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Stock Assessment Report
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ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2017 FOR U.S. MANAGEMENT IN 2017-18

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TABLE OF CONTENTS

ACRONYMS AND DEFINITIONS

ABC	acceptable biological catch
ALT	1) alternative stock assessment model; 2) German word meaning ‘old’
AT	Acoustic-trawl survey
BC	British Columbia (Canada)
CA	California
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CCA	Central California fishery
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
CY	Calendar year
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
NOAA	National Oceanic and Atmospheric Administration
ODFW	Oregon Department of Fish and Wildlife
OFL	overfishing limit
OR	Oregon
PNW	northern fleet based on OR, WA, and BC fishery data
PFMC	Pacific Fishery Management Council
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 of stipulating annual harvest specifications for the U.S. fishery. This report serves as a full stock assessment for purposes of advising management for the 2017-18 fishing year. Presently, the assessment/management schedule for Pacific sardine is based on a full assessment conducted every three years, with an update assessment conducted in the interim years. A full stock assessment was conducted in 2014 (Hill et al. 2014; STAR 2014) and update assessments were completed in 2015 and 2016 (Hill et al. 2015, 2016).

Two assessment approaches are presented here, including a survey-based assessment (preferred by the stock assessment team, STAT) and a model-based assessment (alternative, model ALT). The report includes three primary sections: first, a timeline with background information concerning fishery operations and management associated with the Pacific sardine resource (Introduction); second, summaries for various sources of sample data used in the assessments (Data); and third, methods/models used to conduct the assessments (Assessment). The Assessment section includes two parts based on the assessment approach (survey and model). In this context, readers should first consult the section 'Assessment – Acoustic-trawl Survey, Overview,' which serves as the basis of the report, i.e., preferences and justifications regarding the STAT's choice of assessment approach. The two assessment approaches were evaluated at the formal stock assessment review (STAR) in February 2017. Readers should refer to STAR (2017) for details regarding merits and drawbacks of the assessments highlighted during the review, and final decisions from the Panel concerning both short- and long-term recommendations for adopting an assessment approach for advising management in the future. That is, while the survey-based assessment was viewed as the better long-term approach by both the STAT and STAR Panel, the Panel identified a notable shortcoming of the survey-based assessment in the short-term, given the need to forecast stock biomass one full year after the last survey observation. Both the STAT and STAR Panel agreed that the preferred survey-based assessment could be effectively implemented by shifting the fishery start date a few to several months to minimize the time lag between the most recent survey and the official start date of the fishery, e.g., moving the start of the fishery from July 1st to January 1st would accomplish this goal. To summarize, model ALT presently represents the recommended assessment approach to adopt for the upcoming fishing year (2017-18), with a survey-based assessment that accommodates a more workable projection period recommended for subsequent fishing years.

Finally, field, laboratory, and analytical work conducted in support of the ongoing Pacific sardine assessment is the responsibility of the SWFSC and its staff, including: principal investigators (K. T. Hill, P. R. Crone, J. P. Zwolinski); and collaborators (D.A. Demer, E. Dorval, B. J. Macewicz, D. Griffith, and Y. Gu). Principal investigators are responsible for developing assessments, presenting relevant background information, and addressing the merits/drawbacks of the two assessment approaches in the context of meeting the management goal (current estimate of stock biomass each year), which is needed for implementing an established harvest control rule policy for Pacific sardine. An inclusive list of individuals and institutions that have provided information for carrying out the Pacific sardine assessment is presented in Acknowledgements below.

EXECUTIVE SUMMARY

The following Pacific sardine assessment was conducted to inform U.S. fishery management for the cycle that begins July 1, 2017 and ends June 30, 2018. Two assessment approaches were reviewed at the STAR Panel in February 2017: an AT survey-based approach (preferred by the STAT); and a model-based assessment (model ALT). Given forecasting issues highlighted in the review (see STAR 2017 and 'Unresolved Problems and Major Uncertainties' below), the Panel ultimately recommended that management advice be based on model ALT for the 2017-18 fishing year. Model ALT represents the final base model from the February 2017 STAR (Hill et al. 2017, STAR 2017).

Stock

This assessment focuses on the northern subpopulation of Pacific sardine (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 Ensenada (ENS) to British Columbia (BC) were from the northern subpopulation. There is now general scientific consensus that catches landed in the Southern California Bight (SCB, i.e., Ensenada and southern California) likely represent a mixture of the southern subpopulation (warm months) and northern subpopulation (cool 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 SCB, the adult spawning stocks likely move north and south in synchrony each year 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 Ensenada (ENS) and southern California (SCA) ports to exclude both landings and biological compositions attributed to the southern subpopulation.

Catches

The assessment includes sardine landings (mt) 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 modeled years/seasons follow:

Calendar Yr-Sem	Model Yr-Seas	ENS Total	ENS NSP	SCA Total	SCA NSP	CCA	OR	WA	BC
2005-2	2005-1	37,999.5	4,396.7	16,615.0	1,581.4	7,824.9	44,316.2	6,605.0	3,231.4
2006-1	2005-2	17,600.9	11,214.6	18,290.5	17,117.0	2,032.6	101.7	0.0	0.0
2006-2	2006-1	39,636.0	0.0	18,556.0	5,015.7	15,710.5	35,546.5	4,099.0	1,575.4
2007-1	2006-2	13,981.4	13,320.0	27,546.0	20,567.0	6,013.3	0.0	0.0	0.0
2007-2	2007-1	22,865.5	11,928.2	22,047.2	5,531.2	28,768.8	42,052.3	4,662.5	1,522.3
2008-1	2007-2	23,487.8	15,618.2	25,098.6	24,776.6	2,515.3	0.0	0.0	0.0
2008-2	2008-1	43,378.3	5,930.0	8,979.6	123.6	24,195.7	22,939.9	6,435.2	10,425.0
2009-1	2008-2	25,783.2	20,244.4	10,166.8	9,874.2	11,079.9	0.0	0.0	0.0
2009-2	2009-1	30,128.0	0.0	5,214.1	109.3	13,935.1	21,481.6	8,025.2	15,334.3
2010-1	2009-2	12,989.1	7,904.2	20,333.5	20,333.5	2,908.8	437.1	510.9	421.7
2010-2	2010-1	43,831.8	9,171.2	11,261.2	699.2	1,397.1	20,414.9	11,869.6	21,801.3
2011-1	2010-2	18,513.8	11,588.5	13,192.2	12,958.9	2,720.1	0.1	0.0	0.0
2011-2	2011-1	51,822.6	17,329.6	6,498.9	182.5	7,359.3	11,023.3	8,008.4	20,718.8
2012-1	2011-2	10,534.0	9,026.1	12,648.6	10,491.1	3,672.7	2,873.9	2,931.7	0.0
2012-2	2012-1	48,534.6	0.0	8,620.7	929.9	568.7	39,744.1	32,509.6	19,172.0
2013-1	2012-2	13,609.2	12,827.9	3,101.9	972.8	84.2	149.3	1,421.4	0.0
2013-2	2013-1	37,803.5	0.0	4,997.3	110.3	811.3	27,599.0	29,618.9	0.0
2014-1	2013-2	12,929.7	412.5	1,495.2	809.3	4,403.3	0.0	908.0	0.0
2014-2	2014-1	77,466.3	0.0	1,600.9	0.0	1,830.9	7,788.4	7,428.4	0.0
2015-1	2014-2	14,452.4	0.0	1,543.2	0.0	727.7	2,131.3	62.6	0.0
2015-2	2015-1	18,379.7	0.0	1,514.8	0.0	6.1	0.1	66.1	0.0
2016-1	2015-2	22,647.9	0.0	423.5	184.8	1.1	0.7	0.0	0.0
2016-2	2016-1	23,091.6	0.0	857.5	0.0	10.3	2.7	85.2	0.0

Data and Assessment

The integrated assessment model was developed using Stock Synthesis (SS version 3.24aa), and includes fishery and survey data collected from mid-2005 through 2016. The model is based on a July-June biological year (aka ‘model 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 modeled by season as a single PNW fleet (fishery). A single AT survey index of abundance from ongoing SWFSC surveys (2006-2016) was included in the model.

Model ALT incorporates the following specifications:

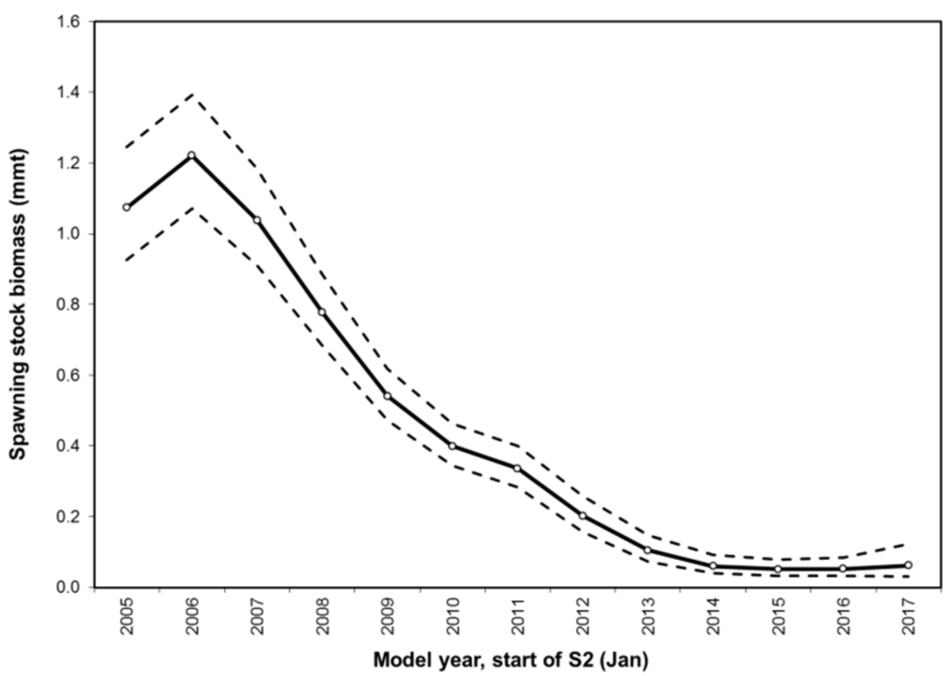
- NSP catches for the MEXCAL fleet computed using an environmental-based optimal habitat index;
- two seasons (semesters, Jul-Dec=S1 and Jan-Jun=S2) for each model year (2005-16);
- sexes were combined;
- maximum age=10, with nine age bins (ages 0-8+);
- two fleets (MEXCAL and PNW), with an annual selectivity pattern for the PNW fleet and seasonal selectivity patterns (S1 and S2) for the MEXCAL fleet;
  - MEXCAL fleet: dome-shaped, age-based selectivity (one parameter per age)
  - PNW fleet: asymptotic, age-based selectivity;
  - age compositions with effective sample sizes calculated by dividing the number of fish sampled by 25 (externally);

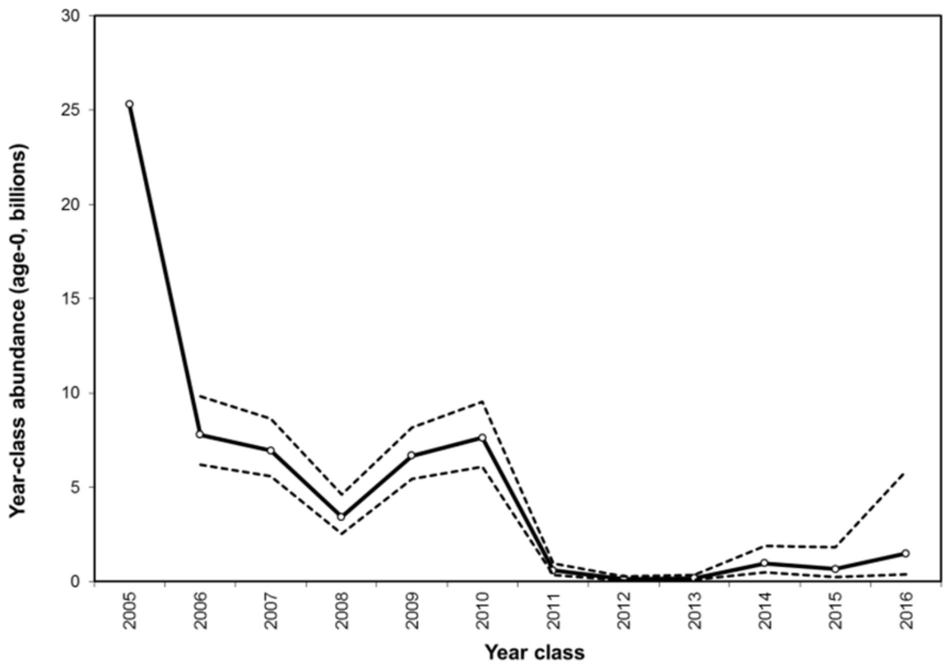
- Beverton-Holt stock-recruitment relationship, with virgin recruitment (R_0), steepness (h), and initial equilibrium recruitment offset (R_1) estimated, and average recruitment variability fixed (σ_R=0.75);
- M was fixed (0.6 yr^{-1});
- recruitment deviations estimated from 2005-15;
- initial fishing mortality (F) was estimated for the MEXCAL_S1 fishery and fixed=0 for MEXCAL_S2 and PNW fisheries;
- single AT survey index of abundance (2006-2013) that includes seasonal (spring and summer) observations in some years, and catchability (Q) estimated;
  - age compositions with effective sample sizes set (externally) to 1 per trawl cluster;
  - selectivity was assumed to be uniform (fully selected) for age 1+ and zero for age 0; and
- no additional data weighting via variance adjustment factors or lambdas was implemented.

Spawning Stock Biomass and Recruitment

Time series of estimated spawning stock biomass (SSB, mmt) and associated 95% confidence intervals are displayed in the figure and table below. The virgin level of SSB was estimated to be 107,915 mt (0.11 mmt). The SSB has continually declined since 2005-06, reaching historically low levels in recent years (2014-present). The SSB was projected to be 61,684 mt (CV=36%) in January 2018.

Time series of estimated recruitment (age-0, billions) abundance is presented in the figure and table below. The virgin level of recruitment (R_0) was estimated to be 1.52 billion age-0 fish. As indicated for SSB above, recruitment has largely declined since 2005-06, with the exception of a brief period of modest recruitment success from 2009-10. In particular, the 2011-15 year classes have been among the weakest in recent history. A small increase in recruitment was observed in 2016, albeit a highly variable estimate (CV=79%) based on limited data.

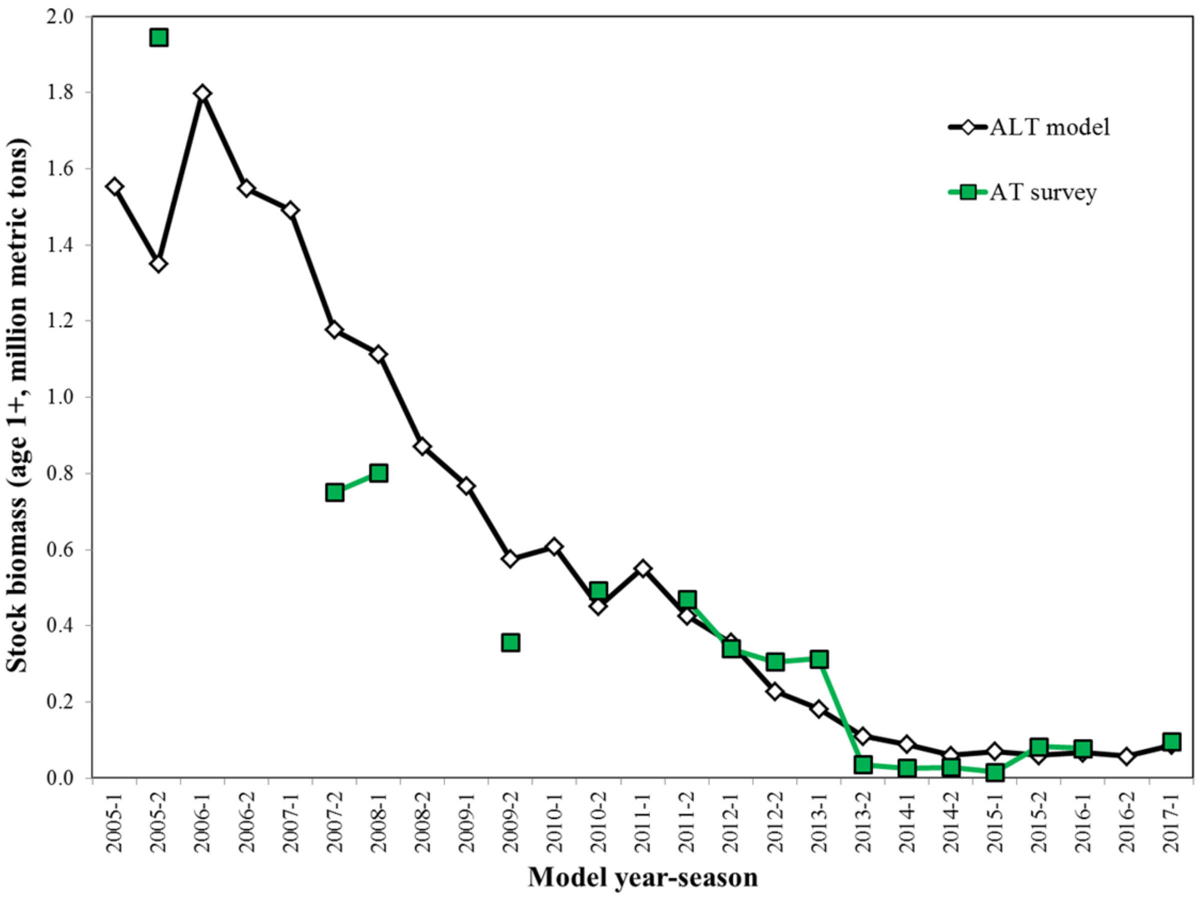




Calendar Yr-Sem	Model Yr-Seas	SSB (mt)	SSB Std Dev	Year class abundance (1000s)	Recruits Std Dev
2005-2	2005-1	---	---	25,280,200	---
2006-1	2005-2	1,073,370	81,231	---	---
2006-2	2006-1	---	---	7,795,940	921,117
2007-1	2006-2	1,220,870	82,137	---	---
2007-2	2007-1	---	---	6,941,430	776,514
2008-1	2007-2	1,038,110	69,463	---	---
2008-2	2008-1	---	---	3,438,450	524,348
2009-1	2008-2	776,752	51,418	---	---
2009-2	2009-1	---	---	6,670,540	698,028
2010-1	2009-2	540,469	36,758	---	---
2010-2	2010-1	---	---	7,626,460	877,556
2011-1	2010-2	399,390	29,801	---	---
2011-2	2011-1	---	---	601,265	152,534
2012-1	2011-2	336,084	29,628	---	---
2012-2	2012-1	---	---	140,769	51,311
2013-1	2012-2	201,813	25,832	---	---
2013-2	2013-1	---	---	185,878	66,165
2014-1	2013-2	104,351	18,784	---	---
2014-2	2014-1	---	---	971,184	337,752
2015-1	2014-2	60,263	13,171	---	---
2015-2	2015-1	---	---	663,664	365,241
2016-1	2015-2	51,186	11,460	---	---
2016-2	2016-1	---	---	1,500,830	1,183,890
2017-1	2016-2	52,353	12,991	---	---

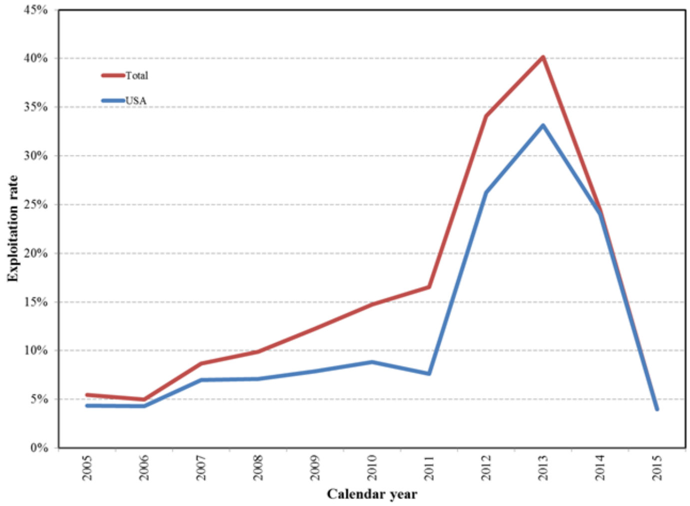
Stock Biomass for PFMC Management in 2017-18

Stock biomass, used for calculating annual harvest specifications, is defined as the sum of the biomass for sardine ages one and older (age 1+) at the start of the management year. Time series of estimated stock biomass (mmt) from model ALT and the AT survey are presented in the figure below. As discussed above for both SSB and recruitment, a similar trend of declining stock biomass has been observed since 2005-06, peaking at 1.8 mmt in 2006, and plateauing at recent historical low levels since 2014. Model ALT stock biomass is projected to be **86,586 mt in July 2017**.



Exploitation Status

Exploitation rate is defined as the calendar year NSP catch divided by the total mid-year biomass (July-1, ages 0+). Based on model ALT estimates, the U.S. exploitation rate has averaged about 11% since 2005, peaking at 33% in 2013. The U.S. and total exploitation rates were <1% in 2016. The U.S. and total exploitation rates for the NSP, calculated from model ALT, are presented in the figure and table below.



Calendar Year	USA	Total
2005	4.4%	5.4%
2006	4.3%	5.0%
2007	7.0%	8.7%
2008	7.1%	9.9%
2009	7.9%	12.2%
2010	8.8%	14.7%
2011	7.6%	16.5%
2012	26.2%	34.1%
2013	33.1%	40.1%
2014	24.0%	24.4%
2015	4.0%	4.0%
2016	0.4%	0.4%

Ecosystem Considerations

Pacific sardine represent an important forage base in the California Current Ecosystem (CCE). At times of high abundance, Pacific sardine can compose a substantial portion of biomass in the CCE. However, periods of low recruitment success driven by prevailing oceanographic conditions can lead to low population abundance over extended periods of time. Readers should consult PFMC (1998), PFMC (2014), and NMFS (2016a,b) for comprehensive information regarding environmental processes generally hypothesized to influence small pelagic species that inhabit the CCE.

Harvest Control Rules

Harvest guideline

The annual harvest guideline (HG) is calculated as follows:

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

where HG is the total U.S. directed harvest for the period July 2017 to June 2018, BIOMASS is the stock biomass (ages 1+, mt) projected as of July 1, 2017, CUTOFF (150,000 mt) is the lowest level of biomass for which directed harvest is allowed, FRACTION (E_{MSY} bounded 0.05-0.20) 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. Based on results from model ALT, estimated stock biomass is projected to be below the 150,000 mt threshold and thus, the HG for 2017-18 would be 0 mt.

OFL and ABC

On March 11, 2014, the PFMC adopted the use of CalCOFI sea-surface temperature (SST) data for specifying environmentally-dependent E_{MSY} each year. The E_{MSY} is calculated as,

$$E_{\mathrm{MSY}} = -18.46452+3.25209(T)-0.19723(T^2)+0.0041863(T^3),$$

where T is the three-year running average of CalCOFI SST, and E_{MSY} for OFL and ABC is bounded between 0 to 0.25. Based on the recent warmer conditions in the CCE, the average temperature for 2014-16 increased to 15.9999 °C, resulting in E_{MSY}=0.2251.

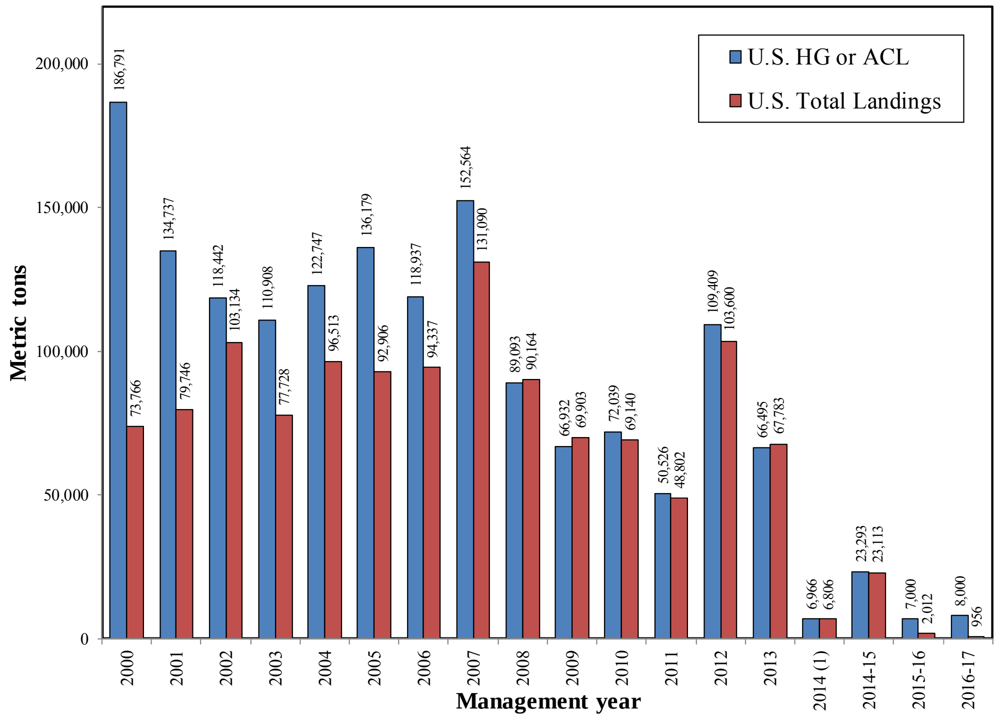
Harvest estimates for model ALT are presented in the following table. Estimated stock biomass in July 2017 was **86,586 mt**. The overfishing limit (OFL, 2017-18) associated with that biomass was **16,957 mt**.

Acceptable biological catches (ABC, 2017-18) for a range of *P-star* values (Tier 1 σ=0.36; Tier 2 σ=0.72) associated with model ALT are presented in the following table.

Harvest control rules for the model-based assessment (model ALT):

Harvest Control Rule Formulas									
OFL = BIOMASS * E_{MSY} * DISTRIBUTION; where E_{MSY} is bounded 0.00 to 0.25									
$ABC_{P\text{-}star}$ = BIOMASS * $BUFFER_{P\text{-}star}$ * E_{MSY} * DISTRIBUTION; where E_{MSY} is bounded 0.00 to 0.25									
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION; where FRACTION is E_{MSY} bounded 0.05 to 0.20									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	86,586								
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier\ 1}$	0.95577	0.91283	0.87048	0.82797	0.78442	0.73861	0.68859	0.63043	0.55314
ABC $Buffer_{Tier\ 2}$	0.91350	0.83326	0.75773	0.68553	0.61531	0.54555	0.47415	0.39744	0.30596
CalCOFI SST (2014-2016)	15.9999								
E_{MSY}	0.225104								
FRACTION	0.200000								
CUTOFF (mt)	150,000								
DISTRIBUTION (U.S.)	0.87								
Harvest Control Rule Values (MT)									
OFL =	**16,957**								
$ABC_{Tier\ 1}$ =	16,207	15,479	14,761	14,040	13,301	12,525	11,676	10,690	9,380
$ABC_{Tier\ 2}$ =	15,490	14,130	12,849	11,625	10,434	9,251	8,040	6,739	5,188
HG =	**0**								

Management Performance
The U.S. HG/ACL values and catches since the onset of federal management are presented in the figure below.



Unresolved Problems and Major Uncertainties
As indicated in the Preface above, the survey-based assessment remains the STAT's preferred approach for advising management regarding Pacific sardine abundance in the future. However, the STAR Panel identified a notable shortcoming of the survey-based assessment that would need to be addressed before adopting this approach for purposes of advising management in the future. Specifically, the issue is related to a need to forecast stock biomass one full year after the last survey observation, i.e., a time lag exists between obtaining the final estimate of stock biomass from the summer AT survey and the start date of the fishery the following year. In particular, it is inherently difficult to reliably estimate the strength of the most recent cohort (age-0 fish) from the previous summer that would be expected to contribute substantially to the age-1+ biomass the following year (e.g., projecting the 2016 year-class size/biomass into July 2017). It is important to note, recent recruitment strength will continue to represent a considerable area of uncertainty, regardless of species or assessment approach (i.e., survey- or model-based), particularly, for coastal pelagic species (e.g., sardine and anchovy) that exhibit highly variable recruitment success in any given year given their high rates of natural mortality. Both the STAT and STAR Panel agreed that uncertainty associated with the forecast needed in the survey-based assessment would be effectively minimized by simply shifting the fishery start date to reduce the time lag between the most recent survey and start date for the fishery (e.g., from July 1st to January 1st).

The STAR Panel ultimately recommended using results from model ALT for sardine management in 2017-18. The Panel identified a number of areas of uncertainty in model ALT, including: 1) best treatment of empirical weight-at-age data from the fisheries and AT survey; 2) treatment of population weight-at-age (time varying vs. time-invariant); 3) use of time-invariant age-length keys to convert AT length compositions to age compositions; 4) selectivity parameterization for the AT survey; 5) lack of empirical justification for increasing natural mortality from 0.4 to 0.6 yr^{-1}; and 6) ongoing concerns about acoustic species identification, target strength estimation, and boundary zone (sea floor, surface, and shore) observations associated with the AT survey (readers should consult sections 3 and 5 in STAR (2017) for further details).

Research and Data Needs

Research and data for improving stock assessments of the Pacific sardine resource in the future address three major areas of need, including AT survey operations, biological data sampling from fisheries, and laboratory-based biology studies (see Research and Data Needs below for further discussion regarding areas of improvement).

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 abundance was low during the 1960-70s, sardines did not generally occur in significant quantities north of Baja California.

There is a longstanding 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 ('NSP'; northern Baja California to Alaska; Figure 1), a southern subpopulation ('SSP'; 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 to temperature-at-capture (Felix-Uraga et al., 2004, 2005; Garcia-Morales et al. 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 (Figure 1), and represents the stock included in the CPS Fishery Management Plan (CPS-FMP; PFMC 1998). The 2014 assessment (Hill et al. 2014) addressed the above stock structure hypotheses in a more explicit manner, by partitioning southern (ENS and SCA ports) fishery catches and composition data using an environment-based approach described by Demer and Zwolinski (2014) and in the following sections. The same subpopulation hypothesis is carried forward in the following assessment.

Pacific sardine migrate extensively when abundance is high, moving as far north as British Columbia in the summer and returning to southern California and northern Baja California in the fall. Early tagging studies indicated that the older and larger fish moved farther north (Janssen 1938; Clark & Janssen 1945). Movement patterns were probably complex, and the timing and extent of movement were affected by oceanographic conditions (Hart 1973) and stock biomass levels. During the 1950s to 1970s, a period of reduced stock size and unfavorably cold sea-surface temperatures together likely 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 waters 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. 2011) 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 (Eschmeyer et al. 1983), but are seldom longer than 30 cm in fishery catches and survey samples. The heaviest sardine on record weighed 0.323 kg. Oldest recorded age of sardine is 15 years, but fish in California commercial catches are usually younger than five years and fish in the PNW are less than 10 years old. Sardine are typically larger and two to three years older in regions off the Pacific Northwest than observed further south in waters off California. 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). McDaniel et al. (2016) analyzed recent fishery and survey data and found evidence for age-based (as opposed to size-based) movement from inshore to offshore and from south to north.

Historically, sardines fully recruited to the fishery when they were ages three and older (MacCall 1979). Recent fishery data indicate that sardines begin to recruit to the SCA fishery at age zero during the late winter-early spring. Age-dependent availability to the fishery 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.

Sardines spawn in loosely aggregated schools in the upper 50 meters of the water column. Sardines are oviparous, multiple-batch spawners, with annual fecundity that is indeterminate, and age- or size-dependent (Macewicz et al. 1996). Spawning of the northern subpopulation typically 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 warm ocean conditions, the center of sardine spawning shifts northward and spawning extends over a longer period of time (Butler 1987; Ahlstrom 1960; Dorval et al. 2016, 2017). Spawning is typically concentrated in the region offshore and north of Point Conception (Lo et al. 1996, 2005) to areas off San Francisco. However, during April 2015 and 2016 spawning was observed in areas north of Cape Mendocino to central Oregon (Dorval et al. 2016; Dorval et al. 2017 in Appendix A).

Ecosystem Considerations

Pacific sardine represent an important forage base in the California Current Ecosystem (CCE). At times of high abundance, Pacific sardine can compose a substantial portion of biomass in the CCE. However, periods of low recruitment success driven by prevailing oceanographic conditions can lead to low population abundance over extended periods of time. Readers should consult PFMC (1998), PFMC (2014), and NMFS (2016a,b) for comprehensive information regarding environmental processes generally hypothesized to influence small pelagic species that inhabit the CCE.

Abundance, Recruitment, and Population Dynamics

Extreme natural variability is characteristic of clupeid stocks, such as Pacific sardine (Cushing 1971). Estimates of sardine abundance from as early as 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; McClatchie et al. 2017). Sardine populations existed throughout the period, with abundance 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. Declines in sardine populations have generally lasted an average of 36 years and recoveries an average of 30 years.

Pacific sardine spawning biomass (age 2+), 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 as low as 10,000 mt (Barnes et al. 1992). The sardine stock began to increase by an average annual rate of 27% in the early 1980s (Barnes et al. 1992).

As exhibited by many members of the small pelagic fish assemblage of the CCE, Pacific sardine recruitment is highly variable, with large fluctuations observed over short timeframes. Analyses of the sardine stock-recruitment relationship have resulted in inconsistent findings, with some studies showing a strong density-dependent relationship (production of young sardine declines at high levels of spawning biomass) and others, concluding no relationship (Clark and Marr 1955; Murphy 1966; MacCall 1979). Jacobson and MacCall (1995) found both density-dependent and environmental factors to be important, as was also agreed during a sardine harvest control rule workshop held in 2013 (PFMC 2013). The current U.S. harvest control rules for sardine couple prevailing SST to exploitation rate (see *Harvest Control Rules* section).

Relevant History of the Fishery and Important Features of the Current Fishery

The sardine fishery was first developed in response to demand for food during World War I. Landings increased rapidly from 1916 to 1936, peaking at over 700,000 mt. Pacific sardine supported the largest fishery in the western hemisphere during the 1930s and 1940s, with landings in Mexico to Canada. The population and fishery soon 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, from 1951 through 1952. The San Pedro fishery closed in the mid-1960s. 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 ceased in 1991 when the directed fishery was offered higher quotas. The renewed fishery initiated in ENS and SCA, expanded to CCA, and by the early 2000s, substantial quantities of Pacific sardine were landed at OR, WA, and BC. Volumes have reduced dramatically in the past several years. Harvest by the Mexican (ENS) fishery is not currently regulated by quotas, but there is a minimum legal size limit of 150 mm SL. The Canadian fishery failed to capture sardine in summer 2013, and has been under a moratorium since summer 2015. The U.S. directed fishery has been subject to a moratorium since July 1, 2015.

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 Pacific sardine are described 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 2014). U.S. harvest specifications and landings since 2000 are displayed in Table 1 and Figure 2. Harvests in major fishing regions from ENS to BC are provided in Table 2 and Figure 3.

ASSESSMENT DATA

Biological Parameters

Stock structure

We presume to model the NSP that, at times, ranges from northern Baja California, México to British Columbia, Canada. As mentioned above, there is general consensus that catches landed in ENS and SCA likely represent a mixture of SSP (during warm months) and NSP (cool months) (Felix-Uraga et al. 2004, 2005; Garcia-Morales 2012; Zwolinski et al. 2011; Demer and Zwolinski 2014) (Figure 1). The approach involves analyzing satellite oceanographic data to objectively partition monthly catches and biological compositions from ENS and SCA ports to exclude data from the SSP (Demer and Zwolinski 2014). This approach was adopted in the 2014 full assessment (Hill et al. 2014; STAR 2014), in the 2015 and 2016 update assessments (Hill et al. 2015, 2016), and is carried forward in the following assessment.

Growth

Analysis of size-at-age from fishery samples (1993-2013) provided no indication of sexual dimorphism related to growth (Figure 4; Hill et al. 2014), so combined sexes were included in the present assessment model with a sex ratio of 50:50.

Past Pacific sardine stock assessments conducted with the CANSAR and ASAP statistical catch-at-age frameworks accounted for growth using empirical weight-at-age time series as fixed model inputs (e.g. Hill et al. 1999; Hill et al. 2006). Stock synthesis models used for management from 2007 through 2016 estimated growth internally using conditional age-at-length compositions and a fixed length-weight relationship (e.g., Hill et al. 2016). Disadvantages to estimating growth internally within the stock assessment include: 1) inability to account for regional differences in age-at-size due to age-based movements (McDaniel et al. 2016); 2) difficulty in modeling cohort-specific growth patterns; 3) potential model interactions between growth estimation and selectivity; and 4) models using conditional age-at-length data are data-heavy, requiring more estimable model parameters than the empirical weight-at-age approach. For these reasons, the model ALT was constructed to bypass growth estimation internally in SS, instead opting for a return to the use of empirical weights-at-age.

Empirical weight-at-age data were included as fixed inputs in model ALT. Fleet- and survey-specific empirical weight-at-age estimates were compiled for each model year and semester. Fishery mean weight-at-age estimates were calculated for seasons with greater than two samples available. Growth patterns were examined by cohort and were smoothed as needed. Specifically, fish of the same cohort were not allowed to shrink in subsequent time steps, and negative deviations were substituted by interpolation. Likewise, missing values were substituted through interpolation. Further details regarding empirical weight-at-age time series for the AT survey are provided in the section 'Fishery-Independent Data \ Acoustic-trawl survey'. All fishery and AT survey weight-at-age vectors are displayed in Figures 5-7. During the STAR Panel (Feb 2017), it was discovered that PNW weight-at-age had not been smoothed by cohort as described above, but instead were input as nominal estimates of weight-at-age. A sensitivity run based on cohort-smoothed PNW data resulted in a negligible impact (<1%) on population estimates, i.e., revised weight-at-age matrix was not included in the final model ALT.

Empirical weight-at-age models require population weight-at-age vectors to convert population number-at-age to biomass-at-age. Model ALT population weight-at-age vectors were derived from the last assessment model (T_2016) after it had been updated with newly available maturity, catch, and survey data (T_2017). Model T_2017 was run once to derive estimates of population weight-at-age at the beginning and middle of each semester. A fecundity*maturity-at-age vector, used to calculate SSB-at-age, was also derived from model T_2017 (see 'Maturity' below). Population- and SSB-at-age vectors are displayed in Figure 8.

Maturity

Maturity was modeled using a fixed vector of fecundity*maturity by age (Figure 8). The vector was derived from the 2016 assessment model after it was updated with newly available information (T_2017). In addition to other data sources, model T_2017 was updated with new parameters for the logistic maturity-at-length function using female sardine sampled from survey trawls conducted from 1994 to 2016 (n=4,561). 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 = -0.9051 and inflexion = 16.06 cm-SL. Maturity-at-length parameters were fixed in the updated assessment model (T_2017) and fecundity was fixed at 1 egg/gram body weight. Once model T_2017 was run, the fecundity*maturity-at-age vector was extracted for use in the current alternative assessment model (ALT) (Figure 8).

Natural mortality
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=0.4-0.8 yr^{-1} (Murphy 1966; MacCall 1979) and 0.51 yr^{-1} (Clark and Marr 1955). Zwolinski and Demer (2013) 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}.

Murphy's (1966) virtual population analysis of the Pacific sardine used M=0.4 yr^{-1} to fit data from the 1930s and 1940s, but M was doubled to 0.8 yr^{-1} from 1950 to 1960 to better fit the trend in CalCOFI egg and larval data (Murphy 1966). Early natural mortality estimates may not be as applicable to the present population, given the significant increase in predator populations since the historic era (Vetter and McClatchie, *in review*). To date, Pacific sardine stock assessments for PFMC management have used M=0.4 yr^{-1}. For reasons explained subsequently, the present alternative assessment (model ALT) was conducted using M=0.6 yr^{-1}. An instantaneous M rate of 0.6 yr^{-1} translates to an annual M rate of 45% of the adult sardine stock dying each year from natural causes. Sensitivities to assumptions regarding M are further explored in this assessment.

Fishery-dependent 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 (not in all cases). A complete list of available port sample data by fishing region, model year, and season is provided in Table 3.

All fishery catches and compositions were compiled based on the sardine's biological year ('model year') to match the July 1st birth-date assumption used in age assignments. Each model year is labeled with the first of two calendar years spanned (e.g., model year '2005' includes data from July 1, 2005 through June 30, 2006). Further, each model year has two six-month seasons, including 'S1'=Jul-Dec and 'S2'=Jan-Jun. Major fishery regions were pooled to represent a southern 'MEXCAL' fleet (ENS+SCA+CCA) and a northern 'PNW' fleet (OR+WA+BC). The MEXCAL fleet was treated with semester-based selectivities ('MEXCAL_S1' and 'MEXCAL_S2'). Rationale for this fleet design is provided in Hill et al. (2011).

Landings
Ensenada monthly landings from 1993-02 were compiled using the 'Boletín Anual' series previously produced by INAPESCA's Ensenada office (e.g., Garcia and Sánchez 2003). Monthly landings from 2003-14 were taken from CONAPESCA's web archive of Mexican fishery yearbook statistics (CONAPESCA 2015). The ENS monthly landings for 2015-16 were provided by INAPESCA-Ensenada (Concepción Enciso-Enciso, pers. comm.).

California (SCA and CCA) directed commercial landings were obtained from the PacFIN database (2005-2015) and CDFW's 'Wetfish Tables' (2016). Given the California live bait industry is currently the only active sector in the U.S. sardine fishery, live bait landings were also included in this assessment for the first time. California live bait landings are recorded on 'Live Bait Logbooks' provided to the CDFW on a voluntary basis. The CDFW compiles estimates of catch weight based on a conversion of scoop number to kg (Kirk Lynn, CDFW, pers. comm.). Monthly live bait landings were pooled with other commercial catches in the MEXCAL fleet.

Oregon (OR) and Washington (WA) landings (2005-16) were obtained from PacFIN. British Columbia (BC) monthly landing statistics (2005-12) were provided by CDFO (Linnea Flostrand and Jordan Mah, pers. comm.). Sardine were not landed in Canada during 2013-16. The BC landings were pooled with OR and WA as part of the PNW fleet.

Available information concerning bycatch and discard mortality of Pacific sardine, as well as other members of the small pelagic fish assemblage of the California Current Ecosystem, is presented in PFMC (2014). Limited information from observer programs implemented in the past indicated minimal discard of Pacific sardine in the commercial purse seine fishery that targets the small pelagic fish assemblage off the USA Pacific coast.

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 (SSP) or northern subpopulation (NSP). The NSP landings by model year-season for each fishing region are presented in Table 2 and Figure 3. The current Stock Synthesis model aggregates regional fisheries into a southern 'MEXCAL' fleet and a northern 'PNW' fleet (Figure 1). Landings aggregated by model year-season and fleet are presented in Table 4 and Figure 9.

Age compositions

Age compositions for each fleet and season were the sums of catch-weighted age 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-based biological compositions.

Age-composition data were partitioned into 9 age bins, representing ages 0 through 8+. Total numbers for ages observed in each fleet-semester stratum were divided by the typical number of fish collected per sampled load (25 fish per sample) to set the sample sizes for compositions included in the assessment model. Seasons with fewer than three samples were excluded from the model. Age compositions were input as proportions. Age-composition time series are presented in Figures 10-12.

Oregon and Washington fishery ages from season 2 (S2, Jan-Jun), were omitted from all models due to inter-laboratory inconsistencies in the application of birth-date criteria during this semester (noting that OR and WA landings and associated samples during S2 are typically trivial). Age data were not available for the BC or ENS fisheries, so PNW and MEXCAL fleet compositions only represent catch-at-age by the OR-WA and CA fisheries, respectively.

Ageing error
Sardine ageing using otolith methods was first described by Walford and Mosher (1943) and extended by Yaremko (1996). Pacific sardines are routinely aged by fishery biologists in CDFW, WDFW, and SWFSC using annuli enumerated in whole sagittae. A birth date of July 1st is assumed when assigning ages.

Ageing-error vectors for fishery data were unchanged from Hill et al. (2011, 2014). Ageing error vectors (SD at true age) were linked to fishery-specific 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 uses a single time series of biomass based on the SWFSC's acoustic-trawl (AT) survey. This survey and estimation methods were vetted through a formal methodology review process in February 2011 (PFMC 2011, Simmonds 2011). The AT survey will be reviewed by the PFMC in January 2018.

Acoustic-trawl survey
The AT time series is based on SWFSC surveys conducted along the Pacific coast since 2006 (Cutter and Demer 2008; Zwolinski et al. 2011, 2012, 2014, 2016, Demer et al. 2012, and Zwolinski et al. in preparation). The AT survey and estimation methods were reviewed by a panel of independent experts in February 2011 (PFMC 2011) and the results from these surveys have been included in the assessment since 2011 (Hill et al. 2011, 2012, 2014, 2015, 2016).

Two new AT-based biomass estimates were included in this assessment; one from the spring 2016 survey off central California to Oregon, and the other from the summer 2016 survey spanning San Diego to northern Vancouver Island, Canada. Biomass estimates and associated size distributions from the 2016 surveys are described in the section 'Assessment – Acoustic Trawl Survey' and Zwolinski et al. (in preparation). Biomass estimates from the spring and summer 2016 surveys, 83,037 (CV=0.493) mt and 78,776 (CV=0.539) mt respectively, represent roughly a four-fold increase from those of 2015 (Table 5, Figure 20). The higher AT biomass estimates are consistent with evidence of moderately successful recruitments in 2014 and 2015 (Table 8, Figure 12).

The time series of AT biomass estimates is presented in Table 5 and Figure 20. In order to comply with the model ALT formulation, estimates of abundance at length (Figure 12) were converted into abundance-at-age using seasonal (spring and summer) age-length keys constructed from survey data from 2006 to the present. Age-length keys were constructed for each survey season using the function 'multinom' from the R package 'nnet'. The 'nnet' function fits a multinomial log-linear model using neural networks. The response is a discrete probability distribution of age-at-length. The AT survey biomass estimates (2006-2016) were used as a single time-series, with q being estimated. Age compositions were fit using asymptotic age-selectivity (ages 1+ fully selected; SS age selectivity option 10) which was fixed for the entire time series. Empirical weight-at-age time series (Figure 7) were calculated for every survey using the following process: 1) The AT-derived abundance-at-length was converted to biomass-at-length using a time-invariant length-to-weight relationship. 2) The biomass- and numbers-at-length were converted to biomass-at-age and numbers-at-age, respectively, using the above-mentioned age-length key. 3) mean weights-at-age were calculated by dividing biomass-at-age by the respective numbers-at-age.

Data Sources Considered but not Used

Daily egg production method spawning biomass

Past sardine stock assessments have included a time series of daily egg production method (DEPM) spawning stock biomass (SSB). The time series was included in the assessments as an index of relative female SSB (*Q* estimated) and has always been considered an underestimate of true SSB (Deriso et al. 1996). The DEPM time series has been described in numerous publications and stock assessment reports. The DEPM time series since 2005 is provided in Table 5. The spring 2016 DEPM survey estimate is summarized in Appendix A of this report. It is worth noting that the 2016 estimate of female SSB was only 5,929 mt, the lowest level since mid-1980s. As stated elsewhere, the DEPM series was excluded from model ALT. As indicated in past assessments, exclusion of the DEPM time series continues to have negligible impact on the stock assessment outcome. Nonetheless, DEPM estimates are still considered useful to corroborate/refute results from either the AT survey and/or model ALT (see 'Assessment – Acoustic-trawl survey \ Additional assessment considerations' below).

ASSESSMENT – ACOUSTIC-TRAWL SURVEY

Overview

Current management of the Pacific sardine population inhabiting the California Current of the northeast Pacific Ocean relies on an estimate of stock biomass (age-1+ fish in mt), which is needed for implementing an established harvest control rule policy for this species on an annual basis (see Harvest Control Rules for the 2017-18 Management Cycle below). It is important to note that the stock assessment team (STAT) recommended that the preferred assessment approach for meeting the management goal was to use results from the acoustic-trawl (AT) survey alone, i.e., not results from an integrated population dynamics model (see Preface above). For purposes of conducting the formal stock assessment review (STAR) in February 2017, methods and results from both the survey-based (AT) and model-based (ALT) approaches were presented in the assessment report distributed for review purposes at the meeting. The final assessment report presented here is similar to the review draft, including the STAT's criteria for choosing an assessment approach for advising management of Pacific sardine in the future, as well as data, parameterizations, and results associated with the two assessment approaches.

Merits of AT survey-based assessment

The AT survey employs objective sampling methods based on state of the art echosounder equipment and an expansive data collection design in the field (Zwolinski et al. 2014). Stock assessments since 2011 indicate that the survey produces the strongest signal of Pacific sardine biomass available for assessing absolute abundance of the stock on an annual basis (i.e., management goal, see Overview above). The survey design is based on an optimal habitat index (Zwolinski et al. 2011), established catchability (Q≈1.0), and commitment to long-term support. Biomass estimates produced by the survey are primarily subjected to random sampling variability and not affected by uncertainty surrounding poorly understood population processes that must be addressed to varying degrees when fitting population dynamics models, simple or complex.

Drawbacks of model-based assessment
In the context of meeting the management goal, a model-based assessment includes considerable additional uncertainty in recent estimated stock biomass of Pacific sardine, given the need to explicitly model critical stock parameters in the assessment that is unnecessary using a survey-based assessment approach. For example, uncertainty surrounding natural mortality (M), recruitment variability (stock-recruitment relationship), biology (longevity, maturity, and growth), and particularly, selectivity, which can substantially influence bottom-line results useful to management. That is, the model-based assessment necessarily includes additional structural and process error, given varying degrees of bias associated with sample data and parameter misspecifications in the model. Further, addressing potential improvements to the AT survey methods and/or design over time (e.g., varying catchability, Q) is less straightforward and more problematic in a model-based assessment approach than basing the formal assessment on the estimate of stock biomass produced from the AT survey each year. Finally, including additional sources of data necessarily degrades the influence of the highest quality data available in the integrated model (AT survey abundance index) for determining recent stock biomass.

Additional assessment considerations
Most importantly, employing a survey-based assessment approach requires projecting estimated stock biomass from the AT survey one year (also required for the model-based approach), given the current assessment/review/management schedule. Currently, management stipulations are set roughly one year following the last year of sample data available for assessing the stock. The Pacific sardine stock assessment reviews (STAR) are conducted early in the year (e.g., February 2017) for applying new management stipulations for the upcoming 'fishing year' (2017-18). Thus, the AT survey biomass estimated in 2016 needs to be projected one year to summer 2017, see Preface above and Projected Estimates (2016-17) below. Second, the integrated model (e.g., model ALT) should be maintained along with the survey-based assessment to evaluate stock parameters of interest, including the stock-recruitment relationship and recent estimates of recruitment, age/length structure of the population, catches and fishing intensity, etc., as well as to use in the unlikely event that the AT survey is unable to be conducted in a particular year. Finally, if workable in the future, the DEPM time series should be maintained as a complementary index of abundance for corroborating/refuting information generated from the AT survey, as well as to help continually improve the AT survey design (e.g., better understanding of the spawning aggregation/migration/timing in the context of range variability exhibited by the population over time).

Methods

Methods and results for the most recent AT survey cruises conducted in spring and summer 2016 are presented in this report. Methods and sampling designs in the field have been generally similar since the survey was first employed in 2006 (model year 2005), noting that changes to areas surveyed occurred seasonally and annually, given the environmental-based optimal habitat index used to select actual transect lines each year. Readers should consult Zwolinski et al. (2014) and Zwolinski et al. (2016) for survey cruises conducted in past years.

The 2016 surveys were conducted onboard the NOAA Fisheries Survey Vessel (FSV) *Reuben Lasker*. Acoustic data were collected during the day to allow sampling of fish schools aggregated throughout the surface mixed layer. Trawling was conducted during the night to sample fish dispersed near the surface (Mais 1974). The spring survey occurred over 30 days (March 22 to April 22), with transects based on sampling the largest extent of the potential sardine habitat, from north to south. Due to persisting warm conditions in the northeast Pacific Ocean, the sardine potential habitat extended into northern California waters farther north than usual for spring and thus, the survey design was modified to accommodate the expanded habitat (Figure 14). The survey started approximately 10 nm north of Newport, Oregon and progressed south to Bodega Bay, California.

The summer survey occurred over 80 days (June 28 – September 22), and transects spanned the west coast of the U.S. and Canada, from the northern end of Vancouver Island to San Diego (Figure 15). Further details on echosounder calibrations, survey design, and sampling protocols are detailed in Stierhoff et al. (*in preparation*) and Zwolinski et al. (*in preparation*).

Acoustic data from each transect were processed using estimates of sound speed and absorption coefficients calculated with contemporary data from Conductivity-Temperature-Depth (CTD) probes. Echoes from schooling CPS were identified with a semi-automated data processing algorithm as described in Demer et al. (2012). The CPS backscatter was integrated within an observational range of 10 m below the sea surface to the bottom of the surface mixed layer or, if the seabed was shallower, to 3 m above the estimated acoustic dead zone (Demer et al. 2009). The vertically integrated backscatter was averaged along 100-m intervals, and the resulting nautical area backscattering coefficients (s_A; m^2 nm^{-2}) were apportioned based on the proportion of the various CPS found in the nearest trawl cluster. The s_A were converted to biomass and numerical densities using species- and length-specific estimates of weight and individual backscattering properties (see details in Demer et al. 2012 and Zwolinski et al. 2014).

Survey data were post-stratified to account for spatial heterogeneity in sampling effort and sardine density. Total biomass in the survey area was estimated as the sum of the biomasses in each individual stratum. Sampling variance in each stratum was estimated from the inter-transect variance calculated using bootstrap methods (Efron 1981), and total sampling variance was calculated as the sum of the variances across strata (see Demer et al. 2012; Zwolinski et al. 2012; and references therein for details). The 95% confidence intervals (CIs) were estimated as the 0.025 and 0.975 percentiles of the distribution of 1,000 bootstrap biomass estimates. Coefficient of variation (CV) for each of the mean values was obtained by dividing the bootstrapped standard errors by the point estimates (Efron 1981).

For each stratum, estimates of abundance were broken down to 1-cm standard length (SL) classes. These abundance-at-length estimates were obtained by raising the length-frequency distribution from each cluster to the abundance assigned to the respective distribution based on the acoustic backscatter. Age-length keys by season were constructed using age and length data from surveys conducted since 2006. In conjunction with a time-invariant weight-length relationship, the number-at-length estimates from the AT survey were transformed into estimates of number-at-age and biomass-at-age for each year. Mean weight-at-age vectors were constructed by dividing the biomass-at-age vectors by the respective vectors of number-at-age. During the STAR Panel (Feb 2017), the STAT was asked to recompile AT weight-at-age matrices using the cohort-smoothing approach applied to fishery samples (see 'Biological Parameters \ Growth'). As noted above, and in STAR (2017), results based on this approach were negligibly different (<1% change in biomass, and one likelihood point improvement) and thus, not included in final model ALT.

The management process requires an estimate of stock biomass (age-1+ fish, mt) at the beginning of the fishing year (July 2017). Since the survey occurred in summer 2016 (considered here July 1, 2016 for simplicity), projection of the biomass to 2017, involved 3 steps: 1) estimating age-0 abundance for 2016; 2) accounting for abundance decrease into 2017 due to natural mortality (M); and 3) accounting for biomass increase due to somatic growth. Because age-0 abundance of sardine is not well characterized from the AT survey (see 'Assessment – Model \ Model Description \ Selectivity' below), the abundance of this age class in July 2016 was estimated using the stock-recruitment (S-R) relationship from the alternative assessment model, model ALT (see 'Assessment – Model \ Results \ Stock-recruitment' below). The SSB input needed for the S-R relationship was obtained by back-calculating the number-at-age estimates for summer 2016 to January 2016 (semester 2 of model year 2015) assuming M=0.3 per semester, followed by conversion into SSB using mean-weight-at-age estimates from the survey and the maturity ogive. The predicted recruitment was then combined accordingly with the vector of other number-at-age estimates from the survey and projected one year into the future assuming M=0.6 yr^{-1} (as assumed in model ALT). The final number-at-age estimates were converted to estimates of biomass-at-age using the estimated mean weight-at-age vector in 2017.

Results

The spring survey totaled 3,850 nm of daytime east-west tracklines and 43 night-time surface trawls resulting in the formation of 18 clusters that were used for species identification and length measurements. The longer summer survey totaled 4,627 nm of daytime east-west tracklines and 121 night-time surface trawls combined into 49 trawl clusters. Post-cruise strata were defined for each survey, considering transect spacing, echoes or catches of CPS, sardine eggs in the Continuous Underway Fish Egg Sampler (CUFES), and the presence of sardine potential habitat (Figures 14 and 16).

In the spring, sardine were primarily concentrated in an area 160 nm long along the coasts of southern Oregon and northern California (Figure 16) and out to 80 nm offshore. Sardine biomass was estimated using 2 strata (Table 6, Figure 16). Stratum 1 contained the largest concentration of CPS backscatter, trawl clusters with sardine, and CUFES samples with sardine eggs (Figures 14 and 16). To the south, stratum 2 contained few adult sardine, no eggs, and relatively low backscatter. Stratum 2 had considerably lower biomass than stratum 1, contributing significantly less to the total biomass in the survey area, which was estimated to be 83,037 mt ($CI_{95\%}$=18,906 to 172,109 mt, CV=49.3 %, Table 6). Globally, the distribution of abundance-at-length estimates had modes at SL=14, 20, and 25 cm (Table 8, Figure 17). The larger-sized cohort was composed of fish age 3 and older, whereas the smaller fish were likely sardine spawned in 2015. The clear separation between the central mode and the two other modes indicates that the central mode encompassed sardine predominantly spawned in 2014.

At the time of the beginning of the summer survey, the sardine potential habitat extended beyond the north of Vancouver Island (Figure 15). Nonetheless, despite the availability of suitable habitat, sardine were only found on the southern end of the Island, around 49 ° N. From there to the south, the stock was highly fragmented and observed in small abundances, except immediately to the north of Point Conception (Figure 15). The entire survey area included an estimated 78,776 mt of Pacific sardine ($CI_{95\%}$=9,538 to 148,287 mt, CV=53.9%, Table 7), with strata 1 and 6 contributing considerably larger biomasses than other strata. The distribution of abundance-at-length estimates had two major modes at 17 and 19 cm, with only minor contributions from other length classes (Table 8, Figure 19). This pattern observed in the length distribution was caused by the disproportionately large abundances observed in strata 1 and 6, which in turn were characterized by a reduced number of clusters. Given the high uncertainty associated with the estimation in these two strata (CV=68.9% and 92.9% for strata 1 and 6, respectively; Table 7), estimated length-at-age of the population was also subject to substantial uncertainty.

Projected Estimates (2016-17)

The projected total estimate of stock biomass (age 1+, mt) for July 2017 from the AT survey was 96,930 mt (Tables 9 and 11). As discussed in Methods above, the projection calculation was based on using number-at-age estimates from the summer 2016 survey (Table 9), along with the recruitment estimate associated with the stock-recruitment relationship in 2016 (from model ALT) discounted for natural mortality (M = 0.6), and finally, converting abundance in numbers to biomass using mean weight-at-age estimates derived from the survey. It is worth noting that this projection is dependent not only on the biomass observed in 2016, but also on the estimated recruitment for 2016. Given the stochastic nature of the past recruitments, it should be expected that a rectification of the 2017 biomass will occur after analysis of the 2017 summer survey. The entire stock biomass time series estimated from the AT survey for 2005-16, including the projected estimate for 2017, is presented in Figure 20. See Appendix 2 in STAR (2017) for additional details regarding biomass projection.

Areas of Improvement for AT Survey

Presently, the AT survey with Q=1.0 is considered to generally provide unbiased measurements of the sardine population (see 'Changes between Last and Current Assessment Model \ Catchability'). Despite this assertion of quality, continued refinement and verification of the survey assumptions will continue in the future. In particular, it is essential that the survey design in the field continues to encompass the entire range of the stock in any given year, as well as expanding areas surveyed by using ancillary sampling tools in situations where the research vessel may have difficulty operating. Combined efforts with state fishery agencies to complement acoustic sampling with optical observations are already underway. Additionally, starting this spring, the SWFSC will begin testing the use of Unmanned Aerial Systems (UAS) to expand its survey capabilities in real time. Besides providing information about the presence of CPS in unnavigable areas, UAS will supplement the use of acoustic sensor to monitor the presence of fish schools near the surface.

Further improvement will continue both in the study of species' target strength (TS), a central parameter to convert acoustic backscatter to numerical densities, and in the improvement of the survey design, particularly in the use of more aggressive adaptive rules that will allow increasing sampling effort in areas with unusually large concentrations of CPS. The use of adaptive sampling procedures will likely reduce the uncertainty of both biomass, species composition, and demography of target species. Also, see 'Assessment Model – Acoustic-trawl Survey / Overview / Additional assessment considerations' above and 'Research and Data Needs' below.

ASSESSMENT – MODEL

History of Modeling Approaches

The population's dynamics and status of Pacific sardine 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. The CANSAR was subsequently modified by Jacobson (Hill et al. 1999) 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, 2006b). In 2007, a STAR Panel reviewed and endorsed an assessment using Stock Synthesis (SS) 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 SS version 3.03a in 2009 (Methot 2009) and was again used for an update 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 assessment (Hill 2013). The 2014 sardine full assessment (Hill et al. 2014), 2015 update assessment (Hill et al. 2015), and 2016 update assessment (Hill et al. 2016) were based on SS version 3.24s. The 2017 full assessment presented here was based on SS version 3.24aa. SS version 3.24aa corrected errors associated with empirical weight-at-age models having multiple seasons.

Responses to 2014 STAR Panel Recommendations

Many of the following recommendations are based on using an integrated model and not directly applicable to the current assessment, given the survey-based assessment represents the preferred approach for advising management of the Pacific sardine resource in the future. Regardless, brief responses are provided for relevant recommendations in the context of the model-based assessment approach using model ALT.

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.

Response: Bilateral stock assessment has long been considered a worthwhile goal. However, a more immediate priority is international collaboration to obtain synoptic survey coverage of the northern subpopulation. Synoptic surveys would also simultaneously provide population estimates of the southern subpopulation, as well as other transboundary CPS stocks (i.e., Pacific mackerel, northern anchovy central subpopulation, and jack mackerel). Synoptic CPS surveys are discussed each year at the Trinational Sardine Forum and Mexico-U.S. bilateral meetings.

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.

Response: Requests for this addition to SS have been made in the past, i.e., it is possible that SS ver. 3.0 will include the error estimate associated with estimated stock biomass. André Punt revised an earlier version of SS to produce this output, however, the results were not markedly different than error estimates produced for SSB.

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.

Response: Fishery managers require advice regarding current and near-future abundance. The STAT considers the above recommendation worthwhile for developing research models, but counterproductive for providing annual management advice.

D. Investigate sensitivity of the assessment to the threshold used in the environmental-based method (currently 50% favorable 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.

Response: No further work has been conducted to address this recommendation.

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).

Response: This recommendation was implemented in model ALT and for the projection model for the AT survey. Methods are described under the Fishery-independent data section above.

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.

<u>Response:</u> *No work has been conducted to address this recommendation.*

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 microstructure, 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.

<u>Response</u>: *Somatic and otolith morphometric analyses were conducted that generally address this recommendation (Felix et al. 2005). The Felix et al. (2005) study complemented a SST-based method published by Felix et al. (2004). Subsequent validation studies have not been undertaken. Genetic methods have been inconclusive.*

H. Continue to investigate the merits/drawbacks of model configurations that include age compositions rather than length-composition and conditional age-at-length data, given some evidence for time- and spatially-varying growth.

<u>Response</u>: *Model ALT incorporates age compositions, age-based selectivity, and empirical weight-at-age time series.*

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.

<u>Response</u>: *While other potential fishery-independent data sources may exist for Pacific sardine (e.g., SWFSC juvenile rockfish survey or California's aerial survey), none have been vetted through a Council-sponsored methodology review. The STAT continues to support and promote use of the single, most objective survey tool available for estimating abundance of CPS, i.e., the SWFSC's AT survey.*

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.

<u>Response</u>: *Very few sardine older than 6 years of age have been observed in either the fishery or survey samples collected to date. Model ALT has been revised to reduce the maximum age from 15 to 10 and the 'accumulator' age for single binning older fish reduced to age 8+.*

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.

<u>Response</u>: *The SWFSC has conducted two surveys per year (spring and summer) since 2012. Summer surveys have typically extended to the northern tip of Vancouver Island, Canada. U.S. survey vessels have not yet had access to Mexican waters and are unlikely to in the near future. INAPESCA recently obtained a new, advanced technology research vessel (BIPO) for surveying the Gulf of California and Baja peninsula. Unfortunately, the BIPO was recently relocated to the Gulf of Mexico and its status for future surveys remains uncertain.*

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.

<u>Response</u>: *No progress has been made toward spatial modeling. Some of the concerns raised regarding regional size-at-age have been accounted for by the use of empirical weight-at-age data and age-based selectivity in model ALT.*

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.

<u>Response</u>: *No further work has been conducted to address this recommendation. That is, this exercise is considered a low priority and unwarranted at this time in the ongoing assessment, given no evidence of sex-specific growth has been observed from biological sample information collected to data (see Assessment Data, Biological Parameters, Growth above).*

N. Consider a model that has separate fleets for Mexico, California, Oregon-Washington and Canada.

<u>Response</u>: *In the past, the STAT has modeled each of these regional fisheries as fleet, which s resulted in an unstable, over-parameterized model. That is, the goal of current model development is to construct a parsimonious assessment model that meets the overriding management objective using/emphasizing the highest quality data available (AT survey abundance time series) in the most straightforward manner (not developed around fine-scale fishery catch and selectivity data).*

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.

<u>Response</u>: *Ensenada fishery length-composition time series are only available at the semester level, so it is not possible to disaggregate the data (either length or age) to account for contribution of NSP fish. For the last several length-based assessments, the semester*

level data were simply down-weighted to account for the NSP catch. The BC fishery length data were not converted to age distributions for model ALT, although this would be theoretically possible to do using an age-length key from the SS model or using data from the OR-WA fisheries. Given the large size of sardines harvested in the BC fishery, this transformation would likely result in skewed age distributions.

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: The SWFSC regularly exchanges survey otolith samples with key personnel with the CDFW for double-reading evaluations. However, as noted in Research and Data Needs below, the STAT has suggested more coordination is needed regarding production ageing across multiple laboratories or possibly, more centralized ageing efforts for Pacific sardine, as well as other CPS stocks.

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.

Response: The DEPM time series is excluded from model ALT.

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.

Response: Assessment model ALT has implemented a change in M from 0.4 yr^{-1} to 0.6 yr^{-1}. Rationale for the change is provided under: Assessment Data, Biological Parameters, Natural mortality above; Changes between Current and Last Assessment Model, Longevity and natural mortality below; and Natural mortality profile below.

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.

Response: Although the newest version of SS (beta ver. 3.0) has added more flexibility for modeling stock-recruitment dynamics, it is uncertain whether such age-specific details will be available in the future.

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.

Response: The SPARC has not met for several years. Canada has no new samples to age, and the majority of existing samples that have been aged are from their summer swept-area trawl survey. The WDFW has aged all samples from the states of Oregon and Washington, but no new samples have been collected since the moratorium. The CDFW and the SWFSC regularly exchange subsamples from the SWFSC's surveys for double reading analysis. Also, see recommendation P above.

Responses to Recent STAR (2017) Panel Requests

During the review in February 2017, additional requests were made during the week-long meeting regarding the proposed survey- and alternative model-based assessments, including evaluating different methods for projecting survey biomass from 2016 to 2017, examining different combinations of data and parameterizations (e.g., growth via empirical weight-at-age matrices and selectivity estimation based on age-vs. length-composition time series) associated with model ALT, and revising outputs and contrasting results across respective models and survey abundance time series. Detailed requests, rationales, and responses associated with sensitivity analysis conducted during the review are presented under Requests made to the STAT during the meeting (STAR 2017).

Changes between Current and Last Assessment Model

Overview

General differences between the current assessment model (ALT) proposed here and the last assessment model (T_2016) used to advise management, as well as model T_2017 that represents an updated T_2016 model are presented in Table 10. Model T_2017 is parameterized similarly as T_2016, with newly available sample information (e.g., catch, composition, and abundance data). As indicated in recent assessments conducted in the past, selectivity estimation continued to result in problematic scaling in model T_2017, with updated length-composition data associated with the AT survey once again resulting in unrealistic estimates of total stock biomass (Figure 21). The AT length-composition time series has continually been poorly fit in the model, with estimated selectivity curves sensitive to even minor additions of new length data. Estimated selectivity of very small, young sardines (6-9 cm, age-0 fish) in the AT survey is low (i.e., in most years, the AT survey does not encounter such sizes/age), so that when small fish are observed occasionally in the survey in limited numbers, selection probabilities translate to implausibly high numbers of young fish present in the population (see STAR 2017). As addressed in past reviews, omitting new length data in the updated assessment alleviated suspect scaling issues (Figure 21) and resulted in a more robust model (e.g., minimized potential for generating retrospective errors generally associated with highly variable terminal estimates of abundance). Given drawbacks of the length-based model above, as well as other data and parameterization considerations noted below (e.g., see Selectivity below), the STAT's proposed model-based assessment in 2017 was model ALT.

In general, model ALT was developed around the most relevant and highest quality source of data available for assessing the status of Pacific sardine, i.e., the focus of model ALT is fitting to the AT survey abundance time series. Finally, it is important to note that model ALT represents the proposed model-based assessment for advising management, but the preferred assessment is a survey-based approach as discussed above (see 'Preface' and 'Assessment – Acoustic-trawl survey \ Overview'). Further details regarding differences/similarities between model ALT and T_2016/T_2017 follow (see accompanying Table 10).

Time period and time step

The modeled timeframe has been shortened by roughly one decade, with the first year in model ALT being 2005, rather than 1993. Time steps in model ALT are treated similarly as in past assessments, being based on two, six-month semester blocks for each fishing year (semester 1=July-December and semester 2=January-June). The need for an extended time period in the model is not supported by the management goal, given that years prior to the start of the AT survey time series provide limited additional information for evaluating terminal stock biomass in the integrated model. Further, although a longer time series of catch may be helpful in a model for accurately determining scale in estimated quantities of interest, estimated trend and scale were not sensitive to changes in start year for model ALT. Finally, Pacific sardine biology (relatively few fish >5 years old observed in fisheries or surveys) further negates the utility of an extended time period in a population dynamics model employed for estimating terminal stock biomass of a short-lived species.

Surveys

Model ALT now includes only an acoustic-trawl survey index of abundance, omitting abundance time series used in past assessments associated with eggs/larvae surveys (daily egg production method – DEPM, and total egg production – TEP). Justification for removing eggs/larvae data from the current model follow: AT survey covers the full range of the stock vs. strictly the spawning aggregation covered by the eggs-larvae surveys; AT survey provides a direct measure of stock biomass vs. an indirect estimate of spawning biomass produced by the eggs/larvae surveys; AT survey provides a snapshot of recent absolute abundance vs. a snapshot of recent relative spawning production generated by the eggs/larvae surveys; and AT survey is based on an efficient survey design that minimizes temporal/sampling biases and maximizes estimate precision vs. much less flexible eggs/larvae surveys that are more prone to sampling biases in the field. Further, shortening the modeled time period necessarily results in omission of the TEP time series, which ended in 2005 (also noting that the TEP method results in a lower quality index of egg production due to lack of adult reproductive parameters). Additionally, the DEPM time series is essentially uninformative in model ALT, which produces similar results with or without inclusion of the eggs/larvae survey. Finally, the AT survey abundance time series in the ALT model is no longer partitioned into independent indices based on spring and summer cruises, but rather, now reflects a single abundance index that, in some years, includes multiple (seasonal) estimates.

Fisheries

Fishery structure in model ALT is similar to past assessments. Three fisheries are included in the model, including two Mexico-California *fleets* separated into semesters (MEXCAL_S1 and MEXCAL_S2) and one *fleet* representing Pacific Northwest fisheries (Canada-WA-OR, PNW). Also, because the California live bait industry currently reflects the only active sector in the U.S. sardine fishery, minor amounts of live bait landings were included in the current assessment based on model ALT.

Longevity and natural mortality

Biology assumptions for Pacific sardine in model ALT have been revised, including decreasing longevity and increasing natural mortality (*M*). Justification for revised assumptions for longevity (15 to 10 years) and *M* (0.4 to 0.6 yr^{-1}) follow: recommended in past assessment reviews; biological parameters are now consistent with observed length and age data collected from the fisheries and surveys (limited numbers of fish >5 years old observed in composition time series since 2000); supportive evidence from mortality studies from AT survey research

(Zwolinski and Demer 2013), as well as from general research addressing underlying correlation between maximum lifespan and mortality (Hoenig 1983); and finally, higher *M* estimates (0.55-0.65 yr^{-1}) were consistent with other estimated parameters associated with the highest priority data in the model, e.g., assumption that AT survey catch rates are applicable to the entire population in any given year ($Q \approx 1$), see Natural mortality profile below. Also, see 'Assessment Data \ Biological Parameters \ Natural mortality' above and 'Natural mortality profile' below.

Growth
A matrix of empirical weight-at-age estimates by year/semester is now used in model ALT to translate derived numbers-at-age into biomass-at-age, rather than estimating growth internally in the model as conducted previously in past assessments. Treatment of growth using empirical weight-at-age matrices associated with the fisheries, survey, and population greatly simplifies the overall assessment, while also allowing growth to vary across time and minimizing potential conflicts with selectivity parameterization. Also, see 'Assessment Data \ Biological Parameters \ Growth' above.

Stock-recruitment relationship
Beverton-Holt stock-recruitment (*S-R*) parameters are estimated in model ALT, including both virgin recruitment ($\log R_0$) and steepness (*h*), which represents a change from recently conducted assessments that estimated $\log R_0$, but fixed *h*=0.8. That is, fixing *h* at an assumed higher value in concert with fixed *M* necessarily constrained the model, resulting in relatively optimistic results, given the assumption that productivity remains high at low parent stock size. Finally, general sensitivity analysis during development of model ALT resulted in robust estimates of $\log R_0$ (~14.2) and *h* (~0.36). Also, see 'Model Description \ Stock-recruitment relationship,' 'Results \ Stock-recruitment relationship,' and 'Uncertainty Analyses \ Sensitivity analysis' below.

Selectivity
Selectivity in model ALT is based on age compositions and age-based selectivity, rather than length compositions and length-based selectivity as used in recently conducted past assessments. Primary justification for changing how selectivity is treated in the integrated model is based on the overriding goal to develop a parsimonious model that includes the most efficient parameterizations in the age-structured modeling platform (SS). Further, results from recent assessments have been particularly sensitive to minor changes (updates) to length-composition time series, which has been highlighted as a problematic area over the last few years in the ongoing assessment (Hill et al. 2014, 2015, 2016; STAR 2014). Also, see 'Model Description \ Selectivity' below.

Catchability
Catchability (*Q*) is freely estimated for the AT survey in model ALT, which is a major change from past assessments that have assumed *Q*=1.0 for the primary index of abundance in the assessment. That is, model ALT illustrates that a critical assumption underlying the survey-based assessment approach (i.e., AT survey methods and design allow efficient sampling within the stock's range in any given year, or $Q \approx 1$) is supported using a relatively simple integrated assessment model that includes other ancillary sources of data (e.g., catch and composition data),

is based on realistic assumptions/parameterizations (e.g., *M*, growth, and stock-recruitment), is internally consistent (data conflicts are minimized), and generates robust results.

Model Description

Important parameterizations in model ALT are described below. Information for particular parameterizations is also presented under ‘Changes between Current and Last Assessment Model’ above.

Assessment program with last revision date

In 2014, the stock assessment team (STAT) transitioned from Stock Synthesis (SS) version 3.21d to version 3.24s (Methot 2013, Methot and Wetzel 2013), which was used for all assessments through 2016. In 2017, the SS model received some additional minor revisions and recompiled (version 3.24aa) to accommodate empirical weight-at-age data in a semester-based model. The SS model is comprised of 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. 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 modeling effort.

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 ‘PNW’ fleet (fishery) includes data from the northern range of the stock’s distribution, where sardine are typically abundant between late spring and early fall. The PNW 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 model ALT is presented in Table 12. The total objective function was based on the following individual likelihood components: 1) fits to catch time series; 2) fits to the AT survey abundance index; 3) fits to age compositions from the three fleets and AT survey; 4) deviations about the stock-recruitment relationship; and 5) minor contributions from soft-bound penalties associated with particular estimated parameters.

Initial population and fishing conditions
Given the Pacific sardine stock has been exploited since the early 20th Century (i.e., well before the start year used in model ALT), further information is needed to address equilibrium assumptions related to starting population dynamics calculations in the assessment model. One approach is to extend the modeled time period backwards in time to the start of the small pelagic fisheries off the U.S. west coast and in effect, ensure no fishing occurred prior to the start year in the model. In an integrated model, this method can be implemented by: 1) extending the catch time series back in time and confirming that harvest continues to decline generally as the onset of the fishery is approached; or 2) estimating additional parameters regarding initial population and fishing conditions in the model. Given assumptions regarding initial equilibrium for Pacific sardine (a shorter-lived species with relatively high intrinsic rates of increase) are necessarily difficult to support regardless of when the modeled time period begins, as well as the extreme length of an extended catch time series (early 1900s) that would be needed in this case, the approach above was adopted in this assessment, as conducted in all previous assessments to date.

The initial population was defined by estimating 'early' recruitment deviations from 1999-04, i.e., six years prior to the start year in the model. Initial fishing mortality (*F*) was estimated for the MEXCAL_S1 fishery and fixed=0 for MEXCAL_S2 and PNW fisheries, noting that results were robust to different combinations of estimated vs. fixed initial *F* for the three fisheries. In effect, the initial equilibrium age composition in the model is adjusted via application of early recruitment deviations prior to the start year of the model, whereby the model applies the initial *F* level to an equilibrium age composition to get a preliminary number-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 here), 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). Ultimately, this parsimonious approach reflects a non-equilibrium analysis or rather, allows for a relaxed equilibrium assumption of the virgin (unfished) age structure at the start of the model as implied by the assumed natural mortality rate (*M*). Finally, an equilibrium 'offset' from the stock-recruitment relationship was estimated and along with the early recruitment deviation estimates allowed the most flexibility for matching the population age structure to the initial age-composition data at the start of the modeled time period.

Growth
See 'Changes between Current and Last Assessment Model \ Growth' above.

Stock-recruitment relationship
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. In the semester-based model ALT, spawning stock biomass (SSB) is calculated at the beginning of S2 (January). Recruitment was specified to occur in S1 of the following model year (consistent with the July 1st birth-date assumption). In past assessments, a Ricker stock-recruitment (S-R) relationship had been assumed following Jacobson and MacCall (1995), however, following recommendations from past reviews, a Beverton-Holt S-R has been implemented in all assessments since 2014.

Virgin recruitment (R_0), initial equilibrium recruitment offset (R_1), and steepness (h) were estimated. Following recommendations from past assessments, the estimate of average recruitment variability (σ_R) assumed in the S-R relationship was set to 0.75 since 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 1999-04 (six years before the start of the model). A recruitment bias adjustment ramp (Methot and Taylor 2011) was applied to the early period and bias-adjusted recruitment estimated in the main period of the model (Figure 31). Main period recruitment deviations were advanced one year from that used in the last assessment, i.e., estimated from 2005-15 (S2 of each model year), which translates to the 2016 year class being freely estimated (albeit poorly) from the 2016 data available in the model.

It is important to note that there exists little information in the assessment to directly evaluate recent recruitment strength (e.g., absolute numbers of age-0, 6-9 cm fish in the most recent year), with the exception of age data from the southern fisheries, which have caught these juveniles infrequently in past years in low volume during their first semester of life (S1), but in greater amounts during their second semester (MEXCAL_S2). Age-0 recruits are rarely observed in the PNW fishery. Age-0 fish are not typically encountered by the AT survey, except for limited occurrences in particular years and in relatively high numbers observed in one cruise (summer 2015).

Selectivity

Age-composition time series from the MEXCAL and PNW fisheries were modeled using age-based selectivity. The MEXCAL compositions were fit based on each age as a random walk from the previous age, which resulted in domed-shaped selectivity similar to fits from a double-normal selectivity form as used in past assessments, i.e., supporting the assumption that older/larger fish are not generally available to the southern fisheries, both historically and presently. Selectivity for the MEXCAL fleet was estimated by semester (S1 and S2) to better account for both seasonal- and decadal-scale shifts in sardine availability to the southern region. The PNW fishery age compositions were fit using asymptotic selectivity (two-parameter logistic form), given this stock's biology and strong evidence that larger, older sardines typically migrate to more northern feeding habitats each summer. A simple asymptotic selectivity form was used for the AT survey, whereby age-0 fish were assumed to be unavailable and age 1+ fish fully selected. Justifications for a simplified selectivity form for the AT survey follow: the survey is based on sound technical methods and an expansive sampling operation in the field using an optimal habitat index for efficiently encountering all adult fish in the stock (Demer and Zwolinski 2014); observations of age-1 fish in length- and age-composition time series, to some degree, in every year; recognition of some level of ageing bias in the laboratory that may confound explicit interpretation of estimated age compositions, e.g., low probability of selection of age-1 fish in a particular year may be attributed to incorrectly assigned ages for age-0 or age-2 fish; and minor constraints to selectivity estimation, which typically reflects a sensitive parameterization that can substantially impact model results, supports the overriding goal of the assessment, i.e., parsimonious model that is developed around the AT survey abundance index. Finally, in addition to potential biases associated with the trawling and ageing processes, the age-1+ selectivity assumption recognizes the vulnerability of adult sardine with fully-developed swim bladders to echosounder energy in the acoustic sampling process. That is, there are three selectivity components to consider with the acoustic-trawl method: 1) fish availability with regard to the actual area surveyed each year; 2) vulnerability of fish to the acoustic sampling gear; and 3) vulnerability of fish to the mid-water trawl (avoidance and/or extrusion). No evidence exists that sardine with fully-developed swim bladders (i.e., greater than age 0) are missed by the acoustic equipment, further supporting the assumption that age-1+ fish are fully-selected by the survey in any given year.

Catchability
See 'Changes between Current and Last Assessment Model \ Catchability' above.

Convergence criteria and status
The iterative process for determining numerical solutions in the model was continued until the difference between successive likelihood estimates was <0.00001. The total likelihood and final gradient estimates for model ALT were 333.256 and 8.97*e*-6, respectively.

Results

The following results pertain to model ALT. Estimates for important parameterizations and derived quantities useful to management are also presented in Tables 10-16.

Parameter estimates and errors
Parameter estimates and standard errors (SE) for model ALT are presented in Table 12.

Growth estimates
Growth parameters were not estimated in model ALT, rather, empirical weight-at-age estimates by year were used to convert estimated numbers into weight of fish for calculating important biomass quantities useful to management (Figures 5-8).

Selectivity estimates and fits to fishery and survey age-composition time series
Age-based selectivity estimates (ogives) for the three fisheries and AT survey are presented in Figure 22. Model fit displays to fishery and AT survey age compositions (including observed and effective sample sizes) and associated Pearson residual plots are presented in Figures 23-26. The fishery (MEXCAL_S1, MEXCAL_S2, and PNW) age-composition time series were fit relatively well in most years, but poor fits were observed in some years, particularly, for the most recent years in the time series (Figures 23-26). Poor fits to the AT survey age-composition time series were indicated in most years (Figure 26). See 'Uncertainty Analyses / Selectivity analysis' below.

Fit to survey index of abundance
Model fits to the AT survey abundance index in arithmetic and log scale are presented in Figure 27. The predicted fit to the survey index was generally good (near mean estimates and within error bounds), particularly, for the most recent years of the time series (Figure 27). As illustrated in past assessments, the notable exception in the fitted time series was for the initial survey year 2005 (spring 2006 cruise), which was under-estimated and outside the estimated confidence interval. Estimated catchability (*Q*) for the AT survey was 1.1 (Table 12). Also, see 'Changes between Current and Last Assessment Model / Catchability' above.

Stock-recruitment relationship
Recruitment was modeled using a Beverton-Holt stock-recruitment (S-R) relationship (Figure 28). The assumed level of underlying recruitment deviation error was fixed (σ_R=0.75), virgin (unfished) recruitment was estimated (logR_0=14.2), and steepness was estimated (h=0.36) (Table 12). Recruitment deviations for the early (1999-04), main (2005-15), and forecast (2016-17) periods in the model are presented in Figure 29). Asymptotic standard errors for recruitment deviations are displayed in Figure 30 and the recruitment bias adjustment plot for early, main, and forecast periods in model ALT is shown in Figure 31.

Population number- and biomass-at-age estimates
Population number-at-age estimates for model ALT are presented in Table 13. On average, age 0-3 fish have comprised roughly 85% of the total number of Pacific sardine in each year from 2005-17. Corresponding estimates of population biomass-at-age, total biomass (age-0+ fish, mt) and stock biomass (age-1+ fish, mt) are shown in Table 14. On average, age 0-3 fish have comprised roughly 65% of the total population biomass in each year from 2005-17.

Spawning stock biomass
Time series of estimated spawning stock biomass (SSB, mmt) and associated 95% confidence intervals are presented in Table 15 and Figure 32. The virgin level of SSB was estimated to be 107,915 mt (0.11 mmt). The SSB has continually declined since 2005-06, reaching historically low levels in recent years (2014-present).

Recruitment
Time series of estimated recruitment (age 0, billions) abundance is presented in Table 15 and Figure 34. The virgin level of recruitment (R_0) was estimated to be 1.52 billion age-0 fish. As indicated for SSB above, recruitment has largely declined since 2005-06, with the exception of a brief period of modest recruitment success from 2009-10. In particular, the 2011-15 year classes have been among the weakest in recent history. A small increase in recruitment was observed in 2016, albeit a highly variable estimate (CV=79%) based on limited data.

Stock biomass for PFMC management
Stock biomass, used for calculating annual harvest specifications, is defined as the sum of the biomass for sardine ages one and older (age 1+) at the start of the management year. Time series of estimated stock biomass (mmt) are presented Table 14 and Figure 33. As discussed above for both SSB and recruitment, a similar trend of declining stock biomass has been observed since 2005-06, plateauing at recent historical low levels since 2014 (roughly 78,000 mt, 0.08 mmt).

Fishing and exploitation rates
Estimated fishing mortality (F) time series by fishery are presented in Figure 35. Fishing mortality has been generally less than 0.4 yr^{-1} since 2005-06, with the exception of the PNW fishery in 2005 and from 2012-13, with F estimates above 1.0 yr^{-1}.

Exploitation rate is defined as the calendar year northern sub-population (NSP) catch divided by the total mid-year biomass (July 1st, ages 0+). The U.S. and total exploitation rates for the NSP are shown in Figure 36. The U.S. exploitation rate was less than 10% from 2005-11, increased sharply from 2012-14 to over 25%, and dropped again to under 5% recent years. The total exploitation rate time series followed a similar trend, with exploitation rates less than 17% from 2005-11, increasing to 40% by 2013, and decreasing to similar levels as for the U.S. in recent years.

Uncertainty Analyses

Virgin recruitment profile

Virgin recruitment (R_0) profiles are useful for identifying the extent conflicts between data components included in the assessment potentially influence underlying scale in the model (Lee et al. 2014). Components in model ALT include composition (fishery and survey age-composition time series) and abundance (AT survey index of abundance) data. A R_0 profile for model ALT is presented in Figure 37. The profile was conducted over a range of assumed (fixed) R_0 values from 13.5 to 15, with multiple runs at each R_0 level, based on jittering starting values for estimated parameters to ensure model convergence. The profile indicated all sources of data in model ALT were generally consistent, with each component illustrating better fitting models were associated with lower vs. higher assumed levels of R_0. The individual total profile indicates the model ALT configuration (R_0=14.236) appears to have realized a global minimum total likelihood estimate.

Natural mortality profile

Treatment of natural mortality (*M*) in model ALT is discussed above, see 'Longevity and natural mortality.' Uncertainty associated with the assumed (fixed) level of natural mortality in model ALT (*M*=0.6 yr^{-1}) was also evaluated by profiling across a range of fixed levels of the stock parameter of interest, *M* (Table 16 and Figure 38). The profile was conducted using a range of *M* values from 0.35 to 0.75 yr^{-1}. In the context of the ALT model, models with higher assumed levels of *M* resulted in lower estimates of AT survey catchability (*Q*), and higher terminal estimates of spawning stock biomass and stock biomass. Model fits to most data components, as well as total likelihood estimates indicated slightly better fits to lower estimates of *M*, however, the AT survey index of abundance and MEXCAL_S1 age-composition data indicated better fitting models at higher *M* (Table 16 and Figure 38). The range of recent estimated stock biomass (2014-17) associated with the *M* profile is presented in Figure 38, with terminal year estimates (2017) that ranged from roughly 40,000 mt (*M*=0.35 yr^{-1}) to 160,000 mt (*M*=0.75 yr^{-1}).

Retrospective analysis

Retrospective analysis provides another means of examining model properties and characterizing uncertainty. A retrospective analysis was performed for model ALT, whereby data were incrementally removed from the terminal year backwards in time to 2000. Estimated stock biomass time series from this analysis are presented in Figure 39. For the most part, no notable retrospective pattern was indicated by the analysis, i.e., no systematic bias of overestimating biomass in the terminal year was illustrated through sequentially removing data from the model backwards in time. A slight retrospective bias was indicated as data were removed four or more years back in time. It is important to note that some degree of retrospective bias would be expected from a stock assessment of short-lived, productive species like Pacific sardine, given little information is available in the integrated model for estimating recruitment that typically is highly variable in any given year based on immediate oceanographic conditions.

Sensitivity analysis (survey abundance indices, AT survey selectivity, stock-recruitment steepness, data weighting methods, and fishery time-varying selectivity)

Sensitivity analyses were conducted prior and during the review in February that addressed assumptions for survey (AT and DEPM) time series included in the model, AT survey selectivity forms, stock-recruitment (S-R) steepness (*h*), and alternative data weighting approaches for model ALT. Estimates for likelihood components, specific parameters, and derived quantities of interest associated with the models evaluated in sensitivity analysis are presented in Table 17. Estimated stock biomass (age-1+ fish, mt) time series are compared between the different model scenarios in Figure 40. Also, further discussion regarding models evaluated in sensitivity analysis, as well as other configurations investigated during the review are presented in STAR (2017). As illustrated in past assessments, inclusion of the DEPM index of abundance in the model had little influence on results, with nearly identical stock biomass trajectories observed and slightly higher terminal estimate of stock biomass for the model that included both indices of abundance. Basing the AT survey selectivity on a simple (two-parameter logistic) asymptotic form as used for the PNW fishery resulted in generally similar estimated selectivity as the age-1+ fully-selected form used in model ALT, but indicating only partially selected younger ages (i.e., 5% vs. 0%, 25% vs. 100%, and 70% vs. 100% selection for ages 0, 1, and 2, respectively), which resulted in higher estimated stock biomass in the terminal year (approximately 153,000 mt vs. 87,000 mt in model ALT). Fixing S-R steepness at the level assumed in recent assessments (h=0.8) had little effect in the model, with estimated stock biomass in the terminal year equal to roughly 112,00 mt vs. 87,000 mt for model ALT (estimated steepness, h=0.36). Two alternative data weighting approaches ('Francis method' and 'harmonic-mean method' in Stock Synthesis) implemented in model ALT resulted in generally similar findings as the non-weighted baseline model, with slightly higher estimated stock biomass in the terminal year than model ALT; see Francis (2011), Methot and Wetzel 2013, and Punt (in press). Finally, modeling time-varying selectivity for the fisheries resulted in notably better fits to the fishery age-composition time series, with generally similar estimates of derived quantities useful to management as estimated in model ALT (i.e., time invariant selectivity configuration). However, models with time-varying fishery selectivity were inherently less stable, with lack of convergence for many runs or indications of local minima when convergence was realized.

Convergence tests

Convergence properties of model ALT were tested to ensure the model represented an optimal solution. Model ALT was run with a wide range of initial starting values for R_0 (13.1 to 15.1). For each run, phase order for estimating parameter components (e.g., R_0, R_1, steepness, initial F, selectivity, and AT survey Q) was randomized from 1 to 5, and all parameters were jittered by 20% (Table 18). All models converged to the same total negative log likelihood estimate (333.256) and had identical final estimates of R_0 (14.2359). Model ALT appeared to have converged to a global minimum (also, see 'Virgin recruitment profile' above).

Historical analysis

Estimates of stock biomass (age-1+ fish, mt) and recruitment (age-0 fish, billions) for model ALT were compared to recently conducted assessments in Figure 41. Full and updated stock assessments since 2009 (Hill et al. 2009-16) are included in the comparison. Stock biomass and recruitment trends were generally similar, with notable differences in scale between particular years. It is important to note that all previous assessments (since 2009) were structured very similarly (e.g., similar model dimensions, data, assumptions, and parameterizations). Whereas, the newly developed ALT model (2017) reflects a much simpler version of past assessments models (See 'Changes between Current and Last Assessment Model' above), necessarily confounding direct comparisons between results from this year's model with past assessments.

HARVEST CONTROL RULES FOR THE 2017-18 MANAGEMENT CYCLE

Harvest Guideline

The annual harvest guideline (HG) is calculated as follows:

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

where HG is the total U.S. directed harvest for the period July 2017 to June 2018, BIOMASS is the stock biomass (ages 1+, mt) projected as of July 1, 2017, CUTOFF (150,000 mt) is the lowest level of biomass for which directed harvest is allowed, FRACTION (E_{MSY} bounded 0.05-0.20) 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. Based on results from model ALT, estimated stock biomass is projected to be below the 150,000 mt threshold and thus, the HG for 2017-18 would be 0 mt. Harvest estimates for model ALT are presented in Table 19.

OFL and ABC

On March 11, 2014, the PFMC adopted the use of CalCOFI sea-surface temperature (SST) data for specifying environmentally-dependent E_{MSY} each year. The E_{MSY} is calculated as,

$$E_{MSY} = -18.46452+3.25209(T)-0.19723(T^2)+0.0041863(T^3),$$

where T is the three-year running average of CalCOFI SST (Table 20, Figure 42), and E_{MSY} for OFL and ABC is bounded between 0 to 0.25 (Figure 42). Based on the recent warmer conditions in the CCE, the average temperature for 2014-16 increased to 15.9999 °C, resulting in E_{MSY}=0.2251.

Estimated stock biomass in July 2017 for model ALT was **86,586 mt** (Table 19). The overfishing limit (OFL, 2017-18) associated with that biomass was **16,957 mt** (Table 19). Acceptable biological catches (ABC, 2017-18) for a range of *P-star* values (Tier 1 σ=0.36; Tier 2 σ=0.72) associated with model ALT are presented in Table 19.

REGIONAL MANAGEMENT CONSIDERATIONS

Pacific sardine, as well as other species considered in the CPS FMP, are not managed formally on a regional basis within the USA, due primarily to the extensive distribution and annual migration exhibited by these small pelagic stocks. A form of regional (spatial/temporal) management has been adopted for Pacific sardine, whereby seasonal allocations are stipulated in attempts to ensure regional fishing sectors have at least some access to the directed harvest each year (PFMC 2014).

RESEARCH AND DATA NEEDS

Research and data needed for improving stock assessments of the Pacific sardine resource in the future address three major areas that are presented in descending order of importance below.

First and foremost, the most important area of focus should be improvements associated with the highest priority data available for assessing recent stock biomass on an annual basis, namely, the acoustic-trawl (AT) survey index of abundance (see 'Assessment – Acoustic-trawl Survey \ Overview' above). This is the case whether future management will be based directly on the AT survey or via an integrated model. The AT survey methods and design are founded currently on objective scientific bases, however, the need for continual improvement for specific areas include: 1) Target-strength estimation for local species; 2) determine potential biases due to the non-sampling of near-surface waters and shallow regions on the east end of the transects; and 3) implications of the time-lag between acoustic observations and trawl sampling operations (see 'Assessment – Acoustic-trawl Survey \ Areas of Improvement for the AT Survey' above). Additionally, improved relations with neighboring countries that also commercially target the northern sub-population of Pacific sardine (particularly, Mexico) are needed to establish a broader survey boundary than possible presently (e.g., Baja California, Mexico to Vancouver Island, Canada), which would allow stock structure hypotheses for this species to be evaluated more objectively. Finally, long-term support and commitment to the AT survey will benefit more than Pacific sardine alone, given these data represent the highest quality information available for determining recent stock biomass for all members of the small pelagic fish assemblage of the California Current ecosystem, including northern anchovy (northern and central sub-stocks), as well as mackerel populations (e.g., Pacific and jack)—noting that further attention is needed surrounding catchability issues that remain unresolved for these transboundary stocks and the extent to which a species' range in any given year may be outside the survey design's boundaries.

Second, maintaining a high quality (accurate and precise) composition time series, both age and size (length and weight), is critical for either assessment approach, but particularly, for using an integrated model for assessing the status of the stock. Data collection of biological samples by the three state fishery agencies (CDFW, ODFW, and WDFW) is adequate presently, but obtaining such data from Canada and particularly Mexico, has been somewhat problematic in the past. Further, multiple ageing operations are relied on currently, which would benefit from further coordination that ensures samples are efficiently processed in a timely manner and related ageing bias is minimized across laboratories. In this context, a major change that warrants further consideration would be to revisit the merits and drawbacks of using multiple ageing laboratories vs. trying to better centralize ageing operations under a single laboratory.

Third, a schedule should be adopted for conducting biology-related studies for informing critical biological parameters in a model-based assessment. For example, revisiting assumed maturity schedules currently used for Pacific sardine (this is done every year when the DEPM data are processed), as well as periodically evaluating growth parameters applicable to the stock, even though growth is no longer an estimated parameter in the model-based assessment. That is, it is important that data for generally informing biology parameters applicable to the stock continue to be collected and processed according to an efficient schedule that allows both the survey- and particularly, model-based assessment to be updated systematically. For example, an ideal schedule for conducting (coastwide) biology projects related to Pacific sardine would be every 5-7 years.

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LITERATURE CITED

Ahlstrom, E. H. 1960. Synopsis on the biology of the Pacific sardine (*Sardinops caerulea*). Proc. World Sci. Meet. Biol. Sardines and Related Species, FAO, Rome, 2: 415-451.

Barnes, J. T., L. D. Jacobson, A. D. MacCall, and P. Wolf. 1992. Recent population trends and abundance estimates of the Pacific sardine (*Sardinops sagax*). CalCOFI Rep. 33: 60-75.

Baumgartner, T., A. Soutar, and V. Ferriera-Bartrina. 1992. Reconstruction of the history of pacific sardine and northern anchovy populations over the past two millennia from sediments of the Santa Barbara Basin, California. CalCOFI Rep. 33: 24-40.

Butler, J. L. 1987. Comparisons of the larval and juvenile growth and larval mortality rates of Pacific sardine and northern anchovy and implications for species interactions. Ph. D. Thesis, Univ. Calif., San Diego, 240 pp.

Butler, J.L., P.E. Smith, and N.C.H. Lo. 1993. The effect of natural variability of life-history parameters on anchovy and sardine population growth. CalCOFI Rep. 34: 104-111.

Clark, F. N., and J. F. Janssen. Jr. 1945. Movements and abundance of the sardine as measured by tag returns. Calif. Div. Fish Game Fish. Bull. 61: 7-42.

Clark, F. N., and J. C. Marr. 1955. Population dynamics of the Pacific sardine. CalCOFI Prog. Rep. 1 July 1953-31 March 1955: 11-48.

CONAPESCA. 2015. Anuario Estadístico de Acuacultura y Pesca. http://www.conapesca.sagarpa.gob.mx/wb/cona/cona_anuario_estadistico_de_pesca

Conser, R. J., K. T. Hill, P. R. Crone, N. C. H. Lo, and D. Bergen. 2003. Stock assessment of Pacific sardine with management recommendations for 2004: Executive Summary. Pacific Fishery Management Council, November 2003. 15 p.

Conser, R., K. Hill, P. Crone, N. Lo, and R. Felix-Uraga. 2004. Assessment of the Pacific sardine stock for U.S. management in 2005: Pacific Fishery Management Council, November 2004. 135 p.

Cushing, D. H. 1971. The dependence of recruitment of parent stock on different groups of fishes. J. Cons. Int. Explor. Mer. 33: 340-362.

Cutter, G. R. and D. A. Demer. 2008. California current ecosystem survey 2006: Acoustic cruise reports for NOAA FSV *Oscar Dyson* and NOAA FRV *David Starr Jordan*. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-415. 103 p.

Demer, D. A., J. P. Zwolinski, K. A. Byers, G. R. Cutter, J. S. Renfree, T. S. Sessions, B. J. Macewicz. 2012. Prediction and confirmation of seasonal migration of Pacific sardine (*Sardinops sagax*) in the California Current Ecosystem. Fish. Bull. 110:52-70.

Demer, D.A., Zwolinski, J.P. 2014. Corroboration and refinement of a method for differentiating landings from two stocks of Pacific sardine (*Sardinops sagax*) in the California Current. ICES Journal of Marine Science 71(2): 328-335.

Deriso, R., T. J. Quinn and P. R. Neal. 1985. Catch-age analysis with auxiliary information. Can. J. Fish. Aquat. Sci. 42:4.

Deriso, R. B., J. T. Barnes, L. D. Jacobson, and P. J. Arenas. 1996. Catch-at-age analysis for Pacific sardine (*Sardinops sagax*), 1983-1995. CalCOFI Rep. 37:175-187.

Dorval, E., McDaniel, J.D., Porzio, D.L., Hodes, V., Felix-Uraga, R., Rosenfield, S. 2013. Computing and selecting ageing errors to include in stock assessment models of Pacific sardine (*Sardinops sagax*). CalCOFI Rep. 54: 1-13.

Dorval, E., B.J. Macewicz, D.A. Griffith, and Y. Gu. 2016. Spawning biomass of Pacific sardine (*Sardinops sagax*) estimated from the daily egg production method off California in 2015.

U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-560. 47 p. https://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-560.pdf

Efron, B. 1981. Nonparametric standard errors and confidence intervals. The Canadian Journal of Statistics, 9: 139-172.

Eschmeyer, W. N., E. S. Herald, and H. Hammann. 1983. A Field Guide to Pacific Coast Fishes of North America. Houghton Mifflin Company, Boston, MA. 336 p.

Félix-Uraga, R., V. M. Gómez-Muñoz, C. Quiñónez-Velázquez, F. Neri Melo-Barrera, and W. García-Franco. 2004. On the existence of Pacific sardine groups off the west coast of Baja California and Southern California. CalCOFI Rep. 45: 146-151.

Felix-Uraga, R., V. M. Gómez-Muñoz, C. Quiñónez-Velázquez, F. Neri Melo-Barrera, K. T. Hill and W. García-Franco. 2005. Pacific sardine stock discrimination off the west coast of Baja California and southern California using otolith morphometry. CalCOFI Rep. 46: 113-121.

Francis, R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68:1,124-1,138.

García F. W. and Sánchez R. F. J. 2003. Análisis de la pesquería de pelágicos menores de la costa occidental de Baja California durante la temporada del 2002. Boletín Anual 2003. Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. Instituto Nacional de la Pesca. Centro Regional de Investigación Pesquera de Ensenada, Cámara Nacional de la Industria Pesquera y Acuícola, Delegación Baja California. 15 p.

Garcia-Morales, R. Shirasago-German, B. Felix-Uraga, R. and Perez-Lezama, E.L. 2012. Conceptual models of Pacific sardine distribution in the California Current system. Current Develop. Oceangr. 5(1): 23-47.

Hart, J. L. 1973. Pacific fishes of Canada. Fish. Res. Board Can., Bull. 180. 740 p.

Hedgecock, D., E. S. Hutchinson, G. Li, F. L. Sly, and K. Nelson. 1989. Genetic and morphometric variation in the Pacific sardine, *Sardinops sagax caerulea*: comparisons and contrasts with historical data and with variability in the northern anchovy, *Engraulis mordax*. Fish. Bull. 87: 653-671.

Hill, K. T. 1999. Determining age composition of coastal pelagic species in northern California, Oregon, and Washington coastal waters. Pacific States Marine Fisheries Commission. Gladstone, Oregon. Project #1-IJ-9 Final Report. 47 p.

Hill, K.T. 2013. Pacific sardine biomass projection in 2013 for U.S. management during the first half of 2014 (Executive Summary). Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220. 8 p.

Hill, K.T., L.D. Jacobson, N.C.H. Lo, M. Yaremko, and M. Dege. 1999. Stock assessment of Pacific sardine for 1998 with management recommendations for 1999. Calif. Dept. Fish. Game. Marine Region Admin. Rep. 99-4. 92 pp.

Hill, K. T., N. C. H. Lo, B. J. Macewicz, and R. Felix-Uraga. 2006a. Assessment of the Pacific sardine (*Sardinops sagax caerulea*) population for U.S. management in 2006. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-386. 75 p.

Hill, K. T., N. C. H. Lo, B. J. Macewicz, and R. Felix-Uraga. 2006b. Assessment of the Pacific sardine (*Sardinops sagax caerulea*) population for U.S. management in 2007. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-396. 99 p.

Hill, K. T., E. Dorval, N. C. H. Lo, B. J. Macewicz, C. Show, and R. Felix-Uraga. 2007. Assessment of the Pacific sardine resource in 2007 for U.S. management in 2008. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-413. 178 p.

Hill, K. T., E. Dorval, N. C. H. Lo, B. J. Macewicz, C. Show, and R. Felix-Uraga. 2008. Assessment of the Pacific sardine resource in 2008 for U.S. management in 2009. PFMC, Nov 2008, Agenda Item G.2.b, 236 p.

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

Hill, K. T., N. C. H. Lo, B. J. Macewicz, P. R. Crone, and R. Felix-Uraga. 2010. Assessment of the Pacific sardine resource in 2010 for U.S. management in 2011. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-469. 137 p.

Hill, K. T., P. R. Crone, N. C. H. Lo, B. J. Macewicz, E. Dorval, J. D. McDaniel, and Y. Gu. 2011. Assessment of the Pacific sardine resource in 2011 for U.S. management in 2012. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-487. 260 p.

Hill, K.T., Crone, P.R., Lo, N. C. H., Demer, D.A., Zwolinski, J.P., Macewicz, B.J. 2012. Assessment of the Pacific sardine resource in 2012 for U.S. management in 2013. NOAA Technical Memorandum NMFS-SWFSC-501.

Hill, K. T., P. R. Crone, D. A. Demer, J. P. Zwolinski, E. Dorval, and B. J. Macewicz. 2014. Assessment of the Pacific sardine resource in 2014 for U.S.A. management in 2014-15. US Department of Commerce. NOAA Tech. Memo. NMFS-SWFSC-531, 305 p. https://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-531.pdf

Hill, K. T., P. R. Crone, E. Dorval, and B. J. Macewicz. 2015. Assessment of the Pacific sardine resource in 2015 for U.S.A. management in 2015-16. US Department of Commerce. NOAA Tech. Memo. NMFS-SWFSC-546, 168 p. https://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-546.pdf

Hill, K. T., P. R. Crone, E. Dorval, and B. J. Macewicz. 2016. Assessment of the Pacific sardine resource in 2016 for U.S.A. management in 2016-17. US Department of Commerce. NOAA Tech. Memo. NMFS-SWFSC-562, 172 p. https://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-562.pdf

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin 82:898-905.

Ianelli, J. P. Spencer, G. Thompson, and J. Heifetz. 2013. Report of the working group on methods for averaging surveys: Updated through 2013. Alaska Fisheries Science Center, Seattle, WA. 18 p.

Jacobson, L. J. and A. D. MacCall. 1995. Stock-recruitment models for Pacific sardine (*Sardinops sagax*). Can. J. Fish. Aquat. Sci. 52:566-577.

Janssen, J. F. 1938. Second report of sardine tagging in California. Calif. Fish Game 24(4): 376-389.

Javor, B.J. 2013. Do shifts in otolith morphology of young Pacific sardine (Sardinops sagax) reflect changing recruitment contributions from northern and southern stocks? CalCOFI Rep. 54: 1-12.

Lee, H.H., K.R. Piner, R.D. Methot, Jr., and M.N. Maunder. 2014. Use of likelihood profiling over a global scaling parameter to structure the population dynamics model: an example using blue marlin in the Pacific Ocean. Fish.Res.158:138-146.

Leet, W. S., C. M. Dewees, R. Klingbeil, and E. J. Larson (Eds.). 2001. California's Living Marine Resources: A Status Report. Calif. Dep. Fish and Game. ANR Publication #SG01-11.

Lo, N. C. H., Y. A. Green Ruiz, Merecedes J. Cervantes, H. G. Moser, R. J. Lynn. 1996. Egg production and spawning biomass of Pacific sardine *(Sardinops sagax*) in 1994, determined by the daily egg production method. CalCOFI Rep. 37:160-174.

Lo, N. C. H., B. J. Macewicz, and D. A. Griffith. 2005. Spawning biomass of Pacific sardine (*Sardinops sagax*) from 1994-2004 off California. CalCOFI Rep. 46: 93-112.

Lo, N. C.H., B. J. Macewicz, and D. A. Griffith. 2011. Migration of Pacific sardine (*Sardinops sagax*) off the west coast of United States in 2003-2005. Bull. Mar. Sci. 87(3): 395-412.

MacCall, A. D. 1979. Population estimates for the waning years of the Pacific sardine fishery. CalCOFI Rep. 20: 72-82.

Macewicz, B. J. and D. N. Abramenkoff. 1993. Collection of jack mackerel, *Trachurus symmetricus*, off southern California during 1991 cooperative U.S.-U.S.S.R. cruise. Southwest Fisheries Science Center, National Marine Fisheries Service, Admin. Rep. LJ-93-07. 13 pp.

Macewicz B. J, J. J. Castro-Gonzalez, C. E. Cotero Altamirano, and J. R. Hunter. 1996. Adult reproductive parameters of Pacific Sardine (*Sardinops sagax*) during 1994 CalCOFI Rep 37:140-151.

McClatchie, S., I. L. Hendy, A. R. Thompson, and W. Watson. 2017. Collapse and recovery of forage fish populations prior to commercial exploitation. Geophys. Res. Lett. 44. doi:10.1002/2016GL071751.

McDaniel J., Piner K., Lee H.-H., and Hill K. 2016. Evidence that the Migration of the Northern Subpopulation of Pacific Sardine (*Sardinops sagax*) off the West Coast of the United States Is Age-Based. PLoS ONE 11(11): e0166780. http://dx.doi.org/10.1371/journal.pone.0166780

Methot, R. 2005. Technical description of the Stock Synthesis II assessment program. Version 1.17-March 2005. NOAA Fisheries, Seattle, WA.

Methot, R. 2007. User manual for the Integrated analysis program stock synthesis 2 (SS2). Model version 2.00c. March 2007. NOAA Fisheries, Seattle, WA.

Methot, R. 2009. User manual for Stock Synthesis. Model version 3.03a. May 11, 2009. NOAA Fisheries, Seattle, WA. 143 p.

Methot, R. 2011. User manual for Stock Synthesis. Model version 3.21d. May 8, 2011. NOAA Fisheries, Seattle, WA. 165 p.

Methot, R., 2013. User manual for stock synthesis, Model Version 3.24s. NOAA Fisheries, Seattle, WA.

Methot, R.D. and I.G. Taylor. 2011. Adjusting for bias due to variability of estimated recruitments in fishery assessment models. Can. J. Fish. Aquat. Sci., 68:1744-1760.

Methot, R.D., Wetzel, C.R. 2013. Stock Synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142, 86-99.

Murphy, G. I. 1966. Population biology of the Pacific sardine (*Sardinops caerulea*). Proc. Calif. Acad. Sci. Vol. 34 (1): 1-84.

National Marine Fisheries Service (NMFS). 2016a. California Current Integrated Ecosystem Assessment (CCIEA) State of the California Current Report, 2016. Briefing book, Agenda Item D.1.a, NMFS Report 1, March 2016. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, OR, 97220. OR. 20 p. http://www.pcouncil.org/wp-content/uploads/2016/02/D1a_NMFS1_2016_IEA_SoCC_FINAL_MAR2016BB.pdf

National Marine Fisheries Service (NMFS). 2016b. Supplementary Materials to the California Current Integrated Ecosystem Assessment (CCIEA) State of the California Current Report, 2016. Briefing book, Agenda Item D.1.a, NMFS Report 2, March 2016. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, OR, 97220. OR. 25 p. http://www.pcouncil.org/wp-content/uploads/2016/02/D1a_NMFS2_2016_SoCC_Supplementary_materials_FINAL_MAR2016BB.pdf

Otter Research Ltd. 2001. An introduction to AD Model Builder (Version 6.0.2) for use in nonlinear modeling and statistics. Otter Research Ltd., Sidney, B.C., Canada. 202 p.

PFMC (Pacific Fishery Management Council). 1998. Amendment 8 (to the northern anchovy fishery management plan) incorporating a name change to: the coastal pelagic species fishery management plan. Pacific Fishery Management Council, Portland, OR.

Pacific Fishery Management Council (PFMC). 2011. Acoustic-trawl survey method for coastal pelagic species. Report of Methodology Review Panel Meeting. PFMC. April 2011 Briefing Book. 31 p.

Pacific Fishery Management Council (PFMC). 2013. Report of the Pacific Sardine Harvest Parameters Workshop. April 2013 briefing book agenda item I.1.b. Pacific Fishery Management Council. Portland, OR. 65 p. http://www.pcouncil.org/wp-content/uploads/I1b_ATT1_SARDINE_WKSHP_RPT_APR2013BB.pdf

Pacific Fishery Management Council (PFMC). 2014. Status of the Pacific coast coastal pelagic species fishery and recommended acceptable biological catches: Stock assessment and fishery evaluation 2014. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, OR, 97220. OR. 19 p. http://www.pcouncil.org/wp-content/uploads/2014_CPS_SAFE_FullDocumentCombined.pdf

Phillips, J. B. 1948. Growth of the sardine, *Sardinops caerulea*, 1941-42 through 1946-47. Calif. Div. Fish Game Fish Bull. 71: 33 p.

Punt, A. E. in press. Some insights into data weighting in integrated stock assessments. Fisheries Research.

Simmonds, E. J. 2011. Center for Independent Experts (CIE) Independent Peer Review Report of Acoustic-Trawl Method Pertaining to Surveys of Coastal Pelagic Fish Species in the California Current Ecosystem. La Jolla, 37 p.

Smith, P.E. 2005. A history of proposals for subpopulation structure in the Pacific sardine (Sardinops sagax) population off western North America. CalCOFI Rep. 46: 75-82.

Soutar, A. and J. D. Isaacs. 1969. History of fish populations inferred from fish scales in anaerobic sediments off California. CalCOFI Rep. 13: 63-70.

Soutar, A., and J. D. Isaacs. 1974. Abundance of pelagic fish during the 19^{th} and 20^{th} centuries as recorded in anaerobic sediment off the Californias. Fish. Bull. 72: 257-273.

STAR (Stock Assessment Review). 2014. Pacific sardine STAR panel meeting report. A. Punt (chair), M. Key, J. De Olivereira, J. Simmonds. Review: NOAA Fisheries, Southwest Fisheries Science Center, La Jolla CA, 92037, March 3-5, 2014. Report: Pacific Fishery Management, Portland, OR, 97220, USA.

STAR (Stock Assessment Review). 2017. Pacific sardine STAR panel meeting report. A. Punt (chair), W. Satterthwaite, E. Brown, J. Vølstad, G. Melvin. Review: NOAA Fisheries, Southwest Fisheries Science Center, La Jolla CA, 92037, February 21-24, 2017. Report: Pacific Fishery Management, Portland, OR, 97220, USA. ? p.

Stierhoff, K., Demer, D. A., Cutter, G. R., Mau, S., Renfree, J. S., and Zwolinski, J. P. in preparation. Report of the data collection during the acoustic-trawl method survey for coastal pelagic species in the California Current Ecosystem in spring 2016. NOAA Technical Memorandum NMFS.

Vetter, R. and S. McClatchie. (In Review). The Rewilding of the California Current: Impacts of Recovering Marine Mammal Populations on Forage Fisheries.

Vrooman, A. M. 1964. Serologically differentiated subpopulations of the Pacific sardine, *Sardinops caerulea*. J. Fish. Res. Bd. Canada, 21: 691-701.

Walford, L. A. and K. H. Mosher. 1943. Studies on the Pacific pilchard or sardine (*Sardinops caerulea*). U.S. Dep. Of Interior, Fish and Wildlife Service, Special Sci. Rep. No. 20. 33 p.

Yaremko, M. L. 1996. Age determination in Pacific sardine, *Sardinops sagax*. NOAA Tech. Mem. NOAA-TM-NMFS-SWFSC-223. 33 p.

Zwolinski, J. P., K. A. Byers, G. R. Cutter Jr., T. S. Sessions, B. J. Macewicz, and D. A. Demer. 2011. Acoustic-trawl survey conducted during the Spring 2011 California Current Ecosystem Survey from FV *Frosti* and FSV *Bell M. Shimada*.

Zwolinski, J. P., Emmett, R. L., and Demer, D. A. 2011. Predicting habitat to optimize sampling of Pacific sardine (*Sardinops sagax*). ICES Journal of Marine Science, 68: 867-879.

Zwolinski, J.P., Demer, D.A. 2013. Measurements of natural mortality for Pacific sardine (*Sardinops sagax*). ICES Journal of Marine Science 70:1,408-1,415.

Zwolinski, J. P., D. A. Demer, K. A. Byers, G. R. Cutter, J. S. Renfree, T. S. Sessions, and B. J. Macewicz. 2012. Distributions and abundances of Pacific sardine (*Sardinops sagax*) and other pelagic fishes in the California Current Ecosystem during spring 2006, 2008, and 2010, estimated from acoustic—trawl surveys. Fish. Bull. 110: 110-122.

Zwolinski, J. P., Demer, D. A., Cutter Jr., G. R., Stierhoff, K., and Macewicz, B. J. 2014. Building on Fisheries Acoustics for Marine Ecosystem Surveys. Oceanography, 27: 68-79.

Zwolinski, J., D. A. Demer, B. J. Macewicz, G. R. Cutter, Jr., B. Elliot, S. Mau, D. Murfin, J. S. Renfree, T. S. Sessions, and K. Stierhoff. 2016. Acoustic-trawl estimates of northern-stock Pacific sardine biomass during 2015. Department of Commerce. NOAA Tech. Memo. NMFS-SWFSC-559, 18 p. https://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-559.pdf

Zwolinski, J. P., Stierhoff, K., Demer, D. A., Cutter, G. R., Palance, D., Mau, S., Murfin, D., et al. (in preparation). Report of the data collection during the acoustic-trawl method survey for coastal pelagic species in the California Current Ecosystem in summer 2016. NOAA Technical Memorandum NMFS.

TABLES

Table 1. U.S. Pacific sardine harvest specifications and landings (metric tons) since the onset of federal management. U.S. harvest limits and closures are based on total catch, regardless of subpopulation source. Landings for the 2016-17 management year are preliminary and incomplete.

Mgmt Year	U.S. OFL	U.S. ABC	U.S. HG or ACL	U.S. Total Landings	U.S. NSP Landings
2000	n/a	n/a	186,791	73,766	67,691
2001	n/a	n/a	134,737	79,746	57,019
2002	n/a	n/a	118,442	103,134	82,529
2003	n/a	n/a	110,908	77,728	65,692
2004	n/a	n/a	122,747	96,513	78,430
2005	n/a	n/a	136,179	92,906	76,047
2006	n/a	n/a	118,937	94,337	79,623
2007	n/a	n/a	152,564	131,090	107,595
2008	n/a	n/a	89,093	90,164	80,986
2009	n/a	n/a	66,932	69,903	64,506
2010	n/a	n/a	72,039	69,140	58,578
2011	92,767	84,681	50,526	48,802	42,253
2012	154,781	141,289	109,409	103,600	93,751
2013	103,284	94,281	66,495	67,783	60,767
2014 (1)	59,214	54,052	6,966	6,806	6,121
2014-15	39,210	35,792	23,293	23,113	19,969
2015-16	13,227	12,074	7,000	2,012	259
2016-17	23,085	19,236	8,000	*956*	*98*

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
2005-2	2005-1	37,999.5	4,396.7	16,615.0	1,581.4	7,824.9	44,316.2	6,605.0	3,231.4
2006-1	2005-2	17,600.9	11,214.6	18,290.5	17,117.0	2,032.6	101.7	0.0	0.0
2006-2	2006-1	39,636.0	0.0	18,556.0	5,015.7	15,710.5	35,546.5	4,099.0	1,575.4
2007-1	2006-2	13,981.4	13,320.0	27,546.0	20,567.0	6,013.3	0.0	0.0	0.0
2007-2	2007-1	22,865.5	11,928.2	22,047.2	5,531.2	28,768.8	42,052.3	4,662.5	1,522.3
2008-1	2007-2	23,487.8	15,618.2	25,098.6	24,776.6	2,515.3	0.0	0.0	0.0
2008-2	2008-1	43,378.3	5,930.0	8,979.6	123.6	24,195.7	22,939.9	6,435.2	10,425.0
2009-1	2008-2	25,783.2	20,244.4	10,166.8	9,874.2	11,079.9	0.0	0.0	0.0
2009-2	2009-1	30,128.0	0.0	5,214.1	109.3	13,935.1	21,481.6	8,025.2	15,334.3
2010-1	2009-2	12,989.1	7,904.2	20,333.5	20,333.5	2,908.8	437.1	510.9	421.7
2010-2	2010-1	43,831.8	9,171.2	11,261.2	699.2	1,397.1	20,414.9	11,869.6	21,801.3
2011-1	2010-2	18,513.8	11,588.5	13,192.2	12,958.9	2,720.1	0.1	0.0	0.0
2011-2	2011-1	51,822.6	17,329.6	6,498.9	182.5	7,359.3	11,023.3	8,008.4	20,718.8
2012-1	2011-2	10,534.0	9,026.1	12,648.6	10,491.1	3,672.7	2,873.9	2,931.7	0.0
2012-2	2012-1	48,534.6	0.0	8,620.7	929.9	568.7	39,744.1	32,509.6	19,172.0
2013-1	2012-2	13,609.2	12,827.9	3,101.9	972.8	84.2	149.3	1,421.4	0.0
2013-2	2013-1	37,803.5	0.0	4,997.3	110.3	811.3	27,599.0	29,618.9	0.0
2014-1	2013-2	12,929.7	412.5	1,495.2	809.3	4,403.3	0.0	908.0	0.0
2014-2	2014-1	77,466.3	0.0	1,600.9	0.0	1,830.9	7,788.4	7,428.4	0.0
2015-1	2014-2	14,452.4	0.0	1,543.2	0.0	727.7	2,131.3	62.6	0.0
2015-2	2015-1	18,379.7	0.0	1,514.8	0.0	6.1	0.1	66.1	0.0
2016-1	2015-2	22,647.9	0.0	423.5	184.8	1.1	0.7	0.0	0.0
2016-2	2016-1	23,091.6	0.0	857.5	0.0	10.3	2.7	85.2	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. Samples from model year 2015-1 onward were from incidental catches so were not included in the model.

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
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	8	8	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	3	0	0
2013-2	2013-1	0	0	39	39	5	5	75	74	66	65	0	0
2014-1	2013-2	0	0	27	26	14	13	0	0	1	1	0	0
2014-2	2014-1	0	0	8	8	6	6	27	27	24	23	0	0
2015-1	2014-2	0	0	18	18	14	14	15	15	1	0	0	0
2015-2	2015-1	0	0	0	0	*2*	*2*	0	0	1	0	0	0
2016-1	2015-2	0	0	*8*	*2*	0	0	*4*	*0*	0	0	0	0
2016-2	2016-1	0	0	*1*	*1*	0	0	*4*	*0*	0	0	0	0

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

Calendar	Model	NSP Catch (model ALT)		
Yr-Sem	Yr-Seas	MEXCAL_S1	MEXCAL_S2	PNW
2005-2	2005-1	13803.0	0.0	54152.6
2006-1	2005-2	0.0	30364.2	101.7
2006-2	2006-1	20726.2	0.0	41220.9
2007-1	2006-2	0.0	39900.3	0.0
2007-2	2007-1	46228.1	0.0	48237.1
2008-1	2007-2	0.0	42910.0	0.0
2008-2	2008-1	30249.2	0.0	39800.1
2009-1	2008-2	0.0	41198.5	0.0
2009-2	2009-1	14044.9	0.0	44841.1
2010-1	2009-2	0.0	31146.5	1369.7
2010-2	2010-1	11274.0	0.0	54085.9
2011-1	2010-2	0.0	27267.6	0.1
2011-2	2011-1	24871.4	0.0	39750.5
2012-1	2011-2	0.0	23189.9	5805.6
2012-2	2012-1	1528.4	0.0	91425.6
2013-1	2012-2	0.0	13884.9	1570.8
2013-2	2013-1	921.6	0.0	57218.0
2014-1	2013-2	0.0	5625.0	908.0
2014-2	2014-1	1830.9	0.0	15216.8
2015-1	2014-2	0.0	727.7	2193.9
2015-2	2015-1	6.1	0.0	66.3
2016-1	2015-2	0.0	185.9	0.7
2016-2	2016-1	10.3	0.0	87.9
2017-1	2016-2	0.0	185.9	0.7
2017-2	2017-1	*10.3*	*0.0*	*87.9*
2018-1	2017-2	*0.0*	*185.9*	*0.7*

Table 5. Fishery-independent indices of Pacific sardine relative abundance. The DEPM time series was not included in model ALT. Complete details regarding calculation of DEPM estimates are provided in Appendix A. In the SS model, indices had a lognormal error structure with units of standard error of log*e*(index). Variances of the observations were available as a CVs, so the SEs were approximated as sqrt(log*e*(1+CV^2)).

Model Yr-Sem	DEPM	S.E. ln(index)	Acoustic	S.E. ln(index)
2005-2	---	---	1,947,063	0.30
2006-1	---	---	---	---
2006-2	198,404	0.30	---	---
2007-1	---	---	---	---
2007-2	66,395	0.27	751,075	0.09
2008-1	---	---	801,000	0.30
2008-2	99,162	0.24	---	---
2009-1	---	---	---	---
2009-2	58,447	0.40	357,006	0.41
2010-1	---		---	---
2010-2	219,386	0.27	493,672	0.30
2011-1	---	---	---	---
2011-2	113,178	0.27	469,480	0.28
2012-1	---	---	340,831	0.33
2012-2	82,182	0.29	305,146	0.24
2013-1	---	---	313,746	0.27
2013-2	---	---	35,339	0.38
2014-1	---	---	26,280	0.63
2014-2	19,376	0.54	29,048	0.29
2015-1	---	---	15,870	0.70
2015-2	5,929	0.54	83,030	0.47
2016-1	---	---	78,770	0.51

Table 6. Pacific sardine biomass by stratum during the spring 2016 survey (see Figures 16 and 17).

Stratum		**Transect**		**Trawls**		**Sardine**		
Number	**Area (n.mi.^{2})**	**Number**	**Distance (n.mi.)**	**CPS clusters**	**Number of sardine**	**Biomass (10^3 tons)**	**95% confidence interval (10^3 tons)**	**CV (%)**
1	13,376	9	2,792	6	13,671	74.65	12.49 - 161.25	51.7
2	8,059	3	459	3	33	8.39	0.08 - 23.65	78.7
1+2	**21,435**	**12**	**3,252**	**9**	**13,704**	**83.04**	**18.91 -172.11**	**49.3**

Table 7. Pacific sardine biomass by stratum during the summer 2016 survey (see Figures 18 and 19).

Stratum		**Transect**		**Trawls**		**Sardine**		
Name	**Area (n.mi.^{2})**	**Number**	**Distance (n.mi.)**	**CPS clusters**	**Number of sardine**	**Biomass (10^3 tons)**	**95% confidence interval (10^3 tons)**	**CV (%)**
1	3,246	5	325	3	4,877	42.62	0.51 - 87.92	68.9
2	7,367	14	730	5	1,692	0.53	0.26 - 0.90	30.8
3	3,304	9	304	1	3,793	6.38	1.61 - 13.61	49.0
4	5,409	9	346	2	3,972	0.34	0.07 - 0.70	57.5
5	3,105	9	287	2	33	0.20	0.00 - 0.43	66.6
6	3,022	8	306	3	8	28.70	0.19 - 83.86	92.9
1+…+6	**25,453**	**54**	**2,298**	**16**	**14,375**	**78.78**	**9.54 – 148.29**	**53.9**

Table 8. Pacific sardine abundance versus standard length for spring and summer 2016 surveys.

	Spring	Summer
Standard length (cm)	**Abundance (millions)**	**Abundance (millions)**
4	0.000	0.000
5	0.000	0.000
6	0.000	11.719
7	0.000	35.156
8	0.000	0.000
9	0.000	11.719
10	0.000	11.719
11	0.051	0.000
12	0.333	11.719
13	40.289	0.453
14	189.427	1.821
15	142.816	11.774
16	32.924	79.878
17	3.658	362.959
18	0.000	195.574
19	44.101	372.646
20	61.907	5.921
21	39.169	0.767
22	11.606	2.620
23	5.513	2.278
24	67.448	4.306
25	101.438	6.286
26	61.341	4.433
27	0.000	0.657
28	0.000	0.000
29	0.000	0.000
30	0.000	0.000

Table 9. The AT survey projection of stock biomass (age 1+, mt) to July 2017. Note that the abundance of age-0 sardine in 2016 is estimated by using the S-R relationship derived from the ALT model. Consequently, the total stock biomass presented here differs from that in Table 7.

Age	Abundance (numbers)	Mean weight (kg)	Biomass (mt)	SSB (mt, January 2016)	Biomass (mt, July 2017)
0	1,254,944,093	0.011	13,563	2,156	NA
1	163,972,918	0.066	10,782	17,095	45,289
2	410,927,780	0.074	30,420	27,439	6,662
3	335,621,177	0.078	26,309	22,515	17,679
4	125,554,639	0.083	10,388	1,763	15,239
5	7,048,585	0.154	1,083	894	10,583
6	3,238,212	0.195	632	697	755
7	2,414,616	0.171	414	366	304
8	1,235,575	0.207	255	52	274
9+	176,923	0.188	33	2,156	146
total	1,254,944,093		93,879	72,976	96,930

Table 10. Model parameterizations and data components for the ALT and T_2016/T_2017 assessment models.

<table>
<tr><th colspan="3"></th><th colspan="2">ASSESSMENT</th></tr>
<tr><th colspan="3"></th><th>T_2016 / T_2017[a]</th><th>ALT</th></tr>
<tr><td rowspan="9" colspan="2">PARAMETERIZATIONS</td><td>Time period</td><td>1993-16 / 1993-17</td><td>2005-17</td></tr>
<tr><td>Surveys</td><td>AT, DEPM, TEP</td><td>AT</td></tr>
<tr><td>Fisheries</td><td>MEX-CAL, PNW</td><td>MEX-CAL, PNW</td></tr>
<tr><td>Longevity</td><td>15 years</td><td>10 years</td></tr>
<tr><td>Natural mortality</td><td>Fix (M=0.4)</td><td>Fix (M=0.6)</td></tr>
<tr><td>Growth</td><td>Estimated</td><td>Emp. weight-at-age</td></tr>
<tr><td>Stock-recruitment</td><td>Beverton-Holt (h fix=0.80)</td><td>Beverton-Holt (h est=0.36)</td></tr>
<tr><td>Selectivity</td><td>Length data/Length-based</td><td>Age data/Age-based</td></tr>
<tr><td>Catchability</td><td>AT (Q fix=1.0)</td><td>AT (Q est=1.1)</td></tr>
<tr><td rowspan="14">DATA COMPONENTS</td><td rowspan="5">Fisheries</td><td>Catch</td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td></tr>
<tr><td>Length comps</td><td style="background:#c0c0c0"></td><td></td></tr>
<tr><td>Age comps (cond. age-at-length)</td><td style="background:#c0c0c0"></td><td></td></tr>
<tr><td>Age comps (aggregated)</td><td></td><td style="background:#c0c0c0"></td></tr>
<tr><td>Emp. weight-at-age</td><td></td><td style="background:#c0c0c0"></td></tr>
<tr><td rowspan="9">Surveys</td><td>AT abundance series (spring)</td><td style="background:#c0c0c0"></td><td></td></tr>
<tr><td>AT abundance series (summer)</td><td style="background:#c0c0c0"></td><td></td></tr>
<tr><td>AT abundance series (annual)</td><td></td><td style="background:#c0c0c0"></td></tr>
<tr><td>DEPM abundance series</td><td style="background:#c0c0c0"></td><td></td></tr>
<tr><td>TEP abundance series</td><td style="background:#c0c0c0"></td><td></td></tr>
<tr><td>AT length comps</td><td style="background:#c0c0c0"></td><td></td></tr>
<tr><td>AT age comps (cond. age-at-length)</td><td style="background:#c0c0c0"></td><td></td></tr>
<tr><td>AT age comps (aggregated)</td><td></td><td style="background:#c0c0c0"></td></tr>
<tr><td>AT emp. weigth-at-age</td><td></td><td style="background:#c0c0c0"></td></tr>
</table>

[a] T_2016 is the last assessment model that was used for management in 2016 and T_2017 is a similarly parameterized model as T_2016, with updated sample information (e.g., catch, abundance, and composition data).

Table 11. Likelihood components and important derived quantities for the AT survey and model ALT.

			ASSESSMENT	
			AT survey[a]	ALT
LIKELIHOODS	Indices	AT survey	na	5.3585
		Subtotal	na	**5.3585**
	Compositions	MEXCAL_S1 age composition	na	50.659
		MEXCAL_S2 age composition	na	75.2038
		PNW age composition	na	89.6647
		AT age composition	na	90.2202
		Subtotal	na	305.748
	Other	**Catch**	na	1.4356E-13
		Recruitment	na	22.148
		Parameter softbounds	na	2.2396E-03
		TOTAL		**333.256**
ESTIMATES		Stock-recruitment ($\ln R_0$)	na	14.2359
		Stock-recruitment (h)	na	0.359
		Spawning stock biomass 2016 (mt)	na	51,187
		Recruitment 2016 (billions of fish)	na	1.50
		Stock biomass peak (mt)	1,947,063	1,798,040
		Stock biomass 2016 (mt)	78,770	66,984
		Stock biomass 2017 (mt)	96,930	86,586

[a] AT survey represents a survey-based assessment and thus, data components, likelihoods, and particular estimated quantities associated with model-based assessments are noted as not applicable (na).

Table 12. Parameter estimates and asymptotic standard errors for model ALT.

					ALT Model	
Parameter	**Phase**	**Min**	**Max**	**Initial**	**Final**	**Std Dev**
NatM_p_1_Fem_GP_1	-3	0.3	0.8	0.6	0.6	_
Wtlen_1_Fem	-3	-3	3	7.5242E-06	7.5242E-06	_
Wtlen_2_Fem	-3	-3	5	3.2332	3.2332	_
SR_LN(R0)	1	3	25	15	14.2359	0.311468
SR_BH_steep	5	0.2	1	0.5	0.359492	0.118458
SR_sigmaR	-3	0	2	0.75	0.75	_
SR_R1_offset	2	-15	15	0	1.82791	0.466138
Early_InitAge_6	_	_	_	_	-0.34461	0.614817
Early_InitAge_5	_	_	_	_	-0.371706	0.556896
Early_InitAge_4	_	_	_	_	-0.350476	0.503177
Early_InitAge_3	_	_	_	_	0.270028	0.419824
Early_InitAge_2	_	_	_	_	1.72383	0.359257
Early_InitAge_1	_	_	_	_	1.20485	0.458441
Main_RecrDev_2005	_	_	_	_	1.36842	0.196122
Main_RecrDev_2006	_	_	_	_	1.24805	0.203673
Main_RecrDev_2007	_	_	_	_	0.557171	0.214939
Main_RecrDev_2008	_	_	_	_	1.24545	0.178846
Main_RecrDev_2009	_	_	_	_	1.42232	0.158794
Main_RecrDev_2010	_	_	_	_	-1.07036	0.238236
Main_RecrDev_2011	_	_	_	_	-2.48923	0.325946
Main_RecrDev_2012	_	_	_	_	-2.08339	0.318891
Main_RecrDev_2013	_	_	_	_	-0.203622	0.328786
Main_RecrDev_2014	_	_	_	_	-0.402663	0.53203
Main_RecrDev_2015	_	_	_	_	0.407849	0.723834
Late_RecrDev_2016	_	_	_	_	0	0.75
ForeRecr_2017	_	_	_	_	0	0.75
InitF_1MEXCAL_S1	1	0	3	1	1.13449	0.638403
InitF_2MEXCAL_S2	-1	0	3	0	0	_
InitF_3PNW	-1	0	3	0	0	_
LnQ_base_5_AT_Survey	4	-3	3	1	0.112508	0.109545
AgeSel_1P_1_MEXCAL_S1	3	-5	9	0.1	2.00011	156.521
AgeSel_1P_2_MEXCAL_S1	3	-5	9	0.1	3.82866	0.897237
AgeSel_1P_3_MEXCAL_S1	3	-5	9	0.1	0.754782	0.16081
AgeSel_1P_4_MEXCAL_S1	3	-5	9	0.1	-1.47545	0.377544
AgeSel_1P_5_MEXCAL_S1	3	-5	9	0.1	-0.232378	0.568367
AgeSel_1P_6_MEXCAL_S1	3	-5	9	0.1	-0.96326	1.35758
AgeSel_1P_7_MEXCAL_S1	3	-5	9	0.1	-0.141954	2.46857
AgeSel_1P_8_MEXCAL_S1	3	-5	9	0.1	-0.363488	4.03621
AgeSel_1P_9_MEXCAL_S1	3	-5	9	0.1	-0.222431	2.8561
AgeSel_1P_10_MEXCAL_S1	-3	-1000	9	-1000	-1000	_
AgeSel_1P_11_MEXCAL_S1	-3	-1000	9	-1000	-1000	_
AgeSel_2P_1_MEXCAL_S2	3	-5	9	0.1	2.00013	156.521
AgeSel_2P_2_MEXCAL_S2	3	-5	9	0.1	0.654966	0.132147
AgeSel_2P_3_MEXCAL_S2	3	-5	9	0.1	-0.983072	0.192291
AgeSel_2P_4_MEXCAL_S2	3	-5	9	0.1	-0.645874	0.345478
AgeSel_2P_5_MEXCAL_S2	3	-5	9	0.1	-0.559952	0.574878
AgeSel_2P_6_MEXCAL_S2	3	-5	9	0.1	0.522301	0.758618
AgeSel_2P_7_MEXCAL_S2	3	-5	9	0.1	-0.225458	1.12833
AgeSel_2P_8_MEXCAL_S2	3	-5	9	0.1	0.575561	1.70181
AgeSel_2P_9_MEXCAL_S2	3	-5	9	0.1	-1.18914	2.61519
AgeSel_2P_10_MEXCAL_S2	-3	-1000	9	-1000	-1000	_
AgeSel_2P_11_MEXCAL_S2	-3	-1000	9	-1000	-1000	_
AgeSel_3P_1_PNW	4	0	10	5	3.3305	0 0 0 0 #
AgeSel_3P_2_PNW	4	-5	15	1	1.34952	0.118184

Table 13. Pacific sardine northern subpopulation numbers-at-age (1,000s) for model ALT.

		POPULATION NUMBERS-AT-AGE (1,000s of fish)										
Calendar Yr-Sem	Model Yr-Seas	0 (R)	1	2	3	4	5	6	7	8	9	10+
---	VIRG	1,522,530	835,580	458,576	251,672	138,120	75,802	41,601	22,831	12,530	6,877	8,365
---	VIRG	1,127,920	619,013	339,722	186,443	102,322	56,156	30,819	16,914	9,282	5,094	6,197
---	INIT	9,471,400	5,167,970	2,172,350	676,088	325,906	161,385	85,162	45,173	24,212	13,038	15,394
---	INIT	6,976,030	2,932,370	912,624	439,927	217,847	114,956	60,977	32,682	17,600	9,513	11,267
2005-2	2005-1	25,280,200	13,793,900	9,979,490	743,397	197,354	97,998	54,423	45,173	24,212	13,038	15,394
2006-1	2005-2	18,718,100	10,102,900	7,075,340	464,975	96,730	44,328	24,342	20,185	10,819	5,826	6,880
2006-2	2006-1	7,795,940	13,619,600	7,229,740	5,173,750	341,985	71,306	32,583	17,916	14,796	7,982	9,396
2007-1	2006-2	5,773,080	9,948,890	5,165,550	3,611,960	221,018	45,024	20,504	11,275	9,313	5,025	5,916
2007-2	2007-1	6,941,430	4,159,010	6,984,530	3,750,530	2,647,740	162,751	33,017	15,067	8,233	6,869	8,098
2008-1	2007-2	5,137,670	2,965,460	4,744,780	2,609,500	1,731,130	105,008	21,253	9,709	5,309	4,432	5,227
2008-2	2008-1	3,438,450	3,597,170	1,970,640	3,374,960	1,892,400	1,266,940	76,212	15,489	6,986	3,898	7,143
2009-1	2008-2	2,544,700	2,550,370	1,324,670	2,371,340	1,273,930	848,174	50,952	10,370	4,681	2,613	4,791
2009-2	2009-1	6,670,540	1,762,310	1,659,490	934,848	1,712,600	930,131	613,133	37,015	7,420	3,431	5,476
2010-1	2009-2	4,937,750	1,263,350	1,140,470	652,745	1,124,630	602,265	396,061	23,932	4,800	2,221	3,545
2010-2	2010-1	7,626,460	3,408,910	817,087	802,803	469,993	816,828	432,492	285,855	17,000	3,497	4,239
2011-1	2010-2	5,645,060	2,444,320	559,601	542,548	284,432	479,373	252,632	167,077	9,941	2,046	2,481
2011-2	2011-1	601,265	4,023,340	1,680,890	403,175	396,103	208,962	350,170	185,066	121,328	7,320	3,350
2012-1	2011-2	444,929	2,848,070	1,120,170	270,780	238,540	122,408	204,220	108,050	70,887	4,279	1,959
2012-2	2012-1	140,769	315,290	1,936,510	801,651	194,075	168,094	85,001	142,115	74,431	49,615	4,390
2013-1	2012-2	104,215	231,500	1,362,700	451,255	72,965	55,223	27,406	45,728	23,945	15,962	1,412
2013-2	2013-1	185,878	70,714	144,810	946,436	320,789	51,985	38,680	19,310	31,584	17,068	12,507
2014-1	2013-2	137,617	51,726	101,981	572,195	144,595	21,269	15,613	7,784	12,732	6,881	5,043
2014-2	2014-1	971,184	91,842	31,340	70,019	405,399	103,393	14,937	11,045	5,378	9,133	8,664
2015-1	2014-2	718,601	64,707	20,696	47,281	248,427	61,942	8,914	6,601	3,217	5,466	5,188
2015-2	2015-1	663,664	523,398	46,386	15,110	34,284	176,655	43,609	6,277	4,630	2,270	7,535
2016-1	2015-2	491,652	387,681	34,350	11,187	25,365	130,671	32,256	4,643	3,424	1,679	5,573
2016-2	2016-1	1,500,830	363,179	285,616	25,394	8,279	18,779	96,701	23,876	3,435	2,536	5,372
2017-1	2016-2	1,111,830	269,003	211,485	18,792	6,117	13,869	71,412	17,632	2,536	1,873	3,967
2017-2	2017-1	1,033,840	821,675	198,356	156,399	13,908	4,529	10,265	52,864	13,045	1,878	4,326

Table 14. Pacific sardine northern subpopulation biomass-at-age for model ALT.

		POPULATION BIOMASS-AT-AGE (mt)											SUMMARY BIOMASS	
Calendar Yr-Sem	Model Yr-Seas	0	1	2	3	4	5	6	7	8	9	10+	Ages 0+	Ages 1+
---	VIRG	11,419	39,189	35,081	26,174	17,583	11,052	6,656	3,897	2,237	1,267	1,619	156,173	144,754
---	VIRG	36,883	38,193	30,813	21,665	14,028	8,614	5,107	2,958	1,686	950	1,205	162,101	125,218
---	INIT	71,036	242,378	166,185	70,313	41,488	23,530	13,626	7,711	4,322	2,402	2,980	645,970	574,934
---	INIT	228,116	180,927	82,775	51,120	29,867	17,634	10,104	5,716	3,196	1,774	2,190	613,420	385,304
2005-2	2005-1	189,602	646,934	763,431	77,313	25,123	14,288	8,708	7,711	4,322	2,402	2,980	1,742,813	1,553,212
2006-1	2005-2	612,082	623,349	641,733	54,030	13,262	6,800	4,034	3,530	1,965	1,087	1,337	1,963,208	1,351,127
2006-2	2006-1	58,470	638,759	553,075	538,070	43,535	10,396	5,213	3,058	2,641	1,470	1,819	1,856,507	1,798,037
2007-1	2006-2	188,780	613,847	468,515	419,710	30,302	6,907	3,397	1,972	1,691	937	1,150	1,737,207	1,548,428
2007-2	2007-1	52,061	195,058	534,317	390,055	337,057	23,729	5,283	2,572	1,470	1,265	1,568	1,544,434	1,492,373
2008-1	2007-2	168,002	182,969	430,352	303,224	237,338	16,108	3,522	1,698	964	826	1,016	1,346,019	1,178,017
2008-2	2008-1	25,788	168,707	150,754	350,996	240,903	184,720	12,194	2,644	1,247	718	1,383	1,140,054	1,114,265
2009-1	2008-2	83,212	157,358	120,148	275,550	174,656	130,110	8,443	1,814	850	487	931	953,558	870,346
2009-2	2009-1	50,029	82,652	126,951	97,224	218,014	135,613	98,101	6,319	1,324	632	1,060	817,920	767,891
2010-1	2009-2	161,464	77,949	103,441	75,849	154,187	92,387	65,627	4,186	872	414	689	737,065	575,600
2010-2	2010-1	57,198	159,878	62,507	83,492	59,830	119,094	69,199	48,795	3,034	644	821	664,492	607,294
2011-1	2010-2	184,593	150,815	50,756	63,044	38,996	73,536	41,861	29,222	1,805	382	482	635,491	450,898
2011-2	2011-1	4,509	188,695	128,588	41,930	50,424	30,467	56,027	31,591	21,657	1,348	648	555,885	551,375
2012-1	2011-2	14,549	175,726	101,599	31,465	32,704	18,777	33,839	18,898	12,873	798	381	441,610	427,060
2012-2	2012-1	1,056	14,787	148,143	83,372	24,706	24,508	13,600	24,259	13,286	9,139	850	357,706	356,650
2013-1	2012-2	3,408	14,284	123,597	52,436	10,004	8,471	4,541	7,998	4,348	2,977	275	232,338	228,930
2013-2	2013-1	1,394	3,317	11,078	98,429	40,836	7,579	6,189	3,296	5,638	3,144	2,421	183,322	181,928
2014-1	2013-2	4,500	3,192	9,250	66,489	19,824	3,263	2,587	1,361	2,312	1,283	980	115,041	110,541
2014-2	2014-1	7,284	4,307	2,398	7,282	51,607	15,075	2,390	1,885	960	1,682	1,677	96,548	89,264
2015-1	2014-2	23,498	3,992	1,877	5,494	34,059	9,502	1,477	1,154	584	1,019	1,009	83,667	60,169
2015-2	2015-1	4,977	24,547	3,548	1,571	4,364	25,756	6,977	1,072	826	418	1,459	75,518	70,540
2016-1	2015-2	16,077	23,920	3,116	1,300	3,478	20,045	5,345	812	622	313	1,083	76,110	60,033
2016-2	2016-1	11,256	17,033	21,850	2,641	1,054	2,738	15,472	4,076	613	467	1,040	78,240	66,983
2017-1	2016-2	36,357	16,597	19,182	2,184	839	2,128	11,833	3,084	461	349	771	93,784	57,427
2017-2	2017-1	7,754	38,537	15,174	16,265	1,771	660	1,642	9,024	2,329	346	837	94,339	**86,586**

Table 15. Spawning stock biomass (SSB) and recruitment (Recruits) estimates and asymptotic standard errors for model ALT. SSB estimates were calculated at the beginning of Season 2 of each model year (January). Recruits were age-0 fish calculated at the beginning of each model year (July).

Model Yr-Seas	SSB (mt)	SSB Std Dev	Recruits (1000s)	Recruits Std Dev
VIRG-1	---	---	1,522,550	474,216
VIRG-2	107,915	33,611	---	---
INIT-1	---	---	9,471,460	4,375,370
INIT-2	324,262	89,816	---	---
2005-1	---	---	25,280,200	---
2005-2	1,073,370	81,231	---	---
2006-1	---	---	7,795,940	921,117
2006-2	1,220,870	82,137	---	---
2007-1	---	---	6,941,430	776,514
2007-2	1,038,110	69,463	---	---
2008-1	---	---	3,438,450	524,348
2008-2	776,752	51,418	---	---
2009-1	---	---	6,670,540	698,028
2009-2	540,469	36,758	---	---
2010-1	---	---	7,626,460	877,556
2010-2	399,390	29,801	---	---
2011-1	---	---	601,265	152,534
2011-2	336,084	29,628	---	---
2012-1	---	---	140,769	51,311
2012-2	201,813	25,832	---	---
2013-1	---	---	185,878	66,165
2013-2	104,351	18,784	---	---
2014-1	---	---	971,184	337,752
2014-2	60,263	13,171	---	---
2015-1	---	---	663,664	365,241
2015-2	51,186	11,460	---	---
2016-1	---	---	1,500,830	1,183,890
2016-2	52,353	12,991	---	---

Table 16. Natural mortality (M=0.35-0.75 yr^{-1}) profile with associated important likelihood (L), parameter (Q), and derived quantity (terminal spawning stock biomass and stock biomass) estimates for model ALT.

Likelihoods / Estimates	Natural mortality (*M*)								
	0.35	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**	**0.65**	**0.70**	**0.75**
AT survey abundance index (*L*)	4.3	4.6	4.9	5.2	5.3	5.4	5.3	5.2	4.9
AT age composition (*L*)	87.0	87.3	87.9	88.6	89.4	90.2	91.0	92.3	92.3
Total (*L*)	325.7	327.6	329.0	330.3	331.7	333.3	334.7	337.2	339.6
AT catchability (*Q*)	2.4	2.1	1.8	1.6	1.3	1.1	0.9	0.7	0.6
Spawning stock biomass 2016 (mt)	26,936	29,921	34,156	39,152	45,083	52,354	59,621	74,587	93,362
Stock biomass 2017 (mt)	42,078	46,536	54,134	63,099	73,676	86,586	99,469	126,021	160,447

Table 17. Estimates for likelihood components, specific parameters, and derived quantities of interest for models evaluated in sensitivity analysis. Models are defined in footnote below.

			MODEL[a]					
			ALT	ALT_AT+DEPM	ALT_AT SELEX=LOGISTIC	ALT_h=0.8	ALT_FDW	ALT_HMDW
LIKELIHOODS	Indices	AT survey	5.36	6.12	10.48	5.38	5.99	6.19
		DEPM	na	12.55	na	na	na	na
		Subtotal	**5.36**	**18.67**	**10.48**	**5.38**	**5.36**	**6.19**
	Compositions	MEXCAL_S1 age composition	50.66	49.92	51.23	50.56	13.51	11.12
		MEXCAL_S2 age composition	75.20	74.02	67.68	75.78	16.60	9.14
		PNW age composition	89.66	92.34	94.82	89.11	28.14	22.85
		AT age composition	90.22	90.52	63.86	90.40	44.92	38.18
		Subtotal	**305.74**	**306.80**	**277.59**	**305.85**	**103.17**	**81.29**
	Other	**Catch**	<1	<1	<1	<1	<1	<1
		Recruitment	22.15	21.44	23.18	23.08	15.09	14.03
		Parameter softbounds	<1	<1	<1	<1	<1	<1
		TOTAL	**333.26**	**346.91**	**311.25**	**334.31**	**123.62**	**101.51**
ESTIMATES		Stock-recruitment ($\ln R_0$)	14.24	14.35	14.42	14.54	14.48	14.52
		Stock-recruitment (h)	0.36	0.37	0.39	0.80	0.35	0.35
		Spawning stock biomass 2016 (mt)	51,187	63,756	46,348	54,462	60,144	61,514
		Recruitment 2016 (billions of fish)	1.50	1.77	1.20	2.31	1.80	1.34
		Stock biomass peak (mt)	1,798,040	1,663,290	1,798,040	1,821,590	1,770,560	1,778,130
		Stock biomass 2016 (mt)	66,984	80,475	145,099	73,389	85,472	61,514
		Stock biomass 2017 (mt)	86,586	102,574	153,020	112,494	108,924	112,534

[a] Models are as follows: ALT is baseline model; ALT_DEPM is model ALT (including DEPM index of abundance); ALT_AT SELEX=LOGISTIC is model ALT (including 2-parameter logistic selectivity for the AT survey); ALT_h=0.8 is model ALT (including steepness fixed, h=0.8); ALT_FDW is model ALT (including Francis data weighting method); and ALT_HMDW is model ALT (including harmonic mean data weighting method).

Table 18. Convergence tests for model ALT, where randomized phase orders and 20% initial parameter jittering were applied to a range (13.2-15.1) of initial starting values of R_0.

	PHASE ORDER BY COMPONENT						RESULTS	
Initial R_0	R_0	R_1	B-H (h)	Init F	ln(Q)	Selectivity	Final R_0	Total -log(L)
13.2	1	5	2	1	3	4	14.2359	333.256
13.3	3	1	4	3	2	5	14.2359	333.256
13.4	2	4	1	2	5	3	14.2359	333.256
13.5	4	5	3	4	1	2	14.2359	333.256
13.6	5	2	4	5	3	1	14.2359	333.256
13.7	5	1	2	5	4	3	14.2359	333.256
13.8	3	5	2	3	4	1	14.2359	333.256
13.9	2	3	5	2	1	4	14.2359	333.256
14.0	1	3	2	1	5	4	14.2359	333.256
14.1	4	1	3	4	2	5	14.2359	333.256
14.2	2	3	4	2	5	1	14.2359	333.256
14.3	4	2	3	4	1	5	14.2359	333.256
14.4	1	3	2	1	4	5	14.2359	333.256
14.5	5	3	4	5	2	1	14.2359	333.256
14.6	3	1	5	3	4	2	14.2359	333.256
14.7	3	1	5	3	4	2	14.2359	333.256
14.8	2	3	1	2	5	4	14.2359	333.256
14.9	5	4	3	5	2	1	14.2359	333.256
15.0	1	5	2	1	3	4	14.2359	333.256
15.1	4	1	5	4	2	3	14.2359	333.256

Table 19. Harvest control rules for the model-based assessment (model ALT).

Harvest Control Rule Formulas									
OFL = BIOMASS * E_{MSY} * DISTRIBUTION; where E_{MSY} is bounded 0.00 to 0.25									
$ABC_{P\text{-}star}$ = BIOMASS * $BUFFER_{P\text{-}star}$ * E_{MSY} * DISTRIBUTION; where E_{MSY} is bounded 0.00 to 0.25									
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION; where FRACTION is E_{MSY} bounded 0.05 to 0.20									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	86,586								
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier\ 1}$	0.95577	0.91283	0.87048	0.82797	0.78442	0.73861	0.68859	0.63043	0.55314
ABC $Buffer_{Tier\ 2}$	0.91350	0.83326	0.75773	0.68553	0.61531	0.54555	0.47415	0.39744	0.30596
CalCOFI SST (2014-2016)	15.9999								
E_{MSY}	0.225104								
FRACTION	0.200000								
CUTOFF (mt)	150,000								
DISTRIBUTION (U.S.)	0.87								
Harvest Control Rule Values (MT)									
OFL =	**16,957**								
$ABC_{Tier\ 1}$ =	16,207	15,479	14,761	14,040	13,301	12,525	11,676	10,690	9,380
$ABC_{Tier\ 2}$ =	15,490	14,130	12,849	11,625	10,434	9,251	8,040	6,739	5,188
HG =	**0**								

Table 20. CalCOFI annual and three-year average sea surface temperatures (SST, °C) since 1984. Three-year average SST is used to calculate E_{MSY} in the harvest control rules.

Calendar year	CalCOFI annual SST (°C)	CalCOFI 3-yr average SST (°C)
1984	16.3533	---
1985	15.7605	---
1986	15.9823	16.0320
1987	16.2973	16.0134
1988	15.7851	16.0216
1989	15.4632	15.8485
1990	15.9946	15.7476
1991	15.7998	15.7525
1992	16.7028	16.1657
1993	16.4182	16.3069
1994	16.4762	16.5324
1995	15.9241	16.2729
1996	16.3252	16.2419
1997	16.6950	16.3148
1998	16.7719	16.5973
1999	15.2843	16.2504
2000	15.7907	15.9490
2001	15.5535	15.5429
2002	14.9414	15.4285
2003	16.0328	15.5092
2004	15.8849	15.6197
2005	15.4585	15.7920
2006	15.9157	15.7530
2007	15.1543	15.5095
2008	15.2724	15.4475
2009	15.3583	15.2617
2010	15.5520	15.3942
2011	15.5618	15.4907
2012	15.2939	15.4692
2013	14.9097	15.2551
2014	14.1932	14.7989
2015	17.4765	15.5265
2016	16.3299	15.9999

FIGURES

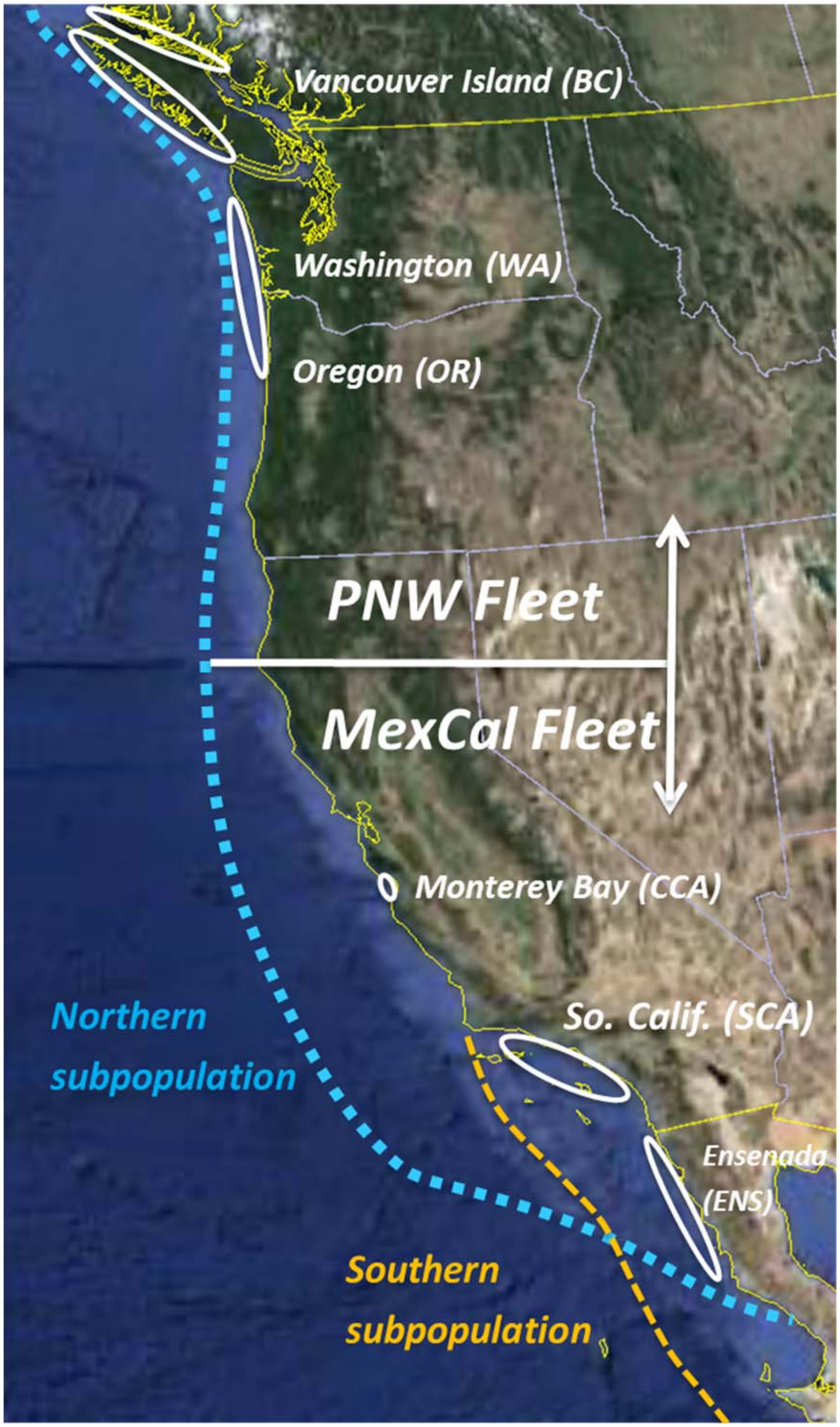


Figure 1. Distribution of the northern subpopulation of Pacific sardine, primary commercial fishing areas, and modeled fleets.

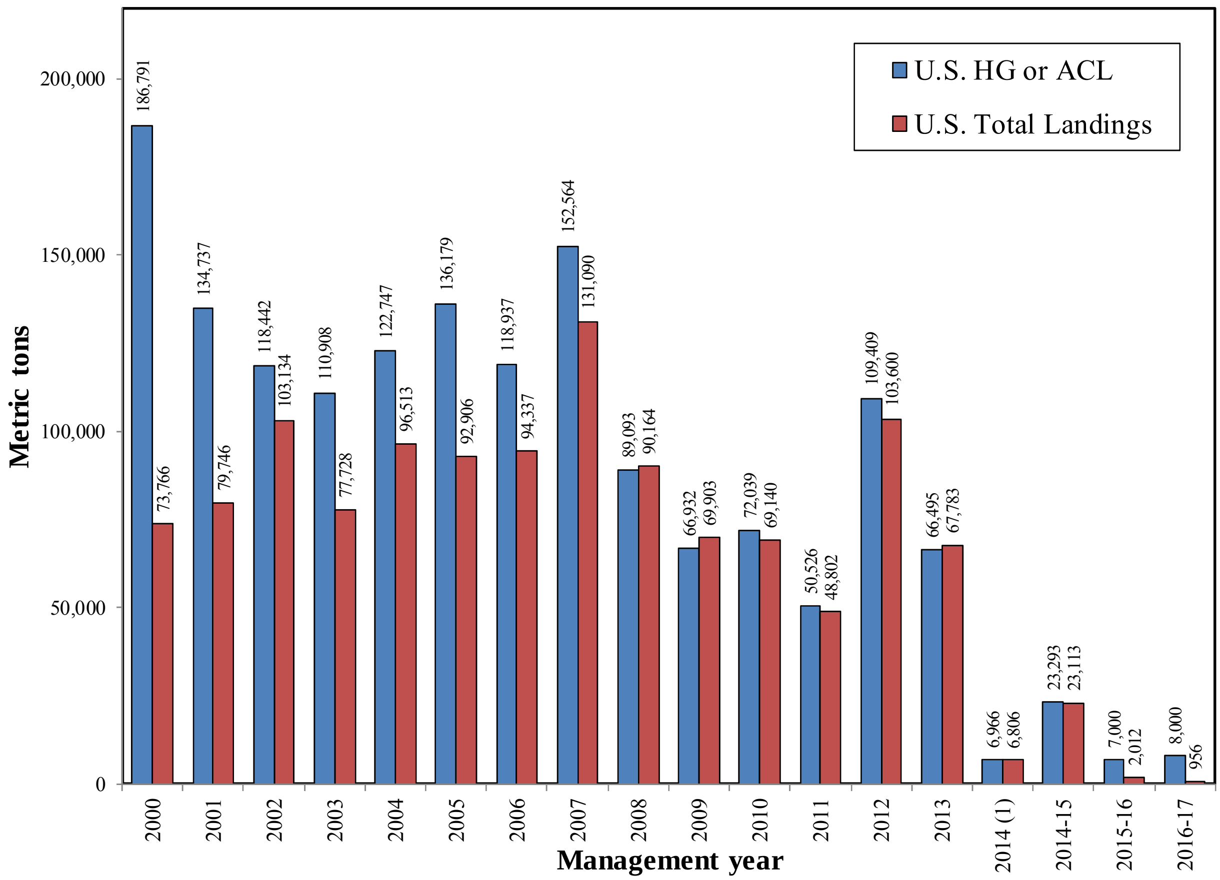


Figure 2. U.S. Pacific sardine harvest guidelines or acceptable catch limits and landings since the onset of federal management.

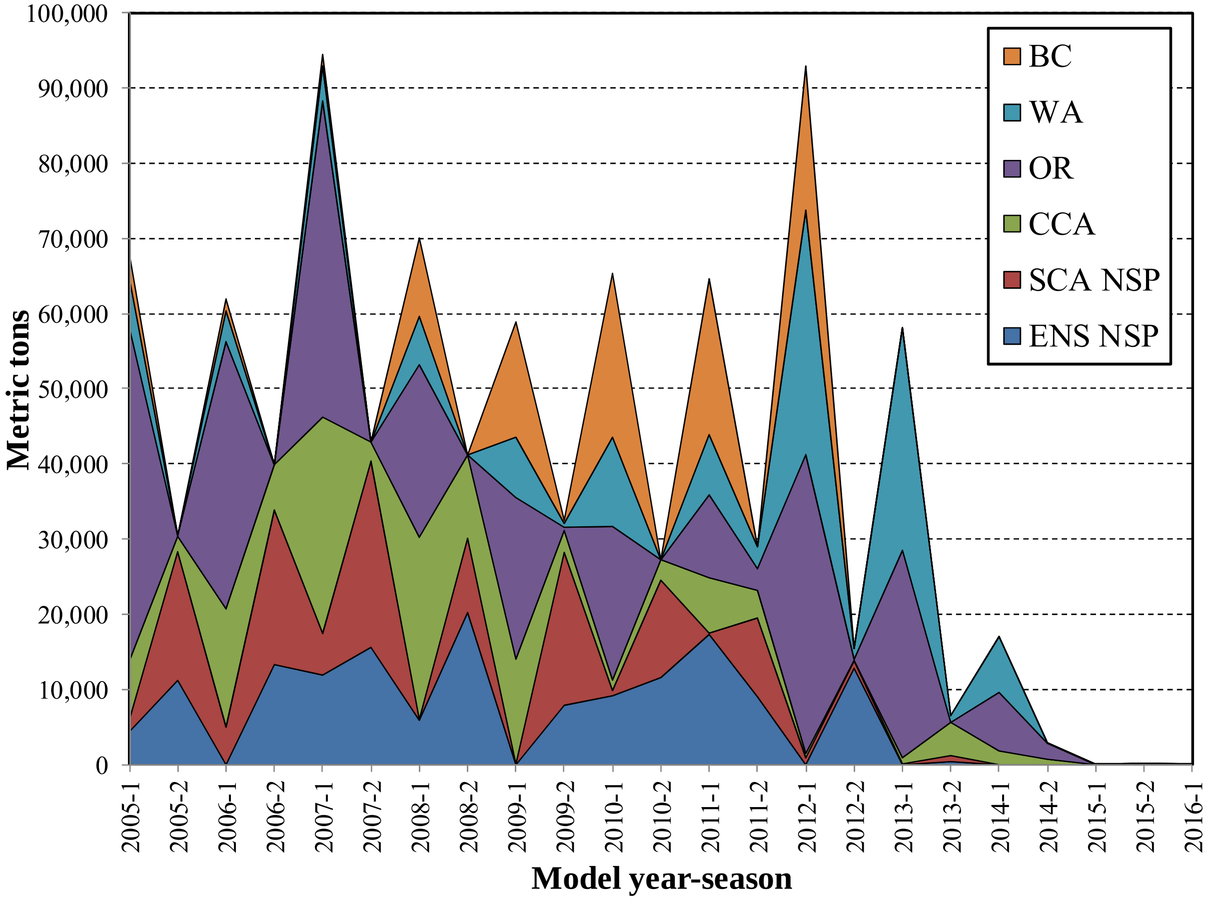


Figure 3. Pacific sardine NSP landings (mt) by major fishing region.

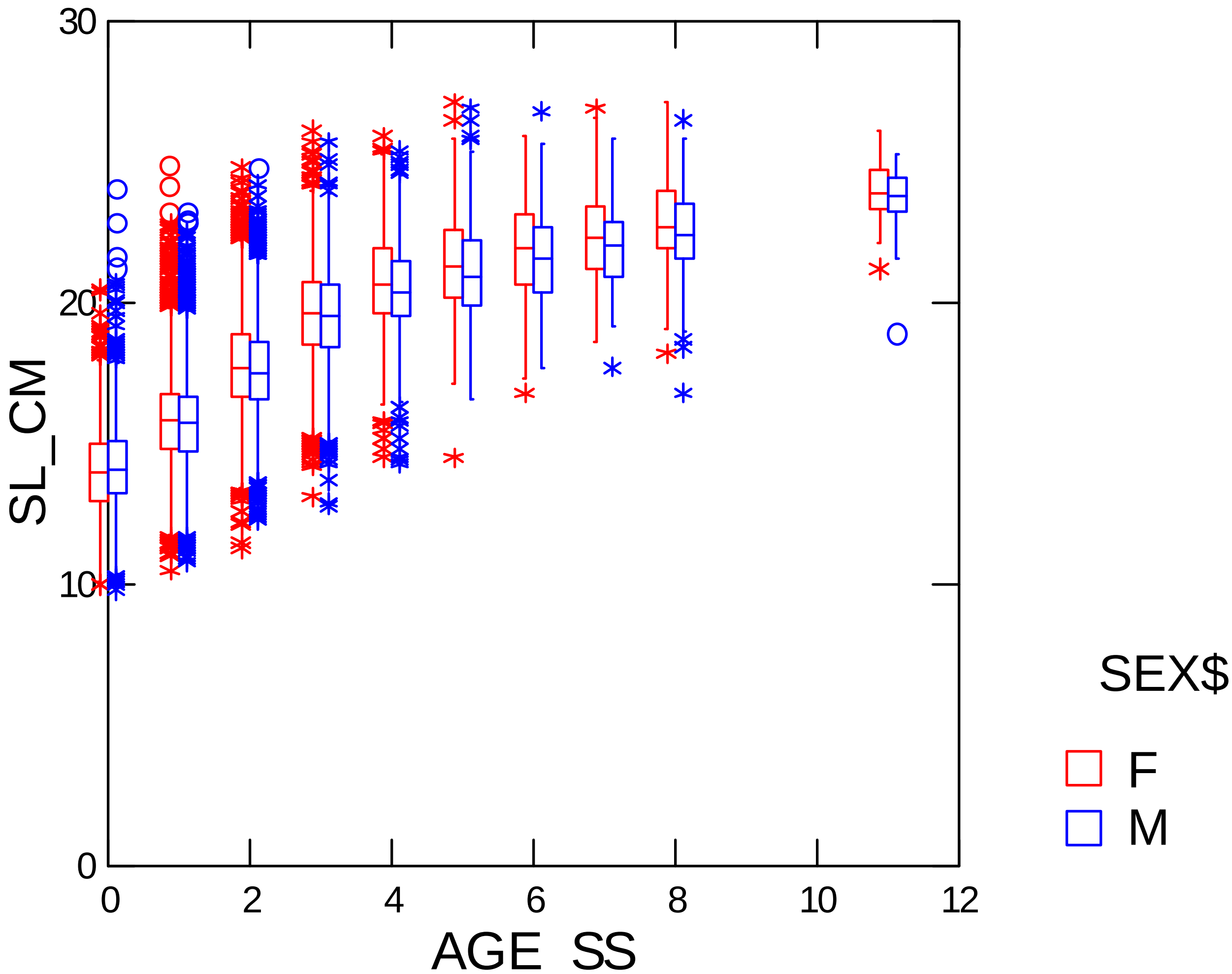


Figure 4. Length-at-age by sex from NSP fishery samples (1993-2013; Hill et al. 2014), indicating lack of sexually dimorphic growth. Box symbols indicate median and quartile ranges for the raw data.

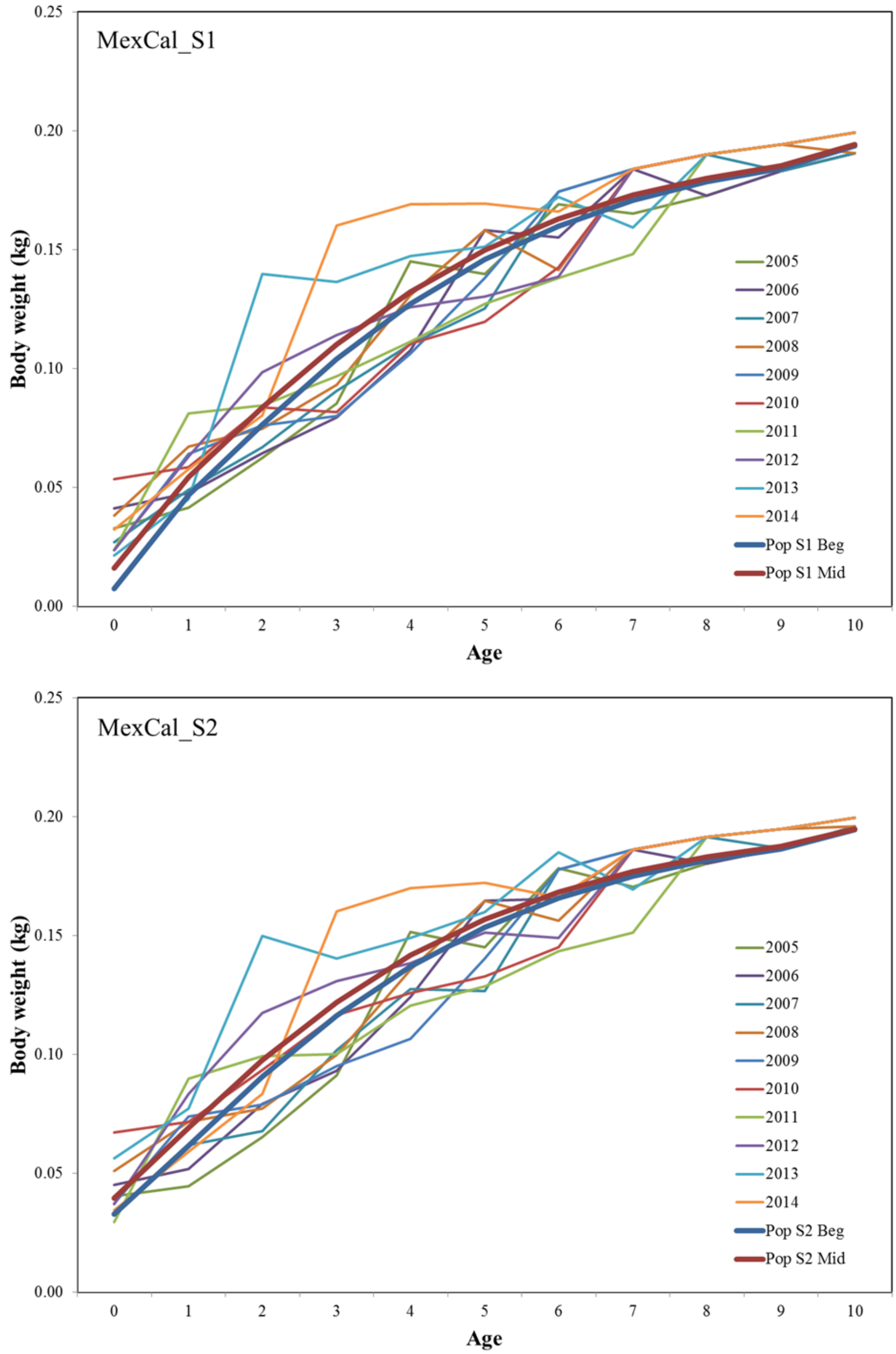


Figure 5. Empirical weight-at-age time series for the MEXCAL fleet in seasons 1 and 2.

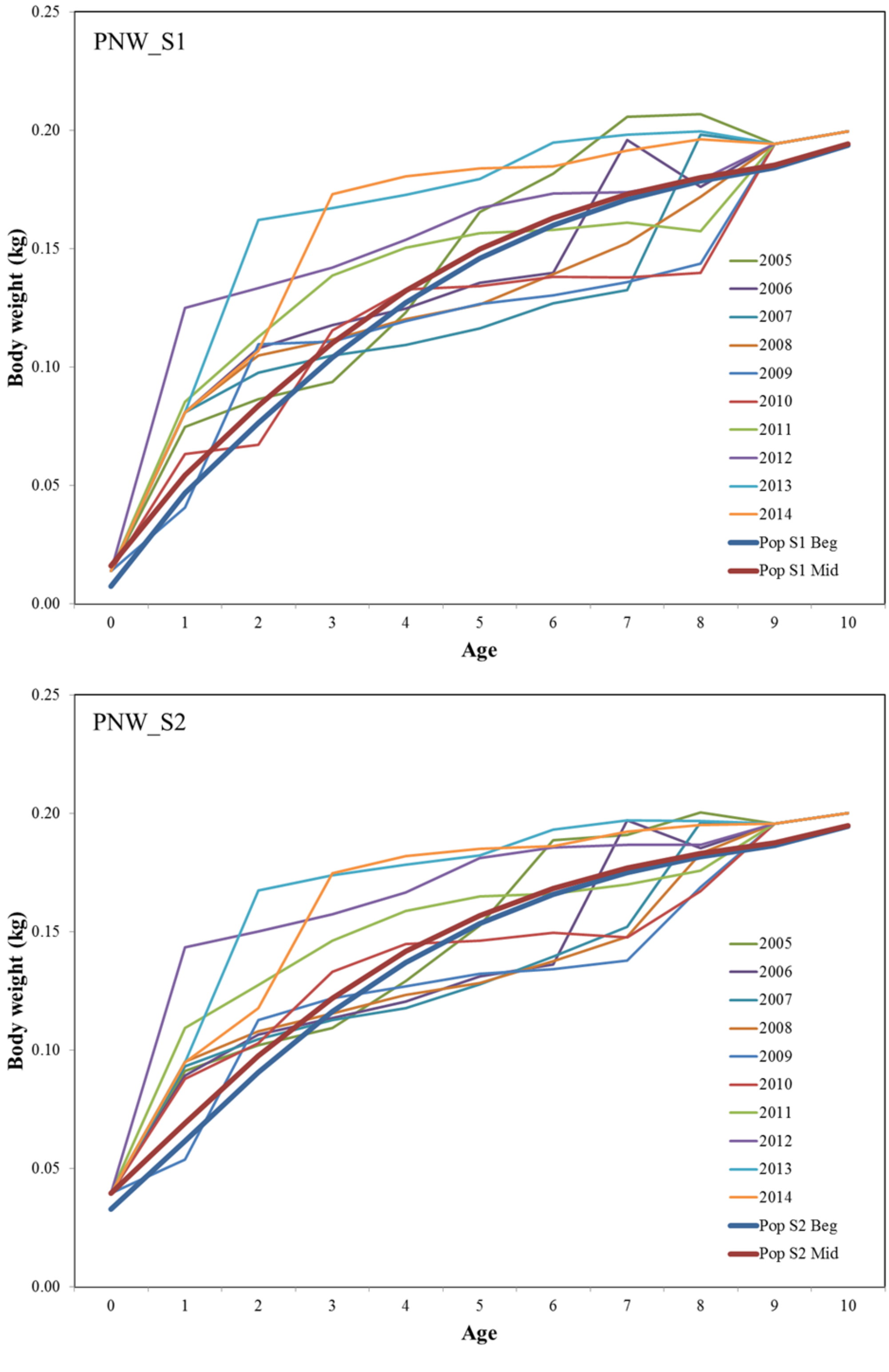


Figure 6. Empirical weight-at-age time series for the PNW fleet in seasons 1 and 2.

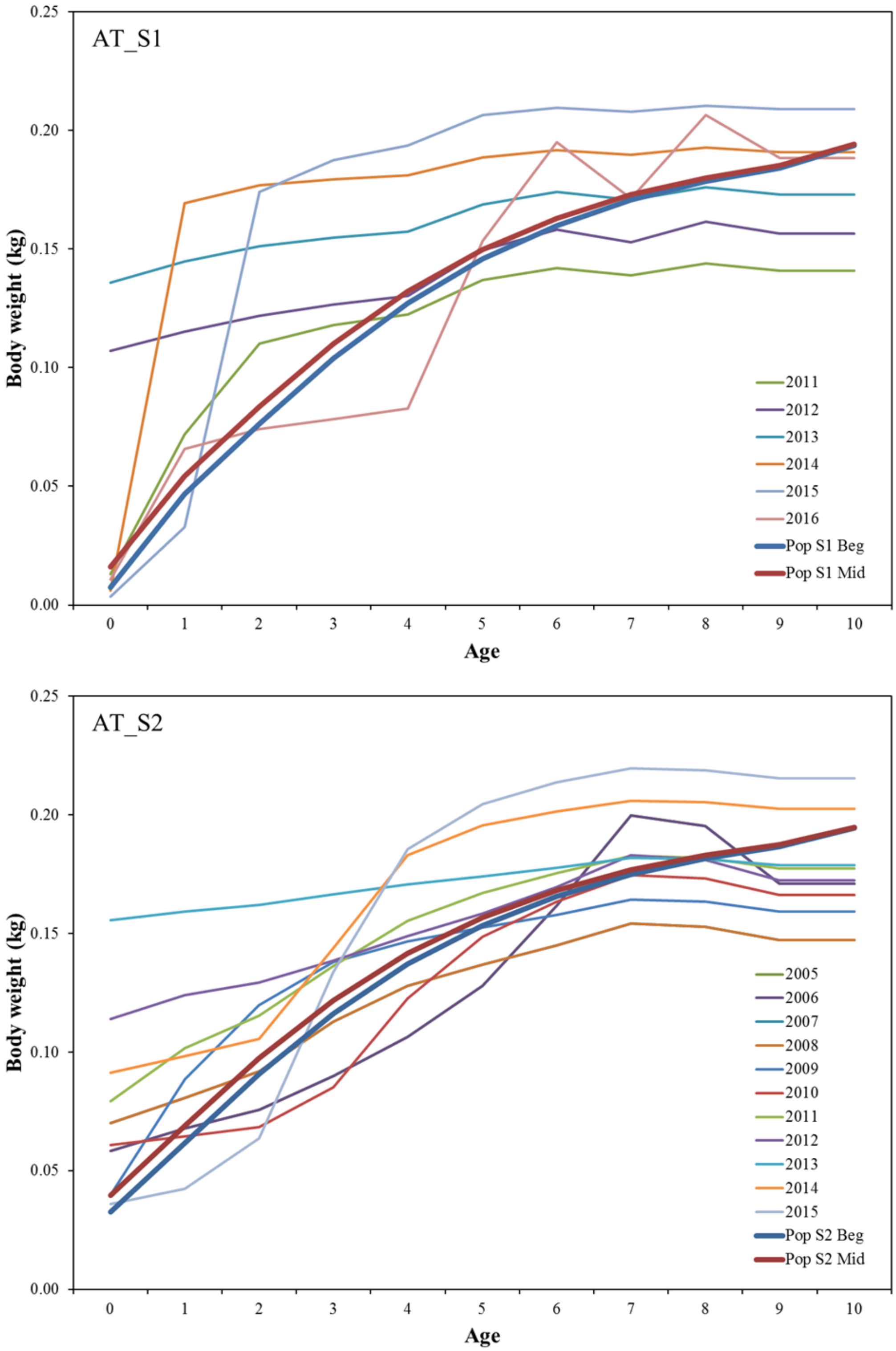


Figure 7. Empirical weight-at-age time series for the AT survey in seasons 1 and 2.

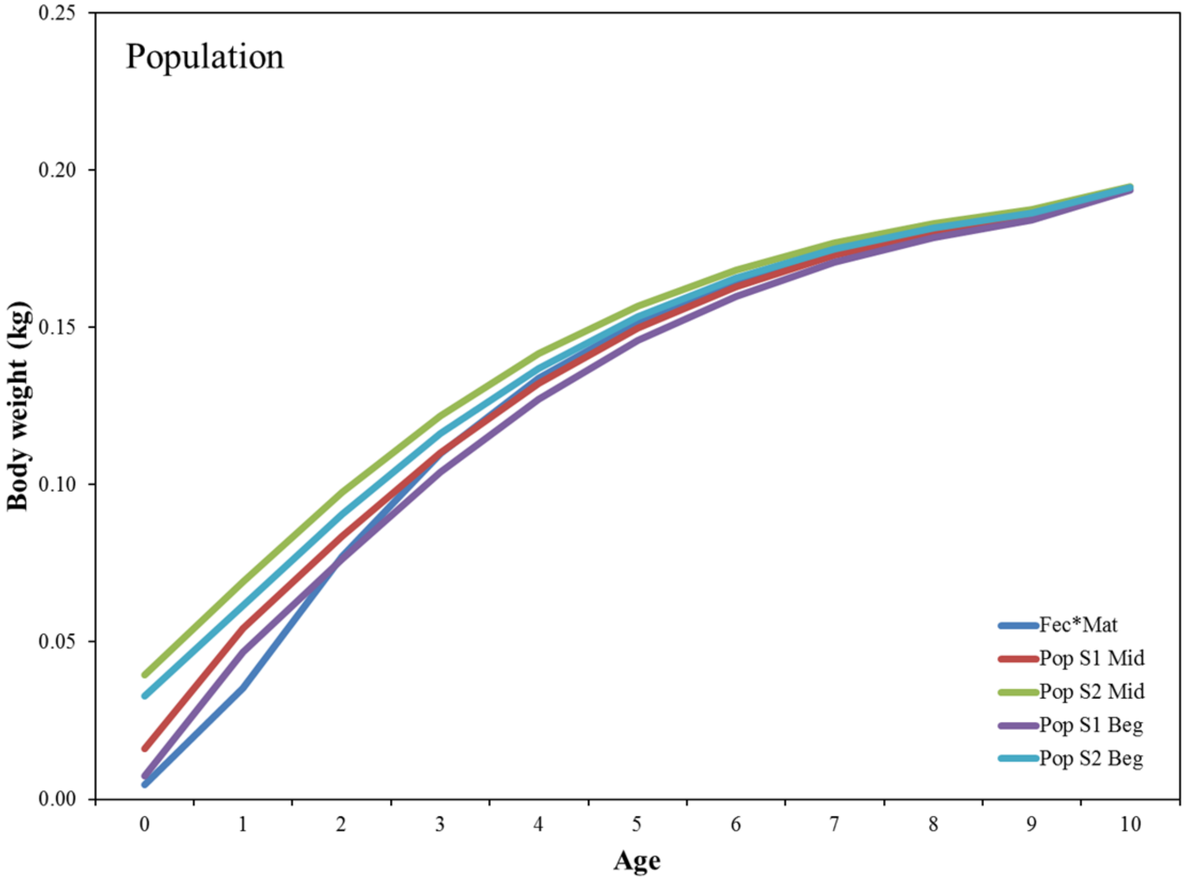


Figure 8. Population body weights-at-age and SSB-at-age applied in model ALT. Population body weights-at-age are provided at the beginning and middle of seasons 1 and 2, and fecundity*maturity-at-age is used to calculate SSB at the beginning of season 2.

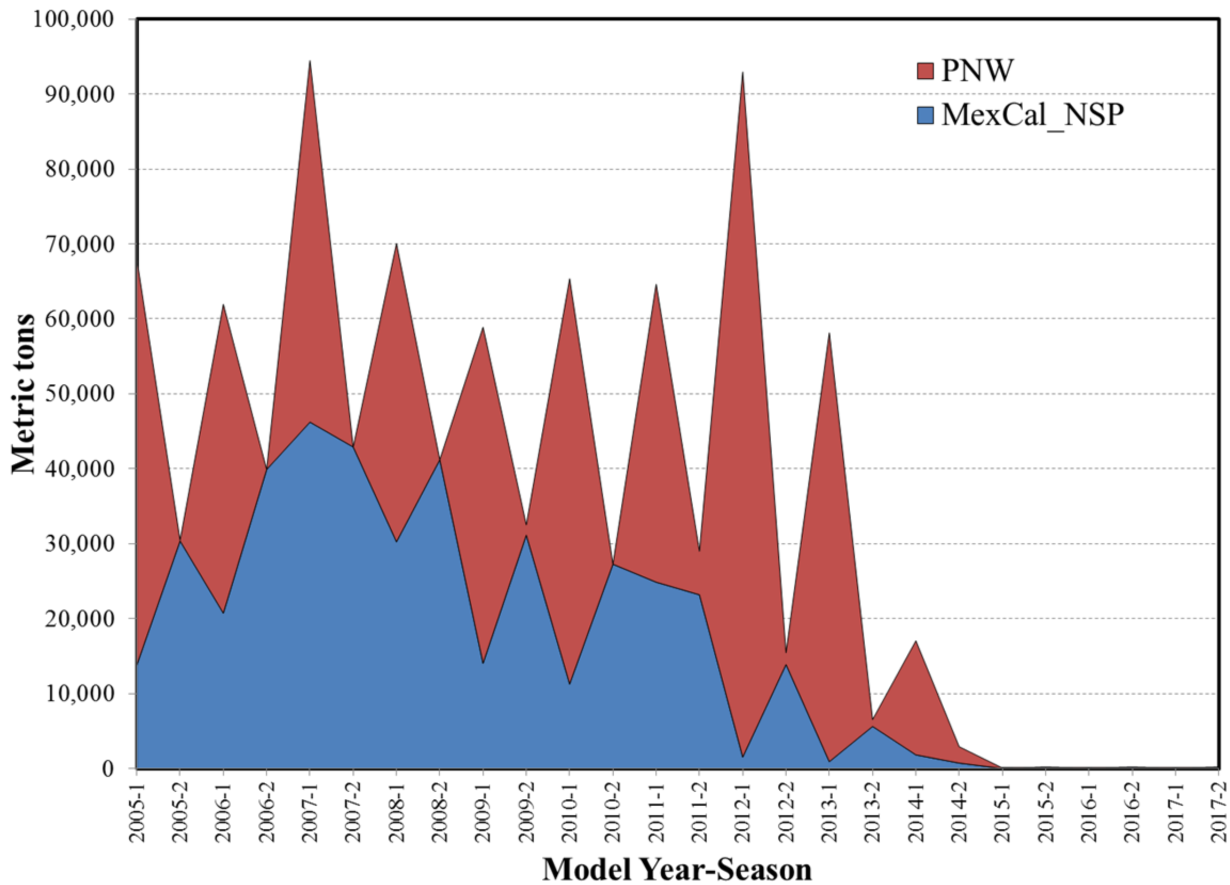


Figure 9. Pacific sardine NSP landings (mt) by fleet, model year and semester as used in model ALT.

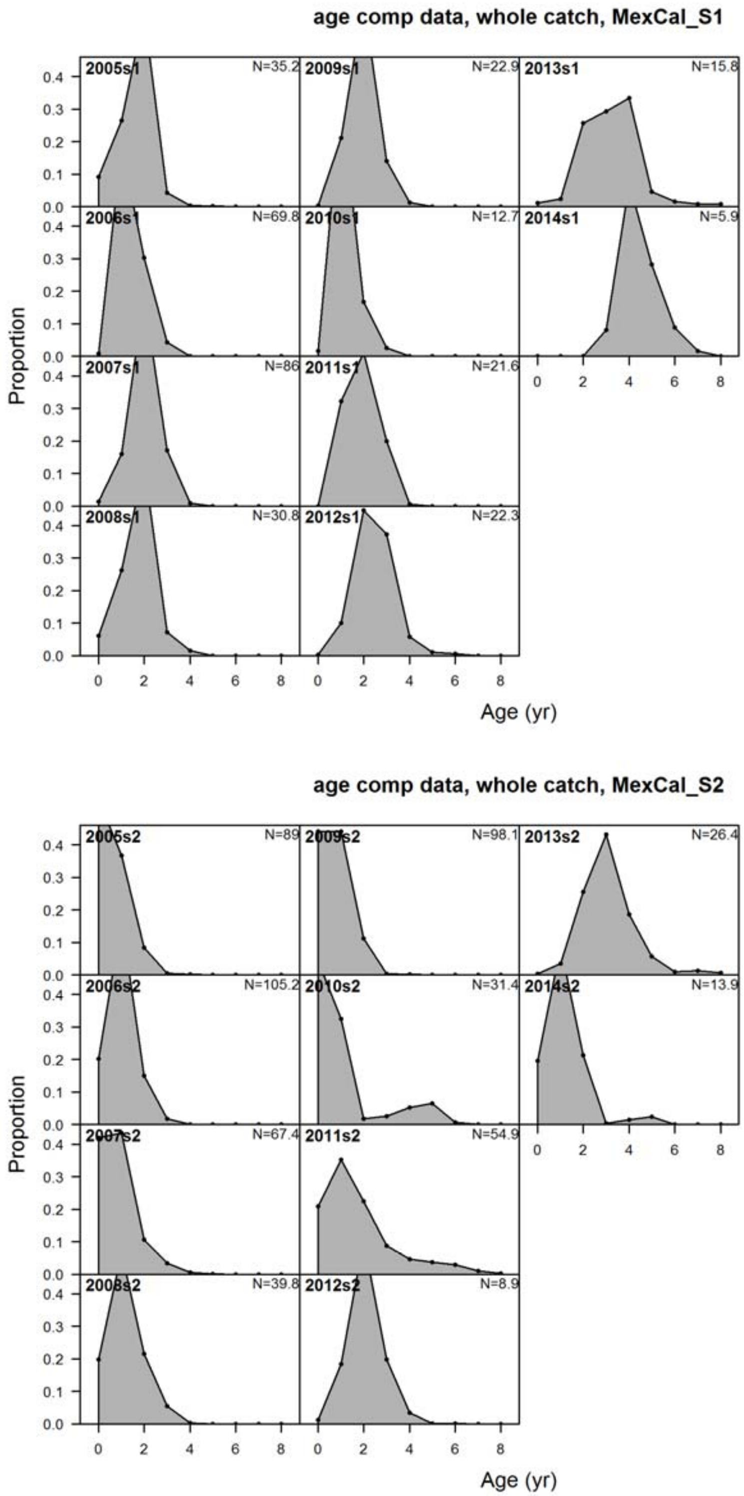


Figure 10. Age composition time series for the MEXCAL fleet in seasons 1 (upper) and 2 (lower). N represents input sample sizes.

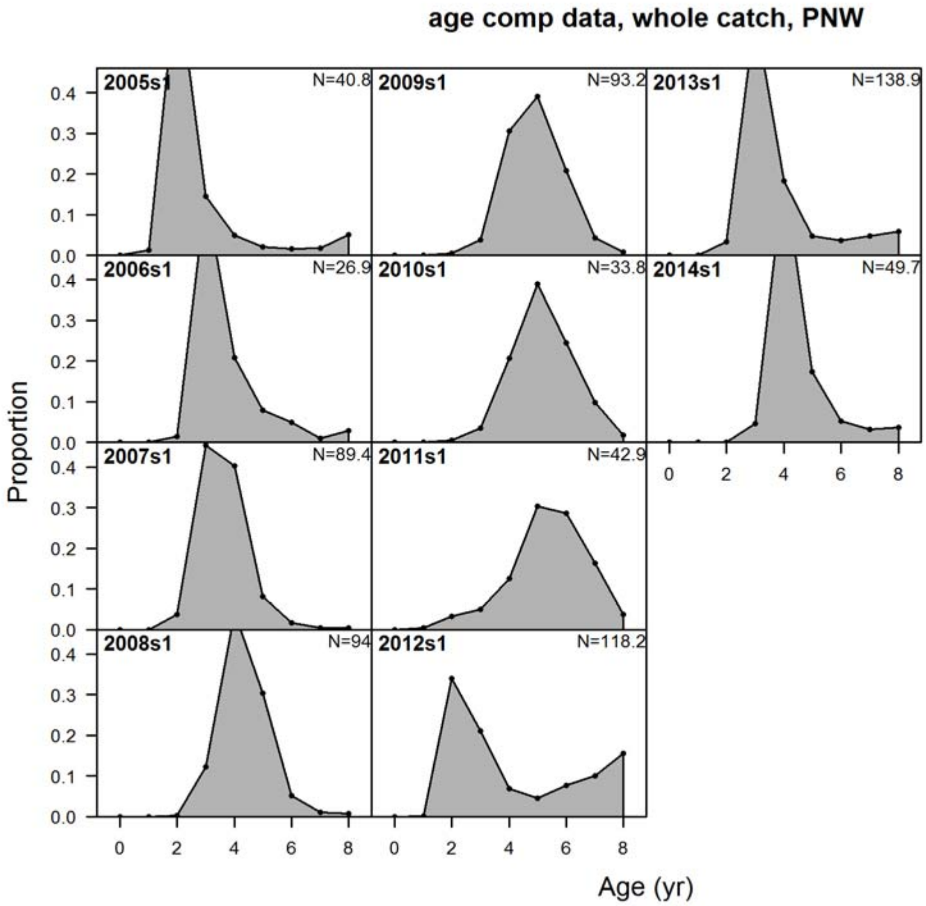


Figure 11. Age composition time series for the PNW fleet in season 1. N represents input sample sizes.

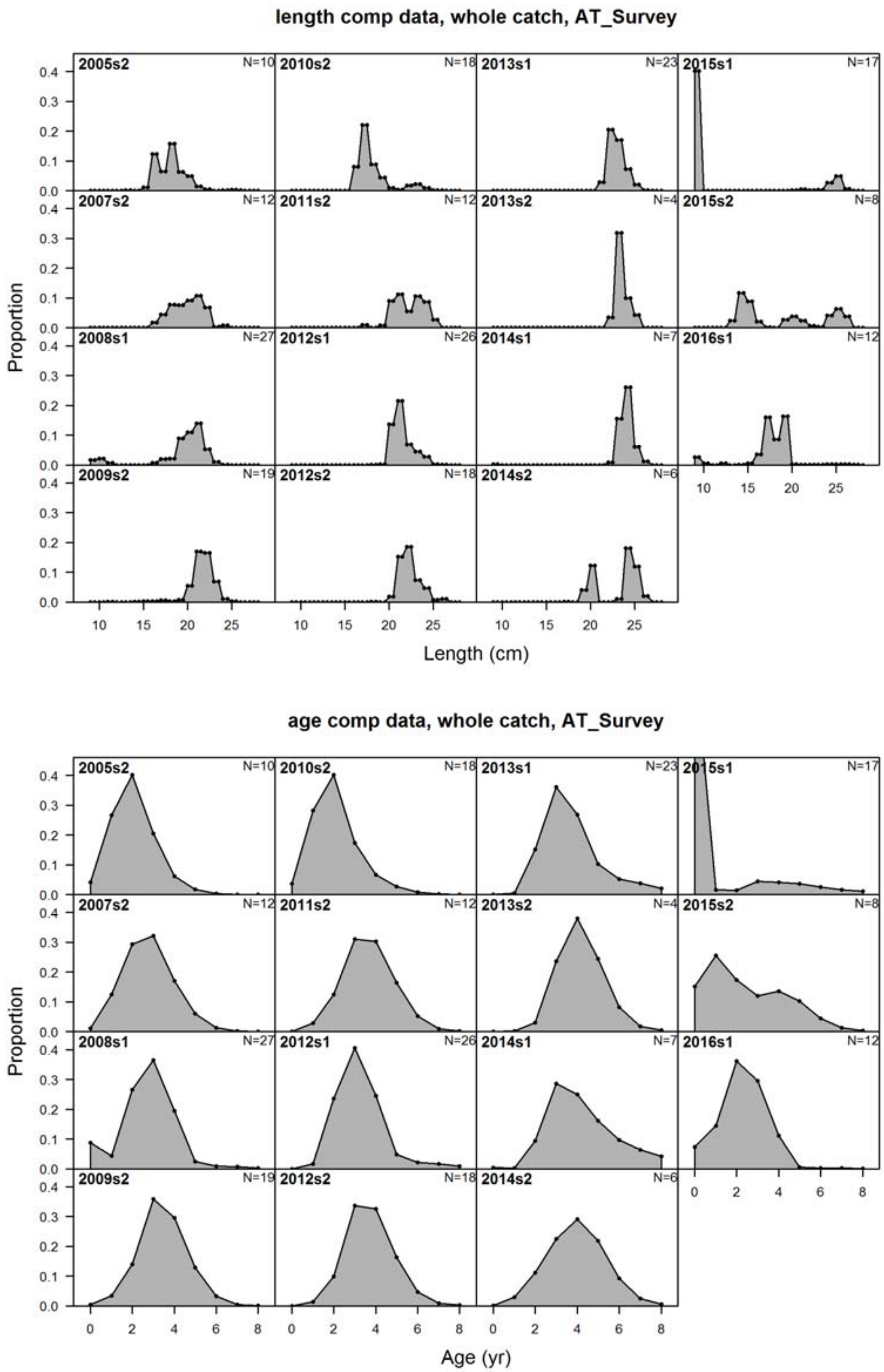


Figure 12. Length- (upper panel) and age-composition (lower panel) time series for the AT survey. N represents input sample sizes.

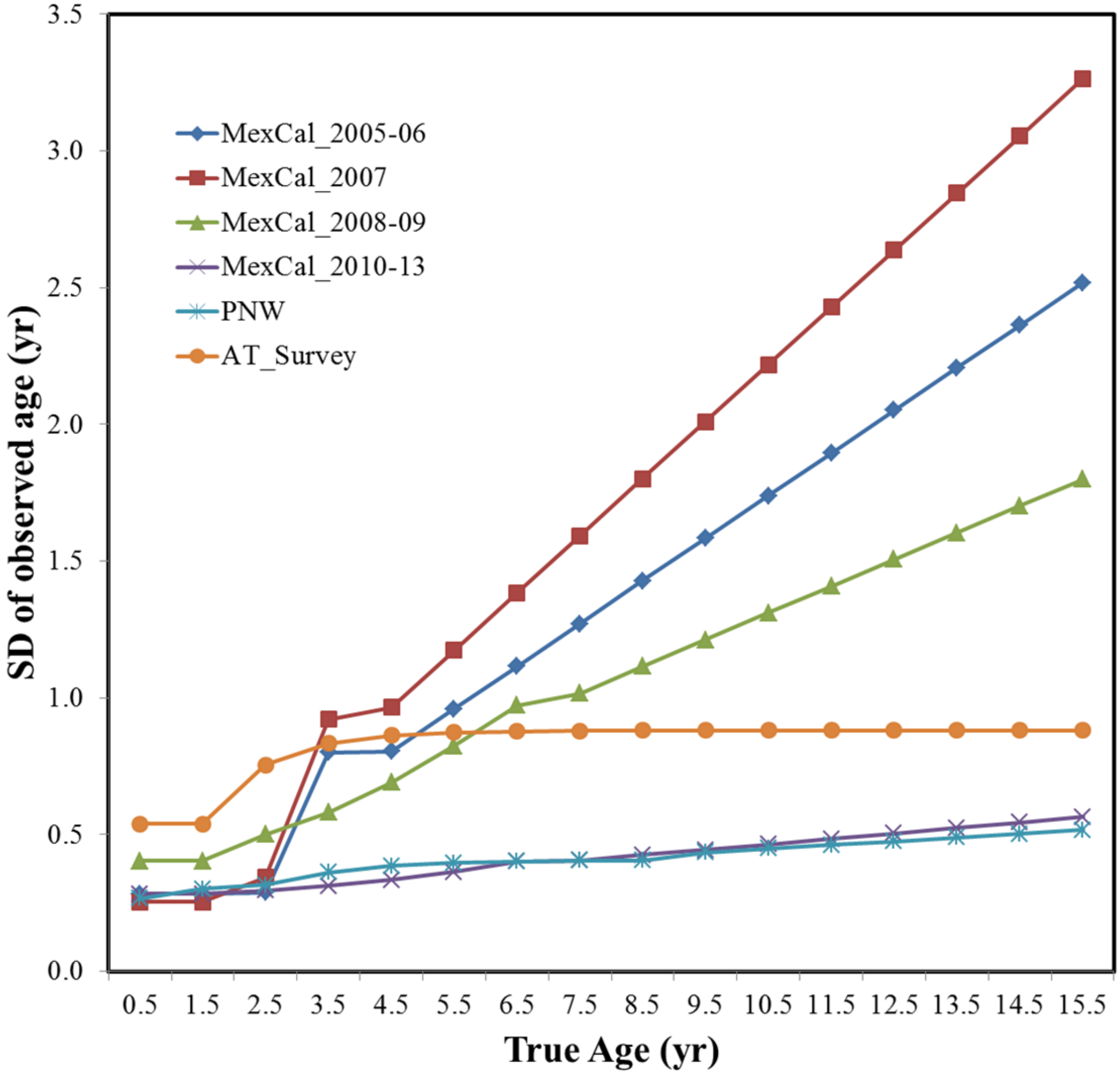


Figure 13. Laboratory- and year-specific ageing errors applied in model ALT.

Figure 14. Results from the AT survey for spring 2016. Acoustic backscatter (s_A, m^2 n.mi.^{2}) from coastal pelagic fish species (CPS) superimposed on the distribution of potential sardine habitat (dashed lines) defined at the mid-period of the survey (left); acoustic proportions of CPS in trawl clusters, including northern anchovy (*Engraulis mordax*), Pacific mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*)(middle); and density (eggs min^{-1}) of sardine eggs from the continuous underway fish egg sampler (right).

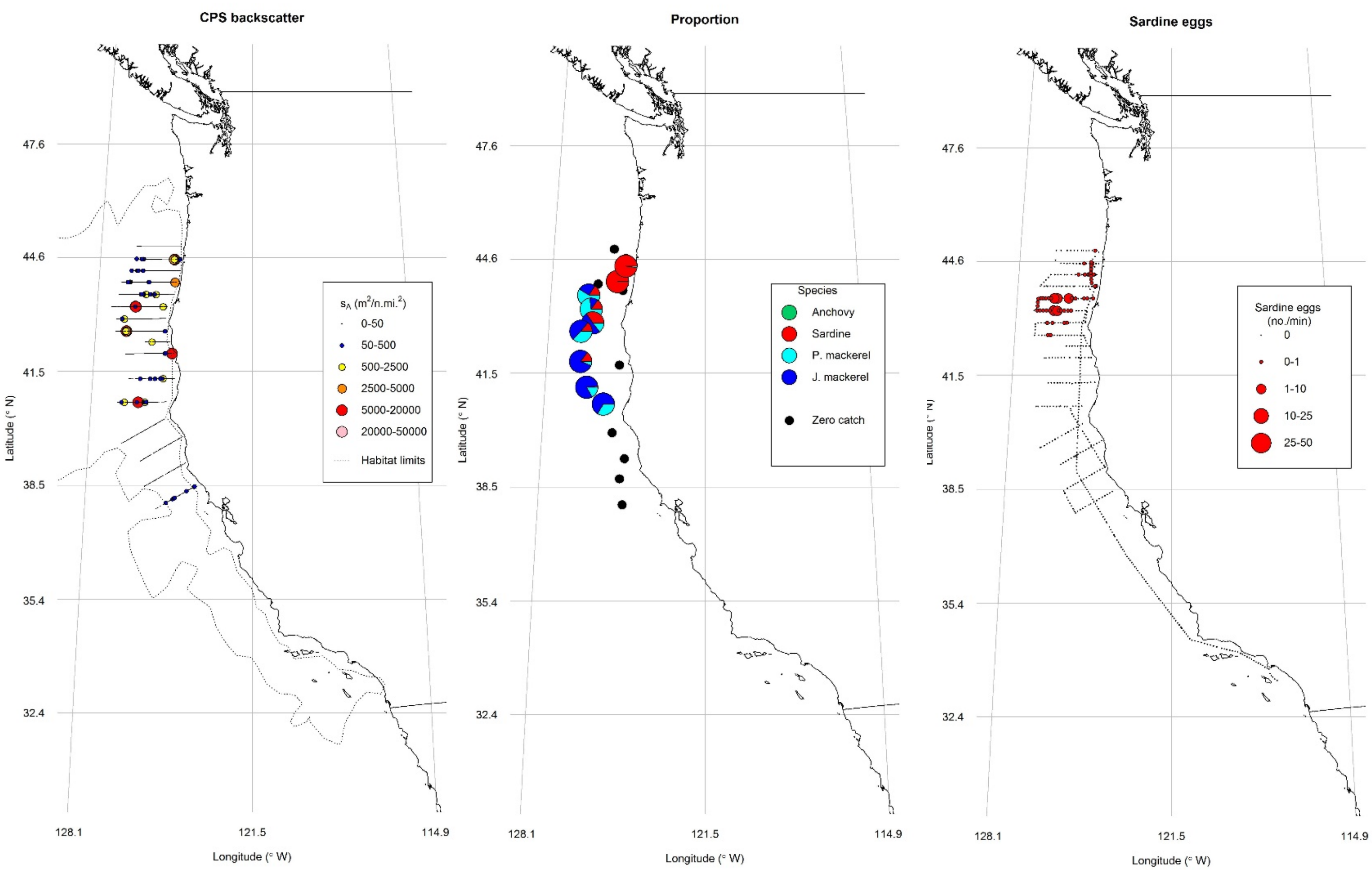


Figure 15. Results from the AT survey for summer 2016. Acoustic backscatter (s_A, m^2 n.mi.^{2}) from coastal pelagic fish species (CPS; left); acoustic proportions of CPS in trawl clusters (right), including northern anchovy (*Engraulis mordax*), Pacific mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*), and Pacific herring (*Clupea pallasii*). Egg samples are not shown because the primary spawning period for sardine is during spring.

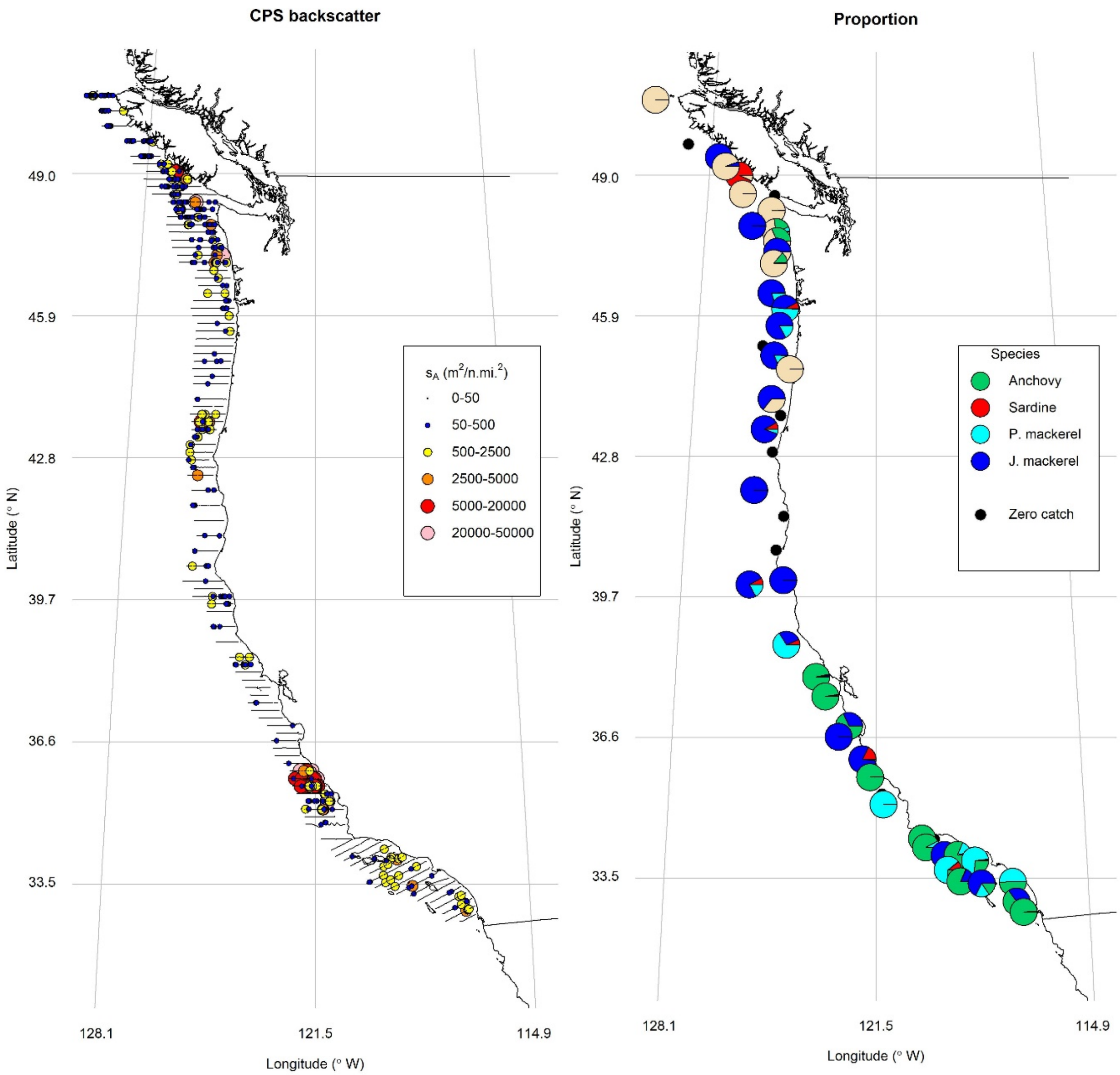


Figure 16. Sardine biomass densities versus stratum (Table 6) estimated in the AT survey for spring 2016. The red numbers represent the locations of trawl clusters with at least one sardine.

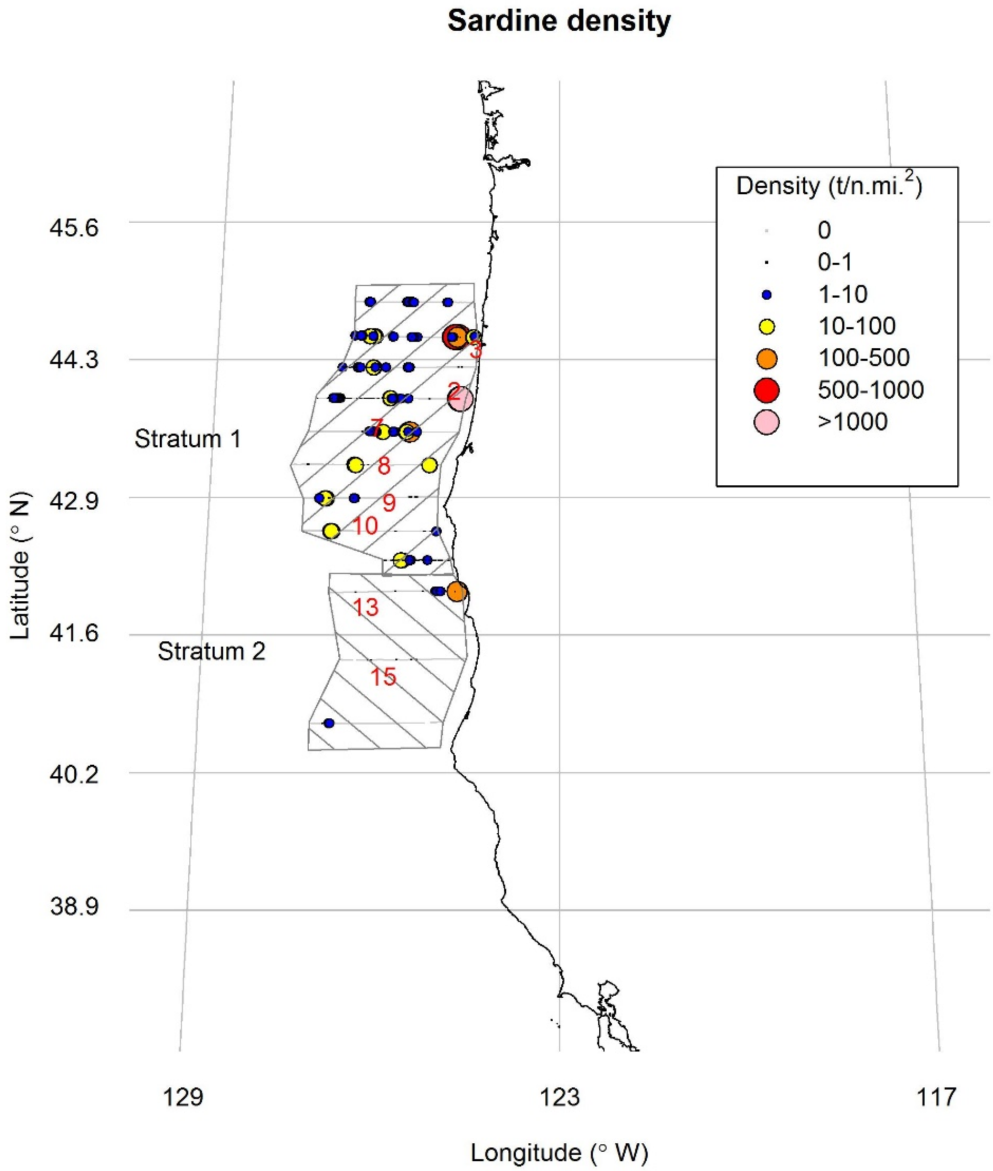


Figure 17. Estimated sardine abundance by length-class for the entire survey area and for the two strata (Figure 16) for the AT survey in spring 2016. The corresponding number of sardine sampled in each stratum is provided in Table 6.

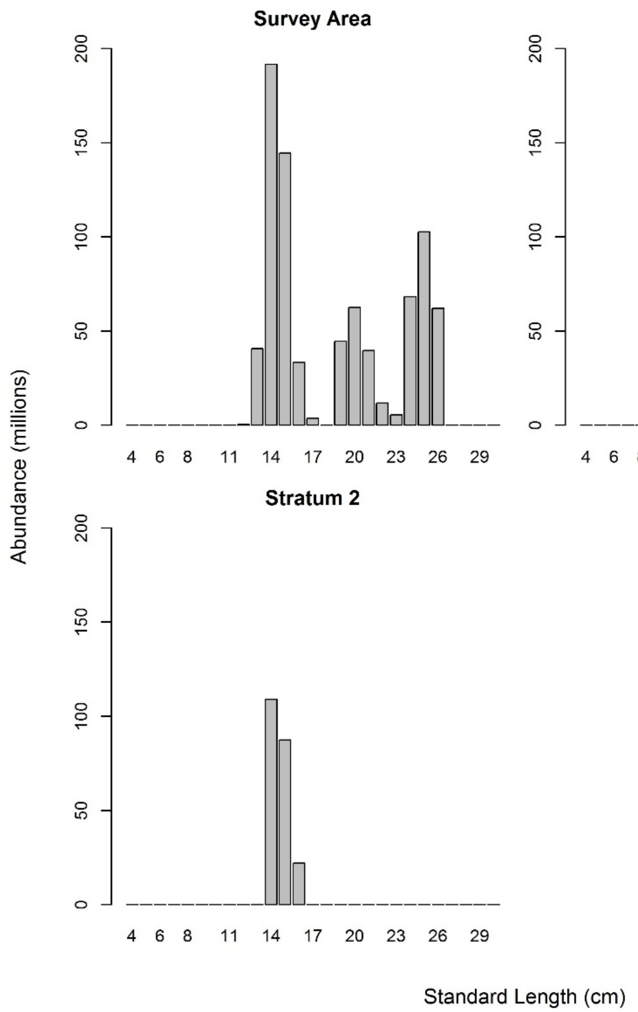


Figure 18. Sardine biomass densities versus stratum (Table 7) estimated in the AT survey for summer 2016. Numbers in red represent the locations of trawl clusters with at least one sardine.

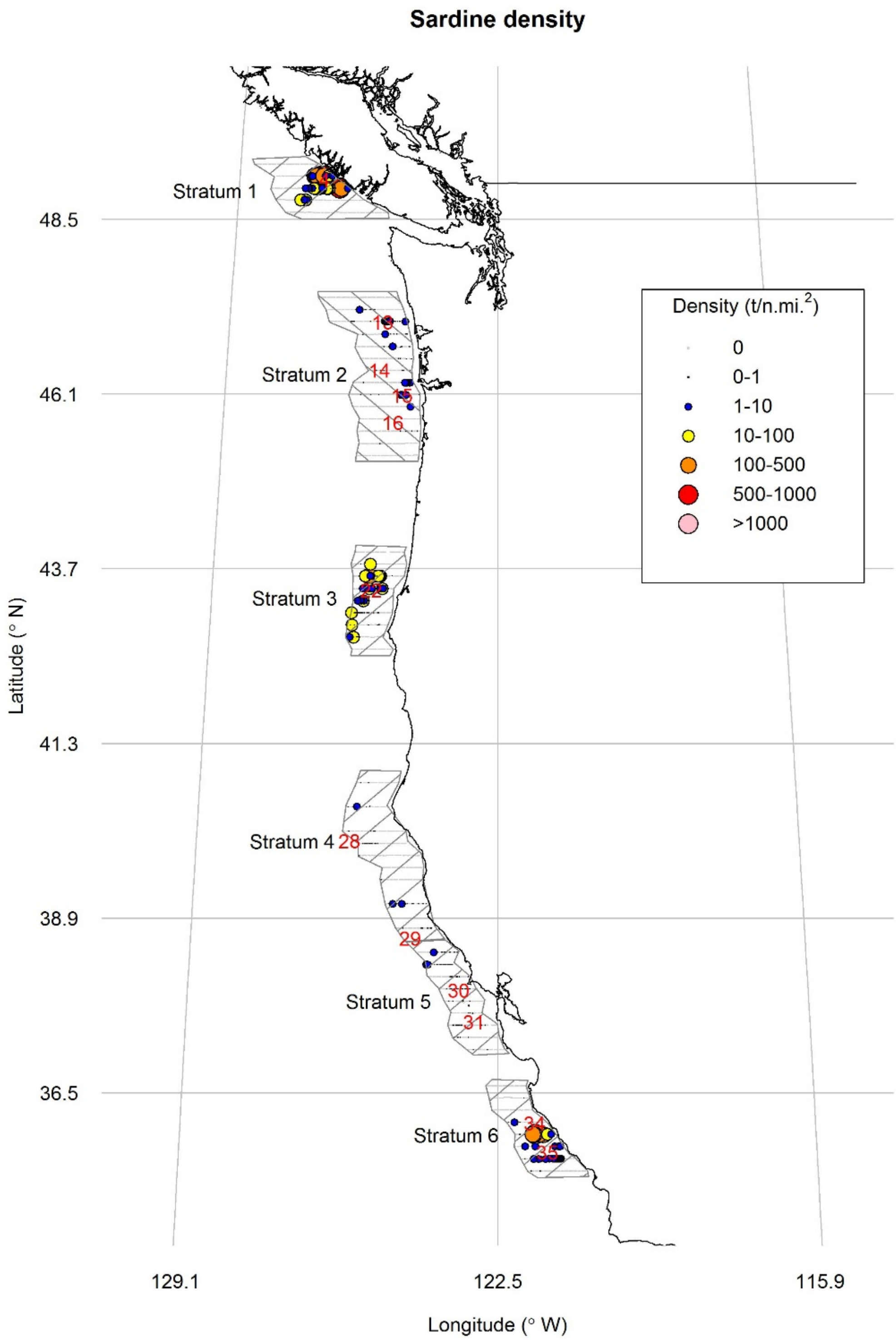
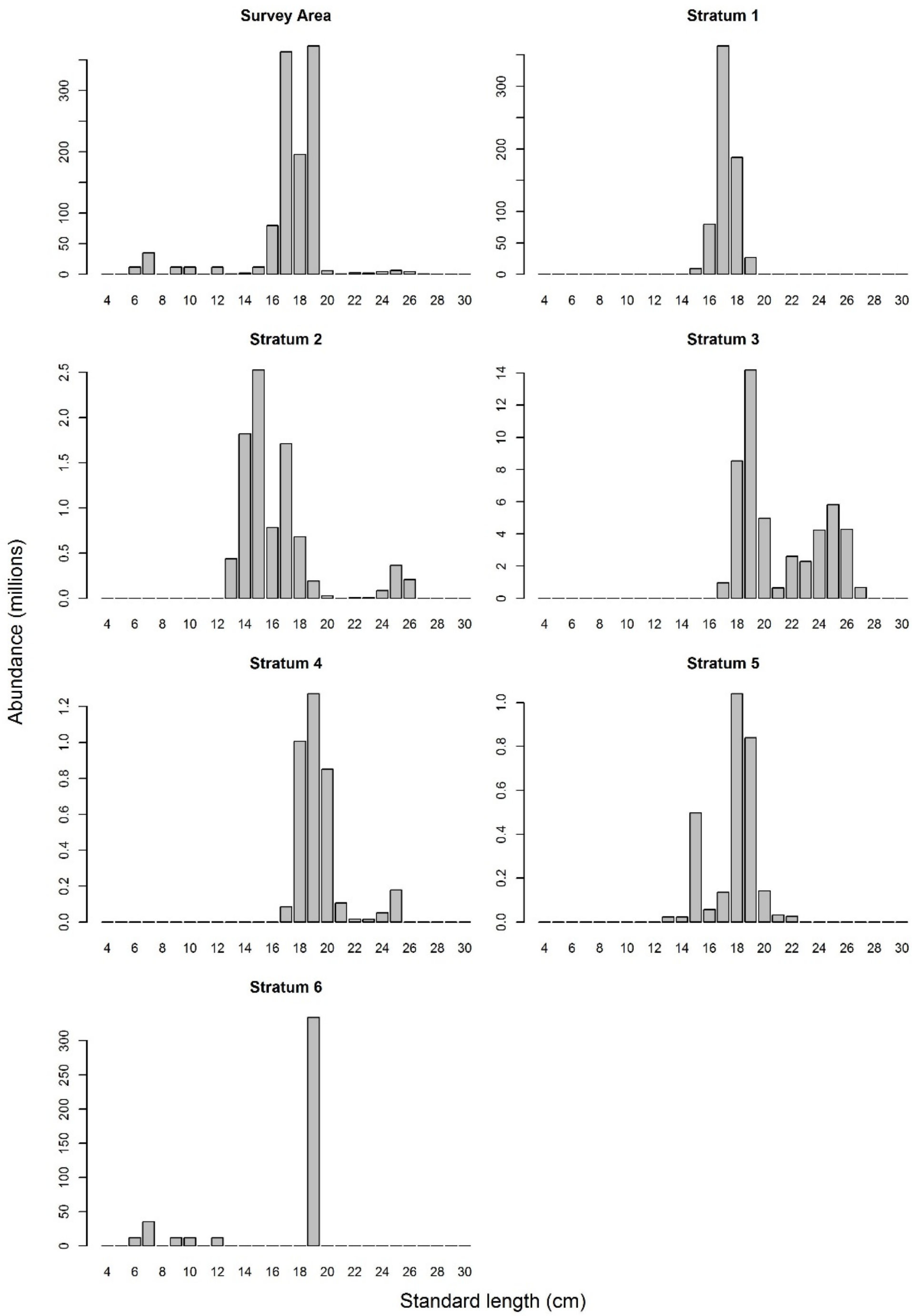


Figure 19. Estimated sardine abundance by length-class for the entire survey area and for the six strata (Figure 18) in the AT survey in summer 2016. The corresponding number of sardine sampled in each stratum is provided in Table 7.



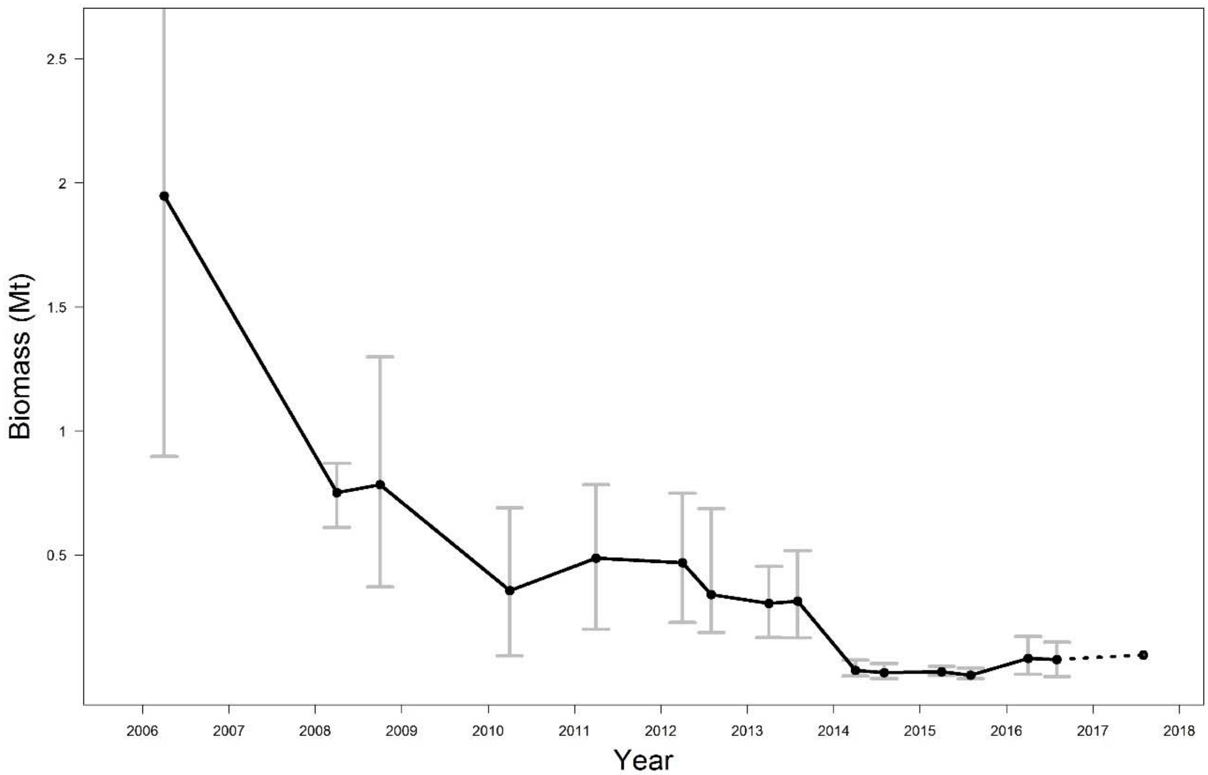


Figure 20. Time-series of Pacific sardine biomass with respective 95% confidence intervals as estimated by acoustic-trawl (AT) surveys. The biomass in July 2017 was projected based on the summer 2016 AT biomass and the expected recruitment using the ALT model's S-R relationship.

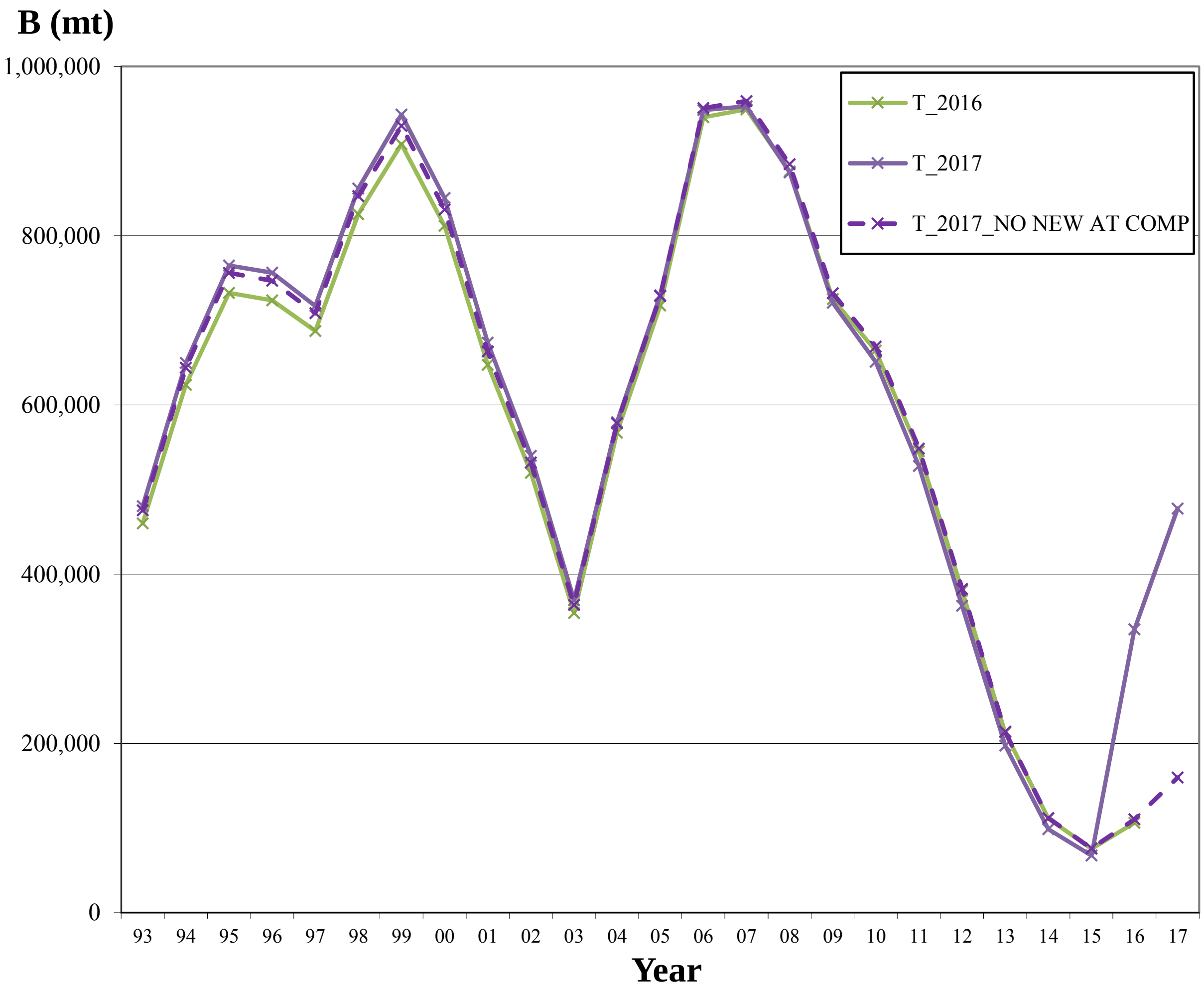


Figure 21. Estimated stock biomass (age 1+ fish, mt) time series for the 2016 update model (T_2016), the update model with 2016 AT biomass and length compositions (T_2017), and the update model with no new AT length compositions.

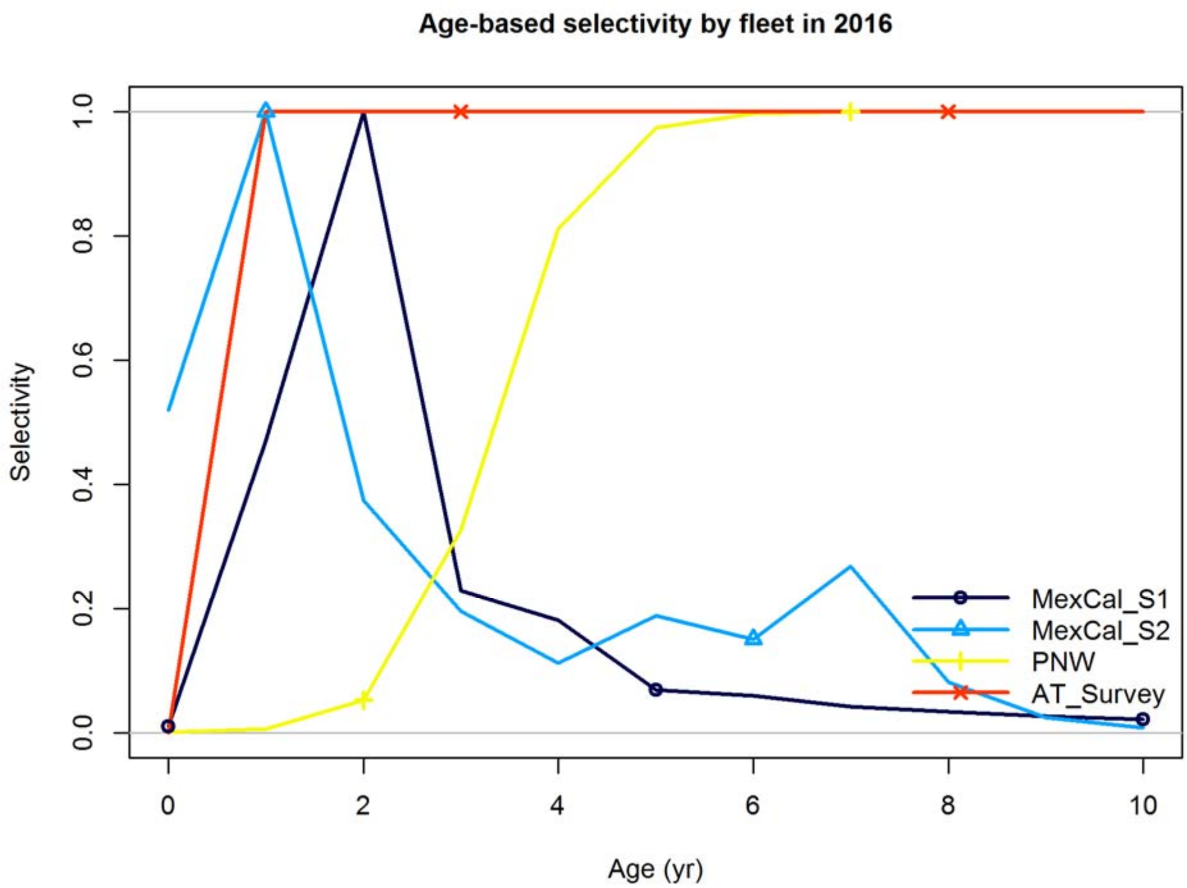
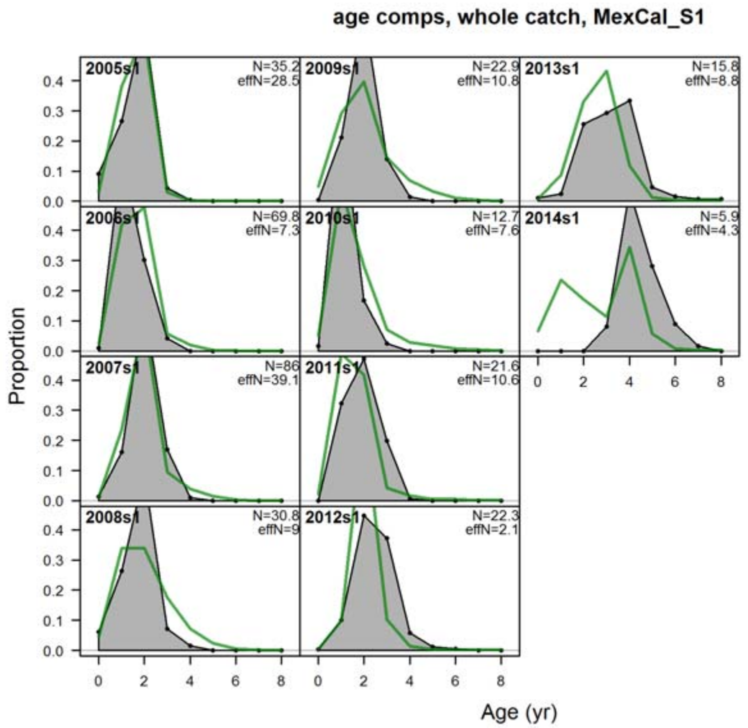


Figure 22. Age-selectivity patterns for model ALT.



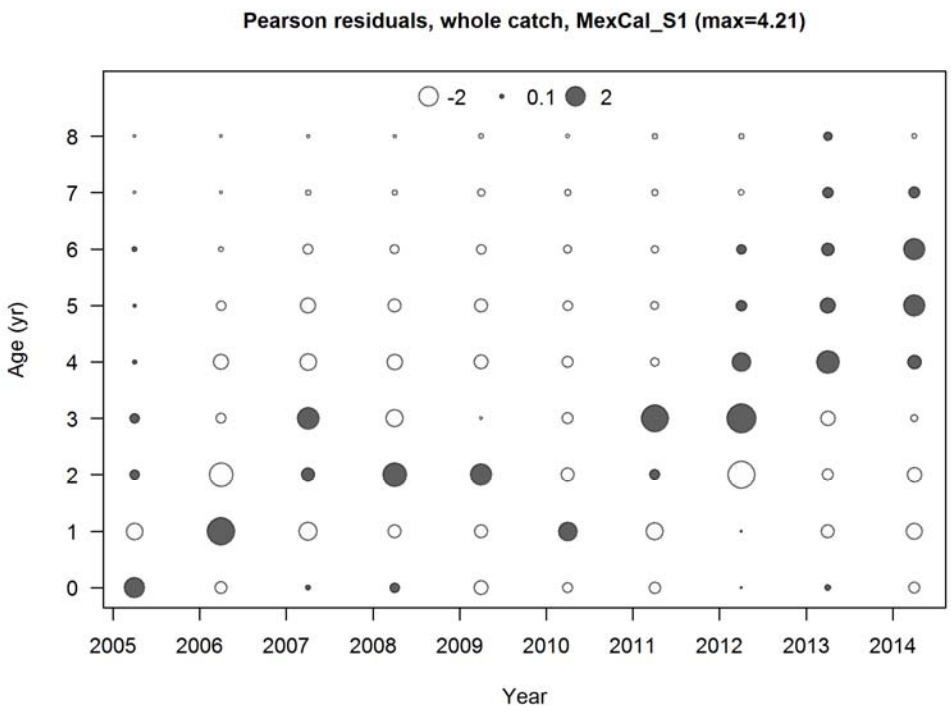
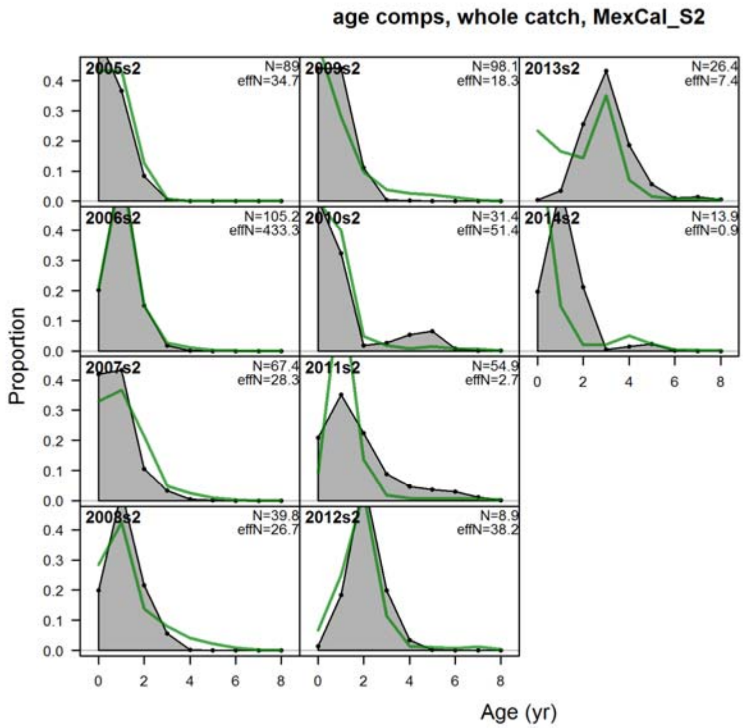


Figure 23. . Fit to age-composition time series and residual plot for the MEXCAL_S1 fleet in model ALT. N represents input sample sizes and effN is the effective sample size given overall statistical fit in the model.



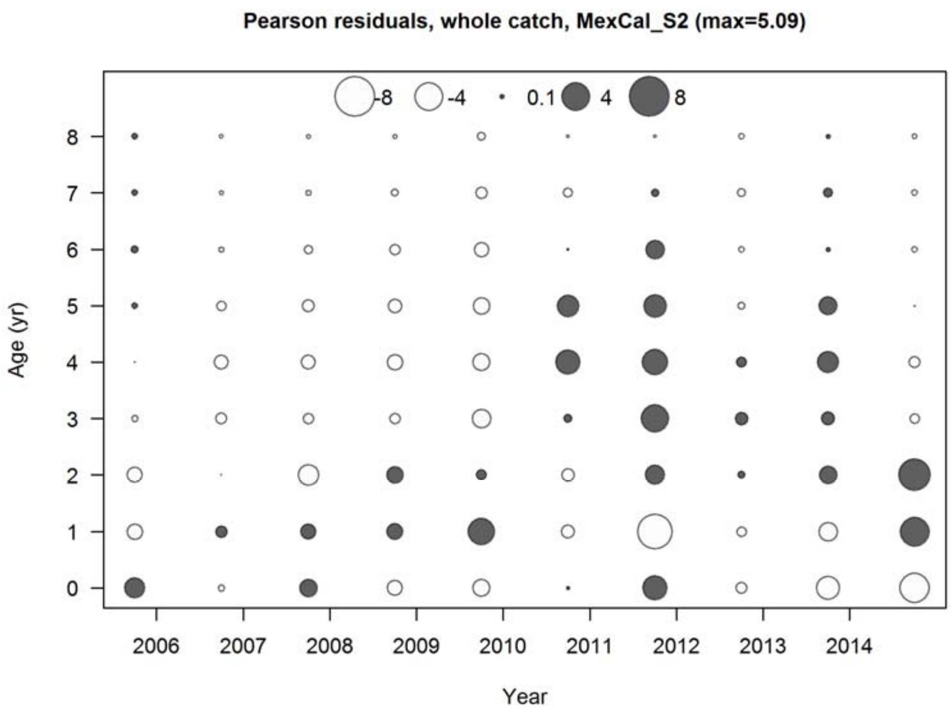
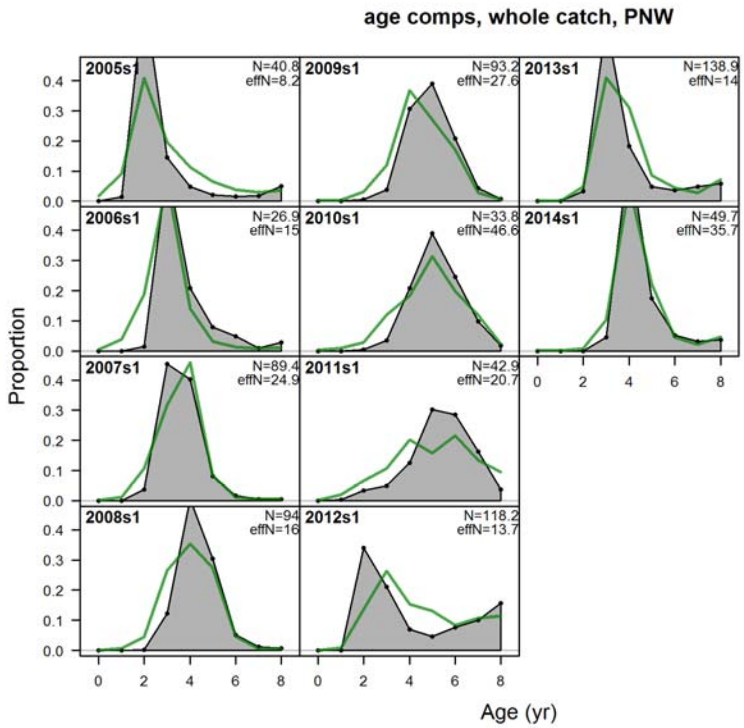


Figure 24. Fit to age-composition time series and residual plot for the MEXCAL_S2 fleet in model ALT. N represents input sample sizes and effN is the effective sample size given overall statistical fit in the model.



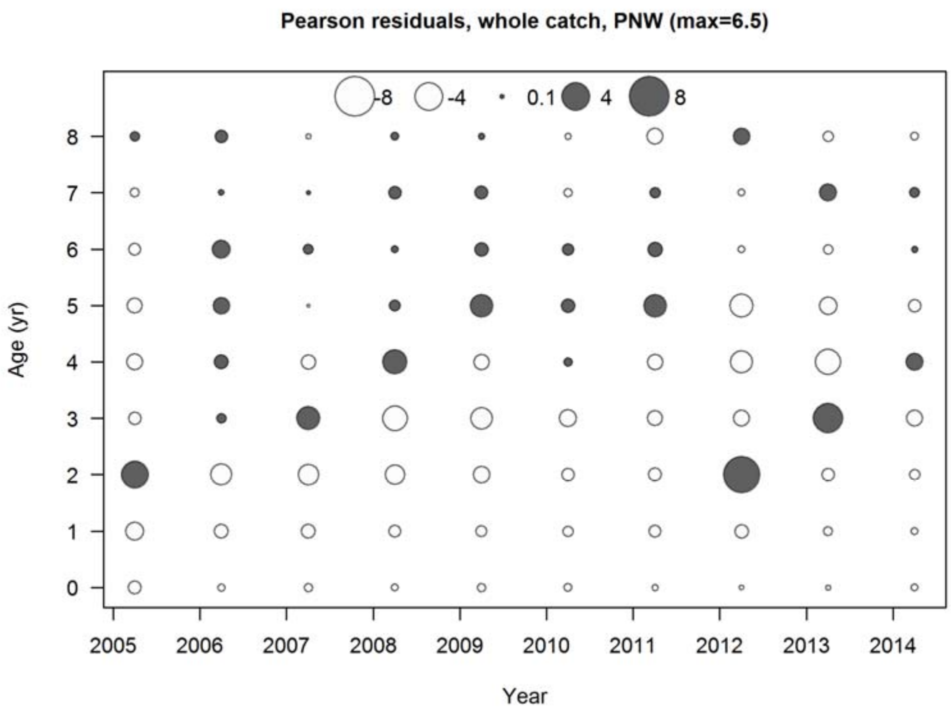


Figure 25. Fit to age-composition time series and residual plot for the PNW fleet in model ALT. N represents input sample sizes and effN is the effective sample size given overall statistical fit in the model.

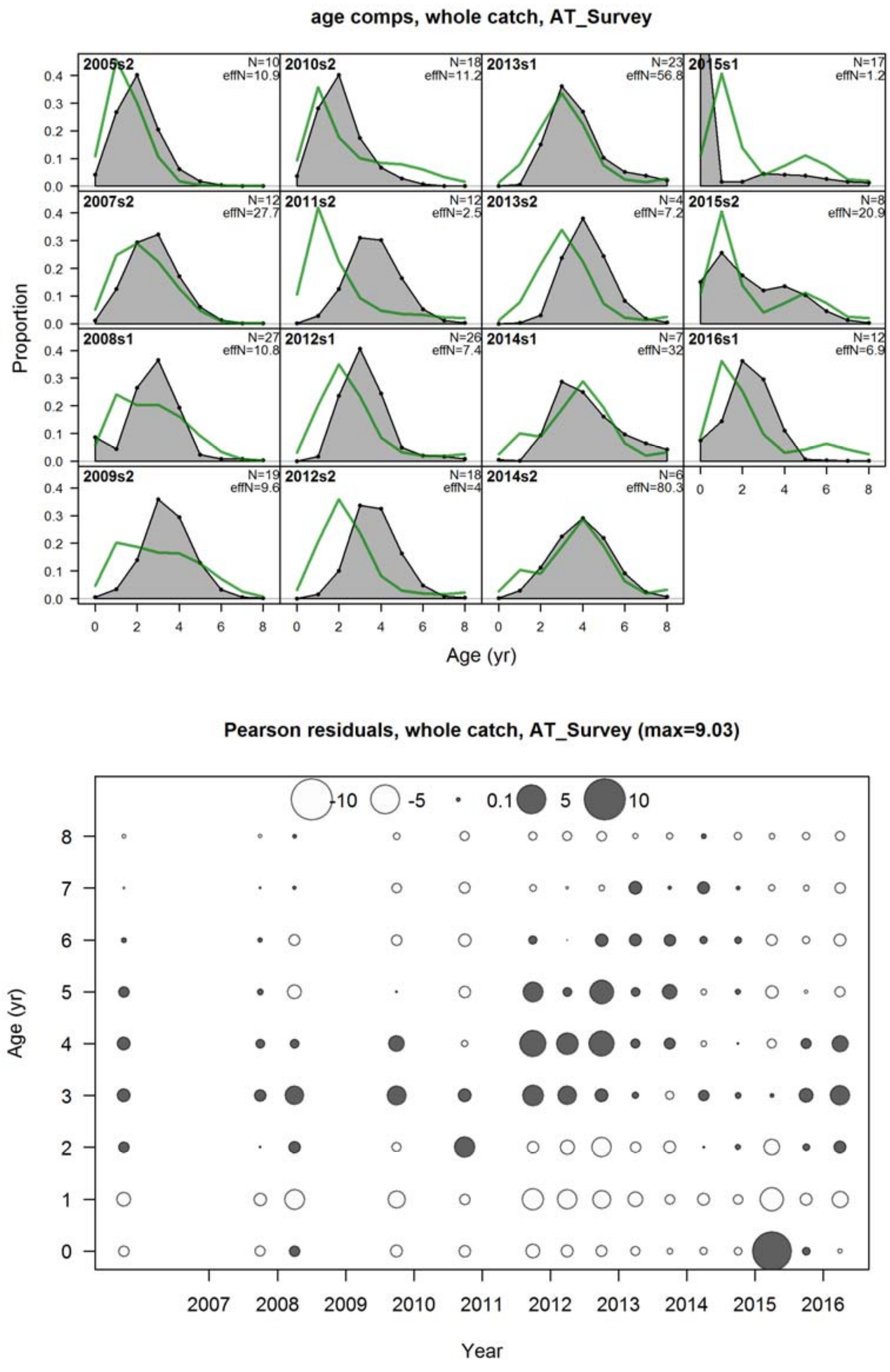


Figure 26. Fit to age-composition time series and residual plot for the AT survey for model ALT. N represents input sample sizes and effN is the effective sample size given overall statistical fit in the model.

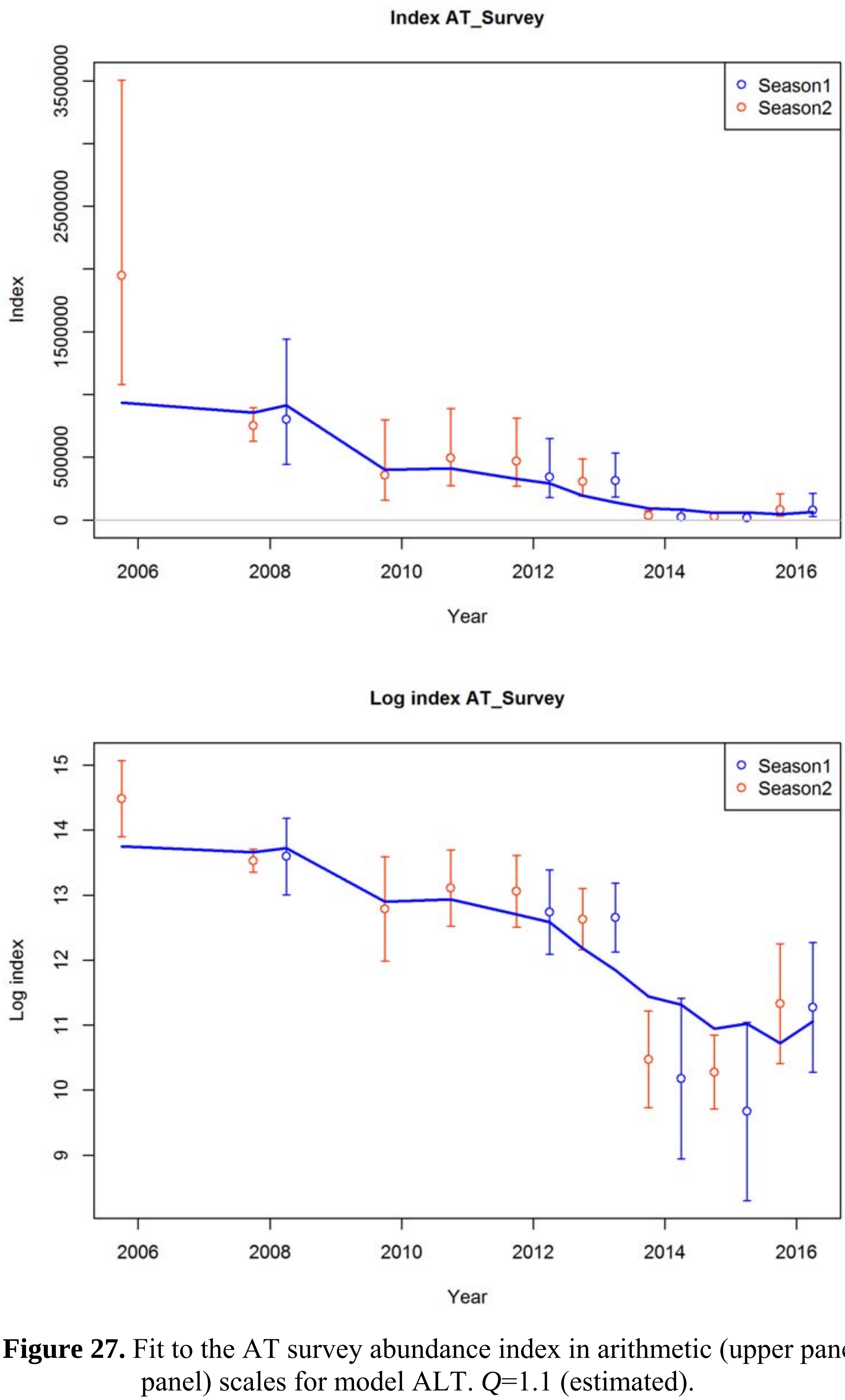


Figure 27. Fit to the AT survey abundance index in arithmetic (upper panel) and log (lower panel) scales for model ALT. *Q*=1.1 (estimated).

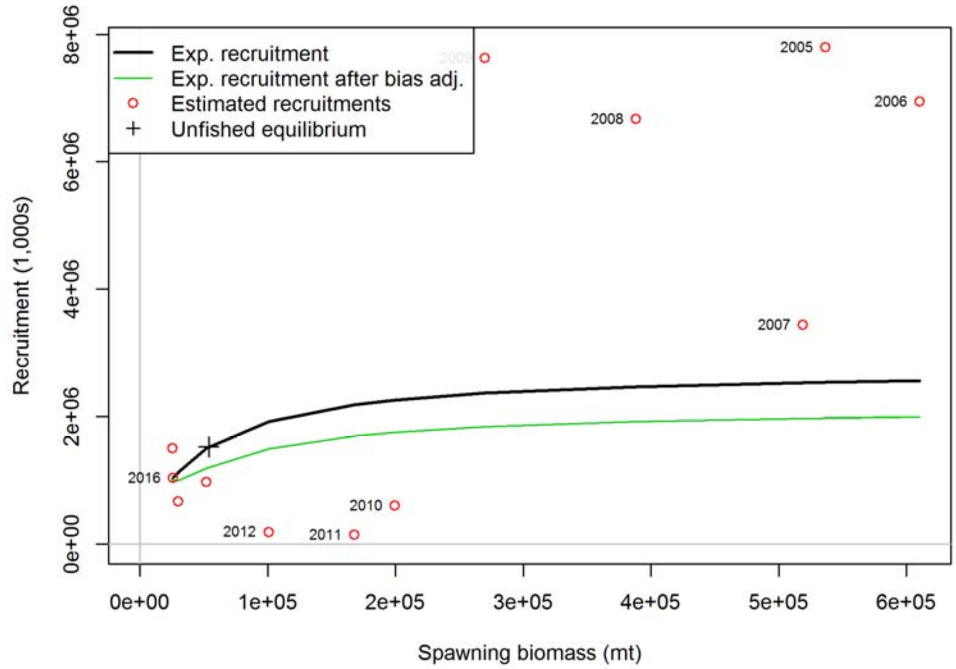


Figure 28. Estimated stock-recruitment (Beverton-Holt) relationship for model ALT. Steepness is estimated (*h*=0.36). Year labels represent year of SSB producing the subsequent year class.

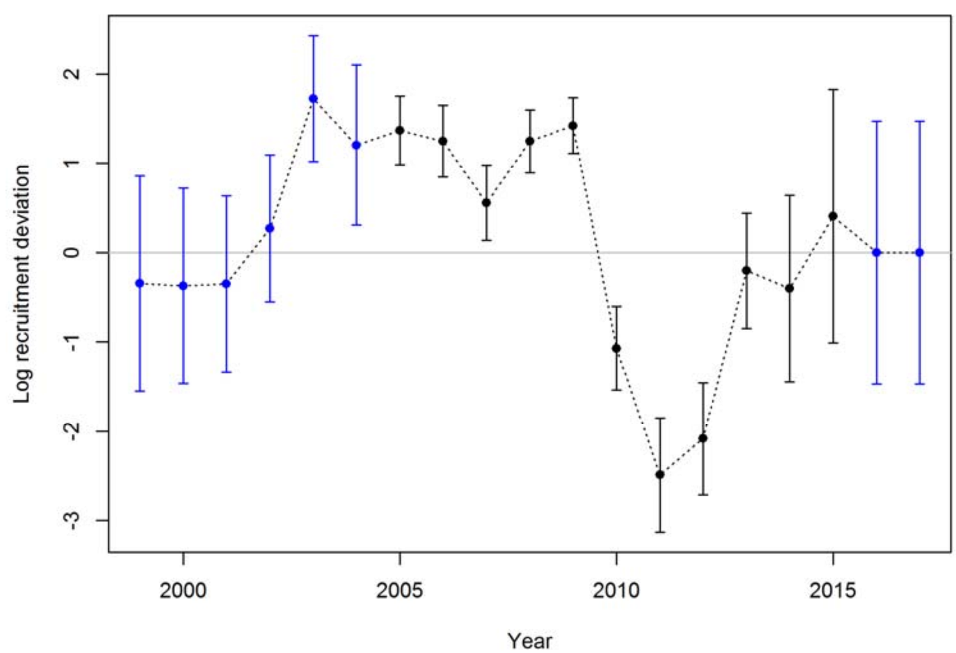


Figure 29. Recruitment deviations and standard errors (σ_R = 0.75) for model ALT. Year labels represent year of SSB producing the subsequent year class.

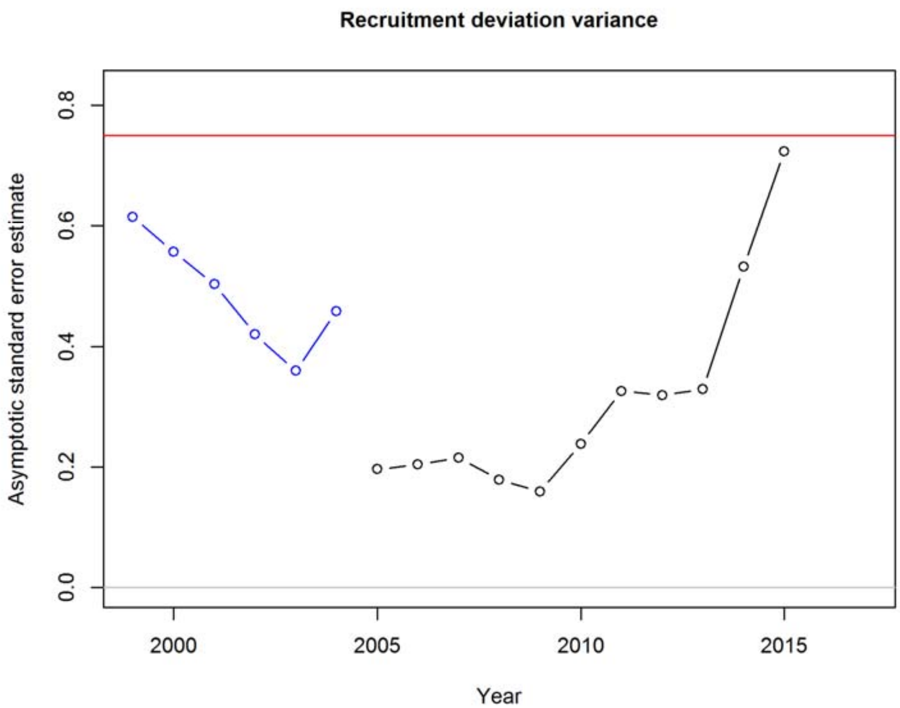


Figure 30. Asymptotic standard errors for estimated recruitment deviations for model ALT.

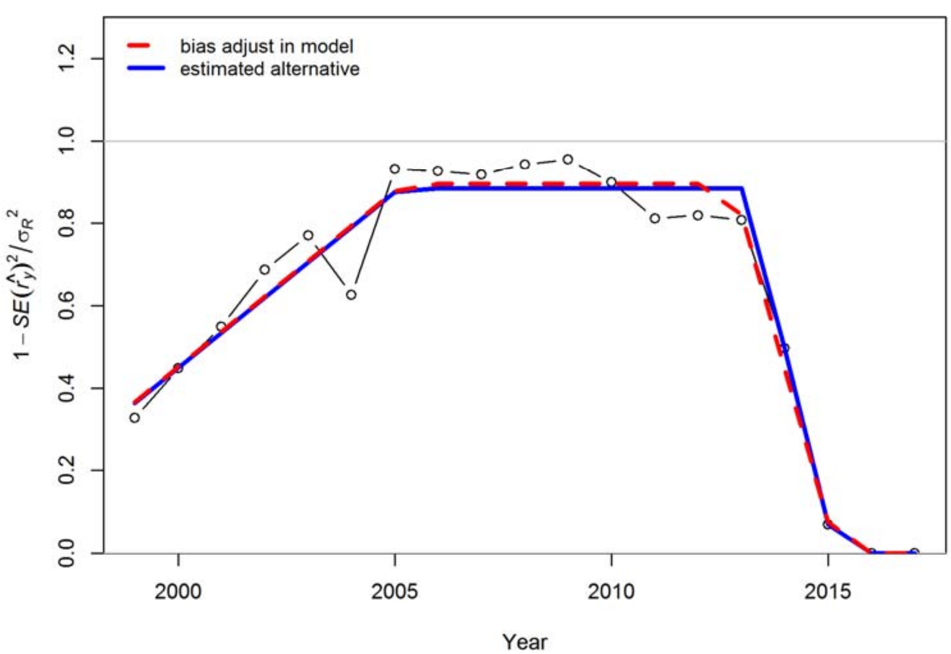


Figure 31. Recruitment bias adjustment plot for early, main, and forecast periods in model ALT.

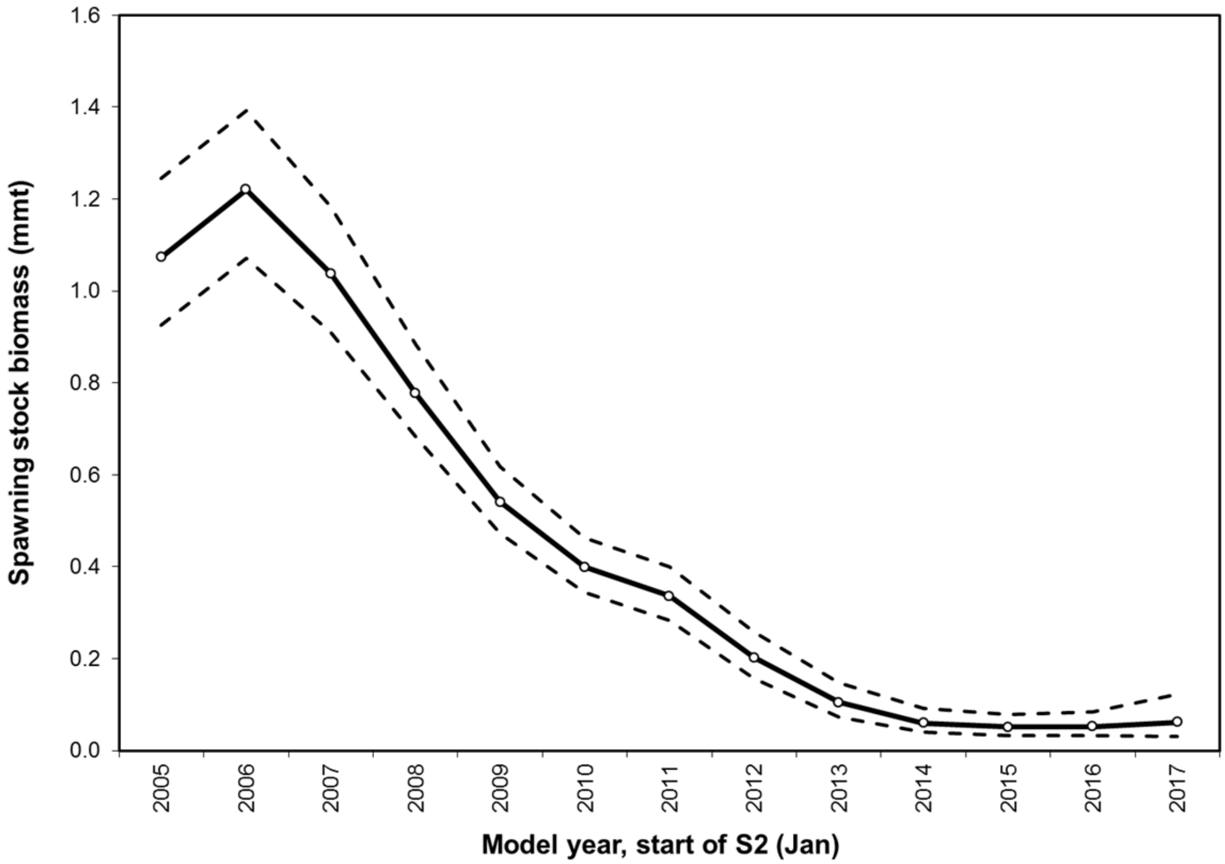


Figure 32. Spawning stock biomass time series (±95% CI) for model ALT.

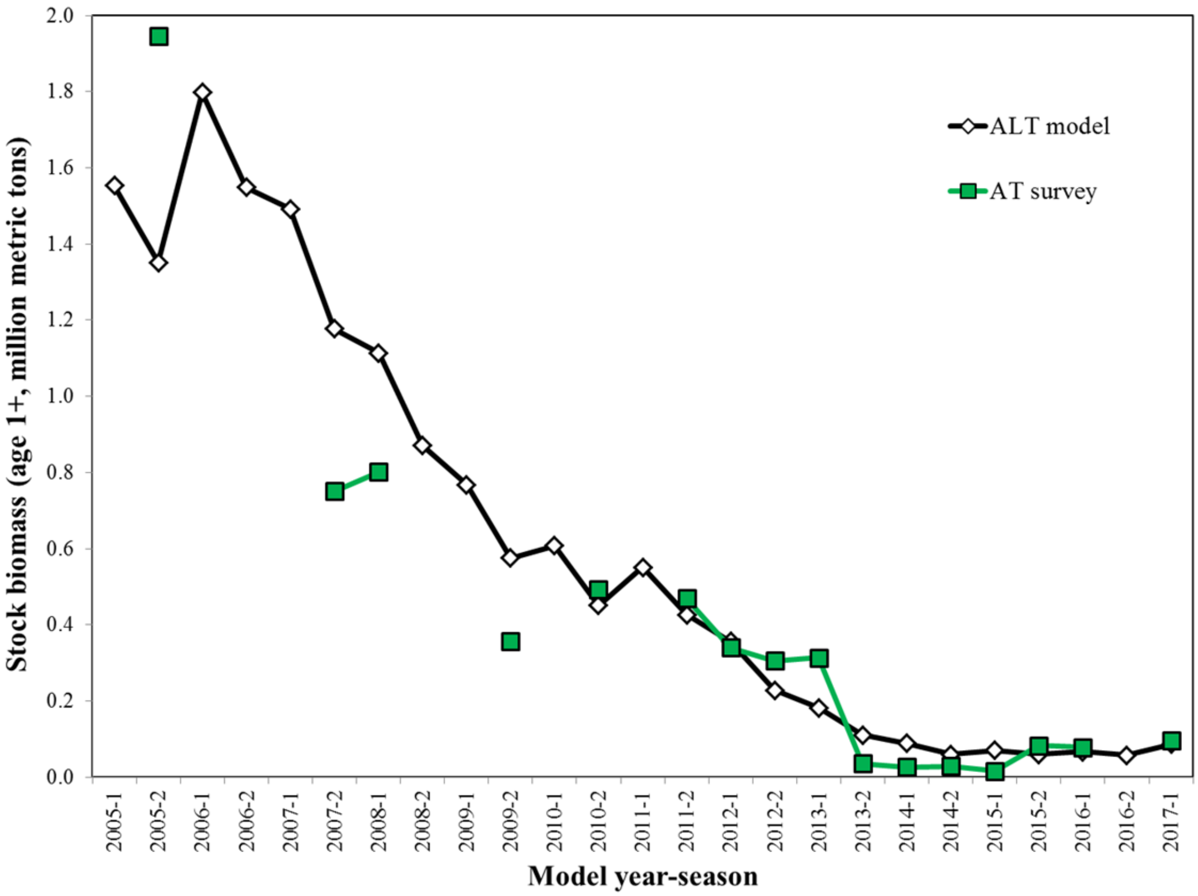


Figure 33. Estimated stock biomass (age 1+ fish, mt) time series for the AT survey and model ALT.

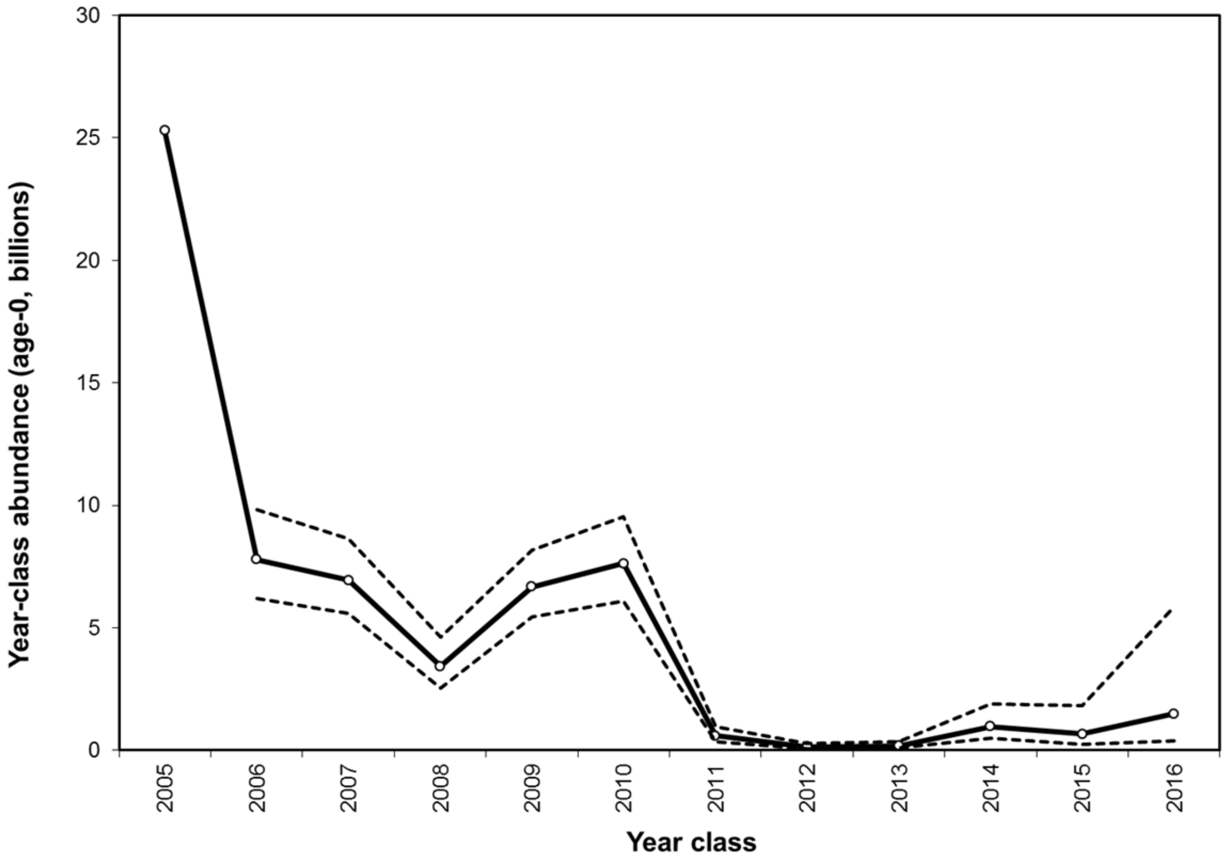


Figure 34. Recruit (age-0 fish, billions) abundance time series (±95% CI) for model ALT.

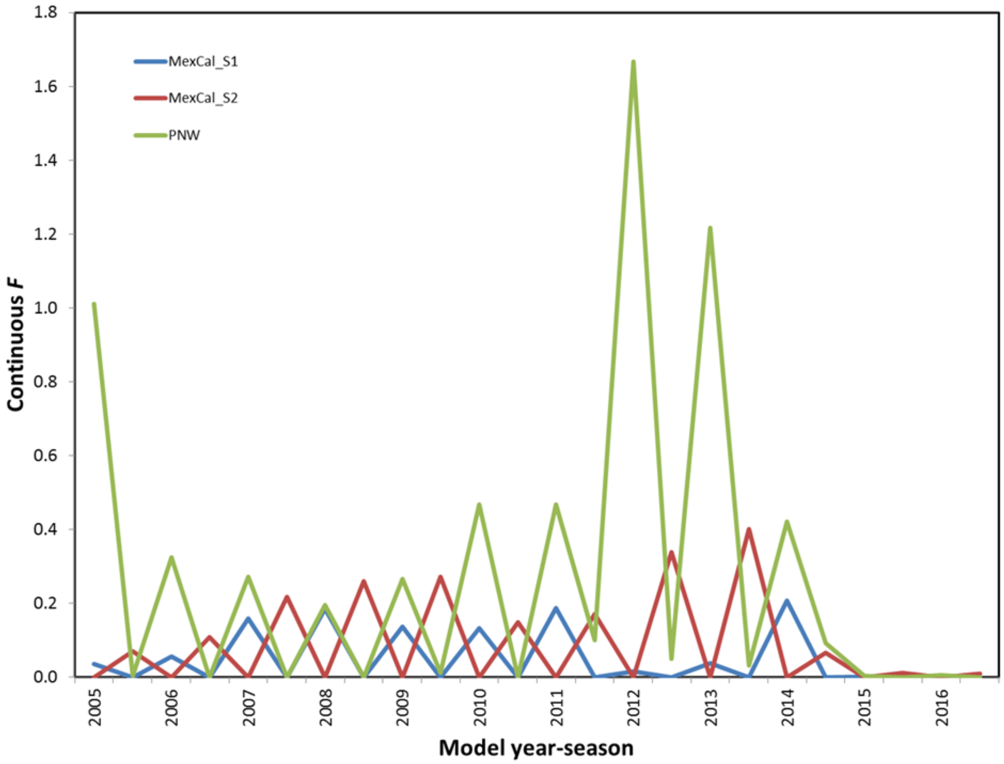


Figure 35. Instantaneous fishing mortality (apical *F*) time series for model ALT. Note that high *F* values for the PNW fleet reflect rates for fishes ages 6 and older.

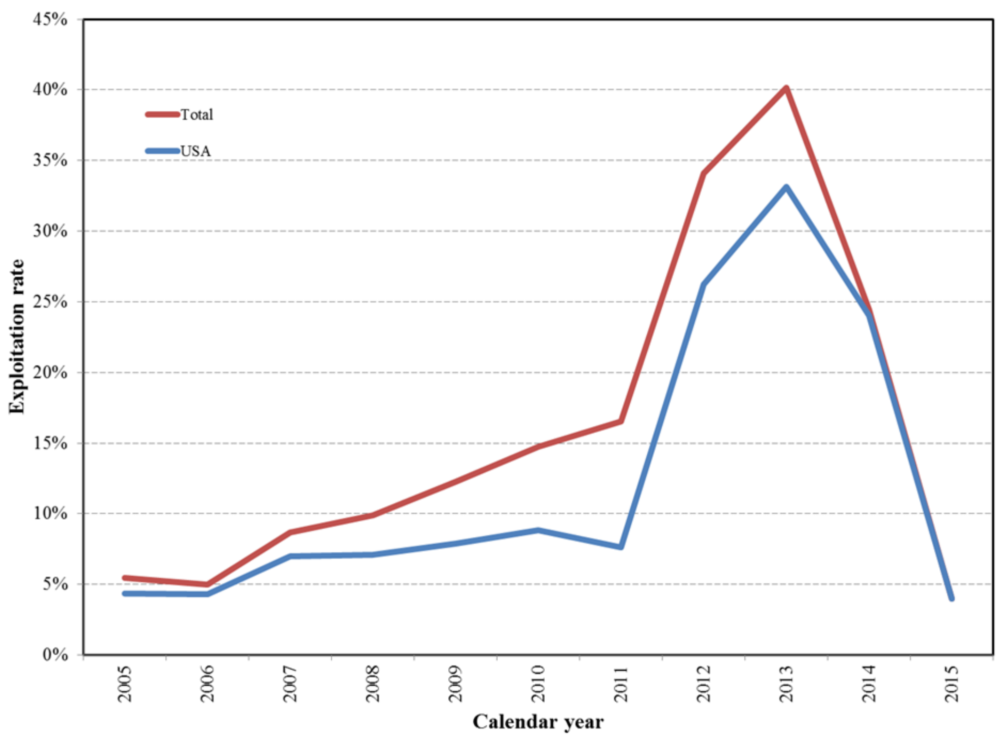


Figure 36. Annual exploitation rate (CY landings / July total biomass) for model ALT.

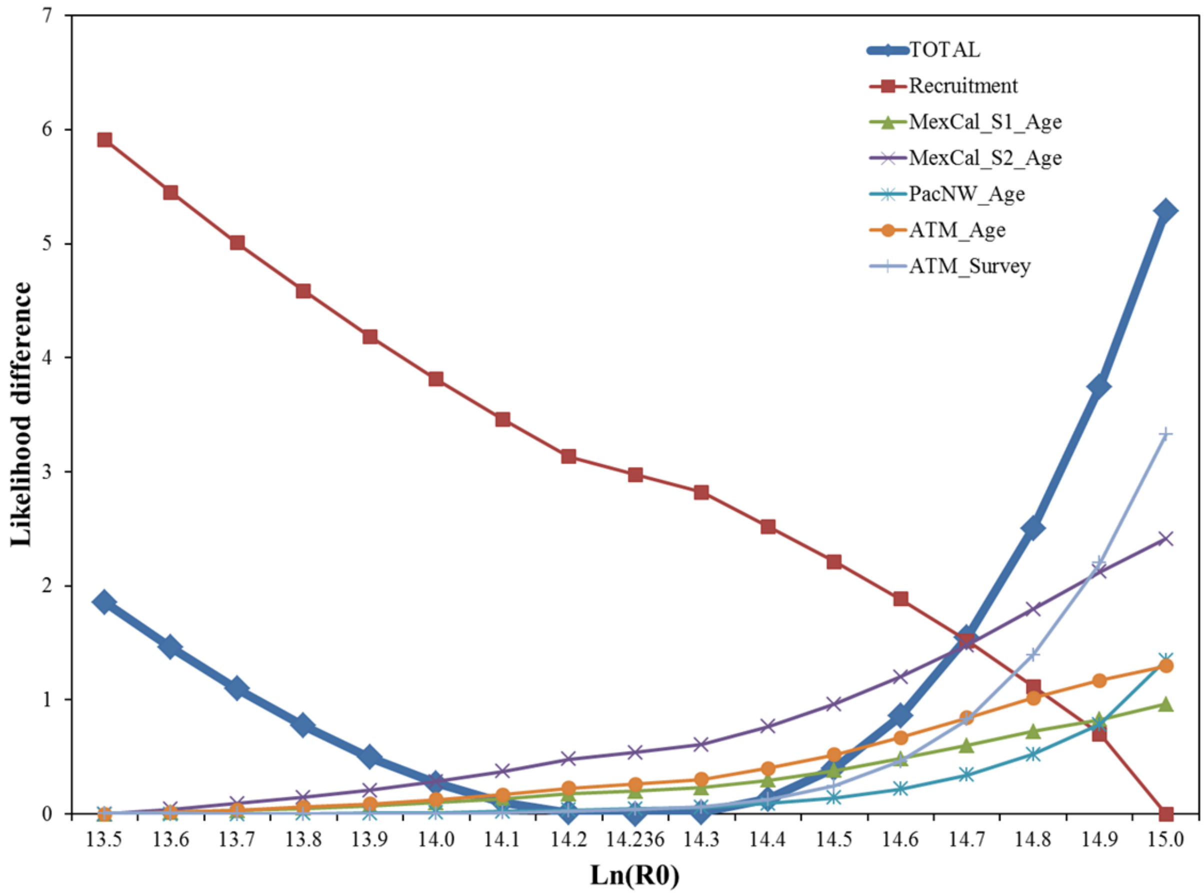


Figure 37. Virgin recruitment (logR_0) profile and associated difference in likelihood estimates for data components, recruitment, and total in model ALT.

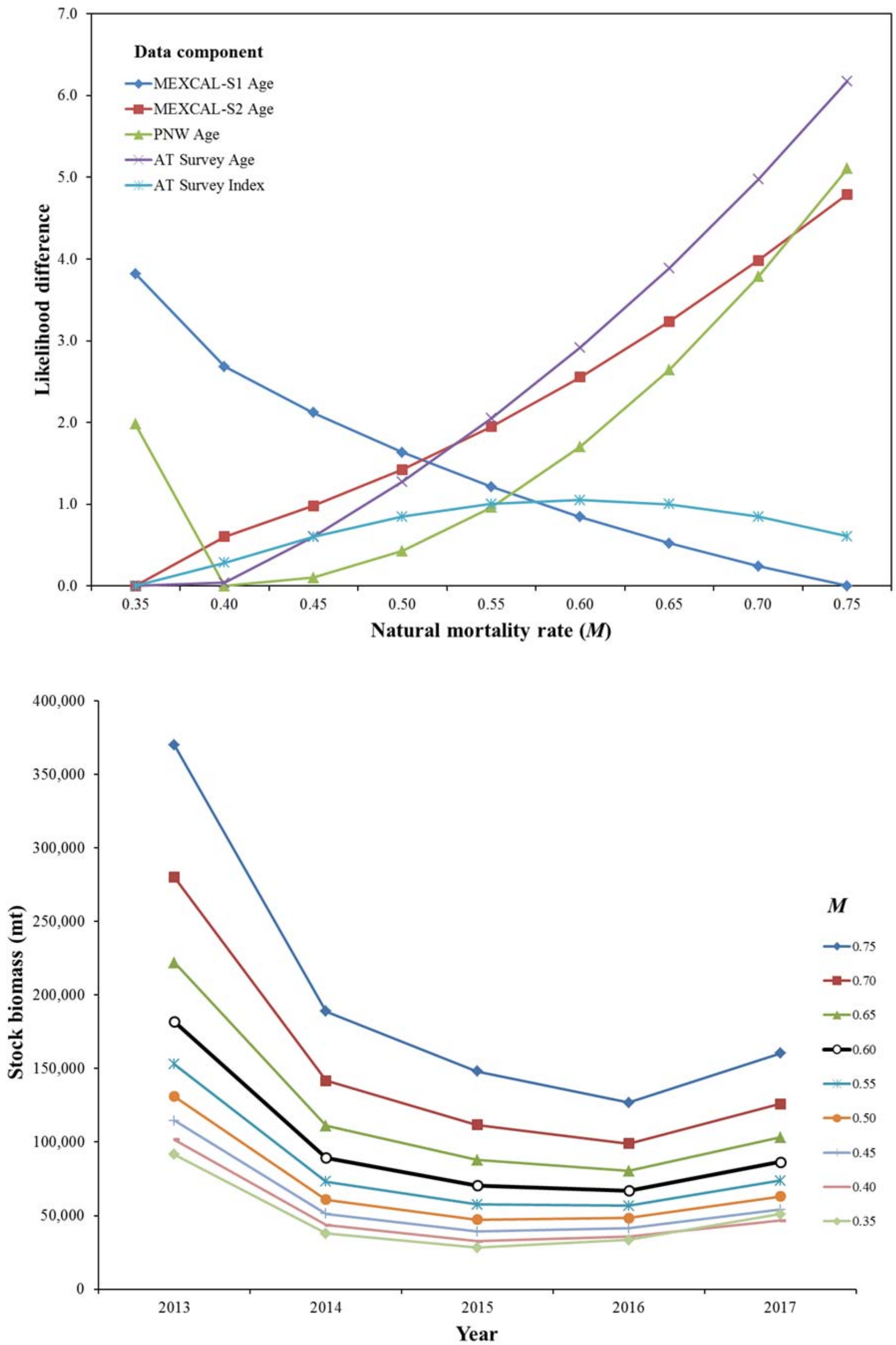


Figure 38. Likelihood differences (upper) and estimated stock biomass (age 1+, mt) for recent years (2014-17) (lower) associated with a range of fixed natural mortality values (M=0.35-0.75 yr^{-1}).

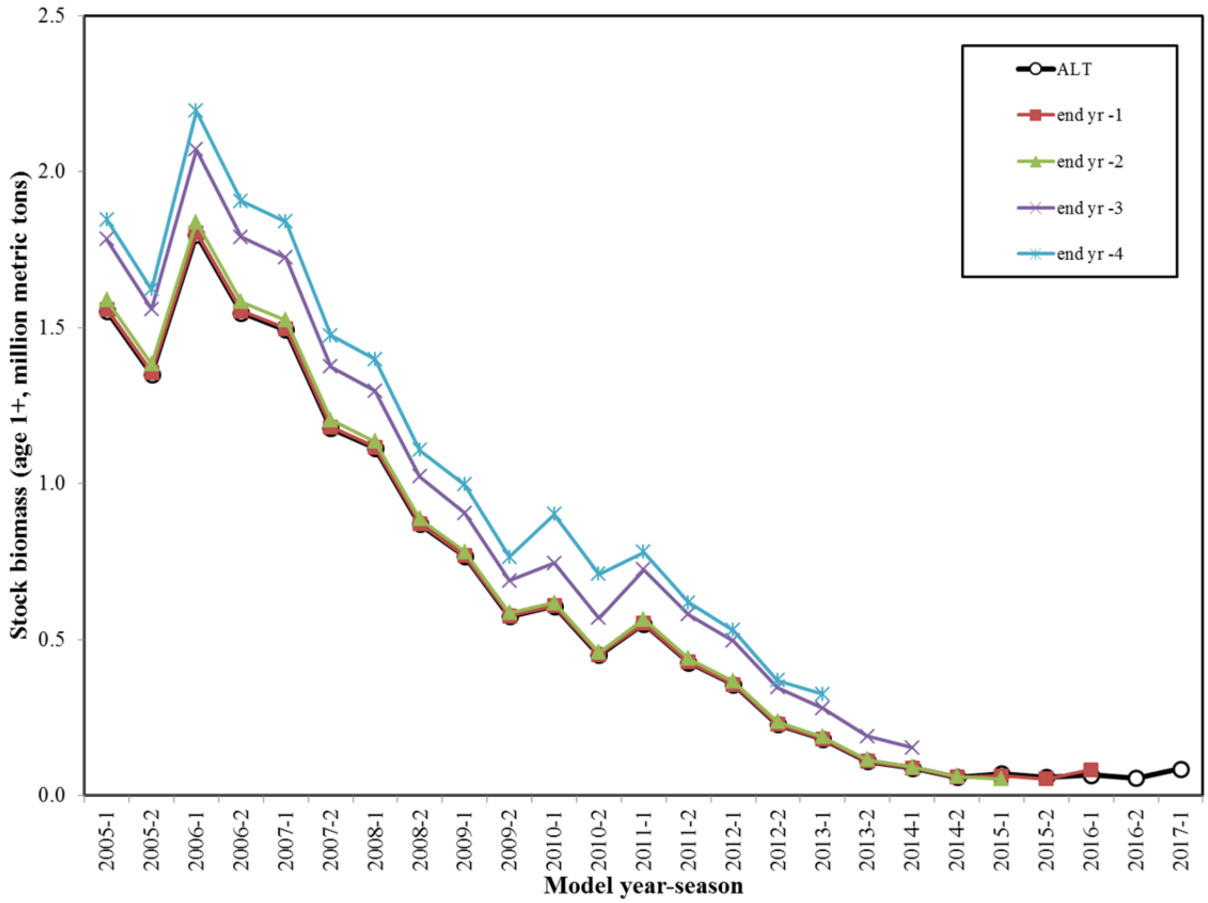


Figure 39. Retrospective analyses of stock biomass (age 1+) for model ALT.

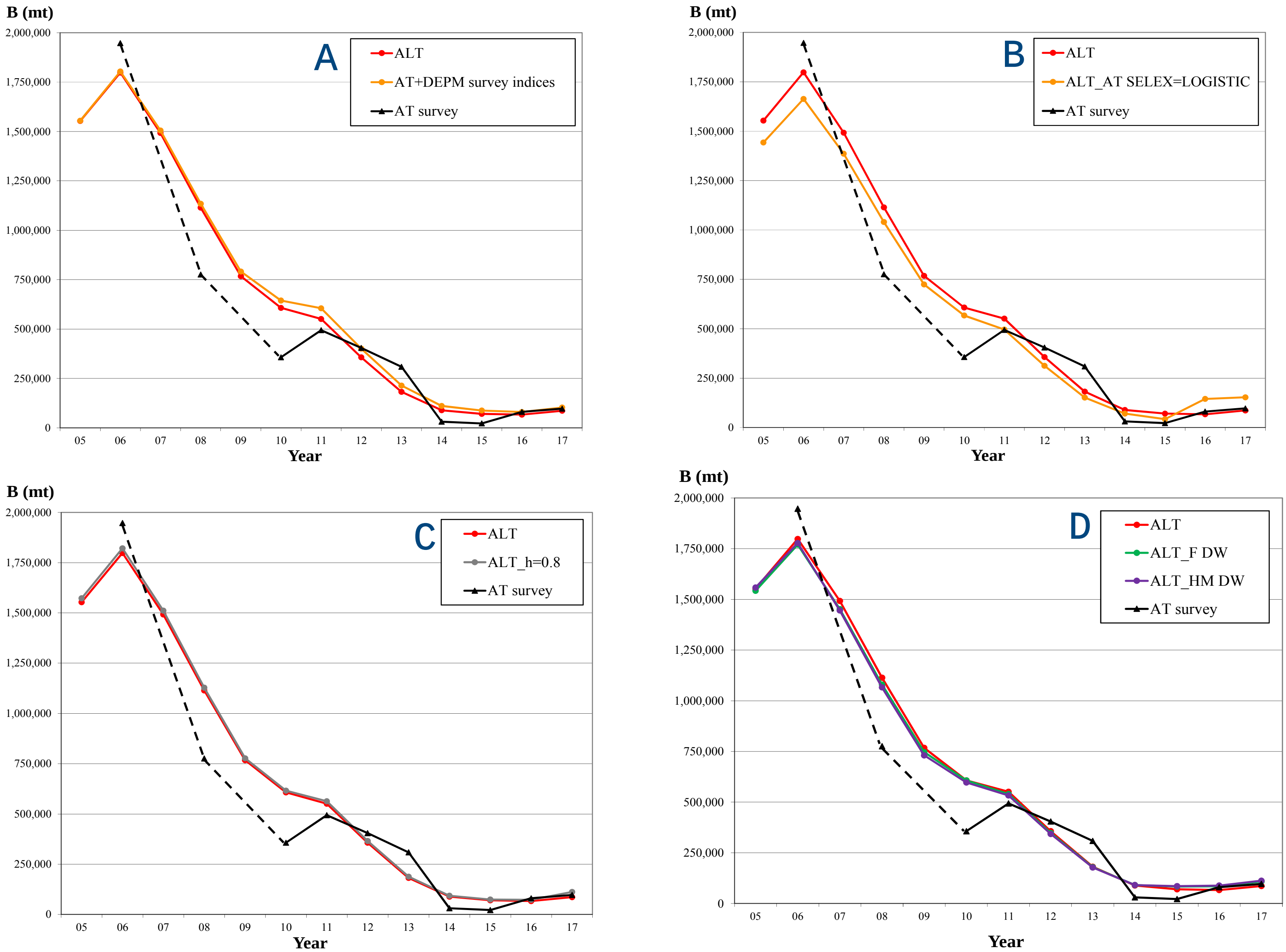


Figure 40. Estimated stock biomass (age-1+ fish, mt) time series associated with sensitivity analysis for model ALT: A) model ALT vs. model ALT (including DEPM abundance index); B) model ALT vs. model ALT (including 2-parameter logistic selectivity for the AT survey); C) model ALT vs. model ALT (including steepness fixed, *h*=0.8); and D) model ALT vs. model ALT (including Francis and harmonic mean data weighting methods). The estimated stock biomass time series for the AT survey is also presented in each display.

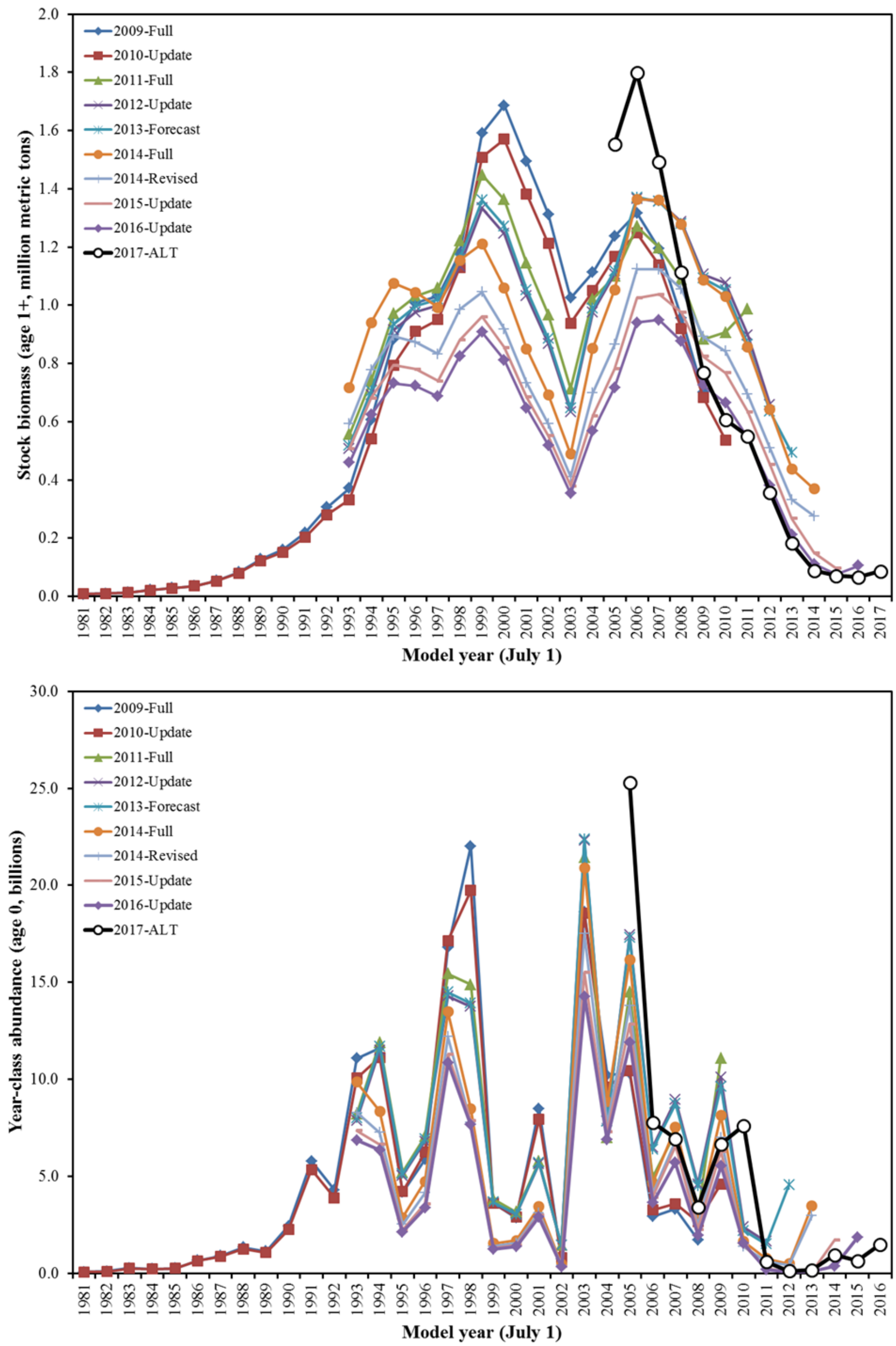


Figure 41. Estimated stock biomass (age 1+ fish, mt, upper panel) and recruitment (lower panel) time series for model ALT and past assessment model used for management.

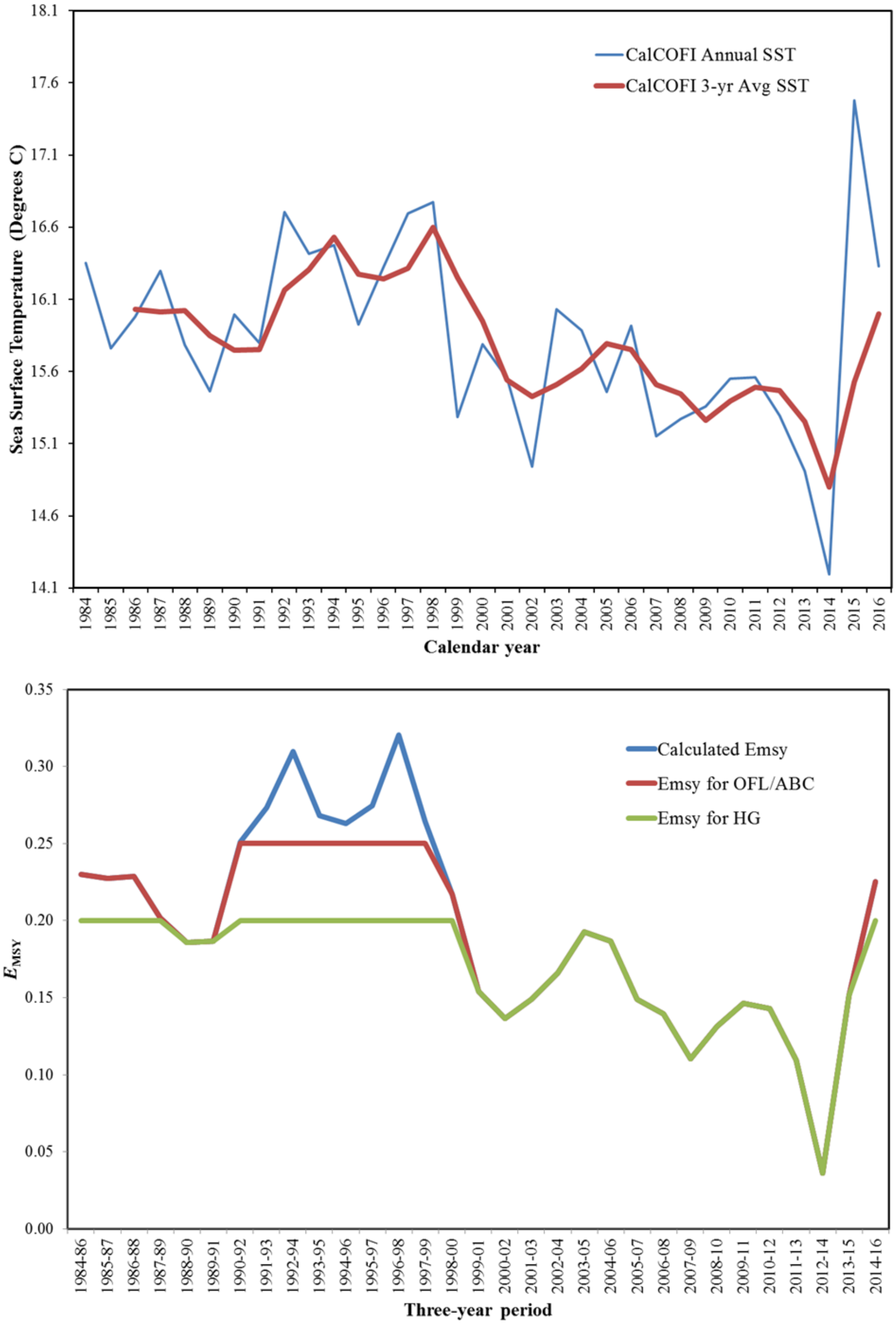


Figure 42. CalCOFI sea surface temperatures (SST, °C, upper panel) and calculated E_{MSY} values (lower panel).

APPENDICES

APPENDIX A

SPAWNING BIOMASS OF PACIFIC SARDINE (*SARDINOPS SAGAX*) ESTIMATED FROM THE DAILY EGG PRODUCTION METHOD OFF THE U.S. WEST COAST IN 2016 (SUMMARY)

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[1]Southwest Fisheries Science Center, La Jolla Laboratory
[2]Ocean Associates contractor at Southwest Fisheries Science Center

From 1994 to 2013 DEPM and TEP estimates of SSB were based on SWFSC ship-based surveys conducted each April between San Diego and San Francisco, California (i.e. standard DEPM area), although in some years the surveys were extended as far north as Washington. In 2015 the survey was mostly north of the standard DEPM area and in 2016 it was completely north of this region. Therefore, in both years the SSB estimate was based on the whole DEPM survey area. The DEPM index of female SSB is used when data for eggs, larvae and adult daily-specific fecundity are available from the survey. The total egg production (TEP) index of SSB is used when survey-specific adult reproductive data are unavailable. The DEPM and TEP series have been used for sardine stock assessment since the 1990s, and the surveys and estimation method were reviewed by a STAR Panel in May 2009. Both time series are treated as indices of relative SSB, with catchability coefficients (*q*) being estimated (Figure 1).

In 2016 the SWFSC conducted the sardine DEPM biomass survey aboard the NOAA ship *Rueben Lasker* (March 22 – April 22) from about Lincoln Beach, Oregon (44.85°N) to north of Muir Beach, California (ending at 37.84°N on CalCOFI line 56.7) (Figure 1). The spring CalCOFI survey was conducted on the NOAA Ship *Bell M. Shimada* (April 1 – April 22) from San Diego to San Francisco Bay. However, data from the CalCOFI survey were not used because no trawling was conducted. Further, during CalCOFI no eggs were collected from CalVET tows, one egg was caught in Bongo tows, and no larvae were collected in both nets (Table 1). Consequently, only data from the DEPM survey on the *Lasker* were included in the estimation of spawning biomass of Pacific sardine. The DEPM survey from the *Lasker* employed all the usual methods for estimating sardine SSB (Lo et al. 2010), but sampling was performed outside of the standard DEPM area (Figure 1).

The 2016 sardine DEPM survey was initially designed with thirty five distinct transects in which eighteen were compulsory and seventeen were adaptive, covering the area from Newport, Oregon to Point Conception, California. The compulsory transects were positioned at forty nautical mile intervals and when adaptive transects were occupied, the spacing between transects was reduced to twenty nautical miles. Similar to the 2015 survey, the Zwolinski et al. (2011)'s habitat model forecast for April 2016 was used to determine potential optimal habitat of sardine and sampling frame of the survey. Since the northern extent of the population was not known, the ship traveled northward and began sampling on the second compulsory line (located at 43.9°N) from the northern most pre-determined transect. Because Pacific sardine eggs were encountered during operations on this transect, the ship continued sampling north until no eggs were encountered, which extended the last northern line to a position just off Lincoln Beach, Oregon. Hence, the whole DEPM survey area was located between 44.85°N and 37.84°N (Figure 1) and effectively occupied 11 compulsory and 5 adaptive lines from the north to the south. Transect spacing was reduced, as much as 20 nautical mile, whenever sardine eggs, larvae or fish were encountered. In areas with no observed eggs, fish or larvae, transect spacing was increased as much as forty nautical miles to save time and cover a broader area of the coast.

The 2016 DEPM index area for the entire survey (44.85°N latitude to CalCOFI line 56.7) was 133,489 km^2 (Figure 1). The egg production (P_0) estimate was 0.54/0.05m^2/day (CV = 0.56) in the high egg-density region and 0.07/0.05 m^2/day (CV = 0.58) for the whole survey area. These areas were computed after a 2.5 nautical mile expansion (i.e. half of the distance between CUFES samples) from survey line or station (see Dorval et al. 2017). Female spawning biomass for the whole survey area was taken as the sum of female spawning biomasses in Regions 1 and 2 (Table 2). The female spawning biomass (sum) and total spawning biomass for the DEPM whole survey area were estimated to be 5,929 mt (CV = 0.58) and 9,536 mt (CV = 0.59), respectively (Table 2).

Adult reproductive parameters for the 2016 whole survey area are presented in Table 3. The estimated daily-specific fecundity was 20.07 (number of eggs/population weight (g)/day) using the following estimates of reproductive parameters from 71 mature females collected from 6 positive trawls: mean batch fecundity (F) was 34,327 eggs/batch (CV = 0.15), fraction spawning (S) was 0.145 females spawning per day (CV = 0.20), mean female fish weight (W_f) was 148.03 g (CV = 0.098), and sex ratio of females by weight (R) was 0.598 (CV = 0.13). 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 2016 survey, 3 tows were positive for mature female sardines in Region 1 and 3 in Region 2. Additionally, during the survey one tow caught solely males and nine tows caught only immature sardines (Dorval et al. 2016). Further, batch fecundity was predicted from a regression model using data collected from the 2016 survey.

In SS, the DEPM series was taken to represent female SSB (length selectivity option '30') in the middle of S2 (April). Since 2009, the time series of spawning biomass was replaced by female spawning biomass for years when sufficient trawl samples were available and the total egg production for other years as inputs to the stock assessment of Pacific sardine. The 2016 DEPM estimate is much lower than in the previous few years (Tables 2 & 3; Figure 1), potentially due to: 1) continuing decline in spawning stock biomass since 2011; 2) the shift of the high egg-density area to off Oregon, a less suitable spring spawning habitat; and 3) the trawl catches were mostly dominated by young, small and immature sardines which were not producing eggs.

Table 1. Number of positive tows of sardine eggs from CalVET, yolk-sac larvae from CalVET and Bongo, eggs from CUFES and positive sardine trawls[a] in Region 1 (high, eggs/min ≥ 0.2), Region 2 (low, eggs/min < 0.2) for the *Reuben Lasker* Sardine DEPM survey in spring 2016 and the *Bell M. Shimada* CalCOFI survey. The *Lasker* whole DEPM survey area (133,488 km^2, between latitudes 44.85°N and 37.84°N) from about Lincoln Beach, Oregon to CalCOFI line 56.7 (Muir Beach, California) was all north of the standard DEPM area (CalCOFI line 60.0 to 95.0).

Gear	Tows and Sampling type	CalCOFI April 1-22, 2016 *Bell M. Shimada*	DEPM March 26 – April 22, 2016 *Reuben Lasker*		
			Region 1	Region 2	Whole
CalVET (Pairovet)	Total tows	87	18	43	61
	Total positive tows	0	10	6	16
	Positive egg tows	0	10	2	12
	Eggs	0	31	41	72
	Positive larvae tows	0	2	5	7
	Yolk sac larvae	0	9	32	41
BONGO	Total tows	101	9	47	56
	Total positive tows	3	3	21	24
	Positive egg tows[b]	1	2	4	6
	Eggs[b]	1	21	67	88
	Positive larvae tows	2	3	21	24
	Yolk sac larvae	0	149	371	520
CUFES	Total samples	577	60	274	334
	Positive samples	9	39	15	54
	Eggs	15	448	32	480
Trawl	Total tows	n/a	6	35	41
	Total positive tows		3	13	16
	Total sardine		212	276	488
	Female sardine		105	107	212
	Area in km^2	354,032	12,778	120,710	133,488

[a] All sardines were captured at night; 10 trawls in Region 2 caught only male or immature sardines.
[b] Egg data from the Bongo net are not used in the daily egg production (P_0) estimation.
[c] Total sardine were those sampled and measured: including males, females, and those of unknown sex
[d] Female sardine were those sampled and measured: including mature and immature.

Table 2. 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 2007-2016.

Calendar Year	Month	Region	[1]P_0/0.05m^2 (cv)	Z (CV)	[2]RSF/Wbased 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.	[6]S	1.48(1)	1.59(0.5)	38.31	43.96	72.84	6478	4362 (1.00)	2632 (1)		9587.44		
		N	0.32(0.25)		8.9	13.34	23.89	5333	2558 (0.33)	1429 (0.28)		1706.56		
		whole	0.95(0.84)		23.61	29.89	49.97	11811	7767 (0.87)	4491 (0.86)	4061 (0.66)	11220.45	18.7	18.5
1987	July	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	April	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	April	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	April	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	April	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	April	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	April	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

Continue
Table 2

Calendar Year	Month	Region	[1]P0/0.05m2 (cv)	Z (CV)	[2]RSF/Wb ased 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
2010	April	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	April	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	April	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	April	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
2014	April	1	--	--	--	--	--	--	--	--	--	--		
		2	--	--	0	23.70	42.28		--	--	--	--		
		whole	--	--	0	23.70	42.28	160305	--	--	--	--	--	14.51
2015	April	1	1.71 (0.71)	1.095(0.15)	37.42	21.38	47.75	8814	14087 (0.79)	6308 (0.74)		15071.9		
		2	0.09 (0.73)		0	12.07	23.46	172436	25408 (0.76)	13068 (0.78)		15329.6		
		whole	0.17 (0.72)		25.62	18.09	37.28	181250	33412 (0.74)	16207 (0.74)	19376 (0.58)	30395.6	12.02	12.64
2016	April	1	0.54 (0.56)	0.64 (0.22)	17.5	20.53	30.20	12778	6738 (0.60)	4581 (0.72)		6918		
		2	0.02 (0.81)		24.11	20.72	39.39	120710	2563 (0.82)	1348 (0.82)		2654		
		whole	0.07 (0.58)		20.07	20.07	33.56	133488	9536 (0.59)	5703 (0.62)	5929 (0.58)	9571	11.99	12.38

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 area is based: in 2015, on CUFES ≥ 0.3 eggs/min; in 2004-2013, on CUFES ≥1 eggs/min; and prior to 1997, from CalVET tows with eggs/0.05m^2 >0.

5: For the spawning biomass, the estimate 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 3. Pacific sardine female adult parameters for surveys conducted in the standard daily egg production method (DEPM) sampling area off California during 1994-2014 (1994 includes females from off Mexico) and off northern California and Oregon in 2015-2016.

		1994	1997	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Midpoint date of 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	26-Apr	14-Apr	7-Apr
Positive collections date range		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	04/25-05/03	04/01-04/17	3/27-04/18
N collections with mature females		37	4	2	6	16	14	7	14	12	29	17	30	16	15	3	4	6
N collection within Region 1		19	4	2	6	16	6	2	8	4	15	3	14	8	8	3	2	3
Average surface temperature (°C) at collection locations		14.36	14.28	12.95	12.75	13.59	14.18	14.43	13.6	12.4	12.93	13.62	13.12	13.18	13.65	12.96	12.54	12.38
Female fraction	**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	0.560	0.485	0.598
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	155.82	192.21	148.03
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	146.35	178.26	140.22
Average batch fecundity[a] (oocytes)	**F**	24283	42002	22456	54403	55711	17662	18474	21760	29802	29790	39304	38369	38681	41339	46124	60916	34327
Relative batch fecundity (oocytes/g)		294	329	284	342	334	270	274	267	292	265	303	301	274	299	296	317	232
N mature females analyzed		583	77	9	23	290	175	86	203	187	467	313	244	126	121	7	25	71
N active mature females		327	77	9	23	290	148	72	187	177	463	310	244	125	119	7	25	71
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	0.143	0.118	0.145
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	0.143	0.118	0.145
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	23.70	18.09	20.07

[a] 1994-2001 estimates were calculated using $F_b = -10858 + 439.53\ W_{of}$ (Macewicz et al. 1996), 2004 used $F_b = 356.46W_{of}$. (Lo and Macewicz 2004), 2005 used $F_b = -6085 + 376.28\ W_{of}$ (Lo and Macewicz 2006), 2006 used $F_b = -396 + 293.39\ W_{of}$ (Lo et al. 2007a), 2007 used $F_b = 279.23W_{of}$ (Lo et al. 2007b), 2008 used $F_b = 305.14W_{of}$ (Lo et al. 2008), 2009 used $F_b = -4598 + 326.78W_{of} + e$ (Lo et al. 2009), 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. 2011), 2012 used $F_b = -12724 + 402.3W_{of} + e$ (Lo et al. 2013), 2013 used $F_b = -9759 + 404.24W_{of} + e$ (Dorval et al. 2014), 2014 used equation from 2013, 2015 used $F_b = -5112 + 365.85W_{of} + e$, and 2016 used $F_b = 12708 + 167.83W_{of} + e$,.

[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.

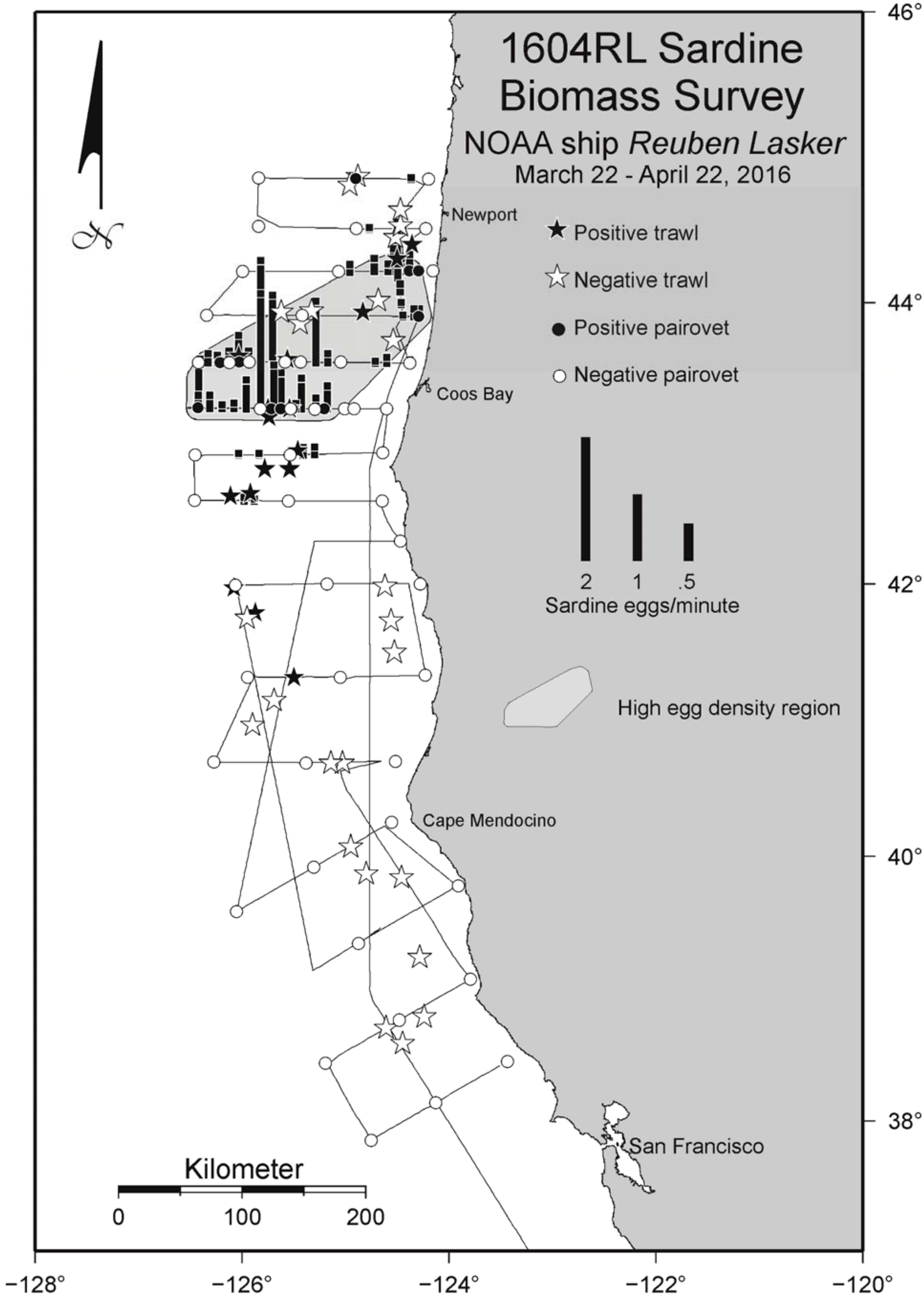

Figure 1. DEPM survey area and location of CalVET (Pairovet) and bongo tows, CUFES, and trawl locations during the 2016 survey aboard the NOAA ship *Reuben H. Lasker*.

APPENDIX B

SS INPUT FILES FOR MODEL ALT

STARTER.SS

```
# Pacific sardine stock assessment (2017-18)
# P.R. Crone, K.T. Hill, J.P. Zwolinski (Nov 2016)
# Model ALT: number of fisheries = 3 / surveys = 1 / time-step = semester / biological distributions = age /
          selectivity = age-based / growth = emp. WAA
# SS model (ver. 3.24s)
# Starter file
#
ALT.dat
ALT.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
0.05 # 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
# Vector of year values
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 8 # 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 (2017-18)
# P.R. Crone, K.T. Hill, J.P. Zwolinski (Nov 2016)
# Model ALT: number of fisheries = 3 / surveys = 1 / time-step = semester / biological distributions = age /
          selectivity = age-based / growth = emp. WAA
# SS model (ver. 3.24s)
# Forecast file
#
# Note: for all year entries except rebuilder, enter either: actual year, -999 for styr, 0 for endyr, neg number
          for relative endyr
1 #_Benchmarks: 0=skip, 1=calc F_spr,F_btgt,F_msy
2 #_MSY: 1= set to F(SPR), 2=calc F(MSY), 3=set to F(Btgt), 4=set to F(endyr)
0.4 #_SPR target (e.g., 0.40)
0.4 #_Biomass target (e.g., 0.40)
# Bmark_years: beg_bio, end_bio, beg_selex, end_selex, beg_relF, end_relF (enter actual year, or values of 0 or
          -integer to be rel. endyr)
0 0 0 0 0 0
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  (enter actual year, or values of 0 or -integer to be
          rel. endyr)
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
# Conditional input if relative F option=2
# Fleet relative F: rows are seasons, columns are fleets
# Fleet: MEXCAL_S1 MEXCAL_S2 PNW
# 0 0 0 # S1
# 0 0 0 # S2
# 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) with units that are from
          fishery units
# Input fixed catch values
# Year Season Fleet Catch/F
2017   1  1   10.30
2017   2  1   0.00
2017   1  2   0.00
2017   2  2   185.87
2017   1  3   87.90
2017   2  3   0.70
999 # End of file
```

ALT.DAT

```
# Pacific sardine stock assessment (2017-18)
# P.R. Crone, K.T. Hill, J.P. Zwolinski (Nov 2016)
# Model ALT: number of fisheries = 3 / surveys = 1 / time-step = semester / biological distributions = age /
          selectivity = age-based / growth = emp. WAA
# SS model (ver. 3.24s)
# Data file
#
2005 # Start year (July 1993)
2016 # End year (ADVANCED ONE YEAR; FORECAST=2017-18)
2 # N_seasons
6 6 # Months per season (2 semesters per fishing year)
2 # Spawning season (Spring semester)
3 # N_fleets
2 # N_surveys
1 # N_areas
MEXCAL_S1%MEXCAL_S2%PNW%DEPM%AT_Survey
0.5 0.5 0.5 0.58 0.75 # Survey timing in season
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
10 # N_ages
1000 0 0 # Initial equilibrium catch for each fishery
48 # N_lines of catch to read
# Catch biomass(mt): columns are fisheries, year, season
# LANDINGS
827.51  0.00    0.00    1993    1
0.00    11679.31        0.00    1993    2
8940.33 0.00    0.00    1994    1
0.00    40439.57        0.00    1994    2
6048.30 0.00    22.68   1995    1
0.00    26820.27        0.00    1995    2
12038.89   0.00 0.00    1996    1
0.00    19489.95        43.54   1996    2
13018.20   0.00 27.22   1997    1
0.00    24916.29        0.82    1997    2
```

```
19062.67	0.00	488.25	1998	1
0.00	63812.26	74.39	1998	2
15060.75	0.00	725.20	1999	1
0.00	58889.27	429.59	1999	2
23750.08	0.00	15586.16	2000	1
0.00	35341.42	2336.90	2000	2
11607.29	0.00	22545.99	2001	1
0.00	41513.06	3136.84	2001	2
16644.36	0.00	35525.69	2002	1
0.00	36906.76	597.29	2002	2
10410.67	0.00	37242.26	2003	1
0.00	22672.97	2618.43	2003	2
17143.09	0.00	46730.80	2004	1
0.00	25890.59	1016.32	2004	2
13802.99	0.00	54152.62	2005	1
0.00	30364.20	101.70	2005	2
20726.23	0.00	41220.90	2006	1
0.00	39900.28	0.00	2006	2
46228.11	0.00	48237.10	2007	1
0.00	42910.05	0.00	2007	2
30249.18	0.00	39800.10	2008	1
0.00	41198.49	0.00	2008	2
14044.87	0.00	44841.15	2009	1
0.00	31146.46	1369.73	2009	2
11273.97	0.00	54085.91	2010	1
0.00	27267.62	0.09	2010	2
24871.40	0.00	39750.49	2011	1
0.00	23189.90	5805.63	2011	2
1528.37	0.00	91425.63	2012	1
0.00	13884.90	1570.78	2012	2
921.56	0.00	57217.96	2013	1
0.00	5625.03	908.01	2013	2
1830.92	0.00	15216.82	2014	1
0.00	727.71	2193.87	2014	2
6.13	0.00	66.28	2015	1
0.00	185.87	0.70	2015	2
10.30	0.00	87.90	2016	1
0.00	185.87	0.70	2016	2	# Repeat of 2015-2
# 10.30	0.00	87.90	2017	1	(PLACED IN FORECAST)
# 0.00	185.87	0.70	2017	2	(PLACED IN FORECAST)
#
27 #_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 # PNW
4 1 0 # DEPM
5 1 0 # ATM
# 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
# 2013  2   4   (No est.)       # DEPM_1404
2014	2	4	19376	0.54	# DEPM_1504
2015	 2	 4	 5929	 0.54	 # DEPM_1604
#
2005	2	5	1947063	0.30	# ATM_0604
2007	2	5	751075	0.09	# ATM_0804
2009	2	5	357006	0.41	# ATM_1004
2010	2	5	493672	0.30	# ATM_1104
2011	2	5	469480	0.28	# ATM_1204
2012	2	5	305146	0.24	# ATM_1304
2013	2	5	35339	0.38	# ATM_1404
2014	2	5	29048	0.29	# ATM_1504
2015	2	5	83030	0.47	# ATM_1604
#
2008	1	5	801000	0.30	# ATM_0807
```

```
2012    1  5    340831  0.33    # ATM_1207
2013    1  5    313746  0.27    # ATM_1307
2014    1  5    26280   0.63    # ATM_1407
2015    1  5    15870   0.70    # ATM_1507
2016    1  5    78770   0.51    # ATM_1607
#
0 # N_fleets with discard
# Discard units: 1=same_as_catch units (bio/num), 2=fraction, 3=numbers
# Discard error type: >0 for DF of T-dist(read CV below), 0 for normal with CV, -1 for normal with se, -2 for
          lognormal
# Fleet discard units and error type
0 # N_discard obs
# Year season index obs error
#
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
89 # 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
```

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                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       16.00  0.00000000     0.00000000     0.00074231     0.00148463     0.00222694
                0.00296925     0.00371157     0.00519619     0.00222694     0.00074231     0.00074231
                0.00000000     0.00000000     0.00000000     0.00000000     0.00000000     0.00148463
                0.00148463     0.00234205     0.02328286     0.02859415     0.05945618     0.04296925
                0.10566584     0.17808666     0.26589605     0.13284417     0.08507572     0.04410319
                0.00867218     0.00000000     0.00000000     0.00000000     0.00000000     0.00000000
                0.00000000     0.00000000     0.00000000     0.00000000
2014    1  1    0       0       6.00   0.00000000     0.00000000     0.00000000     0.00000000     0.00000895
                0.00000000     0.00000000     0.00000000     0.00000895     0.00003133     0.00003581
                0.00001790     0.00000448     0.00000000     0.00000000     0.00000000     0.00000000
                0.00000000     0.00000000     0.00000000     0.00000000     0.00000000     0.00000000
                0.00000000     0.01599821     0.03999552     0.18397941     0.34396598     0.31996419
                0.07199194     0.01599821     0.00799910     0.00000000     0.00000000     0.00000000
                0.00000000     0.00000000     0.00000000     0.00000000
# 2015 1 1 (Was used, but small sample size, incidental landings, omit)
2015    1  -1   0       0       1.00   0.00000000     0.00000000     0.00000000     0.00000000     0.00000000
                0.04000000     0.00000000     0.12000000     0.00000000     0.00000000     0.00000000
                0.00000000     0.00000000     0.00000000     0.00000000     0.00000000     0.00000000
                0.04000000     0.24000000     0.16000000     0.28000000     0.12000000     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
# 2016 1 1 (Not available)
#
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		

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               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
2013   2  2    0       0      28.00  0.00000000     0.00000000     0.00000000     0.00000000     0.00000000
               0.00000000     0.00000000     0.00000000     0.00000000     0.00000000     0.00000000
               0.00026894     0.00287596     0.00971450     0.00404500     0.00323817     0.00206913
               0.00296922     0.00360037     0.00476941     0.01809207     0.02177791     0.03006646
               0.03606958     0.07238448     0.17035400     0.25213401     0.20643699     0.09677617
               0.03764854     0.01076876     0.00506478     0.00634317     0.00253239     0.00000000
               0.00000000     0.00000000     0.00000000     0.00000000
2014   2  2    0       0      14.00  0.00000000     0.00000000     0.00000000     0.00000000     0.00000000
               0.00000000     0.00334979     0.01674895     0.03014811     0.05359663     0.08400949
               0.11768389     0.12398933     0.17300721     0.21933638     0.08066685     0.04959071
               0.00700984     0.00119060     0.00000000     0.00000000     0.00000000     0.00000000
               0.00000000     0.00000000     0.00000000     0.00718278     0.00850714     0.01678294
               0.00122678     0.00597259     0.00000000     0.00000000     0.00000000     0.00000000
               0.00000000     0.00000000     0.00000000     0.00000000
# 2015 2 2 (Not available)
#
1999   1  3    0       0      3.04   0.00000000     0.00000000     0.00000000     0.00000000     0.00000000
               0.00000000     0.00000000     0.00000000     0.00000000     0.00000000     0.00000095
               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     0.00000000
               0.00000000     0.00000000     0.00000000     0.00087005     0.00156608     0.00121806
               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   0.00000000   0.00000000   0.00000000   0.00367294   0.00879451
                  0.04010952   0.09046219   0.18199439   0.21660795   0.19187645   0.13186477
                  0.06604471   0.04323092   0.01074198   0.00880089   0.00289994   0.00048341
                  0.00096629   0.00048288   0.00000000   0.00000000
2002   1  3       0      0     172.79 0.00000000   0.00000000   0.00000000   0.00000313   0.00000626
                  0.00000626   0.00000626   0.00000313   0.00000938   0.00000626   0.00001363
                  0.00000313   0.00062473   0.00031198   0.00094645   0.00136169   0.00143519
                  0.00317196   0.00361648   0.00444832   0.00536365   0.00421846   0.01381946
                  0.03565991   0.11857744   0.20342331   0.21914500   0.14683906   0.11571644
                  0.06020604   0.03543252   0.01287390   0.00777273   0.00240956   0.00164771
                  0.00033310   0.00054432   0.00001901   0.00002414
2002   2  3       0      0     8.44   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   0.00312357
                  0.00000000   0.00000000   0.00624714   0.00937071   0.00937295   0.01249428
                  0.01249652   0.05221134   0.13789484   0.06785376   0.17431751   0.21008191
                  0.06999081   0.08758723   0.05631804   0.06875428   0.00938411   0.00624714
                  0.00312580   0.00312357   0.00000000   0.00000446
2003   1  3       0      0     145.33 0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
                  0.00000397   0.00000000   0.00000397   0.00000397   0.00081444   0.00403192
                  0.00514471   0.00338591   0.00141363   0.00001985   0.00029674   0.00455528
                  0.01661655   0.03216569   0.04716668   0.06356196   0.04611645   0.05368928
                  0.06537740   0.06742541   0.07208935   0.12367128   0.12474048   0.10239500
                  0.07361669   0.04797912   0.02147233   0.01095014   0.00687007   0.00305615
                  0.00071418   0.00062688   0.00001260   0.00001191
2003   2  3       0      0     16.88  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   0.00068529
                  0.01626167   0.03183805   0.07470549   0.17346083   0.15096679   0.24561041
                  0.16554308   0.08604058   0.03407916   0.01027932   0.00915877   0.00137058
                  0.00000000   0.00000000   0.00000000   0.00000000
2004   1  3       0      0     93.35  0.00001567   0.00001567   0.00000000   0.00000000   0.00056254
                  0.00028127   0.00056254   0.00142204   0.00609585   0.00738530   0.00901487
                  0.00780880   0.00880757   0.00314547   0.01122084   0.01449783   0.04081487
                  0.03735165   0.03390459   0.02231370   0.02555715   0.01629821   0.02816169
                  0.02899177   0.05840626   0.06057283   0.09562618   0.08453840   0.14026268
                  0.09805984   0.07524450   0.03709070   0.02707205   0.01236191   0.00425655
                  0.00131717   0.00055007   0.00017067   0.00024033
2004   2  3       0      0     7.88   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   0.02131378   0.05692221   0.15080485
                  0.27920147   0.24587915   0.15038613   0.02495166   0.02063744   0.00998066
                  0.00499033   0.00000000   0.00499033   0.00499033   0.00000000   0.00499033
                  0.00998066   0.00000000   0.00998066   0.00000000   0.00000000   0.00000000
                  0.00000000   0.00000000   0.00000000   0.00000000
2005   1  3       0      0     67.68  0.00000000   0.00000000   0.00000000   0.00000000   0.00000553
                  0.00001355   0.00159531   0.00039392   0.00002710   0.00004066   0.00020755
                  0.00020258   0.00270103   0.02291847   0.05924987   0.09616749   0.20727817
                  0.18328761   0.12443673   0.05097571   0.01877167   0.01515760   0.00998755
                  0.00942919   0.01080600   0.01225695   0.01347518   0.01909393   0.02824136
                  0.03110144   0.04082612   0.02108261   0.01447999   0.00282130   0.00249264
                  0.00027437   0.00014659   0.00002710   0.00002710
2006   1  3       0      0     27.00  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   0.00385525
                  0.01151585   0.04782390   0.16295078   0.33602885   0.24986185   0.11243519
                  0.01737664   0.00466226   0.00994350   0.00193035   0.00122605   0.00686819
                  0.00826354   0.01135211   0.00487000   0.00864962   0.00000000   0.00000000
                  0.00038607   0.00000000   0.00000000   0.00000000
2006   2  3       0      0     3.00   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
                  0.01333333   0.00000000   0.06666667   0.06666667   0.20000000   0.16000000
                  0.09333333   0.09333333   0.05333333   0.02666667   0.05333333   0.00000000
                  0.08000000   0.04000000   0.02666667   0.02666667   0.00000000   0.00000000
                  0.00000000   0.00000000   0.00000000   0.00000000
2007   1  3       0      0     87.86  0.00000000   0.00000000   0.00000000   0.00000000   0.00000000
                  0.00000000   0.00000737   0.00000000   0.00000000   0.00000000   0.00000000
```

```
                0.00000000  0.00000000  0.00000000  0.00001639  0.00061942  0.00255561
                0.01442330  0.07011329  0.13161223  0.21359514  0.23707687  0.18219854
                0.07245245  0.02287642  0.01307278  0.00799927  0.00556329  0.00684479
                0.00802636  0.00410422  0.00215245  0.00214591  0.00115543  0.00071927
                0.00011042  0.00050099  0.00001250  0.00004528
2008  1  3  0    0    129.64  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
                0.00000000  0.00004054  0.00000000  0.00000000  0.00000000  0.00000000
                0.00000000  0.00000000  0.00041928  0.00000000  0.00000000  0.00058332
                0.00460794  0.03193930  0.06132653  0.11715864  0.14270701  0.15921219
                0.11117985  0.07109068  0.04339494  0.04764464  0.06409722  0.06209469
                0.04086420  0.02147774  0.01039633  0.00450936  0.00253737  0.00106315
                0.00059479  0.00056213  0.00027694  0.00022122
2009  1  3  0    0    159.41  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
                0.00000000  0.00000722  0.00000000  0.00000000  0.00000000  0.00000000
                0.00036834  0.00036834  0.00000722  0.00002165  0.00000722  0.00001443
                0.00385185  0.02385351  0.05630274  0.13546005  0.16896254  0.15574778
                0.09681599  0.06985591  0.04410210  0.07537644  0.06582272  0.05197468
                0.02553117  0.01450460  0.00584005  0.00330284  0.00143161  0.00023704
                0.00012583  0.00002508  0.00004879  0.00003229
2009  2  3  0    0    4.33    0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
                0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
                0.00000000  0.01398663  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    119.96  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
                0.00039374  0.01042668  0.04536653  0.10833995  0.15991690  0.16908725
                0.11185223  0.10350004  0.12242207  0.10086189  0.04285995  0.01986392
                0.00450227  0.00011357  0.00000000  0.00000000  0.00049302  0.00000000
                0.00000000  0.00000000  0.00000000  0.00000000
2012  2  3  0    0    3.00    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  0.04000000  0.06666667  0.36000000
                0.28000000  0.10666667  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    141.00  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  0.00031076  0.00826635  0.04840622  0.18377225
                0.25546424  0.23831458  0.13242000  0.07340381  0.03383920  0.01716330
                0.00642818  0.00176975  0.00044137  0.00000000  0.00000000  0.00000000
                0.00000000  0.00000000  0.00000000  0.00000000
2013  2  3  0    0    1.20    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  0.00000000
                0.03333333  0.06666667  0.23333333  0.46666667  0.16666667  0.03333333
                0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
                0.00000000  0.00000000  0.00000000  0.00000000
2014  1  3  0    0    50.88   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     0.00486853
               0.03420662     0.14943202     0.25345626     0.29136535     0.16668853     0.06801615
               0.02262697     0.00535488     0.00398470     0.00000000     0.00000000     0.00000000
               0.00000000     0.00000000     0.00000000     0.00000000
2014   2  3    0      0       15.92  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     0.00518691
               0.01580589     0.14519508     0.26636975     0.32264050     0.18093404     0.04798212
               0.01321244     0.00007982     0.00000000     0.00259345     0.00000000     0.00000000
               0.00000000     0.00000000     0.00000000     0.00000000
# 2015 1 3 (Was used, but small sample size, incidental landings, omit)
2015   1  -3   0      0       1.00   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     0.04000000     0.00000000
               0.04000000     0.00000000     0.00000000     0.00000000     0.04000000     0.00000000
               0.00000000     0.00000000     0.16000000     0.16000000     0.24000000     0.24000000
               0.08000000     0.00000000     0.00000000     0.00000000     0.00000000     0.00000000
               0.00000000     0.00000000     0.00000000     0.00000000
# 2015 2 3 (Not available)
# 2016 1 3 (Not available)
#
2005   2  5    0      0       10.00  0.00000000     0.00000000     0.00000000     0.00000000     0.00000000
               0.00000000     0.00000000     0.00000000     0.00270862     0.00270862     0.00000000
               0.00000000     0.01100873     0.01100873     0.12353364     0.12353364     0.06453880
               0.06453880     0.15773170     0.15773170     0.06426980     0.06426980     0.05009669
               0.05009669     0.01516183     0.01516183     0.00505394     0.00505394     0.00000000
               0.00000000     0.00168465     0.00168465     0.00336930     0.00336930     0.00168465
               0.00000000     0.00000000     0.00000000     0.00000000
2007   2  5    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     0.01871052     0.01871052     0.04456086
               0.04456086     0.07885461     0.07885461     0.07720993     0.07720993     0.09196321
               0.09196321     0.10803940     0.10803940     0.06881783     0.06881783     0.00321240
               0.00321240     0.00825866     0.00825866     0.00037258     0.00037258     0.00000000
               0.00000000     0.00000000     0.00000000     0.00000000
2009   2  5    0      0       19.00  0.00000000     0.00000000     0.00000000     0.00000000     0.00071913
               0.00071913     0.00036184     0.00036184     0.00000000     0.00000000     0.00121512
               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  5    0      0       18.00  0.00000000     0.00000000     0.00000000     0.00000000     0.00000000
               0.00000000     0.00000449     0.00000449     0.00000000     0.00000000     0.00000000
               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  5    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  5    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
2013   2  5    0      0       4.00   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     0.00000000
               0.00000000     0.00000000     0.00000000     0.03553942     0.03553942     0.32050317
               0.32050317     0.10057675     0.10057675     0.04338066     0.04338066     0.00000000
               0.00000000     0.00000000     0.00000000     0.00000000
2014   2  5    0      0       6.00   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     0.00195881
```

```
              0.00195881     0.00000000     0.00000000     0.04068968     0.04068968     0.12361069
              0.12361069     0.00000000     0.00000000     0.00000000     0.00000000     0.01110877
              0.01110877     0.18187444     0.18187444     0.12041276     0.12041276     0.02034484
              0.02034484     0.00000000     0.00000000     0.00000000
2015   2  5   0      0       8.00   0.00000000     0.00000000     0.00000000     0.00000000     0.00003149
              0.00003149     0.00020758     0.00020758     0.02511719     0.02511719     0.11809357
              0.11809357     0.08903510     0.08903510     0.02052566     0.02052566     0.00228070
              0.00228070     0.00000000     0.00000000     0.02749376     0.02749376     0.03859413
              0.03859413     0.02441912     0.02441912     0.00723552     0.00723552     0.00343672
              0.00343672     0.04204884     0.04204884     0.06323913     0.06323913     0.03824149
              0.03824149     0.00000000     0.00000000     0.00000000
#
2008   1  5   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  5   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  5   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
2014   1  5   0      0       7.00   0.00204979     0.00204979     0.00000000     0.00000000     0.00000000
              0.00000000     0.00000000     0.00000000     0.00000000     0.00000000     0.00000369
              0.00000369     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     0.00903077     0.00903077     0.15522242
              0.15522242     0.26099332     0.26099332     0.06138772     0.06138772     0.01131228
              0.01131228     0.00000000     0.00000000     0.00000000
2015   1  5   0      0       17.00  0.40403690     0.40403690     0.00000000     0.00000000     0.00000000
              0.00000000     0.00000000     0.00000000     0.00000000     0.00000000     0.00000000
              0.00000000     0.00000000     0.00000000     0.00000380     0.00000380     0.00000000
              0.00000000     0.00000000     0.00000000     0.00000000     0.00000000     0.00187125
              0.00187125     0.00561487     0.00561487     0.00192622     0.00192622     0.00374361
              0.00374361     0.02701399     0.02701399     0.04906669     0.04906669     0.00666849
              0.00666849     0.00005418     0.00005418     0.00000000
2016   1  5   0      0       12.00  0.02582573     0.02582573     0.00516515     0.00516515     0.00000000
              0.00000000     0.00516515     0.00516515     0.00019948     0.00019948     0.00080251
              0.00080251     0.00518937     0.00518937     0.03520717     0.03520717     0.15997810
              0.15997810     0.08620133     0.08620133     0.16424753     0.16424753     0.00260972
              0.00260972     0.00033790     0.00033790     0.00115483     0.00115483     0.00100394
              0.00100394     0.00189810     0.00189810     0.00277042     0.00277042     0.00195391
              0.00195391     0.00028966     0.00028966     0.00000000
#
9 # N_age bins

0 1 2 3 4 5 6 7 8

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 # 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_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 # 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_CA_2007
0.5    1.5    2.5    3.5    4.5    5.5    6.5    7.5    8.5    9.5    10.5 # 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 # 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 # 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 # 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 # 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 # 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 # 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 # 6_CalCOFI_C
#
75 # 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
# Age comps (CAAL)
# Year Season Fleet/Survey Gender Part Ageerr Lbin_lo Lbin_hi Nsamp datavector(female-male)
1993    1  1    0       0       1       -1      -1      2.72    0.00000000      0.00000000      0.11764706
                0.76470588      0.10294118      0.01470588      0.00000000      0.00000000      0.00000000
1994    1  1    0       0       1       -1   -1 11.76   0.02233392      0.46921325      0.31997955      0.15950127
                0.02897201      0.00000000      0.00000000      0.00000000      0.00000000
1995    1  1    0       0       1       -1   -1 4.76    0.11764706      0.56302521      0.25210084      0.06722689
                0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
1996    1  1    0       0       1       -1   -1 89.28   0.00000000      0.05567822      0.57869148      0.31936116
                0.04119642      0.00460375      0.00000000      0.00046897      0.00000000
1997    1  1    0       0       1       -1   -1 54.92   0.00393055      0.41526377      0.48143507      0.08999595
                0.00760341      0.00177125      0.00000000      0.00000000      0.00000000
1998    1  1    0       0       1       -1   -1 75.32   0.08752419      0.65178011      0.20556040      0.02738368
                0.02185746      0.00530475      0.00058942      0.00000000      0.00000000
1999    1  1    0       0       1       -1   -1 6.96    0.12068966      0.51724138      0.35632184      0.00574713
                0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2000    1  1    0       0       1       -1   -1 22.64   0.05612282      0.21594669      0.47409550      0.23739199
                0.01419224      0.00225076      0.00000000      0.00000000      0.00000000
2001    1  1    0       0       1       -1   -1 37.24   0.19498424      0.24032396      0.10821490      0.29193947
                0.11194383      0.03989310      0.00899338      0.00370711      0.00000000
2002    1  1    0       0       1       -1   -1 30.32   0.17079894      0.53308456      0.23318285      0.04302452
                0.01864624      0.00126289      0.00000000      0.00000000      0.00000000
2003    1  1    0       0       1       -1   -1 17.76   0.56513500      0.22899483      0.18990839      0.01273176
                0.00323001      0.00000000      0.00000000      0.00000000      0.00000000
2004    1  1    0       0       1       -1   -1 33.52   0.00300111      0.90375628      0.06959324      0.00743078
                0.01147566      0.00000000      0.00474293      0.00000000      0.00000000
2005    1  1    0       0       1       -1   -1 35.24   0.09102697      0.26552164      0.59466314      0.04284618
                0.00412282      0.00121284      0.00060642      0.00000000      0.00000000
2006    1  1    0       0       1       -1   -1 69.76   0.00908783      0.64539166      0.30295669      0.04256381
                0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2007    1  1    0       0       2       -1   -1 86.00   0.01357889      0.16055166      0.64593872      0.17061145
                0.00931929      0.00000000      0.00000000      0.00000000      0.00000000
2008    1  1    0       0       3       -1   -1 30.84   0.06153622      0.26350954      0.58776778      0.07218948
                0.01499698      0.00000000      0.00000000      0.00000000      0.00000000
2009    1  1    0       0       3       -1   -1 22.88   0.00349661      0.21120316      0.63114846      0.14041369
                0.01373808      0.00000000      0.00000000      0.00000000      0.00000000
2010    1  1    0       0       4       -1   -1 12.68   0.01577287      0.79179811      0.16719243      0.02523659
                0.00000000      0.00000000      0.00000000      0.00000000      0.00000000
2011    1  1    0       0       4       -1   -1 21.64   0.00000000      0.32278273      0.47187076      0.19905465
                0.00629186      0.00000000      0.00000000      0.00000000      0.00000000
2012    1  1    0       0       4       -1   -1 22.32   0.00335775      0.10053293      0.44773547      0.37325638
                0.05790999      0.01147166      0.00573583      0.00000000      0.00000000
2013    1  1    0       0       4       -1   -1 15.84   0.01132400      0.02443363      0.25675788      0.29354382
                0.33484537      0.04608165      0.01688430      0.00806468      0.00806468
2014    1  1    0       0       4       -1   -1 5.92    0.00009926      0.00000451      0.00000451      0.08063643
                0.53220043      0.28222750      0.08870007      0.01612729      0.00000000
# 2015 1 1 (Was used in lt comps, but small sample size/incidental landings, omit)
# 2016 1 1 (Not available)
#
1993    2  2    0       0       1       -1   -1 30.44   0.21106902      0.38434172      0.30704382      0.06010656
                0.02088125      0.01089044      0.00566720      0.00000000      0.00000000
1994    2  2    0       0       1       -1   -1 120.96 0.36945499       0.45924059      0.11019804      0.05280057
                0.00706495      0.00093579      0.00030505      0.00000000      0.00000000
1995    2  2    0       0       1       -1   -1 58.84   0.24589769      0.44769841      0.28115147      0.02299743
                0.00194198      0.00031302      0.00000000      0.00000000      0.00000000
1996    2  2    0       0       1       -1   -1 45.92   0.29892120      0.35526509      0.28407353      0.05385728
                0.00380762      0.00407529      0.00000000      0.00000000      0.00000000
1997    2  2    0       0       1       -1   -1 47.44   0.16769604      0.44927048      0.17462436      0.14077280
                0.05754727      0.00731508      0.00277398      0.00000000      0.00000000
1998    2  2    0       0       1       -1   -1 72.48   0.26761762      0.47815789      0.21604073      0.02580353
                0.00936489      0.00301533      0.00000000      0.00000000      0.00000000
1999    2  2    0       0       1       -1   -1 55.32   0.27314763      0.51943459      0.18108008      0.01831521
                0.00686090      0.00095133      0.00021026      0.00000000      0.00000000
2000    2  2    0       0       1       -1   -1 48.04   0.27341328      0.37293108      0.27881477      0.06382949
                0.01091465      0.00000000      0.00000000      0.00009674      0.00000000
2001    2  2    0       0       1       -1   -1 71.04   0.67276346      0.18270578      0.09872123      0.03669650
                0.00653717      0.00257586      0.00000000      0.00000000      0.00000000
2002    2  2    0       0       1       -1   -1 76.48   0.18899176      0.59397851      0.16841782      0.03741263
                0.00773647      0.00329546      0.00008367      0.00000000      0.00008367
2003    2  2    0       0       1       -1   -1 74.64   0.83351604      0.04116990      0.06930792      0.03300254
                0.01468797      0.00389736      0.00353461      0.00088365      0.00000000
2004    2  2    0       0       1       -1   -1 59.16   0.04238489      0.87005119      0.07242785      0.01265237
                0.00145970      0.00102400      0.00000000      0.00000000      0.00000000
2005    2  2    0       0       1       -1   -1 89.04   0.53994582      0.36702223      0.08416083      0.00500806
```

```
                0.00132284   0.00090732   0.00072560   0.00045366   0.00045366
2006   2  2     0      0     1     -1  -1 105.16 0.20172661   0.63015996   0.15000726   0.01740041
                0.00070577   0.00000000   0.00000000   0.00000000   0.00000000
2007   2  2     0      0     2     -1  -1 67.44  0.42021952   0.43386305   0.10589809   0.03396340
                0.00544372   0.00061223   0.00000000   0.00000000   0.00000000
2008   2  2     0      0     3     -1  -1 39.76  0.19862191   0.52834154   0.21532639   0.05558720
                0.00212296   0.00000000   0.00000000   0.00000000   0.00000000
2009   2  2     0      0     3     -1  -1 98.08  0.44090117   0.44149224   0.11209083   0.00372405
                0.00179171   0.00000000   0.00000000   0.00000000   0.00000000
2010   2  2     0      0     4     -1  -1 31.40  0.50304830   0.32470002   0.01757707   0.02625377
                0.05345083   0.06594583   0.00763583   0.00069417   0.00069417
2011   2  2     0      0     4     -1  -1 54.88  0.20910019   0.35249163   0.22419952   0.08833225
                0.04648802   0.03648118   0.03009719   0.01083858   0.00197145
2012   2  2     0      0     4     -1  -1 8.92   0.01286056   0.18465132   0.56709595   0.19900628
                0.03408414   0.00153450   0.00076725   0.00000000   0.00000000
2013   2  2     0      0     4     -1  -1 26.40  0.00400245   0.03541231   0.25560467   0.43215639
                0.18609710   0.05679863   0.01021883   0.01366366   0.00604596
2014   2  2     0      0     4     -1  -1 13.88  0.19601085   0.54781269   0.21272334   0.00361995
                0.01478894   0.02384416   0.00120007   0.00000000   0.00000000
# 2015 2 2 (Small sample size, omit)
#
1999   1  3     0      0     5     -1  -1 2.96   0.00000000   0.00000000   0.59151581   0.20074375
                0.04758623   0.12952271   0.03063150   0.00000000   0.00000000
2000   1  3     0      0     5     -1  -1 66.64  0.00000000   0.00661920   0.20664268   0.39154056
                0.21333728   0.10964756   0.05159158   0.01292370   0.00769745
2001   1  3     0      0     5     -1  -1 81.28  0.00000000   0.01319829   0.09882524   0.43321579
                0.28807345   0.09650734   0.05247704   0.01444472   0.00325813
2002   1  3     0      0     5     -1  -1 110.32 0.00000000   0.00376606   0.02888569   0.14173143
                0.37497785   0.24597782   0.11747427   0.05690067   0.03028621
2003   1  3     0      0     5     -1  -1 92.32  0.00000000   0.02102307   0.16425121   0.15811910
                0.10310171   0.18273199   0.16023280   0.09892235   0.11161776
2004   1  3     0      0     5     -1  -1 66.56  0.00000000   0.18029041   0.09935404   0.14911095
                0.11148963   0.14727065   0.15776410   0.06809703   0.08662319
2005   1  3     0      0     5     -1  -1 40.84  0.00000000   0.01355483   0.68729690   0.14494663
                0.04909713   0.02077143   0.01635392   0.01781254   0.05016661
2006   1  3     0      0     5     -1  -1 26.92  0.00000000   0.00000000   0.01497099   0.60873284
                0.20905176   0.07984672   0.04903877   0.00985519   0.02850373
2007   1  3     0      0     5     -1  -1 89.40  0.00000000   0.00000000   0.03684181   0.45391632
                0.40243125   0.08105161   0.01657055   0.00464352   0.00454494
2008   1  3     0      0     5     -1  -1 94.00  0.00000000   0.00000000   0.00238411   0.12188750
                0.50241139   0.30400027   0.05113905   0.01114247   0.00703520
2009   1  3     0      0     5     -1  -1 93.24  0.00000000   0.00000000   0.00497725   0.03834955
                0.30673956   0.39095629   0.20858215   0.04278986   0.00760533
2010   1  3     0      0     5     -1  -1 33.76  0.00000000   0.00000000   0.00486375   0.03556323
                0.20782114   0.39064640   0.24531203   0.09814472   0.01764872
2011   1  3     0      0     5     -1  -1 42.88  0.00000000   0.00357123   0.03311394   0.04935194
                0.12486830   0.30299646   0.28571874   0.16388915   0.03649023
2012   1  3     0      0     5     -1  -1 118.24 0.00000000   0.00058319   0.34026869   0.21053451
                0.06934004   0.04548403   0.07671303   0.10090398   0.15617254
2013   1  3     0      0     5     -1  -1 138.92 0.00000000   0.00000000   0.03331987   0.59242727
                0.18326590   0.04825943   0.03647473   0.04773246   0.05852034
2014   1  3     0      0     5     -1  -1 49.68  0.00000000   0.00000000   0.00000000   0.04583663
                0.65905889   0.17432845   0.05249064   0.03186569   0.03641970
# 2015 1 3 (Not available)
# 2016 1 3 (Not available)
2008   1  5     0      0     6     -1     -1     27     0.08731171   0.04380052   0.26575501
                0.36538608   0.19445315   0.02418848   0.00829887   0.00773572   0.00307052
                #_ATM_0807
2012   1  5     0      0     6     -1     -1     26     0.00001520   0.01677598   0.23653229
                0.40645653   0.24558422   0.04880821   0.02070141   0.01687986   0.00824632
                #_ATM_1207
2013   1  5     0      0     6     -1     -1     23     0.00000100   0.00499673   0.15131654
                0.36165968   0.26882845   0.10206614   0.05161105   0.03794263   0.02157775
                #_ATM_1307
2014   1  5     0      0     6     -1     -1     7      0.00401556   0.00178747   0.09319014
                0.28674884   0.25004562   0.16133568   0.09638624   0.06409438   0.04239605
                #_ATM_1407
2015   1  5     0      0     6     -1     -1     17     0.79121499   0.01653593   0.01533798
                0.04501253   0.04114013   0.03734153   0.02580894   0.01569317   0.01191480
                #_ATM_1507
2016   1  5     0      0     6     -1     -1     12     0.07423564   0.14454549   0.36224125
                0.29585694   0.11067899   0.00621347   0.00285455   0.00212853   0.00124515
                #_ATM_1607
2005   2  5     0      0     6     -1     -1     10     0.04097055   0.26719664   0.40185645
                0.20502934   0.06231908   0.01777227   0.00392903   0.00072135   0.00020532
                #_ATM_0604
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2007   2  5   0      0      6      -1     -1     12     0.01096180     0.12544972     0.29386586
              0.32190324    0.17145667    0.06094926     0.01307678     0.00178334     0.00055332
              #_ATM_0804
2009   2  5   0      0      6      -1     -1     19     0.00481952     0.03387770     0.13939793
              0.35867340    0.29524038    0.12936332     0.03219387     0.00494117     0.00149270
              #_ATM_1004
2010   2  5   0      0      6      -1     -1     18     0.03694126     0.28170239     0.40268130
              0.17414783    0.06689676    0.02781991     0.00788978     0.00149273     0.00042807
              #_ATM_1104
2011   2  5   0      0      6      -1     -1     12     0.00125332     0.02871729     0.12482482
              0.31089259    0.30276895    0.16512145     0.05264767     0.01074155     0.00303233
              #_ATM_1204
2012   2  5   0      0      6      -1     -1     18     0.00021479     0.01468604     0.09973243
              0.33734389    0.32554332    0.16291630     0.04769501     0.00923904     0.00262919
              #_ATM_1304
2013   2  5   0      0      6      -1     -1     4      0.00001100     0.00230515     0.03046514
              0.23762094    0.37986376    0.24421439     0.08331543     0.01732321     0.00488095
              #_ATM_1404
2014   2  5   0      0      6      -1     -1     6      0.00096497     0.02929461     0.11198702
              0.22449596    0.29105970    0.21911163     0.09227308     0.02431374     0.00649928
              #_ATM_1504
2015   2  5   0      0      6      -1     -1     8      0.15162306     0.25553182     0.17387315
              0.11993204    0.13544885    0.10271864     0.04501109     0.01254897     0.00331238
              #_ATM_1604
#
75 # N_mean_length-at-age_obs_ (Not used)
# 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
              0.00   0.00   0.32   2.08   0.28   0.00   0.00   0.00   0.00
1994   1  1   0      0      1      11.76  17.8   17.2   18.4   18.9   20.6   -1.0   -1.0   -1.0   -1.0
              0.32   5.32   3.80   2.00   0.32   0.00   0.00   0.00   0.00
1995   1  1   0      0      1      4.76   15.0   18.1   17.2   19.0   -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
1996   1  1   0      0      1      89.28  -1.0   17.5   18.5   19.2   19.6   21.6   -1.0   -1.0   -1.0
              0.00   5.12   52.28  27.72  3.68   0.44   0.00   0.00   0.00
1997   1  1   0      0      1      54.96  12.3   16.4   18.3   19.6   21.6   -1.0   -1.0   -1.0   -1.0
              0.16   25.80  24.68  3.92   0.32   0.00   0.00   0.00   0.00
1998   1  1   0      0      1      75.32  12.7   14.5   17.0   19.6   21.0   21.9   -1.0   -1.0   -1.0
              3.56   53.52  14.84  1.76   1.24   0.36   0.00   0.00   0.00
1999   1  1   0      0      1      6.96   13.7   15.1   15.7   -1.0   -1.0   -1.0   -1.0   -1.0   -1.0
              0.84   3.60   2.48   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   -1.0   -1.0   -1.0   -1.0
              1.08   3.92   10.64  6.56   0.36   0.00   0.00   0.00   0.00
2001   1  1   0      0      1      37.24  11.6   17.3   17.5   21.3   22.1   23.3   23.5   23.8   -1.0
              8.36   7.68   4.28   10.68  4.24   1.52   0.36   0.12   0.00
2002   1  1   0      0      1      30.32  16.1   16.3   17.6   18.4   21.6   -1.0   -1.0   -1.0   -1.0
              5.36   16.48  6.84   1.16   0.44   0.00   0.00   0.00   0.00
2003   1  1   0      0      1      17.76  12.0   16.9   18.2   20.0   -1.0   -1.0   -1.0   -1.0   -1.0
              8.56   4.48   4.36   0.32   0.00   0.00   0.00   0.00   0.00
2004   1  1   0      0      1      33.52  13.9   15.6   16.9   18.5   22.1   -1.0   -1.0   -1.0   -1.0
              0.16   30.12  2.72   0.20   0.24   0.00   0.00   0.00   0.00
2005   1  1   0      0      1      35.24  13.4   14.3   16.4   18.3   21.8   -1.0   -1.0   -1.0   -1.0
              4.72   12.56  16.48  1.20   0.16   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
              0.92   47.36  18.60  2.88   0.00   0.00   0.00   0.00   0.00
2007   1  1   0      0      2      86.00  12.9   15.2   16.7   19.1   20.5   -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
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
              1.60   8.56   18.08  2.24   0.36   0.00   0.00   0.00   0.00
2009   1  1   0      0      3      22.88  -1.0   16.4   17.4   17.9   19.5   -1.0   -1.0   -1.0   -1.0
              0.00   5.40   13.20  3.92   0.28   0.00   0.00   0.00   0.00
2010   1  1   0      0      4      12.68  15.8   16.0   18.2   17.8   -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
2011   1  1   0      0      4      21.64  -1.0   17.4   17.7   19.4   20.9   -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
2012   1  1   0      0      4      22.32  -1.0   16.4   18.9   19.9   20.7   21.3   22.6   -1.0   -1.0
              0.00   1.60   10.44  8.52   1.36   0.24   0.12   0.00   0.00
2013   1  1   0      0      4      8.84   11.5   14.0   20.7   21.1   21.8   22.3   22.9   -1.0   -1.0
              0.60   0.52   1.32   2.56   3.04   0.60   0.12   0.00   0.00
2014   1  1   0      0      4      5.92   13.9   -1.0   -1.0   22.6   22.8   22.8   22.8   -1.0   -1.0
              0.88   0.00   0.00   0.40   2.64   1.40   0.44   0.00   0.00
1993   2  2   0      0      1      30.44  15.8   17.5   18.4   20.6   22.1   23.6   24.5   -1.0   -1.0
              6.44   11.52  9.24   1.96   0.72   0.40   0.16   0.00   0.00
1994   2  2   0      0      1      120.96 17.9   17.2   18.7   19.7   20.6   22.1   -1.0   -1.0   -1.0
              47.44  54.28  12.08  6.24   0.76   0.12   0.00   0.00   0.00
1995   2  2   0      0      1      58.84  15.5   18.3   17.3   19.3   20.5   -1.0   -1.0   -1.0   -1.0
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			13.20	29.12	14.96	1.36	0.16	0.00	0.00	0.00	0.00				
1996	2	2	0	0	1	45.92	13.9	17.9	18.5	19.2	22.2	22.7	-1.0	-1.0	-1.0
			14.00	15.16	13.80	2.60	0.16	0.20	0.00	0.00	0.00				
1997	2	2	0	0	1	47.44	13.2	16.6	19.5	21.0	21.7	22.2	23.8	-1.0	-1.0
			8.36	15.04	9.64	9.84	3.76	0.64	0.16	0.00	0.00				
1998	2	2	0	0	1	72.48	13.4	15.1	17.1	19.6	21.0	21.9	-1.0	-1.0	-1.0
			23.24	33.12	13.80	1.52	0.60	0.20	0.00	0.00	0.00				
1999	2	2	0	0	1	55.32	15.0	15.3	16.0	17.6	21.6	-1.0	-1.0	-1.0	-1.0
			16.72	26.68	10.44	1.04	0.36	0.00	0.00	0.00	0.00				
2000	2	2	0	0	1	48.04	14.1	17.1	17.2	17.6	20.7	-1.0	-1.0	-1.0	-1.0
			13.04	19.12	12.76	2.60	0.48	0.00	0.00	0.00	0.00				
2001	2	2	0	0	1	71.08	13.1	17.5	18.0	21.4	22.5	23.3	-1.0	-1.0	-1.0
			49.64	13.44	5.28	2.20	0.40	0.12	0.00	0.00	0.00				
2002	2	2	0	0	1	76.48	16.5	16.7	17.8	18.9	21.7	22.8	-1.0	-1.0	-1.0
			12.88	43.52	14.92	3.92	0.92	0.24	0.00	0.00	0.00				
2003	2	2	0	0	1	74.64	13.4	16.9	18.5	20.9	22.1	21.9	23.9	-1.0	-1.0
			63.08	2.76	4.60	2.16	1.24	0.40	0.32	0.00	0.00				
2004	2	2	0	0	1	59.16	14.2	16.0	17.6	19.7	-1.0	-1.0	-1.0	-1.0	-1.0
			3.32	50.76	4.36	0.60	0.00	0.00	0.00	0.00	0.00				
2005	2	2	0	0	1	89.04	14.4	14.8	16.9	19.2	21.8	23.4	24.6	-1.0	-1.0
			44.68	31.32	11.56	0.80	0.16	0.16	0.20	0.00	0.00				
2006	2	2	0	0	1	105.16	14.9	15.8	18.2	19.3	21.2	-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				
2007	2	2	0	0	2	67.44	13.4	16.3	17.3	20.1	21.7	21.4	-1.0	-1.0	-1.0
			22.96	27.76	10.64	5.12	0.84	0.12	0.00	0.00	0.00				
2008	2	2	0	0	3	39.76	15.2	17.2	17.6	19.0	21.8	-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				
2009	2	2	0	0	3	98.08	14.2	17.3	17.6	18.0	20.1	-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				
2010	2	2	0	0	4	31.40	16.6	16.9	19.1	20.8	21.5	22.1	23.0	-1.0	-1.0
			13.84	7.96	0.68	1.52	3.08	3.80	0.44	0.00	0.00				
2011	2	2	0	0	4	54.88	13.4	18.1	18.2	19.8	21.0	21.7	22.1	23.0	-1.0
			9.40	18.92	14.96	5.24	2.44	2.08	1.28	0.48	0.00				
2012	2	2	0	0	4	8.92	-1.0	18.2	19.1	20.1	20.9	-1.0	-1.0	-1.0	-1.0
			0.00	1.36	4.72	2.32	0.32	0.00	0.00	0.00	0.00				
2013	2	2	0	0	4	26.40	16.0	17.5	20.9	21.8	22.4	22.8	24.5	23.6	-1.0
			0.28	1.80	6.24	11.28	4.84	1.52	0.16	0.20	0.00				
2014	2	2	0	0	4	13.88	14.0	16.0	17.5	-1.0	23.2	23.3	-1.0	-1.0	-1.0
			2.32	7.36	2.56	0.00	0.40	1.12	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	-1.0	-1.0	-1.0
			0.00	0.00	1.56	0.60	0.20	0.52	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	22.6	22.7	22.1
			0.00	0.44	12.40	25.16	14.76	8.16	4.00	1.12	0.60				
2001	1	3	0	0	5	81.28	-1.0	16.3	20.4	20.8	21.2	22.1	22.8	22.6	23.4
			0.00	1.76	8.68	34.96	22.88	7.56	4.08	1.12	0.24				
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
			0.00	0.96	4.28	15.36	39.76	26.68	12.80	6.64	3.84				
2003	1	3	0	0	5	92.32	-1.0	18.9	19.6	20.4	21.8	22.5	22.7	22.9	23.6
			0.00	1.80	15.12	14.40	10.40	17.80	14.88	8.08	9.84				
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
			0.00	18.80	8.80	9.76	6.44	7.64	8.04	3.12	3.96				
2005	1	3	0	0	5	40.84	-1.0	17.0	17.5	19.7	21.3	22.6	23.3	24.0	24.1
			0.00	0.96	22.12	5.48	2.72	1.76	1.52	1.64	4.64				
2006	1	3	0	0	5	26.92	-1.0	-1.0	19.1	19.5	19.8	21.5	22.6	23.5	24.0
			0.00	0.00	0.48	17.64	5.40	1.80	0.76	0.32	0.52				
2007	1	3	0	0	5	89.40	-1.0	-1.0	18.6	19.3	19.7	20.1	21.7	22.7	24.4
			0.00	0.00	3.00	38.36	37.80	7.76	1.68	0.40	0.40				
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
			0.00	0.00	0.24	11.76	45.96	29.12	5.24	1.08	0.60				
2009	1	3	0	0	5	93.24	-1.0	-1.0	19.1	19.1	19.5	19.9	20.3	21.0	21.8
			0.00	0.00	0.64	4.16	28.68	35.48	19.56	4.00	0.72				
2010	1	3	0	0	5	33.76	-1.0	-1.0	16.4	19.9	19.9	20.0	20.2	20.3	21.0
			0.00	0.00	0.16	1.12	6.88	13.04	8.40	3.48	0.68				
2011	1	3	0	0	5	42.88	-1.0	17.4	19.0	20.0	20.7	20.9	21.0	21.1	20.3
			0.00	0.12	1.24	2.12	5.16	13.08	12.60	7.04	1.52				
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
			0.00	0.12	41.72	25.04	8.12	5.44	8.92	11.76	17.12				
2013	1	3	0	0	5	138.92	-1.0	-1.0	20.7	20.9	21.1	21.3	22.0	22.2	22.2
			0.00	0.00	4.24	80.44	26.12	6.80	5.52	6.96	8.84				
2014	1	3	0	0	5	49.68	-1.0	-1.0	-1.0	21.9	22.0	22.0	22.1	22.7	22.8
			0.00	0.00	0.00	2.40	32.68	8.64	2.60	1.60	1.76				
2008	1	5	0	0	6	28.56	10.2	-1.0	20.0	20.8	21.6	22.1	-1.0	-1.0	-1.0
			1.08	0.00	3.24	12.48	11.08	0.60	0.00	0.00	0.00				
2012	1	5	0	0	6	23.16	-1.0	20.4	20.8	21.1	22.0	23.1	23.7	23.8	23.9
			0.00	0.36	6.00	7.00	3.28	2.40	1.60	1.60	0.92				
2013	1	5	0	0	6	14.16	-1.0	-1.0	22.3	22.4	22.4	23.7	24.2	23.8	24.3

```
                0.00    0.00    3.88    6.48    1.60    1.00    0.80    0.16    0.24
2014    1  5    0       0       6       8.48    -1.0    18.7    23.5    23.7    23.7    24.2    25.0    -1.0    -1.0
                0.00    0.12    2.40    3.96    1.40    0.20    0.24    0.00    0.00
2015    1  5    0       0       6       7.44    7.2             21.4    22.8    24.6    25.1    25.2    25.0    -1.0
                -1.0    3.36    0.20    0.16    0.60    2.12    0.76    0.12    0.00    0.00
2016    1  5    0       0       6       10.44   -1.0    17.1    21.4    22.8    24.6    25.1    24.5    25.6    -1.0
                0.00    2.04    4.28    2.32    0.76    0.76    0.12    0.12    0.00
2005    2  5    0       0       6       11.56   16.3    17.8    18.9    19.0    21.2    -1.0    -1.0    -1.0    -1.0
                0.44    1.80    6.40    2.44    0.36    0.00    0.00    0.00    0.00
2007    2  5    0       0       6       18.2    -1.0    17.7    19.2    21.4    21.7    21.6    -1.0    -1.0    -1.0
                0.00    0.12    2.64    11.80   3.00    0.60    0.00    0.00    0.00
2009    2  5    0       0       6       34.72   -1.0    17.0    20.0    21.8    22.1    22.3    22.9    24.3    -1.0
                0.00    0.68    0.84    7.88    15.60   8.00    1.56    0.12    0.00
2010    2  5    0       0       6       30.64   17.7    17.8    18.6    21.0    22.8    23.0    23.2    23.1    -1.0
                0.20    7.16    8.00    3.84    5.72    3.96    1.52    0.24    0.00
2011    2  5    0       0       6       13.68   -1.0    20.3    20.7    21.8    22.9    23.6    23.3    23.3    -1.0
                0.00    1.16    4.48    2.20    2.44    1.88    1.28    0.24    0.00
2012    2  5    0       0       6       8.68    -1.0    -1.0    21.6    21.8    22.2    23.3    23.7    24.3    23.9
                0.00    0.00    1.84    3.76    1.20    0.52    0.64    0.36    0.32
2013    2  5    0       0       6       0.64    -1.0    -1.0    23.1    23.3    23.2    -1.0    -1.0    -1.0    -1.0
                0.00    0.00    0.24    0.20    0.16    0.00    0.00    0.00    0.00
2014    2  5    0       0       6       2.44    19.0    18.7    24.1    24.1    24.3    24.6    25.0    -1.0    -1.0
                0.12    0.12    0.20    0.24    0.80    0.72    0.16    0.00    0.00
2015    2  5    0       0       6       4.28    14.4    21.4    22.8    24.6    25.1    20.0    -1.0    -1.0    -1.0
                4.08    2.44    0.56    0.32    0.48    0.16    0.00    0.00    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
```

WTATAGE.SS

```
184  #_user_must_replace_this_value_with_number_of_lines_with_wtatage_below

10 # maxage

# if yr=-yr, then fill remaining years for that seas, growpattern, gender, fleet

# fleet 0 contains begin season pop WT

# fleet -1 contains mid season pop WT

# fleet -2 contains maturity*fecundity

#yr seas gender growpattern birthseas fleet  0 1 2 3 4 5 6 7 8 9 10

-1993   2  1    1       1       -2      0.0046 0.0354 0.0773 0.1100 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858
                0.1939  #_fecundity*maturity from T_2017_abbrev with Bev's new ogive
-1993   1  1    1       1       -1      0.0161 0.0542 0.0837 0.1103 0.1323 0.1497 0.1630 0.1729 0.1801 0.1854
                0.1941  #_Popn S1 Mid-season from T_2017_abbrev
-1993   2  1    1       1       -1      0.0396 0.0691 0.0975 0.1219 0.1416 0.1568 0.1683 0.1768 0.1830 0.1875
                0.1948  #_Popn S2 Mid-season from T_2017_abbrev
-1993   1  1    1       1       0       0.0075 0.0469 0.0765 0.1040 0.1273 0.1458 0.1600 0.1707 0.1785 0.1842
                0.1936  #_Popn S1 Beg-season from T_2017_abbrev
-1993   2  1    1       1       0       0.0327 0.0617 0.0907 0.1162 0.1371 0.1534 0.1657 0.1749 0.1816 0.1865
                0.1944  #_Popn S2 Beg-season from T_2017_abbrev
1993    1  1    1       1       1       0.0210 0.0362 0.0771 0.0620 0.0744 0.0886 0.1959 0.2205 0.2113 0.1831
                0.1906  #_MexCal_S1_Sem1
1994    1  1    1       1       1       0.0210 0.0723 0.0885 0.0996 0.1278 0.1508 0.1777 0.1959 0.2205 0.2113
                0.1906  #_MexCal_S1_Sem1
1995    1  1    1       1       1       0.0429 0.0581 0.0848 0.0885 0.1117 0.1355 0.1547 0.1788 0.1959 0.2205
                0.2113  #_MexCal_S1_Sem1
1996    1  1    1       1       1       0.0210 0.0825 0.0977 0.1098 0.1173 0.1288 0.1547 0.1652 0.1798 0.1959
                0.2205  #_MexCal_S1_Sem1
1997    1  1    1       1       1       0.0340 0.0598 0.0844 0.1043 0.1361 0.1600 0.1574 0.1652 0.1728 0.1831
                0.1959  #_MexCal_S1_Sem1
1998    1  1    1       1       1       0.0260 0.0446 0.0743 0.1086 0.1289 0.1450 0.1626 0.1721 0.1728 0.1831
                0.1906  #_MexCal_S1_Sem1
1999    1  1    1       1       1       0.0330 0.0487 0.0550 0.0792 0.1346 0.1355 0.1547 0.1652 0.1728 0.1831
                0.1906  #_MexCal_S1_Sem1
2000    1  1    1       1       1       0.0393 0.0658 0.0720 0.0712 0.0889 0.1606 0.1547 0.1652 0.1728 0.1831
                0.1906  #_MexCal_S1_Sem1
2001    1  1    1       1       1       0.0210 0.0772 0.0959 0.1325 0.1513 0.1218 0.1866 0.1633 0.1728 0.1831
```

```
                0.1906  #_MexCal_S1_Sem1
2002    1  1    1       1       1       0.0630  0.0668  0.0868  0.0958  0.1405  0.1556  0.1547  0.1866  0.1728  0.1831
                0.1906  #_MexCal_S1_Sem1
2003    1  1    1       1       1       0.0219  0.0734  0.0945  0.1191  0.1267  0.1476  0.1685  0.1652  0.1866  0.1831
                0.1906  #_MexCal_S1_Sem1
2004    1  1    1       1       1       0.0383  0.0530  0.0753  0.0952  0.1295  0.1512  0.1547  0.1652  0.1728  0.1866
                0.1906  #_MexCal_S1_Sem1
2005    1  1    1       1       1       0.0329  0.0416  0.0623  0.0852  0.1450  0.1398  0.1692  0.1652  0.1728  0.1831
                0.1906  #_MexCal_S1_Sem1
2006    1  1    1       1       1       0.0411  0.0477  0.0645  0.0795  0.1077  0.1581  0.1552  0.1840  0.1728  0.1831
                0.1906  #_MexCal_S1_Sem1
2007    1  1    1       1       1       0.0270  0.0490  0.0670  0.0906  0.1103  0.1253  0.1743  0.1840  0.1901  0.1831
                0.1906  #_MexCal_S1_Sem1
2008    1  1    1       1       1       0.0380  0.0671  0.0747  0.0931  0.1307  0.1581  0.1415  0.1840  0.1901  0.1941
                0.1906  #_MexCal_S1_Sem1
2009    1  1    1       1       1       0.0237  0.0642  0.0762  0.0800  0.1064  0.1380  0.1743  0.1840  0.1901  0.1941
                0.1992  #_MexCal_S1_Sem1
2010    1  1    1       1       1       0.0534  0.0585  0.0836  0.0818  0.1105  0.1197  0.1427  0.1840  0.1901  0.1941
                0.1992  #_MexCal_S1_Sem1
2011    1  1    1       1       1       0.0237  0.0812  0.0845  0.0967  0.1113  0.1272  0.1381  0.1481  0.1901  0.1941
                0.1992  #_MexCal_S1_Sem1
2012    1  1    1       1       1       0.0237  0.0630  0.0984  0.1141  0.1257  0.1302  0.1387  0.1840  0.1901  0.1941
                0.1992  #_MexCal_S1_Sem1
2013    1  1    1       1       1       0.0214  0.0452  0.1398  0.1365  0.1473  0.1512  0.1723  0.1592  0.1901  0.1941
                0.1992  #_MexCal_S1_Sem1
-2014   1  1    1       1       1       0.0323  0.0577  0.0803  0.1601  0.1690  0.1693  0.1659  0.1840  0.1901  0.1941
                0.1992  #_MexCal_S1_Sem1
1993    2  1    1       1       1       0.0210  0.0362  0.0771  0.0620  0.0744  0.0886  0.1959  0.2205  0.2113  0.1831
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
1994    2  1    1       1       1       0.0210  0.0723  0.0885  0.0996  0.1278  0.1508  0.1777  0.1959  0.2205  0.2113
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
1995    2  1    1       1       1       0.0429  0.0581  0.0848  0.0885  0.1117  0.1355  0.1547  0.1788  0.1959  0.2205
                0.2113  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
1996    2  1    1       1       1       0.0210  0.0825  0.0977  0.1098  0.1173  0.1288  0.1547  0.1652  0.1798  0.1959
                0.2205  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
1997    2  1    1       1       1       0.0340  0.0598  0.0844  0.1043  0.1361  0.1600  0.1574  0.1652  0.1728  0.1831
                0.1959  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
1998    2  1    1       1       1       0.0260  0.0446  0.0743  0.1086  0.1289  0.1450  0.1626  0.1721  0.1728  0.1831
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
1999    2  1    1       1       1       0.0330  0.0487  0.0550  0.0792  0.1346  0.1355  0.1547  0.1652  0.1728  0.1831
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2000    2  1    1       1       1       0.0393  0.0658  0.0720  0.0712  0.0889  0.1606  0.1547  0.1652  0.1728  0.1831
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2001    2  1    1       1       1       0.0210  0.0772  0.0959  0.1325  0.1513  0.1218  0.1866  0.1633  0.1728  0.1831
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2002    2  1    1       1       1       0.0630  0.0668  0.0868  0.0958  0.1405  0.1556  0.1547  0.1866  0.1728  0.1831
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2003    2  1    1       1       1       0.0219  0.0734  0.0945  0.1191  0.1267  0.1476  0.1685  0.1652  0.1866  0.1831
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2004    2  1    1       1       1       0.0383  0.0530  0.0753  0.0952  0.1295  0.1512  0.1547  0.1652  0.1728  0.1866
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2005    2  1    1       1       1       0.0329  0.0416  0.0623  0.0852  0.1450  0.1398  0.1692  0.1652  0.1728  0.1831
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2006    2  1    1       1       1       0.0411  0.0477  0.0645  0.0795  0.1077  0.1581  0.1552  0.1840  0.1728  0.1831
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2007    2  1    1       1       1       0.0270  0.0490  0.0670  0.0906  0.1103  0.1253  0.1743  0.1840  0.1901  0.1831
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2008    2  1    1       1       1       0.0380  0.0671  0.0747  0.0931  0.1307  0.1581  0.1415  0.1840  0.1901  0.1941
                0.1906  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2009    2  1    1       1       1       0.0237  0.0642  0.0762  0.0800  0.1064  0.1380  0.1743  0.1840  0.1901  0.1941
                0.1992  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2010    2  1    1       1       1       0.0534  0.0585  0.0836  0.0818  0.1105  0.1197  0.1427  0.1840  0.1901  0.1941
                0.1992  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2011    2  1    1       1       1       0.0237  0.0812  0.0845  0.0967  0.1113  0.1272  0.1381  0.1481  0.1901  0.1941
                0.1992  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2012    2  1    1       1       1       0.0237  0.0630  0.0984  0.1141  0.1257  0.1302  0.1387  0.1840  0.1901  0.1941
                0.1992  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
2013    2  1    1       1       1       0.0214  0.0452  0.1398  0.1365  0.1473  0.1512  0.1723  0.1592  0.1901  0.1941
                0.1992  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
-2014   2  1    1       1       1       0.0323  0.0577  0.0803  0.1601  0.1690  0.1693  0.1659  0.1840  0.1901  0.1941
                0.1992  #_MexCal_S1_Sem2_(same_as_MexCal_S2)
1993    1  1    1       1       2       0.0520  0.0724  0.0866  0.1240  0.1488  0.1772  0.1959  0.2205  0.2043  0.1866
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
1994    1  1    1       1       2       0.0440  0.0723  0.0885  0.0996  0.1317  0.1527  0.1782  0.1959  0.2205  0.2043
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
1995    1  1    1       1       2       0.0493  0.0628  0.0973  0.0885  0.1238  0.1417  0.1559  0.1793  0.1959  0.2205
```

```
                0.2043  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
1996    1 1     1       1       2       0.0354 0.0835 0.1010 0.1230 0.1588 0.1431 0.1559 0.1706 0.1803 0.1959
                0.2205  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
1997    1 1     1       1       2       0.0393 0.0616 0.1008 0.1256 0.1406 0.1613 0.1718 0.1706 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
1998    1 1     1       1       2       0.0338 0.0496 0.0743 0.1216 0.1322 0.1498 0.1639 0.1724 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
1999    1 1     1       1       2       0.0474 0.0498 0.0581 0.0840 0.1476 0.1417 0.1559 0.1706 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2000    1 1     1       1       2       0.0582 0.0808 0.1022 0.0781 0.1053 0.1736 0.1559 0.1706 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2001    1 1     1       1       2       0.0311 0.0820 0.0958 0.1365 0.1535 0.1382 0.1866 0.1706 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2002    1 1     1       1       2       0.0682 0.0807 0.1030 0.1113 0.1441 0.1578 0.1559 0.1866 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2003    1 1     1       1       2       0.0315 0.0744 0.0949 0.1243 0.1422 0.1511 0.1791 0.1706 0.1866 0.1866
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2004    1 1     1       1       2       0.0390 0.0576 0.0763 0.1103 0.1347 0.1602 0.1559 0.1706 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2005    1 1     1       1       2       0.0403 0.0445 0.0653 0.0913 0.1516 0.1450 0.1782 0.1706 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2006    1 1     1       1       2       0.0451 0.0518 0.0793 0.0931 0.1240 0.1647 0.1655 0.1860 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2007    1 1     1       1       2       0.0326 0.0619 0.0678 0.1019 0.1274 0.1267 0.1777 0.1860 0.1913 0.1866
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2008    1 1     1       1       2       0.0511 0.0716 0.0773 0.0997 0.1356 0.1647 0.1563 0.1860 0.1913 0.1947
                0.1959  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2009    1 1     1       1       2       0.0372 0.0739 0.0790 0.0952 0.1065 0.1403 0.1777 0.1860 0.1913 0.1947
                0.1995  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2010    1 1     1       1       2       0.0673 0.0715 0.0934 0.1166 0.1258 0.1329 0.1451 0.1860 0.1913 0.1947
                0.1995  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2011    1 1     1       1       2       0.0296 0.0898 0.0993 0.1000 0.1205 0.1286 0.1433 0.1512 0.1913 0.1947
                0.1995  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2012    1 1     1       1       2       0.0370 0.0833 0.1175 0.1307 0.1385 0.1513 0.1490 0.1860 0.1913 0.1947
                0.1995  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
2013    1 1     1       1       2       0.0563 0.0773 0.1499 0.1402 0.1489 0.1599 0.1850 0.1694 0.1913 0.1947
                0.1995  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
-2014   1 1     1       1       2       0.0344 0.0591 0.0833 0.1601 0.1700 0.1721 0.0830 0.1860 0.1913 0.1947
                0.1995  #_MexCal_S2_Sem1_(same_as_MexCal_S1)
1993    2 1     1       1       2       0.0520 0.0724 0.0866 0.1240 0.1488 0.1772 0.1959 0.2205 0.2043 0.1866
                0.1959  #_MexCal_S2_Sem2
1994    2 1     1       1       2       0.0440 0.0723 0.0885 0.0996 0.1317 0.1527 0.1782 0.1959 0.2205 0.2043
                0.1959  #_MexCal_S2_Sem2
1995    2 1     1       1       2       0.0493 0.0628 0.0973 0.0885 0.1238 0.1417 0.1559 0.1793 0.1959 0.2205
                0.2043  #_MexCal_S2_Sem2
1996    2 1     1       1       2       0.0354 0.0835 0.1010 0.1230 0.1588 0.1431 0.1559 0.1706 0.1803 0.1959
                0.2205  #_MexCal_S2_Sem2
1997    2 1     1       1       2       0.0393 0.0616 0.1008 0.1256 0.1406 0.1613 0.1718 0.1706 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem2
1998    2 1     1       1       2       0.0338 0.0496 0.0743 0.1216 0.1322 0.1498 0.1639 0.1724 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem2
1999    2 1     1       1       2       0.0474 0.0498 0.0581 0.0840 0.1476 0.1417 0.1559 0.1706 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem2
2000    2 1     1       1       2       0.0582 0.0808 0.1022 0.0781 0.1053 0.1736 0.1559 0.1706 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem2
2001    2 1     1       1       2       0.0311 0.0820 0.0958 0.1365 0.1535 0.1382 0.1866 0.1706 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem2
2002    2 1     1       1       2       0.0682 0.0807 0.1030 0.1113 0.1441 0.1578 0.1559 0.1866 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem2
2003    2 1     1       1       2       0.0315 0.0744 0.0949 0.1243 0.1422 0.1511 0.1791 0.1706 0.1866 0.1866
                0.1959  #_MexCal_S2_Sem2
2004    2 1     1       1       2       0.0390 0.0576 0.0763 0.1103 0.1347 0.1602 0.1559 0.1706 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem2
2005    2 1     1       1       2       0.0403 0.0445 0.0653 0.0913 0.1516 0.1450 0.1782 0.1706 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem2
2006    2 1     1       1       2       0.0451 0.0518 0.0793 0.0931 0.1240 0.1647 0.1655 0.1860 0.1803 0.1866
                0.1959  #_MexCal_S2_Sem2
2007    2 1     1       1       2       0.0326 0.0619 0.0678 0.1019 0.1274 0.1267 0.1777 0.1860 0.1913 0.1866
                0.1959  #_MexCal_S2_Sem2
2008    2 1     1       1       2       0.0511 0.0716 0.0773 0.0997 0.1356 0.1647 0.1563 0.1860 0.1913 0.1947
                0.1959  #_MexCal_S2_Sem2
2009    2 1     1       1       2       0.0372 0.0739 0.0790 0.0952 0.1065 0.1403 0.1777 0.1860 0.1913 0.1947
                0.1995  #_MexCal_S2_Sem2
2010    2 1     1       1       2       0.0673 0.0715 0.0934 0.1166 0.1258 0.1329 0.1451 0.1860 0.1913 0.1947
                0.1995  #_MexCal_S2_Sem2
2011    2 1     1       1       2       0.0296 0.0898 0.0993 0.1000 0.1205 0.1286 0.1433 0.1512 0.1913 0.1947
```

															0.1995	#_MexCal_S2_Sem2
2012	2	1	1	1	2	0.0370	0.0833	0.1175	0.1307	0.1385	0.1513	0.1490	0.1860	0.1913	0.1947	
															0.1995	#_MexCal_S2_Sem2
2013	2	1	1	1	2	0.0563	0.0773	0.1499	0.1402	0.1489	0.1599	0.1850	0.1694	0.1913	0.1947	
															0.1995	#_MexCal_S2_Sem2
-2014	2	1	1	1	2	0.0344	0.0591	0.0833	0.1601	0.1700	0.1721	0.1659	0.1860	0.1913	0.1947	
															0.1995	#_MexCal_S2_Sem2
1993	1	1	1	1	3	0.0138	0.0809	0.1067	0.1283	0.1477	0.1638	0.1760	0.1846	0.1904	0.1943	
															0.1996	#_PacNW_Sem1
1994	1	1	1	1	3	0.0138	0.0809	0.1067	0.1283	0.1477	0.1638	0.1760	0.1846	0.1904	0.1943	
															0.1996	#_PacNW_Sem1
1995	1	1	1	1	3	0.0138	0.0809	0.1067	0.1283	0.1477	0.1638	0.1760	0.1846	0.1904	0.1943	
															0.1996	#_PacNW_Sem1
1996	1	1	1	1	3	0.0138	0.0809	0.1067	0.1283	0.1477	0.1638	0.1760	0.1846	0.1904	0.1943	
															0.1996	#_PacNW_Sem1
1997	1	1	1	1	3	0.0138	0.0809	0.1067	0.1283	0.1477	0.1638	0.1760	0.1846	0.1904	0.1943	
															0.1996	#_PacNW_Sem1
1998	1	1	1	1	3	0.0138	0.0809	0.1067	0.1283	0.1477	0.1638	0.1760	0.1846	0.1904	0.1943	
															0.1996	#_PacNW_Sem1
1999	1	1	1	1	3	0.0138	0.0809	0.0869	0.1270	0.1568	0.1826	0.1760	0.1846	0.1904	0.1943	
															0.1996	#_PacNW_Sem1
2000	1	1	1	1	3	0.0138	0.1440	0.1193	0.1530	0.1685	0.1798	0.1883	0.1957	0.2040	0.1943	
															0.1996	#_PacNW_Sem1
2001	1	1	1	1	3	0.0138	0.0735	0.1403	0.1480	0.1570	0.1741	0.1902	0.1862	0.1982	0.1943	
															0.1996	#_PacNW_Sem1
2002	1	1	1	1	3	0.0138	0.1256	0.1505	0.1714	0.1782	0.1881	0.2005	0.2089	0.2151	0.1943	
															0.1996	#_PacNW_Sem1
2003	1	1	1	1	3	0.0138	0.1094	0.1236	0.1386	0.1670	0.1855	0.1933	0.1973	0.2124	0.1943	
															0.1996	#_PacNW_Sem1
2004	1	1	1	1	3	0.0138	0.0734	0.1235	0.1547	0.1834	0.1998	0.2063	0.2105	0.2151	0.1943	
															0.1996	#_PacNW_Sem1
2005	1	1	1	1	3	0.0138	0.0747	0.0864	0.0938	0.1229	0.1655	0.1816	0.2058	0.2067	0.1943	
															0.1996	#_PacNW_Sem1
2006	1	1	1	1	3	0.0138	0.0809	0.1080	0.1176	0.1247	0.1355	0.1397	0.1959	0.1762	0.1943	
															0.1996	#_PacNW_Sem1
2007	1	1	1	1	3	0.0138	0.0809	0.0977	0.1050	0.1093	0.1163	0.1269	0.1324	0.1980	0.1943	
															0.1996	#_PacNW_Sem1
2008	1	1	1	1	3	0.0138	0.0809	0.1050	0.1116	0.1202	0.1264	0.1392	0.1522	0.1718	0.1943	
															0.1996	#_PacNW_Sem1
2009	1	1	1	1	3	0.0138	0.0405	0.1095	0.1108	0.1194	0.1267	0.1304	0.1359	0.1436	0.1943	
															0.1996	#_PacNW_Sem1
2010	1	1	1	1	3	0.0138	0.0632	0.0673	0.1156	0.1328	0.1341	0.1380	0.1379	0.1399	0.1943	
															0.1996	#_PacNW_Sem1
2011	1	1	1	1	3	0.0138	0.0853	0.1127	0.1386	0.1505	0.1565	0.1580	0.1609	0.1575	0.1943	
															0.1996	#_PacNW_Sem1
2012	1	1	1	1	3	0.0138	0.1250	0.1334	0.1421	0.1536	0.1671	0.1733	0.1737	0.1790	0.1943	
															0.1996	#_PacNW_Sem1
2013	1	1	1	1	3	0.0138	0.0809	0.1621	0.1670	0.1728	0.1795	0.1949	0.1980	0.1994	0.1943	
															0.1996	#_PacNW_Sem1
-2014	1	1	1	1	3	0.0138	0.0809	0.1067	0.1730	0.1805	0.1838	0.1846	0.1915	0.1961	0.1943	
															0.1996	#_PacNW_Sem1
1993	2	1	1	1	3	0.0396	0.0947	0.1178	0.1383	0.1562	0.1704	0.1807	0.1878	0.1926	0.1957	
															0.2000	#_PacNW_Sem2
1994	2	1	1	1	3	0.0396	0.0947	0.1178	0.1383	0.1562	0.1704	0.1807	0.1878	0.1926	0.1957	
															0.2000	#_PacNW_Sem2
1995	2	1	1	1	3	0.0396	0.0947	0.1178	0.1383	0.1562	0.1704	0.1807	0.1878	0.1926	0.1957	
															0.2000	#_PacNW_Sem2
1996	2	1	1	1	3	0.0396	0.0947	0.1178	0.1383	0.1562	0.1704	0.1807	0.1878	0.1926	0.1957	
															0.2000	#_PacNW_Sem2
1997	2	1	1	1	3	0.0396	0.0947	0.1178	0.1383	0.1562	0.1704	0.1807	0.1878	0.1926	0.1957	
															0.2000	#_PacNW_Sem2
1998	2	1	1	1	3	0.0396	0.0947	0.1178	0.1383	0.1562	0.1704	0.1807	0.1878	0.1926	0.1957	
															0.2000	#_PacNW_Sem2
1999	2	1	1	1	3	0.0396	0.1001	0.1199	0.1478	0.1683	0.1855	0.1807	0.1878	0.1926	0.1957	
															0.2000	#_PacNW_Sem2
2000	2	1	1	1	3	0.0396	0.1422	0.1336	0.1550	0.1713	0.1850	0.1873	0.1969	0.1991	0.1957	
															0.2000	#_PacNW_Sem2
2001	2	1	1	1	3	0.0396	0.1120	0.1559	0.1631	0.1725	0.1873	0.1996	0.2007	0.1962	0.1957	
															0.2000	#_PacNW_Sem2
2002	2	1	1	1	3	0.0396	0.1246	0.1446	0.1692	0.1819	0.1907	0.1989	0.2107	0.2047	0.1957	
															0.2000	#_PacNW_Sem2
2003	2	1	1	1	3	0.0396	0.1165	0.1392	0.1610	0.1834	0.1959	0.2019	0.2062	0.2034	0.1957	
															0.2000	#_PacNW_Sem2
2004	2	1	1	1	3	0.0396	0.0799	0.1086	0.1388	0.1745	0.1907	0.2060	0.2086	0.2047	0.1957	
															0.2000	#_PacNW_Sem2
2005	2	1	1	1	3	0.0396	0.0913	0.1020	0.1092	0.1292	0.1526	0.1887	0.1910	0.2005	0.1957	

```
                0.2000  #_PacNW_Sem2
2006    2  1    1       1       3       0.0396  0.0893  0.1065  0.1135  0.1205  0.1312  0.1361  0.1969  0.1853  0.1957
                0.2000  #_PacNW_Sem2
2007    2  1    1       1       3       0.0396  0.0930  0.1046  0.1126  0.1178  0.1278  0.1395  0.1521  0.1961  0.1957
                0.2000  #_PacNW_Sem2
2008    2  1    1       1       3       0.0396  0.0952  0.1079  0.1155  0.1234  0.1284  0.1376  0.1479  0.1830  0.1957
                0.2000  #_PacNW_Sem2
2009    2  1    1       1       3       0.0396  0.0539  0.1126  0.1218  0.1268  0.1323  0.1341  0.1379  0.1689  0.1957
                0.2000  #_PacNW_Sem2
2010    2  1    1       1       3       0.0396  0.0879  0.1029  0.1331  0.1447  0.1461  0.1495  0.1477  0.1671  0.1957
                0.2000  #_PacNW_Sem2
2011    2  1    1       1       3       0.0396  0.1094  0.1274  0.1461  0.1588  0.1649  0.1659  0.1699  0.1759  0.1957
                0.2000  #_PacNW_Sem2
2012    2  1    1       1       3       0.0396  0.1435  0.1502  0.1574  0.1666  0.1810  0.1857  0.1866  0.1866  0.1957
                0.2000  #_PacNW_Sem2
2013    2  1    1       1       3       0.0396  0.0947  0.1675  0.1738  0.1783  0.1821  0.1932  0.1971  0.1968  0.1957
                0.2000  #_PacNW_Sem2
-2014   2  1    1       1       3       0.0396  0.0947  0.1178  0.1747  0.1819  0.1851  0.1862  0.1922  0.1952  0.1957
                0.2000  #_PacNW_Sem2
1993    1  1    1       1       5       0.0125  0.0461  0.0839  0.1173  0.1434  0.1622  0.1754  0.1843  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
1994    1  1    1       1       5       0.0125  0.0461  0.0839  0.1173  0.1434  0.1622  0.1754  0.1843  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
1995    1  1    1       1       5       0.0125  0.0461  0.0839  0.1173  0.1434  0.1622  0.1754  0.1843  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
1996    1  1    1       1       5       0.0125  0.0461  0.0839  0.1173  0.1434  0.1622  0.1754  0.1843  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
1997    1  1    1       1       5       0.0125  0.0461  0.0839  0.1173  0.1434  0.1622  0.1754  0.1843  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
1998    1  1    1       1       5       0.0125  0.0461  0.0839  0.1173  0.1434  0.1622  0.1754  0.1843  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
1999    1  1    1       1       5       0.0125  0.0461  0.0839  0.1173  0.1434  0.1622  0.1754  0.1843  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
2000    1  1    1       1       5       0.0125  0.0461  0.0839  0.1173  0.1434  0.1622  0.1754  0.1843  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
2001    1  1    1       1       5       0.0125  0.0461  0.0839  0.1173  0.1434  0.1622  0.1754  0.1843  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
2002    1  1    1       1       5       0.0125  0.0461  0.0839  0.1173  0.1434  0.1622  0.1754  0.1843  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
2003    1  1    1       1       5       0.0125  0.0461  0.0839  0.1173  0.1434  0.1622  0.1754  0.1843  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
2004    1  1    1       1       5       0.0125  0.0688  0.1243  0.1380  0.1640  0.1737  0.1850  0.1914  0.1921  0.1942
                0.1995  #_ATM_Survey_Sem1
2005    1  1    1       1       5       0.0125  0.0445  0.0734  0.1278  0.1443  0.1676  0.1778  0.1920  0.2003  0.1942
                0.1995  #_ATM_Survey_Sem1
2006    1  1    1       1       5       0.0125  0.0563  0.0750  0.0817  0.1313  0.1506  0.1754  0.1843  0.1923  0.2003
                0.1995  #_ATM_Survey_Sem1
2007    1  1    1       1       5       0.0125  0.0451  0.0705  0.0969  0.0996  0.1348  0.1569  0.1843  0.1903  0.1942
                0.2003  #_ATM_Survey_Sem1
2008    1  1    1       1       5       0.0134  0.0461  0.1040  0.1153  0.1181  0.1221  0.1383  0.1843  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
2009    1  1    1       1       5       0.0125  0.0446  0.0890  0.1182  0.1257  0.1264  0.1368  0.1547  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
2010    1  1    1       1       5       0.0125  0.0480  0.0708  0.1088  0.1348  0.1368  0.1402  0.1463  0.1903  0.1942
                0.1995  #_ATM_Survey_Sem1
2011    1  1    1       1       5       0.0131  0.0720  0.1101  0.1179  0.1224  0.1369  0.1419  0.1389  0.1440  0.1410
                0.1410  #_ATM_Survey_Sem1
2012    1  1    1       1       5       0.1071  0.1152  0.1220  0.1265  0.1302  0.1496  0.1581  0.1528  0.1615  0.1564
                0.1564  #_ATM_Survey_Sem1
2013    1  1    1       1       5       0.1358  0.1449  0.1513  0.1548  0.1574  0.1689  0.1740  0.1708  0.1761  0.1730
                0.1730  #_ATM_Survey_Sem1
2014    1  1    1       1       5       0.0061  0.1694  0.1768  0.1794  0.1812  0.1885  0.1916  0.1897  0.1930  0.1910
                0.1910  #_ATM_Survey_Sem1
2015    1  1    1       1       5       0.0036  0.0329  0.1741  0.1874  0.1937  0.2066  0.2095  0.2078  0.2105  0.2089
                0.2089  #_ATM_Survey_Sem1
-2016   1  1    1       1       5       0.0108  0.0658  0.0740  0.0784  0.0827  0.1536  0.1951  0.1713  0.2065  0.1883
                0.1883  #_ATM_Survey_Sem1
1993    2  1    1       1       5       0.0283  0.0651  0.1015  0.1313  0.1536  0.1694  0.1803  0.1876  0.1924  0.1956
                0.1999  #_ATM_Survey_Sem2
1994    2  1    1       1       5       0.0283  0.0651  0.1015  0.1313  0.1536  0.1694  0.1803  0.1876  0.1924  0.1956
                0.1999  #_ATM_Survey_Sem2
1995    2  1    1       1       5       0.0283  0.0651  0.1015  0.1313  0.1536  0.1694  0.1803  0.1876  0.1924  0.1956
                0.1999  #_ATM_Survey_Sem2
1996    2  1    1       1       5       0.0283  0.0651  0.1015  0.1313  0.1536  0.1694  0.1803  0.1876  0.1924  0.1956
                0.1999  #_ATM_Survey_Sem2
1997    2  1    1       1       5       0.0283  0.0651  0.1015  0.1313  0.1536  0.1694  0.1803  0.1876  0.1924  0.1956
```

```
               0.1999  #_ATM_Survey_Sem2
1998    2  1    1       1       5       0.0283  0.0651  0.1015  0.1313  0.1536  0.1694  0.1803  0.1876  0.1924  0.1956
               0.1999  #_ATM_Survey_Sem2
1999    2  1    1       1       5       0.0283  0.0651  0.1015  0.1313  0.1536  0.1694  0.1803  0.1876  0.1924  0.1956
               0.1999  #_ATM_Survey_Sem2
2000    2  1    1       1       5       0.0283  0.0651  0.1015  0.1313  0.1536  0.1694  0.1803  0.1876  0.1924  0.1956
               0.1999  #_ATM_Survey_Sem2
2001    2  1    1       1       5       0.0283  0.0651  0.1015  0.1313  0.1536  0.1694  0.1803  0.1876  0.1924  0.1956
               0.1999  #_ATM_Survey_Sem2
2002    2  1    1       1       5       0.0283  0.0651  0.1015  0.1313  0.1536  0.1694  0.1803  0.1876  0.1924  0.1956
               0.1999  #_ATM_Survey_Sem2
2003    2  1    1       1       5       0.0665  0.1150  0.1349  0.1622  0.1729  0.1781  0.1825  0.1917  0.1924  0.1956
               0.1999  #_ATM_Survey_Sem2
2004    2  1    1       1       5       0.0250  0.0711  0.1261  0.1411  0.1658  0.1745  0.1919  0.2003  0.1924  0.1956
               0.1999  #_ATM_Survey_Sem2
2005    2  1    1       1       5       0.0584  0.0677  0.0756  0.0899  0.1063  0.1281  0.1616  0.1998  0.1952  0.1709
               0.1709  #_ATM_Survey_Sem2
2006    2  1    1       1       5       0.0584  0.0677  0.0756  0.0899  0.1063  0.1281  0.1616  0.1998  0.1952  0.1709
               0.1709  #_ATM_Survey_Sem2
2007    2  1    1       1       5       0.0702  0.0806  0.0920  0.1128  0.1279  0.1369  0.1451  0.1542  0.1529  0.1471
               0.1471  #_ATM_Survey_Sem2
2008    2  1    1       1       5       0.0702  0.0806  0.0920  0.1128  0.1279  0.1369  0.1451  0.1542  0.1529  0.1471
               0.1471  #_ATM_Survey_Sem2
2009    2  1    1       1       5       0.0399  0.0884  0.1197  0.1381  0.1467  0.1524  0.1579  0.1642  0.1633  0.1593
               0.1593  #_ATM_Survey_Sem2
2010    2  1    1       1       5       0.0609  0.0644  0.0684  0.0851  0.1228  0.1485  0.1635  0.1745  0.1731  0.1663
               0.1663  #_ATM_Survey_Sem2
2011    2  1    1       1       5       0.0792  0.1016  0.1154  0.1364  0.1554  0.1669  0.1755  0.1827  0.1818  0.1773
               0.1773  #_ATM_Survey_Sem2
2012    2  1    1       1       5       0.1141  0.1239  0.1294  0.1386  0.1489  0.1585  0.1694  0.1830  0.1811  0.1724
               0.1724  #_ATM_Survey_Sem2
2013    2  1    1       1       5       0.1556  0.1593  0.1619  0.1664  0.1707  0.1742  0.1778  0.1819  0.1813  0.1787
               0.1787  #_ATM_Survey_Sem2
2014    2  1    1       1       5       0.0914  0.0984  0.1055  0.1438  0.1829  0.1955  0.2015  0.2058  0.2052  0.2026
               0.2026  #_ATM_Survey_Sem2
-2015   2  1    1       1       5       0.0359  0.0424  0.0638  0.1338  0.1855  0.2045  0.2137  0.2196  0.2189  0.2153
               0.2153  #_ATM_Survey_Sem2
```

ALT.CTL

```
# Pacific sardine stock assessment (2017-18)
# P.R. Crone, K.T. Hill, J.P. Zwolinski (Nov 2016)
# Model ALT: number of fisheries = 3 / surveys = 1 / time-step = semester / biological distributions = age /
          selectivity = age-based / growth = emp. WAA
# SS model (ver. 3.24s)
# Control file
#
1 #_N_growth patterns
1 # N_Morphs within growth pattern
# Cond 1 # Morph between/within SD ratio (no read if N_morphs=1)
# Cond 1 # Vector morphdist (-1 for first value gives normal approximation)
1 # N_recruitment assignments (overrides GP*area*season parameter values)
0 # Recruitment interaction requested
# GP season area for each recruitment assignment
1 1 1
# Cond 0 # N_movement_definitions goes here if N_areas >1
# Cond 1 # First age that moves (real age at begin of season, not integer) also conditioned on Do_migration >0
# Cond 1 1 1 2 4 10 # Example move definition for seas=1, morph=1, source=1 dest=2, age1=4, age2=10
3 # N_block patterns
3 7 5 # N_blocks per pattern
# Begin and end years of blocks (pattern 1)
2005 2005 2006 2011 2010 2014 # MEXCAL_S1
# Begin and end years of blocks (pattern 2)
2005 2005 2006 2009 2010 2010 2011 2011 2012 2012 2013 2013 2014 2017 # ATM
# Begin and end years of blocks (pattern 3)
2005 2012 2013 2013 2014 2014 2015 2015 2016 2017 # ATM
0.5 # Fraction female
0 # Natural mortality type: 0=1 Parm, 1=N_breakpoints, 2=Lorenzen, 3=agespecific, 4=age-specific with season
          interpolation
# No additional input for M_type=0 (read 1 parametr per morph)
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)
5 # Maturity_option: 1=length logistic, 2=age logistic, 3=read age-maturity matrix by growth pattern, 4=read
```

```
          age-fecundity, 5=read fecundity/wt from wtatage.ss
# Placeholder for empirical age-maturity by growth pattern
0 # First mature age
1 # Fecundity option:(1) eggs=Wt*(a+b*Wt),(2) eggs=a*L^b,(3) eggs=a*Wt^b, (4) eggs=a+b*L, (5)eggs=a+b*W
0 # Hermaphroditism option: 0=none, 1=age-specific
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, 2=logistic transform keeps in base parm bounds, 3=standard w/ no
          bound check
# Growth parameters
# LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev block block_Fxn
0.3 0.8 0.6 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 0.5 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
#
# Cond 0  # Custom MG-env_setup (0/1)
# Cond -2 2 0 0 -1 99 -2 # Placeholder when no MG-env parameters
# Custom MG-block_setup (0/1)
# Cond No MG parm trends
# 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
# Cond -2 2 0 0 -1 99 -2 # Placeholder when no seasonal MG parameters
# Cond -4 # MGparm_dev Phase
#
# Spawner-recruit (SR) parameters
3 # SR function: 1=Null, 2=Ricker (2 parm), 3=std_B-H (2 parm), 4=S-CAA, 5=Hockey stick, 6=flat-top_B-H,
          7=Survival_3Parm
# LO HI INIT PRIOR PR_type SD PHASE
3 25 15 0 -1 99 1 # SR_R0
0.2 1 0.5 0 -1 99 5 # 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
2005 # First year of main rec_devs (early devs can preceed this era) (was 1993 in 2016 assessment)
2015 # Last year of main rec_devs (forecast devs start in following year) (was 2014 in 2016 assessment)
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
#
1994.7 # Last early_yr nobias adjustment in MPD (was 1984 in 2016 assessment)
2005.2 # First yr fullbias adjustment in_MPD (was 1993 in 2016 assessment)
2012.8 # Last yr fullbias adjustment in MPD (was 2011 in 2016 assessment)
2015.2 # First recent_yr nobias adjustment in MPD (was 2015 in 2016 assessment)
0.8956 # 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
# End of advanced SR options
#
# Placeholder for full parameter lines for recruitment cycles
# Read specified rec_devs
# Yr Input_value
#
# 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)
# No additional F input needed for F method 1
# If F method=2 then read overall start F value, overall phase, N_detailed inputs to read
# If F method=3 then read N_iterations for tuning for F method=3
10 # N_iterations for tuning F (F method=3 only, e.g., 3-7)
#
# Initial F parameters
# LO HI INIT PRIOR PR_type SD PHASE
0 3 1 0 -1 99 1 # Init F_MEXCAL_S1
0 3 0 0 -1 99 -1 # Init F_MEXCAL_S2
0 3 0 0 -1 99 -1 # Init F_PNW
#
# Catchability (Q) parameters
# Den_dep: 0=off and survey is proportional to abundance, 1=add parameter for non-linearity
# Env_var: 0=off, 1 = add parameter for env effect on Q
# Extra_SE: 0=off, 1 = add parameter for additive constant to input SE in ln space
# Q_type: <0=mirror, 0=median_float, 1=mean_float, 2=estimate parameter for ln(Q), 3=parameter with random_dev,
          4=parameter with random walk, 5=mean unbiased float assigned to parameter
#         <0=mirror
#         0=Q floats as a scaling factor (no variance bias adjustment is taken into account)
#         1=Q floats as scaling factor (variance bias adjustment is used) ** recommended option **
#         2=Q is a parameter (variance bias adjustment is NOT used, so produces same result as option=0)
#         3=parameter with random_dev
#         4=parameter with random walk
#         5=mean unbiased float assigned to parameter
# Note: a new option will be created to include bias adjustment in the parameter approach
# Den-dep  Env-var  Extra_SE  Q_type
0 0 0 0 # MEXCAL_S1
0 0 0 0 # MEXCAL_S2
0 0 0 0 # PNW
0 0 0 2 # DEPM
0 0 0 2 # AT
#
# Cond # If Q has random component then 0=read one parameter for each fleet with random Q, 1=read a parameter
          for each year of index
# Q parameters (if any)
# LO HI INIT PRIOR PR_type SD PHASE
-3 3 1 0 -1 99 4 # Q_DEPM
-3 3 1 0 -1 99 4 # Q_AT
#
# Size selectivity types
# Pattern Discard Male Special
0 0 0 0 # MEXCAL_S1
0 0 0 0 # MEXCAL_S2
0 0 0 0 # PNW
30 0 0 0 # DEPM
0 0 0 0 # ATM
#
# Age selectivity types
# Pattern Discard Male Special
17 0 0 10 # MEXCAL_S1
17 0 0 10 # MEXCAL_S2
12 0 0 0 # PNW
0 0 0 0 # DEPM
10 0 0 0 # AT
#
# Age selectivity
# LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
# MEXCAL_S1 (age-specific, random walk)
-5    9        0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-0
-5    9        0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-1
-5    9        0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-2
-5    9        0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-3
-5    9        0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-4
-5    9        0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-5
-5    9        0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-6
-5    9        0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-7
-5    9        0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-8
-1000 9        -1000  -1      -1      99   -3  0 0 0 0 0 0 0 # Age-9
-1000 9        -1000  -1      -1      99   -3  0 0 0 0 0 0 0 # Age-10
#
# MEXCAL_S2 (age-specific, random walk)
-5    9        0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-0
```

```
-5    9       0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-1
-5    9       0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-2
-5    9       0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-3
-5    9       0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-4
-5    9       0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-5
-5    9       0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-6
-5    9       0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-7
-5    9       0.1    -1      -1      99   3  0 0 0 0 0 0 0 # Age-8
-1000 9       -1000  -1      -1      99   -3  0 0 0 0 0 0 0 # Age-9
-1000 9       -1000  -1      -1      99   -3  0 0 0 0 0 0 0 # Age-10
#
# PacNW (asymptotic)
0 10 5 0 -1 99 4 0 0 0 0 0 0 0 # AgeSel_P1_PacNW
-5 15 1 0 -1 99 4 0 0 0 0 0 0 0 # AgeSel_P2_PacNW
#
# DEPM (SSB) - No parameter lines
#
# ATM (Asymptotic option 10, no parameter lines)
#
# Cond: Custom sel-env setup (0/1)
# Cond: Env_fxns setup
# 1 # Cond: Custom sel-blk setup (0/1)
#
# 1 # Cond: Selectivity parameter trends
# 4 # Cond: Selectivity parm_dev phase
# 2 # Cond: Env/Block/Dev_adjustment method: 1=standard, 2=logistic trans to keep in base parameter bounds,
          3=standard with no bound check
#
# Tag loss and Tag reporting parameters
0 # Tag custom:  0=no read, 1=read if tags exist
# Cond -6 6 1 1 2 0.01 -4 0 0 0 0 0 0 0  # Placeholder if no parameters
#
1 # Variance adjustments
# Fleet/Survey: 1 2 3 4 5
0.000000  0.000000    0.000000       0.000000       0.000000 # add_to_survey_CV
0.000000  0.000000    0.000000       0.000000       0.000000 # add_to_discard_stddev
0.000000  0.000000    0.000000       0.000000       0.000000 # add_to_bodywt_CV
1.000000    1.000000    1.000000    1.000000    1.000000 # mult_by_lencomp_N
1.000000    1.000000    1.000000    1.000000    1.000000 # mult_by_agecomp_N
1.000000    1.000000    1.000000    1.000000    1.000000 # mult_by_size-at-age_N
#
1 # Max lambda phase
1 # SD_offset
#
17 # Number of changes to make to default Lambdas (default value=1)
# Like_comp codes: 1=survey, 2=discard, 3=mean_wt, 4=length, 5=age, 6=size-freq, 7=size_age, 8=catch,
#                  9=initial equilibrium catch, 10=rec_dev, 11=parameter_prior, 12=parameter_dev,
#                  13=crash penalty, 14=morph composition; 15=tag composition, 16=tag neg_bin
# Like_comp fleet/survey  phase  value  size-freq_method
1 4 1 0 1 # DEPM
1 5 1 1 1 # ATM
4 1 1 0 1 # MEXCAL_S1 (length)
4 2 1 0 1 # MEXCAL_S2 (length)
4 3 1 0 1 # PNW (length)
4 5 1 0 1 # ATM (length)
5 1 1 1 1 # MEXCAL_S1 (age)
5 2 1 1 1 # MEXCAL_S2 (age)
5 3 1 1 1 # PNW (age)
5 5 1 1 1 # ATM (age)
7 1 1 0 1 # MEXCAL_S1 (Mean LAA)
7 2 1 0 1 # MEXCAL_S2 (Mean LAA)
7 3 1 0 1 # PNW (Mean LAA)
7 5 1 0 1 # ATM (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 (PNW)
#
0 # Read specs for more SD reporting (0/1)
# 0 1 -1 5 1 5 1 -1 5 # Placeholder for selectivity type, lt/age, year, N_selectivity bins, growth pattern,
          N_growth ages, natage_area (-1 for all), natage_yr, N_natages
# Placeholder for vector of selectivity bins to be reported
# Placeholder for vector of growth ages to be reported
# Placeholder for vector of natage ages to be reported
999 # End of file
```