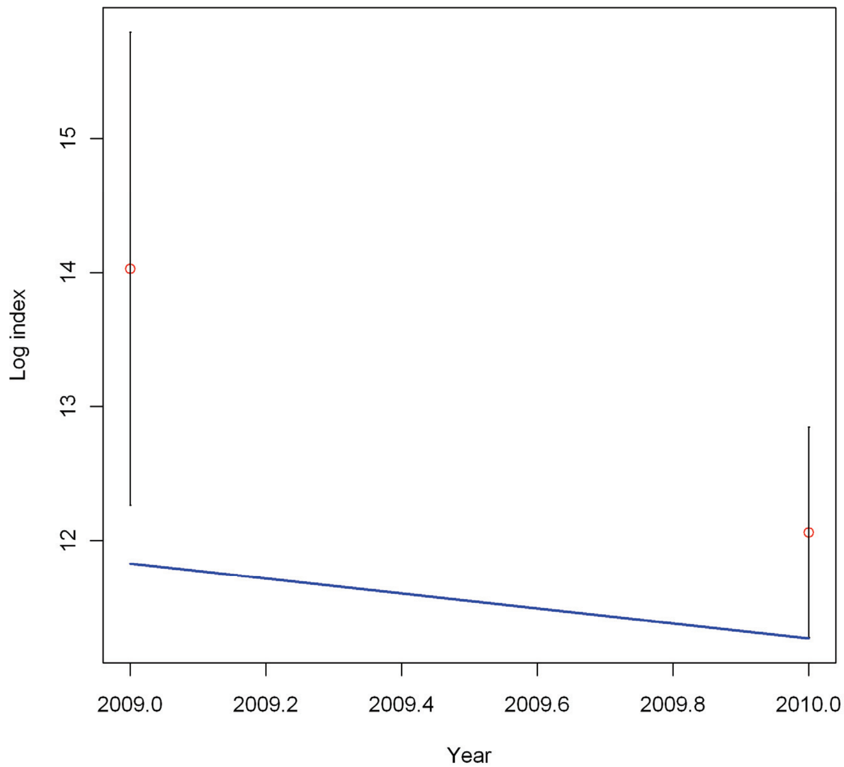


Figure 45a (from Figure 35a). Update model '10w' fit to Aerial_N estimates of biomass (*q* fixed to 1), where aerial survey lengths were fit using dome-shaped selectivity.

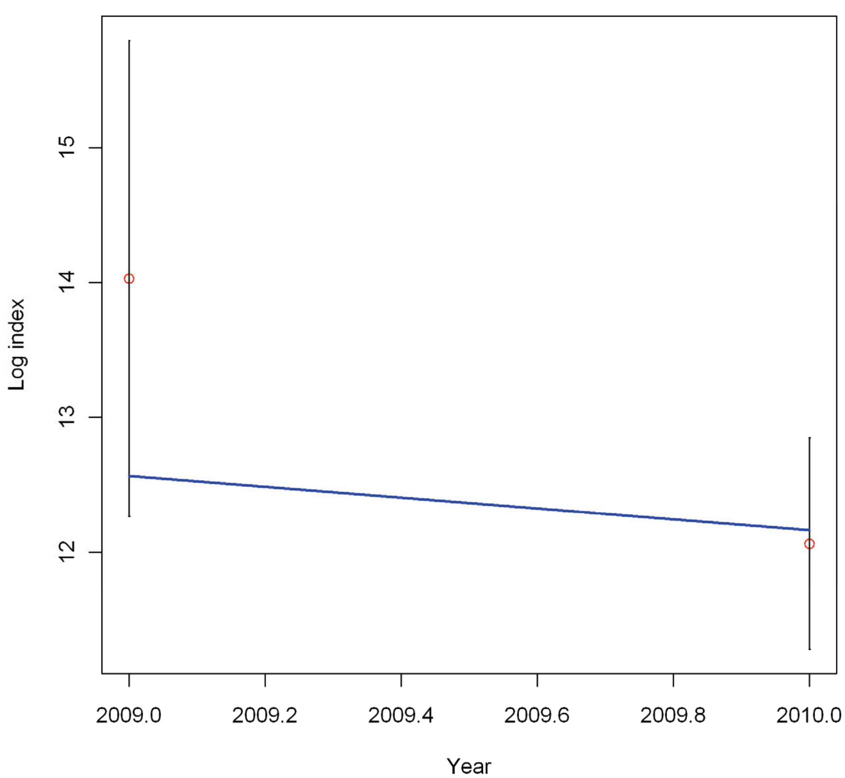


Figure 45b. Update model '10x1' fit to Aerial_N estimates of biomass (*q* fixed to 1), where aerial survey length compositions were fit using asymptotic selectivity.

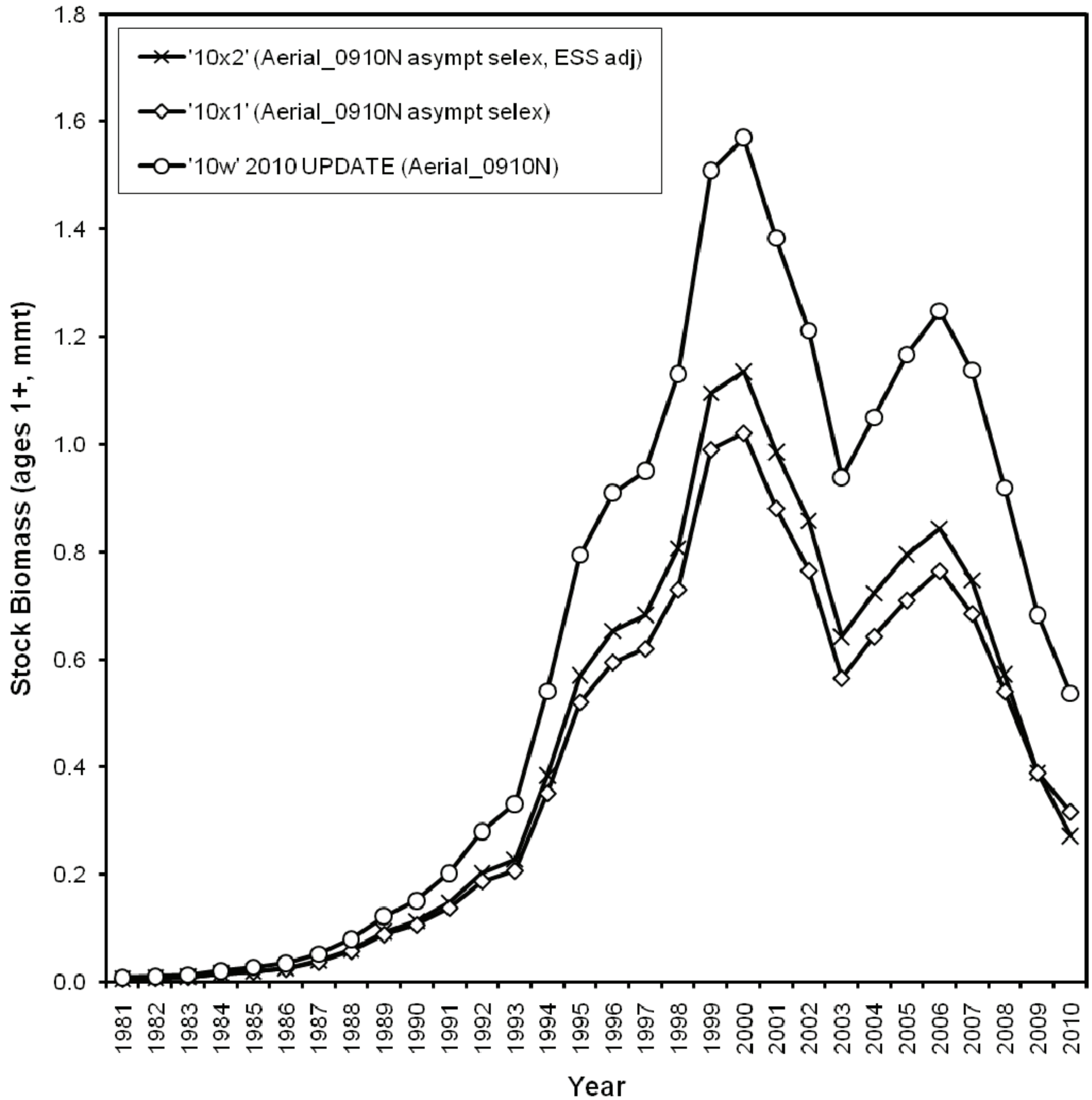


Figure 46a. Pacific sardine stock biomass (ages 1+) from the 2010 update model '10w' compared to models '10x1' and '10x2', where aerial survey length compositions were fit using asymptotic selectivities. Model 10x2 adjusts the aerial length composition variances to match model estimates from '10x1'.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

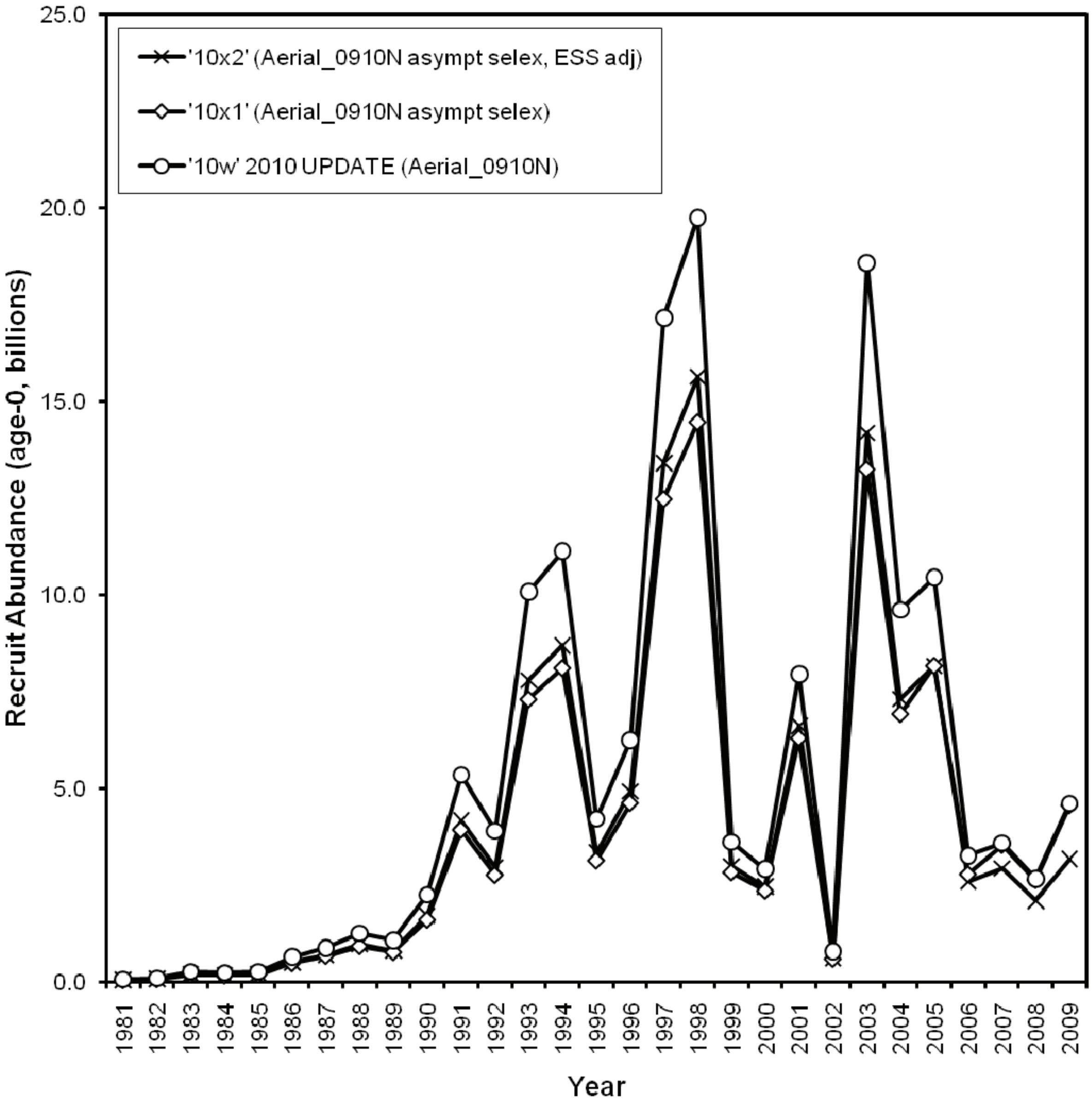


Figure 46b. Pacific sardine recruit (age-0) abundance from the 2010 update model '10w' compared to models '10x1' and '10x2', where aerial survey length compositions were fit using asymptotic selectivities. Model '10x2' adjusts the aerial length composition variances to match model estimates from '10x1'.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

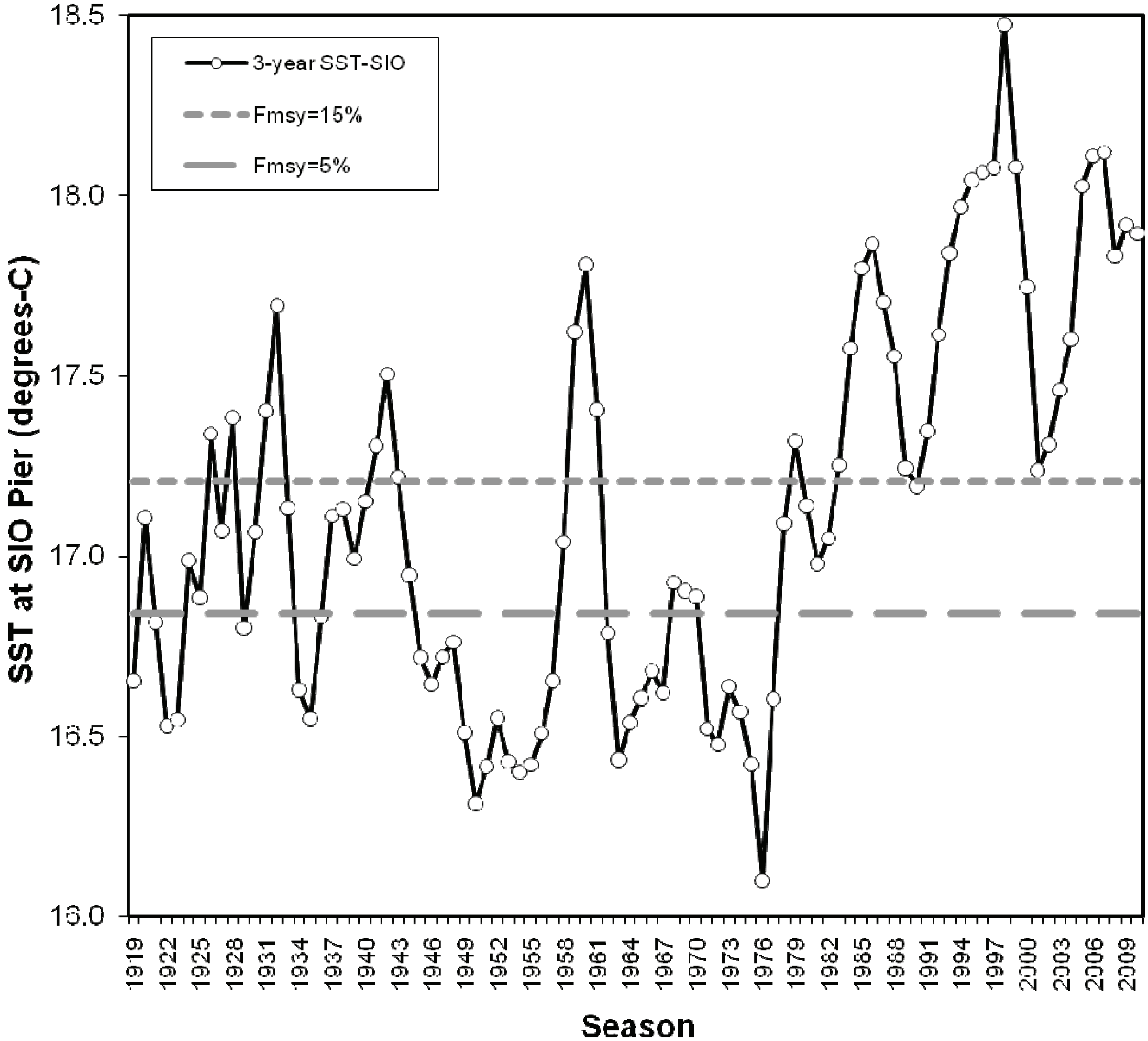


Figure 47. Three-season running average of sea surface temperature (SST) data collected daily at Scripps Institution of Oceanography pier since 1916. For any given season, SST is the running average temperature during the preceding three seasons (July-June), e.g. the 2010 estimate is the average from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

APPENDIX

1) Report of the Scientific and Statistical Committee (SSC) CPS Subcommittee assessment update review held October 5-7, 2010 at the SWFSC in La Jolla, California.

2) Report of the full SSC review held November 4, 2010 at the PFMC meeting in Costa Mesa, California.

SSC CPS Subcommittee Report on the Pacific Sardine Stock Assessment Update and Other CPS Matters

1. Introduction

Members of the Scientific and Statistical Committee's (SSC) coastal pelagic species (CPS) subcommittee met on October 5-6, 2010 at the SWFSC in La Jolla to (a) review the recently completed stock assessment update for Pacific sardine, (b) discuss possible revisions to the Terms of Reference for the CPS Stock Assessment Review Process and Stock Assessment Methodology Reviews, (c) review approaches proposed to set OFLs and ABCs for CPS monitored species, and (d) comment on proposed changes to the Essential Fish Habitat designations for CPS species.

The review occurred during a joint session that also included members of the CPS Management Team (CPSMT) and the CPS Advisory Subpanel (CPSAS). SSC CPS Subcommittee members in attendance were André Punt (meeting chair), Selina Heppell, Tom Jagielo, and Ray Conser (serving as rapporteurs). Tom Jagielo recused himself for the sardine assessment review, but participated as a member of the CPS subcommittee for the remaining items.

2. Terms of Reference for CPS Stock Assessments and Methodology Reviews

Two draft documents were reviewed at the September (2010) Pacific Fishery Management Council meeting: 1) Draft 2011 Terms of Reference for a Coastal Pelagic Species Stock Assessment Review Process, and 2) Draft Terms of Reference for Coastal Pelagic Species Stock Assessment Methodology Review. The Council will adopt final versions of both documents at its November 2010 meeting.

While there was general agreement among the Council advisory bodies (SSC, CPSMT, and CPSAS) on the guiding principles contained in both documents, somewhat differing views remained on a small number of issues. Discussion at this meeting was undertaken in an effort to reach consensus on these issues and thereby facilitate the final adoption process in November 2010. The meeting attendees reached consensus on all editorial issues for both documents and, after extended discussion, agreed on the remaining major issues summarized below.

<u>2011 Terms of Reference for a Coastal Pelagic Species Stock Assessment Review Process</u>

- It is the role of the SSC to resolve any scientific disputes between the STAT and the STAR Panel (SSC CPS subcommittee in the case of an assessment update). The CPSMT and the CPSAS provide input and feedback to the STAR Panel (SSC CPS subcommittee for updates) through their representative(s) who participate in the review. The TOR for CPS stock assessments was modified in 2009 to allow additional flexibility regarding the modifications to STAR-approved stock assessments which can be made during stock assessment updates, owing in particular to the short time between update review meetings and the Council meeting at which the update assessment is to be presented. Some members of the CPSMT suggested that if after the review, the CPSMT has scientific views that differ from both the STAT and the STAR, the SSC should consider its view as well and make a judgment between the STAR (SSC CPS subcommittee) and the CPSMT. For groundfish assessment reviews, the SSC has occasionally resolved disputes between STATs and STAR Panels, but not with the GMT. This experience has demonstrated that the process of resolving disputes is time-consuming and disruptive if it occurs more than on rare occasions. In order to minimize the number of conflicts for CPS and to provide consistency between the Council's Groundfish and CPS Review Processes, the SSC's conflict resolution process for CPS should only address conflicts between STATs and STAR Panels (SSC CPS subcommittee for updates). If necessary, the CPSMT could raise any remaining scientific concerns in its statement to the Council. However, given the timing of CPS assessments, these concerns will likely only be raised after the SSC has made its recommendations regarding OFLs.

- A STAT may include a general, qualitative summary of relevant ecological factors when describing the uncertainty associated with stock assessment results, and the Council may wish to consider these factors when setting ACLs. However, if such factors are to affect OFLs and ABCs recommended by the SSC, they will need to be fully reviewed and incorporated into the stock assessment model.

Terms of Reference for Coastal Pelagic Species Stock Assessment Methodology Review

- Methodological reviews are appropriate when a major new data source is introduced into a stock assessment or when a major change in the stock assessment modelling is contemplated. In both cases, a methodological review is needed when the change(s) from how assessments have been conducted in the past are deemed to be more than what a STAR Panel can reasonably be expected to handle. For example, the introduction of a new survey will generally require a methodological review; as will a change to a new stock assessment model platform. However, changes to the structure of a previously reviewed assessment model (e.g., changes in selectivity year-blocking) fall within the scope of what a STAR Panel would be expected to review as part of its normal activities.
- Some aspects of changes to the control rules could also be considered by a methodological review. In this case, however, care must be taken to separate the scientific analysis supporting the change (e.g. the structure and technical aspects of simulation studies used to compare a revised control rule against the *status quo*) and the management objectives used to measure performance (e.g. minimize year-to-year catch variance, maximize long-term average catch, etc.). The former are amenable to methodological review (provided adequate background analyses have been completed), but the latter are management decisions – not well suited to a methodological review.

3. Pacific Sardine Stock Assessment Update

Results of two analyses presented; the 2010 aerial survey by Tom Jagielo, the lead scientist for the aerial survey, and the 2010 sardine stock assessment update by Kevin Hill, the lead member of the STAT. The sardine assessment was conducted as an update to a stock assessment that had undergone a full STAR review in 2009. Updates are appropriate in situations where no alterations to a stock assessment model have occurred, other than to incorporate recent data, although changes to: (a) analytical methods used to summarize data prior to input to the model (e.g. how the compositional data are pooled across sampling strata), (b) the weighting of the various data components (including the use of methods for tuning the variances of the data components), and (c) how selectivity is modeled, (e.g., the time periods for the selectivity blocks), are acceptable as long the update assessment clearly documents and justifies the changes.

As specified in the "2009 Terms of Reference for Coastal Pelagic Species Stock Assessment Review Process," the review focused on two central questions: (1) did the assessment carry forward its fundamental structure from a model that was previously reviewed and endorsed by a STAR Panel, and (2) are the new input data and model results sufficiently consistent with previous data and results that the updated assessment can form the basis for Council decision-making.

The CPS subcommittee received the draft report of the 2010 aerial survey and the draft stock assessment less than two weeks before the meeting. However, there was sufficient time for the subcommittee to review these documents. The aerial survey and assessment STAT teams were prepared to conduct alternative analyses during the meeting.

The stock assessment reviewed by the subcommittee included updated catch data for Ensenada (ENS) (calendar years 2008 and 2009), Southern California (SCA) (calendar year 2009), Central California (CCA) (calendar year 2009), and the Pacific northwest (PNW) (calendar year 2009), and an updated abundance estimate and CV from the 2009 aerial survey. The assessment also included new data that have been collected since the 2009 assessment: (a) 2010 catch data for the SCA and CCA (January through July) and PNW (January through July, projected to September), (b) length composition data (July 2009-June 2010) for the SCA, CCA, and PNW, (c) a DEPM survey estimate of abundance for 2010, and (d) an aerial survey estimate of abundance for 2010.

In relation to the aerial survey, the subcommittee noted that the spatial coverage was much greater in 2010 than during 2009, thanks to the dedicated efforts of the research team and industry partners. Three replicate sets of transects were conducted during 2010, as requested by the SSC in 2009. This provided a more appropriate basis for calculating a CV for the 2010 survey estimate. Point sets were collected in the northwest and also from southern California and used to develop a school biomass-area relationship. Overall, the point sets covered more area and school sizes, but were unable to meet the suggestions for coverage by depth and latitude strata, primarily due to logistical constraints of bad weather and boats available for sampling in areas far from processor ports. Nevertheless, this year's survey represents a significant advance in the analysis and evaluation of aerial transects as a tool for estimating sardine biomass.

The method used to calculate a CV for the 2009 aerial survey estimate of abundance was updated to better account for the variance associated with the relationship between school surface area and biomass. This increased the CV set by the 2009 STAR Panel (0.55) to 1.12. One consequence of the increase to the CV was that the influence of the 2009 survey biomass estimate on assessment outcomes was greatly reduced.

The subcommittee evaluated the most appropriate means for using the 2009 and 2010 survey data to provide input for the model, and considered issues such as whether point set data should be pooled over years (2008, 2009, and 2010) as well as over space and how to compute a CV for the resultant abundance estimates. In the following list of requests, Oregon+Washington is referred to as the "northern area" and California as the "southern area". The subcommittee also considered analyses that further subdivided the "southern area" using data for north and south of Point Conception.

Requests for the survey STAT

A. Revise the survey CV for the 2010 aerial survey

Request. Revise the approach used to calculate the CV for the abundance estimates so that instead of randomly sampling one of the three replicate biomass estimates, biomass estimates should be computed for each replicate, three biomass estimates should be selected at random with replacement, and the bootstrap biomass estimate for each bootstrap simulation should be set to the average of the three randomly selected biomass estimates.

Rationale. The original approach used to compute the survey CV may overestimate the true CV.

Response. The survey data used in analyses were based on the revised approach.

B. Revise aerial survey estimates for 2010

Request. A variety of estimates of abundance were provided in the draft aerial survey report. Compute survey estimates of abundance for the northern and southern areas where the point sets used for each area-year stratum are those collected in the respective strata. If the estimate of asymptote of the school biomass-area relationship hits a boundary, the value for this parameter should be set to 0.0057 (the estimate of the asymptote based on the 2009 pooled data).

Rationale. There was a statistically significant difference ($p<0.05$) between the school biomass-area relationships for the northern and southern point sets. The assessment STAT did not wish to use the pooled point set data to compute survey estimates for 2009 and 2010 as this would lead to correlated estimates, but SS3 cannot account for such correlation.

Response. The estimate of the asymptote for the northern area hit a bound and was set to 0.0057. The resulting estimates of abundance for the northern and southern areas for 2010 were 173,390 mt (CV 0.42), and 27,695 mt (CV 0.56).

C. Plot the point set data and the biomasses by transect

Request. Plot the point set data and the biomass by transect.

Rationale. The subcommittee was concerned about the representativeness of the point set data.

Response. Maps of the requested information were prepared and displayed. The point set data for the northern area occurred roughly in the middle of the range of transects at which sardine schools were observed. The point set data for the southern area occurred in the California Bight, but most of the biomass (>90% for some replicates) occurred off Monterey.

D. Create a length frequency for the southern area

Request. Compute a length-frequency for the southern area by combining the survey length-frequency data for 2010 for this area, and the catch length-frequency for July 2010 for Monterey (CDFG block 508), weighting each length-frequency by the biomass estimate for the areas north and south of Point Conception.

Rationale. For reasons noted above, the point set data in the southern area were all obtained from the California Bight but the bulk of the biomass was observed off central California (primarily Monterey) and no point sets were possible in this region. Fishery data indicates a significant difference in the length compositions of fish caught in these two regions.

Response. The length-frequency distributions were calculated and presented.

The assessment STAT provided the subcommittee with a variety of model configurations, illustrating the impact of adding each revised source of data and new data source to the 2009 assessment. The outcomes from the assessments behaved as expected given the results of the 2009 assessment and the new data (e.g. increasing the survey CV for 2009 led to a markedly lower estimate of biomass). The assessment STAT proposed to only use the data from the northern area because: (a) most of the biomass in the southern area was found in the Monterey area, but the point sets came from the California Bight, and (b) there is a statistically significant difference in the school biomass-area relationship between the northern and southern areas, but is not clear how to assign a school biomass-area relationship to a region between where the northern and southern point sets occurred (Monterey area). The subcommittee agreed that this approach represented the best available science, even though survey data collected using protocols recommended by the SSC were not used.

Requests to the assessment STAT

A. Fit the survey estimates of abundance for the northern and southern area separately

Request. Assemble the survey data (biomass estimates and length-frequency) separately for the northern and southern areas. Fit the model estimating separate selectivity patterns for each area.

Rationale. The length-frequency distribution for the whole coast is bimodal.

Response. The results were provided to the subcommittee, but the STAT did not support use of the aerial survey data for the southern area in the assessment (see above).

B. Explore whether the selectivity pattern for the 2009 and 2010 survey are the same

Request. Conduct a model run in which the dome-shaped selectivity patterns for the 2009 and 2010 aerial surveys are assumed to be same and compare the results with a model run in which these selectivity patterns are allowed to differ.

Rationale. The 2009 and 2010 aerial surveys in the northern area occurred in similar locations and times, so it is plausible for the selectivity patterns to be the same.

Response. The selectivity patterns for the 2009 and 2010 differed slightly, but there was no support for different selectivity patterns based on changes in the value of the likelihood function.

A key remaining source of uncertainty is that the model outcomes change markedly with the exclusion of the aerial survey data, as noted during the 2009 STAR Panel.

The resulting assessment model (denoted "10w") satisfied the criteria for assessment updates and the subcommittee recommends that the SSC adopt it as the best available science for the management of Pacific sardine in 2011. The resultant OFL (US only) is estimated to be 92,767 mt. There were no disagreements between the STAT and subcommittee.

The subcommittee would like to compliment Kevin Hill and Tom Jagielo for their thorough documentation and willingness to conduct supplemental analyses during the meeting.

Recommendations for further analyses (2011 STAR Panel)

Aerial survey estimates

1. Compute CVs for each aerial survey replicate to identify the magnitude of each source of uncertainty.
2. Further explore the implications of different treatments of the northern and southern areas, including where the boundary is placed between the northern and southern point sets.
3. Explore the implications for changing where the aerial survey is conducted in terms of the impact of bias and variance.
4. Explore the biological data for the point sets that were not deemed acceptable for inclusion in the school biomass-area relationship calculation.
5. Include the full specifications for how the CV for the 2009 and 2010 survey estimate were estimated in the final version of the aerial survey report.

Stock assessment

1. 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.

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

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

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

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

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

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

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

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

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

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

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

OFLs and ABCs for Monitored Species

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

RECENT TECHNICAL MEMORANDUMS

SWFSC Technical Memorandums are accessible online at the SWFSC web site (http://swfsc.noaa.gov). Copies are also available form the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (http://www.ntis.gov). Recent issues of NOAA Technical Memorandums from the NMFS Southwest Fisheries Science Center are listed below:

NOAA-TM-NMFS-SWFSC-459 Assessing trends in abundance for vaquita using acoustic monitoring: within refuge plan and outside refuge research needs.
L. ROJAS-BRANCHO, A. JARAMILLO-LEGORETTA, G. CARDENAS, E. NIETO, P. LADRON DE GUEVARA, B.L. TAYLOR, J. BARLOW, T. GERRODETTE, A. HENRY, N. TREGENZA, R. SWIFT, and T. AKAMATSU
(June 2010)

460 Estimates of sustainable yield for 50 data-poor stocks in the Pacific Coast groundfish fishery management plan.
E.J. DICK, and A.D. MacCALL
(June 2010)

461 Documentation of the California catch reconstruction project.
S. RALSTON, D.E. PEARSON, J.C. FIELD, and M. KEY
(July 2010)

462 Serious injury determinations for cetaceans caught in Hawaii longline fisheries during 1994-2008.
K.A. FORNEY
(October 2010)

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N.C.H. LO, B.J. MACEWICZ, and D.A. GRIFFITH
(October 2010)

464 Ecosystem survey of *Delphinus* species cruise report.
S.J. CHIVERS, W.L. PERRYMAN, N.M. KELLAR, J.V. CARRETTA, F.I. ARCHER, J.V. REDFERN, A.E. HENRY, M.S. LYNN, C. HALL A. JACKSON, G. SERRA-VALENTE, T.J. MOORE, C. SURREY-MARSDEN, and L.T. BALLANCE
(October 2010)

465 Oregon, California and Washington line-transect and ecosystem (ORCAWALE) 2008 cruise report.
J. BARLOW, A.E. HENRY, J.V. REDFERN, T. YACK, A. JACKSON, C. HALL, E. ARCHER, and L.T. BALLANCE
(October 2010)

466 A forward-looking scientific frame of reference for steelhead recovery on the south-central and southern California coast.
D.A. BOUGHTON
(October 2010)

467 Some research questions on recovery of steelhead on the south-central and southern California coast.
D.A. BOUGHTON
(October 2010)

468 Is the September 1 river return date approximation appropriate for Klamath River fall Chinook?
M.R. O'FARRELL, M.L. PALMER-ZWAHLEN and J. SIMON
(October 2010)