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AUGUST 2014

ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2014 FOR U.S.A. MANAGEMENT IN 2014-15

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Juan Zwolinski[2], Emmanis Dorval[3], and
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NOAA-TM-NMFS-SWFSC-531

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

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ACRONYMS AND ABBREVIATIONS

ABC	acceptable biological catch
ACT	annual catch target
ATM	Acoustic-trawl method
BC	British Columbia (Canada)
CA	California
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CCA	Central California fishery
CCE	California Current Ecosystem
CDFW	California Department of Fish and Wildlife
CDFO	Canada Department of Fisheries and Oceans
CICIMAR	Centro Interdisciplinario de Ciencias Marinas
CONAPESCA	National Commission of Aquaculture and Fishing (México)
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)
FMP	fishery management plan
HG	harvest guideline
INAPESCA	National Fisheries Institute (México)
Model Year	July 1 (year) to June 30 (year+1)
mt	metric tons
mmt	million metric tons
MexCal	southern fleet based on ENS, SCA, and CCA fishery data
NMFS	National Marine Fisheries Service
NSP	Northern subpopulation of Pacific sardine, as defined by satellite oceanography data
NWSS	Northwest Sardine Survey (aka 'Aerial Survey')
NOAA	National Oceanic and Atmospheric Administration
ODFW	Oregon Department of Fish and Wildlife
OFL	overfishing limit
OR	Oregon
PacNW	northern fleet based on OR, WA, and BC fishery data
PFMC	Pacific Fishery Management Council
S1 & S2	Model Season 1 (Jul-Dec) and Season 2 (Jan-Jun)
SAFE	Stock Assessment and Fishery Evaluation
SCA	Southern California fishery
SCB	Southern California Bight (Pt. Conception, CA to northern Baja California)
SS	Stock Synthesis model
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
VPA	Virtual Population Analysis
WA	Washington
WDFW	Washington Department of Fish and Wildlife

PREFACE

The Pacific sardine resource is assessed each year in support of the Pacific Fishery Management Council (PFMC) process for recommending annual harvest specifications for the U.S. fishery. This sardine assessment report represents a *full assessment* for advising management in fishing year 2014 (newly-established to span July 1, 2014 - June 30, 2015). The last *full assessment* for Pacific sardine was conducted in 2011 (Hill et al. 2011, includes review report), followed by an *update assessment* in 2012 (Hill et al. 2012, includes review report), and *projection assessment* in 2013 (Hill 2013).

This assessment report presents pertinent discussion and results for important model scenarios highlighted in the formal Stock Assessment Review (STAR) held at NOAA's Southwest Fisheries Science Center in La Jolla, CA, March 3-5, 2014. All model scenarios include updated fishery-dependent and -independent time series and reflect different 'states of nature' (model configurations) that include alternative choices for input data (e.g., biological-composition and survey time series) and/or different assumptions or estimators for particular parameterizations of interest (e.g., underlying stock structure and biology, stock-recruitment relationships, data weighting methods for time series, etc.). In this final assessment report, information pertains generally to sensitivity analysis, review (STAR), and STAR panel decisions associated with categories/model scenarios presented in Table 8, particularly, model G (one of two blended, 'preferred' model scenarios initially presented at the STAR) and base model T (final model from STAR meeting). At the onset of the review, both the STAT and STAR panel supported and prioritized model G (length data/length-based selectivity) over blended model H (age data/age-based selectivity) for carrying on more focused evaluations at the meeting. That is, considerable sensitivity analysis was conducted on model G at the meeting to confirm/refute estimates and results from the initial baseline model, as well as further address details of particular data sets/parameterizations/results/diagnostics as identified by the STAR panel during the meeting. Readers should consult both the initial draft assessment report (Hill and Crone 2014) and final review report (STAR 2014) for background information regarding various model scenarios investigated in the initial sensitivity analysis and bases for final choices, assumptions, and parameterizations associated with base model T. Ultimately, model T represented a nearly similar configuration and outcome as model G, with a few key differences based on work conducted at the meeting.

The main objective in this year's assessment development addressed the overriding recommendation from past reviews concerning the importance of survey time series for accurate determination of total abundance of this and other small pelagic fish stocks. Recent estimates of total stock biomass are often the derived quantities most requested by fishery managers for setting harvest guidelines, as is the case for Pacific sardine of the California Current Ecosystem. Attention to direct information regarding abundance from surveys, particularly the more recent acoustic-trawl method (ATM) survey, served as the basis of the overall sensitivity analysis and associated model scenarios presented here. Indirect information regarding stock abundance from related sources of data and parameterizations, particularly pertaining to fitting biological composition time series in the integrated model, was modeled accordingly and in concert with the main goal to produce robust fits to abundance time series and estimates of current total stock abundance for advising management.

EXECUTIVE SUMMARY

The following Pacific sardine assessment was conducted to inform U.S. fishery management for the fishing year that begins July 1, 2014 and ends June 30, 2015. Model T represented the final base model from the formal stock assessment review (STAR) conducted in March 2014 for advising management in 2014-15.

Stock

This annually conducted assessment focuses on the Pacific sardine northern subpopulation (NSP) that ranges from northern Baja California, México to British Columbia, Canada and extends up to 300 nm offshore. In all past assessments, the default approach has been to assume that all catches landed in ports from ENS to BC were from the northern subpopulation. There is now general consensus that catches landed in ENS and SCA likely represent a mixture of southern subpopulation (warm months) and northern subpopulation (cold months) (Felix-Uraga et al. 2004, 2005; Garcia-Morales 2012; Zwolinski et al. 2011; Demer and Zwolinski 2014). Although the ranges of the northern and southern subpopulations can overlap within the Southern California Bight, the adult spawning stocks likely move north and south in synchrony and do not occupy the same space simultaneously to any significant extent (Garcia-Morales 2012). Satellite oceanography data (Demer and Zwolinski 2014) were used to partition catch data from ENS and SCA ports in order to exclude landings and biological compositions attributed to the southern subpopulation.

Catches

The assessment includes sardine landings (metric tons) from six major fishing regions: Ensenada (ENS), southern California (SCA), central California (CCA), Oregon (OR), Washington (WA), and British Columbia (BC). Landings for each port and for the NSP over the past ten years follow:

Calendar Yr-Sem	Model Yr-Seas	ENS Total	ENS NSP	SCA Total	SCA NSP	CCA	OR	WA	BC
2004-1	2003-2	11,212.9	3,922.9	15,232.0	15,232.0	2,145.7	2,203.5	235.3	179.6
2004-2	2004-1	30,684.0	2,373.9	17,161.5	1,512.5	13,162.6	33,908.3	8,564.1	4,258.4
2005-1	2004-2	17,323.0	11,186.6	15,419.0	13,948.1	115.3	691.9	324.0	0.4
2005-2	2005-1	37,999.5	4,396.7	14,833.6	1,508.6	7,824.9	44,316.2	6,605.0	3,231.4
2006-1	2005-2	17,600.9	11,214.6	17,157.7	16,504.9	2,032.6	101.7	0.0	0.0
2006-2	2006-1	39,636.0	0.0	16,128.2	4,909.8	15,710.5	35,546.5	4,099.0	1,575.4
2007-1	2006-2	13,981.4	13,320.0	26,343.6	19,900.7	6,013.3	0.0	0.0	0.0
2007-2	2007-1	22,865.5	11,928.2	19,855.0	5,350.3	28,768.8	42,052.3	4,662.5	1,522.3
2008-1	2007-2	23,487.8	15,618.2	24,127.2	24,114.3	2,515.3	0.0	0.0	0.0
2008-2	2008-1	43,378.3	5,930.0	6,962.1	21.8	24,195.7	22,939.9	6,435.2	10,425.0
2009-1	2008-2	25,783.2	20,244.4	9,250.8	9,221.3	11,079.9	0.0	0.0	0.0
2009-2	2009-1	30,128.0	0.0	3,310.3	29.8	13,935.1	21,481.6	8,025.2	15,334.3
2010-1	2009-2	12,989.1	7,904.2	19,427.7	19,427.7	2,908.8	437.1	510.9	421.7
2010-2	2010-1	43,831.8	9,171.2	9,924.7	562.7	1,397.1	20,414.9	11,869.6	21,801.3
2011-1	2010-2	18,513.8	11,588.5	12,526.4	12,515.4	2,713.3	0.1	0.0	0.0
2011-2	2011-1	51,822.6	17,329.6	5,115.4	11.9	7,358.4	11,023.3	8,008.4	20,718.8
2012-1	2011-2	10,235.0	6,823.3	11,906.2	10,018.8	3,672.7	2,873.9	2,931.7	0.0
2012-2	2012-1	39,575.0	0.0	6,896.1	883.6	568.7	39,744.1	32,509.6	19,172.0
2013-1	2012-2	9,780.0	6,520.0	2,636.0	769.7	84.2	149.3	1,421.4	0.0
2013-2	2013-1	40,509.0	0.0	3,654.8	0.0	739.0	27,535.9	25,425.2	0.0

Data and Assessment

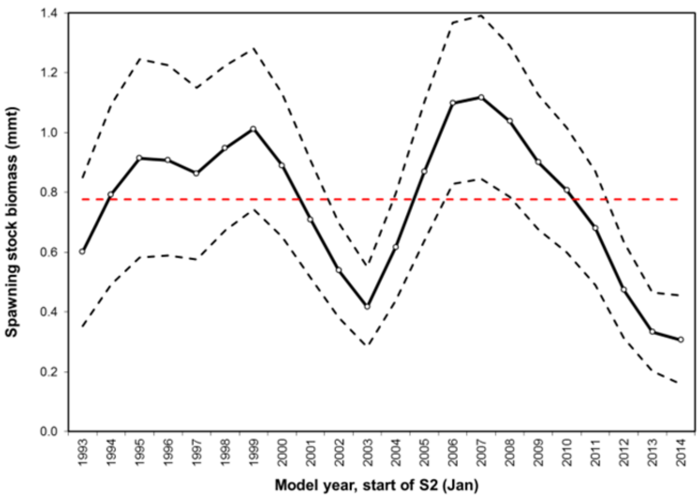
The assessment was conducted using the Stock Synthesis model (SS, version 3.24s), and includes fishery and survey data collected from mid-1993 through 2013. The model is based on a July-June fishing year, with two semester-based seasons per year (S1=Jul-Dec and S2=Jan-Jun). Catches and biological samples for the fisheries off ENS, SCA, and CCA were pooled into a single MexCal fleet (fishery), for which selectivity was modeled separately in each season (S1 and S2). Catches and biological samples from OR, WA, and BC were combined into a single PacNW fleet (fishery) in the model. Three indices of abundance from ongoing surveys were included in the base model: daily and total egg production method (DEPM and TEPM) estimates of spawning stock biomass off CA (1994-2013) and acoustic-trawl method (ATM) estimates of biomass along the west coast (2006-2013). Catchability (q) for the ATM surveys (spring and summer) was fixed (1.0) in the final base model T and q's for the egg production surveys were estimated without constraint. The spring and summer ATM time series were modeled with independent, asymptotic selectivities.

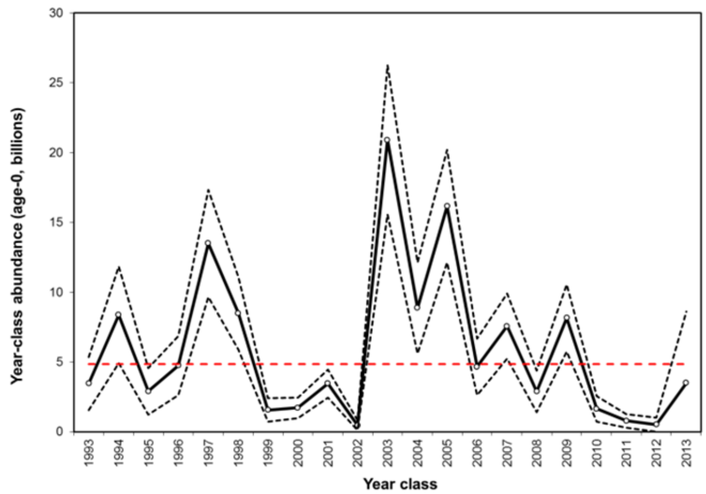
The following data were new to the 2014 assessment:

- Landings for 2012 and 2013 were updated for all fishing regions (ENS to BC), including and projected estimates for the first half of 2014 (2013/semester 2);
- Length compositions from SCA, CCA, OR, WA, and BC fisheries were updated for model year 2012 and the first semester of model year 2013 (July-December 2013 samples). No new length data were available for the ENS fishery;
- Conditional age-at-length data from SCA, CCA, OR, and WA were appended through June 2013;
- DEPM estimate of SSB from the spring 2013 survey off California; and
- ATM-survey estimates of biomass from the spring 2013 survey off California; and the summer 2013 SaKe survey off the U.S. west coast from San Diego to Vancouver Island were added to the model.

Spawning Stock Biomass and Recruitment

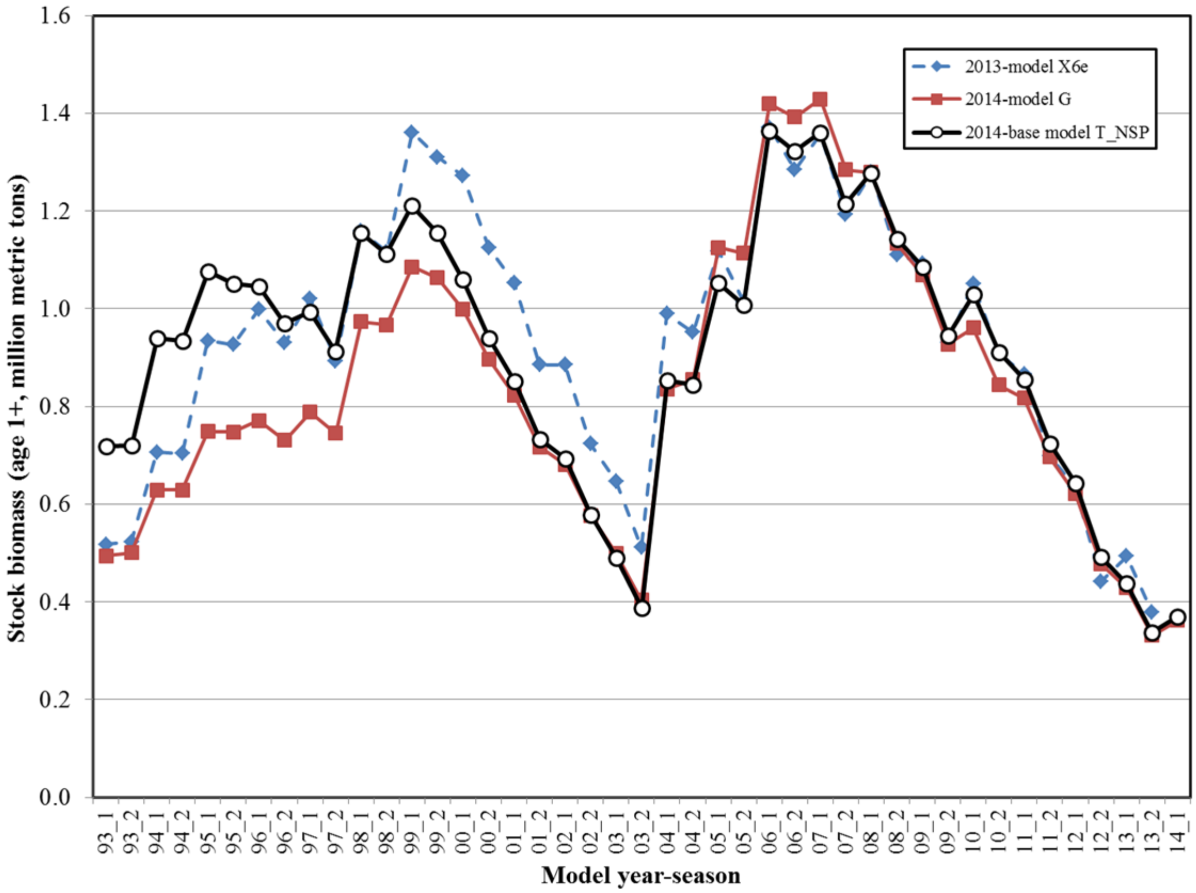
Recruitment was modeled using the Beverton-Holt (B-H) stock-recruitment relationship (σ_R=0.75). Steepness estimates typically bounded at 1 for most model scenarios evaluated in sensitivity analysis, with steepness being fixed at 0.8 in the final base model, based on a reasonable range for clupeid stocks indicated from stock-recruitment meta-analysis research. Virgin recruitment (R_0) for the final base model was estimated to be 4.828 billion age-0 fish. The virgin value of the spawning stock biomass (SSB) was estimated to be 0.78 million metric tons (mmt). The SSB increased throughout the 1990s, peaking at 1.01 mmt in 1999 and 1.117 mmt in 2007. Recruitments (age-0 abundance) peaked at 13.5 billion fish in 1997, 20.9 billion in 2003, 16.2 billion in 2005, and 8.1 billion in 2009. The 2010 to 2012 year classes were among the weakest in recent history. The 2013 year class, derived largely from the predicted stock-recruitment curve, was poorly estimated (CV=0.73), but included in calculation of total stock biomass (age 1+ fish, mt) for July 2014.





Model year	SSB (mt)	SSB Std Dev	Year class abundance (billions)	Recruits Std Dev
2000	889,929	119,525	1.707	0.368
2001	709,131	97,968	3.450	0.502
2002	538,750	79,127	0.467	0.175
2003	416,424	67,014	20.895	2.673
2004	616,788	89,430	8.860	1.636
2005	868,822	115,871	16.154	2.017
2006	1,098,180	134,709	4.652	1.012
2007	1,117,080	136,349	7.551	1.166
2008	1,037,970	126,448	2.884	0.742
2009	900,161	112,589	8.147	1.207
2010	806,697	104,196	1.648	0.458
2011	680,004	94,716	0.775	0.239
2012	473,374	80,309	0.514	0.251
2013	333,268	65,697	3.498	2.559
2014	306,237	74,121	---	---

Stock Biomass
Stock biomass, used for calculating harvest specifications, is defined as the sum of the biomass for sardine ages one and older (age 1+). Stock biomass increased throughout the 1990s, peaking at 1.27 mmt in 1999 and 1.42 mmt in 2007. Stock biomass is projected to be 369,506 mt as of July 2014.



Exploitation Status

Exploitation rate is defined as the calendar year catch divided by the total mid-year biomass (July-1, ages 0+). Exploitation rate for the U.S. fishery peaked at 14.4% in 2012 and total exploitation peaked at 18.4% that same year. The U.S. and total exploitation rates for the NSP calculated from the final base model are as follows:

Calendar year	USA	Total
2000	6.25%	9.13%
2001	6.47%	8.16%
2002	11.79%	13.84%
2003	9.93%	12.91%
2004	8.34%	9.51%
2005	6.39%	7.98%
2006	5.63%	6.55%
2007	7.52%	9.40%
2008	6.17%	8.62%
2009	5.55%	8.64%
2010	5.52%	9.29%
2011	4.83%	10.59%
2012	14.40%	18.42%
2013	12.06%	13.47%

Harvest Control Rules

Harvest guideline

Based on results from final base model T, the preliminary harvest guideline (HG) for the U.S. fishery in management year 2014-15 is 28,646 mt. The HG is calculated as follows:

HG = (BIOMASS – CUTOFF) • FRACTION • DISTRIBUTION,

where HG is the total U.S. quota for the period July 2014 to June 2015, BIOMASS (369,506 mt) is the stock biomass (ages 1+) projected as of July 1, 2014, CUTOFF (150,000 mt) is the lowest level of biomass for which harvest is allowed, FRACTION (15%) is the percentage of biomass above the CUTOFF that can be harvested, and DISTRIBUTION (87%) is the average portion of BIOMASS assumed in U.S. waters. The HG values and catches since 2000 are displayed under Management Performance. The recommended HG will be the lowest since the onset of federal management. The 28,646 mt HG will be divided into seasonal and related allocations during the April 2014 PFMC meeting.

OFL and ABC

Until now, Pacific sardine OFL and ABC calculations have been based on a temperature-independent E_{MSY} average value of 0.18. On March 11, 2014, the PFMC adopted the use of CalCOFI SST data for specifying environmentally-dependent E_{MSY} each year, beginning July 2014. Based on this recent decision, the following table of OFL and ABCs is based on an E_{MSY} = 0.122, which corresponds to the three-year running average of CalCOFI SST for 2011-13 (15.335 °C). The OFL for 2014-15 is calculated to be 39,210 mt.

Harvest Control Rule Formulas

OFL = BIOMASS * F_{MSY} * DISTRIBUTION

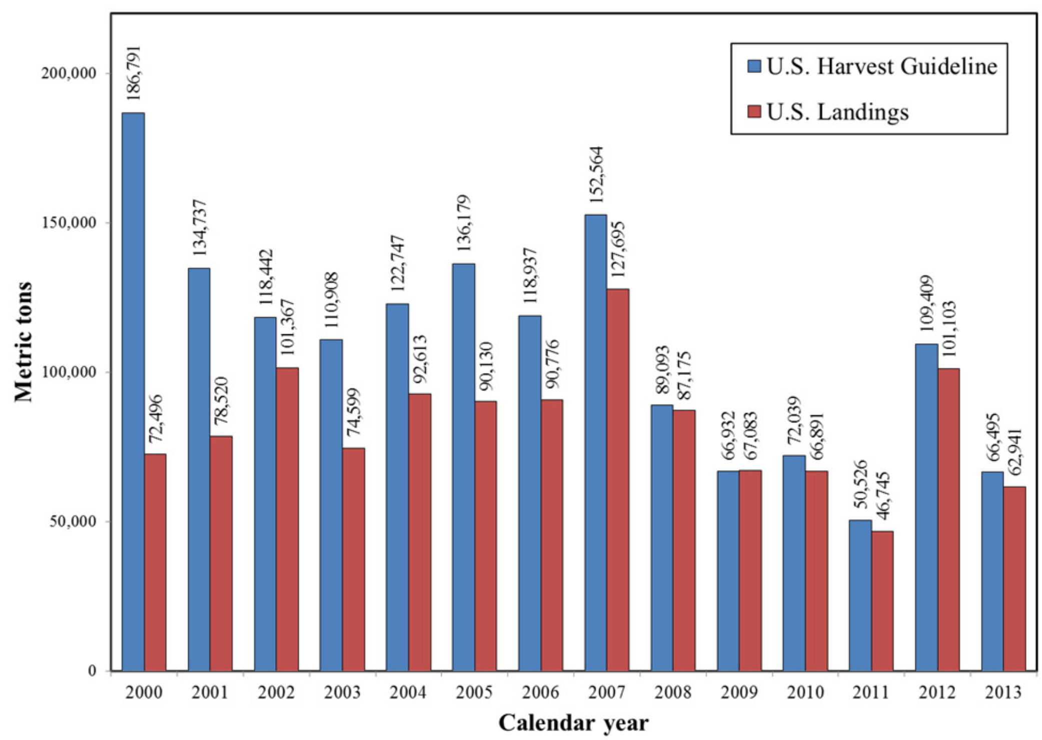
$ABC_{P\text{-}star}$ = BIOMASS * $BUFFER_{P\text{-}star}$ * E_{MSY} * DISTRIBUTION

HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION

Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	369,506								
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier\ 1}$	0.9558	0.9128	0.8705	0.8280	0.7844	0.7386	0.6886	0.6304	0.5531
ABC $Buffer_{Tier\ 2}$	0.9135	0.8333	0.7577	0.6855	0.6153	0.5455	0.4741	0.3974	0.3060
CalCOFI SST (2011-2013)	15.335								
E_{MSY}	0.122								
FRACTION	0.15								
CUTOFF (mt)	150,000								
DISTRIBUTION (U.S.)	0.87								
Harvest Control Rule Values (MT)									
OFL =	**39,210**								
$ABC_{Tier\ 1}$ =	37,475	35,792	34,131	32,464	30,757	28,961	26,999	24,719	21,688
$ABC_{Tier\ 2}$ =	35,818	32,672	29,710	26,879	24,126	21,391	18,591	15,583	11,997
HG =	**28,646**								

Management performance

U.S. HG values and catches since the onset of federal management follow:



Unresolved Problems and Major Uncertainties

In this stock assessment, four primary areas of uncertainty warrant further research attention to improve current knowledge of this species' biology and provide robust estimates of total abundance for management purposes on an annual basis. First, there exists considerable uncertainty surrounding absolute levels of recruitment (age-0, as well as age-1 fish) in the most recent years of the modeled time series, which are believed to be strongly related to environmental conditions, particularly, large-scale oceanographic phenomena (e.g., PDO, SST, sea-surface height, etc.). Further research is needed to better inform stock-recruitment estimation/parameterization in the present assessment, including best practices for identifying and accommodating such environmental information in the integrated SS model. Second, stock structure/distribution hypotheses and related catch/composition determinations were addressed in this assessment using environment-based indices vs. port-based as was conducted in all past assessments. Although general consensus from both STAT/STAR panel supported using environmental data to more objectively address subpopulation (northern and southern populations that potentially mix seasonally) assumptions in the model than simply assuming subpopulations can be identified directly from landing site data (e.g., ports), further empirical (otoliths, length/weight, reproductive/genetic tissue, meristics etc.) evidence should be collected annually from fish during periods of mixing to corroborate results from the environment-based index approach. Third, uncertainty surrounding catchability (q) for the primary ATM survey indices of abundance remains largely unresolved at this time and thus, q remains a fixed parameter (1.0) in the model, as assumed in past assessments. That is, while preliminary models presented at the 2014 STAR panel (e.g., model G) produced reasonable estimates of q for the ATM survey, further evaluations/review indicated the scale of important management quantities (stock biomass and recruitment), as well as estimates of q for the survey, remained sensitive to relatively small changes made to the model (see stock-recruitment estimation above). In this context, stability concerning the scale of sardine population estimates has been an ongoing issue since the application of fully integrated, age-structured models to assess the status this stock (Deriso et al. 1995). Fourth, and related to survey abundance parameterizations in the model, data weighting considerations associated with both fishery and survey composition time series largely reflect ad hoc practices for de-emphasizing these data to minimize their impacts on abundance estimation relative to the direct information provided in the survey indices. Further research associated with both data weighting and related selectivity parameterization is needed, particularly pertaining to conditional age-at-length compositions, to address potential model misspecification due to the treatment of composition data in the present assessment. Finally, based on the points above, the 2013 year-class strength is highly uncertain and poorly informed by the available data. This estimate, which may be biased high, factors into calculation of the age 1+ biomass for July 2014. One alternative approach would be to base age-1 biomass for 2014 on an average of the most recent few years and to add this value to the age 2+ biomass for purpose of setting management specifications in 2014-15. This issue was not explored during the STAR panel.

Research and Data Needs

See Research and Data Needs below for a summary of critical areas in need of further attention to generally improve the ongoing Pacific sardine assessment.

INTRODUCTION

Distribution, Migration, Stock Structure, Management Units

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

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

There is a longstanding, general consensus in the scientific community that sardines off the west coast of North America represent three subpopulations (see review by Smith 2005). A northern subpopulation (northern Baja California to Alaska), a southern subpopulation (outer coastal Baja California to southern California), and a Gulf of California subpopulation were distinguished on the basis of serological techniques (Vrooman 1964) and in studies of oceanography as pertaining temperature-at-capture (Felix-Uraga et al., 2004, 2005; Garcia-Morales 2012; Demer and Zwolinski 2014). An electrophoretic study (Hedgecock et al. 1989) showed, however, no genetic variation among sardines from central and southern California, the Pacific coast of Baja California, or the Gulf of California. Although the ranges of the northern and southern subpopulations can overlap within the Southern California Bight, the adult spawning stocks likely move north and south in synchrony and do not occupy the same space simultaneously to a significant extent (Garcia-Morales 2012). The northern subpopulation (NSP) is exploited by fisheries off Canada, the U.S., and northern Baja California, and is included in the CPS Fishery Management Plan (CPS-FMP; PFMC 1998). The current assessment addresses the above stock structure hypotheses in a more explicit manner, by partitioning southern (Ensenada and Southern California ports) fishery catch and composition data using an environment-based approach described by Demer and Zwolinski (2014) and in the following sections (see Assessment Data)..

Pacific sardines probably migrated extensively during historical periods when abundance was high, moving north as far as British Columbia in the summer and returning to southern California and northern Baja California in the fall. Tagging studies indicate that the older and larger fish moved farther north (Janssen 1938; Clark & Janssen 1945). Migratory patterns were probably complex, and the timing and extent of movement were affected by oceanographic conditions (Hart 1973) and stock biomass. During the 1950s to 1970s, a period of reduced stock size and unfavorably cold sea surface temperatures apparently caused the stock to abandon the northern portion of its range. In recent decades, the combination of increased stock size and warmer sea surface temperatures resulted in the stock re-occupying areas off Central California, Oregon, Washington, and British Columbia, as well as distant-offshore areas off California. During a cooperative U.S.-U.S.S.R. research cruise for jack mackerel in 1991, several tons of sardine were collected 300 nm west of the Southern California Bight (SCB) (Macewicz and Abramenkoff 1993). Resumption of seasonal movement between the southern spawning habitat and the northern feeding habitat has been inferred by presence/absence of size classes in focused regional surveys (Lo et al. 2011a) and measured directly using the acoustic-trawl method (Demer et al. 2012).

Life History Features Affecting Management

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

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

Age-specific mortality estimates are available for the entire suite of life history stages (Butler et al. 1993). Mortality is high at the egg and yolk sac larvae stages (instantaneous rates in excess of 0.66 d^{-1}). The adult natural mortality rate has been estimated to be M=0.4 yr^{-1} (Murphy 1966; MacCall 1979) and 0.51 yr^{-1} (Clark and Marr 1955). Zwolinski and Demer (2013b) studied natural mortality using trends in abundance from the acoustic-trawl method (ATM) surveys (2006-2011), accounting for fishery removals, and estimated M=0.52 yr^{-1}. A natural mortality rate of M=0.4 yr^{-1} means that 33% of the adult sardine stock would die each year of natural causes. Sensitivities to assumptions regarding M were addressed in this year's assessment (see Assessment Model).

Pacific sardines spawn in loosely aggregated schools in the upper 50 meters of the water column. The northern subpopulation spawning begins in January off northern Baja California and ends by August off the Pacific Northwest (Oregon, Washington, and Vancouver Island), typically peaking off California in April. Sardine eggs are most abundant at sea-surface temperatures of 13 to 15 ^{o}C, and larvae are most abundant at 13 to 16 ^{o}C. The spatial and seasonal distribution of spawning is influenced by temperature. During periods of warm water, the center of sardine spawning shifts northward and spawning extends over a longer period of time (Butler 1987; Ahlstrom 1960). Recent spawning has been concentrated in the region offshore and north of Point Conception (Lo et al. 1996, 2005). Sardines are oviparous, multiple-batch spawners, with annual fecundity that is indeterminate and age- or size-dependent (Macewicz et al. 1996).

Abundance, Recruitment, and Population Dynamics

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

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

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

Relevant History of the Fishery

The sardine fishery was first developed in response to demand for food during World War I. Landings increased from 1916 to 1936, peaking at over 700,000 mt. Pacific sardines supported the largest fishery in the western hemisphere during the 1930s and 1940s, with landings in Canada, WA, OR, CA, and Mexico. The population and fishery declined, beginning in the late 1940s and with some short-term reversals, to extremely low levels in the 1970s. There was a southward shift in catch as the fishery collapsed, with landings ceasing in the Pacific Northwest in 1947 through 1948, and in San Francisco in 1951 through 1952. Sardines were primarily reduced to fish meal, oil, and canned food, with small quantities used for bait.

In the early 1980s, sardines were taken incidentally with Pacific and jack mackerel in the SCA mackerel fishery. As sardine continued to increase in abundance, a directed purse-seine fishery was re-established. The incidental fishery for sardines ended in 1991. Besides SCA and CCA, substantial quantities of Pacific sardines are now landed at OR, WA, BC, and ENS. Total annual harvest by the Mexican fishery is not yet regulated by quotas, but there is a minimum legal size limit of 150 mm SL.

Recent Management Performance

Management authority for the U.S. Pacific sardine fishery was transferred to the PFMC in January 2000. The Pacific sardine was one of five species included in the federal CPS-FMP (PFMC 1998). The CPS-FMP includes harvest control rules intended to prevent Pacific sardines from being overfished and to maintain relatively high and consistent, long-term catch levels. Harvest control rules for the sardine are provided at the end of this report. A thorough description of PFMC management actions for sardines, including HG values, may be found in the most recent CPS SAFE document (PFMC 2011). U.S. HG values and landings since 2000 are displayed in Table 1 and Figure 1. Harvests at major fishing regions from ENS to BC are provided in Table 2 and Figure 2a-b.

ASSESSMENT DATA

Biological Parameters

Stock structure

For this assessment, we model the northern subpopulation (NSP, or 'cold stock') that ranges from northern Baja California, México to British Columbia, Canada and extends up to 300 nm offshore (Macewicz and Abramenkoff 1993). In past assessments, the approach has been to assume that all catches landed at ports from ENS to BC were from the northern subpopulation. As mentioned above, there is general consensus that catches landed in ENS and SCA likely represent a mixture of southern subpopulation (during warm months) and northern subpopulation (cold months) (Felix-Uraga et al. 2004, 2005; Garcia-Morales 2012; Zwolinski et al. 2011; Demer and Zwolinski 2014). For this assessment, we applied an objective method to partition data from ENS and SCA ports in order to exclude catch and composition data attributed to the southern subpopulation (see Assessment Model).

Efforts to survey, assess, and manage Pacific sardine in the California Current may depend on accurate differentiation of the purported two migrating stocks (Smith, 2005). A decade ago, a practical method was proposed for differentiating landings from the two stocks using concomitant measurements of sea surface temperature (SST)(Felix-Uraga *et al.*, 2004, 2005). Demer and Zwolinski (2013) independently corroborated and refined the method using regional indices of optimal and good potential habitat for the northern stock (Zwolinski *et al.*, 2011), and SST-based indices associated with the probability of including 99.9 % of all the sardine egg sampled over a 12-year period. The alternative indices equal the proportions of each fishing region containing optimal or good potential habitat for the northern sardine stock habitat (Zwolinski et al. 2011) and SST <16.4°C, respectively. For months when either index is <0.5, (i.e. when the minority of a fishing region probably includes potential northern stock habitat), the commercial landings are attributed to the southern stock, and vice versa. Because sardine landings at Ensenada or San Pedro were often low when the local habitat was transitioning (Felix-Uraga *et al.* 2004, 2005), the efficacy of the method is largely insensitive to the choice of index. To potentially improve the assessment estimates of northern stock biomass, Demer and Zwolinski's SST-index was calculated for the Ensenada and San Pedro regions, monthly since 1980, enabling the exclusion of southern stock sardine landings and their respective length compositions from the SS model.

Growth
The weight-at-length relationship for Pacific sardines (combined sexes) was modeled by the standard power function,

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

where W is weight (kg) at length L (cm), and a and b are regression coefficients. The length-weight relationship was re-examined for this assessment using least-squares fit to sample data from the modeled period, 1993-2013. Coefficients for the NSP (subscript '2' models) data set were, a = 7.5242e-06, b = 3.2332 (n = 104,326; corrected R^2 = 0.936) (Figure 3).

The largest recorded Pacific sardine was standard length SL = 41.0 cm (Eschmeyer et al. 1983), but the largest Pacific sardine commercially captured fish since 1981 was SL = 29.7 cm. The heaviest sardine weighed 0.323 kg. The oldest recorded Pacific sardine was 15 years old, but commercially-caught Pacific sardine are typically less than seven years old.

Sardine ageing using otolith methods were first described by Walford and Mosher (1943) and elaborated by Yaremko (1996). Pacific sardines are routinely aged by fishery biologists in México, CA, and the PNW using annuli enumerated in whole sagittae. A birth date of July 1 is assumed when assigning year class. Lab-specific ageing errors were calculated and applied as described in Hill et al. (2011).

Sardine growth was first estimated outside the SS model to provide initial parameter values and CV values for length at Age_{min} (0.5 yrs), length at Age_{max} (15 yrs), and growth coefficient K (Figure 4b). A re-analysis of size-at-age from fishery samples (1993-2013) did not indicate sexual dimorphism (Figure 4a) and thus, combined sexes are included in the present assessment model.

Maturity
Maturity-at-length parameters were updated using sardines sampled from survey trawls conducted from 1994 to 2013. Their reproductive state was primarily established through histological examination, although some immature individuals were simply identified through gross visual inspection. Parameters for the logistic maturity function were estimated using,

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

where slope = -0.89252 and inflexion = 15.44 cm-SL. Maturity-at-length parameters were fixed in the assessment model. Fecundity was fixed at 1 egg/gram body weight. Maturity- and fecundity-at-length vectors are presented in Figure 5a. Maturity-at-age during the spawning season (beginning of S2), as derived from growth estimation in final base model T is presented in Figure 5b.

Natural mortality
The instantaneous rate of adult natural mortality has been estimated to be M = 0.4 yr^{-1} (Murphy 1966; MacCall 1979), 0.51 yr^{-1} (Clark and Marr 1955), and 0.52 yr^{-1} (Zwolinski and Demer

2013b). Consistent with all previous sardine assessments, our base models were parameterized with $M = 0.4$ yr^{-1} for all ages and years (Murphy 1966, MacCall 1979, Deriso et al. 1996, Hill et al. 1999, Hill et al. 2012). A natural mortality rate of $M = 0.4$ yr^{-1} means that roughly 33% of the stock die of natural causes each year.
This assessment did examine sensitivity to alternative natural mortality assumptions based on 1) new analyses by Zwolinski and Demer (2013b), where M = 0.52 yr^{-1} for all ages, and 2) using Lorenzen's bent hockey stick function based on the hypothesis that *M* is higher at younger ages (Butler et al. 1993). A general Lorenzen formulation was applied,

$$M_{\text{age}} = M_c\ (L_{mat}/L_{age})\ \text{ for }\ a<a_{mat};$$

where $M_c = 0.4$, L_{mat}=15.44 cm-SL, and L_{age} =8 cm for age 0, 13.46 cm for age 1, and a_{mat}=2 years. This resulted in an M_{age} vector of 0.77 yr^{-1} for age-0 fish, 0.46 yr^{-1} for age-1 fish, and 0.4 yr^{-1} for fish ages 2 and older.

Fishery Data

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

The INAPESCA has collected sardine samples from the port of Ensenada since 1989. Sampling has been comparable to that of the U.S. with respect to randomness, frequency, and types of biological data. INAPESCA has collected roughly 10 random samples of 25 fish per month for size, sex, and reproductive condition, with a random subset being aged using otoliths (Table 3). We include length compositions (catch-weighted semester aggregates provided by INAPESCA) representing the full set of INAPESCA samples collected from mid-1988 through mid-2009. INAPESCA also provided a full complement of conditional age-at-length compositions, however, those data were not included this year due to unresolved issues. No new composition data have been obtained since the previous full assessment (Hill et al. 2011).

The CDFW has collected sardine samples from SCA and CCA ports on a regular basis since 1981. CDFW currently collects 12 random port samples (25 fish per sample) per month from each region. ODFW has collected port samples since 1999, and WDFW since 2000 (Table 3). Oregon and Washington fishery samples are collected at higher frequency due to the compressed fishing season, but each sample contains 25 fish.

The CDFO has sampled the BC sardine fishery since 1998. The CDFO collects 100 fish per sample and requires 50%-100% observer coverage, so many of the BC loads are sampled relative to other fisheries. The CDFO's protocol does include collection of otoliths, however, their ageing efforts have primarily focused on survey samples, with no fishery ages being available for this assessment.

All fishery catches and compositions were compiled based on the sardine's biological year ('model year') to match the July-1 birth date assumption used in age assignments. Each model year is labeled with the first of two calendar years spanned (e.g., model year '1993' includes data from July 1, 1993 through June 30, 1994). Further, each model year has two six-month seasons, where 'S1'=Jul-Dec and 'S2'=Jan-Jun. Major fishery regions were pooled to represent a southern 'MexCal' fleet (ENS+SCA+CCA) and a northern 'PacNW' fleet (OR+WA+BC), where the MexCal fleet was treated with semester-based selectivities ('MexCal_S1' and 'MexCal_S2'). Rationale for this design is provided in Hill et al. (2011).

Landings

Ensenada monthly landings, 1993 to 2002, were compiled using the 'Boletín Anual' series previously produced by INAPESCA's Ensenada office (e.g., Garcia and Sánchez 2003). Monthly landings from 2003 to 2011 were taken from CONAPESCA's web archive of Mexican fishery yearbook statistics (CONAPESCA 2012). Landings for 2012 and the first half of 2013 were provided by Dr. Manuel O. Nevarrez (INAPESCA-Mexico City) as semester totals. Semester aggregate catches in 2012-2013 were equally apportioned across months for purposes of assigning catch to the NSP.

California (SCA and CCA) commercial landings were obtained from CDFW's 'Wetfish Tables' (1993 to 1999, 2013) and the PacFIN database (2000 to 2012). Oregon (OR) and Washington (WA) landings (1999-2013) were also obtained solely from PacFIN. British Columbia monthly landing statistics, 1999 to 2010, were provided by CDFO (Linnea Flostrand and Jordan Mah, pers. comm.).

As stated above, satellite oceanography data were used to characterize ocean climate (SST) within typical fishing zones off Ensenada and Southern California and attribute monthly catch for each fishery to either the southern or northern subpopulation (NSP) Landings by model year-season for each fishing region and stock scenario (port-based versus environment-based NSP) are presented in Table 2 and Figure 2. The current SS model aggregates regional fisheries into a southern 'MexCal' fleet and a northern 'PacNW' fleet. Landings aggregated by model year-season and fleet for each stock scenario are presented in Table 4 and Figure 6.

Length compositions

Length compositions for each fleet and season were the sums of catch-weighted length observations, with monthly landings within each port and season serving as the weighting unit. As indicated above, environmental criteria used to assign landings to subpopulations were also applied to monthly port samples to categorize NSP fish. New catch-based weighting vectors were also calculated for creating aggregate NSP length compositions.

Length compositions were comprised of 0.5-cm bins ranging from 9 to 28 cm standard length (39 bins total). The 9-cm bin reflects all fish $\leq$9.49 cm, the 28-cm bin reflects all fish $\geq$28 cm, and all other bins (9.5 to 27.5 cm) reflect the lower bound of the respective 0.5-cm interval (e.g., the 9.5-cm bin includes fish ranging 9.5 to 9.99 cm).

Total numbers of lengths observed in each fleet-semester stratum were divided by the typical number of fish collected per sampled load (25 fish per sample for most regions, 100 fish per sample in Canada) to calculate the sample sizes for compositions included in the assessment model. Compositions having fewer than two samples per semester were omitted from the model. Length compositions were input as proportions. While raw sample data were not available from the ENS and BC regional fisheries, catch-weighted length distributions, assembled per above, were made available by INAPESCA and CDFO. To combine ENS with SCA-CCA data ('MexCal') and to combine BC with OR-WA data ('PacNW'), the respective length distributions and sample sizes were weighted by catch from each region and summed at the season level. Length compositions and input sample sizes by fleet are displayed in Figure 7, 8, and 9. Length compositions for the two stock structure assumptions (All vs. NSP) are presented side-by-side in these displays.

Age compositions

Age compositions were compiled based on the same fishery samples and weighting methods described above. For the length data/length-based selectivity model scenarios, implied ('ghost') age-compositions were included as model inputs (but omitted from likelihood calculations) to facilitate comparison of model predictions of age composition with the inferred values through examination of model residual patterns. For age data/age-based selectivity model scenarios, length and conditional age-at-length data were disabled and the above aggregate age compositions were included in the model with appropriate sample sizes. Aggregate age-composition data for both stock scenarios are presented in Figures 7, 8, and 9.

Conditional age-at-length compositions, used to estimate growth in length-based models, were constructed from the same fishery samples and weighting methods described above. Age bins included 0, 1, 2, 3, 4, 5, 6, 7, 8-10, 11-15 (10 bins total). The age 11-15 bin served as an accumulator allowing growth to approach maximum length (L_∞). Age compositions were input as proportions of fish in 1-cm length bins. As was done for the length compositions, the number of individuals comprising each bin was divided by the number of fish per sample to set the initial, input sample size. In most cases, age data were available for every length observation. Conditional age-at-length compositions for each fishery are presented in Figures 10-12.

Oregon and Washington fishery ages from model season 2 (S2, Jan-Jun), which would have been included in the PacNW fleet, were omitted from all models due to inter-laboratory inconsistencies in the application of birth-date criteria during this semester. Total OR and WA landings and samples during S2 are typically small, so this omission did not represent a major loss of information to the model.

It is important to note that length data, but not age data, were available for the BC fishery. As a result, length-based models more accurately represent sizes-at-removal for the aggregate PacNW fleet, but age-based models only represent removals-at-age by the OR and WA fleets. The same problem applies to the southern MexCal fleet, where lengths, but not ages, were available from the ENS fishery.

Ageing error
Ageing-error vectors for fishery data were unchanged from Hill et al. (2011). Ageing error vectors (SD at true age) were linked to fishery-specific conditional age-at-length or aggregate age-composition data (Figure 13). For complete details regarding age-reading data sets, model development and assumptions, see Hill et al. (2011), Appendix 2, as well as Dorval et al. 2013.

Fishery-independent Data

Overview
This assessment/review considered four time series obtained from fishery-independent surveys: 1) daily egg production method (DEPM) estimates of female spawning biomass; 2) total egg production (TEP) estimates of total spawning biomass; 3) NWSS aerial photogrammetric surveys of biomass; and 4) acoustic-trawl method (ATM) surveys of biomass. All of these surveys and estimation methods have been vetted through PFMC-SSC Methodology Reviews (panels included representatives from the PFMC-SSC and the Center for Independent Experts). The DEPM/TEP and aerial survey methods were reviewed in May 2009, and the ATM survey was reviewed in February 2011 and included in the 2011 assessment. Survey data are presented in Tables 5-7, Figures 14-20, and Appendices A and B (Zwolinski et al. 2014a, b) of this report.

Daily egg production method spawning biomass
The DEPM and TEP estimates of SSB were based on SWFSC ship-based surveys conducted each April between San Diego and San Francisco. The DEPM index of female SSB is used when adult daily-specific fecundity data are available from the survey. The total egg production (TEP) index of SSB is used when survey-specific fecundity data are unavailable. The DEPM and TEP series have been used for sardine stock assessment since the 1990s, and the surveys and estimation method were reviewed by a STAR panel in May 2009. Both time series are treated as indices of relative SSB (Figure 20), with estimated catchability coefficients (q).

In 2013, the SWFSC conducted the sardine DEPM biomass survey aboard the chartered research vessel R/V *Ocean Starr* (April 8 - May3) and the NOAA ship *Bell M. Shimada* (April 23 - April 30) within the standard DEPM area (CalCOFI line 60 to 95). The *Ocean Starr* covered the area off California from just south of Monterey Bay to Oceanside (CalCOFI lines 68.3 to 91.7) while the *Bell M. Shimada* covered the area from Avila Beach to Half Moon Bay (CalCOFI lines 76.7 to 63.3)(Figure 14). The *Bell M. Shimada* also conducted the standard spring CalCOFI survey from April 8 to April 22. Because egg and larval densities were generally low and no trawls were taken during the CalCOFI survey, only the data from the DEPM portion of *Shimada* were included in the estimation of egg production (*i.e.*, data from April 23 to April 30). The DEPM survey from both research vessels employed all the usual methods for estimating sardine SSB (Lo et al. 2011). 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 14).

The 2013 DEPM index area off California (CalCOFI lines 63.3 to 91.7, about 37.18˚ – 32.36˚N) was 141,397 km^2 (Figure 14). The egg production (P_0) estimate was 1.34/0.05m^2 (CV = 0.299)(Dorval et al. 2014). Female spawning biomass for the standard area was taken as the sum of female spawning biomasses in regions 1 and 2 (Table 6). The female spawning biomass and total spawning biomass (sum) for the DEPM area were estimated to be 82,182 mt (CV = 0.30) and 144,880 mt (CV = 0.36), respectively (Table 6).

Adult reproductive parameters for the survey are presented in Table 7. The estimated daily specific fecundity was 26.22 (number of eggs/population weight (g)/day) using the following estimates of reproductive parameters from 121 mature females collected from 15 positive trawls: mean batch fecundity (*F*) was 41,339 eggs/batch (CV = 0.06), fraction spawning (*S*) was 0.149 females spawning per day (CV = 0.16), mean female fish weight (W_f) was 138.18 g (CV = 0.03), and sex ratio of females by weight (*R*) was 0.586 (CV = 0.09). 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 2013 survey, the number of tows positive for mature female sardines was similar in Regions 1 and 2 (8 and 7 respectively), while three additional tows caught solely male sardines (Dorval et al. 2014).

In the SS model, the DEPM series is treated as an index of female SSB in the middle of S2 (April). Since 2009, the time series of spawning biomass was replaced by female spawning biomass for years when sufficient trawl samples were available and the total egg production for other years as inputs to the stock assessment of Pacific sardines. The 2013 DEPM estimate is considerably lower than in the previous few years (Tables 5 & 6; Figure 20).

Total egg production spawning biomass

Adult sardine samples are needed to calculate the daily specific fecundity for true DEPM estimates. Trawls were not always conducted during the egg production surveys. In the 2007 assessment, we chose to include these data as a Total Egg Production (TEP) series, which is simply the product of egg density (P_0) and spawning area (km^2). Calculated TEP values are provided in Tables 5 and 6 and displayed in Figure 20. TEP was also taken to represent relative SSB (length selectivity option 30) in the model (*q* estimated), but in this case the female fraction was unknown (Tables 5 and 6, Figure 20).

Aerial survey

The Pacific sardine industry (Northwest Sardine Survey, LLC; NWSS) funded aerial photogrammetric surveys of sardine abundance off the coast of OR and WA, beginning with a pilot survey in summer 2008. The pilot survey was critiqued by a PFMC-SSC Methodology Review panel in May 2009. Surveys were subsequently conducted during summer 2009 through 2012 (Jagielo et al. 2009-2012).

Aerial survey methods and results are described by Jagielo et al. (2012). The Aerial survey employs two sampling elements: 1) high-resolution aerial photographs, collected using spotter planes, to estimate the number and surface areas of sardine schools; and 2) non-random point sets targeted on sardine schools, prosecuted with commercial purse-seine vessels, to estimate the relationship between surface area and biomass and the size composition of the schools. Distributions of photographed fish schools and directed point sets, 2009-2012, are presented in Figure 15. Weighted length compositions and biomass estimates from the four surveys are displayed in Figure 16. In past assessments, aerial survey lengths had been fitted with domed-selectivity, however, we consider this to be inconsistent with fits to fishery composition data characterized by asymptotic selectivity and problematic in theoretical terms for surveys in general. Past assessments have treated this abundance time series both as an absolute index (fixed q=1.0; Hill et al. 2009, 2010), as well as a relative index (estimated q; Hill et al. 2011, 2012).

Acoustic-trawl method survey
The ATM time series is based on SWFSC surveys conducted along the Pacific coast since 2006 (Cutter and Demer 2008; Zwolinski et al. 2011, 2012, and Zwolinski et al. (see Appendices A and B of this report)). The ATM survey and estimation methods were reviewed by a panel in February 2011 and the results from these surveys have been included in the assessment since 2011 (Hill et al. 2011, Hill et al. 2012).

Two new ATM-based biomass estimates were included in this assessment; one from the spring 2013 survey off CA and the other from the summer 2013 SaKe survey spanning San Diego to northern Vancouver Island, Canada. Biomass estimates and associated size distributions from these two surveys are described in detail by Zwolinski et al. (see Appendices A and B of this report). The time series of ATM biomass estimates is presented in Table 5 and Figure 20, and associated biomass-weighted length compositions are displayed in Figure 17. A backlog of otoliths samples collected from survey trawls has been aged, so a full complement of aggregate age composition and conditional age-at-length data was available (Figures 18-19). The ageing error vector used for the SWFSC trawl ages is displayed in Figure 13.

Past assessments (Hill et al. 2011, 2012) have treated the spring and summer ATM biomass estimates as a single, combined time series of absolute biomass (q fixed = 1). Treating the spring and summer surveys with the same selectivity might not be optimal due to fish distributions observed among seasons, i.e., the bulk of sardine (and their habitat) are observed offshore of California during spring, and the majority of sardine (and their habitat) are off the coasts of Oregon and Washington during summer. Additionally, when smaller sardine are present in the ATM survey, it is usually during the spring cruises off California. Given the assumption that seasonal migrations are size-dependent, size and abundance for the spring and summer ATM surveys should theoretically be treated with different selectivity patterns. For these reasons, we explored sensitivity of the model to independent treatment of the spring (model season S2) and summer (model season S1) surveys. Additionally, much sensitivity analysis in this year's assessment addressed fixed vs. estimated catchability (q) assumptions for the ATM surveys (see Assessment Model).

Data Sources Considered but not Used

Following consensus from STAT/STAR discussions in this year's review meeting, the aerial survey was omitted from the assessment model, including all abundance and composition data, given: 1) as noted in past reviews, the vulnerability of this survey method to prevailing ocean conditions potentially affecting catchability (q) over short and long time frames (e.g., water clarity, sea state, water column stratification, and associated changes in vertical distribution) has resulted in highly variable estimates, with field protocols that are inherently difficult to 'control' in survey terms; 2) the survey design is space-restricted and non-synoptic, spanning largely the northern reaches of this species' annual movement/distribution; 3) the survey strictly reflects a species-specific sampling effort that is highly weather dependent; and finally, 4) the basic survey is likely to be conducted on an intermittent basis vs. conducted on a continual basis (e.g., not fully conducted last summer and no plans for continuing the survey next summer). Also, see *STAR (2011*) and *SSC (2012a*, *2012b)* Recommendations and Responses below for further information regarding the utility/drawbacks associated with aerial surveying efforts relative to the flexibility/merits of the ATM survey for assessing total population abundance of this species. It is important to note that the aerial survey could potentially be beneficial to the overall assessment if used in concert (vs. competing) with the primary ATM survey for purposes of evaluating specific areas of uncertainty associated with the acoustic-trawl sampling effort. For example, using aerial-sighted schools to evaluate the ATM's potential 'blind' areas within the upper 10 m of the water column and more coastal areas of the overall survey area that can be more problematic for ATM surveys. If deemed worthwhile, a rigorous 'dual surveying' approach could be employed to ensure results from the two surveys can be compared straightforwardly.

Also, it is important to note that although not utilized in this assessment, aggregate age data and associated age-based selectivity assumptions for modeling fishery and survey compositions (model H, see Hill and Crone 2014) remains a potentially meaningful configuration for future assessments. Such a model scenario represents the most practical approach for meeting the goal of the assessment, given current problems can be resolved accordingly, including obtaining reliable age data from both the Mexico and Canada fisheries, providing weighted age-composition time series for the ATM survey, and conducting more sensitivity analysis for objective comparisons with the length data/length-based selectivity model that has been used for all past assessments.

ASSESSMENT MODEL

History of Modeling Approaches

The Pacific sardine population's dynamics and status prior to the collapse in the mid-1900s was first modeled by Murphy (1966). MacCall (1979) refined Murphy's virtual population analysis (VPA) model using additional data and prorated portions of Mexican landings to exclude the southern subpopulation. Deriso et al. (1996) modeled the recovering population (1982 forward) using CANSAR, a modification of Deriso's (1985) CAGEAN model. CANSAR was subsequently modified by Jacobson (NOAA) into a *quasi*, two-area model CANSAR-TAM to account for net losses from the core model area. The CANSAR and CANSAR-TAM models were used for annual stock assessments and management advice from 1996 through 2004 (e.g., Hill et al. 1999; Conser et al. 2003). In 2004, a STAR panel endorsed the use of an Age Structured Assessment Program (ASAP) model for routine assessments. The ASAP model was used for sardine assessment and management advice from 2005 to 2007 (Conser et al. 2003, 2004; Hill et al. 2006a,b). In 2007, a STAR panel reviewed and endorsed an assessment using Stock Synthesis 2 (Methot 2005, 2007), and the results were adopted for management in 2008 (Hill et al. 2007) as well as an update for 2009 management (Hill et al. 2008). The sardine model was transitioned to Stock Synthesis version 3.03a in 2009 (Methot 2009) and was again used for an updated assessment in 2010 (Hill et al. 2009 & 2010). Stock Synthesis version 3.21d was used for the 2011 full assessment (Hill et al. 2011), the 2012 update assessment (Hill et al. 2012), and the 2013 catch-only projection (Hill 2013).

STAR (2011) and SSC (2012a, 2012b) Recommendations and Responses

The following information serves recommendations and responses provided prior to the STAR meeting in March 2014, i.e., recommendations and associated sensitivity analysis/responses made at the meeting are presented in STAR 2014, as well as generally addressed in *Model Selection and Evaluation* below. Finally, for particular recommendations below, applicable sensitivity analysis in Table 8 is referenced accordingly, given such analysis reflects the initial work undertaken for addressing past review recommendations.

STAR (2011) - Responses to unresolved problems and major uncertainties

1. The ongoing uncertainties, in particular regarding absolute biomass, are likely to persist until the information content of the data increases substantially.
   Response: Agreed, and likely applicable to every stock assessment.
2. The Panel wishes to highlight that the level of variation in terminal biomass evident from the retrospective pattern (on the order of 100,000s of tons from one year to the next is not unexpected, and changes in terminal 1+ biomass estimates of this extent may occur when the 2012 assessment update occur.
   Response: Agreed, and likely to persist for some time, given under/over-estimation of current biomass/recruitment strength (retrospective patterns) is typical in this, as well as most, assessments, particularly those conducted annually for productive, broadly distributed, small pelagic fish populations.
3. The indices of abundance do not exhibit consistent trends even after allowing for the differences in their respective selectivities, and remain in conflict even when the age and length data are greatly down-weighted.
   Response: See model scenarios for Surveys (B) and Biological compositions (C and D) in summary sensitivity Table 8. Also, see *SSC (2012a, 2012b)* G and K responses below.
4. The data set is able to estimate general trends in abundance fairly robustly, but the likelihood is flat over a wide range of current biomass levels, which means that relatively small changes to the data set or assumptions can lead to marked changes in current abundance. The current assessment has somewhat reduced the influence of this lack of information by fixing survey catchability. Ultimately, it is only through further data collection (or the development of informative priors for survey catchability) that these uncertainties may be overcome.
   Response: Agreed. See model scenarios for Surveys (B), Table 8. Also, see R_0 likelihood component profiles associated with models G and T (Figure 42).
5. The STAT evaluated a large number of model configurations to identify a more stable model that fits the data better. However, the residual patterns for the composition data and indices remain unsatisfactory. Furthermore, attempts to split the data by fleet to reduce some of these patterns led to unrealistic results (e.g. Fs > $2yr^{-1}$ in recent years for the MexCal fishery). The Panel identified the need to consider models with sex and spatial-structure, but there was insufficient time to develop, test, and evaluate such models during the Panel meeting.
   Response: As presented in past reviews, the limited information available indicates Pacific sardine growth is generally similar for males and females (e.g., size-at-age, Figure 4a), with sex ratio information indicating more females than males (higher *M* and/or differences in availability for males), depending on year/area evaluated. Given the numerous areas of uncertainty investigated here, configuration of sex-specific models for exploratory sensitivity analysis was considered a low priority and inefficient for meeting the main goal of the

assessment (see Preface). Subpopulation hypotheses and associated distributions in any given year are addressed, to various extents via sensitivity analysis under Stock structure (A), Table 8. Also, see *STAR (2011)* L response below.

6. Further down-weighting the age and length data is warranted given the analyses. However, time is needed to find a model configuration that does not lead to undesirable diagnostics (such as a low value for the root mean square error for the recruitment deviations, or a poor fit to the size-at-age data, as found in initial models examined during the meeting).
   Response: See model scenarios for Biological compositions (C and D models), Table 8.
7. The period covered by the current assessment starts in 1993 (rather than in 1981 as in past assessments). This change was necessary because of a variety of factors, including lack of precise abundance estimates for the years 1981-92, lack of age and length data for the Ensenada fishery (only three years of data), and the fact that the age and length data for southern California were collected from an incidental fishery for sardine for much of this period. In addition, the growth data for these years are inconsistent with the later growth data and was one reason for the previous assessment invoking the assumption of time-varying growth. While the Panel supports the change in start year, dropping the early data means that it is no longer possible to assess the state of the stock prior to 1993, which adds to uncertainty about the dynamics of this population and current biomass levels.
   Response: See *STAR (2011)* H, L, and O responses below. Pacific sardine recruit quickly to the fisheries, are short-lived species (few fish >6-years old), and have exhibited consistent, robust growth over the last one to two decades. Models based on an abbreviated time period are structured/parameterized most efficiently for addressing the primary management goal of this assessment to produce robust estimates of recent stock abundance. Models that include extended time periods would allow for historical contrasts of stock status, but necessarily complicate/confound the current assessment goals by including much more (early) composition data and little to no additional (quality) abundance information.
8. The scarcity of old and large sardines in the data relative to model estimates is a fundamental tension in the assessment that may be due to assumptions about, for example, growth, selectivity, natural mortality, and data weighting.
   Response: Although still indicated, to some extent, in most model scenarios, age data/age-based models reflect efforts to further evaluate this issue. See Biological compositions (C vs. D models) and Stock-recruitment (E models), Table 8. Also, less detailed binning for age composition time series may also provide further insight into this model uncertainty.

STAR (2011) - Responses to research recommendations

A. Continue to explore possible additional fishery-independent data sources. As noted by previous Panels, there would be value in attempting to include the data from the midwater trawl surveys off the west coast of Vancouver Island in the assessment. However, inclusion of a substantial new data source would likely require review which would not be easily accomplished during a standard STAR Panel meeting so would likely need to be reviewed during a Council-sponsored Methodology Panel. Similarly, the information provided on presence of sardine in the SWFSC juvenile rockfish survey should be explored further for possible inclusion in the future assessment.
   Response: This recommendation was addressed in previous review (Hill et al. 2011). The PFMC reviewed a number of requests for CPS survey methodology reviews during 2011-12, including SWFSC's acoustic-trawl survey, Southern California aerial-LIDAR survey, and

Pacific NW satellite imagery survey. However, CDFO's swept-area trawl survey has not been formally proposed for review at this time. The assessment team feels Canada DFO's swept-area trawl survey would be of limited utility in the assessment, given: (1) spatial coverage is limited to areas off Vancouver Island, the northern tail of the stock's distribution, and (2) DFO's biomass estimates (night-time trawls, 2006-2012) are highly variable (CVs = 1.5~3.0) and unlikely an informative time series within the assessment model. The SWFSC's pelagic juvenile rockfish survey has been previously reviewed (Hill et al. 2011) and found to have substantial limitations as a fishery-independent data source for inclusion in the current Pacific sardine assessment, given: (1) the survey (core area) design represents a limited spatial area in relation to this species' biology and movement, (2) the survey was not designed to accurately sample coastal pelagic species in general, which exhibit highly variable depth distributions and overall availabilities to a survey/fishery due largely to prevailing oceanographic conditions (e.g., no sardines were observed in 2010-12), and, (3) as for the Canada DFO trawl survey, a formal methods review of the rockfish survey should be conducted before potentially including results (abundance and/or size-composition data) in the ongoing Pacific sardine assessment. Interpretation of CPS distributions from the juvenile rockfish survey indicate that Pacific sardine (and other CPS) are typically more abundant in the core area during oceanographic regimes of low productivity and/or low upwelling. Finally, an environmental (PDO) index is currently being developed for possible inclusion in future assessments for purposes of better informing S-R and recruitment estimation, i.e., based on the assumption that juvenile survival of age '0' fish is strongly influenced by immediate oceanographic conditions (see Zwolinski and Demer 2013a).

B. The Panel continues to support expansion of coast-wide sampling of adult fish for use when estimating parameters in the DEPM method (and when computing biomass from the acoustic-trawl surveys). It also encourages sampling in Mexican and Canadian waters (aerial and acoustic-trawl surveys).

   <u>Response</u>: The SWFSC continues to attempt coast-wide surveys as frequently as possible for both the DEPM and acoustic-trawl surveys. Since 2011, these surveys have included coast-wide trawl samples of adult fish. Mexico carried out an ATM survey along the outer Baja coast in summer 2012, but specific details of their ATM methods may differ and are not able to be compared straightforwardly to the U.S. ATM. The INAPESCA has a new vessel this year, and plans to conduct regular surveys of the outer Baja coast. It is hoped that collaborative technical exchanges and research surveys will be realized in the near future with particularly Mexico. Finally, two collaborative summer *SaKe* surveys (2012, 2013) with the NWFSC hake survey efforts have been conducted and are incorporated in the summer ATM index.

C. Temperature-at-catch could provide insight into stock structure and the appropriate catch stream to use for assessments, because the southern subpopulation is thought to prefer warmer water. Conduct sensitivity tests to alternative assumptions regarding the fraction of the MexCal catch that comes from the northern subpopulation.

   <u>Response</u>: Subpopulation hypotheses and associated distributions in any given year are addressed under Stock structure (A), and the environment-based method for partitioning catches/compositions was applied for both blended models (G and H), Table 8.

D. The assessment would benefit not only from data from Mexico and Canada, but also from joint assessment, which includes assessment team members from these countries.

Response: A joint Mexico INP-NMFS sardine assessment workshop was held in La Paz in September 2010, which resulted in exchange of information regarding the SS modeling platform, as well as standardized data sets for the respective fisheries off Mexico and the U.S. However, no formal arrangements are in place currently for conducting a collaborative Pacific sardine (or other CPS) assessment between the SWFSC staff and researchers from Mexico or Canada, although limited momentum continues, given the ongoing MexUS-Pacifico forums held annually between NOAA Fisheries and INAPESCA administration staff. We strongly feel such collaboration is needed for accurate assessment of this transboundary species' status, particularly with Mexico, given sardine's hypothesized range and potential mixing with the southern subpopulation, as well as the observed elevated catches over more recent timeframe.

E. Conduct additional studies on stock structure -otolith and microchemistry studies are useful tools for this purpose.

   Response: Past otolith morphometric studies have been conducted (Felix et al. 2005 and Javor 2013), but provide limited findings that can be directly incorporated in the assessment model. Recently, the SWFSC has submitted proposals for funding further research projects for evaluating otolith development and associated banding patterns identified in ageing laboratory efforts. Also, some research has been conducted recently addressing spatial variability of age/growth for this species (see Hill et al. 2011, Appendix 2).

F. The relationship between environmental correlates and abundance should be examined. In particular, the relationship between environmental covariates and overall recruitment levels, as well as recruitment deviations should be explored further.

   Response: See *STAR (2011)* A response above and Stock-recruitment (E models), Table 8.

G. Consider spatial models for Pacific sardine, which can be used to explore the implications of regional recruitment patterns and region-specific biological parameters. These models could be used to identify critical biological data gaps, as well as better represent the latitudinal variation in size-at-age.

   Response: Subpopulation hypotheses and associated distributions in any given year are addressed under Stock structure (A), and the environment-based method for partitioning catches/compositions is applied in models G and H. Explicit spatial models with fish movement (vs. fleets as proxies for movement/availability) have not been explored thoroughly to date. It is likely such a detailed model would have limited value for direct application in an assessment model, but would allow for fishery/spatial model assumptions to be more critically examined in the future. See Hurtado-Ferro et al. (2013) for general simulation study that broadly addresses this issue.

H. Explore models which consider a much longer time-period (e.g., 1931 onwards) to determine whether it is possible to model the entire period and determine whether this leads to a more informative assessment and to provide a broader context for evaluating changes in productivity.

   Response: See *STAR (2011)* 7 response above. The period covered by the current assessment starts in 1993 (rather than in 1981 as in past assessments), given: (1) lack of precise abundance estimates for the years 1981-92, (2) lack of age and length data for the Ensenada fishery (only three years of data), (3) age and length data for southern California were largely collected from an incidental fishery for sardine for much of the early period of the fishery, and (4) growth data for these years is inconsistent with the later growth data (time-varying growth was considered in previous assessment reviews).

I. Modify Stock Synthesis (SS) so that the standard errors of the logarithms of 1+ biomass can be reported. These biomasses are used when computing the Overfishing Level, the Acceptable Biological catch, and the Harvest Level, but the CV used when applying the ABC control rule is currently that associated with spawning biomass and not 1+ biomass.
Response: This request for technical changes to SS has been received and is to be included in a major version change of the SS model scheduled for release in 2014-15.

J. In relation to the aerial survey: (a) provide the otoliths collected from the point sets to the SWFSC for possible ageing, (b) explore different functional forms for the mean relationship between school density and area (e.g., splines) as well as the variation about the mean curve (e.g., gamma), and (c) consider possible covariates (e.g., average fish size) in the relationship between catch weight and area.
Response: Presently, there is no information available from laboratory-related research regarding overall abundance estimation associated with the aerial survey.

K. Modify the r4SS package to include a plot of correlations among the residuals for the length data, as well as the fit of the model to the mean length or age in each composition.
Response: These software changes are forthcoming later this year, i.e., Francis method for weighting data based on correlations between bins (length/age) is to be included, along with the current McAllister and Ianelli method, in the r4SS package used to generate displays associated with the SS modeling framework.

L. Consider a model which explicitly models the sex-structure of the population and the catch.
Response: The need/justification for a sex-specific assessment model for Pacific sardine has been addressed previously (Hill et al. 2011; STAR 2011), with results from evaluations of length-at-age relations from fishery samples (1993-present) indicating no evidence of sexual dimorphism related to growth. Further, during the 2009 STAR panel, examination of residuals for the age- and length-composition data revealed that growth was apparently not constant over time. Specifically, there was evidence for a shift in growth rates in 1991. To address this in past assessments, growth parameters were modeled in two time blocks: 1981-1990 and 1991-2009 (Hill et al. 2009, 2010). However, it is still unclear whether this change in growth rate was due to density-dependence (compensatory growth) during the early stages of population recovery or some other factor. For example, the early difference in size-at-age could have been due to size-selective schooling, as many of these sardines were sampled from incidental catches (mixed with larger mackerel). Uncertainty around growth and representativeness of early samples was one of several reasons for starting the model in the early 1990s. See *STAR (2011)* 5 response above.

M. Consider a model which has separate fleets for Mexico, California, Oregon-Washington, and Canada.
Response: Fishery structure in the current models is based on objective evaluations of fishery catches in relation to similarities in fishing processes (selectivity parameterization) and hypothesized fish distributions resulting from hypothesized movement patterns of the stock. Finally, this recommendation was addressed in past assessments/reviews (2007-09), and was a primary reason for combining fisheries as presented here.

N. Develop a relationship between egg production and age which accounts for the duration of spawning, batch fecundity, etc. by age.
Response: Again, a recommendation previously addressed (assessment/review conducted in 2011), i.e., this laboratory activity was considered a much lower priority research undertaking at this time.

O. Consider model configurations which use age-composition rather than length-composition and conditional age-at-length data given evidence for time- and spatially-varying growth.
Response: See Biological compositions (D vs. C models) and blended models H vs. G, Table 8. Also, see Model Selection and Evaluation below.

P. Further explore methods to reduce between-reader ageing bias. In particular, consider comparisons among laboratories and assess whether the age-reading protocol can be improved to reduce among-ager variation.
Response: Some research has been conducted recently addressing spatial variability of age/growth for this species, which has been incorporated in past and this year's assessment (see Hill et al. 2011, Appendix 2). The SWFSC has encouraged further development of the newly established *Small Pelagic Ageing Research Committee* (SPARC) that includes researchers from the USA, Mexico, and Canada.

Q. The reasons for the discrepancy between the observed and expected proportions of old animals in the length and age compositions should be explored further. Possible factors to consider in this investigation include ageing error/ageing bias and the way dome-shaped selectivity has been modeled.
Response: See *STAR (2011)* 8 response above.

R. Any future management strategy evaluation work to compare control rules should focus on alternatives which are as robust as possible to uncertainty regarding absolute abundance.
Response: A recently conducted harvest control rule workshop did generally address MSEs associated with Pacific sardine that accounted for uncertainty in abundance (assessment error) and uncertainty in the S-R relationship (Hurtado and Punt 2014). Results from these workshops/paper are to be formally presented early this year to the PFMC (CPSMT 2014).

S. Profiles on key parameters should be included in future draft assessment to facilitate initial review.
Response: Key parameters profiled in the initial assessment report, as well as the final report here include R_0 (models G/H and T) and M (model T), Figure 42.

SSC (2012a, 2012b) - Responses to research recommendations

A. Consider the spatial-temporal relationship of acoustic and aerial surveys and fishery catches to compare estimates of biomass from stratified areas of the coast between surveys, and to evaluate effect of the timing of fishing on the biomass observed by the surveys in any year. This could take the form of a spatial population model operating on a short time-step (daily or weekly).
Response: See *SSC (2012a, 2012b)* G, H, J, and K responses below.

B. Consider a Beverton-Holt (B-H) or other S-R relationship in place of the Ricker model to investigate if such a change will stabilize the model relative to the number of recent years of recruitments estimated, while providing a biologically realistic relationship.
Response: See model scenarios for Stock-recruit (E models), and blended models G and H incorporate a B-H S-R relationship, Table 8.

C. Consider placing a smaller σ_R (as well as bias correction) on the final recruitment estimated to reflect the reduced amount of information available for estimating that recruitment (this will likely require a change in the SS3 platform).
Response: This treatment of recruitment error is not possible in the current version of SS, and unsure if the recommended change is currently even recognized by the SS development team.

D. Consider the changes within and between years in targeting in considering the proper treatment of fishery selectivities and blocks and proper weighting of these data.
Response: See blocking/data weighting schemes for Biological compositions (C and D models).

E. Conduct a methodology review on how to compare and best utilize data from the acoustic and aerial surveys in the sardine stock assessment. Among other possible issues, the review should consider if and how to improve their combined use in the assessment and consider incorporating the aerial survey as a minimum estimate (most easily done with a change in SS3, but doable with a prior on q for this survey).
Response: See *SSC (2012a, 2012b)* A response above, and G, H, J, and K responses below.

F. Consider the proper weighting of both fishery and survey biological data vs. survey time series data. Consider down-weighting biological compositions and emphasizing particular survey time series in future sensitivity analyses, e.g., see Francis (2011).
Response: See goals of assessment in Preface above and model scenarios for Biological compositions (C and D models), and blended model G, Table 8.

G. The summer ATM survey found that trawls in the northern area had highly mixed species composition.
Response: During the summer 2012 survey, the nighttime trawls often included, as usual, multiple coastal pelagic species. That is, the night-time ATM trawls are 'random' sets that does not involve targeting a particular species, whereas the aerial survey point-sets explicitly targets sardine schools. Further, the near-surface CPS caught off Oregon and Washington by the ATM survey during late July to early August 2012 included Pacific sardine with 39% mackerels (number proportion). In contrast, near-surface aerially observed CPS schools were attributed almost exclusively to sardine. More of those schools were likely mackerels.

H. Discrepancy between biomass estimate in the northern (WA/OR) portion of the ATM survey area and the fishery landings (as well as the aerial survey estimate).
Response: Between 07/31/2012 and 08/10/2012, the ATM survey sampled the region encompassed between 44° 47.2'N and 48° 18.0'N and from the 50m to the 1500m depth isobaths. The resulting point estimate of sardine biomass was 13,333 metric tons. The sampling variance was high, resulting in a 95% confidence interval of [3,918, 27,559] metric tons. During the same period, the commercial fishery off Oregon and Washington captured 9,747 mt. Immediately following these operations, the ATM surveyed the area to the north, including northern Washington and Western Vancouver Island. There, the sardine biomass was estimated at 18,675 with a 95% confidence interval of [2661, 54017] metric tons. Admitting that the all the sardine observed off western Vancouver Island migrated from the south, it is likely that by 08/10/2012, 32,008 mt of sardine, with 95% confidence interval of [12,439, 68,945 mt], were available for the Oregon and Washington fisheries. In summary, the ATM survey of the fished regions off Oregon and Washington spanned a couple weeks. In contrast, the surveyed region was fished for multiple months. It is, of course, incorrect to compare quasi-synoptic and time-integrated samples of a migrating population. Finally, the aerial survey point-sets in 2012 covered a small subset of the aerial photo transects and thus, it remains uncertain what portion of the photographed schools outside of that range were indeed sardine. Also, see *SSC (2012a, 2012b)* K response below.

I. Vessel avoidance and the acoustic transducer on the survey vessel missing fish were raised as possible explanations for this discrepancy.

Response: Guided by a validated model of potential sardine habitat, the ATM surveys have consistently spanned the northern sub-population of sardine. During the spring, sardine were found offshore of central and southern California, and roughly 30-70 m deep. During summer, sardine had migrated north to the shallow, coastal regions off Oregon and Washington. ATM surveys conducted during spring and summer of the same year (e.g., 2008, 2012, and 2013) indicate that the estimated biomasses are not statistically different. Therefore, the aforementioned 'possible explanations' for the supposed 'discrepancy' are unsupported.

J. There appear to be discrepancies between survey and fishery data with regard to the timing and location of sardine occurrence. Summer fisheries in the Pacific Northwest encounter sardine in unmixed schools during the day, while the acoustic survey found relatively few sardine north of southern Oregon, typically in mixed assemblages at night. Sardine is sampled by the acoustic survey in offshore areas off California but not in nearshore areas (up to 1 or 2 miles off shore) which account for significant fishery landings. The CPSMT representative supports addressing these discrepancies with concurrent sampling by fishery seasons and geography, as well as by sampling in nearshore areas with vessels suited to that habitat. The timing of surveys relative to fishery prosecution may also affect survey results and this should also be considered.

   Response: See *SSC (2012a, 2012b)* H response above. Although a good suggestion for addressing this issue, no detailed spatial/timing-related evaluations of fishery catches and survey sampling off OR/WA have been conducted to date.

K. The aerial survey used the one complete set of transects (set B) for school number and surface area estimates, while the point sets were taken after completion of the transects, rather than concurrently. More problematically, only 14 acceptable point sets were conducted, and they were not spatially representative of the sardine schools photographed during the transects. Given this lack of spatial coverage of the point sets, and the highly mixed Coastal Pelagic Species found in the ATM trawls in the same area as many of the photographed schools, there are potential species composition problems with the estimates derived from the aerial photographs. However, the composition of photographed schools and ATM trawls are not directly comparable, as the former are taken during the day and the latter at night when CPS are dispersed.

   Response: Agreed. As presented here and illustrated in the overall sensitivity analysis for meeting the main goal of the assessment, the ATM survey is founded on the most objective/defendable field/laboratory protocols for assessing absolute abundance of small pelagic fish stocks in any given year. It is difficult to compare the aerial survey directly with the ATM survey effort, given the less rigorous survey design and biomass estimation methods employed in the latter. That is, aerial survey catchability is likely to be highly variable and difficult to 'control' in survey terms, is space-restricted and non-synoptic, largely reflects a species-specific sampling effort that is highly weather dependent, and finally, likely to be conducted on an intermittent basis vs. conducted on a continual basis and representative of the extended range of this (and other) small pelagic populations. The aerial survey could potentially be used in concert (vs. competing) with the primary ATM survey for purposes of evaluating specific areas of noted uncertainty associated with the acoustic-trawl sampling effort. For example, using aerial-sighted schools to evaluate the ATM's potential 'blind' areas within the upper 10 m of the water column and more coastal areas of the overall survey area that can be more problematic for ATM surveys. If deemed worthwhile, a rigorous 'dual surveying' approach could be employed to ensure results from the two surveys can be compared straightforwardly.

Changes Between Current and Last Assessment Model

Henceforth, in this final assessment report, information pertains generally to sensitivity analysis, review (STAR), and STAR panel decisions associated with categories/model scenarios presented in Table 8, particularly, model G (one of two blended, 'preferred' model scenarios initially presented at the STAR) and model T (final model from STAR meeting). That is, both the STAT and STAR panel highlighted model G (over blended model H) for beginning further sensitivity analysis at the meeting. Considerable sensitivity analysis was conducted on model G at the meeting to confirm/refute estimates and results from the initial baseline model, as well as further address details of particular data sets/parameterizations/results/diagnostics as identified by the STAR panel during the meeting. Readers should consult both the initial draft assessment report (Hill and Crone 2014) and final review report (STAR 2014) for background information regarding various model scenarios investigated in the initial sensitivity analysis and bases for final choices, assumptions, and parameterizations associated with final base model T. Ultimately, model T represented a nearly similar configuration and outcome as model G, with a few key differences noted below.

Table 8 presents summary statistics for all of the model scenarios associated with the alternative stock structure hypothesis for Pacific sardine based on practical methods for differentiating/partitioning both catch and associated composition time series for the MexCal fishery between southern and northern subpopulations using environmental information, including sea surface temperature time series and regional indices of optimal and good potential habitat (Felix-Uraga et al. 2004, 2005; Smith 2005; Garcia-Morales et al. 2012, and Demer and Zwolinski 2014). Stock structure was considered one of the highest priority categories in the sensitivity analysis conducted in 2014, given the assumptions concerning spatial/temporal ranges of this transboundary population impact final fishery catches and compositions (for MexCal fisheries) used in the assessment. Finally, general consensus from the STAR 2014 was that this species' biology is strongly driven by environmental factors and the use of satellite/oceanographic data to partition landings accordingly was deemed more objective than relying on the current allocation scheme based simply on region (port) where the landing was made.

Differences between model X6e_2013, model G, and model T follow:

- **Model X6e_2013** – Final model (SS ver. 3.21d) used to conduct most recent projections for formal management (SSC 2012b, Hill et al. 2012, Hill 2013), Figure 21.
  a. assessment is based on a 'fishing' year that spans July 1st-June 30th (July 1st birthdate assumption).
  b. model time period is from 1993-12, with two seasons ('semesters,' S1=Jul-Dec and S2=Jan-Jun) per fishing year (a year/semester model time-step).
  c. sexes are combined.
  d. catch/composition (MexCal) time series derived using the port-based method.

e. two fisheries (MexCal and PacNW), with an annual selectivity pattern for the PacNW fleet, and selectivity patterns by semester for the MexCal fleet (MexCal_S1 and MexCal_S2).
f. length and conditional age-at-length compositions for all fisheries and the ATM and aerial surveys.
g. length-based/dome-shaped selectivity with time-blocking (1993-98, 1999-12) for the MexCal fisheries and length-based/asymptotic selectivity for the PacNW fishery.
h. Ricker stock-recruitment relationship with estimated steepness (σ_R = 0.727, tuned).
i. spawning occurs in S2 and recruitment in S1.
j. virgin (R_0) and initial recruitment offset (R_1) are estimated.
k. recruitment deviations associated with SSB are estimated from 1987-10.
l. initial fishing mortality (*F*) set to 0 for all fleets (non-equilibrium model using the initial age composition method in SS).
m. hybrid-*F* estimation method is used.
n. natural mortality (*M*) = 0.4 yr^{-1} for all ages.
o. DEPM and TEP survey time series reflect measures of spawning biomass and catchability (*q*) is estimated.
p. aerial survey time series reflect measures of biomass, with length-based/dome-shaped selectivity and *q* estimated.
q. ATM survey time series reflect measure of biomass for a single combined (spring and summer) survey, with length-based/asymptotic selectivity and *q* fixed (1.0).
r. data weighting (varied) for all survey abundance and fishery/survey composition time series.

- **Model G** – One of two 'blended' models (G and H) from the initial sensitivity analysis conducted prior to the STAR meeting and collectively, served as meaningful scenarios (configurations) for beginning the review and focused discussion. Essentially, models G and H were parameterized similarly, but included different biological compositions and selectivity assumptions, i.e., model G included length data and employed length-based selectivity as in past assessments and model H incorporated age data/age-based selectivity. Review consensus, both STAT and STAR, deemed model H less desirable/lower quality than model G at this time, given the absence of age data from both Canada and Mexico fisheries (for further informing the PacNW and MexCal fisheries, respectively), and the ATM age compositions represented unweighted estimates, i.e., these concerns were not applicable to model G, given length data were available from other countries and ATM length compositions were weighted accordingly. Presented list of data and parameterizations associated with model G follows the list for model X6e_2013 above.
  a. same as X6e_2013.
  b. model time period is from 1993-13, with two seasons ('semesters,' S1=Jul-Dec and S2=Jan-Jun) per fishing year (a year/semester model time-step).
  c. same as model X6e-2013.
  d. catch/composition (MexCal) time series derived using the environmental-based method (see stock structure category point above).
  e. same as model X6e_2013.
  f. length and conditional age-at-length compositions for all fisheries and the two ATM surveys (spring and summer, see q below); also see p below.

g. length-based/dome-shaped selectivity with time-blocking (1993-98, 1999-13) for the MexCal fisheries and length-based/asymptotic selectivity for the PacNW fishery.
h. Beverton-Holt stock-recruitment relationship with steepness fixed (0.8).
i. same as model X6e_2013.
j. same as model X6e_2013.
k. recruitment deviations associated with SSB are estimated from 1987-12.
l. same as model X6e_2013.
m. same as model X6e_2013.
n. same as model X6e_2013.
o. same as model X6e_2013.
p. aerial survey time series omitted, both index of abundance and length-composition data.
q. ATM survey time series reflect measures of biomass for two split (spring and summer), with length-based/asymptotic selectivity and *q* estimated for both surveys (see f above).
r. data weighting (0.5) for all fishery/survey conditional age-at-length compositions, and no other weighting applied to survey abundance time series or fishery/survey length compositions.

- **Model T** – Final model from sensitivity analysis conducted at the STAR meeting. Model T is similar to model G, except for f, q, and r below. Presented list of data and parameterizations associated with model G follows the lists for model X6_2013 and model G above.
  a. same as X6e_2013 and model G.
  b. same as model G.
  c. same as model X6e_2013 and model G.
  d. same as model G.
  e. same as model X6e_2013 and model G.
  f. length and conditional age-at-length compositions for all fisheries, and length compositions but no conditional age-at-length compositions for spring and summer ATM surveys.
  g. same as model G.
  h. same as model G.
  i. same as model X6e_2013 and model G.
  j. same as model X6e_2013 and model G.
  k. same as model G.
  l. same as model X6e_2013 and model G.
  m. same as model X6e_2013 and model G.
  n. same as model X6e_2013 and model G.
  o. same as model X6e_2013 and model G.
  p. same as model G.
  q. ATM survey time series reflect measures of biomass for two split (spring and summer) surveys, with *q* fixed (1.0) for both surveys.
  r. data weighting (0.2) for all fishery conditional age-at-length compositions, and no other weighting applied to survey abundance time series or fishery/survey length compositions.

Model Description

Assessment program with last revision date
The STAT transitioned from Stock Synthesis (SS) version 3.21d to version 3.24s (compiled 12/16/2013; Methot 2013, Methot and Wetzel 2013) for conducting the stock assessment in 2014. The SS model is founded on the AD Model Builder software environment, which serves as a suite of C++ libraries of automatic differentiation code for nonlinear statistical optimization (Otter Research 2001). The modeling framework allows for the full integration of both population size and age structure, with explicit parameterization both spatially and temporally. The model incorporates all relevant sources of variability and estimates goodness of fit in terms of the original data, allowing for final estimates of precision that accurately reflect uncertainty associated with the sources of data used as input in the overall modeling effort.

The SS model comprises three sub-models: (1) a population dynamics sub-model, where abundance, mortality, and growth patterns are incorporated to create a synthetic representation of the true population; (2) an observation sub-model that defines various processes and filters to derive expected values for different types of data; and (3) a statistical sub-model that quantifies the difference between observed data and their expected values and implements algorithms to search for the set of parameters that maximizes goodness of fit (Methot 2013; Methot and Wetzel 2013). This modeling platform is also very flexible in terms of estimation of management quantities typically involved in forecast analysis. Finally, from an international context, the SS model is rapidly gaining popularity, with SS-based stock assessments being conducted on numerous marine species throughout the world.

Definitions of fleets and areas
Data from major fishing regions are aggregated to represent southern and northern fleets (fisheries). The southern 'MexCal' fleet includes data from three major fishing areas at the southern end of the stock's distribution: northern Baja California (Ensenada, Mexico), southern California (Los Angeles to Santa Barbara), and central California (Monterey Bay). Fishing can occur throughout the year in the southern region. However, availability-at-size/age changes due to migration. Selectivity for the southern 'MexCal' fleet was therefore modeled separately for seasons 1 and 2 (semesters, S1 and S2).

The 'PacNW' fleet (fishery) includes data from the northern range of the stock's distribution, where sardines are typically abundant between late spring and early fall. The PacNW fleet includes aggregate data from Oregon, Washington, and Vancouver Island (British Columbia, Canada). The majority of fishing in the northern region typically occurs between July and October (S1).

Likelihood components and model parameters
A complete list of model parameters for base model T is provided in Table 9. The total objective function for the base model T included likelihood component contributions from: 1) fits to catch time series; 2) fits to the DEPM, TEP, and ATM survey abundance indices; 3) fits to length compositions from the three fleets and ATM surveys; 4) fits to conditional age-at-length data from the three fleets; 5) deviations about the spawner-recruit relationship; and 6) minor

contributions from soft-bound penalties associated with particular estimated parameters (Table 10).

Selectivity assumptions

Length data from the MexCal and PacNW fisheries were fit using length-based selectivity. The MexCal compositions were based on domed-shaped selectivity (using a 'double-normal' function), given the assumption that not all larger sardines were available to the Baja California and California fisheries from 1993 onward. At that stage in the population's recovery, large spawning events were observed off central California (Lo et al. 1996), and sardines were captured in trawls 300 nm off the California coast (Macewicz and Abramenkoff 1993). Selectivity for the MexCal fleet was estimated by season and in two time blocks (1993-1998, 1999-2011) to better account for both seasonal- and decadal-scale shifts in sardine availability to the southern region. The PacNW fishery length compositions were fit using asymptotic selectivity. Large sardines are typically found in the northern region, and it is assumed the largest sardines typically migrate to northern feeding habitats in the summer. The 2007 STAR recommended fitting PacNW length compositions based on two time blocks (breakpoint at 2003/2004) to better fit a decrease in sizes observed following the large 2003 recruitment event. While the additional time block had resulted in a slightly better fit to the PacNW length compositions (Hill et al. 2007), the time blocking was removed in recent and this year's assessment, given no theoretical basis for its application. Finally, in this context, further sensitivity analysis surrounding time-blocking was conducted prior to and at the review meeting in 2014, but again was not considered a meaningful parameterization, largely given the extent to which data weighting investigations were identified as the more meaningful evaluations to address potential selectivity misspecification and compromised fits to the composition data.

Stock-recruitment constraints and components

Pacific sardines are believed to have a broad spawning season, beginning in January off northern Baja California and ending by July off the Pacific Northwest. The SWFSC's annual egg production surveys are timed to capture (as efficiently as possible) the peak of spawning activity off the central and southern California coast during April. In our semester-based model, we calculated SSB at the beginning of S2. Recruitment was specified to occur in S1 of the following model year (consistent with the July-1 birth date assumption). In past assessments, a Ricker stock-recruitment (S-R) relationship has been assumed following Jacobson and MacCall (1995), however, following recommendations from past reviews, a Beverton-Holt S-R was investigated in the current assessment. Sensitivity analysis that addressed plausible values for steepness (0.5-0.9 for clupeids, see Myers et al. 1999) produced robust results that were generally similar to model configurations that were based on a Ricker S-R form.

In base model T, virgin recruitment (R_0) and initial recruitment offset (R_1) were estimated and steepness was fixed (0.8). Assumptions concerning recruitment variability (σ_R) to apply in S-R estimation was adjusted from 0.73 to 0.75 for strictly rounding purposes, given largely subjective basis for modeling underlying recruitment uncertainty in S-R calculations, i.e., Pacific sardine recruitment is highly variable in any given year and likely highly correlated with prevailing oceanographic conditions (e.g., large-scale environmental indices, such as the PDO, Zwolinski and Demer 2014). Recruitment deviations were estimated as separate vectors for the early and main data periods in the overall model. Early recruitment deviations for the initial population were estimated from 1987 (6 years before the start of the model). A recruitment bias adjustment ramp (Methot and Taylor 2011) was applied to the early period (Figure 37d). Main period recruitment deviations were estimated from 1993-12, which means that the 2013 year class was freely estimated from the data.

It is important to note that there exists little to no data in the assessment to directly evaluate recent recruitment strength (e.g., absolute numbers of age-0, 6-9 cm fish), with the exception of length data from the southern fisheries (MexCal), which in past years, have caught these juveniles sporadically during their first semester of life (S1). Age-0 fish are not encountered by the ATM survey, with reliable identification of age-1 fish typically only during strong recruitment years. Implied age-selectivities (product of length selectivity and the age-length key) from the fisheries and surveys are displayed in Figures 26b and 30b, respectively. In the ATM spring survey, fish are 50% selected by age 2. Fish caught in the MexCal_S2 fishery (1999-2013 block) are ~70% selected by age 0 (approaching their first birthday) and fully selected by age 1 (approaching their second birthday). In the MexCal_S1 fishery (same time block), fish are fully selected by age 2.

Further evaluations of influential environmental measures and as importantly, robust approaches for using this information in the ongoing assessment model are critical to meeting the primary goal of the assessment and provide reliable estimates of absolute abundance on an annual basis. See STAR (2014) and Research and Data Needs below.

Selection of first modeled year and treatment of initial population

The initial population was calculated by estimating early recruitment deviations from 1987-1992, six years prior to the model start year. Initial *F* values were fixed to zero, following recommendations from past assessments/reviews (see STAR 2011). The 'early years' recruitment deviations are applied to the initial equilibrium age frequency to adjust this composition before the time series start, whereby the model applies the initial *F* level to an equilibrium age composition to get a preliminary numbers-at-age time series, then applies the recruitment deviations for the specified number of younger ages in this initial vector. If the number of estimated ages in the initial age composition is less than the total number of age groups assumed in the model (as is the case with Pacific sardine assessment), then the older ages will retain their equilibrium levels. Because the older ages in the initial age composition will have progressively less information from which to estimate their true deviation, the start of the bias adjustment was set accordingly (see Methot 2013; Methot and Wetzel 2013).

Convergence criteria

The iterative process for determining numerical solutions in the model was continued until the difference between successive likelihood estimates was <0.0001. Final gradient for the base model was 8.77*e*-6.

Critical assumptions and consequences of assumption failures

In this assessment, there exists considerable uncertainty surrounding absolute levels of recruitment (age-0, as well as age-1 fish) in the most recent years of the estimated time series of numbers-at-age, which can comprise a substantial portion of the total biomass of short-lived, small pelagic species such as Pacific sardine in some years (Figure 47-48 and see Stock-recruitment constraints and components above). Further, it is important to note that the most recent samples from both fisheries and surveys indicate recruitment remains at depressed levels and thus, extended periods of weak compensation exhibited by the population in recent years, which is expected to produce a plateaued or decreasing total stock biomass in the immediate future. Additionally, a major change regarding stock structure assumptions and related partitioning of catches/compositions between hypothesized southern and northern sub-populations was made in this year's assessment, which resulted in considerable amounts of both catch and composition data being omitted from MexCal fisheries for particular seasons (see Changes Between Current and Last Assessment Model above). A third area of uncertainty in this ongoing assessment regards catchability (q) assumptions for the primary (ATM) survey abundance indices in the model, which are currently fixed at 1.0 for the two, seasonally (spring and summer) split ATM surveys. Sensitivity analysis that addressed a parallel model scenario to base model T (as well as for model G) with estimated *q's* for the ATM surveys (0.6 and 0.82 for spring and summer surveys, respectively) produced generally similar findings in terms of derived management quantities of interest as the fixed *q's* configuration (1.0 for both surveys). However, as expected, such assumptions/constraints concerning the survey's underlying probability of detection (q=1.0) indicated more notable potential conflicts between the data sources (survey abundance vs. composition data) about absolute abundance and thus, this critical assumption would benefit from continued evaluation in ongoing assessment development for this species (e.g., see diagnostic display Figure 42). Finally, considerable time at the meeting was devoted to data weighting approaches applied to composition data for purposes of de-emphasizing these time series in the overall model (relative to the emphasis on the survey abundance time series), given notable sensitivity of the results, particularly to the conditional age-at-length composition data (see Preface, STAR 2014, and Francis 2011). In this context, only limited time was available for evaluating alternative approaches for fitting composition data without compromising fits to the abundance indices, e.g., model scenarios that included time-varying assumptions for particular fishery and/or survey compositions were considered less desirable, primarily given little information for objective determination of appropriate blocking schemes to employ.

Model Selection and Evaluation

In preparation for the review meeting, model scenarios were developed systematically, based on four broad categories highlighted and emphasized in past reviews as areas of uncertainty (choices/assumptions for data/parameterizations) that warranted further attention: stock structure, surveys, biological compositions, and stock-recruit relations (Table 8 and STAR (2011) and SSC (2012a, 2012b) Recommendations and Responses). Data and parameterizations associated with the final base model T were based on discussions/sensitivity analysis during the meeting regarding the four primary categories above (see STAR 2014). In this context, model selection (justification/decisions) concerning important choices, assumptions, parameterizations incorporated in model T are presented in various areas in this assessment report. Critical areas of sensitivity analysis and subsequent model selection pertaining to this assessment involved: 1) stock structure (catch/composition estimation using environment-based vs. port-based information), see Changes Between Current and Last Assessment Model; 2) survey indices of abundance (see Fishery-independent Data and Critical assumptions and consequences of assumption failures); 3) stock-recruitment relationships (Beverton-Holt vs. Ricker), see Stock-recruitment constraints and components; and biological-composition data (fitting composition data without compromising fits to abundance indices), see Selectivity assumptions. Finally, although substantial baseline progress has been made regarding these four categories/considerations in the current assessment model, additional research is needed to improve understanding and reduce uncertainty surrounding each parameterization (see Research and Data Needs).

It is important to note that the STAT/STAR panel agreed that the age data/age-based selectivity model scenario (model H, Hill and Crone 2014) represents a promising, straightforward configuration for meeting the primary goal of the assessment (current estimate of absolute biomass determined annually), given the model scenario would include the most meaningful data that are available from sampling in-the-field to laboratory activities to accommodating/treating in the integrated age-structured SS model for assessing the status of this species. In this context, see the review report (STAR 2014) and *Research and Data Needs* for priority areas to consider in the future and the critical need for continued support of the newly established *Small Pelagic Ageing Research Cooperative* (SPARC) between NOAA, CDFW, ODFW, WDFW, Canada, and Mexico.

Base Model Results

Parameter estimates and errors
Base model T parameter estimates and standard errors (SE) are presented in Table 9.

Growth and fits to conditional age-at-length data
Modeled length-at-age is displayed in Figure 22. Length at age 0.5 was estimated to be 11.8 cm SL, L_{∞} was 23.5 cm, and the growth coefficient K was 0.386. Standard deviations for growth parameters are provided in Table 9. Fits to conditional age-at-length data are shown in Figures 23-25. Most conditional age-at-length compositions fit reasonably well, with the exceptions of MexCal_S1 in 2001-2003 (Figure 23) and PacNW in 2008-2010 (Figure 25).

Selectivity estimates and fits to fishery length-composition data
Length selectivity estimates for each fleet and time period are displayed in Figure 26a. Implied age selectivities (product of length selectivity and the age-length key) for each fleet and period are shown in Figure 26b. The MexCal fleets (S1 and S2) captured progressively smaller fish between the early and latter time blocks (Figure 26a).

Model fits to fleet length frequencies, implied age-frequencies, Pearson residuals, and observed and effective samples sizes are displayed in Figures 27-29. Results are grouped by fleet so the reader can examine fits to length compositions, bubble plots of Pearson residuals, and corresponding fits to implied age compositions on opposing pages. Results indicate random residual patterns for most data and fleets. The MexCal_S1 and S2 fleet length data were poorly fit in 2012 and 2013, when larger sardine were taken by the fishery (Figures 27-28). The PacNW fleet displayed notable residuals patterns for strong year classes (1997, 1998, and 2003) moving through the fishery (Figure 29).

Selectivity estimates and fits to survey length-composition data
Length selectivity estimates for surveys are displayed in Figure 30a and implied age selectivities for each survey are shown in Figure 30b. Selectivities for the ATM spring and summer surveys are notably different, with the spring survey selecting for smaller, younger sardine than in summer (Figure 30). We presume this difference is due to spatial differentiation of the migrating stock distribution the spring (off California) and summer (primarily PacNW) seasons.

Model fits to ATM survey length compositions, Pearson residuals, and observed and effective samples sizes are displayed in Figures 31-32. Fits to the ATM survey length data are less than optimal, with notable misfits to the spring 2010 composition (Figure 31).

Fits to survey indices of abundance
Model fits to the DEPM, TEP, and ATM spring and summer survey time series are displayed in both arithmetic and log scale in Figures 33-36. Model fits to the ATM surveys were reasonable (near mean estimates and within error bounds, Figures 33-34), with the exception of the estimate for the initial survey year 2005 (spring 2006 survey), which was notably under-estimated based on this (and all other) modeling scenarios (Figure 33). Fits to the spring ATM survey also displays a trend in the residuals (over-fitting in 2010-2013) that was not evident in results for pre-STAR model G (Hill and Crone 2014).

Fits to the DEPM and TEP surveys are displayed in Figures 35-36. Both time series are poorly fit compared to the ATM time series, however, the fit to the DEPM survey is slightly better than the fitted TEP time series. Catchability coefficient (q) for the DEPM series of female SSB was estimated to be 0.16, and the TEP series was best fit with q=0.55.

Population numbers- and biomass-at-age
Model T estimates of summary biomass (age 0+, age 1+, and SSB) and number-at-age are provided in Table 11a. Corresponding estimates of population biomass-at-age are shown in Table 11b.

Stock-recruitment relationship
Recruitment was modeled using the Beverton-Holt stock-recruitment relationship (σ_R=0.75). Steepness estimates for preliminary model runs typically bounded high (h=1), so steepness was fixed at 0.8 – a value considered reasonable for clupeid stocks (see Myers et al. 1999). The Beverton-Holt stock-recruitment relationship for base model T is displayed in Figure 37a. Recruitment deviations for the main era were estimated from SSB years 1993 to 2012 (2013 Year Class) (Figure 37b). Asymptotic standard errors for recruitment deviations are displayed in Figure 37c and the S-R bias adjustment ramp (Methot and Taylor 2011) is shown in Figure 37d.

Spawning stock biomass
Base model estimates (with 95% confidence intervals) of total SSB are provided in Table 12 and Figure 38a. The estimate of virgin SSB was 0.78 mmt. SSB increased throughout the 1990s, peaking at 1.01 million metric tons (mmt) in 1999 and 1.12 mmt in 2007 (Table 12, Figure 38a).

Recruitment
Estimated time series of recruit (age-0) abundance is provided in Table 12 and Figures 38b and 40. Virgin recruitment (*R_0*) for base model T was estimated to be 4.828 billion age-0 fish. Recruitments (year-class abundance) peaked at 13.5 billion fish in 1997, 20.9 billion in 2003, 16.2 billion in 2005, and 8.1 billion in 2009. The 2010 to 2012 year classes were among the weakest in recent history. The 2013 year class, derived primarily from the B-H predicted curve, was poorly estimated (CV=0.73; Table 12, Figures 38b and 40), but is included in calculation of the age 1+ biomass for July 2014.

Stock biomass for PFMC management
Stock biomass, used for setting management specifications, is defined as the sum of the biomass for ages 1 and older. Model estimates of stock biomass are provided in Table 11a and displayed in Figures 39 and 49. Stock biomass increased throughout the 1990s, peaking at 1.27 mmt in 1999 and 1.42 mmt in 2007. Stock biomass is projected to be 369,506 mt as of July 2014, but may be biased high given uncertainty in the strength of the 2013 year class and recent recruitment trends (Figure 38b). The 2013 year-class estimate factors into calculation of the age 1+ biomass for July 2014, but is based largely on the predicted stock-recruitment curve. One alternative approach would be to base age-1 biomass for 2014 on an average of the most recent few years (e.g. 2011-2013; see Table 11b and Figure 48) and to add this value to the age 2+ biomass for purpose of setting management specifications in 2014-15 (Figure 49).

Harvest and exploitation rates
Harvest rates (catch per selected biomass, continuous-*F*) by fleet are displayed in Figure 41a. Instantaneous *F* estimates were all within a plausible range of values and less than 0.7 in most seasons.

Exploitation rate is defined as the calendar year catch divided by the total mid-year biomass (July-1, ages 0+). U.S. and total exploitation rates for the NSP are shown in Figure 41b. Exploitation rate for the U.S. fishery peaked at 14.4% in 2012 and total exploitation peaked at 18.4% that same year (Figure 41b).

Uncertainty and Sensitivity Analysis

Likelihood profile for virgin recruitment
Likelihood profiles for virgin recruitment (R_0) can provide insight as to which data components are influencing scale in a stock assessment model. Pre-STAR model G and base model T were profiled for ln(R_0) values ranging from 14.8 to 16.4 (Figure 42). In the case of model G, the total likelihood surface was smooth and had a global minimum at R_0=15.489. All survey data fit best at moderate and higher R_0 values. Model G fleet length compositions fit best at low values of R_0, with PacNW lengths have the most influence on scale. ATM lengths fit best at higher values of R_0. Most conditional age-at-length data, in particular, the PacNW fleet, but also the MexCal_S2 fleet fit better at high values of R_0. So, while the total likelihood surface was smooth, there was conflict among the various data components within the model, in particular, the length compositions versus conditional age-at-length data for the PacNW fleet.

The R_0 profile for base model T, where ATM qs are fixed at 1, displays an uneven surface, with a global minimum at R_0=15.3 and a local minimum at R_0=15.7 (Figure 42). The R_0 estimate for base model T was 15.389, which is within the saddle of the global minimum, but slightly higher than the overall minimum (15.3). Likelihood profiles for the individual model components are likewise uneven and, in some cases, displaying different patterns than from pre-STAR model G (Figure 42). So while assuming a fixed q=1 may ultimately provide more stability in scaling, the model may yet change unpredictably when additional data are included due to this inherent tension in the model.

Likelihood profile for natural mortality
Natural mortality (M) was profiled for base model T (M=0.4) using values ranging from 0.24 yr^{-1} to 0.56 yr^{-1} in 0.02 yr^{-1} increments. Likelihood profiles for key model components (surveys, lengths, ages, and total) are displayed in Figure 43. As noted above, the likelihood surface for model T was uneven due to fixing of catchability parameters for the ATM time series. The likelihood profile for M displayed similar characteristics and are thus somewhat difficult to interpret for some individual components. The total likelihood was best fit for M=0.36, with a local minimum at M=0.46. ATM Spring had minima at 0.34-0.38 and 0.42-0.44. Most length composition data fit better at lower values of M, but PacNW lengths fit better at M=0.42-0.44. Conditional age-at-length data tended to fit best at higher M values.

Sensitivity to data weighting
For the most part, the review meeting focused primarily on sensitivity analysis pertaining to appropriate data weighting methods for meeting the assessment goal. In particular, conditional age-at-length compositions were identified as problematic in the present assessment model configuration, given the extent to which these data inform not only growth estimation, but also produce conflicts with selectivity parameterizations associated with both fisheries and the ATM surveys. Final base model T includes de-emphasized conditional age-at-length compositions for all fisheries and omits such information from the ATM survey that had been used in past assessment. However, continued examinations are needed of model fits to composition data based on both data weighting schemes, as well as time-vary assumptions for particular fisheries (e.g., PacNW), see Research and Data Needs.

Retrospective analysis
Retrospective analysis can provide another means of examining model properties and characterizing uncertainty. A retrospective analysis of base model T was performed, where data were incrementally removed from the end year back to 2008 (STAR 2014). Stock biomass estimates for these analyses are displayed in Figure 44. The model displayed some systematic pattern of under-estimation for recent years, with the greatest change in scale occurring for the model ending in 2012 (Figure 44).

Historical analysis
Model T estimates of stock biomass and recruitment are compared to recent assessments in Figures 45-46. Full and updated SS models since 2009 (Hill et al. 2009-2013) were included in the comparison. Biomass and recruitments are similar in trend across models, with some differences in scale for peak and low periods (Figures 45-46).

HARVEST CONTROL RULES FOR THE 2014-15 MANAGEMENT CYCLE

Harvest guideline

Based on results from final base model T, the preliminary harvest guideline (HG) for the U.S. fishery in management year 2014-15 is 28,646 mt (Table 13). The HG is calculated as follows:

HG = (BIOMASS – CUTOFF) • FRACTION • DISTRIBUTION,

where HG is the total U.S. quota for the period July 2014 to June 2015, BIOMASS (369,506 mt) is the stock biomass (ages 1+) projected as of July 1, 2014, CUTOFF (150,000 mt) is the lowest level of biomass for which harvest is allowed, FRACTION (15%) is the percentage of biomass above the CUTOFF that can be harvested, and DISTRIBUTION (87%) is the average portion of BIOMASS assumed in U.S. waters. The HG values and catches since 2000 are displayed in Figure 1. The recommended HG will be the lowest since the onset of federal management. The 28,646 mt HG will be divided into seasonal and related allocations during the April 2014 PFMC meeting.

OFL and ABC

Until now, Pacific sardine OFL and ABC calculations have been based on a temperature-independent E_{MSY} average value of 0.18. On March 11, 2014, the PFMC adopted the use of CalCOFI SST data for specifying environmentally-dependent E_{MSY} each year, beginning July 2014. Based on this recent decision, the table of OFL and ABCs is based on an $E_{\mathrm{MSY}} = 0.122$, which corresponds to the three-year running average of CalCOFI SST for 2011-13 (15.335 °C) (Table 13). The OFL for 2014-15 is calculated to be 39,210 mt.

RESEARCH AND DATA NEEDS

The following list presents three related areas for addressing a critical understanding of spawner-recruit relations and estimation, both spatially and temporally, for this species of the CCE. Unarguably, uncertainty surrounding underlying Pacific sardine stock-recruitment (S-R) variability/scale, estimation, and model parameterization is the most important area for future research efforts. Figure 47-48 illustrates the contribution and variability of recruitment to the total biomass in any given year. Consequently, further evaluation and/or new research focus should be directed toward the following areas of research to address the primary goal of the assessment, to provide accurate measures of total population biomass and related derived management quantities useful to fishery management following a short-term schedule. The following list represents a synthesis of important areas of future research previously noted in the report, and highlights critical collaborative work needed in the field, laboratory, and analysis/modeling. Finally, the STAR (2014) provides further details on each of the needs listed here (see Technical Merits and/or Deficiencies of the Assessment). Collectively, both lists present the most important areas of research to focus on, both immediately and long-term, to most efficiently address the management goal.

Stock-Recruitment: Dynamics, Data, Assumptions/Estimation/Modeling

Field

Relative to the other marine resource surveys available to the assessment, the ATM survey produces the most objective (say scientifically accurate and representative) information for determining absolute abundance of this population on a systematic basis. Minimally, a synoptic survey needs to be continually supported and conducted at least seasonally and ideally, in both the spring and summer, given recruitment variability and uncertainty as noted above. The long-term CalCOFI surveys collect valuable information, in terms of providing: a longer-term index of abundance in the current model; and egg/larval abundance and distribution data for informing/complementing and corroborating/refuting findings from the primary ATM surveys relied on in this assessment (see STAR 2014 for further discussion and related research details applicable to the ATM and DEPM surveys).

Laboratory

Age and growth studies and continued production ageing efforts in the laboratory are critical to a better understanding of stock structure and distribution of hypothesized sub-populations and ultimately, total catch determination for the northern sub-population used in management. Foremost, the newly established *Small Pelagic Ageing Research Cooperative* (SPARC) between NOAA, CDFW, ODFW, WDFW, Canada, and Mexico is considered a high priority undertaking, given: 1) the utility of age data/compositions to the ongoing assessment development for this and other members of the small pelagic fish assemblage and the importance of standardized protocols for ageing fish across the various countries/laboratories; and 2) a recognized international working group such as this can arrange/conduct needed projects in the most efficient manner. For example, validation studies that address the critical stock structure assumption based on environmental indices for partitioning catches/compositions adopted in this assessment should be conducted to confirm/refute this method for separating the northern and southern subpopulations using the habitat-related model. This will entail collection of morphometric, otolith morphology/micro-chemistry, and genetic data from fish in the mixing/transition areas between the two subpopulations and subsequently, can be evaluated using straightforward statistical methods to identify/verify potential differences based on empirical evidence from actual samples of fish collected systematically in the field.

Analysis

The following areas represent additional (sensitivity) analysis that would benefit the ongoing assessment, including:

1) Continued evaluations of the most plausible/robust assumption for modeling spawner-recruit dynamics in the stock assessment model. For example, Beverton-Holt vs. Ricker form, steepness considerations, potential environmental data/indices for informing recent recruit estimation, and accommodation of environmental information in the model (internally, based on potential oceanographic covariates within the S-R parameterization itself or externally, based on an environmental index (e.g., PDO) derived outside the model and treated as a ‘survey’ index of fully-selected age-0 fish in the model). The STAR (2014) presents specific analysis-related considerations to further pursue regarding estimation of both age-0 and age-1 recruitment in the most recent year of the assessment model.

2) Further examinations are needed regarding reliability/robustness of catchability (q) assumptions associated with the primary ATM survey indices, including: fixed vs. estimated approaches; split surveys according to season-based cruises or combined into a single annual-based index; and using informative priors in q estimation/parameterization.

3) Model fits to biological-composition time series, particularly the conditional age-at-length data, are variable, indicate various residual patterns, and can be sensitive to relatively minor changes (e.g., inclusion/omission of particular fishery/survey compositions). In this assessment/review, substantial sensitivity analysis was conducted based on various weighting methods. To date, data weighting schemes investigated included the McAllister and Ianelli method as part of the internal SS model modeling framework, as well as both ad hoc weighting approaches and using Francis (2011) methods that include correlation variability inherent in composition data, but often ignored for practical purposes in calculations of effective sample sizes. However, further sensitivity analysis is needed to better understand the extent to which fitting composition data using time-varying selectivity assumptions/parameterizations and/or data weighting approaches provides the most robust estimates of total biomass that are needed to meet the goal of the assessment.

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TABLES

Table 1. U.S. Pacific sardine harvest guidelines (HG) and landings since the onset of federal management.

Year	U.S. HG	U.S. Landings
2000	186,791	72,496
2001	134,737	78,520
2002	118,442	101,367
2003	110,908	74,599
2004	122,747	92,613
2005	136,179	90,130
2006	118,937	90,776
2007	152,564	127,695
2008	89,093	87,175
2009	66,932	67,083
2010	72,039	66,891
2011	50,526	46,745
2012	109,409	101,103
2013	66,495	61,646

Table 2. Pacific sardine landings (mt) for major fishing regions off northern Baja California (Ensenada, Mexico), the United States, and British Columbia (Canada). ENS and SCA landings are presented as totals and northern subpopulation (NSP) portions.

Calendar Yr-Sem	Model Yr-Seas	ENS Total	ENS NSP	SCA Total	SCA NSP	CCA	OR	WA	BC
1993-2	1993-1	13,396.8	0.0	3,728.8	487.6	335.2	0.0	0.0	0.0
1994-1	1993-2	5,711.6	2,994.5	7,738.5	7,722.5	628.8	0.0	0.0	0.0
1994-2	1994-1	15,165.4	6,079.3	2,607.4	1,029.2	1,730.2	0.0	0.0	0.0
1995-1	1994-2	18,227.3	11,183.6	28,122.2	28,122.2	442.7	0.0	0.0	0.0
1995-2	1995-1	17,168.9	0.0	8,439.2	1,508.1	4,485.2	0.0	0.0	22.7
1996-1	1995-2	15,665.9	11,643.9	14,409.4	12,435.9	2,485.9	0.0	0.0	0.0
1996-2	1996-1	23,398.8	4,394.2	10,761.5	1,123.9	6,399.2	0.0	0.0	0.0
1997-1	1996-2	13,498.4	8,911.1	11,523.5	9,905.0	342.6	0.0	0.0	43.5
1997-2	1997-1	54,940.6	0.0	21,313.3	0.0	13,018.2	0.0	0.0	27.2
1998-1	1997-2	20,238.8	4,980.8	19,094.1	16,800.1	2,746.7	0.8	0.0	0.0
1998-2	1998-1	27,573.4	3,792.0	12,880.5	8,799.1	6,334.0	0.2	0.0	488.1
1999-1	1998-2	34,759.8	31,656.8	24,049.9	23,880.8	7,740.8	50.1	0.0	24.3
1999-2	1999-1	23,809.6	6,203.7	18,813.1	2,649.3	6,143.2	725.0	0.0	0.2
2000-1	1999-2	33,933.4	23,716.6	34,119.2	33,339.8	1,285.0	205.0	62.2	162.4
2000-2	2000-1	33,911.9	5,526.6	12,715.5	8,084.4	10,082.4	9,324.0	4,703.2	1,559.0
2001-1	2000-2	16,544.9	9,937.5	29,343.4	24,467.3	774.4	2,288.0	48.5	0.4
2001-2	2001-1	29,526.4	3,609.5	18,318.3	1,474.0	6,467.0	10,492.0	10,788.5	1,265.5
2002-1	2001-2	17,421.7	13,552.0	26,620.6	25,991.6	1,574.8	2,724.0	412.3	0.5
2002-2	2002-1	29,423.6	0.0	22,745.3	4,059.7	12,503.0	19,987.0	14,799.8	738.9
2003-1	2002-2	15,514.3	12,405.4	20,379.6	18,639.6	5,085.7	503.0	93.9	0.4
2003-2	2003-1	25,827.5	6,081.9	9,909.5	1,896.1	2,362.6	24,755.0	11,510.0	977.3
2004-1	2003-2	11,212.9	3,922.9	15,232.0	15,232.0	2,145.7	2,203.5	235.3	179.6
2004-2	2004-1	30,684.0	2,373.9	17,161.5	1,512.5	13,162.6	33,908.3	8,564.1	4,258.4
2005-1	2004-2	17,323.0	11,186.6	15,419.0	13,948.1	115.3	691.9	324.0	0.4
2005-2	2005-1	37,999.5	4,396.7	14,833.6	1,508.6	7,824.9	44,316.2	6,605.0	3,231.4
2006-1	2005-2	17,600.9	11,214.6	17,157.7	16,504.9	2,032.6	101.7	0.0	0.0
2006-2	2006-1	39,636.0	0.0	16,128.2	4,909.8	15,710.5	35,546.5	4,099.0	1,575.4
2007-1	2006-2	13,981.4	13,320.0	26,343.6	19,900.7	6,013.3	0.0	0.0	0.0
2007-2	2007-1	22,865.5	11,928.2	19,855.0	5,350.3	28,768.8	42,052.3	4,662.5	1,522.3
2008-1	2007-2	23,487.8	15,618.2	24,127.2	24,114.3	2,515.3	0.0	0.0	0.0
2008-2	2008-1	43,378.3	5,930.0	6,962.1	21.8	24,195.7	22,939.9	6,435.2	10,425.0
2009-1	2008-2	25,783.2	20,244.4	9,250.8	9,221.3	11,079.9	0.0	0.0	0.0
2009-2	2009-1	30,128.0	0.0	3,310.3	29.8	13,935.1	21,481.6	8,025.2	15,334.3
2010-1	2009-2	12,989.1	7,904.2	19,427.7	19,427.7	2,908.8	437.1	510.9	421.7
2010-2	2010-1	43,831.8	9,171.2	9,924.7	562.7	1,397.1	20,414.9	11,869.6	21,801.3
2011-1	2010-2	18,513.8	11,588.5	12,526.4	12,515.4	2,713.3	0.1	0.0	0.0
2011-2	2011-1	51,822.6	17,329.6	5,115.4	11.9	7,358.4	11,023.3	8,008.4	20,718.8
2012-1	2011-2	10,235.0	6,823.3	11,906.2	10,018.8	3,672.7	2,873.9	2,931.7	0.0
2012-2	2012-1	39,575.0	0.0	6,896.1	883.6	568.7	39,744.1	32,509.6	19,172.0
2013-1	2012-2	9,780.0	6,520.0	2,636.0	769.7	84.2	149.3	1,421.4	0.0
2013-2	2013-1	40,509.0	0.0	3,654.8	0.0	739.0	27,535.9	25,425.2	0.0

Table 3. Pacific sardine length and age samples available for major fishing regions off northern Baja California (Mexico), the United States, and Canada.

Calendar Yr-Sem	Model Yr-Seas	ENS Length	ENS Age	SCA Length	SCA Age	CCA Length	CCA Age	OR Length	OR Age	WA Length	WA Age	BC Length	BC Age
1993-2	1993-1	83	0	22	15	0	0	0	0	0	0	0	0
1994-1	1993-2	33	0	105	31	0	0	0	0	0	0	0	0
1994-2	1994-1	37	0	26	26	0	0	0	0	0	0	0	0
1995-1	1994-2	38	0	278	121	0	0	0	0	0	0	0	0
1995-2	1995-1	51	0	59	35	0	0	0	0	0	0	0	0
1996-1	1995-2	27	0	61	60	11	11	0	0	0	0	0	0
1996-2	1996-1	43	0	34	33	88	87	0	0	0	0	0	0
1997-1	1996-2	21	0	59	58	2	2	0	0	0	0	0	0
1997-2	1997-1	50	0	54	53	55	55	0	0	0	0	0	0
1998-1	1997-2	18	0	60	59	5	5	0	0	0	0	0	0
1998-2	1998-1	41	0	54	53	52	51	0	0	0	0	0	0
1999-1	1998-2	58	0	61	61	14	14	1	1	0	0	0	0
1999-2	1999-1	41	0	49	49	0	0	3	3	0	0	3	0
2000-1	1999-2	46	0	58	58	0	0	4	4	0	0	0	0
2000-2	2000-1	51	0	56	56	0	0	32	31	36	35	29	0
2001-1	2000-2	46	0	68	68	4	4	7	7	4	4	6	0
2001-2	2001-1	29	0	67	67	28	28	28	28	54	54	12	0
2002-1	2001-2	37	0	65	65	13	12	10	10	17	9	3	0
2002-2	2002-1	36	0	70	10	35	30	50	47	125	64	93	0
2003-1	2002-2	18	0	70	70	19	19	1	1	7	4	3	0
2003-2	2003-1	41	0	61	60	8	8	38	37	109	56	92	0
2004-1	2003-2	201	0	67	67	8	8	5	5	12	6	0	0
2004-2	2004-1	205	0	69	69	24	23	35	35	61	32	67	0
2005-1	2004-2	168	0	71	70	1	1	2	2	6	3	0	0
2005-2	2005-1	115	0	73	72	24	23	14	14	54	27	65	0
2006-1	2005-2	53	0	67	66	32	31	0	0	0	0	0	0
2006-2	2006-1	46	0	61	61	58	58	12	12	15	15	0	0
2007-1	2006-2	22	0	74	72	47	46	3	3	0	0	0	0
2007-2	2007-1	46	0	72	72	68	68	80	80	10	10	23	0
2008-1	2007-2	43	0	53	53	15	15	0	0	0	0	0	0
2008-2	2008-1	83	0	25	25	30	30	80	80	14	14	229	0
2009-1	2008-2	50	0	20	20	20	20	0	0	0	0	0	0
2009-2	2009-1	0	0	13	12	23	23	82	81	12	12	285	0
2010-1	2009-2	0	0	62	62	37	36	3	1	2	2	2	0
2010-2	2010-1	0	0	25	25	13	13	64	26	8	8	287	0
2011-1	2010-2	0	0	22	21	11	11	0	0	0	0	0	0
2011-2	2011-1	0	0	22	22	22	22	34	33	10	10	362	0
2012-1	2011-2	0	0	48	47	16	16	8	8	7	7	0	0
2012-2	2012-1	0	0	44	41	18	17	83	82	37	37	106	0
2013-1	2012-2	0	0	16	16	2	2	0	0	3	0	0	0
2013-2	2013-1	0	0	39	0	5	0	54	0	66	0	0	0

Table 4. Pacific sardine landings (mt) by model year-season and SS fleet for total catch and NSP catch scenarios.

Calendar Yr-Sem	Model Yr-Seas	Total Catch Models (A1 Scenarios) MexCal_S1	MexCal_S2	PacNW	NSP Catch Models (A2 Scenarios) MexCal_S1	MexCal_S2	PacNW
1993-2	1993-1	17,460.78	0.00	0.00	822.80	0.00	0.00
1994-1	1993-2	0.00	14,078.85	0.00	0.00	11,345.83	0.00
1994-2	1994-1	19,503.00	0.00	0.00	8,838.65	0.00	0.00
1995-1	1994-2	0.00	46,792.12	0.00	0.00	39,748.42	0.00
1995-2	1995-1	30,093.29	0.00	22.68	5,993.28	0.00	22.68
1996-1	1995-2	0.00	32,561.24	0.00	0.00	26,565.72	0.00
1996-2	1996-1	40,559.48	0.00	0.00	11,917.29	0.00	0.00
1997-1	1996-2	0.00	25,364.55	43.54	0.00	19,158.65	43.54
1997-2	1997-1	89,272.03	0.00	27.22	13,018.20	0.00	27.22
1998-1	1997-2	0.00	42,079.67	0.82	0.00	24,527.60	0.82
1998-2	1998-1	46,787.92	0.00	488.25	18,925.15	0.00	488.25
1999-1	1998-2	0.00	66,550.51	74.39	0.00	63,278.38	74.39
1999-2	1999-1	48,765.83	0.00	725.20	14,996.21	0.00	725.20
2000-1	1999-2	0.00	69,337.59	429.59	0.00	58,341.39	429.59
2000-2	2000-1	56,709.77	0.00	15,586.16	23,693.38	0.00	15,586.16
2001-1	2000-2	0.00	46,662.67	2,336.90	0.00	35,179.21	2,336.90
2001-2	2001-1	54,311.70	0.00	22,545.99	11,550.53	0.00	22,545.99
2002-1	2001-2	0.00	45,617.11	3,136.84	0.00	41,118.36	3,136.84
2002-2	2002-1	64,671.88	0.00	35,525.69	16,562.71	0.00	35,525.69
2003-1	2002-2	0.00	40,979.60	597.29	0.00	36,130.69	597.29
2003-2	2003-1	38,099.55	0.00	37,242.26	10,340.64	0.00	37,242.26
2004-1	2003-2	0.00	28,590.55	2,618.43	0.00	21,300.55	2,618.43
2004-2	2004-1	61,008.15	0.00	46,730.80	17,048.96	0.00	46,730.80
2005-1	2004-2	0.00	32,857.28	1,016.32	0.00	25,249.92	1,016.32
2005-2	2005-1	60,658.00	0.00	54,152.62	13,730.19	0.00	54,152.62
2006-1	2005-2	0.00	36,791.15	101.70	0.00	29,752.00	101.70
2006-2	2006-1	71,474.68	0.00	41,220.90	20,620.28	0.00	41,220.90
2007-1	2006-2	0.00	46338.25	0.00	0.00	39234.00	0.00
2007-2	2007-1	71489.22	0.00	48237.10	46047.30	0.00	48237.10
2008-1	2007-2	0.00	50130.29	0.00	0.00	42247.81	0.00
2008-2	2008-1	74536.03	0.00	39800.10	30147.46	0.00	39800.10
2009-1	2008-2	0.00	46113.91	0.00	0.00	40545.56	0.00
2009-2	2009-1	47373.39	0.00	44841.15	13964.90	0.00	44841.15
2010-1	2009-2	0.00	35325.50	1369.73	0.00	30240.66	1369.73
2010-2	2010-1	55153.61	0.00	54085.91	11130.97	0.00	54085.91
2011-1	2010-2	0.00	33753.60	0.09	0.00	26817.27	0.09
2011-2	2011-1	64296.47	0.00	39750.49	24700.00	0.00	39750.49
2012-1	2011-2	0.00	25813.96	5805.63	0.00	20514.89	5805.63
2012-2	2012-1	47039.78	0.00	91425.63	1452.24	0.00	91425.63
2013-1	2012-2	0.00	12500.25	1570.78	0.00	7373.93	1570.78
2013-2	2013-1	44761.01	0.00	52961.07	739.00	0.00	52961.07
2014-1	2013-2	0.00	13280.00	1500.00	0.00	13280.00	1500.00
2014-2	2014-1	45000.00	0.00	5000.00	739.00	0.00	5000.00
2015-1	2014-2	0.00	10000.00	1500.00	0.00	10000.00	1500.00

Table 5. Fishery-independent indices of Pacific sardine relative abundance. Complete details regarding calculation of DEPM and TEP estimates are provided in Tables 6 and 7. In the SS model, indices had a lognormal error structure with units of standard error of loge(index). Variances of the observations were available as a CVs, so the S.E.s were approximated as sqrt(log*e*(1+CV^2)).

Model yr-seas	DEPM	S.E. ln(index)	TEP	S.E. ln(index)	Aerial	S.E. ln(index)	Acoustic	S.E. ln(index)
1993-2	69,065	0.29	---	---	---	---	---	---
1995-2	---	---	97,923	0.40	---	---	---	---
1996-2	---	---	482,246	0.21	---	---	---	---
1997-2	---	---	369,775	0.33	---	---	---	---
1998-2	---	---	332,177	0.34	---	---	---	---
1999-2	---	---	1,252,539	0.39	---	---	---	---
2000-2	---	---	931,377	0.38	---	---	---	---
2001-2	---	---	236,660	0.17	---	---	---	---
2002-2	---	---	556,177	0.18	---	---	---	---
2003-2	145,274	0.23	---	---	---	---	---	---
2004-2	459,943	0.55	---	---	---	---	---	---
2005-2	---	---	651,994	0.25	---	---	1,947,063	0.30
2006-2	198,404	0.30	---	---	---	---	---	---
2007-2	66,395	0.27	---	---	---	---	751,075	0.09
2008-1	---	---	---	---	---	---	801,000	0.30
2008-2	99,162	0.24	---	---	---	---	---	---
2009-1	---	---	---	---	1,236,911	0.90	---	---
2009-2	58,447	0.40	---	---	---	---	357,006	0.41
2010-1	---		---	---	173,390	0.40	---	---
2010-2	219,386	0.27	---	---	---	---	493,672	0.30
2011-1	---	---	---	---	201,888	0.29	---	---
2011-2	113,178	0.27	---	---	---	---	469,480	0.28
2012-1	---	---	---	---	696,251	0.37	340,831	0.33
2012-2	82182	0.29	---	---	---	---	305,146	0.24
2013-1	---	---	---	---	---	---	313,746	0.27

Table 6. The spawning biomass related parameters: daily egg production/0.05m^2 (P_0),daily mortality rate (z), survey area (km^2), two daily specific fecundities: (RSF/W), and (SF/W); s. biomass, female spawning biomass, total egg production (TEP) and sea surface temperature for 1986, 1987, 1994, 2004, 2005 and 2007-2013.

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 (Jul)	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

Table 6 (cont.).

Calendar year	Season	Region	P0/0.05m2 (cv)	Z (CV)	RSF/W based on S_1	RSF/W based on S_{12}	FS/W based on S_{12}	Area (km^2)	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
2010	2009	1	1.70(0.22)	0.33(0.23)	21.08	24.02	51.56	27462	38875 (0.44)	18111 (0.39)		46685.4		
		2	0.22(0.42)		14.55	16.20	26.65	244311	66345 (0.58)	40336 (0.58)		53748.42		
		whole	0.36(0.29)		16.08	18.07	31.49	271773	108280 (0.46)	62131 (0.46)	58447 (0.42)	97838.28	13.7	13.9
2011	2010	1	5.57(0.24)	0.51(0.14)	19.03	24.26	41.16	41878	192332 (0.31)	113340 (0.30)		233260.5		
		2	0.487(0.33)		11.40	14.67	25.04	272603	181016 (0.48)	106046 (0.49)		132757.7		
		whole	1.16(0.26)		14.85	19.04	32.40	314481	383286 (0.32)	225155 (0.32)	219386 (0.28)	364798.0	13.5	13.6
2012	2011	1	5.28 (0.27)	0.66(0.11)	17.76	19.25	42.17	32322	177289 (0.37)	80930 (0.33)		170660.16		
		2	0.24 (0.27)		15.34	14.67	35.52	238669	78102 (0.60)	32248 (0.46)		57280.56		
		whole	0.84 (0.27)		16.14	16.14	37.65	270991	282110 (0.43)	120902 (0.36)	113178 (0.27)	227632.44	13.57	13.3
2013	2012	1	5.47 (0.29)	0.64(0.16)	32.35	27.41	47.91	29176	116455 (0.40)	66633 (0.36)		159592.72		
		2	0.27 (0.44)		13.20	24.71	39.00	112221	24547 (0.48)	15549 (0.49)		30299.67		
		whole	1.34 (0.299)		26.22	26.22	44.70	141397	144880 (0.36)	84972 (0.33)	82182 (0.30)	198471.98	13.51	13.47

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

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

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

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

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

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

Table 7. Pacific sardine female adult parameters for surveys conducted in the standard daily egg production method (DEPM) sampling area off California (1994 includes females from off Mexico).

		1994	1997	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Midpoint date of trawl survey		22-Apr	25-Mar	1-May	21-Apr	25-Apr	13-Apr	2-May	24-Apr	16-Apr	27-Apr	20-Apr	8-Apr	19-Apr	25-Apr
Beginning and ending dates of positive collections		04/15-05/07	03/12-04/06	05/01-05/02	04/18-04/23	04/22-04/27	03/31-04/24	05/01-05/07	04/19-04/30	04/13-04/27	04/17-05/06	04/12-04/27	03/23-04/25	04/08-04/28	04/18-05/03
N collections with mature females		37	4	2	6	16	14	7	14	12	29	17	30	16	15
N collection within Region 1		19	4	2	6	16	6	2	8	4	15	3	14	8	8
Average surface temperature (°C) at collection locations		14.36	14.28	12.95	12.75	13.59	14.18	14.43	13.6	12.4	12.93	13.62	13.12	13.18	13.65
Female fraction by weight	**R**	0.538	0.592	0.677	0.385	0.618	0.469	0.451	0.515	0.631	0.602	0.574	0.587	0.429	0.586
Average mature female weight (grams): with ovary	W_f	82.53	127.76	79.08	159.25	166.99	65.34	67.41	81.62	102.21	112.40	129.51	127.59	141.36	138.17
without ovary	W_{of}	79.33	119.64	75.17	147.86	156.29	63.11	64.32	77.93	97.67	106.93	121.34	119.38	131.58	129.76
Average batch fecundity[a] (mature females, oocytes)	**F**	24283	42002	22456	54403	55711	17662	18474	21760	29802	29790	39304	38369	38681	41339
Relative batch fecundity (oocytes/g)		294	329	284	342	334	270	274	267	292	265	303	301	274	298
N mature females analyzed		583	77	9	23	290	175	86	203	187	467	313	244	126	121
N active mature females		327	77	9	23	290	148	72	187	177	463	310	244	125	119
Spawning fraction of mature females[b]	**S**	0.074	0.133	0.111	0.174	0.131	0.124	0.0698	0.114	0.1186	0.1098	0.1038	0.1078	0.1376	0.149
Spawning fraction of active females[c]	S_a	0.131	0.133	0.111	0.174	0.131	0.155	0.083	0.134	0.1187	0.1108	0.1048	0.1078	0.1388	0.153
Daily specific fecundity	$\frac{RSF}{W}$	11.7	25.94	21.3	22.91	27.04	15.67	8.62	15.68	21.82	17.53	18.07	19.04	16.14	26.22

[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), 2010 used F_b = 5136 + 287.37W_{of} + e (Lo et al. 2010), 2011 used F_b = -2252 + 347.6W_{of} + e (Lo et al. 2011b), and 2012 used F_b = -12724 + 402.3W_{of} + e (Lo et al. 2013).

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

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

Table 8. Likelihood components and derived quantities of interest for model A2 and its scenarios, including base model T (next page).

ESTIMATES	TRANSITION		STOCK	SURVEYS				BIOLOGICAL COMPOSITIONS									
								Length composition						Age composition			
	X6e_2013	X6e_2014	A2	B2d	B2h	B2i	B2j	C2b	C2c	C2d	C2e	C2f	C2g	D2a	D2b	D2c	D2d
Likelihood																	
DEPM Survey	0.72	0.72	13.86	14.47	14.36	14.15	---	12.27	12.45	12.44	10.17	14.18	12.46	7.55	10.08	8.17	5.32
TEP Survey	-0.02	-0.02	7.56	7.88	7.74	7.77	---	7.37	8.57	8.91	7.51	7.57	8.09	9.47	8.93	9.57	8.66
Aerial Survey	1.22	1.22	3.61	3.93	3.84	---	---	4.03	3.30	3.70	3.39	3.68	2.93	3.59	3.59	3.32	3.30
ATM Survey (all or Spring)	-1.76	-1.76	-2.00	-0.77	-1.22	-1.29	-0.75	-3.11	-2.50	-1.03	-2.94	-1.65	-4.61	-2.44	-2.74	-0.25	-2.90
ATM Survey (Summer)	---	---	---	---	-3.50	-3.49	-3.48	---	---	---	---	---	---	---	---	---	---
Subtotal - Survey	**0.15**	**0.15**	**23.04**	**25.52**	**21.22**	**17.14**	**-4.23**	**20.56**	**21.82**	**24.03**	**18.14**	**23.78**	**18.87**	**18.17**	**19.87**	**20.81**	**14.38**
MexCal_S1 Length	398.70	398.70	198.13	199.04	199.56	199.65	199.31	198.49	200.58	182.26	201.29	197.06	33.38	---	---	---	---
MexCal_S2 Length	329.36	329.36	196.21	196.15	197.16	196.72	199.33	195.79	192.65	183.67	196.76	195.25	33.34	---	---	---	---
PacNW Length	219.00	219.00	422.68	419.63	420.82	421.63	418.30	429.08	336.09	394.88	429.67	421.98	71.81	---	---	---	---
Aerial Length	25.16	25.14	42.78	42.96	42.69	---	---	41.85	43.27	42.26	43.38	63.83	6.33	---	---	---	---
ATM Length (all or Spring)	181.74	181.74	83.91	85.35	44.42	44.46	45.15	81.47	87.41	78.46	85.68	84.54	16.01	---	---	---	---
ATM Length (Summer)	---	---	---	---	35.61	35.77	35.61	---	---	---	---	---	---	---	---	---	---
Subtotal - Length	**1153.95**	**1153.94**	**943.70**	**943.15**	**940.26**	**898.22**	**897.70**	**946.68**	**860.00**	**881.53**	**478.38**	**962.65**	**160.88**	**---**	**---**	**---**	**---**
MexCal_S1 Age	279.24	279.24	233.28	233.90	233.22	232.94	233.14	236.37	235.32	236.90	233.75	234.13	212.09	107.23	107.22	104.70	43.63
MexCal_S2 Age	234.71	234.70	246.32	246.37	245.80	245.98	245.82	248.65	252.07	263.67	246.54	247.12	215.85	107.36	106.95	108.74	43.18
PacNW Age	198.89	198.89	354.16	353.95	353.17	353.23	351.26	341.39	321.87	418.84	355.01	355.85	251.67	119.11	120.16	130.66	51.05
ATM Age (all or Spring)	52.11	52.11	116.99	110.91	71.05	70.74	69.00	129.99	121.76	118.06	118.16	116.50	105.53	48.11	48.17	45.52	39.26
ATM Age (Summer)	---	---	---	---	43.17	42.71	42.08	---	---	---	---	---	---	---	---	---	---
Subtotal - Age	**764.94**	**764.94**	**950.75**	**945.13**	**946.40**	**945.60**	**941.30**	**826.41**	**931.03**	**518.73**	**476.73**	**953.60**	**785.13**	**381.82**	**382.49**	**389.61**	**177.11**
MexCal_S1 Size-at-age	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	98.64	---
MexCal_S2 Size-at-age	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	118.10	---
PacNW Size-at-age	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	190.33	---
ATM Size-at-age (all or Spring)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	76.61	---
ATM Size-at-age (Summer)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Subtotal - Size-at-age	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**483.68**	**---**
Catch	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Recruitment	14.71	14.71	13.95	14.88	13.90	14.05	16.20	14.92	13.35	13.89	7.70	13.97	5.34	6.96	6.84	8.97	4.24
Forecast Recruitment	0.50	0.50	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Parameter Softbounds	0.009	0.006	0.034	0.038	0.035	0.029	0.029	0.032	0.031	0.031	0.028	0.028	0.023	0.006	0.006	0.006	0.005
Total	**1934.27**	**1934.25**	**1931.47**	**1928.70**	**1921.82**	**1875.05**	**1851.00**	**1808.61**	**1826.23**	**1438.21**	**980.98**	**1954.02**	**970.24**	**406.95**	**409.20**	**903.08**	**195.74**
ATM q																	
ATM q (all or Spring)	1 (fixed)	1 (fixed)	1 (fixed)	3.062	0.887	0.939	0.984	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)
ATM q (Summer)	---	---	---	---	1.444	1.565	1.690	---	---	---	---	---	---	---	---	---	---
Estimated parameters	65	65	69	70	73	70	70	69	75	69	69	66	69	63	63	66	63
Derived quantities																	
$\ln(R_0)$	15.64	15.64	15.51	15.17	15.31	15.27	15.20	15.76	15.60	15.56	15.61	15.51	15.39	15.20	15.25	15.22	15.26
Stock biomass (mt) - unfished	1,135,950	1,136,030	1,008,430	706,880	815,329	784,271	726,737	1,292,770	1,070,970	1,068,470	1,106,880	1,001,560	893,708	796,558	791,022	814,429	843,020
Stock biomass (mt) - 2013_2	378,120	378,064	375,282	197,868	257,977	234,857	223,761	458,116	422,407	409,636	422,869	387,745	384,158	296,297	288,665	302,993	343,077
Stock biomass (mt) - 2014_1	---	---	435,846	253,418	324,838	300,639	283,824	516,477	482,876	468,711	513,515	447,852	490,774	405,967	398,111	407,527	467,345

Table 8 (cont.). Likelihood components and derived quantities of interest for model A2 and its scenarios, including base model T.

ESTIMATES	2013 FINAL	STOCK	S-R	NATURAL MORTALITY					BLENDED		FINAL STAR
	X6e_2013	A2	E2	F2a - 0.3	F2a - 0.4	F2a - 0.52	F2a - 0.6	F2b	G	H	T
Likelihood											
DEPM Survey	0.72	13.86	13.98	16.07	13.86	12.29	11.96	13.82	12.69	7.42	11.91
TEP Survey	-0.02	7.56	7.59	8.02	7.56	7.64	7.94	7.58	9.12	9.39	12.89
Aerial Survey	1.22	3.61	3.63	3.29	3.61	3.75	3.73	3.60	---	---	---
ATM Survey (all or Spring)	-1.76	-2.00	-2.06	0.20	-2.00	-2.70	-2.42	-1.97	-1.03	-0.03	2.42
ATM Survey (Summer)	---	---	---	---	---	---	---	---	-3.41	-3.52	-3.10
Subtotal - Survey	**0.15**	**23.04**	**23.14**	**27.58**	**23.04**	**20.99**	**21.22**	**23.03**	**17.37**	**13.26**	**24.12**
MexCal_S1 Length	398.70	198.13	197.39	197.16	198.13	199.44	200.37	197.98	182.52	---	167.00
MexCal_S2 Length	329.36	196.21	195.67	196.20	196.21	197.53	197.55	196.36	183.22	---	170.56
PacNW Length	219.00	422.68	422.99	421.08	422.68	426.93	431.73	422.59	395.44	---	367.69
Aerial Length	25.16	42.78	42.75	42.51	42.78	43.02	43.20	42.76	---	---	---
ATM Length (all or Spring)	181.74	83.91	83.39	84.76	83.91	84.33	85.95	83.82	40.89	---	41.04
ATM Length (Summer)	---	---	---	---	---	---	---	---	33.26	---	31.57
Subtotal - Length	**1153.95**	**943.70**	**942.19**	**941.71**	**943.70**	**951.24**	**958.80**	**943.52**	**835.32**	---	**777.85**
MexCal_S1 Age	279.24	233.28	233.37	237.70	233.28	230.52	230.85	231.93	236.16	110.05	49.57
MexCal_S2 Age	234.71	246.32	247.06	257.24	246.32	237.93	236.13	246.12	264.40	106.67	63.27
PacNW Age	198.89	354.16	353.98	361.42	354.16	347.55	342.06	354.23	417.60	116.39	101.70
ATM Age (all or Spring)	52.11	116.99	117.44	121.57	116.99	112.21	108.14	116.52	70.96	28.92	---
ATM Age (Summer)	---	---	---	---	---	---	---	---	45.71	14.54	---
Subtotal - Age	**764.94**	**950.75**	**951.85**	**977.93**	**950.75**	**928.21**	**917.17**	**948.80**	**517.41**	**376.57**	**214.54**
MexCal_S1 Size-at-age	---	---	---	---	---	---	---	---	---	---	---
MexCal_S2 Size-at-age	---	---	---	---	---	---	---	---	---	---	---
PacNW Size-at-age	---	---	---	---	---	---	---	---	---	---	---
ATM Size-at-age (all or Spring)	---	---	---	---	---	---	---	---	---	---	---
ATM Size-at-age (Summer)	---	---	---	---	---	---	---	---	---	---	---
Subtotal - Size-at-age	---	---	---	---	---	---	---	---	---	---	---
Catch	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Recruitment	14.71	13.95	15.22	18.36	13.95	12.61	12.10	13.91	14.65	7.89	17.27
Forecast Recruitment	0.50	---	---	---	---	---	---	---	---	---	---
Parameter Softbounds	0.009	0.034	0.034	0.034	0.034	0.040	0.040	0.034	0.031	0.005	0.004
Total	**1934.27**	**1931.47**	**1932.42**	**1965.62**	**1931.47**	**1913.08**	**1909.32**	**1929.29**	**1384.78**	**397.73**	**1033.79**
ATM q											
ATM q (all or Spring)	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)	0.712	1.607	1 (fixed)
ATM q (Summer)	---	---	---	---	---	---	---	---	1.046	1.648	1 (fixed)
Estimated parameters	65	69	68	69	69	69	69	69	69	66	63
Derived quantities											
$\ln(R_0)$	15.64	15.51	15.60	14.71	15.51	16.66	17.30	15.94	15.49	15.19	15.39
Stock biomass (mt) - unfished	1,135,950	1,008,430	1,100,110	733,542	1,008,430	1,957,040	2,801,140	1,005,480	991,994	795,098	905,000
Stock biomass (mt) - 2013_2	378,120	375,282	378,647	331,025	375,282	642,887	843,361	375,451	331,752	152,050	337,081
Stock biomass (mt) - 2014_1	---	435,846	401,120	358,020	435,846	799,360	1,137,130	435,846	362,020	209,126	369,506

Table 8 (cont'd). Description of model scenarios in Table 8.

X6e_2013 – most recent assessment model (Hill et al. 2013).
X6e_2014 – X6e_2013 using the most recent version of SS model (ver. 3.24s).
A2 – MexCal catch/composition=environment-based
B2d – A2, with ATM *q* estimated
B2h – A2, with ATM *q* estimated and split into two surveys (spring and summer)
B2i – A2, with ATM *q* estimated/split into two surveys, aerial omitted
B2j – A2, with ATM *q* estimated/split into two surveys, aerial/DEPM/TEP omitted
C2b – A2, with ATM conditional age-at-length compositions omitted
C2c – A2, with PacNW selectivity blocked (4-yr)
C2d – A2, with all conditional age-at-length compositions downweighted (0.5)
C2e – A2, with all compositions downweighted (0.5), conditional age-at-length and length
C2f – A2, with asymptotic selectivity for aerial
C2g – A2, with all compositions downweighted (Francis method)
D2a – A2, with age data/age-based selectivity, growth fixed (internal V-B)
D2b – A2, with growth fixed (external V-B)
D2c – A2, with growth estimated, mean length-at-age time series included
D2d – Al, with growth fixed (internal V-B), age compositions downweighted (Francis method)
E2 – A2, with B-H S-R (steepness=0.8)
F2a_ 0.3-0.6 – A1, with *M* profile
F2b – A2, with Lorenzen M
G – blended, length data/length-based selectivity model
H – blended, age data/age-based selectivity model
T – length data/length-based selectivity model, ATM catchabilities fixed (*q*=1), ATM spring & summer selectivities independent, ATM CondAL data not used, fishery CondAL data downweighted (λ=0.2), Aerial survey not used.

Table 9. Parameters and asymptotic standard deviations for base model T.

Parameter	Phase	Min	Max	Initial Value	Final Value	Std Dev	Status
NatM_p_1_Fem_GP_1	-3	0.3	0.7	0.4000	0.4000	_	fixed
L_at_Amin_Fem_GP_1	3	3	15	10.0000	11.7754	0.2718	OK
L_at_Amax_Fem_GP_1	3	20	30	25.0000	23.4636	0.1806	OK
VonBert_K_Fem_GP_1	3	0.05	0.99	0.4000	0.3855	0.0232	OK
CV_young_Fem_GP_1	3	0.05	0.3	0.1400	0.1274	0.0071	OK
CV_old_Fem_GP_1	3	0.01	0.1	0.0500	0.0491	0.0030	OK
Wtlen_1_Fem	-3	-3	3	0.0000	0.0000	_	fixed
Wtlen_2_Fem	-3	-3	5	3.2332	3.2332	_	fixed
Mat50%_Fem	-3	9	19	15.4400	15.4400	_	fixed
Mat_slope_Fem	-3	-20	3	-0.8925	-0.8925	_	fixed
Eggs/kg_inter_Fem	-3	0	10	1.0000	1.0000	_	fixed
Eggs/kg_slope_wt_Fem	-3	-1	5	0.0000	0.0000	_	fixed
SR_LN(R0)	1	3	25	16.0000	15.3899	0.1018	OK
SR_BH_steep	-6	0.2	1	0.8000	0.8000	_	fixed
SR_sigmaR	-3	0	2	0.7500	0.7500	_	fixed
SR_R1_offset	2	-15	15	0.0000	-0.3356	0.2587	OK
Early_InitAge_6	_	_	_	_	-0.3790	0.6395	act
Early_InitAge_5	_	_	_	_	-0.4169	0.6278	act
Early_InitAge_4	_	_	_	_	-0.3988	0.6224	act
Early_InitAge_3	_	_	_	_	-0.0771	0.6092	act
Early_InitAge_2	_	_	_	_	0.3516	0.4843	act
Early_InitAge_1	_	_	_	_	1.2824	0.2787	act
Main_RecrDev_1993	_	_	_	_	0.8290	0.1904	act
Main_RecrDev_1994	_	_	_	_	-0.2509	0.2708	act
Main_RecrDev_1995	_	_	_	_	0.2351	0.2073	act
Main_RecrDev_1996	_	_	_	_	1.2799	0.1377	act
Main_RecrDev_1997	_	_	_	_	0.8195	0.1550	act
Main_RecrDev_1998	_	_	_	_	-0.8884	0.2622	act
Main_RecrDev_1999	_	_	_	_	-0.7929	0.2092	act
Main_RecrDev_2000	_	_	_	_	-0.0824	0.1419	act
Main_RecrDev_2001	_	_	_	_	-2.0683	0.3507	act
Main_RecrDev_2002	_	_	_	_	1.7539	0.1109	act
Main_RecrDev_2003	_	_	_	_	0.9213	0.1747	act
Main_RecrDev_2004	_	_	_	_	1.4853	0.1163	act
Main_RecrDev_2005	_	_	_	_	0.2177	0.2075	act
Main_RecrDev_2006	_	_	_	_	0.6903	0.1530	act
Main_RecrDev_2007	_	_	_	_	-0.2729	0.2417	act
Main_RecrDev_2008	_	_	_	_	0.7689	0.1334	act
Main_RecrDev_2009	_	_	_	_	-0.8222	0.2546	act
Main_RecrDev_2010	_	_	_	_	-1.5699	0.2761	act
Main_RecrDev_2011	_	_	_	_	-2.0573	0.4508	act
Main_RecrDev_2012	_	_	_	_	-0.1959	0.6890	act
LnQ_base_4_DEPM	5	-3	3	-1.3900	-1.8502	0.1561	OK
LnQ_base_5_TEP	5	-3	3	-0.6900	-0.5997	0.1631	OK
LnQ_base_8_ATM_Spring & Summer	-5	-3	3	0.0000	0.0000	_	fixed

Table 9 (cont.). Parameters and asymptotic standard deviations for base model T.

Parameter	Phase	Min	Max	Initial Value	Final Value	Std Dev	Status
SizeSel_1P_1_MexCal_S1_NSP	4	10	28	18.0000	18.5134	0.3667	OK
SizeSel_1P_2_MexCal_S1_NSP	-4	-5	3	-4.9850	-4.9850	_	fixed
SizeSel_1P_3_MexCal_S1_NSP	4	-1	9	2.5000	2.9077	0.1959	OK
SizeSel_1P_4_MexCal_S1_NSP	4	-1	9	4.0000	0.5753	0.5684	OK
SizeSel_1P_5_MexCal_S1_NSP	-4	-10	10	-10.0000	-10.0000	_	fixed
SizeSel_1P_6_MexCal_S1_NSP	4	-10	10	-10.0000	-3.4271	1.0621	OK
SizeSel_1P_1_MexCal_S1_NSP_BLK1repl_1999	4	10	28	18.0000	17.0451	0.1980	OK
SizeSel_1P_2_MexCal_S1_NSP_BLK1repl_1999	-4	-5	3	-4.9980	-4.9980	_	fixed
SizeSel_1P_3_MexCal_S1_NSP_BLK1repl_1999	4	-1	9	2.5000	2.1075	0.1372	OK
SizeSel_1P_4_MexCal_S1_NSP_BLK1repl_1999	4	-1	9	4.0000	-0.0949	0.4573	OK
SizeSel_1P_5_MexCal_S1_NSP_BLK1repl_1999	-4	-10	10	-10.0000	-10.0000	_	fixed
SizeSel_1P_6_MexCal_S1_NSP_BLK1repl_1999	4	-10	10	-10.0000	-2.4192	0.2287	OK
SizeSel_2P_1_MexCal_S2_NSP	4	10	28	18.0000	16.4577	0.2923	OK
SizeSel_2P_2_MexCal_S2_NSP	-4	-5	3	-4.9930	-4.9930	_	fixed
SizeSel_2P_3_MexCal_S2_NSP	4	-1	9	2.5000	1.8849	0.1993	OK
SizeSel_2P_4_MexCal_S2_NSP	4	-1	9	4.0000	1.8145	0.3861	OK
SizeSel_2P_5_MexCal_S2_NSP	-4	-10	10	-10.0000	-10.0000	_	fixed
SizeSel_2P_6_MexCal_S2_NSP	4	-10	10	-10.0000	-2.2433	0.5862	OK
SizeSel_2P_1_MexCal_S2_NSP_BLK1repl_1999	4	10	28	18.0000	14.6115	0.2116	OK
SizeSel_2P_2_MexCal_S2_NSP_BLK1repl_1999	-4	-5	3	-4.9970	-4.9970	_	fixed
SizeSel_2P_3_MexCal_S2_NSP_BLK1repl_1999	4	-1	9	2.5000	1.6284	0.2177	OK
SizeSel_2P_4_MexCal_S2_NSP_BLK1repl_1999	4	-1	9	4.0000	2.2416	0.1742	OK
SizeSel_2P_5_MexCal_S2_NSP_BLK1repl_1999	-4	-10	10	-10.0000	-10.0000	_	fixed
SizeSel_2P_6_MexCal_S2_NSP_BLK1repl_1999	4	-10	10	-10.0000	-3.0857	0.3432	OK
SizeSel_3P_1_PacNW	4	10	28	19.0000	20.9834	0.2330	OK
SizeSel_3P_2_PacNW	-4	-5	10	2.5000	2.5000	_	fixed
SizeSel_3P_3_PacNW	4	-5	10	5.0000	1.8487	0.1242	OK
SizeSel_3P_4_PacNW	-4	-5	10	5.0000	5.0000	_	fixed
SizeSel_3P_5_PacNW	-4	-10	10	-10.0000	-10.0000	_	fixed
SizeSel_3P_6_PacNW	-4	-10	10	10.0000	10.0000	_	fixed
SizeSel_8P_1_ATM_Spring	4	10	28	18.0000	23.2458	1.7109	OK
SizeSel_8P_2_ATM_Spring	-4	-5	3	3.0000	3.0000	_	fixed
SizeSel_8P_3_ATM_Spring	4	-1	9	2.5000	3.4423	0.5041	OK
SizeSel_8P_4_ATM_Spring	-4	-1	9	4.0000	4.0000	_	fixed
SizeSel_8P_5_ATM_Spring	-4	-10	10	-10.0000	-10.0000	_	fixed
SizeSel_8P_6_ATM_Spring	-4	-10	10	10.0000	10.0000	_	fixed
SizeSel_9P_1_ATM_Summer	4	10	28	18.0000	22.8332	0.9872	OK
SizeSel_9P_2_ATM_Summer	-4	-5	3	3.0000	3.0000	_	fixed
SizeSel_9P_3_ATM_Summer	4	-1	9	2.5000	2.2279	0.5083	OK
SizeSel_9P_4_ATM_Summer	-4	-1	9	4.0000	4.0000	_	fixed
SizeSel_9P_5_ATM_Summer	-4	-10	10	-10.0000	-10.0000	_	fixed
SizeSel_9P_6_ATM_Summer	-4	-10	10	10.0000	10.0000	_	fixed

Table 10. Likelihood components and data weightings for base model T.

COMPONENT	-log(L)	MexCal_S1	MexCal_S2	PacNW	DEPM	TEP	ATM_Spring	ATM_Summer
Catch	1.08383E-14	4.87797E-15	4.84106E-15	1.11925E-15	---	---	---	---
Survey	24.123	---	---	---	11.912	12.894	2.419	-3.102
Length comp	777.847	167.000	170.558	367.685	---	---	41.037	31.567
Age comp	214.543	49.571	63.271	101.701	---	---	---	---
Recruitment	17.270							
Parm softbounds	0.00414167							
TOTAL	1033.79							

VARIANCE ADJUSTMENTS	MexCal_S1	MexCal_S2	PacNW	DEPM	TEP	ATM_Spring	ATM_Summer
Index_extra_CV	---	---	---	0.0	0.0	0.0	0.0
effN_mult_Lencomp	1.0	1.0	1.0	---	---	1.0	1.0
effN_mult_Agecomp	1.0	1.0	1.0			1.0	1.0

LAMBDA WEIGHTINGS	MexCal_S1	MexCal_S2	PacNW	DEPM	TEP	ATM_Spring	ATM_Summer
Survey	---	---	---	1.0	1.0	1.0	1.0
Length comp	1.0	1.0	1.0	---	---	1.0	1.0
Age comp	0.2	0.2	0.2	---	---	0.0	0.0

Table 11a. Summary biomass and population numbers-at-age (1,000s) by model year and semester for base model T.

		SUMMARY BIOMASS (mt)			POPULATION NUMBERS-AT-AGE (1,000s of fish)										
Calendar Yr-Sem	Model Yr-Seas	Age 0+	Age 1+	SSB	0 (R)	1	2	3	4	5	6	7	8	9	10+
---	VIRG	942,828	905,000	---	4,827,830	3,236,190	2,169,280	1,454,120	974,722	653,376	437,971	293,581	196,793	131,914	268,214
---	VIRG	941,335	849,880	776,158	3,952,690	2,649,570	1,776,060	1,190,530	798,035	534,939	358,580	240,364	161,121	108,002	219,595
---	INIT	674,041	646,997	---	3,451,490	2,313,600	1,550,850	1,039,570	696,843	467,108	313,112	209,885	140,690	94,307	191,750
---	INIT	672,974	607,591	554,886	2,825,840	1,894,220	1,269,730	851,126	570,527	382,435	256,354	171,839	115,187	77,212	156,992
1993-2	1993-1	795,260	717,990	---	9,861,620	6,610,440	1,798,510	808,461	404,426	274,064	196,436	209,885	140,690	94,307	191,750
1994-1	1993-2	907,236	720,432	601,201	8,073,600	5,406,210	1,469,670	660,842	330,805	224,275	160,783	171,808	115,171	77,203	156,976
1994-2	1994-1	1,005,700	940,175	---	8,362,780	6,570,310	4,339,240	1,183,700	536,031	269,355	182,907	131,215	140,254	94,033	191,225
1995-1	1994-2	1,092,370	934,009	792,142	6,844,420	5,337,230	3,504,470	958,025	435,935	219,759	149,455	107,289	114,714	76,922	156,447
1995-2	1995-1	1,098,840	1,076,150	---	2,895,720	5,506,340	4,125,050	2,735,830	763,415	351,258	177,901	121,225	87,099	93,168	189,610
1996-1	1995-2	1,105,740	1,050,890	913,715	2,370,310	4,487,010	3,349,700	2,224,410	622,503	286,972	145,474	99,168	71,265	76,237	155,165
1996-2	1996-1	1,081,970	1,044,780	---	4,746,280	1,916,520	3,525,690	2,650,930	1,786,360	503,888	233,066	118,312	80,703	58,013	188,424
1997-1	1996-2	1,060,600	970,734	906,839	3,884,010	1,552,200	2,832,680	2,136,150	1,449,090	410,563	190,298	96,691	65,982	47,441	154,113
1997-2	1997-1	1,098,390	992,710	---	13,487,400	3,142,040	1,221,690	2,244,810	1,716,750	1,173,450	333,530	154,799	78,701	53,722	164,148
1998-1	1997-2	1,167,370	912,050	862,620	11,034,900	2,533,290	973,871	1,796,910	1,387,230	954,161	272,006	126,408	64,305	43,908	134,197
1998-2	1998-1	1,221,420	1,154,910	---	8,488,040	8,902,180	1,975,840	766,008	1,438,030	1,120,590	773,801	220,952	102,759	52,293	144,887
1999-1	1998-2	1,272,050	1,111,390	947,369	6,943,540	7,153,920	1,565,830	609,960	1,158,050	909,227	630,094	180,201	83,866	42,694	118,330
1999-2	1999-1	1,222,800	1,210,690	---	1,546,230	5,530,830	5,351,400	1,189,790	478,612	924,603	731,263	508,315	145,573	67,797	130,255
2000-1	1999-2	1,184,770	1,155,490	1,011,470	1,265,560	4,451,360	4,282,890	962,985	389,661	753,852	596,389	414,586	118,733	55,297	106,239
2000-2	2000-1	1,073,400	1,060,020	---	1,706,800	948,210	3,211,010	3,282,890	765,189	313,777	609,911	483,394	336,304	96,351	131,133
2001-1	2000-2	971,030	938,722	889,929	1,396,350	743,660	2,472,240	2,580,380	607,556	249,589	485,200	384,532	267,515	76,642	104,306
2001-2	2001-1	877,893	850,859	---	3,450,280	1,032,350	526,183	1,874,060	2,036,970	486,818	201,047	391,636	310,660	216,218	146,305
2002-1	2001-2	798,441	733,127	709,131	2,822,880	811,929	405,434	1,464,030	1,600,900	382,738	158,010	307,740	244,089	169,878	114,945
2002-2	2002-1	696,224	692,564	---	467,052	1,979,030	532,441	295,226	1,133,780	1,268,180	305,631	126,571	246,846	195,921	228,731
2003-1	2002-2	587,714	578,877	538,750	381,930	1,511,720	391,688	221,559	857,733	959,118	230,942	95,597	186,403	147,934	172,698
2003-2	2003-1	653,179	489,455	---	20,895,400	257,725	939,150	277,771	169,943	677,291	765,163	184,974	76,702	149,687	257,646
2004-1	2003-2	783,437	388,039	416,424	17,089,000	197,960	691,133	205,323	125,465	498,211	561,762	135,696	56,250	109,759	188,903
2004-2	2004-1	922,633	853,213	---	8,859,730	13,542,200	154,575	550,320	165,246	101,350	402,976	454,620	109,842	45,539	241,814
2005-1	2004-2	1,011,770	844,007	616,788	7,250,750	10,795,600	117,738	400,596	116,772	70,701	279,828	315,184	76,106	31,544	167,473
2005-2	2005-1	1,179,690	1,053,120	---	16,153,700	5,800,220	8,547,870	94,614	324,642	94,917	57,530	227,794	256,625	61,972	162,071
2006-1	2005-2	1,313,250	1,007,320	868,822	13,222,400	4,672,120	6,637,210	70,383	234,945	67,904	40,992	162,086	182,504	44,063	115,215
2006-2	2006-1	1,400,650	1,364,200	---	4,651,700	10,552,700	3,688,290	5,331,910	57,129	191,435	55,404	33,464	132,347	149,037	130,083
2007-1	2006-2	1,410,470	1,322,380	1,098,180	3,807,240	8,469,160	2,895,580	4,130,380	43,837	146,206	42,238	25,495	100,808	113,508	99,065
2007-2	2007-1	1,420,150	1,360,980	---	7,550,930	3,002,740	6,573,790	2,306,030	3,339,970	35,649	119,135	34,444	20,798	82,248	173,459
2008-1	2007-2	1,356,660	1,213,750	1,117,080	6,176,690	2,335,270	4,958,790	1,757,510	2,553,610	27,220	90,875	26,262	15,854	62,692	132,208
2008-2	2008-1	1,300,960	1,278,360	---	2,884,120	4,781,000	1,764,780	3,894,750	1,412,360	2,069,620	22,127	73,958	21,384	12,913	158,772
2009-1	2008-2	1,198,010	1,143,420	1,037,970	2,359,450	3,739,150	1,345,340	3,004,680	1,094,540	1,603,090	17,128	57,229	16,544	9,990	122,826
2009-2	2009-1	1,149,770	1,085,930	---	8,147,000	1,798,490	2,764,510	1,044,730	2,402,340	884,636	1,300,620	13,917	46,529	13,456	108,054
2010-1	2009-2	1,098,530	944,273	900,161	6,666,920	1,430,310	2,149,190	809,379	1,853,810	680,612	999,336	10,688	35,726	10,331	82,951
2010-2	2010-1	1,042,180	1,029,270	---	1,647,580	5,156,890	1,079,620	1,685,690	649,311	1,499,590	552,179	811,684	8,685	29,039	75,842
2011-1	2010-2	942,246	911,047	806,697	1,348,410	4,124,820	841,204	1,292,020	491,930	1,129,670	415,075	609,674	6,522	21,803	56,936
2011-2	2011-1	861,722	855,648	---	775,148	1,043,940	3,118,110	660,804	1,038,360	398,709	918,343	337,816	496,445	5,312	64,147
2012-1	2011-2	738,011	723,342	680,004	633,987	805,521	2,324,610	499,216	788,000	302,219	695,359	255,667	375,643	4,019	48,529
2012-2	2012-1	647,185	643,160	---	513,704	479,719	588,685	1,786,560	394,821	629,645	242,363	558,441	205,457	301,969	42,257
2013-1	2012-2	501,138	491,408	473,374	420,532	388,305	453,821	1,284,950	271,855	425,992	162,997	374,806	137,791	202,453	28,323
2013-2	2013-1	465,228	437,821	---	3,497,860	325,831	293,742	356,064	1,029,790	219,562	344,992	132,146	304,008	111,790	187,255
2014-1	2013-2	403,335	337,081	333,268	2,863,470	264,129	229,001	262,854	734,560	154,458	241,551	92,374	212,384	78,078	130,767
2014-2	2014-1	404,433	369,506	---	---	2,159,810	192,262	176,026	208,566	589,646	124,495	195,006	74,627	171,641	168,826

Table 11b. Biomass-at-age (metric tons) by model year and semester for base model T.

		POPULATION BIOMASS-AT-AGE (METRIC TONS)										
Calendar Yr-Sem	Model Yr-Seas	0	1	2	3	4	5	6	7	8	9	10+
1993-2	1993-1	77,270	253,877	130,473	84,865	53,373	41,892	33,060	37,653	26,341	18,172	38,285
1994-1	1993-2	186,804	298,884	131,239	78,800	47,356	36,151	28,028	31,554	21,906	15,036	31,478
1994-2	1994-1	65,526	252,335	314,790	124,254	70,742	41,173	30,783	23,540	26,260	18,119	38,180
1995-1	1994-2	158,363	295,070	312,943	114,237	62,406	35,423	26,053	19,705	21,820	14,981	31,372
1995-2	1995-1	22,689	211,473	299,252	287,183	100,750	53,692	29,940	21,747	16,308	17,953	37,857
1996-1	1995-2	54,843	248,066	299,122	265,243	89,114	46,257	25,359	18,213	13,555	14,847	31,115
1996-2	1996-1	37,189	73,605	255,771	278,271	235,751	77,022	39,224	21,225	15,110	11,179	37,621
1997-1	1996-2	89,867	85,814	252,953	254,719	207,444	66,179	33,173	17,758	12,550	9,239	30,904
1997-2	1997-1	105,679	120,671	88,628	235,640	226,565	179,369	56,132	27,770	14,735	10,352	32,848
1998-1	1997-2	255,321	140,054	86,965	214,267	198,589	153,802	47,416	23,216	12,231	8,551	26,960
1998-2	1998-1	66,507	341,892	143,337	80,409	189,781	171,289	130,228	39,638	19,239	10,076	29,019
1999-1	1998-2	160,657	395,507	139,826	72,733	165,781	146,559	109,837	33,096	15,952	8,315	23,790
1999-2	1999-1	12,115	212,414	388,217	124,893	63,164	141,331	123,069	91,190	27,255	13,064	26,087
2000-1	1999-2	29,282	246,095	382,454	114,828	55,782	121,514	103,962	76,143	22,584	10,769	21,358
2000-2	2000-1	13,373	36,416	232,943	344,608	100,984	47,963	102,646	86,719	62,966	18,566	26,210
2001-1	2000-2	32,308	41,113	220,766	307,690	86,975	40,232	84,580	70,623	50,883	14,926	20,935
2001-2	2001-1	27,034	39,648	38,172	196,722	268,825	74,413	33,836	70,258	58,165	41,663	29,157
2002-1	2001-2	65,315	44,888	36,204	174,574	229,177	61,694	27,544	56,520	46,428	33,084	23,015
2002-2	2002-1	3,660	76,005	38,626	30,990	149,628	193,849	51,437	22,706	46,217	37,752	45,353
2003-1	2002-2	8,837	83,576	34,977	26,419	122,789	154,601	40,258	17,557	35,455	28,811	34,434
2003-2	2003-1	163,724	9,898	68,131	29,158	22,428	103,528	128,775	33,184	14,361	28,843	51,150
2004-1	2003-2	395,398	10,944	61,717	24,483	17,961	80,307	97,926	24,922	10,699	21,376	37,704
2004-2	2004-1	69,420	520,094	11,214	57,768	21,808	15,492	67,820	81,557	20,566	8,775	48,120
2005-1	2004-2	167,765	596,838	10,514	47,768	16,716	11,396	48,779	57,887	14,476	6,143	33,491
2005-2	2005-1	126,571	222,760	620,105	9,932	42,844	14,509	9,682	40,866	48,048	11,941	32,431
2006-1	2005-2	305,935	258,300	592,690	8,393	33,634	10,945	7,146	29,769	34,714	8,581	23,146
2006-2	2006-1	36,448	405,281	267,567	559,696	7,539	29,262	9,324	6,003	24,779	28,718	26,035
2007-1	2006-2	88,090	468,220	258,570	492,515	6,275	23,567	7,363	4,682	19,174	22,106	19,905
2007-2	2007-1	59,165	115,321	476,896	242,066	440,786	5,449	20,050	6,179	3,894	15,848	34,493
2008-1	2007-2	142,914	129,106	442,811	209,569	365,562	4,388	15,841	4,823	3,016	12,210	26,423
2008-2	2008-1	22,598	183,616	128,026	408,836	186,393	316,354	3,724	13,268	4,004	2,488	31,649
2009-1	2008-2	54,592	206,720	120,136	358,284	156,689	258,404	2,986	10,511	3,147	1,946	24,597
2009-2	2009-1	63,835	69,072	200,551	109,666	317,044	135,222	218,890	2,497	8,712	2,593	21,683
2010-1	2009-2	154,257	79,075	191,919	96,512	265,382	109,709	174,203	1,963	6,795	2,012	16,704
2010-2	2010-1	12,909	198,052	78,321	176,949	85,692	229,221	92,930	145,614	1,626	5,596	15,267
2011-1	2010-2	31,199	228,042	75,118	154,063	70,422	182,093	72,355	111,973	1,240	4,246	11,495
2011-2	2011-1	6,074	40,093	226,203	69,365	137,035	60,945	154,554	60,603	92,949	1,024	12,875
2012-1	2011-2	14,669	44,533	207,583	59,528	112,806	48,715	121,214	46,956	71,450	783	9,774
2012-2	2012-1	4,025	18,424	42,706	187,537	52,106	96,245	40,789	100,183	38,468	58,186	8,517
2013-1	2012-2	9,730	21,468	40,525	153,220	38,917	68,666	28,413	68,837	26,209	39,429	5,724
2013-2	2013-1	27,407	12,514	21,310	37,376	135,904	33,561	58,061	23,707	56,919	21,541	36,928
2014-1	2013-2	66,254	14,602	20,449	31,343	105,156	24,897	42,107	16,965	40,397	15,206	25,957
2014-2	2014-1	---	82,948	13,948	18,478	27,525	90,131	20,952	34,983	13,972	33,074	33,495

Table 12. Derived SSB (mt) and recruits (year-class abundance, billions of age-0 fish) for base model T. SSB estimates are calculated at the beginning of Season 2 of each model year, e.g. the 2013 value is SSB January 2014. Recruits are age-0 fish calculated at the beginning of each model year (July).

Model year	SSB (mt)	SSB Std Dev	Year class abundance (billions)	Recruits Std Dev
Virgin	776,158	78,284	4.828	0.492
1993	601,201	124,461	3.451	0.951
1994	792,142	150,467	8.363	1.731
1995	913,715	165,750	2.896	0.838
1996	906,839	158,846	4.746	1.054
1997	862,620	143,290	13.487	1.921
1998	947,369	137,789	8.488	1.297
1999	1,011,470	134,525	1.546	0.422
2000	889,929	119,525	1.707	0.368
2001	709,131	97,968	3.450	0.502
2002	538,750	79,127	0.467	0.175
2003	416,424	67,014	20.895	2.673
2004	616,788	89,430	8.860	1.636
2005	868,822	115,871	16.154	2.017
2006	1,098,180	134,709	4.652	1.012
2007	1,117,080	136,349	7.551	1.166
2008	1,037,970	126,448	2.884	0.742
2009	900,161	112,589	8.147	1.207
2010	806,697	104,196	1.648	0.458
2011	680,004	94,716	0.775	0.239
2012	473,374	80,309	0.514	0.251
2013	333,268	65,697	3.498	2.559
2014	306,237	74,121	---	---

Table 13. Pacific sardine harvest control rules for the 2014-15 management year based on stock biomass estimated in base model T.

Harvest Control Rule Formulas

OFL = BIOMASS * F_{MSY} * DISTRIBUTION

$ABC_{P\text{-}star}$ = BIOMASS * $BUFFER_{P\text{-}star}$ * E_{MSY} * DISTRIBUTION

HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION

Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	369,506								
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier\ 1}$	0.9558	0.9128	0.8705	0.8280	0.7844	0.7386	0.6886	0.6304	0.5531
ABC $Buffer_{Tier\ 2}$	0.9135	0.8333	0.7577	0.6855	0.6153	0.5455	0.4741	0.3974	0.3060
CalCOFI SST (2011-2013)	15.335								
E_{MSY}	0.122								
FRACTION	0.15								
CUTOFF (mt)	150,000								
DISTRIBUTION (U.S.)	0.87								
Harvest Control Rule Values (MT)									
OFL =	**39,210**								
$ABC_{Tier\ 1}$ =	37,475	35,792	34,131	32,464	30,757	28,961	26,999	24,719	21,688
$ABC_{Tier\ 2}$ =	35,818	32,672	29,710	26,879	24,126	21,391	18,591	15,583	11,997
HG =	**28,646**								

FIGURES

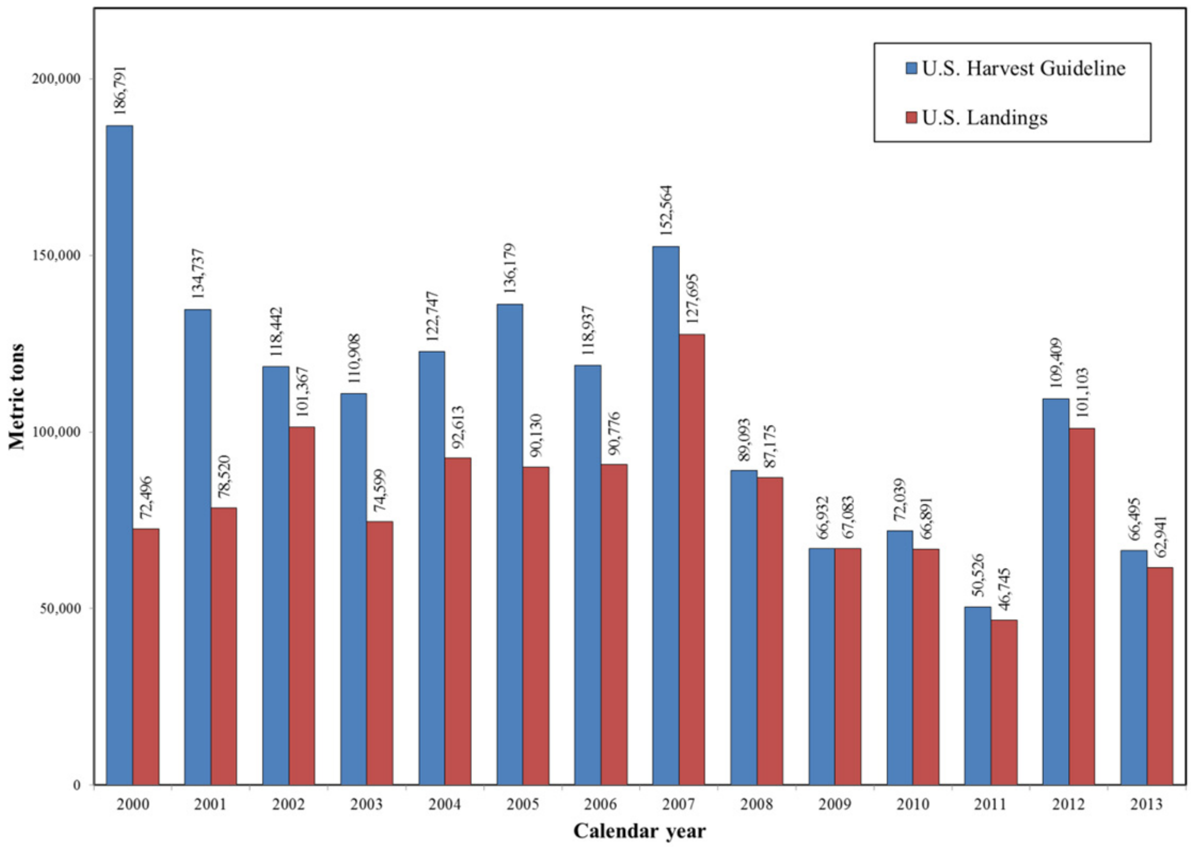


Figure 1. U.S. Pacific sardine harvest guidelines and landings since the onset of federal management.

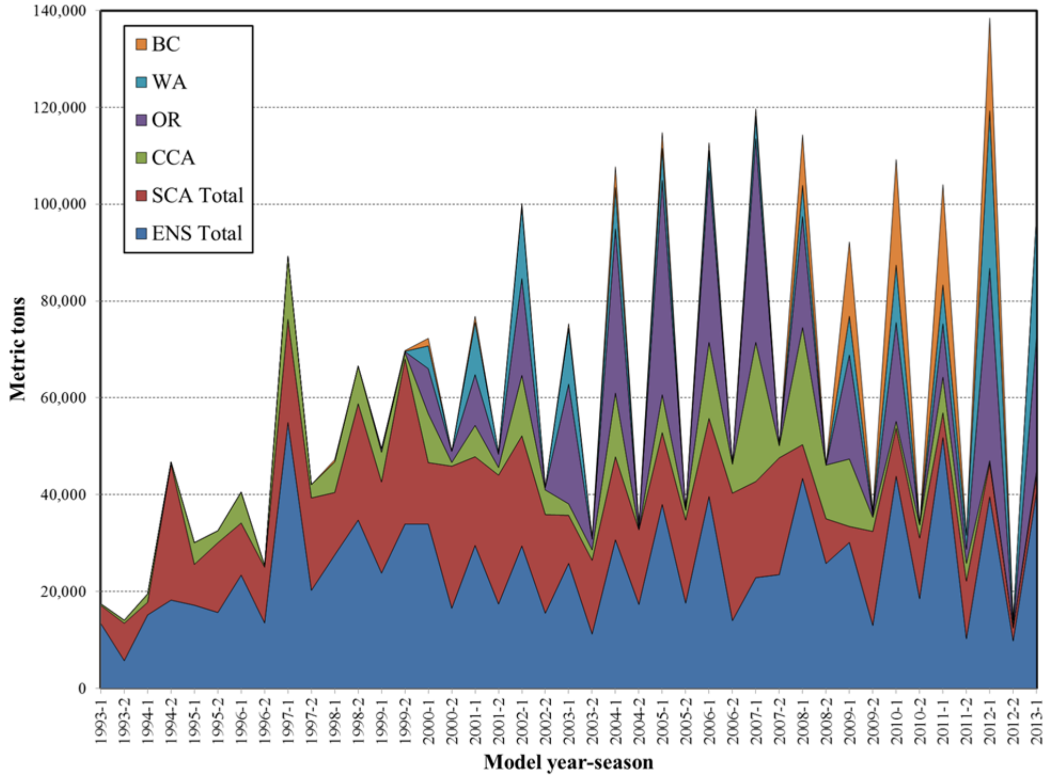


Figure 2a. Pacific sardine total landings (mt) by major fishing region.

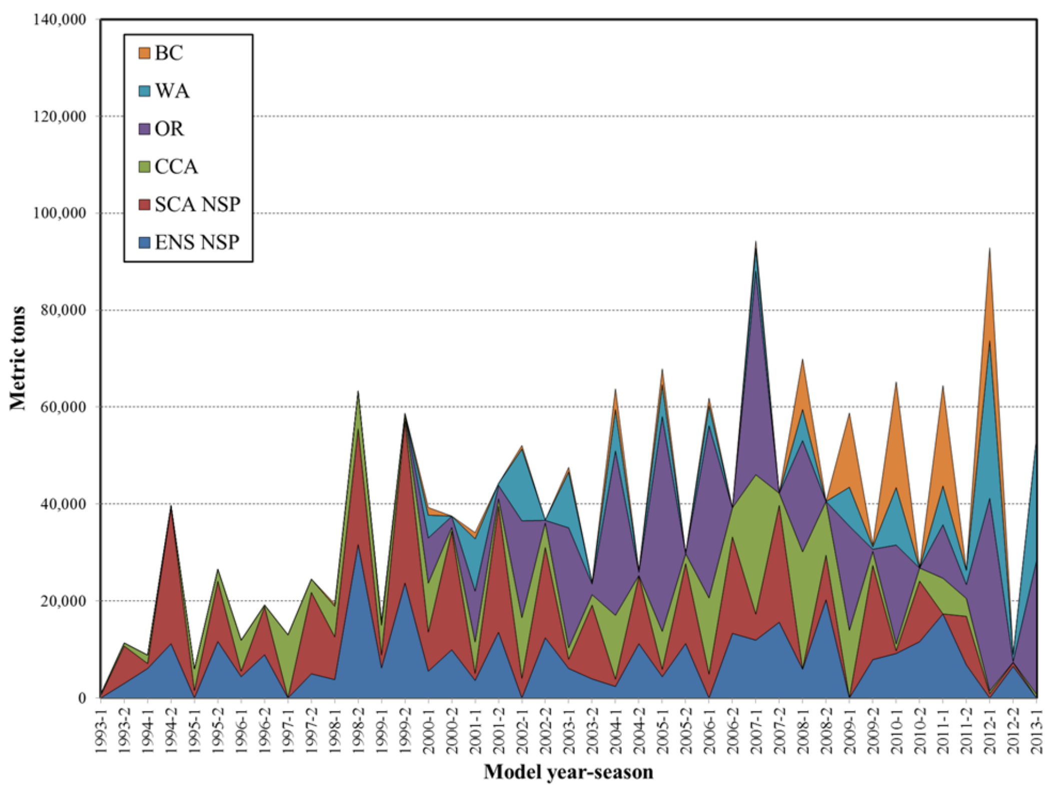


Figure 2b. Pacific sardine NSP landings (mt) by major fishing region.

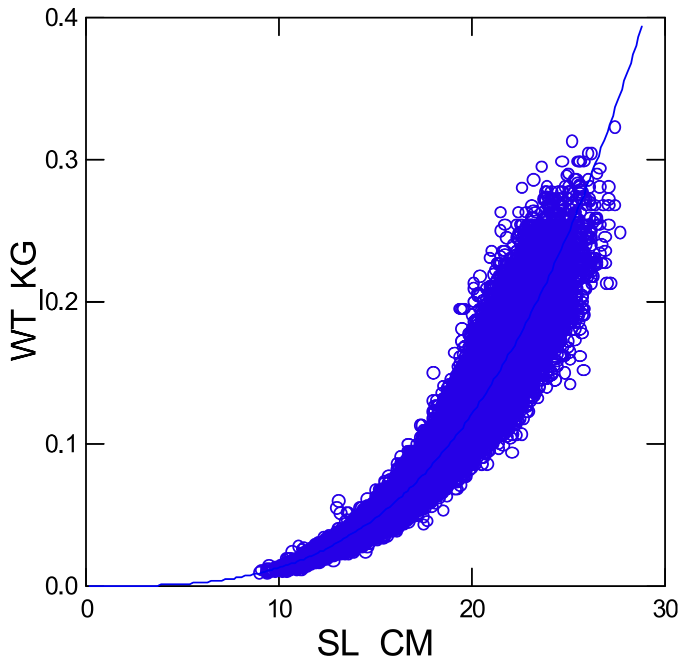


Figure 3. Weight-at-length regression from NSP fishery samples as applied in model T, where: *a* = 7.5242e-06 and *b* = 3.2332 (n=104,326, R^2 = 0.936).

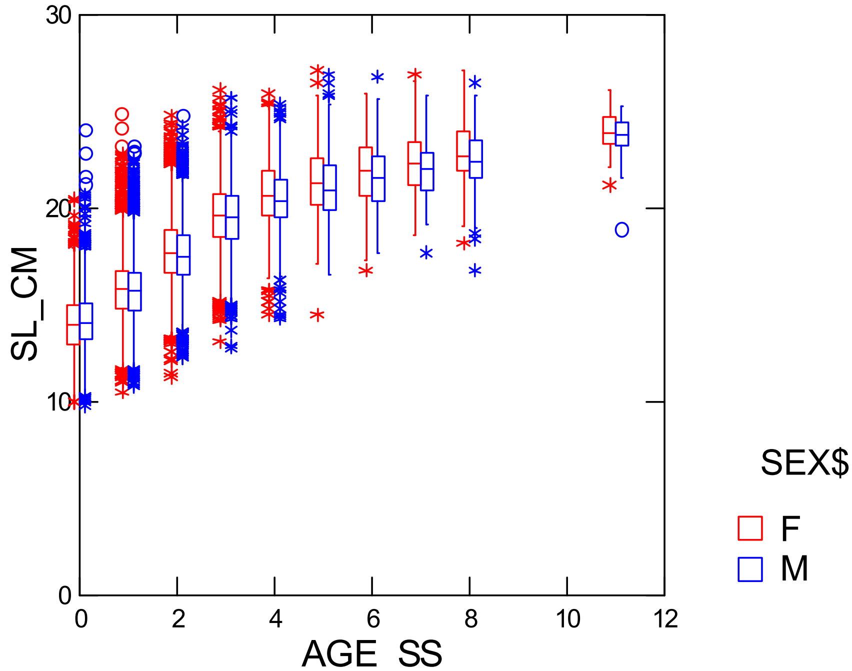


Figure 4a. Length-at-age by sex from fishery samples. Box symbols indicate median and quartile ranges for the raw data. The SS model is based on pooled sexes.

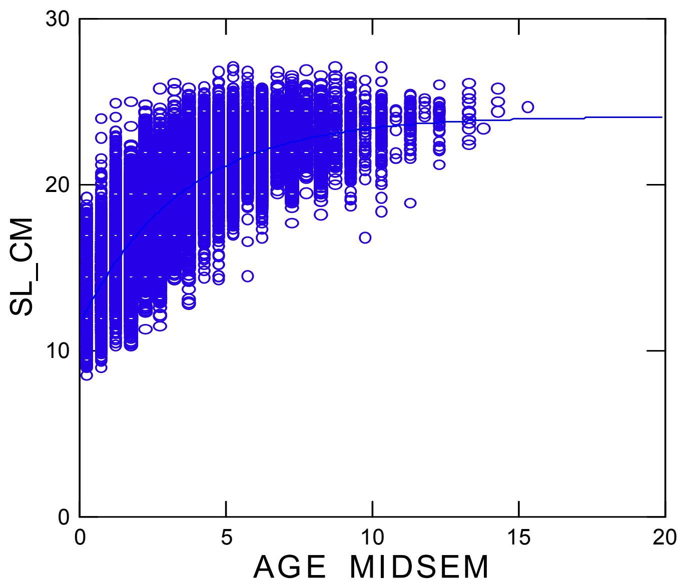


Figure 4b. von Bertalanffy growth from NSP fishery samples, sexes combined, as estimated outside of the SS model (t_0 = -2.01, K = 0.318, L_∞ = 23.788).

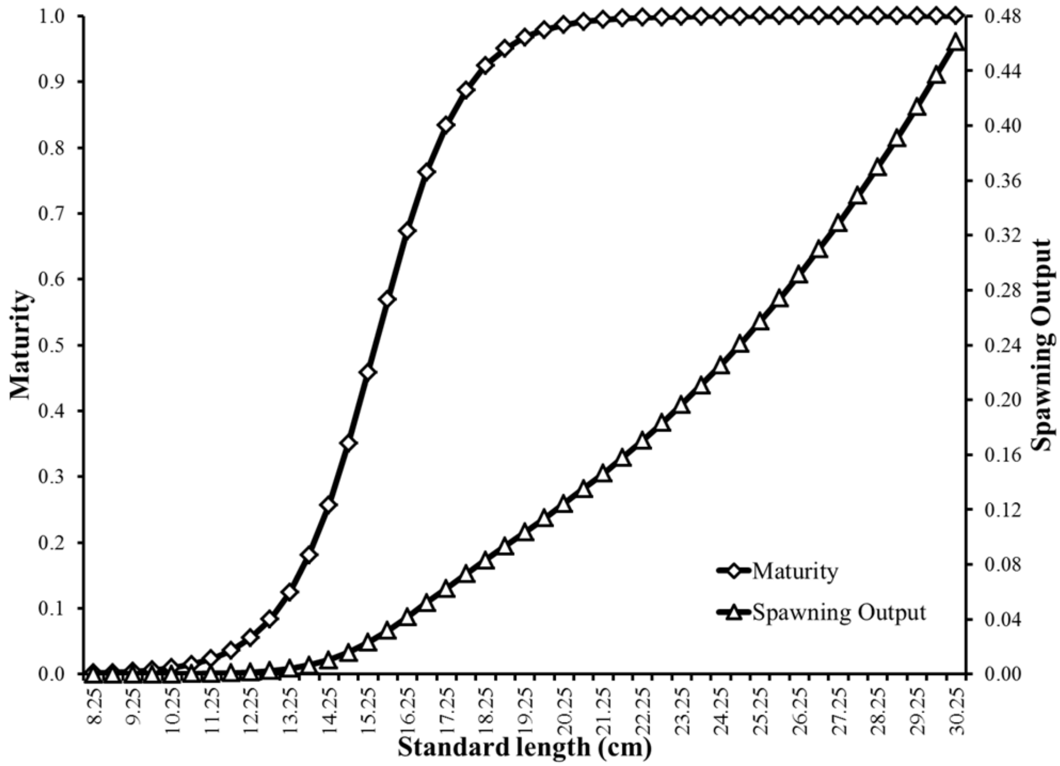


Figure 5a. Maturity (L_{50} = 15.44 cm) and spawning output as a function of length.

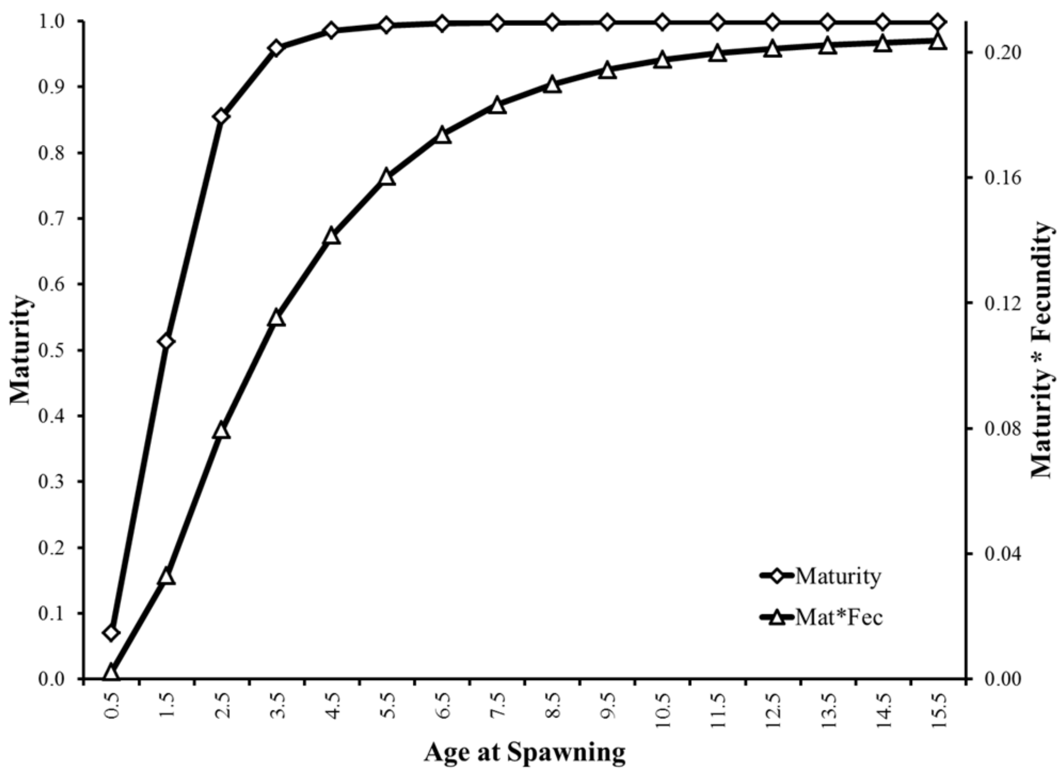


Figure 5b. Maturity and fecundity as a function of age derived from growth in model T.

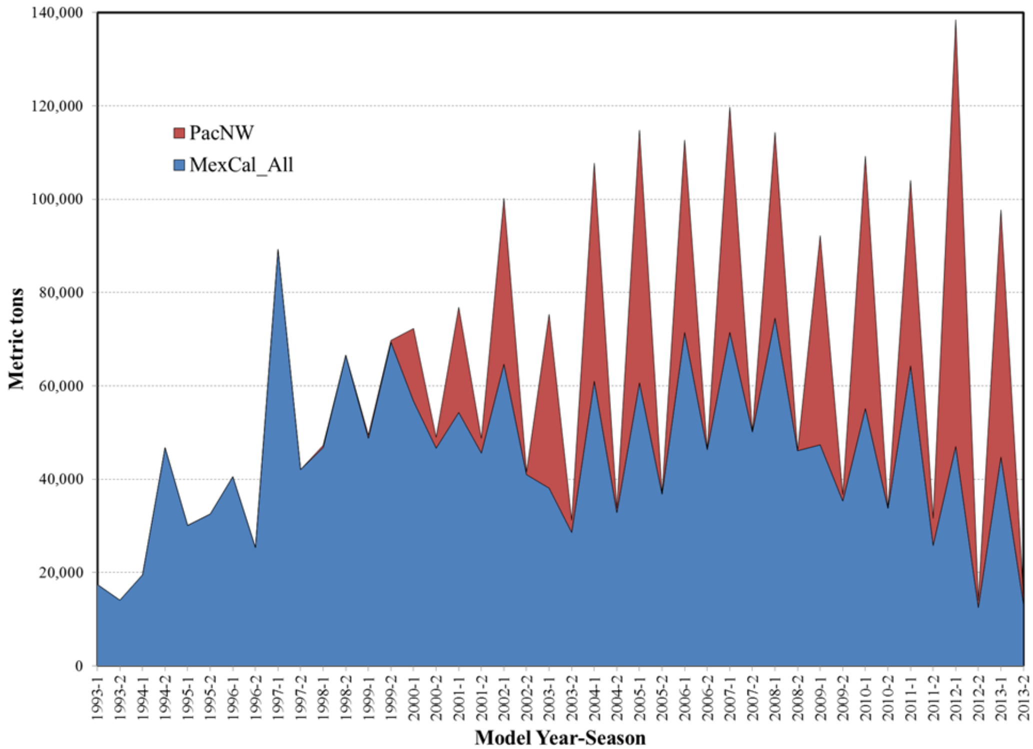


Figure 6a. Pacific sardine landings (mt) by fleet, model year and semester as used in model A1 model scenarios (total catch).

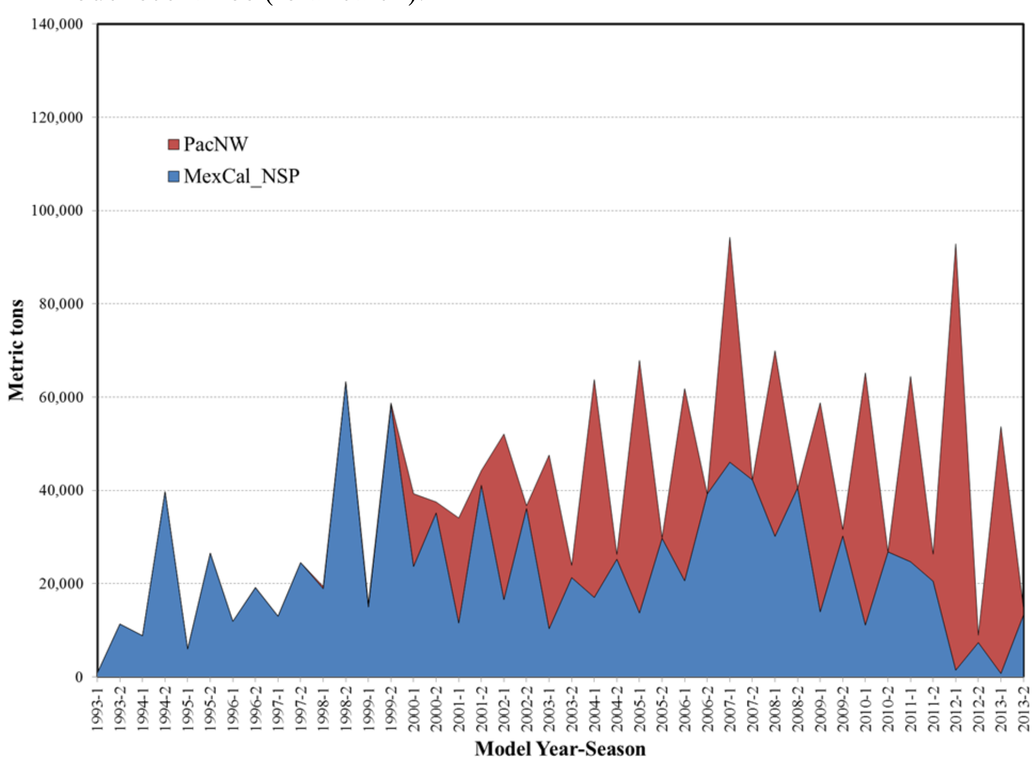
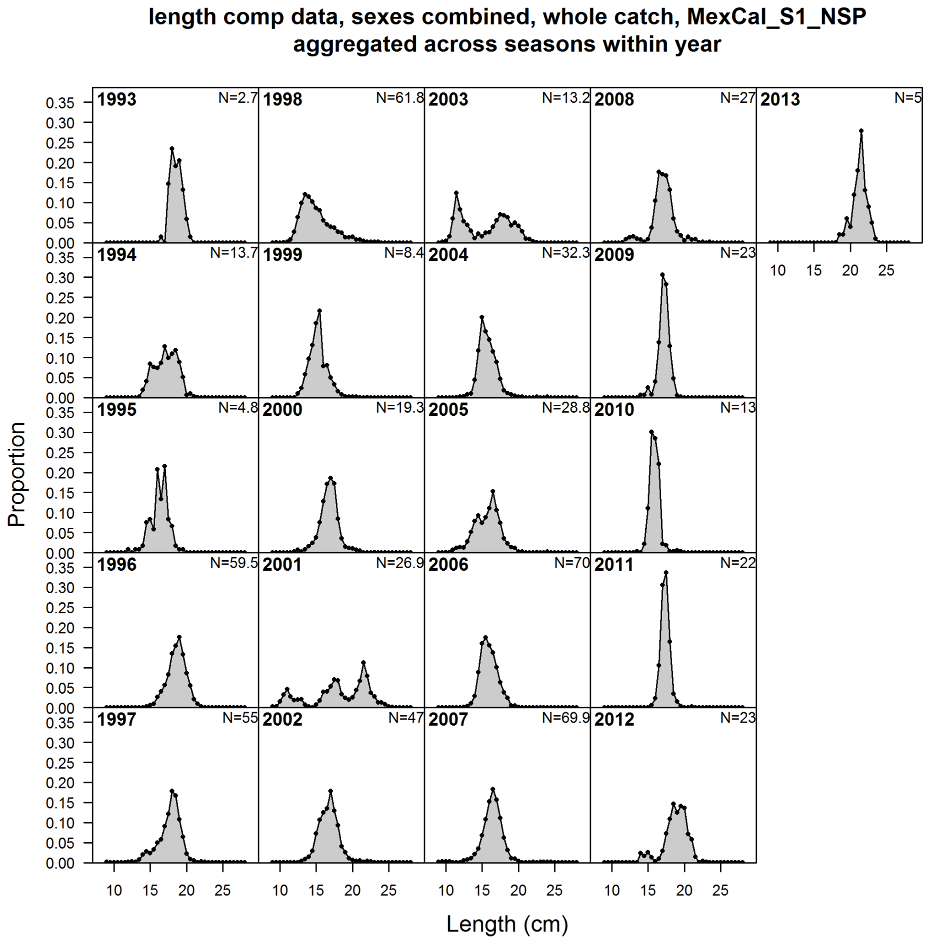


Figure 6b. Pacific sardine landings (mt) by fleet, model year and semester as used in NSP model scenarios, including final base model T.



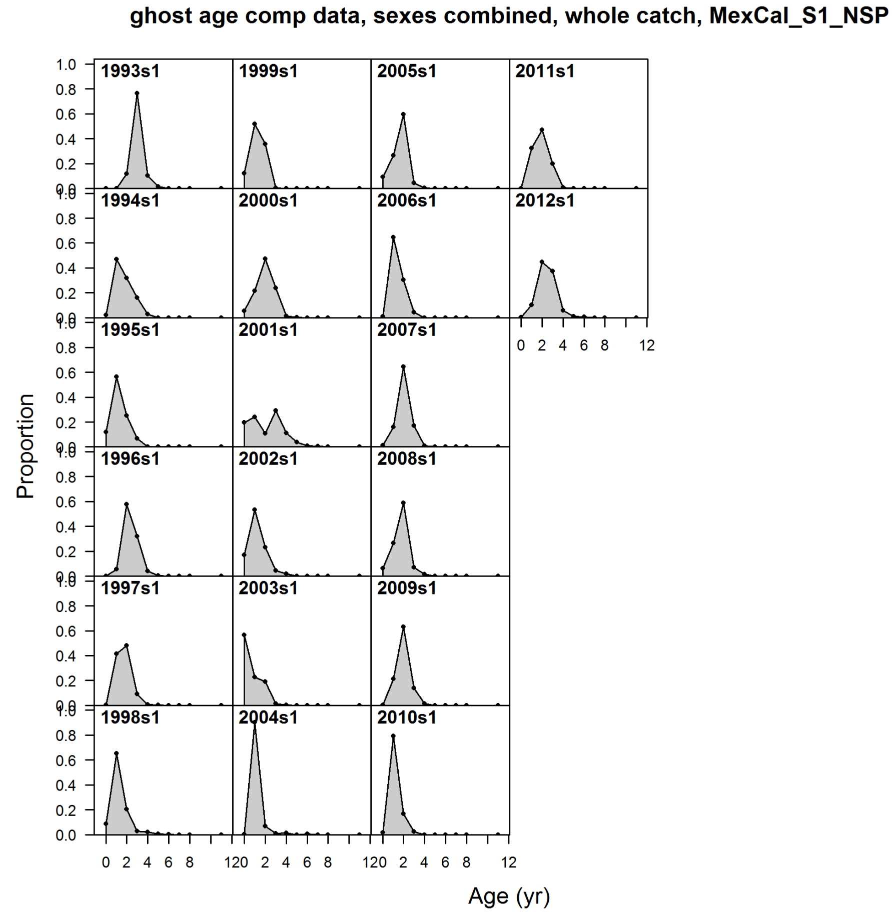


Figure 7. Length-composition (left panel) and implied age composition (right panel) data for the MexCal_S1 fleet.

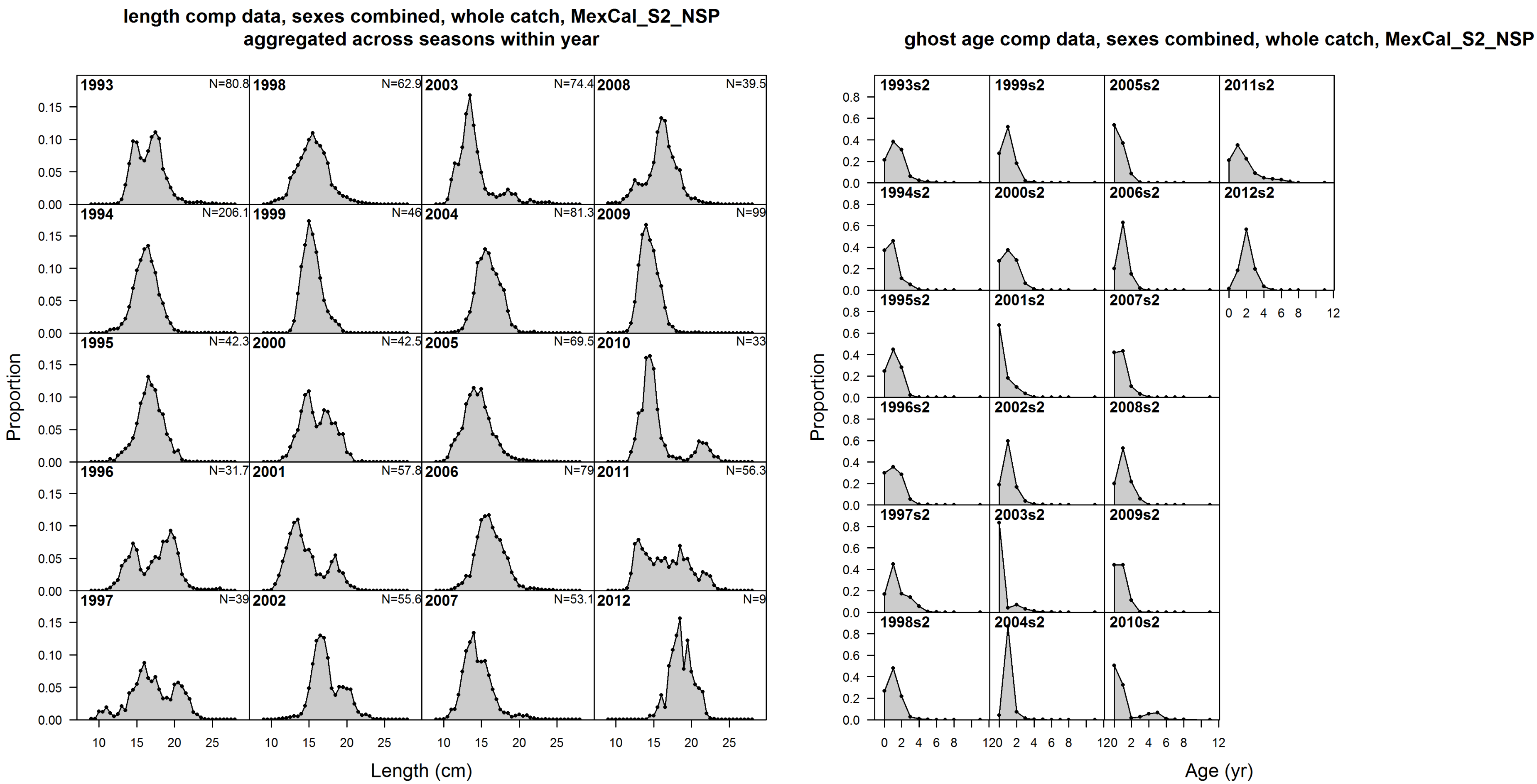


Figure 8. Length-composition (left panel) and implied age composition (right panel) data for the MexCal_S2 fleet.

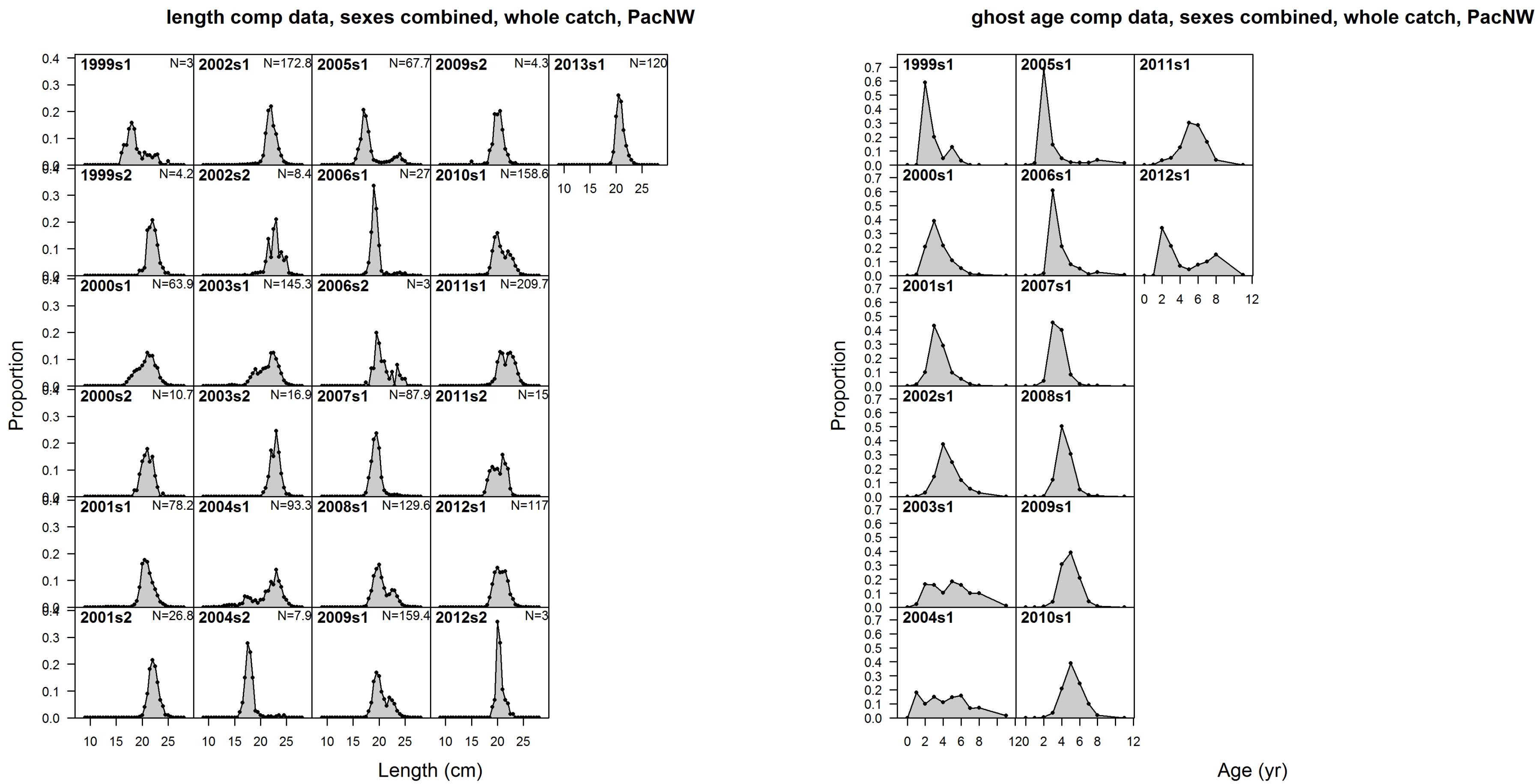


Figure 9. Length-composition (left panel) and implied age-composition (right panel) data for the PacNW fleet.

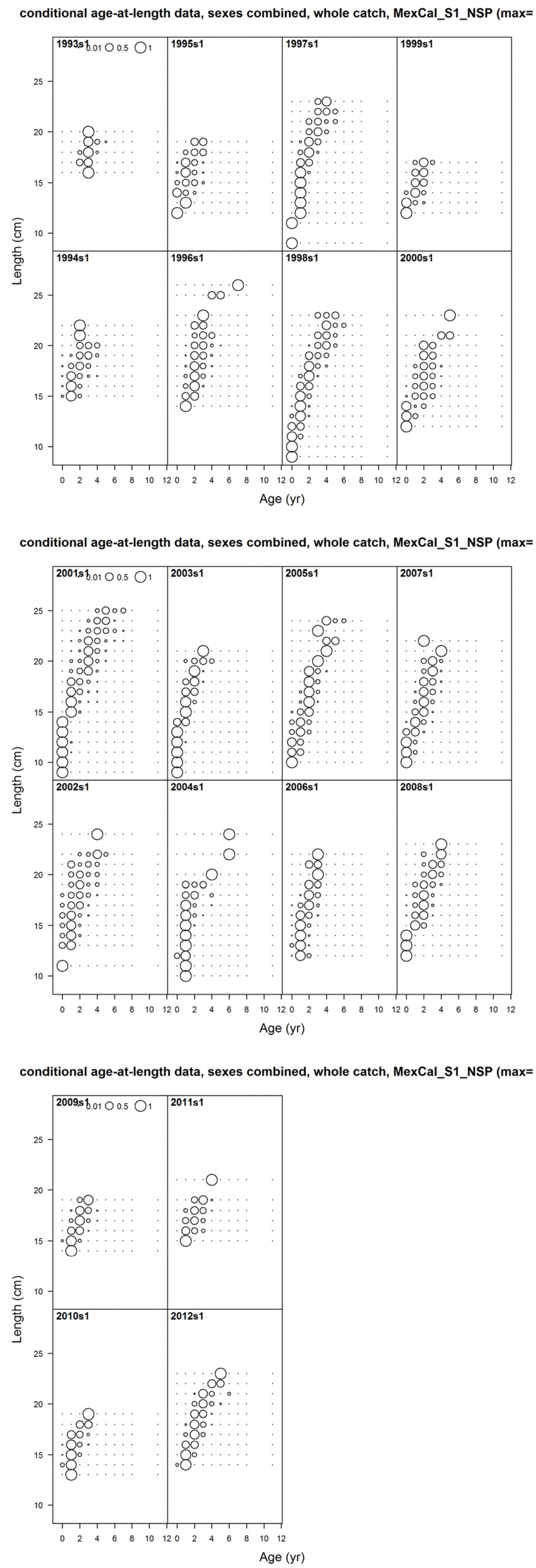


Figure 10. Conditional age-at-length data for the MexCal_S1 fleet.

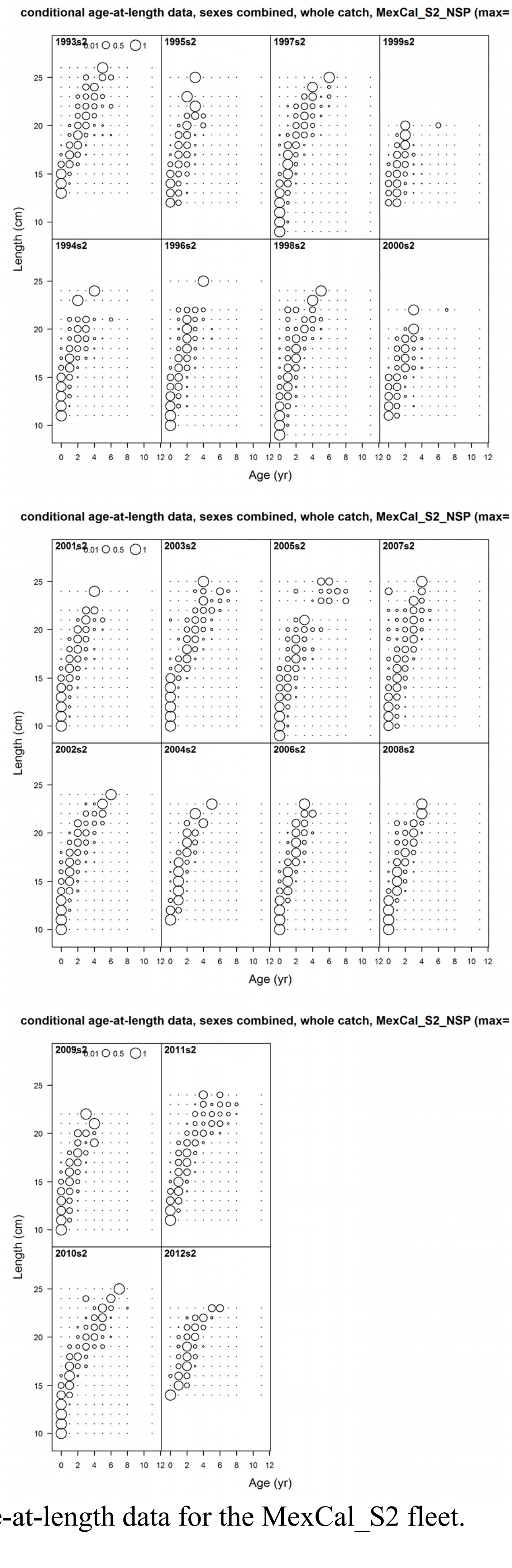
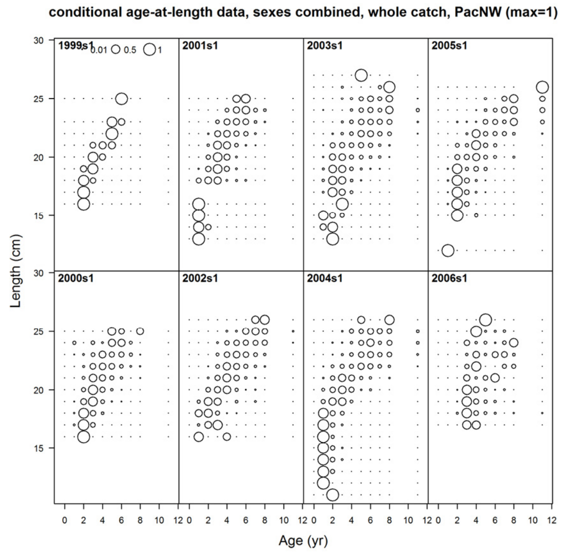


Figure 11. Conditional age-at-length data for the MexCal_S2 fleet.



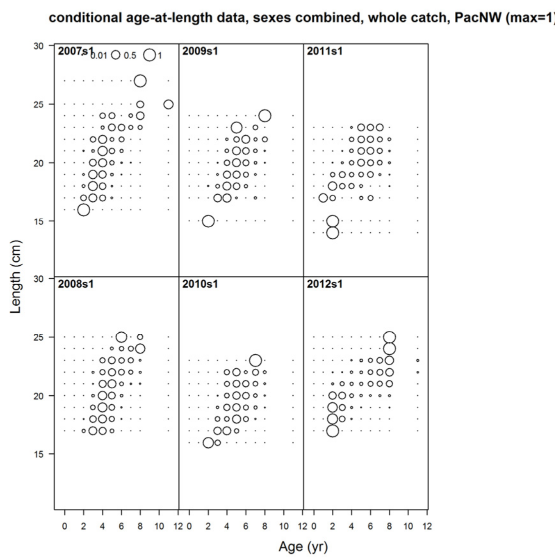


Figure 12. Conditional age-at-length data for the PacNW fleet.

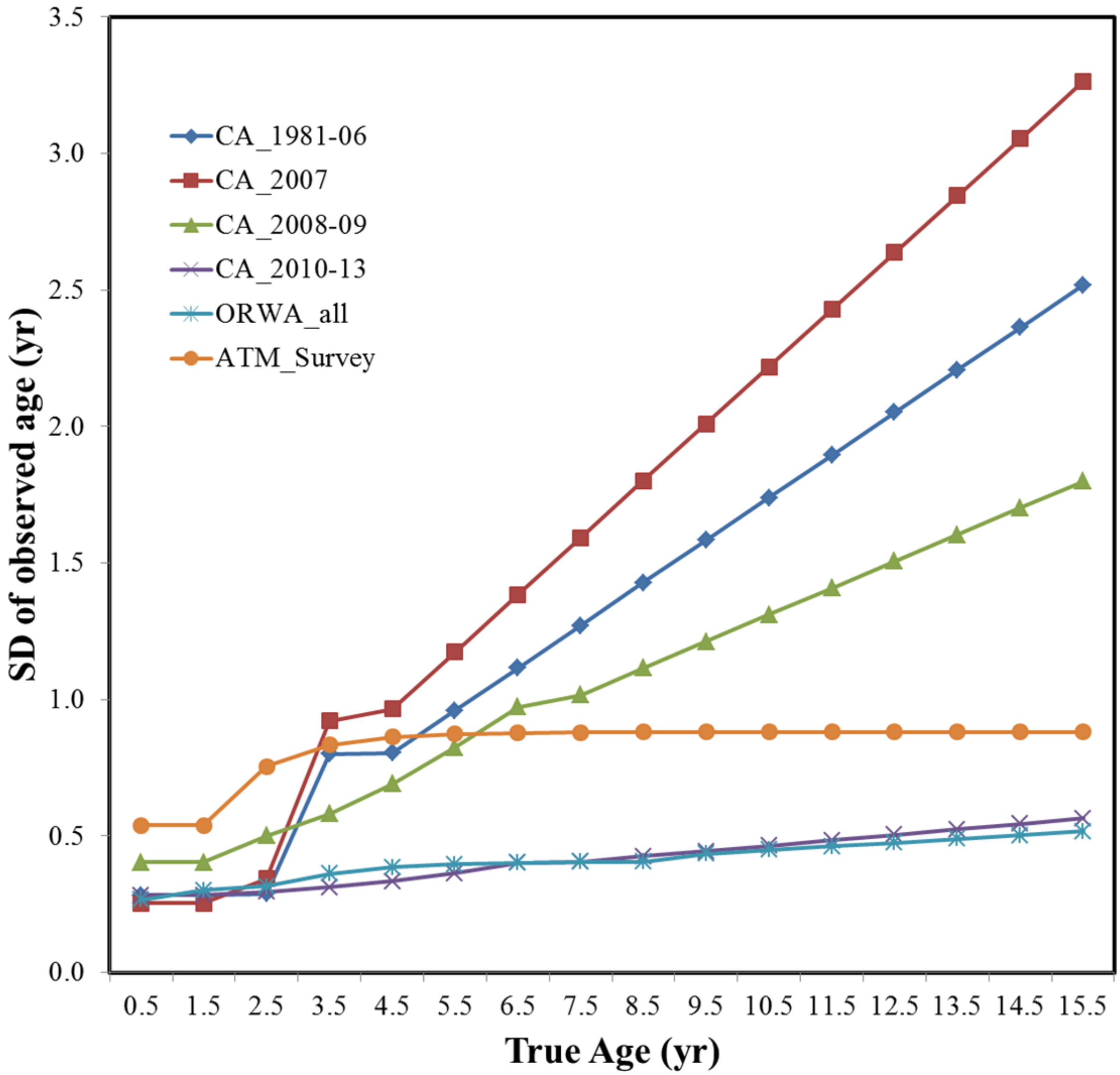


Figure 13. Laboratory- and year-specific ageing errors applied in all models.

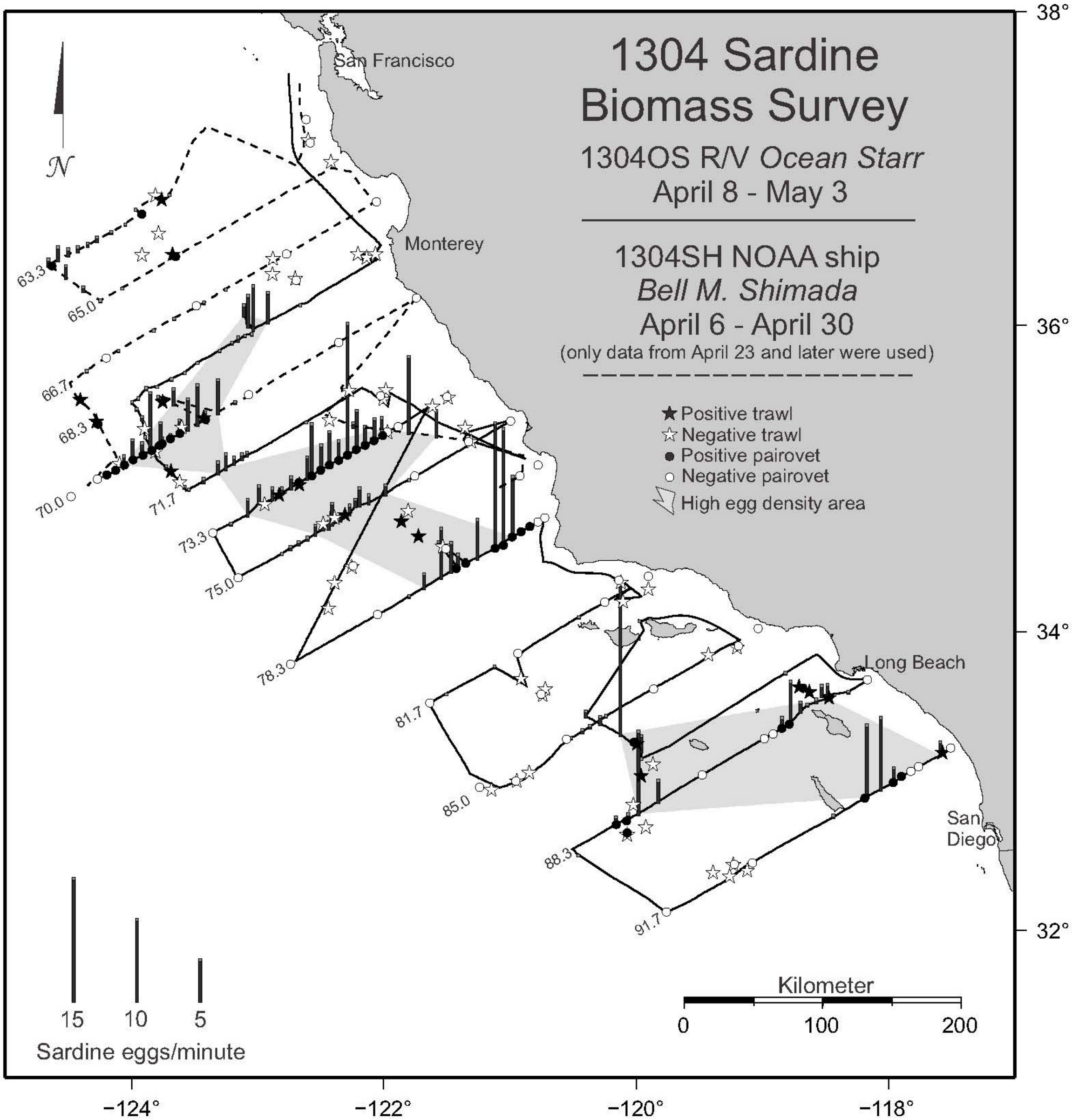


Figure 14. Distribution of CUFES, and Pairovet, and adult trawl samples from the SWFSC 1304 sardine survey in the standard sampling area for the DEPM index, conducted onboard the R/V *Ocean Starr* and the NOAA ship *Bell M. Shimada* during spring 2013.

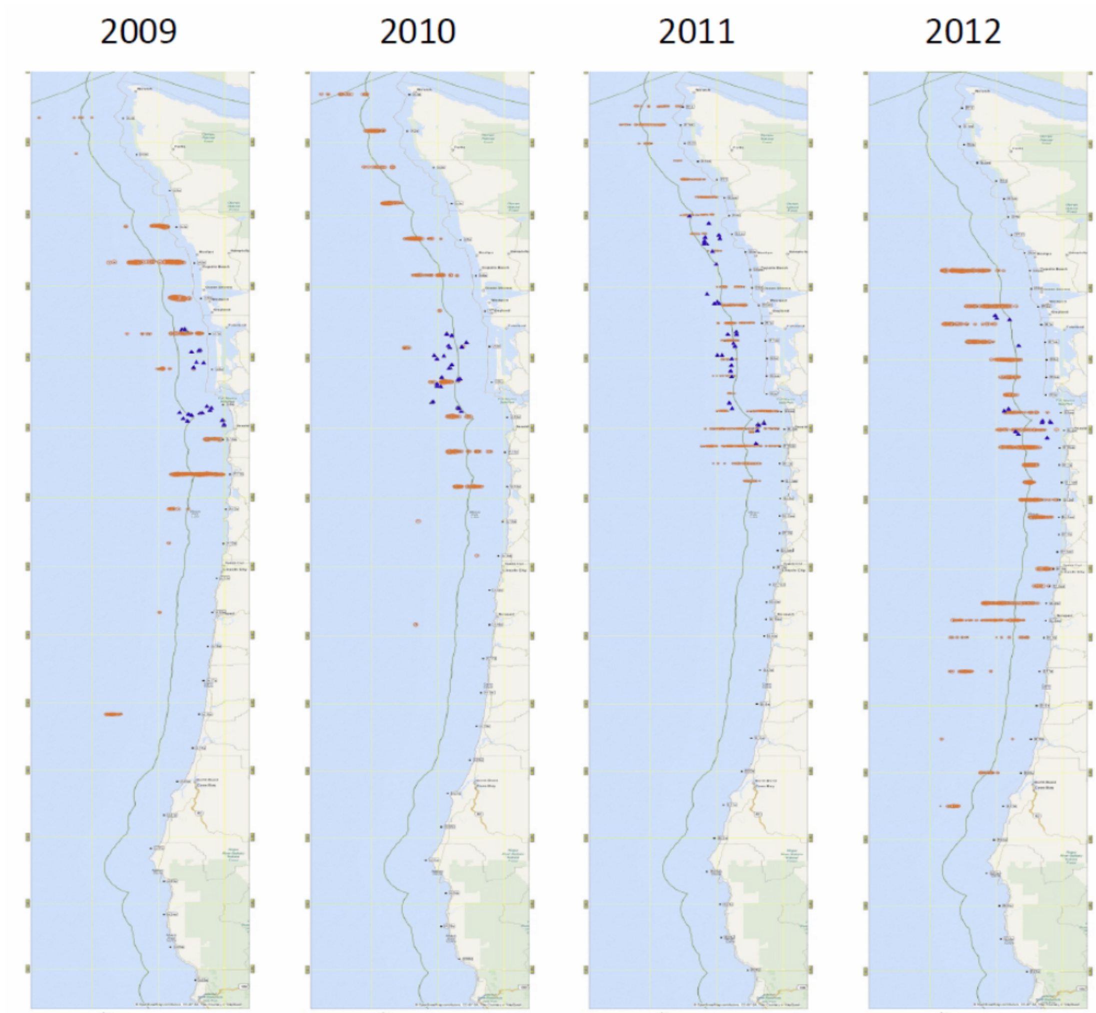


Figure 15. NWSS aerial survey distributions of fish schools observed from photographs and sardine-directed point sets (blue markers) (from Jagielo et al. 2012).

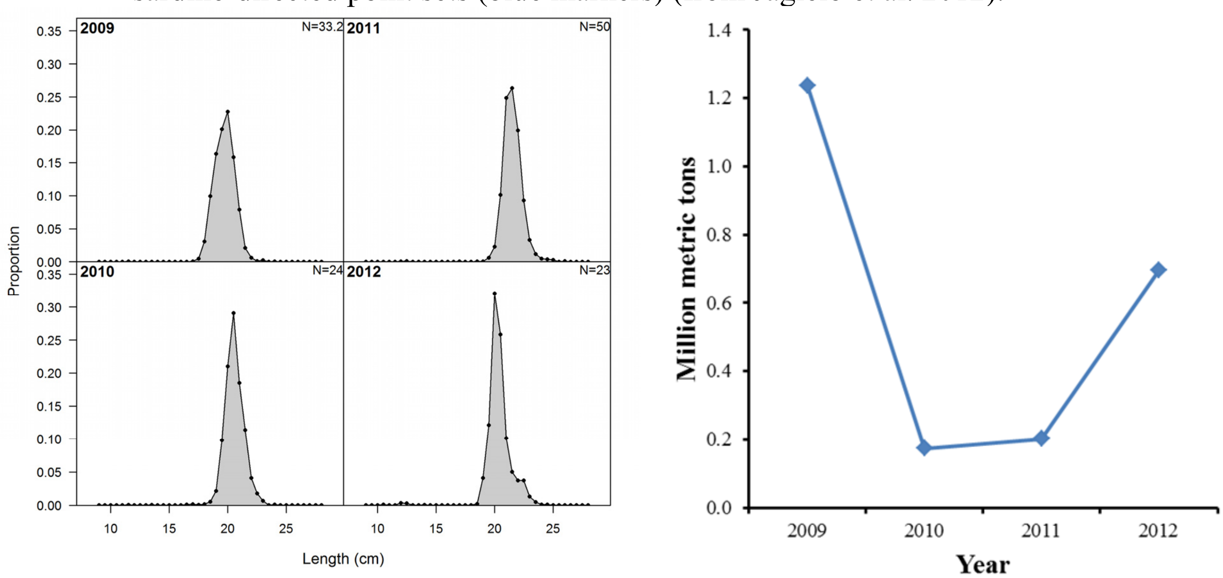
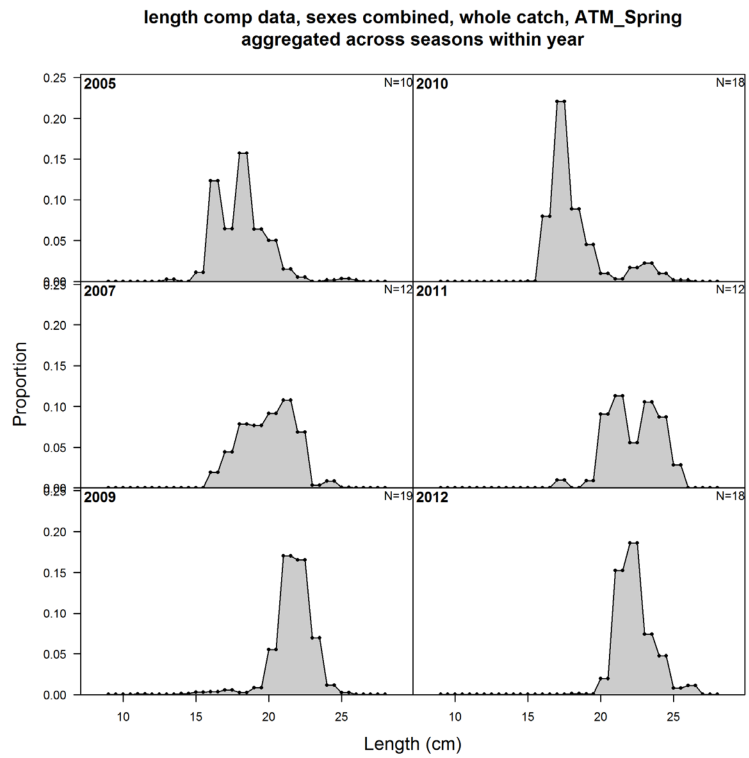


Figure 16. Length compositions (left) and biomass estimates (right) for the NWSS aerial survey.



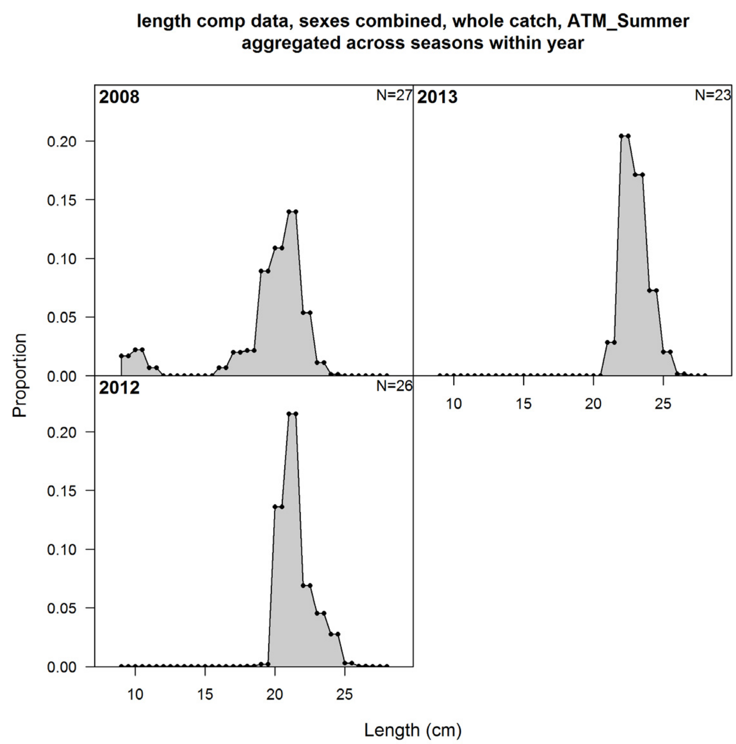
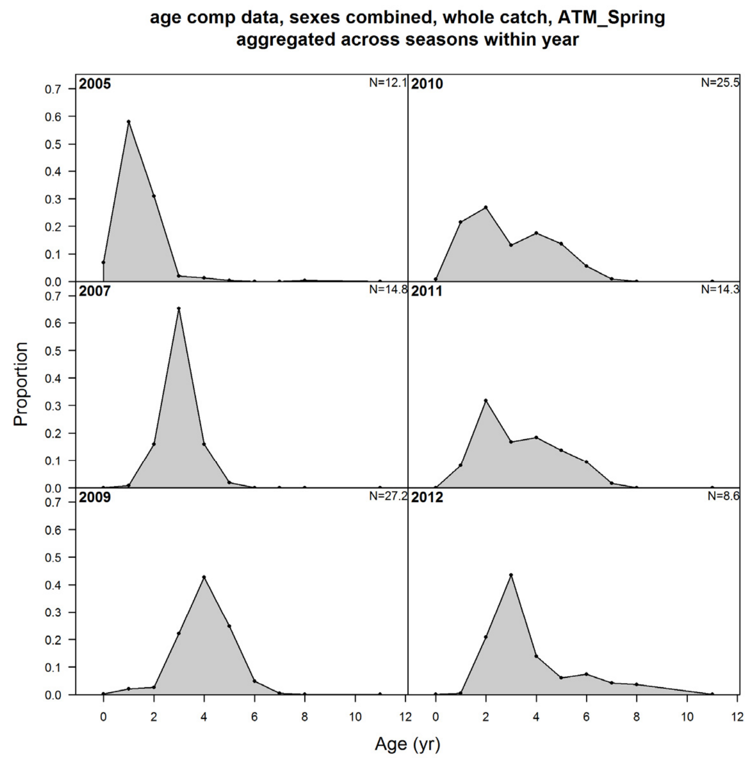


Figure 17. Length-composition data (1-cm resolution) for the ATM Spring (upper panel) and Summer (lower panel) surveys.



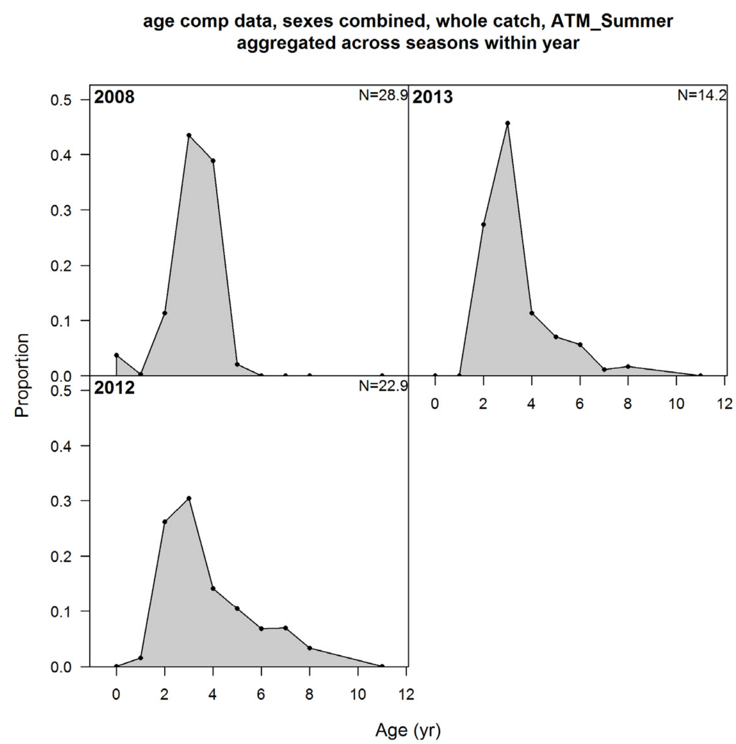
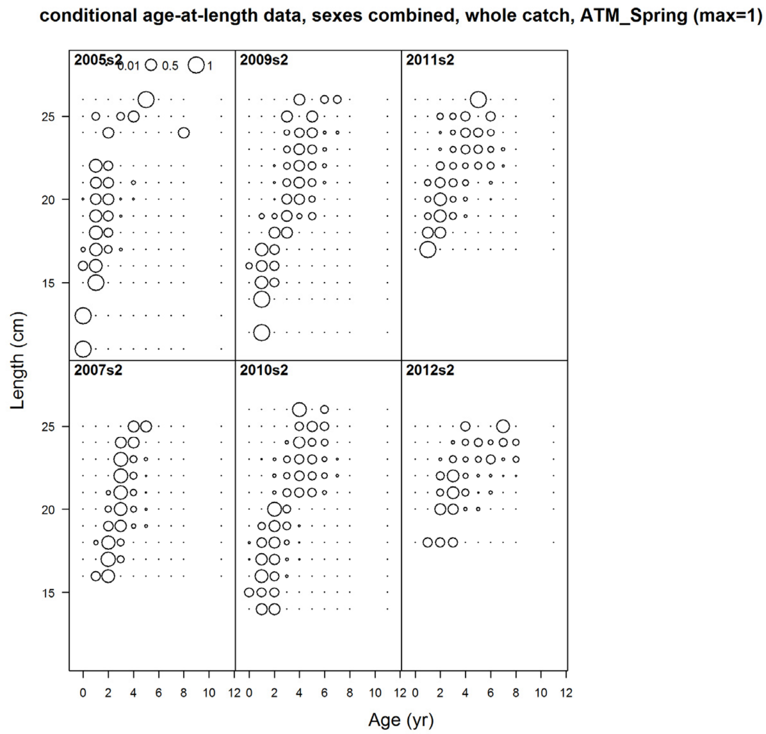


Figure 18. Implied age-composition data for the ATM Spring (upper panel) and Summer (lower panel) surveys.



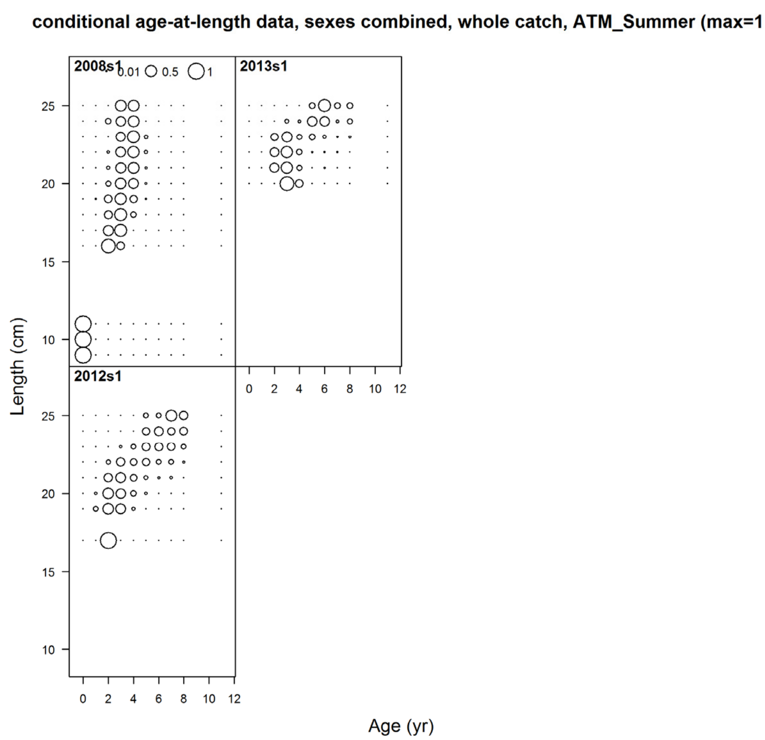


Figure 19. Conditional age-at-length composition data for the ATM Spring (upper) and Summer (lower) surveys.

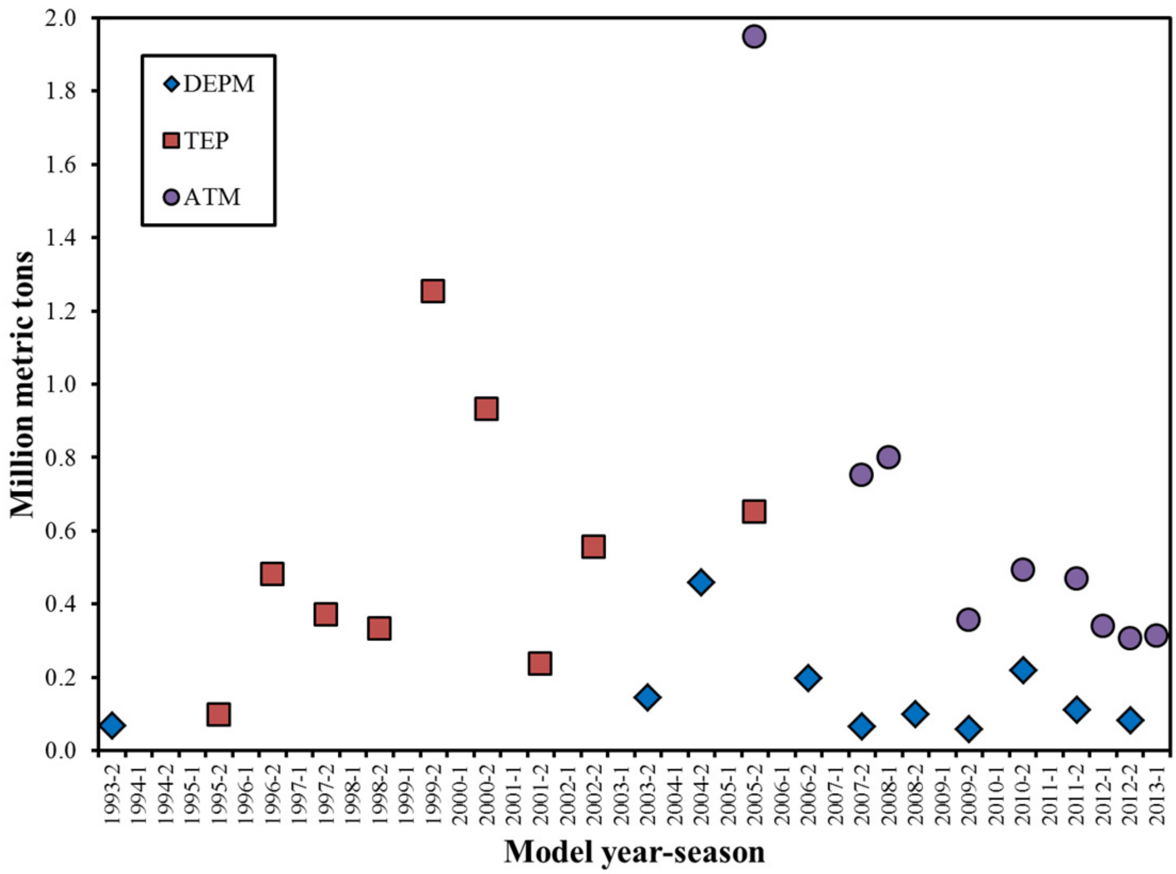


Figure 20. Survey indices of abundance (biomass units) included in final base model T. TEP is modeled as total SSB, and DEPM as female SSB. Error bars for survey estimates are shown in subsequent displays for model fits to respective surveys.

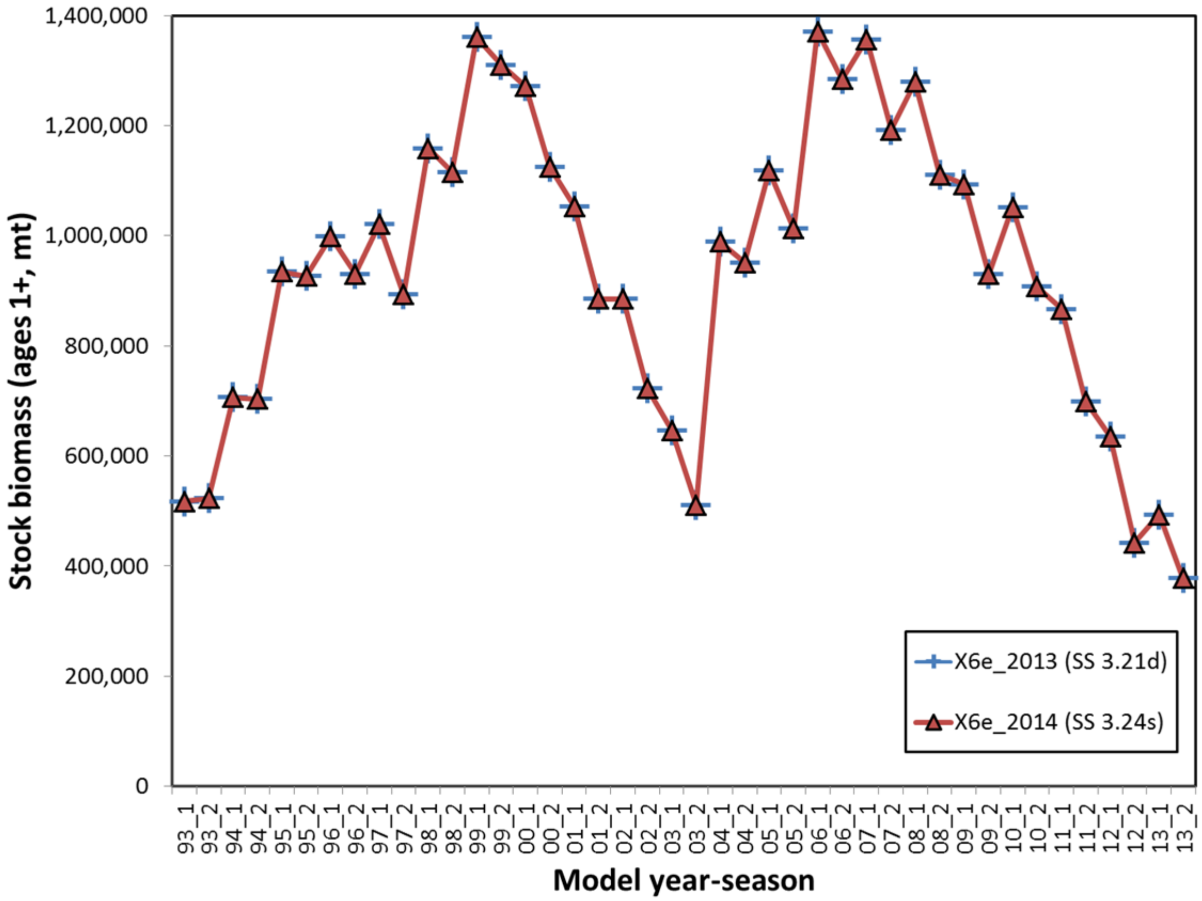


Figure 21. Estimated biomass (*B*) time series for the final assessment model used by management in 2013 (Hill 2013), as modeled with SS 3.21d, and the same data modeled with SS 3.24s.

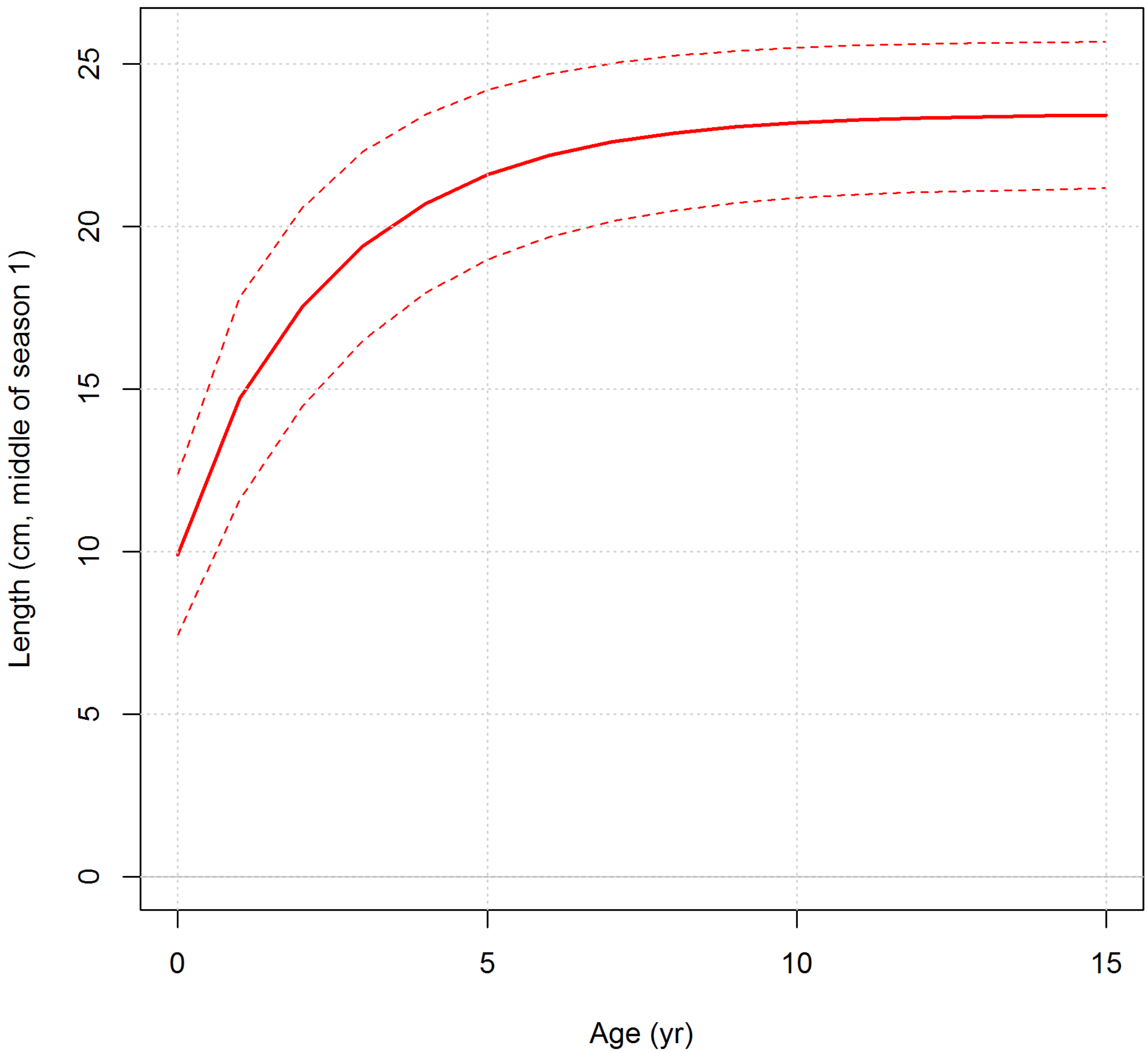
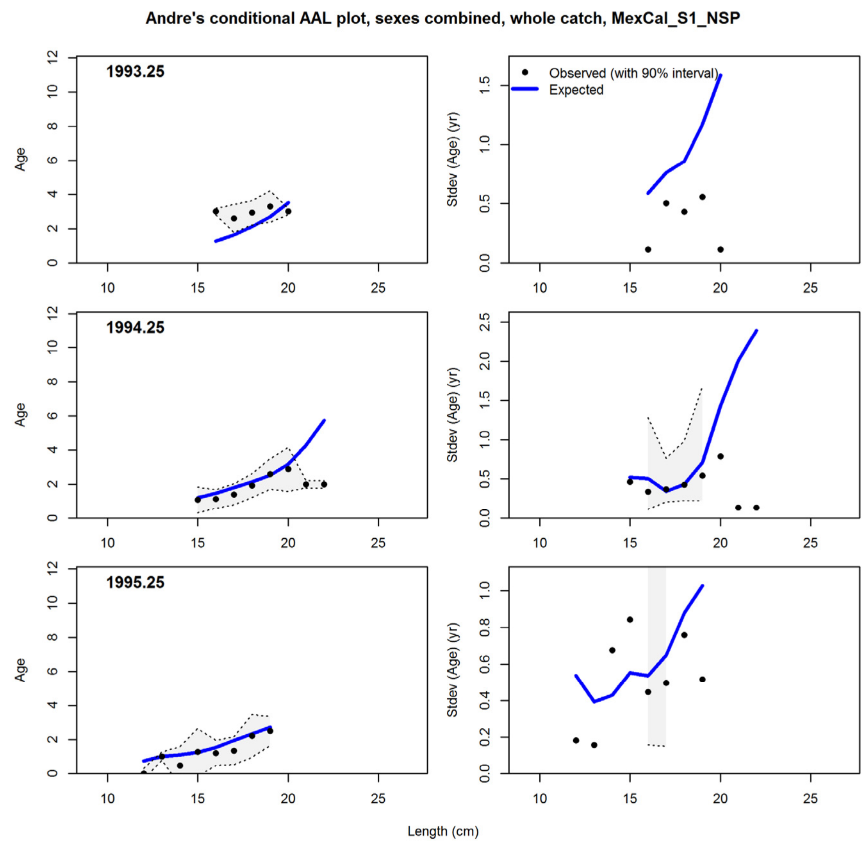


Figure 22. Length-at-age relationship estimated in base model T ($L_{0.5yr}$ = 11.7754 (0.0491), L_∞ = 23.4636 (0.1274), K = 0.3855).



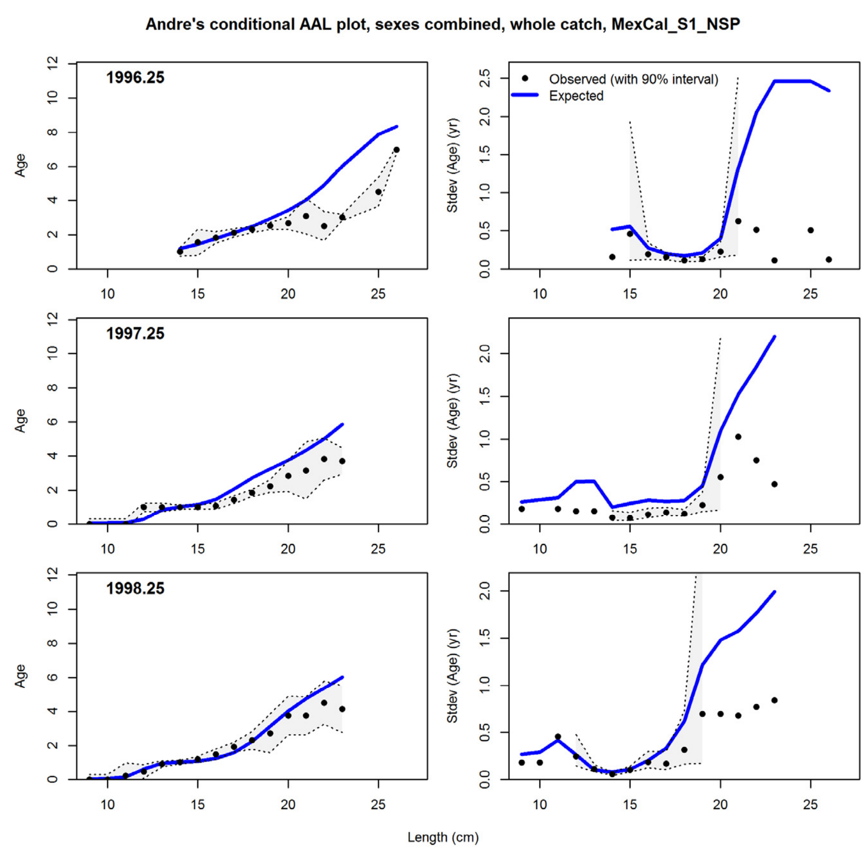
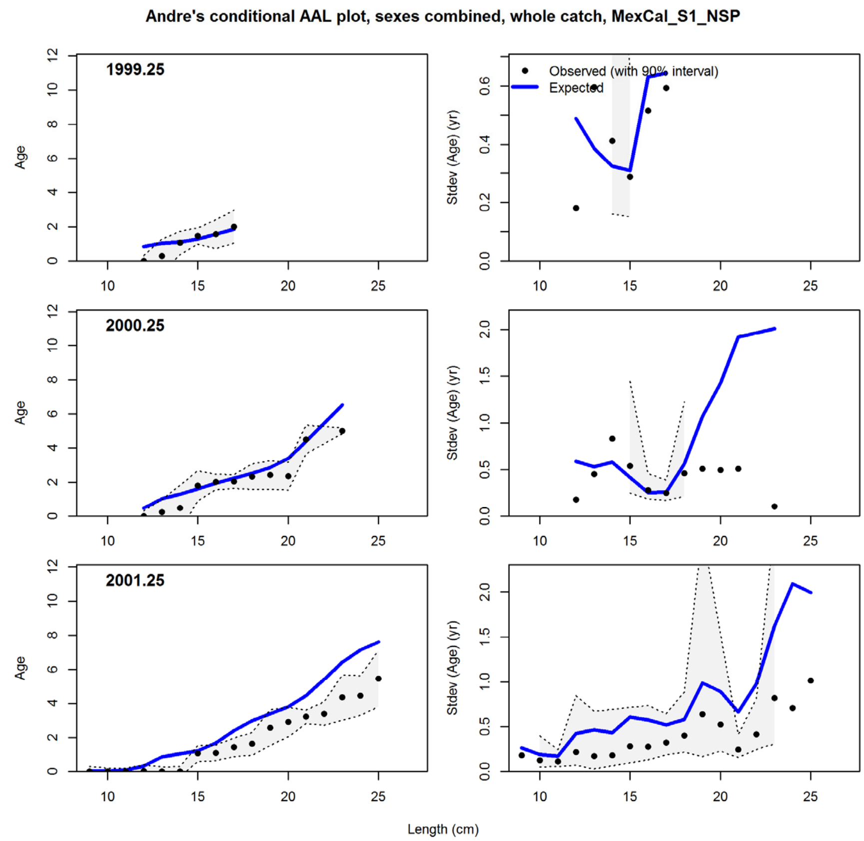


Figure 23. Model T fit to conditional age-at-length compositions for the MexCal_S1 fleet.



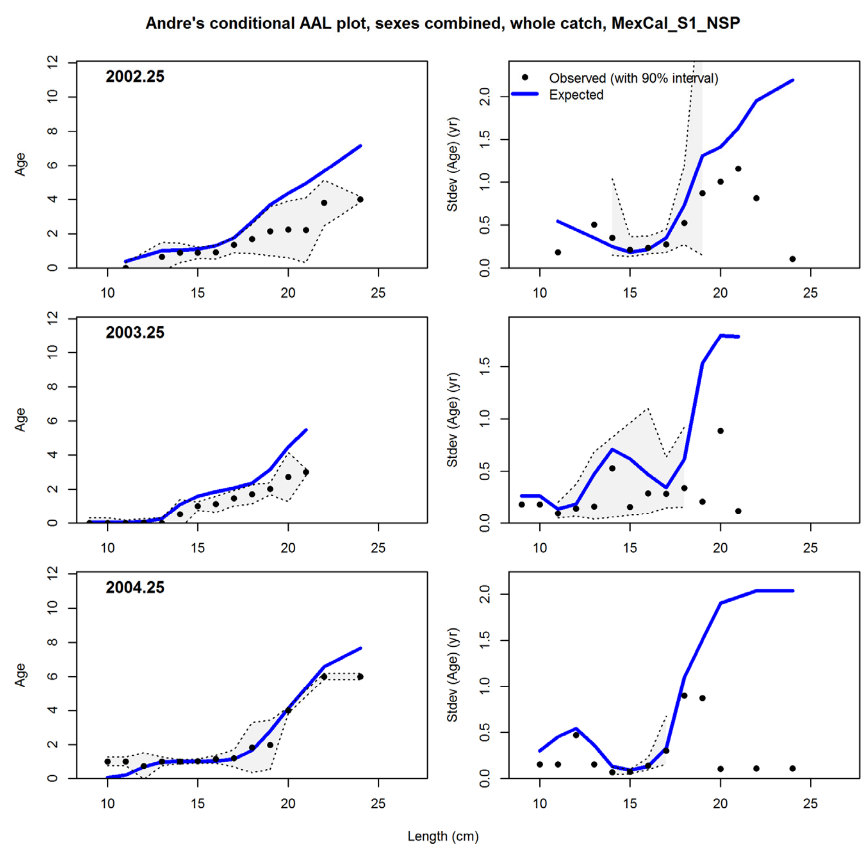
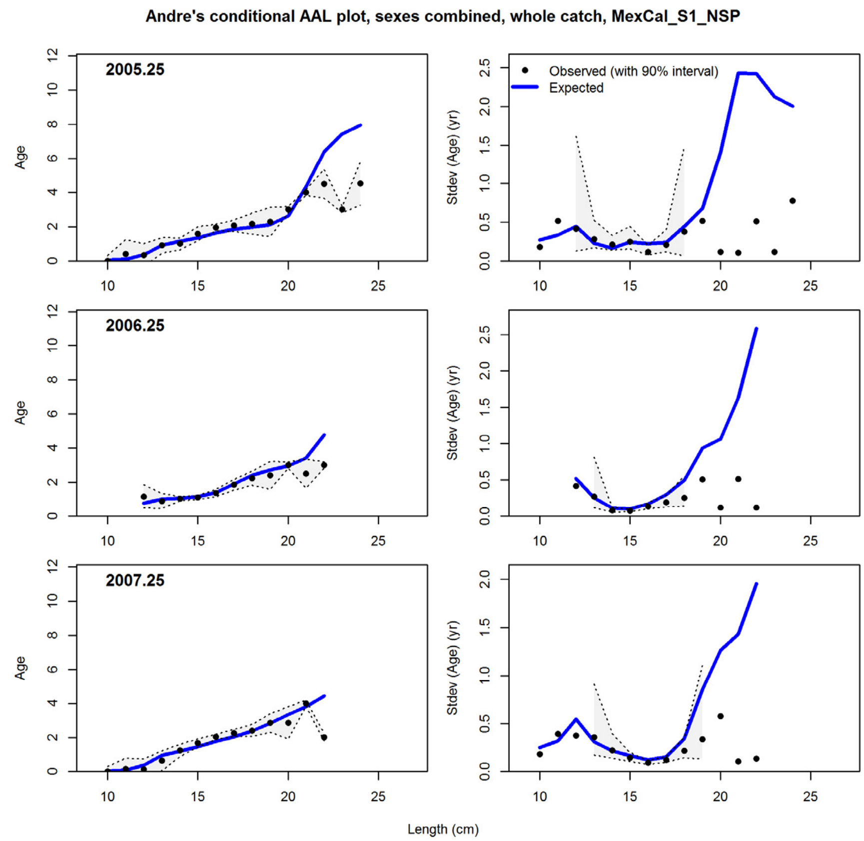


Figure 23 (cont.). Model T fit to conditional age-at-length compositions for the MexCal_S1 fleet.



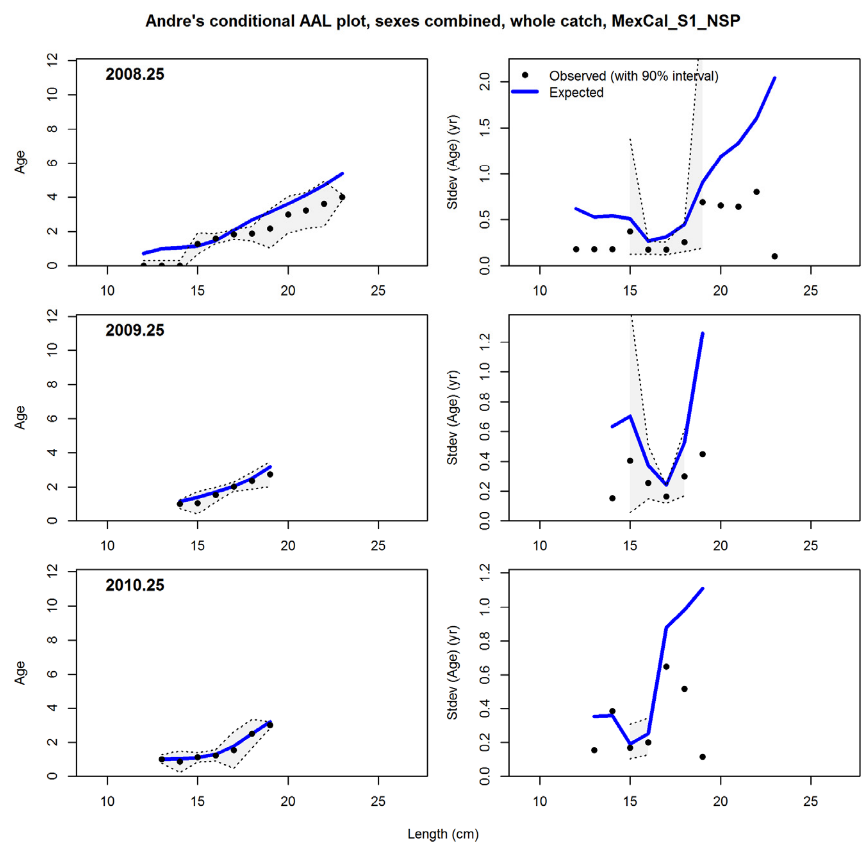


Figure 23 (cont.). Model T fit to conditional age-at-length compositions for the MexCal_S1 fleet.

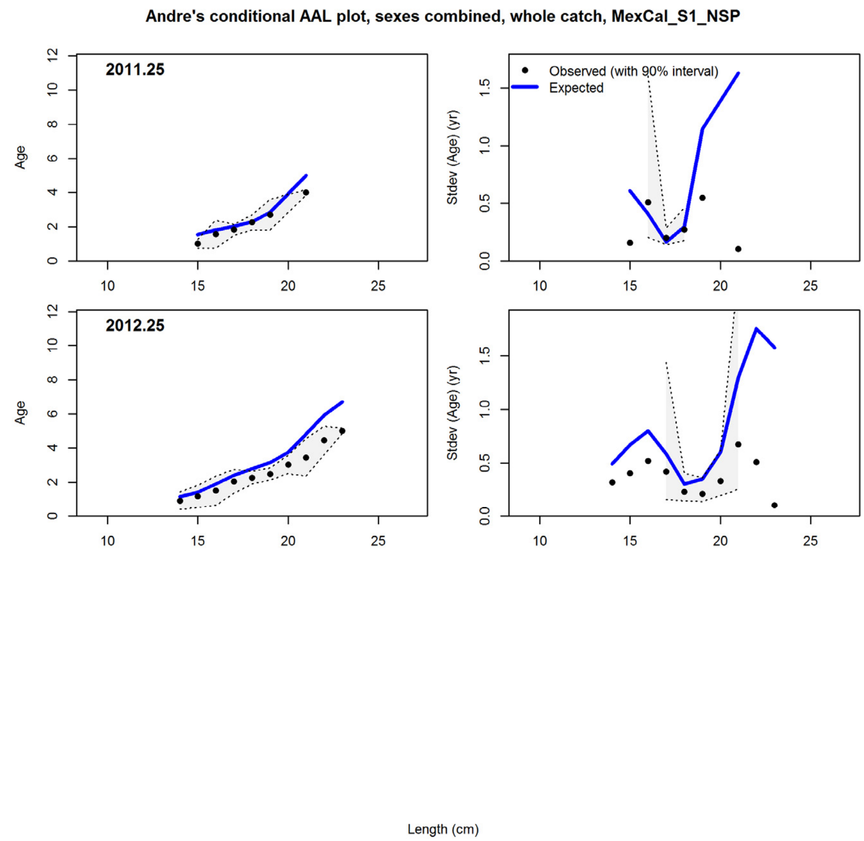


Figure 23 (cont.). Model T fit to conditional age-at-length compositions for the MexCal_S1 fleet.

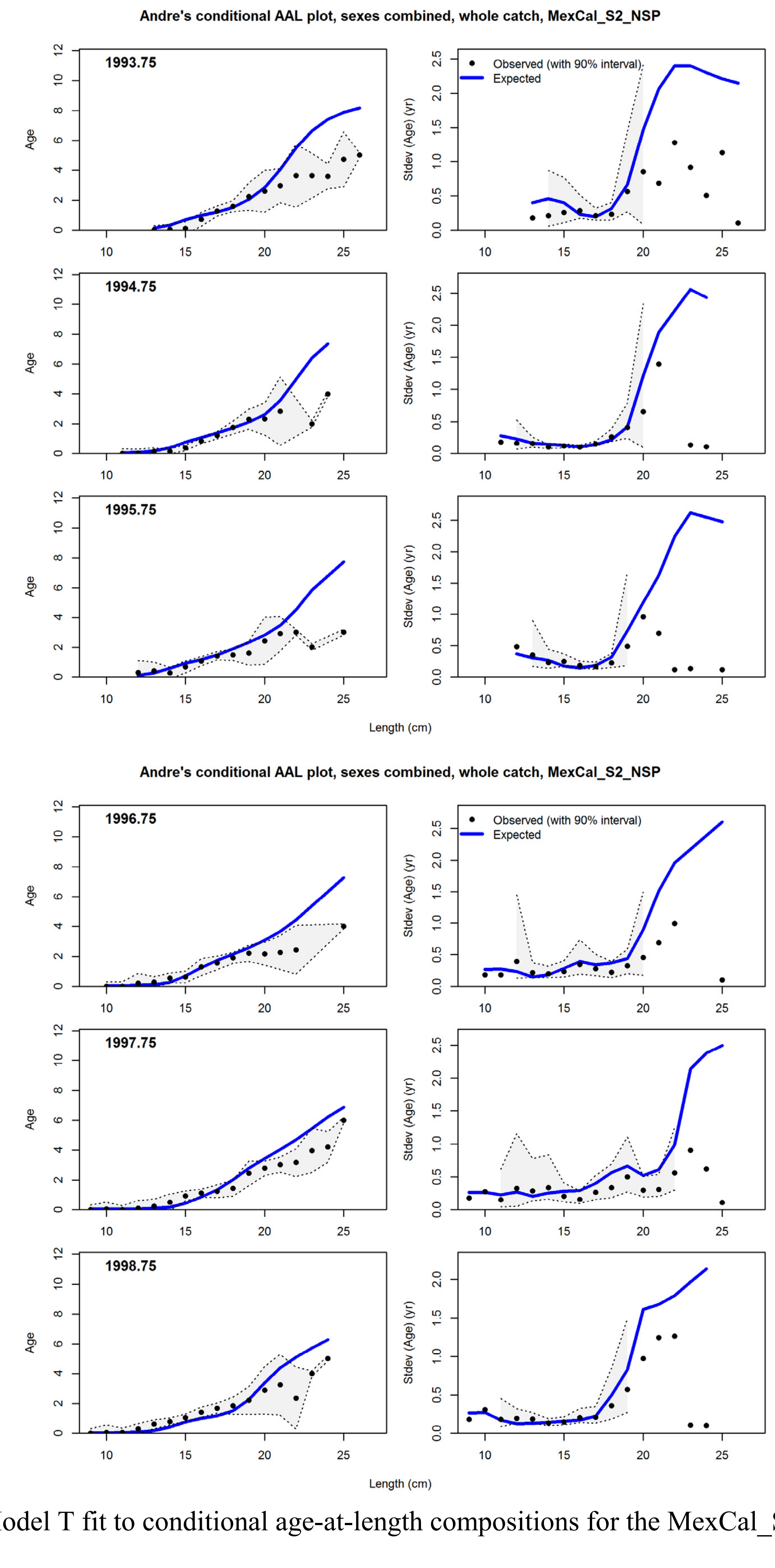
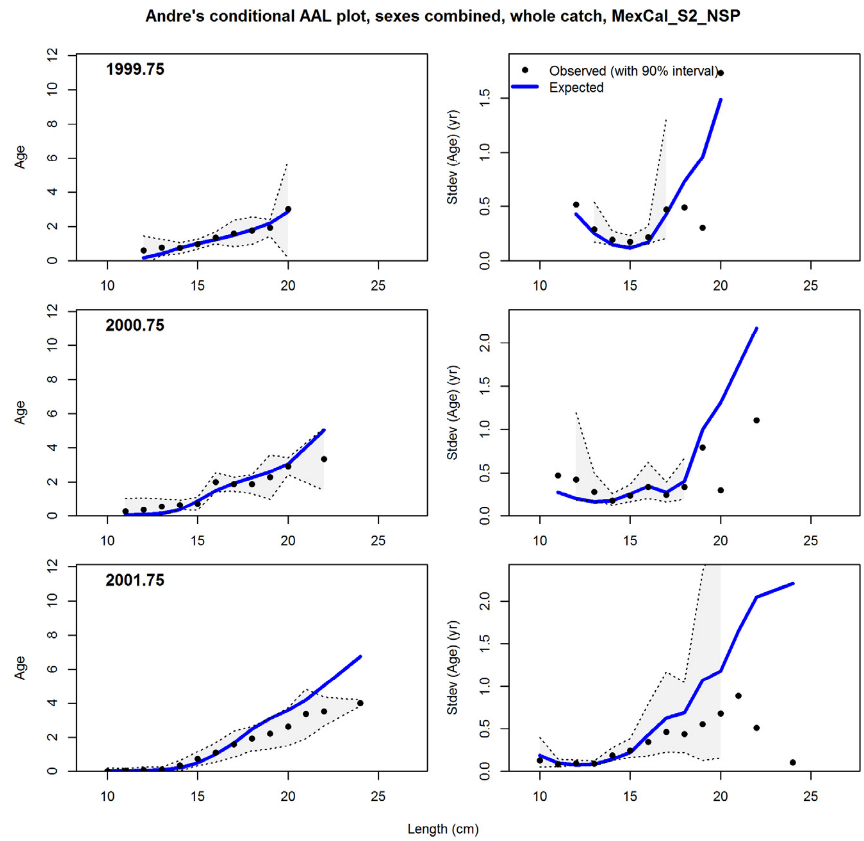


Figure 24. Model T fit to conditional age-at-length compositions for the MexCal_S2 fleet.



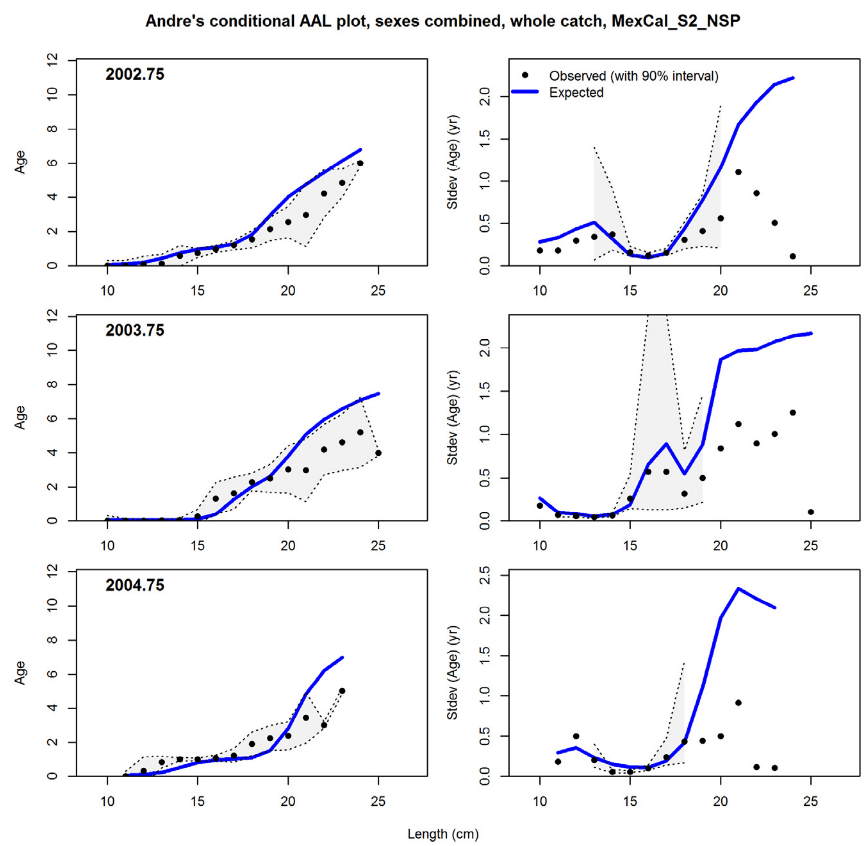
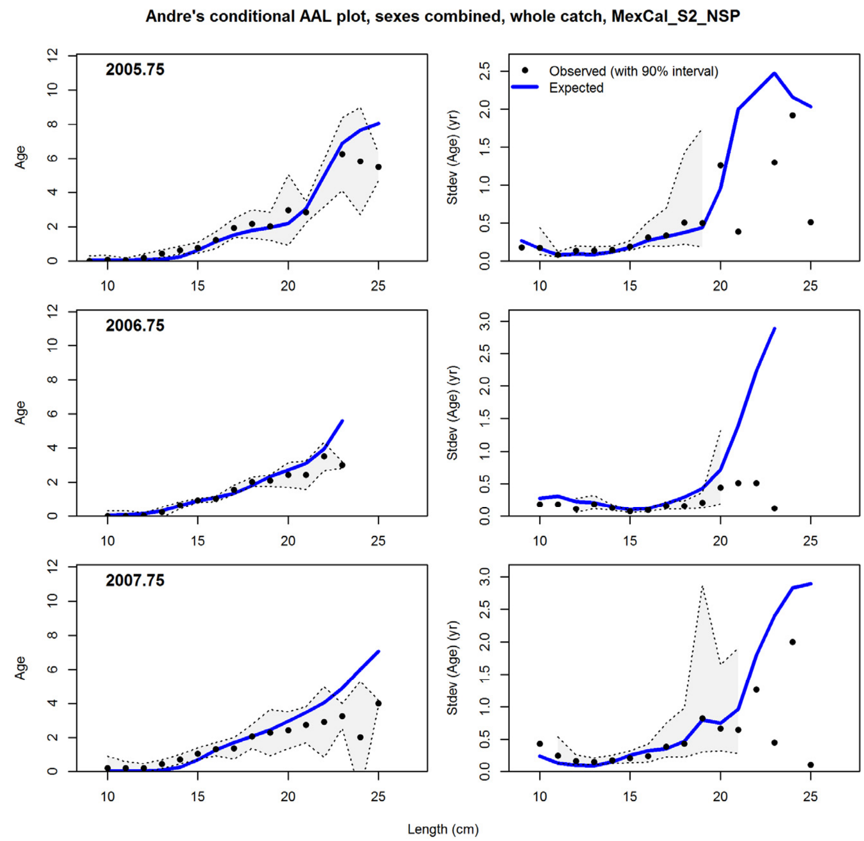


Figure 24 (cont.). Model T fit to conditional age-at-length compositions for the MexCal_S2 fleet.



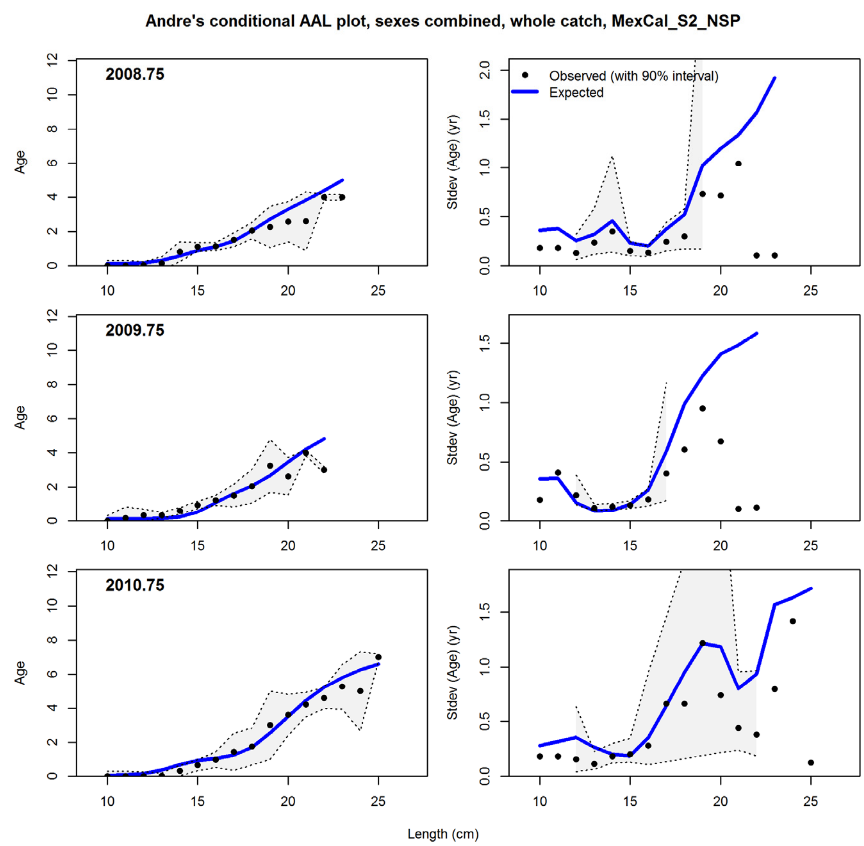


Figure 24 (cont.). Model T fit to conditional age-at-length compositions for the MexCal_S2 fleet.

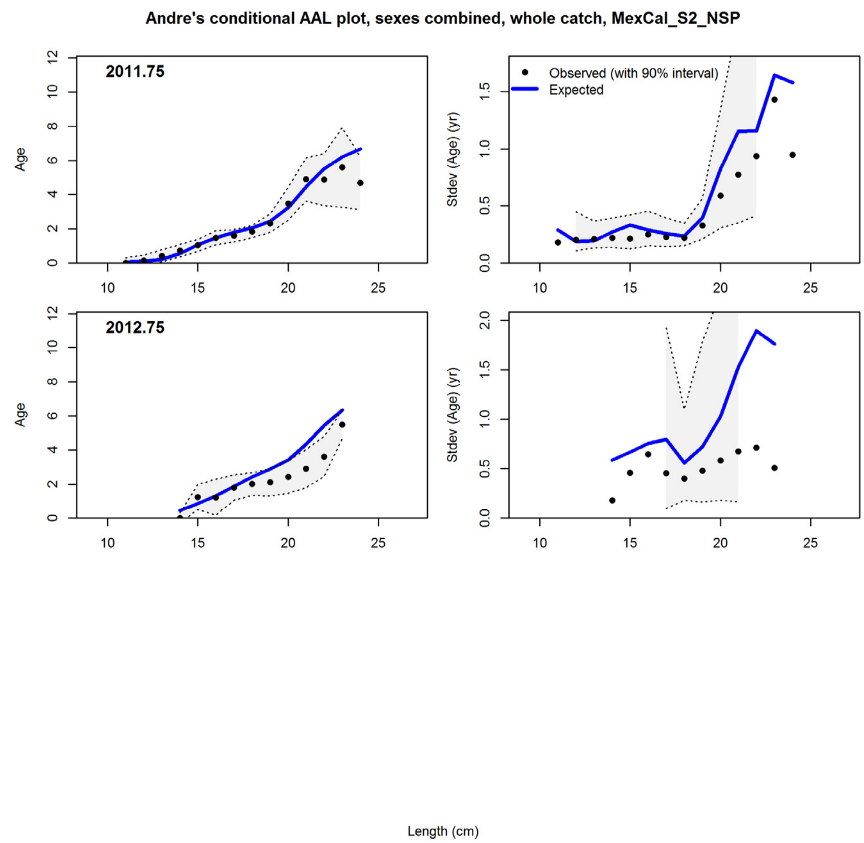
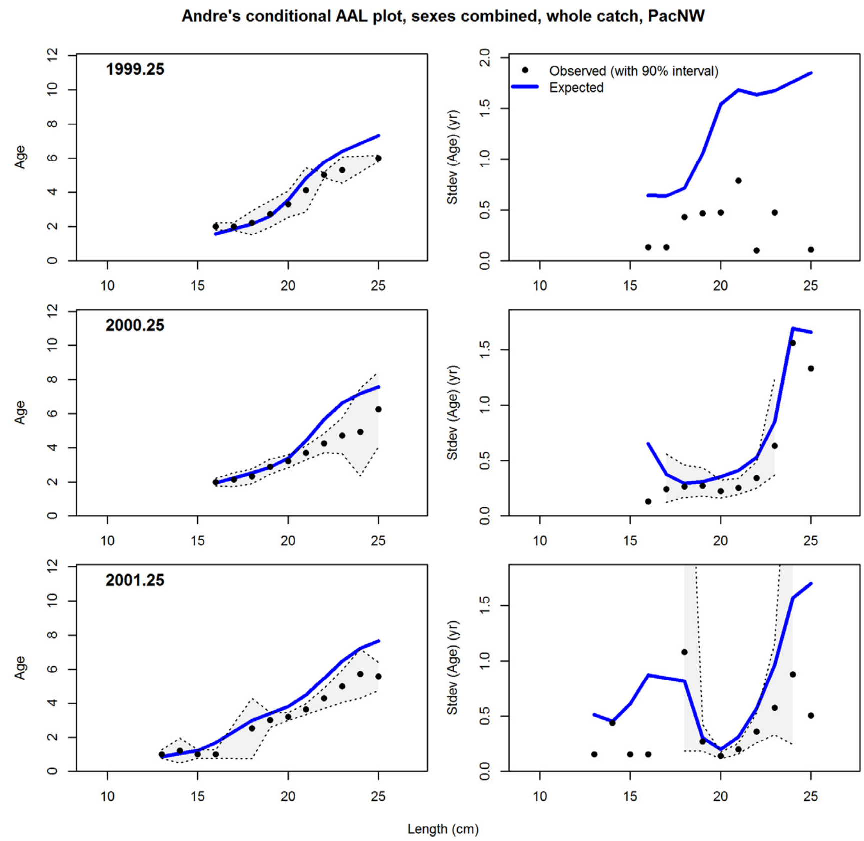


Figure 24 (cont.). Model T fit to conditional age-at-length compositions for the MexCal_S2 fleet.



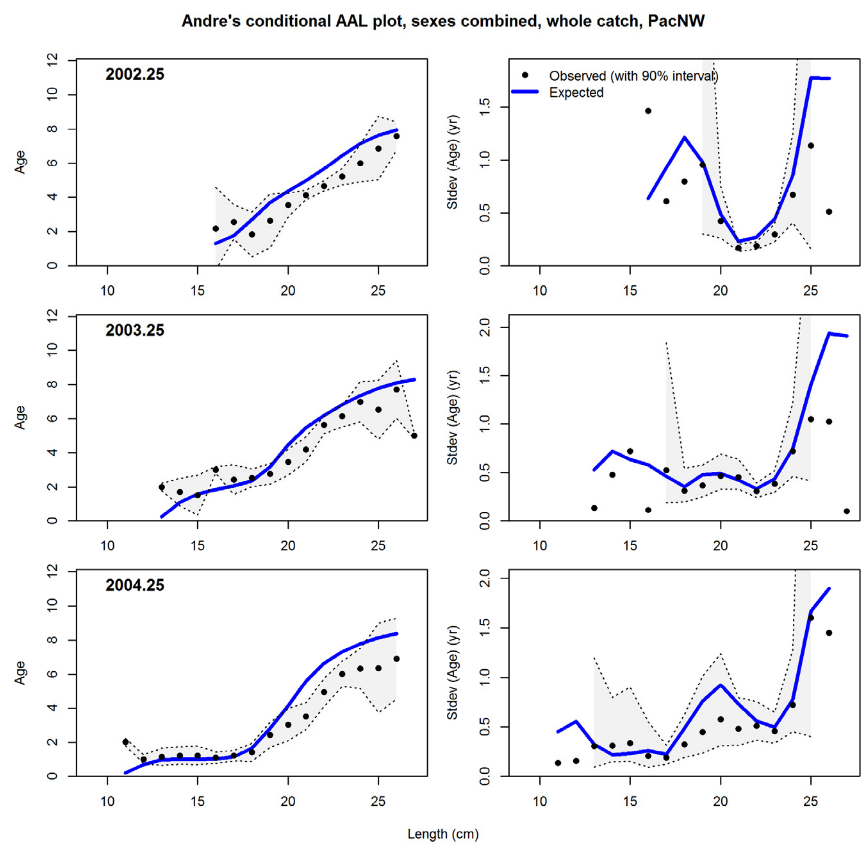
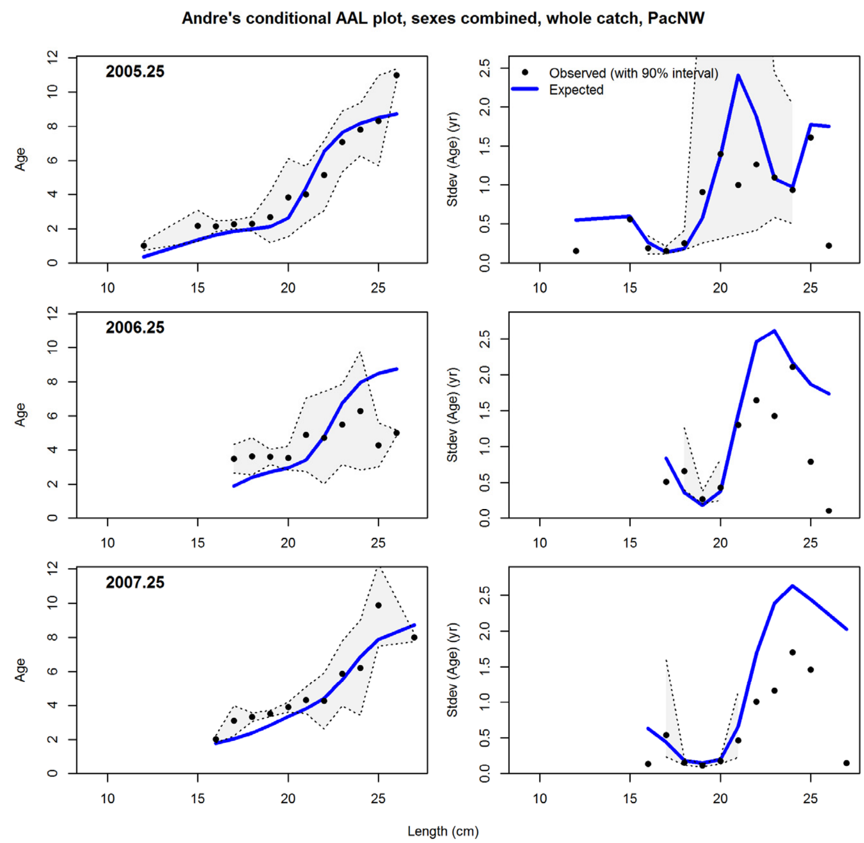


Figure 25. Model T fit to conditional age-at-length compositions for the PacNW fleet.



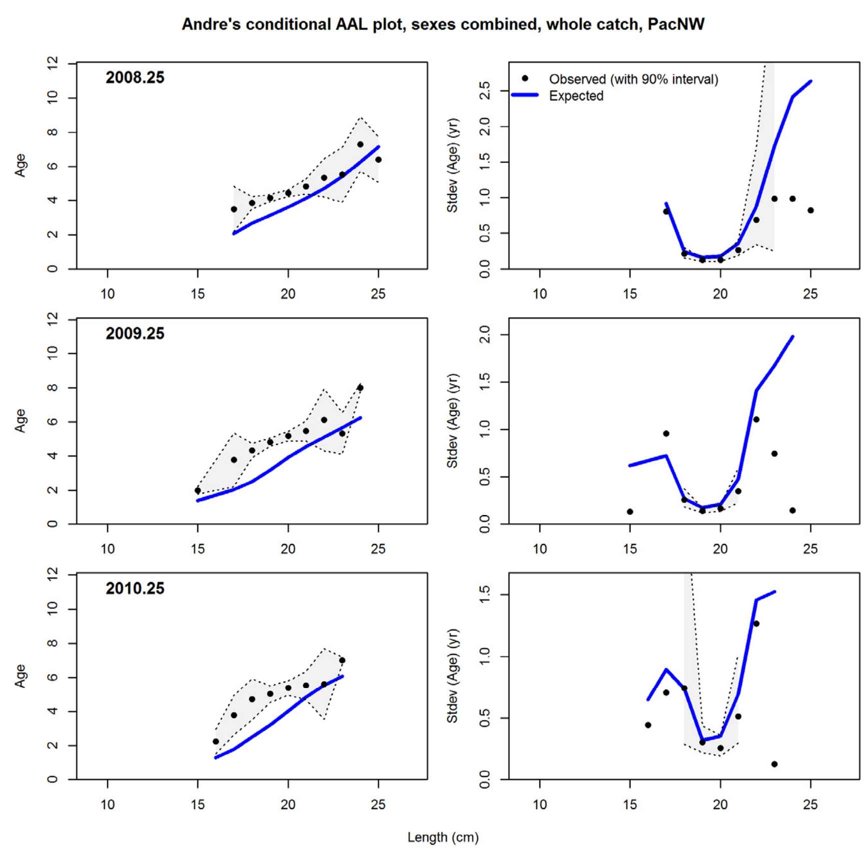


Figure 25 (cont.). Model T fit to conditional age-at-length compositions for the PacNW fleet.

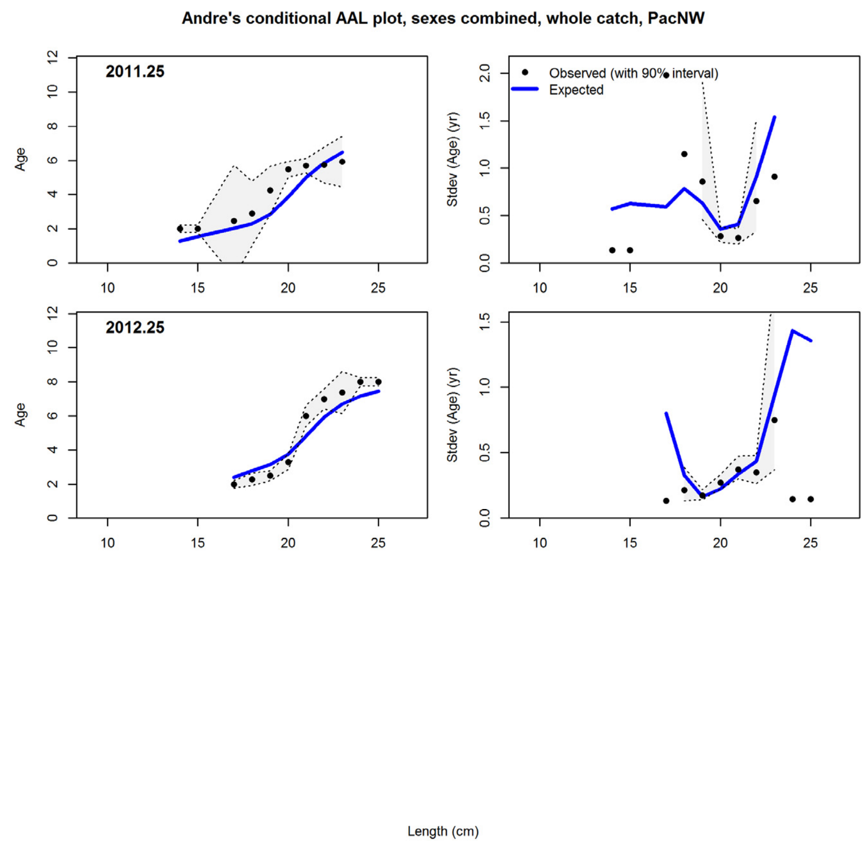


Figure 25 (cont.). Model T fit to conditional age-at-length compositions for the PacNW fleet.

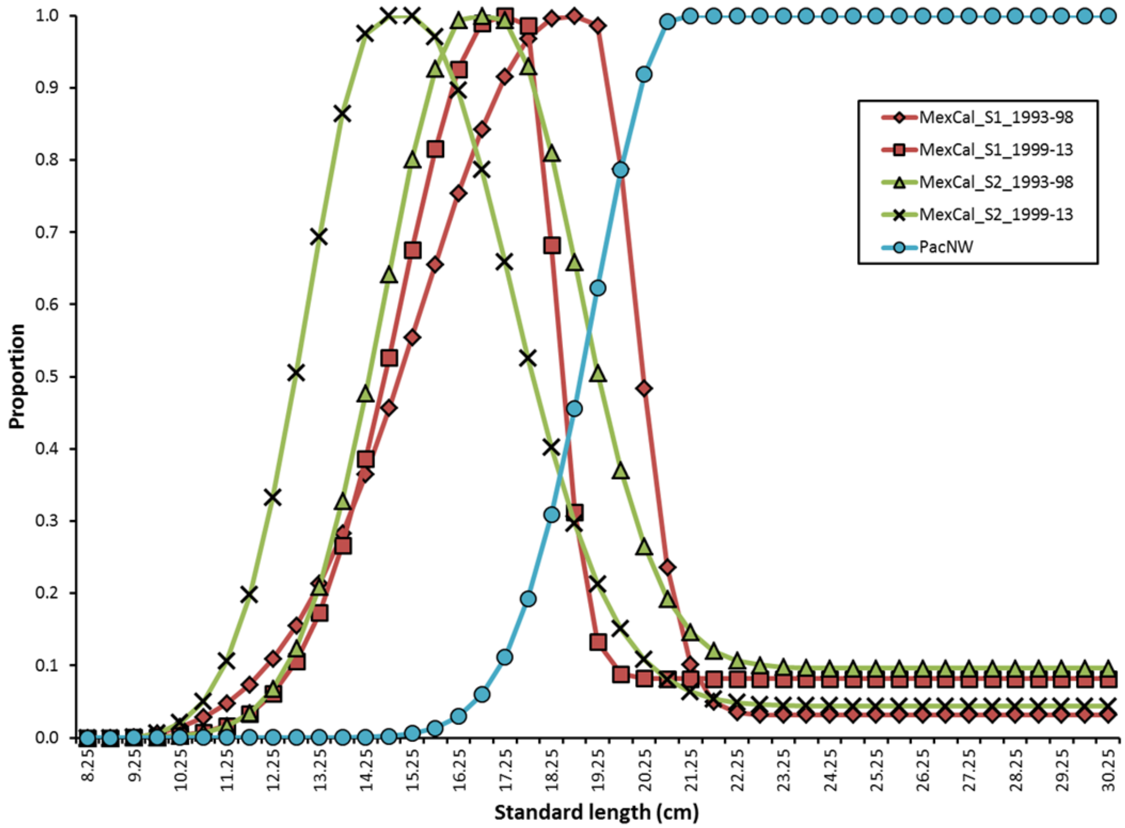


Figure 26a. Length-based selectivity patterns for fleets in base model T.

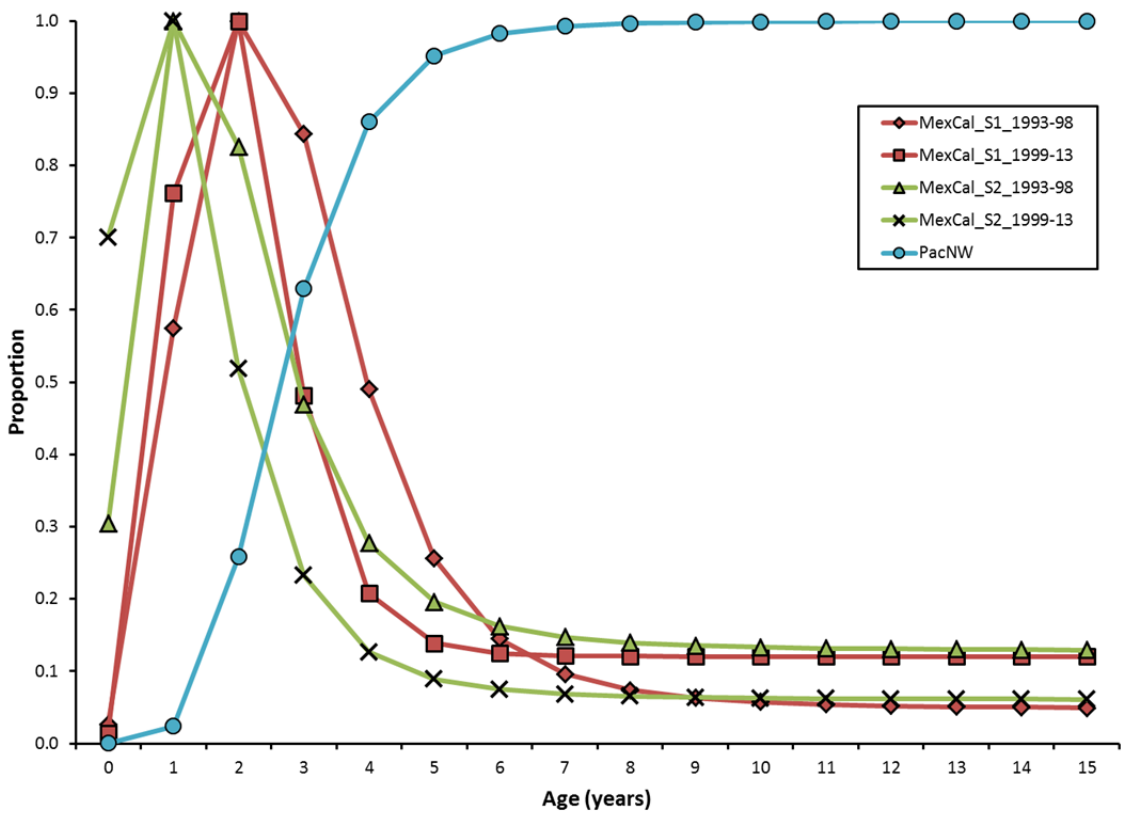


Figure 26b. Implied age-selectivity patterns for fleets in base model T.

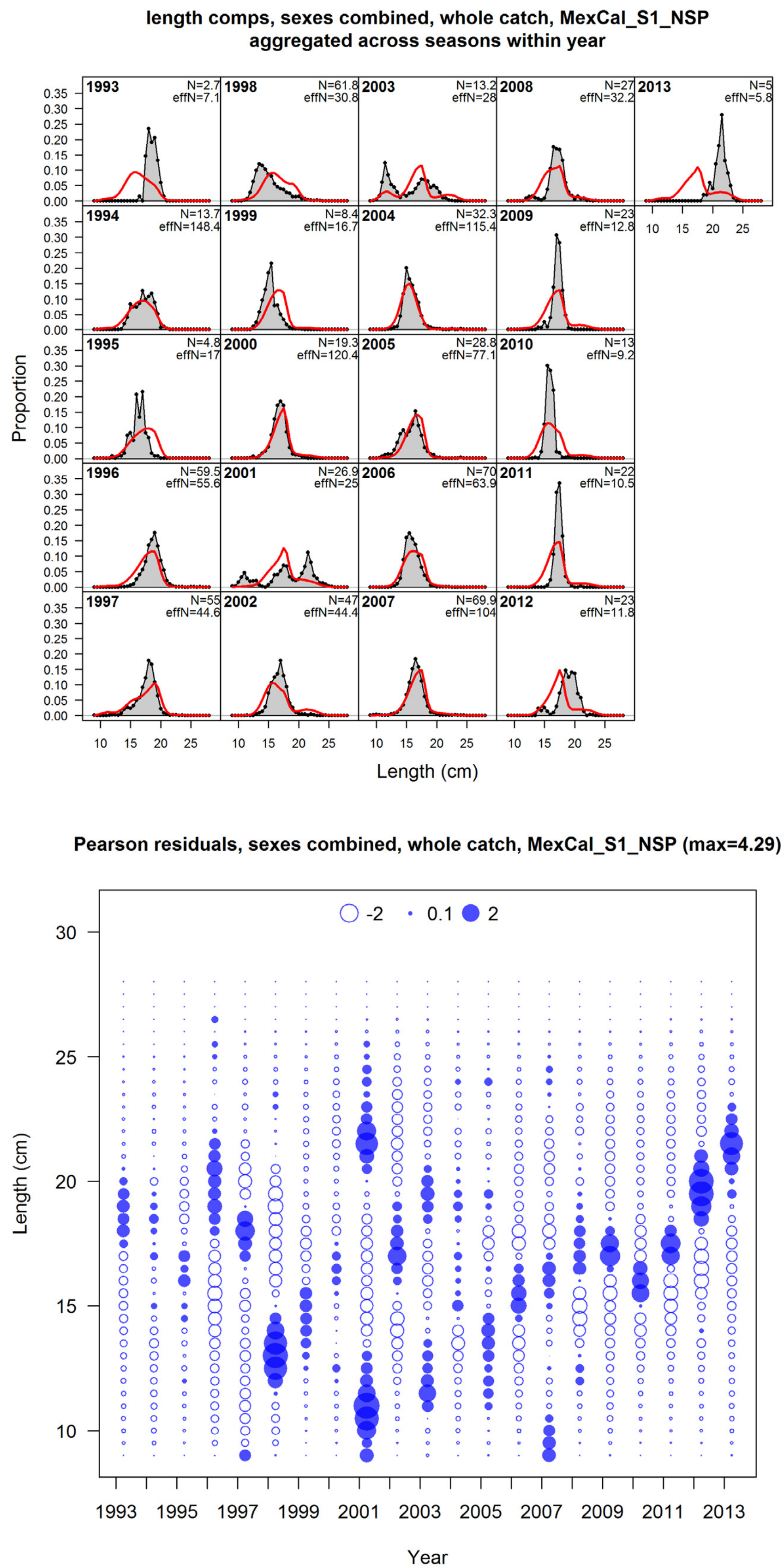


Figure 27a. Fits to length compositions and associated residual plot for MexCal_S1 fishery for base model T.

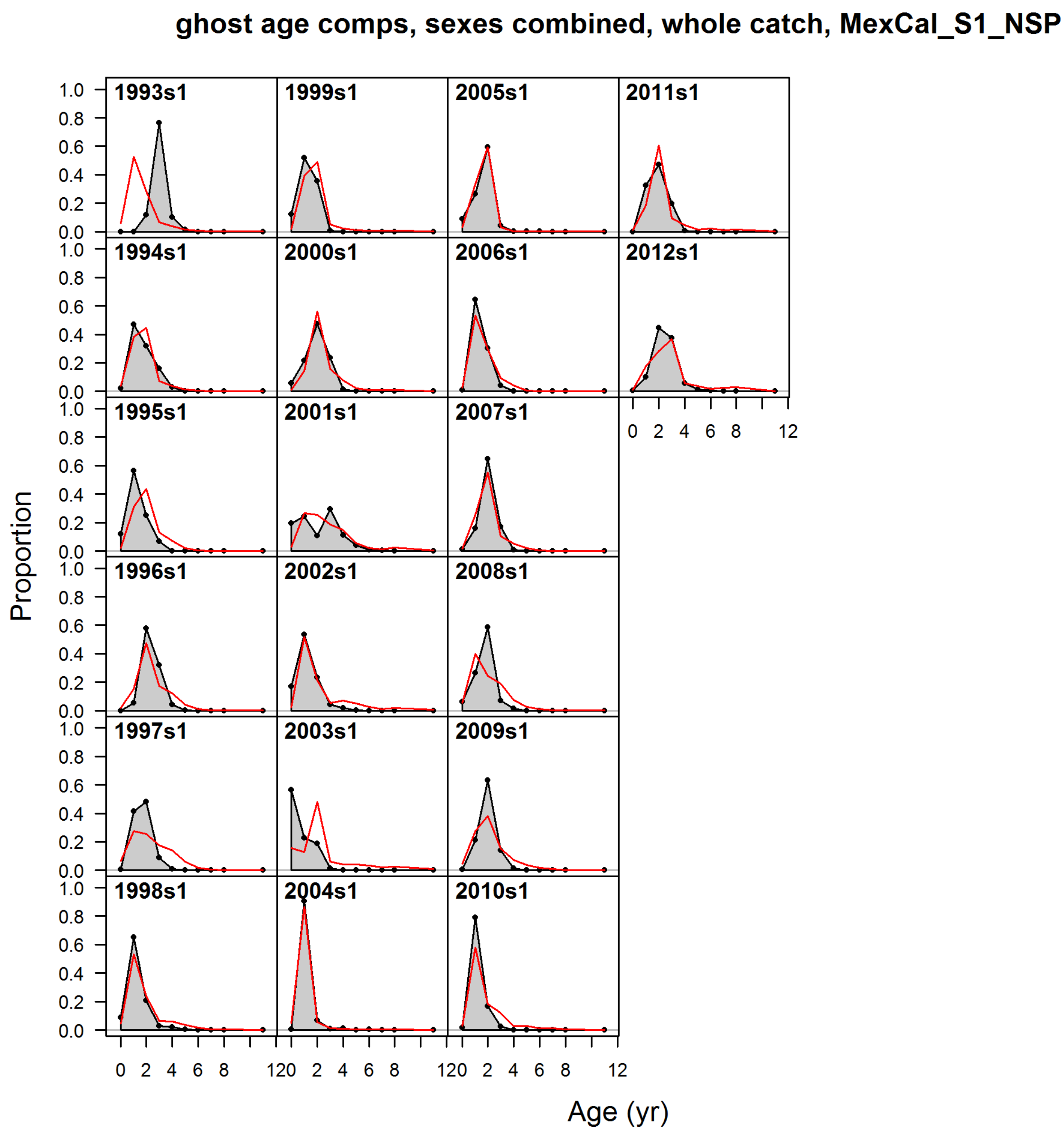


Figure 27b. Fits to implied age compositions for MexCal_S1 fleet in base model T.

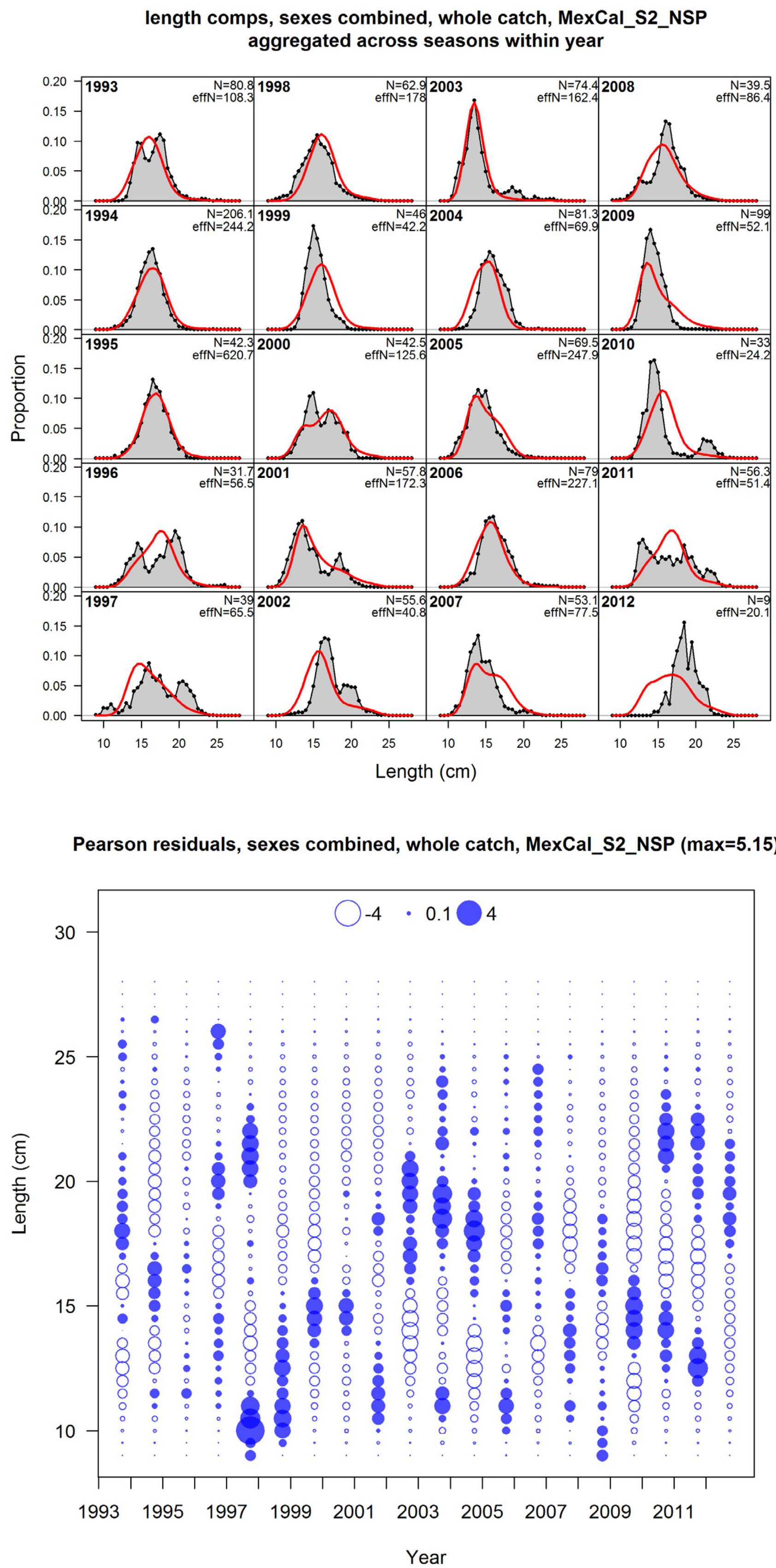


Figure 28a. Fits to length compositions and associated residual plot for MexCal_S2 fleet for base model T.

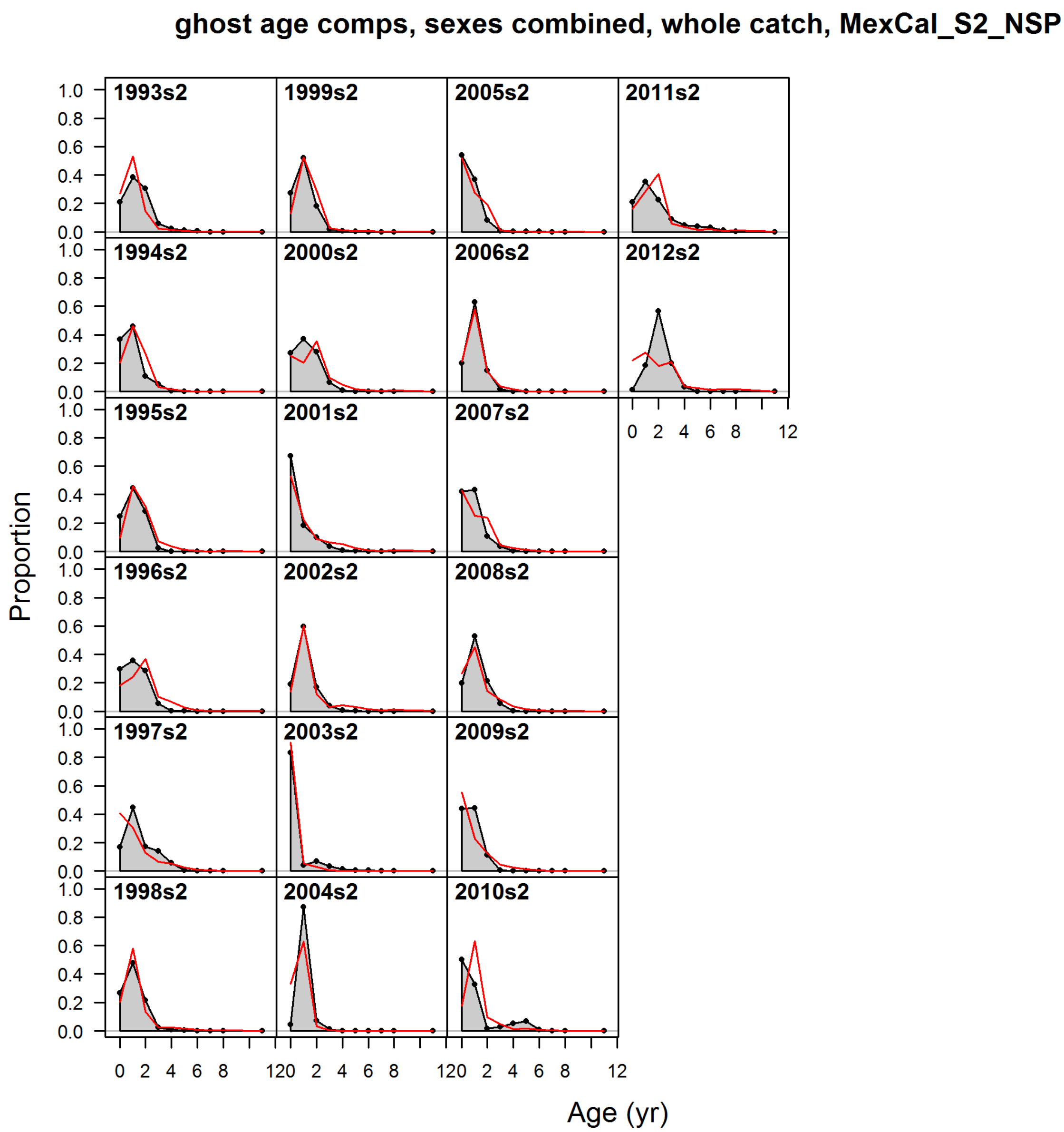


Figure 28b. Fits to implied age-compositions for MexCal_S2 fleet for base model T.

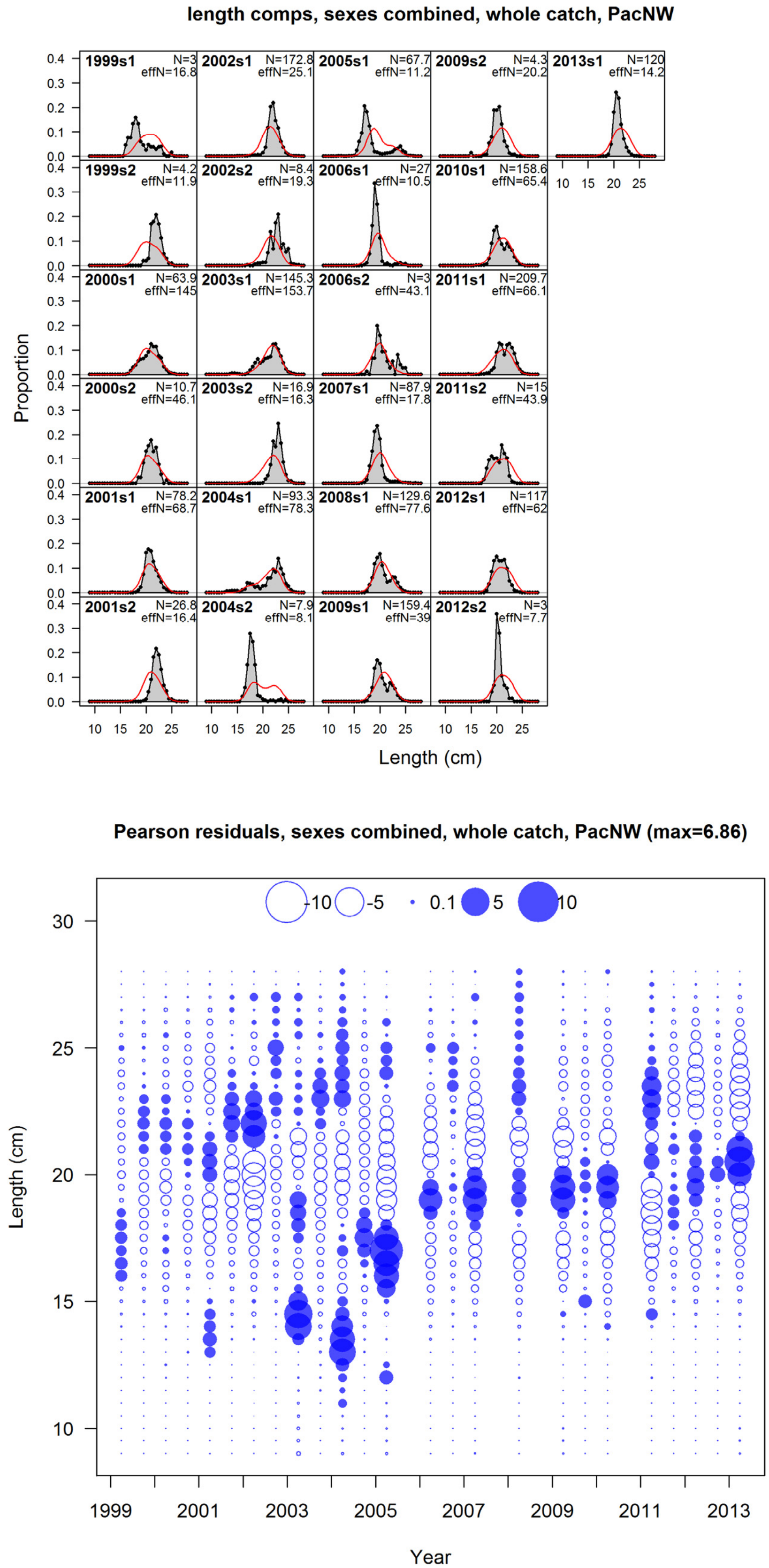


Figure 29a. Fits to length compositions and associated residual plot for PacNW fishery for base model T.

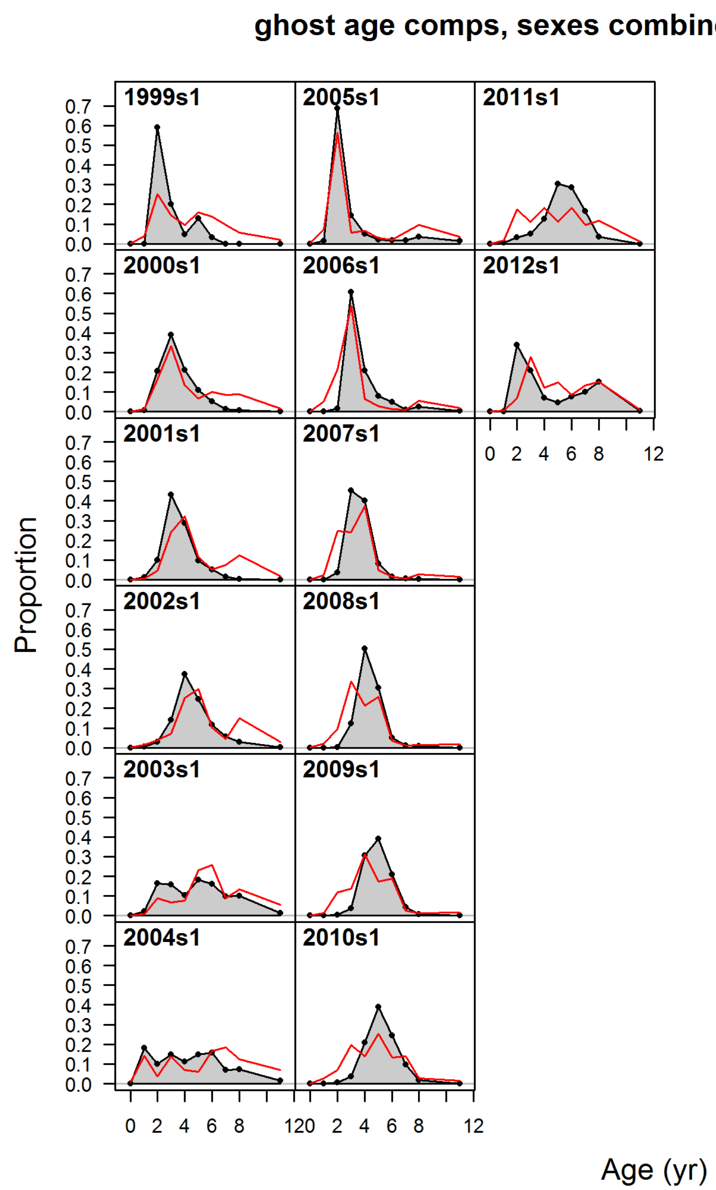


Figure 29b. Fits to implied age compositions for PacNW fishery for base model T.

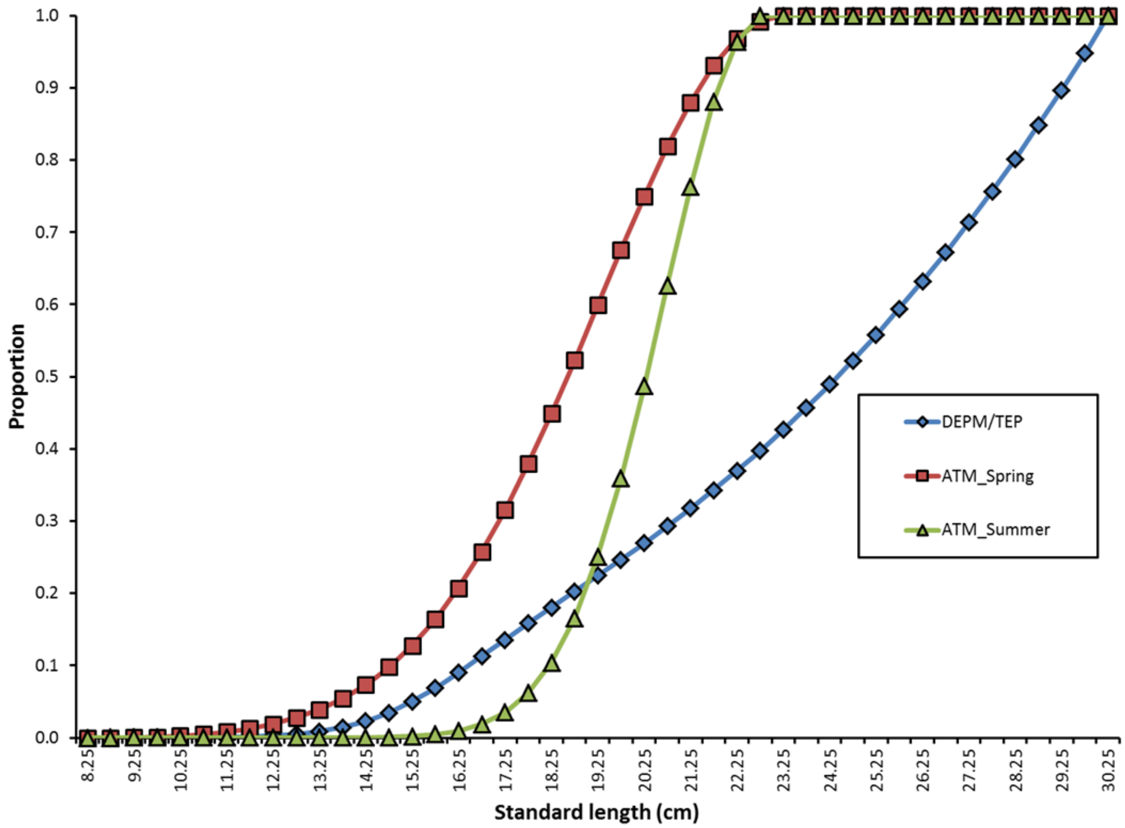


Figure 30a. Length-based selectivity patterns for surveys in base model T.

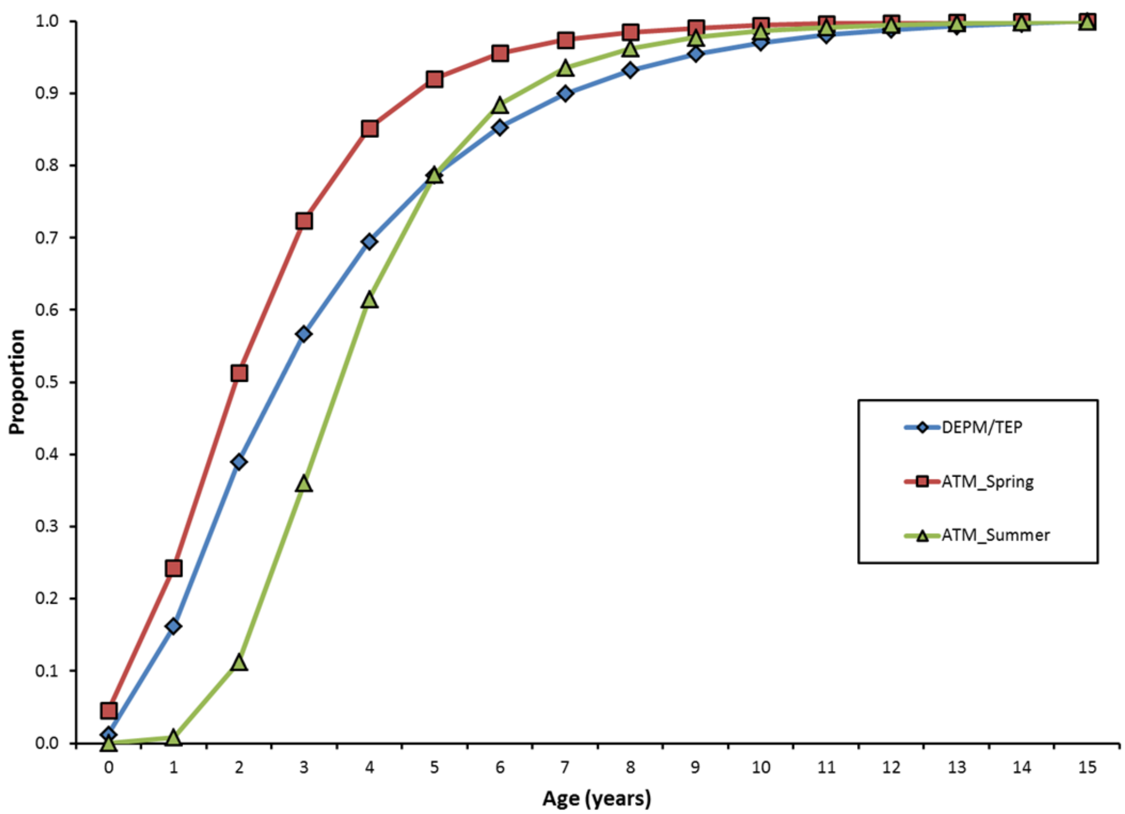
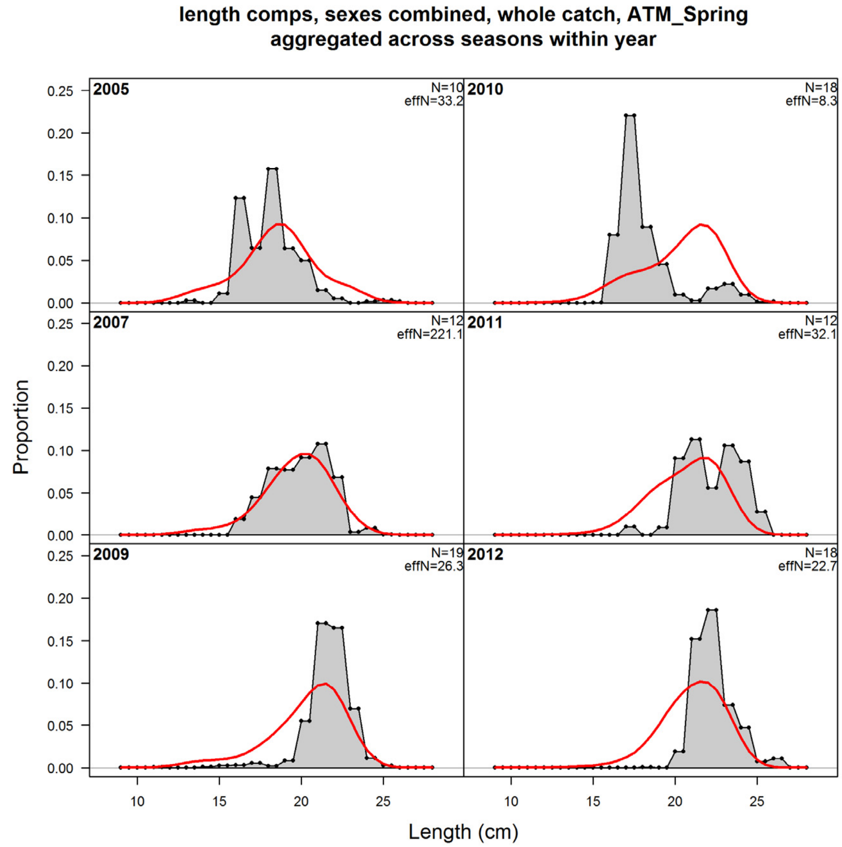


Figure 30b. Implied age-selectivity patterns for surveys in base model T.



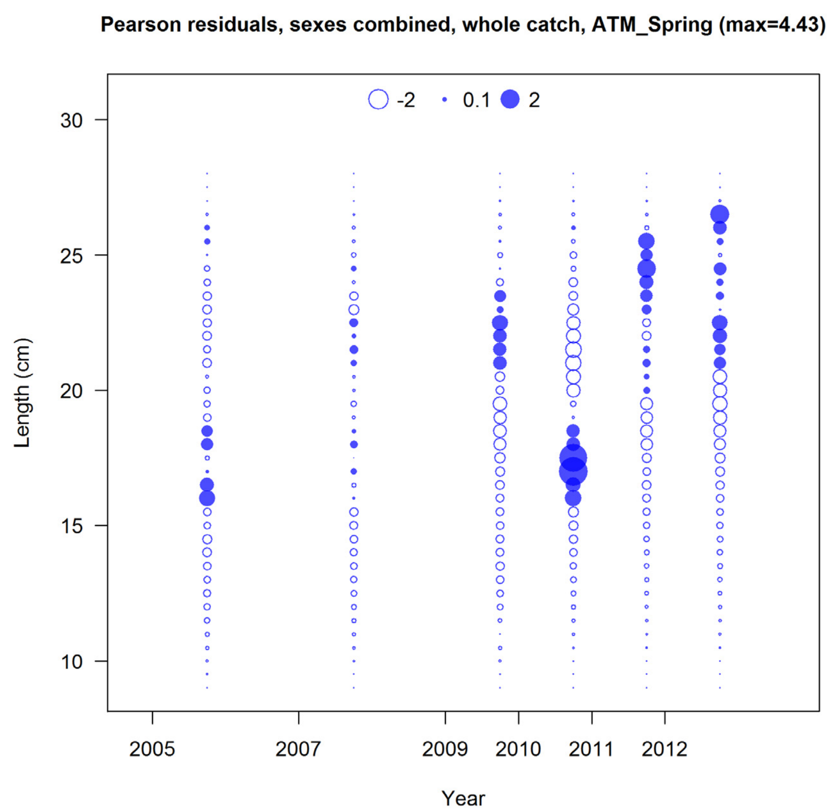
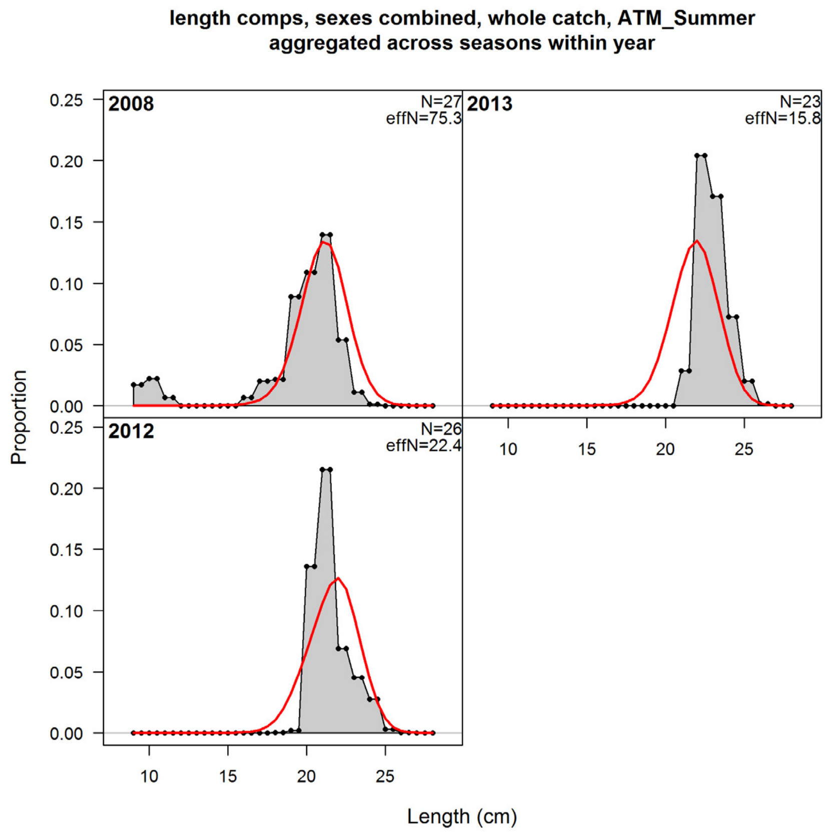


Figure 31. Fits to length compositions and associated residual plot for the Spring ATM survey for base model T.



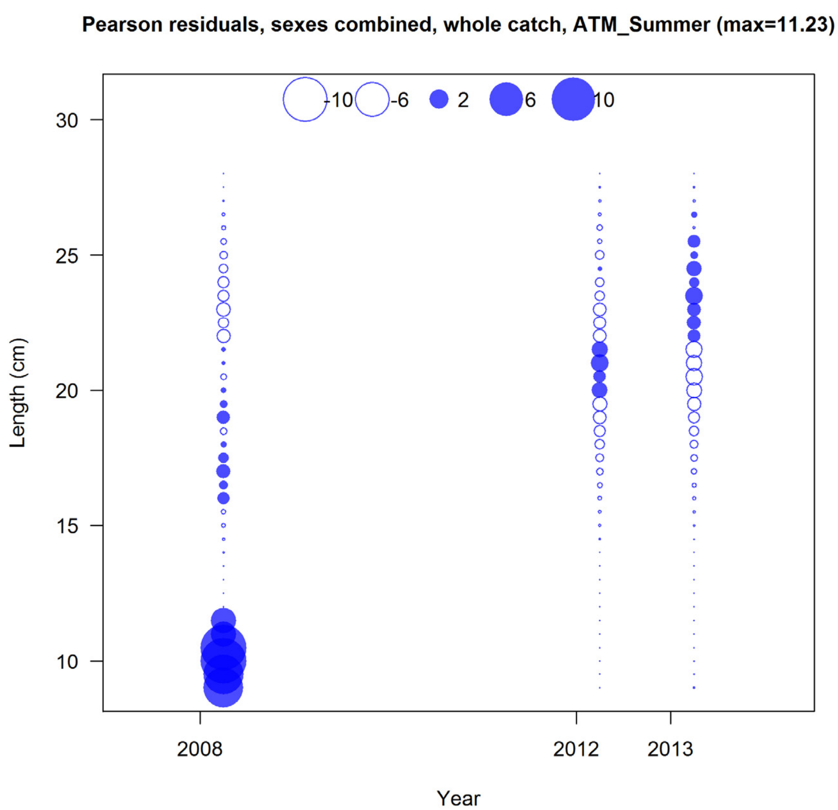
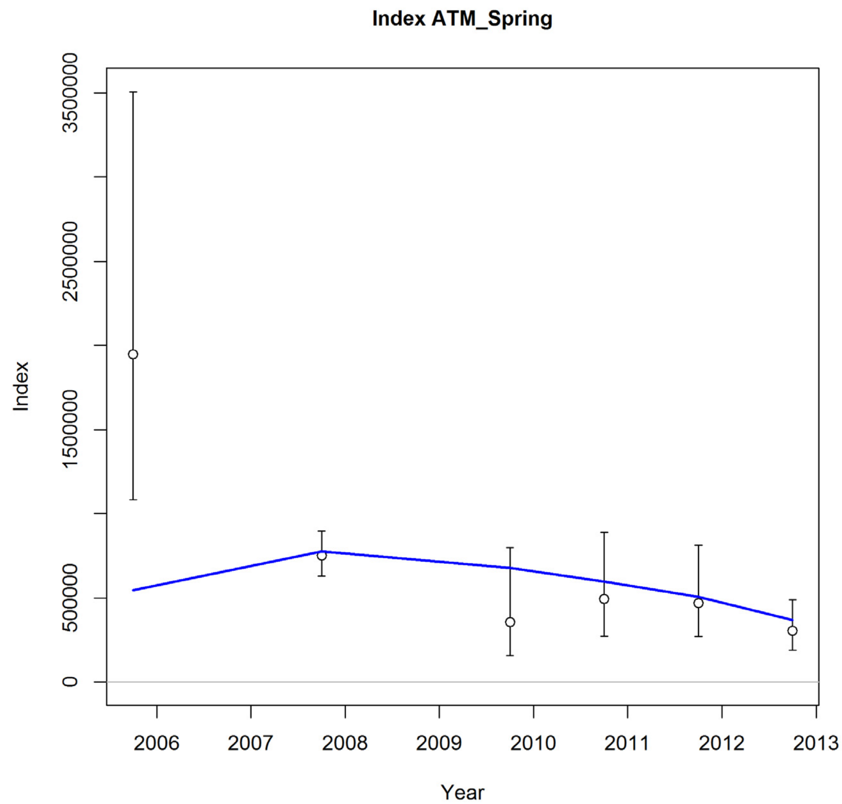


Figure 32. Fits to length compositions and associated residual plot for the Summer ATM survey for base model T.



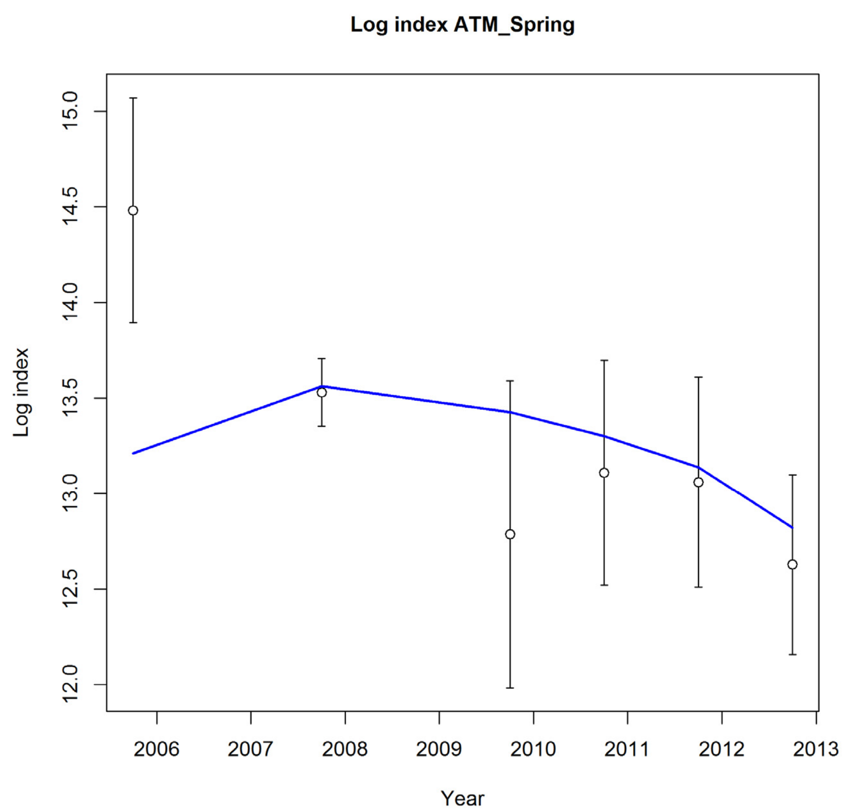
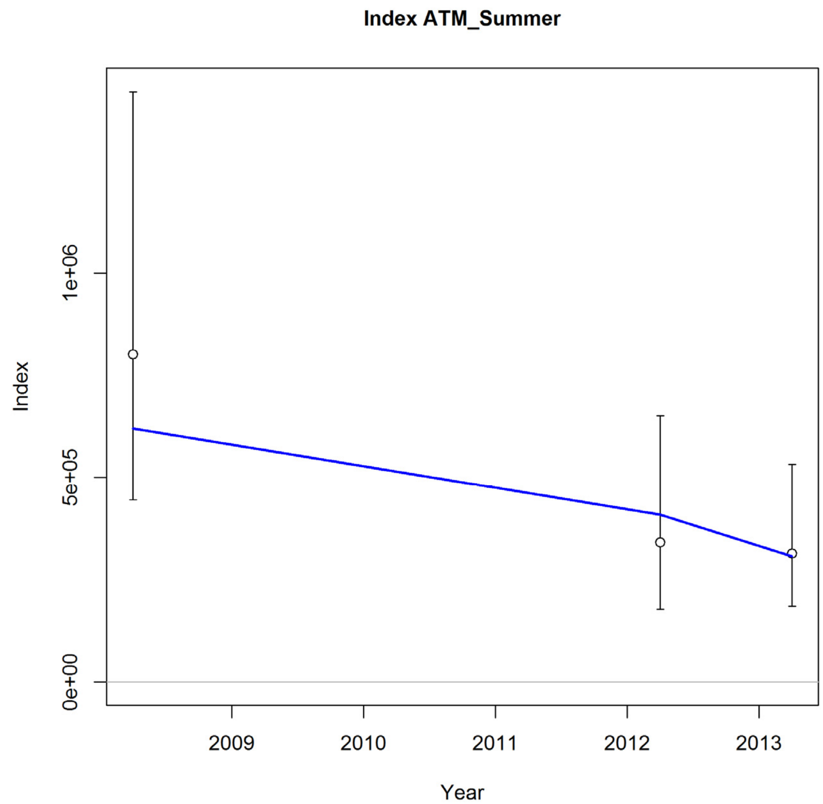


Figure 33. Fits to Spring ATM survey abundance index for base model T: arithmetic (upper) and log (lower) scales. q=1.0 (fixed).



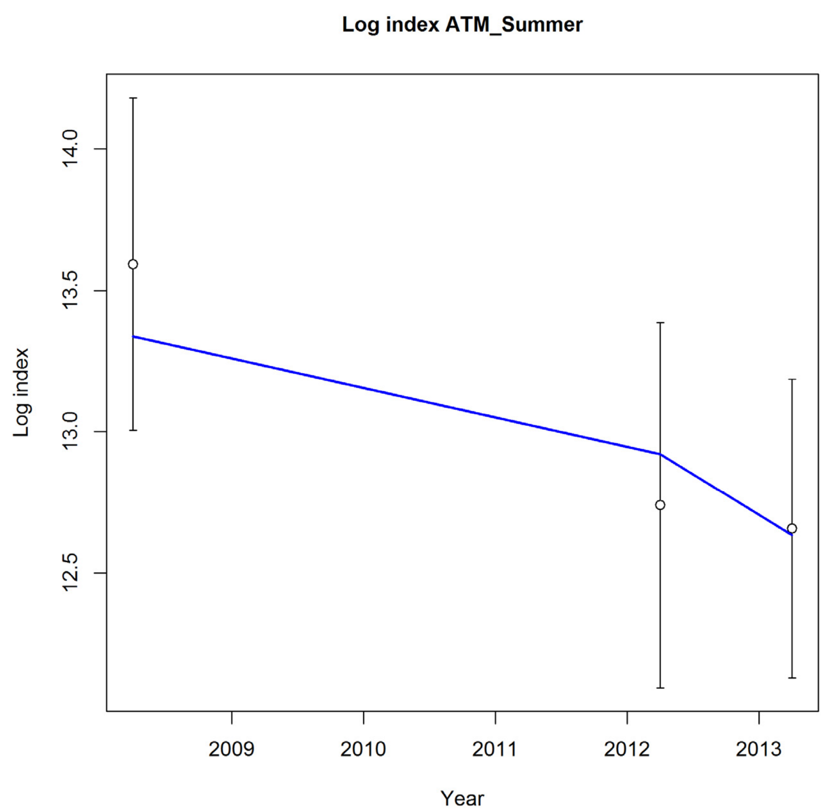
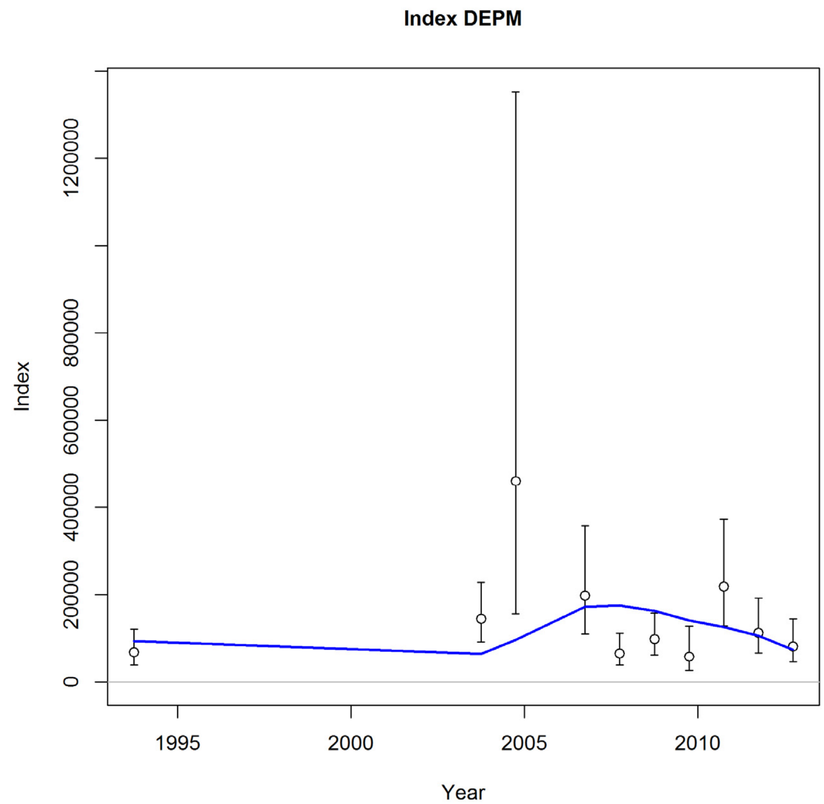


Figure 34. Fits to Summer ATM survey abundance index for base model T: arithmetic (upper) and log (lower) scales. q=1.0 (fixed).



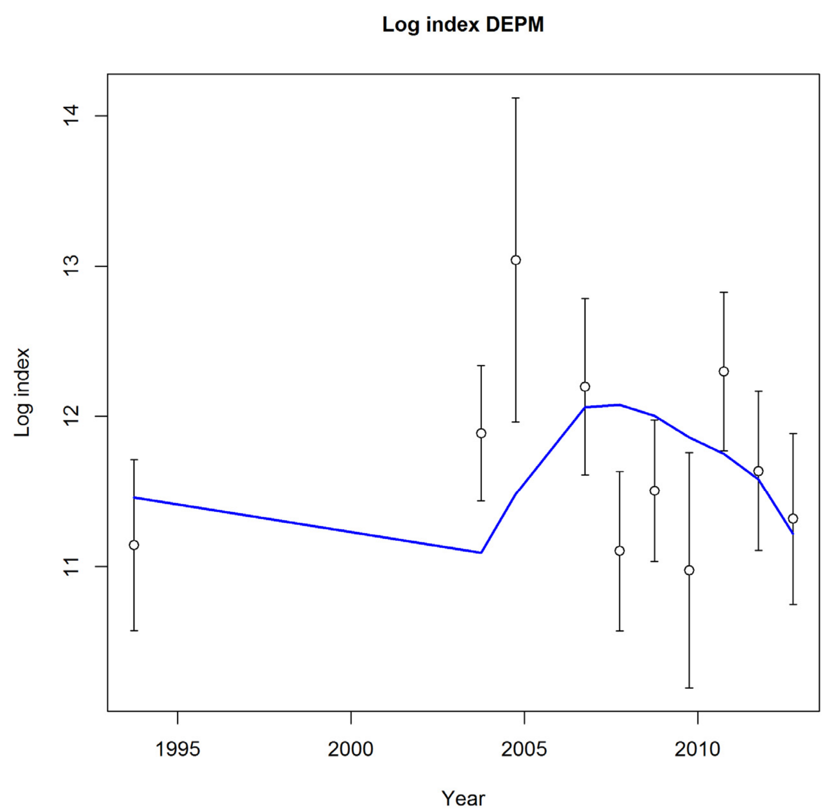


Figure 35. Fits to DEPM survey abundance index for base model T: arithmetic (upper) and log (lower) scales. q=0.1572.

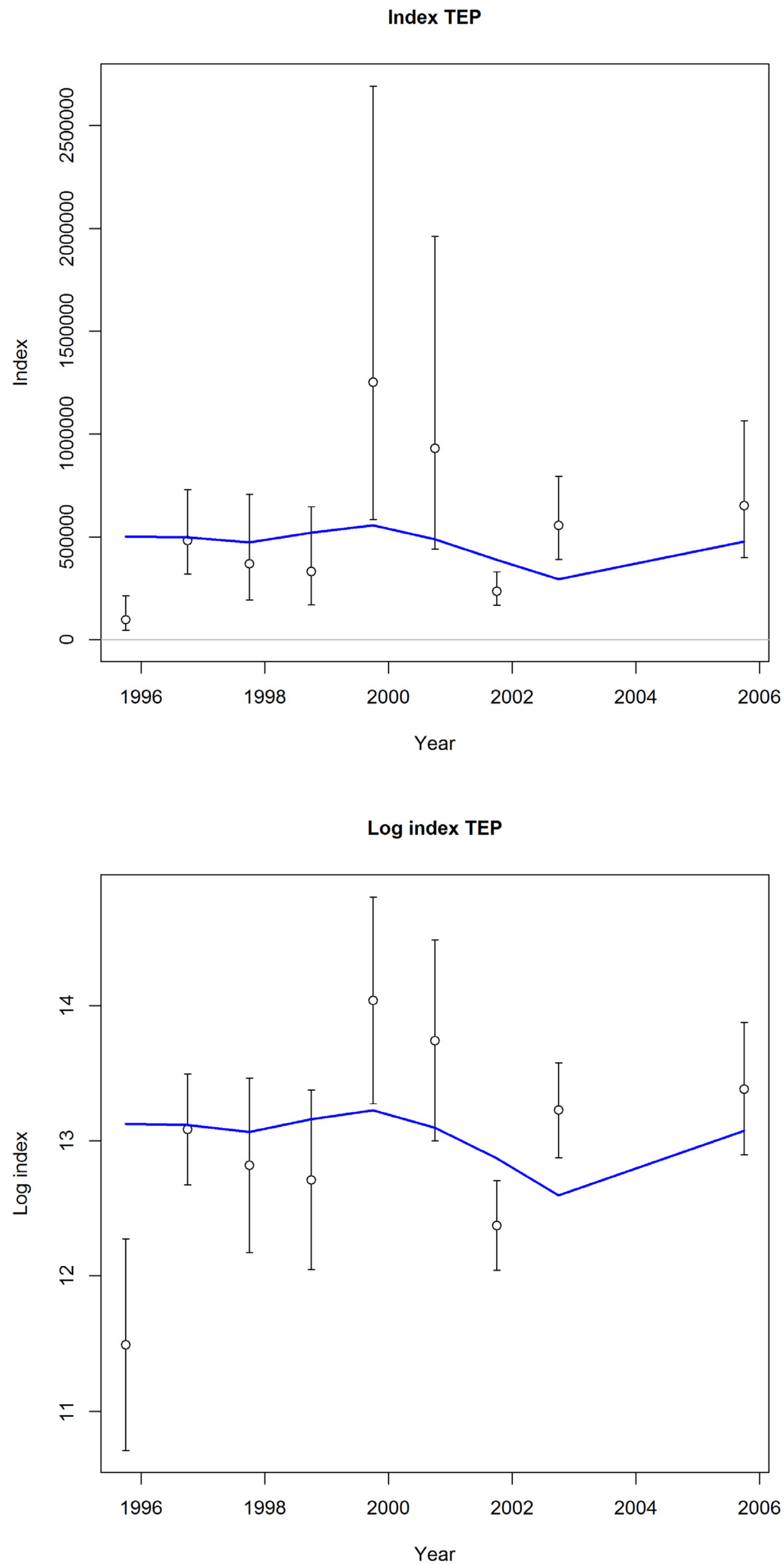


Figure 36. Fits to TEP survey abundance index for base model T: arithmetic (upper) and log (lower) scales. q=0.549.

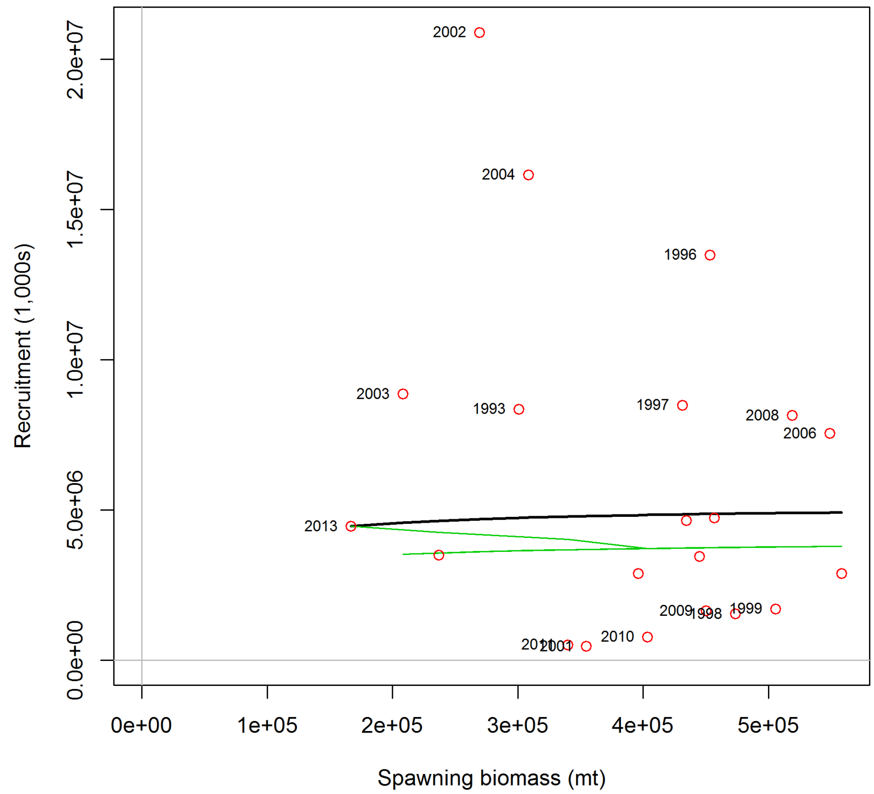


Figure 37a. Estimated stock-recruitment (Beverton-Holt) relationship for base model T. Year labels represent year of SSB producing the subsequent year class.

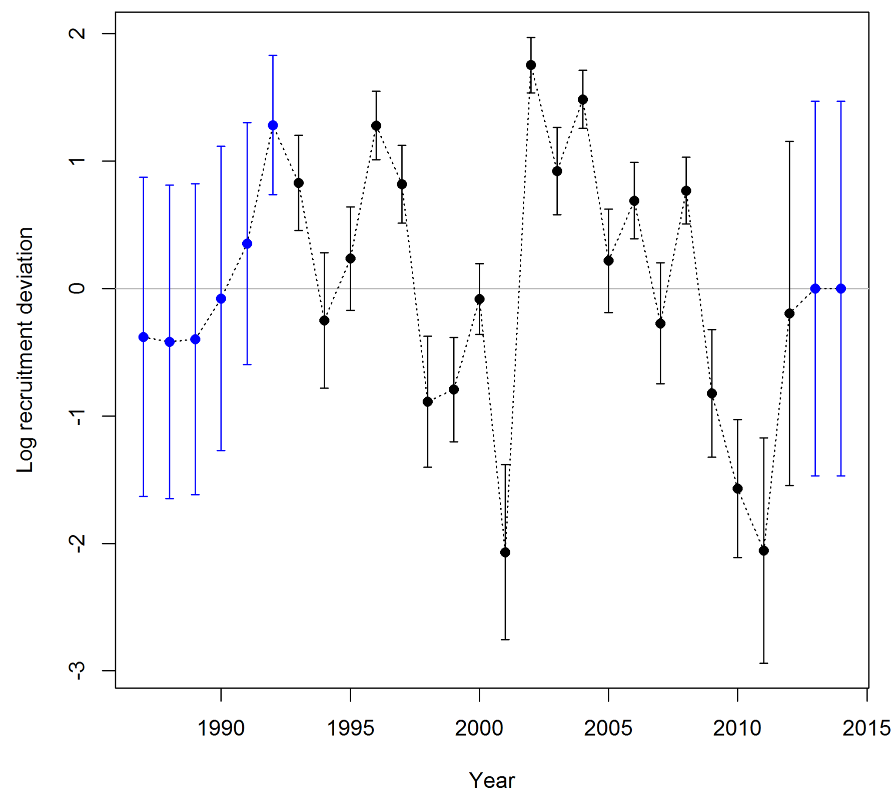


Figure 37b. Recruitment deviations and standard errors estimated in base model T ($\sigma_R = 0.75$). Year labels represent year of SSB producing the subsequent year class.

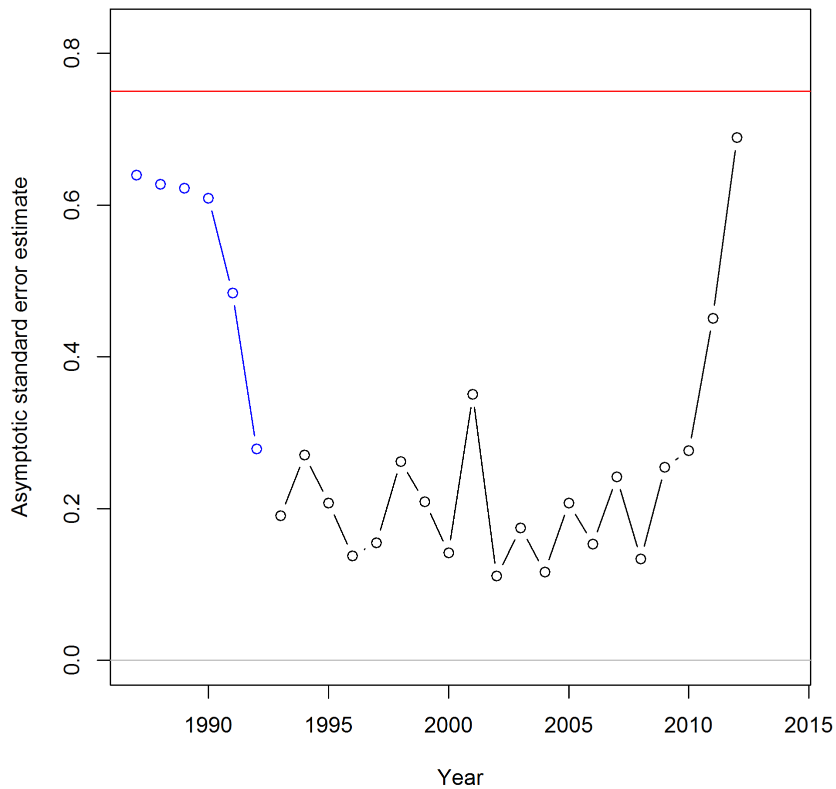


Figure 37c. Asymptotic standard errors for estimated recruitment deviations in base modelT.

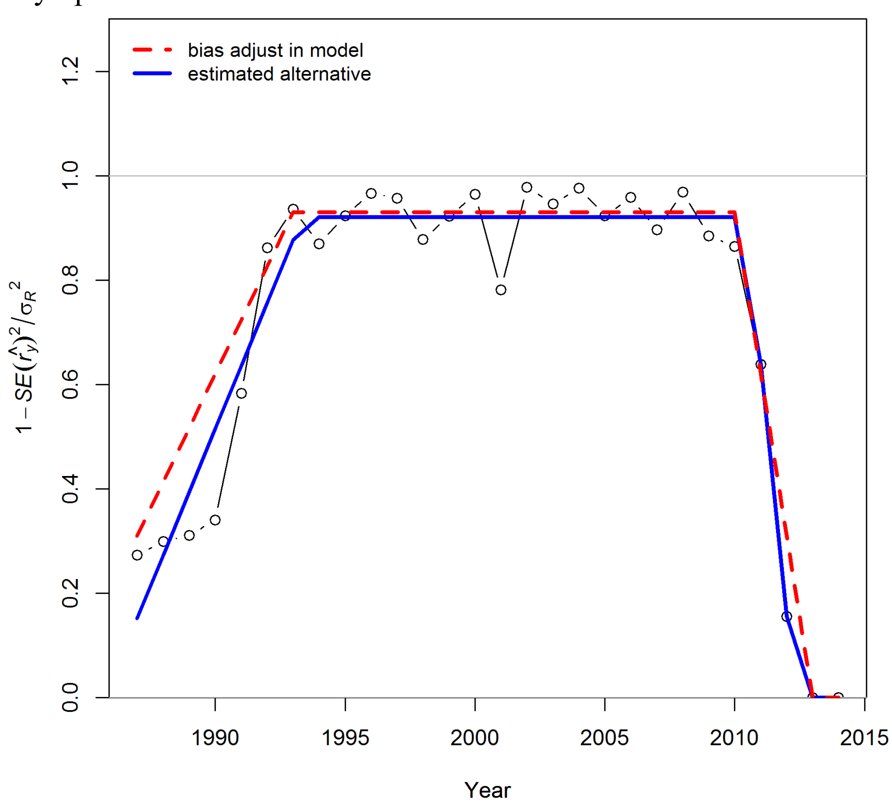


Figure 37d. S-R bias adjustment ramp applied in base model T.

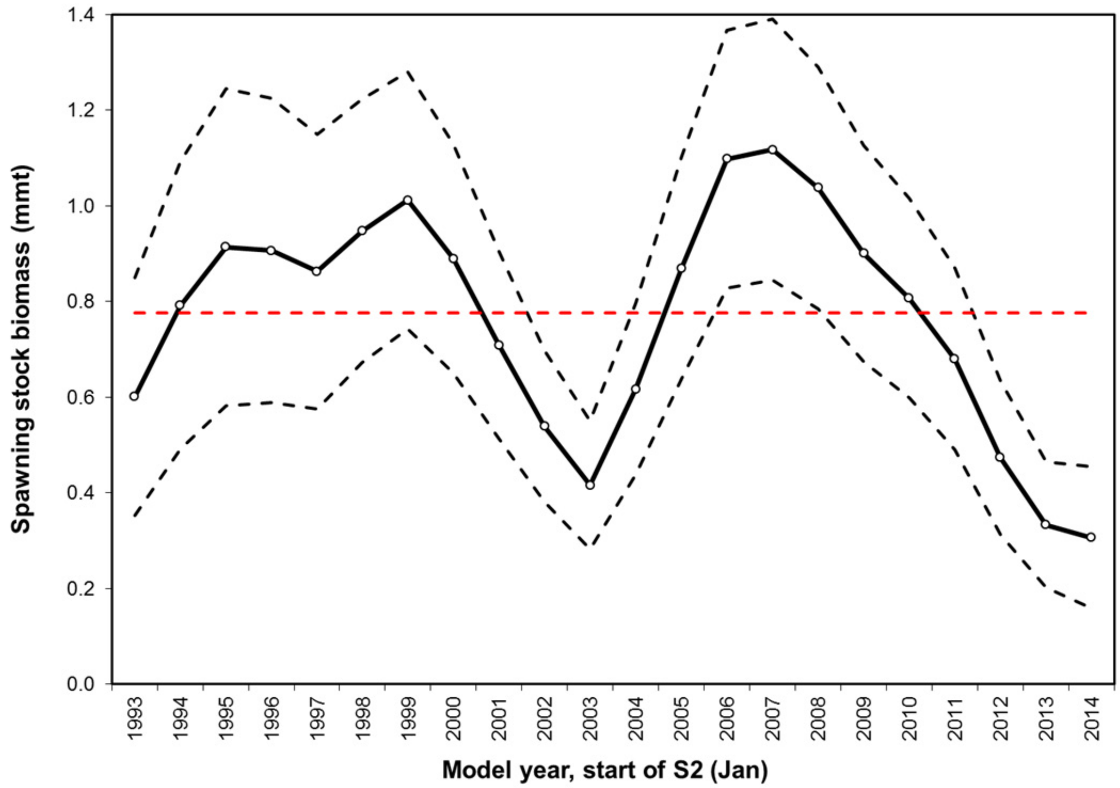


Figure 38a. Spawning stock biomass with ~95% confidence intervals for base model T. Red line is SSB-zero.

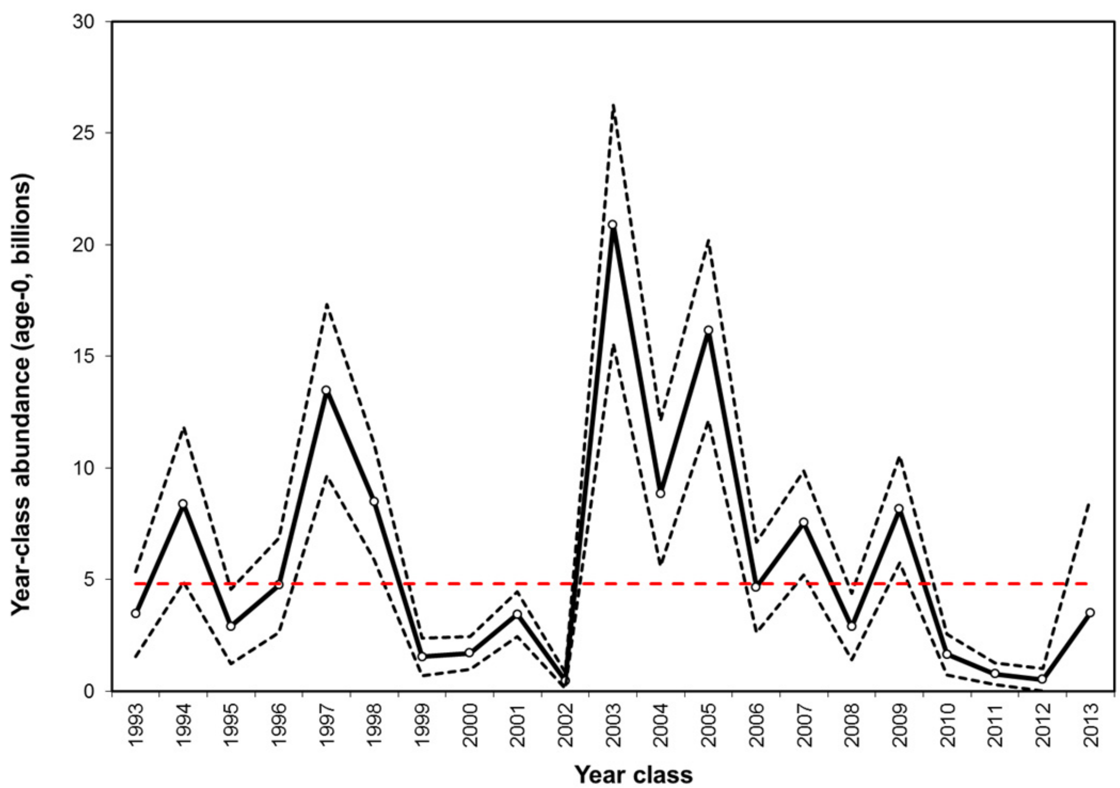


Figure 38b. Year-class abundance with ~95% confidence intervals for base model T. Red line is R-zero.

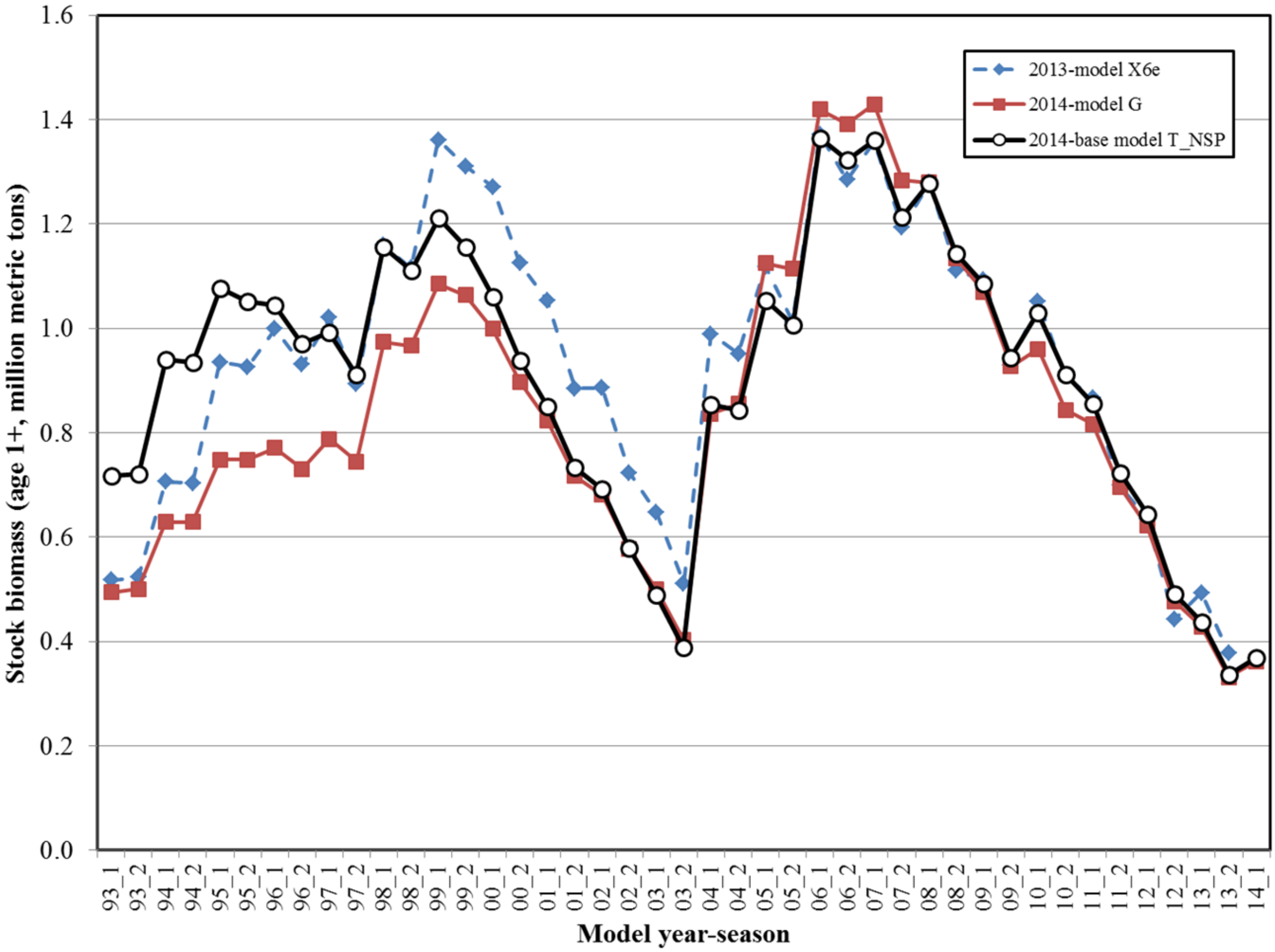


Figure 39. Estimated stock biomass (age 1+ fish) time series for fisheries for most recent management model X6e_2013, model G and base model T.

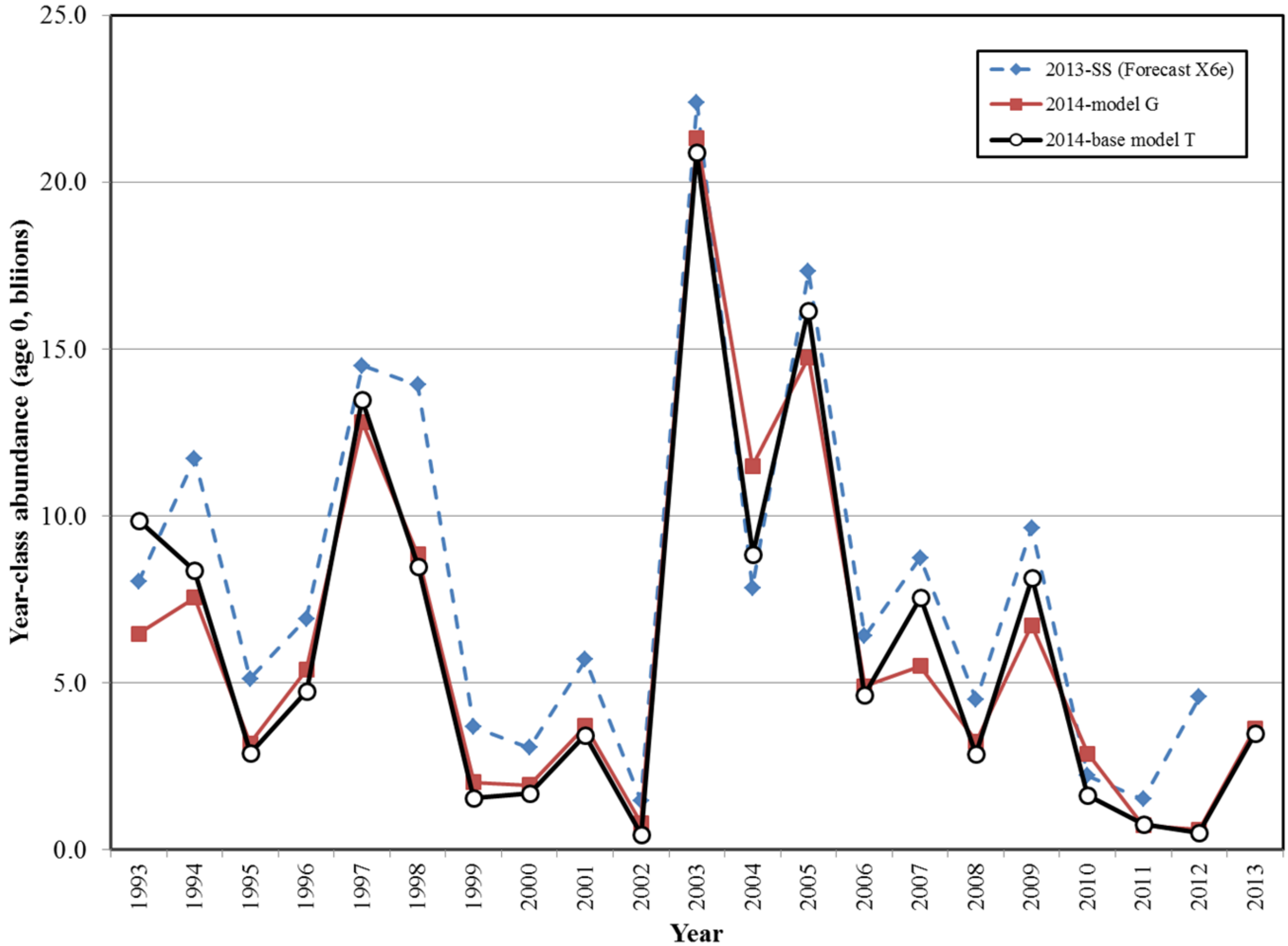


Figure 40. Estimated recruitment (age 0 fish) time series for fisheries for most recent management model X6e_2013, model G and base model T.

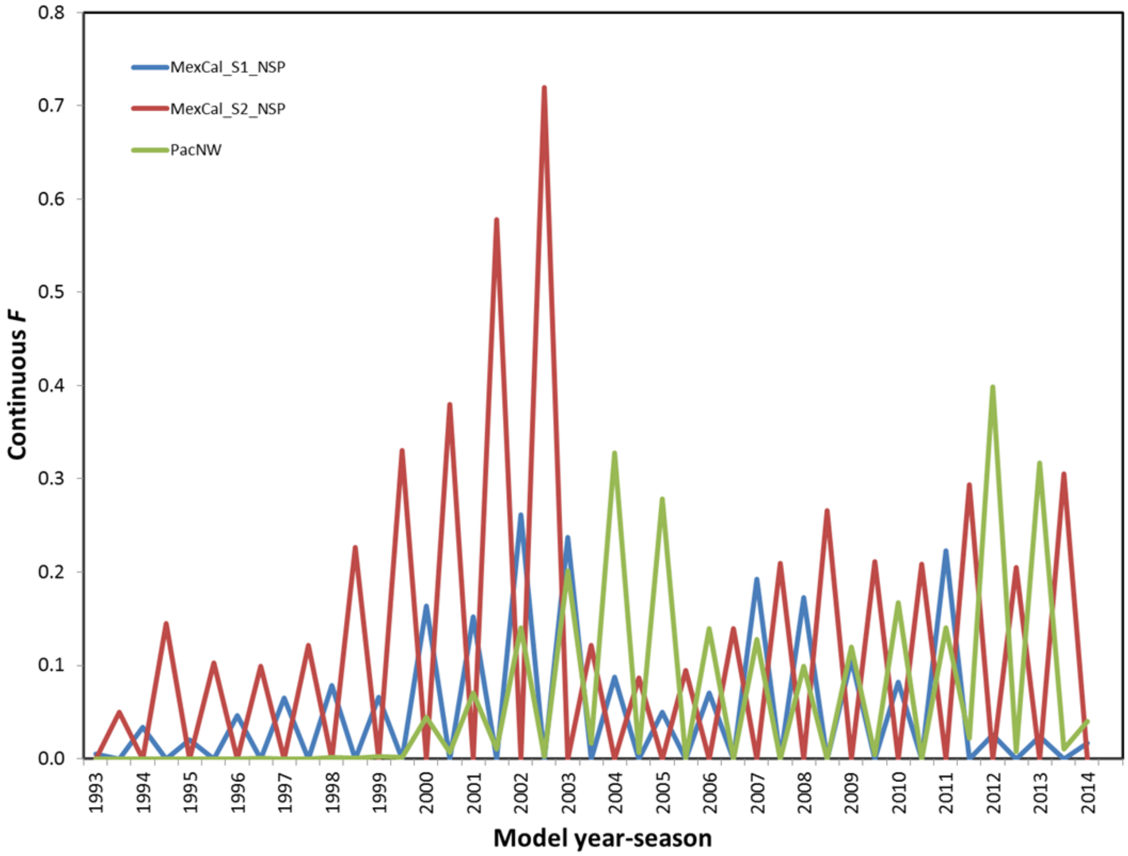


Figure 41a. Estimated fishing mortality (*F*) time series for fisheries for base model T.

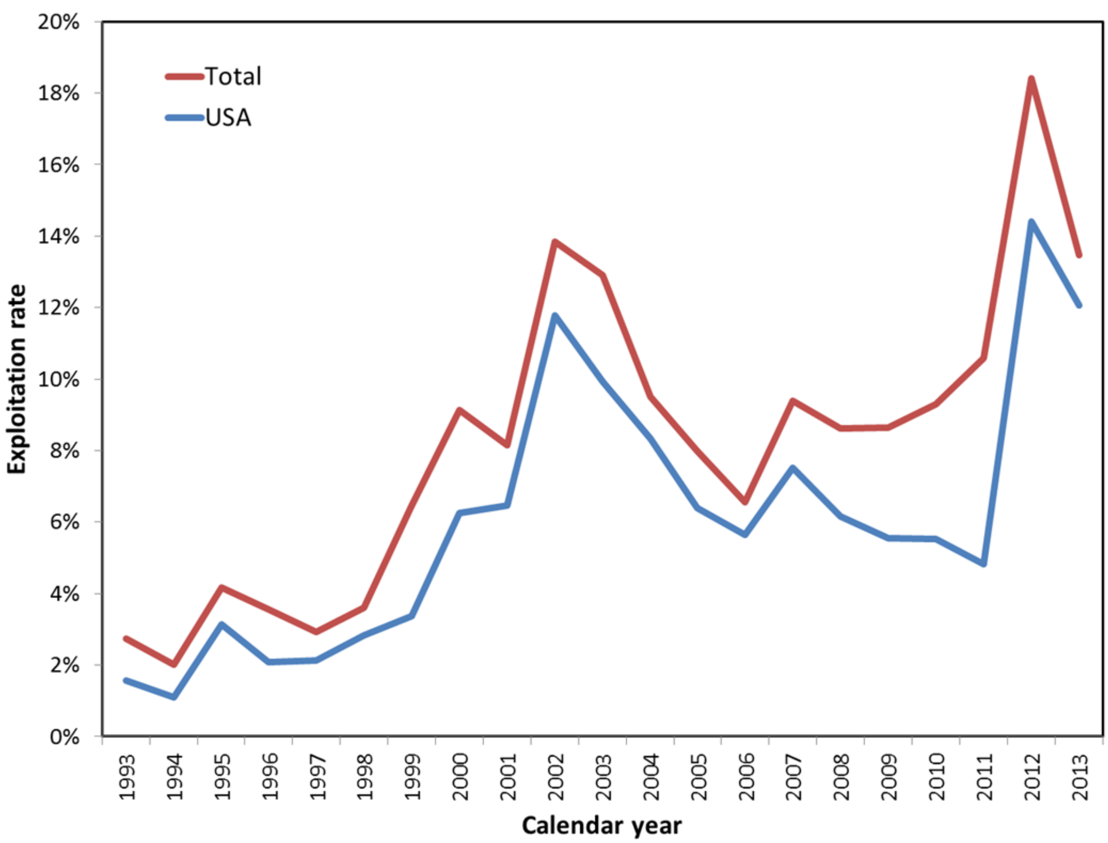


Figure 41b. Annual exploitation rate (CY landings / July total biomass) for base model T.

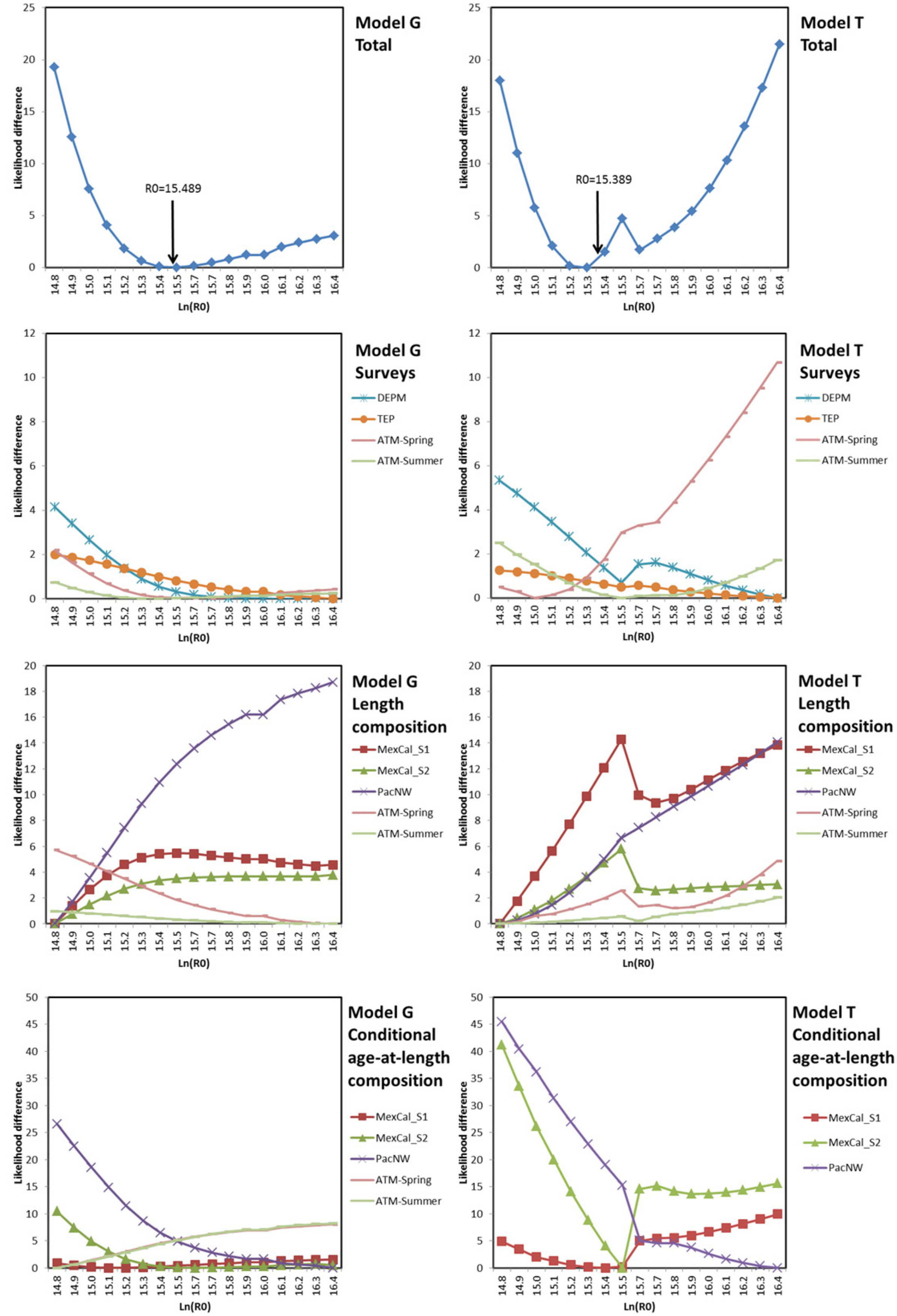


Figure 42. R_0 profiles for model G (left) and base model T (right) components.

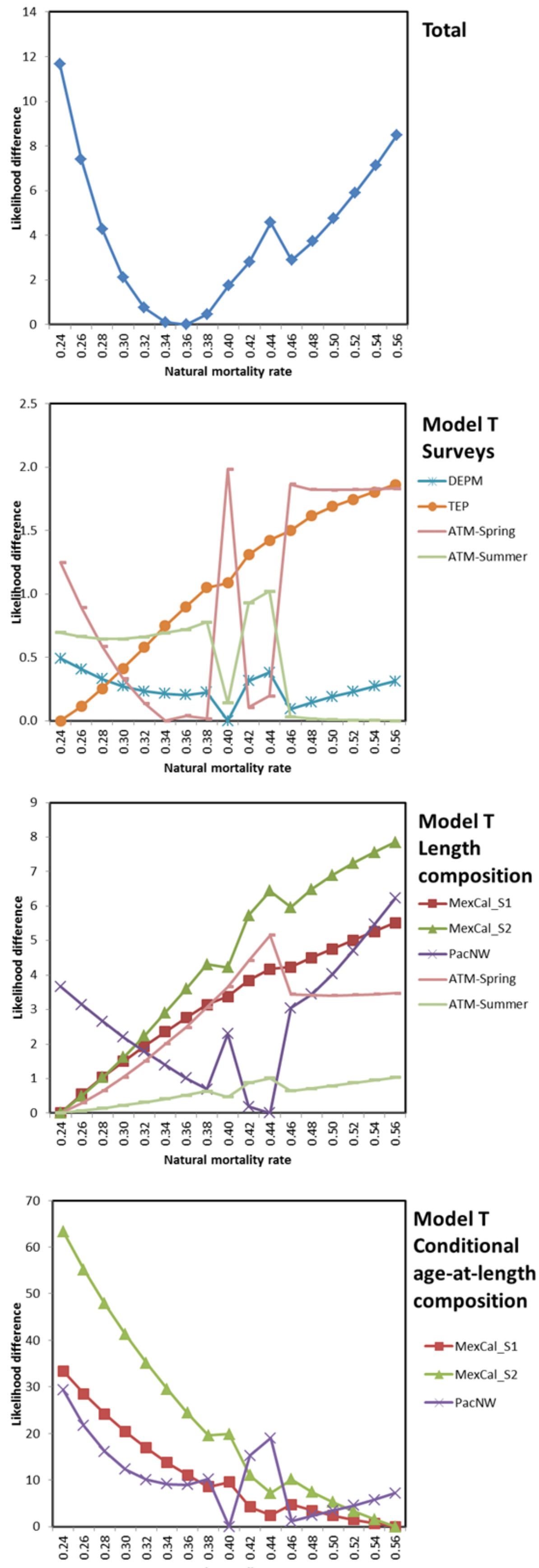


Figure 43. Natural mortality rate profiles for base model T components

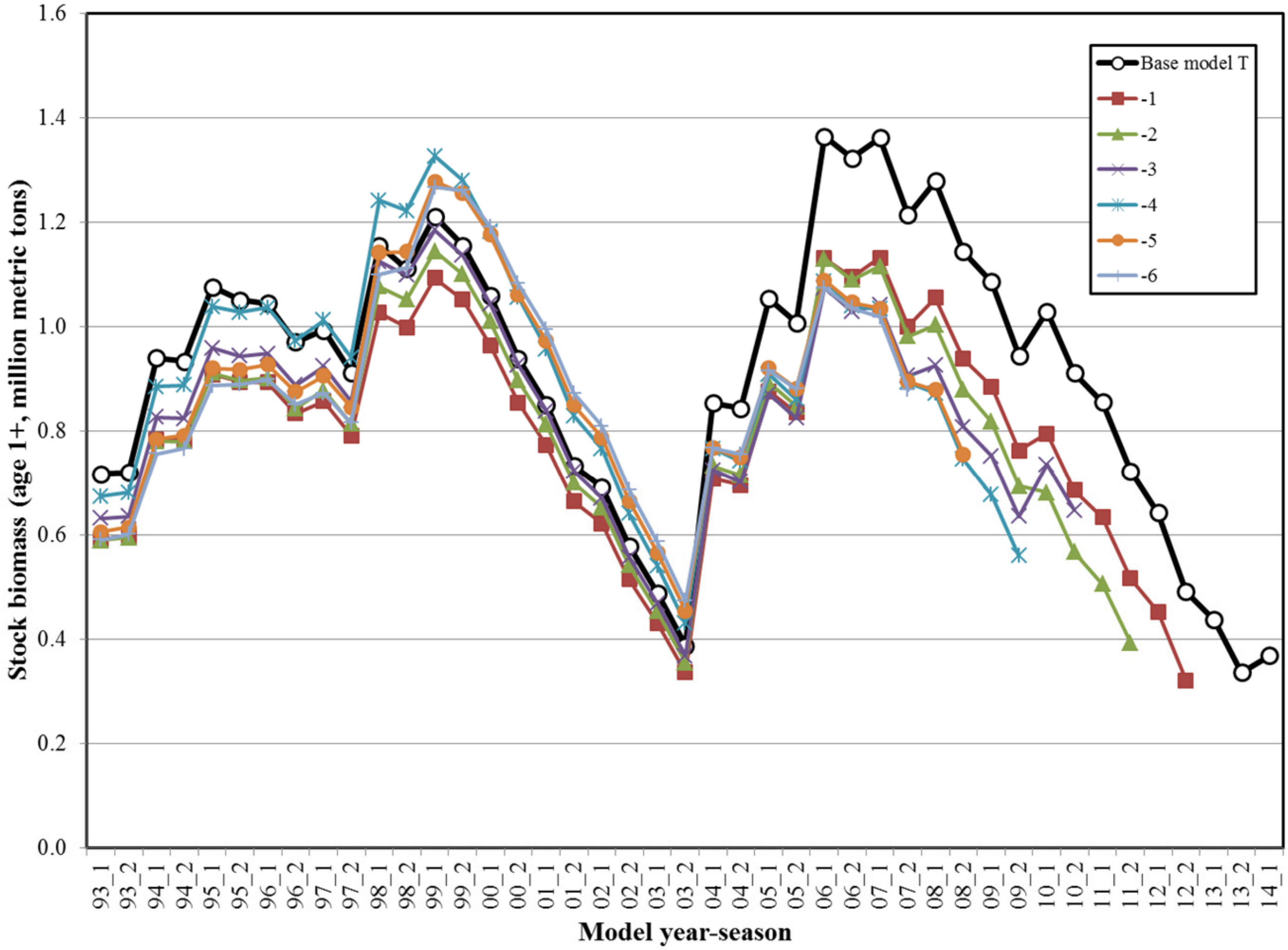


Figure 44. Retrospective analysis of stock biomass (age 1+) for base model T..

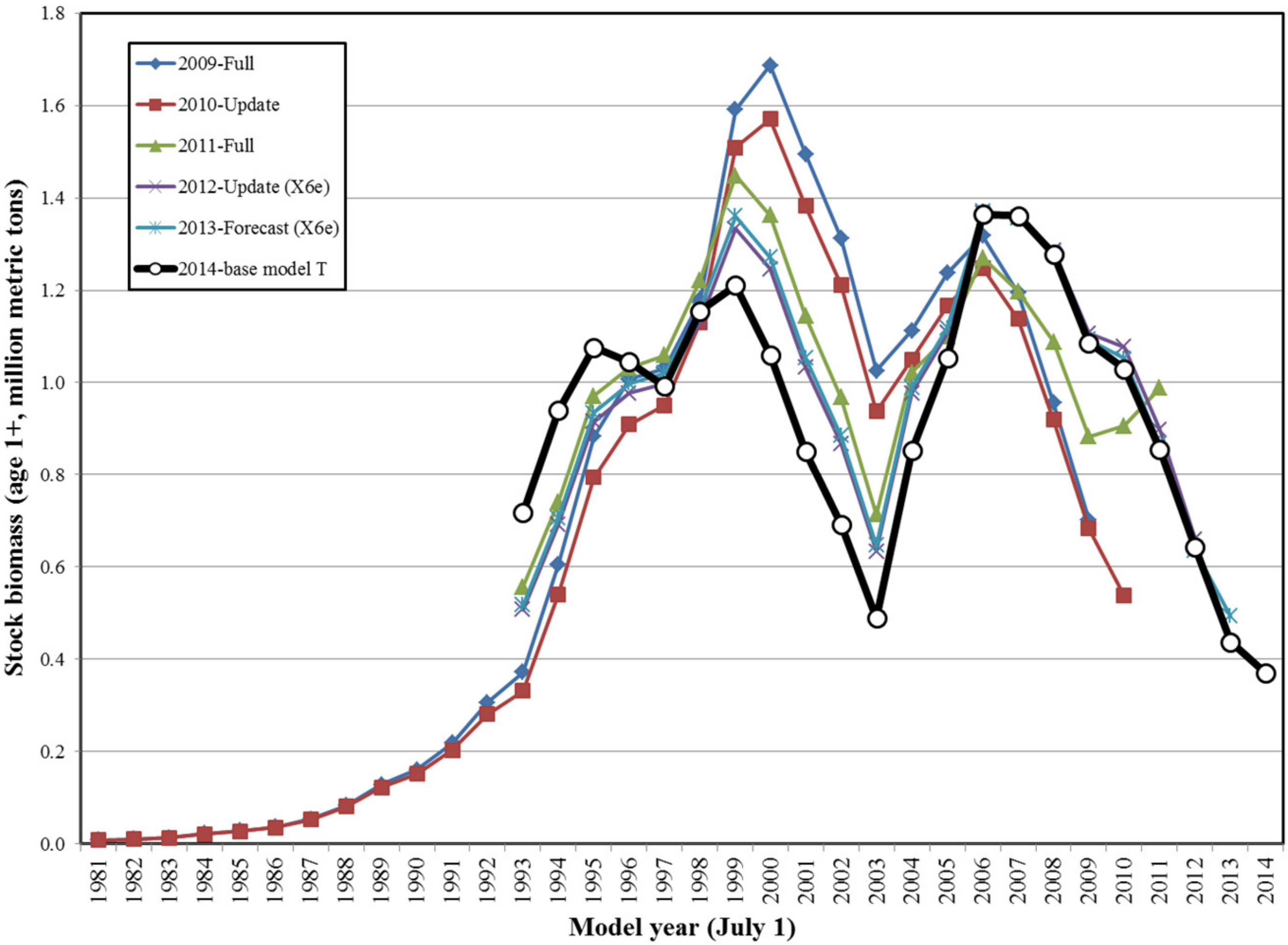


Figure 45. Estimated stock biomass (age 1+ fish) time series for fisheries for the base model and past management models.

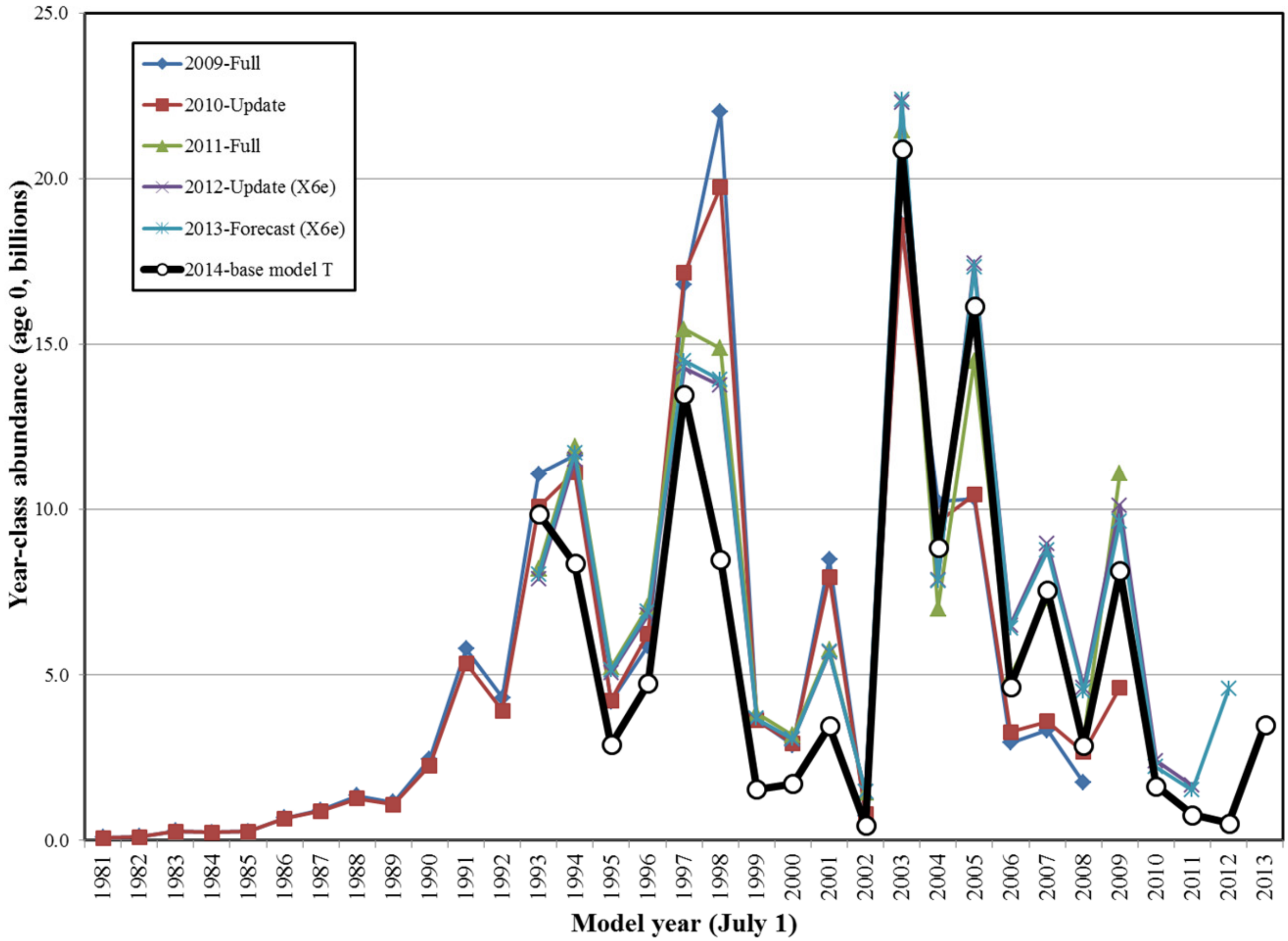


Figure 46. Estimated recruitment (age 0 fish) time series for fisheries for the base model and past management models.

Figure 47. Age 0-1 biomass as percentage of total population biomass (base model T).

Figure 48. Biomass of age-1 sardine (base model T).

Figure 49. Base model T stock biomass (age 1+) for a range of possible projection scenarios for July 2014: 1) the 2013year-class is estimated from the S-R curve (default); 2) age-1 biomass in 2014 is based on the age-1 biomass averaged from 2011-13; and 3) age-1 biomass in July 2014 is zero (i.e. 2013 year-class failure).

APPENDICES

APPENDIX A

Acoustic-trawl estimates of sardine biomass off California during Spring 2013

Juan Zwolinski, David A. Demer, Beverly J. Macewicz, George R. Cutter Jr., Brian Elliot, Scott Mau, David Murfin, Josiah S. Renfree, Thomas S. Sessions, and Kevin Stierhoff

This report summarizes results from the spring 2013 acoustic-trawl method (ATM) survey off central and southern California (Fig. 1). The survey was conducted from NOAA FSV *Bell M. Shimada* and chartered FV *Ocean Starr*.

The ATM survey totaled 2791 n.mi. of east-west tracklines between the US and Mexico border and San Francisco, and spanning offshore beyond the expected distribution of the northern stock of Pacific sardine (Fig. 1). From sunrise to sunset, multifrequency echosounders were used to sample acoustic backscatter from epipelagic coastal pelagic species (CPS). During nighttime, up to 4 surface trawls were used to identify the proportions of CPS and their lengths. Due to their temporal-spatial proximity, data from trawl catches conducted each night were combined into clusters. Day and night, a continuous underway fish egg sampler (CUFES) was used to sample CPS eggs within 5m of the sea-surface. Overall, 15 of the 26 clusters included CPS, and these clusters included, in average 28 sardine. Overall, 416 sardine were caught in the survey area.

Post-survey strata were defined with considerations to the sampling intensity, the presence of CPS in the echosounder and net samples, and the existence and abundance of sardine eggs in the CUFES samples (Fig. 1). The coastal region and the far offshore oceanic transects had no sardine (Fig. 2). The remaining survey area was split into two strata (north and south; Fig. 2) for biomass estimations (Table 1).

The northern stratum contained the largest concentration of CPS backscatter; trawl clusters with sardine; and CUFES samples with sardine eggs (Figs. 1, 2 and 3). The two strata (Table 1) contained a total sardine biomass of 0.305 Mt ($CI_{95\%}$ = [0.167; 0.454]; *CV*

= 24.4%). The sampled population had a modal standard length (*SL*) at ~ 22 cm (Table 2; Fig. 4).

Table 1. Sardine biomass by stratum for the spring 2013 survey.

Stratum		Transect		Trawls		Sardine		
Name	**Area (n.mi.)**	**Number**	**Distance (n.mi.)**	**CPS clusters**	**Number of sardine**	**Biomass (1000 tons)**	**95% confidence interval (1000 tons)**	***CV***
North	24094	12	1210	10	363	286.4	148.3 – 428.7	26.0
South	11466	5	505	6	53	18.8	5.2 – 33.0	36.3
Total	**35560**	**17**	**1715**	**16**	**416**	**305.1**	**166.6 – 453.6**	**24.4**

Table 2. Sardine abundance versus standard length for the spring 2013 survey.

Standard length (cm)	**Abundance (number);**
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	3657973
19	1828987
20	81284877
21	641628498
22	783577984
23	311376788
24	199652238
25	31872240
26	46746359
27	0
28	0
29	0
30	0

Figure 1. Acoustic backscatter from coastal pelagic fish species (CPS, left), acoustic proportions of CPS in trawl clusters (middle), and sardine egg densities from continuous underway fish egg sampler (CUFE; right).

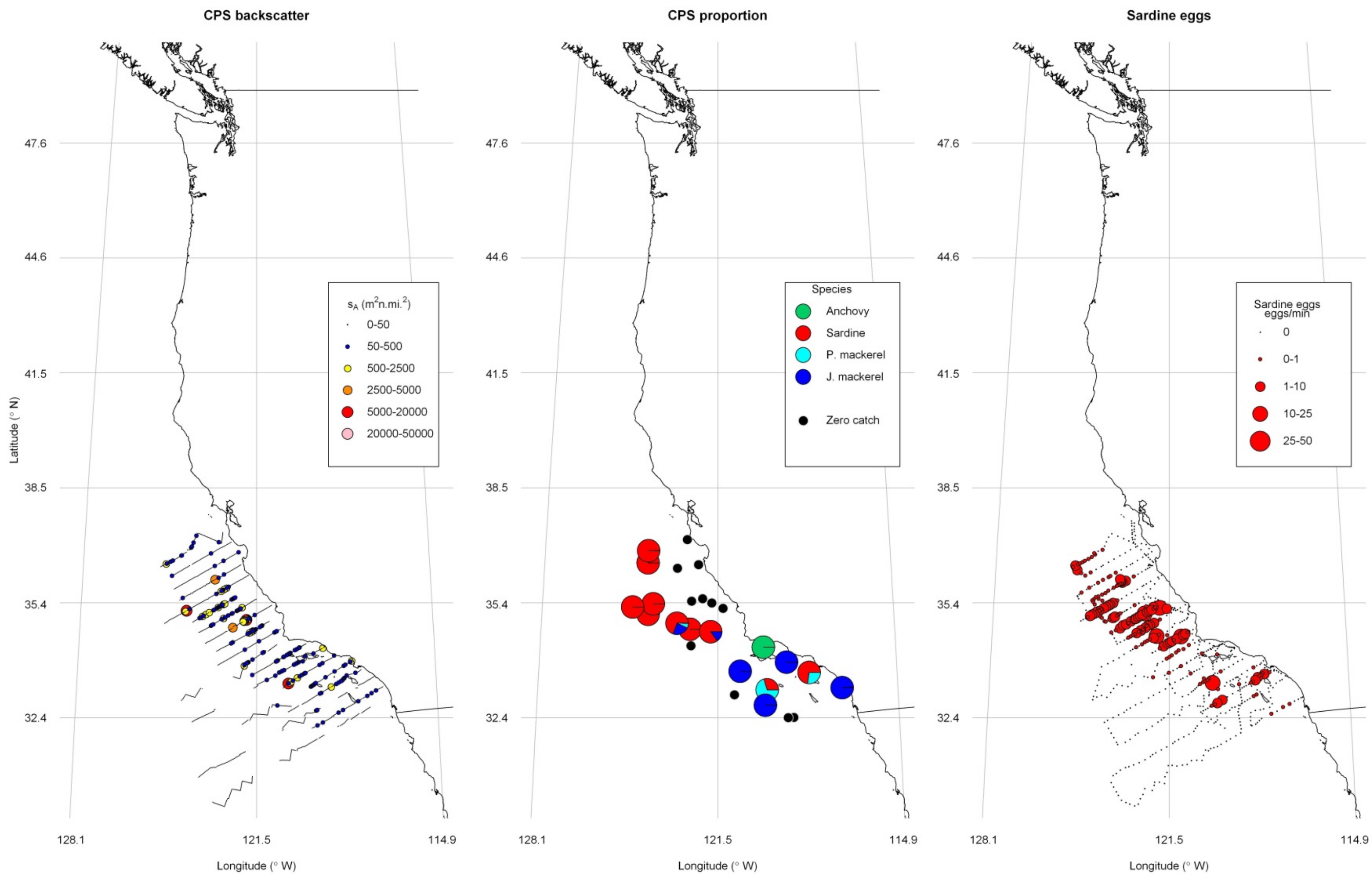


Figure 2. Sardine biomass densities versus stratum (Table 1) estimated using the acoustic-trawl method (ATM). The numbers in blue represent the location of trawl clusters with at least 1 CPS.

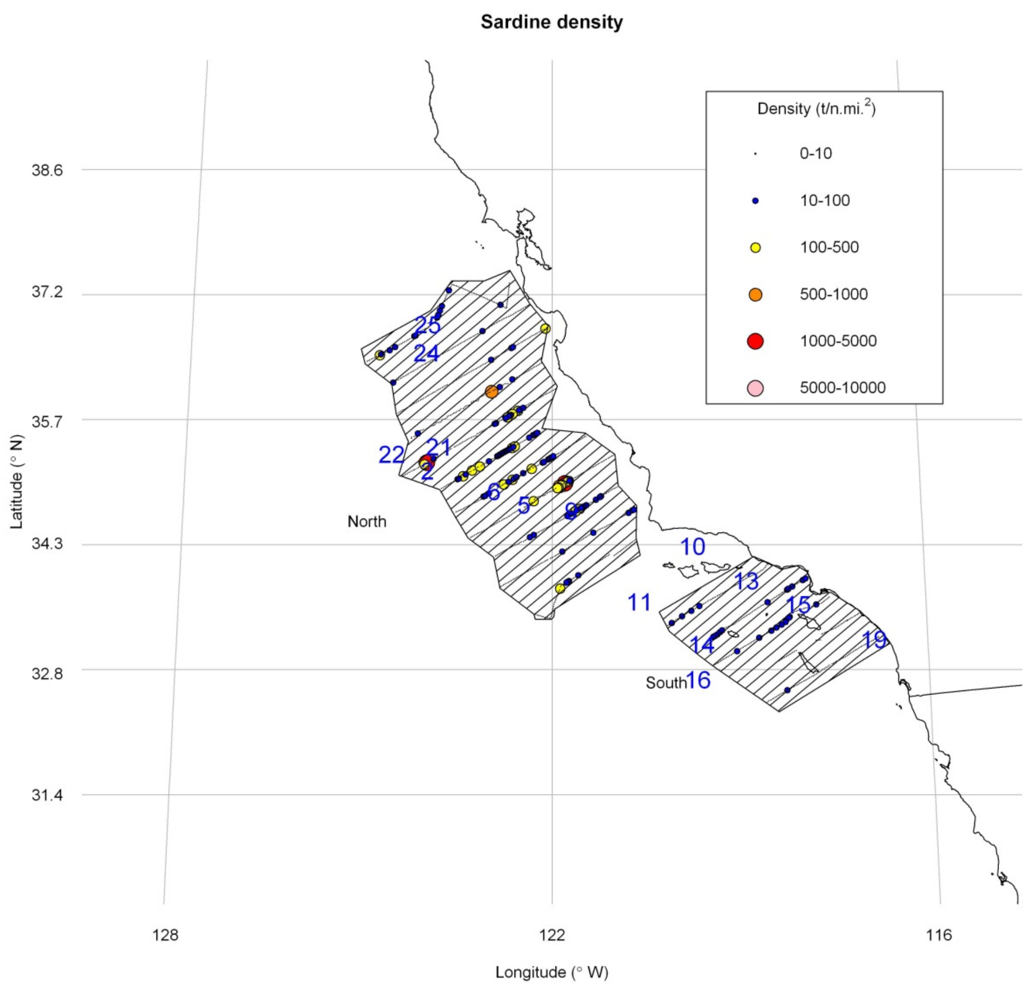


Figure 3. Distributions of sardine lengths versus trawl cluster, the total number of sardine caught in each cluster, and the proportions of the sardine abundances within each respective stratum represented by these data. The locations of the trawl clusters are shown in Fig. 2.

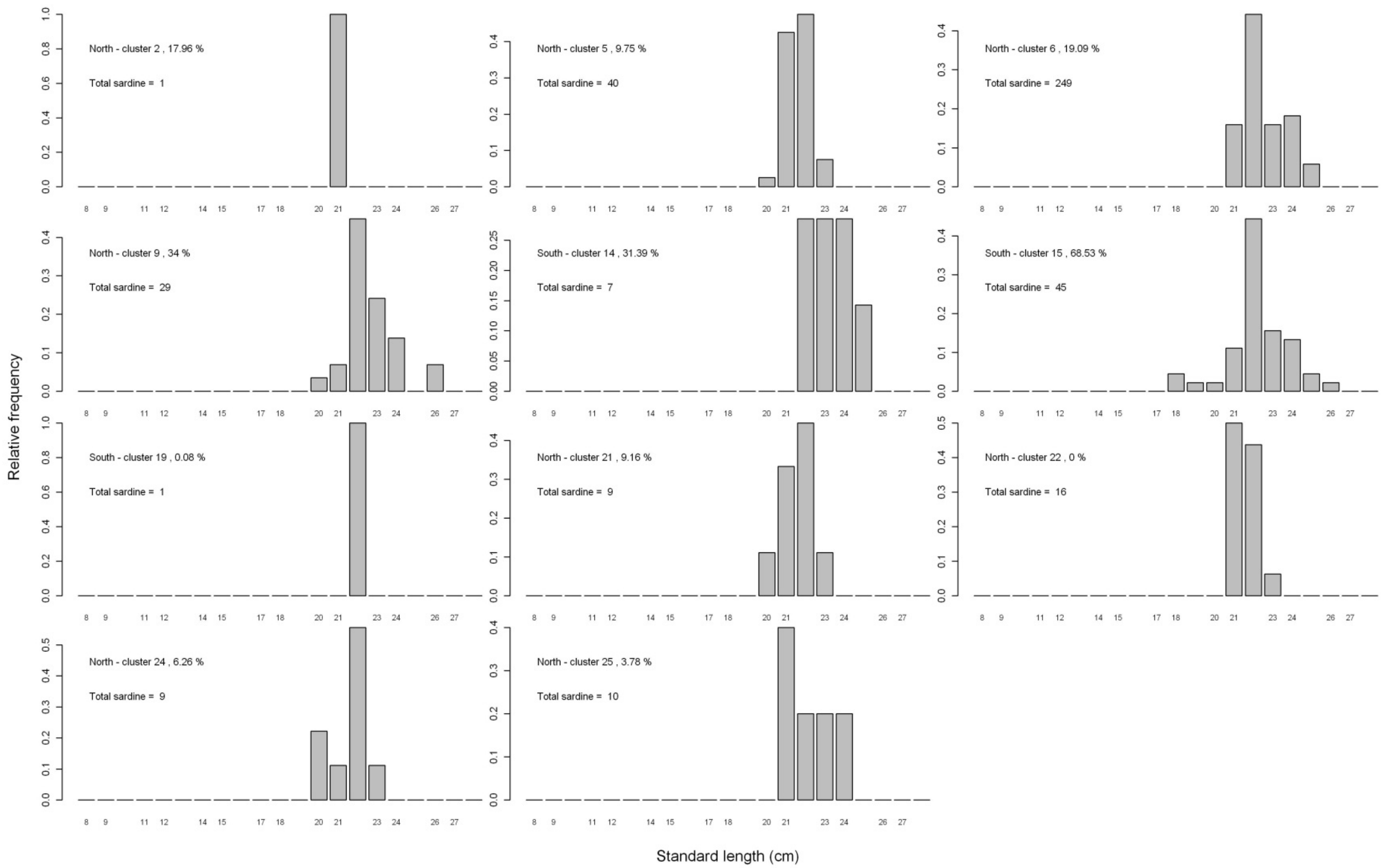
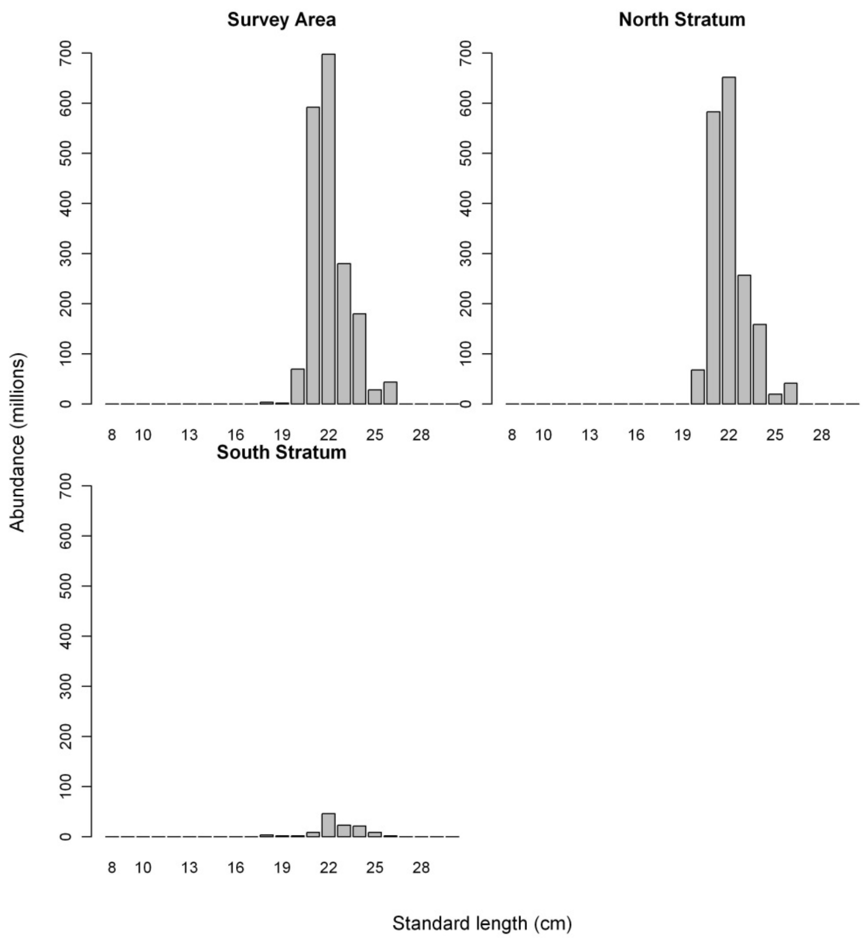


Figure 4. Sardine abundance versus standard length and stratum for the spring 2013 survey. Abundance per length class for the survey is provided in **table 2**.



APPENDIX B

Acoustic-trawl estimates of sardine biomass off California during the Summer SaKe 2013 survey

Juan Zwolinski, David A. Demer, Beverly J. Macewicz, George R. Cutter Jr., Brian Elliot, Scott Mau, David Murfin, Josiah S. Renfree, Thomas S. Sessions, and Kevin Stierhoff

This report summarizes results from the SaKe 2013 acoustic-trawl method (ATM) survey off the west coast of USA and West Vancouver Island (Fig. 1). The survey was conducted from NOAA FSV *Bell M. Shimada*.

The ATM survey totaled ~ 4420 n.mi. of east-west tracklines between the US and Mexico border and the northern end of Vancouver Island (Canada), spanning the expected distribution of the northern stock of Pacific sardine (Fig. 1). Offshore, the survey extended to the longest of a distance of 35 miles off the coast or the 1500 m isobath. From sunrise to sunset, multifrequency echosounders were used to sample acoustic backscatter from epipelagic coastal pelagic species (CPS). During nighttime, up to 4 surface trawls were used to identify the proportions of CPS and their lengths. Due to their temporal-spatial proximity, data from trawl catches conducted each night were combined into clusters. Overall, 32 catch clusters included CPS, and these clusters included an average catch of 223 sardine.

Post-survey strata were defined with considerations to the sampling intensity, the presence of acoustic CPS targets and net samples (Fig. 1). Sardine were predominantly found in the vicinity of the Columbia River mouth, and between San Francisco and Monterey Bay (Fig. 2). For biomass estimation, the survey area was split into three strata (Table 1; Fig 2).

The Washington-Oregon stratum contained the largest concentration of CPS backscatter and sardine catches; (Figs. 1, 2 and 3). The three strata (Table 1) contained a total sardine biomass of 0.314 Mt ($CI_{95\%}$ = [0.166; 0.517]; *CV* = 27.5%). The sampled population had a modal standard length (*SL*) at ~ 22 cm (Table 2).

A salient result of this survey is the absence of sardine off Vancouver Island. This is the first time that it occurred since the sardine resumed their migrations in the mid 1990s. Also, in line with the results from the summer survey in 2012, no sardine were found south of Monterey Bay.

Table 1. Sardine biomass by stratum for the 2013 SaKe survey.

Stratum		**Transect**		**Trawls**		**Sardine**		
Name	**Area (n.mi.)**	**Number**	**Distance (n.mi.)**	**CPS clusters**	**Number of sardine**	**Biomass (1000 tons)**	**95% confidence interval (1000 tons)**	***CV***
Washington-Oregon	5627	14	560	6	6650	210.3	75.3 – 410.7	37.7
Oregon-California	17824	44	1751	10	1092	9.8	1.4 – 19.5	53.7
Central California	2039	4	204	3	254	93.7	22.5 – 145.6	34.9
Total	**26391**	**62**	**2516**	**18**	**2011**	**313.7**	**166.1 – 517.0**	**27.5**

Table 2. Sardine abundance versus standard length for the 2013 SaKe survey.

Standard length (cm)	**Abundance (number);**
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	0
20	106181
21	113736358
22	821577566
23	687195532
24	292367516
25	81155376
26	6486959
27	0
28	0
29	0
30	0

Figure 1. Acoustic backscatter from coastal pelagic fish species (CPS; left), proportions of CPS in trawl clusters (right).

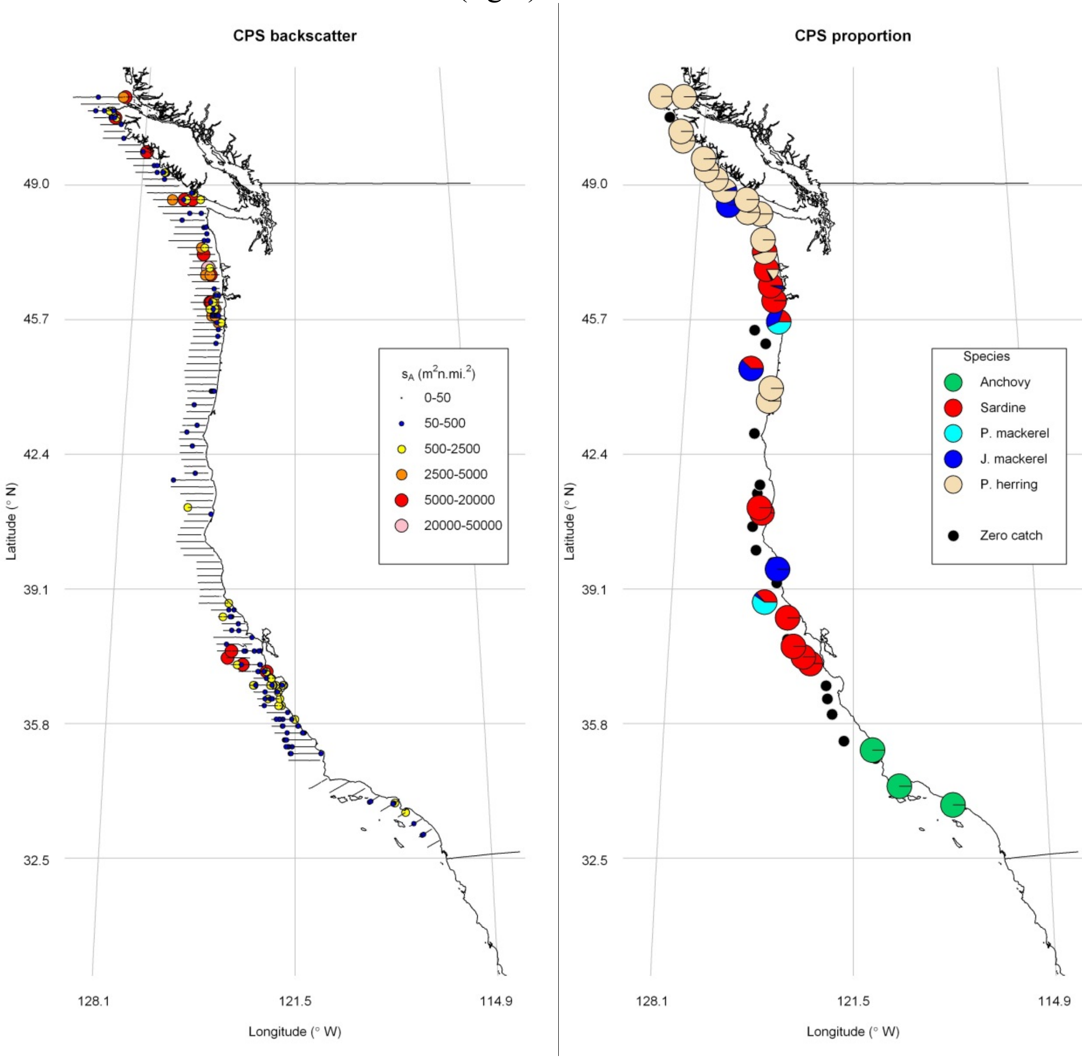


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Figure 2. Sardine biomass densities versus stratum (**Table 1**) estimated using the acoustic-trawl method (ATM). The numbers in blue represent the location of trawl clusters with at least 1 CPS.

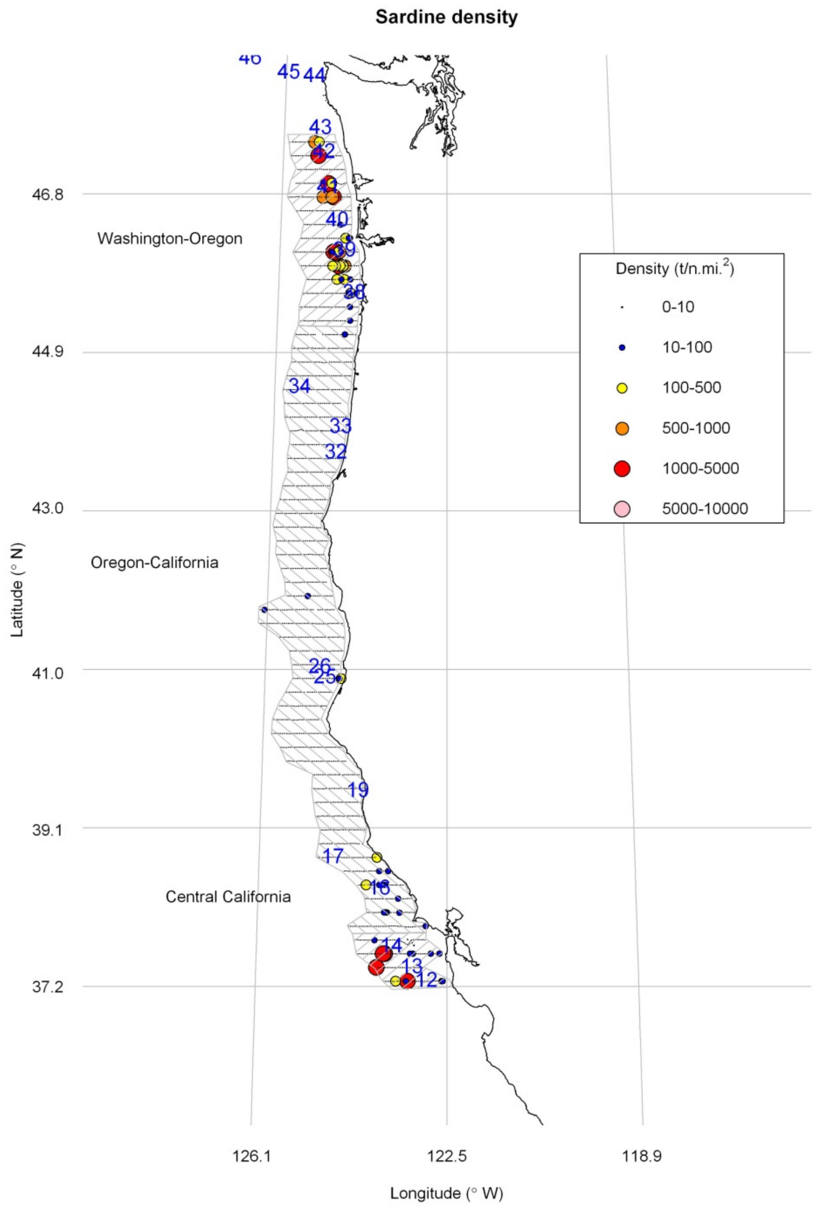


Figure 3. Distributions of sardine lengths versus trawl cluster, the total number of sardine caught in each cluster, and the proportions of the sardine abundances within each respective stratum represented by these data. The locations of the trawl clusters are shown in Fig. 2.

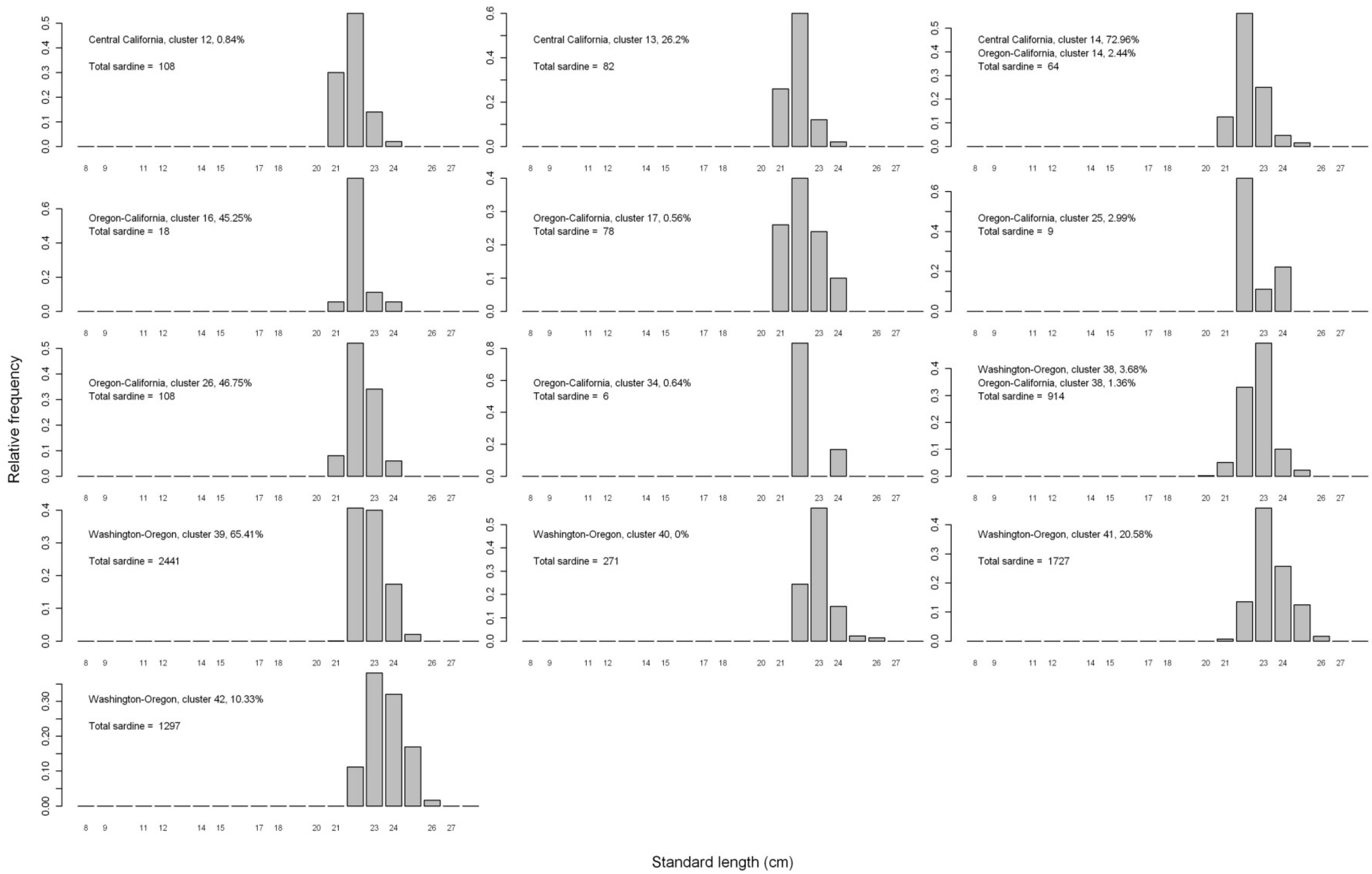
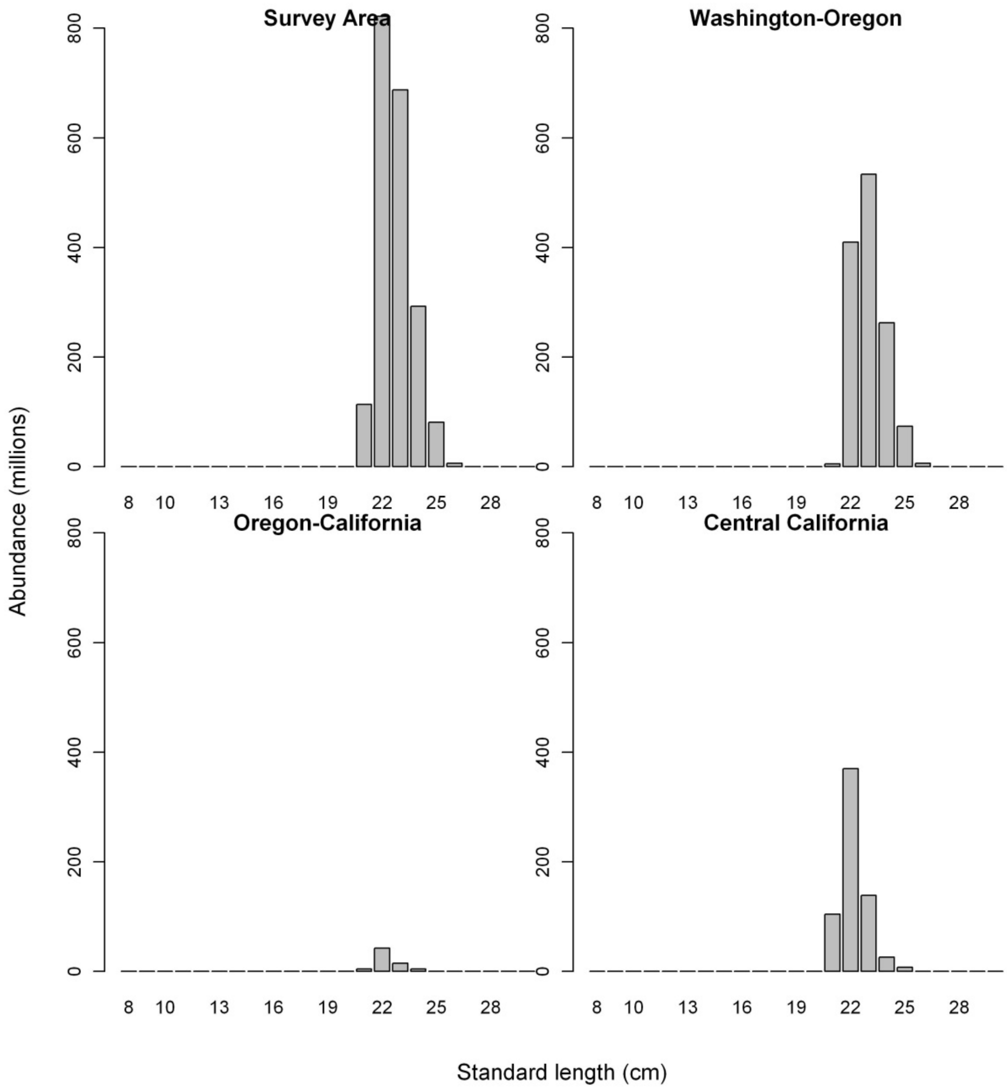


Figure 4. Sardine abundance versus standard length for the summer SaKe 2013 survey. Abundance per length class for the survey is provided in **table 2**.



Appendix C
SS Input Files for Base Model T

STARTER.SS

```
# Pacific sardine stock assessment for 2014-15
# K. T. Hill and P. R. Crone (March 2014)
# SS ver. 3.24s
T2_0.2.dat
T2_0.2.ctl
0 # 0=use init values in control file; 1=use ss3.par
1 # Run display detail (0,1,2)
2 # Detailed age-structured reports in REPORT.SSO: (0,1,2)
1 # Write detailed checkup.sso file (0,1)
3 # Write parm values to ParmTrace.sso (0=no,1=good,active; 2=good,all; 3=every_iter,all_parms; 4=every,active)
2 # Write to cumreport.sso (0=no, 1=like&timeseries, 2=add survey fits)
0 # Include prior_like for non-estimated parameters (0,1)
1 # Use soft boundaries to aid convergence: (0,1)
1 # Number of datafiles to produce: 1st is input, 2nd is estimates, 3rd and higher are bootstrap
10 # Turn off estimation for parameters entering after this phase
10 # MCeval burn interval
2 # MCeval thin interval
0 # Jitter initial parm value by this fraction
-1 # Min yr for sdreport outputs (-1 for styr)
-2 # Max yr for sdreport outputs (-1 for endyr; -2 for endyr+Nforecastyrs
0 # N individual STD years
0.00001 # Final convergence criteria (e.g., 1.0e-05)
0 # Retrospective year relative to end year (e.g. -4)
1 # Min age for calc of summary biomass
1 # Depletion basis:  denom is: 0=skip; 1=rel X*B0; 2=rel X*Bmsy; 3=rel X*B_styr
1 # Fraction (X) for depletion denominator (e.g. 0.4)
4 # SPR_report_basis: 0=skip; 1=(1-SPR)/(1-SPR_tgt); 2=(1-SPR)/(1-SPR_MSY); 3=(1-SPR)/(1-SPR_Btarget); 4=rawSPR
4 # F_report_units: 0=skip; 1=exploitation(Bio); 2=exploitation(Num); 3=sum(Frates); 4=true F for range of ages
0 13 # Min and max age over which average F will be calculated with F_reporting=4
2 # F_report_basis: 0=raw; 1=F/Fspr; 2=F/Fmsy ; 3=F/Fbtgt
999 # End of file
```

FORECAST.SS

```
# Pacific sardine stock assessment for 2014-15
# K. T. Hill and P. R. Crone (March 2014)
# SS ver. 3.24s
1 #_Benchmarks: 0=skip, 1=calc F_spr,F_btgt,F_msy
2 #_MSY: 1= set to F(SPR), 2=calc F(MSY), 3=set to F(Btgt), 4=set to F(endyr)
0.4 #_SPR target (e.g., 0.40)
0.4 #_Biomass target (e.g., 0.40)
0 0 0 0 0 0
1 # Bmark_relF_basis: 1 = use year range; 2 = set relF same as forecast below
1 # Forecast: 0=none; 1=F(SPR); 2=F(MSY) 3=F(Btgt); 4=Ave F (uses first-last relF yrs); 5=input annual F scalar
1 # N forecast years
0 # F scalar (only used for Do_Forecast==5)
# Fcast_years: beg_selex, end_selex, beg_relF, end_relF
0 0 0 0
1 # Control rule method (1=catch=f(SSB) west coast, 2=F=f(SSB) )
0.5 # Control rule Biomass level for constant F (as frac of Bzero, e.g. 0.40); (Must be > the no F level below)
0.1 # Control rule Biomass level for no F (as frac of Bzero, e.g. 0.10)
0.75 # Control rule target as fraction of Flimit (e.g. 0.75)
3 # N forecast loops
3 # First forecast loop with stochastic recruitment
0 # Forecast loop control #3 (reserved for future bells&whistles)
0 # Forecast loop control #4 (reserved for future bells&whistles)
0 # Forecast loop control #5 (reserved for future bells&whistles)
2020 # FirstYear for caps and allocations (should be after years with fixed inputs)
0 # Stddev of log(realized catch/target catch) in forecast (set value>0.0 to cause active impl_error)
0 # Do West Coast gfish rebuilder output (0/1)
0 # Rebuilder: first year catch could have been set to zero (Ydecl)(-1 to set to 1999)
0 # Rebuilder: year for current age structure (Yinit) (-1 to set to endyear+1)
1 # Fleet relative F: 1=use first-last alloc year, 2=read seas(row) x fleet(col) below
# Note: fleet allocation is used directly as average F if Do_Forecast=4
2 # Basis for forecast catch tuning and for forecast catch caps and allocation: 2=deadbio, 3=retainbio,
5=deadnum, 6=retainnum
# Max total catch by fleet (-1 to have no max): must enter value for each fleet
-1 -1 -1
# Max total catch by area (-1 to have no max): must enter value for each fleet
```

```
-1
# Fleet assignment to allocation group (enter group ID# for each fleet, 0 for not included in an alloc group)
0 0 0
# Conditional on >1 allocation group
# Allocation fraction for each of: 0 allocation groups
# No allocation groups
6 # Number of forecast catch levels to input (or else calculate catch from forecast F)
2 # Basis for input forecast catch: 2=dead catch, 3=retained catch, 99 = input Hrate(F
# Input fixed catch values
# Year Season Fleet Catch/F
2014   1      1      739
2014   2      1      0
2014   1      2      0
2014   2      2      10000
2014   1      3      5000
2014   2      3      1500
#
999 # End of file
```

CONTROL FILE 'T2_0.2.CTL'

```
# Pacific sardine stock assessment for 2014-15
# K. T. Hill and P. R. Crone (March 2014)
# SS ver. 3.24s
1 #_N_growth patterns
1 # N_Morphs within growth pattern
1 # N_recruitment assignments (overrides GP*area*season parameter values)
0 # Recruitment interaction requested
1 1 1 # GP season area for each recruitment assignment
1 # N_block patterns - selectivity
1 # N_blocks per pattern 1
1999 2013 # Block pattern 1 - MexCal_S1 and MexCal_S2
0.5 # Fraction female
0 # Natural mortality type
1 # Growth model: 1=vonBert with L1&L2, 2=Richards with L1&L2, 3=age_speciific_K, 4=not implemented
0.5 # Growth_age for_L1
999 #_Growth_age for_L2 (999=use Linf)
0 # SD add to LAA (set to 0.1 for SS2 V1.x compatibility)
0 # CV_growth pattern: (0) CV=f(LAA), (1) CV=F(A), (2) SD=F(LAA), (3) SD=F(A), (4) log(SD)=F(A)
1 # Maturity_option: 1=length logistic
0 # First mature age
1 # Fecundity option:(1) eggs=Wt*(a+b*Wt),(2) eggs=a*L^b,(3) eggs=a*Wt^b, (4) eggs=a+b*L, (5)eggs=a+b*W
0 # Hermaphroditism option: 0=none, 1=age-specific
1 # Parameter offset approach: 1=none, 2=Mortality, growth, CV_growth as offset from female-GP1, 3=like SS2 V1.x
1 # Env/block/dev adjust method: 1=standard
#
# Growth parameters
0.3 0.7 0.4 0 -1 99 -3 0 0 0 0 0 0 0 # NatM_p_1_Fem_GP_1
3 15 10 0 -1 99 3 0 0 0 0 0 0 0 # LAA_min_Fem_GP_1
20 30 25 0 -1 99 3 0 0 0 0 0 0 0 # LAA_max_Fem_GP_1
0.05 0.99 0.4 0 -1 99 3 0 0 0 0 0 0 0 # VonBert_K_Fem_GP_1
0.05 0.3 0.14 0 -1 99 3 0 0 0 0 0 0 0 # CV_young_Fem_GP_1
0.01 0.1 0.05 0 -1 99 3 0 0 0 0 0 0 0 # CV_old_Fem_GP_1
-3 3 7.5242e-006 0 -1 99 -3 0 0 0 0 0 0 0 # WtLt_1_Fem
-3 5 3.233205 0 -1 99 -3 0 0 0 0 0 0 0 # WtLt_2_Fem
9 19 15.44 0 -1 99 -3 0 0 0 0 0 0 0 # Mat50%_Fem
-20 3 -0.89252 0 -1 99 -3 0 0 0 0 0 0 0 # Mat_slope_Fem
0 10 1 0 -1 99 -3 0 0 0 0 0 0 0 # Eggs/kg_inter_Fem
-1 5 0 0 -1 99 -3 0 0 0 0 0 0 0 # Eggs/kg_slope_wt_Fem
-4 4 0 0 -1 99 -3 0 0 0 0 0 0 0 # RecrDist_GP_1
-4 4 1 0 -1 99 -3 0 0 0 0 0 0 0 # RecrDist_Area_1
-4 4 1 0 -1 99 -3 0 0 0 0 0 0 0 # RecrDist_Seas_1
-4 4 0 0 -1 99 -3 0 0 0 0 0 0 0 # RecrDist_Seas_2
1 1 1 0 -1 99 -3 0 0 0 0 0 0 0 # Cohort Growth_Dev
# Seasonal effects on biology parameter
0 0 0 0 0 0 0 0 0 0 # femwtlt1, femwtlt2, mat1, mat2, fec1, fec2, malewtlt1, malewtlt2, L1, K
# Spawner-recruit (SR) parameters
3 # SR function: 3=std_B-H
3 25 16 0 -1 99 1 # SR_R0
0.2 1 0.8 0 -1 99 -6 # SR_steepness
0 2 0.75 0 -1 99 -3 # SR_sigmaR
-5 5 0 0 -1 99 -3 # SR_env link
-15 15 0 0 -1 99 2 # SR_R1_offset
0 0 0 0 -1 99 -3 # SR_autocorr
```

```
0 # SR_env link
0 # SR_env target: 0=none, 1=devs, 2=R0, 3=steepness
1 # Do recdev:  0=none, 1=devvector, 2=simple deviations
1993 # First year of main rec_devs (early devs can preceed this era)
2012 # Last year of main rec_devs (forecast devs start in following year)
1 # Rec_dev phase
1 # Read 13 advanced options (0/1)
-6 # Rec_dev early start: 0=none (neg value makes relative to rec_dev)
2 # Rec_dev early phase
0 # Forecast rec phase (includes late rec): 0 value sets to maxphase+1
1 # Lambda for Forecast rec likelihood occurring before endyr+1
1984 # Last early_yr nobias adjustment in MPD
1993 # First yr fullbias adjustment in_MPD
2010 # Last yr fullbias adjustment in MPD
2013 # First recent_yr nobias adjustment in MPD
0.93 # Max bias adjustment in_MPD (-1 to override ramp and set bias adjustment=1.0 for all estimated rec_devs)
0 # Period of cycles in recruitment (N_parms read below)
-5 # Min rec_dev
5 # Max rec_dev
0 # Read rec_devs
# Fishing mortality (F) parameters
0.1 # F ballpark for tuning early phases
-2006 # F ballpark year (neg value to disable)
3 # F method: 1=Pope, 2=instant F, 3=hybrid
4 # Max F or harvest rate (depends on F method)
10 # N_iterations for tuning F
# Initial F parameters
0 4 0 0 -1 99 -1 # Init F_MexCal_S1
0 4 0 0 -1 99 -1 # Init F_MexCal_S2
0 4 0 0 -1 99 -1 # Init F_PacNW
# Catchability (Q) parameters
# Den-dep  Env-var  Extra_SE  Q_type
0 0 0 0 # 1 MexCal_S1
0 0 0 0 # 2 MexCal_S2
0 0 0 0 # 3 PacNW
0 0 0 2 # 4 DEPM
0 0 0 2 # 5 TEP
0 0 0 2 # 6 TEP_all
0 0 0 2 # 7 Aerial
0 0 0 2 # 8 ATM_Spring
0 0 0 -8 # 9 ATM_Summer (share q with ATM_Spring)
# Q parameters (if any)
-3 3 -1.39 0 -1 99 5 # Q_DEPM
-3 3 -0.69 0 -1 99 5 # Q_TEP
-3 3 -0.69 0 -1 99 5 # Q_TEP_full
-3 3 0 0 -1 99 5 # Q_Aerial
-3 3 0 0 -1 99 -5 # Q_Acoustic_Spring
# -3 3 0 0 -1 99 5 # Q_Acoustic_Summer
# Size selectivity types
# Pattern Discard Male Special
24 0 0 0 # 1 MexCal_S1
24 0 0 0 # 2 MexCal_S2
24 0 0 0 # 3 PacNW
30 0 0 0 # 4 DEPM
30 0 0 0 # 5 TEP
30 0 0 0 # 6 TEP_full
24 0 0 0 # 7 Aerial
24 0 0 0 # 8 Acoustic_Spring
24 0 0 0 # 9 Acoustic_Summer
# Age selectivity types
# Pattern Discard Male Special
0 0 0 0 # 1 MexCal_S1
0 0 0 0 # 2 MexCal_S2
0 0 0 0 # 3 PacNW
0 0 0 0 # 4 DEPM
0 0 0 0 # 5 TEP
0 0 0 0 # 6 TEP_full
0 0 0 0 # 7 Aerial
0 0 0 0 # 8 Acoustic_Spring
0 0 0 0 # 9 Acoustic_Summer
# Size selectivity
# MexCal_S1 (dome)
10 28 18 0 -1 99 4 0 0 0 0 0 1 2 # SizeSel_P1_MexCal_S1
-5 3 -4.985 0 -1 99 -4 0 0 0 0 0 1 2 # SizeSel_P2_MexCal_S1
-1 9 2.5 0 -1 99 4 0 0 0 0 0 1 2 # SizeSel_P3_MexCal_S1
```

```
-1 9 4 0 -1 99 4 0 0 0 0 0 1 2 # SizeSel_P4_MexCal_S1
-10 10 -10 0 -1 99 -4 0 0 0 0 0 1 2 # SizeSel_P5_MexCal_S1
-10 10 -10 0 -1 99 4 0 0 0 0 0 1 2 # SizeSel_P6_MexCal_S1
#_MexCal_S2 (dome)
10 28 18 0 -1 99 4 0 0 0 0 0 1 2 # SizeSel_P1_MexCal_S2
-5 3 -4.993 0 -1 99 -4 0 0 0 0 0 1 2 # SizeSel_P2_MexCal_S2
-1 9 2.5 0 -1 99 4 0 0 0 0 0 1 2 # SizeSel_P3_MexCal_S2
-1 9 4 0 -1 99 4 0 0 0 0 0 1 2 # SizeSel_P4_MexCal_S2
-10 10 -10 0 -1 99 -4 0 0 0 0 0 1 2 # SizeSel_P5_MexCal_S2
-10 10 -10 0 -1 99 4 0 0 0 0 0 1 2 # SizeSel_P6_MexCal_S2
# PacNW (Asymptotic)
10 28 19 0 -1 99 4 0 0 0 0 0 0 0 # SizeSel_P1_PNW
-5 10 2.5 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P2_PNW
-5 10 5 0 -1 99 4 0 0 0 0 0 0 0 # SizeSel_P3_PNW
-5 10 5 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P4_PNW
-10 10 -10 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P5_PNW
-10 10 10 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P6_PNW
# Aerial (Asymptotic)
10 28 18 0 -1 99 4 0 0 0 0 0 0 0 # SizeSel_P1__Aerial
-5 3 3 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P2__Aerial
-1 9 2.5 0 -1 99 4 0 0 0 0 0 0 0 # SizeSel_P3__Aerial
-1 9 4 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P4__Aerial
-10 10 -10 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P5__Aerial
-10 10 10 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P6__Aerial
# Acoustic_Spring (Asymptotic)
10 28 18 0 -1 99 4 0 0 0 0 0 0 0 # SizeSel_P1_Acoustic
-5 3 3 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P2_Acoustic
-1 9 2.5 0 -1 99 4 0 0 0 0 0 0 0 # SizeSel_P3_Acoustic
-1 9 4 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P4_Acoustic
-10 10 -10 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P5_Acoustic
-10 10 10 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P6_Acoustic
# Acoustic_Summer (Asymptotic)
10 28 18 0 -1 99 4 0 0 0 0 0 0 0 # SizeSel_P1_Acoustic
-5 3 3 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P2_Acoustic
-1 9 2.5 0 -1 99 4 0 0 0 0 0 0 0 # SizeSel_P3_Acoustic
-1 9 4 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P4_Acoustic
-10 10 -10 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P5_Acoustic
-10 10 10 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_P6_Acoustic
1 # Custom sel-blk setup (0/1)
#_MexCal_S1 (Block 2)
10 28 18 0 -1 99 4 # SizeSel_P1_MexCal_S1_Blk2
-5 3 -4.998 0 -1 99 -4 # SizeSel_P2_MexCal_S1_Blk2
-1 9 2.5 0 -1 99 4 # SizeSel_P3_MexCal_S1_BLK2
-1 9 4 0 -1 99 4 # SizeSel_P4_MexCal_S1_Blk2
-10 10 -10 0 -1 99 -4 # SizeSel_P5_MexCal_S1_Blk2
-10 10 -10 0 -1 99 4 # SizeSel_P6_MexCal_S1_Blk2
#_MexCal_S2 (Block 2)
10 28 18 0 -1 99 4 # SizeSel_P1_MexCal_S2_Blk2
-5 3 -4.997 0 -1 99 -4 # SizeSel_P2_MexCal_S2_Blk2
-1 9 2.5 0 -1 99 4 # SizeSel_P3_MexCal_S2_Blk2
-1 9 4 0 -1 99 4 # SizeSel_P4_MexCal_S2_Blk2
-10 10 -10 0 -1 99 -4 # SizeSel_P5_MexCal_S2_Blk2
-10 10 -10 0 -1 99 4 # SizeSel_P6_MexCal_S2_Blk2
1 # Cond # Env/Block/Dev_adjustment method: 1=standard
0 # Tag custom:  0=no read, 1=read if tags exist
1 # Variance adjustments
# Fleet/Survey: 1 2 3 4 5 6 7 8 9
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     #_add_to_survey_CV
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     #_add_to_discard_stddev
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     #_add_to_bodywt_CV
1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     #_mult_by_lencomp_N
1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     #_mult_by_agecomp_N
1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     #_mult_by_size-at-age_N
1 # Max lambda phase
1 # SD_offset
25 # Number of changes to make to default Lambdas (default value=1)
# Like_comp fleet/survey  phase  value  size-freq_method
1 4 1 1 1      # DEPM
1 5 1 1 1      # TEP
1 6 1 0 1      # TEP_full
1 7 1 0 1      # Aerial
1 8 1 1 1      # Acoustic_Spring
1 9 1 1 1      # Acoustic_Summer
4 1 1 1 1      # MexCal_S1 (length)
4 2 1 1 1      # MexCal_S2 (length)
```

```
4 3 1 1 1      # PacNW (length)
4 7 1 0 1      # Aerial (length)
4 8 1 1 1      # Acoustic_Spring (length)
4 9 1 1 1      # Acoustic_Summer (length)
5 1 1 0.2 1    # MexCal_S1 (Cond AAL)
5 2 1 0.2 1    # MexCal_S2 (Cond AAL)
5 3 1 0.2 1    # PacNW (Cond AAL)
5 8 1 0 1      # Acoustic_Spring (Cond AAL)
5 9 1 0 1      # Acoustic_Summer (Cond AAL)
7 1 1 0 1      # MexCal_S1 (Mean LAA)
7 2 1 0 1      # MexCal_S2 (Mean LAA)
7 3 1 0 1      # PacNW (Mean LAA)
7 8 1 0 1      # Acoustic_Spring (Mean LAA)
7 9 1 0 1      # Acoustic_Summer (Mean LAA)
9 1 1 0 1      # Initial equilibrium catch (MexCal_S1)
9 2 1 0 1      # Initial equilibrium catch (MexCal_S2)
9 3 1 0 1      # Initial equilibrium catch (PacNW)
0 # Read specs for more SD reporting (0/1)
999 # End of file
```

DATA FILE 'T2_0.2.DAT' (NSP Data)

```
# Pacific sardine stock assessment for 2014-15
# K. T. Hill and P. R. Crone (March 2014)
# SS ver. 3.24s
#
1993 # Start year (July 1993)
2013 # End year (forecast=2014)
2 # N_seasons
6 6 # Months per season (2 semesters per fishing year)
2 # Spawning season (Spring semester)
3 # N_fleets
6 # N_surveys
1 # N_areas
MexCal_S1_NSP%MexCal_S2_NSP%PacNW%DEPM%TEP%TEP_full%Aerial%ATM_Spring%ATM_Summer
0.5 0.5 0.5 0.58 0.58 0.58 0.2 0.58 0.2 # Survey timing in season
1 1 1 1 1 1 1 1 1 # Area assignments for each fishery/survey
1 1 1 # Units of catch: 1=biomass, 2=number
0.05 0.05 0.05 # SE of log(catch), only used for initial equilibrium catch and for Fmethod=2-3
1 # N_genders
15 # N_ages
0 0 0 # Initial equilibrium catch for each fishery
42 # N_lines of catch to read
# Catch biomass(mt): columns are fisheries, year, season
822.80  0.00     0.00     1993    1
0.00    11345.83          0.00    1993    2
8838.65 0.00     0.00     1994    1
0.00    39748.42          0.00    1994    2
5993.28 0.00     22.68    1995    1
0.00    26565.72          0.00    1995    2
11917.29         0.00     0.00    1996    1
0.00    19158.65          43.54   1996    2
13018.20         0.00     27.22   1997    1
0.00    24527.60          0.82    1997    2
18925.15         0.00     488.25  1998    1
0.00    63278.38          74.39   1998    2
14996.21         0.00     725.20  1999    1
0.00    58341.39          429.59  1999    2
23693.38         0.00     15586.16        2000    1
0.00    35179.21          2336.90 2000    2
11550.53         0.00     22545.99        2001    1
0.00    41118.36          3136.84 2001    2
16562.71         0.00     35525.69        2002    1
0.00    36130.69          597.29  2002    2
10340.64         0.00     37242.26        2003    1
0.00    21300.55          2618.43 2003    2
17048.96         0.00     46730.80        2004    1
0.00    25249.92          1016.32 2004    2
13730.19         0.00     54152.62        2005    1
0.00    29752.00          101.70  2005    2
20620.28         0.00     41220.90        2006    1
0.00    39234.00          0.00    2006    2
46047.30         0.00     48237.10        2007    1
0.00    42247.81          0.00    2007    2
```

```
30147.46       0.00    39800.10       2008    1
0.00    40545.56       0.00    2008    2
13964.90       0.00    44841.15       2009    1
0.00    30240.66       1369.73 2009    2
11130.97       0.00    54085.91       2010    1
0.00    26817.27       0.09    2010    2
24700.00       0.00    39750.49       2011    1
0.00    20514.89       5805.63 2011    2
1452.24 0.00    91425.63       2012    1
0.00    7373.93 1570.78 2012    2
739.00  0.00    52961.07       2013    1
0.00    13280.00       1500.00 2013    2       #_Mexcal=9780+3500
#
51 #_N_cpue_and_surveyabundance_observations
#_Units:  0=numbers; 1=biomass; 2=F
#_Errtype:  -1=normal; 0=lognormal; >0=T
#_Fleet Units Errtype
1 1 0 # MexCal_S1
2 1 0 # MexCal_S2
3 1 0 # PacNW
4 1 0 # DEPM
5 1 0 # TEP
6 1 0 # TEP_full
7 1 0 # Aerial
8 1 0 # Acoustic_Spring
9 1 0 # Acoustic_Summer
# Year season index obs error
1993    2       4       69065   0.29    #_DEPM_9404
2003    2       4       145274  0.23    #_DEPM_0404
2004    2       4       459943  0.55    #_DEPM_0504
2006    2       4       198404  0.30    #_DEPM_0704
2007    2       4       66395   0.27    #_DEPM_0804
2008    2       4       99162   0.24    #_DEPM_0905
2009    2       4       58447   0.40    #_DEPM_1004
2010    2       4       219386  0.27    #_DEPM_1104
2011    2       4       113178  0.27    #_DEPM_1204
2012    2       4       82182   0.29    #_DEPM_1304
1995    2       5       97923   0.40    #_TEP_9604
1996    2       5       482246  0.21    #_TEP_9704
1997    2       5       369775  0.33    #_TEP_9804
1998    2       5       332177  0.34    #_TEP_9904
1999    2       5       1252539 0.39    #_TEP_0004
2000    2       5       931377  0.38    #_TEP_0104
2001    2       5       236660  0.17    #_TEP_0204
2002    2       5       556177  0.18    #_TEP_0304
2005    2       5       651994  0.25    #_TEP_0604
1993    2       6       73374   0.21    #_TEPall_9404
1995    2       6       97923   0.40    #_TEPall_9604
1996    2       6       482246  0.21    #_TEPall_9704
1997    2       6       369775  0.33    #_TEPall_9804
1998    2       6       332177  0.34    #_TEPall_9904
1999    2       6       1252539 0.39    #_TEPall_0004
2000    2       6       931377  0.38    #_TEPall_0104
2001    2       6       236660  0.17    #_TEPall_0204
2002    2       6       556177  0.18    #_TEPall_0304
2003    2       6       307795  0.24    #_TEPall_0404
2004    2       6       486950  0.40    #_TEPall_0504
2005    2       6       651994  0.25    #_TEPall_0604
2006    2       6       306297  0.26    #_TEPall_0704
2007    2       6       128118  0.21    #_TEPall_0804
2008    2       6       162188  0.22    #_TEPall_0904
2009    2       6       97838   0.39    #_TEPall_1004
2010    2       6       364798  0.26    #_TEPall_1104
2011    2       6       227632  0.27    #_TEPall_1204
2012    2       6       198472  0.29    #_TEPall_1304
2009    1       7       1236911 0.90    #_Aerial_09N
2010    1       7       173390  0.40    #_Aerial_10N
2011    1       7       201888  0.29    #_Aerial_11N
2012    1       7       696251  0.37    #_Aerial_12N
2005    2       8       1947063 0.30    #_Acoustic_0604
2007    2       8       751075  0.09    #_Acoustic_0804
2009    2       8       357006  0.41    #_Acoustic_1004
2010    2       8       493672  0.30    #_Acoustic_1104
2011    2       8       469480  0.28    #_Acoustic_1204
2012    2       8       305146  0.24    #_Acoustic_1304
```

```
2008	1	9	801000	0.30	#_Acoustic_0807
2012	1	9	340831	0.33	#_Acoustic_1207
2013	1	9	313746	0.27	#_Acoustic_1307
0 # N_fleets with discard
0 # N_discard obs
0 # N_meanbodywt obs
100 # DF for_meanbodywt t-distribution likelihood
2 # Length bin method: 1=use databins; 2=generate from binwidth,min,max below; 3=read vector
0.5 # Bin width for population size composition
8 # Minimum size in the population (lower edge of first bin and size at age 0)
30 # Maximum size in the population (lower edge of last bin)
-0.0001 # Composition tail compression
0.0001 # Add to composition
0 # Combine males into females at or below this bin number
39 # N_length bins
9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15 15.5 16 16.5 17 17.5 18 18.5 19 19.5 20 20.5 21 21.5 22 22.5 23
23.5 24 24.5 25 25.5 26 26.5 27 27.5 28
79 # N_length obs
# Year Season Fleet/Survey Gender Part Nsamp Datavector(female-male)
1993	1	1	0	0	2.72	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.01470588	0.00000000	0.14705882
	0.23529412	0.19117647	0.20588235	0.13235294	0.05882353	0.01470588	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1994	1	1	0	0	13.74	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00192997	0.01865635
	0.04117263	0.08430434	0.07591361	0.07404029	0.08683868	0.12757807	0.09884957
	0.10926901	0.11878046	0.08880898	0.05178937	0.00695027	0.01026562	0.00365034
	0.00060123	0.00000000	0.00060123	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	1	1	0	0	4.80	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00833333	0.00000000	0.00833333	0.00833333	0.01666667
	0.07500000	0.08333333	0.05833333	0.20833333	0.13333333	0.21666667	0.08333333
	0.06666667	0.01666667	0.00833333	0.00833333	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1996	1	1	0	0	59.54	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00034806	0.00058009
	0.00219937	0.00576503	0.00957964	0.02611018	0.04050980	0.05620072	0.08282782
	0.13533238	0.15435462	0.17604004	0.13254345	0.08564194	0.05547979	0.02087313
	0.00993156	0.00286865	0.00069611	0.00023204	0.00062219	0.00000000	0.00000000
	0.00042114	0.00042114	0.00000000	0.00042114	0.00000000	0.00000000	0.00000000
1997	1	1	0	0	54.96	0.00161047	0.00000000	0.00000000	0.00000000
	0.00000000	0.00070613	0.00190931	0.00249531	0.00157254	0.00740264	0.02034422
	0.02746041	0.02356657	0.03226502	0.04920364	0.05812807	0.09131547	0.12217437
	0.17851369	0.16690609	0.10823880	0.06410378	0.02256286	0.00874199	0.00479242
	0.00070613	0.00249531	0.00176969	0.00030895	0.00070613	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1998	1	1	0	0	61.82	0.00000000	0.00013950	0.00000000	0.00054913
	0.00217145	0.00754043	0.02660605	0.06328062	0.09928446	0.12017588	0.11452861
	0.10222652	0.08662035	0.08022393	0.05559320	0.04519876	0.03979356	0.03720684
	0.02689637	0.02425384	0.01374267	0.01309129	0.01455336	0.00735521	0.00736115
	0.00379924	0.00202174	0.00182034	0.00226600	0.00169950	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1999	1	1	0	0	8.45	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00970931	0.02427327	0.05825584	0.09709307
	0.13107564	0.18600867	0.21698374	0.07874420	0.08045604	0.05037072	0.03313752
	0.01627580	0.00727624	0.00325516	0.00229776	0.00229776	0.00153184	0.00038296
	0.00019148	0.00038296	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2000	1	1	0	0	19.31	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00214444	0.00687013	0.00236284	0.00816075	0.01610311
	0.02362844	0.03736871	0.07557145	0.12782502	0.17187176	0.18629126	0.17216776
	0.08516998	0.03492402	0.01434741	0.01172984	0.01007111	0.00731811	0.00463296
	0.00036867	0.00000000	0.00000000	0.00107222	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1	1	0	0	26.92	0.00299140	0.00273498	0.01506817	0.03187710
	0.04628212	0.02810027	0.01845921	0.01980049	0.02094225	0.00689629	0.00233494
	0.00009139	0.00702992	0.01724077	0.03944303	0.04010245	0.05293178	0.06963658
	0.06813359	0.03349161	0.02422864	0.01998817	0.02567865	0.04374940	0.06629584
	0.11235528	0.07962582	0.03629326	0.02802019	0.01335362	0.01339213	0.00843442
	0.00307756	0.00191866	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2002	1	1	0	0	46.96	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00058534	0.00000000	0.00000000	0.00427117	0.00856097	0.01383827
```

```
     0.02882084  0.07292346  0.10667321  0.12477102  0.13591949  0.17905045  0.12960308
     0.09350153  0.04093142  0.02615243  0.01065275  0.00566682  0.00430140  0.00526596
     0.00146460  0.00420899  0.00225146  0.00000000  0.00000000  0.00000000  0.00058534
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
2003 1     1     0     0     13.15  0.00000000  0.00169262  0.00451718  0.01608292
     0.06021648  0.12408570  0.08347189  0.05346355  0.04403720  0.02879712  0.01144579
     0.02279141  0.01563165  0.02462320  0.02606885  0.03942352  0.05607711  0.07024577
     0.06869371  0.06366968  0.04343752  0.04937621  0.04233675  0.02762563  0.01033400
     0.00851117  0.00243153  0.00091182  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
2004 1     1     0     0     32.30  0.00000000  0.00000000  0.00000000  0.00024514
     0.00024514  0.00073543  0.00205767  0.00283243  0.00824157  0.00988930  0.04485433
     0.11745533  0.20110987  0.16552816  0.14517069  0.11552133  0.08888914  0.04629335
     0.01857389  0.01104107  0.00756468  0.00443794  0.00243413  0.00239788  0.00000806
     0.00000201  0.00000000  0.00223572  0.00000000  0.00000000  0.00223572  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
2005 1     1     0     0     28.75  0.00000000  0.00000000  0.00071949  0.00143897
     0.00653511  0.01157153  0.01384485  0.01309843  0.02798175  0.05168794  0.07930643
     0.09237886  0.07490876  0.08847601  0.11085534  0.15343903  0.10619562  0.07417982
     0.03501566  0.02276698  0.01374071  0.01125064  0.00258153  0.00246207  0.00002240
     0.00056560  0.00000000  0.00113119  0.00056560  0.00000000  0.00271410  0.00056560
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
2006 1     1     0     0     70.00  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000817  0.00139593  0.00370309  0.01051305  0.02830085
     0.08812453  0.16038481  0.17472994  0.15633215  0.13757842  0.10032027  0.06327177
     0.03845569  0.02449167  0.00528078  0.00445611  0.00132639  0.00033160  0.00033160
     0.00033160  0.00033160  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
2007 1     1     0     0     69.87  0.00164969  0.00247453  0.00329937  0.00264684
     0.00076071  0.00094036  0.00106112  0.00505987  0.00726599  0.01044510  0.02075499
     0.03448703  0.06756079  0.10788447  0.15231813  0.18353671  0.15746569  0.11193402
     0.06189772  0.03095113  0.01131497  0.00936246  0.00448928  0.00070277  0.00070277
     0.00049491  0.00111500  0.00082484  0.00181466  0.00164969  0.00164969  0.00115478
     0.00032994  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
2008 1     1     0     0     27.00  0.00000000  0.00001951  0.00001951  0.00007805
     0.00007805  0.00025365  0.00812568  0.01322437  0.01507600  0.01012736  0.00703638
     0.00222432  0.00815459  0.03743973  0.10519409  0.17673635  0.17069402  0.16753307
     0.13252684  0.05969125  0.02792098  0.01779568  0.00494964  0.01433373  0.00739166
     0.00899568  0.00066448  0.00187718  0.00005853  0.00177962  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
2009 1     1     0     0     23.00  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00718480
     0.00659772  0.02510462  0.00834218  0.03988813  0.13822895  0.30734108  0.28332180
     0.12859970  0.04820622  0.00544034  0.00174446  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
2010 1     1     0     0     13.00  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00307692  0.00000000
     0.02153846  0.11076923  0.30153846  0.28615385  0.22153846  0.02153846  0.01846154
     0.00307692  0.00307692  0.00615385  0.00307692  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
2011 1     1     0     0     22.00  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00550160  0.02270543  0.10592845  0.30705434  0.33715847
     0.16548304  0.03472523  0.01524281  0.00344984  0.00000000  0.00000000  0.00275080
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
2012 1     1     0     0     22.96  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.02288534
     0.01634667  0.02615468  0.01307734  0.00326933  0.00980800  0.02916482  0.07258330
     0.10858359  0.14709358  0.12463433  0.14112953  0.13635974  0.07152817  0.05732066
     0.01399447  0.00048164  0.00372320  0.00186160  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
2013 1     1     0     0     5.00   0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
     0.00016205  0.01991898  0.02008102  0.05975693  0.04000000  0.11967591  0.17991898
     0.28000000  0.13060767  0.09012153  0.04979744  0.00995949  0.00000000  0.00000000
     0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1993 2     2     0     0     80.83  0.00000000  0.00000000  0.00000000  0.00000000
     0.00000000  0.00000000  0.00024233  0.00140226  0.00726413  0.02974873  0.06247855
     0.09739572  0.09557449  0.07134655  0.06703480  0.08193713  0.10366195  0.11143525
     0.10144129  0.05447251  0.03973350  0.02527592  0.01453475  0.00850628  0.00787906
```

```
        0.00345701      0.00250677      0.00214831      0.00346978      0.00312588      0.00135054      0.00021661
        0.00128376      0.00093526      0.00000000      0.00014086      0.00000000      0.00000000      0.00000000
1994    2       2       0       0       206.08 0.00000000     0.00000000     0.00000000     0.00000000
        0.00145457      0.00504078      0.00606898      0.00700771      0.01410691      0.02242621      0.04034287
        0.06906816      0.09654861      0.11238178      0.12955228      0.13501642      0.11091489      0.09320556
        0.05899874      0.04552064      0.02495894      0.01511850      0.00540478      0.00359894      0.00066879
        0.00092576      0.00026691      0.00000000      0.00012087      0.00000000      0.00029208      0.00069722
        0.00000000      0.00000000      0.00000000      0.00029208      0.00000000      0.00000000      0.00000000
1995    2       2       0       0       42.30  0.00000000     0.00000000     0.00000000     0.00000000
        0.00000000      0.00483005      0.00181639      0.00978760      0.01443863      0.02041858      0.02632739
        0.03677194      0.05949842      0.09049866      0.10561619      0.13138787      0.11886270      0.11101527
        0.07941884      0.07368271      0.04314995      0.03412017      0.01538229      0.01735834      0.00323563
        0.00100235      0.00056203      0.00000000      0.00040900      0.00000000      0.00000000      0.00000000
        0.00040900      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1996    2       2       0       0       31.69  0.00000000     0.00000000     0.00000001     0.00000006
        0.00208698      0.00474184      0.01105977      0.01641602      0.03848093      0.04640019      0.05225376
        0.07284165      0.06293899      0.03267289      0.02526977      0.03481597      0.04474040      0.05224002
        0.05002577      0.07588550      0.07647282      0.09283255      0.08189359      0.05770817      0.02553826
        0.01572120      0.00742768      0.00448802      0.00253262      0.00168842      0.00168842      0.00168842
        0.00168842      0.00238407      0.00337683      0.00000000      0.00000000      0.00000000      0.00000000
1997    2       2       0       0       39.04  0.00116688     0.00116688     0.01283567     0.01168079
        0.01911496      0.00995550      0.00463359      0.00836094      0.02093227      0.01412310      0.04077870
        0.04592240      0.05486011      0.07529587      0.08758462      0.06419613      0.05883337      0.06624342
        0.04634799      0.03228601      0.03351542      0.03099222      0.05453763      0.05713365      0.05113369
        0.04096875      0.03221245      0.01144112      0.00765009      0.00308468      0.00057263      0.00023650
        0.00020197      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    2       2       0       0       62.89  0.00000000     0.00052375     0.00292399     0.00531268
        0.00807976      0.00892394      0.01445008      0.04007347      0.04947419      0.06018640      0.07160912
        0.08430841      0.09930662      0.11026781      0.09545976      0.09022715      0.07892527      0.06308014
        0.02943892      0.02494755      0.01733738      0.01275855      0.01065188      0.00689855      0.00555941
        0.00337949      0.00283313      0.00163188      0.00071536      0.00040797      0.00030739      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1999    2       2       0       0       45.97  0.00000000     0.00000000     0.00000000     0.00000000
        0.00000000      0.00000000      0.00000000      0.00373364      0.01858885      0.06092482      0.10283009
        0.13630227      0.17321851      0.15257482      0.12476550      0.08514671      0.05049129      0.03310700
        0.02304860      0.01857073      0.01262764      0.00349994      0.00042741      0.00014219      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2000    2       2       0       0       42.47  0.00000000     0.00000000     0.00000000     0.00007818
        0.00031273      0.00695721      0.00948363      0.02298990      0.03958827      0.04929372      0.07791587
        0.10364298      0.10939476      0.07624154      0.05471634      0.05940971      0.08000407      0.07736515
        0.05906656      0.05988523      0.04314596      0.04274591      0.01443181      0.01154905      0.00083513
        0.00000000      0.00086812      0.00007818      0.00000000      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2001    2       2       0       0       57.78  0.00000000     0.00000000     0.00114442     0.01008725
        0.02360642      0.04515338      0.06577894      0.08827063      0.10528246      0.11005028      0.08543740
        0.06257413      0.06371308      0.05222215      0.02452615      0.02527951      0.02070571      0.02867169
        0.04446623      0.05499618      0.03036332      0.02717653      0.01354428      0.00784013      0.00561628
        0.00208727      0.00069576      0.00069576      0.00000000      0.00000000      0.00001467      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2002    2       2       0       0       55.61  0.00000000     0.00000000     0.00000000     0.00037996
        0.00113988      0.00189980      0.00264471      0.00378459      0.00573358      0.00469099      0.00904018
        0.02153204      0.04856377      0.08579611      0.12189739      0.13011447      0.12668342      0.09525103
        0.04868384      0.03776127      0.05061458      0.05005716      0.04759173      0.04675377      0.02437622
        0.01196384      0.00688184      0.00781155      0.00573013      0.00095678      0.00080336      0.00086203
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2003    2       2       0       0       74.37  0.00000000     0.00000000     0.00002333     0.00737407
        0.03796815      0.06330862      0.06164288      0.08781023      0.13955871      0.16815734      0.12204441
        0.08096378      0.04889651      0.02406924      0.01538764      0.01563158      0.01102487      0.01358790
        0.01561320      0.02270900      0.01540512      0.01581931      0.00585443      0.00228531      0.00198207
        0.00690423      0.00409315      0.00215683      0.00243203      0.00283737      0.00324271      0.00081068
        0.00040534      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2004    2       2       0       0       81.35  0.00000000     0.00000000     0.00000000     0.00000000
        0.00093783      0.00153447      0.00348067      0.00686443      0.02125242      0.03295020      0.06153444
        0.10844211      0.11494040      0.12997977      0.12299243      0.09934347      0.09079576      0.07490959
        0.06642619      0.03379681      0.01274994      0.00944827      0.00238726      0.00082184      0.00068687
        0.00101954      0.00203739      0.00000000      0.00066788      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2005    2       2       0       0       69.54  0.00003323     0.00016617     0.00198183     0.00724287
        0.02546488      0.03423464      0.04343134      0.05161252      0.08921533      0.10317372      0.11440362
        0.10395214      0.11260776      0.08466520      0.06700801      0.04312203      0.03875394      0.02639734
        0.01505989      0.01090155      0.00709011      0.00530332      0.00273073      0.00352497      0.00253710
        0.00095835      0.00156157      0.00078078      0.00027632      0.00048453      0.00064604      0.00035514
        0.00032302      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
```

2006	2	2	0	0	79.01	0.00000000	0.00000000	0.00000000	0.00007155
	0.00193274	0.00448013	0.00870836	0.01190914	0.02276871	0.02245554	0.05508678		
	0.08312489	0.10950482	0.11508847	0.11718795	0.09778619	0.08344183	0.07797438		
	0.05950222	0.04982304	0.02853562	0.01769640	0.00778031	0.00668425	0.00192038		
	0.00407420	0.00371857	0.00243818	0.00184306	0.00148743	0.00148743	0.00148743		
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000		
2007	2	2	0	0	53.13	0.00000000	0.00000000	0.00056916	0.00458294
	0.01523107	0.01624194	0.03828270	0.07429633	0.10589583	0.11936676	0.13445629		
	0.09028317	0.08948056	0.09093413	0.06813034	0.04676708	0.03148477	0.01534756		
	0.01102726	0.00991497	0.00445812	0.00594738	0.00799020	0.00561403	0.00666222		
	0.00305137	0.00193240	0.00055948	0.00018649	0.00055948	0.00018649	0.00018649		
	0.00037299	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000		
2008	2	2	0	0	39.53	0.00130827	0.00130827	0.00261985	0.00174435
	0.00820997	0.01240801	0.02192600	0.03724275	0.03155898	0.02949098	0.03131780		
	0.04421268	0.06406849	0.11119877	0.13321561	0.12895909	0.08889473	0.07252151		
	0.05604855	0.05270723	0.02472053	0.01390128	0.00841632	0.00910891	0.00492096		
	0.00313298	0.00174435	0.00198249	0.00043609	0.00067422	0.00000000	0.00000000		
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000		
2009	2	2	0	0	99.00	0.00000000	0.00000000	0.00000000	0.00033110
	0.00098937	0.00364222	0.01526663	0.04815485	0.10491762	0.15225861	0.16727933		
	0.14395945	0.12763433	0.09200956	0.07251219	0.03921100	0.01392598	0.00964499		
	0.00259569	0.00164641	0.00095708	0.00053046	0.00065827	0.00089258	0.00090368		
	0.00000000	0.00000000	0.00007860	0.00000000	0.00000000	0.00000000	0.00000000		
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000		
2010	2	2	0	0	32.96	0.00000000	0.00000000	0.00000000	0.00000329
	0.00000986	0.00000000	0.01533814	0.03545198	0.07505310	0.08012643	0.16082054		
	0.16409807	0.14395429	0.08121932	0.03649645	0.02499783	0.00880498	0.00803841		
	0.00505031	0.00646200	0.00190905	0.00326271	0.00879883	0.01489032	0.03181114		
	0.02910381	0.02842698	0.01759765	0.00812199	0.00744516	0.00067683	0.00135367		
	0.00067683	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000		
2011	2	2	0	0	56.28	0.00000000	0.00000000	0.00000000	0.00000000
	0.00042055	0.00393862	0.02649871	0.07254863	0.07899923	0.06480918	0.05727363		
	0.04957664	0.04043675	0.05008019	0.04620495	0.05065969	0.03636937	0.04610942		
	0.04153957	0.06936597	0.04808470	0.04969147	0.03341529	0.02532542	0.01673552		
	0.02905829	0.02593557	0.02224027	0.00818459	0.00324890	0.00108297	0.00216593		
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000		
2012	2	2	0	0	9.00	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000		
	0.00634863	0.00634863	0.01904590	0.03809180	0.01904590	0.08292541	0.10792675		
	0.13008930	0.15627021	0.07814954	0.12219678	0.07438000	0.05428802	0.04833258		
	0.04339435	0.00937866	0.00227252	0.00151501	0.00000000	0.00000000	0.00000000		
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000		
1999	1	3	0	0	3.04	0.00000000	0.00000000	0.00000000	0.00000000
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	0.00000095	0.00000285	0.00001236	0.04484245	0.07472347	0.07472918	0.13447410		
	0.15869488	0.13446554	0.05976204	0.04482153	0.02422648	0.04642701	0.03714674		
	0.03716576	0.02788359	0.03717908	0.03919457	0.00929548	0.00000666	0.00000285		
	0.01494051	0.00000000	0.00000095	0.00000000	0.00000000	0.00000000	0.00000000		
1999	2	3	0	0	4.24	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000		
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000		
	0.00000000	0.00000000	0.00000000	0.01886792	0.01886792	0.02830189	0.16981132		
	0.17924528	0.20754717	0.16981132	0.11320755	0.04716981	0.02830189	0.00943396		
	0.00943396	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000		
2000	1	3	0	0	63.93	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00003375	0.00006482	0.00000000	0.00003375	0.00000000		
	0.00003375	0.00000000	0.00000000	0.00063677	0.00308924	0.01570860	0.02898601		
	0.03823612	0.05495875	0.06093348	0.06560425	0.07664897	0.09104633	0.12502336		
	0.11358864	0.11316074	0.07608888	0.06753608	0.03163643	0.01814741	0.01018023		
	0.00428843	0.00365138	0.00060061	0.00003107	0.00003970	0.00000000	0.00001246		
2000	2	3	0	0	10.72	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000026	0.00012460	0.00000000	0.00000000		
	0.00000026	0.00000000	0.00000026	0.00000000	0.00000000	0.00000000	0.00000000		
	0.00000000	0.02350879	0.02375825	0.08315347	0.13179081	0.15417981	0.17881393		
	0.13080486	0.14894118	0.07718786	0.03579353	0.00003091	0.01189510	0.00000951		
	0.00000449	0.00000106	0.00000079	0.00000000	0.00000000	0.00000000	0.00000026		
2001	1	3	0	0	78.15	0.00000000	0.00000000	0.00000000	0.00000000
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	0.00115894	0.00060192	0.00046425	0.00000000	0.00046425	0.00000000	0.00000002		
	0.00261835	0.01024098	0.02323570	0.07467192	0.16300429	0.17738632	0.16996193		
	0.12669923	0.09158078	0.06693893	0.04293152	0.02073142	0.01275755	0.00758599		
	0.00156533	0.00158897	0.00011092	0.00004628	0.00000000	0.00000000	0.00000002		
2001	2	3	0	0	26.76	0.00000000	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000		
	0.00000000	0.00000000	0.00000000	0.00000000	0.00048288	0.00048288	0.00000053		

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       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
       0.00000000   0.01398663   0.00000000   0.00000000   0.00000000   0.00000000   0.00640983
       0.00764838   0.05363834   0.07792424   0.18996976   0.18962297   0.20269211   0.13261832
       0.06086833   0.03818737   0.01244710   0.00622355   0.00776308   0.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2010   1   3   0   0   158.60 0.00000000   0.00000000   0.00000000   0.00000000
       0.00001429   0.00001429   0.00001429   0.00001429   0.00001429   0.00001429   0.00044699
       0.00000000   0.00000121   0.00000000   0.00182244   0.00202608   0.00164970   0.00257329
       0.00747769   0.02929572   0.09131722   0.14271426   0.15874857   0.10985279   0.08726802
       0.06754262   0.09067348   0.07714994   0.06213060   0.03582122   0.02020100   0.00620373
       0.00350799   0.00107204   0.00019082   0.00002417   0.00005373   0.00002859   0.00012036
2011   1   3   0   0   209.70 0.00000000   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.00003151   0.00000000   0.00000000   0.00001309   0.00000000
       0.00098545   0.00003928   0.00059179   0.00017022   0.00011007   0.00198926   0.00187005
       0.00458734   0.00621298   0.01733638   0.02663686   0.09056926   0.12766615   0.12250119
       0.08001007   0.12016808   0.12573893   0.10839274   0.08486996   0.04554796   0.01977992
       0.00882012   0.00339068   0.00107283   0.00055389   0.00018109   0.00013134   0.00003151
2011   2   3   0   0   15.00  0.00000000   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.01595748
       0.06102858   0.09574485   0.11202126   0.10134751   0.10393621   0.08544319   0.15735814
       0.12312026   0.10388306   0.02943256   0.00803189   0.00269502   0.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2012   1   3   0   0   117.03 0.00000000   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00031117
       0.00824020   0.03585317   0.08625069   0.13020785   0.14781588   0.13078359   0.13096350
       0.13450060   0.09826163   0.04865465   0.03019293   0.01048763   0.00505848   0.00152875
       0.00035161   0.00046650   0.00003843   0.00000000   0.00001799   0.00000000   0.00001476
2012   2   3   0   0   3.00   0.00000000   0.00000000   0.00000000   0.00000000
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       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
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       0.06666667   0.05333333   0.01333333   0.01333333   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2013   1   3   0   0   120.00 0.00000000   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.00685106   0.04776269   0.18189361   0.26149113   0.23789051
       0.13015577   0.07123941   0.03532203   0.01864533   0.00687701   0.00133591   0.00053554
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2009   1   7   0   0   33.20  0.00000000   0.00000000   0.00000000   0.00000000
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       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00057622   0.00495836
       0.03103000   0.09960013   0.16374495   0.20219759   0.22838807   0.15886180   0.07916015
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       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
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       0.00132264   0.00518994   0.02150013   0.09853051   0.21071417   0.29173440   0.18574131
       0.11417842   0.04092949   0.01770211   0.00669268   0.00000000   0.00129411   0.00000000
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2011   1   7   0   0   50.00  0.00000000   0.00000000   0.00000000   0.00000000
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       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00067671   0.00000000
       0.00017503   0.00058270   0.00081600   0.00639086   0.02291477   0.10158366   0.24939403
       0.26460441   0.20025064   0.09328675   0.03327509   0.01190588   0.00477899   0.00363973
       0.00294363   0.00000000   0.00101779   0.00000000   0.00000000   0.00000000   0.00000000
2012   1   7   0   0   23.00  0.00000000   0.00000000   0.00000000   0.00096182
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       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
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       0.05042019   0.03717053   0.03715582   0.01294936   0.00496227   0.00104007   0.00111157
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
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       0.15773170   0.15773170   0.06426980   0.06426980   0.05009669   0.05009669   0.01516183
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2007   2   8   0   0   12.00  0.00000000   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
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        0.00121512      0.00265337      0.00265337      0.00332081      0.00332081      0.00555546      0.00555546
        0.00224440      0.00224440      0.00833426      0.00833426      0.05506318      0.05506318      0.17107802
        0.17107802      0.16580872      0.16580872      0.06954074      0.06954074      0.01153821      0.01153821
        0.00243023      0.00243023      0.00027301      0.00000000      0.00000000      0.00000000      0.00000000
2010    2       8       0       0       18.00   0.00000000      0.00000000      0.00000000      0.00000000
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        0.00000000      0.00015121      0.00015121      0.08020558      0.08020558      0.22135962      0.22135962
        0.08918809      0.08918809      0.04535153      0.04535153      0.00957193      0.00957193      0.00287216
        0.00287216      0.01710648      0.01710648      0.02239309      0.02239309      0.00960401      0.00960401
        0.00139900      0.00139900      0.00158562      0.00000000      0.00000000      0.00000000      0.00000000
2011    2       8       0       0       12.00   0.00000000      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00966230      0.00966230
        0.00000000      0.00000000      0.00874343      0.00874343      0.09109599      0.09109599      0.11348639
        0.11348639      0.05587484      0.05587484      0.10595060      0.10595060      0.08715280      0.08715280
        0.02797210      0.02797210      0.00006153      0.00006153      0.00000000      0.00000000      0.00000000
2012    2       8       0       0       18.00   0.00000000      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
        0.00087027      0.00087027      0.00043514      0.00043514      0.01933857      0.01933857      0.15265050
        0.15265050      0.18642185      0.18642185      0.07407997      0.07407997      0.04749947      0.04749947
        0.00758276      0.00758276      0.01112147      0.01112147      0.00000000      0.00000000      0.00000000
2008    1       9       0       0       27.00   0.01700544      0.01700544      0.02210707      0.02210707
        0.00680218      0.00680218      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00680218      0.00680218      0.02009720      0.02009720
        0.02164783      0.02164783      0.08951514      0.08951514      0.10939327      0.10939327      0.14029251
        0.14029251      0.05385909      0.05385909      0.01118376      0.01118376      0.00129435      0.00129435
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2012    1       9       0       0       26.00   0.00000000      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
        0.00035481      0.00035481      0.00193496      0.00193496      0.13636929      0.13636929      0.21595031
        0.21595031      0.06930702      0.06930702      0.04528789      0.04528789      0.02760803      0.02760803
        0.00294741      0.00294741      0.00024028      0.00024028      0.00000000      0.00000000      0.00000000
2013    1       9       0       0       23.00   0.00000000      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00002651      0.00002651      0.02839681
        0.02839681      0.20512511      0.20512511      0.17157365      0.17157365      0.07299605      0.07299605
        0.02026224      0.02026224      0.00161961      0.00161961      0.00000000      0.00000000      0.00000000

10 # N_age bins
0 1 2 3 4 5 6 7 8 11
6  # N_ageerror definitions
#
0.5     1.5     2.5     3.5     4.5     5.5     6.5     7.5     8.5     9.5     10.5    11.5    12.5    13.5    14.5
        15.5    #_1_CA_1981-06
0.2832  0.2832  0.289   0.8009  0.8038  0.9597  1.1156  1.2715  1.4274  1.5833  1.7392  1.8951  2.051   2.2069  2.3627
        2.5186  #_1_CA_1981-06
0.5     1.5     2.5     3.5     4.5     5.5     6.5     7.5     8.5     9.5     10.5    11.5    12.5    13.5    14.5
        15.5    #_2_CA_2007
0.2539  0.2539  0.3434  0.9205  0.9653  1.1743  1.3832  1.5922  1.8011  2.0101  2.219   2.428   2.6369  2.8459  3.0548
        3.2638  #_2_CA_2007
0.5     1.5     2.5     3.5     4.5     5.5     6.5     7.5     8.5     9.5     10.5    11.5    12.5    13.5    14.5
        15.5    #_3_CA_2008-09
0.4032  0.4032  0.4995  0.58    0.6902  0.8246  0.9727  1.0165  1.1144  1.2123  1.3102  1.4082  1.5061  1.604   1.702
        1.7999  #_3_CA_2008-09
0.5     1.5     2.5     3.5     4.5     5.5     6.5     7.5     8.5     9.5     10.5    11.5    12.5    13.5    14.5
        15.5    #_4_CA_2010-13
0.2825  0.2825  0.2955  0.3125  0.3347  0.3637  0.4017  0.4046  0.4245  0.4445  0.4645  0.4844  0.5044  0.5243  0.5443
        0.5643  #_4_CA_2010-13
0.5     1.5     2.5     3.5     4.5     5.5     6.5     7.5     8.5     9.5     10.5    11.5    12.5    13.5    14.5
        15.5    #_5_ORWA_all
0.26655 0.30145 0.3149  0.3615  0.3847  0.3961  0.4018  0.4047  0.4061  0.4352  0.4487  0.4622  0.4756  0.4891  0.5026
        0.516   #_5_ORWA_all
0.5     1.5     2.5     3.5     4.5     5.5     6.5     7.5     8.5     9.5     10.5    11.5    12.5    13.5    14.5
        15.5    #_6_CalCOFI_C
0.5386  0.5386  0.7547  0.8341  0.8634  0.8741  0.8781  0.8796  0.8801  0.8801  0.8801  0.8801  0.8801  0.8801  0.8801
        0.8801  #_6_CalCOFI_C
#
```

```
800 # N_age composition obs
3 # Length bin method: 1=poplenbins, 2=datalenbins, 3=lengths
-1 # Combine males into females at or below this bin number
# Year Season Fleet/Survey Gender Part Ageerr Lbin_lo Lbin_hi Nsamp datavector(female-male)
1993  1  1  0  0  1  16  16.5  0.04  0.00000000  0.00000000  0.00000000
      1.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1993  1  1  0  0  1  17  17.5  0.40  0.00000000  0.00000000  0.40000000
      0.60000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1993  1  1  0  0  1  18  18.5  1.16  0.00000000  0.00000000  0.13793103
      0.79310345  0.06896552  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1993  1  1  0  0  1  19  19.5  0.92  0.00000000  0.00000000  0.00000000
      0.73913043  0.21739130  0.04347826  0.00000000  0.00000000  0.00000000  0.00000000
1993  1  1  0  0  1  20  20.5  0.20  0.00000000  0.00000000  0.00000000
      1.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1994  1  1  0  0  1  15  15.5  0.64  0.06555503  0.80333490  0.13111007
      0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1994  1  1  0  0  1  16  16.5  1.56  0.02720121  0.82987390  0.14292490
      0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1994  1  1  0  0  1  17  17.5  3.92  0.01800542  0.66544962  0.23382015
      0.06471939  0.01800542  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1994  1  1  0  0  1  18  18.5  3.20  0.02584465  0.24477748  0.51450358
      0.21051706  0.00435722  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1994  1  1  0  0  1  19  19.5  2.04  0.00651038  0.05119051  0.39133174
      0.44858636  0.10238102  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1994  1  1  0  0  1  20  20.5  0.28  0.00000000  0.00000000  0.37554250
      0.37554250  0.24891501  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1994  1  1  0  0  1  21  21.5  0.08  0.00000000  0.00000000  1.00000000
      0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1994  1  1  0  0  1  22  22.5  0.04  0.00000000  0.00000000  1.00000000
      0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1995  1  1  0  0  1  12  12.5  0.04  1.00000000  0.00000000  0.00000000
      0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1995  1  1  0  0  1  13  13.5  0.08  0.00000000  1.00000000  0.00000000
      0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1995  1  1  0  0  1  14  14.5  0.44  0.63636364  0.27272727  0.09090909
      0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1995  1  1  0  0  1  15  15.5  0.64  0.18750000  0.43750000  0.31250000
      0.06250000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1995  1  1  0  0  1  16  16.5  1.64  0.04878049  0.73170732  0.19512195
      0.02439024  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1995  1  1  0  0  1  17  17.5  1.44  0.02777778  0.63888889  0.30555556
      0.02777778  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1995  1  1  0  0  1  18  18.5  0.40  0.00000000  0.20000000  0.40000000
      0.40000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1995  1  1  0  0  1  19  19.5  0.08  0.00000000  0.00000000  0.50000000
      0.50000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1996  1  1  0  0  1  14  14.5  0.12  0.00000000  1.00000000  0.00000000
      0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1996  1  1  0  0  1  15  15.5  1.28  0.00000000  0.44897248  0.55102752
      0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1996  1  1  0  0  1  16  16.5  6.24  0.00000000  0.20902801  0.75030358
      0.04066841  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1996  1  1  0  0  1  17  17.5  14.96  0.00000000  0.10419308  0.69554700
      0.18400205  0.01500520  0.00125267  0.00000000  0.00000000  0.00000000  0.00000000
1996  1  1  0  0  1  18  18.5  28.44  0.00000000  0.04005148  0.64987230
      0.28378437  0.02424253  0.00204932  0.00000000  0.00000000  0.00000000  0.00000000
1996  1  1  0  0  1  19  19.5  26.68  0.00000000  0.01621994  0.50808503
      0.42049373  0.05031671  0.00488459  0.00000000  0.00000000  0.00000000  0.00000000
1996  1  1  0  0  1  20  20.5  9.92  0.00000000  0.01435739  0.40880868
      0.48247061  0.07970037  0.01466295  0.00000000  0.00000000  0.00000000  0.00000000
1996  1  1  0  0  1  21  21.5  1.40  0.00000000  0.00000000  0.23003121
      0.45723664  0.31273215  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1996  1  1  0  0  1  22  22.5  0.08  0.00000000  0.00000000  0.50000000
      0.50000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1996  1  1  0  0  1  23  23.5  0.04  0.00000000  0.00000000  0.00000000
      1.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1996  1  1  0  0  1  25  25.5  0.08  0.00000000  0.00000000  0.00000000
      0.00000000  0.50000000  0.50000000  0.00000000  0.00000000  0.00000000  0.00000000
1996  1  1  0  0  1  26  26.5  0.04  0.00000000  0.00000000  0.00000000
      0.00000000  0.00000000  0.00000000  0.00000000  1.00000000  0.00000000  0.00000000
1997  1  1  0  0  1  9  9.5  0.04  1.00000000  0.00000000  0.00000000
      0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
1997  1  1  0  0  1  11  11.5  0.04  1.00000000  0.00000000  0.00000000
      0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
```

```
1997    1       1       0       0       1       12      12.5    0.16    0.00000000      1.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1997    1       1       0       0       1       13      13.5    0.72    0.00000000      1.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1997    1       1       0       0       1       14      14.5    4.04    0.00000000      1.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1997    1       1       0       0       1       15      15.5    4.56    0.00000000      1.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1997    1       1       0       0       1       16      16.5    7.36    0.00000000      0.92361566      0.07638434
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1997    1       1       0       0       1       17      17.5    13.84   0.00000000      0.56076615      0.43632757
        0.00290628      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1997    1       1       0       0       1       18      18.5    15.36   0.00000000      0.20645551      0.74805856
        0.04548592      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1997    1       1       0       0       1       19      19.5    6.88    0.00934460      0.04764680      0.63951375
        0.30349485      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1997    1       1       0       0       1       20      20.5    1.44    0.00000000      0.00000000      0.31385049
        0.54512566      0.14102386      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1997    1       1       0       0       1       21      21.5    0.24    0.00000000      0.00000000      0.29289001
        0.41776573      0.12842148      0.16092278      0.00000000      0.00000000      0.00000000      0.00000000
1997    1       1       0       0       1       22      22.5    0.16    0.00000000      0.00000000      0.00000000
        0.37760183      0.41493211      0.20746606      0.00000000      0.00000000      0.00000000      0.00000000
1997    1       1       0       0       1       23      23.5    0.08    0.00000000      0.00000000      0.00000000
        0.30435611      0.69564389      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       9       9.5     0.04    1.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       10      10.5    0.08    1.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       11      11.5    0.72    0.77179412      0.22820588      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       12      12.5    4.56    0.52354126      0.47645874      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       13      13.5    14.04   0.12472173      0.83932736      0.03595091
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       14      14.5    19.88   0.00755918      0.95562857      0.03681224
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       15      15.5    15.92   0.00189458      0.81696133      0.18114409
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       16      16.5    7.84    0.00000000      0.51773405      0.48226595
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       17      17.5    5.72    0.00000000      0.12190583      0.84714166
        0.03095251      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       18      18.5    3.20    0.00000000      0.00000000      0.75348715
        0.19827166      0.04824119      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       19      19.5    1.28    0.00000000      0.00000000      0.48477799
        0.31566788      0.19955413      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       20      20.5    0.88    0.00000000      0.00000000      0.02174408
        0.33200944      0.52769706      0.11854942      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       21      21.5    0.64    0.00000000      0.00000000      0.00000000
        0.39164730      0.47995442      0.12839828      0.00000000      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       22      22.5    0.24    0.00000000      0.00000000      0.00000000
        0.00000000      0.66666667      0.16666667      0.16666667      0.00000000      0.00000000      0.00000000
1998    1       1       0       0       1       23      23.5    0.28    0.00000000      0.00000000      0.00000000
        0.28571429      0.28571429      0.42857143      0.00000000      0.00000000      0.00000000      0.00000000
1999    1       1       0       0       1       12      12.5    0.08    1.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1999    1       1       0       0       1       13      13.5    0.68    0.76470588      0.17647059      0.05882353
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1999    1       1       0       0       1       14      14.5    1.88    0.12765957      0.70212766      0.17021277
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1999    1       1       0       0       1       15      15.5    3.24    0.00000000      0.54320988      0.45679012
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1999    1       1       0       0       1       16      16.5    0.84    0.00000000      0.42857143      0.57142857
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1999    1       1       0       0       1       17      17.5    0.24    0.00000000      0.16666667      0.66666667
        0.16666667      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2000    1       1       0       0       1       12      12.5    0.24    1.00000000      0.00000000      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2000    1       1       0       0       1       13      13.5    0.20    0.77547183      0.22452817      0.00000000
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2000    1       1       0       0       1       14      14.5    0.76    0.73513244      0.05947023      0.20539733
        0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2000    1       1       0       0       1       15      15.5    2.48    0.04184241      0.34985918      0.38220788
        0.22609053      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
```

2000	1 1	0 0	1 16	16.5 7.32	0.00789018	0.23451758	0.50324882
	0.24287279	0.01147062	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2000	1 1	0 0	1 17	17.5 8.52	0.00000000	0.22372714	0.52623066
	0.23738678	0.01265541	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2000	1 1	0 0	1 18	18.5 2.52	0.00000000	0.10780866	0.49898474
	0.35130144	0.04190515	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2000	1 1	0 0	1 19	19.5 0.28	0.00000000	0.00000000	0.57142857
	0.42857143	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2000	1 1	0 0	1 20	20.5 0.20	0.00000000	0.00000000	0.64477748
	0.35522252	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2000	1 1	0 0	1 21	21.5 0.08	0.00000000	0.00000000	0.00000000
	0.00000000	0.50000000	0.50000000	0.00000000	0.00000000	0.00000000	0.00000000
2000	1 1	0 0	1 23	23.5 0.04	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 9	9.5 0.28	1.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 10	10.5 2.00	1.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 11	11.5 3.44	0.98962726	0.01037274	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 12	12.5 1.52	0.95694052	0.04305948	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 13	13.5 1.12	1.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 14	14.5 0.12	1.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 15	15.5 0.72	0.00000000	0.94144234	0.05855766
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 16	16.5 2.52	0.00000000	0.93072865	0.04908709
	0.01009213	0.01009213	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 17	17.5 4.32	0.00000000	0.65761214	0.28043072
	0.04490983	0.01704730	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 18	18.5 3.48	0.00000000	0.52059262	0.35201836
	0.11348088	0.01390813	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 19	19.5 1.32	0.00000000	0.09566902	0.28511142
	0.57373618	0.04548338	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 20	20.5 2.20	0.00000000	0.08098452	0.09414834
	0.69451401	0.11021743	0.02013571	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 21	21.5 6.68	0.00000000	0.01097761	0.04893767
	0.69266867	0.21654653	0.03086952	0.00000000	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 22	22.5 4.56	0.00000000	0.01013073	0.06708930
	0.56915583	0.26557073	0.06115037	0.01677232	0.01013073	0.00000000	0.00000000
2001	1 1	0 0	1 23	23.5 1.80	0.00000000	0.00000000	0.02801048
	0.19328092	0.36134382	0.26859609	0.12075821	0.02801048	0.00000000	0.00000000
2001	1 1	0 0	1 24	24.5 0.96	0.00000000	0.00000000	0.00000000
	0.08790503	0.40295158	0.47433427	0.03480912	0.00000000	0.00000000	0.00000000
2001	1 1	0 0	1 25	25.5 0.20	0.00000000	0.00000000	0.00000000
	0.00000000	0.15206736	0.46391019	0.15206736	0.23195510	0.00000000	0.00000000
2002	1 1	0 0	1 11	11.5 0.04	1.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2002	1 1	0 0	1 13	13.5 0.64	0.34819315	0.65180685	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2002	1 1	0 0	1 14	14.5 2.16	0.19080057	0.74295168	0.06624776
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2002	1 1	0 0	1 15	15.5 6.08	0.18228648	0.74492089	0.07279263
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2002	1 1	0 0	1 16	16.5 8.64	0.26111752	0.60128336	0.11432186
	0.02327725	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2002	1 1	0 0	1 17	17.5 7.48	0.12851185	0.43163453	0.41302223
	0.02683138	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2002	1 1	0 0	1 18	18.5 3.24	0.10308813	0.30784160	0.40739980
	0.16097894	0.02069153	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2002	1 1	0 0	1 19	19.5 1.12	0.00000000	0.22094657	0.54446895
	0.10340392	0.13118056	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2002	1 1	0 0	1 20	20.5 0.44	0.00000000	0.24521992	0.42641430
	0.16884672	0.15951906	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2002	1 1	0 0	1 21	21.5 0.20	0.00000000	0.41949119	0.11978151
	0.29970968	0.16101762	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2002	1 1	0 0	1 22	22.5 0.24	0.00000000	0.00000000	0.10316942
	0.13868663	0.61945732	0.13868663	0.00000000	0.00000000	0.00000000	0.00000000
2002	1 1	0 0	1 24	24.5 0.04	0.00000000	0.00000000	0.00000000
	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2003	1 1	0 0	1 9	9.5 0.08	1.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

2003	1	1	0	0	1	10	10.5	0.84	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2003	1	1	0	0	1	11	11.5	3.72	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2003	1	1	0	0	1	12	12.5	2.52	0.98245740	0.01754260	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2003	1	1	0	0	1	13	13.5	1.24	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2003	1	1	0	0	1	14	14.5	0.44	0.48294759	0.51705241	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2003	1	1	0	0	1	15	15.5	0.52	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2003	1	1	0	0	1	16	16.5	1.52	0.00000000	0.88536046	0.11463954	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2003	1	1	0	0	1	17	17.5	3.36	0.00000000	0.54652359	0.45347641	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2003	1	1	0	0	1	18	18.5	2.40	0.00000000	0.31560192	0.66200264	0.02239544	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2003	1	1	0	0	1	19	19.5	0.72	0.00000000	0.00000000	0.97348824	0.02651176	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2003	1	1	0	0	1	20	20.5	0.36	0.00000000	0.09488687	0.28466061	0.43351017	0.18694235	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2003	1	1	0	0	1	21	21.5	0.04	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	10	10.5	0.04	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	11	11.5	0.12	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	12	12.5	0.32	0.26982236	0.73017764	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	13	13.5	0.60	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	14	14.5	6.08	0.00188560	0.99391267	0.00420173	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	15	15.5	13.64	0.00000000	0.97925637	0.01732336	0.00000000	0.00342027	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	16	16.5	8.20	0.00505216	0.86811527	0.11755742	0.00927515	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	17	17.5	3.32	0.00000000	0.85656519	0.11887042	0.00558631	0.01897807	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	18	18.5	0.76	0.00000000	0.39684213	0.49701007	0.00000000	0.10614780	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	19	19.5	0.28	0.00000000	0.38960446	0.25214348	0.35825205	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	20	20.5	0.08	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	22	22.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000
2004	1	1	0	0	1	24	24.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000
2005	1	1	0	0	1	10	10.5	0.08	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	1	1	0	0	1	11	11.5	1.00	0.60000000	0.40000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	1	1	0	0	1	12	12.5	1.48	0.66372335	0.33627665	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	1	1	0	0	1	13	13.5	4.92	0.23073098	0.62970257	0.13956644	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	1	1	0	0	1	14	14.5	8.84	0.18573131	0.63240199	0.18186670	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	1	1	0	0	1	15	15.5	5.60	0.04064125	0.33093795	0.62373605	0.00468476	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	1	1	0	0	1	16	16.5	6.80	0.00000000	0.06282689	0.91934231	0.01783080	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	1	1	0	0	1	17	17.5	4.32	0.00000000	0.05576095	0.83201279	0.11222627	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	1	1	0	0	1	18	18.5	1.12	0.00000000	0.00000000	0.82757016	0.17242984	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	1	1	0	0	1	19	19.5	0.72	0.00000000	0.00000000	0.74964298	0.22394597	0.02641105	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	1	1	0	0	1	20	20.5	0.08	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	1	1	0	0	1	21	21.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

2005	1	1	0	0	1	22	22.5 0.08	0.00000000	0.00000000
	0.00000000	0.00000000	0.50000000	0.50000000	0.00000000	0.00000000	0.00000000	0.00000000	
2005	1	1	0	0	1	23	23.5 0.04	0.00000000	0.00000000
	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2005	1	1	0	0	1	24	24.5 0.12	0.00000000	0.00000000
	0.00000000	0.00000000	0.65509203	0.17245399	0.17245399	0.00000000	0.00000000	0.00000000	
2006	1	1	0	0	1	12	12.5 0.64	0.00969274	0.82381022
	0.16649704	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2006	1	1	0	0	1	13	13.5 2.12	0.12950784	0.85495467
	0.01553749	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2006	1	1	0	0	1	14	14.5 11.92	0.01372349	0.94883032
	0.03744619	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2006	1	1	0	0	1	15	15.5 24.12	0.00827923	0.88315188
	0.10720699	0.00136190	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2006	1	1	0	0	1	16	16.5 17.08	0.00617434	0.64052788
	0.33200330	0.02129448	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2006	1	1	0	0	1	17	17.5 9.12	0.00634360	0.22254651
	0.68627996	0.08482992	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2006	1	1	0	0	1	18	18.5 3.56	0.00000000	0.01820135
	0.73249892	0.24929974	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2006	1	1	0	0	1	19	19.5 0.88	0.00000000	0.00000000
	0.59828848	0.40171152	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2006	1	1	0	0	1	20	20.5 0.20	0.00000000	0.00000000
	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2006	1	1	0	0	1	21	21.5 0.08	0.00000000	0.00000000
	0.50000000	0.50000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2006	1	1	0	0	1	22	22.5 0.04	0.00000000	0.00000000
	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	10	10.5 0.08	1.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	11	11.5 0.56	0.85714286	0.14285714
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	12	12.5 0.80	0.87626801	0.12373199
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	13	13.5 2.68	0.40483739	0.55358268
	0.04157993	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	14	14.5 5.68	0.01803592	0.75380995
	0.20726697	0.02088716	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	15	15.5 14.56	0.00387012	0.34648381
	0.62501079	0.02463528	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	16	16.5 28.80	0.00028385	0.09330496
	0.77807930	0.12710868	0.00122320	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	17	17.5 23.16	0.00281026	0.04058452
	0.66877144	0.26920715	0.01862662	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	18	18.5 7.36	0.00000000	0.01236885
	0.59949472	0.35606275	0.03207368	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	19	19.5 1.84	0.00000000	0.00000000
	0.18710923	0.78336207	0.02952870	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	20	20.5 0.40	0.00000000	0.00000000
	0.24239178	0.66239470	0.09521352	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	21	21.5 0.04	0.00000000	0.00000000
	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2007	1	1	0	0	2	22	22.5 0.04	0.00000000	0.00000000
	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2008	1	1	0	0	3	12	12.5 0.56	1.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2008	1	1	0	0	3	13	13.5 0.52	1.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2008	1	1	0	0	3	14	14.5 0.12	1.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2008	1	1	0	0	3	15	15.5 1.60	0.00000000	0.72257965
	0.27742035	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2008	1	1	0	0	3	16	16.5 10.08	0.01437160	0.40213365
	0.57334683	0.01014792	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2008	1	1	0	0	3	17	17.5 10.40	0.01495756	0.20893843
	0.71709879	0.05900522	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2008	1	1	0	0	3	18	18.5 5.12	0.01158259	0.19549447
	0.70461698	0.08830597	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2008	1	1	0	0	3	19	19.5 1.36	0.00000000	0.19981464
	0.49211465	0.25835350	0.04971721	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2008	1	1	0	0	3	20	20.5 0.60	0.00000000	0.00000000
	0.21969054	0.58469349	0.19561597	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2008	1	1	0	0	3	21	21.5 0.36	0.00000000	0.00000000
	0.11111111	0.55555556	0.33333333	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	

2008	1	1	0	0	3	22	22.5	0.08	0.00000000	0.00000000	0.19646010	0.00000000	0.80353990	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	1	1	0	0	3	23	23.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	1	1	0	0	3	14	14.5	0.56	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	1	1	0	0	3	15	15.5	1.08	0.05215629	0.84353112	0.10431259	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	1	1	0	0	3	16	16.5	4.44	0.00000000	0.47928776	0.50836509	0.01234715	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	1	1	0	0	3	17	17.5	12.64	0.00296329	0.13276991	0.72454418	0.12490618	0.01481644	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	1	1	0	0	3	18	18.5	4.00	0.00000000	0.02948402	0.60770512	0.33461294	0.02819793	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	1	1	0	0	3	19	19.5	0.16	0.00000000	0.00000000	0.25073428	0.74926572	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	1	1	0	0	4	13	13.5	0.04	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	1	1	0	0	4	14	14.5	0.28	0.14285714	0.85714286	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	1	1	0	0	4	15	15.5	5.28	0.01515152	0.86363636	0.12121212	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	1	1	0	0	4	16	16.5	6.36	0.01257862	0.77358491	0.19496855	0.01886792	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	1	1	0	0	4	17	17.5	0.52	0.00000000	0.53846154	0.38461538	0.07692308	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	1	1	0	0	4	18	18.5	0.08	0.00000000	0.00000000	0.50000000	0.50000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	1	1	0	0	4	19	19.5	0.12	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	1	1	0	0	4	15	15.5	0.08	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	1	1	0	0	4	16	16.5	1.96	0.00000000	0.55600263	0.32620509	0.11779228	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	1	1	0	0	4	17	17.5	12.36	0.00000000	0.33958915	0.50120495	0.15920590	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	1	1	0	0	4	18	18.5	6.60	0.00000000	0.12877487	0.50542429	0.35157075	0.01423009	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	1	1	0	0	4	19	19.5	0.60	0.00000000	0.00000000	0.33656921	0.62603421	0.03739658	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	1	1	0	0	4	21	21.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2012	1	1	0	0	4	14	14.5	0.48	0.08333333	0.91666667	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2012	1	1	0	0	4	15	15.5	0.48	0.00000000	0.83333333	0.16666667	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2012	1	1	0	0	4	16	16.5	0.16	0.00000000	0.50000000	0.50000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2012	1	1	0	0	4	17	17.5	1.76	0.00000000	0.12388536	0.70653509	0.16957955	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2012	1	1	0	0	4	18	18.5	5.92	0.00000000	0.03878870	0.67166629	0.27666426	0.01288075	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2012	1	1	0	0	4	19	19.5	6.60	0.00000000	0.00093824	0.53772555	0.44589212	0.01544409	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2012	1	1	0	0	4	20	20.5	4.92	0.00000000	0.00000000	0.20675044	0.59305156	0.16229851	0.03789949	0.00000000	0.00000000	0.00000000	0.00000000
2012	1	1	0	0	4	21	21.5	1.80	0.00000000	0.00000000	0.02764022	0.66790505	0.22153409	0.00000000	0.08292065	0.00000000	0.00000000	0.00000000
2012	1	1	0	0	4	22	22.5	0.16	0.00000000	0.00000000	0.00000000	0.00000000	0.55727171	0.44272829	0.00000000	0.00000000	0.00000000	0.00000000
2012	1	1	0	0	4	23	23.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	13	13.5	0.20	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	14	14.5	1.36	0.97070472	0.02929528	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	15	15.5	2.12	0.87662406	0.12337594	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	16	16.5	5.36	0.38724536	0.51316166	0.09959298	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	17	17.5	9.44	0.07213542	0.61158283	0.29388355	0.01953423	0.00286397	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	18	18.5	6.28	0.01233362	0.40889523	0.55275049	0.02602066	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

1993	2	2	0	0	1	19	19.5	2.64	0.00000000	0.10547058	0.68579430	0.14425622	0.02149297	0.02149297	0.02149297	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	20	20.5	1.04	0.00000000	0.06147662	0.42885278	0.41036671	0.05459334	0.04471056	0.00000000	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	21	21.5	0.56	0.00000000	0.00000000	0.24819545	0.54255200	0.20925255	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	22	22.5	0.52	0.00000000	0.00000000	0.19223104	0.33136029	0.26109730	0.07177046	0.14354091	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	23	23.5	0.52	0.00000000	0.00000000	0.12733396	0.27876739	0.42428329	0.16961536	0.00000000	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	24	24.5	0.16	0.00000000	0.00000000	0.00000000	0.40563177	0.59436823	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	25	25.5	0.20	0.00000000	0.00000000	0.00000000	0.26700525	0.00000000	0.46598950	0.26700525	0.00000000	0.00000000	0.00000000
1993	2	2	0	0	1	26	26.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	11	11.5	0.72	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	12	12.5	1.88	0.98302973	0.01697027	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	13	13.5	6.64	0.86880561	0.12761125	0.00358315	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	14	14.5	15.00	0.87264589	0.12512599	0.00222812	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	15	15.5	23.80	0.64265504	0.33692582	0.01875050	0.00166863	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	16	16.5	31.56	0.23602009	0.70894433	0.04969618	0.00367082	0.00000000	0.00166858	0.00000000	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	17	17.5	23.40	0.08662464	0.67844162	0.16526082	0.06184184	0.00783109	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	18	18.5	11.84	0.04546867	0.40515272	0.33567341	0.19105666	0.02083700	0.00181155	0.00000000	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	19	19.5	4.60	0.01420067	0.14104731	0.44919582	0.32473849	0.06329571	0.00752201	0.00000000	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	20	20.5	1.08	0.00000000	0.11300204	0.44817926	0.43881870	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	21	21.5	0.36	0.00000000	0.16665558	0.23680924	0.41616224	0.07015366	0.00000000	0.11021929	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	23	23.5	0.04	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1994	2	2	0	0	1	24	24.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	12	12.5	0.44	0.71231509	0.28768491	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	13	13.5	2.68	0.59996788	0.37064073	0.02939139	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	14	14.5	4.80	0.73717939	0.24782276	0.01499785	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	15	15.5	10.08	0.50967566	0.31351836	0.17303392	0.00377205	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	16	16.5	16.44	0.23707804	0.48564470	0.25976314	0.01751411	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	17	17.5	14.76	0.04581167	0.53108806	0.39150329	0.03044360	0.00000000	0.00115339	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	18	18.5	7.20	0.01242179	0.52624193	0.41951324	0.04182304	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	19	19.5	1.76	0.00000000	0.46335195	0.48609034	0.03570396	0.01485375	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	20	20.5	0.32	0.00000000	0.08174470	0.66468272	0.00000000	0.25357259	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	21	21.5	0.24	0.00000000	0.00000000	0.29285599	0.51848817	0.18865585	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	22	22.5	0.04	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	23	23.5	0.04	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1995	2	2	0	0	1	25	25.5	0.04	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	10	10.5	0.40	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	11	11.5	0.60	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	12	12.5	1.60	0.80975028	0.16683245	0.02341728	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

1996	2	2	0	0	1	13	13.5	5.96	0.73478866	0.24312398	0.02208736
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	14	14.5	8.12	0.46518847	0.51089433	0.02391719
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	15	15.5	6.24	0.41849666	0.54255775	0.03894559
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	16	16.5	3.76	0.08756362	0.56516625	0.31965063
	0.02761951		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	17	17.5	5.36	0.00000000	0.50925012	0.41255772
	0.07819215		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	18	18.5	5.60	0.00000000	0.18027972	0.73786000
	0.08186028		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	19	19.5	5.56	0.00797248	0.09130891	0.65341448
	0.21119852		0.00797248		0.02813313		0.00000000		0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	20	20.5	1.88	0.00000000	0.04190018	0.78996467
	0.14355012		0.00000000		0.02458503		0.00000000		0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	21	21.5	0.56	0.00000000	0.06665516	0.66672422
	0.19996547		0.06665516		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	22	22.5	0.24	0.00000000	0.20026673	0.31989331
	0.31989331		0.15994665		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1996	2	2	0	0	1	25	25.5	0.04	0.00000000	0.00000000	0.00000000
	0.00000000		1.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	9	9.5	0.08	1.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	10	10.5	0.88	0.95240426	0.04759574	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	11	11.5	1.40	1.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	12	12.5	1.08	0.91020233	0.08979767	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	13	13.5	2.48	0.76619269	0.23380731	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	14	14.5	2.80	0.51770442	0.46377638	0.01851919
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	15	15.5	4.40	0.11696030	0.83583819	0.04620143
	0.00100008		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	16	16.5	5.40	0.00086050	0.87069252	0.12844699
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	17	17.5	4.48	0.02019942	0.75406485	0.19363098
	0.02872855		0.00337619		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	18	18.5	3.88	0.05477172	0.47661077	0.43935640
	0.02926111		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	19	19.5	3.48	0.02384269	0.09743413	0.41598185
	0.33822133		0.11611399		0.00840601		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	20	20.5	6.56	0.00000000	0.01314396	0.37161014
	0.43608829		0.17341751		0.00574010		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	21	21.5	6.20	0.00000000	0.01452790	0.19985641
	0.56258895		0.18587032		0.03715641		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	22	22.5	3.36	0.00000000	0.02844437	0.22226700
	0.42427703		0.23657884		0.05998839		0.02844437		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	23	23.5	0.80	0.00000000	0.00000000	0.00000000
	0.29555010		0.55667486		0.02630317		0.12147188		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	24	24.5	0.12	0.00000000	0.00000000	0.00000000
	0.00000000		0.89581040		0.00000000		0.10418960		0.00000000	0.00000000	0.00000000
1997	2	2	0	0	1	25	25.5	0.04	0.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		1.00000000		0.00000000	0.00000000	0.00000000
1998	2	2	0	0	1	9	9.5	0.08	1.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1998	2	2	0	0	1	10	10.5	1.00	0.93302808	0.06697192	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1998	2	2	0	0	1	11	11.5	2.76	0.93937164	0.06062836	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1998	2	2	0	0	1	12	12.5	7.20	0.70798306	0.27701796	0.01499898
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1998	2	2	0	0	1	13	13.5	11.32	0.45328775	0.48748534	0.05922691
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1998	2	2	0	0	1	14	14.5	14.92	0.25039999	0.70896504	0.04063497
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1998	2	2	0	0	1	15	15.5	12.56	0.10807270	0.74316709	0.14876021
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1998	2	2	0	0	1	16	16.5	8.56	0.03179538	0.53952165	0.41540227
	0.01328071		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1998	2	2	0	0	1	17	17.5	6.92	0.02123072	0.29925113	0.67254621
	0.00697193		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000

1998	2	2	0	0	1	18	18.5	3.08	0.03216085	0.18604913	0.69226176	0.08952826	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
1998	2	2	0	0	1	19	19.5	2.56	0.01770014	0.15680268	0.53573909	0.21011342	0.06194454	0.01770014	0.00000000	0.00000000	0.00000000	0.00000000	
1998	2	2	0	0	1	20	20.5	0.76	0.00000000	0.12209916	0.12209916	0.55328948	0.15824033	0.04427187	0.00000000	0.00000000	0.00000000	0.00000000	
1998	2	2	0	0	1	21	21.5	0.56	0.00000000	0.18419311	0.00000000	0.32230705	0.36957328	0.12392657	0.00000000	0.00000000	0.00000000	0.00000000	
1998	2	2	0	0	1	22	22.5	0.12	0.00000000	0.34126400	0.31747200	0.00000000	0.34126400	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
1998	2	2	0	0	1	23	23.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
1998	2	2	0	0	1	24	24.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
1999	2	2	0	0	1	12	12.5	0.20	0.40000000	0.60000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
1999	2	2	0	0	1	13	13.5	4.96	0.32014309	0.59185826	0.07961241	0.00838624	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
1999	2	2	0	0	1	14	14.5	14.76	0.38169092	0.53787963	0.05824497	0.01109225	0.00792438	0.00316786	0.00000000	0.00000000	0.00000000	0.00000000	
1999	2	2	0	0	1	15	15.5	20.56	0.29216020	0.50155986	0.18149188	0.01622977	0.00855830	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
1999	2	2	0	0	1	16	16.5	11.52	0.09831156	0.50838282	0.36209246	0.02387339	0.00733978	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
1999	2	2	0	0	1	17	17.5	2.32	0.01043611	0.49352601	0.39132747	0.09949235	0.00521806	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
1999	2	2	0	0	1	18	18.5	0.76	0.00000000	0.26746419	0.71685887	0.01567694	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
1999	2	2	0	0	1	19	19.5	0.16	0.00000000	0.07997843	0.92002157	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
1999	2	2	0	0	1	20	20.5	0.08	0.00000000	0.00000000	0.75037064	0.00000000	0.00000000	0.00000000	0.24962936	0.00000000	0.00000000	0.00000000	
2000	2	2	0	0	1	11	11.5	0.72	0.74752075	0.25247925	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2000	2	2	0	0	1	12	12.5	2.28	0.69582437	0.27982735	0.00000000	0.02434828	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2000	2	2	0	0	1	13	13.5	5.76	0.54811614	0.38124029	0.06174778	0.00889578	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2000	2	2	0	0	1	14	14.5	11.24	0.40848094	0.55352931	0.03355320	0.00443655	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2000	2	2	0	0	1	15	15.5	9.52	0.42979540	0.45185267	0.10229483	0.01605710	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2000	2	2	0	0	1	16	16.5	5.08	0.01642085	0.19905252	0.60775348	0.13866829	0.03810485	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2000	2	2	0	0	1	17	17.5	7.80	0.00000000	0.27828201	0.59017585	0.11411492	0.01742722	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2000	2	2	0	0	1	18	18.5	4.36	0.00000000	0.28601716	0.57222152	0.11953874	0.02222258	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2000	2	2	0	0	1	19	19.5	0.92	0.00000000	0.14449116	0.48172259	0.31375949	0.06002676	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2000	2	2	0	0	1	20	20.5	0.24	0.00000000	0.00000000	0.08261869	0.91738131	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2000	2	2	0	0	1	22	22.5	0.12	0.00000000	0.00000000	0.00000000	0.91738131	0.00000000	0.00000000	0.00000000	0.08261869	0.00000000	0.00000000	
2001	2	2	0	0	1	10	10.5	2.00	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2001	2	2	0	0	1	11	11.5	7.60	0.97427376	0.02572624	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2001	2	2	0	0	1	12	12.5	14.40	0.92240780	0.07443303	0.00000000	0.00315917	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2001	2	2	0	0	1	13	13.5	16.48	0.90627331	0.08890553	0.00482116	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2001	2	2	0	0	1	14	14.5	10.28	0.70552085	0.25611000	0.03357300	0.00479614	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2001	2	2	0	0	1	15	15.5	8.20	0.39784787	0.47685263	0.12242888	0.00287063	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2001	2	2	0	0	1	16	16.5	3.28	0.13467477	0.63572470	0.22298713	0.00661341	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2001	2	2	0	0	1	17	17.5	2.72	0.01132070	0.51465616	0.37410852	0.07508872	0.02482590	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2001	2	2	0	0	1	18	18.5	2.96	0.00000000	0.29324400	0.54354648	0.13118093	0.03202859	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2001	2	2	0	0	1	19	19.5	1.24	0.00000000	0.09918852	0.59034994	0.31046154	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	

2001	2	2	0	0	1	20	20.5	1.24	0.00000000	0.00000000	0.51528889
	0.37935414		0.07775853		0.02759844		0.00000000		0.00000000	0.00000000	0.00000000
2001	2	2	0	0	1	21	21.5	0.52	0.00000000	0.00000000	0.09031628
	0.63873488		0.09031628		0.18063256		0.00000000		0.00000000	0.00000000	0.00000000
2001	2	2	0	0	1	22	22.5	0.08	0.00000000	0.00000000	0.00000000
	0.50000000		0.50000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2001	2	2	0	0	1	24	24.5	0.04	0.00000000	0.00000000	0.00000000
	0.00000000		1.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	10	10.5	0.04	1.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	11	11.5	0.32	1.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	12	12.5	0.60	0.94090193	0.05909807	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	13	13.5	1.16	0.88345627	0.11654373	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	14	14.5	2.88	0.48918927	0.44747715	0.06333357
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	15	15.5	13.12	0.31065759	0.63716391	0.04841090
	0.00376759		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	16	16.5	23.64	0.16463876	0.70856009	0.12022830
	0.00632938		0.00000000		0.00000000		0.00000000		0.00000000	0.00024347	0.00000000
2002	2	2	0	0	1	17	17.5	21.24	0.11234893	0.62532418	0.22200514
	0.03331450		0.00700723		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	18	18.5	6.84	0.05496442	0.48012677	0.34689512
	0.10915720		0.00885649		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	19	19.5	3.96	0.00000000	0.21147060	0.47842753
	0.26219346		0.04790841		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	20	20.5	1.80	0.00000000	0.03922441	0.48545390
	0.36552610		0.10979558		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	21	21.5	0.40	0.00000000	0.00000000	0.49698361
	0.18994586		0.17934508		0.13372545		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	22	22.5	0.24	0.00000000	0.00000000	0.00000000
	0.27921688		0.22613844		0.49464468		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	23	23.5	0.20	0.00000000	0.00000000	0.00000000
	0.05517708		0.05517708		0.88964584		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	2	0	0	1	24	24.5	0.04	0.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		1.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	10	10.5	0.52	1.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	11	11.5	7.40	1.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	12	12.5	11.16	1.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	13	13.5	26.04	0.99216013	0.00783987	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	14	14.5	15.40	0.97074099	0.02925901	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	15	15.5	3.96	0.76533365	0.21262370	0.02204265
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	16	16.5	1.24	0.08207484	0.51377819	0.40414697
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	17	17.5	1.24	0.03396623	0.34689388	0.57761967
	0.04152022		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	18	18.5	2.64	0.00000000	0.00000000	0.74075755
	0.23570895		0.02353350		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	19	19.5	2.20	0.00000000	0.05383938	0.46209001
	0.42658630		0.04311323		0.01437108		0.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	20	20.5	0.64	0.00000000	0.00000000	0.28011714
	0.46931240		0.19601734		0.05455312		0.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	21	21.5	0.64	0.06615850	0.00000000	0.18886008
	0.42216843		0.27713679		0.04567620		0.00000000		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	22	22.5	0.60	0.00000000	0.00000000	0.00000000
	0.25966959		0.36244571		0.31296731		0.06491740		0.00000000	0.00000000	0.00000000
2003	2	2	0	0	1	23	23.5	0.52	0.00000000	0.00000000	0.00000000
	0.00000000		0.69230769		0.07692308		0.15384615		0.07692308	0.00000000	0.00000000
2003	2	2	0	0	1	24	24.5	0.40	0.00000000	0.00000000	0.00000000
	0.10000000		0.30000000		0.00000000		0.50000000		0.10000000	0.00000000	0.00000000
2003	2	2	0	0	1	25	25.5	0.04	0.00000000	0.00000000	0.00000000
	0.00000000		1.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2004	2	2	0	0	1	11	11.5	0.20	1.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2004	2	2	0	0	1	12	12.5	0.84	0.67276468	0.32723532	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000

2004	2 2	0 0	1 13	13.5 4.20	0.17333774	0.82666226	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	2 2	0 0	1 14	14.5 14.12	0.01354159	0.98015485	0.00630357
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	2 2	0 0	1 15	15.5 18.92	0.02407765	0.96462996	0.01129239
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	2 2	0 0	1 16	16.5 13.52	0.02694741	0.88209742	0.09095517
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	2 2	0 0	1 17	17.5 4.36	0.00662725	0.78340253	0.18912430
	0.02084592	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	2 2	0 0	1 18	18.5 1.84	0.00000000	0.22342592	0.66408266
	0.11249141	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	2 2	0 0	1 19	19.5 0.72	0.00000000	0.00000000	0.76369562
	0.23630438	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	2 2	0 0	1 20	20.5 0.16	0.00000000	0.00000000	0.62830617
	0.37169383	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	2 2	0 0	1 21	21.5 0.12	0.00000000	0.00000000	0.28697889
	0.00000000	0.71302111	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	2 2	0 0	1 22	22.5 0.12	0.00000000	0.00000000	0.00000000
	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2004	2 2	0 0	1 23	23.5 0.04	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 9	9.5 0.24	1.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 10	10.5 2.72	0.94665661	0.05334339	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 11	11.5 10.68	0.96530636	0.03469364	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 12	12.5 10.36	0.81270629	0.18729371	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 13	13.5 17.28	0.59682376	0.38056749	0.02260874
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 14	14.5 17.12	0.41831331	0.53139427	0.05029242
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 15	15.5 14.80	0.39763833	0.44064831	0.16171335
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 16	16.5 6.76	0.20647100	0.39320685	0.38209007
	0.01823208	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 17	17.5 4.00	0.00145799	0.22876657	0.64096402
	0.10121078	0.02760064	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 18	18.5 2.28	0.00000000	0.13419048	0.65656358
	0.12972242	0.07952352	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 19	19.5 1.72	0.00000000	0.19742790	0.58505873
	0.21751337	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 20	20.5 0.40	0.00000000	0.15374970	0.18538703
	0.35336388	0.15374970	0.15374970	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 21	21.5 0.12	0.00000000	0.00000000	0.15765441
	0.84234559	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2005	2 2	0 0	1 23	23.5 0.16	0.00000000	0.00000000	0.00000000
	0.00000000	0.03208177	0.32263941	0.32263941	0.00000000	0.32263941	0.00000000
2005	2 2	0 0	1 24	24.5 0.32	0.00000000	0.00000000	0.16131970
	0.00000000	0.00000000	0.16131970	0.19340148	0.32263941	0.16131970	0.00000000
2005	2 2	0 0	1 25	25.5 0.08	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.50000000	0.50000000	0.00000000	0.00000000	0.00000000
2006	2 2	0 0	1 10	10.5 0.04	1.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2006	2 2	0 0	1 11	11.5 0.96	1.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2006	2 2	0 0	1 12	12.5 2.88	0.99618629	0.00381371	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2006	2 2	0 0	1 13	13.5 6.12	0.77428590	0.22571410	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2006	2 2	0 0	1 14	14.5 16.36	0.36825533	0.63118455	0.00056011
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2006	2 2	0 0	1 15	15.5 25.96	0.10019307	0.88164250	0.01816443
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2006	2 2	0 0	1 16	16.5 20.96	0.06804923	0.84951026	0.08244051
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2006	2 2	0 0	1 17	17.5 13.92	0.01400216	0.43528504	0.53121210
	0.01950069	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2006	2 2	0 0	1 18	18.5 9.92	0.00000000	0.10728396	0.77280768
	0.11990836	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2006	2 2	0 0	1 19	19.5 5.56	0.00000000	0.06548736	0.77827275
	0.15623989	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

2006	2	2	0	0	1	20	20.5	2.12	0.00000000	0.01675003	0.59447114	0.33123547	0.05754335	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2006	2	2	0	0	1	21	21.5	0.20	0.00000000	0.00000000	0.58224916	0.41775084	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2006	2	2	0	0	1	22	22.5	0.08	0.00000000	0.00000000	0.00000000	0.50000000	0.50000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2006	2	2	0	0	1	23	23.5	0.08	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	10	10.5	0.52	0.81161422	0.18838578	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	11	11.5	3.56	0.81748933	0.16948738	0.01302330	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	12	12.5	7.96	0.80789846	0.18543433	0.00666722	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	13	13.5	13.60	0.58443765	0.40077974	0.01478262	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	14	14.5	12.40	0.35239361	0.57909543	0.06851095	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	15	15.5	8.40	0.13962133	0.67446158	0.18591708	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	16	16.5	5.72	0.04265578	0.60969432	0.34455928	0.00309062	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	17	17.5	4.52	0.13907978	0.44035193	0.35454781	0.06602048	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	18	18.5	3.24	0.00000000	0.25882826	0.41917676	0.32199498	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	19	19.5	1.72	0.13230410	0.04936132	0.24787050	0.54753177	0.02293231	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	20	20.5	2.76	0.10336144	0.05906368	0.25102064	0.48319280	0.10336144	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	21	21.5	2.16	0.01919929	0.09599643	0.17973905	0.56372476	0.11519571	0.02614477	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	22	22.5	0.56	0.07484045	0.07484045	0.10191455	0.44904273	0.22452136	0.07484045	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	23	23.5	0.16	0.00000000	0.00000000	0.00000000	0.75000000	0.25000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	24	24.5	0.08	0.50000000	0.00000000	0.00000000	0.00000000	0.50000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2007	2	2	0	0	2	25	25.5	0.08	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	10	10.5	0.04	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	11	11.5	0.84	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	12	12.5	2.80	0.98557929	0.01442071	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	13	13.5	2.80	0.85459472	0.14540528	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	14	14.5	1.92	0.21852994	0.75404580	0.02742427	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	15	15.5	7.56	0.02649326	0.84675852	0.12433842	0.00240980	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	16	16.5	11.56	0.03125844	0.83304051	0.12357623	0.01212482	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	17	17.5	5.56	0.01343018	0.47528389	0.49238317	0.01890276	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	18	18.5	4.44	0.00380832	0.15793925	0.63661667	0.20163576	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	19	19.5	1.24	0.00000000	0.22595676	0.28517288	0.48887036	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	20	20.5	0.60	0.00000000	0.09286446	0.27321611	0.60214765	0.03177178	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	21	21.5	0.32	0.00000000	0.24674396	0.08441868	0.50000000	0.16883736	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	22	22.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2008	2	2	0	0	3	23	23.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	2	2	0	0	3	10	10.5	0.04	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	2	2	0	0	3	11	11.5	0.40	0.83691728	0.16308272	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	2	2	0	0	3	12	12.5	5.72	0.68145305	0.30663268	0.01191427	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

2009	2	2	0	0	3	13	13.5	22.80	0.68617830	0.30180153	0.01202017	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	2	2	0	0	3	14	14.5	31.00	0.50072394	0.41119099	0.08808506	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	2	2	0	0	3	15	15.5	24.56	0.24486876	0.58373796	0.17103486	0.00035843	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	2	2	0	0	3	16	16.5	10.52	0.06872480	0.66651811	0.25241790	0.01233919	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	2	2	0	0	3	17	17.5	2.20	0.01588792	0.50372935	0.45454300	0.02583974	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	2	2	0	0	3	18	18.5	0.48	0.00000000	0.15610386	0.64984043	0.19405571	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	2	2	0	0	3	19	19.5	0.16	0.00000000	0.00000000	0.35660263	0.05284122	0.59055614	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	2	2	0	0	3	20	20.5	0.12	0.00000000	0.00000000	0.47296513	0.42445713	0.10257774	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	2	2	0	0	3	21	21.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	2	2	0	0	3	22	22.5	0.04	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	10	10.5	0.04	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	11	11.5	0.08	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	12	12.5	1.36	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	13	13.5	4.12	0.97937873	0.02062127	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	14	14.5	7.52	0.67153245	0.32846755	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	15	15.5	6.28	0.34882731	0.65117269	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	16	16.5	1.80	0.07426376	0.88304453	0.04269171	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	17	17.5	0.64	0.00000000	0.66556773	0.24839031	0.08604197	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	18	18.5	0.48	0.00000000	0.36659141	0.51582438	0.11758421	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	19	19.5	0.28	0.00000000	0.14661550	0.14661550	0.41353799	0.14661550	0.14661550	0.00000000	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	20	20.5	1.40	0.00000000	0.00000000	0.08571429	0.37142857	0.42857143	0.08571429	0.02857143	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	21	21.5	3.60	0.00000000	0.00000000	0.03333333	0.15555556	0.40000000	0.40000000	0.01111111	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	22	22.5	2.72	0.00000000	0.00000000	0.00000000	0.04411765	0.33823529	0.58823529	0.02941176	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	23	23.5	0.92	0.00000000	0.00000000	0.00000000	0.00000000	0.08695652	0.65217391	0.21739130	0.00000000	0.04347826	0.00000000
2010	2	2	0	0	4	24	24.5	0.12	0.00000000	0.00000000	0.00000000	0.33333333	0.00000000	0.00000000	0.66666667	0.00000000	0.00000000	0.00000000
2010	2	2	0	0	4	25	25.5	0.04	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000
2011	2	2	0	0	4	11	11.5	0.16	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	2	2	0	0	4	12	12.5	3.48	0.87151784	0.12848216	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	2	2	0	0	4	13	13.5	6.12	0.58895794	0.41104206	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	2	2	0	0	4	14	14.5	5.72	0.31002959	0.66498769	0.02498273	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	2	2	0	0	4	15	15.5	4.40	0.07834036	0.82494300	0.09671665	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	2	2	0	0	4	16	16.5	5.36	0.01103939	0.53018555	0.43864331	0.02013174	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	2	2	0	0	4	17	17.5	6.16	0.01002697	0.40719167	0.56696774	0.01581362	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	2	2	0	0	4	18	18.5	8.72	0.00000000	0.30312009	0.57538979	0.11721027	0.00427985	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	2	2	0	0	4	19	19.5	6.24	0.00000000	0.15416024	0.43440474	0.35481783	0.05159881	0.00501838	0.00000000	0.00000000	0.00000000	0.00000000
2011	2	2	0	0	4	20	20.5	3.20	0.00000000	0.00225041	0.19916413	0.29504166	0.36341325	0.10256523	0.03756533	0.00000000	0.00000000	0.00000000
2011	2	2	0	0	4	21	21.5	2.36	0.00000000	0.00000000	0.02370815	0.15957820	0.11678121	0.34331561	0.32697276	0.02964408	0.00000000	0.00000000

```
2011   2   2   0   0   4   22   22.5   2.28   0.00000000   0.00000000   0.00000000
       0.23982904   0.15442350   0.27219333   0.17317178   0.14299539   0.01738697   0.00000000
2011   2   2   0   0   4   23   23.5   0.56   0.00000000   0.00000000   0.00000000
       0.02066462   0.34328736   0.06199386   0.26923320   0.21010218   0.09471878   0.00000000
2011   2   2   0   0   4   24   24.5   0.12   0.00000000   0.00000000   0.00000000
       0.00000000   0.66666667   0.00000000   0.33333333   0.00000000   0.00000000   0.00000000
2012   2   2   0   0   4   14   14.5   0.04   1.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2012   2   2   0   0   4   15   15.5   0.16   0.00000000   0.75000000   0.25000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2012   2   2   0   0   4   16   16.5   0.36   0.11111111   0.55555556   0.33333333
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2012   2   2   0   0   4   17   17.5   1.20   0.00000000   0.24086491   0.72472581
       0.03440927   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2012   2   2   0   0   4   18   18.5   2.40   0.00000000   0.18265179   0.63037559
       0.18697263   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2012   2   2   0   0   4   19   19.5   1.60   0.00000000   0.09506487   0.73668091
       0.13460337   0.03365084   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2012   2   2   0   0   4   20   20.5   1.48   0.00000000   0.11634427   0.34903280
       0.52873563   0.00588730   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2012   2   2   0   0   4   21   21.5   1.28   0.00000000   0.00887236   0.31640548
       0.44277321   0.23194894   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2012   2   2   0   0   4   22   22.5   0.32   0.00000000   0.00000000   0.06501548
       0.32507740   0.54489164   0.06501548   0.00000000   0.00000000   0.00000000   0.00000000
2012   2   2   0   0   4   23   23.5   0.08   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.50000000   0.50000000   0.00000000   0.00000000   0.00000000
1999   1   3   0   0   5   16   16.5   0.32   0.00000000   0.00000000   1.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
1999   1   3   0   0   5   17   17.5   0.56   0.00000000   0.00000000   1.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
1999   1   3   0   0   5   18   18.5   0.76   0.00000000   0.00000000   0.78519341
       0.21480659   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
1999   1   3   0   0   5   19   19.5   0.28   0.00000000   0.00000000   0.28571429
       0.71428571   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
1999   1   3   0   0   5   20   20.5   0.24   0.00000000   0.00000000   0.00000000
       0.69739439   0.30260561   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
1999   1   3   0   0   5   21   21.5   0.32   0.00000000   0.00000000   0.00000000
       0.25000000   0.37500000   0.37500000   0.00000000   0.00000000   0.00000000   0.00000000
1999   1   3   0   0   5   22   22.5   0.28   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   1.00000000   0.00000000   0.00000000   0.00000000   0.00000000
1999   1   3   0   0   5   23   23.5   0.16   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.69162500   0.30837500   0.00000000   0.00000000   0.00000000
1999   1   3   0   0   5   25   25.5   0.04   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   1.00000000   0.00000000   0.00000000   0.00000000
2000   1   3   0   0   5   16   16.5   0.24   0.00000000   0.00000000   1.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2000   1   3   0   0   5   17   17.5   3.16   0.00000000   0.02971019   0.81568211
       0.15460770   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2000   1   3   0   0   5   18   18.5   6.20   0.00000000   0.01663748   0.69778813
       0.22384006   0.05787131   0.00000000   0.00386302   0.00000000   0.00000000   0.00000000
2000   1   3   0   0   5   19   19.5   7.80   0.00000000   0.01005256   0.26678825
       0.58022529   0.11436740   0.02079638   0.00777013   0.00000000   0.00000000   0.00000000
2000   1   3   0   0   5   20   20.5   12.20   0.00000000   0.00000000   0.12132936
       0.62061646   0.19578829   0.04921868   0.01167967   0.00000000   0.00136755   0.00000000
2000   1   3   0   0   5   21   21.5   18.48   0.00000000   0.00000000   0.07284473
       0.43584726   0.29043133   0.13631424   0.05024663   0.00393816   0.01037764   0.00000000
2000   1   3   0   0   5   22   22.5   13.32   0.00000000   0.00376028   0.04421478
       0.24078300   0.31639225   0.25016788   0.09655734   0.03249653   0.01562794   0.00000000
2000   1   3   0   0   5   23   23.5   4.48   0.00000000   0.00996131   0.02853334
       0.11903465   0.33924029   0.19843023   0.21097310   0.08115465   0.01267242   0.00000000
2000   1   3   0   0   5   24   24.5   0.60   0.00000000   0.08604282   0.00000000
       0.09553265   0.03549035   0.35597674   0.35597674   0.07098070   0.00000000   0.00000000
2000   1   3   0   0   5   25   25.5   0.16   0.00000000   0.00000000   0.00000000
       0.00000000   0.00000000   0.44069022   0.21415281   0.00000000   0.34515697   0.00000000
2001   1   3   0   0   5   13   13.5   0.56   0.00000000   1.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2001   1   3   0   0   5   14   14.5   0.36   0.00000000   0.78526625   0.21473375
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2001   1   3   0   0   5   15   15.5   0.16   0.00000000   1.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2001   1   3   0   0   5   16   16.5   0.04   0.00000000   1.00000000   0.00000000
       0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
2001   1   3   0   0   5   18   18.5   1.12   0.00000000   0.18051209   0.33614455
       0.37483373   0.03610242   0.04280481   0.02960240   0.00000000   0.00000000   0.00000000
```

2001	1 3	0 0	5 19	19.5 8.44	0.00000000	0.01925963	0.21266479	
	0.54224992	0.19662330	0.02920235	0.00000000	0.00000000	0.00000000	0.00000000	
2001	1 3	0 0	5 20	20.5 29.64	0.00000000	0.00422791	0.14436947	
	0.54004602	0.27399952	0.03365278	0.00370430	0.00000000	0.00000000	0.00000000	
2001	1 3	0 0	5 21	21.5 23.96	0.00000000	0.00526833	0.05438869	
	0.44296758	0.35803980	0.09663834	0.02718394	0.01385955	0.00165377	0.00000000	
2001	1 3	0 0	5 22	22.5 11.28	0.00000000	0.00000000	0.02739324	
	0.27709108	0.31245259	0.20449538	0.14091520	0.03370418	0.00394833	0.00000000	
2001	1 3	0 0	5 23	23.5 4.16	0.00000000	0.00000000	0.00000000	
	0.09938270	0.26174016	0.29696200	0.25522179	0.06547067	0.02122267	0.00000000	
2001	1 3	0 0	5 24	24.5 1.36	0.00000000	0.00000000	0.00000000	
	0.00000000	0.11400278	0.29653276	0.41151161	0.11324999	0.06470286	0.00000000	
2001	1 3	0 0	5 25	25.5 0.20	0.00000000	0.00000000	0.00000000	
	0.00000000	0.00000000	0.42632700	0.57367300	0.00000000	0.00000000	0.00000000	
2002	1 3	0 0	5 16	16.5 0.08	0.00000000	0.61079433	0.00000000	
	0.00000000	0.38920567	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2002	1 3	0 0	5 17	17.5 0.20	0.00000000	0.05397122	0.33719811	
	0.60883067	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2002	1 3	0 0	5 18	18.5 0.96	0.00000000	0.36692199	0.47794134	
	0.13307801	0.01102933	0.01102933	0.00000000	0.00000000	0.00000000	0.00000000	
2002	1 3	0 0	5 19	19.5 1.48	0.00000000	0.08124207	0.44744620	
	0.37831800	0.00351850	0.06096807	0.00000000	0.02850716	0.00000000	0.00000000	
2002	1 3	0 0	5 20	20.5 5.72	0.00000000	0.00096806	0.16028495	
	0.29077515	0.43336995	0.08898633	0.00974430	0.01587127	0.00000000	0.00000000	
2002	1 3	0 0	5 21	21.5 36.20	0.00000000	0.00138445	0.03422952	
	0.20205619	0.45716363	0.23106171	0.05486628	0.01522131	0.00401691	0.00000000	
2002	1 3	0 0	5 22	22.5 40.68	0.00000000	0.00120007	0.00769523	
	0.10957576	0.40541534	0.26660646	0.13228271	0.05251317	0.02390997	0.00080130	
2002	1 3	0 0	5 23	23.5 18.56	0.00000000	0.00027504	0.00304354	
	0.07014138	0.23002191	0.30895891	0.22516891	0.11658483	0.04580547	0.00000000	
2002	1 3	0 0	5 24	24.5 5.08	0.00000000	0.00000000	0.00000000	
	0.03031816	0.15396709	0.22605776	0.19593474	0.18364555	0.20308000	0.00699671	
2002	1 3	0 0	5 25	25.5 1.08	0.00000000	0.00000000	0.00000000	
	0.00000000	0.03411823	0.03411823	0.29486547	0.38081541	0.22892806	0.02715461	
2002	1 3	0 0	5 26	26.5 0.28	0.00000000	0.00000000	0.00000000	
	0.00000000	0.00000000	0.00000000	0.00000000	0.40176012	0.59823988	0.00000000	
2003	1 3	0 0	5 13	13.5 0.04	0.00000000	0.00000000	1.00000000	
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2003	1 3	0 0	5 14	14.5 0.64	0.00000000	0.29858794	0.70141206	
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2003	1 3	0 0	5 15	15.5 0.32	0.00000000	0.62500000	0.25000000	
	0.12500000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2003	1 3	0 0	5 16	16.5 0.04	0.00000000	0.00000000	0.00000000	
	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2003	1 3	0 0	5 17	17.5 1.72	0.00000000	0.02889942	0.59388085	
	0.29995467	0.07726506	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2003	1 3	0 0	5 18	18.5 6.04	0.00000000	0.04616067	0.48016399	
	0.39541506	0.05770611	0.02055418	0.00000000	0.00000000	0.00000000	0.00000000	
2003	1 3	0 0	5 19	19.5 8.72	0.00000000	0.04256105	0.42806829	
	0.36049142	0.09471140	0.04309680	0.02116158	0.00990946	0.00000000	0.00000000	
2003	1 3	0 0	5 20	20.5 10.76	0.00000000	0.01717435	0.29797333	
	0.31388290	0.13396080	0.11909415	0.05801165	0.05330316	0.00659966	0.00000000	
2003	1 3	0 0	5 21	21.5 13.28	0.00000000	0.00954035	0.17388138	
	0.21066376	0.16657500	0.20443594	0.15382384	0.05487022	0.02620950	0.00000000	
2003	1 3	0 0	5 22	22.5 24.52	0.00000000	0.00433987	0.02139465	
	0.05261511	0.10155919	0.29939187	0.26100100	0.14053818	0.11045425	0.00870587	
2003	1 3	0 0	5 23	23.5 17.40	0.00000000	0.00000000	0.00580201	
	0.03805724	0.09739760	0.22253494	0.22808285	0.19974443	0.18466718	0.02371374	
2003	1 3	0 0	5 24	24.5 6.56	0.00000000	0.00900865	0.00193705	
	0.00576173	0.04555107	0.15018181	0.20368581	0.12017707	0.38184532	0.08185148	
2003	1 3	0 0	5 25	25.5 1.92	0.00000000	0.00000000	0.00000000	
	0.03311641	0.05115135	0.14950034	0.27774722	0.13268709	0.34825686	0.00754073	
2003	1 3	0 0	5 26	26.5 0.32	0.00000000	0.00000000	0.00000000	
	0.04130292	0.00000000	0.00000000	0.00000000	0.08260584	0.87609124	0.00000000	
2003	1 3	0 0	5 27	27.5 0.04	0.00000000	0.00000000	0.00000000	
	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2004	1 3	0 0	5 11	11.5 0.04	0.00000000	0.00000000	1.00000000	
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2004	1 3	0 0	5 12	12.5 0.24	0.00000000	1.00000000	0.00000000	
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2004	1 3	0 0	5 13	13.5 1.48	0.00000000	0.86640401	0.13359599	
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	
2004	1 3	0 0	5 14	14.5 2.64	0.00000000	0.81022906	0.16028563	
	0.02948531	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	

2004	1	3	0	0	5	15	15.5	2.44	0.00000000	0.81693870	0.15224300
	0.02701525	0.00380304	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000				
2004	1	3	0	0	5	16	16.5	2.44	0.00000000	0.91506888	0.08493112
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000				
2004	1	3	0	0	5	17	17.5	7.08	0.00000000	0.82911979	0.13811037
	0.03276984	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000				
2004	1	3	0	0	5	18	18.5	4.64	0.00000000	0.70590326	0.18379993
	0.11029681	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000				
2004	1	3	0	0	5	19	19.5	3.28	0.00000000	0.12849706	0.38179877
	0.42007401	0.06963017	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000				
2004	1	3	0	0	5	20	20.5	3.60	0.00000000	0.06764562	0.22718819
	0.43632745	0.20513650	0.02123408	0.04246816	0.00000000	0.00000000	0.00000000				
2004	1	3	0	0	5	21	21.5	7.12	0.00000000	0.02507256	0.14317139
	0.40119569	0.27665293	0.08143410	0.04737353	0.00000000	0.02509980	0.00000000				
2004	1	3	0	0	5	22	22.5	10.88	0.00000000	0.01339372	0.07334027
	0.13251533	0.12700182	0.29782043	0.20631143	0.09216441	0.05026100	0.00719159				
2004	1	3	0	0	5	23	23.5	13.56	0.00000000	0.00000000	0.01271574
	0.04461322	0.10214081	0.22098845	0.27593474	0.15398881	0.15826834	0.03134988				
2004	1	3	0	0	5	24	24.5	5.76	0.00000000	0.00000000	0.01698676
	0.01580170	0.05125012	0.18765518	0.40400194	0.08129150	0.18450322	0.05850957				
2004	1	3	0	0	5	25	25.5	1.28	0.00000000	0.00000000	0.00000000
	0.02532908	0.13645475	0.14911929	0.25845116	0.20716081	0.15798550	0.06549941				
2004	1	3	0	0	5	26	26.5	0.08	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.36623068	0.00000000	0.00000000	0.63376932	0.00000000				
2005	1	3	0	0	5	12	12.5	0.08	0.00000000	1.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000				
2005	1	3	0	0	5	15	15.5	0.84	0.00000000	0.00000000	0.91882170
	0.00000000	0.08117830	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000				
2005	1	3	0	0	5	16	16.5	5.32	0.00000000	0.02117241	0.81569472
	0.15807194	0.00506093	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000				
2005	1	3	0	0	5	17	17.5	14.84	0.00000000	0.00643022	0.78357060
	0.16751096	0.03437875	0.00732624	0.00078323	0.00000000	0.00000000	0.00000000				
2005	1	3	0	0	5	18	18.5	7.20	0.00000000	0.02142792	0.74255130
	0.18572045	0.03920476	0.00770222	0.00134353	0.00000000	0.00204982	0.00000000				
2005	1	3	0	0	5	19	19.5	1.36	0.00000000	0.01819245	0.64158675
	0.08655097	0.16711887	0.08655097	0.00000000	0.00000000	0.00000000	0.00000000				
2005	1	3	0	0	5	20	20.5	0.72	0.00000000	0.00000000	0.18644387
	0.21159555	0.37478461	0.11262507	0.07764151	0.00000000	0.03690940	0.00000000				
2005	1	3	0	0	5	21	21.5	1.00	0.00000000	0.00000000	0.11058216
	0.08033075	0.58483462	0.14392172	0.08033075	0.00000000	0.00000000	0.00000000				
2005	1	3	0	0	5	22	22.5	1.56	0.00000000	0.00000000	0.00000000
	0.04232762	0.46888188	0.14965618	0.13515448	0.12377543	0.06188772	0.01831669				
2005	1	3	0	0	5	23	23.5	3.40	0.00000000	0.00000000	0.02270702
	0.01580238	0.01941793	0.16224316	0.18771401	0.09741119	0.37852811	0.11617621				
2005	1	3	0	0	5	24	24.5	3.56	0.00000000	0.00000000	0.00000000
	0.00000000	0.01297664	0.06131838	0.11939381	0.25404643	0.37055304	0.18171170				
2005	1	3	0	0	5	25	25.5	0.88	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.05049915	0.00000000	0.20199661	0.52275381	0.22475042				
2005	1	3	0	0	5	26	26.5	0.08	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000				
2006	1	3	0	0	5	17	17.5	0.24	0.00000000	0.00000000	0.00000000
	0.51704397	0.48295603	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000				
2006	1	3	0	0	5	18	18.5	4.76	0.00000000	0.00000000	0.04347242
	0.63966086	0.16481578	0.07602547	0.04062132	0.00000000	0.01770207	0.01770207				
2006	1	3	0	0	5	19	19.5	14.92	0.00000000	0.00000000	0.00727865
	0.64061532	0.20355835	0.08308284	0.04645900	0.00000000	0.01900585	0.00000000				
2006	1	3	0	0	5	20	20.5	4.56	0.00000000	0.00000000	0.01204775
	0.62924849	0.24556590	0.07757939	0.00612325	0.02943522	0.00000000	0.00000000				
2006	1	3	0	0	5	21	21.5	0.72	0.00000000	0.00000000	0.00000000
	0.28199047	0.05286559	0.15688084	0.50826311	0.00000000	0.00000000	0.00000000				
2006	1	3	0	0	5	22	22.5	0.32	0.00000000	0.00000000	0.00000000
	0.14380492	0.61156791	0.00000000	0.00000000	0.12231358	0.12231358	0.00000000				
2006	1	3	0	0	5	23	23.5	0.52	0.00000000	0.00000000	0.00000000
	0.05102799	0.32632300	0.05102799	0.27081202	0.24529802	0.05551098	0.00000000				
2006	1	3	0	0	5	24	24.5	0.64	0.00000000	0.00000000	0.00000000
	0.22881018	0.04759812	0.07557884	0.02379906	0.09519624	0.52901755	0.00000000				
2006	1	3	0	0	5	25	25.5	0.20	0.00000000	0.00000000	0.00000000
	0.00000000	0.85825403	0.04463446	0.04463446	0.05247705	0.00000000	0.00000000				
2006	1	3	0	0	5	26	26.5	0.04	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000	0.00000000	0.00000000				
2007	1	3	0	0	5	16	16.5	0.04	0.00000000	0.00000000	1.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000				
2007	1	3	0	0	5	17	17.5	2.16	0.00000000	0.00000000	0.23740467
	0.45780179	0.27618093	0.02861261	0.00000000	0.00000000	0.00000000	0.00000000				

2007	1 3	0 0	5 18	18.5 18.56	0.00000000	0.00000000	0.07683540
	0.57588439	0.31802187	0.02626425	0.00299409	0.00000000	0.00000000	0.00000000
2007	1 3	0 0	5 19	19.5 41.00	0.00000000	0.00000000	0.03081318
	0.50919315	0.39309440	0.05765305	0.00637106	0.00287516	0.00000000	0.00000000
2007	1 3	0 0	5 20	20.5 23.36	0.00000000	0.00000000	0.00437021
	0.32889907	0.48632183	0.14330941	0.02698247	0.00772495	0.00239205	0.00000000
2007	1 3	0 0	5 21	21.5 2.84	0.00000000	0.00000000	0.01790312
	0.06248941	0.60674578	0.22974585	0.08311583	0.00000000	0.00000000	0.00000000
2007	1 3	0 0	5 22	22.5 0.36	0.00000000	0.00000000	0.00000000
	0.21943393	0.48478081	0.10971697	0.18606829	0.00000000	0.00000000	0.00000000
2007	1 3	0 0	5 23	23.5 0.64	0.00000000	0.00000000	0.00000000
	0.00000000	0.09044068	0.34236015	0.31113120	0.12166964	0.13439832	0.00000000
2007	1 3	0 0	5 24	24.5 0.28	0.00000000	0.00000000	0.00000000
	0.00000000	0.23026346	0.26146231	0.00000000	0.09267026	0.41560397	0.00000000
2007	1 3	0 0	5 25	25.5 0.12	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.37093453	0.62906547
2007	1 3	0 0	5 27	27.5 0.04	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000
2008	1 3	0 0	5 17	17.5 0.88	0.00000000	0.00000000	0.08076731
	0.45003422	0.35683235	0.11236612	0.00000000	0.00000000	0.00000000	0.00000000
2008	1 3	0 0	5 18	18.5 13.12	0.00000000	0.00000000	0.01184838
	0.32043582	0.46529163	0.19547765	0.00694651	0.00000000	0.00000000	0.00000000
2008	1 3	0 0	5 19	19.5 32.08	0.00000000	0.00000000	0.00088424
	0.15493135	0.57736237	0.24563050	0.01859373	0.00259781	0.00000000	0.00000000
2008	1 3	0 0	5 20	20.5 32.48	0.00000000	0.00000000	0.00000000
	0.05859962	0.53023043	0.34778716	0.05769815	0.00246186	0.00322279	0.00000000
2008	1 3	0 0	5 21	21.5 10.88	0.00000000	0.00000000	0.00000000
	0.01475106	0.36452259	0.47038098	0.10796971	0.02632704	0.01604862	0.00000000
2008	1 3	0 0	5 22	22.5 2.80	0.00000000	0.00000000	0.00000000
	0.03766021	0.19998154	0.35594165	0.24583760	0.12291880	0.03766021	0.00000000
2008	1 3	0 0	5 23	23.5 1.28	0.00000000	0.00000000	0.00000000
	0.00000000	0.19731636	0.34757381	0.22868898	0.19401355	0.03240729	0.00000000
2008	1 3	0 0	5 24	24.5 0.40	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.07480361	0.14173213	0.17913393	0.60433033	0.00000000
2008	1 3	0 0	5 25	25.5 0.08	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.79120760	0.00000000	0.20879240	0.00000000
2009	1 3	0 0	5 15	15.5 0.04	0.00000000	0.00000000	1.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2009	1 3	0 0	5 17	17.5 0.68	0.00000000	0.00000000	0.00000000
	0.42804400	0.48314281	0.03371438	0.00000000	0.05509881	0.00000000	0.00000000
2009	1 3	0 0	5 18	18.5 11.68	0.00000000	0.00000000	0.02050733
	0.12037526	0.46365604	0.31060975	0.08018280	0.00466882	0.00000000	0.00000000
2009	1 3	0 0	5 19	19.5 41.76	0.00000000	0.00000000	0.00226916
	0.03590519	0.36741479	0.37324927	0.18827612	0.02953106	0.00335441	0.00000000
2009	1 3	0 0	5 20	20.5 31.56	0.00000000	0.00000000	0.00219593
	0.01342498	0.21422056	0.43913111	0.25999418	0.06078386	0.01024938	0.00000000
2009	1 3	0 0	5 21	21.5 6.80	0.00000000	0.00000000	0.00212453
	0.00568681	0.10318651	0.44777766	0.31985777	0.10280451	0.01856221	0.00000000
2009	1 3	0 0	5 22	22.5 0.56	0.00000000	0.00000000	0.00000000
	0.00000000	0.04893710	0.22695408	0.46075579	0.08550180	0.17785124	0.00000000
2009	1 3	0 0	5 23	23.5 0.12	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.83888941	0.00000000	0.16111059	0.00000000	0.00000000
2009	1 3	0 0	5 24	24.5 0.04	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000
2010	1 3	0 0	5 16	16.5 0.20	0.00000000	0.00000000	0.76934528
	0.23065472	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2010	1 3	0 0	5 17	17.5 0.20	0.00000000	0.00000000	0.00000000
	0.38467264	0.46130945	0.15401791	0.00000000	0.00000000	0.00000000	0.00000000
2010	1 3	0 0	5 18	18.5 1.84	0.00000000	0.00000000	0.00000000
	0.16788478	0.16797029	0.46967550	0.17677483	0.01769459	0.00000000	0.00000000
2010	1 3	0 0	5 19	19.5 12.44	0.00000000	0.00000000	0.00000000
	0.04896287	0.27875690	0.38697070	0.18333172	0.08992043	0.01205738	0.00000000
2010	1 3	0 0	5 20	20.5 14.44	0.00000000	0.00000000	0.00000000
	0.01016532	0.16180590	0.40427576	0.30760341	0.09572334	0.02042628	0.00000000
2010	1 3	0 0	5 21	21.5 4.28	0.00000000	0.00000000	0.00000000
	0.00000000	0.17346526	0.35308184	0.28013074	0.16224575	0.03107640	0.00000000
2010	1 3	0 0	5 22	22.5 0.32	0.00000000	0.00000000	0.00000000
	0.00000000	0.20110753	0.39240600	0.07009449	0.26629749	0.07009449	0.00000000
2010	1 3	0 0	5 23	23.5 0.04	0.00000000	0.00000000	0.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000	0.00000000	0.00000000
2011	1 3	0 0	5 14	14.5 0.04	0.00000000	0.00000000	1.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
2011	1 3	0 0	5 15	15.5 0.04	0.00000000	0.00000000	1.00000000
	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

2011 1 3 0 0 5 17 17.5 0.36 0.00000000 0.51810763 0.21835447
0.00000000 0.00000000 0.08820160 0.17533631 0.00000000 0.00000000 0.00000000
2011 1 3 0 0 5 18 18.5 0.88 0.00000000 0.00000000 0.50596905
0.21929168 0.19223208 0.06856094 0.00000000 0.00000000 0.01394624 0.00000000
2011 1 3 0 0 5 19 19.5 3.40 0.00000000 0.00000000 0.15072866
0.26068154 0.13777478 0.16189115 0.23719457 0.03802670 0.01370261 0.00000000
2011 1 3 0 0 5 20 20.5 18.40 0.00000000 0.00000000 0.00859330
0.03904601 0.13922408 0.33680258 0.27486556 0.15650820 0.04496027 0.00000000
2011 1 3 0 0 5 21 21.5 16.08 0.00000000 0.00000000 0.00422339
0.01197875 0.10077749 0.31338103 0.33280820 0.20914405 0.02768709 0.00000000
2011 1 3 0 0 5 22 22.5 3.12 0.00000000 0.00000000 0.00000000
0.00000000 0.14846829 0.30437049 0.28564527 0.18671576 0.07480019 0.00000000
2011 1 3 0 0 5 23 23.5 0.56 0.00000000 0.00000000 0.00000000
0.00000000 0.03268375 0.34533842 0.27886041 0.34311741 0.00000000 0.00000000
2012 1 3 0 0 5 17 17.5 0.04 0.00000000 0.00000000 1.00000000
0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2012 1 3 0 0 5 18 18.5 5.48 0.00000000 0.00000000 0.74304840
0.23730442 0.01964719 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2012 1 3 0 0 5 19 19.5 30.96 0.00000000 0.00094202 0.66082840
0.26778733 0.03782638 0.00983471 0.00554848 0.00428623 0.01294645 0.00000000
2012 1 3 0 0 5 20 20.5 35.76 0.00000000 0.00116550 0.38557432
0.33735691 0.11024423 0.04944098 0.03141783 0.04173074 0.04306948 0.00000000
2012 1 3 0 0 5 21 21.5 26.64 0.00000000 0.00000000 0.03900776
0.12680052 0.08678037 0.08175227 0.18143254 0.19322295 0.28507335 0.00593025
2012 1 3 0 0 5 22 22.5 16.44 0.00000000 0.00000000 0.01068538
0.00799751 0.04921246 0.06488152 0.15952159 0.27504714 0.41065066 0.02200375
2012 1 3 0 0 5 23 23.5 2.84 0.00000000 0.00000000 0.00000000
0.00000000 0.02087101 0.05696684 0.12747367 0.23738363 0.51556283 0.04174203
2012 1 3 0 0 5 24 24.5 0.04 0.00000000 0.00000000 0.00000000
0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 1.00000000 0.00000000
2012 1 3 0 0 5 25 25.5 0.04 0.00000000 0.00000000 0.00000000
0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 1.00000000 0.00000000
2005 2 8 0 0 6 11 11.5 0.04 1.00000000 0.00000000 0.00000000
0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2005 2 8 0 0 6 13 13.5 0.04 1.00000000 0.00000000 0.00000000
0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2005 2 8 0 0 6 15 15.5 0.12 0.00000000 1.00000000 0.00000000
0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2005 2 8 0 0 6 16 16.5 1.60 0.35000000 0.65000000 0.00000000
0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2005 2 8 0 0 6 17 17.5 1.80 0.08888889 0.62222222 0.24444444
0.04444444 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2005 2 8 0 0 6 18 18.5 2.40 0.00000000 0.68333333 0.31666667
0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2005 2 8 0 0 6 19 19.5 3.24 0.00000000 0.56790123 0.40740741
0.02469136 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2005 2 8 0 0 6 20 20.5 1.92 0.02083333 0.45833333 0.47916667
0.02083333 0.02083333 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2005 2 8 0 0 6 21 21.5 0.56 0.00000000 0.50000000 0.42857143
0.00000000 0.07142857 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2005 2 8 0 0 6 22 22.5 0.12 0.00000000 0.66666667 0.33333333
0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2005 2 8 0 0 6 24 24.5 0.08 0.00000000 0.00000000 0.50000000
0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.50000000 0.00000000
2005 2 8 0 0 6 25 25.5 0.16 0.00000000 0.25000000 0.00000000
0.25000000 0.50000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2005 2 8 0 0 6 26 26.5 0.04 0.00000000 0.00000000 0.00000000
0.00000000 0.00000000 1.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2007 2 8 0 0 6 16 16.5 0.12 0.00000000 0.33333333 0.66666667
0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2007 2 8 0 0 6 17 17.5 0.40 0.00000000 0.00000000 0.80000000
0.20000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2007 2 8 0 0 6 18 18.5 0.96 0.00000000 0.08333333 0.70833333
0.20833333 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
2007 2 8 0 0 6 19 19.5 1.00 0.00000000 0.00000000 0.36000000
0.52000000 0.08000000 0.04000000 0.00000000 0.00000000 0.00000000 0.00000000
2007 2 8 0 0 6 20 20.5 2.84 0.00000000 0.00000000 0.16901408
0.66197183 0.14084507 0.02816901 0.00000000 0.00000000 0.00000000 0.00000000
2007 2 8 0 0 6 21 21.5 4.96 0.00000000 0.00000000 0.08870968
0.73387097 0.16935484 0.00806452 0.00000000 0.00000000 0.00000000 0.00000000
2007 2 8 0 0 6 22 22.5 3.40 0.00000000 0.00000000 0.00000000
0.77647059 0.21176471 0.01176471 0.00000000 0.00000000 0.00000000 0.00000000
2007 2 8 0 0 6 23 23.5 0.80 0.00000000 0.00000000 0.00000000
0.75000000 0.20000000 0.05000000 0.00000000 0.00000000 0.00000000 0.00000000

2007	2	8	0	0	6	24	24.5	0.24	0.00000000	0.00000000	0.00000000
	0.50000000		0.50000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2007	2	8	0	0	6	25	25.5	0.08	0.00000000	0.00000000	0.00000000
	0.00000000		0.50000000		0.50000000		0.00000000		0.00000000	0.00000000	0.00000000
2009	2	8	0	0	6	12	12.5	0.04	0.00000000	1.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2009	2	8	0	0	6	14	14.5	0.04	0.00000000	1.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2009	2	8	0	0	6	15	15.5	0.12	0.00000000	0.66666667	0.33333333
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2009	2	8	0	0	6	16	16.5	0.24	0.16666667	0.50000000	0.33333333
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2009	2	8	0	0	6	17	17.5	0.32	0.00000000	0.62500000	0.37500000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2009	2	8	0	0	6	18	18.5	0.16	0.00000000	0.00000000	0.50000000
	0.50000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2009	2	8	0	0	6	19	19.5	0.36	0.00000000	0.11111111	0.11111111
	0.44444444		0.11111111		0.22222222		0.00000000		0.00000000	0.00000000	0.00000000
2009	2	8	0	0	6	20	20.5	2.72	0.00000000	0.00000000	0.01470588
	0.39705882		0.42647059		0.16176471		0.00000000		0.00000000	0.00000000	0.00000000
2009	2	8	0	0	6	21	21.5	8.12	0.00000000	0.00000000	0.01970443
	0.25123153		0.44827586		0.25123153		0.02955665		0.00000000	0.00000000	0.00000000
2009	2	8	0	0	6	22	22.5	9.72	0.00000000	0.00411523	0.01646091
	0.18518519		0.45679012		0.25514403		0.07818930		0.00411523	0.00000000	0.00000000
2009	2	8	0	0	6	23	23.5	4.16	0.00000000	0.00000000	0.00000000
	0.17307692		0.46153846		0.30769231		0.05769231		0.00000000	0.00000000	0.00000000
2009	2	8	0	0	6	24	24.5	0.96	0.00000000	0.00000000	0.00000000
	0.12500000		0.37500000		0.41666667		0.04166667		0.04166667	0.00000000	0.00000000
2009	2	8	0	0	6	25	25.5	0.08	0.00000000	0.00000000	0.00000000
	0.50000000		0.00000000		0.50000000		0.00000000		0.00000000	0.00000000	0.00000000
2009	2	8	0	0	6	26	26.5	0.16	0.00000000	0.00000000	0.00000000
	0.00000000		0.50000000		0.00000000		0.25000000		0.25000000	0.00000000	0.00000000
2010	2	8	0	0	6	14	14.5	0.08	0.00000000	0.50000000	0.50000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2010	2	8	0	0	6	15	15.5	0.12	0.33333333	0.33333333	0.33333333
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2010	2	8	0	0	6	16	16.5	1.28	0.00000000	0.65625000	0.31250000
	0.03125000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2010	2	8	0	0	6	17	17.5	3.76	0.01063830	0.51063830	0.42553191
	0.04255319		0.01063830		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2010	2	8	0	0	6	18	18.5	5.60	0.02142857	0.37142857	0.50000000
	0.10000000		0.00714286		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2010	2	8	0	0	6	19	19.5	2.24	0.00000000	0.23214286	0.50000000
	0.25000000		0.01785714		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2010	2	8	0	0	6	20	20.5	0.48	0.00000000	0.00000000	0.75000000
	0.25000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2010	2	8	0	0	6	21	21.5	1.56	0.00000000	0.00000000	0.05128205
	0.25641026		0.33333333		0.28205128		0.07692308		0.00000000	0.00000000	0.00000000
2010	2	8	0	0	6	22	22.5	4.92	0.00000000	0.00000000	0.04878049
	0.15447154		0.36585366		0.27642276		0.12195122		0.03252033	0.00000000	0.00000000
2010	2	8	0	0	6	23	23.5	4.16	0.00000000	0.00961538	0.03846154
	0.17307692		0.33653846		0.32692308		0.09615385		0.01923077	0.00000000	0.00000000
2010	2	8	0	0	6	24	24.5	0.84	0.00000000	0.00000000	0.00000000
	0.04761905		0.52380952		0.23809524		0.19047619		0.00000000	0.00000000	0.00000000
2010	2	8	0	0	6	25	25.5	0.28	0.00000000	0.00000000	0.00000000
	0.00000000		0.28571429		0.42857143		0.28571429		0.00000000	0.00000000	0.00000000
2010	2	8	0	0	6	26	26.5	0.16	0.00000000	0.00000000	0.00000000
	0.00000000		0.75000000		0.00000000		0.25000000		0.00000000	0.00000000	0.00000000
2011	2	8	0	0	6	17	17.5	0.04	0.00000000	1.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2011	2	8	0	0	6	18	18.5	0.08	0.00000000	0.50000000	0.50000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2011	2	8	0	0	6	19	19.5	1.84	0.00000000	0.17391304	0.58695652
	0.19565217		0.04347826		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2011	2	8	0	0	6	20	20.5	3.20	0.00000000	0.13750000	0.62500000
	0.15000000		0.07500000		0.00000000		0.01250000		0.00000000	0.00000000	0.00000000
2011	2	8	0	0	6	21	21.5	2.00	0.00000000	0.16000000	0.40000000
	0.26000000		0.14000000		0.00000000		0.04000000		0.00000000	0.00000000	0.00000000
2011	2	8	0	0	6	22	22.5	1.60	0.00000000	0.00000000	0.27500000
	0.17500000		0.12500000		0.20000000		0.20000000		0.02500000	0.00000000	0.00000000
2011	2	8	0	0	6	23	23.5	3.72	0.00000000	0.00000000	0.03225806
	0.15053763		0.32258065		0.29032258		0.15053763		0.05376344	0.00000000	0.00000000
2011	2	8	0	0	6	24	24.5	1.56	0.00000000	0.00000000	0.02564103
	0.10256410		0.35897436		0.33333333		0.17948718		0.00000000	0.00000000	0.00000000

2011	2	8	0	0	6	25	25.5	0.24	0.00000000	0.00000000	0.16666667
	0.16666667		0.33333333		0.00000000		0.33333333		0.00000000	0.00000000	0.00000000
2011	2	8	0	0	6	26	26.5	0.04	0.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		1.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2012	2	8	0	0	6	18	18.5	0.12	0.00000000	0.33333333	0.33333333
	0.33333333		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2012	2	8	0	0	6	20	20.5	0.84	0.00000000	0.00000000	0.47619048
	0.42857143		0.04761905		0.04761905		0.00000000		0.00000000	0.00000000	0.00000000
2012	2	8	0	0	6	21	21.5	3.12	0.00000000	0.00000000	0.20512821
	0.53846154		0.19230769		0.01282051		0.05128205		0.00000000	0.00000000	0.00000000
2012	2	8	0	0	6	22	22.5	2.64	0.00000000	0.00000000	0.25757576
	0.54545455		0.10606061		0.03030303		0.03030303		0.01515152	0.01515152	0.00000000
2012	2	8	0	0	6	23	23.5	1.04	0.00000000	0.00000000	0.03846154
	0.19230769		0.11538462		0.15384615		0.30769231		0.03846154	0.15384615	0.00000000
2012	2	8	0	0	6	24	24.5	0.76	0.00000000	0.00000000	0.00000000
	0.05263158		0.15789474		0.26315789		0.10526316		0.26315789	0.15789474	0.00000000
2012	2	8	0	0	6	25	25.5	0.12	0.00000000	0.00000000	0.00000000
	0.00000000		0.33333333		0.00000000		0.00000000		0.66666667	0.00000000	0.00000000
2008	1	9	0	0	6	9	9.5	0.40	1.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	9	0	0	6	10	10.5	0.52	1.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	9	0	0	6	11	11.5	0.16	1.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	9	0	0	6	16	16.5	0.16	0.00000000	0.00000000	0.75000000
	0.25000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	9	0	0	6	17	17.5	0.48	0.00000000	0.00000000	0.41666667
	0.58333333		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	9	0	0	6	18	18.5	0.88	0.00000000	0.00000000	0.27272727
	0.59090909		0.13636364		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	9	0	0	6	19	19.5	4.76	0.00000000	0.00840336	0.25210084
	0.51260504		0.21848739		0.00840336		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	9	0	0	6	20	20.5	7.60	0.00000000	0.00526316	0.11578947
	0.45263158		0.40526316		0.02105263		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	9	0	0	6	21	21.5	9.32	0.00000000	0.00000000	0.05150215
	0.43347639		0.49356223		0.02145923		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	9	0	0	6	22	22.5	3.52	0.00000000	0.00000000	0.03409091
	0.40909091		0.51136364		0.04545455		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	9	0	0	6	23	23.5	0.68	0.00000000	0.00000000	0.00000000
	0.35294118		0.58823529		0.05882353		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	9	0	0	6	24	24.5	0.32	0.00000000	0.00000000	0.12500000
	0.37500000		0.50000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	9	0	0	6	25	25.5	0.08	0.00000000	0.00000000	0.00000000
	0.50000000		0.50000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2012	1	9	0	0	6	17	17.5	0.04	0.00000000	0.00000000	1.00000000
	0.00000000		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2012	1	9	0	0	6	19	19.5	0.80	0.00000000	0.10000000	0.45000000
	0.40000000		0.05000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2012	1	9	0	0	6	20	20.5	6.80	0.00000000	0.03529412	0.44705882
	0.35882353		0.12941176		0.02941176		0.00000000		0.00000000	0.00000000	0.00000000
2012	1	9	0	0	6	21	21.5	8.12	0.00000000	0.00492611	0.28571429
	0.39901478		0.18719212		0.06896552		0.02463054		0.02955665	0.00000000	0.00000000
2012	1	9	0	0	6	22	22.5	3.04	0.00000000	0.00000000	0.07894737
	0.28947368		0.18421053		0.22368421		0.09210526		0.10526316	0.02631579	0.00000000
2012	1	9	0	0	6	23	23.5	2.40	0.00000000	0.00000000	0.00000000
	0.03333333		0.10000000		0.26666667		0.26666667		0.23333333	0.10000000	0.00000000
2012	1	9	0	0	6	24	24.5	1.28	0.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.21875000		0.31250000		0.21875000	0.25000000	0.00000000
2012	1	9	0	0	6	25	25.5	0.40	0.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.10000000		0.10000000		0.50000000	0.30000000	0.00000000
2013	1	9	0	0	6	20	20.5	0.16	0.00000000	0.00000000	0.00000000
	0.75000000		0.25000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2013	1	9	0	0	6	21	21.5	3.40	0.00000000	0.00000000	0.35294118
	0.51764706		0.11764706		0.00000000		0.01176471		0.00000000	0.00000000	0.00000000
2013	1	9	0	0	6	22	22.5	6.00	0.00000000	0.00000000	0.32666667
	0.52000000		0.12666667		0.01333333		0.00666667		0.00666667	0.00000000	0.00000000
2013	1	9	0	0	6	23	23.5	3.24	0.00000000	0.02469136	0.22222222
	0.43209877		0.11111111		0.14814815		0.04938272		0.01234568	0.02469136	0.00000000
2013	1	9	0	0	6	24	24.5	1.08	0.00000000	0.00000000	0.00000000
	0.07407407		0.03703704		0.37037037		0.37037037		0.03703704	0.11111111	0.00000000
2013	1	9	0	0	6	25	25.5	0.28	0.00000000	0.00000000	0.00000000
	0.00000000		0.00000000		0.14285714		0.57142857		0.14285714	0.14285714	0.00000000
1993	1	-1	0	0	1	9	28	2.72	0.00000000	0.00000000	0.11764706
	0.76470588		0.10294118		0.01470588		0.00000000		0.00000000	0.00000000	0.00000000

1994	1	-1	0	0	1	9	28	11.76	0.02233392	0.46921325	0.31997955
	0.15950127		0.02897201		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1995	1	-1	0	0	1	9	28	4.76	0.11764706	0.56302521	0.25210084
	0.06722689		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
1996	1	-1	0	0	1	9	28	89.28	0.00000000	0.05567822	0.57869148
	0.31936116		0.04119642		0.00460375		0.00000000		0.00046897	0.00000000	0.00000000
1997	1	-1	0	0	1	9	28	54.92	0.00393055	0.41526377	0.48143507
	0.08999595		0.00760341		0.00177125		0.00000000		0.00000000	0.00000000	0.00000000
1998	1	-1	0	0	1	9	28	75.32	0.08752419	0.65178011	0.20556040
	0.02738368		0.02185746		0.00530475		0.00058942		0.00000000	0.00000000	0.00000000
1999	1	-1	0	0	1	9	28	6.96	0.12068966	0.51724138	0.35632184
	0.00574713		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2000	1	-1	0	0	1	9	28	22.64	0.05612282	0.21594669	0.47409550
	0.23739199		0.01419224		0.00225076		0.00000000		0.00000000	0.00000000	0.00000000
2001	1	-1	0	0	1	9	28	37.24	0.19498424	0.24032396	0.10821490
	0.29193947		0.11194383		0.03989310		0.00899338		0.00370711	0.00000000	0.00000000
2002	1	-1	0	0	1	9	28	30.32	0.17079894	0.53308456	0.23318285
	0.04302452		0.01864624		0.00126289		0.00000000		0.00000000	0.00000000	0.00000000
2003	1	-1	0	0	1	9	28	17.76	0.56513500	0.22899483	0.18990839
	0.01273176		0.00323001		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2004	1	-1	0	0	1	9	28	33.52	0.00300111	0.90375628	0.06959324
	0.00743078		0.01147566		0.00000000		0.00474293		0.00000000	0.00000000	0.00000000
2005	1	-1	0	0	1	9	28	35.24	0.09102697	0.26552164	0.59466314
	0.04284618		0.00412282		0.00121284		0.00060642		0.00000000	0.00000000	0.00000000
2006	1	-1	0	0	1	9	28	69.76	0.00908783	0.64539166	0.30295669
	0.04256381		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2007	1	-1	0	0	2	9	28	86.00	0.01357889	0.16055166	0.64593872
	0.17061145		0.00931929		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2008	1	-1	0	0	3	9	28	30.84	0.06153622	0.26350954	0.58776778
	0.07218948		0.01499698		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2009	1	-1	0	0	3	9	28	22.88	0.00349661	0.21120316	0.63114846
	0.14041369		0.01373808		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2010	1	-1	0	0	4	9	28	12.68	0.01577287	0.79179811	0.16719243
	0.02523659		0.00000000		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2011	1	-1	0	0	4	9	28	21.64	0.00000000	0.32278273	0.47187076
	0.19905465		0.00629186		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2012	1	-1	0	0	4	9	28	22.32	0.00335775	0.10053293	0.44773547
	0.37325638		0.05790999		0.01147166		0.00573583		0.00000000	0.00000000	0.00000000
1993	2	-2	0	0	1	9	28	30.44	0.21106902	0.38434172	0.30704382
	0.06010656		0.02088125		0.01089044		0.00566720		0.00000000	0.00000000	0.00000000
1994	2	-2	0	0	1	9	28	120.96	0.36945499	0.45924059	0.11019804
	0.05280057		0.00706495		0.00093579		0.00030505		0.00000000	0.00000000	0.00000000
1995	2	-2	0	0	1	9	28	58.84	0.24589769	0.44769841	0.28115147
	0.02299743		0.00194198		0.00031302		0.00000000		0.00000000	0.00000000	0.00000000
1996	2	-2	0	0	1	9	28	45.92	0.29892120	0.35526509	0.28407353
	0.05385728		0.00380762		0.00407529		0.00000000		0.00000000	0.00000000	0.00000000
1997	2	-2	0	0	1	9	28	47.44	0.16769604	0.44927048	0.17462436
	0.14077280		0.05754727		0.00731508		0.00277398		0.00000000	0.00000000	0.00000000
1998	2	-2	0	0	1	9	28	72.48	0.26761762	0.47815789	0.21604073
	0.02580353		0.00936489		0.00301533		0.00000000		0.00000000	0.00000000	0.00000000
1999	2	-2	0	0	1	9	28	55.32	0.27314763	0.51943459	0.18108008
	0.01831521		0.00686090		0.00095133		0.00021026		0.00000000	0.00000000	0.00000000
2000	2	-2	0	0	1	9	28	48.04	0.27341328	0.37293108	0.27881477
	0.06382949		0.01091465		0.00000000		0.00000000		0.00009674	0.00000000	0.00000000
2001	2	-2	0	0	1	9	28	71.04	0.67276346	0.18270578	0.09872123
	0.03669650		0.00653717		0.00257586		0.00000000		0.00000000	0.00000000	0.00000000
2002	2	-2	0	0	1	9	28	76.48	0.18899176	0.59397851	0.16841782
	0.03741263		0.00773647		0.00329546		0.00008367		0.00000000	0.00008367	0.00000000
2003	2	-2	0	0	1	9	28	74.64	0.83351604	0.04116990	0.06930792
	0.03300254		0.01468797		0.00389736		0.00353461		0.00088365	0.00000000	0.00000000
2004	2	-2	0	0	1	9	28	59.16	0.04238489	0.87005119	0.07242785
	0.01265237		0.00145970		0.00102400		0.00000000		0.00000000	0.00000000	0.00000000
2005	2	-2	0	0	1	9	28	89.04	0.53994582	0.36702223	0.08416083
	0.00500806		0.00132284		0.00090732		0.00072560		0.00045366	0.00045366	0.00000000
2006	2	-2	0	0	1	9	28	105.16	0.20172661	0.63015996	0.15000726
	0.01740041		0.00070577		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2007	2	-2	0	0	2	9	28	67.44	0.42021952	0.43386305	0.10589809
	0.03396340		0.00544372		0.00061223		0.00000000		0.00000000	0.00000000	0.00000000
2008	2	-2	0	0	3	9	28	39.76	0.19862191	0.52834154	0.21532639
	0.05558720		0.00212296		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2009	2	-2	0	0	3	9	28	98.08	0.44090117	0.44149224	0.11209083
	0.00372405		0.00179171		0.00000000		0.00000000		0.00000000	0.00000000	0.00000000
2010	2	-2	0	0	4	9	28	31.40	0.50304830	0.32470002	0.01757707
	0.02625377		0.05345083		0.06594583		0.00763583		0.00069417	0.00069417	0.00000000

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2011    2     -2     0     0     4     9     28    54.88  0.20910019   0.35249163   0.22419952
        0.08833225   0.04648802   0.03648118   0.03009719   0.01083858   0.00197145   0.00000000
2012    2     -2     0     0     4     9     28    8.92   0.01286056   0.18465132   0.56709595
        0.19900628   0.03408414   0.00153450   0.00076725   0.00000000   0.00000000   0.00000000
1999    1     -3     0     0     5     9     28    2.96   0.00000000   0.00000000   0.59151581
        0.20074375   0.04758623   0.12952271   0.03063150   0.00000000   0.00000000   0.00000000
2000    1     -3     0     0     5     9     28    66.64  0.00000000   0.00661920   0.20664268
        0.39154056   0.21333728   0.10964756   0.05159158   0.01292370   0.00769745   0.00000000
2001    1     -3     0     0     5     9     28    81.28  0.00000000   0.01319829   0.09882524
        0.43321579   0.28807345   0.09650734   0.05247704   0.01444472   0.00325813   0.00000000
2002    1     -3     0     0     5     9     28    110.32 0.00000000   0.00376606   0.02888569
        0.14173143   0.37497785   0.24597782   0.11747427   0.05690067   0.02950284   0.00078337
2003    1     -3     0     0     5     9     28    92.32  0.00000000   0.02102307   0.16425121
        0.15811910   0.10310171   0.18273199   0.16023280   0.09892235   0.09975931   0.01185845
2004    1     -3     0     0     5     9     28    66.56  0.00000000   0.18029041   0.09935404
        0.14911095   0.11148963   0.14727065   0.15776410   0.06809703   0.07147469   0.01514850
2005    1     -3     0     0     5     9     28    40.84  0.00000000   0.01355483   0.68729690
        0.14494663   0.04909713   0.02077143   0.01635392   0.01781254   0.03540648   0.01476013
2006    1     -3     0     0     5     9     28    26.92  0.00000000   0.00000000   0.01497099
        0.60873284   0.20905176   0.07984672   0.04903877   0.00985519   0.02477402   0.00372971
2007    1     -3     0     0     5     9     28    89.40  0.00000000   0.00000000   0.03684181
        0.45391632   0.40243125   0.08105161   0.01657055   0.00464352   0.00366742   0.00087752
2008    1     -3     0     0     5     9     28    94.00  0.00000000   0.00000000   0.00238411
        0.12188750   0.50241139   0.30400027   0.05113905   0.01114247   0.00703520   0.00000000
2009    1     -3     0     0     5     9     28    93.24  0.00000000   0.00000000   0.00497725
        0.03834955   0.30673956   0.39095629   0.20858215   0.04278986   0.00760533   0.00000000
2010    1     -3     0     0     5     9     28    33.76  0.00000000   0.00000000   0.00486375
        0.03556323   0.20782114   0.39064640   0.24531203   0.09814472   0.01764872   0.00000000
2011    1     -3     0     0     5     9     28    42.88  0.00000000   0.00357123   0.03311394
        0.04935194   0.12486830   0.30299646   0.28571874   0.16388915   0.03649023   0.00000000
2012    1     -3     0     0     5     9     28    118.24 0.00000000   0.00058319   0.34026869
        0.21053451   0.06934004   0.04548403   0.07671303   0.10090398   0.15072623   0.00544631
2005    2     -8     0     0     6     9     28    12.12  0.06930693   0.58085809   0.31023102
        0.01980198   0.01320132   0.00330033   0.00000000   0.00000000   0.00330033   0.00000000
2007    2     -8     0     0     6     9     28    14.80  0.00000000   0.00810811   0.15945946
        0.65405405   0.15945946   0.01891892   0.00000000   0.00000000   0.00000000   0.00000000
2009    2     -8     0     0     6     9     28    27.20  0.00147059   0.02058824   0.02647059
        0.22205882   0.42794118   0.24852941   0.04852941   0.00441176   0.00000000   0.00000000
2010    2     -8     0     0     6     9     28    25.48  0.00784929   0.21507064   0.26844584
        0.13186813   0.17582418   0.13657771   0.05494505   0.00941915   0.00000000   0.00000000
2011    2     -8     0     0     6     9     28    14.32  0.00000000   0.08100559   0.31843575
        0.16759777   0.18435754   0.13687151   0.09497207   0.01675978   0.00000000   0.00000000
2012    2     -8     0     0     6     9     28    8.64   0.00000000   0.00462963   0.20833333
        0.43518519   0.13888889   0.06018519   0.07407407   0.04166667   0.03703704   0.00000000
2008    1     -9     0     0     6     9     28    28.88  0.03739612   0.00277008   0.11357341
        0.43628809   0.38919668   0.02077562   0.00000000   0.00000000   0.00000000   0.00000000
2012    1     -9     0     0     6     9     28    22.88  0.00000000   0.01573427   0.26223776
        0.30419580   0.14160839   0.10489510   0.06818182   0.06993007   0.03321678   0.00000000
2013    1     -9     0     0     6     9     28    14.16  0.00000000   0.00000000   0.27401130
        0.45762712   0.11299435   0.07062147   0.05649718   0.01129944   0.01694915   0.00000000
#
63 # N_mean size-at-age_obs
# Year Season Fleet/Survey Gender Part Ageerr Nsamp datavector(female-male) Nfish (female-male)
1993    1     1     0     0     1     2.72   -1.0   -1.0   18.0   18.8   19.3   -1.0   -1.0   -1.0
        -1.0  -1.0  0.00  0.00  0.32  2.08   0.28   0.00   0.00   0.00   0.00   0.00
1994    1     1     0     0     1     11.76  17.8   -1.0   18.4   18.9   19.0   -1.0   -1.0   -1.0
        -1.0  -1.0  0.32  0.00  3.80  2.00   0.32   0.00   0.00   0.00   0.00   0.00
1995    1     1     0     0     1     4.76   15.0   16.5   16.9   17.7   -1.0   -1.0   -1.0   -1.0
        -1.0  -1.0  0.56  2.68  1.20  0.32   0.00   0.00   0.00   0.00   0.00   0.00
1996    1     1     0     0     1     89.28  -1.0   17.5   18.5   19.2   19.6   20.2   -1.0   26.6
        -1.0  -1.0  0.00  5.12  52.28 27.72  3.68   0.44   0.00   0.04   0.00   0.00
1997    1     1     0     0     1     54.92  13.5   16.4   18.3   19.6   21.6   22.0   -1.0   -1.0
        -1.0  -1.0  0.12  25.80 24.68 3.92   0.32   0.08   0.00   0.00   0.00   0.00
1998    1     1     0     0     1     75.32  12.7   14.5   17.0   19.6   20.8   21.9   22.4   -1.0
        -1.0  -1.0  3.56  53.52 14.84 1.76   1.24   0.36   0.04   0.00   0.00   0.00
1999    1     1     0     0     1     6.96   13.7   15.1   15.7   17.9   -1.0   -1.0   -1.0   -1.0
        -1.0  -1.0  0.84  3.60  2.48  0.04   0.00   0.00   0.00   0.00   0.00   0.00
2000    1     1     0     0     1     22.64  14.1   16.7   17.1   17.1   18.1   22.2   -1.0   -1.0
        -1.0  -1.0  1.08  3.92  10.64 6.56   0.36   0.08   0.00   0.00   0.00   0.00
2001    1     1     0     0     1     37.24  11.6   17.3   18.8   21.3   22.1   23.3   23.5   23.8
        -1.0  -1.0  8.36  7.68  4.28  10.68  4.24   1.52   0.36   0.12   0.00   0.00
2002    1     1     0     0     1     30.32  16.1   16.3   17.6   18.4   20.8   22.8   -1.0   -1.0
        -1.0  -1.0  5.36  16.48 6.84  1.16   0.44   0.04   0.00   0.00   0.00   0.00
2003    1     1     0     0     1     17.76  12.0   16.9   18.2   20.0   20.7   -1.0   -1.0   -1.0
        -1.0  -1.0  8.56  4.48  4.36  0.32   0.04   0.00   0.00   0.00   0.00   0.00
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2004	1	1	0	0	1	33.52	13.9	15.6	16.9	18.5	18.5	-1.0	23.7	-1.0
	-1.0	-1.0	0.16	30.12	2.72	0.20	0.24	0.00	0.08	0.00	0.00	0.00		
2005	1	1	0	0	1	35.24	13.4	14.3	16.4	18.3	21.8	23.3	24.5	-1.0
	-1.0	-1.0	4.72	12.56	16.48	1.20	0.16	0.00	0.00	0.00	0.00	0.00		
2006	1	1	0	0	1	69.76	14.5	15.4	16.9	18.2	-1.0	-1.0	-1.0	-1.0
	-1.0	-1.0	0.92	47.36	18.60	2.88	0.00	0.00	0.00	0.00	0.00	0.00		
2007	1	1	0	0	2	86.00	12.9	15.2	16.7	17.6	18.1	-1.0	-1.0	-1.0
	-1.0	-1.0	2.24	16.16	52.00	14.80	0.80	0.00	0.00	0.00	0.00	0.00		
2008	1	1	0	0	3	30.84	14.1	16.9	17.4	18.9	21.2	-1.0	-1.0	-1.0
	-1.0	-1.0	1.60	8.56	18.08	2.24	0.36	0.00	0.00	0.00	0.00	0.00		
2009	1	1	0	0	3	22.88	16.1	16.4	17.4	17.9	-1.0	-1.0	-1.0	-1.0
	-1.0	-1.0	0.08	5.40	13.20	3.92	0.00	0.00	0.00	0.00	0.00	0.00		
2010	1	1	0	0	4	12.68	15.8	16.0	16.3	17.8	-1.0	-1.0	-1.0	-1.0
	-1.0	-1.0	0.20	10.04	2.12	0.32	0.00	0.00	0.00	0.00	0.00	0.00		
2011	1	1	0	0	4	21.64	-1.0	17.4	17.7	17.9	19.4	-1.0	-1.0	-1.0
	-1.0	-1.0	0.00	5.64	10.76	5.12	0.12	0.00	0.00	0.00	0.00	0.00		
2012	1	1	0	0	4	22.32	14.3	16.4	18.9	19.9	20.7	21.3	21.3	-1.0
	-1.0	-1.0	0.04	1.60	10.44	8.52	1.36	0.24	0.12	0.00	0.00	0.00		
1993	2	2	0	0	1	30.44	15.8	17.5	18.4	20.6	22.1	23.6	-1.0	-1.0
	-1.0	-1.0	6.44	11.52	9.24	1.96	0.72	0.40	0.00	0.00	0.00	0.00		
1994	2	2	0	0	1	120.96	15.0	16.7	18.0	18.6	19.1	-1.0	21.0	-1.0
	-1.0	-1.0	47.44	54.28	12.08	6.24	0.76	0.00	0.04	0.00	0.00	0.00		
1995	2	2	0	0	1	58.84	15.5	16.6	17.3	18.1	20.5	-1.0	-1.0	-1.0
	-1.0	-1.0	13.20	29.12	14.96	1.36	0.16	0.00	0.00	0.00	0.00	0.00		
1996	2	2	0	0	1	45.92	13.9	15.9	18.5	19.2	22.2	-1.0	-1.0	-1.0
	-1.0	-1.0	14.00	15.16	13.80	2.60	0.16	0.00	0.00	0.00	0.00	0.00		
1997	2	2	0	0	1	47.44	13.2	16.6	19.5	21.0	21.5	21.8	23.8	-1.0
	-1.0	-1.0	8.36	15.04	9.64	9.84	3.76	0.64	0.16	0.00	0.00	0.00		
1998	2	2	0	0	1	72.48	13.4	15.1	17.1	19.6	20.8	21.2	-1.0	-1.0
	-1.0	-1.0	23.24	33.12	13.80	1.52	0.60	0.20	0.00	0.00	0.00	0.00		
1999	2	2	0	0	1	55.32	15.0	15.3	16.0	16.1	-1.0	-1.0	20.5	-1.0
	-1.0	-1.0	16.72	26.68	10.44	1.04	0.00	0.00	0.04	0.00	0.00	0.00		
2000	2	2	0	0	1	48.04	14.1	15.2	17.2	17.6	17.7	-1.0	-1.0	22.6
	-1.0	-1.0	13.04	19.12	12.76	2.60	0.48	0.00	0.00	0.04	0.00	0.00		
2001	2	2	0	0	1	71.04	13.1	15.4	17.7	19.3	20.3	21.1	-1.0	-1.0
	-1.0	-1.0	49.60	13.44	5.28	2.20	0.40	0.12	0.00	0.00	0.00	0.00		
2002	2	2	0	0	1	76.48	15.5	16.7	17.8	18.9	20.0	22.8	24.8	-1.0
	-1.0	-1.0	12.88	43.52	14.92	3.92	0.92	0.24	0.04	0.00	0.04	0.00		
2003	2	2	0	0	1	74.64	13.4	15.7	18.5	19.8	22.1	-1.0	23.9	-1.0
	-1.0	-1.0	63.08	2.76	4.60	2.16	1.24	0.00	0.32	0.00	0.00	0.00		
2004	2	2	0	0	1	59.16	14.2	15.4	17.6	19.7	21.7	23.4	-1.0	-1.0
	-1.0	-1.0	3.32	50.76	4.36	0.60	0.08	0.04	0.00	0.00	0.00	0.00		
2005	2	2	0	0	1	89.04	13.0	14.8	16.9	19.2	20.0	23.4	24.6	-1.0
	-1.0	-1.0	44.68	31.32	11.56	0.80	0.16	0.16	0.20	0.00	0.00	0.00		
2006	2	2	0	0	1	105.16	14.0	15.8	18.2	19.3	21.2	-1.0	-1.0	-1.0
	-1.0	-1.0	17.08	61.52	23.04	3.40	0.12	0.00	0.00	0.00	0.00	0.00		
2007	2	2	0	0	2	67.44	13.4	14.8	17.3	20.1	21.7	-1.0	-1.0	-1.0
	-1.0	-1.0	22.96	27.76	10.64	5.12	0.84	0.00	0.00	0.00	0.00	0.00		
2008	2	2	0	0	3	39.76	13.1	16.2	17.6	19.0	21.8	-1.0	-1.0	-1.0
	-1.0	-1.0	7.16	21.88	8.44	2.08	0.20	0.00	0.00	0.00	0.00	0.00		
2009	2	2	0	0	3	98.08	14.2	15.0	15.6	18.0	20.1	-1.0	-1.0	-1.0
	-1.0	-1.0	49.52	37.36	10.56	0.48	0.16	0.00	0.00	0.00	0.00	0.00		
2010	2	2	0	0	4	31.40	14.2	15.5	19.1	20.8	21.5	22.1	23.0	25.1
	-1.0	-1.0	13.84	7.96	0.68	1.52	3.08	3.80	0.44	0.04	0.00	0.00		
2011	2	2	0	0	4	54.88	13.4	15.9	18.2	19.8	21.0	21.7	22.0	22.5
	23.0	-1.0	9.40	18.92	14.96	5.24	2.44	2.08	1.28	0.48	0.08	0.00		
2012	2	2	0	0	4	8.92	15.5	18.2	19.1	20.1	20.9	22.8	23.1	-1.0
	-1.0	-1.0	0.08	1.36	4.72	2.32	0.32	0.08	0.04	0.00	0.00	0.00		
1999	1	3	0	0	5	2.96	-1.0	-1.0	17.8	19.7	21.0	22.5	24.2	-1.0
	-1.0	-1.0	0.00	0.00	1.56	0.60	0.20	0.52	0.08	0.00	0.00	0.00		
2000	1	3	0	0	5	66.64	-1.0	19.9	19.1	20.7	21.5	22.1	22.3	22.7
	-1.0	-1.0	0.00	0.44	12.40	25.16	14.76	8.16	4.00	1.12	0.00	0.00		
2001	1	3	0	0	5	81.28	-1.0	16.3	20.4	20.8	21.2	22.1	22.8	-1.0
	23.4	-1.0	0.00	1.76	8.68	34.96	22.88	7.56	4.08	0.00	0.00	0.00		
2002	1	3	0	0	5	110.32	-1.0	19.5	20.7	21.7	22.0	22.3	22.8	23.2
	23.5	24.1	0.00	0.96	4.28	15.36	39.76	26.68	12.80	6.64	3.72	0.12		
2003	1	3	0	0	5	92.32	-1.0	18.9	19.6	20.4	21.8	22.5	22.7	22.9
	23.5	23.8	0.00	1.80	15.12	14.40	10.40	17.80	14.88	8.08	8.72	1.12		
2004	1	3	0	0	5	66.56	-1.0	16.9	19.7	21.2	22.5	23.1	23.4	23.5
	23.6	23.8	0.00	18.80	8.80	9.76	6.44	7.64	8.04	3.12	3.32	0.64		
2005	1	3	0	0	5	40.84	-1.0	17.0	17.5	17.9	19.6	21.9	22.9	24.0
	24.0	24.3	0.00	0.96	22.12	5.48	2.72	1.76	1.52	1.64	3.20	1.44		
2006	1	3	0	0	5	26.92	-1.0	-1.0	19.1	19.5	19.8	20.4	20.7	23.5
	-1.0	-1.0	0.00	0.00	0.48	17.64	5.40	1.80	0.76	0.32	0.48	0.04		

```
2007    1       3       0       0       5       89.40   -1.0    -1.0    18.6    19.3    19.7    20.1    20.8    21.1
        24.1    25.5    0.00    0.00    3.00    38.36   37.80   7.76    1.68    0.40    0.32    0.08
2008    1       3       0       0       5       94.00   -1.0    -1.0    18.5    19.2    19.9    20.3    21.0    21.8
        22.8    -1.0    0.00    0.00    0.24    11.76   45.96   29.12   5.24    1.08    0.60    0.00
2009    1       3       0       0       5       93.24   -1.0    -1.0    19.1    19.1    19.5    19.9    20.1    20.4
        20.9    -1.0    0.00    0.00    0.64    4.16    28.68   35.48   19.56   4.00    0.72    0.00
2010    1       3       0       0       5       33.76   -1.0    -1.0    16.4    19.0    19.9    20.0    20.2    20.3
        20.4    -1.0    0.00    0.00    0.16    1.12    6.88    13.04   8.40    3.48    0.68    0.00
2011    1       3       0       0       5       42.88   -1.0    17.4    19.0    20.0    20.7    20.9    21.0    21.1
        21.0    -1.0    0.00    0.12    1.24    2.12    5.16    13.08   12.60   7.04    1.52    0.00
2012    1       3       0       0       5       118.24  -1.0    19.9    19.8    20.1    20.8    21.4    21.7    21.8
        21.9    22.4    0.00    0.12    41.72   25.04   8.12    5.44    8.92    11.76   16.52   0.60
2005    2       8       0       0       6       12.12   16.4    18.6    19.4    20.1    23.3    26.8    -1.0    -1.0
        -1.0    -1.0    0.84    7.04    3.76    0.24    0.16    0.04    0.00    0.00    0.04    0.00
2007    2       8       0       0       6       14.80   -1.0    17.7    19.4    21.4    21.8    22.0    -1.0    -1.0
        -1.0    -1.0    0.00    0.12    2.36    9.68    2.36    0.28    0.00    0.00    0.00    0.00
2009    2       8       0       0       6       27.20   16.6    16.9    19.7    21.8    22.1    22.3    22.7    24.3
        -1.0    -1.0    0.04    0.56    0.72    6.04    11.64   6.76    1.32    0.12    0.00    0.00
2010    2       8       0       0       6       25.48   17.7    17.9    18.6    21.0    22.9    23.0    23.1    -1.0
        -1.0    -1.0    0.20    5.48    6.84    3.36    4.48    3.48    1.40    0.24    0.00    0.00
2011    2       8       0       0       6       14.32   -1.0    20.3    20.7    21.9    23.0    -1.0    23.3    23.3
        -1.0    -1.0    0.00    1.16    4.56    2.40    2.64    0.00    1.36    0.00    0.00    0.00
2012    2       8       0       0       6       8.64    -1.0    18.1    21.5    21.8    22.2    23.3    -1.0    24.3
        -1.0    -1.0    0.00    0.04    1.80    3.76    1.20    0.52    0.00    0.36    0.32    0.00
2008    1       9       0       0       6       28.88   10.2    19.7    19.9    20.7    21.2    21.5    -1.0    -1.0
        -1.0    -1.0    1.08    0.08    3.28    12.60   11.24   0.60    0.00    0.00    0.00    0.00
2012    1       9       0       0       6       22.88   -1.0    20.4    20.8    21.1    21.5    22.6    23.3    23.3
        24.0    -1.0    0.00    0.36    6.00    6.96    3.24    2.40    1.56    1.60    0.76    0.00
2013    1       9       0       0       6       14.16   -1.0    -1.0    22.3    22.4    22.4    23.7    -1.0    -1.0
        24.1    -1.0    0.00    0.00    3.88    6.48    1.60    1.00    0.00    0.00    0.24    0.00
0 # N_environment variables
0 # N_environment obs
0 # N_sizefreq methods to read in
0 # No tag data
0 # No morph composition data
999 # End of file
```

Appendix D
PFMC Scientific Peer Reviews and Advisory Body Reports.

Pacific Sardine
STAR Panel Meeting Report

NOAA / Southwest Fisheries Science Center
La Jolla, California
March 3-5, 2014

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), University of Washington
Meisha Key, SSC, California Department of Fish and Wildlife
José De Oliveira, Center for Independent Experts (CIE)
John Simmonds, Center for Independent Experts (CIE)

Pacific Fishery Management Council (Council) Representatives:
Kerry Griffin, Council Staff
Diane Pleschner-Steele, CPSAS Advisor to STAR Panel
Chelsea Protasio, CPSMT Advisor to STAR Panel

Pacific Sardine Stock Assessment Team:
Kevin Hill, NOAA / SWFSC
Paul Crone, NOAA / SWFSC
Dave Demer, NOAA / SWFSC
Juan Zwolinski, NOAA / SWFSC
Emmanis Dorval, NOAA / SWFSC
Beverly Macewicz, NOAA / SWFSC

1) Overview

The Pacific Sardine Stock Assessment and Review (STAR) Panel (Panel) met at the Southwest Fisheries Science Center, La Jolla, CA from March 3-5, 2014 to review a draft assessment by the Stock Assessment Team (STAT) for Pacific Sardine. Introductions were made (see list of attendees, Appendix 1), and the agenda was adopted. A draft assessment document and background materials were provided to the Panel in advance of the meeting on a SWFSC FTP site.

Paul Crone and Kevin Hill presented the assessment methodology and the results from a draft assessment utilizing the Stock Synthesis Assessment Tool, Version 3.24s (SS model) to the Panel. The assessment report included many model runs. However, two "blended" models (G and H) were the focus for Panel discussion. Model G included the following features: (a) the data were updated through 2013, (b) the catches for the MexCal fleet were derived from the environmental-based method, (c) the weight-length and maturity-at-length relationships were updated, (d) the data for the aerial survey were omitted from the assessment, (e) the acoustic-trawl (ATM) survey was split into spring and summer surveys (with separate catchability and selectivity parameters), with catchability parameters (*q*s) no longer fixed, (f) no additional data weighting for survey abundance data beyond input coefficients of variation (CVs) (i.e., lambda=1), (g) no additional data weighting for the length composition data for fisheries/surveys beyond the input effective sample sizes (lambda=1), (h) weighting for the conditional age-at-length data in addition to the input effective sample sizes (lambda=0.5), (i) the value for σ_R was rounded and fixed to 0.75, and (j) recruitment was related to spawning stock size according to a Beverton-Holt stock-recruitment relationship with pre-specified steepness (set to 0.8). Model H differed from Model G by assuming age- rather than length-specific selectivity patterns, by fitting to age-composition data rather than length-composition and conditional age-at-length data, and by fixing the parameters of the growth curve. Model H included no additional data weighting to the abundance or composition data.

David Demer presented the environmental-based method for identifying the catches from the northern subpopulation (NSP). This method led to excluding some of the data (catches and associated composition data) for the Ensenada and San Pedro fisheries from the assessment as those catches were predicted to have come from the southern subpopulation. The Panel welcomed this new approach, noting that past Panels had recommended that developing and applying a method for a more appropriate splitting of catches between the northern and southern subpopulations was a high research priority. The Panel noted that adopting this new catch series meant that there would be no assessment for the population (southern) part of which is subject to being caught during the fall off southern California. The CPS representative commented during the Panel that a pragmatic way to address issues of stock structure might be to conduct an assessment based on catches from US waters only, since the proportions of the southern and northern stocks landed at San Pedro and Ensenada respectively were approximately equal.

David Demer and Emmanis Dorval presented aspects of the methodology and results for the ATM and Daily Egg Production Method (DEPM) respectively. No representative of the Northwest Aerial Survey was available to present the results from the 2013 aerial survey, but Tom Jagielo provided a summary of the results by email on February 27, just prior to the review (Appendix 2). Chris Francis (NIWA, retired) provided a presentation regarding data weighting and the use of conditional age-at-length data in assessments. The Panel noted, and was particularly appreciative of, the efforts made by the STAT to respond to the recommendations from past panels and the SSC. The draft assessment report did not include a summary of progress relative to the recommendations from the ATM survey methdology panel that was held in 2011. Appendix 3 was produced by the end of the Panel meeting, which summarizes this progress. This document was not reviewed by the Panel, but is included in this report for completeness.

The review and subsequent explorations of the assessment through sensitivity analyses were motivated primarily by the need to determine the weightings assigned to the compositional data, particularly given the obvious sensitivity of the results of the assessment to how the conditional age-at-length data are weighted. The Panel also explored various configurations for how selectivity and catchability are parameterized for the ATM survey.

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

2) Day 1 requests made to the STAT during the meeting – Monday, March 3rd

[Note: Request numbers do not necessarily correspond with the model numbers given in Table 1.]

A. ***Request***: Compare the yearly length-composition data for the Ensenada fishery that are included in the MexCal data set for the NSP scenario with the corresponding southern California length compositions. Also, compare the yearly length-composition data for the Oregon-Washington catches with those for the British Columbia fishery.
Rationale: There are no age-length data for the Ensenada fishery or for the British Columbia fishery available for use in the assessment at this time, but model H implicitly assumes that the length frequencies for the Ensenada fishery are the same as those for the southern California fishery and that the length-frequencies for the British Columbia fishery are the same as those for the Oregon-Washington fishery.
Response: This request was not required because the Panel focused on model G (length-based) that was presented as the potential base case model and not model H (age-based). Model H was not a focus for the Panel review because it was not as fully tested as model G, and because the construction of the catch age-composition data ignored the length data for Mexico and British Columbia. However, this request has been put forward as a research recommendation.

B. ***Request***: Compute age-compositions for the ATM survey by multiplying the survey length-frequencies by the associated age-length keys. Compare the mean age-at-length time-series north and south of 40°10’ from the ATM survey.
Rationale: The age data for the ATM survey presented in the draft report were unweighted.

Response: This request was not required because the Panel focused on model G (length-based) that was presented as potential base case model and not model H (age-based). However, this request has been put forward as a research recommendation.

C. ***Request***: Construct catch time series using a one month shorter and longer monthly duration for when the San Pedro and Ensenada fisheries are catching southern subpopulation fish.
Rationale: To evaluate the sensitivity of the catches to the cutoff (50%) that is used to assign catches to the NSP.
Response: Figure 1 shows that the results are likely to be somewhat sensitive to the cut-off chosen to define catches from the northern subpopulation. A research recommendation was raised to examine this issue further.

D. ***Request***: Overlay the habitat map with the spring survey results for the 2013 ATM survey.
Rationale: The survey did not go north of San Francisco. The Panel was interested to know whether the areas north of San Francisco would have been expected to have been suitable habitat for Pacific sardine.
Response: The plots showed no evidence of substantial suitable habitat north of San Francisco in the two weeks around the time the survey was conducted, which suggests that the survey should have provided an adequate sample of the population.

E. ***Request***: Provide additional information regarding the apparent discrepancy between the biomass estimates from the ATM survey in the Washington / Oregon area and the landings in this area, based on the information from 2012.
Rationale: The Panel wished to have more information on this apparent discrepancy.
Response: Juan Zwolinski noted that the ATM survey sampled the region between 44° 47.2'N and 48°18'N and from the 50m to the 1500m depth isobaths from 07/31/2012 to 08/10/2012. The resulting point estimate of sardine biomass was 13,333 mt. The sampling variance was high, resulting in a 95% confidence interval of [3,918, 27,559] mt. During the same time period, the commercial fishery off Oregon and Washington caught 9,747 mt. The ATM surveyed the area to the north, including northern Washington and western Vancouver Island, B.C. There, the sardine biomass was estimated at 18,675 mt, with a 95% confidence interval of [2,661, 54,017] mt. It was likely that by 08/10/2012, 32,008 mt of sardine, with 95% confidence interval [12,439, 68,945] mt, would have been available for the Oregon and Washington fisheries, assuming that all the sardine observed off western Vancouver Island migrated from the south.

F. ***Request***: With model G (from initial draft), reweight the fishery and survey length-composition and conditional age-at-length data by applying the Francis (2011) weighting method (Equation TA1.8). The weighting factors should be implemented as changes to the lambdas in the SS model.
Rationale: The compositional data may not be appropriately weighted.
Response: The upper panel of Table 2 lists the factors to weight the input sample sizes (which are lower than the actual number of fish sized and aged), for each length-composition and conditional age-at-length data component that needs to be weighted. The

response to this request (and requests L, M, and N) was based on model 'K' in which the conditional age-at-length data are not downweighted by 0.5 (see Table 1 for the specifications for the models investigated during the Panel requests). The Francis method suggested that the length-compositions needed to be downweighted substantially. In contrast, this method also suggested that the conditional age-at-length data for the MexCal fleets and the ATM survey need to be upweighted. Implementing these weighting factors (model F) led to a markedly lower biomass trajectory and substantially changed selectivity patterns for the two MexCal fisheries. The results from this request led to requests L, M, N and O.

G. *Request*: With model G (from initial draft), include the NWSS aerial survey data. Summarize the results in terms of residual patterns and the information given in Table 8 of the draft document.
Rationale: The Panel wished to understand whether the aerial survey data would be influential if they were included in the assessment.
Response: The biomass trajectory was lower than for model G when the NWSS aerial survey was included in the assessment, but otherwise the results were not substantially different. The Panel did not see evidence to disagree with the STAT's recommendation to leave this survey out of the assessment.

H. *Request*: With model G (from initial draft), examine scenarios in which catchability is the same for the spring and summer ATM surveys. Consider values for ATM survey catchability from 0.7 to 1.1 in steps of 0.2. Summarize the results in terms of residual patterns and the information given in Table 8.
Rationale: The Panel noted that the ATM survey scientists expressed the view that the spring and summer surveys were directly comparable and wished to understand whether this view is supported by the data included in the assessment.
Response: There is no evidence to support having separate q's for the spring and summer ATM surveys in terms of the change to the value of the objective function. The single q is closer to that from the spring surveys, which is expected given the relative number of ATM survey data points for spring (6) and summer (3). The spring survey selectivity pattern switches to being less knife-edged for the higher qs, but the change for this and the biomass trajectory did not occur in a systematic way as the ATM survey catchability was changed from 0.7 to 1.1. This request led to an additional request (P).

I. *Request*: With model G (from initial draft), replace the Beverton-Holt stock-recruitment relationship with the Ricker form of this relationship. Estimate steepness rather than assuming it equals 0.8.
Rationale: Several past assessments were based on the Ricker form of the stock-recruitment relationship, with steepness estimated. The Panel wished to explore the sensitivity to this change from prior assessments.
Response: The scale of biomass is slightly lower with the Ricker stock-recruitment relationship, with no difference in likelihoods between the two model runs. Steepness was estimated at 2.05.

J. *Request*: With model G (from initial draft), set $M = 0.5\text{yr}^{-1}$.

Rationale: The analysis of Zwolinski and Demer (2013) suggests that *M* is higher ($0.52yr^{-1}$) than the model G assumption of $0.4yr^{-1}$.
Response: As expected, the scale of the biomass was higher, and the ATM survey *q*'s were lower (spring=0.58, summer=0.63). The change in likelihood was 3 units with the higher *M*, but given the concerns with the weights assigned to the length and conditional age-at-length data, this is not considered to be a substantial change.

Day 2 requests made to the STAT during the meeting – Tuesday, March 4th

K: ***Request***: Conduct an assessment where all the weighting factors (lambdas) are set to 1 and compare the results for this model to those for model G (from the initial draft assessment).
Rationale: The selection of the factors to weight the length-composition and conditional age-at-length data was based on this model.
Response: The STAT provided model K which showed increasing the weights on the conditional age-at-length data from 0.5 to 1 substantially lowered the biomass trajectory.

L. ***Request***: Based on model K, apply the Francis method to estimate weighting factors for the length-composition and conditional age-at-length data, pooling the two MexCal fleets, pooling the spring and summer ATM survey data and analyzing the PacNW separately.
Rationale: Some of the weighting factors are based on very few compositions and consequently the weighting factors are uncertain (Table 2, upper).
Response: This was model L. The weighting factors for the pooled fleets are as expected, but the confidence intervals, particularly for the ATM survey, are narrower (Table 2, lower). The Panel considered it appropriate to pool across fleets when computing the weights for the length-composition and conditional age-at-length data.

M. ***Request***: Based on model K, change only the weights assigned to the length-composition data using the weighting factors from Request F.
Rationale: The Panel wished to understand whether the length-frequency or conditional age-at-length data were most influential.
Response: This was model M. The biomass estimates for the early years were sensitive to changing the weights assigned to the length-frequency data. However, the trend in abundance over recent years was unchanged, and the biomass scale was largely unchanged. The Panel concluded that how the conditional age-at-length data are weighted was the major cause of the change in results observed for request F.

N. ***Request***: Based on model K, change only the weighting factors assigned to the conditional age-at-length data using the weighting factors from Request F.
Rationale: The Panel wished to understand whether the length-frequency or conditional age-at-length data were most influential.
Response: The biomass trajectory for model N was markedly lower (and survey *q* markedly higher) when the conditional age-at-length data were changed.

O. ***Request***: Same as for request N, except that the weighting factor for the conditional age-at-length data sets for the PacNW fishery is assumed to equal 1.

Rationale: The weighting factor for the conditional age-at-length data for the PacNW fleet was less than one, in contrast to the weighting factors for the MexCal fleets and the ATM survey.
Response: The results for model O were essentially identical to those for request N.

P. *Request*: Same as for model G, except that catchability and selectivity for the spring and summer ATM surveys are assumed to be the same.
Rationale: The Panel wished to understand whether there is support for separating the two surveys.
Response: The fits to the survey length-frequency data for model P were not as good as for model G, even after accounting for there being three fewer parameters. The biomass trajectory was lower than for model G, and the ATM survey catchability was 2.38, a value considered implausible. The single ATM survey selectivity was less knife-edged and to the right of those for the spring and summer ATM survey selectivities from model G, which was unexpected. The model appeared to increase the selection at smaller lengths to account for the summer survey which had appreciable catches at these lengths. The consequence was to then reduce selection at the greater lengths that were previously fully selected when the surveys were fitted with separate selection patterns.

Q. *Request*: Same as for model P, except that the weight assigned to ATM survey length-frequency data was increased from 1 to 20.
Rationale: The Panel wished to understand whether it is possible to fit the length-frequency data for the ATM survey, at least in principle.
Response: The fits to the ATM length-frequency data for model Q were better, but the model was still unable to adequately mimic all of the length-frequencies.

R. *Request*: Conduct models R, S, T, W and U.
Rationale: The Panel wished to understand the trade-offs in results among various treatments of ATM survey catchability and selectivity. Some of these models ignore the ATM survey conditional age-at-length data because these data were not computed accounting for the sampling scheme for the survey.
Response: Figure 2 summarizes the biomass trajectories from these models. Models R and S, in which selectivity for the spring and summer ATM surveys was assumed to be the same, led to higher estimates of biomass compared to model G, whereas model T which estimated separate selectivity patterns for the spring and summer ATM surveys, led to lower estimates of biomass; in contrast model W, which is the same as model T but estimates separate catchabilities for the ATM surveys, led to higher estimates of biomass than even model S. Model U in which the conditional age-at-length data for the MexCal and PacNW fisheries were markedly downweighted led to much lower biomass estimates and unrealistically high estimates of survey catchability.

S. *Request*: Repeat request Q, but omit the ATM survey length-frequency data for spring 2012.
Rationale: This length-frequency was considered unreliable by the ATM survey team.
Response: This model (V) was not able to adequately fit the remaining ATM survey length-frequencies.

T. Request: Conduct analyses for a range of values for the extent which the conditional age-at-length data are downweighted. The analyses should be conducted for model specifications G-2, W-2, W-3, and T-2 (See Table 1).
Rationale: The Panel wished to understand the impact of different weighting factors on the results of the model.
Response: The outputs for models based on configuration W-3 all led to values for the ATM survey catchability coefficients which were considered unrealistically low (~0.25). The biomass trajectories for recent years were more robust for the models based on configuration T-2, but there was considerable sensitivity of biomass estimates for the early years (Figure 3). The biomass trajectories for recent years fell into two groups (one group based on weighting factors on the conditional age-at-length data of 0.1, 0.2 and 0.4; another group based on weighting factors of 0.3, and 0.5 and larger). The biomass trajectories were more stable for model runs based on configuration W-2 than configuration W-3. The weighting factor is 0.035 for configuration W-2 if it is chosen so that the average ATM (spring and summer) survey catchability is 1. Alternatively, this weighting factor is ~0.7 if the analysis is based on configuration G-2. Downweighting is more severe for model configuration W-2 because this model configuration ignores the ATM conditional age-at-length data which tends to support lower biomass estimates. However, the STAT noted that choosing a weighting factor to achieve a given average ATM survey catchability coefficient may not be a robust way to provide management advice. The Panel concurred with this view.

Day 3 requests made to the STAT during the meeting – Wednesday, March 5th

At this point in the meeting, the STAT and Panel agreed to proceed with models which are variants of configuration T-2, i.e. the weighting factors for the length-frequency data are set to 1, catchability is set to 1 for both the spring and summer ATM surveys, separate selectivity patterns are estimated for the spring and summer ATM surveys, and the ATM survey conditional age-at-length data are ignored. The STAT and Panel agreed to focus on two models: T-2_0.2 and T-2_0.7. The difference between these two models is the weight assigned to the fishery conditional age-at-length data. These choices for weighting factors were selected because they are representative of the two groups in Figure 3.

U. Request: Apply models T-2_0.2 and T-2_0.7 when the length-frequencies for the 2011 and 2012 spring ATM surveys are ignored.
Rationale: It was speculated that some of the model sensitivity was due to attempts to fit these two length-frequencies (the fits to these length-frequencies are always poor).
Response: The results when the weighting factor for the conditional age-at-length data was set to 0.7 were similar to those when the weighting factor was set to 0.2 (Figure 4), suggesting that at least one reason for the two groups of results in Figure 3 are conflicts when fitting to the length-frequencies for the 2011 and 2012 spring ATM surveys.

V. Request: Apply models T-2_0.2 and T-2_0.7 when the data for the last four years are ignored.

Rationale: The Panel wished to understand whether a retrospective analysis might help to distinguish between these two models.
Response: The results from both models changed markedly when the data for last four years were ignored (Figure 5).

The STAT and Panel agreed that model T-2_0.2 would be the base model given the relative lack of sensitivity to omitting data (see request U).

3) Technical Merits and/or Deficiencies of the Assessment
Recruitment estimation and environmental variables
The estimate of the most recent recruitment (age 1 in 2013) is uncertain and estimated to be close to the expected value from the stock-recruitment function (Figure 6). Deviations of sardine recruitment from a fitted stock-recruitment model of either Ricker or Beverton-Holt form are observed to be correlated in time, such that there appear to be periods of 'high' recruitment and separate periods of 'low' recruitment. Investigations of the potential for environmental factors to be informative have been conducted by Zwolinski and Demer (in press). They showed that the variability in sardine recruitment in the California Current during the last three decades mimics aspects of the environment in the North Pacific indicated by the Pacific Decadal Oscillation (PDO) index. Research indicated that the average number of recruits per biomass during "warm" periods was more than threefold higher than during "cold" periods. In addition to the environmental conditions experienced by sardine larvae, variability in sardine recruitment is also partially explained by both the environmental conditions several months before the spawning season and the adult's condition factor prior to spawning.

Management of the stock uses information on the biomass of age 1+ sardine when applying the Overfishing Level and Acceptable Biological Catch control rules. Recruitment in the last few years has been lower than expected from the stock-recruitment relationship used in the assessment model. Improved estimation (or prediction) of age-1 recruitment for the most recent year would improve management of the stock given that the assessment model currently leads to a rather imprecise estimate of this quantity (Figure 6). There are a number of potential approaches to do this.

1. A prediction model based on recent recruitment and observed autocorrelation could be used to provide more likely estimates of recruits in the final year without assigning any specific underlying reason for the recruitment.
2. A recruitment prediction index such as that proposed by Zwolinski and Demer (in press), could be used outside the assessment model to replace the assessed value with an alternative value based on a weighted mean of the assessed and index-derived values. One method of determining appropriate weights is given by Shepherd (1997).
3. Inclusion of informative environmental indices in stock-recruitment estimation within the assessment model.

When investigating environmental drivers to explain recruitment, a number of issues need to be considered:

1. The spawning biomass and recruitment pairs estimated in an assessment are subject to uncertainty, and this needs to be accounted for when estimating the prediction intervals for any potential index.
2. Development of environmental indices (for recruitment) through regression analysis needs to be undertaken with care. There are often many explanatory environmental variables. The approach is often to examine many variables to establish the most significant explanatory set. However, to understand the significance of the conclusions, it is important to recognise that exclusion of unsuitable variables is effectively setting the coefficient for the relationship to zero. This needs to be accounted for correctly in tests for overall significance by, for example, removing one degree of freedom for every variable (or variable at lag) rejected. This can be done easily for variables formally tested, but may be more difficult to include when variables are rejected at an early stage based on simple graphical investigation. Currently there are 20 stock-recruitment pairs for Pacific sardine; rejection of 18 potential variables (and or lags) while a relationship is being developed should result in a perception of no significant fit. Failure to consider this can lead to an over-optimistic conclusion of the utility of explanatory functions; see for example Gröger *et al*. (2010) who examined many potential indices and a wide variety of lags, and concluded they had found significant drivers for recruitment.

DEPM Survey

The analysis of the egg survey has some minor issues, mostly to do with the raising of density to survey area. The survey design is intended to sample the region of higher density, because, ideally, the survey obtains lower values around the periphery. A high density stratum is then drawn around a group of observations that contain the higher values, by creating a 'simple' (relatively smooth) boundary using the location of the points. The main idea behind this approach is that the survey objective is to map a peak density in space. There is therefore an assumption that the survey will have higher values towards the centre of the area and lower values around the edges. This is then analysed using a two stratum analysis approach that has two minor issues:

1. the current method for placing the boundary between the high and low density areas by placing the boundary on the observation locations means the higher density area is smaller than the region represented by those observations, and conversely the low density area is a little larger, resulting in a small underestimate. The method should be changed so that the correct area allocation is used for each point in each of the two strata. The effect is likely small on the index value used in the assessment because the current procedure is applied for all years.
2. The post stratification and CV calculations may not be correctly calculating the CV used to weight the survey index values in the assessment. The use of post stratification may result in underestimation due to the separation into strata based on the observed values. The use of a simple variance based on the within-stratum observations in the two strata may result in overestimation given there is expected to be some spatial trend within each stratum. A method that accounts for transect-based sampling, and correlated observations, and reflects the presence of a spawning aggregation would be an improvement.

Construction of conditional age-at-length for the ATM survey

Currently fish aged during the ATM survey are combined into an unweighted age-length key, and subsequently used to construct the conditional age-at-length data for each complete ATM survey. This treatment is not considered to be optimal given the possibility for age- and size-specific distribution of sardine. The use of separate age-length keys for the MexCal and PacNW fleets suggests that there may be differences in age-length keys from these regions. The implication of the current method for the ATM surveys is that this is not occurring. The alternatives are to develop separate age-length keys for the different regions covered by the ATM survey, or to use appropriate biomass-based weighting for each part of the survey area.

Sensitivity of biomass estimates

During its deliberations (see Section 2 of this report) the Panel found, as have several previous Panels, that the trend in abundance for Pacific sardine is generally well-determined by the available data. However, the absolute scale of the population is not well-determined by the data and seemingly small changes to the specifications of the assessment (e.g. the relative weighting of the composition data) can lead to marked changes to the scale of the population. The sensitivity to scale is most obvious in the early years of the assessment period, for which the only index data are the (relatively uninformative) DEPM and Total Egg Production (TEP) estimates. The 2011 assessment addressed this "stability" issue by fixing the q for one of the surveys. The 2011 Panel noted that this is not an ideal approach, and it recommended that this assessment include the development of informative priors for the q parameters for the DEPM, aerial and ATM surveys. However, it also noted that development of informative priors is a non-trivial task and should involve people in addition to the STAT, in particular the survey teams. The last assessment imposed the assumption q=1 for the ATM survey because (a) there are more estimates of abundance for this series than for the aerial survey, (b) the ATM survey is more synoptic (in terms of area coverage) than the aerial survey, (c) the estimates are generally more precise than those for the aerial survey, and (d) the assumption q=1 for the DEPM survey leads to unrealistic values of q for the aerial and ATM surveys (>1.8).

The current assessment team and Panel examined sensitivity to weighting factors (lambdas), and the ATM survey q and selectivity options, and concluded the following:

1. *Sensitivity to the weighting of the ATM conditional age-at-length data*: Estimates of biomass were particularly sensitive to this factor (see models G, K, F, L, N), and the time series were not appropriately assembled (see "Construction of conditional age-at-length for the ATM survey" above). Due to both of these considerations, the ATM conditional age-at-length data were excluded from the final model.
2. *Sensitivity to the weighting of the ATM length-composition data*: When compared to weighting by haul (model K), model results for recent years were insensitive to alternative weighting of the ATM length-composition data, including the use of Francis weights (model M) and arbitrary up-weighting (by a factor of 20; models Q and V).

3. *Sensitivity to weighting of the fishery conditional age-at-length*: A range of weighting factors less than 1 were explored (see models G-2, W-2, W-3, T-2). The sensitivity observed depended on whether the ATM *q* was estimated or fixed (*q*=1). Model outputs were more stable when *q* was fixed (model T-2).
4. *Sensitivity to weighting of the fishery length-composition data*: Two options were investigated: weighting by haul and using the Francis data weighting method. When *q* is estimated (W-3), the use of Francis weights resulted in unrealistically low estimates of *q* (0.2-0.3). For haul-based weights (G-2, W-2), estimates of *q* included the value of 1 over the range of weights considered.
5. *Sensitivity to estimation of ATM q*: Three options were explored: (a) separate estimated *q*s for the spring and summer surveys, (b) a single estimated *q* for both surveys, and (c) a fixed *q*=1 for both surveys. The sensitivity to how the fishery conditional age-at-length data are weighted was considerably reduced for recent years when fixing *q*=1 (e.g. compare models W-2 and T-2). Given the rather arbitrary conditional age-at-length weights being applied for Model G, and that the sensitivity to these could be considerably reduced by fixing *q*=1, it was decided to choose this option in the final model, thereby reducing the sensitivity of the model results to weighting. Generally similar reasoning was used in past assessment reviews (e.g., PFMC, 2011).
6. *Sensitivity to selectivity options for ATM survey*: Two options were explored: (a) a single selectivity pattern for both ATM surveys (spring and summer) or (b) separate selectivity patterns for each survey. When estimated separately, selectivity for the spring survey was nearly knife-edged at around 16cm, and in comparison, that for the summer survey shifted to higher lengths (e.g., model G). When estimated as a single selection pattern, the result was a much shallower curve, starting in a similar place to that estimated for the spring survey and extending to even greater lengths than that estimated for the summer survey (e.g. model P). This probably results from a requirement to include fish between 15 and 18cm in the spring survey, while giving reduced selection at around 20cm for the summer survey and thereby implying a reduction in selectivity for a range of lengths greater than 22cm that were fully selected with separate selection patterns.

The final base model incorporates the following specifications:

- catches for the MexCal fleet computed using the environmentally-based method;
- two seasons (semesters, Jul-Dec=S1 and Jan-Jun=S2) for each assessment year from 1993 to 2013;
- sexes were combined;
- two fisheries (MexCal and PacNW fleets), with an annual selectivity pattern for the PacNW fleet and seasonal selectivity patterns (S1 and S2) for the MexCal fleet;
  - MexCal fleet:
    - dome-shaped length-based selectivity with two periods of time blocking (1993-1998, 1999-2013);
  - PacNW fleet:
    - asymptotic length-based selectivity for a single time period;
  - length compositions with effective sample sizes calculated by dividing the number of fish sampled by 25 (externally) and lambda weighting=1 (internally);

- o conditional age-at-length compositions with effective sample sizes calculated by dividing the number of fish sampled by 25 (externally) and lambda weighting=0.2 (internally);
- Beverton-Holt stock-recruitment relationship "steepness" was fixed (0.8);
- *M* was fixed (0.4 yr^{-1});
- recruitment deviations estimated from 1987-2012;
- virgin (R_0), and initial recruitment offset (R_1) were estimated, and σ_R fixed (0.75);
- initial *F*s set to 0 for all fleets (non-equilibrium model following the initial age composition method in SS);
- DEPM and TEP indices of spawning biomass with *q* estimated for both surveys;
- ATM survey biomass 2006-2013, partitioned into two (spring and summer) surveys, with *q*=1 for each survey;
  - o length compositions with effective sample sizes set to 1 per haul (externally) and lambda weighting=1 (internally);
  - o asymptotic length-based selectivity for spring and summer surveys;
  - o conditional age-at-length data from the ATM surveys excluded;
- NWSS aerial survey index of abundance (biomass) and associated length compositions excluded.

The Panel agrees that the final base model represents the best available science regarding the status of the northern subpopulation of Pacific sardine. The Panel wishes to highlight that the level of variation in terminal biomass evident from the retrospective pattern (on the order of 100,000s of tons from one year to the next; Figure 7 of this report) is not unexpected and has been seen in previous assessments (e.g., PFMC, 2011). Changes in terminal age-1+ biomass estimates used for management of this magnitude may occur when the 2015 assessment update takes place.

On the final day of the review, the STAT provided the Panel with a model in which ATM survey catchability was assumed to be 1 or estimated, separate selectivity patterns were estimated for the spring and summer ATM surveys, the weighting factors for all the length-frequency data were set to 1, and for the conditional age-at-length data were set to 1 for the fishery data and to zero for the ATM surveys, and there were three time blocks for selectivity for the PacNW fishery. There was insufficient time to fully evaluate these models, but the Panel agreed that it would be a valuable model configuration to consider for a future full assessment. That is, model configurations that include time-varying selectivity for suspect fishery/survey composition data that potentially influence absolute abundance estimation is an alternative to downweighting data sources as was largely conducted during this review.

Figure 8 shows time-trajectories of biomass based on applying the final base model (T-2_0.2) in which the catch series is constructed by assuming that all catches in the MexCal fleet are from the northern subpopulation. This model could be used to form the basis for management advice if the model using the environmentally-based catch series cannot be used for management purposes.

4) Areas of Disagreement

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

5) Unresolved Problems and Major Uncertainties

1. The ongoing uncertainties, in particular regarding absolute biomass, are likely to persist until the information content of the data increases substantially, and perhaps not even then.
2. The Panel wishes to highlight that the level of variation in terminal biomass evident from the retrospective analysis (on the order of 100,000s of tons from one year to the next; Figure 7 of this report) is not unexpected, and changes in terminal age 1+ biomass estimates of this extent may occur when the 2015 assessment update takes place.
3. The indices of abundance do not exhibit consistent trends even after allowing for the differences in their respective selectivities, and remain in conflict even when the age and length data are greatly down-weighted.
4. The data set is able to estimate general trends in abundance fairly robustly, but the likelihood is flat over a wide range of current biomass levels, which means that relatively small changes to the data sets or assumptions can lead to marked changes in current abundance.

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

a) CPSMT issues

The CPSMT representative commends the STAT for their efforts accomplished prior to and during the meeting. The CPSMT representative notes that the Panel thoroughly reviewed the stock assessment and the survey data informing the stock assessment. The CPSMT representative appreciates the STAT's effort in addressing data weighting, specifically related to the conditional age-at-lengths from the ATM survey and fisheries. The CPSMT representative agrees with the Panel's attempt to dampen the sensitivity of weighting the data.

The Panel recognized the scaling in the model is not defined given the available data and has been a recurring concern for Pacific sardine and mackerel assessments. Given this instability often seen in the model, the CPSMT representative urges careful consideration when establishing sardine harvest management measures. Ultimately, it is only through further data collection and refinement of data collected that these uncertainties may be resolved. An increase in trawl sampling during the ATM survey could help to increase the amount of size/age data in the model and to potentially reduce conflict between the survey and fishery data.

b) CPSAS issues

The CPSAS representative commends the Panel and STAT for their significant body of work throughout the 2014 sardine STAR panel. Unfortunately, the 2014 sardine assessment encountered the same basic difficulty with scaling issues observed in the 2011 assessment. The SS model is very sensitive to weighting of the input length and conditional age-at-length data from the ATM surveys. Most of the work at the meeting was spent making further analyses to resolve the source of these problems, which included very high variability in the biomass estimates for the first half of the time series. It became apparent from sensitivity runs that data weighting matters. The STAT and Panel attempted to find a solution that made results less sensitive by down-weighting certain conditional age-at-length data.

The sardine assessment model was improved by a more realistic separation of the landings from the northern and southern stocks (excluding the landings of southern stock sardine from Ensenada and Southern California). This reduces the biomass estimates and largely resolves problems associated with the distribution parameter in the harvest guideline.

The final base model ultimately fixed catchability (Q) at 1 for the ATM surveys, as in prior years, attempting to achieve model stability. The CPSAS has voiced concern in the past that acoustic surveys as currently deployed have been unable to measure the full biomass, particularly in the Pacific Northwest. The point is that fishermen observed and caught significantly more fish in the area than the point estimate of the ATM cruise – which measured only one spot in time but contributed to a low overall sardine biomass estimate.

The CPSAS also voices concern that stock assessments seem to be gravitating toward one independent index based on ATM surveys. We encourage a continuation of multiple surveys as each survey type has similar constraints. We acknowledge and applaud the acquisition of the RV Reuben Lasker and its capability to survey with forward and side-scanning sonar. We can support the ATM with the use of sonar to augment acoustic search of water columns that the downsounder does not effectively measure (i.e. the top 10 meters of the water column).

On behalf of the CPSAS and industry at large, the CPSAS representative also expresses disappointment that the aerial survey has been dropped from consideration in this and presumably future stock assessments. Ultimately, industry wants to see a sustainable resource (to the degree that environmental conditions will allow) that is in no danger of being overfished. Current sardine stock assessments and harvest policy are very precautionary. We sincerely hope that going forward we can develop a truly collaborative research program for the CPS complex.

Appendix 4 elaborates on the above concerns and provides recommendations for future stock assessments.

7) Research Recommendations

High priority

A. The assessment would benefit not only from data from Mexico and Canada, but also from joint assessment activities, which would include assessment team members from both countries during assessment development.
B. Modify Stock Synthesis so that the standard errors of the logarithms of age-1+ biomass can be reported. These biomasses are used when computing the Overfishing Level, the Acceptable Biological catch, and the Harvest Level, but

the CV used when applying the ABC control rule is currently that associated with spawning biomass and not age-1+ biomass.

C. Explore models that consider a much longer time-period (e.g. 1931 onwards) to determine whether it is possible to model the entire period and determine whether this leads to a more informative assessment as well as provide a broader context for evaluating changes in productivity.
D. Investigate sensitivity of the assessment to the threshold used in the environmental-based method (currently 50% favourable habitat) to further delineate the southern and northern subpopulations of Pacific sardine. The exploration of sensitivity in the present assessment was limited given time available, but indicated potential sensitivity to this cut-off.
E. Compute age-composition data for the ATM survey by multiplying weighted length-frequencies by appropriately constructed age-length keys (i.e. taking account of where the samples were taken).
F. Investigate alternative approaches for dealing with highly uncertain estimates of recruitment that have an impact on the most recent estimate of age-1+ biomass that is important for management. Possible approaches are outlined in Section 3 of this report.
G. Validation of the environmentally-based stock splitting method should be carried out if management is to be based on separating the northern and southern subpopulations using the habitat model. It may be possible to develop simple discriminant factors to differentiate the two sub-populations by comparing metrics from areas where mixing does not occur. Once statistically significant discriminant metrics (e.g. morphometric, otolith morphology, otolith micro-structure, and possibly using more recent developments in genetic methods) have been chosen, these should be applied to samples from areas where mixing may be occurring or where habitat is close to the environmentally-based boundary. This can be used to help set either a threshold or to allocate proportions if mixing is occurring.
H. Continue to investigate the merits/drawbacks of model configurations that include age compositions (e.g., model H) rather than length-composition and conditional age-at-length data, given some evidence for time- and spatially-varying growth.

Medium priority

I. Continue to explore possible additional fishery-independent data sources. However, inclusion of a substantial new data source would likely require review, which would not be easily accomplished during a standard STAR Panel meeting and would likely need to be reviewed during a Council-sponsored Methodology Review.
J. The reasons for the discrepancy between the observed and expected proportions of old fish in the length and age compositions should be explored further. Possible factors to consider in this investigation include ageing error / ageing bias and the way dome-shaped selectivity has been modelled.
K. The Panel continues to support expansion of coast-wide sampling of adult fish for use when estimating parameters in the DEPM method (and when computing

biomass from the ATM surveys). It also encourages sampling in waters off Mexico and Canada.

L. Consider spatial models for Pacific sardine that can be used to explore the implications of regional recruitment patterns and region-specific biological parameters. These models could be used to identify critical biological data gaps as well as better represent the latitudinal variation in size-at-age.
M. Consider a model that explicitly models the sex-structure of the population and the catch. An analysis of length-at-age samples did not indicate sexual dimorphism for this stock (see Figure 4a in Hill et al. 2014), so all models presented were combined-sex configurations. Nevertheless, it was felt that a sex-specific model was needed minimally as a sensitivity test to investigate the possibility that accounting for sex will have an impact on stock-assessment results for this resource.
N. Consider a model that has separate fleets for Mexico, California, Oregon-Washington and Canada.
O. Compare annual length-composition data for the Ensenada fishery that are included in the MexCal data sets for the NSP scenario with the corresponding southern California length compositions. Also, compare the annual length-composition data for the Oregon-Washington catches with those from the British Columbia fishery. This is particularly important if a future age data/age-based selectivity model scenario is further developed and presented for review.
P. Further explore methods to reduce between-reader ageing bias. In particular, consider comparisons among laboratories and assess whether the age-reading protocol can be improved to reduce among-ager variation.
Q. Change the method for allocating area in the DEPM method so that the appropriate area allocation for each point is included in the relevant stratum. Also, apply a method that better accounts for transect-based sampling and correlated observations that reflects the presence of a spawning aggregation.
R. Consider future research on natural mortality. Note that changes to the assumed value for natural mortality may lead to a need for further changes to harvest control rules.

Low Priority

S. Develop a relationship between egg production and fish age that accounts for the duration of spawning, batch fecundity, etc. by age. Using this information in the assessment would require that the stock-recruitment relationship in SS be modified appropriately.

Finally, the Panel notes that value of the *Small Pelagic Ageing Research Cooperative*, which should improve consistency in age-reading methods generally, and in particular for Pacific sardine. Lack of consistency in age estimates was the reason for not using age data for British Columbia.

8) References

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Zwolinski, J.P. and D.A. Demer. In press. Environmental and parental control of Pacific sardine (Sardinops sagax) recruitment. *ICES Journal of Marine Science* 00: 00-00. doi:10.1093/icesjms/fst173.

9) Tables and Figures

Table 1. Summary of the models requested of the STAT during the review. "F" indicates that the weights assigned to the composition type were based on the Francis (2011) TA1.8 method, "F-pool" indicates that factor to weight the composition concerned pooled information across fleets / seasons, "split" under the "ATM Q" and "ATM sel" (selectivity) columns indicates that separate parameters were estimated for the spring / summer surveys, "equal" under the "ATM Q" and "ATM sel" columns indicates that the parameters concerned were assumed to be the same for the spring / summer surveys, "1" indicates that survey catchability was assumed to be 1. "profile" in the last three lines implies that the STAT were requested to profile over the weighting factor concerned.

	Lambda: Length composition			Lambda: Conditional age-at-length			ATM	ATM
	MexCal (1+2)	PacNW	ATM	MexCal (1+2)	PacNW	ATM	Q	Sel
G	1	1	1	0.5	0.5	0.5	split	split
K	1	1	1	1	1	1	split	split
F	F	F	F	F	F	F	split	split
L	F-pool	F	F-pool	F-pool	F	F-pool	split	split
M	F	F	F	1	1	1	split	split
N	1	1	1	F	F	F	split	split
O	1	1	1	F	1	F	split	split
P	1	1	1	0.5	0.5	0.5	equal	equal
Q	1	1	20	0.5	0.5	0.5	equal	equal
R	1	1	1	0.5	0.5	0	equal	equal
S	1	1	1	0.5	0.5	0	1	equal
T	1	1	1	0.5	0.5	0	1	split
U	1	1	1	0.01	0.01	0.5	split	split
V	1	1	20, excl spr12	0.5	0.5	0.5	equal	equal
W	1	1	1	0.5	0.5	0	split	split
G-2	1	1	1	profile	profile	profile	split	split
W-2	1	1	1	profile	profile	0	split	split
W-3	F-pool	F	F-pool	profile	profile	0	split	split
T-2	1	1	1	profile	profile	0	1	split

Table 2. Weighting factors and 95% confidence intervals. Results are shown when the Francis (2011) method TA1.8 is applied separately by fleet,and when it is applied to data pooled over fleets or surveys.

Fishery/Survey	Weighting factors Length	 Conditional age-at-length
Single data source		
MexCal_S1	**0.17** (0.11-0.43)	**1.79** (1.43-2.33)
MexCal_S2	**0.15** (0.10-0.31)	**1.69** (1.40-2.11)
PacNW	**0.11** (0.08-0.22)	**0.39** (0.30-0.54)
Aerial	NA	NA
ATM_Spr	**0.15** (0.09-1.13)	**2.11** (1.52-3.49)
ATM_Sum	**0.04** (0.03-Inf)	**1.61** (1.0-3.64)
Pooled data source		
MexCal_S1-S2	**0.17** (0.12-0.28)	**1.66** (1.40-1.98)
PacNW	**0.11** (0.08-0.22)	**0.39** (0.30-0.53)
ATM_Spr-Sum	**0.09** (0.06-0.42)	**1.87** (1.37-2.85)

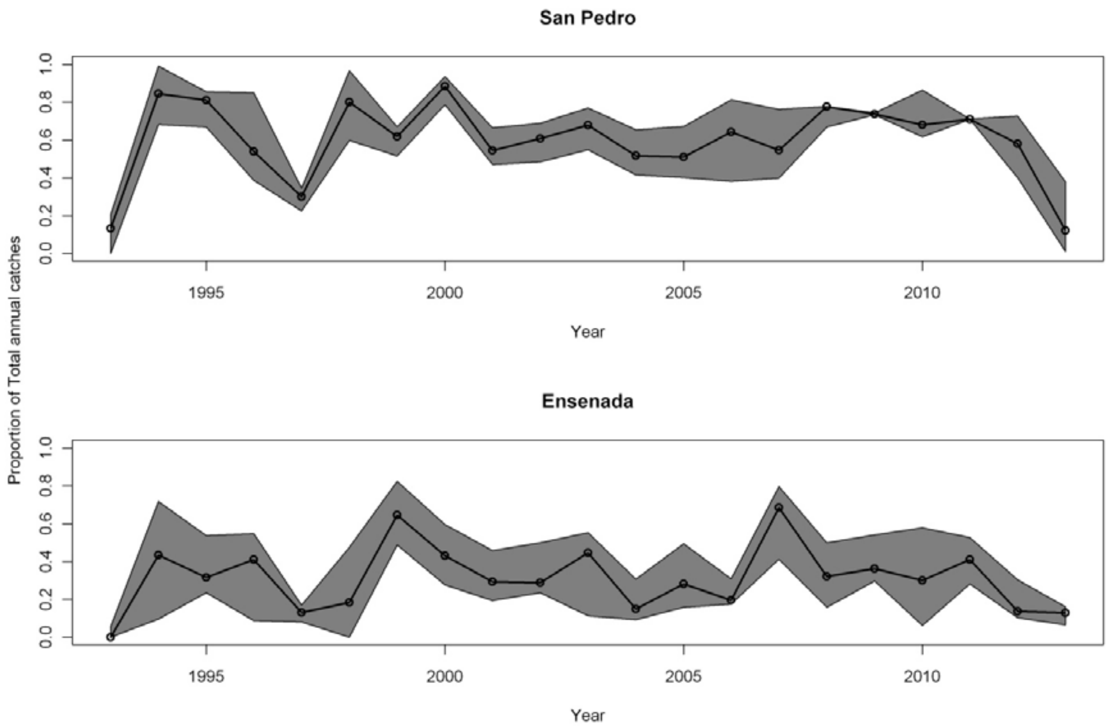

Figure 1. Sensitivity of the proportion of the total catch off San Pedro and Ensenada that is estimated to be from the northern subpopulation to basing the apportionment method on one additional and one fewer month.

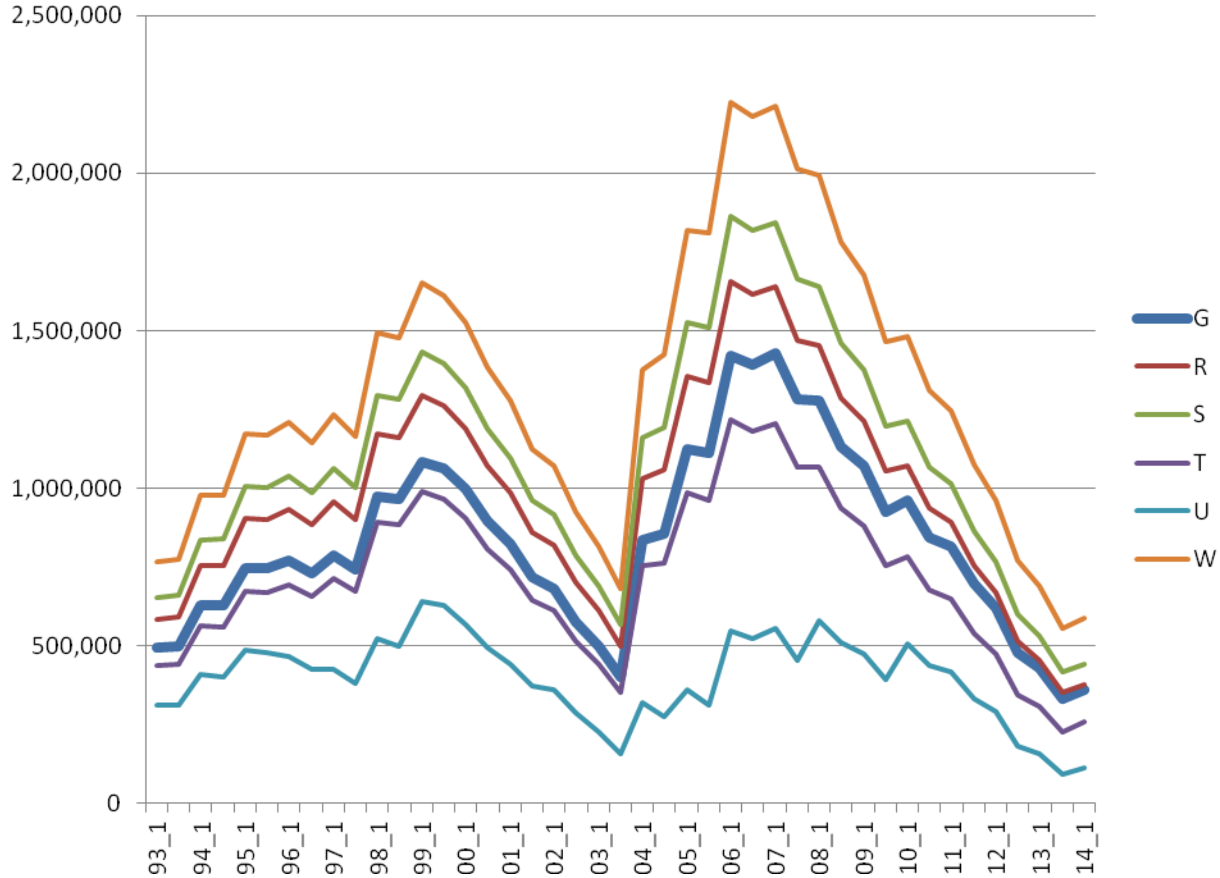

Figure 2. Sensitivity of the results of model G to varying the treatment of the ATM survey selectivity and catchability.

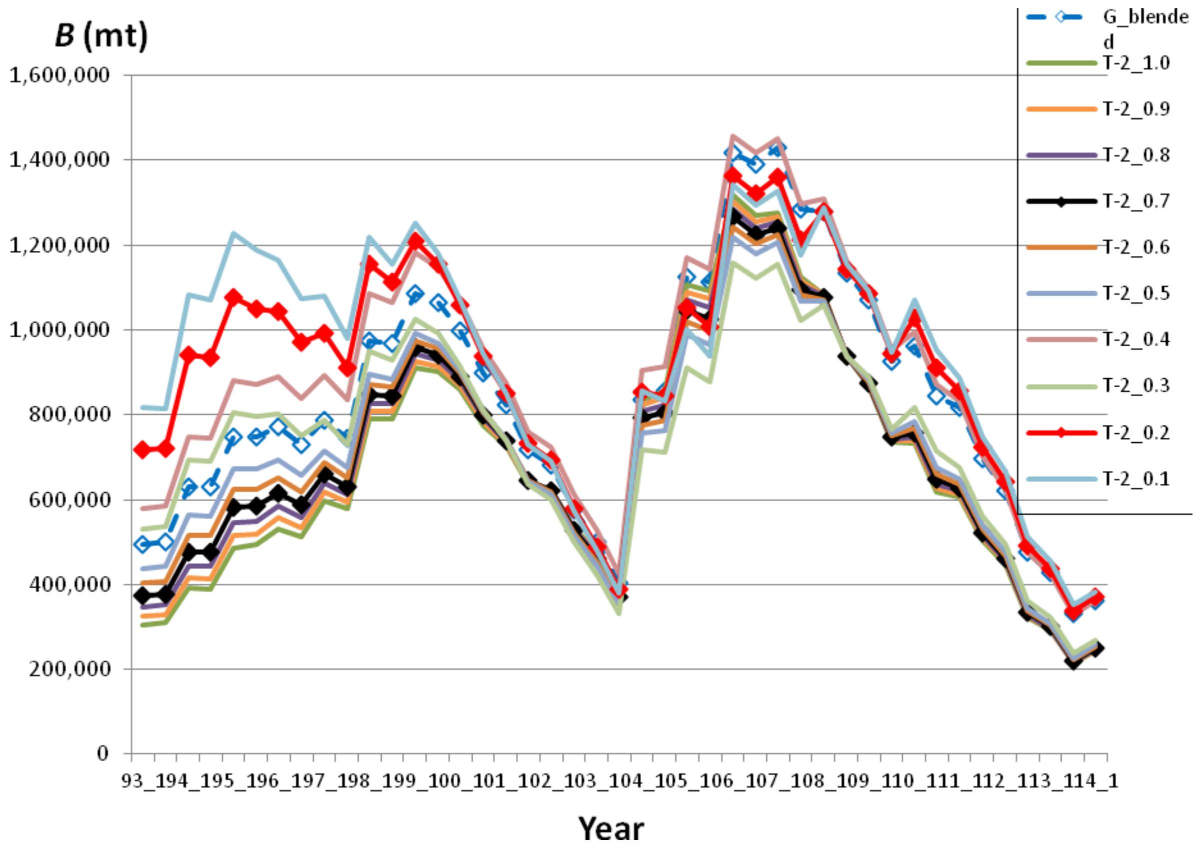

Figure 3. Biomass trajectories for variants of model configuration T-2 constructed by changing the weighting factor for the conditional age-at-length data for the MexCal and PacNW fisheries.

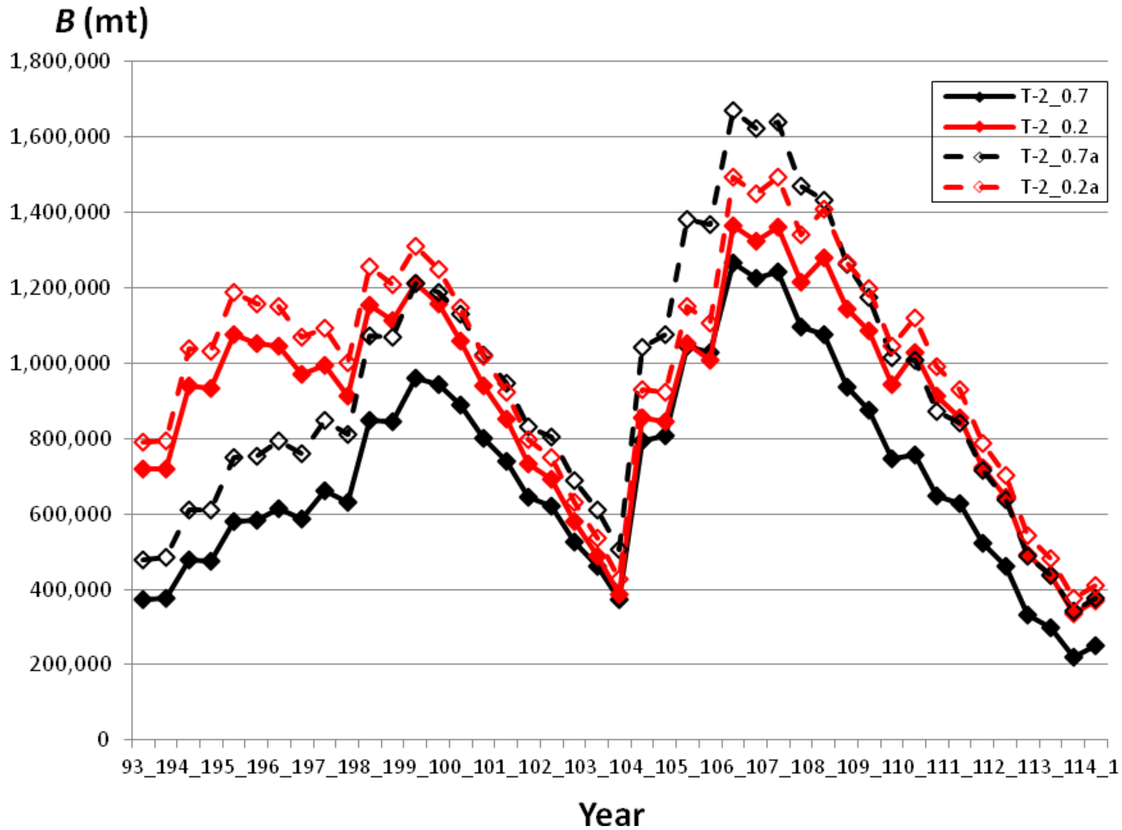

Figure 4. Biomass trajectories for models T-2_0.2 and T-2_0.7 and variants thereof that ignore the length-frequencies for the 2011 and 2012 spring ATM surveys.

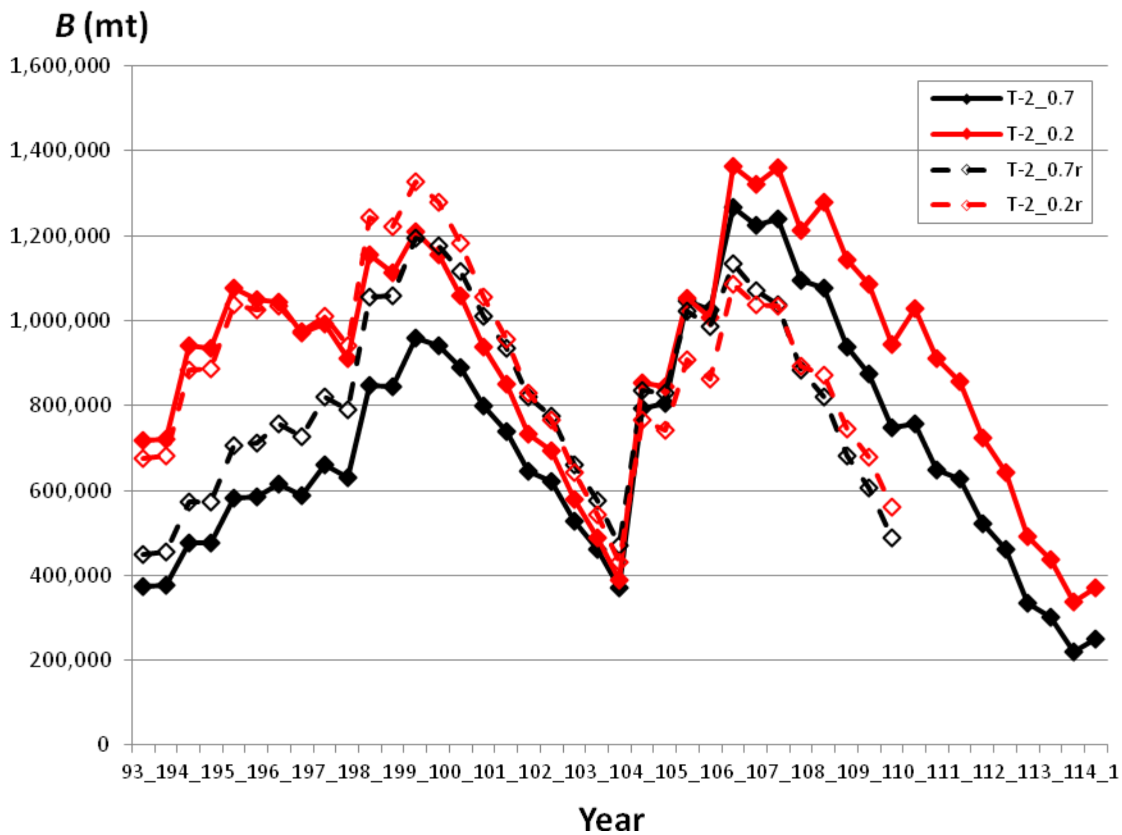

Figure 5. Biomass trajectories for models T-2_0.2 and T-2_0.7 and variants thereof that ignore data for the last four years.

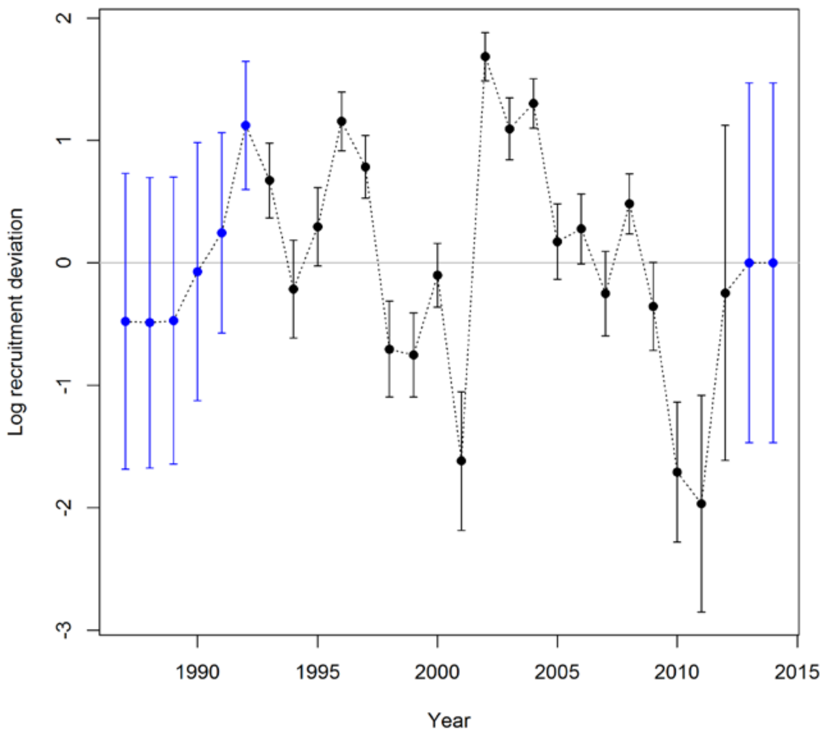

Figure 6. Estimates of the recruitment deviations for model G with their asymptotic standard errors.

Figure 7. Results of a retrospective analysis based on the final base model T-2_0.2.

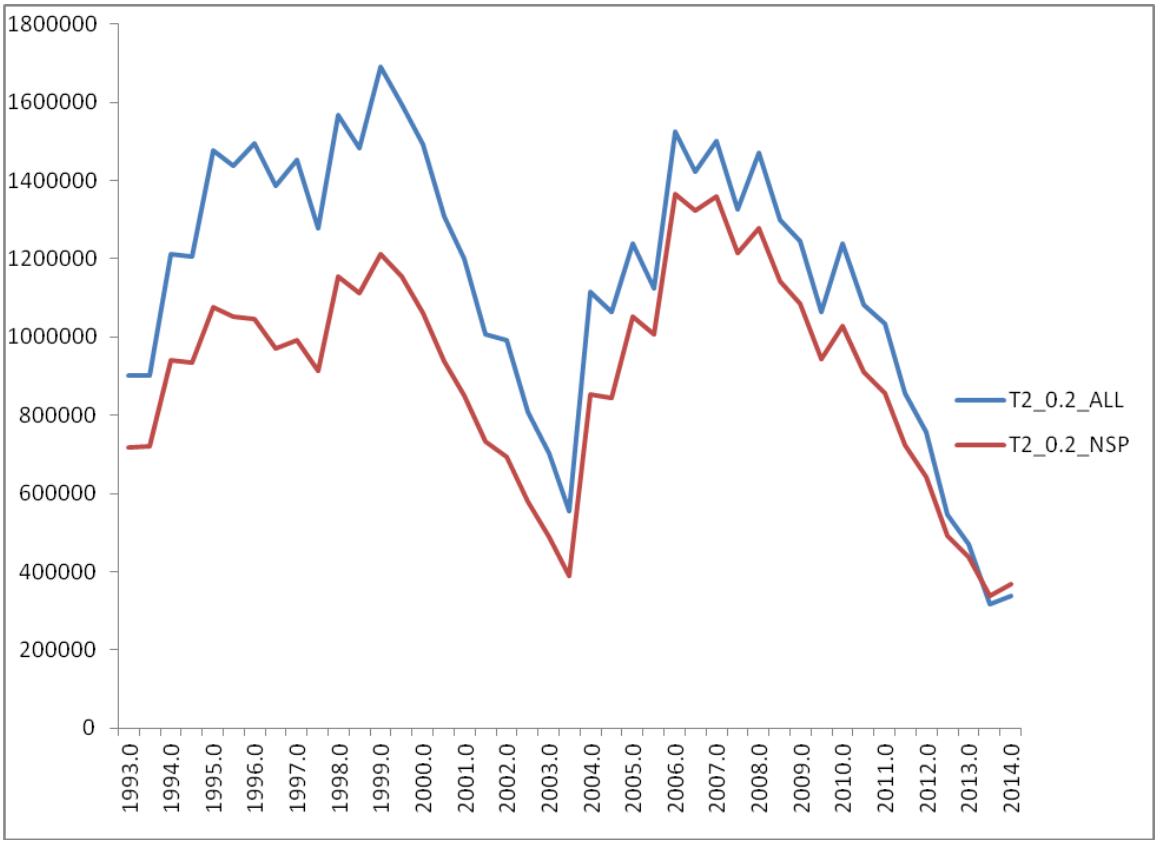

Figure 8. Comparison of the biomass trajectory for model T-2_0.2 when it is applied to the NSP only (differentiating catches) and the total catch time series.

Appendix 1
2014 Pacific Sardine STAR Panel Meeting Attendees

STAR Panel Members
André Punt (Chair), SSC, University of Washington
Meisha Key, SSC, CDFW
José De Oliveira, CIE Reviewer, CEFAS
John Simmonds, CIE Reviewer, ICES

Pacific Fishery Management Council Represenatives
Diane Pleschner-Steele, CPSAS Advisor to STAR Panel
Chelsea Protasio, CPSMT Advisor to STAR Panel
Kerry Griffin, PFMC

STAT Members
Kevin Hill, SWFSC
Paul Crone, SWFSC
Dave Demer, NOAA / SWFSC
Juan Zwolinski, NOAA / SWFSC
Emmanis Dorval, NOAA / SWFSC
Beverly Macewicz, NOAA / SWFSC

Other Attendees
Jenny McDaniel, SWFSC
Kirk Lynn, CDFG
Dale Sweetnam, SWFSC
Erin Reed, SWFSC
Ed Weber, SWFSC
Josh Lindsay, NMFS WCR
Russ Vetter, SWFSC
Al Carter, Ocean Companies
Richard Carroll, Jessie's Ilwaco Fish Company
Elizabeth Helmers, CDFW
Nancy Lo, SWFSC
Sam McClatchie, SWFSC
Richard Parrish, NMFS Emeritus
Yukong Gu, SWFSC
Jeff Laake, AFSC
Kevin Piner, SWFSC
William Watson, SWFSC
Elaine Acuňa, SWFSC
Anna Holder, CDFW
Joel Van Nord, CWPA
Noelle Bowlin, SWFSC
Mike Okoniewski, Pacific Seafood
Cisco Werner, SWFSC

Sarah Shoffler, SWFSC
Kristen Koch, SWFSC
Chris Francis, NIWA
Emily Gardner, SWFSC
Alex Da Silva, IATTC
Steven Teo, SWFSC
George Cutter, SWFSC
Mark Maunder, IATTC

AFSC – Alaska Fisheries Science Center
CDFW – California Department of Fish and Wildlife
CEFAS - Centre for Environment, Fisheries & Aquaculture Science
CPSAS - Coastal Pelagic Species Advisory Subpanel
CIE – Council on Independent Experts
CPSMT - Coastal Pelagic Species Management Team
CWPA – California Wetfish Producers Association
IATTC – Inter-American Tropical Tuna Commission
ICES – International Council for the Exploration of the Sea
NIWA - National Institute of Water and Atmospheric Research
NMFS - National Marine Fisheries Service
SSC - Scientific and Statistical Committee (of the Pacific Fishery Management Council)
SWFSC - Southwest Fisheries Science Center (National Oceanic and Atmospheric Administration)
WCR – West Coast Region

Appendix 2
Email from Tom Jagielo regarding the 2013 aerial survey

Hi Kevin,

I just completed crunching the numbers for the 2013 aerial sardine survey. We are now in the process of preparing a survey report with all the details about the 2013 sampling season, but I wanted to forward the "bottom line" to you in advance of finishing that.

The survey occurred on 8-12-2013 and 8-13-2013 and covered a latitudinal distance of about 48 miles, ranging from The Columbia River to the area offshore of Garibaldi, OR. A total of 21 transects were used for the analysis.

Biomass = 160,763
CV = 0.3488

As noted previously, no new point sets were conducted in 2013. Thus, the biomass estimate was derived using the same point set data as last year (n=123 collected from 2008-2012).

Also noted previously, no bio-data were collected in 2013. Thus, I have no new length composition data for you. In previous years, we saw very good agreement between length comps from the fishery and the point sets sampled. In general, both operate in the same area using the same gear. This suggests that fishery length comps could serve as a proxy for estimating selectivity for the survey, depending on what you may have from the fishery in 2013.

Please do not hesitate to call me with any questions.

Thank you for your consideration,

Tom

Appendix 3
Progress related to the recommendations from ATM survey review
Juan Zwolinski and David Demer

1. Immediate (prior to the next stock assessments)

a. Analyses be conducted using auxiliary information (e.g. trends in density along transects, information from ichythoplankton surveys south of the survey area, and catch information) to provide best estimates for the biomass outside of the survey area, as well as the range of possible biomass levels.

Response: During spring surveys (i.e., April and early May), the northern stock of Pacific sardine resides ~30-70 m deep and spawn offshore of central and southern California. During summer surveys, (i.e., June through August), the same stock resides shallower and closer to the shore off central California, Oregon, Washington, and Vancouver Island. The sardine biomass estimates from the spring and summer ATM surveys during 2008 (Demer et al., 2012), 2012 (Zwolinski et al. in Hill et al. 2012), and 2013 (Zwolinski et al. in Hill et al. 2013) were not statistically different, indicating that any biomass outside of the survey areas are small compared to the stock biomass and the survey precision.

b. The CVs for the estimates need to be modified to fully account for the uncertainty of the trawl data.

Response: In the case that the trawl information was used to characterize independently the length and species composition of each transect (i.e., by having at least one transect per trawl), bootstrapping of the transect means would provide an unbiased of the sampling CV (Demer et al., 2012). Since 2011, efforts were made to obtain a larger number of trawls in order to get closer to the full independence of the transects.

2. Short-term

a. Investigate potential species selectivity effects by comparing the ratios of catch rates and acoustically-estimated densities in areas where single species dominate.

Response: There are strong limitations on the use of the surface, night-time trawls as quantitative measurements of fish density that preclude us to compare them to the measurements of daytime, depth-integrated fish densities from acoustics. The three main ones are: 1) There is strong vertical variability on the opening of the net by trawling at the surface, especially under bad weather; 2) It is difficult to determine with accuracy the horizontal dimension of the net to be used in the calculation of the swept area. Some studies suggest that the herding of fish begins at the doors, which have a distance much larger than that of the horizontal dimension of the net; 3) For the data already collected, there is no way to determine if all the fish that were vertically integrated by the echosounder are contained in the depth interval spanning the surface and the foot rope.

b. Compare total CPS backscatter along transects to trawl catch rates using statistical techniques.

Response: Positive trawls were associated with acoustic samples with significantly higher than average backscatter (Zwolinski et al., 2012).

c. Conduct sensitivity tests in which stations are pooled and allocated to acoustic values over a larger area.

   Response: The trawl catches from each night are pooled. Species and size composition data from these "trawl clusters" are associated to the most proximate acoustic samples (see Appendices A and B in Hill et al., 2012).

d. Consult experts in trawl design to evaluate the current trawl design in relation to the survey objectives.

   Response: Trawl experts have been consulted.

e. Develop methods that categorize the acoustic record and thus support automatic species identification and continue to work on definition and precision of the VMR process

   Response: Due to the overlap in size of the various schooling CPS, acoustic classification of species is inherently difficult when the number of samples within a school is small (for example, when using a large interval between pings when recording acoustic data over 750 m depth while conducting at a survey 10 kts). The first approach to ameliorate the quality of the data was the development the EK60 Adaptive Logging software (EAL). This software allows the reduction of the interval between acoustic pings when the bottom is shallower than 750 meters, effectively increasing the sampling intensity of schools observed over the continental shelf and slope.

   The VMR is part of a larger algorithm aiming to identify and eliminate the backscatter of non-CPS targets from echograms. The algorithm is tested on a survey basis to ensure that the retained backscatter of the echoes identified as CPS is at least 95% of the original backscatter.

f. Evaluate the potential use of the echosounder in a non-vertical position.

   Response: Multibeam observations have been made of CPS schools since the initial ATM survey in 2006. These data have been used to evaluate potential avoidance of CPS to the survey ship (see report of the PFMC/CIE review of the ATM). The new FSV Reuben Lasker is equipped with Simrad EK60, ME70, MS70, and SX90 echosounders/sonars, which will facilitate improved characterizations of fish behaviours and abundances.

g. Check the filtering algorithm every year to ensure that it is still suitable under changing conditions.

   Response: The filtering results are checked on a subset of fish schools during every survey to ensure that at least 95% of the acoustic backscatter of CPS schools is retained in the filtered echograms.

h. Study trends in frequency response over depth strata in schools.

   Response: We observed that the CPS echoes of tightly schooling fish in areas with positive trawls for anchovy, mackerels, and sardine had very little depth contrasts due to their association with the mixed layer. There, there were no obvious patterns of variability in the frequency response of the schools.

i. Compare results from the 18-kHz and other transducers to examine possible avoidance reactions.

   Response: The recommendation is unclear.

j. Continue to consider the advantages and disadvantages of conducting ATM surveys at different times of the year.

Response: This was addressed in the January 2014 CIE review of the summer sardine-hake survey (SaKe).

k. Evaluate the potential to give age-based abundance or biomass estimates for sardine and consider their utility in the SS3 assessment, given the lack of contrast in length-at-age at older ages and the ability to directly estimate total mortality from the survey result.

   Response: Age-based abundances can be estimated from the ATM using age-to-length keys derived from sardine collected on the survey themselves, or from a composite age-to-length key from the fisheries.

   The ATM survey showed the persistence of dominant cohorts over time, allowing the estimation of total and natural mortality (Zwolinski and Demer, 2013).

l. Conduct standard (ICES) vessel noise measurements for all vessels.

   Response: Vessel noise measurements are made for all NOAA FSVs. Noise measurements have not been made for RV Ocean Starr, formerly RV David Starr Jordan.

3. Long-term

a. Evaluate if different trawling practices or gears, or both would be beneficial.

b. Use the current variance estimation procedure to investigate the trade-offs in terms of variance of different time allocations between acoustic transect and trawl data collection.

c. Use a trawl/vessel configuration that can support directed trawl sampling.

d. Conduct repeated trawl sampling experiments to obtain a better understanding of small-scale variability.

   Response: The current sampling technique involves three trawls per night with inter-trawl distance of less than 10-nmi.

e. Test the efficiency and selectivity of the trawl by comparing samples from same area taken with the survey trawl and purse seine.

f. Apply state-of-the-art acoustic and optic technology to investigate fish behavior and escapement at various critical positions of the trawl.

   Response: Cameras attached to the trawl in front of the cod end have been developed and used extensively in the spring and summer 2013 surveys to observe and quantify fish behaviour and MMED performance.

g. Conduct validation tows on various kinds of backscatter to assure that the filtering algorithm is performing as intended to apportion backscatter to CPS.

h. Make efforts to obtain TS measurements for *in situ* CPS in the California Current Ecosystem.

i. Focus on utilizing more advanced instrumentation and resource-demanding research for studying vessel impacts.

   Response: The state-of-the-art instrumentation aboard the FSV Reuben Lasker (EK60s, ME70, MS70, SX90) should facilitate studies of fish behaviour that could potentially impact the estimations of abundances.

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Appendix 4
Full CPSAS representative comments
Diane Pleschner-Steele

The CPSAS representative commends the Panel and STAT for their significant body of work throughout the 2014 sardine STAR panel. Unfortunately, the 2014 sardine assessment encountered the same basic difficulty with scaling issues observed in the 2011 assessment. The SS model is very sensitive to weighting of the input length and conditional age at length (CAAL) compositions from the ATM surveys. Most of the work at the meeting was spent making further analyses to resolve the source of these problems; which included very high variability in the biomass estimates for the first half of the time series. It became apparent from sensitivity runs that data weighting matters. The STAT and Panel attempted to find a solution that made results less sensitive by down-weighting certain conditional age-at-length data.

The sardine assessment model was improved by a more realistic separation of the landings from the northern and southern stocks (excluding the landings of southern stock sardine from Ensenada or Southern California). This reduces the biomass estimate and largely resolves problems associated with the distribution parameter in the harvest guideline.

The final base model ultimately fixed catchability (Q) at 1 for the ATM surveys, as in prior years, attempting to achieve model stability. The CPSAS has voiced concern in the past that acoustic surveys as currently deployed have been unable to measure the full biomass, particularly in the Pacific Northwest. For example, in 2012 the ATM survey went through waters from Newport to the Canadian border in 11 days and estimated the total biomass for that area at 13,000mt. We understand that the CV for that survey leg was estimated at 0.63. In the same 11 days the fishery landed 9,747mt. Previous to the arrival of the NOAA vessel the harvest in that area was 35,531mt. After the NOAA vessel left those waters the harvest was 32,781mt for the remainder of the season. The point is that fishermen observed and caught significantly more fish in the area than the point estimate of the ATM cruise – which measured only one spot in time but contributed to a low overall sardine biomass estimate. In contrast, the NWSS-sponsored aerial survey for that summer (which was later down-weighted due to too few point sets) estimated more than 900,000mt in the PNW. The inconsistency in the two data points remains unresolved.

On behalf of the CPSAS and industry at large, the CPSAS representative also expresses disappointment that the aerial survey has been dropped from consideration in this and presumably future stock assessments. It should be noted that the rationale for eliminating the aerial survey, "*vulnerability of this survey method to prevailing ocean conditions potentially affecting q over short and long time frames (water clarity, sea state, water column stratification, and associated changes in vertical distribution,…*" *co*uld be applied to other fishery independent indices as well. Moreover, the aerial survey assumption that daylight-photographed schools represented sardines was questioned by comparing species composition from night-time ATM trawls. The CPSAS notes that schooling patterns day vs. night differ and should not be compared.

The CPSAS also voices concern that stock assessments seem to be gravitating toward one independent index based on ATM surveys. We encourage a continuation of multiple surveys, recognizing that each survey type has issues with varying ocean conditions and assumptions. Although the CPSAS and industry express serious reservations about use of only one index for sardines developed solely around the ATM survey, we acknowledge and applaud the acquisition of the RV Reuben Lasker and its capability to survey with forward and side-scanning sonar. We can support the ATM with the use of sonar to augment acoustic search of water columns that the downsounder does not effectively measure (i.e. the top 10 meters of the water column). Further, sonar can offer clues to school behavior. As stated by a sitting Council member who has had many years of experience fishing for sardines: First choice: sonar: second choice spotter plane: third choice downsounder.

Ultimately, industry wants to see a sustainable resource (to the degree that environmental conditions will allow) that is in no danger of being overfished. Current sardine stock assessments and harvest policy are very precautionary. We sincerely hope that going forward we can develop a truly collaborative research program for the CPS complex.

Recommendations:

- Continue to involve industry in collaborative research.
- Recognize that the 2014 assessment is “déjà vu all over again” and most of the unresolved problems and major uncertainties listed in the 2011 STAR panel report still exist
- Also, many of the research recommendations in 2011 also are applicable in 2014, i.e.
    - Explore models which consider a much longer time-period (e.g. 1931 onwards) to determine whether it is possible to model the entire period
    - Consider model configurations which use age-composition rather than length-composition and conditional age-at-length data given evidence for time- and spatially-varying growth.

Center for Independent Experts (CIE) Independent Peer Review Report of:

STAR Panel Review of the 2014-2015 Pacific Sardine Stock Assessment

La Jolla
California
March 3-5, 2014

E J Simmonds

Table of Contents

1. Executive summary

The meeting to review the Pacific Sardine (*Sardinops sagax caerulea*) Stock Assessment took place in the Southwest Fisheries Science Center in La Jolla, California from 3-5 February 2014. The reports and presentations provided an excellent basis to evaluate the performance of the assessments. Following an extensive model exploration, the Panel agreed on a single model formulation that is accepted for estimating 1+biomass that is suitable for biomass estimation for management. The main differences between the initial model and the final model were different data weighting for survey conditional age at length and use of a common q for both spring and summer ATM surveys. The science reviewed was of a high standard and could be classed as 'of the best scientific information available'.

2. Background

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

3. Description of the review and role in the review activities.

The STAR Panel Review met in the Southwest Fisheries Science Center in La Jolla California from 3-5 February 2014 to review Pacific sardine (*Sardinops sagax caerulea*) stock assessment. The review committee was composed of André Punt, SSC, University of Washington (Chair), Meisha Key, SSC, California Department of

Fish and Wildlife, José de Oliveira, CIE Reviewer, CEFAS - Centre for Environment, Fisheries & Aquaculture Science, UK, and John Simmonds, CIE Reviewer, ICES – International Council for the Exploration of the Sea, Denmark.

At the beginning of the meeting introductions were made (see list of attendees, Appendix 3), and the agenda was adopted (Appendix 3). A draft assessment document and background materials had been provided to the Panel in advance of the meeting on a SWFSC FTP site (Hill and Crone 2014). Paul Crone introduced the draft assessment report. Then David Demer, SWFSC, presented the Acoustic Trawl Survey (ATM) results. Emmanis Dorval, SWFSC, presented the Egg survey results (DEPM). Juan Zwolinski, SWFSC, presented the information on split of the fishery data into subpopulations. Paul Crone and Kevin Hill presented the assessment methodology and the results from a draft assessment utilizing the Stock Synthesis Assessment Tool, Version 3.24s to the Panel. The assessment report included many model options but concentrated on two main models (designated G and H in the draft report). The review examined the underlying assumptions of these two models, selected G as the methodologically most appropriate and then concentrated on exploring model G and a number of potential modified versions (see Section 4.4 below).

I participated in all aspects of the review, paying particular attention to input survey data, and its use in the assessment, which consisted of a) Acoustic Trawl Method (ATM) in spring and summer, b) egg surveys utilizing; total egg production method (TEPM), and daily egg and daily egg production method (DEPM), and c) combined aerial photogrammetric and fishing surveys of biomass. In addition, I also participated in the Panel review and exploration of the Pacific sardine stock assessment and the sensitivity analyses presented in the draft report and developed during the meeting.

Comments given throughout this report should not be read as direct criticism of what has been done, rather ideas of areas for development. In retrospect, one can always find room for improvement and, as such, minor suggestions have been made throughout this report. These should not be considered prescriptive or limiting but rather as aspects for careful consideration.

4. Findings by ToR

4.1. Introduction

The complete ToR for the Pacific Sardine review are given in the statement of work (Appendix 2), the main aspects are repeated here.

1. Reviewing draft stock assessment and other pertinent information (e.g.; previous assessments and STAR Panel reports);
2. Working with STAT Teams to ensure assessments are reviewed as needed;

3. Documenting meeting discussions;
4. Reviewing summaries of stock status (prepared by STAT Teams) for inclusion in the Stock Assessment and Fishery Evaluation (SAFE) document;
5. Recommending alternative methods and/or modifications of proposed methods, as appropriate during the STAR Panel meeting, and;
6. The STAR Panel's terms of reference concern technical aspects of stock assessment work. The STAR Panel should strive for a risk neutral approach in its reports and deliberations.

Items 1 and 4 form the main body of the review, which is discussed in detail in this Section below. Items 2 and 3 and 6 were the process of the review, which are dealt with under proceedings of the review, Section 5 of this report. Item 5 is dealt with under recommendations and conclusions in Section 6.

4.2. Survey data available for the assessment

4.2.1. Acoustic survey

Use of the survey in the model: Two series of acoustic trawl surveys (ATM) are currently available for the assessment. The acoustic survey is carried out to a high standard. The procedures and performance of the ATM has been documented in the methodological review (2011), which concluded that it was possible to consider the ATM as an absolute estimate, but also considered that it would be necessary to check if the resulting residuals in the assessment were compatible with that assumption. As a general principle surveys with short time series that have q close to unity can be considered absolute initially; however, as the number of observations in the survey time series increases over time, it may in the end be possible to detect bias and fit the survey with an estimated q. The 2013 assessment used the ATM survey as absolute, Model G (See Section 4.4) presented in the draft assessment report, used both the spring and summer ATM as relative indices with separately estimated qs. The confidence intervals on these fitted qs included q=1 (ATM absolute) within the estimated range (Figure 4.1).

Survey procedures: Overall the survey is carried out to a high standard particularly in terms of the acoustic aspects, but there are a few aspects that should be examined to see if improvements can be made. The ATM survey takes night trawl samples and uses these to apportion observed daytime biomass between species and additionally uses the samples of Pacific sardine to estimate length and conditional age at length. In many cases catches are a high proportion of one species, so allocation to species is often quite precise. However, the local biomass estimates can be rather variable, so while the samples appear to be sufficient to obtain local estimates of species proportions to allocate to the acoustically derived biomass estimates, the procedure of using night time trawls to assign daytime biomass proportions is not ideal, as it assumes that the species encountered acoustically during the day are then available in the same proportions to night time fishing. Catch rates appear relatively low which is not encouraging. Also the catch rates and age sampling can end up giving only marginally sufficient information on length and conditional age at length. This issue is discussed in detail further under section 4.4.

Development of techniques either to allocate acoustic records directly to species or to obtain direct samples of daytime aggregations would greatly improve the confidence in the age and length structure, as well as for areas where mixtures are encountered the species proportions (see Section 6).

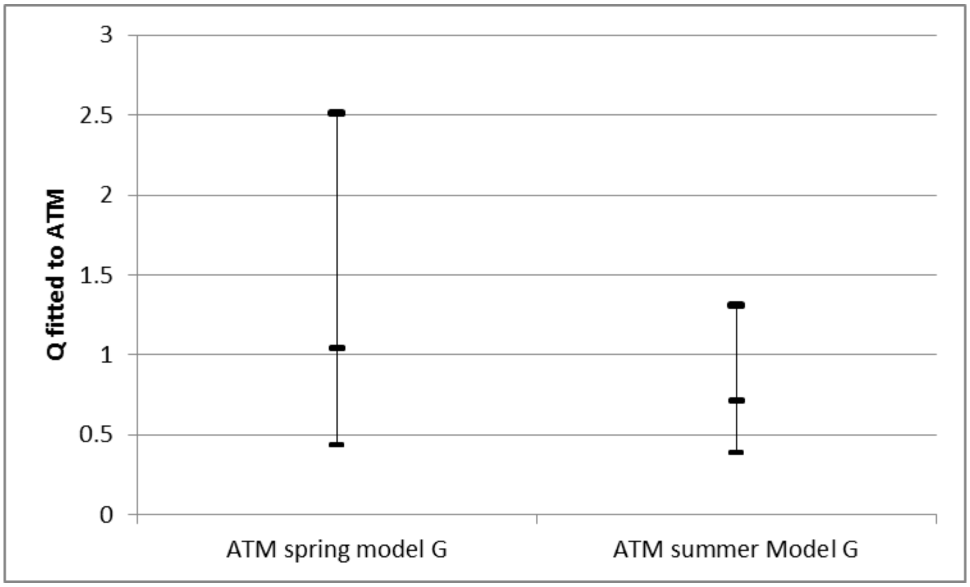

Figure 4.1 Estimated Q with 95% intervals from Model Q, assessment report.

Construction of conditional age-at-length for the ATM survey

Currently fish aged during the ATM survey are combined into an unweighted age-length key, and this is used to construct the conditional age-at-length data for each complete ATM survey. This treatment is not considered to be optimal given the possibility for age- and size-specific distribution of sardine. The use of separate conditional age-length keys for the MexCal and PacNW fleets suggests that there may be differences in age-length keys from these regions. The current method for estimating conditional age at length from the ATM surveys assumes that this is not occurring. The alternatives are to develop separate age-length keys for the different regions covered by the ATM survey, or to use appropriate biomass-based weighting for each part of the survey area.

4.2.2. Egg Survey

The long running combined CALCOFI and DEPM survey provides the longest time series of relative abundance estimates for use in the assessment of Pacific sardine. The survey is well developed and the DEPM method is organized to give biomass estimates which are used to give relative estimates of sardine stock abundance. Because of the long time period over which this survey has been developed, the survey index has considerable utility in the assessment and provides biomass related information that is useful for the kind of model used.

Examination of the data collected and analytical methods highlights a number of areas which may benefit from improvement. Whilst these issues have been identified it seems unlikely that they result in sufficient uncertainty to warrant exclusion of series from the assessment. Thus it is appropriate that the survey is used in the assessment. The identified issues fall into two areas, sampling of adult sardine to obtain biological parameters, and analytical methods to obtain abundance indices.

Sampling of adult sardine on the egg surveys

The numbers of adult sardine samples to give fecundity (at age), proportion spawning on the sampling day and two previous days are only sufficient to provide at best global means. Sardine are known to distribute by size or age and currently the numbers obtained are very few and do not allow investigation of the dependence of the DEPM on any other factors. A better fish sampling scheme might allow the biological samples to be used to verify that the proportions at length or age that appear to be contributing to the egg abundance do or do not conform to the estimated population, this would help understand the underlying assumptions of the DEPM method.

Analytical methods to derive DEPM estimates from the egg surveys

The analysis of the egg survey has some minor issues, mostly to do with the raising of density to survey area. The survey design is intended to sample the region of higher density, because, ideally, the survey obtains lower values around the periphery. A high density stratum is then drawn around a group of observations that contain the higher values, by creating a 'simple' (relatively smooth) boundary using the location of the points. The main idea behind this approach recognizes that the survey objective is to map a peak density in space. There is therefore an assumption that the survey will have higher values towards the center of the area and lower values around the edges. This is then analyzed using a two stratum analysis approach which has two minor issues:

a) The current method for placing the boundary between high and low density areas by placing the boundary on the observation locations means the higher density area is smaller than the region represented by those observations, and conversely the low density area is a little larger resulting in a small underestimate of DEPM abundance. The method should be changed so that the area is allocated to include the correct area allocation for each sampling point included in each of the two strata. The effect is likely small on the index value used in the assessment because the current procedure is applied for all years and the DEPM is used as a relative index.

b) The post stratification and CV calculations may not be correctly calculating the CV used to weight the survey index values in the assessment. The post stratification may result in underestimation of the CV due to the process of separating into strata based not on some independent measure but on the observed values themselves. Such a post stratification procedure is known to be negatively biased. Conversely the use of simple variance based on the within-stratum observations in the two strata may result in overestimation as there is expected to be some spatial trend within each strata. As the two effects are in opposite directions, the end result may not be a major problem. An improved method which accounts for transect-based sampling and correlated observations that reflect the presence of a spawning aggregation would be an improvement.

4.2.3. Aerial Survey

Previously this index had been used in the assessment. No new data from the Aerial Survey were presented at the meeting, though a copy of an Email indicating some work had been done was provided to the meeting and is attached to the main STAR Panel report. Historic Survey estimates were available and although it was indicated that new data was being prepared, no new data was provided to the group so it was not possible to extend the series. The previous values from this survey exhibit considerably more variability than other abundance indices (ATM and DEPM) over the same period (See Figure 20 in the draft assessment report (Hill and Crone 2014)).

The survey potentially provides a good method for estimating the number of near surface fish schools in the area. Though this may be degraded if the schools are too deep or visibility (due to weather) affects the coverage. However, counting schools alone may not give a very precise estimate of biomass. Marchal and Petigas (1993) partitioned variance between school counting and mean school size and school density estimation for a sardine survey. Estimating the number of schools through school counting was shown to be responsible for only a small part of the variance of the abundance estimate, whereas estimating within school density dominated the precision. The indications from the information on the aerial survey provided to the review panel was that while some limited school count data were collected this year and last year, school size information was spatially very limited and missing in some years. It is possible that shortage of good school identification, and possibly more importantly good school density information, is limiting the precision of the aerial survey.

4.3. Fishery data

The assessment presented was based on a substantial subset of the fishery data. The sardine catches were partitioned into three major groupings, a) Canadian, Washington and Oregon fisheries, b) Mexican and Californian fisheries on the northern component of the Pacific sardine, treated as seasonally dependent groupings, and c) southern component. The primary assessment was based on parts a and b, and classed as the NSP component, though an additional assessment based on all three parts using reported catches from Ensenada in Mexico, USA, and Canada was also presented.

Splitting the catch among components

A habitat based separation method was used to define regions in space and time that were allocated to northern and southern components of the Pacific Sardine. The method was based on 100% allocation to each component on a monthly basis derived from a 50% habitat threshold. The sensitivity to the choice of 50% decision threshold was investigated, and because generally the rate of change of this parameter was rapid in time, the resulting allocation was rather insensitive to the choice of threshold value. The consequences of the assumed temporal stability of the habitat choice were investigated during the review by extending or contracting the allocation period by a month. It was shown overall that the total catch was not substantially sensitive to the split. However, no information was presented on direct validation of component allocation by habitat by checking the correct population assignment of catches. An investigation of the environmentally-based stock splitting method should be carried out if management is to be based on separating the northern and southern subpopulations using the habitat model. It may be possible to develop simple discriminant factors to differentiate the two sub-populations by comparing metrics from areas where mixing does not occur. Once statistically significant discriminant metrics have been chosen these should be applied to samples from areas where mixing may be occurring or where habitat is close to the environmentally-based boundary. This can be used to help to set either a threshold or to allocate proportions if mixing is occurring. If mixed catches are occurring, the accuracy of 100% allocation among the alternate components will be sensitive to population size and may not be the best approach. A number of methods have been found useful to identify pelagic fish to stock component, body morphometrics, otolith morphology, otolith micro-structure, otolith micro chemistry, and possibly using more recent developments in genetic methods. In the case of herring stocks the low tech methods of morphology outperformed the more complex methods of genetics and otolith-microchemistry (see WESTHER project information http://www.clupea.net/westher/).

In addition to the split catch which was used in the main stock assessment model, the total catch was also made available and a second assessment run on the total available catch estimates from all catch Ensenada northwards. The assessment appears to perform equally well for the NSP or the total catch, so the sensitivity for managers only relates to the correct allocation of total catch.

Length and age data in the catch

While sampling at length appears to provide a good description of the landings in all the areas included in the assessment, sampling for age was sparse. In particular both northern and southern extremes of the region were missing age information. In general age data is being treated with a lower priority. Although substantial length information is being collected, there are indications that the modeling assumptions of consistent growth over the years may be responsible for part of the uncertainty in the overall scaling that is the major issue with the assessment. In the absence of good age data it is difficult to determine if migration and the resulting selection are more correctly modeled by age or by length (see discussion in Section 4.4).

4.4. Stock Assessment

Paul Crone and Kevin Hill presented the assessment methodology and the results from a draft assessment (Hill and Crone 2014) to the Panel. The assessment utilized the Stock Synthesis Assessment Tool, Version 3.24s. The assessment report included results from many model runs and some sensitivity analyses. However, two specific model formulations were selected as the main models for consideration (Models G and H). The full model outputs for these runs were provided on the FTP prior to the review and the focus for Panel discussion concentrated on these models and Model G included the following features:

(a) The data were updated to 2013,
(b) The catches for the MexCal fleet were split from the total catch by the environmental-based method,
(c) The weight-length and maturity-at-length relationships were updated,
(d) The data for the aerial survey were omitted from the assessment,
(e) The ATM survey was split into spring and summer surveys (with separate catchability and selectivity parameters), with catchability parameters estimated,
(f) No additional data weighting for survey abundance data beyond input CVs (i.e. lambda=1),
(g) No additional data weighting for length composition data for fishery/surveys beyond input effective sample sizes (lambda=1),
(h) Weighting for conditional age-at-length data in addition to input effective sample sizes (lambda=0.5),
(i) The value for σ_R was rounded and fixed to 0.75, and
(j) Recruitment was related to spawning stock size according to a Beverton-Holt stock-recruitment relationship with pre-specified steepness (set to 0.8).

Model H differed from Model G by assuming age- rather than length-specific selectivity patterns, by fitting to age-composition data rather than length-composition and conditional age-at-length data, and by fixing the parameters of the growth curve.

Table 1. Summary of the models requested of the STAT during the review. "F" indicates that the weights assigned to the composition type concerned were based on the Francis (2011) method, "F-pool" indicates that factor to weight the composition concerned pooled information across fleets / seasons, "split" under the "ATM Q" and "ATM selectivity" columns indicates that parameters were estimated for the spring / summer surveys separately, "equal" under the "ATM Q" and "ATM selectivity" columns indicates that the parameter concerned were assumed to be the same for the spring / summer surveys, "1" indicates that survey catchability was assumed to be 1. The "profile" in the last three lines implies than the STAT were requested to profile over the weighting factor concerned.

	Lambda: Length composition			Lambda: Conditional age-at-length			ATM	
	MexCal (1+2)	PacNW	ATM	MexCal (1+2)	PacNW	ATM	Q	Sel
G	1	1	1	0.5	0.5	0.5	split	split
K	1	1	1	1	1	1	split	split
F	F	F	F	F	F	F	split	split
L	F-pool	F	F-pool	F-pool	F	F-pool	split	split
M	F	F	F	1	1	1	split	split
N	1	1	1	F	F	F	split	split
O	1	1	1	F	1	F	split	split
P	1	1	1	0.5	0.5	0.5	equal	equal
Q	1	1	20	0.5	0.5	0.5	equal	equal
R	1	1	1	0.5	0.5	0	equal	equal
S	1	1	1	0.5	0.5	0	1	equal
T	1	1	1	0.5	0.5	0	1	split
U	1	1	1	0.01	0.01	0.5	split	split
V	1	1	20, excl spr12	0.5	0.5	0.5	equal	equal
W	1	1	1	0.5	0.5	0	split	split
W-2	1	1	1	profile	profile	0	split	split
W-3	F-pool	F	F-pool	profile	profile	0	split	split
T-2	1	1	1	profile	profile	0	1	split

The stock assessment team had also explored an extensive number of model options within this framework to illustrate model sensitivity, but the results as presented were not conclusive and raised concerns regarding the sensitivity of the assessment, particularly to the data weighting. The weighting method presented was essentially *ad hoc* so it was difficult to justify without further exploration. Therefore further sensitivity analysis was conducted throughout the review, this sensitivity analysis concentrated mostly on weighting of different sources of length frequency and conditional age at length information, but also on the interaction of a few model assumptions such as the ATM survey q and ATM selectivity with the size and age data weighting. The main features explored during the review are given in Table 1 as a list of different model parameterizations. In addition to these main model formulations model T-2 (Table 1) was explored further with the sensitivity to two years of ATM length composition data (2011 and 2012) which were omitted from the ATM spring survey data series to resolve a specific switch in population state under different weighting assumption for the ATM length data.

Based on the set of sensitivity analyses given in Table 1 the following general conclusions were drawn:

1. Sensitivity to the weighting of the ATM conditional age at length data: Estimates of biomass were particularly sensitive to this weighting factor, and the information was not appropriately assembled (see Section 4.2.1 above). Due to both these considerations, the ATM conditional age at length data were excluded from the final model.
2. Sensitivity to the weighting of the ATM length composition data: Model results were insensitive to the use of a) Francis weights (see TA1.8 in Appendix A of Francis, 2011), b) weighting by haul, and c) arbitrary up-weighting (by a factor of 20). In conclusion weighting of ATM length composition was regarded as a minor issue. However, close examination of year 2011 and 2012 data from the ATM indicates potential incompatibility between the observed length frequencies and the model assumptions of invariant growth over years. The disparity resulted in the potential for two different states which depended on the data weighting. Sensitivity to these two years length composition data was tested (by omission of length from those years), and the weighting chosen that minimized the influence of these data. Overall it is unclear if the observations are correct and the growth assumptions in the assessment model are too simplistic or the precision of the local estimates used to raise local length compositions in the ATM survey are too large. (See research recommendations).
3. Sensitivity to weighting of the fishery conditional age at length data: A range of weighting factors less than 1 were explored. The sensitivity observed depended on whether ATM *q* was estimated or fixed (*q*=1). Model outputs were more stable when q was fixed.
4. Sensitivity to weighting of the fishery length composition data: Two options were investigated: weighting by haul and using the Francis (2011) method. When *q* is estimated, the use of Francis weights resulted in unrealistically low estimates of *q* (0.2-0.3). For haul-based weights, estimates of ATM *q* included the value of 1 within the range of weights considered.
5. Sensitivity to estimation of ATM *q*: Three options were explored: (a) separate estimated *q*s for the spring and summer surveys, (b) a single estimated *q* for both surveys, and (c) a fixed *q*=1 for both surveys. The sensitivity of the model output to how the fishery conditional age at length data are weighted was considerable. Given the rather arbitrary conditional age at length weights being applied for Model G, and that the sensitivity to these could be considerably reduced by fixing

q=1, it was decided to choose this option in the final model, thereby reducing the sensitivity of the model results to weighting which could not be easily justified.

6. Sensitivity to selectivity options for ATM survey: Two options were explored: a single selectivity pattern for both ATM surveys or separate selectivity patterns by survey. When estimated separately, selectivity for the spring survey was near-knife edge at around 16cm, and that for the summer survey shifted to higher lengths in comparison. When estimated as a single selection pattern, the result was a much longer shallower curve, starting in a similar place to that estimated for the spring survey and extending to even greater lengths than that estimated for the summer survey. This change probably results from a requirement to include fish between 15 and 18cm in the spring survey, while giving reduced selection at around 20cm for the summer survey. This results in a reduction in selectivity for a range of lengths greater than 22cm that were not observed for either of the surveys when used with the separate selection patterns. This change to catchability of larger sardine was considered an inappropriate model response resulting from an unreasonable limitation of a single selection pattern. Based on these considerations two separate selections patterns were used in the final model.

It was clear from the sensitivity exploration (Table 1) that solutions that gave plausible q close to unity for the ATM were preferred. This could be obtained by setting data weights to achieve this or explicitly including this requirement in the model. Given that the assessment would be used for at least one more year before further review data weighting, that might be sensitive to new data values, was considered a poor option and setting q=1 for the ATM was the preferred option.

The final base model incorporates the following specifications:

- two seasons (Jul-Dec and Jan-Jun) (assessment years 1993 to 2013);
- sex is combined;
- two fishery fleets (MexCal, PacNW), with an annual selectivity pattern for the PacNW fleet, and seasonal selectivity patterns (S1 and S2) for the MexCal fleet;
    - MexCal fleet:
        - double-normal (i.e. dome-shaped) length-selectivity with two periods of time-blocking (1993-1998, 1999-2012)
    - PacNW fleet:
        - asymptotic length-selectivity for the a single period
    - Length compositions with effective sample size set to 1 per haul and lambda weighting =1
    - Conditional age at length with effective sample size set to 1 per haul and lambda weighting = 0.2
- Beverton-Holt stock-recruitment relationship "steepness" set to 0.8;
- $M = 0.4$ yr^{-1}; $\sigma_R = 0.75$ (fixed value);
- recruitment residuals estimated for 1987-2013;
- length-frequency and conditional age-at-length data for all fisheries;
- virgin (R_0) and initial recruitment offset (R_1) were estimated;
- initial *F*s set to 0 for all fleets;
- DEPM and TEP indices of spawning biomass; *q* estimated;

- acoustic-trawl (ATM) survey biomass 2006-2013, *q*=1;
  - Length compositions with effective sample sizes set by dividing the number of fish sampled by 25 and lambda weighting =1
  - asymptotic length-selectivity separately for spring and summer surveys
  - Conditional age at length from the ATM surveys excluded
- NWSS aerial photogrammetric surveys of biomass excluded
  (The Panel agrees that the final base model represents the best available science regarding the status of the northern subpopulation of Pacific sardine. The Panel wishes to highlight that the level of variation in terminal biomass evident from the retrospective pattern (on the order of 100,000s of tons from one year to the next; Figure 7 of this report) is not unexpected and has been seen in previous assessments (PFMC, 2011). Changes in terminal 1+ biomass estimates used for management of this magnitude may occur when the 2015 assessment update take place.)

On the final day of the review, the STAT provided the Panel with additional model variants with three time blocks for selectivity for the Pacific Northwest fishery. The other settings were: ATM survey catchability was assumed to be 1 or estimated, separate selectivity patterns were estimated for the spring and summer ATM surveys, the weighting factors for the length-frequency, and the conditional age-at-length data were set to 1 for the fishery data and to zero for the ATM surveys. There was insufficient time to fully evaluate these options, but it is considered that it would be a valuable model configuration to consider along with sensitivity to data weighting for a future full assessment.

A further 'bases case' assessment based on applying the final base model (see above) in which the catch series is constructed by assuming that all catches off Ensenada and north are from the northern subpopulation (See Section 4.7). It is considered that this model could be used to form the basis for management advice if the model using the environmentally-based catch series cannot be used for management purposes.

Some additional aspects were considered relevant.

- There is some misalignment between the modeled and observed length. The time step in the model is 6 months, whereas the ATM survey is completed in around one month. Growth occurs through the six month period so the width (sigma) on the catch length distribution needs to be wider than the distribution at length observed by the survey. This can be seen in either bubble plots of residuals at length for the survey or observed and modeled length distributions. Such conflict which relates to the model formulation / time step might be resolved if age based data were used or the ATM survey given a different sigma for spread of length.
- While the ATM survey appears, at first glance, to pick up cohorts correctly, there is some mismatch between spring survey estimates at length in 2010 and 2011. This mismatch does appear to lead to some instability in the model estimates of abundance.
- There are indications that the overall growth assumptions do not align with the conditional age at length information. This is one reason for observed model

instability and the decision to remove the conditional age at length data for the ATM and to down-weight the conditional age at length data for the catch though the first of these was not necessarily assembled correctly and the latter is partial, missing Mexican and Canadian age at length data. Nevertheless it is unclear if fixing these deficiencies will solve the problems.

- If there is a desire to look for ways to stabilize the model, other than the assumption of ATM q=1, collection of more complete age at length data, on both ATM surveys and fisheries, may be one way to resolve whether the issues are that, fishery selection is changing due to different spatial distributions at length by season, or whether growth is more variable than the current model implies. As selection in the fisheries is dominated by the spatial interaction of the migrating stock and different locations of each of the regional fisheries, unlike selection based on gear characteristics it is not possible to determine a priori the form of the selection (by age or by length). Alternatives to the collection of more complete and better quality age data would be: a) to invest more in the aerial survey, both in terms of spatial coverage and more rigorous sampling for species identification and size, and more accurate school density estimation; and b) to investigate further what would be needed to improve the accuracy of the DEPM. However, both of these are likely to be much more expensive than improving the collection of age data.

4.5. Estimates of 1+ biomass in the advice year

The assessment provided estimates of 1+ biomass which are required to give catch advice for Pacific sardine. However, the modeling environment does not provide estimates of precision of the 1+ biomass. It is understood that it is intended to extend the model output to include precision of this quantity, and this development should be encouraged. However, it needs to be kept in mind that a substantial part of the uncertainty regarding 1+ biomass comes from the model specification, not just from precision of the estimates given the model and the data. To fully include useful estimates of precision requires methodology that accounts for multiple models with precision, to at least account for some of the model uncertainty.

Recruitment estimation and environmental variables

The estimate of the most recent recruitment in the assessment model (age 1 in 2013) is rather uncertain and is estimated by the model to be close to the expected value from the stock-recruitment function. Deviations of sardine recruitment from a fitted stock-recruitment model of either Ricker or Beverton-Holt form is observed to be correlated in time, such that there appear to be periods of ‘high’ recruitment and separate periods of ‘low’ recruitment. Investigations of the potential for environmental factors to be informative have been conducted by Zwolinski and Demer (2014 in press). They showed that the variability in sardine recruitment in the California Current during the last three decades mimics aspects of the environment in the North Pacific indicated by the Pacific Decadal Oscillation (PDO) index. They report that the average number of recruits per biomass during "warm" periods was more than threefold higher than that during "cold" periods. In addition to the environmental conditions experienced by sardine larvae, variability in sardine recruitment is also partially explained by both the environmental conditions many months before the spawning season and the adult condition factor.

Management of the stock uses information on the biomass of age 1+ sardine when applying the Overfishing Level and Acceptable Biological Catch control rules.

Estimated recruitment in the last few years has been lower than expected from the stock-recruitment relationship used in the assessment model. Improved estimation (or prediction) of age 1 recruitment for the most recent year would improve management advice for the Pacific sardine stock as the assessment model currently leads to a rather imprecise and, because of the correlation, potentially biased estimate of this quantity. There are a number of potential approaches to improve on this:

1. Use of a prediction model based on recent recruitment and observed autocorrelation could be used to give potentially more likely estimates of recruits in the final year without assigning any specific underlying reason for the recruitment.
2. Development of a recruitment prediction index such as that proposed by Zwolinski and Demer (2014 in press) could be used outside the assessment to replace the assessed value with an alternative value based on a weighted mean of the assessed and index-derived values. One method of determining appropriate weights might be taken from Shepherd (1997).
3. Inclusion of informative environmental indices within the assessment.

When investigating environmental drivers to explain recruitment, a number of issues need to be considered:

- The spawning biomass and recruitment pairs estimated in an assessment are subject to uncertainty, and this needs to be accounted for when estimating the prediction intervals for any potential index.
- Development of environmental indices (for recruitment) through regression analysis needs to be undertaken with care. There are often many explanatory environmental variables available to be tested. The approach is often to examine many potential variables to establish the most powerful explanatory set. However, to understand the significance of the conclusions it is important to recognise that exclusion of unsuitable variables is effectively setting the coefficient for the relationship for that variable to zero. This needs to be accounted for correctly in tests for overall significance by, for example, removing one degree of freedom for every variable (or variable at lag) rejected. This can be done easily for variables formally tested, but may be more difficult to include where variables are rejected at an early stage based on simple graphical investigation. Currently there are 20 stock-recruitment pairs for Pacific sardine; rejection of 18 potential variables (and or lags) while a relationship is being developed should result in a perception of no significant fit. Failure to consider this can lead to an over-optimistic perception of the utility of explanatory functions;

see for example Gröger *et al*. (2010) who examined many potential indices and a wide variety of lags and considered they had found significant drivers for recruitment.

The stock assessment was based on NSP catch data only (See Section 4.3). The model can also be fitted to all catches from US, Canada and Ensenada, A comparison of the biomass trajectory for final model when it is applied to the NSP and total catch series shows a simple relationship and either estimate can be used for management of the fisheries depending on the stock definition requirements of managers.

4.6. Research Recommendations

Research recommendations have been provided in the STAR Panel report. Many, but not all, are repeated here as they result from this specific review.

High priority

1. The assessment would benefit not only from data from Mexico and Canada, but also from joint assessment, which includes assessment team members from these countries.
2. Modify Stock Synthesis so that the standard errors of the logarithms of 1+ biomass can be reported. These biomasses are used when computing the Overfishing Level, the Acceptable Biological catch, and the Harvest Level, but the CV used when applying the ABC control rule is currently that associated with spawning biomass and not 1+ biomass.
3. Investigate sensitivity of the assessment to the threshold used in the environmental-based method (currently 50% favorable habitat) to delineate the southern and northern subpopulations of Pacific sardine; the exploration of sensitivity in the present assessment was limited given time available, but suggested there would be some sensitivity to this cut-off.
4. Compute age-composition data for the ATM survey by multiplying weighted length-frequencies by appropriately constructed age-length keys (i.e. taking account of where the samples were taken).
5. Explore the disparity between ATM estimates at length and conditional age at length. Consider increased sampling at age to obtain clear understanding if differences at length are also the result of differences in age or just differences in growth.
6. Investigate alternative approaches for dealing with highly uncertain estimates of recruitment that have an impact on the most recent estimate of 1+biomass that is important for management. Possible approaches are outlined in Section 4.5 of this report.
7. Validation of the environmentally-based stock splitting method should be carried out if management is to be based on separating the northern and southern subpopulations using the habitat model. It may be possible to develop simple discriminant factors to differentiate the two sub-populations by comparing metrics from areas where mixing does not occur. Once statistically significant discriminant metrics (e.g. morphometric, otolith morphology, otolith micro-structure and possibly using more recent

developments in genetic methods) have been chosen, these should be applied to samples from areas where mixing may be occurring or where habitat is close to the environmentally-based boundary. This can be used to help to set either a threshold or to allocate proportions if mixing is occurring.

Medium priority

1. Continue to explore possible additional fishery-independent data sources.
2. The Panel continues to support expansion of coast-wide sampling of adult fish for use when estimating parameters in the DEPM method and when computing biomass from the acoustic-trawl surveys. Direct comparison between individual samples in survey and fishery should be used to inform model choices. Also encourage sampling in Mexican and Canadian waters.
3. Consider spatial models for Pacific sardine, which can be used to explore the implications of regional recruitment patterns and region-specific biological parameters. These models could be used to identify critical biological data gaps as well as better represent the latitudinal variation in size-at-age.
4. Consider a model which has separate fleets for Mexico, California, Oregon-Washington and Canada.
5. Consider model configurations which use age-composition rather than length-composition and conditional age-at-length data given evidence for time- and spatially-varying growth.
6. Compare annual length-composition data for the Ensenada fishery that are not omitted from MexCal data set for the NSP scenario with the corresponding southern California length compositions. Also, compare the annual length-composition data for the Oregon-Washington catches with those for the British Columbia fishery. This is particularly important if a future age-based model is to be applied.
7. Further explore methods to reduce between-reader ageing bias. In particular, consider comparisons among laboratories and assess whether the age-reading protocol can be improved to reduce among-ager variation.
8. Change the method for allocating area in the DEPM method so that the appropriate area allocation for each point is included in the relevant stratum. Also, apply a method that better accounts for transect-based sampling and correlated observations that reflect the presence of a spawning aggregation.
9. Consider future research on natural mortality. Note that changes to the assumed value for natural mortality may lead to a need for further changes to harvest control rules.

5. Panel review proceedings

Item 3 of the ToR involved documenting meeting discussion with reference to technical aspects of stock assessment work. Item 6 related to the requirement for the STAR Panel to provide 'a risk neutral approach' in its reports and deliberations.

I was impressed overall with the quality of this review and all who participated in it, I would like to thank all involved for their efforts. In particular I would like to thank the presenters for their hard work in prepared presentations and the chair for his work guiding the review and for the work assembling and editing the review group report. In particular I would like to thank Paul Crone and Kevin Hill for their willingness to carry out additional model runs to help clarify the model sensitivity and Andre Punt for this hard work as chair of the Panel.

All the data and assessment reports were provided on time. The presentations covered most issues well. A small improvement would be to ask presenters to refocus the presentation of the assessment results more to sensitivities than primarily the model results. The current approach was a description of the approach and the stages along the way, which provides an insight to the process rather than the results. The important aspects are the differences between the new model and previously agreed assessments, the changes resulting from new data and then the sensitivity to critical assumptions. Nevertheless these aspects are minor and I consider that overall the final review was of a high standard.

The final draft of the Star Panel report was completed on time.

6. Conclusion and Recommendations

The reports and presentations and additional model runs provided an excellent basis to evaluate the performance of the assessment. It is agreed that the assessments are effective in delineating stock status, they are particularly good at projecting probable short-term trends in stock biomass, fishing mortality, and catches. The science reviewed was of a high standard and could be classed as 'of the best scientific information available'. Comments given throughout this report should not be read as direct criticism of what has been done, rather ideas of areas for development. In retrospect one can always find room for improvement, and as such minor suggestions have been made throughout this report which should not be considered prescriptive or limiting but rather as aspects for careful consideration. A number of research recommendations are included in Section 4.6.

I fully endorse the panel agreement that the final base model represents the best available science regarding the status of the northern subpopulation of Pacific sardine. It is also important to reiterate that the level of variation in terminal biomass evident from the retrospective pattern (on the order of 100,000s of tons from one year to the next) is not unexpected and has been seen in previous assessments (PFMC, 2011). It is likely that changes in terminal 1+ biomass estimates used for management of this magnitude may occur when the 2015 assessment update takes place.

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Appendix 1: Bibliography of materials provided for review

Main report and outputs

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Appendix 2: Statement of Work

External Independent Peer Review by the Center for Independent Experts

STAR Panel Review of the 2014-2015 Pacific Sardine Stock Assessment

March 3-5, 2014

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

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

Requirements for CIE Reviewers: Two CIE reviewers shall participate during a panel review meeting in La Jolla, California during 3-5 March, and shall conduct an impartial and independent peer review accordance with the SoW and ToRs herein. The CIE reviewers shall have the expertise as listed in the following descending order of importance:

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

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

Location/Date of Peer Review: The CIE reviewers shall conduct an independent peer review during the STAR Panel review meeting at NOAA Fisheries, Southwest Fisheries Science Center, 8901 La Jolla Shores, La Jolla, California from March 3-5, 2014.

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

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

<u>Foreign National Security Clearance</u>: When CIE reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE reviewers who are non-US citizens. For this reason, the CIE reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number,

country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send by electronic mail or make available at an FTP site to the CIE reviewers all necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. The CIE reviewers shall read all documents in preparation for the peer review, for example:

- Recent stock assessment documents since 2013;
- STAR Panel- and SSC-related documents pertaining to reviews of past assessments;
- CIE-related summary reports pertaining to past assessments; and
- Miscellaneous documents, such as ToR, logistical considerations.

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

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

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

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

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

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

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

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review;
2) Participate during the panel review meeting in La Jolla, California during March 3-5, 2014 as called for in the SoW, and conduct an independent peer review in accordance with the ToRs (Appendix 2);
3) No later than March 24, 2014, the CIE reviewers shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and Dr. David Die., CIE Regional Coordinator, via email to ddie@rsmas.miami.edu. The CIE report shall be written using the format and content requirements specified in Appendix 1, and address each ToR in Appendix 2.

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

January 20, 2014	CIE sends reviewers contact information to the COTR, who then sends this to the NMFS Project Contact

February 14, 2014	NMFS Project Contact sends the CIE Reviewers the pre-review documents
March 3-5, 2014	The reviewers participate and conduct an independent peer review during the panel review meeting
March 24, 2014	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
April 14, 2014	CIE submits CIE independent peer review reports to the COTR
April 22, 2014	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

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

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

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

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

Support Personnel:

William Michaels, Program Manager, COTR
NMFS Office of Science and Technology
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Key Personnel:

Dale Sweetnam, **NMFS Project Contact**
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Dr. Russ Vetter, Director, FRD,
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8901 La Jolla Shores Dr., La Jolla, CA 92037
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Appendix 1: Format and Contents of CIE Independent Peer Review Report

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

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

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

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

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

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

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

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

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

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

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

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

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

The review solely concerns technical aspects of stock assessment. It is therefore important that the Panel strive for a risk neutral perspective in its reports and deliberations. Assessment results based on model scenarios that have a flawed technical basis, or are questionable on other grounds, should be identified by the Panel and excluded from the set upon which management advice is to be developed. The STAR Panel should comment on the degree to which the accepted model scenarios describe and quantify the major sources of uncertainty Confidence intervals of indices and model outputs, as well as other measures of uncertainty that could affect management decisions, should be provided in completed stock assessments and the reports prepared by STAR Panels.

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

Appendix 3: Review Group Agenda CPS STAR PANEL and Participants

Monday 3 March

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

Tuesday 4 March

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

Wednesday 5 March

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

Participants 2014 Pacific Sardine STAR Panel

STAR Panel Members

André Punt (Chair), SSC, University of Washington
Meisha Key, SSC, CDFW – California Department of Fish and Wildlife
José de Oliveira, CIE Reviewer, CEFAS - Centre for Environment, Fisheries & Aquaculture Science, UK
John Simmonds, CIE Reviewer, ICES – International Council for the Exploration of the Sea, Denmark
Diane Pleschner-Steele, CPSAS - Coastal Pelagic Species Advisory Sub panel Advisor to STAR Panel
Chelsea Protasio, CPSMT - Coastal Pelagic Species Management Team Advisor to STAR Panel

STAT Report

Kevin Hill, SWFSC - Southwest Fisheries Science Center
Paul Crone, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER

Other STAT presenters

David Demer, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Emmanis Dorval, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Juan Zwolinski, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER

Other Attendees

Jenny McDaniel, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Beverly Macewicz, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Kirk Lynn, CDFG – California Department of Fish and Game
Dale Sweetnam, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Erin Reed, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Ed Weber, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Josh Lindsay, NMFS WCR National Marine Fisheries Service, West Coast Region
Russ Vetter, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Al Carter, Ocean Companies
Richard Carroll, Jessie's Ilwaco Fish Company
Elizabeth Helmers, CDFW
Nancy Lo, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Sam McClatchie, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Richard Parrish, NMFS Emeritus
Yukong Gu, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Jeff Laake, AFSC – Alaska Fisheries Science Center
Kevin Piner, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
William Watson, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Elaine Acuña, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Anna Holder, CDFW – California Department of Fish and Wildlife
Joel Van Nord, CWPA – California Wetfish Producers Association
Noelle Bowlin, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Mike Okoniewski, Pacific Seafood
Cisco Werner, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Sarah Shoffler, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Kristen Koch, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Chris Francis, NIWA - National Institute of Water and Atmospheric Research
Emily Gardner, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Alex Da Silva, IATTC – Inter-American Tropical Tuna Commission
Steven Teo, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
George Cutter, SWFSC - SOUTHWEST FISHERIES SCIENCE CENTER
Mark Maunder, IATTC – Inter-American Tropical Tuna Commission

Individual CIE Report

STAR Panel Review of 2014-2015 Pacific Sardine Stock Assessment

Southwest Fisheries Science Center, La Jolla, California, 3-5 March 2014

Prepared for the Center for Independent Experts

By

Dr José A. A. De Oliveira

April 2014

Cefas Contract C5386

COMMERCIAL IN CONFIDENCE

Executive Summary

A STAR Panel review of the 2014-2015 stock assessment of the northern subpopulation of Pacific sardine (*Sardinops sagax*) was held during 3-5 March 2014 in La Jolla, California. The review activities included reviewing the draft stock assessment and other pertinent information provided in advance of the review meeting, working with the STAT team to ensure input data and assessment models are reviewed as necessary, and recommending alternative methods and/or modifications to proposed methods, as appropriate. This report describes the material and methods provided for the review, and focuses on the review activities leading up to the selection of the final model for the 2014-2015 stock assessment, providing a summary of findings and recommendations. Review activities focussed primarily on alternative weighting for compositional data and found that, although abundance trends were generally well-determined by the available data, the absolute scale of the population was highly uncertain, with small changes to the model leading to large changes in scale. The assumption of catchability equal to 1 for both the ATM spring and summer surveys was key to reducing sensitivity to scale, although biomass estimates for the early years of the assessment remained volatile. The Panel could find no reason to disagree with the STAT's decision to omit the NWSS aerial survey from the assessment, and also supported the omission of the ATM conditional age-at-length data from the assessment, because the age-length keys that they relied on were inappropriately assembled, and model results were highly sensitive to alternative weightings for these data. The final model continued to show a high level of variation in terminal biomass (reflected by a strong retrospective pattern), but this has been seen in the past for this stock and will likely continue to be the case in future assessments. The Panel report provides results for the final model for both options for assigning catch to the northern subpopulation, the first using an environmentally-based method to remove southern subpopulation fish from the Mexican-southern Californian fleet data, and the second assuming all catches taken by the Mexican-southern Californian fleet belong to the northern subpopulation. The Panel concluded that the final model represented the best available science regarding the current status of the northern subpopulation of Pacific sardine. The CIE reviewer fully supports and endorses the Panel's findings and recommendations, as reflected in their report.

Background

The review concerns the 2014-2015 stock assessment for the northern subpopulation of Pacific sardine (*Sardinops sagax*). The majority of review material (including detailed output for two proposed models, and the draft assessment report) was made available through the FTP site (http://swfscftp.noaa.gov/) between 19-21 February 2014 – the review material made available before, during and after the STAR Panel review meeting is given in Annex 1. The actual STAR Panel review took place at the Southwest Fisheries Science Center in La Jolla, California over 3-5 March 2014. Details of this meeting, including Terms of Reference and Agenda, can be found in Annex 2 and its Appendices, and a list of participants in Annex 3.

The STAR Panel comprised four equal members, two of which were CIE reviewers (see Annex 3). The main responsibilities of the STAR Panel were as follows:

(a) Review stock assessment data inputs.
(b) Review the analytical models presented.
(c) Provide complete STAR Panel reports.

In particular, the STAR Panel are responsible for determining if a stock assessment or technical analysis is sufficiently complete, with any decision on this having to be made by Panel consensus.

Along with the entire STAR Panel, the CIE Reviewer's duties included the following:

1. Reviewing the draft stock assessment and other pertinent information (e.g. previous assessments and STAR Panel reports).
   This was done by reviewing material provided prior to and during the meeting (Annex 1).
2. Working with STAT Team to ensure assessments are reviewed as needed.
   A number of requests were made to explore model sensitivity to alternative parameterisations and data weighting scenarios, including the exclusion of some data (Annex 4).
3. Documenting meeting discussions.
   These are reflected in the STAR Panel report and below.
4. Reviewing summaries of stock status (prepared by STAT Team) for inclusion in the Stock Assessment and Fishery Evaluation (SAFE) document.
   These were provided during the meeting in the form of detailed model outputs for the final model (T-2_0.2; see Annex 5 for description), uploaded to the FTP site.
5. Recommending alternative methods and/or modifications of proposed methods, as appropriate, during the STAR Panel meeting.
   These were reflected in the number of requests the STAR Panel made to the STAT (Annex 4) as well as the research recommendations (see STAR Panel report and below).
6. The STAR Panel's terms of references concern technical aspects of stock assessment work. The STAR Panel should strive for a risk neutral approach in its reports and deliberations.
   The STAR Panel indeed kept to technical aspects of the stock assessment and its input data.

Following the meeting, a careful review of the STAR Panel report was conducted and suggestions made for improvements, making sure that all statements and conclusions were backed up and justified by model outputs and results. The STAT was requested to add key model outputs to the FTP site that were needed for the purposes of corroboration.

Review activities and findings

The Agenda for the meeting is given in Appendix 3 of Annex 2, and detailed descriptions with accompanying rationale and outcomes for all review requests provided in Annex 4. This section attempts to summarise these activities and their findings.

Presentations

Presentations included a description of the seasonal distributions of the northern subpopulation, with associated fishing areas and modelled fleets; a description of the fishery data (landings and length and age compositions for the MexCal fleet by semester, and for the PacNW fleet by year); a description of the general survey areas for the spring and summer ATM surveys, the spring DEPM/TEP survey, and the summer NWSS aerial survey; a description of the survey time series available for each of these surveys, as well as the associated length and age compositions for the ATM surveys, and the length compositions for the NWSS aerial survey. In-depth presentations were made on methodology for the DEPM surveys and estimation procedure, and the ATM spring and summer surveys, including the environmental method used to differentiate between the northern and southern subpopulations of Pacific sardine. There was no specific presentation on the NWSS aerial survey, but a summary was provided by email and included in the Panel report. Key aspects of blended models G and H (results of which had been made available prior to the meeting on the FTP site and in the draft assessment document, along with a range of sensitivity analyses) were presented and compared with each other and with previous assessment results. The key difference between models G and H was that the former assumed length-specific selection by fitting to length-composition data, and estimated growth by fitting to conditional age-at-length data (which was down-weighting further relative to input weights), while the latter assumed age-specific selection by fitting the age-composition data and setting growth parameters to pre-specified values. The Stock Synthesis version used for the 2014-2015 assessment models was Version 3.24s. A presentation on issues affecting the use of composition data, including data weighting (a key concern for the Pacific sardine assessment) was given.

Exploring input data

Differentiating the northern subpopulation
A key concern for the assessment (and one highlighted by past Panels as a high research priority) was that catches should be appropriately allocated to the northern and southern subpopulations of Pacific sardine; to this end, an environmentally-based method was developed and used to exclude some of the data (catches and associated composition data) belonging to the southern subpopulation (taken in the San Pedro and Ensenada fisheries, the southern portion of the MexCal fleet) from the assessment. The Panel and STAT were in favour of this new approach, but foresaw difficulties for management related to setting catch levels for a portion of a population (the southern subpopulation) for which there is no assessment. A decision was therefore made to conduct all sensitivity analyses using the environmentally-based method for deriving the northern subpopulation fishery data, but then to present the final model as two versions, one where the environmentally-based method is

used to remove southern subpopulation fish from the MexCal fleet data, and the other assuming that all catches taken in the MexCal fleet belong to the northern subpopulation. Request C (Annex 4) found that the environmentally-based method was potentially sensitive to the threshold used to switch between whether an area was more suitable for the northern or for the southern subpopulation; if further analysis continues to find the method sensitive for plausible alternative threshold values, it may require further refinement.

DEPM survey
The Panel highlighted two minor issues with the DEPM estimation procedures that, although they may not lead to large changes in the estimates, nevertheless need to be corrected. These related to the appropriate area allocation for each point in each of two strata (high and low density), and appropriately accounting for transect-based sampling and correlated observations.

ATM surveys
During spring 2013, it was noticed that the ATM survey did not venture north of San Francisco, and concern was expressed that suitable habitat for sardine at the time may have been missed (Request D, Annex 4). However, an overlay of a habitat map with the survey results did not show evidence of this being the case, suggesting that the survey did indeed provide an adequate sample of the population. Furthermore, the ATM survey team considered the spring 2012 ATM survey length frequency as unreliable, and sensitivity tests explored the omission of this data (Request S, Annex 4) as well as the omission of the spring 2011 ATM survey length frequency data (Request U, Annex 4), since model fits to both these length frequencies were always poor. The latter request (U) helped in the selection of appropriate weighting for compositional data in the final model; however, the final model included both these length frequencies. The ATM survey team were also asked to investigate the apparent discrepancy between the biomass estimates from the ATM survey in the Oregon-Washington area during summer 2012 and the contemporaneous landings in the area (Request E, Annex 4); they found that point estimates from the survey comfortably exceeded the landings, and that assuming fish had migrated from the south, the landings were below the lower 95% confidence bound for combined survey estimate for the same period and area, and for the area to the north of it surveyed immediately afterwards.

Conditional age-at-length for the ATM surveys
When constructing ALKs for fish aged during ATM surveys, no weighting was used (aged fish were simply combined into a single ALK), despite possible differences between regions (e.g. separate ALKs were used for the MexCal and PacNW fleets). This treatment is not optimal, given the possibility for age- and size-specific distribution of sardine. This was one of the reasons the Panel supported the removal of conditional age-at-length data for the ATM surveys from the final model. Panel Request B (Annex 4) was intended to investigate this more closely, but was not pursued during the meeting because blended model H (age-based) was ignored; however, a research recommendation was raised.

NWSS aerial survey
Apart from a sensitivity analysis (Request G, Annex 4), the aerial survey was omitted from blended models G and H and all subsequent models developed during the meeting, including the final model. The Panel did not see evidence to disagree with the STAT's recommendation to omit the aerial survey.

Sensitivity analyses
[Note, in an attempt to follow a narrative (grouping similar areas of investigation together), the order that requests are discussed below is not necessarily chronological or the same as followed in the Panel report.]

It was decided early on to focus on blended model G (length-based) because blended model H (age-based) was not as fully tested, and because the fishery age composition data ignored the length compositions for the fisheries at the extremes of the northern subpopulation distribution (i.e. in Canada and Mexico), thereby implicitly assuming that these length compositions were the same as those from adjacent fisheries (i.e. Oregon-Washington and southern California respectively). The first two of the Panel requests (Requests A and B, Annex 4) were therefore not considered, and instead put forward as research recommendations. This issue (assuming length compositions at the extremes are the same as adjacent areas for the purpose of compiling age data) remains a concern for the conditional age-at-length data used in the final model, although the additional weighting (λ=0.2) in the final model does further down-weight this data (see Annex 5).

The primary concern for the review was that appropriate weights were established and justified for the compositional data, particularly given the high sensitivity of stock assessment results to alternative weighting of the conditional age-at-length data. Sensitivity analyses focussed primarily on this aspect, but also looked at sensitivity to combining/splitting the spring and summer ATM survey *q*s (catchability) and selectivities, estimating/fixing the ATM survey *q*s, and omitting certain ATM spring survey length frequencies. Sensitivity to an alternative stock-recruit formulation (Request I, Annex 4) and to an alternative value for M (Request J, Annex 4) was also checked, but results were found to be either relatively insensitive (former) or predictable (latter).

Applications of "Francis weights" to compositional data
Blended model G applied rather arbitrary weights to the compositional data (λ=1 for all length composition data, and λ=0.5 for all conditional age-at-length data; Table A4.2, Annex 4). These weights were in addition to the input weights which accounted for effective sample sizes (note: when referring to weighting below, it is always in this context – i.e. in addition to input weights). One of the first tasks related to the stock assessment model itself was to investigate the effect of applying one of the weighting methods proposed by Francis (2011; method TA1.8) to the compositional data, referred to here and in the Panel report as "Francis weights". In order to derive these Francis weights, the STAT team first developed model K by setting all weights to 1 (λ=1 for all compositional data), then estimated the Francis weights using model K. The Panel supported this approach. Compared to model G, model K, which gave more weight to the conditional age-at-length data, substantially lowered estimates of biomass, and changed the spring ATM selection to be less knife-edge and more like the summer ATM selection pattern.

Francis weights derived from model K (and implemented as changes to λ) were applied to all compositional data (model F) which resulted in a severe down-weighting of all length composition data and up-weighting of all conditional age-at-length data apart from that for the PacNW fleet. However, some of the weights were poorly determined (e.g. for the ATM summer survey), so the Panel requested pooling of similar data sources (the summer and spring ATM surveys were pooled, and the first and second semester MexCal fleets were pooled), which led to improved estimates for weights (model L). Models F and L showed similar behaviour to each other; however, compared to G they gave substantially lower estimates of biomass (like K), and substantially different selection patterns for the two MexCal fleets (whereas K had shown changed selection for the spring ATM survey). These results led to further requests in order to isolate what was causing the differences.

In order to investigate whether it was the length composition data or the conditional age-at-length data that were most influential, model M assigned Francis weights only to the length composition data, while model N assigned Francis weights only to the conditional age-at-length data; in both cases, the compositional data that were not assigned Francis weights were allocated λ=1. Although biomass estimates for the earlier years for model M were affected, the scale and trend in biomass in recent years were relatively insensitive, whereas biomass estimates for model N were markedly lower throughout the times series, leading to the conclusion that weighting of the conditional age-at-length caused the most sensitivity. When allocating Francis weights to conditional age-at-length data for models F, L and N, it was noticed that weights greater than 1 were allocated to all but the PacNW fleet (λ well below 1), so model O was the same as model N but forced λ=1 for the conditional age-at-length data of the PacNW fleet. Results for model O were almost identical to model N.

Although they did not apply Francis weights, models U and W looked further into the question of which of the different sources of conditional age-at-length data were most influential. Considering the weighting for conditional age-at-length data only and compared to model G (for which λ=0.5 was used throughout for these data), model U kept λ=0.5 for the ATM survey but down-weighted all the fishery data (λ=0.01), while model W set λ=0 for the ATM survey (i.e. omitted the ATM survey conditional age-at-length data) but kept λ=0.5 for all the fishery data (see Annex 4, Table A4.2). The contrast between models U and W was quite marked, with U leading to much lower biomass levels than model G (and consequently unrealistically high estimates of survey *q*), and W much higher ones. Given these results and the Panel's unease with the way in which the conditional age-at-length data were constructed for the ATM surveys (see "Exploring input data" above), some of the later sensitivity tests and the final model ignored the conditional age-at-length data from the ATM surveys.

ATM survey q and selection

In order to investigate whether assessment data supported a single *q* for ATM surveys, one of the first assessment model requests (Request H, Annex 4) was to force *q* to be the same for the ATM spring and summer surveys, and instead of estimating the single *q*, scanning over a range of values for it (0.7 to 1.1 was run in steps of 0.1). From a likelihood point of view, there was no support for separate *q*s; furthermore, the biomass trajectory re-scales with changing *q*, and the selection pattern for the ATM spring survey flips from being almost knife-edged to being closer to the ATM summer survey selection as *q* increases. The lack of these changes occurring in a systematic way (as pointed out in the Panel report) is likely to do with the model not having obtained a global minimum in some cases. This behaviour (ATM spring survey selection markedly changing) was also noted for model K when conditional age-at-length data were up-weighted (λ changed from 0.5 to 1).

These results led to further requests (Requests P, Q and V, Annex 4) to investigate whether there was any support for treating the ATM spring and summer surveys as a single survey time series (i.e. with a common *q* and selection pattern for both spring and summer surveys). For model P the ATM spring and summer survey *q* and selection were forced the same, and when compared to model G resulted in a poorer fit to the ATM survey length frequency data, lower biomass estimates and consequently an unrealistically high survey *q*. Furthermore, for fish lengths below ~15cm and above ~20cm, the single ATM survey selection was respectively above and well below both the ATM spring and summer selection curves estimated under model G – the use of a single ATM selection curve with only two parameters to estimate for model P means there is less flexibility to deal with differences in the length frequencies (after accounting for growth and mortality) in the spring and summer surveys, and so a "compromise" selection curve is obtained, with the inevitable poorer fits to some length frequency data. Model Q was the same as P, but gave a much higher weighting (λ=20) to the ATM survey length frequency data in an attempt to improve the fits to these data. Although there were some improvements, the model was still unable to fit all the length frequencies adequately. Model V was an attempt to improve the fit to the ATM length frequencies by removing one of the ATM survey length frequencies (spring survey held in 2012) that the ATM survey team considered unreliable; the model (same as model Q but with the 2012 ATM spring survey compositional data omitted) was still unable to fit the remaining ATM survey length frequencies adequately.

Models R, S and T were an attempt to further understand the trade-offs involved depending on how the estimation of the ATM survey *q*s and selectivities were treated; in all these cases, the conditional age-at-length data for the ATM surveys were ignored (λ=0) for the reasons explained in the final paragraph of "Applications of 'Francis weights' to compositional data" above, and in the section "Exploring input data" also above. Models R and S assume the same *q* and selection pattern for the ATM spring and summer surveys, but the former estimates the single *q* while the latter sets it to 1; both cases result in higher estimates of biomass than model G (S being more optimistic than R). Model T sets the single *q* to 1, but estimates separate selectivities for the ATM spring and summer surveys; this results in lower estimates of biomass than model G and contrasts with model W (described earlier), which estimates separate ATM spring and summer *q*s (this is the only difference to model T) that results in even higher biomass estimates than model S. Given the difficulties encountered when assuming a single selection pattern for the ATM spring and summer surveys (previous paragraph), the Panel was leaning towards estimating separate selection patterns for the ATM spring and summer surveys.

Profiling over weights for the conditional age-at-length data

The Panel continued to have difficulty with the *ad-hoc* weighting assumed for the conditional age-at-length data (λ=0.5). Further requests therefore focussed on profiling over the λ weights for these data for a selection of models in order to better justify a value for λ. The models were: G (the base model), W (estimating separate ATM spring and summer survey *q*s) and T (a single ATM survey *q* fixed at 1), and the profiling models were labelled G-2, W-2 and T-2 respectively. A further version of model W was considered, where Francis weights were used for the length composition data, pooled for the MexCal fishery and for the ATM surveys (as was done for these data in model L), and this was labelled W-3. All these models estimated separate ATM spring and summer survey selection patterns. The initial approach, particularly for G-2, W-2 and W-3, was to specify a λ value that would result in the average of the ATM spring and summer survey *q*s being around 1. This was achieved for λ≈0.7 for G-2 and for λ≈0.035 for W-2, but was not achievable for W-3, the latter resulting in unrealistically low values for *q* for all λ values tried. Inclusion of the ATM survey conditional age-at-length data, and increasing λ on these data had the tendency of reducing biomass estimates (e.g. models G and K), so omission of these data led to higher biomass estimates (model W) which then required a much lower value of λ in order to reduce these biomass estimates to achieve an average ATM survey *q* of 1.

At this point the STAT and Panel agreed that selecting a weighting factor in order to achieve some average value of a survey *q* (in this case 1) was not a robust and sensible way to provide management advice, so focus shifted instead to model T-2, which explicitly assumed *q*=1 for both ATM surveys. Setting *q*=1 also helped reduce model sensitivity to weighting. Although profiling over the λ applied to the fishery conditional age-at-length data showed model T-2 to be quite sensitive to changes in this λ for the early years of the biomass trajectory, it was fairly robust for recent years; nevertheless, biomass trajectories for recent years fell into two groups, one where λ was 0.1, 0.2 and 0.4, and the other where it was 0.3, 0.5 and higher, which seemed to depend on which sort of data the model "latched onto" (similar "flipping" behaviour was described earlier under "ATM survey *q* and selection"; as before, the lack of this happening in a systematic way is likely due to the model not reaching its global minimum in some cases). This led the Panel to explore a means for selecting which group was most appropriate, so the λ values at the midpoint of each group were selected for further exploration, leading to models T-2_0.2 and T-2_0.7 (the numbers after the underscore reflecting the midpoint λ values).

Two approaches were used to try to isolate which of models T-2_0.2 and T-2_0.7 was the most appropriate to serve as a final model. The first approach (Request U, Annex 4) refitted each model without two ATM spring survey length frequencies (2011 and 2012), assuming that the observed "flipping" behaviour was due to trying to fit these two length frequencies (which were always poorly fitted); furthermore, the 2012 ATM spring survey length frequency was considered unreliable by the ATM survey team. The models using the first approach were re-labelled T-2_0.2a and T-2_0.7a respectively. The second approach (Request V, Annex 4) conducted a retrospective analysis (comparing the models with and without the most recent four years of data). The second approach did not provide a decisive means to distinguish between the two candidates (both models changing markedly), but the first approach did: models T-2_0.2a and T-2_0.7a both fell into the same group as T-2_0.2, indicating that the grouping behaviour discussed in the preceding paragraph was at least partially being caused by conflicts when fitting the two ATM survey length frequencies. Model T-2_0.2 was selected as the final model because it showed less sensitivity to the omission of 2011 and 2012 ATM spring survey length frequencies (but note that the final model did include these length frequencies). The specifications of the final model are provided in Annex 5.

Additional STAT runs
The STAT presented additional model runs on the final day that included time-varying selectivity (models X and X-1 in Table A4.2 of Annex 4), but there wasn't sufficient time to fully evaluate these models. However the Panel agreed that they would be valuable options to consider for future assessments.

Conclusions and recommendations

The STAT, with input from the Panel during the review, conducted a thorough investigation of input data and model settings leading up to selection of the final model (T-2_0.2) to be used for the 2014-2015 Pacific sardine stock assessment (Annex 5). These investigations focussed particularly on alternative weighting for compositional data. Although the trend in abundance is generally well determined by the available data, the absolute scale of the population continues to be uncertain (as found in previous years), with small changes to the model (e.g. relative weights assigned to compositional data) leading to large changes in model results (including population scale). The assumptions of *q*=1 for both ATM surveys was important to reduce model sensitivity, particularly to scale, but despite this, the scale of early years continued to be relatively sensitive. Previous assessments had investigated setting q=1 for the DEPM survey, but found that this lead to unrealistic qs for the ATM surveys.

The Panel could not find reason to disagree with the STAT's view that the NWSS aerial survey should be omitted from the assessment, so the final model excludes this data source. The final model also excludes the ATM spring and summer conditional age-at-length data because it was felt that the ALKs used were not appropriately assembled and because model results were particularly sensitive to alternative weights assigned to these data. In contrast, model results were relatively insensitive to alternative weights assigned to the length composition data (compare the following models: K to M, N to F, and P to Q and V). However, this conclusion (relative insensitivity to alternative weights for length composition data) only held while the ATM conditional age-at-length data were included (Figure 1). As soon as ATM conditional age-at-length data were omitted, model results became very sensitive to alternative weights assigned to the length composition data (compare W-2_0.3 and W-3_0.3 in Figure 1, where the "_0.3" refers to the value for λ assigned to the fishery conditional age-at-length data; this λ value was used because it was the only common value for which results were available on the FTP site for both models W-2 and W-3). This result supports the choice of q=1 for the ATM surveys in the final model (because it acts to stabilise the scale), but also raises the possibility that it may be worth including once again in future assessments the conditional age-at-length data for ATM surveys once the ALKs on which they are based have been appropriately assembled.

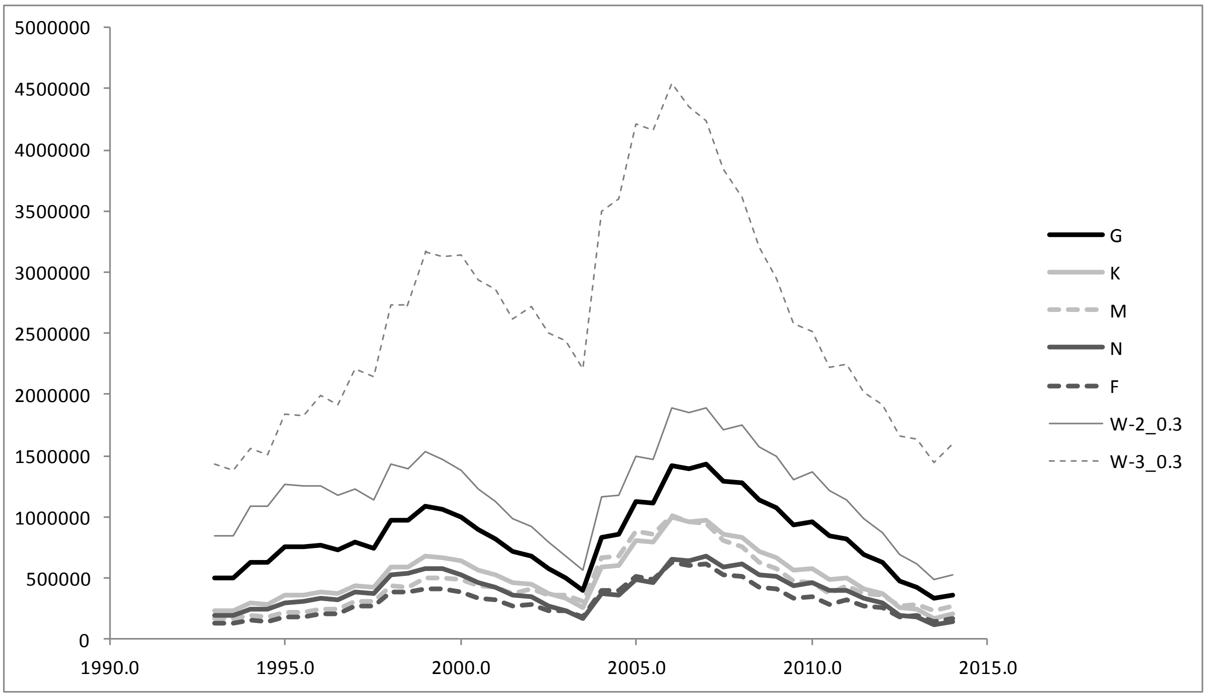

Figure 1. A comparison of models that assign Francis weights to the length composition data (broken lines), given a particular model configuration (solid line in the same colour). Model G is included for comparison. For a description of model differences, see Table A4.2 in Annex 4.

The final model uses separate selection patterns for the ATM spring and summer surveys, given the additional difficulties encountered when forcing these patterns to be the same (poorer fits to survey length frequency data and unrealistically high survey qs). The Panel concluded that the final model represented the best available science regarding the current status of the northern subpopulation of Pacific sardine, and that the level of variation in terminal biomass, reflected by a strong retrospective pattern, was both expected and seen in previous assessments, and will likely occur again in future assessments. The Panel report provides results for the final model for both options for assigning catch to the northern subpopulation, the first using the environmentally-based method to remove southern subpopulation fish from the MexCal fleet data, and the second assuming all catches taken in the MexCal fleet belong to the northern subpopulation.

A number of recommendations arose from the review, and these were classified as high (H), medium (M) or low (L) priority. Most of them were "rolled over" from previous STAR Panel reviews and related to the benefits of greater international cooperation (H), needed changes to the Stock Synthesis package (H), the need to consider models with a longer period of data for a broader context of changes in productivity (H), exploring additional fishery-independent data sources (H), exploring reasons for discrepancies in the observed and expected proportions of older fish in length and age compositions (M), continued support for the expansion of coast-wide sampling of adult fish (M), the need to consider spatial models in order to better capture regional variations in population dynamics (M), the need to explicitly consider sex-structure in models (despite the lack of sexual dimorphism in length-at-age samples demonstrated during this review) because of sensitivity to this seen in the past (M), the need to model fleets separately (Mexico, California, Oregon-Washington, Canada) (M), continued investigation of the pros and cons of age-based models rather than age-length ones given evidence for time- and spatially-varying growth (despite being presented as an option, age-based models were not really given any attention during this review) (M), further exploration of methods to reduce between-reader ageing bias (M), and developing a relationship between egg production and fish age that accounts for processes by age (e.g. duration of spawning and batch fecundity) (L).

Recommendations that specifically arose from this review were the following:

- Investigate the sensitivity of the assessment model to the threshold used in the environmentally-based method to delineate the northern and southern subpopulations of Pacific sardine. An initial investigation conducted during the review did not consider changing the threshold itself (this would require more time than available), but instead used a rough proxy for this and found that proportion allocated to each subpopulation was potentially sensitive to the threshold used. [H]
- Carry out validation of the environmentally-based method used to split catches between the northern and southern subpopulation of Pacific sardine. The development of simple discriminant factors from areas where mixing doesn't occur (e.g. morphometrics, otolith morphology and microstructure, latest developments in genetics) to be applied where mixing does occur or to areas close to the separation boundary was suggested. [H]
- Compute age compositions for the ATM surveys by applying weighted length frequencies to appropriately derived ALKs (i.e. taking into account where sampling occurred). This was one of the main reasons for ignoring the conditional age-at-length information for the ATM surveys. [H]
- Investigate alternative ways to deal with the most recent estimates of those that tend to be among the most uncertain and have a large impact on the estimation of 1+ biomass used for management. In the absence of information, the most recent recruitment estimates rely heavily on stock-recruit assumptions. The Panel report highlights several options for

dealing with these estimates of recruitment, including: a prediction model based solely on recent recruitment and observed autocorrelation; a recruitment prediction index developed outside the assessment model, such as proposed by Zwolinski and Demer (in press), and then combined with the assessment model estimate of recruitment in the form of a weighted mean, with weights derived by, for example, the method proposed by Shepherd (1997); direct inclusion of environmental indices within the assessment model that are informative about recruitment. The Panel report also highlights the challenges involved when investigating environmental drivers to explain recruitment – in particular that assessment uncertainty should not be ignored when using stock-recruit pairs, and that the degrees of freedom effect (leading to over-fitting data) should also not be ignored when considering a range of environmental indices (see e.g. De Oliveira and Butterworth 2005). [H]

- For the MexCal data, compare annual length compositions from Ensenada to those from California, and for the PacNW data, compare annual length compositions from British Columbia with those from Oregon-Washington. The length compositions from Ensenada and British Columbia were ignored in the age-based model (blended model H), because no age data was made available for these regions, and age compositions for adjacent areas were assumed to apply to these regions (i.e. implicitly assuming length compositions were the same as in adjacent areas). This recommendation is seen as important if age-based models are pursued in future, but it is also important because conditional age-at-length data (used in the age-length models presented for review) will have the same problem. [M]
- For the DEPM estimation methodology, change the method used to allocate area for each point included in each stratum, and apply a method that better accounts for transect-based sampling and correlated observations. These suggested changes have a potentially minor effect on estimates, but are nevertheless regarded as more appropriate. [M]
- Consider future research on natural mortality. The assessment models currently assume a time- and age-invariant value of 0.4. [M]

Comments on Terms of Reference

The terms of reference are given in "Background" above and in Appendix 2 of Annex 2. As a CIE reviewer, I participated fully in the activities of the STAR Panel, and provide full support to, and endorse the Panel's findings and recommendations, as reflected in their report. Comments on the individual terms of reference are already provided in italics in the "Background" section.

Comments on NMFS review process

The review process was thorough, but also fast-moving. Although understanding of the difficulty of doing it (lack of time and personnel, and volume of material), the one thing I did find frustrating was that model results produced during the meeting were not automatically made fully available on the FTP site, either during the meeting or afterwards (apart from those specifically requested for corroboration of report statements). I found that this did hamper slightly the review process for me, particularly when compiling this report (as I wanted to give careful consideration to all the model results covered during the meeting). If the volume of material was a concern, then even just making available the Report.sso files for all model runs would have been helpful. As a caveat to this, I must add that when I did ask for information, it was always provided. Apart from this, I found the review to be well-run, professionally handled and very informative, and I was appreciative of the efforts of the STAT to provide everything needed for the review, and of the organisers for their background work to ensure a smoothly run meeting.

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Annex 1

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Prior to the meeting
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Comprehensive model outputs (all files and plots) for models G and H.

During the meeting
Selected model outputs for models H, I, J, P, Q, R, S, T, U, W, G-2 and W-2
Comprehensive model outputs for T-2_0.2_NSP (including retrospective patterns) and T-2_0.2_all (i.e. where environmental-based splitting of fishery data is not applied).

After the meeting
Comprehensive model outputs for models F, G, I, K, M, N, Q, V, W
Selected model outputs for W-3_0.3 and W-3_0.8

Presentations (during the meeting)

Assessment overview
Paul Crone

Assessment data
Background, sub-stocks, biology, fisheries, surveys, management – Kevin Hill
Stock structure and environment-based index (catch/composition) –Juan Zwolinski
Acoustic-trawl method (ATM) survey – David Demer
Daily egg production model (DEPM)/Total egg production (TEP) surveys – Emmanis Dorval
Overlaying spring 2013 survey with favourable habitat – Juan Zwolinski

Assessment results
Blended model (G and H) overview – Paul Crone
Data weighting considerations (composition vs. abundance time series) – Chris Francis
Sensitivity analysis and model G and H results – Paul Crone

Interactive assessment results during the meeting
Paul Crone and Kevin Hill

Annex 2

Copy of CIE Statement of Work

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

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

Requirements for CIE Reviewers: Two CIE reviewers shall participate during a panel review meeting in La Jolla, California during 3-5 March, and shall conduct an impartial and independent peer review accordance with the SoW and ToRs herein. The CIE reviewers shall have the expertise as listed in the following descending order of importance:

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

- It is desirable for the CIE reviewer to be familiar with the design and application of fisheries underwater acoustic technology to estimate fish abundance for stock assessment.
- It is desirable for the CIE reviewer to be familiar with the design and application of aerial surveys to estimate fish abundance for stock assessment.

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

Location/Date of Peer Review: The CIE reviewers shall conduct an independent peer review during the STAR Panel review meeting at NOAA Fisheries, Southwest Fisheries Science Center, 8901 La Jolla Shores, La Jolla, California from March 3-5, 2014.

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

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

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

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send by electronic mail or make available at an FTP site to the CIE reviewers all necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. The CIE reviewers shall read all documents in preparation for the peer review, for example:

- Recent stock assessment documents since 2013;
- STAR Panel- and SSC-related documents pertaining to reviews of past assessments;
- CIE-related summary reports pertaining to past assessments; and

- Miscellaneous documents, such as ToR, logistical considerations.

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

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

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

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

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

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

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

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review;
2) Participate during the panel review meeting in La Jolla, California during March 3-5, 2014 as called for in the SoW, and conduct an independent peer review in accordance with the ToRs (Appendix 2);
3) No later than March 24, 2014, the CIE reviewers shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and Dr. David Die., CIE Regional Coordinator, via email to ddie@rsmas.miami.edu. The CIE report shall be written using the format and content requirements specified in Appendix 1, and address each ToR in Appendix 2.

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

January 20, 2014	CIE sends reviewers contact information to the COTR, who then sends this to the NMFS Project Contact
February 14, 2014	NMFS Project Contact sends the CIE Reviewers the pre-review documents
March 3-5, 2014	The reviewers participate and conduct an independent peer review during the panel review meeting
March 24, 2014	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
April 14, 2014	CIE submits CIE independent peer review reports to the COTR
April 22, 2014	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

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

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

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

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

Support Personnel:

William Michaels, Program Manager, COTR
NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
William.Michaels@noaa.gov Phone: 301-427-8155

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Key Personnel:

Dale Sweetnam, **NMFS Project Contact**
Fisheries Resources Division, Southwest Fisheries Science Center,
8901 La Jolla Shores Dr., La Jolla, CA 92037
Dale.Sweetnam@noaa.gov Phone: 858-546-7170

Dr. Russ Vetter, Director, FRD,
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8901 La Jolla Shores Dr., La Jolla, CA 92037
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Appendix 1: Format and Contents of CIE Independent Peer Review Report

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

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

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

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

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

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

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

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

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

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

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

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

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

The review solely concerns technical aspects of stock assessment. It is therefore important that the Panel strive for a risk neutral perspective in its reports and deliberations. Assessment results based on model scenarios that have a flawed technical basis, or are questionable on other grounds, should be identified by the Panel and excluded from the set upon which management advice is to be developed. The STAR Panel should comment on the degree to which the accepted model scenarios describe and quantify the major sources of uncertainty Confidence intervals of indices and model outputs, as well as other measures of uncertainty that could affect management decisions, should be provided in completed stock assessments and the reports prepared by STAR Panels.

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

Appendix 3: Draft agenda: CPS STAR Panel

Monday 3 March

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

Tuesday 4 March

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

Wednesday 5 March

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

Thursday 6 March (Optional, CIE Reviewers not required to attend)

08h00 Data Preparation for future CPS Stock Assessments

17h00 Adjourn

Appendix 4: STAR Panel Summary Report (Template)

- Names and affiliations of STAR Panel members

- List of analyses requested by the STAR Panel, the rationale for each request, and a brief summary the STAT responses to each request

- Comments on the technical merits and/or deficiencies in the assessment and recommendations for remedies

- Explanation of areas of disagreement regarding STAR Panel recommendations
    - Among STAR Panel members (including concerns raised by the CPSMT and CPSAS representatives)
    - Between the STAR Panel and STAT Team

- Unresolved problems and major uncertainties, e.g., any special issues that complicate scientific assessment, questions about the best model scenario, etc.

- Management, data or fishery issues raised by the public and CPSMT and CPSAS representatives during the STAR Panel

- Prioritized recommendations for future research and data collection

Annex 3

STAR Panel membership and other pertinent information

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
Meisha Key, SSC, California Department of Fish and Wildlife
José De Oliveira, Center for Independent Experts (CIE); Cefas
John Simmonds, Center for Independent Experts (CIE); ICES

Pacific Fishery Management Council (Council) Representatives:
Kerry Griffin, Council Staff
Diane Pleschner-Steele, CPSAS Advisor to STAR Panel
Chelsea Protasio, CPSMT Advisor to STAR Panel

Pacific Sardine Stock Assessment Team:
Kevin Hill, NOAA / SWFSC
Paul Crone, NOAA / SWFSC
Dave Demer, NOAA / SWFSC
Juan Zwolinski, NOAA / SWFSC
Emmanis Dorval, NOAA / SWFSC
Beverly Macewicz, NOAA / SWFSC

Other Attendees
Jenny McDaniel, SWFSC
Kirk Lynn, CDFG
Dale Sweetnam, SWFSC
Erin Reed, SWFSC
Ed Weber, SWFSC
Josh Lindsay, NMFS WCR
Russ Vetter, SWFSC
Al Carter, Ocean Companies
Richard Carroll, Jessie's Ilwaco Fish Company
Elizabeth Helmers, CDFW
Nancy Lo, SWFSC
Sam McClatchie, SWFSC
Richard Parrish, NMFS Emeritus
Yukong Gu, SWFSC
Jeff Laake, AFSC
Kevin Piner, SWFSC
William Watson, SWFSC
Elaine Acuňa, SWFSC
Anna Holder, CDFW
Joel Van Nord, CWPA
Noelle Bowlin, SWFSC
Mike Okoniewski, Pacific Seafood
Cisco Werner, SWFSC
Sarah Shoffler, SWFSC
Kristen Koch, SWFSC
Chris Francis, NIWA
Emily Gardner, SWFSC

Alex Da Silva, IATTC
Steven Teo, SWFSC
George Cutter, SWFSC
Mark Maunder, IATTC

AFSC – Alaska Fisheries Science Center
CDFW – California Department of Fish and Wildlife
CEFAS - Centre for Environment, Fisheries & Aquaculture Science
CPSAS - Coastal Pelagic Species Advisory Subpanel
CIE – Council on Independent Experts
CPSMT - Coastal Pelagic Species Management Team
CWPA – California Wetfish Producers Association
IATTC – Inter-American Tropical Tuna Commission
ICES – International Council for the Exploration of the Sea
NIWA - National Institute of Water and Atmospheric Research
NMFS - National Marine Fisheries Service
SSC - Scientific and Statistical Committee (of the Pacific Fishery Management Council)
SWFSC - Southwest Fisheries Science Center (National Oceanic and Atmospheric Administration)
WCR – West Coast Region

Annex 4

Relevant information from STAR Panel Report

Table A4.1. Requests, Rationale and Responses from STAR Panel Report. [Note: all Figures and tables referred to in the following table refer back to the STAR Panel Report, unless otherwise indicated.]

Nr	Request	Rationale	Response	Model(s)
A	Compare the yearly length-composition data for the Ensenada fishery that are included in the MexCal data set for the NSP scenario with the corresponding southern California length compositions. Also, compare the yearly length-composition data for the Oregon-Washington catches with those for the British Columbia fishery.	There are no age-length data for the Ensenada fishery or for the British Columbia fishery available for use in the assessment at this time, but model H implicitly assumes that the length frequencies for the Ensenada fishery are the same as those for the southern California fishery and that the length-frequencies for the British Columbia fishery are the same as those for the Oregon-Washington fishery.	This request was not required because the Panel focused on model G (length-based) that was presented as the potential base case model and not model H (age-based). Model H was not a focus for the Panel review because it was not as fully tested as model G and because the construction of the catch age-composition data ignored the length data for Mexico and British Columbia. However, this request has been put forward as a research recommendation.	-
B	Compute age-compositions for the ATM survey by multiplying the survey length-frequencies by the associated age-length keys. Compare the mean age-at-length time-series north and south of 40°10' from the ATM survey.	The age data for the ATM survey presented in the draft report were unweighted.	This request was not required because the Panel focused on model G (length-based) that was presented as potential base case model and not model H (age-based). However, this request has been put forward as a research recommendation.	-
C	Construct catch time series using a one month shorter and longer monthly duration for when the San Pedro and Ensenada fisheries are catching southern subpopulation fish.	To evaluate the sensitivity of the catches to the cutoff (50%) that is used to assign catches to the NSP.	Figure 1 shows that the results are likely to be somewhat sensitive to the cut-off chosen to define catches from the northern subpopulation. A research recommendation was raised to examine this issue further.	-
D	Overlay the habitat map with the spring survey results for the 2013 ATM survey.	The survey did not go north of San Francisco. The Panel was interested to know whether the areas north of San Francisco would have been expected to have been suitable habitat for Pacific sardine.	The plots showed no evidence of substantial suitable habitat north of San Francisco in the two weeks around the time the survey was conducted, which suggests that the survey should have provided an adequate sample of the population.	-
E	Provide additional information regarding the apparent discrepancy between the biomass estimates from the ATM survey in the Washington / Oregon area and the landings in	The Panel wished to have more information on this apparent discrepancy.	Juan Zwolinski noted that the ATM survey sampled the region between 44° 47.2'N and 48°18'N and from the 50m to the 1500m depth isobaths from 07/31/2012 to 08/10/2012. The resulting point estimate of sardine	-

Nr	Request	Rationale	Response	Model(s)
	this area, based on the information from 2012.		biomass was 13,333 mt. The sampling variance was high, resulting in a 95% confidence interval of [3,918, 27,559] mt. During the same time period, the commercial fishery off Oregon and Washington caught 9,747 mt. The ATM surveyed the area to the north, including northern Washington and western Vancouver Island, B.C. There, the sardine biomass was estimated at 18,675 mt, with a 95% confidence interval of [2,661, 54,017] mt. It was likely that by 08/10/2012, 32,008 mt of sardine, with 95% confidence interval [12,439, 68,945] mt, would have been available for the Oregon and Washington fisheries, assuming that all the sardine observed off western Vancouver Island migrated from the south.	
F	With model G (from initial draft), reweight the fishery and survey length-composition and conditional age-at-length data by applying the Francis (2011) weighting method (Equation TA1.8). The weighting factors should be implemented as changes to the lambdas in the SS model.	The compositional data may not be appropriately weighted.	The upper panel of Table 2 lists the factors to weight the input sample sizes (which are lower than the actual number of fish sized and aged), for each length-composition and conditional age-at-length data component that needs to be weighted. The response to this request (and requests L, M, and N) was based on model 'K' in which the conditional age-at-length data are not downweighted by 0.5 (see Table 1 for the specifications for the models investigated during the Panel requests). The Francis method suggested that the length-compositions needed to be downweighted substantially. In contrast, this method also suggested that the conditional age-at-length data for the MexCal fleets and the ATM survey need to be upweighted. Implementing these weighting factors (model F) led to a markedly lower biomass trajectory and substantially changed selectivity patterns for the two MexCal fisheries. The results from this request led to requests L, M, N and O.	F
G	With model G (from initial draft), include the NWSS aerial survey data. Summarize the results in terms of residual patterns and the information given in Table 8 of the draft document.	The Panel wished to understand whether the aerial survey data would be influential if they were included in the assessment.	The biomass trajectory was lower than for model G when the NWSS aerial survey was included in the assessment, but otherwise the results were not substantially different. The Panel did not see evidence to disagree with the STAT's recommendation to leave	G, but including aerial survey

Nr	Request	Rationale	Response	Model(s)
			this survey out of the assessment.	
H	With model G (from initial draft), examine scenarios in which catchability is the same for the spring and summer ATM surveys. Consider values for ATM survey catchability from 0.7 to 1.1 in steps of 0.2. Summarize the results in terms of residual patterns and the information given in Table 8 {draft assessment document}.	The Panel noted that the ATM survey scientists expressed the view that the spring and summer surveys were directly comparable and wished to understand whether this view is supported by the data included in the assessment.	There is no evidence to support having separate *q*'s for the spring and summer ATM surveys in terms of the change to the value of the objective function. The single *q* is closer to that from the spring surveys, which is expected given the relative number of ATM survey data points for spring (6) and summer (3). The spring survey selectivity pattern switches to being less knife-edged for the higher *q*s, but the change for this and the biomass trajectory did not occur in a systematic way as the ATM survey catchability was changed from 0.7 to 1.1. This request led to an additional request (P).	G-H
I	With model G (from initial draft), replace the Beverton-Holt stock-recruitment relationship with the Ricker form of this relationship. Estimate steepness rather than assuming it equals 0.8	Several past assessments were based on the Ricker form of the stock-recruitment relationship, with steepness estimated. The Panel wished to explore the sensitivity to this change from prior assessments.	The scale of biomass is slightly lower with the Ricker stock-recruitment relationship, with no difference in likelihoods between the two model runs. Steepness was estimated at 2.05.	G-I
J	With model G (from initial draft), set $M = 0.5\text{yr}^{-1}$.	The analysis of Zwolinski and Demer (2013) suggests that *M* is higher (0.52yr^{-1}) than the model G assumption of 0.4yr^{-1}.	As expected, the scale of the biomass was higher, and the ATM survey *q*'s were lower (spring=0.58, summer=0.63). The change in likelihood was 3 units with the higher *M*, but given the concerns with the weights assigned to the length and conditional age-at-length data, this is not considered to be a substantial change.	G-J
K	Conduct an assessment where all the weighting factors (lambdas) are set to 1 and compare the results for this model to those for model G (from the initial draft assessment).	The selection of the factors to weight the length-composition and conditional age-at-length data was based on this model.	The STAT provided model K which showed increasing the weights on the conditional age-at-length data from 0.5 to 1 substantially lowered the biomass trajectory.	K
L	Based on model K, apply the Francis method to estimate weighting factors for the length-composition and conditional age-at-length data, pooling the two MexCal fleets, pooling the spring and summer ATM survey data and analyzing the PacNW separately.	Some of the weighting factors are based on very few compositions and consequently the weighting factors are uncertain (Table 2, upper).	This was model L. The weighting factors for the pooled fleets are as expected, but the confidence intervals, particularly for the ATM survey, are narrower (Table 2, lower). The Panel considered it appropriate to pool across fleets when computing the weights for the length-composition and conditional age-at-length data.	L
M	Based on model K, change only the weights assigned to the length-composition data using	The Panel wished to understand whether the length-frequency or conditional age-at-	This was model M. The biomass estimates for the early years were sensitive to changing the weights assigned	M

Nr	Request	Rationale	Response	Model(s)
	the weighting factors from Request F.	length data were most influential.	to the length-frequency data. However, the trend in abundance over recent years was unchanged and the biomass scale was largely unchanged. The Panel concluded that how the conditional age-at-length data are weighted was the major cause of the change in results observed for request F.	
N	Based on model K, change only the weighting factors assigned to the conditional age-at-length data using the weighting factors from Request F.	The Panel wished to understand whether the length-frequency or conditional age-at-length data were most influential.	The biomass trajectory for model N was markedly lower (and survey *q* markedly higher) when the conditional age-at-length data were changed.	N
O	Same as for request N, except that the weighting factor for the conditional age-at-length data sets for the PacNW fishery is assumed to equal 1.	The weighting factor for the conditional age-at-length data for the PacNW fleet was less than one, in contrast to the weighting factors for the MexCal fleets and the ATM survey.	The results for model O were essentially identical to those for request N.	O
P	Same as for model G, except that catchability and selectivity for spring and summer ATM surveys are assumed to be the same.	The Panel wished to understand whether there is support for separating the two surveys.	The fits to the survey length-frequency data for model P were not as good as for model G, even after accounting for there being three fewer parameters. The biomass trajectory was lower than for model G, and the ATM survey catchability was 2.38, a value considered implausible. The single ATM survey selectivity was less knife-edged and to the right of those for the spring and summer ATM survey selectivities from model G, which was unexpected. The model appeared to increase the selection at smaller lengths to account for the summer survey which had appreciable catches at these lengths. The consequence was to then reduce selection at the greater lengths that were previously fully selected when the surveys were fitted with separate selection patterns.	P
Q	Same as for model P, except that the weight assigned to ATM survey length-frequency data was increased from 1 to 20.	The Panel wished to understand whether it is possible to fit the length-frequency data for the ATM survey, at least in principle.	The fits to the ATM length-frequency data for model Q were better, but the model was still unable to adequately mimic all of the length-frequencies.	Q
R	Conduct models R, S, T, W and U.	The Panel wished to understand the trade-offs in results among various treatments of ATM survey catchability and selectivity. Some of these models ignore the ATM	Figure 2 summarizes the biomass trajectories from these models. Models R and S, in which selectivity for the spring and summer ATM surveys was assumed to be the same, led to higher estimates of biomass	R, S, T, U, W

Nr	Request	Rationale	Response	Model(s)
		survey conditional age-at-length data because these data were not computed accounting for the sampling scheme for the survey.	compared to model G, whereas model T which estimated separate selectivity patterns for the spring and summer ATM surveys, led to lower estimates of biomass; in contrast model W, which is the same as model T but estimates separate catchabilities for the ATM surveys, led to higher estimates of biomass than even model S. Model U in which the conditional age-at-length data for the MexCal and PacNW fisheries were markedly downweighted led to much lower biomass estimates and unrealistically high estimates of survey catchability.	
S	Repeat request Q, but omit the ATM survey length-frequency data for spring 2012.	This length-frequency was considered unreliable by the ATM survey team.	This model (V) was not able to adequately fit the remaining ATM survey length-frequencies.	V
T	Conduct analyses for a range of values to the extent which the conditional age-at-length data are downweighted. The analyses should be conducted for model specifications G-2, W-2, W-3, and T-2 (See Table 1).	The Panel wished to understand the impact of different weighting factors on the results of the model.	The outputs for models based on configuration W-3 all led to values for the ATM survey catchability coefficients which were considered unrealistically low (~0.25). The biomass trajectories for recent years were more robust for the models based on configuration T-2, but there was considerable sensitivity of biomass estimates for the early years (Figure 3). The biomass trajectories for recent years fell into two groups (one group based on weighting factors on the conditional age-at-length data of 0.1, 0.2 and 0.4; another group based on weighting factors of 0.3, and 0.5 and larger). The biomass trajectories were more stable for model runs based on configuration W-2 than configuration W-3. The weighting factor is 0.035 for configuration W-2 if it is chosen so that the average ATM (spring and summer) survey catchability is 1. Alternatively, this weighting factor is ~0.7 if the analysis is based on configuration G-2. Downweighting is more severe for model configuration W-2 because this model configuration ignores the ATM conditional age-at-length data which tends to support lower biomass estimates. However, the STAT noted that choosing a weighting factor to achieve a given average ATM survey catchability coefficient may not be a robust way to provide management advice. The Panel concurred	G-2, W-2, W-3, T-2, T-2_0.2, T-2_0.7

Nr	Request	Rationale	Response	Model(s)
			with this view.	
At this point in the meeting, the STAT and Panel agreed to proceed with models which are variants of configuration T-2, i.e. the weighting factors for the length-frequency data are set to 1, catchability is set to 1 for both the spring and summer ATM surveys, separate selectivity patterns are estimated for the spring and summer ATM surveys, and the ATM survey conditional age-at-length data are ignored. The STAT and Panel agreed to focus on two models: T-2_0.2 and T-2_0.7. The difference between these two models is the weight assigned to the fishery conditional age-at-length data. These choices for weighting factors were selected because they are representative of the two groups in Figure 3.				
U	Apply models T-2_0.2 and T-2_0.7 when the length-frequencies for the 2011 and 2012 spring ATM surveys are ignored.	It was speculated that some of the model sensitivity was due to attempts to fit these two length-frequencies (the fits to these length-frequencies are always poor).	The results when the weighting factor for the conditional age-at-length data was set to 0.7 were similar to those when the weighting factor was set to 0.2 (Figure 4), suggesting that at least one reason for the two groups of results in Figure 3 are conflicts when fitting to the length-frequencies for the 2011 and 2012 spring ATM surveys.	T-2_0.2a, T-2_0.7a
V	Apply models T-2_0.2 and T-2_0.7 when the data for the last four years are ignored.	The Panel wished to understand whether a retrospective analysis might help to distinguish between these two models.	The results from both models changed markedly when the data for last four years were ignored (Figure 5).	Retros on T-2_0.2 and T-2_0.7
The STAT and Panel agreed that model T-2_0.2 would be the base model given the relative lack of sensitivity to omitting data (see request U).				

Table A4.2. Summary of the models requested of the STAT during the review. "F" indicates that the weights assigned to the composition type were based on Francis (2011), method TA1.8; "F-pool" indicates that the factor to weight the composition concerned pooled information across fleets / seasons; "split" under the "ATM Q" and "ATM sel" (selectivity) columns indicates that separate parameters were estimated for the spring / summer surveys; "equal" under the "ATM Q" and "ATM sel" columns indicates that the parameters concerned were assumed to be the same for the spring / summer surveys, "1" under "ATM Q" indicates that survey catchability was assumed to be 1; "profile" in the last three lines implies that the STAT were requested to profile over the weighting factor concerned. The final model is in bold and shaded grey.

	Lambda: Length composition			Lambda: Conditional age-at-length			Q	Sel	Additional
Model	MexCal (1+2)	PacNW	ATM	MexCal (1+2)	PacNW	ATM	ATM	ATM	
G	1	1	1	0.5	0.5	0.5	split	Split	
K	1	1	1	1	1	1	split	Split	
F	F	F	F	F	F	F	split	Split	
L	F-pool	F	F-pool	F-pool	F	F-pool	split	Split	
M	F	F	F	1	1	1	split	Split	
N	1	1	1	F	F	F	split	Split	
O	1	1	1	F	1	F	split	Split	
P	1	1	1	0.5	0.5	0.5	equal	Equal	
Q	1	1	20	0.5	0.5	0.5	equal	Equal	
R	1	1	1	0.5	0.5	0	equal	Equal	
S	1	1	1	0.5	0.5	0	1	Equal	
T	1	1	1	0.5	0.5	0	1	Split	
U	1	1	1	0.01	0.01	0.5	split	Split	
V	1	1	20	0.5	0.5	0.5	equal	Equal	Excl. ATM spr 2012
W	1	1	1	0.5	0.5	0	split	Split	
G-2	1	1	1	profile	profile	profile	split	Split	
W-2	1	1	1	profile	profile	0	split	Split	
W-3	F-pool	F	F-pool	profile	profile	0	split	Split	
T-2	1	1	1	profile	profile	0	1	Split	
T-2-0.2	**1**	**1**	**1**	**0.2**	**0.2**	**0**	**1**	**Split**	
T-2-0.7	1	1	1	0.7	0.7	0	1	Split	
T-2_0.2a	1	1	1	0.2	0.2	0	1	Split	Excl. ATM spr 2011-12
T-2_0.7a	1	1	1	0.7	0.7	0	1	Split	Excl. ATM spr 2011-12
X	1	1	1	1	1	0	1	Split	Time blocking PNW
X-1	1	1	1	1	1	0	split	Split	Time blocking PNW

Models X and X-1, although supplied by STAT, were not requested or considered by the STAR panel due to time constraints.

Annex 5

Final model (T-2_0.2)

The final base model incorporates the following specifications (from STAR Panel report):

- catches for the MexCal fleet computed using the environmentally-based method;
- two seasons (semesters, Jul-Dec=S1 and Jan-Jun=S2) for each assessment year from 1993 to 2013;
- sexes were combined;
- two fisheries (MexCal and PacNW fleets), with an annual selectivity pattern for the PacNW fleet and seasonal selectivity patterns (S1 and S2) for the MexCal fleet;
    - MexCal fleet:
        - dome-shaped length-based selectivity with two periods of time blocking (1993-1998, 1999-2013);
    - PacNW fleet:
        - asymptotic length-based selectivity for a single time period;
    - length compositions with effective sample sizes calculated by dividing the number of fish sampled by 25 (externally) and lambda weighting=1 (internally);
    - conditional age-at-length compositions with effective sample sizes calculated by dividing the number of fish sampled by 25 (externally) and lambda weighting=0.2 (internally);
- Beverton-Holt stock-recruitment relationship "steepness" was fixed (0.8);
- *M* was fixed (0.4 yr^{-1});
- recruitment deviations estimated from 1987-2012;
- virgin (R_0), and initial recruitment offset (R_1) were estimated, and σ_R was fixed (0.75);
- initial *F*s set to 0 for all fleets (non-equilibrium model following the initial age composition method in SS);
- DEPM and TEP indices of spawning biomass with *q* estimated for both surveys;
- ATM survey biomass 2006-2013, partitioned into two (spring and summer) surveys, with *q*=1 for each survey;
    - length compositions with effective sample sizes set to 1 per haul (externally) and lambda weighting=1 (internally);
    - asymptotic length-based selectivity for spring and summer surveys;
    - conditional age-at-length data from the ATM surveys excluded;
- NWSS aerial survey index of abundance (biomass) and associated length compositions excluded.

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON SARDINE ASSESSMENT, SPECIFICATIONS, AND MANAGEMENT MEASURES

The Scientific and Statistical Committee (SSC) reviewed the 2014 stock assessment of the northern subpopulation of Pacific sardine. Dr. Kevin Hill presented the results of the stock assessment and Dr. André Punt provided an overview of the Stock Assessment Review (STAR) Panel report.

A number of changes were made to the 2014 assessment in comparison to the 2011 full assessment. These include: 1) A new sea surface temperature-based method used for assigning catch by port and month to the northern or southern subpopulations. The SSC agrees that this is an improvement over previous methods, but more research could be done to better differentiate catch of the two stocks, as outlined in the STAR Panel report. A result of this approach is a reduction in estimated historical catch for the northern subpopulation. 2) The acoustic-trawl method (ATM) survey was split into spring and summer survey time series with independently estimated selectivity curves.

The 2014 assessment uses four indices of abundance: Daily-Egg-Production Method (DEPM) indices; Total Egg Production indices (for those years without a DEPM index); the spring ATM index; and the summer ATM index, with length composition data from the ATM surveys. Catchability for both ATM surveys are fixed at 1, as was the case for the single ATM time series in the last assessment. The northwest aerial survey indices and composition data were not included in the current assessment.

Fishery data are grouped into two fleets (PacNW and MexCal). Length data and conditional age-at-length data from both fleets are used in the model. After considerable exploration of alternative weighting schemes, fishery conditional age-at-length data were downweighted relative to the other data in the assessment, while ATM survey conditional age-at-length data were removed altogether.

Four areas of uncertainty are highlighted in the stock assessment: 1) uncertainty in recent recruitments, and relationship of recruitment to environmental conditions; 2) uncertainty in the stock structure of Pacific Sardine off of North America; 3) uncertainty in catchability for the ATM surveys; 4) appropriate data weighting in the stock assessment model.

While the recent trend in biomass is well defined, there is considerable uncertainty in the absolute scale of the population. Related to this, the difference in absolute scale between the aerial and summer ATM survey indices in the area of overlap remains a point of concern. The SSC recommends research into the catchability for the ATM surveys and the representativeness of the nighttime tow samples in terms of both the coastal pelagic species composition and sardine size- and age-composition. Similar research into the accuracy of the aerial survey could be conducted. The SSC reiterates the need for a methodology review of the ATM surveys.

Additional uncertainty in the age 1+ biomass is due to the considerable uncertainty in the 2013 recruitment. Modeling a temperature-recruitment relationship in the assessment could help address this issue. The declining trend in sea surface temperature, along with poor recruitments in 2010, 2011 and 2012 leads to some concern that the 2013 recruitment estimate in the assessment may be biased high.

The SSC notes that the assessment and overfishing limit (OFL) are for the northern subpopulation of Pacific sardine, but some portion of the U.S. catch in each year is likely from the southern subpopulation. In addition, age-0 sardine are being harvested, but these fish are not included in the summary biomass.

The change in timing of the assessment review from September to March provided five extra months for the Stock Assessment Team (STAT) to receive and analyze the data and develop the model. Dr. Hill commented that this extra time was helpful in developing the assessment. The SSC notes that, despite this, some materials for review were not complete before the STAR Panel, and recommends that in future the Pacific sardine STAT should endeavour to follow the Terms of Reference.

The SSC endorses the 2014 Pacific sardine stock assessment as the best available science, and recommends an OFL of 39,210 mt for the northern subpopulation of Pacific sardine. The SSC further recommends that the assessment be considered a category 1 assessment.

PFMC
04/07/14

COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON SARDINE ASSESSMENT, SPECIFICATIONS, AND MANAGEMENT MEASURES

The Coastal Pelagic Species Management Team (CPSMT) and the Coastal Pelagic Species Advisory Subpanel (CPSAS) jointly received a presentation from Dr. Kevin Hill concerning the Pacific sardine stock assessment conducted in 2014. The CPSMT recommends that the Pacific Fishery Management Council (Council) adopt the full assessment (model T) for management of the 2014-2015 sardine fishery (Agenda Item H.1.b, Stock Assessment Report). Based upon the 369,506 metric tons (mt) age 1+ biomass estimated from this assessment, the harvest control rule produces a harvest guideline (HG) of 28,646 mt (Table 1 below).

The upcoming season marks the implementation of a new fishery year schedule, from July 1- June 30. The CPSMT notes the biomass of age 1+ fish (369,506 mt as of July 1) estimated from the assessment, and used to set harvest guidelines, now coincides with the start date for the fishing year, unlike past years when the fishery year began on January 1. The CPSMT notes the stock assessment produced an estimate that is very similar to the catch-only projection of 378,120 mt for the interim (January –June) 2014 fishery.

The CPSMT commends the Stock Assessment Team (STAT) for incorporating numerous changes based on previous research recommendations. These improvements result in better model parameterization and stock structure. These changes include: defining the assessed stock using an environmental variable instead of port of landing, basing the spawner-recruit relationship on Beverton-Holt instead of using the Ricker curve, and the Acoustic-Trawl Method survey splitting from a single to a spring and summer time series.

As indicated above, the current stock assessment uses an environmentally-based method from satellite-based sea surface temperature (SST) data to differentiate sardine catch into northern and southern stocks, for the purpose of excluding the southern stock catch from the assessment model. The catch differentiation method is used to refine the estimate of fishery exploitation rate and biomass for the northern stock. Based on the overall distribution of both stocks and the low amount of southern stock harvested in U.S. waters, the CPSMT does not consider catch of southern stock as negatively impacting either stock. The CPSMT notes that there is some de facto management of the southern stock in U.S. waters, given that all U.S. catch of Pacific sardine is counted towards allocation limits and that all Pacific sardine harvest must comply with federal and/or tribal regulations. The CPSMT recognizes that this is a complex issue and may need additional evaluation in the future as the science develops.

Regarding the uncertainty surrounding the recruitment of the 2013 year class into the 2014-2015 fishery, the CPSMT notes this results from moving the start of the sardine fishery year from January to July. In past assessments, this year class would not have been incorporated in the estimate of stock biomass for management purposes. But with the timing change, recruitment of this year class was taken from the stock recruitment relationship and had no observed data from which to derive the estimate. There was insufficient time to address this uncertainty during this year’s Stock Assessment Review (STAR) Panel review. For future assessments, the STAT has identified methods to reduce the level of uncertainty.

We encourage efforts to provide complementary and/or corroborative information to improve our understanding and assessment of the sardine stock. The CPSMT believes that a methodology review of the aerial survey is necessary before new survey data are incorporated in the stock assessment. Likewise, the CPSMT encourages a methodology review of the acoustic trawl method (ATM) survey.

Harvest Specifications for 2014-2015

Table 1 (below) contains the overfishing limit (OFL) and a range of acceptable biological catch (ABC) values based on various P* (probability of overfishing) values. Considering the results of the full stock assessment conducted in 2011 for 2012, the Council chose a P* of 0.40 for the 2013 and interim 2014 fisheries. At its March 2014 meeting, and based on SSC guidance, the Council approved changing the temperature index from Scripps Pier (SIO) to CalCOFI (California Cooperative Oceanic Fisheries Investigations) for the purposes of estimating F_{MSY} (or E_{MSY}) in the OFL and ABC control rules for the 2014-2015 fishery and beyond. The estimated value of E_{MSY} derived from the CalCOFI index is 0.1219697. Also at the March 2014 meeting, the Council initiated action to change the temperature index for purposes of calculating HG FRACTION, with final action scheduled for November 2014. For the 2014-2015 fishery, the value for FRACTION (15 percent) used to calculate the HG is based on the Scripps Institution of Oceanography (SIO) temperature index.

Based on the values in Table 1, the CPSMT computed the HG according to the current fishery management plan formula (with SIO index) and also an alternative harvest level (expressed as annual catch limit [ACL]/ACT) using the CalCOFI index. Seasonal allocation schemes for HG and ACL are presented in Tables 2 and 3, respectively.

The Quinault Indian Nation requests 4,000 mt of Pacific sardine for their participation in the 2014-2015 fishery (Agenda Item H.1.a, Attachment 1). Acknowledging that a set-aside for the Quinault Indian Nation has yet to be determined, the CPSMT presents allocation schemes (Tables 2 and 3 below) incorporating the requested set-aside of 4,000 mt.

The Northwest Sardine Survey LLC notified the Council it is withdrawing its request for an exempted fishing permit for 2014-2015 (Agenda Item H.1.a, Attachment 2), so no set aside is necessary for an exempted fishing permit this year

The CPSMT incorporates the CPSAS recommendation that the incidental catch for CPS fisheries in each of the three allocation periods should be set to 500 mt (Tables 2 and 3) and that the incidental landing allowance for CPS fisheries be no more than 45 percent Pacific sardine by weight after the directed fishery closes.

Although the fishery year changed, the rollover provisions from the first fishing period to the second and from the second to the third remain the same as in previous years. The first fishing period is now July 1- September 14; the second period is September 15 – December 31 and the third fishing period is January 1- June 30. Any allocation remaining on June 30 is not rolled over to the next fishery year.

According to the CPS FMP framework, the ACL must be equal to or below the ABC, and typically the Council has set the ACL equal to the ABC. An ACT is equal to the HG or ACL, whichever value is less. Although the HG based on SIO is below the ABC, the Team recommends adopting the ACT based on the calculation in Table 1. Table 1 presents a calculation for an ACL, substituting the CalCOFI index for the SIO index in the HG formula. This resulting ACL is below the calculated HG and therefore, it would be the basis for the ACT for the 2014-2015 fishery.

The use of the ACL for setting the harvest level is atypical, but the team recognizes that the HG is likely to be based on the CalCOFI index for future fishery years and therefore, the CPSMT recommends the Council use the CalCOFI index, as the SSC has determined that it is best available science for the other sardine harvest control rules (OFL and ABC).

Table 1. Pacific sardine harvest formula parameters for 2014-2015.

Harvest Control Rule Formulas	
OFL = BIOMASS * E_{MSY} * DISTRIBUTION	(CalCOFI temperature index)
ABC = BIOMASS * $BUFFER_{P\text{-}star}$ * E_{MSY} * DISTRIBUTION	(CalCOFI temperature index)
HG = (BIOMASS – CUTOFF) * FRACTION * DISTRIBUTION	(SIO temperature index)
ACL/ACT = (BIOMASS – CUTOFF) * E_{MSY} * DISTRIBUTION	(CalCOFI temperature index)

Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	369,506								
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier\ 1}$	0.9558	0.9128	0.8705	0.8280	0.7844	0.7386	0.6886	0.6304	0.5531
E_{MSY}	0.12197								
FRACTION	0.15								
CUTOFF (mt)	150,000								
DISTRIBUTION (U.S.)	0.87								
Harvest Control Rule Values (MT)									
OFL =	**39,210**								
$ABC_{Tier\ 1}$ =	37,475	35,792	34,131	32,464	30,757	28,961	26,999	24,719	21,688
HG =	28,646								
ACL/ACT =	**23,293**								

Table 2. Preliminary allocation scheme based on HG (with SIO index) for the 2014-2015 Pacific sardine fishery. Values in metric tons (mt)

HG = 28,646 mt; Tribal set-aside = 4,000 mt; Adjusted HG = 24,646 mt				
	Jul. 1 - Sep. 14	Sep. 15 - Dec. 31	Jan. 1 – Jun. 30	Total
Seasonal Allocation	9,858 (40%)	6,162 (25%)	8,626 (35%)	24,646
Incidental Set-Aside	500	500	500	1,500
Adjusted (Directed) Allocation	9,358	5,662	8,126	23,146

Table 3. Proposed preliminary allocation scheme based on ACL/ACT (with CalCOFI index) for the 2014-2015 Pacific sardine fishery. Values in metric tons (mt)

ACL/ACT = 23,293 mt; Tribal set-aside = 4,000 mt; Adjusted ACL/ACT = 19,293 mt				
	Jul. 1 – Sep. 14	Sep. 15 – Dec. 31	Jan. 1 – Jun. 30	Total
Seasonal Allocation	7,718 (40%)	4,823 (25%)	6,752 (35%)	19,293
Incidental Set-Aside	500	500	500	1,500
Adjusted (Directed) Allocation	7,218	4,323	6,252	17,793

PFMC 04/08/14

COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON SARDINE ASSESSMENT, SPECIFICATIONS, AND MANAGMENT MEASURES

The Coastal Pelagic Species Advisory Subpanel (CPSAS) and Coastal Pelagic Species Management Team (CPSMT) received a joint briefing from Dr. Kevin Hill. The CPSAS also reviewed the Pacific Sardine Stock Assessment Review (STAR) Panel Report and Northwest Aerial Survey Report (Agenda Items H.1.a), and the Sardine Stock Assessment Report for USA management in 2014-15 (Agenda Item H.1.b).

The CPSAS thanks the STAR Panel and Stock Assessment Team for their efforts to improve management of the U.S. sardine fishery. The CPSAS appreciates the Council's consideration of the following points in deliberating management measures for the 2014-2015 sardine fishery:

1. Although the current stock assessment reflects a declining trend, the absolute scale of the population is still in question, as it was in 2011.
2. Industry remains concerned about the ability of the current acoustic trawl method (ATM) surveys to measure the full extent of the biomass. The ATM surveys are now driving the assessment model. We are also disappointed that industry-sponsored aerial surveys have been removed. We sincerely hope that going forward we can develop a truly collaborative research program for the CPS complex.
3. Sardine recruitment is influenced by environmental conditions. La Niña conditions in 2000-2002 caused a dip in the sardine population similar to the last three years, but El Niño restored the biomass to 1.37 million mt in 2006. Another El Niño is likely on the way this fall.
4. Recent analysis shows that the Amendment 8 Harvest Control Rule (HCR) was ultra-conservative, and the Amendment 13 HCR is even more conservative, with the overfishing limit (OFL) and acceptable biological catch (ABC) control rules added as additional layers of precaution.
5. Based on the CPS Fishery Management Plan, the current HCR prescribes a 15 percent FRACTION, and results in a HG of 28,646 mt. This HG is considerably lower than the OFL of 39,210 mt and Category 1 ABC of 35,792 mt at P* .40, and is even lower than an ABC at a P* of 0.20.
6. Until the HG harvest FRACTION changes are implemented, it would be premature to apply a different HCR FRACTION for setting harvest.
7. The CPSAS appreciates efforts to better address catches of northern and southern substocks in the stock assessment. We concur with recommendations of the STAR Panel and Scientific and Statistical Committee that more research is needed. Absent additional research, we expect that all sardines landed in U.S. waters will be managed status quo under the CPS FMP.
8. Please consider that achieving Optimum Yield requires balancing fishery opportunity, economic stability, and ecosystem needs. Each 1,000 mt reduction in harvest equates to a loss of $800,000 in direct economic activity. The sardine HCR is a highly precautionary management policy. The industry wants to maintain a sustainable resource.

Management Measures

(1) The CPSAS recommends the following management measures for the July 1, 2014 – June 30, 2015 sardine fishery, based on the harvest guideline of 28,646 metric tons (mt) as outlined in the Stock Assessment Report (Agenda Item H.1.b).

HG = 28,646 mt Tribal Allocation = 4,000 mt Adjusted HG = 24,646 mt				
	Jul 1- Sep 14	Sep 15 – Dec 31	Jan 1- Jun 30	Total
Seasonal Allocation (mt)	9,858 (40%)	6,162 (25%)	8,626 (35%)	24,646
Incidental Set-Aside (mt)	500	500	500	1,500
Adjusted (Directed) Allocation (mt)	9,358	5,662	8,126	23,146

(2) After the closure of the directed sardine fishery in any period, the incidental landing allowance in other CPS fisheries should be 45 percent Pacific sardine by weight, to account for the possibility of mixed-fish catches. We recommend only 500 mt incidental set-aside per period, which is half of prior incidental set-asides. Any unused allocation in each of the first two periods will be rolled into the next period's directed fishery. Any incidental set aside not used in the third period will be foregone.

The CPSAS is considering options for 2015-2016 and beyond to shift a portion of the incidental set-aside from future periods.

PFMC
04/08/14

DECISION SUMMARY DOCUMENT
PACIFIC FISHERY MANAGEMENT COUNCIL
April 5-10, 2014

HABITAT

Current Habitat Issues

The Council directed staff to send a letter, to the National Marine Fisheries Service (Agenda Item B.1.a, Supplemental Attachment 3) on the Bay-Delta Conservation Plan, with the edits recommended by the Habitat Committee (HC). The Council also directed staff to send the letter in Agenda Item B.1.a, Supplemental Attachment 4, to the Bureau of Ocean Energy Management but to include striking the section on the Oregon Ocean Uses Atlas and substituting the language recommended by the Groundfish Advisory Subpanel. In addition, the Council directed the HC to draft a general letter on the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries' boundary expansion process for the advance June briefing book, towards a goal of enabling input and additions by other Council advisory bodies. The Council also tasked the HC with several other matters for Council consideration at the June Council meeting (see Council blog at http://www.pcouncil.org/blog/).

PACIFIC HALIBUT MANAGEMENT

Final Incidental Landing Restrictions for 2014-2015 Salmon Troll Fishery

The Council recommended maintaining the current Pacific halibut landing limits in regulation of no more than one Pacific halibut per each four Chinook, except one Pacific halibut may be landed without meeting the ratio requirement, and no more than 12 halibut landed per trip. These limits would remain in regulation, unless modified by inseason action, from May 1, 2014 through December 31, 2014 and April 1-30, 2015. Additionally, to improve the accounting of landings, the Council recommends that both pounds and numbers of Pacific halibut be reported on state fish tickets.

GROUNDFISH MANAGEMENT

Fisheries in 2015-2016 and Beyond: Adopt Biennial Specifications Final Preferred Alternatives

The Council adopted all the 2015 and 2016 overfishing limits (OFLs) endorsed by the Scientific and Statistical Committee (SSC). The Council also confirmed all the preliminary preferred 2015 and 2016 acceptable biological catches (ABCs) previously adopted, with the exception of specifying an overfishing probability (P*) of 0.4 for spiny dogfish and a P* of 0.45 for the Washington substock of cabezon to determine the ABCs for those stocks. The Council adopted a reconfigured Other Fish complex comprised of kelp greenling coast wide, the Washington substock of cabezon, and leopard shark with OFL and ABC contributions from kelp greenling in California, Washington cabezon, and leopard shark to determine the complex specifications. The Council confirmed the preliminary preferred 2015 and 2016 annual catch limits, except higher values were adopted for Dover sole (50,000 mt), widow rockfish (2,000 mt), and spiny dogfish (2,101 mt in 2015 and 2,085 mt in 2016). The Council confirmed the preliminary preferred annual catch target (ACT) of 4 mt and an ACL of 10 mt for cowcod south of 40º10' N latitude. Adopted values for these catch limits are shown in Table 5 of Agenda Item C.4.a, Supplemental REVISED Attachment 2.

The Council elected to defer a decision on a new target year to rebuild cowcod until their June 2014 meeting. The Council confirmed its Ecosystem Component species designations displayed in Table 4, page 12 of Agenda Item C.4.a, Supplemental REVISED Attachment 2; and noted that would include all other skates, other than longnose skate.

The Council also adopted preliminary preferred management measures, including allocations for all fisheries. Final action on harvest specifications and management measures is scheduled for the 2015-2016 groundfish fisheries and Amendment 24 to the fishery management plan is scheduled for the June 2014 Council meeting.

Implement 2014 Pacific Whiting Fishery under the U.S.-Canada Pacific Whiting Agreement

The Council adopted a yield set-aside of 1,500 mt of Pacific whiting to accommodate 2014 research activities and incidental bycatch in the pink shrimp fishery.

Sablefish Catch Share Program Review Phase 1 (This Includes Electronic Fish Tickets for Open Access Sablefish Deliveries)

The Council requested the program review document be expanded to provide additional explanation and data on the origins of the endorsement system and changes to the regulatory environment which have occurred since the program was implemented, as well as to respond to recommendations in the SSC report. A topic the Council may take up in June 2014 is whether to consider allowing vessels in the fixed gear sablefish catch share program to switch between longline and fishpot gear. With respect to the rules for determining which permits an entity controls for the purpose of evaluating compliance with the three-permit control limit, the Council selected Action Alternative 2a: for up to two vessels, if a vessel owner has a 20 percent or less ownership share in a vessel the limited entry fixed gear permits associated with that vessel would be exempt from counting against that owner's three-permit control. With respect to consideration of Federal requirement for electronic fish tickets for fixed gear sablefish landings, the Council modified the alternatives by adopting the NMFS recommendations that are contained in Agenda Item C.6.a, Supplemental Attachment 3 (eliminating unnecessarily specific language and removing suboptions for maintaining paper tickets). It should be noted that Alternative 4 would require electronic fish tickets for vessels delivering sablefish taken on open access trips.

Electronic Monitoring Program Development Including Preliminary Approval of Exempted Fishing Permits

The Council recommended that four of the five Exempted Fishing Permit (EFP) applications for use of electronic monitoring be forwarded for further consideration and potential final approval at the June 2014 meeting in Garden Grove, California, Agenda Item C.7.a, Attachment 7 (Leipzig), Attachment 8 (CA Risk Pool), and Attachment 9 (Mann/Paine); and in Agenda Item C.7.a, Supplemental Attachment 12 (Eder et al.). The Council provided guidance to the applicants for refinement and asked that applicants consider resubmitting applications for the June 2014 Council meeting. The following additions to the applications were requested by the Council: regarding the Leipzig EFP application – limit the number of vessels and require up to 100 percent observer coverage; regarding the CA Risk Pool application – limit the number of vessels and require up to 100 percent observer coverage on the bottom trawl vessels; regarding the Eder et al. application – limit the number of vessels. The Council also requested that the EFPs, address how the halibut viability assessments could be conducted without the presence of a human observer, with the intention that halibut retention not be permitted. In addition, the Council recommended that EFP applicants include a feature requiring providing National Marine Fisheries Service (NMFS) and the States a list of vessels and processors that will be participating in the EFP a minimum of 30 days before they commence their EFP. The West Coast Region Sand Point office also volunteered to work with applicants on an ad hoc basis to improve EFP applications and would consider convening a meeting in the near future.

Regarding the full fleet regulatory development process, a Groundfish Electronic Monitoring Policy Advisory Committee and Technical Advisory Committee meeting is scheduled for May 7-8 in Seattle, Washington to refine regulatory options for each fleet sector. The Council will consider sector specific progress at the June 2014 Council meeting.

Fisheries in 2015-2016 and Beyond: Stock complex Restructuring

The Council adopted the status quo slope rockfish complexes with a sorting requirement for rougheye and blackspotted rockfish as the preliminary preferred alternative for 2015 and beyond. In addition, only the action alternative proposed for analysis under Agenda Item C.8.a, Attachment 2, Option A was forwarded for additional detailed analysis. More detailed analysis of these two alternatives will be provided for the June 2014 Council meeting when the final preferred alternative will be decided.

SALMON MANAGEMENT

Methodology Review for 2014

The Council adopted the following preliminary topics for the 2014 methodology review (lead agencies are in parentheses):

- Willapa Bay natural coho conservation objective, annual catch limit and status determination criteria (Salmon Technical Team, Washington Department of Fish and Wildlife (WDFW).
- Southern Oregon coastal Chinook conservation objective (Oregon Department of Fish and Wildlife).
- Standardized method for calculation of age-2 Fishery Regulation Assessment Model (FRAM) stock scalars Model Evaluation Workgroup (MEW).
- Progress report on new Chinook FRAM base period (MEW).
- New conservation objective for Grays Harbor Chinook (WDFW, Quinault Indian Nation).

The Council is scheduled to review progress and select final topics at the September 2014 Council meeting in Spokane, Washington.

Lower Columbia Natural Coho Harvest Rate Matrix Review

The Council received a status update from the Lower Columbia River Natural Coho Workgroup (LRC Workgroup) and approved a process, schedule, and initial assignments. The LRC Workgroup is tentatively scheduled to meet in Portland on May 15, 2014 to review the status of Lower Columbia River coho stocks, alternative harvest policies, risk assessment methods and criteria, and to draft a report on coho populations in the upper Willamette River. The Council is scheduled to receive an update on progress at the June 2014 Council meeting in Garden Grove, California.

Final Action on 2014 Salmon Management Measures

The Council adopted management measures for commercial and recreational ocean salmon fisheries for 2014. Details are posted on the Council website at http://www.pcouncil.org.

COASTAL PELAGIC SPECIES MANAGEMENT

Sardine Assessment, Specifications, and Management Measures

The Council approved an OFL of 39,210 mt and an ABC of 35,792 mt, based on a P* value of 0.40. The Council set the ACL and ACT equal to 23,293 mt, and adopted a 500 mt incidental set aside for each of the three fishing periods. Accounting for a Quinault Indian Nation allotment of 4,000 mt and a total of 1,500 mt incidental set-aside, the period allocations will be as follows: Period 1 (July 1-September 14, 2014) = 7,218 mt; Period 2 (September 15-December 31, 2014) = 4,323 mt; and Period 3 (January 1-June 30, 2015) = 6,252 mt. Any uncaught allocation from Periods 1 and 2 will be rolled into the subsequent period. Any uncaught allocation from Period 3 will not be rolled into the subsequent period. The Council also adopted a mixed load allowance of up to 45 percent sardines caught in other coastal pelagic species fisheries, after directed fishing is closed.

ECOSYSTEM BASED MANAGEMENT

Protecting Unfished and Unmanaged Forage Fish Species Initiative

The Council approved a range of alternatives for protecting unfished and unmanaged forage fish species and identified the Ecosystem Trophic Role pathway as a preliminary preferred alternative. Under this pathway, protective measures for forage species would be added to each of the Council's four fishery management plans (FMP), perhaps under an omnibus process aggregating the four actions into one process. The Council is scheduled to review the alternatives and proposed amendatory FMP language at the September Council meeting in Spokane, Washington.

ADMINISTRATIVE MATTERS

Advisory Body Position Appointments and Council Operating Procedures

The Council Chair appointed Dr. Galen Johnson to the Scientific and Statistical Committee seat on the Model Evaluation Workgroup.

The Council appointed LCDR Joe Giammanco to the USCG 11th District seat on the Enforcement Consultants and LT Shannon Anthony as his alternate.

The Council added a seat on the Groundfish Management Team for the West Coast Groundfish Observer Program, with seating an individual scheduled for the June 2014 Council meeting.

The Council approved an updated management schedule for Pacific halibut in Council Operating Procedure 9.

Future Council Meeting Agenda and Workload Planning

The next meeting of the Pacific Fishery Management Council is scheduled for June 2014 in Garden Grove, California. The Council made a number of changes to the draft proposed June Council meeting graphic shown in Agenda Item J.3.a, Supplemental Attachment 4; a revised graphic will be posted on the Council website in the near future. In particular, the Pacific Halibut Catch Share Plan Change Scoping agenda item was dropped, the Highly Migratory EFP and swordfish fishery changes were postponed to further discussion at the June 2014 Council meeting, and the Habitat Committee meeting was postponed until later in the week.

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RECENT TECHNICAL MEMORANDUMS

SWFSC Technical Memorandums are accessible online at the SWFSC web site (http://swfsc.noaa.gov). Copies are also available from 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-521 Abundance and biomass estimates of demersal fishes at the footprint and piggy bank from optical surveys using a remotely operated vehicle (ROV).
STIERHOFF, K. L., J. L. BUTLER, S. A. MAU, and D. W. MURFIN
(September 2013)

522 Klamath-Trinity basin fall run chinook salmon scale age analysis evaluation.
SATTERTHWAITE, W. H., M. R. O'FARRELL, and M. S. MOHR
(September 2013)

523 Status review of the Northeastern Pacific population of white sharks *(CARCHARODON CARCHARIAS)* under the endangered species act.
DEWAR, H., T. EGUCHI, J. HYDE, D. KINZEY, S. KOHIN, J. MOORE, B. L. TAYLOR, and R. VETTER
(December 2013)

524 AMLR 2010-2011 field season report.
WALSH, J. G., ed.
(February 2014)

525 The Sacramento harvest model (SHM).
MOHR, M. S., and M. R. O'FARRELL
(February 2014)

526 Marine mammal, sea turtle and seabird bycatch in California gillnet fisheries in 2012.
CARRETTA, J. V., L. ENRIQUEZ, and C. VILLAFANA
(February 2014)

527 White abalone at San Clemente Island: population estimates and management recommendations.
STIERHOFF, K. L., M. NEUMANN, S. A. MAU and D. W. MURFIN
(May 2014)

528 Recommendations for pooling annual bycatch estimates when events are rare.
CARRETTA, J. V. and J. E. MOORE
(May 2014)

529 Documentation of a relational database for the California recreational fisheries survey onboard observer sampling program,1999-2011.
MONK, M., E. J. DICK and D. PEARSON
(July, 2014)

530 Life cycle modeling framework for Sacramento River winter-run chinook salmon.
HENDRIX, N., A. CRISS, E. DANNER, C.M. GREENE, H. IMAKI, A. PIKE, and S. LINDLEY
(July, 2014)